# POWER AMPLIFIER NON LINEARITES AND PRE-CORRECTION MODULE IMPACT ON DVB-T2 OFDM TRANSMITTER SYSTEM

*Elson Agastra*, Aleksander Biberaj, Elda Mihaj, Bexhet Kamo*

Faculty of Information Technology, Polytechnic University of Tirana
Sheshi Nënë Tereza 1, 1004, Tirana,
Albania

* Corresponding Author, e-mail: eagastra@fti.edu.al

**Abstract:** Modulation Error Rate (MER) is one of the metrics for evaluating Orthogonal Frequency Division Multiplexing (OFDM) transmitter signal quality. Due to high number of sub-carriers of any OFDM transmitter and the high amplitude differences of symbol – to – symbol modulating each sub-carrier, high Peak to Average Power Ratio (PAPR) is common. This paper deals with a real system setup of measuring MER of a DVB-T2 transmitter (Digital Video Broadcasting — Second Generation Terrestrial) operating in Albania territory. The focus is in analyzing transmitter behavior on different power amplifier gain, measuring in-band and out-band signal quality and spurious emission. The importance of pre-distortion is drowned for DVB-T2 transmitters and extended as a conclusion to a more generic OFDM transmitters.

**Key words:** OFDM transmitter; DVB-T2 pre-correction; PA pre-distortion; MER; DVB-T2 MER measurement.

## 1. INTRODUCTION

Most of modern wireless communication technologies are based on OFDM (Orthogonal Frequency Division Multiplexing) signal wave form techniques or enhancements of this technique [1]. OFDM has been a key enabling for most of actual and future wireless communication as 4G LTE (Long Term Evolution), 5G [2-4] for mobile communication, Wi-Fi, Bluetoooth for short range communication, DVB-T/T2, for Multimedia Broadcasting, as to name a few.

In common to all OFDM radio transmitters, is the RF (radio frequency) front end architecture which is composed by the power amplifier and relative band-pass filters and combiners [5-7]. One of the critical issues of OFDM transmitters is the high rate of PAPR (Peak to Average Power Ratio) of modulated signal [8]. Higher differences from multiple signal carriers' amplitude and a finite power amplifier input linearity brings higher modulation errors in the transmitter side. MER or Modulation Error Rate is a key parameter to evaluate signal quality and defined in decibel scale smaller MER values are indicators of poor signal quality.

Reduced MER performance is mostly caused by nonlinear elements in the transmitter chain. Also, higher OFDM sub-carriers increase the possibility to have higher PAPR rates and worst MER performance [9].

Most of the research are carried in the optimization of PAPR or to adapt the transmitter chain to better perform under high PAPR values [9-12]. There are proposals of reducing the transmitter power and consequently, the amplifier to operate in a more linear region. This choice is not widely used due to the reduced amplifier efficiency in the linear region and relative overall power consumption issue [5-7]. Other techniques are based on operating in the baseband signal to add additional information as to predict and reduce the PAPR in RF before the input on the PA (Power Amplifier) [8, 9]. Other techniques are based on filtering the modulated signal and/or combining advanced signal modulations and prediction techniques [10-13]. All those techniques are valid solutions and are based on how to prevent or reduce PAPR values.

The scope of this work is to measure, analyze and interpret the way of operation of an OFDM transmitter in the presence of high PAPR values. The overall transmitter signal quality is being analyzed for different power amplifier gain settings and with TR-PAPR (Tone Reservation-PAPR) reduction technique used [12]. Also, the predistortion module preceding amplifier chain is being analyzed.

In this project, a real DVB-T2 transmitter has been chosen and analyzed to evaluate of reducing transmitter power gain in received signal quality. This work is supported by the Albanian national broadcaster as it is required time by time to reduce transmitted power, especially in good weather conditions as to reduce residual RF power amplitude propagated with not sufficient weather attenuated amplitude outside a designed geographical area.

