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DVB-T2 MISO System Influenced by I/Q-Errors in Mobile and Portable Transmission Scenarios

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***Abstract*—The Second Generation Digital Video Broadcasting Terrestrial (DVB-T2) system is the only DVB standard that supports the multiple-input single-output (MISO) transmission technique. This paper explores the performance of the DVB-T2 MISO system under laboratory conditions, focusing mainly on the impact of imperfections in the Orthogonal Frequency-Division Multiplexing (OFDM) modulator, referred to as *I/Q*-errors. Next, special broadcast channel conditions are emulated using different channel models created for mobile and portable transmission scenarios. The measurement setup is designed for flexibility, enabling easy interchangeability of measurement equipment (e.g., TV signal analyzers) and set-top boxes (STBs). The results indicate that different professional measurement instruments measure the performance of DVB-T2 MISO systems in terms of objective parameters with different accuracy.**

***Index Terms*—BER, DVB-T2, I/Q–errors, MISO, MER, transmission scenarios, QEF.**

I. INTRODUCTION

The multiple-input single-output (MISO) transmission technique is one of the key features supported by the Second Generation Digital Video Broadcasting Terrestrial (DVB-T2) system [1]. In DVB-T2, the MISO technique enhances coverage and improves the performance of Single Frequency Networks (SFNs) [2], [3] due to own transmit diversity in overlapping service coverage areas. Furthermore, transmission paths between transmitters (TXs) and the receiver (RX) often have varying conditions (line-of-sight, echoes), which, in some cases, can reduce the requirement on carrier-to-noise ratio $\mathrm{C/N}$ [4]. However, the use of MISO-based signal requires advanced signal processing on the RX side [5]–[7].

Over the past decade, numerous works have focused on the performance study of the DVB-T2 MISO system under various transmission scenarios [8]–[15]. Simulation-based performance analysis of the DVB-T2 MISO system, emulating different transmission scenarios with various fading channel models, was presented in [8]–[10]. These studies shown better performance of MISO diversity, in terms of bit and modulation error ratio (BER and MER), compared to conventional DVB-T2 SISO configuration. However, these simulations did not address potential power imbalances between TXs or other errors in the radio frequency (RF) chain.

Laboratory and field measurements of the DVB-T2 MISO system were conducted and reported in [11]–[15]. The outputs of these studies generally validated the simulation-based results, highlighting that MISO diversity gain in SFNs is significantly affected by the conditions in transmission channels, selected DVB-T2 MISO system configurations, transmission scenarios (fixed, mobile, portable), and by power imbalances between TXs. However, the impact of Imbalance and Quadrature (*I/Q*-errors) in the Orthogonal Frequency Division Multiplexing (OFDM) block of the DVB-T2 MISO system has not been extensively explored. To the best of our knowledge, only the study presented in [15] examined the DVB-T2 MISO system under different fixed reception scenarios influenced by *I/Q*-errors. This study confirmed that such errors can not be ignored for DVB-T2 MISO configuration employing high M-order quadrate amplitude modulation (M-QAM).

Contribution: The aim of this paper, compared to previous studies, is twofold. First, it presents a measurement-based performance analysis of the DVB-T2 MISO system under the influence of various *I/Q*-errors in the OFDM modulator of TX_1 for mobile and portable transmission scenarios. These scenarios are emulated by using Typical and Rural Urban (TU6 and RA6), and Personal Indoor and Outdoor (PI3 and PO3) fading channel models [16]. Second, this paper explores the DVB-T2 MISO system performance using different measurement equipment and set-top-boxes (STBs). It aims to identify DVB-T2 compatible measurement devices that may not adequately support the MISO signal configuration. The results presented in this paper are based on the findings provided in [17].

This paper is organized as follows. Section II provides a short overview of the considered DVB-T2 MISO transmission scenario. The laboratory measurement setup and methodology are described in Section III. The results are analyzed in Section IV. This paper concludes with the Section V.

II. DVB-T2 MISO TRANSMISSION SCENARIO

The DVB-T2 MISO network considered in this work (see Fig. 1) is based on our previous studies [13], [14]. The configuration consists of two TXs and a single RX. The correlation between the signals radiated by TX_1 and TX_2 is suppressed by employing of the modified Alamouti coding [1].

