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Guidance for selection of system parameters and implementation of second generation DTTB systems

BT Series

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REPORT ITU-R BT.2468-1

Guidance for selection of system parameters and implementation of second generation DTTB systems

(Question ITU-R 132-5/6)

(2019-2021)

1 Introduction

The objectives of this Report are to provide guidance where an existing DTTB network exists and how assessment of parameters for the 2nd generation can be reliably chosen to either:

– maintain the same coverage;
– improve the coverage;
– maintain the same data bit rate in a 6/7/8 MHz channel;
– improve the data bit rate in a 6/7/8 MHz channel;
– obtain a mode with more robustness to interference;
– evaluate a mode with less robustness to interference while enhanced with other features; and
– consider the consequences to the receiving audience of the characteristics to be selected.

2 Selection of 2nd generation DTTB System A and System B digital television broadcasting modulation parameters for evaluation

2.1 2nd Generation System B parameters

The error-correction, data framing, modulation and emission parameters for the second generation of multi-carrier system DTTB (DVB-T2) transmission systems with multiple physical layer pipes (PLP) should be selected from Table 1 of Recommendation ITU-R BT.1877-3 – Error-correction, data framing, modulation and emission methods for second generation of digital terrestrial television broadcasting systems. Noting that the System B standards are:

– ETSI EN 302 755. Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2).
– ETSI TR 102 831. Digital Video Broadcasting (DVB); Implementation guidelines for a second generation digital terrestrial television broadcasting system (DVB-T2).

The DVB-T2 system parameters offer a wider range of modes than DVB-T which results in options for increasing bit rate capacity or the robustness of the signal.

The objective is to identify the possible modulation parameter permutations by assessing the potential for increased wide area single frequency network performance, increased bit rates and coverage of different DVB-T2 modes and coding when compared to the DVB-T parameters at an equivalent *C*/*N* value. For example:

a) Same coverage – resultant DVB-T2 capacity
b) Less coverage – more capacity
c) More coverage – less capacity
d) More coverage – more capacity

2.2 2nd Generation System A parameters

The error-correction, data framing, modulation and emission parameters for the 2nd Generation System A (ATSC 3.0) physical layer should be selected from Table 2 of Recommendation ITU-R BT.1877-3. Noting that the 2nd Generation System A standards are:

– ATSC Standard A/300: ATSC 3.0 System

– ATSC Standard A/322: Physical Layer Protocol.

The ATSC physical layer protocol is intended to offer far more flexibility, robustness and efficient operations than the ATSC A/53 (ATSC 1.0) standard, and as a result, it is non-backwards compatible with A/53. This physical layer allows broadcasters to choose from among a wide variety of physical layer parameters for personalized broadcaster performance that can satisfy many different broadcaster needs. In addition to the capability to have high-capacity/low-robustness and low-capacity/high-robustness modes in the same emission, technologies can be selected for special use cases like Single Frequency Networks, Multiple Input Multiple Output channel operation, channel bonding and more, well beyond a single transmitting tower. There is a large range of selections for robustness including, but not limited to, a wide range of guard interval lengths, forward error correction code lengths and code rates.

3 Television broadcasting system parameters and service coverage requirements

There are two scenarios for the transition to 2nd generation digital terrestrial television broadcasting, either:

– transition from analogue television to 2nd generation digital television broadcasting, or

– transition from 1st to 2nd generation digital television broadcasting.

Each administration will seek to determine the national regulatory transitional arrangements.

In many cases a ‘simulcast’ of the existing terrestrial television broadcasting system with 2nd generation digital television broadcasting will be considered.

The parameters of the existing television broadcasting system and its network structure will assist in determining the impact of the transition on the TV audience and most appropriate approach for a switchover from analogue to digital. There may also be differences between the performance of the 2nd generation digital television broadcasting and the existing 1st generation digital television broadcasting which may need to be considered.

a) Parameters for the existing analogue television broadcasting system

The radio-frequency specifications defined in Recommendation ITU-R BT.1701 can be referenced for characteristics of radiated signals of analogue television systems.

