MWA DUAL LNA (REV2) Measurements

Hamdi Mani, Judd Bowman

***Abstract*—The MWA Dual LNA (REV2) was measured on the Low Frequency Radio astronomy Lab using state of the art test equipment. S-parameters of the amplifier were measured; gain and impedance were computed as well as common mode rejection ratio (CMRR). The coupling between the input of one LNA to the output of the second LNA was measured.**

***Index Terms*—radio telescope arrays, Dipole antennas, differential, common and mixed mode s-parameters, Low noise amplifiers, noise measurement, differential amplifier, VHF band instrumentation.**

I. Introduction

The MWA LNA is connected to the dipole antenna using a twin lead balanced transmission line. The LNA has a balanced input and an un-balanced 50 ohm output. The DC bias is injected from the output connector using a bias tee. The design is a single stage matched amplifier stages made of the Avago ATF35143 enhancement mode low noise HEMT [1]. The transistor is a surface mount component; the board is made on FR4 material. The dual LNA has 2 differential LNAs each one of them has its own ground plane and the 2 LNAs are separated by a metal layer

II. DIFFERENTIAL AMPLIFIER IMPLEMENTATIONS

There are few ways to realize differential amplifier:

1. 2 single ended matched amplifier stages followed by a 180deg ,3dB coupler (or balun)
2. 2 single ended matched amplifier stages preceded by a 180deg ,3dB coupler (or balun)
3. "Long tail pair": same circuit topology than what is commonly used in operational amplifier design: 2 matched transistors with common source.

The circuit topology used for the MWA LNA is: 2matched single ended amplifier stage combined in and out of phase using a transformer into a single ended output.

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III. S-PARAMETER MEASUREMENT

The amplifier has a 50 Ohm SMA as RF output/ DC input. The input consisted of microstrip lines on FR4 board where the 2 twin leads connecting to the antenna are soldered.
The twin lead connection cannot be used to connect to test equipment to do the measurement; it was also found that the impedance of the twin leads change when their shape is changed.
Low profile SMA Connectors are mounted on the input of each LNA. The center pin of the SMA is soldered to the microstrip input lines and the jacket of the SMA is soldered to the GND layer (solder mask was removed). This transition can be thought of as a vertical microstrip to coax transition. Fig1 shows the amplifier with the SMA connectors.

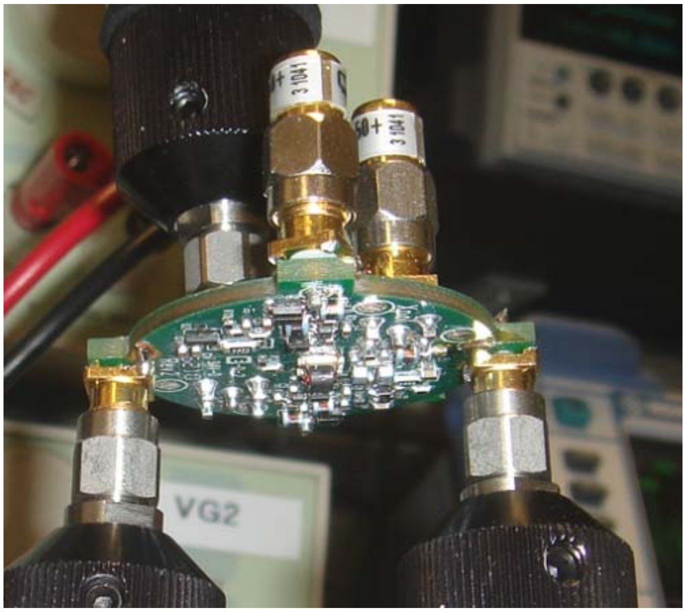


Fig1. MWA Dual LNA with SMA connectors soldered to the input and connected to the VNA. All ports not connected to the VNA are terminated with 50 Ohm load.

Each LNA is 2-port network composed of a balanced input port and a single ended output port 2.
To measure the S-parameters of the LNA, it can be considered as a 3 single ended port network. The balanced input port is made of ports 1 and 2 as shown on Fig2.
Measuring the s parameters of the LNA is reduced to measuring the 9 s-parameters of the 3 single ended networks.

