Statement of Hammett & Edison, Inc., Consulting Engineers

The firm of Hammett & Edison, Inc., Consulting Engineers, has been retained by EchoStar Satellite L.L.C. to prepare an engineering statement in response to the FCC's Notice of Inquiry in ET Docket No. 05-182, "Technical Standards for Satellite-Delivered Network Signals."[1]

Background

In its Notice of Inquiry in ET Docket No. 05-182 ("NOI"), the Commission seeks, among other things, information and comment on current regulations that identify households that are unserved by local analog broadcast television stations in order to determine if the regulations may be accurately applied to local digital broadcast stations for the same purpose. Specifically, the Commission seeks technical information in the following areas: (1) whether a new standard should 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 the codified system of "cluster measurements"[2] should be amended to create different procedures for determining the requisite digital signal strength, (3) whether a standard should be developed that does not require the presence of a signal of certain strength to ensure that a household can receive a high-quality picture, (4) whether to develop a predictive methodology for determining whether a household is unserved by an adequate digital signal, (5) whether there is wide variation in the ability of reasonably priced consumer digital television ("DTV") sets to receive over-the-air signals, and (6) whether to account for factors such as building loss, external interference, and clutter.

In digital television, all of these technical factors impact not only the quality of the picture received, but whether a picture can be received *at all*. As the General Accounting Office has noted, "[t]here are some concerns that digital television sets in locations with a weak signal will have difficulty receiving over-the-air broadcasts. This issue is important for the DTV transition because with a digital signal, unlike an analog signal, the picture is lost completely when the signal is inadequate. Over-the-air viewers who may currently tolerate a weak, snowy analog signal could find themselves without any signal at all when they try to receive the digital broadcast signal."[3]

---

1 FCC 05-94, adopted April 29, 2005

2 47 CFR §73.686(d)

3 GAO report GAO-03-7, "Telecommunications: Additional Federal Efforts Could Help Advance Digital Television Transition," released December 2, 2002

1. Consumer Receiving Antennas

Uncommon use of rotatable outdoor receiving antennas

Implicit in the Commission's distant network eligibility rules is the assumption that all viewers employ outdoor directional antennas, which are adjusted (rotated) to achieve optimum reception.[4,5] This is a flawed assumption for several reasons. The U.S. Congress' Government Accounting Office (GAO) found that 19% or 20.8 million U.S. households rely upon over-the-air antennas exclusively.[6] One might expect that many homes also have secondary or tertiary television receivers in the kitchen, bedroom, workshop, etc., which are typically connected only to set-top antennas. Indeed, the GAO also found that another 15% of households that subscribe to either cable television or direct broadcast satellite (DBS) service have at least one TV set that utilizes an over-the-air antenna. In sum, the GAO found that 34% of U.S. households receive at least some television signal off-air using an antenna.

Our corporate experience over the past 53 years has been that only a small fraction (perhaps 10–15%) of households having outdoor antennas also utilize an antenna rotor. The vast majority of consumers who have antennas for over-the-air reception are believed to use antennas that are fixed and not rotatable. Even so, most if not all rotors do not have automatic or remote-control adjustments, so the typical viewer must arise from the couch to adjust the antenna rotor; such physical activity seems unlikely in this age of remote-control "channel surfing." Also, the rotor itself has some latency of perhaps one second per 6° of rotation;[7] because DTV receivers typically require about one second to lock onto a channel and produce a picture, this latency further slows the channel surfing process, and would be expected to result in consumer dissatisfaction.

---

4 47 CFR §73.686(d)(2)(iv) states in pertinent part that testers should "[o]rient the testing antenna in the direction which maximizes the value of field strength for the signal being measured."

5 FCC/OET Bulletin No. 72 states in pertinent part that, "[t]he ILLR model was adopted for SHVIA purposes based on the Commission's experience with using the model for predicting service and interference for digital television (DTV). The parameters to be used in a computer implementation of the ILLR model for SHVIA purposes are mostly the same as were used for DTV purposes, with only a few exceptions, stemming from their somewhat different objectives."

The model used for DTV purposes is described in OET Bulletin No. 69, which states in pertinent part that, [t]he receiving antenna is assumed to have a directional gain pattern which tends to discriminate against off-axis undesired stations. … The discrimination ... provided by the assumed receiving pattern is a … function of the angle between the … desired and undesired stations …. When both desired and undesired stations are dead ahead, the angle is 0.0 giving … no discrimination. When the undesired station is somewhat off-axis, … discrimination [comes] into play; and when the undesired station is far off axis, the maximum discrimination given by the front-to-back ratio is attained."

6 GAO-05-258T, "Digital Broadcast Television Transition: Estimated Cost of Supporting Set-Top Boxes to Help Advance the DTV Transition," February 17, 2005.

