Evaluation of the Interferences of GNSS (Galileo/GPS) signals on Air Traffic Control Radar and Wind Profiler Radar

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Abstract: *GNSS systems use frequency band close to that of L-band primary surveillance radar for Air Traffic Contro, i.e. 1250-1350 MHz, and of some Wind Profiler Radar (1290 MHz). According to the World Radio Communication Conference 2003 (WRC-03)resolution, in order to protect Aeronautic Radio Navigation System (ARNS) systems, Radio Navigation Satellite System (RNSS) administrations shall ensure that the equivalent power flux density (pfd) level produced by all RNSS space stations of all systems does not exceed –121.5 dB(W/m2) in any 1 MHz band.*
However, in order to assess the performance of ATC L-Band radar, DME and Wind Profiler Radar with GNSS interfering signals, it is useful not only to reason in terms of pfd but, rather, to model (at least for some critical cases) the Radar receiver chains and evaluate the impact of the interfering signal (if present) on every stage of the receiver and on the overall output, i.e at the user level.

1. Introduction

Both GPS and Galileo system use frequency band close to that of primary long range surveillance radar for Air Traffic Control, i.e. 1250-1350 MHz, and very close to some Wind Profiler Radar (1290 MHz). Radio Communication Conference 2003 (WRC-03) resolves that in order to protect Aeronautic Radio Navigation System systems, Radio Navigation Satellite System (RNSS) administrations shall ensure that the equivalent power flux density (pfd) level produced by all RNSS space stations of all systems does not exceed the level –121.5 dB(W/m^2) in any 1 MHz band (resolution 609 – WRC03). Another resolution also established the importance of the study for the protection for the radiodetermination systems operating in the frequency band 1215-1300 MHz[8][9] (Resolution 608 –WRC03) [1][5][6].
In order to asses the performance of ATC L-Band radar and Wind Profiler Radar in the presence of GNSS (i.e. Galileo/GPS) signals and of GNSS receivers in the presence of radar signals, it is useful not only to reason in terms of pfd but, rather, to model the pertaining receiver chains and to evaluate the impact of the interfering signal (if present) on every component of the receivers and on the overall output, i.e at the user level. To achieve this result, a survey on ATC and Wind Profiler Radars operating in Italy in L band has been done and a frequency domain model of all the signal in space affecting their receivers as been implemented.

2. Interfering signal (GNSS Signal)

GPS transmits 2 signals: L1 (1575.42 MHz) and L2 (1227.6 MHz). In the future blocks IIF and III, signal L5 (1176.45 MHz) will also be transmitted [1].

The EGNOS system is a satellite navigation system to support GPS providing augmentation data. EGNOS transmits at the same GPS frequencies and therefore the analysis presented below for GPS signals can also be applied to EGNOS ones [1].
Galileo, the civil European-controlled world-wide satellite navigation system, will transmit in 3 main frequency bands, namely E5(1191.795MHz), E6(1278.750MHz) and around the GPS L1 band (1575.420MHz) in Right Hand Circular Polarization.The E6 and L2 signals are transmitting at a central frequency that can interfere the ATC Radar in L band. Table 2 shows the specifications of these signal (that we simulated and sent to the input to the radar receiver chain[1][2].

Frequency Band	**Channel**	**Modulation Type**	**Chip Rate (Mchip/s)**	**Symbol Rate (sps)**	**User Minimum Received Power Above 10° Elevation (dBW)**
E6(Galileo)	E6P	Boc(10,5)	5.115	-	-155
	E6C data	BPSK(5)	5.115	1,000	-155
	E6C pilot	BPSK(5)	5.115	N/A	-155
L2(GPS)	-	BPSK(10)	10.23	50	-158

Table 2. E6 and L2 signals specifications

3. Italian ATC Radar

As defined by ICAO (International Civil Aviation Organization), an ATC system should assure a safe and expedite flow of traffic, providing necessary services to avoid collisions. Therefore, surveillance with both Secondary (SSR) and Primary Radar is required in the controlled airspace.In the Italian environment the Primary ATC Radars that operate in the L band are reported in the following table:

Site	**PSR**	**Coordinates**	**Coverage(n.m.)**
Masseria O.	ATCR44K	40°41'33"N – 17°12'52"E	PSR:150, SSR:200
Ustica	ATCR22D	38°42'27"N – 13°10'33"E	PSR:180, SSR:200
Maccarese	ATCR44K	41°53'02"N – 12°15'44"E	PSR:150, SSR:220
Ravenna	ATCR22D	44°22'06"N – 12°13'58"E	PSR:180, SSR:230
Monte Codi	ATCR44K	39°42'28"N – 09°30'48"E	PSR:160, SSR:200
Poggio Lecceta	ATCR2T	43°31'13"N – 10°25'00"E	PSR:160, SSR:200

Table 1: Coordinates of the Italian radars (PSR: Primary Surveillance Radar) that operate in L band. ATCR stands for Air Traffic Control Radar, K for Klystron, D for Digital, T for Transitorized.