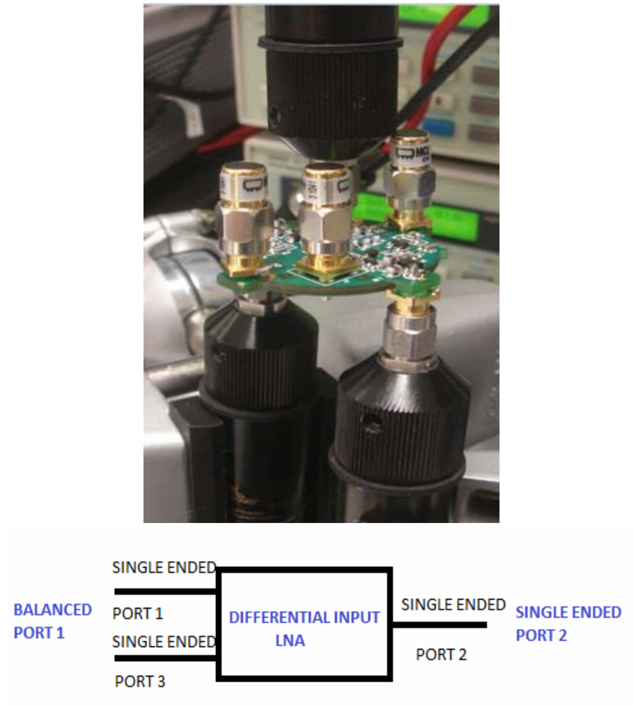


Fig2.The LNA as a 3 single ended port network.

The R&S ZVA24 4Port VNA was used with these settings:

- Start Frequency: 10MHz
- Stop Frequency: 1000MHz
- Frequency Points: 991 points.
- Test Port Power: -40dBm (for the 3 Ports)
- IF Bandwidth: 100Hz (Lower IF BW at lower frequencies)
- Averaging: 10 sweeps
- Calibration: SOLT using HP 85052B Cal Kit
- Internal bias tees of the VNA were used to bias the LNA
- Single ended ports 1 and 3 is logical port 1 (balanced), single ended port 2 is logical port2 (unbalanced)

The length of SMA connector is 12mm in Air (measured) and was corrected for.
The LNA was biased at 5.5V, 120mA total. The voltage measured on the output SMA 5V (0.5v voltage drop across the bias tee), the gate to source voltage for both transistors is 0.5V and the drain to source voltage is 2.8V.

The single ended S11 for both inputs of POLX is shown on the smith chart of Fig3. S11 of input1 and input2 are almost equal on the 50-300MHz band; the amplifier pair is well balanced.
The single ended gains of the 2 amplifier pairs are shown on Fig4 and the single ended reverse gain is shown on Fig6
The isolation (or coupling) between the 2 single ended inputs is about 20dB.

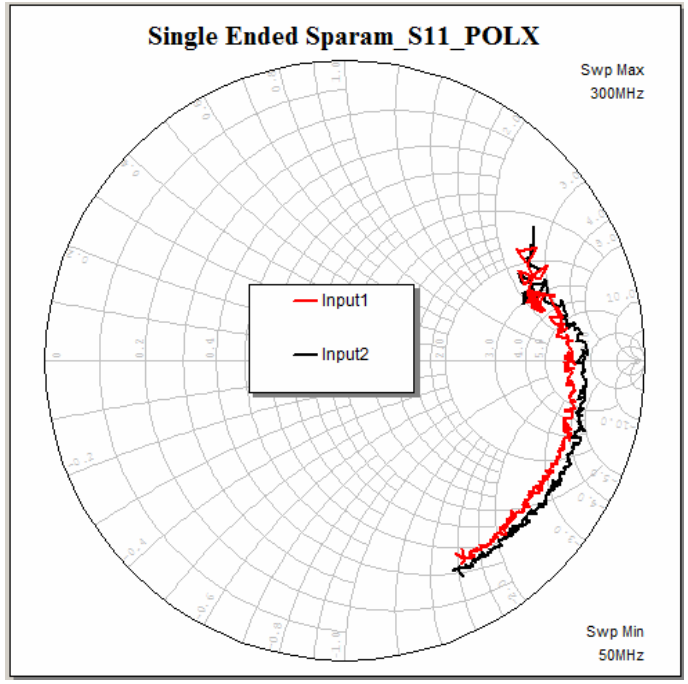


Fig3. Measured Single Ended S11(2 single ended inputs of the POLX LNA)

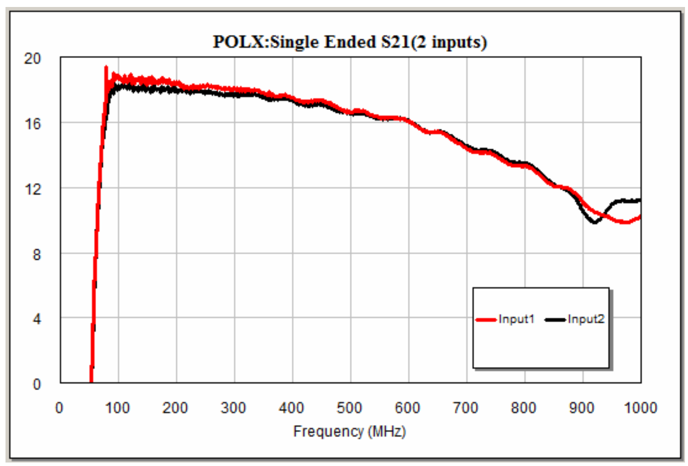


Fig4. Measured single ended gain of the amplifier pair showing good balance.