7 Sinclair Broadcast Group, Inc., Petition for Partial Reconsideration in FCC Docket 00-39.

Antenna pointing errors

Few viewers of over-the-air television have or use outdoor antennas that are rotatable, but unless a fixed antenna is properly oriented less than optimum signal levels will be obtained. In most markets, not all television stations transmit from a common site, so reception of one or more stations will be impaired due to the reduced off-axis performance of television receive antennas. The Terrain Integrated Rough-Earth Model (TIREM)[8] was used to project the coverage of all full-service NTSC stations in the U.S. over a random sample of 4.4 million calculation points covering the continental U.S.[9] This large sample indicates that the majority of all persons in the U.S. are able to receive at least two NTSC signals of Grade B or greater intensity.[10] Of the households that are predicted to receive at least two stations, the calculations show that the majority receive at least one of those stations from an angle that differs by greater than 25° from another station. A half-power beamwidth of about 50° (±25° from the direction of maximum gain) is assumed in the Commission's planning factors for DTV,[11] so almost all households will have impaired reception of at least one station.

Significantly, most "fringe" viewers (70.5%), *i.e.*, households predicted to receive comparatively weak signals in the Grade A to Grade B range from at least two stations, receive those stations from directions differing by 25° or greater. A majority of these fringe viewers have pointing errors such that the full front-to-back ratios assumed by the Commission for its allocation and interference analyses would apply. That is, at least one signal level would be reduced from the predicted value by 10, 12, or 14 dB, depending upon whether the station involved operates at VHF-low band, VHF-high band, or UHF frequencies, respectively. From these data, it seems clear that most viewers will not be able to receive optimally all available DTV stations without a properly oriented rotatable antenna.

Indoor antennas

As discussed above, the GAO found that about 34% of U.S. households utilize over-the-air receiving antennas for TV reception,[12] and many of these antennas are expected to be indoor (*e.g.*, back-of-set) models. As discussed below, indoor receiving antennas are generally not very directional, have lesser gain than most outdoor antennas, and are often not easily adjusted. The service signal strength levels specified by the FCC in Section 73.622(e), which are predicated on the use of an outdoor antenna, are inadequate when the receiving antenna is an indoor model.

---

[8] Developed by the U.S. Government Joint Spectrum Center, Annapolis, Maryland.

[9] It is believed that the number of DTV stations operating with full power facilities is not yet representative of the coverage conditions that would exist in an "all DTV" environment, but the current universe of NTSC stations can be assumed to be representative of that environment, based upon the Commission's goal of replication.

[10] A few are predicted to receive as many as 38 signals of Grade B or greater intensity.

[11] Fortran computer code including receive antenna pattern details is found at: http://www.fcc.gov/Bureaus/Engineering_Technology/Databases/mmb/dtv/mo&o2/readme.html

[12] Kutzner, *op cit*.

Because of practical limitations on the physical dimensions of indoor antennas, they have always had less gain than typical outdoor antennas. Consumer television antenna gain figures have been published at various times. In 1959, TASO, based upon manufacturer data and data supplied by AMST (now MSTV), reported average gain values of 3.7, 6.8, and 8.0 dBd, for VHF-low, VHF-high, and UHF channels, respectively. These values are comparable with the values given in the DTV planning factors, which are 4, 6, and 10 dBd. Indoor antennas, however, have much lower gains. A PBS study[13] reported gain figures for various UHF antennas, finding an average gain of 9.3 dBd for UHF outdoor antennas (8.6 dBd for combination VHF/UHF outdoor antennas), and an average gain of just –1.1 dBd for indoor UHF antennas, representing a penalty of about 10 dB for users of indoor antennas. Similarly, the Institute for Telecommunication Sciences published a study in 1979,[14] which showed average gains of 3.5, 7.5, and 6.0 dBd for outdoor antennas, but –4.4, –2.8, and –3.0 dBd for indoor antennas, demonstrating a UHF "indoor antenna penalty" of 9 dB. Recently, Dielectric Communications published measured antenna performance data on several consumer antennas currently being marketed for DTV reception. These data show average gains at UHF of 11.6 dBd for outdoor antennas, but 2.4 dBd for indoor models — a difference of 9.2 dB.[15,16] Thus, the gains associated with indoor antennas at UHF are consistently about 9 dB, or more, below those for outdoor antennas, and persons relying upon indoor antennas for DTV reception will be at a considerable disadvantage.

