C-BAND TELEMETRY AT AIRBUS FLIGHT TESTS CENTRE

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ABSTRACT

Airbus is authorized to use S-band for Telemetry transmission until 2015. In October 2011, the decision was taken to move to C-band in 2013, to cope with Airbus development aircraft planning. The objective was a real challenge for 2 main reasons: C-band channel was not characterized in Airbus transmission environment and it was necessary to validate the propagation performance for Flight Tests uses.
The selected solution is based on Coded Orthogonal Frequency Division Multiplexing (COFDM) modulation. There was no existing solution so it has led the Airbus Test Centre to drive the development of its own C Band solution.
C-band telemetry at Airbus has been tested and evaluated in flight from April 2012. The first goal was to check the coverage and the impact of the bad weather condition. Besides, it was necessary to characterize the channel to choose the optimised parameters for the waveform in the Toulouse Blagnac environment. This selection of parameters allows the high quality and increased data rate required for Airbus Telemetry to be reached.
The test results consolidated the choice of a COFDM modulation, when given the high sensitivity to multipath of usual Frequency Modulation in the airport environment full of buildings and aircrafts. Moreover, it has been possible to reach a similar quality to the S-band telemetry systems , thanks to a fine tuning of the waveform parameters, and tracking system.
Deployment of the system by modifying 8 reception antennas and 12 development aircrafts was done over a span of 4 weeks in January 2014. No impact on Airbus A350 certification campaign occurred due to close collaboration with Flight Test Operations.
The new Telemetry system enables an increase of telemetry capabilities in the future, especially the data throughput, simplified remote control and monitoring.
This experience is an opportunity to set up a new standard.

Keywords: Airbus, C Band, COFDM, Telemetry

INTRODUCTION

Airbus's master telemetry centre located at Toulouse (France) has the capacity to follow three different flights test simultaneously. Airbus sites at Filton (UK), Bremen and Hamburg (Germany) are also equipped with a telemetry room which can be connected to the Toulouse master Centre. Toulouse can also be inter-connected with the Airbus Defence & Space Telemetry Centre in Sevilla (Spain).

Since its creation in 1987, the Telemetry Centre has had huge progress. Although the mission hasn't changed, the level of aircraft support has grown and technical analysis has been improved. The Telemetry Centre was initially dedicated to flights testers. Now, thanks to improvements in the tools and change mind-set, the centre has become a privileged place where people coming from different activities share their questions and solutions.

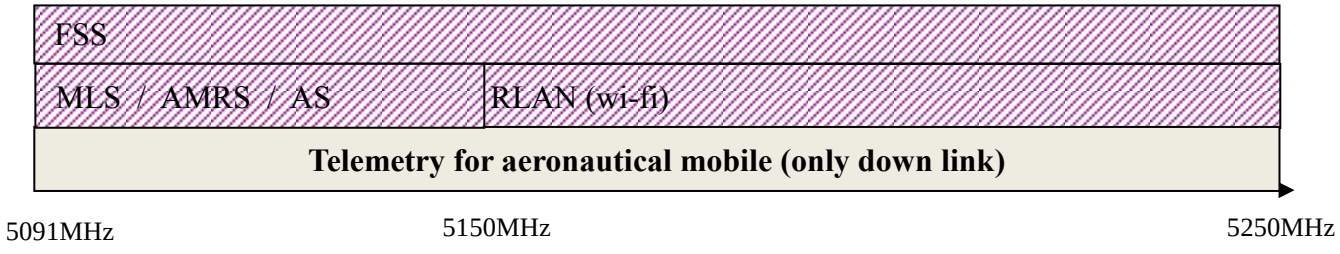
The development of the Telemetry facilities at Airbus continues to be a key strategic choice to manage flight tests.

In 2009 the French frequency authority asked Airbus to move to C Band in accordance to the WRC07 (World Radio Conference 2007) decision: allocation of C Band for aeronautical telemetry.

This paper describes the main topics addressed by Airbus to manage the "Move to C Band" project.

