EX PARTE OR LATE FILED Docket 87-268

SS/WP2-1354
19 Sep 94

RECEIVED
DEC - 6 1994

Field Test Results of the Grand Alliance HDTV Transmission Subsystem

Submitted to

SS/WP2 Field Testing Task Force
of the
Advisory Committee on Advanced Television Service
of the
Federal Communications Commission

by

Association for Maximum Service Television, Inc.
Cable Television Laboratories, Inc.
Public Broadcasting Service

September 16, 1994

No. of Copies rec'd 1
List A B C D E

ABSTRACT

This document reports the results of broadcast and cable field tests on the VSB transmission system designed and built by the HDTV Grand Alliance. Conducted over several months by the FCC's Advisory Committee on Advanced Television Service, the tests were designed to compare 8VSB's broadcast coverage and 16 VSB's cable robustness to the performance of the current U.S. television system, NTSC. Additional field tests on the complete Grand Alliance HDTV system will be conducted subsequent to laboratory testing next year.

The broadcast results indicate that the ATV transmission system performance was significantly better than NTSC. In the UHF band, satisfactory reception for ATV was found at 92% of locations compared to 76% for NTSC. In the VHF band, ATV was satisfactorily received at twice as many locations as NTSC. The ATV average power was 12 dB below the NTSC peak power. In addition, the 8VSB system performed well under the real world conditions of multipath, impulse noise and other propagation phenomena, and in limited indoor reception testing.

The cable test results were equally encouraging. At sites where cable connections meet FCC specifications, a significant power margin above receiver noise was measured. Even at cable sites not meeting FCC specifications, directly-fed receivers were able to operate above the necessary threshold.

TABLE OF CONTENTS

	Page
Executive Summary	1
SECTION I. TERRESTRIAL FIELD TEST REPORT	
I. Introduction	5
II. Field Test Plan	6
III. Analysis of Test Results	11
A. Service Availability	
1. Overall NTSC Service Availability	12
2. Overall ATV Service Availability	13
3. Comparison of Overall NTSC and ATV Service Performance	14
4. Comparison of ATV and NTSC Service Availability for Grid and Radial Measurements	15
5. Comparison of ATV and NTSC Service Availability Versus Distance	17
B. ATV System Performance	
1. Effect of 6 dB Increase in Transmitter Power	19
2. ATV Margin	20
2.1. ATV Margin Versus CCIR Impairment Rating	21
2.2. ATV Margin Statistics for Grid Measurements	22
2.3. ATV Margin Statistics Versus Distance	24
3. Equalizer Tap Energy	25
3.1. Equalizer Tap Energy Statistics	26
3.2. Equalizer Tap Energy Statistics for Grid Measurements	27
3.3. Equalizer Tap Energy Versus Distance	28

	Page
4. Noise Floor Measurements	29
5. C/N Ratio at BER Threshold	30
6. Presence of Cochannel NTSC Signal	31
IV. Supplementary Tests	32
A. Cochannel Interference	33
B. Reception on Indoor Antennas	33
C. Reception from a UHF Directional Transmitting Antenna	34
V. Summary of Findings	34
A. Service Availability Performance	34
B. ATV System Performance	35
VI. Acknowledgments	36
References	36
Figures	
APPENDIX 1, 2, 3, 4, 5	
SECTION II. CABLE SYSTEM FIELD TEST REPORT	

SECTION I

TERRESTRIAL FIELD TEST REPORT

TESTING THE GRAND ALLIANCE FIELD TRANSMISSION SUBSYSTEM
REPORT FROM THE FIELD TESTING TASK FORCE TO SS/WP2

Executive Summary

On the basis of laboratory testing, the 8VSB transmission subsystem was selected by the Grand Alliance, and approved by the FCC Advisory Committee on Advanced Television Service (ACATS), as a component of the high definition television (HDTV) system under development and intended to replace the fifty year old NTSC system now in use. To provide a measure of the suitability of the system operating under real world conditions of propagation, a prototype of the transmission subsystem was provided in the spring of 1994 for testing under the sponsorship of the Field Testing Task Force of Systems Subcommittee Working Party 2 (SS/WP2). An important objective of the field testing was a determination of whether the HDTV system would provide satisfactory or superior service where NTSC service is presently available.