Many countries have established specific planning criteria for the planning of analogue television services and conducted surveys to verify the coverage established. These are likely to be used to compare the coverage and signal performance of the analogue television services and those proposed for the digital television services.

Report ITU-R BT.2043 – Analogue television systems currently in use throughout the world, gives information on different television systems used by different countries.

Individual countries may have established specific system performance criteria for the Analogue television systems in use, i.e. NTSC, PAL and SECAM.

The objective of identifying parameters for the existing analogue television broadcasting system is to ensure the coverage of the newly introduced digital television broadcasting reliably meets the

coverage boundary of the existing analogue service which may have been established many years ago.

b) Parameters for the 1st generation digital television broadcasting system

Recommendation ITU-R BT.1306 – Error correction, data framing, modulation and emission methods for digital terrestrial television broadcasting, defines error-correction, data framing, modulation and emission methods for digital terrestrial television broadcasting system B (DVB-T) and system A (ATSC 1.0).

Many countries have either established or are developing planning criteria for the planning of DVB-T and ATSC television services and some may have conducted surveys to verify the coverage established for these television services. This planning is likely to have to take into account the following for television services:

– suitable propagation prediction model;
– target minimum field / signal strengths;
– effective radiated power;
– wanted signal characteristics (% time and location availability);
– DVB-T and ATSC protection ratios for continuous and tropospheric interference; and
– other parameter values of importance within certain geographic areas.

Recommendation ITU-R BT.1306 provides parameters which allow for different levels of modulation and different code rates to be used to trade bit rate versus ruggedness. For countries within Region 1, as some variants can be selected as representative of the much larger set of all variants, it is necessary to select such a sub-set suitable for GE06.

Report ITU-R BT.2140 – Transition from analogue to digital terrestrial broadcasting, provides advice on deployment scenarios of digital television broadcasting in use throughout the world. Report ITU-R BT.2140-9 (07/2015) specifically for DVB-T provides deployment scenarios in Australia, Bulgaria, Germany, Guinea, Italy, Kenya, Russian Federation and Rwanda. Report ITU-R BT.2140-12 describes ATSC deployment scenarios for Canada, Mexico, the United States and the Republic of Korea.

In some countries, the recent DVB-T planning was based upon requirements also for DVB-T2.

DVB-T has been deployed in VHF Band III (174-230 MHz) and UHF Bands IV/V (470-862 MHz). Where Band III has been considered for DVB-T in some countries, Band III propagation is particularly suitable for portable and mobile reception, because of the uniform field strength distribution that can be achieved in that band, together with the possibility of achieving large area coverage with lower power than would be needed using UHF frequencies.

The objective of identifying parameters for the 1st generation digital television broadcasting system is to ensure the coverage of the 2nd generation digital television broadcasting service reliably meets the coverage boundary of the existing 1st generation digital television broadcasting service which may have been established previously.

c) Single frequency networks

Digital broadcasting techniques, that have been massively developed during the last 15 years, allowing the use of single frequency networks (SFN), in which the same frequency is assigned to all transmitters in a given service area in order to broadcast the same programme(s).

Although the implementation of SFNs permits a use of the spectrum in a more efficient way, SFNs are not the panacea for the resolution of the increasing spectrum demand.

Report ITU-R BT.2386 – Digital terrestrial broadcasting: Design and implementation of single frequency networks (SFN), provides analysis of benefits and drawbacks of SFNs. Many practical examples are described with the aim to share experiences and to give guidance in design and implementation to those have the intention to start the deployment of this kind of network.

Various DVB-T2 modes allow for a SFN Guard Interval not less than 256 µs (76.75 km) and are considered in the simulations, excluding some tuneable features which affect the system robustness.

d) Coverage prediction methods for DTTB

The implementation of DTTB services in parallel with existing analogue services in several countries has created the need to refine some of the traditional computer-based frequency planning techniques to enable a greater degree of accuracy in coverage predictions.