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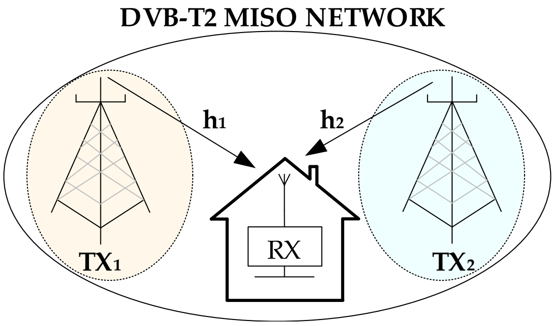


Fig. 1. DVB-T2 MISO network (based on [14]).

In this study, we assume that the transmission path h_1 is affected by various *I/Q*-errors resulting from amplitude and phase imbalances [1] in the OFDM modulator of TX_1. For the transmission path h_2, the channel conditions are modeled as Additive White Gaussian Noise (AWGN), effectively representing a strong connection between TX_2 and RX. Next, we consider zero power imbalance between TX_1 and TX_2 ($\Delta P = 0\,\text{dB}$), which further do not influence the overall performance of the MISO-based system.

III. DVB-T2 MISO Measurement Setup

The basic block diagram of the measurement setup, originally introduced in [15], [17], is shown in Fig. 1. The TX_1 and TX_2 transmitters are represented by the SFU and SFE DVB-T2 signal generators from Rohde & Schwarz (R&S) [18], which are used to generate the DVB-T2 MISO signal. To ensure proper synchronization, both signal generators must be precisely aligned at the modulator interface (T2-MI) level, using a $10\,\text{MHz}$ reference clock and a 1pps signal [14]. For the DVB-T2 MISO broadcasting, the transport stream (TS), configured according to the selected system settings (see Table I valid for both signal generators), is generated in the SFU generator using the video TS option. The power levels of the signals generated were set to $P_{\text{TX}_1} = -35\,\text{dBm}$ and $P_{\text{TX}_2} = -35\,\text{dBm}$ in the SFU and SFE signal generators, respectively. These signals are RF modulated and combined using a TEROZ T 226 K RF signal combiner. Throughout the measurements, the C/N values are simultaneously adjusted on both SFU and SFE signal generators. For the transmission path h_2, generated by the SFE, the AWGN channel model is permanently applied. The SFU signal generator supports the configuration of various *I/Q*-errors and fading channel models, while the SFE permits only varying the C/N values.

In the OFDM-based modulation process, the signal undergoes RF modulation utilizing an *I/Q* modulator. During this process [15], the *I* component is multiplied by a cosine signal, while the *Q* component is multiplied by a sine signal. It is crucial to maintain precise amplitude ratios and phase alignment between the *I* and *Q* signal paths. Any deviations can result in two main types of *I/Q*- errors, which may occur separately or simultaneously: Amplitude Imbalance (AI) – if the amplitude levels of the *I* and *Q* signal paths are unequal. Phase Imbalance (PI) – when the phase difference deviates from the ideal 90° alignment [1], [15], [17]. In this study, the following *I/Q*-errors were emulated: AI $= 10\%$, AI $= 10\%$ and PI $= 10°$.

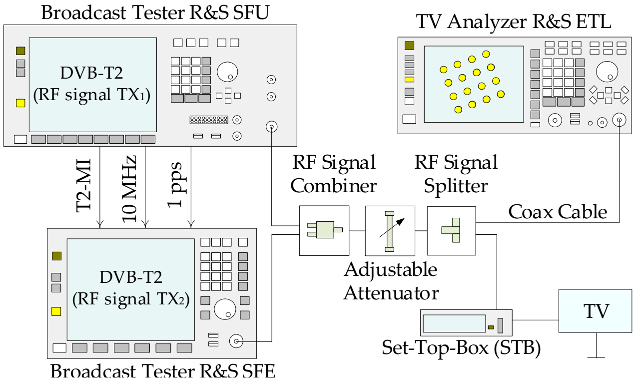


Fig. 2. Measurement of the DVB-T2 MISO signal (based on [14]). As mentioned in Section III, different equipment and STBs were used in the measurement.

