# D06.2: AeroMACS Verification Report

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| **Task contributors** | |
| *THALES; SELEX; INDRA; AIRBUS; EUROCONTROL; DSNA* | |


***Abstract***

The general purpose of the 15.2.7 project is to verify the AeroMACS Data Link. This document describes the Verification report within the 15.2.7 Project regarding phase 1 testing.

# Authoring – D06-Part 2

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# Executive summary

The goal of project 15.2.7, in strong collaboration with Project 9.16, is to define, validate and demonstrate the technical standard based upon existing IEEE 802.16e of the future airport surface data link as foreseen by the aviation community and ICAO. Therefore, it includes the modification of the IEEE 802.16e standard and the developing of a new AeroMACS profile dedicated for airport surface datalink for ATC / AOC services, in order to be compliant with SESAR / ICAO FCI recommendations.

The mentioned evaluation will assess the performance and capacity of the technology by means of analytical work and simulations in order to develop design specifications. Moreover, prototypes were defined and developed to demonstrate results through measurements and trials, in strong coordination with the appropriate standardization bodies.

Therefore, 9.16 and 15.2.7 projects are contributing to the development of an aviation technical standard to be recognized by ICAO in direct and strong cooperation with Eurocae WG82 and RTCA SC 223.

The purpose of the present document is to report tests results corresponding to the verifications performed in project 15.2.7 phase 1 as described in the dedicated 15.2.7. Verification plan [3].

# 1 Introduction

## 1.1 Purpose of the document

The overall 15.2.7 verification activity has been divided in two separate working activities phases as described in the verification strategy (see D05.2 document [1]):

- Phase 1 is related to Laboratory Tests only. This Task verifies the main part of the MS/BS Interoperability and RF performances objectives.
- Phase 2 is related both to additional Laboratory Tests and Toulouse Airport Tests (task T10).

Within the 15.2.7 project, verification tests consist in:

- Laboratory tests, held in SELEX and THALES premises, with both partners pieces of equipment,
- Field tests, held in Toulouse Airport, by THALES & DSNA, with THALES pieces of equipment.

The overall verification tests will cover the following aspects:

- MS/BS Interoperability, including AeroMACS Profile,
- RF specification and performances,
- RF performances in real environment (Airport).

This document provides the Verification report for the phase 1 testing activities of the AeroMACS Data Link performed within the 15.2.7 project. It describes the results of the verification exercises defined in the "AeroMACS - verification plan [3]" and how they have been conducted.

## 1.2 Intended readership

This document is a deliverable for the task "WA6: Integration & testing". It is intended to be used primarily by the partners of the 15.2.7 Project. However, for coordination reasons, also Projects SESAR 9.16, SANDRA SP6 and SANDRA SP7 should take this deliverable into account.
Other operational/system projects, like WP3, could make use of the deliverables of 15.2.7/9.16 projects.

## 1.3 Structure of the document

The structure of the document is based on 7 chapters:

- Chapter 1 is an introduction describing the purpose of the document and the intended readership.
- Chapter 2 describes the context of the Verification.
- Chapter 3 gives a brief description of the conduct of the verification exercises.
- Chapter 4 summarizes verification exercises results
- Chapter 5 gives conclusion and recommendations
- Chapter 6 reports in details the results for each test case
- Chapter 7 lists the reference documents

## 1.4 Glossary of terms

For terminology clarification, the following terms are defined below:

- "Mock-up" : Part of MS test equipment
- "Prototype" : Base/Mobile station prototype equipment
- "System (test) platform": Bring together several prototypes, mock-up and tools

## 1.5 Acronyms and Terminology

| Term | Definition |
|---|---|
| **ADD** | Architecture Definition Document |
| **ATM** | Air Traffic Management |
| **CLI** | Command Line Interface |
| **DOD** | Detailed Operational Description |
| **E-ATMS** | European Air Traffic Management System |
| **E-OCVM** | European Operational Concept Validation Methodology |
| **GS** | Ground Station (Base Station in WiMAX terminology) |
| **IRS** | Interface Requirements Specification |
| **INTEROP** | Interoperability Requirements |
| **MS** | Mobile Station (Subscriber Station or CPE in WiMAX terminology) |
| **OFA** | Operational Focus Areas |
| **OSED** | Operational Service and Environment Definition |
| **SESAR** | Single European Sky ATM Research Programme |
| **SESAR Programme** | The programme which defines the Research and Development activities and Projects for the SJU. |
| **SJU** | SESAR Joint Undertaking (Agency of the European Commission) |
| **SJU Work Programme** | The programme which addresses all activities of the SESAR Joint |

| Term | Definition |
|---|---|
| | Undertaking Agency. |
| **SPR** | Safety and Performance Requirements |
| **SUT** | System Under Test |
| **TAD** | Technical Architecture Description |
| **TS** | Technical Specification |
| **VALP** | Validation Plan |
| **VALR** | Validation Report |
| **VALS** | Validation Strategy |
| **VP** | Verification Plan |
| **VR** | Verification Report |
| **VS** | Verification Strategy |

# 2 Context of the Verification

Project 15.2.7 is a technological project dealing with the adaptation of the WiMAX 802.16-2009 standard (in the aeronautical C band) and with the definition of a profile suited to airport surface communications supporting both ATS and AOC data exchanges.

In this context, the verification approach consists in assessing and collecting evidences on the suitability and performances of the proposed technology (AeroMACS) against the on-going standardization of the new generation of airport data link system, performed in close conjunction with RTCA SC223 and Eurocae WG82.

The objective of the verification phase is thus to perform operational evaluation using lab testing and field trials together with analysis and modeling to deliver the appropriate material for decision making and for preparation of pre-operational and implementation decisions.

## 2.1 System Overview

As already stated, AeroMACS Data Link global overall verification is addressed by Project 15.2.7, but also by Projects 9.16, SANDRA SP6 and SANDRA SP7.

*This section provides the general verification background.*

*Identify the scope of the intended verification: It could be mainly IBP/V&V Platform Verification for WP03 or System / Sub-system / Function Verification for Sys L3 X.Y.Z.*

*Describe who the stakeholders are and how they are concerned by the scope of verification.*

*In any case, tell which systems will be verified. If relevant, tell which Operational Package/Sub-Package/Operational Focus Areas are concerned by the verification scope.*

*Prerequisites to the scoped verification as integration activities or preliminary verification activities are stated at §**¡Error! No se encuentra el origen de la referencia.**.*

This document focusses on the Verification test cases achieved within the 15.2.7 Project, namely:

- Lab tests: performances measurement related to the new AeroMACS profile and interoperability between different vendors pieces of equipment,
- Field tests: tests in real airport environment focused on the ground segment datalink.

The table below gives an overview of main partners involved in lab and field tests within project 15.2.7 and close contributing project 9.16:

| | **P 15.2.7** | **P 9.16** |
|---|---|---|
| **Lab. test** | THALES, THALES Lab. | SELEX ES Selex Lab. |
| | SELEX ES, Selex Lab. | |
| **Field test** | THALES + DSNA | SELEX ES + Airbus |
| | Toulouse airport | Toulouse airport |
| | Focus on ground component of AeroMACS | Focus on airborne component of AeroMACS |

**Table 1: Testing organization**

## 2.2 Summary of Verification Exercise/s

### 2.2.1 Summary of Verification Objectives and Success Criteria

The verification objectives addressed by the phase 1 can be found in the D05.2 document [1]. They are listed in table below.

| General VO Id | Title | VO description |
|---|---|---|
| AeroMACS_VO_Interop_01 | Profile compliance | Verify that the AeroMACS profile parameters selected in the AeroMACS BS and MS are interoperable, and that they are suited to the SESAR usage. |
| AeroMACS_VO_Interop_02 | Link adaptation | Assessment of the different modulation schemes and the throughput hence supported. Verify proper DCD reception and decoding. |
| AeroMACS_VO_Interop_03 | Network Entry | Verify that AeroMACS MS and BS perform all relevant actions at Network Entry that affects the air interface. |
| AeroMACS_VO_Interop_04 | Quality of Service | Verify that the MS-BS interface supports nrtPS, rtPS and BE QoS classes and the corresponding fields: delay, jitter, packet loss, and throughput. |
| AeroMACS_VO_Interop_05 | SF establishment, change and deletion | Verify the completion of the control messages transmission to successfully complete the creation, change and deletion of a service flow to the MS. |
| AeroMACS_VO_Interop_07 | Dynamic BW allocation | Verification of correct allocation of MAC resources. |
| AeroMACS_VO_Interop_09 | ARQ testing | Verify the correct frame retransmission after packet losses. |
| AeroMACS_VO_Interop_10 | Uplink Power Control | Check that a data transfer continues properly when there is a fading in the UL channel. Verify that MS-BS interface supports the closed loop power control. |
| AeroMACS_VO_Interop_11 | Security functions | Verify that the security functions on the air interface are interoperable between AeroMACS MS and BS. Verify the fragmentation and correct reassembling of the packets and the data integrity (FCS). |
| AeroMACS_VO_RF_01 | Cell Coverage | Verify the cell coverage. |
| AeroMACS_VO_RF_02 | Interferences | Verify the out of band interference level generated. |
| AeroMACS_VO_RF_03 | Spurious emissions | Verify the spurious emissions transmitted by AeroMACS. |
| AeroMACS_VO_RF_06 | Transmission grid | Verify that AeroMACS MS transceiver can be tuned by 250 kHz steps with respect to the 5145 MHz reference frequency. |
| AeroMACS_VO_RF_07 | Power classes | Verify the compliance of AeroMACS BS/MS to one of the defined power classes |
| AeroMACS_VO_RF_08 | Transmit power requirements | Verify AeroMACS Transmit power requirements |

**Table 2: Covered verification Objectives in Phase 1**

## 2.2.2 Verification Exercises List and Dependencies

In the first verification phase, SELEX and THALES performed the test cases reported in following tables. The corresponding detailed tests cases as well as their success criteria are to be found in the verification plan for phase 1 (see [3]).

| Test Case nr. | Test Case Name | Lab. Environment | VO's addressed |
|---|---|---|---|
| TLAB_010 | Profile compliance | Lab_test_bed_01 | AeroMACS_VO_Interop_01_A/B/C/D/E |
| TLAB_020 | Quality of Service | Lab_test_bed_01 | AeroMACS_VO_Interop_04_A/E<br>AeroMACS_VO_Interop_07_A<br>AeroMACS_VO_Interop_09_A/B/C |
| TLAB_030 | Security | Lab_test_bed_01 | AeroMACS_VO_Interop_11_E |
| TLAB_040 | Power & sensitivity | Lab_test_bed_01 | AeroMACS_VO_RF_01_B/C<br>AeroMACS_VO_Interop_02_A/B<br>AeroMACS_VO_RF_07_B/C/D/E |
| TLAB_050 | Radio Performances and interferences | Lab_test_bed_01 | AeroMACS_VO_RF_06_B/C<br>AeroMACS_VO_RF_02_A<br>AeroMACS_VO_RF_03_A/B<br>AeroMACS_VO_RF_08_F<br>AeroMACS_VO_RF_08_G |

**Table 3: Phase 1 Thales lab. Tests**

| Test Case nr. | Test Case Name | Lab. Environment | VO's addressed |
|---|---|---|---|
| LAB1_1 | Connection Establishment | LAB1 | Interop_01_A/B/C/D/E<br>Interop_03_A/C/D/E/F<br>RFReal_01_A |
| LAB1_2 | Power Control | LAB1 | Interop_10_A/B |
| LAB1_3 | Quality of Service | LAB1 | Interop_04_ B/C/D<br>Interop_05_A<br>Interop_07_A /D |
| LAB1_4 | Security | LAB1 | Interop_11_A/B |
| LAB1_5 | Radio Performance | LAB1 | RF_06_A/B |
| LAB1_6 | Transmit Power | LAB1 | RF_07_A<br>RF_08_A/C/D |

**Table 4: Phase 1 Selex lab. tests**

# 3 Conduct of Verification Exercises

## 3.1 Verification Exercises Preparation

Prior to lab testing, the test beds described in the verification plan ([3]) identified Lab_test_bed_0x (x=1,2) were configured in order to be able to perform the tests in THALES and SELEX labs.

In the verification plan, the Thales test bed was described as follows.

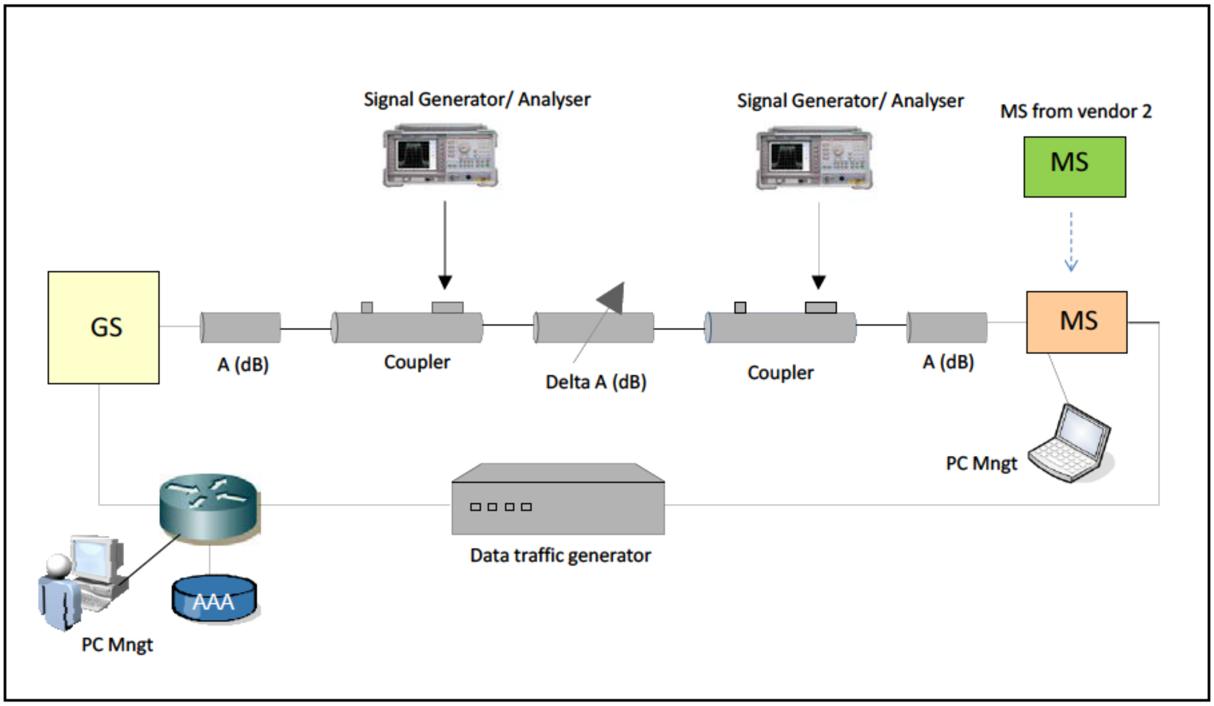



**Figure 1: Lab_test_bed_01 (Thales)**

Same preparation was performed with Selex test bed as described below.

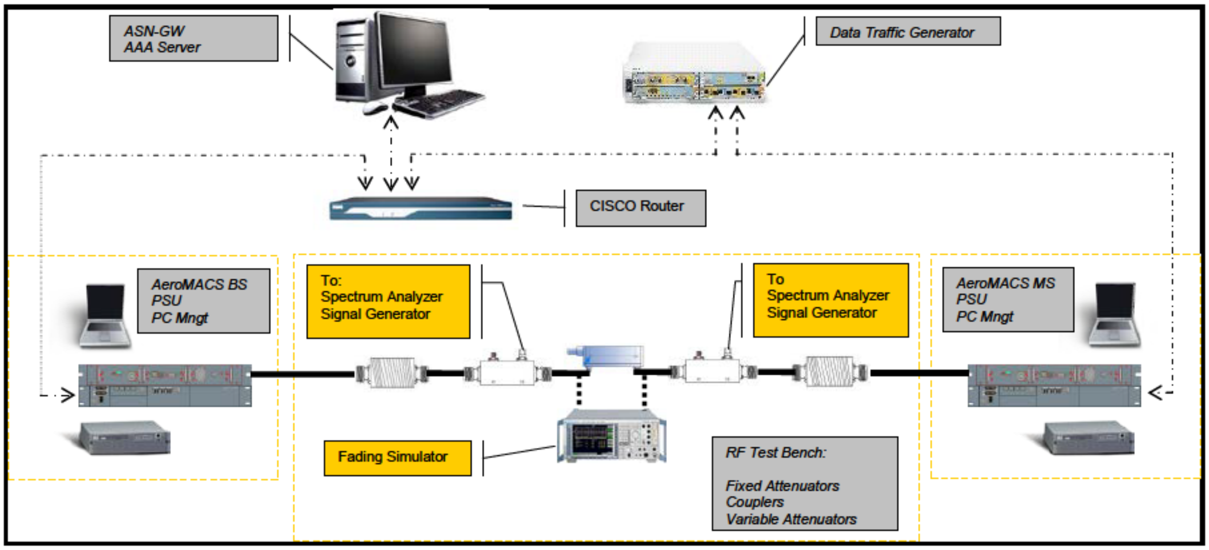



**Figure 2: Lab_test_bed_02 (Selex)**

## 3.2 Verification Exercises Execution

Verification Exercises execution took place in the planned time frame for phase 1.

## 3.3 Deviations from the Planned Activities

Most aspects related to the verification activities were described in the Verification Plan. However, even if it was provided in the Verification Plan this may have changed from the planning to the conduction of the verification exercise e.g. modification of a verification objective, requirements not addressed by unexpected constraints during prototype development phase, etc... The purpose of this chapter is to highlight the changes in respect to the content within the Verification Plan.

### 3.3.1 Deviations with Respect to the Verification Strategy

The verification strategy described in the verification plan is applied.

### 3.3.2 Deviations with Respect to the Verification Plan

If any, deviations with respect to the verification plan are highlighted in each verification exercise report in § Appendix A. Slights deviations were noted concerning TLAB_020, LAB1_1 and LAB1_5 Verification Exercises without changing verification strategy (see § A.2.2.3, § A.6.2.3, § A.10.2.3 for detailed description).

# 4 Verification exercises Results

## 4.1 Summary of Verification Exercises Results

The results of the different Verification test cases are summarized in following tables:

- OK: Verification objective achieves the expectations
- NOK: Verification objective does not achieve the expectations

| Test Case nr. | Test Case Name | Lab. Environment | VO's addressed | Result |
|---|---|---|---|---|
| TLAB_010 | Profile compliance | Lab_test_bed_01 | AeroMACS_VO_Interop_01_A/B/C/D/E | OK |
| TLAB_020 | Quality of Service | Lab_test_bed_01 | AeroMACS_VO_Interop_04_A/E<br>AeroMACS_VO_Interop_07_A<br>AeroMACS_VO_Interop_09_A/B/C | OK |
| TLAB_030 | Security | Lab_test_bed_01 | AeroMACS_VO_Interop_11_E | OK |
| TLAB_040 | Power & sensitivity | Lab_test_bed_01 | AeroMACS_VO_RF_01_B/C<br>AeroMACS_VO_Interop_02_A/B<br>AeroMACS_VO_RF_07_B/C/D/E | OK |
| TLAB_050 | Radio Performances and interferences | Lab_test_bed_01 | AeroMACS_VO_RF_06_B/C<br>AeroMACS_VO_RF_02_A<br>AeroMACS_VO_RF_03_A/B<br>AeroMACS_VO_RF_08_F<br>AeroMACS_VO_RF_08_G | OK |

**Table 5: Summary of Thales lab. tests results for phase 1**

| Lab Test Case nr. | Test Case Name | Lab. Environment | VO's addressed | Result |
|---|---|---|---|---|
| LAB1_1 | Connection Establishment | LAB1 | Interop_01_A/B/C/D/E<br>Interop_03_A/C/D/E/F<br>RFReal_01_A | OK |
| LAB1_2 | Power Control | LAB1 | Interop_10_A/B | OK |
| LAB1_3 | Quality of Service | LAB1 | Interop_04_ B/C/D<br>Interop_05_A<br>Interop_07_A /D | OK |
| LAB1_4 | Security | LAB1 | Interop_11_A/B | OK |
| LAB1_5 | Radio Performance | LAB1 | RF_06_A/B | OK |
| LAB1_6 | Transmit Power | LAB1 | RF_07_A<br>RF_08_A/C/D | OK |

**Table 6: Summary of Selex Lab. tests results for phase 1**

## 4.2 Analysis of Verification Exercises Results

The detailed analysis of the verification Exercises can be found in each verification exercise report in §Appendix A.

# 5 Conclusions and recommendations

The main objective of the verification phase is to assess the performances of AeroMACS prototypes.

By analyzing the phase 1 verification results reported in this report, the verification objectives were successfully tested in labs: among others, profile compliance verification, quality of service assessment, sensitivity and radio performances measurement allowed collecting positive evidences on the suitability of the prototypes to assess the AeroMACS technology regarding the on-going standardization.

In conclusion, these phase 1 lab measurements gave a good characterization of the prototypes with positive test results. This gives a good confidence before the field testing to be conducted in Toulouse Airport (phase 2).

This phase 2 testing will gather additional measurements in real environment of Airport surface datalink and thus complement significantly the assessment of the AeroMACS technology in ground segment context with some important information as cell coverage, LOS / nLOS propagation behavior, mobility effect...

# 6 References

## 6.1 Reference Documents

The following documents were used to provide input:

**[1]** P 15.02.07 D05.2 - AeroMACS Verification Strategy

**[2]** P 15.02.07 D05.1 - AeroMACS Prototypes Description

**[3]** P 15.02.07 D06.1 - AeroMACS Verification Plan

# Appendix A Detailed Verification Exercises report

This appendix includes the detailed the verification exercise reports.

## A.1 Verification Exercise # TLAB_010 Report

### A.1.1 Verification Exercise Scope

Verify that the AeroMACS profile parameters (OFDMA, Channel bandwidth, frame length, TDD, channel frequency) selected in the AeroMACS GS and MS are interoperable.

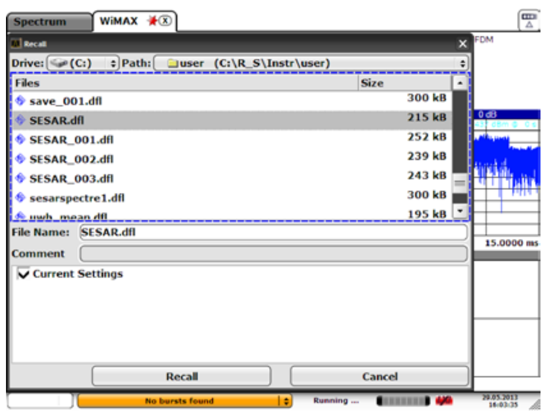
### A.1.2 Conduct of Verification Exercise

#### A.1.2.1 Verification Exercise Preparation

*Lab_test_bed_01*

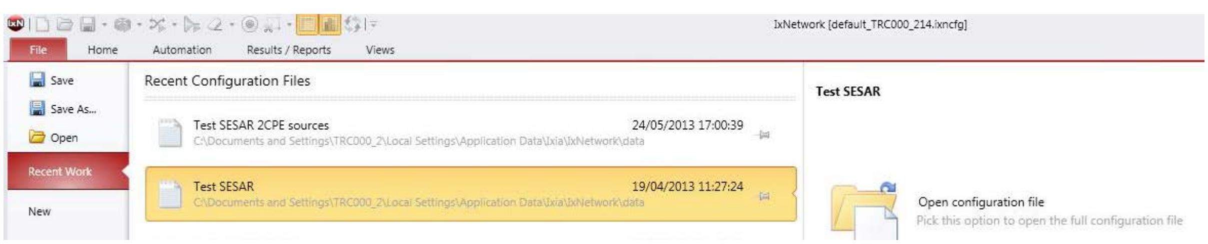
*<u>Spectrum Analyzer</u>: Rohde & Schwarz FSV-7 with WiMAX option R&S FSV-K93*

The configuration defined for Sesar is loaded before the measurement.




*<u>Data Traffic generator/analyzer</u>: IXIA*

IXIA is configured with prepared configuration file that generate one traffic stream in each direction (UL and DL).

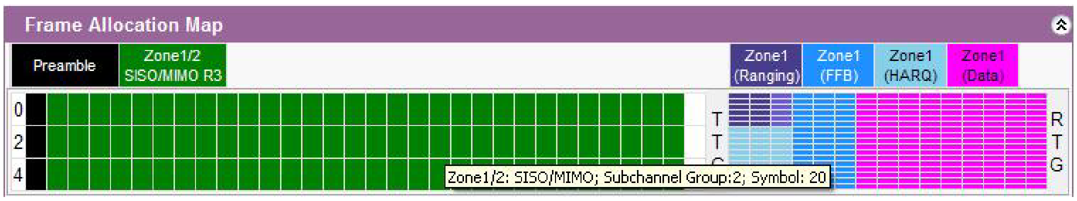


*Equipment*:

MS/GS are configured according to AeroMACS profile. Namely, prepared configuration files are loaded in the equipment:

| | |
|---|---|
| RF Profile | SESAR_RF_conf2 |
| MCS Profile | SESAR_MCS_conf2 |
| PHY Profile | SESAR_PHY_conf2 |
| MAC Profile | SESAR_MAC_conf2 |

As an example, main selected physical parameters are: bandwidth 5 MHz, frame length 5 ms, TDD split 32:15, (UL 15 symbols : including 12 symbols for data -pink, 3 reserved for FFB -blue).




Concerning modulation and coding scheme, the whole set of possibilities for DL and for the UL the optional 64 QAM is selected when needed for the test:

| | | |
|---|---|---|
| ☑ | 0 | QPSK (CTC) 1/2 |
| ☑ | 1 | QPSK (CTC) 3/4 |
| ☑ | 2 | 16-QAM (CTC) 1/2 |
| ☑ | 3 | 16-QAM (CTC) 3/4 |
| ☑ | 4 | 64-QAM (CTC) 1/2 |
| ☑ | 5 | 64-QAM (CTC) 2/3 |
| ☑ | 6 | 64-QAM (CTC) 3/4 |
| ☑ | 7 | 64-QAM (CTC) 5/6 |

| | | |
|---|---|---|
| ☑ | 1 | QPSK (CTC) 1/2 |
| ☑ | 2 | QPSK (CTC) 3/4 |
| ☑ | 3 | 16-QAM (CTC) 1/2 |
| ☑ | 4 | 16-QAM (CTC) 3/4 |
| ☑ | 5 | 64-QAM (CTC) 1/2 |
| ☑ | 6 | 64-QAM (CTC) 2/3 |
| ☑ | 7 | 64-QAM (CTC) 3/4 |
| ☑ | 8 | 64-QAM (CTC) 5/6 |

MS & GS are linked together according to test bed configuration with proper attenuation and switched on.

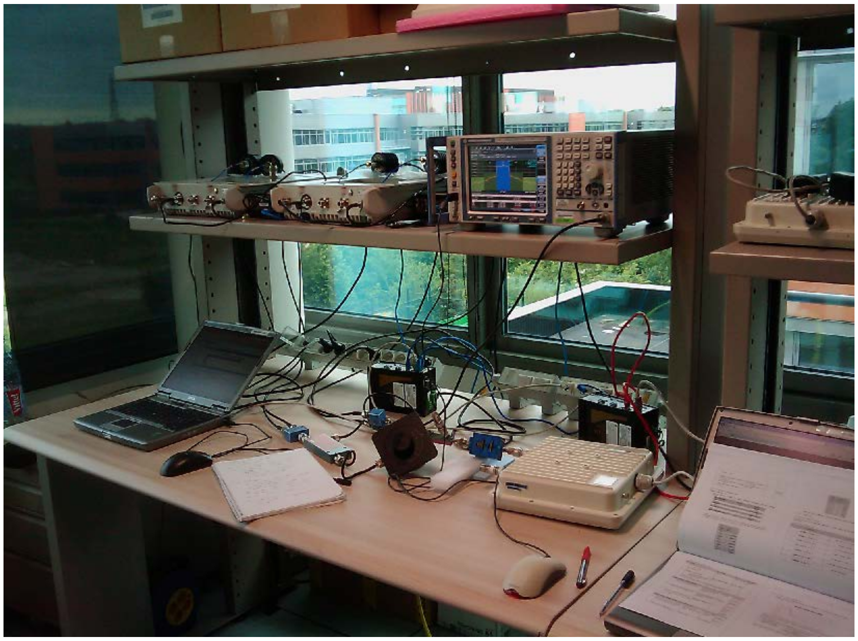


Figure 3: Picture of test bed in Thales Lab

### A.1.2.2 Verification Exercise execution

| Step | action | Action result | PCO | Result |
|---|---|---|---|---|
| 1 | Set frequency on the GS :<br>- 5120,5 MHz<br>Provision new RF parameter on the GS | New frequency provisioned on GS | GS control MMI<br>Spectrum analyzer | OK |
| 2 | Set frequency scan of MS :<br>- 5093,5 – 5147,5 MHz, step 250 kHz (5002,5 + n*0.25 for n = {364…580} in MHz.) | MS connects eventually to the GS | GS control MMI | OK |
| 3 | Initiate traffic in the UL or DL thanks to the traffic generator (either Ixia or Iperf) | Communication established in both directions (UL and DL) | Ixia | OK<br>(Ixia) |
| 4 | Confirm the GS OFDMA mode<br>(Spectrum analyzer on GS side) | GS Preamble demodulated | Spectrum Analyzer | OK |
| 5 | Measure the GS bandwidth<br>(Spectrum analyzer on GS side)<br>Note: Focus on main channel + adjacent + alternate | Most of Energy included in main central channel 5 MHz | Spectrum Analyzer | OK |
| 6 | Measure the GS Frame Length<br>(Spectrum analyzer on GS side) | Frame of 5 ms | Spectrum Analyzer | OK |
| 7 | Check that MS and GS operate in TDD mode<br>(Spectrum analyzer on GS side) | MS et BS alternately emits with ratio as defined on the GS<br>(Note: activity seen only on DL as UL is attenuated by directional coupler to spectrum analyzer) | Spectrum Analyzer | OK |
| 8 | Set frequency on the GS :<br>- 5093,5 MHz | MS connect to new GS frequency | GS control MMI | OK |
| 9 | Set frequency on the GS :<br>- 5147,5 MHz | MS connect to new GS frequency | GS control MMI | OK |
| 10 | Set frequency on the GS :<br>- 5098.5 | MS connect to new GS frequency | GS control MMI | OK |
| 11 | Set frequency on the GS :<br>- 5103.5 | MS connect to new GS frequency | GS control MMI | OK |

| | | | | |
|---|---|---|---|---|
| 12 | Measure the MS bandwidth<br>(Spectrum analyzer on MS side) | Bandwidth 5 MHz | Spectrum Analyzer | OK |

#### A.1.2.3 Deviation from the planned activities

None.

