Test Report AeroMACS and C Band Telemetry
EMBRAER

1 Abbreviations and Acronyms

A0	Attenuation of free space
AeroMACS	*Aeronautical Mobile Airport Communications System*
CPE	*Customer Premises Equipment*
F0	*Central Frequency*
OMS	*Onboard Maintenance System*
PCM	*Pulse Code Modulation*
WiMAX	Worldwide Interoperability for Microwave Access

2 Objective

The test consists of verifying the operation of the C band telemetry system operating close to the AeroMACS service with Siemens radios, the scenario will be simulated in the ground with static operation of both services.

2.1 Data Source

a. PCM: For the airplane simulation, a tripod with 1 antenna and 1 PCM modulated data telemetry transmitter with a rate of 7Mbps @ 40W spaced at 10MHz F0 will be used.

b. AeroMACS: Next to the airplane simulator, the mobile AeroMACS transmitter will be installed, and on the parapet 30 meters high next to the hall in the control tower, the AeroMACS Base Radio Station should be installed, considering its emission at maximum power and total bandwidth occupancy.

2.2 Tests

a. In view of the set scenario, direct the telemetry tracking antenna towards the plane and check the spurious emissions out of range, and interference between the services as well as the quality of the PCM link.

b. Check the frequency spacing conditions of the services in case interference occurs and simulate spacing between the two, measure the signals of both channels and record through the spectrum analyzer.

c. Reduce the power of the C-band transmitter to simulated reception levels considering the airplane at a distance of 300Km, considering: A0 = 156, 19 dB @ 5130MHz, observe in the spectrum analyzer and telemetry receivers the influence of the AeroMACS radio on the PCM, verify BER and number of bad frames of the PCM decoder, measure the signals of both channels and record by the spectrum analyzer.

2.3 Systems Topology

2.3.1 Aeronautical Telemetry - FTI

Through the Aeronautical Telemetry system the aircraft sends data generated by the embedded system to the ground telemetry unit, where they will be treated and presented to the flight test engineers, who can follow the test of the aircraft in real time. It is not possible, however, the communication in the opposite direction, that is, the Earth Station is not able to send information to the Aircraft.

Main features of Aeronautical Telemetry:

a. The Frequency Band: 5091-5150 MHz (for test, transmitter was set to 5100 MHz)
b. Power transmitted: 40 W
c. Signal Modulation: PCM / FM
d. Antenna Type and Gain (Aircraft): Omnidirectional, 3 dBi
e. Type and antenna gain (ground): Parabolic, 35 dBi
f. Minimum signal level at receiver: -85 dBm
g. Link range: 320 km

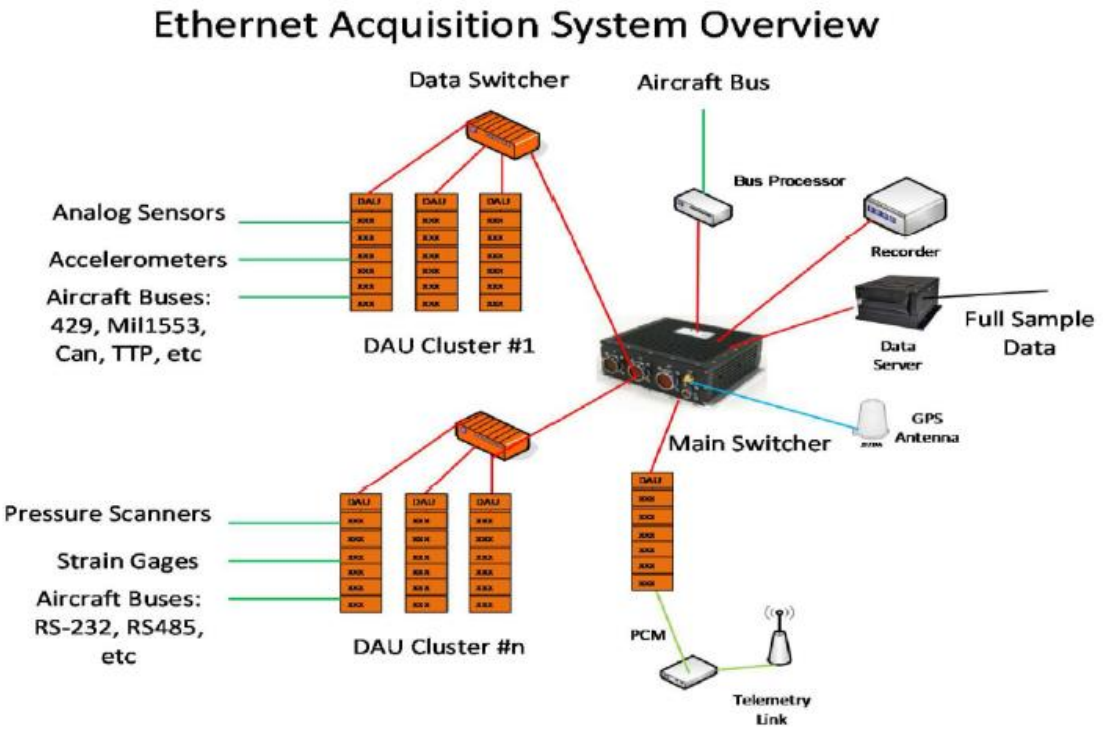


Figure 1: Topology of the System of Acquisition of Data embarked in the aircraft + Telemetry.

2.3.2 AeroMACS (Sending OMS packages on AeroMACS)

For AeroMACS communication tests, we used the OMS (Onboard Maintenance System) service normally shipped on Embraer aircraft as a packet generator and acknowledgment of receipt, simulating in full the interferences that could be generated in an aircraft or airport. The OMS service is responsible for the aircraft maintenance, detecting and isolating faults, generating maintenance messages and recording all this information in an internal memory to later send to the maintenance engineers when the aircraft touches the ground.

AeroMACS system features:

a. The frequency band: 5091-5150 MHz (for test, transmitter was set to 5145 MHz)
b. Transmitted Power: 125mW
c. Modulation: 64QAM
d. Antenna type and gain (aircraft): 6 dBi
e. Type and antenna gain (ground): 17 dBi
f. Minimum signal level at receiver: -87dBm
g. Link range: 3 km

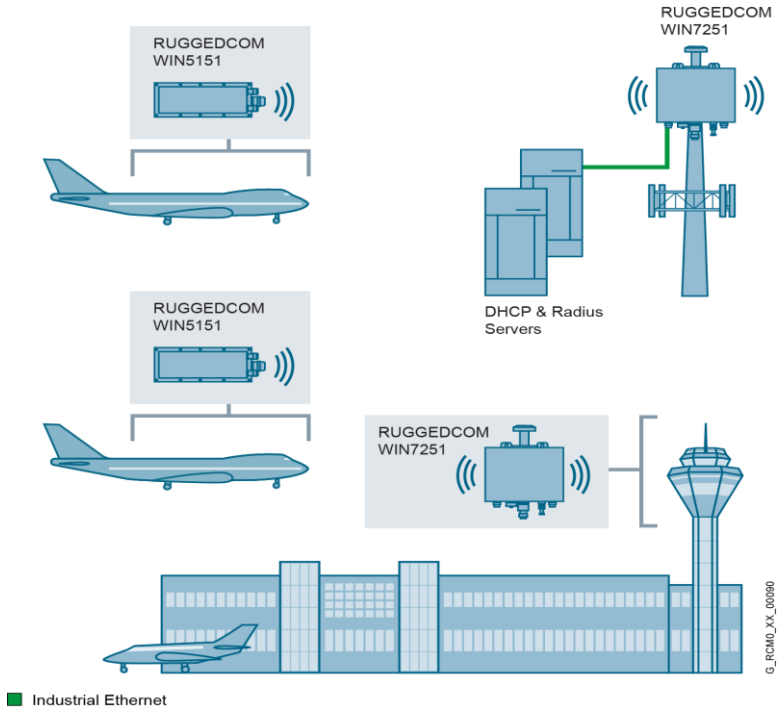


Figure 2: AeroMACS Topology

2.3.2.1 System Assignment

Provide high-speed Wireless communication for aircraft during landing, taxiing and take-off.

