1 Scope

This document establishes the operational guidelines for the TV 3.0 (DTV+) Over-the-Air Physical Layer, defining the parameters, configurations, and recommended practices for terrestrial broadcasting within the Brazilian Digital Terrestrial TV Forum (SBTVD) framework.

It provides technical orientations for the generation, modulation, and transmission of Radiofrequency (RF) signals, addressing aspects such as waveform configuration, multiplexing techniques, Multiple-Input Multiple-Output (MIMO) operation, Layer Division Multiplexing (LDM), and synchronization in both Single Frequency Networks (SFNs) and Multi-Frequency Networks (MFNs).

The objective is to ensure interoperability, efficient spectrum utilization, and robust reception performance across different propagation environments and service types, supporting both fixed and mobile reception.

This document is non-normative and intended to guide system designers, broadcasters, and equipment manufacturers in implementing and testing the TV 3.0 Physical Layer in accordance with Brazilian Association of Technical Standards (ABNT) Brazilian Standard (NBR) 25601 [1], ABNT NBR 25602 [2] and ABNT NBR 25609 [3] standards.

2 Terms and Definitions

For the purposes of this Document, the following terms and definitions apply.

MIMO mode

transmission mode in which a Physical Layer Pipe (PLP) is configured to create two transmitter signal paths that ultimately feed a pair of cross-polarized transmitting antennas

Layered MIMO

mode of operation in which MIMO and LDM are both active

Layered MIMO Type A

mode of operation in which MIMO is applied to both the Core Layer (CL) and the Enhanced Layer (EL)

Layered MIMO Type B

mode of operation in which MIMO is applied only to the EL while the associated CL operates in a Single-Input Single-Output (SISO) configuration

Polarization

orientation of the electric field vector of a radiated electromagnetic (radio) wave with respect to the horizon as seen from the antenna

TV 3.0

Digital Terrestrial Television Broadcasting (DTTB) system defined in the suite of standards ABNT NBR 25601 to ABNT NBR 25609 (which includes this document), also known as DTV+

txid_ddress

A 13 bits (8192) value shall be uniquely assigned to each transmitter on a given RF channel and that value shall be used by the scheduler for control individual transmitter

Occupied bandwidth

Useful bandwidth in which there are carriers for conveying information and other data. Calculated from channel bandwidth and carrier reduction coefficient.

3 Abbreviations

For the purposes of this document, the following abbreviations apply.

ABNT	*Brazilian Association of Technical Standards*
ALP	*ATSC Link-Layer Protocol*
BBP	*Baseband Packet*
BCH	*Bose, Chaudhuri, and Hocquenghem*
CRC	*Cyclic Redundancy Check*
DASH	*Dynamic Adaptive Streaming over HTTP*
DTTB	*Digital Terrestrial Television Broadcasting*
FEC	*Forward Error Corrector*
GPS	*Global Positioning System*
IL	*Injection Level*
LDM	*Layer Division Multiplex*
LDPC	*Low Density Parity Check*
MFN	*Multi-Frequency Networks*
MIMO	*Multiple-Input Multiple-Output*
ModCod	*Modulation and Coding*
NUC	*Non-Uniform Constellation*
NoC	*Number of useful Carriers*
OBW	*Occupied Bandwidth*
OFDM	*Orthogonal Frequency Division Multiplex*
PLP	*Physical Layer Pipe*
PAPR	*Peak-to-Average Power Ratio*

QAM	*Quadrature Amplitude Modulation*
QPSK	*Quaternary Phase Shift Keying*
RF	*Radiofrequency*
ROUTE	*Real-Time Object Delivery over Unidirectional Transport*
SBTVD-T	*Brazilian Digital Terrestrial TV Forum*
SISO	*Single-Input Single-Output*
SFN	*Single Frequency Networks*
SP	*Scatter Pilots*
STLTP	*Studio-to-Transmitter Link Transport Protocol*
UHF	*Ultra-High Frequency*
VHF	*Very High Frequency*

4 Overview

The TV 3.0 (DTV+) physical layer is designed to be highly flexible in terms of the parameters and settings that can be adjusted, so that it can meet more varied demands (high robustness with reduced transmission capacity, or greater transmission capacity at the price of greater susceptibility to interference).

Coded audio and video data are formatted into Base-band Packets (BBPs) and grouped for the Physical Layer Pipes (PLPs) according to the Scheduler's programming. These packets have sizes determined based on certain configurable parameters, i.e. they do not have fixed, predetermined sizes.

The BBPs are then sent to the Bose, Chaudhuri, and Hocquenghem (BCH) and the Low Density Parity Check (LDPC), respectively, external and internal error correctors. These correctors will ensure that bit errors can be detected and corrected on reception.

The mapper groups the bits into symbols according to the modulation selected and converts these symbols to I (In-Phase) and Q (Quadrature) values (modulation symbols) then normalizes these values so that the output power is always constant, regardless of the modulation selected.

Multiple-Input Multiple-Output (MIMO) and Layer Division Multiplexing (LDM) processing are mandatory, but MIMO processing must precede LDM. The modulation symbols pass through a temporal interleaver (convolutional, hybrid, or none), which generates a delay in the symbols. The Orthogonal Frequency Division Multiplex (OFDM) frame is assembled, incorporating a preamble and bootstrap data. Once again, these symbols are interleaved, but now with respect to frequency. Pilot carriers are added, which carry information about the modulation parameters and other signaling information (Layer One (L1) signaling). Finally, these symbols go through Inverse Fast Fourier Transform (IFFT) then some signal power ratio techniques may be applied as well as guard interval may be added to the transmitted signal.

5 Waveform Generation

5.1 Transmission frequency

TV 3.0 can operate on any Very High Frequency (VHF) or Ultra High Frequency (UHF) band used for terrestrial television, ranging from 44 MHz to 960 MHz, on 6 MHz, 7 MHz, or 8 MHz Radiofrequency (RF) bandwidth channels. Please refer to the local regulations for the RF channel frequencies and RF bandwidth used in each country or territory.

The bandwidth is determined from the value of *system_bandwidth* signaled in bootstrap symbol 1 of ATSC A/321:2025-07 [4], corresponding to *bsr_coefficient*. According to Table 1, the value for the *bsr_coefficient* defined in part of bootstrap symbol 2 of ATSC A/321:2025-07 [4]. For the occupied bandwidth, the *bsr_coefficient* defined in ATSC A/322:2025-07 [5] should be one of the values shown in Table 2. For maximum spectral efficiency, the *Cred_coeff* should be 0.

Table 1 – Defined Values of *bsr_coefficient*.

bsr_coefficient	**Applicability**
2	6 MHz bandwidth
5	7 MHz bandwidth
8	8 MHz bandwidth

Source: Table 9.1 of ATSC A/322:2025-07 [5].

Table 2 – Number of Carriers (NoC) and Occupied Bandwidth.

Cred_coeff	**Number of Carriers (NoC)**			**Occupied Bandwidth (OBW) [MHz]**		
	8K FFT	**16K FFT**	**32K FFT**	***bsr_coefficient* = 2**	***bsr_coefficient* = 5**	***bsr_coefficient* = 8**
0	6913	13825	27649	5.832844	6.804984	7.777125
1	6817	13633	27265	5.751844	6.710484	7.669125
2	6721	13441	26881	5.670844	6.615984	7.561125
3	6625	13249	26497	5.589844	6.521484	7.453125
4	6529	13057	26113	5.508844	6.426984	7.345125

Source: Table 7.1 of ATSC A/322:2025-07 [5].

5.2 Frequency offset

If required, the frequency offset of the terrestrial transmission carrier can be defined by local regulations.

5.3 Frequency stability and permissible transmission frequency deviation

The frequency stability and its deviation must be ± 0.5 Hz (item 10.3.1 of ATSC A/324:2025-07 [6]).

5.4 Transmission spectrum mask

Local regulations can define the allowed out-of-band emission limits.

5.5 Frequency network

TV 3.0 can operate in Single Frequency Networks (SFNs) or Multiple Frequency Networks (MFNs). In this regard, it is essential to consider the Guard Interval (GI) and synchronization references.

For MFN, the GI should be adjusted to achieve the desired robustness, considering the possible multipath that may occur due to natural and artificial obstructions (e.g., mountains and buildings).

For SFN, all transmitters shall be synchronized by the same reference, usually Global Positioning System (GPS), and each transmitter must be adjusted with a delay (*tx_time_offset*), to synchronize the transmitted content (ATSC A/324:2025-07), so that all transmitters transmit the same content at the same time. If the broadcaster chooses to transmit different content based on the viewer's geographic location, it is recommended to use the Geographic Segmented Localcasting (GSL) technique, which allows the transmission of wide-range content on a PLP (CL) using SFN and regionalized content being transmitted on a second PLP (EL), which operates in MFN. Since both PLPs are part of the same subframe, they use the same GI value. Due to the SFN operation of the CL, the choice of GI must take into account the distance between each transmitter (ATSC A/327:2025-07 [7]).

5.6 TxID

The Transmitter Identification (TxID) allows each transmitter to be uniquely identified by 13-bit (8192) values and can use the same or different TxID addresses in each polarization. The TxID is added to the OFDM signal through the Injection Level (IL), which functions as a watermark in the RF signal. It should recommend using different TxIDs in each polarization to improve channel estimation and utilize an IL of 24 dB.

On the other hand, the addition of the TxID may cause interference with the preamble's first symbol. Therefore, TxID should primarily be used for adjustment and monitoring of SFN measurements (ATSC A/327:2025-07 [7]).

NOTE: Despite the above paragraph, referring to the ATSC A/327:2025-07 [7] recommendation, in TV 3.0, the use of TxID shall be mandatory.

5.7 MIMO Mode

There are two MIMO modes of operation: Layered MIMO Type A and B. For maximum spectral efficiency, MIMO Type A should be used.

When MIMO mode is on, it is possible to assign different TxIDs to each polarization (ABNT NBR 25602 [2]). This also results in more accurate delay profile measurements.

5.8 MIMO Precoding

MIMO precoding is based on spatial multiplexing and consists of three different stages (stream combining, In-Phase and Quadrature (IQ) polarization interleaving, and phase hopping) and is applied only to subframes. The stages that make up the MIMO Precoder are optional and can be disabled using the *L1D_plp_mimo_stream_combining*, *L1D_plp_mimo_IQ_interleaving*, and *L1D_plp_mimo_PH flags*. If the three stages that make up MIMO Precoding are disabled, the technique used in MIMO is known as simple spatial multiplexing. All stages of MIMO Precoding should be enabled and applied in the PLPs.

5.9 Bootstrap

The bootstrap is used to convey information about the TV 3.0, including the Emergency Alert System (EAS), the transmitted signal bandwidth, preamble structure, and the information needed to decode the preamble symbols. The bootstrap always occupies a 4.5 MHz bandwidth and uses an IFFT of size 2K. The flags bootstrap minor and minor versions shall be set to 0 (item 9.1.1 of ATSC A/322:2025-07 [5]).

5.10 Guard Interval

GI is a cyclic extension of the OFDM symbol. The number of samples for GI can be set according to the iFFT size, as shown in Table 3.

Table 3 – GI duration for bandwidth of 6 MHz.

GI Pattern	Samples	GI duration [μs]		
		8K FFT	16K FFT	32K FFT
GI1_192	192	27.7778	27.7778	27.7778
GI2_384	384	55.5556	55.5556	55.5556
GI3_512	512	74.0741	74.0741	74.0741
GI4_768	768	111.1111	111.1111	111.1111
GI5_1024	1024	148.1481	148.1481	148.1481
GI6_1536	1536	222.2222	222.2222	222.2222
GI7_2048	2048	296.2963	296.2963	296.2963
GI8_2432	2432	-	351.8519	351.8519
GI9_3072	3072	-	444.4444	444.4444
GI10_3648	3648	-	527.7778	527.7778
GI11_4096	4096	-	592.5926	592.5926
GI12_4864	4864	-	-	703.7037

Source: Adapted from Table 8.9 of ATSC A/322:2025-07 [5].

Equation 1 shows how the duration calculation in μs is performed, where T is the fundamental period and is expressed in Equation 2.

$$GI_{duration} = GI_{samples} \cdot T \ [\mu s] \quad (1)$$

$$\mathrm{T} = \frac{1}{0.384\mathrm{MHz} \times (16 + \mathrm{bsr\_coefficient})} \ [\mu s] \quad (2)$$

5.11 PAPR

There are two techniques used to adjust the transmitted signal power ration: Tone reservation (TR), in which some frequencies are reserved for carriers that do not contain data nor signaling information; and Active

Constellation Extension (ACE) where the constellation points from the mapper are modified. ACE should not be used with LDM, MISO or MIMO.

5.12 IFFT sizes

The IFFT size (*L1D_fft_size*) can be adjusted to one of the following values: 8K (8192), 16K (16384), or 32K (32768). The IFFT size does not change the payload, but it does have an impact on reception. Due to the frequency spacing between the carriers (1/Tu) shown in Equation 3, an IFFT size of 8K is recommended for mobile reception, and an IFFT size of 32K is recommended for fixed reception. The IFFT size of 16K should be used for mobile and fixed reception (Doc. CIT-196r23 [8]). T is the fundamental period and is expressed in Equation 2.

$$1/Tu = \frac{1}{iFFT_{size} \cdot T} [Hz] \quad (3)$$

5.13 Pilots

There are five types of pilots: scattered, continual, edge, preamble and subframe boundary pilots.

Scattered pilots are used for channel estimation at the receiver and can be adjusted by two parameters, Dx and Dy. The Dx parameter determines the spacing of the scattered pilot on the x-axis (frequency) of the frame, and the Dy parameter represents the repetition interval in the OFDM symbol (time). Reducing the order of Dx and Dy increases the accuracy of channel estimation, but it reduces the system's payload. The Dx value used for the scattered preamble pilots of a frame should be less than or equal to the Dx value used for the scattered pilots of the first subframe of the same frame, to provide more accurate equalization for the preamble symbols. The Dy value of the scattered preamble pilot should always be 1.

The first and last pilots of the OFDM frame are referred to as edge pilots.

Continual pilots are a set of pilots in predefined positions, tied to the iFFT size, that are transmitted at the same position. These pilots are used in channel estimation.

Between subframes, there are pilots called subframe boundary pilots, which signal the beginning and end of each subframe within the frame. For improved reception, the First and Last subframe boundary symbols shall be enabled (Doc. CIT-196r23 [8]). There are also pilots specific to the preamble (L1) that are referred to as preamble pilots.

MIMO Pilot encoding is detailed on annex L of ATSC A/322:2025-07 [5], and tables L9.3 and L9.4 give possible combinations of pilot schemes, iFFT sizes, and GI pattern. However, MP4_2 shall not be used for an iFFT size of 32K, as it will overlap with data pilots.

5.14 Channel payload

The estimated PLP bitrate can be calculated as follows (adjusted from Doc. CIT-196r23 [8] and valid for MIMO transmission. For SISO transmission, just omit the “2 x” in the beginning of the Equation 4.

$$2 \times \log_2(M) \times \left(\frac{LDPC_{codelength} \times FEC_{coderate} - 192}{LDPC_{codelength}}\right) \times OBW \times (1 - Pilot_{overhead})[Mbps] \quad (4)$$

M is the modulation scheme (Quadrature Phase Shift Keying (QPSK) = 4, 16 Quadrature Amplitude Modulation (QAM) = 16, etc), OBW is the Occupied Bandwidth, CP is the number of continual pilots (Table 8.4 of ATSC

A/322:2025-07 [5]), Dx and Dy are the SP pattern (Table 8.3 of ATSC A/322:2025-07 [5]). The pilot overhead calculation was adapted to reflect a more accurate result, as shown in Equation 5.

$$Pilot_{overhead} = \frac{\frac{NoC}{Dx \times Dy} + CP}{NoC} \quad (5)$$

6 Framing and Interleaving

6.1 Frequency Interleaving

The frequency interleaving is a block interleaver that acts on the data cells of the OFDM symbol. Frequency interleaving is mandatory for the preamble and optional for the other symbols. The frequency interleaving can be turned on and/or off by the *L1D_frequency_interleaver* flag.

To improve reception, frequency interleaving should be turned on (Doc. CIT-196r23 [8]).

6.2 Preamble

The Preamble consists of L1 Basic (L1B) and L1 Detail (L1D) information. L1B transmits 200 bits, which are used to indicate the L1D parameters. L1D transmits the signaling bits, which can vary between 200 and 6312 depending on the mode and modulation parameters. There are seven modes (1 up to 7) for configuring the Forward Error Correction (FEC) and Modulation of L1B and L1D, using Uniform Constellation (UC) and Non-Uniform Constellation (NUC). They are transmitted after bootstrapping and within the OFDM frame. Table 4 shows the allowed FEC and modulation combinations. The most robust mode should be used to improve reception, as per Annex H.1 PREAMBLE STRUCTURE PARAMETER VALUES of ATSC A/322:2025-07 [5].