Whereas analogue systems fail rather gracefully, the 'cliff-edge' failure characteristics of digital systems can mean that in some situations 'holes' in DTTB coverage will result from the various factors that affect signal coverage. These include, but may not be restricted to, propagation characteristics of the bands used for DTTB transmissions, limits imposed on DTTB transmission power in order to protect the existing analogue services, terrain obstruction and man-made clutter.

Clearly the identification of geographic areas where such holes might be expected is important for coverage planning as well as for the receiver retail trade, where clear advice to potential viewers is essential.

It is for these reasons that improved coverage prediction methods have been introduced in a number of countries with considerable success, and that it is considered important that the new methods being developed are studied and documented by ITU with a view to achieving an appropriate degree of standardization worldwide.

Recommendation ITU-R P.1546 – Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz, has been widely used by administrations for field strength prediction methods and clutter height for field evaluation of DVB-T and ATSC.

Recommendation ITU-R SM.1682-1 (09/2011) – Methods for measurements on digital broadcasting signals, specifies parameters and methods for measurements on digital broadcasting signals coverage evaluation.

Report ITU-R BT.2137-0 (11/2008) – Coverage prediction methods and planning software for digital terrestrial television broadcasting (DTTB) networks, provides a brief outline of the results of comparisons between predicted and measured signal levels as reported by some administrations. These results show wide divergences between predicted and measured signal levels in terms of both mean error and standard deviation of errors. While these variations may have been acceptable in analogue television planning, the rapid failure of digital television signals means that a much closer match of predictions with measurements is required. An approach is discussed for predicting received field strength with particular discussion of profile extraction, radial prediction and the use of clutter data to take into account the effect of terrain, buildings and trees. Transmitter and population databases are also discussed.

Report ITU-R BT.2143-2 – Boundary coverage assessment of digital terrestrial television broadcasting signals, provides guidance on methods for boundary coverage assessment of digital terrestrial television broadcasting signals based upon characteristics of the DTTB systems parameters and the reception conditions at the coverage area boundary.

The objective of identifying parameters for the coverage prediction methods for DTTB is to recognize that coverage prediction methods for point-to-area predictions for terrestrial television broadcasting have been improved over time to take account of path loss due to both signal enhancements and fading in the frequency range 30 MHz to 3 000 MHz. What may have been applied for analogue and 1st

generation terrestrial television broadcasting services have been surpassed by those now available for 2nd generation terrestrial television broadcasting. This should be considered when comparing coverage characteristics between the implementations of terrestrial television broadcasting.

4 Selection of reception mode for 2nd generation digital television broadcasting – fixed, portable, mobile

4.1 Reception modes for DVB-T2

DVB-T2 is a 2nd generation terrestrial broadcast transmission system developed by DVB project since 2006. The main purpose was to increase capacity, ruggedness and flexibility to the DVB-T system. The first version was published by ETSI as EN 302 755 in 2009.

Report ITU-R BT.2254 – Frequency and network planning aspects of DVB-T2, has been developed by European Broadcasting Union members involved in planning of DVB-T2 networks. It provides guidance on frequency and network planning of DVB-T2, including reception modes in planning of DVB-T2 networks. It is intended to help broadcast network operators in their planning and administrations in defining the most suitable set of parameters from the large possibilities offered by the DVB-T2 system.

The objective of selecting reception modes for 2nd generation digital television broadcasting – fixed, portable, mobile is to ensure the television coverage requirements for television broadcasting are met where previously television coverage may have only focused on one reception mode e.g. fixed rooftop reception.

4.2 Reception modes for ATSC 3.0

ATSC 3.0 is a 2nd generation terrestrial broadcast transmission system developed by ATSC since 2011. The main purpose was to provide service enhancements over the 1st generation digital television broadcasting systems. The first version was published by ATSC as A/300:2017 in 2017. ATSC 3.0 should be evaluated across multiple reception modes:

– *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.

– *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, etc.) 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.

– 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.

– 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.

– 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.

To assist in the evaluation of ATSC 3.0, these reception modes are shown in Table 1, along with analogous terms used elsewhere in this Report that refer to Report ITU-R BT.2254.

