



## HIGH INTERCEPT LOW NOISE AMPLIFIER with GaAs pHEMT MMIC

By: Goran Popovic AD61W

### Abstract

#### Design requirements for LNA:

Simple construction, small size, no tune, low noise, wide band, high linearity, unconditional stable, high reverse isolations, frequency coverage from VHF up to L band. Resistance to large input signals up to 27 dBm without destruction.

The LNA was utilized with SPF-5122Z GaAs pHEMT MMIC device, from RFMD.

### Stability first

Stability is important because it is affecting overall performance of LNA. High gain, poor return loss and reverse isolation, together with feedback are major cause for oscillations.

Feedback may be conducted through a bias or radiated inside cavity.

Oscillations may occur even unnoticed, or suppressed. They will appear as modulated carrier, spurious or mixing products together with desired signal on high frequencies.

Stability of amplifier should be provided over all frequencies.

LNA should be carefully designed to suppress conducted and radiated feedback.

New MMIC are spatially combined with its intrinsically low VSWR, and

High reverse isolation  $S_{12}$ ,  $> -30\text{dB}$  at low frequency. They are unconditional stable with any source or load impedances, whose reflection magnitude is less than 1.

By definition, unconditional stable amplifier is the one with  $\Gamma_{\text{Source}} < 1$  and  $\Gamma_{\text{load}} < 1$  for all source and load impedances.

Conditional stable amplifier, or potentially unstable amplifier has it same

Definition as above except it would be stable only with certain source and load impedances. Stability may be checked with simulation software (Rollet factor  $K > 1$ ) or tested with phase shifter and different termination resistors.

### MMIC LNA description

MMIC simplified LNA design. MMIC is already matched to 50 Ohms.

No additional matching networks are needed. Bias circuit is done internally, and it is temperature compensated.

This LNA PCB was designed for multi purpose. Few configurations are possible.

Low noise amplifier with external supply needs only few capacitors, C1, C7, C8, C9 single inductor L4, and 5V regulator with C11 and C12, and R2, R3.

This configuration has low noise figure. MMIC has lower noise at 3V, but Linearity and gain is higher at 5V supply. Selection is done with R1 and R2 resistors. On 3V supply MMIC current is 58 mA and on 5V is 90 mA.

Additional input matching network will not improve noise figure, because every additional component will only increase losses. To achieve low noise LNA, input-coupling capacitor C1 should have low reactance. Capacitor series resonance frequency should be close to the LNA operational frequency, where his insertion loss is low.

Improved input matching is done with L1 and C2 network.

Series inductor improves input RL but increases NF. This option is useful for driver amplifier application where good input return loss is needed.

70CM LNA with 2M Notch filter was done with L2 and C3 network. Two meter signal is attenuated  $>30\text{dB}$ , and return loss is improved. NF is slightly higher.

See simulation and measurement plots.

Negative feedback network, C4, L3, R1 provide flat gain up to 2.4GHz and better return loss. This is convenient for wide band applications, but on the cost of higher noise figure, and IP. The small inductor 1 to 2nH in the feedback circuits improves a gain and RL at the high frequency.

This inductor may be replaced it with 0 Ohm resistor because the trace inductance is sufficient. Bias Tee T1 is used for voltage supply and T2 as wide band drain inductor for flat frequency gain response. Bias tee have no resonances or ripples inside pass band, and it has low insertion loss.

With small modifications and different matching components this board may be used

with ATF-531P8 device, from Avago.

## Application

The MMIC is designed as low noise amplifier for frequencies between 50MHz and 2.4GHz. Because of the size the whole LNA was encapsulated in N connector and supplied thru the Coax cable. External feed thru is available too.

Three pole helix filters are installed at the receiver side, see block diagram.

Attenuator and band pass filter preventing receiver overload, from in and out of band signals. Large input signal, -3dBm drive LNA in P1dB or up to 23dBm at 5V supply. If this is a case limiter or attenuator is needed to protect receiver or mixer.

## Construction

Either very simple design, but construction may not be easy.

The pcb and components are small size. Hand soldering is not recommended.

Easiest way to assemble the board is to put solder paste on the pads, and place all components on the board, under the microscope or magnifying glass, and then re-flow the board in oven.

Those boards were done with inexpensive infrared toaster oven, with temperature control. Exactly temperature profile for soldering, type of solder and procedure is available in Manufacturer App note. See Avago AN-1316.

Finally, re-flow method is faster and gives better performance than hand soldering, But it will require some practice.

Enclosure and PCB ground connection and connectors attachment are directly related to the performance of LNA. Board was fixed with silver epoxy to the bottom of enclosure.

## Results:

Unfortunately, simulation noise parameters and non linear model was not available for this device. Simulations were done with s parameters.

## Bench tests

MDS, Blocking, IP3, Noise figure, Gain, RL, Reverse isolation and compression, tests were performed.

See simulation and measurements plots, and measurement chart

## Field tests

LNA was successfully used in high RFI environment at 70CM with single Yagi antenna during Last Arecibo EME test, from NASA radio club NA6MF