The old ATCR 2T has been introduced for completeness but it is not considered in the following because it is to be replaced. The ATCR 44K is a radar with a Klystron power amplifier and it is also important to consider the ATCR 44S i.e the Solid State version, even if it is not yet used in Italian environment, as it represents the future of ATC Radars in Italy. All these ATCR are designed and manufactured by Selex-SI. In this paper only the case of the ATCR 44S are shown.The ATCR 44S is a radar with a solid state power amplifier and its receiving chain is shown in the Figure 1 [3][4], the antenna gain is also considered.

After these chains an A/D conversion is done and the remaining chain can be modeled as in Figure 1 where the AMTD (Adaptive Moving Target Detector) is a signal processing element to detect moving targets in clutter while CFAR (Constant False Alarm Rate) threshold is used to decide the presence/absence of the target[3][4].
Galileo E6 signal, thermal noise, echo radar and radar chain were modeled and simulated.
In the case of ATCR-44S receiver chain, the first two filters has been supposed to be a gaussian filter with 1 MHz bandwidth. After the third state amplifier, taking into account the loss produced by the two mixers, the last filter is a fourth-order base-band Bessel filter, very close to the matched filter.

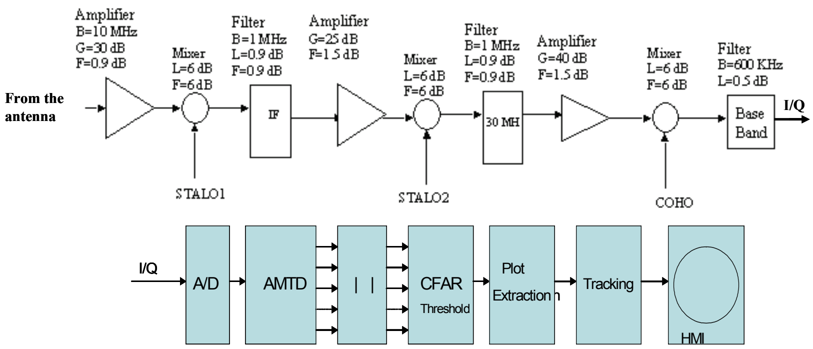

Figure 1 : Receiving chain of an ATCR-44S

In Figure 2 some examples of the PFD in various stages of the chain are reported.
The power level of the eco-radar, thermal noise and interfering signal for each stage of the receiver chain has been computed. The values are shown in Table 2.

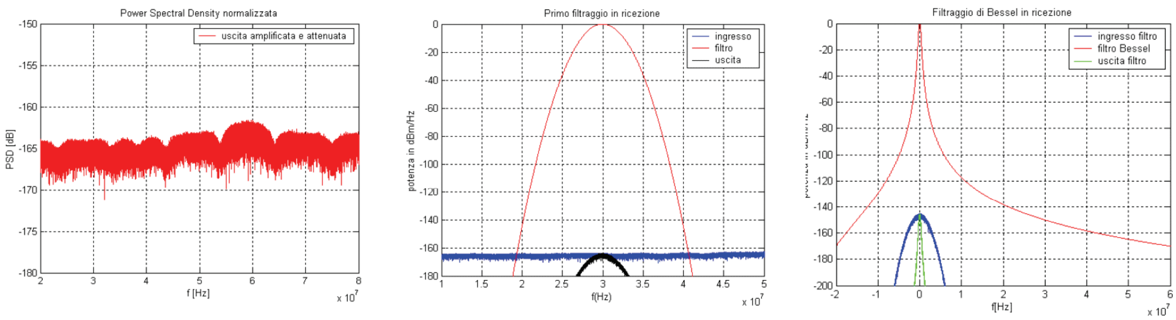

Figure 2 : PSD at various stages of the receiver chain: output of First Amplifier, input/output of First Gaussian Filter, input/output of Bessel Filter

The E6 Galileo signal produces an interference to be modeled like an additive gaussian process, therefore it can be added to the thermal noise. At the end of the simulation the interfering signal, eco-radar and thermal noise, the power level at the end of each block is reported in table 2:

	1	2	3	4	5	6	7	8	9	10	11	12	13
S[dBm]	- 110	- 80	- 86	- 87	- 87	- 62	- 68	- 69	- 69	- 29	- 35	- 35	- 35
N[dBm]	- 102	- 72	- 78	- 79	- 89	- 64	- 70	- 71	- 71	- 31	- 37	- 38	- 41
I[dBm]	- 96	- 66	- 72	- 73	- 104	- 79	- 85	- 86	- 88	- 48	- 54	-54	- 61

Table 2: Values of the eco-radar (S), noise (N) and interfering signal (I) at the end of each stage of the ATCR- 44S receiver: 1. input; 2. LNA; 3. STALO1; 4. losses introduced by the filter; 5. gaussian filter; 6. pre-amplifier; 7. STALO2; 8. losses introduced by the second filter; 9. gaussian filter; 10. amplifier; 11. COHO; 12. losses introduced by the Bessel filter; 13. Bessel filter

Since the interference is about 20 dB below the noise, also in this case it is possible to state that there is no conflict with the operations of the ATCR 44S.
A simulation analysis (not shown here in detail for lack of space) has been done for the GPS L2 signal, thermal noise, echo radar and radar chain was modeled and simulated as described before. In the GPS case, the level of the interference power results as low as 15 dB below the thermal noise.

In the chain that follows the A/D conversion it has been verified that the Interference increase the Pfa, with a fixed threshold, from a value of 10^{-6} to $1.17*10^{-6}$ for the Galileo system and to $1,56*10^{-6}$ for the GPS. The extractor is capable to cope with this very small (less then 6%) increase of false alarm rate . In the tracker the presence of interference is insignificant due to the uncorrelation of the false plots. In the case of adaptive thresholds (CFAR), the Pfa remains constant (10^{-6}) with a slight reduction of the Probability of detection(P_D) (less than 2%). These Results show that the interfering effect of Galileo and GPS signals on L-band primary radars including Track While Scan level is negligible, both working with fixed or adaptive thresholds.

4.Italian Wind Profiler

The Wind Profiler is used to supplying meteorological information and, in particular, on the vertical profile of the wind. A Radar Wind Profiler (RWP) has three to five nearly vertically-pointing beams. The high gain , (nearly) vertical pensil beams and the choise of 1290 MHz makes them particularly sensitive to GNSS interference. In Italy only one L band Wind Profiler is installed, i.e the LAP (Lower Atmosphere Profile) at the slopes of the Gran Sasso, near L'Aquila.

This Wind Profiler uses five different beams to measure the Doppler shift of the wind at the varius altitudes and can't estimate the wind vector if the data coming from 3 or more beams are corrupted. In [7] it is shown that we can considerd corrupted the data if the I/N ratio is more then -6dB for each beam. Assuming the same condition as in previus section of the paper we calculete that Galileo Interferences is 20.7 dB over these value. This condition involves an out of service of about 8-9 hours on 72 (11-12% of the time) for the latitude of the Italian Wind Profiler (ca. 42°N)[7].

At least a I/N ratio decrease of 20 dB is necessary in order to avoid that the Galileo system will severely affect the operation of the Wind Profiler Radar.

In the Italian case it would be enough to slighty change the WPR center Frequencies from 1290 MHz in order to mitigate these effects (the Frequency bandwith of Galileo E6 signal is 40.92 MHz).

5.Conclusion and Acknowledgement

In this paper it has been shown that the GNSS signals are not producing harmful interference for the Italian ATC Radar that works in L band. In the case of Wind Profiler Radar interferences due to GNSS signal can be significant; for the Italian case a slightly change of the nominal frequency would permit to reduce these harmful interferences.

We would like to thank Selex-SI for all the specifications regarding the ATCR receiver chain.

Reference:

[1] Elliott D. Kaplan, Christopher J. Hegarty, "Understanding GPS**",** *Artech House, 2006*

[2] "Signal in Space ICD (SIS ICD)", ver. 6, *Galileo Industries*.

[3] "ATCR-22D L Band Air Traffic Control Surveillance Radar", *Selex-SI*

[4] "ATCR – 44S", *Selex-SI*

[5] "Resolution 609 (WRC-03)", *World Radiocommunication Conference 2003*

[6] "Resolution 608 (WRC-03)", *World Radiocommunication Conference 2003*

[7] "Compatibility & sharing of Wind Profiler Radars with the Radionavigation Satellite Service in the band 1270 – 1295 MHz", *Electronic Communications Committee (ECC) within the European Conference of Postal and Telecommunications Administrations (CEPT)*