International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R BT.2495-0

(11/2021)

Methods for laboratory and field measurements for the assessment of ATSC 3.0 reception quality

BT Series

Broadcasting service

(television)

International Telecommunication Union

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Electronic Publication
Geneva, 2021

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REPORT ITU-R BT.2495-0

Methods for laboratory and field measurements for the assessment of ATSC 3.0 reception quality

(Question ITU-R 132-5/6)

(2021)

Objective

The objective of this Report is to introduce methods that have been used for evaluating the quality of service of second-generation digital television broadcasting systems using the VHF and UHF bands.

The final goal is to obtain criteria that could, by looking at a limited number of parameters, assist manufacturers in verifying functionality of their receiver's physical layer design, and to provide information to broadcasters evaluating service reception.

This Report gives some details about the relevant parameters for ATSC 3.0 and the results of some measurements in order to identify a possible method for objective reception quality assessment for this and other DTTB systems.

Measurements in the field should be performed in a known controlled order to validate the proposed method(s) in real world environments.

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PART 1

Laboratory measurement method for the assessment of ATSC 3.0 reception quality

1 Introduction

Advanced Television Systems Committee (ATSC) has developed and published a Recommended Practice for evaluating physical layer performance of ATSC 3.0 in a laboratory environment [1]. The following sections provide an overview of ATSC 3.0 performance metrics, laboratory setup and tests used to characterize performance.

This Part 1 summarizes processes used to test the RF performance of ATSC 3.0 in a laboratory environment. The intention of this Part 1 is to describe test processes and test results for manufacturers attempting to verify RF performance of their receiver's physical layer designs. This Part 1 should be used by manufacturers to ensure their lab testing is conducted consistently and can be independently verified by the ATSC 3.0 development team.

2 Assumptions for ATSC 3.0

ATSC 3.0 provides an expanded range of services above and beyond those provided in the first-generation system (ATSC 1.0), while also leveraging multiple physical layer enhancements to deliver those services. The performance of the ATSC-3.0-capable device receiver can be characterized with multiple metrics that are measurable in a laboratory environment. The physical layer has many configurations, and some strenuous tests will only use selected configurations. Results of these tests will indicate realistic performance levels of devices in the market and will also aid broadcasters in their network planning efforts.

The Device Under Test (DUT) will also have different device types, ranging from experimental implementations to fully integrated units with display screens, and can include both professional and consumer products. Tests in this Part 1 should accommodate all device types, and thresholds can be determined with different measurements of bits or packets or observable errors in motion pictures.

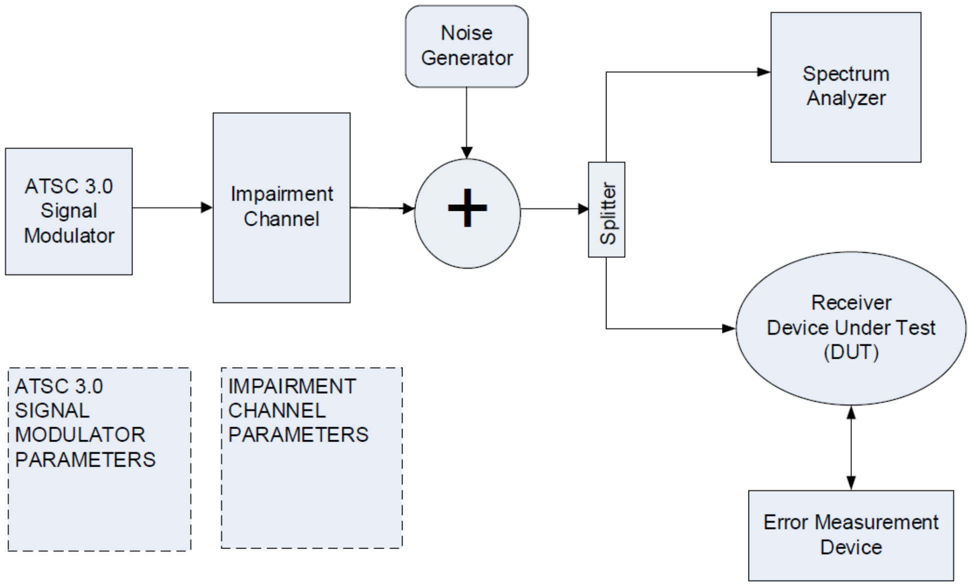
Lab performance is tested with two methods, one without a tuner and one with a tuner. Lab tests without a tuner are labelled 'Lab Performance – Demodulator' to exercise the demodulation of the waveform, and lab tests with a tuner are labelled 'Lab Performance – System' to account for both tuner and demodulator effects.