2. Cluster Measurements

The small percentage of consumers having or using rotatable antennas calls into question continued justification of the requirement under Section 73.686(d) that the measurement antenna be rotated for greatest signal strength. While one might assume that, given the ability to do so, consumers would rotate their antenna for best reception, the direction of best reception may vary from station to station. Viewers without rotatable antennas obviously cannot simultaneously achieve optimum reception for all stations. In addition, the direction of maximum signal strength often produces a poor picture (or no picture, in the case of DTV). For example, a viewer located in a valley, which is obstructed by terrain from TV stations, might find that the strongest signals are those reflected off a wall of the valley, but that signals from that direction also include strong multipath (ghost images) making them unwatchable. Instead, residents may orient their antennas toward the opening of the valley, which results in weaker, but usable signals. It would therefore seem logical when taking cluster measurements to orient the measurement antenna in the same direction as other antennas in the area, since it can be assumed that those antennas would be

---

13 Free and Smith, Georgia Institute of Technology, 1978.

14 FitzGerrel, R.G., *et al.*, "Television Receiving Antenna System Component Measurements," NTIA Report 79-22, June 1979.

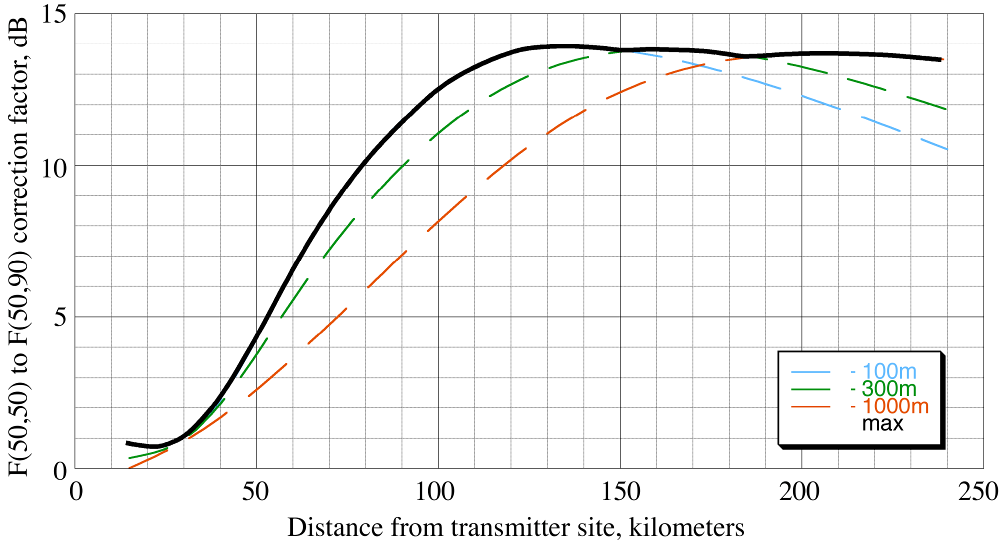
15 Kerry W. Cozad, "Measured Performance Parameters for Receive Antennas used in DTV Reception," Proceedings of the NAB Engineering Conference, 2005.

16 Kerry W. Cozad, private communication, June 16, 2005.

oriented toward a direction that provides the best reception overall (but perhaps not optimum for any station).

The cluster measurement method accounts only for so-called "location variability" of the TV signal. As will be shown, TV signals may also be subject to significant time variability. Indeed, the FCC's criterion for DTV coverage is a specified threshold field strength at the best 50% of the locations, 90% of the time, that is, a location variability factor of 50% and a time variability factor of 90%, commonly written as F(50,90). Because a single set of cluster measurements is assumed to capture the median time signal strength value, it cannot adequately characterize the time variability to provide reasonable assurance that the DTV signal will be available 90% of the time. DTV reception fails completely below the threshold signal level, so it is critical to characterize this time variability.

Time variability might be characterized in several ways. For instance, the 90% time reliability factor could be derived by applying a correction factor to the assumed median value obtained during the cluster measurements. The graph below shows the difference in decibels between the UHF F(50,50) and F(50,90) values used by the FCC for contour projection, as a function of distance from the transmitter site for three values of transmit antenna height above average terrain (HAAT). To adjust the assumed "typical" measured field strength to a 90% time value, the appropriate correction factor is subtracted from the measured value. This method requires knowledge of the distance to the transmit site, as well as the transmitter HAAT toward the receiving location, which can be a difficult parameter to determine. As a simplification, the dark line shows the maximum at any of the three values of HAAT and might be used if the appropriate value of HAAT is not known.



As an example, if the cluster measurements show a median field strength of 43 dBμV/m at a distance of 50 kilometers from the transmitter site, the F(50,90) value would be 43 – 5 = 38 dBμV/m.

