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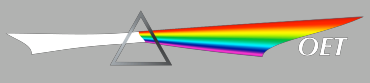
The ILLR Computer Program for Predicting Digital Television Signal Strengths at Individual Locations



November 23, 2010

THE ILLR COMPUTER PROGRAM FOR PREDICTING DIGITAL TELEVISION SIGNAL STRENGTHS AT INDIVIDUAL LOCATIONS

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I. Introduction

In the Satellite Television Extension and Localism Act of 2010 (STELA), Congress instructed the Commission to "develop and prescribe by rule a point-to-point predictive model for reliably and presumptively determining the ability of individual locations, through the use of an antenna, to receive digital television broadcast signals of network affiliated stations in accordance with the signal intensity standard in Section 73.622(e)(1) of title 47, Code of Federal Regulations, or a successor regulation."[1] As codified in Section 339(c)(3) of the Communication Act, this law further 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."[2] Terrain features (such as hills), buildings, and land cover (such as forests) have a major effect on the strength of received signals, and Congress instructed the Commission to make the predictive model as accurate as possible by taking these factors into account. In the Satellite Home Viewer Improvement Act of 1999 (SHVIA), Congress previously required that, in determining household eligibility for reception of satellite retransmission of analog TV broadcast network signals, the courts rely on the ILLR model for making a presumptive determination of whether a household is capable of receiving the over-the-air signal of the local station affiliated with that network with at least a certain threshold intensity of signal strength.[3]

This bulletin publishes the detailed definition on the model for making point-to-point predictions of the intensity of digital television (DTV) signals adopted by the Commission as prescribed under the STELA. The model uses an ILLR computer program for DTV stations that is based generally on the ILLR program for analog stations previously-established by the Commission in the SHVIA *First Report and Order* in ET Docket No. 00-11 adopted May 22, 2000.[4] This new version of the ILLR computer program computes the predicted signal strength of DTV stations as received over-the-air at individual viewing locations. Individual locations where a network TV signal is below the prescribed signal strength level are eligible to receive distant network broadcast as subscribers of satellite TV services. The program is used by Satellite TV service providers to determine whether particular TV network signals may be included in the package of channels delivered to individual subscribers. To facilitate use of the program by others, this bulletin provides details for combining the program elements on other computers.

As defined by STELA, a viewer location is "served," or "unserved," depending on whether the signal strength received at that location is at least equal to, or is less than, respectively, the noise-limited service level with a certain statistical probability as set forth in the FCC Rules.[5] A location found by

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[1] See Satellite Television Extension and Localism Act of 2010, Title V of the American Workers, State, and Business Relief Act of 2010 ("STELA"), Pub.L. 111-175, 124 Stat. 1218 (2010) relating to copyright licensing and carriage of broadcast signals by satellite carriers, codified in scattered sections of 17 and 47 U.S.C; *see also* 47 C.F.R. § 73.622(e)(1).

[2] In CS Docket No. 98-201 the Commission endorsed a prediction procedure it referred to as the Individual Location Longley-Rice model. 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*, adopted February 1, 1999, 14 FCC Rcd 2654 (1999).

[3] Satellite Home Viewer Improvement Act of 1999 (SHVIA), Pub.L. 106-113, 113 Stat. 1501, 1501A-526 to 1501A-545 (Nov. 29, 1999), codified in the Communications Act at 47 U.S.C. § 339(c)(3). 17 U.S.C. § 119(a)(2)(B)(ii)(I).

[4] *See* Report and Order in CS Docket No. 98-201 (SHVA Report and Order), 14 FCC Rcd 2654 (1999).

[5] *See* 47 C.F.R. § 73.622(e). The signal strength values for noise-limited digital television service are 28 dBμV/m for TV channels 2-6; 36 dBμV/m for channels 7-13; and 41 dBμV/m (adjusted by a dipole factor equal to 20 log [615/(channel mid-frequency in MHz)] for channels 14 and above. These signal strength values are to be used in all cases, whether the DTV station is full-service, Class A, Low Power, or a DTV Translator.

