Report To Congress

The Satellite Home Viewer Extension And Reauthorization Act Of 2004

Study Of Digital Television Field Strength Standards And Testing Procedures

ET Docket No. 05-182

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I. SUMMARY

1. Section 204(b) of the Satellite Home Viewer Extension and Reauthorization Act of 2004 (SHVERA) requires that the Federal Communication Commission (Commission) conduct an inquiry and develop recommendations regarding whether the Commission's digital signal strength standard and the signal testing procedures used to identify if a household is "unserved" for purposes of the satellite statutory copyright license for distant digital signals should be revised.[1] This Report is in fulfillment of Congress' directives to the Commission in Section 204(b) of the SHVERA.

2. Consistent with the SHVERA Section 204(b) directives, the Report describes the results of the Commission's study and *Inquiry* on this matter and the Commission's findings regarding whether changes should be made to the statutes or the Commission's rules. As set forth in detail below, the Commission specifically finds that:

- No specific changes are needed to the digital television field strength standards and/or planning factors for purposes of determining whether a household is eligible to receive retransmitted distant network television signals.
- The Commission should conduct a rule making proceeding to specify procedures for measuring the field strength of digital television signals at individual locations that are generally similar to the current procedures for measuring the field strength of analog television stations. Certain modifications to those procedures are needed, however, to address differences in analog and digital television signals. The proper procedures for measuring digital television signals would be developed through the recommended rule making proceeding.
- The existing improved Individual Location Longley-Rice (ILLR) model should be used for predicting whether a household is unserved by digital television signals. The Commission specifically recommends that Congress amend the copyright law, as well as the Communications Act, to allow a predictive model to be used in connection with eligibility for a distant digital signal. The Commission further recommends that Congress provide the Commission with authority to adopt the existing improved ILLR model as a predictive method for determining households that are unserved by local digital signals for purposes of establishing eligibility to receive retransmitted distant network signals under the SHVERA.

The Report also includes a study of digital television receiver performance, attached hereto as Appendix C, that, *inter alia*, finds that there is no relationship between the ability of currently available digital television receivers' to receive over-the-air signals and the prices of those receivers.

II. BACKGROUND

3. Broadcast television stations have rights, under the Copyright Act[2] and private contracts, to control the distribution of the national and local programming that they transmit. In 1988, Congress adopted the Satellite Home Viewer Act (SHVA) as an amendment to the Copyright Act in order to protect the broadcasters' interests in their programming while simultaneously enabling satellite carriers to provide broadcast programming to those satellite subscribers who are unable to obtain broadcast network programming over the air. Under the SHVA, these subscribers were generally considered to be

[1] *See* The Satellite Home Viewer Extension and Reauthorization Act of 2004, Pub. L. No. 108-447, § 207, 118 Stat 2809, 3393 (2004) (codified at 47 U.S.C. § 339(c)). The SHVERA was enacted as title IX of the "Consolidated Appropriations Act, 2005." Hereinafter Section 204(b) is cited as codified in 47 U.S.C. 339(c).

[2] 17 U.S.C. § 119.

"unserved" by their local stations. In the SHVA, Congress linked the definition of "unserved households" to a Commission-defined measure of analog television signal strength known as "Grade B intensity."[3] The Grade B signal intensity standard, as set forth in Section 73.683(a) of the Commission's rules, is used to identify a geographic contour that defines an analog television station's service area.[4] For digital television stations, the counterpart to the Grade B signal intensity standards for analog television stations are the values set forth in Section 73.622(e) of the Commission's Rules describing the DTV noise-limited service contour.[5]

4. The new Section 339 requires the Commission to conduct an inquiry regarding whether, for purposes of identifying if a household is unserved by a digital signal under Section 119(d)(10) of Title 17, United States Code, the digital signal strength standards in Section 73.622(e)(1) of the Commission's rules, or the testing procedures in Section 73.686(d) of the Commission's rules, should be revised to take into account the types of antennas that are available to consumers.[6] In 1999, the Commission adopted a *Report and Order* (*SHVA Report and* Order) addressing three major issues that arose in the context of the SHVA and several pending court actions and petitions to the Commission.[7] First, it affirmed the existing definition of a signal of Grade B intensity for use in determining eligibility for reception of distant network signals. Second, the Commission adopted rules for determining whether a household is able to receive an analog television signal of this strength.[8] In particular, the Commission adopted rules establishing a standardized method for measuring the strength of analog television signals on-site at individual locations. And finally, it endorsed a method for predicting the strength of such signals that could be used in place of actually taking measurements.[9]

5. As added under the Satellite Home Viewer Improvement Act of 1999 (SHVIA),[10] the then-new Section 339(c)(3) of the Communications Act required that the Commission develop and prescribe by rule a point-to-point predictive model for reliably and presumptively determining the ability of individual locations to receive signals in accordance with the signal intensity standard in effect under Section 119(d)(10)(A) of Title 17 of the Unites States Code, that is, the Grade B standards.[11] Section 339(c)(3) further required that the Commission rely on the ILLR model which the Commission had earlier developed for such predictions and that the Commission ensure that such model takes into account

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[3] See 17 U.S.C. § 119(d)(10)(A); 47 C.F.R. § 73.683(a).

[4] 47 C.F.R. § 73.683(a); *see also* 47 C.F.R. § 73.684.

[5] 47 CFR § 73.622(e); *see* also 47 CFR § 73.625(b) (determining coverage). As set forth in Section 73.622(e), a station's DTV service area is defined as the area within its noise-limited contour where its signal strength is predicted to exceed the noise-limited service level.

[6] 47 U.S.C. § 119(d)(10); 47 C.F.R. § 73.622(e)(1); 47 C.F.R. § 73.686(d).

[7] Satellite Delivery of Network Signals to Unserved Households for Purposes of the Satellite Home Viewer Act, CS Docket No. 98-201, *Report and Order*, 14 FCC Rcd 2654, 2655 at ¶ 2 (1999) (*SHVA Report and Order*); *Order on Reconsideration*, 14 FCC Rcd 17373 (1999).

[8] *SHVA Report and Order*, 14 FCC Rcd at 2656 ¶ 4.

[9] *SHVA Report and Order*, 14 FCC Rcd at 2657 ¶ 8.

[10] *See* Consolidated Appropriations Act for 2000, Pub. L. 106-113, § 1000(9), 113 Stat. 1501 (enacting S. 1948, including the Satellite Home Viewer Improvement Act of 1999, Title I of the Intellectual Property and Communications Omnibus Reform Act of 1999, relating to copyright licensing and carriage of broadcast signals by satellite carriers, codified in scattered sections of 17 and 47 U.S.C.). Section 1008(a) of SHVIA added, *inter alia*, new Section 339 ("Carriage of Distant Television Stations by Satellite Carriers") to the Communications Act of 1934, 47 U.S.C. § 151 *et seq*.

[11] *See also* 47 C.F.R. § 73.683(a) (Grade B field strength contours for channels 2-6, 7-13, and 14-69).

terrain, building structure, and other land cover variations. In response to these provisions, the Commission adopted a *First Report and Order* in May 2000 in which it amended its rules to prescribe use of an improved point-to-point ILLR model for establishing whether individual households are eligible to receive distant analog network television signals.[12] This model includes adjustments for land use and land cover loss values. The rules also provide for a neutral and independent entity to evaluate the qualifications of potential testers to conduct on-site signal strength measurements in cases where a network television station denies a subscriber's request for a waiver of the ILLR prediction that the viewer is "served."

6. In addition, in the SHVIA Congress directed the Commission to conduct an inquiry and prepare a report regarding the broadcast TV signal strength standard used for satellite carrier purposes. The then-new Section 339(c)(1) of the Communications Act required that this investigation evaluate all possible standards and factors for determining eligibility to receive retransmitted network station signals and, if appropriate, recommend modification of, or alternative standards or factors, to the Grade B intensity standard for analog television signals and to make a further recommendation relating to an appropriate standard for digital television signals.[13] In response to this directive, the Commission inquired into and evaluated the possible standards and factors for determining eligibility of households to receive retransmissions of network station signals by satellite carriers. It specifically considered whether to recommend modifications to, or alternative standards or factors for, the Grade B intensity standard for analog television signals. On November 29, 2000, the Commission issued a *Report to Congress* (*SHVIA Report*) in which it recommended retention of the Grade B signal intensity standard and eight of the nine planning factors used in developing that standard as the basis for predicting whether a household is eligible to receive retransmitted distant TV network analog signals under the SHVIA.[14] The Commission recommended modification of the remaining planning factor (time fading) by replacing the existing fixed values with location-dependent values determined for the actual receiving locations using the Individual Location Longley-Rice (ILLR) prediction model. With regard to digital signals, the Commission found that it would be premature to construct a distant network signal eligibility standard for DTV signals at that time. The Commission therefore recommended that establishment of a distant network signal eligibility standard for digital signals be deferred until such time as more substantial DTV penetration is achieved and more experience is gained with DTV operation.[15]

7. In December 2004, Congress enacted the SHVERA, which revised the statutory provisions of the SHVA and SHVIA, including Section 339 of the Communications Act of 1934.[16] Under the

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[12] *See* In the Matter of Establishment of an Improved Model for Predicting the Broadcast Television Field Strength Received at Individual Locations, *First Report and Order* in ET Docket No. 00-11 (*ILLR First Report and Order*), 15 FCC Rcd 12118 (2000); recon. *Memorandum Opinion and Order* in ET Docket No. 00-11, 19 FCC Rcd 9963 (2004); appeal pending, EchoStar L.L.C. v. FCC & USA, No. 04-1304 (D.C. Circuit).

[13] *See* 47 U.S.C. § 339(c). *See also* 17 U.S.C. § 119(a)(2)(b) and (d)(10). Section 339(c) sets forth the circumstances in which Direct Broadcast Satellite (DBS) subscribers are eligible to receive retransmission of distant network signals. *See also* 47 U.S.C. 339(c)(1) *as amended by* the SHVERA.

[14] *See Report to Congress, In the Matter of Technical Standards for Determining Eligibility for Satellite Delivered Network Signals Pursuant to the Satellite Home Viewer Improvement Act*, 15 FCC Rcd 24321 (2000). The eight planning factors recommended for retention were: thermal noise, transmission line loss, receiving antenna gain, dipole factor, terrain factor, urban noise, signal-to-noise ratio, and urban noise. The development of the Grade B signal intensity standard and its use in connection with the authorization of analog television stations and the determination of stations' service areas and contours is also discussed in greater detail in the *SHVIA Report*.

[15] *Id.*

[16] 47 U.S.C. § 339.

SHVERA, viewers in individual households who are not able to receive network digital television signals over-the-air from local television stations and who are in circumstances that meet certain additional qualifying criteria are eligible to receive those digital network television signals from distant stations carried via satellite. It is therefore important that the standard for determining whether a local digital television station's signal strength at a specific location is sufficient for reception of service and that the procedures for evaluating digital television signal strength provide an accurate means for determining whether a household can receive a local network station's digital signal. Subsection 339(a)(2)(D)(vi), as revised by SHVERA, provides that the digital signal strength standard defined in Section 73.622(e) of the Commission's rules shall serve as the basis for determining whether a satellite TV subscriber is eligible to receive retransmitted distant TV network digital signals.[17] Section 73.622(e)(1) provides that the service area of a DTV station is the geographic area within the station's noise-limited F(50, 90) contour where its signal is predicted to exceed the noise-limited service level.[18] Within this contour, service is considered available at locations where the station's signal strength, as predicted using the terrain dependent Longley-Rice point-to-point propagation model, exceeds the following noise-limited service levels:[19]

Channels 2-6 (low-VHF)..28 dBu
Channels 7-13 (high-VHF).....................................36 dBu
Channels 14-69 (UHF)...41 dBu

8. Subsection 339(c)(1), as revised by the SHVERA, requires the Commission, not later than December 8, 2005, to complete an inquiry and submit a report recommending whether, for purposes of identifying if a household is unserved by an adequate digital signal, the digital signal strength standard set forth in Section 73.622(e)(1) of the Commission's Rules or the testing procedures in Section 73.686(d) of the Commission's Rules should be revised to take into account the types of antennas that are available to consumers.[20] Subsection 339(c)(1) requires that, in conducting the required study, the Commission consider six specific issues relating to the question of digital signal strength in the context of the "unserved household":[21]

- Whether to account for the fact that an antenna can be mounted on a roof or placed in a home and can be fixed or capable of rotating;
- Whether the Commission's rules should be amended to create different procedures for determining if the requisite digital signal strength is present than for determining if the requisite analog signal strength is present;

[17] 47 U.S.C. § 339(a)(2)(D)(vi).

[18] *See* Section 73.622(e)(1) of the Commission's Rules, 47 C.F.R. § 73.622(e)(1). The F(50, 90) contour describes the outer edge of a geographic area in which a transmitter's signal strength is predicted to exceed the field strength standard at 50 percent of the locations 90 percent of the time.

[19] *See* Section 73.622(e) (1) and (2) of the Commission's Rules, 47 C.F.R. § 73.622(e) (1), (2). Guidance for evaluating digital television station coverage areas using the Longley-Rice methodology is provided in OET Bulletin No. 69, *see* OET Bulletin No. 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference" (July 2, 1997). OET Bulletin No. 69 is available on the Commission's website at http://www.fcc.gov/oet/info/documents/bulletins/.

[20] 47 U.S.C. § 339(c)(1). The report is to be submitted to the Committee on Energy and Commerce of the House of Representatives and to the Committee on Commerce, Science, and Transportation of the Senate. The report is to contain recommendations, if any, as to what changes should be made to Federal statues or regulations. See 47 U.S.C. § 339(c)(1)(C).

[21] 47 U.S.C. 339(c)(1)(B)(i)-(vi), *as amended by* Section 204(b) of the SHVERA. The complete text of the new Section 339(c)(1) is set forth in Appendix A.

- Whether a standard should be used other than the presence of a signal of a certain strength to ensure that a household can receive a high-quality picture using antennas of reasonable cost and ease of installation;
- Whether to develop a predictive methodology for determining whether a household is unserved by an adequate digital signal;
- Whether there is a wide variation in the ability of reasonably priced consumer digital television sets to receive over-the-air signals, such that at a given signal strength some may be able to display high-quality pictures while others cannot, whether such variation is related to the price of the television set, and whether such variation should be factored into setting a standard for determining whether a household is unserved by an adequate digital signal; and
- Whether to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter.

The above specifications for study address three separate but interrelated concerns: 1) the appropriateness of the DTV planning factors that underlie the DTV signal strength standard, 2) the appropriateness of the objective test-site methodology for measuring digital signals, and 3) whether a predictive model should be developed for determining whether a household is unserved by an adequate digital TV signal for purposes of eligibility to receive distant network TV signals.

9. On April 29, 2005, the Commission initiated an inquiry to gather information pursuant to Section 339(c)(1).[22] The Commission received 9 comments and 5 reply comments in response to its *Notice of Inquiry* (*Inquiry*) in this proceeding. The results of the Commission's study and analysis of the record of its *Inquiry* and other research and information in this matter and its recommendations are described in the following sections of this Report. These sections address the digital signal strength standards, testing procedures, and predictive models and specifically include consideration of the six issues that Congress specifically asked the Commission to address in Section 204 of the SHVERA.

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[22] In the Matter Of Technical Standards For Determining Eligibility For Satellite-Delivered Network Signals Pursuant To The Satellite Home Viewer Extension and Reauthorization Act, ET Docket No. 05-182, *Notice of Inquiry (Inquiry)*, 20 FCC Rcd. 9349 (2005).

III. THE DIGITAL TV SIGNAL STRENGTH STANDARDS

10. Eligibility to receive distant network signals retransmitted by a satellite carrier has been, in principle, based on the inability of a household subscribing to a Direct Broadcast Satellite (DBS) service is not able to receive network signals over-the-air at its location using a receiving system that conforms to the assumed receiving system on which the television service area standards are based.[23] If a household is not able to receive a network signal at a field strength level equal to or greater than the TV service area Grade B (analog TV) or noise-limited (digital TV) standards, that household may be eligible to receive the signal of a distant station affiliated with that network that is retransmitted on the household's DBS service if it meets other criteria for eligibility. Congress has asked the Commission to investigate whether the noise-limited DTV service standard should be revised to take into account the types of antennas that are available to consumers. In considering this issue, the Commission must consider: 1) whether to account for the fact that an antenna can be mounted on a roof or placed in a home and can be fixed or capable of rotating, 2) whether there is a wide variation in the ability of reasonable priced consumer digital television sets to receive over-the-air signals such that at a given signal strength some may be able to display high-quality pictures while others may not, whether such variation is related to the price of the television set, and whether such variation should be factored into setting a standard for determining whether a household is unserved by an adequate digital signal, and 3) whether to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter. In this section, we discuss the digital TV signal strength standards and evaluate the factors underlying those standards, including those specified in Section 204, in light of our *Inquiry* and study. We also consider whether any adjustments to those standards are warranted in light of our findings.

A. The DTV Service Area Field Strength Intensity Standards

11. As indicated above, the service areas of broadcast television stations, in the absence of interference, are defined on the basis of a concept known as "noise-limited" service. Under this concept, a TV station's service extends to cover geographic locations out to the edge of where reception is no longer possible because of interference from background electrical noise. The background noise limiting reception of service arises both from the environment and from within the equipment used to receive service. Both the analog TV Grade B field strength intensity standards and the digital TV noise-limited field strength intensity standards are defined on this basis. These standards were developed in the early days of both methods of television modulation as a key component of the Commission's television station channel allotment and service area regulations.[24] The DTV service area definitions further specify that service is considered to be present in areas within the noise-limited contour where signal strength is

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[23] The criteria for eligibility to receive a distant network signal from a DBS service also include factors in addition to the ability of a household to receive that network signal over-the-air from a local TV station, *see* Section 339 of the Communications Act, 47 U.S.C. § 339.

[24] *See* Television Broadcast Service, *Third Notice of Further Proposed Rule Making*, Appendix B, 16 Fed. Reg. 3072, 3080 (April 7, 1951), adopted in Amendment of Section 3.606 of the Commission's Rules and Regulations and Amendment of the Commission's Rules, Regulations, and Engineering Standards Concerning the Television Broadcast Service in the Band 470 to 890 MHz for Television Broadcasting, *Sixth Report and Order*, 41 FCC 148 (1952); *see also* Advanced Television Systems and Their Impact upon the Existing Television Broadcast Service, *Sixth Report and Order* in MM Docket No. 87-268, 12 FCC Rcd 14588 (1997) (*DTV Sixth Report and Order*), at ¶¶183-196.

predicted to exceed the noise-limited signal level using the terrain-dependent Longley-Rice point-to-point propagation model.[25]

12. The field strength of television signals decreases with distance from the transmitter and varies across individual locations and time. At locations close to a station's transmitter the variation of signal strength across time and location are generally not great. However, as distance increases, the variability of the available signal strength with both location and time increases significantly. At the edge of a station's service area, its signal will be available in some locations more of the time than at others. Historically, if service is not available all, or most of the time, it is simply considered not available. Under both the analog Grade B and digital noise-limited F(50,90) service standards, an acceptable television picture and sound service is available at 50% of the locations for 90% of the time at locations on the outer edge of a station's service area. The signal strength values of the analog TV standards were selected to provide service at these levels of availability and the digital television standards were specified to enable DTV stations to replicate their analog service.[26]

13. The noise-limited digital TV field strength standards were derived from a set of assumptions for the several technical planning factors that are present in a typical DTV receiving system and for a defined level of service. The DTV receiving system includes all elements in the electrical path from the point where a DTV signal is converted from electromagnetic energy to electric energy at the receive antenna to the point in the tuning function of a TV set where the received signal is delivered to the demodulator that produces the 19.39 mbps digital TV bitstream. The effect of each of the elements in the receiving system and the factors for time and location variability are summed to determine the minimum signal level that must be available over-the-air to provide an F(50,90) level of service at the edge of a station's noise-limited service area contour. These factors and their assumed values as used in establishing the DTV noise-limited service area field strength intensity standards are:[27]

[25] Guidance for evaluating DTV coverage areas using the Longley-Rice methodology is provided in *OET Bulletin No. 69*, which is available through the Internet at the Commission's website, http://www.fcc.gov/oet/info/documents/bulletins/.

[26] *See DTV Sixth Report and Order*, *supra* note 24, at ¶¶ 29-33 and Appendix B.

[27] *See DTV Sixth Report and Order*, *supra* note 24, at Appendix A.

Planning Factor:	Symbol	Low VHF (2-6)	High VHF (7-13)	UHF (14-69)
Geometric Mean Frequency (MHz)	F	69	194	615
Dipole Factor (dBm-dBu)	K_d	-111.8	-120.8	-130.8
Thermal Noise (dBm)	N_t	-106.2	-106.2	-106.2
Antenna Gain (dB)	G	4 *	6 *	10 *
Front-to-back ratio (dB) (ratio of forward gain to maximum response over rear 180^o)	FB	10	12	14
Downlead line loss (for 50 ft/15 m. of coaxial cable (dB)	L	1	2	4
System (receiver) noise figure (dB)	N_s	10	10	7
Required receiver S/N ratio (dB)	S/N	15.2**	15.2**	15.2**
Time variability factor (90% availability) (dB)	dT	0***	0***	0***
Location variability factor (50% availability) (db)	dL	0	0	0

* Antenna placement is assumed outdoors at 9 meters (30 feet).

** The required S/N value stated in the *DTV Sixth Report and Order* and OET Bulleting No. 69 is 15. That value was rounded from the 15.19 value set forth in the FCC Advisory Committee on Advanced Television Service's (ACATS) *Final Technical Report* (October 31, 1995) at Table 5.1.

*** The time variability factor is defined as the difference between the F(50,10) minus F(50,50), where these two values are determined from the charts in Section 73.699 of the Commission's rules, 47 C.F.R. § 73.699. This factor is a function of the distance between the transmitting and receiving antennas.

14. Using the factors in the above chart, the minimum signal level that needs to be present at the input terminal of a television receiver, to provide service is the sum of the thermal noise, the receiver noise figure, and the receiver signal-to-noise (S/N) ratio, that is:

Minimum receiver signal level R = $N_t + N_s$+ S/N
for low and high VHF channels = -106.2 + 10 + 15.2 = -81.0 dBm
for UHF channels = -106.2 + 7 + 15.2 = -84.0 dBm

15. Considering the entire receiving system, the minimum field strength needed to be available at the antenna is the sum of the minimum signal level needed at the receiver, the downlead line loss, and the dipole factor, less the antenna gain:

Minimum field strength to receive service MFS = R + L + K_d – G
for low VHF channels = -81.0 dBm + 1 + 111.8 – 4 = 27.8 dBµV/m
for high VHF channels = -81.0 dBm + 2 + 120.8 – 6 = 35.8 dBµV/m
for UHF channels = -84.0 dBm + 4 + 130.8 – 10 = 40.8 dBµV/m

16. Rounding to the nearest decibel, we have 28, 36, and 41 dBu as the minimum field strength standards for channels in the low VHF, high VHF, and UHF channel bands, respectively. As indicated in the chart of planning factors, above, no adjustments were needed to compensate for time or location variability beyond that already afforded by F(50, 90) level of service.

B. Review of the DTV Field Strength Intensity Standards

17. Several parties commenting in the *Inquiry* indicate that the Commission should continue to determine whether a household is unserved based on the current assumed planning factors, which include an assumption that an outdoor stationary antenna is mounted at a height of 9 meters.[28] The National Association of Broadcasters (NAB) states the assumptions made in the Commission's DTV planning factors and in the Longley-Rice model about household reception equipment are reasonable and realistic.[29] In particular, NAB asserts that, as was the case for analog television, the Commission's digital transition proceeding has always assumed that consumers in fringe areas would use rooftop antennas that are properly oriented to achieve the best reception from the station in question.[30] As a consequence, NAB reasons that broadcasters have built transmission systems based on these Commission assumptions and standards and, thus, it would now be unfair to assume, as a DTV planning factor, that viewers will use indoor antennas.[31] Also, NAB contends that, because rooftop antennas provide much better service than indoor antennas, households have long used rooftop antennas to achieve over-the-air reception, particularly if the household is at some distance from the transmitting tower. It notes that rural households often rely on small towers – with over-the-air antennas placed considerably higher than the assumed rooftop level – to receive a strong signal from stations several dozen miles away.[32] Additionally, NAB asserts that satellite dish antennas can only be used outdoors, usually atop a roof, and, therefore, it would be "egregiously discriminatory" for the Commission to conclude that while satellite subscribers are expected to rely on a rooftop antenna for their satellite reception, they cannot be expected to do the same to pick up over-the-air signals.[33] The Consumer Electronics Association (CEA) submits that broadcast television households should have a right to a consistent definition of whether their households are considered served by a TV station.[34]

18. In their comments, the ABC, CBS, and NBC Television Affiliate Association (Network Affiliates) state that the Commission's DTV planning factors established appropriate signal strength thresholds for reception of real-world DTV signals.[35] These planning factors, Network Affiliates assert, contain a "safety margin" to ensure that quality DTV reception is achievable precisely where the

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[28] The Association for Maximum Service Television, Inc. (MSTV) comments at 2 (Commission should reaffirm the DTV signal strength standards for determining DTV service availability and for identifying underserved households pursuant to SHVERA); Consumer Electronics Association (CEA) comments at 3 (although antenna type and placement is a critical factor in DTV reception, it should not be considered in determining household eligibility for distant DTV network signal reception; instead, such eligibility should be determined based on the failure of a signal of at least a given field strength to be present at a specified height above the location); NAB comments, *passim;* and Network Affiliates comments, *passim.*

[29] NAB comments at 16.

[30] *Id.* at 14 and 18-20. NAB points out that, in comparison to outdoor antennas, indoor antennas do not perform as well at receiving over-the-air TV signals, have lower gain, are placed in inferior locations for over-the-air reception, are typically nondirectional, and are affected by the movement of people within the room. *Id.* at 16-17.

[31] *Id.* at 18-19.

[32] Id. at 17.

[33] *Id.* at 18.

[34] *See* CEA comments at 2.

[35] Network Affiliates comments at 13-38.

Commission expects it to be, namely, in the replicated analog TV service area.[36] With these considerations in mind, and realizing that satellite antennas must be mounted outdoors and must be oriented to the satellite for proper reception, the Network Affiliates contend that it would be "inappropriate to essentially penalize" local TV stations for those consumers who were only willing to install an indoor antenna (or an antenna that was incapable of being oriented to the desired signal), especially when those consumers are willing to take additional, necessary steps to obtain adequate satellite reception.[37] Moreover, they state that real-world equipment, including fifth generation DTV receivers whose performance in terms of whether they are able to receive service does not vary by price, demonstrates that the Commission's current signal strength thresholds are more than adequate to receive a high-quality digital picture.[38] The MSTV, the NAB and the Network Affiliates argue that there is no need for the Commission to consider modifying the inherent assumptions regarding DTV antenna receiving systems in the DTV planning factors and that it should recommend to Congress that the DTV signal strength standards remain the same for purposes of determining whether a household is "unserved" by a digital signal for purposes of 17 U.S.C. § 119(d)(10).[39] CEA argues that it is not appropriate for the Commission to take into consideration that an antenna can be mounted on a roof or placed inside a home or can be fixed or capable of rotating. It submits rather that it is necessary and sufficient for the Commission to state that a given field strength, predicted or measured, at a known height above the location determines whether a household is served.[40]

19. Other commenting parties assert that the planning factors should be substantially modified or are otherwise insufficient for use in determining household eligibility pursuant to SHVERA.[41] EchoStar argues that the signal strength standard should be revised to account for DTV receiver performance, man-made noise, indoor antenna use, and the lack of rotation in outdoor antennas.[42] It submits that the signal sensitivities of the current generation of receivers are worse than the signal sensitivities assumed in the DTV planning factors and that as a result many consumer DTV sets may not be able to display a DTV picture even when the signal strength meets the Commission's standards. EchoStar also argues that for the low VHF channels man-made noise was not adequately taken into account in the planning factors and that as a result the Commission did not build in a sufficient margin for noise when it set the signal strength standard for those channels. With regard to indoor antenna, EchoStar argues that an outdoor antenna is not practical for many households, particularly those located in apartment buildings. It further contends that even households with outdoor antennas often do not have rotating antennas or have a practical means of re-pointing their antennas "on the fly" to achieve optimum reception for every broadcast station in the market. EchoStar suggests that the Commission should take these factors into account and recommend modifications to the signal strength standard.

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[36] *Id*. at 15-33.

[37] *Id.* at 34.

[38] *Id.* at 35.

[39] MSTV comments at 2; NAB comments at 16-25; Network Affiliates comments at 13-15 and 37-38.

[40] CEA comments at 3.

[41] EchoStar comments at 4 and 6*;* Robinson Telephone comments, *passim*; and Viamorph, Inc. comments, *passim* (predictive model should include methods to account for variations in antenna performance, including receiving antenna characteristics and detailed geographical, botanical, atmospheric and other data; Viamorph states that it is introducing a new "digital smart antenna" technology into the consumer marketplace).

[42] EchoStar comments at 4 and 6.

20. In the subsections below we examine the signal strength questions addressed in the SHVERA and other planning factor issues raised in the *Inquiry*. We will consider the comments above and our evaluations of the issues in these subsections in developing our recommendations to Congress on DTV signal strength standards, which are set forth at the end of this section.

1. Antenna Gain, Orientation, and Placement

21. An antenna is the first element in the path that constitutes a household's TV receiving system. The antenna receives the electromagnetic energy of a television signal and converts it into electrical energy. The effectiveness of receiving antennas is determined both by factors intrinsic to the specific antenna design and by external factors. With regard to the former, antennas are designed with varying amounts of antenna gain or directivity. The greater the gain of a receiving antenna is, the greater the antenna's ability to capture weak signals. However, there is a significant tradeoff when incorporating additional gain in an antenna design. That is, designing an antenna with greater gain requires that it also be designed to have a narrower beamwidth. Beamwidth, in turn, refers to the antenna's angle of orientation within which the gain occurs. The narrower the beamwidth of a receiving antenna, the more critical it is to accurately aim the antenna directly at the source of the signal of interest. The signal strength of a transmission that is received by an antenna's main lobe beamwidth will be stronger than if that transmission was received from a direction outside that main lobe. With regard to external factors, considerations relating to antenna placement and orientation affect the ability of a household to receive an adequate DTV signal. For example, because structures located within the line of sight between the transmitter and the receiving antenna can block or weaken the strength of received signals, an outdoor antenna installation, such as upon a rooftop, will generally allow a stronger signal to be received by the antenna than will an indoor antenna installation. Thus, for households located in the same general area, an indoor antenna will generally need an antenna with greater gain than will a household in which the antenna is placed outdoors. If an antenna is oriented/directed so that its maximum gain is not focused on the desired TV signal, the received energy from that station's signal will be much lower.

22. Inherent in the Commission's definition of digital television service area are certain assumptions regarding the receiving antenna. For DTV, the Commission assumes that the receiving antenna is located outdoors at a height of 9 meters above ground.[43] In addition, the Commission's procedures for evaluating DTV service areas set forth specific values for antenna gain that depend upon the specific DTV channel band, namely, 4 dB for low VHF, 6 dB for high VHF, and 10 dB for UHF and assume that the antenna is oriented in the direction which maximizes the values of the field strength received for the signal being measured.[44]

23. In the *Inquiry*, we sought comment and information regarding the antenna equipment available to and used by consumers as a possible factor in the DTV signal availability standards. Consistent with the provisions of Section 339(c)(1)(B)(*i*), we asked whether there is a need to revise the standards by which adequate DTV network signals are deemed available to households in order to account for the facts that DTV antennas can be mounted on a roof or within a home and can be installed in a fixed position or in a mounting that allows them to be rotated. As required under Section 339(c)(1)(B)(iii), we also requested comment and information on whether a standard other than the presence of a signal of a certain strength should be used to ensure that a household can receive a high-quality picture using antennas of reasonable cost and installation. Specifically, we asked if the inherent assumptions regarding DTV antenna receiving systems should be modified or extended insofar as they

[43] *See* OET Bulletin 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference" (February 6, 2004), at 6 Table 4; *see also* 47 C.F.R. § 73.699.

[44] *Id.* at 9.

relate to the proper determination of whether households are unserved by adequate broadcast DTV network signals and are thus eligible to receive distant DTV network signals from a satellite service provider. We requested that commenting parties provide information on the types of antennas that are in use currently, or soon to be available for outdoor or indoor residential use, including technical specifications (*e.g.*, size, gain, beamwidth) and how those factors affect cost and deployment. Further, we requested information on the availability and cost of various devices that can be used to aim these antennas (*e.g.*, rotors) toward DTV transmitters. In this regard, we requested comment on how the addition of a rotor would affect the size of an antenna system and thus the ability of consumers to mount an antenna indoors. We asked that commenting parties provide an evaluation of whether the use of an indoor antenna with or without a rotor would provide similar performance to that expected based on the Commission's assumed planning factors.

24. *Inquiry Record*. The parties commenting in the *Inquiry* who represent broadcast and consumer electronics interests generally state that the Commission should continue to determine whether a household is unserved based on the assumed planning factors, including the use of an outdoor stationary antenna mounted at a height of 9 meters. For example, the NAB states that broadcasters have built transmission systems based on the Commission's standards and it would be unfair to now assume that viewers will use indoor antennas.[45] In a statement attached to the NAB's comments, the engineering firm of Meintel, Sgrignoli, and Wallace (MSW) argue that the planning factors for the DTV receive antenna setup are reasonable based on moderately priced equipment that is readily available to consumers in the marketplace.[46] The Network Affiliates argue that it would be inappropriate to penalize local TV stations for consumers who are only willing to install an indoor antenna when the consumer is willing to take additional, necessary steps to obtain adequate satellite reception.[47] Thus, in the Network Affiliates' view, there is no basis for modifying the inherent assumptions regarding DTV antenna receiving systems in the DTV planning factors.[48] EchoStar and Paul Robinson, the General Manager of Robinson Telephone, take a different position, arguing that the antenna planning factors should be revised to take into account indoor antennas, with EchoStar adding that the lack of rotation capability in outdoor antennas should also be considered.[49]

25. Looking first at the record on antenna performance, commenting parties representing the interests of broadcasters and the consumer electronics industry submit that reasonably priced antennas that exceed the gain and front-to-back ratios assumed in the planning factors are readily available.[50] The Network Affiliates argue that the planning factors should consider the TV receiving antenna to be outside on the roof or adjacent to the house.[51] They further submit that the antenna should be considered oriented to the desired signal, and if the desired stations are not located in the same direction, then the antenna should be considered orientable in the direction of the desired signal(s).[52] The Network Affiliates submit

[45] NAB comments at 18-19.

[46] NAB comments, Attachment 1 (engineering statement of MSW) at 3.

[47] Network Affiliates comments at 34.

[48] *Id.* at 34-35.

[49] EchoStar comments at 6-8; Robinson Telephone comments, *passim.*

[50] Network Affiliates comments at 29-32; NAB comments at 35-43; MSTV comments, Attachment (Engineering Statement of Louis Robert du Treil, Jr. of dLR at 5-6; *see also* ATI Technologies comments, *passim.*

[51] Network Affiliates comments at 34.

[52] *Id.*

that the equipment for a high quality outdoor antenna receiving system, including an eight-way bowtie-with-screen antenna and a rotor with remote control can be purchased for approximately $100.[53]

26. Jules Cohen, in an engineering appendix to the Network Affiliates comments, states that manufacturers' specified antenna gains vary from averages of 12 dB or more for UHF, mostly about 10 dB for high VHF, and 5-7 dB for low VHF.[54] The NAB and the Network Affiliates submit that the best UHF antenna, considering both performance and value, is an eight-bay bowtie-with-screen antenna.[55] The Network Affiliates state that an FCC study in 1980 determined that this design provides an average gain of 13.4 dB.[56] They also state that antennas with higher average UHF gains are available, although they are slightly more expensive.[57] The consulting engineering firm of du Treil, Lundin & Rackley (dLR) (in an attachment to MSTV's comments), the Network Affiliates and Viamorph each compiled data from several leading manufacturers of consumer television antennas.[58] Their compilations show, in part, that Channel Master offers an eight-bay bowtie-with-screen UHF antenna, Model No. 4228, with an average gain of 12.0 dB; Winegard offers a UHF antenna designed for deep fringe areas, Model PR-9032, with a gain of 15.6 dB; and Antennas Direct offers a long-range UHF antenna, Model 91XG, with a gain of 16.7 dB.[59] The Network Affiliates indicate that the Channel Master 4228 retails for $38.99 from Solid Signal (solidsignal.com); Winegard's PR-9032 retails for $34.99 from Solid Signal; and Antenna Direct's Model 91XG sells for $79 (antennasdirect.com).[60] Based on this information, the Network Affiliates submit that the Commission's DTV planning factor of 10 dB for UHF antenna gain is very conservative and can easily be achieved with readily available consumer antennas.[61]

27. The Network Affiliates submit that the most recent study of VHF antennas of which they are aware was conducted by the Institute for Telecommunications Sciences (ITS), an agency of the Department of Commerce, in 1979. That study indicated that the average gain of an antenna for low VHF use was 4.43 dB and for high VHF band use was 8.43 dB. The Network Affiliates note that these gain values exceed the DTV planning factor gain values of 4 dB and 6 dB, respectively.[62] The Network Affiliates also state that currently there are a number of VHF antennas on the market that exceed the gain assumed in the DTV planning factors. They submit that these include the Antennacraft Model CS 1100,

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[53] *Id.* at 35.

[54] Network Affiliates comments, Appendix (Engineering Statement of Jules Cohen) at 2.

[55] Network Affiliates comments at 18 and 35; NAB comments at 27-28.

[56] Network Affiliates comments at 18. The Network Affiliates further note that the Electronics Technicians Association, a group whose members install and work in the field with antennas on a day-to-day basis, stated in its comments in the Commission's proceeding in CS Docket No. 98-201 that the eight-bay and four-bay bowtie-with-screen antennas are the conventional UHF antennas for fringe rural areas. *Id.* (citing CS Docket No. 98-201, Electronics Technicians Association, International, Inc. (ETA) Comments at 23).

[57] *Id.* at 18-19.

[58] *Id.* at 19; see also MSTV comments, Attachment (Engineering Statement of dLR) at 6 (Table 2); Viamorph comments at 1-2.

[59] Network Affiliates comments at 19.

[60] *Id.* at 19 n.51.

[61] *Id.* at 19.

[62] *Id.* at 19-20.

with an average gain in the low VHF band of 6.9 dB and an average gain in the high VHF band of 9.6 dB; the Channel Master Model No. 3610, with an average gain in the low VHF band of 5.8 dB and an average gain in the high VHF band of 11.4 dB; and the Winegard Model HD4053P, with a gain in the low VHF band between 5.9 and 6.6 dB and in the high VHF band of between 9.6 and 11.4 dB.[63] The Network Affiliates state that the Antennacraft CS 1100 has a list price of $96.08 (antennacraft-tpd.com) and that Winegard's HD4053P retails for $119.99 from Solid Signal.[64] They submit that with antennas offering these levels of performance, it is apparent that the DTV planning factors of 4 dB gain for low VHF signals and 6 dB for high VHF signals are also very conservative and can easily be achieved with readily available consumer VHF antennas. The NAB submits that another option for consumers is the Winegard SquareShooter SS-2000, a small, attractive directional antenna with a preamplifier.[65] The NAB states that while the manufacturer states that the antenna alone has a gain of 4.5 dB at UHF (below the planning factor assumption), the gain of combined setup with the preamplifier far exceeds the planning factors. It submits that the SquareShooter 2000 is available for about $98.99 from Solid Signal.[66]

28. The Network Affiliates further submit that although combination VHF/UHF antennas do not generally perform as well as separate VHF and UHF antennas, there are consumer models available that exceed the assumed gains in the DTV planning factors. For example, they state that Winegard's Model D7084P has gain of from 6.2 dB to 7.6 dB in the low VHF band, from 10.8 dB to 12.0 dB in the high VHF band, and from 11.8 dB to 14.6 dB in the UHF band and that Antennacraft's Model HD1850 has an average gain of 6.2 dB in the low VHF band, 10.7 dB in the high VHF band, and 10.0 dB in the UHF band.[67] The Network Affiliates indicate that Winegard's HD7084 retails for $127.99 from Solid Signal and Antennacraft's HD1850 has a list price of 174.97.[68] They further note that even Channel Master's eight-bay bowtie-with-screen UHF antenna, Model No. 4228, has been measured by an independent engineering firm, Dielectric Communications, to possess an average gain of approximately 3.0 dB in the low VHF band, approximately 9.0 dB in the high VHF band, and approximately 15.0 dB in the UHF band (which exceeds the manufacturer's own specifications) and that it retails for $38.99 from Solid Signal.[69]

29. The Network Affiliates state that such high-gain antennas are not appropriate for all receiving locations and that where signal strength is already adequate or nearly adequate, such a high-gain antenna could overload a receiver. They note that for those circumstances antenna manufacturers produce smaller antennas with less gain. They point out that CEA, in conjunction with Decisionmark, has established a website, AntennaWeb.org, that is designed to assist consumers in selecting an appropriate outdoor receiving antenna. The Network Affiliates submit that even if the gain of an antenna is less than the gain assumed in the planning factors, that does not mean that the planning factors are defective, because at locations where those antennas are appropriate the ambient signal strength will already exceed the thresholds set forth in the planning factors.[70]

[63] *Id.* at 20.

[64] *Id.* at 20 n.53 (pricing information for Channel Master No. 3610 not available).

[65] NAB comments at 22.

[66] *Id.* at 22 and Attachment 1 (Engineering Statement of MSW) at 16.

[67] Network Affiliates comments at 20.

[68] *Id.* at 20, n.54.

[69] *Id.* at 20-21 and n.55.

[70] *Id.* at 21.

30. The Network Affiliates observe that, although it is not an element affecting the digital signal strength standards, the Commission did assume that TV receiving antennas would have a directional gain pattern in order to discriminate against off-axis undesired stations and thereby ameliorate interference.[71] They note that the ATSC recommends the use of a directional gain antenna to enhance receiver performance with respect to multipath: "[A]n antenna with a directional pattern that gives only a few dB reduction in a specific multipath reflection can dramatically improve the equalizer's performance. Such modest directional performance can be achieved with antennas of consumer-friendly size, especially at UHF."[72] The DTV planning factors account for this directionalization in the assumed front-to-back ratios of 10 dB for low VHF, 12 dB for high VHF, and 14 dB for UHF. The Network Affiliates indicate that it is common for readily available consumer antennas to meet or exceed these assumed front-to-back ratios. They state that, of the antennas mentioned above, the front-to-back ratio of Channel Master's eight-bay bowtie-with-screen UHF Model No. 4228 exceeds 19 dB at all UHF frequencies and is 24 dB at channel 43. Similarly, the front-to-back ratio of Winegard's UHF Model PR-9032 is 14 dB at Channel 14 and 20 dB at both channel 32 and channel 50. The Network Affiliates state that commonly available VHF antennas also appear to easily exceed the assumed front-to-back ratios for the low and high VHF bands. They state that Antennacraft's Model CS 1100 has a front-to-back ratio of 19.4 dB in the low VHF band and 17.6 dB in the high VHF band; and that the front-to-back ratio of Winegard's VHF Model HD4053P is 17 dB or greater across both the low and high VHF bands.[73]

31. The Network Affiliates state that VHF/UHF combination antennas also greatly exceed the assumed front-to-back ratios for the low and high VHF bands and meet the assumed ratios for the UHF band. They indicate that the front-to-back ratio of Winegard's VHF/UHF combination antenna Model HD7084P is 20 dB or greater in the low VHF band, 15 dB or greater in the high VHF band, and is 11 dB at channel 14 and 20 dB at both channel 32 and channel 50. They state that the front-to-back ratio of Antennacraft's VHF/UHF combination antenna, Model HD1850, is 20.2 dB in the low VHF band, 17.3 dB in the high VHF band, and 13.7 dB in the UHF band.[74]

32. Jules Cohen, MSW, the NAB, and the Network Affiliates submit that in addition to selecting antenna with performance criteria that meet their needs, consumers can be expected to exert the same efforts to receive DTV signals that they have always been expected to exert to receive analog signals. They state that this may include the use of a rotor to properly orient the antenna to receive different signals if needed and, in fringe areas where signal strength is known to be weak, use of a low-noise amplifier (LNA) or "pre-amplifier."[75] Jules Cohen, dLR, MSW, and the Network Affiliates report that there are many current offerings of moderately priced LNAs with signal amplification available in values between 18-30 dB and with noise figure values between 3-5 dB.[76] For example, they observe that Winegard currently offers 16 different LNAs with gains ranging from 17 dB to 29 dB and note that the Winegard Model AP-8275 provides an average gain of 29 dB for VHF and 28 dB for UHF with an

[71] *Id.* at 21-22.

[72] *Id.* at 22 (quoting *ATSC Recommended Practice: Receiver Performance Guidelines*, Doc A/74 (June 18, 2004) at 24).

[73] *Id.* at 22-23.

[74] *Id.* at 23.

[75] *Id.* at 23-24; NAB comments at 16-23.

[76] NAB comments, Attachment 1 (Engineering Statement of MSW) at 17-18; see also Network Affiliates comments at 25-26 and Appendix (Engineering Statement of Jules Cohen) at 3.

internal noise figure of only 2.9 dB and 2.8 dB in those respective bands, with a retail price of $77.99 from Solid Signal.[77] Similarly, the Channel Master 7777 has an average gain of 23 dB for VHF and 26 dB for UHF with internal noise figures of 2.8 VHF and 2.0 dB for those respective bands, and it retails for $56.99 from Solid Signal.[78] Also, Antennacraft offers an LNA with adjustable gain to prevent overload, Model 10G212, that provides an average gain of 30 dB for both VHF and UHF with a noise figure of less than 4.0 dB for VHF and less than 3.5 dB for UHF, with a list price of $33.63.[79] The Network Affiliates identify Blonder Tongue and Advanced Receiver Research as additional LNA manufacturers. MSW submits that the ready availability of these preamplifiers provides a substantial "cushion" against the possibility of any losses not specifically accounted for in the planning factors.[80] Jules Cohen states that a conservative choice of parameters to illustrate the advantage of using a pre-amplifier at the antenna would be: amplifier noise figure 5 dB, amplifier gain 20 dB and receiver noise figure of 12 dB.[81] He further states that the resulting system noise figure would be 5.2 dB, which considering that the system noise figures in the planning factors are 10 dB for VHF and 7 dB for UHF, would provide an extra margin to minimize the impact of system mismatches.[82]

33. With regard to proper orientation of antennas, EchoStar contends that even households with outdoor antennas often do not have rotating antennas or have a practicable means of re-pointing their antennas "on the fly" to achieve optimum reception for every broadcast station in the market.[83] It states that in some markets not all of the network stations may be transmitting from the same site, so that there may be no single "optimal" pointing solution. EchoStar further contends that even households with antennas that are capable of rotating generally do not have the ability to adjust the orientation of their antennas "on the fly" so that for most purposes the antenna is non-rotating. In a statement appended to EchoStar's comments, the consulting engineering firm of Hammett & Edison, Inc. (H&E) claims a worst case loss scenario of 14 dB for a high-performance (*i.e.*, high-gain) antenna at UHF.[84] H&E further states that it conducted a study using the Terrain Integrated Rough-Earth Model (TIREM) that found that the majority of all households in the United States are able to receive at least two analog TV stations of Grade B intensity and that, of those households, the majority receive at least one from an angle that differs by greater than 25^{o} from another station.[85] As a result, it contends that almost all households will have impaired reception of at least one station. EchoStar believes that this analysis suggests that signal strength loss from the lack of a rotating antenna can be significant and should therefore be taken into account.[86] It states that one way to do so would be to conduct further study to determine the "average"

[77] Network Affiliates comments at 25 and n.70.

[78] *Id.* at 25 and n.71.

[79] *Id.* at 25-26.

[80] NAB comments at 23, and Attachment 1 (Engineering Statement of MSW) at 18.

[81] Network Affiliates comments, Appendix (Engineering Statement of Jules Cohen) at 3.

[82] *Id.*

[83] EchoStar comments at 7-8.

[84] *Id.,* Attachment A (Engineering Statement of H&E) at 3 (worst case scenarios are 10, 12 and 14 dB for low VHF, high VHF and UHF, respectively). H&E does not provide a value for average signal loss from mispointing,

[85] *Id.*

[86] EchoStar comments at 7-8.

signal loss caused by the lack of a rotating antenna and to subtract that amount from the measured signal strength before comparing it to the Commission's signal strength standards.

34. On the other hand, dLR, the Network Affiliates, and the NAB argue that the Commission should continue to assume that DTV antennas are oriented towards the desired signal, and if the desired stations are not located in the same direction, that that antenna will be orientable in the direction of the desired signal.[87] They argue that this assumption remains appropriate given the availability of reasonably priced antennas and rotors as described above. The Network Affiliates submit that the Electronics Technicians Association (ETA) showed in the Commission's proceeding in CS Docket No. 98-201 that the majority of home antenna systems in Putnam County, Indiana, a location representative of the outer reaches of the service areas of several broadcast stations, contain a rotor (in addition to a LNA) and that this is true even though homeowners in Putnam County can receive network programming from each of the four major networks from stations all located in Indianapolis.[88] They argue that consumers can and will obtain rotors when they believe that they need them. They note statements by the ETA that rotors are economical ($60-$75) and do not require constant rotation and that "to circumvent the intent of the SHVA because the homeowner prefers not to invest in a rotor where needed is not right."[89] The NAB argues that it would be discriminatory to assume that a DBS household's over-the-air antenna is improperly oriented when that same household's satellite antenna must be precisely oriented towards the satellite to get any service at all.[90] It notes that the DTV transition has been premised on the assumption that viewers will use properly oriented antennas to receive digital TV signals.[91]

35. The NAB states that, in most instances consumers can use a single, fixed antenna, because the TV transmitters in many markets are co-located. In such cases, there will be no need for a rotor. It states that in markets where TV towers are located at different sites, local electronics installers sometimes offer a special antenna designed to receive signals from two different directions, again without the need for a rotor. And NAB states that for those instances which differ from the situations just discussed, consumers can acquire, at a modest cost, a rotor that enables a rooftop antenna to be oriented to achieve the best signal from a particular station.[92]

36. With regard to the availability of antenna rotors, the engineering statements and comments submitted by dLR and the Network Affiliates point out that many models, such as those sold by Channel Master, Antennacraft, Delhi (formerly Jerrold), and Radio Shack, are readily available. The comments also indicate that some of these rotors are available with a remote control so that the viewer can properly orient the antenna conveniently, from the couch or other location.[93] The NAB and the Network Affiliates submit that prices for rotors range from $68.99 for a Channel Master unit with remote control (CM 9521A, available from Solid Signal) to $94.88 for an Antennacraft model (available at antennacraft-

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[87] MSTV comments at 2 and Attachment (Engineering Statement of dLR) at 9; Network Affiliates comments at 34-35; NAB comments at 19-20 and Att.1 (Engineering Statement of MSW) at 13-15.

[88] Network Affiliates comments at 27.

[89] *Id.* (quoting CS Docket No. 98-201, ETA Comments, *supra* note 56, at 6).

[90] NAB comments at 19-20.

[91] *See* NAB comments at 25-26.

[92] *Id.* at 20.

[93] MSTV comments, Attachment (Engineering Statement of dLR) at 9; Network Affiliates comments at 27 and Appendix (Engineering Statement of Jules Cohen), Exhibit 3 (Rotors).

tpd.com).[94] Viamorph, a manufacturer and licensor of antenna technologies, states that its research indicates that aiming a directional antenna is more difficult for digital TV signals than for analog TV signals and that a fixed digital TV antenna may not be a viable solution for many consumers.[95] Viamorph submits that it is introducing a new class of antennas which it calls DiSA (Digital Smart Antenna) that automatically adjust their electrical shapes in response to changes in environment and signal conditions so as to maintain optimal performance. We also observe that CEA has issued a voluntary industry standard (CE-909) for TV antennas that automatically adjust their receive pattern to increase their gain in specific directions to receive individual signals. We have examined an antenna system constructed to this standard, the DTA 5000 (manufactured by DX Antenna Co.) which was small enough to be used indoors as well as outdoors, and have observed that it does appear to provide significantly improved reception of individual digital TV signals.

