# Analysis of Transmission Measurements of ISDB-T


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**Abstract – This paper shows the performance of standard ISDB-T, based on the signal generated by a laboratory transmitter and the signal generated by the transmitter of the channel Ecuadorian state (ECTV), which propagates in the city Quito and its surroundings. The channel power, the modes of operation and the modulation accuracy were analyzed.**



***Keywords- TDT, ISDB-T, Adjacent Channel, CCDF, MER, EVM***


## I. I. INTRODUCTION

The Integrated Services Digital Broadcasting -Terrestrial, Brazilian version (ISDB-Tb) developed by Brazil, was based on the standard previously developed by the Japanese, but with substantial changes in the middleware, and encoding audio and video used. Fig. 1 shows the layers of the model of the Brazilian Standard Architecture [1].

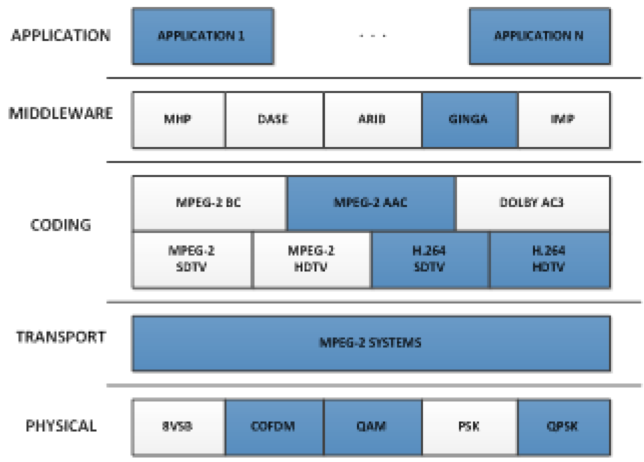


Figure 1. Architecture System ISDB-Tb

The ISDB-Tb system is rugged to multipath channels because it uses Band Segmented Transmission- Orthogonal Frequency Division Multiplexing (BST-OFDM), and it consists of 13 OFDM segments. This structure divides a 6 MHz channel into 14 segments, of which occupies 13 segments of 429 kHz each one. This allows great flexibility in choosing the services offered. Fig. 2 shows the distribution of the layers [2].

The system supports hierarchical transmissions of up to three layers, A, B, and C. The transmission parameters can be changed in each of these layers. The center segment of the hierarchical transmission can be received by one-segment handheld receivers. Each layer is responsible for a configurable number of segments. This configuration is valid whenever the number of segments resulting from the sum of the three layers is equal to 13 [2], [3]. Layer A is responsible for the first segments of the OFDM symbols, followed by segments of the layer B and finally the layer C [2], [3].

The system has three transmission modes, 1, 2, and 3. The mode defines the total number of carriers, the type of modulation of each carrier, the guard interval and the rate of the convolutional code. The basic parameters of each mode are listed in Tab. 1.