Temporal variation of signal level

There are considerable empirical data available concerning the variation with time of narrowband radiofrequency signals.[17] Indeed, the FCC's propagation curves and the Longley-Rice propagation model are based upon the statistical distributions of such data. There are scant data available concerning actual measurements of wideband DTV signals, however, and concern has been expressed that the Longley-Rice algorithm used for distant network qualification may not be usable for wideband signals.[18] One might expect those data to be similar to the narrowband data, at least in terms of first-order statistics (*e.g.,* median amplitude and variation with time). The availability of a DTV signal is a function both of this temporal variation of signal strength and the ability of the receiver to compensate for frequency-selective fading effects. Since DTV reception is largely an "all or nothing" proposition, such temporal variation data can be used to infer consumer satisfaction with DTV over time.

Hammett & Edison, Inc. has collected temporal data on the amplitudes of fourteen DTV signals that could be received at its Sonoma, California, offices. Initial data collection occurred over an approximately two-week period from May 18 until June 1, 2005. Some of the temporal data are shown in Figure 1. These data represent a variety of paths, both obstructed and unobstructed, as shown in the included transmitter-receiver path profiles, and clearly show significant variations in signal strength. These

[17] Longley, A.G., *et al.,* "Measured and Predicted Long-term Distributions of Tropospheric Transmission Loss," NTIA/ITS Report OT/TRER 16, June 1971.

[18] Oded Bendov, "On the Validity of the Longley-Rice (50,90/10) Propagation Model for HDTV Coverage and Interference Analysis," Proc. NAB Broadcast Engineering Conference, 1999.

variations occur because of changes in atmospheric conditions, including rain rate, humidity, barometric pressure, and temperature.[19] All of these factors apply to some degree everywhere in the U.S.

Figures 1A and 1B show data for three line-of-sight paths. The short paths (less than 20 kilometers) shown in Figure 1A clearly show a strong Rician (fixed path loss) component, with minimal variance about the mean.[20] The cumulative distribution function (CDF) of signal strengths is almost constant within a range of 2–3 dB, over the 10%–99% time probabilities. Figure 1B is also a line-of-sight path, but it is much longer at over 100 kilometers, and the amplitudes span a wide range from -60 to -75 dBm (15 dB) over the same time probability range.

Figure 1C shows data for three non-LOS paths of significant length (greater than 60 kilometers) showing signal level variations ranging from 6–9 dB for the shorter paths (KPIX-DT and KKPX-DT) to over 12 dB for the longest path (KNTV-DT).

Of particular interest is the variation in signal level less than 10% the time. Recall that F(50,90) statistical reliability is stated in the FCC planning factors for DTV. A temporal reliability of 90% can represent no DTV picture for the viewer 36.5 days a year (10% of the time). Because a DTV signal below threshold results in no picture at all, allowing for just 90% time reliability (*i.e.,* up to five weeks of outage) seems not to be in the consumer's best interest. An increase in temporal reliability to 99% (or better) seems prudent until there is greater experience with consumer reception of DTV signals, although this represents still 3.65 days a year without a usable signal.

At VHF high band Channel 12, signal strength variation with time about the median was found to be about 3.5 dB for 90% probability. Thus, 90% time reception would be expected only if the measured median signal strength is made 3.5 dB stronger than the DTV threshold. This is the value that must be exceeded during short-term cluster measurements. Taking the 99% probability level increases the required signal level by 4.7 dB. At UHF Channel 41, 90% probability of reception requires a signal 4.9 dB above the DTV threshold, while 99% probability requires a signal of about17.5 dB above threshold. The measured 90% time values agree reasonably well with the chart shown on page 5.

The most striking feature of Figure 1 is the pronounced fading during a mild storm in the San Francisco Bay Area, which decreased UHF signal levels by about 15 dB during portions of May 18 and 19. Rain rates at the receive site measured as high as 15.5 mm/hr, but were typically about one-third of that value.

---

[19] R.E. Gray, "The Refractive Index of the Atmosphere as a Factor in Tropospheric Propagation Far Beyond the Horizon," Institute of Radio Engineers National Convention Record, 1957.

[20] The parameter describing the power ratio of the fixed and fluctuating components is called the Rician K-factor, which is very high for these short line-of-sight paths. Field measurement of the Rician K-factor may be a useful indicator of reliability with time of the DTV signal.

3. Factors Other Than Signal Strength that Affect Reception

Four major factors that impact the ability to receive a DTV signal are:[21]

- carrier to noise ratio
- multipath
- noise interference (especially impulsive noise)
- interference from other signals

All of the technical information sought by the Commission in this NOI pertains to the impact of practical or empirical implementations of DTV technology on one or more of these factors. Note that signal strength is not one of the four major factors listed above.