37. With regard to indoor antennas, EchoStar states that, because structures located within the line of sight between a TV transmitter and receiving antenna can block or weaken the strength of received signals, an outdoor antenna will generally allow a stronger signal to be received than will an indoor antenna.[96] It argues that households in which the antenna is placed indoors will generally need an antenna with greater gain than will a household in which the antenna is placed outdoors. EchoStar argues, however, that because of limitations on the physical dimensions of indoor antennas, they have always had less gain than typical outdoor antennas. EchoStar notes that a review by H&E of the existing literature published as recently as 2005 and as far back as 1959 shows that indoor antenna gain is consistently about 9 dB or more below the values for outdoor antennas.[97] EchoStar also submits that signal loss due to building penetration before it reaches an indoor antenna can be as great as 30 dB for VHF signals in a highly populated area like New York City, but this will vary depending on which floor of a building the indoor antenna is located.[98] EchoStar argues that these factors mean that households relying on an indoor antenna for DTV reception are at a considerable disadvantage. It further argues that an outdoor antenna is not practical for many households, particularly those located in apartment buildings and that for these reasons the DTV signal strength standards should take into account indoor antenna use.[99] Paul Robinson similarly argues that in a dense urban area most people may be living in multi-story apartment buildings

[94] NAB comments at 20; Network Affiliates comments at 27-28.

[95] Viamorph comments at 2-4. Viamorph indicates that its DiSA™ antenna is amenable to indoor and outdoor mounting, with the current standard model consisting of a flat, rectangular package about 60 cm by 40 cm (approximately 23 inches by 16 inches) on a side and less than two inches (*i.e.*, about 5 cm) thick.

[96] EchoStar comments at 6. EchoStar (Comments, Attachment A (Engineering Statement of H&E) at 4 and 14-15) points to a study published by the Institute for Telecommunication Sciences in 1979 (FizGerrel, R.G.. *et al.*, "Television Receiving Antenna System Component Measurements," NTIA Report 79-22, June 1979) and to more recent data published by Dielectric Communications (Kerry W. Cozad, "Measured Performance Parameters for Receive Antennas Used in DTV Reception," *Proceedings of the NAB Engineering Conference*, 2005 (Cozad Study)).

[97] EchoStar comments at 6-7. H&E indicates that studies show that indoor antennas typically provide about 8 dB, 10 dB, and 9 dB less gain than outdoor antennas in the low VHF, high VHF, and UHF bands, respectively. EchoStar comments, Att. A (Engineering Statement of H&E) at 4.

[98] EchoStar comments at 7.

[99] EchoStar comments at 6-7.

or in condominium complexes and may be unable to install an external antenna.[100] He urges that the planning factors should take these situations into account.

38. The NAB agrees that indoor antennas provide inferior reception capability to outdoor antennas.[101] In this regard, it observes that indoor antennas are often non-directional and more prone to interference due to being mounted at lower heights and behind wall(s) thus reducing the ambient field strength available to the antenna.[102] NAB also states that indoor antennas are usually nondirectional and therefore more prone to problems from both multipath and interference and are more easily affected by the proximity to viewers whose movement may contribute to altering its reception characteristics.[103] The NAB and MSW further state that it is because rooftop antennas are so much better than indoor antennas that households have long used rooftop antennas to achieve reliable over-the-air reception, particularly where the households are at some distance from the TV transmitting tower.[104] The NAB stresses that rural households often rely on small towers - with over-the-air antennas considerably higher than rooftop level - to receive a strong signal from stations several dozen miles away. This is in contrast to the case of indoor antennas, for which the NAB indicates that recent tests by Kerry W. Cozad show that some currently available indoor antennas deliver a weaker signal than a reference dipole antenna (*i.e.*, these antennas actually have negative gain).[105] The Network Affiliates point out, however, that some indoor antennas currently available have an average gain of approximately 4 dB and, note that the Silver Sensor, with its short connection wire, does not have the line loss assumed in the planning factors.[106]

39. Contrary to EchoStar, the NAB and the Network Affiliates argue that indoor antennas should not be considered in the DTV signal strength standards.[107] They submit that it would be unfair to broadcasters to assume that viewers will use only indoor (or low-quality outdoor) antennas in determining whether DBS subscribers are eligible to receive retransmitted digital network signals. The NAB states that it is specifically because indoor antennas perform so poorly that they should not be considered for defining DTV service.[108] It further states that introducing an assumption that consumers would use indoor antennas would be contrary to one of the most fundamental assumptions of the Commission's entire DTV planning process, leaving broadcasters in the position of having built a system to Commission specifications that the Commission would not deem as adequate because it is not designed to provide service to indoor antennas.[109] The NAB and MSW also state that, had the Commission assumed use of indoor antennas in the planning the digital TV transition, that process would have been radically different, with stations needing enormously higher power levels to reach indoor antennas 50 to 60 miles away.[110]

[100] Robinson Telephone Company comments at 2.

[101] NAB comments at 16-17.

[102] *Id.* at 17.

[103] *Id*.

[104] *Id.* at 17 and Att.1 (Engineering Statement of MSW) at 11-12.

[105] *Id.* at 17 and Att.1 (Engineering Statement of MSW) at 11; see also *id.* at Att. 2 (Cozad Study, *supra* note 96)).

[106] Network Affiliates reply comments at 6.

[107] *Id,* at 16-19; Network Affiliates comments at 34, 39-40.

[108] NAB reply comments at 3-4 and Att. (Reply Engineering Statement of MSW) at 5-6.

[109] *Id.* at 4.

They add that such higher power levels would have changed the interference calculations. The Network Affiliates similarly argue that it is critical to the Commission's plan to replicate analog TV service areas to presume that households will exert similar efforts to receive DTV signals as they have always been expected to do to receive analog TV signals.[111]

40. *Evaluation*. After considering the above information, in response to Section 339(c)(1)(B)(iii) we conclude that the current DTV planning factor assumptions for antenna gain, orientation, and placement remain appropriate and should not be altered for the reasons discussed below. Following from that conclusion, we also find that the current signal strength standard for determining whether a household can receive a high-quality picture using antennas of reasonable cost and ease of installation remains satisfactory and that a different standard is not needed. With respect to Section 339(c)(1)(B)(i), we also specifically conclude that the digital television signal strength standards in the Commission's rules should not be modified to account for the fact that an antenna can be mounted on a roof or placed within a home and can be fixed or capable of rotating.

41. The record on the performance capabilities and availability of antenna receiving equipment indicates that there are a very large number of options for antennas that meet or exceed the gain and front-to-back ratio capabilities assumed in the planning factors. In particular, we observe that antennas that provide gain of 7 dB, 11 dB, and 14 dB or more and front-to-back ratios of 19 dB, 17 dB, and 20 dB in the low VHF, high VHF, and UHF bands respectively are readily available in a variety of models and at a range of affordable prices, *i.e.*, from about $35 to about $100. These capabilities compare favorably to the respective planning factors gain values of 4 dB, 6 dB, and 10 dB and front-to-back ratios of 10 dB, 12 dB, and 14 dB by a fair margin (these performance levels exceed the gain standards by 3 dB, 5 dB, and 4 dB and the front-to-back ratio standards by 9 dB, 5 dB, and 6 dB, respectively). In cases where additional margin in the received signal-to-noise ratio is needed, there are numerous models of low-noise amplifiers available. Similarly, we observe that there is a wide variety of models of antenna rotor devices available, including units with remote controls, at reasonable prices. As the Network Affiliates point out, the Commission has long recommended that households in outlying or difficult reception areas use equipment and mounting locations appropriate to their needs. This equipment can include separate UHF and VHF antennas, which generally provide better performance than a combination UHF/VHF antenna at little or no additional cost. Our own review of the websites of various TV receive system retailers also indicates that products with lower performance levels and prices that can meet many households digital TV receive system needs are readily available. Thus, it is clear that the availability of digital TV receive systems that meet or exceed the antenna performance planning factors is not a constraint on viewers ability to receive signals under the current noise-limited DTV field strength signal intensity standards. The parties commenting in our *Inquiry* did not specifically address the issue of ease of antenna installation. However, based on the experience of the Commission and its staff over many years we do not believe that ease of installation is generally a concern for households in installing the types of antenna needed for use with over-the-air DTV service. Those antennas are essentially of the same design and mounting configuration as those that have been used for analog TV service (antenna design depends on the desired frequency, gain, and front-to-back ratio characteristics, but not on the modulation type, *e.g.*, analog or digital, of the signals to be received). TV antennas can in almost all cases be installed by a household resident or, if the resident desires, a professional installer for a modest charge.

42. We recognize that in some situations the transmitters of digital TV signals that households may desire to view are located in directions that vary by more than the 25^{o} of main beam reception capability provided by typical TV antennas. In such cases the households need either a multiple direction

[110] *Id.* at 18-19 and Att. 1 (Engineering Statement of MSW) at 3-4.

[111] Network Affiliates comments at v, 13-15.

antenna system or an antenna with a rotor that allows the single antenna to be re-oriented in the direction of the desired signal. We find that the signal strength standards do not need to be modified to account for situations where households need to be able to receive signals from multiple directions. We agree with dLR, the Network Affiliates, and the NAB that the digital TV planning model should continue to assume that a) digital TV antennas are oriented towards the desired station and b) if the stations that a household desires to view are not all located in the same direction, then the household employ an antenna that can be re-oriented in the proper direction to receive any such desired station at any given time. As supported by the pattern of antenna rotor use in Putnam County, Indiana that is described in the record of our *Inquiry*, we conclude that consumers will obtain and use rotors if they need them. Likewise, in the many instances where households view signals radiating from one particular direction only, we conclude that those households would not need a rotor and therefore would not install one. We recognize EchoStar's point that a large number of households might be able to better receive signals from stations transmitting from different directions, often from neighboring markets, if they used a rotor. We believe, however, that it is best left to individual households to determine whether signals emanating from different directions are sufficiently desirable to view and, thus, whether to install a rotor to enable their reception. In any case, where a rotor could assist in the reception of television signals for whatever reason, consumers are able now to obtain them readily at affordable prices. We also conclude that it would unnecessarily penalize broadcasters and distort the digital TV service planning model to reduce the assumed available DTV field strength by some factor based on a households' use of a rotor as suggested by EchoStar. We do not recommend such action.

43. We also find that it would not be appropriate to account for the use of indoor antennas in the DTV field strength signal standards for purposes of determining eligibility for reception of distant network signals. As observed by the commenting parties, the strength of signals available for indoor reception is lower due to signal attenuation caused by walls and other structural features and, in most cases, lower antenna height available indoors. The amount of signal attenuation indoors will depend on the material used in a building's construction and where the antenna is located within the building. In addition, the smaller antenna designs that are suitable for indoor use provide less gain than their outdoor counterparts. The differences in the indoor and outdoor reception conditions mean that service will be receivable in many areas with an outdoor antenna but not with an indoor antenna. We believe that it would be impractical to attempt to account for indoor reception conditions in the DTV planning factors. As NAB and MSW observe, the technical standards for the digital television service were established assuming use of outdoor antennas at 9 meters/30 feet height above ground and with the gain set forth in the planning factors. If DTV service were instead based on consideration of indoor reception, then the power levels needed to replicate stations' analog service at distances of 55-60 miles or greater would be substantially higher. For example, if the antenna difference were assumed to be -9 dB, as suggested by EchoStar and H&E, for indoor antennas and building penetration loss were assumed to be a conservative 21 dB, then stations would need to transmit signals with an additional 30 dB of power, or 1000 times the power now authorized for DTV stations.[112] Such power levels are not practical as they would greatly increase the potential for interference between stations and pose power costs for stations that would likely be so high as to threaten the economic viability of many stations. In addition, as discussed more fully below in the section on the digital television measurement procedure, it is not practical or reasonable to specify an indoor reception situation as the signal level that is available indoors will vary significantly at different locations within a residence. For example, the signal level available near an unobstructed window is likely to be higher than that which is available in a basement or an interior room with masonry walls.

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[112] A 30 dB power increase would mean that a station operating at 1 MW DTV power would need to operate with 1000 MW, an enormously high power level that is not achievable by currently available TV transmitters.

44. We therefore believe that the current DTV service and operating model that allows stations to replicate their analog service areas based on similar assumptions, *i.e.*, service to outdoor antennas at 9 meters, remains the most appropriate plan for this service. As with analog TV, digital TV signals are receivable at many locations with an indoor antenna. As the distance between the DTV transmitter and receive locations increases, the received signal strength decreases and the opportunities for indoor reception decrease in the same manner as for analog service. We also believe that it would be impracticable to establish a regime whereby households with indoor antennas are subject to different signal strength standards than those with outdoor antennas. The difficulty would arise in setting and applying standards for situations in which a household could not use an outdoor antenna.

45. We recognize that there are instances such as those in which households are located in apartment buildings and condominium complexes where viewers may be unable to use an outdoor antenna. However, we find that commenting parties representing broadcast interests make a compelling point in their observation that satellite dishes likewise can not provide service indoors to such households. We anticipate that if a household were able to install a satellite dish outdoors, it could, in some instances, co-locate an effective broadcast receive antenna with that dish.

2. Receiver Performance

46. At the other end of a household's TV receiving system path is the television receiver. This device receives the broadband electric energy that is taken from the air by the antenna and conveyed to it by the downlead connecting wire, selects the channel desired by the viewer, and processes the information on that channel to provide digital television and other services to the consumer. The desired channel is selected by the receiver's tuner section and then demodulated to produce the 19.4 mbps ATSC digital bitstream that carries the program and other information provided on the signal by the broadcast TV station. The performance of a digital television receiver with respect to reception of service for purposes of SHVERA eligibility determinations depends on its noise figure, signal-to-noise (S/N) ratio, and adaptive equalizer capabilities.[113] Noise figure is a measure of the level of noise generated internally within the device.[114] Signal-to-noise ratio is a measure of the receiver's ability to discern a desired digital television signal from other energy (noise) that is present in the signal's channel. The adaptive equalizer is a feature of a digital television receiver's tuner section that determines its ability to handle reflections of the desired signal. These reflections are also known as multipath signals and can be observed on analog television pictures as "ghosts."[115] The noise figure and S/N measures are included in the DTV planning factors as indicated above. The planning factors assume use of a receiver that has noise figure levels of not more than 10 dB in the low and high VHF bands and 7 dB in the UHF band and that can provide service when the received S/N ratio is 15 dB or more. If the representative values of actual receiver noise figures and S/N ratios are different from those of the planning factors it could affect the minimum field strength needed for service. If the sum of these factors is greater or lower than that assumed in the planning factors, a higher field or lower field strength, respectively, would be needed for service. Adaptive equalizer performance is not included in the planning factors because it was assumed that the receiver designs for this feature would adequately handle multipath signals. However, adaptive equalizer performance did become of concern more recently when it was determined that multipath was a

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[113] There are other receiver performance factors such as selectivity, overload, and shielding against signal ingress that affect its ability to reject unwanted signals. These factors are less important in the context of this Report.

[114] All electronic devices generate some amount of internal noise, the level of which depends on their design and the components used in their construction.

[115] With digital television service, if a receiver's adaptive equalizer is unable to handle multipath the result is no service.

larger challenge than initially anticipated and that a high level of ability to cope with multipath signals is important to reception of DTV signals.

47. In the *Inquiry*, as directed by Section 339(c)(1)(B)(v) we requested comment and information on whether there is a wide variation in the ability of reasonably priced consumer digital television sets to receive over-the-air signals, so that at given signal strengths some sets are able to display high-quality pictures while other sets cannot, and if so, whether this variation is related to the price of the television set. As further directed by Section 339(c)(1)(B)(v), we also requested comment on whether such variation should be factored into setting a standard for determining whether a household is unserved by an adequate digital signal. In considering these questions, we note that the nature of digital television operation is such that a receiver will provide a high-quality picture (consistent with its display capabilities) at all signal levels at or above its threshold of service.[116] When the received signal/field strength falls below the minimum service threshold there is a very sudden loss of service that occurs over a signal strength change of less than 1 dB. This sudden loss of picture service, which first appears as blocking and freezing of portions of the image, is called the DTV "cliff effect." This operating characteristic is in contrast to analog TV service in which picture quality degrades gradually as signal strength declines. Thus, we will assume in our evaluation of digital television receiver performance that picture quality remains high at all signal/field strength levels above the minimum threshold needed for service.

48. In the *Inquiry*, we specifically requested that commenting parties provide information regarding the sensitivity of various receivers and their interference rejection capability. We asked that this technical information be accompanied by price data and analysis regarding the correlation between performance and price. Finally, we asked if there are significant differences in digital receiver performance quality and, if so, should those differences be factored into the determination of whether a household is unserved by an adequate digital signal. The Commission's Laboratory staff also undertook a technical measurement study of the performance capabilities of a sample of the digital television receivers currently on the market, looking at noise figure, S/N/ ratio, adaptive equalizer/multipath handling performance, and price.

49. *Inquiry Record*. With regard to DTV receiver noise figure performance, dLR states that it has not independently tested a representative sample of DTV receivers for their noise figure performance and assumed that information would be developed from the Commission's receiver study in this matter.[117] MSW and the NAB submit that while there is little published data about receiver noise figures, consumers can, in any event make the noise figure of a receiver irrelevant by employing an inexpensive preamplifier.[118]

50. Concerning the DTV receiver S/N ratio, dLR states that laboratory measurements by Bouchard, *et al*., of the Communications Research Center Canada (CRC) in late 2000 (Bouchard study) demonstrate S/N levels consistent with the Commission's assumed value of 15.2 dB for this planning

[116] Digital television receivers are typically designed to provide picture quality at one of several maximum quality levels: standard definition (similar to analog 480i service), enhanced definition (480p or 640p), or high definition (720p or 1080i). The price of receivers generally increases with higher picture quality capability.

[117] MSTV comments, Att. (Engineering Statement of dLR) at 8.

[118] NAB comments at 22, Att. 1 (Engineering Statement of MSW) at 17.

factor.[119] The measurements in this study were conducted on a sample of six DTV receivers manufactured in the period 1999-2000. For a weak desired signal, the study found a S/N range or 15.3 dB to 17.8 dB, with a median S/N of 15.6 dB. The five best out of the six had a S/N of 15.3 dB to 16.6 dB with a median S/N of 15.4 dB.[120] dLR further states that laboratory measurements by the CRC on a Zenith fifth generation DTV receiver in September 2003 also show S/N measurement results that are consistent with the Commission's planning factor value.[121] dLR submits that these results show a measured S/N of 15.9 dB in the presence of a weak signal level, which is within .7 dB of the planning factor value and indicates that the latest generation of DTV receivers will perform in line with those of earlier manufacture.

51. EchoStar argues that the DTV signal strength standards should be revised upwards because the signal sensitivities of the current generation of consumer DTV receivers can be significantly worse than the signal sensitivities, *i.e.*, S/N ratio plus noise figure, assumed in the planning factors for UHF and VHF reception.[122] It argues that as a result of this difference in performance versus assumption, many consumer DTV sets may not be able to display a DTV picture even when the signal strength meets the Commission's standards. In support of EchoStar's position, H&E evaluated five DTV receivers for sensitivity in comparison to the DTV planning factor values.[123] H&E submits that its results show that the measured sensitivities range as much as 6.6 dB higher than the planning factor values of -81.4 dBm and -84.4 dBm, that the receivers differed in sensitivity by 2-6 dB under favorable field conditions, *e.g.*, no multipath signals, and the average receiver in its study was 2.6 dB less sensitive than the planning factor value. In its reply comments, ATI points out that the H&E study considered older receivers that did not conform to the ATSC A/74 receiver performance standards or incorporate current models of VSB demodulators and so it is not surprising that the receivers H&E tested suffer from the shortcomings that the fifth generation of VSB demodulators was designed to resolve.[124]

52. EchoStar and H&E submit that multipath handling capability can affect a digital television receiver's ability to provide service.[125] They state that multipath can be measured and its severity can be expressed as a signal strength penalty caused by the adaptive equalizer in a receiver attempting to compensate for the multipath. H&E states that a receiver's adaptive equalizer, in attempting to compensate for the multipath will increase the system's noise level at the frequencies of compensation. H&E submits that at a good receiver location with little multipath, the adaptive equalizer tap energy might be about -10 dB, corresponding to a white noise penalty of less than 0.5 dB and that at a poor

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[119] MSTV comments, Att. (Engineering Statement of dLR) at 8 and n.3 (citing Bouchard, Pierre, *et al.*, "Digital Television Test Results – Phase I," Communications Research Centre (Ottawa, Canada), *CRC Report No. CRC-RP-2000-11*, November 2000).

[120] The worst performing receiver in the Bouchard study was the oldest measured unit.

[121] MSTV comments, Att. (Engineering Statement of dLR) at 8-9 and n.4 (citing "Results of the Laboratory Evaluation of Zenith 5th Generation VSB Television Receiver for Terrestrial Broadcasting," Report Version 1.1, Communications Research Centre Canada, September 2003).

[122] EchoStar comments at 4 and Att. A (Engineering Statement of H&E) at 12-13.

[123] EchoStar comments, Att. A (Engineering Statement of H&E) at 12-13. Three of the receivers in the H&E study were obtained from retailers in May 2005, the fourth was an older model purchased in 2000, and the fifth was a professional ATSC demodulator.

[124] ATI reply comments at 2.

[125] EchoStar comments at 5 and Att. A (Engineering Statement of H&E) at 8-9.

location the white noise penalty may exceed 2 dB. H&E further states that laboratory tests by others showed that receiver sensitivity decreased on the order of 0-5.3 dB in the presence of multipath.[126]

53. Other commenting parties generally observe that in the early stages of the DTV transition, multipath was found to be much more difficult for digital TV reception than it was for analog TV reception. dLR, MSW, the NAB and the Network Affiliates state that the fifth generation DTV receivers now commercially available in integrated sets from manufacturers such as LG and Zenith have made substantial improvements in equalizer architecture and can now handle 50 microsecond pre-ghosts and 50 microsecond post-ghosts.[127] dLR submits that a paper by Tim Laud of Zenith reports laboratory results demonstrating fifth generation equalizer capability to handle ghosts of up to 50 microseconds and at a level of 100% (that is, the ghost reflection would be at the same level as the principal signal).[128] dLR, MSW, and NAB note that Tim Laud's paper also reports on field tests on fifth generation receivers in Washington, DC, Ottawa, Canada, and Baltimore, MD, where significant improvements in performance at known "difficult" locations were demonstrated. dLR states that in these field tests, fifth generation receivers showed improvements ranging from an elimination to near elimination of failures (in the Ottawa and Baltimore tests) to a reduction in failures by a factor of three (in the Washington tests). ATI, a manufacturer of electronic components including DTV receiver chips, recommends that in evaluating multipath, the Commission specify the multipath field ensembles set forth in the ATSC's "A/74 Recommended Practice: Receiver Performance Guidelines." It submits that, in contrast to the field ensembles, the "laboratory ensembles" referenced in that document do not provide an adequate basis for predicting how well a receiver will perform in the field.[129]

54. The Network Affiliates submit that because multipath is not a function of signal strength *per se* and because current fifth generation receivers can handle multipath even in generally poor reception conditions, the Commission's DTV planning factors do not need to be adjusted to account for multipath by increasing the value of the minimum field strength assumed to be needed to receive service.[130] The Network Affiliates state that the effects of multipath can be mitigated greatly, if not wholly, by the use of the latest generation receiver, by the use of an outdoor antenna raised to 9 meters/30 feet that will place the antenna above the principal multipath reflectors (*e.g.*, moving vehicles and neighboring residences), and by the use of highly directional antennas with high front-to-back ratios, properly oriented to the strongest desired signal.[131] They point out that the ATSC has stated that "[A]n antenna with a directional

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[126] EchoStar comments, Att. A (Engineering Statement of H&E) at 12 and nn.37-38.(citing Charles Einhoff, "DTV Receiver Performance in the Real World," *Proceedings of the NAB Broadcast Engineering Conference*, 2000, and Bernard Caron, *et al.*, "ATSC 8-VSB Receiver Performance Comparison," *Proceedings of the NAB Broadcast Engineering Conference*, 2000).

[127] MSTV comments, Att. (Engineering Statement of dLR) at 8-9; NAB comments at 39-40 and Att. 1 (Engineering Statement of MSW) at 35-43; Network Affiliates comments at 29-31.

[128] MSTV comments, Att. (Engineering Statement of dLR) at 9 and n.5 (citing Tim Laud, *et al.*, "Performance of 5th Generation 8-VSB Receivers," IEEE Transactions of Consumer Electronics, Vol. 50, No. 4, Nov. 2004, and Yiyan Wu, *et al.*, "An ATSC DTV Receiver With Improved Robustness to Multipath and Distributed Transmission Environments," IEEE Transactions on Broadcasting, Vol. 50, No. 1, March 2004).

[129] ATI comments at 3-5. ATI also indicates that in cooperation with its customers in all affected industries it has developed a robust test procedure and grading system for evaluating multipath based on the A/74 field ensembles. See *id.* at 5-7 and Att. B (ATI White Paper, June 2005).

[130] Network Affiliates comments at 30.

[131] *Id.* at 37.

pattern that gives only a few dB reduction in a specific multipath reflection can dramatically improve the equalizer's performance. Such modest directional performance can be achieved with antennas of consumer-friendly size, especially at UHF."[132] Further, the Network Affiliates observe that there is no principled basis to include multipath in the distant signal eligibility standards since there still remains no objective means to predict or evaluate multipath at any particular location or to evaluate the impact of multipath on local television service generally.

55. ATI submits that the current DTV receiver marketplace offers end-users superior performance that is highly affordable, with market trends projecting increasing affordability and performance as manufacturers integrate the latest generations of DTV receiver chips into their products.[133] ATI and the Network Affiliates state that variations in DTV set prices should play no role in determining whether a household is unserved by an adequate DTV network signal.[134] They state that there is as yet very little consumer penetration of DTV receivers and that most households will therefore have or will acquire DTV receivers with integrated tuners incorporating the latest generational chip design (fifth generation or later), including adaptive equalizers with superior multipath handling performance capabilities. ATI states that neither price nor brand name indicates to consumers the performance of DTV receivers and using the best chips does not necessarily cost more.[135] It submits that as a result, consumers lack sufficient information for purchasing products based on DTV receiver performance. CEA submits that in a market guided by competition and not Government intervention, it should be expected that there will be products that optimize for different parameters.[136] CEA states that these variations are relatively small, as every manufacturer is motivated by competition to build good receivers, but the variations still serve the market. For example, it states that a DTV receiver that has relatively poor weak signal reception as compared to every other receiver in the market might have excellent selectivity and prove to be the ideal receiver for a particular location with closely packed channels. Conversely, CEA states that even if the Commission were to determine that there is very little variation in the ability of existing DTV sets to receive over-the-air signals, those same sets when connected to the many different available antennas and placed in the infinitely complex RF environment will certainly demonstrate a wide variation in reception capability.

56. The Network Affiliates submit that with digital tuners manufactured in mass quantities to satisfy the Commission's digital tuner mandate, the cost of an integrated DTV set is not particularly dependent on the cost of the generation of chip design (for example, fourth generation vs. fifth generation).[137] Instead, they argue that DTV set prices are largely dependent on features such as ATSC format/resolution capabilities (standard definition, enhanced definition, and high definition), screen size, screen technology (CRT, plasma, LCD, DLP), contrast ratio, and integration of other functions such as digital video recorders. The Network Affiliates submit that a survey of the Sharp "Aquos" and LG websites revealed no difference in the type of ATSC tuner included in integrated DTV sets within each manufacturer's product lines. They state that it would be inconsistent with the principal of localism and the objective standards Congress has always imposed on the "unserved household" definition to permit a

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[132] *Id.* (citing *ATSC Recommended Practice: Receiver Performance Guidelines,* Doc. A/74 (June 18, 2004) at 24).

[133] ATI comments at 7-9.

[134] *Id.;* Network Affiliates comments at 35-37.

[135] ATI comments at 7-9.

[136] CEA comments at 4-5.

[137] Network Affiliates comments at 36.

satellite carrier to deliver a duplicating distant network signal to a household merely because the household had purchased, probably unknowingly, an inferior DTV set. They note that the current analog "unserved household" definition is not dependent on whether a household buys a $59 13-inch television set or a $400 27-inch set. They state that there is no reasonable basis to make such a distinction in the digital context.

57. *FCC Laboratory Receiver Study*. In order to obtain additional information on the performance of DTV receivers, the Commission's Laboratory conducted a technical measurement study (FCC Study) of a sample of 28 DTV receivers currently available on the market.[138] The objectives of this study were to provide empirical information on the minimum signal level needed by consumer DTV receivers to provide service and whether the minimum signal level needed to provide service varies across DTV receivers by price. It also examined these receivers with respect to their S/N ratios, inferred noise-figures, and performance in the presence of multipath reflections using 47 of the 50 ATSC recommended difficult reflection "captures," or "ensembles."[139] Tests were performed on three TV channels (channels 3, 10, and 30) in order to evaluate performance in the low VHF, high VHF, and UHF bands, respectively. The study receiver sample consisted of 28 products in two categories, set-top-boxes (STBs) and integrated DTV receivers. STBs were included because connection of an STB to an existing television set represents the lowest-cost alternative for DTV reception. All receivers were standard, off-the-shelf consumer products currently on the market and were provided on our request by their manufacturers. In examining the components of DTV receiver performance, the study considered that the minimum signal level needed to receive service is determined by the combined influence of the effective internal noise created by a receiver's internal circuitry (noise figure), signal-to-noise ratio (also termed white noise S/N threshold), and thermal noise, as included in the DTV planning factors. The minimum signal level needed to receive service is the threshold level at which errors become visible in the displayed picture, *i.e.*, threshold of visibility (TOV). Thus, we have:

Minimum Signal at TOV (dBm) = Thermal Noise (dBm) + Noise Figure (dB) + Required CNR (dB) [140]

58. The receivers were measured in the presence of conditions of white noise and of the multipath reflections indicated above. The results were reported by category (STB or integrated receiver) and price range ($370 - $1000, $1001 - $2000, and $2001 - $4200). Brands and model numbers were not reported. The results of this study are described below.

59. The summary results for the minimum signal level factor over all samples in the white noise conditions are shown in Table 1:

[138] *See* "Tests of ATSC 8-VSB Reception Performance of Consumer Digital Television Receivers Available in 2005," OET Report FCC/OET TR 05-1017, Stephen R. Martin, FCC Laboratory Division, November 2, 2005 (*FCC Study*). A copy of this report is attached hereto as Appendix C.

[139] See "*ATSC Recommended Practice: Receiver Performance Guidelines*," ATSC Doc. A/74, Advanced Television System Committee, 17 June 2004. A multipath capture is a recording of the multipath signal pattern that is present at a given location. These are also termed ensembles because a set of specific reflections, *i.e.*, ensemble, will be present at any given location. Three of the 50 recommended captures were excluded from our Laboratory testing because they contain no video content and therefore require specially instrumented receivers for testing.

[140] Receiver noise figures were determined by inference from this equation using the thermal noise figure common to all receivers and the measured S/N for each receiver.

MINIMUM SIGNAL LEVEL AT TOV	Chan 3	Chan 10	Chan 30
Planning factor values (dBm)	-81.0	-81.0	-84.0
Median across all receivers (dBm)	-82.2	-83.2	-83.9
Difference from OET-69 planning factors	-1.2	-2.2	0.1
Deviations of receivers from median (dB)			
--Best performing receiver (dB)	-2.5	-1.7	-1.4
--Worst performing receiver (dB)	12.5	4.3	2.5
--90th percentile receiver (dB)	5.1	3.1	1.3
Standard deviation (dB)	3.7	1.6	0.9
Total span from worst to best receiver (dB)	15.0	6.0	3.9

Table 1 Statistics of Minimum Signal Level at TOV

60. The median minimum signal levels for the study sample were slightly better - by 1.2 dB and 2.2 dB, respectively – than the low-VHF and high-VHF planning factor value (-81.0 dBm) and closely matched the UHF planning value (-84.0 dBm). At low VHF, only 21% of the tested receivers performed more poorly in minimum signal level than the performance measures modeled in OET Bulletin No. 69 by an amount exceeding 1 dB, the approximate tolerance of the measurements.[141] At high VHF and UHF, this figure was 11% and 18% respectively. The variation among receivers at low VHF was fairly large, with a 3.7 dB standard deviation. The two receivers exhibiting the poorest performance were at levels 10.6 dB and 12.5 dB worse than the median. These two receivers, both the same brand, were responsible for much of the variability and omitting them from the results reduces the low VHF standard deviation to 2.3 dB. The third worst performer at low VHF was 6.7 dB above the median. 89% of the receivers (all but three) were within 5.1 dB of the median at low VHF.

61. The performance results for the individual receivers are shown in Figure 1:

[141] The absolute measurement accuracy of the vector signal analyzer on the amplitude range that was used for the measurements was +/- 1.5 dB maximum and +/- 0.5 dB typical.

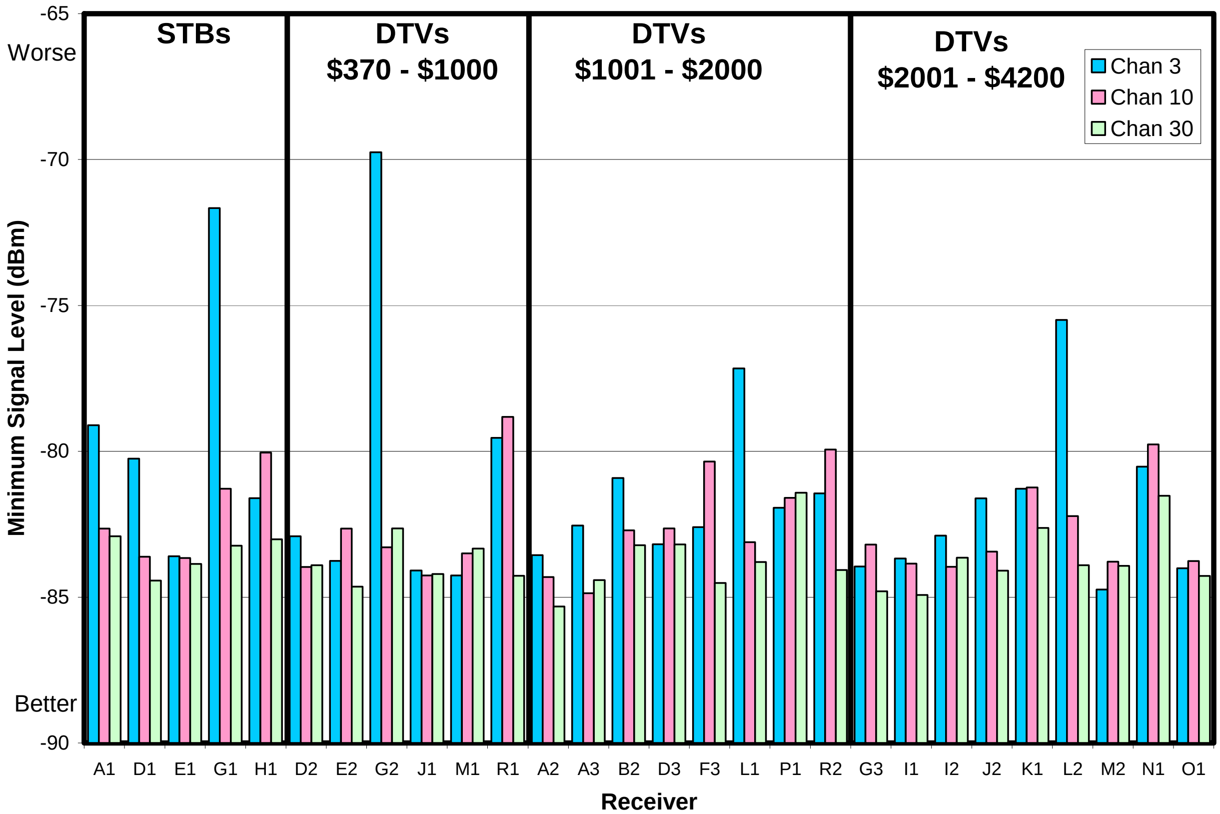

Figure 1. Measured Minimum Signal Level at TOV on Three Channels[142]

62. Looking at the variation of the minimum signal level factor under the benign conditions by product category and price, as shown in Table 2 the FCC Study found:

MINIMUM SIGNAL LEVEL AT TOV (difference from the median by category and price)	**Chan 3**	**Chan 10**	**Chan 30**
Difference of Set-Top Boxes from Overall Median (dB)	2.0	0.5	0.7
Difference of Low-Price DTVs from Overall Median (dB)	-1.1	-0.2	-0.2
Difference of Medium-Price DTVs from Overall Median (dB)	0.0	0.5	0.0
Difference of High-Price DTVs re Overall Median (dB)	-0.7	-0.3	0.0

Table 2 Product-Type Variations of Minimum Signal at TOV

63. This chart shows that the observed variations in minimum signal level across product and price categories were very small. The category medians for high VHF and UHF differ from the overall median by less than 1 dB and for low VHF differ by only 2.0 dB. At low VHF the median performance of the set-top boxes was 2.0 dB worse than the overall median of all receivers and the best median performance was achieved by the low-price DTV receiver category, which slightly outperformed the medium and high-priced categories. At low-VHF, the median of the highest priced sets was only 0.7 dB

[142] The letter/number designations indicate the individual receivers tested.

better than the overall median. In the high VHF and UHF bands the performance differences from the overall median were even less. Most of the differences in median values between categories are so small as to be considered insignificant. We believe that even the largest of these differences would affect perceived performance only in locations where the signal margin was very small and in the general case would not be noticeable to consumers at all.

64. The FCC study found that the white-noise S/N threshold for the median receiver in the sample was 15.3 dB, only 0.1 dB above (worse than) the planning factor value. The white-noise S/N threshold results are summarized in Table 3:

WHITE NOISE S/N THRESHOLD	
Planning Factor Value (dBm)	15.2
Median across all receivers (dBm)	15.3
Difference from OET-69 planning factor	0.1
Deviations of receivers from median (dB)	
--Best performing receiver (dB)	-0.4
--Worst performing receiver (dB)	0.5
--89th percentile receiver (dB)	0.3
Standard deviation (dB)	0.2
Total span from best to worst receiver (dB)	0.8[143]

Table 3 Statistics of White Noise Threshold

65. These results show that the variations in S/N performance among receivers is quite small, with the standard deviation of the S/N measurements across all of the sample receivers amounting to only 0.2 dB. The total range from best to worst performing receiver was 0.8 dB, with the worst performing receiver only 0.5 dB above the median performance. Similar lack of variation in S/N performance was found with respect to price, as shown in Table 4. The median performance of the least expensive receivers, the STBs, was only 0.1 dB worse than the overall median. The median low-cost and mid-cost integrated sets performed at the median, while the median high-cost integrated set performance is only 0.2 dB better than the overall median.

WHITE NOISE THRESHOLD	
Difference of Set-Top Boxes from Overall Median (dB)	0.1
Difference of Low-Price DTVs from Overall Median (dB)	0.0
Difference of Medium-Price DTVs from Overall Median (dB)	0.0
Difference of High-Price DTVs from Overall Median (dB)	-0.2

Table 4 Product-Type/Price Variations of White Noise Threshold

[143] The span does not match the difference between worst and best performing receivers due to the rounding of results to the nearest 0.1 dB.

66. The study derived the receivers' inferred noise figure performance from the measurements of minimum signal level and S/N level under benign conditions and using -106.2 dBm as the value for thermal noise. The inferred noise figure values are shown in Table 5.

NOISE FIGURE	Chan 3	Chan 10	Chan 30
Planning Factor Values	10	10	7
Median across all receivers (dBm)	8.8	7.6	6.9
Difference from OET-69 planning factors	-1.2	-2.4	-0.1
Deviations of receivers from median (dB)			
--Best performing receiver (dB)	-2.5	-1.3	-1.3
--Worst performing receiver (dB)	12.2	4.5	2.6
--89th percentile receiver (dB)	4.5	3.3	1.2
Standard deviation (dB)	3.6	1.6	0.9
Total span from worst to best receiver (dB)	14.7	5.7	3.9

Table 5 Statistics of Receiver Noise Figure

67. These data show that the noise figures for the currently available receivers in the FCC study are generally better than the planning factor values by 1 or 2 dB at low and high VHF and are the same as the planning factor value at UHF. There is considerable variation in the sample receivers' noise figure performance at low VHF, with a standard deviation of 3.6 dB and with two receivers performing at levels 10.3 dB and 12.2 dB worse than the median. However, 89% of the receivers (all but three) were no more than 4.5 dB above (worse than) the median performance at VHF.

68. As shown in Table 6, the observed variations in noise figure with product category and price were small, with the category medians differing from the overall median by less than 1 dB for channels at high VHF and at UHF, but were slightly larger at low VHF. At low VHF the median performance of set-top boxes was 1.7 dB worse than the overall median of all receivers, and the median performance of the highest priced TV category was 0.8 dB better than the median. The best median noise figure, 1.4 dB better than the overall median, occurred in the lowest priced integrated receiver category. Such differences as shown in Table 6 are likely to influence performance only in locations where the signal margin is very small and generally would not be noticeable to consumers.

NOISE FIGURE	Chan 3	Chan 10	Chan 30
Difference of Set-Top Boxes from Overall Median (dB)	1.7	0.1	0.6
Difference of Low-Price DTVs from Overall Median (dB)	-1.4	-0.1	0.1
Difference of Medium-Price DTVs from Overall Median (dB)	0.0	0.4	-0.1
Difference of High-Price DTVs from Overall Median (dB)	-0.8	-0.3	0.0

Table 6 Product-Type/Price Variations of Receiver Noise Figure

69. Finally, measurements of the performance of the sample DTV receivers in the presence of the 47 multipath ensembles are shown in Figure 2:[144]

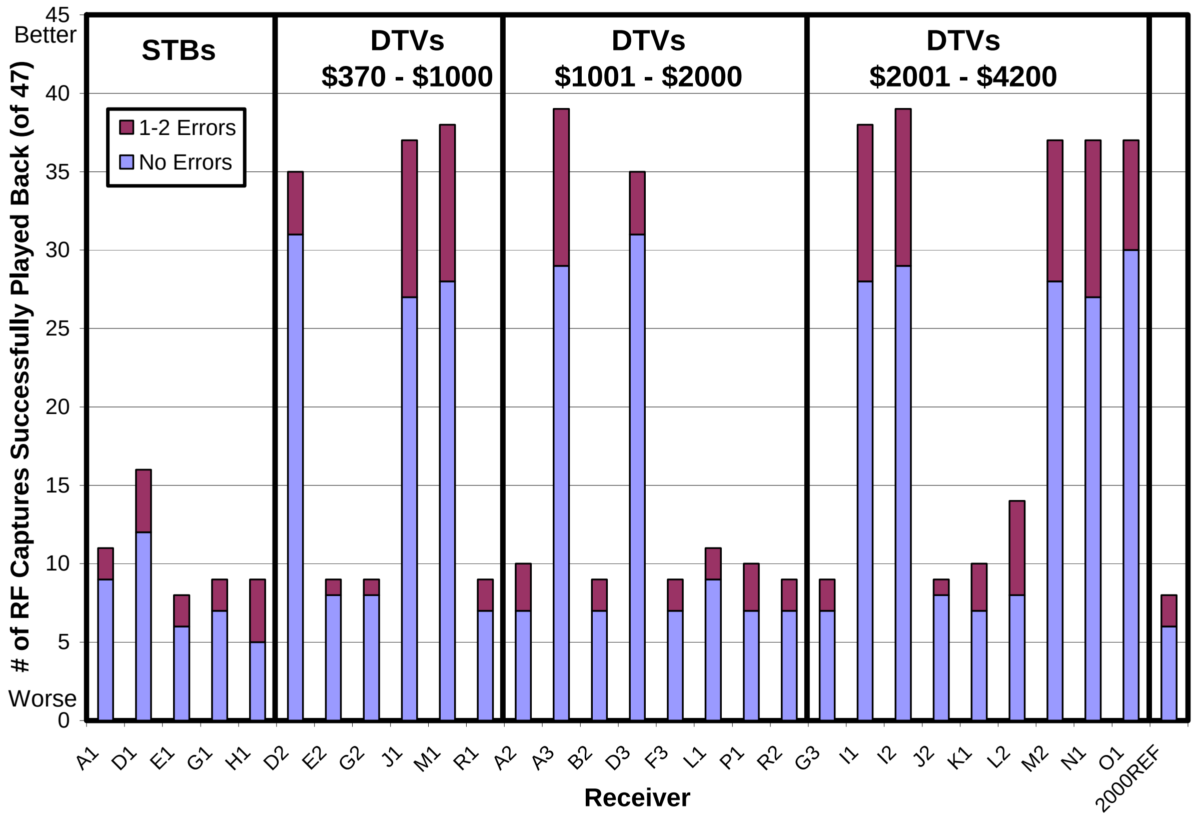

Figure 2 Performance against 47 RF Captures

70. Unlike the results for white noise performance, the results of testing against the RF captures were heavily clustered into two performance tiers.[145] The better performers successfully played 29 captures without error and about 37 captures with two or fewer errors. The lower tier performers successfully played about 7 captures without error and about 9 with two or fewer errors. Except for

[144] In this testing, each receiver was subjected to exactly the same multipath conditions for each capture (the captures are recordings). The lower portion of each bar represents the number of captures that played without a visible error during a single loop, *i.e.*, recording of the capture (a recording of multipath capture is played continuously in a loop). The upper portion of each bar adds the captures that played with no more than two visible errors during a single loop of capture. This chart also includes a bar on the right showing the results for the reference receiver used the FCC field tests in 2000, *see* "A Study of ATSC (8-VSB DTV Coverage in Washington, DC, and Generational Changes in DTV Receiver Performance," (Interim Report) OET Report, FCC/OET TRB-00-2 (2001 FCC Field Test Receiver Study), William H. Inglis and David L. Means, February 2, 2001.

[145] It should be noted that some of the RF captures may contain recording flaws that could prevent error-free demodulation regardless of how advanced the demodulator technology may be, *see FCC Study*, *supra* note 138, at 6-3. For example, four of the captures for which no tested receiver achieved demodulation free of visual errors were identified by the ATSC as having possible non-linearities caused by high-level adjacent channels overdriving the recording system. These or other potential flaws may preclude a 100% success rate on the 47 captures from ever being achieved by any demodulator. Thus, the FCC Study views the multipath performance data based on these captures to be useful for purposes of comparing receivers, but not as an absolute measure of performance.

receivers D1 and L2, all results fall within ±2 captures of one of these nominal results. Receivers D1 and, perhaps, L2 appear to represent an additional performance level slightly above the lower tier. The upper tier performers provide a significant improvement in the ability to handle the most difficult multipath conditions.[146] The tested receivers in this tier are known to include the latest generation of demodulator chips from at least two of the major DTV chip manufacturers. The results on Figure 2 are summarized in Table 7.

	Number of Consumer Receivers	Number of Captures Played with No Errors	Number of Captures Played with No More Than 2 Errors
Lower Tier	16	7 ±2	9 +2/-1
Lower Tier+	2	8 and 12	14 and 16
Upper Tier	10	29 ±2	37 ±2

Table 7 Number of Captures Successfully Played By Each Performance Tier (Out of 47 Captures)

71. Looking next at the variation of multipath handling performance with product type and price, the FCC Study found that while none of the STBs, which are all of older design, perform at the upper tier level, upper and lower tier performing products appear in all three price categories of integrated receivers. This suggests that multipath handling performance is not a function of price. Among the integrated receivers, the study found that introduction dates in or after March 2005 were consistent with the likelihood of including newer technology. Among the tested receivers that were introduced on or after March 1, 2005, 48% were found to perform at the upper tier level. The study also notes that it is probable that some of the products introduced in this time frame carried over tuner/demodulator designs from a previous generation.

72. In reviewing these results, the FCC Study also considered that there might be some reason to expect that improvements in multipath performance - which is achieved in part by increasing the number of taps in the demodulator's equalizer circuit - might come at the expense of a reduced white noise threshold, because the additional taps could be expected to add noise that is related to carrier amplitude.[147] Figure 3 shows measurements of white noise threshold plotted against multipath performance as measured by the number of RF captures (out of 47) that were successfully played without error. The lower tier of multipath performers (presumably containing earlier generation VSB decoders) had a median S/N threshold of 15.3 dB, slightly worse than the 15.2 dB threshold achieved by the ACATS Grand Alliance prototype receiver. The 15.1 dB median S/N ratio for the upper tier of multipath performers suggests that the characteristic of a worsening of S/N ratio as a trade-off for multipath no longer occurs.

[146] We emphasize that the tested multipath conditions are those known to be most difficult and are not typical of conditions that most households will encounter in receiving digital television service.

[147] Since an automatic gain control would be expected to provide sufficient gain to amplify the input signal - whatever its level - to a fixed level for processing in the demodulator, one would expect that the tap noise generated after this variable amplification would be at a fixed level relative to the DTV signal rather than at a fixed level relative to the antenna input - hence the impact would appear as a degradation to required S/N (white noise threshold) rather than as an increase in noise figure.

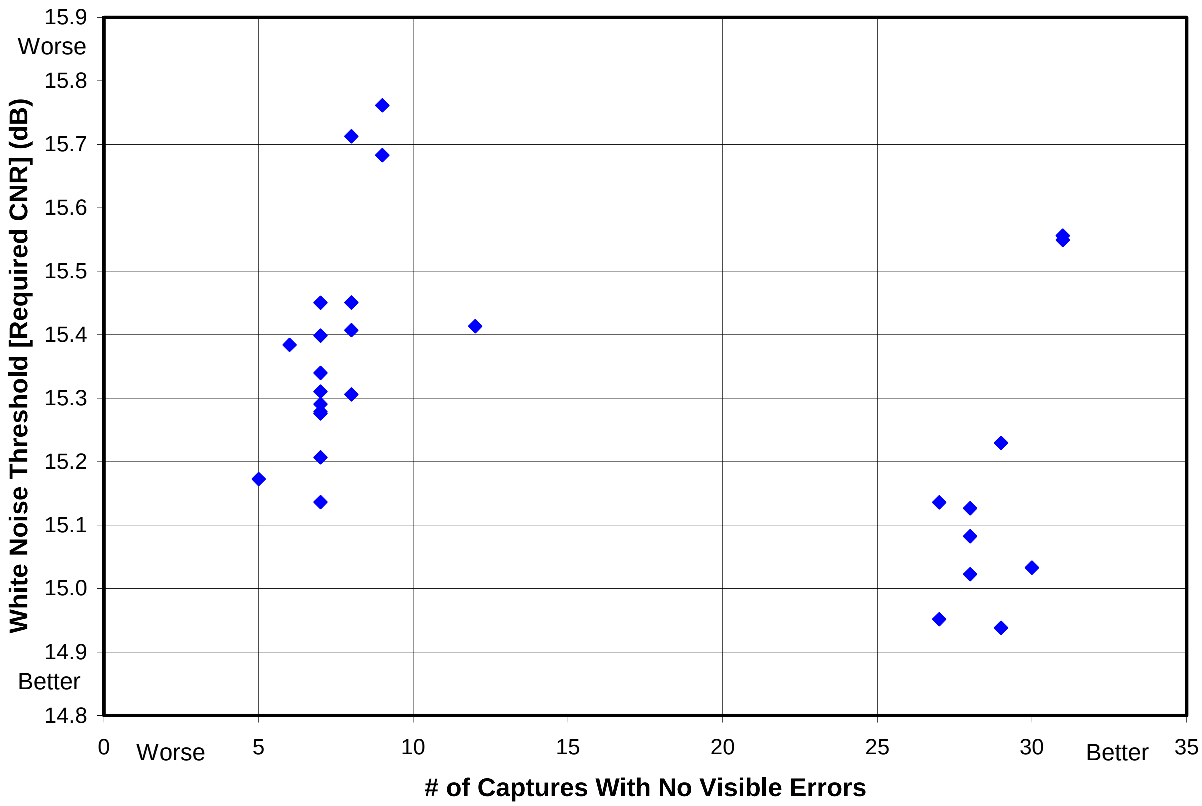

Figure 3 White Noise Threshold Versus Multipath Performance

73. *Evaluation*. Based on our evaluation of both the *Inquiry* record and the FCC study, we conclude that neither the S/N ratio nor the receiver noise figure values in the DTV planning factors should be modified in determining the DTV field signal strength standards to be used for determining whether a household is eligible to receive retransmitted network DTV signals from a satellite service. In answer to Section 339(c)(1)(B)(v), we see no significant variability in the ability of reasonably priced consumer digital television sets to receive over-the-air signals in the high VHF and UHF bands such that some sets are able to display high-quality pictures while others cannot, and the variation that is present does not appear to be closely related to price. We note that in the low VHF band, there were two receivers that were significant outliers and a third receiver that was 6.7 dB above the median. We find that this few number of receivers with high low-VHF thresholds does not obviate our general conclusion that price is not a factor in the availability of DTV receivers that are able to display high-quality pictures.