## 2. OFDM HPA LINEARIZATION AND EFFICIENCY PROBLEM

DVB-T2 transmitters are based on OFDM techniques. Figure 1 presents an example of DVB-T2 multi-band OFDM transmitter connected at the same antenna. The configuration can be quite well any other multi-frequency and multi-band OFDM transmitters as LTE, 5G and similar. The main differences of mobile communication transmitters versus television transmitters can be the overall transmitted power which is relatively smaller than those used in the television broadcasting systems.

In this work the overall transmitter signal quality is being analyzed for different power amplifier gain reduction. Despite, this is not a daily task for DVB-T2 broadcasting systems, time by time is required to reduce transmitted power as to compensate less weather attenuation in UHF frequency band, especially in spring and summer period.

DVB-T2 transmitter are based on OFDM techniques, the analyzed results can be quite well extended to other OFDM services such as LTE, 5G and so on, were changing transmitter power gain can be a more common daily task as to dynamically adapt the coverage area to new added transmitters or to adapt to the overall network load balancing [2-4].

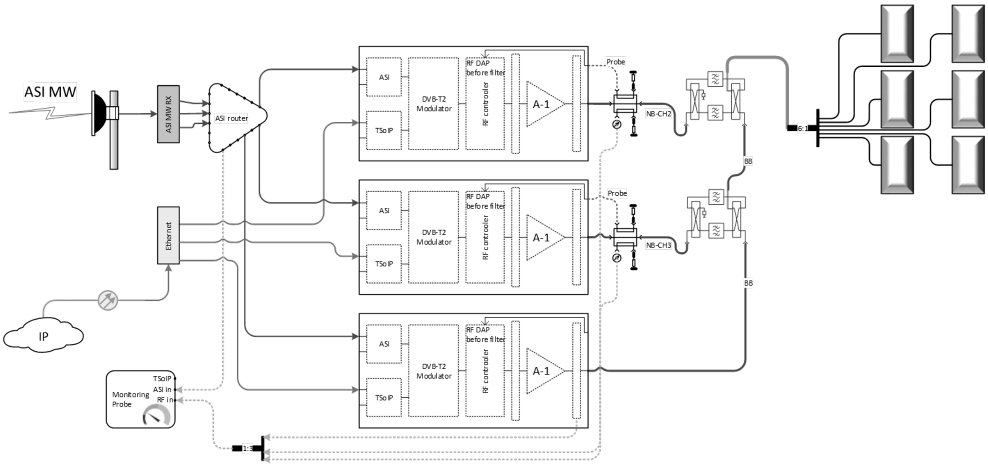


*Fig. 1. Three channel DVB-T2 transmitter chain.*

Amplifier non linearities can be in first approximation classified in two main categories: in band effects and out-band effects [14]. The first category, in band effect, is related to the non-uniform amplification of each symbol, non-linear AM/AM characteristic and not the same phase AM/PM characteristic.

The second category, out of band effect, is a consequence of the first, and a raising of spectrum shoulder is observed due to intermodulation of various sub-carriers caused by non-linear AM/AM and AM/PM characteristics of PA.

Both this effect brings an increase in intersymbol interference and consecutively a reduction of MER performance. Higher non linearities values corresponds to higher modulation errors and smaller MER values expressed in dB as by equation (1).

$$MER = 10 \times \log_{10} \left\{ \frac{\sum_{j=1}^{N} \left( I_j^2 + Q_j^2 \right)}{\sum_{j=1}^{N} \int \left( \delta I_j^2 + \delta Q_j^2 \right)} \right\} \tag{1}$$

Where *I* and *Q* are respectively In Phase and In Quadrature digital signals. The nominator is the sum over *N* received symbols in a period of time of the expected Phase and Quadrature values. In the denominator is expressed the sum of the error of the real received symbol to the expected one. This parameter can be roughly seen as ration of signal power over signal error. Higher MER values are indicators of small errors and higher digital signal quality.

To reduce the non-linearities effect, the PA can be set in a working point of more linear region, even with input amplitude variation of up to 10 dB due to PAPR of the OFDM signal. This approach is not practical due to a reduced PA efficiency approximately of 20% for class A or AB amplifier [14-16].