A field test plan was approved by SS/WP2. The Public Broadcasting Service (PBS) was selected to manage the testing and the Association for Maximum Television Service, Inc. (MSTV) was selected to provide data analysis. CableLabs had the responsibility for conducting performance tests of the ACATS-approved 16VSB cable system and analyzing the results. A 1,337-foot tower and building near Charlotte, North Carolina, were made available by Lodestar Towers Charlotte, Inc. Transmitters, antennas, test equipment and field truck were loaned to the project by a number of companies listed in Appendix 1.

The primary testing, described in the report on broadcasting, consisted of over-the-air reception measurements and observations at 199 sites, including 128 locations on eight radials extending to approximately 55 miles, and 71 locations in two large grids and three small grids, or clusters. The sample size for analysis included the full 199 locations for UHF performance on channel 53; however, because of interference encountered on cable channel 6, the VHF test sample included only 169 locations. Testing was performed also on cable system reception. The results of the cable testing appear in a separate report accompanying the over-the-air broadcasting report.

To avoid interference to operating NTSC television stations and to limit the need for a UHF transmitter with higher NTSC power output than 60 kilowatts, testing was done at a power 10 dB below (one-tenth) the maximum permitted for NTSC television operations. To provide the appropriate comparison of NTSC and ATV (HDTV) reception, average ATV effective radiated power (ERP) was restricted to a level 12 dB below (approximately one-sixteenth) the peak visual ERP of the NTSC transmissions. The 12 dB reduction had been determined by Working Party Three of the Planning Subcommittee (PS/WP3) to provide an equivalence in NTSC and ATV service areas based on planning factors derived from laboratory test results. The lower than permissible ERP limited the total service reach for both NTSC and ATV. However, by maintaining the appropriate ratio of powers, a valid comparison was made of performance of the ATV system relative to NTSC. If both NTSC and ATV power were increased 10 dB (10 times), the useful service distance would increase for both services. Throughout the test program, the peak NTSC ERP was 10 kW on VHF channel 6 and 500 kW on UHF channel 53. Average ERP during ATV transmission was 0.63 kW on channel 6 and 31.6 kW on channel 53.

The limit of ATV reception is sharply defined by a bit error rate (BER) of 3×10^{-6}; however, the limit of satisfactory NTSC reception is not as easily defined. For the purpose of these tests, a CCIR impairment rating of 3 (slightly annoying) or better was taken as the NTSC criterion for reception.

For the entire sample of 169 for VHF and 199 for UHF, satisfactory VHF NTSC reception was found at only 39.6 percent of the locations compared to 81.7 percent for ATV reception. Satisfactory UHF NTSC reception was found at 76.3 percent of the locations compared to 91.5 percent for ATV. The relatively poor performance of the VHF signals relative to UHF is believed to be attributable to the prevalence of high impulse noise within the service area, interference from distant co-channel stations, the presence of low level interference from cable use of channel 6, and/or interference to channel 6 reception from close-by noncommercial educational FM stations.

ATV performance was better than NTSC performance at all distances from the transmitter. For the entire range of distances, and for all sites where observations and measurements were made, 82 percent of the locations demonstrated satisfactory ATV results on channel 6 contrasted with 40 percent for NTSC. On channel 53, 91 percent of the sites showed that ATV reception would be expected to be satisfactory compared to 75 percent for NTSC. At the outermost portions of the radials, beyond 50

miles, 3 of a total of 15 sites demonstrated satisfactory reception for ATV on channel 6, but none of the 15 had NTSC service with a CCIR impairment grade of 3 or better. For the same points beyond 50 miles, 9 of the 16 sites had satisfactory UHF ATV reception compared to only 4 of the 16 sites having satisfactory NTSC reception.

The ATV system performed well under real world conditions of multipath and other propagation phenomena such as impulse noise and cochannel interference. For locations where NTSC had a CCIR impairment rating 3, the system provided ample ATV margin --a median of 25.6 dB for channel 6 and 19.9 dB for channel 53-- to deal with changes in signal level from location to location. The multipath conditions in Charlotte were well within the performance range of the equalizer. The ATV system also performed well in the presence of strong cochannel NTSC signals. The ATV system performed significantly better than NTSC in the presence of impulse noise.

In addition to the basic radial and grid measurements described above, three supplementary tests were performed: UHF cochannel interference, UHF reception on indoor antennas, and reception from a directional UHF transmit antenna. Cochannel testing of all three combinations of ATV to NTSC, NTSC to ATV, and ATV to ATV produced results in close agreement to those determined at the Advanced Television Test Center (ATTC). Indoor observations and measurements were made at twelve sites ranging in distance from 4.6 to 24.1 miles from the transmitter site. At all sites, with peak visual NTSC ERP 10 dB below maximum permitted, and average ATV ERP 12 dB below the NTSC level, ATV was received error-free with adequate margin. Impairment ratings of the NTSC pictures at the indoor sites ranged from 2.5 to 4 without ghost cancelling and 3 or 4 with ghost cancelling in use. The UHF directional tests were not extensive, however measurements revealed no unusual performance.

