INAF/IRA AAlo AAVS0 LNA

Federico Perini, Marco Schiaffino,

Sergio Mariotti and Jader Monari.

IRA Technical Report N° 463/12

Revised by: Germano Bianchi

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List of acronyms

AAlo: low frequency Aperture Array, the low frequency part of the SKA instrument.

AAVP: Aperture Array Verification Program (http://www.ska-aavp.eu/)

AAVS0: Aperture Array Verification System level 0, a mini array of 9 to 16 antennas to perform measurements of pattern and mutual coupling.

SKA: Square Kilometre Array (http://www.skatelescope.org/).

Introduction

In the frame of the AAVP activities, it was programmed to perform some antenna measurements in occasion of the "Path to SKA Low" workshop held in Perth in September 2011. Aim of the test was primary the measurement of the antenna pattern. It was also agreed that testing the antenna with its own LNA was a desirable option in order to evaluate also the effect of the mismatch between antenna and LNA. For these reasons, in summer 2011, IRA/INAF realised a dual polarisation Vivaldi antenna prototype and a pair of LNA (one for each polarisation) which have been sent to Australia before the workshop. This report describes the LNA circuitry, part list and collects all the measurements performed on the prototypes.

The report contains also the description and the measurements of the modified LNA which has been used during the AAVS0 test held in Medicina during Summer 2012.

(a) (b)

Fig 1. Vivaldi antenna prototype (a) and the LNA for the antenna measurements (b)

General description

The LNA is based on the RF Micro Devices SPF-5122Z low noise MMIC amplifier. The biasing network (input and output DC block and the output choke) has been designed in order to optimise the LNA performance in the desired frequency band 50-450MHz. DC power is provided through the output RF connector. Both +3V and +5V DC supplies are allowed by the MMIC but, in order to reduce both power consumption and noise figure, the former (3V, 58mA) has been chosen. To keep the correct MMIC bias point, which has to be independent from the DC losses of the output coaxial cable, a low dropout (LDO) voltage regulator (LP2950) has been included in the LNA. If the RFI scenario would request more dynamic range, the +5V bias point has to be chosen. In order to do that, the only operation requested is to replace the LDO regulator. The LNA doesn't include any gain equalization network since it will be included in the receiver chain.

The LNA prototypes have been produced considering:

1. Printed circuit board (PCB) on FR4 (h=1.575mm, t=17.5um, ε_r=4.7).
2. PCB production through LPKF C30 milling machine.
3. Via holes metallisation with LPKF ProConduct paste.
4. SMA 50 Ohm input and output female connectors, LNA version for measurements in the lab.
5. TNC 50 Ohm input and output female connectors, LNA version to be mounted inside the Vivaldi antenna.

Main specifications

Table 1. Summary of the main LNA specifications

Item	Symbol	Conditions	Nom	Min	Max	Unit
Gain	G	50-450MHz		21.9	25.5	dB
Gain Variation	ΔG	50-450MHz	±1.8			dB
Input Match	IRL	50-450MHz		6.5		dB
Output Match	ORL	50-450MHz		19.5		dB
Reverse Isolation	ISO	50-450MHz		27		dB
Noise Figure	NF	50-450MHz Tamb=300K			0.5	dB
Noise Temperature	Te	50-450MHz Tamb=300K			35	K
Compression point	OP1dB	50-450MHz (200-450MHz)		+12 (+18)		dBm
3rd Order Intercept Point	OIP3	50-450MHz		+30.5		dBm
2nd Order Intercept Point	OIP2	50-225MHz Input (100-450MHz Output)		+48		dBm
Current Consumption	Idd	Include LDO quiescent current	60			mA
Power Supply Voltage	Vdd	Internal 3V LDO regulator		3.5	30	V