Adequate signal strength is necessary but is not, by itself, sufficient for DTV reception. Summary data for twelve DTV field measurement campaigns through 1999 have been reported.[22] These data show that at UHF, 12% of locations having the requisite DTV signal strength at the location of an outdoor antenna failed to produce a usable picture. This percentage increased to 18% for sites that were obstructed from the transmitting antenna. For indoor antennas, the ATSC system failed to produce a picture at 26% of the locations having adequate signal strength. From these data, it might be expected that one-eighth to one-quarter of viewers having adequate signal strength will be unable to receive a DTV picture. Future DTV receivers will undoubtedly be able to produce a DTV picture in some locations where the earlier receivers could not, but these results illustrate that there has been a significant failure rate where consumers cannot receive DTV even though a theoretically-adequate signal level is present.

Static Multipath

The presence of multipath ("echoes") in the DTV signal, which can be of fixed delay (typically due to reflections from terrain and large man-made features such as buildings), causes the so-called "equalizer" circuitry in the DTV receiver to operate. The equalizer, in attempting to create an idealized amplitude and phase response to compensate for the non-ideal transmission channel, will increase the system's noise at the frequencies of compensation. The increased noise due to equalizer action is commonly called "white noise enhancement" and is a function of how much correction the various equalizer taps must apply (*i.e.*, how "hard" the equalizer is working). The white noise enhancement, in effect, increases the necessary signal threshold for detection of the DTV signal.

---

21 James A. Kutzner, "The Challenges of Indoor DTV Reception," Proc. NAB Broadcast Engineering Conference, 2001.

22 Gary Sgrignoli, "DTV Field Test Methodology and Results and Their Effect on VSB Receiver Design," IEEE Transactions on Consumer Electronics, Vol. 45, No. 3, August 1999.

Sgrignoli[23] published the relationship between total equalizer tap energy relative to the main tap and white noise enhancement. Over the tap energy range of -20 to 0 dB, the white noise enhancement ranges from 0 to 3 dB. At a "good" receiver location (having little multipath), the tap energy might be about -10 dB, corresponding to a white noise penalty of less than 0.5 dB. However, at a poor location, the white noise penalty may exceed 2 dB. Therefore, field measurements should include collection of white noise enhancement values, or equivalently, tap energy data. Such data can be obtained from professional DTV demodulators, which are available from several sources.[24] The resulting white noise enhancement would then be subtracted from the measured field strength.

Dynamic Multipath

There remain some types of channel impairments (*e.g.,* impulse noise and dynamic multipath) and co- and adjacent-channel (and perhaps other types of) DTV interference that even the latest DTV receivers cannot handle. For example, so-called "third generation" DTV receivers, which (along with fourth-generation receivers) are commonly available today, have difficulty handling single dynamic echoes greater than 40% of the amplitude of the main component.[25] Such dynamic multipath can occur, for example, when a DTV signal is reflected off an airplane (which leads to so-called "airplane flutter" in NTSC systems). Even poorer performance results when multiple dynamic echoes are present, as when cars are moving on the street or people are walking in the vicinity of an indoor antenna.[26]

Man-Made Noise

With regard to DTV receiver performance in the presence of impulse-type noise, it is well known that such noise is the likely cause of many reported failures to receive DTV signals, even though adequate signal strength is present.[27] Man-made impulse noise includes sources such as power line arcing, industrial machinery, automotive ignition systems, appliances having electric motors (*e.g.*, vacuums, dishwashers, hair dryers, etc.), devices having switching power supplies (*e.g.*, computers, and many modern electronic devices), and microwave ovens. A suspected flaw in the DTV technical specifications (FCC Rules, Section 73.622(e)(1)) is the specified minimum usable signal level at low-band VHF channels (2–6). It has been widely reported that the specified value of 28 dBμV/m is inadequate in many

---

23 Gary Sgrignoli, "DTV Field Test Methodology and Results and Their Effect on VSB Receiver Design," IEEE Trans. on Consumer Electronics, Vol. 45, No. 3, August 1999.
24 Sources include Zenith and Z Technologies, Inc.
25 Strolle, C.H., *et al.*, "Feasibility of Reliable 8-VSB Reception," Proc. NAB Broadcast Engineering Conference, 2000.
26 Simon Wegerif, "The Evolution of Front Ends for Digital TV," Proc. NAB Broadcast Engineering Conference, 1999.
27 Gary Sgrignoli and Richard Citta, "Summary of Grand Alliance VSB Transmission System Field Test," Proc. NAB Broadcast Engineering Conference, 1996.

contexts, particularly where there is man-made noise (especially impulse noise) present in the environment.

The Commission's DTV planning factors do not appear to adequately account for this significant source of man-made noise, particularly at low-band VHF frequencies (TV Channels 2–6), where the minimum required signal level is assumed to be just 25.2 dB above thermal noise.[28] Thermal (kTB) noise power is -106.2 dBm in a bandwidth of 6 MHz, and the minimum signal level required for DTV reception specified in the planning factors is -81 dBm, giving a difference of 25.2 dB for system noise, demodulation, and other factors. The system noise figure of 10 dB assumed in the FCC DTV planning factors, and the 15 dB signal-to-noise ratio required for DTV receiver operation, leave an implementation margin of just 0.2 dB.