2.1 Lab Performance – Demodulator

General Lab setup for channel impairment testing without tuners may be found in Fig. 1. No transmitter upconverter or receiver tuner is intended to be used but rather an IF signal is used to perform this test. These tests may also be used with a tuner using RF channel amplitude of −53 dBm.

FIGURE 1

Test configuration for Lab Performance – Demodulator



The DUT will be probed at the forward error correction (FEC) outer decoder (BCH/CRC) output; i.e. ATSC Link-layer Protocol (ALP) packets, and appropriate internal registers that may exist.

Moderate signal level should be used, that is, 20 to 30 dB above the threshold of visibility of receiver errors. This provides more Desired/Undesired (D/U) range for tests to be conducted without running into hardware limitations. A value of −53 dBm is typically used elsewhere and will be used here as well for power levels of the desired signals.

Tests should be performed objectively by observing Bit Error Rate (BER) using pseudo random binary sequence (PRBS) test sequences or Packet Error Rate (PER) for implementation of *C*/*N* measurements or Erroneous-Second Ratio (ESR5) for quality of service at the output of the receiver, depending on the device type. ESR5 is defined in [2]. Zero errors is a useful metric for determining demodulator performance. Zero errors is defined as all measured samples within a defined time window resulting in a BER or PER below a defined negligible threshold.

The transmitter has an interface at the ALP construction point and there is likely a receiver exit point with ALP packets. This may make for an easy access test point. Datagrams of up to 1 500 bytes can be long enough to not have difference between BER and PER per the criteria being tested.

PHY has FEC frames which may produce BER, but at the transport layer there are only packets. If packet errors occur in packet header, the entire packet will be lost. If packet errors occur in data, there is a corrupted packet (lost packets vs packet errors).

Physical layer OFDM frames have bootstrap (BS) and preamble (Pre) symbols as overhead to the data symbols that contain multiplexed time interleaved QAM symbol cells. Errors are equally likely to occur in the overhead and subframe(s) sections. If an error occurs in any of the four bootstrap symbols, the entire frame (all blue subframes after that bootstrap) may be lost. If an error occurs in the (usually) one preamble symbol, the subframe data may or may not be affected, depending on severity of the echo or signal loss.

Bootstrap symbols are designed to be the most robust part of the physical layer transmission and show error resiliency below −6 dB *C*/*N* in Rayleigh channels. To affect those bootstrap symbols, signal energy loss must be lower than 4× the environment noise level. Preamble symbols are less robust than bootstrap symbols but more robust than data payload symbols. There are several selections of robustness levels for preamble symbols. There are also three FFT sizes combined with various combinations of different guard intervals and pilot patterns yielding 160 cases of preamble operation. SNR data threshold is estimated to range from around −6 dB to 25 dB for those preamble symbols in Rayleigh channels. To affect the preamble symbols signal energy loss must be greater than the estimated SNR threshold for that mode selected. Data payload symbols have the largest range of SNR depending on the mode of operation (i.e. the selected FEC and modulation parameters).

In summary, there are four very robust bootstrap symbols, (usually) 1 robust preamble symbol and a large number of data payload symbols. Symbol errors are statistically equally likely to occur in each of them, but the effect depends on the robustness of that affected symbol. Data symbol loss will be affected first when testing echoes of a certain power as they are the least robust. That data symbol loss translates to ALP packet (data and header) loss. ALP headers contain information regarding packet type and length and whether there is segmentation/concatenation. ALP header contents are expected to be static, i.e. they are not likely to change during Lab Performance testing, and packet lengths and types can therefore be expected to be a fixed size for the length of each test. With constant expected data in ALP headers, ALP packets may be used for Lab Performance testing as DUT may use expected settings.

Procedures for each test are general enough to apply to all device types (e.g. hardware prototypes, chips, devices, integrated products with video screens only) and results have respective metrics to apply to different scopes of devices.

ATSC 3.0 Signal Modulator Parameters are a list of configuration settings from [4] which are useful for lab testing. There are many settings and only a select few are chosen for lab performance testing to satisfy configurations of interest to broadcasters as well as testing enough settings for confidence. A list of those settings used is given in Appendix B.1.

