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ATSC Recommended Practice: Developing DTV Field Test Plans

Advanced Television Systems Committee

1750 K Street, N.W.

Suite 1200

Washington, D.C. 20006

www.atsc.org

The Advanced Television Systems Committee (ATSC), is an international, non-profit membership organization developing voluntary standards for the entire spectrum of advanced television systems.

Specifically, ATSC is working to coordinate television standards among different communications media focusing on digital television, interactive systems, and broadband multimedia communications. ATSC is also developing digital television implementation strategies and presenting educational seminars on the ATSC standards.

ATSC was formed in 1982 by the member organizations of the Joint Committee on InterSociety Coordination (JCIC): the Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Television Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). Currently, there are approximately 190 members representing the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

ATSC Digital TV Standards include digital high definition television (HDTV), standard definition television (SDTV), data broadcasting, multichannel surround-sound audio, and satellite direct-to-home broadcasting.

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ATSC Recommended Practice for Developing DTV Field Test Plans

1. SCOPE

This document presents the objectives of, and general methodology for conducting field tests of over-the-air terrestrial digital television (DTV) systems. The scope of the work includes reception, demodulation, and recovery of the transmitted data. The scope of the work herein is not concerned with the decoded data or analog signals except when these signals are used as a means to determine that the data has been correctly recovered.

2. NORMATIVE REFERENCES

Normative references should be added to any Test Plan document developed.

[1] 47 CFR 73.686—Coverage Measurements

[2] 47 CFR 73.622—DTV Allocations

[3] 47 CFR 73.625—DTV Coverage of Principal Community and Antenna Systems

3. INTRODUCTION

This document presents the recommended objectives and methodology for development of field test plans. Such plans would be useful to gather field data of Digital Television systems in order that useful conclusions about DTV signal coverage, service area, and receivability can be obtained. While tests and measurements may be conducted for different reasons and objectives, the resultant data may be analyzed by others and for other reasons and objectives. Consequently, it is recommended that all tests and measurements documented herein be conducted and data gathered using the set of principles and general procedures in order that data analysis of different tests and resultant conclusions are consistent and meaningful.

4. FIELD TESTING OBJECTIVES

This document provides recommendations for development of test plans to meet the following objectives. DTV Test Plan implementations may focus on certain aspects of the objectives depending upon the immediate requirements of the testing entity. Thus, plans developed using this document have one or more of the following objectives.

- a) Identify the variables in the environment and recommend the minimum set of variables to be measured.
- b) To measure actual “service” versus predicted “coverage”.
- c) To collect data useful in improving the DTV system performance.

The goal is to provide a uniform series of test procedures whose results and data can be compared with results of other tests conducted by various organizations in different locations, or at different times, or both.

Testing may be conducted for specific goals and objectives that include but are not limited to the following:

- Comparison of one digital transmission system to another
- Comparison of a digital transmission system to an analog system
- Comparison of various transmission and receiving components
- Comparison of different generations of components

- Comparison of different environments
- Statistical characterization of the RF environment

5. DEFINITIONS

5.1 Coverage Testing

Coverage is defined as the determination of actual field strengths measured for a given transmission facility. There are generally two purposes for coverage measurements: 1) Ascertain the proper functioning of the transmit antenna, and 2) provide supplementary data for terrain propagation algorithms that could be used for spectrum allocation planning and estimation of potential interference.

Coverage measurements are conducted using the standardized test methods described in section 73.686 of the FCC Rules and Regulations (see Section 2). These standardized test methods, which typically use antennas calibrated to a standard dipole and placed at 9.1 meters (30 ft) height above ground, are used worldwide for verifying coverage, verifying transmit antenna radiation patterns, and providing data to develop propagation algorithms used for the planning factors for allocating broadcast station spectrum.

Coverage tests are often carried out in formal fashion with measurements made along radials, arcs, grids and clusters. Typically only field strengths are recorded.

Limited coverage tests may be planned to achieve particular goals and objectives such as determining that a directional transmit antenna pattern is achieved or maintained, or to measure the effects of terrain that blocks broadcast signals in certain areas. Such tests will not predict overall coverage.

5.2 Service (Receivability) Testing

Service or **Receivability** testing for purposes of this document is defined as the process of determining the conditions under which digital television signals can be received and decoded under various actual operating conditions. Such operating conditions include any location where television viewers normally use television receivers for entertainment and information for short and long periods of time. These operating conditions include use of antennas selected as those likely to be used with the receiving mode or modes under test.

Service (Receivability) measurements normally use digital television receivers designed to be connected to recording equipment to obtain signal level, margin-to-threshold, error rate, adaptive equalizer characteristics, and other information. These measurements can employ a variety of antennas for various lengths of time and may not be as easily repeatable as the more formal Coverage measurements.

A sample containing a large number of measurements needs to be taken to develop statistically significant results. By adhering to a standard set of Service test procedures consistent with this document, data obtained from these tests can be used to develop a statistical database from which a level of service can be derived.

5.3 Capturing Channel Characteristics

Capturing **Channel Characteristics** has the specific meaning, for the purpose of this document, to determine channel characterization and is accomplished by the detailed measurement of specific signal conditions at specific times and in specific locations using specific fixed and

movable antennas. The detailed measurements of signal characteristics include effects of channel impairments such as level variations, impulse noise, in-band interference, and multipaths.

5.4 Receiving Modes

The Ad Hoc Group on Broadcasters' Requirements identified four different Receiving Modes: Fixed, Portable, Pedestrian and Mobile.

- **Fixed** reception is defined as reception by an immobile receiver and receive antennas. Typically, this includes a roof-top mounted antenna or a fixed-location indoor antenna.
- **Portable** reception is defined as reception by a receiver that can be moved from place to place, that uses a self-contained receiving antenna, but that remains stationary during operation.
- **Pedestrian** reception is defined as reception by a receiver that is moving at no more than 5 kph (3.1 mph). Typically, this is a receiver that may be used while walking, or a hand-held receiver where occasional and frequent short movements occur.
- **Mobile** reception is defined as reception by a receiver that is moving at greater than 5 kph (3.1 mph). Typically, this is a receiver used in a vehicle moving faster than walking speed.

5.5 Test Signals

5.5.1 In-Service Measurements

In-Service Measurements will use the DTV signal itself with no modifications or may use a repetitive video sequence with appropriate sound to enable evaluation of picture quality.