Past studies have shown that, in rural locations, man-made noise levels are typically 20 dB above kTB, and in urban areas such noise is typically 30 dB above kTB near 54 MHz (TV Channel 2).[29] The increasing use of electrical and electronic equipment in the U.S. suggests that current noise levels could become much greater. Indeed, more recent studies[30] have found median noise levels in Boulder, Colorado, approaching 20 dB at 137 MHz, which implies a median value approaching 30 dB at 54 MHz. If 20 or 30 dB of man-made noise is added to the thermal noise floor, certainly, some viewers in urban areas will be unable to receive low-band DTV signals due to excessive man-made noise.

DTV measurements on low-band VHF channels conducted in the Washington, DC and Cleveland, Ohio, areas found a relatively high level of failures at moderate and weak signal levels, which "suggested that the planning factors adopted by the FCC to predict low VHF service are inadequate – probably attributed to increase[s] in the environmental noise threshold."[31] It has been reported that the minimum field strength at which the DTV signal is decodable at Channel 2 in an indoor environment is at least 40 dBu, compared with the specified value of 28 dBu.[32] Thus it appears that an additional margin of 12–30 dB could be required for adequate reception of low-band VHF DTV signals.

Low-band VHF stations will probably represent a small fraction of all DTV stations, but they may include large rural land areas where DBS providers have many subscribers. According to available

---

[28] The FCC planning factors reflect a "system noise figure" of 10 dB at VHF frequencies, which reportedly includes 5 dB for receiver noise and 5 dB for environmental noise. This value is significantly lower than reported by Spaulding and Disney and ITU Recommendation ITU-R P.372-8 (2003). See text.

[29] 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, Jun. 1974.

[30] Robert J. Achatz and Roger A. Dalke, "Man-Made Noise Power Measurements at VHF and UHF Frequencies," NTIA Report No. 02-390, December 2001.

[31] Victor Tawil, MSTV, "Considerations in Using Low-VHF Channels for DTV," Proc. IEEE Broadcast Technology Symposium, 2001.

[32] Carl G. Eilers and Gary Sgrignoli, "An Analysis of DTV Propagation into and within a Room in a Domestic Environment," IEEE Broadcast Technology Symposium, 2001.

information, 1,693 of 1,761 U.S. television stations (96%) have made a DTV channel election. Of these 1,693, the vast majority (1,223 or 72%) elected a UHF channel, while 427 (25%) elected a high-band VHF channel and 43 (3%) elected a low-band VHF channel. Of the 43 stations electing a low-band channel, 28 are affiliates of the "big-four" networks, while 4 are affiliated with other networks, and 11 are non-commercial.

4. Predictive model

It appears that the predictive methodology presently used in the SHVA context (ILLR) has considerable applicability to the DTV world, but there remain improvements that might be made to properly accommodate reliable DTV reception. Some of these improvements are discussed below.

The FCC intends that DTV stations replicate their NTSC "Grade B" service areas. The Grade B F(50,50) service contours are based upon the assumption that an "acceptable" quality of service will be available at the best 50% of locations, 90% of the time.[33] Thus, to "replicate" coverage, the DTV signal also needs to produce an acceptable picture with50% situation reliability at least 90% of the time. Of course, in the case of NTSC, the difference between an acceptable picture and an unacceptable one might be an increase in the amount of snow; in DTV, the difference between an acceptable picture and an unacceptable one is no picture at all. So, the statistical parameters of the ILLR model should be set to the appropriate values. Presently, the ILLR model, as specified in OET Bulletin No. 72 for NTSC signals specifies that the time and situational variability factors are to both be set at 50%. We believe that for DTV, the appropriate factors would be 50% situation (confidence) variability[34] and 90–99% time variability, with the greater value being most prudent, at least until there is greater experience with consumer reception of DTV signals.

Factors for building penetration loss and use of an indoor antenna, as suggested elsewhere in this report could be incorporated into the ILLR model, when appropriate. A factor to account for ubiquitous antenna pointing errors is also appropriate for consumers having access to outdoor antennas.

Although a system noise figure has been assumed in the FCC planning factors for DTV receivers, that figure assumes a conjugate-impedance match between the receiver and antenna. In fact, a household antenna is rarely matched to the receiver.[35] Many of the antennas presently available for DTV have VSWR values that exceed 3:1 over much of their design bandwidth and exceed 2:1 over essentially all of

---

33 Robert A. O'Conner, "Understanding Television's Grade A and Grade B Service Contours," IEEE Trans. on Broadcasting, Vol. BC-14, No. 4, December 1968.