ATV signal transmission capability was tested on eight cable systems located in the Charlotte area. The channel 53 ATV signal was received off-air at the headend locations of the test cable systems, error corrected as necessary, combined with a second, locally generated pseudo-random bit sequence and modulated by the high data rate (35.6 Mb/s net) 16VSB cable modulator. The ATV RF signal was inserted at an average power level 6 dB below NTSC peak sync power on the cable either within the normal transmission band, if a spare channel was available, or above the top end of the spectrum used for NTSC if no other channel was available.

The receive margin was determined at the headend location and at a total of 41 remote sites at the extremes of the eight cable systems. The transmission path included an assortment of long trunk amplifier cascades, amplitude-modulated microwave and fiber links, terminated by either a direct path to a receiver or a simulated multi-TV home, at the end of the cascade. In all instances where the direct feed met the FCC specifications, there was at least a 5.9 dB margin above the noise threshold of the receiver. At test points that did not meet specifications due to low signal levels and/or tilt, the threshold was reduced but, in all instances, the direct fed receiver was able to operate above the error threshold of 3×10^{-6}. In three instances, all below FCC signal level specifications, the multi-TV house "worst case" simulation was below the threshold of data errors but the receiver had acquired and locked to the signal.

The objective of the field tests in Charlotte were met. The Grand Alliance HDTV transmission subsystem provided satisfactory reception where the NTSC service is presently available, and in many instances where NTSC reception was unacceptable

I. INTRODUCTION

The Grand Alliance, a consortium formed by AT&T, David Sarnoff Research Center, General Instrument Corporation, Massachusetts Institute of Technology, Philips Electronics North America Corporation, Thomson Consumer Electronics and Zenith Electronics Corporation, proposed the use of the eight-level, vestigial side band (8VSB) transmission subsystem after comparative testing of 8VSB and 32QAM at the Advanced Television Test Center (ATTC) and CableLabs. A 16VSB system for use in cable television systems was proposed also. The Advisory Committee on Advanced Television Service (ACATS) concurred in the recommendation. In the spring of 1994, a prototype 8VSB transmission subsystem was delivered to the Charlotte, North Carolina, Advanced Television Test Site for testing in the terrestrial broadcasting environment pursuant to procedures developed by the Systems Subcommittee Working Party Two (SS/WP-2) Field Testing Task Force. Additionally, a 16VSB prototype was made available for cable television tests.

The primary objective of the field testing program is to evaluate the in-band performance of the transmission subsystem under real world conditions of multipath and other propagation phenomena. Interference to adjacent channels were not evaluated. An important part of that evaluation is a comparison of the advanced television system with the NTSC system which has provided domestic television to North American viewers for fifty years. Stated otherwise, can the 8VSB transmission system provide satisfactory picture and sound where NTSC reception is satisfactory or, even better, might the newer system provide reception in locations where NTSC service is not satisfactory? Contrary to the gradual degradation of NTSC performance as signal strength decreases or interference increases, digital transmission reception above the threshold of visibility of interference (from either noise or other stations) can be expected to be an almost exact replication of what was transmitted; then, when the threshold is reached, picture and likely sound as well are lost.

It was deemed necessary to assess both the VHF and the UHF performance of the system. The Federal Communications Commission granted experimental authority to operate on VHF channel 6 and UHF channel 53, based on a study indicating that use of these channels presented little likelihood of causing interference to, or receiving substantial interference from, any existing television broadcast operation. As will be noted herein, the use of channel 6 presented an unexpected opportunity to observe problems of interference to cable reception The report that follows describes the facilities employed,

the test procedures used, the analysis method and the experimental results.

The Charlotte facility and field test operations were managed and staffed by the Public Broadcasting Service with guidance from The Association for Maximum Service Television, Inc. and Cable Television Laboratories, Inc.

II. FIELD TEST PLAN

SS/WP2 established a Field Testing Task Force to deal with field testing issues. A procedure for field testing was developed by that Task Force and submitted to the SS/WP2 parent body for approval. Implementation of the plan is described in the following paragraphs.