Schematic, bill of materials and layout

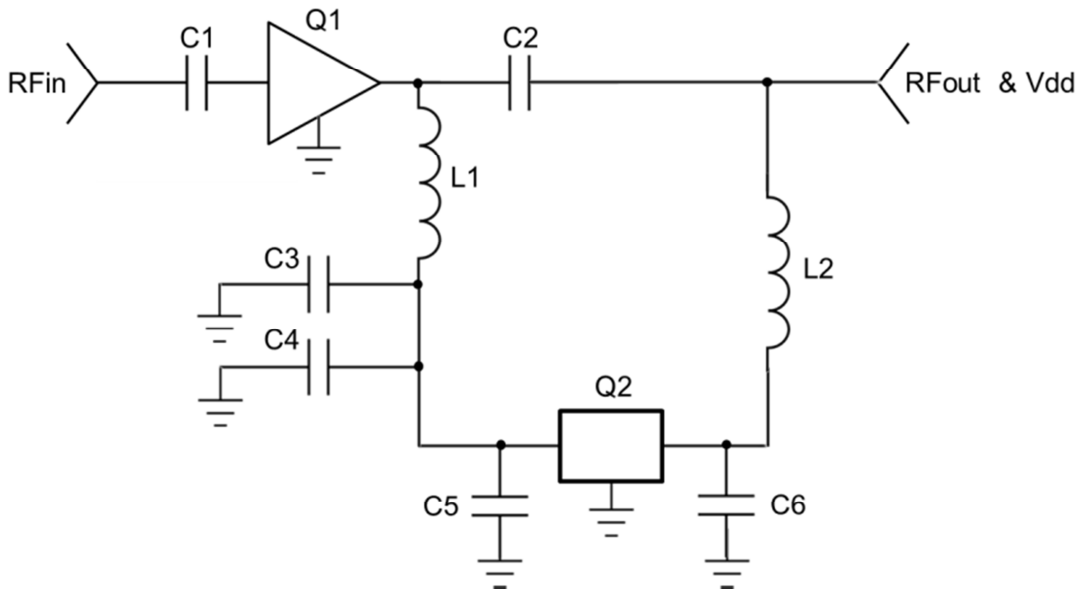


Fig 2. LNA schematic

Table 2. Bill of materials

C1	Murata, 150pF, 0603, GRM1885C1H151JA01
C2	Murata, 150pF, 0603, GRM1885C1H151JA01
C3	Murata, 150pF, 0603, GRM1885C1H151JA01
C4	Murata, 100nF, 0603, GRM188R71H104KA93
C5	AVX, 4.7uF, Case B, TAJB475K010RNJ
C6	AVX, 1uF, Case B, TAJB105K035RNJ
L1	Coilcraft, 1.2uF, 1008LS-122XJLB
L2	Minicircuits, RF choke, ADCH-80A
Q1	RFMD, MMIC Amplifier, SPF-5122Z
Q2	National Semiconductors, LDO regulator, LP2950

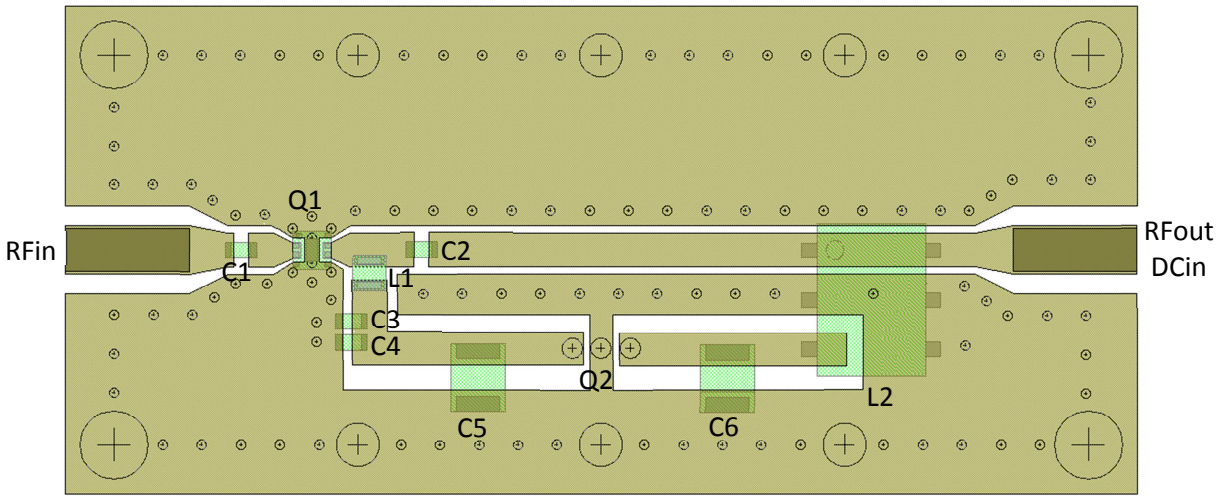


Fig 3. Top view layout (Q2 is mounted on the bottom layer)