A more intelligent and efficient approach is to use pre-correction techniques with PAPR reduction techniques. In this approach, a predistortion on digital symbols can be applied as to compensate in advance the non-linearities of the power amplifier. To realize the predistorter logic, different approach can be used, but the main logic is the same: feedback approach of sampling PA output and estimating PA input as to inverse reproduce amplifier nonlinearity [17, 18].

To better understand the linearization of the actual configuration, let refer to the schematic presented in figure 2.

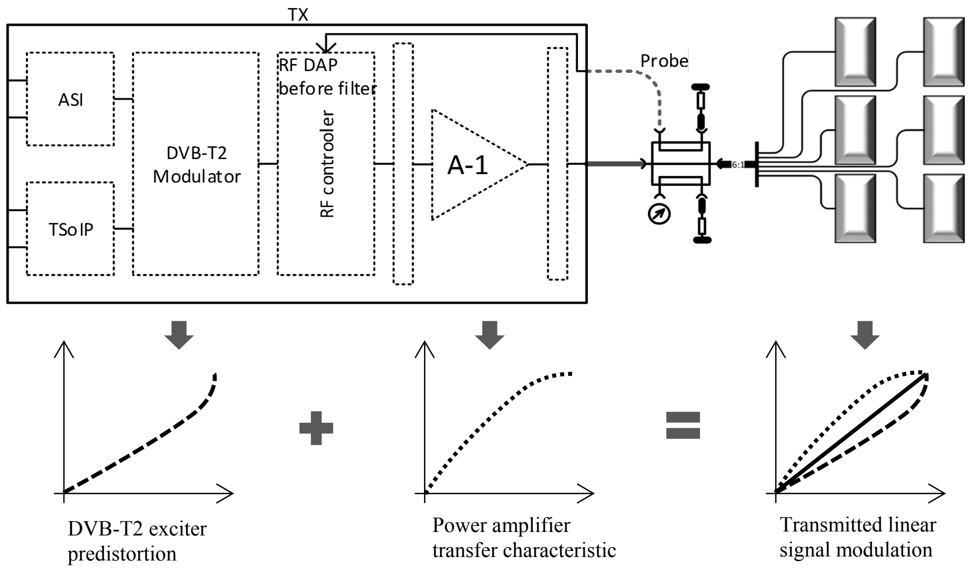


*Fig. 2. Logical concept of predistortion behaviour.*

In common to all non-linearities estimator and pre-correction modules is the increase transmitter complexity and a time-consuming task of propagating PA output and estimating its non-linearity for each sub-carrier of OFDM signals [19, 20].

It is worth noting that the performance of various PAPR reduction techniques is not analyzed during those test cases. What we wanted to accomplish is to evaluate/measure signal quality in the receiver and the influence of amplifier gain change [21, 22]. During those tests, TR-PAPR technique has been used in the transmitter configuration. PAPR reduction techniques and their impact on signal quality can be found in numerous literatures [8-13].

## 3. MEASUREMENTS AND ANALYSIS

In this project, a live operation of DVB-T2 transmitter was analyzed and configuration changes are performed, and relative transmitted signal was monitored. The chosen DVB-T2 transmitter operates at 578 MHz frequency channel with 1140W RMS transmitted power as nominal value. Based on live system monitoring of residual energy transmitted outside the SFN area, increase values are recorded when very low atmospheric loss is present. In this case is required from the operator to reduce the overall transmitted power, especially in springer and summer period.

Transmitter monitoring and configuration interface used by the Albanian National TV broadcaster is presented in figure 3.

