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Subproject 2 Receiver parameters

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1. LNA

The experience gained on hybrid LNA's, developed by NRAO on InP 0.1 μ technology for space projects such as Sport and Cassini [1], put a limit to the achieved gain of about 36 dB. Above this level, problems of saturation, oscillation or intermodulation may occur [2] and IP3 turns out to be very low.

The amplifier we need has the following characteristics:

- Center frequency 22 GHz
- Bandwidth goal 18-26 GHz (Faraday specs 21-26 GHz may be improved)
- Gain up to 36 dB
- Optimised noise temperature < 20 K

We then suggest two possible solutions for the MMIC LNA:

- Single 4 stage amplifier with a maximum gain of 36 dB, conceptually similar to what done by NRAO for hybrid amplifiers,
- A 26 dB gain LNA, optimised for low noise, combined with a two stage 20dB LNA, optimised for IP3 as shown in fig. 1.

First approach allows us to make the ideal amplifier, which may be followed by the downconversion mixer which may need an IF ampl with 10 dB gain. This latter device could still be conceived in the GaAs technology, more suitable for IP3 hardness.

Second approach foresees an amplifier cascade, interlacing the MMIC's with waveguide isolators in order to prevent possible gain instabilities and bandpass filters to limit intermodulation effects.

The overall LNA gain should be such that the RF signal at the mixer input is not high thus allowing to make the mixer in InP technology.

The input return loss of the LNA is highly dependent on the noise optimisation. An ideal LNA should have minimum input noise with a reasonably high return loss (say at least 15 dB). In any case since noise temperature optimisation has the top priority for the first stage we may think about the use of isolators.

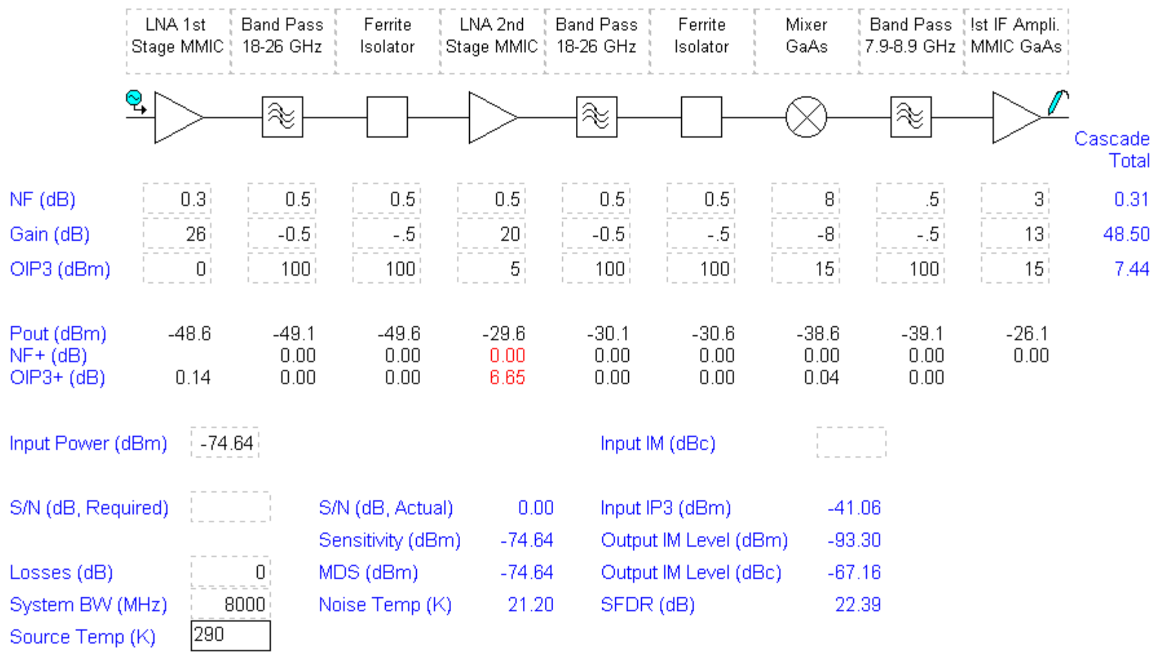

Fig. 1 The receiver configuration in the case of two LNAs

Cryogenic isolators suitable for this design are commercially available and their losses are compatible with the noise specs.[2]. If needed, the waveguide isolator is more suitable with respect to the stripline circulator. The waveguide component although more critical to thermal stresses, has been tested in many cryogenic systems and can be purchased on the market. The only problem could be a selection among components since the performance at cryogenic temperature may vary mainly on the bandwidth. Expected insertion losses are of the order of 0.5 dB thus introducing only few K in the receiver noise temperature. A kit for calibration in waveguide could be necessary if many components have to be tested.
One requirement driven by the isolator choice is waveguide LNA input/output.
Concerning the intermodulation level, the requirement is about –20 dBm at the output of the LNA chain.

