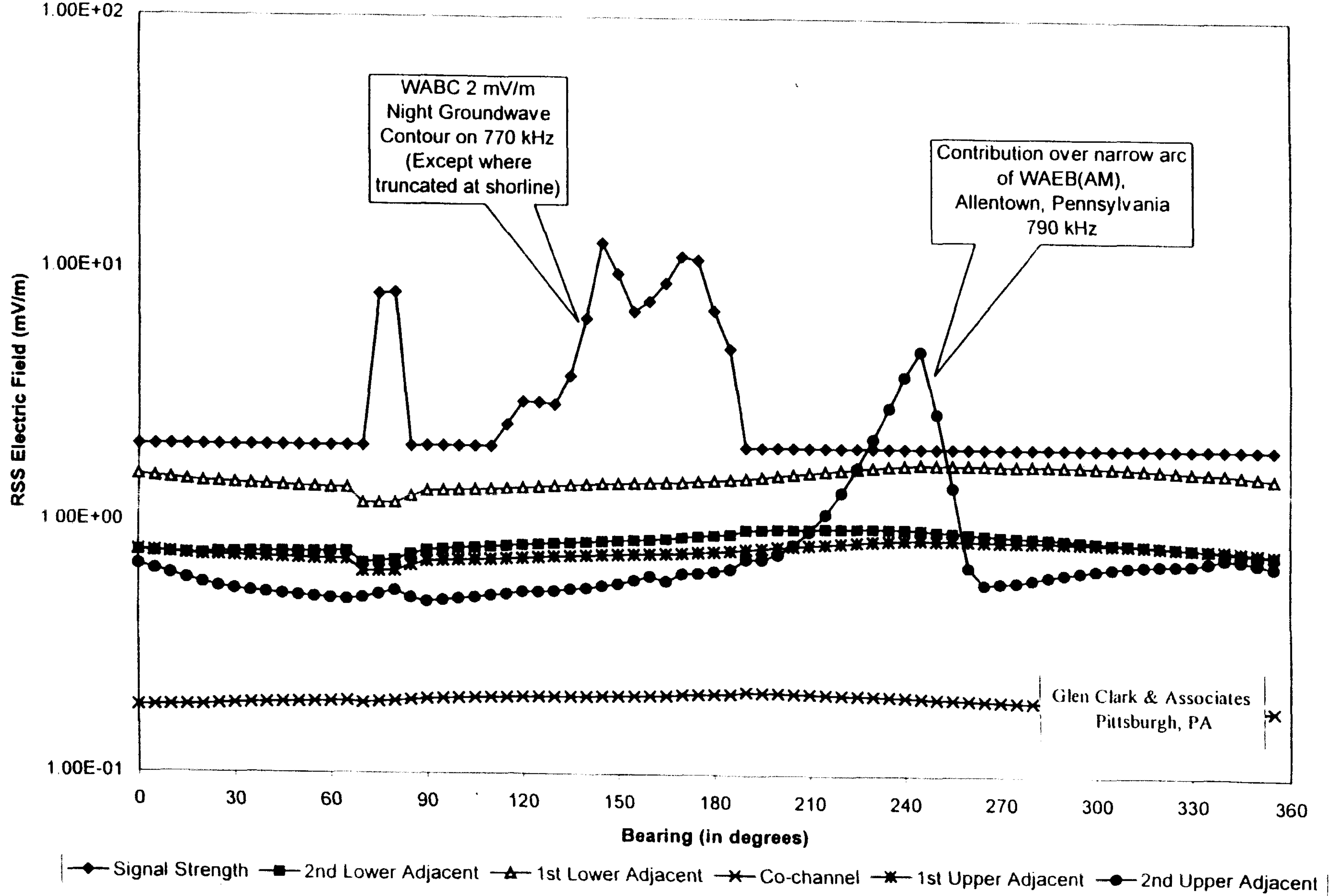
FIGURE C-8A - Incoming Nighttime Interference to WABC(AM), New York, New York (770 kHz)



ALL CONTOURS BASED ON FCC FIGURE M3 CONDUCTIVITIES.