5.5.2 Out-of-Service Measurements

Out of service is defined as not available for regular program viewing. For out-of-service measurements, the transmission/reception may use specially tailored test signals. These test signals must occupy the same spectrum and have the same average power as a DTV signal, but may be tailored for specific out-of-service measurements such as channel characterization.

A common test signal is the PN23 sequence (pseudo noise of $2^{23} - 1$ random bits) injected into a standard DTV modulator before ATSC FEC, trellis coding, and interleaving. (For VSB, this stream replaces 187 bytes of every 188-byte transport packet as the transport sync byte is replaced with the VSB segment sync in the modulator.) The PN23 signal excels in measurements of passband flatness, signal power, peak power probability, interference characteristics, and bit error rate (BER). Other PN sequences can be used with similar results. (See Annex C.)

Another common test signal is a repetitive video sequence with appropriate sound to enable easy evaluation of the program stream errors. Care should be taken that the transport stream (TS) consists of a seamless loop that does not create a disturbance in the video or audio. The bit rate of this signal should nearly fill the available bit capacity of the channel to maximize the accuracy of the visual error probability. This signal excels in quick field error measurements when other, more accurate error measurement techniques are not available.

The test signal to assess channel response has different needs. In the field environment, the channel could be Rayleigh or Rician. The test signal repetition rate should be short enough to characterize time-varying channels, yet be long enough to cover the expected multipath. Anticipated multipath covers the range of $-30 \mu\text{s}$ to $+60 \mu\text{s}$, dictating a sequence capable of

measuring a range greater than 90 μ s. If a standard VSB modulator is used, almost any TS, including pure null packets, is acceptable since the stream is convolved with an internal PN16 generator (per ATSC A/53). However, a known sequence is desirable for synchronized processing and null packets are recommended.

5.6 Antenna Class and Orientation

5.6.1 Antenna for Coverage Measurement

Any receive antenna used for coverage measurement must be calibrated with respect to a Standard dipole mounted on a mast at the prescribed height above ground (9.1 meters or 30 ft). Documentation for the antenna must be included in the test report. Antennas for Coverage measurements are normally oriented towards the transmission tower, which means in the direction of maximum signal. For purposes other than Coverage in some instances optional measurements may be made with the antenna oriented in other directions. Such measurements are also recorded with the orientation data field indicating the directions.

5.6.2 Antenna for Service and Channel Characterization

Antennas for service and channel characterization measurements may be professional or consumer products as desired according to the goals and objectives of the Field Test Plan. Such antennas typically will be employed in an “in-service” setting, and are often used only a few feet above the floor or ground and relatively close to people and nearby surrounding objects. Such antennas should be mounted in a manner that allows the testing personnel to easily and repeatably point, tilt and position the antenna with accuracy and to record meaningful results from such movements. Antennas may be oriented in an optimal (maximum signal or most easily received signal) or non-optimal position (as might be used for a single setting but receiving signals from multiple directions). Antennas for service and channel characterization measurements include but are not limited to the following classes and orientation:

- a) Measurement with an antenna at 9.1 m above ground can be used. Orientation may be optimal or non-optimal and must be so indicated in the database.
- b) An indoor antenna, associated with a fixed receiving installation, and when used for service or channel characterization measurements is normally a consumer style antenna. It should be characterized for gain and pattern with respect to a dipole, and mounted about 1.5 meters (5 ft) above the floor. This class of antenna may be used in an optimal or non-optimal orientation according to the field test plan and which must be indicated in the database. It should be noted that the antenna’s performance characteristics may markedly change in the indoor environment from measured values made in a controlled test environment.
- c) An indoor antenna, associated with a portable receiving applications, and used for service or channel characterization measurements is normally a consumer style antenna that may be designed as non-directional (monopole) or directional (dipole or multiple element). It must be characterized for gain and pattern with respect to a dipole. Portable antennas are normally positioned about 1 meter (3.3 ft) above the floor (ground) and may be oriented in an optimal or non-optimal position according to the field test plan and indicated in the database.
- d) An antenna, associated with pedestrian use, can be considered to be of random directional characteristics with little or no gain. If possible, the antenna should be characterized for gain and pattern with respect to a dipole, and mounted about 1.8 meters (6 ft) above the

floor. Because of the relative insensitivity (gain) the antennas used in pedestrian applications the orientation is normally considered to be non-optimal. (See Annex B.)

- e) Antennas associated with mobile applications are normally considered to be non-directional (monopole or similar design) and mounted in fixed positions on vehicles in a manner to maximize their exposure to radio signals. Mobile antennas must be characterized for gain with respect to a dipole. The orientation of an antenna used in mobile applications is considered to be undefined (none or non-optimal). (See Annex B.)

5.7 Test Duration

Test durations are defined according to the receiving mode and encompass a wide range including seasonal (months or years), very long term (days or months), long term (minutes or hours), short term (seconds to minutes) and very short term (seconds to less than a second). See Annex B: Test Summary Chart, Footnote #1.

5.7.1 Coverage Measurements

Coverage measurements are normally conducted for short periods of time. That is, the time it takes to conduct a 30.5 meter (100 ft) horizontal run or a series of cluster measurements. The purpose of the run or cluster is to average out the effect of multipath and nearby obstructions that could otherwise adversely affect the measured value. Fixed position coverage measurements over long periods of time (hours, days, months, years) provide useful information about the effect of weather, seasons and day-night variations.

5.7.2 Service Measurements

For Service measurements, the test duration should be a minimum of 5 minutes. During that time single (averaged over the period) or multiple measurements may be made according to the field test plan.

5.7.3 Capturing Channel Characteristics

For capturing channel characteristics, the test duration can be any range that is suitable to both the field test plan and storage capability of the test equipment. Channel characteristics measurements are made for short durations (a minimum of 20 seconds) for this reason.

5.8 Site Conditions

A description of site conditions is essential for each location in which field test measurements are made. The test plan should include documentation of the location of each site with geographic coordinates to the nearest second (or better), address, surrounding area (photographs), nature of buildings including their construction, vegetation, weather conditions at time of test and, if possible, specific marking of the pavement or ground where the measurement was taken or the center of the run or cluster measurements.

