AeroMACS Final Verification Report

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Abstract

This document provides the Verification report from Project 9.16 on the AeroMACS system. It describes the results of verification exercises defined in 9.16-D06 ([6]) and how they have been conducted.

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Executive summary

This document provides the Verification report from Project 9.16 on the AeroMACS system.

The Project 9.16 Verification Exercises have been done using the AeroMACS Mobile System (MS) and Base Station (BS) prototypes developed by Selex ES in the scope of Project 9.16 and 15.2.7.

The Project 9.16 Verification campaign had been organized in 4 steps:

- *Step 1: Local tests in closed environment in Selex Laboratory*
- *Step 2: Deployed static tests with a MS installed in Airbus laboratory in interoperation with a BS installed at the Toulouse Airport*
- *Step 3: Deployed mobile tests with a MS installed on a car rolling on the Toulouse Airport, and interoperating with the two BS installed at the Airport*
- *Step 4: Tests with the MS installed on an Airbus test Aircraft*

Step 1 tests have demonstrated the AeroMACS capacities and performances in accordance with the AeroMACS Profile and accomplished the majority of the verification objectives. Limitations on the AeroMACS system/network have prevented the validation of a few VVOs, namely the observation of 16QAM ¾ and 64QAM modulations and relative traffic throughput together with the possibility to do Security and Handover testing with DL/UL data transfer between the end systems.

Step 2 tests were globally successful. AeroMACS connectivity was successfully established in between the MS located in Airbus Laboratory, and the BS located at the Airport, over a distance of 1.9Km. In this environment, QoS and Service Flows have been successfully tested; Measured Round Trip Time values were consistent with the expectations (several tenth ms); and throughput of several hundreds of Kbit/s was reached in uplink and downlink, which is also consistent with the expectations. The measured jitter values were appropriately short. However, a high rate of packet loss, traducing instability of the AeroMACS link, was observed

Step 3 tests were partially successful. With the car moved on the Airport surface, MS-BS connectivity was established at 3 only out of the 11 tested static positions. Because of the difficulties encountered, it was not possible to perform all tests initially envisaged. Notably Doppler, NLOS, mobility, Hand-over and adjacent channel tests were not done. Only LOS tests were performed on and between few points where the MS was able to register to AeroMACS network. At these "good" points, where the signal level was such as to have the data from -87 dBm up, the MS was able to register both motionless and in movement (at 40Km/h) on both the BS on North or South side, and the measured RTT, throughput, jitter, CINR/RSSI were in line with the expectations and better than the results obtained during step 2 from the Airbus laboratory (good throughput with low Packet Error Rate was achieved, allowing TCP/IP data transfers).

During Step 3 tests, no interference in between MLS and AeroMACS were observed.

The level of interferences between AMT and AeroMACS was tested at Airbus laboratory, by using an AMT signal generator, injecting AMT signal on MS side during MS-BS AeroMACS data traffic. The observations tend to conclude that:

- *No interference from AMT onto AeroMACS is observed when a guard band greater than or equal to 3Mhz exist between AMT and AeroMACS signal*
- *No interference is observed when the AMT transmitter (i.e. the test A/C) is at a distance greater than 2Km (even with no guard band or if AMT and AeroMACS are used on overlapping channels)*

Hence, cases of interferences in between AeroMACS and Airbus AMT seem to be manageable, because in-flight AMT-equipped Aircraft should not interfere with AeroMACS communications at Airport. Interference issues may be encountered only on few French Airports where AMT-equipped Aircraft can land.

For Step 4, the AeroMACS system (including the MS, the AeroMACS antenna, the wiring, the IP router and the surrounding test equipment) has been installed on an Airbus A320 test Aircraft.

Electromagnetic Interference tests have been done on Aircraft to check if the AeroMACS system disturbs the aircraft's navigation and communication systems. The MS was forced in emission with a special mode command. No interference has been detected between AeroMACS and VHF, ATC, DME, MMR, Localizer, VOR and Marker systems. Test with Radio Altitude was not possible because it is inactive on ground. It was impossible to perform test with GPS because antenna connector was not accessible on A320 MSN1.

The tests with Aircraft movement have been cancelled because the MS did not succeed to register with the BS at and between points close to the taxiways and runways. The AeroMACS signal was measured by spectrum analyser and was too weak for the MS. Unfortunately, this confirmed the poor BS coverage on the Toulouse Airport surface already observed during the car tests.

Influence of A/C radio systems on AeroMACS was also not verified because AeroMACS data link was needed to perform data transfer and see the influence of A/C radio systems.

The main cause of the difficulties encountered during the tests in deployed environment on Toulouse Airport is related to the poor coverage of the airport by the Base Stations, and is linked to a signal level quite below the threshold expected.

The report provides an explanation of the probable causes for the bad coverage obtained from the BS across the Toulouse Airport area.

The tests results analysis concludes that three principal preliminary activities are recommended for any future trials/deployments to be executed on the Airport:

- *Perform Survey and Coverage Prediction Analysis: prediction analysis is the most important activity before deploying a radio mobile network, particularly in the 5 GHz band.*
- *Perform Coverage Assessment and Optimization using a closed-loop process consisting in performing prediction, assessing them, tuning the model, predicting again until reaching a high confidence on results.*
- *Use proper antennas and antennas installation: coverage prediction can also provide accurate indications on type and characteristics of antennas to be used and installation options (azimuth, down tilt and pattern overlap). And a particular attention shall be paid on the quality of the components (notably the wires, the antennas, the electronic equipment that may be faced to variable environmental conditions).*

The verification activities also identified some aspects that need to be further investigated and refined; they include further testing notably: security, handover, mobility and performance for connection establishment/network entry.

Finally, the report considers that the AeroMACS technology has reached a very mature stage of TRL5 level, between OCVM level V2 and V3, closer to V3, despite the difficulties encountered during the car and aircraft tests, given that these problems relate to Base Station coverage and installation issues, and that good performances of the technology have been demonstrated in laboratory and on the field in areas appropriately covered by the Base Stations.

1 Introduction

1.1 Purpose of the document

This document provides the Verification report from Project 9.16 on the AeroMACS system. It describes the results of verification exercises defined in 9.16-D06 ([6]) and how they have been conducted.

1.2 Intended readership

This document is expected to be of primary interests for partners of the 9.16 and 15.02.07 Projects, who will get from this report the factual data on the performance of the AeroMACS system, that have been collected by the SESAR 9.16 AeroMACS verification exercises, using the AeroMACS prototype developed by SELEX ES .

This document is also intended to serve as input for the validation of AeroMACS standards, and should hence be of interest to the organisations involved in these standardisation groups, including notably the ICAO Communication Panel WG-S, the Eurocae WG82 and the RTCA SC223.

1.3 Structure of the document

This document is structured as follows:

- Chapter 1 is an introduction describing the purpose of the document and the intended readership.
- Chapter 2 describes the context of the Verification. It includes a summary of the verification exercises.
- Chapter 3 defines the verification approach, describing how the verification scenarios were implemented in the various test locations (Manufacturers Laboratories, Toulouse Airports).
- Chapter 4 gives a summary of the verification exercises results
- Chapter 5 provides the conclusions and recommendations
- Chapter 6 includes the report on the SELEX Verification Exercises, done in closed environment at SELEX laboratory
- Chapter 7 is the report on the AIRBUS tests done in a deployed environment between a static MS located at Airbus laboratory and the BS located at Toulouse Airport
- Chapter 8 provides the report on the car tests on Toulouse Airport
- Chapter 9 includes the report on the Aircraft tests on Toulouse Airport
- Chapter 10 lists the referenced documents

1.4 Glossary of terms

Not used

1.5 Acronyms and Terminology

Term	Definition
A320 MSN1	A320 Manufacturing Serial Number 1
A/C	AirCraft
A/L	Airline
A/P	Airport
ADSL	Asymmetric Digital Subscriber Line

Term	Definition
AeroMACS	Aeronautical Mobile Airport Communications System
AGC	Auto Gain Control
AMT	Aeronautical Mobile Telemetry
ASN Gateway	Access Service Network Gateway
ATC	Air Traffic Control
ATM	Air Traffic Management
ATP	Acceptance Test Procedure
ATS	Air Traffic Service
BE	Best Effort
BER	Bit Error Rate
BS	Base Station
CINR	Carrier to Interference-plus-Noise Ratio
CL	Closed loop
CLI	Command Line Interface
COTS	Commercial Off-The-Shelf
CQICH	Channel Quality Information Channel
CWLU	Cabin Wireless LAN Unit
dB	deciBel
dBm	deciBel milliwatt
DHCP	Dynamic Host Configuration Protocol
DL	Downlink
DME	Distance measuring
DSNA/DTI	Direction des Services de la Navigation Aérienne/Direction de la Technique et de l'Innovation
E-ATMS	European Air Traffic Management System
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
EMS	Estimated power
ertPS	extended-real-time Polling Service
E-OCVM	European Operational Concept Validation Methodology
FCH	Frame Control Header
FEC Code	Forward Error Correction Code
FTR	Flight Test Request
Ge	Gigabit Ethernet interface
GHz	Giga Hertz
GPS	Global Positioning System
GS (BS)	Ground Station (Base Station in WiMAX terminology) Same meaning as BS
HCS	Header Check Sequence
HO	Hand-Over
HP	Hewlett-Packard
HMI	Human Machine Interface
ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronics Engineers
ILS	Instrument Landing System
IP	Internet Protocol
IPSec	Internet Protocol Secured
IOS	Internetwork Operating System
IOT	Inter-Operability Tests
INTEROP	Interoperability Requirements
Kbit/s	Kilo Bit per second
KHz	Kilo Hertz
Km	kilometres
Km/h	Kilometres/hour
Kt	Knot

Term	Definition
LAN	Local Area Network
LOC	LOCalizer
LOS	Line Of Sight
LTR	Lab Test Request
LTRA	Lab Test Request Analysis
Ms	Milli second
Mbit/s	Mega Bit per second
MHz	Mega Hertz
MIB	Management Information Base
MKR	Marker(Radio) Beacon
MLS	Microwave Landing System
MMR	Multi-Mode Receiver
MTU	Maximum Transmission Unit
MS	Mobile Subscriber
N/A	Not Applicable
NAT	Network Address Translation
NAV/COM	Navigation/Communication systems
NLOS	Non Light of Sight
nrtPS	non-real-time Polling Service
OFA	Operational Focus Areas
OFDMA	Orthogonal Frequency Division Multiple Access
OID	Object IDentifier
OS	Operating System
OSED	Operational Service and Environment Definition
PC	Personal Computer
PCO	Point of COntrol
QOS	Quality Of Service
PER	Packet Error Rate
PLR	Packet Loss Rate
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase-Shift Keying
RBW	Resolution Bandwidth
R&S	Rohde & Schwarz
RF	Radio Frequency
RFU	Radio Frequency Unit
RSSI	Received Signal Strength Indicator
RTPS	Real-Time Polling Service
RTT	Round Trip Time
RX	Reception
SA	Spectrum Analyzer
SANDRA	Seamless Aeronautical Networking through integration of Data links Radios and Antennas
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SF	Service Flow
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SNMP	Simple Network Management Protocol
SNR	Signal Noise Report
SPR	Safety and Performance Requirements
SSH	Secure SHell
SUT	System Under Test

Term	Definition
SWR	Standing Wave Ratio
TBC	To Be Confirmed
TBD	To Be Defined
TCP	Transmission Control Protocol
TNC	Threaded Neil-Concelman
TWLU	Terminal Wireless LAN Unit
TX	Transmission
UDP	User Datagram Protocol
UGS	Unsolicited Grant Service
UL	Uplink
VAC	Voltage in Alternating Current
VALP	Validation Plan
VALR	Validation Report
VALS	Validation Strategy
VBW	Video bandwidth
VDC	Voltage of Direct Current
VHF	Very High Frequency
VOR	VHF Omnidirectional
VP	Verification Plan
VR	Verification Report
VS	Verification Strategy
WACS	Wireless Airport Communication System
WP	Work Package
WoW	Wake on Wheel

2 Context of the Verification

Project 9.16 (in cooperation with Project 15.2.7) is a technological project dealing with the adaptation of the WiMAX 802.16-2009 standard toward a profile (in the aeronautical C band) 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 this new generation of airport data link system, performed in close conjunction with RTCA SC223 and EUROCAE WG82.

The objective of the verification phase was thus to perform real evaluation of the AeroMACS technology, using prototypes in laboratory testing and field trials.

The corresponding Verification Plan / Strategy is documented in the document 9.16-D06 [6].

2.1 System Overview

Aeronautical Mobile Airport Communications System (AeroMACS) is a new C-band (5091 to 5150MHz) communications system being defined to support dedicated aeronautical communication services at airport surface. The AeroMACS technology will be enabled by the deployment of ground AeroMACS systems at Airports and of mobile AeroMACS Systems typically installed onboard aircraft or other mobile vehicles operating at the airports surface.

This document, produced in the scope of the SESAR project 9.16 (New Communication Technology at Airport), includes the test results of the SELEX ES AeroMACS Mobile System prototype.

The SELEX ES AeroMACS Prototype Transceiver, used for both BS and MS, is composed by two 19" boxes:

- The Base Band Box, in charge of interfacing with the IP router, performing AeroMACS MAC layer and Physical functions up to Modulation.
- The RF Head Box, in charge of BaseBand interfacing, RF Control, frequency up/down conversion and final amplification.

The Base Band Box and the RF Head Box are connected by a high speed Bus.

Figure 1: SELEX ES AeroMACS Prototype Equipment

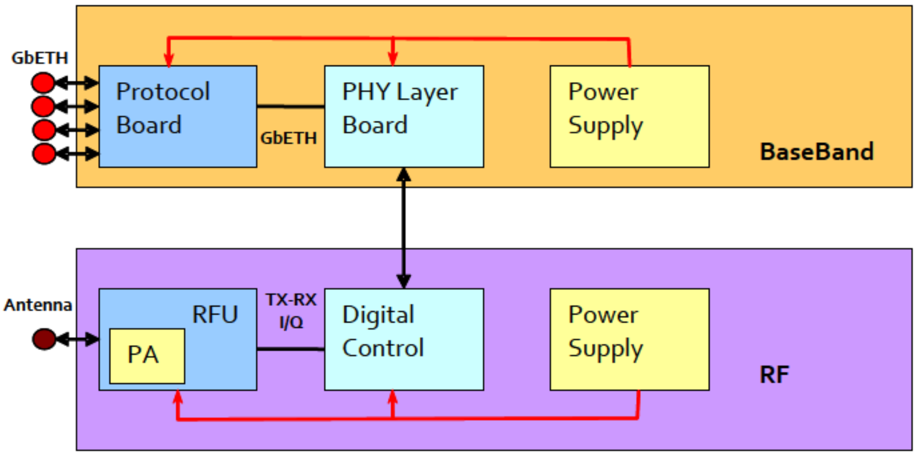

Figure 2: AeroMACS Prototype Equipment Functional Architecture

The AeroMACS Prototype Transceiver provides the following interfaces:

- Two 10/100 BASE-TX IEEE 802.3/Ethernet RJ45 type Interfaces
  - for Data Transport (On-Board IP Router)
  - for Prototype Management/Configuration (WEB)
- A TNC Female, 50 Ω AeroMACS Antenna RX/TX
- An EIA-RS232 type Interface for Prototype Management/Configuration (CLI)
- A 28 VDC Power
- An "ON/OFF" toggle switch for manual power on/off
- A On-Ground/ On-Air toggle switch for On-Ground/On-Air environment setting (e.g. WoW)
- A Reset Button for Prototype restart
- A high speed Interface for Base-Band box to RF Head box Interface

The main characteristics of the AeroMACS MS Antenna used during the tests are reported below.

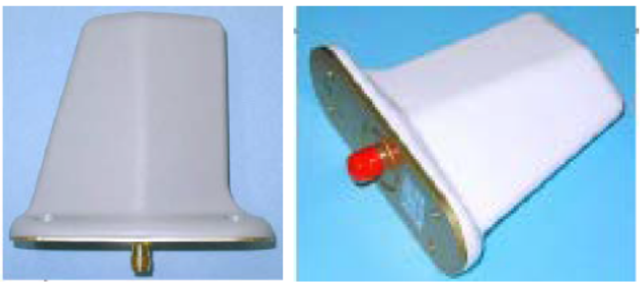

Figure 3: AeroMACS MS Prototype Airborne Antenna

- Electrical Specification
  - Frequency: 4400 ÷ 5250 MHz
  - Pattern: OMNIDIRECTIONAL

- Polarization: VERTICAL
- Gain: 5dBi
- VSWR: 2.0:1
- Output Impedance: 50Ω
- Power Handling: ≥50W

• Mechanical Specification

- Size: WIDTH: 2.055 in. [52 mm], LENGTH: 5.25 in. [133 mm], HEIGHT: 1.982 in. [50 mm]
- Weight: 139g
- Finish: SKYDROL RESISTANT POLYURETHANE ENAME L BASE IRIDITE PER MIL-C-5441
- Color: GLOSS WHITE #17925 PER FED-STD-595B
- Material: 6061 -T6 ALUMINUM ALLOY BASE, THERM OSET PLASTIC RADOME, UV, ABRASI ON AND SKYDROL RESISTANCE
- Connector: TNC FEMALE CONNECTORS, (OPTIONAL: SMA, N, BNC, TNC)

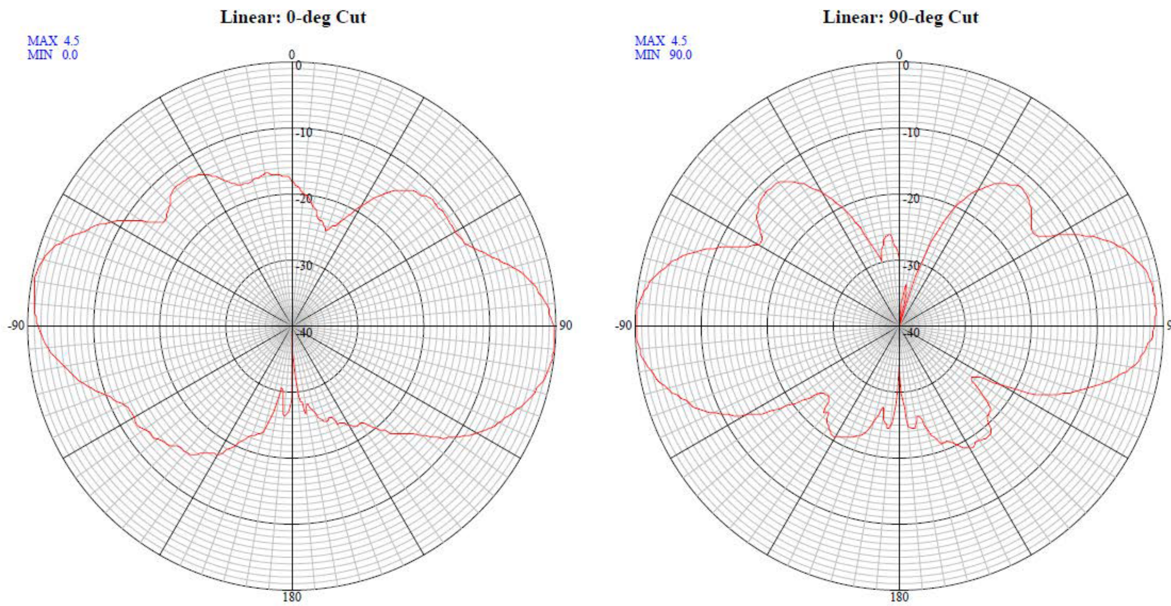

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Figure 4: AeroMACS MS Prototype Airborne Antenna Radiation Pattern

2.2 Summary of Verification Exercise/s

2.2.1 Summary of Verification Objectives and Success Criteria

The AeroMACS Verification Objectives have been globally defined in coordination between SESAR P15.2.7, P9.16 and the SANDRA project, and parts of these Verification Objectives have then been sub-allocated to these different project.

The AeroMACS Verification Objectives that have been sub-allocated to P9.16 are listed in the document 9.16-D06 ([6]). Because the list of the Verification Objectives allocated to P9.16 is rather long, it will not be repeated in this summary and introductory section. However, we may indicate or remind here that the AeroMACS Verification Objectives have been classified and grouped in the following top level categories:

- MS/GS interoperability, including AeroMACS profile verification

This domain covers all requirements related to the interface between the Mobile Station and the Base Station. It includes overall verification of the AeroMACS prototype against the specification of the Air Interface as derived from the IEEE 802.16-2009, and the parameters included in the profile.

- RF specifications and performances

This domain covers RF requirements in terms of frequency, power, in and out of the allocated band. It includes also verification of the prototype against all requirements related to the signal modulation and coding, and the expected propagation performances.

- Integration on the Aircraft

This domain is related to requirements which enable the installation within the Aircraft. It includes thus validation that the AeroMACS mobile system (including antenna) can be installed in compliance with the applicable installation rules. It also covers validation and verification of compliance of the AeroMACS technology in terms of RF interferences with the other radio systems (communication, navigation and surveillance) operating on the Aircraft.

- Performances in real environment

This covers verification of performances requirements of the AeroMACS systems which can only be verified with tests on the field, implying the installation of BS, and MS operating on a vehicle (including Aircraft). This covers for examples requirements about handover, maximum speed of the MS, cell coverage, etc…

- Integration with ground network

This domain is related to requirements which enable end-to-end connection between the AeroMACS Mobile system and the ground network. It includes interconnection of the AeroMACS BS with ground network provided by DSP, and addresses mainly IP and upper layers.

Each Verification Objective sub-allocated to P9.16 has been associated to one or more test cases, as presented in the multiple Tables of section 4.1.3. The success criteria for each objective is directly linked to the result (passed or failed) of the associated test case(s).

2.2.2 Choice of methods and techniques

Refer to the Verification Plan (9.16-D06 - [6]) and procedures document (9.16-D07 - [7])

3 Conduct of Verification Exercises

3.1 Verification Exercises Preparation

The main activities for the Verification Exercises preparation were:

- The definition of verification strategy and plan, the identification of the verification objectives, and the determination of the required test infrastructures. These points were addressed within 9.16 Task 6, and their resolution was documented in the deliverable 9.16-D06 ([6])
- The Selex MS prototype development, within 9.16-Task 5. A second version of the prototype, including the development of an enhanced version of the RF Unit was also completed in 9.16 Task 17
- The test beds development and the definition of the test procedures for the laboratory testing and for the car tests and aircraft tests scenarios. .This was achieved within 9.16 Tasks 7, and the results are documented in the deliverable 9.16-D07 ([7]).

3.2 Verification Exercises Execution

The Figure 5 below illustrates the sequence of the different tests phases carried out within projects 15.2.7 and 9.16 .

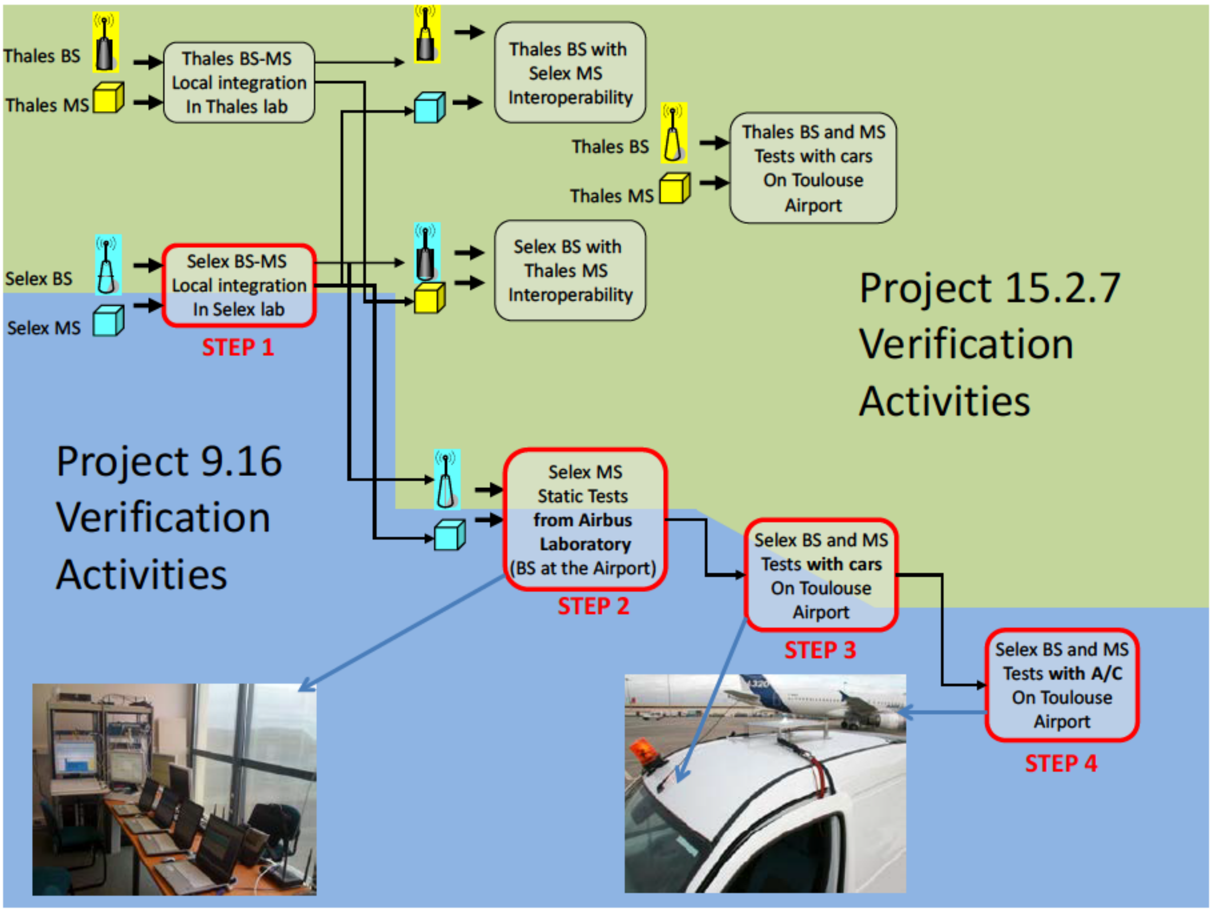

Figure 5: SESAR projects 15.2.7 and 9.16 test phases

As shown by the figure, the SESAR 9.16 tests were organized in 4 main steps:

Test steps	Tests context	Leader of the Tests
STEP 1	Local tests in closed environment in Selex Laboratory, with Selex MS and BS	SELEX
STEP 2	Deployed static tests with a Selex MS installed in Airbus laboratory in interoperation with a Selex BS installed at the Airport	AIRBUS
STEP 3	Deployed mobile tests with a Selex MS installed on a car rolling on the Toulouse Airport, and interoperating with the two Selex BS installed at the Airport	AIRBUS
STEP 4	Tests with a Selex MS installed on an Airbus test Aircraft.	AIRBUS

Table 1 below indicates the dates of execution and analysis of these Verification Exercises

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date
STEP 1	Local tests in Selex laboratory	30/06/2013	30/09/2013	01/10/2013	01/12/2013
STEP 2	Deployed static tests from Airbus Laboratory	10/06/2014	10/10/2010	01/07/2014	21/10/2014
STEP 3	Car tests	18/08/2014	15/10/2014	18/08/2014	31/10/2014
STEP 4	Aircraft tests	03/11/2014	11/12/2014	03/11/2014	13/01/2014

Table 1: Verification Exercises execution/analysis dates

3.3 Deviations from the Planned Activities

3.3.1 Deviations with Respect to the Verification Strategy

None

3.3.2 Deviations with Respect to the Verification Plan

The deviations with respect to the Verification Plan are summarized in the table below:

Test Id	Test procedure objective	Nature and Reason of the deviation
	Deviations for STEP 1 Verification Exercises (Selex laboratory tests)	
Lab3_X	Link Adaptation	16QAM ¾ and 64QAM not observed due to HW limitations on the AeroMACS MS RF Unit
Lab6_x	Security	Security was not tested with DL/UL data transfer due to a Limitation at the level of the ASN-GW
	Deviations for STEP 2 Verification Exercises (Airbus laboratory tests)	
T003	Verify data traffic when encryption is used	Cancelled due to a Limitation at the level of the ASN-GW
T004	Verify and Measure MS ranging time	Cancelled because Ranging time value not available in the MIB
	Deviations for STEP 3 Verification Exercises (Car tests)	
T101	Verify CL power control performance	Unconclusive because of the very limited BS coverage
T102	Verify the Cell radius/coverage	Limited due to the poor BS coverage
T103	Verify MS and BS dynamic adaptation to modulation and coding	Limited due to the poor BS coverage
T104	Verify AeroMACS performance at various speeds	Cancelled due to the poor BS coverage
T105	Verify and Measure MS ranging time at several static points on the Airport	Cancelled because Ranging time value not available in the MIB
T111	Evaluate the impact of obstructions in amplitude and in phase (LOS/NLOS performance comparisons)	Cancelled because MS-BS connectivity not available in NLOS and due to the difficulties encountered and the wasted time during the tests in LOS
T112	Measure Handover interruption time	Cancelled due to a Limitation at the level of the ASN-GW
T113	Verify impact of adjacent channel interference on data throughput	Cancelled because the mask currently implemented in the prototype does not allow simultaneous data traffic in adjacent channels
T114	Verify impact of non-adjacent channel interference on data throughput	Cancelled of the difficulties encountered and the wasted time during the tests in LOS
T116	Measure data throughput and modulation at 50km/h and at 90km/h speed	Cancelled due to the poor BS coverage
	Deviations for STEP 4 Verification Exercises (Aircraft tests)	
T201	Verify that the MS is able to correctly measure the adjacent BS in term of RSSI and CINR and take appropriate handover decision	Cancelled because no information on BS signal measurements is available in the MIB of the MS
T203	Check maximum sustainable speed for AeroMACS on Aircraft	Cancelled because the MS on Aircraft did not succeed to establish communication with the BS, due to the poor BS coverage
T210	Measure RSSI and CINR in both DL and UL on Aircraft	
T212	Measure Round Trip Times during aircraft movements	
T213	Measure latency and throughput in UL and DL during aircraft movements	
T214	Measure Jitters in DL and UL during aircraft movements	
T215	Evaluate the impact of obstructions in amplitude and in phase (LOS/NLOS performance comparisons) during aircraft movements	
T216	Measure Handover interruption time and Handover impact on data throughput during aircraft movements	
T217	Measure RSSI below and inside the aircraft	
T218	Measure data throughput and modulation scheme at static point (0km/h), as a function of the aircraft position	
T219	Measure data throughput and modulation at 50km/h and at 90km/h speed on aircraft	

Table 2: Deviations with Respect to the Verification Plan

4 Verification exercises Results

4.1 Summary of Verification Exercises Results

4.1.1 Summary on tests performed by SELEX in STEP 1

SELEX ES has organized the SESAR 9.16 AeroMACS Validation and Verification activities into the following list of test procedures:

Test Id	Test procedure objective	Test result
Lab0_1	Physical features - Verify the physical casing and basic requirements	OK
Lab1_1	Power on MS with BS already transmitting -Verify that MS start frequency scanning, synchronize on the channel, and make Network Entry when the BS is already transmitting	OK
Lab1_2	Power on MS with BS Powered OFF -Verify that AeroMACS MS Prototype start frequency scanning, synchronize on the channel, and make Network Entry when the BS is put into transmission after the MS power ON	OK
Lab1_3	MS Frequency Scanning (the overall bandwidth) – Verify that AeroMACS MS Prototype scan all the channels in the AeroMACS bandwidth	OK
Lab1_4	MS Frequency Scanning (range of Channels) - Verify that AeroMACS MS Prototype scan only the channels configured in a specific range	OK
Lab1_5	MS Network Entry after a RF Link Disconnection - Verify that AeroMACS MS Prototype perform a successfully network Entry procedure after an RF link disconnection	OK
Lab1_6	MS Network Entry after a Link Loss - Verify that AeroMACS MS Prototype perform a successfully network Entry procedure after an RF link loss	OK
Lab1_7	MS Network Entry after a BS Reboot - Verify that AeroMACS MS Prototype perform a successfully network Entry procedure after a BS reboot	OK
Lab1_8	MS Network Entry after a MS Reboot - Verify that AeroMACS MS Prototype perform a successfully network Entry procedure after a MS reboot	OK
Lab2_1	Closed loop power control - Verify that AeroMACS MS Prototype adjust its transmission power based on the BS' s power measurements	OK
Lab2_2	Passive open loop power control - Verify that AeroMACS MS Prototype adjust its transmission power on propagation loss estimation without BS' s power measurements information	OK
Lab2_3	Enable/Disable passive open loop power control - Verify that AeroMACS MS Prototype power control configurations are correctly applied and implemented	OK
Lab3_1	Verify the MCS - Verify that AeroMACS MS Prototype uses the expected modulation schemes depending on the channel quality	OK
Lab3_2	Verify the MCS variation against the variation of CINR - Verify that AeroMACS MS Prototype uses the expected modulation schemes based on the CINR conditions	OK
Lab4_1	SFs Support verification - Verify that AeroMACS MS Prototype implements the SF configuration configured in the ASN-GW	OK
Lab4_2	"Rule Based on TCP/UDP Port" SF support verification - Verify that AeroMACS MS Prototype correctly implements the traffic rules configured on TCP/UDP ports	OK
Lab4_3	"Rule Based on protocol" SF support verification - Verify that AeroMACS MS Prototype correctly implements the traffic rules configured on protocol (e.g DHCP)	OK
Lab4_4	"Rule Based on IP Address" SF support verification - Verify that AeroMACS MS Prototype correctly implements the traffic rules configured on defined IP Addresses	OK
Lab4_5	MSTR throughput compliance verification - Verify that AeroMACS MS Prototype data inputs exceeding the MSTR is dropped or delayed	OK
Lab4_6	Throughput distribution over 2 SFs with different MSTR verification - Verify that AeroMACS MS Prototype uses the SF configured with the right MSTR	OK
Lab4_7	Bandwidth distribution over 2 SF with the same QoS parameter verification - Verify that AeroMACS MS Prototype SFs' uses half the bandwidth available	OK
Lab4_8	Bandwidth distribution over 2 SF with different priority verification - Verify that AeroMACS MS Prototype SF with high priority have assigned the higher bandwidth (throughput) and the SF with lower priority have assigned the remaining bandwidth (throughput)	OK
Lab5_1	ARQ features for BE Flow verification - Verify that AeroMACS MS Prototype packet loss decrease when the ARQ is configured	OK
Lab5_2	ARQ features for nRTPS Flow verification - Verify that AeroMACS MS Prototype packet loss decrease when the ARQ is configured	OK
Lab6_1	MS authentication verification - Verify that AeroMACS MS Prototype authentication and data cyphering is correctly implemented	OK

Lab7_1	MS HO towards neighbor BS verification - Verify that AeroMACS MS Prototype correctly performs HO between two BS	OK
Lab7_2	MS HO during data transfer verification - Verify that AeroMACS MS Prototype correctly performs HO between two BS and data transfer is not interrupted	KO
Lab8_1	MS no link loss verification (using channel simulation with Doppler effect activated after MS Net Entry) - Verify that AeroMACS MS Prototype doesn't lose the link when Doppler effects are present	OK
Lab8_2	MS no link loss verification (using channel simulation with Doppler effect activated before MS Net Entry) - Verify that AeroMACS MS Prototype doesn't lose the link when Doppler effects are present	OK
Lab8_3 to Lab8_12	MS no link loss verification (using channel simulation with Doppler effect and 1 to 5TAP Fading effect activated after/BEFORE MS Net Entry) - Verify that AeroMACS MS Prototype doesn't lose the link when Doppler and Fading effects are present	OK
Lab8_13 and Lab8_14	MS no link loss verification (using channel simulation with SESAR Barajas model activated after MS Net Entry) - Verify that AeroMACS MS Prototype doesn't lose the link when the Barajas airport channel model is simulated	OK
Lab9_1	Two MS registered on BS, simultaneous data transfer for the 2 MS verification – Verify that two AeroMACS MS Prototypes makes successful net entry and data transfer with one BS	OK
Lab10_1	RSSI correct value verification with measurement based on preamble or pilot - Verify that AeroMACS MS Prototype correctly measures RSSI	OK
Lab11_1	MS SW Download tests	OK
Lab11_2	MS Manual reset - Verify that AeroMACS MS Prototype correctly performs Net Entry and registration after a manual MS reset	OK
Lab11_3	MS Configuration tests	OK
Lab11_4	MS Monitoring/IT verification - Verify that AeroMACS MS Prototype correctly monitor required parameters (e.g. SNR)	OK
Lab11_5	MS TX Spurious Emission - Verify that AeroMACS MS Prototype TX spurious emissions are within the limits of AeroMACS MOPS	OK

Table 3: Summary of Verification Exercises Results (STEP 1)

Notes:

(1) All these tests have been done in a closed and static laboratory environment, on the test benches described in section 6.2.1.

(2) In the 3rd column:
OK means the test has been successfully completed
KO means that the test failed

4.1.2 Summary on tests performed by airbus

Airbus has organized the SESAR 9.16 AeroMACS Validation and Verification activities into the following list of test procedures:

Test Id	Test procedure objective	Done from	S/M (1)	Test status
T000	Verify that the MS is compliant to RF-specifications	MS at Airbus lab	S	OK
T001	Verify that both BS and MS use 5MHz Channel bandwidth		S	OK
T002	Verify priority and QoS mechanisms		S	OK
T003	Verify data traffic when encryption is used		S	KO
T004	Verify and Measure MS ranging time		S	PART
T005	Verify MS-IP router IEEE 802.3 - CSMA-CD/Ethernet interface		S	OK
T006	Verify MS data transmissions are disabled "in flight" and "enabled "on ground"		S	OK
T007	Verify compliance of the MS-Antenna interface and connectors		S	OK
T008	Verify that the MS is able to use all channels from 5091MHz to 5150 MHz		S	OK
T009	Measure Round Trip Time		S	OK
T010	Measure latency and throughput in UL and DL		S	OK
T011	Measure Jitters in DL and UL		S	OK
T012	Verify the Channel frequencies		S	OK
T101	Verify CL power control performance		S&M	PART
T102	Verify the Cell radius/coverage		M	PART
T103	Verify MS and BS dynamic adaptation to modulation and coding		S	PART
T104	Verify AeroMACS performance at various speeds		M	KO

T105	Verify and Measure MS ranging time at several static points on the Airport	MS on a Vehicle	S	PART
T106	Measure RSSI and CINR in both DL and UL		S&M	OK
T107	Geo-localisation		S&M	OK
T108	Measure Round Trip Time as a function of the MS position		S&M	OK
T109	Measure latency and throughput in UL and DL as a function of the MS position		S&M	OK
T110	Measure Jitters in DL and UL as a function of the MS position		S&M	OK
T111	Evaluate the impact of obstructions in amplitude and in phase (LOS/NLOS performance comparisons)		S	KO
T112	Measure Handover interruption time		M	KO
T113	Verify impact of adjacent channel interference on data throughput		S	KO
T114	Verify impact of non-adjacent channel interference on data throughput		S	KO
T115	Measure data throughput at static point (0km/h), as a function of the MS position		S	OK
T116	Measure data throughput and modulation at 50km/h and at 90km/h speed		M	KO
T117	Verify the impact of AMT system on the AeroMACS under co-channel conditions.		S	OK
T118	Verify the impact of AeroMACS system on the AMT under co-channel conditions.		S	OK
T119	Verify the impact of MLS system on the AeroMACS under co-channel conditions.		S	OK
T120	Verify the impact of AeroMACS system on the MLS under co-channel conditions		S	OK
T201	Verify that the MS is able to correctly measure the adjacent BS in term of RSSI and CINR and take appropriate handover decision	MS on Aircraft	S+M	KO
T202	Assessment of AeroMACS spurious emissions in Anechoic chamber		S	OK
T203	Check maximum sustainable speed for AeroMACS on Aircraft		M	KO
T204	Verify that the AeroMACS MS does not interfere with all RadioNav equipment installed into the Aircraft.		S	OK
T205	Verify on the Aircraft that MS data transmissions are disabled “in flight” and “enabled “on ground”		S	OK
T206	Verify the physical/mechanical installation of the AeroMACS Antenna on Aircraft		S	OK
T207	Verify AeroMACS RF cable installation and performance on Aircraft		S	OK
T208	Verify Antenna location provides 40dB space isolation with other aircraft systems in C-Band		S	OK
T209	Verify Antenna location provides 20dB space isolation with other aircraft systems		S	OK
T210	Measure RSSI and CINR in both DL and UL on Aircraft		S&M	KO
T211	Geo-localization		S&M	OK
T212	Measure Round Trip Times during aircraft movements		S&M	KO
T213	Measure latency and throughput in UL and DL during aircraft movements		S&M	KO
T214	Measure Jitters in DL and UL during aircraft movements		S&M	KO
T215	Evaluate the impact of obstructions in amplitude and in phase (LOS/NLOS performance comparisons) during aircraft movements		S	KO
T216	Measure Handover interruption time and Handover impact on data throughput during aircraft movements		M	KO
T217	Measure RSSI below and inside the aircraft		S	KO
T218	Measure data throughput and modulation scheme at static point (0km/h), as a function of the aircraft position		S	KO
T219	Measure data throughput and modulation at 50km/h and at 90km/h speed on aircraft		M	KO

Table 4: Summary of Verification Exercises Results (STEPS 2, 3 and 4))

Notes:

(1) In the 4th column:
S means that tests are done with the MS being kept at a STATIC location on the Airport
M means that tests are done with a MOBILE MS carried on a car or on the test aircraft

(2) In the 5 column:
OK means the test has been successfully completed
KO means that the test failed or that the test could not be performed
PART means that part of the test has been partially completed

4.1.3 Verification summary in regard to the verification objectives

4.1.3.1 MS/BS interoperability

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_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.	Lab1_x Lab2_x Lab3_x Lab4_x Lab5_x Lab6_x Lab7_x Lab8_x Lab9_x Lab10_x Lab11_x T001 T012	Partially OK	The AeroMACS MS/BS profile compliance is OK. However, the AeroMACS MS/BS prototypes and the AeroMACS network limitations prevented the verification of the following profile compliances: • MCS: 16QAM ¾ and 64QAM • DL/UL Data Transfer with Security • Hard Handover with UL/DL Data Transfer	PART
AeroMACS_VVO_Interop_02	Link adaptation	Assessment of the different modulation schemes and the throughput hence supported. Verify proper DCD/UCD reception and decoding	Lab2_x	Partially OK	The AeroMACS MS/BS Link adaptation is OK. However, the AeroMACS MS/BS prototypes limitations prevented the verification of the following: • MCS: 16QAM ¾ and 64QAM	PART
AeroMACS_VVO_Interop_03	Network Entry	Verify that AeroMACS MS and BS perform all relevant actions at Network Entry that affects the air interface	Lab1_x	OK	The AeroMACS MS successfully performed the Network Entry Procedure, i.a.w. the IEEE Std 802.16™-2009 and the AeroMACS Profile.	OK

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_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, throughput	Lab4_1 T002	OK	The AeroMACS MS successfully supported the QoS classes, i.a.w. the IEEE Std 802.16™-2009 and the AeroMACS Profile.	OK
AeroMACS_VVO_Interop_05	Service Flows establishment, change and deletion	Verify the completion of the control messages transmission to succesfully complete the creation, change and deletion of a service flow to the MS.	Lab4_1	OK	The AeroMACS Profile foresee that the AeroMACS MS receives the SFs during the NET Entry Procedure; if the AeroMACS MS request a service the AeroMACS BS checks if this service can be supported by one of the already configured SF. NO new SF will be added.	OK
AeroMACS_VVO_Interop_06	MS channel quality report	Verify the Fast Feedback Channel Allocation of the BS in order to get information on the currently SNR the MS has.	Lab2_x	OK	These tests have verified the correct use of CQI channels during the Closed Loop Power Control Execution, also verifying the CLPC performance. AeroMACS MS and BS were switched on, and the Network Entry was completed. The CQICH procedure and Closed Loop Power Control had been previously enabled on the BS, which allocated a CQICH sub-channel to the MS using a CQICH IE (CQICH Allocation IE), in order to allow the MS to send periodic CINR reports. The CQICH Allocation, together with the periodicity expressed in frames (8 in this case).	OK

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO _Interop_07	Dynamic BW allocation	Verification of correct allocation of MAC resources	Lab4_1 Lab4_7 Lab4_8	OK	These tests verified the capability of the AeroMACS MS prototype : • To reserve the bandwidth i.a.w. the QoS schema adopted when requested • to assign high priority service (SF data) more bandwidth than lower priority services (SF data)	OK
AeroMACS_VVO _Interop_08	Scanning for cell selection (HO)	This should be related to the scanning procedure the MS makes periodically just to figure out what are the neighbour BSs.	Lab7_1 T004 T105	OK OK	These series of tests have verified the AeroMACS MS prototype inter-frequency MS-Triggered Handover (hard handover) features are correctly implemented, namely: • Verify the MS Handovers towards a neighbor BS (without data transfer) Scanning for cell selection has been verified to work properly in a deployed environment	OK
AeroMACS_VVO _Interop_09	ARQ testing	Verify the correct frame retransmission after packet losses	Lab5_x	OK	These series of tests have verified the AeroMACS PLR improvements when the link quality between MS and BS is poor.	OK

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_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.	Lab2_1 Lab2_2 T101	OK KO	These series of tests have verified that the AeroMACS MS operations in OLPC/CLPC and without PC, namely: • that the AeroMACS MS Prototype properly applies a (passive) open loop power control technique • that the MS properly applies a closed loop power control technique • that the Channel Quality Information channels are properly allocated in the CQICH region and used by the MS to transmit channel quality measures to the BS • that the channel quality measurements are sent to the BS with the chosen periodicity and verify any other option that might be applied • that all closed loop parameters (power levels, power steps, power range ...) are all applied within the specified tolerances • that the closed loop power control satisfactorily sustains a data transfer without causing any oscillation or instability in the system, The issues encountered during the car tests prevented to draw interesting conclusion on CL power control performance	PART

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_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)	Lab6_1 T003	OK KO	These tests have shown the AeroMACS MS Security features implementation. In the first step it was verified that the chosen authentication method was supported, namely No authentication or EAP based authentication. Second it was verified that after Authentication, data was properly encrypted, according to the required Private Key Management Protocol. It was not possible to these tests on Toulouse Airport due to a limitation at the level of the ASN-GW.	PART

4.1.3.2 RF specifications and performances

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_RF_01	Cell Coverage	Verify the cell coverage	Lab1_1 Lab3_1 Lab10_1 T102 T103	OK PART	The coverage was tested in Lab, with variable attenuation, to simulate a distance of approx. 3Km (Class 1 BS) The cell coverage on Toulouse Airport has been found very limited. Connectivity was possible only at some points on the Airport surface	PART
AeroMACS_VVO_RF_02	Interferences (ITU-R M1827)	Verify the out of band interference level generated	T202	OK	Some spurious signals have been detected, but these were considered acceptable in the scope of 9.16 tests	OK

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_RF_03	Spurious emissions (CEPT/ERC/REC/74-01)	Verify the spurious emissions transmitted by AeroMACS	T202	OK	Some spurious signals have been detected, but these were considered acceptable in the scope of 9.16 tests	OK
AeroMACS_VVO_RF_06	Transmission grid	Verify that AeroMACS MS transceiver can be tuned by 250 kHZ steps with respect to the 5145 MHz reference frequency.	Lab1_3 Lab11_5	OK	In this test the AeroMACS MS has been configured to perform the frequency scanning in the 5.09-5.15 GHz band, with configurable step intervals (multiple of 250KHz or 500KHz).	OK
AeroMACS_VVO_RF_09	MS scanning performance	Verify that MS can perform the frequency and channel scanning within the required durations.	Lab2_x	OK	The AeroMACS MS has been configured to scan frequencies between F_{init} and F_{Final} (configurable), with steps of 250KHz and 500KHz. Different scanning durations have been observed, depending on F_{init} and F_{Final} and frequency step selection, then an estimation for the single frequency scanning has been done, and the values is 30ms.	OK
AeroMACS_VVO_RF_10	MS ranging performance	Verify the successful completion of the ranging process	Lab1_1 T004 T105	OK KO	Initial and periodic ranging time has been tracked during Net-Entry and OLPC/CPLC processing MS Ranging performance tests could not be done in Toulouse, because of missing information in the SNMP MIB	PART

4.1.3.3 Integration of the airborne part within Aircraft

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_INT_02	Interferences with Radionav	Verify that the AeroMACS MS does not interfere with all RadioNav equipment installed on the Aircraft.	T204	OK	Electromagnetic Interference tests have been done on Aircraft to check if the AeroMACS system disturbs the aircraft's navigation and communication systems. No interference has been detected.	OK
AeroMACS_VVO_INT_04	Ethernet interface	Verify that AeroMACS MS interface complies with IEEE 802.3 – CSMA-CD/Ethernet Protocol on the interface connected to the on-board IP network.	Lab1_0 T005	OK OK	Compliance verified	OK
AeroMACS_VVO_INT_05	On-Ground power-on	Verify that the AeroMACS MS is powered on when the aircraft is on ground	Lab1_0 T006 T205	OK	Compliance verified	OK
AeroMACS_VVO_INT_06	In Flight Inhibition	Verify that the AeroMACS MS data function transmissions is automatically inhibited when the Aircraft is in flight	Lab1_0 T006 T205	OK	Compliance verified	OK

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_INT_07	Antenna installation	Verify that the AeroMACS antenna can be installed according to the rules defined in the document WP9.16-D02; Verify that the Antenna Subsystem can be installed in pressurized or unpressurized area. Verify that the AeroMACS antenna installation and connection to the AeroMACS MS unit complies with the 3 dB losses requirements. Verify that AeroMACS MS antenna connector complies with TNC 50Ω connector standard.	Lab1_0 T007 T206 T207	OK OK OK OK	The AeroMACS MS Antenna was successfully installed on Aircraft	OK
AeroMACS_VVO_INT_08	Antenna isolation	Verify that the AeroMACS MS antenna installation provides 20 dB space isolation with other Aircraft systems. Verify that the AeroMACS MS antenna installation provides 40 dB space isolation with other Aircraft systems operating in C-Band.	T208 T209	OK	Measurement on A/C have confirmed that the isolation space between the AeroMACS MS antenna and other A/C systems operating in C-Band is more than 40dB. Moreover, the space isolation between AeroMACS antenna and other aircraft systems is better than 20dB.	OK

4.1.3.4 Performances in real environment

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_RFReal_01	Spectrum operations	Verify that Aero MACS BS/MS operates in the extended MLS band between 5091 and 5150 MHz with a 5MHz spacing between channels.	Lab1_1 T008	OK	Compliance verified	

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_RFReal_02	Real deployment	Characterize the coverage (signal strength) of Airbus facilities and runways in real testing environment.	T106 T210	OK KO	In between the MS located at Airbus laboratory and the BS located at the Airport, AeroMACS connectivity was successfully established and data transfers were done. A high packet loss rate has been observed however. The cell coverage on Toulouse Airport has been found very limited. Connectivity was established and data transfer done only at some points on the Airport surface	PART
AeroMACS_VVO_RFReal_03	Modulations performances	Characterize the performances of the AeroMACS modulations in real environment (uplink and downlink data latency, round-trip time, real throughput available, jitter…).	T009 T010 T011 T107 T108 T109 T110 T211 T212 T213 T214	OK OK OK OK OK OK OK OK KO KO KO	The performances of AeroMACS have been characterized in real environment with static tests from Airbus laboratory tests and static+mobile car tests. From Airbus lab and with the car, the measured data latency, RTT, throughput, and jitter are in line with the expectations. However a high packet loss rate was also observed Tests on Aircraft were unsuccessful.	PART
AeroMACS_VVO_RFReal_04	NLOS performances	Evaluate the impacts of buildings, hangars, aircrafts and other obstructions on the coverage and the strength of the signal (phase difference).	T111 T215	KO KO	Tests in NLOS were unsuccessful. The MS failed to register to the BS.	KO

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_RFReal_05	Hard Handover	Verify that the AeroMACS MS supports the hard handover procedures as required in the AeroMACS profiles. Verify that the AeroMACS MS supports handover over infrastructures implementing all cell sectorisation types. Verify the impacts of handover on data exchanges.	T112 T216	KO KO	A problem discovered on the ASN-GW (the ASN-GW was not able to set up automatically an IP-IP data tunnel between itself and the PC behind it) prevented the possibility to do Security and Handover testing with DL/UL data transfer between the end systems. Because of this problem, and because of the difficulties for the MS to receive signals from the BS on large part of the Airport surface, the handover tests were cancelled.	KO
AeroMACS_VVO_RFReal_06	Reception at Aircraft	Measure the level of signal received in some significant places near and below the aircraft. Measure the level of signal received in some significant places inside the aircraft (cockpit, avionic hold, cabin).	T217	KO	At the place where the Aircraft could be parked for these tests (see Figure 153), no signal was received from the BS by the MS	KO
AeroMACS_VVO_RFReal_07	Multi-channel utilisation	Validate the possibility to communicate simultaneously on several channels without interference or impact on performances from one channel to the others.	T113 T114	KO KO	The mask currently implemented in the prototype does not allow simultaneous data traffic in adjacent channels. Simultaneous traffic in non-adjacent channels was not tested due to lack of time after the long time spent and difficulties encountered with the tests on one single channel.	KO

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_RFReal_08	Mobility performances	Evaluate the impact of mobility on the communications, with speeds below the one specified in the technology standard (without handover and at a constant speed).	T116 T218 T219 T102	KO KO KO PART	Mobility tests with the car and with the Aircraft on the taxiways, as initially envisaged were cancelled, because the MS-BS connectivity could be established only at some points on the Airport surface. However, during the cell coverage measurement tests, while moving the car from one static position to another, the MS succeeded at some occasion to register to the BS and to maintain the AeroMACS connection while the car was moving at around 40Km/h	PART

VVO ID	VVO Title	VVO Description	9.16 Test	Test Result	Tests results summary / Comments	VVO Status
AeroMACS_VVO_RFReal_09	Interferences to/from AMT	Verify the impact of AeroMACS system on AMT in co-channel. Verify the impact of AMT system on the AeroMACS in the same band.	T117 T118	OK OK	No interference from AMT onto AeroMACS is observed when a guard band greater than or equal to 3Mhz exist between AMT and AeroMACS signal No interference is observed when the AMT transmitter (i.e. the test A/C) is at a distance greater than 2Km (even with no guard band or if AMT and AeroMACS are used on overlapping channels) Hence, cases of interferences in between AeroMACS and Airbus AMT seem to be manageable, because in-flight AMT-equipped Aircraft should not interfere with AeroMACS communications at Airport. Interference issues may be encountered only on few French Airports where AMT-equipped Aircraft can land No issue of interference from AeroMACS onto AMT is identified	OK
AeroMACS_VVO_RFReal_10	Interferences to/from MLS	Verify the impact of AeroMACS system on MLS in co-channel. Verify the impact of MLS system on the AeroMACS in the same band.	T119 T120	OK OK	No interference in between MLS and AeroMACS was observed	OK

4.2 Analysis of Verification Exercises Results

Selex ES verification exercises strategy did not focus on the definition of punctual test cases for the single VVOs verification but rather on the main AeroMACS profile operational parameters validation, by means of the following test categories:

- Physical Cases
- Environmental and EMI/EMC
- Connection Establishment/Network Entry
- Power Control
- Link Adaptation
- QoS
- ARQ
- Security
- Handover
- Mobility
- Multiple MS
- MS TX Characteristics, Configuration & Monitoring

The results are summarized in the following paragraphs.

The analysis of Airbus Verification Exercises in deployed environment at the Toulouse Airport is given under the form of conclusions and recommendations in Chapter 5.

4.2.1 Physical Cases

These series of tests have demonstrated the AeroMACS MS prototype compliance to the requirements set in D04 Deliverable.

4.2.2 Environmental and EMI/EMC

These series of tests have demonstrated the AeroMACS MS prototype Environmental and EMI features are i.a.w. the Airbus requirements, namely:

- Ground Survival High Temperature
- Ground Survival Low Temperature
- Operating High Temperature
- Operating Low Temperature
- Radiated RF emissions
- Conducted RF emission
- Radiated Susceptibility
- Conducted Susceptibility
- Lightning Cable Bundle on Power and Ethernet lines

4.2.3 Connection Establishment/Network Entry

These series of tests have demonstrated that AeroMACS MS prototype start frequency scanning, synchronize on the channel, and make successfully Network Entry, namely:

- both BS and MS use orthogonal frequency-division multiple access
- both BS and MS use 5 MHz Channel Bandwidth
- both BS and MS use 5 ms Frame Length
- both BS and MS are able to operate in TDD mode
- the Channel Frequencies used in the AeroMACS are in 5091- 5150 MHz range
- MS starts with the scanning of the spectrum. It has been checked the correct decoding of the preamble by the MS in order to get synchronized with the BS. In addition, It has been verified the correct decoding of DCD message for getting all the DL parameters.
- after successful DL Synchronization, MS send a CDMA code at a power level below PTX_IR_MAX, measured at the antenna connector.
- 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.
- the correct reception of Basic CID and Primary CID.
- the correct exchange of Service Basic Capability information
- the Admission Control Procedure
- BS and MS successfully conclude the registration procedure
- MS connects successfully to BS for each configured channel
- MS, after a signal loss is able to re-establish the DL Sync

Results of these tests have demonstrated the AeroMACS MS capability to connect to the AeroMACS Net in several conditions, even when moving, with and without security (authorization and crypto). The main concern for this validation exercise is about Net Entry timing, currently longer than required, mainly due to the following factors;

- AeroMACS MS run into service; this factor will be certainly reduced when final products will be implemented;
- the Scanning Procedure algorithm implementation. The possibility to scan the AeroMACS band between F1 to F2, with 250KHz and 500KHz steps, is powerful and allows Airport frequency selection flexibility, but at the cost of significant timing increase to find the operative AeroMACS channel. To reduce the network entry timing and comply with the requirement different solution has to be found the make the AeroMACS MS ready for operations as soon as possible after aircraft landing.

Several RF measurements have been done, to show mainly:

- the AeroMACS MS Prototype TX Power is 30dBm (Class 3, i.a.w the AeroMACS profile)
- the AeroMACS MS Prototype TX spectrum is 5MHz wide
- the AeroMACS MS Prototype TX spurious emissions are within the limit i.a.w AeroMACS MOPS 2013-02-13 draft P

4.2.4 Power Control

These series of tests have demonstrated the AeroMACS MS Prototype operations in OLPC/CLPC and without PC, namely:

- the AeroMACS MS Prototype properly applies a (passive) open loop power control technique
- the MS properly applies a closed loop power control technique
- the Channel Quality Information channels are properly allocated in the CQICH region and used by the MS to transmit channel quality measures to the BS
- the channel quality measurements are sent to the BS with the chosen periodicity and verify any other option that might be applied
- all closed loop parameters (power levels, power steps, power range ...) are all applied within the specified tolerances
- the closed loop power control satisfactorily sustains a data transfer without causing any oscillation or instability in the system, facing channel gain variations of up to 30 dB/s

The results of these tests have demonstrated the AeroMACS MS OLPC/CLPC capability compliant to the AeroMACS Profile requirements.

4.2.5 Link Adaptation

These series of tests have demonstrated the AeroMACS MS Prototype link adaptation in different link conditions, namely:

- the MCS in different link conditions
- the MCS against the variations of CINR

The results of these tests have demonstrated the AeroMACS MS Prototype capability to use different MCS in different link conditions, in compliance with the AeroMACS profile; anyway, even in LAB environment, the CINR has never exceeded 15÷20 db, due to a limitation on the AeroMACS MS RF Unit, then it has not been possible to observe higher MCS, namely 16QAM ¾ and 64QAM. These higher MCS have been observed only simulating the RF channel, therefore in absence of noise.

4.2.6 QoS

These tests have demonstrated the AeroMACS MS Prototype QoS implementation in compliance with the AeroMACS profile, namely:

- all the type of SF is supported, namely BE/RTPS/nRTPS/eRTPS/UGS
- multiple SFs support (up to four)
- DL data throughput for several FEC Codes and types of flow
- UL data throughput for several FEC Codes and types of flow
- DL-UL data throughput for several FEC Code and types of flow
- from-to MS Round Trip Transit Delay
- rule based on port is supported
- rule based on protocol is supported
- rule based on IP address is supported
- throughput is compliant with the MSTR configured
- throughput distribution for 2 SFs with different MSTRs configured
- bandwidth distribution for 2 SF with the same QoS parameter configured
- bandwidth distribution for 2 SF with the different priority configured

The results for DL/UL data throughput for several MCS and FEC Codes have demonstrated the AeroMACS MS Prototype capability to transmit/receipt data at the theoretical speed limit (e.g. MCS 16QAM 1/2, DL:UL Ratio 35:12 => DL throughput = 5Mbps, UL throughput=1.3Mbps).

The results for From – MS RTT and To – MS RTT (95th percentile), in the two cases, have been < 61ms and < 64ms

4.2.7 ARQ

These tests have demonstrated the AeroMACS MS Prototype ARQ feature, and its benefits in terms of Packet Loss Radio reduction when the AeroMACS link quality is poor.

4.2.8 Security

These tests have demonstrated the AeroMACS MS Prototype Security features implementation.

In the first step it has been demonstrated that the chosen authentication method was supported, namely:

- No authentication
- EAP based authentication.

In the second step it has been demonstrated that after Authentication, data (actually the DHCP only message) was properly encrypted, according to the required Private Key Management Protocol.

The results for Authentication have demonstrated the AeroMACS MS Prototype capability to authenticate and register on the AeroMACS network using X.509 certificates.

A network problem, identified on the ASN-GW component, prevented the data exchange after registration between the end system behind the MS and the one behind the ASN-GW. This bug is currently under investigation by the ASN-GW supplier.

4.2.9 Handover

These tests have demonstrated the AeroMACS MS Prototype MS prototype inter-frequency MS-Triggered Handover (hard handover) features implementation, namely:

- the MS Handovers towards a neighbor BS (without data transfer)
- the MS Handover during data transfer

The Selex ES AeroMACS implementation foresee the possibility to handover only with the security features active (MS authenticated on to the AeroMACS network before the registration). Due to the network problem, described in Par. 4.2.8, It has not been possible to perform a complete Hard Handover test with data transfer between the end systems. Anyway it has been demonstrated the AeroMACS MS Prototype capability to perform hard handover between two BS, observing the complete hard handover procedure (cell reselection, HH Decision and initiation, synch to the second BS, ranging and net re-entry), up to the MS registration on the second BS; the MS handover interruption time measured was less than the required 200ms.

4.2.10 Mobility

These series of tests have demonstrated the AeroMACS MS prototype mobility features, using a PropSim simulator, namely:

- the MS doesn't lose the link and data with the BS in Doppler condition
- the MS doesn't lose the link and data with the BS in Doppler & Fading conditions. The fading applied vary in both delay and attenuation characteristics

The results demonstrated the AeroMACS MS prototype capability to maintain the link up (and the AeroMACS MS prototype registered on the AeroMACS network) and the data DL/UL transmission (in the worst case with PLR) in several Doppler and Fading conditions, as requested by the AeroMACs Profile, with speeds up to 105Kmph and deep fading.

4.2.11 Multiple MS

These series of tests have demonstrated the AeroMACS BS capabilities to support multiple MSs. The results demonstrated the capability of multiple MSs UL/DL data traffic to/from an AeroMACS BS.

4.2.12 MS TX characteristics, Configuration & Monitoring

These series of tests have shown the presence of TX spurious emissions out of the AeroMACS MS Prototype; This emission are below the limits i.a.w. AeroMACS MOPS 2013-02-13 draft P. The tests demonstrated also the AeroMACS MS configuration & monitoring features, as requested by the D04 Document.

4.2.13 Unexpected Behaviours/Results

During the verification exercises the following problems have been encountered:

- AeroMACS MS – The RF unit has been developed with a TX spectrum mask not compliant to the one of the MOPS/SARPS, due to the fact that RF unit developments have started before the standardization. This prevented many of the tests/demonstrations concerning the RF VVOs.
- AeroMACS MS – RF Unit HW limitations prevented the observation of high level MCS; the CINR measured, that is the values upon which the MCS is selected, never exceeded 15÷20 dB even in Selex ES LAB environment, therefore it has not been possible neither to observe nor to measure throughput for the 16QAM ¾ and 64QAM modulations
- Network Security Settings – A problem discovered on the ASN-GW (the ASN-GW was not able to set up automatically an IP-IP data tunnel between itself and the PC behind it) prevented the possibility to do Security and Handover testing with DL/UL data transfer between the end systems.
- AeroMACS MS Monitoring – The SNMP V3 MIB required in the D04 Deliverable has been developed partially, prevented the collection of some parameters (e.g. PLR). The following key information elements were missing (not implemented) in the Management Information Base of the AeroMACS system prototype:
    - The selected radio modulation
      Note: It was on the other hand possible to read the Forward Error Correction (FEC) code in log files, which allows determining the selected radio modulation. However, it was impractical to correlate the different performance metrics being extracted from the MIB with the FEC code contained in log files.
    - The Single Noise Report (SNR)
    - The TX power
    - The Bit Error Rate (BER)
    - The Packet Error Rate (PER)
    - Uplink CINR & RSSI (on BS side)
      Note: the only values available are downlink CINR & RSSI given by the MS.
    - The Ranging Time

- Poor coverage of the Toulouse Airport Surface by the BS. The probable causes of this problem are given in the next chapter. This problem heavily impacted the success of the car tests and Aircraft tests.

5 Conclusions and recommendations

5.1 Conclusions

In the following paragraphs conclusions of the verification exercises STEPs 1/2/3/4 are summarized.

5.1.1 Selex ES LAB Test Session Results (STEP 1)

Selex ES Lab tests have demonstrated the AeroMACS capacities and performances i.a.w. the AeroMACS Profile and validated the majority of VVOs. Limitations on the AeroMACS system/network have prevented the validation of a few VVOs, namely the observation of 16QAM ¾ and 64QAM modulations and relative traffic throughput together with the possibility to do Security and Handover testing with DL/UL data transfer between the end systems.

5.1.2 Real Environments Test Session Results (STEPs 2/3/4)

Concerning the Toulouse Airport AeroMACS signal coverage, the following three main AeroMACS functional behaviours have been observed as a result of the Car and Aircraft Test Sessions:

1. Areas where the signal level was such as to have the RSSI of data from -87 dBm up and where the MS was able to register both motionless and in movement on both the BS on North or South side.
2. Areas where the MS did not register and was not able to receive a proper signal level and where the absence of signal was confirmed by Spectrum Analyzer measurements;
3. Areas where quality of signal received was poor (both motionless and in movement), resulting in several packet errors, causing MS impossibility to register, reduced transmission capabilities and de-registration.

The main interesting aspect in results evaluation is to investigate while, in areas of type 2 or 3, signal level received was not sufficient to provide good quality connections for surface area coverage The main interesting aspect in propagation analysis is in trying to understand the cause of a reduction of the signal level, with respect to several estimation models, in the range of 10 to 20 dB, across the whole service area even in conditions that, at a first glance, seemed very close to optical Line-Of-Sight.

The following section describes the results of the analysis of the possible causes which could explain the above behaviors.

5.1.2.1 Propagation Investigation

Post-processing investigation of results and data from car and aircraft tests, even in the absence of an extensive coverage assessment and verification activity, provide for some probable list of causes for bad coverage across Toulouse Airport area.

- Antenna Vertical Beamwidth: the antennas installed in the BS site of Toulouse had a 3 dB Vertical Beamwidth of 7°. This type of vertical radiation pattern could be too narrow for providing proper mobile coverage, especially on an area which extends up to 2.5 Km north and south bound from the BS site. In fact, in the 5 GHz bandwidth, it’s typically required to spread the radiated signal as much as possible to extend the signal coverage over wide area.
- Suboptimal installation: Antennas were installed in the only possible position in the airport, reserved to the SANDRA/SESAR ground network, on the roof of the gate building close to the south aprons of the airport. Unfortunately, this installation could impair signal radiation because of two major causes:
    - o Antennas in backward position with respect to the front of the building and airport taxiways aprons;
    - o Antennas in proximity to the metal roof of the building and metal fences of the installation platform.

- Antennas not at sufficient heights above the airport surface

- Two-rays effects: the Two-Rays model is often used as a propagation model to gain a preliminary insight on the received signal level in open and approximately plane areas with no obstruction. According to the model, It's possible to identify three different zones with respect to distance from the transmitting site:
  - LOS zone (close to the BS site): where propagation attenuation follows a free-space loss model. In several test points, received signal was quite below the expected model value as It could be in case of suboptimal installation.
  - Zone with Signal Oscillation: zone where signal incurs several oscillations across the average free space signal with deep nulls. The deep nulls effect could result in very low signal, especially in case the received free-space signal was lower than what expected (see above point).
  - Fourth-power attenuation zone: beyond cross-over distance, signal attenuates rapidly with a fourth-power law strongly reducing the radio coverage. While It's true that typically the cross-over distance (for this wavelength and MS&BS antennas' heights) is greater than the airport extension, the effective antenna heights above the reflection area, could in some case reduce this distance (this could explain some sudden signal break-over into areas of type 2). It is important to note that the crossover distance is function of BS and MS antennas heights, due to the oscillation of the landscape between BS and MS (for example of 1 or 2 meters) the "effective" antennas heights are reduced of this quantity. The effect of this subtraction is that the "effective" height of the MS antenna approach to zero, and consequently the crossover distance.

- BSs coverages not overlapped: installed antennas had a 3 dB Horizontal Beamwidth of 90° so providing a 180°-wide coverage of the runways and taxiways of the airport, resulting in a very limited coverage overlap in the area approximately facing the Airbus factory buildings. Hence, even in this area, close-to-LOS for propagation condition (even with the two-rays effect mentioned above), measured signal in several test points was well below from what expected.

- NLOS points: due to backward antenna position installations, and excluding areas shadowed by buildings, some points of the airport surface remains in pure NLOS condition and with very poor signal levels due to terrain surface variations.

5.1.2.2 Conclusions

As it should be clear from the above evaluations the main cause related to poor coverage on the Toulouse airport was linked to a signal level quite below the threshold expected as evaluated by the reference theoretical models, usually employed for radio propagation estimation, on open areas with no obstruction. Due to that, all the propagation impairments can be greatly amplified, resulting in a suboptimal functional system behavior.

5.1.3 Conclusion regarding the level of maturity achieved

The prototypes development and intensive verification activities performed in P9.16 allowed to demonstrate that AeroMACS is able to support the different services it is designed for: fixed and mobile airport ground communications, Airline Operational Communications (AOC) and Air Traffic Control (ATC). Trials conducted on airport surface even show that with an appropriate coverage of the surface by Base Stations, it can supports bandwidth demanding services in mobility.

The laboratory tests executed in closed environment in Selex laboratory and in a deployed environment from Airbus laboratory across the Toulouse airport surface, have demonstrated the AeroMACS capacities and performances in accordance with the AeroMACS Profile and validated the majority of AeroMAcs features. Limitations on the AeroMACS system/network have prevented the validation of a few points, namely the observation of 16QAM ¾ and 64QAM modulations and relative traffic throughput together with the possibility to do Security and Handover testing with DL/UL data transfer between the end systems. Difficulties have been encountered with tests done when moving at the Aircraft surface with a car, as it was observed that AeroMACS connectivity between the MS and BS could be established only at and between some points on the Airport surface. These difficulties were confirmed during the Aircraft tests, which resulted in aborting the Aircraft test session. However, the cause of these difficulties is attributed to the poor coverage of the airport surface by the Base Stations and to installation issues, and not to particular deficiencies of the AeroMACS technology. And P9.16 car tests still allowed to demonstrate, in areas appropriately covered by the Base Stations, that the Mobile System is able to register both motionless and in movement (at 40Km/h) and to support data exchanges with very good performances in line with the expectations.

Taking into account the combination of the P15.2.7 and P9.16 project results, and the above analysis on the causes of the difficulties encountered during P9.16 car and aircraft tests, the project considers that the AeroMACS technology has reached a very mature stage of TRL5 level. For OCVM, the correspondent maturity level is placed between V2 and V3, closer to V3.