TABLE I: System parameters of the measured DVB-T2 MISO signals

Parameter	Portable Scenario	Mobile Scenario
Frequency	570 MHz	570 MHz
OFDM mode	16 K-extended	4 K
Guard Interval (GI)	1/8	1/8
Code Rate (FEC)[a]	1/2	2/3
FECFRAME length	64 800 bits	64 800 bits
Pilot Pattern (PP)	PP1	PP2
Inner-Modulation	16-QAM	QPSK
Constellation rotation	Yes	Yes
I/Q-errors	AI, AI & PI	AI , AI & PI
Channel model	AWGN, PI3, PO3	AWGN, RA6, TU6

[a] Forward Error Correction

The DVB-T2 RF signal, via an adjustable attenuator, is received at the side of RX and divided into two paths. The first path leads to equipment for measuring various objective parameters, such as BER and MER. In this work, three different devices were used [15]: the R&S ETL TV analyzer, the Sefram TV analyzer, and the DVMS1 DTV monitoring system. The second path, via a STB, is connected to a TV for monitoring the Quasi-Error Free (QEF) reception condition [1]. For the STB testing, three models were used [15]: the Thomson THT712, the Sencor SDB 5002T, and the STC6000HD PVR.

IV. Results

The results obtained from the laboratory measurements are presented graphically in Figs. 4 – 6. According to the studied transmission scenarios, the measurements were divided into three scenarios. First scenario, also labeled as the reference scenario, represents a situation when the TV signal broadcast is not affected by any errors in the *I/Q* modulator. The second scenario emulates the occurrence of AI with a value of 10%. Finally, worst case scenario represents the most adverse conditions, when both AI and PI occur simultaneously, with values of 10% and $10°$, respectively.

TABLE II: Required $\mathrm{C/N}$ in unit of dB for QEF reception at different transmission scenarios

Channel model	*I*/*Q*-errors	STB			Measurement Equipment		
		Thomson	Sencor	STC	ETL	Sefram	DVMS1
RA6	no *I*/*Q*-errors	14	14	14	13	14	14
	$\mathrm{AI} = 10\%$	14	14	14	13	14	14
	$\mathrm{AI} = 10\%\ \&\ \mathrm{PI} = 10°$	14	14	14	13	14	14
TU6	no *I*/*Q*-errors	12	13	12	13	12	12
	$\mathrm{AI} = 10\%$	12	13	12	13	12	12
	$\mathrm{AI} = 10\%\ \&\ \mathrm{PI} = 10°$	12	13	12	13	12	12
PI3	no *I*/*Q*-errors	7	7	6	8	6	6
	$\mathrm{AI} = 10\%$	7	7	7	8	7	7
	$\mathrm{AI} = 10\%\ \&\ \mathrm{PI} = 10°$	7	7	6	8	7	6
PO3	no *I*/*Q*-errors	7	7	6	8	6	6
	$\mathrm{AI} = 10\%$	6	7	6	8	7	6
	$\mathrm{AI} = 10\%\ \&\ \mathrm{PI} = 10°$	7	7	7	8	7	6

The objective-based performance of DVB-T2 MISO broadcasting for the mobile transmission scenario, modeled using RA6 and TU6 channel models and influenced by *I*/*Q*-errors, are shown in Fig. 3 and Fig. 4. The results, similarly as in [15], clearly show that the simultaneous presence of AI and PI in the *I*/*Q* modulator has the most significant influence on the measured BER and MER values. This impact is particularly visible for the RA6 fading channel model, which exhibits higher BER and lower MER values. This behavior is primarily attributed to the characteristics of the RA6 channel model and the higher Doppler shift, as the movement of RX is considered approximately $\mathrm{v} = 100\,\mathrm{km/h}$ [16]. On the other hand, no significant differences were observed between the RA6 and TU6 channel models regarding the number of FEC decoding iterations per FECFRAME [1].

The measurement for the mobile transmission scenario also raveled that the Sefram TV analyzer and DVMS1 DTV monitoring system are not fully suitable for long-term DVB-T2 MISO signal measurements in terms of BER and MER parameters. In the case of the DVMS1 DTV monitoring system, this limitation arises because this device is primarily designed for monitoring the video transport stream and not for long-term measurements on the physical layer of the DVB-T2 MISO system. On the other hand, this shortcoming for the Sefram TV analyzer may be due to the absence of the advanced measurement profiles (e.g., mobile profiles), which, among other measurement profiles, are fully supported by the R&S ETL TV analyzer.