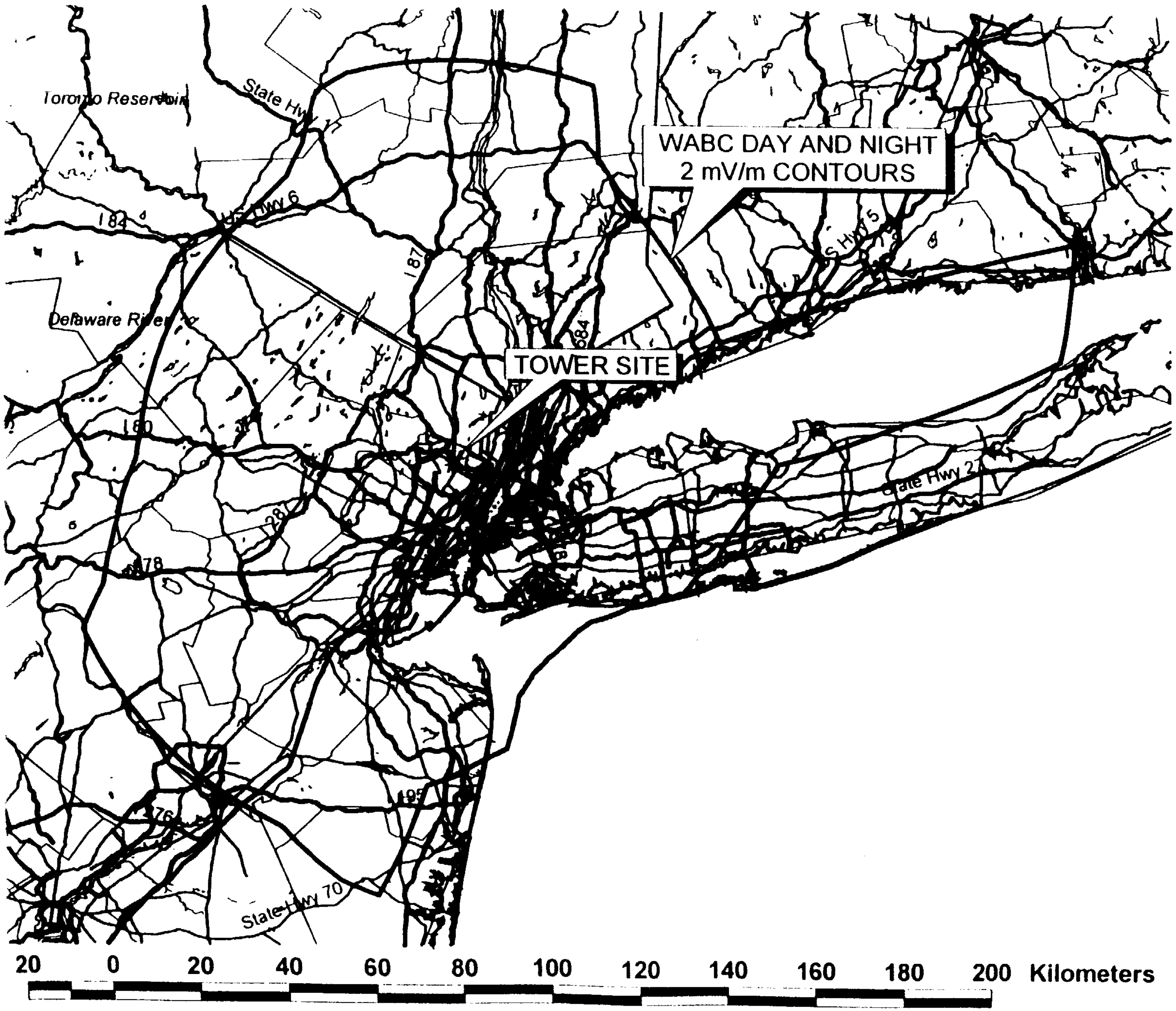


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FIGURE C-8B

STATION #67

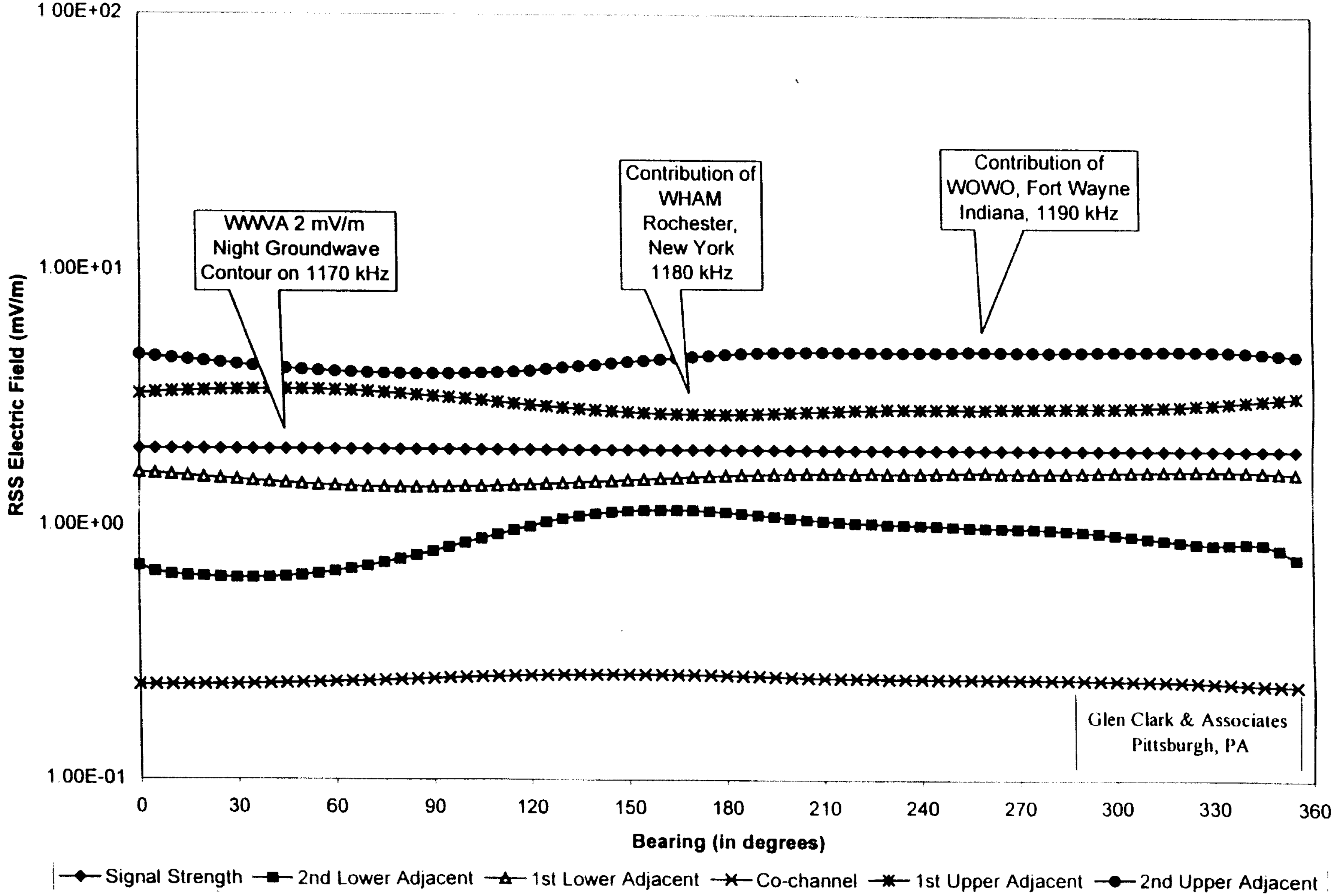
WABC

NEW YORK, NY
MARKET #1

770 kHz, 50 kW, ND-U
CLASS A
40-52-50 North
74-4-12 West

Glen Clark & Associates
Pittsburgh, PA

FIGURE C-9A - Incoming Nighttime Interference to WWVA(AM), Wheeling, West Virginia (1170 kHz)