Table 4 – L1B and L1D FEC types.

<table>
<tr><th colspan="2">FEC Type</th><th>K_{sig}</th><th>Code Length</th><th>Code Rate</th><th>Constellation</th><th>Length (cells)</th></tr>
<tr><td rowspan="7">L1B</td><td>1</td><td rowspan="7">200</td><td rowspan="14">16200</td><td rowspan="9">3/15
(Type A MET)</td><td>QPSK</td><td>3820</td></tr>
<tr><td>2</td><td>QPSK</td><td>934</td></tr>
<tr><td>3</td><td>QPSK</td><td>484</td></tr>
<tr><td>4</td><td>NUC_16_8/15</td><td>259</td></tr>
<tr><td>5</td><td>NUC_64_9/15</td><td>163</td></tr>
<tr><td>6</td><td>NUC_256_9/15</td><td>112</td></tr>
<tr><td>7</td><td>NUC_256_13/15</td><td>69</td></tr>
<tr><td rowspan="7">L1D</td><td>1</td><td>200-2352</td><td>QPSK</td><td></td></tr>
<tr><td>2</td><td>200-2352</td><td>QPSK</td><td></td></tr>
<tr><td>3</td><td rowspan="5">200-6312</td><td rowspan="5">6/15
(Type B IRA)</td><td>QPSK</td><td></td></tr>
<tr><td>4</td><td>NUC_16_8/15</td><td></td></tr>
<tr><td>5</td><td>NUC_64_9/15</td><td></td></tr>
<tr><td>6</td><td>NUC_256_9/15</td><td></td></tr>
<tr><td>7</td><td>NUC_256_13/15</td><td></td></tr>
</table>

Source: Table 6.17 of ATSC A/322:2025-07 [5].

6.3 Time Interleaving

There are three possible configurations for Time Interleaving (TI): Convolutional Time Interleaving (CTI), Hybrid Time Interleaving (HTI), or disabled. The TI is applied individually for each defined PLP.

There is also the possibility of extending the TI duration, but it can only be used for the QPSK modulation scheme, and if LDM is inactive.

Table 5 – Convolutional Time Interleaving duration.

L1D_plp_CTI_depth	L1D_plp_TI_extended_ interleaving	Depth	Approximate duration [ms]
000	0	512	50
001	0	724	100
010	0	887	150
011	0	1024	200
010	1	1254	300
011	1	1448	400

Source: Table 9.26 of ATSC A/322:2025-07 [5].

The TI should be enabled to improve reception, mode “None” is not recommended (Doc. CIT-196r23 [8]).

7 Multiplexing Techniques

To perform the multiplexing process of different PLPs, three multiplexing techniques can be employed: Time Division Multiplexing (TDM), Frequency Division Multiplexing (FDM), and LDM. LDM should be used for the transmission of PLPs with unequal error protection.

7.1 LDM

It is the constellation superposition that combines several PLPs (with different modulation and coding parameters) in up to two layers, each with different power levels, for transmission on a single RF channel.

The layers are referred to as the CL and the EL. The CL must use modulation parameters at least equal to those of the EL, but never less robust, as per item 6.4.1 of ATSC A/322:2025-07 [5].

The EL has its level adjusted by a parameter named IL, which reduces its level from 0 to 25 dB relative to the CL.

When using LDM, it is recommended that the CL use QPSK, 16 QAM, or 64 QAM. If 64 QAM is chosen, code rates higher than 7/15 should be avoided (ATSC A/327:2025-07 [7]).

8 BICM

Bit Interleaved Coded Modulation (BICM) is a fundamental technique in the physical layer of ATSC 3.0 and TV 3.0, acting as a processing block that combines interleaving, coding, and modulation steps.

8.1 Forward Error Correction

There are two FEC techniques: external code (BCH, Cyclic Redundancy Check (CRC) or none) and internal code LDPC. The external code receives a Baseband Packet (BBP), and the output of the LDPC is an FEC frame. Later, this FEC frame will be mapped into IQ symbols.

The FEC frame payload length will vary according to the LDPC and the external code, as per the following tables. For N_{iiner} = 64800 bits the BCH will add 192 bits to the end of the payload, while for N_{inner} = 16200 it will add 168 bits, as shown in Table 6 and in Table 7, respectively. No matter the Inner size, the CRC will always add 32 bits to the end of the payload, and the option no external code will add none.

Table 6 – FEC frame payload length for N_{inner} = 64800.

Code Rate	BCH		CRC		No external code	
	Payload (bits)	Parity (bits)	Payload (bits)	Parity (bits)	Payload (bits)	Parity (bits)
2/15	8448	192	8608	32	8640	0
3/15	12768	192	12928	32	12960	0
4/15	17088	192	17248	32	17280	0
5/15	21408	192	21568	32	21600	0
6/15	25728	192	25888	32	25920	0
7/15	30048	192	30208	32	30240	0
8/15	34688	192	34528	32	34560	0
9/15	38688	192	38848	32	38880	0
10/15	43008	192	43168	32	43200	0
11/15	47328	192	47488	32	47520	0
12/15	51648	192	51808	32	51840	0
13/15	55968	192	56128	32	56160	0

Source: Table 6.1 ATSC A/322:2025-07-Physical-Layer-Protocol [5].

Table 7 – FEC frame payload length for N_{inner}= 16200.

Code rate	BCH		CRC		No external code	
	Payload (bits)	Parity (bits)	Payload (bits)	Parity (bits)	Payload (bits)	Parity (bits)
2/15	1992	168	2128	32	2160	0
3/15	3072	168	3208	32	3240	0
4/15	4152	168	4288	32	4320	0
5/15	5232	168	5368	32	5400	0
6/15	6312	168	6448	32	6480	0
7/15	7392	168	7528	32	7560	0
8/15	8472	168	8608	32	8640	0
9/15	9552	168	9688	32	9720	0
10/15	10632	168	10768	32	10800	0
11/15	11712	168	11848	32	11880	0
12/15	12792	168	12928	32	12960	0
13/15	13872	168	14008	32	14040	0

Source: Table 6.2 ATSC A/322:2025-07-Physical-Layer-Protocol [5].

The closer the Code Rate is to 1, the greater the useful payload, but also the error probability.

To improve reception, use BCH, as it can detect and correct errors, while the CRC code can only detect errors. The BCH code implemented must correct 12 wrong bits.

The internal code is LDPC. Its code length size, N_{inner}, must be 16200 (short code) or 64800 (long code) bits. The primary difference between these two sizes lies in latency and performance: the first has lower latency and lower performance, while the second has higher latency but higher performance. There are also two implementations for LDPC code matrices: Type A Multi-Edge Type (MET) and Type B Irregular Repeat Accumulate (IRA), and their performance varies mainly with the choice of code rate, as shown in Table 8. Type A performs better with lower code rates, whereas Type B behaves oppositely.

Table 8 – Structure of LDPC Encoding.

Code rate	Ninner = 16200	Ninner = 64800
2/15	A	A
3/15	A	A
4/15	A	A
5/15	A	A
6/15	B	B
7/15	B	A
8/15	B	B
9/15	B	B
10/15	B	B
11/15	B	B
12/15	B	B
13/15	B	B

Source: Table 6.4 of ATSC A/322:2025-07 [5].

To improve reception The N_{inner} of 64800, or long frame, is recommended due to its higher protection (Doc. CIT-196r23 [8]).

8.2 Mapper

The bits of the FEC frame are grouped into modulation symbols according to the modulation scheme chosen, which are 6 in total: QPSK, 16 QAM, 64 QAM, 256 QAM, 1024 QAM and 4096 QAM. All QAM modulations have NUC.

The modulation symbols are then mapped to IQ values. For the same modulation schemes these values will change according to the code rate, except for QPSK, which will always be the same.

Not all modulations and code rate combinations are required. The mandatory combinations are presented in Table 9 and in Table 10.

Table 9 – Mandatory combinations of modulation and Code Rate - N_{iiner} = 64800.

	2/15	3/15	4/15	5/15	6/15	7/15	8/15	9/15	10/15	11/15	12/15	13/15
QPSK	X	X	X	X	X	X	X	X		X		
16 QAM			X	X		X	X	X		X		
64 QAM		X	X	X	X	X	X	X	X	X		
256 QAM			X	X		X	X	X	X	X	X	X
1024 QAM				X		X	X	X	X	X	X	X
4096 QAM						X		X		X	X	X

Source: Table 6.12 ATSC A/322:2025-07 [5].

Table 10 – Mandatory combinations of modulation and Code Rate - N_{inner} = 16200.

	2/15	3/15	4/15	5/15	6/15	7/15	8/15	9/15	10/15	11/15	12/15	13/15
QPSK	X	X	X	X	X	X	X	X				
16 QAM				X	X	X	X			X		
64 QAM				X	X	X	X	X	X	X		
256 QAM				X		X	X	X	X	X	X	X

Source: Table 6.13 ATSC A/322:2025-07 [5].

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ANNEX A

TRANSMITTER STATION CONFORMANCE TESTS

1 SCOPE

The objectives of this annex are to recommend test items and procedures for newly installed TV 3.0 (DTV+) transmitter stations. This document covers only the PHY Layer testing. More precisely, the tests are conducted directly at the transmitter output using a directional coupler, which is called interface IF-3 by ITU-R, in the Document ITU R-HDB-63 - "Handbook on digital terrestrial television broadcasting networks and systems implementation" [1], as shown in Figure A 1. It also corresponds to the interface C, defined by ETSI in the document ETSI TR 101 290 - "Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems" [2].

Note: Depending on the test item, there may be a difference in the test point, as specified in the Test Procedures.

The measurements recommended herein should be carried out before the launch of the commercial transmission to ensure that the transmitted signal fulfils the requirements established by the local Regulator, as well as the performance and configurations established by the ATSC 3.0 PHY Standard.

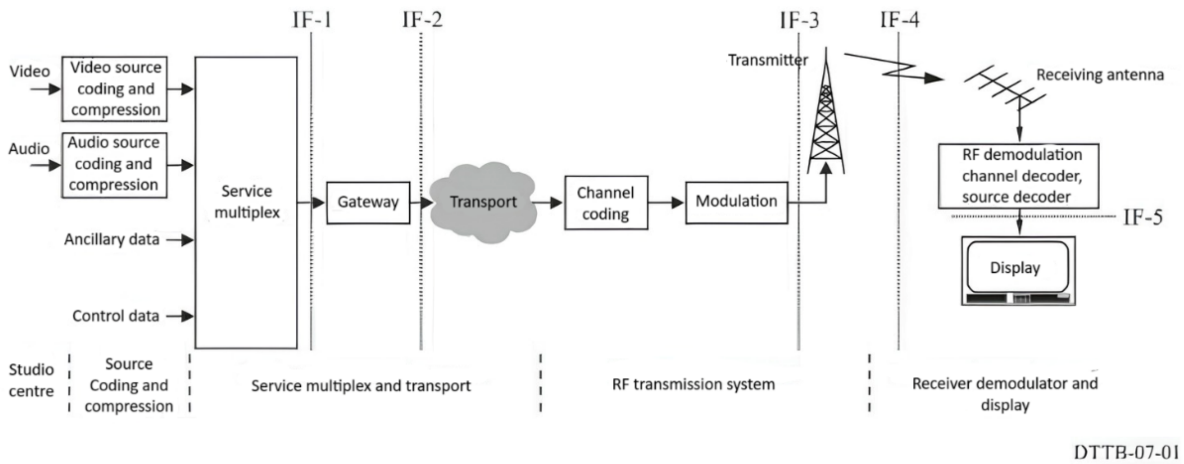

Figure A 1 – Test Interface Covered (extracted from ITU-R Handbook [1]).

2 General Test Conditions

The tests conducted should be classified as "service measurement", according to the document ITU-R Report BT.2035 – "Guidelines and techniques for the evaluation of digital terrestrial television broadcasting systems" [3]. As such, it will be conducted under the environmental conditions at the local Broadcasting Transmitter Station, including temperature, humidity, and the power source of the transmitter equipment installed in the station for commercial operation.

Any test procedure should be conducted with the transmitter equipment under test, as well as every test equipment, energized for at least one hour.

3 Recommended Test Items

The test items recommended in this document are listed in the Table A 1, are categorized as “Spectrum Regulation”, “Performance”, and/or “Configuration Verification”.

The test results for the items categorized as Spectrum Regulation should conform to the specifications established by the local Regulator Authority. The other test results should conform to the specifications established in the ATSC 3.0 PHY Standards. In cases where the Local Regulatory Authority has established specifications for such test items, these local specifications should take priority.

Table A 1 – Test Items and categories.

Test item		Category
1	RF Frequency accuracy and stability	Spectrum regulations
2	RF Output Power (E.R.P.)	
3	RF Occupied Bandwidth (Emission Mask and OOB Emissions)	
4	Spurious Emissions	
5	Constellation	Performance
6	MER	
7	PHY Configurations	Configuration

4 TEST PROCEDURES

4.1 Spectrum Regulation Tests

4.1.1 RF Frequency accuracy and stability

a. Background Considerations

The RF frequency accuracy and stability are defined in the ATSC 3.0 Standard Document A324 2025 – Paragraph 10.3.1 [4] – “To enable both SFN operation and the co-channel interference mitigation methods discussed in Section 10.3.3, the Transmitter Center Frequency shall be maintained at the nominal Center Frequency ±0.5Hz, with a long-term-averaged error of zero. Use of Global Navigation Satellite System (GNSS) as a time base and frequency reference can enable such precision “.

It is necessary to consider the Transmission Network Architecture to define the details of the test procedures. In a MIMO transmission configuration, it is necessary to know the Hardware (HW) configuration of the Modulator and Up Converter local oscillator. There is an HW implementation using two distinct local oscillators, one in the V polarization and the other in the H polarization. In such a case, it is necessary to conduct tests on both polarizations. In case of doubt, it is recommended to conduct the test on both polarizations.

b. Test Setup

Consider the Figure A 2.

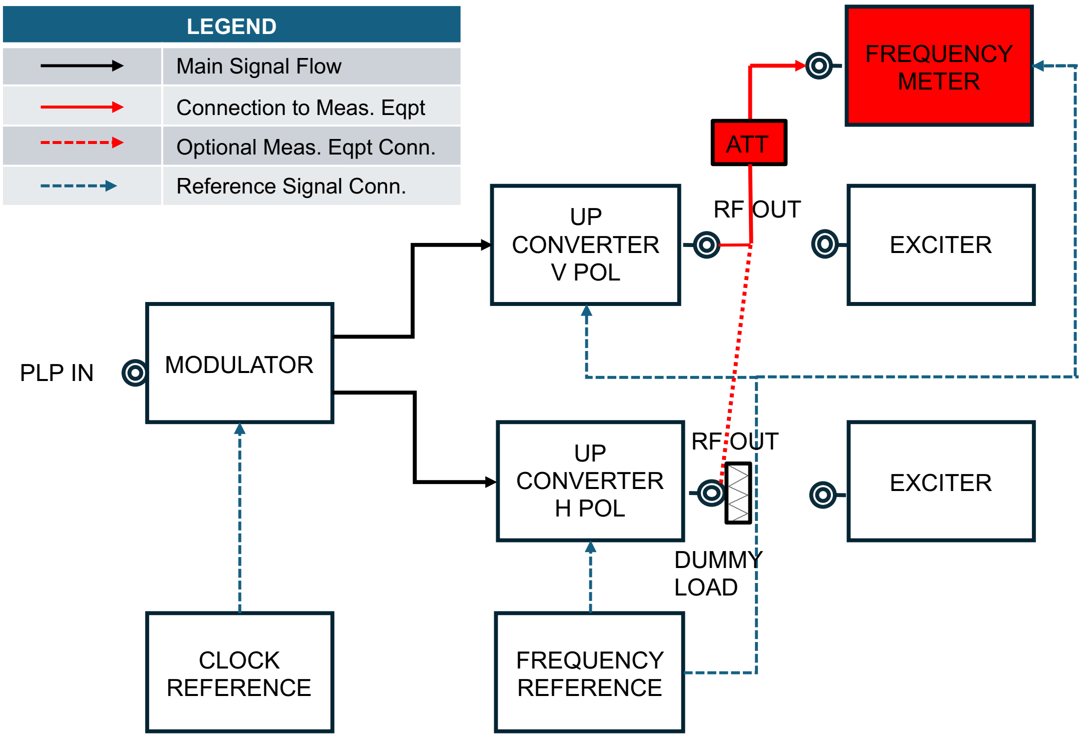

Figure A 2 – RF frequency accuracy and stability test setup.