74. We stated earlier that picture quality does not depend on the level of signal strength. Rather, the importance of the level of signal strength is simply whether service can be received, and the factors that determine that level are a receiver's S/N ratio and noise figure. Our FCC study results indicate that currently available DTV receivers are generally able to provide service with signals at levels very close to those assumed in the planning factors and in a few cases with signals at lower levels. We did find some variation in the reception performance with respect to the minimum signal level needed to provide service, but this was mostly at low VHF. In addition, H&E reported some receivers that need higher minimum signal levels to provide service. We do not view with concern those products needing higher minimum signal levels because it is apparent that the greater portion of products perform generally on a par with the planning factor value. Given that a large number of receivers performed well at signal levels at or close to the minimum signal level assumed by the planning factors, we do not believe that there are

any technical difficulties in providing performance that meets the planning factor target. We believe that it is best to rely on market forces to determine whether those products or perhaps others performing at similarly high threshold levels remain available to consumers. At high VHF and UHF, the variation in reception performance among the receivers in our FCC study was small.

75. As indicated above, we also find no indication that increasing price levels are associated with improved minimum signal level performance. With the exception of set-top boxes, in fact, it appears that there is very little relationship between price and the minimum signal level needed to provide service. Because the set-top boxes studied, and indeed all of those now on the market, are of older designs, we believe that their general design, rather than their price, is the reason for their somewhat lower performance. Thus there do not appear to be any technical reasons that would impede the economical manufacture of products that perform at the expected minimum signal levels currently assumed in the planning factors for the DTV field strength standards.

76. The information on receiver signal-to-noise ratios and noise figures provided in the *Inquiry* record and from our study indicate performance levels consistent with the minimum signal level performance discussed above. This is reasonable given the close relationship of the three measures. It appears that most receivers now on the market exhibit S/N performance within levels very close to the 15.2 dB level assumed in the planning factors, and a few perform slightly better. Again, we do not view those products that are 5 dB or more above the planning factor value for minimum signal level to receive service as an indicator of a deficiency in the planning factor value, given that so many products do perform at or near the expected level. From our FCC study, it appears that most of the variation in the minimum signal level needed to provide service is the result of differences in receiver noise figures rather than S/N ratio. The noise figure variations were larger than the minimum S/N ratio variations by factors ranging from 3.9 dB, in the UHF band, to 14.7 dB in the low VHF band.

77. We conclude that it is not necessary to augment the DTV receiver planning factors with an additional factor for multipath. As EchoStar and others commenting in our Inquiry observe, multipath can pose difficulties for reception of digital television signals and, at the beginning of the DTV transition, receiver adaptive equalizers were not able to adequately process many real world multipath conditions. From the record of our Inquiry and our on-going monitoring of DTV receiver performance, including the testing performed in the FCC study, it is apparent that the current generation of digital TV receivers is able to provide service under most multipath conditions that they may encounter. This can be seen from an earlier field study by the Commission in 2001 that examined DTV reception at a number of sites randomly selected throughout the Washington, DC area. That study, which was based on second and third generation receivers, observed successful reception of DTV service at 99% of the locations where the field strength was at or above the level expected to be needed for service using a mast-mounted antenna at 30 feet. Similarly, that study found successful reception at 85% of the tested locations when using an indoor antenna outdoors at 7-feet. The reason for that level of successful reception with those older receivers is that the number of locations where multipath conditions are difficult is relatively low. The FCC Study indicates that these reception success rates were achieved using a receiver performing in the lower tier of Figure 2. Figure 2 demonstrates that the latest generation of equalizer technology - represented by the upper tier of Figure 2 - provides service when subjected to most of the difficult ATSC multipath ensembles, most of which were recorded with indoor antennas.

78. We also considered the information provided by EchoStar and H&E indicating that, in processing multipath signals, a DTV receiver's adaptive equalizer could generate additional noise that could effectively increase the receiver's noise figure, and thus reduce its sensitivity so that a higher level of input signal could be needed to provide service. It is true that the process of multipath cancellation can cause a "white noise enhancement" - a degradation in performance that causes a higher input S/N to be required in the presence of multipath than in its absence; however, difficult multipath conditions leading

to degradations by as much as 2 dB, as argued by EchoStar and H&E, are not expected to be the norm. The *2001 Field Test Receiver Study* demonstrated that the then-latest generation receiver (with equalizer technology that is now obsolete by two generations) performed better in terms of required S/N in typical multipath conditions than older receivers—indicating a trend toward less degradation in performance in the presence of multipath with successive generations of hardware. That receiver exhibited a median required S/N of 15.9 to 16.0 dB across all of the "coverage sites" tested in those field tests using an outdoor-type antenna. This performance is only 0.7 to 0.8 dB worse than the 15.2-dB S/N in the planning factors.[148] Though the FCC has not tested the newer generations of equalizers in this regard, there is information to suggest that the noise enhancement of the fifth generation is even lower than past generations.[149] Furthermore, the FCC Study notes that, if noise enhancement raises the required S/N to 16.0 dB, when this change is combined with the median measured noise figures of the 28 tested receivers, the overall result is a more optimistic prediction than the value stated in OET Bulletin No. 69 by 0.4 dB and 1.6 dB, respectively, in the low-VHF and high-VHF bands and a less optimistic prediction than the current OET-69 by only 0.7 dB in the UHF band.[150] Accordingly, we do not believe that a factor for multipath should be added to the minimum signal level assumed to be needed to receive DTV service.

3. Other Planning Factors

79. *Thermal Noise and Man-made Noise*. The thermal noise planning factor of -106.2 dBm is based on a 6 MHz bandwidth channel and an assumed temperature of 290^{o} K. As pointed out by dLR and the Network Affiliates, thermal noise is a function of the laws of physics and has not and will not change.[151] We therefore find that the planning factor value for thermal noise is appropriate and should not be changed.

80. In their comments and engineering statement, EchoStar and H&E argue that the digital TV field strength standards should be revised to account for man-made noise.[152] They contend that man-made noise is typically impulse noise from sources such as power line arcing, industrial machinery, automotive ignition systems, appliances having electric motors (vacuums, dishwashers, hair dryers, etc.), devices with switching power supplies (computers), and microwave ovens. They submit that man-made noise was not adequately taken into account in the DTV planning factors, particularly at the low VHF channels. EchoStar and H&E state that, as a result, the Commission did not build in a sufficient margin for noise when it set the DTV signal strength standard for those channels. H&E submits that a 1974 study by NTIA found that in rural locations man-made noise levels are typically above 20 dB and in urban areas such noise is typically above 30 dB near 54 MHz (channel 2).[153] It also states that a more recent 2001

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[148] The "coverage sites" measured in the *2001 Field Test Receiver Study* were selected without regard to multipath conditions. *See 2001 Field Test Receiver Study, supra* note 144.

[149] *See e.g.*, Laud, Tim, Aitken, Mark; Bretl, Wayne; and Kwak, K. Y., "Performance of 5th Generation 8-VSB Receivers", IEEE Transactions on Consumer Electronics, Vol. 50, No. 4, November 2004, which states that the fifth generation receiver includes "techniques for reduced noise enhancement.

[150] *See* FCC Study at 8-4.

[151] MSTV comments, Att. (Engineering Statement of dLR) at 3-4; Network Affiliates comments at 15.

[152] EchoStar comments at 4-5 and Att. A (Engineering Statement of H&E) at 9-11.

[153] EchoStar comments, Att. A (Engineering Statement of H&E) at 10 and n.29 (citing A.D. Spaulding and R.T. Disney, "Man-made radio noise, part 1: estimates for business, residential, and rural areas," NTIA Office of Telecommunications Report OT 74-38, June 1974).

NTIA study found that median noise levels in Boulder, Colorado approached 20 dB at 137 MHz, which it argues implies a median value approaching 30 dB at 54 MHz.[154] H&E contends that if 20 dB or 30 dB of man-made noise is added to the thermal noise floor, some viewers in urban areas will be unable to receive low VHF signals due to excessive man-made noise. EchoStar and H&E therefore submit that the signal strength standard for low VHF channels should be increased by 12-30 dB to account for such noise.

81. In their reply comments, the Network Affiliates state that EchoStar and H&E have misrepresented the results of the NTIA reports.[155] They submit that the 2001 NTIA study cited by EchoStar and H&E actually found man-made noise at 137 MHz (between the low VHF and high VHF bands) to be 17.5 dB in business areas and only 3.6 dB in residential areas.[156] The Network Affiliates state that at UHF frequencies, this study found that it was not possible to differentiate man-made noise from system noise, which indicates that man-made noise is insignificant in the UHF band. They further submit that a 1998 NTIA study found that residential man-made noise had decreased, amounting to no more than 3 or 4 dB in residential areas.[157] They submit that if the 10 dB receiver noise figure for VHF channels is comprised of 5 dB for receiver noise and 5 dB for environmental noise, then the 2001 NTIA study shows that man-made noise at VHF frequencies is within the planning margin (as it also is at UHF frequencies). The Network Affiliates therefore argue that EchoStar and H&E have provided no evidence to warrant adjustment of the digital TV signal strength standards, even at low VHF, for man-made noise. The NAB similarly submits that the 2001 NTIA study relied on by EchoStar in fact says exactly the opposite of what EchoStar claims, namely that man-made noise in residential areas is very low - only 3.6 dB.[158] The NAB further states that if the Commission were to conclude that there is a concern about man-made noise at low VHF channels, the way to address it would be to alter the plans for the DTV transition, for example, by authorizing low VHF channel stations to operate at higher power.[159]

82. We find that the record does not contain any current or substantial studies or other information that would indicate that man-made noise is present in the low VHF or other TV bands at levels that would warrant the addition of this element to the planning factors that underlie the DTV field strength standard. Given the information on residential man-made noise from both the 1974 and 2001 NTIA studies, it appears that the level of man-made noise typically occurring on the low-VHF channels in residential locations is only 3 or 4 dB, a level that is well within the tolerance of the low-VHF noise figure. We also note that TV viewers are likely to become aware of any effects on their TV reception by man-made noise arising from specific devices such as hair dryers, computers, microwave ovens and similar appliances through the simple act of turning those devices on and off. The solution in such cases is to make sure that those devices that might cause interference are turned-off when someone is watching television. Accordingly, we recommend that no revisions be made to the DTV planning factors and field strength standards for man-made noise.

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[154] *Id.* at 10 and n.30 (citing Robert J. Atchaz and Roger A. Dalke, "Man-Made Noise Power Measurements at VHF and UHF Frequencies," NTIA Report No. 02-390, December 2001 (2001 NTIA study)).

[155] Network Affiliates reply comments at 8-10.

[156] *Id.* at 8 and n.25 (citing 2001 NTIA study, *supra* note 153, at 25).

[157] *Id.* at 9 and n.27 (citing R.J. Achatz *et al*, "Man-Made Noise in the 136 to 138 MHz VHF Meteorological Satellite Band," NTIA Report 98-355 (Sept. 1998), at 31).

[158] NAB reply comments at 11 (citing 2001 NTIA study, *supra* note 153, at 25).

[159] *Id.* at 12.

83. *Transmission (Downlead) Line Loss*. The TV receive antenna and receiver are connected by a transmission line that carries the received signal to the receiver's input terminal. The received signal will experience some amount of attenuation as it travels over this line due to the line's inherent resistance and impedance characteristics. Today, most TV receiver systems use 75-ohm shielded cabling for this downlead connection. The 1 dB, 2 dB, and 4 dB downlead line loss figures for low VHF, high VHF, and UHF digital TV channels are based on the assumed use of 50 feet of 75-ohm shielded cable, *i.e.*, RG-6 coaxial cable.

84. In their comments responding to our *Inquiry*, dLR, Jules Cohen, MSW, the NAB and the Network Affiliates submit that the existing downlead loss planning factor values appear reasonable in light of published values for 75-ohm RG-6 cable.[160] The Network Affiliates point out that the ITU has assumed a downlead line loss of 1.1 dB for low-VHF, 1.9 dB for high-VHF, and 3.3 dB for UHF, and that the ITU VHF line loss values are virtually the same as those assumed in the planning factor while the ITU UHF value is lower.[161] In addition, dLR provides the following table of cable specifications for three different cable manufacturers, as shown in Table 7:[162]

Specifications from Manufacturers of Coaxial Cable (75 ohm)				
Frequency	Manufacturer	Cable Type and Model	Attenuation (dB/100 ft)	Attenuation (db/50 ft)
69 MHz (low VHF)	Belden	RG 6/U Model 9116	1.71	0.86
	Channel Master	RG6 9533-500	1.79	0.90
	Coleman	RG 6/U Model 992127	1.9	0.95
194 MHz (high VHF)	Belden	RG 6/U Model 9116	2.73	1.37
	Channel Master	RG6 9533-500	2.89	1.45
	Coleman	RG 6/U Model 992127	3.2	1.6
615 MHz (UHF)	Belden	RG 6/U Model 9116	5.00	2.50
	Channel Master	RG6 9533-500	5.57	2.79

Table 7. Coaxial Cable Performance Specifications

85. dLR points out that in all cases the attenuation values assumed in the downlead loss planning factor exceed those of available products. They therefore submit that the current DTV planning factor values use conservative estimates of transmission line loss. Based on similar information, the NAB states

[160] MSTV comments, Att. (Engineering Statement of dLR) at 4 and 7-8; Network Affiliates comments at 31 and App. (Engineering Statement of Jules Cohen) at 4; and NAB comments at 23-24 and Att. 1 (Engineering Statement of MSW) at 18-19.

[161] Network Affiliates comments at 31 and n.88 (citing *Draft Revision of* Recommendation *ITU-R BT.1368-4* at Table 13).

[162] MSTV comments, Att. (Engineering Statement of dLR) at 7-8 (Table 4).

that it is reasonable to assume that consumer downlead losses will be no greater, and often less than, those specified in the DTV downlead-loss planning factor. MSW indicates that the most expensive RG 6 or RG 59 cable costs about $25 for the typical 50 foot length assumed in the planning factor.

86. In reply comments, EchoStar and H&E argue that it is not realistic to assume that most consumers will use RG 6 cable and that a number of other sources of loss, including baluns (matching transformers), splitters, and impedance mismatch are not accounted for at all.[163] They state that it is not necessarily realistic to assume that consumers will use RG-6 cable and that budget conscious consumers may favor a less expensive alternative that subjects TV signals to greater attenuation. H&E argues that loss from baluns used to connect 300 ohm antennas to 75 ohm cabling results in loss of 0.6 dB at low VHF, 1.5 dB at high VHF and 2.5 dB at UHF. It also argues that the use of splitters that divide signals for delivery to serve more than one outlet will cause losses. H&E further argues that downlead attenuation will increase with the age of the cable. MSW counters that any significant losses from impedance mismatching or baluns can be corrected by use of a mast-mounted low-noise pre-amplifier.[164] They state that the low-noise pre-amplifier would isolate the antenna impedance from that of the downlead cable and the DTV tuner impedance and also provide an output impedance much closer to the 75 ohm cable impedance. In their reply comments, the Network Affiliates state that while it is true that the DTV planning factors do not account for impedance mismatch between the antenna and the receiver front end, EchoStar's claim that the Voltage Standing Wave Ratio (VSWR) on downleads exceeds 2:1 and therefore results in an impedance mismatch loss of 3 dB is not based on empirical studies of consumer equipment. The Network Affiliates submit that a study by Schnelle and Wetmore concluded that the results of tests conducted on professional grade antennas show that it is possible for antennas to have low return and mismatch loss.[165] That report concludes that it is therefore reasonable to conclude that consumer-grade antennas with good impedance matching capabilities are feasible.

87. Based on the record summarized above, we conclude that the current DTV downlead loss planning factor values continue to provide a conservative estimate of the attenuation a received signal will experience between the antenna and receiver. While we recognize that there are additional sources of loss that could reduce the signal level that arrives at a viewer's receiver, those sources are not likely to be present in a typical installation and could be addressed by using better cable or a pre-amplifier at any individual locations where those sources might pose a problem for DTV reception. We note that options for achieving the level of performance specified in the downlead loss planning factor are readily available at reasonable cost. We also understand that in some cases, lower cost downlead cabling with greater attenuation may be used by consumers. In this regard, we observe that in many instances the available DTV signals will be at levels that such cabling will provide satisfactory service. But these considerations do not alter the fact that cabling that meets and indeed exceeds the performance levels assumed in the planning factors is readily available at reasonable prices. Further, if the performance of cabling decreases with age it can and should be replaced in the same manner as any other component whose performance deteriorates or fails over time. We find that any losses from use of baluns would generally be of levels low enough to be compensated for by the margin present in the conservative planning factor values for downlead loss and antenna gain. Similarly, impedance mismatch has not generally been a problem for television reception and, as indicated by MSW, there are solutions available if it were to be so in specific cases. We reject EchoStar and H&E's argument that splitter loss should be included in the planning factors. The issue of whether sufficient signal strength is present for over-the-air rooftop reception is

[163] EchoStar reply comments at 14-15 and Att. A (Engineering Reply Statement of H&E) at 2-3.

[164] NAB reply comments, Att. (Engineering Reply Statement of MSW) 14-15.

[165] *See* D. Schnelle and R.E. Wetmore, "Evaluation of Antenna and Receiver Mismatch Effects on DTV Reception," *48 IEEE Trans. on Broadcasting* 365, 369 (Dec. 2002).

independent of a household's choice to use splitters to distribute signals to multiple TV sets within the home. In any event, "no loss splitters," *i.e.*, distribution splitters, the use of which does not result in any splitter loss, are readily and inexpensively available. Accordingly, we conclude that the current downlead loss planning factor values remain appropriate and recommend that these values not be changed.

88. *Time and Location Variability*. The field strength of digital television signals, like that of other radiofrequency signals, varies by time and location. That is, DTV signal strength will vary over time at the same location and will also vary from location to location. These variations of field strength with time and location are incorporated into the DTV planning model through use of the F(50,90) field strength curves to define a DTV station's noise-limited contour. As indicated above, the F(50,90) level of service means that at the edge of a station's noise-limited contour, 50% or more of the locations can be expected to receive a signal that exceeds the field strength standards at least 90% of the time. It is possible to adjust these percentages by incrementing the field strength values upwards or downwards to reflect a desired level of signal availability. In the planning factors, the values for adjustments to provide different levels of time and location availability were set to zero.[166]

89. In their comments in the *Inquiry*, EchoStar and H&E argue that the time variability assumption that a signal is available at least 90% of the time means that households predicted to be served may not actually have digital TV service for up to five weeks of the year.[167] They argue that an increase in temporal reliability to 99% or better would be prudent until there is greater experience with consumer reception of DTV signals. H&E submits that it collected temporal data on the amplitudes of fourteen DTV signals that could be received at its Sonoma, California offices. It states that it found that variation in signal strength around the median for six of the stations to be about 3.5 dB and 4.9 dB for 90% probability at high VHF and UHF, respectively. It argues that these values must be added to the DTV signal strength standard to achieve 90% and 99% reliability of signal availability respectively. H&E states that its data also show that 4.7 dB and 17.5 dB would need to be added to the high VHF and UHF signal strength standards to increase to the 99% probability level.

90. In their reply comments, MSW, the NAB and the Network Affiliates contend that EchoStar and H&E's claim that 90% reliability means that a viewer will not receive a DTV picture for five weeks a year does not make sense.[168] The Network Affiliates state that the statistical nature of the probability function means that any dips below the digital signal strength threshold will be randomly spaced over very long time periods and thus have no meaning in the sense of a consecutive time period. MSW, the NAB, and the Network Affiliates argue that it would be unfair to broadcasters to change the statistical definition of DTV service at this stage of the transition and that a change to 99% probability would greatly shrink local service areas. The Network Affiliates also argue that H&E's data collection is flawed in that H&E does not explain its methodology or its reasons for reporting data for only six of the fourteen stations it studied. In its reply statement, MSW submits that the results of the daytime field strength measurements taken by H&E ignore the fact that signal strength measurements taken during the daytime

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[166] In the case of analog TV service, the planning factors include adjustments to the time variability factors in order to provide for service at 50% of locations 90% of the time. Those values add 6 dB at low VHF, 5 dB at high VHF, and 4 dB at UHF to the F(50,50) contour values to define the analog Grade B contour values. The analog location variability factors were set at zero. This adjustment was not needed for DTV signals as the signal strength standards were based on the F(50,90) levels of signal availability rather than the F(50,50) levels.

[167] EchoStar comments at 9 and Att. A (Engineering Statement of H&E) at 6-7.

[168] NAB reply comments at 7-8 and Att. (Reply Engineering Statement of MSW) at 10; Network Affiliates reply comments at 7-8.

will be lower than at night when the majority of television viewing occurs.[169] It notes that the original TASO studies in the late 1950's, as reported in FCC Report No. R-6602 and which provided the basis for the current FCC statistical propagation curves in Section 73.699 of the rules, were meticulously determined from testing and evaluation over a three year period.[170] MSW states that most of the TASO data was collected over a period of at least six months and sometimes longer than two years, and from a multitude of locations. It therefore argues that a measurement program such as that conducted by H&E, consisting of only six paths taken over a two-week period, is not statistically valid and has little probative value, particularly when additional data was collected but not reported. MSW further submits that, according to FCC Report No. R-6602, signal strength for UHF signals are roughly 2-3 dB lower during the daytime, depending on path distance. As a result, MSW reasons that signal strength measurements during the daytime are likely to be below the median over time.

91. We do not find persuasive reasons in EchoStar's and H&E's submissions for changing the DTV time variability planning factor value. The time variability value is an important factor in determining the area served by a television station and the amount of power needed to cover a planned service area. We believe that this value should not be changed in the absence of a strong indication that its use would be inconsistent with our DTV service model and channel allotment plan. In this regard, we note that radiofrequency signal propagation is always statistical in nature and that the power and/or antenna height needed to approach 100% reliability increases in a non-linear manner. As indicated by MSW, the NAB, and the Network Affiliates, changing the time variability factor values to 99% reliability at this stage of the transition would greatly shrink local DTV service areas. The current values were established based on an industry-Government consensus that relied on the traditional TV service model that worked well for analog TV service (the analog field strength values are based on the F(50, 50) service level with an augmentation to provide F(50, 90) reliability). We also observe, as pointed out by MSW in their reply filing, that the assumed 10% reduction in service availability occurs at the outermost limit of a station's service area; it is not the typical figure for time reliability across a station's entire service area. As the distance to a station's transmitter decreases, the time availability figure increases. Households at the edge of a station's service area can also improve their reception (and thereby reduce or eliminate periods when the station's signal is not available) by mounting their antenna higher, using a higher gain antennas, or using low-noise pre-amplifiers at their antenna.

92. We find that EchoStar's and H&E's argument that the F(50,90) values result in a loss of DTV service reception for more than five weeks a year ignores the fact that any actual interruptions of service tend to occur for short periods in a non-consecutive manner. There also appear to be serious methodological shortcomings in the data collection exercise conducted by H&E, in that it only examined daytime conditions for a short period and for a single location. Moreover, we see no theoretical justification for increasing the signal strength standard by adding a reliability factor amount equal to the variation in DTV signal strength measured over time. Considering all of the information on this issue, we are not persuaded that changes to the time variability planning factor values are warranted. In addition, no commenting party suggested changing the location variability factor and we know of no considerations that would lead us to recommend changing the current zero values for this factor.

93. *Dipole Factor*. The dipole factor expresses the quantitative relationship between the radiofrequency power received by a half-wave dipole antenna and the electrical energy that is present at the terminals of that antenna. This relationship is a function of the laws of physics. Essentially the dipole factor provides for the conversion of radiofrequency power to electrical power. In the DTV planning factors, the dipole factor is expressed in logarithmic form as the relationship between radiofrequency

[169] NAB reply comments, Att. (Reply Engineering Statement of MSW) at 9;

[170] The FCC propagation curves are set forth in Section 73.699 of the Commission's rules, 47 C.F.R. § 73.699.

electric field strength and voltage, assuming a 75-ohm load. As indicated above, the DTV dipole factor values are -118.8 dBm, -120.8 dBm, and -130.8 dBm for low VHF, high VHF, and UHF, respectively.

94. In their comments in the *Inquiry*, the Network Affiliates observe that the dipole factor is dependent on frequency and that the planning factors use a geometric mean frequency of a UHF band extending from 470 MHz to 806 MHz (channels 14-69).[171] They argue that because the core DTV channels extend only to channel 51, rather than 69, the dipole factor for the UHF band should be recalculated on the basis of the geometric mean frequency of the UHF band extending from 470 MHz to 698 MHz (channels 14-51). The Network Affiliates state that the geometric mean frequency of the core DTV UHF band is 573 MHz, which results in a dipole factor of -130.2 dB, or 0.6 dB lower than the current UHF dipole planning factor value. The effect of such a change would be to reduce the field signal strength level needed to receive UHF DTV signals by 0.6 dB, to 83.4 dBm.

95. While the geometric frequency of the UHF band will indeed change from 615 MHz to 573 MHz at the end of the transition when all UHF DTV stations will operate in the channels 14-51 core spectrum, as indicated by the Network Affiliates, we do not believe that a change in the UHF dipole planning factor value is warranted. Initially, we note that the planning factors specify a single dipole factor value for the UHF band and additional single values for the low VHF and high VHF bands. Reducing the UHF dipole planning factor value would have the effect of reducing the minimum signal strength accepted as needed to receive service and thereby increase the geographic areas served by stations. The true dipole values are specific to each individual channel, as the conversion factor from electromagnetic energy to electric energy through an antenna varies with frequency. Thus, the planning factor dipole values for each channel range are only approximations of the actual dipole values for each channel. We note that unlike the planning factors, the Longley-Rice Model in OET Bulletin No. 69 includes a dipole modification factor that is added to the planning factor value so that DTV service area computations within a station's noise-limited contour are made using the true dipole factor.[172] Thus, modification of the dipole factor to reflect the geometric mean frequency of the core spectrum would not have any effect on the actual service areas of individual DTV stations, because nothing in the physical operation of the stations would be changed. Given that the difference in the current UHF dipole factor and the dipole factor for the core spectrum UHF channels is only .6 dB and the fact that changing this planning factor would not actually affect the minimum threshold level of signal needed to receive individual stations, we find that this planning factor should not be changed. We conclude that the interests of maintaining stability in the service areas of TV stations outweigh the benefits of providing a small apparent reduction in the level of signal needed to receive UHF DTV stations.[173]

[171] Network Affiliates comments at 16.

[172] *See* OET Bulletin No. 69 at 3-4.

[173] We note that Jules Cohen, the consulting engineer for Network Affiliates, appears to agree with this conclusion. *See* Network Affiliates comments, Appendix (Engineering Statement of Jules Cohen) at 5 ("in light of an absence of need to change other [planning factors]," the dipole factor is not proposed to be changed).

4. Additional Considerations

96. In response to Section 339(c)(1)(B)(vi) we also considered whether to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter in the digital television field strength standards. Our assessment of building loss in the case of indoor antennas as a potential factor in the digital television field strength standards are set forth in the discussion above concerning antenna gain, orientation, and placement. There, we observe that building losses are dependent on the materials with which the building is constructed and the location of an antenna within the building. Because of these variabilities, we conclude that it would be impractical to establish an indoor digital television field strength standard. We also observe that while the location of buildings with respect to outdoor antennas may have an effect on the signal strength that reaches an outdoor antenna, in most cases there will be many paths by which a digital television signal can generally be expected to reach that antenna despite the presence of buildings, other man-made clutter, and vegetation in the signal path. We therefore conclude that building loss should not be considered in the digital television field strength standard. On the other hand, blockage from buildings, other man-made clutter and vegetation is likely to be a factor in the digital television signal strength that is available at individual locations. These elements were previously factored into the predictive model used for determining analog television field strengths at individual locations, and we find that it would be appropriate to include those same factors into a predictive model for determining digital television field strengths at individual locations. That issue is discussed in the section below on the digital television predictive model.

97. Looking at the performance of DTV receivers in the presence of interfering signals, we observe that in general a radio receiver's immunity to interference is dependent on a number of factors in its technical design and, in addition, on the characteristics of the signals it is designed to receive. These factors may be closely related and possibly interdependent, and a receiver's performance on one factor may often affect its performance on others. The factors determining receiver immunity performance generally include selectivity, sensitivity, dynamic range, automatic RF gain control, shielding, modulation method, and signal processing. Receiver selectivity is the ability to isolate and acquire the desired signal from among all of the undesired signals that may be present on other channels. Sensitivity is the measure of a receiver's ability to receive signals of low strength. Greater sensitivity means a receiver can pick up weaker signals.[174] Dynamic range is the range of the highest and lowest received signal strength levels over which the receiver can satisfactorily operate. The upper side of a receiver's dynamic range determines how strong a received signal can be before failure due to overloading occurs. Automatic RF gain control allows a receiver to adjust the level of a received signal as it appears at the unit's signal processing and demodulation sections.

98. In the *Inquiry*, we noted that many factors can affect the reception of radio frequency signals and the ability of a receiver to resolve these signals and produce a picture.[175] Most notably, interference from both co-channel and adjacent channel TV transmitters could cause interference to the desired signal. Selectivity is a central factor in the control of adjacent channel interference.[176] However, we also noted

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[174] Greater sensitivity can also result in reception of unwanted signals at low levels that then must be eliminated or attenuated by the selectivity characteristics of the receiver.

[175] *Inquiry*, *supra* note 22, at ¶ 19.

[176] There are several ways to describe the selectivity of a radio receiver. One way is to simply give the bandwidth of the receiver over which its response level is within 3 dB of its response level at the center frequency of the desired signal. This measure is often termed the "bandwidth over the -3db points." This bandwidth, however, is not necessarily a good means of determining how well the receiver will reject unwanted frequencies.

that different receiver designs may account for the differing abilities of receivers to reject greater or lesser amounts of interference. We requested comment on the interference rejection capabilities of digital TV receivers and satellite set-top-boxes with built-in off-air receivers.

99. In their comments responding to our *Inquiry*, ATI notes that in 2003 the Commission suggested that the ATSC develop voluntary standards for DTV receiver performance[177] and that in response the ATSC developed such standards and published them in its "A/74 Recommended Practice: Receiver Performance Guidelines" (A/74 Recommended Practice).[178] The ATSC recommended DTV receiver performance standards were developed by industry parties representing broadcasters, consumer electronics manufacturers, consumers, and others. These standards address DTV receiver performance in the areas of sensitivity, multisignal overload, phase noise, selectivity, multipath, antenna interface and consumer interface. ATI recommends that the Commission adopt the ATSC A/74 Recommended Practice for receiver performance because it reflects this cross-industry agreement and provides the most appropriate and accepted parameters for evaluating receiver performance.

100. H&E submits that two respected engineers have expressed concern about interference from adjacent channel intermodulation interference sources.[179] It further states that it is aware of several failures of DTV reception that are attributable to "image interference" from strong undesired signals and notes that image interference (typically resulting from signals seven or eight channels above or below the desired channel) is not currently addressed by the Commission's DTV allotment standards. H&E states that while there currently is not enough information to assess typical receiver performance with regard to image interference, the existing protection ratios as documented in OET Bulletin No. 69 might be presumptively used to determine the presence of interference and provide reasonable goals for DTV receiver designs.

101. We observe that a receiver's ability to provide service in the presence of interfering signals is not relevant to the field strength needed to provide service. While the presence of other signals on the same or adjacent channels does have the potential for causing interference that can cause loss of service, the effects of other signals are a separate matter from the basic functioning of a receiver in an interference-free environment that forms the basis for the Commission's field strength standards. In general, interference caused by the presence of a signal in the same channel as the desired channel (co-channel interference) is a problem that cannot be addressed by receiver improvements and must be addressed by avoidance of signal overlap. Interference from signals one or more channels removed from the desired channel (adjacent channel interference), however, can be addressed by designing receivers to be more selective and using antennas that provide discrimination against unwanted signals through directivity.

Consequently, it is common to give the receiver bandwidth at two levels of attenuation; for example, -6dB and -60 dB. The ratio of these two bandwidths is called the shape factor. Ideally, the two bandwidths would be equal and the shape factor would be one. However, this value is very difficult to achieve in a practical circuit.

[177] *See* Interference Immunity Performance Specifications for Radio Receivers; Review of the Commission's Rules and Policies Affecting the Conversion to Digital Television, *Notice of Inquiry* in ET Docket No. 03-65 and MM Docket No. 00-39, 18 FCC Rcd 6039 (2003).

[178] *See* "A/74 Recommended Practice: Receiver Performance Guidelines," Advanced Television Systems Committee, Inc., June 18, 2004.

[179] H&E citing Oded Bendov, "Interference to DTV Reception by First Adjacent Channels," *IEEE Trans. on Broadcasting*, Vol. 51, No. 1, March 2005 and Charles W. Rhodes, "Interference between Television Signals Due to Intermodulation in Receiver Front-Ends," *IEEE Trans. on Broadcasting*, Vol. 51, No. 1, March 2005.

102. As a general matter, the Commission has traditionally refrained from attempting to regulate the ability of receivers to provide service in the presence of adjacent channels. Instead, it has relied on market forces to direct manufacturers to produce television sets that provide satisfactory service in the RF environment allowed by the Commission's rules. In this regard, the rules provide engineering and inter-station spacing standards that limit the signal strength of co-channel and adjacent channel signals that are present in a licensed station's service area. Manufacturers are then free to build receivers to whatever levels of performance they choose with respect to selectivity and other performance characteristics. Market forces provide incentives for manufacturers to design products that will operate within the RF environment that may exist in an area. If a receiver does not provide service in that environment, a consumer would very likely return it to the place of purchase thereby providing economic feedback to the manufacturer.

103. Over the years, this approach has worked very well and the Commission has not found it necessary to establish performance standards for TV receivers to avoid interference. For example, most recently in the 1999-2000 time frame it became apparent that the performance of the active equalizer function of digital television receivers that provides immunity to multipath was not adequate in the early models of receivers.[180] Manufacturers responded to this performance problem by improving the performance of the adaptive equalizer function. That improvement effort, which is still on-going, has now produced the fifth generation DTV receivers that are able to provide satisfactory performance under most conditions of multipath. We continue to believe that reliance on market forces is the most appropriate approach for ensuring that DTV receivers perform satisfactorily with regard to their ability to handle interfering signals. That approach allows manufacturers the freedom to design products that meet a variety of consumer needs and also to implement changes that may be needed to implement new components, address a new understanding of the television signal environment, or meet changes in the consumer market. While we understand that a few parties may be concerned about the interference immunity performance of DTV receivers, the DTV receiver products currently on the market generally appear to be performing satisfactorily in rejecting interference. In this regard, we have not seen any obvious problems with the receivers on the market now failing to provide service because of interference. Thus, it appears that market forces are adequately providing for interference immunity.

104. We do believe that the ATSC A/74 Recommended Practice provides a strong benchmark for the performance capabilities. The standards in this document provide clear performance targets for the development of DTV receivers that provide quality performance within an economically feasible cost structure. While we strongly encourage manufacturers to consider and adhere to the performance standards in A/74 Recommended Practice, we do not find any compelling reason to make compliance with those or any other DTV receiver performance standards mandatory to ensure that television service is not affected by interference at this time. Accordingly, we do not recommend that Congress take any action with regard to the digital television field strength standards or otherwise adjust the methods for determining whether it is possible to receive television signals at a location to account for receiver interference performance.

C. Alternative Standards to Field Strength

105. In Section 339(c)(1)(B)(iii), Congress requested that the Commission consider whether a standard should be used other than the presence of a signal of a certain strength to ensure that a household can receive a high-quality picture using antennas of reasonable cost and ease of installation. In response to the *Inquiry*, CEA states that it believes that the presence of a signal of a certain strength is the right

[180] *See* Review of the Commission's Rules and Policies Affecting the Conversion to Digital Television, *Report and Order and Further Notice of Proposed Rule Making*, 16 FCC Rcd 5946 (2001). That decision also discusses the Commission's approach to regulation of television receiver performance.

level of involvement of the FCC in determining the availability of TV service.[181] It states that going beyond that approach would invite a quagmire of assessing reasonableness, cost effectiveness, and ease of installation. The NAB similarly submits that field strength standards are better than alternative approaches such as those that would use a "picture quality" test because qualitative tests involve subjective judgments. It argues that because the results of field testing by experienced engineers show that objective signal strength is an excellent proxy for the availability of a high-quality digital picture, there is no need for such judgments to be made. Based on our long experience with radio services, we do not believe that any alternative to field strength standards would provide a better indicator of whether a household can receive service. In this regard, we note that the DTV field strength standards in fact incorporate a large number of considerations, as evidenced by the technical criteria represented in the planning factors. We believe that the numerous elements that affect reception of digital television service are adequately and appropriately included in the standard through the DTV planning factors. Accordingly, we recommend that the current plan of field strength values and their specification remain the standards for determining whether digital television signals can be received. We further recommend that the Congress continue to allow the Commission to modify or replace those standards through the rule making process as may be necessary. We believe the flexibility of that process provides an adequate means for both identifying when and if changes are necessary and for developing appropriate revisions.

D. Summary Field Strength Standards Recommendations

106. From the above discussion, we observe that households face a wide range of situations in receiving over-the-air digital television service, just as they always have with analog television service. In the variability of receive sites there are some cases, *i.e.*, where a station's signal is particularly weak, in which a household that is within a TV station's service area may not be able to receive service using the typical TV reception system. In those cases there are readily available options to improve the capability of the households' receive systems to obtain over-the-air service. In other cases, *i.e.*, where a station's signal is particularly strong, a household may not need a receive system with the full capabilities of the typical receive system and, for example, may be able to use an indoor antenna. Given the ready availability of equipment for receiving service in locations with different levels of available field strength and the administrative efficiency of providing a simple, easy to understand and apply definition of DTV service area and signal availability, we continue to believe that it is appropriate to define digital television signal availability/service area using field strength standards that are specified on the basis of a typical receive system. For the reasons indicated in this discussion above, we believe any other approach that would introduce more variables and complexity could lead to subjectivity and arbitrariness in making determinations of signal availability. We also conclude that there is no alternative approach to field strength standards that would provide a more accurate measure of service area and/or signal availability at individual locations.

107. The variability that exists in receive conditions extends to the performance of the specific elements of the receive systems used by consumers. For example, a given household may not need to use a downlead that approaches 50 feet or the antenna it uses may provide less gain than that specified in the planning factors. In the evaluations above, we balanced the variability of these situations. The planning factor values were established as typical values that could be expected in a household's TV reception system. We also believe that the planning factor values as specified are in some instances, such as antenna gain, downlead loss, and receiver noise figure somewhat conservative. These values appear to provide a few dB of additional margin in the summation of factors that determine the minimum signal level needed for service so that the level of signal that is needed for service would be a little lower. On the other hand, certain other factors such as downlead impedance mismatch, balun loss, and in some cases

[181] *See* CEA comments at 3-4.

additional noise from adaptive equalizer operation may tend to increase the minimum signal level needed for service by a few dB. We believe that these plus and minus elements generally negate one another and should have no impact on the basic calculation of the minimum signal level needed for service.

108. We therefore make the following recommendations with respect to the digital television field strength standards for use in determining households' eligibility to receive distant network television signals that are retransmitted by satellite:

- Maintain the approach that specifies DTV service areas on the basis of field strength standards for the low-VHF, high-VHF, and UHF bands;
- Maintain the existing planning factors in determining the DTV field strength standard,
- Do not augment the field strength standards to account for indoor antennas, antenna rotational capability, receiver price, external interference sources including undesired from both digital and analog television stations, building loss, foliage, man-made clutter;
- Maintain the existing DTV field strength standards for use in determining the availability of DTV service at the locations of individual households.

IV. DIGITAL TELEVISION FIELD STRENGTH MEASUREMENT PROCEDURES

109. The Commission has standardized procedures for measuring the field strength of analog television signals at individual locations.[182] Now, as we are on the horizon of transitioning to digital television, Congress has asked us to consider whether, for evaluating if a household is unserved for purposes of determining eligibility to receive distant network signals retransmitted from a satellite service, different field strength measurement procedures are necessary.[183] Specifically, in Section 339(c)(1)(B)(ii) of the Communications Act, as amended by the SHVERA, Congress asked the Commission to consider whether Section 73.686(d) of the Commission's rules should be amended to create different procedures for determining if the requisite digital signal strength is present than for determining if the requisite analog signal strength is present.

110. Currently, Section 73.686(d)(1)(i) requires that field strength measurements be made using either a half–wave dipole antenna that is tuned to the station's visual carrier frequency or a gain antenna, provided that the antenna factor for the channel under test is known.[184] In addition, the rules specify that the intermediate frequency (i.f.) bandwidth of the measuring instrumentation be at least 200 kilohertz but no more than 1,000 kilohertz.[185] Measurements are to be taken in five locations, preferably close to the actual antenna or where one is likely to be mounted.[186] In addition, the rules specify that the measurement antenna is to be raised to a height of 6.1 meters (20 feet) above ground for one story structures and 9.1 meters (30 feet) above ground for two story or taller structures.[187] Finally, because the current rule was written specifically to determine the field strength of analog TV signals, the procedures specify that the field strength measurement is to be made on the visual carrier.[188] The measured values are then to be compared to the field strength that defines the Grade B contour for the station in question to determine if the measured location is receiving a signal of sufficient intensity for analog television reception.

111. In the *Inquiry*, the Commission recognized that the rules defining measurement procedures for analog television cannot simply be applied to digital television signals.[189] Thus, some modifications are necessary. As described above, the current measurement procedure requires that measurements be conducted on the visual carrier. Digital television signals, however, do not contain a visual carrier. Instead, all information – video and audio – is encoded within the bit stream that makes up the entire signal. We stated, therefore, that a new rule would be needed to deal with the measurement of digital television signals, at least insofar as it relates to the specific frequency on which to tune.[190] The Commission pointed out that the digital television signal contains a pilot signal that is used by a receiver's

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[182] *See* 47 C.F.R. § 73.686(d); *see* also, *SHVA Report and Order*, 14 FCC Rcd 2654 at ¶ 8.

[183] 47 U.S.C. 339(c)(1)(B)(ii), *as amended by* Section 204(b) of the SHVERA.

[184] *See* 47 CFR 73.686(d)(1)(i).

[185] *See* 47 C.F.R. § 73.686(d)(2)(i).

[186] *See* 47 C.F.R. § 73.686(d)(1)(ii).

[187] *See* 47 C.F.R. § 73.686(d)(2)(iii).

[188] *See* 47 C.F.R. §§ 73.686(d)(1)(i) and 73.686(d)(2)(i).

[189] *Inquiry*, *supra* note 22, at ¶ 13.

[190] *Id.*

tuner to lock onto the desired received signal and suggested that this signal could be used for measurement purposes.[191] More generally, the Commission asked commenting parties to provide information on the signal characteristics to which the measurement instrumentation should be tuned (*e.g.*, pilot signal, center of channel, etc.). We also noted that the portion of the current rule for determining if a household is unserved by comparing the measured signal strength value to the Grade B contour field strength is not appropriate for digital television signals. For digital television stations, instead of a contour defined by Grade B signal intensity, the noise-limited service contour, as defined in Section 73.622(e) of the Commission's Rules, is used.[192]

112. In addition to the Commission's request for comment regarding the aforementioned differences between analog and digital television signals, comment was also sought on other portions of the analog signal strength measurement rule and their applicability to digital television signals. We asked whether the i.f. bandwidth of the measurement equipment that is specified for analog television signals is also appropriate for digital TV signals. We further requested comment on the height that should be specified for the receiving antenna equipment to measure outdoor signals, and on whether specific procedures should be created for measuring the availability of indoor signals. Regarding indoor measurements, we asked if the Commission were to adopt such procedures, what criteria should be applied to determine whether an indoor or an outdoor measurement would be performed at a specific location. Finally, we asked if there are any other aspects of our measurement procedures that need to be modified for the purpose of determining if households are unserved by an adequate digital TV signal.

113. Congress, in SHVERA, also requested that the Commission consider whether to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter. In the *Inquiry*, we requested that commenting parties provide information regarding how to account for these factors.[193] We noted that many factors can affect the reception of radio frequency signals such as interference from both co-channel and adjacent channel TV transmitters. We also noted that other external forces can affect the signal that ultimately reaches a TV receiver. These include natural and man-made structures that lie between the transmitter and the receiver. We observed that these obstructions can affect a signal in various ways such as by attenuating the signal so that the actual signal received is weaker than that predicted in the absence of any such obstructions or by creating multipath interference, which occurs when a signal bounces off structures and the main and reflected signals arrive at the receiver at different times.

114. *Inquiry Record*. NAB and the Network Affiliates state that existing methods for measuring field intensity at individual locations will, with a few minor modifications, work well for digital signals.[194] Many of the suggested modifications are straightforward and are a direct result of the questions the Commission asked. For example, NAB points out that the rules for digital television measurements must reference the appropriate noise-limited field strength value rather than the Grade B contour.[195]

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[191] The pilot signal is located 0.31 MHz inside the lower band edge of the DTV channel and has a power level that is 3 dB lower than the average power of the DTV signal.

[192] 47 CFR § 73.622(e); *see also* 47 CFR § 73.625(b) (determining coverage).

[193] *Inquiry, supra* note 22, at ¶ 20.

[194] NAB comments at 25; Network Affiliates comments at 38.

[195] NAB comments at 26.

115. In the *Inquiry*, the Commission observed that a change was necessary regarding how to actually measure the digital television signal strength given that the current rule is analog specific. The NAB and the Network Affiliates state that the Commission's suggestion to substitute a measurement of the pilot signal of a digital television signal for the analog measurement of the visual carrier would not be appropriate.[196] They state that the problem with using the pilot signal is that in practice, multipath can create fluctuations of ±10 dB which in turn would cause corresponding measurement errors.[197] Instead, the NAB and the Network Affiliates specify that consistent with the Commission's definition of the power of a digital television signal, measurements should be conducted by tuning to the center of the digital television RF channel and measuring the integrated average power over the signal's 6 megahertz bandwidth. Several methods for performing this measurement are suggested: 1) using a swept-tuned spectrum analyzer with a variety of small i.f. bandwidths; 2) using a calibrated field strength meter that has one fixed narrow bandwidth, but can be swept across the entire 6 megahertz band; and 3) using a calibrated fixed tuned receiver that has an i.f. bandwidth equal to the 6 megahertz digital television channel.[198]

116. The Network Affiliates and the NAB both suggest that the measurement system include a directional antenna rather than a simple dipole. Use of such an antenna, they assert, will help ameliorate the effects of multipath and also ensure that the measured power levels are sufficiently high to permit accurate measurement at all channel ranges.[199] The NAB suggests use of a calibrated directional antenna with a front-to-back ratio protection consistent with Commission planning assumptions.

117. On another point, the Network affiliates and the NAB both suggest that the current procedure remain unchanged with respect to measurement height. They state that measurements should continue to be made outside at a height of 6.1 meters (20 feet) for a one-story home and 9.1 meters (30 feet) for a two-story home.[200] While not disagreeing with the position of the Network Affiliates and the NAB on this point for outdoor measurements, EchoStar suggests that we establish indoor testing procedures. EchoStar states that because it is not practical for many households, such as those living in apartments, to use an outdoor antenna, procedures for testing with an indoor antenna are needed and that indoor testing should be required.[201] To bolster this position, it references the statement from H&E which claims that due to limitations on physical size, indoor antennas have gain of about 9 dB below those for outdoor antennas. Therefore, EchoStar and H&E offer that indoor testing should be done using a typical indoor antenna or, if a professional antenna were used, then the signal test result should be reduced by 9 dB or more to account for the lower gain of the indoor antennas.[202] The NAB and the Network Affiliates disagree. For example, the NAB states that the Commission should not permit testing of indoor antennas as it would be inconsistent with the premise of the DTV transition that households will make the same efforts to receive digital signals that they have historically made to receive analog signals.[203] Further,

[196] NAB comments at 26-27; Network Affiliates comments at 38-39.

[197] *E.g.*, NAB comments, Att. 1 (Engineering Statement of MSW) at 21.

[198] *Id.* at 20-21.

[199] *Id.* at 38.

[200] NAB comments at 27; Network Affiliates comments at 39.

[201] EchoStar comments at 6-7.

[202] *Id.* at 7.

[203] NAB comments at 27.

they state that indoor testing would be impossible to standardize.[204] The Network Affiliates add that local service would be eviscerated if the Commission was to recommend measuring signal strength indoors or establishing an indoor standard that the entire DTV service was never intended to meet.[205] The NAB and the Network Affiliates state that this is because the signal attenuation due to building materials coupled with the lower gain antenna would have the effect of decreasing the service area size. Moreover, the Network Affiliates state that EchoStar's claims with respect to indoor antennas and building penetration are irrelevant given that the Commission has always assumed that homeowners would use an outdoor directional gain antenna for over-the-air reception. The NAB adds that EchoStar does not provide any explanation for the unfairness of assuming that the same household that uses an outdoor dish to receive satellite TV would use an indoor antenna for over-the-air signals.[206]

118. A second area where EchoStar believes the current testing procedures should be modified is with regard to antenna pointing. The current procedure specifies that the measurement is to be taken with the antenna oriented in the direction of maximum signal strength. EchoStar claims that this requirement implicitly assumes that every household has a rotating antenna that can be re-pointed to optimize reception for each local station, which it contends is unrealistic.[207] To this point, it suggests that signal strength loss from mispointing should be taken into account in the measurement procedures. EchoStar suggests further study to determine the "average" signal loss due to mispointing and submits that this value should be subtracted from the measured signal before comparing to the Commission's signal strength standard.[208] It further suggests that because only 10-15% of households have rotors, those that do not may point the antenna in a direction other than the direction of maximum signal strength to achieve optimum reception for all stations. H&E argues that it would make sense to orient the measurement antenna in the same direction as other antennas in the area.[209]

119. The NAB and the Network affiliates disagree with EchoStar on this point. NAB avers that EchoStar fails to explain why it would be good policy to assume an incorrectly pointed antenna when the entire DTV transition has been premised on use of a properly oriented antenna.[210] The NAB and the Network Affiliates also state that EchoStar ignores obvious problems with their suggestion to point the measuring antenna in the direction of antennas at neighboring households. These include: 1) neighboring household's may have rotors and only temporarily point their antennas in a certain direction; 2) neighboring households may have antennas that have been abandoned; 3) there may be no neighboring households with outdoor antennas; and 4) there is no readily available methodology to determine the direction that neighboring households have oriented their antennas and translate that into a direction for orienting a test antenna.[211] NAB further points out that in many areas local installers can supply antennas that are non-rotating, but that point correctly at all of the local stations when installed.[212] They also state

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[204] NAB comments at 27 and Att. 1 (Engineering Statement of MSW) at 22.

[205] Network Affiliates comments at 39-40.

[206] NAB reply comments at 3.

[207] EchoStar comments at 7.

[208] EchoStar comments at 8.

[209] *Id.*, Att. 1 (Engineering Statement of H&E) at 4.

[210] NAB reply comments at 4.

[211] Network Affiliates reply comments at 15; NAB reply comments at 6.

