DELIVERABLE D11.2

NGH-PH.1 LAB TEST REPORT

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EXECUTIVE SUMMARY

This document describes the results of the laboratory measurements carried out in TF11, to test the prototypes developed in TF10 that implement “NGH-Phase1” features, as described in ENGINES deliverable D10.2: “Identification and Specification of "NGH-Ph.1" Prototypes to be Built” [1]. These laboratory tests are based on the thorough planning described in ENGINES Technical Report TR11.2 "NGH-Ph.1 Lab Tests Validation Plan” [2].

The main goals of the laboratory tests are focused on testing the “NGH-Phase 1” new features (T2-Lite & SC-OFDM) implemented by the prototypes developed in TF10. The T2-Lite features are validated in a full simulated chain, checking the HW interoperability of the equipment from different providers and checking that the prototypes fulfill the specifications defined in the standard. Regarding the SC-OFDM feature, the purpose of the test is to assess the suitability of the SC-OFDM modulation for satellite broadcasting towards handheld terminals. Besides, in these laboratory tests some channel propagation models have been emulated to validate the performance of the prototypes in different reception scenarios.

Section 1 presents a general introduction of the laboratory tests.

Section 2 describes the laboratory measurements carried out to test the T2-lite features. Firstly, a general description of the tests and the equipment to be used is described, including some logistic information of the plug fest. Subsections 2.8 to 2.11 describe the specific measurements carried out in the T2-Lite tests and the mixed T2-Base/T2-Lite tests, both in MFN and SFN scenarios. For each test, the configuration modes and the channel models tested are defined. Afterwards, the set-up of the equipment used is described. The measurement methodology used in each test is also explained, and the results and conclusions of the test are presented.

Section 3 describes the SC-OFDM evaluation for satellite segment, including a general overview of the test, the description of the prototype, the set-up and the test procedure. Regarding the results and conclusions obtained, it should be noted that the platform developed for testing the SC-OFDM feature was based on a new board. Due to a few hardware issues met in the development of the board firmware, the design of the system has been completed just by the end of the project. Therefore, it has not been possible to carry out all the SC-OFDM measurements as initially planned and, in this deliverable, only the initial results are provided.

The T2-Lite new features laboratory sessions were carried out in Barcelona (Spain) between the 17th and 18th September 2012 and the SC-OFDM laboratory session took place in Rennes (France) in the first weeks of December 2012.

LIST OF CONTRIBUTORS

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1 INTRODUCTION

The laboratory sessions from TF11 were dedicated to the NGH-Ph.1 new features. The main objective of these tests was to check the HW interoperability of all the prototypes from TF10 by testing them with an emulated Gaussian channel profile. Moreover, it is necessary to guarantee their correct operation for the posterior TF12 field trials by testing the equipments also with portable and/or mobile channels. The prototypes described in D10.2 [1] that have been evaluated in the laboratory measurements are presented in *Table 1.1*:

Table 1.1. TF10 prototypes tested.

Id.	***Prototype***	***Provider***
P.1	T2 Modulator	TeamCast
P.4	T2 Transmitter	Mier
P.5	T2 Gap-Filler	Mier
P.7	SC-OFDM Evaluation Platform	MERCE
P.8	T2 Gateway	Enensys
P.11	T2 Demodulator	UPV/EHU

Considering the Deliverable D10.2, the new features to test that should be considered for validation are presented in *Table 1.2*:

Table 1.2. "NGH Phase 1" features to test.

Id.	***NGH Phase 1 FEATURE***
Test 1	T2-Lite FEF, with support of T2-MI rel 1.3.1
Test 2	Mixed T2 and T2-Lite
Test 3	T2-Lite in SFN networks
Test 4	Mixed T2 and T2-Lite in SFN networks
Test 5	SC-OFDM for satellite segment

The four first tests were related to the new features of the T2-Lite standard while the last one was related to the SC-OFDM modulation. For this reason, the tests were divided in two different blocks. The first one included tests from 1 to 4 and will be named as "*T2-Lite new features plug fest*" from this point. The other one included test 5 and will be named as "*SC-OFDM plug fest*" from this point.

2 T2-Lite New Features Plug Fest

2.1 Description

The inclusion of T2-Lite in the DVB-T2 standard has supposed a new profile with new features, such as the effect of *post-scrambling* and *subslicing* as well as the new code-rates that increase the robustness of the transmitted signal.

Besides, mixed modes are now a reality, transmitting T2-Base and T2-Lite at once so as to transmit different contents with different modulations depending on its use. One of the parts will usually be a high data rate content that should be correctly received at fixed points. For this reason, the T2-Base with big constellation sizes will be used for this part. Low data rate contents will also be transmitted in order to be correctly received in mobility. In this case, the T2-Lite standard will be used, increasing the robustness of the transmitted signal with new code-rates.

Considering these novelties, four different tests related to the T2-Lite standard were carried out during this plug fest. The main goal of these laboratory measurements was to test some of the new features of T2-Lite both in MFN (*Multiple Frequency Networks*) and in SFN (*Single Frequency Networks*). Besides, a mixed T2-Base and T2-Lite mode was also tested in both MFN and SFN as well.

The main objective of the four tests was to check the HW interoperability of all the prototypes from TF10 by testing them with an emulated Gaussian channel profile. Moreover, as it was necessary to guarantee their correct operation for the posterior TF12 field trials, some of the equipments were also tested with portable and/or mobile channels.

Figure 2.1.1 resumes the main characteristics of the four tests about T2-Lite new features in MFN and SFN, including general information about the configuration modes for each test. Besides, the number of equipments that will be tested for each channel model to be tested and each main goal are also included. In SFN tests, two different measurements will be carried out: one with a transmitter for the secondary transmission and another one with a gapfiller for the secondary transmission.

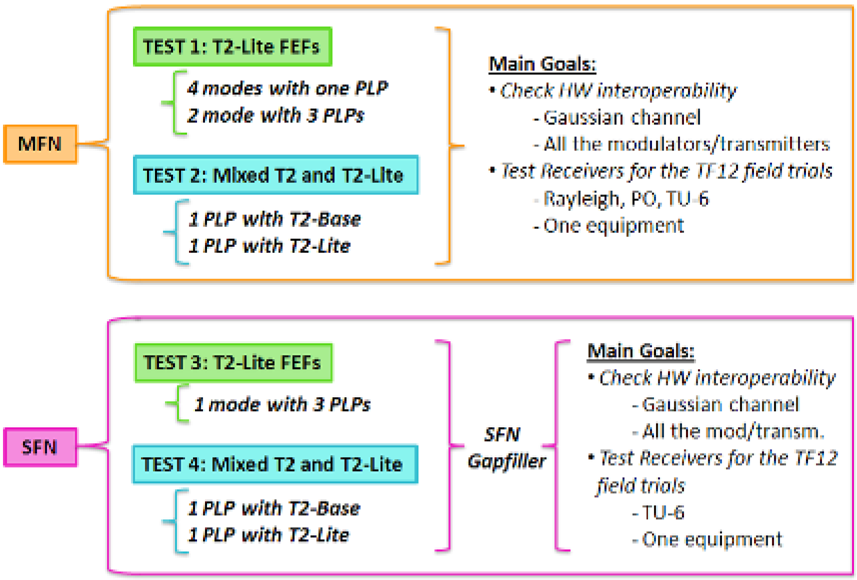

Figure 2.1.1. Main characteristics of the T2-Lite new features plug fest

2.2 Equipment

Regarding the transmission side, there was a modulator from TeamCast and a transmitter from Mier and there were only two gateways from Enensys. Both modulator/transmitters were tested with the Gaussian channel in all the four tests, but only the Mier transmitter was tested for all the other channel profiles (Rayleigh, PO, TU-6) as it has the same TeamCast modulator inside and it is better to obtain reference values for the field trials with the same transmitter that was going to be used then.

The propagation channels were simulated using the Radio Channel Emulator provided by Turku University of Applied Sciences.

Regarding the reception side, there was only a demodulator from the University of the Basque Country (UPV/EHU). However, another one was also used during the plug fest so as to have reference values to compare with the UPV/EHU demodulator. This receiver was tested and validated in the DVB *T2-Lite Plug Fest* in Paris (March 2012). It will be named as "*Receiver B*" in this document.

2.3 Threshold values

The threshold criterion for the DVB-T2 performance measurements is typically defined as Quasi Error Free (QEF) reception. That corresponds to a BER = 10^{-11} at the TS data level at the input of the MPEG-2 demultiplexer.

Due to the measurement time required to obtain BER = 10^{-11} values and considering the measurement capabilities of the UPV/EHU demodulator, the threshold criterion was set as FER = 0 after BCH. When errors are detected, the FER after BCH value turns in red in the measurement screen, while when the reception is correct, this value remains green as it can be seen in the top part of *Figure 2.2*.

Alternatively, the threshold criterion for the Receiver B was set to a reception with no TS packets with errors during a period of about 20s. When errors happen, some "*Unknown*" information appears as it can be seen in the down part of *Figure 2.3.1*.

These threshold criteria have been used in the four tests to obtain the minimum C/N required.

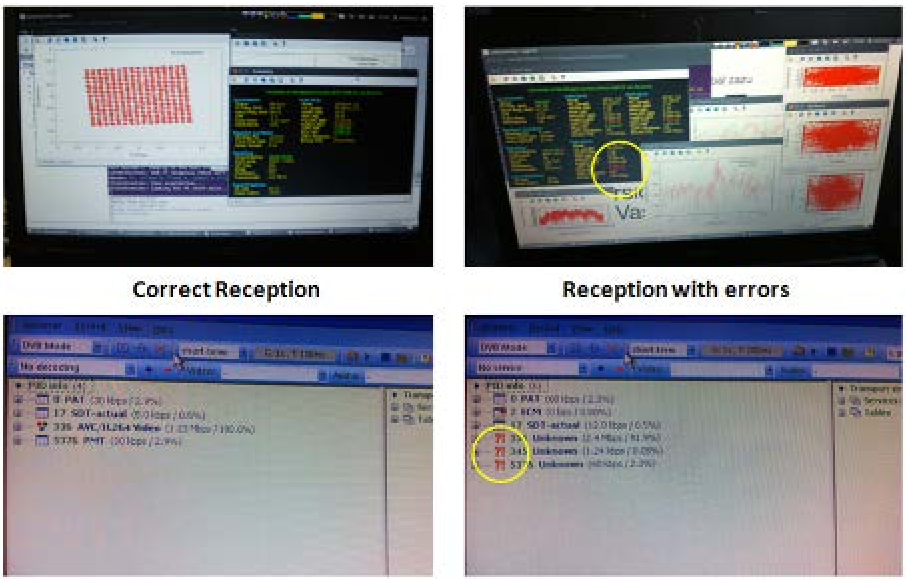

Figure 2.3.1. QEF point detection procedure for the UPV/EHU demodulator (top part) and the Receiver B (down part) in the T2-Lite new features plug fest

2.4 Transport Stream (TS) files

For these tests 11 different Transport Stream (TS) files have been generated. Each one is adapted to the PLP capacity in order to avoid the insertion of null packets in the TS for each configuration mode tested. By this way, any transmission error would affect the video and would be correctly detected.

All TS files contain the same video program (13min 17sec length), specially edited for ENGINES tests. This video shows a tandem paragliding flight at the Basque Country. *Figure 2.4.1* shows a screenshot of this video.

Figure 2.4.1. Screenshot of the video service included in the TS files

Table 2.4.1 resumes the main information about the different TS files used in the laboratory measurements.

Table 2.4.1. TS files main information

Filename	*Bitrate (bit/s)*	*Video Service*	*PLP Id.*	*Ts Id.*	*Other info*
ENGINES.TF11.(M1)(M2).ts	3,980,000	'Test Modo2 3980kbps'	0	13056 (0x3300)	Length: 13 minutes and 17 seconds Network id: 4386 (0x1122) Service id: 21862 (0x5566) Contains 1 video service coded at MPEG-4/AVC, High@4.0, 1920x720, 29.976fps, VBR to fit TS-size
ENGINES.TF11.(M3).ts	3,850,000	'Test Modo3 3850kbps'	0	13056 (0x3300)	
ENGINES.TF11.(M4).ts	3,960,000	'Test Modo4 3960kbps'	0	13056 (0x3300)	
ENGINES.TF11.(M5_PLP0).ts	2,300,000	'Test Modo5 PLP0 2300kbps'	0	13056 (0x3300)	
ENGINES.TF11.(M5_PLP1).ts	1,930,000	'Test Modo5 PLP1 1930kbps'	1	13057 (0x3301)	
ENGINES.TF11.(M5_PLP2).ts	960,000	'Test Modo5 PLP2 960kbps'	2	13058 (0x3302)	
ENGINES.TF11.(M6_PLP0).ts	1,290,000	'Test Modo6 PLP0 1290kbps'	0	13056 (0x3300)	
ENGINES.TF11.(M6_PLP1).ts	1,560,000	'Test Modo6 PLP1 1560kbps'	1	13057 (0x3301)	
ENGINES.TF11.(M6_PLP2).ts	1,740,000	'Test Modo6 PLP2 1740kbps'	2	13058 (0x3302)	
ENGINES.TF11.(M7_Lite).ts	1,270,000	'Test Modo7 Lite 1270kbps'	0	13056 (0x3300)	
ENGINES.TF11.(M7_Base).ts	27,120,000	'Test Modo7 Base 27120kbps'	0	13056 (0x3300)	

2.5 Place of Tests

The *T2-Lite new features plug fest* took place at the ABERTIS facilities in Barcelona, Spain.

ABERTIS PARC LOGISTIC Av. Parc Logistic, 12-20 Building C 08040, Barcelona (SPAIN)
GPS coordinates : N 41º 20’ 28.8” , E 2º 7’ 40.1”

Figure 2.5.1 shows a map of Barcelona with the location of the Abertis facilities in yellow. *Figure 2.5.2* shows different views of the Abertis building C where the T2-Lite laboratory measurements were carried out.

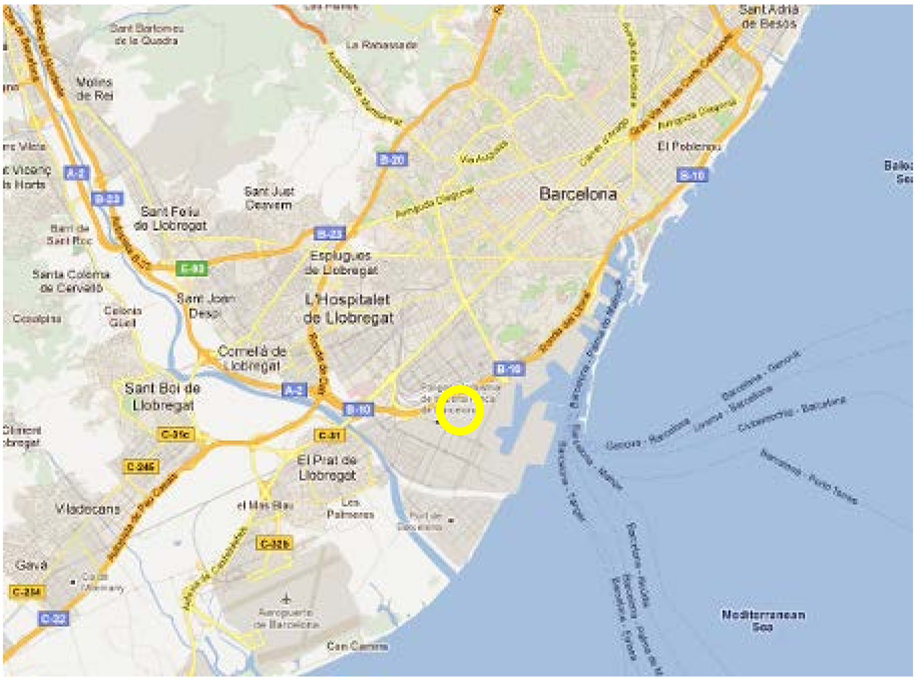

Figure 2.5.1. Barcelona map

Figure 2.5.2. Abertis facilities top view (left) and front view (right)

Two rooms were booked in the second floor of the building C in the ABERTIS facilities. These are shown in purple in *Figure 2.5.3*. The fisrt one, the ”*Excellence room*”, has been booked to hold the meetings. It was also possible to configure and control all the equipments through the “*Management Network*” in that room. Apart from that, a part of the ”*Exploitation Laboratory*” was used as the laboratory where laboratory measurements were carried out.

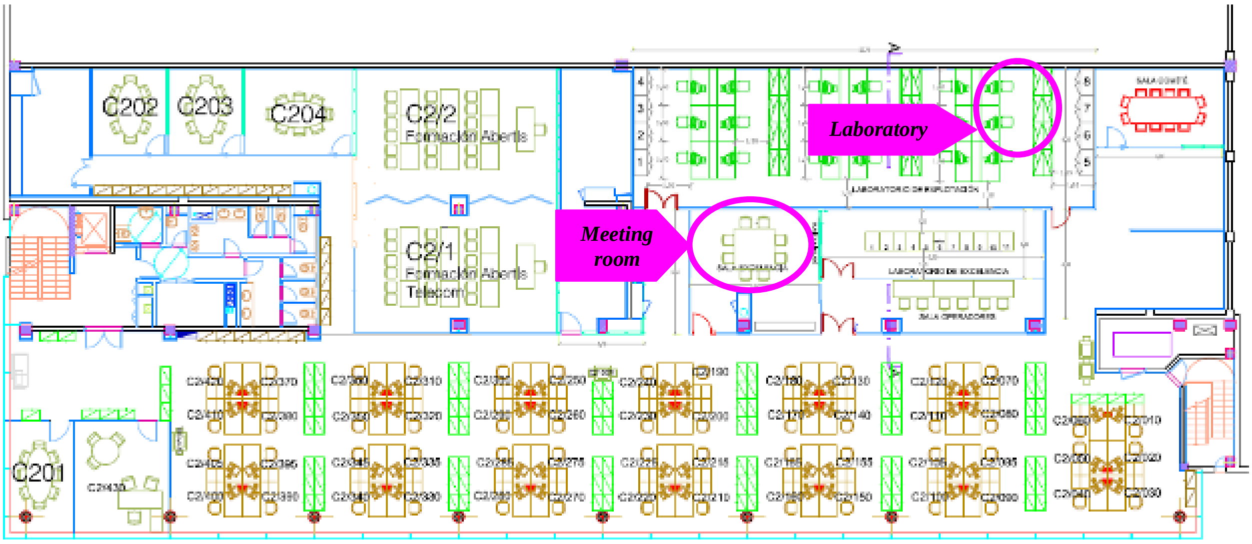

Figure 2.5.3. Abertis detailed layout and floor plan

Figure 2.5.4 shows a floor plan with the equipment location in the room available in the Exploitation laboratory in the Abertis facilities in purple. Apart from the prototypes to be tested, three Transport Streams (TS) players were needed to replay up to 3 TS at once. A channel simulator was also needed so as to emulate the different channels profiles. A T2-Lite Receiver B tested in the DVB last 6-7th March *T2-Lite Plug Fest* in Paris was also used as reference (Receiver B). Finally, an external GPS PPS signal generator was also used to synchronize all the equipments. *Figure 2.5.5* shows the testing room.