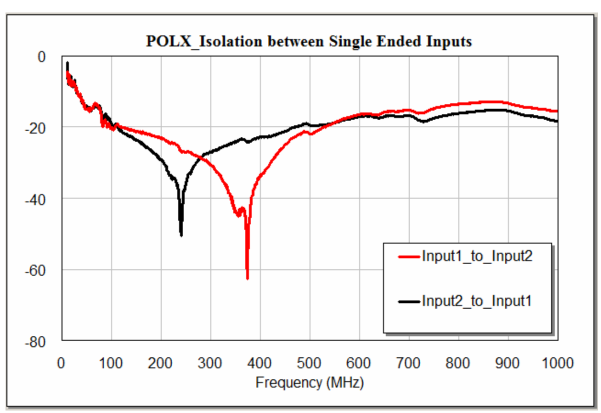


Fig5. Measured isolation between the 2 single ended input ports; the output (port 3) is terminated with a 50 Ohm load.

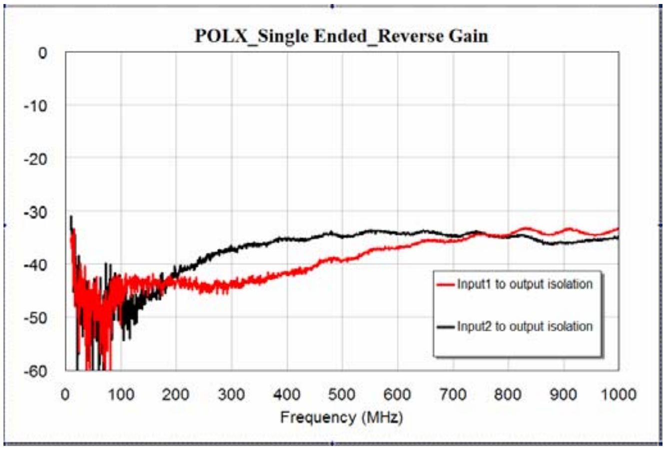
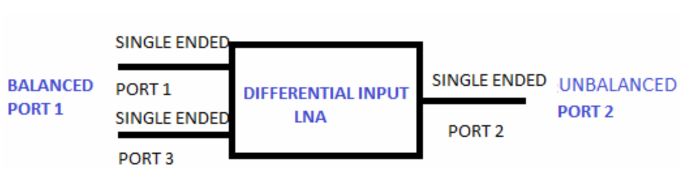


Fig6. Single ended reverse gain of the amplifier pair.

The measured single ended s-parameters need to be converted to differential, common and mixed mode s-parameters to describe the behavior of the LNA to different mode signals. Fig7. Shows the needed s-parameters for this network.

			STIMULUS		
			LOGICAL PORT 1		LOGICAL PORT 2
			DIFF MODE	COM MODE	SE
RESPONSE	LOGICAL PORT 1	DIFF MODE	Sdd11	Sdc11	Sds12
		COM MODE	Scd11	Scc11	Scs12
	LOGICAL PORT 2	SE	Ssd21	Ssc21	Sss22

Fig7. Mixed mode s-parameters for a 2 port network where: Port1 is balanced and port 2 is single ended. The network is fully characterized by these 9 parameters.



The different sparameters are computed in Microwave office (MWO) [4] design environment using the “MMCONV” mixed mode converter function built into MWO.

Fig8 shows the circuit used to compute the differential mode input reflection coefficient Sdd11 and the actual result (Fig9).

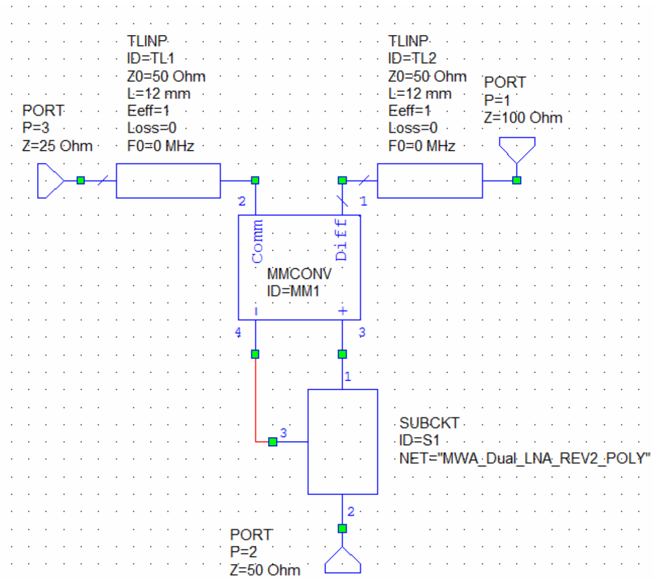


Fig8.Circuit used to compute differential, common and mixed mode sparameters in MWO.