## Conclusion



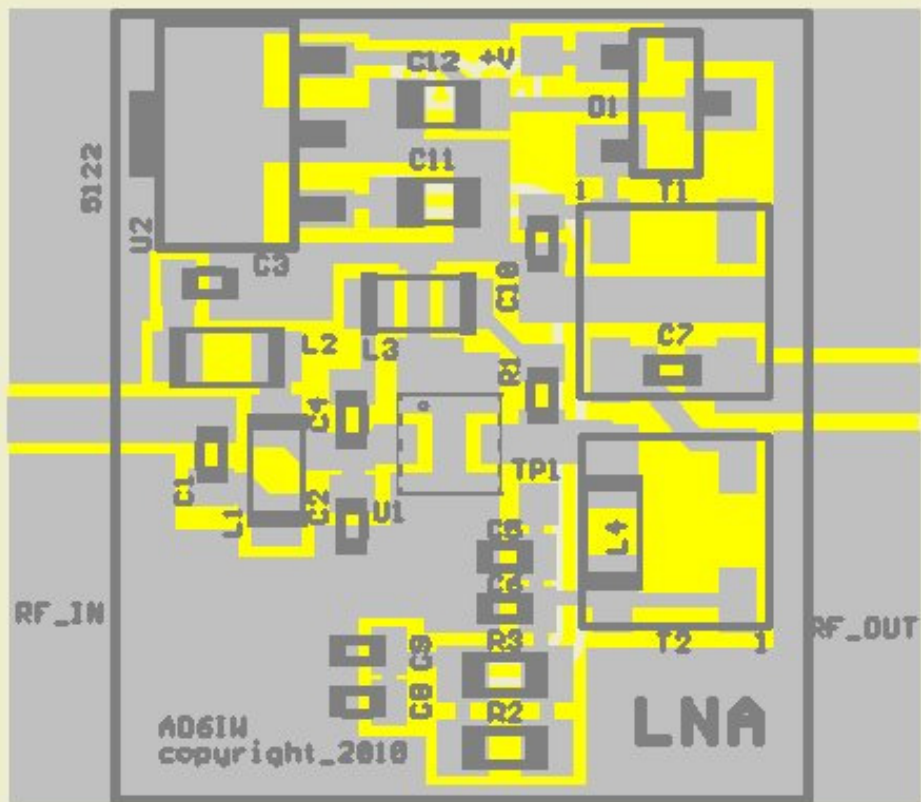


Figure 2

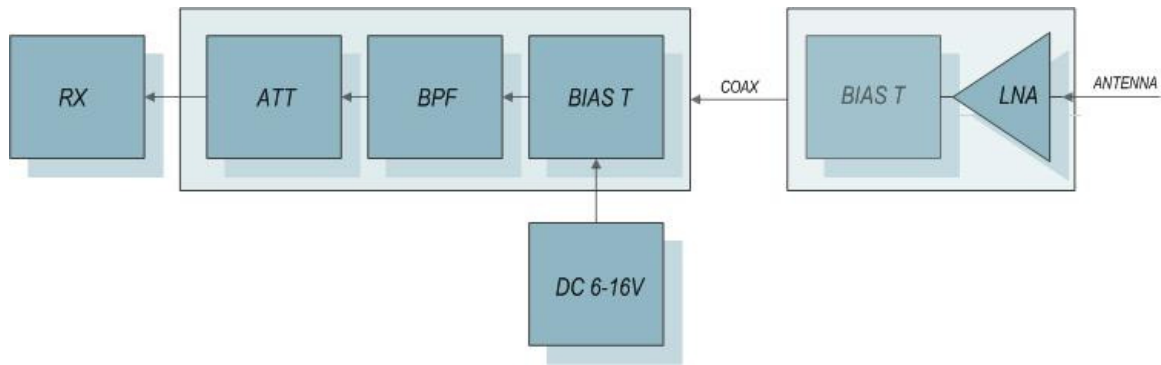


Figure 3

**Low Noise Amplifier part list**

NAME	VALUE	SIZE	REMARKS
C1, C7, C8	100 p	0402	
C9	0.1u	0402	
C10, C12	0.1u / 50V	0603	
C11	4.7u / 6.3V	0603	
R2, R3	68 or zero Ohms	0603	
L4	100nH	LL2012	TKS2388CT TOKO
D1	BAT-54C	SOT-23	Dual diode
U1	SPF-5122Z	QFN 2x2 mm	RMD
U2	TK11650U	SOT-89	5V / 150mA TOKO

**Wide Band with Bias Tee**

T1, T2	TCBT-2R5G+	SMD	Mini Circuits
C4	27 p	0402	
L3	1.8 nH or zero Ohms	0402	Vishay Dale ILC-0402
R1	220	0402	

**2M Notch Filter 30dB**

C1	15 p	0402	
C3	56 p	0402	
L3	22 nH	0805	Toko

**Input matching RL, NF 1.2 dB @ 2M**

C1	18 p	0402	
C2	6.8 p	0402	
L1	120 nH	0805	Toko

**Measured IP 3, Gain and NF vs. Frequency**

Frequency MHz	IP 3 dBm	Gain dB	NF dB
50	30	25.4	0.6
70	30	25.5	0.5
144	31	25.3	0.37
222	32	24.6	0.36
432	33	22.6	0.39
1296	35	15.7	0.62
2304	37	10.3	0.8
Measured at 3V	at 5V > for 1-2dB	at 5V > .5-1dB	at 5V > .1dB

