

**A STUDY OF ATSC (8-VSB) DTV COVERAGE IN WASHINGTON, DC,
AND GENERATIONAL CHANGES IN DTV RECEIVER PERFORMANCE**

**Project TRB-00-1
Interim Report**

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Executive Summary

This report presents the results to date of a field study being conducted by the Office of Engineering and Technology (OET) of ATSC-standard 8-VSB digital television coverage in the Washington, DC, area using current-generation receiving equipment. It also compares the performance of five DTV receivers representing the developmental evolution of 8-VSB receivers from first-generation consumer receivers to the latest prototypes.

Data collection in the Washington, DC, area is approximately 50% complete. Fifty-one coverage sites and nine sites specially selected for strong-signal, high-multipath characteristics have been measured so far. A similar data collection and analysis effort for the Baltimore, MD, area is planned to commence immediately upon completion of the Washington effort.

Receiver comparison measurements indicate an approximately 2 - 3 dB improvement in the median signal-to-noise ratio required to produce a picture between the earliest-generation receivers and the latest prototypes at the sites used for coverage evaluation. This spread increases to 6 - 7 dB for the sites selected for strong-signal, high-multipath characteristics. This is indicative that improved channel equalizers in newer receivers will improve overall DTV coverage.

The study also compared NTSC reception with 8-VSB DTV reception at most of the 51 sites in the coverage sample using both the directional antenna on the 30-foot mast and the indoor antennas mounted on the 7-foot the tripod. For these studies, reception on analog channels 32 and 50 was compared with DTV reception on channels 34 and 48. These pairings yielded a total of 98 observations comparing NTSC and DTV service using the mast antenna and 93 observations using the tripod antenna. With the 30-foot mast mounted antenna, 67 percent of the observations produced an NTSC picture with a CCIR rating of 3 or above; 99 percent of the observations (all except one) produced a DTV picture without impairments. With the tripod-mounted indoor antennas (either a bowtie antenna and/or a "Silver Sensor" at each site), only 27 percent of the observations produced an NTSC picture with a rating above 3; 85 percent of the observations produced an unimpaired DTV picture.

Background

In December, 1996, the Commission adopted the Advanced Television Systems Committee (ATSC) Doc. A/52 ("ATSC Standard Digital Audio Compression (AC-3), 20 Dec 95") and the ATSC Doc. A/53 ("ATSC Digital Television Transmission Standard, 16 Sep 95"), except for Section 5.1.2 ("Compression Format Constraints") of Annex A as

the U.S. broadcast digital television transmission system. The standard specifies eight-level vestigial side band (8-VSB) as the digital television modulation method. The modulation method decision was based on a recommendation by the Advisory Committee for Advanced Television Service (ACATS) after nine years of exhaustive study by this very broad-based group, supported by the work of hundreds of industry technical experts and an extensive battery of laboratory and field tests. One of the alternative transmission systems analyzed and discarded during this effort was coded orthogonal frequency division multiplex (COFDM) modulation. In the interim since COFDM was first analyzed in the US, COFDM was chosen as the European broadcast digital transmission system, i.e. Digital Broadcast Television – Terrestrial or DVB-T, under a somewhat different broadcast television system architecture, and has benefited from substantial investment in development. In the rush to get 8-VSB consumer receivers to market in the US, the first generation of receivers sold were implemented with channel equalizer technology in a relatively early stage of development. In the two years since the first receivers were offered for sale, manufacturers have introduced sets incorporating second-generation technologies, and have developed prototype receivers using integrated circuit chip sets with what now can be considered third-generation technologies.

The Commission was petitioned to allow COFDM as an alternative to 8-VSB, with proponents of this position offering field demonstrations purporting to show the relative superiority of COFDM in difficult reception conditions and emphasizing anecdotal failures of early 8-VSB consumer receivers.¹ This controversy has, however, spurred the continued development of the 8-VSB receivers, particularly the channel equalizers, and also focused the attention of the Commission on the need for an objective and scientific analysis of the state of 8-VSB receiver performance.

Objectives

This study has been undertaken to independently assess the state of digital television receiver development in the US. The primary objectives are twofold: first, to demonstrate the performance of early and present generations of digital receivers with respect to predicted coverage under the FCC's DTV planning factors, and second, to document differences in performance between the first generation of consumer 8-VSB receivers and those more recently available, as well as those in prototype stages. This interim report realizes these objectives through field test data collected to date in the Washington, DC, area on two DTV stations, WETA-DT (Channel 34) and WRC-DT (Channel 48). Data collection is continuing, and it is anticipated that the findings in this report will be supplemented in the future with additional data from the Washington area, as well as from the Baltimore, MD, area as time and resources allow.

As a secondary objective, data was also collected on two NTSC stations (Channels 32 and 50), which are near to the DTV test subject stations both in frequency and geographical location, in order to allow rough comparisons to NTSC coverage at

¹ See letter of denial to Martin R. Leader on behalf of the Sinclair Broadcast Group, Inc., by direction of the Commission, FCC 00-35, February 8, 2000. The Commission reaffirmed the ATSC 8-VSB system as the U. S. broadcast DTV modulation standard in the *Report and Order and Further Notice of Proposed Rule Making* in its first periodic review of the DTV transition, MM Docket No. 00-39, FCC 01-24, released January 19, 2001, at paras. 88-92.

individual sites. The extent to which such comparisons can be drawn is, of course, limited by considerations of geometry and transmission system parameters.

The matter of noise-limited performance is not part of this study. We believe that even COFDM proponents agree that 8-VSB has superior performance at distances near the noise-limited contour. Weak signals will be addressed only with regard to performance in low signal areas within the predicted service contour.

General Description of Approach

Reception sites to be measured for coverage data were pre-plotted and fell into two categories: radial sites and randomly selected sites. Radial sites to be measured were plotted at five-mile intervals on each of the cardinal radials and intercardinal radials at 45-degree increments, out to the protected contour of the subject DTV station. Two hundred sites were also randomly selected by computer algorithm and plotted within a box approximately 17.5 miles on a side. For coverage analysis, current plans call for completing measurements on all 80 radial sites as well as at least 20 of the randomly selected sites.

To fully exercise receiver equalizers, an additional set of sites was specially selected by location and surroundings for a high probability of a combination of strong-signal, high-multipath conditions. These sites were analyzed separately from the coverage sites.

Identical data is being collected at each site using two antenna systems: a log-periodic antenna on a 30-ft. mast, and one of two indoor-type antennas on a 7-ft. tripod (measurements taken out-of-doors). This allows coverage and relative receiver performance comparisons to be drawn under both circumstances.

To the extent possible while maintaining consistency with the objectives of this study, the field-testing methodology, data collection spreadsheet, and test vehicle design are kept compatible with those developed initially for the ACATS field testing in Charlotte, NC, and further refined by the Model HDTV Station (WHD-TV) technical subcommittee for use by early-adopter DTV broadcasters.² This standardized approach allows easy comparison of the data from this effort with the results of other studies in other locations and allows the data to be easily incorporated into cumulative databases.

¹ "Field Test Vehicle Design," Gary Scignoli, Zenith Electronics Corporation, Model Station Technical Subcommittee document, November 1998, and "Model Station Outdoor Field Test Plan," Model Station Technical Subcommittee document, July 1999.

The Test Vehicle

The Commission has outfitted a field measurements vehicle to make the measurements required in this study. The truck implementation fundamentally follows the guidelines contained in the document entitled "ATSC Test Vehicle Design Information" prepared by the ATSC and the Model HDTV Station technical subcommittee. Photographs of the test vehicle and its equipment complement are included in Appendix F.

A block diagram of the equipment configuration for measurements using the 30-ft. mast-mounted "outdoor" log-periodic antenna is shown in Figure 1.

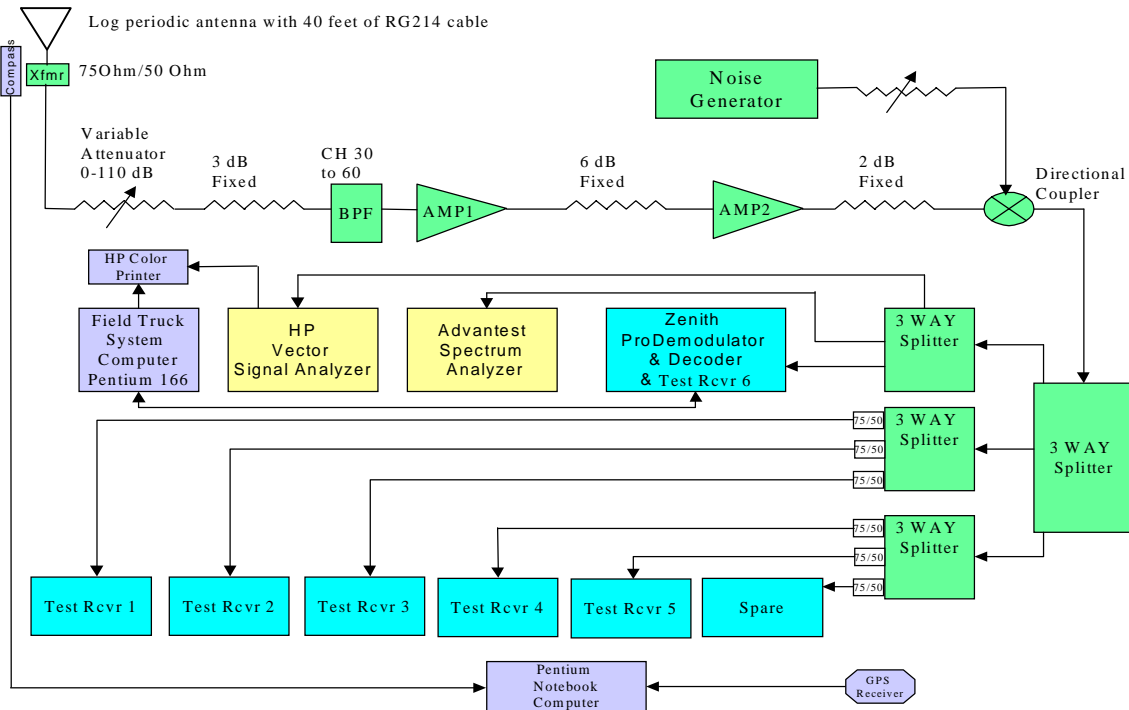


Figure 1

The block diagram of the equipment configuration used for measurements using the 7-ft. tripod-mounted "indoor" antenna is shown in Figure 2.

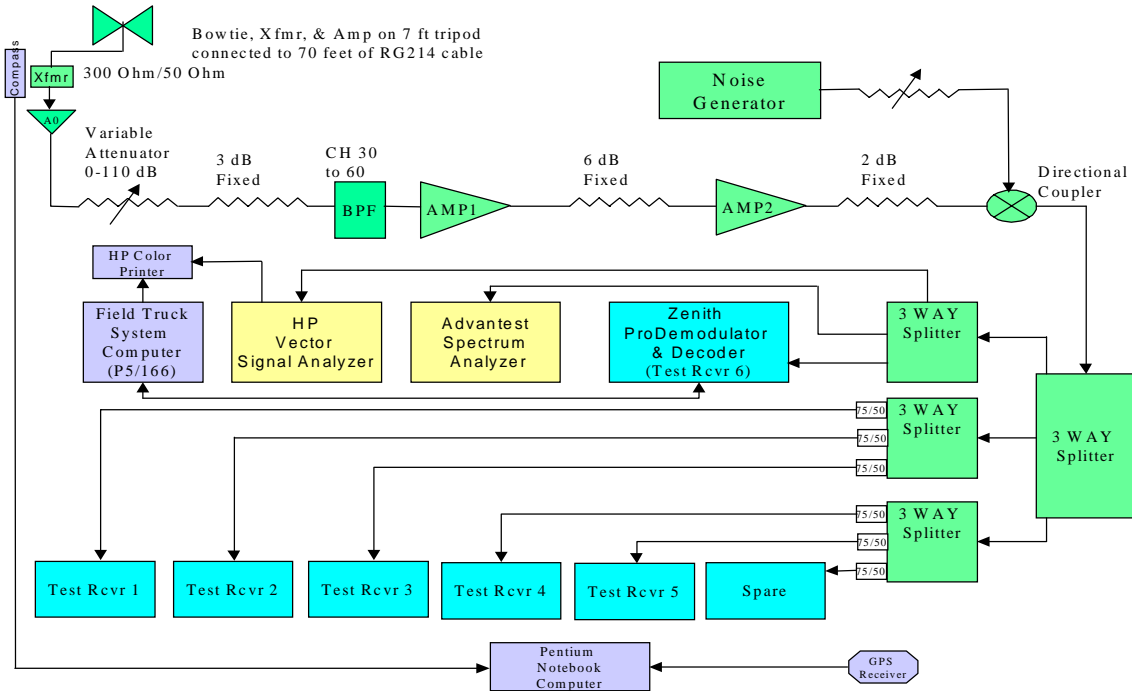


Figure 2

A vector signal analyzer (VSA) is the primary measurement instrument for making signal and noise power measurements within the test bed. The VSA, along with a swept-filter spectrum analyzer and the channel equalizer tap outputs of a Zenith ProDemodulator, is also relied upon for characterization of site conditions such as received signal strength, band tilt, adjacent-channel signals, and multipath reception. The system computer, a color printer, and a color plotter connected to the swept-filter spectrum analyzer provide the means for documenting these site conditions.