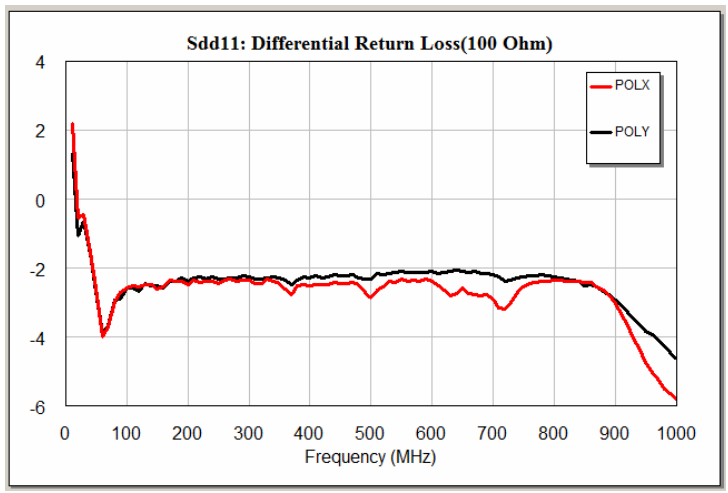


Fig9. Sdd11 relative to 100 Ohm computed from measured single ended s-parameters.

Fig9 is the input return loss of the LNA relative to 100 Ohm impedance.

Fig10. Is the return loss relative to 200 Ohm impedance.

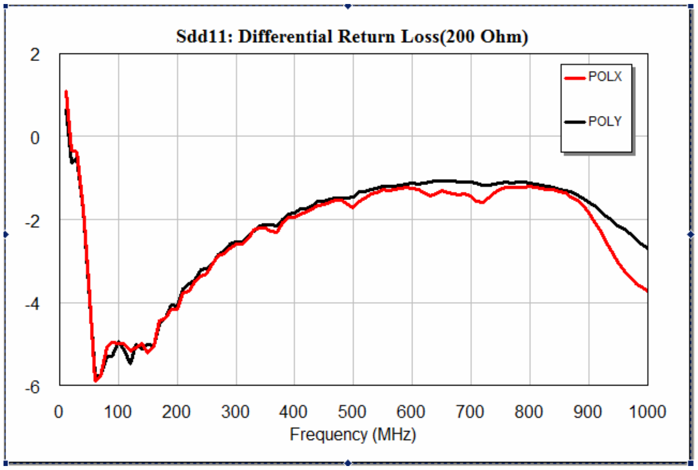


Fig10. Sdd11 relative to 200 Ohm impedance.

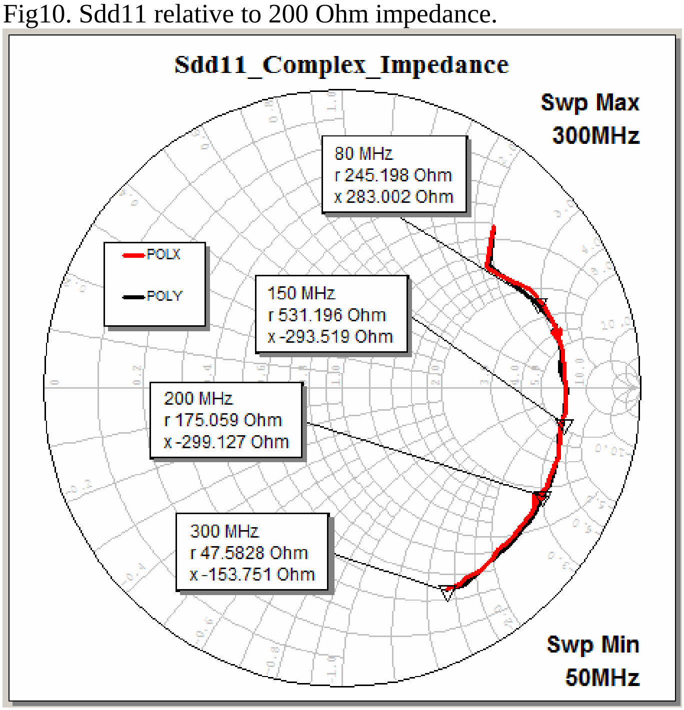


Fig11. Complex Sdd11 of the LNA on a Smith Chart. The markers display de-normalized impedance.