FREQUENCY ALLOCATION

1°) WORLD RADIO COMMUNICATION 2007: allocation for telemetry (only down link)



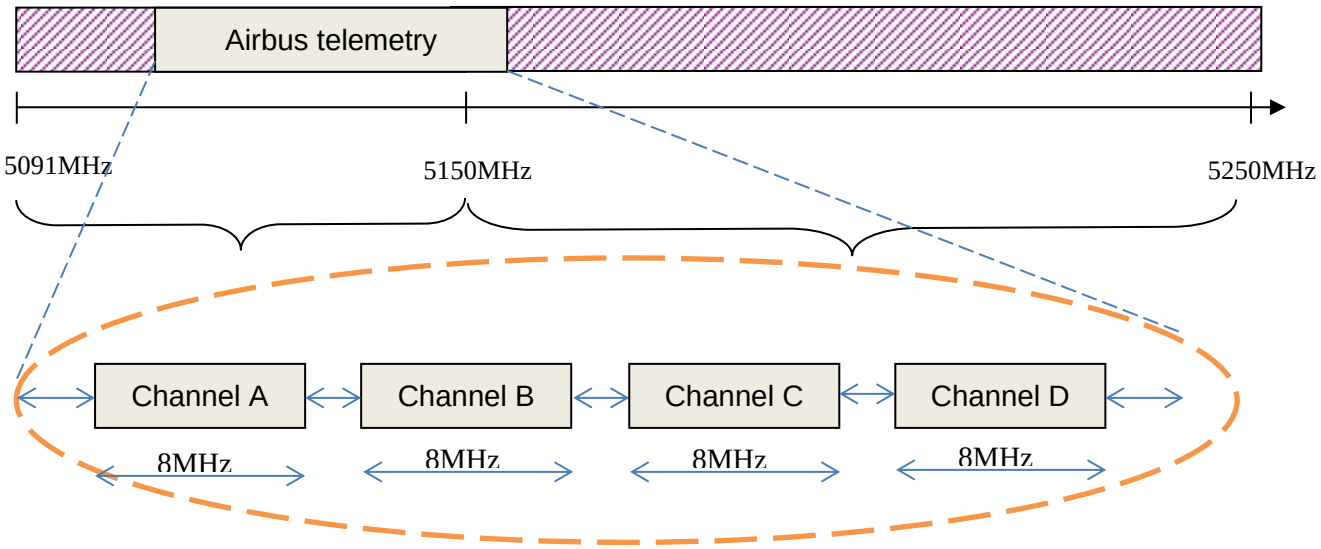
- ✓ Worldwide allocation
- ✓ All primary services
- ✓ FSS sharing possible
- ✓ AS and AMRS sharing feasible

- ✓ Region 1 allocation (Europe/Africa/Brazil)
- ✓ All primary services
- ✓ FSS sharing possible
- ✓ RLAN sharing possible but some constraints on telemetry

AMRS : Aeronautical Mobile Route Service
AS : Aeronautical Security
FSS : Fixed Satellite Service
WRC : World Radio Conference

1°) ALLOCATION TO AIRBUS TELEMETRY in FRANCE

The current frequency allocation for Airbus telemetry is described here after:



MODULATION

Airbus has been using COFDM modulation since 1999. This modulation improved dramatically the quality of service of the transmission. The goal at Airbus telemetry test Centre is to get an error free transmission whatever the location of the aircraft: in the air, on the runway, in the parking…

The airports environment generate a lot of multi-path (Figure 1) and single carrier modulations like PCM/FM are not robust enough to multipath frequency even using complex equalizer to mitigate these kind of defects.