And it is considered that the difficulties experienced during car and aircraft tests in P9.16 do not put at risk the above assessment, given that:

- these problems can be explained by the poor coverage of the airport surface by the Base Stations combined with installation issues,
- with a better placement (higher) of the Base Stations, P15.2.7 has demonstrated that these difficulties are not encountered.
- The AeroMACS profile has been extensively tested and validated with Steps 1 and 2 exercizes

5.2 Recommendations

Concerning AeroMACS system/network limitations observed in the successive verification exercises, a better system design will for sure resolve the modulation issues; resolution of ASN-GW bugs will allow to have secure DL/UL data transfer and handover. Hence:

- AeroMACS prototypes RF performances improvements should be implemented, tested and verified on field in order to validate full modulation coding scheme (up to 64QAM) performances.
- AeroMACS prototypes Security and Handover features and performance for connection establishment/network entry would need to be re-tested and validated on field, having solved the issue concerning Airport Signal Coverage and ASN-GW Bug, as already reported in the deliverable
- Mobility features (doppler and Handover) would need to be re-tested and validated on field at maximum speed (50 knots)

Concerning Airport AeroMACS signal Coverage observed in STEPs 2/3/4 the above propagation analysis cannot be considered exhaustive; three principal preliminary activities are recommended for any future trials/deployments to be executed on the Airport:

- Perform Survey and Coverage Prediction Analysis: prediction analysis is the most important activity before deploying a radio mobile network, particularly in the 5 GHz band. Careful site survey can guarantee for an optimal installation and/or provide fundamental information for coverage prediction. During Coverage Prediction Analysis, several prediction models can be evaluated and customized to provide signal level and service level estimations as well as "what-if" estimations for site and antenna positioning. Based on result of Coverage Predictions a detailed map of the service area can be used as a guideline for the service levels expected across the area of interest.
- Perform Coverage Assessment and Optimization: Coverage assessment should be performed after having obtained the coverage prediction in order to assess and/or tune the prediction model and possibly identify any discrepancy between measured signal levels and expected ones. A closed-loop process can be identified by performing prediction, assess them, tune the model, predict again until reaching a high confidence on results. Based on that, radio and network coverage could be optimized towards a better service level and improved performances.
- Use proper antennas and antennas installation: coverage prediction can also provide accurate indications on type and characteristics of antennas to be used and installation options (azimuth, down tilt and pattern overlap). And a particular attention shall be paid on the quality of the components (notably the wires, the antennas, the electronic equipment that may be faced to

variable environmental conditions). The components shall be selected to sustain the changing environmental condition (rain, snow, wind, cold, warmth) for the full duration of the exercise, the manipulations by operators on the field (installation/desinstallation on cars, shipment of the product through international delivery services, etc..), and the condition of the verification exercises (e.g. vibrations)

6 STEP 1 Verification Exercises Report (SELEX Laboratory tests)

6.1 Verification Exercise Scope

The scopes of Selex ES laboratory tests, i.a.w. the deliverable D06 - Airborne AeroMACS test strategy, objectives, and test beds architecture, are summarized hereafter:

- Validate the AeroMACS Profile, in collaboration with the WP 15.2.7, and the detailed Airborne AeroMACS requirements
- Verify the AeroMACS MS prototype against the specifications (D04) to prepare the implementation of the AeroMACS MS prototype on the Aircraft
- Validate and verify the interoperability between Selex AeroMACS MS prototype and AeroMACS BS prototype to test the field environment in preparation of the Car and Aircraft tests.

6.2 Conduct of Verification Exercises

6.2.1 Verification Exercise Preparation

The Verification Exercise has been performed in the SELEX ES Lab Test Bench architecture, represented on Figure 6 and Figure 7 below. The Test Bench is composed of:

- The AeroMACS MS Avionic Prototype
- One or two AeroMACS BS prototypes
- The Power Supply Unit
- A Control PC
- An RF Bench (Fixed Attenuator, Coupler and Stepped Attenuator)
- Traffic Generator
- Fading Simulator
- Cisco Router
- ASN-GW
- AAA Server
- Spectrum Analizer
- PROPSim wideband Multi-Channel Simulator

The AeroMACS MS Avionic Prototype is connected to the AeroMACS BS through the RF Bench.

The Control PC is used to monitor the AeroMACS MS Prototype and AeroMACS BS State/activities. The Router is used to connect the ASN-GW and the Traffic Generator to the AeroMACS BS. The Traffic Generator is used to test the Traffic between AeroMACS BS and AeroMACS MS Prototype. The PROPSim Simulator is used to simulate Speed and Distance effects on AeroMACS MS.

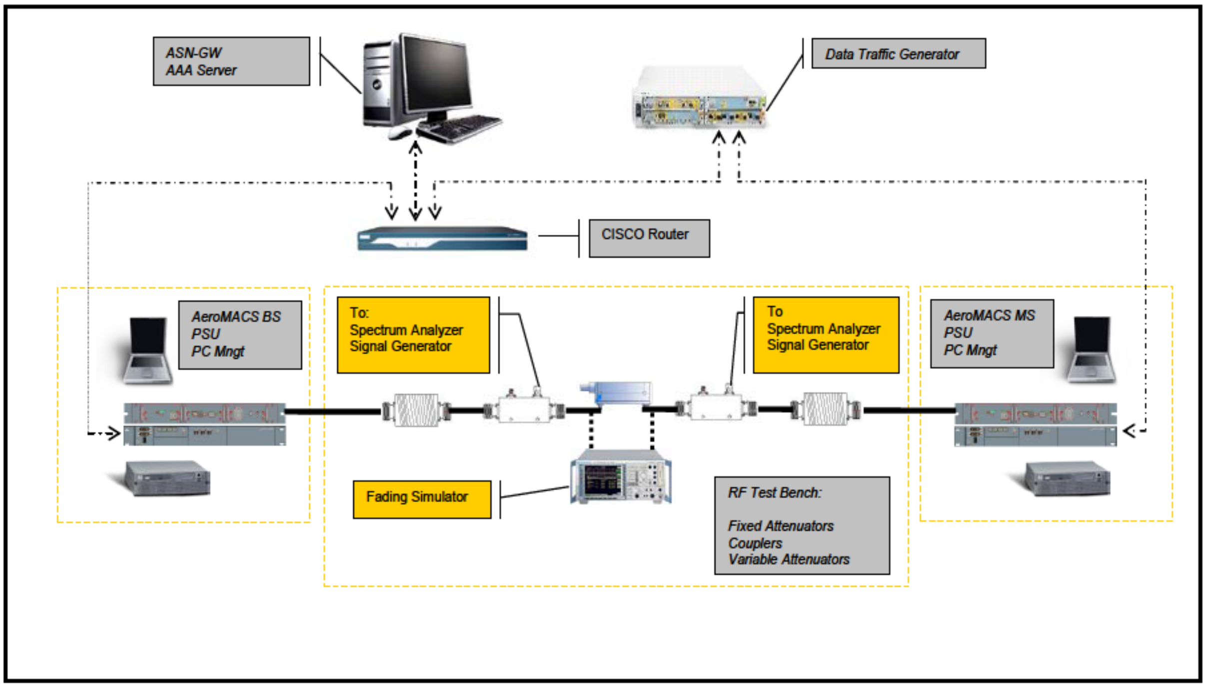

Figure 6: Test Bench used for AeroMACS PtP fixed Tests

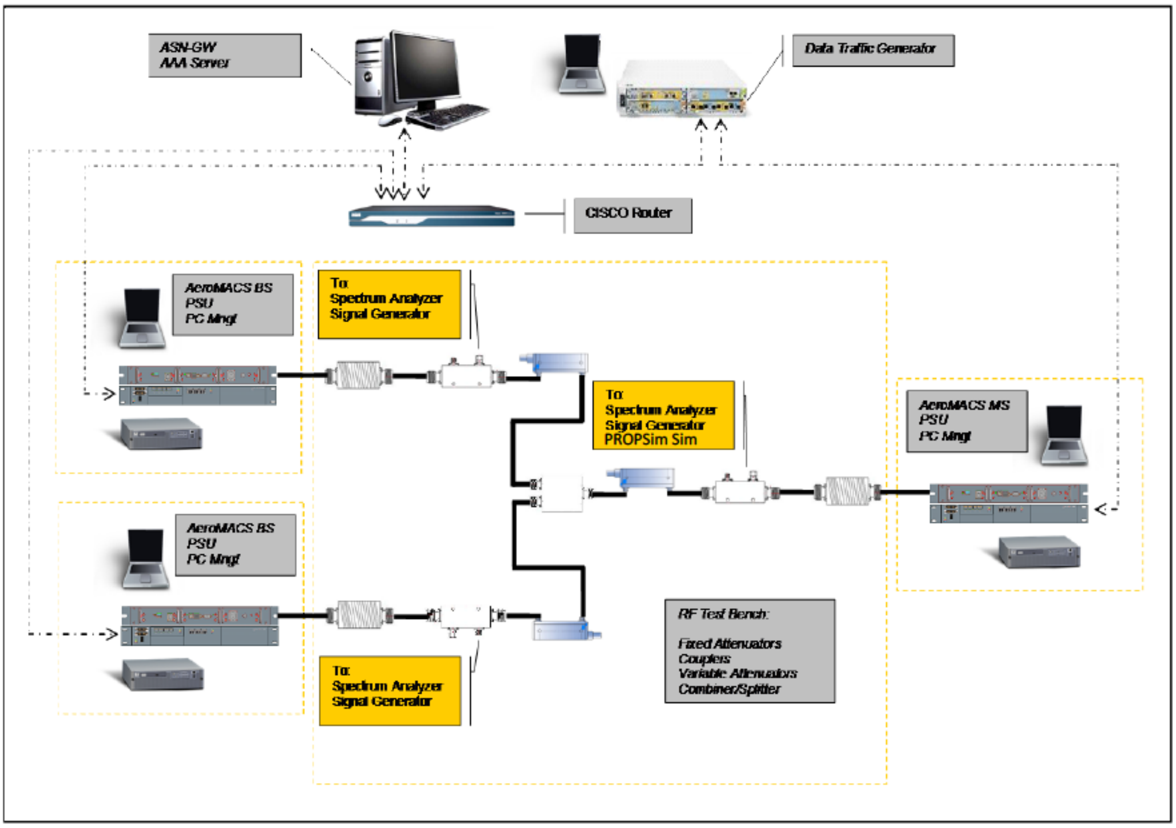

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Figure 7: Test Bench used for AeroMACS Handover and Mobility Tests

6.2.2 Verification Exercise execution

Refer to Table 1 in section 3.2 for the overall timing of Step 1 exercises.

The approach followed during execution of the Verification Exercise is described in Annex A of 9.16-D05 ([9]).

6.2.3 Deviation from the planned activities

Refer to Table 2 on page 23.

6.3 Verification exercise Results

6.3.1 Summary of Verification exercise Results

Refer to Table 3 on page 25.

6.3.2 Analysis of Verification Exercise Results

In the following paragraphs are reported the STEP1 verification exercises.

6.3.2.1 Lab0_X Physical Features

These series of tests have verified, by tests, observation and check, some AeroMACS MS Prototype physical requirements' set in deliverable 9.16-D04 [8], namely:

- Power-on indicator light
- Connectivity indicator light
- Ground/Flight indicator light
- Reset push-button operation
- On/Off Toggle switch
- 50Ω output impedance TNC connector
- Two Ethernet Full Duplex RJ45 interfaces
- Coaxial cables
- 28VDC feed
- Rack ability in an avionics 19" Rack
- Environmental and EMI Qualification (partial)

The results of Environmental and EMI qualification tests are available for consultation.

6.3.2.1.1 Deviation from the planned activities

None

6.3.2.2 Lab1_X Connection Establishment

These series of tests have verified that MS start frequency scanning, synchronize on the channel, and make successfully Network Entry, namely:

1. Verify that both BS and MS use orthogonal frequency-division multiple access
2. Verify that both BS and MS use 5 MHz Channel Bandwidth
3. Verify that both BS and MS use 5 ms Frame Length
4. Verify that both BS and MS are able to operate in TDD mode
5. Verify that the Channel Frequencies usable in the AeroMACS are in 5091- 5150 MHz range

6. Verify 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. In addition, it should be verified the correct decoding of DCD message for getting all the DL parameters.

7. Verify that, after successful DL Synchronization, MS send a CDMA code at a power level below PTX_IR_MAX, measured at the antenna connector.

8. 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.

9. Verify the correct reception of Basic CID and Primary CID.

10. Verify the correct exchange of Service Basic Capability information

11. Verify the Admission Control Procedure

12. Verify that BS and MS successfully conclude the registration procedure

13. Verify that MS connects successfully to BS for each configured channel

14. Verify that MS, after a signal loss is able to re-establish the DL Sync

Many Objectives were verified by visual inspection of the Spectrum Analyser wired to the BS. In Figure 8 and Figure 9 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 8: Spectrum Analyser connected to AeroMACS BS

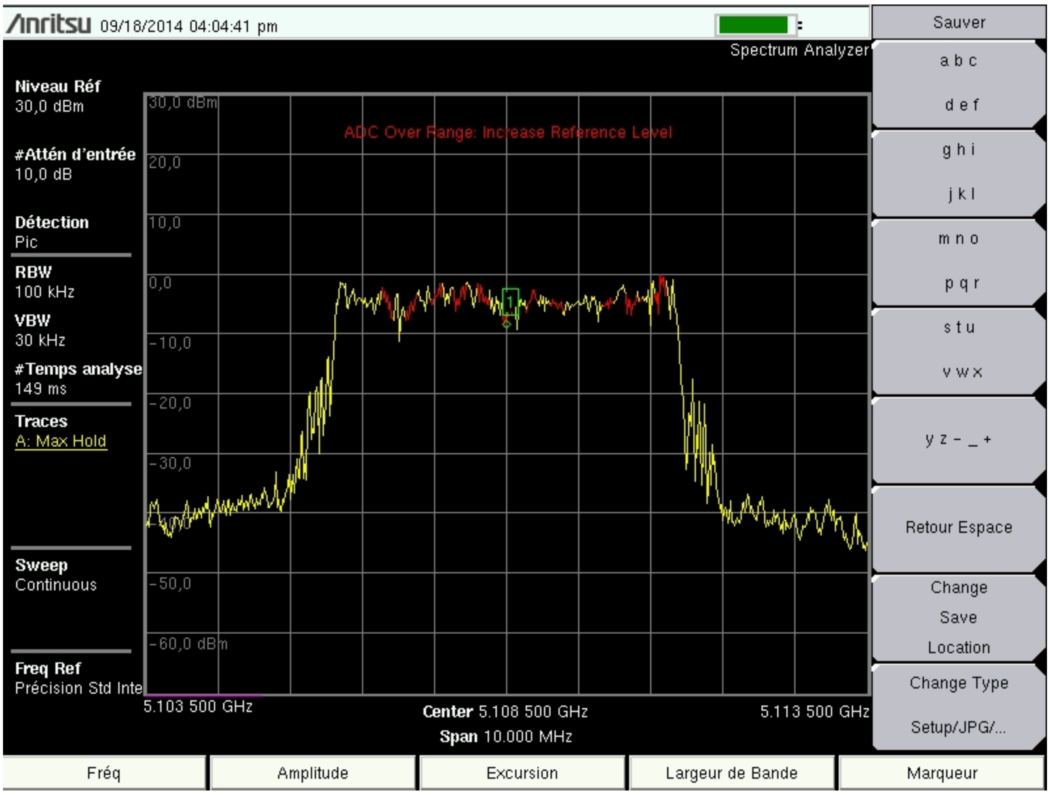
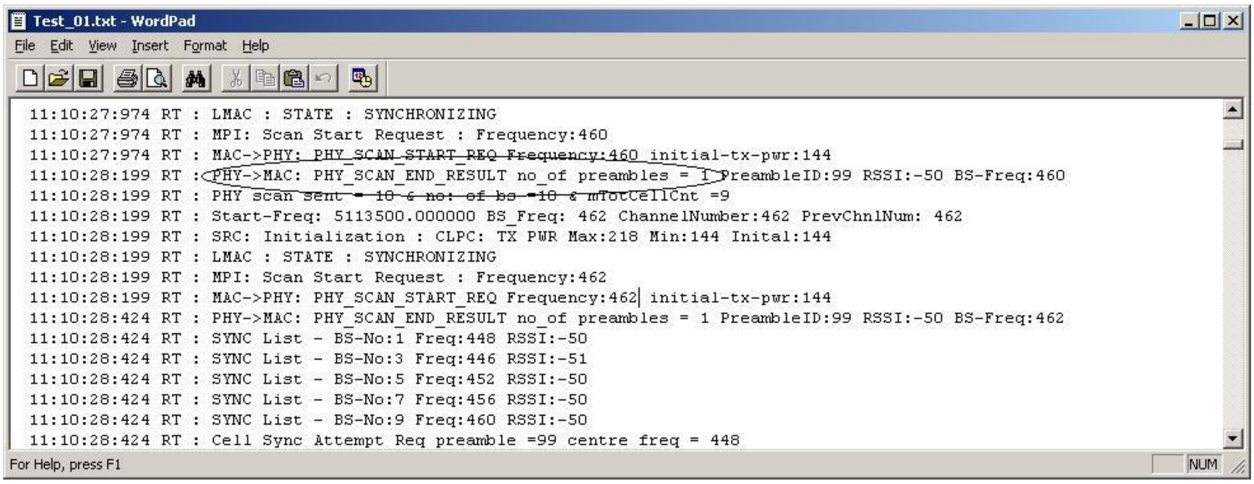


Figure 9: MS/BS Spectrum

During the test the various phases of Initial Network Entry were executed by BS and MS. 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 10: Preamble Detection by MS

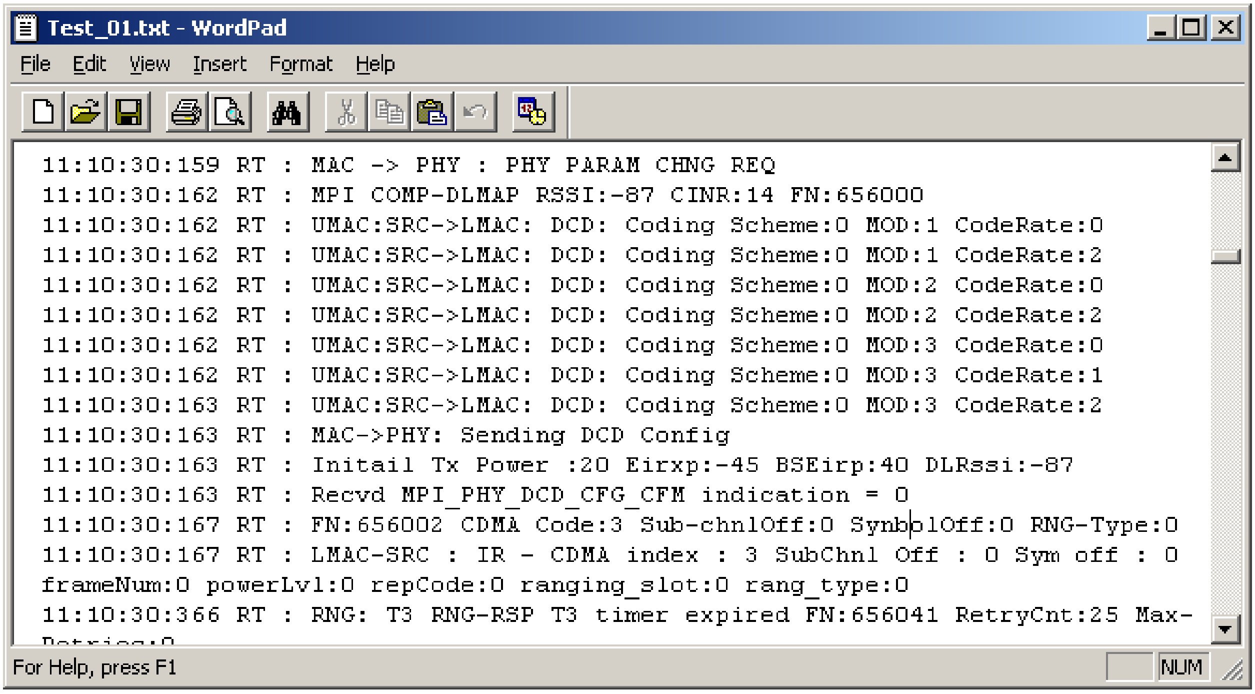


Figure 11: DCD Decoding by MS

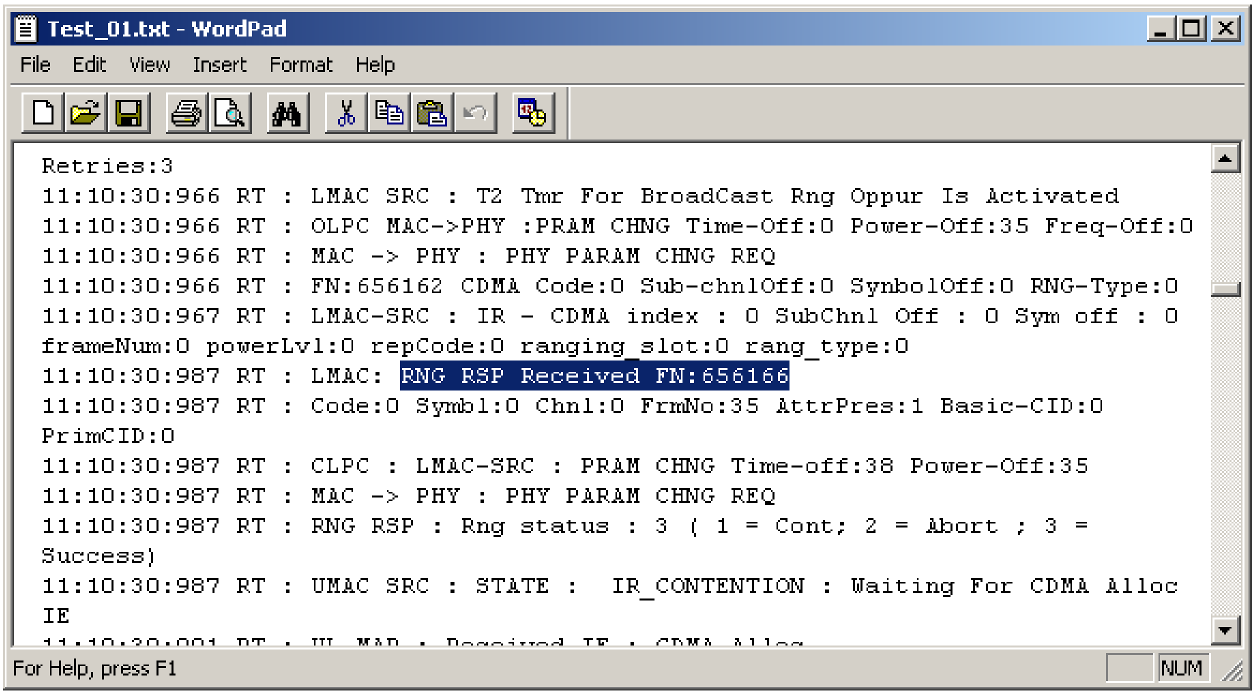
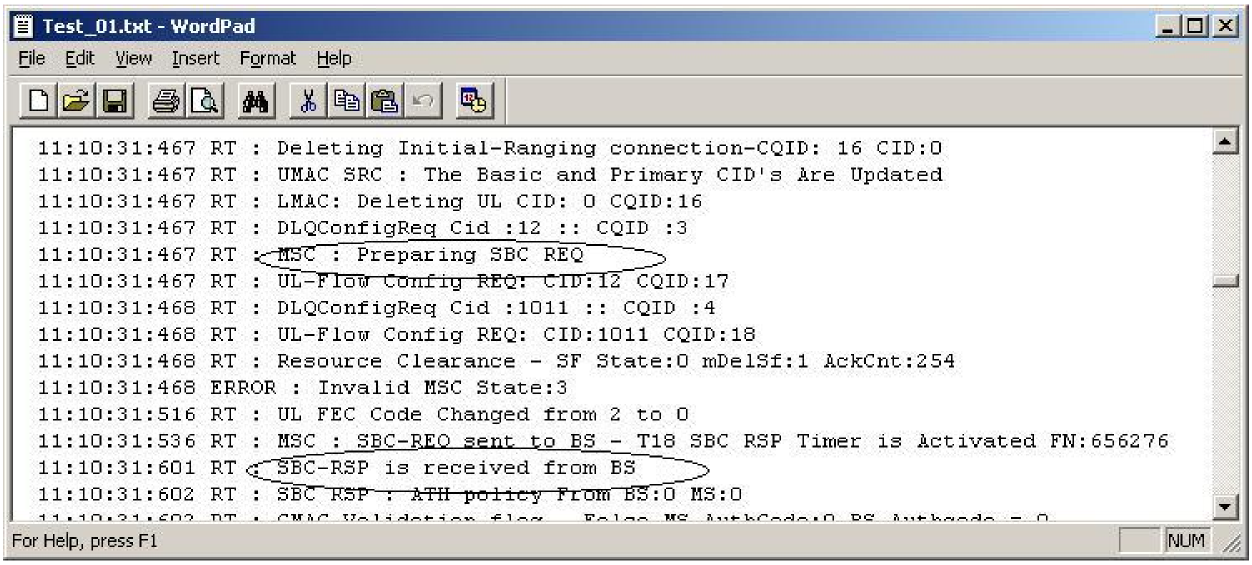


Figure 12: Initial Ranging - the MS receives a RNG_RSP with Status Success



Test_01.txt - WordPad

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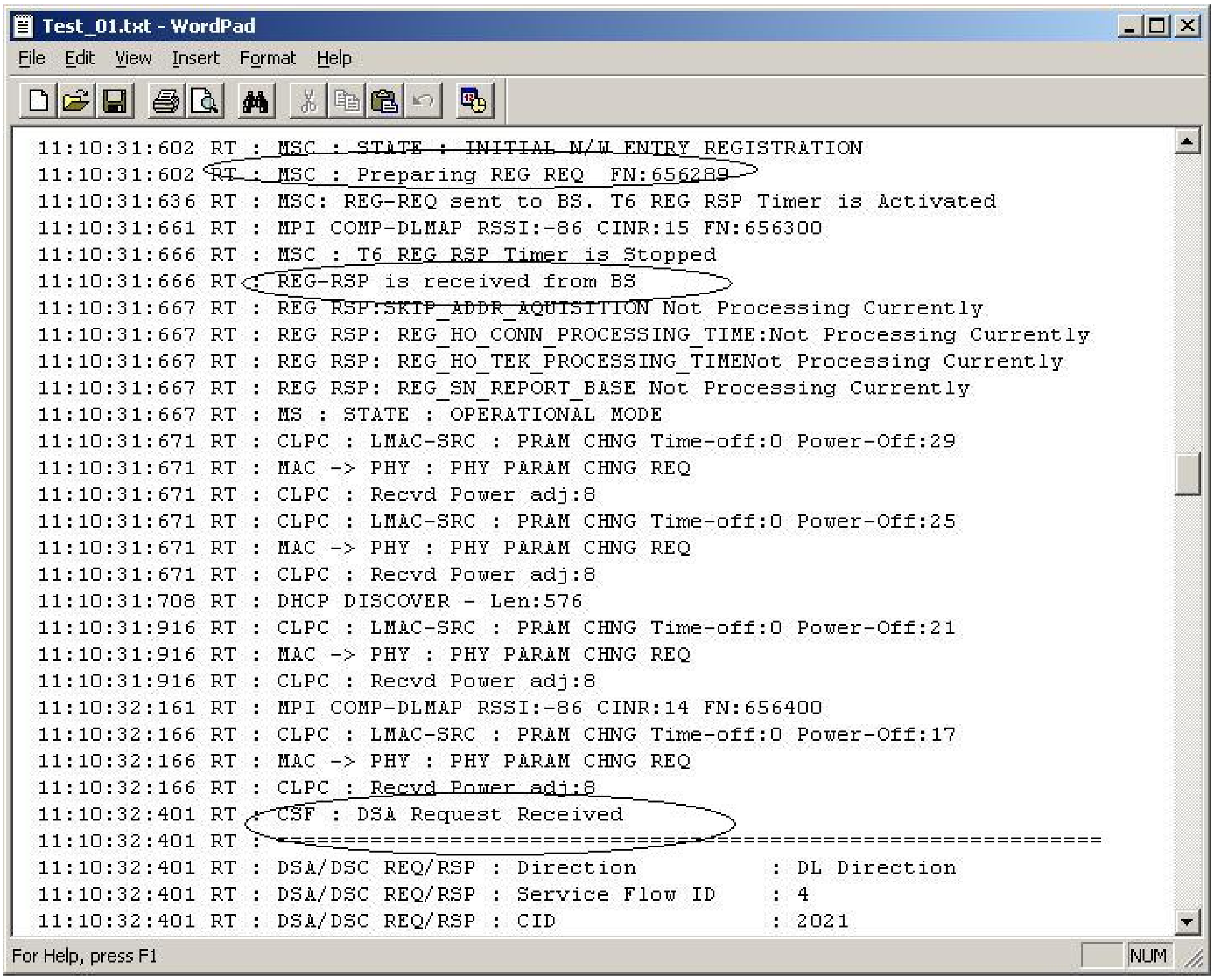
```
11:10:31:467 RT : Deleting Initial-Ranging connection-CQID: 16 CID:0
11:10:31:467 RT : UMAC SRC : The Basic and Primary CID's Are Updated
11:10:31:467 RT : LMAC: Deleting UL CID: 0 CQID:16
11:10:31:467 RT : DLQConfigReq Cid :12 :: CQID :3
11:10:31:467 RT : MSC : Preparing SBC REQ
11:10:31:467 RT : UL-Flow Config REQ: CID:12 CQID:17
11:10:31:468 RT : DLQConfigReq Cid :1011 :: CQID :4
11:10:31:468 RT : UL-Flow Config REQ: CID:1011 CQID:18
11:10:31:468 RT : Resource Clearance - SF State:0 mDelSf:1 AckCnt:254
11:10:31:468 ERROR : Invalid MSC State:3
11:10:31:516 RT : UL FEC Code Changed from 2 to 0
11:10:31:536 RT : MSC : SBC-REQ sent to BS - T18 SBC RSP Timer is Activated FN:656276
11:10:31:601 RT : SBC-RSP is received from BS
11:10:31:602 RT : SBC RSP : ATH policy From BS:0 MS:0
```

For Help, press F1 NUM

Figure 13: SS Basic Capabilities Exchange between MS and BS



Test_01.txt - WordPad

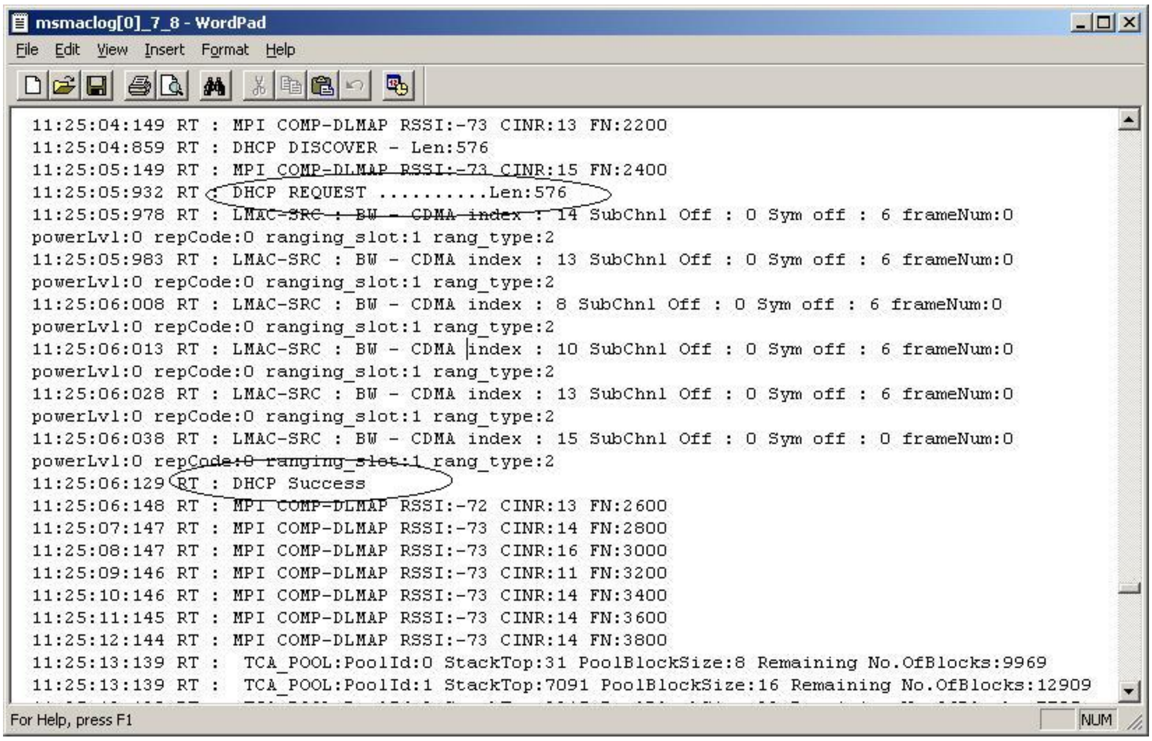
File Edit View Insert Format Help

```
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 14: Registration procedure and Service Flow Creation

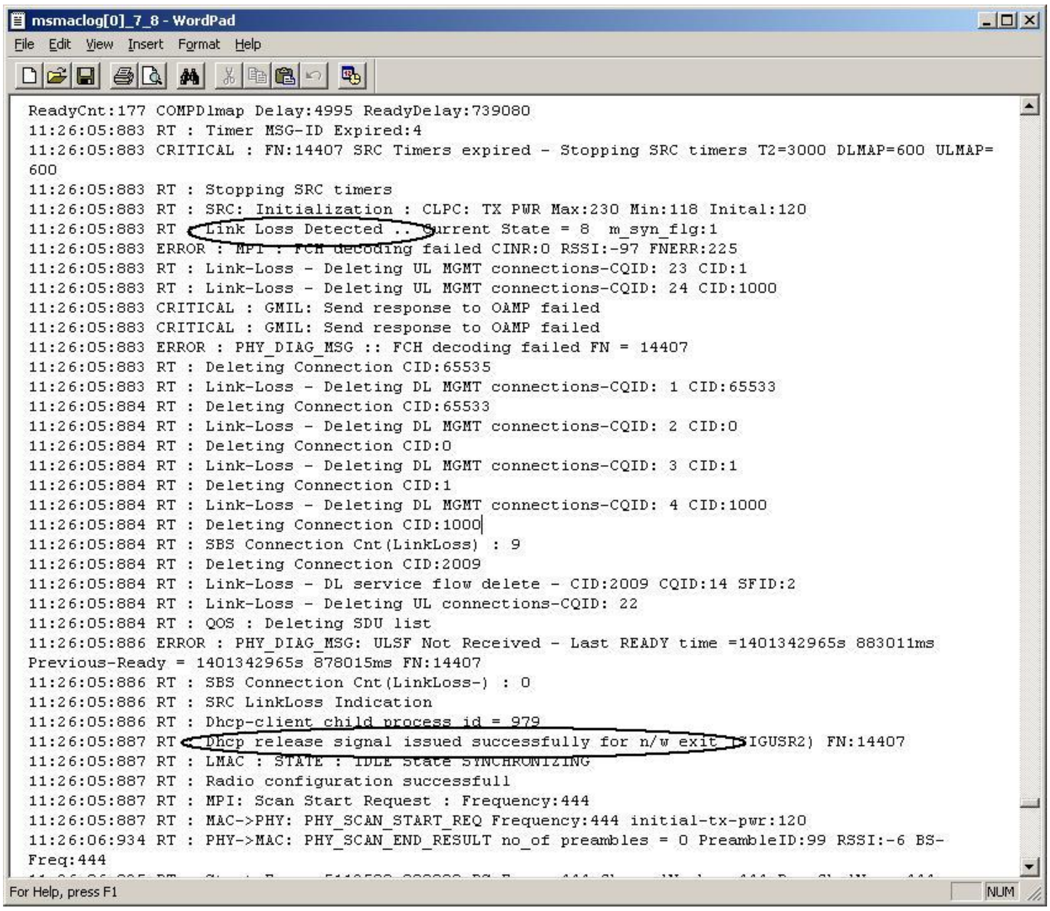
As a test preamble, the various phases of the normal Initial Network Entry was executed by BS and MS. Figure 14 shows the last step (MS DHCP Registration),



```
msmaclog[0]_7_8 - WordPad
File Edit View Insert Format Help
11:25:04:149 RT : MPI COMP-DLMAP RSSI:-73 CINR:13 FN:2200
11:25:04:859 RT : DHCP DISCOVER - Len:576
11:25:05:149 RT : MPI COMP-DLMAP RSSI:-73 CINR:15 FN:2400
11:25:05:932 RT : DHCP REQUEST .........Len:576
11:25:05:978 RT : LMAC-SRC : BW - CDMA index : 14 SubChnl Off : 0 Sym off : 6 frameNum:0
powerLvl:0 repCode:0 ranging_slot:1 rang_type:2
11:25:05:983 RT : LMAC-SRC : BW - CDMA index : 13 SubChnl Off : 0 Sym off : 6 frameNum:0
powerLvl:0 repCode:0 ranging_slot:1 rang_type:2
11:25:06:008 RT : LMAC-SRC : BW - CDMA index : 8 SubChnl Off : 0 Sym off : 6 frameNum:0
powerLvl:0 repCode:0 ranging_slot:1 rang_type:2
11:25:06:013 RT : LMAC-SRC : BW - CDMA index : 10 SubChnl Off : 0 Sym off : 6 frameNum:0
powerLvl:0 repCode:0 ranging_slot:1 rang_type:2
11:25:06:028 RT : LMAC-SRC : BW - CDMA index : 13 SubChnl Off : 0 Sym off : 6 frameNum:0
powerLvl:0 repCode:0 ranging_slot:1 rang_type:2
11:25:06:038 RT : LMAC-SRC : BW - CDMA index : 15 SubChnl Off : 0 Sym off : 0 frameNum:0
powerLvl:0 repCode:0 ranging_slot:1 rang_type:2
11:25:06:129 RT : DHCP Success
11:25:06:148 RT : MPI COMP-DLMAP RSSI:-72 CINR:13 FN:2600
11:25:07:147 RT : MPI COMP-DLMAP RSSI:-73 CINR:14 FN:2800
11:25:08:147 RT : MPI COMP-DLMAP RSSI:-73 CINR:16 FN:3000
11:25:09:146 RT : MPI COMP-DLMAP RSSI:-73 CINR:11 FN:3200
11:25:10:146 RT : MPI COMP-DLMAP RSSI:-73 CINR:14 FN:3400
11:25:11:145 RT : MPI COMP-DLMAP RSSI:-73 CINR:14 FN:3600
11:25:12:144 RT : MPI COMP-DLMAP RSSI:-73 CINR:14 FN:3800
11:25:13:139 RT :  TCA_POOL:PoolId:0 StackTop:31 PoolBlockSize:8 Remaining No.OfBlocks:9969
11:25:13:139 RT :  TCA_POOL:PoolId:1 StackTop:7091 PoolBlockSize:16 Remaining No.OfBlocks:12909
For Help, press F1                                                                     NUM
```

Figure 15: MS Log - Initial Net Entry: MS Registration

After the address assignment to the MS, the attenuation between MS and BS was gradually increased; this caused a Link Loss, with a subsequent Network Exit by the MS side (see Figure 15).



msmaclog[0]_7_8 - WordPad

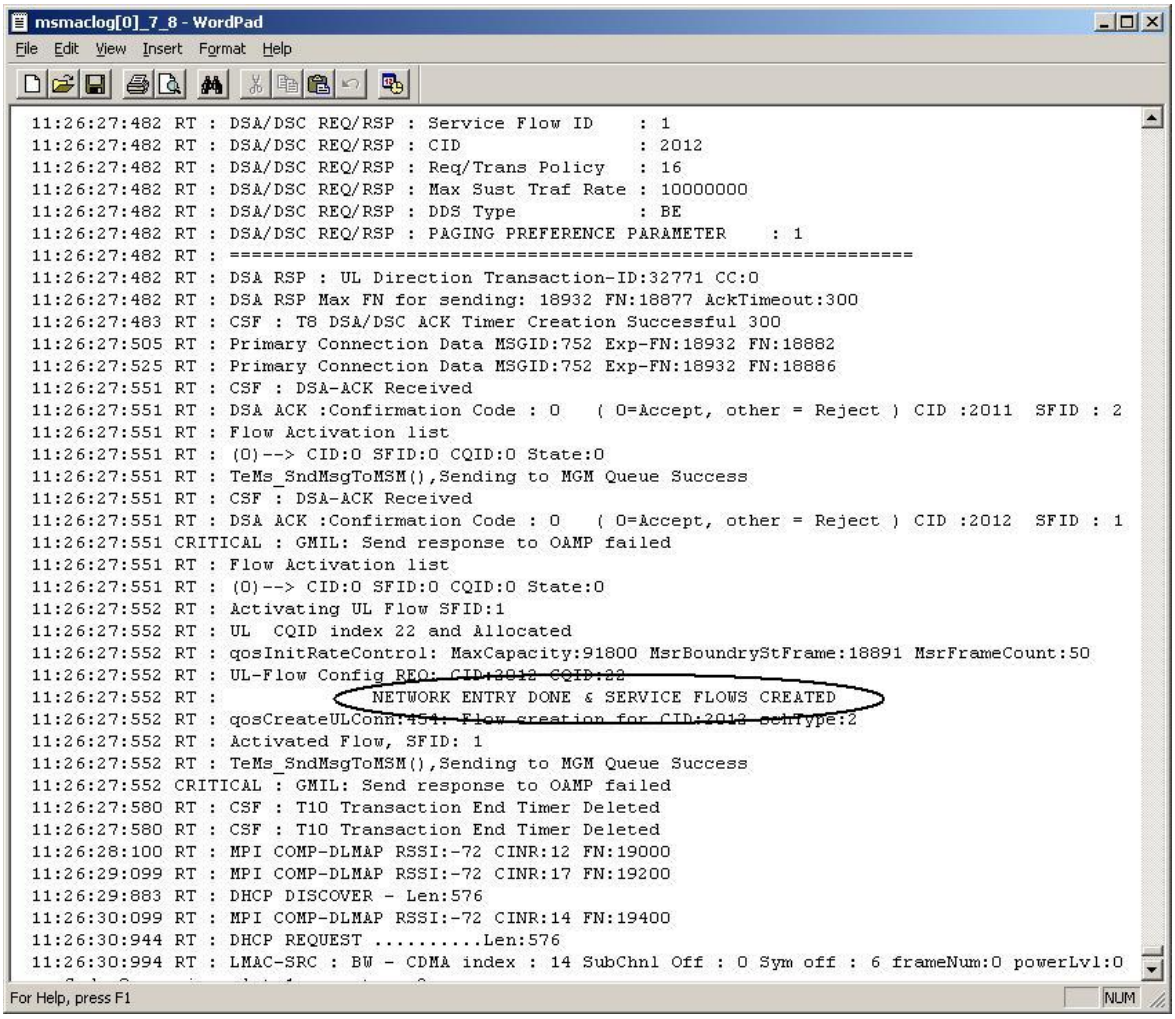
File Edit View Insert Format Help

```
ReadyCnt:177 COMPDlmap Delay:4995 ReadyDelay:739080
11:26:05:883 RT : Timer MSG-ID Expired:4
11:26:05:883 CRITICAL : FN:14407 SRC Timers expired - Stopping SRC timers T2=3000 DLMAP=600 ULMAP=
600
11:26:05:883 RT : Stopping SRC timers
11:26:05:883 RT : SRC: Initialization : CLPC: TX PWR Max:230 Min:118 Inital:120
11:26:05:883 RT : Link Loss Detected .. Current State = 8  m_syn_flg:1
11:26:05:883 ERROR : MPI : FCH decoding failed CINR:0 RSSI:-97 FNERR:225
11:26:05:883 RT : Link-Loss - Deleting UL MGMT connections-CQID: 23 CID:1
11:26:05:883 RT : Link-Loss - Deleting UL MGMT connections-CQID: 24 CID:1000
11:26:05:883 CRITICAL : GMIL: Send response to OAMP failed
11:26:05:883 CRITICAL : GMIL: Send response to OAMP failed
11:26:05:883 ERROR : PHY_DIAG_MSG :: FCH decoding failed FN = 14407
11:26:05:883 RT : Deleting Connection CID:65535
11:26:05:883 RT : Link-Loss - Deleting DL MGMT connections-CQID: 1 CID:65533
11:26:05:884 RT : Deleting Connection CID:65533
11:26:05:884 RT : Link-Loss - Deleting DL MGMT connections-CQID: 2 CID:0
11:26:05:884 RT : Deleting Connection CID:0
11:26:05:884 RT : Link-Loss - Deleting DL MGMT connections-CQID: 3 CID:1
11:26:05:884 RT : Deleting Connection CID:1
11:26:05:884 RT : Link-Loss - Deleting DL MGMT connections-CQID: 4 CID:1000
11:26:05:884 RT : Deleting Connection CID:1000
11:26:05:884 RT : SBS Connection Cnt(LinkLoss) : 9
11:26:05:884 RT : Deleting Connection CID:2009
11:26:05:884 RT : Link-Loss - DL service flow delete - CID:2009 CQID:14 SFID:2
11:26:05:884 RT : Link-Loss - Deleting UL connections-CQID: 22
11:26:05:884 RT : QOS : Deleting SDU list
11:26:05:886 ERROR : PHY_DIAG_MSG: ULSF Not Received - Last READY time =1401342965s 883011ms
Previous-Ready = 1401342965s 878015ms FN:14407
11:26:05:886 RT : SBS Connection Cnt(LinkLoss-) : 0
11:26:05:886 RT : SRC LinkLoss Indication
11:26:05:886 RT : Dhcp-client child process id = 979
11:26:05:887 RT : Dhcp release signal issued successfully for n/w exit (SIGUSR2) FN:14407
11:26:05:887 RT : LMAC : STATE : IDLE State SYNCHRONIZING
11:26:05:887 RT : Radio configuration successfull
11:26:05:887 RT : MPI: Scan Start Request : Frequency:444
11:26:05:887 RT : MAC->PHY: PHY_SCAN_START_REQ Frequency:444 initial-tx-pwr:120
11:26:06:934 RT : PHY->MAC: PHY_SCAN_END_RESULT no_of preambles = 0 PreambleID:99 RSSI:-6 BS-
Freq:444
```

For Help, press F1 NUM

Figure 16: Forced Link Loss and Network Exit

Subsequently, the attenuation between MS and BS was gradually decreased, until the MS correctly repeated the Network Entry (Figure 16).



```
msmaclog[0]_7_8 - WordPad
File Edit View Insert Format Help
11:26:27:482 RT : DSA/DSC REQ/RSP : Service Flow ID    : 1
11:26:27:482 RT : DSA/DSC REQ/RSP : CID                : 2012
11:26:27:482 RT : DSA/DSC REQ/RSP : Req/Trans Policy   : 16
11:26:27:482 RT : DSA/DSC REQ/RSP : Max Sust Traf Rate : 10000000
11:26:27:482 RT : DSA/DSC REQ/RSP : DDS Type           : BE
11:26:27:482 RT : DSA/DSC REQ/RSP : PAGING PREFERENCE PARAMETER    : 1
11:26:27:482 RT : ==============================================================
11:26:27:482 RT : DSA RSP : UL Direction Transaction-ID:32771 CC:0
11:26:27:482 RT : DSA RSP Max FN for sending: 18932 FN:18877 AckTimeout:300
11:26:27:483 RT : CSF : T8 DSA/DSC ACK Timer Creation Successful 300
11:26:27:505 RT : Primary Connection Data MSGID:752 Exp-FN:18932 FN:18882
11:26:27:525 RT : Primary Connection Data MSGID:752 Exp-FN:18932 FN:18886
11:26:27:551 RT : CSF : DSA-ACK Received
11:26:27:551 RT : DSA ACK :Confirmation Code : 0   ( 0=Accept, other = Reject ) CID :2011  SFID : 2
11:26:27:551 RT : Flow Activation list
11:26:27:551 RT : (0)--> CID:0 SFID:0 CQID:0 State:0
11:26:27:551 RT : TeMs_SndMsgToMSM(),Sending to MGM Queue Success
11:26:27:551 RT : CSF : DSA-ACK Received
11:26:27:551 RT : DSA ACK :Confirmation Code : 0   ( 0=Accept, other = Reject ) CID :2012  SFID : 1
11:26:27:551 CRITICAL : GMIL: Send response to OAMP failed
11:26:27:551 RT : Flow Activation list
11:26:27:551 RT : (0)--> CID:0 SFID:0 CQID:0 State:0
11:26:27:552 RT : Activating UL Flow SFID:1
11:26:27:552 RT : UL  CQID index 22 and Allocated
11:26:27:552 RT : qosInitRateControl: MaxCapacity:91800 MsrBoundryStFrame:18891 MsrFrameCount:50
11:26:27:552 RT : UL-Flow Config REQ: CID:2012 CQID:22
11:26:27:552 RT :             NETWORK ENTRY DONE & SERVICE FLOWS CREATED
11:26:27:552 RT : qosCreateULConn:454: Flow creation for CID:2012 schType:2
11:26:27:552 RT : Activated Flow, SFID: 1
11:26:27:552 RT : TeMs_SndMsgToMSM(),Sending to MGM Queue Success
11:26:27:552 CRITICAL : GMIL: Send response to OAMP failed
11:26:27:580 RT : CSF : T10 Transaction End Timer Deleted
11:26:27:580 RT : CSF : T10 Transaction End Timer Deleted
11:26:28:100 RT : MPI COMP-DLMAP RSSI:-72 CINR:12 FN:19000
11:26:29:099 RT : MPI COMP-DLMAP RSSI:-72 CINR:17 FN:19200
11:26:29:883 RT : DHCP DISCOVER - Len:576
11:26:30:099 RT : MPI COMP-DLMAP RSSI:-72 CINR:14 FN:19400
11:26:30:944 RT : DHCP REQUEST .........Len:576
11:26:30:994 RT : LMAC-SRC : BW - CDMA index : 14 SubChnl Off : 0 Sym off : 6 frameNum:0 powerLvl:0
For Help, press F1                                                        NUM
```

Figure 17: Network Re-entry

There are discussions about the need to specify a maximum allowed Net Entry Time for AeroMACS MSs. Currently the maximum value required in the MASPS is 90 seconds.

Measurements done in these tests 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 17 describes a possible initial Network Entry procedure comprising MS-to-Network EAP authentication process and multiple Domain authentications.

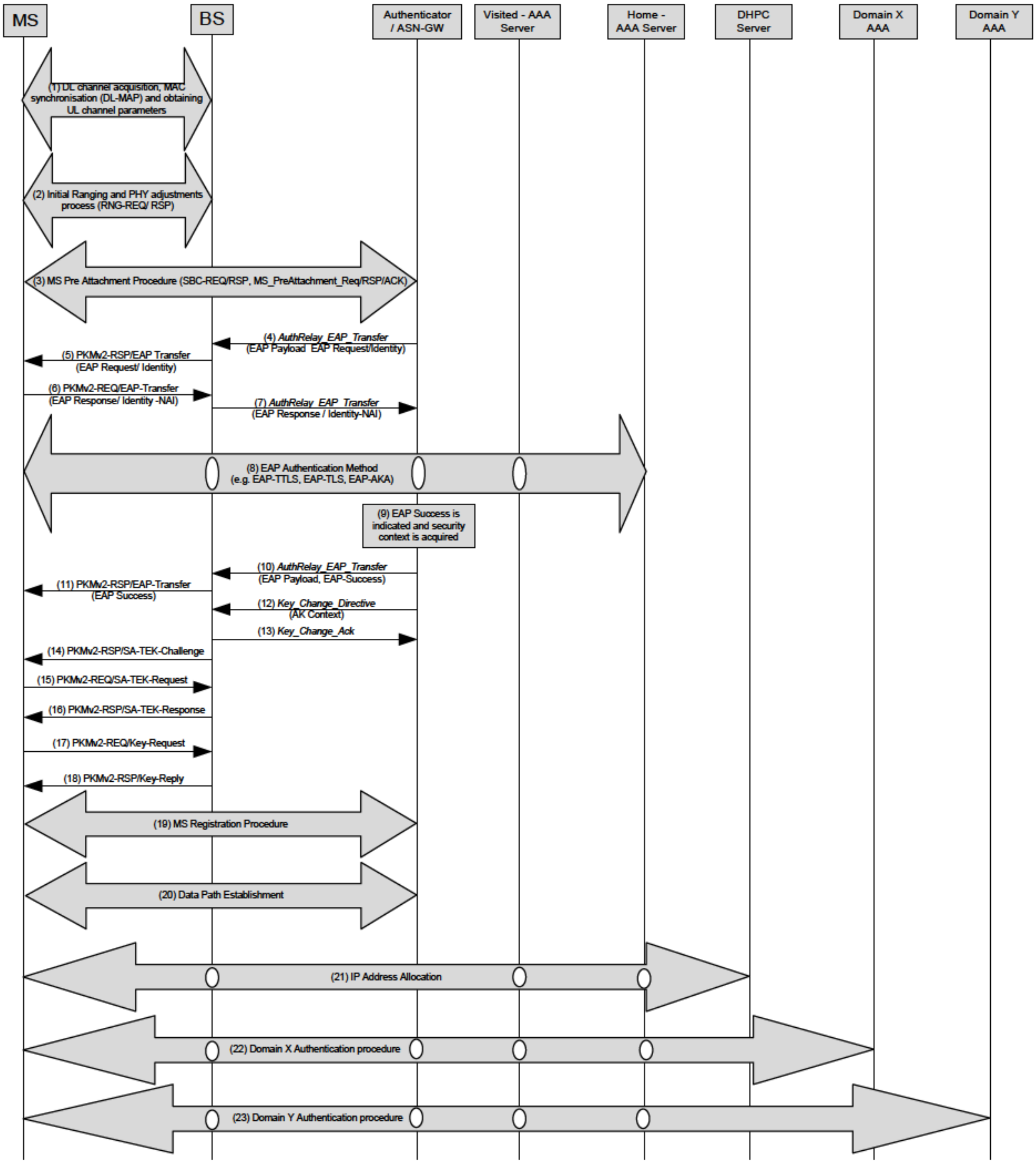


Figure 18:Initial Network Entry Time

In these tests 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 required by the EUROCAE MASPS as maximum net entry time are considered appropriate.

6.3.2.2.1 Deviation from the planned activities

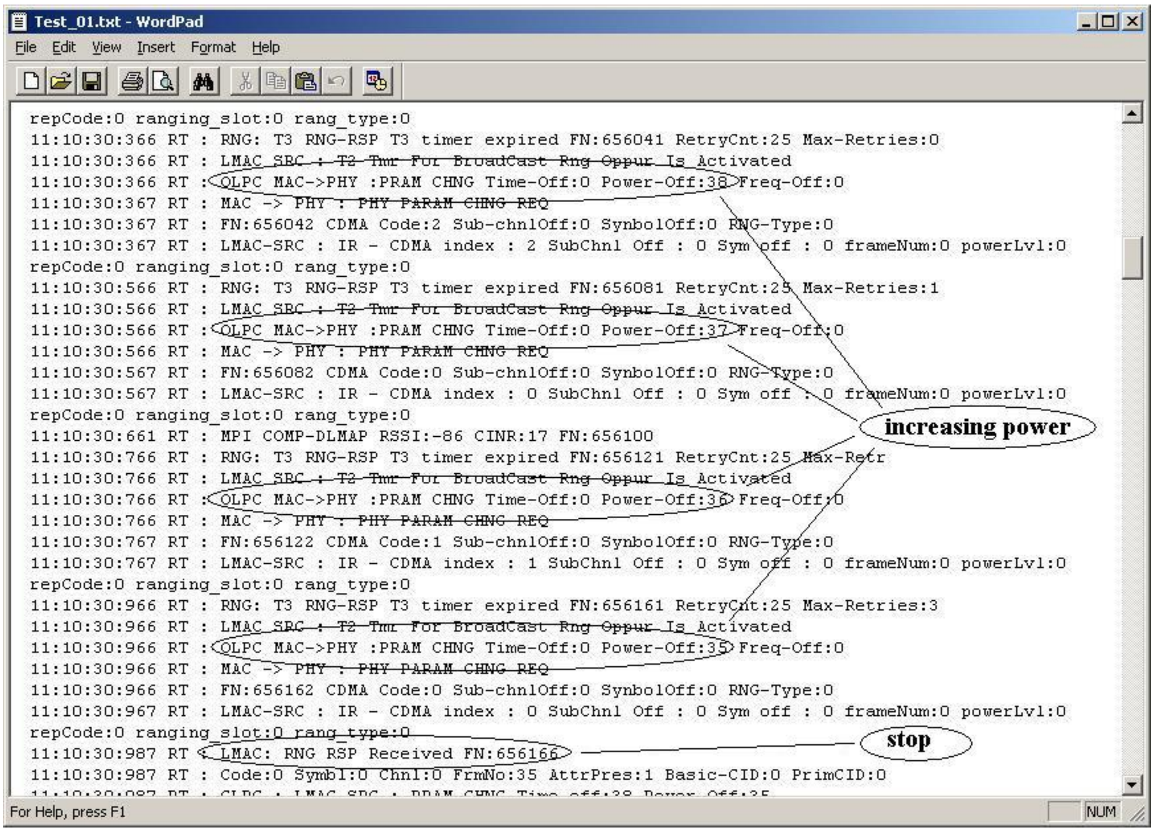
None

6.3.2.3 Lab2_X Power Control

These series of tests have verified that the AeroMACS MS Prototype operations in OLPC/CLPC and without PC, namely:

1. Verify that the AeroMACS MS Prototype properly applies a (passive) open loop power control technique
2. Verify that the MS properly applies a closed loop power control technique
3. Verify that the Channel Quality Information channels are properly allocated in the CQICH region and used by the MS to transmit channel quality measures to the BS
4. Verify that the channel quality measurements are sent to the BS with the chosen periodicity and verify any other option that might be applied
5. Verify that all closed loop parameters (power levels, power steps, power range ...) are all applied within the specified tolerances
6. Verify that the closed loop power control satisfactorily sustains a data transfer without causing any oscillation or instability in the system, facing channel gain variations of up to 30 dB/s

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.

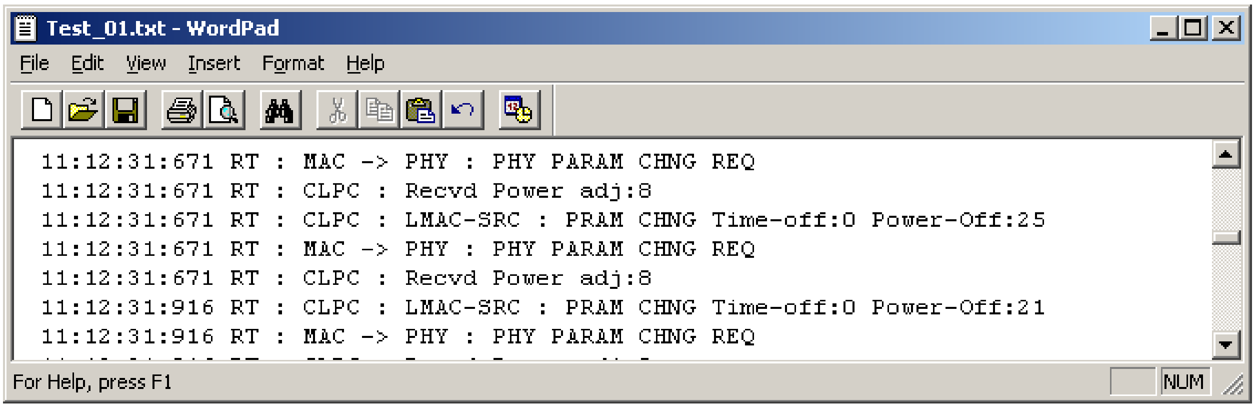


```
repCode:0 ranging_slot:0 rang_type:0
11:10:30:366 RT : RNG: T3 RNG-RSP T3 timer expired FN:656041 RetryCnt:25 Max-Retries:0
11:10:30:366 RT : LMAC_SRC : T2 Tmr For BroadCast Rng Oppur Is Activated
11:10:30:366 RT : OLPC MAC->PHY :PRAM CHNG Time-Off:0 Power-Off:38 Freq-Off:0
11:10:30:367 RT : MAC -> 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 19: 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 20: Closed Loop Power Control adjustment at the MS

In a second phase (steps 3-6) it has been verified the correct use of CQI channels during the Closed Loop Power Control Execution, also verifying the CL PC performance.

MS and BS were switched on, and the Network Entry was completed. The CQICH procedure and Closed Loop Power Control had been previously enabled on the BS, which allocated a CQICH sub-channel to the MS using a CQICH IE (CQICH Allocation IE), in order to allow the MS to send periodic CINR reports. The CQICH Allocation, together with the periodicity expressed in frames (8 in this case) is evidenced in the BS Log file shown in Figure 20.

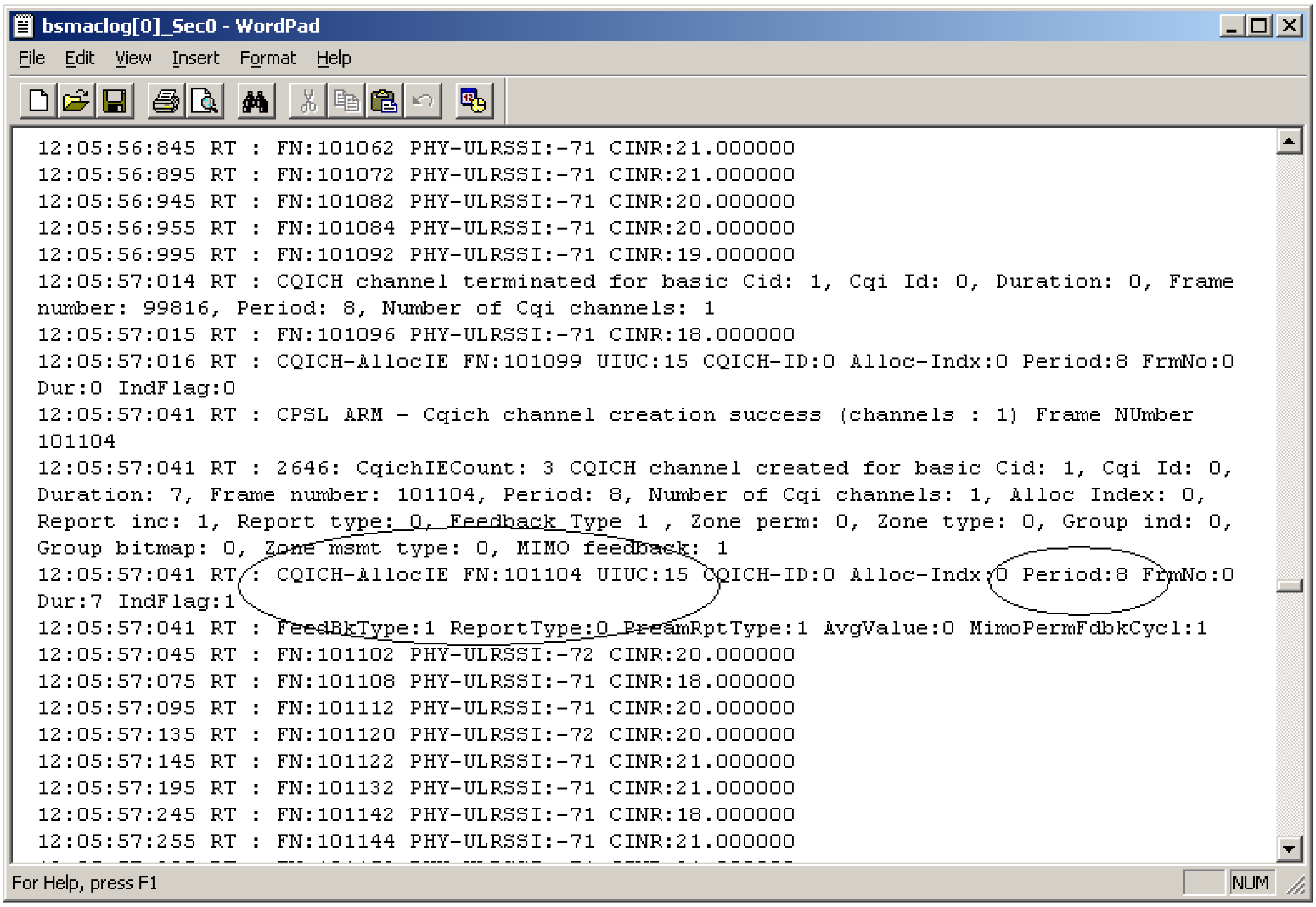
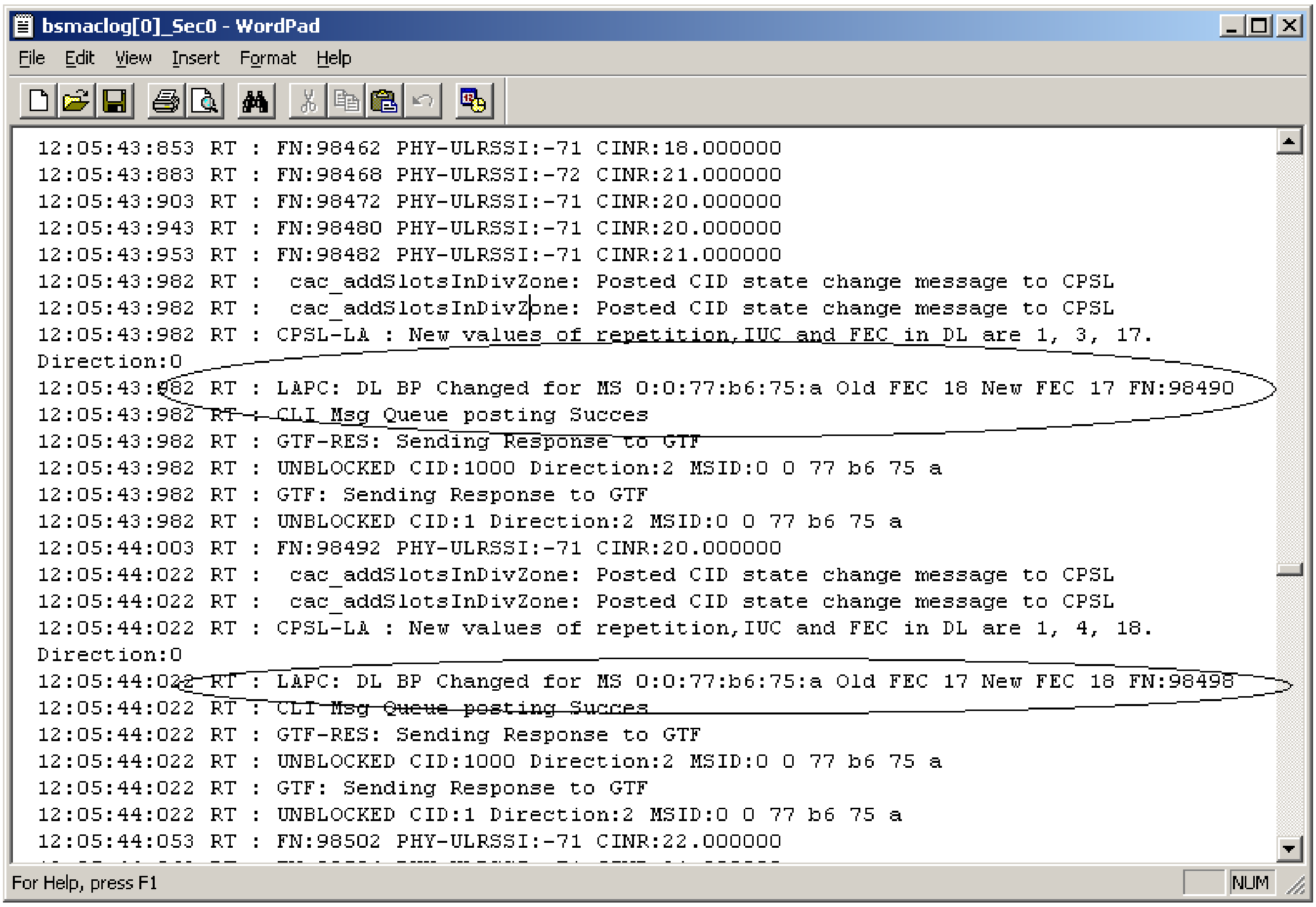


Figure 21: BS Log - CQICH Allocation

After that, it was observed that the MS started to send periodically its measurements in the allocated CQICH channels. In Figure 22 it is possible to appreciate that the measurements periodicity is 8 frames as expected.


bsmaclog[0]_Sec0 - WordPad

File Edit View Insert Format Help

```
12:05:43:853 RT : FN:98462 PHY-ULRSSI:-71 CINR:18.000000
12:05:43:883 RT : FN:98468 PHY-ULRSSI:-72 CINR:21.000000
12:05:43:903 RT : FN:98472 PHY-ULRSSI:-71 CINR:20.000000
12:05:43:943 RT : FN:98480 PHY-ULRSSI:-71 CINR:20.000000
12:05:43:953 RT : FN:98482 PHY-ULRSSI:-71 CINR:21.000000
12:05:43:982 RT :  cac_addSlotsInDivZone: Posted CID state change message to CPSL
12:05:43:982 RT :  cac_addSlotsInDivZone: Posted CID state change message to CPSL
12:05:43:982 RT : CPSL-LA : New values of repetition,IUC and FEC in DL are 1, 3, 17.
Direction:0
12:05:43:982 RT : LAPC: DL BP Changed for MS 0:0:77:b6:75:a Old FEC 18 New FEC 17 FN:98490
12:05:43:982 RT : CLI Msg Queue posting Succes
12:05:43:982 RT : GTF-RES: Sending Response to GTF
12:05:43:982 RT : UNBLOCKED CID:1000 Direction:2 MSID:0 0 77 b6 75 a
12:05:43:982 RT : GTF: Sending Response to GTF
12:05:43:982 RT : UNBLOCKED CID:1 Direction:2 MSID:0 0 77 b6 75 a
12:05:44:003 RT : FN:98492 PHY-ULRSSI:-71 CINR:20.000000
12:05:44:022 RT :  cac_addSlotsInDivZone: Posted CID state change message to CPSL
12:05:44:022 RT :  cac_addSlotsInDivZone: Posted CID state change message to CPSL
12:05:44:022 RT : CPSL-LA : New values of repetition,IUC and FEC in DL are 1, 4, 18.
Direction:0
12:05:44:022 RT : LAPC: DL BP Changed for MS 0:0:77:b6:75:a Old FEC 17 New FEC 18 FN:98498
12:05:44:022 RT : CLI Msg Queue posting Succes
12:05:44:022 RT : GTF-RES: Sending Response to GTF
12:05:44:022 RT : UNBLOCKED CID:1000 Direction:2 MSID:0 0 77 b6 75 a
12:05:44:022 RT : GTF: Sending Response to GTF
12:05:44:022 RT : UNBLOCKED CID:1 Direction:2 MSID:0 0 77 b6 75 a
12:05:44:053 RT : FN:98502 PHY-ULRSSI:-71 CINR:22.000000
```

For Help, press F1 NUM

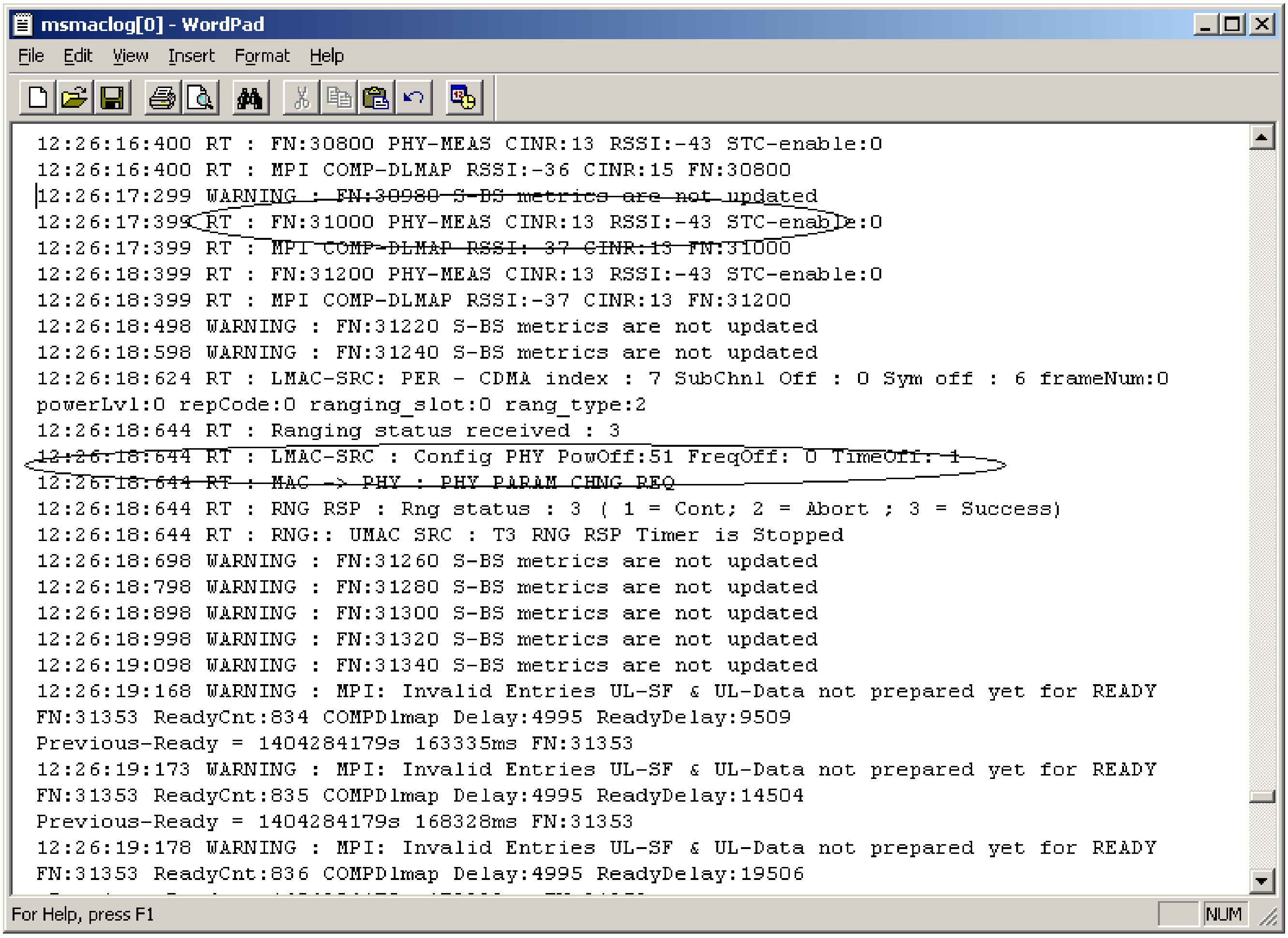
Figure 22: CQICH measurements

Finally the Closed Loop Power Control was also successfully verified. In particular, it was verified that the Algorithm was able to face a sudden attenuation of 30 dB/s during a data transfer, without any connection loss.