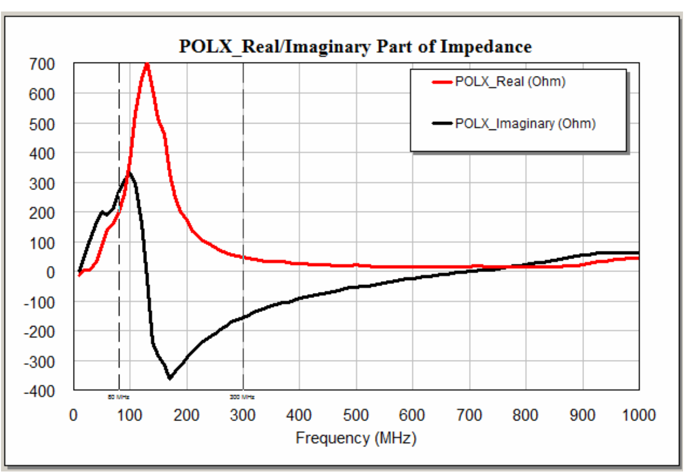


Fig12. Real and Imaginary parts of the differential input impedance

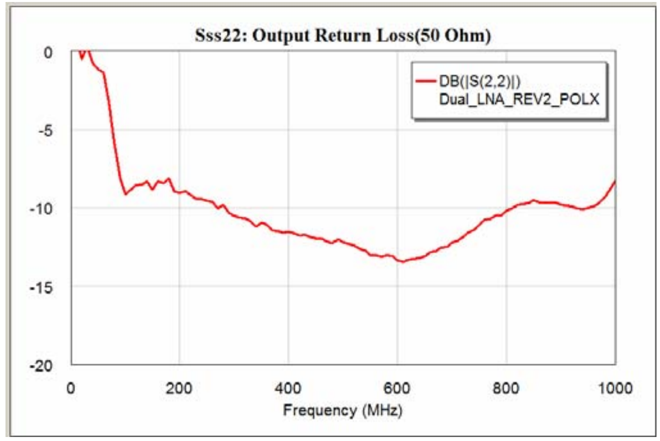


Fig13. Return loss of the LNA output showing good impedance match to 50 Ohm.

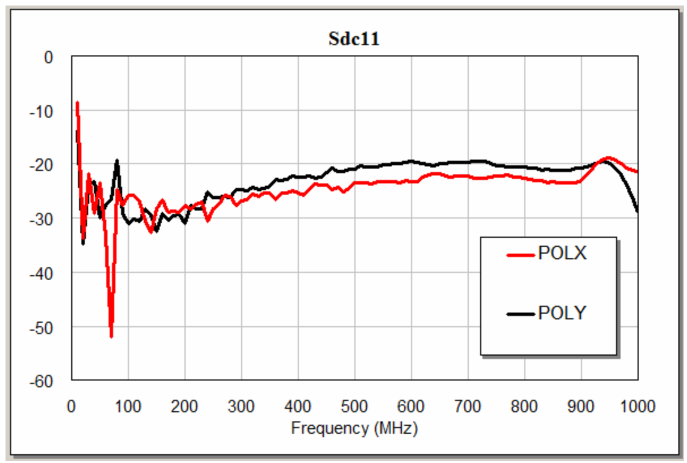


Fig14. Commom mode to differential conversion parameter showing low conversion factor.

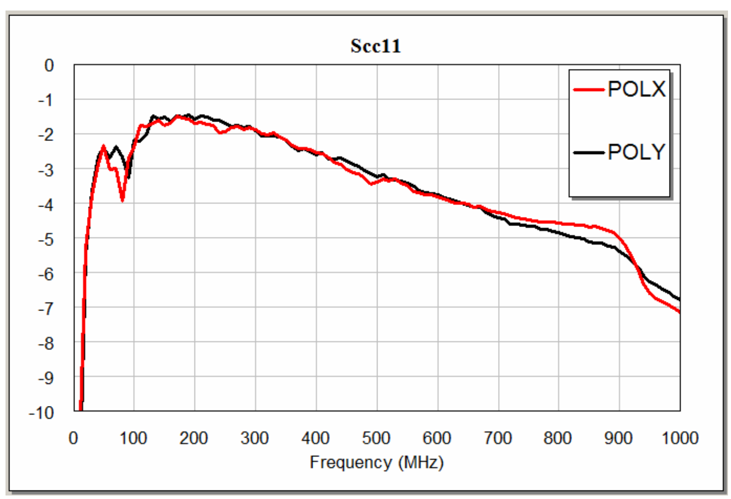


Fig15. Common mode input reflection coefficient (relative to 25 Ohm) showing reflective rejection of common mode signals at the input of the LNA.