6. MEASUREMENT PROCEDURES

6.1 Coverage Measurement

Coverage measurements are made at a series of test sites. The following is a recommendation for establishment of procedures to be performed at each selected site.

6.1.1 General Criteria

6.1.1.1 Antenna Height

DTV coverage (field strength) measurements are conducted at an antenna height of 9.1 meters (30 feet) above ground level (AGL).

6.1.1.2 Safety

The measurement platform, antenna, mast, and coaxial feedline represent potential safety hazards from electrical shock and/or falling objects. For this reason, it is imperative that the paramount criterion for measurement site selection is worker safety. Accordingly, all measurement sites must be free of overhead power lines, steeply sloped terrain, wet surfaces, high winds, thunderstorms, and other natural or man made obstructions or conditions which could threaten the safety of persons or property. The test plan should require that operators should be trained in proper safety procedures.

6.1.1.3 Market Coverage

Coverage measurements are to be conducted at specific points along multiple radials and arcs. Radials should extend from the transmitter location to the limit of predicted Grade B or noise-limited coverage. A minimum of eight, reasonably evenly spaced, radials shall be measured. Measurement radials should be oriented so as to traverse representative terrain and population centers. These radials should also include reception areas selected for service testing (see Section 6.2) where practicable.

6.1.1.4 When to Conduct Field Tests

When practical, coverage measurements should be timed such that seasonal and climatic propagation variations can be correlated to coincident service and channel characteristics measurements in a given reception area.

6.1.2 Field Test Facility

The design of a field test facility can take two forms:

- Mandatory, for which certain equipment is necessary to take the measurements.
- Optional, that includes other measurement equipment used at the tester's discretion.

6.1.2.1 Mandatory

An instrumentation vehicle with telescoping mast that is capable of elevating a rotatable standard reference antenna to a height of 9.1 m AGL (30 ft.) and transporting said elevated antenna a linear distance of 30.5 m (100 ft.) for FCC "mobile run" measurements. This vehicle should also be equipped with a means for implementing cluster measurements when individual site measurements are required or mobile runs are not feasible. Equipment includes the following:

- Calibrated, horizontally polarized, reference antenna(s), UHF and VHF.
- Calibrated antenna balun (if required—depends upon reference antenna type in use) and antenna/coax impedance matching network.
- Calibrated coaxial RF distribution system (which may include a bandpass filter, low noise amplifier, RF splitter (if multiple taps are used for simultaneous field strength measurements at different frequencies), and/or optional instrumentation devices.

- Calibrated, average reading RF voltmeter(s) and system components with sufficient dynamic range, bandwidth, selectivity and sensitivity to measure DTV field strength to predicted noise limited thresholds without introducing instrumentation bias or distortion to the measurement.
- Differentially corrected GPS receiver.

6.1.2.2 Optional

Optional equipment includes the following:

- Spectrum Analyzer for ‘best reception azimuth’ antenna orientation indicator and for spectrum display image capture or recording.
- Digital television receivers.
- Bit or segment error rate measurement set.
- Other analyzers, computers, printers, as desired.
- Integrated data acquisition system to collect and store, on magnetic media, measurement data and tester’s comments.
- Signal margin instrumentation—requires calibrated RF attenuator plus threshold detection hardware (vector analyzer plus ‘reference’ tapped equalizer).
- Optional receiving antenna(s) and polarization modes.
- Camera to record test site and surrounds.
- Vertical alignment adjusting equipment.

6.1.3 Measurement Data Set

Measurement data should include, but should not be restricted to, the following information:

- Field strength (minimum, maximum, and median value) in dBuV/M.
- Distance and bearing to transmitting antenna location.
- Ground elevation at measuring location (measured or calculated).
- Date, time of day, topography, and weather observations.
- Azimuth orientation of receiving antenna for best reception and for maximum field strength (if different) with vertical angle of mast/antenna support structure.
- A detailed equipment list specifying each antenna, measuring instrument, and system component, its manufacturer, type, serial number, rated accuracy and date of most recent calibration by either its manufacturer or a qualified calibration laboratory.
- A detailed block diagram of the coverage survey system.
- A detailed description of the procedure, date, time, and tabulated data for the pre-test field calibration check of each of the coverage survey system components conducted at the beginning of each measurement cycle.

6.1.3.1 Number of Measurement Points

The number of measurement points in coverage area is a function of the following issues:

- “Community” (adapted from 47 CFR 73.686):

Minimum of eight reasonably evenly spaced radials with a minimum of 15 points per radial. Measurement points are selected to begin at a distance of 16.1 kilometers (10 miles) from the

transmitter location and are to be repeated at intervals of 3.2 kilometers (2 miles) to the maximum distance at which measurements are to be made. The total number of measurement locations, per radial, cannot be fewer than 15 but shall be approximately equal to $0.1 (P^1)^{1/2}$ if this number is greater than 15.

At least 20% of all measurement points must include 30.5 M (100 feet) mobile measurement runs and continuous data collection over the length of the run.

If overhead obstacles preclude a mobile run of 30.5 M, a “cluster” of five “spot” measurements may be made in lieu of the mobile run. For this purpose, the “cluster” is defined as one identifiable initial measurement point and at least four additional measurement points within a distance of the initial measurement point as specified in Figure 1.

Mobile runs must be conducted at measurement points where the orientation of the receiving antenna yielding the strongest signal differs from that of a direct bearing to the transmitter. Under this scenario, after the mobile run, additional “cluster” measurements at a minimum of five fixed points must be conducted within 61M of the center point of the mobile run. At each of the “cluster” measurement points, field strengths with the antenna oriented toward the transmitter and with the antenna oriented toward the strongest signal are read and recorded.

- Arcs: Arcs should be normally measured around the full 360° azimuth, except where terrain prohibits. Individual selection points should be made at 20° spacing or less.
- Individual location cluster measurements: A minimum of five, evenly spaced, measurement points are required. (See Section 6.1.4.)

6.1.4 Methodology

Use the FCC Rules for NTSC (CFR 47 §73.686) as a general guide. Substitute the first sentence of §73.686 (C)(2) *Measurement procedure* with: “The field strength of the digitally modulated television signal shall be measured with a voltmeter capable of indicating accurately the average amplitude of that signal.”