The variable attenuation was manually increased by 30 dBs in about 1 second, and it was verified that the MS did not lose the connection with MS. From the MS log in Figure 23 it is possible to appreciate the initial situation, in which RSSI= -43 dBm, and as a consequence the MS is applying a certain TX power offset, evidenced in the picture.

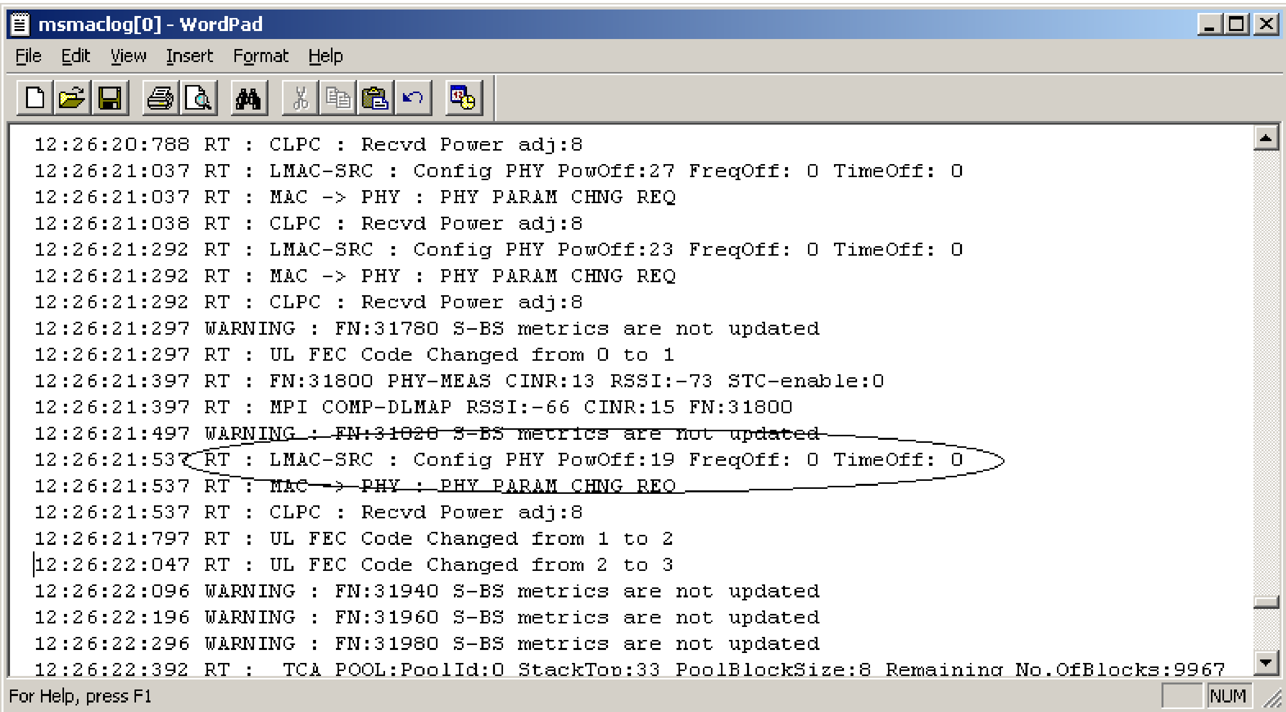
After the sudden attenuation by 30 dBs, the BS started commanding power adjustments to the MS, until the TX power offset became 32 dBs higher than the initial one (see “PHY PowOff” in Figure 24).

Subsequently, the initial attenuation was restored, and the proper working of the MS-BS connection was observed.




```
12:26:16:400 RT : FN:30800 PHY-MEAS CINR:13 RSSI:-43 STC-enable:0
12:26:16:400 RT : MPI COMP-DLMAP RSSI:-36 CINR:15 FN:30800
12:26:17:299 WARNING : FN:30980 S-BS metrics are not updated
12:26:17:399 RT : FN:31000 PHY-MEAS CINR:13 RSSI:-43 STC-enable:0
12:26:17:399 RT : MPI COMP-DLMAP RSSI:-37 CINR:13 FN:31000
12:26:18:399 RT : FN:31200 PHY-MEAS CINR:13 RSSI:-43 STC-enable:0
12:26:18:399 RT : MPI COMP-DLMAP RSSI:-37 CINR:13 FN:31200
12:26:18:498 WARNING : FN:31220 S-BS metrics are not updated
12:26:18:598 WARNING : FN:31240 S-BS metrics are not updated
12:26:18:624 RT : LMAC-SRC: PER - CDMA index : 7 SubChnl Off : 0 Sym off : 6 frameNum:0
powerLvl:0 repCode:0 ranging_slot:0 rang_type:2
12:26:18:644 RT : Ranging status received : 3
12:26:18:644 RT : LMAC-SRC : Config PHY PowOff:51 FreqOff: 0 TimeOff: 1
12:26:18:644 RT : MAC -> PHY : PHY PARAM CHNG REQ
12:26:18:644 RT : RNG RSP : Rng status : 3 ( 1 = Cont; 2 = Abort ; 3 = Success)
12:26:18:644 RT : RNG:: UMAC SRC : T3 RNG RSP Timer is Stopped
12:26:18:698 WARNING : FN:31260 S-BS metrics are not updated
12:26:18:798 WARNING : FN:31280 S-BS metrics are not updated
12:26:18:898 WARNING : FN:31300 S-BS metrics are not updated
12:26:18:998 WARNING : FN:31320 S-BS metrics are not updated
12:26:19:098 WARNING : FN:31340 S-BS metrics are not updated
12:26:19:168 WARNING : MPI: Invalid Entries UL-SF & UL-Data not prepared yet for READY
FN:31353 ReadyCnt:834 COMPDlmap Delay:4995 ReadyDelay:9509
Previous-Ready = 1404284179s 163335ms FN:31353
12:26:19:173 WARNING : MPI: Invalid Entries UL-SF & UL-Data not prepared yet for READY
FN:31353 ReadyCnt:835 COMPDlmap Delay:4995 ReadyDelay:14504
Previous-Ready = 1404284179s 168328ms FN:31353
12:26:19:178 WARNING : MPI: Invalid Entries UL-SF & UL-Data not prepared yet for READY
FN:31353 ReadyCnt:836 COMPDlmap Delay:4995 ReadyDelay:19506
```

Figure 23: CL PC - initial situation




```
12:26:20:788 RT : CLPC : Recvd Power adj:8
12:26:21:037 RT : LMAC-SRC : Config PHY PowOff:27 FreqOff: 0 TimeOff: 0
12:26:21:037 RT : MAC -> PHY : PHY PARAM CHNG REQ
12:26:21:038 RT : CLPC : Recvd Power adj:8
12:26:21:292 RT : LMAC-SRC : Config PHY PowOff:23 FreqOff: 0 TimeOff: 0
12:26:21:292 RT : MAC -> PHY : PHY PARAM CHNG REQ
12:26:21:292 RT : CLPC : Recvd Power adj:8
12:26:21:297 WARNING : FN:31780 S-BS metrics are not updated
12:26:21:297 RT : UL FEC Code Changed from 0 to 1
12:26:21:397 RT : FN:31800 PHY-MEAS CINR:13 RSSI:-73 STC-enable:0
12:26:21:397 RT : MPI COMP-DLMAP RSSI:-66 CINR:15 FN:31800
12:26:21:497 WARNING : FN:31820 S-BS metrics are not updated
12:26:21:537 RT : LMAC-SRC : Config PHY PowOff:19 FreqOff: 0 TimeOff: 0
12:26:21:537 RT : MAC -> PHY : PHY PARAM CHNG REQ
12:26:21:537 RT : CLPC : Recvd Power adj:8
12:26:21:797 RT : UL FEC Code Changed from 1 to 2
12:26:22:047 RT : UL FEC Code Changed from 2 to 3
12:26:22:096 WARNING : FN:31940 S-BS metrics are not updated
12:26:22:196 WARNING : FN:31960 S-BS metrics are not updated
12:26:22:296 WARNING : FN:31980 S-BS metrics are not updated
12:26:22:392 RT :  TCA POOL:PoolId:0 StackTop:33 PoolBlockSize:8 Remaining No.OfBlocks:9967
```

Figure 24: CL PC - Final situation

6.3.2.3.1 Deviation from the planned activities

None

6.3.2.4 Lab3_X Link Adaptation

These series of tests have verified the AeroMACS MS Prototype link adaptation in different link conditions, namely:

1. Verify the MCS in different link conditions
2. Verify the MCS against the variations of CINR

The MCS schemes, the FEC code and the CINR thresholds used in DL and UL are hereafter reported.

Modulation Scheme for DL	FEC Code	CINR Interval
QPSK-1/2	0	0-5
QPSK-3/4	1	5-10
16QAM-1/2	2	10-15
16QAM-3/4	3	15-18
64QAM-1/2	4	17-21
64QAM-2/3	5	21-24
64QAM -3/4	6	24-28

Figure 25: DL MCS

Modulation Scheme for UL	FEC Code	CINR Interval
QPSK-1/2	0	3-11
QPSK -3/4	1	11-16
16QAM-1/2	2	16-20
16QAM-3/4	3	20-34
64QAM-1/2	4	34-40
64QAM-2/3	5	40-46
64QAM-3/4	6	46-52

Figure 26: UL MCS

An example of AeroMACS BS Prototype LOGs showing the use of different MCS against CINR ratio is reported below (starting from a link condition allowing 16Qam-3/4 – FEC Code 3, and passing to a link condition for 16Qam-1/2 – FEC Code 2).

```
03:00:25:528 RT : FN:2165290 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:3
03:00:25:578 RT : FN:2165300 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3
03:00:25:628 RT : FN:2165310 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3
03:00:25:678 RT : FN:2165320 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:3
```

```
03:00:25:728 RT : FN:2165330 PHY-ULRSSI:-70 CINR:22.000000 UL FEC:3
03:00:25:778 RT : FN:2165340 PHY-ULRSSI:-70 CINR:22.000000 UL FEC:3
03:00:25:828 RT : FN:2165350 PHY-ULRSSI:-70 CINR:25.000000 UL FEC:3
03:00:25:878 RT : FN:2165360 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3
03:00:25:928 RT : FN:2165370 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:3
03:00:25:978 RT : FN:2165380 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:3
03:00:26:028 RT : FN:2165390 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:3
03:00:26:078 RT : FN:2165400 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:3
03:00:26:128 RT : FN:2165410 PHY-ULRSSI:-70 CINR:22.000000 UL FEC:3
03:00:26:178 RT : FN:2165420 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3
03:00:26:228 RT : FN:2165430 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3
03:00:26:278 RT : FN:2165440 PHY-ULRSSI:-72 CINR:23.000000 UL FEC:3
03:00:26:328 RT : FN:2165450 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3
03:00:26:378 RT : FN:2165460 PHY-ULRSSI:-71 CINR:20.000000 UL FEC:3
03:00:26:428 RT : FN:2165470 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3
03:00:26:478 RT : FN:2165480 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:3
03:00:26:527 RT : FN:2165490 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:3
03:00:26:577 RT : FN:2165500 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:3
03:00:26:627 RT : FN:2165510 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3

.

.

03:00:28:207 RT : CLI Msg Queue posting Succes
03:00:28:207 RT : UL-LA : BurstProfile Changed: IUC:3 Feccode:2 Rep:1

.

.
03:00:28:276 RT : FN:2165840 PHY-ULRSSI:-74 CINR:0.000000 UL FEC:2
03:00:28:326 RT : FN:2165850 PHY-ULRSSI:-71 CINR:16.000000 UL FEC:2
03:00:28:376 RT : FN:2165860 PHY-ULRSSI:-71 CINR:18.000000 UL FEC:2

.

.
03:00:28:526 RT : FN:2165890 PHY-ULRSSI:-70 CINR:24.000000 UL FEC:2
03:00:28:576 RT : FN:2165900 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:2
03:00:28:626 RT : FN:2165910 PHY-ULRSSI:-71 CINR:19.000000 UL FEC:2
03:00:28:676 RT : FN:2165920 PHY-ULRSSI:-71 CINR:20.000000 UL FEC:2
03:00:28:726 RT : FN:2165930 PHY-ULRSSI:-71 CINR:20.000000 UL FEC:2

.

.
03:00:31:474 RT : FN:2166480 PHY-ULRSSI:-71 CINR:25.000000 UL FEC:2
03:00:31:524 RT : FN:2166490 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:2
03:00:31:574 RT : FN:2166500 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:2
03:00:31:624 RT : FN:2166510 PHY-ULRSSI:-71 CINR:24.000000 UL FEC:2
03:00:31:674 RT : FN:2166520 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:2
03:00:31:724 RT : FN:2166530 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:2
03:00:31:774 RT : FN:2166540 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:2
03:00:31:824 RT : FN:2166550 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:2
03:00:31:874 RT : FN:2166560 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:2
03:00:31:924 RT : FN:2166570 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:2
03:00:31:955 RT : CLI Msg Queue posting Succes
03:00:31:955 RT : UL-LA : BurstProfile Changed: IUC:4 Feccode:3 Rep:1
03:00:31:955 RT :  cac_addSlotsInDivZone: Posted CID state change message to CPSL
03:00:31:955 RT :  cac_addSlotsInDivZone: Posted CID state change message to CPSL
03:00:31:955 RT :  cac_addSlotsInDivZone: Posted CID state change message to CPSL
03:00:31:955 RT :  cac_addSlotsInDivZone: Posted CID state change message to CPSL
03:00:31:955 RT :  MSID : 0 0 77 b6 75 a - UL-BPIndx(change)=3 FN=2166579
ULCinr:20.425936
03:00:31:955 RT : UNBLOCKED CID:2037 Direction:1 MSID:0 0 77 b6 75 a
03:00:31:955 RT : UNBLOCKED CID:2035 Direction:1 MSID:0 0 77 b6 75 a
03:00:31:956 RT : UNBLOCKED CID:1004 Direction:1 MSID:0 0 77 b6 75 a
03:00:31:956 RT : GTF-RES: Sending Response to GTF
03:00:31:956 RT : UNBLOCKED CID:5 Direction:1 MSID:0 0 77 b6 75 a
```

```
03:00:31:956 RT : GTF: Sending Response to GTF
03:00:31:974 RT : FN:2166580 PHY-ULRSSI:-71 CINR:22.000000 UL FEC:3
03:00:32:024 RT : FN:2166590 PHY-ULRSSI:-71 CINR:21.000000 UL FEC:3
03:00:32:074 RT : FN:2166600 PHY-ULRSSI:-71 CINR:24.000000 UL FEC:3
03:00:32:124 RT : FN:2166610 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:3
03:00:32:174 RT : FN:2166620 PHY-ULRSSI:-71 CINR:23.000000 UL FEC:3
```

Figure 27: UL MCS

6.3.2.4.1 Deviation from the planned activities

HW limitations on the AeroMACS MS RF Unit, have prevented to observe higher MCS, namely 16QAM ¾ and 64QAM during the tests. These higher MCS have been observed only simulating the RF channel, therefore in absence of noise.

6.3.2.5 Lab4_X Quality of Service

These tests have shown the AeroMACS MS Prototype QoS implementation. The following tests have been conducted successfully:

1. Verification all the type of SF is supported, namely BE/RTPS/nRTPS/eRTPS/UGS
2. Verification of the multiple SFs support (up to four)
3. Verification of DL data throughput for several FEC Codes and types of flow
4. Verification of UL data throughput for several FEC Codes and types of flow
5. Verification of DL-UL data throughput for several FEC Code and types of flow
6. Verification of from-to MS Round Trip Transit Delay
7. Verification of rule based on port is supported
8. Verification of rule based on protocol is supported
9. Verification of rule based on IP address is supported
10. Verification of the throughput is compliant with the MSTR configured
11. Verification of throughput distribution for 2 SFs with different MSTRs configured
12. Verification of distribution of the bandwidth for 2 SF with the same QoS parameter configured
13. Verification of the distribution of the bandwidth for 2 SF with the different priority configured

To verify the multiple SFs Support hereafter is reported a Log of the AeroMACS MS prototype showing the creation of Four (4) SFs.

……

```
==============================================================

16:30:55:152 RT : DSA/DSC REQ/RSP : Direction          : UL Direction

16:30:55:152 RT : DSA/DSC REQ/RSP : Service Flow ID    : 1

16:30:55:153 RT : DSA/DSC REQ/RSP : CID                : 2028

16:30:55:153 RT : DSA/DSC REQ/RSP : Req/Trans Policy   : 16

16:30:55:153 RT : DSA/DSC REQ/RSP : Max Sust Traf Rate : 10000000

16:30:55:153 RT : DSA/DSC REQ/RSP : DDS Type           : BE

16:30:55:153 RT : DSA/DSC REQ/RSP : PAGING PREFERENCE PARAMETER    : 1

==============================================================
```

……

```
==============================================================
```

```
16:30:55:159 RT : DSA/DSC REQ/RSP : Direction          : UL Direction
16:30:55:159 RT : DSA/DSC REQ/RSP : Service Flow ID    : 3
16:30:55:159 RT : DSA/DSC REQ/RSP : CID                : 2030
16:30:55:159 RT : DSA/DSC REQ/RSP : Grant Sched Type   : RTPS
16:30:55:160 RT : DSA/DSC REQ/RSP : Req/Trans Policy   : 19
16:30:55:160 RT : DSA/DSC REQ/RSP : Max Sust Traf Rate : 10000000
16:30:55:160 RT : DSA/DSC REQ/RSP : Min Rsrv Traf Rate : 400000
16:30:55:160 RT : DSA/DSC REQ/RSP : Max Latency        : 60
16:30:55:160 RT : DSA/DSC REQ/RSP : Unsol Poll Interval  : 5
16:30:55:160 RT : DSA/DSC REQ/RSP : DDS Type           : RTPS
16:30:55:160 RT : DSA/DSC REQ/RSP : PAGING PREFERENCE PARAMETER    : 1
==============================================================
……
==============================================================
16:30:55:164 RT : DSA/DSC REQ/RSP : Direction          : UL Direction
16:30:55:164 RT : DSA/DSC REQ/RSP : Service Flow ID    : 5
16:30:55:164 RT : DSA/DSC REQ/RSP : CID                : 2032
16:30:55:164 RT : DSA/DSC REQ/RSP : Grant Sched Type   : NRTPS
16:30:55:164 RT : DSA/DSC REQ/RSP : Req/Trans Policy   : 16
16:30:55:164 RT : DSA/DSC REQ/RSP : Max Sust Traf Rate : 10000000
16:30:55:164 RT : DSA/DSC REQ/RSP : Min Rsrv Traf Rate : 200000
16:30:55:165 RT : DSA/DSC REQ/RSP : DDS Type           : NRTPS
16:30:55:165  RT  :  DSA/DSC  REQ/RSP  :  PAGING  PREFERENCE  PARAMETER         :  1
==============================================================
……
==============================================================
16:30:55:171 RT : DSA/DSC REQ/RSP : Direction          : UL Direction
16:30:55:172 RT : DSA/DSC REQ/RSP : Service Flow ID    : 7
16:30:55:172 RT : DSA/DSC REQ/RSP : CID                : 2034
16:30:55:172 RT : DSA/DSC REQ/RSP : Grant Sched Type   : NRTPS
16:30:55:172 RT : DSA/DSC REQ/RSP : Req/Trans Policy   : 19
16:30:55:172 RT : DSA/DSC REQ/RSP : Max Sust Traf Rate : 10000000
16:30:55:172 RT : DSA/DSC REQ/RSP : Min Rsrv Traf Rate : 200000
16:30:55:172 RT : DSA/DSC REQ/RSP : Traffic Priority   : 7
16:30:55:172 RT : DSA/DSC REQ/RSP : DDS Type           : NRTPS
16:30:55:172 RT : DSA/DSC REQ/RSP : PAGING PREFERENCE PARAMETER    : 1
==============================================================
……
16:30:55:257 RT : Activated Flow, SFID: 7
16:30:55:261 RT : Activated Flow, SFID: 5
16:30:55:263 RT : Activated Flow, SFID: 3
16:30:55:265 RT : Activated Flow, SFID: 1
```

Figure 28: Multiple SFs Creation

To verify data throughput, the attenuation imposed to the link between MS and BS was set to have a MCS QPSK 3/4 (FEC Code 1); in this conditions the theoretical allowed DL throughput (excluding FCH+DLMAP+ULMAP overheads in DL) is about 2.7Mbps and allowed UL throughput is 0.88Mbps. Below are reported the IPERF data transfer between MS and BS for both DL and UL, showing DL/UL throughputs close to the allowed theoretical values.

```
al 125.125.40.61 port 5001 connected with 125.125.4.55 port 40498
[  3]  0.0- 1.0 sec    302 KBytes  2.48 Mbits/sec  2.174 ms   3/  608 (0.49%)
[  3]  1.0- 2.0 sec    306 KBytes  2.50 Mbits/sec  2.161 ms   0/  611 (0%)
[  3]  2.0- 3.0 sec    305 KBytes  2.50 Mbits/sec  2.170 ms   0/  610 (0%)
[  3]  3.0- 4.0 sec    306 KBytes  2.50 Mbits/sec  2.155 ms   0/  611 (0%)
[  3]  4.0- 5.0 sec    302 KBytes  2.47 Mbits/sec  2.173 ms   7/  610 (1.1%)
[  3]  5.0- 6.0 sec    304 KBytes  2.49 Mbits/sec  2.159 ms   3/  611 (0.49%)
[  3]  6.0- 7.0 sec    305 KBytes  2.50 Mbits/sec  2.168 ms   0/  610 (0%)
[  3]  7.0- 8.0 sec    304 KBytes  2.49 Mbits/sec  2.152 ms   4/  611 (0.65%)
[  3]  8.0- 9.0 sec    305 KBytes  2.50 Mbits/sec  2.167 ms   0/  610 (0%)
[  3]  9.0-10.0 sec    296 KBytes  2.43 Mbits/sec  2.160 ms  18/  611 (2.9%)
[  3]  0.0-10.0 sec  2.96 MBytes  2.49 Mbits/sec  2.161 ms  34/ 6105 (0.56%)
[  3]  0.0-10.0 sec  1 datagrams received out-of-order
```

Figure 29: QPSK ½ DL Throughput

```
al 125.125.4.55 port 5001 connected with 125.125.40.61 port 60821
[  4]  0.0- 1.0 sec  80.0 KBytes   803 Kbits/sec  0.809 ms   48/  208 (0%)
[  4]  1.0- 2.0 sec  92.5 KBytes   799 Kbits/sec  1.599 ms   10/  195 (0%)
[  4]  2.0- 3.0 sec  95.0 KBytes   799 Kbits/sec  0.622 ms    6/  196 (0%)
[  4]  3.0- 4.0 sec  95.0 KBytes   803 Kbits/sec  1.567 ms    6/  196 (0%)
[  4]  4.0- 5.0 sec  94.5 KBytes   799 Kbits/sec  1.156 ms    4/  193 (0%)
[  4]  5.0- 6.0 sec  95.5 KBytes   799 Kbits/sec  1.876 ms    4/  195 (0%)
[  4]  6.0- 7.0 sec  93.0 KBytes   803 Kbits/sec  1.680 ms   12/  198 (0%)
[  4]  7.0- 8.0 sec  93.5 KBytes   799 Kbits/sec  1.409 ms    7/  194 (0%)
[  4]  8.0- 9.0 sec  94.5 KBytes   799 Kbits/sec  2.219 ms    4/  193 (0%)
[  4]  0.0- 9.9 sec   926 KBytes   803 Kbits/sec  1.649 ms  103/ 1954 (0%)
```

Figure 30: QPSK ½ UL Throughput

To verify the from-MS RTT the test bench of Figure 6 and a window of 600 messages have been used. The results is shown in the figure below.

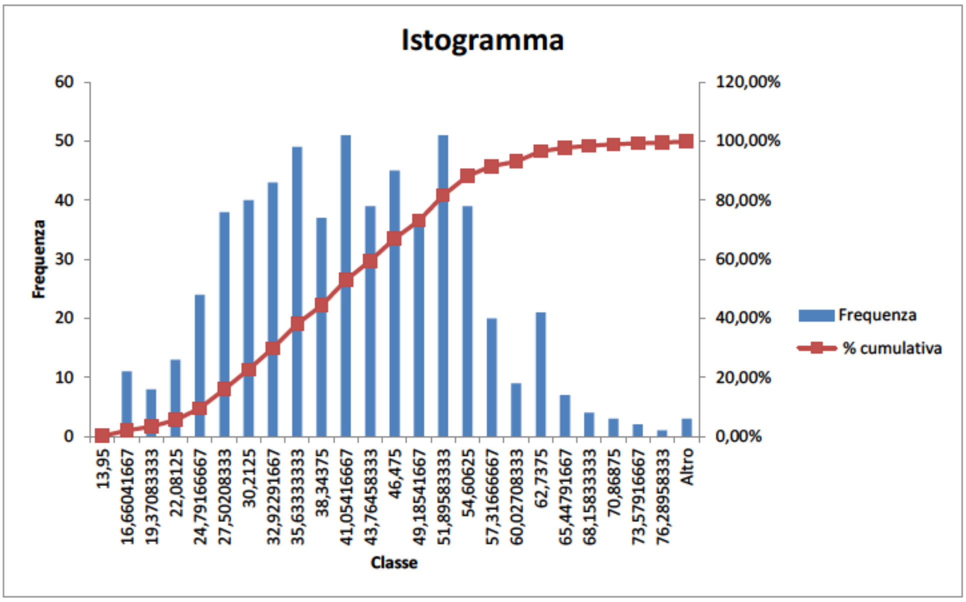


Figure 31: from-MS RTT

Showing the RTT (95th percentile) is less than 61ms.

To verify the to-MS RTT the test bench of Figure 6 and a window of 600 messages have been used. The results is shown in the figure below.

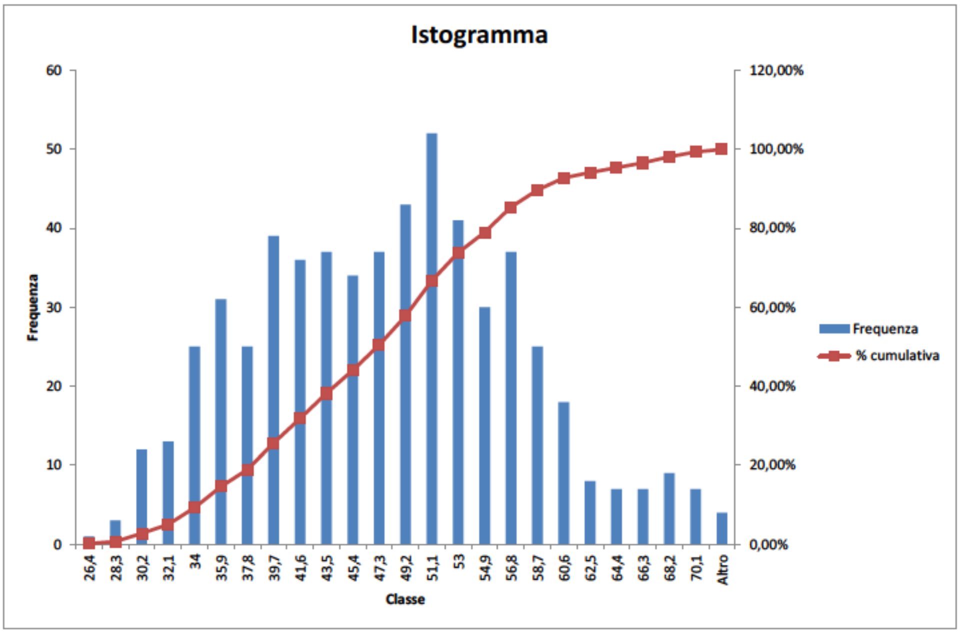


Figure 32: to-MS RTT

Showing the RTT (95th percentile) is less than 64ms.

To verify that the data traffic for a SF is managed following the QoS configuration in this case the nrtPS and rtPS Classes of Services were tested. Initially, a 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 33)

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.

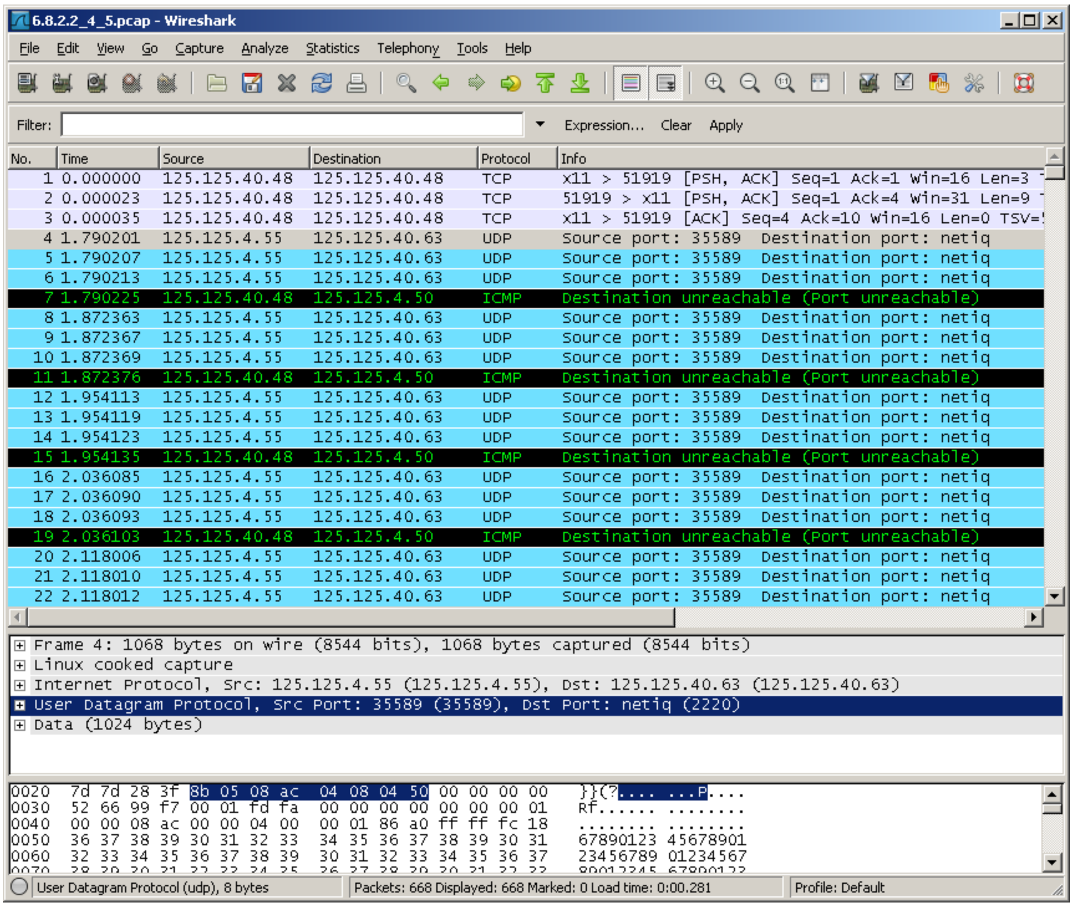


Figure 33: Wireshark Log on ASN-GW ports: no transmission for IP flow not compatible with the SF Classification for DL

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 34).

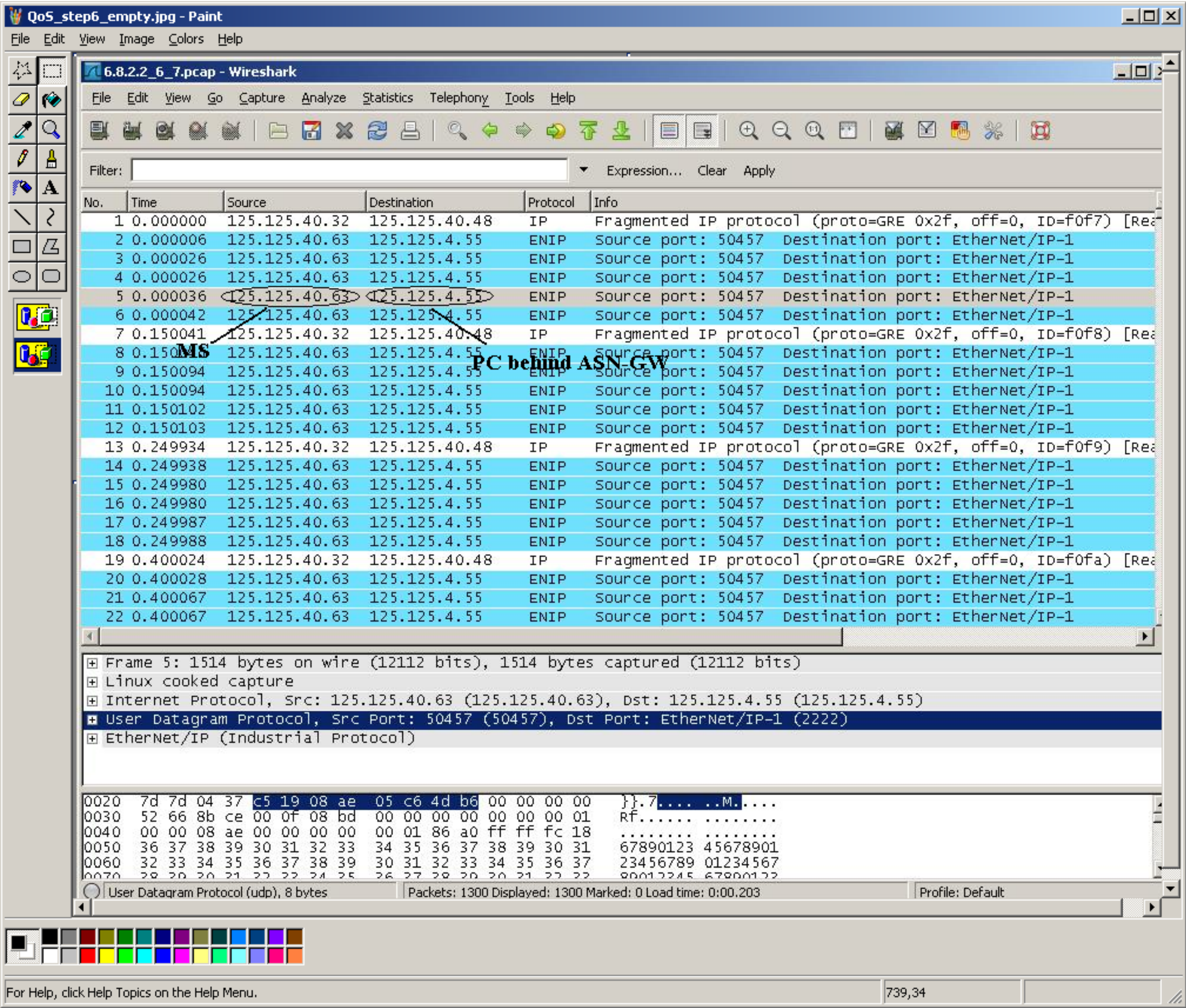
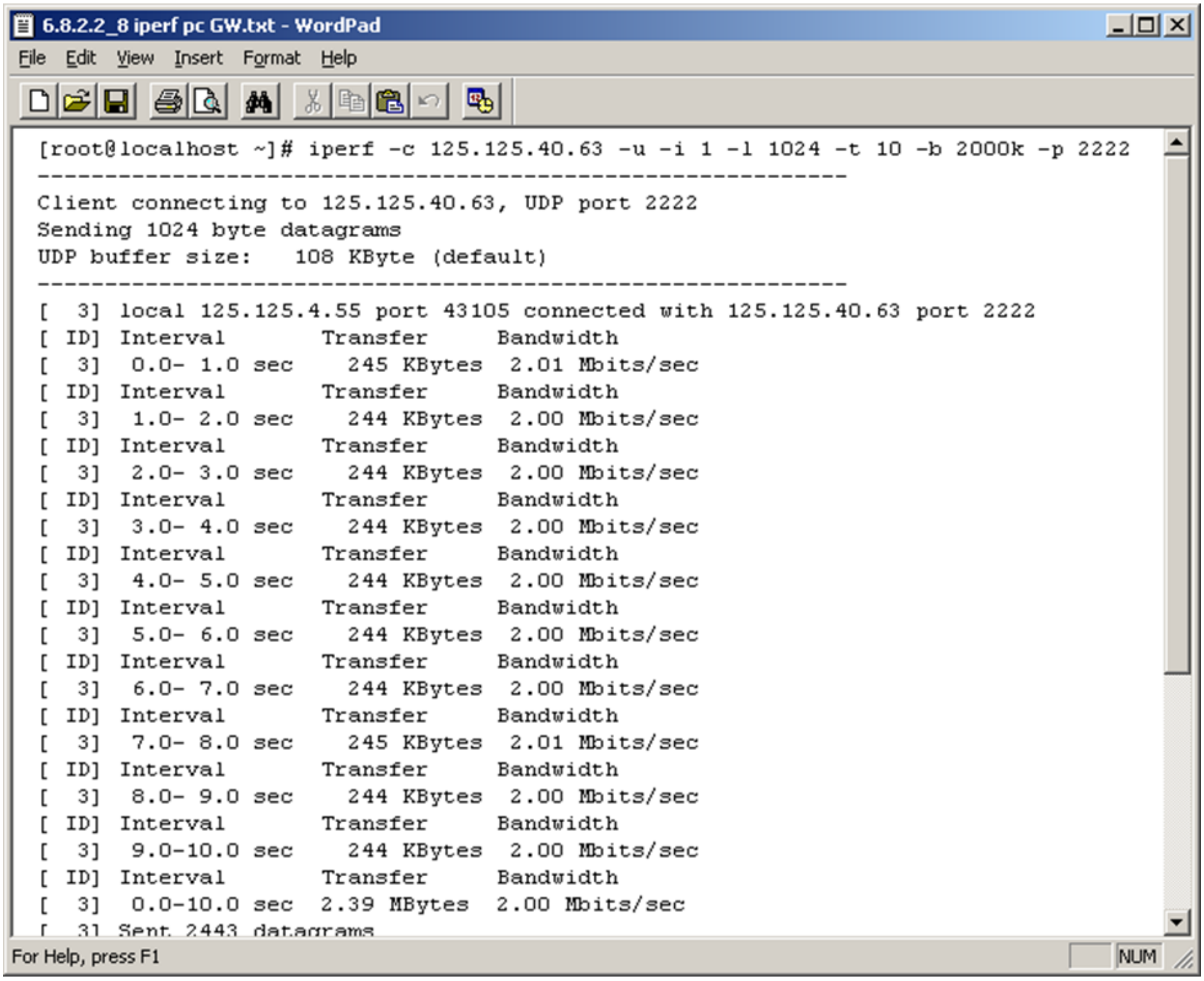


Figure 34: Successful IP Flow in UL

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.

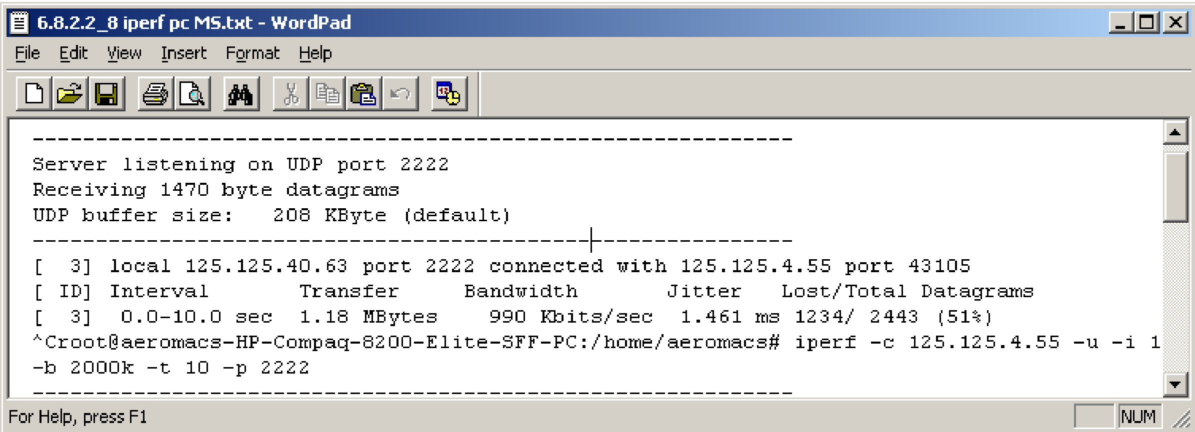
Subsequently, it has been verified that data exceeding the MSTR were dropped. In fact, using IPERF on the PC behind ASN-GW, an IP flow with 2 Mbps Baud Rate was sent to the ASN-GW to be transmitted to the MS (see Figure 35) without changing the previously configured 1 Mbps Max Baud Rate allowed to SF1. 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 35: 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 36: IPERF Log at the MS: 1Mbps Max Baud Rate respected

To verify multiple service flows behaviors, as usual MS and BS were switched on, and the Network Entry was completed. The attenuation was set at a value such to allow BS and MS to establish a 16-QAM ½ connection.

Since the BS imposed a DL:UL ratio equal to 35:12, the maximum data throughput available in DL (channel capacity) is estimated being about 3.7 Mbps (excluding FCH+DLMAP+ULMAP overheads in DL)

Under these conditions, two Service Flows with Scheduling Type Best Effort and same priority but different MSTRs were set up at the BS as follows:

Service Flow	Scheduling Type	DL MSTR	UL MSTR
SF1	BE	4 Mbps	600 Kbps
SF2	BE	3 Mbps	400 Kbps

Then, two IP Flows were subsequently started with IPERF, compatibly with the SFs classification rules for DL and with the following throughputs:

- IP flow on SF1: 4.5 Mbps
- IP flow on SF2: 5 Mbps.

The needed bandwidth was assigned by the BS to the MS thanks to the BW-REQ/BW-RSP mechanism, and the data transfer started. In Figure 37 it may be observed certain fairness between the exchanged data flows. The difference between them is compatible with the difference between MSTR1 and MSTR2 values.

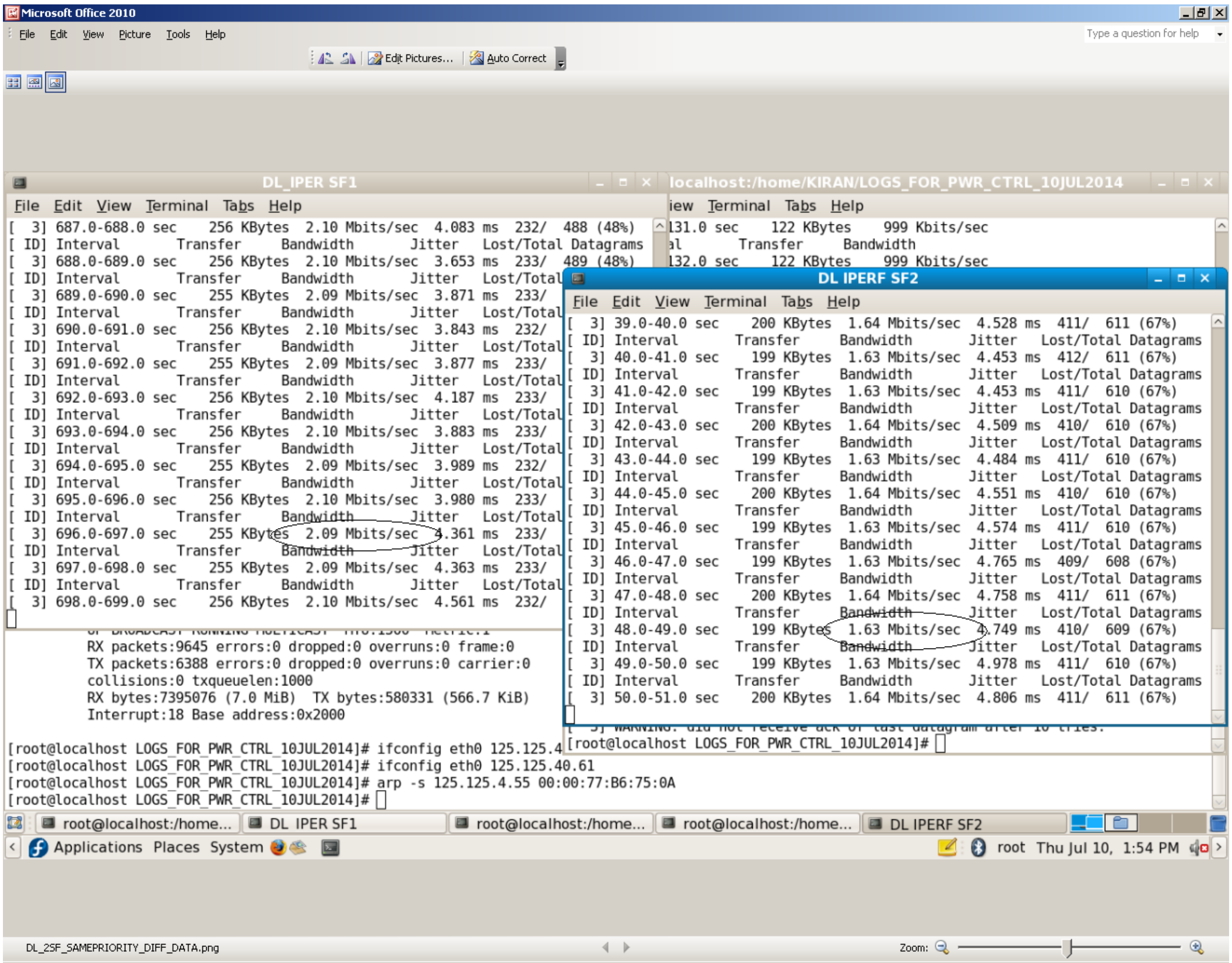
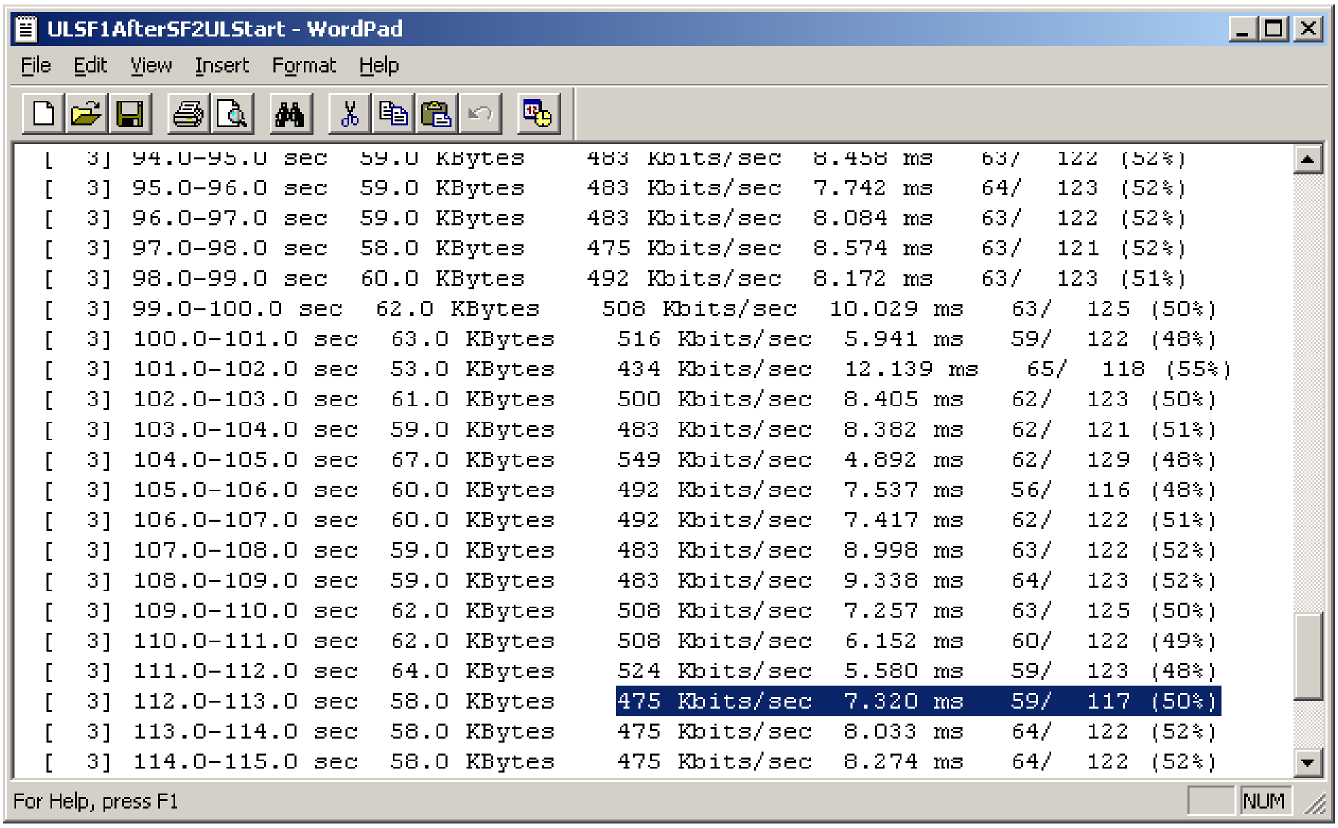


Figure 37: IPERF Log - 2 SFs with the same priority but different MSTR

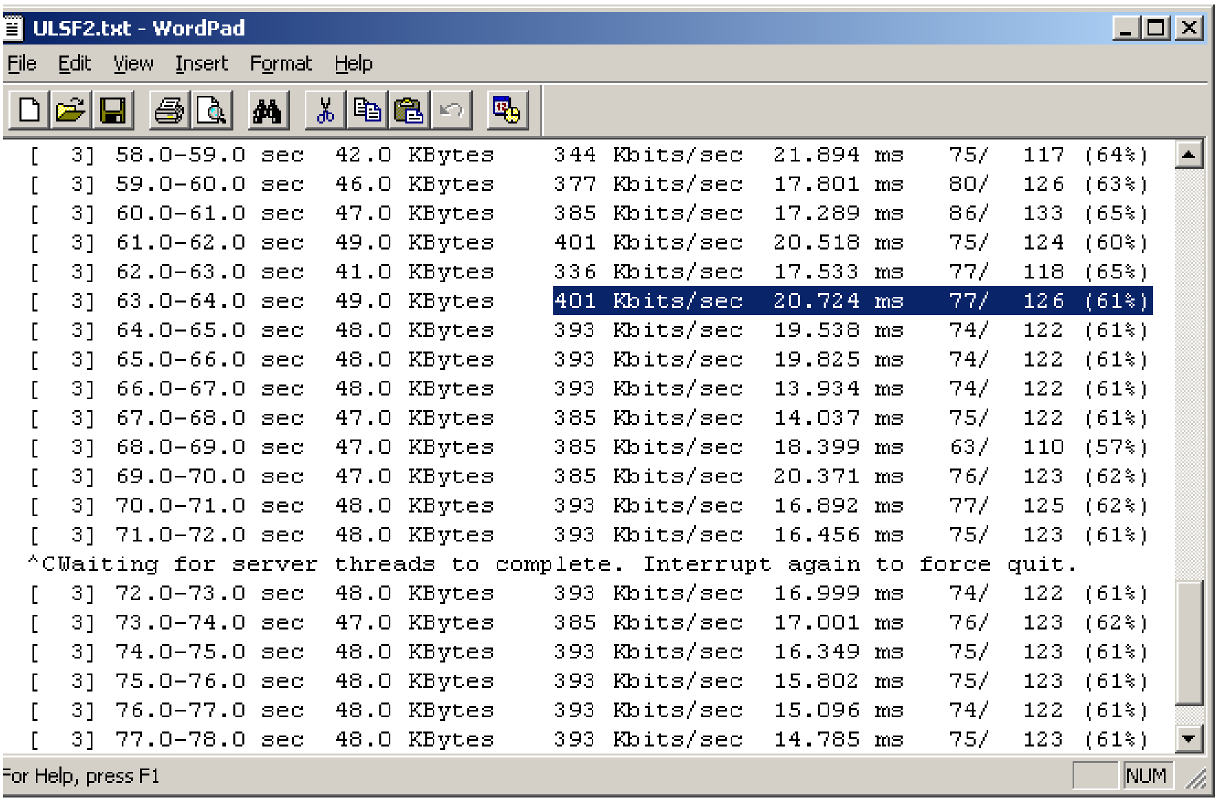
Then the test was repeated for the UL, using the same Service Flows set before. This time the IP Flows were both set to 1 Mbps. However, this time the channel capacity was about 880 Kbps, as the active MCS was QPSK ¾.

As it is possible to see from the IPERF logs in Figure 38 and Figure 39 the total throughput was compliant with the channel capacity. Again, the difference between the throughputs is compatible with the difference between UL MSTR1 and MSTR2 values.




```
[  3] 94.0-95.0 sec  59.0 KBytes   483 Kbits/sec  8.458 ms   63/  122 (52%)
[  3] 95.0-96.0 sec  59.0 KBytes   483 Kbits/sec  7.742 ms   64/  123 (52%)
[  3] 96.0-97.0 sec  59.0 KBytes   483 Kbits/sec  8.084 ms   63/  122 (52%)
[  3] 97.0-98.0 sec  58.0 KBytes   475 Kbits/sec  8.574 ms   63/  121 (52%)
[  3] 98.0-99.0 sec  60.0 KBytes   492 Kbits/sec  8.172 ms   63/  123 (51%)
[  3] 99.0-100.0 sec  62.0 KBytes   508 Kbits/sec  10.029 ms   63/  125 (50%)
[  3] 100.0-101.0 sec  63.0 KBytes   516 Kbits/sec  5.941 ms   59/  122 (48%)
[  3] 101.0-102.0 sec  53.0 KBytes   434 Kbits/sec  12.139 ms   65/  118 (55%)
[  3] 102.0-103.0 sec  61.0 KBytes   500 Kbits/sec  8.405 ms   62/  123 (50%)
[  3] 103.0-104.0 sec  59.0 KBytes   483 Kbits/sec  8.382 ms   62/  121 (51%)
[  3] 104.0-105.0 sec  67.0 KBytes   549 Kbits/sec  4.892 ms   62/  129 (48%)
[  3] 105.0-106.0 sec  60.0 KBytes   492 Kbits/sec  7.537 ms   56/  116 (48%)
[  3] 106.0-107.0 sec  60.0 KBytes   492 Kbits/sec  7.417 ms   62/  122 (51%)
[  3] 107.0-108.0 sec  59.0 KBytes   483 Kbits/sec  8.998 ms   63/  122 (52%)
[  3] 108.0-109.0 sec  59.0 KBytes   483 Kbits/sec  9.338 ms   64/  123 (52%)
[  3] 109.0-110.0 sec  62.0 KBytes   508 Kbits/sec  7.257 ms   63/  125 (50%)
[  3] 110.0-111.0 sec  62.0 KBytes   508 Kbits/sec  6.152 ms   60/  122 (49%)
[  3] 111.0-112.0 sec  64.0 KBytes   524 Kbits/sec  5.580 ms   59/  123 (48%)
[  3] 112.0-113.0 sec  58.0 KBytes   475 Kbits/sec  7.320 ms   59/  117 (50%)
[  3] 113.0-114.0 sec  58.0 KBytes   475 Kbits/sec  8.033 ms   64/  122 (52%)
[  3] 114.0-115.0 sec  58.0 KBytes   475 Kbits/sec  8.274 ms   64/  122 (52%)
```

Figure 38: UL - throughput on SF1


ULSF2.txt - WordPad

File Edit View Insert Format Help

```
[  3] 58.0-59.0 sec   42.0 KBytes    344 Kbits/sec  21.894 ms   75/   117 (64%)
[  3] 59.0-60.0 sec   46.0 KBytes    377 Kbits/sec  17.801 ms   80/   126 (63%)
[  3] 60.0-61.0 sec   47.0 KBytes    385 Kbits/sec  17.289 ms   86/   133 (65%)
[  3] 61.0-62.0 sec   49.0 KBytes    401 Kbits/sec  20.518 ms   75/   124 (60%)
[  3] 62.0-63.0 sec   41.0 KBytes    336 Kbits/sec  17.533 ms   77/   118 (65%)
[  3] 63.0-64.0 sec   49.0 KBytes    401 Kbits/sec  20.724 ms   77/   126 (61%)
[  3] 64.0-65.0 sec   48.0 KBytes    393 Kbits/sec  19.538 ms   74/   122 (61%)
[  3] 65.0-66.0 sec   48.0 KBytes    393 Kbits/sec  19.825 ms   74/   122 (61%)
[  3] 66.0-67.0 sec   48.0 KBytes    393 Kbits/sec  13.934 ms   74/   122 (61%)
[  3] 67.0-68.0 sec   47.0 KBytes    385 Kbits/sec  14.037 ms   75/   122 (61%)
[  3] 68.0-69.0 sec   47.0 KBytes    385 Kbits/sec  18.399 ms   63/   110 (57%)
[  3] 69.0-70.0 sec   47.0 KBytes    385 Kbits/sec  20.371 ms   76/   123 (62%)
[  3] 70.0-71.0 sec   48.0 KBytes    393 Kbits/sec  16.892 ms   77/   125 (62%)
[  3] 71.0-72.0 sec   48.0 KBytes    393 Kbits/sec  16.456 ms   75/   123 (61%)
^CWaiting for server threads to complete. Interrupt again to force quit.
[  3] 72.0-73.0 sec   48.0 KBytes    393 Kbits/sec  16.999 ms   74/   122 (61%)
[  3] 73.0-74.0 sec   47.0 KBytes    385 Kbits/sec  17.001 ms   76/   123 (62%)
[  3] 74.0-75.0 sec   48.0 KBytes    393 Kbits/sec  16.349 ms   75/   123 (61%)
[  3] 75.0-76.0 sec   48.0 KBytes    393 Kbits/sec  15.802 ms   75/   123 (61%)
[  3] 76.0-77.0 sec   48.0 KBytes    393 Kbits/sec  15.096 ms   74/   122 (61%)
[  3] 77.0-78.0 sec   48.0 KBytes    393 Kbits/sec  14.785 ms   75/   123 (61%)
```

For Help, press F1 NUM

Figure 39: UL - throughput on SF2

Subsequently, the Traffic Priority of Service Flow #2 was increased with respect to SF1, and the MS was restarted; the same tests done before in DL and UL were repeated. This time, a reversal of results was observed, both in DL and UL: in fact this time, thanks to the SF2 higher priority, its throughput got higher, to the detriment of SF1 throughput (and despite of the lower MSTR2 threshold). Figure 40 shows the DL case.

The tests were repeated with different Scheduling Types (rtps, e-rtps, nrtps), giving similar results.

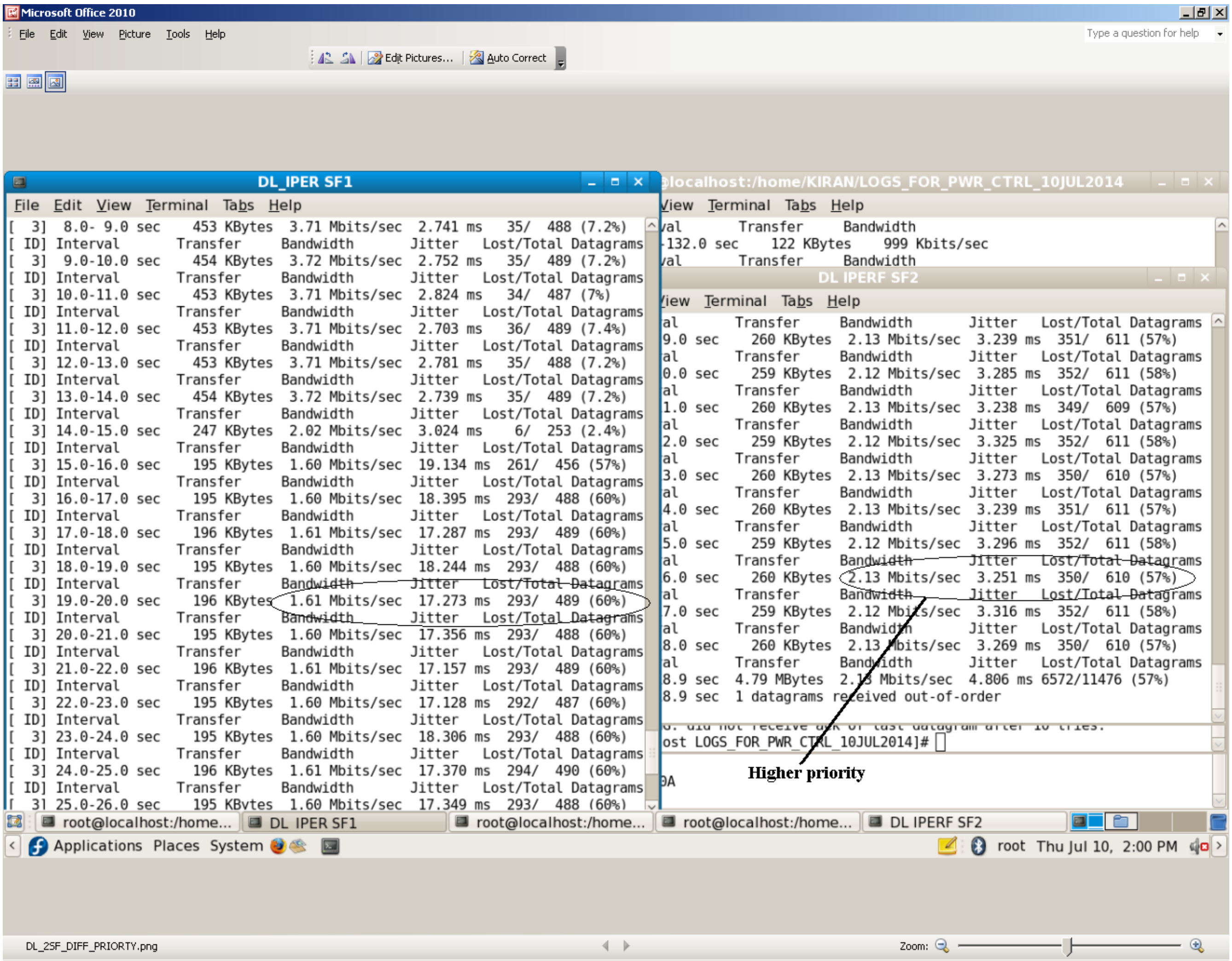


Figure 40: SF2 with higher priority

6.3.2.5.1 Deviation from the planned activities

None

6.3.2.6 Lab5_X ARQ

The purpose of these Test Cases is to verify that ARQ is properly working. In Figure 41 is shown the MS Log with the creation of SFs BE for both UL and DL and the indication of statistics of the packets that have to be retransmitted.

```
16:39:17:776 RT :
==============================================================
16:39:17:776 RT : DSA/DSC REQ/RSP : Direction          : DL Direction
16:39:17:776 RT : DSA/DSC REQ/RSP : Service Flow ID    : 2
16:39:17:776 RT : DSA/DSC REQ/RSP : CID                : 2019
16:39:17:776 RT : DSA/DSC REQ/RSP : Req/Trans Policy   : 16
16:39:17:776 RT : DSA/DSC REQ/RSP : Max Sust Traf Rate : 10000000
16:39:17:777 RT : DSA/DSC REQ/RSP : DDS Type           : BE
16:39:17:777 RT : DSA/DSC REQ/RSP : PAGING PREFERENCE PARAMETER     : 1
16:39:17:777 RT :
==============================================================
16:39:17:783 RT :
==============================================================
```

```
16:39:17:783 RT : DSA/DSC REQ/RSP : Direction          : UL Direction
16:39:17:783 RT : DSA/DSC REQ/RSP : Service Flow ID    : 1
16:39:17:783 RT : DSA/DSC REQ/RSP : CID                : 2018
16:39:17:783 RT : DSA/DSC REQ/RSP : Req/Trans Policy   : 16
16:39:17:784 RT : DSA/DSC REQ/RSP : Max Sust Traf Rate : 10000000
16:39:17:784 RT : DSA/DSC REQ/RSP : DDS Type           : BE
16:39:17:784 RT : DSA/DSC REQ/RSP : PAGING PREFERENCE PARAMETER    : 1
16:39:17:784 RT :
==============================================================
16:39:17:865 RT : CSF : DSA-ACK Received
16:39:17:865 RT : DSA ACK :Confirmation Code : 0   ( 0=Accept, other = Reject
) CID :2017  SFID : 8
16:40:37:678 RT : FN:391793 Feedback Not received on Time: PrevFbFN:377034
Diff:14759
16:40:37:718 RT : MPI COMP-DLMAP RSSI:-75 CINR:10 FN:391800
16:40:38:713 RT : FN:392000 Fresh:6  ReTx[1]:0 ReTx[2]:0 ReTx[3]:0 ReTx[4]:0
Discad:2018
16:40:38:713 RT : ARQ UL Block Statistics: Fresh-Tx=6 ReTx=0 Duplicat=0
16:40:38:713 RT : Ack Stats:Sel:0 Cum:0 Cum + Sel:0 Cum+ BlkSeq:0

16:41:08:695 RT : FN:398000 Fresh:4  ReTx[1]:0 ReTx[2]:0 ReTx[3]:0 ReTx[4]:0
Discad:2018
16:41:08:695 RT : ARQ UL Block Statistics: Fresh-Tx=4 ReTx=0 Duplicat=0
16:41:08:695 RT : Ack Stats:Sel:0 Cum:0 Cum + Sel:0 Cum+ BlkSeq:0
16:42:06:756 ERROR : COMPRESSED DLMAP-ULMAP missed for frame number:409618
16:42:08:660 RT : FN:410000 Fresh:586  ReTx[1]:28 ReTx[2]:7 ReTx[3]:0
ReTx[4]:0 Discad:2018
16:42:08:660 RT : ARQ UL Block Statistics: Fresh-Tx=955 ReTx=35 Duplicat=0
16:42:08:660 RT : Ack Stats:Sel:0 Cum:0 Cum + Sel:0 Cum+ BlkSeq:0
16:42:17:659 RT : MPI COMP-DLMAP RSSI:-74 CINR:6 FN:411800
16:42:18:654 RT : FN:412000 Fresh:7746  ReTx[1]:152 ReTx[2]:4 ReTx[3]:0
ReTx[4]:0 Discad:2018
16:42:18:654 RT : ARQ UL Block Statistics: Fresh-Tx=7792 ReTx=156 Duplicat=0
16:42:18:654 RT : Ack Stats:Sel:0 Cum:0 Cum + Sel:0 Cum+ BlkSeq:0
16:42:28:648 RT : FN:414000 Fresh:421  ReTx[1]:0 ReTx[2]:0 ReTx[3]:0
ReTx[4]:0 Discad:2018
16:42:28:648 RT : ARQ UL Block Statistics: Fresh-Tx=6 ReTx=0 Duplicat=0
16:42:28:648 RT : Ack Stats:Sel:0 Cum:0 Cum + Sel:0 Cum+ BlkSeq:0
16:42:28:652 RT : DL PDU CRC Stats :Pass and Failure count in Last Half
minute ,PASS:416 FAIL:0 HCS FailCnt:0
16:43:08:425 RT : MPI RX-BRST RSSI:-74 CINR:7 FN:421960
16:43:08:625 RT : FN:422000 Fresh:562  ReTx[1]:38 ReTx[2]:0 ReTx[3]:0
ReTx[4]:0 Discad:2018
16:43:08:625 RT : ARQ UL Block Statistics: Fresh-Tx=1018 ReTx=38 Duplicat=0
16:43:08:625 RT : Ack Stats:Sel:0 Cum:0 Cum + Sel:0 Cum+ BlkSeq:0
16:43:08:629 RT : MPI COMP-DLMAP RSSI:-74 CINR:7 FN:422000
16:43:08:814 ERROR : MPI : DL-MAP decoding failed: CINR:5 RSSI:-74
16:43:08:814 ERROR : PHY_DIAG_MSG ::  DL MAP decoding failed  FN = 42203
```

Figure 41: ARQ Statistics

Figure 42 shows a log with the downlink data transfer without ARQ. The packet loss increased because of the link attenuation addition between MS and BS.

```
root@aeromacs-HP-Compaq-8200-Elite-SFF-PC:/home/aeromacs# iperf -s -u -i 1 -p 5001
------------------------------------------------------------
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size:   208 KByte (default)
```

```
------------------------------------------------------------
[  3] local 125.125.40.61 port 5001 connected with 125.125.4.55 port 54035
[ ID] Interval       Transfer     Bandwidth        Jitter   Lost/Total Datagrams
[  3]  0.0- 1.0 sec    118 KBytes    971 Kbits/sec  1.783 ms   20/  257 (7.8%)
[  3]  1.0- 2.0 sec    115 KBytes    942 Kbits/sec  1.889 ms   26/  256 (10%)
[  3]  2.0- 3.0 sec    114 KBytes    934 Kbits/sec  1.914 ms   28/  256 (11%)
[  3]  3.0- 4.0 sec    120 KBytes    983 Kbits/sec  1.907 ms   16/  256 (6.2%)
[  3]  4.0- 5.0 sec    117 KBytes    958 Kbits/sec  1.648 ms   20/  254 (7.9%)
[  3]  5.0- 6.0 sec    114 KBytes    938 Kbits/sec  1.779 ms   29/  258 (11%)
[  3]  6.0- 7.0 sec    120 KBytes    983 Kbits/sec  1.789 ms   16/  256 (6.2%)
[  3]  7.0- 8.0 sec    111 KBytes    909 Kbits/sec  1.690 ms   34/  256 (13%)
[  3]  8.0- 9.0 sec    114 KBytes    930 Kbits/sec  1.788 ms   29/  256 (11%)
[  3]  9.0-10.0 sec    117 KBytes    958 Kbits/sec  1.792 ms   22/  256 (8.6%)
[  3]  0.0-10.0 sec    1.13 MBytes    951 Kbits/sec  1.747 ms  239/ 2561 (9.3%)
[  3]  0.0-10.0 sec    1 datagrams received out-of-order
```

Figure 42: Downlink data transfer without ARQ

With the same level of attenuation on the downlink path, the ARQ has been enabled, and the results is shown in the log of Figure 43. The packet loss decreased to 0% at the cost of a jitter increase.

```
root@aeromacs-HP-Compaq-8200-Elite-SFF-PC:/home/aeromacs# iperf -s -u -i 1 -p 5001
------------------------------------------------------------
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size:   208 KByte (default)
------------------------------------------------------------
[  4] local 125.125.40.61 port 5001 connected with 125.125.4.55 port 43243
[  4]  0.0- 1.0 sec    128 KBytes  1.05 Mbits/sec  3.214 ms    0/  256 (0%)
[  4]  1.0- 2.0 sec    128 KBytes  1.05 Mbits/sec  1.785 ms    0/  256 (0%)
[  4]  2.0- 3.0 sec    128 KBytes  1.05 Mbits/sec  1.692 ms    0/  256 (0%)
[  4]  3.0- 4.0 sec    128 KBytes  1.05 Mbits/sec  2.081 ms    0/  256 (0%)
[  4]  4.0- 5.0 sec    128 KBytes  1.05 Mbits/sec  1.669 ms    0/  256 (0%)
[  4]  5.0- 6.0 sec    128 KBytes  1.05 Mbits/sec  1.663 ms    0/  256 (0%)
[  4]  6.0- 7.0 sec    128 KBytes  1.05 Mbits/sec  1.677 ms    0/  256 (0%)
[  4]  7.0- 8.0 sec    128 KBytes  1.05 Mbits/sec  1.667 ms    0/  256 (0%)
[  4]  8.0- 9.0 sec    128 KBytes  1.05 Mbits/sec  1.681 ms    0/  256 (0%)
[  4]  9.0-10.0 sec    128 KBytes  1.05 Mbits/sec  1.689 ms    0/  256 (0%)
[  4]  0.0-10.0 sec    1.25 MBytes  1.05 Mbits/sec  1.843 ms    0/ 2561 (0%)
[  4]  0.0-10.0 sec    1 datagrams received out-of-order
```

Figure 43: Downlink data transfer with ARQ

6.3.2.6.1 Deviation from the planned activities

None

6.3.2.7 Lab6_X Security

These tests have shown the AeroMACS MS Prototype Security features implementation.

