

The Rapid Test Array Balun (G250R)

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Abstract

This report documents the active balun designed to facilitate the Rapid Prototype Array (RTA) – the G250R balun. The G250R balun provides an additional 12 dB gain over the baseline balun design, includes a voltage regulator, and incorporates an experimental feedpoint interconnect scheme based on common hardware. The noise temperature ($T_{\text{sys}} = 250\text{K}$) is approximately equivalent to the baseline balun (LWDA), and the system linearity remains acceptable for LWA prototyping applications. Presenting the best price and performance characteristics to date, the G250R design will readily extend to a dual-polarization version that will become our leading active-balun candidate for the LWA.

I. Introduction

The construction of the RTA provided a unique opportunity to experiment with incremental improvements to the baseline (LWDA) balun design. It was decided that additional gain, a voltage regulator, and more robust feed-point connections would be valuable improvements. The PCB was designed to fit into a PVC drain flange and allow for direct connection of the antenna elements to plated bolts pressed and soldered into the circuit board material (Figure 6).

II. Device Details

The G250R circuit (Figure 1) is an extension of the LWDA balun design through the addition of a voltage regulator (U3) and a Gali-6 amplifier (U4) and its associated bias network (L5, R6, L4, FB3, C9, C10). The PCB layout is shown in Figure 2 and 3; an assembled balun is presented in Figures 4 and 5.

The SMA connectors that were used for feedpoint connections in the LWDA balun have been replaced with Penn Engineering self-broaching $\frac{1}{4}$ -20 studs (KFH-0420-8ET) in this design (Figures 4, 5, 6). These phosphor bronze fasteners are specifically designed to facilitate PCB interconnects and are electroplated with tin. A cost savings of \$5 per polarization was achieved by replacing the SMA connectors with these parts (Appendix A).