- All the systems must be switched off, and the coaxial cable between the Up Converter and the Exciter must be disconnected. If the upconverter is equipped with an RF Output monitor, connect a dummy load to the RF Output. If there is no RF Output monitor, connect an adequate attenuator between the RF Output and the Frequency Meter Input. Then, turn on all the equipment and the measuring equipment;

- The Frequency meter to be utilized must be of high accuracy and precision and operated with the same reference signal used by the Transmitter Network.

c. Test Procedure

- All the equipment must be running on power for at least one hour (pre-burn-in);

- The Modulator should be set in CW mode;

- Configure the attenuator to have a signal level suitable for the Frequency Meter operation (check the Frequency Meter manual);

- The measurements should be taken in the space of one hour, for 6 hours (IEC 62273-1) [5].

4.1.2 RF Output Power (ERP)

a. Background Considerations

The Regulators grant the operation license to a TV Broadcasting Station by classes of ERP emitted by the antenna, according to the desired coverage area for the licensed TV Station. To verify the conformance to the licensed radiated power of a station, it is necessary to measure the RF Output Power of the station, preferably after the output of the RF Filter, and then compute the ERP.

b. Test setup

The setup shown in Figure A 3 should be applied for the RF output power and RF Occupied Bandwidth tests.

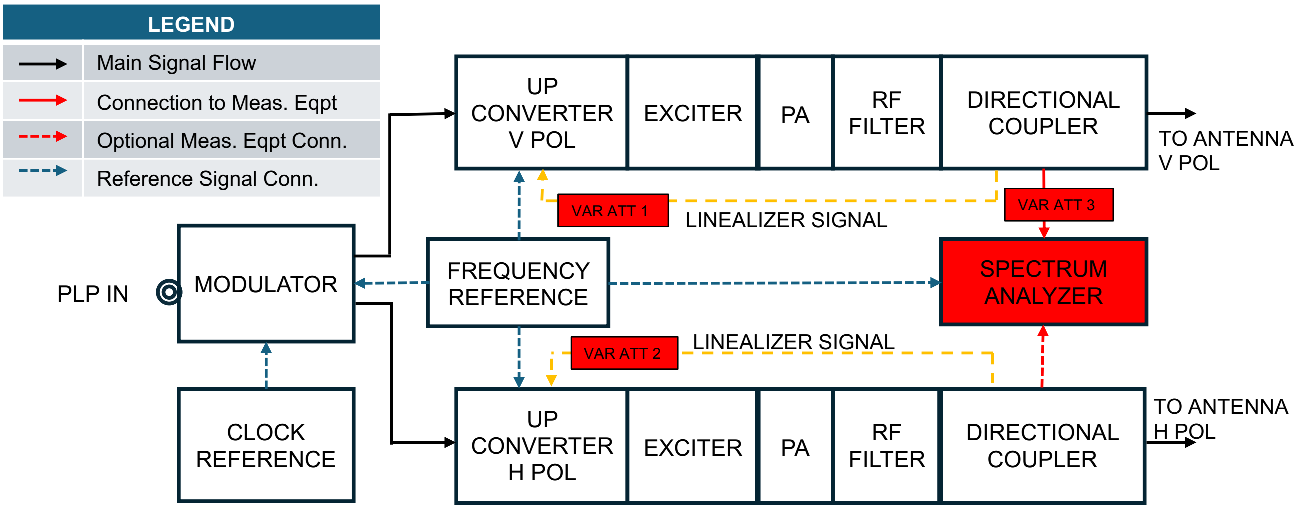

Figure A 3 – RF output Power/RF Occupied Bandwidth Test Setup.

- Verify that the RF Power Amplifier Linearizer circuit is connected, appropriately configured, and in operation;
- Certify the connection of the Frequency Reference to the Modulator, Up Converter, and to the Spectrum Analyzer;
- In case of MIMO Transmission configuration, the test should be done for each Antenna Polarization, connecting the Variable Attenuator – VAR ATT 3 and Spectrum Analyzer alternately to each Polarization Directional Coupler.

c. Test Procedure

- All the equipment must be running on power for at least one hour (pre-burn-in);
- The Modulator and Up Converter should be configured for standard commercial transmission (use Table 5 or 6 from ABNT NBR 25609:2025) [6], using as input a baseband signal, a Pseudo-Random Binary Sequence (PRBS) sequence of length 2^{23}-1;
- Adjust the VAR ATT 3 for a convenient level for the Spectrum Analyzer operation. It is suggested that a level of around -30 dBm to -40 dBm;

- Configure the Spectrum Analyzer to "Channel Power" measurement, which exists in most modern Spectrum Analyzers. The channel power bandwidth should be set according to the selected channel bandwidth and the carrier reduction coefficient (C_{red_coeff});

- Spectrum Analyzer configuration parameters suggested are as follows:

  ⇒ Span - 30 MHz;

  ⇒ RBW - 10 kHz;

  ⇒ VBW - 300 Hz.

- Compute the ERP using the equation:

$$ERP = CP - G_{ANT} - K_d + L_f + L_{DC} + L_{VA} + L_C$$

G_{ANT}	*Antenna Gain relative to half-wave dipole (dBd);*
K_d	*Dipole factor (dBm- dBμV/m);*
L_f	*Feeder loss between Antenna to Directional Coupler (dB);*
L_{DC}	*Directional Coupler coupling loss (dB);*
L_{VA}	*Loss of VAR ATT 3 (dB);*
L_C	*Cable Loss between Directional Coupler to Spectrum Analyzer Input (dB);*
CP	*Channel Power measured by the Spectrum analyzer.*

4.1.3 RF Occupied Bandwidth (Emission Mask and OOB Emissions)

a. Background Considerations

Out-of-Band (OOB) emissions are specified by ITU-R in the Recommendation ITU-R SM.1541-7 – "Unwanted emissions in the out-of-band domain" [7] and the definitions are shown in Figure A 4. Unwanted emissions are classified into Out-of-Band domain emissions and Spurious domain emissions.

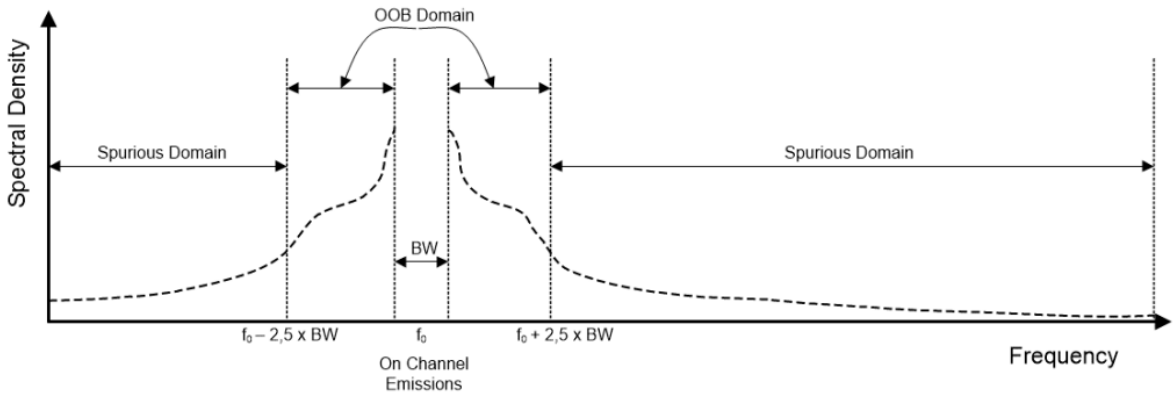

Figure A 4 – OOB domain and Spurious domain.

From the above definition, the OOB domain for 6 MHz TV channels encompasses the frequency bandwidth of $f_c \pm 15$ MHz, for a 7 MHz TV channel $f_c \pm 17.5$ MHz, and for 8 MHz $f_c \pm 20$ MHz.

Generally, regulatory bodies define an Emission Mask for Terrestrial Broadcasting Digital TV transmissions based on the ERP class. The test result should be judged according to the emission mask to be applied for the particular TV Station under test.

b. Test setup

The test setup is presented in Figure A 3.

- Verify that the RF Power Amplifier Linearizer circuit is connected, appropriately configured, and in operation;
- Certify the connection of the Frequency Reference to the Modulator, Up Converter, and to the Spectrum Analyzer;
- In case of MIMO Transmission configuration, the test should be done for each Antenna Polarization, connecting the Variable Attenuator – VAR ATT 3 and Spectrum Analyzer alternately to each Polarization Directional Coupler.

c. Test Procedure

- All the equipment must be running on power for at least one hour (pre-burn-in);
- The Modulator and Up Converter should be configured for the standard commercial transmission (use Table 5 or 6 from ABNT NBR 25609:2025 [6]), using as input a base band signal, a PRBS sequence of length 2^{23}-1;
- Adjust the VAR ATT 3 for a convenient level for the Spectrum Analyzer operation. It is suggested that a level of around -30 to -40 dBm;
- Spectrum Analyzer configuration parameters suggested are as follows:
  - ⇒ Span - 40 MHz (for 8 MHz CH), 35 MHz (for 7 MHz CH), and 30 MHz (for 6 MHz CH);
  - ⇒ RBW - 3 kHz;
  - ⇒ VBW - 300 Hz.

4.1.4 Spurious Emissions

a. Background Considerations

Spurious emissions are unwanted emissions in the spurious domain identified in Figure A 4. The spurious emission limits and their measurement methods are specified in ITU-R Recommendation SM.329-13 [8]. The following measurement parameters and specifications for the DTTB, Transmission systems are defined in the SM.329-13 [8] and presented below:

- Frequency range for measurement of unwanted emissions – Table A 2 is excepted from SM.329-13 [8], Table 1, limited to the frequency range of DTTB systems.

Table A 2 – Frequency range for measurement of spurious emission.

Fundamental frequency range	Frequency range for measurements	
	Lower limit	**Upper limit (The test should include the entire harmonic band and not be truncated at the precise upper frequency limit stated)**
100 MHz-300 MHz	9 kHz	10th harmonic (max. 3GHz)
300 MHz-600 MHz	30 MHz	3 GHz

- Recommended reference bandwidth - A reference bandwidth is a bandwidth in which spurious domain emission levels are specified. The following reference bandwidths are recommended:

  – 1 kHz between 9 and 150 kHz;

  – 10 kHz between 150 kHz and 30 MHz;

  – 100 kHz between 30 MHz and 1 GHz;

  – 1 MHz above 1 GHz.

  As a general guideline, the resolution bandwidths of the measuring receiver (RBW in the case of the Spectrum Analyzer should be equal to the reference bandwidths. To improve measurement accuracy, sensitivity, and efficiency, the resolution bandwidth can be set to a value different from the reference bandwidth. For instance, a narrower resolution bandwidth is sometimes necessary for emissions close to the center frequency. When the resolution bandwidth is smaller than the reference bandwidth, the result should be integrated over the reference bandwidth.

- Limits of spurious domain emissions – The Table A 3 shows the limits for the DTTB systems. This is an excerpt from SM.329-13 [8], Table 2, for DTTB systems.

Table A 3 – Spurious domain emission limits – Category A.

Service category in accordance With RR Article 1, or equipment type(1), (2)	Attenuation (dB) below the power (W) supplied to the antenna transmission line
Broadcast television	46 + 10 log P, or 60 dBc, whichever is less stringent, without exceeding the absolute mean power level of 1 mW for VHF stations or 12 mW for UHF stations. However, greater attenuation may be necessary on a case-by-case basis.

Notes to Table A 3:

P: mean power (W) at the antenna transmission line, in accordance with RR No. 1.158. When burst transmission is used, the mean power P and the mean power of any spurious domain emissions are measured by averaging power over the burst duration.

dBc: decibels relative to the unmodulated carrier power of the emission. In cases where a carrier is not present, for example, in some digital modulation schemes where the carrier is inaccessible for measurement, the reference level equivalent to dBc is decibels relative to the mean power P.

The value of the equation 46 + 10 log *P* results in 60 dBc with *P* = 50 W. Therefore, it is possible to adopt a limit of 60 dBc for the most practical implementations of DTTB stations.

b. Test setup

The test setup is presented in Figure A 3.

Important remarks:

- The test setup proposed presents the merit that allows the verification with the system in operation. Still, it presents a problem concerning the use of the Directional Coupler just after the RF Filter of the transmission system. Due to the measurement frequency range of 9 kHz to 3 GHz, there is a possibility of significant variation in the coupling factor of the device, and in some cases, the impossibility of measurement in the lower and higher frequency ranges. In any case, it is necessary to know the frequency response of the Directional Coupler in the range of 9 kHz to 3 GHz and compute the necessary corrections to the measurement results;
- When possible, it is recommended to insert a Band Reject Filter (or a combined high-pass and low-pass filter) to attenuate the primary signal. It will make the Spectrum Analyzer configuration easier by avoiding the generation of harmonic and intermodulation distortions of its test equipment. In the absence of the Band Reject Filter, the use of a Spectrum Analyzer with a very high dynamic range is recommended, along with careful configuration.

c. Test Procedure

- All the equipment must be running on power for at least one hour (pre-burn-in);
- The Modulator and Up Converter should be configured for the standard commercial transmission (use Table 5 or 6 from ABNT NBR 25609:2025 [6]), using as input a baseband signal, a PRBS sequence of length 2^{23}-1;
- Adjust the VAR ATT 3 for a convenient level for the Spectrum Analyzer operation. It is suggested that a level of around -20 dBm be measured with the Spectrum Analyzer configured to “Channel Power” mode;
- Calibrate the Spectrum Analyzer reference level. As defined in the second bullet of 4.1.4., depending on the spurious domain frequency range, there is a recommended RBW to be used. The value of 60 dBc of the spurious emission should be measured considering the power integrated in the same RBW of the Spectrum Analyzer. The reference level “0” will be higher than the top of the modulated

spectrum seen on the screen by the modulated signal bandwidth in kHz divided by the RBW in kHz.In the case of a 6 MHz system and the spurious domain in the range of 30 MHz to 1 GHz (RBW = 100 kHz), the difference will be 10 × log (6000/100) = 17.8 dB;

- It is recommended to start the measurement in full range, and in case of the identification of any spurious signal, configure the center frequency of the equipment to the spurious frequency and then configure the span for 20 MHz.

4.2 Performance Tests

4.2.1 Constellation and MER

a. Background Considerations

Analyzing the “Constellation” allows for determining the modulation parameters, both for the CL and the EL, and gaining a good understanding of the LDM IL. The images in all quadrants must be perfect mirrors of each other, and any irregularity indicates non-linear distortions.

Modulation Error Rate (MER) shows the modulator’s imperfections and the phase noise level of the local oscillators, when measured just at the output of the RF Filter of the Transmitter. In the absence of precise specifications, a value of 40 dB is considered acceptable when measured at the output of the RF Filter of the Transmitter, except for the CL in case of LDM transmission configuration, due to the EL presence, which causes degradation in the MER value of CL signal.

b. Test Setup

The Figure A 5 shows the Test Setup for the Constellation and MER.

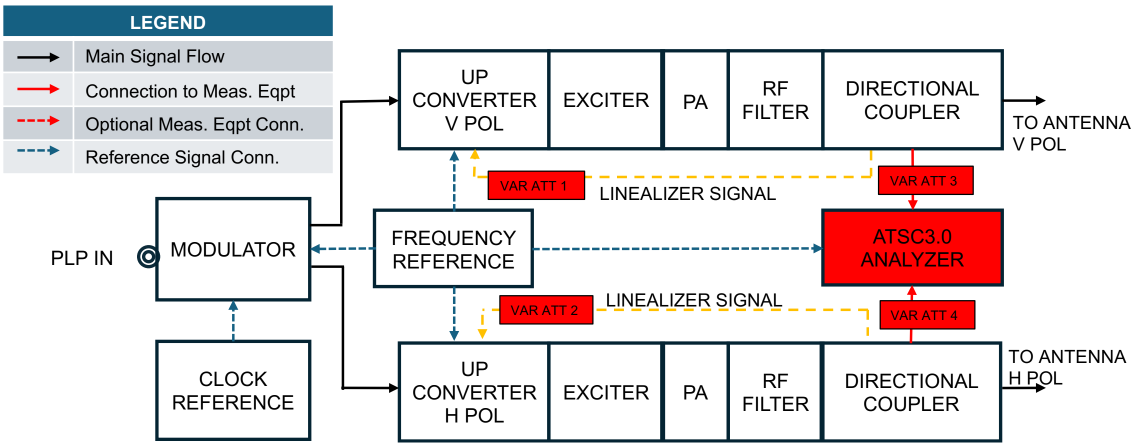

Figure A 5 – Performance Tests Setup.

c. Test Procedure

- All the equipment must be running on power for at least one hour (pre-burn-in);

- The Modulator and Up Converter should be configured for the standard commercial transmission (use Table 5 or 6 from ABNT NBR 25609:2025 [6]), using as input a baseband signal, a PRBS sequence of length 2^{23}-1;
- Confirm the connection and regular operation of the Linearizer system;
- Adjust the VAR ATT 3 and 4 for a convenient level for the ATSC 3.0 Analyzer in use.