ALL CONTOURS BASED ON FCC FIGURE M3 CONDUCTIVITIES

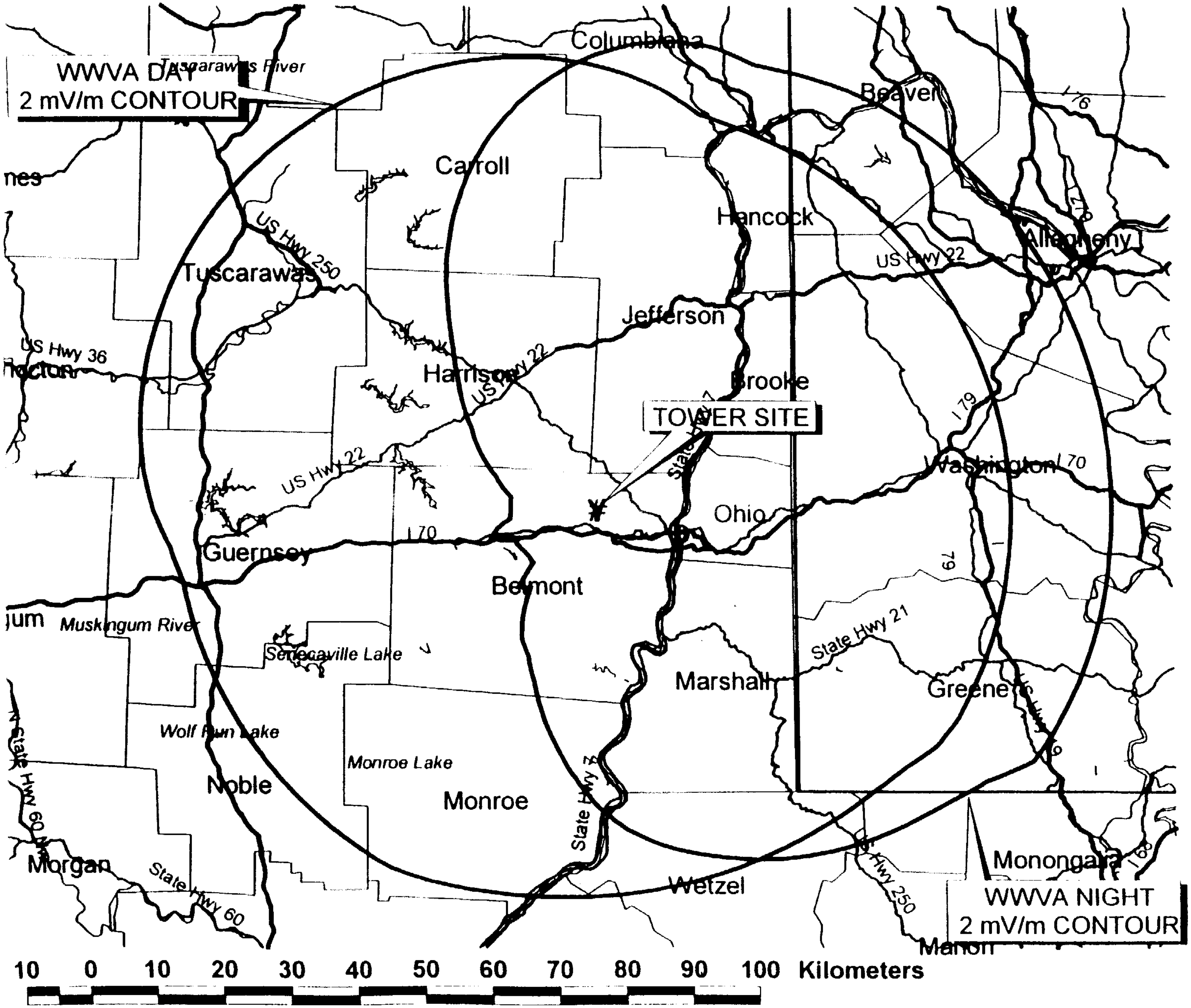


FIGURE C-9B

STATION #98

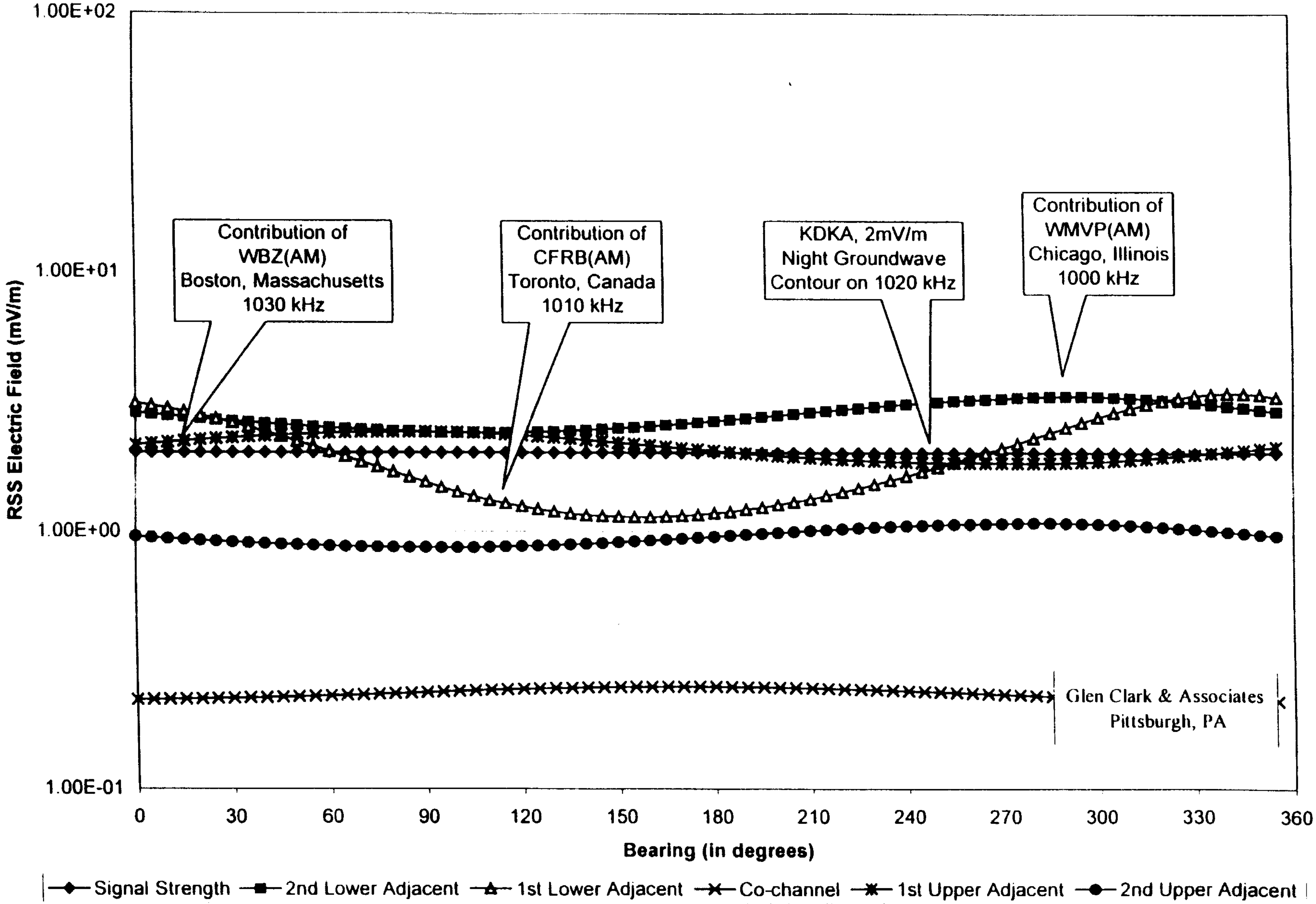
WWVA

WHEELING, WV
MARKET #218

1170 kHz, 50 kW, DA-N
CLASS A
40-6-7 North
80-52-2 West

Glen Clark & Associates
Pittsburgh, PA

FIGURE C-10A - Incoming Nighttime Interference to KDKA(AM), Pittsburgh, Pennsylvania (1020 kHz)