As experience has dictated from previous DTV field studies, the recommended practice of maintaining signal levels within the test bed at sufficiently high levels to minimize the effects of any EMI/RFI ingress has been followed. Adding white noise to the signal at the directional coupler while maintaining high signal levels in the RF system allows measurement of the combined effect of the white noise margin of each of the digital receivers and the minimum C/N required by each receiver under the extant multipath and non-white-noise interference condition.

A GPS receiver and linked software running on the notebook computer provide accurate tracking and documentation of vehicle location and allow computation of the bearing to the transmitter. Automated input of bearings from a fluxgate compass mounted on the antenna mast and manual input of compass bearings taken with the tripod-mounted antenna into this software allow documentation of antenna azimuth.

The Receiver Sample

The sample of receivers being tested in this study was selected based on the requirements of the objectives of the study, the availability of receivers on loan from

manufacturers, and the space and signal ports available in the measurement vehicle. This study documents data from five DTV receivers. A sixth DTV receiver, a prototype, was also available in the vehicle for most of the duration of the study, but performed unreliably or was totally inoperative at the majority of measurement sites, so the data from this receiver has not been included in this report.

The objectives and methodology for this study require the use of at least one receiver capable of outputting information on channel equalizer tap energy and segment error rates to allow characterization of the nature of the signal received at a given site and to establish acceptable signal thresholds. The Zenith ProDemodulator and Decoder combination was selected to perform this function because of its long history of use as the standard test receiver in other DTV field tests. In addition to this role as a site characterization receiver, the Zenith receiver's performance data is tabulated alongside that of the other four DTV receivers in the sample, and the Zenith receiver is treated as part of the sample. It appears in the test results as Receiver #6.

At the outset of the study, the Zenith receiver installed in the test vehicle was a second-generation version, the most recent available at the time. On July 17, 2000, a third-generation Zenith ProDemodulator became available, was installed, and was used for the balance of the testing (except for one site where the third-generation version failed to operate and the second-generation version was substituted). The principal difference between the second- and third-generation versions is an improved channel equalizer in the third-generation version, with longer ghost cancellation times and improved pre-ghost performance, traded off against slightly degraded white noise performance.

The manufacturers' names and models for the balance of the DTV receiver sample are blinded at the request of the manufacturers. They are designated Receivers #1, #2, #4 and #5 in the test results. Receiver #3 was the receiver for which data was omitted because of its intermittent operation.

Receiver #1 is a first-generation consumer receiver. Receiver #2 is a consumer receiver that, because of the timing of its introduction to the market, might best be described as "late first-generation" or "generation 1.5." Receiver #4 is a prototype receiver containing a chip set which has been incorporated into second-generation consumer receivers. Receiver #5 is a prototype receiver containing a chip set intended to be incorporated into third-generation consumer receivers.

The current test sample receiver complement is summarized in Table 1.

Sample #	Receiver Type	Generation	Comment
1	Production Consumer	First	
2	Production Consumer	Late First	
3	-----	-----	Sample deleted due to unreliable performance
4	Prototype	Second	
5	Prototype	Third	
6	Commercial Test	Third	Replaced second-generation version used for first few weeks of field test

Table 1.

Site Selection

Measurements for this study are being taken at sites falling into each of the three following categories:

1. Sites at 5-mile intervals on each of the cardinal radials and 45-degree-increment intercardinal radials centered on the Channel 48 transmitter site, out to the Channel 48 predicted coverage contour (approximately 52 miles).
2. Sites in a randomly selected set of 200 locations within a box approximately 17.5 miles on a side, centered on the Channel 48 transmitter location
3. Sites chosen because the location and surroundings indicated a high probability of strong-signal, high-multipath conditions

A total of 51 sites in categories 1 and 2 have been measured to date. In category 3, measurements have been taken at 11 sites.

Measurements taken at sites in categories 1 and 2 are analyzed in this report for purposes of determining DTV signal coverage. Category 3 sites are excluded from statistical coverage analyses, but were added to the data collection effort to increase the number of sites with strong-signal, high-multipath conditions. This was done in order to obtain statistical significance in separate analyses intended to highlight inter-generational differences in 8-VSB receivers under these conditions.

In every instance, measurements were taken as near to the pre-plotted site locations as practicable, within the constraints of geography and access. For category 1 sites, where measurement at the pre-plotted site was impossible, the actual measurement location was never more than one-half mile away (with the exception of the few sites whose plotted location fell in a sizable body of water), and was typically less than one-tenth mile away. Also, the actual site measured was chosen to be along the radial to avoid placing the site in a different part of the transmitting antenna's pattern. For category 2 sites, measurements were always taken within one-quarter mile of the pre-plotted site, and typically within one-tenth mile.

Data collection continues in this project, and roughly half of the 80 potential sites in category 1 have been measured to date. Within category 2, the randomly selected locations, efforts were focused initially on areas near to the transmitters, and most of these sites that fall within the District of Columbia have been measured, as well as several of the sites that are near to the FCC Laboratory in Columbia, MD. Measurements at a minimum of 20 category 2 sites are anticipated to be included in the final report.

The locations of sites measured to date have been plotted on maps included in Appendix A.

System Calibration Procedure

Power levels in the measurement system are calibrated each morning with a signal generator that does not travel with the vehicle. The FCC Laboratory's metrology

department maintains calibration of the signal generator, with calibration traceable to primary standards. At each site, calibration of the RF system and the VSA may be checked with an on-board tracking generator. The entire system from antenna output to DTV receiver has been examined component by component, and as a system, for insertion loss. Components were interchanged so that each receiver port would receive identical signals to the extent practicable. The band tilt and ripple have been recorded for the RF system. The data is re-recorded each time a component in the RF system is replaced.

Following morning calibration, the on-board generator is left running, and instrumentation is left in the operational state during transit to the first site to be visited and between sites.

Measurements at each Site

The sample Microsoft Excel spreadsheet included in Appendix B lists the measurement data recorded at each site. RF signal data is taken using the VSA and the site characterization receiver, presently the Zenith ProDemodulator/Decoder combination. The data is reported for both nominal signal level and threshold conditions for both the mast (30 ft high log periodic antenna) and tripod-mounted (7ft high “bow tie” or “Silver Sensor” indoor-type antenna) for DTV channels 34 and 48 and NTSC channels 32 and 50. Threshold of visibility (TOV) of picture impairments is then determined for each of the other test receivers. The range of antenna azimuths that does not produce segment errors in the data collection receiver is also measured and recorded.

While most of the data collected with the tripod-mounted antenna was done using a typical “bow tie” indoor-type antenna, at sites where the bow tie antenna did not produce a reliable picture on the site characterization receiver, a “Silver Sensor” directional indoor-type antenna was substituted.

The specific procedures followed at each site are detailed in Appendix B.

Coverage Analysis Methodology

This interim report restricts analysis at present to development of statistics for parameters such as service availability, system performance index, field strength, and margin above the white noise floor. These are parameters that have been developed for coverage analysis in a standardized manner in previous DTV field tests, and are generally well understood.

Service availability (SA) is defined as the raw percentage of all measured test sites with sufficient field strength to theoretically have successful DTV reception. Successful DTV reception is defined as no picture “hits” (segment error rates exceeding 3 errors per second) as measured by the reference receiver during a five-minute observation period. As the denominator in the expression used for calculating this percentage includes sites that had too little field strength to make DTV reception theoretically possible, this parameter is generally considered to be the equivalent of a “raw batting average,” a first-order indication that suggests overall service availability for a station’s coverage area for a given transmitter ERP and antenna HAAT.

System performance index (SPI), on the other hand, is generally acknowledged to be an indicator of how well the 8-VSB transmission system performs with signals that are above the minimum field strength required for successful reception by the reference field test system (antenna, test bed, and site characterization receiver). It is the percentage of sites with field strengths adequate to exceed the white-noise threshold of data errors in the site characterization receiver that had successful reception. This parameter removes from the analysis those sites which were precluded from any chance of successful reception because of low field strength due to terrain obstructions or antenna pattern nulls. SPI is generally considered to be a good performance indicator with regard to non-white-noise impairment conditions such as multipath, impulse noise, or interference from other sources. The minimum required field strength used in computing this parameter was the median value reported from the daily morning calibrations of the test vehicle's receiving system.

The field strength statistics developed for this study represent measured values at the immediate location of the antenna, with no attempt made to develop site characteristics using "cluster measurement" or "100-foot run" techniques. Reasonable precautions were taken during setup at each site to avoid taking measurements in a deep, localized signal null due to multipath conditions.

Site margin statistics represent the amount of signal loss, in decibels, that a site can experience before the threshold of errors is reached in the reference receiver. Plotting site margin against field strength provides an indication of the effects of non-white-noise impairments over the coverage area.

Tabulations of the service availability and system performance index calculations, as well as charts displaying the cumulative distribution of field strength and site margin vs. field strength are presented in Appendix C for all "coverage" sites (categories 1 and 2).

DTV Receiver Comparison Methodology

While the site characterization receiver was used to document the signal conditions under which the comparison measurements were performed, it was not used as a standard for comparison. After adjusting the added noise attenuator to establish the general signal-to-noise range over which the sample of receivers would fail, noise was added in one-dB steps while observations were made of the displays of all the receivers under test (including the site characterization receiver) until picture impairments and/or failure were observed in each receiver. The incremental level of added noise that first produced picture impairments (the threshold of visibility or TOV) and the level that produced total picture failure (the threshold of unusability or TOU) were recorded individually for each DTV receiver under test. Because the smallest increment of added noise available was 1 dB, TOV and TOU often occurred at the same increment. This procedure relates the performance of any receiver in the sample to any other.

To document the signal conditions under which the comparison tests were conducted, the added noise was then set at 1 dB below the TOU point for the data collection receiver, and threshold measurements and tap energy data were recorded from the data collection receiver. If the input signal exhibited a range of variability exceeding 0.5 dB, the range was rounded off to the nearest dB and the noise attenuator was adjusted to

the appropriate setting to keep the S/N ratio just above threshold for the data collection receiver during signal variations. If signal level variability was present, the TOV and TOU levels for each receiver were checked several times in order to establish confidence in the order of failure and the magnitude of the differences.

Because the category 1 and 2 sites measured to date did not contain a large number of sites that had apparently high multipath conditions combined with strong signals, an effort was made to search out additional sites with these characteristics (category 3 sites) in order to have sufficient data to comparatively assess receiver performance under these stressful conditions. Data on these eleven strong-signal, high-multipath sites was maintained and analyzed separately from the coverage site data.

In order to allow easy assessment of the overall relative performance of the five DTV receivers tested under each set of conditions, cumulative distribution charts of S/N at threshold of visibility of impairment were prepared for both the coverage and the strong-signal, high-multipath sites. These charts are presented in Appendix D, along with a tabulation of the median TOV values for each chart.

NTSC Comparison Methodology

In order to provide a rough assessment of 8-VSB reception as compared with NTSC reception at each site, observations were made of the picture quality of an NTSC signal near in frequency and transmitter location to each DTV signal evaluated. Channel 32 NTSC reception was compared to channel 34 DTV reception; channel 50 NTSC reception was compared to DTV channel 48.

At each site, and for each channel/antenna combination, NTSC picture quality was subjectively assessed according to the CCIR impairment rating scale, and the corresponding NTSC carrier-to-noise ratio and field strength were calculated and recorded.³ NTSC to 8-VSB comparison results are tabulated and presented in Appendix E.

Observations on the Data

Care must be taken not to misinterpret the calculated service availability and system performance index values for the Silver Sensor antenna in Table C-1. Because the Silver Sensor antenna was used only at sites at which the bowtie antenna failed to produce a reliable picture using the site characterization receiver, the calculated SA and SPI values for the Silver Sensor represent its performance only at these difficult sites.

Care must also be taken not to misinterpret the receiver relative performance data presented in the charts in Appendix D. Because these are cumulative distributions, vertically aligned data points on each receiver curve **do not** represent comparative values at any given site. Receiver curves that do not extend all the way to 100% on the X-axis indicate that receiver did not produce a reliable picture at some of the measured sites or, in the case of Receiver 6, indicate the portion of the total number of sites at

³ See ITU Recommendation ITV-R BT.500-9 Geneva, 1998

which each generation of the receiver was used. Receiver comparison conclusions should be drawn from the curves as a whole as well as the median values for each receiver.

Statistical analysis has been performed on the receiver relative performance data to determine if the sample size and distribution were adequate to define statistically significant differences between the receiver data sets. Using the Wilcoxon Signed Ranks Test, it has been determined that significant differences do exist between the earliest and the latest generations of receivers for each channel/antenna combination at the coverage sites. For the strong-signal, high-multipath sites, there was insufficient data available from Receiver 1 in most cases to establish a significant difference from the other receivers using the Wilcoxon Signed Ranks Test. However, when Receiver 2 was compared to the third-generation receivers, in all cases the data showed significant statistical differences.