2.3.2.2 Solution

The Ruggedcom Base Radio Station WIN7251 can provide a solid cover over the entire surface of the aerodrome, allowing mobility in various services.

2.3.2.3 Benefits

Aircraft are exchanging an ever-increasing amount of data with the tower during landing, taxiing and takeoff. The AeroMACS solution is a robust solution to meet this growth, as it currently provides significantly higher data rates and service flow control to distinguish priorities.

3 Test Setup

Figure 3: AeroMACS Base Radio installation in the Embraer Command Tower.

Figure 4: Antenna and Radio installation pointing to the runway.

Figure 5: Installation simulating the plane in C-band.

Figure 6: Setup of the installation simulating the AeroMACS client.

The Anatel 545 resolution was adopted to support the test:

Art.1 To allocate, additionally, the band from 5.091 MHz to 5.151 MHz to the Mobile Service, on a primary basis.

Art.2 Allocate the band from 5.091 MHz to 5.151 MHz to the Aeronautical Mobile Service, in Telemetry applications, on a primary basis.

Article 3 To approve the Regulation on Conditions of Use of Radio frequencies in the Range from 5.091 MHz to 5.151 MHz.

The figure shows the available channels in the spectrum and the spacing between them,

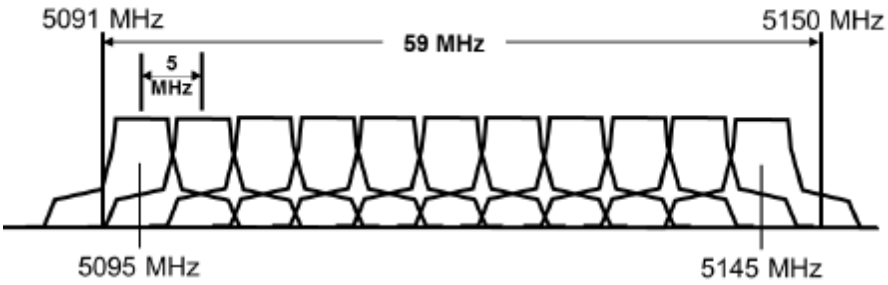


Figure 7: Channels available for the test.

Topology of communication systems application

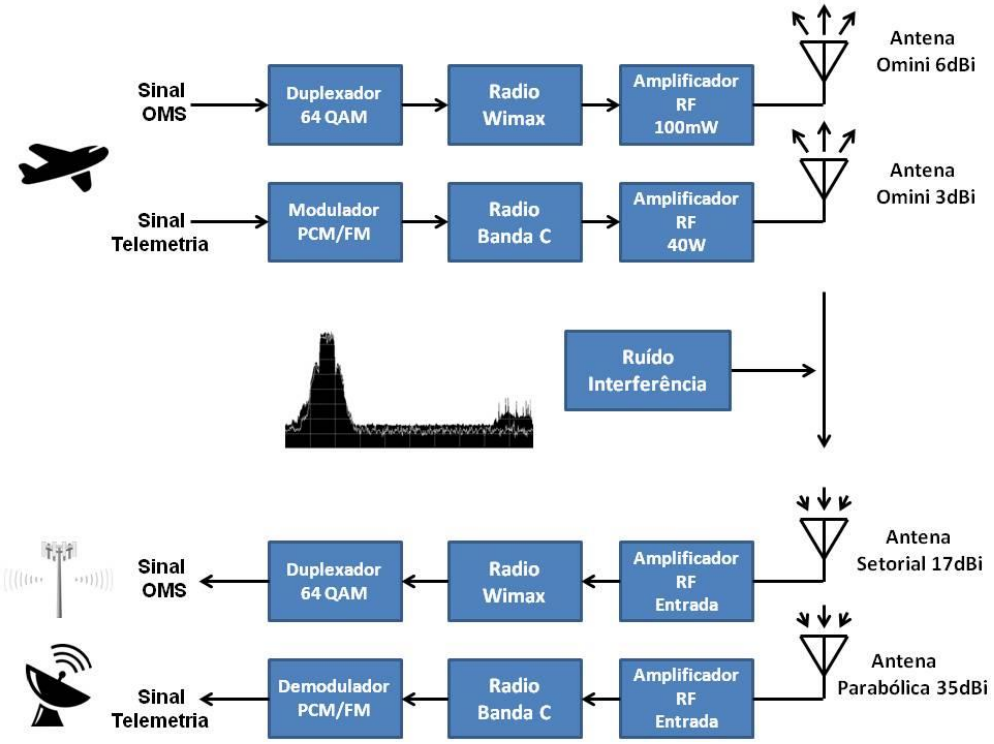


Figure 8: Communication diagram of services.

Illustration of the tests installation in distancing from the Services

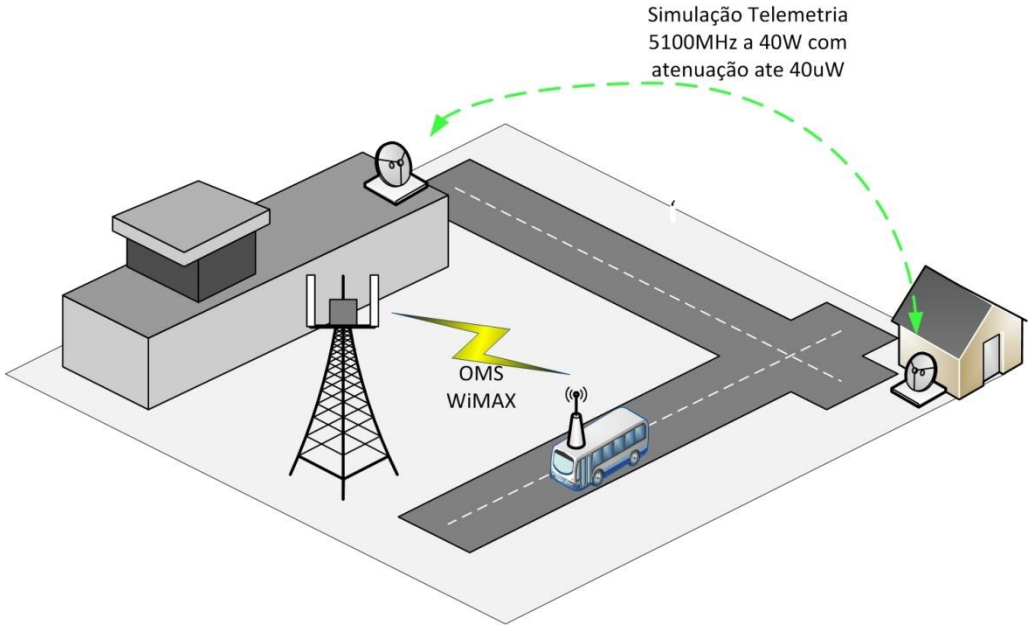


Figure 9: Installation setup simulating the AeroMACS client and long distance telemetry.

3.1 Test Results

3.1.1 Condition 1

a. Telemetry Transmitter Frequency: 5100 MHz
b. Telemetry transmitter power: 40 W
c. AeroMACS Frequency Service: 5145 MHz
d. Maximum power condition of the Telemetry over the AeroMACS service
e. AeroMACS reception service operating besides the telemetry transmitter.