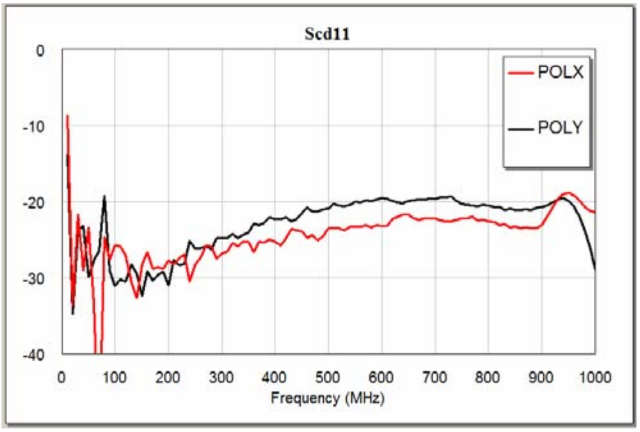


Fig16. Differential to commom mode conversion parameter showing low conversion factor.(low EMI generation)

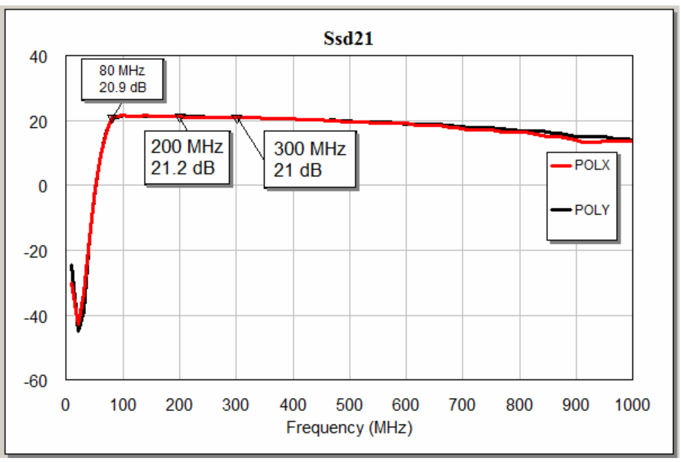


Fig17. Differential mode Gain Ssd21

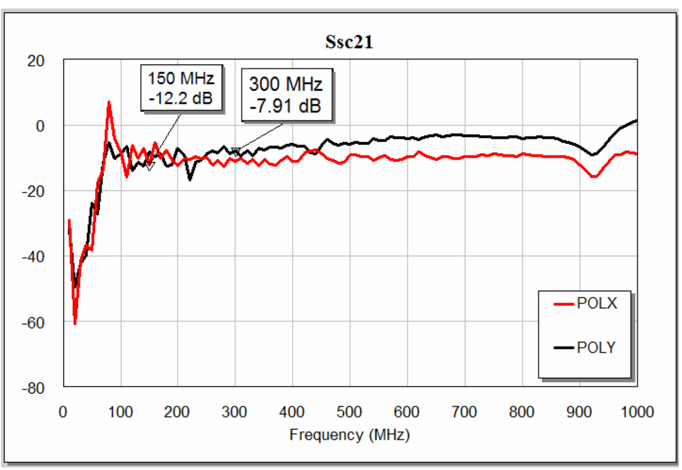


Fig18. Ssc21 common mode noise at balanced port1 transferred to single ended port2

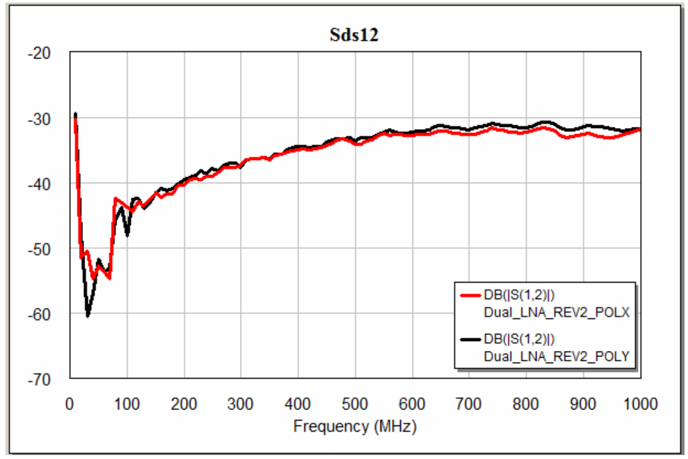


Fig19. Reverse Differential Gain showing good isolation.