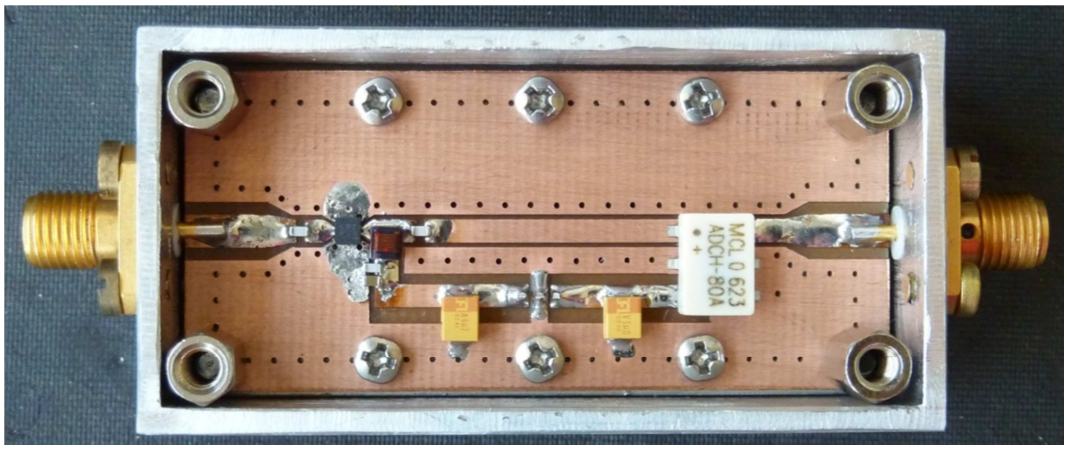


Fig 4. Picture of the LNA for test and measurements

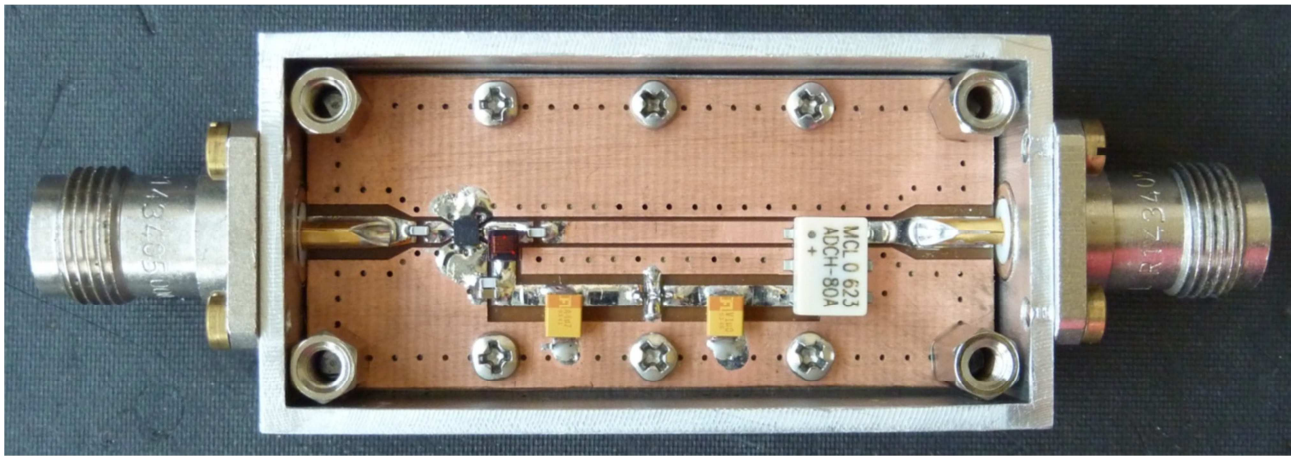


Fig 5. Picture of the LNA to be mounted inside the antenna

N.B: the Female TNC input connectors have been replaced with Male TNC connectors in Perth after the workshop.

Measurements

S-parameters

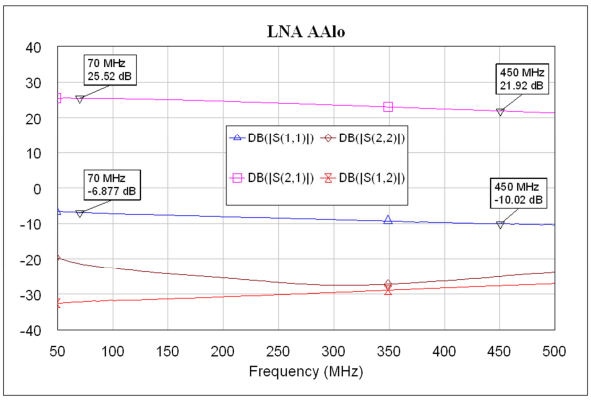


Fig 6. S-parameters (AAlo band)

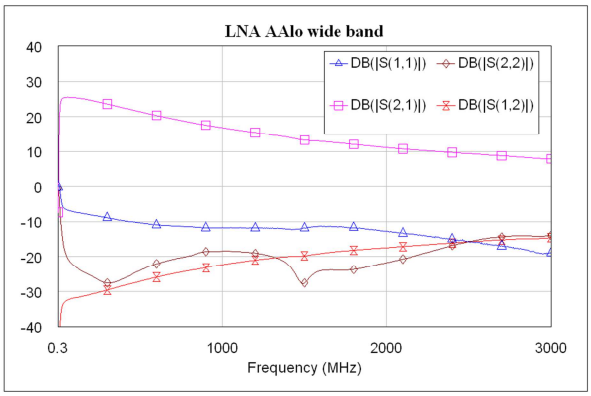


Fig 7. S-parameters (wide band)