### A.1.3 Verification exercise Results

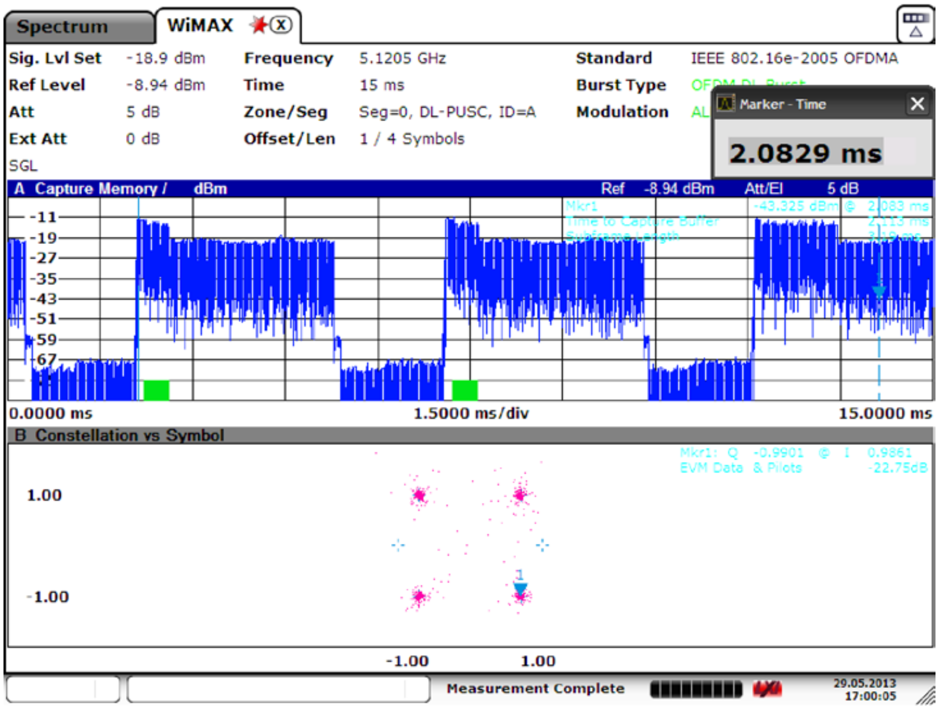
#### A.1.3.1 Summary of Verification exercise Results

- Step 4: OFDMA mode verified
- Step 5/12: GS/MS 5MHz bandwidth confirmed
- Step 6: Frame Length measured and OK
- Step 7: TDD Mode verified
- Step 8/9: Edge frequencies reached
- Step 10/11: Complementary measurement at future airport frequencies OK.

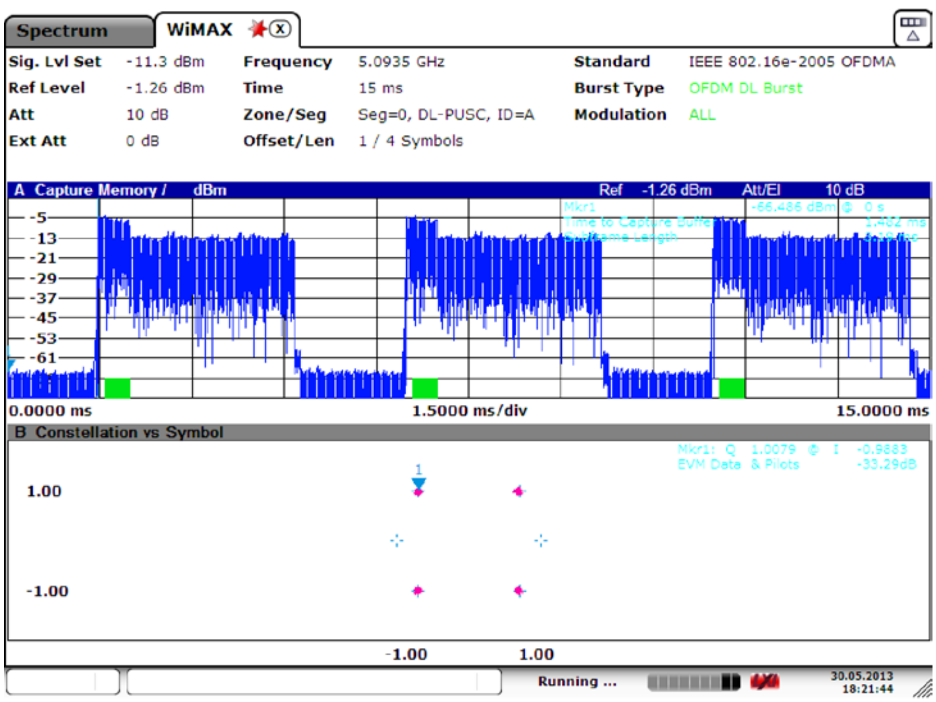
#### A.1.3.2 Analysis of Verification Exercise Results

The testing of these core AeroMACS functionalities (OFDMA, TDD, Frame length, frequency) are done through a configured spectrum analyzer with WiMAX measurement functions.

DL synchronization and frame structure verification done at 5120,5 MHz and also at 5093,5 and 5098,5 MHz, 5147,5 MHz is shown below (Spectrum analyzer was wired on BS side so that UL bursts are sufficiently attenuated to focus on DL activity). One can see that the DL OFDM burst is properly synchronized and demodulated.




Date: 29.MAY.2013 17:00:06

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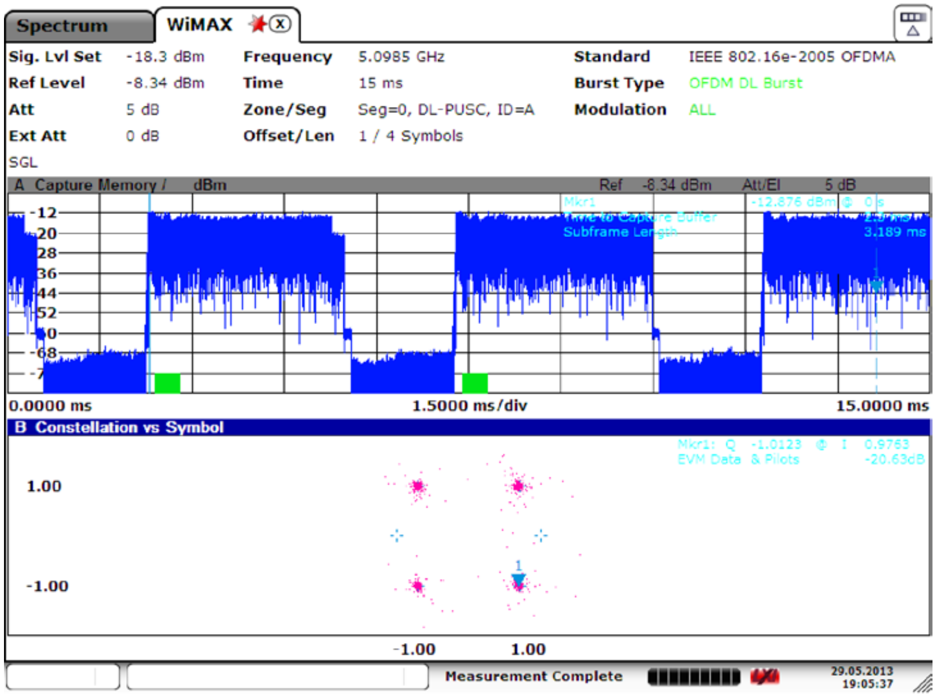
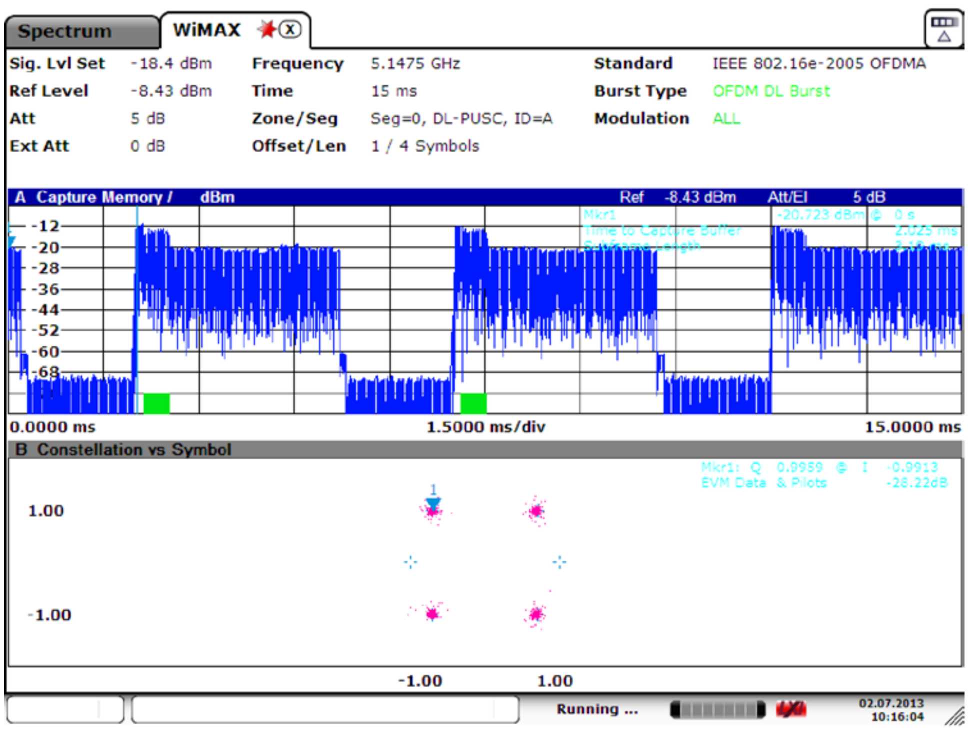



Date: 29.MAY.2013 19:05:37

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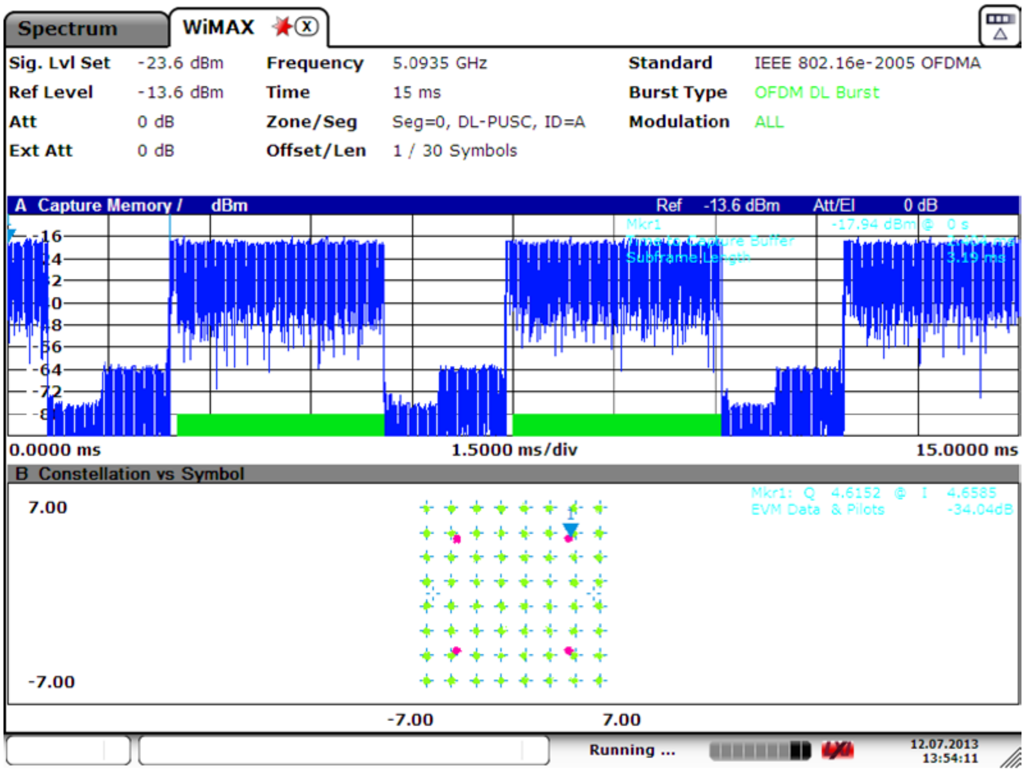
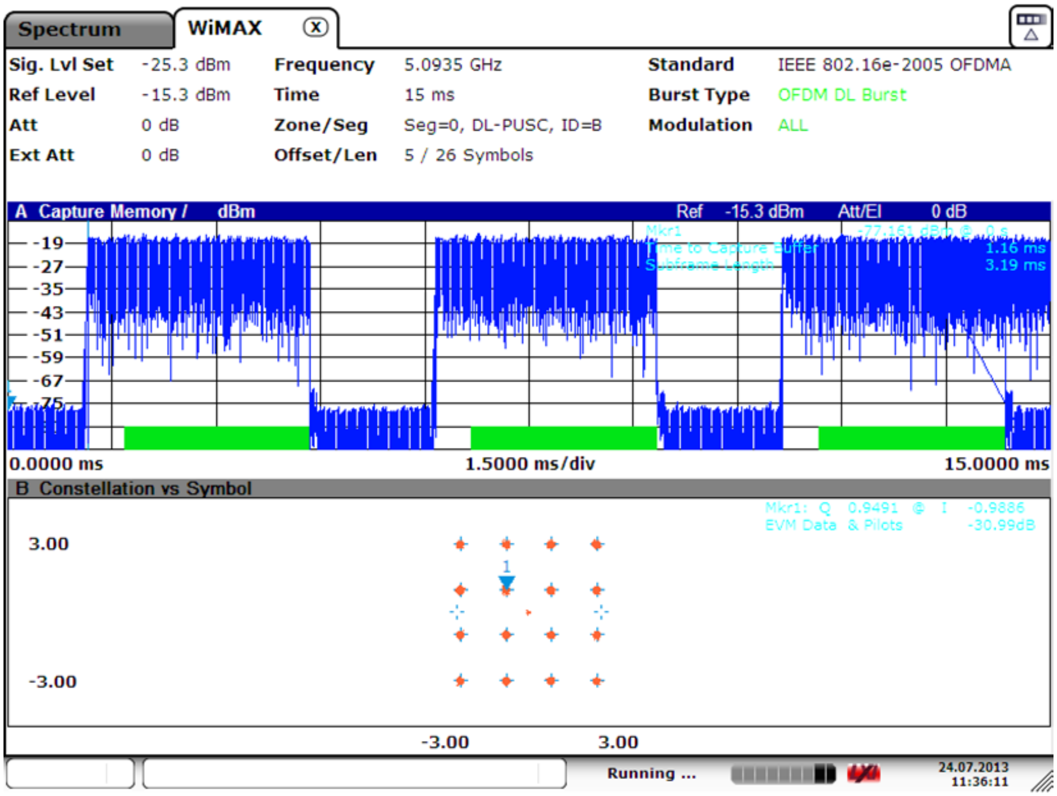
Below is given an example of DL demodulation with 64QAM traffic and 16QAM traffic.

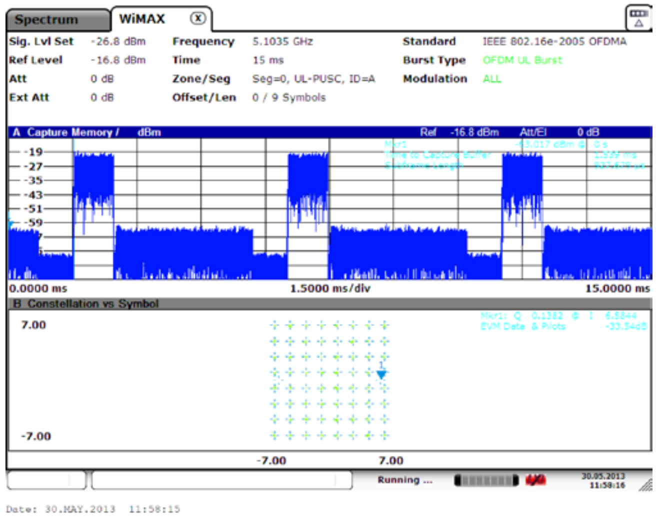



Date: 12.JUL.2013 13:54:12



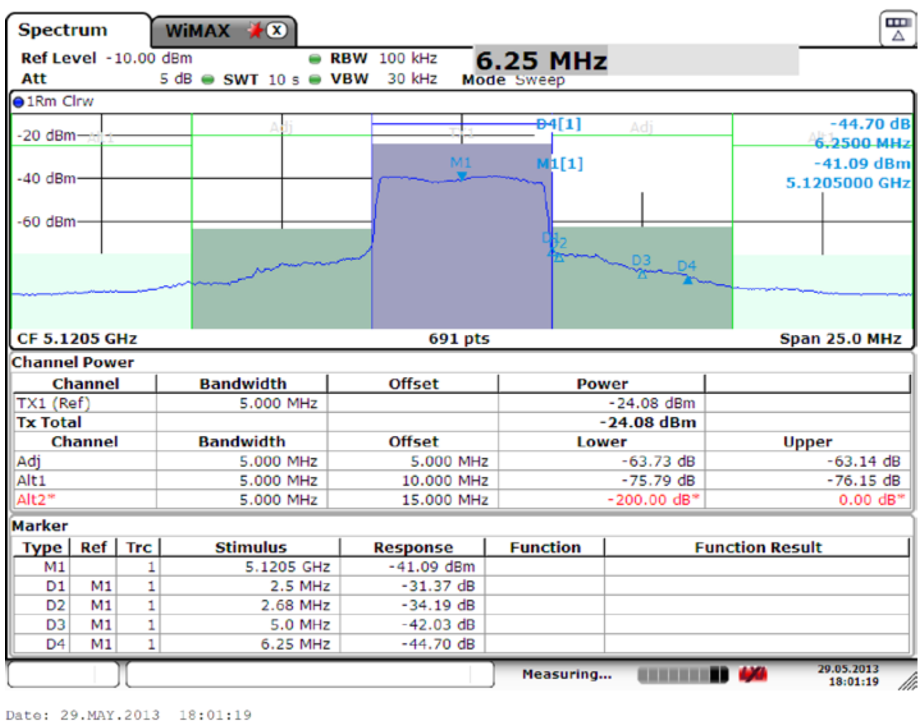

Date: 24.JUL.2013 11:36:12

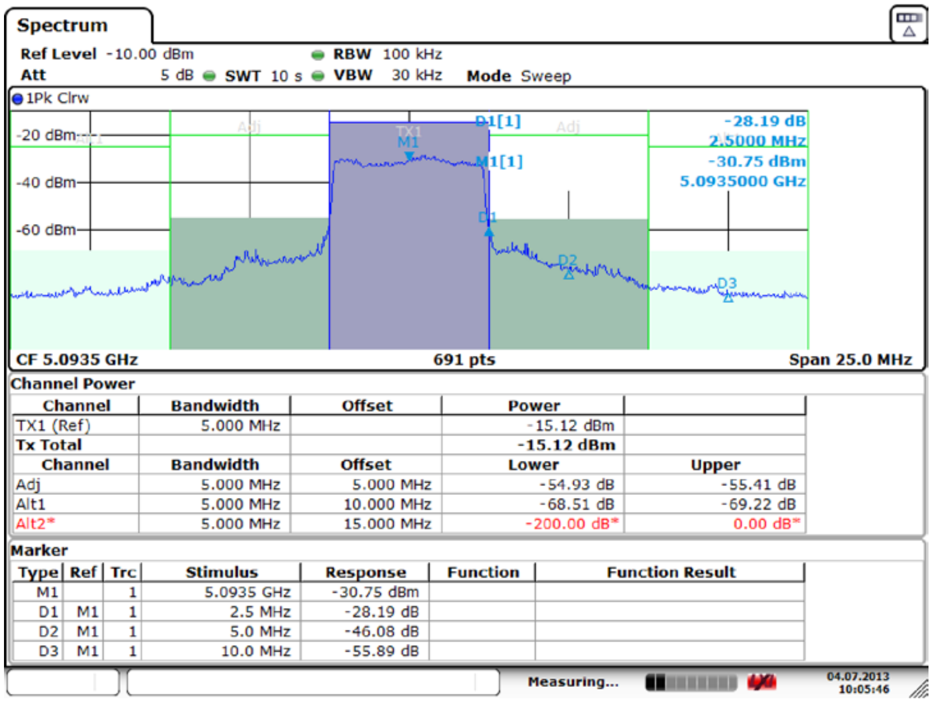
Same positive result for the UL OFDM burst (example below at 5103,5 MHz for QPSK, 16QAM, 64QAM) (spectrum analyzer was wired on MS side so that DL bursts are sufficiently attenuated to focus on UL activity).


On the pictures above, measured frame duration is 5 ms (3 repetitions can be observed as the analysis time duration of spectrum analyzer is tuned to 15 ms). Detailed time measurements reveals an active DL Burst of 3,2 ms long and an UL burst of 1,5 ms long, consistent with ratio 32:15. The TDD nature of the frame is also clearly shown.

About the 5 MHz bandwidth, it was confirmed through spectrum measurement as shown below, where energy is concentrated on the centered 5 MHz channel for the edges of the band and the center.





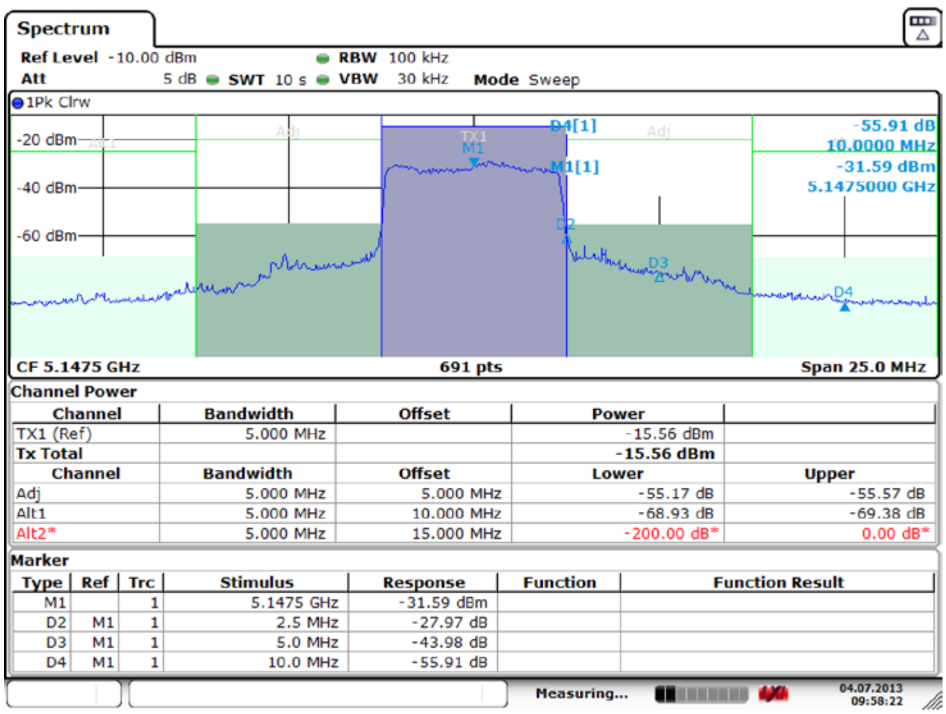

Channel Power

| Channel | Bandwidth | Offset | Power | |
|---|---|---|---|---|
| TX1 (Ref) | 5.000 MHz | | -15.12 dBm | |
| Tx Total | | | -15.12 dBm | |
| Channel | Bandwidth | Offset | Lower | Upper |
| Adj | 5.000 MHz | 5.000 MHz | -54.93 dB | -55.41 dB |
| Alt1 | 5.000 MHz | 10.000 MHz | -68.51 dB | -69.22 dB |
| Alt2* | 5.000 MHz | 15.000 MHz | -200.00 dB* | 0.00 dB* |

Marker

| Type | Ref | Trc | Stimulus | Response | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 5.0935 GHz | -30.75 dBm | | |
| D1 | M1 | 1 | 2.5 MHz | -28.19 dB | | |
| D2 | M1 | 1 | 5.0 MHz | -46.08 dB | | |
| D3 | M1 | 1 | 10.0 MHz | -55.89 dB | | |

Date: 4.JUL.2013 10:05:46




Channel Power

| Channel | Bandwidth | Offset | Power | |
|---|---|---|---|---|
| TX1 (Ref) | 5.000 MHz | | -15.56 dBm | |
| Tx Total | | | -15.56 dBm | |
| Channel | Bandwidth | Offset | Lower | Upper |
| Adj | 5.000 MHz | 5.000 MHz | -55.17 dB | -55.57 dB |
| Alt1 | 5.000 MHz | 10.000 MHz | -68.93 dB | -69.38 dB |
| Alt2* | 5.000 MHz | 15.000 MHz | -200.00 dB* | 0.00 dB* |

Marker

| Type | Ref | Trc | Stimulus | Response | Function | Function Result |
|---|---|---|---|---|---|---|
| M1 | | 1 | 5.1475 GHz | -31.59 dBm | | |
| D2 | M1 | 1 | 2.5 MHz | -27.97 dB | | |
| D3 | M1 | 1 | 5.0 MHz | -43.98 dB | | |
| D4 | M1 | 1 | 10.0 MHz | -55.91 dB | | |

Date: 4.JUL.2013 09:58:22

#### A.1.3.3 Unexpected Behaviors/Results

None.

### A.1.4 Conclusions and recommendations

The testing allowed checking the core AeroMACS functionalities (OFDMA, TDD, Frame length, frequency). No recommendations for next phase (Airport tests) as all verification objectives are addressed satisfactory.

# A.2 Verification Exercise # TLAB_020 Report

## A.2.1 Verification Exercise Scope

Test QOS: verify the traffic priority functionality, verify SF BE rules, verify of correct allocation of MAC resources and verify the correct frame retransmission after packet losses in case of ARQ or not.

## A.2.2 Conduct of Verification Exercise

### A.2.2.1 Verification Exercise Preparation

Same as for TLAB_010 see § A.1.2.1.
Additionally, QOS service flows are configured as defined in verification exercise execution.

### A.2.2.2 Verification Exercise execution

| Step | action | Action result | PCO | Result |
|---|---|---|---|---|
| P1: Test QOS priority | | | | |
| 1 | Set frequency on the GS :<br>- 5120,5 MHz<br>Switch on the GS | GS on | GS control MMI | OK |
| 2 | Configure on the GS two SF, each with a different classifier based on @IP source from each source. The SFs have the same characteristics except the priority: in one case 0 and in the other case 7. | SF defined | GS control MMI | OK |
| 3 | Set frequency scan of MS :<br>- 5093,5 – 5147,5 MHz, step 250 kHz (5002,5 + n*0.25 for n = {364…580} in MHz)<br>Switch on the MS | MS connects eventually to the GS | GS control MMI | OK |
| 4 | Tune the variable attenuator so to obtain the max available modulation. | 64QAM | GS control of MMI | OK |
| 5 | Simulate two UP streams on the IXIA generator with two different @IP sources.<br>The sum of data rate is more than can be achieved with QPSK and less that can be achieved with 64QAM | Communication established with no packet loss | IXIA MMI<br>GS control MMI | OK |
| 6 | Increase the attenuation so to obtain a QPSK modulation. Data rate decreases. | QPSK | GS control of MMI | OK |

| | | | | |
|---|---|---|---|---|
| 7 | Check that the stream with less priority is affected first by data rate downgrade. | Packet loss on the stream with less priority | IXIA | OK |
| P2: test BE | | | | |
| 1 | Configure on the GS one DL SF of BE type with a maximum data rate of 300 kbps and a classifier based on any stream. Check that for BE type only the max data rate can be set. | BE parameters set | GS control MMI | OK |
| 2 | Simulate one DL stream on the IXIA generator with a data rate of 1 Mbps. | One stream generated. | IXIA<br>GS control MMI | OK |
| 3 | Check that the DL stream data rate is limited corresponding to the max data rate of SF. | Data rate limited to 300 kbps | IXIA<br>GS control MMI | OK |
| P3: ARQ testing | | | | |
| 1 | ARQ is activated on the BS. Simulate a data stream through IXIA and generate some impairments: attenuation at the sensitivity limit of a modulation (modulation is fixed, ACM disabled).<br>Check the packet losses after a long time | Packet losses written down and latencies | IXIA | OK |
| 2 | ARQ is deactivated on the BS, modulation is fix, ACM disabled. Simulate a data stream through IXIA and same attenuation as above.<br>Check the packet losses after a long time | Packet losses written down and latencies | IXIA | OK |
| 3 | Compare the packet losses and latencies | Packet losses in greater when no ARQ | IXIA | OK |
| P4: BW allocation | | | | |
| 1 | Configure on the GS one UL SF of BE type. | SF parameters set | GS control MMI | OK |
| 2 | First generate a stream corresponding to BE service flow and almost max data rate. | Check that stream is generated and that bandwidth is allocated only when stream is generated | IXIA | OK |
| 3 | Configure on the GS with one UL SF of UGS type a fixe bandwidth can be allocated. | SF UGS parameters set.<br>Bandwidth allocated to UGS even if no streams generated for this SF.<br>BE stream reduced. | GS control MMI<br>IXIA | OK |

#### A.2.2.3 Deviation from the planned activities

In P4.3 steps on the test, the test is adapted as follows to be executed based on the guaranteed rate of the flows. BE and UGS streams are generated simultaneously, and one shall observe that, in case of bandwidth shortage, the stream related to UGS is prioritized compared to the BE one and that the UGS stream is maintained in a regular way (for UGS scheduling the BS provides the MS with fixed size grants in a periodic manner) whereas in the BE case the allocated bandwidth to the stream varies (for BE scheduling the BS does not provide dedicated polling opportunities to the MS).

### A.2.3 Verification exercise Results

#### A.2.3.1 Summary of Verification exercise Results

- Phase 1: QOS priority is working as expected. The stream classified in a SF with the higher priority is privileged.

- Phase 2: It was verified that the Best Effort type QOS essentially offers to set a max data rate limit and the test shows that it is correctly enforced by the equipment.