TABLE 1

Reception modes for DTTB

ATSC 3.0	Report ITU-R BT.2254
Fixed outdoor reception	Fixed reception
Portable reception	Portable outdoor reception/urban (Class A) Portable indoor reception/urban (Class B)
Pedestrian reception	Handheld portable outdoor reception (Class H-A)
Mobile reception	Mobile reception/rural, Handheld mobile reception (Class H-D)

5 Selection of planning parameters for 2nd generation digital television broadcasting (VHF and UHF bands)

For many broadcasting organisations the transition from analogue to digital television required application of accurate planning parameters to ensure the public did not lose television services.

Recommendation ITU-R BT.2033 – Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands, defines planning criteria, including protection ratios, for various methods of providing the second generation (DVB-T2) digital terrestrial television broadcasting (DTTB) system in the VHF/UHF bands which can be selected by an administration.

Report ITU-R BT.2140 provides advice on deployment scenarios of digital television broadcasting in use throughout the world. Report ITU-R BT.2254 in Chapter 5 considers a number of common applications of DVB-T2 and discusses some possible parameter sets which may be suitable for each of the scenarios.

The objective of selecting planning parameters for 2nd generation digital television broadcasting (VHF and UHF bands) is to ensure any of the new characteristics of the new 2nd generation system are taken into consideration in the planning features for the new service(s), minimum receiver signal levels, protection ratios and impacts on network design.

6 Coverage prediction methods for 2nd generation digital television broadcasting (VHF and UHF bands)

The implementation of DVB-T2 in reduced spectrum allocations than was available in some countries for DVB-T has created the need to refine even further the traditional computer-based frequency planning techniques to enable a greater degree of accuracy in coverage prediction, than say for

Recommendation ITU-R P.1546 which was widely used by administrations for field strength prediction methods and clutter height for field evaluation for DVB-T and ATSC.

ITU-R Study Group 3 has now developed revisions of:

a) Recommendation ITU-R P.1812 – A path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands.

b) Recommendation ITU-R P.2001 – A general purpose wide-range terrestrial propagation model in the frequency range 30 MHz to 50 GHz.

Report ITU-R BT.2254 provides guidance on frequency and network planning of DVB-T2, including SFN extension.

The objective of selecting coverage prediction methods for 2nd generation digital television broadcasting (VHF and UHF bands) is to ensure any impact of the new 2nd generation transmission characteristics are fully examined with respect to the planning and coverage predictions for the existing services.

7 Field measurement campaign to evaluate actual coverage provided by 2nd generation digital television broadcasting (VHF and UHF bands)

Report ITU-R BT.2035 – Guidelines and techniques for the evaluation of digital terrestrial television broadcasting systems including assessment of their coverage areas, includes a field survey methodology developed for fixed measurement of digital television reception.

Each field survey measurement is to be representative of the surrounding localities within a small area (typically 100 m by 100 m). However, actual signal parameters will be statistically distributed, even over such a small area. The signal variations are the result of various characteristics, such as the local environment around the receiver (local clutter such as surrounding buildings, vegetation etc.). In addition to the coverage evaluation at a single measurement location, this methodology incorporates some area specific analysis in order to be representative of the majority of locations in the surrounding (100 m by 100 m) area. It is proposed this methodology is applied to the comparative evaluation of DVB-T and DVB-T2 at each measurement location.

It is also proposed a specific set of parameters are contained within the measurement campaign to ensure exhaustive analysis may be undertaken post the field survey and to ensure best practice.

The ATSC 3.0 coverage field measurements described in A/326, ATSC Recommended Practice: ATSC 3.0 Field Test Plan include a description and methodology in which coverage (field strength) measurements are conducted along a minimum of eight evenly-spaced radials from the test transmitter site. A minimum of 15 measurements are recommended along each radial, starting at a distance of 16.1 km from the transmitter site and then incrementally increasing by 3.2 km. Depending on the local terrain, each of these measurement sites along the radials may consist of a ‘cluster’ of at least five measurements within a nine-metre square area. The referenced ATSC 3.0 field test plan provides further details on this methodology for determining coverage.