4.3 Configuration Tests

4.3.1 PHY Configuration Tests

a. Background Considerations

All the PHY configurations should be checked with the planned one for the Transmitting Station.

b. Test Setup

The Test Setup shown in Figure A 5, should be applied.

c. Test procedure

- All the equipment must be running on power for at least one hour (pre-burn-in);
- The Modulator and Up Converter should be configured for standard commercial transmission (use Table 5 or 6 from ABNT NBR 25609:2025 [6]), using as input base band signal a PRBS sequence of length 2^{23}-1;
- Confirm the connection and regular operation of the Linearizer system;
- Adjust the VAR ATT 3 and 4 for a convenient level for the ATSC 3.0 Analyzer in use;
- The following parameters should be verified:
    - ⇒ Bootstrap configuration;
    - ⇒ FFT size;
    - ⇒ Guard Interval;
    - ⇒ Pilot pattern (Dx, scattered);
    - ⇒ FEC codeword length;

⇒ Modulation order and Code Rate;

⇒ Pilot boost value;

⇒ Subframe boundary symbols;

⇒ Frequency Interleaver;

⇒ Time Interleaver mode and settings;

⇒ MPLP configurations;

⇒ LMT configuration.

Bibliography

[1] ITU R-HDB-63: Handbook on digital terrestrial television broadcasting networks and systems implementation, 2020.

[2] ETSI TR 101 290: Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems, v. 1.4.1, June 2020.

[3] ITU-R Report BT.2035: Guidelines and techniques for the evaluation of digital terrestrial television broadcasting systems, 2008.

[4] ATSC Standard: Scheduler / Studio to Transmitter Link, Doc. A/324:2025-04, April 2025.

[5] IEC 62273-1: Methods of measurement for radio transmitters - Part 1: Performance characteristics of terrestrial digital television transmitters.

[6] Brazilian Standard. TV 3.0 – Receivers. ABNT NBR 25609. First edition, 01 December 2025.

[7] ITU-R SM.1541-7: Unwanted emissions in the out-of-band domain, September 2024.

[8] ITU-R Recommendation SM.329-13: Unwanted emissions in the spurious domain, September 2024.

Annex B

TV3.0 PHYSICAL LAYER LABORATORY TESTS

1 SCOPE

The objectives of this annex are to recommend test items and procedures for "Basic DTV+ Physical Layer Transmission Equipment" tests in Laboratory environment.

In this document the "Basic TV3.0 Physical Layer Transmission Equipment", consists of the Modulator and Up Converter, also called as Exciter in case of products to be installed in the Transmission Station. The RF Power Amplifiers – RF AMPs and RF Filters are not considered, as they are difficult to handle in the Laboratory environment, considering the necessity of huge Power Sources and Dummy Loads. Annex A of this document – "TV3.0 TX Station Conformance Tests" should be considered when the tests involve RF AMPs and RF Filters.

The measurements recommended herein should be carried out for Modulator/Up Converter prototypes as well as production Exciter units.

Figure B 1 shows a generic Test Setup to clarify the scope of the document.

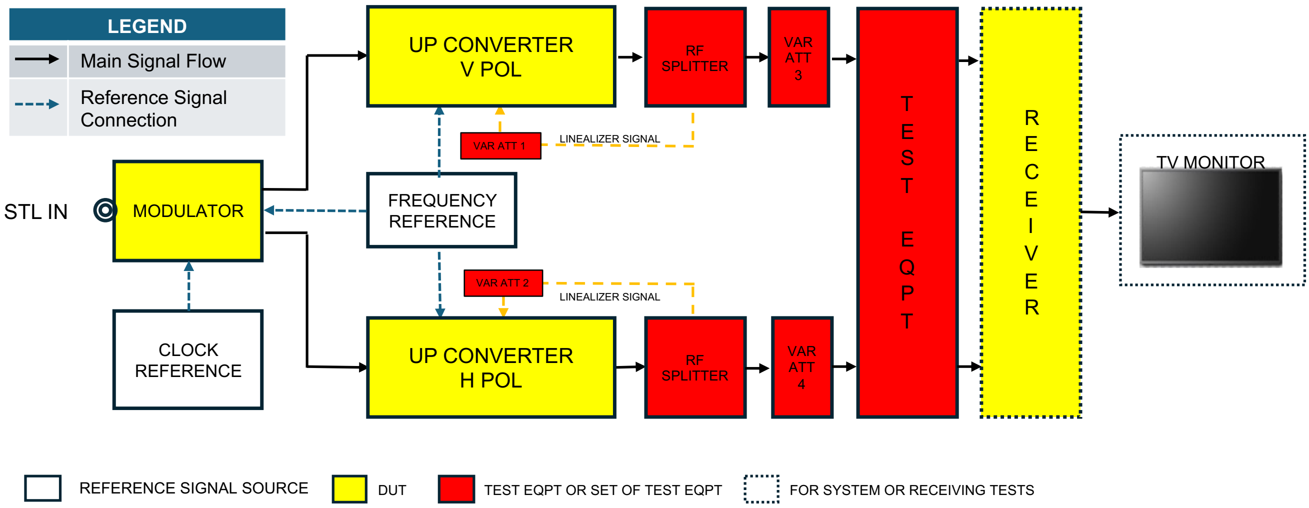

Figure B 1– *Generic Test Setup.*

NOTE 1: There is a clear tendency to implement Modulator and Up Converter as an individual 19-inch rack, and MIMO implementations in both 2 separate 19-inch racks product, as well as in one 19-inch rack.

NOTE 2: DUT – Device Under Test.

2 GENERAL TEST CONDITIONS

The tests should be conducted in the environment of general Test Laboratory, preferably inside a Faraday Cage to avoid external RF signal interferences, with commercial AC Power Supply.

In case of system and/or receiver tests, use of ATSC 3.0 MIMO Signal Generator – in the place of Modulator and Up Converter in the, is recommended.

Any test procedure should be conducted with the transmitter equipment under test, as well as every test equipment, energized for at least one hour.

3 RECOMMENDED TEST ITEMS

The test items recommended in this document and listed in the Table B 1, are categorized as “Transmitter Equipment”, “Receiver Equipment” and/or “PHY System”.

Some of the test categorized as “Transmitter Equipment”, are classified as Spectrum Regulation and should conform to the specifications established by the local Regulator Authority.

The other tests results should conform to the specifications established in the ATSC 3.0 Standards and, in case there are specifications established for such test items by the Local Regulatory Authority, the local specifications should be prioritized.

Some of the test categorized as “PHY System”, should also be considered as “Receiver Equipment”. Selectivity – Protection Ratio and C/N in Rayleigh environment are dependent of the system parameters itself, as well as by the receiver technology implementation. In such case the test item is categorized as “PHY System”.

Table B 1– Test Items and categories.

	Test Item	Category
1	RF Frequency accuracy	Transmitter Equipment (Spectrum Regulation)
2	RF Occupied Bandwidth (Emission Mask and OOB Emissions)	Transmitter Equipment (Spectrum Regulation)
3	Spurious Emissions	Transmitter Equipment (Spectrum Regulation)
4	Constellation & MER	Transmitter Equipment
5	PHY Configurations	Transmitter Equipment
6	C/N - Carrier power vs AWGN	PHY System
7	C/N - Carrier power vs Rayleigh and AWGN	Receiver Equipment
8	Receiver maximum and minimum level	Receiver Equipment
9	Co-channel Interference with own system	PHY System
10	Adjacent channel interference (at N±1 and N±2 channels) from own system	Receiver Equipment
11	Adjacent channel interference (at N±1 and N±2 channels) from ISDB-T	Receiver Equipment
12	Single echo static multipath interference	Receiver Equipment
13	TxID Channel Identification Degradation to Preamble	PHY System
14	GSL – Geographically Segmented Local Cast	PHY System
15	LTE Interference over TV3.0	Receiver Equipment

4 TEST PROCEDURES

4.1 Tests of Transmitter Equipment Category

In the tests of this Paragraph, the Modulator and Up Converter should be configured for the standard transmission parameters specified in Table 5 and 6 of ABNT NBR 25609:2025 [1], using as input a PRBS sequence of length 2^{23}-1 as baseband signal.
The tests shall be conducted with the transmission system configured to operate in MIMO with Stream combining, IQ polarization Interleaving and Phase Hopping, activated. Additionally, TxID shall be configured with 24 dB of Injection Level.

All the tests shall be conducted for RF channel 277.

4.1.1 RF Frequency Accuracy

4.1.1.1 Background Considerations.

The ATSC 3.0 specification for Frequency Accuracy and Stability, require the accuracy of ±0.5Hz from nominal Center Frequency, in the ATSC 3.0 Standard Document ATSC A/324:2025-07 [2] – Paragraph 10.3.1.

Frequency stability is not required to be verified in the Laboratory environment, as its conformance is required for the Transmitter Station environment.

4.1.1.2 Test Setup and Procedure.

According to the Annex A – Paragraph 4.1.1, conducted once. No need to repeat the test 6 times in intervals of one hour.

4.1.2 RF Occupied Bandwidth (Emission Mask and OOB Emissions)

4.1.2.1 Background Considerations.

This test item is required to be in conformance to the specification in the Transmission Station environment and measured after the RF AMP and RF Filter. But it is recommended to verify the performance of the Modulator/Up Converter, as reference. The Linearizer system shall be connected as shown in Figure B 1.

4.1.2.2 Test Setup and Procedure.

According to the Annex A – Paragraph 4.1.3, just changing the connection point of the Spectrum Analyzer, which corresponds to the TEST EQUIPMENT in Figure B 1, to the Up Converter output.

4.1.3 Spurious Emissions

4.1.3.1 Background Considerations.

This test item is required to be in conformance to the specification in the Transmission Station environment and measured after the RF AMP and RF Filter. But it is recommended to verify the performance of the Modulator/Up Converter, as reference. The Linearizer system shall be connected as shown in Figure B 1.

4.1.3.2 Test Setup and Procedure.

According to the Annex A – Paragraph 4.1.4, just changing the connection point of the Spectrum Analyzer, which corresponds to the TEST EQUIPMENT in Figure B 1, to the Up Converter output.

4.1.4 Constellation & MER

4.1.4.1 Background Considerations.

Analyzing the “Constellation” it is possible to know the modulation parameters, both for the CL and EL, and a good idea of the LDM IL. The images in all the quadrants must be a perfect mirror of each other, and any irregularity is an indication of non-linear distortions.

Modulation Error Rate - MER, shows the modulator's imperfections and the phase noise level of the local oscillator. In absence of clear specifications, the value of the order of 40 dB is considered good.

4.1.4.2 Test Setup and Procedure.

According to the Annex A – Paragraph 4.2.1, using the Test Setup of Figure B 1, with Spectrum Analyzer, as the TEST EQUIPMENT.

4.1.5 PHY Configurations.

4.1.5.1 Background Considerations.

All the configurations of the standard transmission parameters specified in Table 5 and 6 of ABNT NBR 25609:2025 [1], shall be verified, as well as the MIMO configurations.

4.1.5.2 Test Setup and Procedure.

According to the Annex A – Paragraph 4.3.1, using the Test Setup of Figure B 1, with ATSC 3.0 Analyzer, as the TEST EQUIPMENT.

4.2 Tests of PHY System and Receiver Equipment Category

In the tests of this Paragraph, the Modulator and Up Converter should be configured for the standard transmission parameters specified in Tables 5 and 6 of ABNT NBR 25609:2025 [1], using a Zone Plate pattern as the video signal and a 1 kHz tone as the audio signal. In some tests, different video signals shall be used, and such conditions will be informed directly in the corresponding Test Procedure.
The tests shall be conducted with the transmission system configured to operate in MIMO with Stream combining, IQ polarization Interleaving, and Phase Hopping, activated. Additionally, TxID shall be configured with a 24 dB IL.

The PHY System and Receiver Equipment tests shall be conducted for the RF channels 7, 277, and 51.

4.2.1 C/N - Carrier Power vs AWGN.

4.2.1.1 Background Considerations.

This test was classified as a PHY System test, considering the evolution status of the tuner Integrated Circuit (IC) chip, which presents a low Noise Figure and indistinguishable performance in this characteristic across all implementations.

4.2.1.2 Specifications

The specifications to be satisfied are presented in Paragraph 15.9.4 of the Document ABNT NBR 25609:2025 [1].

4.2.1.3 Test Setup and Procedure.

A. Test Setup

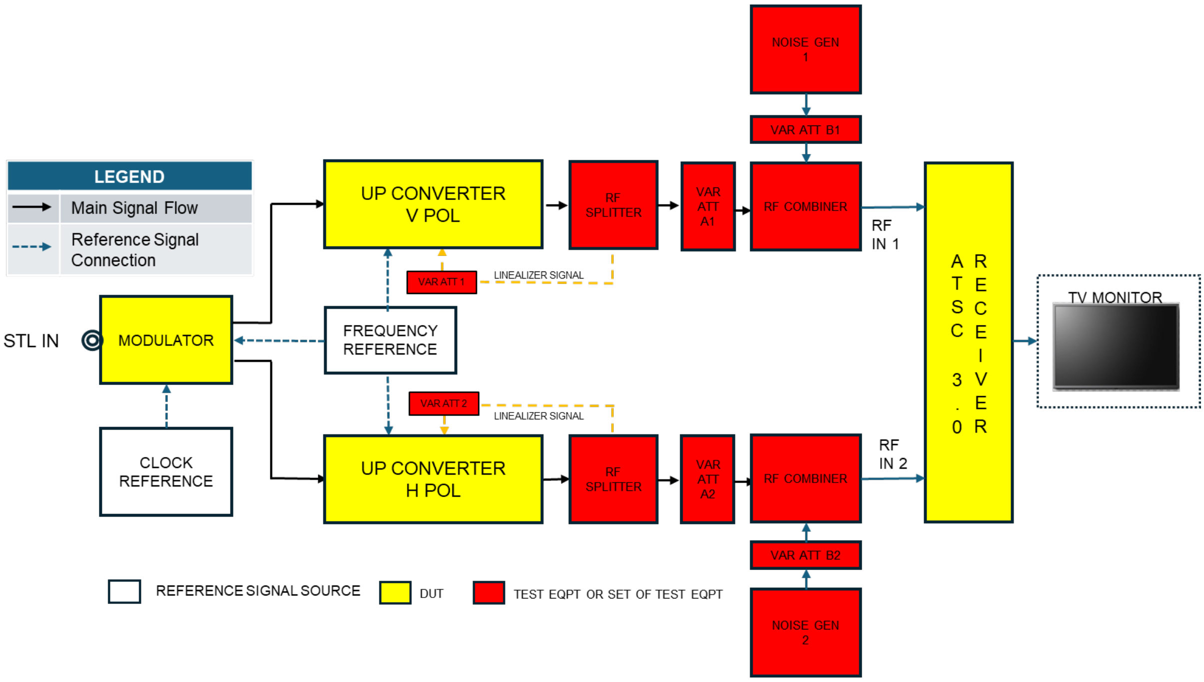

Figure B 2 – Carrier Power vs AWGN Test Setup.

B. Test Procedure

a. Configure the modulation parameters to one of the configurations at the beginning of the Paragraph 4.2, and set the maximum output level, and set the frequency to CH 7;

b. Use as a video signal a Zone Plate Pattern;

c. Set AWGN Noise Generator frequency to the selected channel, and maximum output power, and the Variable Attenuator B1 (and B2) to the maximum attenuation;

d. Adjust the Variable Attenuator A1 (and A2) to obtain -28 dBm in RF IN1 (and RF IN2) of the Receiver;

e. Start to reduce the attenuation of the Variable Attenuator A1 (and simultaneously synchronized attenuation of A2), in steps of 0.1 dB, up to the receiver TOV;

f. Register the input level of RF IN 1 (and RF IN 2 – which must be the same value of RF IN 1), 0.1 dB before the QEF point, and compute the C/N;

g. Register the C/N (dB) computed according to the template in Table B 2;

h. Repeat the test for other channels, and levels specified in step a.;

i. Repeat the test for other modulation configurations.

Table B 2 – Template for recording C/N – Carrier Power vs AWGN test results.