2. **Mixer**

A preliminary approach to the mixer design refers to specifications of commercially available devices [5,6], as following:

RF bandpass 18-26 GHz
IF bandpass 7.9-8.9 GHz
Conversion loss 7 dB
Noise figure 8 dB
LO power 7-10 dBm
IP3 15 dBm
LO/RF port isolation 25 dB

There are some examples of InP solutions for such down converters, with the aim of integration with LNA devices [3,4].
Such mixer may work at ambient temperature thus avoiding the issue of the cryogenic temperature which may also vary the frequency response of the device. [7].

3. **Wafer analysis (by E. Limiti)**

The evaluation about the wafer capability has been based on the available information.

- Wafer diameter is 3 inches (76.2 mm) (Fig. 2)
- Each foundry run produces 6 identical wafers (obtained by the same mask)

- From each run we may expect at least 3 successful wafers (it is possible that meanwhile process and quality of wafers may be improved).

Now looking at fig. 2, where **A** is a typical round wafer, the area is divided into identical cells, each one representing a frame **C**. The wafer area is about 4600 mm^2 and the inner square (**B)** is 2900 mm^2.
The effective area is in between the two figures as:

- Some of the frames are limited by the circular geometry and the inside circuits are no longer usable,
- Near wafer edges, circuits within frames tend to exhibit more defects and are better skipped (this is usually a trend, which may not be the case for TRW)

From these assumptions we may realistically evaluate an useful area of 3500 mm^2.

About frames, from Gough's mail, two configurations are possible: a first one has only one type of frame (as in fig. 2), in a second configuration two types of frames are possible (probably alternate).
In any case the second hypothesis is always done because the foundry will need to insert ad-hoc circuits (PCM) for the process control.