A. Schematic Diagram – G250R Balun

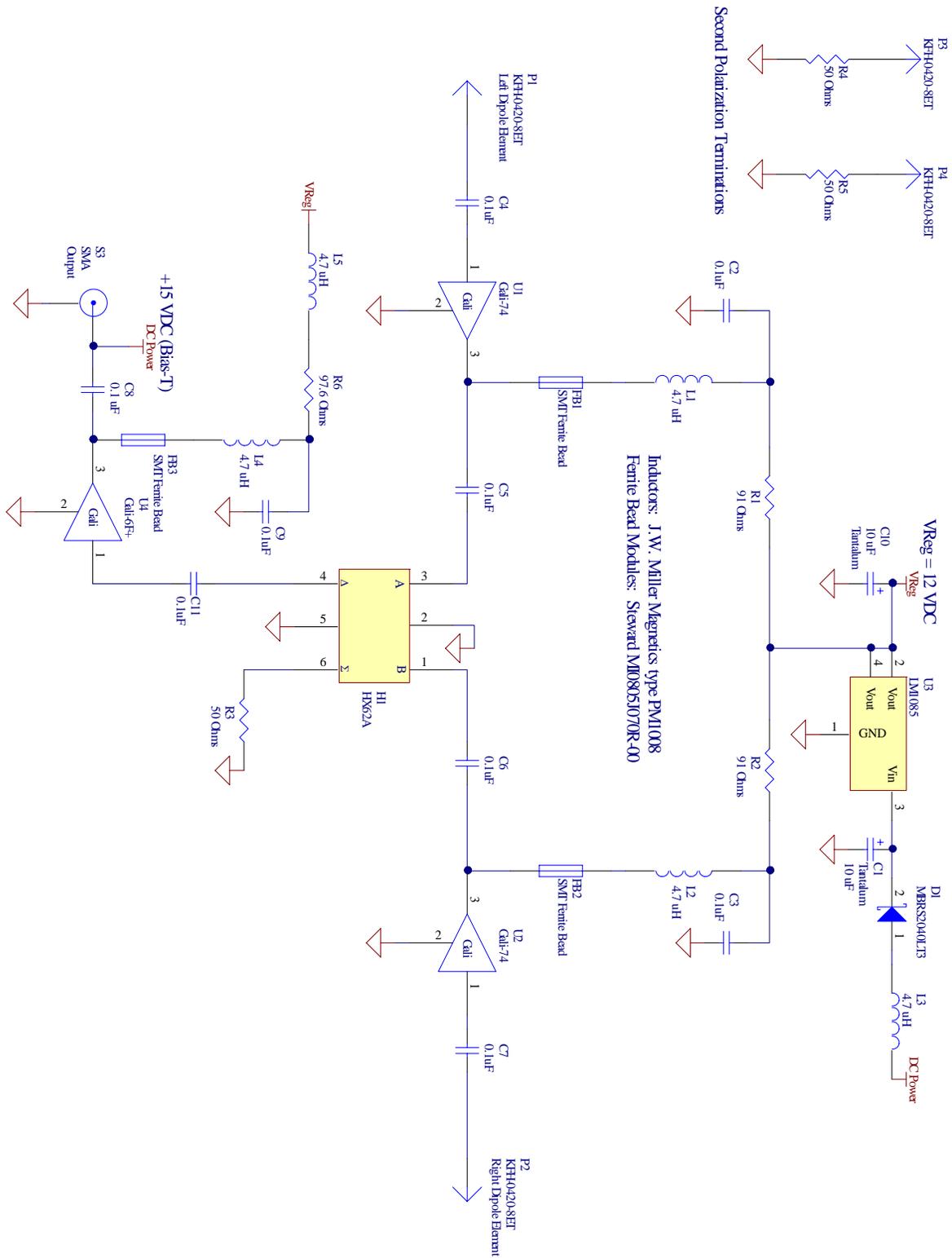


Figure 1 – G250R Balun Schematic

B. PCB Layout – G250R Balun

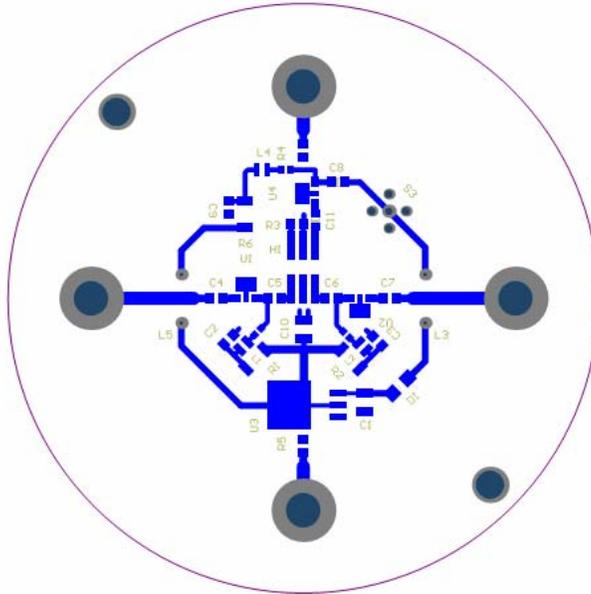


Figure 2 – PCB Layout for G250R (Bottom Layer)

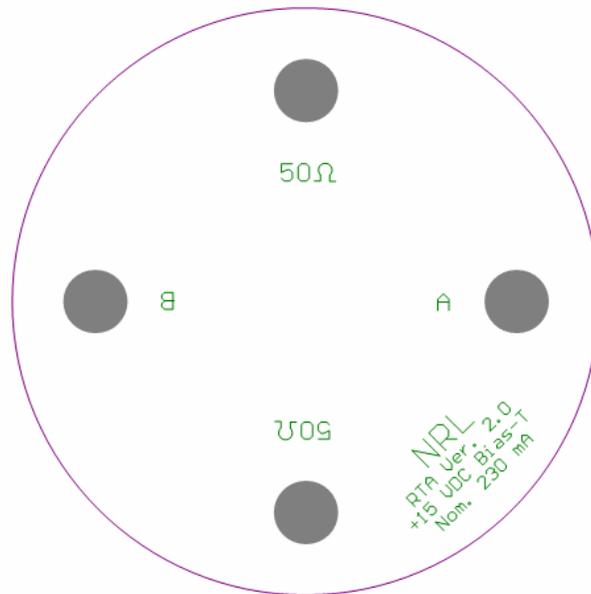


Figure 3 – PCB Layout for G250R (Top Layer)