the ILLR prediction program to be "served" by the signal of a network affiliated station, *i.e.*, the signal strength at that location is at least the noise-limited value, is not entitled to receive satellite transmission of that same network programming. To complement this predictive model, the STELA also mandated establishment of a procedure for on-site testing that may be used for empirically determining signal strength when satellite carriage of network is denied to a subscriber as a result of a predictive determination by the ILLR program. The Commission's on-site measurement procedure for digital television signals as prescribed under the STELA is set forth in Section 73.686 of the rules.[6]

II. The Individual Location Longley-Rice (ILLR) Computer Program for DTV Stations

A. Availability of Software and Databases

Software and Computer Database Requirements to Implement the ILLR Program model are available from the Department of Commerce as discussed below. The software must be combined with terrain elevation data and also with a database describing the local environment of building structures and vegetation. Terrain elevation data and the Land Use and Land Clutter (LULC) database are both available from the U.S. Geological Survey (USGS). To set up a program to run, the source code for the Department of Commerce's Longley-Rice radio propagation prediction model must be compiled with specific parameter values and linked with the terrain elevation data. Finally, a computerized lookup table of local environment values must be constructed from the USGS LULC database. A computer program complying with the technical details specified herein will qualify as the Individual Location Longley-Rice (ILLR) propagation prediction model for DTV stations.

B. Using the ILLR Computer Program

A determination of the served or unserved status of a particular location is made by finding its latitude and longitude coordinates (typically using GPS, maps or geocoding services) and technical information about the desired network affiliated broadcasting station. The ILLR computer program is applied using this information.

C. Implementation of Computer Source Code

Computer code for the Longley-Rice radio propagation prediction model is published in an appendix to 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. The report may be obtained online from the U.S. Department of Commerce, or from the National Technical Information Service, Springfield, Virginia, by requesting Accession No. PB 82-217977. 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. It is available for downloading at the U.S. Department of Commerce Web site, http://flattop.its.bldrdoc.gov/itm.html . This computer software model, when used with the appropriate parameters, is the ILLR model.

The ILLR model was adopted for STELA purposes based on the Commission's experience with using the Longley-Rice radio propagation prediction model for predicting service and interference for digital television (DTV). The parameters to be used in a computer implementation of the ILLR model for STELA purposes are mostly the same as were used for DTV service and interference analysis

[6] *See* 47 C.F.R. § 73.686.

purposes, with only a few exceptions, stemming from their somewhat different objectives. Specific parameter values for the ILLR model are given in Table 1 and the text below:

Table 1
Parameter Values for ILLR Implementation of the Longley-Rice Fortran Code

Parameter	Explanation	Value	Units
EPS	Relative Ground Permittivity	15.0	(none)
SGM	Ground Conductivity	0.005	Siemens/meter
ZSYS	(Coordinated with EN0)	0.0	(none)
EN0	Surface refractivity	301.0	N-units
IPOL	Polarization	0	(horizontal)
MDVAR	Calculation Mode	1	(Individual Mode)
KLIM	Climate Code	5	(Continental Temperate)
XI	Terrain sampling interval	0.1	Kilometers
HG(1)	Transmit antenna height above ground	See note	Meters
HG(2)	Receive antenna height above ground	6 or 9	Meters

Note 1. HG(1) in Table 1 is the height of the radiation center above ground. It is determined by subtracting the ground elevation above mean sea level (AMSL) at the transmitter location from the height of the radiation center AMSL. The latter value is contained in the FCC's CDBS, and may be found by query at http://www.fcc.gov/mb/video/tvq.html . The former is retrieved from the terrain elevation database as a function of the transmitter site coordinates also found in CDBS. Linear interpolation between the surrounding data points in the terrain database is used to determine the ground elevation. Care should be used to ensure that consistent horizontal and vertical datums are employed among all data sets.

Note 2. HG(2) is 6 m or 9 m. Use 6 m for a one-story building, otherwise use 9 m.

Following are the parameters that describe the unique features of the ILLR prediction procedure for STELA purposes (these distinguish the ILLR model from the use of Longley-Rice for digital television coverage and interference calculations as detailed in OET Bulletin No. 69):

- the time variability factor to be used is 90%, based on the fact that the ILLR field strength prediction is to be compared with a required field strength (the noise-limited field intensity defined in Section 73.622(e) of the FCC rules);

- the confidence variability factor to be used is 50%, indicating median situations;[7]

- receiving antenna height is to be assumed to be 6 m above ground for one-story buildings and 9 m above ground for buildings taller than one-story;

- in those cases that error code 3 occurs (KWX = 3), the predicted field strength is nevertheless to be accepted as indicative of whether the noise-limited field strength is available at that location;

[7] When point-to-point mode is used, as in ILLR, there are well-defined paths with fixed terminals, so there is no location variability. There is still a “confidence” or “situational” variability factor, which is taken here to be 50%.