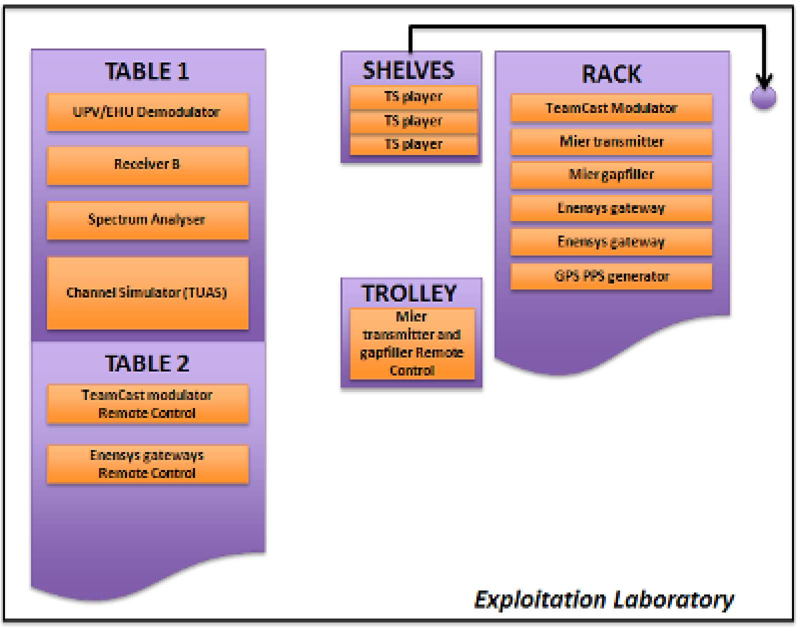

Figure 2.5.4. Equipment location for T2-Lite laboratory tests in the room available

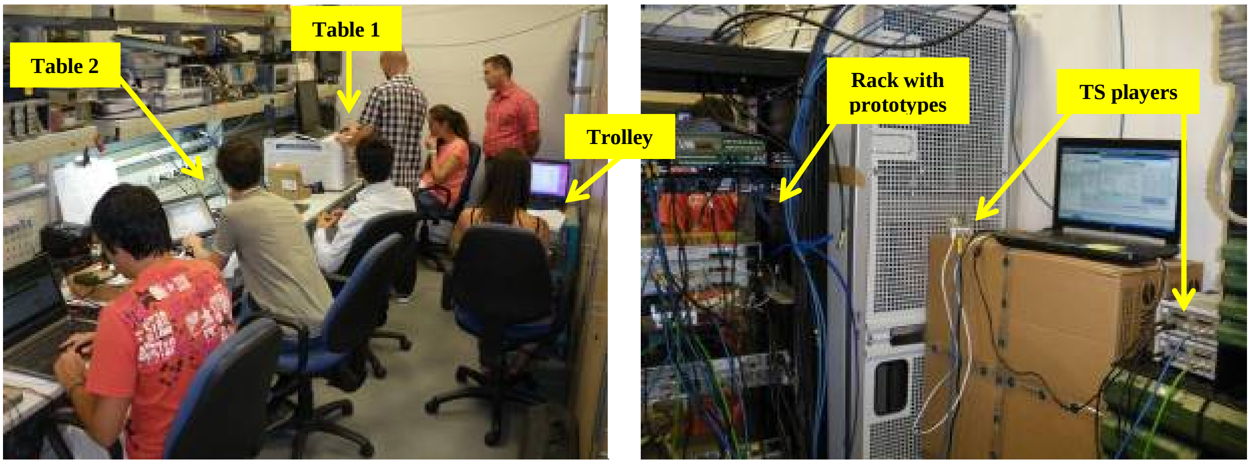

Figure 2.5.5. Abertis testing room

2.6 Participant List

Several companies participated in these laboratory measurements: Abertis Telecom, ENENSYS, MIER Comunicaciones, Teamcast, TUAS and the University of the Basque Country (UPV/EHU). *Table 2.6.1* resumes some information about the partners that have participated in the laboratory tests.

Table 2.6.1. Participant list

Company	***Name and contact email***	***Equipment provided***
AbertisTelecom	Manuel Cañete (*manuel.canete@abertistelecom.com*)	Infrastructure for the T2-Lite plug fest GPS PPS generator
UPV/EHU	Manuel Vélez (*manuel.velez@ehu.es*) Cristina Regueiro (*cristina.regueiro@ehu.es*) Daniel Ansorregui (*daniel.ansorregui@ehu.es*)	Demodulator (Receiver B)
Teamcast	Laurent Boher (*laurent.boher@teamcast.com*)	Modulator
MIER Comunicaciones	Joan Casas (*jcasas@mier.es*) Montserrat Puertolas (*mpuertolas@mier.es*)	Transmitter. Gapfiller
ENENSYS	Matthieu Puton (*matthieu.puton@enensys.com*)	Gateways (x2) and IP to ASI converter
TUAS University	Atte Vainisto (*atte.vainisto@turkuamk.fi*) Niko Aurala (*niko.aurala@turkuamk.fi*)	Channel Simulator

Figure 2.6.1 shows all the participants who took part in the *T2-Lite new features plug fest* in Barcelona.

Figure 2.6.1. T2-Lite Plug fest participants in Barcelona

2.7 Laboratory Tests Schedule

The T2-Lite new features plug fest was held from ***17th September*** until ***18th September 2012***. Each day, testing has started at *09:00 am* and it has finished at *18:00-19:00 pm*. Lunch was from *13:00 pm* to *14:30 pm*.

Table 2.7.1 resumes the different sessions of the plug fest showing the equipments tested in each case. The configuration modes and channel profiles measured are shown as well.

Table 2.7.1. Session characteristics for T2-Lite new features plug fest

Session	**Day**	**Final Timetable**	**Gateway**	**Modulator/transmitter**	**Demodulator**	**Configuration modes**	**Channel profiles**
--	Day 1	09:00-13:00	*Set-up* of equipment				
1	Day 1	14:30-16:00	Enensys	TeamCast mod.	UPV/EHU	M1, M2, M3, M4, M5 and M6	Gaussian
2	Day 1	16:00-18:30	Enensys	Mier trans.	UPV/EHU	M1, M2, M3, M4, M5 and M6	Gaussian Rayleigh
3	Day 2	09:00-11:30	Enensys	Mier trans.	UPV/EHU	M1, M2, M3, M4, M5 and M6	PO TU-6
4	Day 2	11:30-13:00	Enensys	TeamCast mod. Mier trans.	UPV/EHU	M7/T2	Gaussian
				Mier trans.	UPV/EHU	M7/T2	Rayleigh PO TU-6
5	Day 2	14:30-16:30	Enensys	TeamCast mod./Mier trans.	UPV/EHU	M5	Gaussian TU-6
				TeamCast mod./Mier trans.	UPV/EHU	M7/T2	Gaussian TU-6
6	Day 2	16:30-18:30	Enensys	Mier trans./ Mier gapfiller.	UPV/EHU	M5	Gaussian TU-6
					UPV/EHU	M7/T2	
--	Day 2	18:30-19:00	*Packing-up* of equipment				

2.8 T2-Lite FEF, with support of T2-MI rel 1.3.1 Evaluation

2.8.1 Introduction

The main objectives of this test were:

- Test that both transmitters and receivers can implement T2-Lite in Single PLP mode.
- Test that both transmitters and receivers can implement T2-Lite in Multiple PLP mode.
- Test the effect of the *post-scrambling* feature on the signalling.
- Test the effect of using the *sub-slicing* feature.
- Test the effect of the new code-rates introduced in T2-Lite on the robustness of the signal.
- Test how robust the system is by carrying out laboratory tests with different attenuation-delay profiles and measuring the minimum C/N ratio in order to guarantee a correct reception.
- Test TF10 prototypes in full chain to guarantee a correct performance in TF12 field trials.
- Obtain reference performance values for comparison with TF12-field trials results.

The UHF channel C22 (482 MHz) was used in this laboratory test, as it was the same channel was going to be used on the field trials in TF12. *Table 2.8.1 (see next page)* is a restricted table of the different sets of T2-Lite configuration parameters that were used to validate this feature.

- M1 and M2 allowed the testing of the influence of *post-scrambling* feature on the C/N thresholds.
- M3 and M4 allowed the testing of the new code-rates included in T2-Lite (1/3 and 2/5).
- M5 allowed the testing of the multiple PLP feature in the T2-Lite. This mode includes three PLPs with three different interleaving lengths, so as to test the influence of this parameter on the C/N thresholds. This mode was the same as one of the posterior TF12 field trials, so it was important to obtain reference values.
- M6 allowed the testing of the multiple PLP feature in the T2-Lite. This mode includes three PLPs with very long interleaving lengths by using *sub-slicing*, so as to test the influence of this parameter on the C/N thresholds. This mode was the same as one of the posterior TF12 field trials, so it was important to obtain reference values.

The measurements have been done for the set of channel profiles given in *Table 2.8.2*. For each propagation channel model, the related profile column reports on the T2-Lite profiles that have been tested in each case.

Table 2.8.2. Channel models for T2-Lite FEF evaluation.

Configuration	***Propagation Channel Model***	***Related Profiles***
Reference	Gaussian - AWGN	M1, M2, M3, M4, M5 and M6
Portable	Rayleigh Pedestrian Outdoor - PO	
Mobile	TU6 – Doppler = 20 Hz (44Km/h @ 482 MHz)	

The reference mode (Gaussian - AWGN) was tested with all the modulator/transmitters and for all the configuration modes defined in *Table 2.8.1* in order to validate all the TF10 prototypes in a full chain. However, other channel models (Rayleigh, PO and TU-6) were tested only with the transmitter, as it was the one that was going to be used in the posterior TF12 field trials and by this way reference values for the TF12 field trials were obtained.

Table 2.8.1. T2-Lite Profiles for T2-Lite FEF evaluation.

Scenario	T2-Lite FEF	T2-Lite FEF	T2-Lite FEF	T2-Lite FEF	T2-Lite FEF			T2-Lite FEF		
Goals	Post-scrambling ON	Post-scrambling OFF	New code-rate	New code-rate	Multiple PLP			Sub-slicing ON		
Reference	**M1**	**M2**	**M3**	**M4**	**M5**			**M6**		
Single or Multiple PLP	Single	Single	Single	Single	Multiple			Multiple		
Frames per Superframe	2	2	2	2	2			2		
Number of data symbols	109	109	83	98	91			125		
Subslices	1	1	1	1	1			1620		
Channel BW (MHz)	7.61	7.61	7.61	7.61	7.61			7.61		
FFT	8k	8k	8k	8k	8k			8k		
Guard Interval	1/8	1/8	1/8	1/8	1/8			1/8		
Guard Interval Duration (µs)	112	112	112	112	112			112		
Resulting Cell Size (km)	33.5	33.5	33.5	33.5	33.5			33.5		
L1 Constellation	BPSK	BPSK	BPSK	BPSK	BPSK			BPSK		
Post-scrambling	Yes	No	Yes	Yes	Yes			Yes		
Pilot Pattern	PP2	PP2	PP2	PP2	PP2			PP2		
TR-PAPR	L1 & P2	L1 & P2	L1 & P2	L1 & P2	L1 & P2			L1 & P2		
SISO/MISO	SISO_LITE	SISO_LITE	SISO_LITE	SISO_LITE	SISO_LITE			SISO_LITE		
FEF	No	No	No	No	No			No		
	PLP0	**PLP0**	**PLP0**	**PLP0**	**PLP0**	**PLP1**	**PLP2**	**PLP0**	**PLP1**	**PLP2**
PLP Type	Type 2	Type 2	Type 2	Type 2	Type 2	Type 2	Type 2	Type 2	Type 2	Type 2
Constellation	QPSK-R	QPSK-R	QPSK-R	QPSK-R	QPSK-R	QPSK-R	QPSK-R	QPSK-R	QPSK-R	QPSK-R
Code Rate	½	1/2	1/3	2/5	1/2	1/2	1/2	1/3	2/5	1/2
LDPC Frame Length (bits)	16200	16200	16200	16200	16200	16200	16200	16200	16200	16200
Number of FEC blocks	64	64	64	64	31	26	13	32	32	32
HEM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ISSY	None	None	None	None	Yes	Yes	Yes	Yes	Yes	Yes
NPD	No	No	No	No	No	No	No	No	No	No
IL Type	0	0	0	0	0	0	0	0	0	0
IL Length	2	2	2	2	1	1	1	1	1	1
Frame Interval	1	1	1	1	1	1	1	1	1	1
Interleaving time (ms)	41.92	41.92	42.33	42.04	43.74	33.33	16.67	126.22	126.22	126.22
In band Signalling	Type B	Type B	Type B	Type B	Type B	Type B	Type B	Type B	Type B	Type B
Network Topology	SFN	SFN	SFN	SFN	SFN	SFN	SFN	SFN	SFN	SFN
Bit-Rate (Mbps)	**3.99**	**3.99**	**3.90**	**3.97**	**2.38**	**1.93**	**0.97**	**1.31**	**1.58**	**1.77**
Channels to be tested	AWGN / Rayleigh / PO / TU-6									

2.8.2 Prototypes under test

The prototypes that were tested in the T2-Lite FEFs laboratory test are those on *Table 2.8.3*. Some of them are also shown in *Figure 2.8.1*.

Table 2.8.3. Prototypes to test in the T2-Lite FEF laboratory test

EQUIPMENT	***COMPANY***
T2 Modulator	TeamCast
T2 Transmitter	Mier
T2 Gateway	Enensys
T2 Demodulator	UPV/EHU

Figure 2.8.1. Prototypes under test in T2-Lite FEF evaluation (TeamCast modulator, Mier transmitter, UPV/EHU demodulator and ENENSYS gateway)

2.8.3 Set-up

One of the test main objectives of this test focused on checking the correct HW interoperability between TF10 prototypes in MFN in order to guarantee a correct working on the posterior field trials, whose reference set-up is shown in *Figure 2.8.2*. Although the transmitter signal input in the field trials will be by IP, the signal input in the laboratory measurements was by ASI.

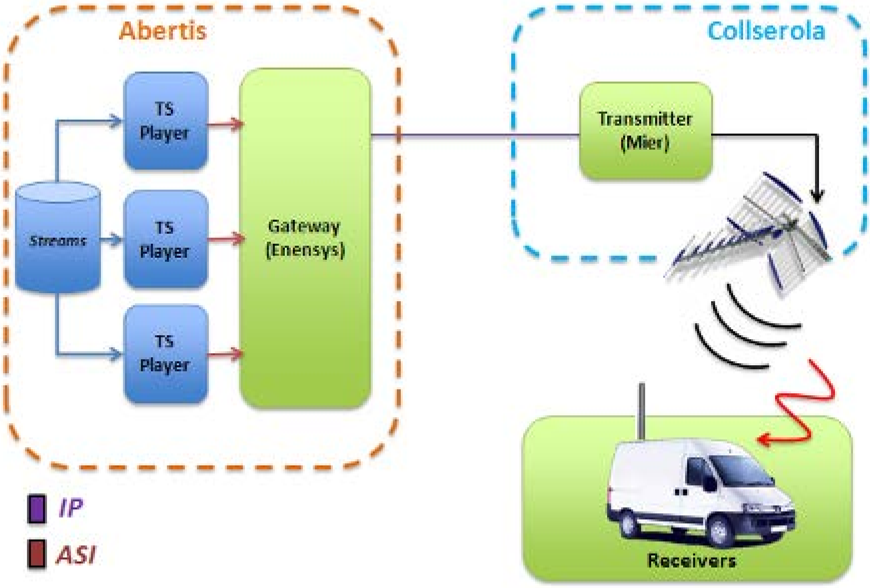

Figure 2.8.2. Reference set-up for T2-Lite in MFN Networks field trials

The equipment for this test and the test set-up in the laboratory is sketched in *Figure 2.8.3*.

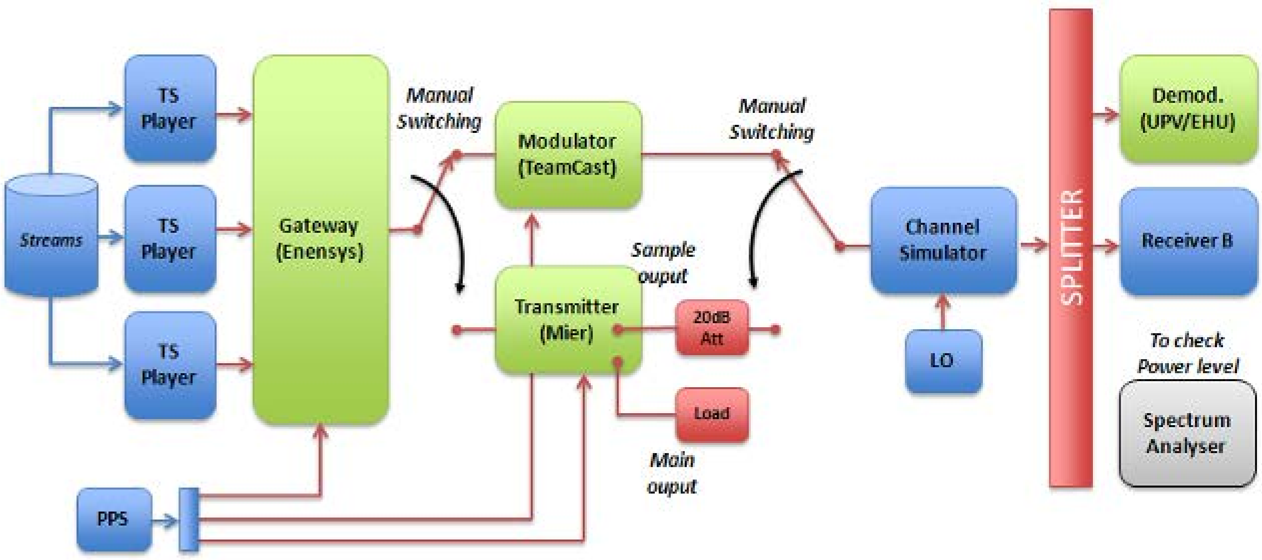

Figure 2.8.3. Reference test set-up for T2-Lite FEFs laboratory test

Apart from the prototypes indicated on *Table 2.8.3*, the laboratory equipments shown on *Figure 2.8.3* in blue (and grey) were also necessary. Three TS players were necessary in order to play the different TS data flows that were modulated using the T2-Lite modulator/transmitter. A channel simulator was also needed so as to simulate the different channel profiles described on *Table 2.8.2* and increase the noise level to measure the C/N ratio at the QEF point. A Local Oscillator was needed in order to make the channel simulator work properly.