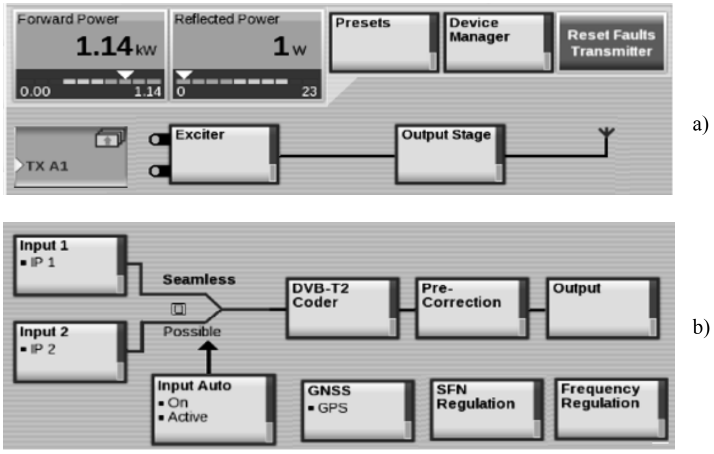


*Fig. 3. Transmitter configuration: a) Exciter -> PA; b) Exciter configuration.*

Figure 4 presents the transmitter interface to check and set the RF transmitted power as percentage of amplifier nominal value. Also, at the same interface, can be monitored the overall power amplifier efficiency as shown in figure 5. In this case, operating the PA at it nominal power output of 1.15kW, an efficiency of 37.5 % is noticed. This means that the overall consumed power for this transmitter is approximately 3 kW.

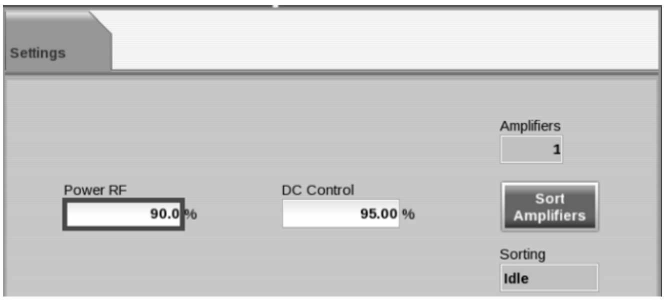


*Fig. 4. Transmitter power change interface.*

Power amplifier efficiency as shown in figure 5 is defined in equation 2.

$$\eta = \frac{P_{out}}{P_{dc}} \times 100 \qquad (\%) \qquad (2)$$

Where $P_{out}$ is the radiofrequency signal transmitted power at amplifier output and $P_{dc}$ is the DC (Direct Current) overall power consumed by the amplifier.

Reducing the amplifier gain as to work in a more linear region of the PA is not an approach as the overall efficiency will dramatically drop down.


*Fig. 5. Monitoring and relative efficiency for two active transmitters.*

As the DVB-T2 system analyzed is OFDM standard with 32k-ext sub-carriers (27841 – sub-carriers), the MER parameter is measured for all of them and graphically are presented in figures 6 to 9 as merogram graphic of the locked signal.

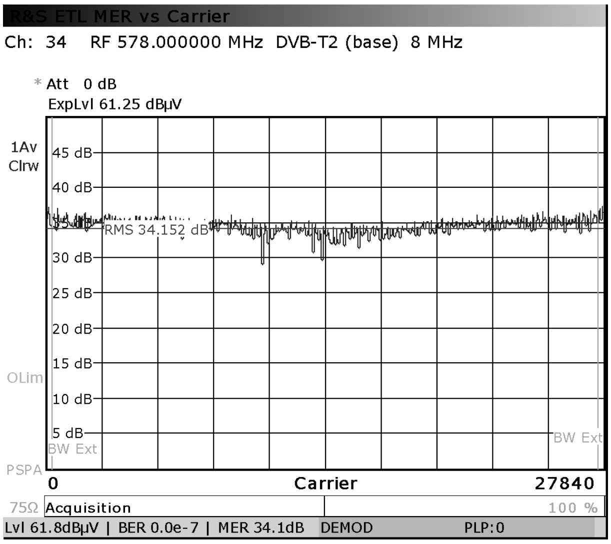


*Fig. 6. Merograma with transmitted power level at 90%.*

In Figure 6 is shown merogram for 90% of nominal transmitted power and RMS (root mean square) of MER = 34.152 dB is observed. In the same windows is displayed the received signal level of 61.8dBuV.

Reducing transmitted power to 80%, a new merogram is recorded and displayed in figure 7 where its RMS value is 33.448 dB and signal strength of 61.3dBuV. From this can be highlighted that a power reduction of approximatively 0.5dB (from 90% to 80%) results in MER reduction of 0.7dB.

