DTV: Gold Mine Or Land Mine?
Will Replication Of The NTSC Service Be Realized?

By Dane E. Ericksen, P.E., CSRTE
Chairman, SBE FCC Liaison Committee
Senior Engineer, Hammett & Edison, Inc., Consulting Engineers
San Francisco, California

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The world of Digital Television (DTV) is upon us, by mandate of the FCC, and life for broadcasters won't ever be the same. Will it be better, or won't it? Perhaps this is a new dawn of prosperity, with the capability for several channels (advertising streams) in the space of one, or perhaps actual over-the-air service to viewers will be something less than advertised.

This article addresses several technical issues that may bear on the critical questions posed above. Some issues were identified early on in the author's work to understand and implement the new FCC coverage and allocations procedures, such as the gross assumptions made by the FCC regarding "Error Code 3" messages from its new propagation prediction software. (For the uninitiated, this problem means that the "replication" percentages claimed by the FCC may not be realized, and it also means that certain stations may be subjected to more interference than would otherwise be allowed. See the Hammett & Edison Petition for Reconsideration, June 16, 1997, at www.h-e.com/misc/he87-268.pdf for further discussion of this issue, as well as the sidebar article about EC3.)

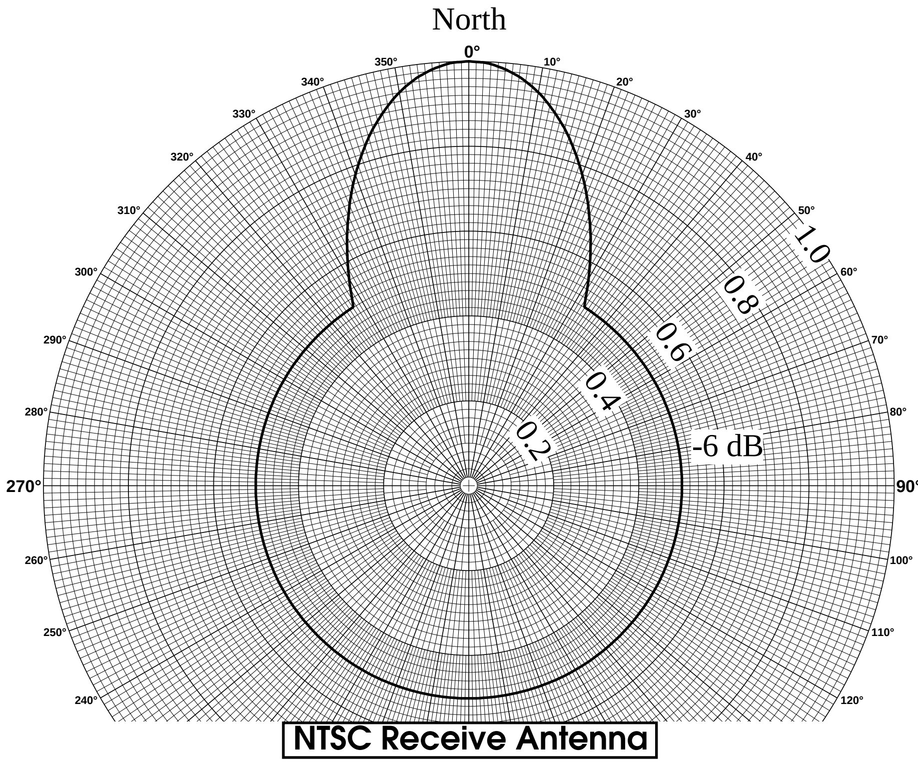
'Magic' Consumer Antennas – Another Odd Assumption By The FCC

As shown by Figures 1A, 1B, and 1C, examination of the FCC source code reveals that the FCC assumed different receiving antenna performance for VHF low-band, VHF high-band, and UHF receiving antennas depending on whether the antenna is receiving an NTSC or DTV signal. This is questionable, as clearly few viewers will erect separate receiving antennas for NTSC and DTV; rather, most viewers not on cable will just use their existing antennas to receive both signals. The off-axis (front-to-back) ratio of the presumed DTV receiving antennas are higher than the corresponding NTSC receiving antenna, as follows:

	low-band VHF	high-band VHF	UHF
rejection improvement vs. NTSC receive antenna	4 dB	6 dB	8 dB

The most likely explanation for the different (and better performing) receiving antennas assumed for DTV is that this was the only way the Commission could come up with high-sounding replication percentages in many markets that were announced with the DTV Table of Allotments. When coverage projections are made, this factor should be taken into account.

Different Consumer Receive Antenna Patterns, as Assumed by FCC "Replication" Program to Develop DTV Allotments
– Low-Band VHF –



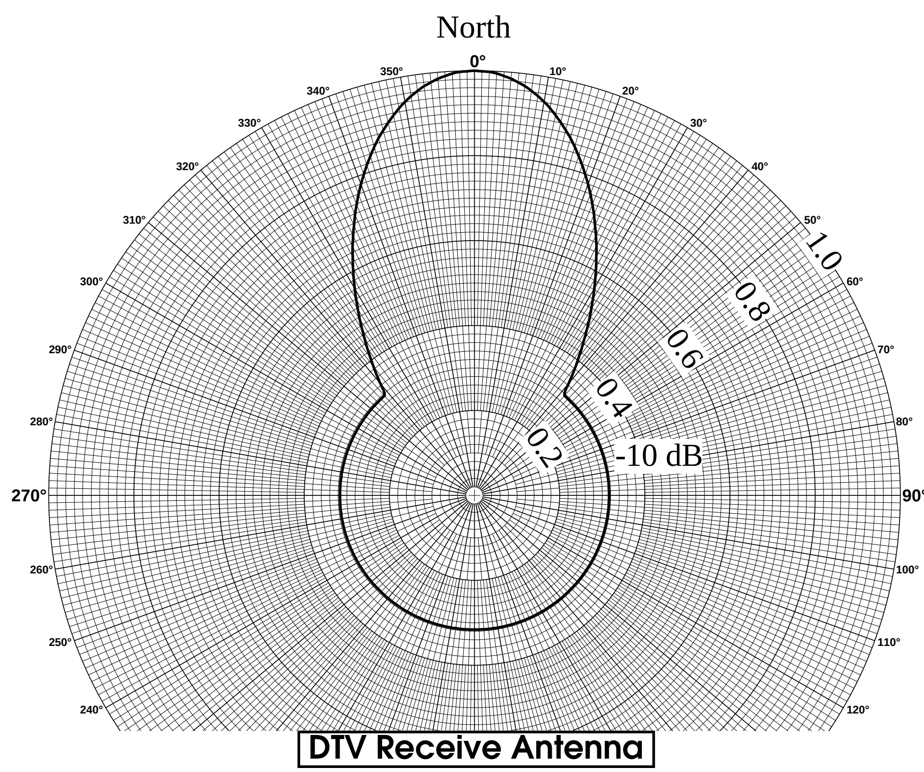
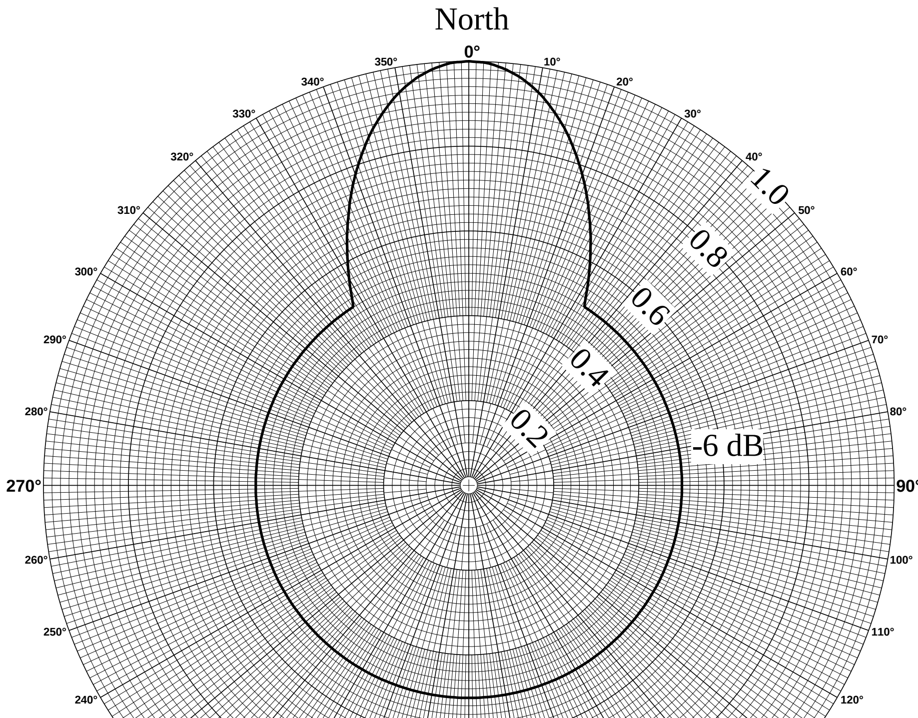
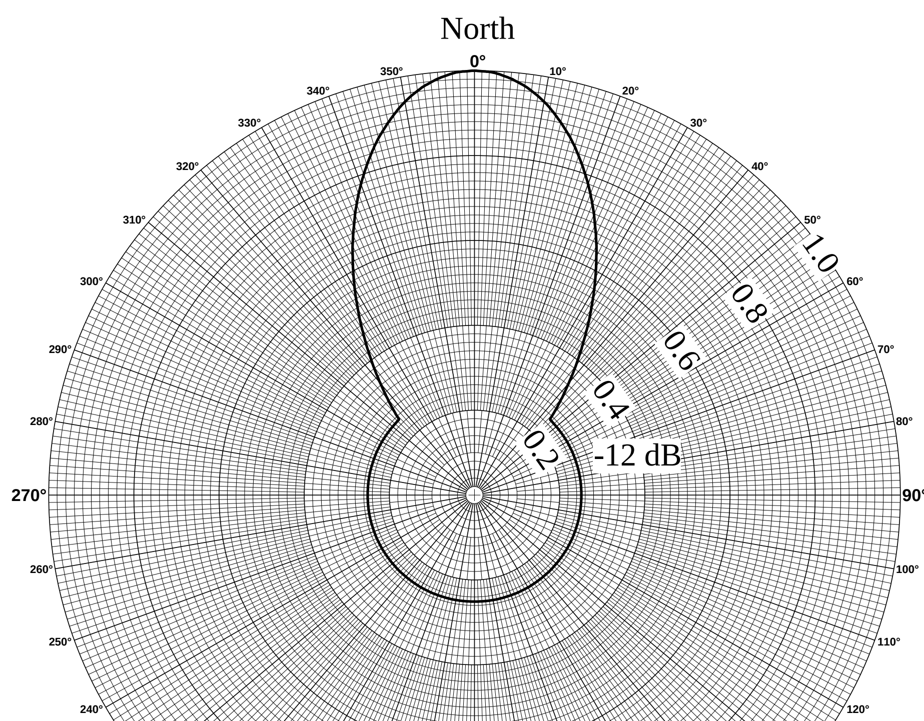