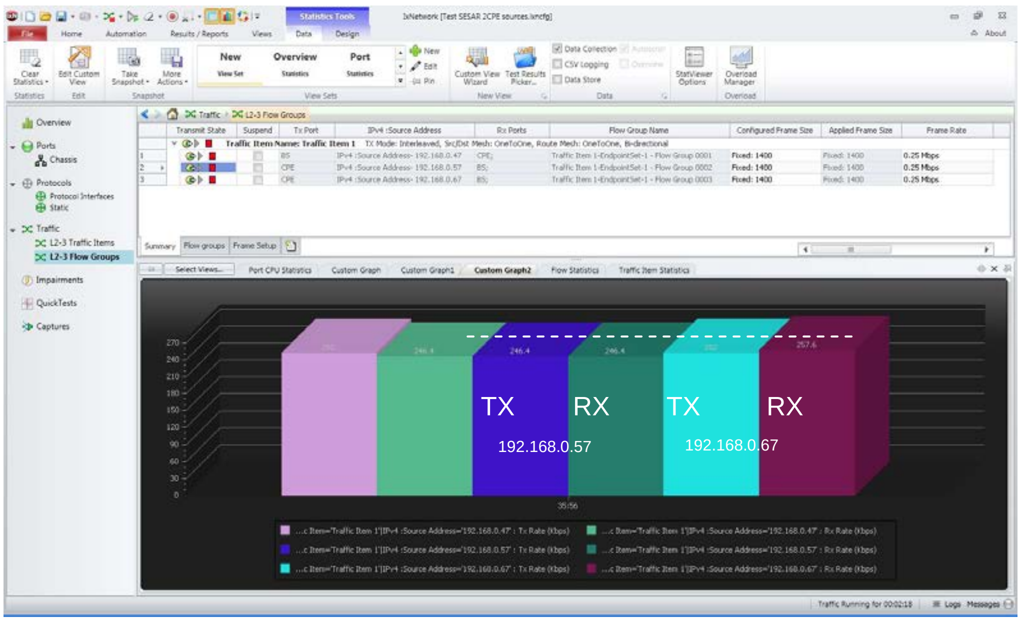
- Phase 3: ARQ testing performed better than Non ARQ in terms of packet loss.

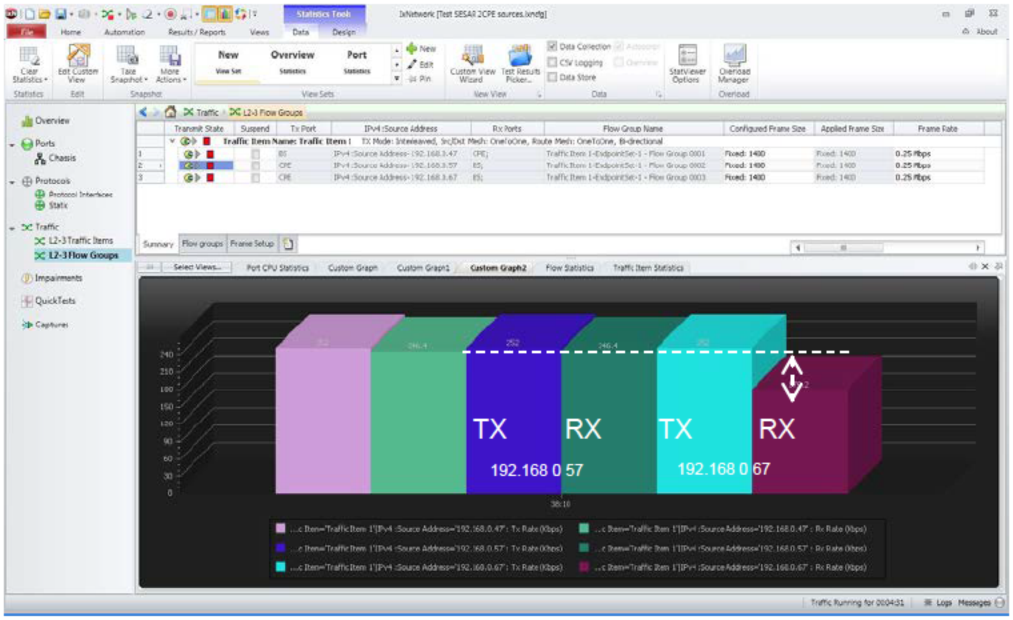
- Phase 4: It was correctly observed that the UGS service flow takes over the BE service flow and that the MS, in case of UGS, is provided with fixed size grants regarding bandwidth allocation.

### A.2.3.2 Analysis of Verification Exercise Results

- Phase 1: QOS priority

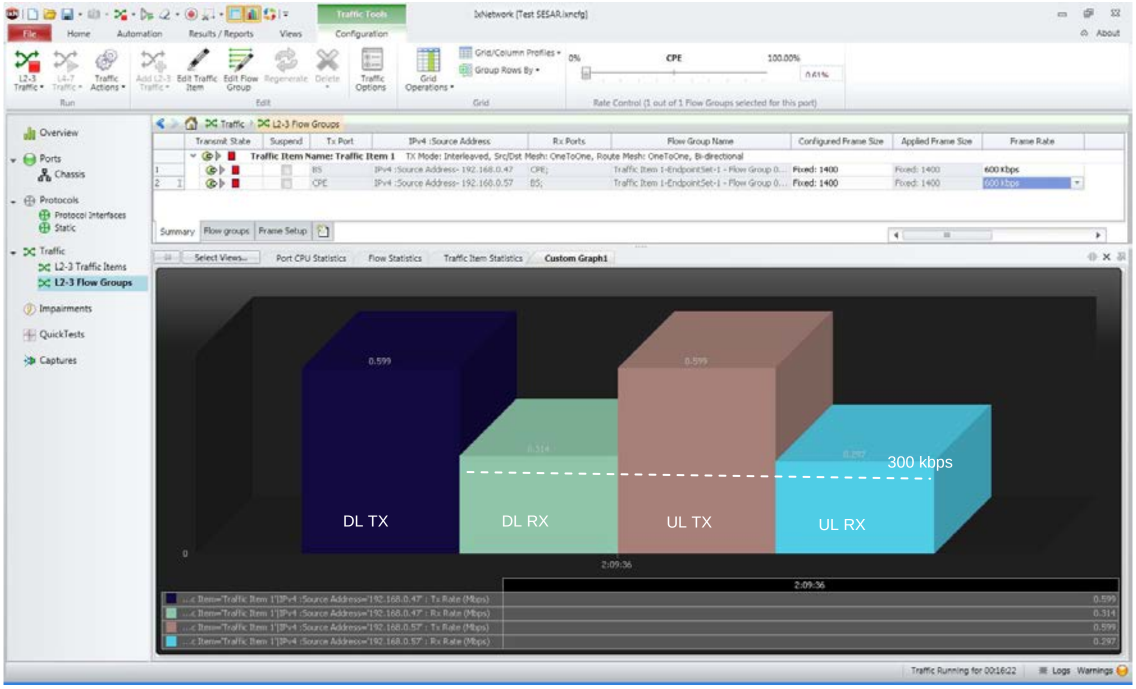
Two UL SF of BE type are defined. One with the lowest priority for the data coming from IP address 192.168.0.67 and one with the highest priority for the data coming from IP address 192.168.0.57. A data rate shortage is created by increasing the attenuation on the link (downgrading of modulation), and the resulting aggregate data rate is lower than the required data rate for data transmission. The observation is that the data flow with a SF of higher priority is privileged over the one with a lower priority in terms of bandwidth allocation.






- Phase 2: Best Effort

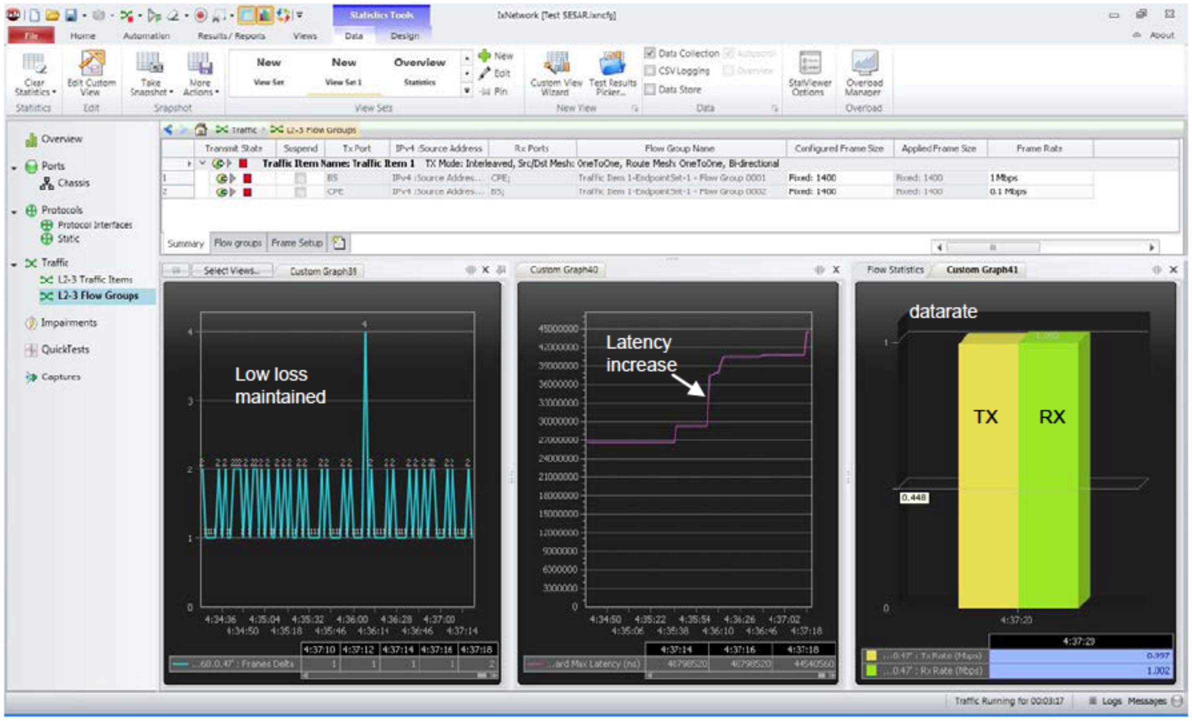
The QoS parameters associated with BE service are maximum sustained traffic rate and traffic priority. It was observed that a data flow with more than the maximum allowed data rate is limited to max. This is showed on following picture. One UL and one DL BE SF with 300 kbps max are defined. When transmitted more than 300 kbps, the received data rate is limited to 300 kbps.

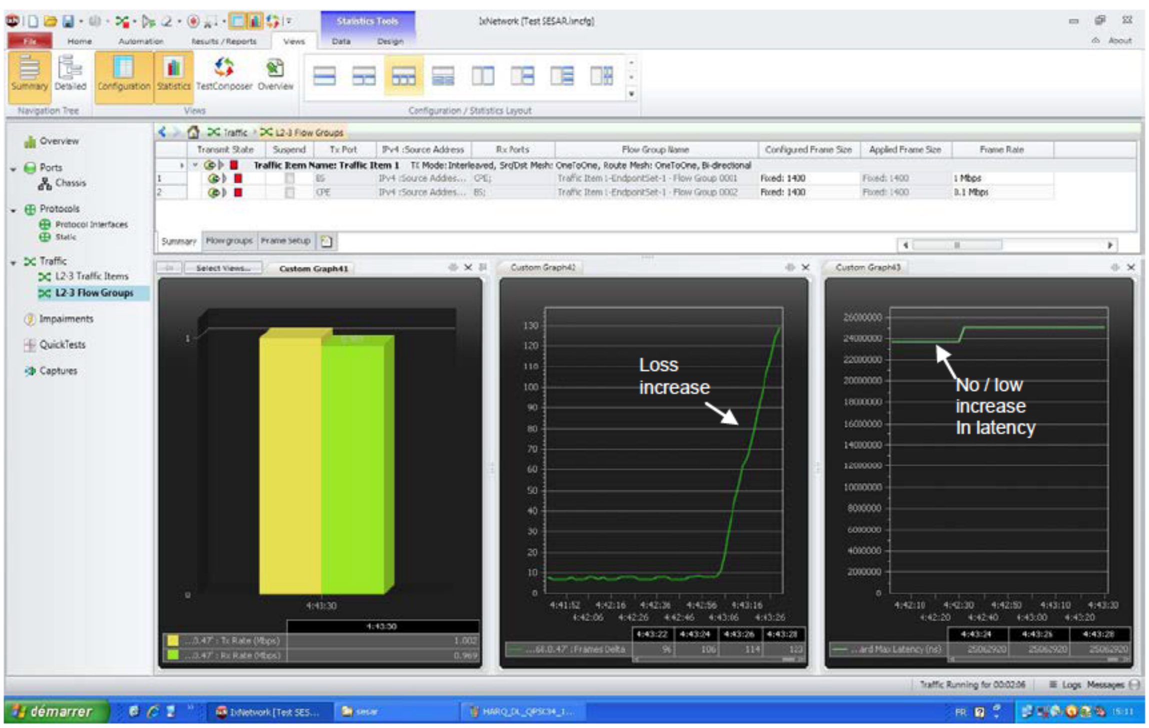



- Phase 3: ARQ testing

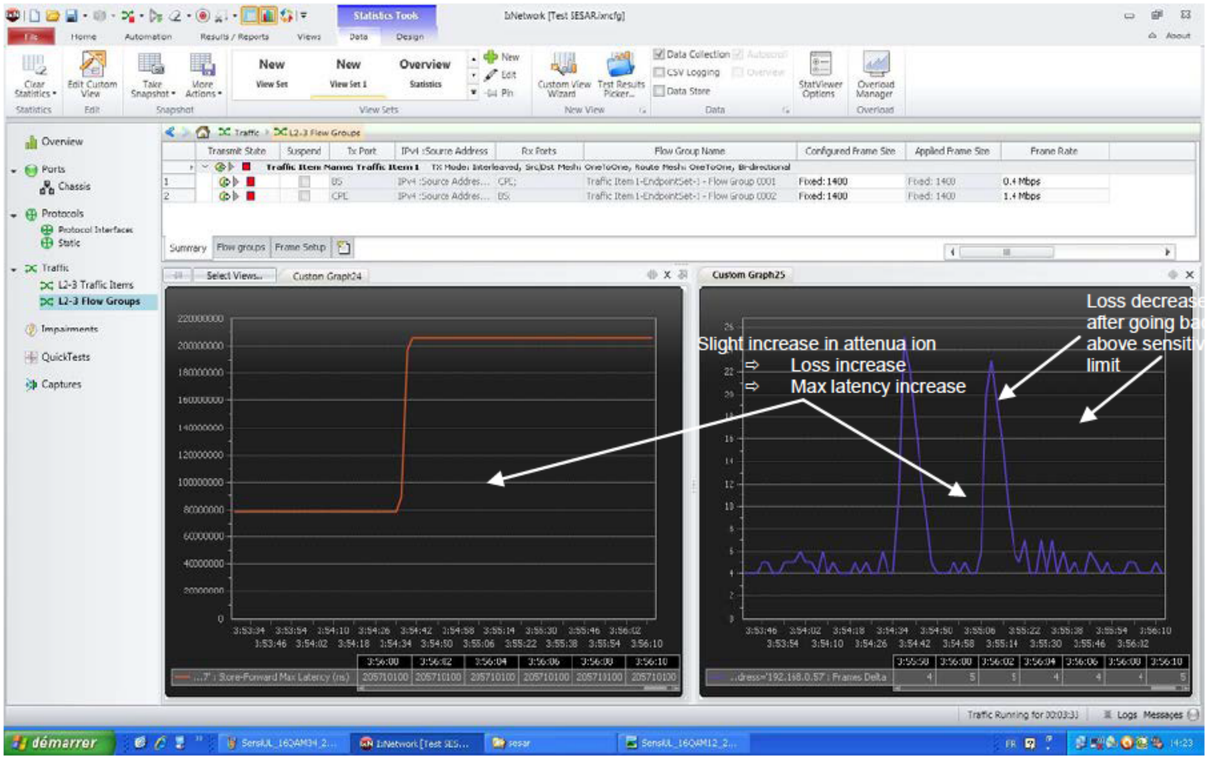
The test consists in verifying that an ARQ connection compared to a non ARQ connection in the same radio conditions, has less packet losses and higher latency, due to the fact that packet are retransmitted.

This is shown in the two pictures below where the attenuator is tuned to be at the sensitivity limit: same signal conditions but in the first case ARQ is activated and in the second case it is deactivated. In first case, we are able to observe that the packet losses are maintained low whereas latency increases due to packet retransmission and in the second case, as no packet retransmission occurs, packet losses increase regularly.


Low loss
maintained
Latency
increase
datarate
TX
RX

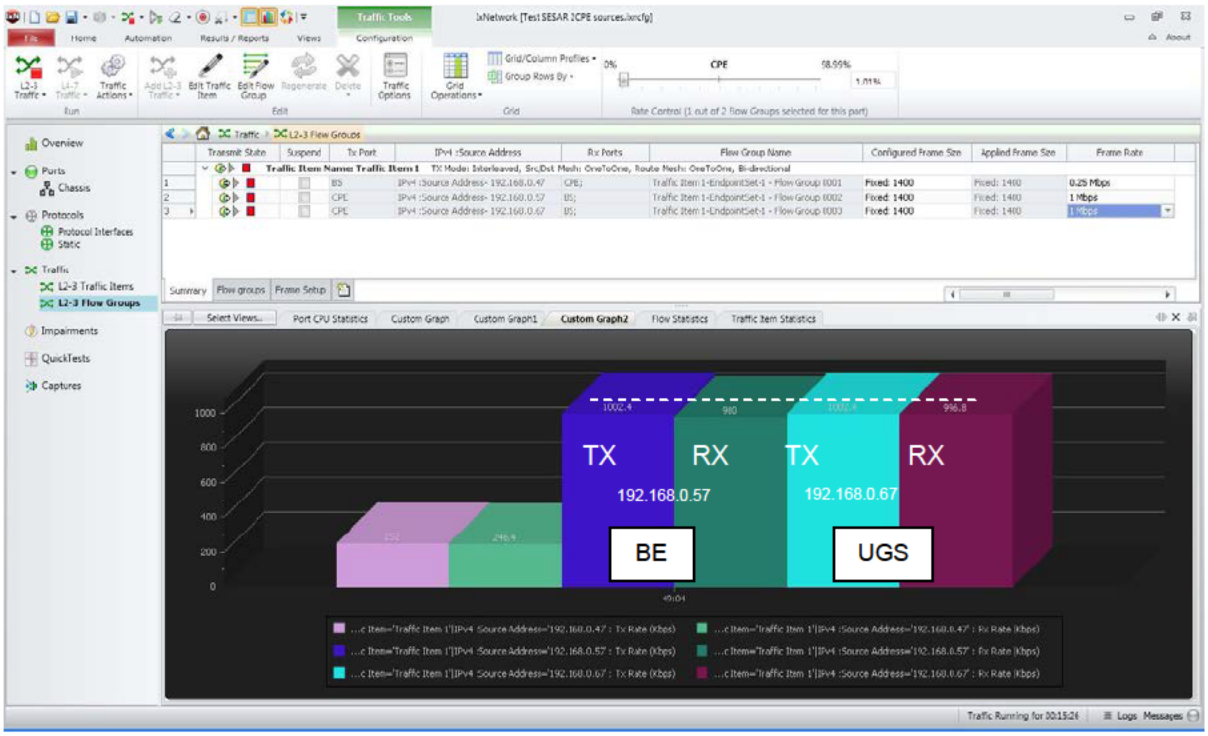

Loss
increase
No / low
increase
In latency

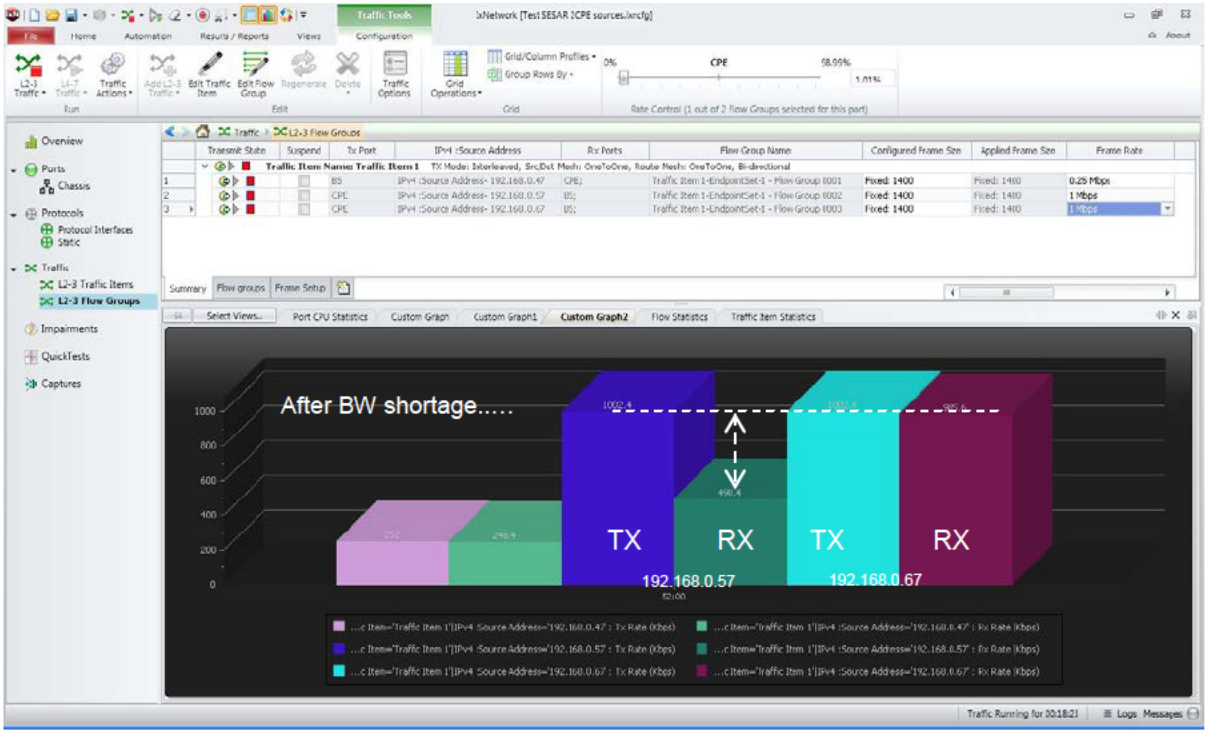
Additional tests are presented below with ARQ enabled. The variable attenuator is tuned one dB below sensitivity threshold (so that packet losses begin) and back above sensitivity threshold. One can see the effect of packet retransmissions to reduce packet losses.



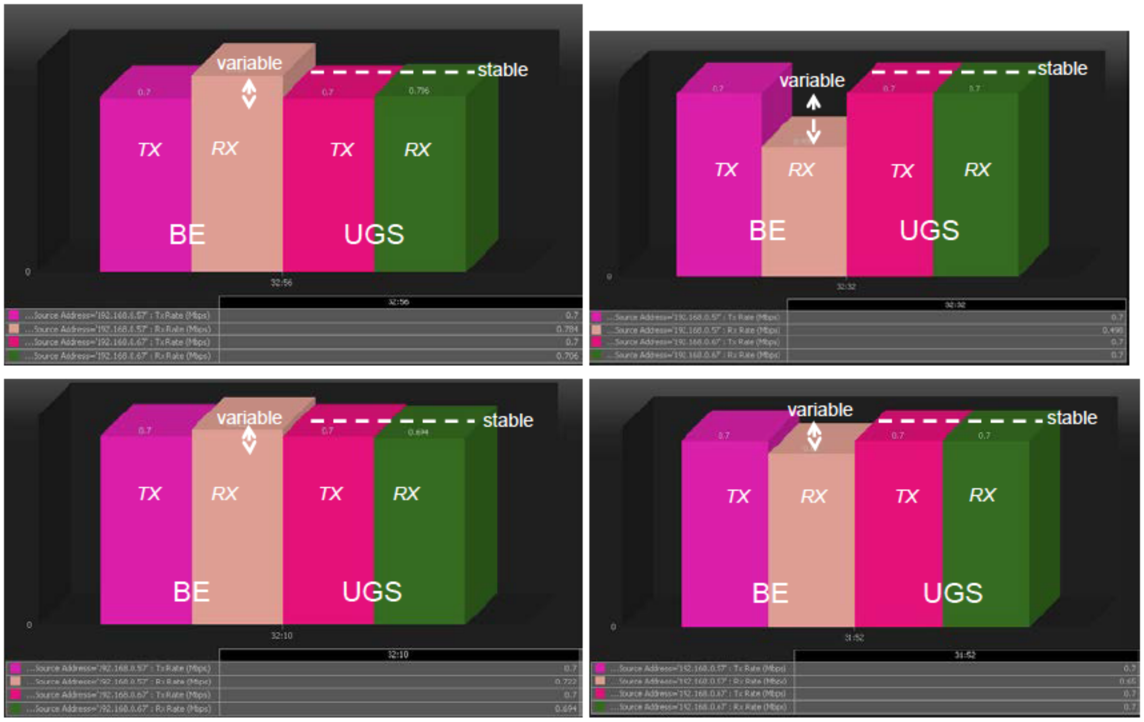
- Phase 4: Bandwidth allocation

Two UL service flows were defined with same priority and same max sustained rate. One is BE and associated with IP SRC 192.168.0.57 and the other is UGS with IP SRC 192.168.0.67. A data rate shortage is then created by increasing the attenuation on the link (downgrading of modulation), and the resulting aggregate data rate is lower than the required data rate regarding the data traffic to transmit. One can see that UGS is privileged over BE.




After BW shortage.....
TX
RX
TX
RX
192.168.0.57
192.168.0.67

In following pictures, one can see that bandwidth allocation granted to MS in case of UGS is fix and stable while the allocation for BE is erratic in time.




### A.2.3.3 Unexpected behaviors/Results

None.

## A.2.4 Conclusions and recommendations

The testing allowed checking QOS functionalities.

# A.3 Verification Exercise # TLAB_030 Report

## A.3.1 Verification Exercise Scope

Security: verify that BS and MS are able to use encryption.

## A.3.2 Conduct of Verification Exercise

### A.3.2.1 Verification Exercise Preparation

Same as for TLAB_010 see § A.1.2.1.
Additionally, a AAA server was used (Freeradius.Net 1.1.7-r0.0.2).

### A.3.2.2 Verification Exercise execution

| Step | action | Action result | PCO | Result |
|---|---|---|---|---|
| 1 | Set frequency on the GS :<br>- 5120,25 MHz<br>Switch on the GS<br>AAA server is on | GS on | GS control MMI | OK |
| 2 | Set frequency scan of MS :<br>- 5093,5 – 5147,5 MHz, step 250 kHz (5002,5 + n*0.25 for n = {364…580} in MHz.)<br>Switch on the MS | MS connects eventually to the GS | GS control MMI | OK |
| 3 | Ping the MS from the PC of the GS | Ping OK | PC MMI | OK<br>(PC of MS) |
| 4 | Sent file via FTP from the PC of the GS to the PC of the MS | File transfer done | PC MMI | OK |
| 5 | Deregister MS<br>Remove secret information on MS | MS tries to connect without success to the GS | GS control MMI | OK |
| 6 | Deactivate authentication on the GS. | MS connects eventually to the GS | GS control MMI | OK |
| 7 | Sent file via FTP from the PC of the GS to the PC of the MS | File transferred (cyphering not used) | PC MMI | OK |

### A.3.2.3 Deviation from the planned activities

None

## A.3.3 Verification exercise Results

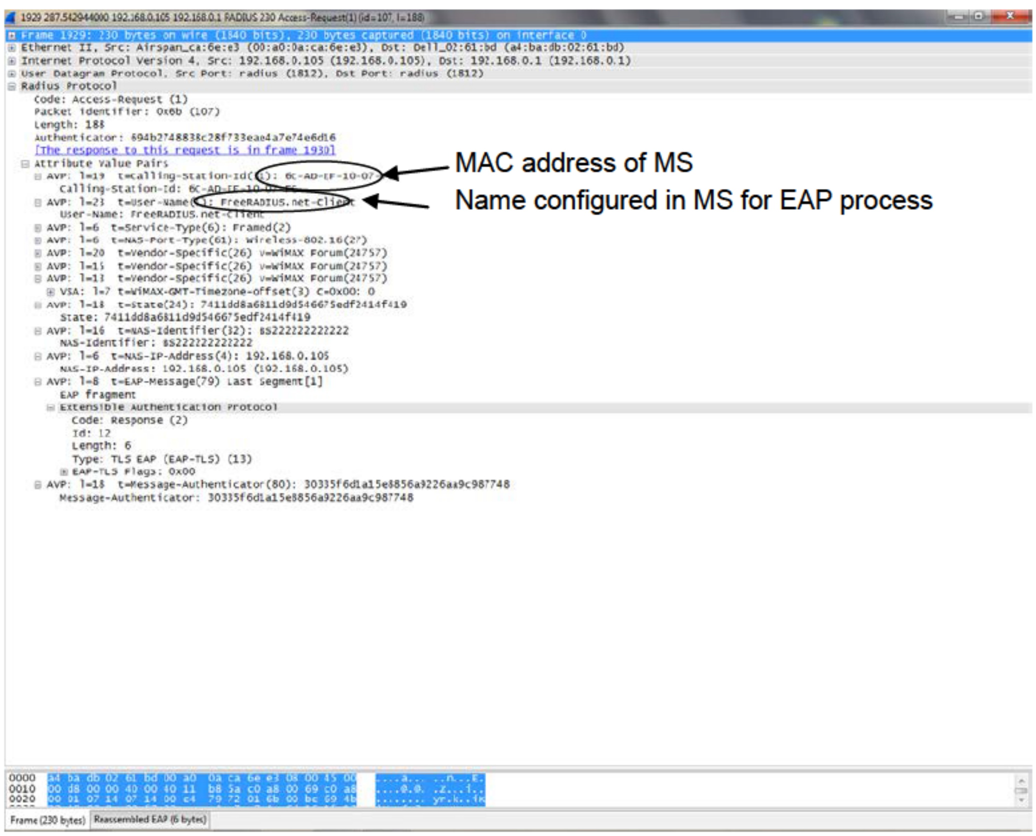
### A.3.3.1 Summary of Verification exercise Results

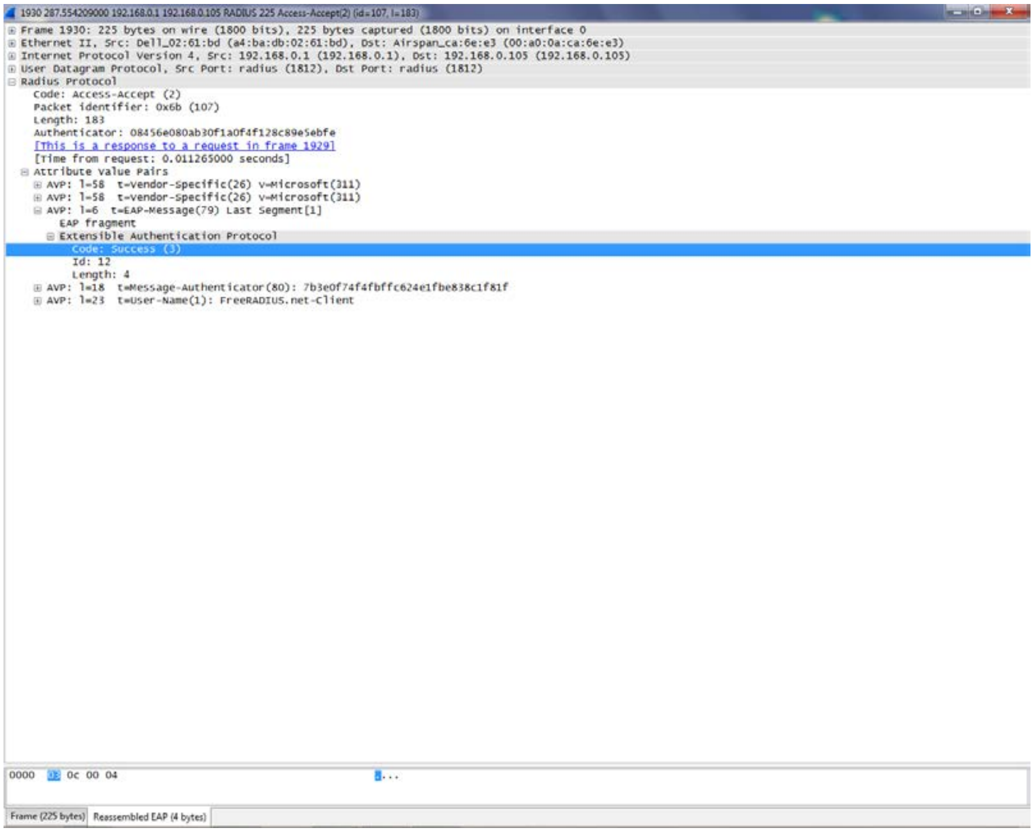
The test showed that the Authentication, Authorization, and Accounting (AAA) process performed as expected.