Conclusions

In attempting to draw coverage conclusions from the data which has been collected to date, one must keep in mind that the total number of sites tested so far is considerably smaller than has been the case in previously completed DTV coverage studies. At least 100 sites are typically preferred to provide statistical confidence in the data; however, analysis of the data using the Wilcoxon Signed Ranks Test indicates statistically significant differences in most cases for receiver comparison purposes. Further, analysis of the coverage results with respect to terrain obstructions has not yet been conducted. However, with these caveats in mind, it is possible to make some preliminary observations about 8-VSB coverage for the sites measured to date.

Summary Table C-1 reveals 98% service availability for the mast-mounted antenna at coverage sites (categories 1 and 2) using the Zenith ProDemod/Decoder receiver. Comparing this figure with SA values of 63% and 78.7% for WETA (channel 34) and WHD (channel 30), respectively, garnered from a September 1998 coverage study allows one to surmise that the present study has, so far, contained measurements on a greater preponderance of sites with adequate field strength. Indeed, comparison of Charts C-1 through C-4 with similar data from the earlier study bears this out. A number of factors may contribute to this difference, not the least of which are the different transmitter locations, HAATs, and EIRPs

The system performance index computed for the sites measured to date in this study using the mast-mounted antenna is 100% for WUSA (channel 34) and 98% for WRC (channel 48). The SPIs for WETA and WHD in the previous study were 83.4% and 81.9%, respectively, using an earlier-generation Zenith receiver. Given that SPI is computed using only sites that have adequate field strength, the improvement in performance could be due to any combination of improved receiver performance, significant overall differences in the site multipath and non-white-noise interference conditions between the studies, and better signal margins due to improvements in transmitting facilities or measurement site selection technique. Until additional data is collected and specific analysis done comparing measured signal conditions in the studies, it can only be concluded that improved receiver performance may have been one factor in the observed coverage improvement.

For the tripod-mounted, indoor-type antennas, SPI was 86% for WUSA and 84% for WRC when the better of either the bowtie antenna or the Silver Sensor directional antenna was used. These SPIs for the combined indoor antenna types exceed the above values for mast-mounted antenna reception computed in the 1998 study.

Lending some credence to the argument that evolving 8-VSB receiver performance is a significant factor in improved measured coverage are the charts presented in Appendix D. For the coverage sites, the improvement in the median values for S/N ratio at threshold for the mast-mounted antenna between the first-generation receiver and the best-performing, latest-generation prototype is approximately 2 dB, and approximately 2 – 2.5 dB for the tripod-mounted antennas.

Examination of the charts for the strong-signal, high-multipath sites reveals an increase in the spread of the median S/N ratios at threshold between the earliest-generation receivers and the latest to about 6 dB. This appears to support the argument that improvements to later-generation receivers has been primarily in their equalizer performance. While statistical analysis using the Wilcoxon Signed Pairs Test was not able to establish significant differences between the data sets from some pairs of receivers for the strong-signal, high-multipath sites because of insufficient numbers of data points, it is clear that there are statistically significant differences in performance between first-generation and third-generation receivers. The simple fact that Receiver 1 was not able to produce a picture at the majority of these sites, while the two third-generation receivers were able to do so with only one exception, bears out this conclusion. Additionally, when Receiver 2 was compared to the third-generation receivers, in all cases the data showed significant statistical differences.

As indicated above, the study also compared NTSC reception with 8-VSB DTV reception at most of the 51 sites in the coverage sample using both the directional antenna on the 30-foot mast and the indoor antennas mounted on the 7-foot the tripod. For this analysis, reception on analog channels 32 and 50 was compared with DTV reception on channels 34 and 48. These pairings yielded a total of 98 observations comparing NTSC and DTV service using the mast antenna and 93 observations using the tripod antenna. The data comparing NTSC reception with 8-VSB DTV reception is summarized in Table E-1. NTSC CCIR ratings were placed into two groups based on the criterion that CCIR level 3 pictures are the worst NTSC pictures suitable for long term viewing. While the CCIR rating system does not allow direct comparison of the best NTSC picture with a normal digital picture, a normal digital picture without impairments must be considered superior to the best NTSC picture. The data show that for NTSC reception, roughly two-thirds of the sites produced a CCIR rating of 3 or above using the mast antenna on both channel pairs. All of the observations which had an NTSC CCIR rating of 3 or above produced a picture on the paired DTV channel without impairments using the same antenna. Overall, 99 percent of the observations with the mast-mounted antenna (all except one) produced a DTV picture without impairments.

With the tripod-mounted antenna (either the bowtie antenna or the Silver Sensor), only 27 percent of the observations produced an NTSC picture with a rating of 3 or above on both channel pairs. Overall, 85 percent of the observations with the tripod mounted antenna produced an unimpaired DTV picture.

The above comparisons of NTSC to DTV performance should be considered in the light of the facts that the paired DTV and NTSC stations are not co-located, and the receiving

antenna was not re-oriented for optimum NTSC reception. Further, it was impossible to ensure equivalence of transmission systems with respect to antenna height and radiated power between the paired DTV and NTSC stations. The effect of these disparities on the comparisons, while perhaps small at outlying sites, can become significant at sites nearer the transmitters, particularly for directional receiving antennas.

Further Work

Data collection is ongoing in this study, and current plans include completion of measurements along the cardinal and additional radials (category 1 sites) as well as measurement of a significant portion of the 200 randomly selected (category 2) sites in the Washington, DC, area to improve confidence in the statistical significance of the data. Time and resources permitting, additional data will be collected in a similar fashion in the Baltimore, MD, area.

A more thorough analysis of the extensive data collected at each site, including spectral plots as well as data-collection receiver tap energy values and distribution plots, is anticipated for the final report. Additionally, analyses of effects of terrain are planned, and comparisons with Longley-Rice algorithm coverage predictions will be done if possible.

To the extent that newly improved prototype or consumer-model receivers can be provided by manufacturers for testing and can be accommodated in the test bed, such additional receivers will be added to the test sample to allow a continuing assessment of progress in receiver performance.

APPENDIX A

TEST SITE LOCATION MAPS



Map A-1.
Category 1 Sites



Map A-2
Category 2 Sites



Map A-3.
Category 3 Sites

APPENDIX B

SPECIFIC PROCEDURES AT EACH TEST SITE

- 1) Confirm system calibration.
- 2) Confirm clearance for the mast antenna and the tripod antenna.
- 3) Move, if necessary, to the nearest location that provides clearance.
- 4) Place traffic cones to warn motorists and pedestrians and erect mast antenna.
- 5) Move truck to assure that mast antenna is not in null.
- 6) Determine location with GPS, and confirm distance and bearing to transmitter. Record data, and, if available, confirm or plot terrain profile.
- 7) Orient the mast antenna for maximum average DTV signal strength on the Advantest SA and confirm the reading on the VSA. Do the same for the tripod antenna. Record the receiver antenna bearing for both antennas. Note that the mast antenna azimuth is within +/- 25 degrees of the transmitter bearing. If the mast antenna is outside the +/-25 degree limit move to the closest practical location within the site and bearing tolerance and describe the reason for the change.
- 8) Record the site number, site name, calculated direction from site to transmitter, peak signal azimuth, date, time, and weather.
- 9) Confirm the RF system gain and noise floor and record data.
- 10) For the mast antenna adjust the truck-input attenuation to provide -30dBm DTV input into the VSA and record attenuator setting.
- 11) Record the DTV pilot power and the signal power level across the 6MHz band and record the dB variation in input level.
- 12) Confirm the Longley-Rice and the FCC F(50,50) entries, as available.
- 13) Compare the Excel calculated DTV field strength to the entries in 12), as available.
- 14) Note the calculated received DTV signal-to-noise at nominal signal level.
- 15) Record the reference receiver's comb (NTSC) filter status.
- 16) Record a DTV tilt plot.
- 17) Record a DTV stopband plot.
- 18) Record the equalizer taps.
- 19) Log the equalizer S/N input at nominal signal level.
- 20) Log the equalizer S/N output at nominal signal level.
- 21) Log the equalizer tap energy at nominal signal level.
- 22) Log the equalizer frame noise at nominal signal level.

- 23) Increase the noise generator output until the demodulator segment error rate (SER) indicates threshold signal level and record the average SER reading. Manually note any instances of SER greater than three hits per second over a five-minute observation period and record the noise generator attenuator setting.
- 24) Record the added noise at threshold.
- 25) Repeat 18 through 22 for threshold.
- 26) Record SER at threshold. Record the added noise level at threshold and at failure for each of the test receivers. For signals with substantial variation repeat the measurements until the order and delta between each receiver is determined.
- 27) Repeat and record the DTV signal-to-noise measurement. Record the range of azimuth angle of the measurement antenna over which no hits are taken.
- 28) Note the calculated DTV S/N at threshold.
- 29) Note whether or not the calculated site margin for FCC planning factor is above zero.
- 30) For the NTSC channel being compared to the DTV channel measured above, note the calculated noise floor.
- 31) Adjust the system input attenuation to provide -20dBm NTSC input to the VSA and record setting.
- 32) Enter the RF system gain and record the NTSC signal power.
- 33) Note the calculated NTSC field strength and carrier-to-noise ratio.
- 34) After consultation with the other observers record the NTSC CCIR rating.
- 35) For the tripod antenna repeat 6 and 8 through 34. Instead of Step 7, site the tripod antenna for least reflection and shadow from truck and maximize signal within a 5 foot square. If zero SER is not achieved when using BT antenna, change to the Silver Sensor antenna.
- 36) Record a description of the site and initial data.
- 37) For the other DTV/NTSC pair repeat 6 through 36.
- 38) Confirm that hardcopies of all plots are in the binders. Save and remove all computer media.
- 39) Restore all equipment to vehicle.
- 40) Move to next site and repeat 1 through 39.

APPENDIX C

DTV FIELD TEST COVERAGE SUMMARY

Service Availability & System Performance Index

Station (Ch)	Antenna	# of Sites	TX HAAT	Service Availability	System Performance
WUSA (34)	Log Periodic on Mast	51	254	98%	100%
WUSA (34)	Bowtie on Tripod	40	254	98%	90%
WUSA (34)	Silver Sensor on Tripod	14	254	93%*	57%*
WUSA (34)	Total for BT&SS on Tripod	50**	254	98%	86%
WRC (48)	Log Periodic on Mast	51	242	98%	98%
WRC (48)	Bowtie on Tripod	42	242	98%	86%
WRC (48)	Silver Sensor on Tripod	13	242	92%*	46%*
WRC (48)	Total for BT&SS on Tripod	50**	242	98%	84%

* Silver Sensor antenna used only at sites which did not produce a reliable picture with the bowtie antenna. Asterisked values represent Silver Sensor performance only at the subset of sites at which it was used.

** Total does not represent the sum of the site numbers for each antenna individually because measurements were taken with both antennas at some sites.

Table C-1.

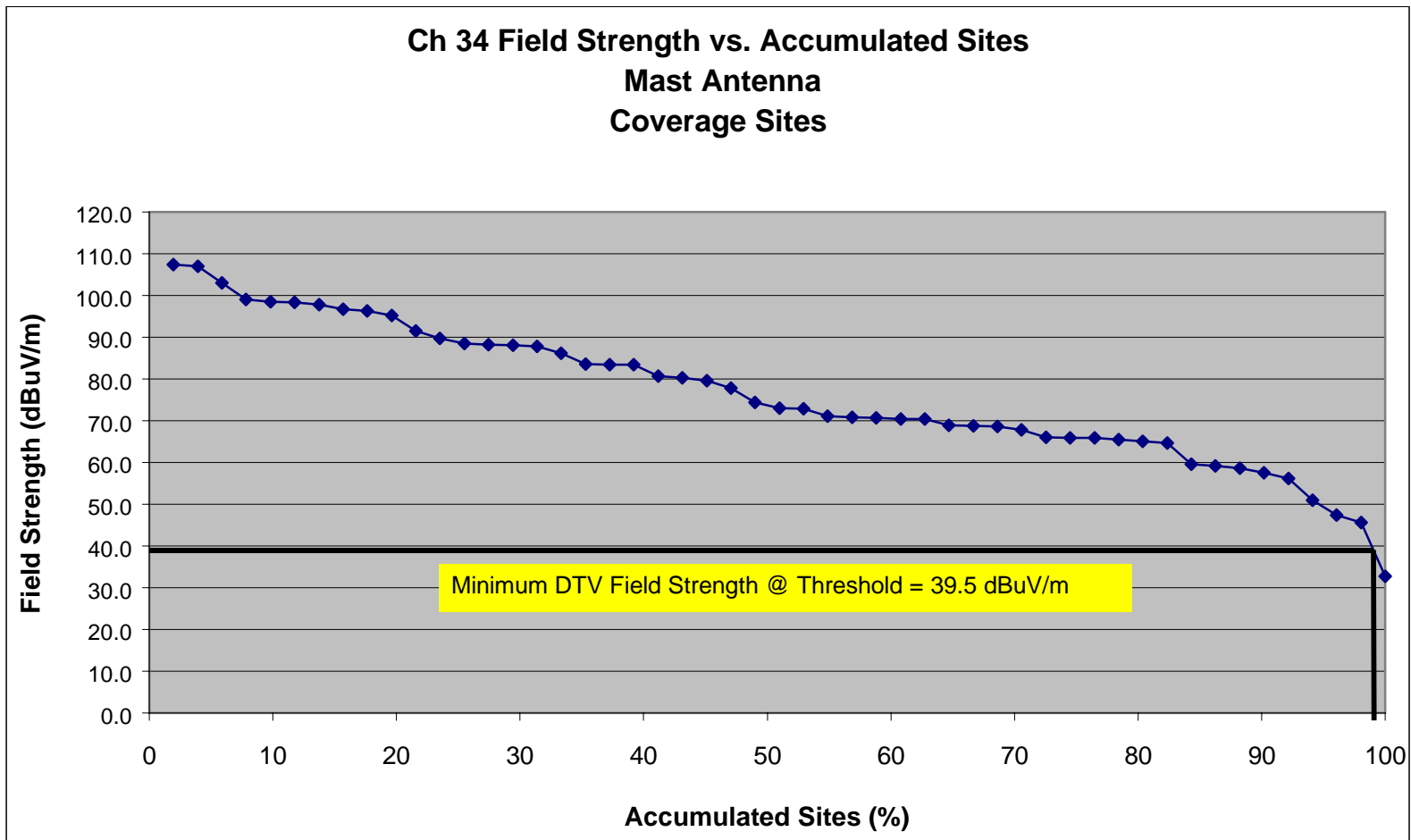


Chart C-1.