34 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 "situation" variability factor of 50% that is sometimes called "location" variability, but the proper term is "situation" probability. See George Hufford, "The ITS Irregular Terrain Model, version 1.2.2: The Algorithm" for more information.

35 Cozad, *op cit.*

their design bandwidth. The latter figure represents an increase in the effective system noise figure of 3 dB, which could also be incorporated into the model.[36]

5. Variability Among Consumer DTV Receivers.

Consumer DTV receiver designs continue to evolve. Five receivers (four consumer and one professional model) were evaluated for sensitivity for comparison with the FCC's planning factors, as follows:

1. LG LST-4200A
2. Samsung SIR-T451
3. Motorola HDT101
4. RCA DTC100
5. Zenith DTVDEMOD-S

Receivers 1, 2, and 3 were obtained from retail vendors in May 2005. Receiver 4 is an older model, purchased in 2000. Receiver 5 is a professional ATSC demodulator, which provides detailed information concerning equalizer performance, error rate, and other parameters.

The receivers were set up at a location (Alameda, California) having favorable path characteristics for DTV reception; that is, relatively constant signal levels, and multipath components having minimal amplitude and short delay. The receivers were connected to a common antenna and attenuation was added in 1 dB steps until visible failure of DTV reception occurred. The measurements show the differences in sensitivity of the receivers under favorable field conditions. The estimated margin of error for these measurements was ±1.5 dB.

	Measured Sensitivity by Channel, dBm						
Receiver	D12	D23	D29	D43	D41	D47	D49
1	-81.9	-82.6	-84.1	-80.4	-82.8	-81.1	-81.8
2	-80.9	-80.6	-83.1	-81.4	-80.8	-81.1	-82.8
3	-78.9	-83.6	-83.1	-83.4	-83.8	-82.1	-82.8
4	-75.9	-78.6	-82.1	-77.4	-77.8	-78.1	-78.8
5	-75.9	-78.6	-79.1	-79.4	-77.8	-79.1	-79.8
Variation in sensitivity RX1–4	6 dB	5 dB	2 dB	6 dB	6 dB	4 dB	4 dB
FCC PF	-81.2	-84.2	-84.2	-84.2	-84.2	-84.2	-84.2

The above results show that consumer receivers can differ in sensitivity by 2–6 dB under favorable field conditions. Laboratory tests (apparently at one channel) showed differences on the order of 0–3.4 dB without multipath and 0–8.7 dB in the presence of static multipath.[37,38]

---

36 Bendov, *op cit.*
37 Charles Einolf, "DTV Receiver Performance in the Real World," Proc. NAB Broadcast Engineering Conference, 2000.

After compensating for the white noise enhancement of the equalizer (typically 0.2 dB), which was taken from Receiver 5 and assumed to apply to all of the other receivers, the sensitivities can also be compared with the FCC planning factor ("PF") values of -81.2 dBm at VHF and -84.2 dBm at UHF. Depending upon the channel involved, some receivers were up to 6.6 dB less sensitive than the planning factors specify. Considering all channels, the typical receiver was 2.6 dB less sensitive than the FCC planning factors.

6. Building Penetration Loss, Interference, and Clutter

Building penetration losses

Indoor receiving antennas, apart from having less gain than their outdoor counterparts, will typically be subject to weaker DTV signals. This is because the TV signal is attenuated as it passes through common building materials. The FCC conducted a measurement campaign, which found median building penetration losses of 30 dB at VHF and 26 dB at UHF for a number of buildings in the most "cluttered" parts of New York City.[39] In relatively less cluttered areas (boroughs outside of Manhattan), the measured building penetration losses were about 25 dB at VHF and 21 dB at UHF. Detailed information concerning the height of the receiving antenna (first floor, second floor, etc.) was not provided. A series of measurements conducted at UHF frequencies in the U.K. found building penetration losses in a six-story building of up to 16.4 dB at ground level, generally decreasing to about 2.5–4.2 dB at the sixth floor.[40] UHF frequencies tend to propagate into buildings better (that is, have less building penetration loss) than VHF frequencies because the dimensions of typical building openings (doors and windows) allow Fresnel clearance at the shorter UHF wavelengths. So, the building penetration losses at VHF television channels are expected to be greater.