3.1.1.1 Test Evidences

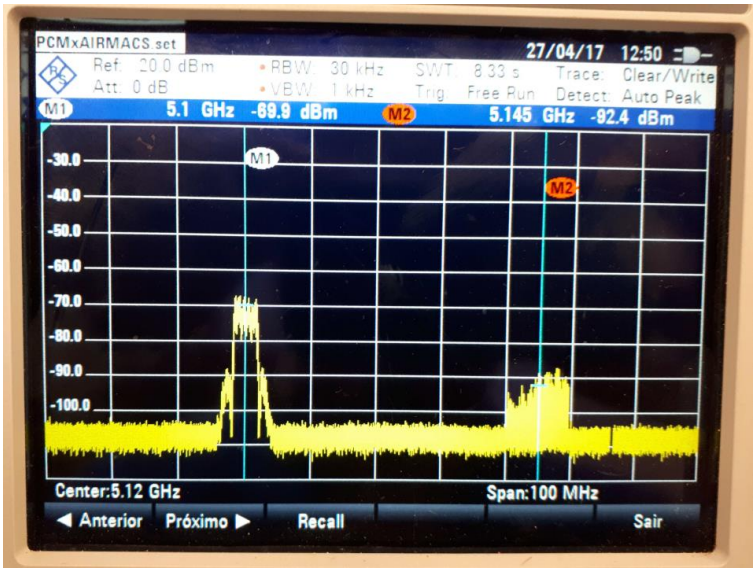


Figure 10: Spectrum analyzer showing the two services (left: Telemetry, right: AeroMACS)

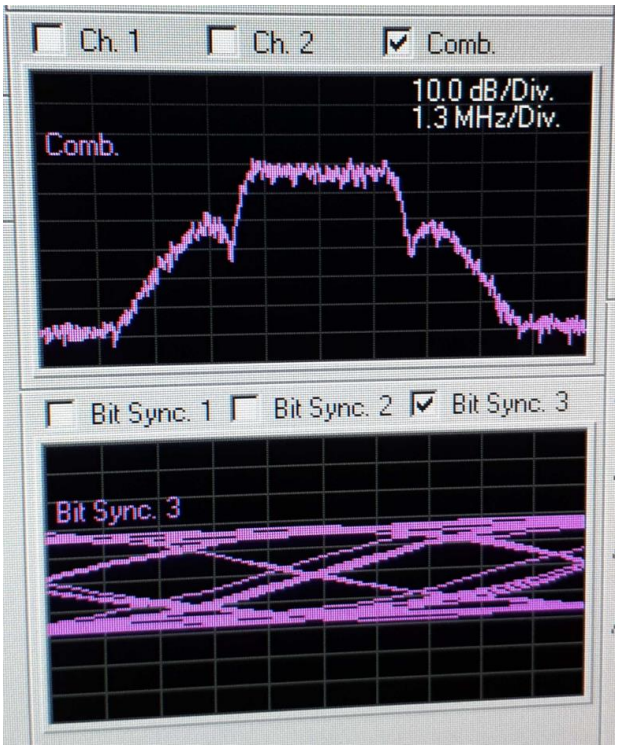


Figure 11: Telemetry station reception

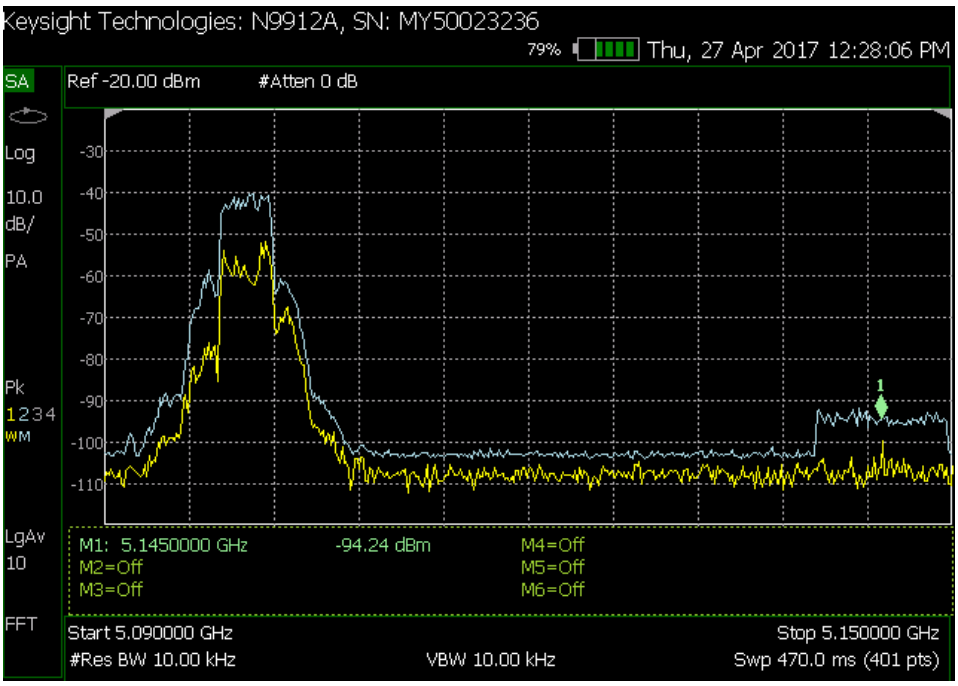


Figure 12: Measurement Analyzer near the truck with the band transmitter with Omnidirectional antenna.

RF

Legend:
requires service restart
requires reboot

CPE Status	Operational
DL RSSI	-71.15
DL CINR	23.72
DL CINR R3	28.81
MIMO mode	MIMO A
TX Power [dBm]	-25.43
UL MCS	QPSK-CTC-1/2
DL MCS	QAM64-CTC-5/6
Estimated Distance from BS [m]	0
Received bytes	4247515
Received packets	4056
Sent bytes	76196
Sent packets	1012
DL rate [Kb/sec]	16
UL rate[Kb/sec]	0

Figure 13: Truck CPE report image with Omnidirectional antenna.

Note: Low modulation was observed in the transmission of the AeroMACS subscriber equipment due to a possible problem with the antenna port RF 1, moreover the reception modulation was in the maximum modulation.