A spectrum analyser was also used for measuring the power level inserted in the channel simulator input due to the limit in the maximum power level allowed in its inputs. An external GPS PPS generator was used in order to synchronise all the equipments used. *Figure 2.8.4* shows some of these additional equipments.

Figure 2.8.4. Additional equipment for T2-Lite FEFs laboratory test (TS players, TUAS channel simulator, spectrum analyser and GPS PPS generator)

Besides, some laboratory accessories were also necessary to connect all the prototypes, as it can be shown in *Figure 2.8.3* in red. These are cables, transitions attenuators, DC blockers, splitters and impedance adapters some of which are shown in *Figure 2.8.5*.

The transmitter's amplifier (50.05 dBm – 101W –) high power level output was connected to a load (250W, 50Ω) so as to turn the high power into hot while the sample output (with around 20dB coupled) was the one used during the plug fest.

Figure 2.8.5. Laboratory accessories for T2-Lite FEFs laboratory test (attenuators, DC blockers and splitters)

2.8.4 Test Procedure

The procedure for this test is shown in *Figure 2.8.6*.

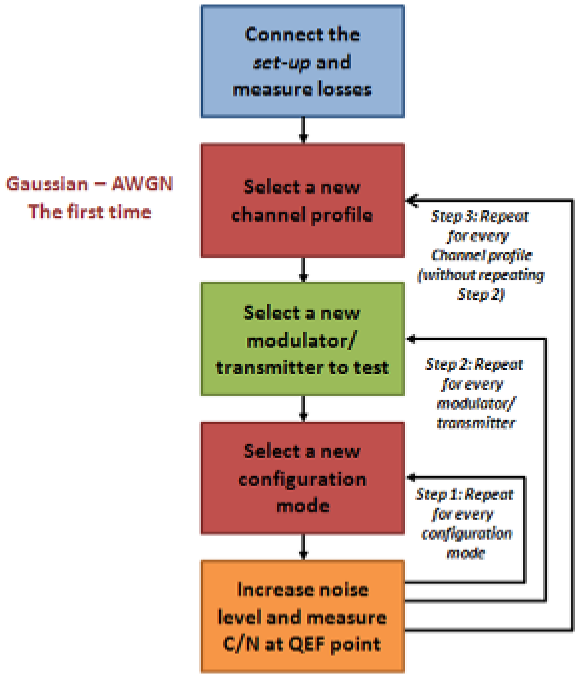

Figure 2.8.6. Test procedure for T2-Lite FEFs laboratory test

1.- Connect the test *set-up* as it is explained in *Figure 2.8.3*. The channel simulator output power level was established in -40dBm.
2.- Set one channel profile from *Table 2.8.2*. The first was the Gaussian-AWGN channel as it is common for all the modulator/transmitters.
3.- Choose one modulator or transmitter to be tested.
4.- Set one T2-Lite configuration mode from *Table 2.8.1*.The modes were selected in the same order that in the table.
5.- Validate that both the transmitters and the receivers work properly, by observing that the signalling detected in the receiver was correct.
6.- Increase the noise level until QEF point is reached This has been done in steps of 0.2dB. The superior limit for the C/N threshold was established in 40dB, in other words, the maximum C/N measured was 40dB, if higher C/N were required, an incorrect demodulation was supposed in the receiver.
7.- Obtain the required C/N value at the QEF point from the channel simulator.
8.- Fill in the measured C/N value in dB in measurements record (excel sheet).
9.- Repeat the process from step 4 to 8 with all the configuration modes in *Table 2.8.1*.
10.- Repeat the process from step 3 to 9 with all the modulators/transmitters.
11.- Repeat the process from step 2 to 9 with all the channel profiles in *Table 2.8.2* with the transmitter as it is the one to be used on the posterior field trials and the results with it could be taken as reference.

Figure 2.8.7 shows some moments of thedescribed procedure.

Figure 2.8.7. Different moments of the T2-Lite FEFs laboratory test

2.8.5 Results and Conclusions

This test allows to check that both the transmitters/modulators and demodulators work properly with the new T2-Lite features, including new code-rates, *post-scrambling*, *sub-slicing* and different interleaving depths, both with single or multiple PLPs configurations.

Table 2.8.4 shows the C/N ratio results obtained for both the TeamCast modulator and the Mier transmitter tested for the Gaussian channel and the C/N ratio results obtained only for the Mier transmitter for the Rayleigh, Pedestrian Outdoor and TU-6.

If the results for the UPV/EHU demodulator and the Receiver B are compared, it can be concluded that the UPV/EHU prototype has a better performance than the Receiver B for all the configuration modes tested (between 1.2 and 1.8 dB better for the fixed channels and between 2 and 4.8 dB for the portable and mobile channels).

Besides, if the results for the modulator and the transmitter are compared for the Gaussian channel, it can be concluded, that the amplifier does not decrease the signal quality a lot as the C/N ratio obtained for both cases are almost the same (the difference is lower than 0.2 dB).

Comparing M1 (*post-scrambling* ON) and M2 (*post-scrambling* OFF), it can be concluded that the *post-scrambling* feature has no influence on the results obtained for the fixed channels, as the C/N ratio obtained are almost the same. However, for the portable and fixed channels the C/N ratio increases in between 0.2 and 0.8 dB when the *post-scrambling* feature is off.

Comparing M1 (code-rate 1/2), M3 (code-rate 1/3) and M4 (code-rate 2/5), it can be concluded that with the new T2-Lite code-rates the C/N ratio results are lower; in other words, the configuration mode is more robust. Comparing M1 and M4, the improvement is between 0.4 and 1.2 dB for the UPV/EHU demodulator, (when using the Receiver B, the improvement reaches to 2 dB). Comparing M1 and M3, the improvement is evidently higher, as the robustness increases. The C/N ratio obtained are between 1.6 and 2.4 dB lower than with the reference M1 (when using the Receiver B, it is up to 3.2 dB).

M5 mode shows the influence of the time interleaving length (PLP0 43.74, PLP1 33.33 and PLP2 16.67 ms) C/N ratio results for the different channels. For the fixed channels, there is no difference in the C/N ratios for the three interleaving lengths tested However, there is some influence on the results when the portable and mobile channels are tested, increasing the C/N values in between 0.2 and 0.6 dB when PLP0 and PLP1 and compared. Nevertheless, there is no difference on the C/N ratios between PLP1 and PLP2 (0 dB in almost all the cases). Moreover, if the M5-PLP0 is compared with the M1 (it is a comparable configuration mode), the same C/N thresholds are obtained for the fixed channels. For the mobile channels, there are some differences of between 0.4 and 0.8 dB. The differences, which are bigger for the TU-6 channel, could be because of the high variability of the TU-6 channel.

M6 is a multiple PLP mode of M1, M3 and M4 together but with *sub-slicing* ON. Comparing this mode with the other three single PLP modes, the influence of the *sub-slicing* feature can be measured. By this way, the new interleaving length for the three modes, changes from around 42 ms to 126 ms. When analysing the C/N ratio results for the fixed channels, the improvement obtained due to the *sub-slicing* is of 0 or 0.2 dB in general. However, when the pedestrian outdoor and TU-6 channel profiles are considered, the improvement in the C/N ratio is of between 1 or 2 dB.

Table 2.8.4. C/N (dB) at QEF point in T2-Lite evaluation

		M1		M2		M3		M4	
		UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B
Gaussian-AWGN	Modulator: TeamCast	1	2,2	1	2,2	-0,6	0,8	0,2	1,6
	Transmitter: Mier	1	2,6	1,2	2,4	-0,8	1	0,2	1,8
Rayleigh	Transmitter: Mier	3,2	4,6	3,2	4,6	1,2	2,4	2,2	3,4
PO	Transmitter: Mier	6	8	6,2	8,8	3,6	6	4,8	7,4
TU-6	Transmitter: Mier	4,8	9,4	5,6	9,8	3,2	6,2	4,4	7,4

		M5						M6					
		PLP0		PLP1		PLP2		PLP0		PLP1		PLP2	
		UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B
Gaussian-AWGN	Modulator: TeamCast	1	2,4	1	2,4	1	2,2	-1	0,8	0	1,6	0,8	2,4
	Transmitter: Mier	1	2,4	1	2,4	1	2,4	-0,8	1	0	1,6	1	2,6
Rayleigh	Transmitter: Mier	3,2	4,6	3,2	4,6	3,2	4,6	0,8	2,6	2	3,6	3	4,6
PO	Transmitter: Mier	5,6	8,6	5,6	8,8	5,6	8,8	3,4	6,4	3,6	6,2	4	8
TU-6	Transmitter: Mier	5,6	9,2	5,8	9,8	6	9,8	3,2	5	4,4	6,8	4,4	7,4

2.9 Mixed T2 and T2-Lite Evaluation

2.9.1 Introduction

The main objectives of this test were:

- Test that both transmitters and receivers can implement this feature transmitting and receiving properly mixed T2 and T2-Lite signals.
- Test that the receivers can decode correctly the T2-Base and the T2-Lite when mixed T2 and T2-Lite signals are transmitted.
- Test how robust the system is by carrying out laboratory tests with different attenuation-delay profiles and measuring the minimum C/N ratio in order to guarantee a correct reception.
- Test TF10 prototypes in full chain to guarantee a correct performance in TF12 field trials
- Obtain reference performance values for comparison with TF12-field trials results.

The UHF channel C22 (482 MHz) was used in this laboratory test, as it is the same channel that will be used on the field trials in TF12. *Table 2.9.1 (see next page*) is a table of the Mixed T2-Base and T2-Lite configuration parameters and the DVB-T2 fixed mode (in the yellow column) that have been used in order to evaluate the correct mixed DVB-T2 and T2-Lite reception.

- M7 and T2 combination mode is the same as one of the field trials modes in TF12. The T2-Base mode has been selected in order to have high *bit-rate* although its robustness is not very high (256QAM). This is because it is thought for high definition fixed reception. The T2-Lite mode has been selected to be quite robust (QPSK 1/2) but with low bit-rate (near 1MBps). By this way, a realistic balance between the T2 and T2-Lite parts is achieved.

The measurements were carried out for the set of channel profiles given in *Table 2.9.2*. For each propagation channel model, the related profile column reports on the Mixed T2-Base and T2-Lite profiles that have been tested in each case.

Table 2.9.2. Channel models for Mixed T2 and T2-Lite evaluation.

Configuration	*Propagation Channel Model*	*Related Profiles*
Reference	Gaussian - AWGN	M7/T2
Portable	Rayleigh Pedestrian Outdoor - PO	
Mobile	TU6 – Doppler = 20 Hz (44Km/h @ 482 MHz)	

The reference mode (Gaussian - AWGN) was tested with all the modulator/transmitters and for all the configuration modes defined in *Table 2.9.1* in order to validate all the TF10 prototypes in a full chain. However, other channel models (Rayleigh, PO and TU-6) were tested only with the transmitter, as it was the one that was going to be used in the posterior TF12 field trials and by this way reference values for the TF12 field trials were obtained

Table 2.9.1. T2-Lite Profiles for Mixed T2 and T2-Lite evaluation

Scenario	Mixed T2 and T2-Lite	
	T2-Lite	**T2-Base**
Reference	**M7**	**T2**
Single or Multiple PLP	Single	Single
Frames per Superframe	2	2
Number of data symbols	39	31
Subslices	1	1
Channel BW (MHz)	7.61	7.77
FFT	8k	32k ext.
Guard Interval	1/8	1/16
Guard Interval Duration (µs)	112	224
Resulting Cell Size (km)	33.5	67
L1 Constellation	BPSK	BPSK
Post-scrambling	Yes	Yes
Pilot Pattern	PP2	PP4
TR-PAPR	L1 & P2	L1 & P2
SISO/MISO	SISO_LITE	SISO
FEF	Yes	Yes
FEF Length	1.116.160	379.904
FEF Interval	1	1
	PLP0	**PLP0**
PLP Type	Type 2	Type 2
Constellation	QPSK-R	256QAM-R
Code Rate	1/2	2/3
LDPC Frame Length (bits)	16200	64800
Number of FEC blocks	30	103
HEM	Yes	Yes
ISSY	Long	Long
NPD	No	No
IL Type	0	0
IL Length	1	2
Frame Interval	1	1
Interleaving time (ms)	41.32	60.92
In band Signalling	Type B	Type A
Network Topology	SFN	SFN
Bit-Rate (Mbps)	**1.28**	**27.18**
Channels to be tested	AWGN / Rayleigh / PO / TU-6	

2.9.2 Prototypes under test

The prototypes that have been tested in the Mixed T2 and T2-Lite laboratory test are those on *Table 2.9.3*. Some of them are also shown in *Figure 2.9.1*.

Table 2.9.3. Prototypes to test in the Mixed T2 and T2-Lite laboratory test

EQUIPMENT	***COMPANY***
T2 Modulator	TeamCast
T2 Transmitter	Mier
T2 Gateway (x2)	Enensys
T2 Demodulator	UPV/EHU

Two gateways were necessary in this test because both the modulator and the transmitter need to receive the T2-Base signal and the T2-Lite signal in different inputs so as to combine them and generate the mixed signal.

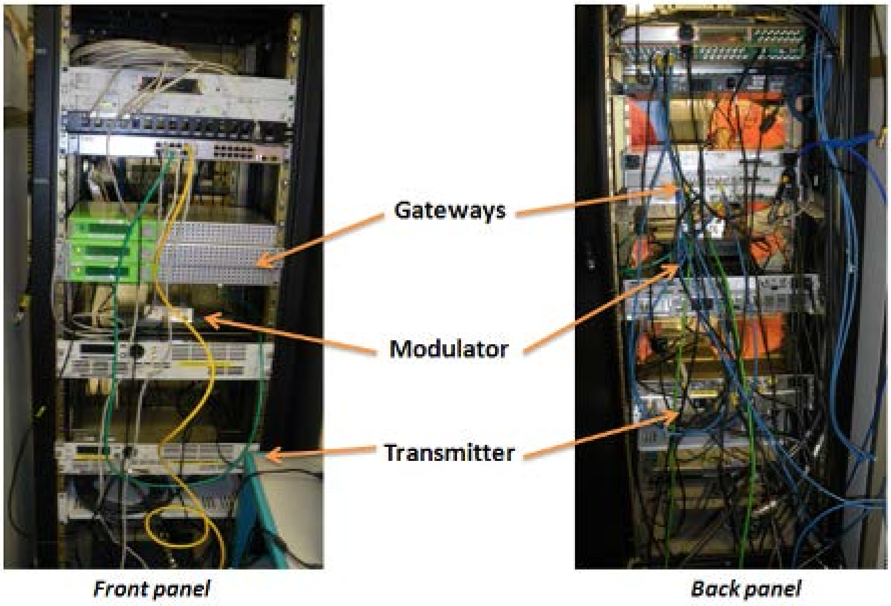

Figure 2.9.1. Prototypes under test in Mixed T2 and T2-Lite evaluation (front and back panels of the rack)

2.9.3 Set-up

One of the test main objectives of this test focused on checking the correct HW interoperability between TF10 prototypes when using mixed modes in MFN in order to guarantee a correct working on the posterior field trials, whose reference set-up is shown in *Figure 2.9.2*. The transmitter is capable of combining the T2-Base and T2-Lite signals when they are received both by ASI or one by ASI and one by IP. For this reason, an IP to ASI converter will be used in the field trials due to the necessity to convert one of the IP signals to ASI.

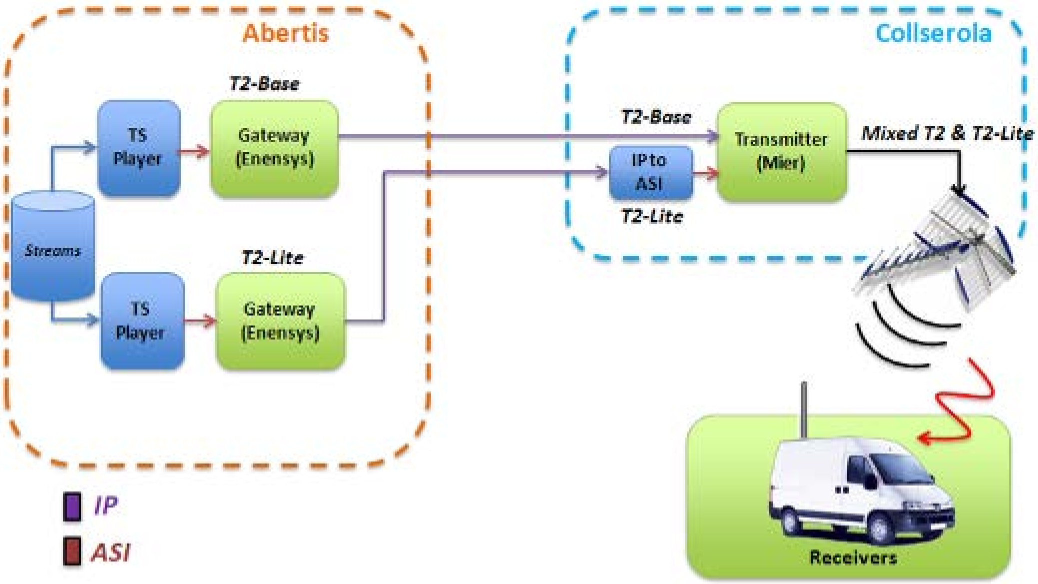

Figure 2.9.2. Reference set-up for Mixed T2 and T2-Lite in MFN Networks field trials

The equipment for this test and the test set-up in the laboratory is sketched in *Figure 2.9.3*.