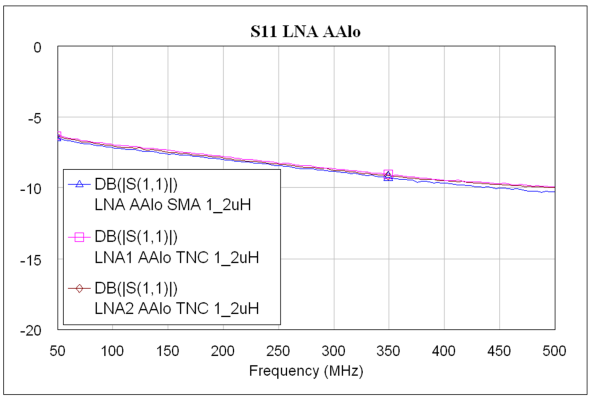


Fig 8. Input matching

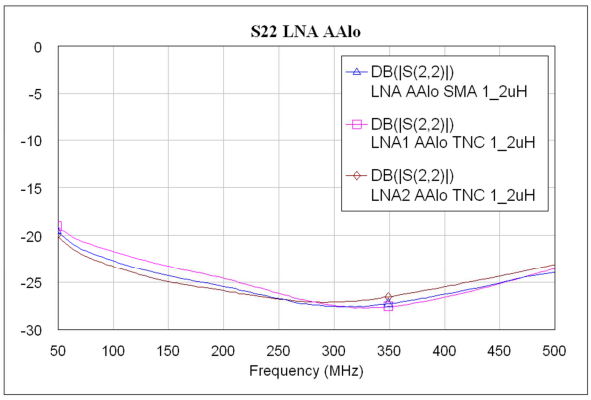


Fig 9. Output matching

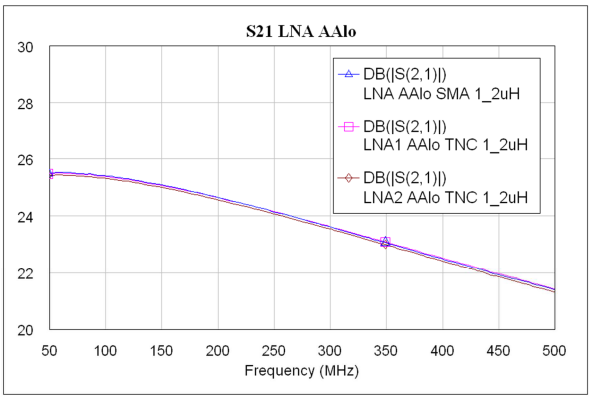


Fig 10. Insertion gain

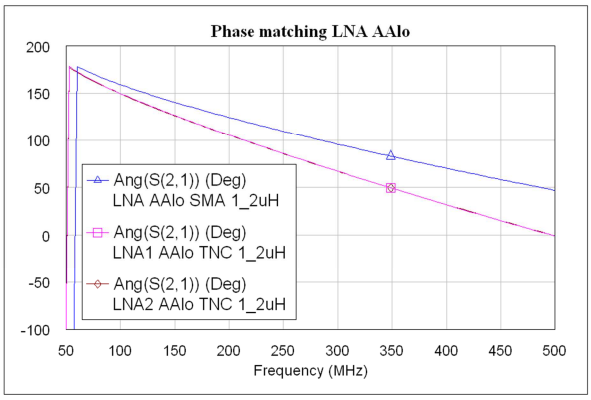


Fig 11. Insertion phase

Measurement notes: HP8753C VNA with HP85047 test set
Full 2 port Calibration
LNA Bias from port 2 of the VNA

Noise

Table 3. Noise measurement

Freq (MHz)	Te (K)	NF (dB)
60	33.71	0.48
110	28.17	0.40
160	27.19	0.39
210	27.27	0.39
260	27.76	0.40
310	28.47	0.41
360	29.58	0.42
410	31.03	0.44
460	32.19	0.46

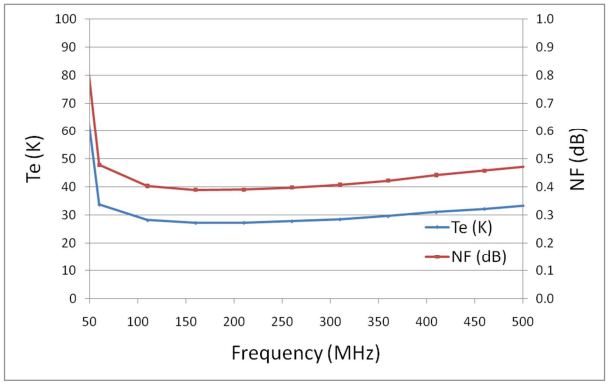


Fig 12. Noise measurement

Measurement notes: Noise measurement with Hot/Cold load by Maury
NF meter HP8970B
Tamb=297.4K
Reference plane = IN Connector
Estimated measurement accuracy = +/- 3.5K (with 346A noise source = +/-12K)