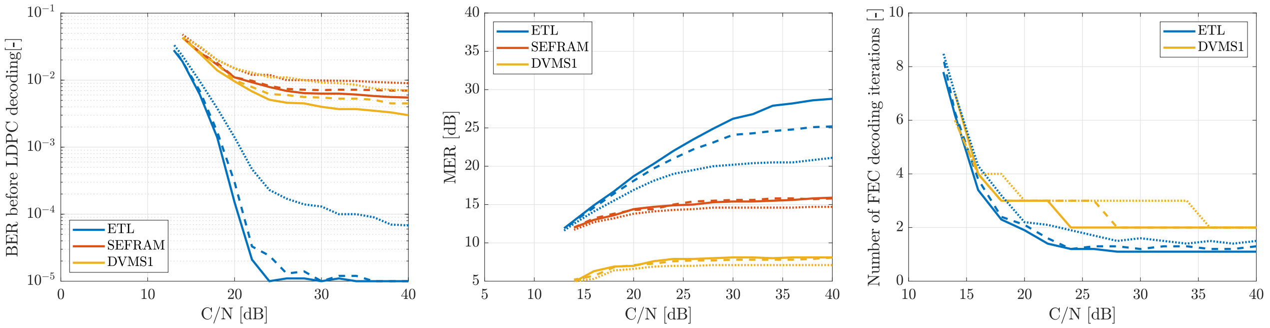
The same measurements were conducted for portable scenarios and the results are plotted in Fig. 5 and Fig. 6. There were used the PI3 and PO3 channel models to emulate slowly moving ($\mathrm{v} = 3\,\mathrm{km/h}$) of the RX at indoor and outdoor reception of the TV signal, respectively [16]. As seen in the results, this characteristic is reflected by the BER and MER measurements, even with 16-QAM inner modulation. There is not much difference between the BER and MER curves for the PI3 and PO3 channel models due to their similar channel model profiles and the system configuration considered.

As in the the previous measurements, the simultaneous occurrence of $\mathrm{AI} = 10\%$ and $\mathrm{PI} = 10°$ had a noticeable impact on the results. Once again, the DVMS1 DTV monitoring system provided the least accurate results. However, the Sefram TV analyzer measures with similar accuracy as the professional R&S ETL TV analyzer. On the other hand, similar to the previous findings, the Sefram TV analyzer lacks the ability to measure the number of FEC decoding iterations due to the absence of this feature. The higher number of FEC decoding iterations observed in this measurement (see Fig. 5) is due to the use of 16-QAM modulation.

A comparison of the $\mathrm{C/N}$ values required for Quasi-Error Free (QEF) reception [1], [19], [20], when BER after FEC is $\leq 10^{-7}$, is shown in Table II. This table includes $\mathrm{C/N}$ values obtained through two approaches: objective measurement (performed using various measurement equipment) and subjective assessment (based on the picture quality observed on TV). In most cases, there are no significant differences between the results from professional measurement devices and STBs. Among the STBs tested, the STC6000HD PVR showed the best performance. Although the DVMS1 DTV monitoring system achieved the best results in terms of QEF monitoring, its BER and MER measurements indicate that these results should be interpreted with caution.

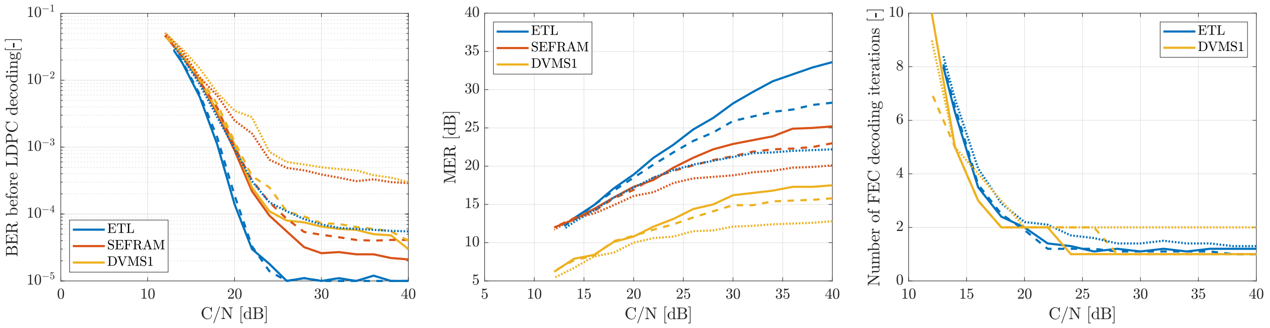
V. CONCLUSION

This paper presented a performance study of the DVB-T2 MISO signal for special mobile and portable transmission scenarios, considering various errors that may occur in the *I*/*Q*-modulator of one of the TXs. Different measurement devices and STBs were utilized during the measurements. The results revealed that the performance of the DVB-T2 MISO system is minimally affected when AI is the only error in the *I*/*Q*-modulator. The worst case scenario arises when both AI and PI occurs simultaneously. Furthermore, it was shown the importance of selecting appropriate equipment for the long-term measurement and evaluation of the DVB-T2 MISO signal to ensure accurate and reliable results.