In the first step it was verified that the chosen authentication method was supported, namely No authentication or EAP based authentication. Second it was verified that after Authentication, data was properly encrypted, according to the required Private Key Management Protocol.

In the first step the ASN-GW was configured in order to not 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 44.

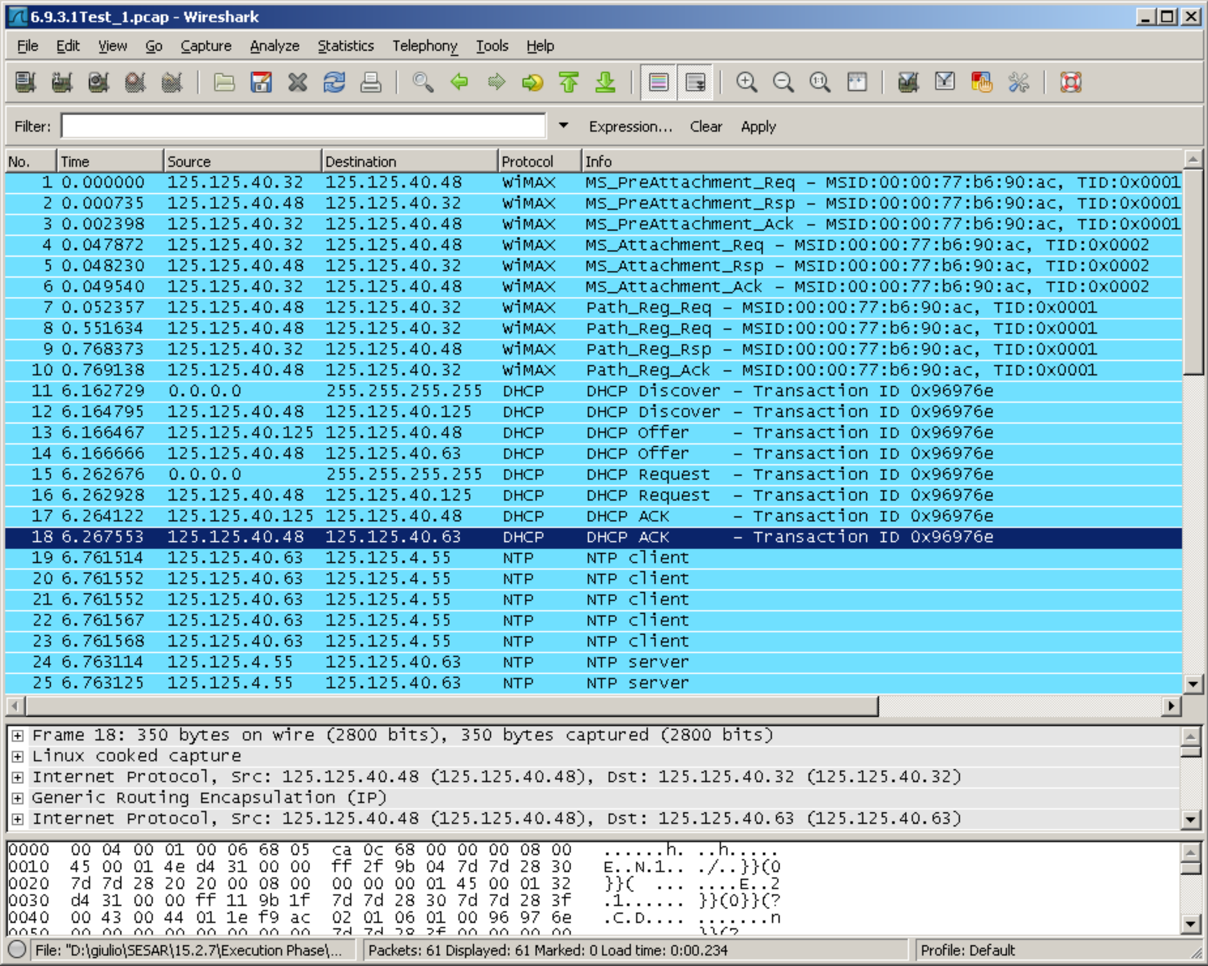


Figure 44: Net Entry without authentication - WS Log

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 45 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 45 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 45).
- 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 back 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 was successfully concluded and the final Registration/SF Creation may be started.

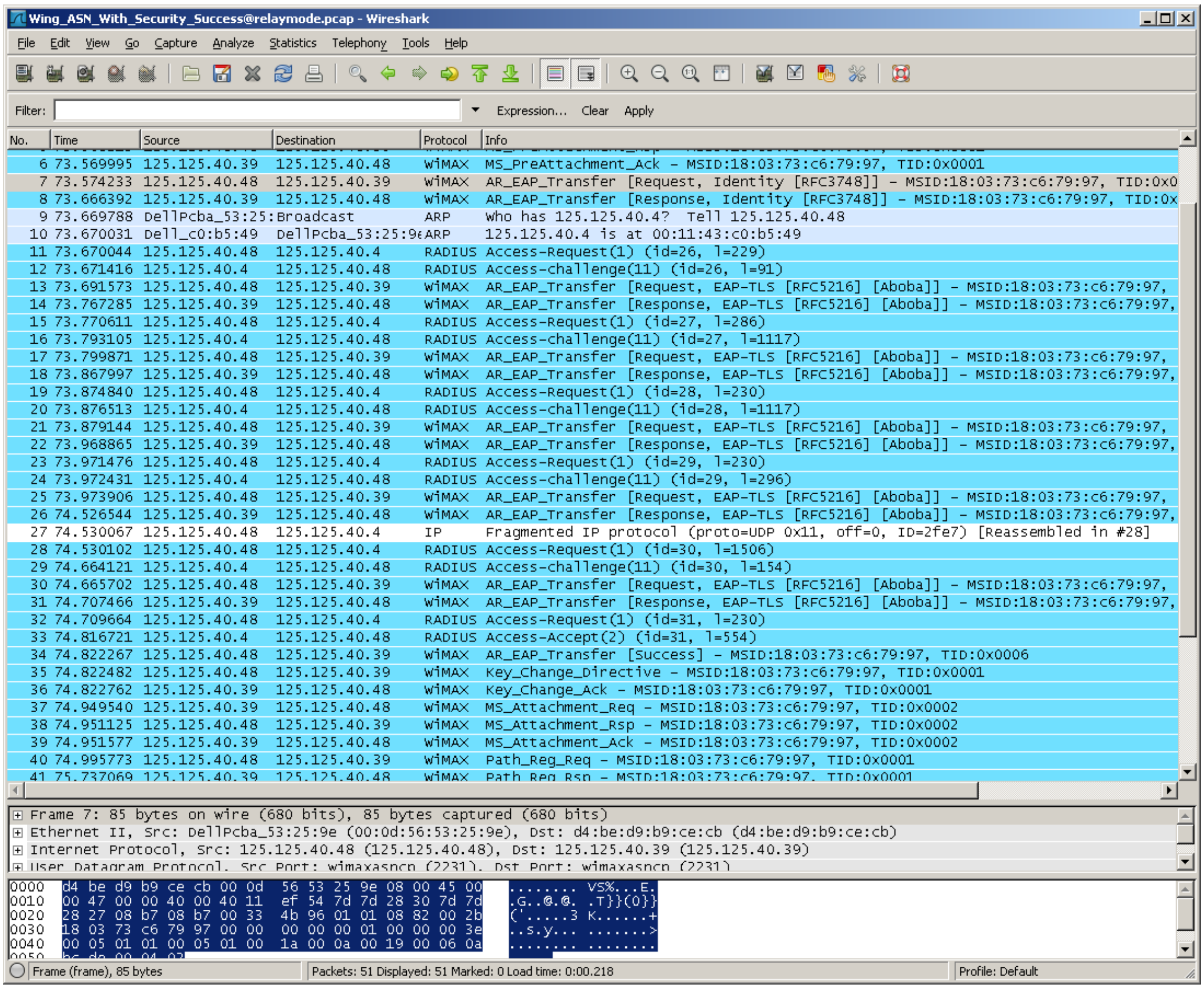


Figure 45: EAP-based Authentication Procedure

Concerning the Authentication procedure, Wireshark log in Figure 46shows the “Client Hello” message sent by the BS (125.125.40.32, on behalf of the MS) to the ASN-GW (125.125.40.48) starting the Handshake for Authentication, In particular the picture shows the Cipher Suites supported by the MS. The ASN-GW will then select one of the supported suites in a subsequent “Server Hello” message, containing also the BS Certificate (see Figure 47). So it is possible to see that the MS and BS negotiate the AES128 Encryption method for data plane.

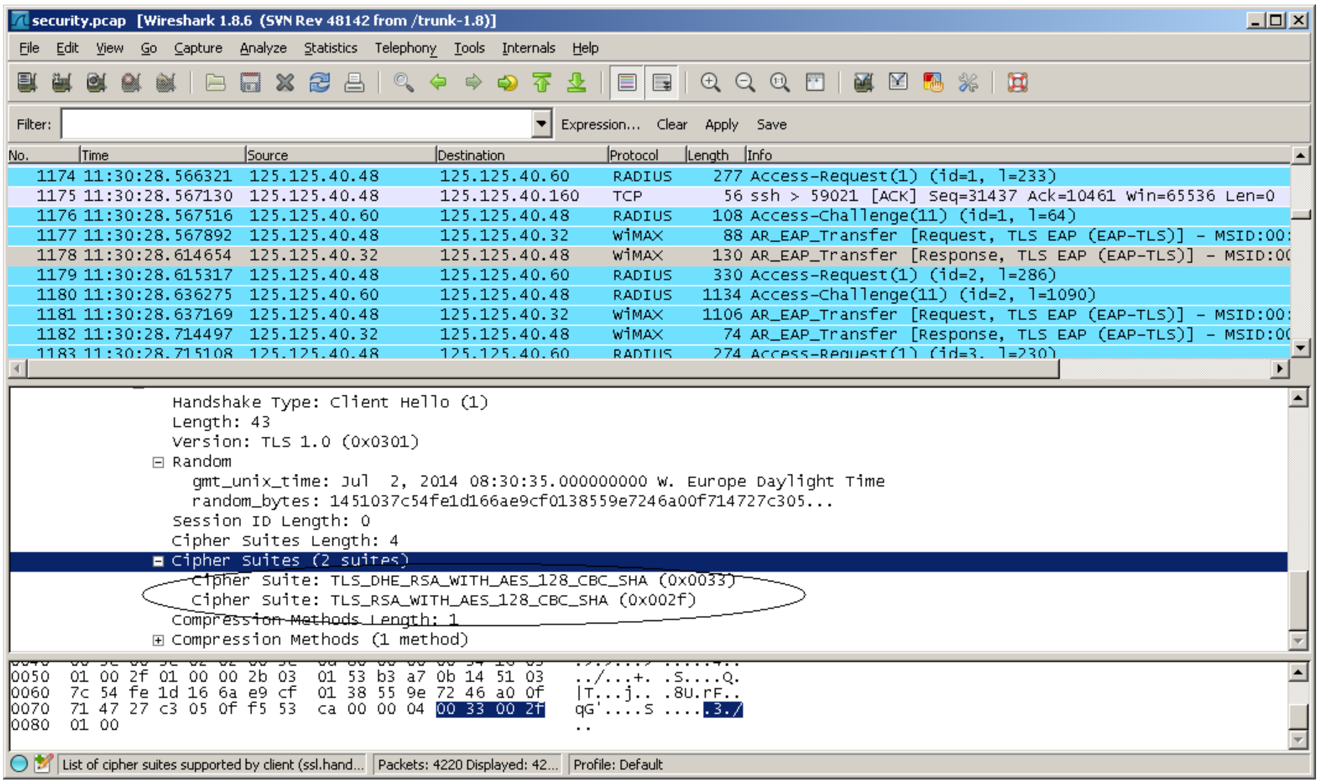


Figure 46: Cipher Suites supported by MS

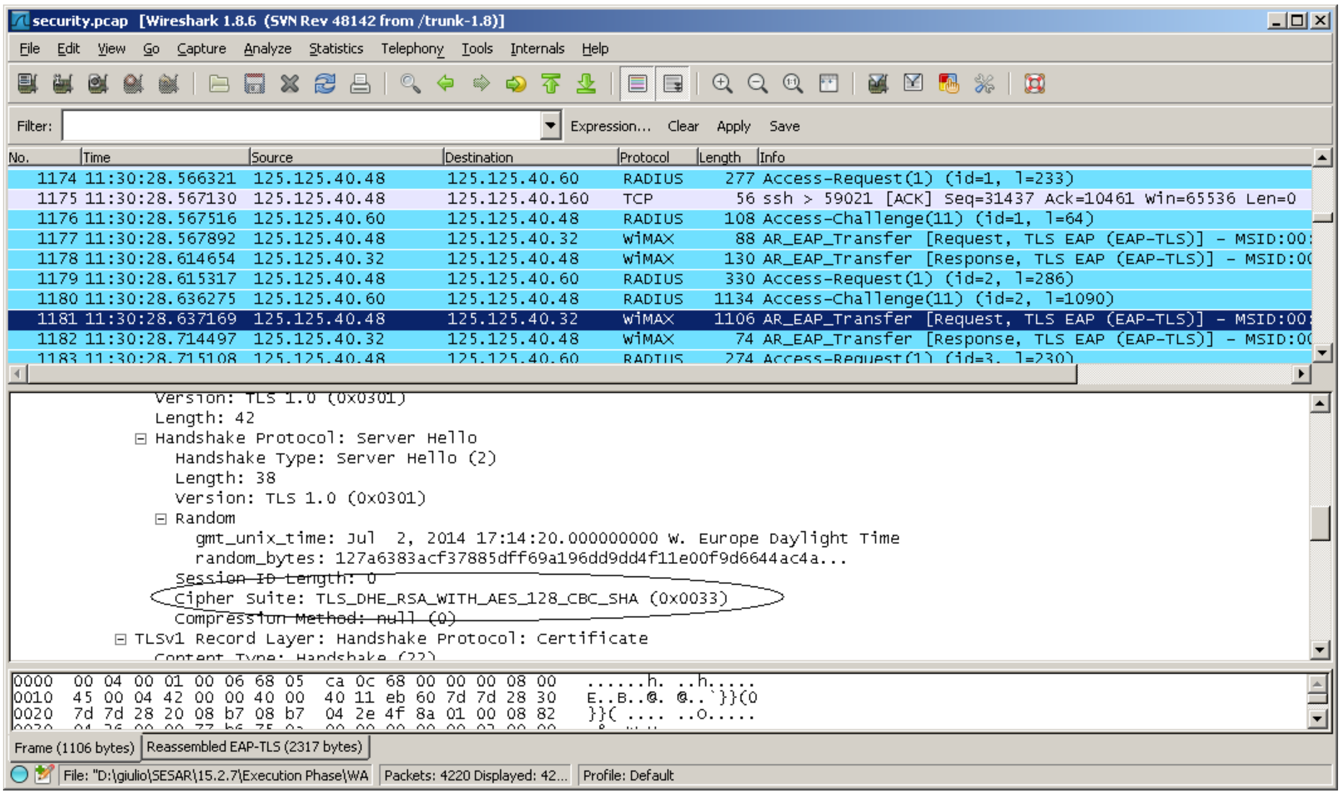


Figure 47: "Server Hello" from ASN-GW

After the successful MS authentication, the subsequent phase of Registration started. It is possible to observe in Figure 48 that the PKMv2 is used. From this point on, all of the Data exchanged between BS and MS were cyphered, and the proper reception at the addressee was observed.

After the expiration of the AK Lifetime timer, the proper Re-Authentication was observed.

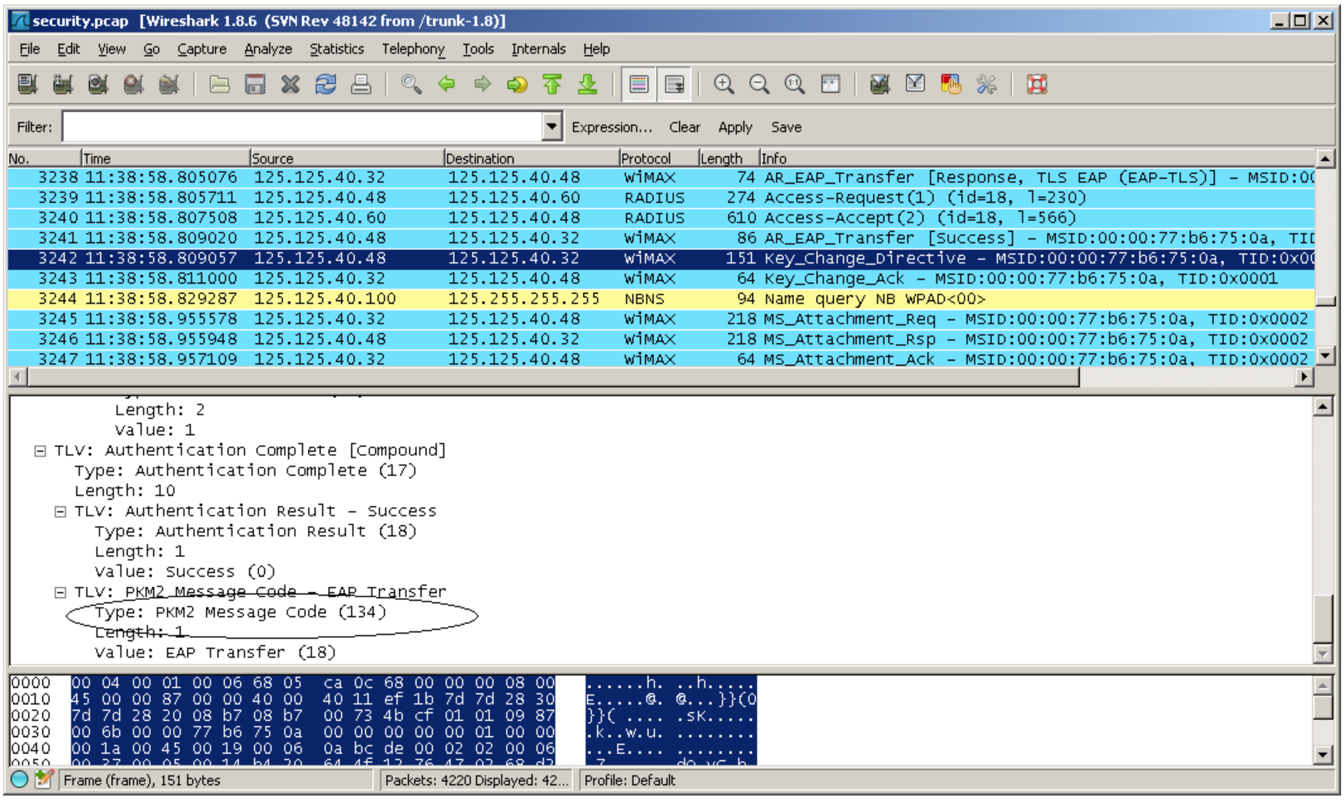


Figure 48: Privacy Key Management Protocol

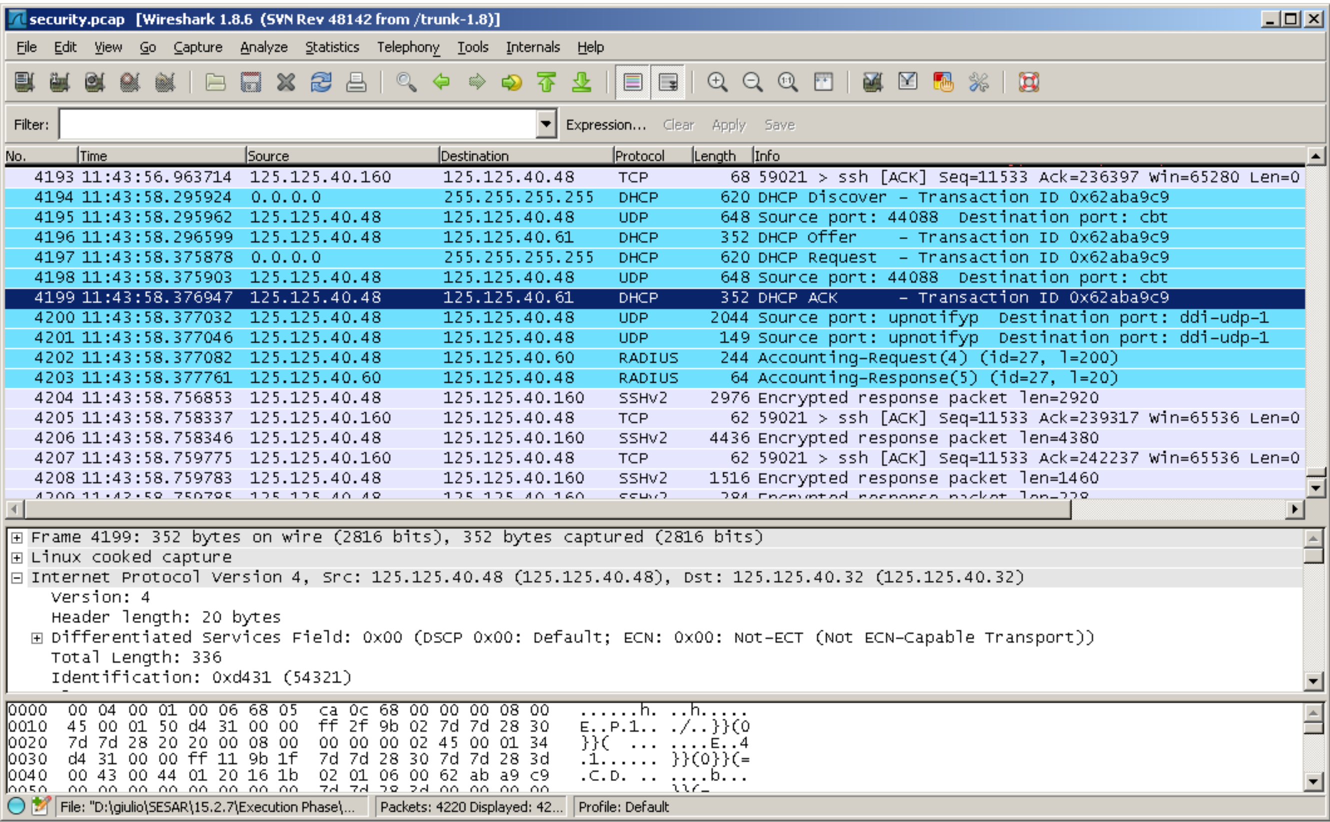


Figure 49: First cyphered messages after Authentication: DHCP

6.3.2.7.1 Deviation from the planned activities

A problem discovered on the ASN-GW (the ASN-GW was not able to set up automatically an IP-IP data tunnel between itself and the PC behind it) prevented the possibility to do Security testing with DL/UL data transfer between the end systems.

6.3.2.8 Lab7_X Handover

These series of tests have verified, using the scheme of Figure 7, the AeroMACS MS prototype inter-frequency MS-Triggered Handover (hard handover) features are correctly implemented, namely:

1. Verify the MS Handovers towards a neighbor BS (without data transfer)
2. Verify MS Handover during data transfer

Firstly the handover feature has been successfully tested without data transmission (see Figure 50); the test was conducted starting the MS1 net entry with BS1 (see step1 in Figure 50); after the MS1 registration and DHCP procedure the BS1-MS1 link attenuation was increased to get closer to the AeroMACS MS1 prototype sensitivity threshold (~-88dBm) and trigger the Handover condition (see step2 in Figure 50). After the MS1-HO request the ASN-GW transfers MS1 contex information to BS2 (see step3 in Figure 50), then MS1 requests deregistration to BS1 and registers on BS2 (see step4/5 in Figure 50). All the MS1 triggered handover process steps were observed, according to the IEEE 816.2e; the MS1 handover interruption time lasted less than 200ms.

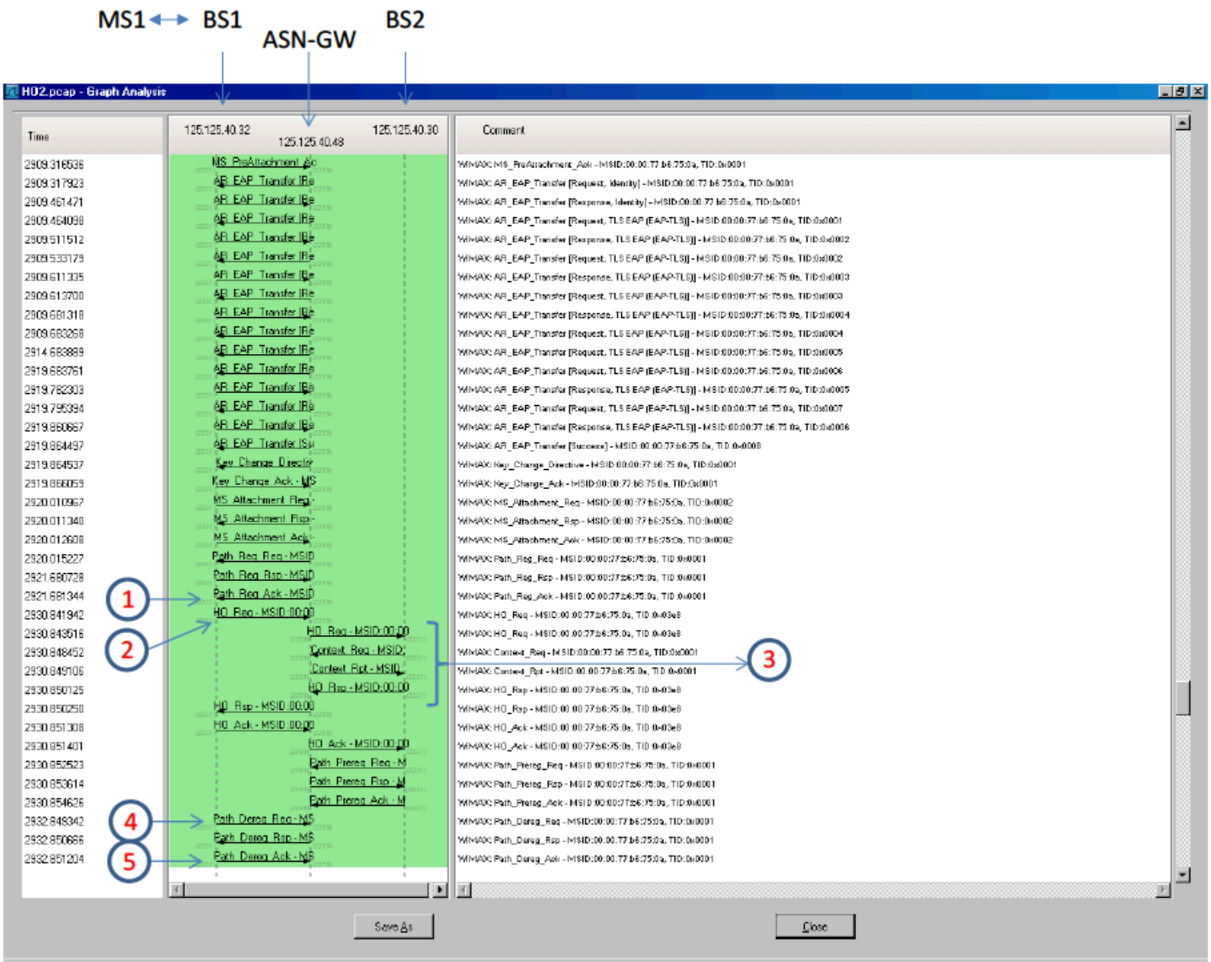


Figure 50: MS Handover Log

Later the HO features has been tested with data transmission; the test failed because the ASN-GW was not able to set up automatically an IP-IP data tunnel between itself and the PC behind it. There is a ticket open with the ASN-GW supplier to resolve this issue and then repeat the test.

6.3.2.8.1 Deviation from the planned activities

A problem discovered on the ASN-GW (the ASN-GW was not able to set up automatically an IP-IP data tunnel between itself and the PC behind it) prevented the possibility to do Handover testing with DL/UL data transfer between the end systems.

6.3.2.9 Lab8_X Mobility

These series of tests have verified, using the scheme of Figure 7, the AeroMACS MS prototype mobility features, using a PropSim simulator, namely:

1. Verify the MS doesn't lose the link and data with the BS in Doppler condition
2. Verify the MS doesn't lose the link and data with the BS in Doppler & Fading conditions. The fading applied vary in both delay and attenuation characteristics.

The PropSIM tool has been used to simulate Doppler and Doppler+Fading airport conditions at the cell border (worst case) to stress the AGC and PLL performances as close as possible at the RX sensitivity threshold.

In the first steps the PropSim has been configured to simulate a Doppler condition of 105Kmph.

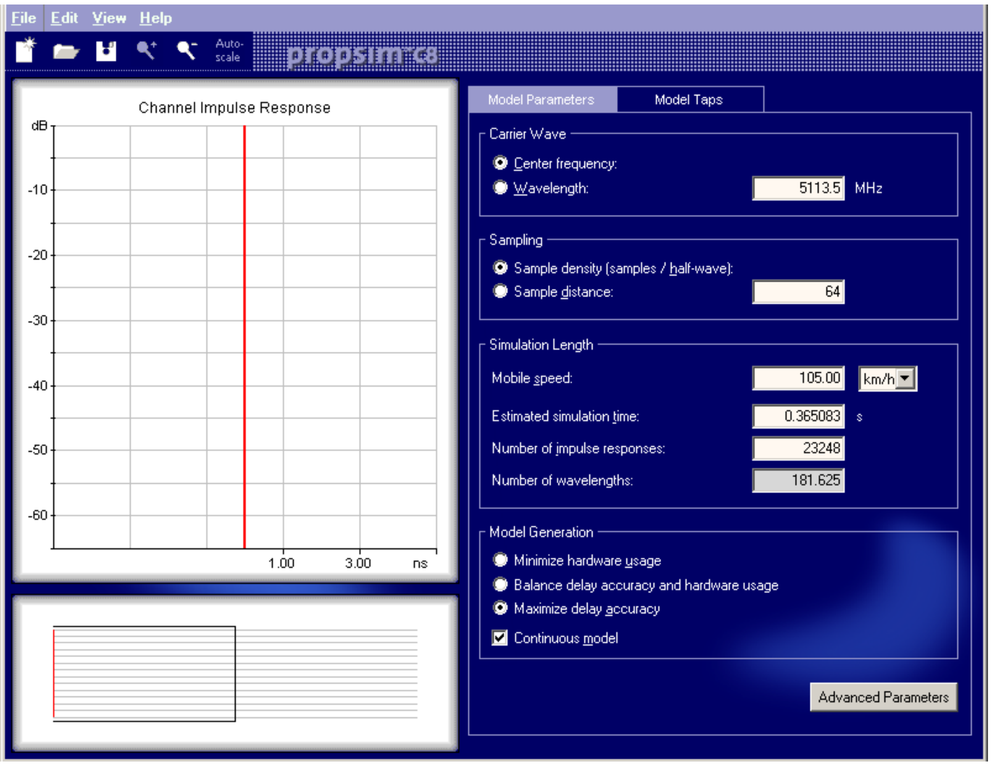


Figure 51: Pure doppler parameter configuration

and the channel conditions as indicated in the picture before (plus a fix channel attenuation of 50dB):

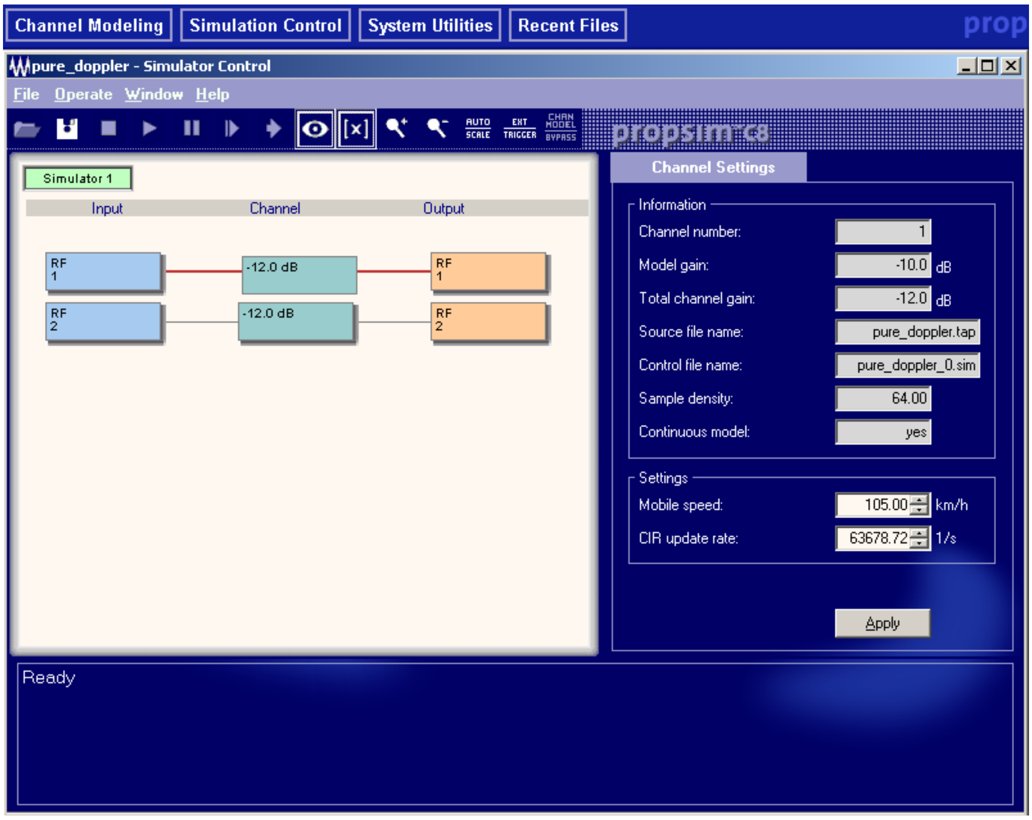


Figure 52: Pure doppler channel configuration

With these conditions the DL RSSI observed was in the range -58÷-64dbm (CINR 8÷11) and the UL RSSI in the range -55÷-62dbm (CINR 8÷14). Neither link disconnection nor packet loss were observed.

In the second step the PropSim has been configured to simulate a Doppler & Fading with different delay&attenuation characteristics (Constant to 5 TAPs Fading, together with the simulation of Barajas Airport conditions).

As an example of the outcomes of the tests the Five_TAP_Fading_2 channel model results are reported.

The PropSim has been configured, concerning input, channel, taps model, and output as shown in the following pictures:

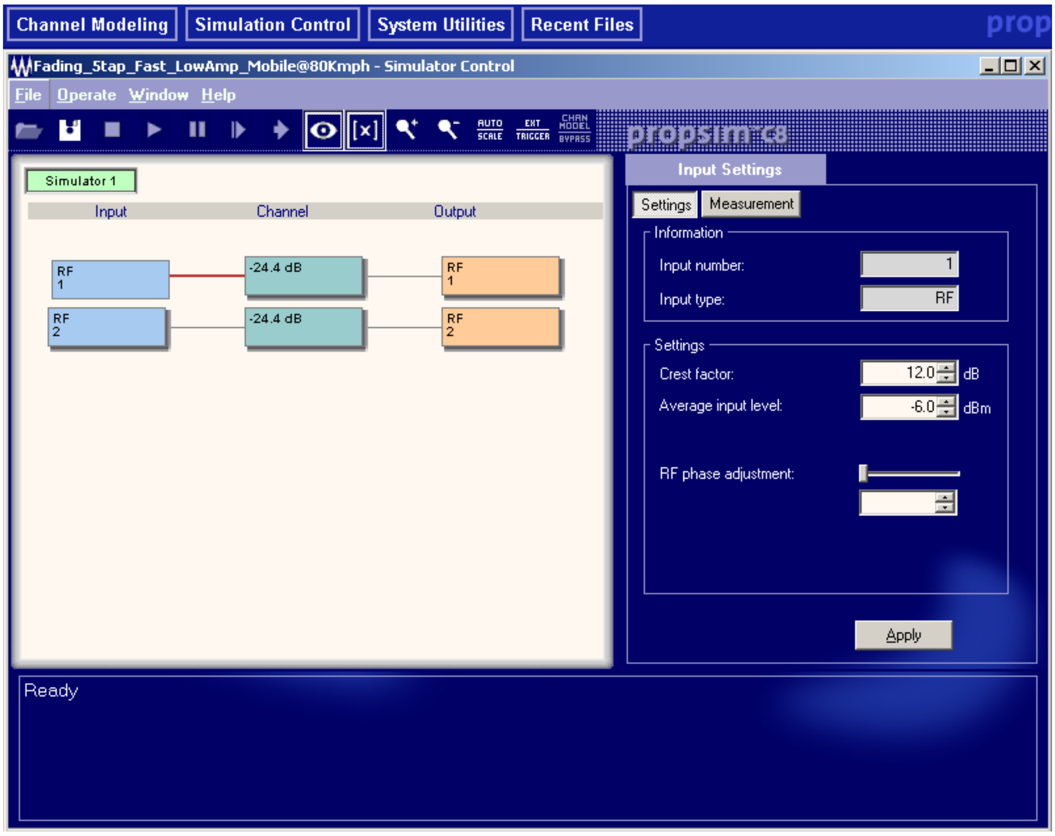


Figure 53: Doppler + 5 TAP fading input settings

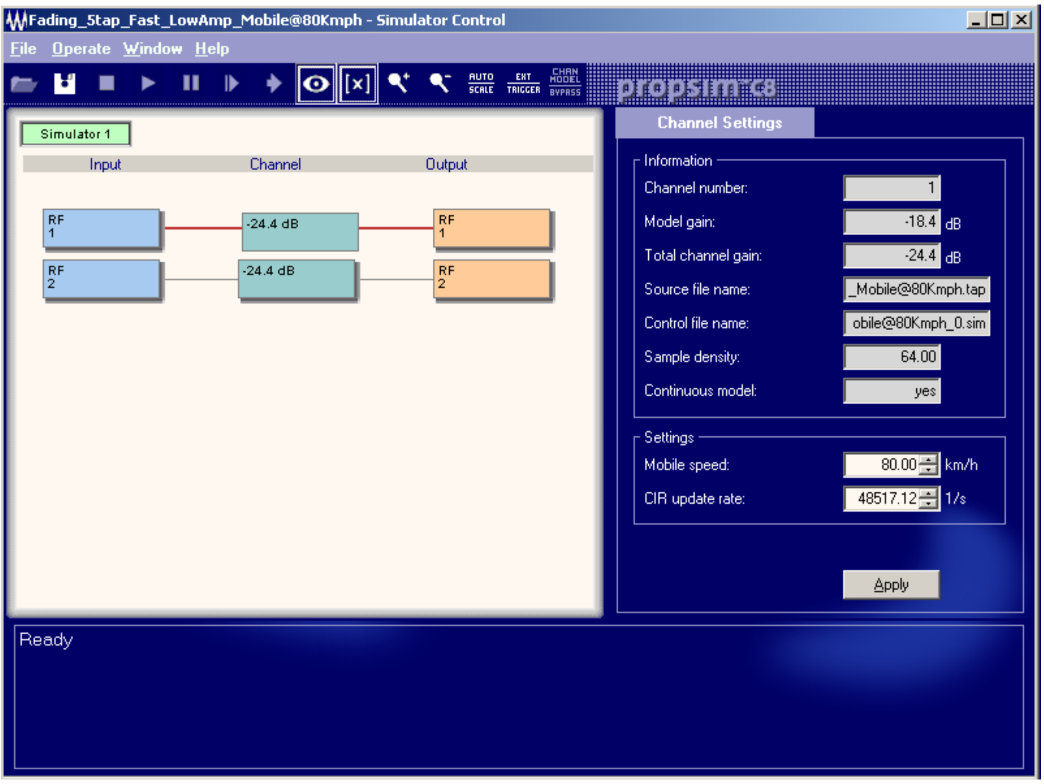


Figure 54: Doppler + 5 TAP fading channel settings

(Plus a fix attenuation of 50dB)

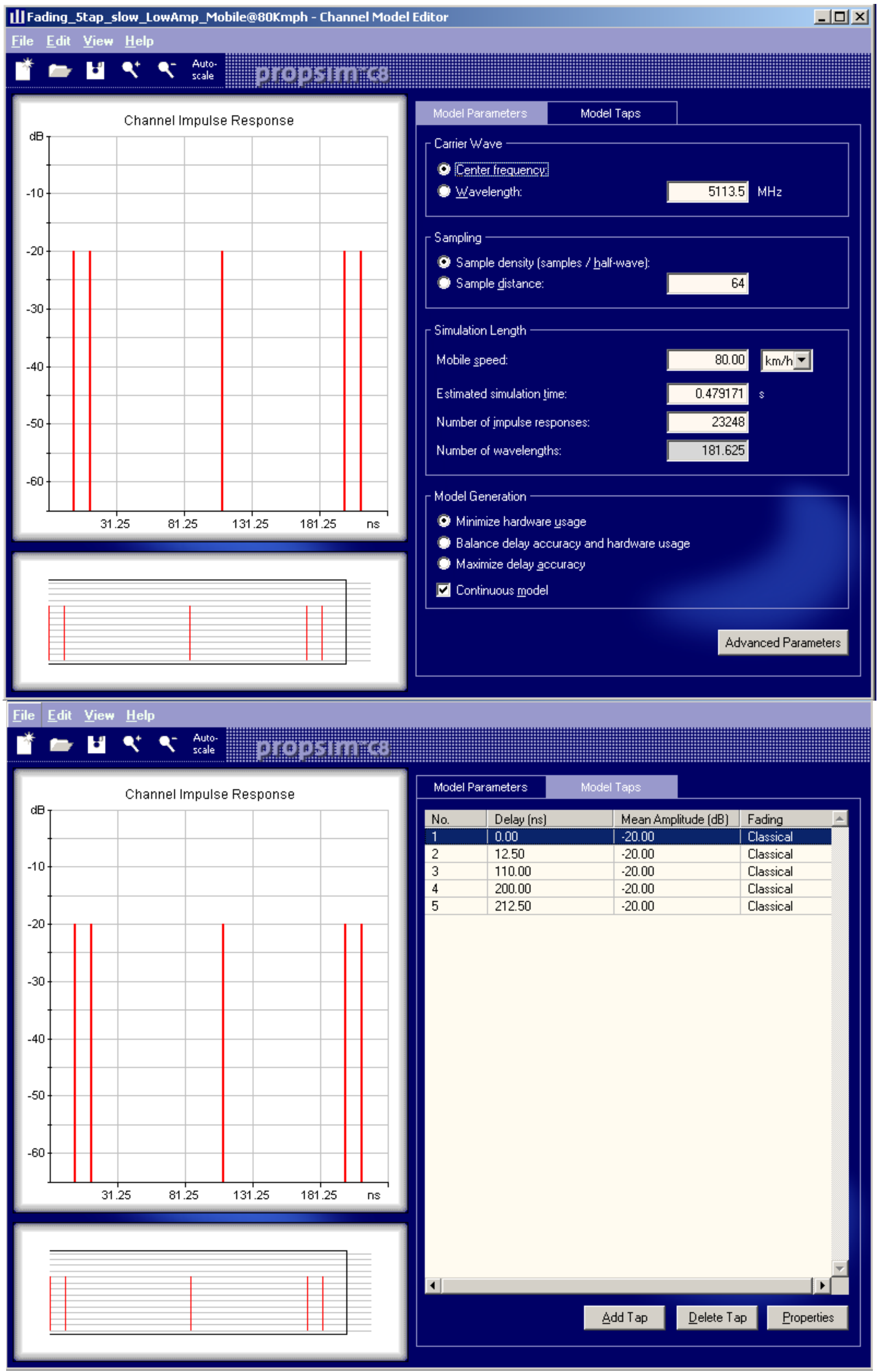


Figure 55: Doppler + 5 TAP fading TAP settings

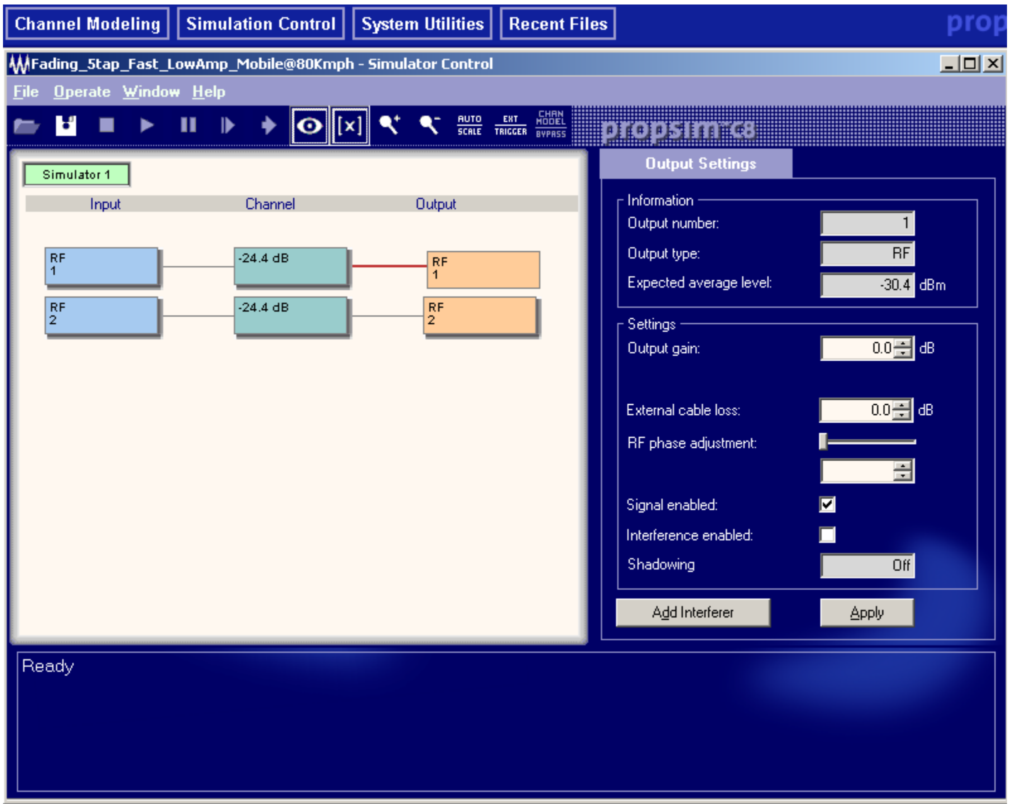


Figure 56: Doppler + 5 TAP fading Output settings

With these conditions the DL RSSI observed was in the range -62÷-85dbm (CINR 0÷8) and the UL RSSI in the range -62÷-86dbm (CINR 0÷11). No link disconnection was observed but packet loss errors were present in bad channel conditions with the AeroMACS MS Prototype working close to its sensitivity threshold (RSSI around -85 dBm).

6.3.2.9.1 Deviation from the planned activities

None

6.3.2.10 Lab9_X Multiple AeroMACS MS

These series of tests have shown multiple AeroMACS MSs registration and UL/DL data transfer to/from an AeroMACS BS.

In Figure 57 is shown the AeroMACS BS Log with the indication of the multiple AeroMACS MSs registration with the relevant statistics.

```
REGISTRATION MS 00 00 77 b5 e1 8c
16:30:14:157 RT :  FN: 1885 : SBC-REQ Received on CID: 1    MSID : 0x 0  0 77
b5 e1 8c
16:30:14:157 STAT : In SBC Req, Auth is not supported
16:30:14:158 STAT : BSMM-R6CTRL: MS_PreAttachment_Req sent to ASN-GW
16:30:14:161 STAT : BSMM-R6CTRL: Recieved MS_PreAttachment_Rsp from ASN-GW
16:30:14:162 RT : SBC-RSP: Number of DL Channels:7
16:30:14:163 RT :   FN: 1886 : Sending SBC-RSP to MS on CID: 1    MSID : 0x 0
0 77 b5 e1 8c
16:30:14:163 STAT : BSMM-R6CTRL: MS_PreAttachment_Ack sent to ASN-GW
16:30:14:208 STAT : BSMM-R6CTRL: MS_Attachment_Req sent to ASN-GW
16:30:14:209 STAT : BSMM-R6CTRL: Recieved MS_Attachment_Rsp from ASN-GW
```

```
16:30:14:213 RT :  FN: 1896 : Sending REG-RSP to MS on CID: 1000       MSID :
0x 0  0 77 b5 e1 8c
16:30:14:213 STAT : BSMM-R6CTRL: MS_Attachment_Ack sent to ASN-GW
16:30:14:220 RT : FN:1897 ASNGW-R6: Recieved R6_PATH_REG_REQ from ASN-GW
16:30:22:187 RT : FN:219618 ASNGW-R6: Recieved R6_PATH_REG_ACK from ASN-GW
16:30:22:187 RT : HODBG:: Decoding of PATH_REG_ACK successful
16:30:24:922 RT :  FN: 2438 : Sending DSA_ACK to MS on CID: 1000       MSID :
0x 0  0 77 b5 e1 8c
```

End of REGISTRATION MS 00 00 77 b5 e1 8c

```
16:38:31:416 RT : MSID : 0 0 77 b5 e1 8c- UL Mean CINR =12.881418 Mean RPD =-
71.877472 Current TPD =-24.000000
16:38:45:408 RT : MSID : 0 0 77 b5 e1 8c- UL Mean CINR =13.076640 Mean RPD =-
71.304497 Current TPD =-24.000000
16:39:49:370 RT : MSID : 0 0 77 b5 e1 8c- UL Mean CINR =13.432693 Mean RPD =-
71.699989 Current TPD =-24.000000
16:40:39:341 RT : MSID : 0 0 77 b5 e1 8c- UL Mean CINR =13.834854 Mean RPD =-
71.493828 Current TPD =-24.000000
16:40:53:333 RT : MSID : 0 0 77 b5 e1 8c- UL Mean CINR =14.114210 Mean RPD =-
71.892601 Current TPD =-24.000000
16:41:43:303 RT : MSID : 0 0 77 b5 e1 8c- UL Mean CINR =14.205266 Mean RPD =-
71.823586 Current TPD =-24.000000
16:41:57:295 RT : MSID : 0 0 77 b5 e1 8c- UL Mean CINR =14.548279 Mean RPD =-
72.012260 Current TPD =-24.000000
```

REGISTRATION MS 00 00 77 b6 91 72

```
16:48:21:334 STAT : RNG REQ received from MS with MSID 0:0:77:b6:91:72 in
frame number 219445
16:48:21:430 STAT : In SBC Req, Auth is not supported
16:48:21:433 RT : SBC-RSP: Number of DL Channels:7
16:48:21:433 STAT : BSMM-R6CTRL: MS_PreAttachment_Ack sent to ASN-GW
16:48:21:433 RT : CPSU-MS: SBC-RSP Message post to CPSL Layer Success
16:48:21:436 RT :   FN: 219468 : Sending SBC-RSP to MS on CID: 2       MSID :
0x 0  0 77 b6 91 72
16:48:21:479 RT :  FN: 219476 : REG-REQ Received on CID: 1001     MSID : 0x 0
0 77 b6 91 72
16:48:21:481 STAT : BSMM-R6CTRL: MS_Attachment_Req sent to ASN-GW
16:48:21:482 STAT : BSMM-R6CTRL: Recieved MS_Attachment_Rsp from ASN-GW
16:48:21:483 STAT : BSMM-R6CTRL: MS_Attachment_Ack sent to ASN-GW
16:48:21:489 RT : FN:219478 ASNGW-R6: Recieved R6_PATH_REG_REQ from ASN-GW
16:48:22:187 RT : FN:219618 ASNGW-R6: Recieved R6_PATH_REG_ACK from ASN-GW
16:48:22:187 RT : HODBG:: Decoding of PATH_REG_ACK successful
16:48:22:191 RT :  FN: 219619 : Sending DSA_ACK to MS on CID: 1001      MSID :
0x 0  0 77 b6 91 72
16:48:22:191 RT :  FN: 219619 : Sending DSA_ACK to MS on CID: 1001      MSID :
0x 0  0 77 b6 91 72
```

End of REGISTRATION MS 00 00 77 b6 91 72
Registered MS STATISTICS

```
16:49:04:075 RT : UL: MSID 00:00:77:b5:e1:8c,FEC Code: 2, CINR: 16.72, RPD: -
72.00, TPD: -24.00, Max Subchannels: 17
16:49:04:075 RT : UL: MSID 00:00:77:b6:91:72,FEC Code: 2, CINR: 16.48, RPD: -
73.00, TPD: -24.00, Max Subchannels: 17
```

Figure 57: Multiple MSs Registration

In Figure 58 the ASN-GW log is shown, with the indication of the current number of AeroMACS MSs registered.

```
PARAMETERS                                   VALUES

MS Info
___________________________

                 GW-Role              ANCHOR/AUTHENTICATOR
                MS-STATE                            ACTIVE
                   MS-ID                      000077b5e18c

                     NAI
                   MS-IP                    125.125.40.61
            PMK Lifetime                             3600
                   HA-IP                     125.125.4.50
              Lease Time                                0
                  AAA-IP                          0.0.0.0
                   BS-ID                     0abcde000101

                MIP-MODE                                -
         Connection-Type               PREPAID CONNECTION
         Accounting-Type                                -
___________________________


MS Info
___________________________

                 GW-Role              ANCHOR/AUTHENTICATOR
                MS-STATE                            ACTIVE
                   MS-ID                      000077b69172

                     NAI
                   MS-IP                    125.125.40.62
            PMK Lifetime                             3600
                   HA-IP                     125.125.4.50
              Lease Time                                0
                  AAA-IP                          0.0.0.0
                   BS-ID                     0abcde000101

                MIP-MODE                                -
         Connection-Type               PREPAID CONNECTION
         Accounting-Type                                -
```

Figure 58: Multiple MSs Registration – ASN-GW information

6.3.2.10.1 Deviation from the planned activities

None

6.3.2.11 Lab10_X Lab Measurements based on preamble OR pilots

These series of tests have shown the correct RSSI measurements done by the AeroMACS MS Prototype.

In many of the logs shown throughout the validation exercises descriptions' the RSSI measurements are reported. The verification of the RSSI measurement have been tested by means of a manual reduction of the link attenuation and checking the relative RSSI equal increase.

6.3.2.11.1 Deviation from the planned activities

None

6.3.2.12 Lab11_X Miscellaneous Tests

The following test have been performed:

- AeroMACS MS Prototype Monitoring capabilities
- AeroMACS MS Prototype TX Spurious emissions

Concerning AeroMACS MS Prototype monitoring, have been proved the correct measurements of the following parameters:

- The BS received signal quality
- The output signal power
- Users data and QOS mapping
- UTC time with date
- BS RSSI (dBm)
- Cell ID on which is the MS
- Handover
- Radio power level
- SNR (dB)
- Frequency used (Hz)
- Radio Modulation used
- Volume of data transmitted/received
- BER/PLR
- Maintenance Password Protection

Concerning AeroMACS MS Prototype TX spurious emissions, measurements have shown the presence of the following TX Spurious frequencies:

- F=1,14GHz (oscillator frequency)
- F=4.908GHz (4th harmonic of the oscillator)
- F=5.320GHz (modulated signal)

All the TX spurious emissions are below the limits of the table reported below (AeroMACS MOPS 2013-02-13 draft P)

FREQUENCY BAND	MEASUREMENT BANDWIDTH	MAXIMUM LEVEL
30MHz < f < 1 GHz	100 kHz	-36 dBm
1GHz < f < 12,75 GHz	30kHz if 2,5xBW<=|fc-f|<10xBW	-30 dBm
	300kHz if 10xBW<=|fc-f|<12xBW	-30 dBm
	1MHz if 12xBW<=|fc-f|	-30dBm

Table 5 - Transmitter spurious emissions

6.3.2.12.1 Deviation from the planned activities

The AeroMACS MS RF unit has been developed with a TX spectrum mask not compliant to the one of the MOPS/SARPS, due to the fact that RF unit developments have started before the standardization. This prevented many of the tests/demonstrations concerning the RF VVOs.

6.4 Conclusions and Recommendations

6.4.1 Conclusions

The STEP1 verification exercise allowed the preparation of the Airbus LAB, CAR and A/C Tests (STEPs 2/3/4). Attention has been paid on the verification of AeroMACS MS Prototype compliance to the requirements set in the D04 - Airborne AeroMACS Prototype Specification, on the verification of AeroMACS MS Prototype compliance with the AeroMACS profile and on the interoperability verification between the AeroMACS MS Prototype and the AeroMACS Network. The verification exercise has succeeded in general, anyway some AeroMACS system and network limitations has prevented the verification of :

- The complete AeroMACS MS Prototype RF characterization, in particular the TX Spectrum Mask compliance to the SARPS/MOPS;
- The High level MCS, namely 16QAM ¾ and 64QAM modulations
- The DL/UL data transmission with Security
- The Hard Handover with DL/UL data transfer
- The collection of some requested SNMP MIB parameters measurements, like PLR;

6.4.2 Recommendations

The issues noted during the STEP 1 verification exercise can be resolved implementing the following actions:

- Resolution of AeroMACS system HW/SW limitations
- Improve the AeroMACS network design and resolution of AeroMACS network security issues', implementing a common/standard PKI infrastructure and a common/standard solution to connect the ASN-GW to the end systems behind it.
- Propose, design, develop and implement a standard SNMP V3 MIB, common to the overall AeroMACS network elements (MS/BS/ASN-GW)

7 STEP 2 Verification Exercises Report (Airbus laboratory tests)

7.1 Verification Exercises Scope

The scope of the Airbus laboratory tests (Step 2 of the P9.16 Verification exercises) was to verify the operation of the Selex MS prototype and the performance of the AeroMACS technology in a deployed environment over the Toulouse Airport, with the MS being installed at a static point in the coverage of the Selex AeroMACS BS installed at the Airport in the scope of the project 15.2.7.

The main objectives of these tests were to:

1. re-check (after Selex Step 1 verification) the compliance of the prototype against some key requirements of the prototype specification (9.16-D4 ([8])),
2. Verify the integration of the MS prototype within the Airbus test environment, notably the correct end-to-end operation of the complete chain of equipment and its readiness to be used for later step 3 (car tests) and step 4 (Aircraft tests).
3. Get a first level evaluation of the behaviour and the performance of AeroMACS in this deployed and static environment

More details are given in the Verification Plan (9.16-D06 ([6])) and in the Test procedures document (9.16-D07 ([7]))

7.2 Conduct of Verification Exercise

This verification exercise was performed in coordination with the following partners:

- SELEX provided the AeroMACS prototypes, and (mainly off-site) support during the experiments, notably for trouble-shooting.
- SITA was in charge of the ground AeroMACS infrastructure deployment, and provided support during the experiments.
- DSNA/DTI managed regulatory aspects for 5GHz frequency use at TLS Airport.
- Airbus was in charge of the “Airborne” AeroMACS infrastructure deployment, and of the execution of the tests covering the Validation and Verification Objectives allocated to this AeroMACS verification exercise.

7.2.1 Verification Exercise Preparation

7.2.1.1 General

Figure 59 presents the test infrastructure deployed around Toulouse Airport for SESAR P9.16 test steps 2, 3, and 4.

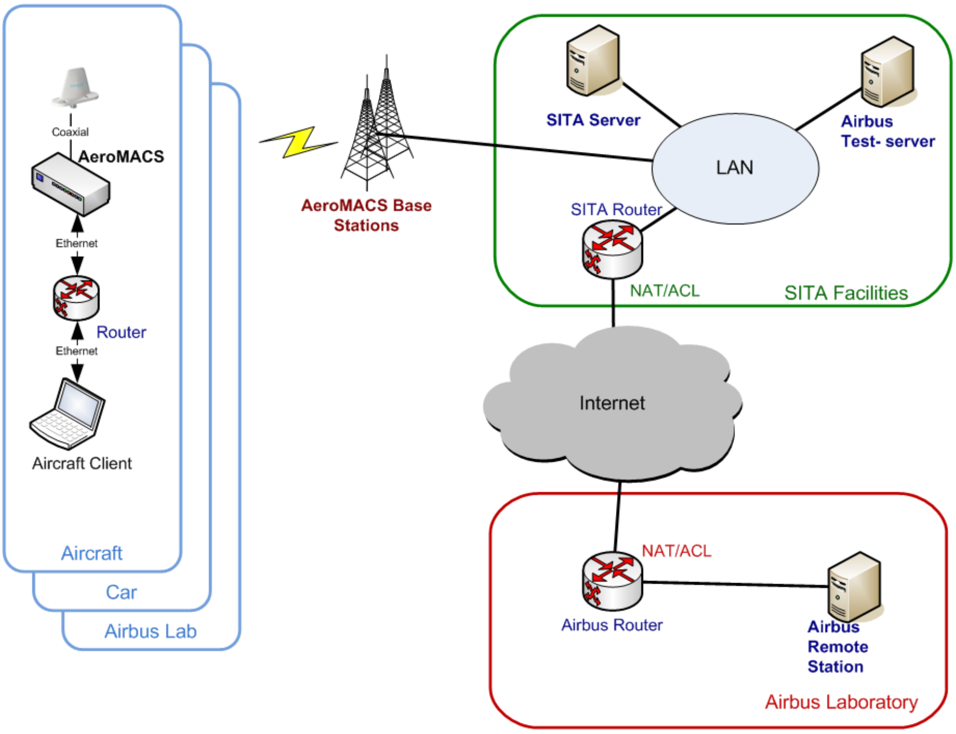


Figure 59: Test Infrastructure used during SESAR 9.16 test steps 2, 3 and 4

It consists of:

- A mobile part composed of the MS prototype, the MS antenna, a router and a test laptop. This mobile part has been alternatively installed:
    - In a room of the Airbus Test Center during Step 2
    - On a car during Step 3
    - On a test Aircraft during Step 4.
- A Ground AeroMACS domain, deployed by SITA and composed of two SELEX Base Stations, one ASN gateway running on a SITA server, and an IP router. The location and coverage of the BSs is represented on Figure 60. They cover most of the Toulouse Blagnac Airport runways and taxiways, as well as the Airbus test Center building which is located on the other side of runway at 1900 m in line of sight from the BS location.
- A Ground End System domain, consisting of an IP router, and a Ground test server, located in the Airbus Test Center (in the same room as where is located the MS during step 2), and interconnected to the SITA Ground AeroMACS domain through an internet connection.

Figure 60: SESAR 9.16 Base Stations coverage

7.2.1.2 Geographical context of Airbus Laboratory tests

All (step 1) laboratory tests took place into the Airbus laboratory, in building M24 B389 room (third roof) of Airbus TOULOUSE SAINT-MARTIN-DU-TOUCH facilities. Figure 61 below shows the location of Airbus laboratory in regard to Toulouse-Blagnac Airport:

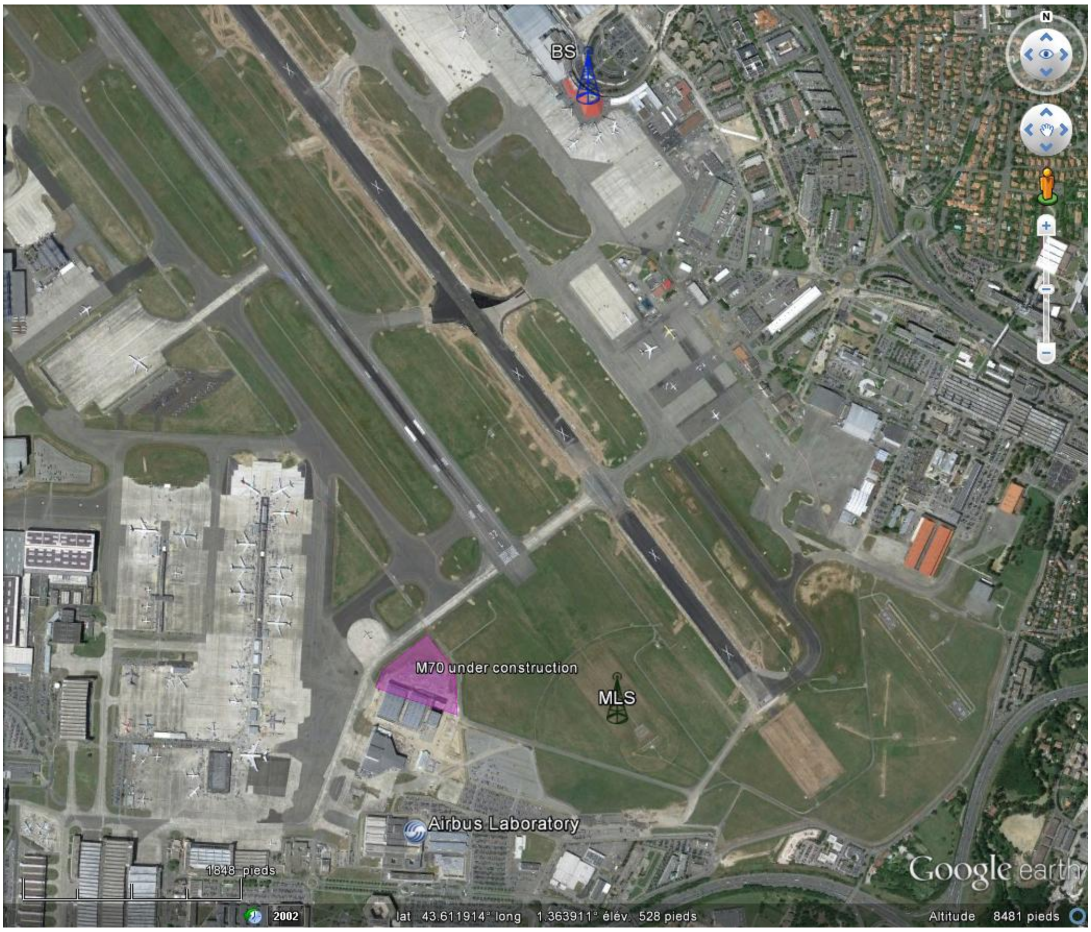


Figure 61: Test Location – Airbus Laboratory

The Airbus Laboratory room dedicated to AeroMACS tests is equipped with one MS. An AeroMACS antenna is anchored to the building wall, outside, at the level of the test room on the third floor.

The two BS antennas are installed on the roof of one of the Airport buildings. The distance separating the MS from the BS is around 2Km in LOS. There is a building (M70) located close to the MS-BS direct line of sight and which could potentially decrease the AeroMACS beam.

7.2.1.2.1 BS Antenna configuration 1: Theoretical Coverage of BS1 (Ratio 35:12)

In a first round, the AeroMACS network was configured to operate with a Ratio modulation of 35:12. BS antennas were installed vertically on a mast as illustrated here-after:

Figure 62: BS antennas vertical implementation

The tests were performed with the BS1 installed with an azimuth of 165° from the NORTH and a down-tilt of 7°.

The Figure 63 roughly illustrates the BS1 theoretical coverage at the Airport of Toulouse during this first phase.

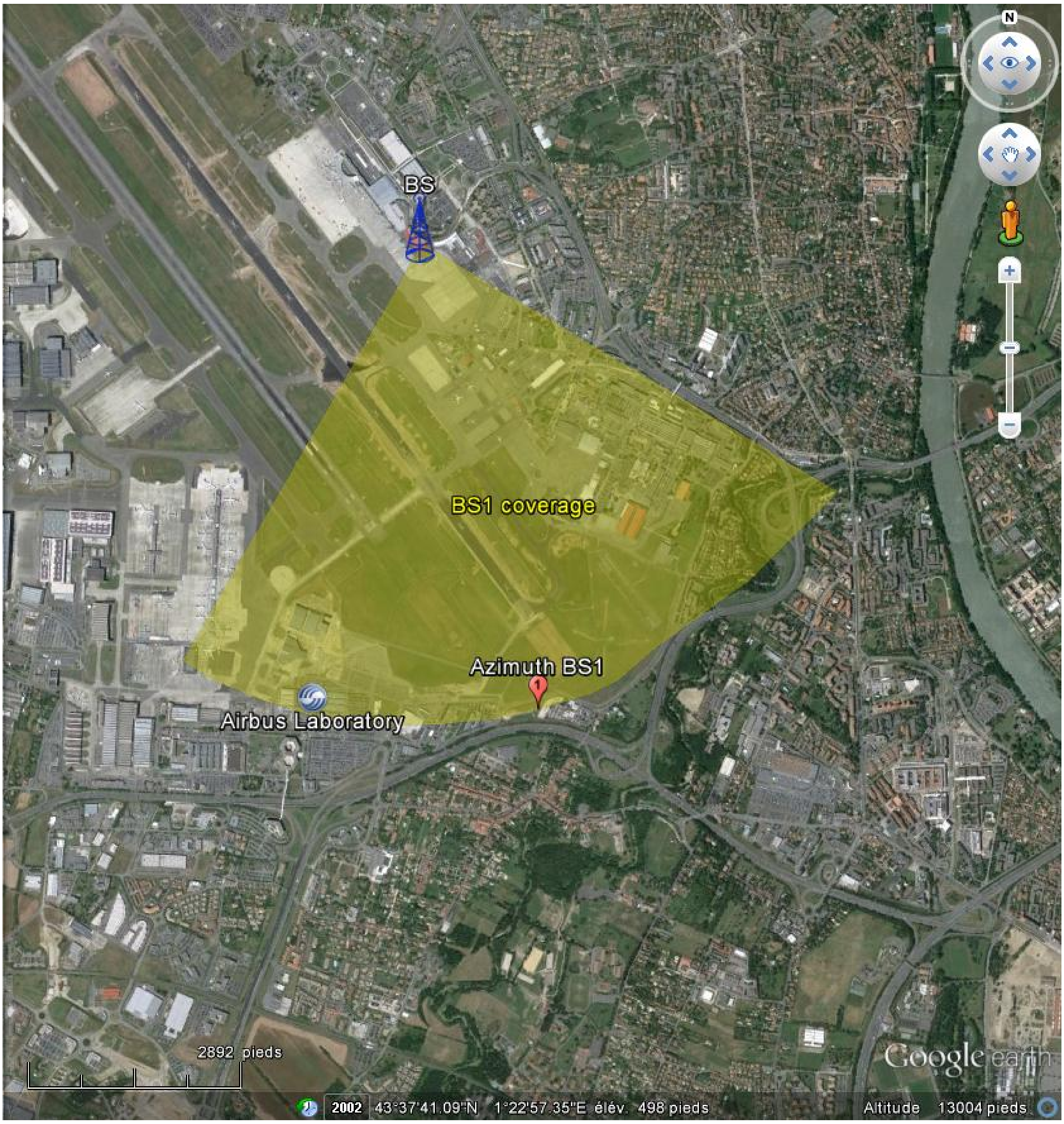


Figure 63: Laboratory Test - Theoretical BS1 coverage (Ratio 35:12)

Note: the above illustration is a rough evaluation of the BS antenna theoretical coverage: its horizontal aperture is 90° and its vertical is equal to 7°. It has not been derived from the use of signal propagation modelling tools and does not necessarily fully correspond to the real BS1 coverage.

7.2.1.2.2 BS Antenna configuration 2: Theoretical Coverage of BS1 (Ratio 32:15)

In a second round, the AeroMACS network was configured to operate with a Ratio modulation of 32:15. At the same time, the azimuth of the BS1 was changed to 200° from the NORTH and a down-tilt of 4°. The Figure 64 illustrates the modified BS1 theoretical coverage.