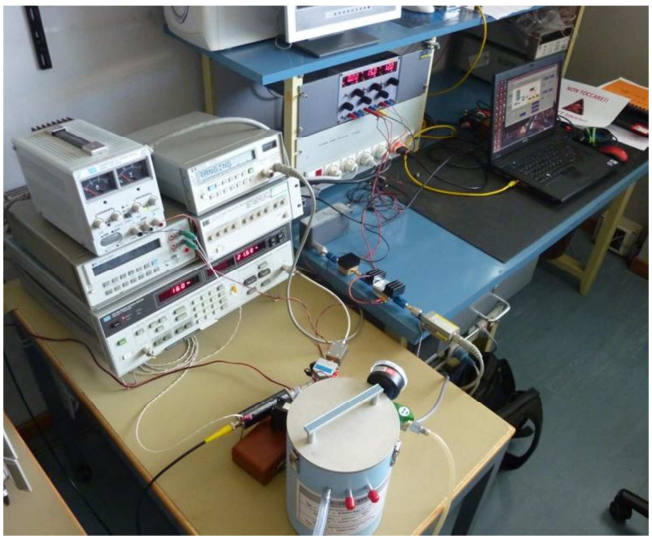


Fig 13. Noise figure measurement set up

Dynamic range

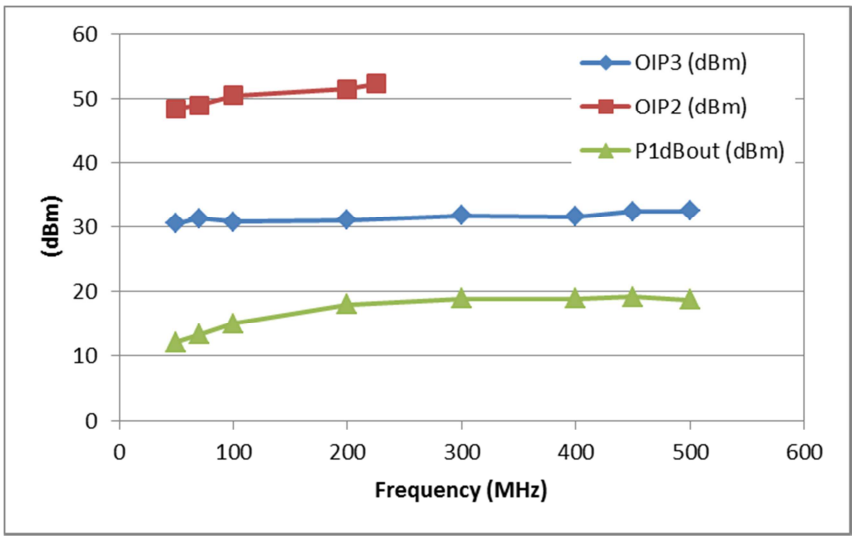


Fig 14. Dynamic range measurements

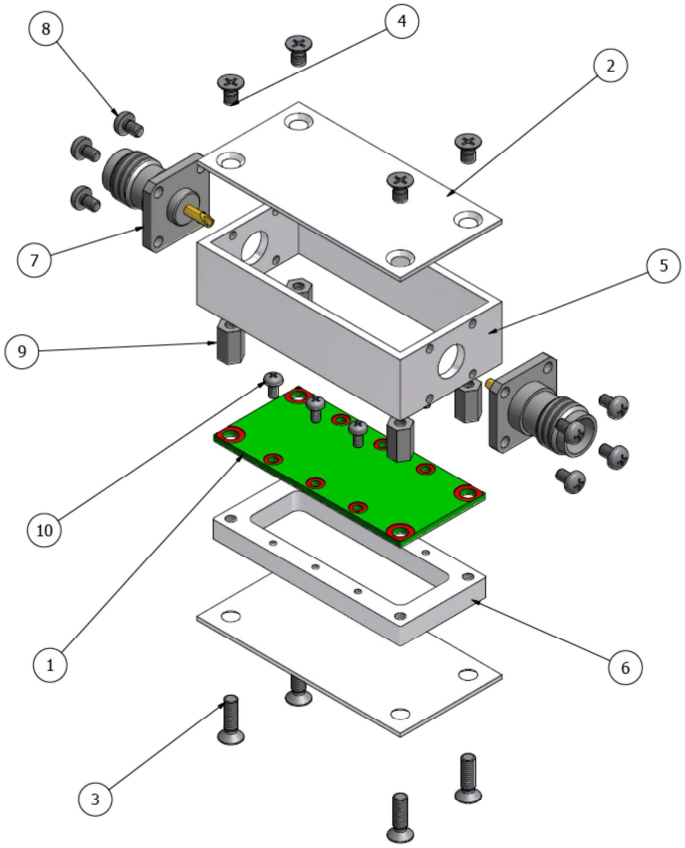
Table 4. P1dB and IP3 measurements

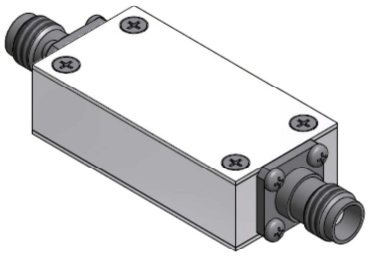
Freq (MHz)	P1dBout (dBm)	OIP3 (dBm)
50	12.1	30.5
70	13.2	31.3
100	14.9	30.8
200	17.9	31.0
300	18.8	31.7
400	18.8	31.6
450	19.1	32.4
500	18.7	32.4

Table 5. IP2 measurement

Freq (MHz)	OIP2 (dBm)
50	48.39
70	48.91
100	50.49
200	51.46
225	52.25

Mechanical assembly



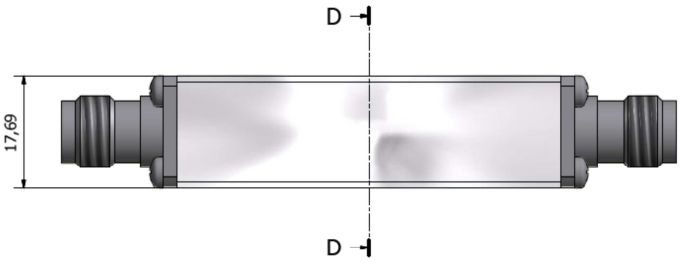


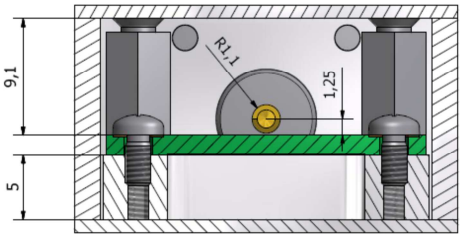
PART LIST			
ITEM	QT	PART NUMBER	DESCRIPTION
1	1	AALO.LNA.00	LNA board
2	2	AALO.LNA.01	LNA_Cover_plate_2
3	4	ISO 7046-1 - M3 x 10 - 4.8 - H	Recessed countersunk flat head screws
4	4	ISO 7046-1 - M3 x 5 - 4.8 - H	Recessed countersunk flat head screws
5	1	AALO.LNA.03	LNA_box_3
6	1	AALO.LNA.02	LNA_mounting_board_2
7	2	R143 405 000	TNC female connector Radiall
8	8	ISO 7045 - M2,5 x 4 - 4.8 - H	Recessed raised cheese head screws
9	4	Spacer M3 L 08	Spacer M3 L 08 F-F
10	6	ISO 7045 - M2 x 4 - 4.8 - H	Recessed raised cheese head screws

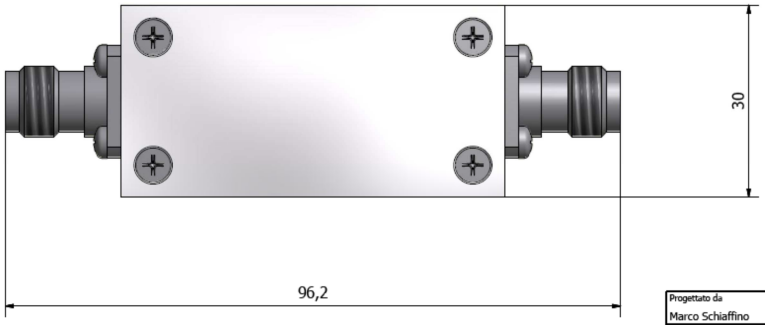
Progettato da	Controllato da	Materiale	Quantità	Data	Scala Dis.	Scala Plt.
Marco Schiaffino				22/06/2011		

INAF Istituto Nazionale di Astrofisica
ISTITUTO DI RADIOASTRONOMIA
Radiotelescopi di Medicina
Via Fiorentina 3508/B - 40059 MEDICINA (BO)
Tel. 0516965823 Fax. 0516965810