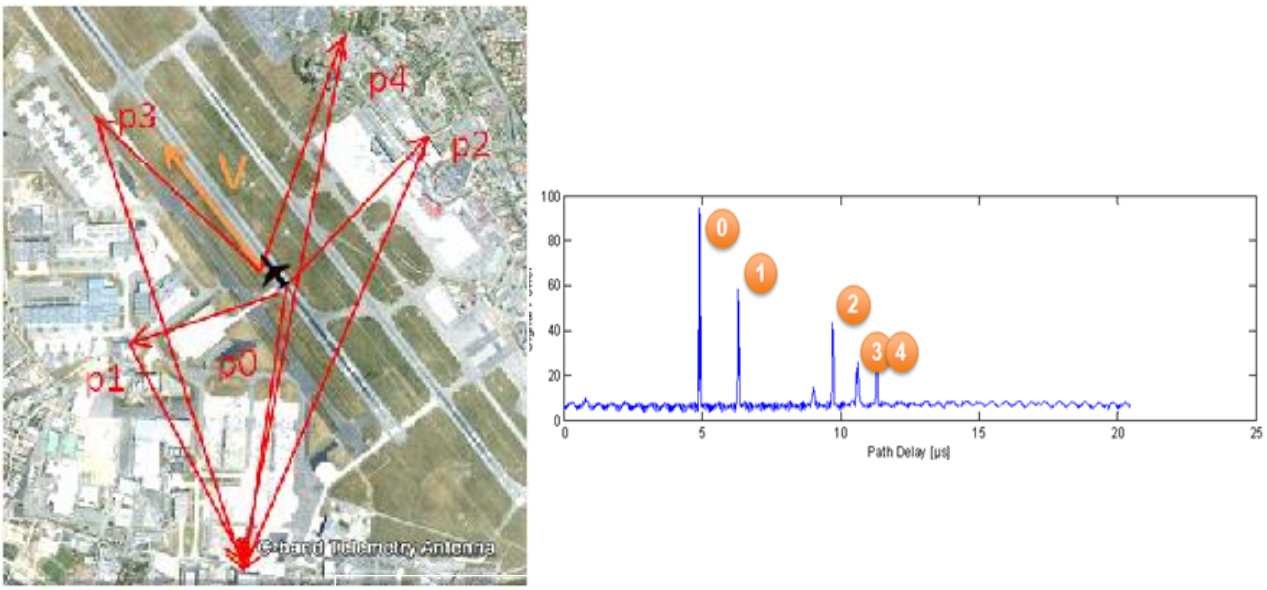


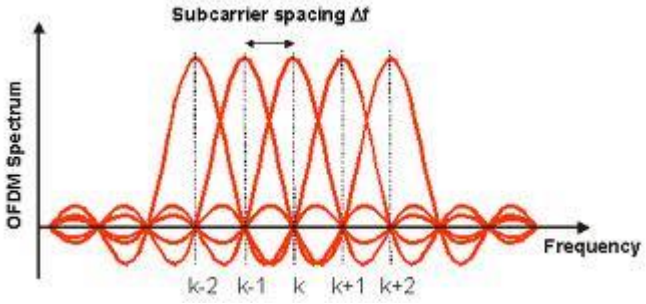
Figure 1: Example of multipath at Toulouse airport

The multi-carrier modulations like COFDM (Coded Orthogonal Frequency Division Multiplexing) largely used in telecommunication transmission DVB-T, DAB, WiFi, Wimax,…are intrinsically designed to overcome multipath.

When Airbus made the decision to move to C Band, the key question of the modulation was raised. After a strong theoretical and practical study on this topic it's clearly appeared that COFDM modulation is still state of the art today for managing multipath.

However, COFDM modulation has never been used in C Band bandwidth allocated for the aeronautical world.