C. Implementation – G250R Balun

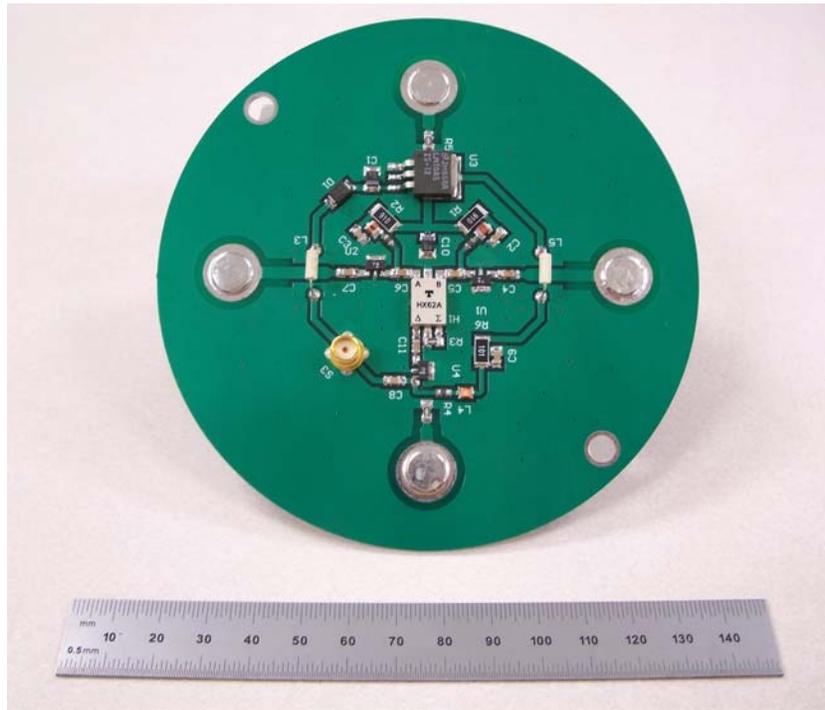


Figure 4 – Bottom of G250R Balun

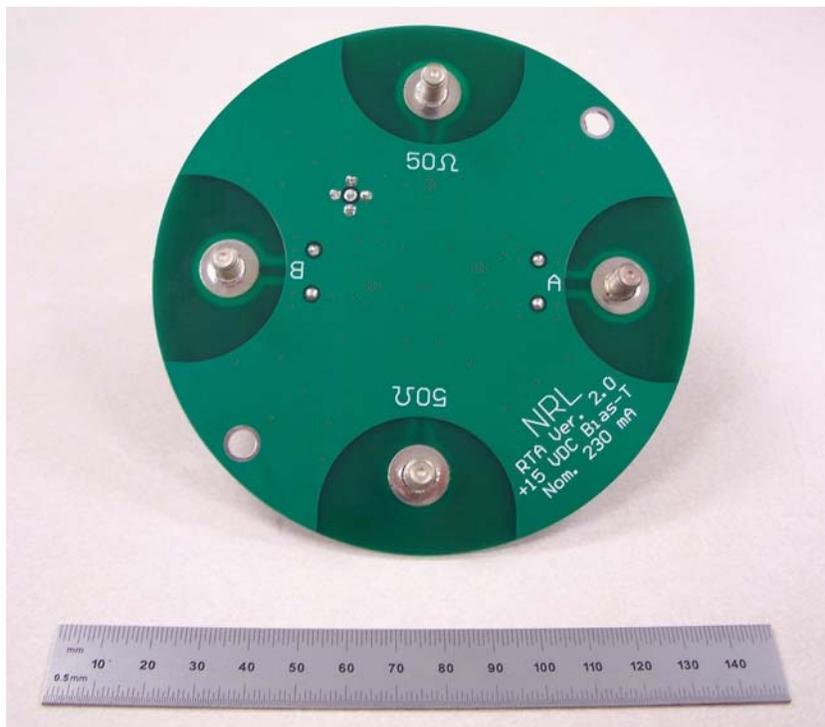


Figure 5 – Top of G250R Balun



Figure 6 – Feedpoint Connections to G250R Balun



Figure 7 – Experimental Dipole Connected to G250R Balun

III. Summary of Device Performance – G250R Balun

Current Draw (at +15 VDC)	230 mA
Voltage Range	+/- 5%
Gain	36 dB
Noise Temperature	250 K
Input 1 dB Compression Point	-18.30 dBm
Input IP3	-1.8 dBm

The single ended cascade analysis performed to determine IIP3 and noise temperature is provided in Appendix B. All other parameters were directly measured.

IV. Field Measurements

In the summer of 2007 we conducted an extensive field campaign to exhaustively characterize all of the available combinations of prototype antennas and active baluns. An upcoming LWA memo will provide extensive coverage of this effort. Using data from this trip we are able to compute the sky noise dominance of the baseline balun and the G250R when paired with the Large Blade antenna.

Figure 8 compares the sky noise dominance of the baseline balun (LWDA) and G250R baluns when used in conjunction with the baseline antenna (Large Blade). The G250R balun is seen to clearly provide greater than 6dB sky noise dominance over the entire LWA frequency band.