Figure 64: Laboratory Test - Theoretical BS1 coverage (Ratio 32:15)

7.2.1.2.3 BS Antenna configuration 3: Theoretical Coverage of BS1 & BS2 antennas

In a third round, the AeroMACS network was let configured to operate with a Ratio modulation of 32:15. For technical reason, azimuth and down-tilt of the mast highest antenna (BS2) could not be changed and was kept configured with an azimuth of 165° and a down-tilt of 5°. In order to keep an overlap area, the azimuth of the BS1 was changed to 240° from the NORTH and a down-tilt of 4°. As it is necessary to cover all the Airport area from Airbus to the bottom of the terminal 1, 4° of down tilt is normally optimal for the target coverage. The Figure 65 illustrates roughly the BS1 & BS2 theoretical coverage.

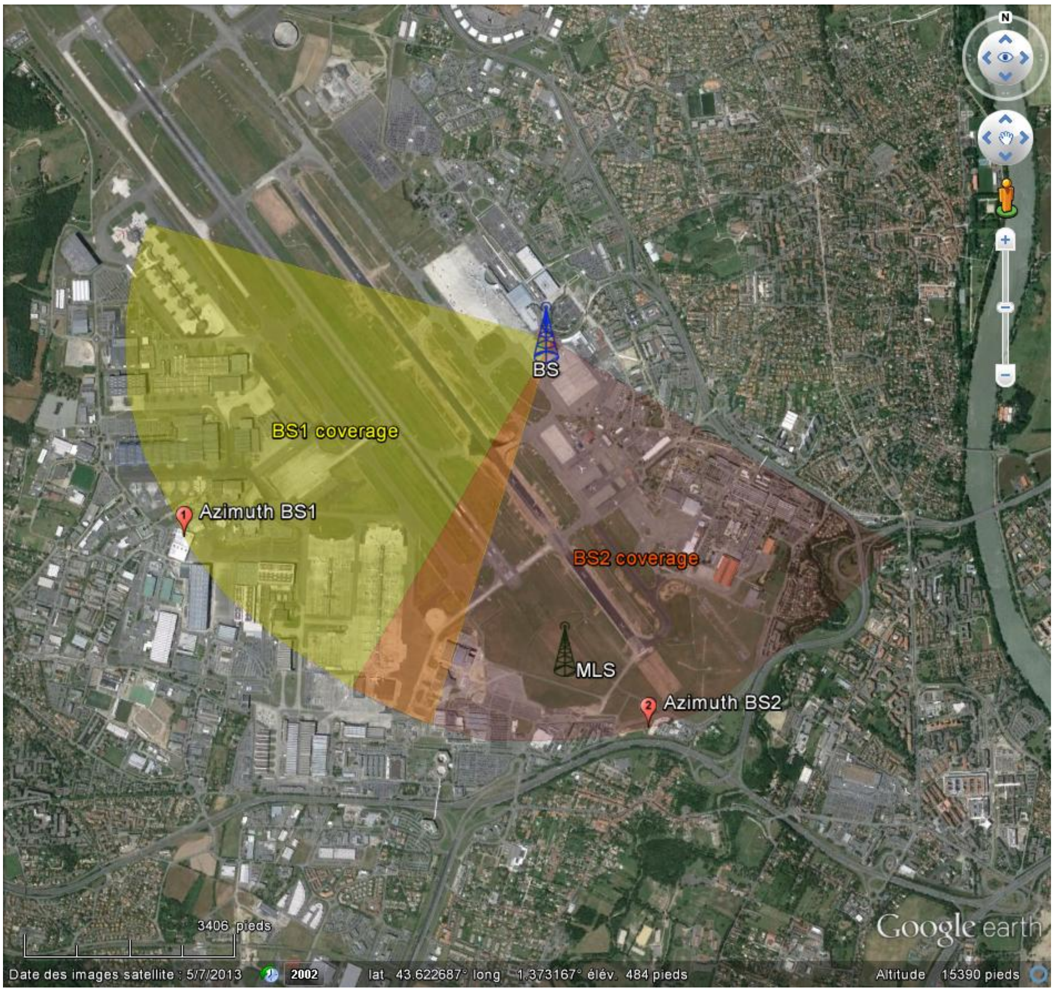


Figure 65: Laboratory Test - Theoretical BS1 & BS2 coverage (Ratio 32:15)

7.2.1.2.4 BS Antenna configuration 4: Theoretical Coverage of BS1 & BS2 antennas

A "site survey" with RF specialists from the ANOVO company was performed to enhance again the BS antennas orientation. It concluded (see §A.3) that with a slight reorientation of the two BS antennae's the entire airport platform should be covered with good levels: in NLOS conditions, the signal received was acceptable (around -103dBm); in LOS location, the signal received was always higher than -95dBm.

The two antennas were relocated at the same height (modification done by SITA), as illustrated here-after:

Figure 66: BS antennas implementation at the same height

With this fourth antennas configuration, the BS1 antenna was configured with 280° of azimuth & 6.6° of tilt; and the BS2 antenna with 174° as azimuth & 3.5° of tilt. The Figure 67 illustrates the modified BS1 & BS2 theoretical coverage:

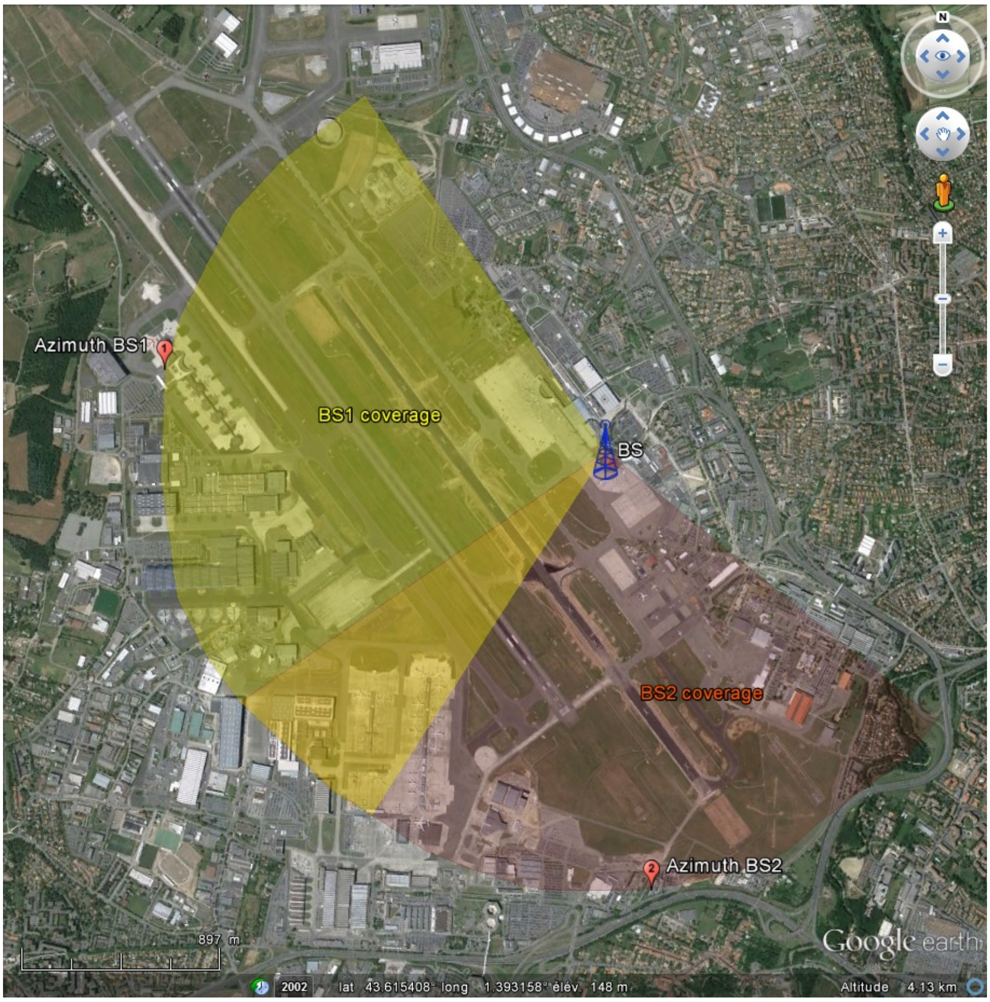


Figure 67: Laboratory Test - Theoretical BS1 & BS2 coverage (ultimate antenna configuration)

7.2.2 Verification Exercise execution

Refer to Table 1 in section 3.2 for the overall timing of Step 2 exercises.

The approach followed during execution of the Verification Exercise is described in 9.16-D07 ([7]).

7.2.3 Deviation from the planned activities

Refer to Table 2 on page 23.

7.3 Verification exercise Results

7.3.1 Summary of Verification exercise Results

Refer to Table 4 on page 26.

7.3.2 Analysis of Verification Exercise Results

7.3.2.1 T000 - RF calibration & preliminary tool validation

It was verified that the MS and BS are equipped with the appropriate connectors (TNC plug) . Through the RF plug and the wire, the MS can be connected to the antenna, or also to a spectrum RF analyzer or a Wattmeter.

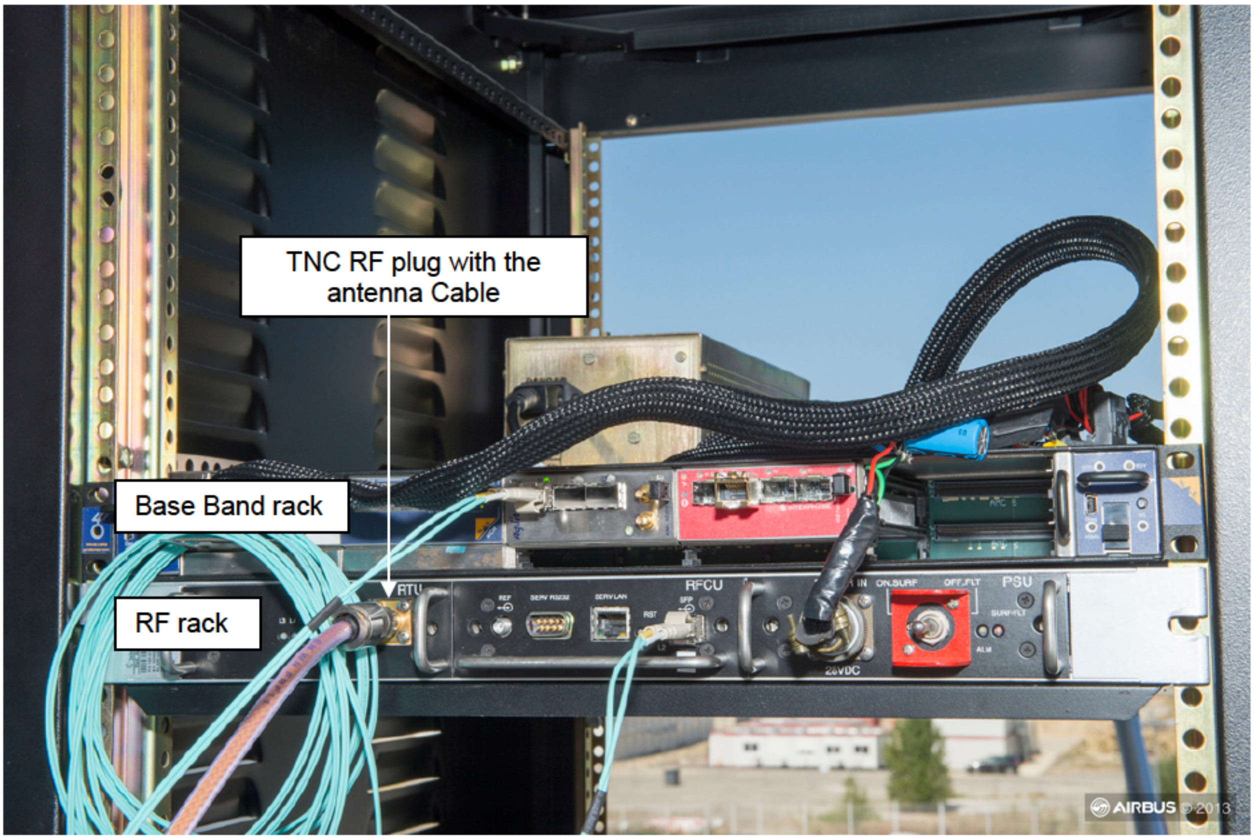


Figure 68: SELEX MS RACKs

7.3.2.2 T001 - Channel bandwidth test

The T001 test procedure has been passed over several different 5MHz channels in the band from 5091MHz to 5150MHz. The following figures illustrate different channel use (5096MHz, 5108.5MHz, 5118.5MHz & 5145MHz).

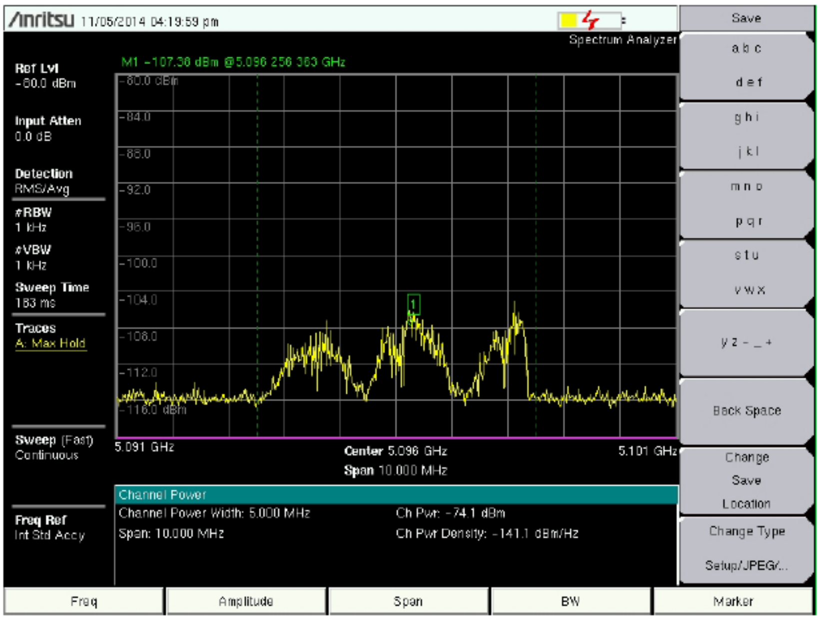


Figure 69: AeroMACS Bandwidth measure at 5096MHz

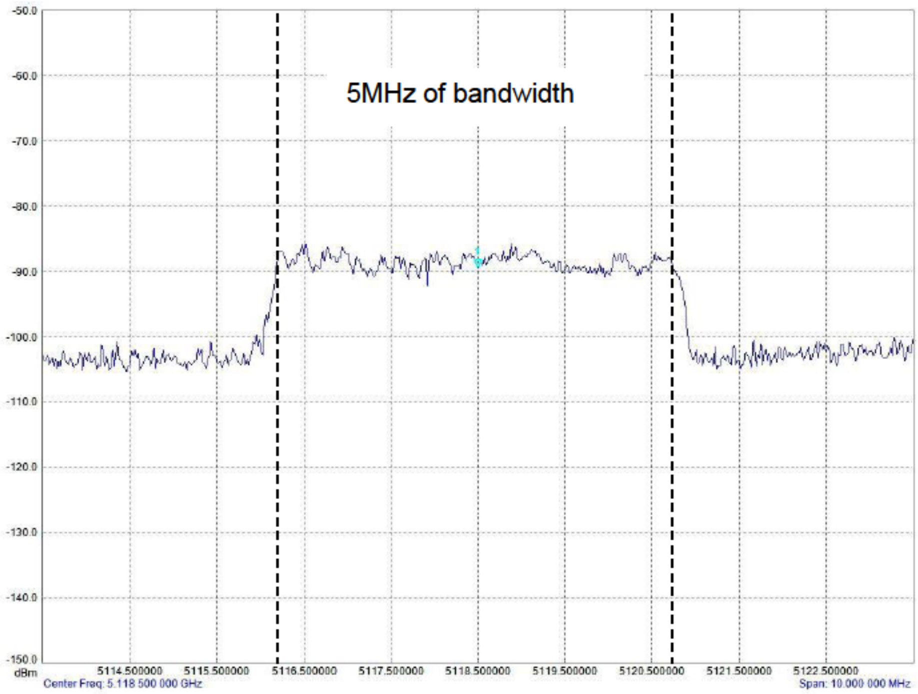


Figure 70: AeroMACS Bandwidth measure at 5118.5MHz

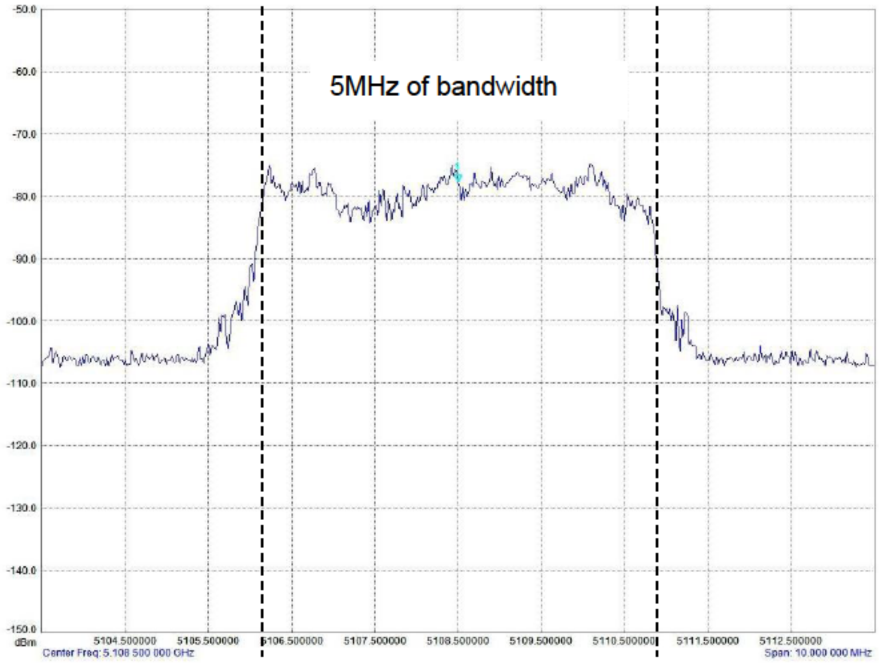


Figure 71: AeroMACS Bandwidth measure at 5108.5MHz

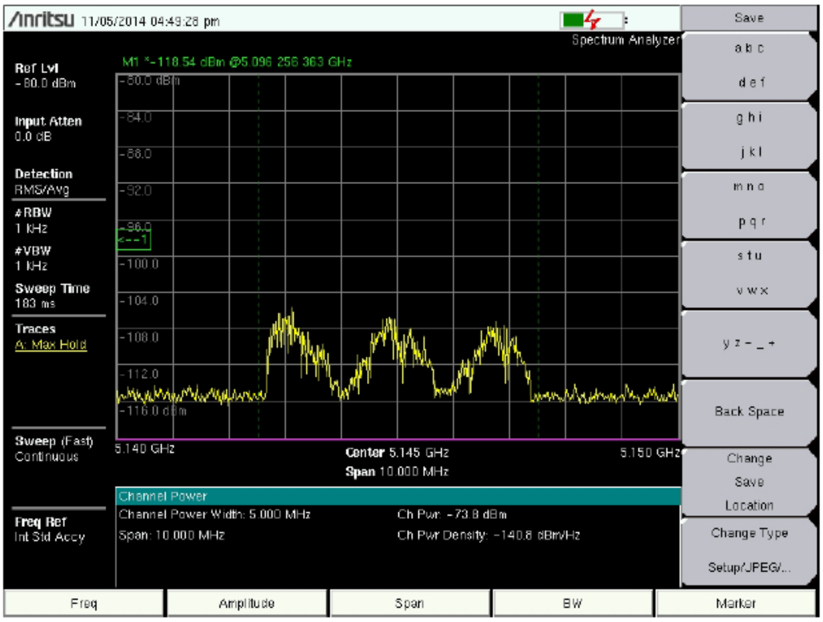


Figure 72: AeroMACS Bandwidth measure at 5145MHz

Note: The configuration of the spectrum analyzer is:

- Input Attenuation = 0.0 dB
- RBW = 100.0 kHz
- VBW = 30.0 kHz
- Detection = Peak (max hold)
- Frequency Span = 10 MHz

It was confirmed that the AeroMACS prototype can use the different 5MHz channels from 5091MHz to 5150MHz.

7.3.2.3 T012 - Channel frequency test

With the previous measure taken in the context of the T001 tests (see previous section), it was possible to verify that AeroMACS can operate into 5GHz C-Band, within the 5091-5150MHz range. The configuration of the channels can be changed with a step of 250KHz.

7.3.2.4 T003 - Encrypted Data traffic test

It was not possible to perform Encrypted Data traffic tests (T003) from Airbus laboratory, due to a limitation at the level of the ASN-GW.

With the Selex prototype, the encrypted Data traffic tests require the creation of an IP/IP tunnel between the ASN gateway and the interfaced router behind it. Despite the efforts spent on attempting to find a solution or an appropriate workaround, the test teams did not succeed in finding the appropriate ASN Gateway configuration that would have allowed the creation of such IP/IP tunnel.

7.3.2.5 T002 - Traffic priority & Maximum Sustained Traffic Rate

T002 tests on QoS and traffic priority have been performed in uplink and downlink.

The following Service Flows had been configured for the test:

Service Flow	Protocol	Port number	Bandwidth (Kbit/s)	
			Minimum	Maximum
BE	TCP	5001	10	10000
nrtPS	TCP	5006	200	10000
rtPS	TCP	5008	400	10000

Note: From previous tests, it was known that the maximum bandwidth available in uplink was around 800Kbit/s and of several Mbit/s in downlink.

Tests were executed in laboratory with a horn antenna (directional antenna with a gain of 10dB), so that to enhance the received and be in position to perform these tests in better conditions.

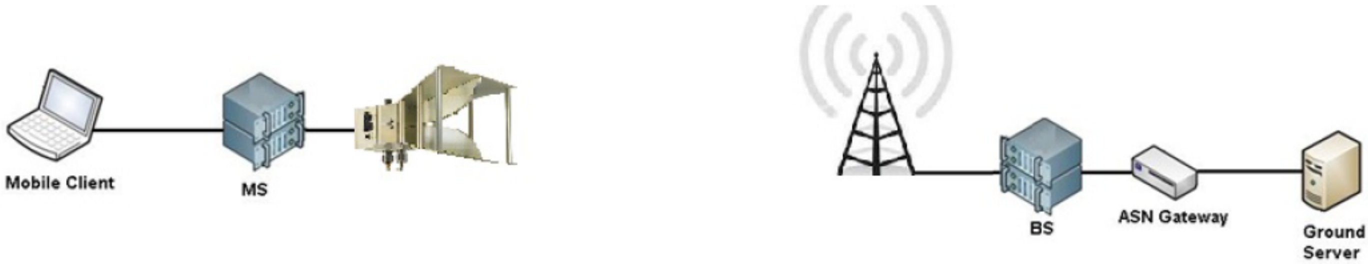


Figure 73: Laboratory tests - Configuration used for QoS tests

With the Wireshark tool (network sniffer), It is possible to differentiate each flow and trace the bandwidth graphs shown on Figure 74. On the graphs, the good operation of the QoS management mechanisms, and the compliance of flow throughput to the service flow configuration can be observed.

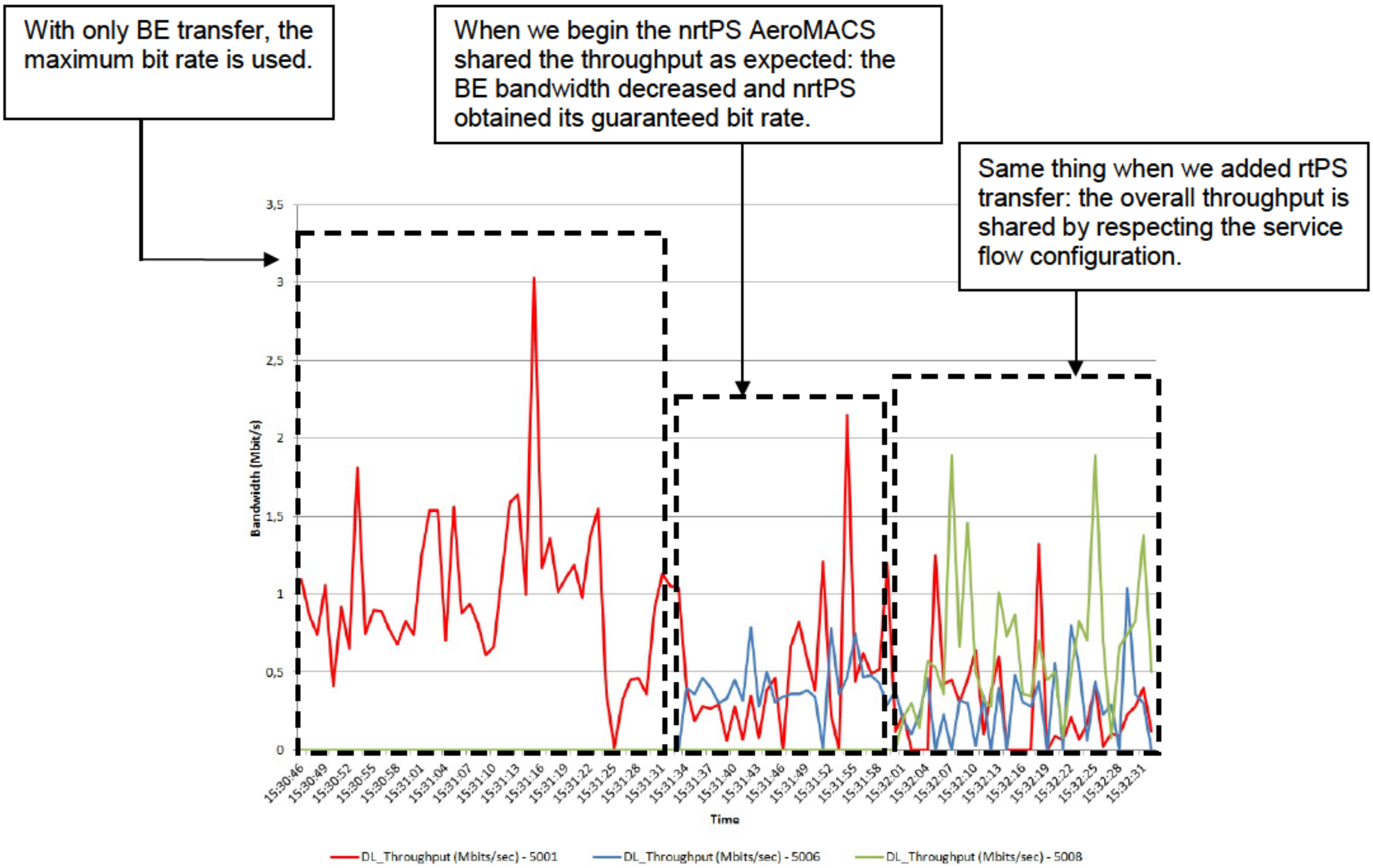


Figure 74: DL throughput used by different service flow

The measured average and maximum bandwidth achieved on each service flow are reported in the table below.

Service Flow	Throughput (Kbit/s)	
	Average	Maximum
BE	260	1320
nrtPS	270	1040
rtPS	660	1890

In uplink, the appropriate behaviour of QoS management functions was also observed (see Figure 75)

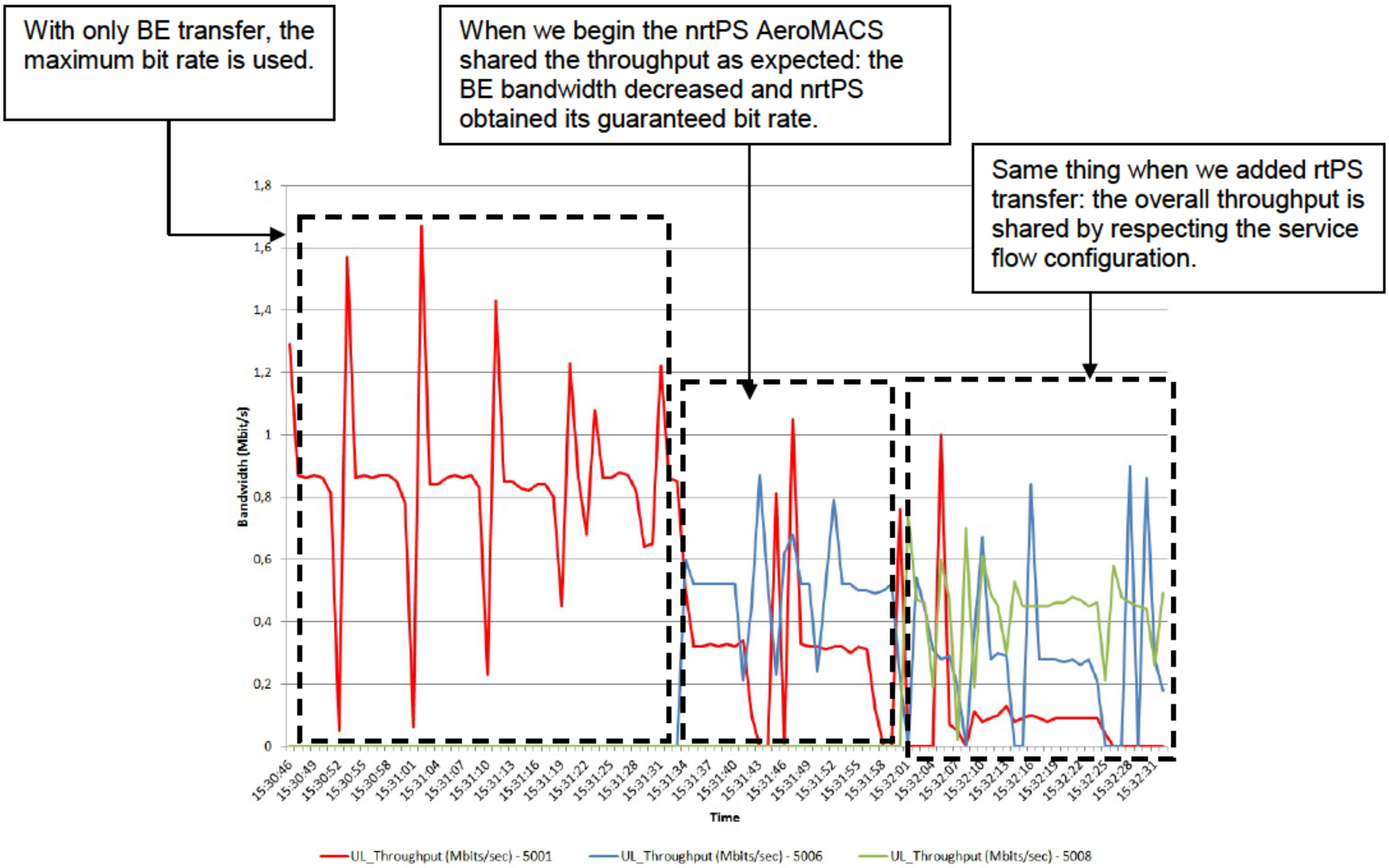


Figure 75: UL throughput used by different service flow

The average and maximum values of uplink throughputs obtained for each service flow are indicated in the following table:

Service Flow	throughput (Kbit/s)	
	Average	Maximum
BE	80	1000
nrtPS	290	900
rtPS	440	740

It can be seen that the average measured bandwidths are consistent with the service flow configuration, and hence that the AeroMACS prototype correctly manages service flow configurations and Quality of Service requirements.

In conclusion, the Best Effort, NrtPS, and rtPS service flows were concurrently and successfully tested, in uplink & downlink, in a deployed environment. It was shown that the traffic regulation complies with the configured flow characteristics.

7.3.2.6 T004 - RF Specifications and Performances (MS ranging performance)

MS Ranging Time is a dynamic time alignment process that allows the BS to receive transmitted signals from MS in an exact time slot.

Because the SNMP Object about this MS Ranging Time was not implemented in the SNMP MIB of the prototype, it was not possible to monitor this variable. Hence the test "T004 - MS ranging performance" was not performed.

Instead, measures of the scanning duration were taken, computed as the time between when the MS starts scanning the channels and when the MS is registered (synchronized) on the BS. These are reported in the table below:

First frequency scanned	Last frequency scanned	Scanning step	Number of channels scanned	Scanning duration
5108,5	5114MHz	250Khz	22	1 minute
5108,5	5109,5MHz	250Khz	4	30 sec

7.3.2.7 T005 - Ethernet interface

It was verified that the MS (and BS) supports several Gigabit Ethernet interfaces (based on IEEE 802.3 standard):

- 1 for data with which the node behind the MS is able to send useful data (like files, video streaming, ...)
- 1 for management with which it is possible to manage the MS (or BS).

Note: the management interface is not auto negotiated. Without a device interconnected with Gigabit Ethernet, the MS is not able to change its interface to Fast Ethernet (100Mbit/s) or Ethernet (10Mbit/s).

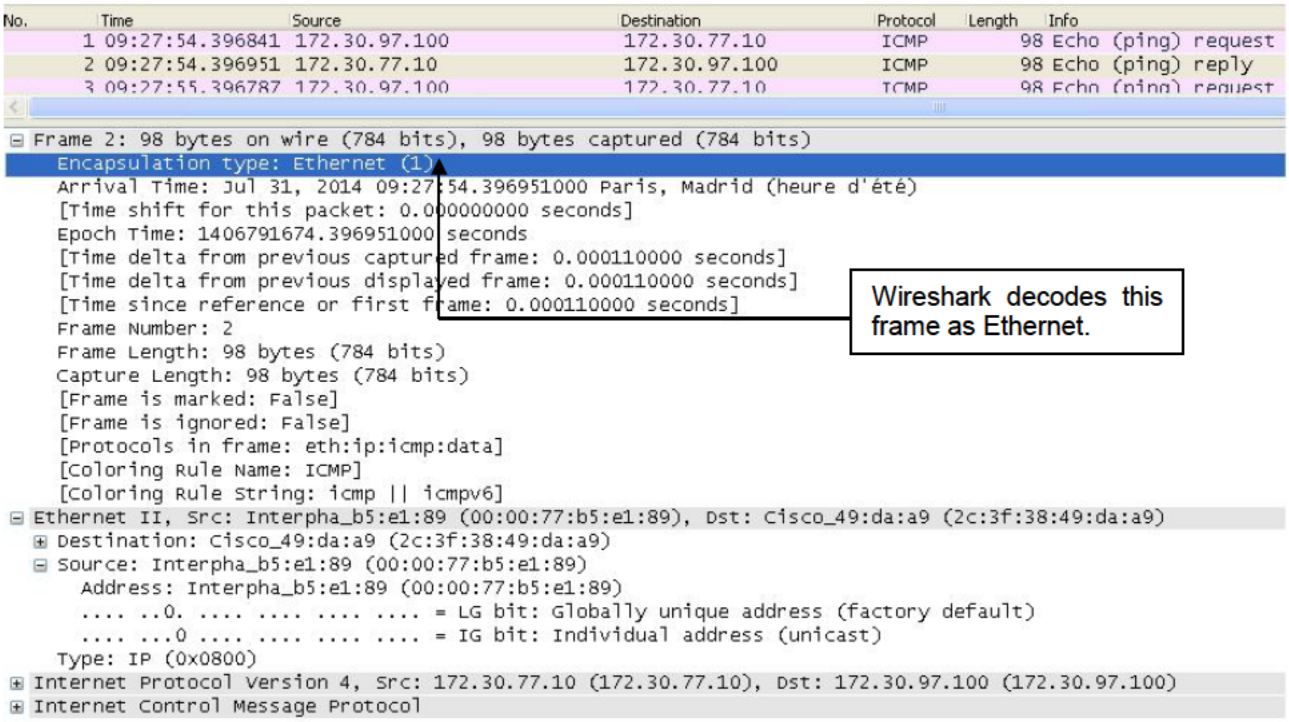


Figure 76: Laboratory tests - Wireshark capture on MS Ethernet Interface

This test with T010 & T011 also confirmed that AeroMACS can support TCP/IP and UDP/I data packet services.

7.3.2.8 T006 – On Ground Power-on/ In Flight Inhibition

The MS is divided into two separate units: the Base Band Unit and RF Unit.
Each of these units has its own power supply interface.
The RF unit comprises a manual switch that allows turning ON/OFF the RF unit.

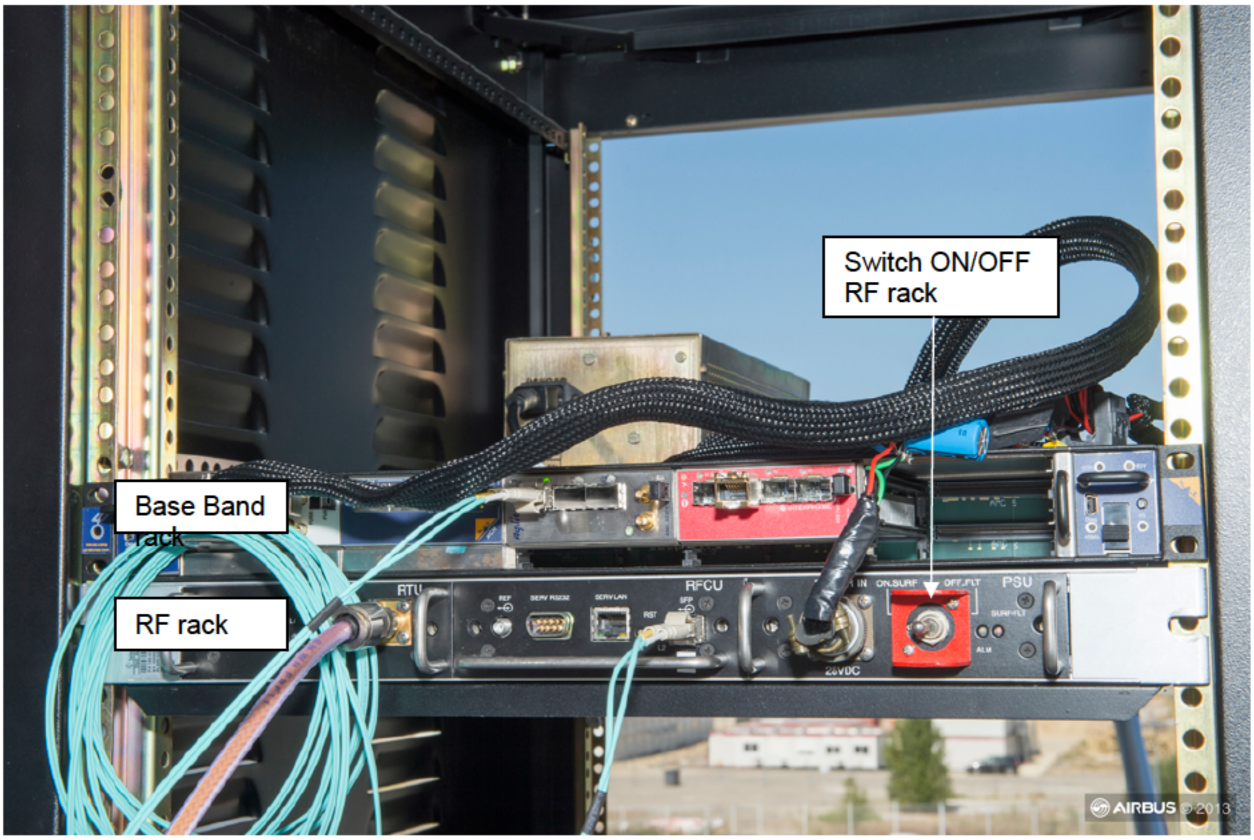


Figure 77: Laboratory tests - SELEX MS RACKs

Using the RF unit On/Off switch it is possible to simulate the “On Ground” and “In Flight” Aircraft condition, and obtain respectively activation or inhibition of the AeroMACS RF signal transmission.

Using the RF unit On/Off switch it has been successfully verified that the MS prototype stops any RF transmission when the switch is set on the “Off/In Flight” position and that RF transmissions are enabled when the switch is set on the “On/On Ground” position.

Although, the use of a switch button is not a suitable interface to be used for interconnection with real Aircraft systems, it is sufficiently representative of the typical Aircraft discrete interfaces used to propagate the ‘in flight/on ground” Aircraft conditions, to conclude that it has been verified that the requirement for “In flight inhibition” and “On ground activation” of AeroMACS is achievable on Aircraft.

7.3.2.9 T007 - Antenna interface

Radio specialists checked the impedance of coaxial cable with its TNC connectors: it was confirmed that the impedance is 50Ω as required.

7.3.2.10 T008 - Available channels

With the measures taken in the context of the T001 and T012 tests (see sections 7.3.2.2 and 7.3.2.3), it was possible to verify that AeroMACS can operate onto different 5MHz channels from 5091 to 5150MHz. The configuration of the channels can be changed with a step of 250KHz.

7.3.2.11 T009 - Round Trip Time measurements

7.3.2.11.1 T009 - Round Trip Time measures with Ratio 35:12

The T009 - Round Trip Time (RTT) measurements tests have been performed with PING command (based on ICMP protocol): the mobile laptop was configured to send repetitively ICMP REQUEST packets to the Ground Server; which replies with ICMP REPLY packets. On the command line interface, PING command displays the time spent between the transmission of the request and the receipt of the reply.
During the whole RTT tests, a file transfer was also performed in parallel.

Figure 78 shows curves representing the measured RTT value and the measured radio signal levels of AeroMACS (RSSI) along the test period:

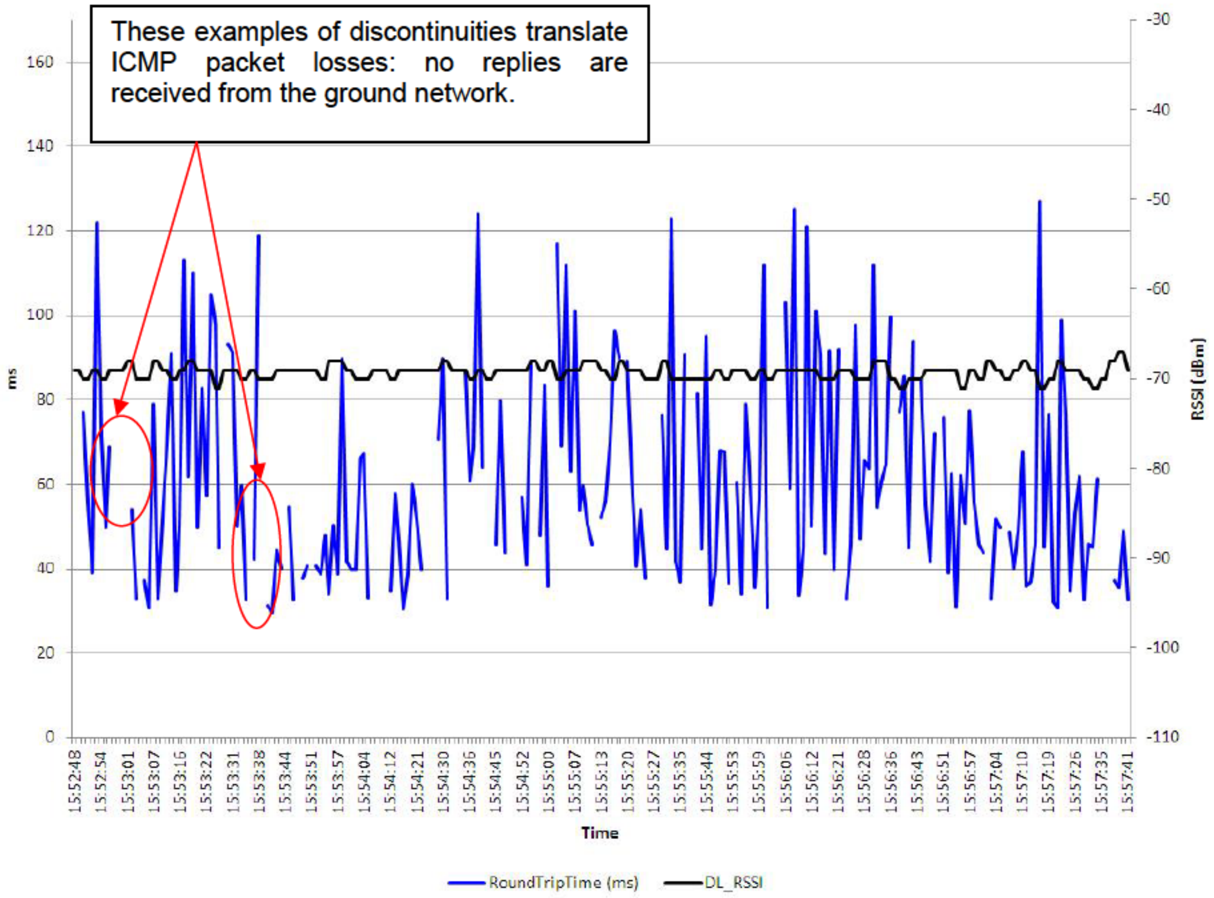


Figure 78: Laboratory tests- Round Trip Time curve during TCP transfer (Ratio 35:12)

On the MS, the RSSI is relatively stable during the test: it varies from -74dBm to -67dBm either in Uplink (UL).

The RTT turns around 50.3ms in average: it varies until a maximum value of 127ms. The RTT variations seem to result from variations on the quality of the radio signal.

As we can see on Figure 79, the radio quality (CINR) was unstable: it varied from 5 to 18 all along the test.

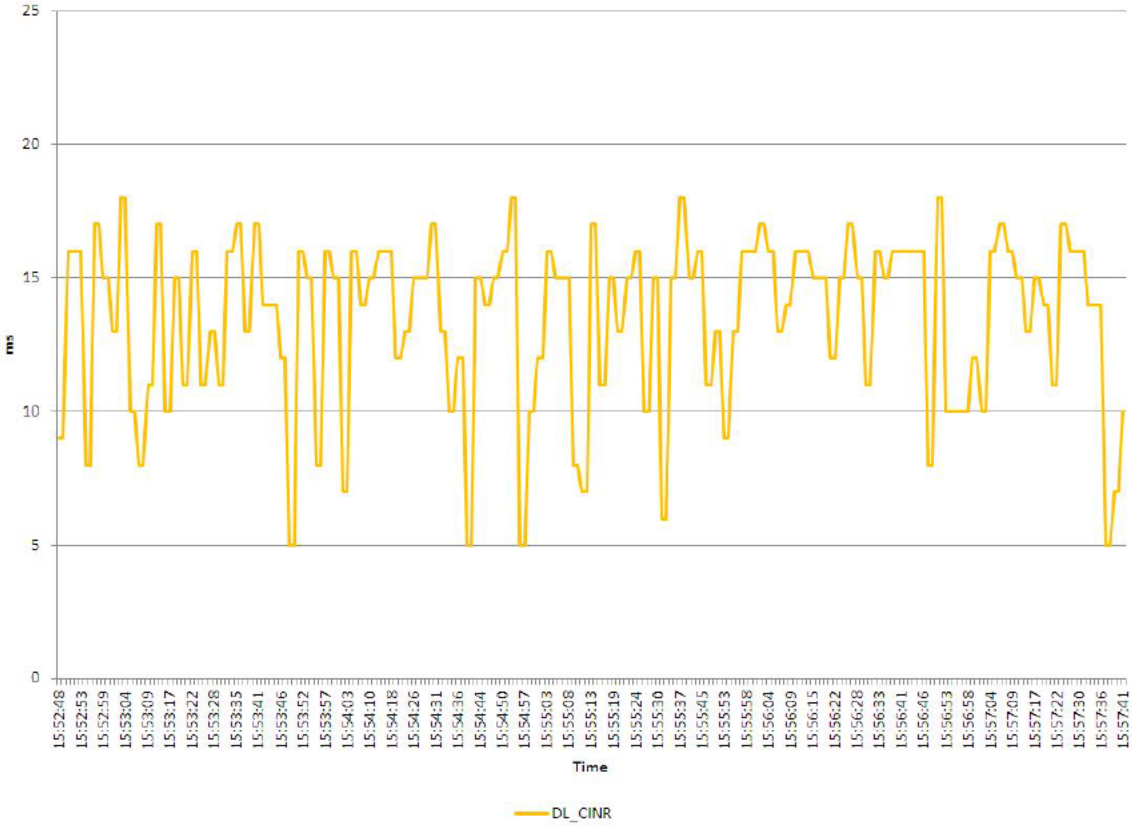


Figure 79: Laboratory tests - CINR during TCP transfer (Ratio 35:12)

These CINR variations can explain the RTT values and also the ICMP packet losses.

MTU evaluation:

The possible impact of the MTU (Maximum Transmission Unit) size on the Packet Loss Rate was verified. Table 6: Laboratory tests - Packet loss rates in function of MTU size shows the packet loss rate measured during sequences of RTT tests launched with variations on the configured MTU size. These RTT tests were done without any background file transfer launched in parallel.

MTU size (Bytes)	Packet Loss Rate (%)	Average CINR	Average RSSI (dBm)
1500	36	14	-68
1478	50		
1450	65		
1400	71		
1028	35		
928	58		
528	8		

Table 6: Laboratory tests - Packet loss rates in function of MTU size

The Packet Loss Rates (PLR) are very high, and seem to be generally uncorrelated to the configured MTU size. The CINR is not particularly bad in average and the RSSI is acceptable.

7.3.2.11.2 T009 - Round Trip Time measures with Ratio 32:15

The T009 RTT tests were replayed with a modulation ratio set to 32:15, in order to compare P9.16 results with those obtained with Thales prototypes in WP15.2.7.

Figure 80 shows curves representing the measured RTT value and the measured radio signal levels of AeroMACS (RSSI) along the test period, when a 32:15 modulation ration was applied:

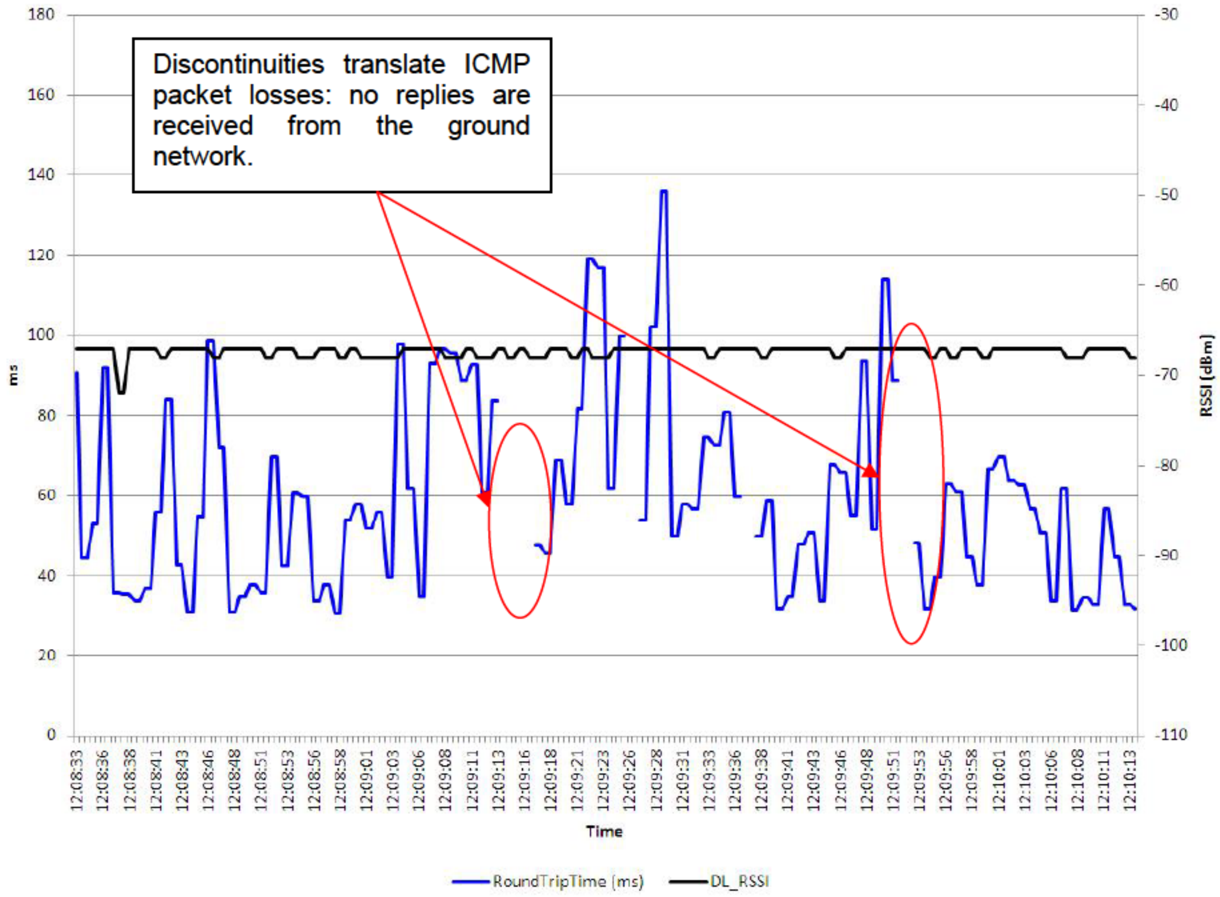


Figure 80: Laboratory tests - Round Trip Time curve during TCP transfer (Ratio 32:15)

As previously, the RTT fluctuates until 136ms: in average, it is equal to 56ms which is a normal value. RSSI is stable in average around -70dBm, varying from -75dBm to -67dBm.

By looking at CINR, we get the same type of curves as with the before ratio 32:15:

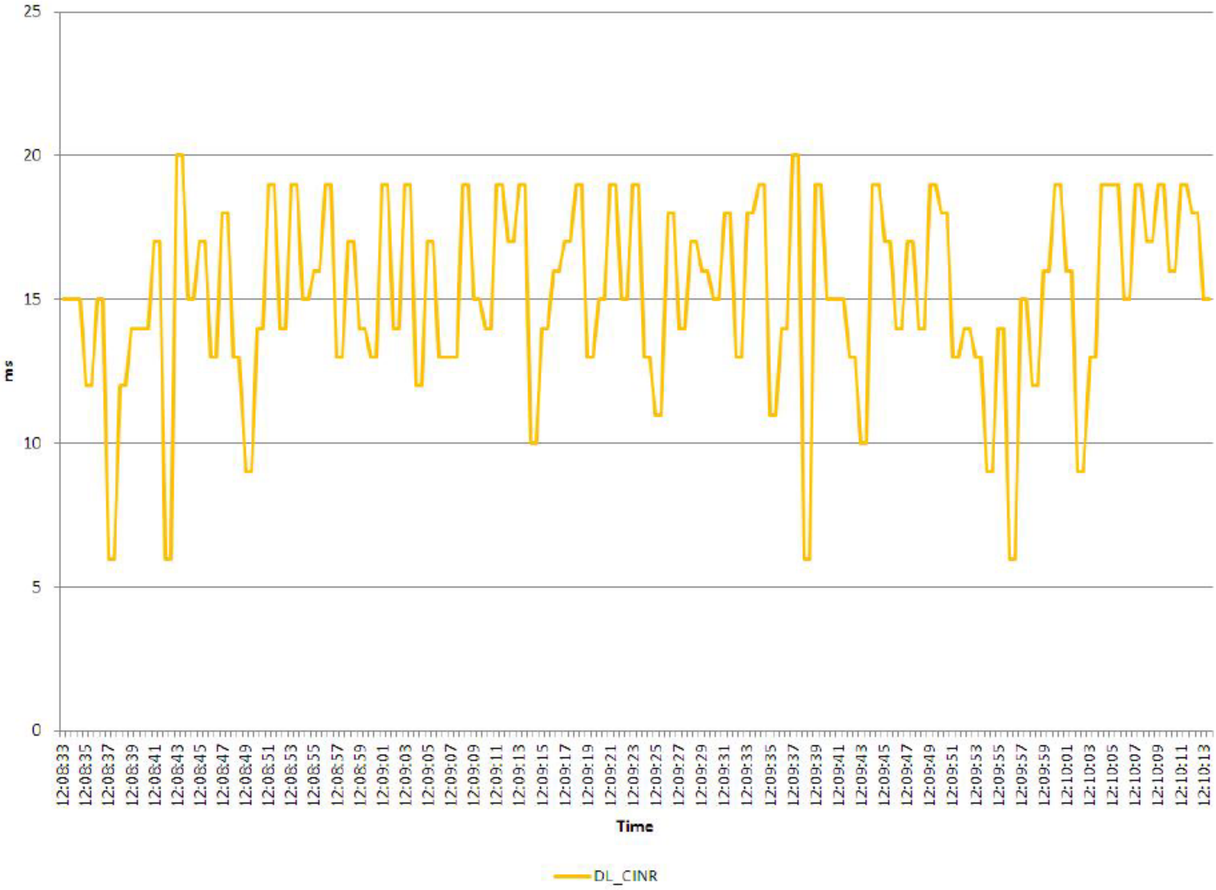


Figure 81: Laboratory tests - CINR during TCP transfer (Ratio 32:15)

The CINR is unstable: it varies from 6 to 20. This can explain the ICMP packet loss and the high RTT values.

All previous RTT tests were performed with file transfers in parallel. Without file transfers in parallel reduced variations of the RTT are observed as shown in the table below:

Time of test	Packet size	RTT (ms)		Packet loss rate
		Average	Maximum	
2875 sec	64 Bytes	72	112	6%

Table 7: Laboratory tests - RTT measured when no file transfer was performed in parallel

The lower Packet Loss Rate observed during these tests can be explained by the reduction of the traffic injected over the link (no file transfer) and by the smaller size of the MTU. However, the PLR remains quite high (6%), certainly because of the insufficient quality of the signal that can be obtained at the location of the MS in the Airbus laboratory room.

7.3.2.11.3 Summary

In conclusion, RTT results are approximately the same with the two different ratios tested. The packet loss traduces instability of the AeroMACS link to transfer data. Some hypothesis can explain it:

- Potential shadowing effects of Aircraft that are rolling, taking off and landing on the airport that can reduce the link quality of the AeroMACS link. However this cannot be the sole explanation; because packet losses were also observed in periods with no aircraft movements.
- The laboratory is installed into a building with lots of metal which can decrease the link quality.
- The antenna of the BS was not well oriented. The BS antennas have a horizontal aperture of 90° and around 7° in vertical. Because of narrow vertical aperture, down-tilt was not optimized to cover the airport and the Airbus laboratory.
- The vertical aperture of the BS antennas is not adapted to our experiment. This kind of sectorial antenna is standard to cellular network; but for our experimentation, we have only two BS to cover a large area.

In any case, if we focus on Round Trip Time values, values measured are equals to what we can expect from an AeroMACS network.

7.3.2.12 T010 - Data Latency & Throughput measurements

7.3.2.12.1 T010 - Data Latency & Throughput results (Ratio 35:12)

T010 was focused on the measurement of the achievable maximum throughput, by submission of the as fast as possible transfer of a large amount of data using the TCP protocol.

Figure 82 shows curves representing the achieved UL and DL throughput and the measured radio signal levels of AeroMACS (RSSI) along the test period, when a 35:12 modulation ratio was applied. The curves show that the RSSI stays at the same level as before (i.e. -70dBm). The DL transfer is performed with an average throughput of 150Kbit/s: it fluctuates from 0 to 1.5Mbit/s.

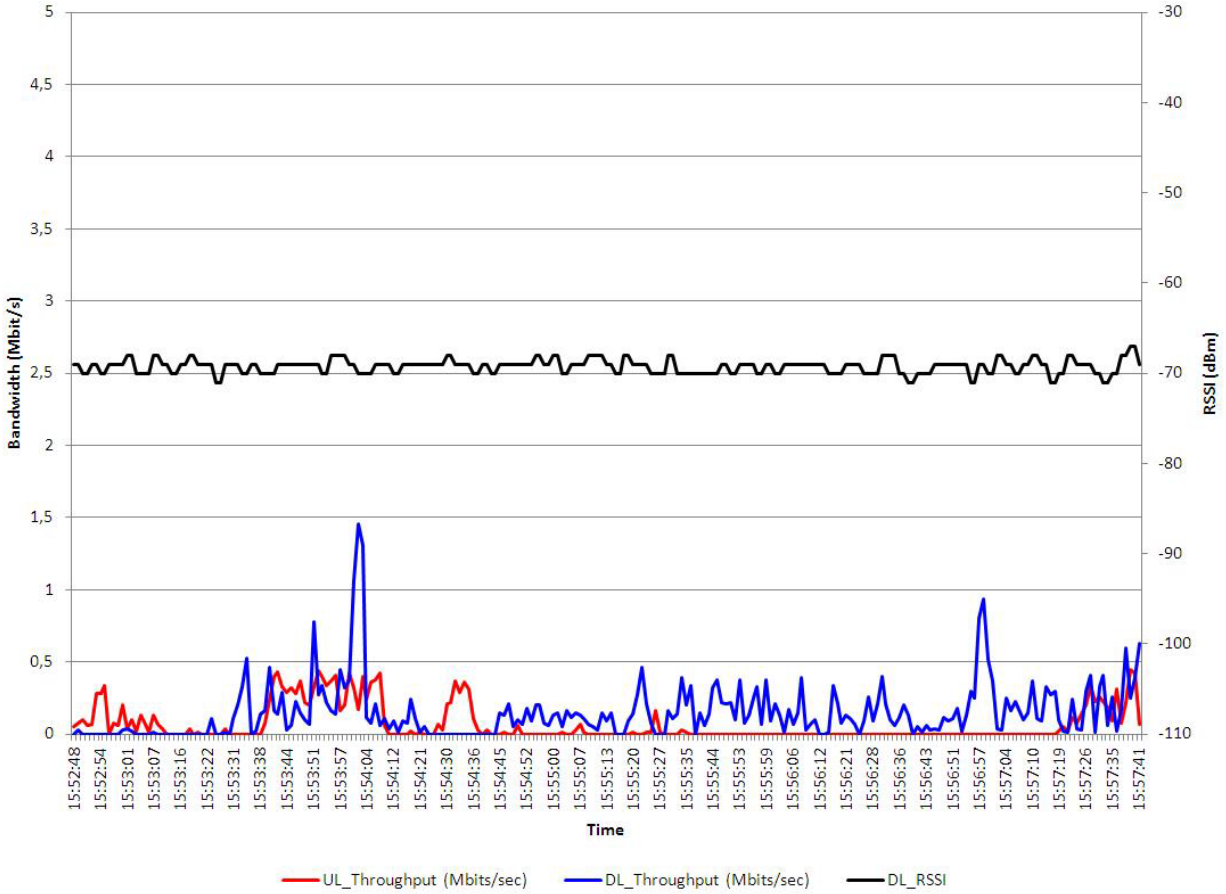


Figure 82: Laboratory tests - TCP transfer Vs RSSI (Ratio 35:12)

The upload has an average throughput of 70Kbit/s which is twice lower than DL: it fluctuated from 0 to 450Kbit/s.

It is observed that the achieved TCP throughput is very variable and falls to 0Kbit/s at multiple occasions: there were in fact a lot of TCP retransmissions due to the high packet loss rates, which explain the low and unstable performances. The upload is worse than the download: during several minutes no transfers occurred in UL whereas data were transferred in DL.

The following graph illustrates the TCP segment sequence number in function of Time. TCP uses few mechanisms of control to check if data are well received: TCP segment are numbered; if the segments are not received into the same order, TCP is able to re-order them.

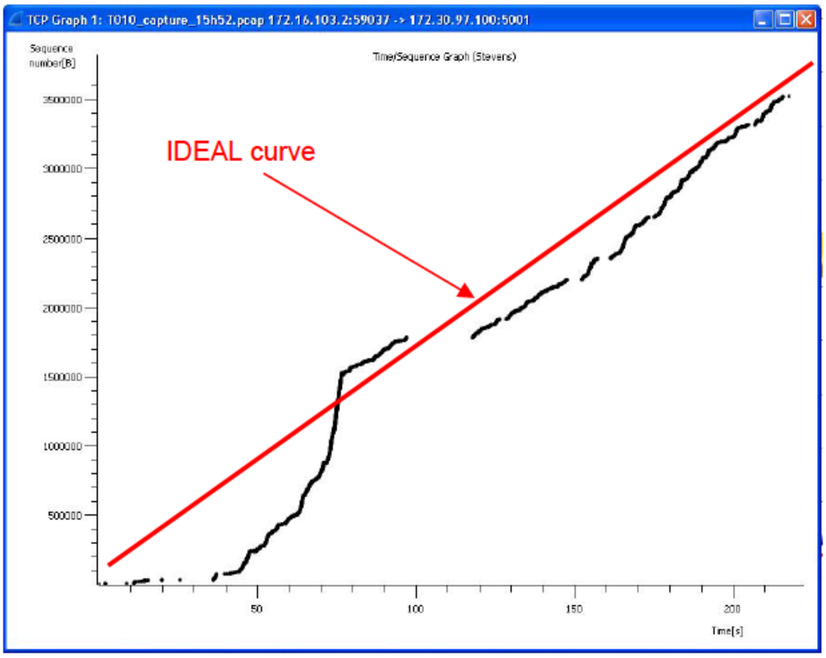


Figure 83: Laboratory tests - UL TCP sequence number vs. Time (Ratio 35:12)

In an ideal situation where no packet are lost or misordered, the graph should be a straight line beginning from the origin to the last value.

In the graphs obtained though these tests, discontinuities, traducing packet losses, can be observed.

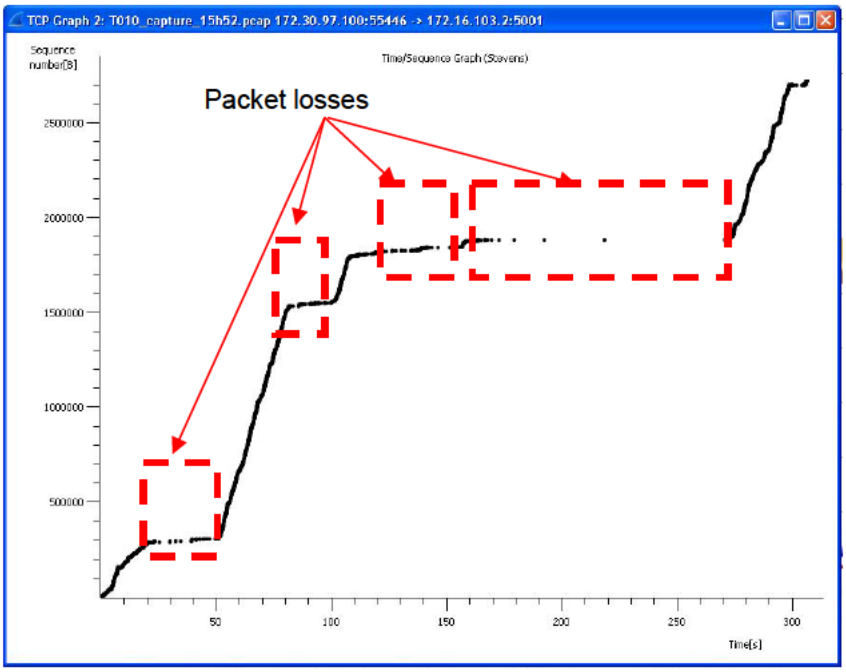


Figure 84: Laboratory tests - DL TCP sequence number vs. Time (Ratio 35:12)

The same discontinuities are visible on the graph obtained during the TCP transfer in downlink.

The average CINR is around 13 and varies between 5 and 18.

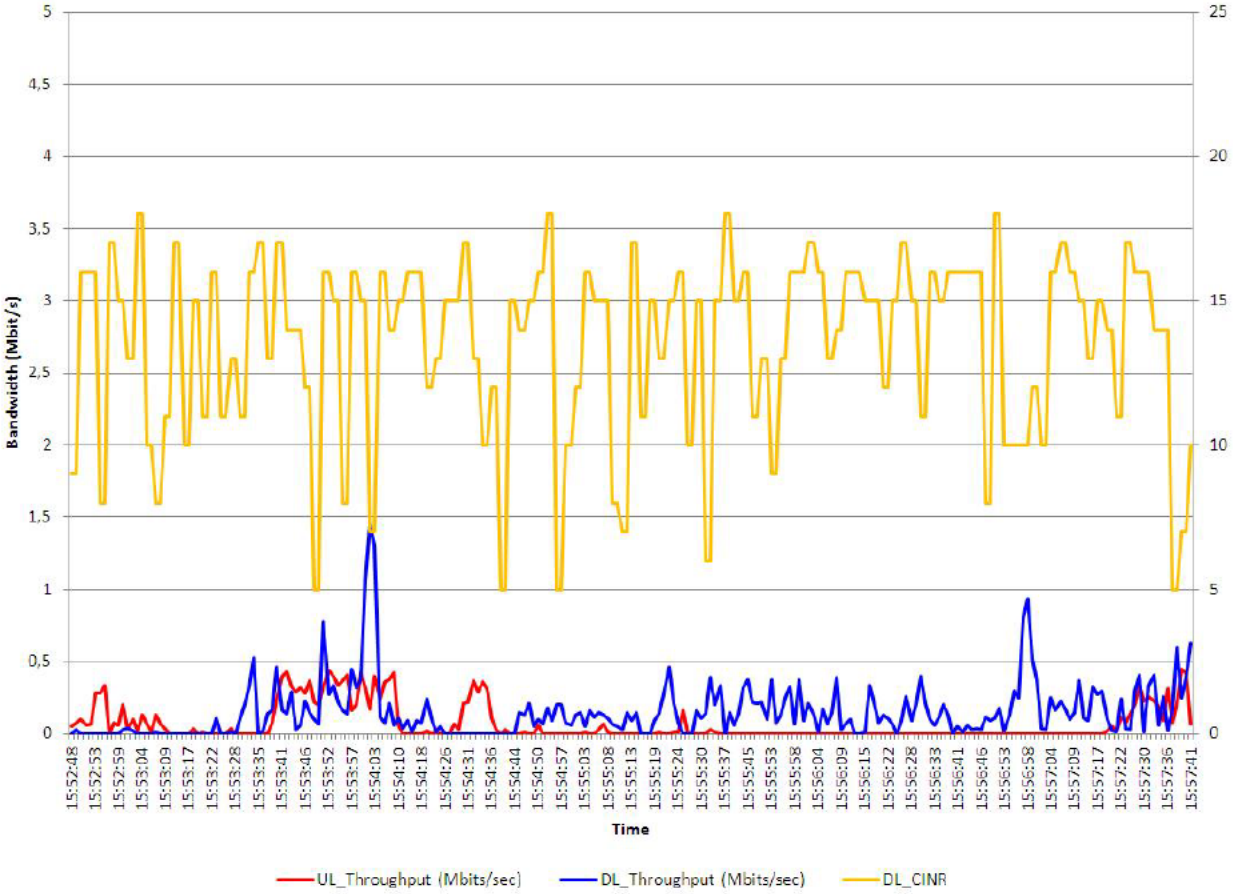


Figure 85: Laboratory tests - TCP transfer Vs CINR (Ratio 35:12)

The next table summarizes the measured network performances:

	UL throughput (Kit/s)	DL throughput (Kbit/s)	MS Radio values	
			RSSI(dBm)	CINR
Minimum	0	0	-71	5
Average	70	149	-69.23	13.45
Maximum	450	1460	-67	18

Table 8: Laboratory tests - TCP throughputs (Ratio 35:12)

Throughputs are better in download than in upload: averages values are quite low. About DL, the variation of CINR can explain the download data rate.

We checked a possible correlation between the low achieved throughput and the configured MTU size: the results are given in Table 9, which shows the average throughput achieved depending on the configured MTU size:

MTU size (Bytes)	Throughput (Kbit/s)		MS Average CINR	MS Average RSSI (dBm)
	UL	DL		
1500	210	0	14.2	-69
1064	0	0		
900	0	0		
600	70	150		

Table 9: Laboratory tests - TCP throughput in function of MTU size

A lower MTU size seems to increase the probability to succeed in transferring TCP traffic when the quality of signal is degraded, especially in the downlink direction.

Summary:

Even if MS RSSI & CINR are quite stable with values not so low, the TCP transfer did not work as expected: there are lots of packet losses and the average throughput is low. In DL, the performances are better than in UL, but not by much.

The causes of these bad results are certainly the same as those given in the analysis of the tests on the RTT in the previous section.

7.3.2.12.2 T010 - Data Latency & Throughput results (Ratio 32:15)

The T010 throughput tests were replayed with a modulation ratio set to 32:15.

Figure 86 shows curves representing the achieved UL and DL throughput and the measured radio signal levels of AeroMACS (RSSI) along the test period, when a 32:15 modulation ratio was applied.