Inter carrier spacing

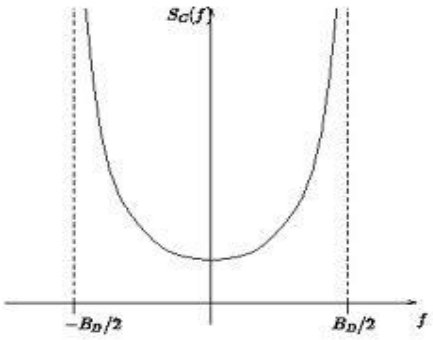


Doppler shift formula

$$f_d = F\frac{v}{C}\cos\alpha$$

- fd : doppler shift
- F : transmission frequency
- v : aircraft speed
- C : wave propagation speed
- α : angle between the receiver and the aircraft

Doppler spread



Guard Interval Tg

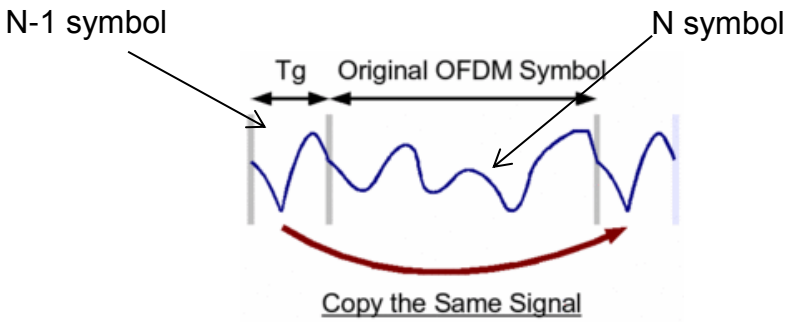


Figure 2: COFDM - Main parameters

CHARACTERIZATION OF THE CHANNEL

Airbus decided to characterize the C Band aeronautical channel in order to determine some key parameters like multipath delay and Doppler spectrum. Those parameters are key to setting up the COFDM waveforms.
No theoretical model of this aeronautical channel existed. A test bench (Figure 4) has been defined at Airbus to perform real measurements in flight using an A380 flight tests aircraft.
The main results of those tests are described in the paper "Paradigms optimization for a C Band COFDM telemetry with high bit efficiency" from Zodiac published and presented at ITC 2013.
The results of those tests show a maximum delay path of 19 µs (6µs in average) and a Doppler spread of 600Hz (1.2KHz during short period of time).