**TABLE 1. Segmentation parameters for ISDB-T (6 MHz)**

| Mode | | Mode 1 | | Mode 2 | | Mode 3 | |
|---|---|---|---|---|---|---|---|
| Bandwidth | | 6000/14 = 428.57..... kHz | | | | | |
| Spacing between Carriers | | 6000/(14X108)= 3.968.....kHz | | 6000/(14X216)= 1.9841.....kHz | | 6000/(14X432)= 0.99206.....kHz | |
| Number of carriers | Total | 108 | 108 | 216 | 216 | 432 | 432 |
| | Data | 96 | 96 | 192 | 192 | 384 | 384 |
| | SP | 9 | 0 | 18 | 0 | 36 | 0 |
| | CP | 0 | 1 | 0 | 1 | 0 | 1 |
| | TMCC | 1 | 5 | 2 | 10 | 4 | 20 |
| | AC1 | 2 | 2 | 4 | 4 | 8 | 8 |
| | AC2 | 0 | 4 | 0 | 9 | 0 | 19 |
| Carrier Modulation | | 16 QAM, 64 QAM, QPSK | DQPSK | 16 QAM, 64 QAM, QPSK | DQPSK | 16 QAM, 64 QAM, QPSK | DQPSK |
| Number of symbols per frame | | 204 | | | | | |
| Effective Symbol Length | | 252 µs | | 504 µs | | 1.008 ms | |
| Guard Interval | | 63 µs (1/4), 31.5 µs (1/8), 15.75 µs (1/16), 7.875 µs (1/32) | | 126 µs (1/4), 63 us (1/8), 31.5 us (1/16), 15.75 us (1/32) | | 252 µs (1/4), 126 µs (1/8), 63 µs (1/16), 31.5 µs (1/32) | |
| Frame Duration | | 64.26 ms (1/4), 57.834 ms (1/8), 54.621 ms (1/16), 53.0145 ms (1/32) | | 128.52 ms (1/4), 115.668 ms (1/8), 109.242 ms (1/16), 106.029 ms (1/32) | | 257.04 ms (1/4), 231.336 ms (1/8), 218.464 ms (1/16), 212.058 ms (1/32) | |
| Clocked FFT | | 512/63 = 8.126984..... MHz | | | | | |
| Internal Code | | Convolutional Code (1/2, 2/3, 3/4, 5/6, 7/8) | | | | | |
| External Code | | RS (204,188) | | | | | |

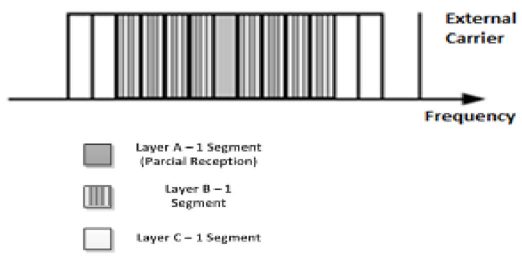


Figure 2. Hierarchical Transmission of the three active layers

## II. MEASUREMENT PARAMETERS

The measurement parameters to evaluate the performance of the transmitters are:

- Power Channel
- Modulation Accuracy
- CCDF Power Statics

For the evaluation of transmission systems, the Spectrum Analyzer Agilent Technologies CXA model, N9000A, based on the test module, was used.

The purpose of measuring the power of the channel is found in the channel intermodulation problems, which is checked by observing the degradation of the OFDM signal level at the ends (shoulder) spectrum [4].

The purpose of measuring the Power Complementary Cumulative Distribution Function (CCDF) is based on many digitally modulated signals that appear in the time domain and frequency as noise. This means that the statistical measures of the signals can be a useful characterization. CCDF curves characterize the statistical power of a digitally modulated signal [5].

The power measured in statistics CCDF curves is given by:

$$P = \frac{I^2 + Q^2}{Z_0}, \qquad (1)$$

where I and Q are the quadrature components of the voltage waveform and $Z_0$ is the characteristic impedance [4].

The modulation accuracy measures all possible mechanisms of error in the chain of transmission, including the base band signal, I / Q modulation, amplitude and phase, non-linear filter and distortion power amplifier [4].

Accuracy of modulation provides the following information:

- Error Vector Magnitude (EVM)
- Modulation Error Ratio (MER)
- Magnitude Error
- Phase Error.
- Frequency Error.
- Quadrature Error.

The modulation error ratio (MER) is a measure of the signal-to-noise ratio (SNR) in a digitally modulated signal. Like SNR, MER is usually expressed in decibels (dB). MER over number of symbols, *N*, is defined as:

$$MER = \frac{\sum_{j=1}^{N}(\tilde{I}j^2 + \tilde{Q}j^2)}{\sum_{j=1}^{N}\left[(Ij - \tilde{I}j)^2 + (Qj - \tilde{Q}j)^2\right]}, \qquad (2)$$

where

$Ij^2$ is the I component of the j-th symbol received,

$Qj^2$ is the Q component of the j-th symbol received,

$\tilde{I}j^2$ is the ideal I component of the j-th symbol received and

$\tilde{Q}j^2$ is the ideal Q component of the j-th symbol received.