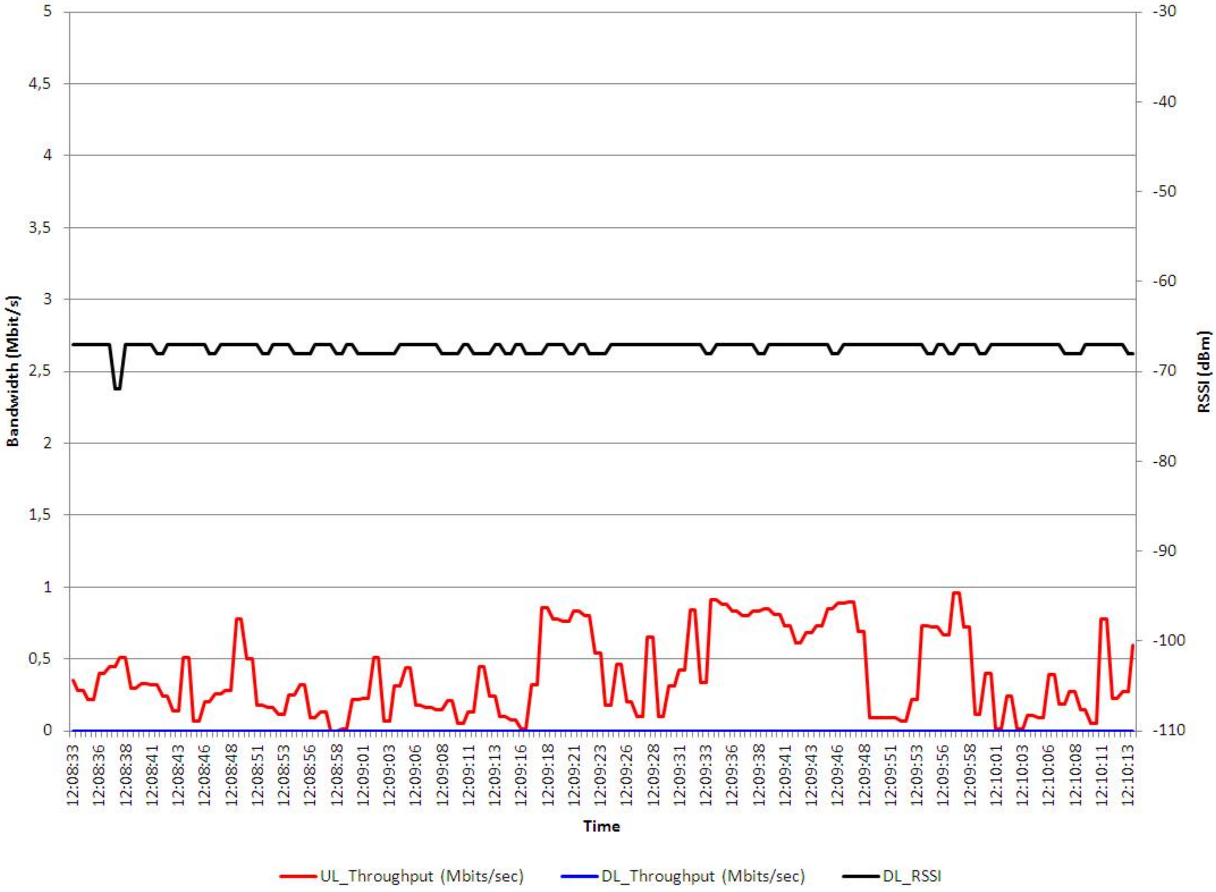


Figure 86: Laboratory tests - TCP transfer Vs RSSI (Ratio 35:12)

As previously, the RSSI is quite stable around -68dBm. However, there are no data transfer performed in DL and the UL fluctuated a lot: we get the opposite of the previous TCP test done with ratio 35:12.

The DL CINR varies from 6 to 20, similar values to those measured during throughput tests with the 32:15 modulation ratio configuration.

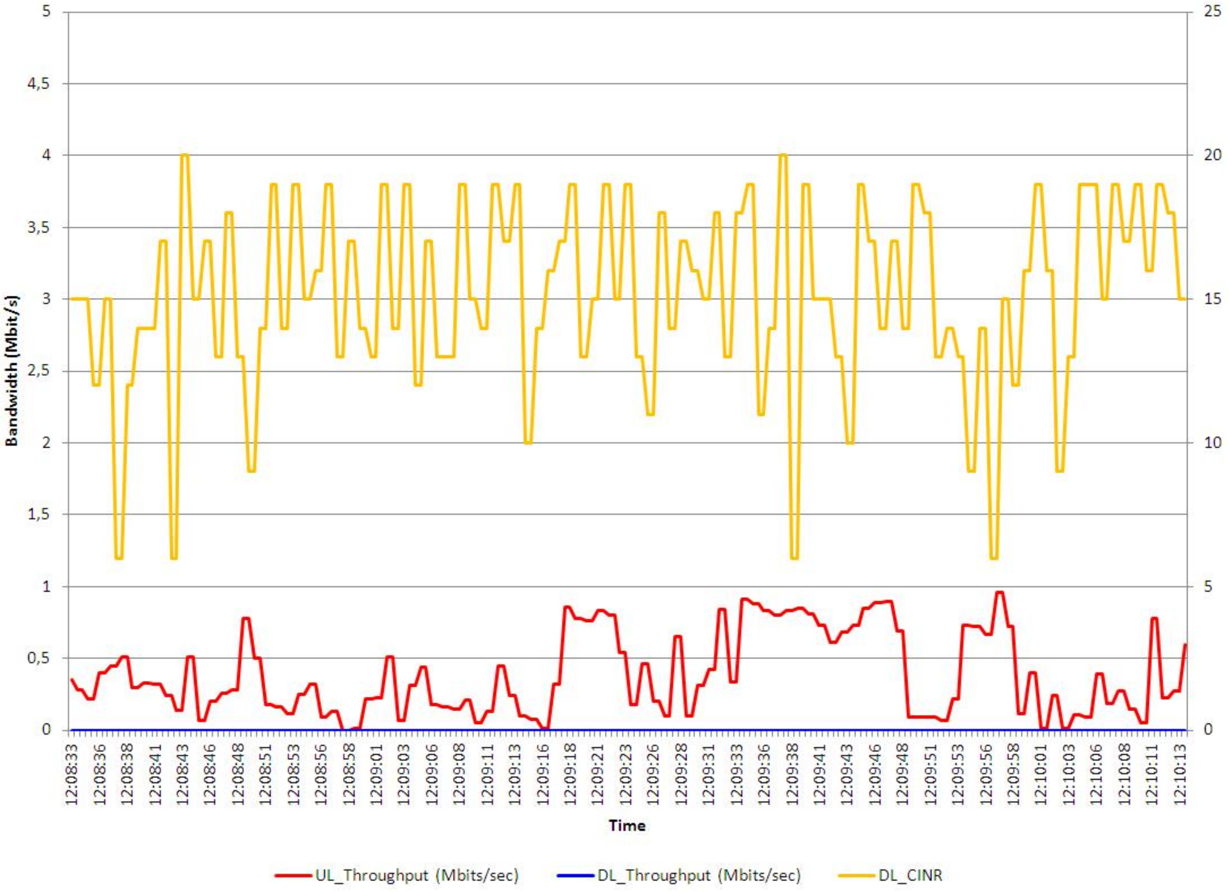


Figure 87: Laboratory tests - TCP transfer Vs CINR (Ratio 35:12)

If we trace the segment number Vs time, the graph seems better than before for the UL: there are less of discontinuities (or at least, shortest discontinuities).

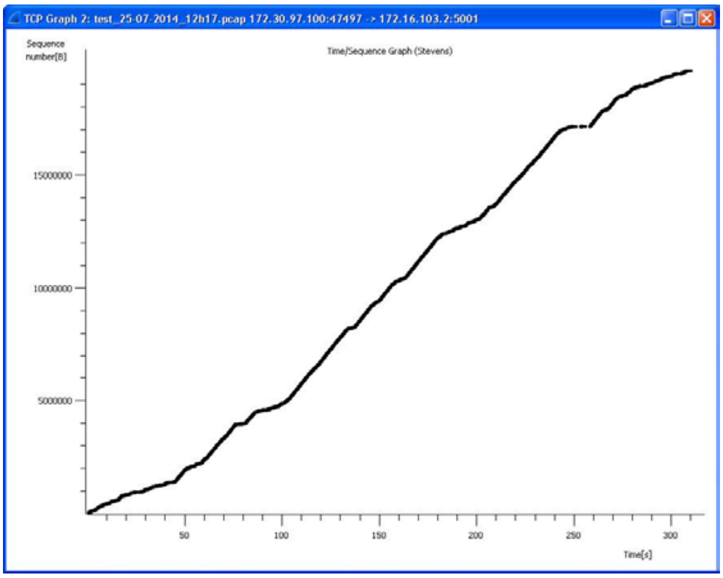


Figure 88: Laboratory tests - UL TCP sequence number Vs. Time (Ratio 32:15)

However, if we zoom on a part of the curve, we can observe several discontinuities traducing again packet losses.

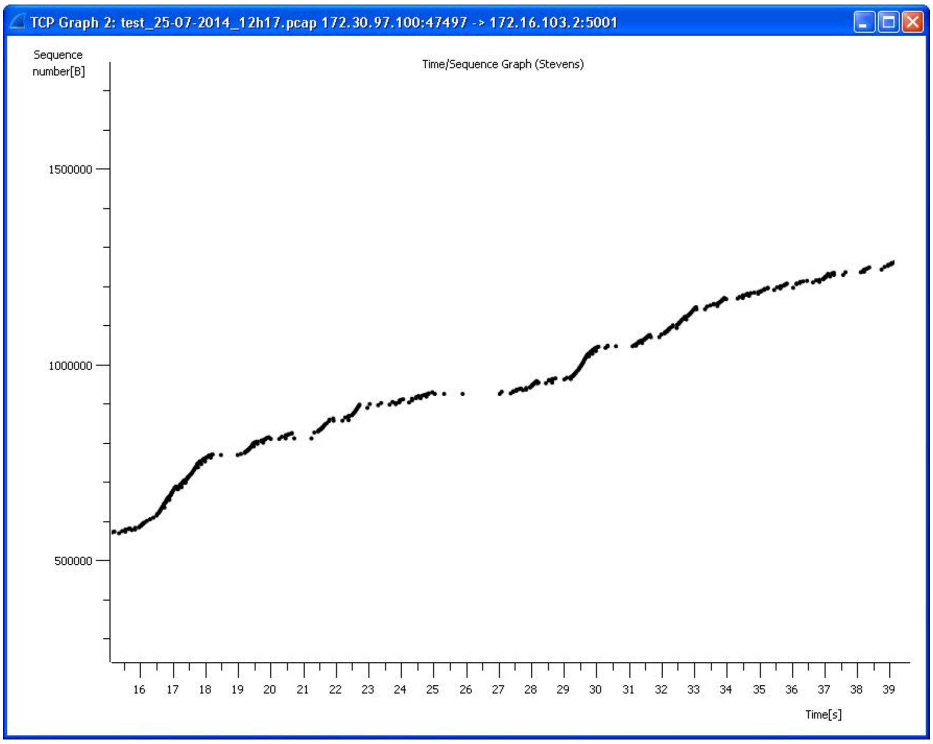


Figure 89: Laboratory tests - UL TCP sequence number vs. Time – Zoom (Ratio 32:15)

In DL, there is no data transfer: so, it is not possible to trace this kind of curve.

The following table summarizes the different values of RSSI, CINR and throughput:

	UL throughput (Kbit/s)	DL throughput (Kbit/s)	MS Radio values	
			RSSI(dBm)	CINR
Minimum	0	0	-72	6
Average	388.27	0	-67.34	15.14
Maximum	960	0	-67	20

Table 10: Laboratory tests - TCP throughputs (Ratio 32:15)

In regards to the previous throughput tests, better performances in UL are observed: 388Kbit/s with a Ratio of 32:15 and 70Kbit/s with 35:12. In DL, no TCP transfer is performed although the RSSI is quite better (-67dBm with 32:15 & -69dBm with 35:12) and the same with RSSI (15 with 32:15 & 13 with 35:12).

Summary:

During these tests, we got the same kind of results whatever the ratio use or antenna azimuth/tilt configuration. TCP data transfers did not work as expected: lots of packet losses have been observed which impacted the achievable TCP throughput, even up to a situation where TCP transfers were impossible.

MS RSSI and CINR seemed to be at correct levels. No correlation can be done between good RSSI value and the link performance. Hence more stable CINR values may be needed to get AeroMACS work as expected with the prototypes.

The suspected causes of these bad results remain those given before:

- Potential shadowing effects of Aircraft that are rolling, taking off and landing on the airport Laboratory environment where there are lots of metal around which can decrease radio link quality.
- BS antenna orientation not optimized to cover the Airbus laboratory room.
- The possibility that vertical aperture of the BS antennas not adapted to our trials.

7.3.2.12.3 T010 - Data Latency & Throughput results (Antenna configuration 4)

After having reworked the orientation of the two Base Stations antennas (Cf. §7.2.1.2 Geographical context of Airbus Laboratory tests), the T010 throughput tests were replayed again with the following results:

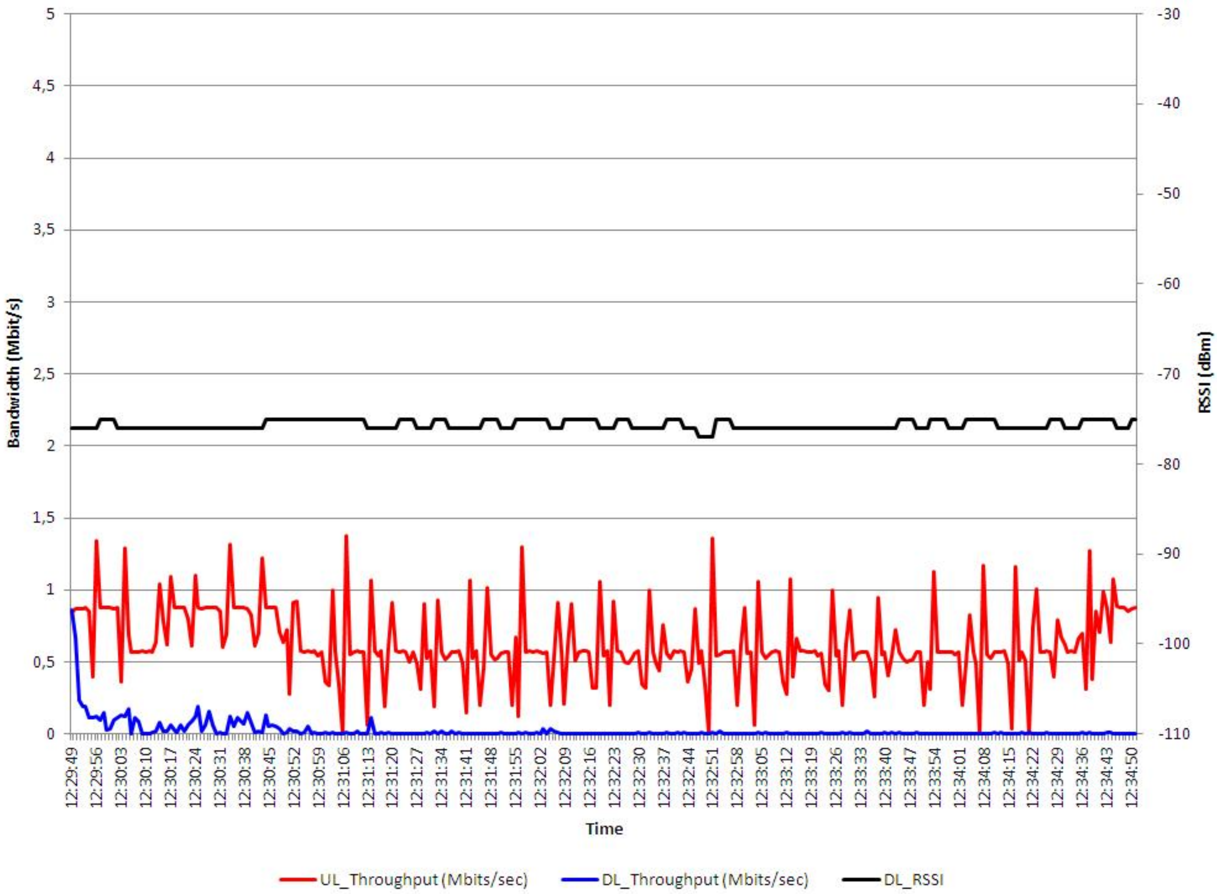


Figure 90: Laboratory tests - TCP transfer Vs RSSI (Antenna configuration 4)

The MS RSSI is stable around -75dBm; the throughput measured fluctuates in uplink and downlink. As we can see, the average throughput is better all along the test; we get downlink transfer at the beginning of the transfer, and after it decreased around 0Kbit/s.

The next figure illustrates the CINR in function of the data bit rates:

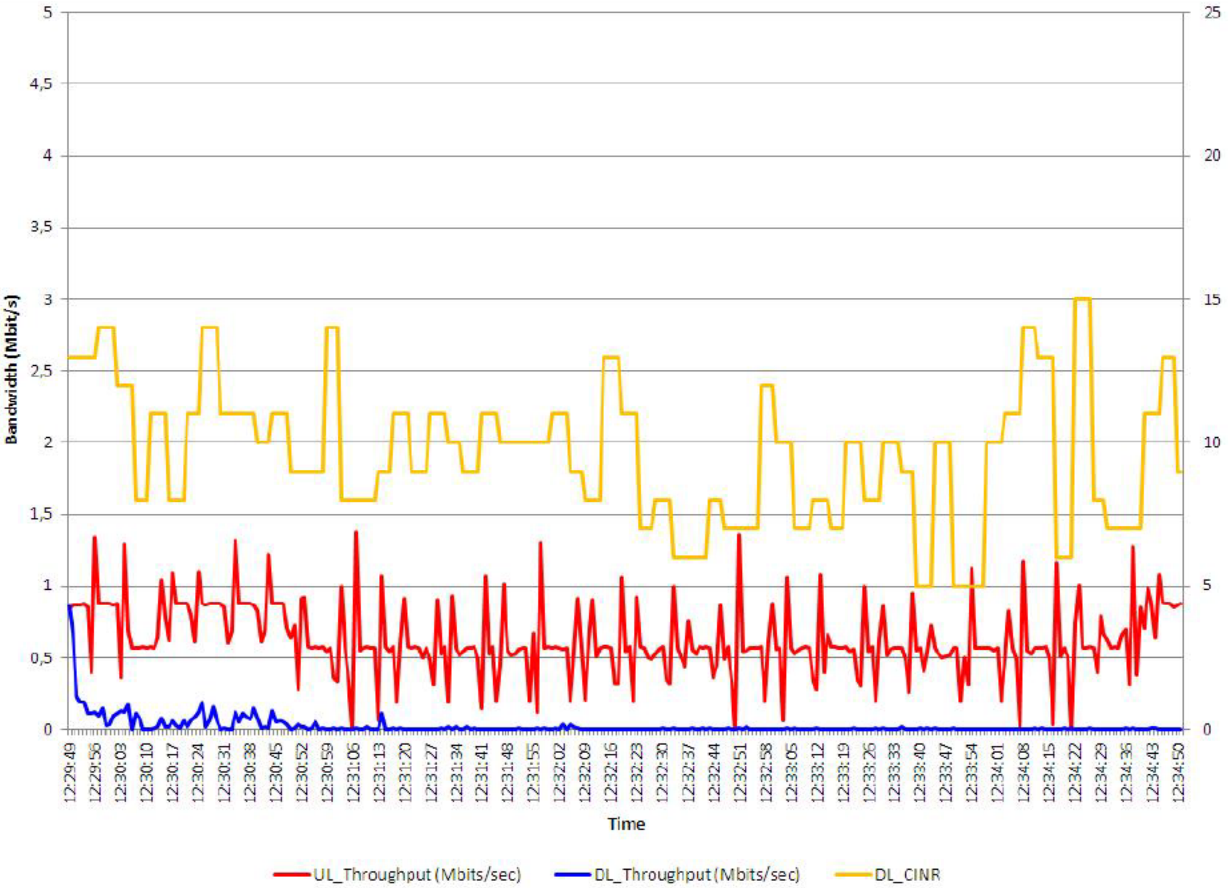


Figure 91: Laboratory tests - TCP transfer Vs CINR (Optimal coverage)

As before, the CINR fluctuates a lot between 5 and 15; this can explain why we did not get a good transfer in downlink. First, the CINR was quite high (around 12); the TCP transfer began with the highest throughput we get in download (i.e. 860Kbit/s). Then, when the CINR fluctuates, the TCP transfer bit rates decreased around 20Kbit/s to stay after to 0 until the end of the test.

	Throughput (Kbits)		MS Radio values	
	UPLOAD	DOWNLOAD	RSSI(dBm)	CINR
Minimum	0	0	-77	5
Average	630	20	-75.63	9.61
Maximum	1380	860	-75	15

Table 11: Laboratory tests - TCP throughputs (Optimal coverage)

The above table summarizes the results of these tests. As with previous tests, the MS RSSI and CINR were at the same level: fluctuation of CINR can explain the bad transfer results in download. On the other hand, the throughput in uplink was the best observed with TCP transfer in the Airbus laboratory with peak of 1380Kbit/s.

Summary:

The change to the BS antenna orientation did not allow enhancing drastically the performances. The achievable bit rates are somewhat higher and more stable; In Uplink, a TCP throughput of several hundreds of Kbit/s was obtained. But in Downlink, the TCP throughput stays very low or null, whereas the RSSI and CINR were at normal levels in average

On the positive side, we may note that with a distance of around 1.9km separating the BS from the laboratory, we succeeded to reach several hundred of Kbit/s transfers in uplink and downlink.

7.3.2.13 T011 - Data Jitter measurements

7.3.2.13.1 T011 - Data Jitter results (Ratio 35:12)

T011 is concerned with the measurement of data jitter values. The Data Jitters were measured during UDP data transfers.

Initially, the first BS configuration (see § 7.2.1.2.1) was used (Ratio 35:12).

Figure 92 shows curves representing the RTT, Jitters, and DL CINR measured along the test period.

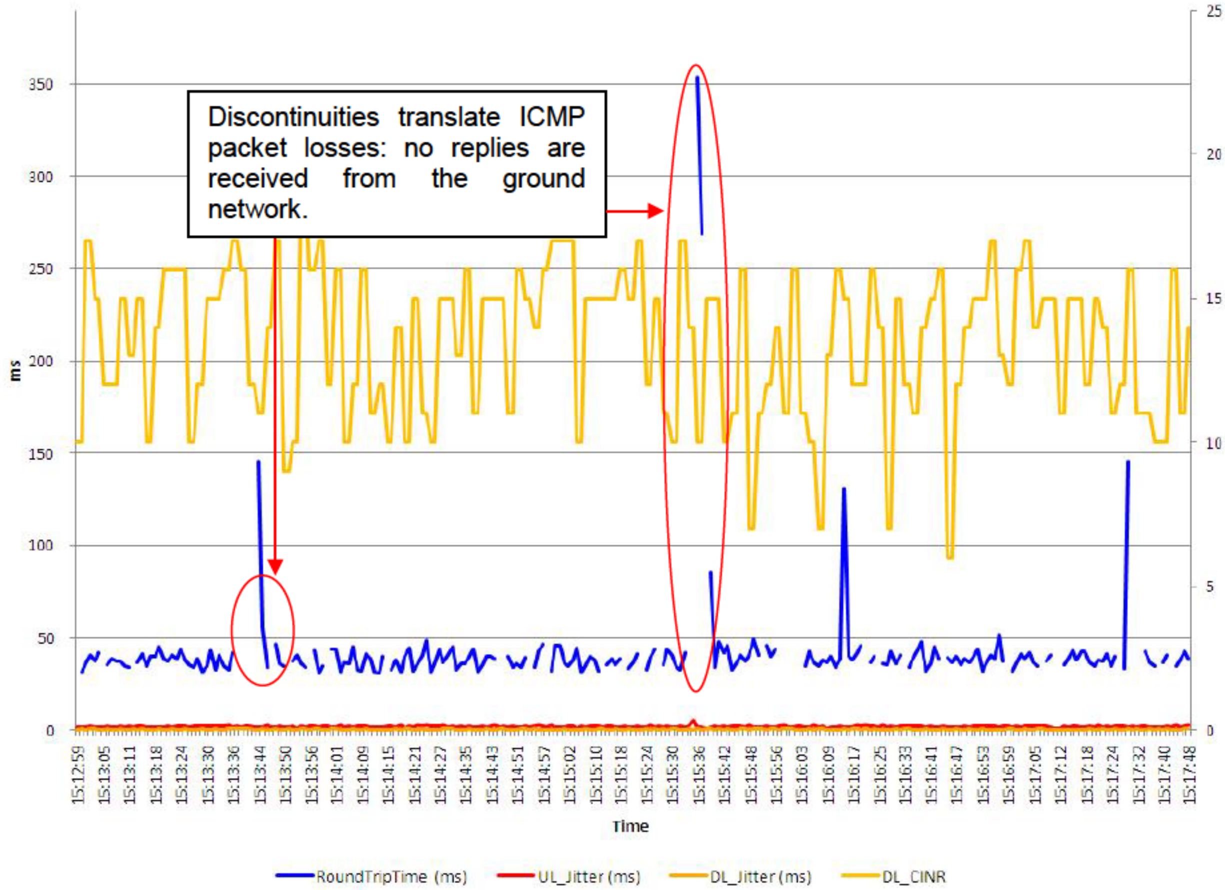


Figure 92: Laboratory tests - Round Trip Time curve (Ratio 32:15)

The average RTT is equal to 36ms. RTT fluctuations are observed, with some peaks up to 324ms. The RSSI was stable and stays in average around -70dBm, varying from -75dBm to -68dBm.

The test was performed with a target throughput of 800Kbit/s. The achieved data bit rate values are illustrated here-below with the MS RSSI:

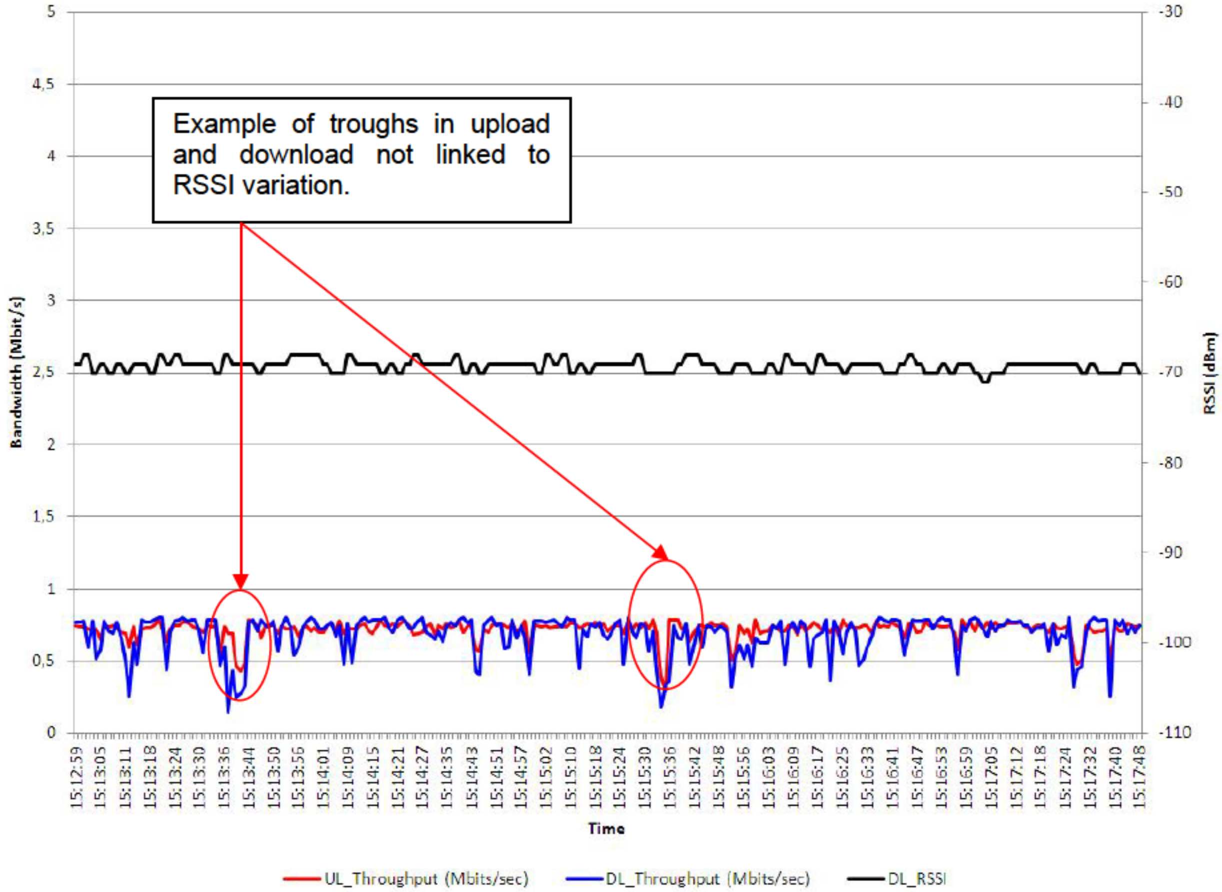


Figure 93: Laboratory tests - UDP transfer Vs RSSI (Ratio 35:12)

The RSSI values stay quite stable around -69dBm. The achieved data bit rates are higher than TCP tests, but periods with degradation of the performances are also observed at multiple occasions..

By tracing the CINR, we get the same type of curve than during TCP tests. The UL & DL CINR have an average equal to around 13.

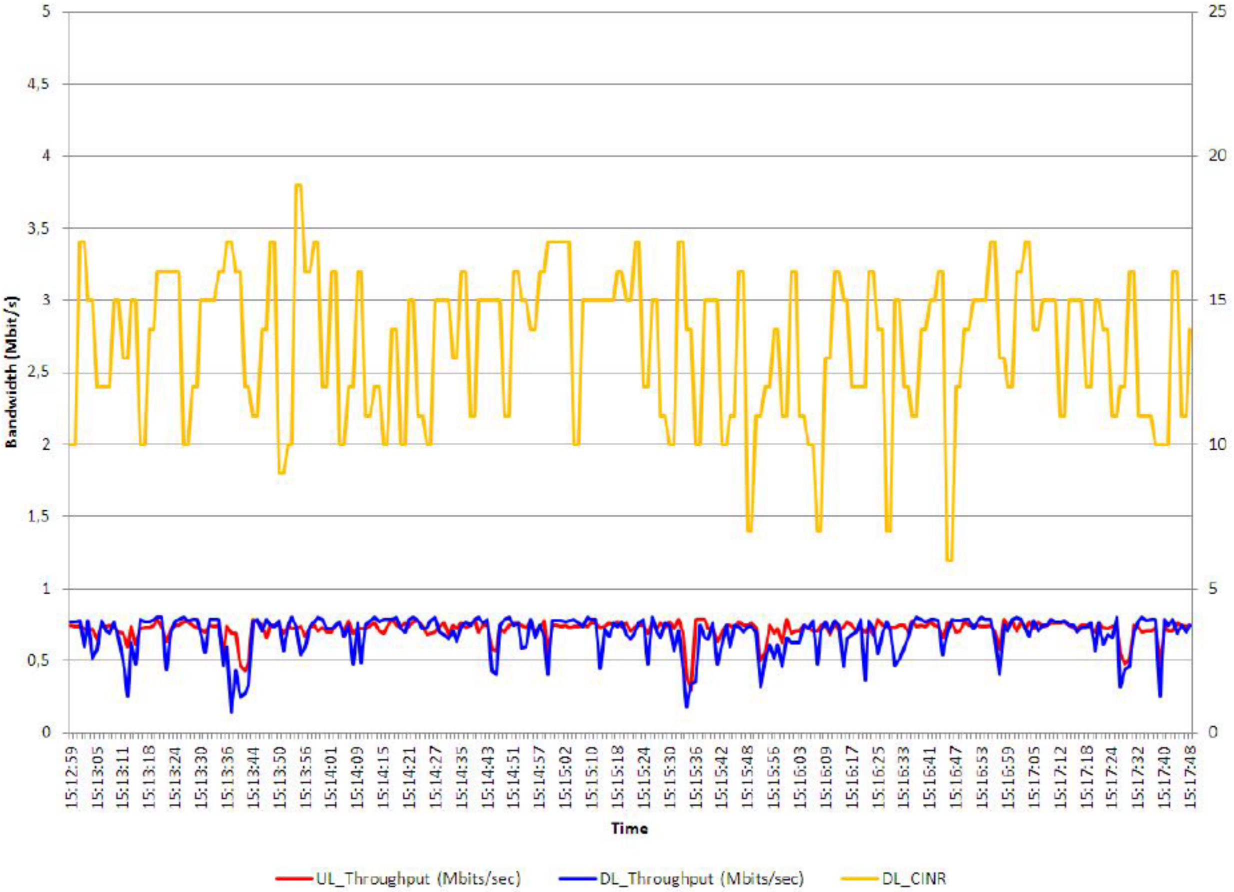


Figure 94: Laboratory tests - UDP transfer Vs CINR (Ratio 35:12)

	UPLOAD			DOWNLOAD			MS Radio values	
	Throughput (Kbit/s)	Jitter(ms)	PLR(%)	Throughput (Kbit/s)	Jitter(ms)	PLR(%)	RSSI(dBm)	CINR
Minimum	300	0.997	1	150	0.348	0	-71	
Average	720.50	1.90	9.79	687.57	0.52	13.78	-69.17	13.46
Maximum	790	5.185	52	800	1.02	84	-68	19

Table 12: UDP throughputs, Jitter and PLR (Ratio 35:12)

The achieved UL and DL data bit rates are the in same order of magnitude (720Kbit/s in UL and 690 in DL). Short Jitter values are observed. The PLR remains quite high (10% in UL and 14% in DL with peaks exceeding several ten percents).

By tracing the PLR curve, we can see its fluctuation in function of time:

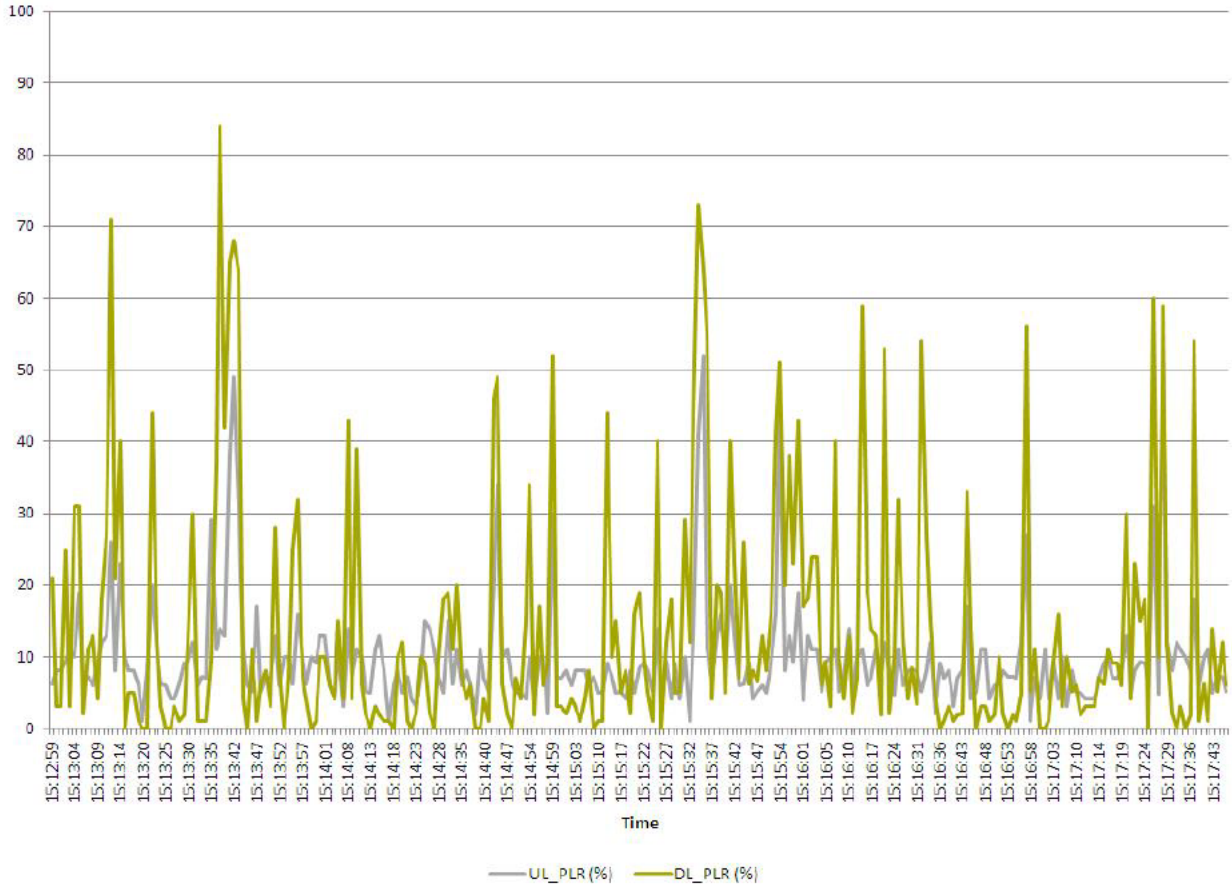


Figure 95: Laboratory tests - Packet loss rate (Ratio 35:12)

Packet losses are very numerous in uplink and downlink.

The values of the PLR as a function of the injected target throughput were verified. The results are given in the next table:

Throughput (Kbit/s)			Jitter (ms)		Packet loss rate (%)		MS Average CINR	MS Average RSSI (dBm)
Target	UL	DL	UL	DL	UL	DL		
800	720	690	0.5	1.9	14	10	14	-69
700	650	610	2.2	3.2	13	7		
500	460	440	2	5	12	8		
100	84	88	2.3	35.5	12	16		

Table 13: Laboratory tests - UDP throughputs, Jitter and PLR (Ratio 35:12) with several target throughputs

This shows that the PLR is not really correlated to the amount of injected traffic.

7.3.2.13.2 T011 - Data Jitter results (Ratio 32:15)

The T011 test procedure was replayed with the second BS configuration (see §7.2.1.2). The target UDP traffic injected in uplink and downlink was set 1000Kbit/s.

Figure 96 shows curves representing the DL and UL throughput and the RSSI measured along the test period.

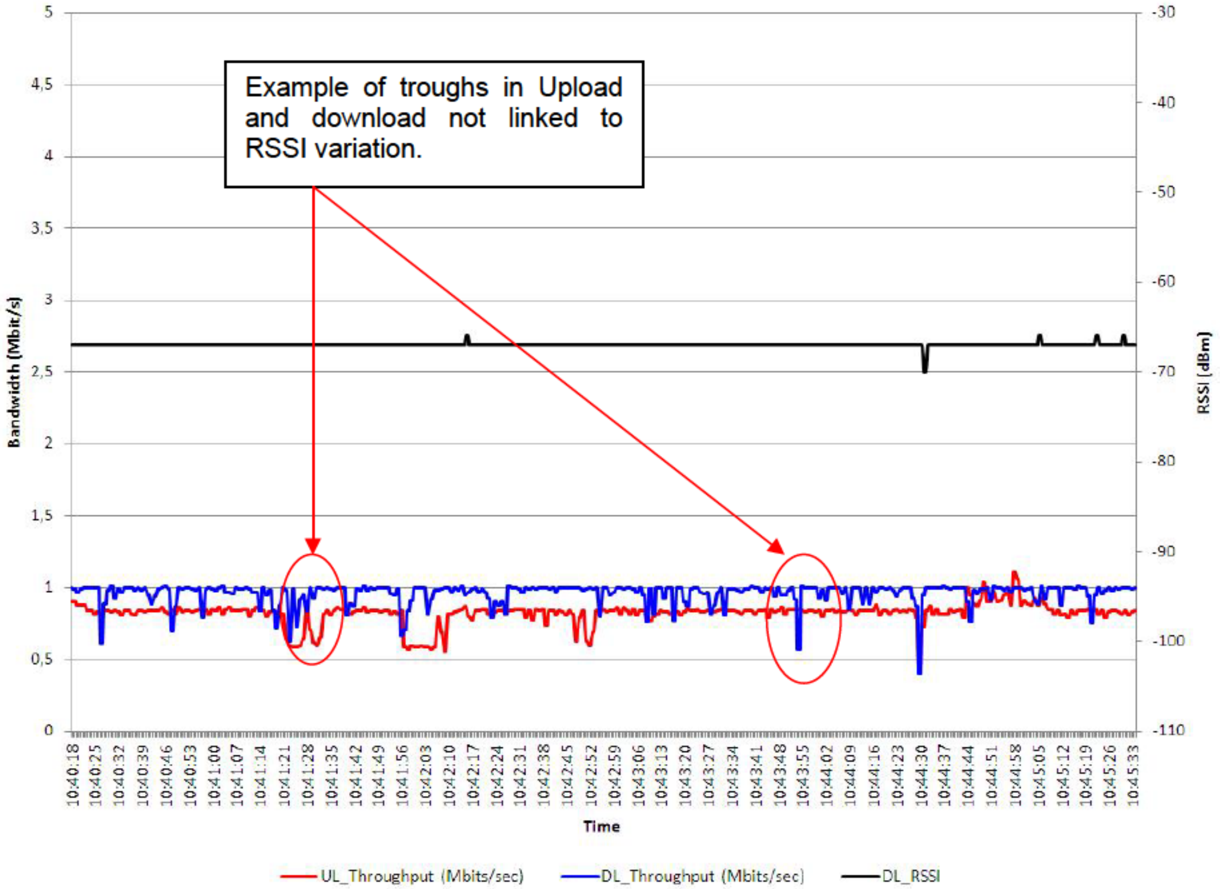


Figure 96: Laboratory tests - UDP transfer Vs RSSI (Ratio 32:15)

As previously, the RSSI is quite stable; the data bit rates are in the same order of magnitude as with the ratio 35:12. Periods with degradation of the performances are observed again. The achieved data bit rates in UL is in average lower of around 100Kbit/s than DL.

CINR variations are similar to those observed with the previous configuration: it varies from 0 to 21 in downlink.

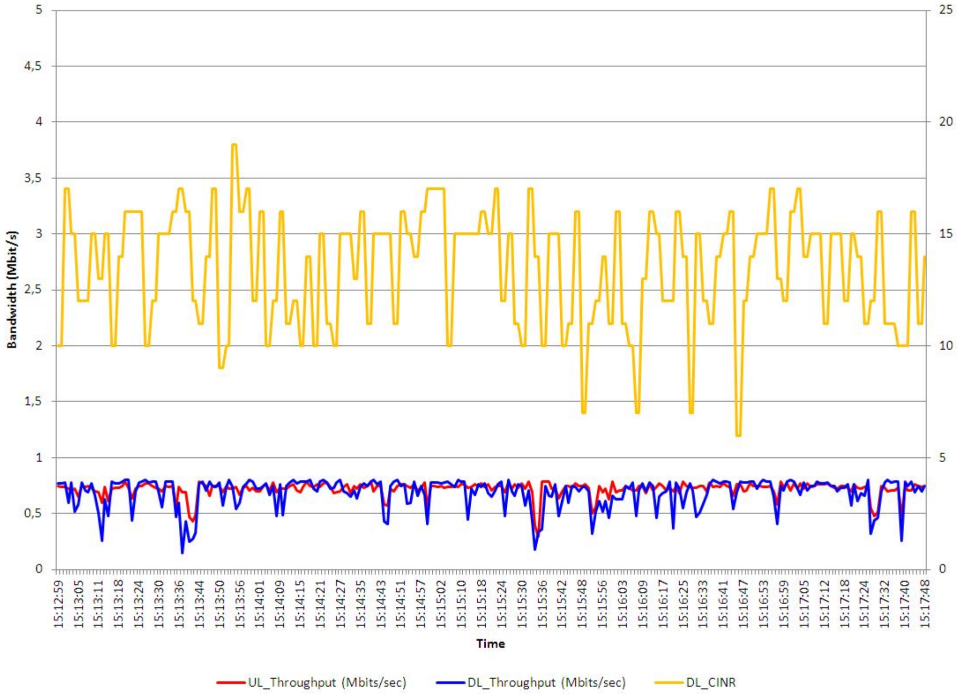


Figure 97: Laboratory tests - UDP transfer Vs CINR (Ratio 32:15)

The jitter is asymmetric between UL & DL: the DL jitter is stable around 2ms in downlink whereas the uplink jitter is quite higher in average (4ms) and can reach 18ms. But in general the jitter values are low and are in adequacy with real time of services (for example to get a good quality with Voice over IP, jitter should not be higher than 50ms).

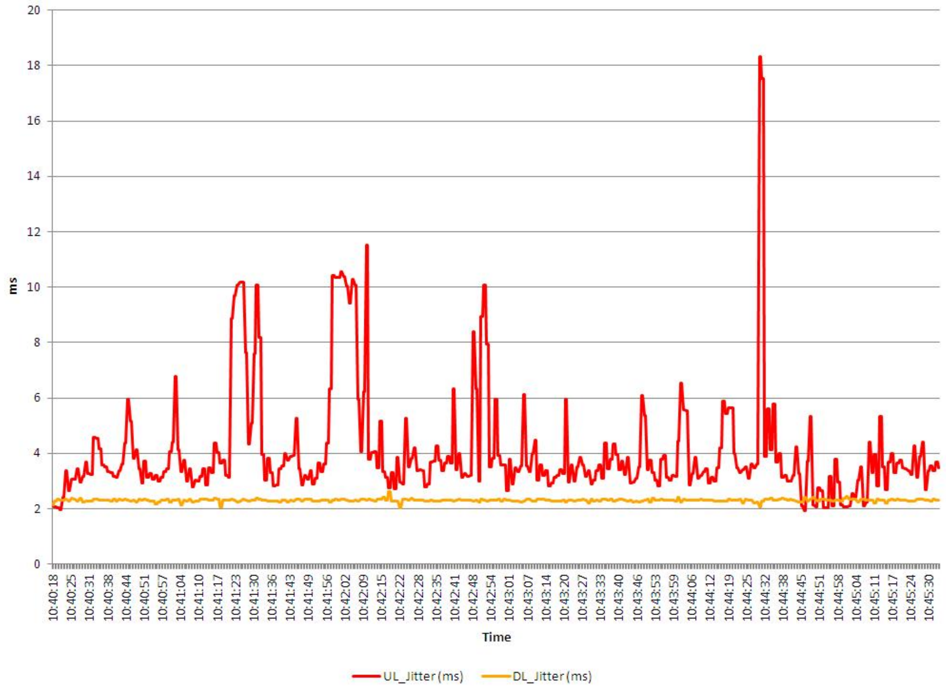


Figure 98: Laboratory tests - Jitter (Ratio 32:15)

Figure 99 illustrates the PLR measure during UDP transfer:

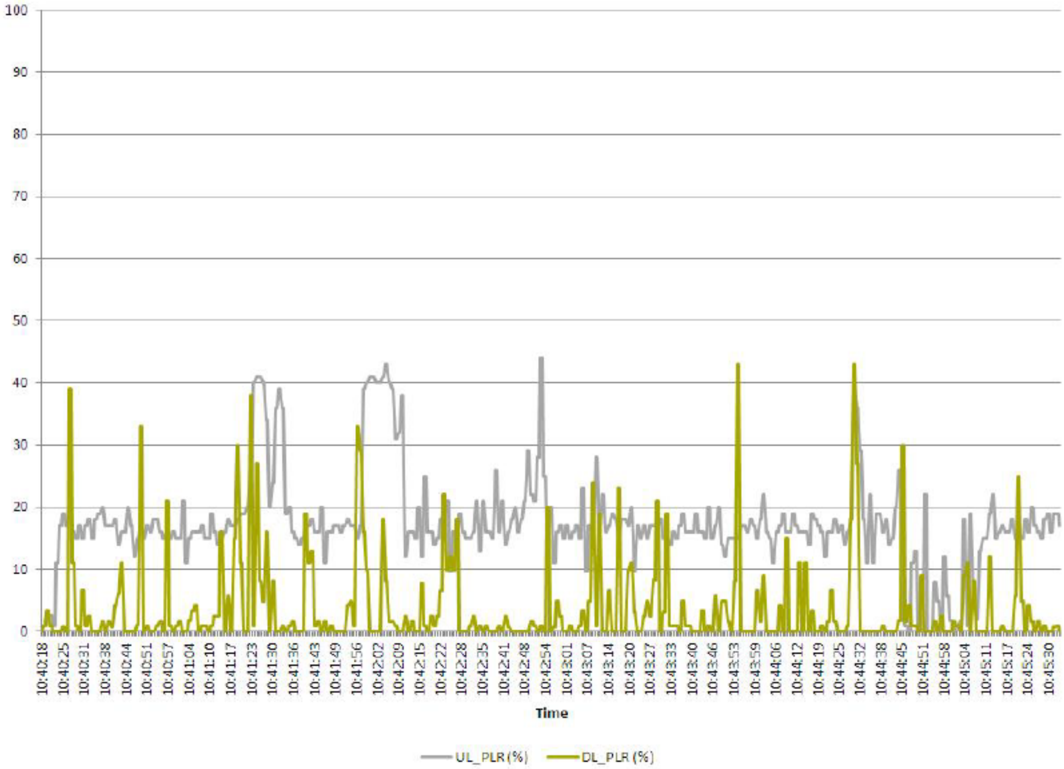


Figure 99: Laboratory tests - Packet Loss Rate (Ratio 32:15)

The DL packet loss rate is in average quite low but equal to around 4% and can increase until several ten percents. The UL packet loss rate is in average higher and has similar peaks periods.

The following table summarizes the different graphs that we saw:

	UPLOAD			DOWNLOAD			MS Radio values	
	Throughput (Kbit/s)	Jitter(ms)	PLR(%)	Throughput (Kbit/s)	Jitter(ms)	PLR(%)	RSSI(dBm)	CINR)
Minimum	430	1.946	0	400	2.04	0	-70	0
Average	821.87	4.12	17.51	960.89	2.31	3.86	-67.00	15.65
Maximum	1110	18.311	44	1010	2.62	43	-66	21

Table 14: Laboratory tests - UDP throughputs, Jitter and PLR (Ratio 32:15)

Summary:

In summary, the change of ratio did not change anything about measured MS radio indicators, data bit rates, jitter and packet loss rates.

7.3.2.13.3 T011 - Data Jitter results (Antenna configuration 4)

After having reworked the orientation of the two Base Stations antennas (see § 7.2.1.2), the T011 test procedure was replayed. The target UDP traffic injected in uplink and downlink was set 600Kbit/s.

Figure 100 shows curves representing the DL and UL throughput and the RSSI measured along the test period.

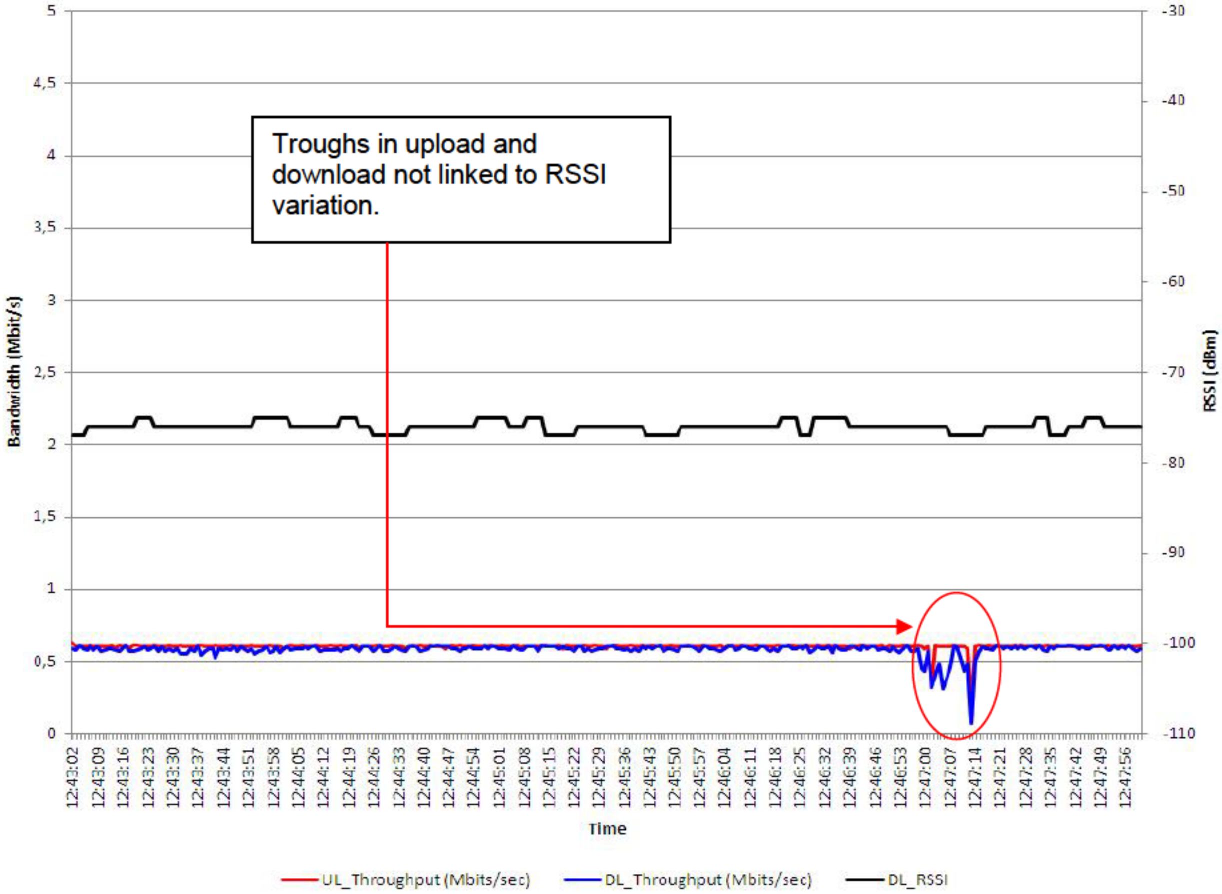


Figure 100: Laboratory tests - UDP transfer Vs RSSI (Optimal coverage)

The RSSI is quite stable around -76dBm; the UDP transfer is also stable around 600Kbit/s in UL and DL. Only one time slot with degraded performances was observed during the test period.

CINR values varied from 8 to 15 and do not seem to play on the time slot of the degradation of the available throughput.

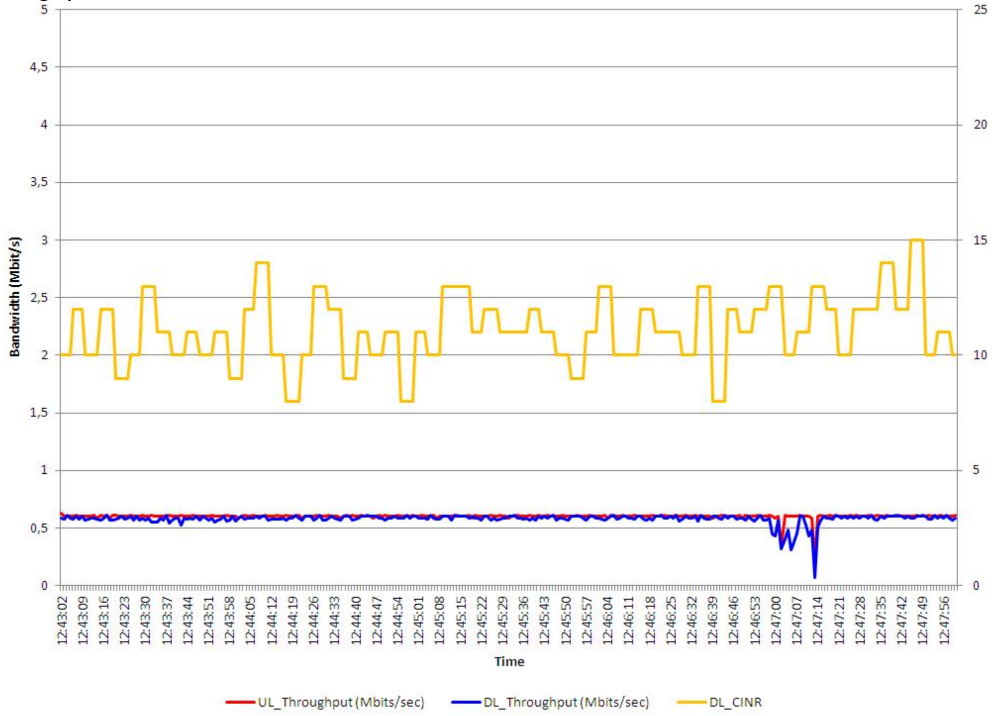


Figure 101: Laboratory tests - UDP transfer Vs CINR (Optimal coverage)

Jitter values did not fluctuate a lot: as illustrated with the following curves, it varies from 2 to 5ms.

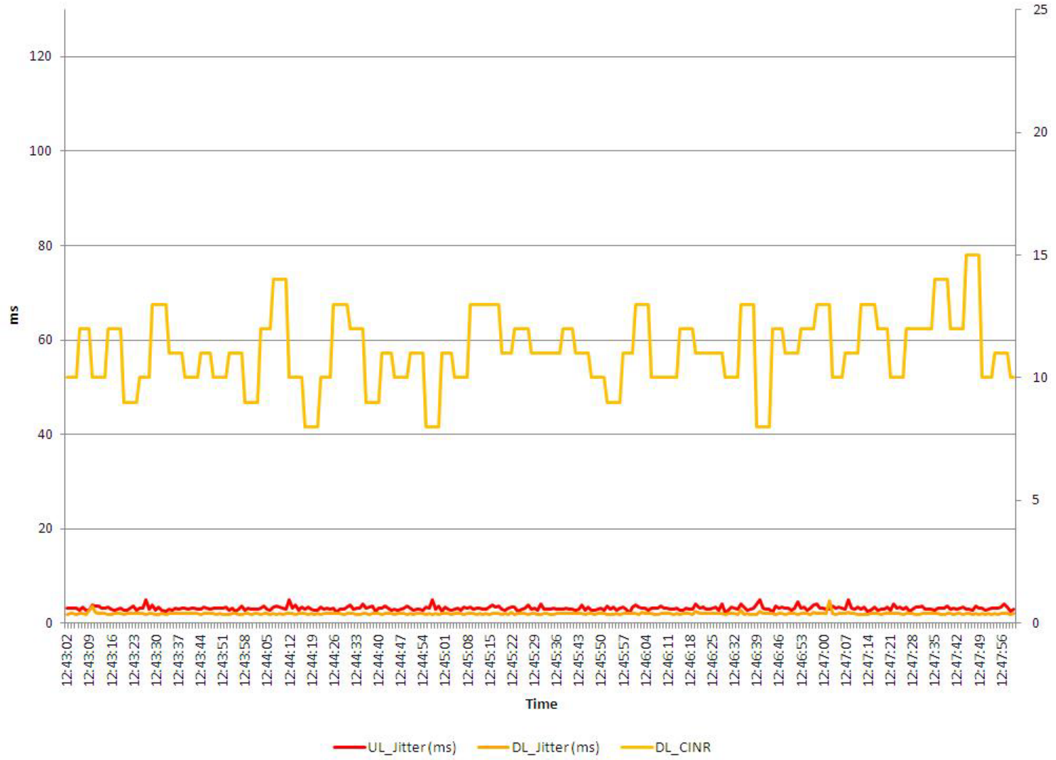


Figure 102: Laboratory tests - Jitter Vs CINR (Optimal coverage)

The packet loss rate is globally better than the previous configurations: it is equal in average of 3% in DL and 0.5% in UL. During the time slot where performance degradation was observed, the PLR reach peaks up to 87% in UL and DL.

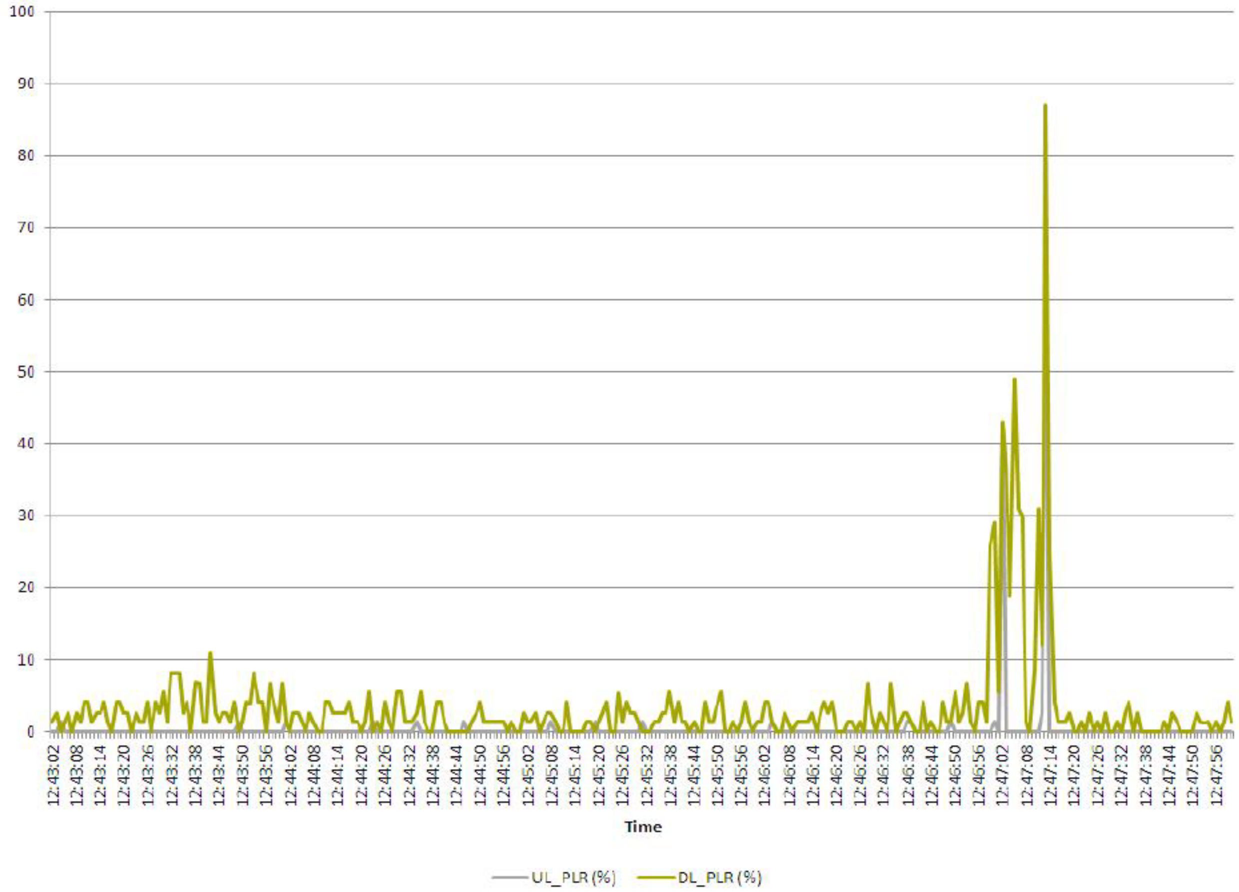


Figure 103: Laboratory tests - UDP Packet Loss Rate (Optimal coverage)

The following table summarizes the test results of the UDP transfer:

	UPLOAD			DOWNLOAD			MS Radio values	
	Throughput (Kbit/s)	Jitter(ms)	PLR(%)	Throughput (Kbit/s)	Jitter(ms)	PLR(%)	RSSI(dBm)	CINR)
Minimum	200	2.16	0	70	1.87	0	-77	8
Average	600	3.18	0.44	581	2.02	3.30	-75.98	11.09
Maximum	630	5.04	67	610	4.68	87	-75	15

Table 15: Laboratory tests - UDP throughputs, Jitter and PLR (Optimal coverage)

Summary:

In summary, the optimization of azimuths & tilts of each BS antenna permitted to reach better network performances. Even if MS radio signal quality indicators (measured on the MS side) did not change very much, higher and more stable data bit rates are achieved. Jitter values remain stable. Packet loss rates were reduced but were still high. No obvious relation between RSSI/CINR values and network performances was observed. The RSSI stayed stable at average levels. The CINR was at normal levels in average but with frequent variations.

Regarding the high average packet loss rates and the very high peak packet loss rates the suspected causes of these bad results remain those given before:

- Potential shadowing effects of Aircraft that are rolling, taking off and landing on the airport. Laboratory environment where there are lots of metal around which can decrease radio link quality and that induce unstable CINR

- The possibility that vertical aperture of the BS antennas not adapted to our experiment.

UDP data transfer throughputs are consistent with the expectations: with a distance of around 1.9km separating the BS from the laboratory, we succeeded to reach several hundred Kbit/s transfers in uplink and downlink. The measured jitter values are appropriately low.

7.4 Conclusions and recommendations

7.4.1 Conclusions

The AeroMACS MS prototype was verified to be compliant with the requested interfaces: it is correctly equipped with a standard TNC connector with an impedance of 50Ω, and with Ethernet interfaces. It also provides a way to simulate the “In flight”/”On ground” Aircraft condition, which allowed to verify the correct behaviour of the MS in these 2 conditions.

It was verified that the AeroMACS MS and BS prototypes operate in deployed environment in compliance with the main characteristics of the AeroMACS standards (channel bandwidth of 5MHz, 5GHz band use, and channel frequencies available from 5091 to 5190MHz).

Connection establishment and data transfer in deployed environment in between the MS statically located at Airbus laboratory at a distance of 1,9 Km far from the BS, were successfully achieved.

QoS and Service Flows have been successfully tested.

Measured Round Trip Time values were consistent with the expectations (several ten ms).

Regarding throughput measurements, several hundreds of Kbit/s was reached in uplink and downlink, which is also consistent with the expectations. The measured jitter values are appropriately short.

On the negative side, a high rate of packet loss, traducing instability of the AeroMACS link, was observed, even up to the point where TCP/IP data transfer could not be completed and resulted in the premature “provider abort” of the TCP connection after multiple unsuccessful retransmission of the lost packets. The following possible cause are assumed:

- Potential shadowing effects of Aircraft that are rolling, taking off and landing on the airport and that can reduce the quality of the AeroMACS link. However this cannot be the sole explanation; because packet losses were also observed in periods with no aircraft movements.

- The antenna of the BS was not fully well oriented. The BS antennas have a horizontal aperture of 90° and around 7° in vertical. Because of narrow vertical aperture, down-tilt was not optimized to cover the airport and the Airbus laboratory.

- The vertical aperture of the BS antennas is not adapted to our experiment. This kind of sectorial antenna is standard to cellular network; but for our experimentation, we have only two BS to cover a large area.

7.4.2 Recommendations

Refer to section 5.2, where recommendations have been factorized.

8 STEP 3 Verification Exercises Report (tests with a vehicle)

8.1 Verification Exercise Scope

The scope of the car tests (Step 3 of the P9.16 Verification exercises) was to verify the operation of the Selex MS prototype and the performance of the AeroMACS technology in a deployed environment over the Toulouse Airport, with the MS being installed in a car moved on the Toulouse Airport surface.

The main objectives of these tests were to:

1. Evaluate the AeroMACS performances in both LOS and NLOS conditions, at different positions and distances from the Base Stations, and the coverage of the Base Stations on the Airport surface
2. Verify the correct operation of AeroMACs during movements of the Mobile Systems on the airport surface, at different speeds (Verification of Doppler compensation mechanisms)
3. Verify the handover mechanisms, when moving the car and the MS from one cell (e.g. under BS1 coverage) to an adjacent cell (under BS2 coverage)
4. Verify the possible impacts of AMT and MLS on AeroMACS
5. Confirm that the Toulouse AeroMACS test platform is operative and ready to be used for the Aircraft tests (Step 4)

More details are given in the Verification Plan (9.16-D06 ([6])) and in the Test procedures document (9.16-D07 ([7]))

8.2 Conduct of Verification Exercise

This verification exercise was performed in coordination with the following partners:

- SELEX provided the AeroMACS prototypes, and support during the experiments,.
- SITA was in charge of the ground AeroMACS infrastructure deployment, and provided support during the experiments.
- DSNA/DTI managed regulatory aspects for 5GHz frequency use at TLS Airport, provided the car and its driver for the “car tests”, and facilitated access to the Airport area for the involved test engineers.
- Airbus was in charge of the “Airborne” AeroMACS infrastructure deployment, and of the execution of the tests covering the Validation and Verification Objectives allocated to this AeroMACS verification exercise.

8.2.1 Verification Exercise Preparation

The Vehicle tests were done using vehicles kindly lent by the French Civil Aviation (DGAC/DSNA). Figure 104 shows one of the vehicles equipped with the AeroMACS MS Antenna.

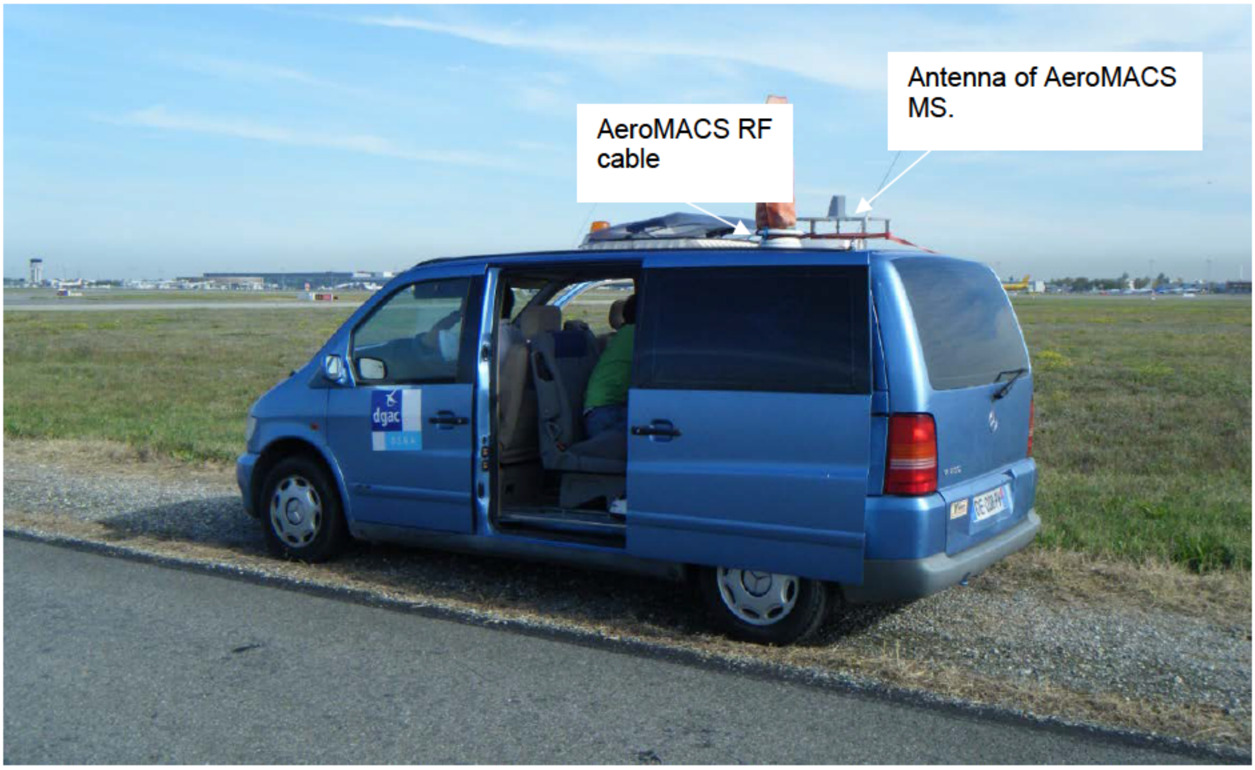


Figure 104: Vehicle installation – Outside installation

The DSNA vehicle is equipped with a 12VDC/220VAC converter on which all pieces of equipment are power supplied. The antenna was installed on a support simulating the aircraft fuselage. This support was fixed on the roof of the vehicle.

Figure 105: Vehicle installation – MS Antenna with support

The IP Router and AeroMACS MS were installed into a RACK 19” as shown hereafter.