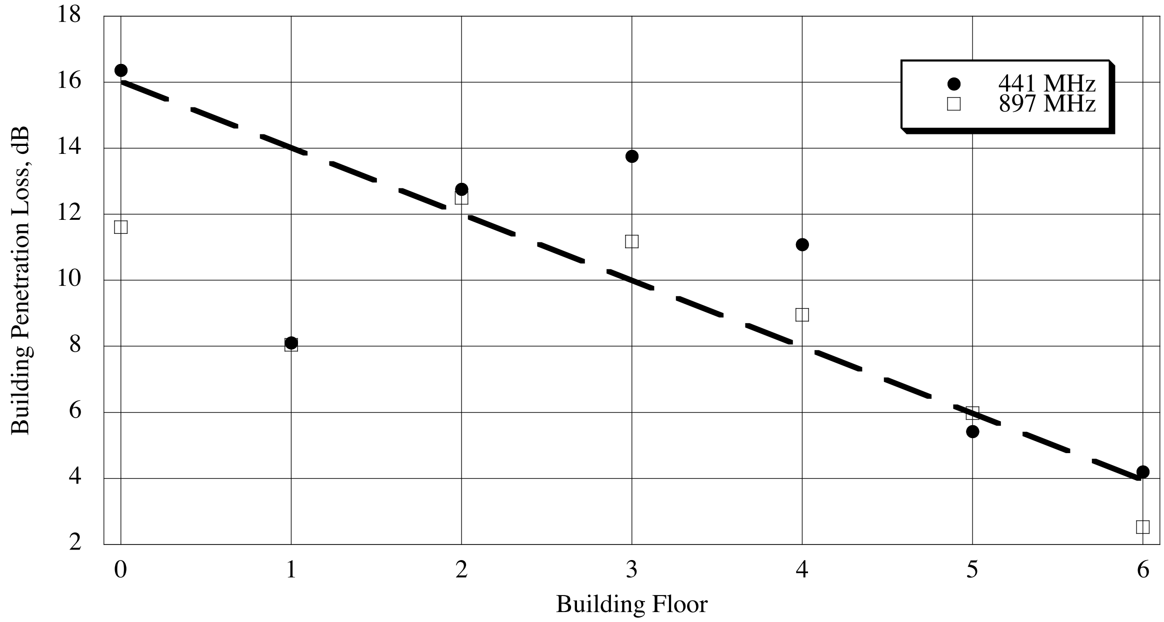
The chart below, adopted from Parsons, shows a possible relationship at UHF between height in stories of the indoor receiving antenna and building penetration loss. For example, a viewer in a third-floor apartment having an indoor back-of-set antenna might be expected to experience a signal 10 dB weaker than an equivalent antenna outside the building. Note that in the United Kingdom, the ground floor is considered Floor zero, and the upper floors begin at one.

---

[38] Bernard Caron, *et al.*, "ATSC 8-VSB Receiver Performance Comparison," Proc. NAB Broadcast Engineering Conference, 2000.

[39] G.V. Waldo, "Report on the Analysis of Measurements: New York City UHF-TV Project," IEEE Trans. Broadcasting, Vol. BC-9, No. 2, 1963.

[40] J.D. Parsons, The Mobile Radio Propagation Channel,(West Sussex: John Wiley & Sons, 1992).



Interference from other signals

Several respected engineers have expressed concern about interference from adjacent-channel and intermodulation interference sources.[41][42] This firm is aware of several failures of DTV reception that are clearly attributable to so-called "image interference" from strong undesired signals. Image interference is not presently considered by the FCC in DTV-to-DTV station allocation. It appears, however, that there are presently insufficient data to assess typical consumer receiver performance in practical situations. This is because of the relatively small number of "full power" DTV stations presently on the air and the small installed base of consumer DTV receivers. With regard to co- and adjacent-channel interference, the existing protection ratios as documented in OET Bulletin No. 69 might be used presumptively to determine the presence of interference in both calculation and measurement. While these protection ratios are not based upon measurements of actual consumer DTV receivers, they can be expected to provide reasonable goals for DTV receiver designs.

Quantifying the circumstances under which current-generation DTV receivers cannot produce a picture when given adequate signal requires considerable data collection and time, and we are aware of no such

---

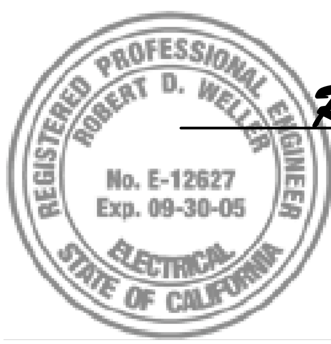
[41] Oded Bendov, "Interference to DTTV Reception by First Adjacent Channels," IEEE Trans. on Broadcasting, Vol. 51, No. 1, March 2005.

[42] Charles W. Rhodes, "Interference between Television Signals Due to Intermodulation in Receiver Front-Ends," IEEE Trans. on Broadcasting, Vol. 51, No. 1, March 2005.

efforts planned or underway. The absence of this critical data should *not* be used to imply that all reception issues have been resolved.

Clutter losses

As with NTSC signals, man-made and environmental clutter also effects DTV reception. Therefore, it remains important to include realistic clutter factors in the predictive model used for DTV.



Robert D. Weller

Robert D. Weller, P.E.

June 17, 2005