### A.3.3.2 Analysis of Verification Exercise Results

We observed that when the MS was well configured with the certificates and other secret information (password…), it was correctly authenticated and authorized to communicate. Without this mandatory information, the MS was not authorized to register.

To illustrate this, below we can see two captures by Wireshark of the Radius exchanges with the AAA server: one shows the Access-Request message from MS relayed to the AAA server and the other shows the Access-Accept response message from the AAA server.






### A.3.3.3 Unexpected behaviors/Results

None.

## A.3.4 Conclusions and recommendations

It was verified that the equipment properly implement authentication via the AAA server to handle an encrypted communication.

# A.4 Verification Exercise # TLAB_040 Report

## A.4.1 Verification Exercise Scope

Verify the modulation and coding schemes supported by MS and BS, measure the modulation sensitivity assess the dynamic modulation change and check the MS/BS maximum tolerable input.

## A.4.2 Conduct of Verification Exercise

### A.4.2.1 Verification Exercise Preparation

Same as for TLAB_010 see § A.1.2.1.
Verification Exercise execution

| Step | action | Action result | PCO | Result |
|---|---|---|---|---|
| Phase 1 : measure performances of the uplink | | | | |
| 1 | On the GS control MMI:<br>- Set frequency : 5093,5 MHz<br>- UL sub channelization is set to fix<br>- Fix the UL modulation to 64QAM 5/6<br>Provision the GS | GS new parameters provisioned | GS control MMI | OK |
| 2 | Set frequency scan of MS :<br>- 5093,5 – 5147,5 MHz, step 250 kHz (5002,5 + n*0.25 for n = {364…580} in MHz.) | MS connects eventually to the GS | GS control MMI | OK |
| 3 | Initiate a communication between MS and GS. | Communication established in UL direction | IXIA | OK |
| 4 | Tune the variable attenuator so to obtain the Max Power on the MS and to be at the limit of sensitivity.<br>Then, write down the RSSI level of the GS and the max attenuation of the link. | Obtained values: Attenuation, GS RSSI, MS emitting power, UL data rate<br>Deduce the sensitivity of the GS and the max emitting power of the MS | GS MMI, MS MMI | OK |
| 5 | Do step 1 to 4 with each available UL modulation: *64 QAM ¾, 16QAM ¾, 16QAM ½, QPSK ¾, QPSK ½* | | | OK |
| Phase 2 : measured performances of the downlink | | | | |
| 1 | On the GS control MMI: | GS on | GS control MMI | OK |

| | | | | |
|---|---|---|---|---|
| | - Set frequency : 5103,5 MHz<br>- Fix the DL modulation to 64QAM 5/6<br>- GS power fixed to max<br>Switch on the GS | | | |
| 2 | Set frequency scan of MS :<br>- 5093,5 – 5147,5 MHz, step 250 kHz (5002,5 + n*0.25 for n = {364…580} in MHz.)<br>Switch on the MS | MS connects eventually to the GS | GS control MMI | OK |
| 3 | Initiate a communication between the GS and the MS. | Communication established in DL direction | Ixia | OK |
| 4 | Tune the variable attenuator so to be at the limit of sensitivity.<br>Then, write down the RSSI level of the GS and the max attenuation of the link. | Obtained values: Attenuation, MS RSSI, GS emitting power, DL data rate<br>Deduce the sensitivity of the MS | GS MMI, MS MMI | OK |
| 5 | Do step 1 to 4 with each available UL modulation: *64 QAM ¾, 16QAM ¾, 16QAM ½, QPSK ¾, QPSK ½* | | | OK |
| Phase 3 : threshold between automatic modulation / coding changes | | | | |
| 1 | On the GS control MMI:<br>- Set frequency : 5098,5 MHz<br>- Automatic Modulation<br>- GS power fixed to max<br>Switch GS on and MS on | GS on. MS connects eventually to the GS | GS control MMI | OK |
| 2 | Initiate a communication in both direction. | Communication established in UL and DL direction | Ixia | OK |
| 3 | Tune the variable attenuator from less attenuation to more attenuation so to obtain modulation change in the UL and the DL.<br>Write down the attenuation corresponding to each modulation change. | Obtained values: Attenuation versus modulation change | GS control MMI | OK |
| Phase 4: Max tolerable input signal at MS | | | | |
| 1 | On the GS control MMI: | GS on. MS connects | GS control MMI | OK |

| | | | | |
|---|---|---|---|---|
| | - Set frequency : 5093,5 MHz<br>- DL sub channelization is set to fix<br>- Fix the DL modulation to QPSK ¾<br>Switch on the GS | eventually to the GS | | |
| 2 | Initiate a communication between the GS and the MS: DL. | Communication established in DL direction | IXIA | OK |
| 3 | Tune the variable attenuator to increase receive level at MS.<br>Write down the attenuation when error occurs. | Receive power threshold of degradation | IXIA | OK |

.

### A.4.2.2 Deviation from the planned activities

None.

## A.4.3 Verification exercise Results

### A.4.3.1 Summary of Verification exercise Results

The results are summarized below:

- Phase 1: measure performances of the uplink
  - UL measured sensitivity and max data rate are summarized in table below. Measurements are made with BS1 @ 5093,5 MHz.

| UL Mod | UL Sensitivity | UL Max datarate |
|---|---|---|
| ***64 qam 2/3*** | *-71 dBm* | *1,91 MBps* |
| ***64 qam 1/2*** | *-82 dBm* | *1,42 MBps* |
| **16 qam 3/4** | -82 dBm | 1,42 MBps |
| **16 qam 1/2** | -84 dBm | 0,94 MBps |
| **qpsk 3/4** | -86 dBm | 0,69 MBps |
| **qpsk 1/2** | -94 dBm | 0,45 MBps |

Note: *64QAM is optional in AeroMACS for the uplink*.

Note: With sub-channelization (down to 2 sub-channels used out of the 17 sub-channels) a gain of more than 6 dB is observed (of course the effect is reduced data rate).

- Phase 2: measured performances of the downlink is summarized in following tables

  - Measured sensitivity @ 5103,5 MHz with BS2 is summarized in table below

| Modulation scheme | DL Sensitivity |
|---|---|
| 64 qam 5/6 | -73 dBm |
| 64 qam 3/4 | -77 dBm |
| 64 qam 2/3 | -79 dBm |
| 64 qam 1/2 | -82 dBm |
| 16 qam 3/4 | -83 dBm |
| 16 qam 1/2 | -87 dBm |
| qpsk 3/4 | -91 dBm |
| qpsk 1/2 | -93 dBm |

  - DL Measured data rate is summarized in table below

| Mod & coding rate | DL Measured Data rate [Mb/s] |
|---|---|
| 64QAM 5/6 | **9.2** |
| 64QAM 3/4 | **8,3** |
| 64QAM 2/3 | **7,4** |
| 64QAM 1/2 | **5,5** |
| 16QAM 3/4 | **5,5** |
| 16QAM 1/2 | **3,7** |
| QPSK 3/4 | **2,7** |
| QPSK 1/2 | **1,8** |

- Phase 3 : threshold between automatic modulation / coding changes

  - In the Downlink:

| Auto DL Mod switching | | Received level |
|---|---|---|
| 64 qam 5/6 -> | 64 qam 3/4 | -74 dBm |
| 64 qam 3/4 -> | 64 qam 2/3 | -77 dBm |
| 64 qam 2/3-> | 64QAM 1/2 | -79 dBm |
| 64QAM 1/2-> | 16 qam 3/4 | -83 dBm |
| 16 qam 3/4-> | 16 qam 1/2 | -84 dBm |
| 16 qam 1/2-> | qpsk 3/4 | -86 dBm |
| qpsk 3/4-> | qpsk 1/2 | -90 dBm |

  - In the Uplink:

| Auto UL Modulation change | | Received level |
|---|---|---|
| 16 qam 3/4-> | 16 qam 1/2 | -78 dBm |
| 16 qam 1/2-> | qpsk 3/4 | -83 dBm |
| qpsk 3/4-> | qpsk 1/2 | -85 dBm |

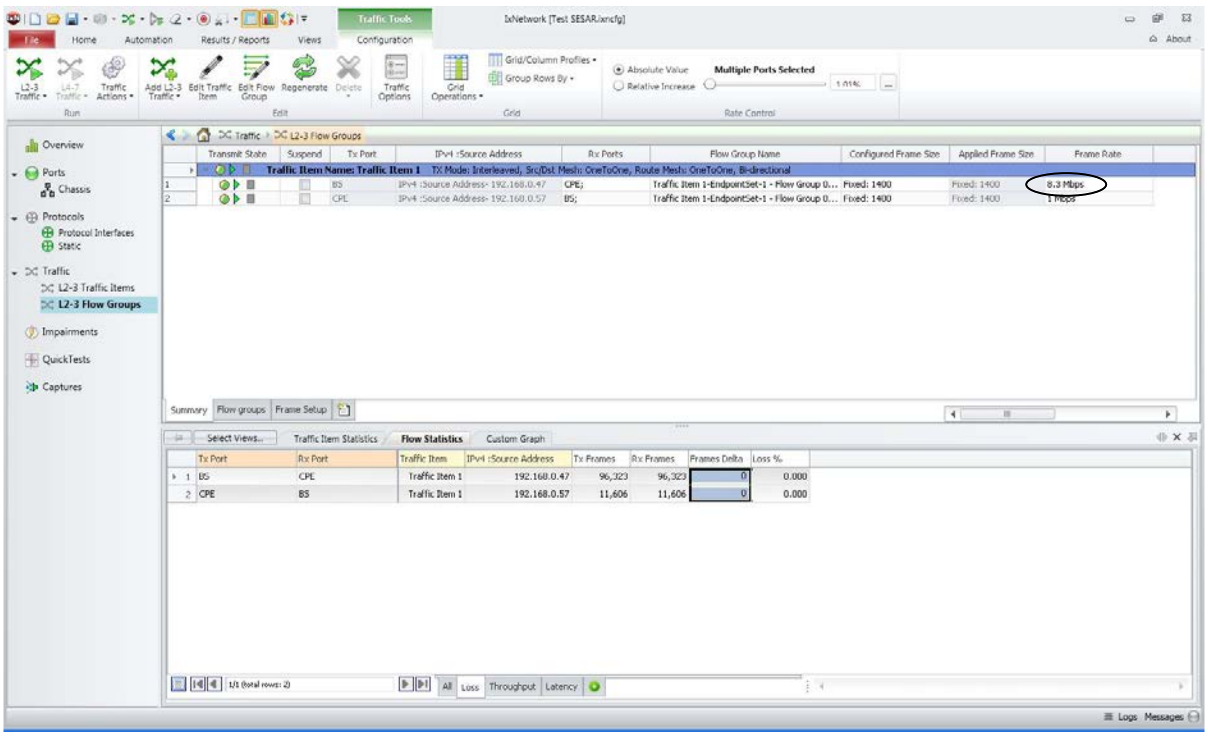
- Phase 4: a -30 dBm input signal is OK at MS receiver.

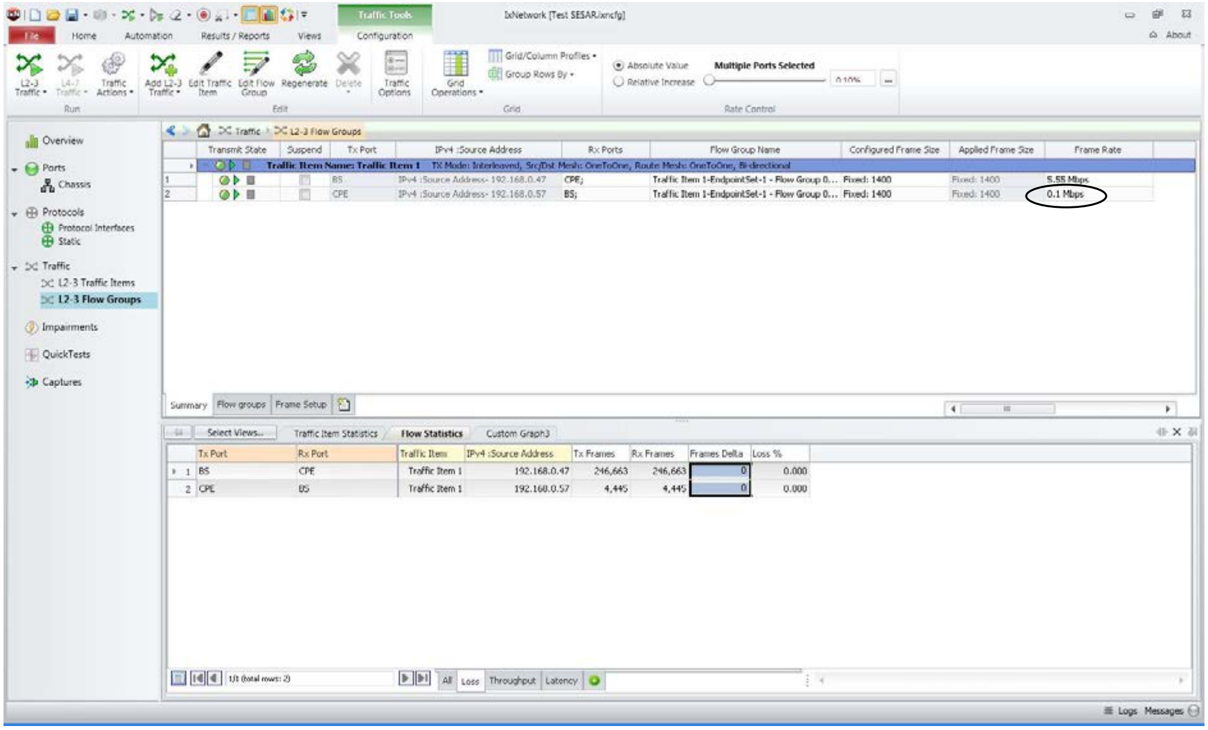
### A.4.3.2 Analysis of Verification Exercise Results

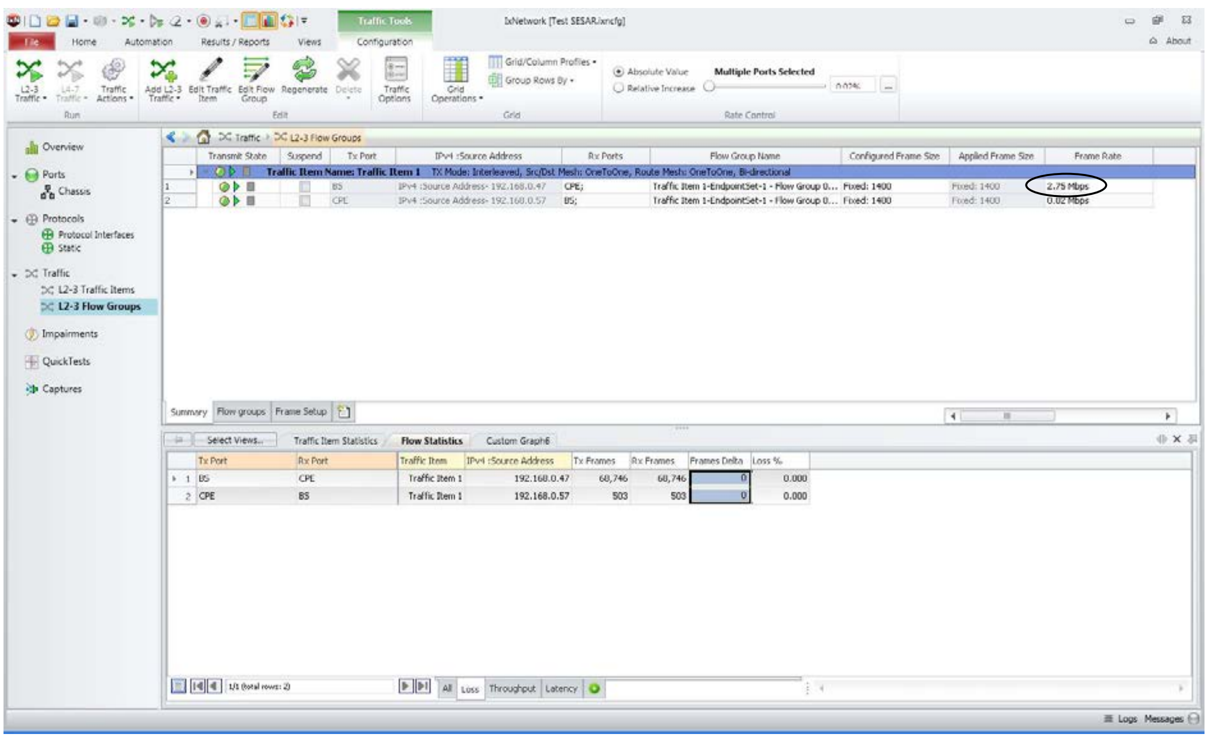
The results are analyzed below:

- DL & UL Data rates are consistent with what was calculated in theory.
- DL & UL Sensitivity is examined relatively to the theoretical table of SRD. The measured sensitivity is between 1 to 2 dB better than theoretical value. Transition margin for automatic modulation / coding changes is found to be consistent with sensitivity measurements.
- In UL, sub-channelization allows greater attenuation hence greater distance (at the prize of a reduced data rate).

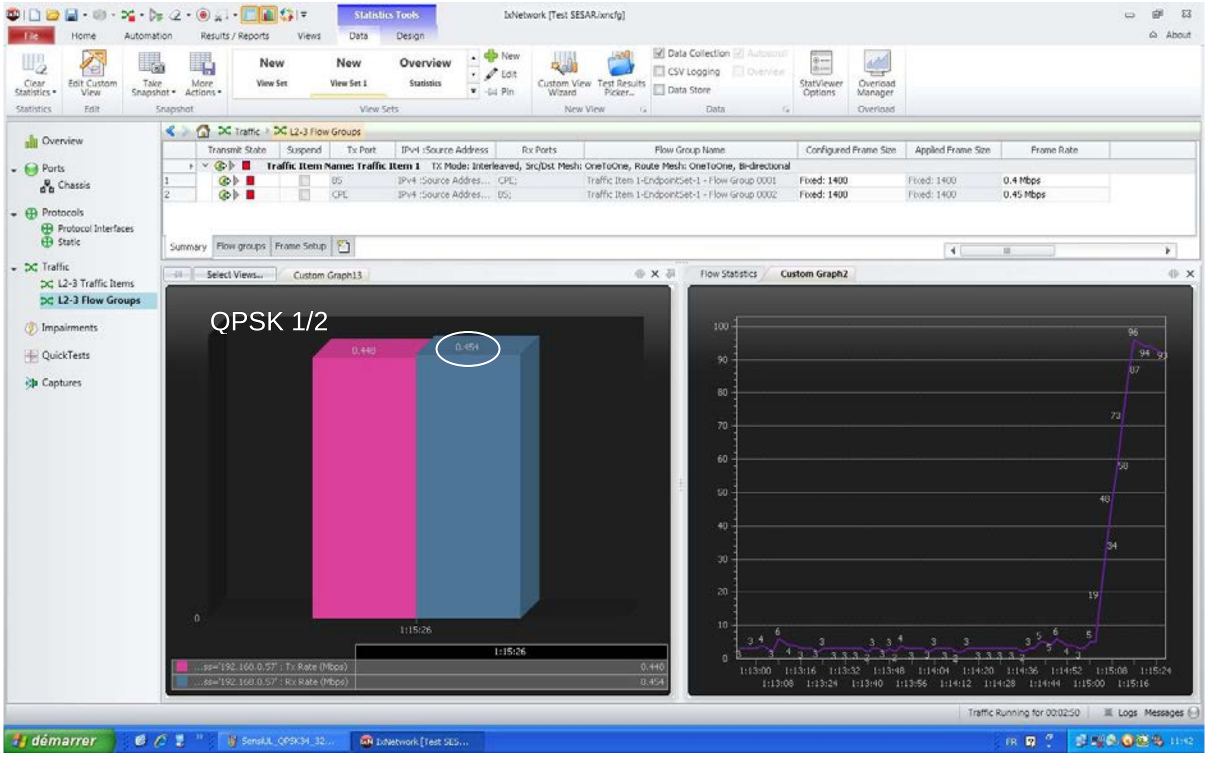
Some IXIA Screenshots to illustrate the results the data rates achieved with 64QAM ¾, 16 QAM ¾, QPSK ¾ in the downlink.

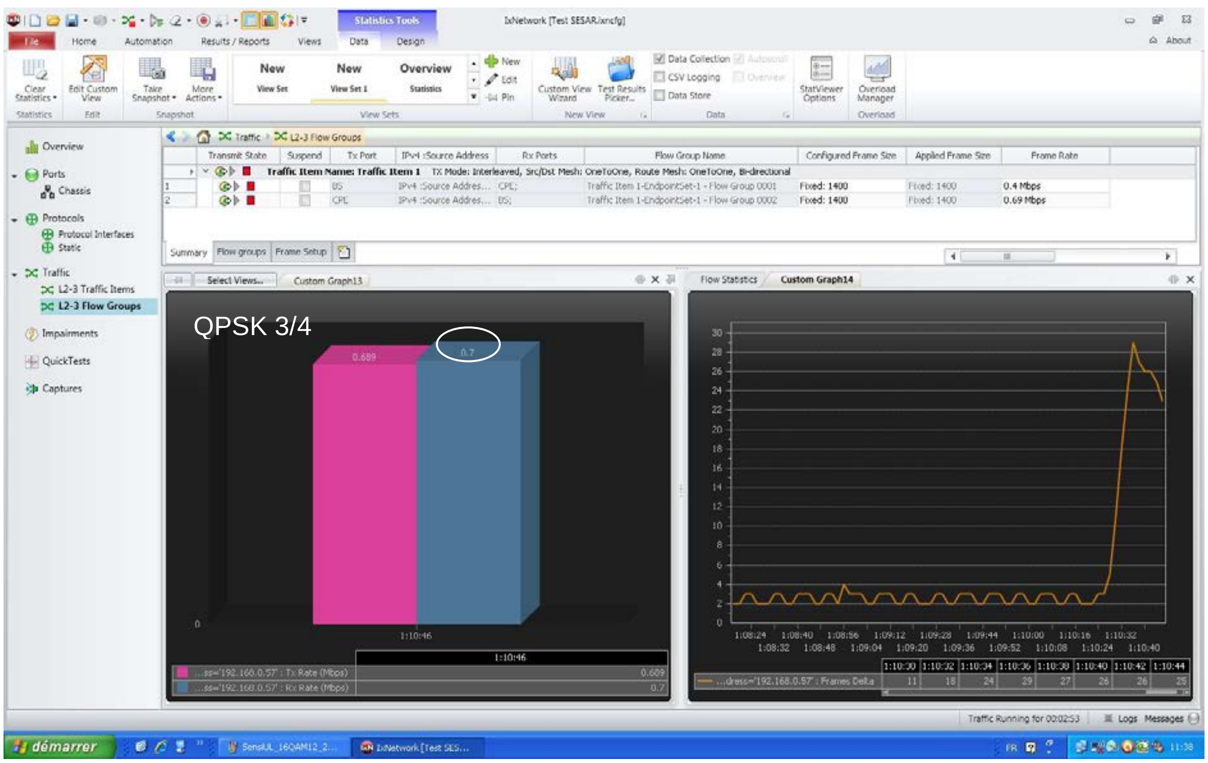


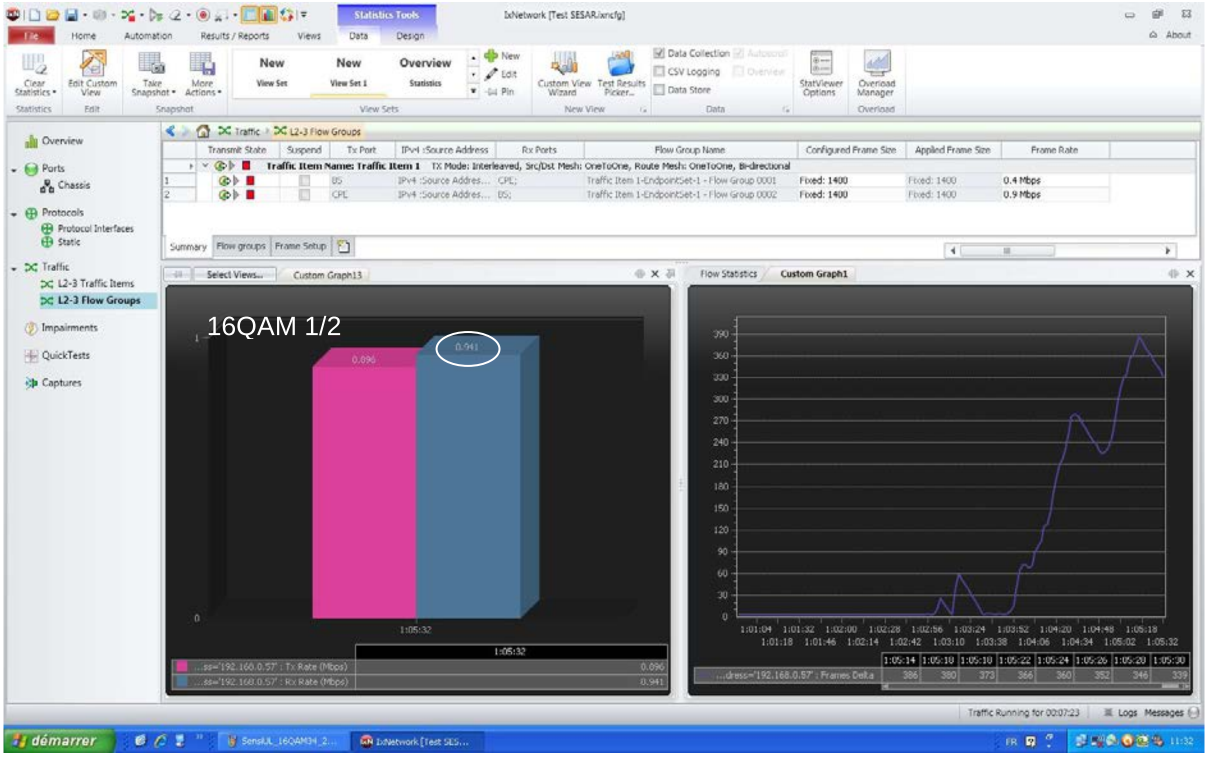


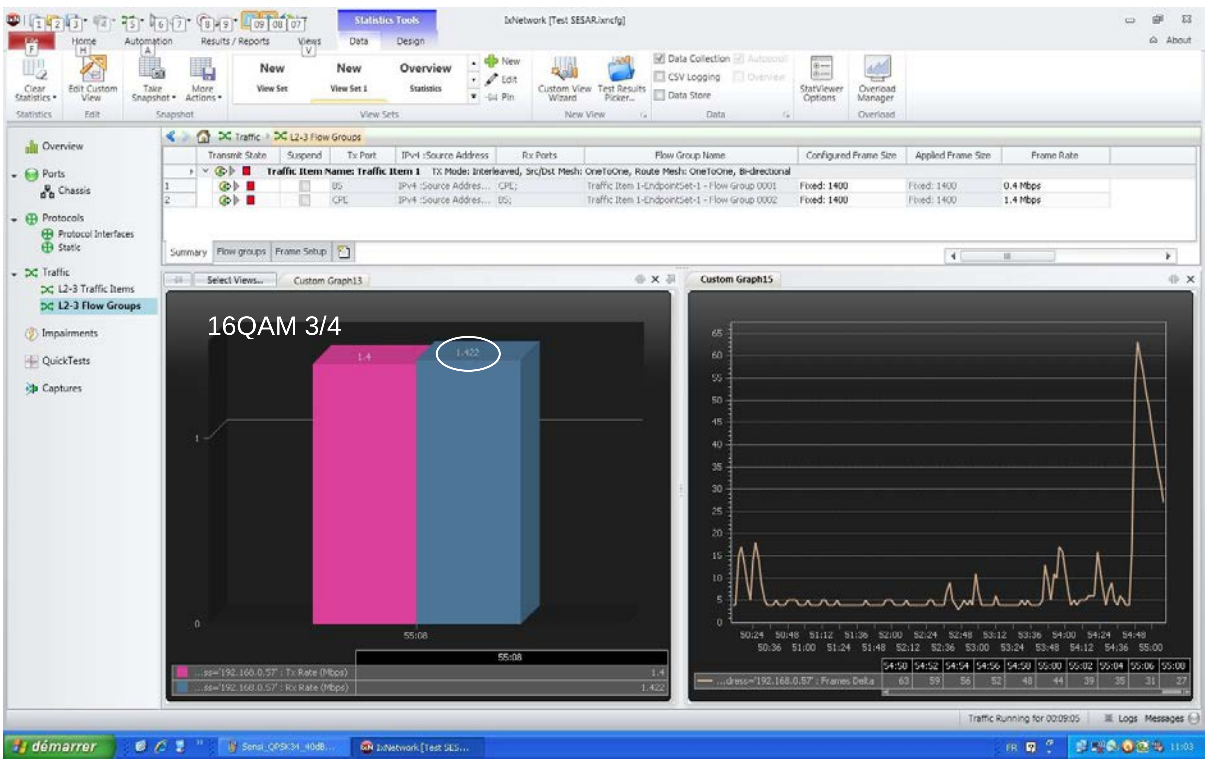


Some screenshots for max data rates in the UL are shown below (the data rate is shown at sensitivity limit).