8 Objective quality assessment methods for 1st generation digital television broadcasting (VHF and UHF bands)

For many broadcasting organisations the transition from analogue to digital television required application of accurate planning parameters to ensure the public did not lose television services.

Recommendation ITU-R BT.1735 – Methods for objective reception quality assessment of digital terrestrial television broadcasting signals of System B specified in Recommendation ITU-R BT.1306, provides methods to assist in quality assessment of the reception of digital terrestrial television

broadcasting services for digital television broadcasting in System B. This Recommendation takes into account relevant ITU-R Recommendations.

Recommendation ITU-R BT.1735 defines the following reception quality grades in terms of the margin to failure of the received signal.

Grade Q1 – Signal level is below minimum planning target.

Grade Q2 – Signal level is below minimum planning target or margin to failure is too low (reception may be possible but signal is very susceptible to failure).

Grade Q3 – Signal level and margin to failure have some margin above minimum planning targets.

Grade Q4 – Signal level and margin to failure above planning targets.

Grade Q5 – No measurable defects can be reasonably detected.

In Recommendation ITU-R BT.1735 two methods are available, one for multi-frequency network (MFN) and one for single frequency network (SFN).

A number of countries have developed networks based on an SFN configuration, whereby transmitters are placed far apart. In such networks, the use of the maximum permissible guard interval together with high code rate (i.e. 3/4 or 5/6) results in a very complex impulse response with a lot of reflected rays, both natural and artificial falling on the shoulder, or outside, the guard interval.

The situation is further complicated, due to field-strength variations at the receiving point originated by the farthest transmitters. Such variations impact on the positioning of the window in the receiver, depending on the strategy implemented by manufacturers, and sometimes one or more rays of sufficient energy fall outside the guard interval.

In such conditions it may easily happen that different receiving situations are detected during the day and it is not easy to find a simple algorithm to determine coverage quality. Moreover the relationship between BER measurements taken before and after Viterbi decoding depends on unpredictable factors hence an evaluation of BER before Viterbi decoding does not permit it to be known if BER after Viterbi decoding would fall below the threshold or above it. Furthermore, since MER and BER measurements are based on different aspects of the phenomenon, no close relationship can be identified between them.

It was concluded there is a need for a new multidimensional evaluation system valid for both MFN and SFN networks that would supersede the one specified in Recommendation ITU-R BT.1735 which remains valid for MFN networks.

Report ITU-R BT.2252 – Objective quality coverage assessment of digital terrestrial television broadcasting signals, was developed in support of Recommendation ITU-R BT.1735. It provides information of this methodology from Australia and Italy for DVB-T and from the United States of America for ATSC 1.0.

The objective of selecting objective quality assessment methods for 1st generation digital television broadcasting (VHF and UHF bands) and was to provide a benchmark for the objective quality assessment sought for the 2nd generation digital television broadcasting service.

However, Report ITU-R BT.2389 addressed the requirements and methods necessary to maintain the quality of technical operations during the deployment and running of digital terrestrial television broadcasting (DTTB) networks. And in particular, in Table 5.1, bit error rate (BER) requirements in DVB systems of the first and second generations where currently the generally accepted practice is to estimate the packet error ratio (PER) and the frame error ratio (FER). Section 5.2 of Report ITU-R BT.2389 addresses specific measurements for ATSC 1.0.

9 Subjective quality assessment methods for 1st generation digital television broadcasting (VHF and UHF bands)

Subjective quality assessment of DTTB signals have been used for identifying the subjective failure point as an indication of the signal interference threshold necessary to maintain a just error-free picture at the TV screen. The SFP method as defined in Annex 8 to Recommendation ITU-R BT.1368-13 corresponds to the picture quality where no more than one error is visible in the picture for an average observation time of 20 seconds.

For the purpose of assessing picture quality Recommendation ITU-R BT.500 provides methodologies including general methods of test, the grading scales and the viewing conditions. It recommends the double-stimulus impairment scale (DSIS) method and the double-stimulus continuous quality-scale (DSCQS) method as well as alternative assessment methods such as single-stimulus (SS) methods, stimulus-comparison methods, single stimulus continuous quality evaluation (SSCQE) and simultaneous double stimulus for continuous evaluation (SDSCE) method. These methods have been established and implemented by many administrations for several decades.