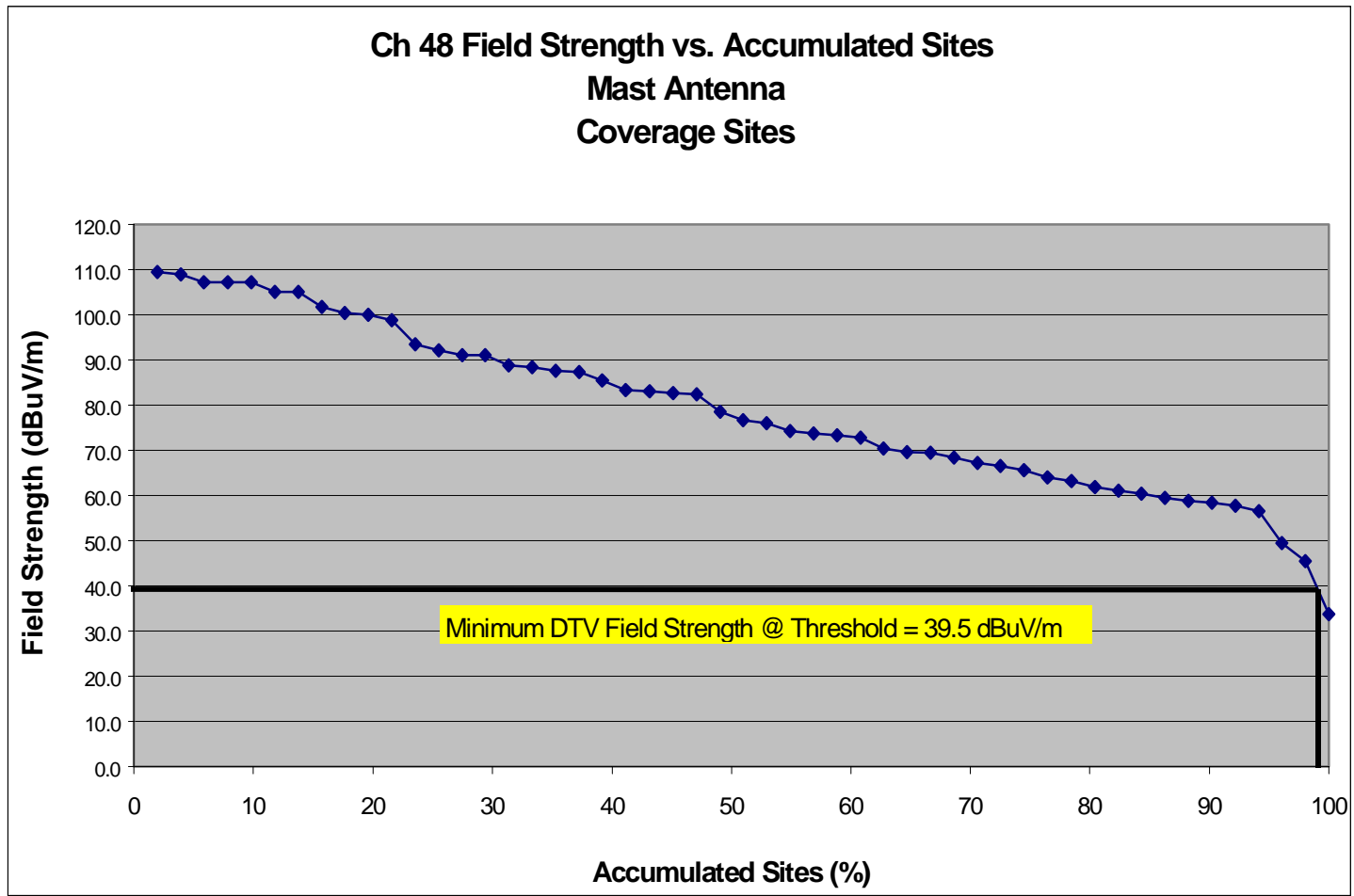


Chart C-2.

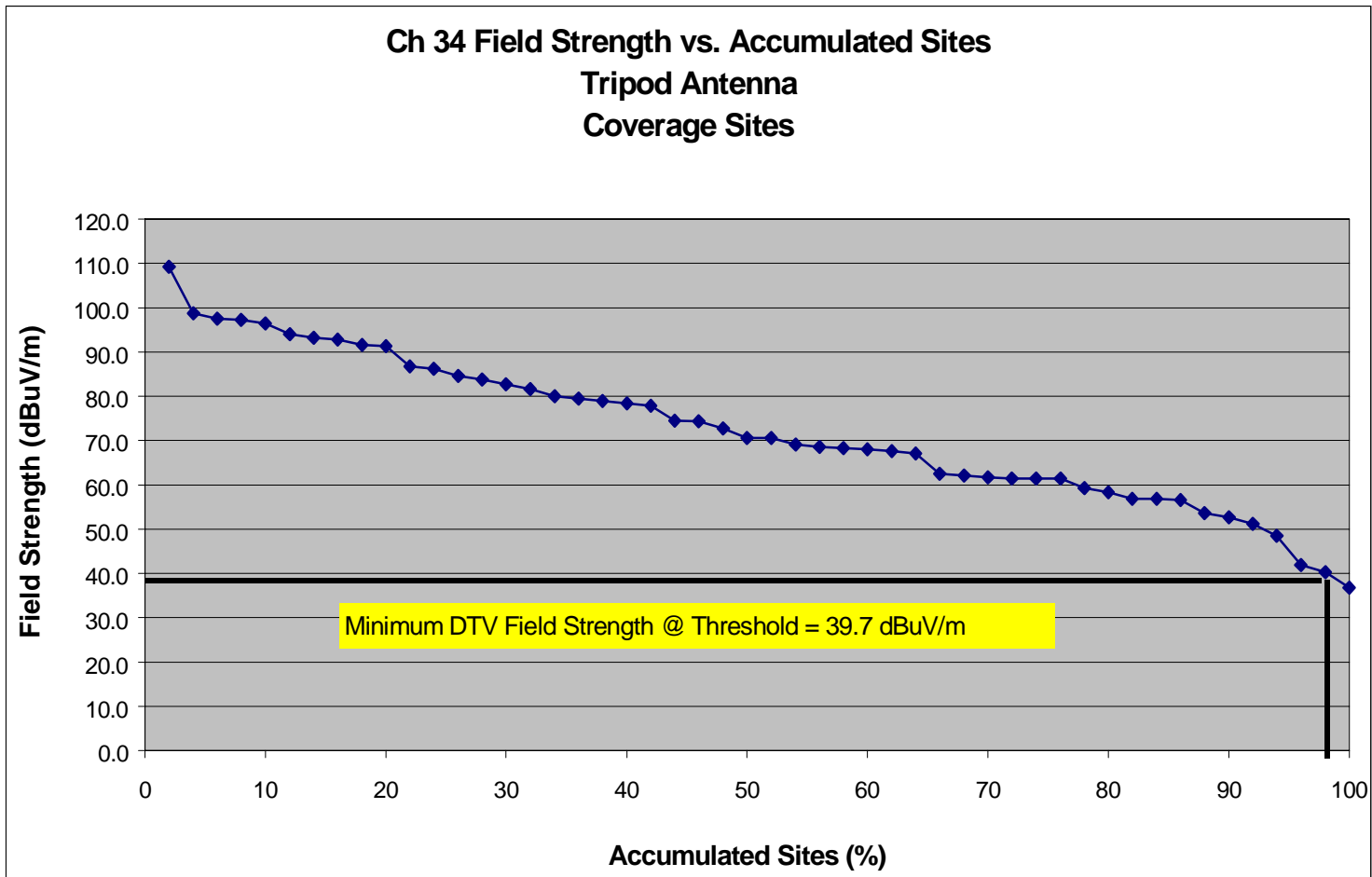


Chart C-3.

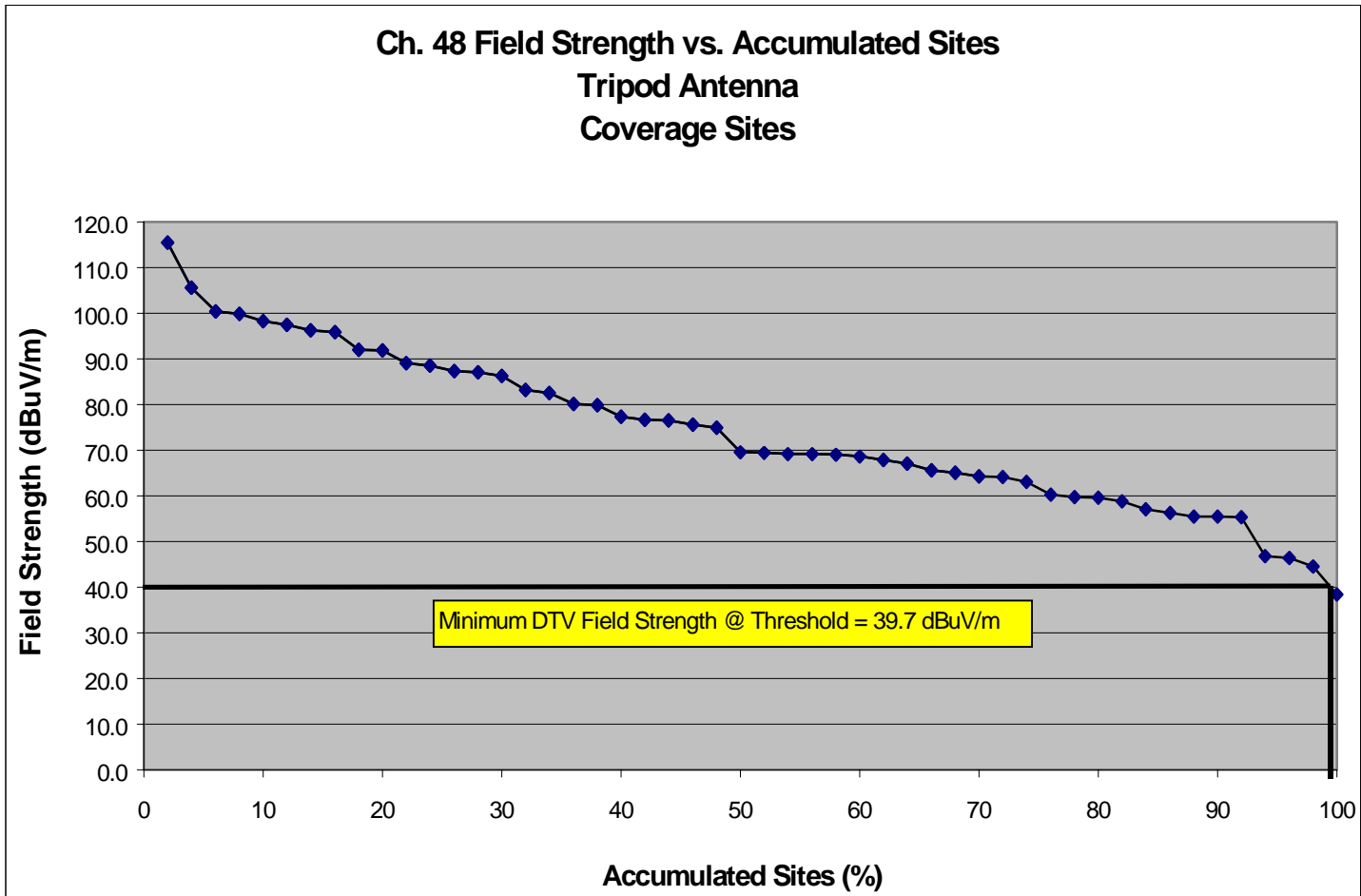


Chart C-4.