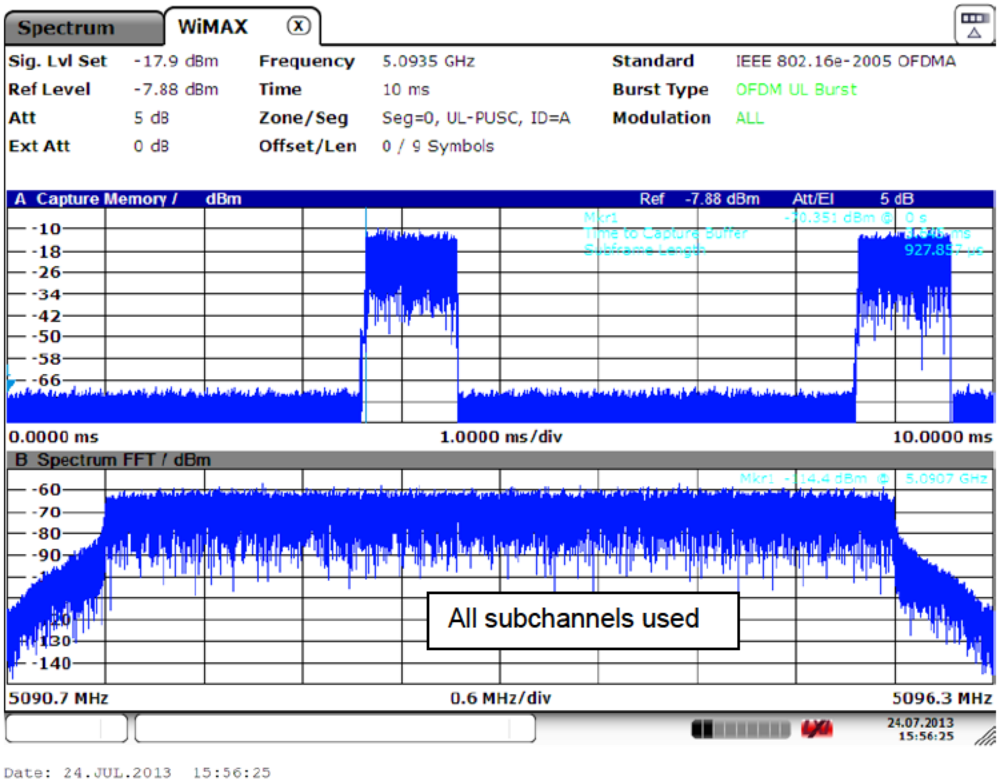

QPSK 1/2
IxNetwork [Test SESAR.ixncfg]
Traffic Item Name: Traffic Item 1
Traffic Item 1-EndpointSet-1 - Flow Group 0001
Traffic Item 1-EndpointSet-1 - Flow Group 0002
Fixed: 1400
0.4 Mbps
0.45 Mbps
Flow Statistics
Custom Graph2
Custom Graph13
0.440
0.454
1:15:26
Traffic Running for 00:02:50

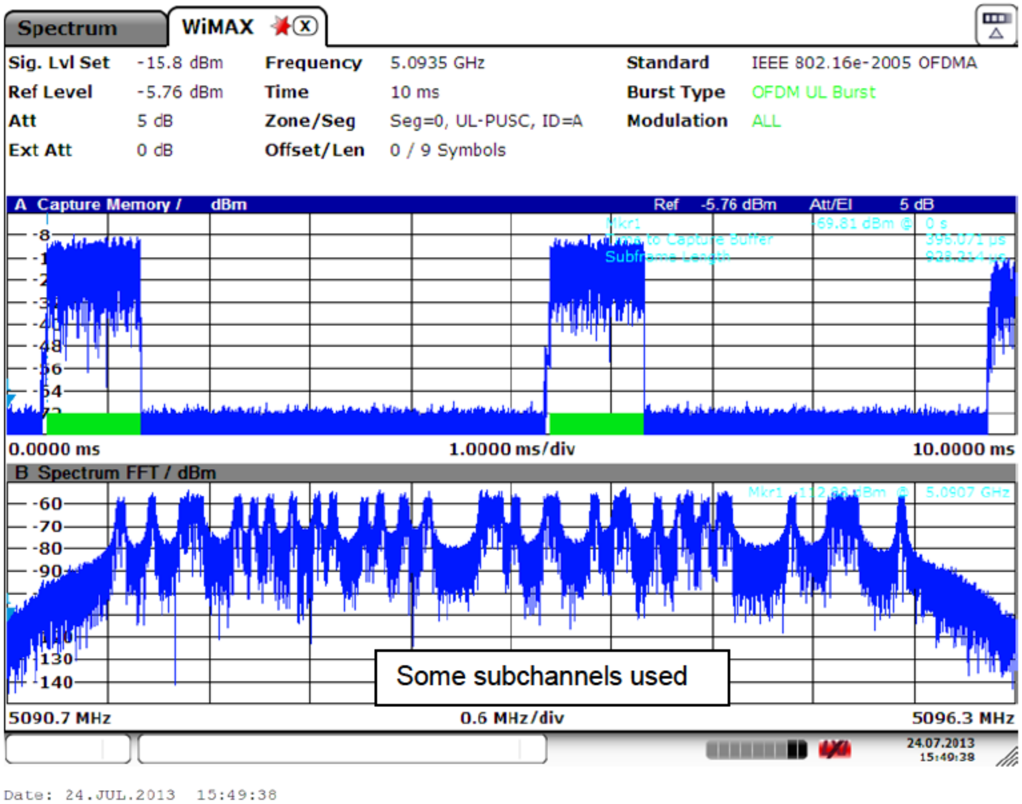

QPSK 3/4
IxNetwork [Test SESAR.ixncfg]
Traffic Item Name: Traffic Item 1
Traffic Item 1-EndpointSet-1 - Flow Group 0001
Traffic Item 1-EndpointSet-1 - Flow Group 0002
Fixed: 1400
0.4 Mbps
0.69 Mbps
Flow Statistics
Custom Graph14
Custom Graph13
0.689
0.7
1:10:46
Traffic Running for 00:02:53


16QAM 1/2


16QAM 3/4

Below the effect of sub channelization in the UL is depicted:






## A.4.3.3 Unexpected behaviors/Results

None.

## A.4.4 Conclusions and recommendations

Measurements performed well. With sub channelization, we can expect to see an increase in cell coverage but with less data rate.

For next phase, one recommendation could be (if possible regarding installation of two antennas in the vehicle) to complement the test in Toulouse Airport with MIMO A for the mobile stations (context of ground segment) in order to assess any improvement in reception performances.

# A.5 Verification Exercise # TLAB_050 Report

## A.5.1 Verification Exercise Scope

The test purpose is to measure radio performances (power spectral flatness, interferences, unwanted emissions).

## A.5.2 Conduct of Verification Exercise

### A.5.2.1 Verification Exercise Preparation

Same as for TLAB_010 see § A.1.2.1.

### A.5.2.2 Verification Exercise execution

| Step | action | Action result | PCO | Result |
|---|---|---|---|---|
| 1 | Set frequency on the GS :<br>- 5120,5 MHz<br>Switch on the GS | GS on | GS control MMI | OK |
| 2 | Set frequency scan of MS :<br>- 5093,5 – 5147,5 MHz, step 250 kHz (5002,5 + n*0.25 for n = {364…580} in MHz.)<br>Switch on the MS | MS connects eventually to the GS | GS control MMI | OK |
| 3 | Initiate a communication in both directions. | Communication established in both directions (UL and DL) | IXIA | OK |
| Phase 1: Spectrum mask measurement | | | | |
| 1 | Measure spectrum Mask and check flatness of the 5 MHz BW of GS | Spectrum measurement of the 5MHz channelization. Measurement of the flatness. | Spectrum Analyzer | OK |
| 2 | Measure spectrum Mask and check flatness of the 5 MHz BW of MS | Spectrum measurement of the 5MHz channelization. Measurement of the flatness. | Spectrum Analyzer | OK |
| 3 | Tune BS to other frequencies and go to 1<br>5093,5 MHz – 5098,5 MHz – 5103,5 MHz – 5147,5 MHz | MS connects eventually to the GS | | OK |

| Phase 2: Test the unwanted emission level outside the band | | | | |
|---|---|---|---|---|
| 1 | Set frequency on the GS : 5093,5 MHz | Frequency tuned | GS control MMI | OK |
| 2 | Measure the spurious emission out of band (particular focus on f= 5126 MHz (AMT) & on f=5038,8 MHz (MLS)) | Delta measurement of out band compared to in band signal | Spectrum Analyzer | OK |
| 3 | Tune BS to 5103,5 MHz and go to 2 | Frequency tuned | GS control MMI | OK |

### A.5.2.3 Deviation from the planned activities

None

## A.5.3 Verification exercise Results

### A.5.3.1 Summary of Verification exercise Results

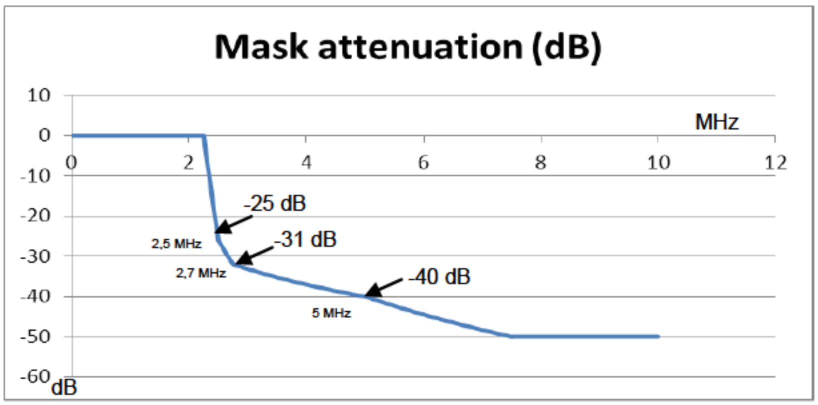
- Phase 1: The 5 MHz spectrum was measured through the spectrum analyzer at the different frequency including the adjacent and alternate channels. It complies with specified mask.

- Phase 2: An analysis is made over the frequencies to detect the unwanted emissions. They are below the specified maximum level.

### A.5.3.2 Analysis of Verification Exercise Results

- Phase 1:

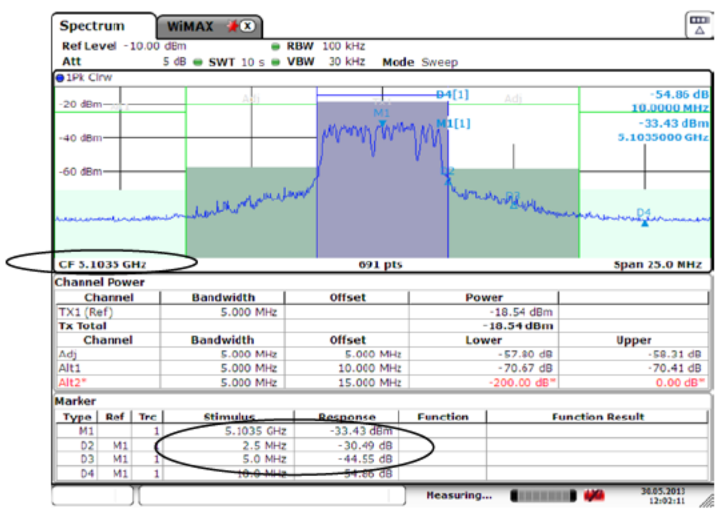
The specified spectrum mask is as follows:




As an example reported for analysis, one can find below the measurement results for the 5093,5 and 5103,5 MHz frequency which are planned to be used at the Toulouse Airport.

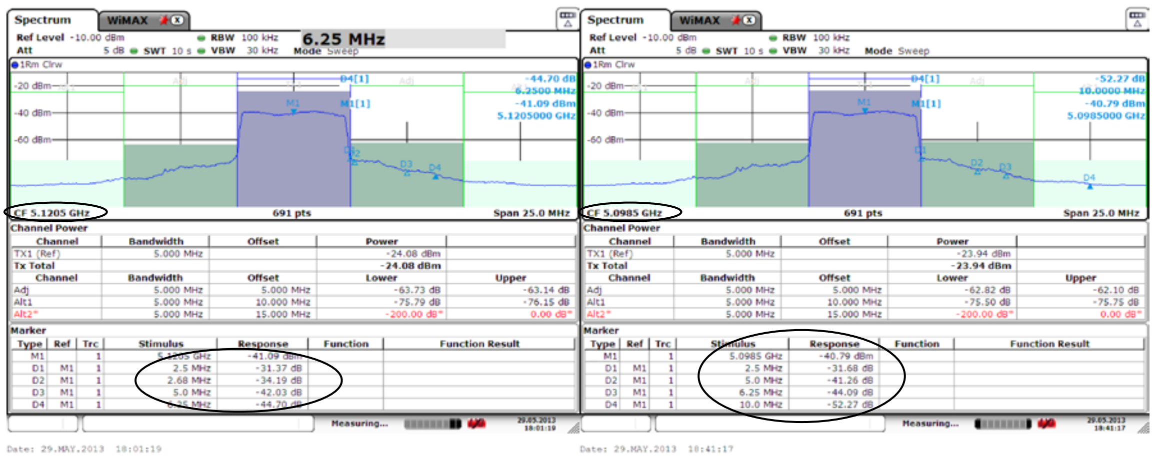
5103,5 MHz DL spectrum is represented below. It fits the mask.


UL spectrum @ 5103,5 MHz represented below fits also the mask.

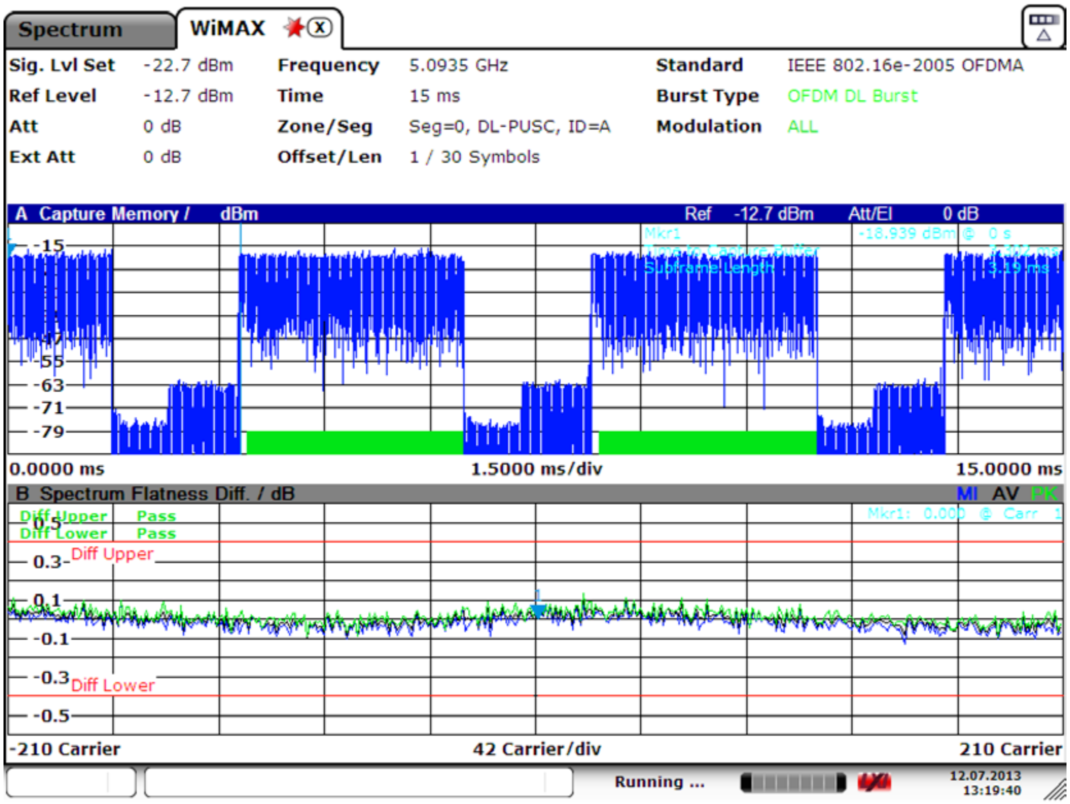



As a confirmation of the analysis, another spectrum measurement is presented for the DL & UL 5093.5 MHz frequency: it is also in conformance with mask.

Two additional tested frequencies UL 5120,5 MHz and UL 5098,5 MHz are given below.

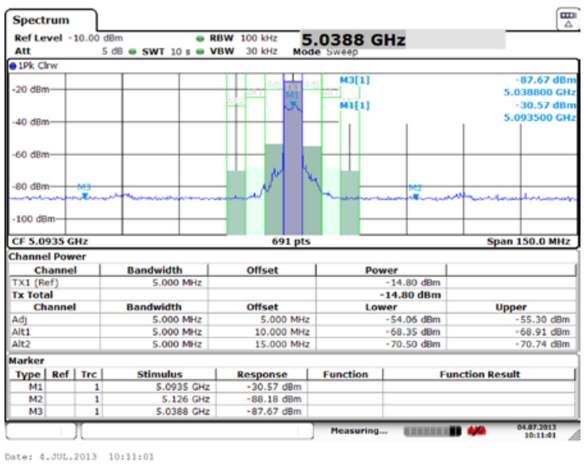


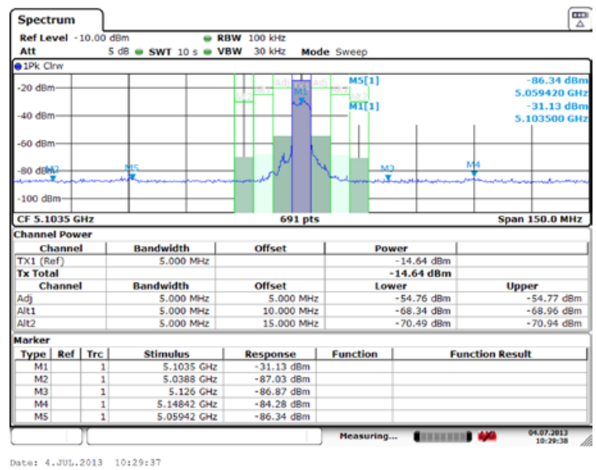
Besides, below a measurement about flatness is highlighted, showing flatness is also OK.




Date: 12.JUL.2013 13:19:41

- Phase 2: Unwanted emissions measurement at output of MS and BS equipment are analyzed below with respect of the frequencies that will be used at the Toulouse airport (5093,5 MHz and 5103,5 MHz). A particular focus is done on the MLS frequency (5038,8 MHz) and the AMT frequency (5126 MHz).




The maximum spurious level is at least 53 dB below the max. If we consider the BS emitting at 23 dBm over 5 MHz, this gives a level of 7 dBm in the RBW100 kHz corresponding to a level of spurious below -46 dBm in RBW 100 kHz.

### A.5.3.3 Unexpected behaviors/Results

None.

## A.5.4 Conclusions and recommendations

The stations perform well regarding spectrum mask and spurious. No particular recommendation for next phase testing.

# A.6 Verification Exercise # LAB1_1 Connection Establishment Report

## A.6.1 Verification Exercise Scope

The purpose of this Verification Exercise is checking that the MS properly connects with the BS, and that both the devices under test (MS and BS) are compliant with the specific AeroMACS RF requirements detailed in the Verification Exercise execution Section.

## A.6.2 Conduct of Verification Exercise

### A.6.2.1 Verification Exercise Preparation

The test bed described in Figure 2 was arranged. The following main components were used:

Spectrum Analyzer: Agilent E4445A PSA Series, 3Hz-13.2GHz; 89600 VSA SW (Build 15.01.356.0).

The specific AeroMACS setup is loaded before test execution.

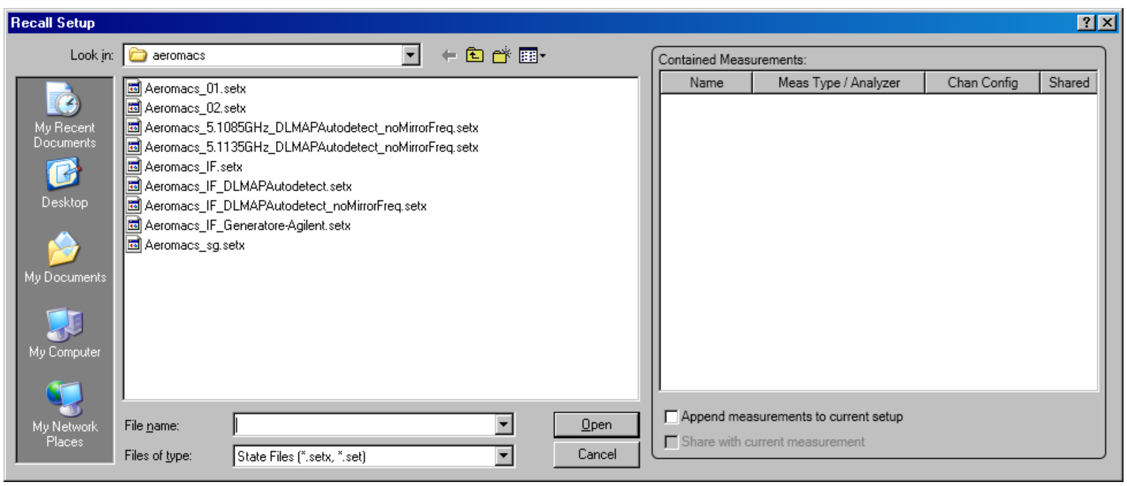



**Figure 4: AeroMACS Setup on Agilent Spectrum Analyzer**

*Equipment:*

MS/BS are configured according to AeroMACS profile (BW 5MHz, frame length 5 ms, TDD Mode, DL/UL split (e.g. 32:15), etc.). In particular, prepared configuration files are pre-loaded in the equipment. For instance, in the BS it is possible to set the BS IP address, the IP address of used ASN GW, Base Station ID, and some other internal parameters.

ASN-GW is an Aricent Wing ASN-GW.

MS, BS and ASN-GW were linked together according to test bed configuration with proper attenuation and switched on.

**Figure 5: Picture of test bed in Selex ES Lab**

Fading Simulator and Data Traffic Generator shown in Figure 2 were not used in this test.

### A.6.2.2 Verification Exercise execution

| Step nr. | Action | Action description | PCO (Point of Control and Observation) | Comment |
|---|---|---|---|---|
| 1. | Switch on MS | Set the center frequency modifying the MS config file and reboot | MS CLI | OK |
| 2. | Verify that MS begins scanning for BS | Check MS status | MS CLI, MS indicator LEDs | OK. |
| 3. | Switch on BS | | | OK |
| 4. | Configure BS to first channel (5093.5 MHz) | Set the center frequency using CLI BS<br><br>Reboot BS | BS CLI | OK |
| 5 | Reboot BS | | | OK |

| | | | | |
|---|---|---|---|---|
| 6. | Verify that MS connects successfully | | MS CLI, MS indicator LEDs | OK |
| 7. | Verify that both BS and MS use orthogonal frequency-division multiple access | | WiMAX Vector Spectrum Analyzer | OK |
| 8. | Verify that both BS and MS use 5 MHz Channel Bandwidth | | WiMAX Vector Spectrum Analyzer | OK |
| 9. | Verify that both BS and MS use 5 ms frame length | | WiMAX Vector Spectrum Analyzer | OK |
| 10. | Verify that both BS and MS are able to operate in TDD mode | | WiMAX Vector Spectrum Analyzer | OK |
| 11. | Configure BS to next channel | | BS CLI | OK |
| 12. | Reboot BS | | | OK |
| 13. | Verify that MS loses connection | | MS CLI and for signal WiMAX Vector Spectrum Analyzer | OK |
| 14. | Verify that MS begins scanning | | MS CLI | OK |
| Repeat steps 6.-13. for channels 5113.5 and 5147.5 MHz | | | | |

### A.6.2.3 Deviation from the planned activities

A different set of frequencies has been used, with respect to what previously hypothesized in [3]. This modification has allowed testing the lowest and highest AeroMACS frequencies in the 5091-5150 MHz band.

## A.6.3 Verification exercise Results

### A.6.3.1 Summary of Verification exercise Results

| ID | Result | Description | When observed | Expected result | Obtained result | VO | Comment |
|---|---|---|---|---|---|---|---|
| 1 | ODFMA | Verify that both BS and MS use orthogonal frequency-division multiple access | Step 7 | OFMA structure | OFMA structure verified | AeroMACS_VO_Interop_01_A | OK- by means of Spectrum Analyzer |
| 2 | Size | Verify that both BS and MS use 5 MHz Channel Bandwidth. | Step 8 | 5 MHz | 5 MHz bandwidth confirmed | AeroMACS_VO_Interop_01_B | OK- by means of Spectrum Analyzer |
| 3 | Frame | Verify that both BS and MS use 5 ms Frame Length | Step 9 | 5 ms | 5 ms Frame Length verified | AeroMACS_VO_Interop_01_C | OK- by means of Spectrum Analyzer |
| 4 | Duplex | Verify that both BS and MS are able to operate in TDD mode | Step 10 | TDD | TDD Mode verified | AeroMACS_VO_Interop_01_D | OK- by means of Spectrum Analyzer |
| 5 | Freqs | Verify that the Channel Frequencies usable in the AeroMACS are in 5091- 5150 MHz range | Step 4<br>Step 11 | Expected channel frequency | Verified use of channels 5093.5, 5113.5 and 5147.5 MHz | AeroMACS_VO_Interop_01_E | OK- by means of Spectrum Analyzer |
| 6 | Scanning | MS starts with the scanning of the spectrum. It should be checked the correct decoding of the preamble by the MS in order to get synchronized with the BS (no step | Step 2<br>Step 6<br>Step 14 | Scanning procedure | Checked correct preamble decoding and correct UCD/DCD decoding by MS | AeroMACS_VO_Interop_03_A | OK – by MS CLI |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2). In addition, it should be verified the correct decoding of DCD message for getting all the DL parameters (no step 2). | | | | | |
| 7 | Initial Ranging | Verify that, after successful DL Synchronization, MS send a CDMA code at a power level below PTX_IR_MAX, measured at the antenna connector.<br>Verify that, in case of no RNG-RSP is received at MS side, MS try to send a new CDMA code at the next appropriate initial ranging transmission opportunity (applying the correct MS power increase) until the BS doesn't send RNG-RSP message or until MS doesn't receive a proper RNG-RSP.<br>Verify the correct reception of Basic CID and Primary CID. | Step 6 | IR procedure | Initial ranging procedure verified | AeroMACS_VO_Interop_03_C | OK – by MS CLI |
| 8 | Basic | Verify the correct exchange of Service Basic Capability information | Step 6 | Basic Negotiation Capabilities | Correct SBC-REQ/SBC-RSP exchange verified | AeroMACS_VO_Interop_03_D | OK – by MS CLI |

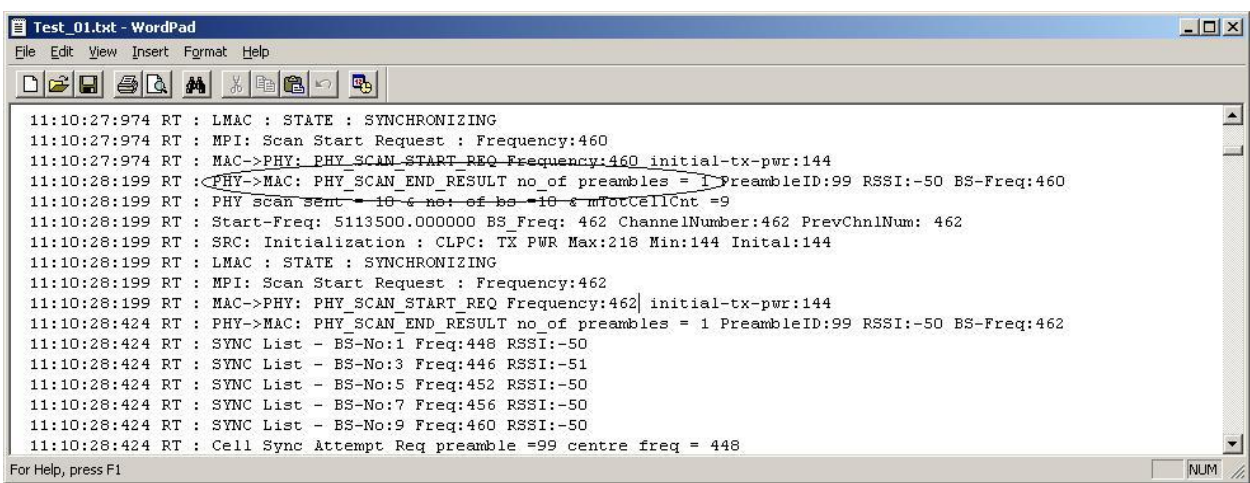
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | Admission | Verify the Admission Control Procedure | Step6 | Admission control procedure | Correct Authentication procedure verified | AeroMACS_VO_Interop_03_E | OK – by MS CLI |
| 10 | Registration | Verify that BS and MS successfully conclude the registration procedure | Step6 | Completed registration procedure | Correct Registration procedure verified | AeroMACS_VO_Interop_03_F | OK – by MS CLI |
| 11 | Available Channels | Verify that MS connects successfully to BS for each configured channel | Step 6 | | | AeroMACS_VO_RFReal_01_A | OK – by MS CLI |

### A.6.3.2 Analysis of Verification Exercise Results

Many Objectives (Result IDs from 1 to 5 in previous Chapter) were verified by visual inspection of the Spectrum Analyzer wired to the BS. In Figure 6 it is possible to appreciate how OFDMA Mode, TDD Mode, Frame Length, Channel Bandwidth and Channel Frequency are evidenced (together with other information out of scope for this test, like EVM and Modulation).