10 Evaluation / assessment criterion for performance of 2nd generation digital television broadcasting (VHF and UHF bands)

Studies on criteria for the evaluation/ assessment for performance of 2nd generation digital television broadcasting (VHF and UHF bands) can be found in Report ITU-R BT.2467.

List of related ITU documents

Recommendation ITU-R BT.2033 defines in Annex 5 the subjective failure point (SFP) method for DVB-T2 protection ratio measurements.

Recommendation ITU-R SM.1875 describes methods for DVB-T/T2 coverage measurements and comparison with coverage predictions.

Report ITU-R BT.2254 provides guidance on frequency and network planning of DVB-T2, including advice on the differences between DVB-T and DVB-T2.

Report ITU-R BT.2035 provides a field survey methodology for fixed measurement of digital television reception which can be applied as a methodology for terrestrial television coverage evaluation at a measurement location. The methodology requires measurements of the field strength and the instantaneous signal quality parameters of the digital television signals using an external antenna at 10 m above the ground.

Report ITU-R BT.2341 – TV receiver subjective failure thresholds and the associated minimum quasi error free levels for good quality reception, provides information on the different measurement methods to determine DTT receiver performances in the presence of noise, multipath effects and interferences. It considers only the case where the channel impairment is static in time.

Report ITU-R BT.2382 – Description of interference into a digital terrestrial television receiver, provides information on the effects that limit the ability of DTT receivers from demodulating the wanted signal correctly.

11 References

Recommendation ITU-R BT.500	Methodology for the subjective assessment of the quality of television pictures
Recommendation ITU-R BT.1306	Error correction, data framing, modulation and emission methods for digital terrestrial television broadcasting

Recommendation ITU-R P.1546	Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz
Recommendation ITU-R BT.1701	Characteristics of radiated signals of conventional analogue television systems
Recommendation ITU-R BT.1735	Methods for objective reception quality assessment of digital terrestrial television broadcasting signals of System B specified in Recommendation ITU-R BT.1306
Recommendation ITU-R P.1812	A path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands
Recommendation ITU-R BT.1877	Error-correction, data framing, modulation and emission methods for second generation of digital terrestrial television broadcasting systems
Recommendation ITU-R P.2001	A general purpose wide-range terrestrial propagation model in the frequency range 30 MHz to 50 GHz
Recommendation ITU-R BT.2033	Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands
Recommendation ITU-R SM.1682	Methods for measurements on digital broadcasting signals
Recommendation ITU-R SM.1875	DVB-T coverage measurements and verification of planning criteria
Report ITU-R BT.2035	Guidelines and techniques for the evaluation of digital terrestrial television broadcasting systems including assessment of their coverage areas
Report ITU-R BT.2043	Analogue television systems currently in use throughout the world
Report ITU-R BT.2137	Coverage prediction methods and planning software for digital terrestrial television broadcasting (DTTB) networks
Report ITU-R BT.2140	Transition from analogue to digital terrestrial broadcasting
Report ITU-R BT.2143	Boundary coverage assessment of digital terrestrial television broadcasting signals
Report ITU-R BT.2252	Objective quality coverage assessment of digital terrestrial television broadcasting signals of Systems A, B and D
Report ITU-R BT.2254	Frequency and network planning aspects of DVB-T2
Report ITU-R BT.2341	TV receiver subjective picture failure thresholds and the associated minimum quasi error free levels for good quality reception
Report ITU-R BT.2386	Digital terrestrial broadcasting: Design and implementation of single frequency networks (SFN)
Report ITU-T BT.2389	Guidelines on measurements for digital terrestrial television broadcasting systems
Report ITU-R BT.2382	Description of interference into a digital terrestrial television receiver

ATSC Standard A53-2007	ATSC Digital Television Standard
ATSC Standard A/300	ATSC 3.0 System
ATSC Standard A/322	ATSC 3.0 Physical Layer Protocol
ATSC Recommended Practice A/326	ATSC 3.0 Field Test Plan