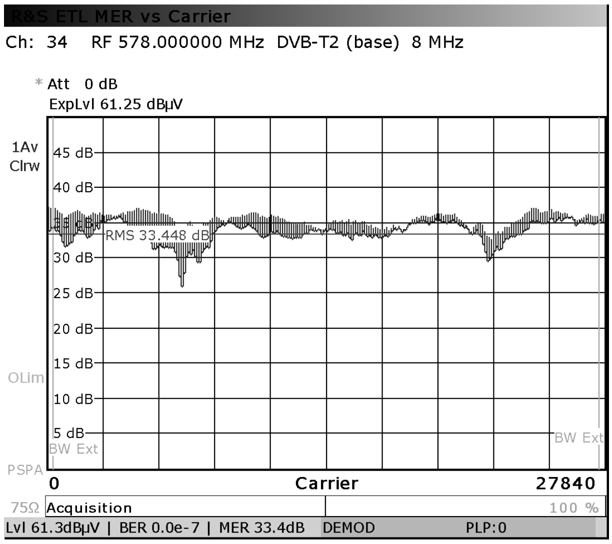


*Fig. 7. Merograma with transmitted power level at 80%.*

Reducing transmitted power to 70% of nominal value, compared to the 90%, a received signal strength of 60.8dBuV and MER 31.563 is observed. Both parameters present a reduction of 1dB for received power and 2.6dB for MER relatively to the 90% transmitted power. The relative merogram for this case is presented in figure 8.

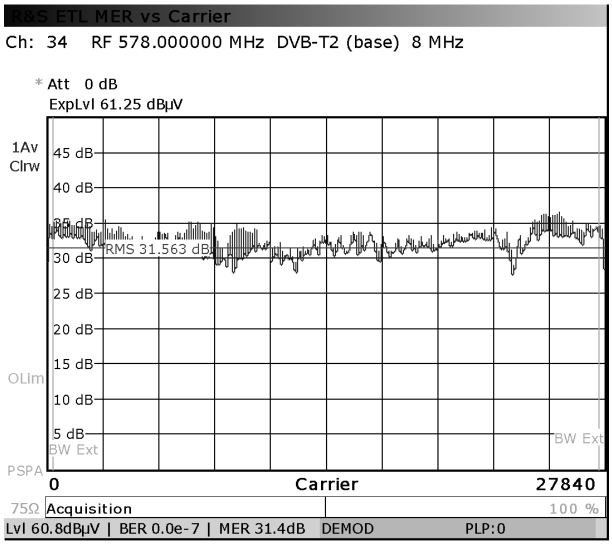


*Fig. 8. Merograma with transmitted power level at 70%.*

Another power reduction to 60% of the nominal value, presented in figure 9, is measured as 1.7 dB less received signal level and 5.6dB for MER referred to the 90% transmitted power.

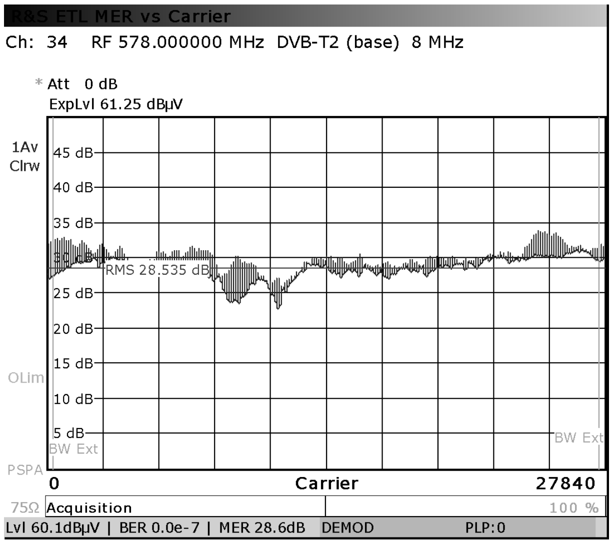


*Fig. 9. Merograma with transmitted power level at 60%.*

The setup has been tested 10 times on different weather conditions and the behavior is the same in all cases. Differences of ±0.1 dB has been observed of received signal strength and. ±0.5 dB for MER for all those tests. The measured numerical values are those presented in table 1.