Cluster measurements require a minimum of five, evenly distributed, measurement points to capture data over an area of approximately 9 square wavelengths. If multiple frequencies are to be measured at one location, the cluster measurement area should be defined as 9 square meters (3 meters per side). Suggested patterns would include those shown in Figure 6.1.

6.1.4.1 Individual Location Coverage

Because coverage is determined by the statistical distribution of individual data point measurements, it is necessary to select individual location measurement sites at which multiple measurements can be conducted over a specified area. These measurements are referred to as “individual location cluster measurements.” Typically, individual measurement sites are selected

1 “P” is the population of the community of interest.

such that the elevated antenna may be accurately positioned at discrete intervals around the perimeter of an area of approximating 9 square meters. (See Figure 6.1.)

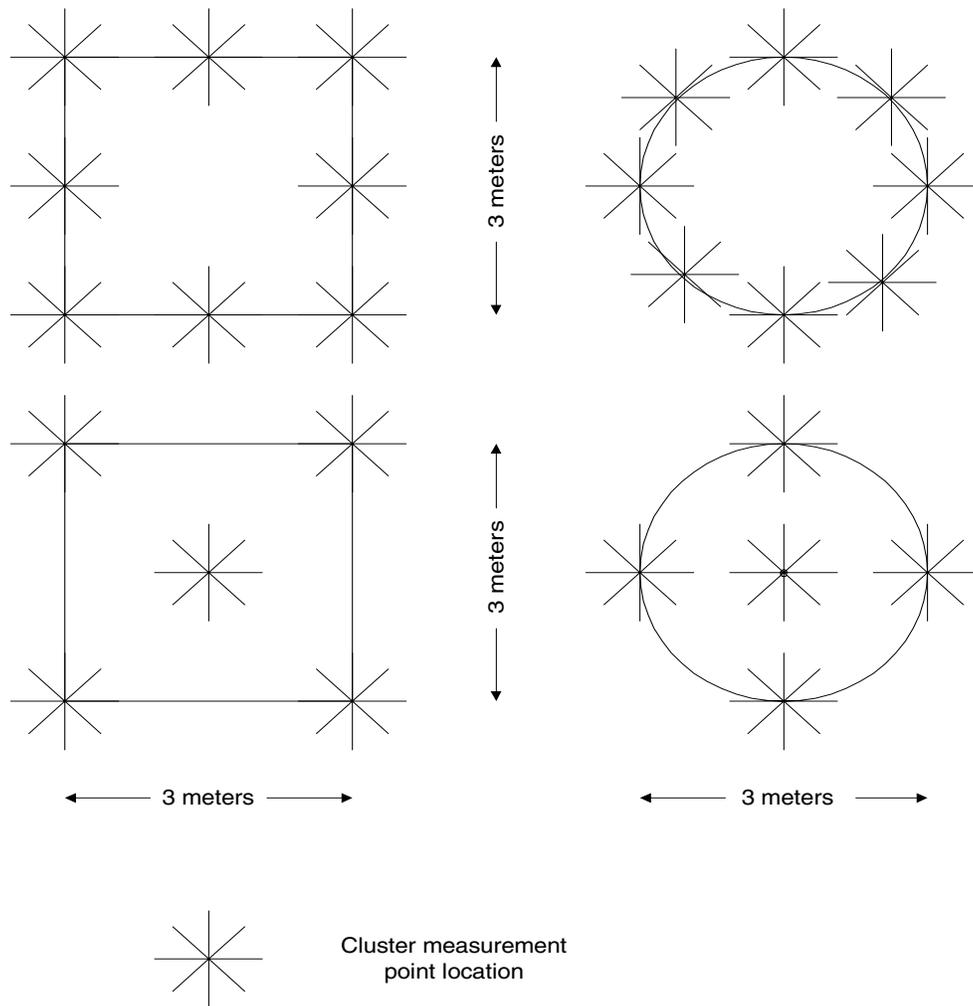


Figure 6.1 Cluster measurement point arrangements.

6.1.5 Analysis Considerations

Tabular database formats are the preferred form of data collection. The format should be compatible with mainstream data base software and is to be described in detail in the Test Report.

Tester's measurement observations are often valuable in describing anomalies in test results and should be included in a comments column or as footnotes in the Test Report.

Photographic (film or digital) records are important ways to explain a site condition in some detail. In addition to the surround area, photographs should be made of the test setup itself in relation to the surrounding environment.

Spectrum display images provide insight into the condition of the signal that is measured as well as the spectrum in which the signal is located. When practical spectrum records of the

measured signal should be made for each major measurement set and should include a wideband display (for example 20 MHz) of the spectrum containing the desired signal.

Coverage data should be used for pair-wise comparison of actual field strength versus calculated field strength.

6.2 Service Measurement

The following descriptions apply to all receiving modes (see Section 6.1) except where noted. Certain measurement procedures may vary with the selection of the receiving mode.

If coverage measurements are required at sites where service measurements are conducted, a set of cluster measurements must be conducted according to the procedures in Section 6.1. If coverage and services measurements are made at the same location it is recommended that they be done at the same time.

6.2.1 Statistical Selection of Sites

Service measurements are typically made in such a manner that they simulate real-world receiving situations. In order to obtain statistically significant results there must be enough data sample points measured to reflect the actual performance of the measured system. Practical considerations lead to a range of 30 to 100 sites, although reasonable statistical confidence intervals may require significantly more.

Service measurements may include a bias towards one or more particular reception factors such as multipath, aircraft flutter or effects of building walls or trees. When a service test is biased in such a manner, rather than random, it must be noted as such in the test results and database.

6.2.2 Field Test Facility Development

This facility is designed to document the propagation channel's characteristics of other signal interference, multipath, and impulse noise. The detailed list of equipment for a coverage field test facility is recommended, although service measurement test plans may not need the full complement to accomplish their objectives. Important elements include the following:

- a) Block Diagram. A block diagram showing the components of the measured signal path must be provided with the test report.
- b) Dynamic range of operational levels. The dynamic range and noise figure of the test facility and its components should be determined and documented.
- c) Antenna. Whatever antenna is employed for service measurements it must 1) be an example of a typical antenna for that application, 2) be calibrated by the factory or on a range or anechoic chamber, and 3) be routinely checked to determine that it is performing as predicted.
- d) Downlead system and related components. The cables, amplifiers, filters, attenuators switches, combiners, splitters, and other devices that could affect the measured signal each must be documented and calibrated. When professional antennas are not employed care should be taken to minimize VSWR effects through a careful selection of amplifiers and attenuators as located as close to the antenna as possible.
- e) Receiver. The receiver used for the service measurements must be described in detail and should have supporting calibration documentation.