[212] NAB reply comments at 5.

that in 83% of the television markets where there is a full complement of major network affiliates (ABC, NBC, CBS, Fox), the digital television stations are co-located.[213]

120. Several other suggestions were made by EchoStar in response to our *Inquiry* questions concerning measurements. Specifically, it recommends that testing include collection of multipath and other interference data and that testing be done over time to account for time variability of the measurement. On the first point, EchoStar states that multipath interference is a more acute problem for digital television than for analog.[214] It argues that dynamic multipath, which occurs due to signals bouncing off of moving objects, is difficult to account for, but that static multipath interference can be measured and its severity can be expressed as a signal strength penalty. EchoStar states that this penalty should be subtracted from the measured digital signal strength before it is compared against the Commission's digital strength standard.[215] In addition, EchoStar submits that field measurements should include the collection of white noise enhancement values.[216] The Network Affiliates and the NAB both argue that such measurements and compensation are unnecessary. They point out that in the past it may have been true that digital television receivers had difficulty with multipath, but that current 5th generation receivers can easily handle multipath conditions that those earlier receivers could not resolve. The NAB also points out that 6th generation receivers that will encompass further improvements will soon be available.[217] The NAB further states that there is no need to account for white noise enhancement since it only adds about 0.2 dB of noise that is more than made up by factors that overestimate the available signal strength required and thereby make the planning factors conservative. It states that these include the fact that real antennas have gains that exceed the planning factors, available coaxial cables have losses less than those assumed, and low noise amplifiers are readily available.

121. With regard to digital television signal time variability, EchoStar comments that the H&E study shows significant variability over time and that because the Longley-Rice predictive propagation model is based on empirical data about time variability, it would be strange for actual testing to ignore it completely. It therefore asserts that the testing procedures be modified to account for variability in signal strength over time. EchoStar suggests that this could be done by taking the specified cluster measurements and assuming they provide a median signal level and then applying a correction factor to achieve 90% time reliability.[218] The result of such a correction would be to increase the minimum signal strength that defines digital television service. The NAB, in response, points out that the minimum signal level that defines digital television service is specified in the statute and as such any change cannot be done by regulation.[219] As with its response to EchoStar on multipath, the NAB again states that the

[213] *Id.*

[214] EchoStar comments at 5.

[215] *Id.*.

[216] White noise enhancement is the increased noise added to the system by the equalizer as it attempts to compensate for multipath. EchoStar comments, Att. A (Engineering Statement of H&E) at 8-9.

[217] NAB reply comments at 10-11; Network Affiliates reply comments at 10.

[218] EchoStar comments at 8. It states that a correction factor can be derived from the F(50. 50) and F(50. 90) curves by using the difference in values given the distance from the transmitter.

[219] NAB reply comments at 8.

Commission's planning factors are already conservative and there is no reason to account for time variability by increasing the minimum signal strength standard.[220]

122. *Evaluation*. Many of the suggestions made by commenters were noncontroversial and went unchallenged in the record of the *Inquiry*. In this regard, we note that the NAB and the Network Affiliates pointed out that the measurement rules are analog specific with respect to the signal strength standard and need to be modified. We agree and as supported by the record of the *Inquiry*, believe that the digital television measurement rules should specify the noise-limited field strength values as the minimum signal level that constitutes service to a household. We also agree with the NAB and the Network Affiliates that use of the average power in the DTV channel, rather than the level of the pilot signal, would provide a better measure of DTV signal strength for the reasons they indicate. Therefore, we plan to initiate a rule making proceeding in the near future to revise the measurement procedure to use average power integrated over the entire 6 megahertz bandwidth as the basis for measuring the digital television signal.[221] As for the question in the *Inquiry* regarding whether the i.f. of the measuring equipment needs to be specified, we believe that it is not necessary to specify an i.f. other than that it cannot be greater than 6 megahertz. Any of the methods suggested above will work and the i.f. is essentially irrelevant so long as it is not larger than 6 megahertz and the equipment is capable of integrating the power over the selected i.f. bandwidth.

123. We make no make no specific recommendation on whether the measurement procedure should include provisions requiring the use of a directional antenna. However, we believe there may be merit to this suggestion by the NAB and the Network Affiliates. We believe that the proper place to address this is through a rule making proceeding conducted by the Commission. We point out, however, that should it be determined through rule making that a calibrated directional antenna is to be used, the requirements of the antenna (*e.g*., gain, half-power beamwidth, etc.) must be standardized so that the measurement test is not arbitrarily subject to the particular antenna selected by the tester.

124. Further, we agree with NAB and the Network Affiliates that digital television measurements should be made at 6.1 meters (20 feet) for one-story structures and 9.1 meters (30 feet) for two-story or taller structures; the same as analog television. This height standard is central to the definition of the planning model for DTV service areas. We therefore recommend that the procedures for measuring digital signals not be changed from the analog standard with respect to measurement height.

125. The SHVERA specifically asks the Commission to consider whether to account for the fact that some households use indoor antennas. As discussed above in the section on signal strength standards, the channel allotment plan for digital television developed by the Commission which defines the DTV service areas is premised on the planning factors; one of which is that an outdoor antenna is used. Households may certainly employ indoor antennas, but for standardized testing and planning an objective procedure must be used. To do otherwise would introduce a level of subjectiveness such that the entire testing process could be rendered meaningless. To begin with, there is the question of where within a household would the testing take place? If the antenna is in an attic, it may not be easily accessible for conducting the test at its location. Then, what if modifications are made to the house, such as new siding or a new roof. Would that subject the household to additional testing? And what if there are several televisions in the household using different antennas? In that situation, it is possible to

[220] *Id.* at 9.

[221] 47 U.S.C. § 339(a)(2)(D)(vii) specifies the dates on which the measurement of stations' signals may begin for the purpose of determining if a household is unserved. The earliest measurement date is April 30, 2006 for stations in top 100 markets that have chosen a tentative digital channel that is the same as its current digital channel or have lost interference protection and not been granted a testing waiver.

conceive a scenario where one television could be eligible for receiving a distant signal and another could be ineligible. Further, there is the issue of what antenna to use for testing. EchoStar suggests using a typical antenna, but does not define a typical antenna. An essential part of the test system cannot be left to choice. A good test must be repeatable. There are too many elements of variation in an indoor measurement that would render such a test essentially meaningless.

126. In addition, the Commission is on record that it expects households to make similar efforts to receive digital television as they made for analog. There is good reason for this position. If it was expected that households could do less, then it could have the effect of drastically shrinking the service areas of television stations. Or, as discussed above, to keep the same service area, stations would need to significantly increase their power, which could lead to interference situations. Neither of these outcomes is desirable. Additionally, many stations already have fully operational digital television facilities that have been built based on the rules and policies in place. It is our opinion that forcing these stations to change now would have an unknown effect on the number of households considered unserved and could have the effect of stifling the transition to digital television. For the reasons articulated above, we recommend that the measurement procedures for determining whether a household is unserved not include provisions for indoor testing.

127. Concerning antenna pointing, we continue to believe that for testing purposes of determining if a household is unserved under SHVERA, the procedures should remain consistent with those in use today. As with the suggestion above regarding the use of indoor antennas, we believe that it would be arbitrary to allow for any practice other than pointing the antenna in the direction of maximum signal strength. To allow other antenna orientation would not satisfy good engineering practice as the outcome would be subject to the individual tester rather than being objective. Further, as discussed above, rotors are readily available at reasonable cost (approximately $55-$100).[222] Thus, there is no undue burden on households to use a rotor. To move away from current practice, especially in a manner that is subjective, for the purpose of determining if a household is unserved under SHVERA would have the effect of treating similarly situated households differently depending on the particular person conducting the measurement. Thus, we recommend that the measurement procedure not be modified with respect to the requirement to orient the test antenna in the direction of maximum signal strength.

128. We do not recommend that the digital television measurement procedures for determining if a household is unserved under SHVERA include adjustments for multipath or time variability as suggested by EchoStar. As the NAB states, our planning factors are already conservative and overestimate available signal strength. Thus, any variation in the signal values due to multipath, white noise enhancement, or time variability are already more than compensated for. In addition, if a time variability factor is added, a long term study possibly over several years would need to be conducted for it to be properly characterized. By the time such a study could be completed, it is likely that the transition to digital television would be near completion. Furthermore, many digital television stations have been operational for some time now and there is no evidence that the current minimum signal strength values have been inadequate over time.

129. Finally, we note that commenters did not address co-channel or adjacent channel interference or clutter with respect to measurement. However, on this point, we note that the Commission's channel allotment procedures were designed to minimize the possibilities of this type of interference. In addition, television manufacturers are aware of the planning factors and the Commission's rules regarding interference levels and account for interference in their receiver designs by adjusting the receiver selectivity and adjacent channel rejection characteristics of the receiver. We also

[222] Network Affiliates comments, exhibit 3 (rotors).

observe that, if interference is present whether from other television channels, clutter, etc., when conducting a measurement, then that interference is directly included in the measurement result. Thus, no special provisions are necessary in the measurement procedures.

130. *Summary of Field Strength Measurement Procedure Recommendations*. As stated above, the current measurement rules are specific to analog television and must be updated to properly provide for measurement of digital television signals. Based on the comments received as well as our own evaluation, we recommend that the procedures for measuring digital television signals generally be similar to the current analog procedures which have been in use for some time with good results. Certain modifications are needed, however, to address differences in the analog and digital television signals. These modifications include the measurement of average power in the 6 MHz channel rather than measurement of the analog video carrier and determination of whether a household is unserved based on comparison of measured field strengths to the DTV noise-limited field strength standards rather than the analog Grade B field strength standards. In addition, we recommend that the DTV measurement procedures allow the use of any i.f. bandwidth so long as it is not greater than 6 MHz bandwidth of the DTV channel.

131. Because the current test procedures are set forth in the Commission's rules, these changes can only be implemented via a rule making proceeding. Because measurements of station's digital signals may begin as early as April 2006, the Commission will explore, in the near future, the rule changes necessary to establish proper procedures for testing the strength of digital television signals in such a rule making proceeding. We provide a brief description of the measurement procedure that we believe should be used for the evaluation of digital television signals below:

- Test antenna - The test antenna shall be either a standard half-wave dipole tuned to the center frequency of the channel being tested or a gain antenna, provided its antenna factor for the channel(s) under test has been determined. Use the antenna factor supplied by the antenna manufacturer as determined on an antenna range.

- Testing locations - At the test site, choose a minimum of five locations as close as possible to the specific site where the site's receiving antenna is located. If there is no receiving antenna at the site, choose a minimum of five locations as close as possible to a reasonable and likely spot for the antenna. The locations shall be at least three meters apart, enough so that the testing is practical. If possible, the first testing point should be chosen as the center point of a square whose corners are the four other locations. Calculate the median of the five measurements (in units of dBu) and report it as the measurement result.

- Multiple signals - If more than one signal is being measured (*i.e.*, signals from different transmitters), use the same locations to measure each signal.

- Measurement procedure - Measurements shall be made in accordance with good engineering practice.

- Testing equipment set-up – Perform an on-site calibration of the test instrument in accordance with the manufacturer's specifications. Tune a calibrated instrument to the center of the channel being tested. Measure the integrated average power over the full 6 megahertz bandwidth of the television signal. The i.f. of the instrument must be less than 6 megahertz and the instrument must be capable of integrating over the selected i.f. Take all measurements with a horizontally polarized antenna. Use a shielded transmission line between the testing antenna and the field strength meter. Match the antenna impedance to the transmission line at all frequencies measured, and, if using an un-balanced line, employ a suitable balun. Take account of the transmission line loss for each frequency being measured.

- Weather - Do not take measurements in inclement weather or when major weather fronts are moving through the measurement area.

- Antenna elevation - When field strength is being measured for a one-story building, elevate the testing antenna to 6.1 meters (20 feet) above the ground. In situations where the field strength is being measured for a building taller than one-story, elevate the testing antenna 9.1 meters (30 feet) above the ground.

- Antenna orientation - Orient the testing antenna in the direction which maximizes the value of field strength for the signal being measured. If more than one station's signal is being measured, orient the testing antenna separately for each station.

- Test Records - Written record shall be made and shall include at least the following: 1) a list of calibrated equipment used; 2) detailed description of the calibration of the measuring equipment, including field strength meters, measuring antenna, and connecting cable; 3) all factors which may affect the recorded field, such as topography, height and types of vegetation, buildings, obstacles, weather, and other local features for each spot at the measuring site; 4) a description of where the cluster measurements were made; 5) the time and date of the measurements and signature of the person making the measurements; and 6) a list of the measured value of field strength (in units of dBu and after adjustment for line loss and antenna factor) of the five readings made during the cluster measurement process, with the median value highlighted for each channel being measured.

V. PREDICTIVE MODELING

132. Currently, households have two methods of determining if they are unserved by a local analog television signal: predictive modeling and testing. Predictive modeling is a simple, cost-effective method for determining if a signal at a given location meets certain criteria for availability, such as its strength over a percentage of time. The Commission has established a predictive model that evaluates the coverage and interference of a particular digital TV station. This model, described in OET Bulletin 69, uses the Longley-Rice radio propagation model to make predictions of radio field strength at specific geographic points based on the elevation profile of terrain between the transmitter and each specific reception point.[223] The Commission, in accordance with SHVIA, has also implemented the use of a modified Longley-Rice model known as the "Individual Location Longley-Rice" (ILLR) model, for identifying unserved households attempting to receive analog broadcast signals.[224] We implemented an improved version of the ILLR model in order to make the predictive model more accurate by taking terrain features (such as hills), buildings, and land cover (such as forests) into account.[225]

133. The ILLR model has proven over time to be an accurate and reliable predictor of signal strength and has been well accepted by both the broadcast and DBS industries. In the current satellite distant signal eligibility scheme for analog television signals, predictive modeling is used first to determine a household's status as served or unserved by a local television signal. Based on the model's results a household may request an actual field measurement if it believes the predictive modeling is not an accurate predictor of actual conditions. Under the SHVERA, Congress provided that eligibility

[223] *See* OET Bulletin 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference". A computer is needed to make these predictions because of the large number of reception points that must be individually examined. Computer code for the Longley-Rice point-to-point radio propagation model is published in an appendix of NTIA Report 82-100, A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. Some modifications to the code were described by G.A. Hufford in a memorandum to users of the model dated January 30, 1985. With these modifications, the code is referred to as Version 1.2.2 of the Longley-Rice model. This version is used by the FCC for its evaluations.

[224] *See* OET Bulletin 72, "The ILLR Computer Program". OET Bulletin 72 details the computer program that the Commission was instructed by Congress to established under SHVIA in Section 339(c)(3) of the Communication Act. It provides that "[i]n prescribing such model, the Commission shall rely on the Individual Location Longley-Rice (ILLR) model set forth by the Federal Communications Commission in Docket No. 98-201 and ensure that such model takes into account terrain, building structures, and other land cover variations." *See* also *See Satellite Delivery of Network Signals to Unserved Households for Purposes of the Satellite Home Viewer Act; Part 73 Definition and Measurement of Signals of Grade B Intensity,* Report and Order, CS Docket No., 98-201, 14 FCC Rcd 2654 (1999). A computer is needed to make these predictions because of the large number of reception points that must be individually examined. Computer code for the ILLR point-to-point radio propagation model is published in an appendix of NTIA Report 82-100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. Some modifications to the code were described by G.A. Hufford in a memorandum to users of the model dated January 30, 1985. With these modifications, the code is referred to as Version 1.2.2 of the Longley-Rice model.

[225] *Id*. The *Inquiry* indicated several features of the improved ILLR model that make it unique. These include: the time variability factor is 50% and the confidence variability factor is 50%; the model is run in individual mode; terrain elevation is considered every 1/10 of a kilometer; the receiving antenna height is assumed to be 20 feet above ground for one-story buildings and 30 feet above ground for buildings taller than one-story; land use and land cover (e.g., vegetation and buildings) is accounted for; where error codes appear, they shall be ignored and the predicted value accepted or the result shall be tested with an on-site measurement; and locations both within and beyond a station's Grade B contour shall be examined.

determinations be made only on the basis of field testing and did not include any provisions for use of predictive modeling. Recognizing the benefits of predictive modeling, however, Congress, in Section 339(c)(1)(B)(iv) of the amended Communications Act, asked the Commission to consider whether to develop a predictive methodology for determining whether a household is unserved by an adequate digital signal under section 119(d)(10) of title 17, United States Code.[226] On a related issue, in Section 339(c)(1)(B)(vi) Congress also requested that the Commission consider whether to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter.[227]

134. To examine these issues, the Commission, in the *Inquiry*, requested comment on whether the improved ILLR model, with appropriate modifications, would accurately predict digital signal coverage at a specific location, or whether there is some other predictive model that would be more appropriate for this purpose. The Commission asked that commenters who propose either specific modifications to the improved ILLR model or alternative models provide detailed analysis as to how their proposed modifications will improve the ILLR model's prediction characteristics and/or an explanation of how the changes or alternatives would more accurately model the available signal level when accounting for terrain and possible signal interference.

135. *Inquiry Record*: The parties commenting in our Inquiry were supportive of the Commission developing a predictive model. For example, DirecTV states that the most important lesson from the last decade of distant network signal qualification with regard to analog television is that predictive modeling is better than on-site testing. EchoStar submits that it appears that the predictive methodology currently used in the SHVA context, *i.e.*, the ILLR model, has considerable applicability to the DTV world, although there remain improvements that might be made to accommodate reliable DTV reception. In supporting the ILLR model, the Network Affiliates explain that on-site testing is not the norm today[228] and that on-site testing frustrates and inconveniences subscribers, costs more money than it is worth, and should only be used as a last resort.[229] DirecTV describes the current process as one in

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[226] See 47 U.S.C. § 339(c)(1)(B)(iv). 17 U.S.C. § 119(d)(10) provides the following definition of unserved household:

> *(10) Unserved household.— The term "unserved household", with respect to a particular television network, means a household that—*
> *(A) cannot receive, through the use of a conventional, stationary, outdoor rooftop receiving antenna, an over-the-air signal of a primary network station affiliated with that network of Grade B intensity as defined by the Federal Communications Commission under section 73.683(a) of title 47 of the Code of Federal Regulations, as in effect on January 1, 1999;*
> *(B) is subject to a waiver granted under regulations established under section 339(c)(2) of the Communications Act of 1934;*
> *(C) is a subscriber to whom subsection (e) applies;*
> *(D) is a subscriber to whom subsection (a)(11) applies; or*
> *(E) is a subscriber to whom the exemption under subsection (a)(2)(B)(iii) applies.*

[227] *See* 47 U.S.C. § 339(c)(1)(B)(vi).

[228] DirecTv states that in last five years only 3,200 customers (0.3%) of those requesting distant network signals asked for an on-site test, and only about 1,400 of those actually received a test. DirecTv comments at 2.

[229] DirecTv comments at 2.

which subscribers must wait at least 30 days after receiving the results of predictive modeling while broadcasters decide whether to grant a waiver for them to receive distant network signals. It states that if such a waiver is denied, then the subscriber must wait until an independent, qualified tester can be identified in their area, wait for the tester to arrange an appointment and wait for the test to take place (and often tests are delayed due to weather or scheduling issues).[230] It further states that because the actual test is of a signal level rather than someone looking at their television picture, customers get frustrated with the testing process.[231] Finally, it provides that testing is a losing proposition as the average cost of a test is approximately $150 (with some as high as $450) and that it takes at least five years to recoup that cost from subscriber revenue.[232]

136. Those that commented on this issue all endorse use of the improved ILLR model that the Commission has already been using. CEA states that the ILLR model is a very good tool with years of engineering development and that it is not aware of any industry discussion regarding a better model for this purpose.[233] The Network Affiliates recommend use of the ILLR model. They state that analog TV coverage is predicated upon this model and the broadcast and satellite industries have five years of experience with its use.[234] However, the NAB and the Network Affiliates submit that a DTV ILLR model should only be used after the transition to digital television is complete. They believe that otherwise the process would be too complicated and confusing.[235] In this regard, the NAB explains that in the short term (prior to the end of the digital transition) problems could arise due to variations in dates that different stations will actually begin broadcasting digital signals.[236] It states that few translator stations have channel assignments, much less fully functioning facilities and many full power stations won't be subject to testing until July 2007 or later.[237] The NAB further states that Congress postponed the date on which many broadcast stations would begin to be subject to testing because Congress recognized that it would be unfair to penalize a station for not delivering a digital signal when it cannot be reasonably expected to do so.[238] It contends that Congress created a complex and somewhat unpredictable schedule for when

[230] *Id*. comments at 2-3.

[231] *Id*. comments at 3-4.

[232] *Id*. comments at 4-l

[233] CEA comments at 4.

[234] Network Affiliates comments at 44-45.

[235] *Id*. comments at 43-44.

[236] NAB comments at vi-vii and 31-33.

[237] *Id*. comments at 31. The testing referred to here is the measurement at an individual subscriber's location of a digital television signal level for the purpose of determining if the subscriber at that location is considered unserved and therefore eligible to receive a distant network signal.

[238] *Id*. comments at 34-35. 47 U.S.C. § 339(a)(2)(D)(vii) provides trigger dates for testing. NAB characterizes the schedule set up by Congress as testing to begin on April 30, 2006, for stations in top 100 markets that have chosen a tentative digital channel that is the same as its current digital channel and have not been granted a testing waiver and for stations in top 100 markets that have been found to have lost interference protection. Testing begins on July 15, 2007 for stations in top 100 markets that have chosen a tentative digital channel different from its current digital channel and have not been granted a testing waiver and for stations below the top 100 markets that have not been granted a testing waiver. Finally, there are unknown future dates for translator stations – one year after the date on which commission completes all actions necessary for allocation and assignment of digital television licenses to translator stations; and for full power stations with testing waivers – continue to be exempt from testing as long as extensions of waivers are approved.

stations would be subject to testing in order to protect stations from a draconian loss of viewers due to circumstances beyond their control. On this point, the NAB argues that since Congress barred site testing of certain station's digital signals, it would be equally improper to subject those stations to predictions of the signal strength of those same signals.[239] The Network Affiliates offer similar comments.[240] The NAB further comments that it believes that what Congress intended here is that if a station is not yet eligible to have its digital signal evaluated, then the analog signal should be evaluated instead. This, the NAB and the Network Affiliates aver, would be the logical way to give stations "credit" for coverage when they have been excluded from testing.[241]

137. The NAB continues that the ILLR model should be used in the long term (after the digital transition) because it does exceptionally well at predicting whether or not particular locations will receive a signal above the DTV minimums. It states that the model provides correct predictions 95% of the time and that when errors do occur they are evenly divided between over and under predictions.[242] MSW draws a similar conclusion for use of the ILLR model with respect to DTV. It studied real world empirical data from thousands of measurements in 12 different U.S. cities and submits that the data shows that the Longley-Rice model correctly predicted 94.4% of the time when the signal would be above the DTV minimum.[243]

138. EchoStar submits that changes are needed in the ILLR predictive model to make it suitable for use in predicting the availability of DTV signals. It states that the model should be modified to include an improved time variability factor and to incorporate more realistic values for system noise, building penetration, and land cover and clutter.[244] EchoStar submits that the analog ILLR model is based on a time variability factor of 50%, which means that the model assumes that a household is unable to receive an analog signal at or above the minimum level about half of the time.[245] It infers that for digital television this similarly means that there will be an inability to receive a digital picture about half the time. EchoStar avers that even a time variability factor of 90% means a subscriber will not have reception for up to 5 weeks a year. As a remedy, it suggests that the model be modified to incorporate an increase in temporal reliability to 99% or more until there is greater experience with digital television.[246] H&E also argues that 90% time reliability seems not to be in the consumer's best interest.[247] The NAB and the Network Affiliates counter EchoStar by stating that changing to a 99% time variability factor amounts to changing the rules in the middle of the game.[248] MSW avers that EchoStar overestimates the

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[239] *Id*. at 36.

[240] Network Affiliates comments at 43-44.

[241] NAB comments at 37.

[242] *Id*. NAB comments at vi.

[243] NAB comments at MSW engineering study at 28.

[244] EchoStar comments at 9.

[245] As discussed below (and above in the section on signal strength), the signal strength standards in the rules are in fact based on an F(50,90) level of signal availability, which implies that a signal would be available at least 90% of the time, not 50% as EchoStar incorrectly states.

[246] *Id*.

[247] EchoStar comments at H&E engineering study at 7.

[248] NAB reply comments at 8; Network Affiliates reply comments at 8.

impact of the time variability factor. It explains that any loss of service does not occur over the entire service area, but only at outer edges of a television station's service area and even there any outage that occur are not consecutive, nor is the time duration of a particular outage known. MSW states that many instances of service loss will occur during times when no one is watching TV or may be so short as to only cause a momentary disruption. MSW offers that for those households at the edge of the service area, reception can be improved with a mast-mounted low noise amplifier (LNA).[249]

139. With respect to system noise, EchoStar states that the planning factors underlying the Commission's DTV field strength standards assume that the impedance is matched between the receiver and the antenna.[250] It claims that this is rarely the case in practice and that the predictive model should take this into account and use a noise figure increased by 3 dB to correct for this inaccuracy in the planning factors.[251] EchoStar obtains this 3 dB figure by observing that many DTV antennas have voltage standing wave ratio[252] (VSWR) values that exceed 3:1 over much of their design bandwidth and that exceed 2:1 over essentially all of their design bandwidth.[253] On this point, MSW argues that impedance mismatch loss between a TV antenna and receiver as well as a higher digital television receiver noise figure can be mitigated by a mast-mounted LNA. In cases where such losses might be a problem, MSW states that an LNA resolves the matter by isolating the antenna impedance from that of the downlead coaxial cable and the DTV tuner input impedance.[254]

140. EchoStar also argues that the DTV predictive model should account for building penetration. It contends that the H&E study shows building loss at VHF can be as high as 30 dB for high clutter areas. It adds that further study may yield a more complete set of figures on building penetration loss for incorporation into the model, especially for apartment dwellers with indoor antennas.[255] MSW argues that as far as the model is concerned building penetration is irrelevant given that TV service should be established on the basis of an outdoor model and that therefore indoor measurements should not be performed.[256]

141. Finally, on the topic of land use and land clutter, EchoStar notes that the Commission has recognized that incorporation of such factors into the predictive model would increase the model's accuracy. However, it observes that the Commission has set almost all the clutter-loss values for VHF channels to zero. It argues that this is a problem for analog television, but an even larger problem for

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[249] MSW reply comments at 10; Network Affiliates reply comments at 7.

[250] Impedance is the total passive opposition offered to the flow of electric current, *see* Federal Standard 1037C, "Telecommunications: Glossary of Telecommunications Terms, 1996."

[251] EchoStar comments at 10.

[252] Voltage standing wave ratio is the ratio of the maximum to the minimum voltage in a standing wave pattern in a transmission line. VSWR is a measure of impedance mismatch between a transmission line and its load; the higher the VSWR, the greater the mismatch, where a VSWR of 1 corresponds to a perfect impedance match. *See* Federal Standard 1037C, "Telecommunications: Glossary of Telecommunications Terms, 1996."

[253] EchoStar comments at H&E engineering statement at 11-12.

[254] MSW reply comments at 14.

[255] EchoStar comments at 10.

[256] MSW reply comments at 14.

digital because if the signal level falls below the minimum needed, then the entire picture is lost.[257] NAB notes that the ILLR model is partially based on actual field measurements and thus already takes clutter into account to a significant degree because clutter affects real world field measurements. It also states that the ILLR model is already in balance at low-VHF and so no additional factors to adjust for clutter loss are needed.[258]

142. *Evaluation*. When it enacted the SHVIA, Congress explicitly provided for the Commission to prescribe a predictive model to evaluate if a household is unserved by an analog television signal. That model – the modified individual location Longley-Rice propagation model - has served the industry well as it has proven to be highly accurate over time. Through the use of this model, both consumers and terrestrial and satellite television operators have saved considerable time, money, and frustration that would come with having to conduct an actual measurement test every time a satellite customer believes that he/she is unable to receive an adequate signal off-the-air from a local television network affiliated station. The same situation is likely to exist with regard to digital television signals. Therefore, we recommend that Congress provide for the Commission to explore a similar model for digital television through a rule making proceeding.

143. Those commenters that provided input on this issue were all in agreement that a predictive model should be available for determining if a household is unserved by a digital television signal and that the model be the ILLR. We agree with those comments. The Longley-Rice propagation model has been used for considerable time and it has proven to be highly accurate at predicting the field strengths of television stations at a location. This is illustrated by the data presented by the commenters showing an accuracy rate of almost 95%.[259] Additionally, because the standard Longley-Rice point-to-point coverage model was used to develop the digital television allotment plan, the industry already has considerable practice using this model for digital television in addition to the experience gained for analog television over the last few years. And since there do not seem to be any candidate models that would offer superior performance to the improved ILLR propagation model, a change at this point in time would entail substantial development and testing which would likely not be completed until after the transition to digital television is complete and a time when the satellite television providers offer local-into-local signals for most, if not all, TV designated market areas (DMAs). It is anticipated that at that point the requirements of SHVERA with respect to distant signal retransmission will be moot in most cases.

144. We note that while endorsing use of the ILLR, NAB and the Network Affiliates advocate its use only after the digital transition is complete, arguing that its use prior to this time would be confusing and serve to penalize stations that transition to broadcasting digital signals later rather than earlier but still in accordance with the prescribed timetable.[260] They argue that local stations that build out their digital facilities at a later time would lose their local viewers to a distant network signal even though they are fully compliant with the law and the Commission's rules. We agree with NAB and the Network Affiliates that the timing governing the use of a predictive model should be consistent with the SHVERA provisions that permit subscribers to receive distant digital signals under specified circumstances. These provisions take account of various factors that could legitimately prevent a station

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[257] EchoStar comments at 10-11.

[258] Network Affiliates comments at 44-47.

[259] NAB comments at MSW engineering study at 28.

[260] NAB comments at 38 and 40-45; Network Affiliates comments at 42-44.

from serving its potential digital service area at this time.[261] The provision of the statute cited by NAB and the Network Affiliates applies to subscribers who are eligible for testing (*i.e.*, subscribers who live within the area predicted to be served by the analog predictive model of a local network station and are seeking a distant digital signal for a station affiliated with the same network as the local network station).[262] This provision further provides that stations that may be subject to a digital signal test may request a waiver from the Commission to prohibit such testing if the station proves that it satisfies the statutory criteria related to unremediable limitations on the station's digital signal coverage.[263] Thus, if Congress amends the statutory provisions to recognize a predictive model with respect to digital signals and provides discretion for the Commission to develop such a model, the appropriate timing for use of the model should also be considered by Congress in conjunction with such legislative changes. Congress could, for example, provide that use of the model would be subject to the same waiver provisions that apply to stations with respect to digital signal testing.[264] We also note that Congress is currently considering legislation to mandate the date on which the transition to digital television would end, which, in turn, is likely to influence the timing for use of a predictive model.

145. There were several suggestions made by commenters for further changing the ILLR model. These include changing the time variability factor, and incorporating different values for system noise figure, building penetration, and land cover and clutter. First, EchoStar argues that the time variability factor for DTV should be increased from 50% to 99%. We first note that the noise-limited contour that defines the digital television service area is based on planning factors which specify use of the F(50, 90) curves, not the F(50, 50) curves as implied by EchoStar; that is the digital signal level is at or above the minimum level at 50% of the locations for 90% of the time, not 50% of the time as suggested by EchoStar.[265] We also note that the 90% availability level defines the edge of a station's service area and that at locations inside this contour the availability percentage would be greater than 90%. Further, as stated by MSW, the time when a signal is below the specified minimum value is likely to occur in small increments, some of which are when viewers are not even watching television. Thus, only a small minority of the total number of viewers may experience outages as high as 10% of the time. We also observe that the 90% availability level has been used to define analog TV service and has historically served viewers well. For these reasons, we do not recommend any changes to the digital television time variability factor for the purposes of SHVERA.

146. EchoStar also argues that the input for the system noise figure to the predictive model should be increased by 3 dB to account for impedance mismatch between the antenna and the receiver. We agree with EchoStar that there may be some loss in the transmission line and associated balun due to impedance mismatch. However, we do not believe that this loss is significant or that the predictive model input needs to be modified to account for such loss. First, as NAB states and we discuss above, our planning factors are conservative in that the available coaxial cable generally have losses less than those

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[261] *See, e.g.,* 47 U.S.C. § 339(a)(2)(D)(viii). These provisions further recognize that household digital signal testing with respect to translators is on a different schedule from full power stations. 47 U.S.C. § 339(a)(2)(D)(vii)(II).

[262] 47 U.S.C. § 339(a)(2)(D)(vii)(I).

[263] 47 U.S.C. § 339(a)(2)(D)(viii). *See also* 47 U.S.C. § 339(a)(2)(D)(ix) (providing special waiver provision for translator stations).

[264] 47 U.S.C. § 339(a)(2)(D)(viii), (ix).

[265] *See* 47 C.F.R. § 73.622(e).

assumed in the planning factors.[266] Second, there are readily available devices that consumers can use, including LNAs, to reduce mismatch in the transmission line and thus reduce such loss. We also believe that the other planning factors such as antenna gain and receiver noise performance are generally conservative such that together there is sufficient margin to compensate for any signal losses that may result from impedance mismatching. We therefore see no reason that the system noise figure should be increased for the purpose of using a predictive model to determine if a household is unserved.

147. Another area where EchoStar seeks changes in the improved ILLR predictive model is signal loss from building penetration. We disagree that this model should be augmented to account for signal loss from building penetration. As discussed above in the section on signal measurement, the channel allotment plan for digital television is based on the assumption that an outdoor antenna is used and the expectation that households will make similar efforts to receive digital television as they made for analog. Thus, any predictive modeling must reflect these assumptions consistent with the digital television planning factors. Otherwise, inaccurate results will ensue which could have the effect of decreasing confidence in the model. In addition, there is no accepted value for modeling the loss for building penetration as this phenomenon varies depending on the building materials, configuration of the structure, and other related factors. For these reasons, and given our recommendation in the section on measurement procedure that all measurements continue to be conducted outside, there is no reason for a predictive model to assume any building penetration loss. Therefore, we do not recommend that the model input reflect any such losses.

148. The last area where commenters seek changes in the predictive model is with respect to land use and land clutter. Currently, the predictive model used for analog television accounts for additional signal loss due to land use and land clutter. In developing the land use and land clutter adjustment values, the Commission determined, after careful consideration of the available data, that the correct loss value for VHF channels is 0 dB in all cases and for UHF channels the loss values vary depending on the type of land cover over which the television signal propagates.[267] EchoStar argues that in addition to the loss added for UHF channels, there should be some loss associated with VHF channels. NAB and the Network Affiliates argue otherwise and take the position that the improved ILLR model already takes clutter into account to a significant degree because the model is partially based on actual field measurements and clutter affects real world field measurements. Any predictive model that is prescribed should provide output that is as accurate as possible; anything less would diminish its value as a tool for determining whether a household is able to receive off-the-air digital television signals. For the analog model, we believe that we struck the correct balance for clutter loss. This has been borne out by the data on the record of its performance, which shows that using the values adopted by the Commission the ILLR model produces approximately an equal number of over predictions as under predictions.[268] Thus, a range of values, including zero, that correspond to different land cover types are valid. For any digital model that may be developed, we believe that the values currently in use for the analog model will similarly yield accurate results. We believe that the proper arena for discussing correct clutter loss values is in a rule making proceeding. Therefore, we believe that a range of clutter loss values ranging from zero upwards may all be valid inputs for a version of the ILLR model that is used for predicting the availability of digital television signals and recommend that clutter loss values be determined and then incorporated into the digital model through a process similar to that used to determine the clutter loss values used in the analog TV ILLR model.

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[266] NAB reply comments at 11.

[267] *See ILLR First Report and Order* at ¶¶ 14-15.

[268] *Id.*

149. *Summary of Predictive Model Recommendations*. In summary then, we recommend that Congress amend the copyright and Communications Act to recognize digital signal strength predictions for the purpose of determining whether a subscriber is "unserved." We also recommend that Congress provide the Commission with authority to develop a predictive model for the purpose of determining households that are unserved by local digital signals for purposes of determining eligibility to receive retransmitted distant network signals under the SHVERA. For such purpose, we recommend that the existing Individual Location Longley-Rice (ILLR) predictive model be used. This model has been used to develop the channel allotment plan and we do not believe that any additional changes to the model inputs are necessary for purposes of SHVERA.

APPENDIX A

Section 339(c)(1) of the Communications Act of 1934, As Amended

Section 339(c)(1) of the Communications Act of 1934, as amended by the SHVERA, provides as follows:

(1) STUDY OF DIGITAL STRENGTH TESTING PRODEDURES-

(A) STUDY REQUIRED- Not later than one year after the date of the enactment of the Satellite Home Viewer Extension and Reauthorization Act of 2004, the Federal Commissions Commission shall complete an inquiry regarding whether, for purposes of identifying if a household is unserved by an adequate digital signal under section 119(d)(10) of title 17, United States Code, the digital signal strength standard in section 73.622(e)(1) of title 47, Code of Federal Regulations, such statutes or regulations should be revised to take into account the types of antennas that are available to consumers.

(B) STUDY CONSIDERATIONS- In conducting the study under this paragraph, the Commission shall consider whether--

(i) to account for the fact that an antenna can be mounted on a roof or placed in a home and can be fixed or capable of rotating;
(ii) section 73.686(d) of title 47, Code of Federal Regulations, should be amended to create different procedures for determining if the requisite digital signal strength is present than for determining if the requisite analog signal strength is present ;
(iii) a standard should be used other than the presence of a signal of a certain strength to ensure that a household can receive a high-quality picture using antennas of reasonable cost and ease of installation;
(iv) to develop a predictive methodology for determining whether a household is unserved by an adequate digital signal under section 119(d)(10) of Title 17, United States Code;
(v) there is a wide variation in the ability of reasonably priced consumer digital television sets to receive over-the-air signals, such that at a given signal strength some may be able to display high-quality pictures while others cannot, whether such variation is related to the price of the television set, and whether such variation should be factored into setting a standard for determining whether a household is unserved by an adequate digital signal; and
(vi) to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter.

(C) REPORT- Not later than one year after the date of the enactment of the Satellite Home Viewer Extension and Reauthorization Act of 2004, the Federal Communications Commission shall submit to the Committee on Energy and Commerce of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report containing—

(*i*) the results of the study under this paragraph; and
(*ii*) recommendations, if any, as to what changes should be made to Federal statutes or regulations.

APPENDIX B

Parties Submitting Comments and Reply Comments

Parties Submitting Comments

1. ABC, CBS, NBC, Network Affiliates
2. The Association for Maximum Service Television, Inc.
3. ATI Technologies, Inc.
4. Consumer Electronics Association (CEA)
5. DIRECTV Inc.
6. EchoStar Satellite L.L.C.
7. National Association of Broadcasters (NAB)
8. Paul Robinson
9. Viamorph

Parties Submitting Reply Comments

1. ATI Technologies, Inc.,
2. ABC, CBS, and NBC Television Affiliate Associations
3. Cohen, Dippell and Everist, P.C.,
4. EchoStar Satellite L.L.C.,
5. National Association of Broadcasters

APPENDIX C

Tests of ATSC 8-VSB Reception Performance of Consumer Digital Television Receivers Available in 2005

November 2, 2005

Technical Research Branch
Laboratory Division
Office of Engineering and Technology
Federal Communications Commission

OET Report
FCC/OET TR 05-1017

Prepared by:
Stephen R. Martin

FOREWORD

The author gratefully acknowledges the advice and technical support offered by the following individuals and organizations. Gary Sgrignoli and Dennis Wallace of MSW provided technical guidance at the inception of the project, and Gary Sgrignoli also provided guidance later and reviewed an early draft of this report. Mark Hryszko, Mike Gittings, Raul Casas of ATI Research, Inc. identified degraded performance of the FCC's RF capture player (which was subsequently repaired and calibrated before conducting the tests reported herein) and provided technical advice; Mark Hryszko and Kevin Murr assisted in comparative testing at ATI's laboratory using ATI's equipment as a double-check of the FCC equipment and measurement procedures for the FCC Laboratory tests reported herein. Wayne Bretl of Zenith Electronics Corp. and Rich Citta of Micronas Semiconductors, Inc. provided technical advice regarding testing with RF captures. Victor Tawil of the Association for Maximum Service Television (MSTV) and Sean Wallace of Wavetech Services, LLC provided RF captures and technical advice.

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EXECUTIVE SUMMARY

This report presents the results of laboratory tests of over-the-air digital (ATSC/8-VSB[*]) reception performance of 28 consumer digital television (DTV) receivers. The tests were performed to provide an empirical basis for answering questions about DTV reception capability that derive from study requirements imposed by Congress as part of the *"Satellite Home Viewer Extension and Reauthorization Act of 2004"* (SHVERA). The Act requires that the FCC conduct a six-element study. The element relevant to this report is as follows:

> *"consider whether … there is a wide variation in the ability of reasonably-priced consumer digital television sets to receive over-the-air signals, such that at a given signal strength some may be able to display high-quality pictures while others cannot, whether such variation is related to the price of the television set, and whether such variation should be factored into setting a standard for determining whether a household is unserved by an adequate digital signal."*

SAMPLES

Two categories of DTV receivers were acquired for this project: digital set-top boxes (STBs) and DTVs with integrated over-the-air ATSC tuners. All receivers are standard, off-the-shelf consumer products currently on the market. STBs were included in the study because connection of an STB to an existing television represents the lowest-cost alternative for DTV reception. The measurement results in this document are reported by category (STB or integrated DTVs) and, within the DTV category, by price range ($370 - $1000, $1001 - $2000, and $2001 - $4200). Brands and model numbers are not reported.

TEST RESULTS

The tests performed for this report were laboratory-based measurements emulating two types of over-the-air reception conditions for DTV receivers:

(1) Unimpaired signal (i.e., no multipath) [Chapters 3 – 5], and

(2) Signal impaired by multipath (ghosts) [Chapter 6].

The unimpaired signal measurements can be used to quantitatively predict receiver performance under benign reception conditions—i.e., with little multipath or interference. The multipath tests, which focus primarily on particularly difficult multipath conditions, provide a basis for comparing the ability of different DTV receivers to handle difficult multipath conditions. A link between these laboratory-based measurements and earlier FCC field-test data provides a basis for anchoring the multipath results to representative, real-world reception conditions [Chapter 7].

Benign Multipath Conditions

Overall performance under benign reception conditions is indicated by minimum signal level at the threshold of visibility of errors (TOV) for each receiver. The median measured values of this parameter across all of the tested consumer DTV receivers were -82.2 dBm, -83.2 dBm, and -83.9 dBm, respectively, in the low-VHF, high-VHF, and UHF bands. These values comply, within measurement accuracy, with the -83 dBm minimum performance standard recommended by the ATSC. The corresponding medians for just the low-cost category of DTVs (-83.3 dBm, -83.4 dBm, and -84.1 dBm, respectively) were very slightly better than the medians across all of the receiver categories.

[*] 8-level Vestigial Side Band (8-VSB) is the over-the-air digital television (DTV) transmission format recommended by the Advanced Television Systems Committee (ATSC) and adopted by the FCC as the U.S. standard for terrestrial DTV transmission.

OET Bulletin No. 69, *"Longley-Rice Methodology for Evaluating TV Coverage and Interference"*, presents a methodology for predicting whether a household is served by a given broadcast signal. The DTV receiver model in that bulletin predicts minimum signal levels at TOV of -81.0 dBm and -84.0 dBm for VHF and UHF, respectively. While the test results presented in this report—together with data based on earlier FCC field tests—could be used to fine tune those parameters, the net effect of such changes would be small; consequently, no compelling reason is seen for such fine tuning.

Variation in minimum signal at TOV among the receivers was found to be moderately high in the low-VHF band, but small in the high-VHF and UHF bands.

In the low VHF band (as represented by TV channel 3 in these tests), the moderately high variability in performance among the samples is indicated by the 3.7-dB standard deviation among the receivers and the fact that two same-brand receivers exhibited performance significantly worse than the median—by 11 and 12 dB. (It is noted that, absent those two receivers, the standard deviation would have been a more modest 2.3 dB.)

Though the performance variation among the receivers in the low VHF band was moderately high, no statistically significant price-dependence of that variation was found. In fact, the median performance of the low-cost TVs was slightly better than that of either the mid-priced or high-priced TVs. The median performance of the tested set-top boxes was poorer than that of the integrated DTVs by 2.3 dB, though it must be noted that these were older designs (2004 and earlier models that were still on the market at the time of this report) than the integrated DTVs.

In the high-VHF and the UHF bands (represented in the tests by channels 10 and 30, respectively), the variation in reception performance among the tested receivers was small—as indicated by the 1.6-dB standard deviation in the high-VHF band and 0.9 dB in the UHF band. The variation of performance with price was judged to be both small and not statistically significant. The median performance of the high-cost TVs differed from that of the low-cost TVs by less that 0.2 dB. Set top boxes exhibited median performance 0.6 dB and 0.7 dB worse than the median of all TVs in the low-VHF and UHF bands, respectively.

Most of the variation in reception performance among the tested receivers was due to differences in *effective* noise figure rather than in the carrier-to-noise ratio (CNR) required for successful demodulation. The noise figure variations were larger than the required-CNR variations by factors ranging from 4, in the UHF band, to 16, in the low-VHF band.

Difficult Multipath Conditions

The tested receivers fall into two distinct tiers of multipath-handling capability—the upper tier representing a significant performance improvement associated with at least two companies' newest generation of demodulator chips. While the difference in ability to handle difficult multipath conditions between the two tiers is large, linkage of the current results with earlier field test results (Chapter 7) suggests that the observed performance differences are of no consequence in the vast majority of reception locations, if an outdoor, mast-mounted antenna is used. When an indoor antenna is used, the linkage suggests that the observed performance differences would be significant in many, but probably not most, locations.

Given that both tiers of performance appeared in all three price ranges of DTVs, there appears to be no price dependence of multipath performance; however, there was a complete absence of upper-tier performers among the tested set-top boxes. This absence is attributed to the older designs of the set-top box products—all of which were introduced in the year 2004 or earlier. Among the tested DTV receivers, none that were introduced before March 2005 were found to exhibit upper-tier performance, whereas 48 percent of those introduced in or after that month performed at the upper tier level.

CHAPTER 1
INTRODUCTION

BACKGROUND

This report presents the results of laboratory tests of terrestrial over-the-air digital (ATSC/8-VSB[*]) reception performance of 28 consumer digital television (DTV) receivers. Though the tests involve terrestrial reception performance, the tests were performed to provide an empirical basis for answering questions about DTV reception capability that derive from study requirements imposed by Congress as part of the *"Satellite Home Viewer Extension and Reauthorization Act of 2004"* (SHVERA).

SHVERA, passed by Congress in December 2004, extends and amends the *"Satellite Home Viewer Act of 1994"*. The Act allows satellite communications providers to provide broadcast programming to satellite subscribers that are unserved by local—over-the-air—broadcast stations.

Section 204 of SHVERA requires that the Commission conduct an inquiry regarding "whether, for purposes of identifying if a household is unserved by an adequate digital signal under section 119(d)(10) of title 17, United States Code, the digital signal strength standard in section 73.622(e)(1) of title 47, Code of Federal Regulations, or the testing procedures in section 73.686(d) of title 47, Code of Federal Regulations, such statutes or regulations should be revised to take into account the types of antennas that are available to consumers."

The act specifies six areas of inquiry. The relevant area for this report is the one that relates to characteristics of consumer digital television receivers. It states that the inquiry should

> *"consider whether … there is a wide variation in the ability of reasonably-priced consumer digital television sets to receive over-the-air signals, such that at a given signal strength some may be able to display high-quality pictures while others cannot, whether such variation is related to the price of the television set, and whether such variation should be factored into setting a standard for determining whether a household is unserved by an adequate digital signal."*

The Act requires that the results and recommendations from this inquiry be reported to the Committee on Energy and Commerce of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate.

OBJECTIVES

This report presents the results of a measurement program that was undertaken by the Technical Research Branch of the FCC Laboratory in order to address those portions of the SHVERA-required inquiry that involve characteristics of consumer digital television receivers. Accordingly, the objectives are to provide an empirical basis for answering three questions.

[*] 8-level Vestigial Side Band (8-VSB) is the over-the-air digital television (DTV) transmission method recommended by the Advanced Television Systems Committee (ATSC) and adopted by the FCC as the U.S. standard for terrestrial DTV transmission.

(1) Is there a wide variation in the ability of reasonably-priced consumer digital television sets to receive over-the-air signals, such that at a given signal strength some may be able to display high-quality pictures while others cannot?
(2) Is such variation is related to the price of the television set?
(3) Should such variation be factored into setting a standard for determining whether a household is unserved by an adequate digital signal.

ABILITY TO RECEIVE SIGNALS

The ability of a television receiver to receive over-the-air signals and display a high quality picture is influenced by the level and quality of the television signal reaching its antenna input terminal from the antenna downlead, the amount of noise or interference reaching the input terminal, and the properties of the television receiver—including the amount of noise created by the input circuitry of the television receiver.

Threshold

When a television receives a signal from an analog TV station using the NTSC transmission system that has been employed in the U.S. for decades, the TV exhibits a noisy picture at low signal levels. The noise is frequently termed "snow". If the signal level increases, the amount of snow in the picture decreases very gradually. If signal level is increased until it exceeds the internally generated noise of the television's input circuits by 34 dB (carrier-to-noise ratio = 34 dB), the picture level improves to the point that typical viewers consider the noise to be "slightly annoying".[*] The noise remains perceptible but is not considered annoying at a 40-43 dB carrier-to-noise ratio,[†] and ceases to be visible at all when the carrier-to-noise ratio (CNR) is 51 dB.[‡]

When a digital television receives a signal from a digital television station using the ATSC transmission system adopted by the FCC for terrestrial DTV broadcasts in the U.S., the transition from no picture to a virtually perfect picture occurs over a much narrower range of signal levels. Once a threshold signal level is reached, the TV picture is virtually perfect—limited only by the quality of the source material and the characteristics of the television display (for example, the picture tube and associated image forming circuits and software). This threshold corresponds to a carrier-to-noise ratio of only about 15 dB. If the signal is reduced below this threshold value, visible errors begin to occur in the picture—becoming more frequent with further reductions in signal level, until the picture becomes essentially unusable at a level only about 1 dB below the threshold.

Part of the task of determining the ability of a DTV receiver to receive over-the-air signals is to determine this threshold when only a DTV signal is applied to the antenna terminal (i.e., without any noise or interfering signals), as well as when both a DTV signal and source of electronic noise are applied simultaneously to the antenna terminal. The resulting measured parameters are the minimum signal at the threshold of visibility of errors (TOV) and the white noise threshold—also known as the required carrier-to-noise ratio (CNR).

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[*] Citta, Richard, and Sgrignoli, Gary, "ATSC Transmission System: VSB Tutorial", Montreuz Symposium, June 12, 1997, p.8.

[†] Sgrignoli, Gary, "Interference Analysis of Co-Sited DTV and NTSC Translators", IEEE Transactions on Broadcasting, Vol. 51, No. 1, March 2005, p.3.

[‡] Eilers, Carl, and Sgrignoli, Gary, "Digital Television Transmission Parameters-- ATSC Compliance Factors", IEEE Transactions on Broadcasting, Vol. 45, No. 4, December 1999, p.12.

Multipath

A propagation phenomenon called multipath causes very different effects for analog versus digital television transmissions. Multipath is caused by the fact that the broadcast signal may reach the television antenna through several propagation paths that reflect off of various natural and man-made objects. A direct signal path encountering no reflections may also be present. The reflected signal paths are essentially delayed versions of the direct-path signal—with the delay being dependent on the additional distance traveled by each reflected signal.

With analog (NTSC) television, multipath causes one or more "ghost" images displaced horizontally from the main image. (The term "ghost" refers to the ghost-like appearance of the displaced image, which appears as a fainter version of the primary image.) Ghosts can significantly degrade picture quality even when the primary signal strength is quite high. In analog television, control of ghosts is usually accomplished by using a directional antenna oriented to selectively receive the stronger signal (usually the direct path signal) and to reject—at least to some extent—other paths, for which signals typically arrive from other directions.

With digital (ATSC) television, multipath does not cause ghost-like displaced images on the screen, though the term "ghost" is still used to describe multipath propagation. Instead, a weak ghost may have no effect on the picture at all. A somewhat stronger ghost may cause picture impairments such as blockiness or freeze frames. An even stronger ghost can completely prevent the television from decoding the digital data necessary to produce a picture and sound. Consequently, all ATSC television receivers contain a circuit called an equalizer, the function of which is to adaptively cancel ghosts. If the equalizer reduces the amplitudes of all but one signal path to a sufficiently low level, the picture will be displayed with no impairment at all. If the cancellation is insufficient, the TV may fail to produce a picture even when signal level is very strong.