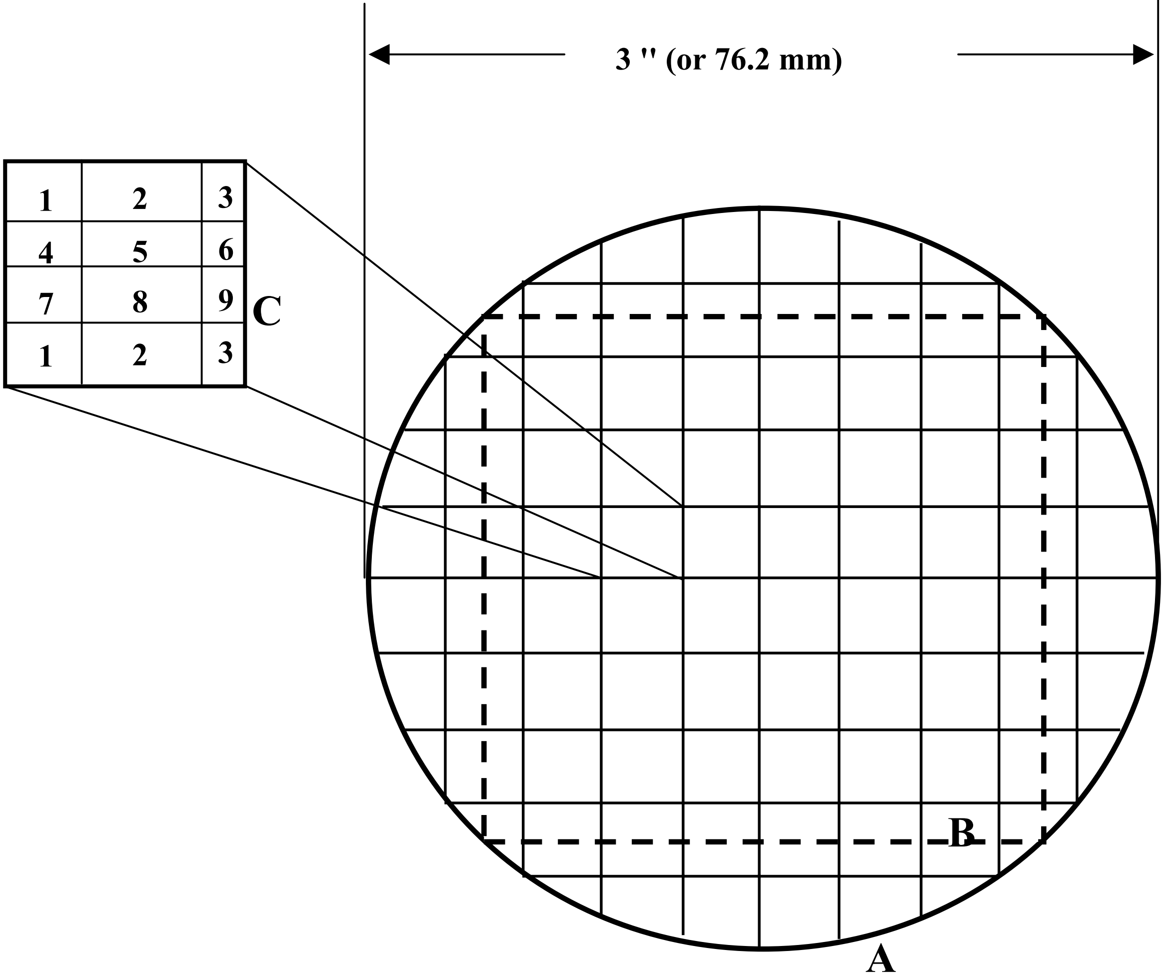

Fig. 2 Schematic of a wafer

However assuming the most of frames are of the same size, we may consider frames of 7.5x19.3 mm (about 150 mm^2) done by Gough. If so, each wafer could be split into 3500/150 = 23 frames. We approximate this figure to 20 owing to the need of the foundry to put their own PCM.

Into each frame we have the chips (numbers in **C**). They can be equal or different in size as first and last row in **C**. It is important that the frame can be cut along a strait line. Then circuits must have some common sizes and for this reason we will soon be asked to define individual chip sizes in order to design the frame.

Of course the number of circuits will depend on their sizes. We assume that a three stage LNA could fill 5-6 mm^2 , at max 7 mm^2 . With this typical size we may expect within a frame 150/7 = 20 chips (again underestimated).

In summary the total number of circuits with different typology in a run (assuming different chips in a frame) is included between 20 frames x 3 wafer = 60 (3 wafers delivered) and 20 x 6 = 120 (6 wafers "good"). Total chip number will be included between 60 chip/type x 20 types = 1200 chips and 120 chip/type x 20 types = 2400 chips.

According to Gough, the yield may account for an efficiency between 40 and 90%. These are not usable numbers, as they rely on many parameters such as chip sizes, active elements in the chip, etc. We may tentatively state a figure of 50% for successful chips, thus limiting the number of chips between 600 and 1200 in the two hypothesis.

Each of the three partners will have 1/3 of these figures (200-400). In both cases it seems better to have more than one type of amplifier, at least two with different project designs or different parameters.

4. Horn design

Subproject 2 includes the construction of a cryogenic receiver based on the heterodyne configuration. In the present phase the IRA-Florence section is working on the design and construction of the passive components (horn, polarizer, etc.) and of the dewar.
Feed design is performed on the basis of mode matching techniques according to the following parameters which account for the optical Cassegrain configuration of Medicina and Noto VLBI radiotelescopes:

- Center frequency 22 GHz
- Bandwidth >20%
- Edge taper 12 dB at 9.5^0
- Crosspolarization < -25 dB
- First sidelobes < -30 dB

The feed has been designed according to dual profiled shape geometry as shown in fig. 3