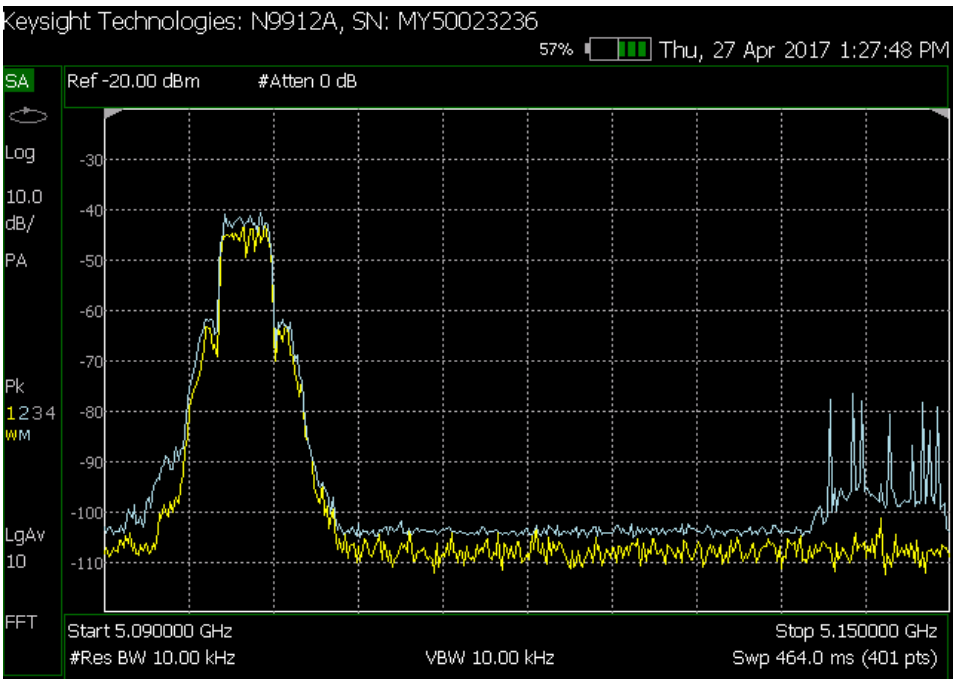
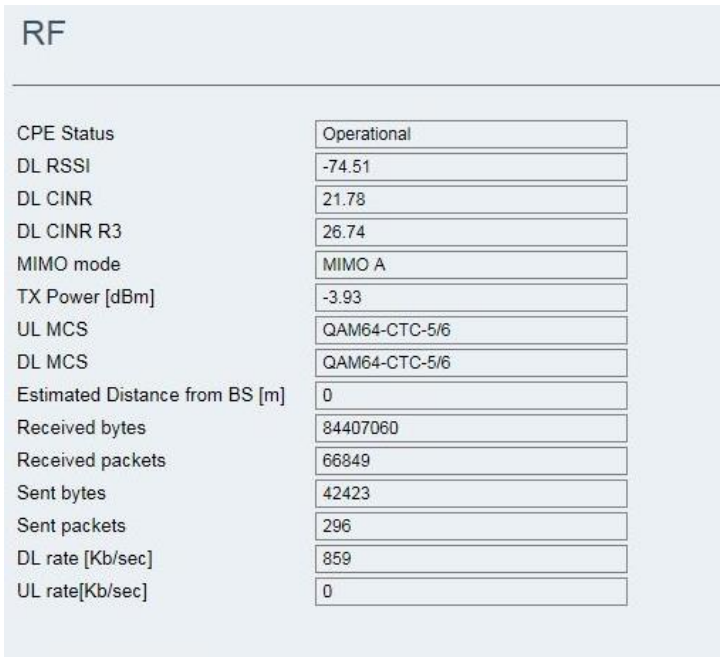


Figure 14: Measurement Analyzer near the truck with Shark antenna.



RF

CPE Status	Operational
DL RSSI	-74.51
DL CINR	21.78
DL CINR R3	26.74
MIMO mode	MIMO A
TX Power [dBm]	-3.93
UL MCS	QAM64-CTC-5/6
DL MCS	QAM64-CTC-5/6
Estimated Distance from BS [m]	0
Received bytes	84407060
Received packets	66849
Sent bytes	42423
Sent packets	296
DL rate [Kb/sec]	859
UL rate[Kb/sec]	0

Figure 15: CPE report image of the truck with Shark uplink antenna without interference.

3.1.2 Condition 2

a. Telemetry Transmitter Frequency: 5100 MHz
b. Telemetry transmitter power: 40.27 µW (EIRP)
c. AeroMACS Frequency Service: 5145 MHz
d. Minimum power condition over the AeroMACS service
e. Telemetry antenna signal reception from an aircraft at 300km distant and AeroMACS service in the ground in line of sight with the telemetry antenna.

3.1.2.1 Test Evidences

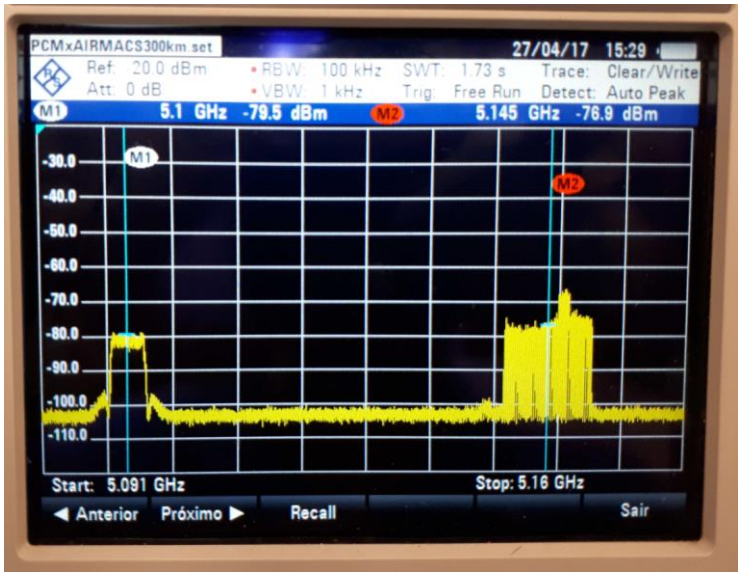


Figure 16: Spectrum analyzer showing the two services (left: Telemetry, right: AeroMACS). Telemetry: 5100MHz; AeroMACS: 5145MHz

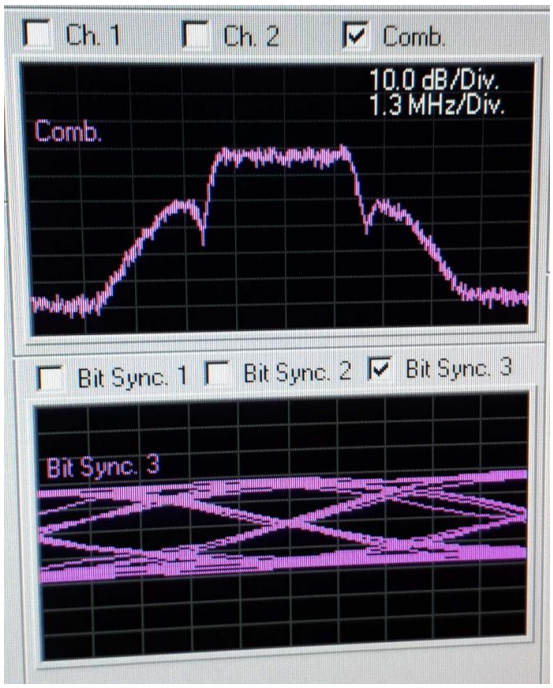


Figure 17: Reception condition of the airplane telemetry station.

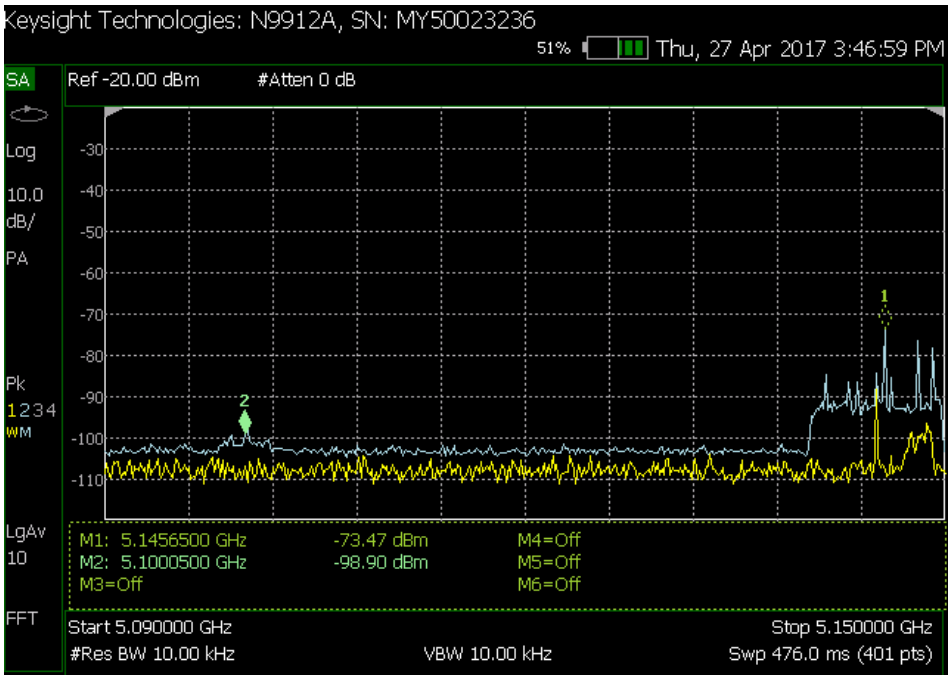


Figure 18: Measurement Analyzer near the truck reception condition of the aircraft telemetry station at 300km.