Channel	RF IN Level (dBm)	C/N (dB)
7	-28	
	-53	
	-68	
	-83	
277	-28	
	-53	
	-68	
	-83	
51	-28	
	-53	
	-68	
	-83	

4.2.2 C/N - Carrier power vs Rayleigh and AWGN.

4.2.2.1 Background Considerations.

This test was classified as a Receiver Test, considering that ATSC 3.0 Standards allow the Receiver designer to implement any algorithm of pilot detection, key to the performance of channel estimation. Also, the receiver designer may choose to implement any technology of equalization of Amplitude and Phase of the received signal to copy with the multipath characteristic in the propagation media. The implementation of such techniques should improve the performance of the receiver to Raleigh fading environment.

4.2.2.2 Test Setup and Procedure.

A. Propagation Channel Models - Channel Ensembles

In this test, the output signal will be submitted to a fading, by emulating the real propagation conditions using Fading Simulators. A set of six (6) propagation channel models was defined:

a) Single Path Rayleigh;

b) Outdoor to Indoor or Pedestrian – A;

c) Outdoor to Indoor or Pedestrian – B;

d) Vehicular – A;

e) Vehicular – B;

f) Modified Typical Urban – 6.

The configuration for the fading simulators for the channel ensembles is presented in the Table B 3 to Table B 8.

The term TBC inside the Tables means "To Be Calculated". The value of the phase of the tap shall be calculated as a function of the RF frequency being used for the test, in case the simulator does not allow for direct input of the speed.

Table B 3 – Channel Ensemble RF1 – Single Path Rayleigh.

Reference	Channel Model Designation	Fading Simulator Setup							Remarks
RF1	Single Path Rayleigh	Speed of 3 Km/h at RF - Doppler in Hz depending on the RF frequency - round up value in Hz for first decimal.							
			Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	
		Profile	Doppler	N/A	N/A	N/A	N/A	N/A	
		Path Loss (dB)	0	N/A	N/A	N/A	N/A	N/A	
		Delay (µs)	0	N/A	N/A	N/A	N/A	N/A	
		Phase (Hz)	TBC	N/A	N/A	N/A	N/A	N/A	

Table B 4 – Channel Ensemble RF2A – Outdoor to Indoor or Pedestrian A.

Reference	Channel Model Designation	Fading Simulator Setup							Remarks
RF2A	Outdoor to Indoor or Pedestrian A	Speed of 3 Km/h at RF - Doppler in Hz depending on the RF frequency - round up value in Hz for first decimal.							ITU-R M.1225
			Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	
		Profile	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	
		Path Loss (dB)	0.0	9.7	19.2	22.8	N/A	N/A	
		Delay (µs)	0.00	0.11	0.19	0.41	N/A	N/A	
		Phase (Hz)	TBC	TBC	TBC	TBC	N/A	N/A	

Table B 5 – Channel Ensemble RF2B – Outdoor to Indoor or Pedestrian B.

Reference	Channel Model Designation	Fading Simulator Setup							Remarks
RF2B	Outdoor to Indoor or Pedestrian B	Speed of 3 Km/h at RF - Doppler in Hz depending on the RF frequency - round up value in Hz for first decimal.							ITU-R M.1225
			Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	
		Profile	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	
		Path Loss (dB)	0.0	0.9	4.9	8.0	7.8	23.9	
		Delay (µs)	0.00	0.20	0.80	1.20	2.30	3.70	
		Phase (Hz)	TBC	TBC	TBC	TBC	TBC	TBC	

Table B 6 – Channel Ensemble RF 3A – Vehicular A.

Reference	Channel Model Designation	Fading Simulator Setup							Remarks
RF3A	Vehicular A	Speed of 120 Km/h at RF - Doppler in Hz depending on the RF frequency - round up value in Hz for first decimal.							ITU-R M.1225
			Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	
		Profile	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	
		Path Loss (dB)	0.0	1.0	9.0	10.0	15.0	20.0	
		Delay (µs)	0.00	0.31	0.71	1.09	1.73	2.51	
		Phase (Hz)	TBC	TBC	TBC	TBC	TBC	TBC	

Table B 7 – Channel Ensemble RF 3B – Vehicular B.

Reference	Channel Model Designation	Fading Simulator Setup							Remarks
RF3B	Vehicular B	Speed of 120 Km/h at RF - Doppler in Hz depending on the RF frequency - round up value in Hz for first decimal.							ITU-R M.1225
			Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	
		Profile	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	

		Path Loss (dB)	2.5	0.0	12.8	10.0	25.2	16.0	
		Delay (µs)	0.0	0.3	8.9	12.9	17.1	20.0	
		Phase (Hz)	TBC	TBC	TBC	TBC	TBC	TBC	

Table B 8 – Channel Ensemble RF4 – Modified Typical Urban 6.

Reference	Channel Model Designation	Fading Simulator Setup							Remarks
RF4	Modified Typical Urban 6	Speed of 120 Km/h at RF - Doppler in Hz depending on the RF frequency - round up value in Hz for first decimal.							COST 207
			Path 1	**Path 2**	**Path 3**	**Path 4**	**Path 5**	**Path 6**	
		Profile	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	
		Path Loss (dB)	3.0	0.0	2.0	6.0	8.0	10.0	
		Delay (µs)	0.0	0.2	0.5	1.6	2.3	5.0	
		Phase (Hz)	TBC	TBC	TBC	TBC	TBC	TBC	

B. Test Setup.

The tests shall be conducted using the Setup shown in Figure B 3.

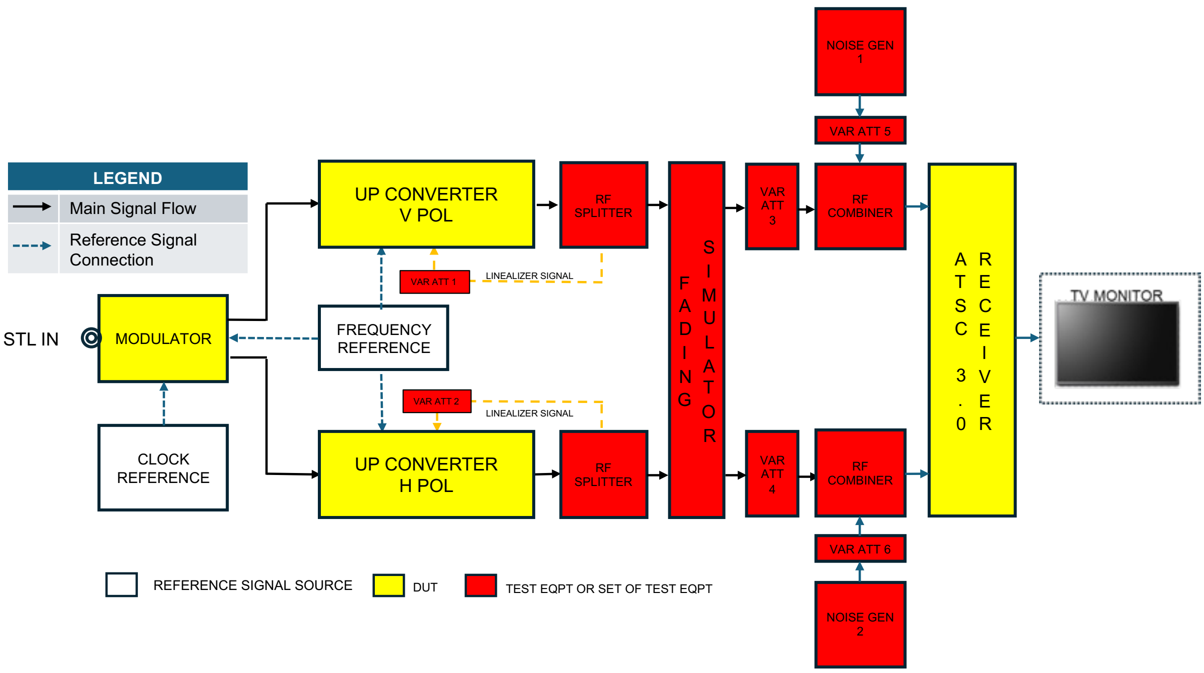

Figure B 3 – Test Setup for the C/N - Carrier Power vs. Rayleigh and AWGN.

C. Test Procedure.

a) Start the testing session with channel ensemble RF1;

b) Configure the modulation parameters to one of the configurations at the beginning of the Paragraph 4.2, set the maximum output level, and set to the CH 7;

c) Use as video signal a Zone Plate Pattern;

d) Set AWGN Noise Generator frequency to the selected channel, and maximum output power, and the Variable Attenuator 5 (and 6) to the maximum attenuation;

e) Adjust the Variable Attenuator 3 and 4 to obtain -28 dBm in the inputs of the ATSC 3.0 Receiver;

f) Start to reduce the attenuation of the Variable Attenuator 5, and simultaneously and synchronously attenuate 6, in steps of 0.1 dB, up to the receiver TOV;

g) Register the thermal noise input level at V Pol Signal Input (and H Pol – which must be the same value of V Pol), 0.1 dB before the TOV point, using a Spectrum Analyzer with channel power set to the system bandwidth, and compute the C/N;

h) Register the C/N (dB) computed in the table of test results (use the template shown in Table B 9), prepared for the corresponding channel ensemble;

i) Repeat the test for other channels, and levels specified in the step "b)";

j) Repeat the test for other modulation configurations;

k) Repeat the test for another channel ensembles.

Table B 9 – Template for recording C/N.

Channel	RF IN Level (dBm)	C/N (dB)
7	-28	
	-53	
	-68	
	-83	
277	-28	
	-53	
	-68	
	-83	
51	-28	
	-53	
	-68	
	-83	

4.2.3 Receiver Maximum and Minimum Level.

4.2.3.1 Background Considerations.

This test was classified as Receiver test considering the evolution status of the tuner IC chip, which presents a low Noise Figure, and undistinguishable, in any implementation, as well as because the Maximum level depends entirely on the hardware characteristics.

4.2.3.2 Test Procedures.

The Test Procedures are presented in Paragraph 15.9.7.4, and the specifications to be satisfied in Table 11, Table 12 and Table 13 of the Document ABNT NBR 25609:2025 [1].

4.2.4 Co-channel Interference with Own System.

4.2.4.1 Background Considerations.

The interference condition is completely independent of the Receiver technology or design, so that the result of the test is only dependent to the system characteristics.

4.2.4.2 Test Conditions.

The Co-channel Interference with Own System test shall be conducted with MIMO configuration with ATSC 3.0 Receiver RF IN 1 and RF IN 2 levels of -53 dBm for the desired signal (D).

The test shall be conducted with two different contents and the complete time synchronization between the desired and undesired signals. It is suggested to use Zone Plate Pattern as the desired video signal (D), and a Color Bar Pattern as the undesired signal (U).

4.2.4.3 Test Setup

Figure B 4 shows the Test Setup for the Co-Channel Interference with Own System, and the details of the block named Basic MIMO Setup are shown in Figure B 5.

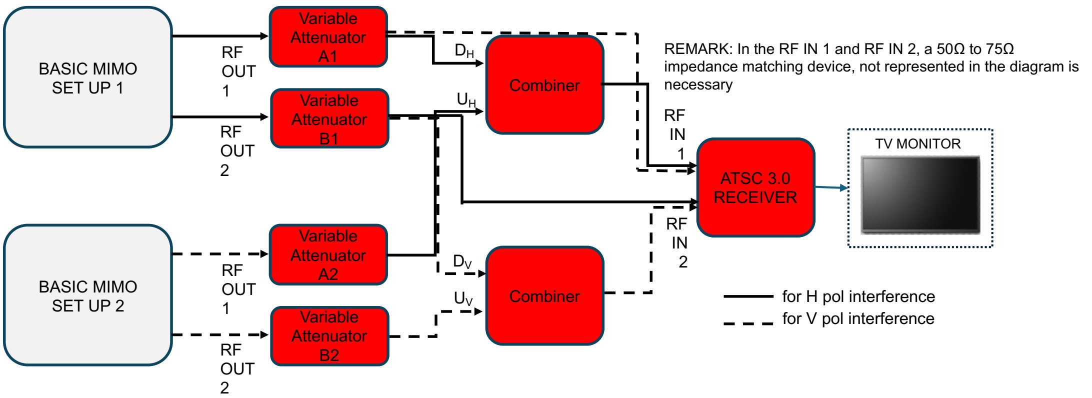

Figure B 4 – Test Setup for Co-Channel Interference with Own System.

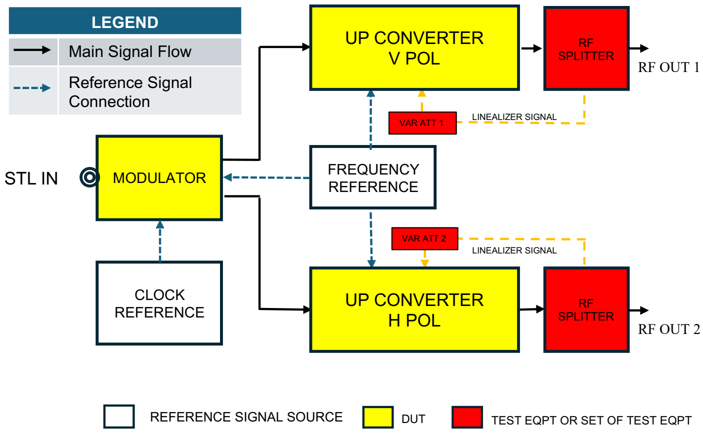

Figure B 5 – Basic MIMO Setup.

4.2.4.4 Test Procedure and Specifications.

The results of the tests shall be in compliance with the values shown in the Table 8 and Table 9 of Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1].

The test procedure itself is detailed as follow:

a) Configure the modulation parameters to one of the configurations at the beginning of the Paragraph 4.2, and set both of Exciter to the maximum output level and to the VHF Ch 7;

b) Set the video signals to be transmitted. A Zone Plate pattern for the D signal and a Color Bar Pattern for the U signal;

c) Consider the output of Exciter of “Basic MIMO SETUP 1” as desired (D) signal and of the output of “Basic MIMO SETUP 2” as undesired or interference (U) signal;

d) Set Variable Attenuator A2 (and B2), corresponding to the U signal, at maximum attenuation;

e) Set Variable Attenuator A1 (and B1) in order that the RF IN 1 (and RF IN 2) input level be -53 dBm. This is the Signal D level;

f) Start decreasing Variable Attenuator A2 (and synchronously B2), at 0.1 dB steps, until the receiver reaches the QEF.

g) Set the Variable Attenuator A1 (and B1) to the maximum attenuation and measure with a Spectrum Analyzer the level at RF IN 1 (and RF IN 2) of the U signal;

h) Compute the receiver D/U and register in the test result table. Use the template of Table B 10;

i) Repeat the test for UHF CH 277;

j) Repeat the tests for the second configuration.

Table B 10 – Template for Test Results of Co-Channel Interference with Own System.

Channel Number	D/U (dB)
7	
277	
51	

4.2.5 Adjacent Channel Interference (at N±1 and N±2 channels) with Own System.

4.2.5.1 Background Considerations.

Selectivity is a characteristic highly dependent on the Receiver design filtering, which causes the tests results dependent on the Receiver design.

4.2.5.2 Test Conditions.

The Adjacent Channel Interference with Own System test shall be conducted with MIMO configuration with ATSC 3.0 Receiver RF IN 1 and RF IN 2 levels of -53 dBm for the desired signal (D).

The test shall be conducted with two different contents and the complete time synchronization between the desired and undesired signals. It is suggested to use Zone Plate pattern as the desired video signal (D), and a Color Pattern as the undesired signal (U).

4.2.5.3 Test Setup

The Test Setup shown in Figure B 4 should be used.

4.2.5.4 Test Specifications and Procedure.

The results of the tests shall be in compliance with the values shown in the Table 8 and Table 9 of Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1].

The test procedure itself is detailed as follow:

a) The desired signal (D) video in the BASIC MIMO SETUP 1 should be a Dynamic Zone Plate;
b) The undesired signal (U) video in the BASIC MIMO SETUP 2 should be a Color Bar Pattern;
c) Configure the modulation parameters of both D and U signal to the first configuration at the beginning of the Paragraph 4.2, and set the RF OUT 1 and RF OUT 2 in both SETUPs to the maximum level;
d) Set the desired signal (D), to the CHI 10, and the interfering signal (U) to the CH 9, for (N-1), or CH 8, for (N-2), for the lower adjacent channel interference test, or to the CH 11, for (N+1), or CH 12, for (N+2), for the upper adjacent channel interference tests;
e) Adjust Variable Attenuator A2 (and B2) to maximum attenuation;
f) Adjust Variable Attenuator A1 (and B1) and set the receiver input level of D signal to -53 dBm using a Spectrum Analyzer;

g) Adjust Variable Attenuator A2 (or B2), corresponding to the U signal, decreasing its attenuation until the TOV condition is reached;

h) Adjust Variable Attenuator A1 (or B1) to the maximum attenuation and read the level of the interfering channel in the Spectrum Analyzer. This is the “U (dBm)” level;

i) Compute the D/U ratio for the adjacent channel interference for CH 10 and register in the test result table. Use the template shown in Table B 11;

j) Repeat the procedure of d) to i) changing the U signal to the second configuration specified at the beginning of the Paragraph 4.2;

k) Repeat the procedure of d) to j) changing the D signal to the second configuration specified at the beginning of the Paragraph 4.2;

l) Repeat the test for the D signal set to CH 277 and the U signal to CH 265, CH 271, CH 283 and CH 289;

m) Repeat the test for the D signal set to CH 33 and the U signal to CH 31 to CH 35.