**Figure 6: Spectrum Analyzer connected to AeroMACS BS**

During the test the various phases of Initial Network Entry were executed by BS and MS (Results ID from 6 to 10). In particular, looking at the MS CLI, it was possible to follow the preamble detection and the DCD decoding by the MS side during scanning, the various steps of Initial Ranging, the exchange of Service Basic Capabilities Information, the Authentication/Registration procedure, and the final allocation of Service Flows. Some examples are evidenced in the next images.



```
Test_01.txt - WordPad
File Edit View Insert Format Help
11:10:27:974 RT : LMAC : STATE : SYNCHRONIZING
11:10:27:974 RT : MPI: Scan Start Request : Frequency:460
11:10:27:974 RT : MAC->PHY: PHY_SCAN_START_REQ Frequency:460 initial-tx-pwr:144
11:10:28:199 RT : PHY->MAC: PHY_SCAN_END_RESULT no_of preambles = 1 PreambleID:99 RSSI:-50 BS-Freq:460
11:10:28:199 RT : PHY scan sent = 10 & no: of bs =10 & mTotCellCnt =9
11:10:28:199 RT : Start-Freq: 5113500.000000 BS_Freq: 462 ChannelNumber:462 PrevChnlNum: 462
11:10:28:199 RT : SRC: Initialization : CLPC: TX PWR Max:218 Min:144 Inital:144
11:10:28:199 RT : LMAC : STATE : SYNCHRONIZING
11:10:28:199 RT : MPI: Scan Start Request : Frequency:462
11:10:28:199 RT : MAC->PHY: PHY_SCAN_START_REQ Frequency:462 initial-tx-pwr:144
11:10:28:424 RT : PHY->MAC: PHY_SCAN_END_RESULT no_of preambles = 1 PreambleID:99 RSSI:-50 BS-Freq:462
11:10:28:424 RT : SYNC List - BS-No:1 Freq:448 RSSI:-50
11:10:28:424 RT : SYNC List - BS-No:3 Freq:446 RSSI:-51
11:10:28:424 RT : SYNC List - BS-No:5 Freq:452 RSSI:-50
11:10:28:424 RT : SYNC List - BS-No:7 Freq:456 RSSI:-50
11:10:28:424 RT : SYNC List - BS-No:9 Freq:460 RSSI:-50
11:10:28:424 RT : Cell Sync Attempt Req preamble =99 centre freq = 448
For Help, press F1                                                NUM
```

**Figure 7: Preamble Detection by MS**

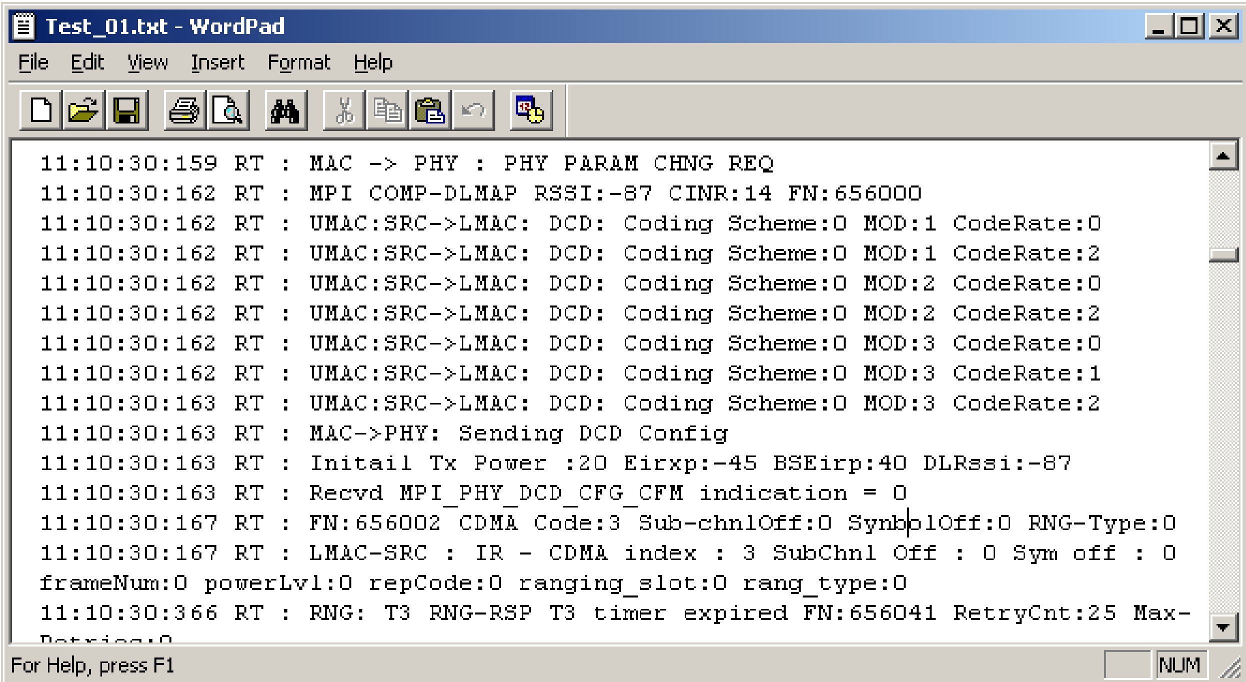



**Figure 8: DCD Decoding by MS**

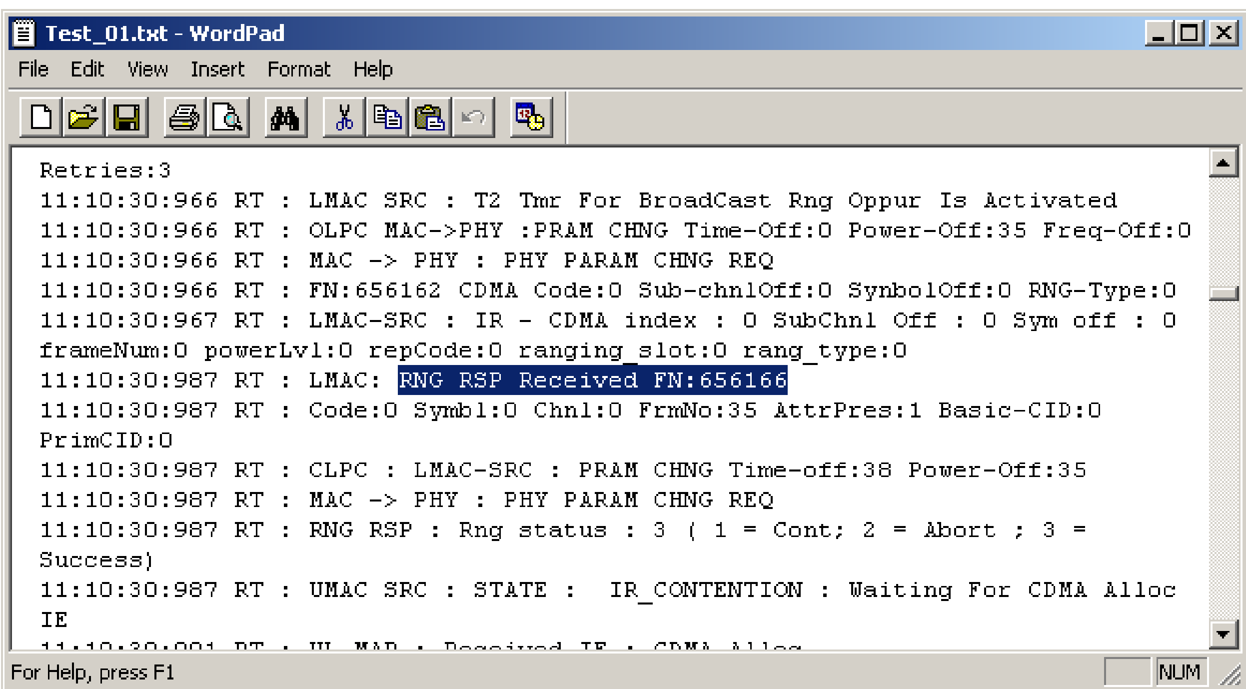



**Figure 9: Initial Ranging - the MS receives a RNG_RSP with Status Success**

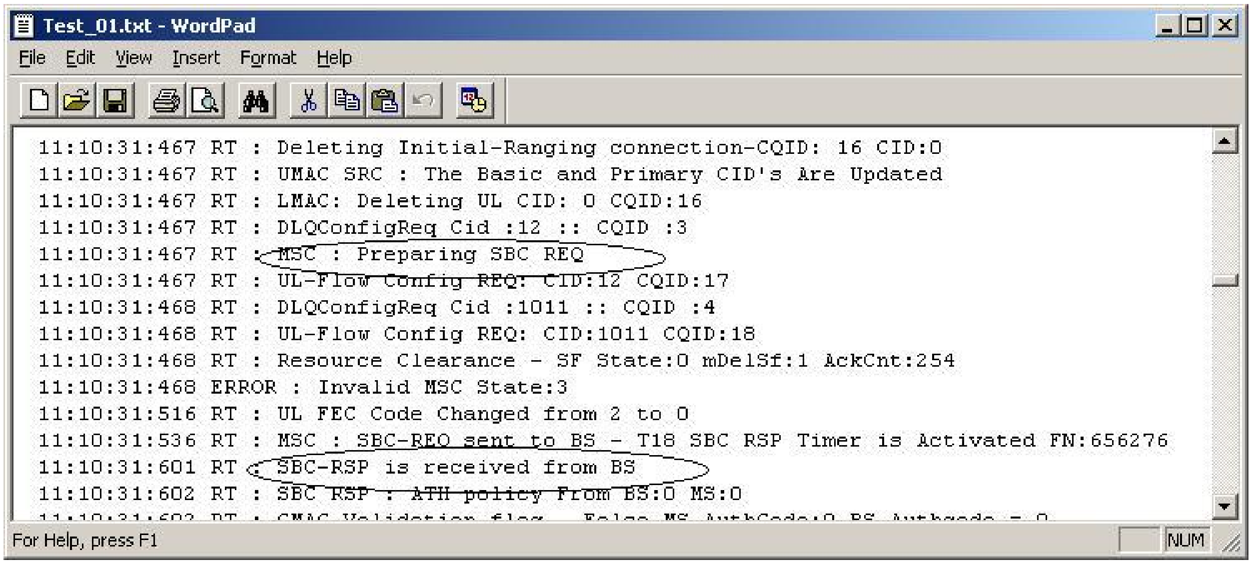
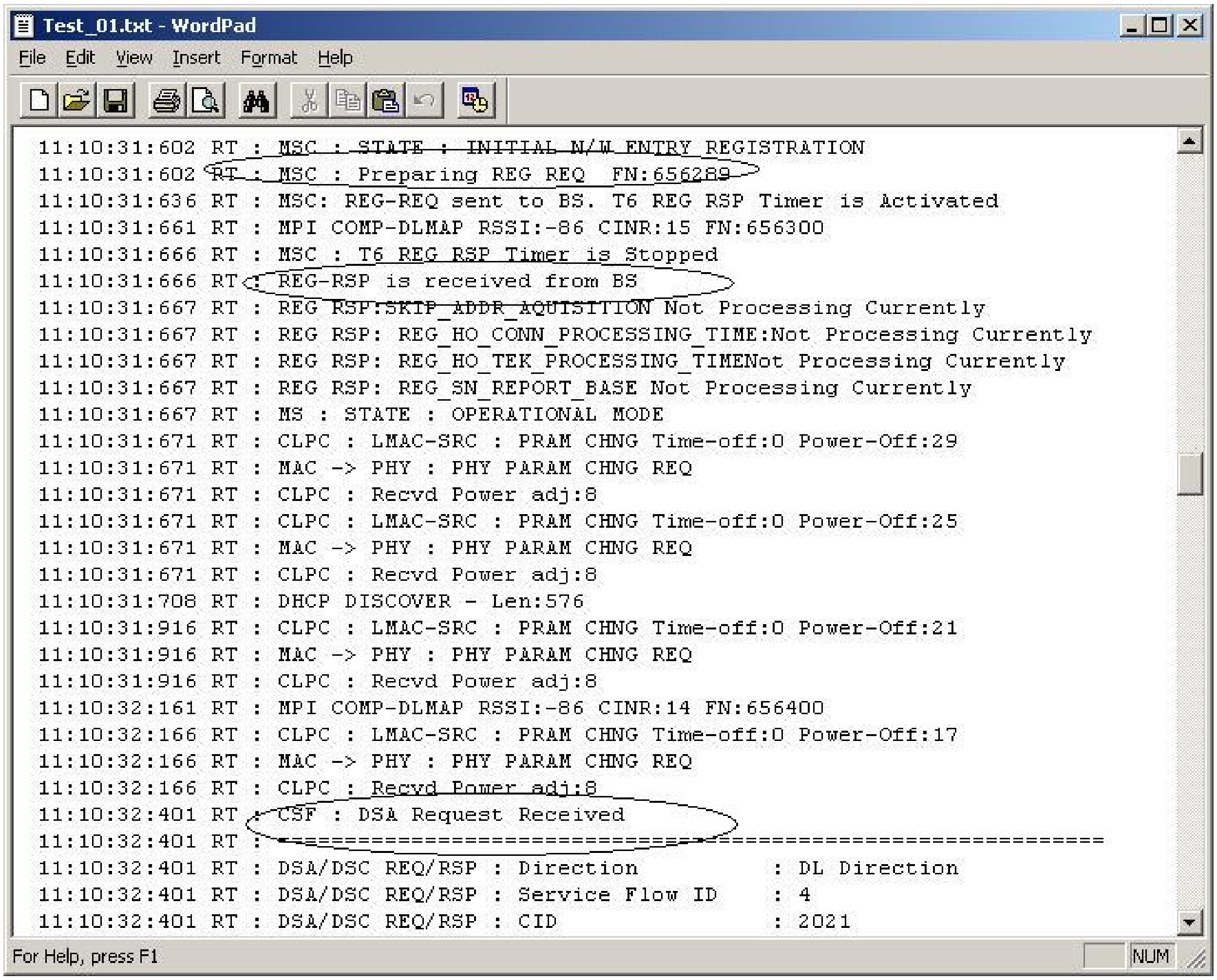



**Figure 10: SS Basic Capabilities Exchange between MS and BS**



```
Test_01.txt - WordPad
File  Edit  View  Insert  Format  Help
11:10:31:602 RT : MSC : STATE : INITIAL N/W ENTRY REGISTRATION
11:10:31:602 RT : MSC : Preparing REG REQ  FN:656289
11:10:31:636 RT : MSC: REG-REQ sent to BS. T6 REG RSP Timer is Activated
11:10:31:661 RT : MPI COMP-DLMAP RSSI:-86 CINR:15 FN:656300
11:10:31:666 RT : MSC : T6 REG RSP Timer is Stopped
11:10:31:666 RT : REG-RSP is received from BS
11:10:31:667 RT : REG RSP:SKIP_ADDR_AQUISITION Not Processing Currently
11:10:31:667 RT : REG RSP: REG_HO_CONN_PROCESSING_TIME:Not Processing Currently
11:10:31:667 RT : REG RSP: REG_HO_TEK_PROCESSING_TIMENot Processing Currently
11:10:31:667 RT : REG RSP: REG_SN_REPORT_BASE Not Processing Currently
11:10:31:667 RT : MS : STATE : OPERATIONAL MODE
11:10:31:671 RT : CLPC : LMAC-SRC : PRAM CHNG Time-off:0 Power-Off:29
11:10:31:671 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:10:31:671 RT : CLPC : Recvd Power adj:8
11:10:31:671 RT : CLPC : LMAC-SRC : PRAM CHNG Time-off:0 Power-Off:25
11:10:31:671 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:10:31:671 RT : CLPC : Recvd Power adj:8
11:10:31:708 RT : DHCP DISCOVER - Len:576
11:10:31:916 RT : CLPC : LMAC-SRC : PRAM CHNG Time-off:0 Power-Off:21
11:10:31:916 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:10:31:916 RT : CLPC : Recvd Power adj:8
11:10:32:161 RT : MPI COMP-DLMAP RSSI:-86 CINR:14 FN:656400
11:10:32:166 RT : CLPC : LMAC-SRC : PRAM CHNG Time-off:0 Power-Off:17
11:10:32:166 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:10:32:166 RT : CLPC : Recvd Power adj:8
11:10:32:401 RT : CSF : DSA Request Received
11:10:32:401 RT : ==============================================================
11:10:32:401 RT : DSA/DSC REQ/RSP : Direction         : DL Direction
11:10:32:401 RT : DSA/DSC REQ/RSP : Service Flow ID   : 4
11:10:32:401 RT : DSA/DSC REQ/RSP : CID               : 2021
For Help, press F1                                     NUM
```

**Figure 11: Registration procedure and Service Flow Creation**

### A.6.3.3 Considerations on Initial Network Entry Time

EUROCAE WG82 is currently discussing about the need to specify, in the MASPS, a maximum allowed Net Entry Time for AeroMACS MSs. Currently the maximum value required in the draft MASPS is 90 seconds.

Measurements done in this Verification Exercise can be used as input for this topic.

Net Entry Time has of course to be minimized, in order to make the AeroMACS MS ready for operations as soon as possible, after landing or switch on.

There are more ways to reach this goal. One possibility is pre-configuring MSs with the list of frequencies operated at destination airports. This solution would surely minimize the Net Entry Time, but would imply the need to use and maintain databases indicating the frequencies in use for any Airport,
Another solution is having the MSs to scan the whole band (5000-5150 MHz) at switch-on (auto-learning). This of course lengthen the Net Entry Time, also considering that various phases of Net Entry involve devices potentially located throughout the world (e.g. in most cases AAA/DHCP Servers will not be

located in the visited Airport). Figure 12 describes a possible initial Network Entry procedure comprising MS-to-Network EAP authentication process and multiple Domain authentications.

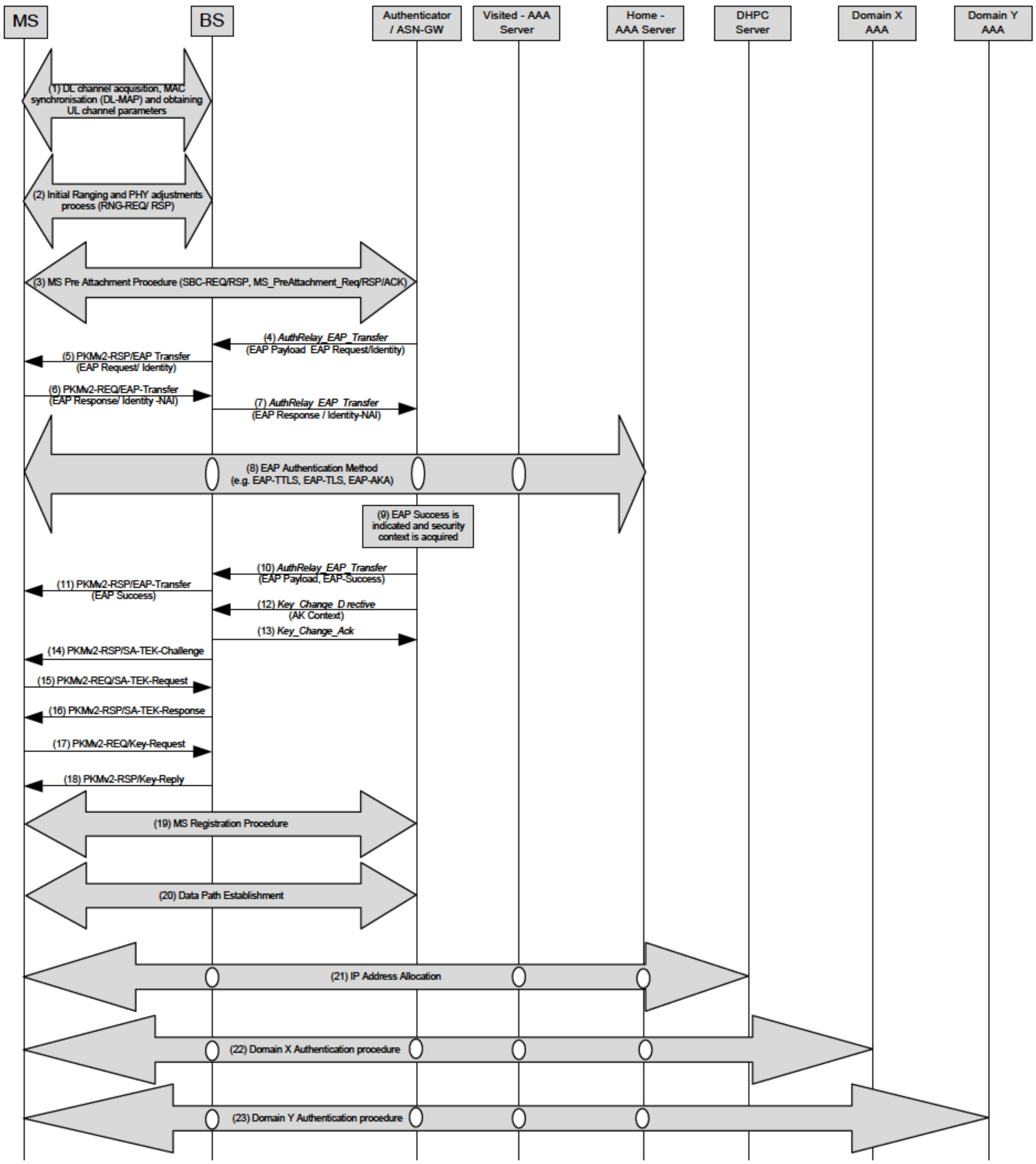



**Figure 12: Initial Network Entry Time**

In this Verification Exercise the Network Entry Time (consisting in Physical/MAC Synchronization, Authentication/Registration and Service Flows Creation) was measured being about 9.330 seconds. This time does NOT include time for self-test and other power up functions. Furthermore, all of the devices involved in the process were located in the same room.

It is worth observing that in this exercise the MS had been previously configured to scan a limited list of frequencies. If instead the MS had to scan the whole frequency band 5000-5150 MHz, an extra time should be considered for physical layer scanning. It is estimated that the order of magnitude of the time needed to span the whole band looking for a valid preamble could be tens of milliseconds per channel. Therefore, assuming for instance this time being 30 ms, the extra-time needed to span the whole band would be 30ms * 580 = 17.4 seconds. This would lead to a total Net Entry Time of 9.33 + 17.4 = 26.73 seconds.

It is also worth underlining that this result has been obtained in a controlled environment (the Lab). Real environments (Airports) can introduce huge degradation factors (attenuation, multipath fading, shadowing, Doppler effects, etc.) that may increase the packet error rate and the number of retransmissions, with subsequent increase in the Net Entry Time. For this reason, the 90 seconds currently hypothesized in the draft EUROCAE MASPS as maximum net entry time are considered appropriate.

#### A.6.3.4 Unexpected behaviors/Results

None.

### A.6.4 Conclusions and recommendations

The Verification Exercise allowed checking the basic AeroMACS functions and Initial Network Entry message exchanges. All the related verification Objectives were checked successfully.

## A.7 Verification Exercise # LAB1_2 Power Control Report

### A.7.1 Verification Exercise Scope

The purpose of this Verification Exercise is checking that the MS properly applies an Open/Closed Loop Power Control procedure and that the physical measurements which drive them are correct within specified tolerances.

### A.7.2 Conduct of Verification Exercise

#### A.7.2.1 Verification Exercise Preparation

The same test bed described in A.6.2.1 was used.

#### A.7.2.2 Verification Exercise execution

| Step nr. | Action | Action description | PCO (Point of Control and Observation) | Comment |
|---|---|---|---|---|
| 1. | Switch on MS | | | OK |
| 2. | Switch on BS | | | OK |
| 3. | Enable OL (passive) PC and disable CL PC | | Mngt PC connected to MS | OK |
| 4. | Verify that MS connects successfully and properly estimates RSSIs | | Mngt PC connected to MS | OK |
| 5. | Verify that MS properly operates in open loop PC | | Mngt PC connected to MS | OK |
| 6. | Disable OL PC and enable CL PC | | Mngt PC connected to MS | OK |
| 7. | Verify that MS properly applies CL PC | | Mngt PC connected to MS | OK |

### A.7.2.3 Deviation from the planned activities

None

## A.7.3 Verification exercise Results

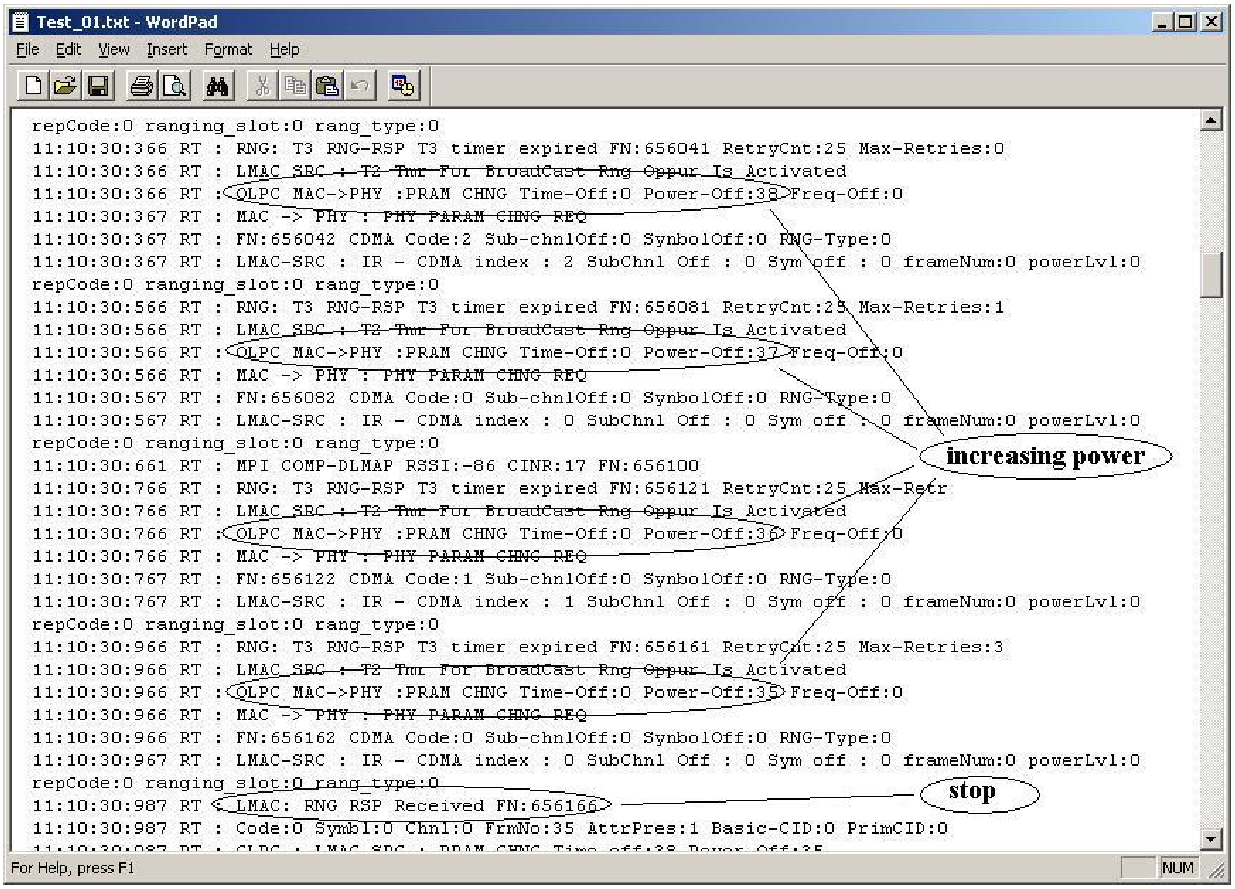
### A.7.3.1 Summary of Verification exercise Results

| ID | Resu lt | Description | When observed | Expected result | Obtained result | VO | Comment |
|---|---|---|---|---|---|---|---|
| 1. | Open Loop | Verify that the MS | Step 5 | Power Control | OL passive | AeroMACS_VO _Interop_10_A | OK – by MS CLI |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | PC | properly applies a (passive) open loop power control technique | | Steps | PC steps correctly verified | | |
| 2. | Closed Loop PC | Verify that the MS properly applies a closed loop power control technique | Step 7 | Power Control Steps | CL PC steps correctly verified | AeroMACS_VO_Interop_10_B | OK – by MS CLI |

### A.7.3.2 Analysis of Verification Exercise Results

The Open Loop passive Power Control has been tested first, during the Initial Ranging phase: from the MS CLI it was possible to observe that the MS starts transmitting a CDMA code at the lowest power level in the transmission opportunity allocated by the BS with the previous UL-MAP message (or the optional Compressed DLMAP-ULMAP). Then the MS starts increasing the transmitting power at 1dB steps, until it does not receive a RNG-RSP from the BS.



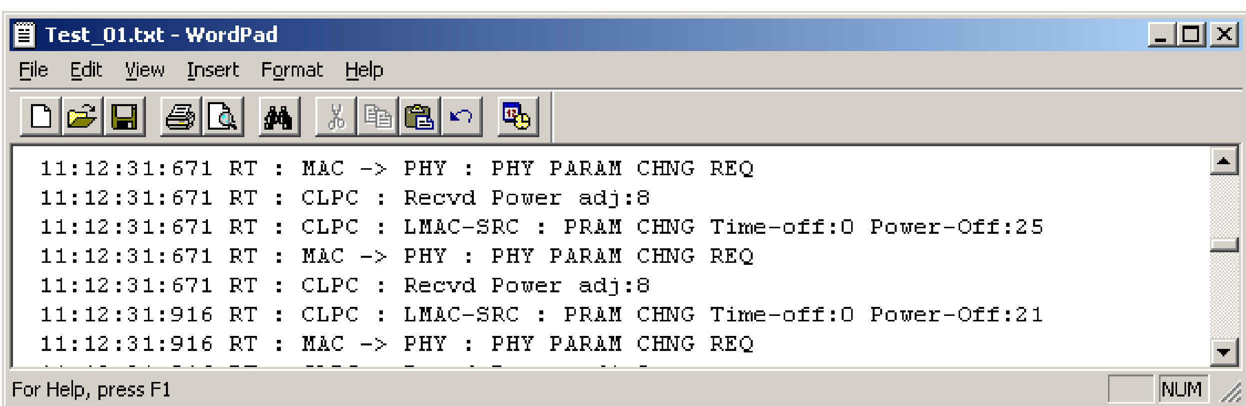
```
repCode:0 ranging_slot:0 rang_type:0
11:10:30:366 RT : RNG: T3 RNG-RSP T3 timer expired FN:656041 RetryCnt:25 Max-Retries:0
11:10:30:366 RT : LMAC_SRC : T2 Tmr For BroadCast Rng Oppur Is Activated
11:10:30:366 RT : OLPC MAC->PHY :PRAM CHNG Time-Off:0 Power-Off:38 Freq-Off:0
11:10:30:367 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:10:30:367 RT : FN:656042 CDMA Code:2 Sub-chnlOff:0 SynbolOff:0 RNG-Type:0
11:10:30:367 RT : LMAC-SRC : IR - CDMA index : 2 SubChnl Off : 0 Sym off : 0 frameNum:0 powerLvl:0
repCode:0 ranging_slot:0 rang_type:0
11:10:30:566 RT : RNG: T3 RNG-RSP T3 timer expired FN:656081 RetryCnt:25 Max-Retries:1
11:10:30:566 RT : LMAC_SRC : T2 Tmr For BroadCast Rng Oppur Is Activated
11:10:30:566 RT : OLPC MAC->PHY :PRAM CHNG Time-Off:0 Power-Off:37 Freq-Off:0
11:10:30:566 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:10:30:567 RT : FN:656082 CDMA Code:0 Sub-chnlOff:0 SynbolOff:0 RNG-Type:0
11:10:30:567 RT : LMAC-SRC : IR - CDMA index : 0 SubChnl Off : 0 Sym off : 0 frameNum:0 powerLvl:0
repCode:0 ranging_slot:0 rang_type:0
11:10:30:661 RT : MPI COMP-DLMAP RSSI:-86 CINR:17 FN:656100
11:10:30:766 RT : RNG: T3 RNG-RSP T3 timer expired FN:656121 RetryCnt:25 Max-Retr
11:10:30:766 RT : LMAC_SRC : T2 Tmr For BroadCast Rng Oppur Is Activated
11:10:30:766 RT : OLPC MAC->PHY :PRAM CHNG Time-Off:0 Power-Off:36 Freq-Off:0
11:10:30:766 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:10:30:767 RT : FN:656122 CDMA Code:1 Sub-chnlOff:0 SynbolOff:0 RNG-Type:0
11:10:30:767 RT : LMAC-SRC : IR - CDMA index : 1 SubChnl Off : 0 Sym off : 0 frameNum:0 powerLvl:0
repCode:0 ranging_slot:0 rang_type:0
11:10:30:966 RT : RNG: T3 RNG-RSP T3 timer expired FN:656161 RetryCnt:25 Max-Retries:3
11:10:30:966 RT : LMAC_SRC : T2 Tmr For BroadCast Rng Oppur Is Activated
11:10:30:966 RT : OLPC MAC->PHY :PRAM CHNG Time-Off:0 Power-Off:35 Freq-Off:0
11:10:30:966 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:10:30:966 RT : FN:656162 CDMA Code:0 Sub-chnlOff:0 SynbolOff:0 RNG-Type:0
11:10:30:967 RT : LMAC-SRC : IR - CDMA index : 0 SubChnl Off : 0 Sym off : 0 frameNum:0 powerLvl:0
repCode:0 ranging_slot:0 rang_type:0
11:10:30:987 RT : LMAC: RNG RSP Received FN:656166
11:10:30:987 RT : Code:0 Symbl:0 Chnl:0 FrmNo:35 AttrPres:1 Basic-CID:0 PrimCID:0
```



**Figure 13: Open Loop passive Power Control Protocol**

The Closed Loop Power Control algorithm is activated after the BS and the MS have exchanged the reciprocal Capabilities, after Ranging.