RF

CPE Status	Operational
DL RSSI	-71.17
DL CINR	24.10
DL CINR R3	29.18
MIMO mode	MIMO A
TX Power [dBm]	2.51
UL MCS	QAM64-CTC-5/6
DL MCS	QAM64-CTC-5/6
Estimated Distance from BS [m]	0
Received bytes	4899
Received packets	38
Sent bytes	4479
Sent packets	28
DL rate [Kb/sec]	0
UL rate[Kb/sec]	0

Figure 19: CPE truck report image with Shark uplink antenna.

3.1.3 Condition 3

a. Telemetry Transmitter Frequency: 5100 MHz
b. Telemetry transmitter power: 40.27 µW (EIRP)
c. AeroMACS Frequency Service: 5120 MHz
d. Minimum power condition over the AeroMACS service
e. Telemetry antenna signal reception from an aircraft at 300km distant and AeroMACS service in the ground in line of sight with the telemetry antenna.

3.1.3.1 Test Evidences

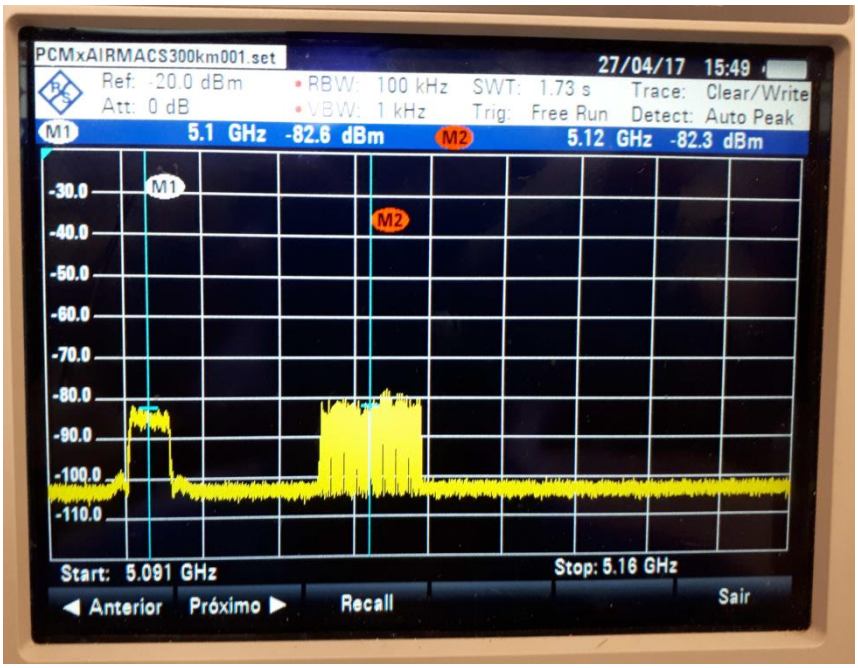


Figure 20: Spectrum analyzer showing the two services (left: Telemetry, right: AeroMACS).

Figure 21: Reception condition of the telemetry station of the airplane at 300Km based on the spacing of 20MHz between services.

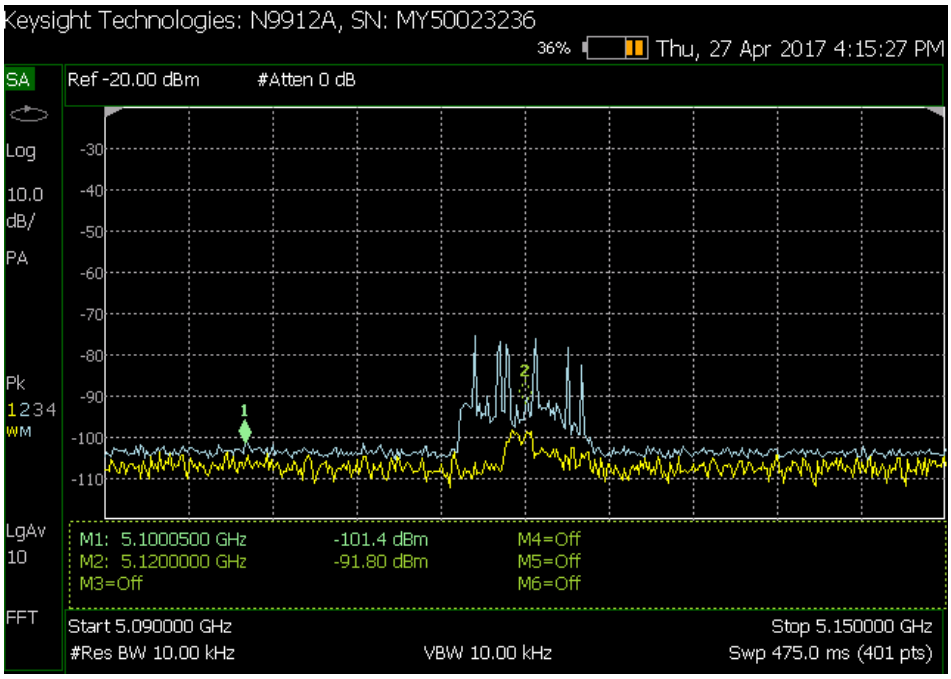


Figure 22: Measurement Analyzer near the truck reception condition of the telemetry station of the airplane at 300Km based on the spacing of 20MHz.

RF

CPE Status	Operational
DL RSSI	-63.31
DL CINR	26.28
DL CINR R3	30.66
MIMO mode	MIMO A
TX Power [dBm]	2.97
UL MCS	QAM16-CTC-3/4
DL MCS	QAM64-CTC-5/6
Estimated Distance from BS [m]	0
Received bytes	2613
Received packets	18
Sent bytes	2788
Sent packets	19
DL rate [Kb/sec]	0
UL rate[Kb/sec]	0

Figure 23: CPE truck report image with Shark 5120MHz antenna.

3.1.4 Condition 4

a. Telemetry Transmitter Frequency: 5100 MHz
b. Telemetry Transmitter Power: 40.27 µW (EIRP
c. AeroMACS Frequency Service: 5110 MHz
d. Minimum power condition over the AeroMACS service
e. Telemetry antenna signal reception from an aircraft at 300km distant and AeroMACS service in the ground in line of sight with the telemetry antenna.

3.1.4.1 Test Evidences

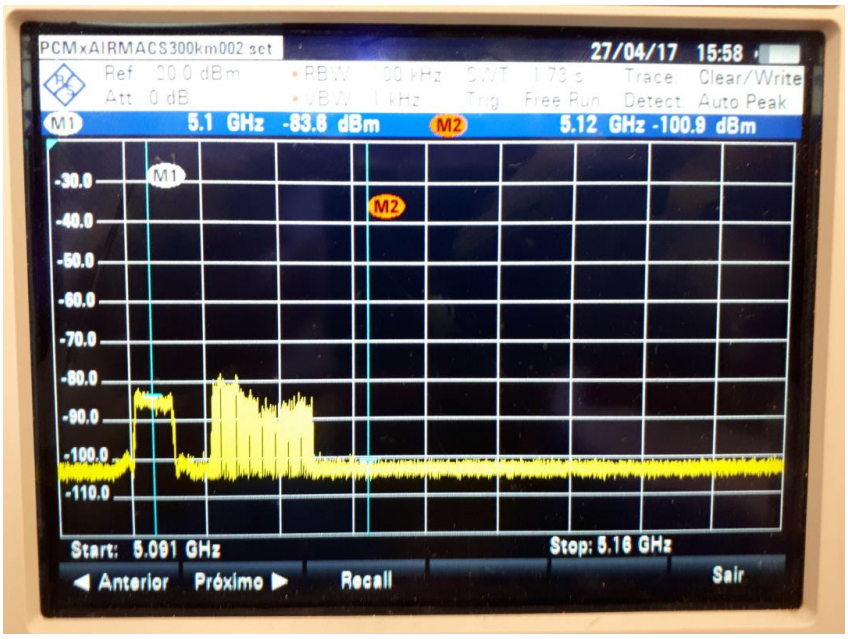


Figure 24: Spectrum analyzer showing the two services (left: Telemetry, right: AeroMACS). Spacing: 10MHz.