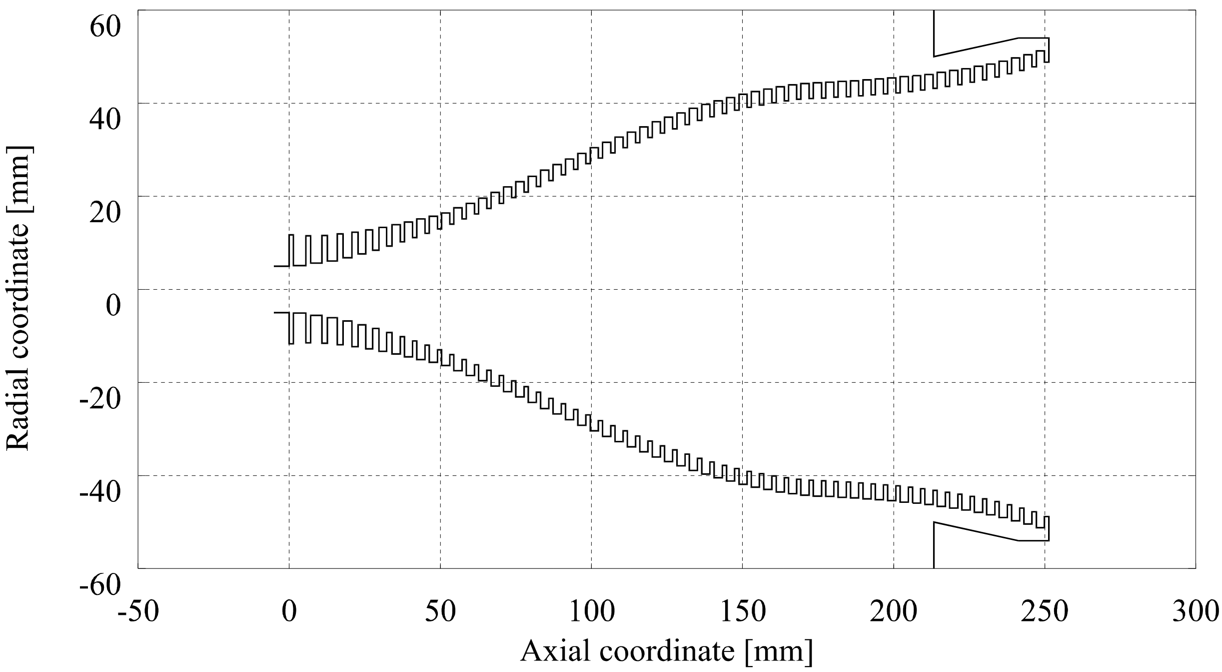

Fig. 3 Medicina horn geometry

The designed perfomance in return loss and crosspolarization of the feed is shown in fig. 4

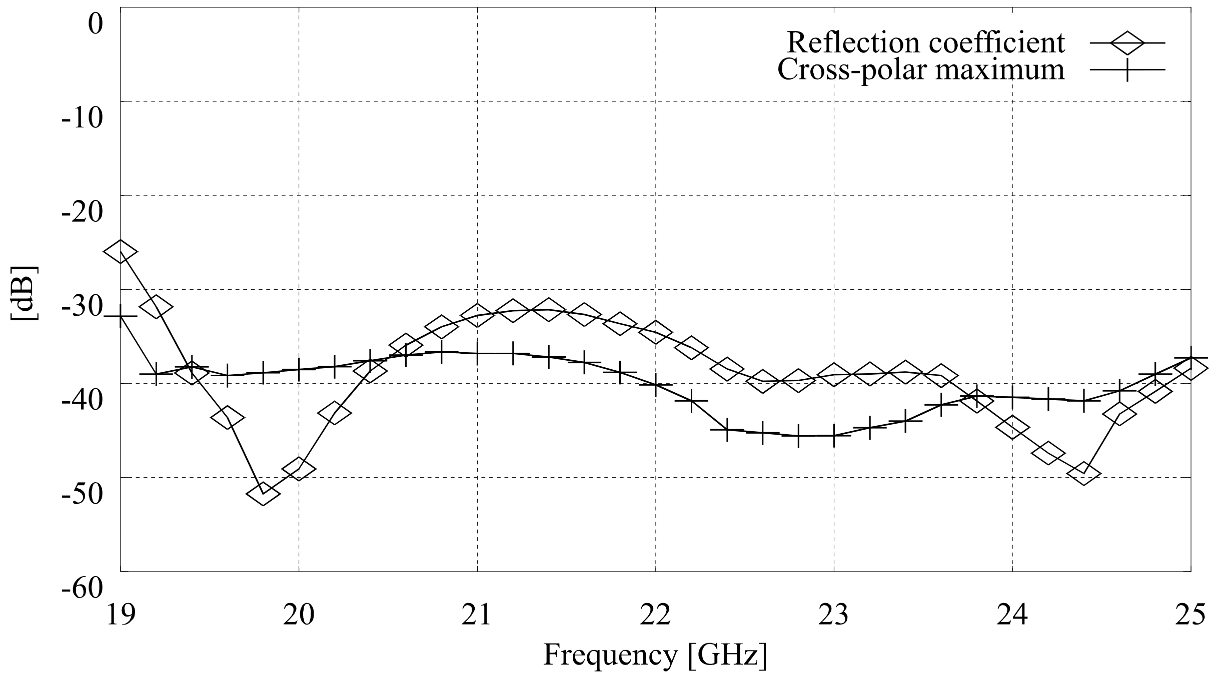

Fig. 4 Horn computed parameters

Horn geometrical sizes define the array configuration. A preliminary design of the dewar is shown in figs. 5 and 6 with the individual horn integration into the dewar and the 5 horn array configuration.