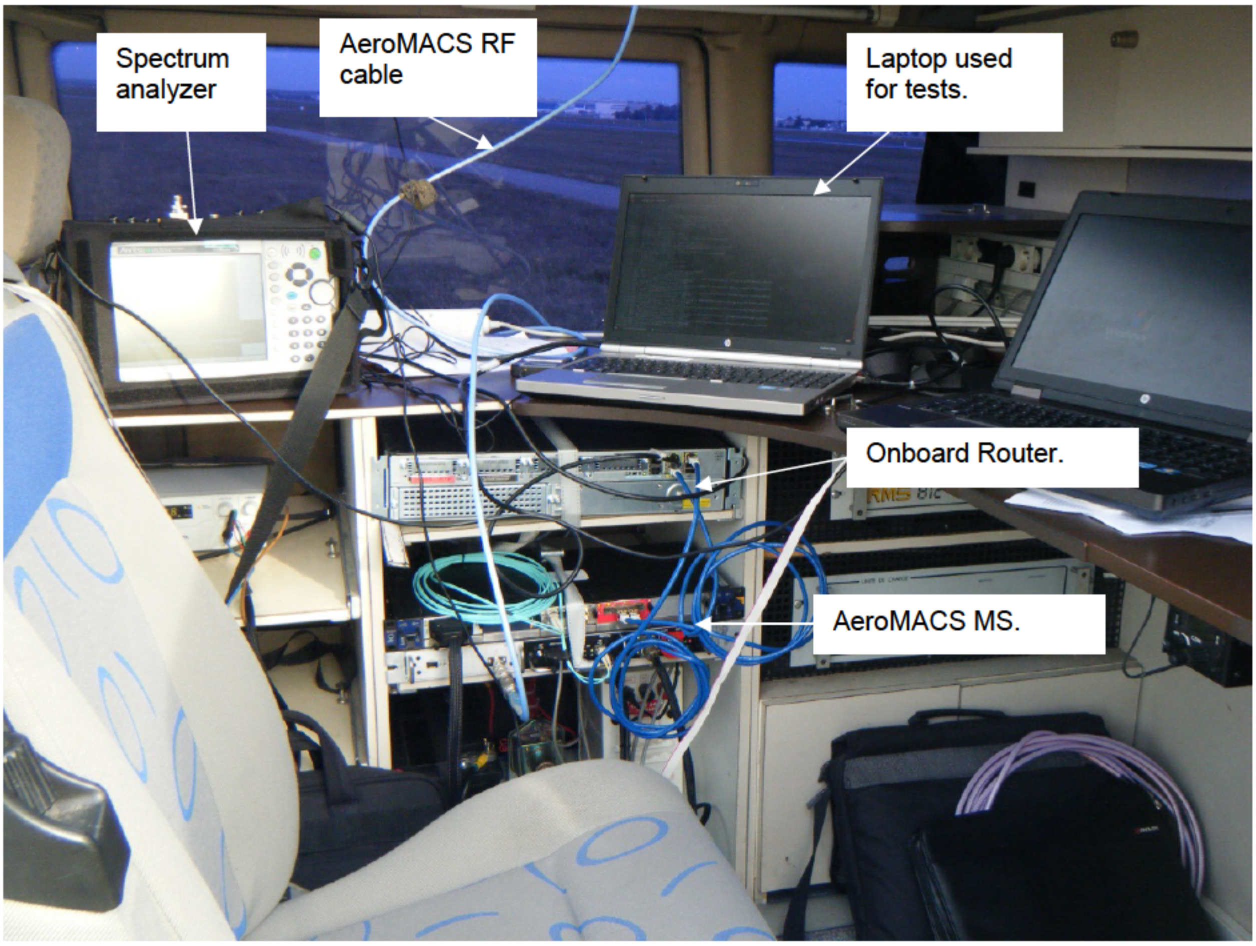


Figure 106: Vehicle installation – Inside installation

The RF cable passes through a top window to link the AeroMACS MS to its antenna that is outside of the vehicle.

The vehicle tests were done as a succession of preliminary or tentative tests spawned over the Weeks 32, 34 and 38 in 2014, before performing the ultimate attempt to play the full set of the test procedures on Week 42.

8.2.1.1 Preliminary tests into Airbus facilities (Week 32)

On Week 32 (2014), preliminary car tests were first done around but outside the Airport, with the car placed at some static points within the limit of the theoretical coverage of the BSs (see Figure 107).

The BS configuration 3 (see section 7.2.1.2.3) was in place for these tests.

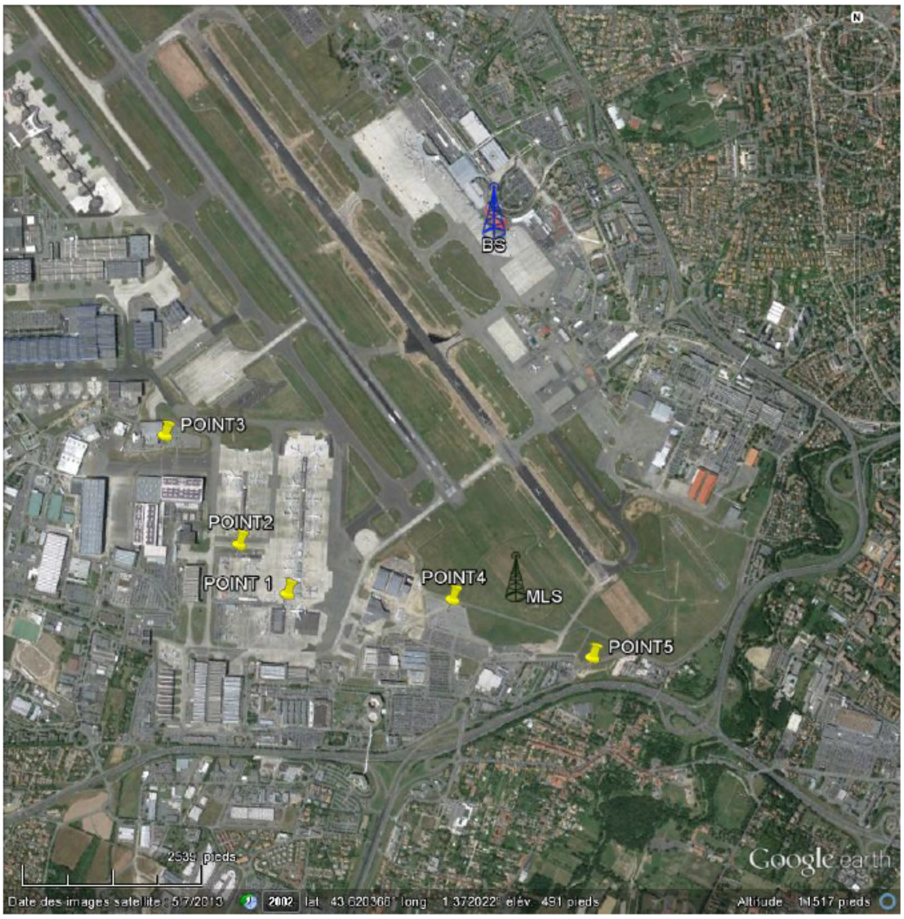


Figure 107: Vehicle tests - Preliminary tests around but outside the Airport

The position of the different tests is summarized in the following table:

Points	1	2	3	4	5
Distance from BS	1909m	1848m	1753m	1720m	2004m
LOS/NLOS	NLOS	NLOS	LOS	LOS	LOS

The tests were unsuccessful. On a spectrum analyzer, it was observed that no AeroMACS signal was received from the BSs, and that the MS did not succeed in establishing a connection with any BS.

Several hypotheses were made for explaining these problems:

- BS antennas had an aperture angle of 90° in horizontal and 7° in vertical. The BS1 antenna down-tilt set to 4° was possibly not optimized to cover Airbus facilities.
- A BS failure during the tests might have occurred
- Wires and connectors on BS side had to be checked

After tests, all these points were checked:

- The BS1 antenna down-tilt and azimuth was optimized for better coverage. For this, an RF generator (16dBm of output power) was connected in the stead of the BS to the RF wire of the BS antenna. On the other side, a ridged horn antenna (10dB of gain on 5GHz) with a spectrum analyzer measured the signal received at interesting positions. An operator adapted the down-tilt of the antenna to get an appropriate and verified coverage.
- Measure on the RF output of BS was performed: the two base stations emitted with a good level (around +26dBm).
- Measure on MS and BS RF cables were in good tolerance for AeroMACS use.

- Measures of the SWR (Standing Wave Ratio) of BS antennas revealed that the adaptation of the cables and RF antennas were acceptable (less than 2.0). See Appendix A.8.

8.2.1.2 Preliminary tests on Airport platform (Week 34)

On Week 34, after having checked and revised the BS1 antenna down-tilt and azimuth, a first session of tests with the car rolling on the path ways inside the Airport (around the Airport field) was done. Figure 108 shows the RSSI values measured by the MS during one round.

It appeared that BS1 coverage (north) was partial, and that BS2 coverage was totally insufficient.

Note: *Points in grey, MS was switched on but not connected*
Points in cyan, MS RSSI was between 0 & -40dBm.
Points in green, MS RSSI was between -40 & -60dBm.
Points in yellow, MS RSSI was between -80 & -60dBm.
Points in red, MS RSSI was between -100 & -80dBm.
Points in black, MS RSSI was lower than -100dBm.

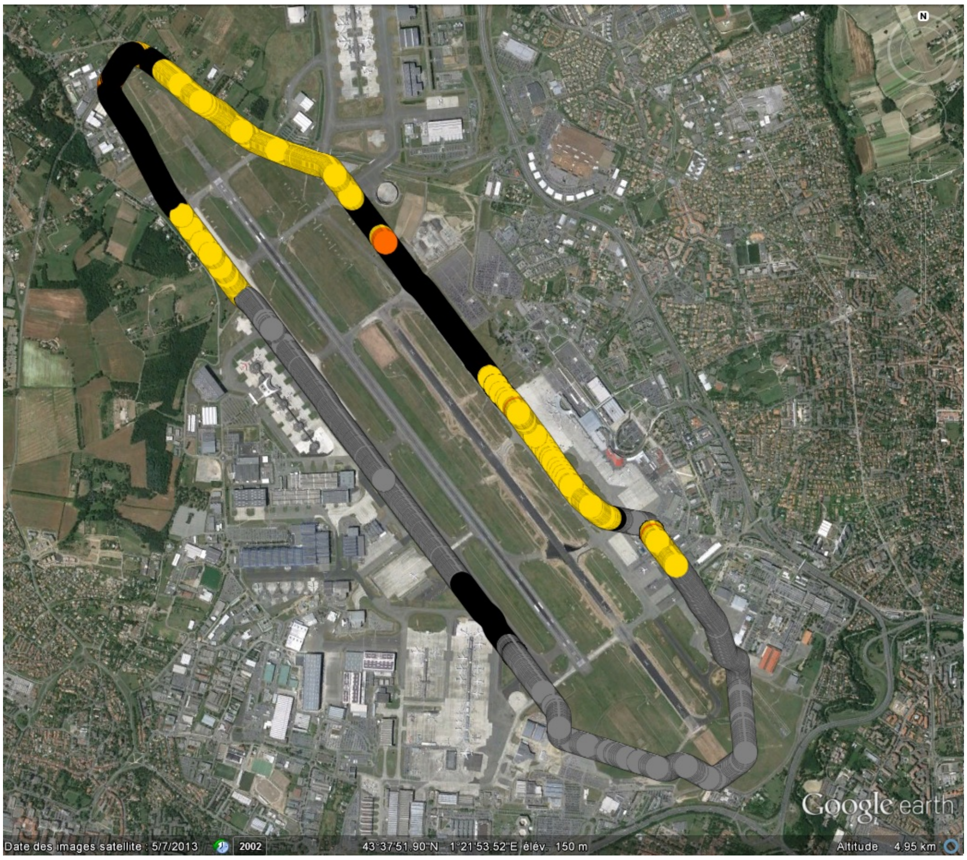


Figure 108: Vehicle - Preliminary tests on Airport platform – First track (Week 34)

A second round was done with similar results.

At the third round, no signal was received from the BS anymore (this was later explained to be due to a software failure on the ground AeroMACS systems side (software process abrupt termination)

After these Week 34 bad test results, SITA undertook a complete revision of the BS1 and BS2 installation. The new and revised BS installation was ready on week 37.

8.2.1.3 Preliminary tests around the Airport (Week 38)

On Week 38, it was planned to play the complete car test procedures on the Airport. The BS configuration 4 (see section 7.2.1.2.4) was in place for these tests.

Unfortunately, many different problems were encountered (MS failure (replaced by another MS) , ASN Gateway shutdown, supplied BS cable discovered to be damaged) and a lot of time was wasted to understand and fix these different problems, leaving only one remaining afternoon to pass some tests. We got then some encouraging results. It was possible to get the MS connected to the BS at static points located approximatively at 1km far from the BSs with a very good performance in terms of RSSI and CINR and sometimes even when moving. Some instability of the MS was observed however: random disconnection, re-connection impossible or difficult at a static point, need to restart the MS.

On week 42, the tests were reattempted. Results are detailed in the next subsections.

8.2.2 Verification Exercise execution

Refer to Table 1 in section 3.2 for the overall timing of Step 3 exercises.

The car tests were attempted a last time on the week 42: the authorization to get access to the Airport surface and the availability of a DSNA vehicle and a driver was obtained for two half-days (13th October Afternoon and 14th October Morning).

The approach followed during execution of the Verification Exercise is described in 9.16-D07 ([7]).

8.2.3 Deviation from the planned activities

Refer to Table 2 on page 23.

8.3 Verification exercise Results

8.3.1 Summary of Verification exercise Results

Refer to Table 4 on page 26.

8.3.2 Analysis of Verification Exercise Results

8.3.2.1 T102 - Maximum Cell Radius

Due to time constraints, this test was not a full “cell radius” measurement. It was reduced to an assessment of the AeroMACS coverage on interesting points: i.e. measure of the signal at different points.

The car was equipped with a Spectrum Analyzer that had a Noise Floor of -73dBm (Max Hold); -80dBm (Average) – measured on 5 MHz bandwidth.

The static tests were performed according to the steps below:

- Stop the car
- Store the GPS reference of the point
- Measure the received signal level with the SA
- Connect the antenna on the AeroMACS MS

The Estimated Power had been evaluated by Selex ES specialists with a basic propagation model for static points based on free space and diffraction with ground reflection losses relying on a free digital terrain model with resolution of approximately 90 x 90 meters. A more detailed analysis using high resolution DTM and more complex propagation models was impossible due to time and cost of the analysis. Please consider that no fade margin has been included in the evaluation of link budget and estimated power.

The list of static points is reported below with the test results and the related system and coverage analysis.

Note: After the test of the different points on the first day of tests, it has been observed that the supplied antenna cable (between antenna and MS) was damaged. The ground contact was unstable and this explains the bad results obtained on the first day. The cable was replaced the second day of the tests and a number of the static points were measured again.

Figure 109 shows the location of the different static points.

Figure 109: Vehicle tests - Measurement assessment

Black points correspond to places tested with a deficient cable. On these points, we did not measure any AeroMACS radio frequency signal on Spectrum analyzer. The MS did not also receive any signal.

Grey points correspond to places where a valid (replaced) RF cable was used between MS and its antenna, but where AeroMACS RF signal was too low and the MS did not receive any AeroMACS radio frequency.

At green points, signal was strong enough to be measured on Spectrum analyzer and the MS was able to connect to AeroMACS network.

Table 16 summarizes the results on static test points on the first day when the deficient MS-to-Antenna cable was installed.

Table 17 summarizes the results on static test points on the second day when a good MS-to-Antenna cable was installed

Results with deficient MS-to-Antenna cable						
Item	**Event Description**	**SELEX comments**	**Coordinates**	**Spectrum Analyzer Measurements**	**EMS**	**Distance from BS**
Point 1	Received signal too low	This is the car parking position in DGAC, (close to Allée Saint Exupery – Blagnac). This position is behind a building (in a shadow area for the BS) and no measurement has been made.	43.63597/1.36812	N/A		820m
Point 2	Received signal too low	The MS starts the registration stopping the "frequency scan" but doesn't terminate the registration procedure. The spectrum analyzer does not measure any signal even if the EMS give a signal 2 dB over the noise floor.	43.64274833/1.342967	N/A	-78.4dBm	2910m
Point 3	Received signal too low	The MS starts the registration stopping the "frequency scan" but doesn't terminate the registration procedure. The SA does not measure any signal even if the EMS give a signal 3 dB over the noise floor.	43.63038167/1.355955	N/A	-78dBm (in this point the EMS provides an high attenuation due to a partially shadow in the first Fresnel zone for a (smooth) hill in the airport landscape)	1484m
Point 4	Received signal too low	The MS starts the registration procedure but it failed. Note: It has been observed that the AGC starts to work and reduces the MS receiver gain of the RX chain of 1 [dB]. Considering that the threshold for the AGC attack is about -82 dBm it means that the signal measured by MS is about -82+1 = -81 dBm as peak power of preamble.	43.62647/1.3600467	-72.7dBm	-76dBm	1212m
Point 5	Received signal too low	The MS starts the registration procedure but it failed. Note: It has been observed that the AGC starts to work and reduces the MS receiver gain of the	43.61693667/1.37001	-69.3dBm	-73dBm	1489m

Results with deficient MS-to-Antenna cable						
Item	**Event Description**	**SELEX comments**	**Coordinates**	**Spectrum Analyzer Measurements**	**EMS**	**Distance from BS**
		RX chain of 1 [dB]. Considering that the threshold for the AGC attack is about -82 dBm it means that the signal measured by MS is about -82+1 = -81 dBm as peak power of preamble.				
Point 6	No signal measured on RF analyzer.	The MS didn't register.	43.62965/1.3638367	N/A	-69dBm	844m

Table 16: Vehicle tests - Maximum cell radius test results (with deficient TNC cable)

Results with replaced (good) cable						
Item	Event Description	SELEX comments	Coordinates	Spectrum Analyzer Measurements	EMS	Distance from BS
Point 12	MS did not see any BS. No signal measured on RF analyzer. We tested by inverting the BS (i.e. 5108MHz on South and 5118.5MHz on North). It was the same.		43.6222/1.3715433	N/A		887m
Point 7	MS began to scan the frequencies. No registration was possible; too low received signal.	**The MS tries to register during the movement of car.** Due to the fact that MS tries to register during the movement of the car, we stop the car and verify that in this position, the MS measures a signal level in the PREAMBLE of -87dBm and tries to register.	43.616755/1.37602	N/A	-76dBm	1470m
Point 8	Received signal is a little better. We got: RSSI = -79dBm CINR = 14 The registration could not be reached, and stayed at a status indicating "Wait for DHCP to be success". There might have been a problem of control power; the MS connection went up to DHCP step, but on BS log side, it was seen that that the DHCP request had not been received on BS side. the DHCP packet had been lost on the uplink. After restart of the MS, the MS finally succeeded to register on the BS. The AeroMACS link was then available and it became possible to perform . TCP & UDP data transfers.	**When the MS registered on the BS,** throughput measurement has been performed: • Bidirectional UL / DL TCP tests: 1.15 Mbit/s in DL and 0.88 Mbit/s in UL • Bidirectional UL / DL UDP tests: 1.2 Mbit/s with error rate of 0.011% (on 18000 packets) The signal measured by MS is RSSI_Preamble = -73dBm as peak power of preamble. **Note:** We observed that the AGC works and reduces the MS receiver gain of the RX chain of 9 [dB]. Considering that the threshold for the AGC attack is about -82 dBm it means that the signal measured by MS is RSSI_Preamble = -82+9 = -73 dBm as peak power of preamble. After the registration the MS provides the RSSI of data (the RSSI readable with SNMP), it was RSSI_MS = -79 dBm: these two measurements are in line considering that, for AEROMACS	43.61599167/1.3834367	-71.4dBm	-77dBm	1716m

Results with replaced (good) cable						
Item	**Event Description**	**SELEX comments**	**Coordinates**	**Spectrum Analyzer Measurements**	**EMS**	**Distance from BS**
	We moved the car while the AeroMACS connection was still established. The connection remained established during one or two minutes, then was lost	standard, the preamble is 5 dB higher respects the data. During the link has been measured a CINR of 13-14 dB and it was very stable. After these throughput tests we leave this point. The MS maintains the registration up to the point **010**, has been made a parking maneuver and then the car arrive up to 40 km/h. During the movement has been observed a reduction of the signal level and a consequent increasing of the AGC gain up to the maximum gain of the RX chain. Between the point 008 and 009 the difference in the free space attenuation is only **0.7 dB** but the EMS indicates that the received signal decreases of about **10 dB** due to the complete darkening of the first Fresnel zone. This simulation is in line with the observation: the MS lost the link due to the very low received signal.				

Results with replaced (good) cable						
Item	Event Description	SELEX comments	Coordinates	Spectrum Analyzer Measurements	EMS	Distance from BS
Point 5	Reboot of MS needed because it was frozen. Then, we got and RSSI of -79dBm; CINR fluctuated between 5 and 12. BS saw the MS registered, but the MS was waiting for DHCP response (DHCP response lost on AeroMACS link: the DHCP packet was lots on the downlink) At 11h57, MS finished to be registered. We tried to execute some network performance tests, but it was impossible because there were too packet losses. After several minutes, the MS unregistered automatically. It was noted that when two aircrafts were passing, "HCS fail" were written into the logs: the movement of airplanes disturb AeroMACS link. We reboot the MS and before moving, we let the MS started..	**The MS register on the BS.** The MS, after registration, measures an RSSI_MS = -77 dBm, about 2 dB more respect the point 009: this is in line with the EMS that gives -78 dBm. After the registration, in the BS log it has been observed "burst" of "HCS Fail" messages: the link in the BS (and the CINR) is good for some tens of seconds and then become absolutely bad for other seconds. During test on point 005 we observed that: ○ ***Observation - 1***: in one case this high number of "HCS Fail" messages was associated with the transit (between BS e MS) of some aircraft. As soon as the aircraft went out of the "ideal line between BS and MS" the "HCS Fail" messages disappeared. ○ ***Observation - 2***: during our stop in this place the SA (in the car) measures some strong signal in the channels immediately above our communication channel, **without any guard channel**. The AMT used the frequency immediately above the channel that has been assigned to Selex-ES for AEROMACS; even if Selex-ES asked to have others channel far away from AMT.	43.6169367/1.37001	N/A	-78dBm	1481m

Results with replaced (good) cable						
Item	**Event Description**	**SELEX comments**	**Coordinates**	**Spectrum Analyzer Measurements**	**EMS**	**Distance from BS**
Point 3	The signal was too low: no connection was possible. We let the MS started before moving.	The MS starts the registration process but with a lot of errors due to a signal level in the PREAMBLE of -88 dBm (that correspond to a signal level on the data of -93dBm). Note: Continuing on the taxiway in the point 012 it has been observed that the MS register itself on the BS Nord during the movement of the car.	43.63038167/1.355955	N/A	-78dBm	1481m
Point11	The MS registered at this point during the trip. We tried to perform network tests but it unregistered just before we were ready to start.	**The MS registered on the BS during car movement.**	43.6332533/1.36617	N/A	-70dBm	754m

Table 17: Vehicle tests - Maximum cell radius test results with good RF cable

About the test on point 005 and the Selex ES observation 2, it was confirmed that the A350 MSN001 test Aircraft was using AMT during this test. With the figure here-after, we can see the spectrum analyzer measure:

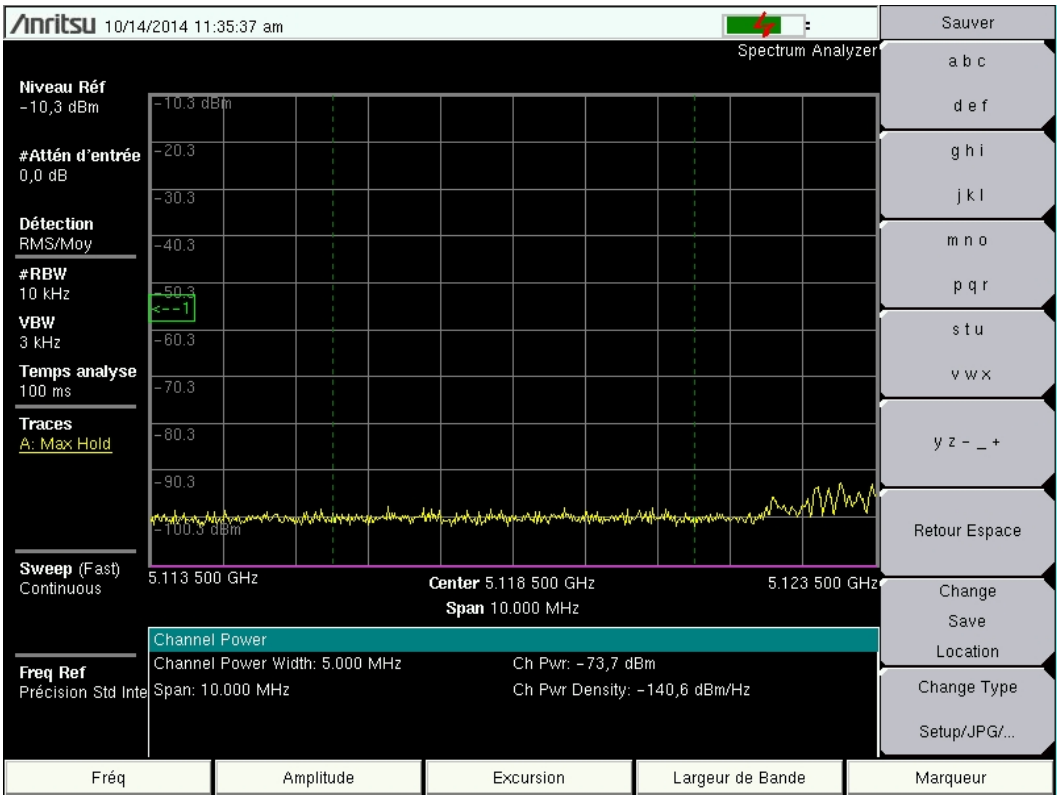


Figure 110: Vehicle – Point 5 measure on 5118.5MHz with spectrum analyzer

This measure was done at point5 where we normally must be on BS2 (i.e. 5108.5MHz). We took this measure to see the level of the AeroMACS signal received from the north BS at this point.

The level of AMT signal was shifted of 1MHz with a low signal of around below -90.3dB.

By looking at the spectrum analyzer measure on south BS, no AMT signal can be seen.

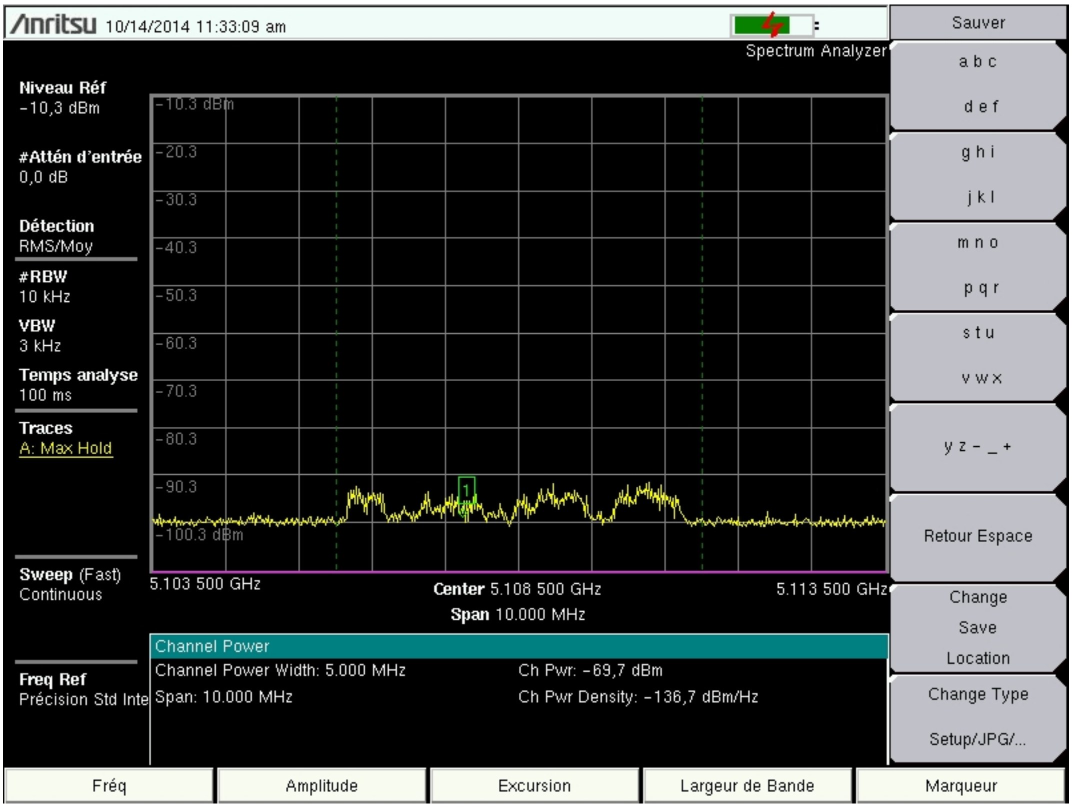


Figure 111: Vehicle – Point5 measure on 5108.5MHz with spectrum analyzer

As we were trying to perform our test on south BS coverage area, AMT use is at more than one frequency channel guard.

During the test timeslots, some aircraft used AMT but at frequencies not close to those used for AeroMACS (except A350 MSN001). This figure summarizes the AMT channel and AeroMACS used on week 42:

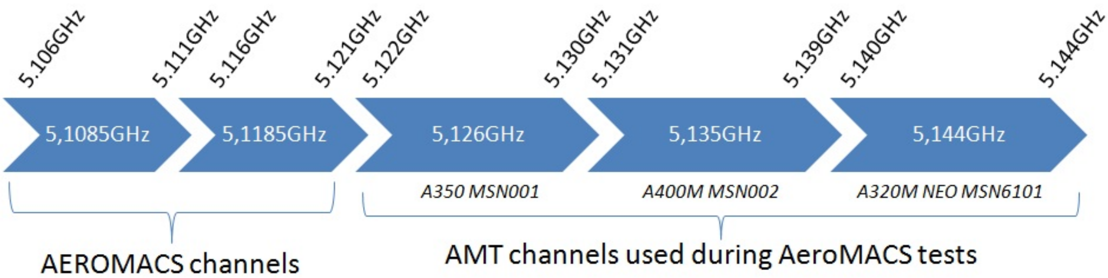


Figure 112: Vehicle – AMT & AeroMACS channels used during test

As we can see with this figure, frequencies between AMT and AeroMACS did not overlap: we can only note the A350 MSN001 that was emitting at 1MHz from the highest AeroMACS used.

Figure 113 shows the period of times during which AMT sessions were active, in regard to time slots of the AeroMACS tests. This shows that the AMT frequency which is closest to AeroMACS (i.e. 5.126GHz) was almost not used during the tests on Point 5. It also shows that this AMT frequency was active during the AeroMACS tests at Point 8, which were successful.

It must also be noted that aircraft using AMT don't stay at Toulouse Airport. They fly away during several hours. Hence, even if we got some AMT perturbation, there are few probabilities that we got these perturbations during the overall timeslot of the tests: and in fact, no AMT emission on 5.126GHz was observed on other test points than 5.

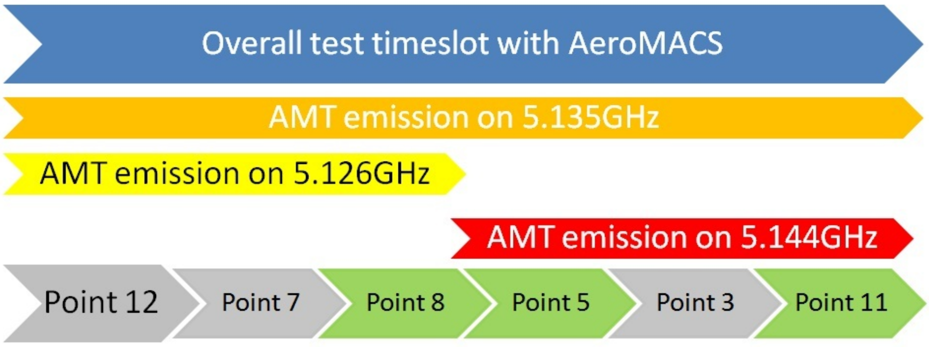


Figure 113: Vehicle – AMT frequency use in function of test points

It happened at some occasions that the MS registered or stayed registered while the car was moving. Figure 114 illustrates the paths where the MS was successfully registered while being mobile:

Figure 114: Vehicle – MS registration when vehicle move

Results with good cable					
Item	**Event Description**	**SELEX comments**	**Velocity**	**Static Point?**	**Distance from BS**
Point8 to Point 9	The MS was static and registered. The vehicle moved to the south of the airport and the MS stayed connected during several minutes.	The MS maintains the registration up to the point 9, has made a parking maneuver, and then the car is moved up to 40 km/h. During the movement has been observed a reduction of the signal level and a consequent increasing of the AGC gain up to the maximum gain of the RX chain. Between the point 008 and 009 the difference in the free space attenuation is only 0.7 dB but the EMS indicates that the received signal decreases of about 10 dB due to the complete darkening of the first Fresnel zone. This simulation is in line with the observation: the MS lost the link due to the very low received signal.	Around 40Km/h	No	Disconnection at around 1920m
Point 10	Around 12h43, while moving, the MS succeeded to register during the trip, but de-registered several seconds after.	**The MS register on the BS during car movement.** The RSSI measured on the BS at registration point is: RSSI_BS = -77 dBm.	Around 40Km/h	No	Connection at around 1170m
Point 10 to Point 3		After this, proceeding in the taxiway, the signal drops at -83 dBm and the BS deregistered the MS. Continuing on the taxiway has been stopped on the point **003**.		No	Disconnection at around 1460m

Table 18: Vehicle – MS registration/unregistration when vehicle move

The MS was able to register to AeroMACS network in mobility at low speeds even if it is only at some areas of the Airport platform.

- **Summary**

Following are Selex conclusion related to the car test session of week 42:

- The bad result obtained in the first day of test was caused by the cable problem: the un-safe (discontinuous) contact between the cable shield and the connector ground makes the connection very unstable. The fact that this damaged cable was used during all the car test sequence explains most of the problems we saw during the previous sessions of the field trial.
- During the second day of test, with the cable problem fixed, we observed that:
    - Where the signal level was such as to have the data from -87 dBm up, the MS was able to register both motionless and in movement on both the BS on North or South side.
    - All the measurement on the MS was confirmed also by the Spectrum Analyzer so where the MS did not register there was no signal on the runway.
- When high number of “HCS Fail” occurred, transits between BS and MS of some aircraft occurred and as soon as the aircraft went out of the “ideal line between BS and MS” the “HCS Fail” disappears. This behaviour is in line with radio propagation for static points in point-to-point links at 5 GHz. This shadowing effect has to be managed by proper radio and network planning for real deployment scenario.
- The unexpected and unpredictable behaviour observed in terms of CINR at point 5 cannot be explained as a failure of the AeroMACS modules because at point 8, with substantially the same conditions, the system has worked perfectly. The most likely explanation for Selex is the interference from AMT (measured in point 005 with Spectrum Analyzer) that makes the link unstable. So the AeroMACS system works correctly in the field if not shadowed by aircrafts or if proper coverage is available or if there is no interference.
- Since BS output power, and RF cables losses have been validated, the only reason that could explain the lack of signal on the airport area is the suboptimal radio coverage. From analysis and comparison of experimental data (signal levels measured on field) and radio propagation estimation, a relative small change of position (tens of meters), especially for static points, can result in 10-20 dB signal variations (which are reasonable in a system like AeroMACS) often due to obstruction of the first Fresnel Zone. This effect can be reduced by an increase of the height of the BS antenna (or of the MS antenna in case of the Aircraft).

Selex concludes that the prototype AeroMACS devices are working correctly because:

- Airbus measured the power of our TX BS at airport, and it is correct.
- On several occasions the system was registered on both BSs during car movement.
- Experiments related to data traffic occurred with positive outcomes and very low BER except in the presence of interfering signals.

Airbus was quite disappointed by the test results: On 11 tested points, the MS succeeded to register three times. The MS succeeded to register when the vehicle was moving, but at few occasions. At all other test points, when BS AeroMACS frequencies were present, the signal was too weak, or no signal was present. No logic was found with the different measured points: even when the car came closer to BS, the signal stayed too low. At points where the MS was registered, the AeroMACS link got lost after moving of some tens of meters.

- No problem was noticed on BS systems. The RF cables of BS had been replaced and checked. It was verified that the BS transmitted with enough power. The check of the SWR of the two BS antennas was positive. For Airbus, BS antennas are well oriented.
- MS antenna had been tested in anechoic chamber and no particular problem had been reported.

- On MS side, the deficiency of the cable supplied with the MS (connector failure) certainly explains the bad results obtained on the first day. On the second day, the defective cable was replaced, but the test results were not drastically better.
- Airbus is doubtful that AMT interferences could have played a big role in the tests failures: First, AMT frequency used were not overlapping AeroMACS channels even if there is no guard channel from north BS. South BS has at least one channel of guard and it did not work better. During tests, an AMT signal was measured at a low level and at only one point. It must also be noted that AMT equipped test aircraft don't generally stay long on the Airport surface. So AMT signal can be present at one moment at one place, but not all the time.
- Airbus is concerned about the fact that shadowing effects from aircraft in transit may cause disruptions of the communications. This is not a good point for AeroMACS if confirmed. But anyway, this can explain decrease of signal quality or short AeroMACS disconnections, but not the fact that the MS only registered at 3 static points.
- After these two measurement campaigns, it's difficult to conclude since there are case when the signal seems to be good enough on the spectrum analyser and there is no connection, and whereas sometimes, the signal seems to be very low and nevertheless the BS and MS succeed to connect.

8.3.2.2 T104 – Doppler & T116 – Performance at 50km/h & 90Km/h

It was planned to perform Doppler tests at different speeds on the following test area on the taxiway:

Figure 115: Vehicle tests - Measurement assessment

But because no AeroMACS RF signal was measured at the location of these tests, the Doppler tests and tests at different speeds were cancelled.

8.3.2.3 T105 - MS Ranging Time

MS Ranging Time is a dynamic time alignment process that allows the BS to receive transmitted signals from MS in an exact time slot.

Because the SNMP Object about this MS Ranging Time was not implemented in the SNMP MIB of the prototype, it was not possible to monitor this variable.

Hence, “T105 - MS Ranging Time” has not been performed.

We can only deduce one value: time between when the MS begins to scan the channels and when it is registered. On Point 8, it was observed that the MS prototype took around 28sec to complete the scanning.

8.3.2.4 T106 - RSSI & CINR measurements

RSSI & CINR values are only available for uplink from MIB with SNMP. These values were collected every 5 seconds during our tests.

The results of the RSSI & CINR measurements are presented together with the results of the RTT, Data Throughput & Data Jitter measurements in section §8.3.2.6, §8.3.2.8 & §8.3.2.9.

8.3.2.5 T107 - Geo-localization

It was verified that the GPS data logger provided valid geographical positions, with a periodicity of one second, during the tests. This test was outside the scope of the AeroMACS technical verification, but was required to be done as an element to ensure an appropriate exploitation of all data collected during the tests.

8.3.2.6 T108 - Round Trip Time

Round Trip Time was measured with a script executing PING commands: RTT values were collected with a periodicity of one second during our tests. The following graphs show the RTT versus RSSI values:

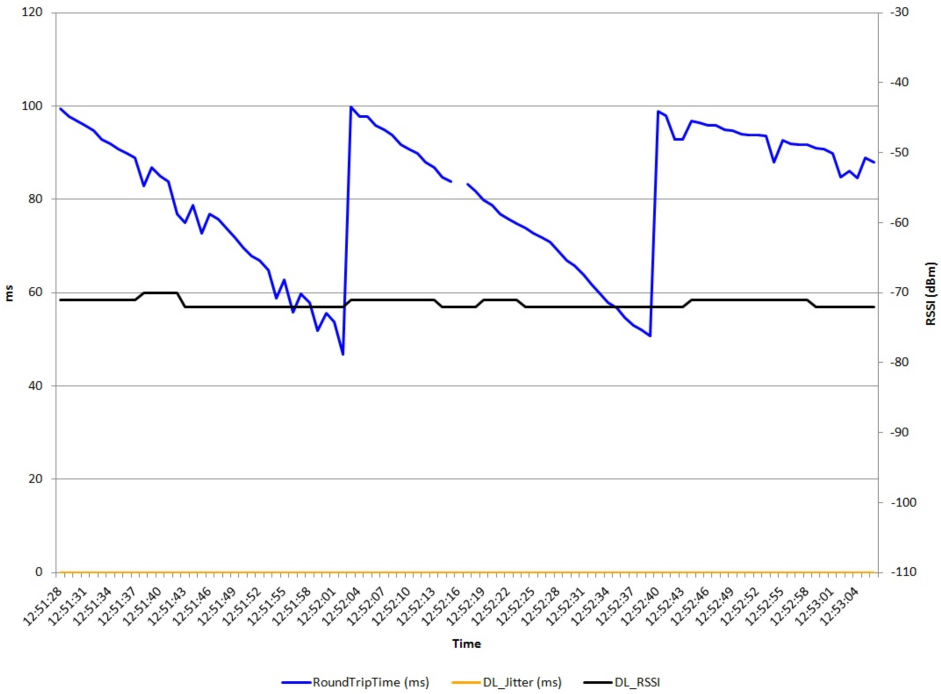


Figure 116: Vehicle tests - RTT vs. RSSI (Point 11)

At point 11, the RTT fluctuated from 46ms to 100ms and is equal in average to around 80ms. Contrarily to previous tests performed from Airbus laboratory, only one ICMP packet loss was observed.

It is interesting to note the saw-tooth patterns of the RTT variations: this is representative situations of network congestion or bad radio link. The network was not congested, however, as no other transfers were in progress during this test. And the RSSI was in average equal to -71dBm which is not at so low.

Figure 118 shows the CINR variations during the test. The CINR was stable.

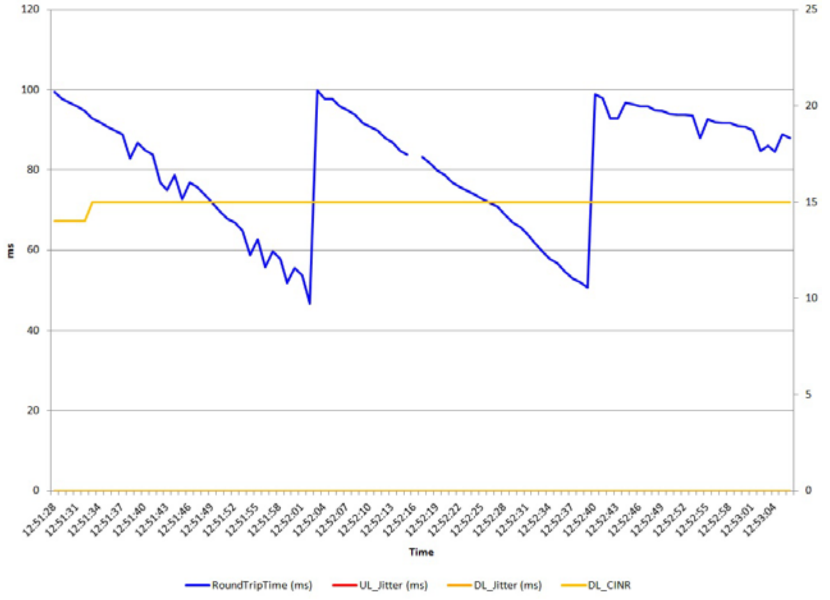


Figure 117: Vehicle tests - RTT vs. CINR (Point16)

Note: The CINR values are MS values but logged by the BS. It may be that CINR values collected in this way are smoothed and that CINR instabilities are not recorded.

The CINR value being quite stable at around 15, this cannot explain the saw-tooth curve of RTT variations.

At point 6, the link was more unstable, but it was possible to observe that RTT is around the same values as at point 11.

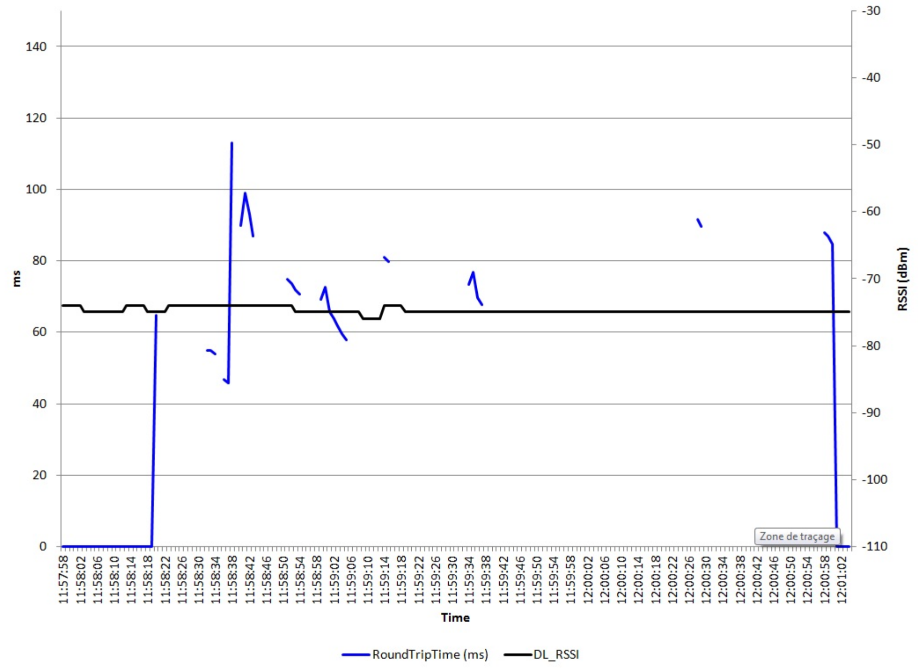


Figure 118: Vehicle tests - RTT vs. RSSI (Point6)

At point 6, the average RTT is 74ms, and the maximum is 113ms. A high ratio of ICMP packets got lost, even if RSSI stayed stable around -75dBm.

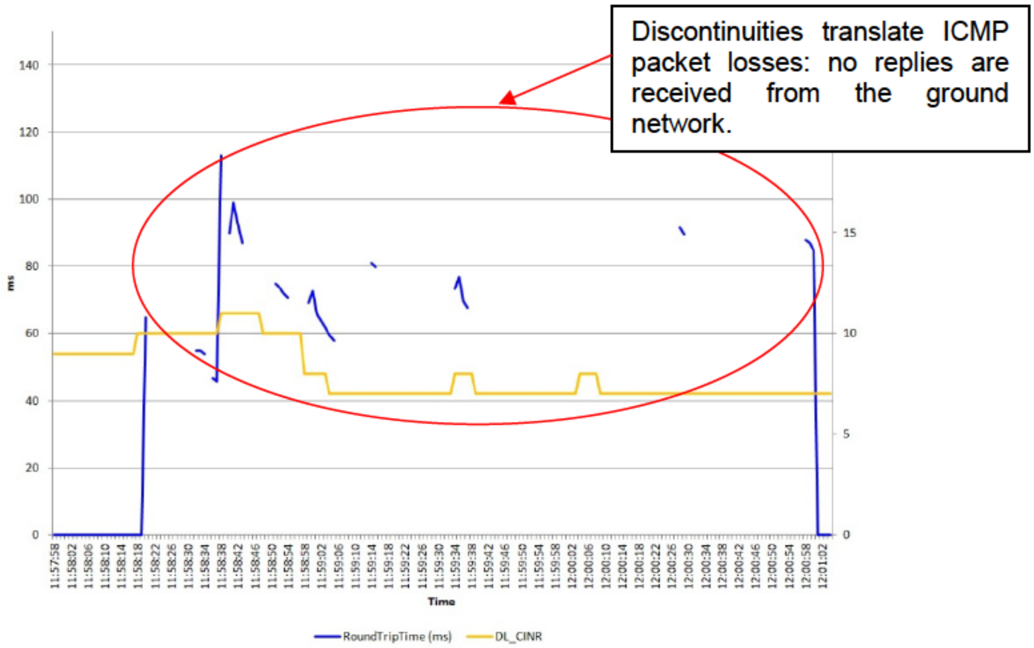


Figure 119: Vehicle tests - RTT vs. CINR (Point6)

On this point, we get lots of packet losses: at the beginning, CINR values were around 10 and several ping succeeded; when CINR decreased to 7, lots of ICMP packets were lost. With this example, we can see again that AeroMACS link directly rely on CINR and not RSSI.

- **Summary**

With vehicle tests, it was observed that RTT values are similar to those measured from Airbus laboratory (in average around 80ms with peaks of 113ms).

On point 6 which is located at 1500m far from the BS, a high packet loss rate was encountered, like this was observed with the tests made from the Airbus laboratory. On this point 6, the MS was positioned in LOS, in an open area far from any building. This eliminates the hypothesis that the Airbus laboratory highly metallic environment can be the cause of the high Packet Loss Rate.

8.3.2.7 T101 - CL power control performance

Closed Loop Power control was planned to be evaluated with measurements made at different static points. As we did not succeed to perform network performances tests at different distance from the BS, it was not possible to assess the variation of RSSI during file transfers in static and mobile contexts, and to draw interesting conclusions on the CL power control performance.

8.3.2.8 T109-T115-T103 - Static LOS – Data throughput & latency

With tests procedures T109 & T115, the available bit rate was measured with TCP traffic exchanges at static points where the MS had been successfully registered to the AeroMACS network. No mobile tests were performed.

The here-after curves show us that the RSSI stays around at the same level as observed before (i.e. -74dBm in uplink & downlink). Hence, the fluctuations of the achievable bit rate cannot be explained by RSSI variations.

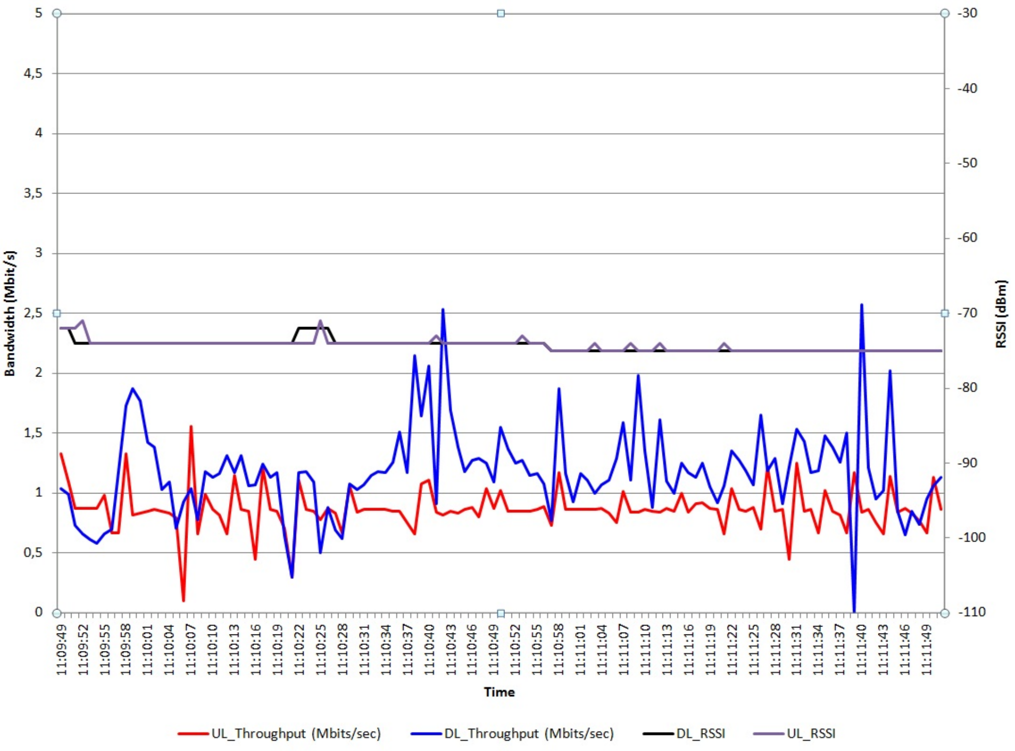


Figure 120: Vehicle tests - TCP transfer Vs RSSI at Point 8

Note: UL_RSSI came from BS logs. DL_RSSI values were logged by MS.

At point 8, the DL transfer was performed with an average throughput of 1.2Mbit/s: the throughput fluctuated from 0 to 2.6Mbit/s. In uplink, an average throughput of 870Kbit/s was observed, which is twice lower than DL: it fluctuated from 0 to 1.6Mbit/s. The TCP transfers did not get interrupted. It was the best performances observed during the whole test campaign.

Regarding the CINR, downlink CINR was in average higher than uplink (16.4 vs. 13.4). Figure 121 shows the variations of the CINR values in relation with the achieved bit rate:

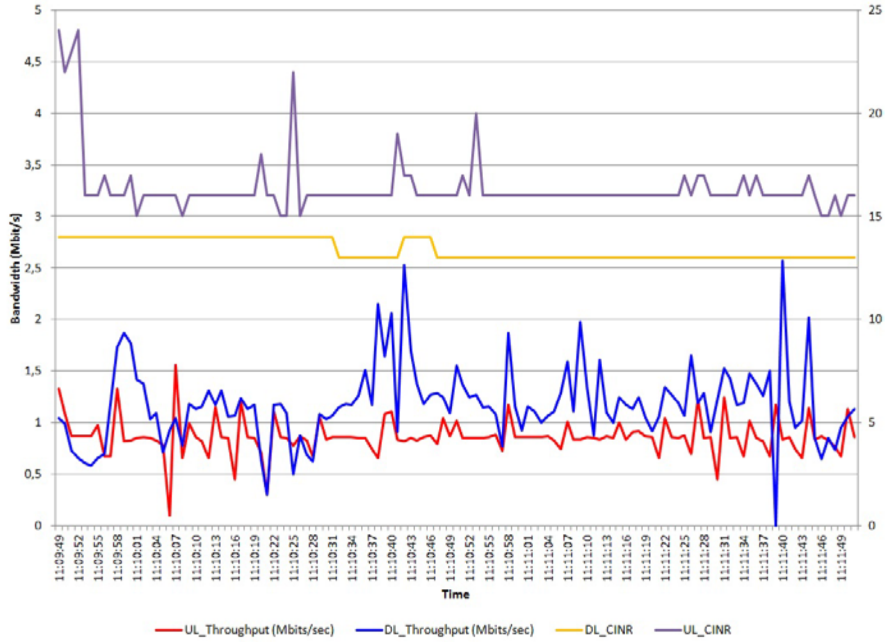


Figure 121: Vehicle tests - TCP transfer Vs CINR at Point 8

Note: UL_CINR came from BS logs. DL_CINR values were logged by MS.

Figure 122 shows the variations of the value of the FEC code (which is an indicator of the modulation used) during the data transfers.

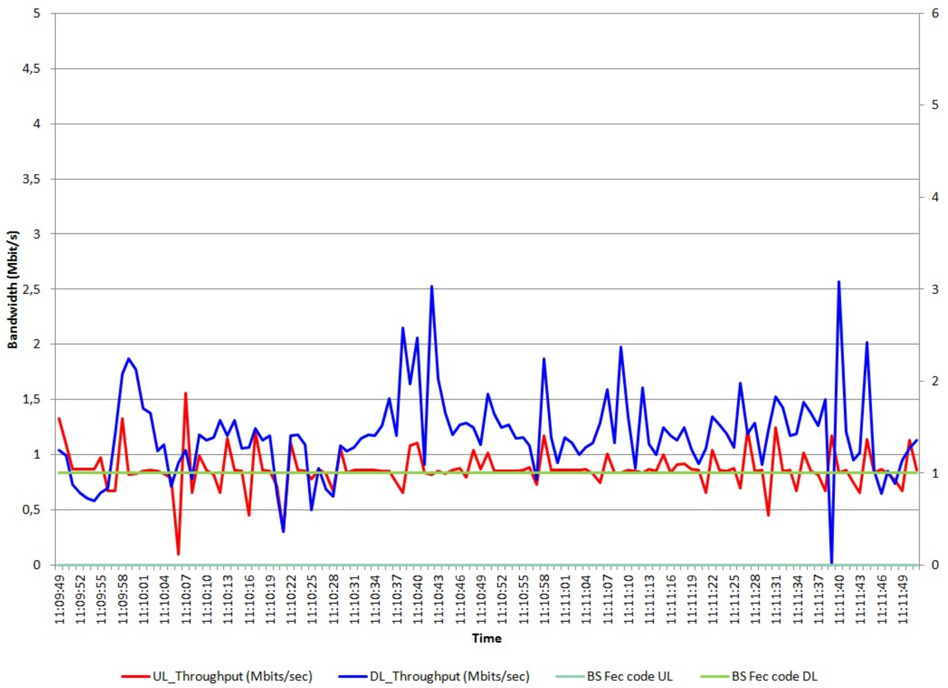


Figure 122: Vehicle tests - TCP transfer Vs FEC Code at Point 8

This shows that FEC code values stayed stable all long data transfers and that the fluctuations of the achieved bit rates cannot be explained by changes in the modulations schemes. It is noted that with a FEC code of 1 (QPSK3/4 modulation), AeroMACS can reach 2.6MBit/s in downlink; with a FEC code of 0 (QPSK1/2 modulation), 1.2Mbps can be reached in uplink.

	Throughput (Mbit/s)		MS Radio values		BS Radio values	
	UPLOAD	DOWNLOAD	RSSI(dBm)	CINR	RSSI(dBm)	CINR
Minimum	0.1	0	-75	13	-75	15
Average	0.87	1.18	-74.33	13.39	-74.30	16.38
Maximum	1.56	2.57	-72	14	-71	24

Table 19: Vehicle tests - TCP throughputs

Note: Theoretically, with an average CINR of 16.38 in uplink, MS should use 16QAM 1/2 modulation available (i.e. FEC Code 1) instead of 0. In downlink, AeroMACS should work with 16QAM 1/2 with a CINR of 13.39). Please refer to Appendix A.11 for CINR & FEC Code mapping details.

- **Summary**

At point 8, TCP transfers worked perfectly with no session interruption, and a very low Packet Loss Rate. The achieved throughputs are in accordance with what can be expected with the AeroMACS technology (i.e. in average 870Kbit/s in uplink and 1.2MBit/s in downlink). The average CINR values are similar to those measured when the MS was installed at the Airbus laboratory. But there was a better stability of the CINR, and higher CINR minimal values.

8.3.2.9 T110-T103 – Static LOS – Data Jitter

Data Jitters were measured on static point 8 during UDP data transfers.

UDP Download

It had been determined with the previous TCP traffic tests that a downlink throughput of 1200Kbit/s was achievable.

The UDP transfer was then configured with an injected target UDP traffic set to 1200Kbit/s, and the Packet Loss Rate and Jitters were measured.

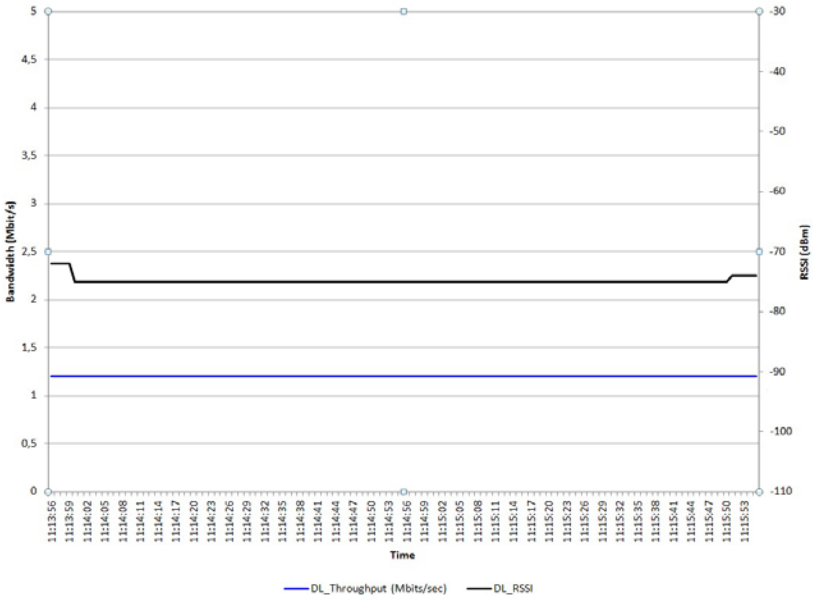


Figure 123: Vehicle tests - UDP download Vs RSSI at Point 8

The achievable throughput was stable and equal to 1200Kbit/s all along the transfer. The RSSI remained stable around -74dBm. The CINR values remained also stable around an average of 12.3.

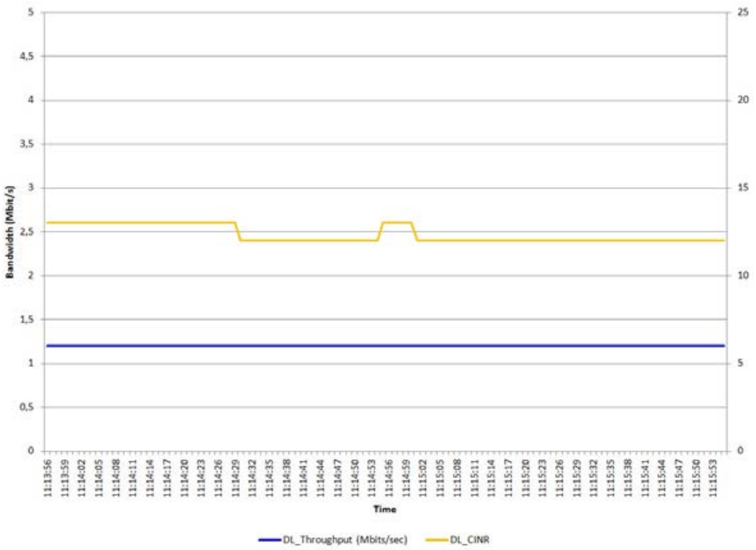


Figure 124: Vehicle tests - UDP download Vs CINR at Point 8

Note: The CINR values are MS values but logged by the BS. It may be that CINR values collected in this way are smoothed and that CINR instabilities are not recorded.

The Jitter values were stable around 2ms.

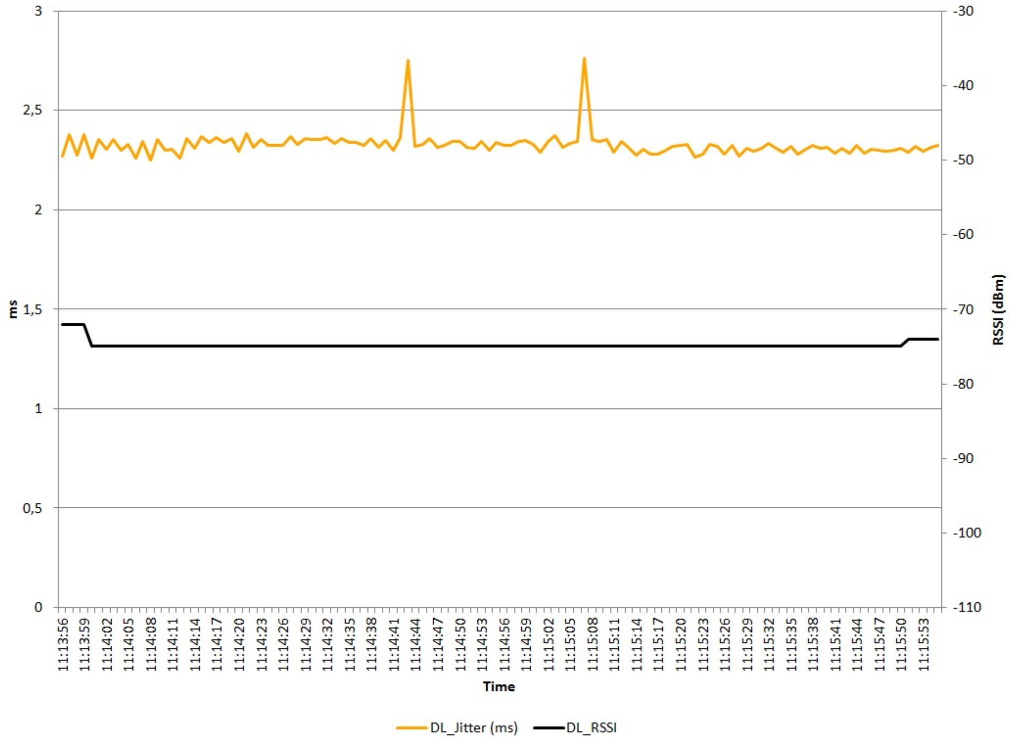


Figure 125: Vehicle tests - DL Jitter Vs CINR at Point 8

The packet loss rate was lower than 0.7%:

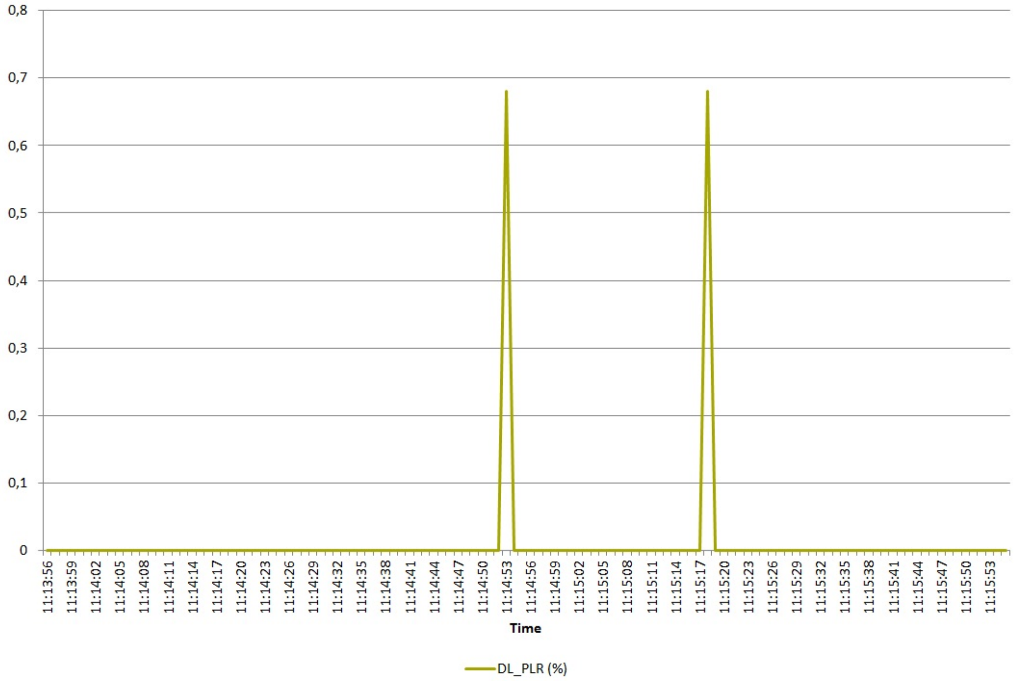


Figure 126: Vehicle tests - DL Packet Loss Rate at Point 8

FEC code remained to 1 (i.e. modulation QPSK 3/4):

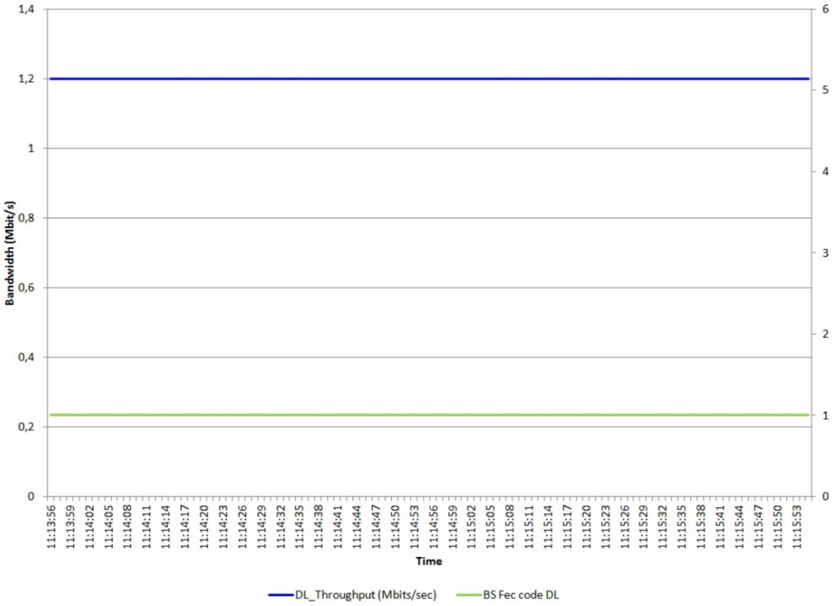


Figure 127: Vehicle tests - DL FEC Code Vs Throughput at Point 8

The next table summarizes these values:

	DOWNLOAD			MS Radio values	
	Throughput (Mbit/s)	Jitter(ms)	PLR(%)	RSSI(dBm)	CINR)
Minimum	1.2	2.25	0	-75	12
Average	1.2	2.33	0.01	-74.86	12.33
Maximum	1.2	2.76	0.68	-72	13

Table 20: Vehicle tests - UDP throughputs, packet loss rate & jitter (DL)

UDP Upload

It had been determined with the previous TCP traffic tests that an uplink throughput of 800Kbit/s was achievable.

The UDP transfer was then configured with an injected target UDP traffic set to 800Kbit/s, and the Packet Loss Rate and Jitters were measured.

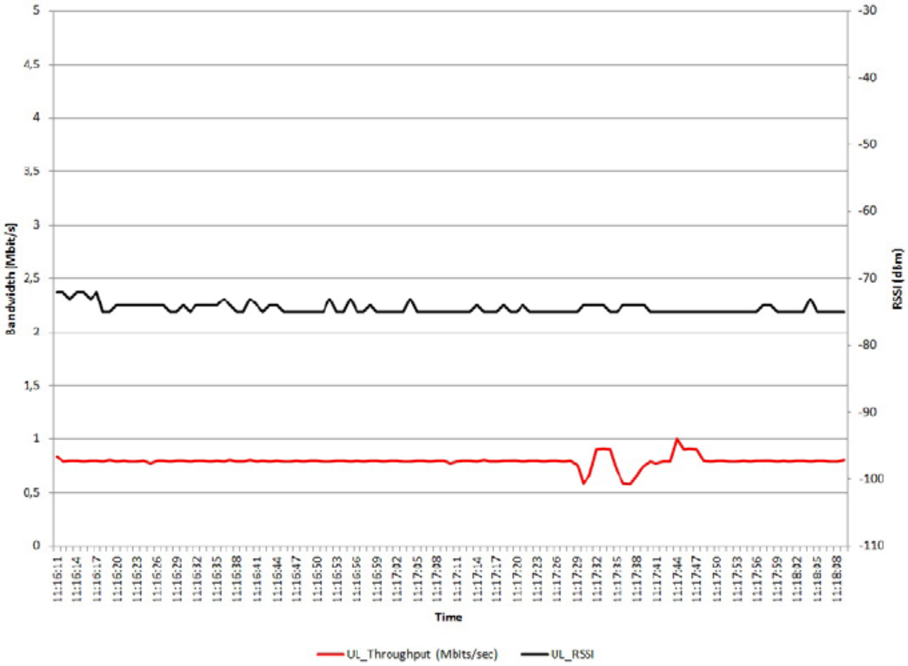


Figure 128: Vehicle tests - UDP upload Vs RSSI at Point 8

The achieved UDP throughput stayed at 800Kbit/s all along the transfer. The RSSI remained stable and around -74dBm. An oscillation of throughput was noted on the end of the transfer which is not in relation with RSSI values.

CINR values varied during UDP upload as we can see with the following figure:

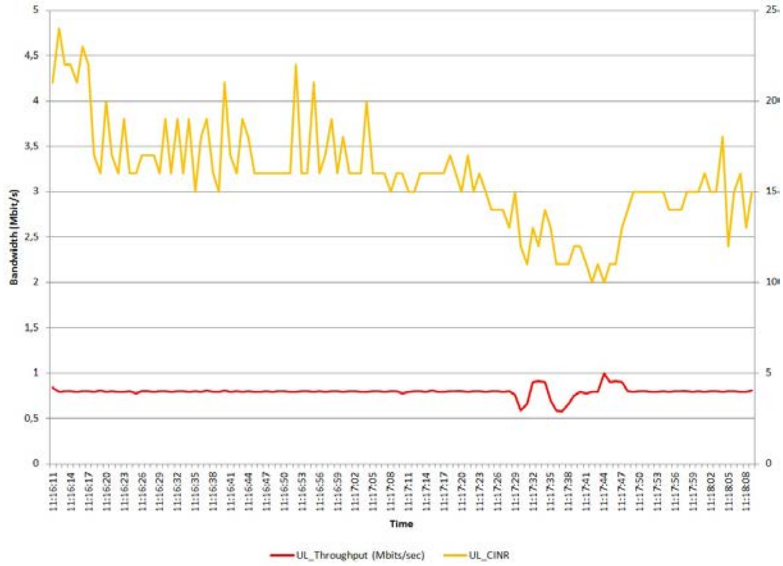


Figure 129: Vehicle tests - UDP upload Vs CINR at Point 8

When the UDP transfer oscillated, CINR was the lowest values (around 10): the quality of the link downgrades and makes decrease the data bit rates.