Equalizer performance has been one of the primary areas of technological improvement as DTV receivers progress from one generation to the next. With advances in equalizer technology, significant improvements have been made in the ability to cancel larger amplitude ghosts, ghosts with larger delays relative to the main signal, and ghost signals arriving earlier than the main signal (in cases for which the direct path signal is either absent or weaker than reflected signals). Other researchers have noted a high degree of improvement in multipath-handling capability of the latest generation of equalizer technology.[*]

Consequently, a part of determining the ability of a DTV receiver to receive over-the-air signals is to characterize the ability of the receiver to handle various multipath conditions. For this study, that characterization was performed by feeding the antenna input terminal of the TV with signals that were recorded from television antennas at various locations in New York City and Washington, D.C.

It is also noted that, for DTV receivers that are compliant with the EIA/CEA-909 Antenna Control Interface specification, smart antenna technology can mitigate the effects of multipath, as well as certain other reception issues, through automatic optimization of various antenna parameters such as the effective pointing direction, polarization, and amplifier gain on a per-channel basis. The ATSC, in its "ATSC Recommended Practice: Receiver Performance Guidelines", recommends that "in addition to the other guidelines contained herein for the handling of signal conditions that are experienced in the field, consideration of a receiver-controlled antenna, as enabled by CEA-909, is recommended" and notes that such a controllable antenna can "work in conjunction with a receiver's equalizer, tuner, and demodulator to improve reception under conditions of multipath and unusually weak or strong signals."[†] This interface

[*] Laud, Tim, Aitken, Mark; Bretl, Wayne; and Kwak, K. Y., "Performance of 5th Generation 8-VSB Receivers", IEEE Transactions on Consumer Electronics, Vol. 50, No. 4, November 2004.

[†] "ATSC Recommended Practice: Receiver Performance Guidelines", ATSC Doc. A/74, Advanced Television Systems Committee, 17 June 2004, p.24.

was included in only one of the DTV receivers tested for this report. Though the smart antenna functionality was not formally tested, we observed that it did offer a user-friendly way to optimize TV reception. Not only does it simplify the initial setup of the DTV for the consumer, but it also provides the advantage of instantaneously switching the antenna pointing direction—electronically—whenever the TV channel is changed.

STANDARD FOR DETERMINING WHETHER A HOUSEHOLD IS UNSERVED

Section 73.622(e) of the Commission's rules, Code of Federal Regulations (CFR) 47, specifies a method for determining the service area of a DTV broadcast station based on OET Bulletin No. 69, *"Longley-Rice Methodology for Evaluating TV Coverage and Interference"*—hereafter referred to as OET-69. The bulletin defines the method for predicting field strength created at any given location by a television transmitter. It further defines television reception system "planning factors" that can be used to determine the field strength required for successful DTV reception.

The FCC's defined reception planning factors include antenna gain, signal loss in the down-lead cable connecting the antenna to the television receiver, noise figure of the receiver, and required carrier-to-noise ratio. The latter two factors are functions of the DTV receiver and are a primary focus of the measurements conducted for this report. These parameters, as specified by OET-69, are shown in Table 1-1.

Table 1-1. Planning Factors for DTV Reception Prediction

Planning Factor	Symbol	Low VHF	High VHF	UHF
Geometric Mean Frequency (MHz)	F	69	194	615
System noise figure (dB)	N_S	10	10	7
Required Carrier-to-Noise ratio (dB)	C/N	15.2 (15)	15.2 (15)	15.2 (15)

Note: The Final Technical Report of the FCC Advisory Committee on Advanced Television Service listed 15.19 dB as the C/N for the Grand Alliance DTV receiver.[*] In OET-69 this value is rounded to the nearest dB—i.e., 15 dB; however, in identifying "OET-69" planning factors and predictions for this report, we will round to the nearest tenth of a dB and use 15.2 dB. Combining this C/N value with the system noise figures and the -106.2 dBm thermal noise level specified in OET-69, yields a minimum signal power at TOV of -81.0 dBm in VHF and -84.0 dBm in UHF.

Although OET-69 was developed for defining service areas for channel-allocation purposes, the same approach could be used for initial prediction of whether a household is unserved by an adequate digital signal for SHVERA purposes. Consequently, this report will evaluate the validity of the OET-69 planning factors based on measurements of current-model consumer DTVs.

OVERVIEW

The laboratory-based measurements performed for this report emulated two types of over-the-air reception conditions for DTV receivers:

(1) Unimpaired signal (i.e., no multipath) [Chapters 3 – 5], and

(2) Signal impaired by multipath (ghosts) [Chapter 6]—focusing on particularly difficult multipath conditions.

[*] Final Technical Report, FCC Advisory Committee on Advanced Television Service's (ACATS), October 31, 1995, p.15 (Table 5.1).

The unimpaired signal measurements can be used to quantitatively predict receiver performance under benign reception conditions—i.e., with little multipath (commonly referred to as a white Gaussian channel). The multipath tests provide a basis for comparing the ability of different DTV receivers to handle difficult multipath conditions. Chapter 7 links the new, laboratory-based measurements to earlier FCC field-test data as a basis for anchoring the multipath results to representative, real-world reception conditions.

CHAPTER 2
SCOPE AND APPROACH

SCOPE OF TESTING

The parameters measured for this report to characterize each television receiver are as follows:
(1) minimum signal at the threshold of visibility of errors (TOV);
(2) the white noise threshold (defined at the TOV)—also known as the required carrier-to-noise ratio (CNR); and,
(3) the number of ATSC-recommended field ensembles (RF captures) that can be successfully demodulated by the receiver.

The first two of these are measures of sensitivity of the receiver for an unimpaired signal. The latter characterizes the ability of the receiver to handle difficult multipath conditions.

While these measurements provide a basis for achieving the stated objectives of this report, it should be recognized that they do not fully characterize the over-the-air reception capability of a DTV receiver. The ATSC recommends that DTV receivers be evaluated on the basis of a wide variety of criteria that are not included in this report, such as multi-signal overload, tolerance to phase noise, co-channel rejection, adjacent-channel rejection, burst noise rejection, and a more complete characterization of multipath capability.[*]

TEST SAMPLES

Given the objectives of determining whether there is a wide variation in reception performance of reasonably-priced consumer digital television receivers and determining whether the variation is related to price of the receiver, an effort was made to select samples over a range of prices, but with emphasis on the lower end of the price range.

Two categories of DTV receivers were acquired for this project: digital set-top boxes (STBs) and DTVs with integrated over-the-air ATSC tuners. The selected receivers are standard, off-the-shelf consumer products currently on the market.

STBs were included in the study because connection of a set-top box to an existing television represents the lowest-cost alternative for DTV reception. Each STB includes a digital tuner and outputs necessary to drive high-definition television displays (through component video, DVI, or HDMI connections) and standard-resolution analog televisions (through a composite video output or an S-Video [Y-C] output). When driving a conventional analog television, high definition programming is down-converted to the resolution of the TV. Besides their use in enabling digital reception with analog TVs, set-top boxes are also useful to consumers who have high-definition, digital-ready televisions that do not include an ATSC tuner.

[*] "ATSC Recommended Practice: Receiver Performance Guidelines", ATSC Doc. A/74, Advanced Television Systems Committee, 17 June 2004.

Selection Criteria

In selecting receivers for this study, several criteria were applied.

1. A total of about 30 samples was planned for the tests in order to balance the need for a large enough sample to provide a degree of statistical confidence in the results with the need to limit sample size for practical reasons.

2. Recently introduced models were selected, where possible, especially if the manufacturer expected a change in over-the-air digital reception performance with the newer model; in some cases this meant requesting a model that was not available when the tests were begun, but was delivered late in the test cycle or, in two cases, was delivered too late to include in this report.

3. An attempt was made to obtain one set-top box from most companies that manufacture one. (All set-top box models were of relatively old designs—introduced in the year 2004 or, in one case, 2003—even though they were the latest models available on the market.)

4. One DTV having an integrated ATSC tuner was selected from at or near the low-price end of each manufacturer's product line.

5. In addition, a mid or mid-to-high priced DTV having an integrated ATSC tuner was requested from many of the manufacturers.

Overview of the Samples

Table 2-1 summarizes the characteristics of the DTV receivers in the test sample. The receivers, which represent 16 brand names, are divided by product type—set-top box versus DTV with integrated ATSC tuner—and, within the DTV type, by price range. In most cases, prices were determined by selecting the median price from a FROOGLE search for each product conducted in August, 2005. Four products not found through FROOGLE were priced through Wal-Mart in August, 2005, and one was priced through Amazon in September, 2005.

Table 2-1. DTV Receiver Samples

Sample Type	Number of Samples	Display Size	Display Aspect Ratio	Display Technology
Set-Top Box (STB)	5	N/A	N/A	N/A
DTV with Integrated ATSC Digital Tuner:				
• $370 - $1000	6	26" – 36"	4:3 or 16:9	Direct-View CRT
• $1001 - $2000	8	26" – 52"	16:9	Direct-View LCD, Plasma, CRT Rear Projection, DLP Rear Projection, LCD Rear Projection
• $2001 - $4200	9	32" – 62"	16:9	Direct-View LCD, Plasma, DLP Rear Projection, LCD Rear Projection
TOTAL	**28**			

Notes:
--*CRT = cathode ray tube (conventional picture tube)*
--*DLP = digital light processing*
--*LCD = liquid crystal display*

In order to avoid revealing specific brands or models of the samples, test results presented in this document are reported by product type and price categories and by a letter and number code assigned to each product. The letter indicates product brand—with letters randomly assigned to brand names. Within each brand, a number is assigned in order of increasing price. For example, the designations A1, A2, and A3 represent three same-brand receivers listed in order of increasing price.

TEST PHILOSOPHY AND APPROACH

Laboratory Versus Field Testing

All testing was performed in the laboratory using either laboratory-generated signals or signals that had been digitally recorded from television antennas at various test sites in New York City and the Washington, DC area, and were replayed in the laboratory using equipment that allowed the signal to translated to any desired TV channel number for playback.

This test method offered two advantages over field-testing of the receivers:
(1) the cost and time required for testing was far lower for lab-based tests than for field testing, which would have required transporting the bulky, heavy TVs and test equipment to multiple sites; (the TVs alone weighed 2200 pounds and had a combined width of 82 feet), and,
(2) tests with signals that are generated or recreated (by playback) in the laboratory are expected to yield more consistent results than are field tests, in which received signal characteristics may vary significantly over the course of testing 28 receivers.

TV Channel Selection

For testing minimum signal at TOV, channels 3, 10, and 30 were selected to represent the low-VHF, high-VHF, and UHF bands, respectively. Selection was based on relatively central locations within the respective bands and an absence of local TV broadcasts on these channels.

Other tests, for which results were not expected to vary with channel, were performed on TV channel 30.

Operation and Connection of Samples

For receivers having multiple antenna inputs that could handle ATSC signals, only the input labeled "antenna A" or "antenna 1" was tested. For receivers having a radio frequency (RF) output associated with the selected antenna input, the output was externally terminated in 75 ohms.

Each set-top box was operated in a high definition mode and was connected to a high definition monitor by means of a component video output.

Test Configurations

All test and measurement setups maintained a 50-ohm impedance throughout, except at the signal source and the consumer TV inputs, which were each specified to be nominally 75 ohms. (An older, instrumented reference receiver included in one test had a 50-ohm input impedance.) The 75-ohm devices were matched to the rest of the test setup through impedance-matching pads, except that, for one of the test setups, an impedance transformer was used at the signal source to reduce losses. In addition to the impedance-matching pads, 50-ohm attenuator pads were used at various places throughout the test setups to reduce the effects of any impedance mismatches at places where such mismatches were considered likely or would be expected to have a significant impact.

The minimum signal at TOV is the only measured parameter for which absolute accuracy of the measurement equipment was a factor; consequently, that parameter was tested by connecting a signal source—through appropriate pads, step attenuators, and cables—to one TV at a time. After adjusting the signal attenuation to achieve TOV on the TV, the output of the entire setup—with the exception of the final impedance-matching pad, was connected to a vector signal analyzer for measurement of the signal level. The only correction then necessary to determine the input to the TV was to subtract the attenuation of the impedance-matching pad from the measured level. That attenuation was measured separately.

For the measuring white noise threshold (required CNR), absolute measurement accuracy was less critical since the value to be determined was the ratio of a signal level to a noise level. To maintain accuracy of the ratio, both measurements were made with the vector signal analyzer on the same amplitude range. The reduced criticality of absolute measurement accuracy enabled the use of a splitter to simultaneously deliver the signal and noise to as many as eight TVs and to the vector signal analyzer for the quantitative measurements. The simultaneous connection reduced measurement time by allowing TV channel scans (required by many of the TVs when a signal was changed) to be performed simultaneously on multiple TVs and by reducing the need to repeatedly disconnect and reconnect cables.

Tests of the ability of each receiver to handle the multipath conditions represented by the ATSC-recommended field ensembles (RF captures) also did not require absolute accuracy in measuring the applied signal levels; consequently, the same splitter arrangement was used. The approach was to apply a signal level well above the minimum signal level at TOV (by about 50 dB) so that signal level was not an issue.

Details on the test methods and configurations are presented in Appendix A.

Thresholds

For both types of threshold measurements (required CNR and minimum signal at TOV), the reported value is the level measured on the maximum attenuation step (lowest signal level) that resulted in no observed errors in 60 seconds of viewing time. The threshold level at which the 60-second viewing time condition was met was nominally somewhere between that reported level and the next higher attenuation level (next lower signal level step); consequently, this approach can be expected to overestimate required signal levels by an average of half the attenuator step size of 0.1 dB. One could therefore justify subtraction of 0.05 dB from the measured signal levels. This subtraction was not performed, in part to compensate for the fact that TOV measurements are often based on longer observation times than the 60 seconds used in these tests.

CHAPTER 3
WHITE-NOISE THRESHOLD MEASUREMENTS
(REQUIRED CARRIER-TO-NOISE RATIO)

White-noise threshold refers to the ratio of signal (“carrier”) power to noise power within the 6-MHz bandwidth of a television channel when both an unimpaired signal (no multipath) and broadband (“white”) Gaussian noise are simultaneously applied to the antenna terminal of a DTV receiver and the signal or noise power is adjusted to the point at which observable errors in the DTV picture just become invisible—i.e., the threshold of visibility (TOV). This is the carrier-to-noise ratio (CNR) required to produce a “clean” DTV picture. The definition assumes that the applied noise power is sufficiently higher than any noise generated internally by the DTV receiver circuitry so as to make the internally generated noise negligible.

At CNR levels below the white-noise threshold, picture quality rapidly degrades to the point that, only about one dB below the white-noise threshold, the picture is typically unwatchable or nonexistent.

At CNR levels above the white-noise threshold, the picture is essentially free of defects that are related to transmission and reception of the signal.

White noise threshold is of direct interest because it indicates the ability of a digital television to receive and process a DTV signal in the presence of high ambient noise levels—assuming that the signal is not significantly impaired by multipath or interference and that the ambient noise has characteristics similar to white Gaussian noise. In cases where the ambient environment is quiet, white noise threshold is useful in understanding the reception performance of a DTV receiver in the presence of noise that is internally generated within the input circuits of the receiver.

The results of this chapter apply only to signals that are unimpaired by multipath. In the presence of multipath, a higher CNR may be required to produce a clean picture. While the measurements performed for this report do not address such an increase, the topic is discussed in Chapter 7, based on earlier field test results.

MEASUREMENT METHOD

White-threshold of each receiver was measured by simultaneously injecting into the antenna port of the receiver both an unimpaired (e.g., no multipath) ATSC signal on channel 30 and white noise from a noise generator. A nine-way splitter feeding equal-length, well-shielded, low-loss cables allowed the same combination of signal plus noise to be applied simultaneously to as many as eight DTV receivers and a vector signal analyzer that was used for the measurements. As a consistency check, receiver D3 was included in each group of eight receivers that were tested; measurements of D3 were consistent within ±0.1 dB.

Impedance-matching attenuator pads (50 ohms to 75 ohms, 5.8 dB power attenuation) at each TV receiver served to match the nominal 75-ohm impedance of the receiver antenna ports to the rest of the 50-ohm measurement system and, through the attenuation it provided, served to reduce the impact of any deviations from that nominal TV input impedance. At the vector signal analyzer, a 6-dB, 50-ohm attenuator served a similar function.

Because the small differences in loss between the various splitter outputs, cables, and pads can be expected to equally affect both the signal and the noise, the measured CNR is not affected by such differences.

The signal source for these tests was an RF player (Sencore RFP-910) playing the "Hawaii_ReferenceA" file supplied with the player. The file consisted of a 25-second repeating loop of motion video scenes shot at several outdoor locations. At each loop restart, most DTV receivers exhibited video errors related to re-locking to the signal; consequently, the first three seconds of each loop were not included in the observation time. (An ATSC signal generator, rather than the RF player, had been intended for these tests. Use of the generator would have avoided issues with loop restart time, but the generator was abandoned due to degraded signal quality.) The signal was amplified before splitting it. A step attenuator following the amplifier was used to adjust the signal level.

The noise source was a noise generator (Noise/Com UFX-7110) band limited to 700 MHz, well above the frequency of TV channel 30, thus leaving the spectrum flat across the bandwidth of the selected TV channel. The injected noise power was set nominally to -70 dBm within the 6-MHz bandwidth of channel 30—about 29 dB above the internally generated noise of a typical DTV receiver—by using a step attenuator with 0.1-dB steps. The noise power measurement (usually within 0.05 dB of -70 dBm) was then recorded. The actual injected noise power was computed by subtracting the effect of instrument noise, which was about 26 dB below the injected noise power.

Signal level was increased in 0.1-dB steps until the TV picture could be viewed for 60 seconds without observing a video error (excluding loop restart periods, as noted above). A measurement was then made of the combined power of both the injected signal and the injected noise, and the signal power was computed by subtracting the noise power (in linear power units); since the noise power at the threshold was typically about 15 dB below the signal, the net signal power was only about 0.1 dB below the measured total power.

Further details on the measurement procedure are contained in Appendix A.

FORMAT OF THE BAR GRAPH DATA

The measurement results are presented in bar-graph form in Figure 3-1. That format, explained here, is also used in subsequent chapters to present other results.

Each bar on the graph represents performance of one DTV receiver. The "Better"/"Worse" labels on the vertical axis indicate that, for the plotted parameter, lower values represent better performance.

Each receiver is designated by a letter and a numeral. The letters, which were assigned randomly, represent brand names. Thus, receivers A1, A2, and A3 are all of the same brand.

The receivers are grouped into categories. The first category is set-top boxes (STBs). The remaining categories are three different price ranges of DTVs. Within each group, the results are listed in order of the randomly assigned brand code letters rather than in price order. This approach was taken so that individual products could not be identified based on price.

The solid blue line represents the median result across all tested receivers. The dashed blue line represents the median result within each category. The dashed red line represents the mean result within each category. A wider dashed green line represents the value of the planning factor assigned to the measured parameter by OET-69.

RESULTS

The results of the white-noise threshold measurements are shown in Figure 3-1.

Nominal Performance and Variation Among Samples

Statistics of the white-noise threshold (required CNR) are shown in Table 3-1. The white noise threshold of the median receiver—measured across all tested receivers—is 15.3 dB. This is only 0.1 dB above (worse than) the corresponding planning factor value in OET-69. (Because the CNR was determined from the ratio of two power measurements performed on the same amplitude range of the same measuring instrument, it's value is not affected by absolute calibration accuracy of the instrument and is therefore expected to be accurate to within 0.2 dB.[*])

Table 3-1. Statistics of White Noise Threshold

WHITE NOISE THRESHOLD	
Median across all receivers (dBm)	15.3
Median re OET-69 planning factors	0.1
Deviations of receivers from median (dB)	
--Best performing receiver (dB)	-0.4
--Worst performing receiver (dB)	0.5
--89th percentile receiver (dB)	0.3
Standard deviation (dB)	0.2
Total span from best to worst receiver (dB)	0.8[†]

The variations among receivers were quite small. The standard deviation of the CNR measurements across all receivers was 0.2 dB. The total span from best to worst performing receiver was 0.8 dB, with the worst measured white noise threshold being 0.5 dB above the median value.

Variation with Price and Type Category

Magnitude of Observed Variations With Product Type and Price

The observed performance variations among the product type and price categories were also small, as shown in Table 3-2. The least expensive way to receive a DTV broadcast is to purchase a digital set-top box and connect it to an existing TV. Median performance of set-top boxes was only 0.1 dB worse than the overall median. The median low-cost and mid-cost DTVs performed at the overall median, and the median high-cost DTV performance was 0.2 dB better than the overall median.

[*] The vector signal analyzer specification sheet states that relative accuracy in RF vector mode on a single range is the sum of frequency response and amplitude linearity. If we ignore the frequency response term because the measurements are made over the same frequency range, we are left with the amplitude linearity term, which is specified as "<0.1 dB" for signal levels between 0 dB and -30 dB with respect to full scale—a condition that was met by both the signal and injected noise measurements. To this we add errors caused by the 0.1-dB attenuator step size.

[†] Span does not match difference between worst and best due to rounding of all numbers to nearest 0.1 dB.

Table 3-2. Product-Type/Price Variations of White Noise Threshold

WHITE NOISE THRESHOLD	
Median of Set-Top Boxes re Overall Median (dB)	0.1
Median of Low-Price DTVs re Overall Median (dB)	0.0
Median of Medium-Price DTVs re Overall Median (dB)	0.0
Median of High-Price DTVs re Overall Median (dB)	-0.2

<u>*Statistical Significance of Observed Variations With Product Type and Price*</u>

Apparent variations in performance of samples with price can be caused by random sampling effects even when there is no underlying performance/price dependence in the overall population; hence, some means is necessary to determine whether an apparent dependence observed in the sample is statistically significant.

In the case of measurements of the required CNR for the tested collection of DTV receivers, the observed variations with price are so small as to be inconsequential; consequently, assessing the statistical validity of those variations is hardly necessary. Nonetheless, an analysis is included here for completeness and to provide a comparative basis for more significant observed variations that are presented in subsequent chapters.

As seen in Table 3-3, the Pearson's correlation coefficient between required CNR and receiver price was computed as -8.6 percent when all receivers were included and +7.0 percent when only the DTVs (not set-top boxes) were included. A negative sign indicates that the required CNR appears to decrease (i.e., improve) with increasing receiver price, while a positive sign indicates that the required CNR increases (i.e., degrades) with increasing price. Determining whether any observed apparent trend is real or is an artifact of the small sample set used in the tests requires a statistical assessment.

Table 3-3. Correlation Coefficient of White Noise Threshold with Price

Pearson's Correlation Coefficient of White Noise Threshold with Price	
All Tested Receivers	-8.6%
DTVs Only (no Set-Top Boxes)	+7.0%

The usual method of assessing the statistical significance of given value of the Pearson's correlation coefficient is to compare the magnitude of the observed correlation to values in a table of critical values of the Pearson's correlation coefficient. The technique is used to determine the likelihood that a correlation as high as that which was observed might occur randomly, for the selected sample, if there is no actual correlation between required CNR and receiver price in the larger population of all DTV receivers. Such a lookup table specifies values as a function of the "number of degrees of freedom", which is two less than the total number of samples—*assuming that the samples are independent*.

For the overall sample size used in this study (28 samples, 26 degrees of freedom), one can determine from such a table that the magnitude of an observed correlation coefficient must be 32 percent or higher in order to ensure that there is no more than a five percent probability that the observed correlation could result by random sampling effects from a larger population that has no such correlation. In the case of the 23 DTVs (i.e., excluding the set-top boxes), the magnitude of an observed correlation would have to be 35 percent or higher to meet the same criterion. (These are single-sided probabilities—i.e., the probability that a correlation magnitude will exceed, in a single direction, a given correlation value. For example, if the overall population has no correlation with price, there is a five percent probability that the correlation of a randomly selected sample of 28 receivers will exceed a 32 percent magnitude with a negative correlation—indicating decreasing CNR with increasing receiver price. There is also a five percent probability of exceeding that same magnitude with a positive correlation—indicating increasing CNR with increasing price.)

It should be noted that these statistical calculations are dependent upon a number of assumptions, including that the shape of the probability distribution of the measured parameter is normal (Gaussian), that the samples were randomly selected, and that the samples are independent. None of these assumptions is strictly true for the case at hand. Of particular concern is the independence assumption, because it is quite likely that some of the receiver samples share critical subsystems. For example, a given tuner or demodulator design may be used in more than one of the receivers. The effect of such a commonality between samples would be to decrease the effective number of degrees of freedom in the computed Pearson's correlation coefficient. Such a decrease would increase the magnitude of correlation that would have to be observed to have a given confidence level in the result.

The observed correlations of -8.6 percent and +7.0 percent in the white-noise threshold measurements are so small as to provide no confidence that the small observed variations in performance with price reflect a real price-dependence in the overall population of DTV receivers currently on the market.

Effect of TV Channel

White noise threshold (required CNR) is expected to be dependent on the demodulator function of a DTV receiver. Since this function occurs after the tuner heterodynes the incoming RF signal from the frequency band of the TV channel to an intermediate frequency (IF), one would expect the white noise threshold to be essentially independent of TV channel number. Consequently, testing was performed on only one channel—channel 30.

In testing minimum signal level of the DTV receivers, as reported in the next chapter, there was a large variation in the results between channels for some TVs. In order to verify that the variation was not related to changes in white noise threshold, the white noise threshold of one DTV receiver was also tested on channel 3. The selected receiver was G2, the receiver with the largest variation in minimum signal level across the channels (a 13 dB difference between channels 3 and 30). For this receiver, the measured white noise thresholds on channels 3 and 30 were 15.6 and 15.5 dB, respectively; this difference is within measurement error.

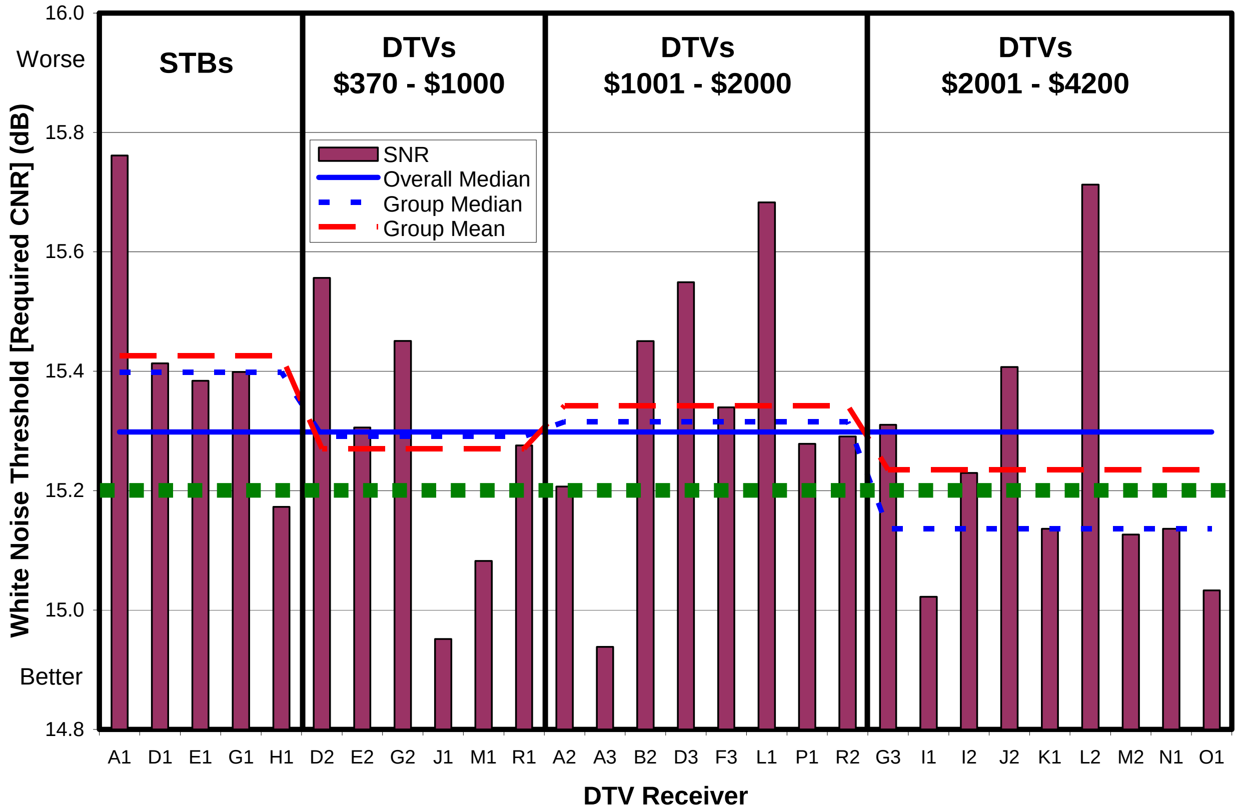


Figure 3-1. Measured White Noise Threshold of Receivers

CHAPTER 4
MINIMUM INPUT SIGNAL MEASUREMENTS

Minimum input signal at the threshold of visibility (TOV) is the signal ("carrier") power at the antenna terminal of a DTV receiver when the signal level is adjusted to the point at which observable errors in the DTV picture just become invisible. It is a direct measure of sensitivity of a DTV receiver to weak signals in the absence of significant externally generated noise or interference—assuming that the input signal is not significantly impaired by multipath. At input levels below this threshold level, picture quality rapidly degrades to the point that, only about one dB below the white-noise threshold, the picture is typically unwatchable or nonexistent. At input levels above the threshold, the TV picture is essentially free of defects that are related to transmission and reception of the signal.

The results of this chapter apply only to signals that are unimpaired by multipath or interference. In the presence of multipath, a higher signal level may be required to produce a clean picture. While the measurements performed for this report do not address such an increase, the topic is discussed in Chapter 7, based on earlier field test results.

MEASUREMENT METHOD

Because minimum input signal at TOV is an absolute measurement rather than a ratio, the splitter was not used for these tests. The receivers were tested sequentially in groups of about eight—with receiver D3 included in each group, as a consistency check; measurements of D3 were consistent within ±0.3 dB. The results are subject to the absolute measurement accuracy of the vector signal analyzer, which is specified as ±1.5 dB maximum and ±0.5 dB typical on the amplitude range that was used for the measurements;[*] additional errors due to adjustment for attenuation of impedance-matching pad—as described below—are expected to be negligible compared to the VSA tolerance.

The tests were performed on three TV channels—3, 10, and 30—in order to evaluate performance in the low VHF, high VHF, and UHF bands, respectively. The selection of those specific channels was based on avoiding local broadcast channels and selection of a relatively central channel within each band.

The signal source for these tests was an RF player (Sencore RFP-910) playing the "Hawaii_ReferenceA" file supplied with the player. The file consisted of a 25-second repeating loop of motion video scenes shot at several outdoor locations. At each loop restart, many DTV receivers exhibited video errors related to re-locking to the signal; consequently, the first three seconds of each loop were not included in the observation time. A step attenuator was used to adjust the signal level. The signal was applied to a single DTV receiver through a low-loss 50-ohm cable followed by a 10-dB attenuator pad and an impedance-matching attenuator pad having 5.8 dB power attenuation. The latter served to match the nominal 75-ohm impedance of the receiver antenna port to the rest of the 50-ohm measurement system. Both pads served

[*] As an additional check on equipment performance, measurements of injected broadband signal level and of injected broadband noise level—at levels typical of those used for white-noise threshold testing (-70 dBm for noise and -55 dBm for signal—both measured across the 6-MHz bandwidth of TV channel 30)—were performed using two instruments, the vector signal analyzer and a spectrum analyzer (Agilent E7405A). The spectrum analyzer measurements were made with the internal preamp on and the internal attenuation set to 0 dB. The spectrum analyzer overall amplitude accuracy is specified as "±(0.54 dB + absolute frequency response)" with the absolute frequency response being specified as ±0.5 dB over the frequency range of interest. For both signal and noise, the spectrum analyzer measurements were 0.1 dB higher than the vector signal analyzer measurements—suggesting that both instruments (which were calibrated no more than two months before the measurements reported in this chapter) were likely performing well within the specified tolerances. (Note that self calibrations were also performed on both instruments before each set of measurements.)

to minimize reflections that might be caused by any deviation of receiver input impedance from the nominal.

Signal level was increased in 0.1-dB steps until the TV picture could be viewed for 60 seconds without observing a video error (excluding loop restart periods, as noted above). The low-loss cable and 10-dB pad were then connected to a vector signal analyzer on its most sensitive amplitude range (-50 dBm) to measure the power of the applied signal. The 10-dB pad served to minimize reflections that would be caused by any deviation of the vector signal analyzer input impedance from 50 ohms. A separate measurement of instrument noise (typically about 19 dB below the measured signal level) was subtracted—in linear power units—from the measured power level to remove the very minor effects of vector signal analyzer self noise from the measurement. The attenuation of the impedance matching pad, which was connected to the TV input but not to the vector signal analyzer, was then subtracted (in dB) from the result to determine the signal level that had been applied to the DTV receiver antenna port. The presence of that pad at the TV input but not at the spectrum analyzer input served a dual purpose—matching the respective input impedances of the two devices and providing a 5.8 dB signal advantage to the vector analyzer to minimize the impact of the vector signal analyzer self noise.

Further details on the measurement procedure are contained in Appendix A.

RESULTS

The results of the minimum signal level measurements for the three tested channels are shown in Figure 4-1. Individual results for TV channels 3, 10, and 30 are shown in Figures 4-2, 4-3, and 4-4, respectively. The general format of the plots is as described in Chapter 3 in the section titled, “Format of the Bar Graph Data”, except that, in the case of Figure 4-1, there are three bars per DTV receiver—representing the three channels tested. Also, note the differences in vertical scales among the four graphs.

Nominal Performance and Variation Among Samples

Table 4-1 shows the statistical properties of the measurements of minimum signal level at TOV.

Table 4-1. Statistics of Minimum Signal Level at TOV

MINIMUM SIGNAL LEVEL AT TOV	Chan 3	Chan 10	Chan 30
Median across all receivers (dBm)	-82.2	-83.2	-83.9
Median re OET-69 planning factors	-1.2	-2.2	0.1
Deviations of receivers from median (dB)			
--Best performing receiver (dB)	-2.5	-1.7	-1.4
--Worst performing receiver (dB)	12.5	4.3	2.5
--89th percentile receiver (dB)	5.1	3.1	1.3
Standard deviation (dB)	3.7	1.6	0.9
Total span from worst to best receiver (dB)	15.0	6.0	3.9

The median minimum signal level at TOV across all measured receivers was found to decrease slightly with increasing channel number—with channel 3 requiring a 1.7-dB higher signal than channel 30. The measured median values match—within 1 dB—the -83 dBm minimum performance standard recommended by the ATSC.*

* “*ATSC Recommended Practice: Receiver Performance Guidelines*”, ATSC Doc. A/74, Advanced Television Systems Committee, 17 June 2004, p.11.

The median required signal levels were slightly better—by 1.2 dB and 2.2 dB, respectively—than that predicted for the VHF-low and VHF-high bands using the OET-69 planning factors (-81.0 dBm) and closely matched the predictions for channel 30 (-84.0 dBm).[*] On channel 3, only 21 percent of the tested receivers performed more poorly in minimum signal level than the performance modeled in OET-69 by an amount exceeding 1-dB—the approximate tolerance of the measurements.[†] On channels 10 and 30, the numbers are 11 percent and 18 percent, respectively.

The variation among receivers was large on channel 3—with a 3.7-dB standard deviation. The two receivers exhibiting poorest performance performed at levels 10.6 and 12.5 dB worse than the median. Those two receivers—both the same brand—are responsible for much of the observed variability; omitting them from the calculations reduces the standard deviation to 2.3 dB. The third worst performer was 6.7 dB above the median. 89 percent of the receivers (all but three) were within 5.1 dB of the median.

Variations were relatively small on channels 10 and 30. Standard deviation across all receivers was 1.6 dB on channel 10 and 0.9 dB on channel 30. The worst performers differed from the median by 4.3 and 2.5 dB, respectively, on channels 10 and 30, and 89 percent of the receivers (all but three) were no more than 3.1 dB above (worse than) the median on channel 10 and no more than 1.3 dB above (worse than) the median on channel 30.

Variations With TV Channel For One Sample

At least two TVs exhibited a much larger than expected variation in reception performance—as measured by minimum signal level at TOV—between the three tested TV channels. In order to further characterize this variation, the receiver exhibiting the largest variation between channels (receiver G2) was further tested to determine minimum signal at TOV for each of the 12 VHF channels and for three UHF channels. The results, shown in Figure 4-5, indicate that the receiver exhibits poor sensitivity throughout the low-VHF band (channels 2 through 6), but good sensitivity throughout the high-VHF band (channels 7 through 13) and the UHF band. On average, the high-VHF and UHF performance is 13 dB better than the low-VHF performance. The reason for this performance difference is not known.

The apparently abrupt change in sensitivity occurring between channels 6 and 7 is easier to understand if the data is plotted as a function of frequency, as in Figure 4-6. It can be seen that there is a large gap in frequency between TV channels 6 and 7, and that the increase in minimum signal at TOV that occurs in moving from the high-VHF band (channels 7-13) to the low-VHF band (channels 2-6) appears to actually begin, to a small degree, in the lower portion of the high-VHF band. (Note that the measured data is indicated by square symbols and measured points are connected by straight lines.)

Variation with Price and Type Category

Magnitude of Observed Variations With Product Type and Price

As can be seen in Table 4-2, the observed variations in minimum signal level at TOV with product type and price categories were very small for channels 10 and 30 (category medians differing from overall median by less than 1 dB) and were somewhat larger for channel 3. On channel 3, median performance of set-top boxes was 2.0 dB worse than the overall median of all receivers and the best median

[*] See note for Table 1-1.

[†] Absolute measurement accuracy of the vector signal analyzer on the amplitude range that was used for the measurements was as ±1.5 dB maximum and ±0.5 dB typical.

performance was achieved by the low-price DTV category, which slightly outperformed the medium and high-priced categories. Most of the differences in median values between categories are so small as to be considered insignificant, and even the largest differences would influence reception performance only in locations where the signal margin is very small.

Table 4-2. Product-Type/Price Variations of Minimum Signal at TOV

MINIMUM SIGNAL LEVEL AT TOV	Chan 3	Chan 10	Chan 30
Median of Set-Top Boxes re Overall Median (dB)	2.0	0.5	0.7
Median of Low-Price DTVs re Overall Median (dB)	-1.1	-0.2	-0.2
Median of Medium-Price DTVs re Overall Median (dB)	0.0	0.5	0.0
Median of High-Price DTVs re Overall Median (dB)	-0.7	-0.3	0.0

Statistical Significance of Observed Variations With Product Type and Price

Table 4-3 shows the Pearson's correlation coefficient between the minimum signal at TOV and the price of each DTV receiver. Random sampling effects can lead to apparent correlations in a given collection of DTV receivers even if the overall DTV population of receivers on the market exhibits no such correlation; consequently, a statistical assessment must be performed in order to judge whether the observed correlation reflects an actual correlation in overall population or is simply an artifact of sampling.

Table 4-3. Correlation Coefficient of Minimum Signal at TOV with Price

Pearson's Correlation Coefficient of Minimum Signal at TOV with Price	Chan 3	Chan 10	Chan 30
All Tested Receivers	-14.3%	-4.9%	+3.9%
DTVs Only (no Set-Top Boxes)	-0.3%	+0.4%	+12.3%

Chapter 3 explains the methods and pitfalls of such a statistical assessment. Using typical assumptions, one would conclude that an observed correlation coefficient with a magnitude of 32 percent or higher is unlikely to occur (less than five percent probability) in a sample size of 28 (the total number of receivers tested for this report) if there is no correlation in the overall population. Similarly, with a sample size of 23 (the number of DTVs—excluding set-top boxes—tested for this report), a correlation coefficient magnitude of 35 percent or higher is unlikely to occur if there is no correlation in the overall population. Thus, we would conclude that an observed correlation is statistically significant only if its magnitude exceeds the appropriate one of these thresholds.[*]

None of the price/performance correlations found here come even close to the threshold for statistical significance. Thus, the measurements of minimum signal at TOV show no statistically significant correlation of performance with price.

[*] As is explained in Chapter 3, the statistical assessment performed above is dependent upon a number of assumptions that are not strictly true for the case at hand. Arguably, the most questionable of these is the assumption that the performance of the each receiver sample is independent of the others. It is quite likely that some of the receiver samples share critical subsystems, which would violate the independence assumption. For example a given tuner or demodulator design may be used in more than one of the receivers. The effect of such a commonality between samples would be to decrease the effective number of degrees of freedom in the computed Pearson's correlation coefficient. Such a decrease would increase the magnitude of correlation that would have to be observed to have a given confidence level in the result. Taking this effect into account would further diminish any statistical significance of the results.

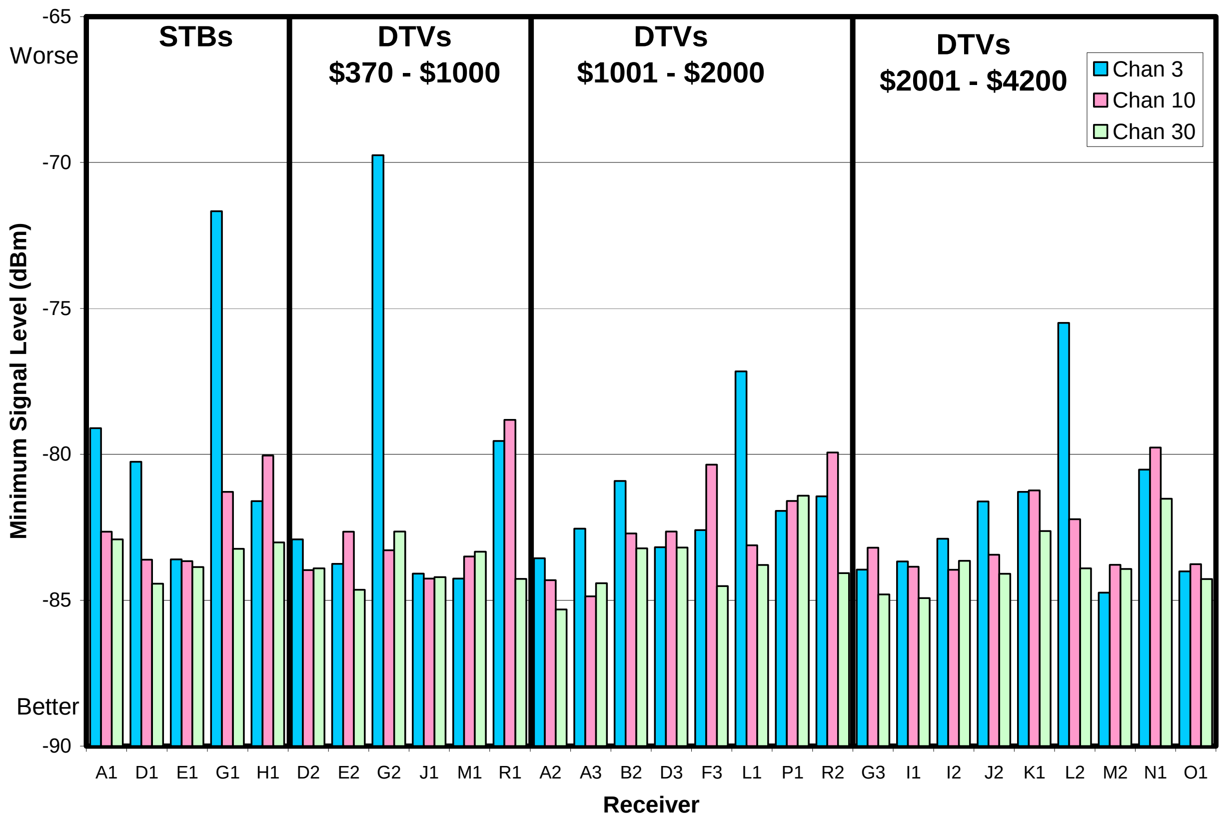


Figure 4-1. Measured Minimum Signal Level at TOV on Three Channels

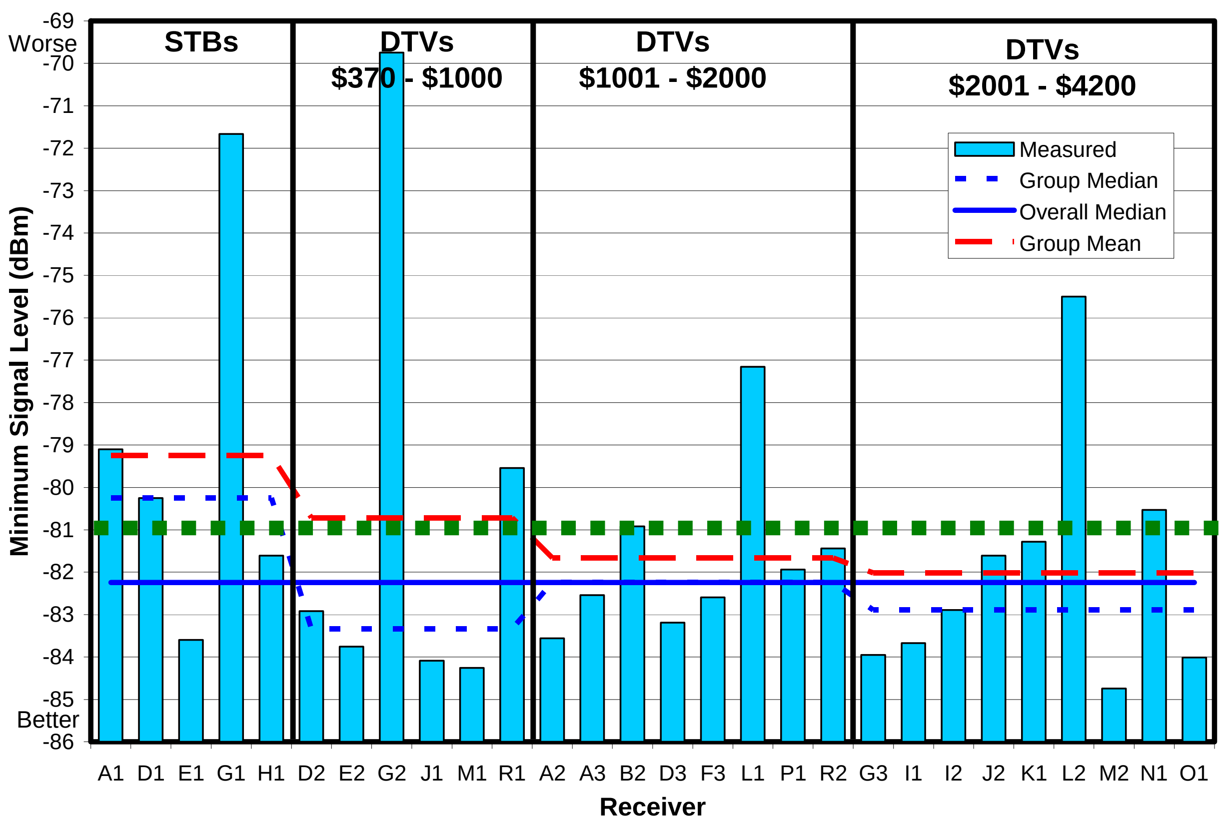


Figure 4-2. Measured Minimum Signal Level at TOV on Channel 3 (Low VHF)

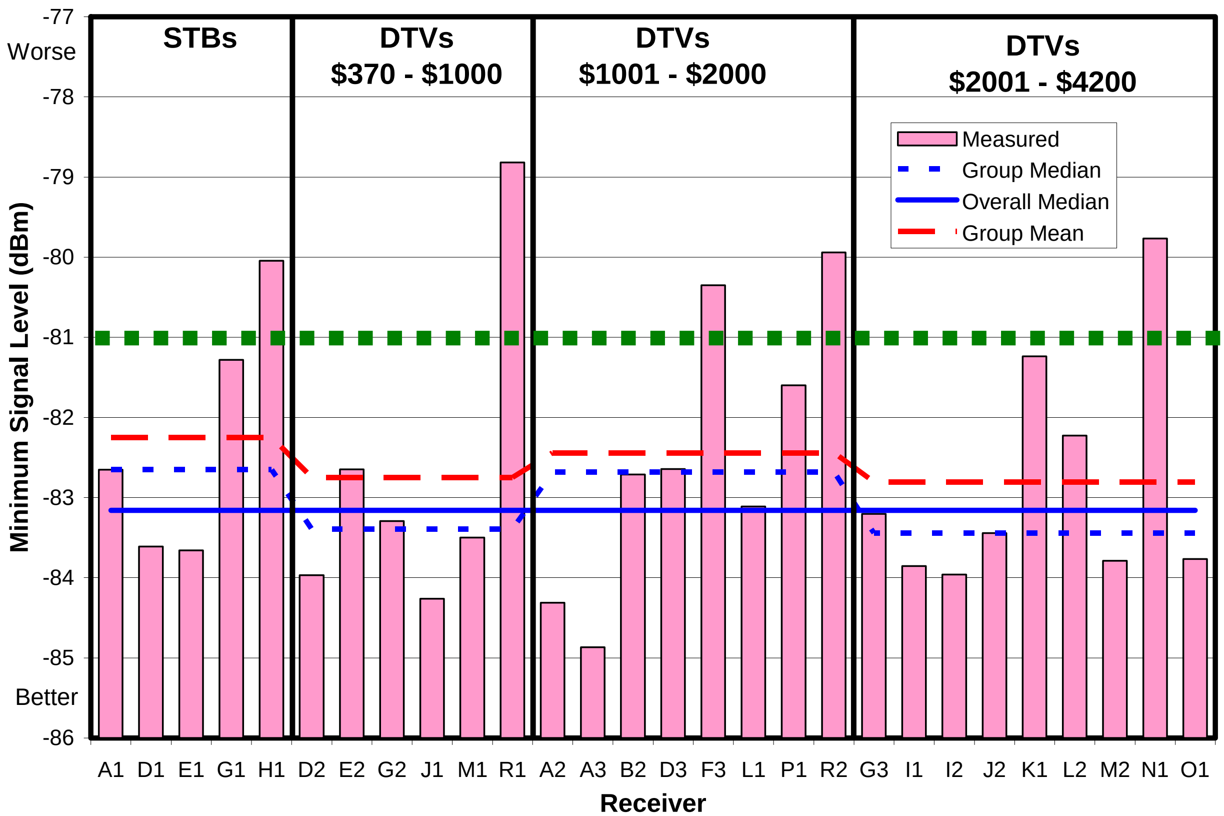


Figure 4-3. Measured Minimum Signal Level at TOV on Channel 10 (High VHF)