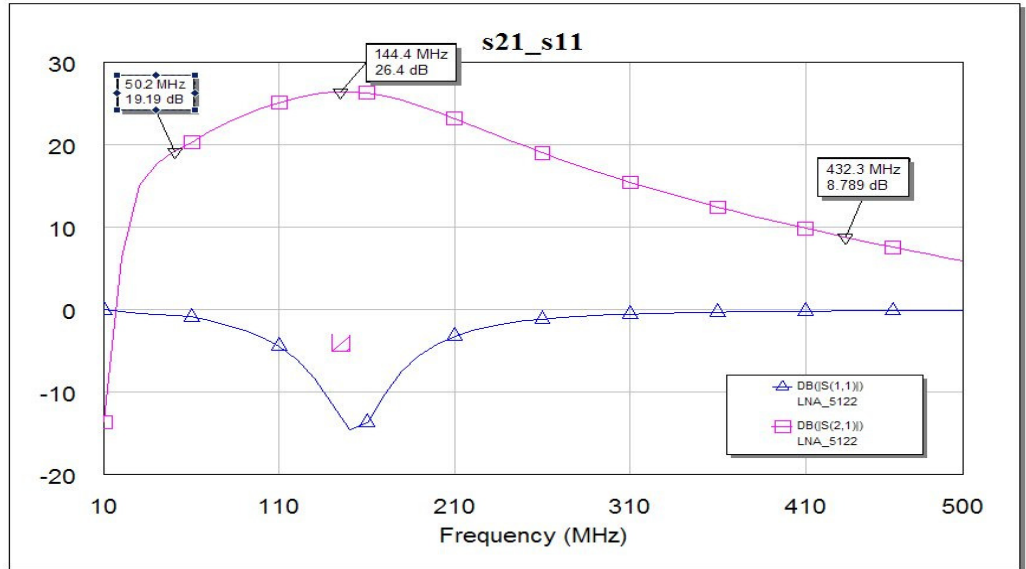


Figure 4



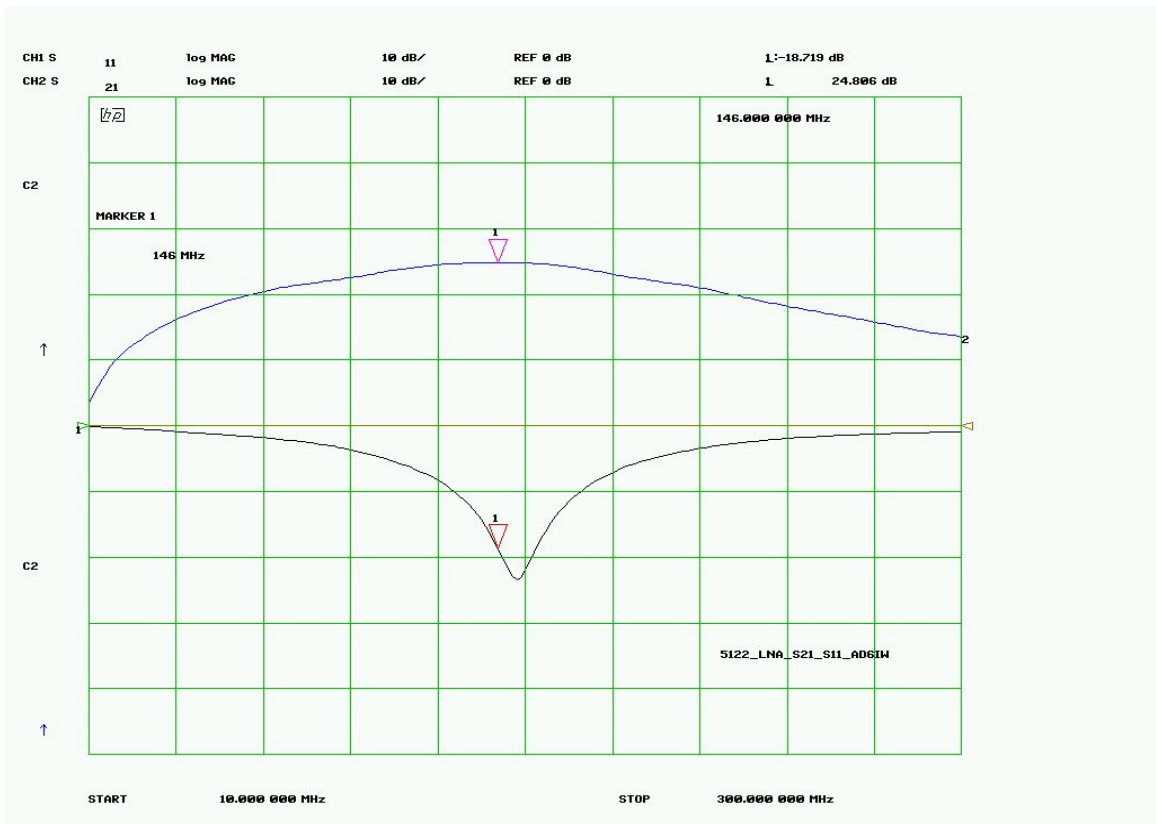


Figure 5