An initial task was the selection of a suitable transmitting site. The objective in site selection was to permit observation of system performance under varying conditions of propagation. Terrain in the site vicinity would need to range from relatively smooth earth to sufficient irregularity to assure that some receiving locations, although within nominal line-of-sight for smooth earth, would be obstructed. In addition, the site would have to be such that some receiving locations would be in a community of substantial size, other locations would be in smaller communities, and still others in a rural environment. Fortunately, a site meeting those requirements was available near Charlotte, North Carolina.

At the field testing site in Charlotte, North Carolina, a 1,337-foot tower and transmitter building have been made available by Lodestar Towers Charlotte, Inc., and the former owner of the tower, Journal Broadcasting of Charlotte, licensee of WCNC-TV. The availability of the tower and building is of prime importance, but Charlotte provides a number of other advantages. Weather in the Charlotte area provides decidedly different conditions with seasonal changes but is sufficiently mild that outdoor measurements can be conducted throughout the entire year. A variety of terrain conditions in the area permits consideration of terrestrial broadcasting performance over paths ranging from relatively smooth to sufficiently irregular to produce many obstructed receiving points. The Charlotte community is of such size that urban reception conditions can be explored, and smaller communities in the vicinity permit the exploration of what may be termed a suburban environment. In addition, a number of technically-diverse cable systems serve the area and were made available to CableLabs for their study of transmission subsystem performance using working cable systems.

Transmitters, transmission lines, transmitting antennas, a field truck, translator and substantial amount of test equipment were loaned to the project. A listing of suppliers to whom the project is indebted is provided in appendix 1 of this report. The transmitter building houses two transmitters, a Comark UHF transmitter with IOT output stage operating on channel 53 and an LDL solid-state VHF transmitter operating on channel 6, together with associated test equipment. Zenith provided an 8VSB modulator for use when either transmitter is delivering an ATV signal. An omnidirectional, top-mounted TFU-24G UHF antenna was provided by Dielectric. Just below the UHF antenna is a single-bay, omnidirectional VHF panel antenna provided by Harris Corporation. In addition, Andrew Corporation provided a directional UHF antenna which is side-mounted on the tower.

To avoid interference to operating NTSC stations and to limit the need for a UHF transmitter with higher NTSC power output than 60 kilowatts, testing was done at a power 10 dB below (one-tenth) the maximum permitted for NTSC operations. To provide the appropriate comparison of NTSC and ATV reception, average ATV effective radiated power (ERP) was restricted to a level 12 dB below the peak visual ERP of the NTSC transmissions. The 12 dB reduction had been determined by Working Party Three of the Planning Subcommittee (PS/WP3) to provide an equivalence in NTSC and ATV service areas based on planning factors derived from laboratory test results. The lower than permissible ERP limited the total service reach for both NTSC and ATV; however, by maintaining the appropriate ratio of powers, a valid comparison was made of performance of the ATV system relative to NTSC. Throughout the test program, ERP was 10 kW on VHF channel 6 and 500 kW on UHF for NTSC. Average ERP during ATV transmission was 0.63 kW on channel 6 and 31.6 kW on channel 53.

The field truck, loaned by Harris Corporation, is complete with AC generator and extendible mast. Installed equipment includes a consumer-type[1] Delhi Model VU-932, all-band receiving antenna, field strength meters, NTSC receiver with switchable ghost canceler, vector signal analyzer, spectrum analyzer, Tektronix demodulator, personal computer for both control and collection of data, waveform monitor, D3 video tape recorder, VM700 video measuring set, bit error rate measuring equipment, noise generator, amplifiers, attenuators, splitters and cabling. The Zenith 8VSB demodulator with associated computer and test equipment provide the capability of reading signal-to-noise ratio at both the input and

---

[1] A consumer-type antenna was selected to provide comparability to what a viewer may use. The choice was consistent with the test objective to determine the suitability of the 8VSB transmitting system as a substitute for the present NTSC system.

output of the equalizer, equalizer tap energy and segment error rate. For communications with the transmitter and elsewhere when necessary, the field truck is equipped with both a broadcast auxiliary transceiver and cellular telephone.

Block diagrams showing the interconnection of the transmitter building equipment and the field truck equipment are shown in Figures 1 and 2, respectively. A copy of the manufacturer's descriptive sheet on the receiving antenna is included as Figure 3.