Figure 1A

Different Consumer Receive Antenna Patterns, as Assumed by FCC "Replication" Program to Develop DTV Allotments – High-Band VHF –



NTSC Receive Antenna

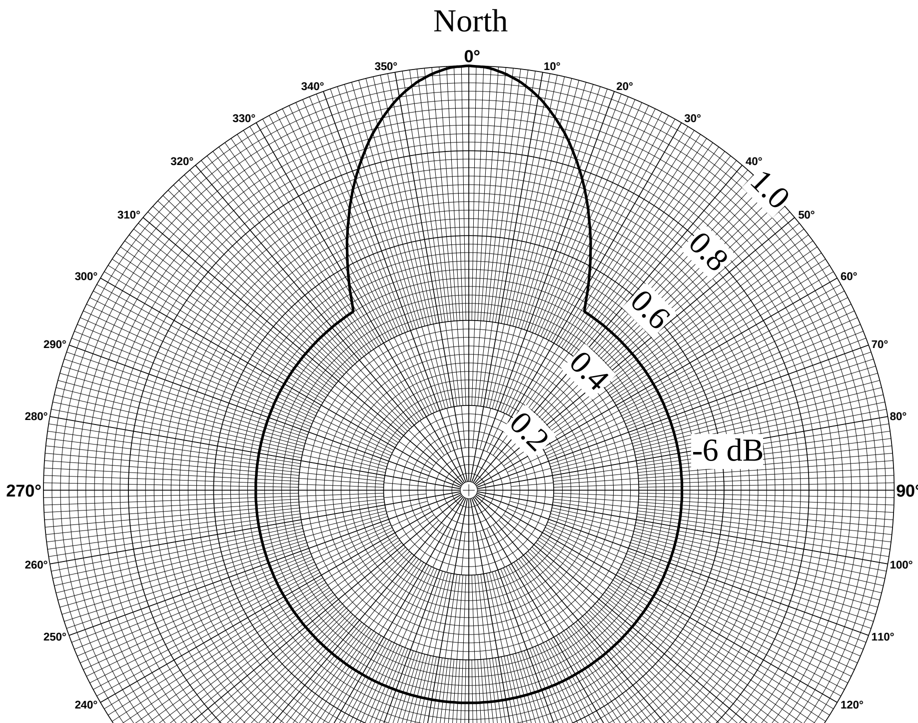


DTV Receive Antenna

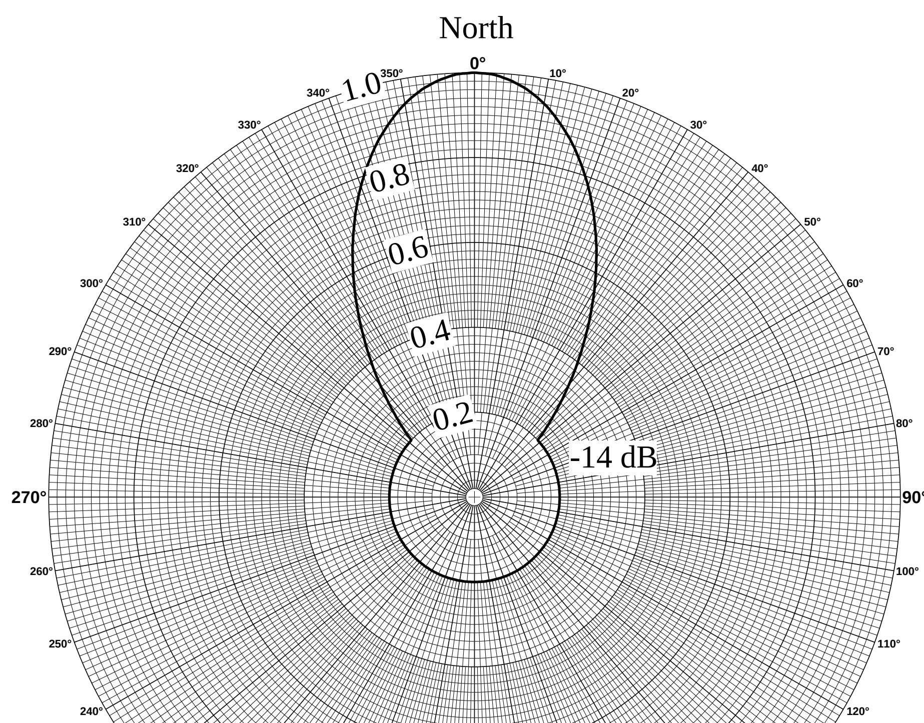
Figure 1B

Different Consumer Receive Antenna Patterns, as Assumed by FCC "Replication" Program to Develop DTV Allotments

– UHF –



NTSC Receive Antenna



DTV Receive Antenna

Figure 1C

The FCC Miscalculates Depression Angle

Another potential land mine involves miscalculation of the depression angle from transmitting antennas. Due to a source code error, the FCC OET-69 computer program calculates the depression angle based on the transmitting antenna's height above ground level (AGL) rather than height above mean sea level (AMSL). For stations that obtain their height from tall buildings or tall towers, this does not introduce much of an error. However, for stations that obtain their height from tall mountains, a significant error can be introduced. For example, the TV stations at Mt. Wilson, near Los Angeles, have typical center-of-radiation heights of only 300 feet AGL but 6,000 feet AMSL. This results in depression angle errors of 2.5 to 3.0 degrees to receive locations in the Los Angeles basin. When combined with the fact that most DTV allotments are UHF, and that UHF antennas typically have elevation pattern half-power beam widths ("HPBW") of 1.5 to 2.5 degrees, a 2.5 to 3 degree error in the calculation of depression angle can be significant.

Unlike the EC3 problem, which was the result of an intentional decision, the depression angle problem appears to have been the unintentional result of a source coding error. As shown by Figure 2, depicting a portion of the actual source code being used by the Commission's Office of Engineering and Technology (OET), there is now a "mod4" option to the source code that allows depression angles to be correctly calculated, if so requested by the Commission engineer running the study; however, as will be explained later in this article, it is believed that normally the Commission will use the uncorrected source code and so intentionally continues to miscalculate the depression angles to cells under study. This practice was pointed out by this writer (also the moderator of the morning and afternoon Technical Regulator Hot Topics for Broadcasters sessions at the recent NAB Convention) during the "Ask the FCC" panel, in response to a request from the Mass Media Bureau (MMB) representative to let him know about any processing problems.

However, the other panelist, representing OET, expressed an opinion that the depression angle calculation method could not be changed, despite the fact that nowhere in the Fifth or Sixth Report & Orders – or in the two Reconsideration Orders, or in OET-69 – were the formulas for the calculation of depression angles discussed, nor was there any indication that the FCC had intentionally planned to miscalculate depression angles.