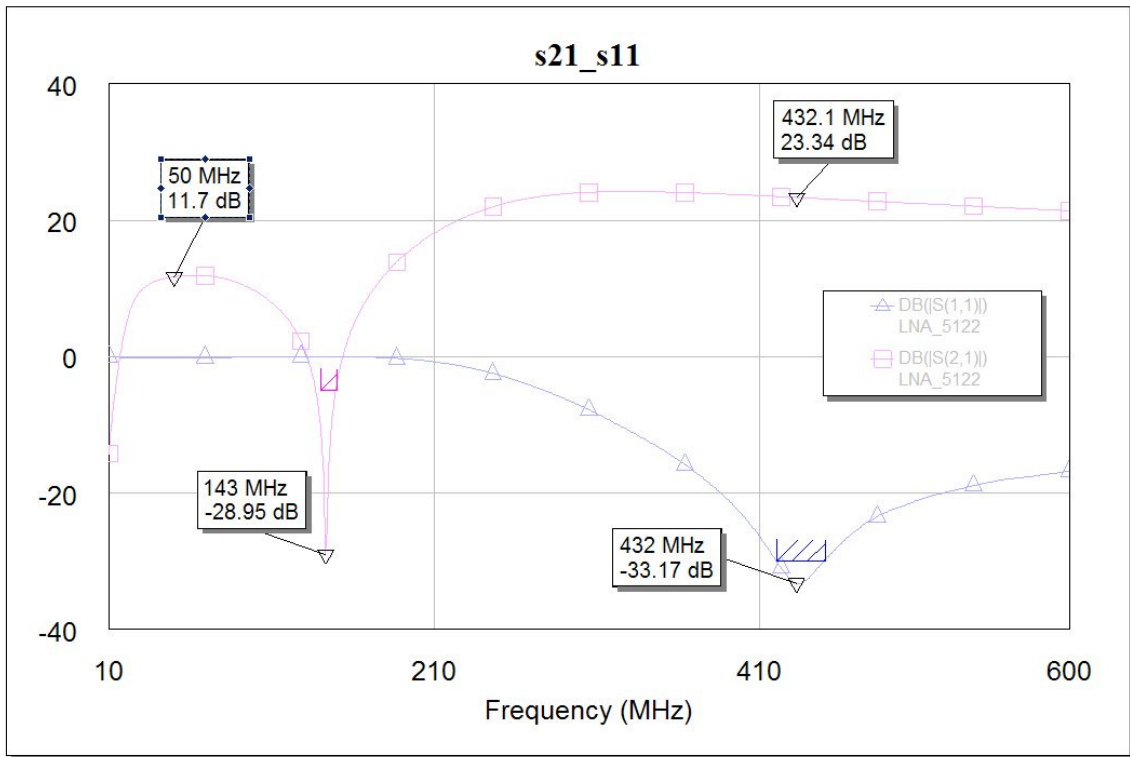


Figure 6

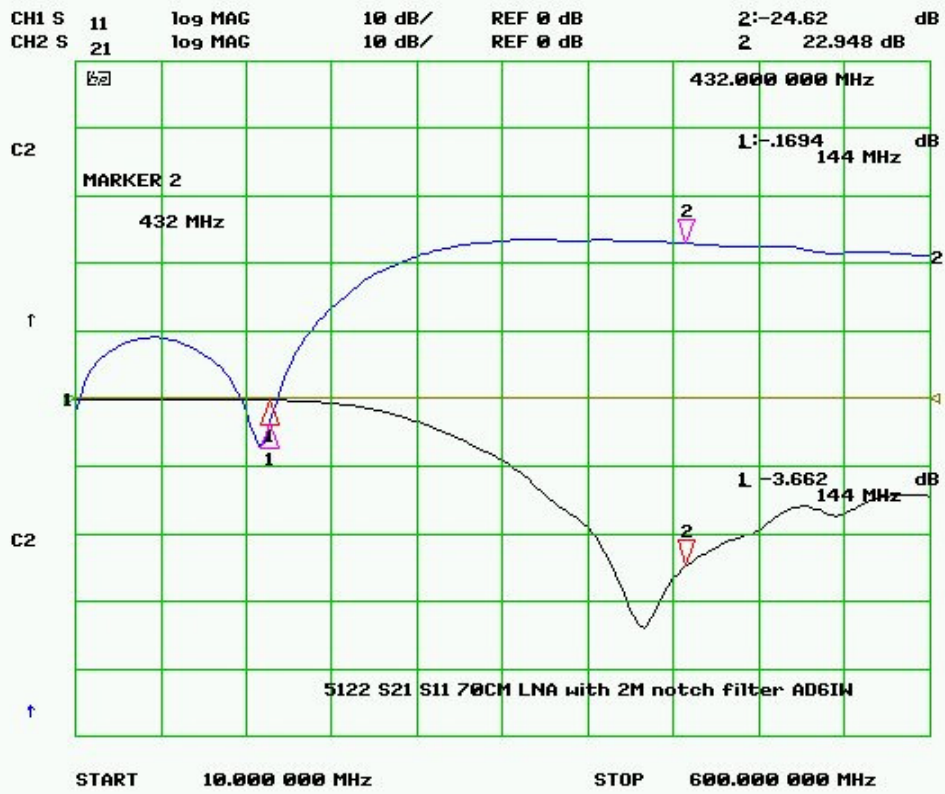


Figure 7