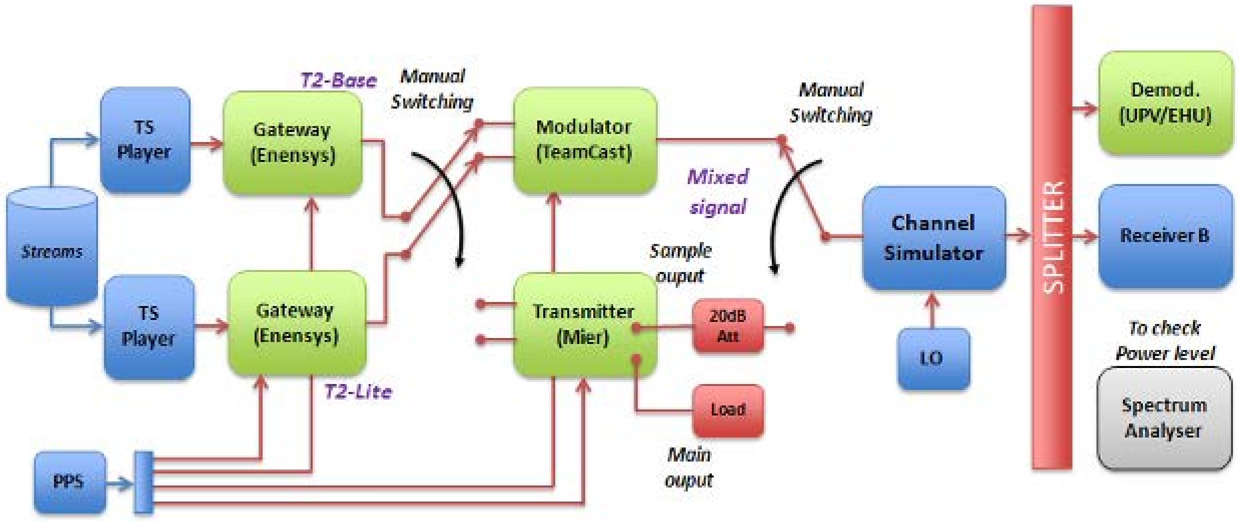

Figure 2.9.3. Reference test set-up for Mixed T2 and T2-Lite laboratory test

Apart from the prototypes indicated on *Table 2.9.3*, the laboratory equipments shown on *Figure 2.9.3* in blue (and grey) were also necessary. Two TS players were necessary in order to play the different TS data flows; one for the T2-Base part and another one for the T2-Lite part. A channel simulator was also needed so as to simulate the different channel profiles described on *Table 2.9.2* and increase the noise level to measure the C/N ratio at the QEF point. A Local Oscillator was needed in order to make the channel simulator work properly.

A spectrum analyser was also used for measuring the power level inserted in the channel simulator input due to the limit in the maximum power level allowed in its inputs. An external GPS PPS generator was used in order to synchronise all the equipments used. *Figure 2.9.4* shows some of these additional equipments.

Figure 2.9.4. Additional equipment for Mixed T2 and T2-Lite laboratory test (channel simulator control screen and GPS PPS generator)

Besides, some laboratory accessories were also necessary to connect all the prototypes, as it can be shown in *Figure 2.9.3* in red. These are cables, transitions attenuators, DC blockers, splitters and impedance adapters. The transmitter amplifier (50.05 dBm – 101W –) high power level output was connected to a resistor (250W, 50Ω) so as to turn the high power into hot while the sample output (with around 20dB coupled) was the one used during the plug fest.

2.9.4 Test Procedure

The procedure for this test is shown in *Figure 2.9.5:*

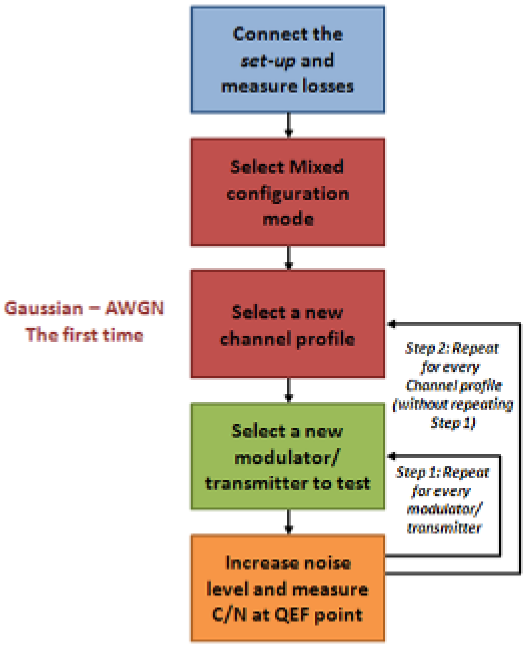

Figure 2.9.5. Test procedure for Mixed T2 and T2-Lite laboratory test

1.- Connect the test *set-up* as it is explained in the *Figure 2.9.3*. The channel simulator output power level was established in -40dBm.
2.- Set the Mixed T2 and T2-Lite configuration mode from *Table 2.9.1*.
3.- Set one channel profile from *Table 2.9.2*. The first one should be Gaussian-AWGN as it is common for all the modulator/transmitters.
4.- Choose one modulator or transmitter to be tested.
5.- Validate that both the transmitters and the receivers work properly, by observing that the signalling detected in the receiver is correct.
6.- Increase the noise level until QEF point is reached. This has been done in steps of 0.2dB. The superior limit for the C/N threshold was established in 40dB, in other words, the maximum C/N measured was 40dB, if higher C/N were required, an incorrect demodulation was supposed in the receiver.
7.- Obtain the required C/N value at the QEF point from the channel simulator.
8.- Fill in the measured C/N value in dB in measurements record (excel sheet).
9.- Repeat the process from step 4 to 8 with all the modulators/transmitters.
10.- Repeat the process from step 3 to 8 with all the channel profiles in *Table 2.9.2* with the transmitter as it is the one to be used on the posterior field trials and the results with it could be taken as reference.

Figure 2.9.7 shows some moments of thedescribed procedure.

Figure 2.9.7. Different moments of the Mixed T2 and T2-Lite laboratory test

2.9.5 Results and Conclusions

This test allows to check that both the transmitters/modulators and demodulators work properly with the new T2-Lite features, specifically with the T2-Base and T2-Lite mixed modes.

Table 2.9.4 shows the C/N ratio results obtained for both the TeamCast modulator and the Mier transmitter tested for the Gaussian channel and the C/N ratio results obtained only for the Mier transmitter for the Rayleigh, Pedestrian Outdoor and TU-6.

If the results for the UPV/EHU demodulator and the Receiver B are compared, it can be concluded that the UPV/EHU prototype has a better performance than the Receiver B for the mixed mode tested (between 1.2 and 4 dB better, depending on the simulated channel profile).

If the results for the modulator and the transmitter are compared for the Gaussian channel, it can be concluded, that the amplifier does not decrease the signal quality as the C/N ratio obtained for both cases are almost the same.

As it can be seen in *Table 2.9.4*, the mixed mode consists on transmit a low rate T2-Lite signal to be received in mobility and a high rate T2-Base that should only be received in fixed reception. This is the reason why the reception of the T2-Base signal is almost impossible with the UPV/EHU demodulator and the receiver B with difficult channel profiles (this is indicated with “XXXX” which means that the limit of 40 dB of C/N has been exceeded).

Considering the T2-Lite part reception, *Table 2.9.4* also shows that the T2-Lite reception in mixed modes is possible for the difficult channel profiles in mobility. Analyzing the M7 results in Test 2 and the M5-PLP0 results in Test 1, they should be comparable because M5-PLP0 is similar to M7 configuration mode. However, around 3dB higher C/N results have always been obtained in Test 2 (between 2.2dB and 3.6dB depending on channel). These unexpected results were not in accordance with the results obtained by the different partners in their individual tests.

Table 2.9.4. C/N (dB) at QEF point in Mixed T2 and T2-Lite evaluation

		M7/T2			
		M7		T2	
		UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B
Gaussian-AWGN	Modulator: TeamCast	3,8	5,2	19	22,2
	Transmitter: Mier	3,8	5	19,2	22,2
Rayleigh	Transmitter: Mier	6,4	8,2	XXXXX	XXXXX
PO	Transmitter: Mier	8,2	10,8	29,6	XXXXX
TU-6	Transmitter: Mier	9,2	13	XXXXX	XXXXX

Not correctly demodulated, C/N>40dB (XXXX)

2.10 T2-Lite in SFN Networks Evaluation

2.10.1 Introduction

The main objectives of this test were:

- Test TF10 prototypes in full chain to guarantee a correct HW interoperability in TF12 field trials using a SFN network with T2-Lite modes
- Test how robust the system is by carrying out laboratory tests with different attenuation-delay profiles and measuring the minimum C/N ratio in order to guarantee a correct reception.
- Obtain reference performance values for comparison with TF12-field trials results.

The UHF channel C22 (482 MHz) was used in this laboratory test, as it is the same channel that was going to be used on the field trials in TF12. *Table 2.10.1* shows the sets of T2-Lite configuration parameters that have been used to validate this feature. The selected mode is one of the modes that will be also used in the field trials so as to guarantee its correct performance.

- M5 allows the testing of the multiple PLP feature in the T2-Lite. This mode includes three PLPs with three different interleaving lengths, so as to test the influence of this parameter on the C/N thresholds. This mode was the same as one of the field trials in TF12.

Table 2.10.1. T2-Lite Profiles for T2-Lite in SFN Networks evaluation

Scenario	T2-Lite in SFN Networks		
	T2-Lite		
Reference	**M5**		
Single or Multiple PLP	Multiple		
Frames per Superframe	2		
Number of data symbols	91		
Subslices	1		
Channel BW (MHz)	7.61		
FFT	8k		
Guard Interval	1/8		
Guard Interval Duration (µs)	112		
Resulting Cell Size (km)	33.5		
L1 Constellation	BPSK		
Post-scrambling	Yes		
Pilot Pattern	PP2		
TR-PAPR	L1 & P2		
SISO/MISO	SISO_LITE		
FEF	No		
	PLP0	**PLP1**	**PLP2**
PLP Type	Type 2	Type 2	Type 2
Constellation	QPSK-R	QPSK-R	QPSK-R
Code Rate	1/2	1/2	1/2
LDPC Frame Length (bits)	16200	16200	16200
Number of FEC blocks	32	26	13
HEM	Yes	Yes	Yes
ISSY	Long	Long	Long
NPD	No	No	No
IL Type	0	0	0
IL Length	1	1	1
Frame Interval	1	1	1
Interleaving time (ms)	43.74	33.33	16.67
In band Signalling	Type B	Type B	Type B
Network Topology	SFN	SFN	SFN
Bit-Rate (Mbps)	**2.38**	**1.93**	**0.97**
Channels to be tested	Gaussian/TU-6		

The measurements were carried out for the set of channel profiles given in *Table 2.10.2*. For each propagation channel model, the related profile column reports on the T2-Lite profiles that have been tested in each case.

Table 2.10.2. Channel models for T2-Lite in SFN Networks evaluation.

Configuration	***Propagation Channel Model***	***Related Profiles***
Reference	Gaussian - AWGN	M5
Mobile	TU6 – Doppler = 20 Hz (44Km/h @ 482 MHz)	

The reference mode (Gaussian - AWGN) was tested with all the modulator/transmitters and for all the configuration modes defined in *Table 2.10.1* in order to validate all the TF10 prototypes in a full chain. However, the other channel model (TU-6) was tested only with the transmitter, as it was the one that was going to be used in the posterior TF12 field trials and by this way reference values for the TF12 field trials were obtained.

2.10.2 Prototypes under test

The prototypes that were tested in the T2-Lite in SFN Networks laboratory test are those on *Table 2.10.3*. Some of them are also shown in *Figure 2.10.1*.

Table 2.10.3. Prototypes to test in the T2-Lite in SFN Networks laboratory test

EQUIPMENT	***COMPANY***
T2 Modulator	TeamCast
T2 Transmitter	Mier
T2 Gapfiller	Mier
T2 Gateway	Enensys
T2 Demodulator	UPV/EHU

Figure 2.10.1. Prototypes under test in T2-Lite in SFN Networks evaluation (Mier gapfiller)

2.10.3 Set-up

Two different *set-ups* were tested for measuring the SFN performance. The first one consisted on a main transmitter and a secondary transmitter while the second one consisted on a main transmitter and a gapfiller. When using the gapfiller, the correct eco suppression was checked by adding the gapfiller output to the gapfiller input.

Figure 2.10.2 and *Figure 2.10.3* show the possible network schemes for the posterior TF12 T2-Lite field trials. As this test focused on a check of the correct HW interoperability in SFN networks in order to guarantee a correct working on the posterior field trials, only the equipments that were going to be possibly used in the field trials were tested in the laboratory. *Figure 2.10.2* shows a SFN network using a secondary transmitter while *Figure 2.10.3* shows an SFN network but with a secondary gapfiller.

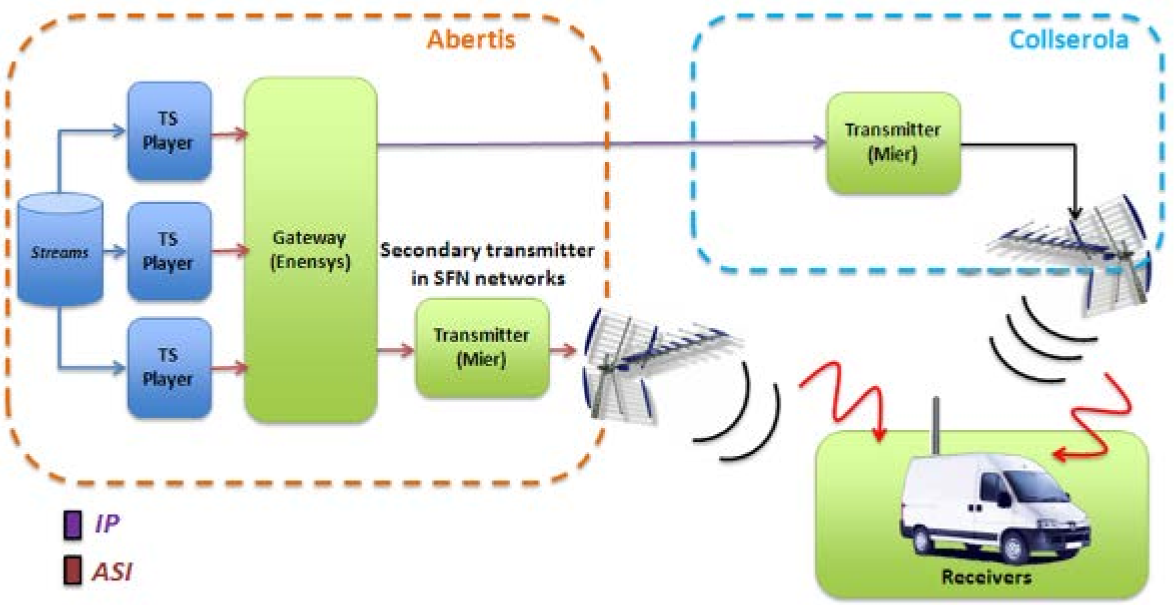

Figure 2.10.2. Reference set-up for T2-Lite in SFN Networks field trials using a secondary transmitter

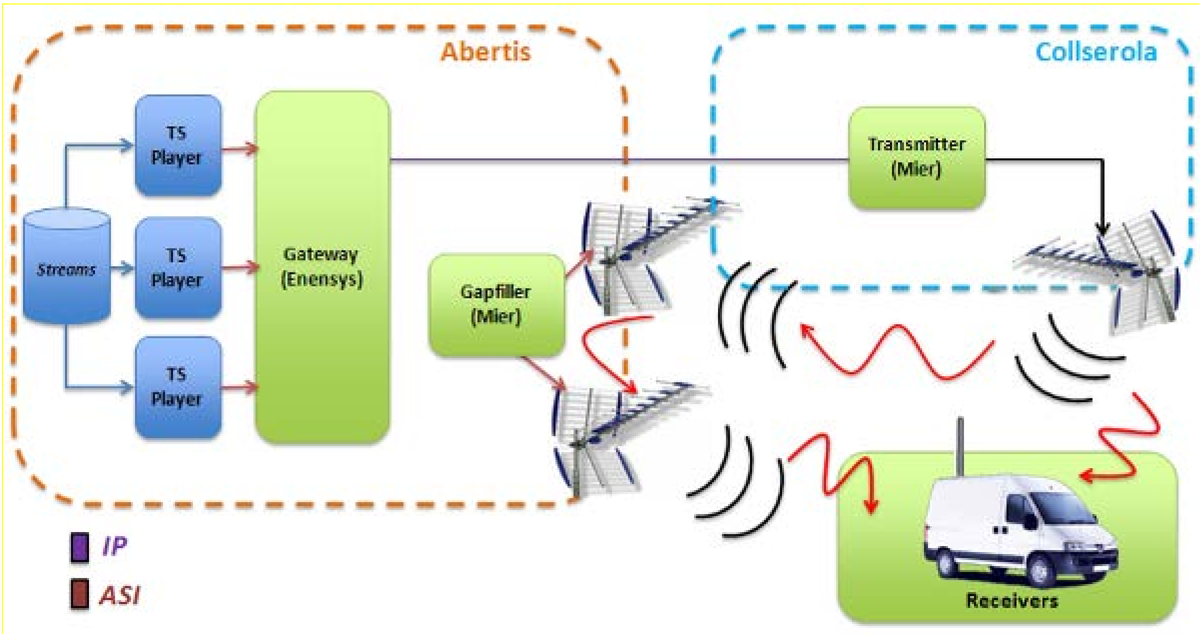

Figure 2.10.3. Reference set-up for T2-Lite in SFN Networks field trials using a gapfiller

Figure 2.10.4 and *Figure 2.10.5* show the reference *set-up* for this laboratory test. The modulator/transmitter/gapfillers selected were those from *Figure 2.10.2* and *Figure 2.10.3*, showing the two possibilities for the SFN networks in the field trials: using a secondary modulator/transmitter (*Figure 2.10.2*) or using a gapfiller (*Figure 2.10.3*), so that both cases were tested.