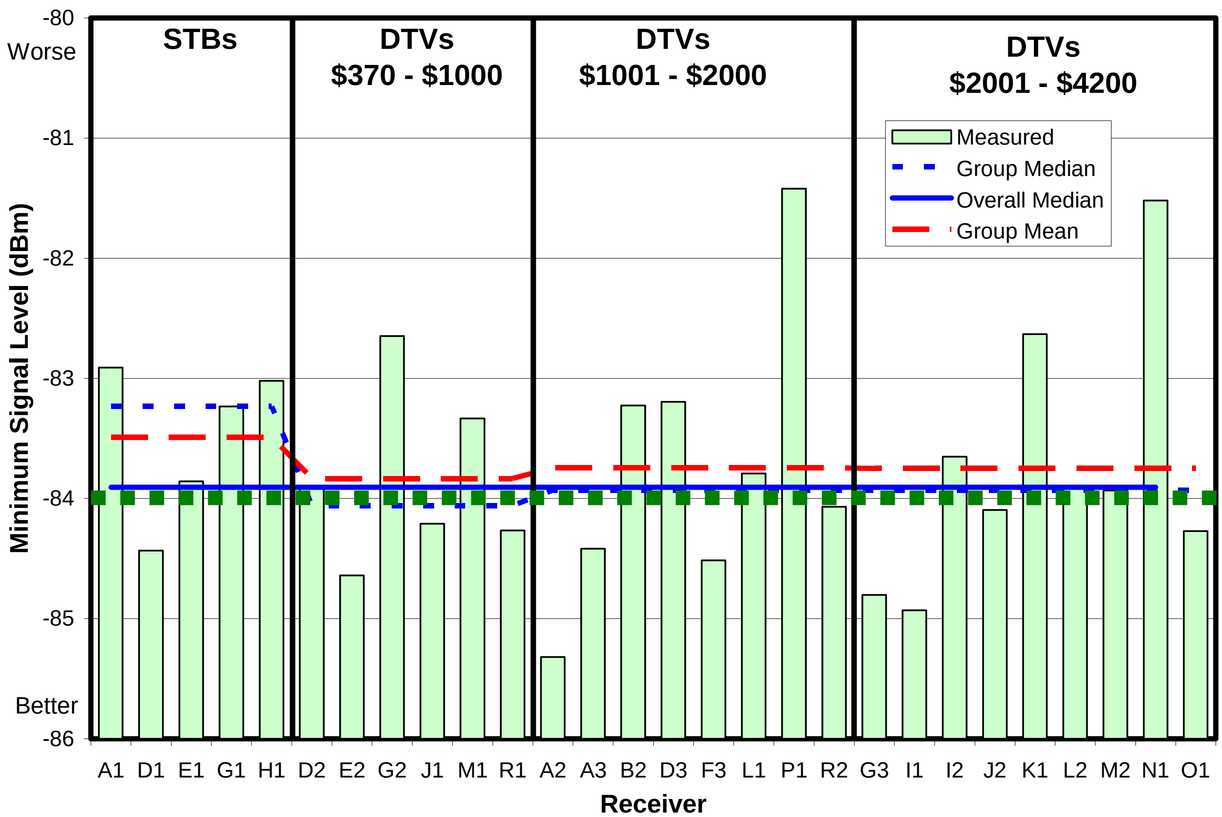


Figure 4-4. Measured Minimum Signal Level at TOV on Channel 30 (UHF)

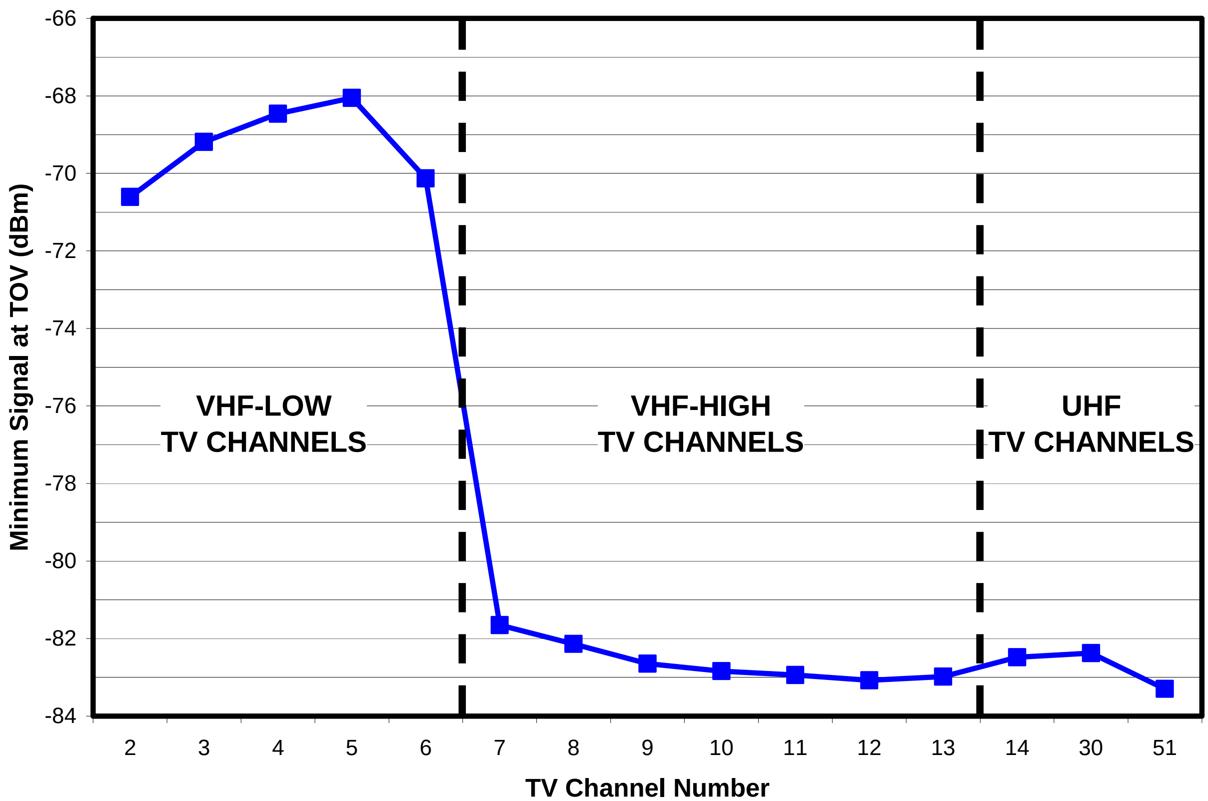


Figure 4-5. Measured Minimum Signal Level at TOV Versus Channel for Receiver G2

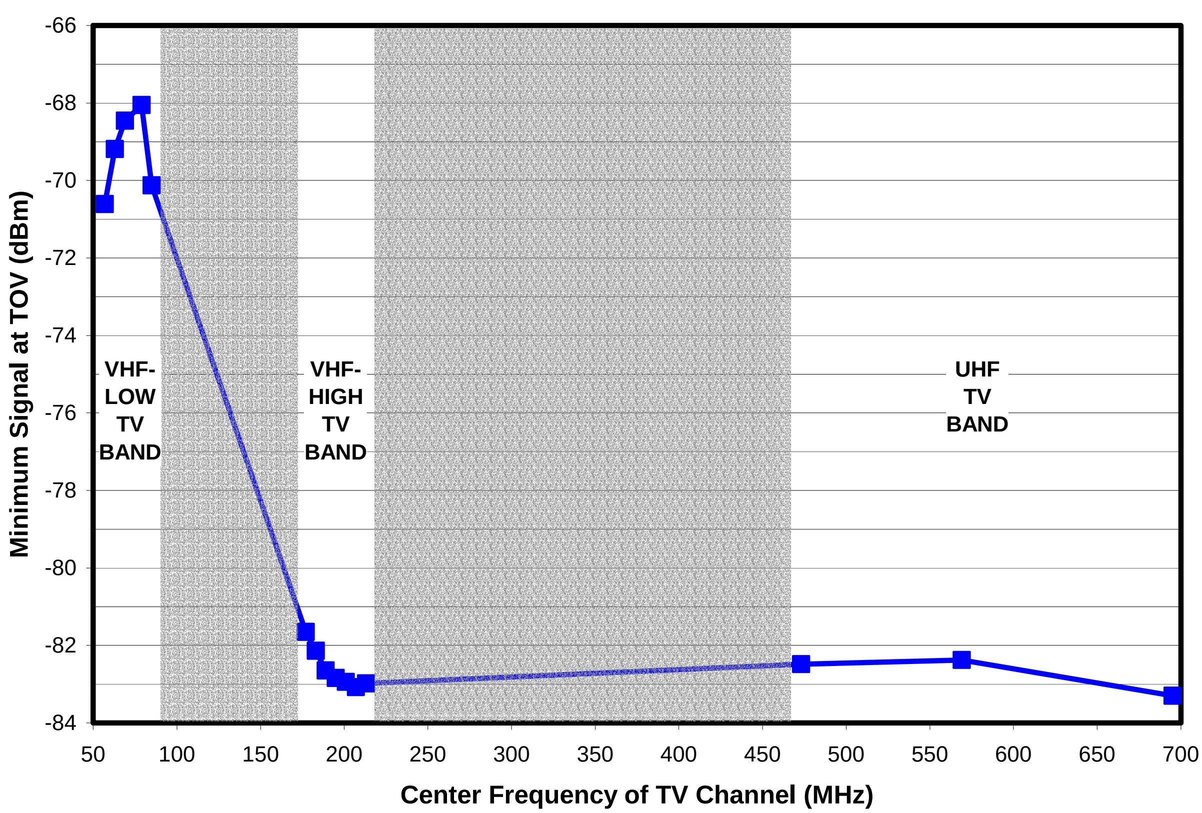


Figure 4-6. Measured Minimum Signal Level at TOV Versus Frequency for Receiver G2

CHAPTER 5
INFERRED NOISE FIGURE

The minimum signal level at TOV, presented in Chapter 4, can be viewed as the combined effect of two properties of the DTV receiver: the internal noise created by the receiver's input circuitry and the CNR required to produce a clean picture. Separating the measurement into those two basic terms provides a better understanding of the differences in performance between DTV receivers. It should be noted that this breakout is strictly valid only when reception sensitivity is limited by the receiver's amplifier noise, which we anticipate to be true for most receivers; however, if other factors limit reception sensitivity, the "inferred" receiver noise calculations in this chapter reflect those other performance limitations rather than actual receiver noise.*

The internal noise created by a receiver is often expressed in terms of noise figure. The noise figure of a receiver is the effective amount of noise created by the input circuitry of the receiver, measured relative to a physical limit on noise known as thermal noise and referenced to the input of the receiver. While noise figure cannot be directly measured externally, the effective noise figure can be inferred from the required CNR measurements of Chapter 3 in conjunction with the minimum signal level at TOV, as measured in Chapter 4.

Figure 5-1(a) illustrates measurement of required CNR (i.e., white noise threshold). The vertical line represents a range of signal and noise amplitudes that could be applied to the antenna terminal of a TV receiver. With external white noise added at a level well above the internal noise of the receiver, signal levels in the lower, red portion of the line will result in no TV picture. Signals in the yellow range will produce a picture degraded by demodulation errors. Signals in the green range, with signal level exceeding the noise level by an amount greater than the required CNR, will produce a picture free of reception-related defects. (The carrier-to-noise ratio (CNR), becomes a difference rather than a ratio, because of the logarithmic scaling implied by measurements in decibels.)

Figure 5-1(b) illustrates measurement of minimum signal at TOV, the minimum signal level required to achieve a clear picture absent any external noise. Assuming that the TV reception is limited by the receiver's broadband internal noise, this minimum signal level can be viewed as the sum (in dB) of two parameters—the internally generated noise level of the DTV receiver and the amount by which the signal must exceed that noise level, i.e., the required CNR. The noise level of the receiver can be expressed as the sum (in dB) of the noise figure of the receiver and the thermal noise at some reference temperature. Thus, we have

Minimum Signal at TOV (dBm) = Thermal Noise (dBm) + Noise Figure (dB) + Required CNR (dB)

Thermal noise is a function only of reference temperature and measurement bandwidth and is given by

Thermal Noise (dBm) = 10 log(k T B) + 10 log(1000 mW/W)

* Various receiver design anomalies could result in reception sensitivity being limited by factors other than receiver noise (noise figure). For example, if the AGC (automatic gain control) does not allow sufficient RF and IF gain to amplify a weak signal to the level necessary for demodulation, reception performance will be limited by gain rather than by amplifier noise. Similarly, receiver performance could also be limited by local oscillator phase noise or by leakage into the tuner of internally-generated interference sources such as impulse noise from digital circuits or narrowband (tonal) interference.

where

k = Boltzmann's constant = 1.38065 x 10^{-23} joules/°K
T = reference temperature in degrees Kelvin (290°K for this report)[*]
B = the measurement bandwidth = 6,000,000 Hz for a television channel
10 log(1000 mW/W) provides the conversion from dBWatts to dBmilliwatts

Using the above values, thermal noise = -106.2 dBm.

If the noise generated internally by the DTV receiver is similar to white Gaussian noise, then the required CNR in Figure 5-1(a) is the same as that in Figure 5-1(b); consequently, noise figure of the receiver can be computed as

Noise Figure (dB) = Minimum Signal at TOV (dBm) – Required CNR (dB) – Thermal Noise (dBm)

RESULTS

The noise figures for all tested receivers on the three tested channels have been computed as above and are shown in Figure 5-2. Individual results for TV channels 3, 10, and 30 are shown in Figures 5-3, 5-4, and 5-5, respectively. The general format of the plots is as described in Chapter 3 in the section titled, "Format of the Bar Graph Data", except that, in the case of Figure 5-2, there are three bars per DTV receiver—representing the three channels tested. The reader should note the differences in vertical scales among the four graphs.

Note that in performing the noise figure calculation, the required CNR is assumed to be constant across the TV channels for the reasons discussed in the "Effect of TV Channel" section of Chapter 3. Thus, the CNR measurements on channel 30 are applied to channels 3 and 10, as well.

Nominal Noise Figure and Variation Among Samples

Table 5-1 shows the statistical properties of the noise figure across all tested receivers.

Table 5-1. Statistics of Receiver Noise Figure

NOISE FIGURE	Chan 3	Chan 10	Chan 30
Median across all receivers (dB)	8.8	7.6	6.9
Median re OET-69 planning factors	-1.2	-2.4	-0.1
Deviations of receivers from median			
--Best performing receiver (dB)	-2.5	-1.3	-1.3
--Worst performing receiver (dB)	12.2	4.5	2.6
--89th percentile receiver (dB)	4.5	3.3	1.2
Standard deviation (dB)	3.6	1.6	0.9
Total span from worst to best receiver (dB)	14.7	5.7	3.9

The median noise figure across all measured receivers was found to decrease with channel—with the noise on channel 30 being 1.9 dB lower than that on channel 3. The median noise figures were 1.2 to 2.4 dB better than those shown in the OET-69 planning factors for the VHF bands (10 dB) and essentially matched the planning factor for the UHF band (7 dB).

[*] The reference temperature is generally taken as the antenna temperature. 290°K = 17°C = 62°F results in a thermal noise level matching the -106.2 dB value used in OET-69.

On channel 3, only 21 percent of the tested receivers performed more poorly in noise figure than the value modeled in OET-69 by an amount exceeding 1-dB—the approximate tolerance of the measurements.* On channels 10 and 30, the numbers are 7 percent and 18 percent, respectively.

The variations among receivers were large on channel 3—with a 3.6 dB standard deviation and two receivers performing at levels 10.3 and 12.2 dB worse than the median. More attention to tuner design for those two receivers might significantly improve performance in weak signal conditions. 89 percent of the receivers (all but three) were no more than 4.5 dB above (worse than) the median noise figure.

Variations were relatively small on channels 10 and 30. Standard deviation across all receivers was 1.6 dB on channel 10 and 0.9 dB on channel 30. The worst performers differed from the median by 4.5 and 2.6 dB, respectively, on channels 10 and 30, and 89 percent of the receivers (all but three) were no more than 3.3 dB above (worse than) the median noise figure on channel 10 and no more than 1.2 dB above the median noise figure on channel 30.

Variation With Product Type and Price

Magnitude of Observed Variations With Product Type and Price

As can be seen in Table 5-2, the observed variations in receiver noise figure with product type and price categories were very small (category medians differing from overall median by less than 1 dB) for channels 10 and 30 and were somewhat larger for channel 3. On channel 3, median noise figure of set-top boxes was 1.7 dB worse than the overall median of all receivers. The best median noise figure—1.4 dB better than the overall median—occurred in the low-price DTV category. Such differences are likely to influence performance only in locations where the signal margin is very small.

Table 5-2. Product-Type/Price Variations of Receiver Noise Figure

NOISE FIGURE	Chan 3	Chan 10	Chan 30
Median of Set-Top Boxes re Overall Median (dB)	1.7	0.1	0.6
Median of Low-Price DTVs re Overall Median (dB)	-1.4	-0.1	0.0
Median of Medium-Price DTVs re Overall Median (dB)	0.0	0.4	-0.1
Median of High-Price DTVs re Overall Median (dB)	-0.8	-0.3	0.0

Statistical Significance of Observed Variations With Product Type and Price

Table 5-3 shows the Pearson's correlation coefficient between the noise figure and the price of each DTV receiver. Given the similarity of results with those for minimum signal at TOV, the reader is referred to Chapter 4 for a discussion of the interpretation of these results. The bottom line is that there is no statistically significant correlation of noise figure with price of the receivers..

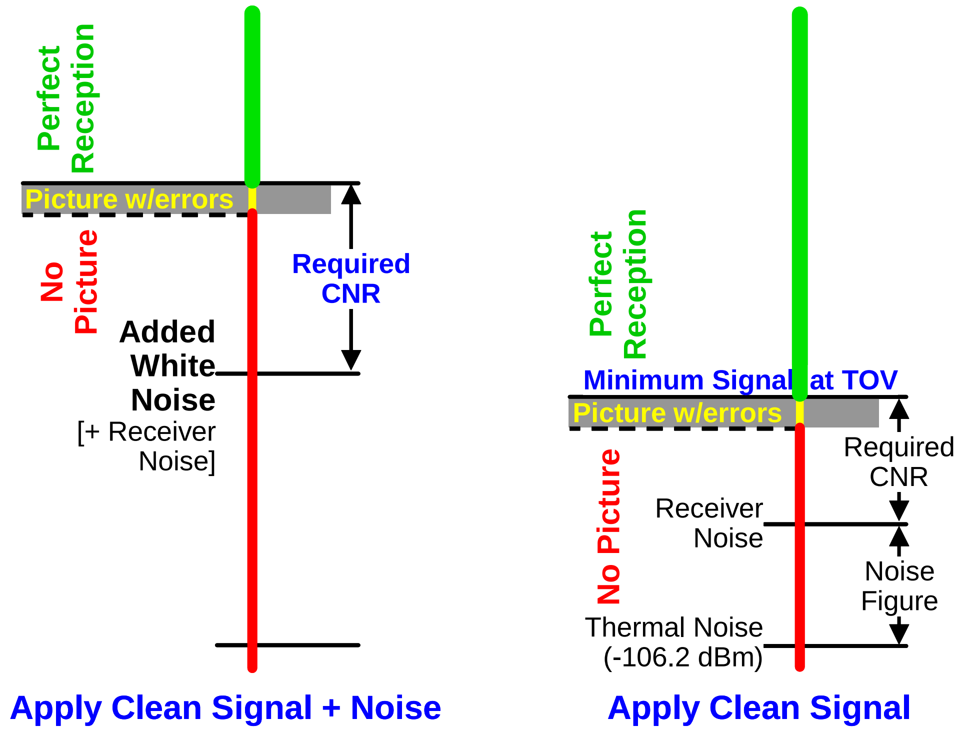
* Absolute measurement accuracy of the vector signal analyzer on the amplitude range that was used for the measurements was as ±1.5 dB maximum and ±0.5 dB typical.

Table 5-3. Correlation Coefficient of Receiver Noise Figure with Price

Pearson's Correlation Coefficient of Noise Figure with Price	Chan 3	Chan 10	Chan 30
All Tested Receivers	-14%	-4%	+6%
DTVs Only (no Set-Top Boxes)	-1%	-1%	+11%

Relative Variations in Noise Figure and Required CNR

Figure 5-6 shows the required CNR for each receiver as a function of noise figure on each of the three tested channels. Contour lines can be used to read the combined effect of the two parameters on minimum signal at TOV. It is clear from the plot that most of the variation in receive sensitivity (i.e., minimum signal level at TOV) of the DTV receivers is due to variations in receiver noise figures rather than variations in the CNR required by the demodulator. In fact, based on standard deviations of the parameters, variability in noise figure among the receivers is 4.2 times as high as the variability in required CNR on channel 30, where the noise figure variations are smallest. On channels 10 and 3, respectively, the noise figure shows 7 and 16 times the variability of required CNR.



(a) Required CNR *(b) Minimum Signal at TOV*

Figure 5-1. Relationship between Minimum Signal at TOV and Required CNR

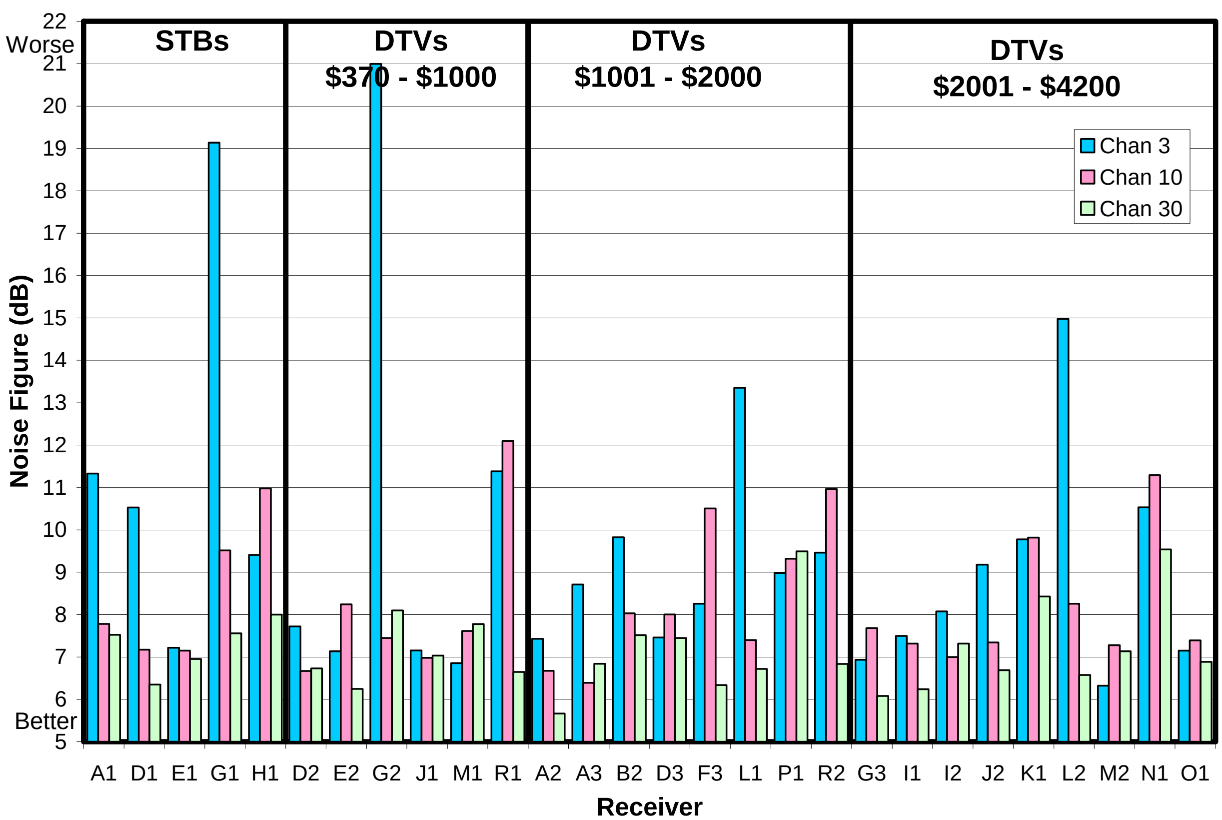


Figure 5-2. Noise Figure on Three Channels

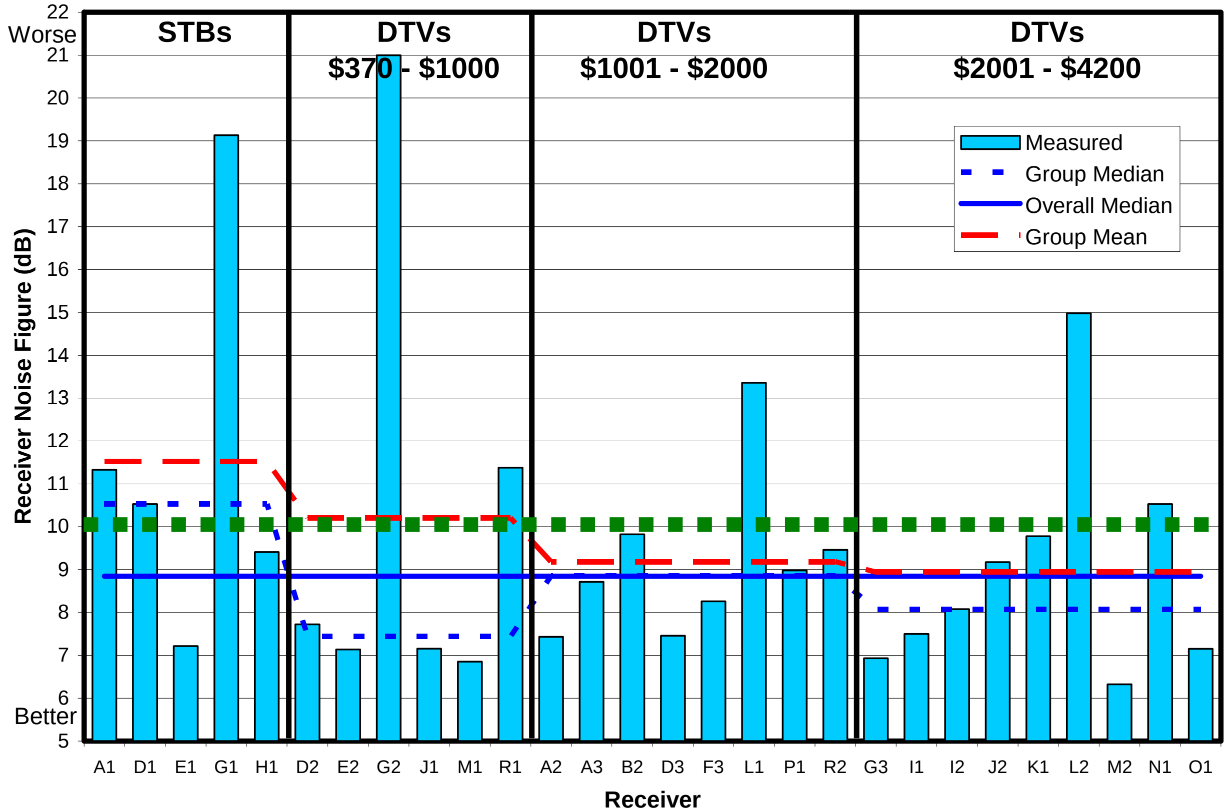


Figure 5-3. Noise Figure on Channel 3 (Low VHF)

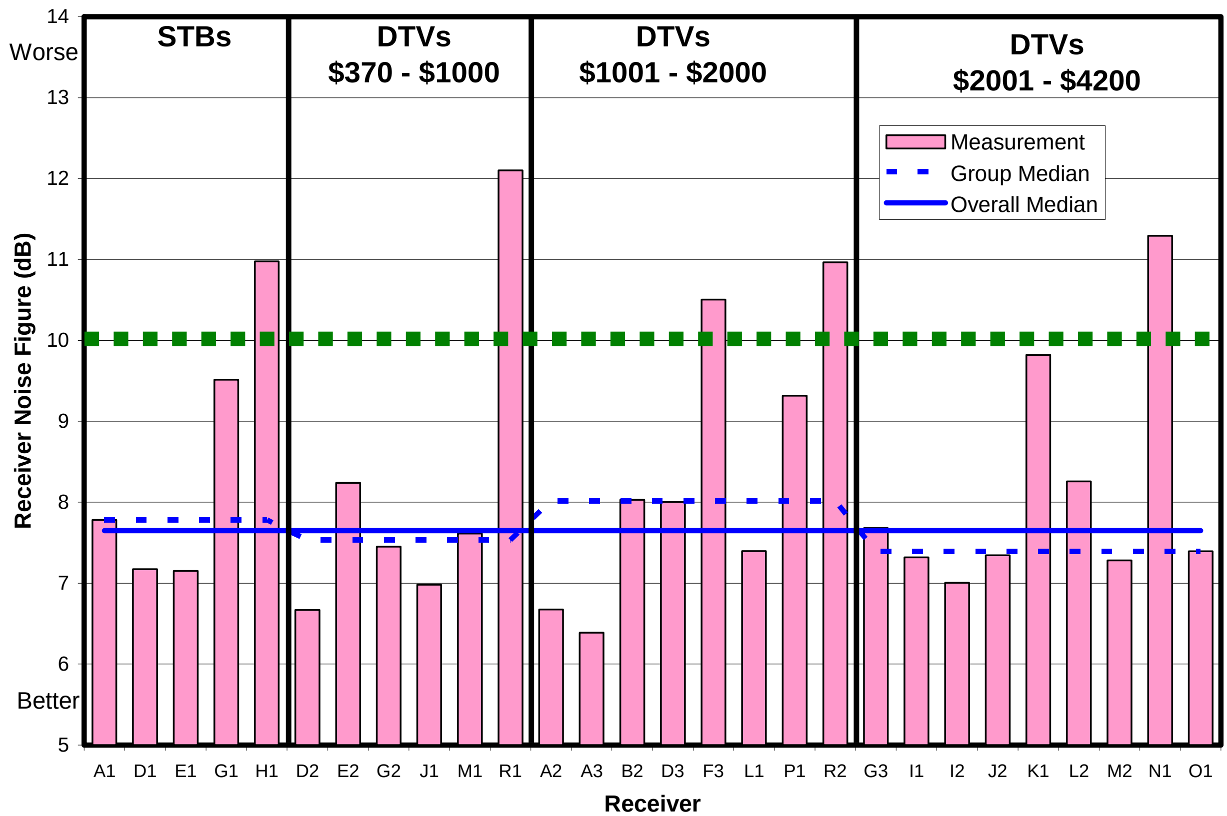


Figure 5-4. Noise Figure on Channel 10 (High VHF)

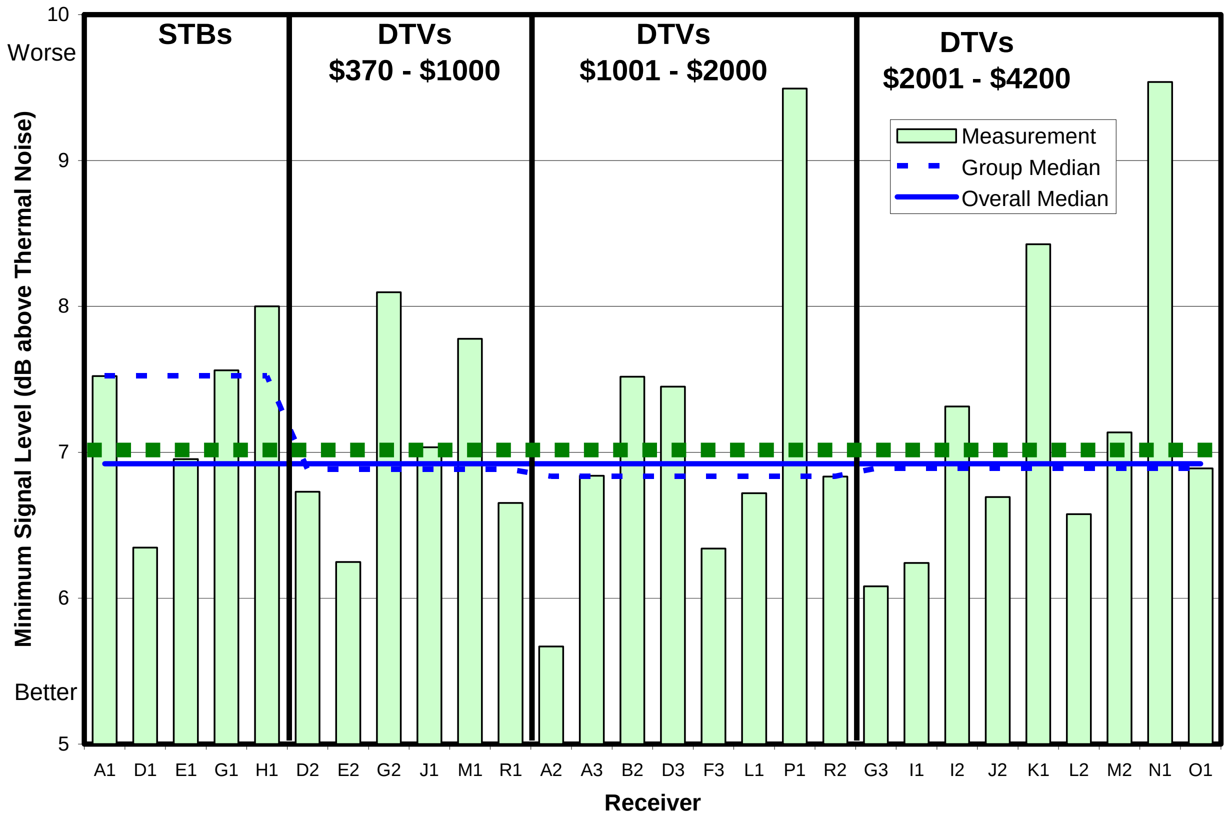


Figure 5-5. Noise Figure on Channel 30 (UHF)

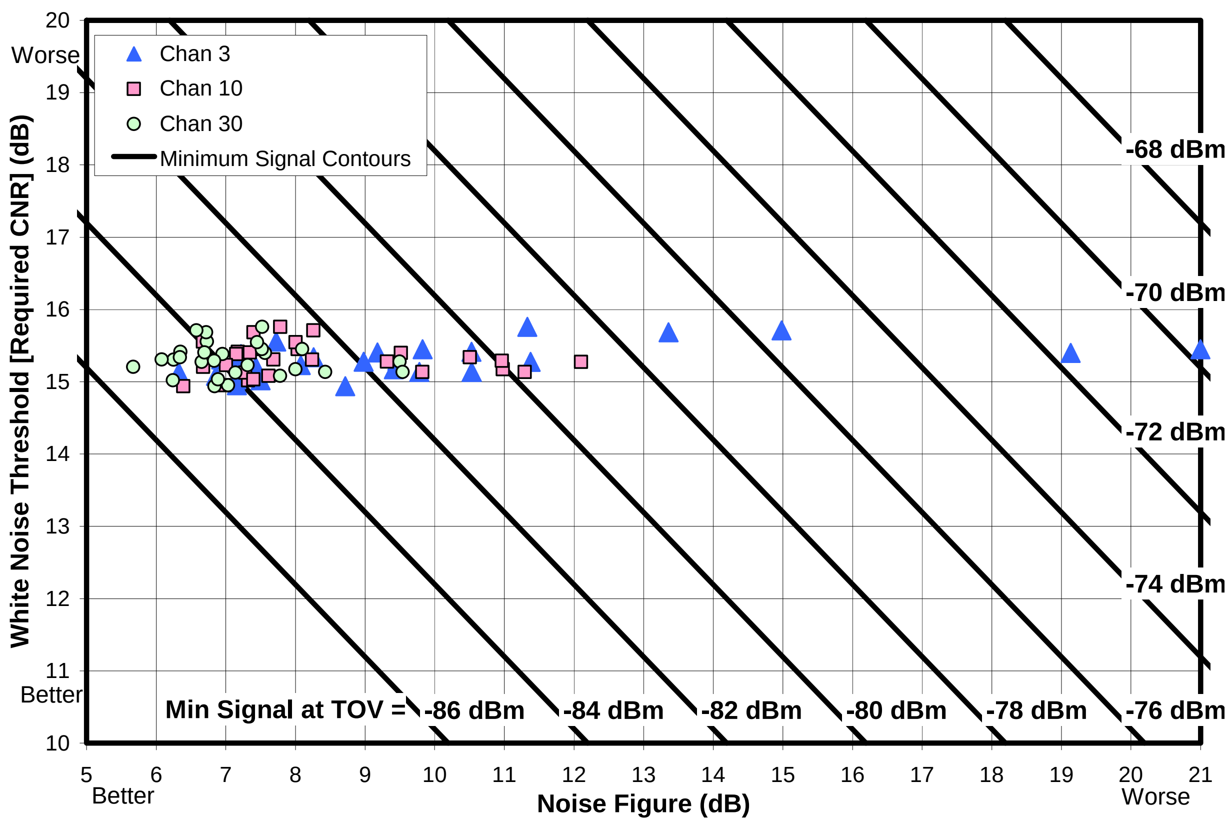


Figure 5-6. Required CNR Versus Noise Figure

CHAPTER 6
PERFORMANCE AGAINST MULTIPATH USING FIELD CAPTURES

Chapters 3 through 5 dealt with over-the-air reception performance of the DTV receivers with a signal that is unimpaired by multipath. Chapter 6 addresses the issue of multipath by determining the ability of each receiver to process broadcast DTV signals that were received and recorded on actual television antennas at various locations in New York City and Washington, DC.

The selected digital RF recordings, also called "captures" or "field ensembles", were 47 of the 50 captures recommended by the ATSC for DTV receiver testing.[*] ATSC's characterization of the 50 captures is worth noting.

> *"Most of the field ensembles contain data captured at sites where reception was difficult. The field ensembles are clearly not meant to represent the statistics of overall reception conditions but rather to serve as examples of difficulties that are commonly experienced in the field."*[†]

Three of the 50-recommended captures were excluded from testing with the consumer DTV receivers because they contain no video content and therefore require specially instrumented receivers for testing; however, extrapolation of instrumented receiver test results for those three captures to the consumer receivers is discussed later in this chapter. The remaining 47 captures break down as follows:

- sites characterized as urban (19), suburban (12), rural (2), and various other categories that overlap these designations (14);
- single-family homes (18), townhouses (8), and apartments (21);
- indoor antennas (39) and outdoor log-periodic antennas (8)

Each of the captures was recorded in the year 2000 by the Advanced Television Test Center (ATTC) or the Association for Maximum Service Television (MSTV) using specialized digital capture equipment. Each capture has duration of either 23 or 25 seconds. An RF player allows the recorded signal to be translated to any standard TV broadcast channel and played back as a repeating loop.

Appendix B lists the captures and summarizes some of the test results.

MEASUREMENT METHOD

The test configuration was essentially the same as that described in Chapter 3, for the white-noise threshold measurements, except that no noise was injected. The nine-way splitter allowed the signal to be simultaneously applied to as many as eight DTV receivers and a vector signal analyzer. All 47 selected RF captures were played through each group of receivers. Performance is reported in this chapter as the number of captures successfully played by a receiver for two different criteria of success. As a consistency check, receiver D3 was included in each group of eight receivers that were tested; the numbers of captures played successfully on receiver D3 on the various tests were consistent within one count.

Signal attenuators were adjusted to provide a nominal input of -30 dBm at the receiver antenna ports. The attenuator was not separately adjusted for each capture file; consequently, the actual injected level within

[*] *"ATSC Recommended Practice: Receiver Performance Guidelines"*, ATSC Doc. A/74, Advanced Television Systems Committee, 17 June 2004.

[†] Ibid., p. 15.

the channel bandwidth of 6 MHz varied from -38 to -28 dBm based on the level recorded in each capture. All but four of the captures played at an in-channel level within 2 dB of the nominal.

Successful playback of a capture was defined in terms of the number of video error bursts observed during a single playback loop after the loop had played at least three times. (In many cases the performance was monitored over several loops and, if the results varied, a median value was chosen.) A video error burst lasting more than one second was counted based on the approximate duration in seconds. Thus, an error burst lasting three seconds was counted as three errors. Errors occurring during or immediately after the loop-restart time were not counted, nor were errors associated with known defects (dropped symbols) in eight of the captures, as documented by the ATSC.[*]

The testing was performed on channel 30. It should be noted that with many of the DTV receivers, simply tuning to channel 30 was not sufficient to ensure successful acquisition of the TV signal—even with one of the easier captures. The original source material for the captures was recorded from eight different DTV broadcast stations in two cities. Because of the facts that multiple programs can be broadcast on a single channel and that most DTV channels are associated with an equivalent analog channel number that is used in selecting the station (PSIP requirements),[†] many of the receivers were "confused" by changing broadcast stations from playback of one capture to playback of the next, even though the RF channel remained constant. As a result, various methods such as rescanning the channels were necessary to get many of the receivers to operate after changing between captures that originated on different TV channels. To save time in the process, the captures were sorted by originating broadcast station before testing, and were further sorted to allow the more benign captures from a given broadcast station to be played first, in order to lock the receivers onto each new broadcast station.

Further details on the measurement procedure are contained in Appendix A.

RESULTS

Figure 6-1 shows the results of testing each DTV receiver with each of the 47 RF captures. The general format of the plot is as described in Chapter 3 in the section titled, "Format of the Bar Graph Data", but with a few differences. The blue (lower) portion of each bar represents the number of captures that played without a visible error during a single loop of the capture. The upper portion of each bar adds the captures that played with no more than two visible errors during a single loop of capture.

It should be noted that, unlike the plots presented in earlier chapters of this report, increased performance in this plot is represented by taller bars. Also, in addition to the four category groupings of DTV receivers, Figure 6-1 includes an additional bar on the right, labeled 2000REF. This receiver was retained from field testing in the year 2000 and was included in the RF capture testing presented here. Further discussion of this receiver is provided later in this chapter as well as in Chapter 7.

[*] See Table B-1 of this report or the "Quality of Capture" column of the continuation of Figure A-1 on p.28 of *"ATSC Recommended Practice: Receiver Performance Guidelines"*, ATSC Doc. A/74, Advanced Television Systems Committee, 17 June 2004.

[†] The Program and System Information Protocol (PSIP) includes a field for establishing this association. Further information is available in Advanced Television Systems Committee documents A/65B "*ATSC Standard: Program and System Information Protocol for Terrestrial Broadcast and Cable (Revision B)*" and A/69 "*ATSC Recommended Practice: Program and System Information Protocol Implementation Guidelines for Broadcasters" for more information*."

Nominal Performance and Variation Among Samples

Unlike the results of other testing presented in this report, the results of testing against the RF captures are heavily clustered into two major performance tiers. The upper-tier (better) performers successfully played about 29 captures without error and about 37 captures with two or fewer errors. The lower-tier performers successfully played about 7 captures without error and about 9 with two or fewer errors. Neglecting receivers D1 and L2, all results fall within ±2 captures of one of these nominal results, as shown in Table 6-1. Receivers D1 and, perhaps, L2, appear to represent an additional performance tier slightly above the lower tier; this tier will be designated as "lower tier+".*

The upper-tier performers represent a quantum leap in ability to handle the most difficult multipath conditions. The receivers that tested in this tier are known to include the latest generation of demodulator chips from at least two of the major DTV chip developers.

Table 6-1. Number of Captures Successfully Played By Each Performance Tier

	Number of Consumer Receivers	Number of Captures Played with No Errors	Number of Captures Played with No More Than 2 Errors
Lower Tier	16	7 ±2	9 +2/-1
Lower Tier+	2	8 and 12	14 and 16
Upper Tier	10	29 ±2	37 ±2

It should be noted that some of the RF captures may contain recording flaws—other than the dropped symbols discussed earlier—that could prevent error-free demodulation regardless of how advanced the demodulator technology may be. For example, four of the captures for which no tested receiver achieved demodulation free of visual errors were identified by the ATSC as having possible non-linearities caused by high-level adjacent channels overdriving the recording system. These or other potential flaws may preclude a 100% success rate on the 47 captures from ever being achieved by any demodulator; consequently, we view the multipath-performance data based on these captures to be useful for purposes of comparing receivers, but not as an absolute measure of performance.

Extrapolation to the Three Captures Lacking Video Content

Three of the ATSC-recommended RF captures lacked video content and could not, therefore, be tested with the consumer DTV receivers; however, they were tested with a five-year-old instrumented DTV receiver, labeled "2000REF" in Figure 6-1. That receiver provides visual and audible indications when segment errors† occur during demodulation of the DTV signal.

Tests were performed first using three captures with video content (labeled as numbers 27, 29, and 45 in Appendix B). These captures exhibited 4, 1, and 2 visual errors, respectively, with the 2000REF receiver.

* Receiver D1 belongs in the "lower tier+" category because it performed above the range of performance for the lower tier both in terms of number of captures played with no errors and number of captures played with two or fewer errors. The case for placing receiver L2 in the "lower tier+" category rather than in the lower tier is weaker, since only one of its performance numbers (number of captures played with two or fewer errors) was above the lower tier range.

† With 8-VSB, each transmission segment consists of one MPEG packet. Thus, a segment error is equivalent to an MPEG packet error.

Results showed a one-to-one correspondence of segment error bursts with observed video error bursts for these captures.*

Tests of the 2000REF receiver with the captures having no video content (labeled 22, 24, and 44 in Appendix B) showed no segment errors. The absence of segment errors indicates that the 2000REF receiver would have exhibited no visible errors on these captures had there been video content to observe. Given that this five-year-old receiver—now obsolete by two demodulator generations—is among the worst performing of the tested receivers in terms of multipath performance (per Figure 6-1), it is considered likely that all of the tested consumer receivers would have exhibited no visual errors for these three captures had there been video content to observe. Consequently, if one wanted to extrapolate performance against the entire set of 50 ATSC-recommended RF captures from the tests of the 47 with video content, it is likely that three zero-error successes should be added to the results for each receiver.

Variation With Product Type and Price

Interestingly, both upper-tier and lower-tier performers appear in all three price categories of DTVs. This suggests that performance is not a function of price—at least in the DTV category.

On the other hand, none of the set-top boxes—the least expensive way to receive a digital broadcast if you connect it to an existing television—perform at the upper tier level.

Some understanding of these results can be achieved by looking at the introduction date of each tested receiver to the U.S. market. Introduction dates (by month and year) for 25 of the 28 receivers tested for this report were provided by the manufacturers; the remaining three were determined by a web search. Though introduction dates are not reported here in order to avoid possible date-based linking of individual product models with the receiver designations used in this report, the following observations are relevant.

- All ten upper-tier performers were introduced in or after March, 2005.
- The set-top boxes—all of which performed at the lower tier or "lower tier+"—were introduced in or before November, 2004.
- Of the lower-tier or lower-tier+ integrated DTVs (i.e., excluding set-top boxes), two were released in the latter part of 2004 and the remaining eleven were introduced between March and July, 2005.

Since the set-top box models available on the market at the time of the reported tests were 2004 or earlier models,† their lower-tier or "lower-tier+" performance reflects the lack of availability of the newer generation of DTV demodulator chips at the time of product design.

Among the DTVs, it is clear that introduction dates in or after March 2005 are consistent with feasibility of including of the newer technology. Among the tested DTVs that were introduced in or after March 2005, 48 percent performed at the upper tier level. It is probable that some of the products introduced in this time frame carried over tuner/demodulator designs from a previous generation.

One would expect that, as future models are released, the newer generation demodulator technology will migrate to an increasing extent into all DTV product categories, including set-top boxes, and that, at some point in the near future, the improved technology will be contained in all newly introduced receivers. In the meantime, there is little publicly available information to assist those consumers who live in locations

* In general, visual errors are expected to occur only when segment errors occur, but the reverse is not always true, depending on effectiveness of MPEG error concealment algorithms for the video content at the time of the errors.

† One of the tested set-top-box models was released to the market in August 2003. The other four were released between July and November 2004.

characterized by challenging multipath conditions in selecting DTV receivers that achieve the upper tier of performance.

Relationship Between Multipath Performance and White Noise Threshold

There is some reason to expect that improvements in multipath performance—which is achieved in part by increasing the number of taps in the demodulator's equalizer circuit—might come at the expense of poorer white noise threshold, because, even in the absence of multipath, the additional taps could be expected to add noise that is related to carrier amplitude. (Since an automatic gain control would be expected to provide sufficient gain to amplify the input signal—whatever its level—to a fixed level for processing by the demodulator, one would expect that the tap noise generated after this variable amplification would be at a fixed level relative to the DTV signal rather than at a fixed level relative to the antenna input—hence the impact would appear as a degradation to required CNR [white noise threshold] rather than an increase in noise figure.)

Figure 6-2, shows the measurements of white noise threshold (from Chapter 3) plotted against multipath performance as measured by the number of RF captures (out of 47) that were successfully played without error. The lower tier of multipath performers (presumably containing earlier generation 8-VSB decoders) had a median CNR threshold of 15.3 dB,[*] which is slightly worse than the 15.19 dB threshold achieved by the ACATS Grand Alliance prototype receiver.[†] Until the most recent VSB decoder generation came to market, the trend of the earlier VSB decoder improvements was a very slight worsening of the CNR at threshold as a tradeoff for improved multipath performance. The 15.1 dB median CNR threshold for the upper tier of multipath performers suggests that this trend is over. In fact, the seven best-performing receivers in terms of white noise threshold are in the upper tier of multipath performance.

[*] 15.3 dB is the median value for those receivers identified as lower tier—not including those identified as "lower tier+". If the lower tier+ receivers are included, the median is 15.4 dB.

[†] "Final Technical Report", Federal Communications Commission Advisory Committee on Advanced Television Service (ACATS), October 31, 1995, p.19.

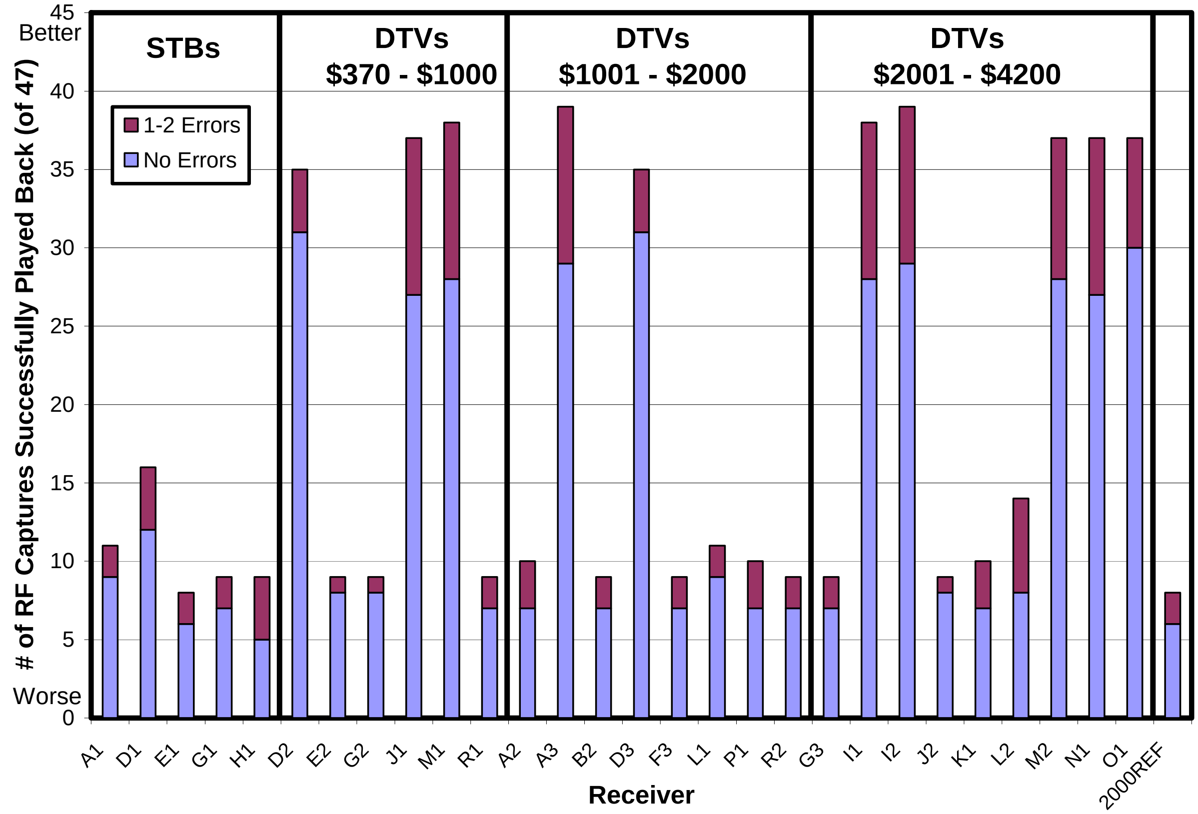


Figure 6-1. Performance Against 47 RF Captures

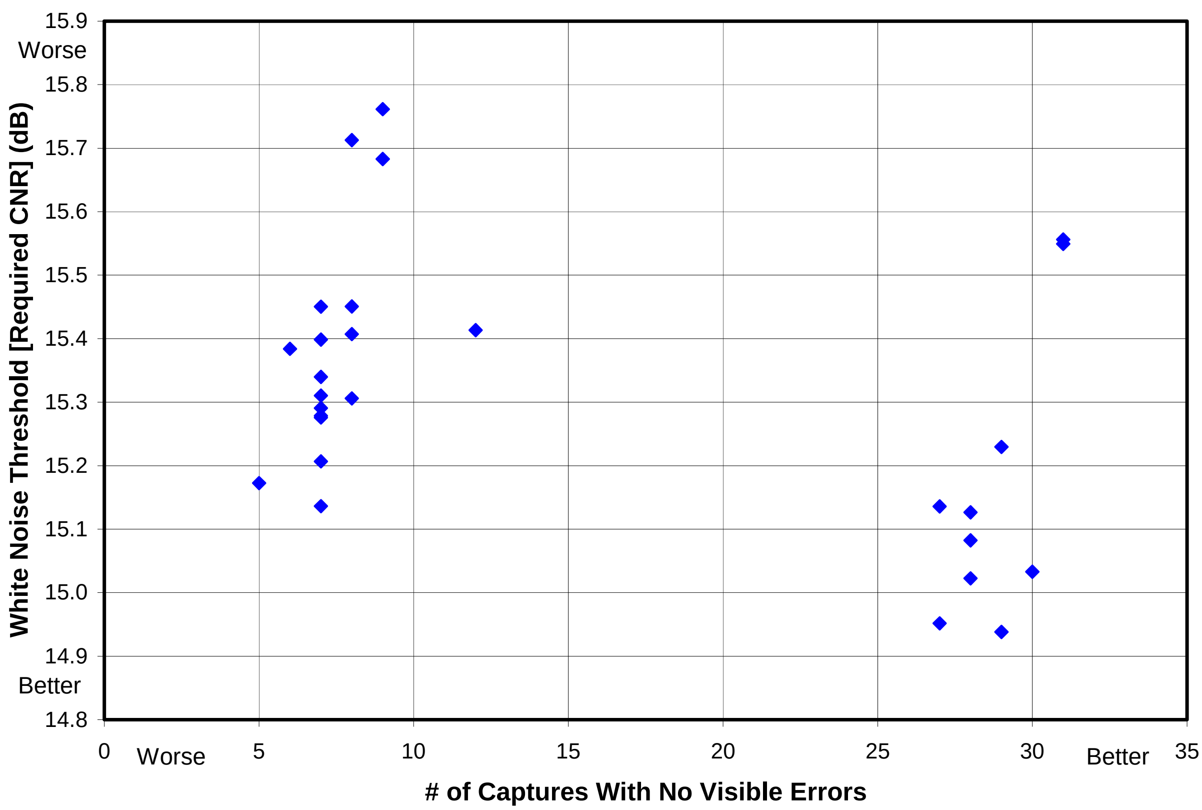


Figure 6-2. White Noise Threshold Versus Multipath Performance

CHAPTER 7
INFERRED PERFORMANCE AGAINST REPRESENTATIVE MULTIPATH CONDITIONS

The measurements presented in the previous chapter show that DTV receivers on the market at the time of these tests differ markedly in their ability to handle certain difficult multipath conditions. In order to understand the impact of these differences, one would also like to know how prevalent are the types of multipath conditions that differentiate receiver performance. If those conditions occur only rarely, then the performance differences will not be of consequence to most consumers; on the other hand, if they occur frequently, then the performance differences between "upper tier" and "lower tier" performers will radically affect many consumers.