Denominazione			
LNA box			
Codice		Edizione	Foglio
AALO.LNA		03	1 / 7







Progettato da	Controllato da	Materiale	Quantità	Data	Scala Dis.	Scala Plt.
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Denominazione			
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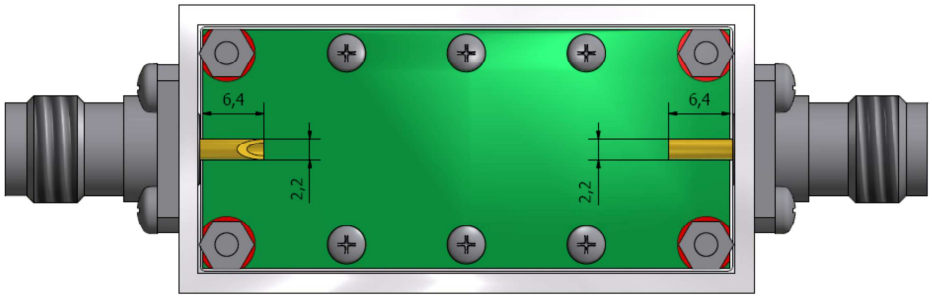

Progettato da	Controllato da	Materiale	Quantità	Data	Scala Dis.	Scala Plt.
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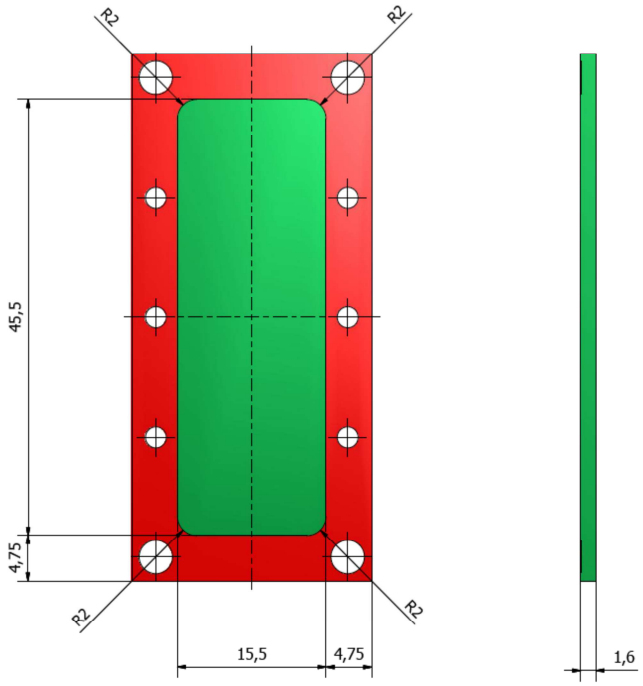
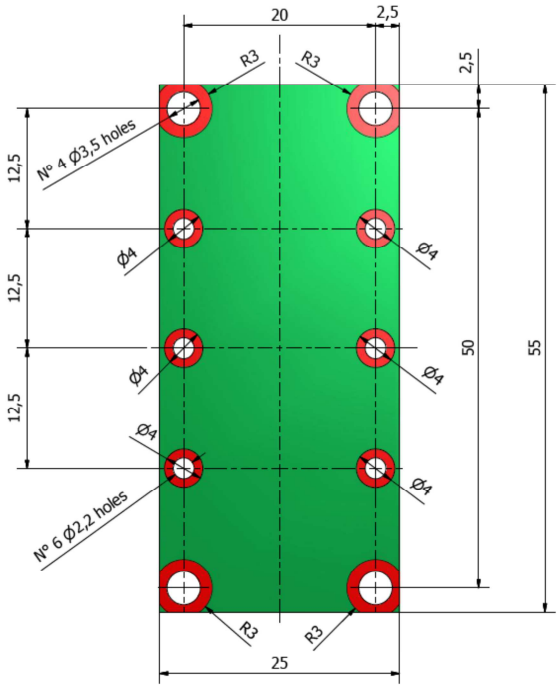
Denominazione			
LNA box			
Codice		Edizione	Foglio
AALO.LNA		03	3 / 7

Red surfaces are in contact with the box





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Denominazione			
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Codice		Edizione	Foglio
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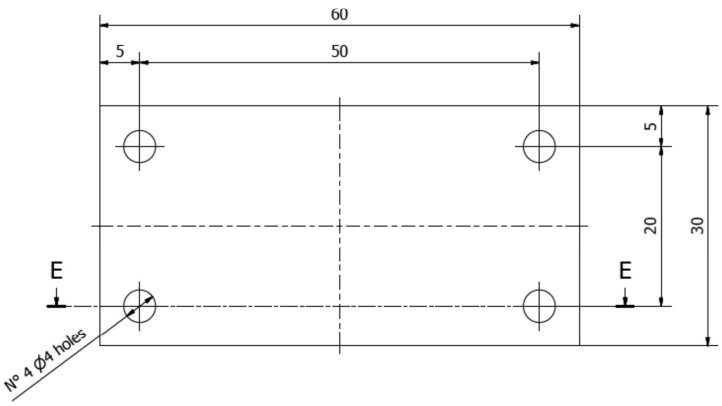