During the test, the Variable attenuator has been gradually increased by a specified amount of dBs, and it has been verified that the MS has subsequently received commands from the BS (PMC-REQ messages) to gradually increase its Transmitted Power by the same amount of dBs.



```
11:12:31:671 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:12:31:671 RT : CLPC : Recvd Power adj:8
11:12:31:671 RT : CLPC : LMAC-SRC : PRAM CHNG Time-off:0 Power-Off:25
11:12:31:671 RT : MAC -> PHY : PHY PARAM CHNG REQ
11:12:31:671 RT : CLPC : Recvd Power adj:8
11:12:31:916 RT : CLPC : LMAC-SRC : PRAM CHNG Time-off:0 Power-Off:21
11:12:31:916 RT : MAC -> PHY : PHY PARAM CHNG REQ
```

**Figure 14: Closed Loop Power Control adjustment at the MS**

### A.7.3.3 Unexpected behaviors/Results

None.

## A.7.4 Conclusions and recommendations

It was verified that the equipment properly implements OLPC and CLPC protocols.

# A.8 Verification Exercise # LAB1_3 Quality of Service Report

## A.8.1 Verification Exercise Scope

The purpose of this Test Case is to verify that all QoS related requirements are satisfied (SF creation and deletion, traffic parameters, bandwidth management) for all the QoS scheduling Types defined.

## A.8.2 Conduct of Verification Exercise

### A.8.2.1 Verification Exercise Preparation

The test bed described in 15 was used (no need for Spectrum Analyzers in this case).

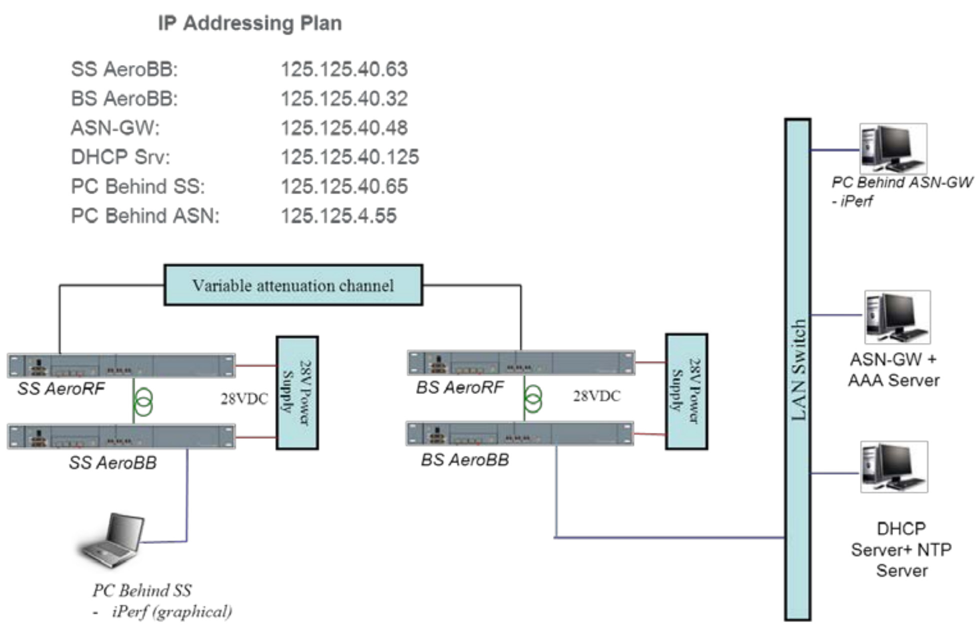



**Figure 15: QoS - Test bed**

### A.8.2.2 Verification Exercise execution

*Please note that in this Test Case, 1 Service Flow (SF) means 1 SF DL and 1 SF UL.*

| Step nr. | Action | Action description | PCO (Point of Control and Observation) | Comment |
|---|---|---|---|---|
| 1. | Switch on BS | | | OK |
| 2. | Set 1 SF (SF1) with the scheduling type (QoS class) to be used as 1 among nrtPS/rtPS | | Mngt PC connected to ASN-GW/AAA | OK |
| 3. | Switch on MS | | | OK |
| 4. | Start an IP Flow not compatible with the SF Classification for DL (then for UL) traffic | Using IPERF | IPERF @ PC connected to ASN-GW x DL (MS x UL) | OK |
| 5. | Verify that the IP packets are not transferred on the air interface | Using IPERF | IPERF @ PC connected to MS x DL (ASN-GW x UL) | OK |
| 6. | Change the IP Flow with a configuration compatible with the SF Classification for DL (then for UL) traffic | Using IPERF | IPERF @ PC connected to ASN-GW x DL (MS x UL) | OK |
| 7. | Verify that the IP packets are transferred on the air interface | Using IPERF | IPERF @ PC connected to MS x DL (ASN-GW x UL) | OK |
| 8. | Verify that data exceeding the MSTR is dropped or delayed | Using IPERF | IPERF @ PC connected to MS x DL (ASN-GW x UL) | OK |
| 9. | Verify that all traffic parameters related to the QoS class respect requirements | | Mngt PCs connected to MS and BS | OK |

| | | | | |
|---|---|---|---|---|
| 10. | Set 1 additional SF (SF2) with the same configuration of the SF of step 2 | | Mngt PC connected to ASN-GW/AAA | OK |
| 11. | Restart MS | | | OK |
| 12. | Start two IP Flow one compatible with SF1 configuration and the other with SF2.<br>SF1 throughput > SF2 throughput<br>SF1 throughput + SF2 throughput > Channel capacity | Using IPERF | IPERF @ PC connected to ASN-GW x DL (MS x UL) | OK |
| 13. | Check fairness between flows (SF1 throughput = SF2 throughput) | Using IPERF | IPERF @ PC connected to MS x DL (ASN-GW x UL) | OK |
| 14. | Switch off MS | | | OK |
| 15. | Pass to another scheduling type (QoS class) and repeat steps from 2 to 14 until all types have been tested | | | OK |

### A.8.2.3 Deviation from the planned activities

None.

## A.8.3 Verification exercise Results

### A.8.3.1 Summary of Verification exercise Results

| ID | Result | Description | When observed | Expected result | Obtained result | VO | Comment |
|---|---|---|---|---|---|---|---|
| 1 | MSTR | Verify that the Maximum Sustained Traffic Rate value for a SF is respected | Step 8 | | | AeroMACS_VO_Interop_04_B | OK |
| 2 | QoS | Verify that the data traffic for a SF is managed following the QoS configuration | Step 9 | | | AeroMACS_VO_Interop_04_C AeroMACS_VO_Interop_04_D | OK |
| 3 | DSA | Verify that the correct DSA procedure is implemented | Step 5 Step 7 Step 9 | | | AeroMACS_VO_Interop_05_A | OK |
| 4 | Dynamic BW allocation | Verification of correct allocation of the MAC resources | Step 5 Step 7 Step 8 Step 9 Step 13 | | | AeroMACS_VO_Interop_07_A AeroMACS_VO_Interop_07_D | OK |

### A.8.3.2 Analysis of Verification Exercise Results

Both the nrtPS and rtPS Classes of Services were tested, as requested in Step #2. Initially, the SF1 was set with nrtPS Class of Service with the following characteristics:

- Priority= 1 (default)

- Max Baud Rate: 1 Mbps (both for UL and DL)

- Classification Rules (both in UL and DL):

- DHCP messages exchange enabled (on ports #67 and #68 in this example)
- ICMP messages exchange enabled (e.g. ping messages)
- NTP messages exchanges (enabled on port #123 in this example)
- UDP messages exchanges enabled (on ports #2222 and #2223 in this example)

An IP flow was then started in DL (using IPERF application running on the PC behind the ASN-GW), and sent to a not allowed destination port (#2220), and it was verified that no UDP messages were sent in any GRE tunnel towards the MS (see Figure 16).

A similar operation was then done in the inverse direction (UL), and it was again verified that no message was transmitted by the MS on the air interface.

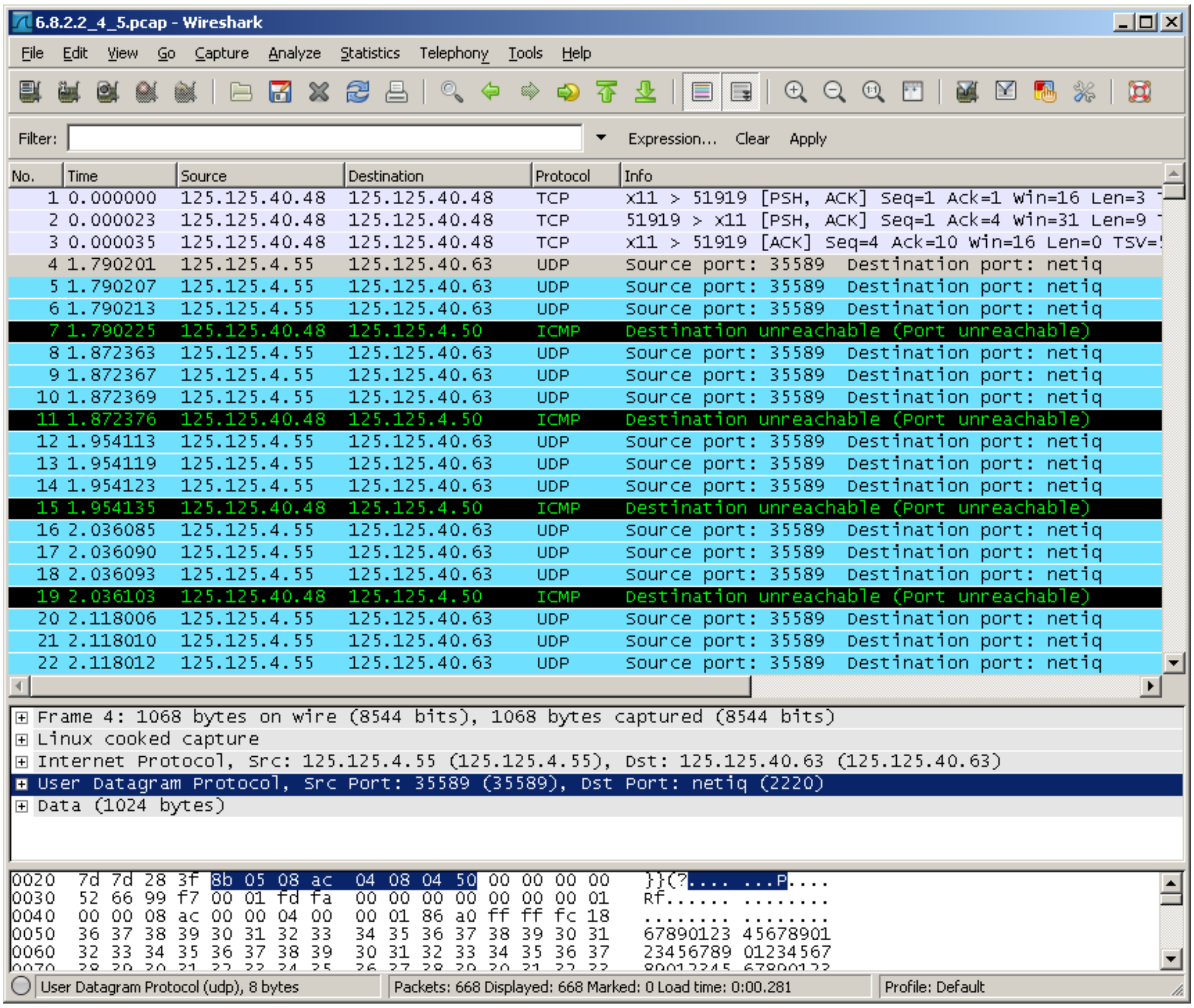



**Figure 16: Wireshark Log on ASN-GW ports: no transmission for IP flow not compatible with the SF Classification for DL**

Then, an IP Flow was started in UL, with a configuration compatible with the SF Classification for UL (in this example the correct destination port), and it was verified that the UDP messages sent by the MS were correctly received by the ASN-GW (see Figure 17).

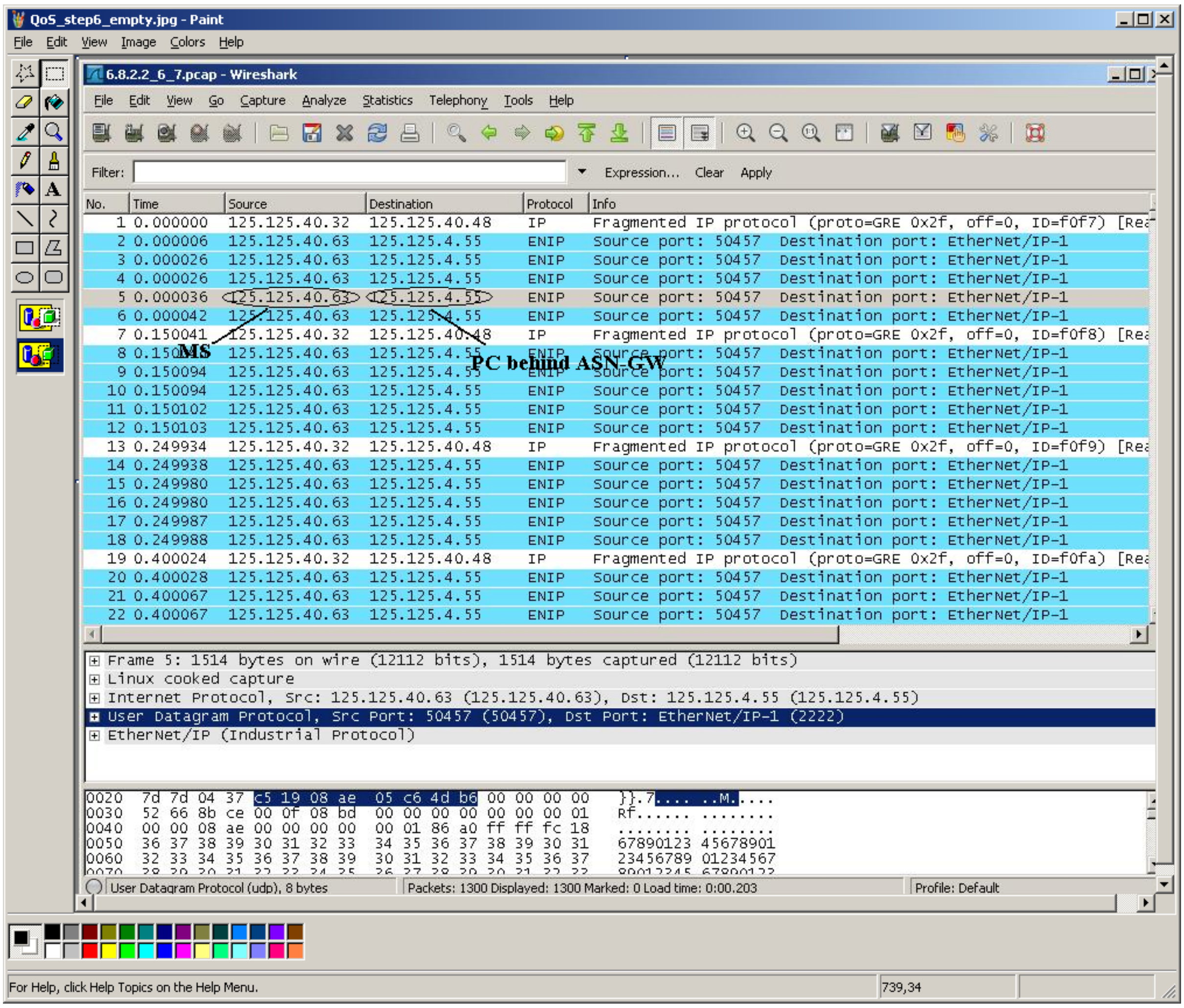
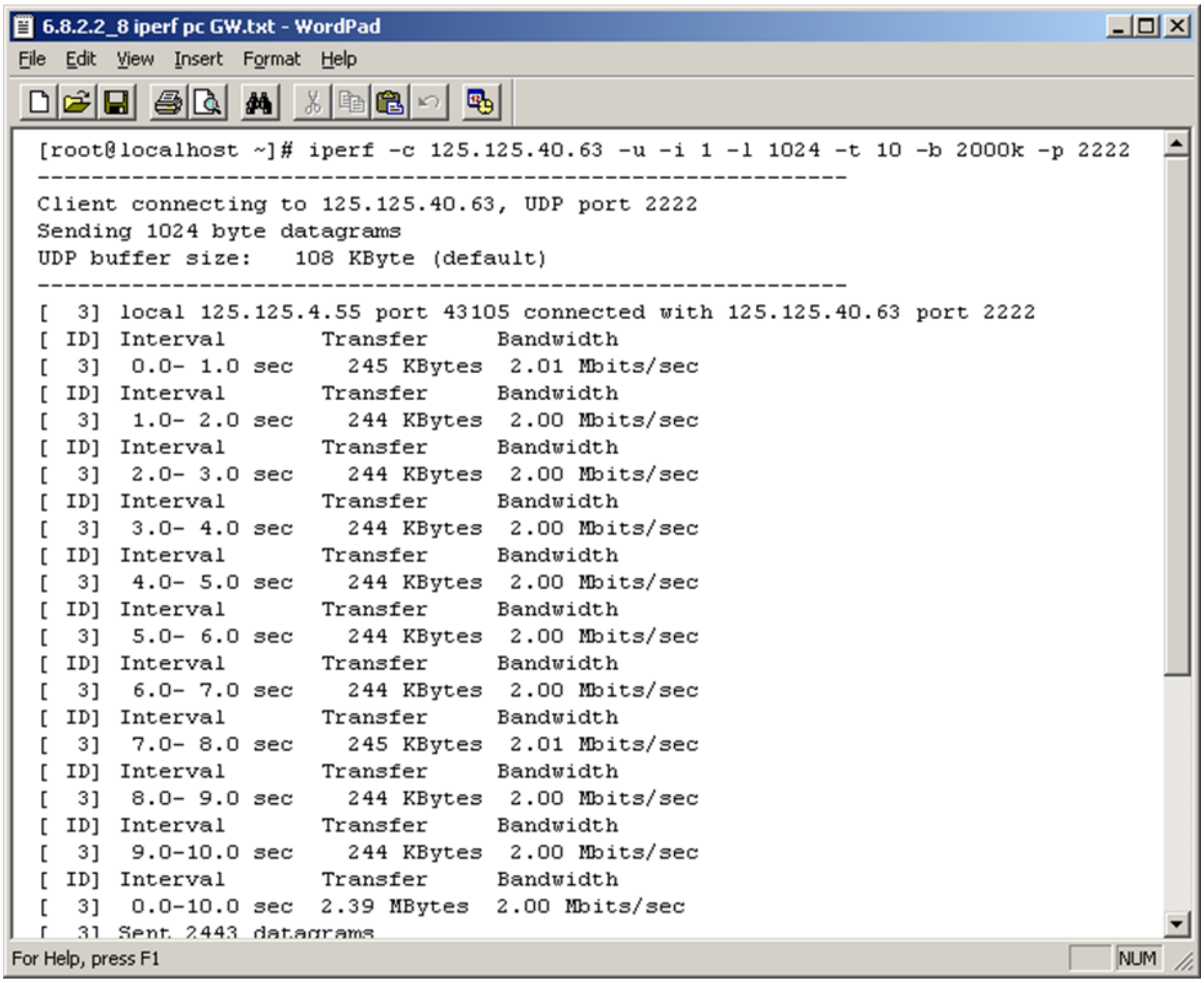



**Figure 17: Successful IP Flow in UL**

Similarly, a DL IP Flow was created with a configuration compatible with the SF Classification for DL (in this case the correct destination port), and it was verified that the UDP messages sent by the PC behind ASN-GW were correctly received by the MS.

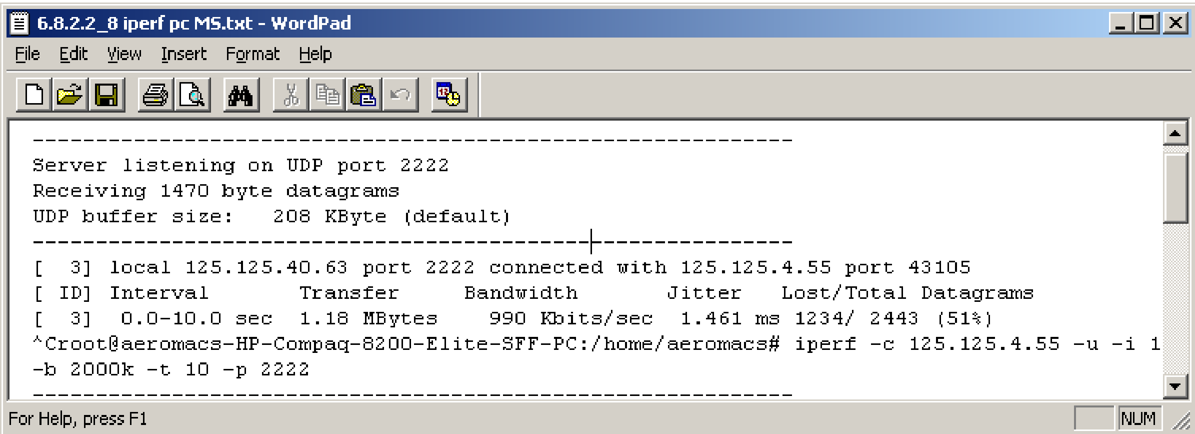
Subsequently, it has been verified that data exceeding the MSTR were dropped (step #8). In fact, using IPERF on the PC behind ASN-GW, an IP flow with 2 Mbps Baud Rate was sent to the ASN-GW to be transmitted to the MS (see Figure 18) without changing the previously configured 1 Mbps Max Baud Rate allowed to SF1. The result was that the data flow bit rate effectively registered at the MS was about 1 Mbps, coherently with the configured MSTR.

The same kind of test was repeated in the opposite direction (UL), and the same correct behavior was observed. It was observed that all traffic parameters related to the QoS class were compliant with the requirements.




```
[root@localhost ~]# iperf -c 125.125.40.63 -u -i 1 -l 1024 -t 10 -b 2000k -p 2222
------------------------------------------------------------
Client connecting to 125.125.40.63, UDP port 2222
Sending 1024 byte datagrams
UDP buffer size:   108 KByte (default)
------------------------------------------------------------
[  3] local 125.125.4.55 port 43105 connected with 125.125.40.63 port 2222
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0- 1.0 sec    245 KBytes  2.01 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  1.0- 2.0 sec    244 KBytes  2.00 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  2.0- 3.0 sec    244 KBytes  2.00 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  3.0- 4.0 sec    244 KBytes  2.00 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  4.0- 5.0 sec    244 KBytes  2.00 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  5.0- 6.0 sec    244 KBytes  2.00 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  6.0- 7.0 sec    244 KBytes  2.00 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  7.0- 8.0 sec    245 KBytes  2.01 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  8.0- 9.0 sec    244 KBytes  2.00 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  9.0-10.0 sec    244 KBytes  2.00 Mbits/sec
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0-10.0 sec  2.39 MBytes  2.00 Mbits/sec
[  3] Sent 2443 datagrams
```

**Figure 18: IPERF Log at the ASN-GW: 2 Mbps requested to be sent in DL**




```
------------------------------------------------------------
Server listening on UDP port 2222
Receiving 1470 byte datagrams
UDP buffer size:   208 KByte (default)
------------------------------------------------------------
[  3] local 125.125.40.63 port 2222 connected with 125.125.4.55 port 43105
[ ID] Interval       Transfer     Bandwidth        Jitter   Lost/Total Datagrams
[  3]  0.0-10.0 sec  1.18 MBytes    990 Kbits/sec  1.461 ms 1234/ 2443 (51%)
^Croot@aeromacs-HP-Compaq-8200-Elite-SFF-PC:/home/aeromacs# iperf -c 125.125.4.55 -u -i 1
-b 2000k -t 10 -p 2222
------------------------------------------------------------
```

**Figure 19: IPERF Log at the MS: 1Mbps Max Baud Rate respected**

Then, a second Service Flow (SF2) was set with the same characteristics of SF1. However, SF1 was loaded with an IP Flow with Baud Rate= 2Mbps, while SF2 was loaded with an IP Flow with Baud Rate= 3 Mbps (see Figure 20 and Figure 21).

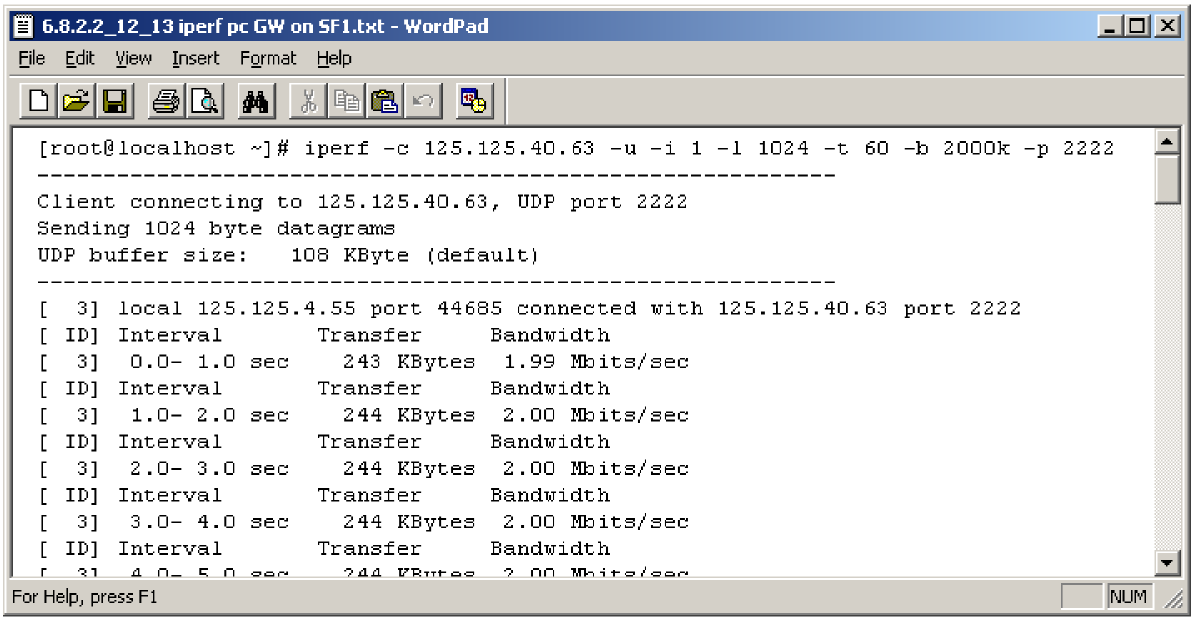



**Figure 20: SF1 loaded with 2 Mbps**

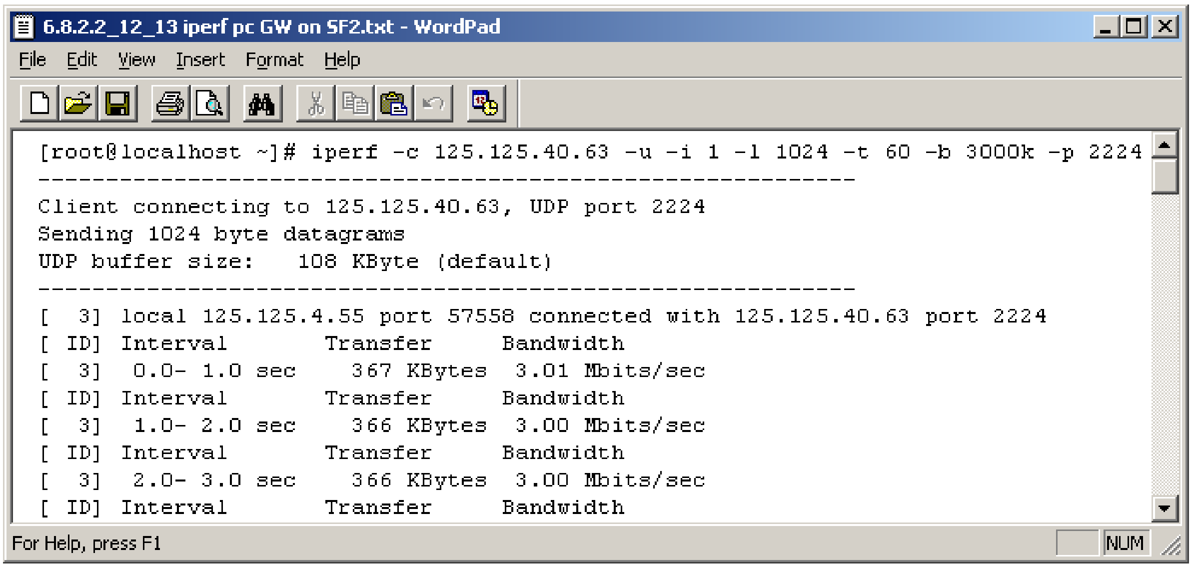



**Figure 21: SF2 loaded with 3 Mbps**

The channel attenuation had been set in order to cause a QPSK ¾ Modulation/Coding, with a consequential Channel Capacity equal to 2,81 Mbps, hence much lower than the total bandwidth needed to support the traffic requested by the 2 IPERF applications (3+2=5Mbps), coherently with the condition requested by step #12.