Although an investigation of the frequency of occurrence of various multipath conditions is beyond the scope of this report, some of the measured data presented in Chapter 6 can be combined with results from a year-2000 FCC field investigation to provide at least a partial answer.

MULTIPATH CAPABILITY BASED ON YEAR-2000 FIELD TESTS

In 2001, the FCC Laboratory reported the results of year-2000 field tests of DTV coverage in Washington, DC and of DTV receiver performance.[*] In that study, the performance of six DTV receivers was evaluated at 60 locations for reception of two broadcast UHF DTV stations (channels 34 and 48). Nine of the locations were specifically selected for high-multipath conditions; however, 51 locations—referred to as "coverage sites", were selected in ways that can be expected to yield more representative results. It is these 51 sites that are of interest for the current analysis.

Of the 51 coverage sites, 38 were located at five-mile intervals along radials from the broadcast antenna of digital channel 48 in Washington, DC. The other 13 coverage sites were chosen from sites randomly selected from within a box 17.5 miles on a side, centered on the same broadcast antenna.[†]

At each site, reception performance measurements were made using at least two antenna systems:
- a log-periodic, outdoor-type antenna on a 30-ft. mast, and
- one of two indoor-type antennas on a 7-ft. tripod located outdoors.

The tripod-mounted antenna measurements were intended to indicate reception performance that could be expected with an antenna located indoors to the extent that could easily be determined given that access to homes or other buildings at randomly selected sites is not generally available. Though the antenna was not located indoors, the height and antenna type were consistent with indoor use. In general, a bow tie antenna was used as the "indoor-type" antenna. If the bow tie failed to achieve reception, a small, indoor, UHF log-periodic antenna ("Silver Sensor") was tried.

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[*] Inglis, William H. and Means, David L., *"A Study Of ATSC (8-VSB) DTV Coverage In Washington, DC,*

And Generational Changes In DTV Receiver Performance", Interim OET Report FCC/OET TRB-00-2, Technical Research Branch, Laboratory Division, Office of Engineering and Technology, Federal Communications Commission, April 9, 2001.

[†] More specifically, 200 sites were randomly selected within the 17.5-mile box. The tested sites were selected from among these—focusing on sites located in Washington, DC and sites near the FCC Laboratory, in Columbia, MD.

The tests included six DTV receivers, one of which was an instrumented prototype receiver to be used as a reference. Initially, the reference receiver was a second-generation Zenith ProDemodulator. After two thirds of the testing was complete (on July 17, 2000), that receiver was replaced with a third-generation Zenith ProDemodulator. The third generation included an equalizer with longer ghost cancellation times and slightly improved pre-ghost performance at the expense of slightly degraded white noise performance, relative to the second generation.

That same third-generation receiver was tested this year, along with the 28 current-generation consumer receivers, to determine performance against the 47 RF captures, as described in Chapter 6. The result for the third generation reference receiver is shown as the right-most bar (labeled “2000REF”) of Figure 6-1. In the current tests, that receiver—with equalizer technology now two generations behind the latest technology—tied for either the worst or second worst performance (depending on whether counting the zero-error data or the two-error data) when included with the current crop of receivers that were tested. Given that the third generation was used for only one third of the year-2000 tests and that a second generation receiver—with inferior equalizer technology—was used for two thirds of those tests, one can assume that the reported field test results for the “reference receiver” from those earlier tests correspond to receiver with multipath performance at or below the level shown by the “2000REF” bar in Figure 6-1.

In the year-2000 tests, all but one of the 51 sites exhibited field strengths judged to be large enough for theoretical DTV reception.[*] Using the mast-mounted, outdoor-type antenna, the reference receiver received channel 34 with no visible picture errors in all 50 of those sites and received channel 48 without visible errors in 49 of the 50 sites. Thus, the reference receiver successfully handled multipath conditions in 99 percent of the test-site/broadcast-station combinations with the mast-mounted antenna. When using the tripod-mounted indoor-type antennas (including the Silver Sensor, when needed), the reference receiver handled 85 percent of the test-site/broadcast-station combinations without visible picture errors.

Thus, receivers performing at or below the level of the 2000REF receiver shown in Figure 6-1 were able to successfully handle 99 percent of the multipath situations in the “coverage tests” when using a mast-mounted outdoor antenna. Though the tests involved only one metropolitan area and the sample size was too small to consider these numbers statistically accurate, the sites selected are expected to be far more representative of randomly selected real world conditions than the ATSC-recommended sites, which were chosen because of their difficult multipath conditions. Given that the 2000REF results show performance at or below almost all of the lower-tier performers in the Figure 6-1, one can reasonably assume that, even lower-tier multipath performance (as defined in Chapter 6) is adequate to handle the vast majority of reception conditions (at least in the Washington, DC area) when the receiver is paired with a good outdoor, mast-mounted antenna.

Similarly, receivers performing at or below the level of the 2000REF receiver shown in Figure 6-1 were able to successfully handle 85 percent of the multipath situations in the “coverage tests” when using a indoor-type antenna at a 7-foot height (but located outdoors). It appears likely, then, that multipath performance at the lower tier of Figure 6-1 may be adequate for most locations in conjunction with an indoor antenna, but that improved multipath performance (e.g., the upper tier of Figure 6-1) might offer benefits in many locations.

IMPACT OF REPRESENTATIVE MULTIPATH ON REQUIRED CNR

The year-2000 field tests also offer some insight into the impact of multipath on required CNR for a receiver.

[*] With the mast-mounted antenna, 51 sites were tested. With the tripod-mounted antennas, 50 sites were tested. In both cases, all but one site had sufficient field strength for theoretical DTV reception.

Those tests included measurements of required CNR at each site. The required CNR was determined by adding white Gaussian noise to an amplified version of the signal received from the antenna and adjusting the noise level until the threshold of visibility (TOV) was observed.

Though the precision of the measurements was limited by the use of one-dB steps in adjusting the noise level, the median required CNR across all of the coverage sites provides an indication of the required CNR in real world multipath conditions. In general it was found that the newer generation receivers performed better—i.e., had a lower required CNR—that older generation receivers. When used with the mast-mounted antenna, the newest generation receiver that was used throughout the test period for the 2001 report (a "third generation" receiver identified as receiver 5 in that report) exhibited a median required CNR of 15.9 dB across all "coverage sites" tested for one of the received broadcast stations and 16.0 dB for the other. With the tripod-mounted antennas, the corresponding numbers were 17.0 and 16.6 dB.

Absent better information, a required CNR of 16.0 dB may be a reasonable estimate of reception performance in typical multipath conditions if an outdoor antenna is used.

CHAPTER 8
SUMMARY AND CONCLUSIONS

The laboratory-based measurements performed for this report emulated two types of over-the-air reception conditions for DTV receivers:

(1) Unimpaired signal (i.e., no multipath) [Chapters 3 – 5], and

(2) Signal impaired by multipath (ghosts) [Chapter 6]—focussing on particularly difficult multipath conditions.

The unimpaired signal measurements can be used to quantitatively predict receiver performance under benign reception conditions—i.e., with little multipath. The multipath tests provide a basis for comparing the ability of different DTV receivers to handle difficult multipath conditions—without directly addressing the frequency of occurrence of those multipath conditions.

The linkage developed in Chapter 7 between the new, laboratory-based measurements performed for this report and earlier FCC field-test data provides a basis for anchoring the multipath results to representative, real-world reception conditions.

The purpose of this report has been to provide an empirical basis for answering three questions that derive from study requirements imposed by Congress as part of SHVERA [Chapter 1]. Those questions are as follows.

(1) Is there is a wide variation in the ability of reasonably-priced consumer digital television sets to receive over-the-air signals, such that at a given signal strength some may be able to display high-quality pictures while others cannot?

(2) Is such variation related to the price of the television set?

(3) Should such variation be factored into setting a standard for determining whether a household is unserved by an adequate digital signal?

In addressing these questions, separate answers will be provided for benign signal conditions (little multipath) and difficult multipath conditions. The third question will be addressed by comparing measured results to the receiver performance planning factors in OET-69.

The benign signal case will be evaluated in terms of the measured values of minimum signal at the threshold of visibility of errors (TOV) for the receivers. This specifies the ability of a DTV receiver to operate with a weak signal—absent significant multipath or interference. To provide a better understanding of differences among receivers, the discussion will also delve into two receiver parameters that combine to determine the minimum signal at TOV. These are:

- the white noise threshold (required carrier-to-noise ratio [CNR]); and
- the effective noise figure of the receiver.

The first of these characteristics is a demodulator characteristic that is independent of which TV channel contains the signal of interest. The second is a measure of the internally generated electronic noise of the receiver; it does vary with TV channel. In reporting channel-dependent data, results are presented for the low-VHF, high-VHF, and UHF bands, which were represented in the measurements by TV channels 3, 10, and 30.

VARIATION IN RECEPTION PERFORMANCE

For Benign Signal Conditions

In the low-VHF band, the variation in reception performance among the tested DTV receivers was moderately high. The minimum signal level at TOV exhibited a 3.7-dB standard deviation among the receivers. 89 percent of the receivers exhibited performance within 5.1 dB of the median performance, but two (seven percent) same-brand receivers were significantly worse than the median—by 10.6 and 12.5 dB. Omitting those two receivers from the data set would reduce the standard deviation to 2.3 dB.

In the high-VHF and the UHF bands, the variation in reception performance among the tested receivers was small. In the high-VHF band, the minimum signal level at TOV exhibited a 1.6-dB standard deviation; 89 percent of the receivers exhibited performance within 3.1 dB of the median, and the poorest performing receiver exhibited a performance level 4.3 dB worse than the median. In the UHF band, the minimum signal level at TOV exhibited a 0.9-dB standard deviation; 89 percent of the receivers exhibited performance no worse than 1.3 dB poorer than the median, and the poorest performing receiver exhibited a performance level 2.5 dB worse than the median.

Most of the variation in reception performance among the tested receivers was due to differences in receiver noise figure rather than in required CNR. The noise figure variations were larger than the required-CNR variations by factors ranging from 4.2, in the UHF band, to 16, in the low-VHF band.

For Difficult Multipath Conditions

Independent of band, there was a wide variation in ability of the receivers to handle difficult multipath conditions; however, linkage of the current results with earlier field test results suggest that the observed performance differences are of no consequence in the vast majority of reception locations, if an outdoor, mast-mounted antenna is used. When an indoor antenna is used, the linkage suggests that the observed performance differences would be significant in many, but probably not most, locations.

In tests against RF captures recorded from antennas at sites specifically selected for their challenging multipath conditions, the multipath-handling capability of the receivers fell primarily into two tiers of performance. The upper (better-performing) tier included ten receivers. The lower tier included 16 receivers. Two receivers fell in between the two tiers, but closer to the lower tier. The upper-tier receivers were able to handle about four times as many of the RF captures as the lower tier.

The FCC's year-2000 field tests at 51 sites that were selected without regard to multipath—and thus more likely to be representative of the typical range of common reception conditions than the RF captures—can be used to put the current multipath test results in perspective. A now-obsolete instrumented receiver left over from those earlier field tests was retested this year against the RF captures and was found to perform at the bottom of the lower performance tier. But, in the year 2000 field tests that now-inferior receiver successfully handled multipath in 99% of the combinations of site and broadcast station,[*] when a mast-mounted outdoor antenna was used. The success rate dropped to 85 percent when an indoor-type antenna was used,[†] indicating an increased likelihood that better multipath performance in the receiver would have helped.

[*] Out of the 50 sites that had sufficient field strength for theoretical DTV reception.

[†] The indoor antenna was mounted at a 7-foot height, consistent with indoor antenna, but tests were performed outdoors.

PRICE-DEPENDENCE OF RECEPTION PERFORMANCE

For Benign Multipath Conditions

In assessing the price-dependence of receiver performance, one must consider two things:
(1) whether an observed variation of performance with price among the tested receivers is statistically significant—i.e., whether it represents a real trend among DTV receivers currently on the market or whether it is a statistical artifact of the particular selection of receivers that were tested; and,
(2) whether an observed variation of performance with price is of sufficient magnitude to significantly affect television performance.

In the low-VHF band, though the variability in performance among the receivers was moderately high, the variability among the price categories was small, and no statistically significant price-dependence of that variation was found. In fact, the median performance of the low-cost TVs was slightly better than that of either the mid-priced or high-priced TVs. The median performance of the tested set-top boxes was poorer than that of the integrated DTVs by 2.3 dB, though it must be noted that these were older designs (2004 and earlier models that were still on the market at the time of this report) than the DTVs.

In the high-VHF and the UHF bands, the variation in reception performance with price was judged to be both small and not statistically significant. The median performance of the high-cost TVs differed from that of the low-cost TVs by less that 0.2 dB. Set top boxes exhibited median performance 0.6 dB and 0.7 dB worse than the median of all TVs in the low-VHF and UHF bands, respectively.

For Difficult Multipath Conditions

The tested receivers fell into two distinct tiers of multipath-handling capability—the upper tier representing a significant performance improvement associated with at least two companies' newest generation of demodulator chips.

Given that both tiers of performance appeared in all three price ranges of DTV receivers, there appears to be no inherent price dependence among the DTVs; however, there was a complete absence of upper-tier performers among the tested set-top boxes. This absence is attributed to the older designs of the set-top box products—all of which were introduced in the year 2004 or earlier. Among the tested receivers, none that were introduced before March 2005 were found to exhibit upper-tier performance, whereas 48 percent of those introduced in or after that month performed at the upper tier level.

RECEPTION PERFORMANCE RELATIVE TO OET-69

For Benign Multipath Conditions

The results show no clear need to adjust planning factors in OET-69 for application to SHVERA. Table 8-1 shows that, for benign multipath conditions, the poorest performing receiver category—*set-top boxes*—exhibited median performance (as indicated by minimum signal at TOV) closely matching predictions based on current OET-69 planning factors, with median performance exceeding the OET-69 predictions by 1.7 dB in high VHF and falling below OET-69 performance levels by less than 1 dB in low VHF and UHF. The median low-cost DTV performance matched OET-69 in the UHF band and was better than OET-69 by about 2 dB in the VHF bands. It should be noted that the tolerance on these measurements is about ±1 dB.

[It is also noted that, in terms of minimum signal at TOV, the overall median performance of the tested receivers (-82.2, -83.2, and -83.9 dBm, in low VHF, high VHF, and UHF, respectively) matches, within measurement accuracy, the minimum performance standard of -83 dBm recommended by the ATSC.*]

Table 8-1. Net Performance for Unimpaired Signal Relative to OET-69 Model

Band	Median of All Test Samples	Median Low-Cost DTV	Median Set-Top Box
Low VHF (Ch.3)	1.2 dB better	2.3 dB better	0.7 dB worse
High VHF (Ch.10)	2.2 dB better	2.4 dB better	1.7 dB better
UHF (Ch.30)	0.1 dB worse	0.1 dB better	0.8 dB worse

A breakdown of the results by individual planning factors is shown in Table 8-2. Median required carrier-to-noise ratios (CNRs) closely match the OET-69 value, as does the system noise figure in UHF. The median VHF noise figures of the tested receivers were better than the OET-69 values, with the exception of the set-top box median in low VHF, which was only 0.5 dB above (worse than) the OET-69 value.

Table 8-2. Planning Factor Measurements with Unimpaired Signal

Planning Factor	OET-69	Overall Median of Test Samples	Median Low-Cost DTV	Median Set-Top Box
Required Carrier-to-Noise Ratio (dB)	15.2†	15.3	15.3	15.4
System Noise Figure (dB) in Low VHF	10.0	8.8	7.4	10.5
System Noise Figure (dB) in High VHF	10.0	7.6	7.5	7.8
System Noise Figure (dB) in UHF	7.0	6.9	6.9	7.5

Note: for all parameters, lower values correspond to better performance

Adjustment for Multipath

The required CNRs presented above were measured for an unimpaired signal. In the presence of significant multipath, it is known that higher CNRs are required. We have performed no measurements of this effect on the current generation of receivers; however, field tests from the year 2000 yielded a value of 16 dB for the median required CNR across 50 test sites using the then newest generation of DTV receiver hardware and an outdoor, mast-mounted antenna. This is only 0.7 dB above the median measured value from the receiver tests using a benign signal. If the net performance data of Table 8-1 were degraded by 0.7 dB to reflect this value for required CNR, it can be seen that the results would still closely match OET-69 predictions.

* "ATSC Recommended Practice: Receiver Performance Guidelines", ATSC Doc. A/74, Advanced Television Systems Committee, 17 June 2004, p.11.

† See note for Table 1-1.

Overall Conclusion Regarding Adjustment to Planning Factors

While adjustments to the OET-69 planning factors could be made based on the test results presented in this report in combination with results from the year-2000 field tests, the overall effect on performance predictions would be small. Combining the 16-dB required CNR value, as discussed above, with the overall median noise figures would yield more optimistic predictions that the current OET-69 by 0.4 dB and 1.6 dB, respectively, in the low-VHF and high VHF bands, and less optimistic predictions by 0.7 dB in the UHF band. Given the tolerances on the measurements, such adjustments to the existing methodology are not recommended.

APPENDIX A: TEST CONFIGURATIONS, ISSUES, AND PROCEDURES

TEST CONFIGURATIONS

This appendix provides additional information regarding test configurations, procedures, and issues that arose during the testing.

General Information on the Test Configurations

All test and measurement setups maintained a 50-ohm impedance throughout, except at the signal source and the consumer TV inputs, which were each specified to be nominally 75 ohms. (An older, instrumented reference receiver identified as 2000REF in this report had a 50 ohm input impedance.) The 75-ohm devices were matched to the rest of the test setup through minimum-loss impedance-matching pads, except that, in the test setup that employed a splitter, an impedance-matching transformer was used at the signal source to reduce losses.

Attenuation pads were used throughout each test configuration to reduce the effects of any impedance mismatches at places where such mismatches were considered likely or would be expected to have a significant impact. A 50-to-75-ohm impedance-matching pad used at the input of each consumer DTV receiver served both as an impedance-matching device and as a 5.8-dB attenuator to attenuate reflections due to deviations of the TV antenna inputs from the nominal 75-ohm value.[*]

Splitter Test Configuration

Figure A-1 shows a block diagram of the “splitter test configuration”, which was used for tests of white noise threshold and multipath performance.

An RF player (Sencore RFP-910) playing the “Hawaii_ReferenceA” file supplied with the player was used as the ATSC 8-VSB signal source, for reasons discussed in the “Test Issues” section of this appendix. Amplifiers for the signal operated at RMS levels that were more than 17-dB below the specified 1-dB compression points in order to ensure linearity.

For the white noise tests, noise was supplied by a noise generator, which was then externally filtered to roll off the noise beyond 700 MHz—well above the tested frequencies.

Both signal and noise levels were adjusted using step attenuators that could provide 0 to 81 dB of attenuation in 0.1-dB steps.

Signal and noise were combined using a directional coupler, then divided nine ways by means of two cascaded layers of three-way splitters, each specified to have a minimum isolation of 14 dB between inputs. The splitters were followed by 25-foot long, well-shielded, low-loss cables, each of which drove either an impedance-matching pad (nominally 5.8-dB power attenuation) for connection to a consumer TV receiver or a 50-ohm attenuator pad (nominally 6-dB attenuation) for connection to measuring instruments or to the instrumented receiver. The nine outputs—at the output of the final pads—are designated by port numbers Pt1, … Pt9 when the final pad is an impedance-matching pad, as when driving a consumer DTV. An “a” is suffixed onto the port numbers when the final pad is a 50-ohm pad,

[*] The intent was both to minimize standing waves on the 25-foot, low-loss cables and to reduce the impact of RF energy reflected back from a poorly matched TV on signals delivered to other TVs through the splitter.

as when driving a measurement instrument (vector signal analyzer or spectrum analyzer) or an instrumented receiver having a 50-ohm input impedance. Port Pt5a was always used as the measurement port.

The splitter arrangement allowed the signal and noise to be simultaneously delivered to as many as eight TVs and to a vector signal analyzer used for measurements. Any amplitude mismatch between the various ports, though small, was not of concern because the signal levels for multipath testing were not critical and because white noise threshold tests involve the ratio of two measurements (signal and noise) that were made on the same port and using the same amplitude range of the spectrum analyzer to eliminate the effect of small errors in absolute measured levels.

Minimum Signal Test Configuration

Figure A-2 is a block diagram of the configuration used for measuring minimum signal at TOV.

An RF player (Sencore RFP-910) playing the “Hawaii_ReferenceA” file supplied with the player was used as the ATSC 8-VSB signal source, for reasons discussed in the “Test Issues” section of this appendix.

Because minimum input signal at TOV is an absolute measurement rather than a ratio, a signal splitter was not used for these tests. The 25-foot low-loss coaxial cable carrying the signal was connected through a 10 dB attenuator and an impedance matching pad (50 to 75 ohms, 5.8 dB power attenuation) to the TV input. After signal level was adjusted to achieve TOV on the TV, the cable and 10-dB pad—but not the impedance matching pad—were moved to the vector signal analyzer input for the signal level measurement, which then had to be corrected for measured loss of the impedance matching pad.

CALIBRATION AND SIGNAL QUALITY TESTS ON TEST SETUPS

Impedance-Matching Devices

The power loss of 14 identical minimum-loss impedance-matching pads (Trilithic model ZM-57) and two impedance-matching transformers (Trilithic ZMT-57) were measured as a function of frequency. The devices were labeled with individual numbers for identification; designations were MLP#1 through MLP#14 for the minimum-loss impedance-matching pads and TT#1 and TT#2 for the transformers.

The losses of the individual impedance matching devices were determined from loss measurements performed on back-to-back pairs of impedance-matching devices. These measurements were performed by measuring signal levels versus frequency for a tracking generator signal and for that signal as attenuated by a back-to-back pair of impedance-matching devices (50 ohms to 75 ohms to 50 ohms) to determine the loss versus frequency for each tested pair of devices. (Loss was computed by subtracting the measured output level versus frequency of the tested devices from the output level versus frequency of the tracking generator, measured with the same spectrum analyzer settings [including input attenuation and reference level] in order to ensure that loss measurements were accurate.) The measured combinations included MLP#13 with each of the other devices and MLP#14 with each of the other devices. The difference between losses of MLP#13 and MLP#14 was computed as the difference between average loss of the combinations of MLP#13 with MLP#1 through MLP#12 and average loss of the combinations of MLP#14 with MLP#1 through MLP#12. The loss of MLP#13 combined with MLP#14 determined the sum of losses of MLP#13 and MLP#14. Combining this information allowed computation of the individual losses of MLP#13 and MLP#14. The loss of each of the other devices could then be computed by subtracting the loss of MLP#13 from the measured loss of the combination of that device with MLP#13, or by performing a similar calculation based on MLP#14; in fact, both computations were performed and the results averaged to determine the loss of those devices.

The unit-to-unit variation of the loss of the impedance matching pads at channel-30 frequencies was of interest because of their use in the splitter test setup. The pads were found to be quite well matched—with samples ranging from 5.79 to 5.84 dB at the frequency of TV channel 30.

All of the pads and both transformers were found to be flat to within 0.02 dB across the 6-MHz bandwidths of each tested channel (3, 10, and 30).

TV-channel-specific measurements of absolute loss of one impedance matching pad (MLP#12) were used in determining minimum signal at TOV because the actual signal level measurement did not include the loss of that pad. Those losses were 5.70, 5.73, and 5.82 dB, respectively, on channels 3, 10, and 30.

The frequency-dependent measurements of the loss of one impedance-matching transformer (TT#1) were used in determining the frequency response of the splitter test configuration to the 50-ohm outputs (Pt5a and Pt8a).

Splitter Test Configuration

Because of the complexity of the splitter test configuration, which included amplifiers, a noise generator, a directional coupler, and splitters that were not a part of the simpler minimum-signal test configuration, additional tests were performed to verify its performance. The tests evaluated the frequency response (including the potential effect of errors in input impedance of the TVs), port-to-port matching, signal and noise spectral characteristics, and signal quality.

Frequency Response and Effect of Mismatched Loads

The splitter test configuration (Figure A-1) provided nine identical output ports, each of which could be configured for connection to a 75-ohm device (the antenna port of a consumer DTV) or to a 50-ohm device (vector signal analyzer, spectrum analyzer, or an instrumented reference receiver having 50 ohms input impedance). Configuration of each port was performed by connection of either an impedance-matching pad (50 to 75 ohms, 5.8 dB nominal power attenuation) or a 50-ohm pad (6 dB ±0.5 dB) at the final output of the port (end of the 25-foot low loss cable). The ports were designated Pt1, … Pt9 when matched to 75 ohms. A suffix "a" was added to the designation of ports matched to 50 ohms. Only two ports were ever configured for 50 ohms during the reported tests: the fifth port (Pt 5a), which always served as the measurement port; and the eight port (designated Pt8a, when so configured), which was used to connect to the instrumented, 50-ohm input receiver designated 2000REF for one set of tests.

Figure A-3 shows the frequency response of the entire test setup from the output of the ATSC signal source (PtA in Figure A-1) to each of the final output ports. For port 8, separate results are shown for the Pt8 and Pt8a configurations. During the measurements, all ports except that being measured were terminated in the appropriate impedance—either 50 or 75 ohms. The response of each port was flat to well within 0.1 dB (maximum – minimum) across the 6-MHz bandwidth of TV channel 30. The gain of each 75-ohm port matched that of the measurement port (Pt5a) within 0.2 dB.

A test was also performed to determine whether frequency response on one port would be significantly affected by impedance mismatches on other ports, since consumer TVs may not have carefully controlled input impedance. Figure A-4 shows three frequency response plots measured on Port Pt5a under three different load conditions for the other eight ports: ideal terminations (75 ohms), actual TVs (tuned to channel 30), and open circuits. With TV's as loads the frequency response across channel 30 remained flat to well within 0.1 dB. With open circuits on all eight ports, flatness degraded somewhat, but was still well within 0.2 dB across channel 30.

All of the above tests were performed by using a spectrum analyzer and tracking generator, as shown in Figure A-5. In all cases the tracking generator signal (connected through an attenuator pad to stabilize the impedance) was injected at PtB in Figure A-1 so that a 50-ohm source could be used. For frequency response tests of 75-ohm ports, the losses in TT#1, the impedance-matching transformer that normally connected the 75-ohm ATSC source to PtB, were included by using TT#1 to match the impedance of the selected port to the 50-ohm input of the spectrum analyzer. For frequency response tests of 50-ohm ports, TT#1 was omitted from the measurement, but its losses as a function of frequency (measured separately) were included in the computed frequency response. In all cases, the tracking generator signal—as attenuated by the 10-dB pad shown in Figure A-5—was measured by the spectrum analyzer as a reference in the frequency response calculations. All measurements were performed with the same spectrum analyzer settings (including input attenuation and reference level) in order to ensure accuracy of the computed frequency response function.)

Signal Spectrum, Noise Spectrum, and Signal Quality

Spectrum and modulation error ratio measurements indicate that a high quality test signal and spectrally flat noise were delivered to the output ports of the test setup.

Figure A-6 shows spectra of the injected signal and noise as measured at Pt5a during playback of the "Hawaii_ReferenceA" file from the RF capture player at a CNR of 15 dB. The spectra were measured with a 30-kHz resolution bandwidth, 300-kHz video bandwidth, RMS detection, and trace-averaging (in linear power units) of 8192 traces. (This averaging was performed across multiple loops of the test signal). The noise spectrum is flat across the 6-MHz bandwidth of TV channel 30 to within 0.34 dB (maximum – minimum) for the spectrum as shown and to within 0.11 dB when a 500-kHz smoothing width is applied to average out some of the randomness of the measurement. Similarly, the signal spectrum is flat across the 4.76-MHz wide "head" (i.e., flat part) of the ATSC signal to within 0.59 dB for the spectrum as shown and 0.38 dB when 500-kHz smoothing is applied.

Modulation error ratio (MER) measured by the vector signal analyzer during the tests of required CNR was a respectable 33 to 35 dB without including any equalization in the vector analyzer and 37 dB with equalization.

Other Checks

A test was performed to ensure that any impedance mismatch at PtC in Figure A-1 would not affect the level of injected noise from the noise generator through the resulting variations in impedance at the signal input to the directional coupler as the signal step attenuator was varied. The noise level step attenuator was adjusted to achieve -70 dBm noise level at Pt5a. Amplifier A2 was then replaced by a short circuit at PtC and the noise level at Pt5a was measured for two different settings of the signal attenuator—0 dB and 81 dB. The measured variation in noise power was only 0.01 dB.

To ensure that amplifier A2 (Figure A-1) was not operated in a non-linear region that might affect signal quality, the signal level at the output of A2 was measured during playback of the "Hawaii_ReferenceA" file. The measured level was 17.5 dB below the 1-dB compression point of the amplifier.

Signal-to-noise ratio of the signal path (excluding any noise generated by the RF player) was measured to ensure that amplifier noise (from A1 and A2 in Figure A-1) did not significantly affect results. SNR in a 6-MHz bandwidth was found to be 64 dB on channel 30.

TEST ISSUES

A few observations regarding issues that arose during the test program may be of value to others who perform DTV receiver performance testing.

Multipath Performance Testing Using the RF Player

After we had tested 16 DTV receivers against each of the 47 RF captures, visiting engineers from a DTV chipset developer (ATI Research) observed video errors on one of the TVs during playback of a few captures. Though all tested TVs were able to play some of the captures with no visible errors, the visiting engineers suggested that the errors observed on some specific captures indicated that the FCC's RF player was not functioning properly. This conclusion was based on two factors: (1) they had tested a TV with the same technology at their labs and found it had produced no visible errors on those specific captures; (2) they reported having had problems with several of their own RF capture players that produced visible errors which went away after calibration and repair of the player.

Based on these observations, we sent our RF player back to the manufacturer for repair and calibration; the manufacturer indicated that our problem had been caused by a ground plane error on one of the cards. After they replaced that card and recalibrated the unit, the difference was dramatic. A TV that had successfully handled only 10 of the captures with no visible errors before the repair was able to handle 31 of the captures without visible errors after the repair. We subsequently discarded all previous results and repeated all testing.

As an additional confirmation of performance of our RF player—in conjunction with our entire splitter-based test setup, ATI allowed us to test two DTV samples (subsequently identified as "upper tier" performers in Chapter 6) at their laboratories using their equipment. The net test results (number of captures played with no visible errors and number played with no more than two visible errors) at the FCC using our test setup with our repaired RF player matched those that we performed at ATI for one of the TVs. For the other TV, the tests at the FCC showed three more captures producing two or fewer errors (including zero errors), but showed two fewer captures producing no errors. Given the variability in results that sometimes occur between playback loops along with the subjective judgment in identifying visual errors, these differences were considered acceptable.

RF Source for Measurements of White Noise Threshold and of Minimum Signal

Our plan had been to use the RF player as an ATSC source only when performing multipath testing. An ATSC signal generator was to be used for testing of white noise threshold and of minimum signal at TOV.

In initial tests of 16 DTV receivers using the signal generator as a source, the white noise threshold of the best tested receiver was found to be 15.25 dB. This was slightly higher than the 14.9 to 15.0 dB that had been expected for the better-performing receivers; consequently, the generator was sent back to its manufacturer for calibration and checkout. Upon its return, retesting of that best performing receiver yielded a white noise threshold 16.0 dB—indicating degraded signal quality.

After the poor result with the signal generator, white noise threshold was measured again, but this time using the RF player and a laboratory-recorded DTV signal file designated "Hawaii_ReferenceA" as the signal source. The measured white noise threshold of that same receiver was then found to be 14.94 dB. Based on these results, the ATSC signal generator was replaced by the RF player, which was then used for all testing reported herein. (Previous test results were discarded and all tests were repeated.)

Getting DTV Receivers to Recognize a DTV Signal

The channel-selection "intelligence" of many DTVs combined with certain artificialities of laboratory-based testing to create some challenges.

With analog television, to receive a signal on a given TV channel you simply select that channel. With DTV, there is another layer involved channel selection. To simplify the DTV transition for the consumer, a DTV signal includes coding that tells the TV the channel number of the analog station that is associated with that DTV signal. In Washington, DC, for example, the DTV broadcast on channel 48 includes information linking it to an analog broadcast on channel 4. A TV viewer not aware of the digital broadcast on channel 48 can tune to a channel he or she may already view—channel 4—and the digital television will automatically set its tuner to channel 48 to select the digital broadcast containing the same programming as the viewer would have seen on analog channel 4.

To facilitate this extra layer in channel selection, DTVs include a channel scan function that is used on initial setup of the TV. The function causes the tuner to sequence through all TV channels searching for analog and digital signals. It creates a mapping from the analog channel numbers to the digital ones and may also identify available sub-channels on each DTV broadcast, since the DTV transmission system enables transmission of more than one program within a single RF TV channel. Many of the TVs will not allow a DTV signal to be received unless it has been identified by such a scan.

The laboratory tests described in this report created two types of anomalies—one associated with the tests of minimum signal at TOV and the other associated with multipath testing using the RF captures.

The minimum signal tests were performed on channels 3, 10, and 30. The available equipment allowed creation of the signal on only one channel at a time; consequently, any channel scan identified only one channel, and when the channel was changed for the next set of tests, the channel scan had to be repeated.

For the multipath testing, a less obvious problem occurred. All testing was performed on channel 30, so one might expect that a single channel scan on each TV would enable testing with all 47 captures. While this worked for some TVs, it did not for others. The original source material for the captures was recorded from eight DTV channels in two cities. Many of the receivers were “confused” by changing broadcast stations (from one capture to the next), even though the RF channel remained constant. Many would not allow selection of the signal as channel 30; instead, the signal had to be tuned indirectly by selecting the channel number of the analog broadcast associated with the recorded digital broadcast—which could only occur after a channel scan.

Thus, each time that an RF capture was loaded, if it originated from a different broadcast station from the last, steps had to be taken to ensure that each TV recognized the new signal. The necessary steps varied among the TVs. Some immediately displayed the new video. For others, simply pressing the channel up or down button caused the signal to be selected. For TVs requiring a new channel scan, some allowed the user to select a single channel number to rescan (channel 30 in this case), while other required a more time consuming rescan of all channels. For some TVs, even a complete rescan was not sufficient to lock in the new signal; unplugging the TV from its power source followed by a channel rescan was usually sufficient in those cases.

To save time in the multipath testing process, the captures were sorted by originating broadcast station before testing. This reduced the number of transitions between broadcast sources so that fewer channel scans would be necessary. To further assist in testing, the captures were sorted—within each originating channel group—to allow the more benign captures from a given broadcast station to be played first in order to lock the receivers onto each new broadcast station using a signal for which success would be likely. It was found, however, that during subsequent testing with captures exhibiting more challenging multipath conditions, some TVs would change channels—or even turn off—during the period when no recognizable signal was received. Consequently, it was often necessary to return to an easier capture from the same broadcast source at various times during the testing to ensure that the TVs were still locked on to that broadcast.

PROCEDURES

Test procedures applicable to the DTV measurements conducted for this report are shown below.

General

The following procedures apply to all measurements.

- Warmup
  - ◊ Allow all test equipment (signal and noise sources, amplifiers, measurement equipment) to warm up for a minimum of 2 hours before testing.
  - ◊ Allow all TVs to warm up at least one hour before testing
- Test equipment calibration
  - ◊ Before each measurement sequence using the spectrum analyzer, perform a full alignment—including RF alignment requiring an external cable connection to the built in calibrated source. (Spectrum analyzer is used only for measurements of test configuration parameters such as frequency response and output spectrum.)
  - ◊ Before each measurement sequence using the vector signal analyzer, invoke the "single cal" function to calibrate the instrument.
- Measurement of applied signal and noise levels
  - ◊ Use averaging times of approximately 21 seconds (1200 averages on vector signal analyzer) when measuring signal levels and ensure that the averaging interval begins just after the start of a playback loop on the RF player and ends before completion of that loop in order to avoid averaging across the loop restart.
  - ◊ For measurements of noise levels, use averaging times ≥ 21 seconds.
- Identifying visual errors in video
  - ◊ Allow the RF player to play the selected signal through at least three complete loops before making observations.
  - ◊ Do not count errors occurring at each loop restart of the RF player
  - ◊ Do not count errors associated with known recording defects due to dropped symbols (Appendix B)
  - ◊ Horizontal streaks occupying a single scan line are judged to be defects in video source material prior to conversion to MPEG format for broadcast and are not counted.
  - ◊ For an error burst lasting longer than one second, count the number of errors as the approximate duration of the burst in seconds.

White Noise Threshold Tests

Note that all measurements are performed using the vector signal analyzer (VSA), and all attenuator settings and measurements are entered into a spreadsheet that performs the required computations.

- Connect equipment as shown in Figure A-1
- VSA setup
  - ◊ Run DTV measurement software[*]
  - ◊ Set number of averages to 2000
  - ◊ Set broadcast channel 30
  - ◊ Execute "single cal"
  - ◊ Set amplitude range to -50 dBm (most sensitive range)
- RF player setup
  - ◊ Load "Hawaii_ReferenceA" file
  - ◊ Set output channel to 30
  - ◊ Set output level to -30 dBm
- Noise generator setup
  - ◊ Set the internal noise attenuator to 0 dB

[*] "Control Software for the HP89400 Vector Signal Analyzer for Measuring DTV and NTSC Signals", VSA5.BAS, Version 5.02, Gary Sgrignoli

- Measure VSA self noise by connecting a 50-ohm termination to the VSA input and performing a "long average power" measurement. (This value will be subtracted—in linear power units—from all subsequent measurements.).
- Connect the VSA to Pt5a (Figure A-1)
- Measure modulation error ratio (MER) as an indication of signal quality
  - ◊ Set noise attenuator to 81 dB
  - ◊ Set signal attenuator to point at which VSA indicates occasional clipping (typically 24 dB attenuation) in order to maximize signal to VSA-noise ratio
  - ◊ Measure MER four times and average the results. The measurements are performed without any equalization in the VSA.
- Set and measure injected noise level
  - ◊ Set signal attenuator to 81 dB
  - ◊ Adjust noise attenuator to the 0.1-dB step that most closely yields a "long average power" reading of -70 dBm
  - ◊ Measure the "long average power" twice. (Actual injected noise power will be computed by averaging these two measurements with two similar measurements performed after the TV tests and subtracting—in linear power units—the VSA self noise. Though the correction for VSA self noise is performed in the spreadsheet, the correction is essentially negligible because VSA self noise is about 27 dB below the injected noise level.)
- Set signal to a high level and take whatever steps are necessary to ensure that all connected TVs are tuned to the signal and producing a picture.
- TV tests. Repeat for each of the connected TVs (typically eight). Include receiver D3 in each test sequence as a consistency check.
  - ◊ Adjust signal level upward as necessary to obtain a picture
  - ◊ Adjust signal level downward until picture either drops out or exhibits a high visual error rate
  - ◊ Adjust signal level upward in 0.1-steps to achieve the lowest signal level that produces a picture that is free of visual errors for 10 seconds. Record this attenuator setting.
  - ◊ Adjust signal level upward in 0.1-steps as needed to achieve the lowest signal level that produces a picture that is free of visual errors for 60 seconds. Record this attenuator setting.
    - – As a consistency check, the spreadsheet computes difference between attenuator setting in previous step and current attenuator setting. This difference is typically between 0 and 0.2 dB.
  - ◊ Perform "long average power" measurement as described below. This measurement represents the total of the injected signal level, the injected noise level (typically about 15 dB below the injected signal level), and the VSA self noise (typically about 42 dB below the injected signal level).
    - – The measurement should be initiated near the end of a playback loop, so that—following the initial operations performed when "long average power" is selected—the actual long integration will begin just after the start of the RF playback loop. The reading of average power should be taken just before the end of that playback loop.
    - – As a consistency check, the spreadsheet calculates the sum of the signal attenuator setting and the measured power level. This sum should be nearly constant across all TV measurements.
    - – Spreadsheet calculates injected signal level by subtracting—in linear power units—the injected noise level and the VSA self noise from the measured power. The injected noise level subtraction typically results in a correction slightly larger than 0.1 dB. The VSA self noise correction is negligible.
    - – Injected signal-to-noise ratio (SNR), termed the carrier-to-noise ratio (CNR) in this report, is computed. (A subsequent adjustment is made for TV self-noise—based on measurements of minimum signal at TOV; however, this correction is essentially negligible.)
  - ◊ Confirm that the measured level is sufficient for relocking on to the DTV signal.
    - – Reduce signal level by 20 dB for 20 seconds. Return to previous level and verify that the TV recaptures the signal.

- ◊ Repeat steps for other TVs
- Measure injected noise level
  - ◊ Set signal attenuator to 81 dB
  - ◊ Measure the "long average power" twice for use as described following 1st measurements of injected noise level.

Because both the injected noise power measurement and the injected signal measurement were performed using the same vector signal analyzer on the same amplitude range, the CNR is expected to be quite accurate, since it doesn't depend on the absolute calibration accuracy of the measuring instrument.

Additional information on the testing is included in the "Measurement Method" section of Chapter 3.

Minimum Signal Tests

Note that all measurements are performed using the vector signal analyzer (VSA), and all attenuator settings and measurements are entered into a spreadsheet that performs the required computations. The tests are performed for TV channels 3, 10, and 30.

- Connect equipment as shown in Figure A-2.
- VSA setup
  - ◊ Run DTV measurement software*
  - ◊ Set number of averages to 1200
  - ◊ Set selected broadcast channel
  - ◊ Execute "single cal"
  - ◊ Set amplitude range to -50 dBm (most sensitive range)
- RF player setup
  - ◊ Load "Hawaii_ReferenceA" file
  - ◊ Set output channel to selected channel
  - ◊ Set output level to -30 dBm
- Measure VSA self noise three times by connecting a 50-ohm termination to the VSA input and performing a "long average power" measurements. (The average of these measurements will be subtracted—in linear power units—from all subsequent measurements.)
- TV tests. Repeat for each of TV to be tested (typically eight). Include receiver D3 in each test sequence as a consistency check.
  - ◊ Connect output of the test setup through impedance-matching pad MLP#12, as shown by the solid lines on the right side of Figure A-2.
  - ◊ Set signal to a high level and take whatever steps are necessary to ensure that TV is tuned to the signal and producing a picture.
  - ◊ Adjust signal level downward until picture either drops out or exhibits a high visual error rate
  - ◊ Adjust signal level upward in 0.1-steps to achieve the lowest signal level that produces a picture that is free of visual errors for 10 seconds. Record this attenuator setting.
  - ◊ Adjust signal level upward in 0.1-steps as needed to achieve the lowest signal level that produces a picture that is free of visual errors for 60 seconds. Record this attenuator setting.
    - – As a consistency check, the spreadsheet computes difference between attenuator setting in previous step and current attenuator setting. This difference is typically between 0 and 0.2 dB.
  - ◊ Perform "long average power" measurement as described below.
    - – The measurement should be initiated near the end of a playback loop, so that—following initial operations performed when "long average power" is selected—the actual long

* "Control Software for the HP89400 Vector Signal Analyzer for Measuring DTV and NTSC Signals", VSA5.BAS, Version 5.02, Gary Sgrignoli

integration will begin just after the start of the RF playback loop. Confirm that the integration ends before completion of the playback loop.
  - As a consistency check, the spreadsheet calculates the sum of the signal attenuator setting and the measured power level. This sum should be nearly constant across all TV measurements.
  - Spreadsheet calculates injected signal level by subtracting—in linear power units—the VSA self noise from the measured power (a correction that is typically less than 0.1 dB) and then subtracting (in dB) the power loss of impedance-matching pad MLP#12 for the specific TV channel tested.
- ◊ Repeat steps for other TVs

Additional information on the testing is included in the "Measurement Method" section of Chapter 4.

Multipath Tests (RF Captures)

Note that in-band injected signal power (6-MHz bandwidth centered at channel 30) was measured at Pt5a (Figure A-1) using the vector signal analyzer (VSA) for each of the 47 RF captures during tests of the first group of eight receivers. These measurements were not repeated for subsequent receivers because small variations in absolute signal level applied to the receivers were not expected to affect the results.

- Connect equipment as shown in Figure A-1
- VSA setup
  - ◊ Run DTV measurement software[*]
  - ◊ Set number of averages to 2000
  - ◊ Set broadcast channel 30
  - ◊ Execute "single cal"
  - ◊ Set amplitude range to -20 dBm
- RF player setup
  - ◊ Set output channel to 30
  - ◊ Set output level to -30 dBm
- Signal and noise attenuators
  - ◊ Set signal attenuator to 0 dB. This was found to provide a median in-band signal power of -29.7 dBm across the 47 RF captures. This is 53 dB above the minimum signal level at TOV for typical receivers; consequently, any variations in absolute level among the captures was not expected to affect the test results.
  - ◊ Set the noise attenuator to 81 dB to effectively eliminate injected noise.
- Measure modulation error ratio (MER) as an indication of signal quality.
  - ◊ Load "Hawaii_ReferenceA" file
  - ◊ In the first series of tests, MER was measured twice with internal equalizer off. The average of the measurements was 35.5 dB.
- Tests for a given capture
  (Note that captures are loaded and tested sequentially in groups for which the originating TV broadcast channel is the same. Within each group, captures that are deemed to be easier to acquire—due to benign multipath conditions—are loaded first to increase the likelihood of a successful channel scan on each TV.)
  - ◊ Load the selected RF capture
  - ◊ Ensure signal acquisition for all TVs, to the extent possible
    - If this capture corresponds to a different broadcast TV channel than the last capture, take whatever steps are necessary to ensure that all connected TVs are tuned to the signal and have an opportunity to produce a picture. This may include channel scans or disconnecting power.

[*] "Control Software for the HP89400 Vector Signal Analyzer for Measuring DTV and NTSC Signals", VSA5.BAS, Version 5.02, Gary Sgrignoli

To improve probability of success, the first capture loaded should have as benign multipath conditions as possible.
  - If this capture corresponds to the same broadcast TV channel as the last, then check to see that all TVs have acquired the signal (i.e., are producing a TV picture). If not, try channel scans or returning to a more benign capture from the same broadcast channel to achieve acquisition.
- ◊ Wait for at least three full playback loops to be completed before judging TV receiver performance.
- ◊ TV tests. Repeat for each of the connected TVs (typically eight). Include receiver D3 in each test sequence as a consistency check.
  - Observe video on the selected TV and count the number of video errors observed during a single playback loop. If performance is monitored over several loops and, if the results vary, select the median number of errors as the value to record. A video error burst lasting more than one second is counted based on the approximate duration in seconds. Thus, an error burst lasting three seconds is counted as three errors. Errors occurring during or immediately after the loop-restart time are not counted, nor are errors associated with known defects (dropped symbols) in eight of the captures, as documented by the ATSC.[*]
  - Repeat for next TV
- ◊ Repeat for next RF capture

Additional information on the testing is included in the "Measurement Method" section of Chapter 4.

[*] See Table B-1 in Appendix B of this report, or the "Quality of Capture" column of the continuation of Figure A-1 on p.28 of "*ATSC Recommended Practice: Receiver Performance Guidelines*", ATSC Doc. A/74, Advanced Television Systems Committee, 17 June 2004.

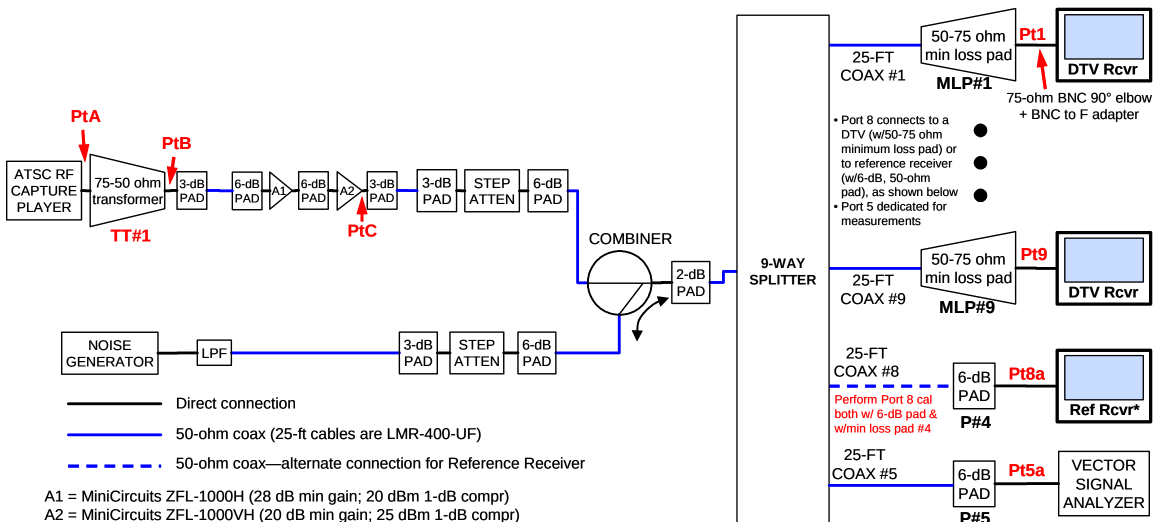
EQUIPMENT

Table A-1 identifies the equipment used for the tests that were conducted for this report.

Table A-1. Equipment List

MAKE	MODEL	EQUIPMENT	S/N	CAL DATE	USE
Sencore	RFP910	RF Player	007, Run 11A	8/10/05	ATSC source for all tests
Agilent	89441A	Vector Signal Analyzer	US40514809 /US39313048	9/17/04	CNR measurements before 8/30/05; amplitude of injected captures before 8/30/05
Agilent	89441A	Vector Signal Analyzer	US40514815 /US39313021	8/8/05	CNR measurements after 8/30/05; All minimum signal measurements
Agilent	E7405A	Spectrum Analyzer	US41160406	10/27/04	Calibration of minimum-loss impedance-matching pads (6/7/05)
Agilent	E7405A	Spectrum Analyzer	US41160425	8/16/05	Frequency response of splitter test configuration
Noise/Com	UFX-7110	Noise Generator	P292-0135	**	Noise source for white-noise threshold tests

Notes:
** Last factory calibration was 8/21/01, but for the reported tests, output was calibrated by means of Agilent E7405A spectrum analyzer at the time of each test.