Figure 2.10.4 refers to the case of a secondary transmitter. In order to test the same case as in the following field trials, the main transmitter/modulator input (the one that simulates the one in Collserola as the Mier transmitter has a TeamCast modulator inside) was by IP, while the secondary transmitter input (the one that simulates the one in the Abertis facilities) was by ASI. The channel simulator is in charge of delaying the secondary transmitter output signal simulating an SFN reception.

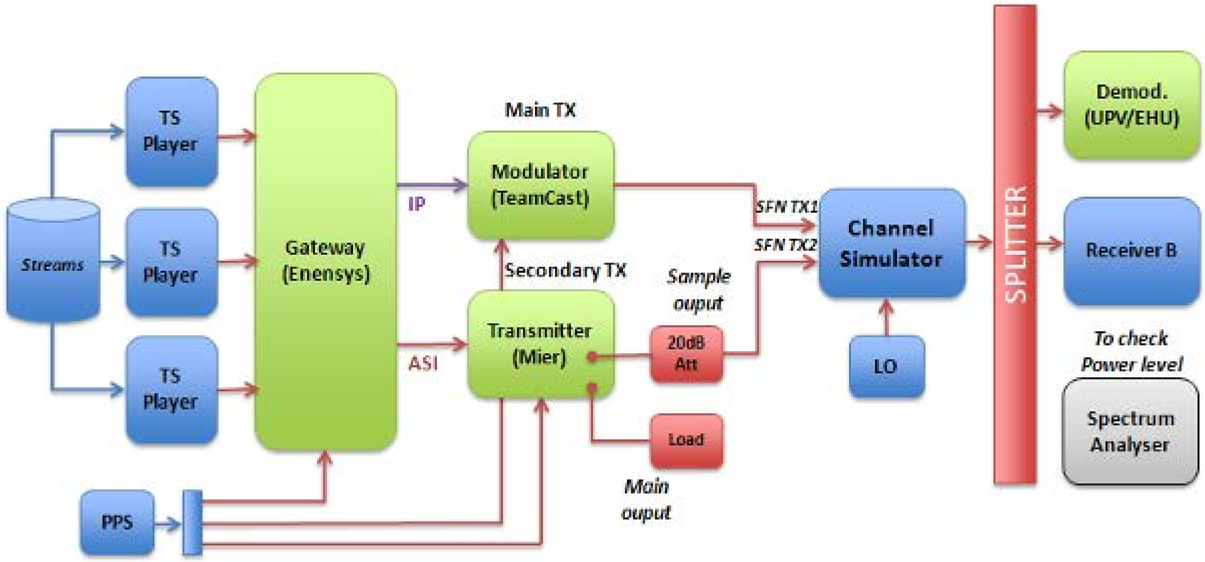

Figure 2.10.4. Test set-up for T2-Lite in SFN Networks laboratory test using a secondary transmitter

Figure 2.10.5 refers to the case of using a gapfiller. In order to test the eco suppression with the gapfiller, the gapfiller output is added to the main transmitter output. In this case only the Mier transmitter was tested in order to simulate the real situation in the posterior field trials.

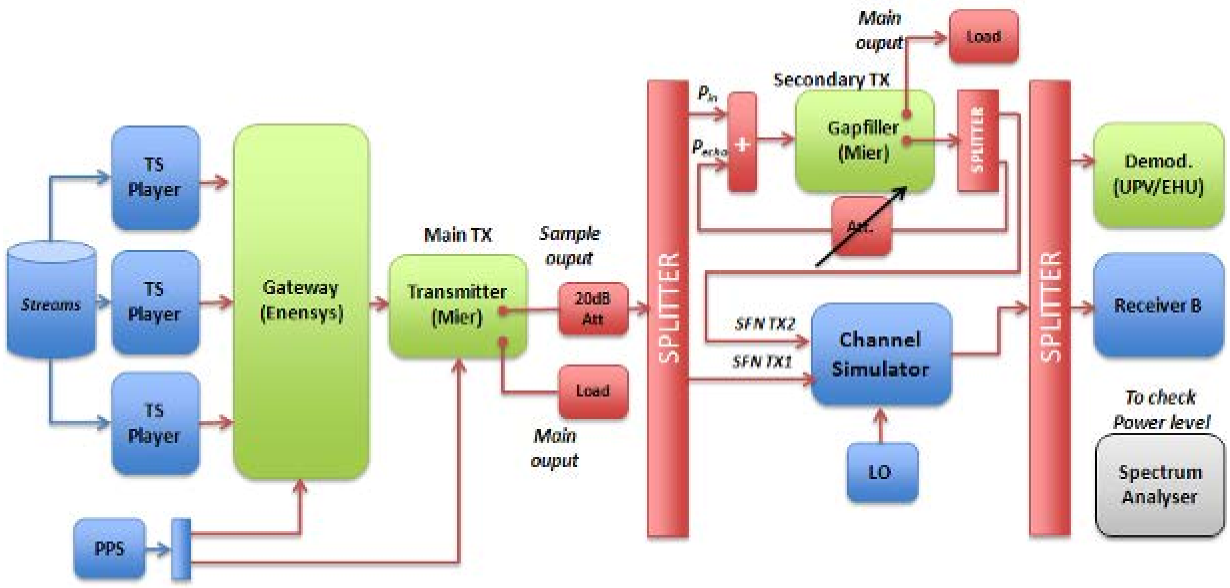

Figure 2.10.5. Reference test set-up for T2-Lite in SFN Networks laboratory test using a gapfiller

Apart from the prototypes indicated on *Table 2.10.3*, the laboratory equipments shown on *Figure 2.10.4* and *Figure 2.10.5* in blue (and grey) were also necessary. Three TS players were necessary in order to play the different TS data flows. A channel simulator was also needed so as to simulate the different channel profiles described on *Table 2.10.2,* increase the delay between its input 1 (from the main transmitter) and its input 2 (from the secondary transmitter or the gapfiller) and increase the noise level to measure the C/N ratio at the QEF point. A Local Oscillator was needed in order to make the channel simulator work properly.

A spectrum analyser was also used for measuring the power level inserted in the channel simulator input due to the limit in the maximum power level allowed in its inputs. An external GPS PPS generator was used to synchronise all the equipments used. *Figure 2.10.6* shows some of these additional equipments.

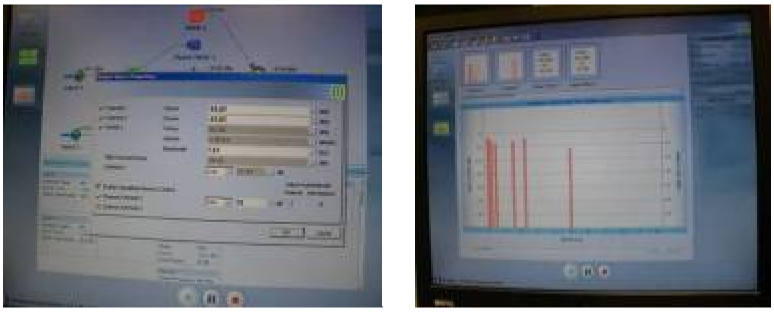

Figure 2.10.6. Additional equipment for T2-Lite in SFN Networks laboratory test (channel simulator control screens for two inputs)

Besides, some laboratory accessories were also necessary to connect all the prototypes, as it can be shown in *Figure 2.10.4* and *Figure 2.10.5* in red. These are cables, transitions attenuators, DC blockers, splitters, adders and impedance adapters. The transmitter amplifier (50.05 dBm – 101W –) high power level output was connected to a resistor (250W, 50Ω) so as to turn the high power into hot while the sample output (with around 20dB coupled) was the one used during the plug fest. The gapfiller high power level output was connected to a channel 22 filter and from here to an antenna. *Figure 2.10.7* shows these additional laboratory accessories.

Figure 2.10.7. Laboratory accessories for T2-Lite in SFN Networks laboratory test (adders, filters and splitters)

2.10.4 Test Procedure

The test procedure to follow in the T2-Lite SFN performance laboratory test is shown on *Figure 2.10.8*.

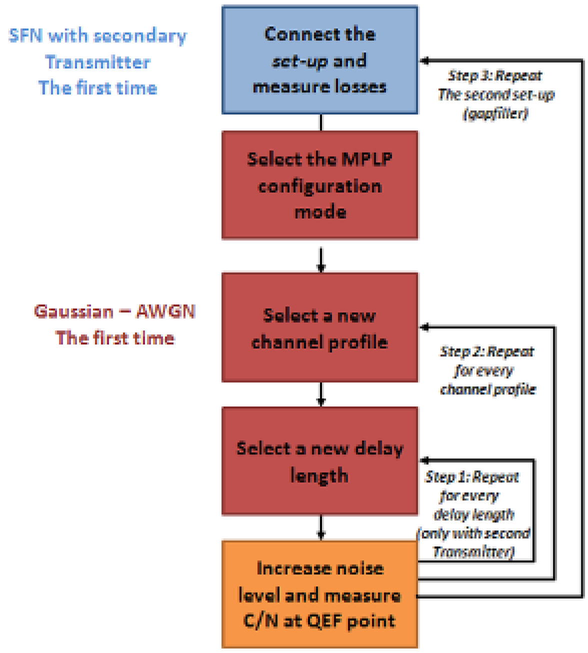

Figure 2.10.8. Test procedure for T2-Lite in SFN Networks laboratory test

1.- Connect the test *set-up* as it is explained in *Figure 2.10.4* (secondary transmitter). The channel simulator output power level was established in -40dBm.
2.- Set the Multiple PLP T2-Lite configuration mode from *Table 2.10.1*.
3.- Set one channel profile from *Table 2.10.2*. The first one should be Gaussian-AWGN.
4.- Set the delay between the main transmitter and the secondary transmitter in 10%, 50% and 100% of the guard interval length (for the case with a secondary transmitter). Set no delay for the case of using a gapfiller, because the delay between the signal from the main transmitter and the gapfiller will be the one introduced by the gapfiller (8.25 µs<10% guard interval).
5.- Validate that both the transmitters and the receivers work properly, by observing that the signalling detected in the receiver is correct.
6.- Increase the noise level until QEF point is reached. This has been done in steps of 0.2 dB. The superior limit for the C/N threshold was established in 40dB, in other words, the maximum C/N measured was 40dB, if higher C/N were required, an incorrect demodulation was supposed in the receiver.
7.- Obtain the required C/N value at the QEF point from the channel simulator.
8.- Fill in the measured C/N value in dB in measurements record (excel sheet).
9.- Repeat the process from step 4 to 8 with all the possible delays (when using the gapfiller, this is not needed).
10.- Repeat the process from step 3 to 9 with all the channel profiles in *Table 2.10.2*.
11.- Repeat the process from step 1 to 10 with the *set-up* explained in *Figure 2.10.5* (gapfiller). First of all, test that the gapfiller is able to suppress correctly the echoes due to its signal output addition to its input.

Figure 2.10.9 shows how the configuration of the different equipments used was done.

Figure 2.10.9. Equipment used in T2-Lite in SFN Networks (laboratory test modulator, transmitter, gateway, channel simulator)

2.10.5 Results and Conclusions

This test allows to check that both the transmitters/modulators and demodulators work properly with the new T2-Lite features in SFN reception both with a secondary transmitter and a gapfiller.

The first result of this test was to check that the gapfiller was able to suppress all the echoes at its input, as it can be seen in *Figure 2.10.10*. The echoes due to the gapfiller appear because the echoes canceller is off. However, the echoes are suppressed when the echoes canceller is on, and a typical time response of a SFN scenario is obtained.

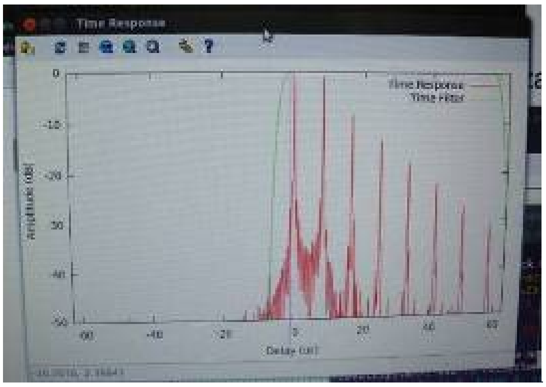

Figure 2.10.10. Time response of the signal on the receiver on a SFN with gapfiller with echoes

Table 2.10.4 shows the C/N ratio results obtained for both the SFN with a secondary transmitter and with the gapfiller for the Gaussian channel and the TU-6 with different delays between the two transmitters.

If the results for the UPV/EHU demodulator and the Receiver B are compared, it can be concluded that the UPV/EHU prototype has a better performance than the Receiver B in SFN (between 1dB and 3 dB better for the fixed channel profile while the improvement could be up to 5 dB for mobile channel profiles).

Table 2.10.4. C/N (dB) at QEF point in T2-Lite in SFN Networks evaluation

		Main transmission	Secondary transmission	M5					
				PLP0		PLP1		PLP2	
				UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B
Gaussian-AWGN	Delay: 8,25 µs (gapfiller)	Transmitter: Mier	Gapfiller: Mier	2,6	4,4	2,6	4,6	2,6	4,4
	Delay: 11,2 µs (10% GI)	Modulator: TeamCast	Transmitter: Mier	3,4	4,4	3,4	4,4	3,4	4,4
	Delay: 56 µs (50% GI)	Modulator: TeamCast	Transmitter: Mier	3,6	6,4	3,6	6,4	3,4	6,4
	Delay: 112 µs (100% GI)	Modulator: TeamCast	Transmitter: Mier	5,6	XXXXX	5,4	XXXXX	5,4	XXXXX
TU-6	Delay: 8,25 µs (gapfiller)	Transmitter: Mier	Gapfiller: Mier	4,6	7	4,4	7,2	5	7,6
	Delay: 11,2 µs (10% GI)	Modulator: TeamCast	Transmitter: Mier	5	8	5,2	8	5,6	8
	Delay: 56 µs (50% GI)	Modulator: TeamCast	Transmitter: Mier	6	10,8	6	10,8	7,2	11
	Delay: 112 µs (100% GI)	Modulator: TeamCast	Transmitter: Mier	13	XXXXX	13	XXXXX	13	XXXXX

Not correctly demodulated, CN>40dB (XXXX)

Comparing the results obtained for the different delays, the main conclusion is that an increment on the delay length from the 10% to the 50% guard interval supposes and increment on the C/N ratio of around 1dB. However, when the 100% guard interval is considered, the situation gets worse. The Receiver B is not capable to demodulate the received signal and with the UPV/EHU demodulator the C/N ratio results increase in between 3 and 5 dB. Comparing the results obtained when using the gapfiller (delay 8.25 µs) and when using the secondary transmitter with 10% guard interval delay (delay 11.2 µs) it can be concluded that the results are around 1dB better than when using the transmitter. This may be because of a lower delay between the two transmissions.

If the results in *Table 2.10.4* are compared with the results from Test 1 for the same configuration mode M5, the results in MFN (Test 1) are better than with SFN (Test 3) for every delay with the Gaussian channel. However, the situation changes when the TU-6 channel is considered. In this case, for the smallest delays (8.25 and 11.2 µs) the C/N threshold in SFN is slightly better (around 1 dB) than in MFN (Test 1); in other words, there is a gain for small delays of almost 1 dB. From the 56 µs delay, the SFN makes the C/N threshold get worse.

2.11 Mixed T2 and T2-Lite in SFN Networks Evaluation

2.11.1 Introduction

The main objectives of this test were:

- Test TF10 prototypes in full chain to guarantee a correct HW interoperability in TF12 field trials using a SFN network with Mixed T2 and T2-Lite modes
- Test how robust the system is by carrying out laboratory tests with different attenuation-delay profiles and measuring the minimum C/N ratio in order to guarantee a correct reception.
- Obtain reference performance values for comparison with TF12-field trials results.

The UHF channel C22 (482 MHz) was used in this laboratory test, as it is the same channel that was going to be used on the field trials in TF12. *Table 2.11.1 (see next page)* shows the sets of Mixed T2 and T2-Lite configuration parameters that were used to validate this feature. The selected mode is one of the modes that was going to be also used in the field trials so as to guarantee its correct performance.

- M7 and T2 combination mode is the same as one of the field trials modes in TF12. The T2-Base mode has been selected in order to have high *bit-rate* although its robustness is not very high (256QAM). This is because it is thought for high definition fixed reception. The T2-Lite mode has been selected to be quite robust (QPSK 1/2) but with low bit-rate (near 1MBps). By this way, a realistic balance between the T2 and T2-Lite parts is achieved.

The measurements were carried out for the set of channel profiles given in *Table 2.11.2*. For each propagation channel model, the related profile column reports on the T2-Lite profiles that have been tested in each case.

Table 2.11.2. Channel models for Mixed T2 and T2-Lite evaluation.

Configuration	***Propagation Channel Model***	***Related Profiles***
Reference	Gaussian - AWGN	M7/T2
Mobile	TU6 – Doppler = 20 Hz (44Km/h @ 482 MHz)	

The reference mode (Gaussian - AWGN) was tested with all the modulator/transmitters and for all the configuration modes defined in *Table 2.11.1* in order to validate all the TF10 prototypes in a full chain. However, the other channel model (TU-6) was tested only with the transmitter, as it was the one that was going to be used in the posterior TF12 field trials and by this way reference values for the TF12 field trials were obtained.