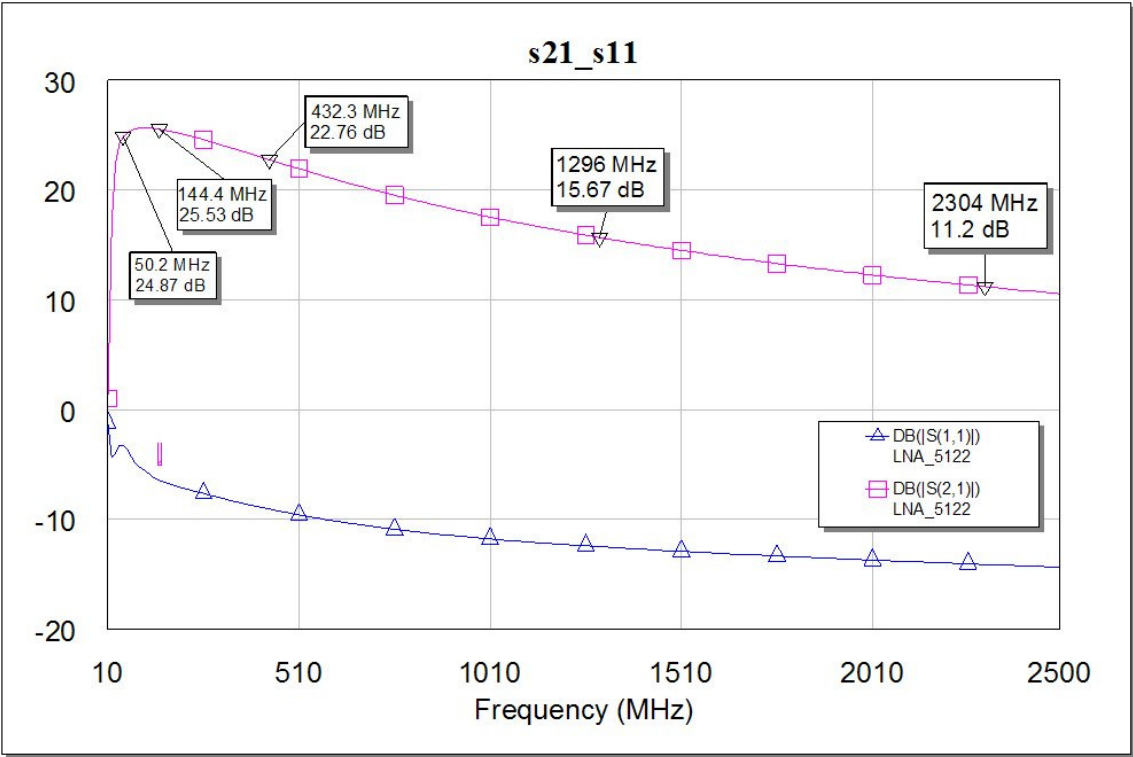


Figure 8

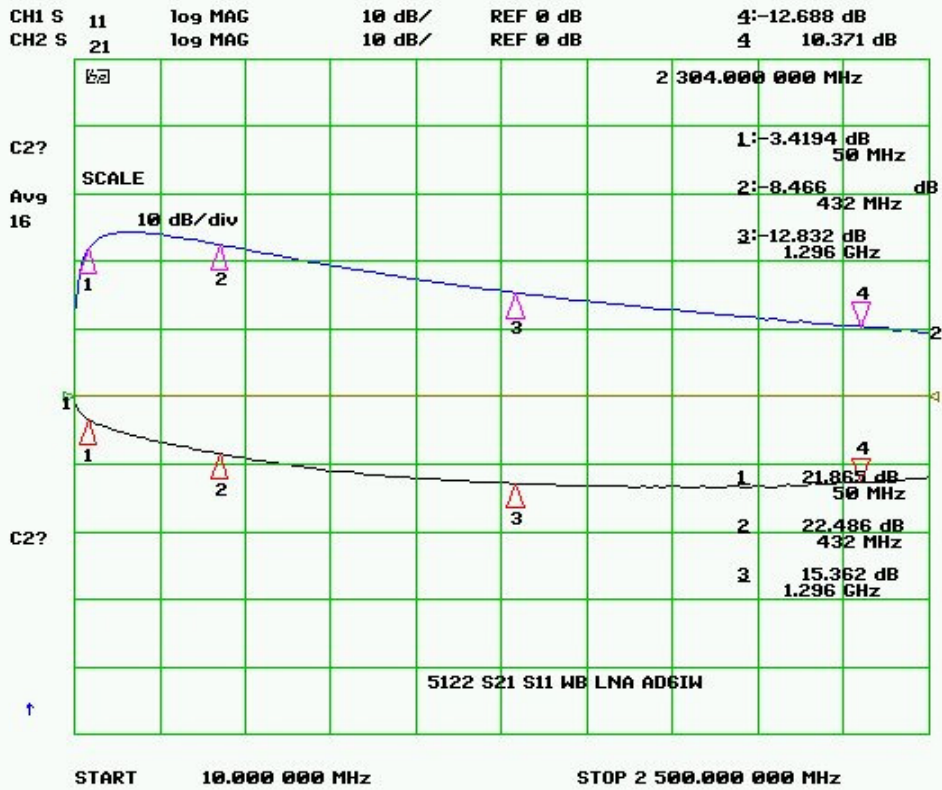
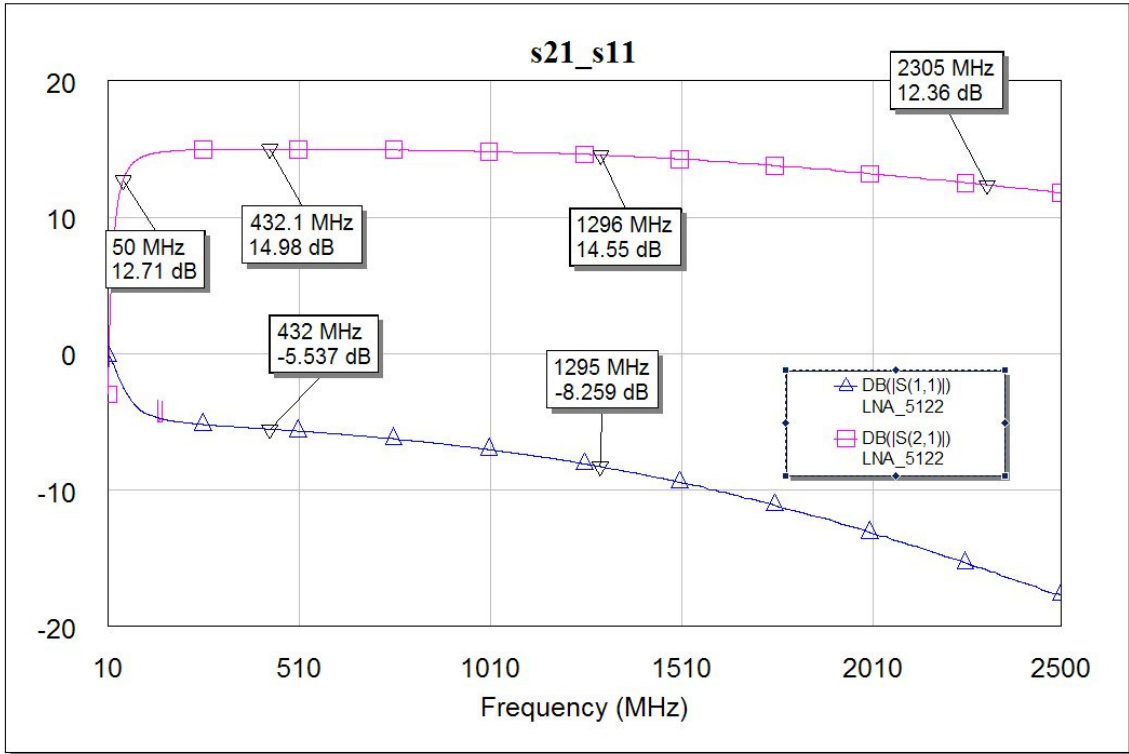