- f) Other Measurement Equipment. Other equipment used for service measurements that provide data for the test report must be documented and should have supporting documentation and test results.

6.2.3 Measurement Sets

More than one set of measurements can be obtained during a service measurement. One is a mandatory or minimum set. Other measurements to enhance or describe a particular reception condition in more detail may be made as desired.

The mandatory set includes:

- Signal strength
- Noise floor
- Noise added threshold
- Calculated margin to threshold
- Segment error rate (SER)
- Equalizer tap values and energy
- Detailed location of antenna
- Antenna description, including its polarization
- Antenna orientation
- Calibration of measurement system
- Site location details (geographical coordinates)
- Time of day
- Description of building in which, or around which measurements are made
- Nature of area immediately surrounding the antenna

Other measurement sets may include:

- Site street address
- Subjective audio and/or video impairments (directly observed or algorithm based)
- Log of activity
- Describe in detail any other measurements made during the service measurements

6.2.4 Measurement Methodology

The following general procedures outline a typical service measurement process.

6.2.4.1 Site Selection

Sites are selected based upon predetermined criteria specified in the Field Test Plan.

6.2.4.2 Field Test Facility Equipment

Equipment is selected and assembled according to test plan goals and objectives.

6.2.4.3 Measurements

Measurements are to be selected and taken to insure that meaningful test results are obtained.

6.2.4.4 Test Duration

Test duration including both observation intervals and durations are selected to adequately capture the desired number of measurements. The Test Plan should set the duration of unimpaired reception. A five-minute period of unimpaired reception is the normal minimum test duration.

The duration of the test may also be adjusted depending on the conditions to be tested, for example, one minute may be used to observe the effect of airplane flutter, or 20 minutes may be used to observe the effects of trees moving in the wind. When a test site is found to have special conditions, such moving traffic close to the test site, a test duration that is representative of typical reception should be used. The degree of bias of such special measurements must be recorded. If the test duration and/or observation interval is biased then the duty factor and periodicity of the special conditions should be recorded.

6.2.4.5 Antenna Class, Height, Orientation, and Polarization

The antenna is selected and used according to the reception mode (fixed, portable, pedestrian and mobile).

6.2.4.6 Calibration Measurements

Calibration measurements shall be made (beginning and end of each test day) of test system components to determine that the facility is performing properly. A known test signal is typically used to simulate the expected unimpaired real-world signals and calibrate the test equipment.

6.2.4.7 Functionality Check

Receiver tests should include measurement of robustness to random noise and performance of static and dynamic multipath. Periodic and routine checks should be performed to ensure proper operation.

6.2.4.8 Service Measurements

Measurement data are obtained according to prescribed methods and specific procedures described for each measurement. Note when and why measurements cannot be taken at a specific site.

The test plan should be designed to take measurements that capture data that show the non-uniformity (“burstiness”) or uniformity of errors over time. The test period must be representative of typical reception conditions and all data taken must be recorded.

6.2.4.9 Site Conditions

Site conditions and environment are recorded as a documentation of the environment of the measurement. Site conditions are not measurements but may be later used to confirm or repudiate that an accurate measurement was taken. Details of building construction as may be observed or are known are recorded. A measurement may be repeated if the site condition indicates that the data may be suspect, and if the procedure allows for the repeat.

Tests should be performed that either specifically require the movement of nearby persons or prohibit movement. Failure to select and document this critical variable can be expected to significantly diminish the value of the test data and would prohibit the consolidation of data from multiple test plans.

6.2.4.10 Documentation of Results

Results are documented in a manner such that the data may be efficiently processed and analyzed at a later time.

6.2.4.11 Accuracy Review

Data is reviewed at the point of measurement for accuracy and reasonableness, but not to the point of discarding data that may appear to be counterintuitive. Confirmation of reasonable data may be made through observations, notes, comparison to expected values, and additional non-mandatory measurements.

6.2.4.12 Test Facility Design

Several documents are available from the ATSC for the development of a test facility for coverage and service measurements. (See Annex A.)

6.2.5 Analysis Considerations

Part of the development of measurement methodology and specific test procedures includes the consideration of collecting and recording of data. That consideration must take into account how that data is to be used. Measurement data should be entered (recorded) into a database where the structure is designed for efficient interchange and analysis. When designing a database and developing the specific measurement procedures, consideration should be given to the kinds of processing and analysis expected to be conducted and how the data might be used in comparison with other tests to be performed at later times and in other locations.

During a “pass/fail” test, an unimpaired signal must be received over a continuous length of time in order for the test reception to “pass.” Typically this length of time will be at least five minutes. However, all data (measurements and site condition records) should be preserved even if the test reception is judged to “fail” or the data is not used in the initial analysis process.

Tabular database formats are the preferred form of data collection. The format should be compatible with mainstream data base software and is to be described in detail in the Test Report.

Tester’s measurement observations are often valuable in describing anomalies in test results and should be included in a comments column or as footnotes in the Test Report.

Photographic (film or digital) records are important ways to explain a site condition in some detail. In addition to the surround area, photographs should be made of the test setup itself in relation to the surrounding environment.

Spectrum display images provide insight into the condition of the signal that is measured as well as the spectrum in which the signal is located. When practical spectrum records of the measured signal should be made for each major measurement set and should include a wideband display (for example 20 MHz) of the spectrum containing the desired signal.

6.3 Capture of Channel Characteristics and Recording of DTV RF Signal

The channel characteristics at a site describe the received signal condition. In addition to indicating parameters like received signal strength; the channel characteristics describe other aspects of the received signal such as impulse response, and particularly multipath conditions as they change with time. A received signal at a particular location will be impacted by the particular location, its surroundings, objects (both man-made and natural) in the transmission path, interference, noise, and the receiving antenna (type, height, orientation).

The received signal generally includes components that took different paths from the transmitter to the receiver. This condition is commonly called “multipath”. The principal or “main” component, normally defined as the strongest of the multipath components, may be the direct-path signal from the transmitter to the receiver if the path is unobstructed. However, depending on the location, one of the reflected signals could be the strongest.