Table B 11 – Template for results of Adjacent Channel Interference of Own System.

Protection Ratio D/U (dB)		
Desired CH	**Interferer CH**	**Receiver D/U (dB)**
D CH - 10	8	
	9	
	11	
	12	
D-CH: 277	265	
	271	
	283	
	289	
D-CH: 33	31	
	32	
	34	
	35	

4.2.6 Adjacent Channel interference (at N±1 and N±2 channels) from ISDB-T.

4.2.6.1 Background Considerations.

As the existing ISDB-T system does not operate in MIMO, the test shall be conducted with the interfering ISDB-T system in SISO, operating in H or V polarization, and the interfered ATSC 3.0 system in MIMO configuration, as is the configuration adopted for all the tests.

4.2.6.2 Test Conditions.

The Adjacent Channel Interference (at N±1 and N±2 channels) from ISDB-T System test shall be conducted with ATSC 3.0 Receiver RF IN 1 and RF IN 2 levels of -53 dBm for the desired signal (D).

The test shall be conducted with two different contents between D and U signals. It is suggested to use Zone Plate pattern as the desired video signal (D), and a Color Bar Pattern as the undesired signal (U).

4.2.6.3 Test Setup.

The Test Setup shown in Figure B 6 should be used.

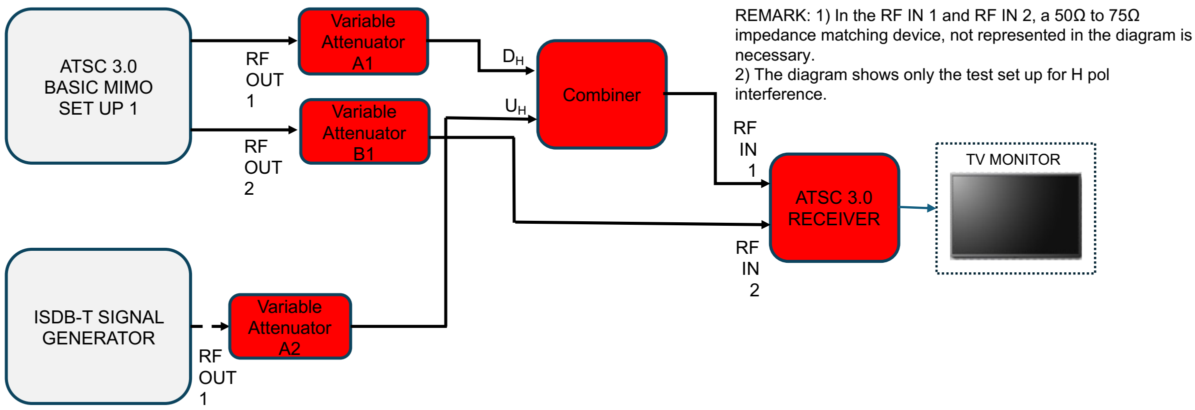

Figure B 6 – Test Setup for Adjacent Channel Interference (at N±1 and N±2 channels) from ISDB-T.

4.2.6.4 Test Specifications and Procedure.

The results of the tests shall be in compliance with the values shown in Table 8 and Table 9 of Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1].

The test procedure itself is detailed as follow:

a) The desired signal (D) video in the ATSC 3.0 BASIC MIMO SETUP 1 should be a Dynamic Zone Plate;

b) The undesired signal (U) video in the ISDB-T SIGNAL GENERATOR should be a Color Bar Pattern;

c) The adoption of the Test Setup exactly as shown in the Figure B 6, will allow the test of ISDB-T interference to the ATSC 3.0 H polarization D signal;

d) Configure the modulation parameters for D signal to the first configuration at the beginning of the Paragraph 4.2, and set the RF OUT 1 and RF OUT 2 in both SETUPs to the maximum level;

e) Configure the ISDB-T signal generator for: Mode 3, 1 x Layer A = 13 segments, 64QAM, CR = 3/4, GI = 1/8, I = 0;

f) Set the desired signal (D), to the CH 10, and the interfering signal (U) to the CH 9, for (N-1), or CH 8, for (N-2), for the lower adjacent channel interference test, or to the CH 11, for (N+1), or CH 12, for (N+2), for the upper adjacent channel interference tests;

g) Adjust Variable Attenuator A2 to maximum attenuation;

h) Adjust Variable Attenuator A1 (and B1) and set the receiver input level of D signal to -53 dBm using a Spectrum Analyzer;

i) Adjust Variable Attenuator A2, corresponding to the U signal, decreasing its attenuation until the TOV condition is reached;

j) Adjust Variable Attenuator A1 (or B1) to the maximum attenuation and read the level of the interfering channel in the Spectrum Analyzer. This is the “U (dBm)” level;

k) Compute the D/U ratio for the adjacent channel interference for CH 10 and register in the test result table. Use the template shown in Table B 12;

l) Repeat the procedure of f) to k) changing the positions of the Dummy Load and U_H. This change will allow the interference of ISDB-T U signal to the ATSC 3.0 D signal to be changed from H polarization signal to V polarization signal;

m) Repeat the procedure of f) to l) changing the D signal to the second configuration specified at the beginning of the Paragraph 4.2;

n) Repeat the test for the D signal set to CH 33 and the U signal to CH 31 to CH 35.

Table B 12 – Protection rate results.

Protection Ratio D/U (dB)		
Desired CH	**Interferer CH**	**Receiver D/U (dB)**
D CH - 10	8	
	9	
	11	
	12	
D-CH: 33	31	
	32	
	34	
	35	

4.2.7 Single Echo Static Multipath Interference

4.2.7.1 Background Considerations.

The performance of a Receiver for the multipath interference highly depends on the algorithm applied in the pilots detection, as well as to the implementation of equalization technologies, which are the reasons to classify this test as Receiver Equipment.

4.2.7.2 Test Conditions.

The single echo static multipath interference shall be conducted for ATSC 3.0 MIMO configuration, for CH 7, CH 277 and CH 51, and receiving input level of -53 dBm. Measurement of Echo Attenuation for receiving threshold TOV shall be performed for Echo Delay between -1000 µs and +1000 µs.

4.2.7.3 Test Setup.

The Test Setup of Figure B 7 should be used.

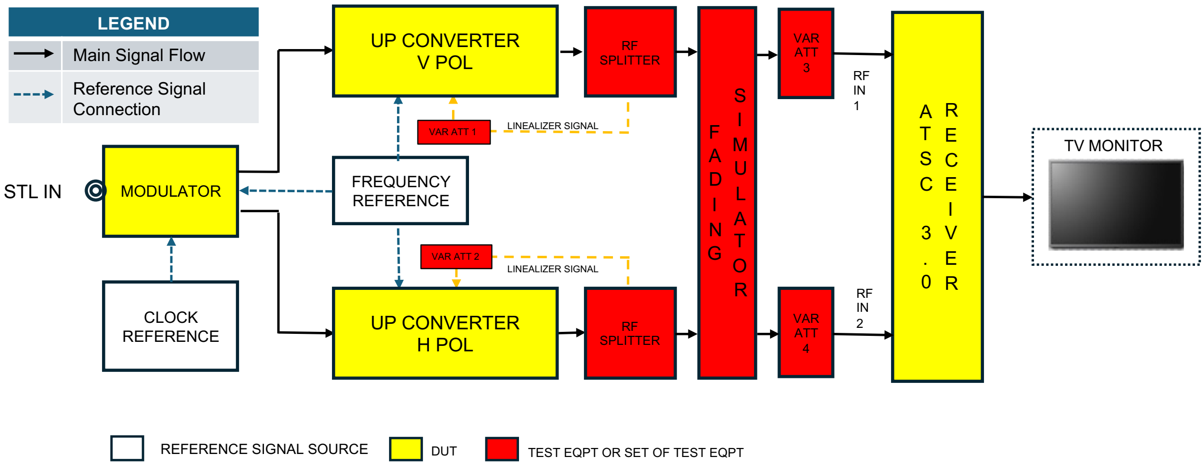

Figure B 7 – Test Setup for Single Echo Static Multipath Interference.

4.2.7.4 Test Specifications and Procedure.

The test procedure itself is detailed as follows:

a) Configure the modulation parameters to the first configuration at the beginning of Paragraph 4.2, and set the output of the H polarization and V polarization signal at the Up Converters, to the maximum output level, and the frequency to the CH 7;

NOTE: Considering that the ATSC 3.0 system modulation is based on the OFDM modulation, the system should work without any error with a pre-echo or post-echo interference of the same level, for interference signal delay inside the guard interval. Some receivers implement equalizers to improve performance in multipath environments.

b) Set a video signal of Zone Plate Pattern;

c) Set the Fading Simulator to work with the 2 paths: the first path should be considered as the main signal and the second path the interference signal, which delay and level should be varied in relation to the main signal. To start the test, set attenuation, delays, and phases of both signals to zero (0), without any impairment as fading, doppler, or noise;

d) Adjust the Variable Attenuator 3 and 4 to obtain a receiving level of -53 dBm in the RF IN 1 and RF IN 2 inputs of the Receiver;

e) Just note that the receiver works properly without any error in such a situation;

f) Then, apply delays (post-echo or pre-echo), inferior to the guard interval (set in the modulator to 111 μs) to the interference path of the Fading Simulator, and verify that the receiver works without any error;

g) Register these results (0 dB Echo Attenuation) in the test result table. Use the template shown in Table B 13;

h) Continue the test applying delays (pre-echo or post-echo) above the GI of the modulation. To start the measurements set maximum attenuation on the interference path of the Fading Simulator. Then start setting delays defined in the Table that is over the guard interval time. Then, reduce the interference path attenuation in steps of 0.1 dB, until the receiver reaches the TOV. Register the attenuation value of the interference path as Echo Attenuation in the correspondent delay row, in the test result table;

i) Repeat the test for the second configuration defined at the beginning of the Paragraph 4.2.

Table B 13 – Template for Single Echo Static Multipath Interference Results.

Pre-Echo		Post-Echo	
Delay (µs)	**Echo Attenuation (dB)**	**Delay (µs)**	**Echo Attenuation (dB)**
0	0.0	0	0.0
-50	0.0	50	0.0
-100	0.0	100	0.0
-111	0.0	111	0.0
-150		150	
-200		200	
-300		300	
-400		400	
-500		500	
.		.	
-1000		1000	

4.2.8 TxID Channel Identification Degradation to Preamble

4.2.8.1 Background Considerations.

The insertion of TxID signal is known to cause degradation in the Preamble detection. This test objective is to determine the degradation caused by the TxID over the Preamble detection, determining the difference of the C/N that cause errors on the detection of L1-Basic and/or L1-Detail signals.

4.2.8.2 Test Conditions.

The TxID Channel Identification Degradation to Preamble test shall be conducted for ATSC 3.0 MIMO configuration, for CH 7, CH 277 and CH 51, and receiving input level of -53 dBm.

4.2.8.3 Test Setup

The Test Setup shown in Figure B 8 should be used.

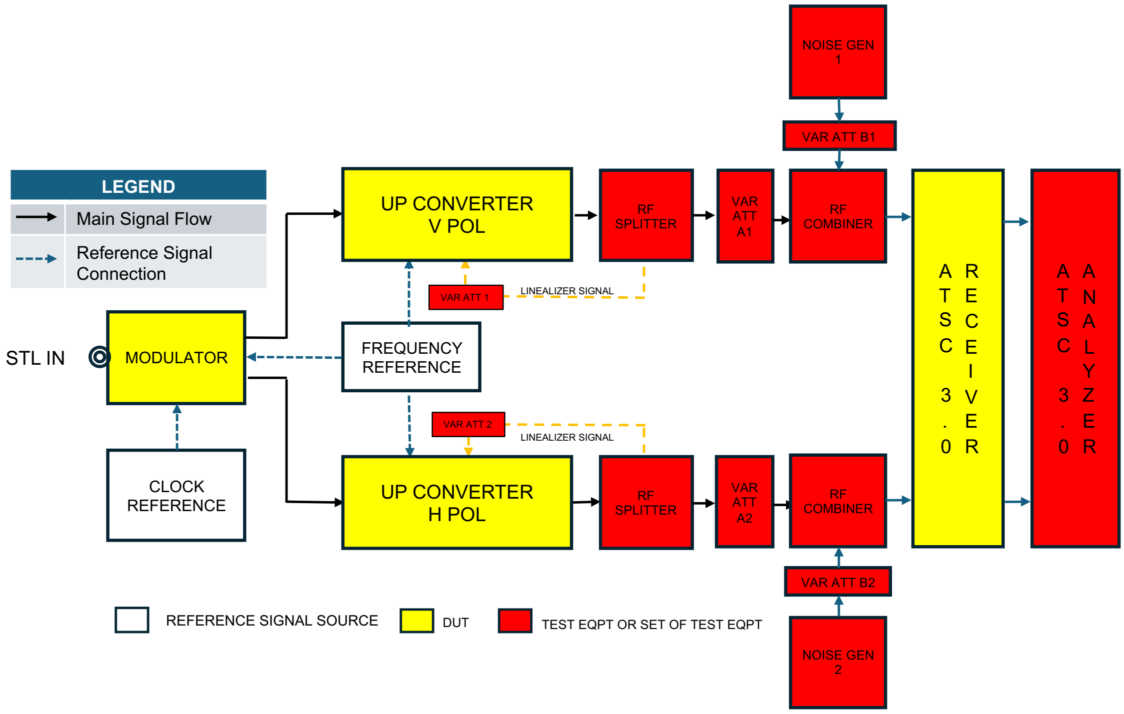

Figure B 8 – Test Setup for TxID Degradation to Preamble.

4.2.8.4 Test Specifications and Procedures.

There are no Specifications fixed for this test.

The test procedure should be conducted as follows:

a) Configure the modulation parameters to one of the configurations at the beginning of the Paragraph 4.2, and set the maximum output level, and set the frequency to the CH 7;

b) Deactivate the TxID transmission;

c) Use as video signal a Zone Plate Pattern;

d) Set AWGN Noise Generator frequency to the selected channel, and maximum output power, and the Variable Attenuator B1 (and B2) to the maximum attenuation;

e) Adjust the Variable Attenuator A1 (and A2) to obtain -53 dBm in RF IN1 (and RF IN2) of the Receiver;

f) Start to reduce the attenuation of the Variable Attenuator A1 (and simultaneously synchronized attenuation of A2), in steps of 0.1 dB, up to the point when the ATSC 3 Analyzer detects an error in L1-Basic and/or L1-Detail signal. Register the Noise level and calculate the $(C/N)_1$, corresponding to the C/N without TxID;

g) Activate the TxID with 24 dB Injection Level;

h) Repeat the procedure between d) to f), and determine the value of $(C/N)_2$, corresponding to the C/N with TxID;

i) Compute the degradation that the TxID caused to the Preamble;

j) Repeat the test for the second configuration for the ATSC 3.0 signal established in Paragraph 4.2.

4.2.9 Geographically Segmented Localcast – GSL.

4.2.9.1 Background Considerations.

The transmission of Geographically Segmented signals should work as an SFN network, and as such, with parameter settings configured according to the TV 3.0 SFN network with Layered MIMO transmission, although with different signals in the EL.

It is suggested to check the D/U ratio between the Desired EL signal and the Undesired EL signal levels, which causes reception problems in the video signal of the Desired EL.

4.2.9.2 Test Conditions.

The tests should be conducted with Layered MIMO signals configured with the parameters specified in Table 6 (Config 2) of Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1], with the transmitters operating at a frequency of 277 MHz.

It is suggested to use a PRBS sequence of length 223-1 as the input signal for the CL, for both the Desired (D) and Undesired (U) signals. As the D signal of EL, a Zone Plate Pattern should be used, and as U signal a Color Bar Pattern. The D signal and the U signal shall be configured for SFN Network operation, as Layered MIMO signals and with TxID applied.

4.2.9.3 Test Setup

The Test Setup presented in Figure B 3 shall be applied with the configurations cited in 4.2.9.2.

4.2.9.4 Test Procedure and Specification.

Provisionally, consider the specification of Co-Channel Interference of Own System for EL signal shown in the Table 9 of Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1].