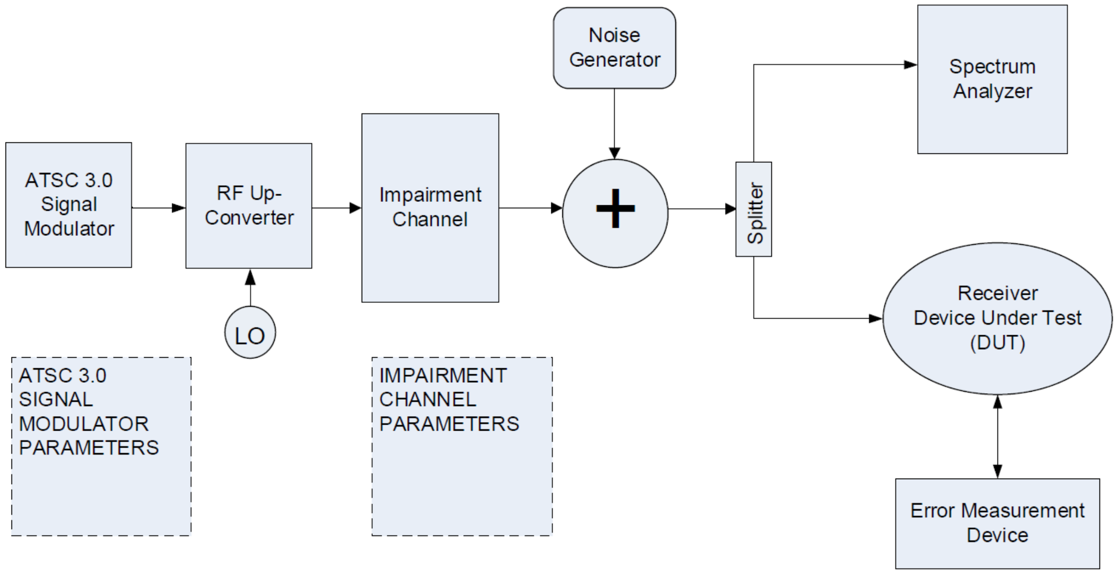
Measurement testing bandwidths use channel bandwidths. ATSC 3.0 offers different signal bandwidths with certain number of carriers and other parameter choices, so to compare performance across many parameter selections, channel bandwidth (e.g. 6 MHz) should be used.

2.2 Lab Performance – System

Lab setup for channel impairment testing may be found below in Fig. 2. This is very similar to Fig. 5.1, but with the RF Up-Converter added, as shown in Fig. 4.1, that allows for a complete receiver system (i.e. including a tuner) to be tested.

FIGURE 2

Test configuration for Lab Performance - System



Tests with a tuner should include weak, moderate, strong, and 3 dB over weakest signal TOV (TOV+3 dB) signal levels to account for non-linearities of the tuner. Weak signal levels of −68 dBm, moderate signal levels of −53 dBm and strong signal levels of −28 dBm were typically used in ACATS testing for the desired signals and can be used here again.

3 Description of the laboratory measurements done to define the method

The ATSC 3.0 test plan described in [1] provides detailed test plans for both types of laboratory test scenarios described above: Demodulator and System tests. These test plans include descriptions of the test setup, test procedures and expected results. Due to the level of detail in these tests, they are not repeated here. The reader is encouraged to refer to § 5 of [1] in order to see the detailed test plans. Below, each individual test is listed with a brief description of the purpose of the test.

3.1 Laboratory Performance – Demodulator tests

3.1.1 Frequency pull-in range

For each channel bandwidth, centre frequency offsets from tuners need to be accounted for in demodulators. This test measures the maximum frequency offset tolerated by the DUT.

3.1.2 Modes of configuration

There are many modes of operation to allow for broadcaster optimization of their channel for their market environment and business goals. Each mode should be tested to verify correct operation at the designed SNR threshold points. This test looks at Gaussian and Rayleigh channels for payload data only, not focusing on preamble or bootstrap performance. The DUT should automatically detect each configuration mode.

3.1.3 Impairment paths

Impairment paths are lab-generated signals that are intended to simulate various challenging RF environment conditions. These signals are combined with other signals to investigate how the demodulator, or complete tuner, performs under scenarios that are more realistic than those generated in a controlled laboratory. Several useful impairment paths are the primary differentiator in the various tests that are described in the following subsections.

3.1.4 Peak-to-average power ratio

The average power of a digitally modulated OFDM signal is of importance, since it determines the transmission range and most interference characteristics. For most of the system to be tested, the average power is constant (i.e. independent of scene content and motion). However, the peak power, in the form of transients, is data dependent and is greater than the maximum symbol power in a band-limited signal. The transient peak power is of concern in the design of transmitters and such high-power RF components as feed lines and transmitting antennas, due to the voltage stress imposed upon them. Efficient operation of high-power transmitters may require that some transients drive the transmitter toward saturation, resulting in compression of these peaks. Interference into adjacent channels may then result from third-order intermodulation due to AM/AM conversion (differential gain).