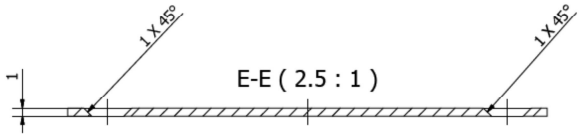

Progettato da	Controllato da	Materiale	Quantità	Data	Scala Dis.	Scala Plt.
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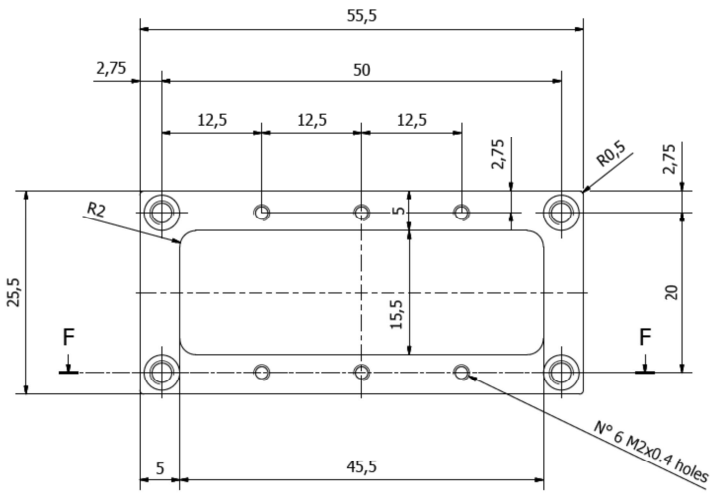

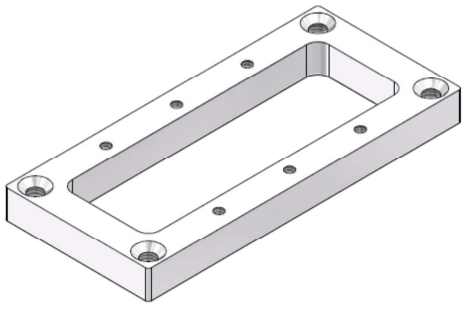

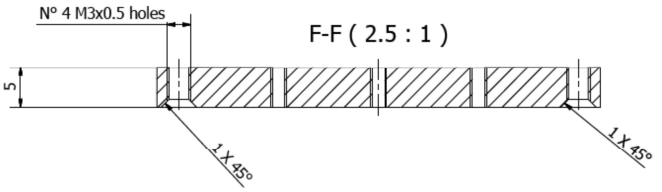

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Denominazione			
LNA_mounting_board_2			
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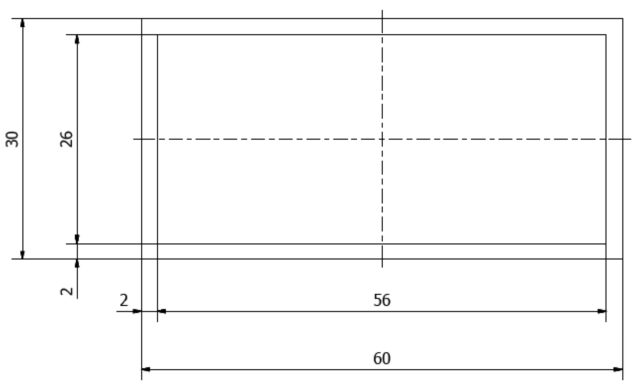

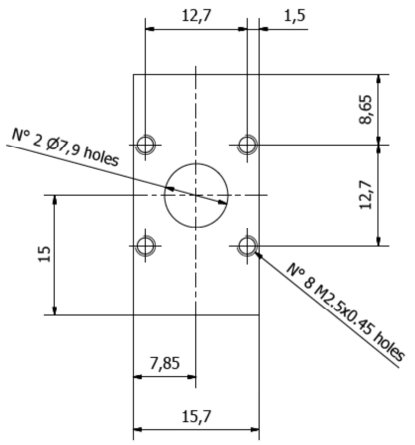

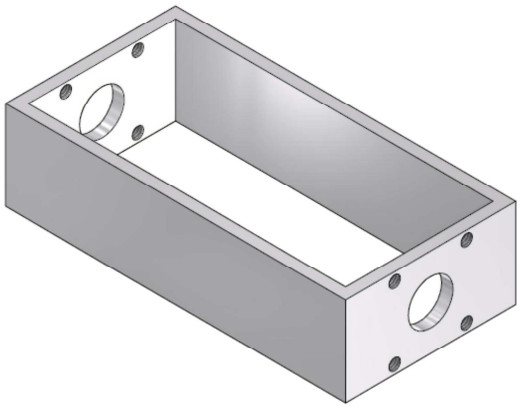

Progettato da	Controllato da	Materiale	Quantità	Data	Scala Dis.	Scala Plt.
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Radiotelescopi di Medicina
Via Fiorentina 3508/B - 40059 MEDICINA (BO)
Tel. 0516965823 Fax. 0516965810

Denominazione: LNA_box_3

Codice: AALO.LNA.03 | Edizione: 03 | Foglio: 7 / 7

AAVS0 LNA production

To perform the AAVS0 test in mid-2012, all the Vivaldi antennas had to be equipped with their LNA, one for each polarisation. Aim of the test were the measurement of the pattern of an isolated and an embedded element in a small array, in our case 3x3 and/or 4x4. For that reason 32 new LNA have been produced with some slight differences respect to the Perth version.

Fig 15. LNA for AAVS tests.

In particular the RF connectors have been changed to TNC male at the input and SMA female at the output. Moreover a feed through has been introduced in order to allow the LNA to be supplied by an external battery which is inserted, along with the LNA, in the wings of the antenna. This is useful when test with all the antennas loaded with the respective LNA has to be performed and when fibre optic links are used instead of coax cables to transport the RF signals from the antennas to the receivers.