- consideration of the land use and land cover (*e.g.,* vegetation and buildings) in the vicinity of the receiving location is to be included through use of a lookup table of clutter losses additional to those inherent in the basic Longley-Rice v1.2.2 model. The lookup table must be constructed from information on the Land Use and Land Cover categories defined by the United States Geological Survey. See Section IV below.

D. Acquiring Terrain Elevation Data

Terrain elevation data for the United States is available from the United States Geological Survey (USGS) in the form of elevations relative to mean sea level at grid points separated by 3 arc-seconds (roughly every 100 feet at mid-latitudes of the U.S.). The Web site for obtaining these data directly from the USGS is http://edc.usgs.gov/geodata/ . The Commission currently uses digital elevation model (DEM) data taken from 1:250,000 scale maps. The data are also available from several commercial sources. Installation of the ILLR program necessarily entails a computer coding task to link the terrain elevation data to the propagation prediction code. Computer program code must be developed to retrieve data representing the elevations of points along the path from the network affiliate's transmitter to the individual reception point of interest. To determine the elevation of a point at particular geographic coordinates along the path, the elevation of points at each corner of the 3-arc-second grid surrounding that point should be retrieved. The elevation of that point is then calculated by 4-point linear interpolation.

E. Acquiring TV Engineering Data

Engineering data for DTV stations in the U.S. (including digital Class A, Low Power, and TV Translator stations) is available from the FCC. Data for individual stations can be found at http://www.fcc.gov/mb/video/tvq.html , and consolidated data for all authorized stations can be found at ftp://ftp.fcc.gov/pub/Bureaus/MB/Databases/cdbs/. Where more than one authorization exists for a particular station, the record associated with the facility actually operating shall be used. Calculation of effective radiated power (ERP) in the direction of the individual location under study is accomplished using the relevant antenna azimuth and elevation patterns (including beam tilt, if any) at the relevant depression angle. Where specific elevation pattern data are not provided in the engineering data, a generic elevation pattern may be used as described generally in OET Bulletin No. 69.

III. Land Use and Land Cover (LULC) Clutter Losses

A. Clutter Losses

The presence of foliage and man-made structures in the radio path tends to reduce the strength of received signals. The Department of Commerce Longley-Rice code was developed from field strength measurements in areas selected for the purpose of investigating effects of terrain elevation profiles, not morphology. Thus, the ILLR computer program defined in this bulletin accounts for additional factors, especially buildings and vegetation, as so-called "clutter losses." The clutter loss, if any, at an individual reception location is determined by reference to the Land Use and Land Cover (LULC) database of the USGS. This database is entered with the geographic coordinates of the reception point to find the point's LULC classification and, subsequently, to determine a clutter loss value from Table 3. Finally, the clutter loss is subtracted from the signal strength predicted by the basic propagation prediction code to determine whether the location is served or unserved.

B. Source of LULC Classification Data

The LULC database is available for downloading at the USGS Web site http://edc.usgs.gov/geodata/ . The FCC presently uses data from at the 1:250,000 scale. In the FCC's implementation of the ILLR program, the LULC classifications are stored in a rasterized fashion like that used for terrain elevations. That is, the classifications are stored as functions of the latitude and longitude coordinates of points of the Universal Transverse Mercator (UTM) system with 200 meters between grid points. The classification of the nearest grid point is then used as the classification of any particular latitude-longitude point.

C. LULC Categories of the ILLR Program

Since the LULC classifications of the USGS have a broader purpose and are not targeted for application to radio propagation analyses, we have regrouped these classifications into more appropriate categories for use in the ILLR program. Table 2 defines this regrouping. For each computer run of the program, the appropriate ILLR clutter category number should be selected from Table 2 according to environmental conditions in the vicinity of the individual reception point. The clutter loss value, if any, is then determined as a function of the ILLR clutter category number and the channel number of the desired network television affiliate, by referring to Table 3.