Rather, the depression angle problem was discovered by H&E while examining the actual source code used by OET to develop the DTV Table of Allotments (available on the FCC OET web site at www.fcc.gov/oet/dtv). It is believed that a similar source code is presently being used by MMB staff to verify OET-69 interference studies submitted in support of NTSC applications and

FCC Source Code Addressing Depression Angle Calculation Error Problem

```
c
c  Vertical radiation factor.  The tables prepared for the 6th R&O and
c  reconsideration orders used antenna heights AGL and forced the
c  transmitter height to be at least 30.0 meters.  Under mod4, these
c  heights are reckoned AMSL and there is no minimum.
c
          n_ant = NTSC
          if (sta_type(k) .eq. 'a') n_ant = ATV
          call antenna_tilt(k, az, vpat_bias)
          if (mod4 .and. .not. per_6th_order) then
             height = rcamsl_tmp
             rec_height = path_elev_pt(n_ter_pts) + rec_ant_hgt
          else
             height = max(30.0, rcamsl_tmp - path_elev_pt(1))
             rec_height = rec_ant_hgt
          end if
          instance = LONGLEY_RICE
          call gt_vert_rad_fac(height, rec_height, dtc, vpat_bias,
     &         instance, iband, n_ant, v_fac)
          if (v_fac .lt. 1.0) then
             v_log = flog10(v_fac)
             field = field + 20.0*v_log
          end if
```

Figure 2

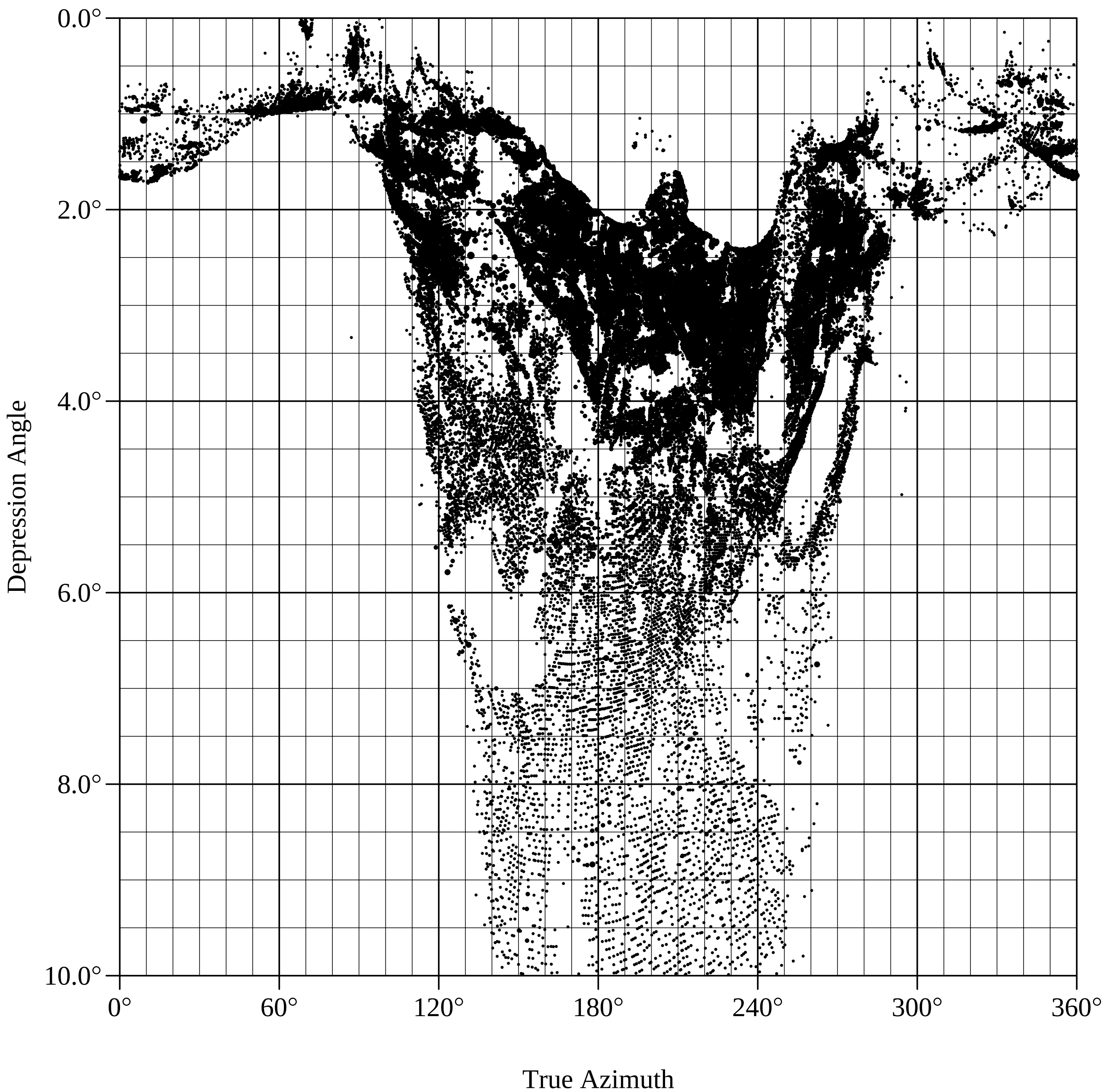
non-checklist DTV applications. "Non-checklist" applications are those proposing greater height or power than allotted by the FCC or a site more than 5 km from the NTSC station.

To appreciate the magnitude of the problem, Figure 3A shows a plot of depression angles to Census population centroids within 160 kilometers of Mt. Wilson, using a center-of-radiation height of 1,817 meters AMSL/80 meters AGL (these are the actual heights proposed for a DTV station at Mt. Wilson). Figure 3B shows those same depression angles calculated by the incorrect FCC method. Obviously, there is a significant difference, with the potential to overwhelm the 2 percent or 0.5 percent de minimus interference thresholds allowed by the FCC.

Actual Elevation Pattern Problem

OET-69 provides generic UHF NTSC and DTV elevation patterns; these are shown in Figures 4A (for NTSC) and 4B (for DTV). Since these patterns were used to develop the DTV Table of Allotments and the “baseline” noise-limited, interference-free service for NTSC stations and DTV allotments, their use is necessary if OET-69 interference studies for facilities maximization are to replicate the FCC baseline populations. Of course, accurately replicating the FCC baseline populations is critical for determining whether a proposed facility will cause no more than de minimus new interference. There are two items to note regarding the OET-69 generic UHF elevation patterns: 1) Table 8 of OET-69 provides values only from 0.75 degrees below the horizontal to 10 degrees below the horizontal (and note that a positive beam tilt indicates an angle below the horizontal; that is, a beam tilt of 90 degrees means straight down, and a beam tilt of -90 degrees means straight up) and 2) an electrical beam tilt (“EBT”) of 0.75 degrees for both the NTSC and the DTV elevation patterns is presumed. Unfortunately, many NTSC stations on tall mountains have more than 0.75 degrees of EBT, and many employ a combination of electrical and mechanical beam tilts. Figures 5A and 5B demonstrate why good designs often employ both electrical and mechanical beam tilts. Figure 5A shows a transmitting antenna with a half-power beam width (“HPBW”) of 3.6 degrees (corresponding to a Dielectric TFU-18GTH antenna) and with 2 degrees of electrical beam tilt. The site is for a DTV station in the California Central Valley, on a 3,400-foot AMSL mountain approximately 30 miles east of the station’s principal community, which has an elevation of about 300 feet AMSL. It can be seen from Figure 5A that 2 degrees of EBT would provide reasonably good coverage of the population distribution (and also that the 0.75 degrees of EBT presumed by OET-69 would not; indeed, an EBT of only 0.75 degrees would result in most of the station’s power being radiated hundreds to thousands of feet over the heads of potential viewers). However, Figure 5B, which adds 1 degree of mechanical beam tilt (“MBT”) toward 250 degrees true, the direction to the major population center, will result in almost a

Depression Angle vs. Azimuth to Population Centroids Within 160 km of Mt. Wilson Based on a COR Height of 1,817 m AMSL



Dots represent 1990 U.S. Census Blocks.

Figure 3A

Depression Angle vs. Azimuth to Population Centroids Within 160 km of Mt. Wilson Based on Incorrect FCC Method