Jitter values stayed low (around 2ms as previously). We can note some jitter peaks when the CINR decreased.

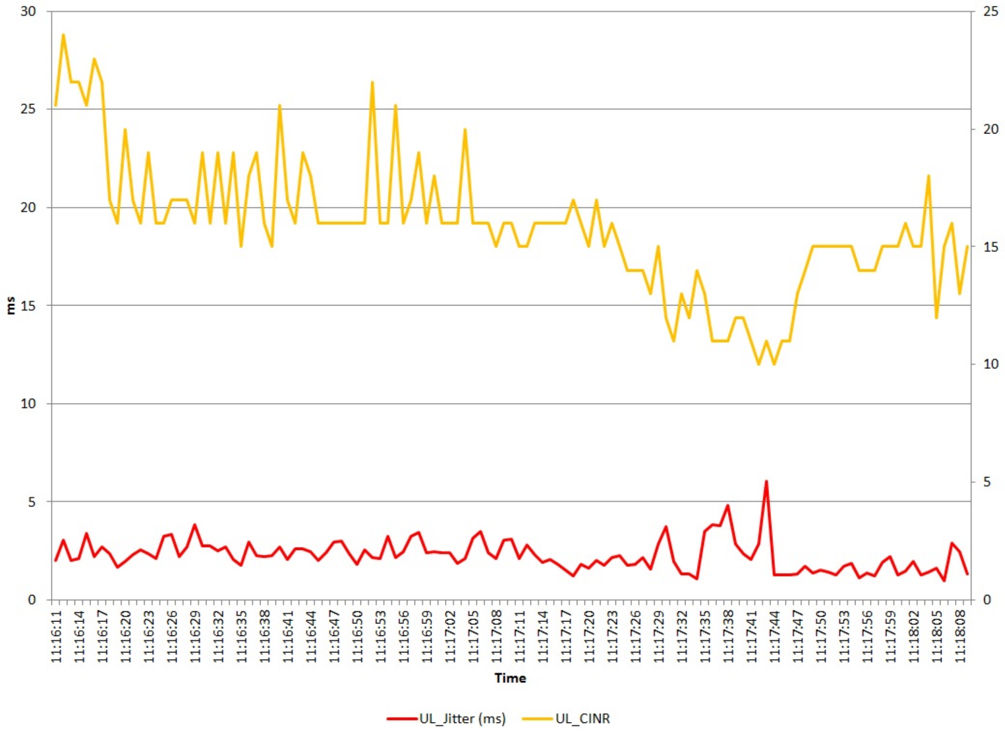


Figure 130: Vehicle tests - UL Jitter Vs CINR at Point 8

Regarding the packet loss rate, it was low and stable except over the time slot where degradation of CINR was noted, and where PLR peak of 22% was observed.

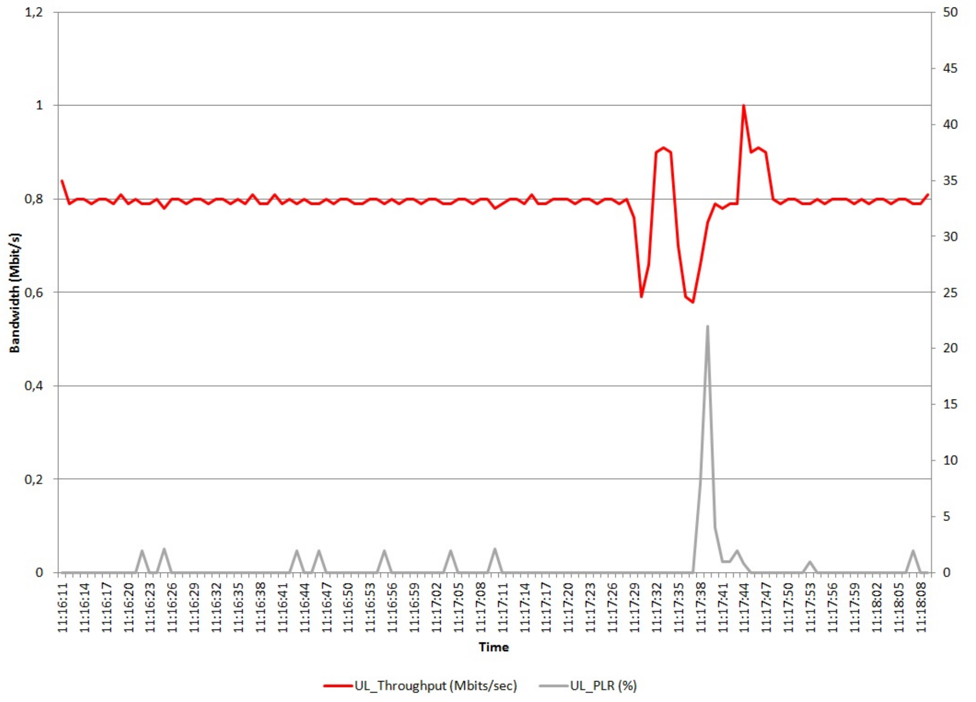


Figure 131: Vehicle tests - UL throughput Vs PLR at Point 8

UL FEC code did not change during data transfer and stayed at 0 (i.e. in QPSK 1/2 modulation) all along.

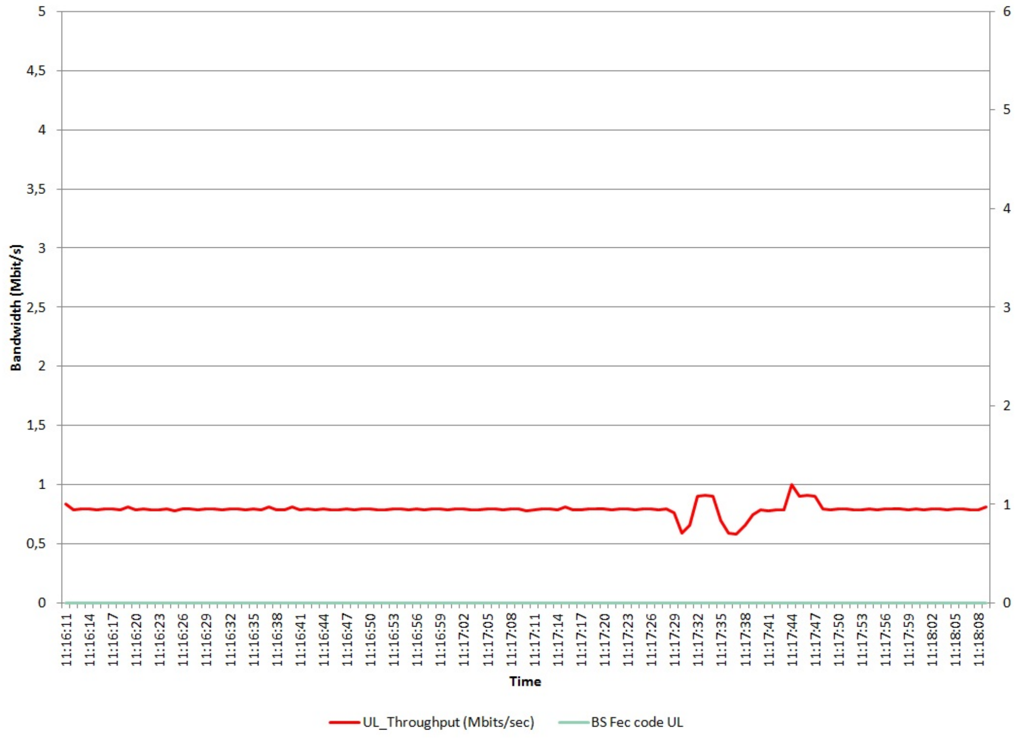


Figure 132: Vehicle tests - UL FEC Code Vs Throughput at Point 8

The following table summarizes UDP upload results:

	UPLOAD			BS radio values	
	Throughput (Mbit/s)	Jitter(ms)	PLR(%)	RSSI(dBm)	CINR)
Minimum	0.58	0.992	0	-75	10
Average	0.79	2.29	0.47	-74.48	15.83
Maximum	1	6.1	22	-72	24

Table 21: Vehicle tests - UDP throughputs, packet loss rate & jitter (UL)

Summary

At point 8, UDP transfer succeeded in download and upload with asymmetric throughput available (1.2Mbit/s during download and 790Kbit/s with upload). The packet loss rates were very low (near from 0%). The average CINR values are similar to those measured when the MS was installed at the Airbus laboratory. But there was a better stability of the CINR, and higher CINR minimal values. Measured jitter values are low.

8.3.2.10 T111- Static NLOS

Due to the difficulties encountered and the wasted time during the tests in Light of Sight, it was not possible to play the tests at static points in Non Light Of Sight (NLOS) from the BS.

8.3.2.11 T113 - Adjacent channel interference on data throughput

This test was not performed because it had been anticipated that with the mask currently implemented in the prototype, adjacent channels would have interfered on each other.

8.3.2.12 T117 – T118 - AMT influence

These tests have been performed in laboratory with an RF Generator simulating AMT emission at different channels. On the RF antenna cable of the MS, a coupler was used to interconnect the RF generator: this installation allows inserting an AMT signal on the AeroMACS RF link.

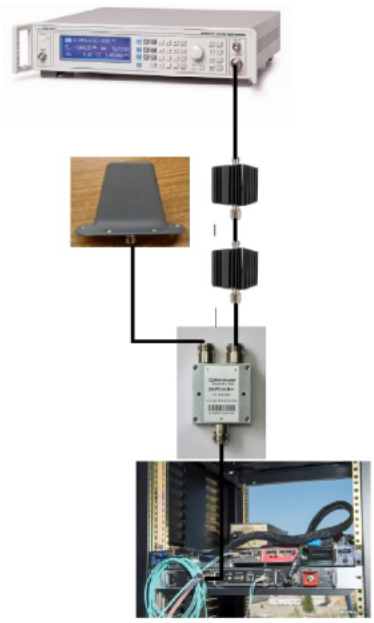


Figure 133: AMT tests – AMT RF signal generator installation

Two attenuators were also inserted in between the AMT signal generator and the coupler. The total attenuation on the AMT signal, introduced by the 2 attenuators, the couplers, and the wires, was of 42,7dB on the AeroMACS band.

The AeroMACS antenna was replaced by a horn antenna (directional antenna with a gain of 10dB – not shown on the above figure), so that to enhance the received signal and be in position to perform the tests in better conditions.

The test consisted in repeated measurements consisting of the following steps:

1. configuring an AMT channel central frequency at a given distance of the available AeroMACS channel centre frequency (5.1185Ghz)
2. While the AMT signal strength is set very low, start a long AeroMACS data transfer in between the MS and BS.
3. Increase the AMT signal until a first slight degradation on the AeroMACS data transfer (some packet losses) is observed. Record this AMT signal level at which a first interference in between AMT and AeroMACS was noted
4. Repeat the above steps after having configured another AMT channel central frequency.

The next table presents the result of these tests:

Type of measure	AMT frequency and level	AeroMACS frequency	Distance in Mhz between center channel	Guard band	Level after the coupler (MS side) (1)	Minimal distance in free space to avoid interference (2)
Same channel	5.1185Ghz / -25dBm	5.1185Ghz	0Mhz	-	-67.7dBm	107.7 dB at 5.1185Ghz →**1150m**
Adjacent channel	5.125Ghz / -18dBm	5.1185Ghz	6.5Mhz	0	-60.7dBm	100.7 dB →**500m**
Adjacent channel	5.112Ghz / -19dBm	5.1185Ghz	6.5Mhz	0	-61.7dBm	111.7dB →**1800m**
Upper minimum guard band	5.128Ghz	5.1185Ghz	9.5Mhz	3	N/A	Minimal guard band 3Mhz
Fixed guard band	5.1097Ghz / 4dBm	5.1185Ghz	9.8Mhz	2.3	-38.7dBm	78.7dB (40+38.7) →**40m**
Fixed guard band	5.11Ghz / -16dBm	5.1185Ghz	8.5Mhz	2	-58.7dBm	98.7dB →**400m**
Fixed guard band	5.111Ghz / -15dBm	5.1185Ghz	7.5Mhz	1	-57.5dBm	112.5dB →**1950m**
Fixed guard band	5.126Ghz / -16dBm	5.1185Ghz	7.5Mhz	1	-58.7dBm	98.7dB →**400m**
Fixed guard band	5.124Ghz / -28dBm	5.1185Ghz	5.5Mhz	-1	-70.7dBm	110.7dB →**1600m**

Table 22: AMT test results

Note 1: The level after the coupler (and at the input of the MS) is computed by summing the level of the AMT signal generated by the RF generator (given in column 2) with the total attenuation on the AMT signal, introduced by the 2 attenuators, the couplers, and the wires, equal to 42,7dB. For instance on the second row, 67.7dBm = 25dBm + 42,7

Note 2: The “Minimal distance in free space to avoid interference” is computed as follows.

- The power out of an AMT transmitter is $P_{out\ AMT}$ = 40dBm (10W)
- The difference in between $P_{out\ AMT}$ and the level of the interfering AMT signal at the input of the MS, is considered as the free space attenuation (without obstacle) of a true AMT signal received by the MS. It is considered that the MS antenna gain compensates the losses introduced by the wires and the connectors on Aircraft.
- From the free space attenuation, the distance of the AMT transmitter is computed using the free space attenuation formula:
    - o Attenuation = 20*LOG10((4*3,1416)/λ)+20*LOG10(Distance in meters)
    - o Which gives the distance in meters

Minimal distance in free space between an AMT emitter and AeroMACS MS is illustrated into the following graph by tracing the values from the table. The yellow area represents the cases where AMT interferes on AeroMACS. Out of the yellow area, including above a distance of separation of 1950m between the AMT transmitter and the AeroMACS receiver, no interference occurs.

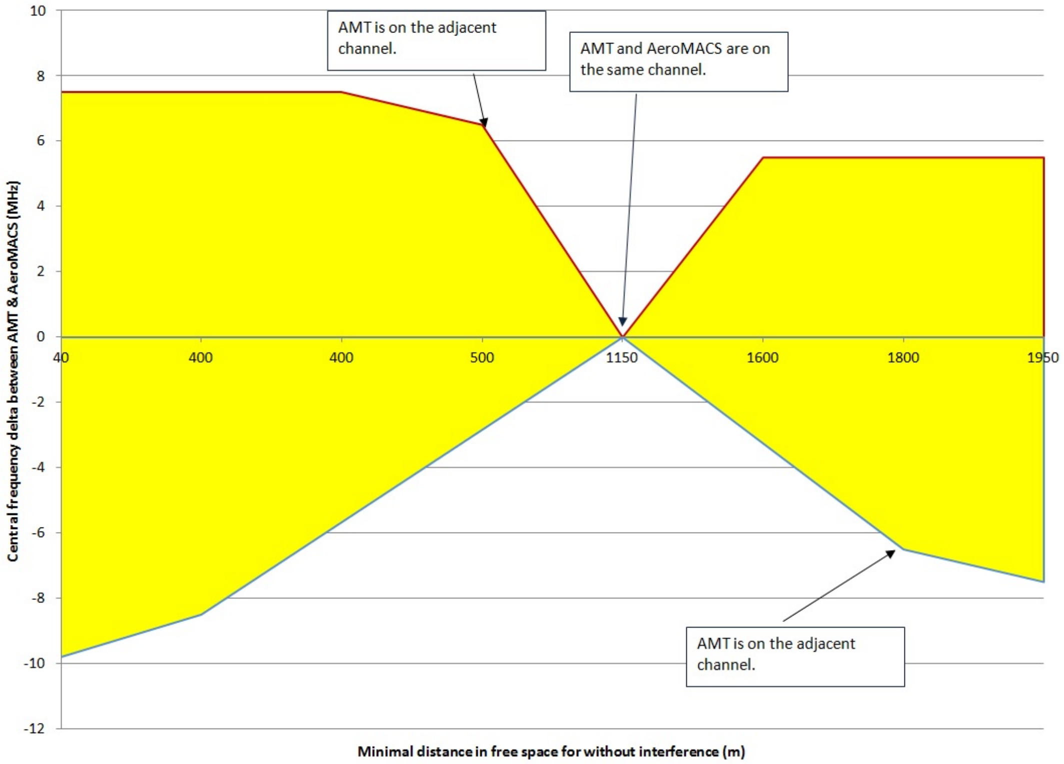


Figure 134: AMT tests – Minimal distance between AMT & AeroMACS MS emitter

From this exercise, we may draw the following interesting conclusions :

- No interference from AMT onto AeroMACS is observed, when the guard band in between the AMT channel and the AeroMACS channel is greater than or equal to 3Mhz
- No interference from AMT onto AeroMACS is observed when the distance between the AMT transmitter and the AeroMACS receiver is greater than 2Km.

From the above, it can also be concluded that:

- An AMT equipped test Aircraft, when in flight, will likely not interfere on AeroMACS communication at Airport surface.
- On the few Airports where flight test Aircraft lands, interference issues may be solved with a guard band of 3Mhz in between the AMT and AeroMACS channels.

8.3.2.13 T119 – 120 - MLS influence

Test with MLS disabled and enabled were performed with AeroMACS MS located around MLS (at a distance of several hundred meters). Because of the complexity to perform tests into operational conditions (i.e. with MS registered to AeroMACS network), AeroMACS was used on channels centered on 5108.5MHz and on 5118.5MHz on Airport platform.

Note: this is a deviation from the initially envisaged procedure which intended to test AeroMACS on the same channel as MLS and on the immediate channel next to MLS.

At point 8 and 5 situated on the following map, we did not observe any interference from the MLS signal on the AeroMACS channels used.

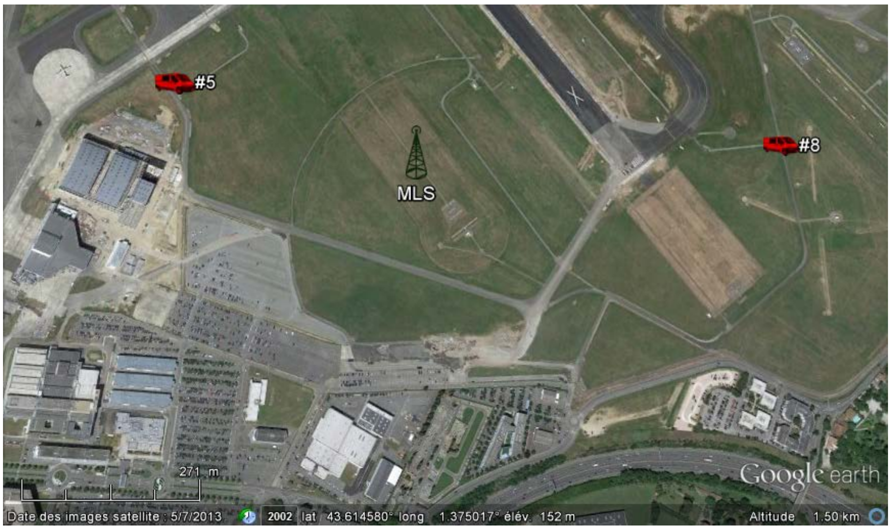


Figure 135: Vehicle tests - Tests points around MLS

At these points, data transfer was performed without any packet loss (see sections 8.3.2.8 and §8.3.2.9). During these tests, MLS system did not generate any radio interference on the AeroMACS signal.

Regarding potential interferences from AeroMACS onto MLS: during these tests, no disturbance on MLS system was noted by the MLS Airbus team.

8.3.2.14 T112 - Handover interruption time & impact on data throughput

It was initially envisaged to perform Handover tests on the taxiway in the area depicted in yellow on Figure 136: below:

Figure 136: Vehicle tests - Test area planned for hand over tests

But because no AeroMACS RF signal was measured at the location of these tests, and because of the limitation explained in 7.3.2.4 (problem with the ASN-GW that prevent to test the hand-over function with data transmission) the hand-over tests were cancelled..

8.3.2.15 T114 - Alternate channel interference on data throughput

Due to the difficulties encountered and the wasted time during other tests, it was not possible to play these tests.

8.4 Conclusions and recommendations

8.4.1 Conclusions

Before beginning official vehicle tests, Airbus with support of SELEX, ANOVO and SITA performed some preliminary tests with a vehicle rolling in the Airbus facilities, around but outside the airport and then on pathways inside the Airport platform around the runways. These preliminary tests were globally not successful: the AeroMACS signal received by the BS from the MS was generally too weak to allow MS-BS registration. Actions were taken to fix the different root causes of the problems (replacement of supplied wires used on BS side, rework of the antenna installation, and optimisation of the azimuth/down-tilt of BS antenna), which seemed effective.

The formal car tests campaign was performed on Week 42, and the results were globally disappointing: with the car moved on the Airport surface, MS-BS connectivity was established at 3 only out of the 11 tested static positions. The problems encountered are assessed to be due to a combination of problems:

- Quality of the installations. some tests failed due to the bad quality of the supplied cable connecting the MS to the Antenna.
- Potential shadowing effects of Aircraft that are rolling, taking off and landing on the airport and that can reduce the quality of the AeroMACS link
- At some occasions, potential interference from AMT that makes the link unstable
- Suboptimal radio coverage. From analysis and comparison of experimental data (signal levels measured on field) and radio propagation estimation, a relative small change of position (tens of meters), especially for static points, can result in 10-20 dB signal variations (which are reasonable in a system like AeroMACS) often due to obstruction of the first Fresnel Zone. This effect could be reduced by an increase of the height of the BS antenna (or of the MS antenna in case of the Aircraft).

Because of the difficulties encountered, it was not possible to perform all tests initially envisaged. Notably Doppler, NLOS, mobility, Hand-over and adjacent channel tests were not done. Only LOS tests were performed on and between few points where the MS was able to register to AeroMACS network. At these “good” points, where the signal level was such as to have the data from -87 dBm up, the MS was able to register both motionless and in movement (at 40Km/h) on both the BS on North or South side, .and the measured RTT, throughput, jitter, CINR/RSSI were in line with the expectations and better than the results obtained during step 2 from the Airbus laboratory (good throughput with low Packet Error Rate was achieved, allowing TCP/IP data transfers).

No interference in between MLS and AeroMACS were observed.

The level of interferences between AMT and AeroMACS was finally tested at Airbus laboratory, by using an AMT signal generator, injecting AMT signal on MS side during MS-BS AeroMACS data traffic. The observations tends to conclude that:

- No interference from AMT onto AeroMACS is observed when a guard band greater than or equal to 3Mhz exist between AMT and AeroMACS signal
- No interference is observed when the AMT transmitter (i.e. the test A/C) is at a distance greater than 2Km (even with no guard band or if AMT and AeroMACS are used on overlapping channels)

Hence, cases of interferences in between AeroMACS and Airbus AMT seem to be manageable, because in-flight AMT-equipped Aircraft should not interfere with AeroMACS communications at Airport. Interference issues may be encountered only on few French Airports where AMT-equipped Aircraft can land

8.4.2 Recommendations

Refer to section 5.2, where recommendations have been factorized.

9 STEP 4 Verification Exercises Report (tests with an Aircraft)

9.1 Verification Exercise Scope

The scope of the aircraft tests (Step 4 of the P9.16 Verification exercises) was to verify the operation of the Selex MS prototype and the performance of the AeroMACS technology in a deployed environment over the Toulouse Airport, with the MS being installed in on an aircraft moved on the Toulouse Airport surface.

The main objectives of these tests were to:

1. Evaluate the AeroMACS performances on Aircraft, when static and during movements of the Aircraft on the Airport surface, including on the taxiways and on the runways
2. Verify the correct operation of AeroMACs on Aircraft, at different speeds (Verification of Doppler compensation mechanisms)
3. Verify the non-interference between AeroMACS and other Aircraft systems and validate the position of the antenna on the Aircraft fuselage

More details are given in the Verification Plan (9.16-D06 ([6])) and in the Test procedures document (9.16-D07 ([7]))

9.2 Conduct of Verification Exercise

This verification exercise was performed in coordination with the following partners:

- SELEX provided the AeroMACS prototypes, and off-site support during the experiments, notably for trouble-shooting.
- SITA was in charge of the ground AeroMACS infrastructure deployment, and provided support during the experiments.
- Airbus was in charge of the installation of the AeroMACS prototype on Aircraft, and of the execution of the tests covering the Validation and Verification Objectives allocated to this AeroMACS verification exercise.

9.2.1 Verification Exercise Preparation

Figure 137 shows the installation of the AeroMACS prototype on the test aircraft (A320 MSN1).

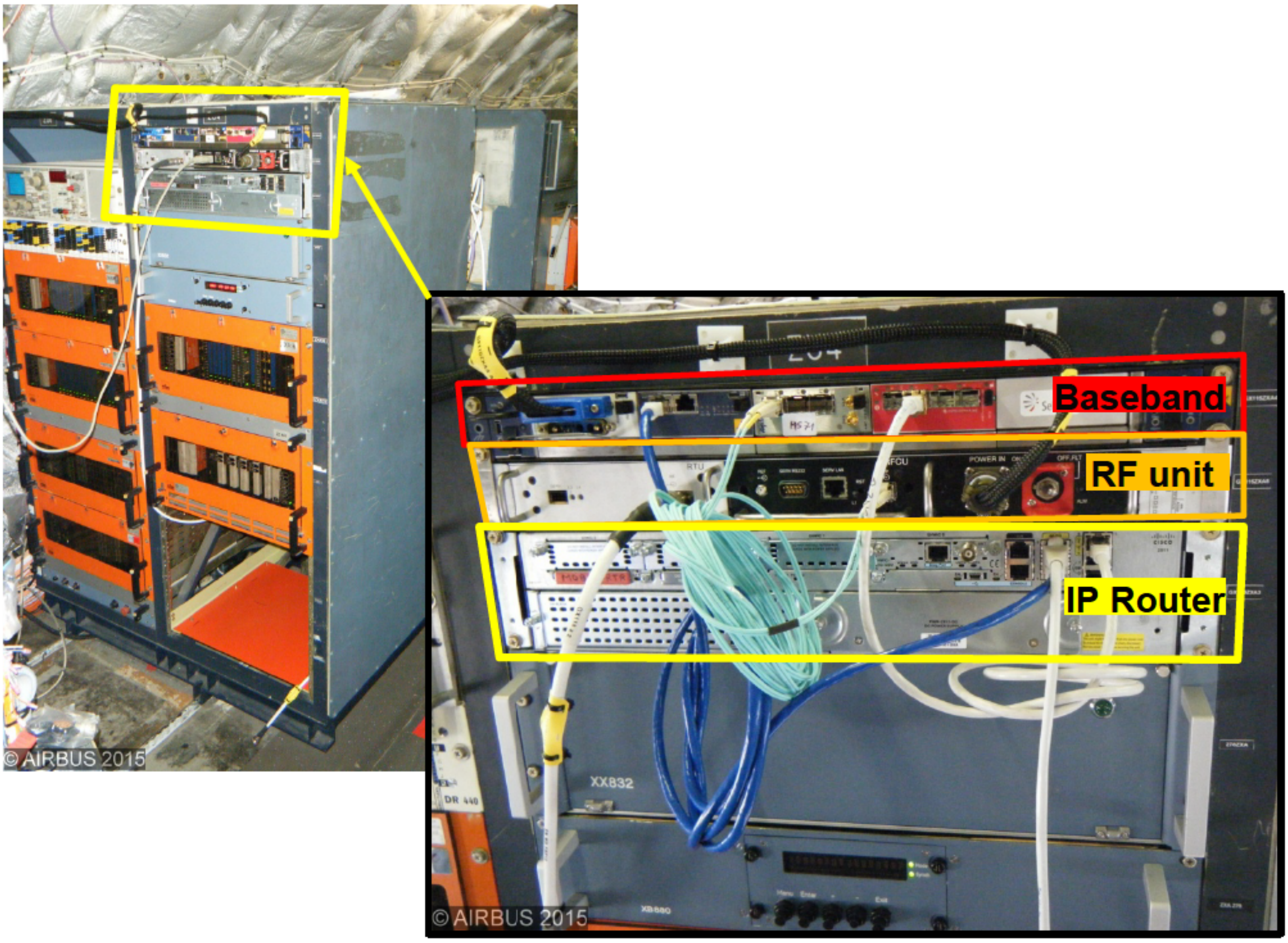


Figure 137: Aircraft installation – Rack installation of MS & IP router

The AeroMACS equipments (i.e. AeroMACS baseband and RF units, IP router) were racked into the test bay of the A230 MSN1.

The laptop used for MS logs and data transfer was installed into the cabin in front of a seat from where flight engineers perform their tests.

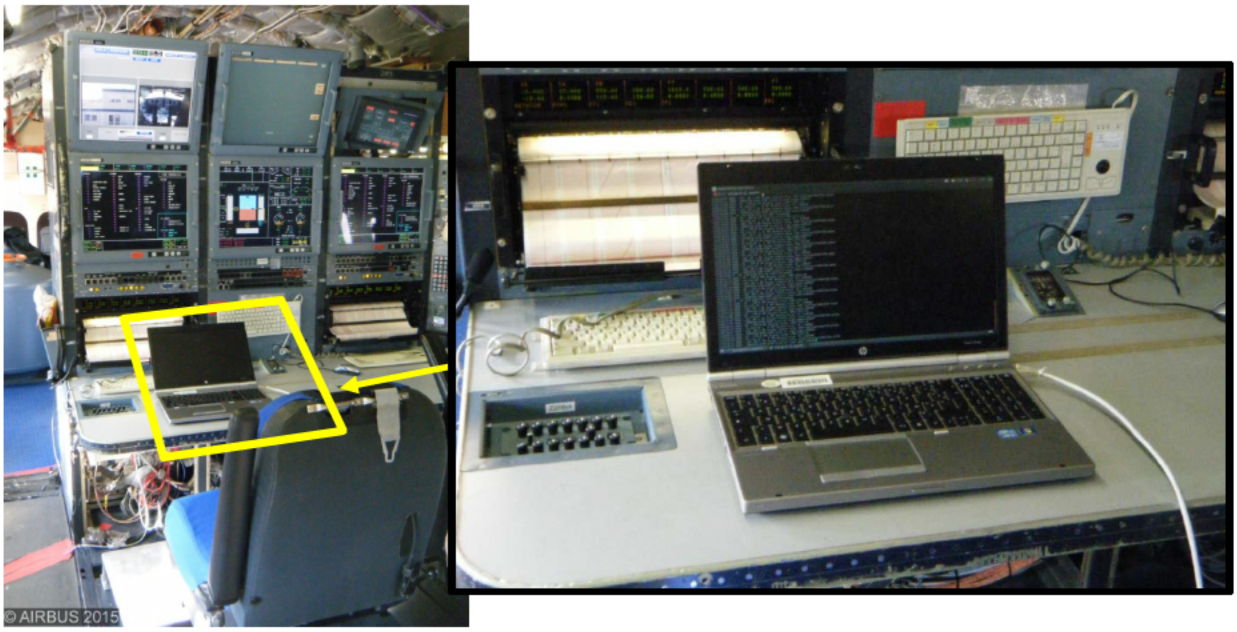


Figure 138: Aircraft installation – Laptop installation

Figure 139 shows the position of the AeroMACS antenna:

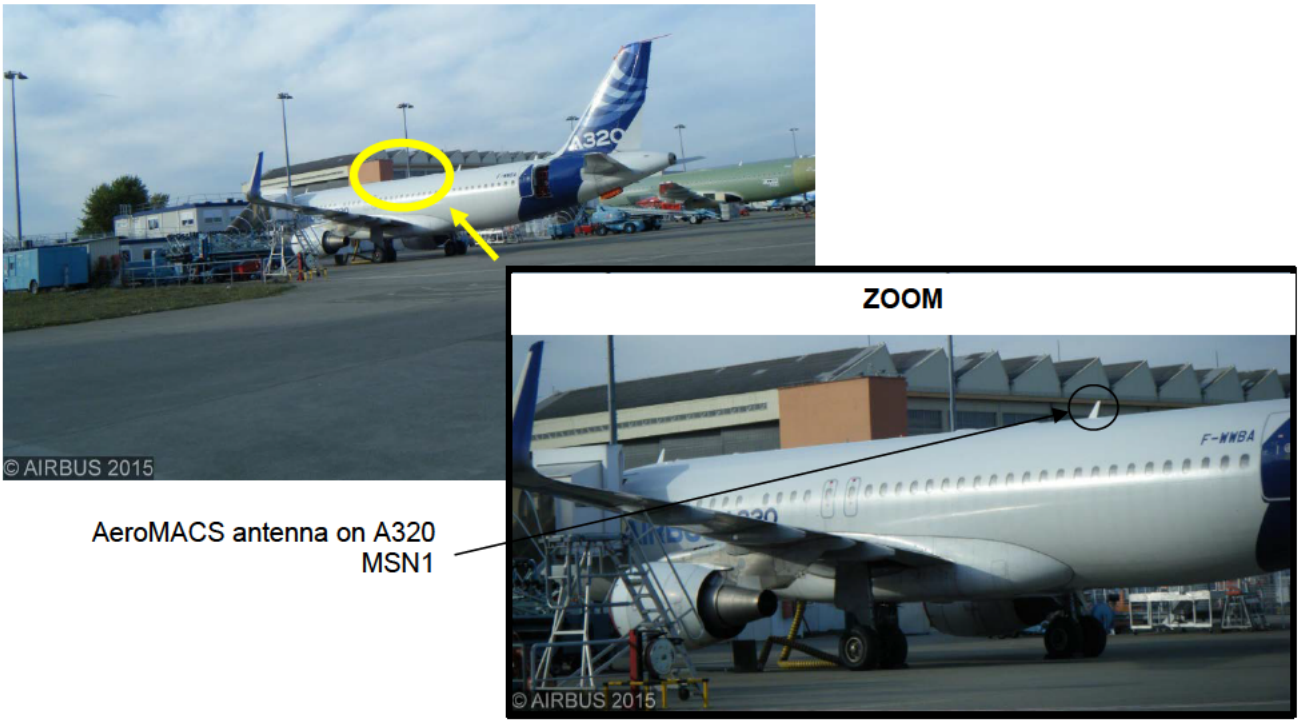


Figure 139: Aircraft installation – Antenna location

9.2.2 Verification Exercise execution

Refer to Table 1 in section 3.2 for the overall timing of Step 4 exercises.

The approach followed during execution of the Verification Exercise is described in 9.16-D07 ([7]).

9.2.3 Deviation from the planned activities

Refer to Table 2 on page 23.

9.3 Verification exercise Results

9.3.1 Summary of Verification exercise Results

Refer to Table 4 on page 26.

9.3.2 Analysis of Verification Exercise Results

9.3.2.1 T201 - MS/BS Interoperability

This test was cancelled because no information on BS signal measurements is available in the MIB of the MS.

9.3.2.2 T202 – Receiver Spurious emissions + Unwanted emissions

These tests have been performed during radio tests performed in anechoic chamber. All details about these tests are given in the attachment stored in appendix in A.6.

The following table summarizes obtained results:

Frequencies (MHz)	Max level (dBc)	Relative value from the graphic (dBm)	Test result
5111 to 5116	0	-19.5	-
5110.75 and 5116.25	-20	-30.6 => -11.2 dBc -30.2 => -10.7 dBc	NOK NOK
5106 and 5121	-40	-60.5 => -41 dBc -60.6 => -41.1 dBc	OK OK
5068.5 and 5158.5	-42	-79.1 => -59.6 dBc -79.9 => -60.4 dBc	OK OK
5059.5 and 5167.5	-47	-79.1 => -59.6 dBc -79.9 => -60.4 dBc	OK OK

Table 23: Aircraft tests – Results of the measurements within the 5GHz band

Two frequencies of unwanted spurious emission within 5GHz band are out of the limits of the transmit spectral power mask of the ETSI EN 301 893 V1.7.1 (2012-06) standard.

Out of 5091-5150MHz radio band, some other spurious signals were measured as indicated in the table below.

V POLARISATION							
Frequency to be tested (MHz)	Relative level (dBm)	Substitution measurements					
		Generator Level (dBm)	Antenna gain (dB)	Cable losses (dB)	Calculated PIRE (dBm)	Limit (dBm)	Margin (dB)
3886.5	-65.4	-14	12.3	15.8	-17.5	-30	-12.5
4913	-71.1	-19.1	12.5	17	-23.6	-30	-6.4
5310.6	-61.3	-1.2	13.1	17.6	-5.7	(1)	-
H POLARISATION							
Frequency to be tested (MHz)	Relative level (dBm)	Substitution measurements					
		Generator Level (dBm)	Antenna gain (dB)	Cable losses (dB)	Calculated PIRE (dBm)	Limit (dBm)	Margin (dB)
3886.5	-70.6	-21	12.3	15.8	-24.5	-30	-5.5
5310.6	-72.8	-15.7	13.1	17.6	-20.2	(1)	-

(1) No limit are given at this frequency in the standard.

Table 24: Aircraft tests – Results of the measurements outside the 5GHz band

Three frequencies in V polarisation and two frequencies in H polarisation are out of the limits of the ETSI EN 301 893 V1.7.1 (2012-06) standard.

9.3.2.3 T203 - Doppler

This test has not been performed because AeroMACS MS did not succeed to register to AeroMACS network (see section 9.3.2.13).

9.3.2.4 T204 – Interferences with RadioNAV

The purpose of the EMI (Electromagnetic Interference) test is to check if AEROMACS system disturbs the aircraft's navigation and communication systems (NAV/COM). Radio communication specialists performed these tests on A320 MSN1 with the AeroMACS MS. The detailed report is attached into Appendix A.5. Because no BS AeroMACS signal was available where the A320 MSN1 was parked (at position called “NAVARRE” (see 9.3.2.11)), the MS was forced in emission with the help of a special command.

The following NAV/COM systems were checked:

- VHF1, 2, 3
- ATC1, 2
- DME1, 2
- ILS1, 2 (LOC and GS, part of MMR computers)
- VOR1, 2
- MKR

9.3.2.4.1 Test Equipment

Measurements were made at the rack connectors through adaptors positioned in place of the receivers. During the VHF COM measurements, a band pass filter was inserted in the measurement path in order to avoid saturation of the spectrum analyzer’s pre-amplifier. For measurements at the NAV antennas ports no band pass filter is needed.

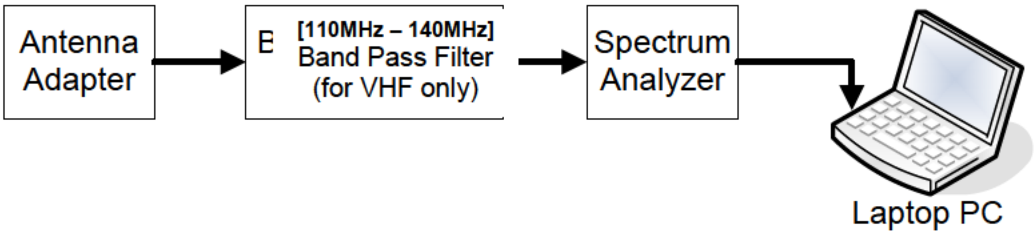


Figure 140: Aircraft tests – EMI - Test Equipment Setup

A personal computer was used for data recording, processing and storing. The EMI measurement software also configures the spectrum analyzer automatically according to the parameters selected by the user.

Figure 141: Aircraft tests – EMI - Spectrum Analyzer and PC (example)

The following table shows the equipment used during the EMI test:

System	Model	S/N	Vendor
Spectrum Analyzer	E4407B	US39440715	Agilent
VHF-Filter	WHLJS115C9/40+140-10EE	1	Wainwright
Signal generator	SML01	106334	Rohde & Schwarz
PC	Toughbook CF-31	1JTCA22518	Panasonic
Software	AMANDA 2.1	n/a	Airbus Deutschland

9.3.2.4.2 Equipment Settings

The settings of the equipment are different for the various NAV/COM systems. The VHF systems were tested twice in order to evaluate the EMI on both 25 kHz and 8.33 kHz channels. To achieve the appropriate resolution of the measured frequency spectra the RBW was set to 10 kHz and 30 kHz on the spectrum analyzer. The parameter values are given in the following table:

NAV/COM System	Start frequency of the scanned frequency range	End of the frequency range to be scanned	Resolution Bandwidth of the spectrum analyzer	Video Bandwidth of the analyzer	Assessed threshold of the NAV/COM system's sensitivity	Preamp. of spectrum analyzer
	f_S /MHz	f_E / MHz	RBW /kHz	VBW /kHz	Thresh. /dBm	ON/OFF
VHF 25kHz	117	137	30	3	-110	ON
VHF 8.33kHz	117	137	10	1	-113	ON
LOC	108	112	10	1	-110	ON
GS	329	335	30	3	-110	ON
DME	962	1213	300	30	-95	ON
VOR	108	118	30	3	-110	ON
MKR	74	76	10	1	-80	ON
ATC-L	1025	1035	30	3	-90	ON
ATC-H	1085	1095	30	3	-90	ON

9.3.2.4.3 Tests results summary

See below the summarized test results for each NAV/COM system.

VHF Communication

Operating frequency range	118-137 MHz
Suspicious signal from AeroMACS	Yes
Interaction test performed	Yes
Result of test	No interference found

Note: The interaction test between AeroMACS *and VHF3 showed neither hangs, breaks nor background noise.*

ATC

Operating frequency range	1030 MHz; 1090MHz

	(two fixed frequencies)
Suspicious signal from AeroMACS	none
Interaction test performed	no
Result of test	No indication for EMI found No further tests needed

DME

Operating frequency range	962 - 1213MHz (two fixed frequencies)
Suspicious signal from AeroMACS	none
Interaction test performed	no
Result of test	No indication for EMI found No further tests needed

MMR

Glideslope

Operating frequency range	328,6 – 335,4 MHz
Suspicious signal from AeroMACS	none
Interaction test performed	no
Result of test	No indication for EMI found No further tests needed

Localizer

Operating frequency range	108 – 112 MHz
Suspicious signal from AeroMACS	none
Interaction test performed	no
Result of test	No indication for EMI found No further tests needed

VOR

Operating frequency range	108-118 MHz
Suspicious signal from AeroMACS	none
Interaction test performed	no
Result of test	No indication for EMI found No further tests needed

Marker

Operating frequency range	75 MHz (fixed frequency)
Suspicious signal from AeroMACS	none
Interaction test performed	no
Result of test	No indication for EMI found No further tests needed

9.3.2.4.4 Summary

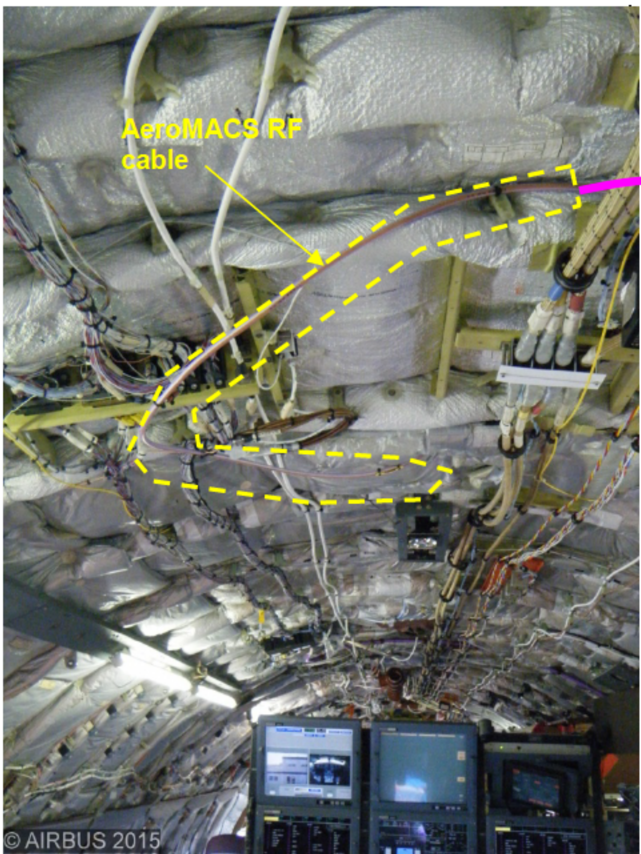
No interference was found between AeroMACS and VHF, ATC, DME, MMR, Localizer, VOR and Marker systems. Test with Radio Altitude was not possible because it is inactive on ground. It was impossible to perform test with GPS because antenna connector was not accessible on A320 MSN1. A320 MSN1 is not equipped with INMARSAT, IRRIDIUM, TWLU/WACS, and CWLU.

9.3.2.5 T207 – RF cable installation

The AeroMACS antenna installation and connection to the AeroMACS unit complied with 3dB losses requirements and taking into account the installation rules defined in WP9.16-D02.

Following photos illustrates the RF cable installation:

Figure 142: Aircraft tests – T207 – RF cable passing through fuselage to antenna



RF cable is linked to a coupler.

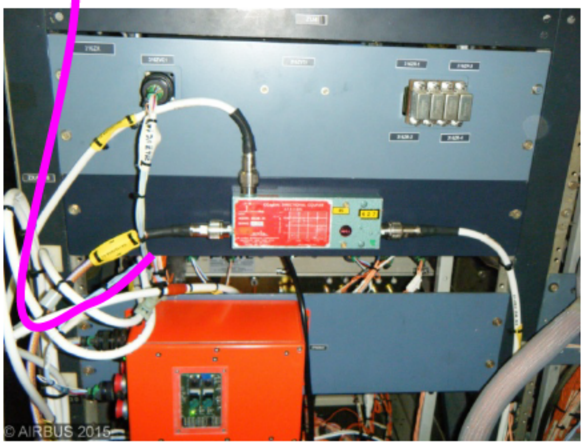


Figure 143: Aircraft tests – T207 – RF cable into cabin

Figure 144: Aircraft tests – T207 – RF cable linked to AeroMACS MS & SA via coupler.

9.3.2.6 T208 – Antenna space isolation specially in C-Band & T209 – Antenna space isolation

Decoupling between the AeroMACS antenna and the other tested systems antenna (ATC1&2, DME1&2, GLIDE1&2, LOC1&2, MKR, VHF1&2&3, VOR1&2) was verified to be more than 40 dB (See Appendix A.7 for more details about this measurement). The SWR measured at the AeroMACS cable access was inferior to 1.5 which is consistent with the specification.

This measure confirmed that the isolation space between the AeroMACS MS antenna and other A/C systems operating in C-Band is more than 40dB. Moreover, the space isolation between AeroMACS antenna and other aircraft systems is better than 20dB. These results are consistent with the specification.

9.3.2.7 T205 – OnGround Power–on + In Flight Inhibition

Using the RF unit On/Off switch it is possible to simulate the “On Ground” and “In Flight” Aircraft condition, and obtain respectively activation or inhibition of the AeroMACS RF signal transmission.

Using the RF unit On/Off switch it has been successfully verified that the MS prototype stops any RF transmission when the switch is set on the “Off/In Flight” position and that RF transmissions are enabled when the switch is set on the “On/On Ground” position.

Although, the use of a switch button is not a suitable interface to be used for interconnection with real Aircraft systems, it is sufficiently representative of the typical Aircraft discrete interfaces used to propagate the ‘in flight/on ground” Aircraft conditions, to conclude that it has been verified that the requirement for “In flight inhibition” and “On ground activation” of AeroMACS is achievable on Aircraft

9.3.2.8 T206 – Antenna accommodation

Airbus installed the antenna according to the rules defined in the document WP9.16-D02.

The MS antenna installed on A320 is the same used since the beginning of the experimentation.

Figure 145: Aircraft installation – Antenna installation on A320 fuselage

9.3.2.9 T210 – RSSI & CINR records

RSSI & CINR values are only available for uplink from MIB with SNMP. These values were collected every 5 seconds during our tests.

Here-after, is written an extract of SNMP MS logs:

```
time=2014-11-04 15:17:33
Interrogation des objets MIBsRSSI= iso.3.6.1.2.1.10.184.1.2.1.2.1.8.1.0 = INTEGER: -
72
CINR= iso.3.6.1.2.1.10.184.1.2.1.2.1.6.1.0 = Gauge32: 15
time=2014-11-04 15:17:38
Interrogation des objets MIBsRSSI= iso.3.6.1.2.1.10.184.1.2.1.2.1.8.1.0 = INTEGER: -
72
CINR= iso.3.6.1.2.1.10.184.1.2.1.2.1.6.1.0 = Gauge32: 14
time=2014-11-04 15:17:43
Interrogation des objets MIBsRSSI= iso.3.6.1.2.1.10.184.1.2.1.2.1.8.1.0 = INTEGER: -
71
CINR= iso.3.6.1.2.1.10.184.1.2.1.2.1.6.1.0 = Gauge32: 14
time=2014-11-04 15:17:48
Interrogation des objets MIBsRSSI= iso.3.6.1.2.1.10.184.1.2.1.2.1.8.1.0 = INTEGER: -
71
CINR= iso.3.6.1.2.1.10.184.1.2.1.2.1.6.1.0 = Gauge32: 18
time=2014-11-04 15:17:54
Interrogation des objets MIBsRSSI= iso.3.6.1.2.1.10.184.1.2.1.2.1.8.1.0 = INTEGER: -
72
CINR= iso.3.6.1.2.1.10.184.1.2.1.2.1.6.1.0 = Gauge32: 14
```

The results of the RSSI & CINR measurements are presented together with the results of the RTT, Data Throughput & Data Jitter measurements in section §9.3.2.12, §9.3.2.13 and 9.3.2.14.

9.3.2.10 T211 - Geo-localization

It was verified that the GPS systems provided valid geographical positions, with a periodicity of one second, during the tests. This test was outside the scope of the AeroMACS technical verification, but was required to be done as an element to ensure an appropriate exploitation of all data collected during the tests.

Note: When the A320 MSN1 was parked, the GPS position was determined with a GPS data logger. When the A320 MSN1 moved, the Aircraft GPS was used: the different positions were logged by the Aircraft recorder system which is used by the Airbus flight test team.

9.3.2.11 T215 - NLOS Static test

On Airbus site, the only place where the A320 MSN1 could be parked was the position named “NAVARRE” which is geo-localized here-after:

Figure 146: Aircraft tests – NLOS Static test point

The distance separating the MS from BS was around 2.12Km. Moreover, there is building building with a height of 2 floors and other aircrafts on the path.

Figure 147: Aircraft tests – NLOS Static test point (zoom)

No signal from BS1 (5118.5MHz) was measured at NAVARRE point. A low signal from BS2 was received (seen on the spectrum analyser).

The signal was too weak for the MS to establish a connection with the BS, and it was hence not possible to perform data transfer and evaluate RTT, maximum throughput available, jitter and packet loss rates at this NLOS static point.

9.3.2.12 T212 - Round Trip Time

9.3.2.12.1 static tests

This test has not been performed because the AeroMACS MS did not succeed to register to AeroMACS network (Cf. 9.3.2.13).

9.3.2.12.2 Mobile tests

This test has not been performed because the AeroMACS MS did not succeed to register to AeroMACS network (Cf. 9.3.2.13).

9.3.2.13 T218 – T213 – Static LOS - Data throughput & latency

During A/C roll we performed AeroMACS static tests at two points without success: the MS did not register to any BS at neither of these two points, nor while the aircraft was moved in between these two points.

Because the connectivity could not be established, the test session was cancelled. It was not possible and worthless to perform performance and mobility tests on the taxiways and runways in these conditions.

Figure 148: Aircraft tests – LOS Static test points

The following table summarized the results obtained at each point.

Measure point	AeroMACS frequency	Distance from BS	Level measured with SA	MS RSSI	MS CINR	Comments
Compensation Area	5.1085GHz	1500m	-80dBm	-71dBm	14	
	5.1185GHz		-100dBm	N/A	N/A	No signal received from North BS.
Bikini	5.1085GHz	1300m	-95dBm	N/A	N/A	Signal disturbed by multipath effect.
	5.1185GHz		-107dBm	N/A	N/A	

- At the compensation area, only the South BS frequency was received on Spectrum analyzer (around -80dBm at 5108.5MHz).

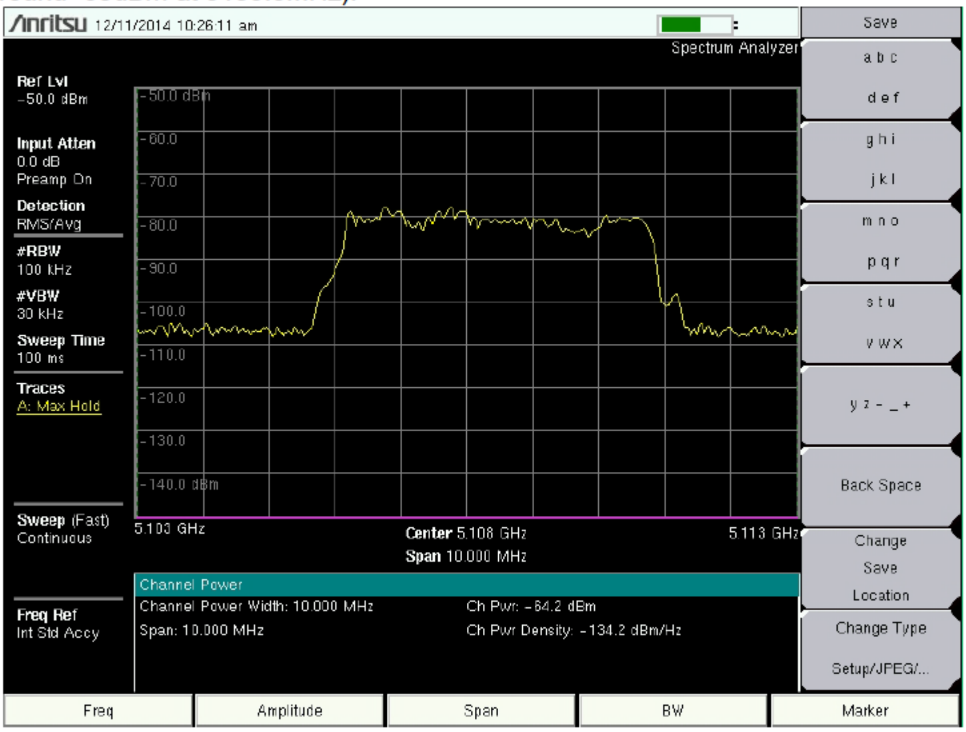


Figure 149: Aircraft tests – LOS Static test point at compensation area (5108.5MHz)

MS succeeded to begin the synchronization with South BS. It tried several synchronization phases but without success.

Lots of HCS ERROR FAIL messages were logged by the South BS. Before these errors, in the MS and BS logs, the average RSSI was around -80dBm and the CINR at 15 in UL. In DL, the RSSI was equal to -71dBm and the CINR around 11, which are good values. The RSSI was quite stable whereas the CINR fluctuated a lot:

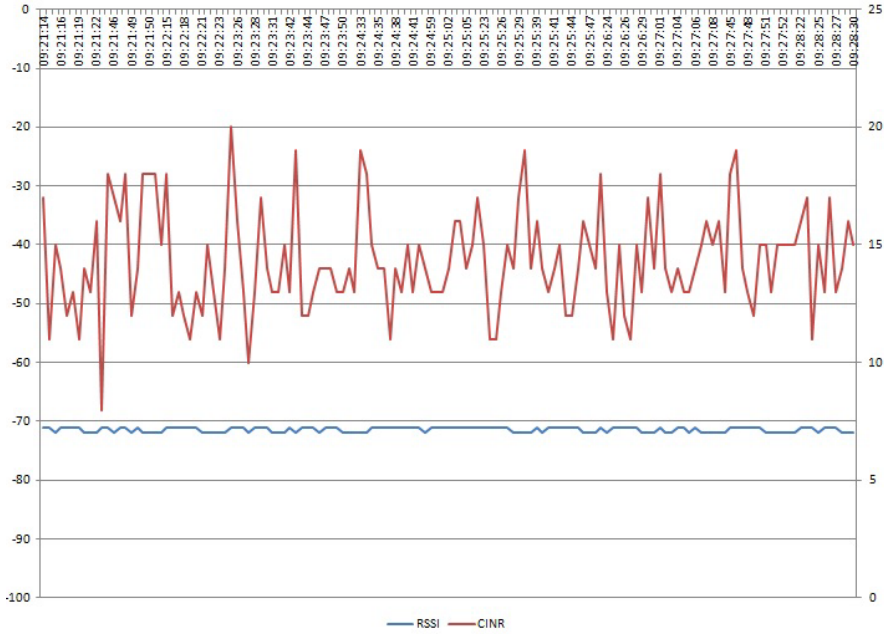


Figure 150: Aircraft tests – Compensation Area – RSSI/CINR

- At Bikini, the two frequencies were measured on AeroMACS antenna with the spectrum analyzer.

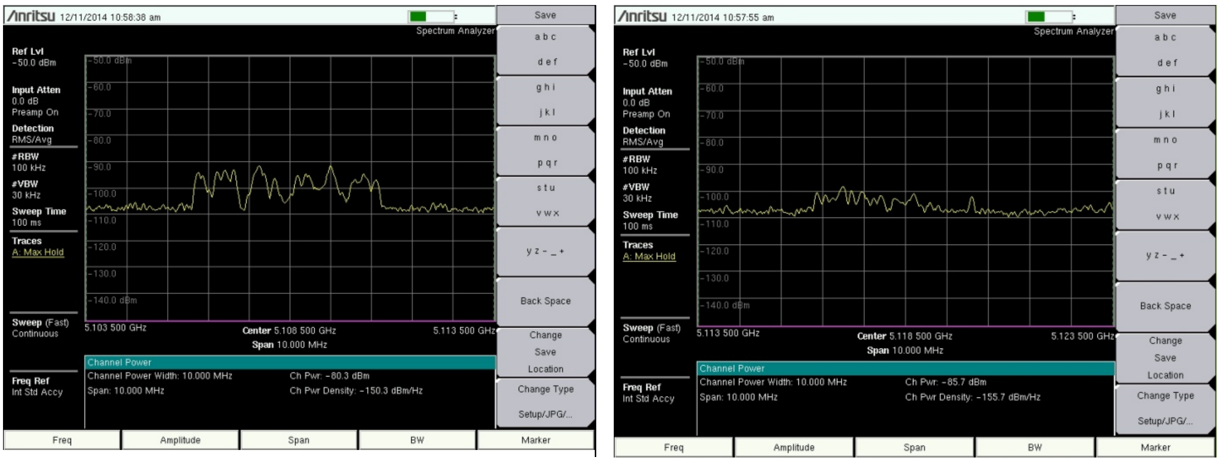


Figure 151: Aircraft tests – LOS Static test point at compensation area (5108.5MHz on left and 5118.5MHz on right)

The received level of North BS (5118.5MHz) was weaker than South (5108.5MHz). The two signals were disturbed by multipath effects induced by bikini walls.

9.3.2.14 T214 – Static LOS - Data jitter

This test has not been performed because the AeroMACS MS did not succeed to register to AeroMACS network (Cf. 9.3.2.13).

9.3.2.15 T216 - Handover interruption time & Impact of Throughput

It was initially planned to perform Handover tests on the runway in the area depicted on yellow on Figure 152 below:

Figure 152 : Aircraft tests - Test area planned for hand over tests

But because of the limitation explained in §8.3.2.14 (problem with the ASN-GW that prevent to test the handover function with data transmission), and because the AeroMACS MS did not succeed to register to AeroMACS network, the handover tests were cancelled.

9.3.2.16 T217 - RSSI measurement below the A/C and onboard

It was planned to perform this test when the A320 MSN1 was parked at the following place:

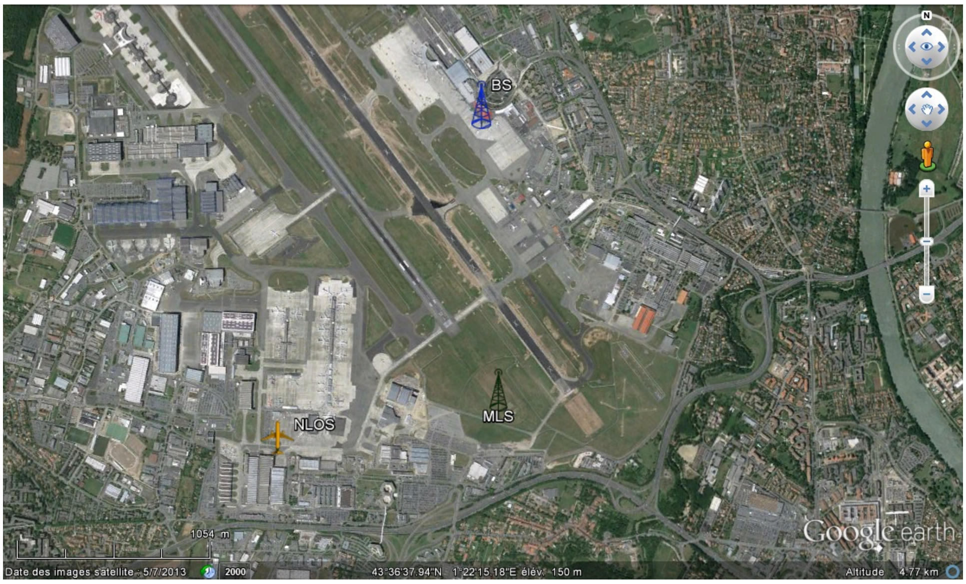


Figure 153: Aircraft tests – RSSI measurement place

As written in §9.3.2.11 T215 - NLOS Static test, no AeroMACS signal was available. RSSI levels could not be measured inside and below the A320 MSN1.

9.3.2.17 T219 – T213 – Performance at 50Km/h & 90Km/h

These tests have not been performed because the AeroMACS MS did not succeed to register to AeroMACS network (Cf. 9.3.2.13).

9.4 Conclusions and recommendations

9.4.1 Conclusions

The AeroMACS system (including the MS, the AeroMACS antenna, the wiring, the IP router and the surrounding test equipment) has been installed on an Airbus A320 test Aircraft.

Electromagnetic Interference tests have been done on Aircraft to check if the AeroMACS system disturbs the aircraft's navigation and communication systems. The MS was forced in emission with a special mode command. No interference has been detected between AeroMACS and VHF, ATC, DME, MMR, Localizer, VOR and Marker systems. Test with Radio Altitude was not possible because it is inactive on ground. It was impossible to perform test with GPS because antenna connector was not accessible on A320 MSN1..

The tests with Aircraft movement have been cancelled because the MS did not succeed to register with the BS at and between points close to the taxiways and runways. The AeroMACS signal was measured by spectrum analyser and was too weak for the MS. Unfortunately, this confirmed the poor BS coverage on the Toulouse Airport surface already observed during the car tests.

Influence of A/C radio systems on AeroMACS was also not verified because AeroMACS data link was needed to perform data transfer and see the influence of A/C radio systems.

9.4.2 Recommendations

Refer to section 5.2, where recommendations have been factorized.

10 References

10.1 Applicable Documents

[1] Template Toolbox 03.00.00 https://extranet.sesarju.eu/Programme%20Library/SESAR%20Template%20Toolbox.dot

[2] Requirements and V&V Guidelines 03.00.00 https://extranet.sesarju.eu/Programme%20Library/Requirements%20and%20VV%20Guidelines.doc

[3] Templates and Toolbox User Manual 03.00.00 https://extranet.sesarju.eu/Programme%20Library/Templates%20and%20Toolbox%20User%20Manual.doc

[4] European Operational Concept Validation Methodology (E-OCVM) - 3.0 [February 2010]

[5] EUROCONTROL ATM Lexicon https://extranet.eurocontrol.int/http://atmlexicon.eurocontrol.int/en/index.php/SESAR

10.2 Reference Documents

The following documents provide input/guidance/further information/other:

[6] SESAR 9.16-D06 “Airborne AeroMACS test strategy - objectives and test beds architecture - 00-01-01” https://extranet.sesarju.eu/WP_09/Project_09.16/Project%20Plan/9.16%20T06%20-%20WA3%20-%20Test%20Plan%20definition%20-%20aircraft%20side%20-%20objectives%20-%20strategy%20-%20and%20test%20bed%20architecture/9.16-D06-Airborne%20AeroMACS%20test%20strategy%20-%20objectives%20and%20test%20beds%20architecture.pdf

[7] SESAR 9.16-D07 “9.16-D07-Airborne Aero Wimax Test Procedures document” https://extranet.sesarju.eu/WP_09/Project_09.16/Project%20Plan/9.16%20T07%20-%20WA3%20-%20Test%20bed%20and%20procedures%20development%20(aircraft%20side)/9.16-D07-Airborne%20Aero%20Wimax%20test%20procedures%20document.docx

[8] SESAR 9.16-D04 “Airborne AeroMACS Prototype Specification” https://extranet.sesarju.eu/WP_09/Project_09.16/Project%20Plan/9.16%20T04%20-%20WA2%20-%20Airborne%20Prototype%20Specification/9.16-D04-Airborne%20AeroMACS%20Prototype%20Specification.doc

[9] SESAR 9.16-D05 “SELEX ES Airborne AeroMACS Prototype Delivery Note” https://extranet.sesarju.eu/WP_09/Project_09.16/Project%20Plan/9.16%20-%20T05%20WA2/9.16-D05-SELEX%20Airborne%20AeroMACS%20Prototype%20Delivery%20Note.doc

ANNEXES

Appendix A List of attached documents (Annexes)

A.1 Acceptance Test Procedure Report

9 16 AeroMACS ATP
july 2014 V2 report.d

A.2 Event logs

Event_logs_12-08-2
014.xlsx

A.3 ANOVO MEASUREMENT REPORT of ANTENNA POINTING

BRV TC
14-077-CRM_ANTENN

A.4 ANOVO MEASUREMENT REPORT of W38 & W42

BRV TC
14-082ed2-CRM_mob

A.5 ANOVO MEASUREMENT REPORT of EMI tests

Rapport EMI
AEROMACS.docx

A.6 ANOVO MEASUREMENT REPORT on AeroMACS MS

BRV TC
14-116-CRM.pdf

A.7 ANOVO MEASUREMENT of aircraft tests

BRV TC
14-122-CRM_aircraft

A.8 SWR measurements on BS antennas

Figure 154 and Figure 155 shows the results of the SWR measurement made on BS2 and BS1. The SWR is less than 2 between the 5091MHz and 5150MHz.

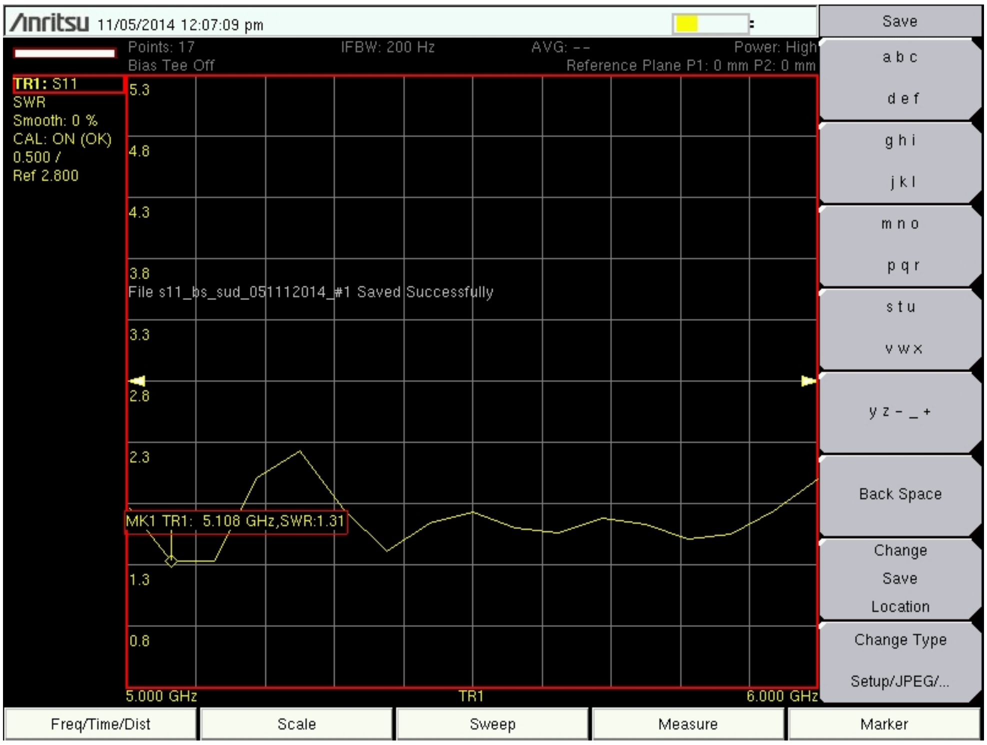


Figure 154: SWR measure on BS2 (South BS)

S11 (i.e. Coefficient of reflexion) is less -13dBm between the 5091MHz and 5150MHz.

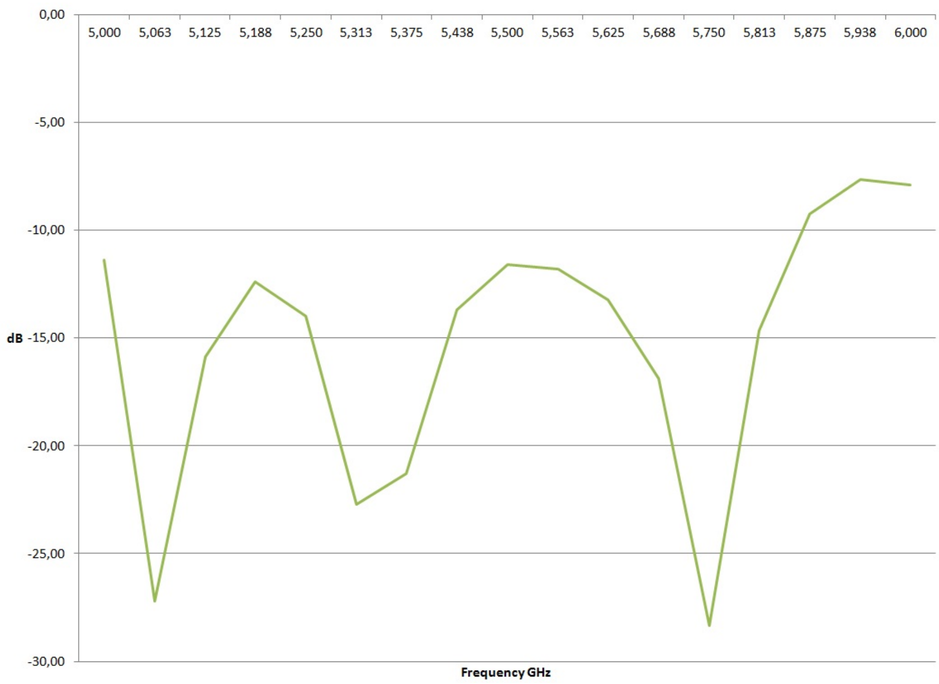


Figure 155: SWR measure on BS1 (North BS)

A.9 Quick Conversion Table

These tables help to have approximate values from aeronautical knots to kilometres per hour (and vice versa).

Knots	1	2	5	10	20	25	40	50	70	100
Km/h	1.85	3.7	9.26	18.52	37.04	46.3	74.08	92.6	129.64	185.2

Table 25: Quick conversion table (Knots-> Km/h)

Km/h	1	2	5	10	20	25	40	50	70	100
Knots	0.54	1.08	2.7	5.4	10.8	13.5	21.6	26.99	37.79	53.99

Table 26: Quick conversion table (Km/h -> Knots)

A.10 Modulation Scheme

As defined in the Compliance Matrix (Cf. D04 deliverable), the AeroMACS prototypes are expected to adapt the current modulation depending on the received signal power. Here is the targeted behaviour:

Modulation	Mode	Received Power Threshold
64 QAM	3/4 1	-74,37 dBm
64 QAM	2/3 1	-76,37 dBm
16 QAM	3/4 1	-80,37 dBm
16 QAM	1/2 1	-83,87 dBm
QPSK	3/4 1	-86,37 dBm
QPSK	1/2 1	-89,37 dBm
QPSK	1/2 with repetition 2 2	-92,37 dBm

Table 27: Link between modulation scheme and Received power threshold

A.11 Mapping CINR & FEC Code

The following tables translate permit to have a translation of FEC Code with modulation scheme and CINR interval values:

Modulation Scheme for DL	FEC Code	CINR Interval
Qpsk-1/2	0	0-5
Qpsk-3/4	1	5-10
16Qam-1/2	2	10-15
16Qam-3/4	3	15-18
64Qam-1/2	4	17-21
64Qam-2/3	5	21-24
64Qam-3/4	6	24-28

Table 28: Link between DL modulation scheme, FEC Code and CINR

Modulation Scheme for UL	FEC Code	CINR Interval
Qpsk-1/2	0	3-11
Qpsk-3/4	1	11-16
16Qam-1/2	2	16-20
16Qam-3/4	3	20-34
64Qam-1/2	4	34-40
64Qam-2/3	5	40-46
64Qam-3/4	6	46-52

Table 29: Link between UL modulation scheme, FEC Code and CINR

-END OF DOCUMENT-