Basic testing included measurements and observations at 199 locations. Of the 199 locations, 128 were along eight radials extending to 55 miles (88.5 km) from the transmitter. The radial directions were selected to provide a range of terrain conditions. The remaining locations were in two large grids with one-mile (1.6 km) spacing and three small grids, or clusters, with one-half mile (0.8 km) spacing. One grid and one cluster are located in Charlotte. The second grid and second cluster are located in the smaller community of Rock Hill, South Carolina. The third cluster is located approximately 2.5 miles (4.0 km) from the transmitter, selected to provide information on performance of the antennas at relatively large depression angles.

Maps showing the locations of all radial and grid receiving sites are included in Appendix 2. Appendix 3 contains the horizontal and vertical radiation characteristics of the omnidirectional VHF and UHF transmitting antennas, Appendix 4 contains the directional UHF antenna characteristics for the translator and maps showing the locations of the sites for the supplemental testing, and Appendix 5 contains the tabulated data for all 199 measurement locations.

Transmitter and field truck calibrations were carried out at the start of each day's work, and critical parameters were again checked at the end of the day. Transmitter and field truck calibration include: NTSC and ATV power, frequency, visual-to-aural carrier ratio (NTSC), linearity, differential gain, ICPM, ATV peak-to-average ratio, ATV pilot carrier frequency, transmitter noise floor, adjacent channel roll-off, carrier-to-noise ratio, ATV equalizer tap settings, field truck system net gain, and field truck noise floor.

At each test location, field strength was recorded on both channels 6[2] and 53 while moving the field truck over a 100-foot path with antenna erected at 30 feet above ground. After completing the 100-foot run, the field truck was returned to the center of the path for measurements and observations at a fixed site. To avoid receiver overload, attenuators were set in strong signal areas to provide suitable input level. (The function of the attenuator is comparable to that of the automatic gain control (AGC) of a television receiver). NTSC peak sync level, noise floor, carrier-to-noise level over the 6 MHz band, and video signal-to-noise were measured. The NTSC picture impairment rating, using the CCIR, five-point grading scale was determined both with and without ghost cancellation and comments are noted relative to the impairment characteristics. A spectrum analyzer "snapshot" and cochannel interfering signal level (if any) were recorded as well as channel characterization data using equipment provided by the Institute of Telecommunication Science (ITS) of the Department of Commerce National Telecommunications and Information Administration (NTIA). In addition, Hitachi America, Inc. provided for a short period during the field tests, digital recording equipment which took feeds from channel 6 and 53 signal paths, downconverted them to basedband and recorded the resulting 8VSB waveform at a sampling rate of 21.524 MHz and 8 bits resolution. The recordings were made in a standard computer format and are available upon request.

ATV data collected includes equalizer signal-to-noise ratio at the input and output of the equalizer, equalizer tap energy, input signal level, pilot level, bit error rate, segment error rate, noise floor and margin to the bit error rate (3×10^{-6}) previously determined in the laboratory to correspond to the threshold of visibility (TOV). Margin is determined by adding a measured amount of white Gaussian noise to the signal. After sufficient noise has been added to increase error rate to the desired level, equalizer parameters are again recorded.

Data collected at each site were recorded on log sheets. In addition, separate personal computers in the NTSC and ATV portions of the field truck were employed to record field strength, determine minimum, median and maximum field strength during the 100-foot runs, preserve spectrum analyzer displays, record vector analyzer output, and record channel characterization data. A D3 videotape recorder was used to record the received NTSC signals on both channels 53 and 6.

---

[2] As noted subsequently, channel 6 measurements had to be curtailed at a minority of the sites to avoid interference to reception on cable channel 6.

Test results were withheld until the completion of testing. All data were held by those charged for analysis until they were reviewed for accurate reporting and incorporated in a draft report first submitted to the Grand Alliance for concurrence that data were being analyzed correctly, then submitted to the Field Testing Task Force for review, suggestions for modification, if appropriate, and approval.

As noted above, channel 6 was selected for VHF testing based on a conclusion that the use of that channel presented the least likelihood of interference to or from any operating VHF television broadcasting station. Use of channel 6 produced unanticipated results and an opportunity to observe phenomena not usually taken into account in the allotment of channels for broadcast purposes. Those phenomena included: interference to cable carriage on channel 6, prevalence of impulse noise originating from a 60-Hz source, and interference to channel 6 reception from FM broadcast stations operating in the band 88.1 to 91.9 MHz, adjacent to channel 6 occupying the band 82 to 88 MHz.