ALL CONTOURS BASED ON FCC FIGURE M3 CONDUCTIVITIES

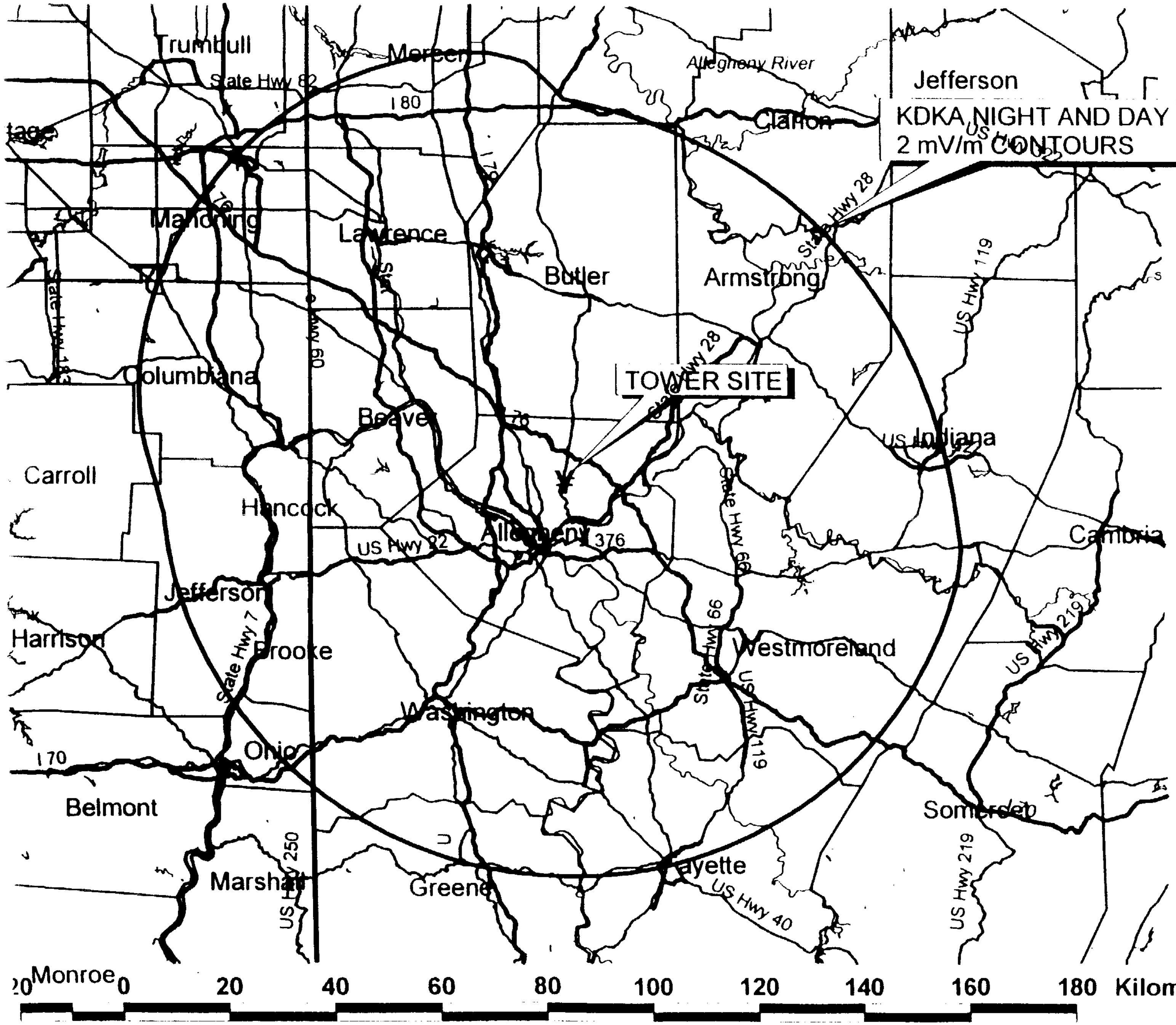


FIGURE C-10B

STATION #78

KDKA

PITTSBURGH, PA
MARKET #20

1020 kHz, 50 kW - U
CLASS A
40-33-33 North
79-57-11 West

Glen Clark & Associates
Pittsburgh, PA

BIOGRAPHICAL SKETCH
OF
RONALD RACKLEY

September 29, 1998

Ron Rackley has been active in the Broadcast Industry since 1970. He is an electrical engineering graduate of Clemson University, where his studies were specialized in the area of electromagnetic fields. Prior to completing his education, he worked for eight years at WFBC Radio and Television in Greenville, South Carolina, where he served as Chief Radio Operator.

Ron worked as a consulting engineer with the firms Palmer Greer & Associates and Jules Cohen & Associates and as a senior RF systems design engineer with Kintronic Laboratories before starting his own consulting practice with Bob du Treil in Washington in 1983. In 1988, du Treil-Rackley Consulting Engineers and A. D. Ring & Associates were combined to form his present firm, du Treil, Lundin & Rackley, Inc.

Ron is a member and past President of the Association of Federal Communications Consulting Engineers. He belongs to the Antennas and Propagation and Broadcast Technology Societies of the Institute of Electrical and Electronic Engineers. He served as Vice President of the Broadcast Technology Society in 1992. He has also served on the FCC/Industry Radio Advisory Committee.

Ron has published numerous articles relating to broadcast antenna systems, including the following papers presented at NAB conventions: "Alternative Antenna Configurations" in 1987, "Modern Methods in Mediumwave Directional Antenna Feeder System Design" in 1991, and "The Towers Industrial Park Project at KTNQ" in 1992. He was co-author of the chapter "Medium Frequency Broadcast Antennas" in the McGraw-Hill Antenna Engineering Handbook, third edition, 1993. He has recently completed, along with an associate, writing the chapter on "Antenna Systems for Medium Frequency Broadcasting" for the new John Wiley & Sons Encyclopedia of Electrical and Electronics Engineering.

Ron is a registered Professional Engineer. He holds General Class Radiotelephone and Amateur Extra licenses from the FCC.

Ron particularly enjoys applying modern technology and analysis methods to AM directional antenna systems. He has adjusted directional antenna patterns ranging in complexity to twelve towers and in power to one megawatt. He has designed and adjusted a number of diplexed (multi-frequency) AM antenna systems, both nondirectional and directional, ranging in power to 200 kilowatts.