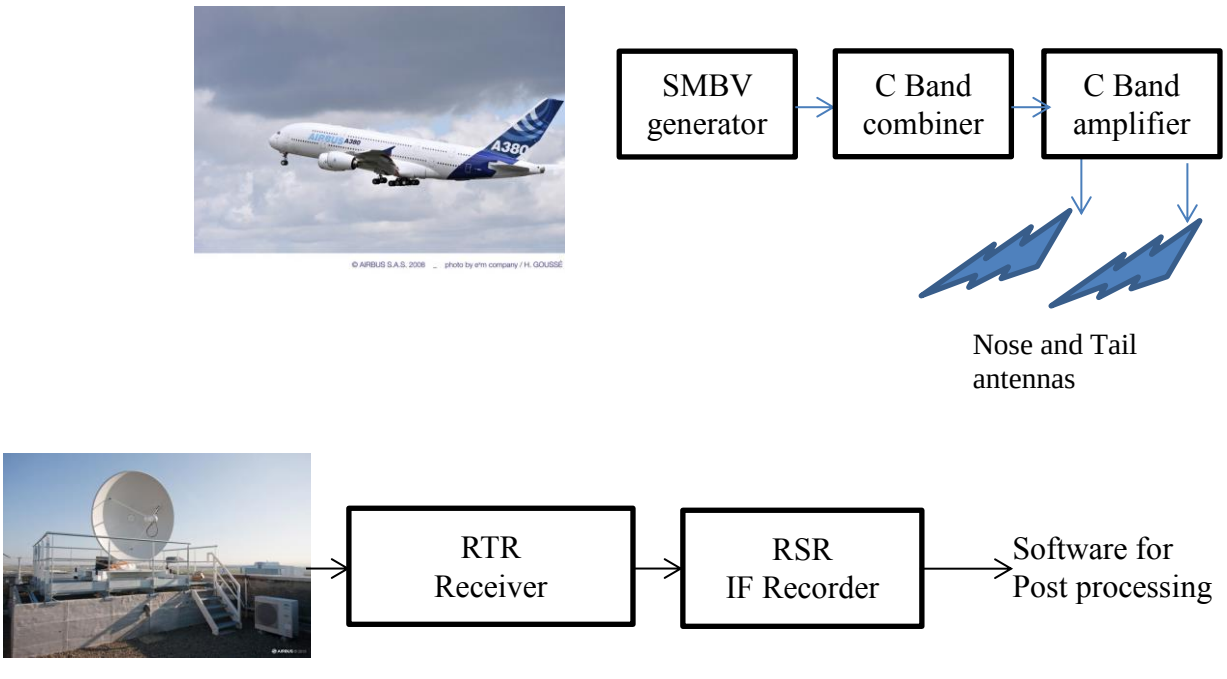


Figure 4: Test bench for channel characterization

WHEATHER CONDITIONS

The worldwide telemetry community shared a fear regarding the influence of the bad weather on the propagation of C Band waves.
We know of the good tests results achieved by Edwards Air Force Base in sunny conditions.
However, to mitigate the bad weather conditions risks we decided to perform a test campaign with a test aircraft during the winter 2012.
The test consisted of measuring the signal to noise ratio between the aircraft and a ground station located in Toulouse and compare it to sunny conditions results.
In the worst case, in heavy rainy conditions encountered during those tests the attenuation of the signal was no more than 2dB.

DATA RATE INCREASE

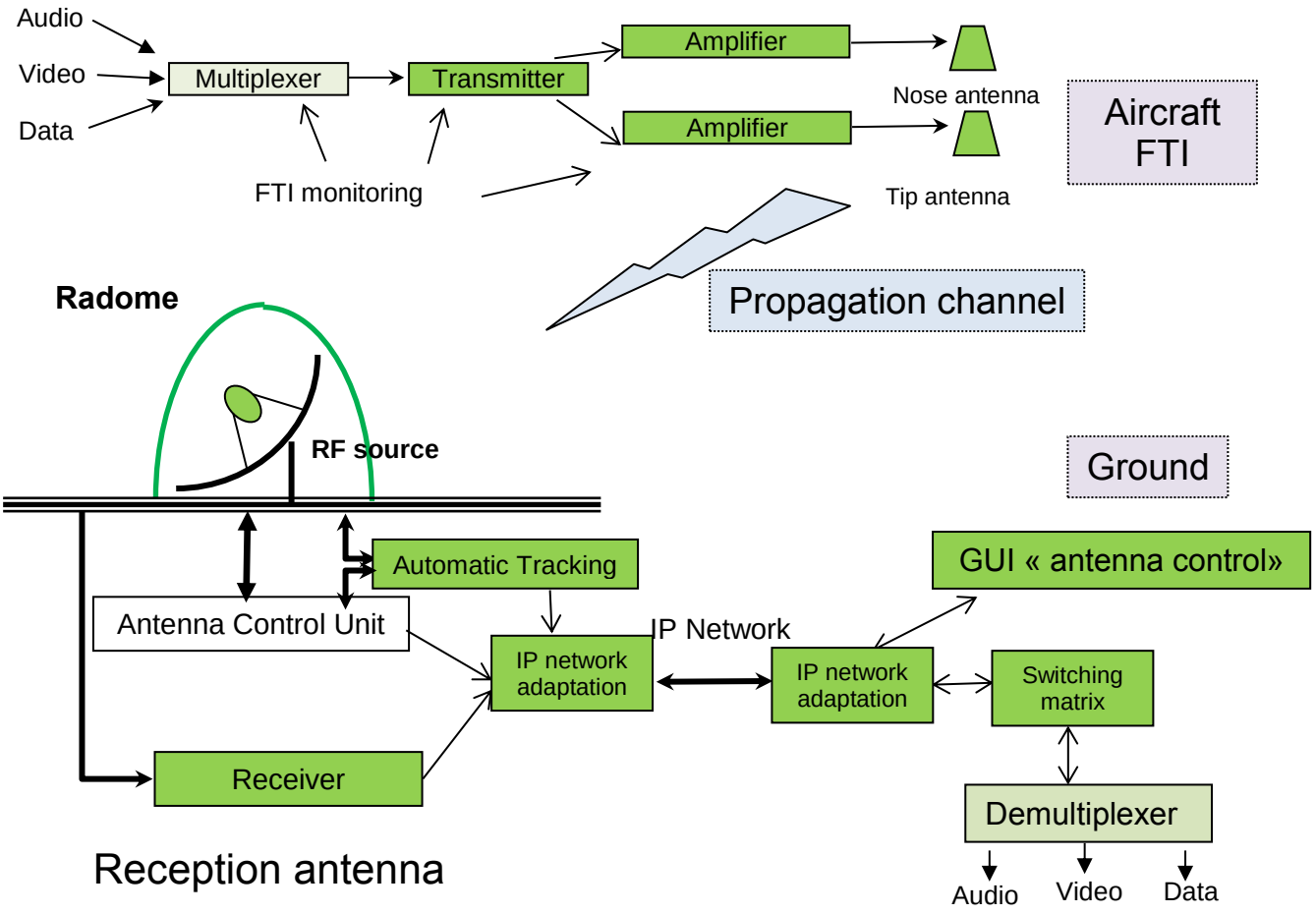
The S Band system used at Airbus before C Band allowed a data rate of 5Mbits (without data compression) simultaneously on 3 flight tests aircrafts.
The C Band move was the opportunity to increase this bandwidth.
Indeed, the complexity of the aircrafts is growing and our internal customers request more and more data through telemetry to analyse in real time the behaviour of the aircraft.
The new C Band telemetry system enabled us to use a data rate (without data compression) of 12 Mbits/s using a ½ FEC (Forward Error Correction) rate and 16QAM modulation on each channel.