A1 = MiniCircuits ZFL-1000H (28 dB min gain; 20 dBm 1-dB compr)
A2 = MiniCircuits ZFL-1000VH (20 dB min gain; 25 dBm 1-dB compr)
Combiner = MiniCircuits ZFDC 10-2 directional coupler (10.75 dB coupling, 10 – 1000 MHz)
9-Way Splitter = 4 Minicircuits ZA3PD-1 three-way power splitters (500 – 1000 MHz); 1st splitter drives the remaining three splitters
Step Attenuators = Alan Industries models 50V70 N, 50V10 N, and 50V1 N cascaded to provide 0 - 81 dB in 0.1-dB steps
LPF = Microlab LP Filter FL701 (700 MHz LPF resulted in output noise at Pt5a being 3 dB down at 750 MHz)
Minimum Loss Pads = Trilithic ZM-57
75-50 ohm transformer = Trilithic ZMT-57
25-ft coax = Times Microwave LMR-400-UF

Figure A-1. Block Diagram of Test Configuration for Required CNR and RF Capture Tests

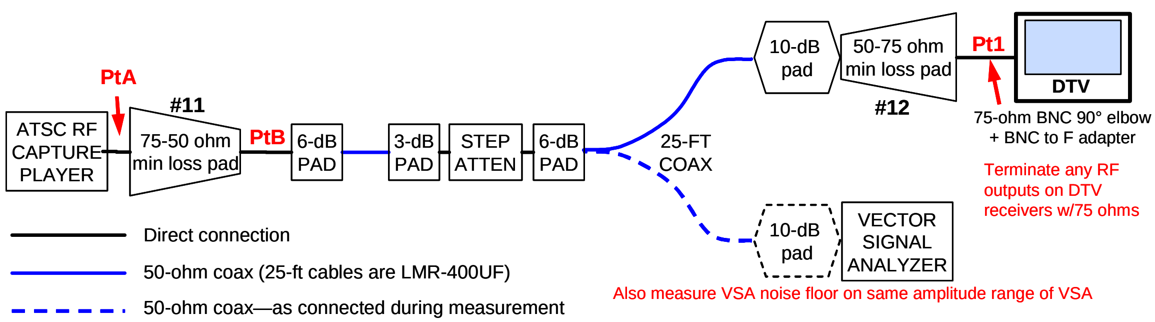


Figure A-2. Block Diagram of Test Configuration for Minimum Signal at TOV

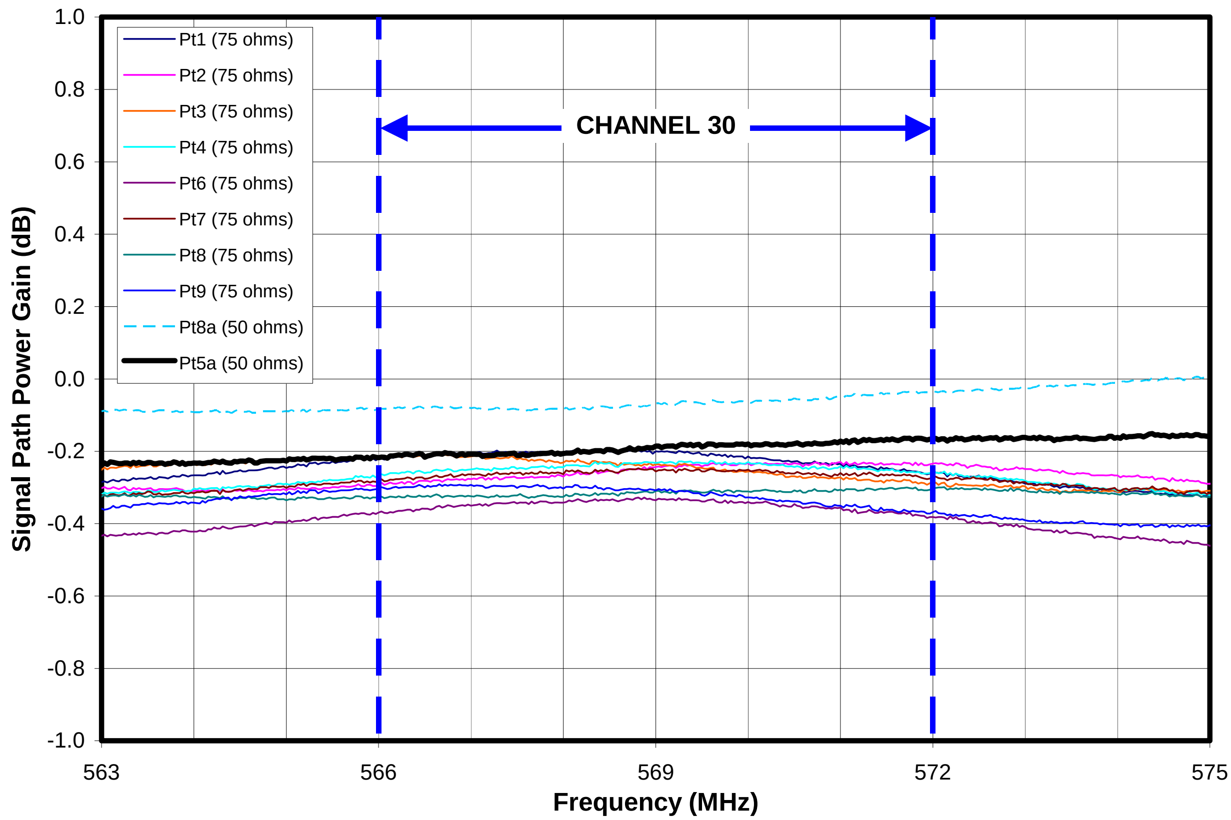


Figure A-3. Frequency Response of Each Port

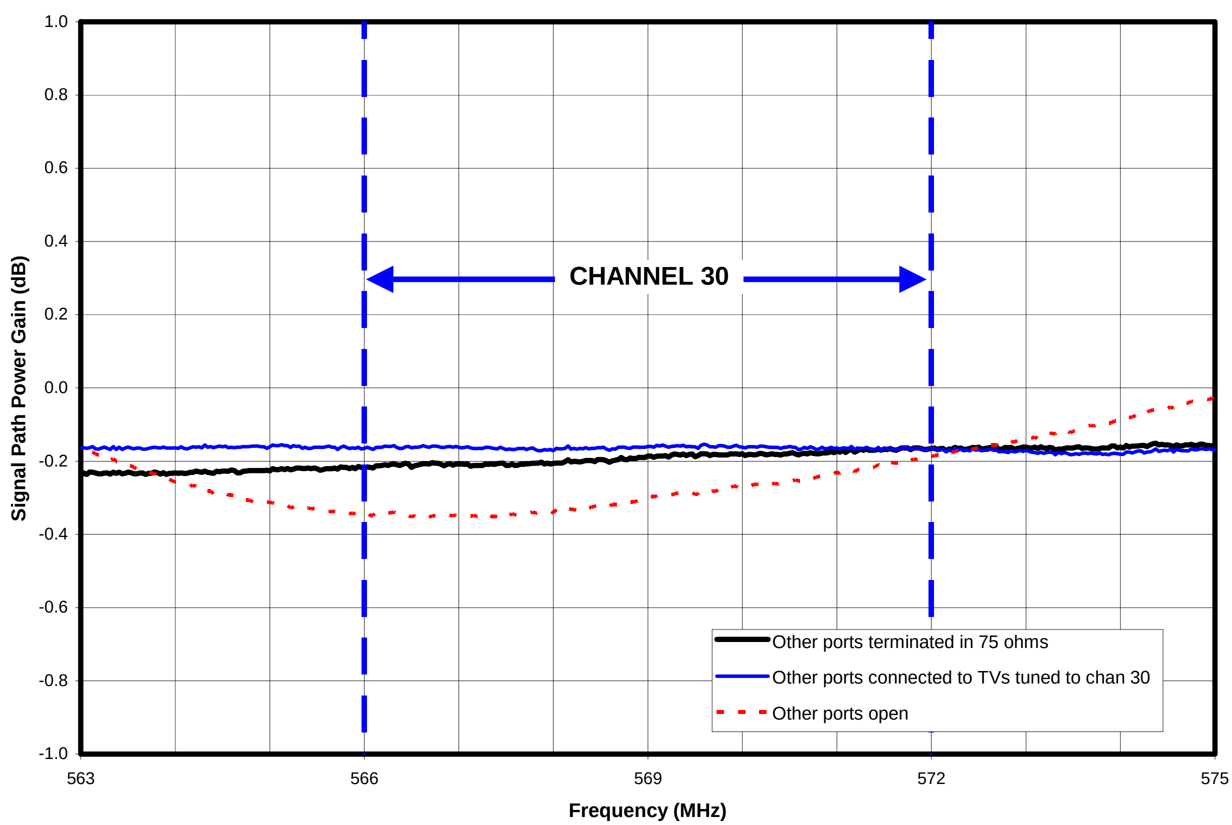


Figure A-4. Effect of Load Impedance Mismatch

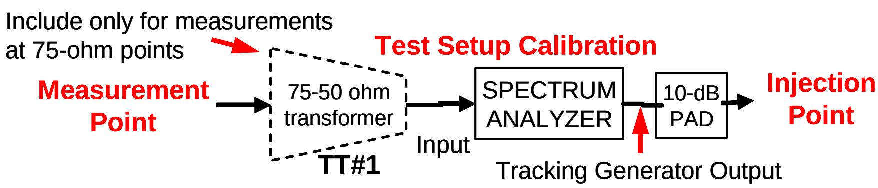


Figure A-5. Calibration Connection for Test Setup for Required CNR and RF Capture Tests

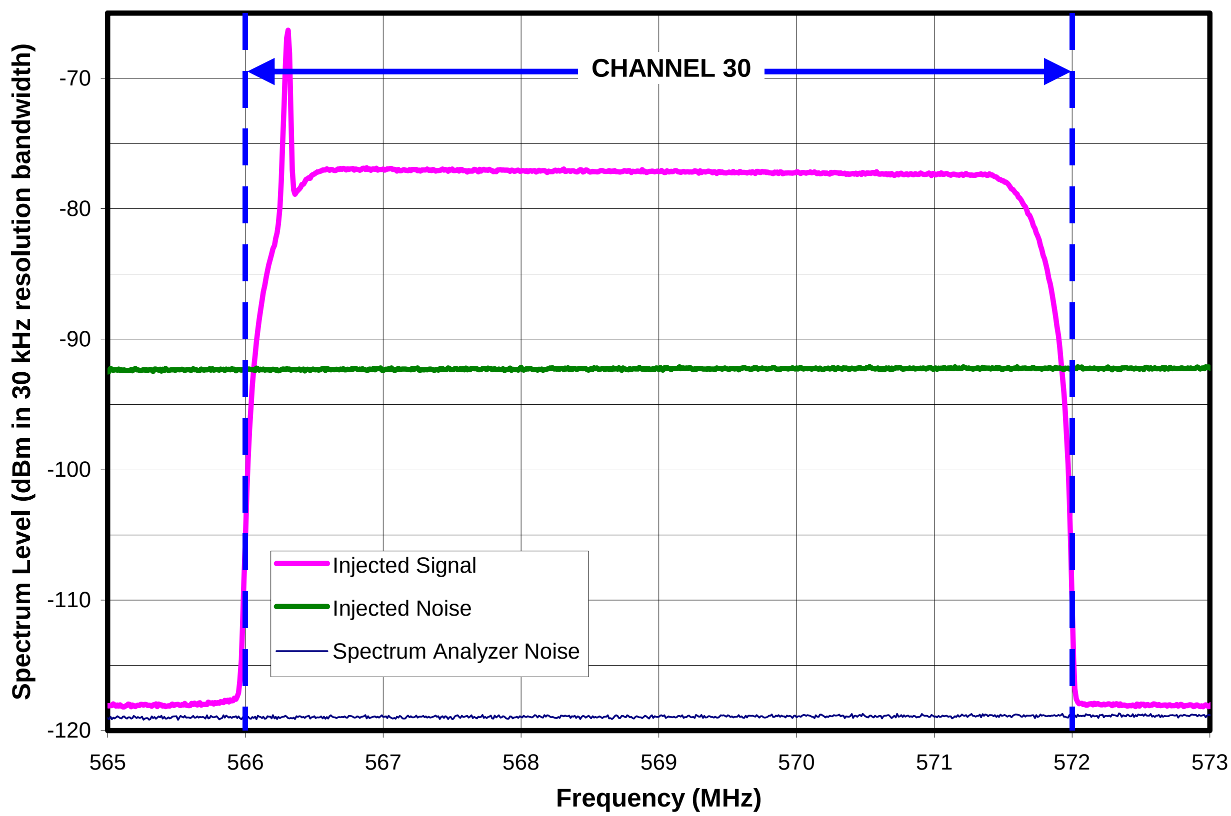


Figure A-6. Spectra of Injected Signal and Noise at 15-dB CNR

APPENDIX B: SUMMARY OF RF FIELD CAPTURES

Table B-1 lists the 50 ATSC-recommended captures, some of their characteristics, and the number of consumer DTV receivers (of 28) that successfully demodulated each capture in tests for this report.

The three captures having no video content (e.g., grey or black screens) were not tested, except with an instrumented receiver which is not included in the tabulated results. In counting observed video errors, errors coinciding with the locations of known symbol drops, as reported by the ATSC, were not counted. Note that four of the captures on which no tested receiver achieved demodulation free of visual errors were identified by the ATSC as having possible non-linearities caused by high-level adjacent channels overdriving the recording system.

Notes on Table B-1 (next page):
All captures have durations of 23 or 25 seconds
* Site: HR = high rise apartment; SF = single family home; TH = townhouse
Antenna: ID = indoors at 6-ft height; OD = outdoors at 30-ft height
**Issues: DS = 48 dropped symbols at specified location; NL = recording may contain nonlinearities due to strong adjacent channel

Table B-1. RF Field Captures

File #	Original data capture filename	Chan	Site / Antenna*	Distance from Tx (Miles)	Known Issues**	# of Receivers w/No Errors	# of Receivers w/≤2 Errors
01	NYC_200_44_10272000_DBT1	44	HR / ID	2.0		10	10
02	NYC_200_44_10272000_LOOP1	44	HR / ID	2.0		0	0
03	NYC_200_44_10272000_MEGA1	44	HR / ID	2.0		10	10
04	NYC_200_44_10272000_RAB1	44	HR / ID	2.0		10	10
05	NYC_200_44_10272000_SSEN1	44	HR / ID	2.0		10	10
06	NYC_200_44_10272000_SSEN2	44	HR / ID	2.0		10	10
07	NYC_200_44_10272000_SSEN3	44	HR / ID	2.0		0	0
08	NYC_200_44_10272000_YAGI1	44	HR / ID	2.0		13	13
09	NYC_200_56_10272000_BWT1	56	HR / ID	2.0		2	10
10	NYC_200_56_10272000_DBT2	56	HR / ID	2.0		10	10
11	NYC_200_56_10272000_DSEN1	56	HR / ID	2.0		10	10
12	NYC_200_56_10272000_DSEN2	56	HR / ID	2.0		1	14
13	NYC_200_56_10272000_LOOP1	56	HR / ID	2.0		10	10
14	NYC_200_56_10272000_MEGA1	56	HR / ID	2.0		11	11
15	NYC_200_56_10272000_RAB1	56	HR / ID	2.0		10	10
16	NYC_200_56_10272000_SSEN1	56	HR / ID	2.0		0	10
17	NYC_200_56_10272000_YAG1	56	HR / ID	2.0		10	10
18	WAS_06_34_06092000_REF	34	SF / OD	10.8		8	10
19	WAS_23_34_06072000_OPT	34	SF / ID	16.7		28	28
20	WAS_23_48_06072000_OPT	48	SF / ID	15.5		0	8
21	WAS_3_27_06022000_REF	27	SF / OD	48.4		9	13
22	WAS_3_35_06022000_REF	35	SF / OD	51.9	No Video	NA	NA
23	WAS_311_34_06052000_OPT	34	HR / ID	4.3	NL	0	0
24	WAS_311_35_06052000_REF	35	HR / OD	3.9	No Video	NA	NA
25	WAS_311_36_06052000_REF	36	HR / OD	4.7		13	14
26	WAS_311_39_06052000_OPT	39	HR / ID	4.3		0	0
27	WAS_311_48_06052000_REF	48	HR / OD	3.9		2	11
28	WAS_32_48_06012000_OPT	48	SF / ID	17.8	NL	0	0
29	WAS_34_27_06082000_OPT	27	TH / ID	7.5		7	27
30	WAS_34_35_06082000_OPT	35	TH / ID	9.6	NL	11	13
31	WAS_34_48_06082000_OPT	48	TH / ID	9.6		7	11
32	WAS_38_34_05312000_OPT	34	TH / ID	14.3	DS@15.0 sec	26	26
33	WAS_38_34_05312000_REF	34	TH / OD	14.3	DS@15.1 sec	27	28
34	WAS_38_36_05312000_OPT	36	TH / ID	14.3	DS@22.2 sec	24	24
35	WAS_47_48_06132000_OPT	48	SF / ID	13.1	DS@13.8 sec	27	28
36	WAS_49_34_06142000_OPT	34	SF / ID	20.2	Possible DS	0	0
37	WAS_49_39_06142000_OPT	39	SF / ID	20.2	DS@24.9 sec	10	11
38	WAS_51_35_05242000_REF	35	SF / OD	20.3		8	8
39	WAS_63_34_06212000_OPT	34	SF / ID	12.7		0	9
40	WAS_68_36_05232000_REF	36	SF / OD	17.7	NL	0	8
41	WAS_75_35_06162000_OPT	35	SF / ID	10.0		0	1
42	WAS_75_36_06162000_OPT	36	SF / ID	10.9	NL	0	0
43	WAS_75_39_06162000_OPT	39	SF / ID	10.5		10	13
44	WAS_80_35_06152000_OPT	35	TH / ID	9.9	No Video	NA	NA
45	WAS_81_36_06192000_OPT	36	SF / ID	9.6		12	27
46	WAS_82_35_06202000_OPT	35	SF / ID	8.3	DS@17.2 sec	27	28
47	WAS_83_36_06222000_OPT	36	TH / ID	3.5	DS@14.9 sec	2	5
48	WAS_83_39_06222000_OPT	39	TH / ID	3.0	DS@12.2 sec	28	28
49	WAS_86_36_07122000_OPT	36	SF / ID	33.3		10	10
50	WAS_86_48_07122000_REF	48	SF / OD	34.4		1	5

See notes on preceding page

APPENDIX D

NOTICE OF INQUIRY

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Technical Standards for Determining Eligibility	)	
For Satellite-Delivered Network Signals Pursuant	)	ET Docket No. 05-182
To the Satellite Home Viewer Extension and Reauthorization Act	)	

NOTICE OF INQUIRY

Adopted: April 29, 2005 **Released: May 3, 2005**

Comment Date: 30 Days after Publication in the Federal Register
Reply Comment Date: 45 Days after Publication in the Federal Register

By the Commission:

1. By this action, the Commission begins an inquiry into the adequacy of the digital signal strength standard and testing procedures used to determine whether households are eligible to receive distant broadcast digital television (DTV) network signals from satellite communications providers. We request comment and information on whether the existing statutes and/or regulations concerning the digital television signal strength standard and testing procedures as used for identifying if households are unserved by local network TV signals for purposes of determining eligibility to receive distant signals from satellite services need to be revised. We specifically intend to study whether such statutes and regulations should be revised to take into account the types of antennas that are available to consumers. The record obtained through this inquiry will be used to prepare a report to Congress describing the results of this study and the Commission's recommendations, if any, for changes that should be made to the applicable Federal statutes or regulations. In this proceeding, we are not considering alteration of the DTV signal strength standard for any purpose other than determining household eligibility to receive retransmitted distant network signals. We are initiating this inquiry in response to provisions of Section 204(b) of the Satellite Home Viewer Extension and Reauthorization Act of 2004 (SHVERA).[310]

BACKGROUND

2. Broadcast television stations have rights, through the Copyright Act[311] and private contracts, to control the distribution of the national and local programming that they transmit.[312] In 1988, Congress adopted the Satellite Home Viewer Act (SHVA) as an amendment to the Copyright Act in order to protect

[310] The Satellite Home Viewer Extension and Reauthorization Act of 2004, Pub. L. No. 108-447, § 207, 118 Stat 2809, 3393 (2004) (to be codified at 47 U.S.C. § 325), § 204(b). The SHVERA was enacted as title IX of the "Consolidated Appropriations Act, 2005."

[311] 17 U.S.C. § 119. The Satellite Home Viewer Act is part of this copyright statute.

[312] *Satellite Delivery of Network Signals to Unserved Households for Purposes of the Satellite Home Viewer Act*, CS Docket No. 98-201, *Report and Order*, 14 FCC Rcd 2654 at ¶ 2 (1999) (*SHVA Report and Order*).

the broadcasters' interests in their programming while simultaneously enabling satellite communications providers to provide broadcast programming to those satellite subscribers who are unable to obtain broadcast TV network programming over the air.[313] Under the SHVA, those subscribers were generally considered to be "unserved" by local stations. Pursuant to the requirements of this statute, which linked the definition of “unserved households” to a Commission-defined measure of analog television signal strength known as “Grade B intensity,”[314] the Commission adopted rules for determining whether a household is able to receive a television signal of this strength.[315] In particular, the Commission adopted rules established a standardized method for measuring the strength of television signals at individual locations and endorsed a method for predicting the strength of such signals that could be used in place of actually taking measurements.[316] For DTV stations, the counterparts to the Grade B signal intensity standards for analog television stations are the values set forth in Section 73.622(e) of the Commission’s rules describing the DTV noise-limited service contour.[317]

3. In the Satellite Home Viewer Improvement Act of 1999 (SHVIA),[318] Congress revised and extended the statutory provisions established by the 1988 SHVA. With regard to prediction of signal availability, the SHVIA added Section 339(c)(3) to the Communications Act of 1934, as amended (47 U.S.C. § 339(c)(3)), which provides that “[T]he Commission shall take all actions necessary, including any reconsideration, to develop and prescribe by rule a point-to-point predictive model for reliably and presumptively determining the ability of individual locations to receive signals in accordance with the signal intensity standard in effect under Section 119(d)(10)(A) of title 17, United States Code.”[319] Section 339(c)(3) further provides that “[I]n prescribing such a model, the Commission shall rely on the Individual Location Longley-Rice model set forth by the Federal Communications Commission in Docket No. 98-201, and ensure that such model takes into account terrain, building structures, and other land cover variations. The Commission shall establish procedures for the continued refinement in the application of the model by the use of additional data as it becomes available.”[320] The Individual

[313] 17 U.S.C. §§ 119, 122 (Copyright Act provisions); 47 U.S.C. §§ 325, 338, 339 (Communications Act provisions).

[314] *See* 17 U.S.C. § 119(d)(10)(A); *see* also 47 CFR § 73.683(a). Section 119(d)(10) (A) of the Copyright Act defines an unserved household as a “household that cannot receive, through use of a conventional stationary, outdoor rooftop receiving antenna, an over-the-air signal of a primary network television station affiliated with that network of Grade B intensity as defined by the Federal Communications Commission under section 73.683(a) of title 47 of the Code of Federal Regulations, as in effect on January 1, 1999.” Section 73.683(a) sets forth field strength levels for the Grade B coverage contours of analog TV stations as follows, units are one micro-volt per meter (dBµ): channels 2-6 47 dBµ, channels 7-13 56 dBµ, channels 14-69 64 dBµ.

[315] *SHVA Report and Order*, 14 FCC Rcd 2654 at ¶ 4.

[316] *Id.* at ¶ 71. The Individual Location Longley-Rice (ILLR) predictive model is used to predict the Grade B signal intensity at a location. 47 CFR Section 73.686(d) specifies the measurement procedure used to obtain the signal intensity at an individual location.

[317] 47 CFR § 73.622(e). *See also* 47 CFR § 73.625(b) (determining coverage).

[318] The Satellite Home Viewer Improvement Act of 1999, Pub.L. No 106-113, 113 Stat. 1501 (1999) (codified in scattered sections of 17 and 47 U.S.C.). The SHVIA was enacted on November 29, 1999, as Title I of the Intellectual Property and Communications Omnibus Reform Act of 1999 (IPACORA) (relating to copyright licensing and carriage of broadcast signals by satellite carriers).

[319] *See* SHVIA, section 1008.

[320] *See Satellite Delivery of Network Signals to Unserved Households for Purposes of the Satellite Home Viewer Act; Part 73 Definition and Measurement of Signals of Grade B Intensity*, Report and Order, CS Docket No., 98-201, 14 FCC Rcd 2654 (1999). A computer is needed to make these predictions because of the large number of reception points that must be individually examined. Computer code for the ILLR point-to-point radio propagation model is published in an appendix of NTIA Report 82-100, *A Guide to the Use of the ITS Irregular*

Location Longley-Rice (ILLR) radio propagation model adopted by the Commission in CS Docket No. 98-201 provides predictions of radio field strength at specific geographic points based on the elevation profile of terrain between the transmitter and each specific reception point.[321] The SHVIA further required that the courts rely on the Individual Location Longley-Rice (ILLR) model established by the Commission for making presumptive determinations of whether a household is capable of receiving broadcast television signals of at least a certain threshold intensity.

4. As indicated above, the threshold signal intensity level for determining eligibility to receive retransmitted distant analog network TV signals is the Grade B standard set forth in Section 73.683(a) of the Commission's rules. The Grade B contour, originally established to describe the service area (or coverage contour) of analog TV stations, defines a geographic boundary curve on which the specified field strength is predicted to be exceeded 50 percent of the time at 50 percent of the locations.[322] However, the values of the Grade B standard are set such that generally, if a household receives a television signal of Grade B intensity, it should receive an acceptable television picture at least 90 percent of the time. More specifically, the Grade B values represent field strengths that are strong enough, in the absence of man-made noise or interference from other stations, to provide at least 90 percent of the time a television picture that the mean observer would classify as "acceptable" using a receiving installation (antenna, transmission line, and receiver) typical of outlying or near-fringe areas.[323]

5. The SHVIA directed the Commission to evaluate all possible standards and factors for determining eligibility for retransmission of signals of network stations to determine whether it may be appropriate to recommend, in a report to Congress, modifying or replacing the Grade B intensity standard for the purpose of determining eligibility, and, if appropriate, to make a further recommendation relating to a standard for digital signals.[324] In November 2000, the Commission issued its Report to Congress in this matter,[325] recommending that the Grade B signal intensity standard and eight of the nine planning

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Terrain Model in the Area Prediction Mode, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. Some modifications to the code were described by G.A. Hufford in a memorandum to users of the model dated January 30, 1985. With these modifications, the code is referred to as Version 1.2.2 of the Longley-Rice model.

[321] *Id*. at ¶69.

[322] *See* 47 C.F.R. 73.683 (a), and 47 C.F.R. 73.684 (c).

[323] The Grade B signal contour describes a boundary around a television station's transmitter. As set forth in Section 73.683(a), a signal of Grade B intensity is defined as a discrete value measured in units of dBµv/m (dB over a microvolt per meter). However, the absolute intensity of broadcast signals at particular locations and at particular times cannot be precisely determined through predictive means, regardless of the predictive method used. Signal strength varies randomly over location and time, so signal propagation must be considered on a statistical basis. This is true regardless of whether the signal intensity is predicted at a fixed location (such as an individual household) or over an area. Some prediction methods, including the Commission's field strength charts (propagation curves), predict the occurrence of median signal strengths (i.e., signal strengths predicted to be exceeded at 50% of the locations in a particular area at least 50 percent of the time). Using these methods, "location" and "time" variability factors are added to the signal level for an acceptable picture so that the desired statistical reliability, *i.e.*, 50 percent of locations 90 percent of the time, is achieved. The values chosen for the Grade B signal intensity standards account for this variability and, therefore, as indicated above, predict that at least 50 percent of the locations along the Grade B contour will receive an acceptable picture 90 percent of the time. For additional information on Grade B contours, see "Understanding Television's Grade A and Grade B Service Contours."

[324] *See* section 339(c)(1) of the Communications Act of 1934, as amended by the SHVIA, section 1008.

[325] *See Technical Standards for Determining Eligibility for Satellite-Delivered Network Signals Pursuant to the Satellite Home Viewer Improvement Act*, *Report*, ET Docket No. 00-90, FCC 00-416 (2000); *see also id.*, *Notice of Inquiry*, FCC 00-184, released May 26, 2000.

factors[326] used in that model be retained as the basis for predicting whether a household is eligible to receive retransmitted distant TV network signals under SHVIA. The Commission also recommended modification of the remaining planning factor, *i.e.*, time fading, by replacing its existing fixed values with location-dependent values determined for the actual receiving locations using the ILLR prediction model. Finally, the Commission found that it would be premature to construct a distant network signal eligibility standard for DTV signals at that time. Therefore, the Commission recommended that establishment of a distant network signal eligibility standard for DTV signals be deferred until such time as more substantial DTV penetration is achieved and more experience is gained with DTV operation.

6. The Commission has established a DTV Table of Allotments, which specifies channels for use by DTV stations in individual communities, using a procedure that closely replicates the service areas of the existing Grade B contours for analog TV stations.[327] In particular, the Commission has defined DTV station service areas based on field strength levels that provide noise-limited service (the Grade B signal strength levels define noise-limited service for analog stations).[328] DTV service areas are defined as the geographic area within a station's noise-limited field strength contour where its signal strength is expected to exceed that field strength level at 50 percent of the locations 90 percent of the time F(50,90).[329] Within that contour, service is considered available at locations where a station's signal strength, as predicted using the terrain dependent Longley-Rice point-to-point propagation model, exceeds the noise-limited standards. The DTV noise-limited field strength standards are: channels 2-6 (low VHF)- 28 dBµ, channels 7-13 (high VHF)- 36 dBµ, channels 14-69 (UHF)- 41 dBµ. These criteria presume that households will exert similar efforts to receive DTV broadcast stations as they have always been expected to exert to receive NTSC analog TV signals.

7. In December 2004, Congress enacted the Satellite Home Viewer Extension and Reauthorization Act of 2004,[330] which again amends the copyright laws[331] and the Communications Act[332] to further aid the competitiveness of satellite carriers and expand program offerings for satellite subscribers. Section 204 of the SHVERA provides that no later than one year after the date of enactment of this Act, the Commission is to complete an inquiry regarding whether, for purposes of identifying if a household is unserved by an adequate digital signal under Section 119(d)(10) of title 17 of the United States Code, the digital signal strength standard in Section 73.622(e)(1) of the Commission' rules or the testing procedures in Section 73.686(d) of those rules should be revised to take into account the types of antennas that are available to consumers.[333] Section 204 of the SHVERA also requires the Commission to submit to the

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[326] The eight planning factors that the Commission recommended should be unchanged were the: Thermal Noise Factor; Receiver Noise Figure; Signal-to-Noise Ratio and Service Quality; Transmission Line Loss; Receiving Antenna Gain; Dipole Factor; Terrain Variability; and Environmental Noise.

[327] The DTV Table of Allotments is set forth in Section 73.622(b) of the rules, 47 C.F.R. § 73.622(b).

[328] "Noise-limited" service means that reception of service at the described signal level is only limited by the presence of radiofrequency noise that is expected to be present at the same level as the desired signal.

[329] *See* 47 C.F.R. § 73.622 (e)(1) and (2). The F(50,90) level of service was established for DTV service areas to account for the fact that DTV service is subject to a "cliff effect" by which full quality service becomes totally unavailable within a very small decrease in signal strength whereas analog TV service quality degrades gradually with declining signal strength. The distance to field strength contours with service at the F(50, 90) levels of service is determined using the charts in Section 73.699 of the rules, 47 C.F.R. § 73.699.

[330] *See SHVERA*, *supra* note 1.

[331] Section 102 of the SHVERA creates a new 17 U.S.C. § 119(a)(3) to provide satellite carriers with a statutory copyright license to offer "significantly viewed" signals as part of their local service to subscribers. 17 U.S.C. § 119(a)(3).

[332] *See* 47 U.S.C. §§ 325, 338, 339 and 340.

[333] *See* 17 U.S.C. § 119(d)(10); 47 C.F.R. § 73.622(e)(1); 47 C.F.R. § 73.686(d).

Congress a report containing the results of that study and recommendations, if any, for what changes should be made to Federal statutes or regulations. The SHVERA specifies that in conducting this inquiry the Commission is to consider the following six specific factors:[334]

- whether to account for the fact that an antenna can be mounted on a roof or placed in a home and can be fixed or capable of rotating;

- whether Section 73.686(d) of title 47, Code of Federal Regulations, should be amended to create different procedures for determining if the requisite digital signal strength is present than for determining if the requisite analog signal strength is present;

- whether a standard should be used other than the presence of a signal of a certain strength to ensure that a household can receive a high-quality picture using antennas of reasonable cost and ease of installation;

- whether to develop a predictive methodology for determining whether a household is unserved by an adequate digital signal under section 119(d)(10) of title 17, United States Code;

- whether there is a wide variation in the ability of reasonably priced consumer digital television sets to receive over-the-air signals, such that at a given signal strength some may be able to display high-quality pictures while others cannot, whether such variation is related to the price of the television set, and whether such variation should be factored into setting a standard for determining whether a household is unserved by an adequate digital signal; and

- whether to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter.

DISCUSSION

8. As specified above, Congress has directed the Commission to take six specific considerations into account during the course of this Inquiry. Below, we deal with each of these areas in turn.

9. *Antenna placement.* We request comment, analysis, and information on whether the procedures and standards for determining if any specific household should be deemed unserved by an adequate DTV network signal, should account for the fact that a receiving antenna can be mounted on a roof or placed in a home and can be fixed or capable of rotating. As an initial matter, we note that the effectiveness of receiving antennas is determined both by factors intrinsic to the specific antenna design and by external factors. More specifically, antennas are designed with varying amounts of antenna gain or directivity. The greater the gain of a receiving antenna, the greater is the antenna's ability to capture weak signals. However, there is a significant tradeoff when incorporating additional gain in an antenna design. That is, designing an antenna with greater gain requires that it also be designed to have a narrower beamwidth. Beamwidth, in turn, refers to the antenna's angle of orientation within which the gain occurs. The narrower the beamwidth of a receiving antenna, the more critical it is to accurately aim the antenna directly at the source of the signal of interest. The signal strength of a transmission that is received by an antenna's main lobe beamwidth will be stronger than if that transmission were received from a direction outside that main lobe. Other factors, such as antenna placement, also affect the ability of a household to receive an adequate DTV signal. For example, because structures located within the line of sight between the transmitter and the receiving antenna can block or weaken the strength of received signals, an outdoor antenna installation, such as upon a rooftop, will generally allow a stronger signal to be received by the

334 *See* SHVERA, *supra* note 1, at § 204(b)(1)(B).

antenna than will an indoor antenna installation. Thus, households in which the antenna is placed indoors will generally need an antenna with greater gain than will a household in which the antenna is placed outdoors.

10. As indicated above, the Commission defines digital television service areas on the basis of stations' noise-limited F(50,90) contour. Within this contour, the Longley-Rice model is used to predict areas where the DTV signal strength level exceeds the noise limited service level.[335] Inherent in this method of predicting received signal strength levels are certain assumptions regarding the receiving system. For DTV, the Commission assumes that the receiving antenna is located outdoors at a height of 10 meters above ground.[336] In addition, the Commission's procedures for evaluating DTV service areas set forth specific values for antenna gain that depend upon the specific DTV channel band, namely, 4 dB for low VHF, 6 dB for high VHF, and 10 dB for UHF and that the antenna be oriented in the direction which maximizes the values for field strength for the signal being measured.[337]

11. With regard to the general characterization of antennas described above, we seek comment on whether there is a need to revise the standard by which adequate DTV network signals are deemed available to households in order to account for the facts that DTV antennas can be mounted on a roof or within a home and can be installed in a fixed position or in a mounting that allows them to be rotated. Specifically, we ask if the inherent assumptions regarding DTV antenna receiving systems should be modified or extended insofar as they relate to the proper determination of whether households are unserved by adequate broadcast DTV network signals and are thus eligible to receive distant DTV network signals from a satellite service provider. To properly evaluate this issue, we must have up-to-date reliable information regarding antennas that are available to the public. Therefore, commenting parties are requested to provide information on the types of antennas that are in use currently, or soon to be available for outdoor or indoor residential use. For these antennas, we request that relevant technical specifications such as size, gain, and beamwidth be provided. In addition, we request that commenting parties provide information on how these factors affect antenna cost and deployment. Further, we request information on the availability and cost of various devices that can be used to aim these antennas (*e.g.*, rotors) toward DTV transmitters. In this regard, we request comment on how the addition of a rotor would affect the antenna size and thus the ability of consumers to mount the antenna indoors. We ask that commenters provide an evaluation of whether the use of an indoor antenna with or without a rotor would provide similar performance to that expected based on the Commission's assumed planning factors. If commenting parties believe that performance would differ significantly, we request that they provide detailed analytical information and explain how they believe our procedures should be modified.

12. *Signal strength measurement.* Congress has requested that the Commission consider whether Section 73.686(d) of the rules should be amended to specify procedures for determining if the requisite digital signal strength is present that are different from the procedures used for determining analog signal strength. Currently, Section 73.686(d) requires that field strength measurements be made using either a half–wave dipole antenna that is tuned to the station's visual carrier frequency or a gain antenna, provided that the antenna factor for the channel under test is known.[338] In addition, the rules specify that the intermediate frequency (i.f.) bandwidth of the measuring instrumentation be at least 200 kilohertz but no more than 1,000 kilohertz. Measurements are to be taken in five locations, preferably close to the actual antenna or where one is likely to be mounted. In addition, the rules specify that the measurement antenna is to be raised to a height of 6.1 meters (20 feet) above ground for one story structures and 9.1 meters (30 feet) above ground for two story or taller structures. Finally, because the current rule was written specifically to determine the field strength of analog TV signals, the procedures specify that the field

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[335] *See* 47 C.F.R. § 73.622(e).

[336] *See* OET Bulletin 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference".

[337] *Id.*

[338] *See* 47 CFR 73.686(d).

strength measurement is to be made on the visual carrier.[339] The measured values can then be compared to the field strength that defines the Grade B contour for the station in question to determine if the measured location is receiving a signal of sufficient intensity for analog television reception.

13. It is readily apparent that Section 73.686(d) needs some modification in order to be applied to digital TV signals. Unlike the analog signal, the digital signal does not contain a visual carrier. Therefore, at a minimum the rule must distinguish between analog and digital signals as it relates to the specific frequency on which to tune. We note that the digital TV signal does have a pilot signal that is used by the tuner to lock in on the desired received signal.[340] Given this fundamental difference between the analog and digital signal, we ask commenting parties to provide information on the signal characteristics to which the measurement instrumentation should be tuned. For example, we believe that it makes most sense to tune the instrumentation either to the pilot signal or to the center of the channel. We also ask for comments on whether the i.f. bandwidth of the measurement equipment that is specified for analog TV signals is also appropriate for digital TV signals. Commenting parties who propose i.f. bandwidths that differ from the current specification should provide specific reasons for their proposals. We also request comment on the height that should be specified for the use of antenna equipment to measure outdoor signals, and on whether specific procedures should be created for measuring indoor signals. Further, if an indoor measurement procedure were adopted for determining signal availability, we seek comment on what criteria should be applied to determine whether an indoor or an outdoor measurement would be performed at a specific location. Finally, we seek comment on whether any other aspects of our measurement procedures need to be modified for the purpose of determining if households are unserved by an adequate digital TV signal. Commenting parties should provide specific technical justification for any aspects that they believe should be modified.

14. *Signal strength standard.* Currently, the rules specify that the field strength of the Grade B contour of an analog TV station be used as the standard for a determination of adequate signal strength. In the SHVERA, Congress requests that that Commission consider, for digital TV signals, whether a standard other than the presence of a signal of certain strength be used to ensure that a household can receive a high-quality picture using antennas of reasonable cost and ease of installation. We request comment on whether the current signal strength standard for noise-limited service should be used to define the availability of a DTV signal for determining whether a household is eligible to receive distant DTV signals from DBS services. In this connection, we also seek comment on whether there is a standard other than one based on signal strength that could be used to determine if a household is capable of receiving a high-quality digital TV picture. Commenting parties who propose a standard not based on signal strength should provide sufficient detail describing how their method would ensure reception of service and should explain how the proposed standard would be affected by the various technical characteristics the various specific antennas that are available or will soon be available for the residential market.

15. *Development of a predictive model.* The SHVERA requires that the Commission consider whether to develop a predictive methodology for determining whether a household is unserved by an adequate digital TV network signal under section 119(d)(10) of title 17, United States Code.[341] As

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[339] *See* 47 C.F.R. §§ 73.686(d)(1)(i) and 73.686(d)(2)(i).

[340] The pilot signal is located 0.31 MHz inside the lower band edge of the spectrum and is 3 dB lower than the average power of the signal.

[341] 17 U.S.C. § 119(d)(10) provides the following definition of unserved household:

> *(10) Unserved household.— The term "unserved household", with respect to a particular television network, means a household that—*
> *(A) cannot receive, through the use of a conventional, stationary, outdoor rooftop receiving antenna, an over-the-air signal of a primary network station affiliated with that network of Grade B intensity as defined by the Federal Communications Commission under section 73.683(a) of title 47 of the Code of*

indicated above, the Commission has already established a predictive model that evaluates the signal strength of a particular digital TV station at a specific location. This model, described in OET Bulletin 69, uses the Longley-Rice radio propagation model to make predictions of radio field strength at specific geographic points based on the elevation profile of terrain between the transmitter and each specific reception point.[342] The Commission, in accordance with SHVIA, has also implemented the use of a modified Longley-Rice model for identifying unserved households attempting to receive analog broadcast signals.[343] We implemented the use of a modified Longley-Rice model in order to make the predictive model as accurate as possible by taking terrain features (such as hills), buildings, and land cover (such as forests) into account.[344] We believe that the modified Longley-Rice is an accurate, practical, and readily available model for determining signal intensity at individual locations when used with analog signals. The modified Longley-Rice has several characteristics, discussed in detail below, which make it unique:

- The time variability factor is 50% and the confidence variability factor is 50%;
- The model is run in individual mode;
- Terrain elevation is considered every 1/10 of a kilometer;
- Receiving antenna height is assumed to be 20 feet above ground for one-story buildings and 30 feet above ground for buildings taller than one-story;
- Land use and land cover (*e.g.*, vegetation and buildings) is accounted for;
- Where error codes appear, they shall be ignored and the predicted value accepted or the result shall be tested with an on-site measurement;
- Locations both within and beyond a station's Grade B contour shall be examined.[345]

> *Federal Regulations, as in effect on January 1, 1999;*
> *(B) is subject to a waiver granted under regulations established under section 339(c)(2) of the Communications Act of 1934;*
> *(C) is a subscriber to whom subsection (e) applies;*
> *(D) is a subscriber to whom subsection (a)(11) applies; or*
> *(E) is a subscriber to whom the exemption under subsection (a)(2)(B)(iii) applies.*

[342] *See* OET Bulletin 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference". A computer is needed to make these predictions because of the large number of reception points that must be individually examined. Computer code for the Longley-Rice point-to-point radio propagation model is published in an appendix of NTIA Report 82-100, A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. Some modifications to the code were described by G.A. Hufford in a memorandum to users of the model dated January 30, 1985. With these modifications, the code is referred to as Version 1.2.2 of the Longley-Rice model. This version is used by the FCC for its evaluations.

[343] *See* OET Bulletin 72, "The ILLR Computer Program". OET Bulletin 72 details the computer program that the Commission was instructed by Congress to established under SHVIA in Section 339(c)(3) of the Communication Act. It provides that "[i]n prescribing such model, the Commission shall rely on the Individual Location Longley-Rice [ILLR] model set forth by the Federal Communications Commission in Docket No. 98-201 and ensure that such model takes into account terrain, building structures, and other land cover variations." *See* also *Report and Order* CS Docket No. 98-201 *supra* note 312, and *Satellite Delivery of Network Signals to Unserved Households for Purposes of the Satellite Home Viewer Act*, CS Docket No.98-201, *Memorandum Opinion and Order*, 14 FCC Rcd 31 17373. (1999).

[344] *Id.*

[345] *See Report and Order* in CS Docket No. 98-201 ¶71 *supra* note 312.

The Commission requests comment on whether the modified Longley-Rice, with appropriate modifications, would accurately predict digital signal coverage at a specific location, or whether there is some other predictive model that would be more appropriate for this purpose. Commenting parties who propose either specific modifications to the modified Longley-Rice or alternative models should provide detailed analysis as to how their proposed modifications will improve the modified Longley-Rice's prediction characteristics and/or an explanation of how the changes or alternatives more accurately model the available signal level when accounting for terrain and possible signal interference.

16. *DTV receiver threshold variation.* We request comment on whether there is a wide variation in the ability of reasonably priced consumer digital television sets to receive over-the-air signals, so that at given signal strengths some sets are able to display high-quality pictures while other sets cannot, and if so, whether this variation is related to the price of the television set. We also request comment on whether such variation should be factored into setting a standard for determining whether a household is unserved by an adequate DTV network signal. We are aware that there are a wide variety of digital TV sets available to consumers which are offered at various prices. We do not know, however, whether the difference in prices correlates to better receiver performance. We further note that many satellite reception set-top-boxes also contain DTV tuners, and seek comment on their reception capabilities. In the *Memorandum Opinion and Order on Reconsideration of the Sixth Report and Order,* the Commission noted that receiver performance involves trade-offs among many factors and that equipment manufacturers were in the best position to determine how best to meet consumer demand.[346] We also noted that we would continue to monitor DTV receiver development, in particular with regard to indoor reception and multi-path signal rejection performance.[347] On this point, we plan to conduct measurements on a variety of digital TV sets and factor the results of those measurements into the report that we will present to Congress as required by the SHVERA.

17. We seek information regarding the performance of digital receivers. Specifically, commenting parties should provide information regarding the sensitivity of various receivers and their interference rejection capability and should point out if there are different receiver signal processing algorithms for interpreting digital TV signals and their level of sophistication. This technical information should be accompanied by price data and analysis regarding the correlation between performance and price. Given that the Commission intends to independently conduct measurements on a sample of digital TV receivers, we ask if there are specific parameters that we should measure. If so, which parameters should we measure and what useful information will they provide? Finally, we ask if there are significant differences in digital receiver performance quality, should those differences be factored into the determination of whether a household is unserved by an adequate digital signal? Are consumers aware of any such differences so that they can take them into account when obtaining DTV equipment in order to assure themselves that they can receive signals at the levels available at their residences? Commenting parties who believe that digital receiver quality should be a factor are requested to provide detailed analysis and explain how receiver quality can be used in ascertaining whether a household is unserved. Finally, we ask commenters to discuss how any limitations in receivers can be mitigated by using higher performance antennas or auxiliary devices.

18. *DTV receiver interference.* A radio receiver's immunity to interference is dependent on a number of factors in its technical design and, in addition, on the characteristics of the signals it receives. These factors may be closely related and possibly interdependent, and a receiver's performance in one factor may often affect its performance in others. The factors determining receiver immunity performance generally include selectivity, sensitivity, dynamic range, automatic RF gain control, shielding, modulation

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[346] *See* In The Matter of Advanced Television Systems And Their Impact Upon the Existing Television Broadcast Service, *Memorandum Opinion and Order on Reconsideration of the Sixth Report and Order*, MM Docket No. 87-268, 13 FCC Rcd. 7418, 7551 (1998) ¶ 171.

[347] *See Report and Order and Further Notice of Proposed Rulemaking*, in MM Docket No.00-39 (first DTV periodic review proceeding), 16 FCC Rcd 5946 at ¶ 96.

method, and signal processing. Receiver selectivity is the ability to isolate and acquire the desired signal from among all of the undesired signals that may be present on other channels. Sensitivity is the measure of a receiver's ability to receive signals of low strength. Greater sensitivity means a receiver can pick up weaker signals.[348] Dynamic range is the range of the highest and lowest received signal strength levels over which the receiver can satisfactorily operate. The upper side of a receiver's dynamic range determines how strong a received signal can be before failure due to overloading occurs. Automatic RF gain control allows a receiver to adjust the level of a received signal as it appears at the unit's signal processing and demodulation sections.

19. We request comment information on whether, and if so, how to account for factors such as signal attenuation from structural penetration, external interference sources (that is, undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets), foliage, and man-made clutter when determining whether a household is unserved by an adequate digital signal. We note that many factors can affect the reception of radio frequency signals and the ability of a receiver to resolve these signals and produce a picture. Most notably, interference from both co-channel and adjacent channel TV transmitters could cause interference to the desired signal. Selectivity is a central factor in the control of adjacent channel interference.[349] However, we also note that different receiver designs may account for the differing abilities of receivers to reject greater or lesser amounts of interference. We request comment on the interference rejection capabilities of digital TV receivers and satellite set-top-boxes with built-in off-air receivers.

20. We also note that external forces can affect the signal that ultimately reaches a TV receiver. These include natural and man-made structures, such as structures, terrain, trees, *etc*., that lie between the transmitter and the receiver. These types of obstructions can affect a signal in various ways. First, they attenuate the signal so that the actual signal received is weaker than that predicted in the absence of any such obstructions. In this connection, we again note that indoor-mounted antennas will generally receive weaker signals than outdoor-mounted antennas. Second, obstructions can create multipath interference where signals that bounce off structures arrive at the receiver at different times. Multipath interference occurs when DTV signals arrive at the receiver via different paths. These signals, although they originate from the same transmitting source, are out of phase and can cause severe interference that can result in the complete loss of the digital service. Given these effects, we request comment on how well digital TV receivers and satellite set-top-boxes with built-in off-air receivers perform in these less than ideal conditions. Should such performance specifications be taken into account by the Commission in determining whether a household is unserved by an adequate digital signal? Commenting parties who propose that such factors be accounted for should provide detailed information regarding how these factors could be used and applied to individual situations. What additional factors, if any, should be included when determining the availability of a DTV signal at an individual location?

21. *Summary.* In sum, we request comment and information regarding how to determine whether any household is unserved by an adequate digital television network signal. This instant inquiry addresses the particular concerns that Congress has specified in section 204(b) of the SHVERA, and the information gathered here will be used to prepare the requisite report to Congress. Commenting parties should be as specific as possible in providing information and describing how such information can be applied to the determination of household eligibility for reception of satellite providers' retransmissions of distant DTV

[348] Greater sensitivity can also result in reception of unwanted signals at low levels that then must be eliminated or attenuated by the selectivity characteristics of the receiver.

[349] There are several ways to describe the selectivity of a radio receiver. One way is to simply give the bandwidth of the receiver over which its response level is within 3 dB of its response level at the center frequency of the desired signal. This measure is often termed the "bandwidth over the -3db points." This bandwidth, however, is not necessarily a good means of determining how well the receiver will reject unwanted frequencies. Consequently, it is common to give the receiver bandwidth at two levels of attenuation; for example, -3dB and -60 dB. The ratio of these two bandwidths is called the shape factor. Ideally, the two bandwidths would be equal and the shape factor would be one. However, this value is very difficult to achieve in a practical circuit.

network signals. Finally, commenting parties who believe that our applicable rules or Federal statutes should be modified are requested to state with particularity the rule and/or statutory modifications they advocate.

ORDERING CLAUSE

22. Accordingly, IT IS ORDERED that, pursuant to Section 339(c) of the Communications Act of 1934, as amended by the Satellite Home Viewer Extension and Reauthorization Act of 2004, this Notice of Inquiry IS ADOPTED.

FEDERAL COMMUNICATIONS COMMISSION

Marlene H. Dortch
Secretary

APPENDIX E

COMMENTS AND REPLY COMMENTS
TO
NOTICE OF INQUIRY