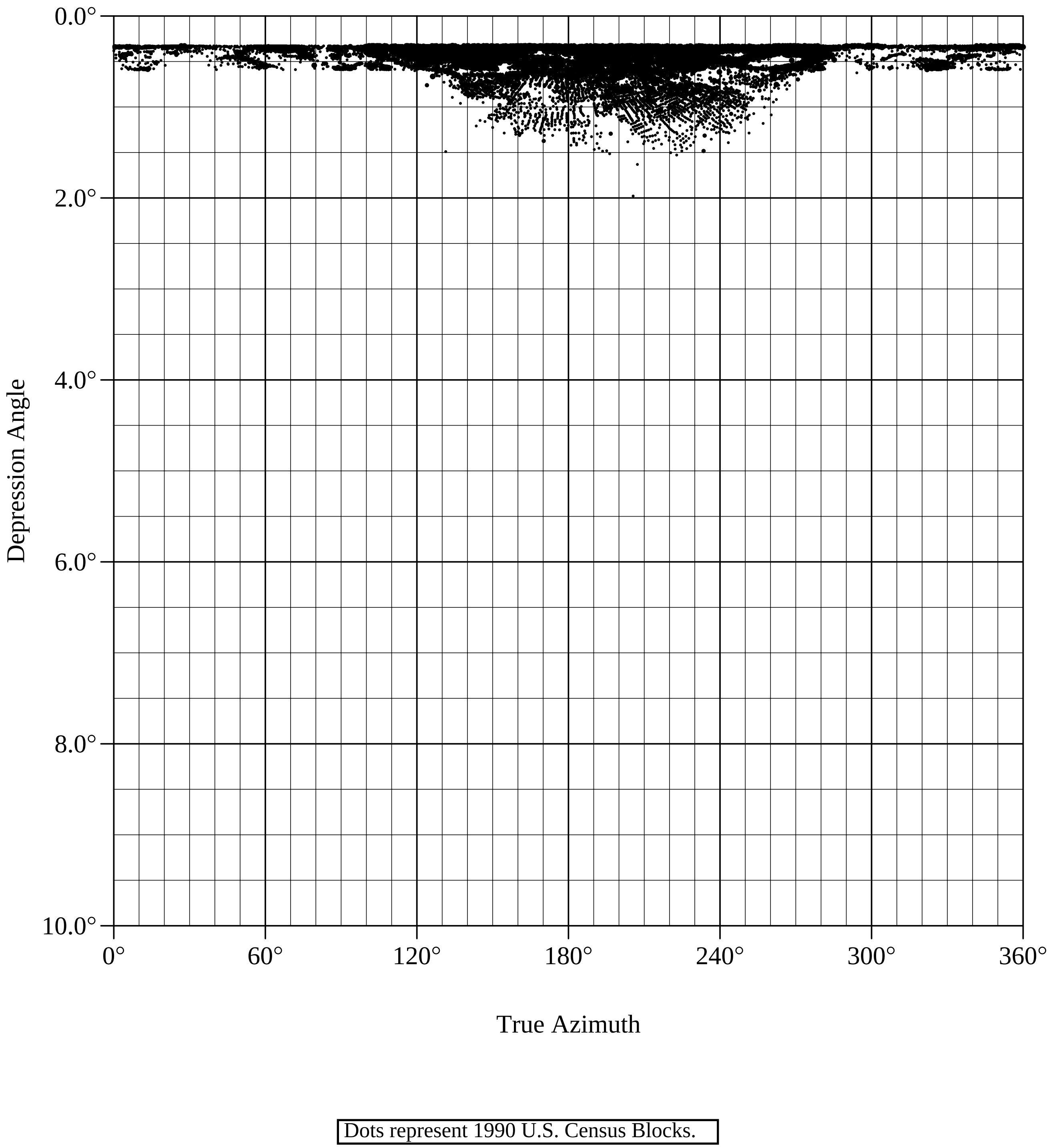
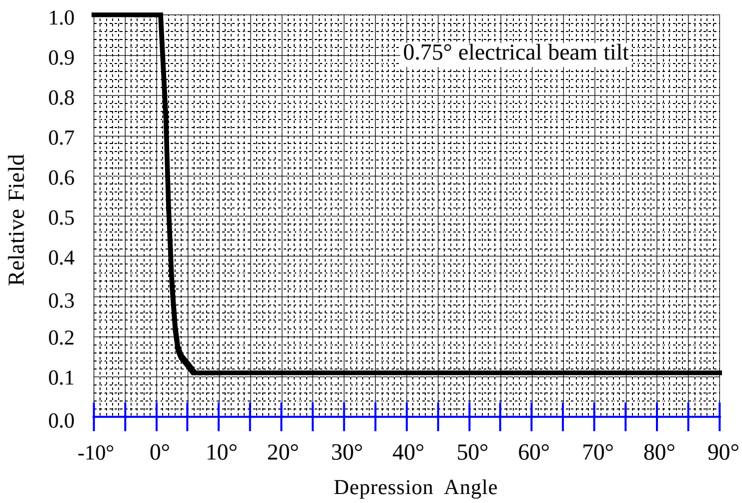
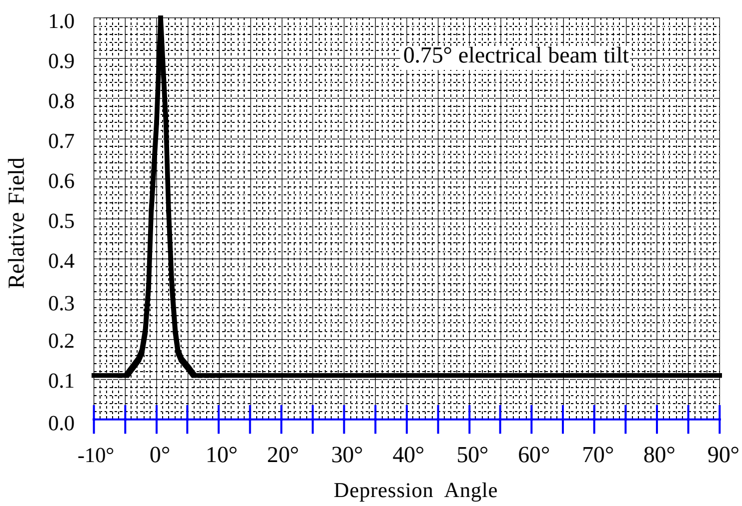


Figure 3B

OET-69 NTSC UHF Elevation Patterns: Flat vs. Symmetric



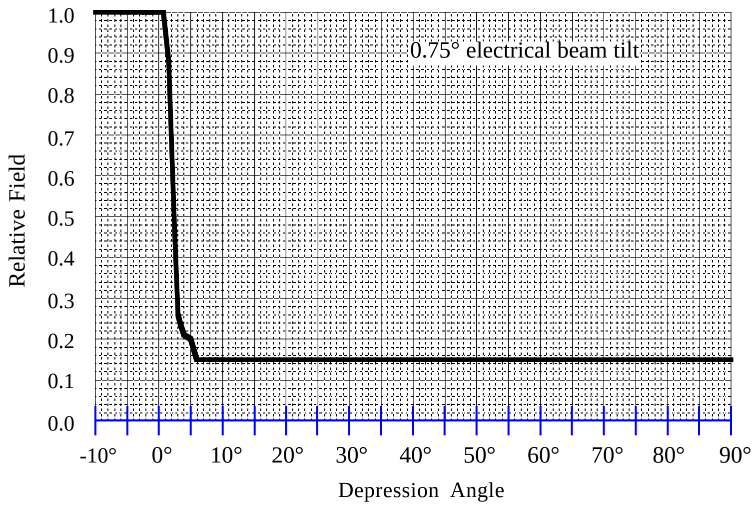
"FLAT"



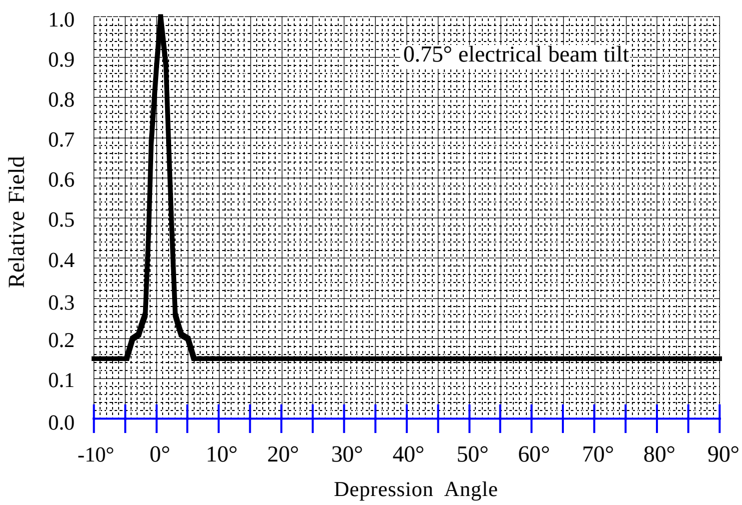
"SYMMETRIC"