Table 2.11.1. T2-Lite Profiles for Mixed T2 andT2-Lite in SFN Networks evaluation

Scenario	Mixed T2 and T2-Lite in SFN Networks	
	T2-Lite	**T2-Base**
Reference	**M7**	**T2**
Single or Multiple PLP	Single	Single
Frames per Superframe	2	2
Number of data symbols	39	31
Subslices	1	1
Channel BW (MHz)	7.61	7.77
FFT	8k	32k ext.
Guard Interval	1/8	1/16
Guard Interval Duration (μs)	112	224
Resulting Cell Size (km)	33.5	67
L1 Constellation	BPSK	BPSK
Post-scrambling	Yes	Yes
Pilot Pattern	PP2	PP4
TR-PAPR	L1 & P2	L1 & P2
SISO/MISO	SISO_LITE	SISO
FEF	Yes	Yes
FEF Length	1.116.160	379.904
FEF Interval	1	1
	PLP0	**PLP0**
PLP Type	Type 2	Type 2
Constellation	QPSK-R	256QAM-R
Code Rate	1/2	2/3
LDPC Frame Length (bits)	16200	64800
Number of FEC blocks	30	103
HEM	Yes	Yes
ISSY	Long	Long
NPD	No	No
IL Type	0	0
IL Length	1	2
Frame Interval	1	1
Interleaving time (ms)	41.32	60.92
In band Signalling	Type B	Type A
Network Topology	SFN	SFN
Bit-Rate (Mbps)	**1.28**	**27.18**
Channels to be tested	Gaussian/TU-6	

2.11.2 Prototypes under test

The prototypes that were tested in the Mixed T2 and T2-Lite in SFN Networks laboratory test are those on *Table 2.11.3*. *Figure 2.11.1* shows some screen captures from the UPV/EHU demodulator, showing SFN impulse response and spectrum screen captures

Table 2.11.3. Prototypes to test in the Mixed T2 and T2-Lite in SFN Networks laboratory test

EQUIPMENT	***COMPANY***
T2 Modulator	TeamCast
T2 Transmitter	Mier
T2 Gapfiller	Mier
T2 Gateway (x2)	Enensys
T2 Demodulator	UPV/EHU

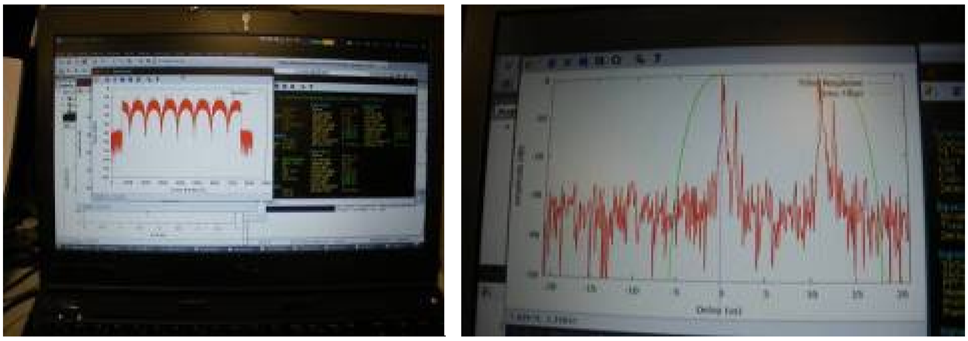

Figure 2.11.1. Spectrum and Time Response in Mixed T2 and T2-Lite in SFN Networks evaluation.

2.11.3 Set-up

Two different *set-ups* were tested for measuring the SFN performance. The first one consisted on a main transmitter and a secondary transmitter while the second one consisted on a main transmitter and a gapfiller.

Figure 2.11.2 and *Figure 2.11.3* show the possible network schemes for the posterior TF12 T2-Lite field trials. As this test focused on a check of the correct HW interoperability in SFN networks in order to guarantee a correct working on the posterior field trials, only the equipment that was going to possibly be used in the field trials were tested in the laboratory. *Figure 2.11.2* shows a SFN network using a secondary transmitter while *Figure 2.11.3* shows an SFN network but with a secondary gapfiller.

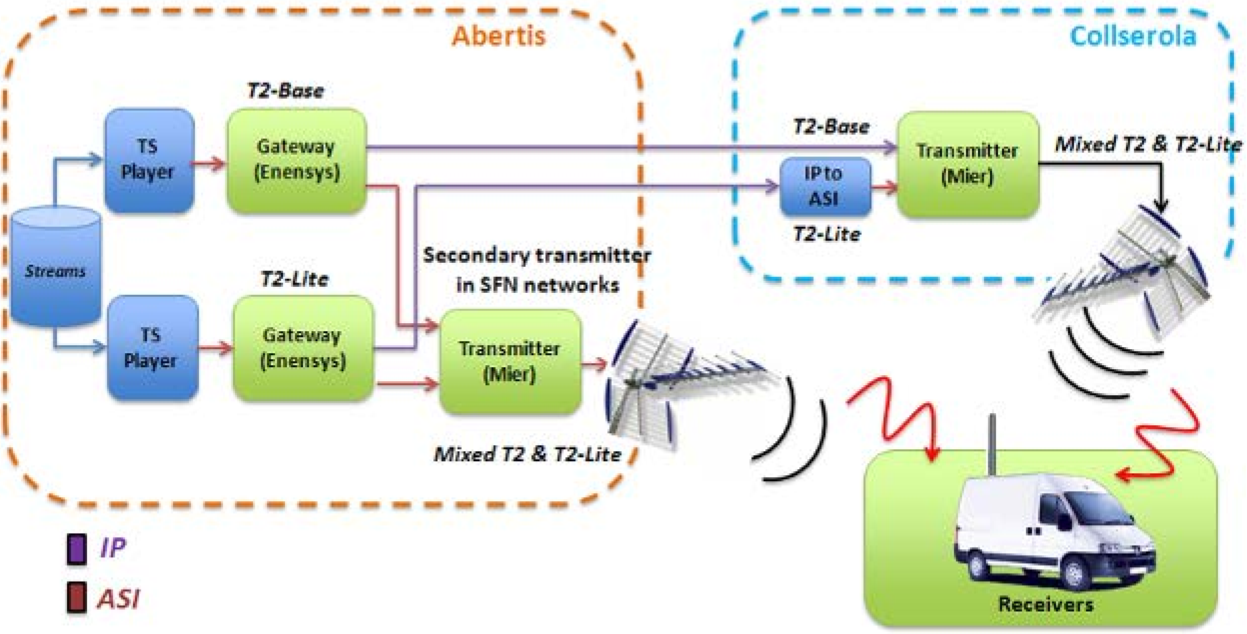

Figure 2.11.2. Reference set-up for Mixed T2 and T2-Lite in SFN Networks field trials using a secondary transmitter

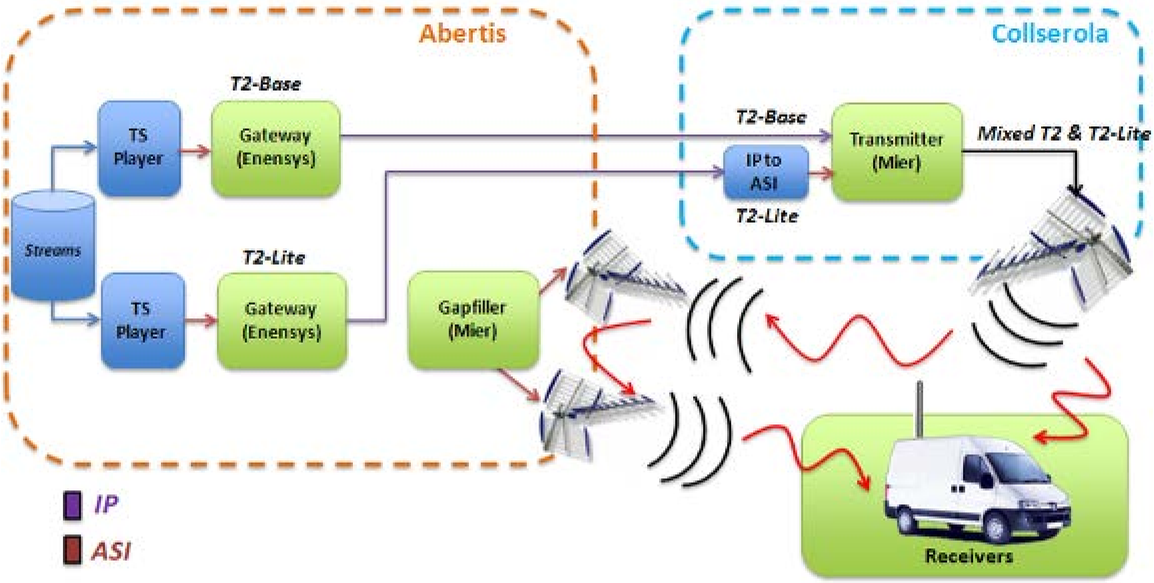

Figure 2.11.3. Reference set-up for Mixed T2 and T2-Lite in SFN Networks field trials using a gapfiller

Figure 2.11.4 and *Figure 2.11.5* show the reference *set-up* for this laboratory test. The modulator/transmitter/gapfillers selected were those from *Figure 2.11.2* and *Figure 2.11.3*, showing the two possibilities for the SFN networks in the field trials: using a secondary modulator/transmitter (*Figure 2.11.4*) or using a gapfiller (*Figure 2.11.5*), so that both cases were tested.

Figure 2.11.4 refers to the case of a secondary transmitter. In order to test the same case as in the following field trials, the main transmitter/modulator input (the one that simulates the one in Collserola as the Mier transmitter has a TeamCast modulator inside) was by IP. However, as it is necessary one ASI input and one IP input to generate the mixed signal, and IP to ASI converter was needed for one of its inputs. The secondary transmitter inputs (the one that simulates the one in the Abertis facilities) were by ASI. The channel simulator is in charge of delaying the secondary transmitter output signal simulating an SFN reception.

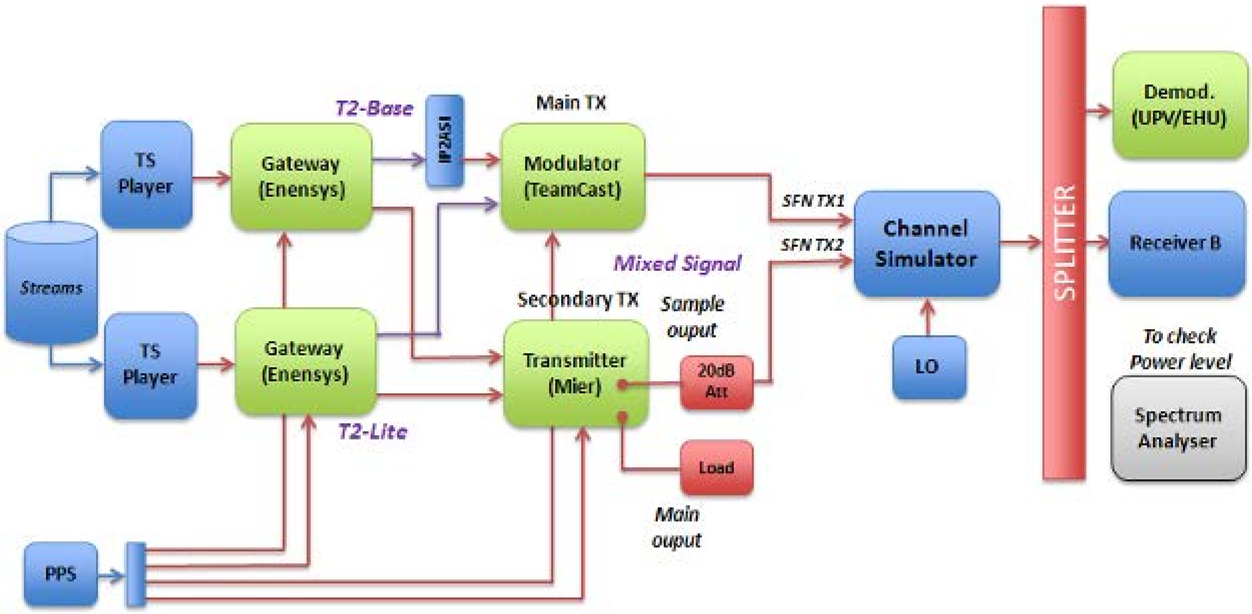

Figure 2.11.4. Reference test set-up for Mixed T2 and T2-Lite in SFN Networks laboratory test using a secondary transmitter

Figure 2.11.5 refers to the case of using a gapfiller. In order to test the eco suppression with the gapfiller, the gapfiller output is added to the main transmitter output- In this case only the Mier transmitter was tested in order to simulate the real situation in the posterior field trials.

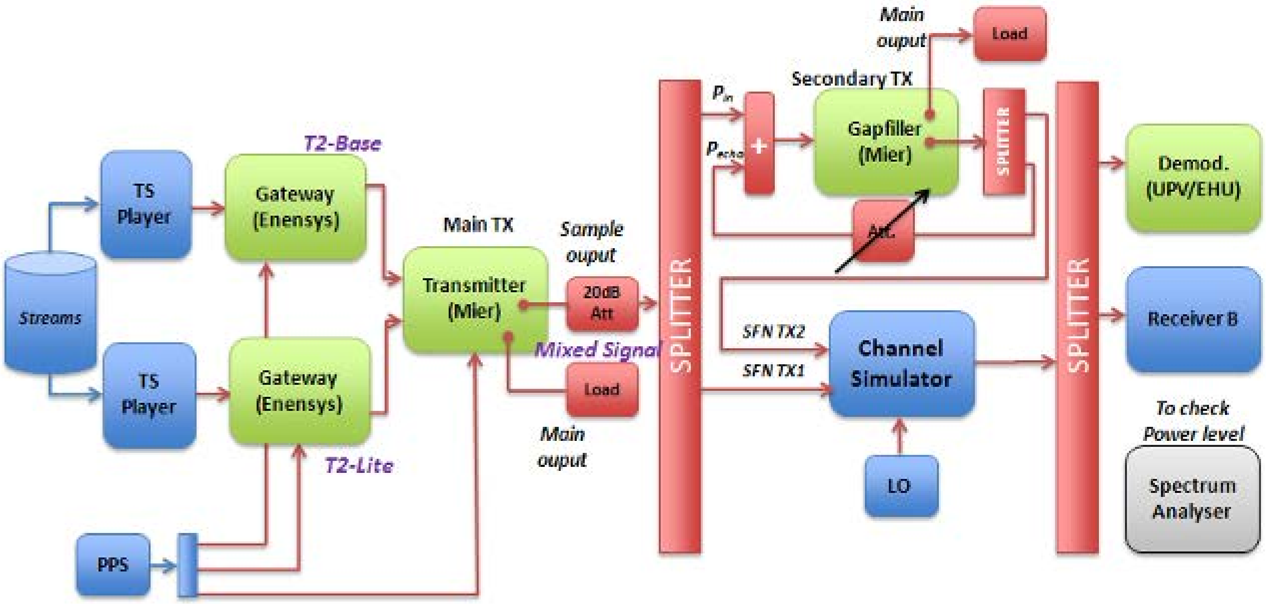

Figure 2.11.5. Reference test set-up for Mixed T2 and T2-Lite in SFN Networks laboratory test using a gapfiller

Apart from the prototypes indicated on *Table 2.11.3*, the laboratory equipments shown on *Figure 2.110.4* and *Figure 2.11.5* in blue (and grey) were also necessary. Two TS players were necessary in order to play the different TS data flows (one for T2-Base and one for T2-Lite). A channel simulator was also needed so as to simulate the different channel profiles described on *Table 2.11.2*, increase the delay between its input 1 (from the main transmitter) and its input 2 (from the secondary transmitter or the gapfiller) and increase the noise level to measure the C/N ratio at the QEF point. A Local Oscillator was needed in order to make the channel simulator work properly.

A spectrum analyser was also used for measuring the power level inserted in the channel simulator input due to the limit in the maximum power level allowed in its inputs. An external GPS PPS generator was used to synchronise all the equipments used.

Besides, some laboratory accessories were also necessary to connect all the prototypes, as it can be shown in *Figure 2.11.4* and *Figure 2.11.5* in red. These are cables, transitions attenuators, DC blockers, splitters, adders and impedance adapters. The transmitter amplifier (50.05 dBm – 101W –) high power level output was connected to a resistor (250W, 50Ω) so as to turn the high power into hot while the sample output (with around 20dB coupled) was the one used during the plug fest. The gapfiller high power level output was connected to a channel 22 filter and from here to an antenna.

2.11.4 Test Procedure

The test procedure to follow in the Mixed T2 and T2-Lite SFN performance laboratory test is shown on *Figure 2.11.6*.

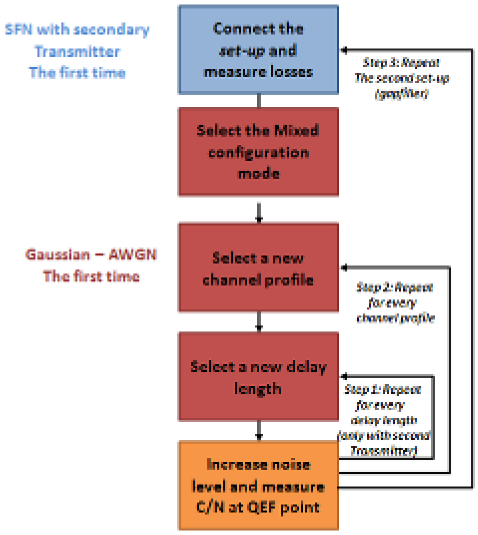

Figure 2.11.6. Test procedure for Mixed T2 and T2-Lite in SFN Networks laboratory test

1.- Connect the test set-up as it is explained in *Figure 2.11.4* (secondary transmitter). The channel simulator output power level was established in -40dBm.
2.- Set the Mixed T2-Base and T2-Lite configuration mode from *Table 2.11.1*.
3.- Set one channel profile from *Table 2.11.2*. The first one should be Gaussian-AWGN.
4.- Set the delay between the main transmitter and the secondary transmitter in 10%, 50% and 100% of the guard interval length (for the case with a secondary transmitter). Set no delay for the case of using a gapfiller, because the delay between the signal from the main transmitter and the gapfiller will be the one introduced by the gapfiller (8.25 µs<10% guard interval).
5.- Validate that both the transmitters and the receivers work properly, by observing that the signalling detected in the receiver is correct.
6.- Increase the noise level until QEF point is reached This has been done in steps of 0.2 dB. The superior limit for the C/N threshold was established in 40dB, in other words, the maximum C/N measured was 40dB, if higher C/N were required, an incorrect demodulation was supposed in the receiver.
7.- Obtain the required C/N value at the QEF point from the channel simulator.
8.- Fill in the measured C/N value in dB in measurements record (excel sheet).
9.- Repeat the process from step 4 to 8 with all the delays (when using the gapfiller, this is not needed).
10.- Repeat the process from step 3 to 9 with all the channel profiles in *Table 2.11.2*.
11.- Repeat the process from step 1 to 10 with the *set-up* explained in *Figure 2.11.5* (gapfiller). First of all, test that the gapfiller is able to suppress correctly the echoes due to its signal output addition to its input.

