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EMBRACE receiver design ⋆

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Abstract. A prototype for the EMBRACE receiver has been developed by the Medicina Italian team. In this contribution, the design details and the final optimisation and integration of the receiver into the EMBRACE system, are showed. The receiver uses a super heterodyne architecture to convert and select a 100 MHz channel from the EMBRACE frequency range. After the first up conversion mixer stage the signal is mixed down to a low IF centred around 150 MHz where it will be digitized.

1. Introduction

The EMBRACE receiver is a low cost, performing and reliable 400-1600 MHz tunable double down conversion unit to 100-200 MHz IF bandwidth. The architecture, LO frequencies and RF, IF amplifiers/ filters have been selected to provide optimal noise figure, intermodulation products, dynamic range and spurious free performance. A selectivity filter bank is incorporated to avoid undesired interferences and increase the dynamic performance. To select the right filter a control signal TTL/Open collector/dip switched must be provided. This receiver includes attenuators and equalization stages to flat the received bandwidth as better as possible.

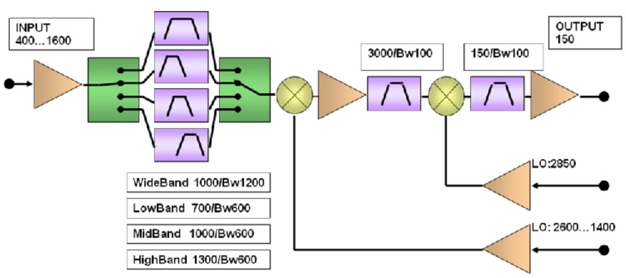

Fig. 1: EMBRACE receiver functional block diagram.

2. Functional block diagram

The frequencies of local oscillators and the architecture of conversion (Upper Conversion + LSB Down Conversion) have been chosen to minimize the undesired spurs, harmonics and intermodulation products in each IF section of the receiver. Considering the time schedule very short for designing the receiver, we adopt a rapid prototyping technique. It consists as an iterations between simulation and measures to reach as soon as possible the goal. This approach permits to verify if any critical part has been designed correctly or are necessary any changing. Several fixtures of the most critical subparts of the receiver have been done and measured. From the original design this technique underline it is necessary to have a RF equalizer to compensate the mixer conversion losses and an equalized LO amplifier to drive with constant power the L port of mixer.

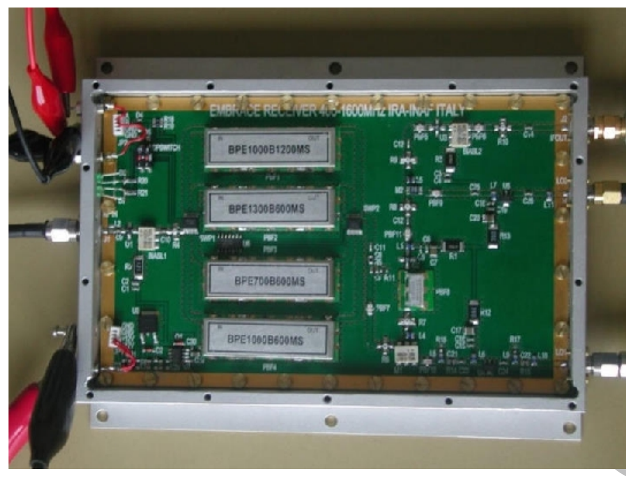

Fig. 2: Picture of the EMBRACE receiver.

3. Main features

Here are listed the main features of the EMBRACE receiver:

- RF input: 400-1600 MHz
- IF output: 100-200 MHz
- Tuning LO1 range: 2600-1400 MHz
- Fixed LO2: 2850 MHz
- Double conversion architecture
- Input ports ESD protected with inductor
- RF/IF equalization
- RF high selectivity filter bank
- TTL/OC/M controls

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- Low power for driving LO, Typ. +2 dBm
- No phase noise degradation
- High reliability
- Substrate FR4, 1.6 mm, 1 Oz.
- Eurocard standard dimensions (160x100 mm)

4. Receiver general specifications

Table 1: Input/Output Ports Specifications

Parameters	Units	Min	Typ	Max
RF Freq	MHz		500-1500	400-1600
Input noise density	dBm/Hz		-151	
RF RL	dB	11	15	
LO1 Freq	MHz		1500-2500	2600-1400
LO1 RL	dB	9	15	
LO1 Level	dBm	0	+2	+5
LO2 Freq	MHz		2850	
LO2 RL	dB		14	
LO2 Level	dBm	0	+2	+6