The positions of the other signals are referenced to the main (the strongest) signal. Thus there would be signals arriving earlier than the main signal and after the main signal. These are called leading (pre-echoes) and lagging (post-echoes) because the signal leads or lags behind the main signal, respectively. Very rarely are these echoes static. Usually they vary continuously in amplitude and/or delay with time and the condition is consequently called dynamic multipath. If the strongest signal varies in amplitude such that another signal becomes stronger, then the reference for the time offset of the other reflections changes. This may appear to indicate that the distribution of the multipath in time has changed when actually only the relative amplitudes of the components varied.

In normal circumstances the receiving antenna characteristics and orientation will affect the degree of received multipath. Consequently, the impact of the choice of antenna and its orientation should be clearly understood when recording any signal for later analysis.

There are several purposes for capturing channel characteristics at test sites:

- a) Create a set of statistics of occurrence of various forms and levels of degradation. Data to satisfy this purpose requires correlation with system performance field tests so that its significance to receiver performance can be assessed. In addition, the data recorded should allow cataloging of characteristics (for example, ghost length or amplitude) for study of correlation among individual signal parameters.
- b) Provide records of challenging sites for testing new and improved DTV designs. In this case as above, the data recorded should allow cataloging of characteristics (for example, ghost length or amplitude) so that records of sites of particular interest can be retrieved. If data is taken specifically for use in receiver development, there should be some “standard normal” sites, some with average multipath, some with long pre- and/or post-echoes, some dynamic and some static. Because it is logical to test the DTV sets for easy, moderate as well as tough sites, there should be criteria to classify sites for later selection for testing. Those criteria could be based on:
 - Static or dynamic nature of multipaths
 - Close-in ($< 1 \mu\text{s}$), near ($< 5 \mu\text{s}$), average ($< 20 \mu\text{s}$), or far ($> 20 \mu\text{s}$) multipaths for both pre- and post echoes,
 - Strong (0 to -3 dB echo strength) and weak (< -3 dB echo strength) multipaths
 - Localized or spread multipaths

Cataloging by these criteria allows the designer to select relevant signals, and also allows selection of a range of signals for comparative testing of receivers.

- c) Recording of characteristics may be according to the specification of certain parameters as listed previously, or by recording of the RF environment, which allows both analysis and reproduction of the signal for input to receivers. The reproduction of a recorded signal for input to a receiver, however, is useful only for the particular transmission system recorded. This may or may not allow general analysis and reproduction of the signal conditions for an arbitrary system. Recording of generic signals, such as PN sequences, may be desirable for use in general characterization of the channel.
- d) Signals can be recorded or captured in the field:

- The DTV RF signal can be recorded live for a minimum of 20 seconds and subsequently played back in the laboratory to test the receivers using this transmission standard.
- A special test or reference signal such as a pseudo-random sequence, is sampled (recorded) at specific intervals (a minimum of 20 seconds) and analyzed off-line to determine the characteristics (impulse response) of a channel (multipath amplitude, delay and phase variation over time) for a particular location. Such information can be used later to program a channel simulator to reproduce the channel conditions. This channel simulator can be fed with a specific DTV signal and used to evaluate the robustness of a transmission system to such channel conditions.
- Long-term testing may also be appropriate.

6.3.1 Selection Criteria

6.3.1.1 Location: Where the Received Signals Appear Interesting

The location may be selected using the same criteria as when making service measurements, or locations may be biased towards specific impairments. When biased, locations may be selected based on an expectation of “easy”, “average” and/or “difficult” receiving conditions.

If biased, the type of bias needs to be noted in database. Some site selections may be made only for their expected future benefit to test improved receivers or systems.

6.3.1.2 Degree of Bias, if Any

Recording of signals should particularly be performed when the receiver under test fails to meet the acceptable performance criteria. This will enable analysis of the channel and may lead to an understanding of why the receiver cannot lock. Recording at a statistically significant sample of sites will also gather information as to whether the impairments present occur with high or low probability. This information can help in the manufacturer’s decision on attacking the impairments via design improvements. Observations of possible receiver overload should be recorded.

6.3.2 Field Test Facility Design

When designing the RF capture system, care must be taken so that the signal can be accurately reproduced at a later time. A minimum of 20 seconds is recommended. See Section 6.1.4 and 6.2.4 for equipment selection guidelines.

6.3.3 Measurement Set

The measurement set is the collection of captured RF signals. Normally, other data such as those items listed in Section 6.2.3 are recorded.

6.3.4 Methodology

6.3.4.1 Capture of Channel Characteristics: Direct Method

A PN sequence signal is transmitted and recorded for analysis. The PN signal may be that contained in the normal transmitted signal or may be a special out-of-service sequence.

6.3.4.2 Capture of Channel Characteristics: DTV RF Signal Method

The tap inferential method may be used if the direct method is not available. The equalizer tap values of a receiver are saved to allow characterization by calculating the multipath.

6.3.4.3 DTV Signal Recording

The RF DTV signal shall be recorded for a minimum of twenty seconds.

6.3.5 Analysis

6.3.5.1 Channel Characteristics

The captured signal provides data suitable for analysis to include at least echo length, phase, and amplitude (channel impulse response). Results can be analyzed to determine the complexity of the impairments and what improvements are needed to acquire such a channel. The RF capturing device should output a data file convertible to the form used in common software simulation and analysis programs.

6.3.5.2 RF DTV Signal Recordings

The recorded DTV RF signals can be fed directly to receivers to evaluate the effects on design improvements or of adjustments on receivers' performance with the signals recorded under all the various selection criteria described previously. The signal can also be fed simultaneously to a number of receivers to compare their performance under exactly the same channel conditions.

6.4 Analog Broadcast Television Measurements

In some instances, DTV field tests may incorporate tests of analog television (NTSC) broadcast signals for comparison with the reception of DTV signals. This kind of testing may be important to stations that wish to compare coverage and receivability of their analog and DTV facilities. While desirable on the surface, such comparisons should be made with extreme care because differences in frequency, power and location of different transmission facilities may have substantive effects on reception at a given location and with a given receive antenna orientation.