Curriculum Vitae
Glen Clark

Mr. Clark holds a BSEE from the Pennsylvania State University and is a registered Professional Engineer. He is President of New Millenium Designs, Inc., parent company of Glen Clark & Associates. The latter is a consulting firm located in suburban Pittsburgh which specializes in computer modeling, RF propagation and the design of high-power, AM antenna.

Before forming his own firm, Mr. Clark was an engineer with the Washington consulting firm of Smith and Fisher (formerly Smith & Powstenko). He has held numerous management positions in radio including as a department head for ABC's owned-and-operated FM station in Chicago. Mr. Clark was President of TEXAR, Inc. and was the designer of the TEXAR Audio Prism, a popular broadcast audio processor.

Mr. Clark is a member of the Association of Federal Communications Consulting Engineers (AFCCE) and has frequently presented professional papers before the National Association of Broadcasters and the IEEE.

* * * * *

Curriculum Vitae

Scott E. Metker

Scott E. Metker received his Doctorate in Electrical Engineering from the Pennsylvania State University in 1998 and his Master's degree from the same university in 1995. He was a Magna Cum Laude graduate of Virginia Polytechnic Institute and State University in 1993. He has performed contract work for corporate clients including Chrysler and Boeing Aerospace. His research covers Finite-Difference Time-Domain (FDTD) and Method of Moments (MoM) formulations for the study of electromagnetic structures as well as traditional antenna analysis tools. Dr. Metker is an associate of the firm Glen Clark and Associates.

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Appendix H

Appendix H

USADR AM IBOC DAB Technical Report

1.0 Executive Summary

By its very nature as an IBOC design, the USADR AM IBOC DAB system must operate wholly within the confines of the existing radio frequency environment in the AM band. As a result, great care was taken to design a system which ensures mutual compatibility between existing analog broadcasts and new digital services.

To verify that the resulting design is indeed capable of harmonious co-existence in both current and future environments, the system was modeled and simulated. The computer simulations focused on two areas of compatibility effects of IBOC signals on existing analog broadcasts, and performance of the IBOC digital signal in an environment comprised of both analog and IBOC signals.

The quality and coverage of existing analog AM broadcasts is often limited by three factors: interference, fading due to Grounded Conductive Structures ("GCS"), and noise. Interference is caused mainly by other AM stations that either share the same frequency as the desired station (co-channel), or are one or two channels removed (first- or second-adjacent channels).

The first group of simulations investigated the impact on existing AM stations of adding IBOC signals to the existing radio frequency environment. First, the simulations measured the degradation introduced by adding DAB to an analog AM signal. Effects on audio quality were measured, studied, and interpreted. Second, the effects of co-channel and adjacent-channel IBOC DAB interference on an analog signal were analyzed.

These investigations revealed that the addition of IBOC digital carriers to an analog AM signal should not significantly affect audio quality Since the Power Spectral Density ("PSD") of the existing AM analog signal, the hybrid IBOC signal, and the all-digital IBOC signal are very similar, the interference from the co-channel and adjacent channel IBOC signals onto to analog is comparable to what presently exists. Thus, the analyses indicate that existing analog service should not be significantly affected by introducing AM IBOC DAB signals to the environment.

The second group of simulations investigated performance of hybrid IBOC signals in the presence of various combinations of co- and adjacent-channel analog and IBOC signals. The simulations indicate the relative levels of co-channel or adjacent-channel interference that can be tolerated by the digital portion of the hybrid signal.

The results of the simulations and analyses show that, for AM hybrid IBOC signals in a benign environment, the levels of co-channel and adjacent-channel interference that can be tolerated (19.5 dB to 28 dB D/U[1] for single or dual interferers) are similar to the protected SNR levels resulting from a co-channel interferer (*i.e.* 26 dB D/U). The degree of coverage beyond the protected contour depends on the number, type, and level of the interfering signals. The actual scenarios which were simulated and analyzed, and the corresponding results, are detailed herein.

Thus, simulations and analyses indicate that the IBOC signal will be compatible with both existing and future radio frequency environments. Existing analog stations will not be significantly affected by the introduction of IBOC signals. In addition, IBOC signals provide high quality digital audio coverage over areas where the existing analog AM signal has an audio SNR of roughly 26 dB or greater. The all-digital IBOC signal provides a substantially greater digital coverage than its hybrid counterpart.

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[1] D/U is defined as the ratio of desired to undesired signal powers.

2.0 Existing Analog AM Environment

The quality and coverage of existing analog AM broadcasts are often limited by three factors: interference, fading due to GCS and noise. The characteristics of these impairments have been studied and measured by USADR for inclusion in the system design and simulation. This section describes each of the impairments, and discusses their role in the design and verification of the AM IBOC system.

2.1 Interfering Stations

The FCC defines the AM band as an interference-limited medium where signals from distant stations often limit potential coverage.[2] During daytime hours, interfering signals arrive via groundwave propagation. At night, additional interference arrives from reflection of distant signals off the ionosphere; this is defined as "skywave interference." The FCC defines the coverage of an AM station as the signal level where its co-channel interferers sum to a signal strength which is 26 dB weaker.

The interference that a listener experiences is a summation of signals from stations operating on the same frequency (co-channel), stations operating one channel higher (upper 1st adjacent), and one channel lower in frequency (lower 1st adjacent). Stations removed in frequency two channels above (upper 2nd adjacent) and below (lower 2nd adjacent) generally do not contribute to interference in analog receivers due to the narrow bandwidth of the IF filter, except at very high signal levels. Each station is assigned a protected contour, which differs from day to night and by class of service.

2.1.1 Daytime Interference

Daytime signal propagation is primarily via groundwave. The strength of groundwave signals decreases with distance, and the rate of the decrease is dependent on ground conductivity,

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[2] *Notice of Proposed Rulemaking* in MM Docket No. 89-46, 4 FCC Rcd 2430, 2430-31 (1989).

which varies throughout the United States. Daytime protections vary by class of station, with Class A stations receiving the highest levels of co-channel protection (0.1 mV/m), and the remaining classes receiving protection to the 0.5 mV/m contour. All classes of stations receive 6 dB D/U of protection at their 0.5 mV/m contour from first-adjacent channel interferers. However, most stations are grandfathered at an earlier, less-protected 0 dB D/U protection ratio.

2.1.2 Nighttime Interference

At night, distant signals reflect off the ionosphere and cause increased skywave interference. Because ionospheric reflectivity increases at night, skywave is considered primarily a nighttime phenomenon.[3] Each station is assigned a protected contour for protection from co-channel interference.[4] These NIF contours range from 0.5 mV/m for a Class A station to over 50 mV/m for some Class B and C stations. Newer facilities must operate in a manner that protects the NIF contour of existing stations.