Upon initiation of testing on channel 6, complaints of interference within cable channel 6 were received. Charlotte television broadcast station WCNC-TV, the NBC affiliate broadcasting on channel 36, is carried on channel 6 by the Charlotte area cable television systems. A study organized by CableLabs indicated that some interference was produced by pickup on the cable system, some interference was produced by direct pickup within the television receiver, but the most common source of the interference was probably the cabling householders installed to connect a VCR into the circuit or for other purposes. The interference could be eliminated in many instances by using improved cabling or, if permitted by the viewer, installing a set top converter. Because of the reported prevalence of interference to cable channel 6, use of that channel, particularly in the NTSC mode, had to be limited to short, well spaced intervals. As a result, not all locations tested for UHF channel 53 reception could also be tested also on channel 6. With the transmission subsystem phase of the field testing now complete, further work is planned to better understand the extent of the problem and how interference might be avoided during the final phase of testing by incorporating the complete ATV prototype.

For almost half of the test locations, impulse noise ranging from moderate to extremely strong was observed. Spectrum analyzer displays of the impulse noise showed it to vary from sharp spikes to fairly broad pulses; however, all demonstrated the 120-Hz repetition rate characteristic of the positive and negative maxima of a 60-Hz signal. Locations of particularly strong impulse noise are to be compared

with the Charlotte area power grid to determine whether or not correlation appears. It is believed that the impulse noise problem in Charlotte may be atypical, and may not be representative of other urban areas.

With no regularly assigned channel 6 television broadcast station in the Charlotte vicinity, the inhibitions against placement of noncommercial FM broadcast stations are not present. Consequently, a number of FM broadcast stations in the 88.1 - 91.9 MHz band exist near Charlotte. At a few locations, adjacent channel interference was sufficiently high that channel 6 data could not be adequately measured.

III. ANALYSIS OF TEST RESULTS

As previously mentioned, a total of 199 measurement locations were selected for this measurement program. Approximately two-thirds of the measurement locations were along eight carefully selected radials, extending to approximately 55 miles, where strong, moderate and weak signals conditions are normally encountered. The remaining one-third were relatively "close-in" measurements, (referred to herein as "grid and cluster" measurements), where predicted signal levels are expected to be strong or moderate, and variations in signal levels are attributed usually to shadowing and reflections from foreground terrain and clutter near the receiving antenna installation. Data were collected at all 199 locations on channel 53; however, because of the complaints of interference to cable channel 6, only 169 locations were measured on channel 6.

For the purpose of this analysis, the bit-error ratio (BER) is used as the principal measure of performance of the digital transmission system. It is assumed that a site which achieves a BER of 3×10^{-6} or better has satisfactory reception. For NTSC, however, the gradual degradation of NTSC performance makes it difficult to determine a threshold at which the NTSC reception is not satisfactory. For this analysis, however, a subjective yardstick was selected --CCIR impairment rating 3 or better-- to define satisfactory performance for NTSC.

To evaluate the performance of the 8VSB system in the field, the analysis is divided into two parts. The first part examines the ATV service performance relative to NTSC, the second examines the performance of the ATV system itself. The evaluation was conducted using a number of standard parameters commonly used in field test analysis.

A. Service Availability

1. Overall NTSC Service Availability

To assess the overall service availability within the predicted NTSC service area, a subjective evaluation method was used. Evaluation consisted principally of visual evaluation of the received television picture by two expert observers rating the overall picture quality using a CCIR impairment scale and Experts Observations and Commentaries (EO&C) to evaluate audio degradation. To rate the signal quality and impairment level, the expert observers each evaluated the image and sound quality and arrived at a rating by consensus. Assessment was made to the nearest half step on the five point scale, an acceptable practice in CCIR studies. Table 1 presents the impairment statistics for both channels (6 & 53) for all the measured locations. The combined grid, cluster and radial measurements were included in the tabulation of the impairment statistics. The sample size is 169 sites for channel 6 and 199 for channel 53.

TABLE 1

Overall Impairment Assessment of NTSC Measurement Sites*

(Channels 6 & 53)

CCIR IMPAIRMENT SCALE	Channel 6 (%)	Channel 53 (%)
5 Imperceptible	2.4	3.5
4 Perceptible, but Not Annoying	13.0	52.3
3 Slightly Annoying	24.2	20.6
2 Annoying	27.2	14.5
1 Very Annoying	33.2	9.1

* NTSC peak power was 10 dB below the maximum allowable power.