The frequency of occurrence of transient peaks above a specified level is statistical. The method described in this section should be used to determine the statistical transient peak-to- average power ratio for digital OFDM systems. This method provides the relative frequency of occurrence of transient peaks with respect to the average power. Note that the method cannot guarantee that a transient peak will never occur above the highest level measured. Also, note that in a practical situation in which some compression of peaks is occurring, the transient peak-to- average power ratio will be lower than the value resulting from laboratory testing using a highly linear RF test bed.

3.1.5 Single frequency network (SFN)

The SFN 2-path channel test involves a desired signal and a copy of the desired signal that has been shifted in time by a number of microseconds from the desired signal. The desired signal should contain content exhibiting enough movement/action to clearly determine the point at which noticeable degradation in the video output of the device has occurred. The undesired signal, or time-shifted copy of the desired signal, in the SFN 2-path channel test is the echo. The echo is set to one of several power levels relative to the desired signal, thus creating a signal-to-echo ratio (S/E), as the time shift is extended in microseconds until the time of validity (TOV) is detected. Due to the assumption that the strongest received signal is the most desired and a device would be oriented accordingly, there is no need to test a negative S/E. The time shift is extended both by positive (lagging) and by negative (leading) microseconds from time zero, relative to the desired signal arrival time. The output of the SFN 2-path channel test is delay in microseconds versus S/E curves.

3.2 Laboratory performance – system tests

3.2.1 Automatic gain control (AGC) dynamic range

Receiver sensitivity will vary depending on architecture, device type, tuner noise figure, self-inflicted tuner front-end electromagnetic interference (EMI), and many other factors. For broadcasting, the receiver range of operation can start from the system noise floor up to full power reception close to a transmitter.

ATSC 3.0 can operate data payloads at −6 dB SNR, which are signal powers below system noise levels, but for AGC dynamic range, only the system noise level will be seen. RF input levels are expected to range from at least the ‘Strong’ signal level (typically defined as −28 dBm) down to the noise floor of the system near −100 dBm, which is just over 70 dB of dynamic range. Tuner noise figures and implementation loss impact the operating points starting at –6 dB SNR, but the test can begin at −100 dBm. Stronger RF signal levels above −28 dBm (e.g. −8 dBm, as recommended by ATSC) can be expected if receivers are close to transmitters (or repeaters).

Gain control of this RF signal level needs to be quick enough to avoid errors in output data during fast dynamic signal conditions and therefore automatic gain control is anticipated. There are likely to be two stages of gain control due to need of greater than 70 dB dynamic range; one may be in the tuner, and one may be in the demodulator. Feedback loop design should compensate for correct overlap of these two feedback loops to avoid gaps in the system gain curve (of Vout/Vin).

3.2.2 Frequency range

ATSC 3.0 receivers should be able to tune to all available low VHF, high VHF and UHF channels currently allocated by the FCC. This frequency range is shown in Table 1.

TABLE 1

Channel band frequencies for the United States of America

Frequency band	Frequencies (MHz)	Channel centre frequencies (MHz)
Low VHF	54.0 → 72.0 and 76.0 → 88.0	57.0, 63.0, 69.0, 85.0
High VHF	174.0 →216.0	177.0, 183.0…213.0
Ultra High Frequency (UHF)	470.0 → 698.0	473.0, 479.0…695.0

3.2.3 Phase Noise

Phase noise relates to short-term frequency deviations of a signal during an observed time window (short). The short-term stability (or lack of) will spill energy away from intended standing carrier wave. A common description of phase noise is with single-sideband phase noise which is denoted here as L(*f*). Single sideband phase noise is the ratio of power spectral density measured at a certain frequency offset from a carrier tone input to the total power of the carrier signal.

The criteria of integrated phase noise power being less than 0.01 rad^2 (0.1 radian phase noise) puts an upper bound on a region of validity for phase noise measurements. The small angle criterion is a line with slope −10 dB /decade passing through a 1 Hz offset at −30 dBc/Hz. This represents a peak phase deviation of approximately 0.1 radians integrated over any one decade of offset frequency. Any measurement below this upper bound line can have a high degree of confidence. This puts measurements to be below −70 dBc/Hz at 10 kHz frequency offset for this test methodology.