Table 2: DC Bias

Parameters	Units	Min	Typ	Max
Vcc	V	10	12	15
I	mA	370		450
Ripple rejection@50Hz	dB	59	75	

5. Typical Electrical Performance

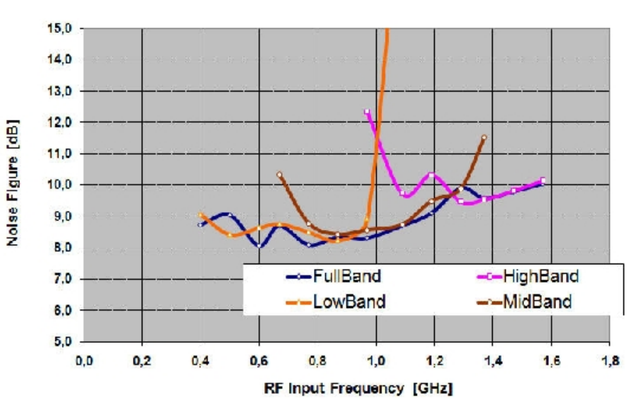

Fig. 3: Noise figure versus Frequency for the 4 bands of the receiver.

Table 3: Receiver RF Specifications

Parameters	Units	Min	Typ	Max
Gain	dB	24	25	27
Ripple	dB		±1	
NF	dB	8	9	10
IIP3	dBm		-1@550MHz 0@850MHz +3@1450MHz	
P1dBout	dBm		+16@550MHz +17@850MHz +17.5@1450MHz	
Image rejection	dB		> 80dB[a]	

[a] Considering a Lofar-Like Filter in front of ADC.

Table 4: Filter bank

Fc (MHz)	3dB Bandwidth (MHz)	Rejection @20dB	Digital control	Filter band
1000	1200	Fc1±750MHz	00	Full
1300	600	Fc2±400MHz	01	High
700	600	Fc3±400MHz	10	Low
1000	600	Fc4±400MHz	11	Mid

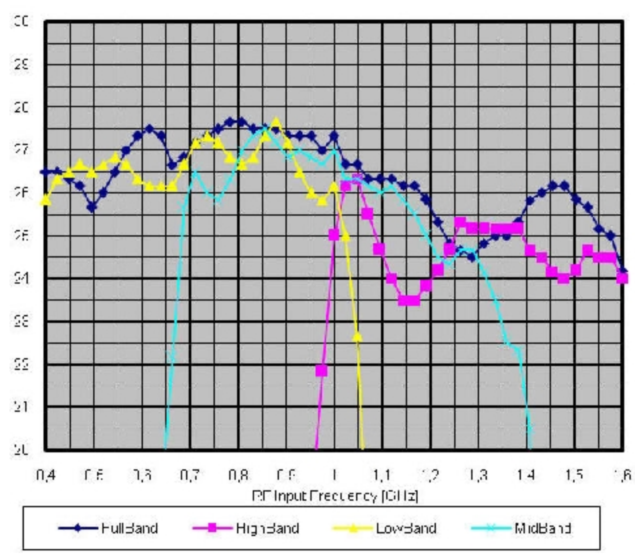

Fig. 4: A zoom of the 4 band versus frequency.

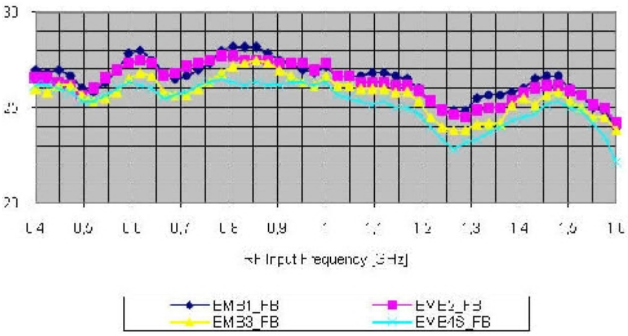

Fig. 5: Comparision gain VS frequency between 4 prototypes: full band.