The statistics in Table 1 reveal that picture impairments were far more prevalent in VHF than UHF. This unanticipated result is believed to be attributable to the prevalence of high impulse noise within the service area, the presence of co-channel interference from distant stations, low level interference from cable installations on channel 6, and/or the interference to channel 6 reception from close-by noncommercial educational FM stations

2. Overall ATV Service Availability

Unlike NTSC, the overall service availability of the ATV system within its predicted service area can be determined with great accuracy since the ATV picture is lost below a certain threshold level. This threshold level was previously determined to correspond to a bit error rate of 3×10^{-6}. Table 2 presents the percentages of all the ATV measurement sites that are less than and greater than the threshold level. The combined grid, cluster and radial measurements were included in the tabulation of the service availability. As before, the sample size is 169 sites for channel 6 and 199 for channel 53.

TABLE 2

Overall Service Availability of ATV Measurement Sites*

(nnel 6 & 53)

ATV SERVICE AVAILABILITY	Channel 6 (%)	Channel 53 (%)
BER $< 3 \times 10^{-6}$	81.7	91.5
BER $> 3 \times 10^{-6}$	18.3	8.5

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

A review of the ATV service availability statistics in Table 2 reveals that the overall service availability is higher for UHF than for VHF. Here again, these unanticipated results are believed to be attributable to the prevalence of high impulse noise within the service area, the presence of cochannel interference from distant stations, low level interference from cable installations on channel 6, and/or the

interference to channel 6 reception from close-by noncommercial educational FM stations.

3. Comparison of Overall NTSC and ATV Service Performance

As stated above, CCIR grade 3 or better was selected as the criterion for satisfactory NTSC reception, while a BER of 3 x 10^{-6} or less is considered as satisfactory reception for ATV. Table 3 presents the percentage of locations, NTSC and ATV, where satisfactory reception was achieved for both channels. The combined grid/cluster and radial measurements were included in the tabulation of the service availability. The sample size is 169 sites for channel 6 and 199 for channel 53.

TABLE 3

Relative Service Performance of NTSC and ATV*

(Channel 6 & 53)

SERVICE PERFORMANCE	NTSC		ATV	
	Ch. 6 %	Ch. 53 %	Ch. 6 %	Ch. 53 %
Percent of Locations with Satisfactory Reception	39.6	76.3	81.7	91.5
Percent of Locations without Satisfactory Reception	60.4	23.7	18.3	8.5

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

The service performance statistics in Table 3 show that the ATV service performance statistics for channel 53 are higher than for NTSC and substantially better than NTSC for channel 6. The data also show that the service availability for both NTSC and ATV is far better on channel 53 than channel 6. Here again, the prevalence of impulse noise within the service area, the presence of co-channel interference from distant stations, low level interference from cable installations on channel, 6 and/or the interference to channel 6 reception from close-by noncommercial educational FM stations are believed

to produce the unanticipated results.

4. Comparison of ATV and NTSC Service Availability for Grid and Radial Measurements

As noted earlier, the grid and cluster measurements were collected primarily to evaluate signal level variations usually attributable to shadowing and reflections from foreground terrain and clutter. By separating the data into grids and radials, ATV and NTSC service performance under these propagation conditions can be determined and compared. Tables 4 and 5 present the service availability, NTSC and ATV, for the grid and radial measurements for channels 6 and 53 respectively.

TABLE 4

ATV and NTSC Service Availability for Grid and Radial Measurements*

(Channel 6)

MEASUREMENT LOCATIONS	Number of Sites Measured	% of NTSC Sites CCIR 3, 4 or 5	% of ATV Sites BER < 3×10^{-6}
Charlotte Grid & Cluster (G1/C1)	33	64	97
Rock Hill Grid & Cluster (G2/C2)	9	33	89
Radial	127	34	77
Total	**169**	**40**	**82**

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

TABLE 5

ATV and NTSC Service Availability for Grid and Radial Measurements*

(Channel 53)

MEASUREMENT LOCATIONS	Number of Sites Measured	% of NTSC Sites CCIR 3, 4 or 5	% of ATV Sites BER < 3 x 10^{-6}
Charlotte Grid & Cluster (G1/C1)	33	85	94
Rock Hill Grid & Cluster (G2/C2)	33	82	94
"Close-in Cluster" (C3)	5	100	100
Radial	128	72	90
Total	**199**	**76**	**91**

* NTSC power peak was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

Tables 4 and 5 show that ATV service performance on channel 6 for both grid and radial measurements is much better than for NTSC. They also show that ATV performance on channel 53 was higher for the grid and radial measurements than for NTSC. The ATV system is capable of dealing adequately with signal variations from location-to-location (i.e., location variability).