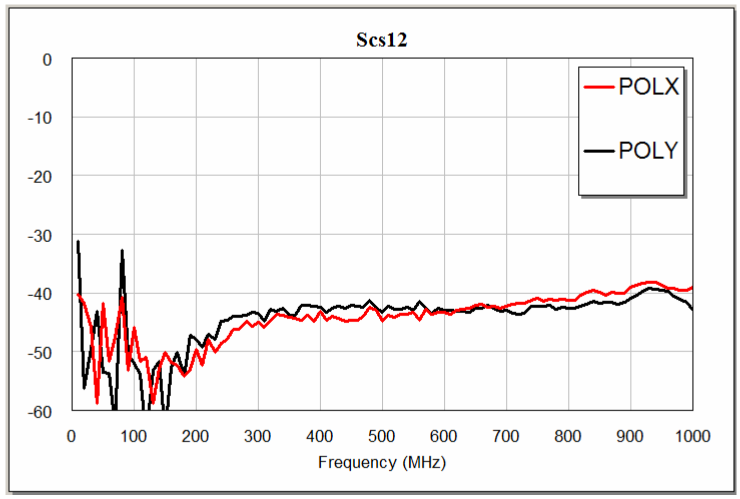


Fig20. Reverse common mode Gain showing good isolation.

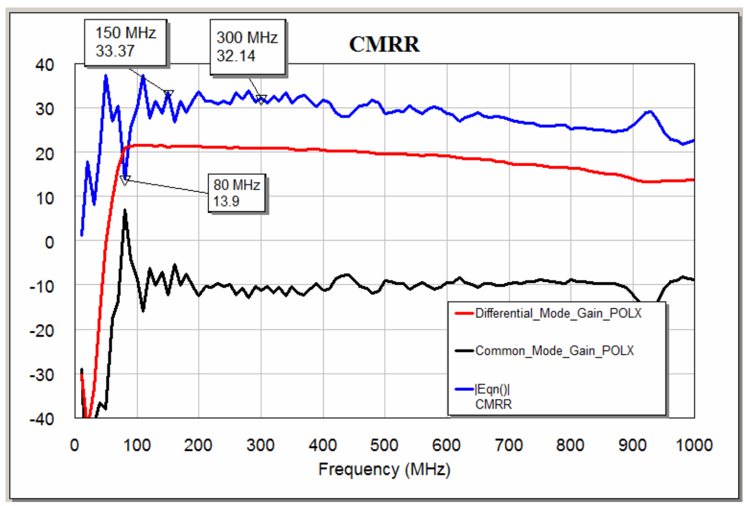


Fig21. Common Mode Rejection Ratio (CMRR) shown with the Differential and Common mode Gains.

The Common mode rejection ratio is the ratio of the differential to common mode gains of the amplifier [5]:
CMRR [dB] =20 x log10(| Ssd21 / Scd21|)
or:

CMRR[dB] = Ssd21[dB] – Scd21[dB]

IV. Cross Talk Between the 2 LNAs of the Dual LNA

The Input of LNAY was connected to balanced Port1of the VNA and the output of LNAX was connected to unbalanced port2 of the VNA. All the other ports were terminated with 50 Ohm loads and the both LNAs are powered. The transmission was measured from X to Y and from Y to X.

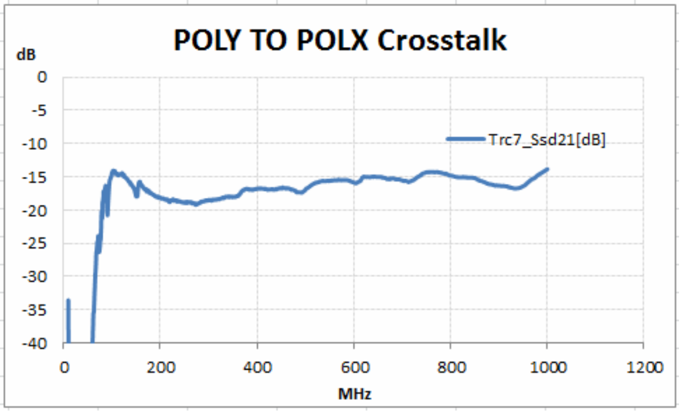


Fig22. Y to X cross talk

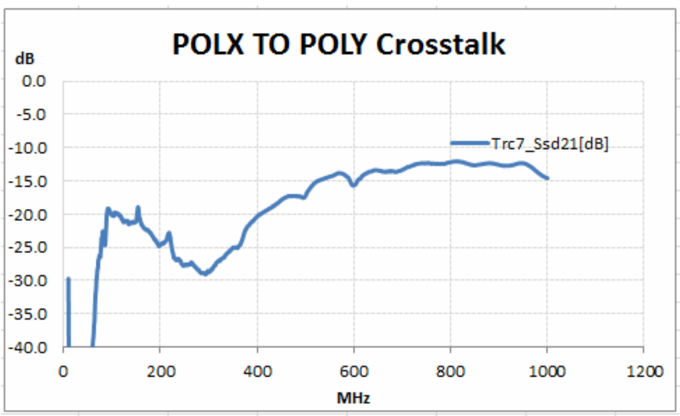


Fig23. X to Y cross talk

V. Noise Measurement

The noise of the LNA was measured on a shielded box to avoid RFI pick up. A calibrated noise source was used as a noise generator. The Y-factor method was used.
A balun and a 10dB Pad of known loss were inserted between the noise source and the LNA .
Fig24. Shows the setup used for the measurement.
Fig25. Shows the noise corrected for the loss of the cables, 10dB Pad and the balun(red curve)