Figure 4A

OET-69 DTV UHF Elevation Patterns: Flat vs. Symmetric



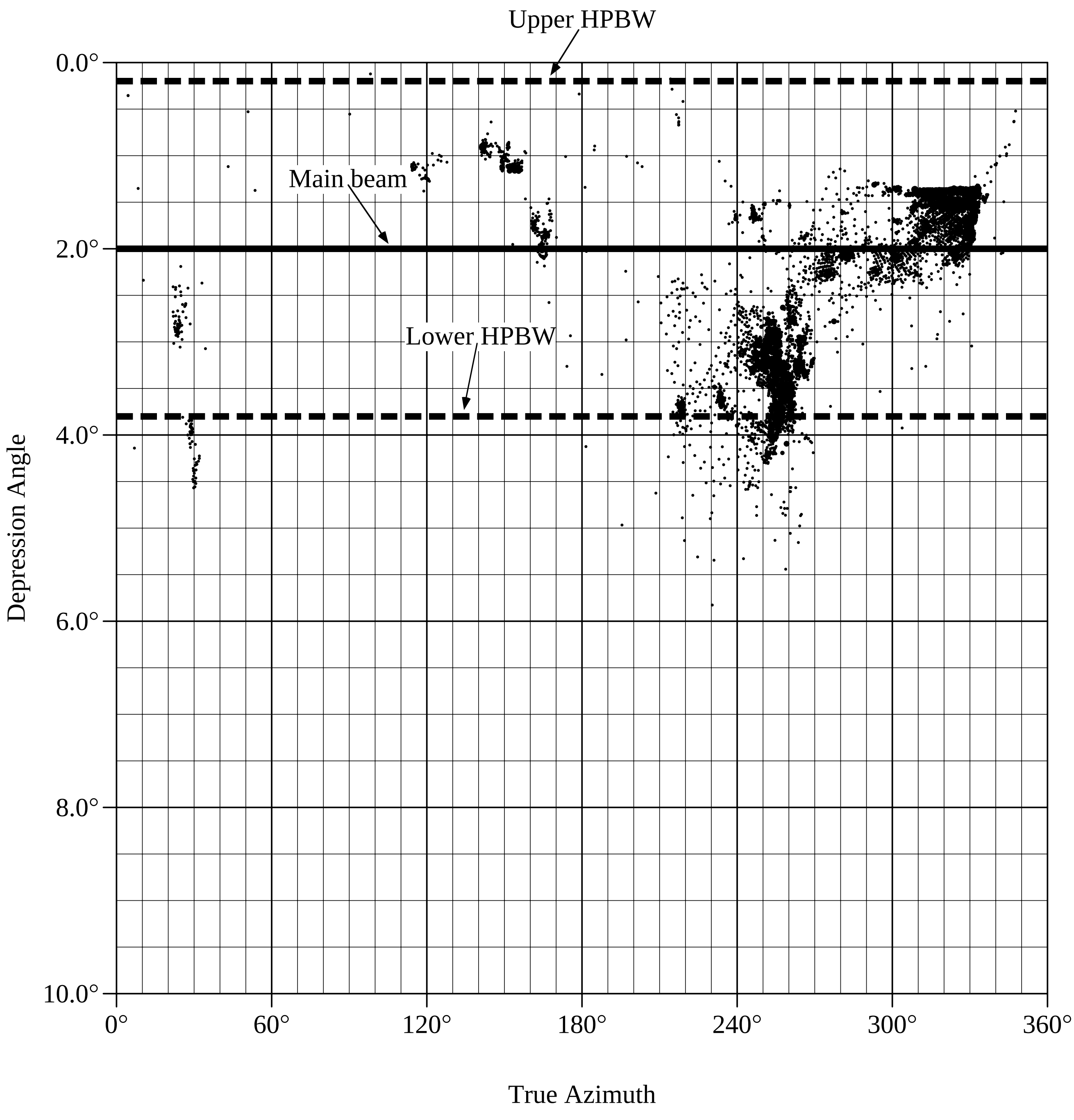
"FLAT"



"SYMMETRIC"

Figure 4B

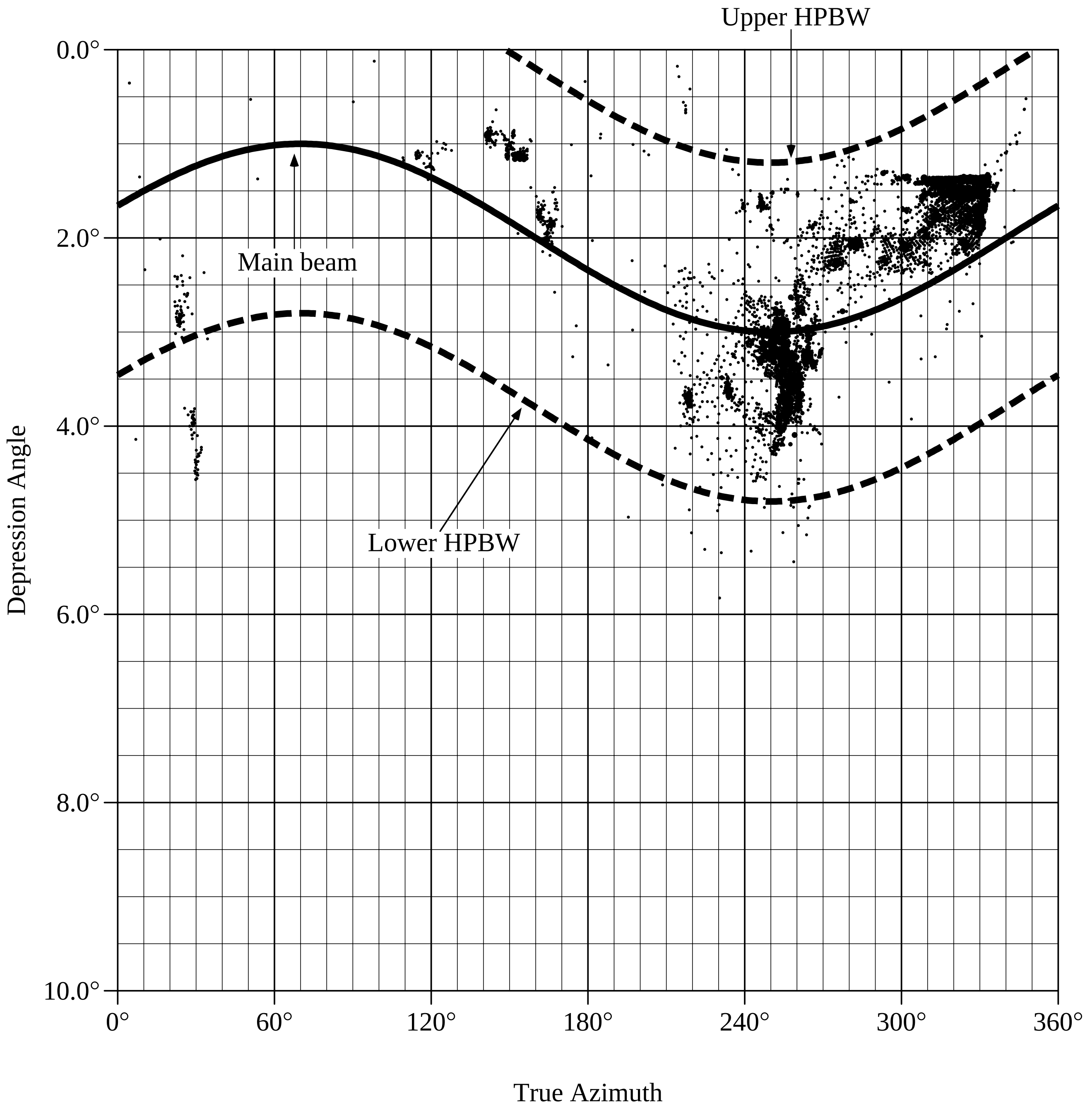
Elevation Pattern Plot for 3.6-Degree HPBW Antenna with 2° of EBT



Dots represent 1990 U.S. Census Blocks.

Figure 5A

Elevation Pattern Plot for 3.6-Degree HPBW Antenna with 2° of EBT Plus 1° MBT Toward 250°T



Dots represent 1990 U.S. Census Blocks.

Figure 5B

doubling of the ERP toward that population center, with no increase in transmitter power output. The mechanical beam tilt also improves coverage to population centers at 120 degrees true, 150 degrees true, and 165 degrees true from the transmitter site.

However, the inclusion of MBT means that the main beam and horizontal plane azimuth patterns are no longer the same, as shown in the attached Figure 6A; the solid line is the main-beam azimuth pattern (corresponding to the Dielectric TLP-M pattern at 270 degrees true) while the dashed line is the horizontal plane azimuth pattern. Even greater departures are possible; for example, Figure 6B shows the main-beam versus horizontal plane patterns for a Mt. Wilson UHF station with 1.6 degrees of EBT and 0.6 degrees of MBT toward 225 degrees true. The main-beam pattern is a Dielectric S180 at 172 degrees true, whereas the horizontal plane pattern has its maximum at 92 degrees true. The horizontal plane pattern is important because it is that pattern that Section 73.685(e)(2) of the NTSC Rules, and Section 73.625(c)(3)(ii) of the DTV Rules, states must be provided in applications that propose a directional transmitting antenna. Further, the Rule states, "Where mechanical beam tilt is intended, the amount of tilt in degrees of the antenna vertical axis and the orientation of the downward tilt with respect to true North must be specified, and the horizontal plane pattern must reflect the use of mechanical beam tilt." Thus, both the NTSC and DTV Rules are clear that 1) it is the horizontal plane azimuth pattern and not the main-beam azimuth pattern that is to be used and 2) the horizontal plane azimuth pattern must reflect the effect of MBT when used. In other words, this is not an ambiguously worded rule. It should also be noted that the magnitude of the "modulating" effect of MBT on the main-beam pattern depends on 1) the elevation pattern shape; 2) the amount of EBT; 3) the amount of MBT; and 4) the direction of the MBT.

Unfortunately, some FCC staff believe applications proposing MBT as well as EBT must be specially studied using the main beam pattern (which neither the Rules nor Form 301/340 nor OET-69 require even be submitted), using correctly calculated depression angles, and using either the actual elevation pattern or a customized version of the OET-69 generic elevation pattern, made symmetrical around its main beam (these are referred to as the "symmetric" versions of the OET-69 patterns). Although this writer agrees these steps result in more accurate interference studies, requiring such additional studies for some applications but not others raises an obvious fairness issue.