The test procedure itself is detailed as follows:

a) Configure the transmission parameters of both signals to Config 2 - Table 6 of Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1] and set both Exciters to the maximum output level and to the VHF CH 277. Select 2 different TxIDs for both Exciters and activate them. Set the 2 Exciters for SFN operation.

b) Consider the output of Exciter of “Basic MIMO SETUP 1” as desired (D) signal and of the output of “Basic MIMO SETUP 2” as undesired or interference (U) signal;

c) Set the video signals to be transmitted: a PRBS sequence of length 2^{23}-1, for both Desired (D) and Undesired (U) signals of Core Layer, a Zone Plate Pattern as the D signal of Enhanced Layer and a Color Bar Pattern as U signal of Enhanced Layer;

d) Set Variable Attenuator A2 (and B2), corresponding to the U signal, at maximum attenuation;

e) Set Variable Attenuator A1 (and B1) in order that the RF IN 1 (and RF IN 2) input level be -53 dBm. This is the Signal D level;

f) Set the receiver to select the signal with the TxID of D signal;

g) Monitoring the Enhanced Layer D signal – Zone Plate Pattern in the video monitor, start decreasing Variable Attenuator A2 (and synchronously B2), at 0.1 dB steps, until the TOV.

h) Set the Variable Attenuator A1 (and B1) to the maximum attenuation and measure with a Spectrum Analyzer the level at RF IN 1 (and RF IN 2) of the U signal;

i) Compute the receiver D/U and register the value as the result of test.

4.2.10 LTE Interference over TV3.0.

4.2.10.1 Background Considerations.

Anatel issued a PUBLIC CONSULTATION Nº. 12 - "Proposal for the Regulatory Council on the Conditions of Use of Radio frequencies, in the range of 698 MHz to 806 MHz", in February 27, 2013 [3]. Later, in November 2013, Anatel issued the Resolution 625/2013 [4], which allocated the frequency range of 698 to 806 MHz to the Mobile Service, as co-primary to Broadcasting Service.

With the introduction of SBTVD system in the VHF and UHF bands and the LTE mobile services in the UHF 698 to 806MHz band, SET and Mackenzie Presbyterian University conducted extensive studies on the interference of LTE Base Station - BS and User Equipment - UE over the SBTVD receivers, as well as mitigations over SBTVD systems. The tests conducted in the occasion and its results are well documented and reported.

The tests developed in occasion and its results, considering that the basic modulation system adopted by the TV 2.x and TV 3.0, are both based on the OFDM, are valid for the TV 3.0.

4.2.10.2 Tests Conditions.

A. TV 3.0 Signal Configuration.

It is suggested to conduct the tests of LTE interference over TV 3.0 over V or H signal polarization, individually. In the real world the interference of Mobile signal to the TV 3.0 should occur in different levels depending on the antenna's installation situation and rotation of the signal polarization due to propagation effects.

B. Parameters of the Interferer Signal.

Only LTE FDD systems signals will be considered.

The interference signal follows one of the settings below. for the Downlink or Uplink:

I) Downlink

One adjacent channel of 10 MHz, occupying the frequency range of 763 to 773 MHz, with all the Resource Blocks (RBs) occupied by users.

The parameters of the configured signal are presented in Figure B 9 to Figure B 12.

- All RBs scheduled simultaneously with PN9, with 64QAM modulation, as shown in Figure B 9;
- Allocation Map of RBs: The horizontal axis represents the time in ms. while the vertical axis represents the RBs.

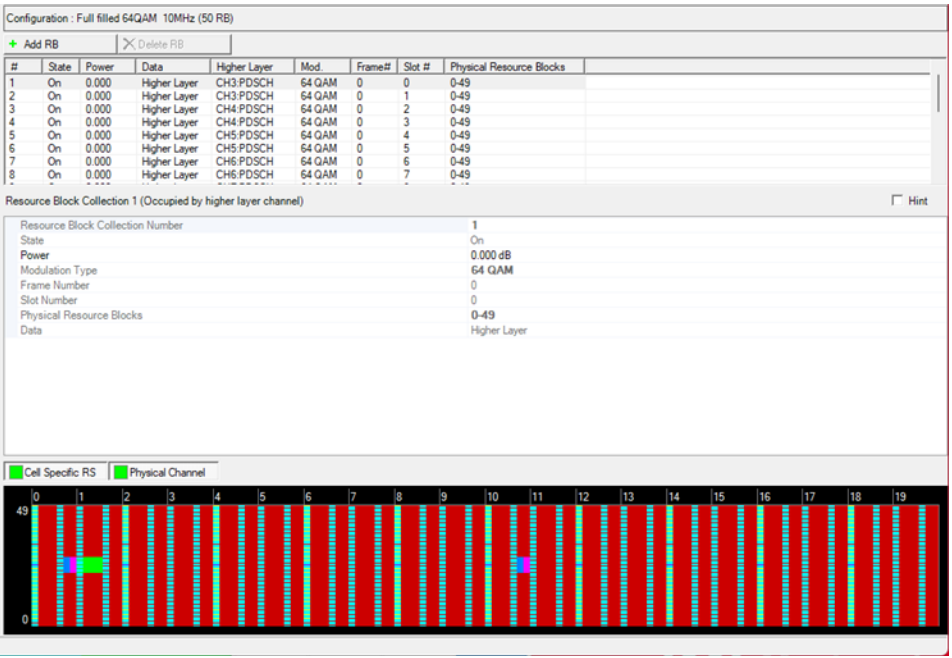

Figure B 9 – Downlink Frame Configuration.

- Envelope of the signal in time (period of 10 ms). as seen in Figure B 10.

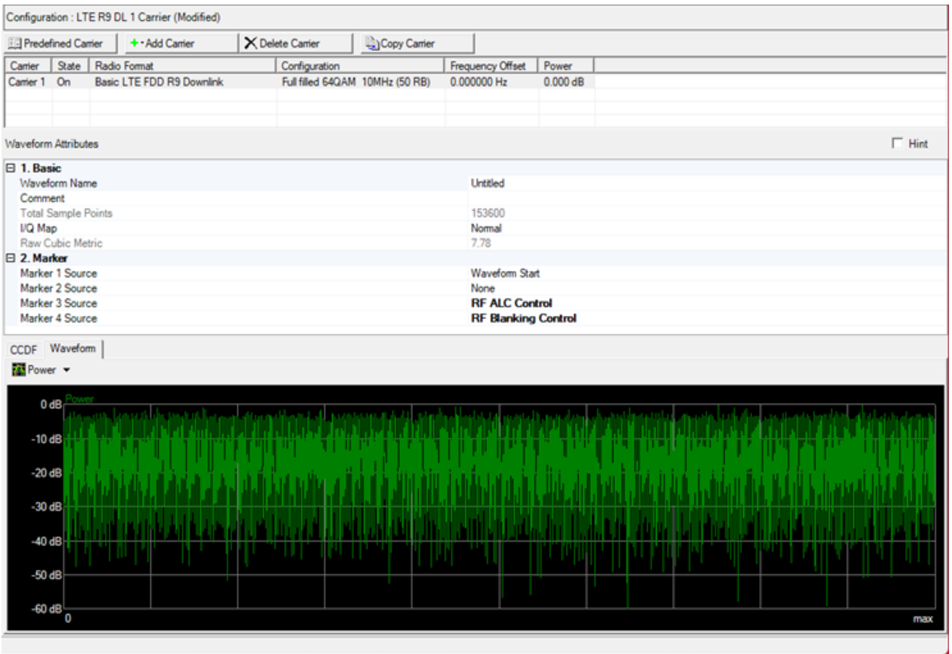

Figure B 10 – Downlink Signal Waveform.

- Complementary Cumulative Distribution Function (CCDF): Function of Distribution of the Amplitude of the envelope of the modulated signal is observed in Figure B 11.

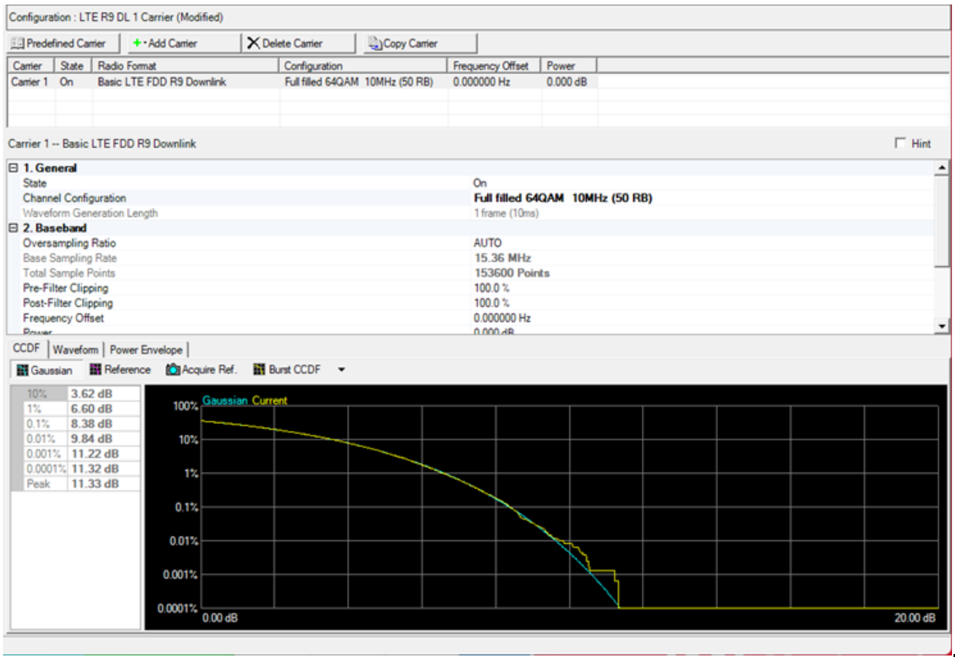

Figure B 11 – Downlink CCDF.

- OFDM Signal Spectrum: LTE Downlink is illustrated in Figure B 12.

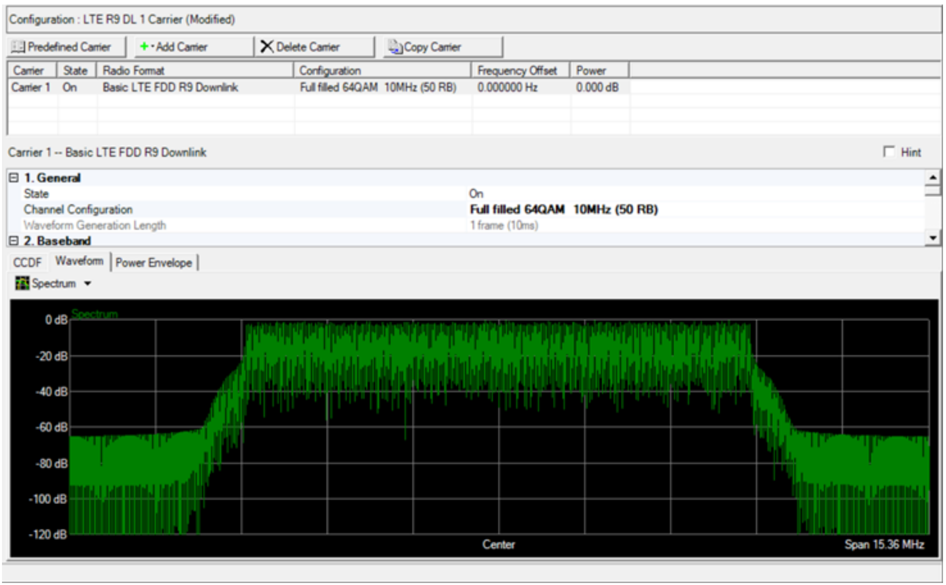

Figure B 12 – Downlink Signal Spectrum.

II) Uplink 10 MHz

A 10 MHz channel. occupying the frequency range of 703 to 713 MHz, in pulsed mode, with PUSCH signal occupying all RBs of the first sub-frame of 1 ms duration and no signal in the subsequent 9 ms, completing a 10 ms frame.

The parameters of the configured signals are presented in Figure B 13 to Figure B 16.

- Configuration of the signal: Only PUSCH. 50 RBs activated during the first sub-frame. and subsequent nine sub-frames without active signal. modulated in 16 QAM, in agreement with Figure B 13.
- Allocation Map of RBs: the horizontal axis represents time in ms while the vertical axis represents the RBs.

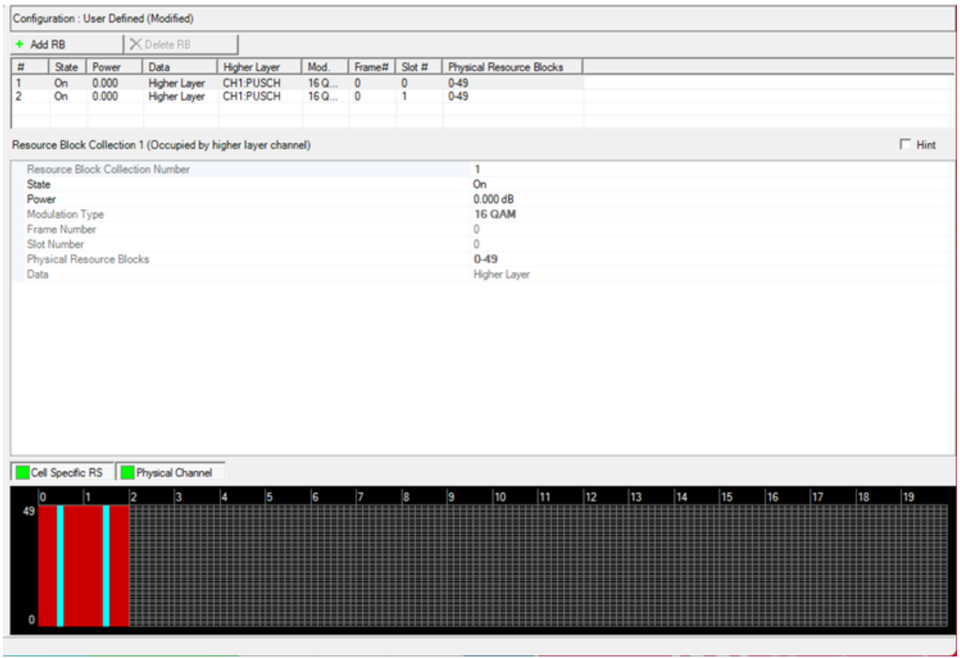

Figure B 13 – Uplink Frame Setting.

- Envelope of the signal in time: period of 0 to 10 ms 1 full frame (1 ms active and 9 ms inactive) seen in Figure B 14.

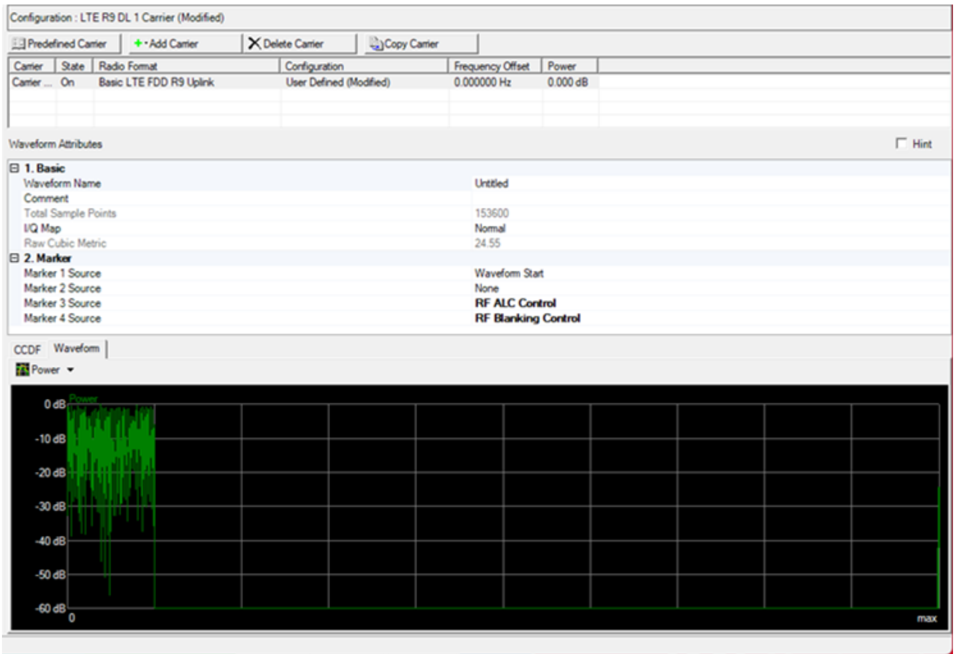

Figure B 14 – Uplink Signal Waveform – 1 Complete Frame.