5. Comparison of ATV and NTSC Service Availability versus Distance

To evaluate service availability under different signal level conditions, (i.e., strong, moderate and weak), ATV and NTSC measurements were grouped in 10-mile increments and sorted by increasing distance. Tables 6 and 7 present a comparison of the service availability versus distance between NTSC and ATV on channels 6 and 53 respectively. The combined grid, cluster and radial measurements were included in the tabulation of the service availability.

TABLE 6

Relative Service Performance for NTSC and ATV versus Distance*

(Channel 6)

DISTANCE (miles)	Number of Sites Measured	% of NTSC sites CCIR 3, 4 or 5	% of ATV Sites BER $< 3 \times 10^{-6}$
0 - 9.9	27	67	96
10.0 - 19.9	38	68	97
20.0 - 29.9	33	42	94
30.0 - 39.9	28	14	89
40.0 - 49.9	28	18	57
50.0 - 56.0	15	0	20
Total	**169**	**40**	**82**

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

TABLE 7

Relative Service Performance for NTSC and ATV versus Distance*

(Channel 53)

DISTANCE (miles)	Number of Sites Measured	% of NTSC Sites CCIR 3, 4 or 5	% of ATV Sites BER < 3×10^{-6}
0 - 9.9	32	88	97
10.0 - 19.9	38	97	97
20.0 - 29.9	51	88	98
30.0 - 39.9	34	59	91
40.0 - 49.9	28	64	86
50.0 - 56.0	16	25	56
Total	**199**	**76**	**91**

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

The data in Tables 6 and 7 illustrate that the service performance versus distance is better for ATV than NTSC, with a significant improvement between 30 and 50 miles.

B. ATV System Performance

The data collected for ATV included a number of parameters that are useful not only in evaluating ATV service availability but also in determining the performance of the ATV system under various interference and impairment conditions. For example, equalizer tap energy statistics could tell how hard the equalizer is working to correct for varying signal levels, and multipath conditions; ATV margin data could tell how far the signal level may vary before ATV reception is lost; and changes in ATV noise floor, C/N, etc., could tell the performance of the ATV system under various impairments

conditions (co-channel, impulse noise, multipath, etc.) A detailed assessment of these various parameters is presented below.

1. Effect of 6 dB Increase in Transmitter Power

As stated above, the tests in Charlotte were conducted at power level of 10 dB below the maximum allowable power on both VHF and UHF. The measurement program allowed for increase in the ATV power by 6 dB to determine whether such an increase will improve the ATV availability of service. Tables 8 and 9 present changes in the availability of service versus distance due to the increase in the ATV power.

TABLE 8

ATV Service Performance for Nominal Power* and 6 dB Power Increase versus Distance

(Channel 6)

DISTANCE (miles)	Number of Sites Measured	% of ATV Sites Tx = nominal BER < 3×10^{-6}	# of ATV Sites Tx = +6 dB BER < 3×10^{-6}
0 - 9.9	27	96	100
10.0 - 19.9	38	97	100
20.0 - 29.9	33	94	97
30.0 - 39.9	28	89	96
40.0 - 49.9	28	57	89
50.0 - 56.0	15	20	67
Total	**169**	**82**	**94**

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

TABLE 9

ATV Service Performance for Nominal Power* and Power Increase versus Distance

(Channel 53)

DISTANCE (miles)	Number of Sites Measured	% of ATV Sites Tx = nominal BER < 3×10^{-6}	% of ATV Sites Tx = +6 dB BER < 3×10^{-6}
0 - 9.9	32	97	97
10.0 - 19.9	38	97	97
20.0 - 29.9	51	98	98
30.0 - 39.9	34	91	97
40.0 - 49.9	28	86	93
50.0 - 56.0	16	56	63
Total	**199**	**91**	**94**

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

The data show that for channel 53, which was primarily limited by white noise, the 6 dB increase in transmitter power slightly improved the availability of service statistics. On the other hand, improvement in service availability statistics for channel 6 were much larger than what would be expected from white noise. These results suggest that other factors, such as impulse noise and adjacent channel interference from FM stations, may have affected the ATV service availability statistics for channel 6.

2. ATV Margin

ATV margin is the measure of how far signal level can fall before the picture and sound are lost to the viewer. Since signal level at the receiver varies with location, time of day, season and meteorological factors, the margin is a good indicator of service reliability. ATV margin will be