The MER expressed in dB is essentially the same SNR in a modulated signal calculated in dB:

$$MER(dB) = \frac{Es}{No}(dB), \qquad (3)$$

The MER measuring instrument receives an ideal input signal and an AWGN corrupted signal is considered. Therefore, this measure ratio corresponds to the SNR of the AWGN channel. The Fig. 3 shows the ratio between the bit error rate, BER and the Es/No, when the BER is less than $10^{-3}$ can be corrected by the channel decoder and frozen picture during the reception periods are eliminated.

The equation used to evaluate the symbol error rate with respect to the symbol energy is given by:

$$P(e|MQAM) = 2\left(1 - \frac{1}{\sqrt{M}}\right) erfc\left(k\sqrt{\frac{Es}{N_0}}\right) - \left(1 - \frac{2}{\sqrt{M}} + \frac{1}{\sqrt{M}}\right) erfc^2\left(k\sqrt{\frac{Es}{N_0}}\right), \qquad (4)$$

where k is given by:

$$k = \sqrt{\frac{1}{\frac{2}{3}(M-1)}}$$

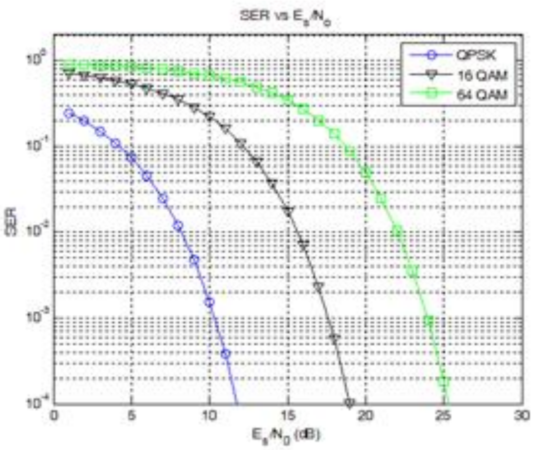


Figure 3. Ratio between BER and Eb/No

EVM is a parameter that is used to quantify the performance of a radio transmitter or receiver digital and reveals the difference between the ideal constellation diagrams compared with the received constellation. The EVM is defined as:

$$EVM = \frac{\sqrt{\frac{1}{N}\sum_{j=1}^{N}\left[(Ij - \tilde{I}j)^2 + (Qj - \tilde{Q}j)^2\right]}}{\sqrt{\frac{1}{N}\sum_{j=1}^{N}(Ij^2 + Qj^2)}} \times 100\% \qquad (5)$$

Substituting (4) in (5) is easy to show that:

$$EVM = 10^{-\frac{MER}{20}} \qquad (6)$$

The minimum recommended operating of MER for QPSK is 18 dB, for 16 QAM is 24 dB and for 64 QAM is 27 dB [5].

Also for these values of MER, the EVM values recommended operational are:

- QPSK de 12,58%,
- 16 QAM de 6,30% y
- 64 QAM de 4,466%, respectively.

The recommended values of Symbol Error Rate (SER) according to the minimum values of MER fluctuate between $10^{-2}$ and $10^{-3}$ [5].

## III. TRANSMITTER'S ECTV PROPAGATION

For the ECTV transmission tests, the coverage in SIRENET simulator [6] was obtained and the parameters summarized in Tab. 2 were used. The propagation model chosen was the REC. ITU-R 526 200 m. Fig. 4 shows the result obtained.

The distance between the receiver which is located in the laboratory (ESPE) and transmitter in Cruz Loma is approximately 17.1 km. Fig. 4 shows in blue color the area covered by it, where the laboratory is located.

TABLE 2
Summary parameters entered in ECTV System Simulator

| Calculation Parameters | Values |
|---|---|
| Transmitter Power | 56.9897 dBm |
| Frequency | 671 MHz |
| Polarization | Vertical |
| Antenna | Folded Dipole |
| Antenna Gain | 2,2 |
| Type of Service | ISDB-Tb |
| Area of Coverage | 20 km. |
| Receiver Sensitivity | -85 dBm |
| Channel | 47 |