OFDM systems are sensitive to phase noise because information from a modulation/coding symbol cell translates between carriers in the frequency domain. Phase noise will alter the received amplitude value of carriers throughout the number of active carriers within the FFT. Low phase noise helps to accurately capture the amplitudes of each carrier, especially in large FFT sizes and higher order modulations (e.g. 1024- and 4096-QAM). Phase noise will largely come from a tuner, or local oscillator driving demodulation, etc. and the amount of phase noise increases with each frequency conversion that occurs in a receiver. Therefore, it is necessary to determine the effect of phase noise on receiver performance and quantify the amount of randomly injected phase noise modulations required to cause perceptible degradation.

3.2.4 Impulse noise

Impulse noise testing will show tolerance levels to in-band spurious noise for specific modulation configuration settings. This type of noise can come from dishwashers, some LED lamps, fluorescent lamps, incandescent light switches being turned on, ignition noise in vehicles, etc.

There are a variety of impulse noise patterns in the environment. Impulse noise pulse patterns may be programmed into popular broadcast test equipment, but arbitrary waveform generators with I/Q vectors and RF up-converters may also be used if the waveforms can be verified to match expected pulse patterns. Arbitrary waveform generator pulses of Additive white Gaussian noise (AWGN) would need to be bandwidth limited to given pulse widths. Also, the reference interferer power would need to be determined for the waveform in order to calibrate D/U ratios. This reference power would have to be based on the RMS of the active portion of the pulses, but as each pulse is different averaging is needed. Note, it is beneficial to use popular test equipment which automatically adjusts power levels with these considerations. If possible, both methods can be tested on a receiver to verify repeatable results.

3.2.5 AWGN with power levels: weak, moderate, strong

AWGN testing will show minimum signal to noise ratio (SNR) threshold levels for specific modulation configuration settings in a Gaussian distributed noise environment. Only the noise generator will be supplied to the channel and all other impairments will not be applied.

3.2.6 Interference with adjacent channel interference, co-channel interference and others

Adjacent Channel(s) Interference (ACI) tests for demodulator DUTs applies for individual N+1 and N–1 signal interferers, and further adjacent channel (N ±2, N ±3, N ±4) interferers. This test looks at undesired digital N ±1 channel energy interfering with desired channel N energy; i.e. how well the receiver filtering (particularly in the tuner) can reject unwanted adjacent channel energy.

4 References

[1] ATSC: "ATSC Recommended Practice: ATSC 3.0 PHY Lab Performance Test Plan" Doc. A325/2018, Advanced Television Systems Committee, 10 December 2018.

[2] ITU-R: "Measurements of protection ratios and overload thresholds for broadcast TV receivers," Report ITU-R BT.2215-6, February 2016.

PART 2

Field measurement method for the assessment of ATSC 3.0 reception quality

1 Introduction

ATSC has developed and published a Recommended Practice for evaluating physical layer performance of ATSC 3.0 in a field test environment [1]. The following sections provide an overview of ATSC 3.0 performance metrics, field setup and tests used to characterize performance.

This Part 2 presents the recommended objectives and methodology for the development of ATSC 3.0 field test plans. Such plans facilitate the gathering of field data of DTV systems in order that useful conclusions about broadcast DTV signal coverage, service area, and receivability may be obtained. While tests and measurements may be conducted for certain and specific reasons and objectives by those performing the tests, the resultant field test data may be analysed by others for completely different reasons and objectives. Consequently, it is recommended that all tests and measurements documented herein be conducted and data gathered using this set of principles and general procedures in order that data analysis from a variety of different tests and their resultant conclusions are both consistent and meaningful. Care should be taken in describing exact field test parameters, conditions, and assumptions in order to provide the best opportunity for accurate and proper sharing of the resulting data.

The ATSC 3.0 physical layer has many configurations, and multiple transmission modes that may be used in field tests. This Part 2 includes recommended test processes, including basic diagrams of the equipment interconnection that should be used to perform the test, the test signal parameters under which the devices under test (DUT) are configured, the RF test parameters to be measured, and the test methodology to be employed in gathering measured data performance in the field. Results of these tests should indicate realistic performance levels of devices in the market and should also aid broadcasters in their network planning efforts (e.g. coverage and service evaluation).

The DUT(s) employed in these field tests may also have different device types, ranging from experimental implementations to fully integrated units with display screens, and can include both professional and consumer products. Tests in this Part 2 should, if possible, accommodate all device types. Data error thresholds can be determined with different measurements, either objectively with data bits/packets or subjectively with observation of errors in motion pictures.