Confusion On Whether NTSC Stations On Taboo Channels Must Be Protected

At the recent 52nd NAB in Las Vegas, it became clear that many engineers were confused

Comparison of Main-Beam and Horizontal Plane Azimuth Patterns for Station with 2° EBT Plus 1° MBT at 250°T - Relative Field -

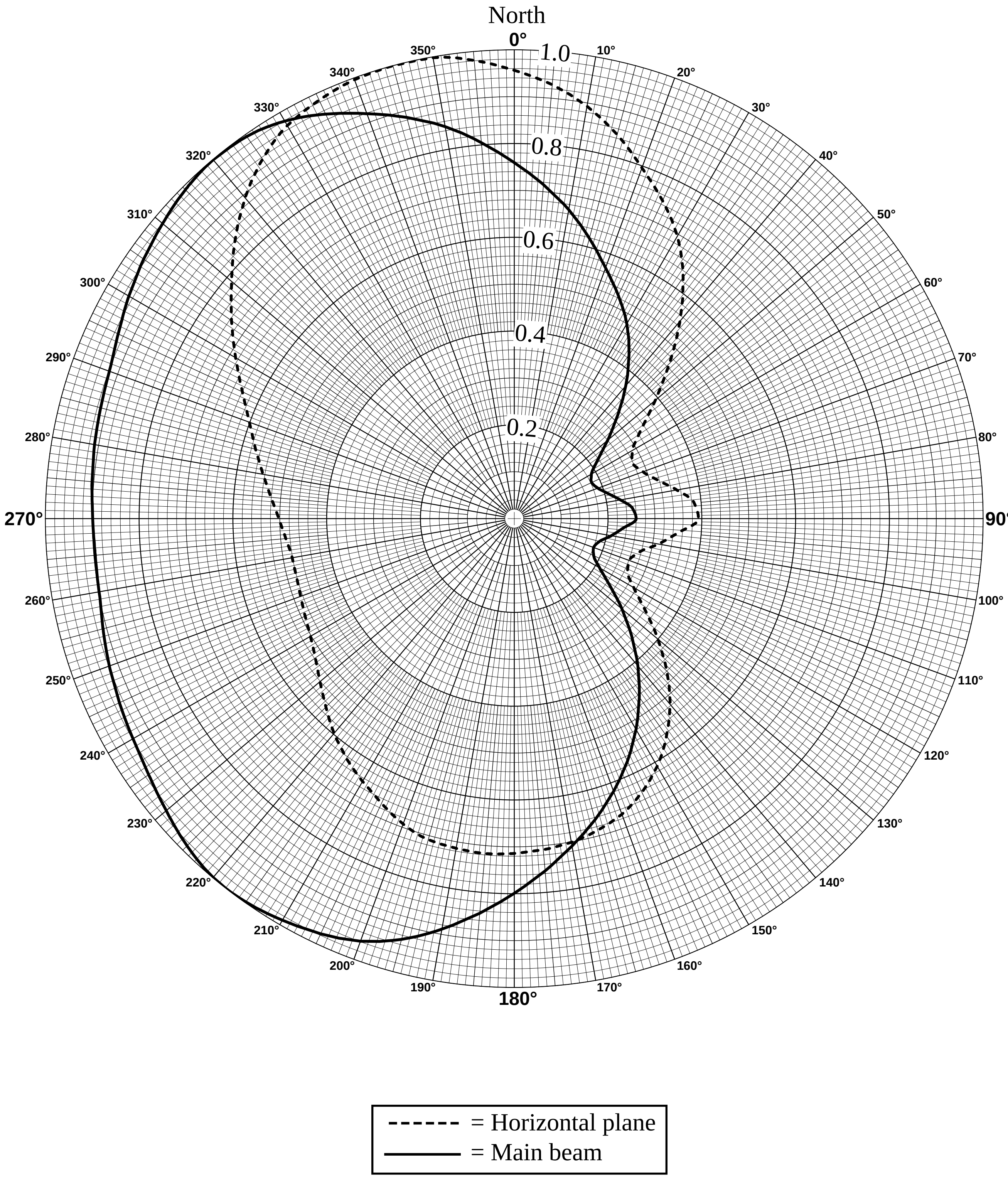


Figure 6A

Comparison of Main-Beam and Horizontal Plane Azimuth Patterns for Station with 1.6° EBT Plus 0.6° MBT at 225°T - Relative Field -

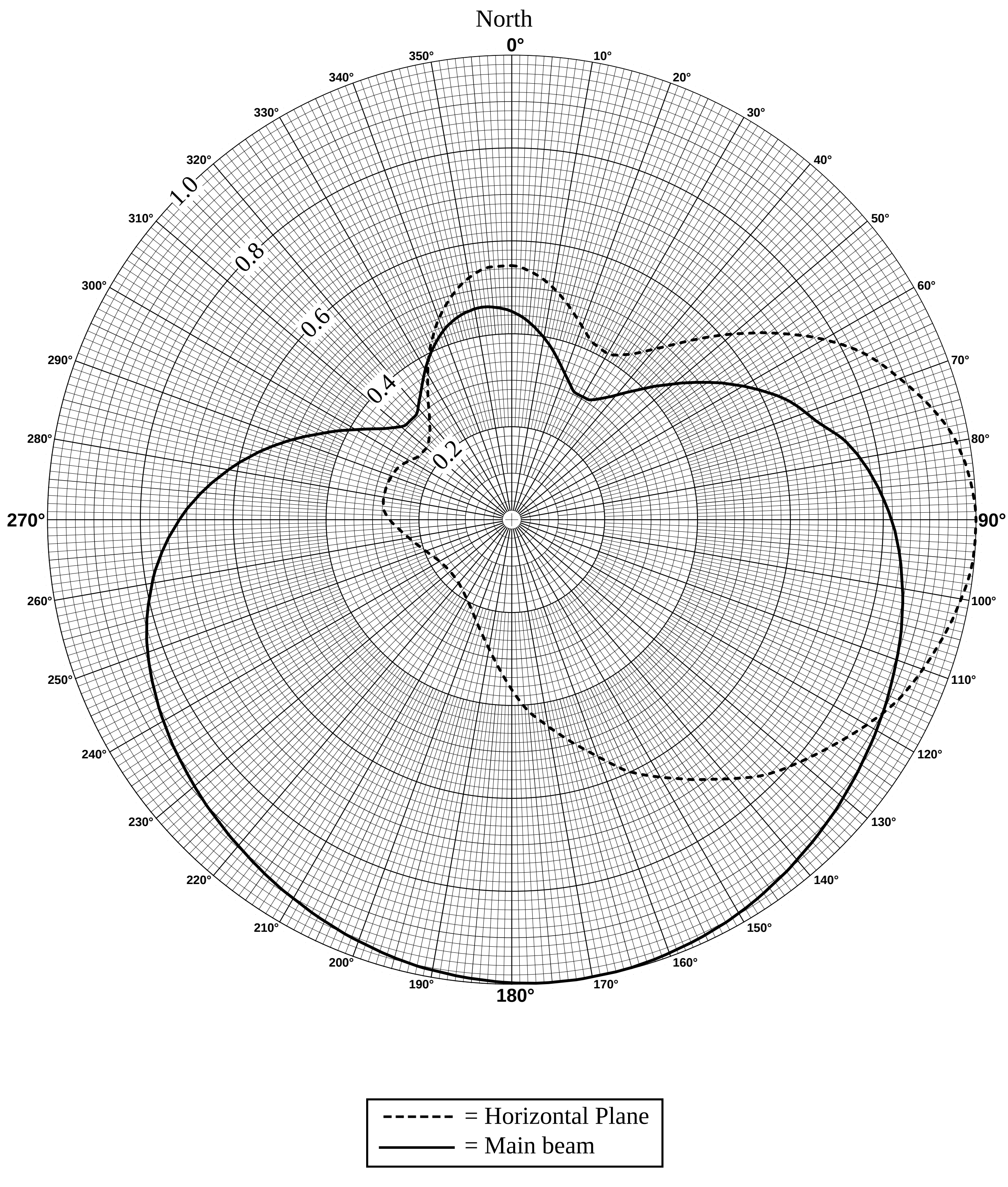


Figure 6B

about whether non-checklist DTV applications must demonstrate protection of NTSC stations on taboo channels; that is, ±2, ±3, ±4, ±7, ±8 channels, +14, and +15 channels removed from the NTSC channel. The protection requirements are spelled out in Section 73.623(c)(2) of the FCC Rules and also by the fact that Table 7 of OET-69 lists triggering distances for the taboo channels (for example, OET-69 requires that receive locations within 35 kilometers must be studied for NTSC stations ±2, ±3, or ±4 channels removed from a DTV station that proposes non-checklist facilities). If the DTV applicant can demonstrate that no more than 2 percent additional interference will result (and assuming that the NTSC station is not one of the 15 "don't touch" NTSC stations listed on Page 17 of the August 10, 1998, FCC Public Notice as already suffering a 10 percent or greater interference loss, or that the new DTV interference would not cause the NTSC station to go from less than 10 percent cumulative interference to greater than 10 percent cumulative interference), then the DTV application should be grantable, assuming no other problems.

There was also discussion of whether DTV stations filing non-checklist applications under the "no contour extension/beam tilting" provisions of Section 73.622(f)(4) of the FCC Rules must serve a copy of that application by certified mail on nearby NTSC stations on taboo channels. According to a senior MMB official at the "Ask the FCC" panel of the 1999 Convention NAB, this requirement only applies to nearby co-channel or adjacent-channel NTSC stations.