Currently, many analog AM stations use reduced transmit power or directional antennas to reduce skywave interference to other stations. These measures are also helpful for a DAB system, but digital signaling technology can use additional techniques such as interleaving, forward error correction, and frequency diversity to provide audio quality and coverage that is superior to existing analog broadcasting.

Understanding the nature of skywave interference is essential to designing an AM IBOC DAB system that can provide robust nighttime performance. The manner in which the signal propagates via reflections from different ionospheric layers, the field strength, and the statistical time varying properties of the signal are important factors to consider in the system design. The

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3 Interference to medium-frequency waves can also be caused by solar activity such as sunspots and flares, caused by an increased or reduced emission of radiation from the sun. The changes in solar radiation levels can cause changes in the ionospheric layers that may result in unusual skywave propagation conditions.

4 At night, this contour is defined as the Nighttime Interference Free ("NIF") contour.

following paragraphs summarize properties of skywave interference. This information has been used in the simulation and design of the AM component of the USADR IBOC DAB system to optimize performance in the presence of skywave interference.

Skywave signals can consist of several components due to reflections from different layers in the ionosphere. The ionosphere is divided into three regions designated as the D, E, and F layers. The D layer is closest to the Earth at a height of about 50 to 90 kilometers and is present only during daylight hours. This layer absorbs frequencies in the AM band rather than reflecting them back to Earth. At night, this layer diminishes, permitting AM waves to propagate to the E and F layers. The E layer is at a height of approximately 110 kilometers. This layer is the principal reflector of AM medium-frequency waves. The F layer is the uppermost layer of the ionosphere. During the day, the F layer splits into two subdivisions. The subdivisions are noted with a number following the layer designation. The F1 layer extends from about 175 to 200 km and the F2 layer extends from about 250 to 400 km. During the night, the F1 and F2 layers merge at about 300 km. Reflections from the F layer also account for a substantial amount of skywave interference.[5]

In order to properly simulate nighttime system performance, the level of skywave interference must be known. Several methods of calculating skywave field strength exist.[6] In general, the calculation is a function of several parameters such as transmit power, distance from the transmitting antenna, hours after sunset or before sunrise, antenna height, polarization

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5 *See* M.H. Barringer and K.D. Springer, "Radio Wave Propagation," NAB Engineering Handbook, § 2.8, 297-99 (8th ed. 1992); International Radio Consultative Committee, "ITU-R Handbook on the Ionosphere and its Effects on Radiowave Propagation," ITU 235-7, Int. Telecomm. Union (Geneva, 1998).

6 *See* International Radio Consultative Committee, "ITU-R Handbook on the Ionosphere and its Effects on Radiowave Propagation," ITU 235-7, Int. Telecommun. Union (Geneva, 1998), for a comparison of several different methods.

coupling loss, slant propagation distance, losses for ionospheric absorption, losses for focusing, and losses for multi-hop paths.

The field strength of skywave signals varies as a function of time. It is necessary to determine the statistical nature of the variations to achieve the optimal AM IBOC DAB system design. For example, the optimal system design for Gaussian interference will differ from that for interference of a non-Gaussian nature. The statistical parameters that describe the variations are important to several waveform parameters such as the interleaver, forward error correction, and frequency diversity of the AM IBOC DAB system. The nature of the variations is also important to several receiver functions such as filtering, automatic gain control, and tracking loops. Variations over one night are such that field strength reaches its maximum value approximately 4 hours after sunset and is within a couple dB of the maximum value until approximately 2 hours before sunrise. Shorter term variations in the skywave signal, which are more important from the standpoint of digital broadcasting, can be characterized by the fading rate and probability density function. The fading rate of a skywave signal has been defined as a crossing of the median value of the field strength in an increasing direction.[7] Fading rates of 10 to 30 fades per hour are reported as typical for the AM band.[8] The field strength of a skywave signal exhibits a log-normal probability distribution both for night-to-night variations in the hourly median value and within-an-hour fading of individual skywave modes.[9] For night-to-

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7 International Radio Consultative Committee, "ITU-R Handbook on the Ionosphere and its Effects on Radiowave Propagation," ITU 235-7, Int. Telecommun. Union (Geneva, 1998); "Propagation Factors Affecting Systems Using Digital Modulation Techniques at LF and MF," Question ITU-R 224/3, 1995.

8 *Id.*

9 *See* "Propagation Factors Affecting Systems Using Digital Modulation Techniques at LF and MF," Question ITU-R 224/3, 1995; "Probability Distributions Relevant to Radiowave Propagation Modeling," Recommendation ITU-R PN.1057, 1994.

night fading, a semi-interdecile range between 3.5 and 9 dB is reported. For fading within an hour, a standard deviation of 3 dB may be assumed.[10]

In order to understand typical levels of skywave interference, USADR sponsored a study to analyze nighttime interference levels of AM stations. Nighttime interfering field strength levels present at the transmitting antennas of 87 desired stations were calculated. Values for co-first adjacent, second adjacent, and third adjacent interferers were obtained. The stations were chosen such that the top, middle, and lower markets were equally represented. USADR is using the above information to simulate and design an AM IBOC DAB system.

2.1.3 Interference Protection

The FCC has allocated AM channels in an interlaced assignment plan that uses carrier frequencies spaced by 10 kHz. Since the signals occupy 20 kHz of bandwidth, they spill over into their neighboring channels, causing interference. The rules currently specify first adjacent channel protections for daytime conditions and, until 1993,[11] had no provisions for nighttime protections. At the time of the adoption of the first adjacent channel protection rules the band was fully populated and the first adjacent daytime protection rules applied only to new or changed facilities. In response to increasing levels of first adjacent channel interference, receiver manufacturers have narrowed their IF bandwidths[12]; however, it is impractical to sufficiently filter out adjacent channel interference and maintain reception of the desired signal.

First adjacent channel interference results in a stochastic/syllabic noise where a higher modulation frequency for the interferer corresponds to a lower interference frequency at the receiver. In June of 1988, the National Association of Broadcasters commissioned a study herein

10 *See* "Propagation Factors Affecting Systems Using Digital Modulation Techniques at LF and MF," Question ITU-R 224/3, 1995.

11 Amended by order in Docket No. 87-267, effective June 11, 1993, 58 FR 27944.

12 National Association of Broadcasters, *AM Technical Improvement* (1984).

referred to as the "Angell Study",[13] to determine the level of interference at which AM reception became unacceptable to the listening public. With the advent of FM radio, and now the CD, listener's sound quality expectations have increased over the years. Listeners found a 26 dB D/U ratio to be acceptable for talk in a 1946 FCC study[14] while the 1988 Angell Study found that listeners wanted an additional 14 dB.