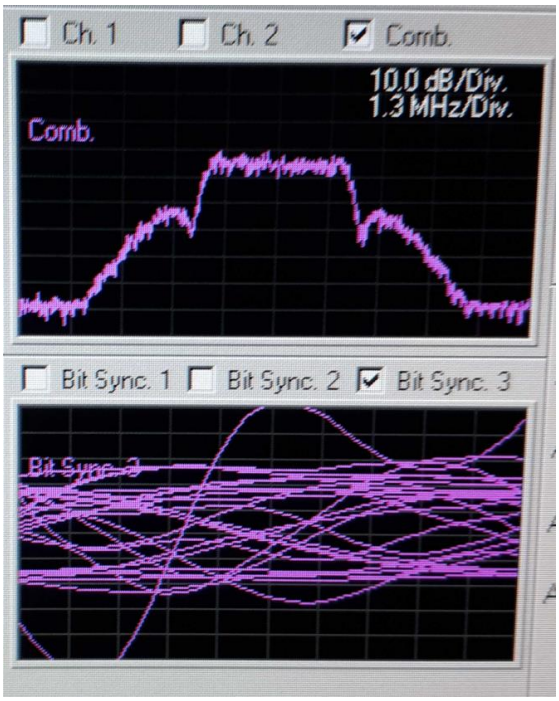


Figure 25: Reception condition of the airplane telemetry station at 300Km based on 10MHz spacing between services.

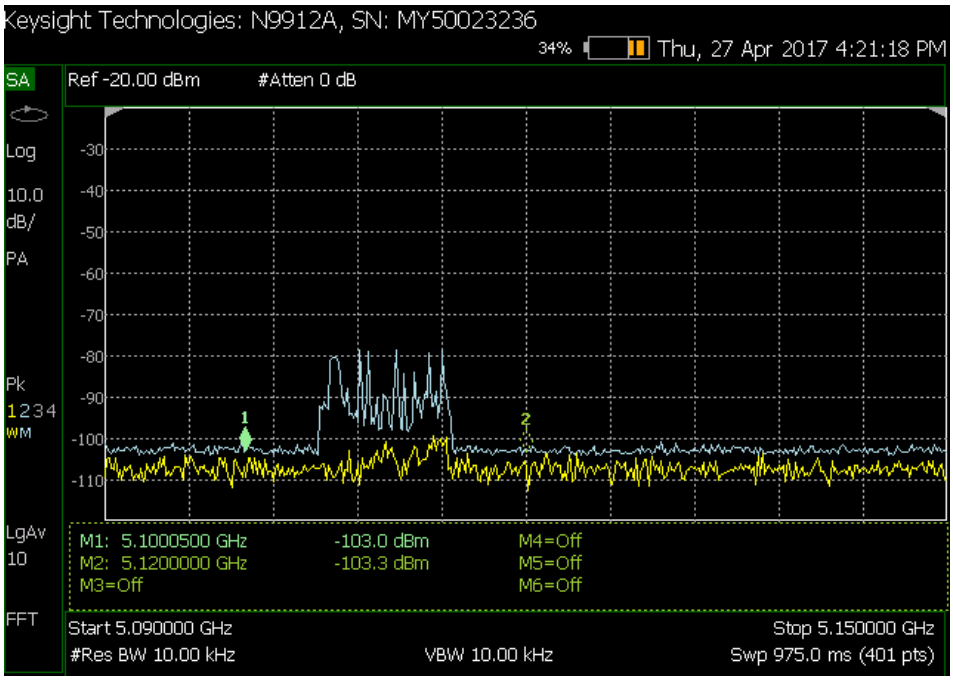
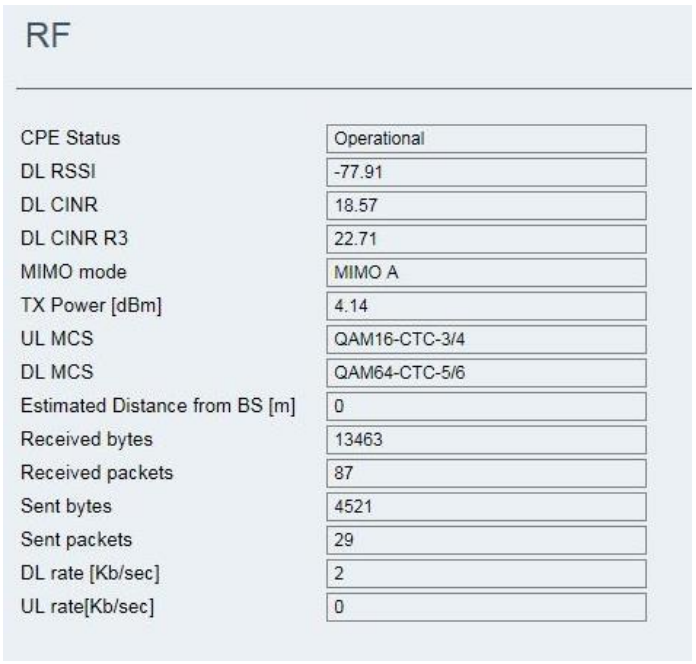


Figure 26: Measurement Analyzer near the truck reception condition of the telemetry station of the airplane at 300Km based on 10MHz spacing.



RF

CPE Status	Operational
DL RSSI	-77.91
DL CINR	18.57
DL CINR R3	22.71
MIMO mode	MIMO A
TX Power [dBm]	4.14
UL MCS	QAM16-CTC-3/4
DL MCS	QAM64-CTC-5/6
Estimated Distance from BS [m]	0
Received bytes	13463
Received packets	87
Sent bytes	4521
Sent packets	29
DL rate [Kb/sec]	2
UL rate[Kb/sec]	0

Figure 27: CPE truck report image with Shark 5110MHz antenna.

3.1.5 Condition 5

a. Telemetry Transmitter Frequency: 5100 MHz
b. Telemetry Transmitter Power: 40.27 µW (EIRP)
c. AeroMACS Frequency Service: 5105 MHz
d. Minimum power condition over the AeroMACS service
e. Telemetry antenna signal reception from an aircraft at 300km distant and AeroMACS service in the ground in line of sight with the telemetry antenna.