2 Background

This Part 2 presents the recommended objectives and methodology for the development of ATSC 3.0 field test plans. Such plans facilitate the gathering of field data of DTV systems in order that useful conclusions about broadcast DTV signal coverage, service area, and receivability may be obtained. While tests and measurements may be conducted for certain and specific reasons and objectives by those performing the tests, the resultant field test data may be analysed by others for completely different reasons and objectives. Consequently, it is recommended that all tests and measurements documented herein be conducted and data gathered using this set of principles and general procedures in order that data analysis from a variety of different tests and their resultant conclusions are both consistent and meaningful. Care should be taken in describing exact field test parameters, conditions, and assumptions in order to provide the best opportunity for accurate and proper sharing of the resulting data.

The ATSC 3.0 physical layer has numerous configurations, and multiple transmission modes that may be used in field tests. This Part 2 includes recommended test processes, including basic diagrams of the equipment interconnection that should be used to perform the test, the test signal parameters under which the devices under test (DUT) are configured, the RF test parameters to be measured, and the test methodology to be employed in gathering measured data performance in the field. Results of these tests should indicate realistic performance levels of devices in the market and should also aid broadcasters in their network planning efforts (e.g. coverage and service evaluation).

The DUT(s) employed in these field tests may also have different device types, ranging from experimental implementations to fully integrated units with display screens, and can include both professional and consumer products. Tests in this Part 2 should, if possible, accommodate all device types. Data error thresholds can be determined with different measurements, either objectively with data bits/packets or subjectively with observation of errors in motion pictures.

3 Test objectives, scenarios and signal types

This Part 2 provides recommendations for the development of field test plans to meet the following objectives. DTV Field Test Plan implementations may focus on certain aspects of these objectives depending upon the immediate requirements of the testing entity. The five different types of reception (outdoor, indoor, portable, pedestrian and mobile) often have overlapping objectives. However, there are important differences between the five different types of reception that are also described in this Part 2.

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

– Identify and statistically characterize propagation variables that exist throughout a variety of urban, suburban, and rural RF environments, including inside buildings.
– Measure actual ‘service’ (reception capability) versus predicted ‘coverage’ (signal strength) in a variety of field environments.
– Obtain a statistically-meaningful correlation between field strength and service for better outdoor and indoor DTV service prediction through uniform data-gathering test methodologies, test procedures and test equipment.
– Determine D/U ratios for the resolution of interference considerations (e.g. CCI, ACI, ‘taboo’ channels, etc.) among ATSC 1.0, ATSC 3.0, LTE, and other signals.
– Collect data useful in verifying and improving the DTV system performance.
– Compare various system modulation/coding configurations.
– Compare one digital transmission system to another (e.g. ATSC 1.0 versus ATSC 3.0).
– Compare various DTV broadcast facilities.
– Compare SFN network parameters.
– Compare various ATSC 3.0 transmission and receiving components.
– Compare different generations of ATSC 3.0 transmission and receiving components.
– Determine indoor reception characteristics in a variety of urban, suburban, and rural RF environments, including determining signal loss and signal quality degradation compared to outdoor reception.

The goal is to provide a uniform series of test methodology and procedures that allow data from one test to be easily and accurately compared with results of other tests conducted by various organizations in different locations at different times.

3.1 Coverage testing objectives

Coverage is defined as the determination of actual field strengths measured in the field for a given transmission facility. There are generally three purposes for coverage measurements:

– Verify the proper functioning of the transmit antenna (azimuth and elevation patterns, etc.).
– Provide supplementary data for terrain attenuation algorithms that could be used for spectrum allocation planning and estimation of potential interference.
– Provide supplementary data for propagation prediction algorithms (e.g. free-space, Longley Rice, TIREM, CRC-Predict, ITU-R P.1546-3, etc.)

Coverage measurements are conducted using the standardized test methods, which typically use antennas calibrated to a standard dipole and placed at 9.1 metres (30 feet) height AGL, 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 at a large number of test sites throughout the desired area.

A transmitter 'proof of performance' should be conducted prior to commencement of the field test to ensure the best signal possible is radiating from the transmitter site.

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.

3.2 Service testing objectives

Service or 'Receivability' testing for purposes of this Part 2 is defined as the process of determining the conditions under which digital television signals can be received and decoded in various actual operating conditions. Such operating conditions include any location where digital devices are normally used 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 typically use digital devices designed to be connected to recording equipment to obtain signal level, margin-to-threshold, error rate, equalization characteristics, RF channel characteristics, and other information. These measurements can employ a variety of calibrated receive antennas (commercial or consumer) for various lengths of testing time and may not be as easily repeatable as the more formal coverage measurements. Moreover, receivers can be prototype, commercial, or consumer types of units.

All receivers used in field testing should be characterized prior to commencement of the field test to ensure the optimum performance of the receiver will accurately reflect service results. At the very least, white noise threshold and dynamic range (overload and sensitivity) should be performed. Other helpful receiver information, if available, would be CCI, ACI, and multipath performance.