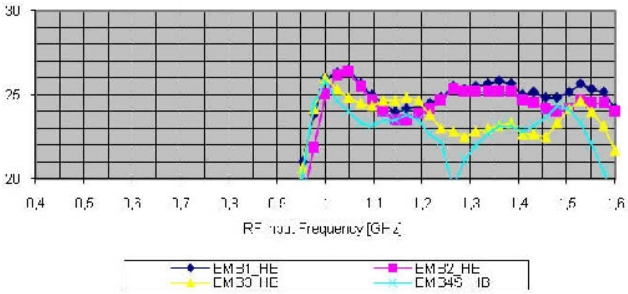

Fig. 6: Comparision gain VS frequency between 4 prototypes: high band.

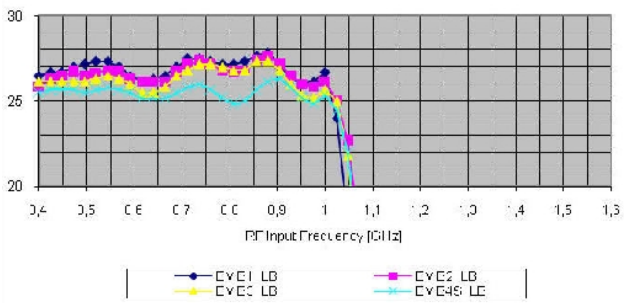

Fig. 7: Comparision gain VS frequency between 4 prototypes: low band.

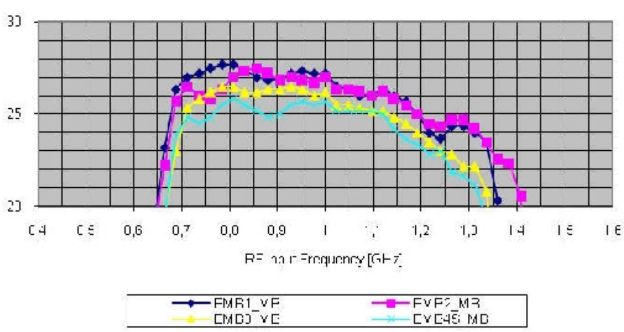

Fig. 8: Comparision gain VS frequency between 4 prototypes: mid band.

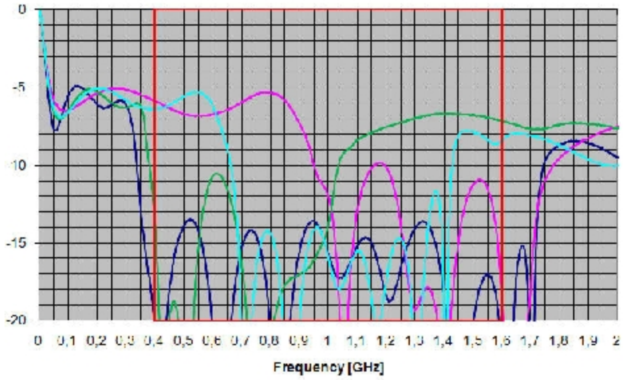

Fig. 9: RF return loss.

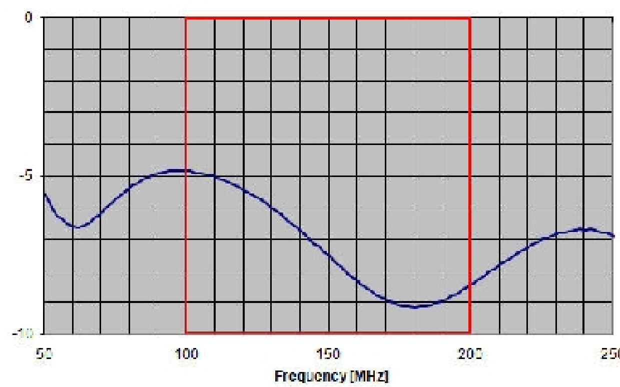

Fig. 10: IF return loss.

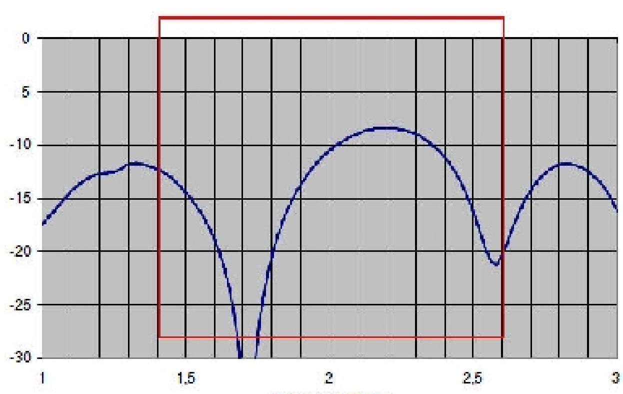

Fig. 11: LO1 return loss.