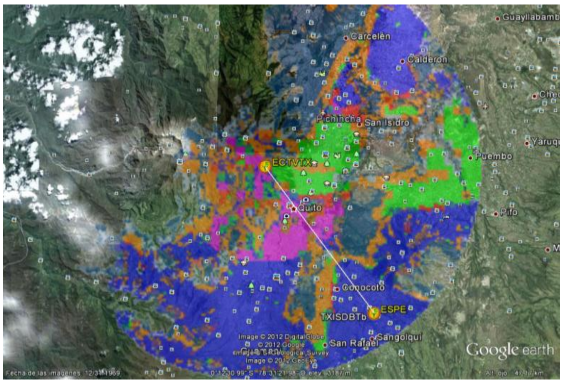


Figure 4. Coverage Area Simulation System to 56 dBm ECTV (500W).

The simulation results of the radiation intensity distribution are described in Table 3, given coverage of 20 km:

TABLE 3. Summary of the coverage areas of ECTV Transmitter

| POWER RANGE OF COVERAGE | COLOR |
|---|---|
| -106.799 dBm ≤ P < -96.7992 dBm | GRAY |
| -96.799 dBm ≤ P < -86.7992 dBm | DARK BLUE |
| -86.799 dBm ≤ P < -76.7992 dBm | ORANGE |
| -76.799 dBm ≤ P < -66.7992 dBm | GREEN |
| -66.799 dBm ≤ P < -56.7992 dBm | RED |
| -56.799 dBm ≤ P < -46.7992 dBm | BLUE |
| -46.799 dBm ≤ P | PINK |

With the results from laboratory tests, it was verified that are within the range of the ECTV transmitter. The distance between the receiver which is located in the laboratory and transmitter in Cruz Loma is approximately 17.1 km.

For the Laboratory case the transmission power, P, is within the coverage area ranging from 66,799 dBm ≤ P <-56.7992 red dBm.

## IV. LABORATORY TRANSMITTER PERFORMANCE

For measurements in the laboratory transmitter were taken into account the following parameters:

- Mode 3 8k
- Output Power -50 dBm
- Channel frequencies from 47 MHz to 862 MHz, with bandwidth (557 MHz, channel 28).
- Channel bandwidth of 6 MHz.
- Area 8 m.

At Tab. 4 shows the configuration parameters of the transmitter laboratory:

TABLE 4. Summary of parameters entered in Laboratory Transmitter

| **Parameter** | **Description** |
|---|---|
| Mode | 3 |
| Modulation | 64 QAM |
| Number of Segments per layer | 13 on layer A |
| Channel Coding | 2/3 |
| Guard Interval | 1/8 |

### A. *Channel Power*

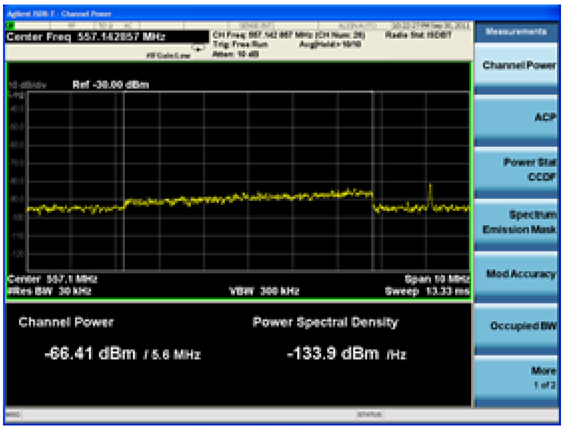


Figure 5. Channel Power Transmitter Laboratories

Fig. 5 shows the spectrum and the channel power of -66.41 dBm / 5.6 MHz and power spectral density of: -133.9 dBm /Hz.

For propagation in free space and calculating the power received at the decoder, at a distance of 6 meters from the antenna to the receiver, the received power is given by:

$$P_R\,(dBm) = P_T\,(dBm) - 10\,\beta \log d$$

$$P_T = -50.64\,dBm$$

$$P_R\,(dBm) = -50{,}64\,dBm - 20\log 6$$

$$P_R\,(dBm) = -66{,}2\,dBm, \qquad (6)$$

The results indicate that has not intermodulation and power calculations agree with the reception channel power, the difference between the power channel measurement and receiver power calculated is minimal.