**Ch 34 DTV Field Strength vs Margin
Mast Antenna
Coverage Sites**

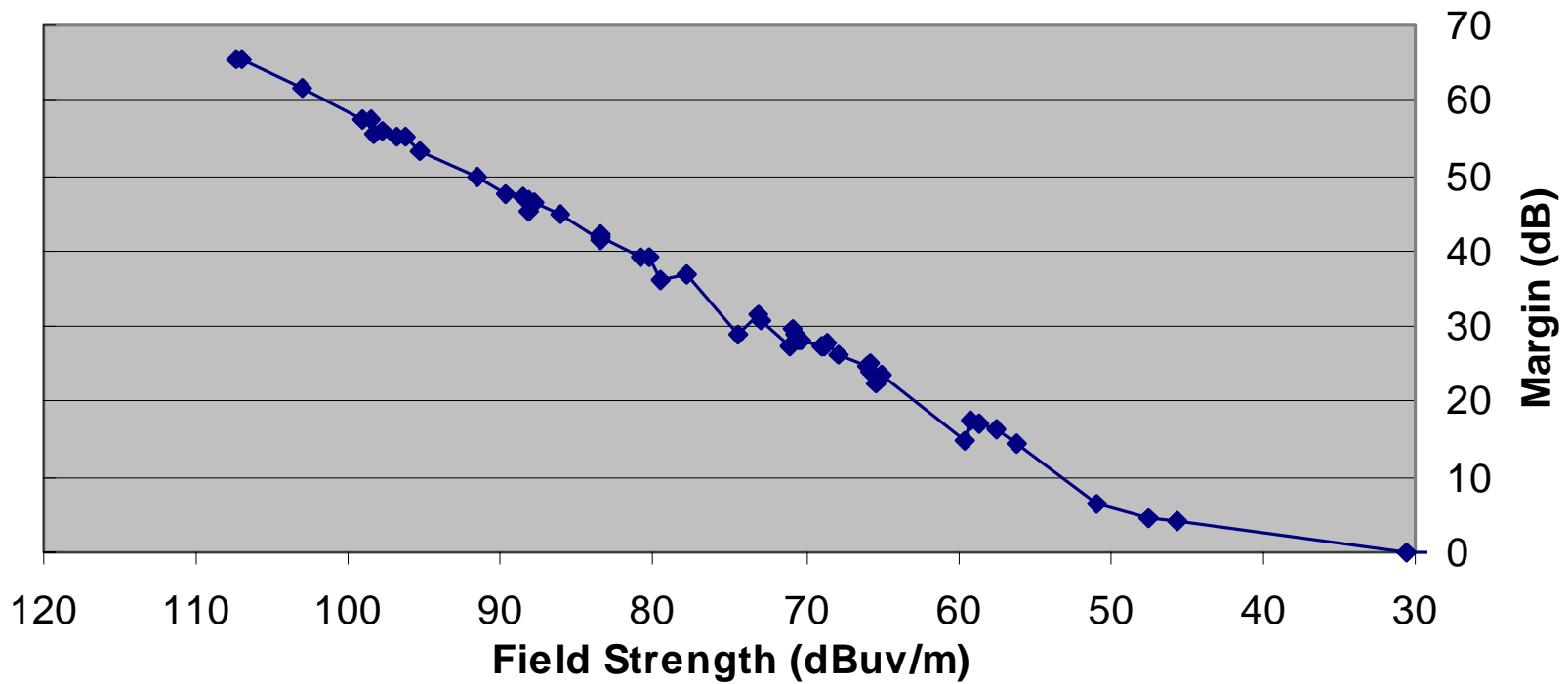


Chart C-5.

Ch 48 DTV Field Strength vs Margin Mast Antenna Coverage Sites

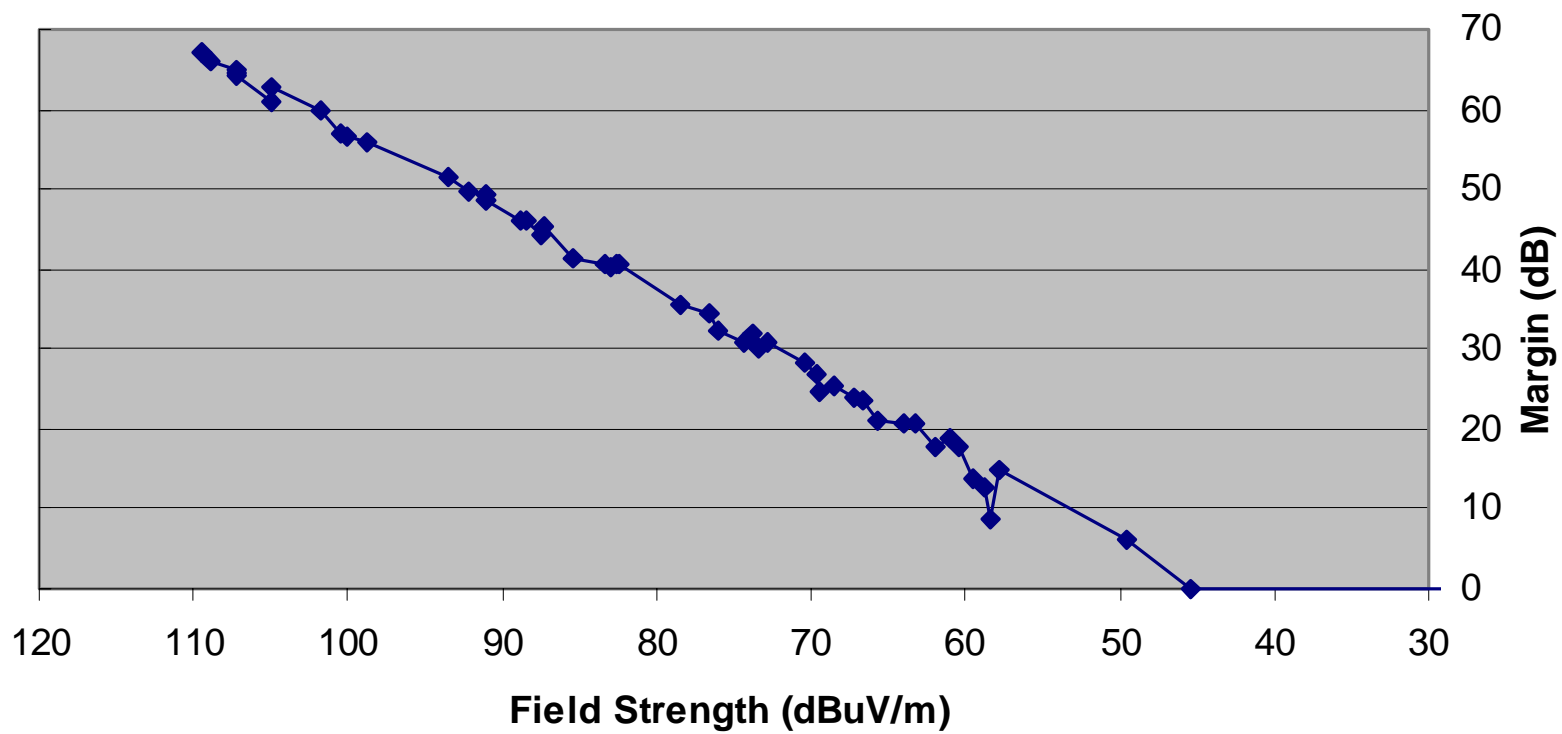


Chart C-6.

Ch 34 DTV Field Strength vs Margin Tripod Antenna Coverage Sites

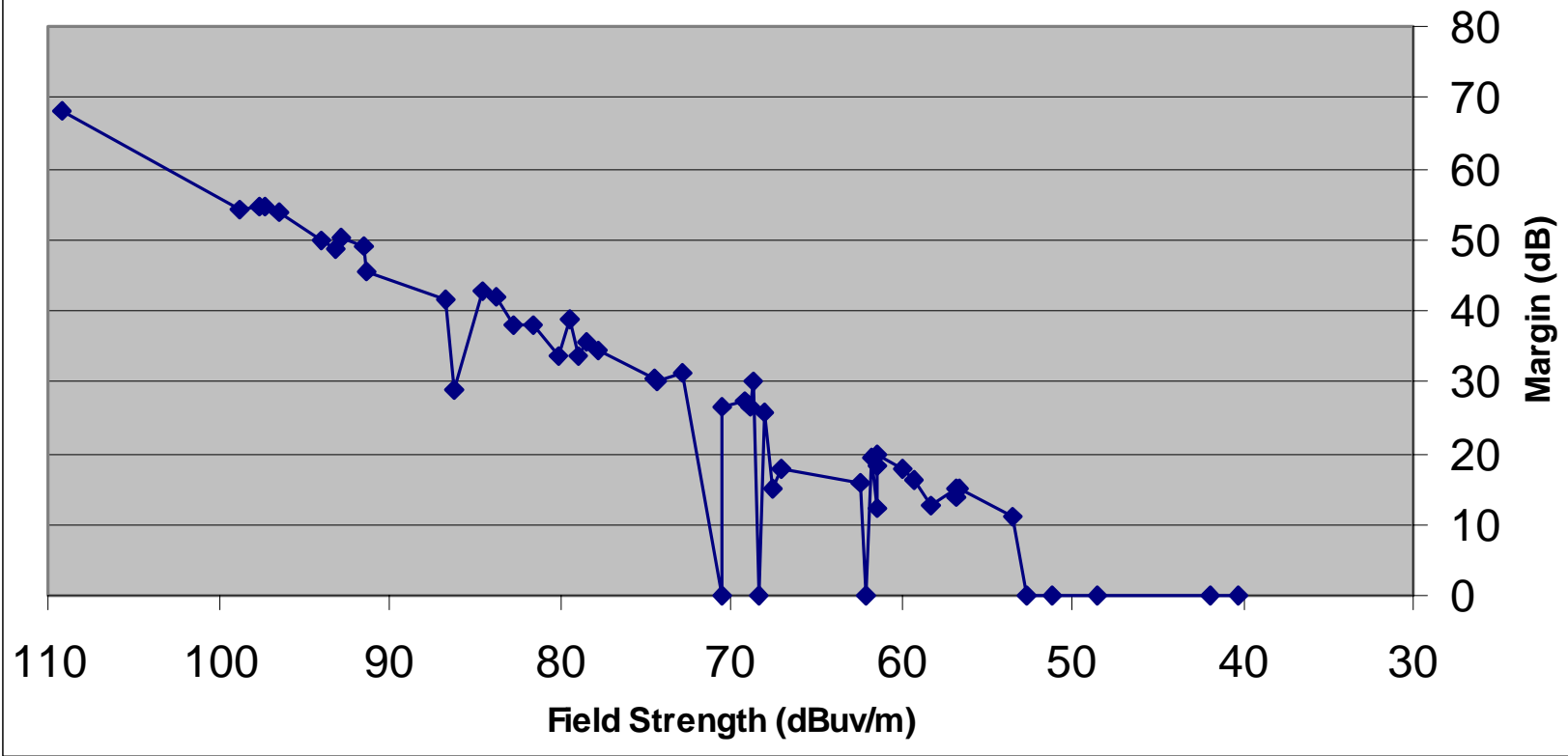


Chart C-7.