3.1.5.1 Test Evidences

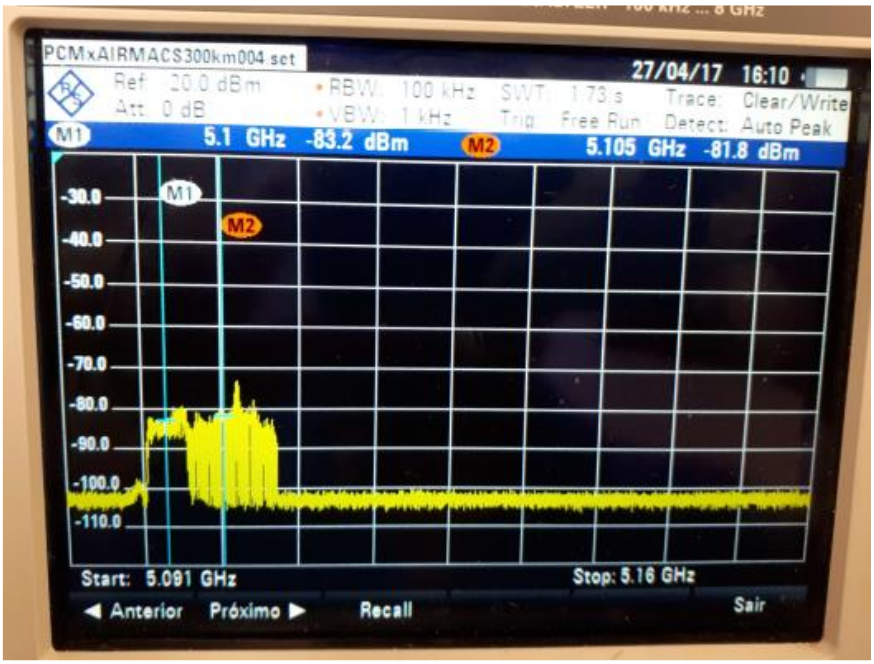


Figure 28: Spectrum analyzer showing the two services (left: Telemetry, right: AeroMACS). Spacing: 5MHz.

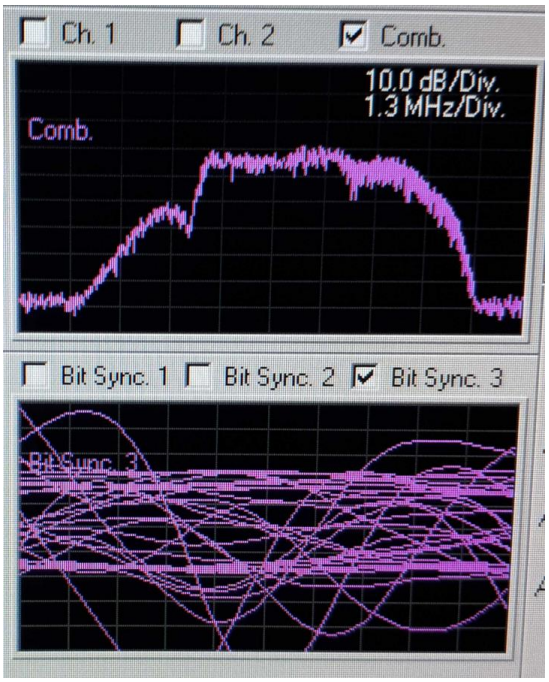


Figure 29: Reception condition of the telemetry station of the airplane at 300Km based on the spacing of 5MHz between services.

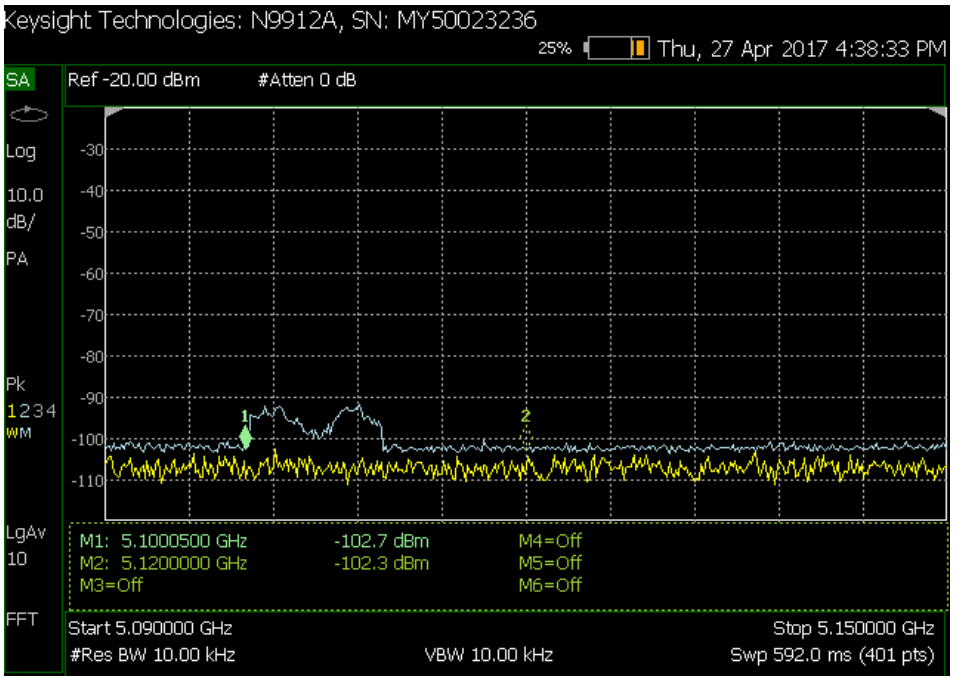


Figure 30: Measurement Analyzer near the truck reception condition of the telemetry station of the airplane at 300Km based on the spacing of 5MHz.

Note: CPE did not connect, so it was not possible to save the screen.

3.1.6 Condition 6

a. Telemetry Transmitter Frequency: 5100 MHz
b. Telemetry Transmitter Power: 40.27 µW (EIRP)
c. AeroMACS Frequency Service: 5100 MHz
d. Minimum power condition over the AeroMACS service
e. Telemetry antenna signal reception from an aircraft at 300km distant and AeroMACS service in the ground in line of sight with the telemetry antenna.

3.1.6.1 Test Evidences

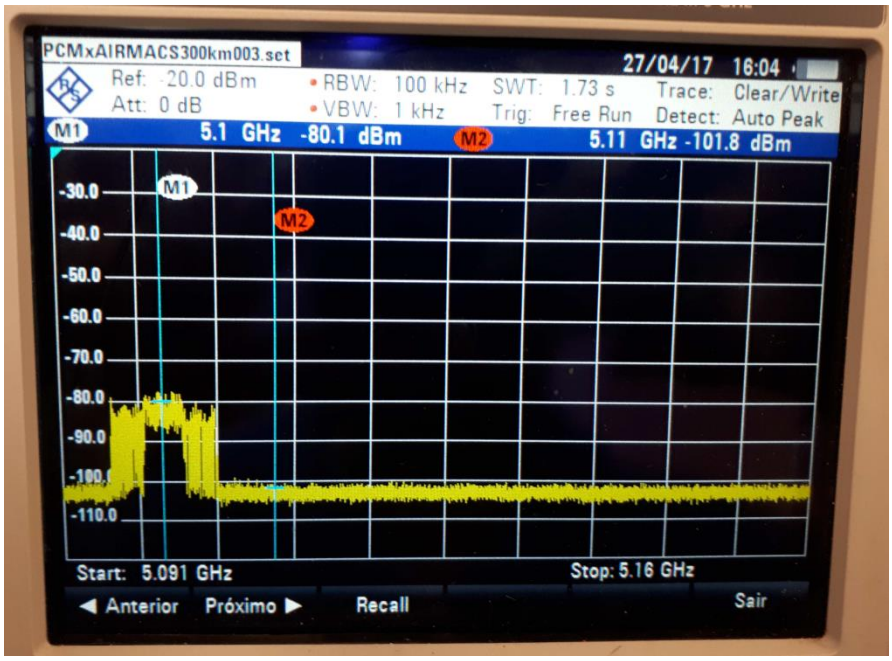


Figure 31: Spectrum analyzer showing the two services (left: Telemetry, right: AeroMACS). Spacing: 0MHz.