### B. Power Complementary Cumulative Distribution Function (CCDF).

The main goal of CCDF curves is completely and unambiguously specifies the power characteristics of the signals that are multiplexed, amplified and decoded [4]. In Fig. 6, the vertical scale represents the percentage of time that the signal power is at or above the specified power. The horizontal scale represents the power level at dB. The reason of using CCDF, it's because emphasized the peak values of the power of the measured signals [4]. The results show that the average power is -62.29 dBm, while the peak power is -48.99 dBm.

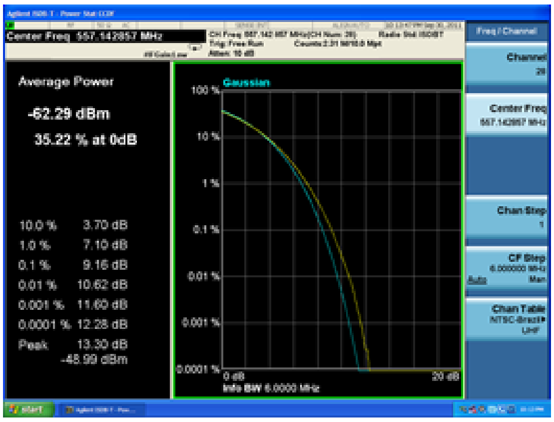

Figure 6. Curves Statistics of Transmitter Laboratories

The signal measured at 10% of the time the signal exceeds to 3.70 dB on the reference signal. At 1% of the signal exceeds 7.10 dB, for the 0.001% of the time the power value is 11.60 dB. According to the values obtained in the Fig. 5, there are no large deviations, having a peak of 13.30 dB at a power of -48.99 dBm.

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### C. Modulation Accuracy

Fig. 7 shows the MER, EVM, constellation diagram and the distribution of laboratory transmitter segments, respectively:

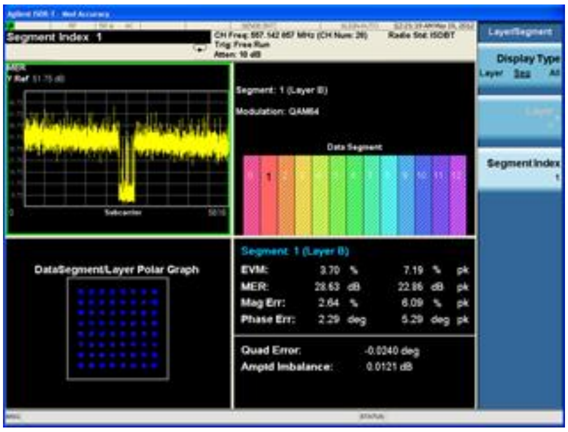

Figure 7. Modulation Accuracy, MER, EVM, Constellation diagram I / Q, of 64 QAM

TABLE 5 Summary measurements in the laboratory transmitter with 64 QAM modulations

| Parameter | RMS | PEAK |
|---|---|---|
| EVM | 12.76% | 55.87% |
| MER | 17.89 dB | 5.06 dB |
| Magnitude Error | 9.28% | 33.15% |
| Phase Error | 6.85 grad | 16.12 grad |

Figure 7 shows the distribution of the signal segment ISDB-T transmitter. Figure 8 shows the TMCC screen where it can be observed the current configuration of equipment in one column and in the next column transmitter configuration, observing all information which is included in the segments, it is noted that the distance between the transmitter and the analyzer is 6 m.

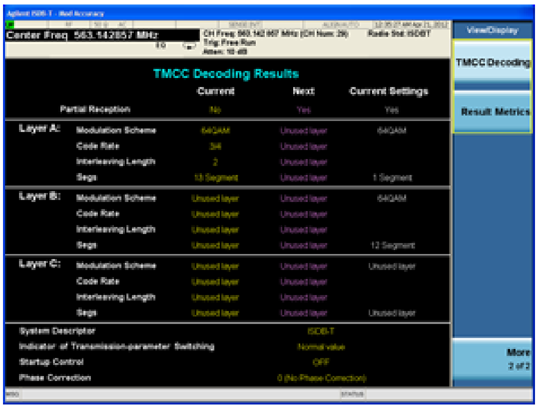

Figure 8. Modulation Accuracy, TMCC transmitter laboratory results

Fig. 8 shows the transmitter laboratory that used a 64 QAM modulation, a code rate of 3/4, an interleaving length 2 and the number of segments 13.