The noise source used is the HP346C (14dB ENR) and the spectrum analyzer is the HP8563E.
A postamplifier was used between the LNA and the spectrum analyzer to boost the SNR at the input of the spectrum analyzer.

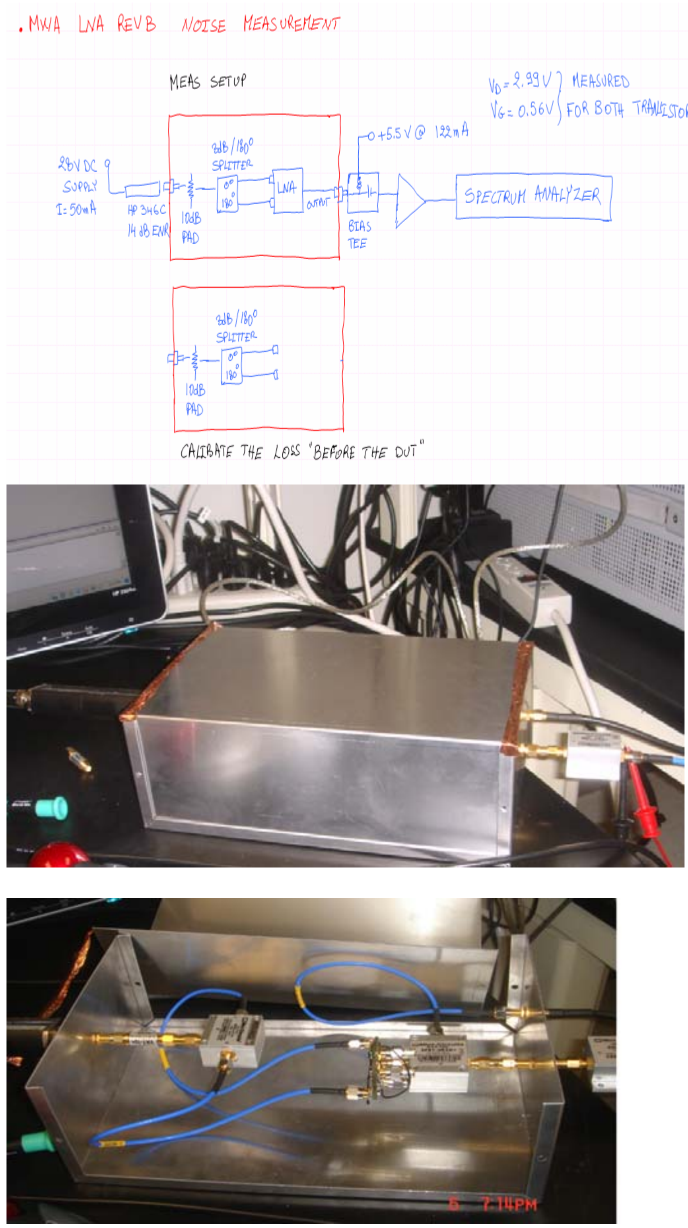


Fig24.Noise measurement setup.

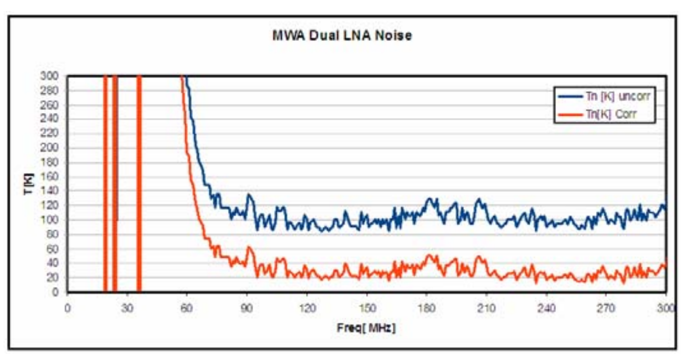


Fig25. Noise of the MWA dual LNA.

VI. CONCLUSION

VII. ACCOMPANYING FILES

VIII. ACKNOLWEGEMENT

IX. REFERENCES

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[4] www.**awrcorp**.com

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