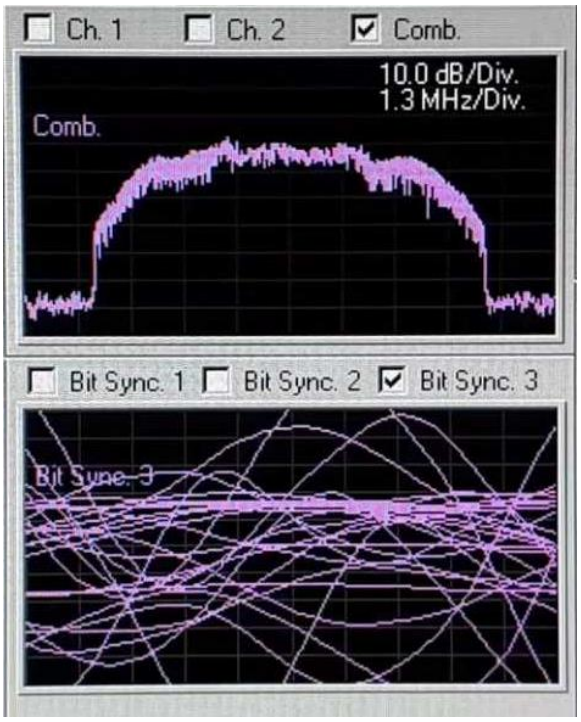


Figure 32: Reception condition of the telemetry station of the airplane at 300Km with base without spacing between services.

3.1.7 Additional Information

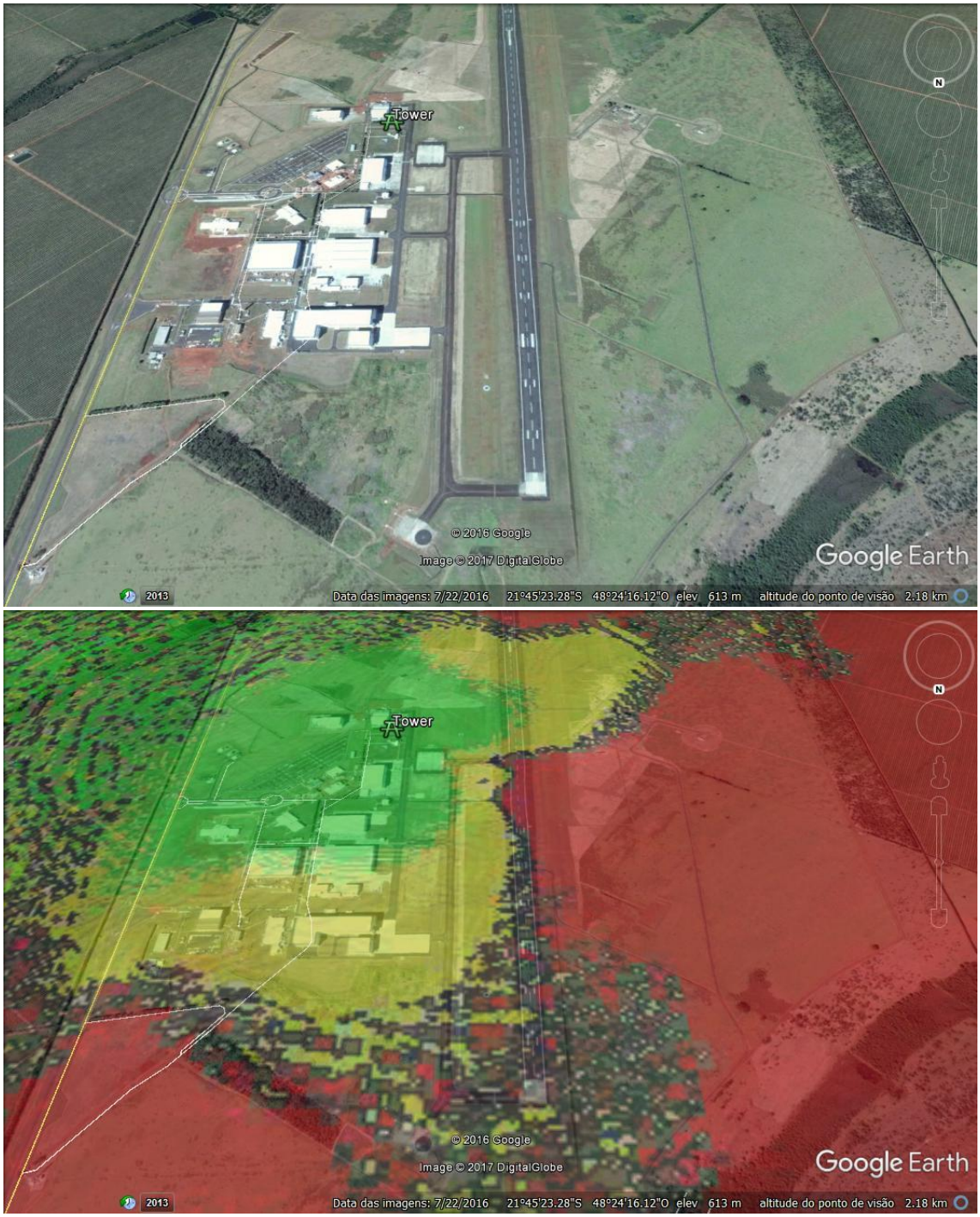


Figure 33: Projection of WiMAX radio coverage (AeroMACS).

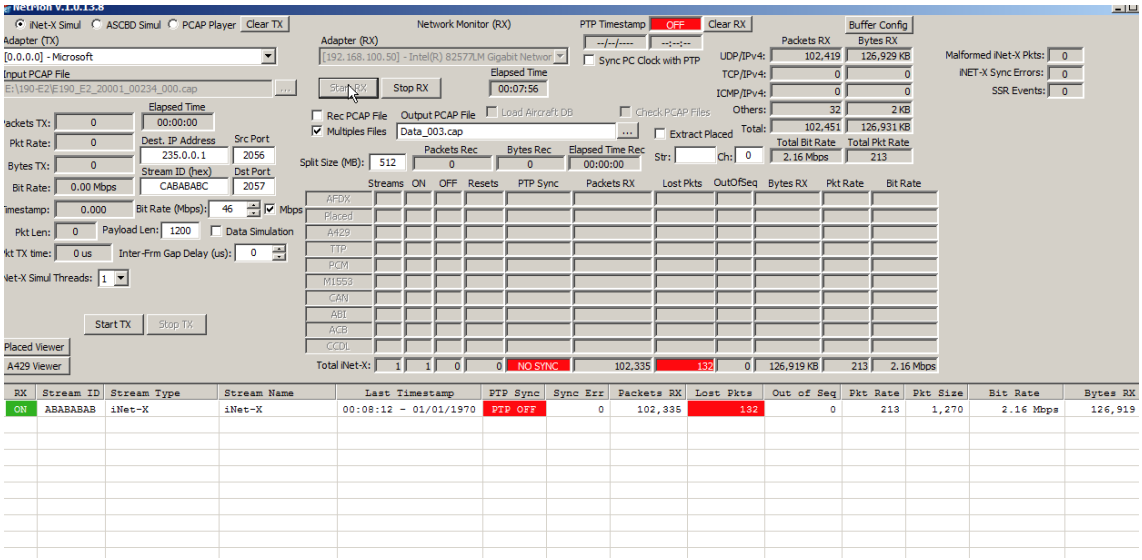


Figure 34: Telemetry payload monitoring system.

Figura 35: DECEA, Embraer and Siemens.

4 Conclusion

Based on the tests described above and considering item 3.1.3, we can state that the best channel spacing condition of the Telemetry and AeroMACS services will be 20 MHz, observe in the test results of item 3.1.4 with a spacing of 10 MHz that The PCM telemetry signal eye diagram begins to degrade causing errors in the demodulator. Minor spacing's simulated in items 3.1.5 and 3.1.6 proved to be impractical for the conviviality of services.