## V. ANALYSIS TRANSMITTER ECTV

The transmission frequency of ECTV system is 671.142857 MHz the frequency according to the transmission channel number is 47.

### A. *Channel Power*

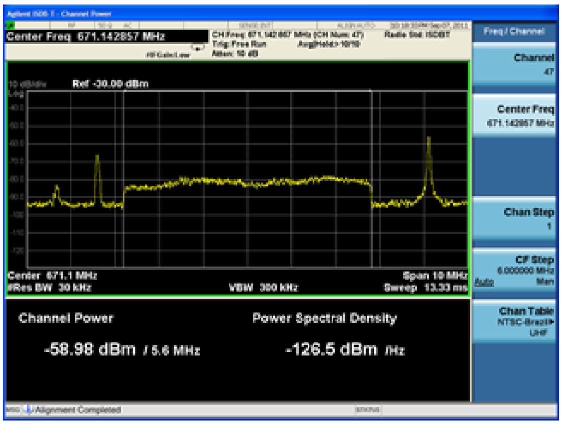


Figure 9. Channel Power, Transmitter ECTV.

Channel Power: -58.98 dBm / 5.6 MHz and the Power Spectral Density: -126.5 dBm /Hz

The results indicate that has not intermodulation and there is a difference between the power channel measurement and receiver power calculated.

### B. *Power Complementary Cumulative Function (CCDF)*

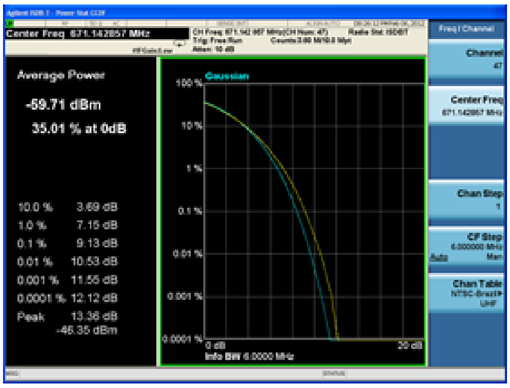


Figure 10 Transmitter ECTV

Fig. 10 shows that the average power of the transmitter is -62.29 dBm and a peak power of -48.99 dBm.

The signal measured at 10% of the time, the signal passes a 3.69 dB on the reference signal, in the Figure 8 is yellow signal. To 1% of the signal exceeds the 7.15 dB, for the 0.001% of the time the power value is 11.55 dB. These results show no considerable deviations, having a peak of 13.36 dB at a power of -46.35 dBm.

Figure 10 shows that there are considerable variations in the power of the transmitter signal having a good performance, which implies a good performance in the pre amplification and amplification.

### C. *Modulation Accuracy*

According to tests with the equipment, it is shown the constellation diagram, the MER, EVM, and the distribution of the segments:

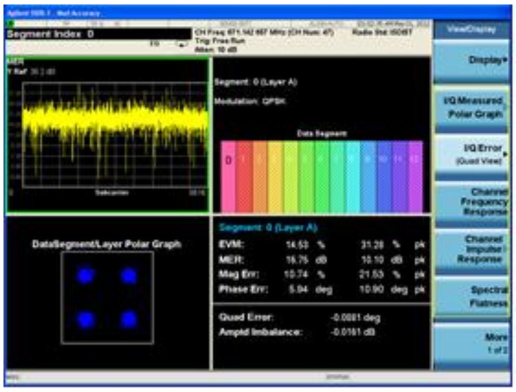


Figure 11. Modulation Accuracy and One Seg, Transmitter ECTV

TABLE 6 Summary of measurements made in the transmitter ECTV

| Parameter | RMS | PEAK |
|---|---|---|
| EVM | 14.53% | 31.28% |
| MER | 16.75 dB | 10.10 dB |
| Magnitude Error | 10.74% | 21.53% |
| Phase Error | 5.94 grad | 10.90 grad |
| Quadrature Error | -0.0881 grad | |
| Power of Signal | -55.17 dBm | |

The results shown in the table, whereas the distance between the receiver and transmitter is 17.1 km, proves that there is an excellent performance of the system, showing the value of EVM and MER acceptable, though differing from those recommended.