A sample containing a large number of measurements needs to be taken to develop statistically valid 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.

3.3 Channel characteristics testing objectives

Channel characteristics testing has the specific meaning, for the purpose of this document, to determine RF propagation channel characterization (e.g. channel impulse response) and is accomplished by the detailed measurement of specific signal conditions at specific times and in specific locations using specific fixed and movable antennas.

In some cases, special transmitter identification (TxID) codes can be embedded 'underneath' normal data as a 'sub-signal' that allows special test equipment to extract them from the noise- like DTV signal, uniquely identifying a transmitter (e.g. as in SFN deployment), and then provide existing channel characteristics such as channel impulse response. Generally, detailed channel characteristic measurements use a variety of methods that provide the effects of channel impairments such as signal level variations, impulse noise, in-band interference, and multipath.

3.4 Single frequency network testing objectives

Single frequency network (SFN) reception is defined as reception from one or more synchronized transmitters (e.g. RF carrier, symbol frequency, and packet arrival timing) radiating identical signals that statistically provide increased signal levels with reduced chances of signal cancelation. In SFN applications, it is possible that multiple received signals of equal amplitude can create severe multipath conditions, allowing for the possibility of destructive interference, i.e. weak signal conditions. Therefore, SFN techniques also allow the multiple transmitters to radiate different signals that have been linearly modified by Transmit Diversity Code Filter Sets (TDCFS) that pre-distort the common waveforms using linear all-pass filters in such a fashion that minimizes the cross-interference among the transmitted signals over the entire reception area. SFNs are applicable and beneficial to all five reception cases described above and defined below.

Testing involves identification and level measurement of individual transmitter signals, composite signals, as well as the relative signal arrival timing over a region of overlapping transmitted signals.

3.5 ATSC 3.0 reception scenarios

Five different DTV receiving scenarios have been identified for possible field testing and are briefly described below. Gathering data in the field for five of these cases allows comparison to coverage (field strength) and service (reception) propagation prediction models.

3.5.1 Fixed outdoor

Fixed outdoor reception is defined as reception by a stationary receiver and receive antenna. Typically, this includes either a roof-top mounted antenna (with or without a rotor) or a fixed-location attic antenna.

Test site selection is typically chosen to be on radials, arcs, grids and clusters.

3.5.2 Fixed indoor

Fixed indoor reception is defined as reception by a stationary receiver and a fixed-location receive antenna inside a building structure.

Test site selection is always a challenge for indoor testing because it involves finding either public buildings (office building, malls, etc.) with accessible rooms available for testing or private buildings (e.g. houses, condos, apartments) with owners who are both 'willing and able' to meet the challenges of indoor testing and the testing group's schedule.

An additional challenge is that indoor testing requires moving enough equipment into this location to make meaningful tests without it being logistically impractical.

3.5.3 Portable

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.

Test sites can be either indoor or outdoor, as desired.

3.5.4 Pedestrian

Pedestrian reception is defined as reception by a receiver that is moving at no more than 5 km/hour (3.1 miles/hour). Typically, this is a receiver that may be used while walking, or a hand-held receiver where occasional and frequent short movements occur.

As an example, a person walking 3 km/hour (1.9 miles/hour) can create multipath RF signals at 695 MHz with Doppler frequencies of about 2 Hz (Doppler frequencies of 0.5 Hz at 177 MHz).

Test sites can be either indoor or outdoor, as desired.

3.5.5 Mobile

Mobile reception is defined as reception by a receiver that is moving at greater than 5 km/hour (3.1 mph). Typically, this is a receiver used in a vehicle moving faster than walking speed.

As an example, a vehicle traveling 120 km/hour (74.4 miles/hour) can create multipath RF signals at 695 MHz with Doppler frequencies about 77 Hz.

A general goal is to study and evaluate mobile system and/or hardware performance in the field in a variety of propagation environments and service (case) models.

3.6 Test signal types

ATSC 3.0 has a multitude of modulation and coding configurations from which to select for field testing. The availability of many transmission modes allows broadcasters to optimize their channel for their market environment, the particular application, and the type of receiver device. A large range of trade-offs between payload data rate and robustness is possible. A field test plan should precisely specify what type of test signals to employ during testing, and what exact transmission parameters are to be used.

If only one PLP is used in field testing, the bit rate of this video test signal should nearly fill the available bit capacity of the channel to maximize the accuracy of visual error probability. A test signal such as the moving HD zone-plate provides a significant challenge to any error concealment algorithms in DTV receivers and facilitates visual recognition of the observer. This type of subjective test signal excels in quick field error measurements when other, more accurate objective error measurement techniques are not available.