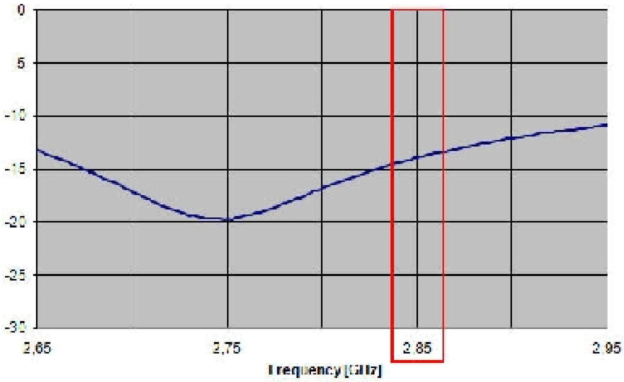

Fig. 12: LO2 return loss.

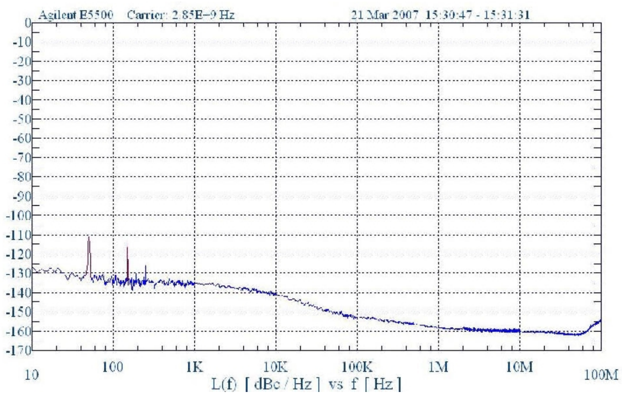

Fig. 13: Residual phase noise of the receiver due to the amplification on the LO chains.

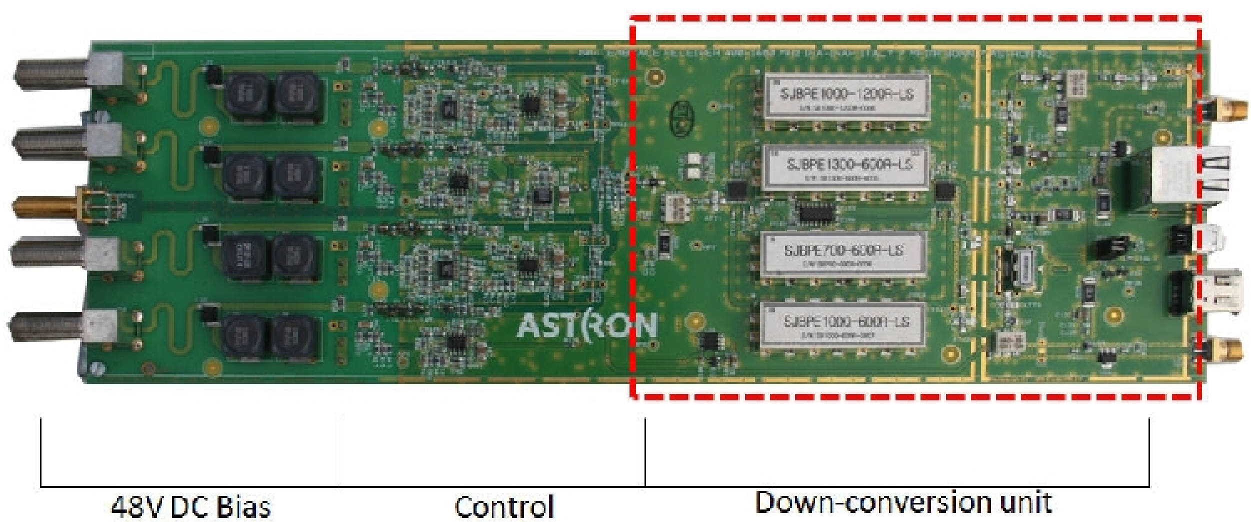

Fig. 14: Final integration of the receiver into the ASTRON CDU board (Control&Down-conversion Unit).

6. Conclusions

- All the specifications have been fulfilled
- All the tasks (i.e. LO noise phase measure and distribution chain design) and test have been accomplished
- Special efforts have been devoted to lower the costs
- Final integration respects all the performances measured for the prototypes