During the measurements, the equipment instantly makes the analysis of the received signals. As it can be observed, the noise causes errors of magnitude EVM of 14.53% and 16.75 dB MER, however despite the noise that has immersed the system, the variations between the ideals values and instantaneous values, and thanks to the channel coding like the convolutional codes, the RS, the error correction mechanism and the type of modulation of ISDB-T, at the instant of decoding the signals exhibits an excellent performance showing the video image on screen without disturbances. Clearly we can see in figure 11 that for the first segment using a QPSK modulation.

Next, Figure 12 shows screen of TMCC, for checking the manner in which it is transmitting the signal the transmitter ECTV.

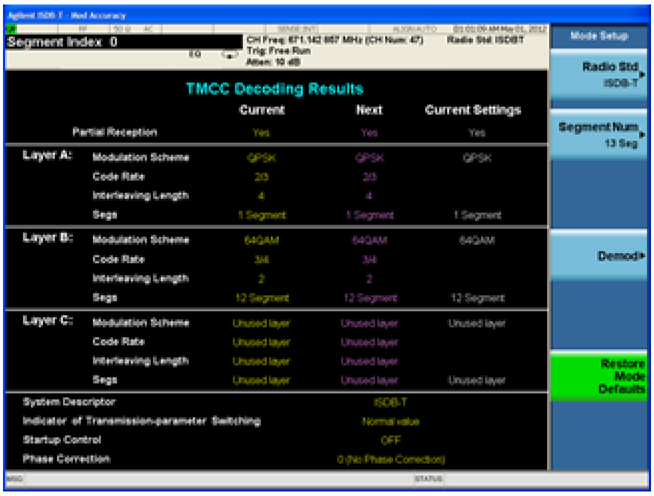


Figure 12 Modulations Accuracy, Segment N° 1 Transmitter ECTV.

## VI. CONCLUSIONS

The transmitter laboratory served as testing to find the actual configuration ECTV transmitter. It was shown in Figure 11 that transmitted work in the mode 3, with a segment in the layer A and twelve segments in the layer B. Also the layer A uses QPSK modulation and layer B uses 64 QAM. The guard interval in this channel is of 1/16 unlike the transmitter of laboratory settings where configure to 1/8.

One way to test the performance of digital modulation in a transmitter of ISDB-T is to measure the modulation accuracy, home values EVM and MER, where it was found that are directly related to the energy of the symbol with respect to the Power Noise, which shows that for constellations with as many as 64-QAM symbols, more energy resulting symbol MER values are more elevated.

Tests with the bandwidth channel, which allow for the calculations made, leaving the channel efficiency of 99%, with 5.57 MHz and 428.57 kHz used separation to the other channels with a total of bandwidth of 6 MHz in the laboratory and transmitter ECTV.

According to the characteristic curves of the transmitters, standard deviation shows no variation with a peak of 13.30 dB, which is an acceptable difference between the ideal curve and measured by the computer. If there is one major difference this would mean a malfunction in the block of pre-amplification and amplification.

Of the most important measurements is the modulation accuracy, parameters such as working with EVM and MER, based on the recommended values as these values show the actual performance of the transmitters. For the case of the two transmitters, the values are acceptable since at the time of decoding the signals, despite the distances and disturbances, there is shown clearly. These values must be 2 or 3 dB above the recommended range to ensure good performance of the same.

According to tests, the channel performance is reflected in the values of MER and EVM. The levels of MER and EVM for when the signal is frozen or distorted when working with QPSK are on average 10 dB. For 17 QAM is For 64 QAM modulations as it uses more power symbol on average are between 22 dB.

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