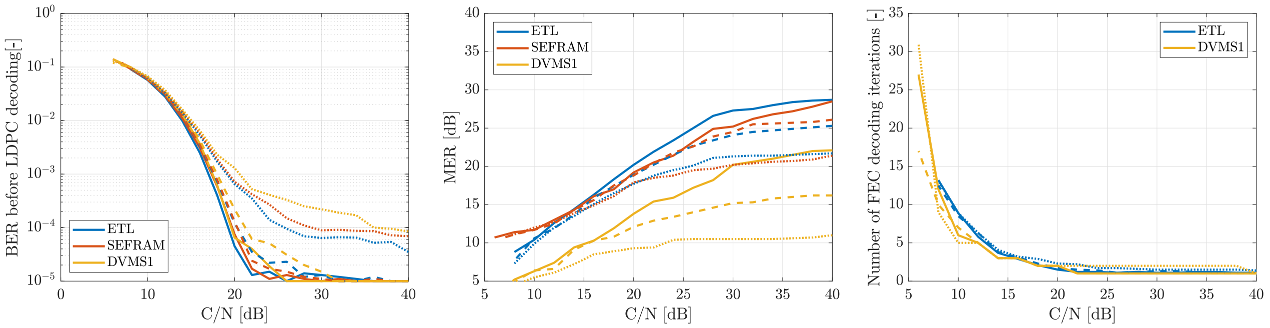
(a) BER vs C/N (b) MER vs C/N (c) Number of FEC decoding vs C/N

Fig. 3. RA6 channel (solid lines: no *I/Q*-errors, dashed lines: AI = 10%, dotted lines: AI = 10% and PI = 10°).



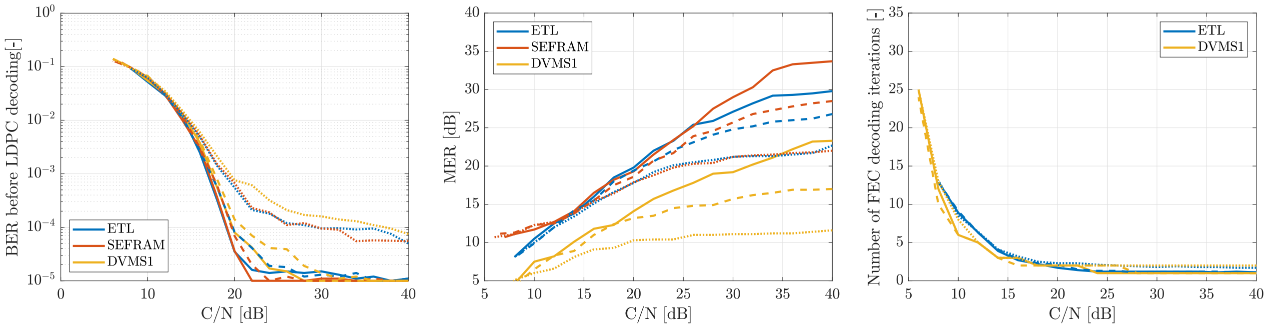
(a) BER vs C/N (b) MER vs C/N (c) Number of FEC decoding vs C/N

Fig. 4. TU6 channel (solid lines: no *I/Q*-errors, dashed lines: AI = 10%, dotted lines: AI = 10% and PI = 10°).



(a) BER vs C/N (b) MER vs C/N (c) Number of FEC decoding vs C/N

Fig. 5. PI3 channel (solid lines: no *I/Q*-errors, dashed lines: AI = 10%, dotted lines: AI = 10% and PI = 10°).



(a) BER vs C/N (b) MER vs C/N (c) Number of FEC decoding vs C/N

Fig. 6. PO3 channel (solid lines: no *I/Q*-errors, dashed lines: AI = 10%, dotted lines: AI = 10% and PI = 10°).

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