- Complementary Cumulative Distribution Function (CCDF): Cumulative Distribution Function of Amplitude of the envelope of the modulated signal. active period of 1 ms (only first sub-frame) observed in Figure B 15. Note the difference of 10 dB in the maximum values of Peak Power/Avg. Power between the situations.

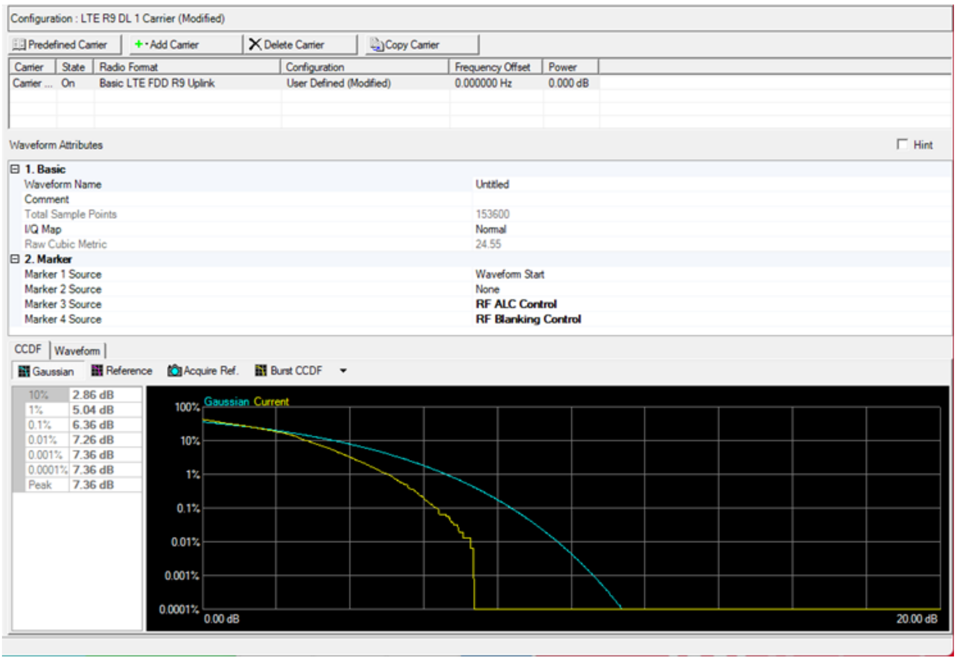

Figure B 15 – Uplink CCDF – 1 ms.

- SC-FDMA Signal Spectrum: LTE Uplink. Figure B 16 shows the spectrum of the signal in the period of the beginning of the one sub-frame until the end of the sub-frame.

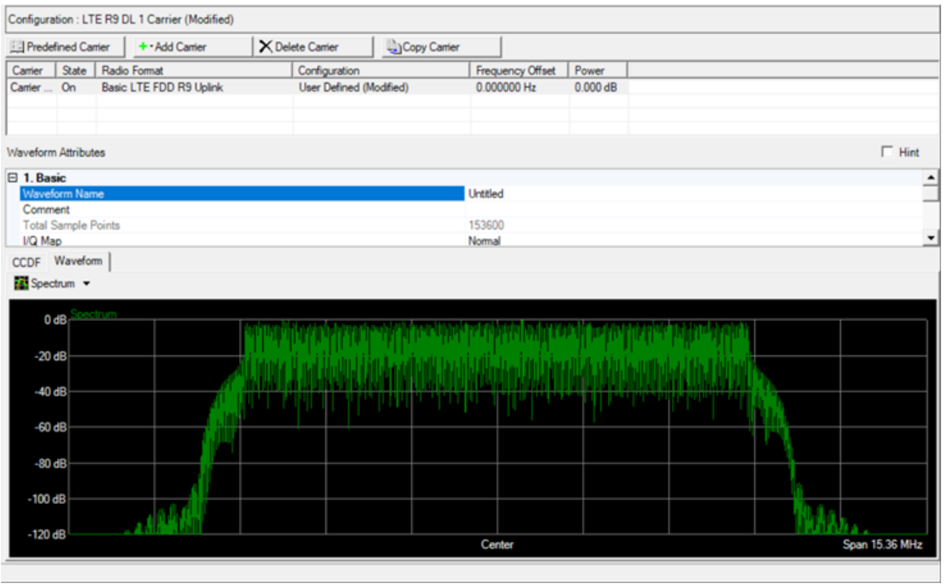

Figure B 16 – Uplink Signal Spectrum.

C. Measurements in the Presence of Time Variant Interfering Signal.

In the tests of interference carried out in Europe, between DVB-T/T2 and LTE, it was found that rapid variations of level of the interferer signal cause degradations in the PR and Oth performance DTV receivers due to the dynamic operation of the Automatic Gain Control (AGC) circuit and the algorithms for the estimation of the channel.

NOTE: Some DTV receivers may present "unstable" behavior in the presence of this type of LTE signal. as reports from abroad and observed during the tests performed in the Mackenzie University Laboratory.

The Uplink mobile system signal may vary considerably, both in the time domain as in the frequency domain, depending on the traffic load. In the frequency domain, the number of RBs allocated to each SC-FDMA symbol can vary quickly. In the time domain, there may be long periods in which the UE does not transmit any signal, generating an irregular profile of pulsed power. The ITU-R BT.2215-4 [5] Report recommends to perform measurements with Uplink signals at various rates of transmission. For these reasons, the adoption of pulsed signals was decided. as defined in II) Uplink 10 MHz.

NOTE: ITU-R BT.2215-4 [5] Report recommends in paragraph "5.8 - Interferer reference power level". to consider in the measurements of pulsed signals, the average power of the signal at its active period. The average power of the Uplink signal in its active period is 10 dB higher than the average power of the complete frame period. Thus, in analyzes and calculations of interference, involving parameters of C/I, C/N, one must consider the average power of the signal in one complete frame.

D. Reference Power Level of LTE Interferer Signal.

Variations of the interference signal level can be obtained by direct action on the signal level. as well as on the occupation rate. To view the degradation caused by time variant interfering signal it is necessary that we keep the RMS power, or the power spectral density of active portions of the time variant interfering signal constant in relation to the RMS power, or in relation to the power spectral density of the interferer with 100% loading (condition of power fixed in time). This situation corresponds to the observation of the spectrum on the Spectrum Analyzer, so that the Power Spectral Density displayed on screen, with the same parameters set on the measuring equipment, have the same amplitudes for the signal loaded at 100% as at 0 %.

E. Methods of Evaluating the Point of Failure.

The ITU-R Recommendation BT.1368 [6] proposes the use of the Subjective Failure Point (SFP) method in a unified manner in relation to protection ratio measurements. The relationship of RF protection for a desired signal of DTV is the value of the ratio between the powers of the desired signal and the unwanted signal (interferer) in the input of the receiver, determined by SFP method and rounding the result to the next higher integer value.

The SFP method corresponds to the quality of image where no more than one error is visible on the screen for an average time of observation of sixty seconds. The adjustments of the levels desired and unwanted signals should be made in small steps, typically of 0.1 dB.

F. Test of Adjacent Channel Leakage Ratio (ACLR).

The Adjacent Channel Leakage Ratio (ACLR) is an important parameter that indicates the quality of the signal generated by a signal generator or a transmitter, in terms of its emissions outside the designated occupied bandwidth. The concept of ACLR applies, in general, to signal generators or transmitters for various types of services, with different settings, different central frequencies and bandwidths of both main and adjacent signals, and inclusive, as is the case of this work, involving different services.

Figure B 17 illustrates the definition of LTE signal ACLR, measured on the TV channel 51. The importance of having a high value of ACLR, and also to perform its measurement, is evident by the figure. When the DTV receiver tunes to the channel 51, the interfering power P51 goes directly into the demodulator, in addition to the DTV signal, and thus, the greater the ACLR, smaller will be the interfering power P51.

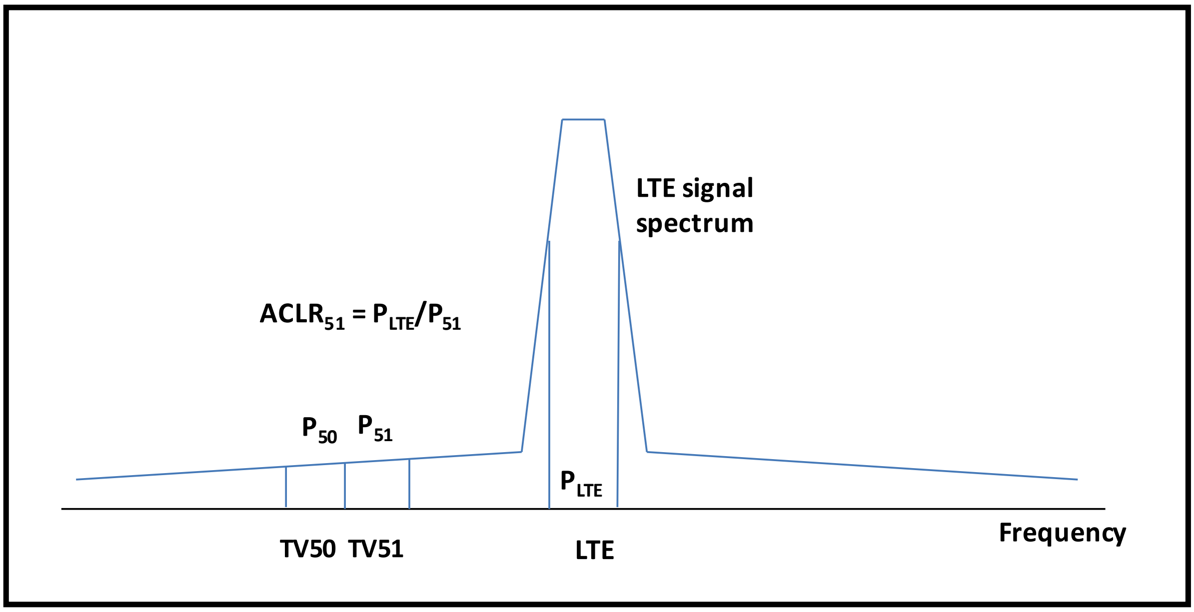

Figure B 17 – ACLR Measurement.

As the ACLR interfering signal depends on the levels of the signal settled up in the signal generator and in the amplifiers employed in the measurement setup, it is important to establish these levels with a lot of care at the beginning of the tests, and maintain this level fixed throughout the measurements, performing variations of levels effectively applied in measurements only by means of external attenuators. For the same reason, the ACLR measurements must be carried out in a measurement setup configuration and levels of signal employed in the actual measurements of LTE x DTV interference.

The interference tests of LTE on the DTV were carried out by Mackenzie, in a setup with LTE signal generators, with more spectrally clean signal, i.e., with better ACLR (larger) than those actual transmitters in operation. The ACLR measured (and this is another reason for its importance) are used together with the results of the measurements, to make more realistic estimates of the interference of the LTEs on DTV, applying conversions on the PR measurements (see paragraph 1.5.2 of ITU-R Recommendation BT.2033 [7]). Considering the out of band emission characteristics of actual LTE Downlink (BS) and Uplink (UE) transmitters, such conversion has been applied in the ITU-R for sharing studies between services.

G. Determination of Protection Ratio - PR and Overloading Threshold - Oth.

The determination of the Protection Ratios - PR and Overloading Threshold – Oth of the Digital TV Receiver against LTE interferences were conducted according to the graphical methodology established by Report ITU-R BT.2215-7 – 2018 [8] – “Measurement of protection ratios and overload thresholds for broadcast TV receivers”, in the Paragraph 5.11 – “Method for determining protection ratios and overload thresholds”.

Instead of tracing one TOV curve for each Digital TV channel we traced a “worst TOV curve”, selecting the worst TOV values. In general, it happens for channel 50 or 51, but we select the worst TOV value and trace the worst curve.

4.2.10.3 Test Setup

The test Setup shown in Figure B 18 shall be considered.

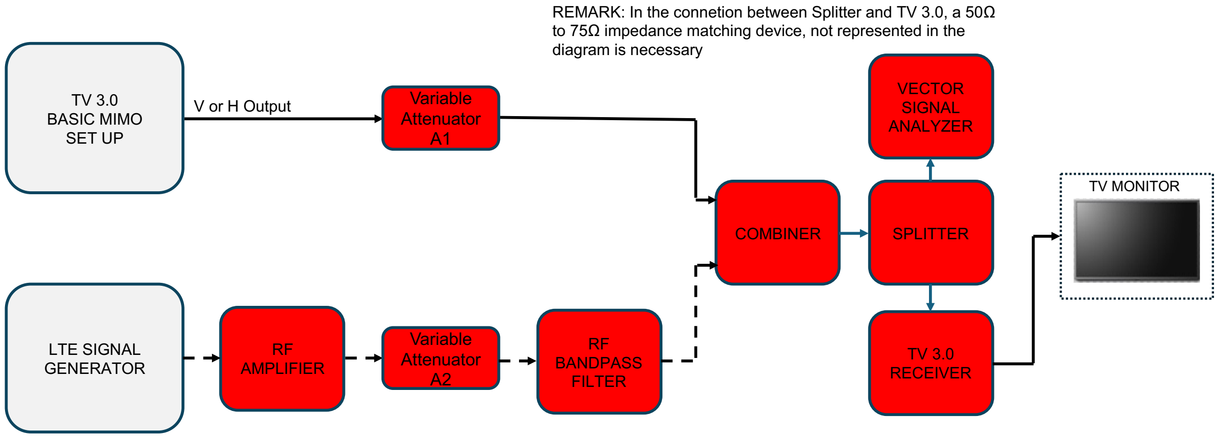

Figure B 18 – LTE Interference Test Setup.

4.2.10.4 Test Procedure and Specification.

The specifications of Table 8 and Table 9, presented in Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1], shall be considered.

The test procedure is presented as follows:

a) Connect the Measuring Equipment's as shown in Figure B 18, starting with LTE interference over TV 3.0 V polarization signal;

b) Configure the modulation parameters to Config 1 of Table 5 in the of Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1], in the TV 3.0 Basic MIMO Setup. The digital TV signal for the desired signal to be tested shall be the Zone Plate Pattern;

c) Set the LTE Signal Generator with the Downlink LTE signal, in accordance to the 4.2.10.2;

d) Set the DTV Modulator to channel 14 (473.143 MHz);

e) Adjust the Variable Attenuator 2, connected to the LTE Signal Generator side, for maximum attenuation;

f) Adjust the Variable Attenuator 1, connected to the DTV signal side, in order to obtain a level of -77 dBm in the input of the receiver in test;

g) Acting over the attenuator connected to the LTE Signal Generator side, lower the attenuation of the LTE signal observing the PER on the receiver GUI screen, up to the point of QEF. We call that the receiver reached its Threshold of Visibility – TOV point;

h) Put the attenuator of the DTV signal to its maximum and read out the level of the interfering LTE signal level – I (dBm), on the Signal Analyzer;

i) Register the I level in the Table B 14;

j) Repeat the procedure from item e) to i), according to the established DTV signal power level;

k) Repeat the procedure from item d) for the other UHF TV channels 15 up to 277 and 277 up to 51;

l) Determine the worst interference channel and trace the PR and Oth graphs, according to the Paragraph 4.2.10.2 - G, and determine the PR and Oth values;

m) Repeat the procedure from item d) to l) for the TV 3.0 H polarization signal;

n) Repeat all the procedure for the Config 2 modulation parameters of Table 6 in the of Paragraph 15.9.6 of Document ABNT NBR 25609:2025 [1].

Table B 14 – TOV for interference of LTE – Uplink/Downlink.

TV Level (dBm)	TV CHANNEL					
	14	15	---------	277	----------	51
	TOV – I (dBm)					
-20						
-30						
-40						
-50						
-60						
-70						
-80						
-83						

Bibliography

[1] Brazilian Standard. TV 3.0 – Receivers. ABNT NBR 25609. First edition, 01 December 2025.

[2] ATSC Standard: Scheduler / Studio to Transmitter Link, Doc. A/324:2025-04, April 2025.

[3] Anatel. Public Consultation nº 12: Proposal for the Regulatory Council on the Conditions of Use of Radio frequencies, in the range of 698 MHz to 806 MHz. February 27, 2013.

[4] Anatel. Resolution 625/2013. November, 2013.

[5] Report ITU-R BT.2215-4: Measurements of protection ratios and overload thresholds for broadcast TV receivers, 2014.

[6] ITU-R Recommendation BT.1368: Planning criteria, including protection ratios, for digital terrestrial television services in the VHF/UHF bands, 2017.

[7] ITU-R Recommendation BT.2033: Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands, 2022.

[8] Report ITU-R BT.2215-7 – 2018: Measurements of protection ratios and overload thresholds for broadcast TV receivers, 2018.