It should be noted that a DTV station wishing to maximize its facilities pursuant to the Commission's December 18, 1998, Second Memorandum Opinion and Order on Reconsideration of the Fifth and Sixth Report and Orders ("Second Reconsideration Order") is under no obligation to serve copies of its application on any nearby NTSC stations, co-channel, adjacent-channel, or otherwise. The Second Reconsideration Order is more liberal than the Section 73.622(f)(4) conditions, which require 1) no extension of the DTV contour and 2) calculations based on the proposed antenna gain augmented by 1 dB; in addition, of course, to a showing of no more than de minimus additional interference to other stations or allotments. DTV stations wishing to maximize their facilities pursuant to the Second Reconsideration Order must instead study all under-200 kW UHF DTV allotments twice: first based on the station's allocated power, and a second time, based on assumed 200 kW ERP facilities.

Too Lenient D/U Ratios For UHF Taboos?

At the "DTV Transmission Systems" session and the 1999 NAB Convention, Mr. Stanley Salamon of the Advanced Television Technology Center (ATTC) presented a paper, "DTV Taboo

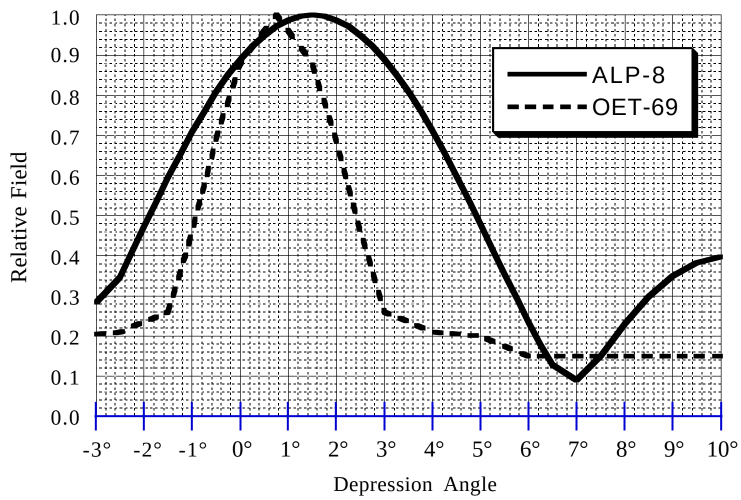
Channel Interference into NTSC at High Power Levels," suggesting that in strong signal areas the desired-to-undesired ("D/U") adopted by the FCC for protection of NTSC stations on taboo channels to a DTV allotment were too lenient by 20 to 23 dB. This suggests that NTSC stations in the unfortunate position of having one or more DTV allotments on their taboo channels may be in for difficult times if those DTV stations are 1) in an area that is a "strong signal" area for the NTSC station and 2) in an area that is heavily populated. For example, one San Francisco UHF NTSC station not located on the Sutro Tower in the Twin Peaks area of San Francisco, home to ten NTSC stations, has taboo channel relationships to no fewer than six of the ten DTV channels allocated to the NTSC stations on the Sutro Tower. If, in fact, the FCC significantly underestimated the NTSC taboo channel ratios, then reception of the taboo-challenged NTSC channel over a wide portion of San Francisco may well become difficult or impossible.

Even if the ATTC findings prove to be a false alarm (and this writer has no reason to believe that to be the case, having heard the presentation first hand), NTSC stations with DTV allotments on their taboo channels would be prudent to keep a wary eye on any non-checklist applications that the DTV stations might file, especially if such modified facilities would result in the DTV stations being constructed in a heavily populated area. Why? Because the OET-69 study may well underpredict the signal levels at the steep depression angles around the DTV site, due to use of a generic elevation pattern that probably does not accurately model the actual elevation pattern. Especially if a relatively low-gain antenna with a wide elevation pattern HPBW is used, or a significant amount of null fill is employed, then the D/U ratios to cells near the proposed DTV station may be incorrectly calculated. For example, Figure 7 compares the elevation pattern of an Andrew ALP-8 elevation pattern with 1.5 degrees of EBT to the OET-69 UHF DTV elevation pattern. It can be seen that use of the actual elevation pattern rather than a generic one would be desirable for application processing purposes.

Conclusion

At Paragraph 116 to the Fifth R&O, the Commission stated it would hold a "periodic review every two years until the cessation of analog service" in order to ensure the smooth introduction of DTV and the timely recovery of spectrum upon the demise of analog television service. The FCC further went on to state that, "During these reviews, we will address any new issues raised by technological developments, necessary alternations in our rules, or other changes necessitated by unforeseen circumstances." That two-year period is now upon us, and it is the hope of this author that the Commission will consider the issues raised in this article. To that end, on August 26, 1999, the firm of Hammett & Edison, Inc. filed formal Biennial Review comments to

Comparison of ALP8 Elevation Pattern with 1.5° EBT to Symmetricized Version of the OET-69 UHF DTV Elevation Pattern



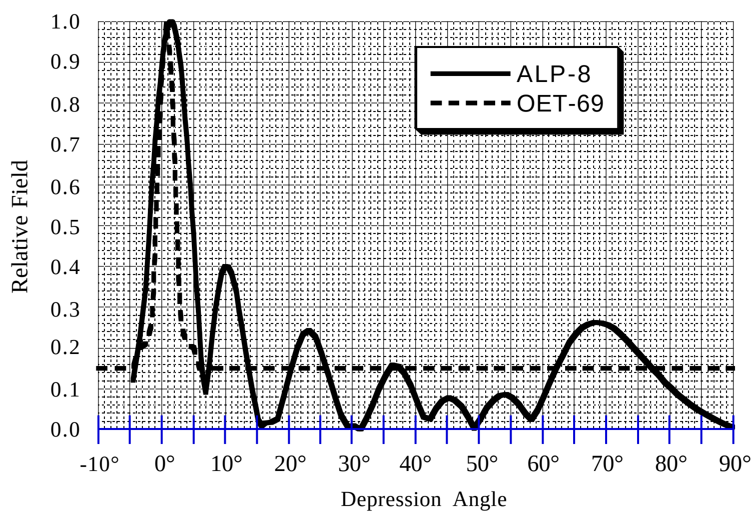


Figure 7

MM Docket 87-268, addressing these, and other, DTV processing issues. Those comments are now in the FCC's Electronic Comment Filing System (ECFS) and can be downloaded as a 34-page Adobe Acrobat portable document file. The author wishes to thank Mr. Robert Eckert of the FCC's Office of Engineering Technology for his cooperation in dealing with a long list of questions on exactly how the FCC implements certain aspects of the Mass Media Docket 87-268 rulemaking; it is caring civil servants like Mr. Eckert who soften the hard edge of federal regulation.

Dane E. Ericksen is a senior engineer with Hammett & Edison, Inc., Consulting Engineers, with offices near San Francisco. Prior to joining H&E in 1982, Mr. Ericksen worked from 1970 to 1982 at the FCC's San Francisco field office, and was an FM/TV/Cable Specialist in charge of the Commission's Western FM/TV Enforcement Unit. Mr. Ericksen serves on the SBE Board of Directors, the NAB/SBE Engineering Conference Committee, the SBE Certification Committee, and Chairs the SBE FCC Liaison Committee, which has responsibility for drafting all national-level SBE filings with the FCC and other regulatory bodies. Mr. Ericksen is a Registered Professional Engineer and is SBE certified at the Senior Broadcast Engineer levels in both Radio and Television.