USADR has conducted a study of 101 AM stations across the United States to determine interference levels to a received analog signal for the existing analog mode of broadcasting. Additionally, the interference levels to a received analog signal were predicted for an IBOC mode of broadcasting. Stations were chosen based on transmitter location, power output, and size of market served. The US time zones were used to categorize stations by location.[15]

Based on a 50% respondent satisfaction criteria contained in the Angell Study[16], the levels of desired to undesired signal ratios at the daytime 2 mV/m contour are acceptable at 91% of the locations for music and 66% of the locations for talk. Nearly 70% of the nighttime points meet the B. Angell criteria for music, but fewer than 1% of the nighttime points meet the criteria for talk.

The B. Angell study reported that first adjacent desired to undesired ratios need to be 20 dB or better to be acceptable to 50% of the test subjects. More than 80% of the points meet the criteria for "listenability" for first adjacent daytime conditions. For nighttime conditions, fewer than 40% of the points meet the criteria.

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13 B. Angell & Associates. National Association of Broadcasters. *AM Radio Interference Study* (1988).

14 *Id.*

15 Details of the categories can be found in Appendix G

16 *Id.*

The results of the USADR investigation show that the AM band in North America is worse than a reading of the FCC rules might indicate. The combination of co- and adjacent channel interference caused nearly 44% (co-channel) of the points to deliver less than acceptable performance for talk programming and 20% (first adjacent channel interference) of the points were rendered unacceptable for music programming. The situation is much worse at night with nearly no acceptable points for talk programming along the protected contour and less than 40% of the points have acceptable performance for music. Clearly, present AM reception lies somewhere within the 2 mV/m contour for daytime conditions and well within the protected contour for nighttime reception.

2.2 Grounded Conductive Structures

The effects of grounded conductive structures on AM broadcasts have always been observed; however, the corresponding mechanism by which they occur and the total effects on the AM signal had not been studied until recently. Examples of grounded conductive structures include bridges, power lines, overpasses, and overhead signs that are commonly found on highways. The degradation of the received signal occurs in part because the wavelength in the AM band is large compared to the dimensions of typical grounded conductive structures.

It is important to understand and characterize the effects of grounded conductive structures so that the proper steps can be taken to ensure the digital signal can be received when a grounded conductive structure is encountered. Prior to a study performed by USADR, little was known about the propagation effects of grounded conductive structures to an AM signal. To obtain this needed information, USADR conducted an extensive study.[17] The goal of the study was to determine the magnitude and phase changes caused by grounded conductive structures.

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[17] "AM Hybrid IBOC DAB System" by David Hartup, Dan Alley and Don Goldston, September 1997 on USADR website.

The results of this study have been used in the design and computer simulation of the USADR AM IBOC waveform. Waveform parameters and receiver processing have been optimized to minimize the effects of grounded conductive structures

USADR measured the AM environment using center frequencies of 740 kHz and 1660 kHz in Cincinnati and 1150 kHz in Boston. USADR selected these frequencies as representative of the low, middle, and high sections of the AM band. For each center frequency used, USADR took measurements in a variety of urban, suburban, and rural locations.

A digital test waveform was transmitted consisting of 61 tones spaced by 500 Hz, resulting in a bandwidth of 30 kHz. A mobile receiver was used to record the received time-domain signal. The collected data was processed to determine how the channel had changed the magnitude and phase of each tone. The effects of the transmitter, antenna, and receiver were extracted from the data records by processing a record taken in a clear channel and subtracting the results from the impairment data. In this way only the effects caused by the channel resulted.

Data for 162 grounded conductive structures was recorded and analyzed during the data collection process. The breakdown of categories is shown in Table H-1.

Frequency	Overpasses	Powerlines	Signs	Others	Totals
1660 kHz (Cincinnati)	15	10	6	0	31
740 kHz (Cincinnati)	31	24	10	23	88
1150 kHz (Boston)	14	21	3	5	43
Totals	60	55	19	28	162

Table H-1 - Grounded Conductive Structures Captured and Analyzed

The processed data for each impairment was used to determine characteristics such as grounded conductive structure length, maximum fading depth and selectivity. For example, a histogram of the grounded conductive structure lengths is shown in Figure H-1.

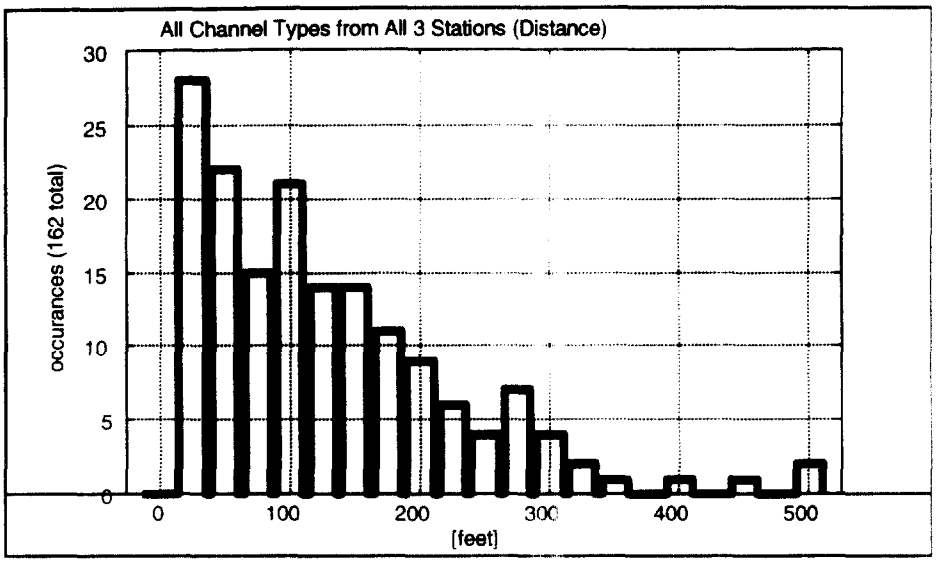

Figure H-1 - Histogram of Grounded Conductive Structure Lengths

During the data collection process it was noted that approximately 5% of all overhead wires, 50% of all overhead signs (such as freeway signs), and almost all overpasses resulted in noticeable changes in the magnitude and phase of the received AM signal. Signal degradation resulting from overhead wires was slightly more severe at higher center frequencies.

Existing analog AM receivers do not attempt to counteract the fading effects of grounded conductive structures. Although analog receivers do have automatic gain control to compensate for long term changes in the level of a received signal, the response time of the automatic gain control is too slow to compensate for rapid changes that occur due to grounded conductive structures. Because of this, an analog receiver typically produces a burst of noise when traveling beneath a grounded conductive structure.