**Ch 48 DTV Field Strength vs Margin
Tripod Antenna
Coverage Sites**

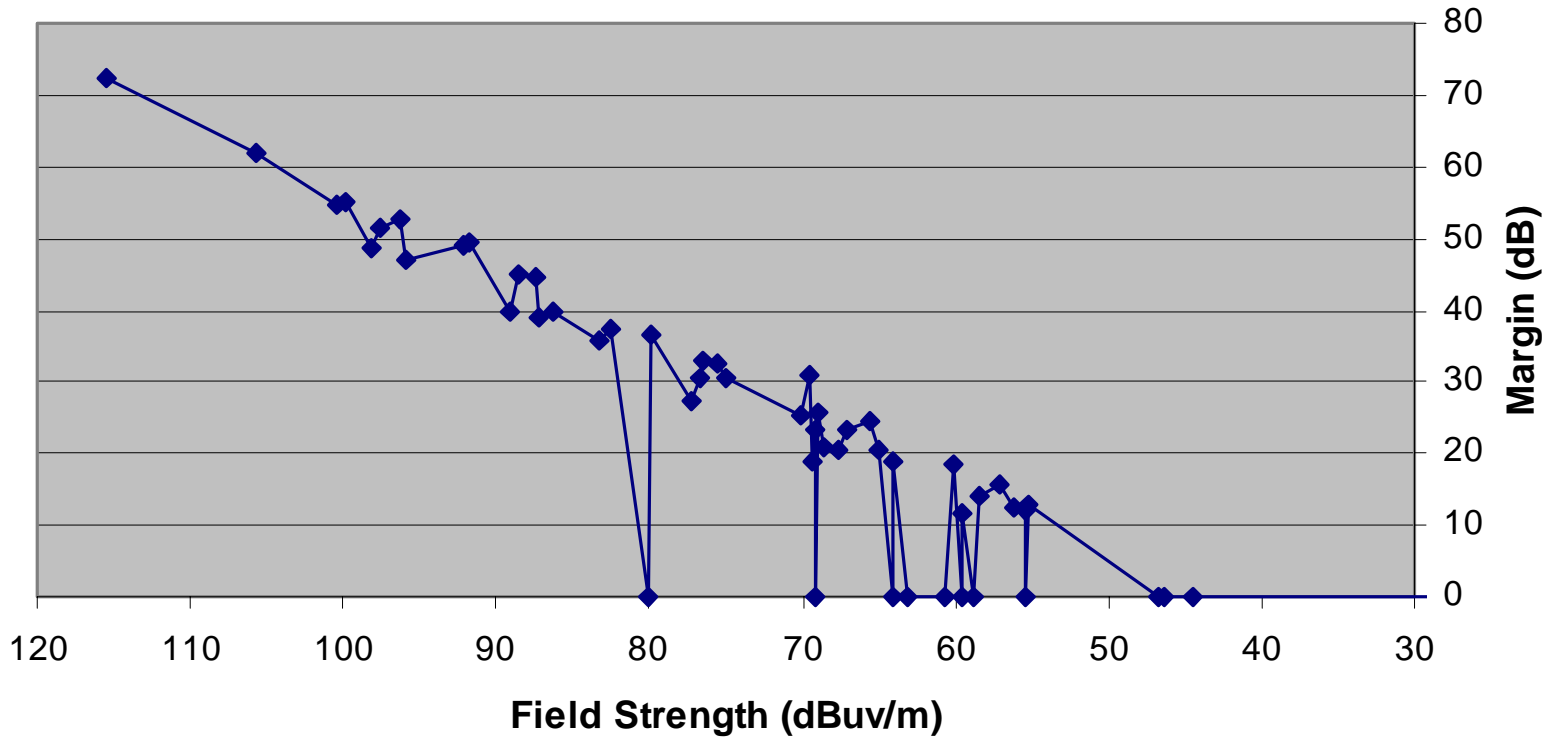
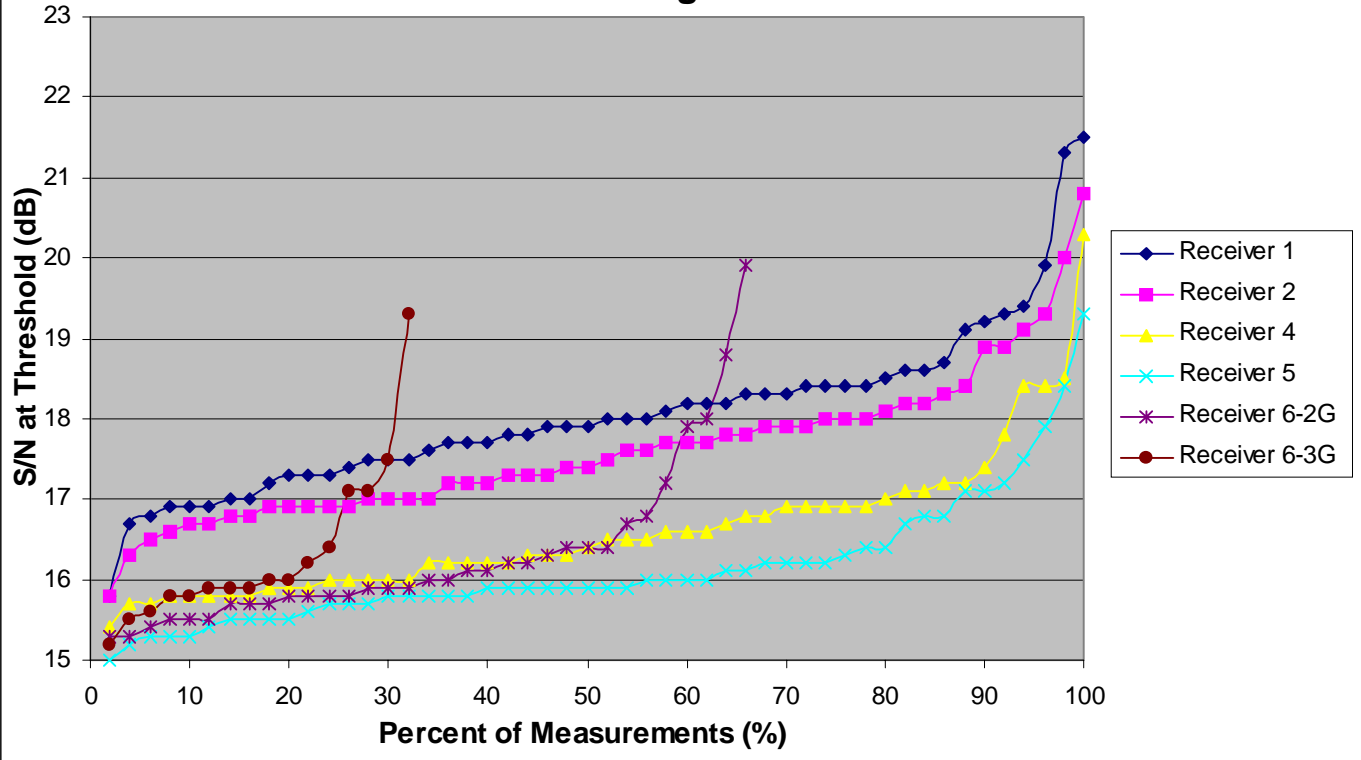


Chart C-8.

APPENDIX D

RECEIVER COMPARISON DATA

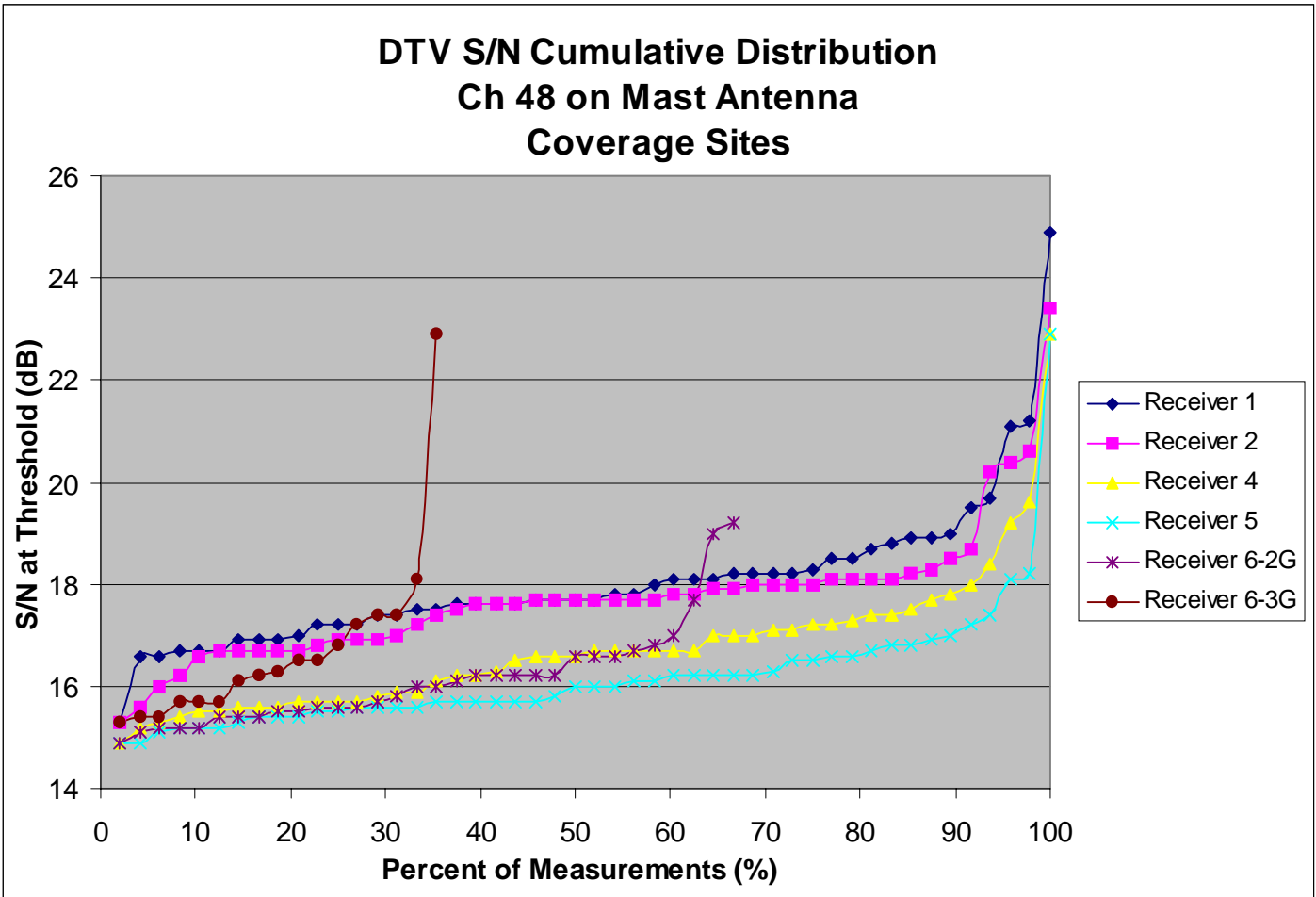
DTV S/N Cumulative Distribution Ch 34 on Mast Antenna Coverage Sites



Medians:

Receiver 1	18.0 dB
Receiver 2	17.7dB
Receiver 4	16.5 dB
Receiver 5	15.9 dB
Receiver 6-2G	16.0 dB
Receiver 6-3G	15.95 dB

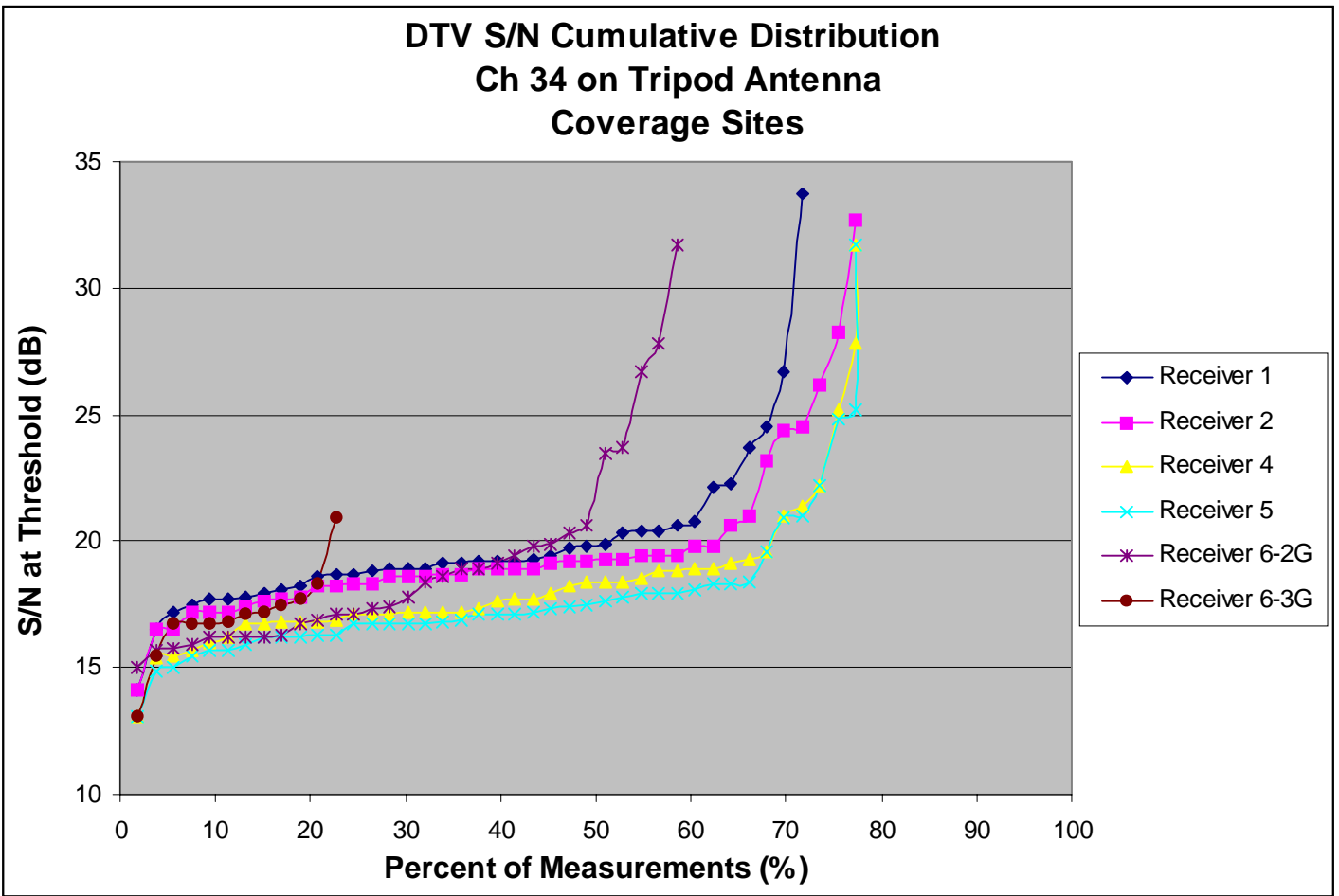
**Chart D-1.
Threshold of Visibility**



Medians:

Receiver 1	17.7 dB
Receiver 2	17.7 dB
Receiver 4	16.6 dB
Receiver 5	16.0 dB
Receiver 6-2G	16.0 dB
Receiver 6-3G	16.3 dB

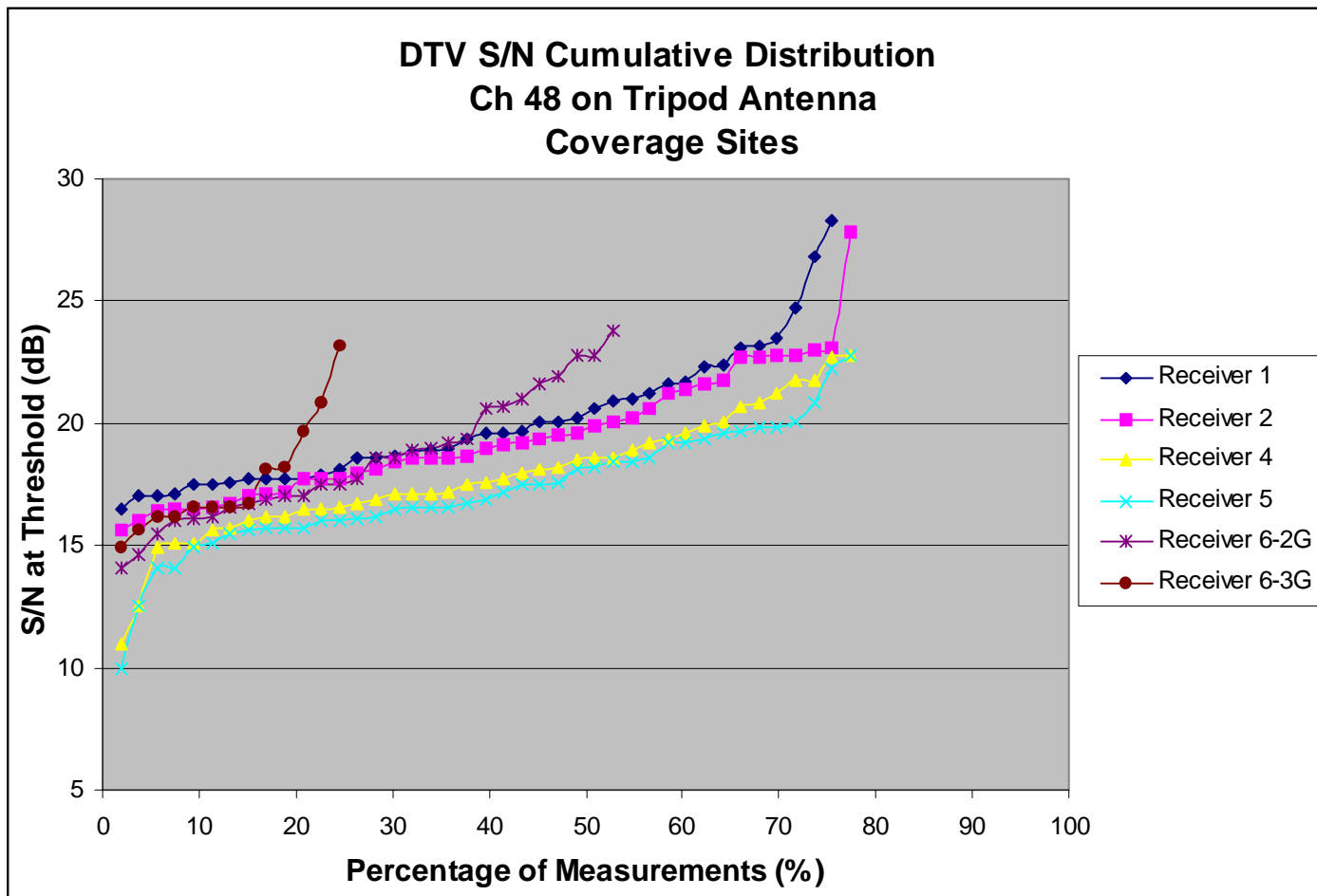
**Chart D-2.
Threshold of Visibility**



Medians:

Receiver 1	19.15 dB
Receiver 2	18.8 dB
Receiver 4	17.25 dB
Receiver 5	17.0 dB
Receiver 6-2G	17.8 dB
Receiver 6-3G	16.95 dB

**Chart D-3.
Threshold of Visibility**

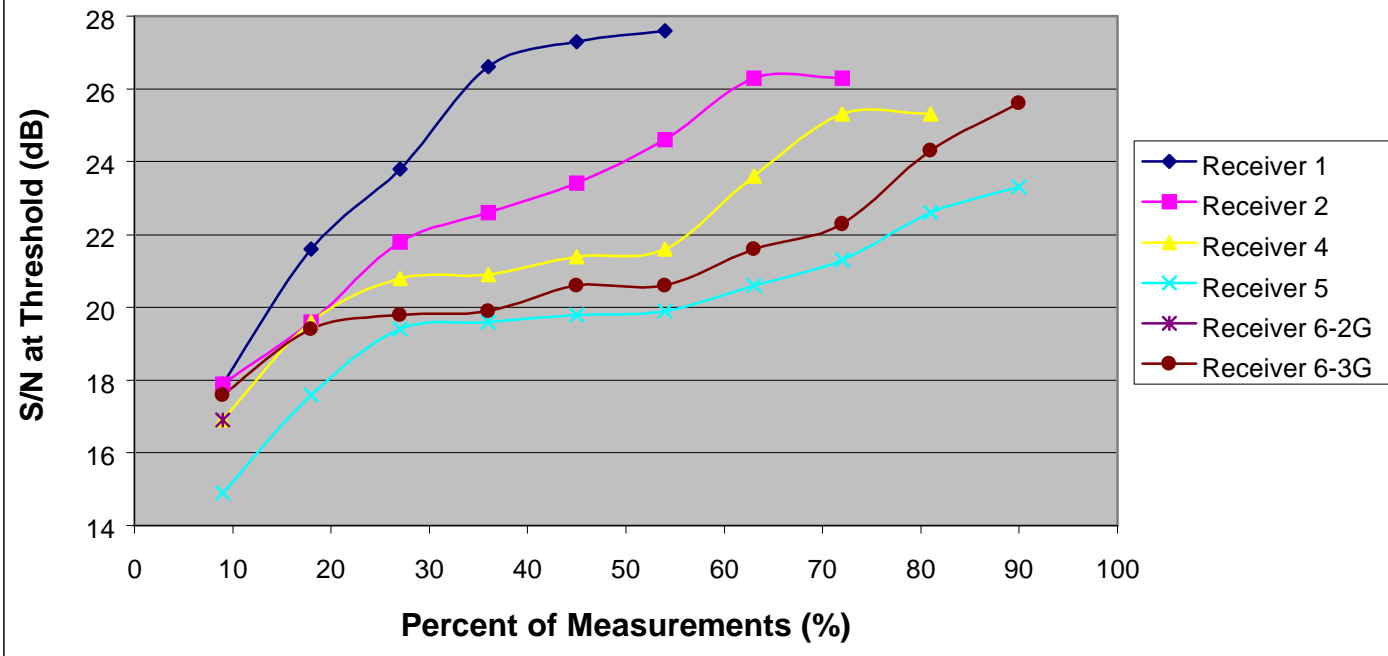


Medians:

Receiver 1	19.2 dB
Receiver 2	18.65 dB
Receiver 4	17.35 dB
Receiver 5	16.65 dB
Receiver 6-2G	18.15 dB
Receiver 6-3G	16.6 dB

**Chart D-4.
Threshold of Visibility**

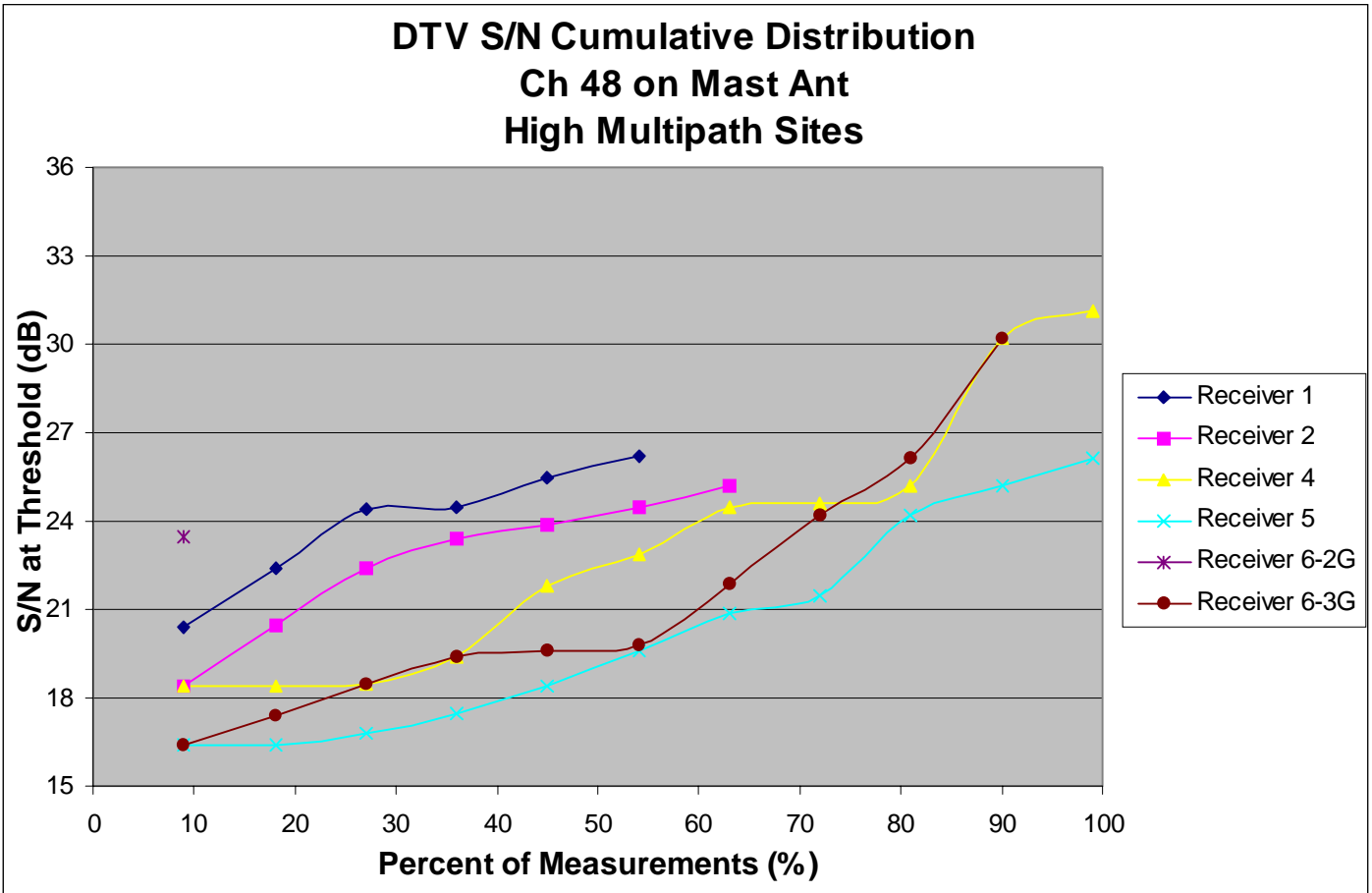
**DTV S/N Cumulative Distribution
Ch 34 on Mast Antenna
High Multipath Sites**



Medians:

Receiver 1	25.2 dB
Receiver 2	23.0 dB
Receiver 4	21.4 dB
Receiver 5	19.9 dB
Receiver 6-2G	16.9 dB (single data point)
Receiver 6-3G	20.6 dB