Figure 2.11.7 shows some configuration screens of some prototypes used on this laboratory session.

Figure 2.11.7. Configuration screens in Mixed T2 and T2-Lite in SFN Networks evaluation.

2.11.5 Results and Conclusions

This test allows to check that both the transmitters/modulators and demodulators work properly with the mixed T2-Base and T2-Lite new configuration modes in SFN reception both with a secondary transmitter and a gapfiller. *Table 2.11.4* shows the C/N ratio results obtained for both the SFN with a secondary transmitter and with the gapfiller for the Gaussian channel and the TU-6.

If the results for the UPV/EHU demodulator and the Receiver B are compared, it can be concluded that the UPV/EHU prototype has a better performance than the Receiver B in SFN (between 1 and 4 dB).

Table 2.11.4. C/N (dB) at QEF point in Mixed T2 and T2-Lite in SFN Networks evaluation

				M7/T2			
				M7		T2	
		Main transmission	Secondary transmission	UPV/EHU Demodulator	Receiver B	UPV/EHU Demodulator	Receiver B
Gaussian-AWGN	Delay: 8,25 µs (gapfiller)	Transmitter: Mier	Gapfiller: Mier	6,4	8,4	XXXXX	XXXXX
	Delay: 11,2 µs (10% GI)	Modulator: TeamCast	Transmitter: Mier	6,2	8,2	XXXXX	XXXXX
	Delay: 56 µs (50% GI)	Modulator: TeamCast	Transmitter: Mier	8	11,2	XXXXX	XXXXX
	Delay: 112 µs (100% GI)	Modulator: TeamCast	Transmitter: Mier	12,6	XXXXX	XXXXX	XXXXX
TU-6	Delay: 8,25 µs (gapfiller)	Transmitter: Mier	Gapfiller: Mier	7,4	11,6	XXXXX	XXXXX
	Delay: 11,2 µs (10% GI)	Modulator: TeamCast	Transmitter: Mier	8,2	11,2	XXXXX	XXXXX
	Delay: 56 µs (50% GI)	Modulator: TeamCast	Transmitter: Mier	11,4	14,6	XXXXX	XXXXX
	Delay: 112 µs (100% GI)	Modulator: TeamCast	Transmitter: Mier	12,8	XXXXX	XXXXX	XXXXX

Not correctly demodulated, C/N>40dB (XXXX)

Comparing the results obtained for the different delays, the main conclusion is that an increment on the delay length from the 10% to the 50% guard interval supposes and increment on the C/N ratio of around 3 dB. The same happens when the delay increases from 50% to 100% guard interval although the Receiver B is not capable to demodulate the received signal. Comparing the results obtained when using the gapfiller (delay 8.25 µs) and when using the secondary transmitter with 10% guard interval delay (delay 11.2 µs) it can be concluded that the results are quite similar.

Considering the T2-Lite part, if the results in *Table 2.11.4* are compared with the results from Test 2 for the same configuration mode M7, the results in MFN (Test 2) are better than with SFN (Test 4) for every delay with the Gaussian channel. However, the situation changes when the TU-6 channel is considered. In this case, for the smallest delays (8.25 and 11.2 µs) the C/N threshold in SFN (Test 4) is slightly better (around 1 dB) than in MFN (Test 2); in other words, there is a gain for small delays of between 1 and 1.8 dB. From the 56 µs delay, the SFN makes the C/N threshold get worse.

Analyzing the M7 in Test 4 and the M5-PLP0 results in Test 3, they should be comparable because M5-PLP0 is similar to M7 configuration mode. However, higher C/N results have always been obtained in Test

4. These unexpected results were not in accordance with the results obtained by the different partners in their individual tests.

Considering the T2-Base component, it was impossible to demodulate the received signal correctly. This result was unexpected and was not in accordance with the results previously obtained by the partners in their individual tests. One possible reason for this may have been the existence of a frequency offset between the transmitter and the modulator that simulated the SFN, as no 10MHz synchronization signal was used. The frequency offset has higher influence on the T2-Base component (32K 256QAM) than in the T2-Lite component (8K, QPSK), and this could have been the reason for the incorrect demodulation of the T2-Base component.

3 SC-OFDM PLUG FEST

3.1 SC-OFDM for satellite segment Evaluation

3.1.1 Introduction

This laboratory test directly deals with the newly standardized DVB-NGH system, and more particularly its satellite component. Indeed, the DVB-NGH natively comprises an optional satellite component to allow for the deployment of hybrid terrestrial/satellite networks over large and sparsely populated areas. Just like the DVB-SH standard, the DVB-NGH specifies two different waveforms for the satellite link. Both systems support the OFDM modulation that can be used either in SFN mode along with the terrestrial OFDM component or in MFN mode with dedicated optimized parameters. However, unlike the DVB-SH, the DVB-NGH does not support the TDM modulation but a closely related waveform, the so-called Single-Carrier Orthogonal Frequency Division Multiplexing modulation (SC-OFDM). Basically, the SC-OFDM applies a Discrete Fourier Tranform (DFT) onto the symbols to be transmitted so that the OFDM modulation produces an oversampled version of the vey same original symbols. The SC-OFDM modulation was adopted in the DVB-NGH standard thanks to its ability to preserve a lot of commonalities with pure OFDM while benefiting from the low power fluctuations of TDM signals, a critical issue when dealing with the non linearity of the satellite power amplifiers.

The purpose of the SC-OFDM test is to assess the suitability of the SC-OFDM modulation for satellite broadcasting towards handheld terminals. It had initially been planned to conduct this evaluation using an existing hardware platform that was partially implementing the uplink scheme of the 3GPP/LTE cellular system, itself relying on the SC-OFDM modulation. This platform was unfortunately suffering of a lack of memory for the implementation of the DVB-NGH long-time interleaving. Besides, the 3GPP/LTE and DVB-NGH physical layers are sensibly different and basic adaptations applied onto the 3GPP/LTE system would not have led to relevant performance evaluation with respect to the satellite broadcasting environment. As the specifications of the DVB-NGH system have been frozen during the lifetime of the ENGINES project, it was decided to implement the actual SC-OFDM component of the DVB-NGH hybrid profile on a new platform (See Deliverable D10.2 [1]).

The SC-OFDM design has been developped merely from scratch starting beginning of 2012. As the platform was developed on a new board, the implementation process has been delayed due to a few hardware issues met in the development of the board firmware. The design of the system has been completed just by the end of the project. It was thus not possible to perform all the measurements as intially planned before the completion of the TF11.D2 deliverable. Nonetheless, the measurements will be performed and the outcome of these tests will be described in a last revision of TF11.D2. The remaining part of the section decribes the test plan that will be followed for the measurements. It also provides initial results, including complexity figures, assessing the completion of the development.

3.1.2 Tests goals

At the exception of the gap-filler scenario, the SC-OFDM modulation can only be applied for the satellite link in MFN where the terrestrial component operates in the VUHF band while the satellite link operates in the L or S-bands. The primary goal of the tests is thus to assess the suitability of the SC-OFDM modulation for satellite transmissions.

With that respect, the following tests will be carried out:

- Test of the SC-OFDM robustness against power amplifier (PA) non-linearity.
- Test of the SC-OFDM performance in the Land Mobile Satellite (LMS) channel with the Convolutional Interleaving (CI) scheme specified in the DVB-NGH standard.

The performance of the SC-OFDM waveform with respect to the power amplifier non-linearity will be evaluated using a FGPA emulator of the satellite power amplifier. The module developed as part of the ENGINES project relies on a memoryless table-based model. It is thus possible to consider different power amplifiers described by their AM/AM response. The impact of the PA non-linearity will be measured in terms of Modulation Error Ratio (MER), Bit Error Rate (BER), and Total Degradation (TD).

The performance of the SC-OFDM modulation with respect to LMS channel will be evaluated using the 3GCC hardware emulator provided by CNES. The corresponding measurements will be thus carried in collaboration between MERCE and CNES. The performance of the SC-OFDM modulation will be measured in terms of BER, Frame Error Rate (FER) and Erroneous Second Ratio (ESR5) criteria. The tests will be performed assuming a perfect synchronization in order to allow for comparision with theoretical simulation results.

3.1.3 Prototype under test

The SC-OFDM modulation is evaluated using the so-called MERCE Hardware Evaluation Platform (HEP), a FPGA re-configurable platform meant to evaluate advanced technologies related to wireless transmissions. In its current version, the platform does not support the DVB physical and logical standard interfaces. It is not possible to interconnect the platform to other DVB compliant products (e.g. DVB-T2 gateway). Instead, the platform will be used in a standalone mode to carry on performance evaluation to be cross checked with simulation. The HEP platform shown on *Figure 3.1.1* is fully specified in Deliverable D10.2 [1].

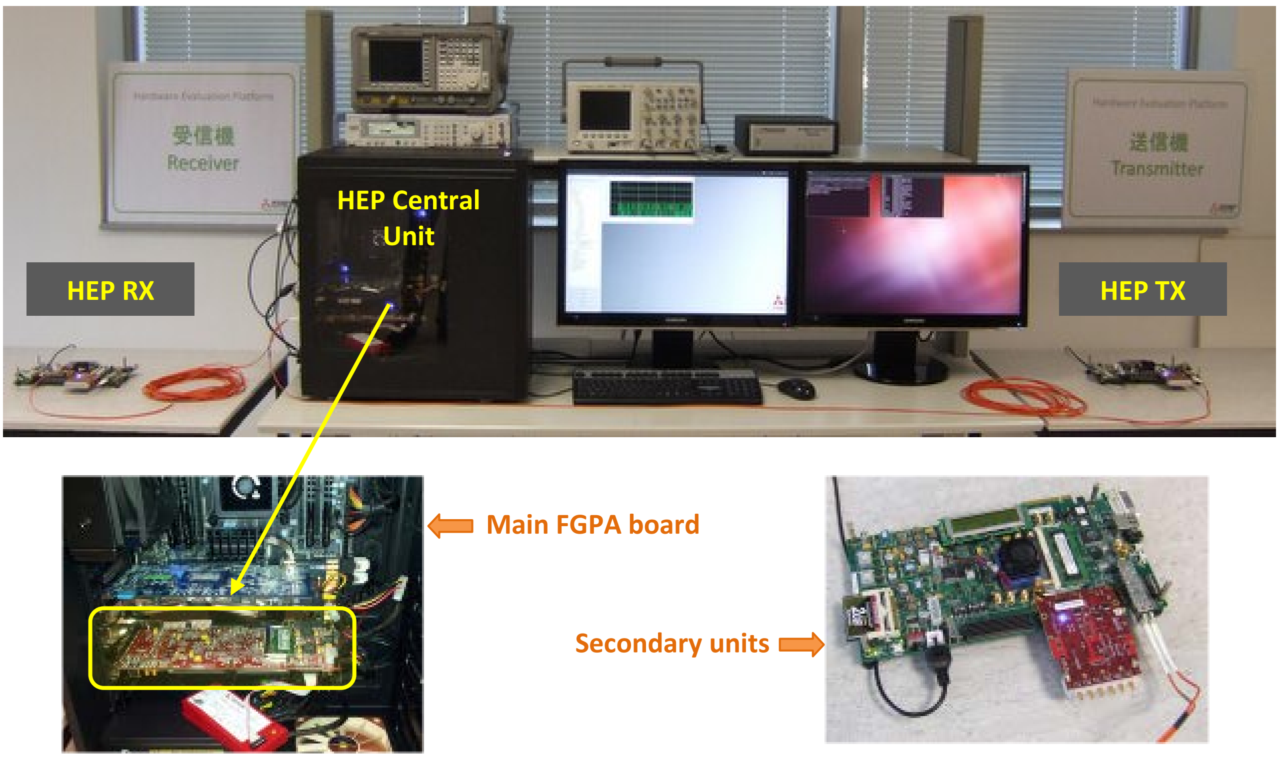

Figure 3.1.1. Overview of the MERCE DVB-NGH SC-OFDM platform.

As shown on *Figure 3.1.1* the HEP platform is made of three entities, the HEP Central Unit and the HEP TX and RX parts. The HEP platform is actually dedicated to the evaluation of new technologies for research purposes. In that purpose, both the transmitter and the receiver are implemented within the same equipment (HEP Central Unit). To still allow for transmission over long distances, the main processing board is connected to 2 secondary units using 5 Gbps full duplex optical links. The first unit (HEP TX) implements the digital to analogue conversion on an intermediate frequency (IF) while the second unit (HEP RX) implements the analogue to digital conversion from IF down to baseband. The HEP Tx and HEP Rx units will be used to interconnect in analogue with the 3GCC channel emulator from CNES shown on *Figure 3.1.2*.

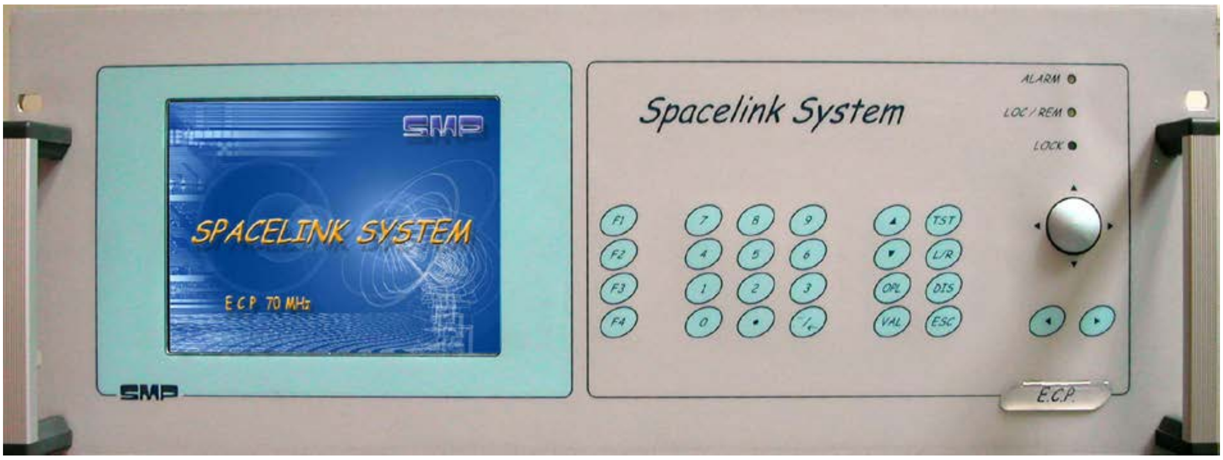

Figure 3.1.2. 3GCC channel emulator from CNES.

The purpose of the HEP platform is to validate the performance of the SC-OFDM modulation in the context of satellite broadcasting. For that reason, the system does not implement the whole set of the DVB-NGH specifications. However, *all the implemented functionalities are fully compliant with the standard*. The platform actually focuses on the satellite component of the hybrid profile, and more particularly the SC-OFDM mode of the satellite component. Thus, neither the OFDM option of the satellite component nor the terrestrial component is supported even if the platform is obviously OFDM capable. The platform also focuses on the physical layer functionalities: the gateway functionalities are simply emulated when needed.

The key functionalities supported by the HEP DVB-NGH platform are as follows:

- Full support of the SC-OFDM waveform (spreading, de-spreading, PP9 pilot pattern)
- Support of type 1 and type 2 multi-PLPs
- Ready for multi-PLPs, but only 1 PLP validated so far
- Support of the logical frames and logical super-frames
  - Only the logical channel of type A
- Support of long-time convolutional interleaving (CI)
  - Also for longer durations than in NGH (up to 10s)

The system parameters supported by the platform are summarized in *Table 3.1.1*.

Table 3.1.1. Parameters supported by the SC-OFDM platform.

Parameter		
Bandwidth	2.5 MHz[(1)]	5 MHz
FFT size (N)	0,5k – 1k	0,5k[(2)]– 1k[(2)]– 2k
Constellation	QPSK – 16QAM	
Guard Interval	1/16 – 1/32 (w.r.t. N)	
Preamble	P1 + aP1[(3)]	
Pilot Pattern	PP9	
FEC	~~1/5~~ ~~4/15~~ 1/3 2/5 ~~7/15~~ 1/2 ~~8/15~~ 3/5 2/3 ~~11/15~~ 3/4[(4)]	

[(1)] Feasible but not supported
[(2)] Implemented but not tested
[(3)] Currently stored as tables
[(4)] Use of a commercial T2-lite IP core

3.1.4 Set-up

The test plan was elaborated by CNES based on its proven expertise in the evaluation of satellite systems. The test bench that will be used for performing the SC-OFDM evaluation in the context of the LMS channel is depicted on *Figure 3.1.3*. The evaluation will be done in the case of a 5 MHz bandwidth.