6.4.1 Selection Criteria

Sites selection should be consistent with sites selected in the coverage section (6.1) or service section (6.2) of this document, depending upon test objectives.

6.4.2 Field Test Facility

The test facility development will be determined by the objective of the test, coverage or service. Both the received analog and digital signals should follow the same or equivalent paths within the test facility.

6.4.3 Measurement Set

Mandatory measurements to be taken for analog field tests include field strength (peak visual carrier), visual/aural ratio, video signal/noise ratio (weighted), subjective rating, and comments on the nature of impairment (noise, interference, multipath, aircraft flutter, other). It is desirable to make a high quality video/audio recording of the received signal at the same time the subjective rating is made. Other measurements may be taken as desired.

6.4.4 Methodology

In general, analog testing can be conducted using the same test setup employed for DTV with the exception of the receiver and some test equipment. If analog measurements are made for comparison purposes, there must be sufficient detail or explanation given in the test report to establish the relationship of the analog signals with respect to the DTV signals.

Use FCC Rules §73.686 as a general guide for measuring field strength. [Modify for international use.]

For subjective measurements of an analog signal (NTSC), the ITU-R 500-3 subjective impairment measurement scale must be employed in addition to standard objective measurements. Assessment by only one individual is not recommended. This is a five-point scale:

- 5 - Impairments are imperceptible
- 4 - Perceptible but not annoying
- 3 - Somewhat annoying
- 2 - Annoying
- 1 - Very annoying

The quality of program material is not considered in the subjective measurement nor are transmission impairments such as differential phase and gain, video noise, audio noise and the like. Only those impairments that occur between the broadcast antenna and receive antenna are to be considered.

Because each person has their own opinion about the levels of impairments it is recommended that at least three viewers with some experience average their subjective rating to arrive at a value to be recorded in the test results.

Subjective viewing is recommended at five picture heights from the screen in a moderately lighted environment. Select monitor size to adjust for constraint of environment.

6.4.5 Analysis

6.4.5.1 Impact of Analysis on Methodology

Part of the measurement methodology and specific test procedures includes the consideration of collecting and recording of data and how that data is to be used. Measurement data should be entered (recorded) into a database that is specifically designed for efficient interchange and analysis. When designing a database and developing the specific measurement procedures, consideration should be given to the kinds of processing and analysis expected to be conducted and how the data might be used in comparison with reports from other tests performed at later times and in other locations.

6.4.5.2 Comparison of Analog and Digital Visual and Aural Performance

For NTSC, an ITU-R500-3 subjective impairment measurement must be made in addition to standard objective measurements². This is a five-point scale:

- 5 - Impairments are imperceptible

2 The use of non-subjective methodology for digital picture quality and impairment analysis (single stimulus continuous quality evaluation) should be further studied for comparison to the ITU-R500-3 five step analog quality and impairment scale. The end result may be an acceptable non-subjective algorithm based tool for comparison of digital-to-digital and digital-to-analog signals.

- 4 - Perceptible but not annoying
- 3 - Somewhat annoying
- 2 – Annoying
- 1 - Very annoying

A minimum panel of three (3) judges is recommended. Programming is not considered in the measurement nor is transmission impairments such as differential phase and gain, video noise, audio noise and the like. Only those impairments that occur between the broadcast and receive antennas are to be considered.

There are a number of reasons to test analog against digital services. Different objectives will determine specific test plans and test facilities. Specifically:

- a) The most desirable approach is to make the NTSC measurement on the same channel as the DTV measurement. To do this the station must switch between DTV and NTSC. This may not be possible because the DTV channel has different planning factors for interference than for NTSC. Also, there is a difference between NTSC and DTV power when NTSC replicates the area of DTV. If the channel already has NTSC on it then switching to DTV is a simpler process. Two DTV systems could be compared using a transmitting power for each system that will generate the same level of interference to adjacent or co-channel.
- b) Make the NTSC measurements on the channel used by the same licensee as for the DTV channel. For example NTSC channel 4 has been assigned channel 48 for DTV. This is an easy measurement because both stations are on the air continuously and no switching is needed.
- c) Make the NTSC measurements on the same band as DTV and as close to the DTV channel as practical. For example, a UHF NTSC station on channel 20 is assigned channel 35 for DTV but channel 32 is closer in frequency and operates from the same tower.

For DTV, transmission or propagation impairments are not visible on the screen or heard in the sound until the impairments cause outages or loss of ability to decode or demodulate. Because of the powerful error correction techniques used the difference between error-free reception and “somewhat annoying” or ITU-R grade 3 is only about 1 dB. Therefore, to attempt to rate DTV with an impairment scale is extremely difficult. Instead, it is more useful to rate the DTV reception based on measured BER or SER or on the number of impairment-caused “hits” on the screen or in the sound within a given period of time. For the Charlotte Field Tests, a “hit” (a visible or audible artifact caused by propagation impairments or interference or noise), in a 10-minute continuous viewing period, was considered to be “acceptable” and more than one “hit” was considered “not acceptable.” In other words, the dividing line between “slightly annoying” (grade 3) or worse. Acceptable was also a maximum of 2.5 segment errors.

Annex A: References (Informative)

1. RELATED FIELD TESTING ORGANIZATIONS AND PLANS

- *ATSC Field Test Vehicle Design Information*, Gary Sgrignoli, Zenith Corporation, December 20, 1999.
- *General Field Test Plan for Digital Television Propagation*, Model HDTV Station Project, Washington, D.C., July 22, 1999.
- *Indoor Field Test Plan for Digital Television Propagation*, Model HDTV Station Project, Washington, D.C., July 22, 1999.
- *ETR290: Measurement Guidelines for DVB Systems*, European Broadcasting Union, May, 1997.
- *General Description of Field Tests*, ABERT/SET, July 2, 2000.
- *ATV Test Procedures Manual*, ACATS/SSWP-2/Document SSWP2-0601, December 15, 1993.
- *ATV Test Procedures Manual: Field Test of the Grand Alliance Prototype*, ACATS/SSWP-2/Document SSWP2-1389, June 28, 1995.