It was observed that the two IP flows were divided fairly between SF1 and SF2 (see Figure 22 and Figure 23). The little difference evidenced is exclusively due to the different observation periods between the 2 Service Flows: in fact the 2 IPERF transmissions were started manually, so the 2 observation periods are different.

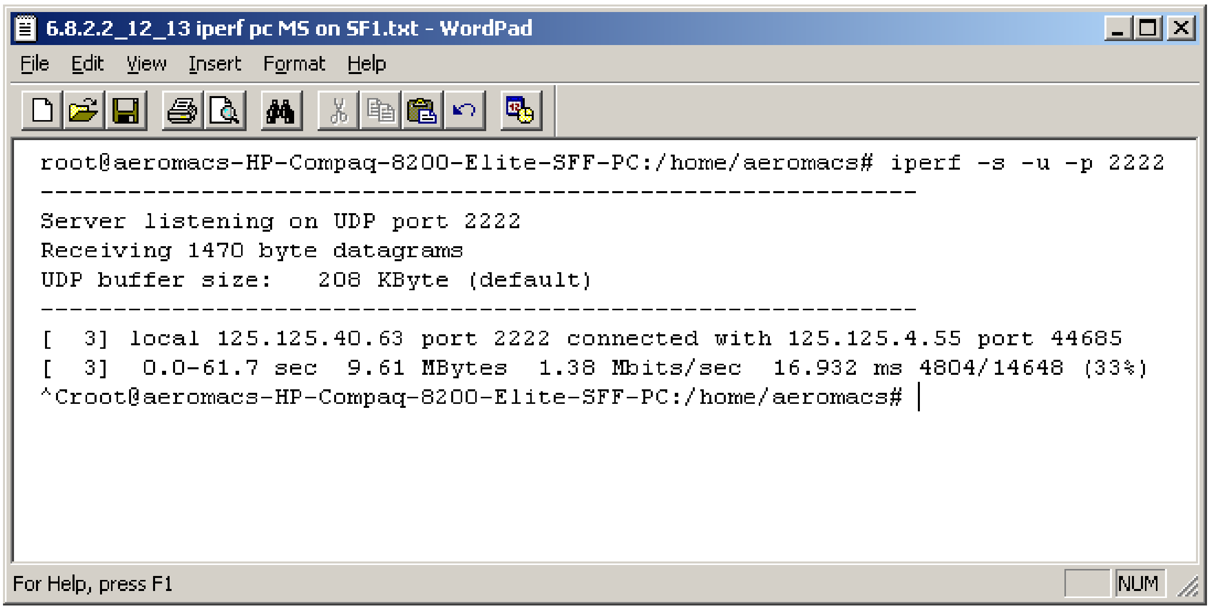



**Figure 22: Baud rate on SF1**

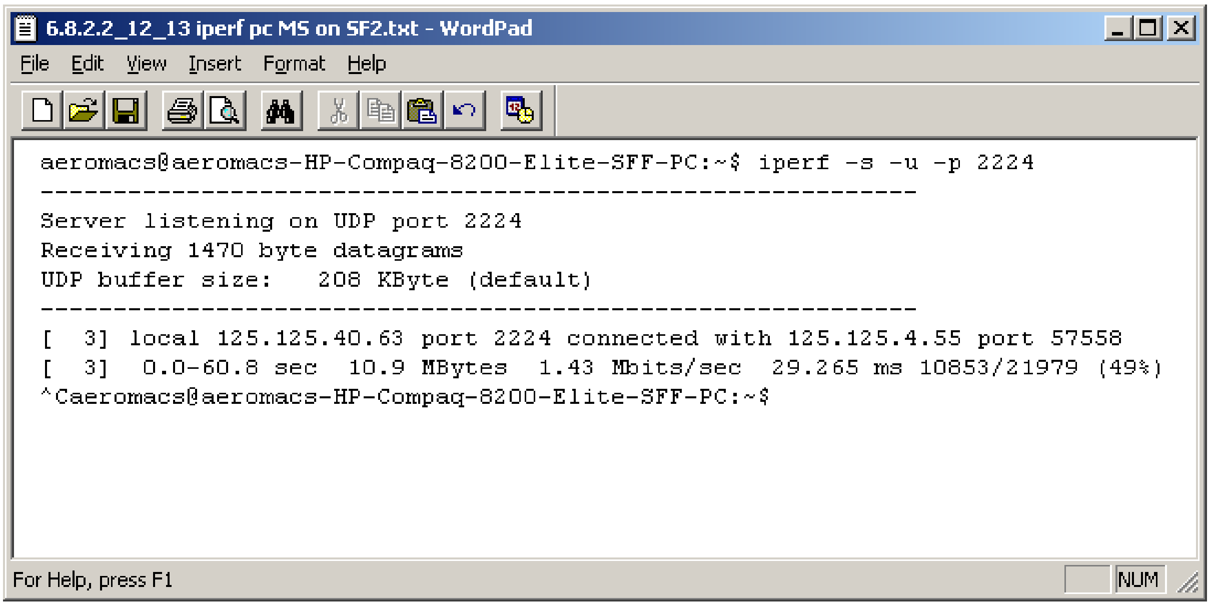



**Figure 23: Baud rate on SF2**

### A.8.3.3 Unexpected behaviors/Results

None

### A.8.4 Conclusions and recommendations

It was verified that all QoS requirements are satisfied for the QoS scheduling Types defined.

## A.9 Verification Exercise # LAB1_4 Security Report

### A.9.1 Verification Exercise Scope

The purpose of this Test Case is to verify proper working of Security features.

### A.9.2 Conduct of Verification Exercise

#### A.9.2.1 Verification Exercise Preparation

The test bed described in 15 was used, except for one difference: in fact, the ASN-GW and AAA Server were located in different devices.

#### A.9.2.2 Verification Exercise execution

| Step nr. | Action | Action description | PCO (Point of Control and Observation) | Comment |
|---|---|---|---|---|
| 1. | Switch on MS | | | |
| 2. | Switch on BS and ASN-GW/AAA | | | |
| 3. | Establish a communication and verify that the chosen authentication method is supported:<br>No authentication or EAP based authentication | | R6 i/f with Wireshark | With Authentication enabled, insert valid credentials |

#### A.9.2.3 Deviation from the planned activities

None.

### A.9.3 Verification exercise Results

#### A.9.3.1 Summary of Verification exercise Results

| ID | Result | Description | When | Expected | Obtained | VVO | Comment |
|---|---|---|---|---|---|---|---|

| | | | observed | result | result | | |
|---|---|---|---|---|---|---|---|
| 1. | No Authentication | Verify that authentication and key exchange steps are skipped | Step 3 | Network entry without authentication | | AeroMACS_VO_Interop_11_A | ASN-GW/AAA shall be configured with no Authentication |
| 2. | Authentication | Verify that authentication and key exchange steps are present | Step 3 | Network entry with authentication | | AeroMACS_VO_Interop_11_B | |

### A.9.3.2 Analysis of Verification Exercise Results

The ASN-GW was initially configured in order not to require Authentication to the MS entering the Network; BS and MS were switched on, and the MS started the Net Entry procedure, that was completed successfully. The related messages exchange in the ground network between BS, ASN-GW and DHCP Server is evidenced in the Wireshark log shown in Figure 24.

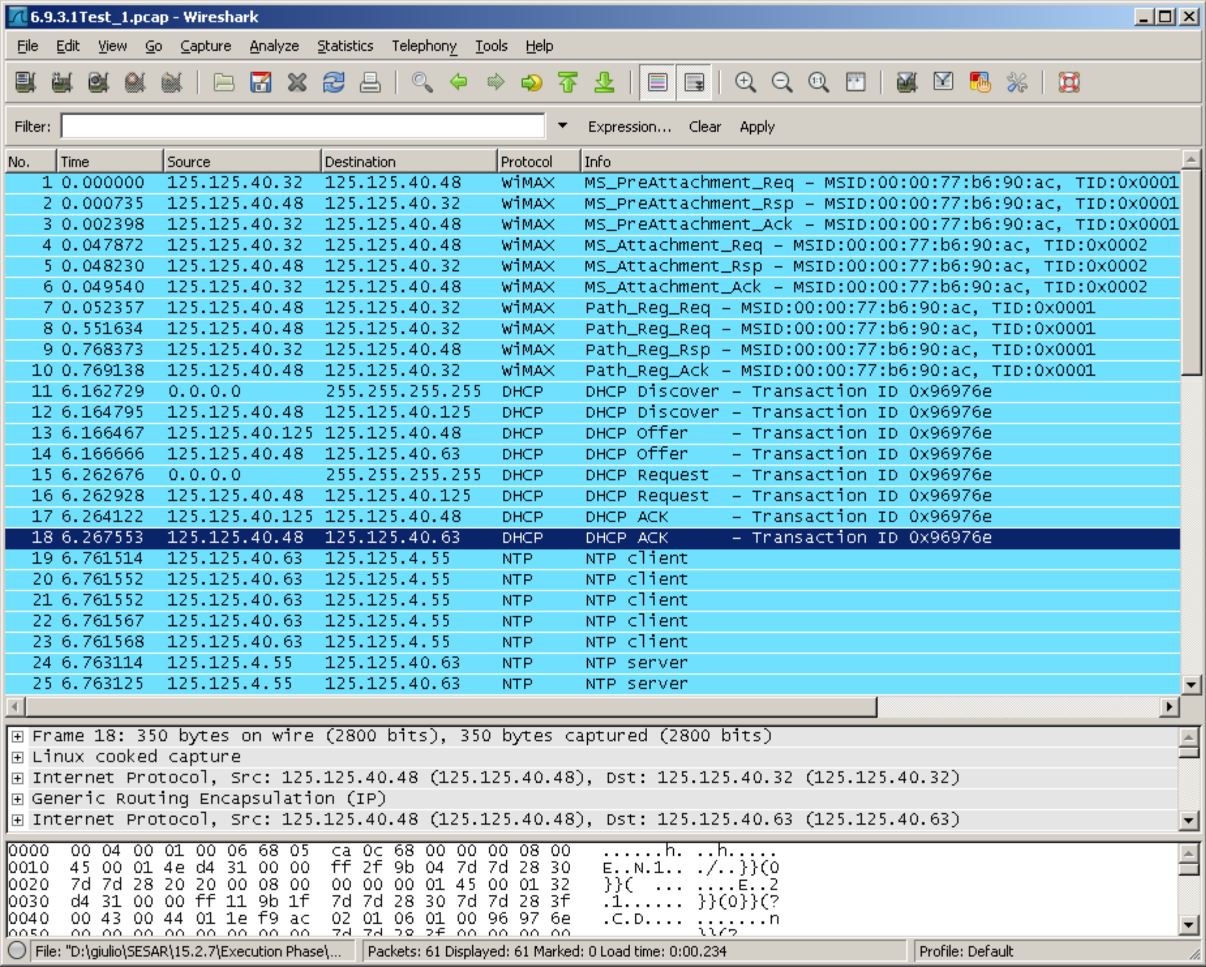



**Figure 24: Net Entry without authentication - WS Log**

Subsequently, the test was repeated after having properly reconfigured ASN-GW/AAA Server in order to require an EAP-based Authentication. The complete procedure was verified.

Figure 25 shows the related Log file, registered at the ASN-GW. In particular, it is possible to appreciate the following steps:

- In step #7 in Figure 25 the ASN-GW sends the ID request to the BS (that has opened a GRE tunnel towards the MS), receiving the BS response (in step #8) containing the MS MAC address and realm.
- The ASN-GW sends an Access-Request to the AAA Server, starting the Authentication Process, and the AAA Server replies with an Access-challenge, after having verified the presence of the MS in its MSs list. This message contains the EAP Message type and the keys to be exchanged in the next transactions.
- The ASN-GW encapsulates the received message in an EAP-REQ to the MS, to which the MS answers with a EAP RSP (Client Hello). The ASN-GW forwards the Client-Hello to the AA Server (step #15 in Figure 25).
- The AAA Server replies the ASN-GW with an Access-challenge (Server-hello) containing also the Server Certificate, and the Request of the Client Certificate. The ASN-GW encapsulates this information in the subsequent EAP-Request to the MS

- The MS answers to the ASN-GW with its Client Certificate, and other information (Client Key Exchange, Certif. Verify, Change Cypher Spec, etc). The ANS-GW encapsulates this information for the AAA Server in step #19

- After a series of acknowledges among the three involved parties, the AAA Server accepts the whole procedure with the Access-accept message in step #24, including the Home Agent Address with which the ASN-GW will create the tunnel for data exchange (PC behind ASN-GW)

- After having successfully created a tunnel with the HA, the ASN-GW sends an EAP_Transfer (Success) to the MS, and subsequently the Key_Change_Directive, containing the keys for Air ciphering (step #35)

- The MS sends beck a Key_Change_Ack and then the first ciphered message (MS_Attachment_Req in step #37)

- After a brief exchange of acknowledges, the ASN-GW sends a Path_Reg_Req to the MS, meaning that the Authentication Phase has successfully concluded and the final Registration/SF Creation may be started.

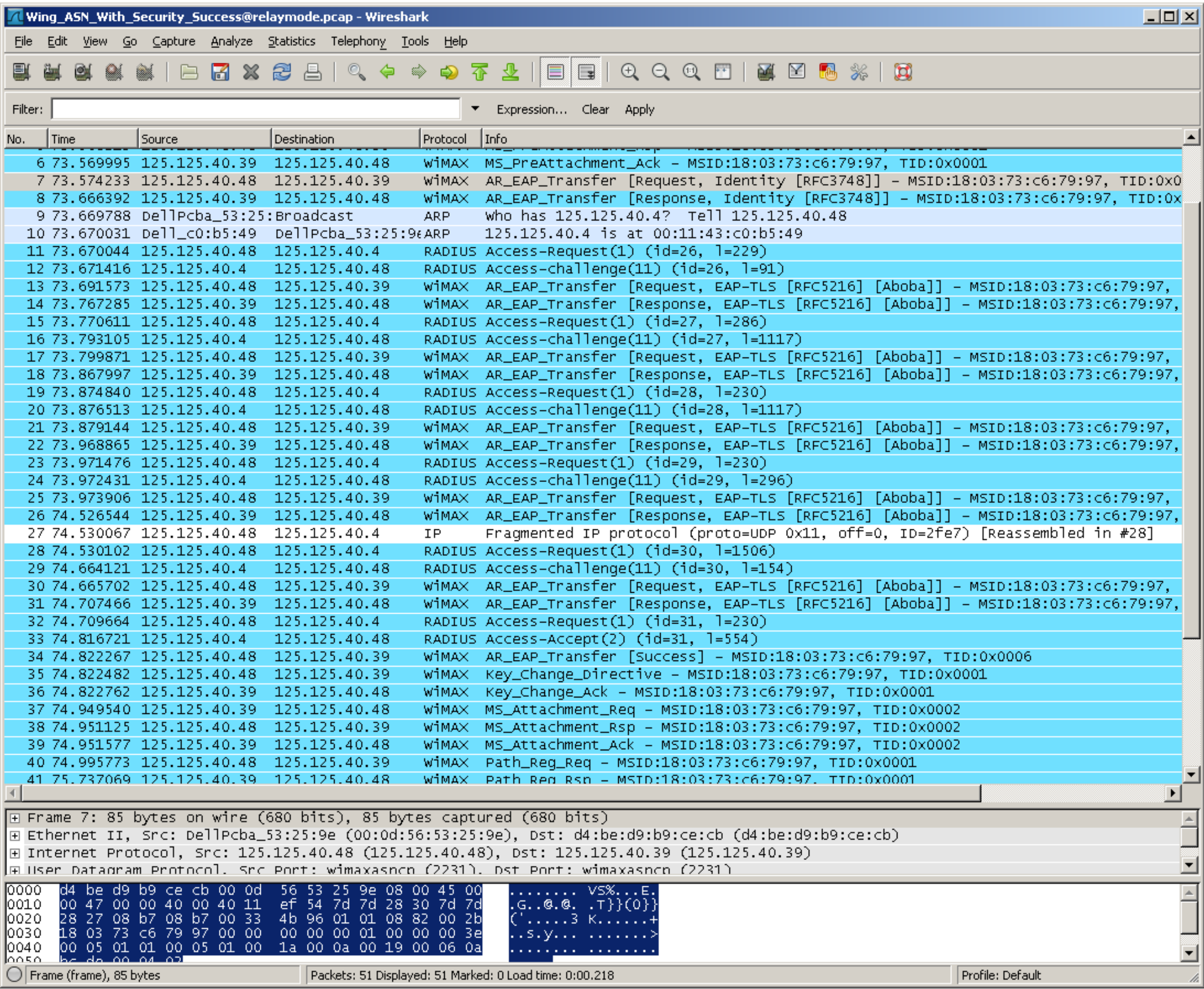



**Figure 25: EAP-based Authentication Procedure**

#### A.9.3.3 Unexpected behaviors/Results

None.

### A.9.4 Conclusions and recommendations

The proper Authentication features were verified in all of the impacted devices (MS, BS, ASN-GW, AAA Server).

## A.10 Verification Exercise # LAB1_5 Radio Characteristics Requirements Report

### A.10.1 Verification Exercise Scope

The purpose of this Verification Exercise is to verify that the BS Radio characteristics requirements are satisfied.

### A.10.2 Conduct of Verification Exercise

#### A.10.2.1 Verification Exercise Preparation

The same test bed described in A.6.2.1 was used, except for the fact that a MS was not needed in this case.

#### A.10.2.2 Verification Exercise execution

| Step nr. | Action | Action description | PCO (Point of Control and Observation) | Comment |
|---|---|---|---|---|
| 1. | Switch on MS | | | Not executed as not needed |
| 2. | Switch on BS | | | OK |
| 3. | Verify that MS connects successfully | | Mngt PCs connected to MS and BS | Not executed as not needed |
| 4. | Send payload to be transmitted by BS | | Mngt PCs connected to BS | Not executed as not needed. The BS starts transmitting autonomously at the start-up. |
| 5. | Verify the tune of center frequencies by the BS | | WiMAX Spectrum | OK |

| | | | | |
|---|---|---|---|---|
| | | | Analyzer | |
| 6. | Verify the supported 5MHz channelization | | WiMAX Spectrum Analyzer | OK |

### A.10.2.3 Deviation from the planned activities

Steps 1, 3, 4 were not executed as not needed (the BS starts transmitting autonomously at the start-up).

## A.10.3 Verification exercise Results

### A.10.3.1 Summary of Verification exercise Results

| ID | Result | Description | When observed | Expected result | Obtained result | VO | Comment |
|---|---|---|---|---|---|---|---|
| 1. | BS TX Spectrum Mask | Verify the tune of center frequencies by the BS | Step 5 | BS Centre Frequency tolerance better than ± $2x10^{-6}$ | BS Centre Frequency tolerance better than ± $2x10^{-8}$ | AeroMACS_VO_RF_06_A | OK- by means of Spectrum Analyzer |
| 2. | BS TX Spectrum Mask | Verify the supported 5Mhz channelization | Step 6 | 5 MHz Channelization | 5 MHz Channelization verified | AeroMACS_VO_RF_06_B | OK- by means of Spectrum Analyzer |

### A.10.3.2 Analysis of Verification Exercise Results

The AeroMACS BS prototype spectrum mask was measured. It is represented in Figure 27.

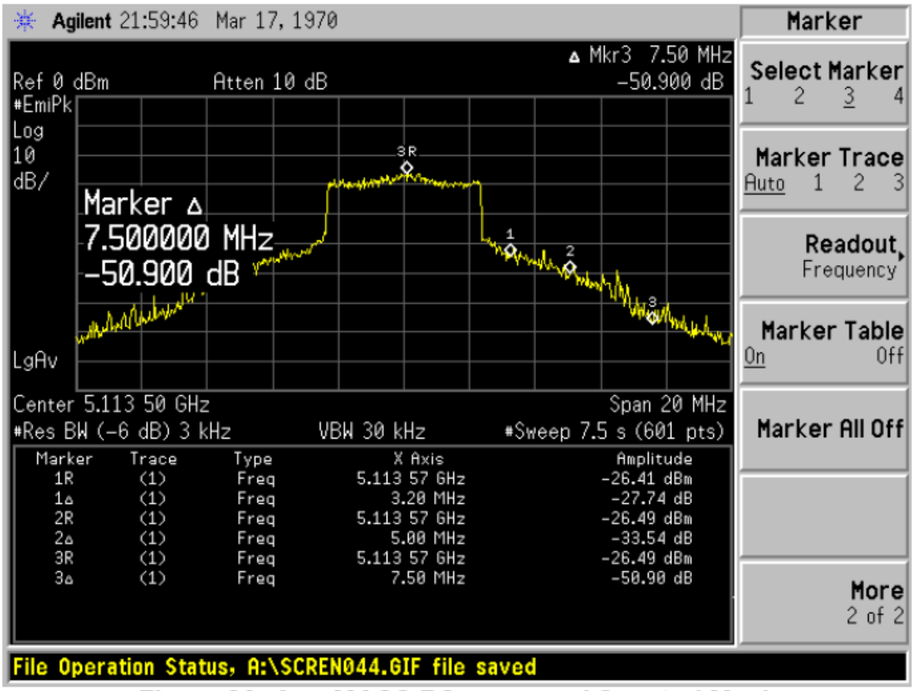



**Figure 26: AeroMACS BS measured Spectral Mask**

The BS center frequency error measured was about ±100 Hz at 5.091 MHz, i.e. less than $2x10^{-8}$.

Note: The BS prototype spectrum mask was implemented making reference to the target mask reported in Figure 27. At the moment of the prototype specification no MOPS were available, and hence no target masks, neither in draft form.

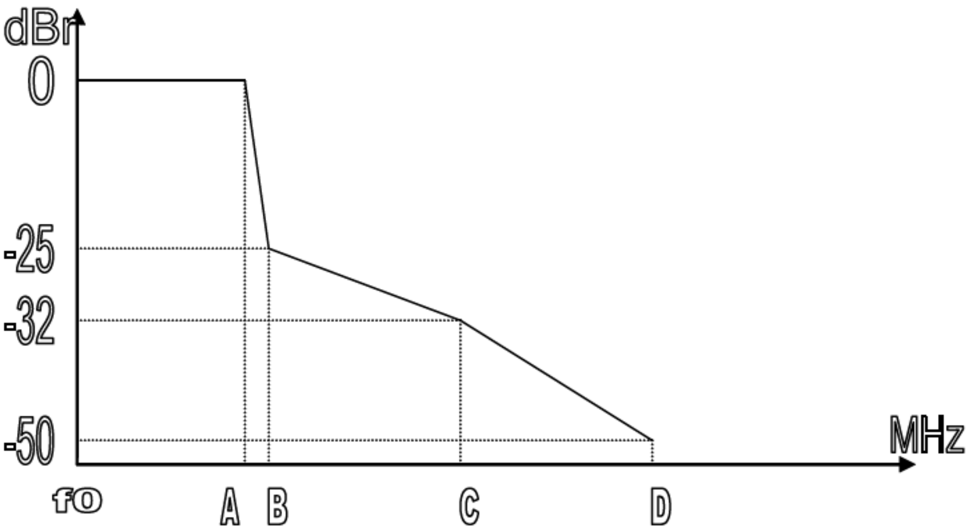



**Figure 27: Selex AeroMACS BS prototype target spectrum mask**

The target Spectrum Mask adopted has the following attenuations:

| param | att. | Freq. |
| --- | --- | --- |
| A | 0 dBr | 2.5 MHz |
| B | -25 dBr | 3.2 MHz |
| C | -32 dBr | 5.0 MHz |
| D | -50 dBr | 7.5 MHz |

#### A.10.3.3 Unexpected behaviors/Results

None.

### A.10.4 Conclusions and recommendations

The AeroMACS BS prototype spectrum mask was measured.

## A.11 Verification Exercise # LAB1_6 Transmit Power Report

### A.11.1 Verification Exercise Scope

The purpose of this Verification Exercise is to verify that the Transmit Power requirements listed in the Verification Exercise execution Section are satisfied.

### A.11.2 Conduct of Verification Exercise

#### A.11.2.1 Verification Exercise Preparation

The exercise was executed with the test bed described in Figure 2.

#### A.11.2.2 Verification Exercise execution

| Step nr. | Action | Action description | PCO (Point of Control and Observation) | Comment |
| --- | --- | --- | --- | --- |
| 1. | Switch on MS | | | OK |
| 2. | Switch on BS | | | OK |
| 3. | Send payload to be transmitted by BS | | Mngt PCs connected to BS | OK |
| 4. | Verify the BS output power range | | Mngt PC connected to BS and for signal<br><br>WiMAX | OK |

| | | | | |
|---|---|---|---|---|
| | | | Spectrum Analyzer | |
| 5. | Verify that if the BS belongs to Class 1, then its transmitted power keeps in the range of 20<PTx,max<23 dBm for QPSK modulation | | Mngt PC connected to BS and for signal<br><br>WiMAX Spectrum Analyzer | OK |
| 6. | Lower and raise the Variable attenuator Level at steps of 1 dB | | Variable Attenuator | OK |
| 7. | Verify that the MS output power is increased or decreased in order to compensate the power fluctuations | Check the MS TX power with the Spectrum Analyzer, check the UL MAP IE on the RF Link | Mngt PCs connected to MS and BS, and for signal<br><br>WiMAX Spectrum Analyzer | OK |

### A.11.2.3 Deviation from the planned activities

None.

## A.11.3 Verification exercise Results

### A.11.3.1 Summary of Verification exercise Results

| ID | Result | Description | When observed | Expected result | Obtained result | VO | Comment |
|---|---|---|---|---|---|---|---|
| 1. | Verify the BS output power range | | Step 4 | | | AeroMACS_VO_RF_08_D | OK- by means of Spectrum Analyzer |
| 2. | Verify that if the BS belongs to Class 1, then its transmitted power | | Step 5 | | | AeroMACS_VO_RF_07_A | OK- by means of Spectrum Analyzer |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | keeps in the range of 20<PTx,max<23 dBm for QPSK modulation | | | | | | |
| 3. | Transmit Power Control and Relative Step accuracy | Verify power control procedure during initial ranging phase, Closed Loop and Open Loop Power Control mode | Step 7 | Verify that the MS output power is increased or decreased in order to compensate the power fluctuations | | AeroMACS_VO_RF_08_A/C | OK- by means of Spectrum Analyzer |

### A.11.3.2 Analysis of Verification Exercise Results

The exercise was executed with the test bed described in Figure 2.

In order to verify the BS TX Output power, the total attenuation introduced by the attenuator and cables between the BS under test and the Spectrum Analyzer was measured. It resulted being 16 dB.

Then the Spectrum Analyzer measured the BS "Band Power", that is the BS TX power actually contained in the 5 MHz band, evidenced by markers in Figure 28.

The resulting BS TX Output Power was calculated as (16 + 6.87) = 22.87 dBm (Class 1).

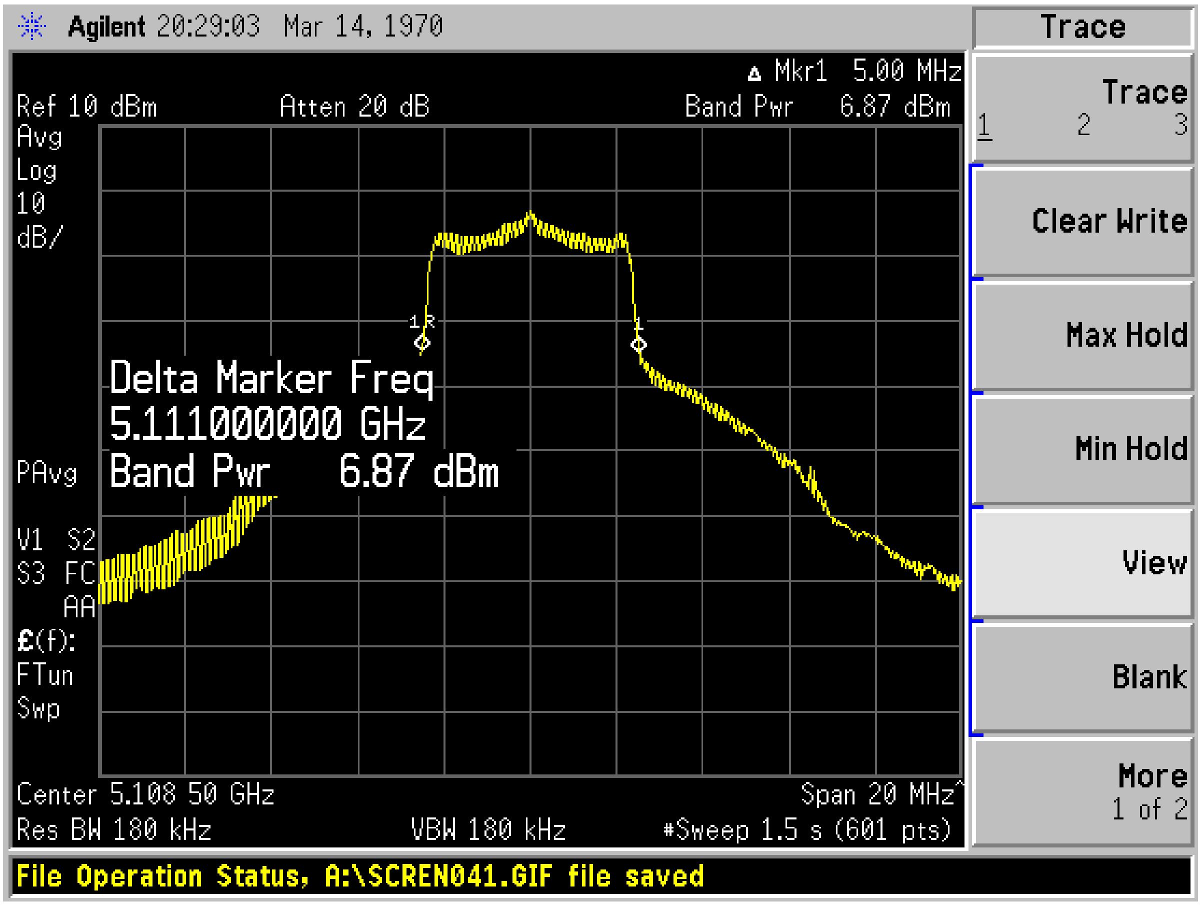



**Figure 28: BS Output Band Power**

The OL passive Power Control and CL Power Control procedures have been verified. Analysis is shown in A.7.3.2.

### A.11.3.3 Unexpected behaviors/Results

None.

## A.11.4 Conclusions and recommendations

The BS TX Output Power has been measured. The OL passive Power Control and CL Power Control procedures have been successfully verified.

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