*Table 1. MER & received signal level with relative tolerance in 10 tests setup.*

| **RF power to nominal value** | **Received power ±0.1 (dBuV)** | **MER ±0.5 (dB)** | **MER after precorrection ±0.5 (dB)** |
|---|---|---|---|
| 90% | 61.8 | 34.15 | 34.15 |
| 80% | 61.3 | 33.45 | 34.10 |
| 70% | 60.8 | 31.56 | 33.51 |
| 60% | 60.1 | 28.54 | 32.85 |

In the same setup, as we expected, changing transmitted power, will operate the power amplifier in different regions of the transfer characteristics. This also implies the transmitted power outside the defined frequency band can vary to. In this case, the upper and lower shoulder attenuations (SA) are recorded and presented in table 2. In harmony with MER analysis, SA have the same behavior, where an overall worsening system performance is observed.

*Table 2. Mean shoulder attenuation (SA) for all tests.*

| RF power to nominal value | Upper SA (dB) | Lower SA (dB) |
|---|---|---|
| 90% | 40.2 | 49.8 |
| 80% | 38.0 | 49.3 |
| 70% | 34.5 | 43.2 |
| 60% | 29.3 | 32.3 |

For OFDM transmitters, reducing transmitted power does not change only the signal level, but also, due to amplifier non linearities, changes modulation quality (MER) and outside band spurious radiation.

In all test cases analyzed, if transmitted power change, is followed by precorrection phase, a better MER and SA are observed. Precorrection phase, needs up to 5 minutes to perform for this particular transmitter.

## 4. CONCLUSION

In OFDM transmitters, due to high PAPR values, the linearity of power amplifiers is one of the major issues in transmitted digital signal quality. Different techniques exist to reduce the PAPR issue, even nonlinear amplifiers are used, but their use is not sufficient to overcome signal quality degradation.

The precorrection techniques used to predistort the digital signal as to have the opposite nonlinearity transfer characteristics of the power amplifier, is an efficient method to reduce nonlinearity issues in signal quality.

Reducing power amplifier working point to a more linear transfer characteristics, not necessary, the overall transmitted signal has better digital quality and better MER despite using the amplifier at a more efficiency region. This is caused by high peak signal variations and the use of predistortion modules tends to equalize the amplifier non linearities at the working point of transfer function. Changing transfer function working point by reducing input power to the PA will result in different nonlinear transfer function, and the predistortion recorded analysis is not more sufficient to equalize the new working point.

To maintain high transmitted signal quality, is recommended that the predistortion function to be periodically performed, especially in case of transmitted amplifier working point modifications. This behavior, despite is tested in DVB-T2 transmitters, is common to all OFDM transmitters.

Predistortion evaluation is a time-consuming task as requires monitoring transmitted signal on each sub-carrier and relative amplitude and phase variation to better estimate power amplifier non linearities. For DVB-T2 transmitters, the required time for predistortion evaluation is not a major issue as the power change are rare and can be in force for months. For other types of OFDM transmitter such as LTE, 5G networks and other OFDM transmitter that uses Multiple Antenna Beam Forming, the required time to equalize the non-linearities of the PA may be comparable to the required power change time.

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### *Information about the authors:*

**Elson Agastra** – Associate Professor at Polytechnic University of Tirana, Faculty of Information Technology, Department of Electronic and Telecommunications. Main research area is on wireless communication systems related to broadcast platforms and antenna design.

**Aleksander Biberaj** – Associate Professor at Polytechnic University of Tirana, Faculty of Information Technology, Department of Electronic and Telecommunications. Main research area is on telecommunication project managements and R&D coordination.

**Elda Mihaj** – Graduated student in Telecommunication Engineering at Polytechnic University of Tirana, Faculty of Information Technology, Department of Electronic and Telecommunications.

**Bexhet Kamo** – Professor at Polytechnic University of Tirana, Faculty of Information Technology, Department of Electronic and Telecommunications. Main research area is on radar system and more in general in radiofrequency systems

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