Table 2

Regrouping of LULC Categories for ILLR Applications

LULC Classification Number	LULC Classification Description	ILLR Clutter Category	ILLR Clutter Category Description
11	Residential	7	Residential
12	Commercial and Services	9	Commercial / Industrial
13	Industrial	9	Commercial / Industrial
14	Transportation, communications & utilities	1	Open land
15	Industrial and commercial complexes	9	Commercial / Industrial
16	Mixed urban and built-up lands	8	Mixed urban / buildings
17	Other urban and built-up land	8	Mixed urban / buildings
21	Cropland and pasture	2	Agricultural
22	Orchards, groves, vineyards, nurseries, and horticultural	2	Agricultural
23	Confined feeding operations	2	Agricultural
24	Other agricultural land	2	Agricultural
31	Herbaceous rangeland	3	Rangeland
32	Shrub and brush rangeland	3	Rangeland
33	Mixed rangeland	3	Rangeland
41	Deciduous forest land	5	Forest land
42	Evergreen forest land	5	Forest land
43	Mixed forest land	5	Forest land
51	Streams and canals	4	Water
52	Lakes	4	Water
53	Reservoirs	4	Water
54	Bays and estuaries	4	Water
61	Forested wetland	5	Forest land
62	Non-forest wetland	6	Wetland
71	Dry salt flats	1	Open land
72	Beaches	1	Open land
73	Sandy areas other than beaches	1	Open land
74	Bare exposed rock	1	Open land
75	Strip mines, quarries, and gravel pits	1	Open land
76	Transitional areas	1	Open land
77	Mixed Barren land	1	Open land
81	Shrub and brush tundra	1	Open land
82	Herbaceous tundra	1	Open land
83	Bare ground	1	Open land
84	Wet tundra	1	Open land
85	Mixed tundra	1	Open land
91	Perennial snowfields	10	Snow and Ice
92	Glaciers	10	Snow and Ice

This regrouping into 10 categories for use with the ILLR model was designed by EDX Engineering, Inc., now EDX Wireless, LLC, Eugene, Oregon.

Table 3

Clutter Loss as a Function of ILLR LULC Clutter Category and TV Channel

		Clutter Loss, decibels (to be subtracted from calculated field strength)			
ILLR Clutter Category	ILLR Clutter Category Description	Channels 2-6	Channels 7-13	Channels 14-36	Channels 38-69
1	Open land	0	0	4	5
2	Agricultural	0	0	5	6
3	Rangeland	0	0	3	6
4	Water	0	0	0	0
5	Forest land	0	0	5	8
6	Wetland	0	0	0	0
7	Residential	0	0	5	7
8	Mixed Urban / Buildings	0	0	6	6
9	Commercial / Industrial	0	0	5	6
10	Snow and Ice	0	0	0	0

IV. Field Strength Calculation

The field strength of a network TV station at an individual location is predicted as follows:

1) Find the engineering facilities data for the network affiliate station of interest by, for example, consulting the TV Query FCC Web site at http://www.fcc.gov/mb/video/tvq.html . Necessary technical data include the station latitude and longitude, height above mean sea level of the antenna radiation center, and the effective radiated power (ERP) in the direction of the individual location under study.

2) Run Longley-Rice v1.2.2 in point-to-point mode with the parameters specified in Section II.C. above (Table 1 and the following text) to find the propagation path loss relative to free space propagation.

3) Find the USGS Land Use and Land Cover classification of the individual receiving location under study by consulting the LULC database, available from the USGS.

4) Convert the USGS Land Use and Land Cover classification to the corresponding ILLR clutter category using Table 2, and find the associated clutter loss from Table 3.

5) Calculate the ILLR field strength prediction from the formula

Field = (Free Space Field) – (Longley-Rice 1.2.2 Path Loss) – (ILLR Clutter Loss)

where the Free Space Field in dB = $106.92 + 10\log_{10}$(ERP in kW) – $20\log_{10}$ (distance in km).

The field strength calculated in the last step determines whether the individual location is presumed to be served or unserved. The signal strength values for noise-limited service are 28 dBμV/m for TV channels 2-6; 36 dBμV/m for channels 7-13; and 41 dBμV/m (adjusted by a dipole factor equal to 20 log [615/(channel mid-frequency in MHz)] for channels 14 and above.