Annex B: Field Test Summary Chart (Normative)

Test Purpose or Type	Primary Information (* indicates principle information sought)	Receiving Mode (4)	Test Duration (1)	Antenna Class and Height	Antenna Orientation	Test Conditions (environment and measurement)
Coverage (coverage model verification)	Field strength—verify the predicted coverage: received signal level impulse noise RF interference	Outdoor: cluster (100 ft run) (multiple points) (azimuth angle)	Short term (8)	Outdoor, 10 m; calibrated directional with gain.	Toward transmission tower	Weather Measurements on: arcs, radials, grids, clusters RF interference Time variability
Service (receivability)	Demodulated and decoded signal statistics—how well can the signal be received? * Impairments: impulse noise RF interference Signal level variations Multipath measurements—include but not limited to: signal strength noise floor error rate noise-added threshold equalizer taps testbed (system) calibration information location antenna direction pilot level, if any No site selection is based on impairments.	Fixed	Seasonal Very long term Long term Short term Very short term	Outdoor, 10 m AGL (2); directional with gain.	Optimal (5) Non-optimal (6)	Weather Impairments (7) Nearby objects in motion (10): nearby neighboring far
	Portable	Seasonal Very long term Long term Short term Very short term	Indoor, 1.5 m AFL (3); directional with some gain reference dipole (9)	Optimal Non-optimal	Weather Impairments (7) Nearby objects in motion near neighboring far	
			Long term Short term Very short term	Indoor, 1 m AFL: monopole directional	Optimal Non-optimal	Weather Impairments Nearby objects in motion: near neighboring far
	Pedestrian: < 5 kph < 3.11 mph	Short term Very short term	Non-directional, 1.5 m AFL: monopole	Not specified	Weather Impairments Nearby objects in motion: near neighboring far	
		Mobile: > 5 kph > 3.11 mph	Short term Very short term	Non-directional, 1.5 m AFL: monopole	Not specified	Weather Impairments Nearby objects in motion: near neighboring far Receiver in motion

Channel Characteristics	Multipath: * amplitude phase delay quantity number and dispersion doppler Field strength Impulse noise Other information as desired: RF interference; e.g., adjacent and taboo decoded signal statistics signal level variations Site selections may be biased as required; e.g., impairments.	Fixed	Seasonal Very long term Long term Short term	Outdoor, 10 m AGL (2): directional with gain Indoor, 1.5 m AFL (3): directional with some gain	Optimal Non-optimal	Weather Impairments Nearby objects in motion: near neighboring far
		Portable	Seasonal Very long term Long term Short term	Indoor, 1 m AFL: monopole directional	Optimal Non-optimal	
		Pedestrian	Short term Very short term	Non-directional, 1.5 m AFL: monopole	Optimal Non-optimal	Impairments Nearby objects in motion: near neighboring far
		Mobile	Short term Very short term	Non-directional, 1.5 m AFL: monopole	Optimal Non-optimal	Receiver in motion

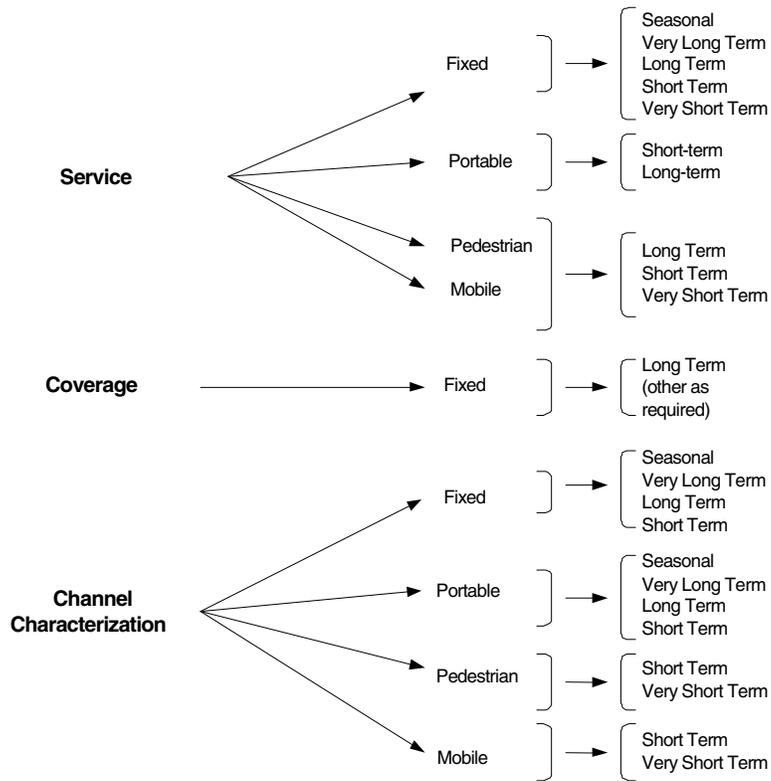
1. TABLE FOOTNOTES

1	Test duration (includes both observation period and observation interval)
	Seasonal
	Months/year (snow)
	Very long term
	Days/months (weather)
	Long term
	Minutes/hours (program length)
	Short term
	Seconds (announcement length/data)
	Very short term
	< Seconds (data)
2	AGL
	Above ground level
3	AFL
	Above floor level
4	Receiving mode
	Fixed
	Permanently located, orientable, or non-orientable
	Portable
	Moveable, stationary during use
	Pedestrian
	In motion during use; < 5 kph
	Mobile
	In motion during use; > 5 kph
5	Optimal
	Antenna oriented for best reception for each channel tested
6	Non-optimal
	Antenna oriented for averaged 'best' reception among all channels to be received

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7	Typical impairments	Street lights, transformers, dimmers, auto ignition Interference, multipath, signal level variations
8	Long term analysis	Coverage may also be measured on a long-term basis to obtain time variability
9	Reference dipole	A calibrated reference dipole may also be used for indoor measurements
10	Nearby objects in motion	
	Near	Within a few wavelengths (e.g., people)
	Neighboring	A few wavelengths to 200 feet (e.g., vehicles)
	Far	More than 200 feet (e.g., airplanes)

2. TEST TYPES, RECEIVING MODES, AND TEST DURATIONS



Annex C: PN Test Sequences (Normative)

Many PN sequences are used for various applications. The following are some that are in use today:

$2^{11} - 1$ (2047) per CCITT Rec. O.152

$2^{15} - 1$ (32767) per CCITT Rec. O.151

$2^{23} - 1$ (8388607) per CCITT Rec. O.151