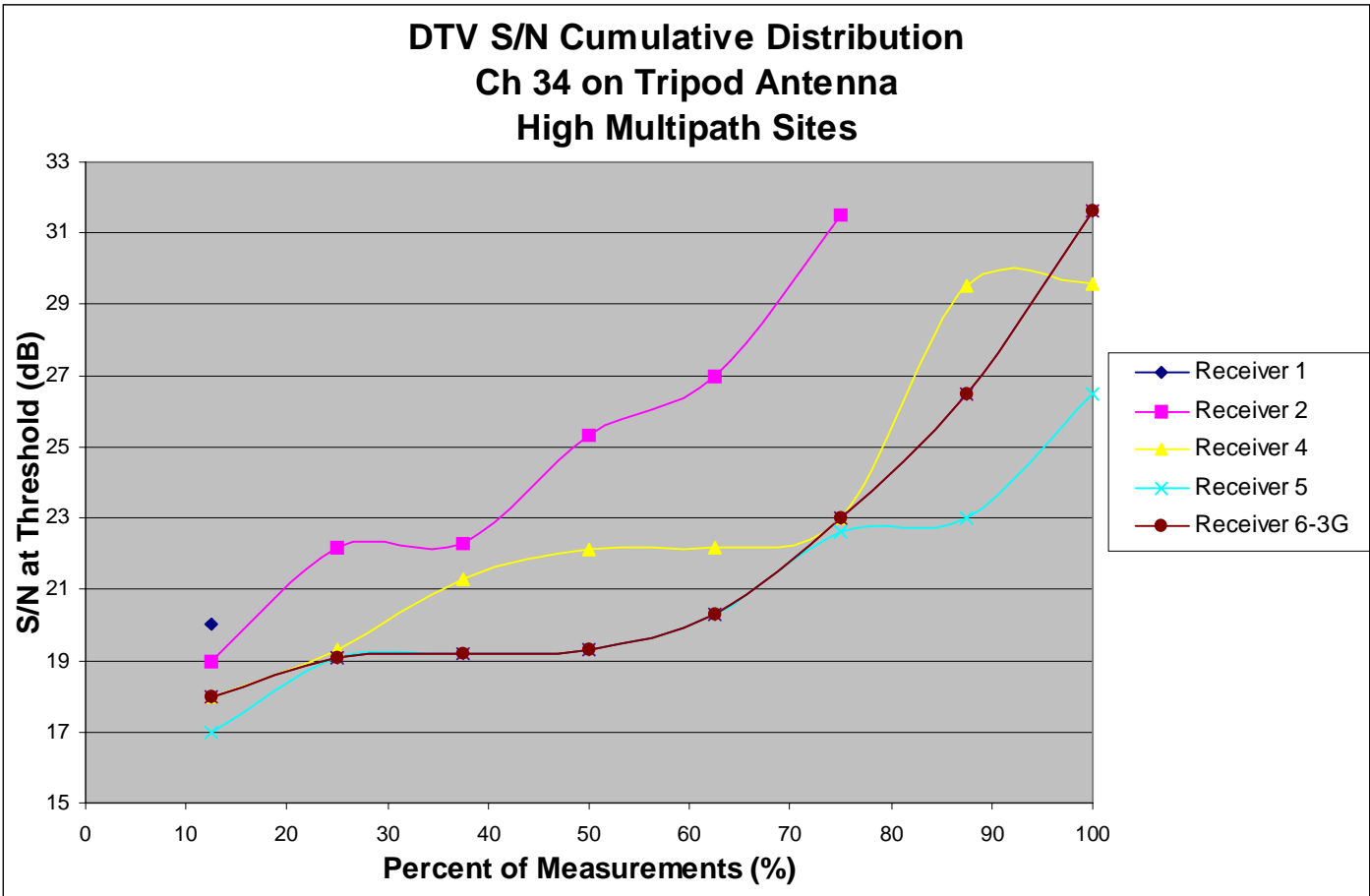
**Chart D-5.
Threshold of Visibility**



Medians:

Receiver 1	24.45 dB
Receiver 2	23.4 dB
Receiver 4	22.9 dB
Receiver 5	19.6 dB
Receiver 6-2G	23.5 dB (single data point)
Receiver 6-3G	19.7 dB

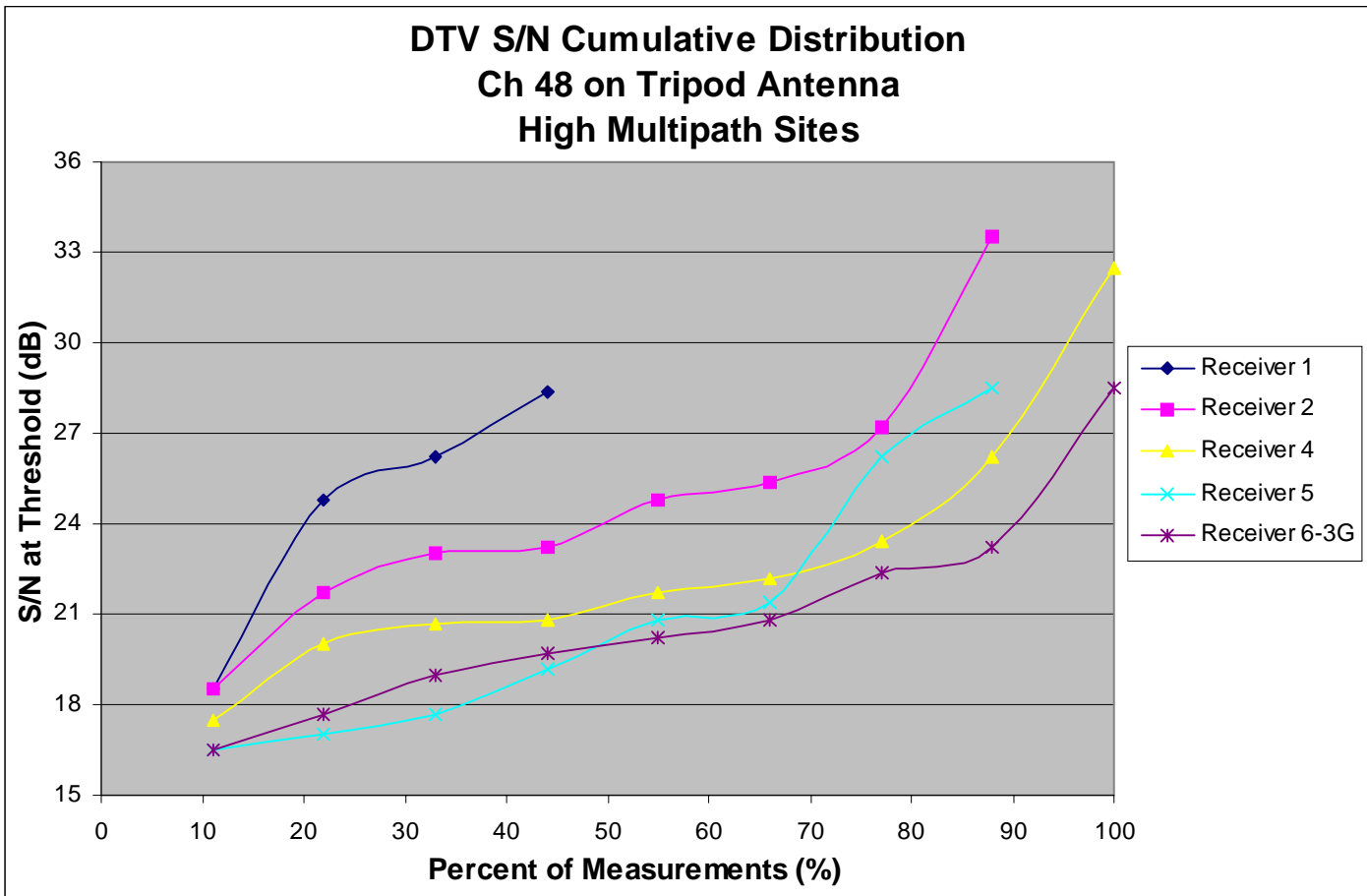
**Chart D-6.
Threshold of Visibility**



Medians:

Receiver 1	20.0 dB (single data point)
Receiver 2	23.8 dB
Receiver 4	22.15 dB
Receiver 5	19.8 dB
Receiver 6-2G	-----
Receiver 6-3G	19.8 dB

**Chart D-7.
Threshold of Visibility**



Medians:

Receiver 1	25.5 dB
Receiver 2	24.0 dB
Receiver 4	21.7 dB
Receiver 5	20.0 dB
Receiver 6-2G	-----
Receiver 6-3G	20.2 dB

**Chart D-8.
Threshold of Visibility**

APPENDIX E

NTSC/DTV COMPARISON

DTV/NTSC Channel (Antenna)	NTSC CCIR Rating	Median DTV Tap Energy	Median DTV Site Margin	# of NTSC Sites	Median NTSC CCIR Rating
34/32(Mast)	3.0-5.0	-15.2 dB	28.5 dB	29	4.0
34/32(Mast)	1.0-2.5	-14.3 dB	45.3 dB	19	2.0
34/32(Tripod)	3.0-5.0	-11 dB	41.8 dB	11	4.0
34/32(Tripod)	1.0-2.7	-9.8 dB	19.4 dB	36	1.5
48/50(Mast)	3.0-5.0	-16.7 dB	40.1 dB	37	4.0
48/50(Mast)	1.0-2.5	-14.4 dB	26.7 dB	13	2.0
48/50(Tripod)	3.0-5.0	-9.9 dB	38.0 dB	14	3.8
48/50(Tripod)	1.0-2.7	-9.4 dB	18.8 dB	32	1.5

Table E-1.

APPENDIX F

**PHOTOGRAPHS OF
TEST VEHICLE AND EQUIPMENT**



Photo F-1.
Front View of Vehicle with Antenna Mast Extended



Photo F-2.
Port Side View of Vehicle with Antenna Mast Extended

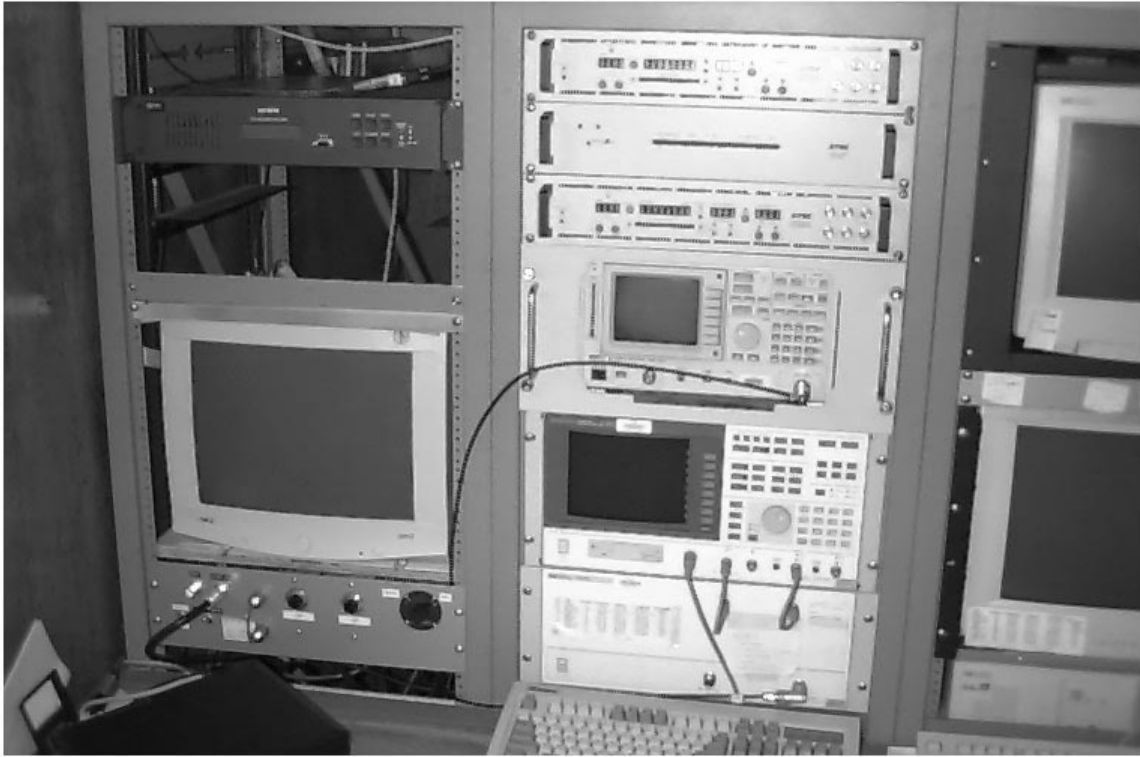


Photo F-3.
Starboard Half of Equipment Rack Showing Signal Attenuator Panel, Data Collection Receivers, Vector Signal Analyzer, and Spectrum Analyzer



**Photo F-4.
Port Half of Equipment Rack Showing Data Collection Computer, Picture
Displays, and Genset and Antenna Controls**



**Photo F-5.
Port Side of Operator Compartment Showing
Picture Displays and Receiver Shelf**



**Photo F-6.
Tripod-Mounted Bowtie Antenna with Preamplifier
and Remote Spectrum Display Viewing Box**