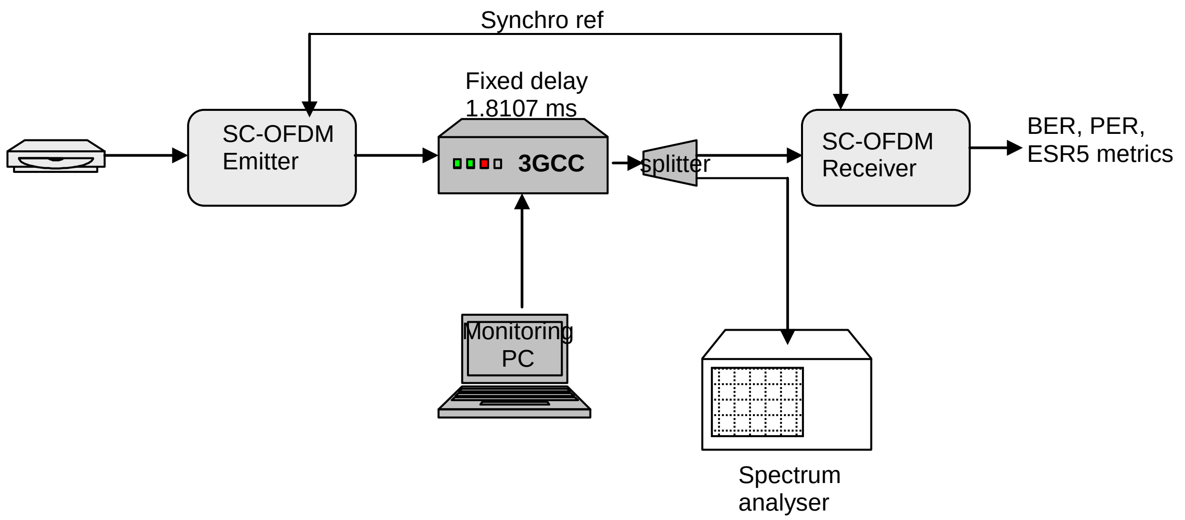

Figure 3.1.3. Reference test set-up for the SC-OFDM laboratory evaluation.

The 3GCC equipement provides the following interfaces:

- Channel 1 RF input (CH1) with intermediate frequency centered at 70 MHz. Ideal power is included between -25 et -50 dBm. A physical attenuator can plugged at the input to decrease signal power if needed.
- CH1 output is also centered at 70 MHz at around -30 dBm power.
- 3GCC can be remotely controlled by PC, using VNC and Filezilla applications. IP adress is 192.168.0.200. 3GCC needs a manuel starting with remote authorization.

The HEP TX and HEP RX units of the SC-OFDM platform have been parametrized in order to interconnect on the 70 MHz intermediate frequency. The signal at the output of the 3GCC will be amplified to match will the optimal input level of the ADC module of the HEP RX unit.

The 3GCC sampling rate is set to 10 MHz. Trade off is made within large scale of C/N ratios to generate and input signal bandwith. Corresponding to 10 MHz samplig rate, delays of 3GCC are (1 ns accuracy) :

- at least 0.232460 ms for gaussian channel
- at least 1.810700 ms for file reading mode

As the tests will be performed assuming a perfect synchronization, the HEP platform implements a delay module to compensate for the delay introduced by the 3GCC emulator.

Using both propagation .dll and exerpts of real measurments, CNES generated direct path and multipaths power (macro parameters) files at 100Hz sampling rate. Generation of real I/Q channel at 10 MHz sampling is then done by 3GCC.

3.1.5 Test Procedure

The HEP platform embeds all the means required to carry on the tests and measurements: PRBS generator and monitoring application for performance measurements. The measurement methodology for BER / FER / ESR5 versus C/N performance is as follows:

1. Set up the instruments.
2. Set test parameters.
3. Set the 3GCC hardware emulator.
4. Set the RF input level to –30dBm.
5. Starting from high C/N, decrease the C/N and fill in the corresponding BER after LDPC value measured by the receiver in measurement record. The goal is to sweep the C/N range in order to get representative BER/PER curves, up to PER 10^{-5}, and ESR5 curves up to 99% criteria fullfilment.

In order to check that 3GCC equipement is working correctly with MERCE equipements Gaussian tests will be carried out. Results may be compared with MERCE tests performed with other Channel Propagation emulator.

<u>*Tests duration:*</u>
Tests have each a 10 mn duration for 1 /CN. Accounting 6 C/N values per case, Each Id cas may take 1h duration.

Table 3.1.2. Test modes for the calibration of the test bed.

Id case	Modulation and coding	Propagation channel	Interleaving duration	Test duration
0.1	QPSK 1/3	Gaussian	-	~ 1H
0.2	QPSK 4/9	Gaussian	-	~ 1H

Once the system calibrated, measurements will be performed for 5 different channel configurations supported by the 3GCC channel emulator:

- ITS_60 : Intermediate wooded tree shadowed vehicular channel at 60 km/h
- SUB_60 : suburban vehicular channel at 60 km/h
- OPN_3 : opened vehicular channel at 3 km/h
- OPN_130 : opened vehicular channel at 130 km/h
- LRY_60 : Saint Lary wooded vehicular real channel à 60 km/h

Each channel has a duration of 7mn30 duration exept the LRY_60 case which has a 2 mn duration. To make ESR5 metrics more accurate, all channels shall be played during the whole duration (7mn30).

Tests duration :

Tests have each a 10 mn duration for 1 /CN. Accounting 6 to 8 C/N values per case, Each Id case may take up to 1h duration. The list of the tests to be performed is given in *Table 3.1.3*.

Table 3.1.3. Test modes for the calibration of the test bed.

Id case	Modulation and coding	Propagation channel	Interleaving duration	Test Duration
1.2	QPSK 1/3	ITS_60	0.25 s	~1H20mn
1.2	QPSK 1/3	ITS_60	2 s	~1H20mn
1.3	QPSK 4/9	ITS_60	2 s	~1H20mn
2.1	QPSK 1/3	SUB_60	0.25 s	~1H20mn
2.2	QPSK 1/3	SUB_60	2 s	~1H20mn
2.3	QPSK 4/9	SUB_60	2 s	~1H20mn
3.1	QPSK 1/3	OPN_3	0.25 s	~1H
3.2	QPSK 4/9	OPN_3	0.25 s	~1H
4.1	QPSK 1/3	OPN_130	0.04 s	~1H
4.2	QPSK 4/9	OPN_130	0.04 s	~1H
5.1	QPSK 1/3	LRY_60	2 s	~1H20mn

3.1.6 Results and Conclusions

As explained in introduction, it was originally planned to evaluate the SC-OFDM modulation using a hardware platform implementing the SC-OFDM modulation as used in the 3GPP/LTE uplink signal. Due to a lack of memory in this existing platform, and also to obtain more relevant results, it was finally decided to implement the SC-OFDM modulation *as specified in the DVB-NGH* standard in a new and more powerful platform. Due to a few hardware issues met with the new platform, it was not possible to finalise the implementation early enough to provide in due time the outcome of the performance evaluation. The platform is actually now fully integrated and is being tuned so as to optimize its performance.

Figure 1.3.4 and *Figure 1.3.5* respectively illustrate the application used to monitor the transmitter and the receiver. On this particular example, the system transmits an SC-OFDM signal in 16QAM with the pilot pattern specified in the DVB-NGH standard (PP9). Prior reception, the signal goes through a simplified LMS channel emulator developed as part of the ENGINES project. This explains the time fluctuation in the received signal on *Figure 1.3.5*.

On *Figure 1.3.4*, the 3D graph on the left hand side shows the T/F samples after spreading and just before OFDM modulation. The pilot pattern is made of reference symbols (in blue) and data (in yellow) interleaved in the frequency domain. One can notice that the frequency samples show important amplitude fluctuations due to the application of the spreading in the frequency domain. Once the OFDM modulation applied, the signal recovers the typical amplitude fluctuation of a 16QAM TDM signal (Transmitted samples on the right hand side). *Figure 1.3.6* shows the same system but configured in OFDM mode. It can then be noticed that the samples in the frequency domain show almost no amplitude fluctuation (16QAM samples). On the other hand, once OFDM modulated, the resulting signal shows more amplitude fluctuations than in SC-OFDM mode (See Transmitted samples). This illustrates the suitability of the SC-OFDM modulation for satellite transmissions.

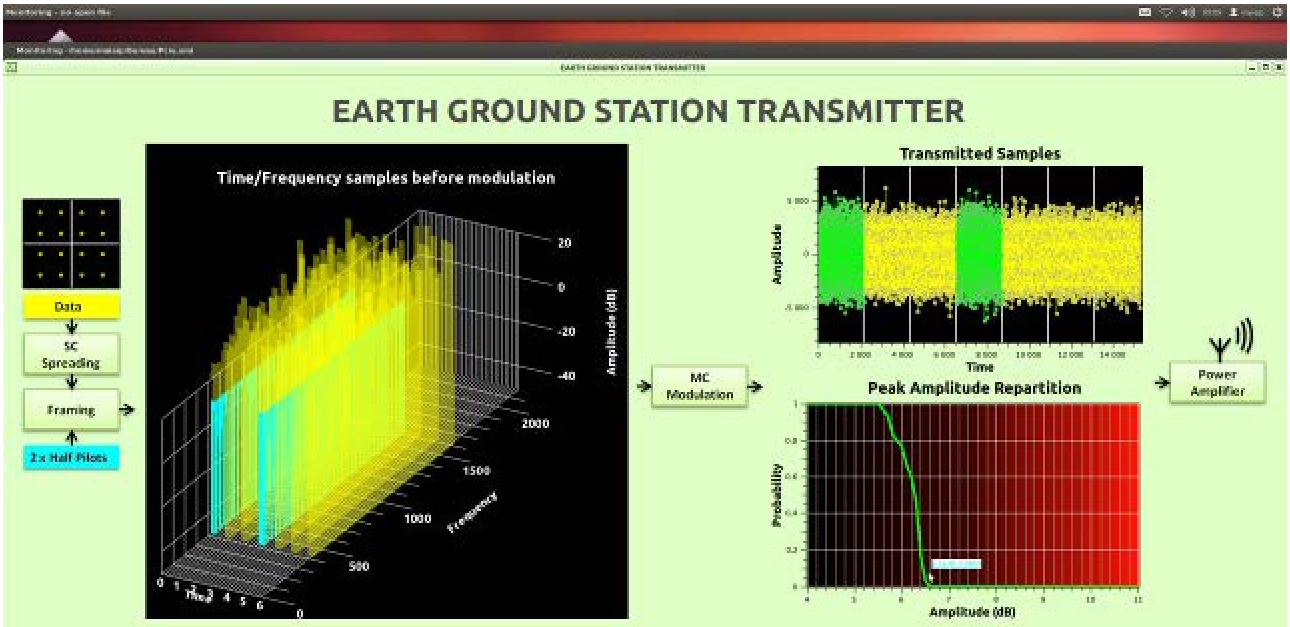

Figure 3.1.3. Illustration of the SC-OFDM transmitter monitoring application.

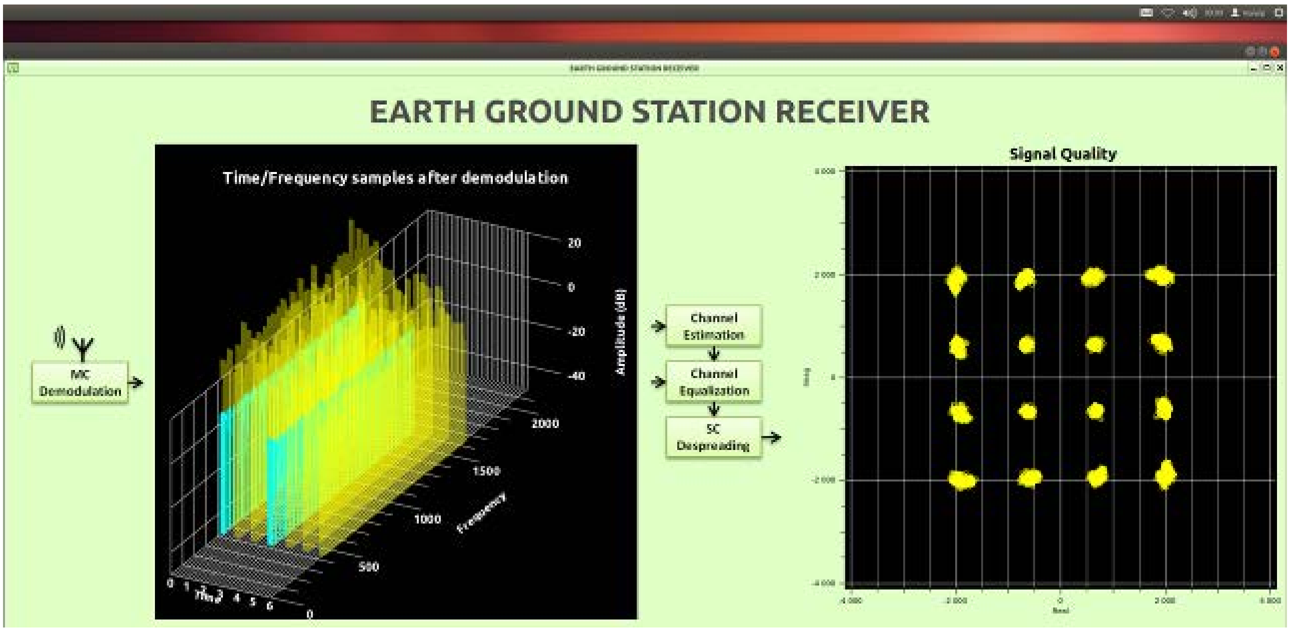

Figure 3.1.4. Illustration of the SC-OFDM receiver monitoring application.

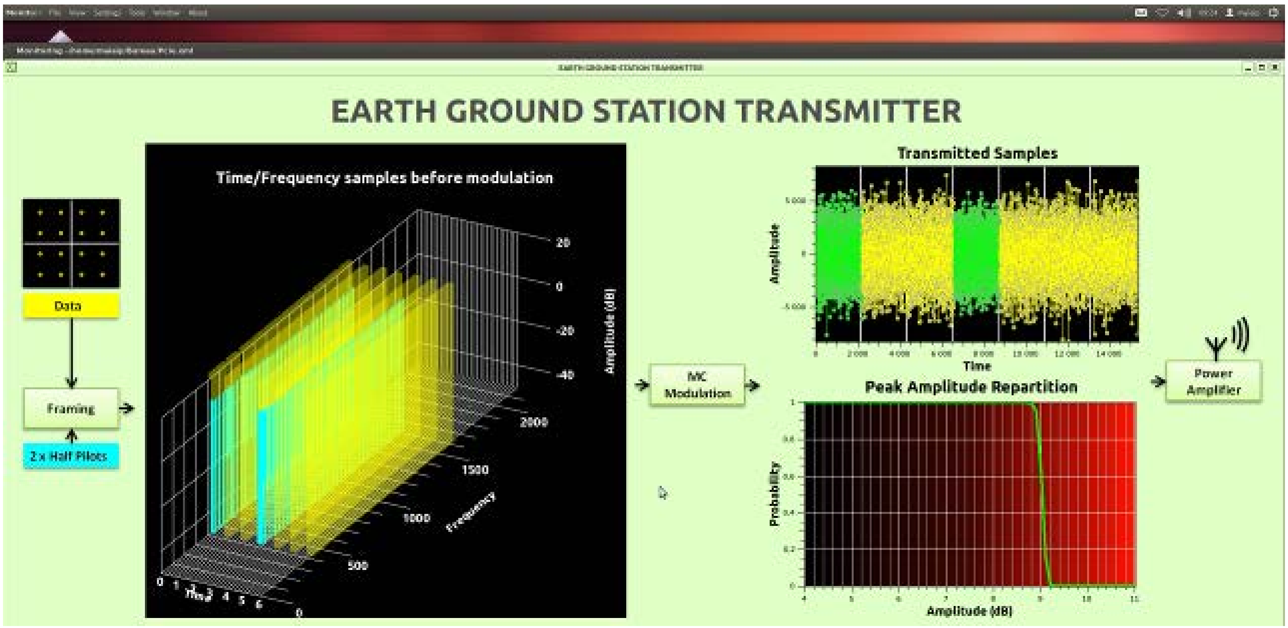

Figure 3.1.6. Illustration of the HEP receiver in OFDM mode.

As an initial result, *Table 3.1.4* and *Table 3.1.5* provide the detailed complexity of the system in terms of Xilinx FPGA resources, here a Virtex-6 HX380T device. Note that the system does not implement so far any synchronization algorithm. The complexity is also given here with the CI memory mapped into the FPGA block RAMs. In the final version, the CI memory will be mapped within an external 1 GB DDR3 SDRAM module. The main difference with a pure OFDM system lies in the implementation of the DFT operator for applying the spreading and de-spreading functions.

Table 3.1.4. SC-OFDM transmitter complexity (FPGA resources).

	Platform Configuration	Input Processing	BICM	Frame Building wo Spreading	Spreading	OFDM Modulation	Total	Available
LUTs	4613	5043	4245	3167	7598	3400	28066	239040
Registers	3468	3970	5006	2647	8450	4993	28534	478080
RAMB36	0	32	142	69	11	7	261	768
DSP48E1	0	1	7	7	17	20	52	864

	Platform Configuration	Input Processing	BICM	Frame Building wo Spreading	Spreading	OFDM Modulation	Total	Available
LUTs	1,9%	2,1%	1,8%	1,3%	3,2%	1,4%	11,7%	239040
Registers	0,7%	0,8%	1,0%	0,6%	1,8%	1,0%	6,0%	478080
RAMB36	0,0%	4,2%	18,5%	9,0%	1,4%	0,9%	34,0%	768
DSP48E1	0,0%	0,1%	0,8%	0,8%	2,0%	2,3%	6,0%	864

Table 3.1.5. SC-OFDM receiver complexity (FPGA resources).

		Output Processing	BICM decoding	Frame Debuilding	Despreading	OFDM De-modulation	Total	Available
LUTs		2209	20570	45754	7598	4342	80473	239040
Registers		3135	21684	56119	8450	5063	94451	478080
RAMB36		1	205	66	11	7	290	768
DSP48E1		0	15	23	17	24	79	864

		Output Processing	BICM decoding	Frame Debuilding	Despreading	OFDM De-modulation	Total	Available
LUTs	0,0%	0,9%	8,6%	19,1%	3,2%	1,8%	33,7%	239040
Registers	0,0%	0,7%	4,5%	11,7%	1,8%	1,1%	19,8%	478080
RAMB36	0,0%	0,1%	26,7%	8,6%	1,4%	0,9%	37,8%	768
DSP48E1	0,0%	0,0%	1,7%	2,7%	2,0%	2,8%	9,1%	864

The complete performance evaluation will carried out as planned in *Section 3.1.5* in January 2013. The results will be provided in a last release of Deliverable TF11.D2.

REFERENCES

[1] ENGINES; “Identification and Specification of "NGH-Ph.1" Prototypes to be Built”; Deliverable D10.2 - V0.4 - March 07, 2012.

[2] ENGINES; “NGH-Ph.1 Lab Test Validation Plan”, Technical Report TR11.2 – V.06 – September 10. 2012.