Figure 9



**Figure 10**

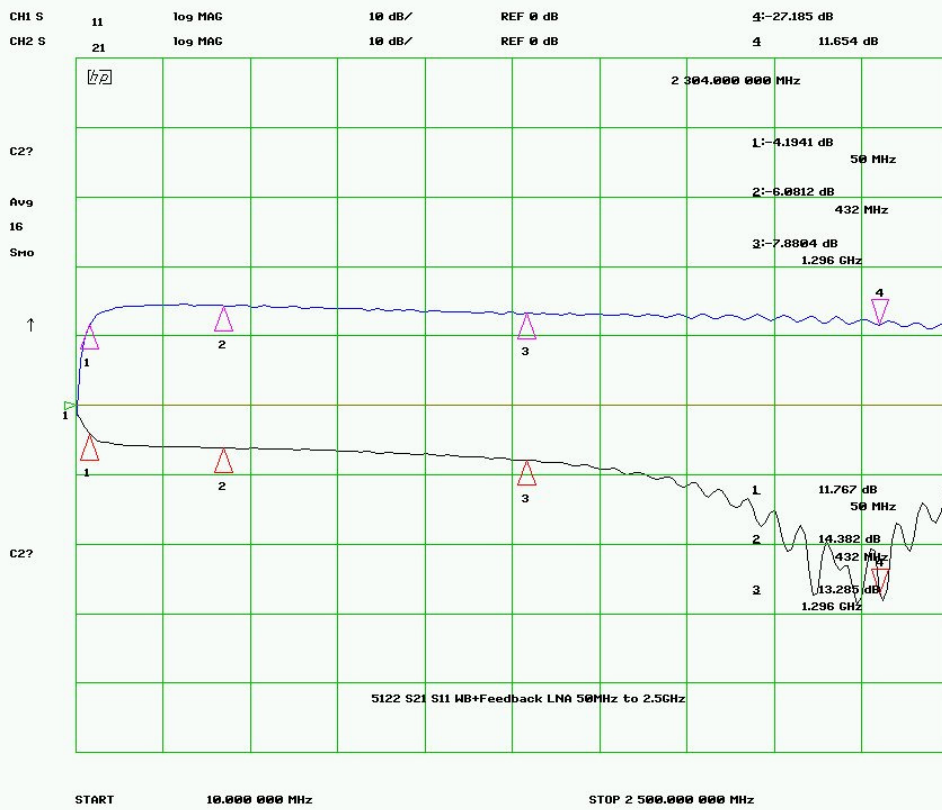


Figure 11

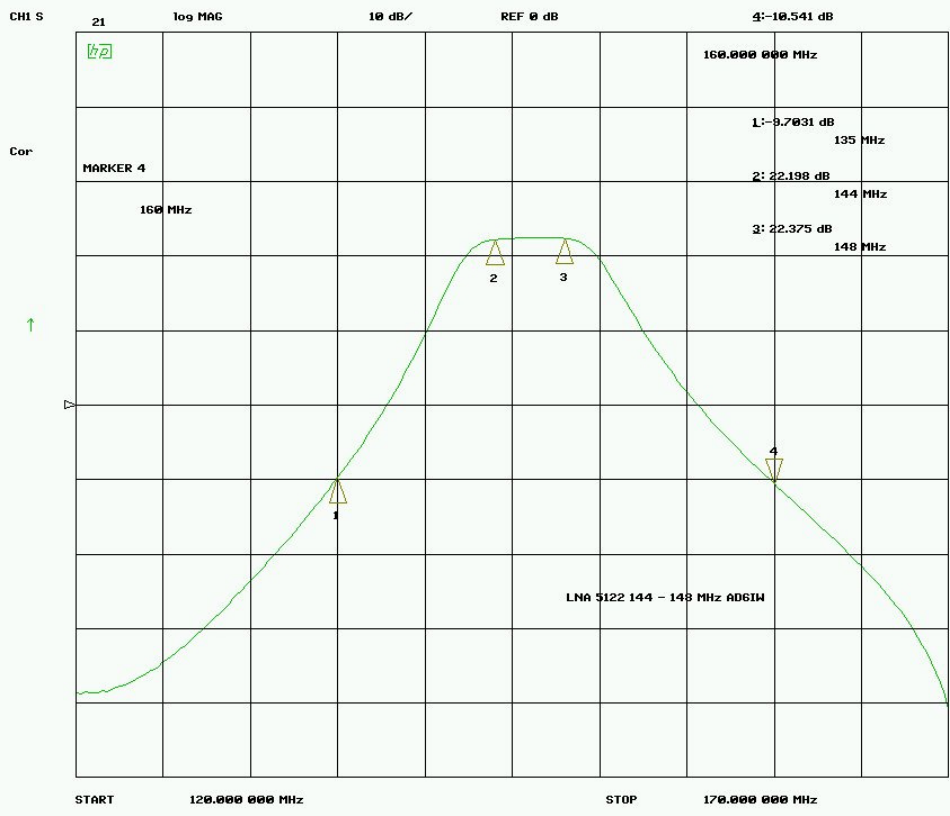


Figure 12



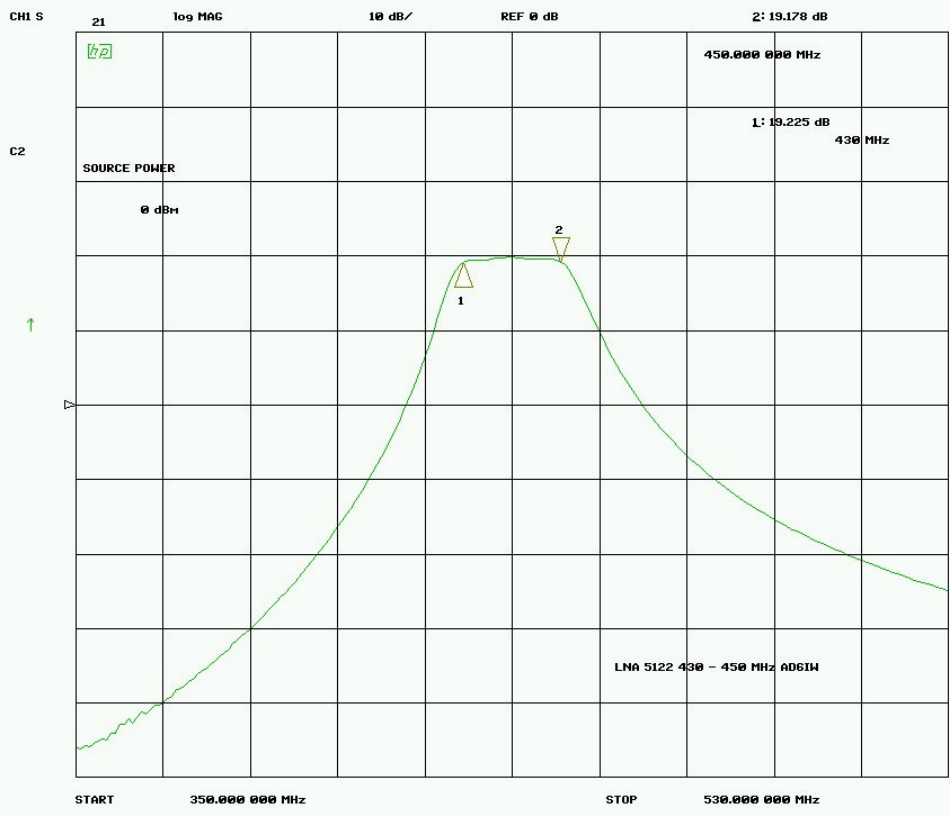


Figure 13

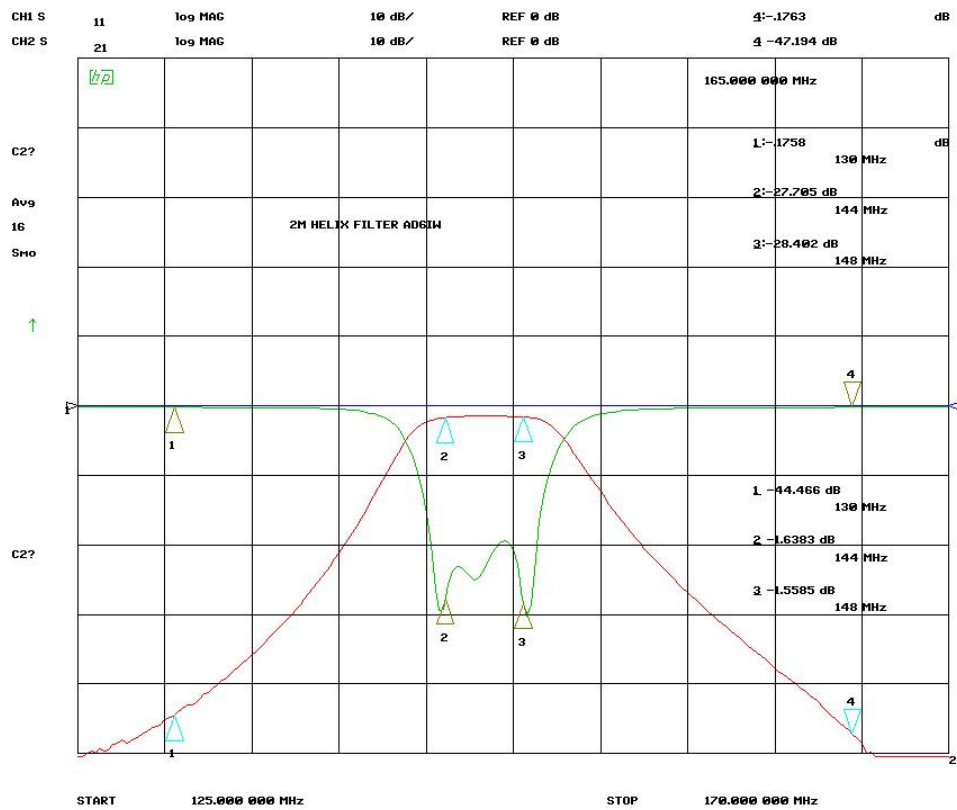