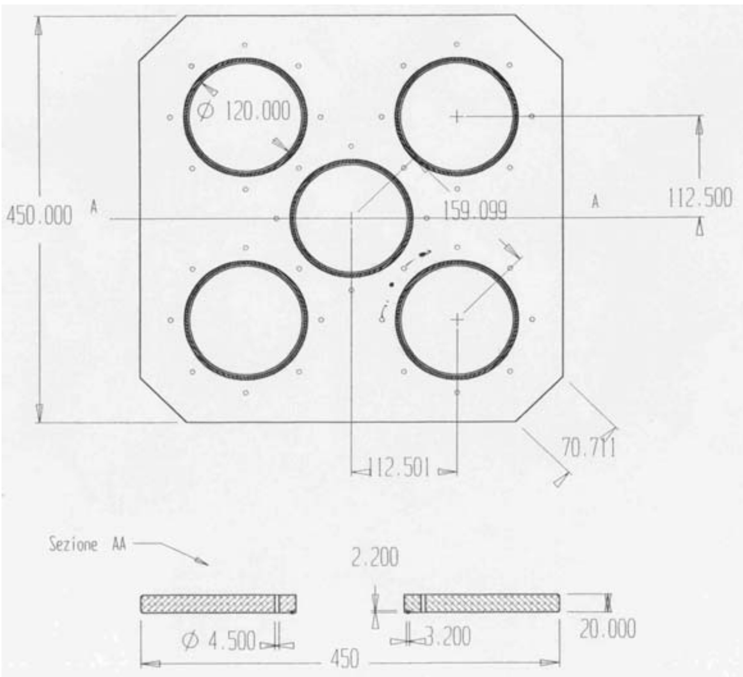

Fig. 5 The preliminary drawing of the dewar: top view

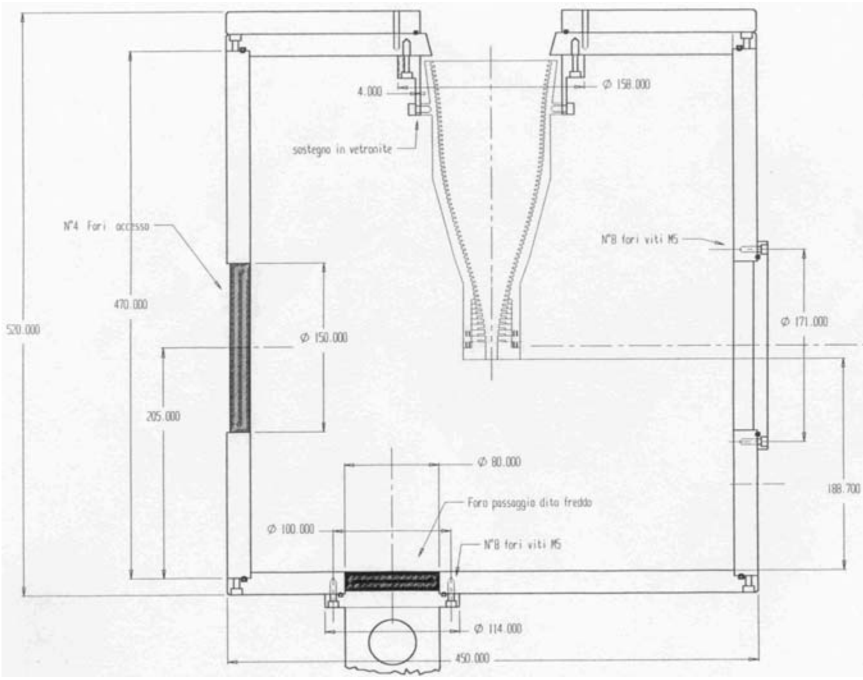

Fig.6 The preliminary drawing of the dewar: inner view

5. References

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[4] K. Chang, H. Wang, K. Tan, S. Bui, T. Chen, G. Dow, J. Bernez, T. Ton, D. Garske, T. Lin, L. Liu- a W-band monolithic downconverter

[5] C.J. Tarantella, Hittite Microwave Corporation- Ultra small mixers for K&Ka band communications

[6] S. Maas Non linear technologies

[7] S. Maas Microwave mixers