In comparison to analog broadcasting, the USADR IBOC DAB system provides significantly enhanced performance in the presence of grounded conductive structures. Unimpaired audio is produced as long as the digital signal is properly received. Measures can be taken in both the waveform and receiver design to minimize the effects of grounded conductive structures. Waveform characteristics such as the interleaver length, forward error correction algorithm, and frequency diversity can be optimized if the characteristics of grounded conductive structures are known. Receiver processing steps such as rapid automatic gain control, carrier and symbol timing tracking, and adaptive equalization can be used to counteract the effects of grounded conductive structures.

Grounded conductive structures significantly affect listener satisfaction. As a result, there is a strong need to minimize their effects. The introduction of digital radio will compound this problem because the potential reacquisition time required by the digital signal may extend grounded conductive structure-related fades. In some instances, such as urban locations and highways near urban areas where overpasses and signs are common, the likelihood of grounded conductive structure outages would have the potential for significant impacts.

2.3 Noise

Interference from noise can impair reception of both the analog and digital signals. Therefore, it is important to understand the characteristics of noise that are encountered in the AM band to properly design an IBOC DAB system. Noise in the AM band comes from both man-made and natural sources. Although characteristics of noise in the AM band are fairly well known, little can be done to counteract the effects for the current analog mode of broadcasting.

The level of noise is typically expressed in terms of F_a, which is the external noise figure of a receive antenna. The external noise figure is defined as

$$F_a = 10 \cdot \log_{10}(f_a) \text{ dB}$$

where f_a is the external noise factor, defined as

$$f_a = \frac{P_n}{kt_0 b}$$

where P_n is the available noise power from an equivalent lossless antenna, k=1.38 * 10^{-23}, t_0 is 290 degrees K, and b is the noise power bandwidth of the receiving system in Hertz. For a short vertical monopole antenna above a perfect ground plane, the vertical component of the r.m.s. field strength is given by

$$E_n = F_a + 20 \cdot \log_{10}(f_{MHz}) + B - 95.5 \quad \text{dB}(\mu\text{V/m})$$

where f_{MHz} is the center frequency in MHz and $B = 10 \cdot \log_{10}(b)$.

The noise temperature, t_a, can be calculated using

$$t_a = \frac{P_n}{kb}$$

2.3.1 Man-made Noise

Although localized exceptions exist for frequencies in the AM band, the dominant source of man-made noise[18] is gap-discharge noise from power lines.[19] The level of man-made noise is highly dependent on the surrounding environment. Four environmental categories of man-made noise have been defined, including business, residential, rural, and quiet rural.[20] In defining these categories, localized intense sources of noise are excluded. The business category has the highest noise levels, with median values of F_a at 85.1, 76.8, and 65.7 dB for frequencies of 0.5, 1, and 2.5 MHz, respectively.

The median values of F_a vary as a function of time and location. The CCIR Report cites the upper and lower decile deviations about the median value of F_a within one hour as a function

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18 Other sources include power generation equipment, automobile ignition systems, fluorescent lights, and electrical equipment, such as arc welders.

19 Power line noise is generated by three types of phenomenon: (1) gap-discharge, which is gas discharge and insulating film breakdown between high-potential points on power line supporting elements, (2) corona discharge, and (3) re-radiation from electrical loads. In the AM band, gap discharges generally exceed all other unintentional sources.

20 See International Radio Consultative Committee, "Man-made Radio Noise," CCIR Report 258-5, Int. Telecommun. Union (Geneva, 1990).

of frequency.[21] Values for the business category are shown in Table H-2. The median values of F_a for the business category were obtained from measurements at 6 locations.[22] The variation in the median value of F_a as a function of location is given by the parameter σ_{NL}, and values for the business category are given in Table H-2.

Frequency (MHz)	Upper Decile (dB)	Lower Decile (dB)	σ_{NL} (dB)
0.5	12.6	8.0	8.2
1	9.8	4.0	2.3
2.5	11.9	9.5	9.1

Table H-2 - Upper Decile, Lower Decile, and σ_{NL} Values for Man-Made Noise in the Business Category

Due to its source, gap-discharge noise is impulsive in nature and the frequency domain nature can be line spectra with lines occurring at multiples of the fundamental frequency.[23] The impulsive nature of the noise can be characterized using a variety of parameters. The upper and lower decile values in Table H-2 give one indication of the impulsive nature of the noise. Also, amplitude probability distributions ("APDs") show the impulsive nature by plotting the percentage of time a level is exceeded. Another parameter that is used to characterize the impulsive nature of the noise is V_d, which is the ratio of the rms envelope voltage to the average noise envelope voltage. The value of this parameter is dependent on the receiver bandwidth used to measure the noise. The value of V_d increases as the noise becomes more impulsive and has a value of 1.05 dB for Gaussian noise. For a 10 kHz receiver bandwidth, the values of V_d for the business category are approximately 4.9, 3.5, and 5.3 dB for frequencies of 0.5, 1, and 2.5 MHz, respectively.

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21 *Id.*

22 *See* E. N. Skomal, *Man-Made Radio Noise*, Van Nostrand Reinhold (1978).

23 *Id.*

Application of the above information allows calculation of noise field strength values. For the business category, the noise would produce field strengths of 0.37, 0.28, and 0.16 mV/m in a 6 kHz bandwidth for a short vertical antenna above a perfect ground plane for frequencies of 0.5, 1, and 2.5 MHz, respectively. This level of noise will result in a signal-to-noise ratio of 37 dB for a 1 MHz carrier if the desired signal has a field strength of 2 mV/m and 10% of the received power is in the message.

2.3.2 Natural Noise

In the AM band, atmospheric noise (lightning) is almost always the predominant source of natural noise in temperate latitudes.[24] The level is dependent on season, time of day, location, and frequency. The level of natural noise can be 15 dB greater than the level of noise given above for the man-made business category. Therefore, the signal-to-noise would be reduced to 22 dB for a high level of natural noise.

One analysis gives measurements of F_a as a function of these parameters for a short vertical monopole over a perfectly conducting ground plane.[25] World maps show contour plots of F_a for a frequency of 1 MHz. Contours are given for winter, spring, summer, and autumn. For each season, contours are provided for six four-hour periods covering a 24-hour day. For each contour map, a separate graph is provided showing the dependence of F_a as a function of frequency.

For the United States, the highest value of F_a for a frequency of 1 MHz is about 90 dB and occurs during the summer from 2000-2400 local time in the Midwestern portion of the

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24 Other sources of natural noise include galactic and solar noise. See International Radio Consultative Committee, "Radio Noise," ITU Recommendation ITU-R PI.372-6, Int. Telecommun. Union (Geneva, 1994); D.G. Fink and D. Christiansen, *Electronics Engineers' Handbook*, McGraw-Hill (3d ed. 1989).

25 International Radio Consultative Committee, "Radio Noise," ITU Recommendation ITU-R PI.372-6, Int. Telecommun. Union (Geneva, 1994).