Figure 14

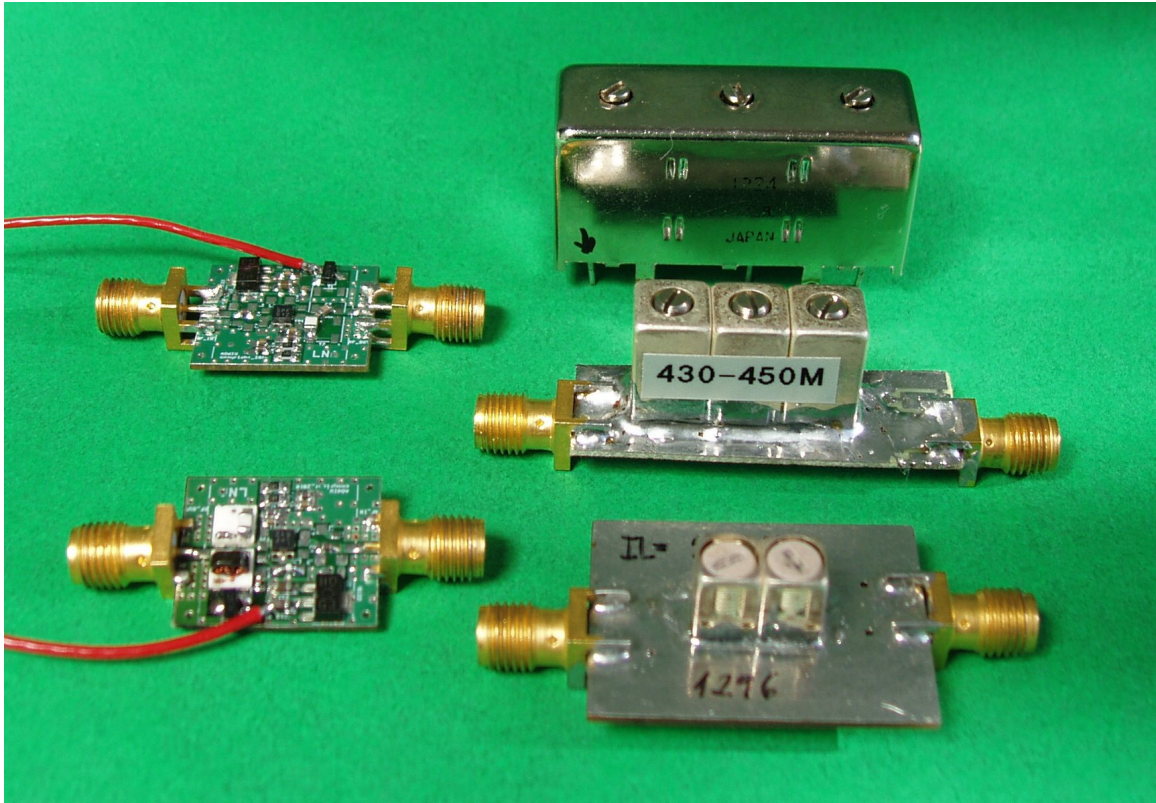


Figure 15

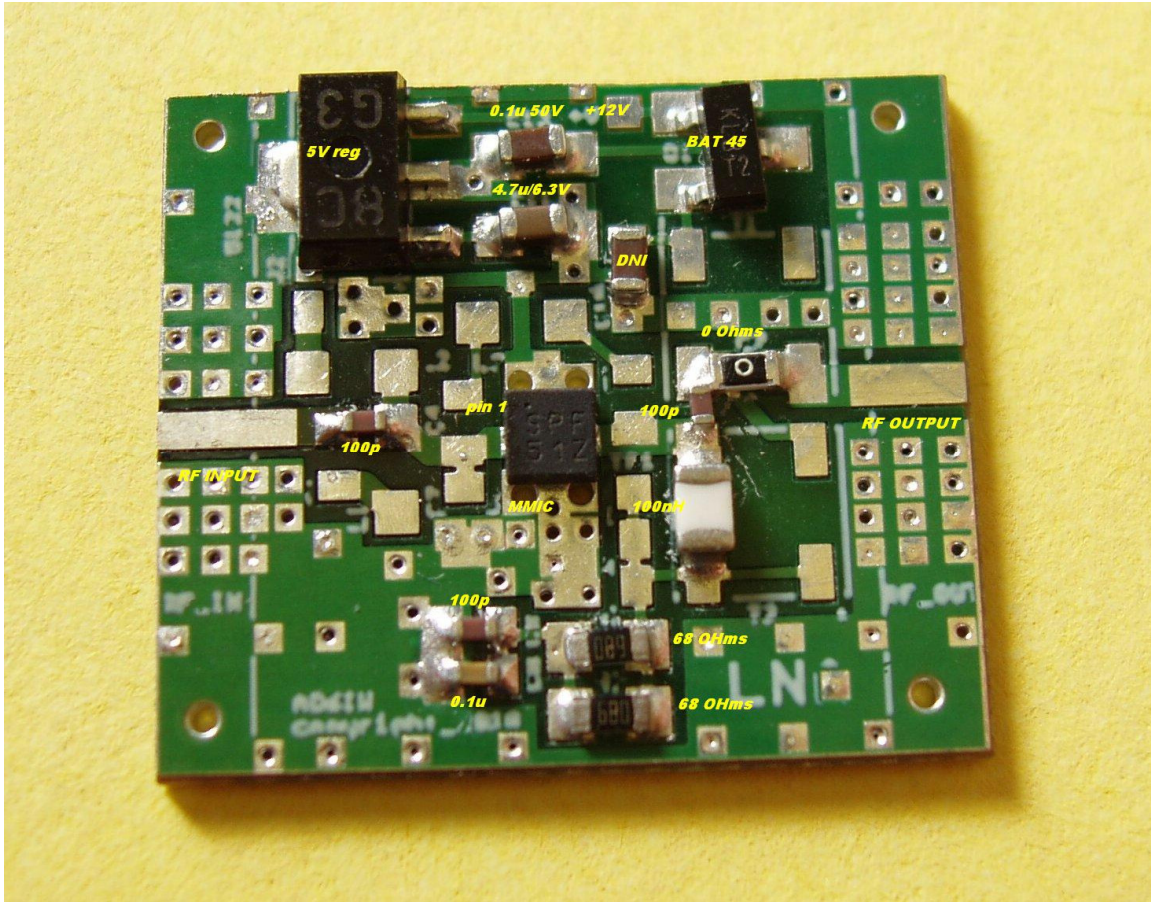


Figure 16

Note

Kits are available for \$25, ready made PCB (figure 16) for \$35 plus shipping  
[goran@ad6iw.com](mailto:goran@ad6iw.com)

References:

Microwave engineering, David M Pozar

SPF-5122Z Data sheet

SPF-5122Z S parameters

AN-027 Sirenza Micro devices

Application Note 1316 Avago

ATF-531P8 Avago Data Sheet