THE MOVE

Airbus decided to move from S to C Band in January 2014 to minimize the impact on flight test operations. This change happened in the middle of the A350 flights tests campaign, so the level of criticality of the decision and the choice of the right time to move were very high.
The strategy of Airbus to manage this move was:

- On board transmission : Double transmission S Band + C Band
- On ground reception : change step by step each telemetry ground station from S to C Band

This way to manage the change allowed us to minimize the impact on the day to day operation without spending a lot of money (We avoided using a double reception chain S+ C Band on each ground station which would have been dramatically more expensive).
Thanks to good preparation, the time to upgrade each ground station was only few hours. We didn't find any unexpected problem and the change from S to C went well.



STATUS AFTER A FEW MONTHS

Six months after the move, the C Band telemetry is used every day at Airbus and it works well.
We confirm that the C Band is more sensitive for tracking aircraft by ground antennas (angle of reception antenna divided by two versus S Band).
The BER (Bite Error Rate) is very good (10e-10) and the quality of service didn't change versus S Band.
For the time being we have some unexpected losses of data for a few seconds on the runway in Toulouse airport. We are currently studying this phenomenon to solve it. It should be the last step of this project.

CONCLUSION

The C Band history for aeronautics started at the end of the 90's when a few dedicated people decided to ask for a specific frequency from the World Radio Communication for aeronautical telemetry.
An incredibly huge amount of working hours, lobbying and discussions was required to get this attribution at WRC 07.
The team in charge of that work succeeded and we can say: THANK YOU GREAT JOB!

C Band project at Airbus was a big project due to the criticality of the telemetry in the Airbus flight tests operations and the amount of money invested. We moved from S to C Band without disturbing the flights and we increased by more than two the effective data rate.
We can say today that it is a great success!

ACKNOWLEDGEMENTS

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A special thanks to our deceased friend Mickael Golackson from the Air Force Test Center at Edwards AFB for his fruitful exchanges on this topic.

REFERENCES

(1) Paradigms optimization for a C Band COFDM Telemetry with high bit efficiency - Zodiac Data systems – ITC 2013
(2) World Radio Communication (WRC07) – ITU International Telecommunication Union