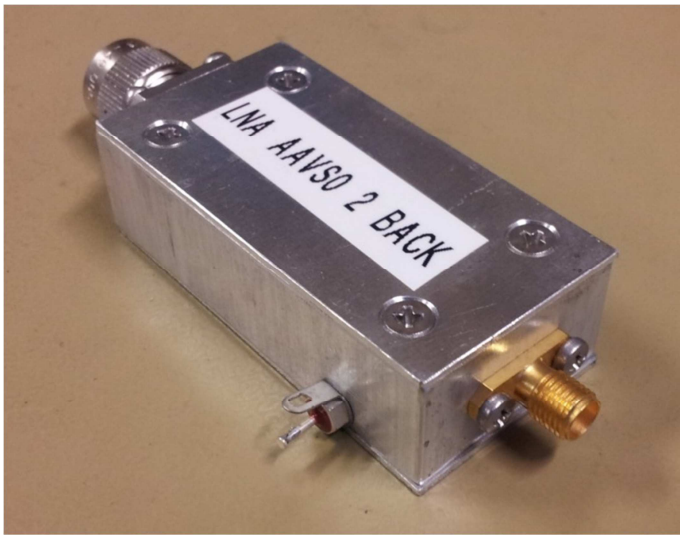
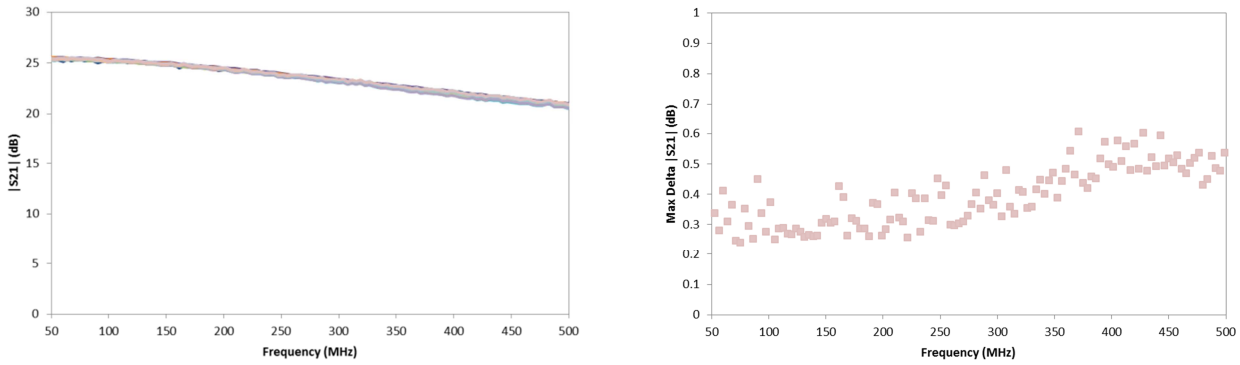


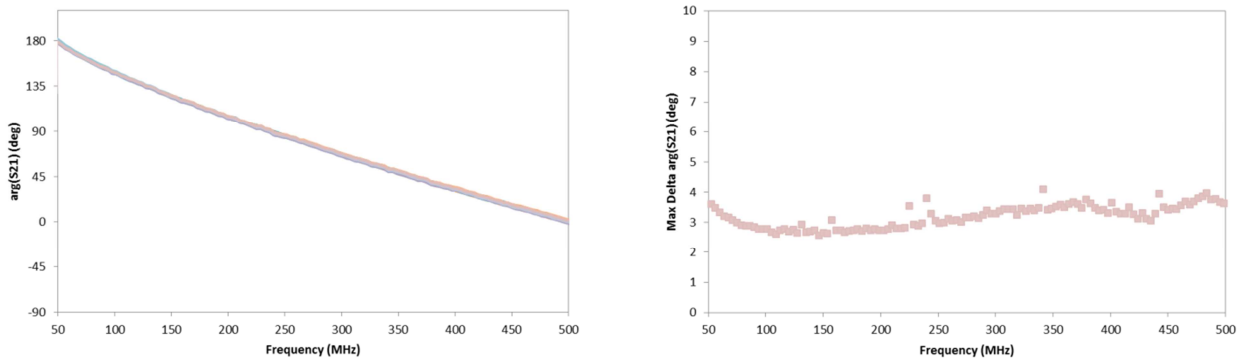
Fig 16. LNA modifications: feed through and SMA output connector

AAVS0 LNA S-parameters uniformity measurement



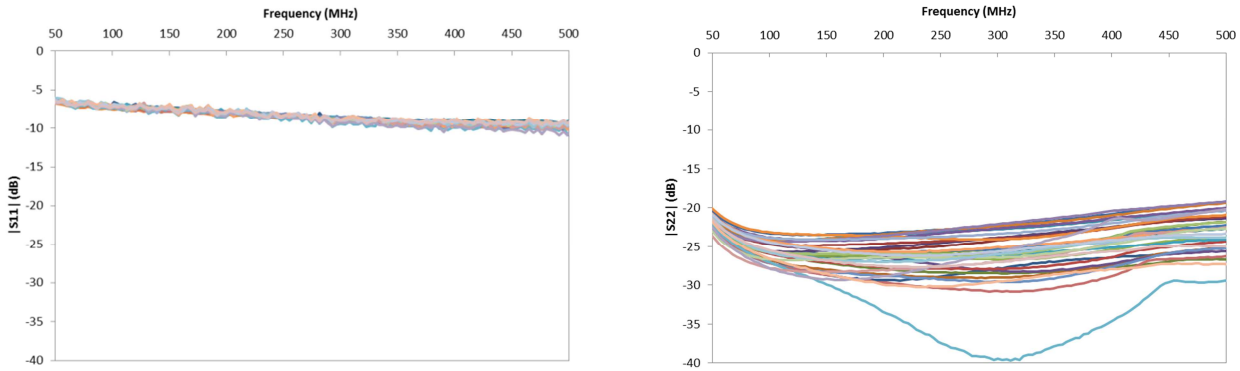
(a) (b)

Fig 17. Insertion gain (a) and max difference (b) among all measurements



(a) (b)

Fig 18. Insertion phase (a) and max difference (b) among all measurements



(a) (b)

Fig 19. Input and Output matching