The Longley-Rice Error Code 3

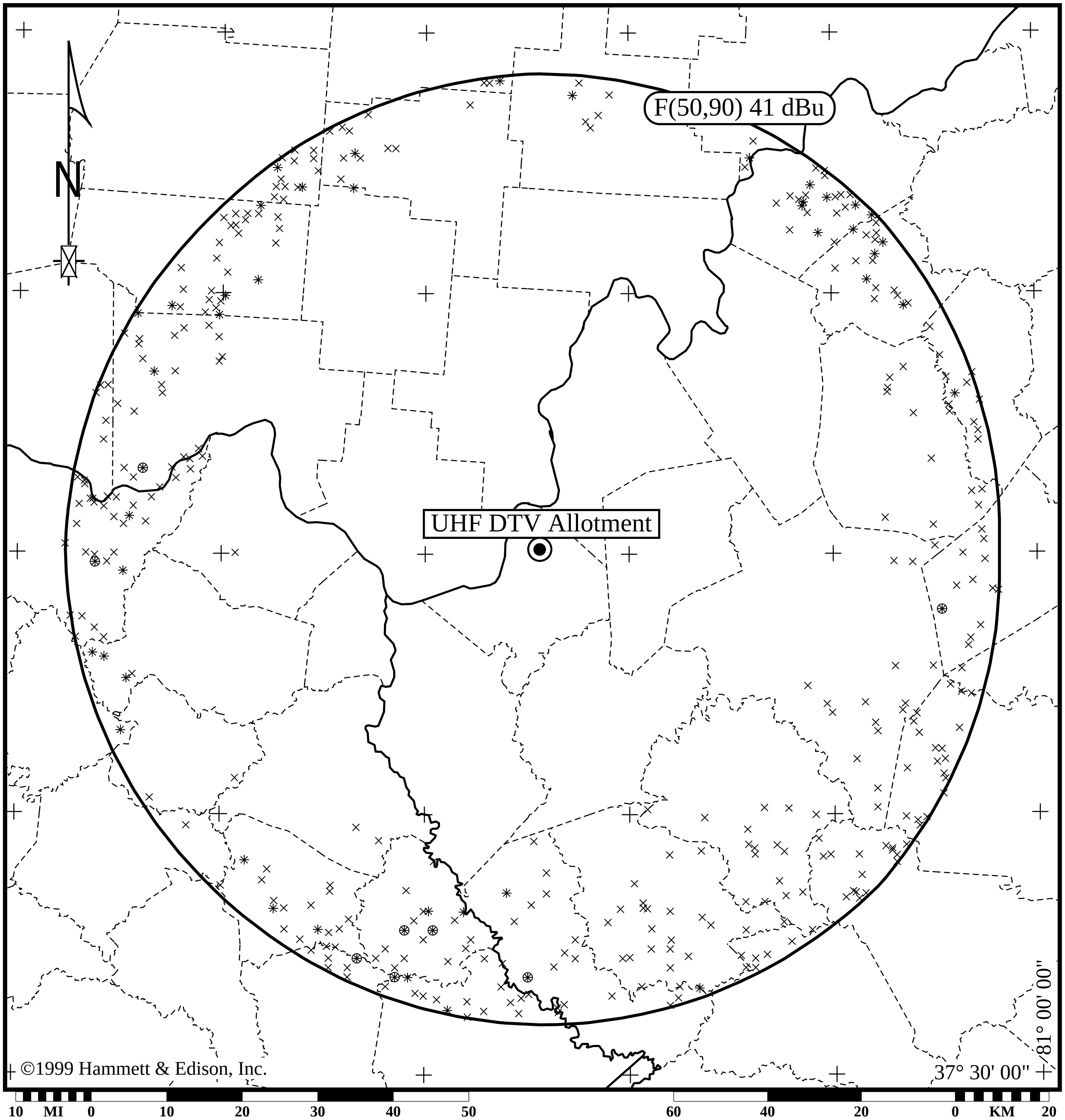
The heart of the Longley-Rice Error Code 3 (EC3) issue is just how often do cells with EC3 occur? At the time that the FCC was creating the DTV Table of Allotments, FCC staff apparently believed that relatively few cells returned EC3, and therefore a policy that 1) assumed that the desired signal was above its NTSC or DTV threshold level and 2) assumed to be interference-free, was a reasonable solution to the problem. However, our analysis of EC3 for 1,601 DTV allotments in the contiguous United States (i.e., excluding Alaska, Hawaii, Puerto Rico, Guam, and the Virgin Islands) reveals the following prevalence:

Percentage of DTV Allotments	Percent of population in Cells with EC3
2.8%	<0.1%
7.1	0.1 – 1
16.0	1 – 5
16.0	5 – 10
23.4	10 – 20
28.1	20 – 50
6.5	50 – 90
0.1	> 90

On the average, 18.2 percent of a DTV allotment's population fell in EC3 cells, which is troubling. It makes little sense to have a 2 percent de minimus criteria for DTV stations, and a 0.5 percent de minimus criteria for NTSC stations, when the underlying prediction model has an average error of 18 percent. Under the FCC's de minimus policy, a modifying DTV station is generally allowed to cause up to 2 percent additional interference to an existing NTSC station or to a DTV allotment on the presumption that such additional interference is minor, or de minimus. NTSC stations that need to modify their facilities are held to a more restrictive criteria where the loss in population served must be less than 0.5 percent of the DTV station's predicted noise-limited, interference-free population. Figure 8A shows the OET-69 coverage for a West Virginia UHF DTV allotment. At first glance, the white areas, representing cells where 1) the cell was predicted to have a signal strength equal to, or greater than, the station's DTV threshold, and 2) the cell was not predicted to receive interference from any other station. However, when the Longley-Rice EC3 cells are added, as shown in Figure 8B, things no longer look so good: 59.7 percent of the cells, containing 57.6 percent of the allotment's potential population, are EC3 cells. (Additional examples of the chronic nature of EC3 can be found on the H&E web page.)

It should be noted that EC3 cells can be defined in two different ways: only count EC3 cells

OET-69 Coverage for West Virginia UHF DTV Allotment (without EC3 Cells)

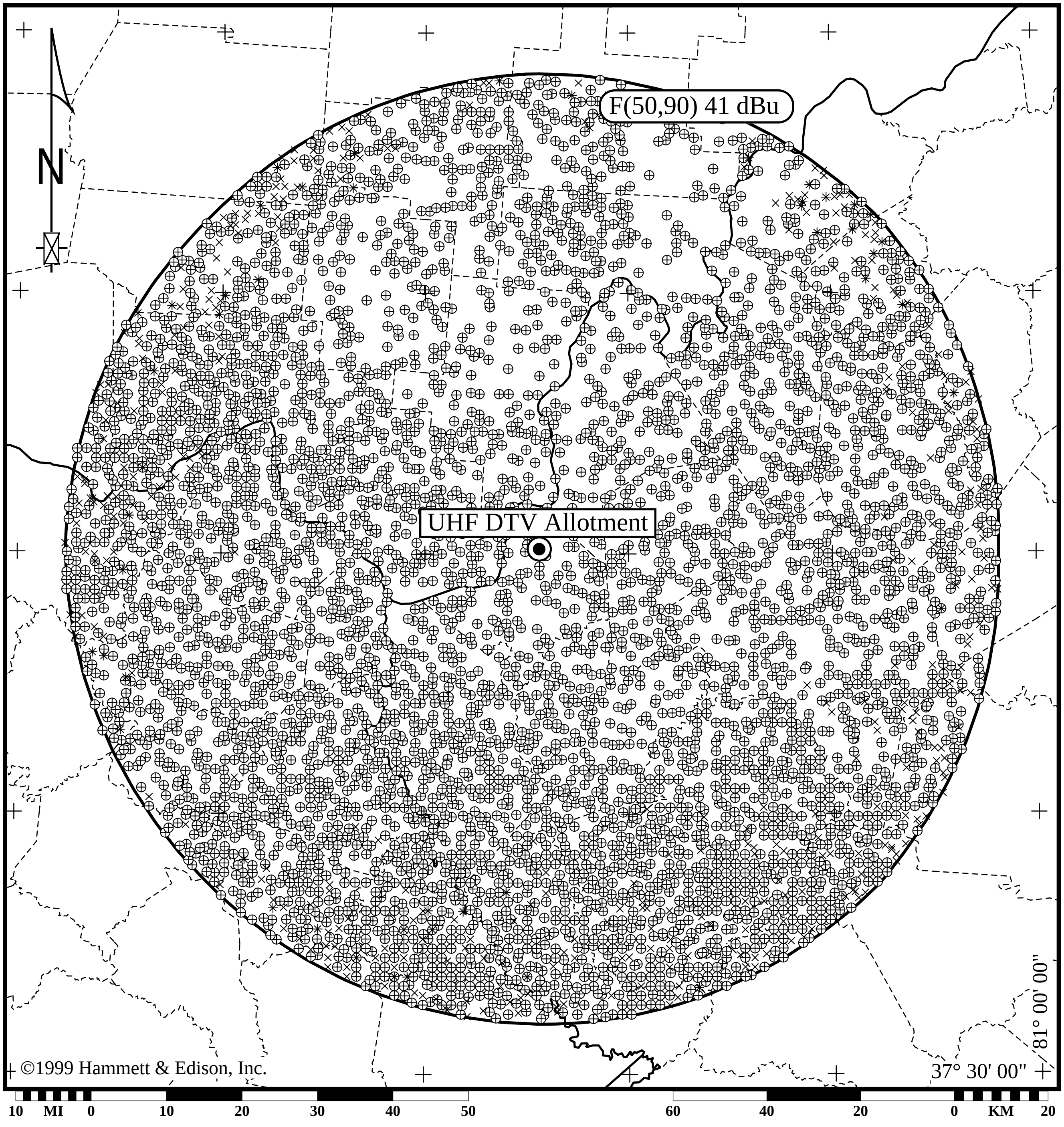


Lambert conformal conic map projection. Geographic coordinate marks shown at 30-minute increments.

×= No Signal (below threshold)
∗= Interference (with population in cell)
⊛= Interference (without population in cell)

Figure 8A

OET-69 Coverage for West Virginia UHF DTV Allotment (with EC3 Cells)



Lambert conformal conic map projection. Geographic coordinate marks shown at 30-minute increments.

×= No Signal (below threshold)
∗= Interference (with population in cell)
⊛= Interference (without population in cell)
⊕= Longley-Rice error cell

Figure 8B

as those cells that return EC3 for a desired signal; or also include cells where EC3 is generated for an undesired signal, if the undesired signal could affect the cell status. For example, if a cell has its desired signal above its NTSC or DTV threshold and is EC3-free, but if there is an interfering signal that returns EC3, then that cell could be counted as an EC3 cell, because the indeterminate status of the interfering signal has the potential to change the cell's status. On the other hand, if a cell has a desired signal that is EC3-free but calculates to below the desired signal's NTSC or DTV threshold, then that cell would not be counted as an EC3 cell if one of more interferors return EC3, because cells that are below the desired signal's NTSC or DTV threshold are not entitled to protection, and therefore an EC3 condition for one or more undesired signals could not affect the cell's status. If the more restrictive EC3 definition is used, then the nation-wide average drops to 7.0 percent, but this is still a troubling uncertainty.