If use of more than one type of test signal is desired for field testing in order to simultaneously evaluate various data rate versus robustness options, then multiple PLPs can be employed. This is referred to as TDM. Use of multiple PLPs avoids the necessity of having to change the transmitter signal mode remotely from the field test vehicle for every different test configuration. However, this requires the use of a test receiver that can allow the observer to select which PLP to be received and evaluated for reception and site margin. See Annex B for some examples of transmission modes that represent various reception situations that might be used in commercial broadcast applications.

The test signal used to assess channel response has different needs than the other test signals. 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. Using a TxID signal with appropriate decoding test equipment is preferable.

The types of test signals described below are encapsulated within ATSC 3.0 physical layer signals as defined in the ATSC standard. They can be employed during field tests for particular types of tests, and fall into multiple categories:

– A typical test signal with general video and audio program material which can be used for either coverage or subjective service testing.

– A special test signal with repetitive test video and audio programming that have special desired characteristics (e.g. moving HD zone plate that encompasses nearly all of the data stream for easy visual detection of errors), and that can be used for either coverage or subjective service testing.

– A special test signal pseudo-random data stream that can be used for objective bit error or packet error measurements as detected internally by the DTV receiver or externally by error testing equipment, and that can be used for either coverage or service testing.

– A typical or special test signal, as described in the three paragraphs above, that has a special TxID signal embedded within, and that can be used for propagation channel response testing (e.g. amplitude and echo delay characteristics). It should be noted that this transmitter ID signal can be added to any of the other ATSC 3.0 test signals described above.

The test plan should clearly identify the specific test signal(s) to be transmitted and received during the course of testing, and the type of test data that is expected to be extracted from them.

4 Test measurement methodology and procedures

As discussed in detail in § 3.5 above, there are multiple reception scenarios to be considered, and these can be tested using the test signals described in § 3.6. Section 5 of [1] provides details of the measurement methodology specific to the coverage, service and channel characteristics measurement scenarios described in § 3 above. These methodology descriptions provide important guidelines for measurement site selection, test equipment and facilities, test setup, data collection and data analysis. Section 6 of [1] gives detailed field test procedures associated with the above scenarios and are consistent with the aforementioned measurement methodologies. The reception scenarios include Fixed Outdoor, Fixed Indoor, Portable, Pedestrian and Mobile.

The ATSC 3.0 test plan described in [1] provides detailed field test plans for the assessment of ATSC 3.0 reception quality. These test plans include descriptions of the test setup, test procedures and expected results. Due to the level of detail in these tests, they are not repeated here, but a summary is provided below. The reader is encouraged to use [1] as a detailed reference for conducting ATSC 3.0 field measurements.

Summary of field test procedure

Site selection and mapping are first carried out, with optional determination of the terrain profile, which would involve determining locations that will provide the most useful information across a wide range of receiving conditions. This may involve producing a series of points along radial lines radiating from the transmit antenna or determining a set of sites determined by the geography and/or service area of the region.

Sites should also be selected where the signal can be recorded at threshold, and the data should then include error indications associated with various stream elements such as bootstrap, preamble, LDPC, etc. If indoor field testing is to be performed, a building assessment is needed to provide a record of structural elements that may affect reception.

The signal coverage measurement is primarily concerned with measuring the outdoor field strength at specific locations. The measurement involves measuring the signal power within the band of interest and then removing the effects of the measurement equipment itself. What is left is an estimate of the field strength at the receiving location.

In addition to the primary measurements being performed as relevant for the specific site (e.g. signal level, SNR, packet error rate, margin, etc.), auxiliary data should be recorded to help in the analysis of the test results after the testing is completed. This information usually includes the GPS coordinates of the test, general test conditions including a description of the surrounding area, any significant signal obstructions, potential interfering signals, time of day, speed (for a mobile test), receiving antenna height and direction, and any unusual circumstances. Digital photographs of the site are a valuable record, if available.

Equipment should be calibrated, and correct operation confirmed. Performing the actual test itself should be done in a systematic manner and done in the same order and manner at all test sites. The setting of any signal distribution equipment as well as the settings of the measurement equipment should be carefully monitored. In particular, if equipment settings are changed for different tests at the same site, errors can easily be made if using incorrect equipment settings. Since equipment is shut down and moved between sites, the results of the tests should be carefully documented and saved in manner where data corruption is a low risk.

5 References

[1] ATSC Recommended Practice: *ATSC 3.0 Field Test Plan*, A326/2017, Advanced Television Systems Committee, 22 February 2017.