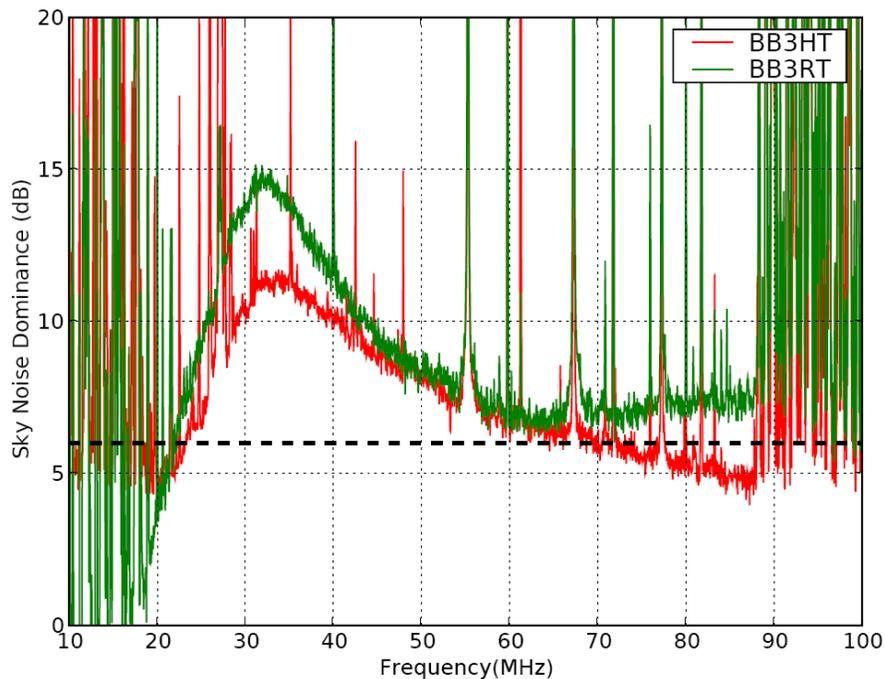


Figure 8 – Comparison of measured sky noise dominance of the LWDA balun/Large Blade (BB3HT) and the G250R balun/Large Blade (BB3RT).

IV. Path Forward

The G250R provides a significant increase in performance over the baseline LWDA balun without adding any appreciable cost (Appendix A). In addition to overcoming cable loss, the final gain stage provides increased isolation between the feedpoints and the output connection. Based on this experience, we advocate the inclusion of a final amplifier stage, such as the Gali-6, in future MMIC-based active baluns.

The next generation balun design will accommodate two polarizations, provide enhanced ESD protection, and incorporate a feedpoint connection method similar to the G250R.

Appendix A. Material Costs

A. G250R Balun Bill of Materials

Bill of Materials G250R (RTA) Balun 1/24/2007

Designation	Value	Tolerance	Type	Manufacturer	Manufacturer's Part Number	Digikey Part Number	Package Style	Unit Cost	Quantity	Extended Cost Bracket (1)	(Note 1)	
L1, L2, L4	4.7 uH	10%	Inductor, Ceramic Core	JW Miller	PM1008-4R7K-RC	M8483TR-ND	PM1008	\$ 0.12	3	\$ 0.36	>2000	
L3, L5	4.7 uH	10%	Inductor, Molded Iron	JW Miller	9250-472-RC	M8219-ND	Axial - 10.4mm body	\$ 0.72	2	\$ 1.44	>1000 (Note 1)	
C1, C10	10 uF	20%	Tantalum Capacitor	Nichicon	F931E106MCC	489-2388-1-ND	SMT-C (6.0 x 3.2 mm)	\$ 0.33	2	\$ 0.66	>250 (Note 2)	
C2, C8, C11	0.1 uF	10%	Capacitor, Ceramic, X7R	Panasonic - ECG	ECJ-3VBE104K	PCC1883TR-ND	1206	\$ 0.06	9	\$ 0.50	>4000	
R1, R2	91 Ohm	5%	Resistor, 1 Watt	Panasonic	ERL-1TYJ910U	P791XCT-ND	2512	\$ 0.19	2	\$ 0.38	>1000	
R6	96.7 Ohm	1%	Resistor, 1 Watt	Panasonic	ERL-1TF97R6U	ERL-1TF97R6U-ND	2512	\$ 0.16	1	\$ 0.16	>1000	
R3, R4, R5	51 Ohm	5%	Resistor, 1/4 Watt	Panasonic - ECG	ERM-P08J510V	P51ALCT-ND	1206	\$ 0.04	3	\$ 0.13	<4000	
U3	LM1085IS-12-ND	N/A	Positive Voltage Regulator	National Semiconductor	LM1085IS-12	LM1085IS-12-ND	TO-263-3	\$ 1.25	1	\$ 1.25	>500	
U1, U2	Galil-74	N/A	Mini-Circuits	Mini-Circuits	Call-74	Must Buy Directly	DF782	\$ 1.85	2	\$ 3.70	>1000	
U4	Galil-6	N/A	MMIC Amplifier	Tele-Tech, Corp.	Call-6	Must Buy Directly	DF782	\$ 1.39	1	\$ 1.39	>1000	
H1	HXG2A	N/A	180 degree hybrid	ON Semiconductor	HXG2A	Must Buy Directly	TT-HK62A	\$ 31.50	1	\$ 31.50	>5000	
D1	MBRS2040	N/A	Diode, Schotky, 40 V, 2A	Steward	MBRS2040LT3G	MBRS2040LT3GOSCT-ND	SMB (6.59 x 3.81)	\$ 0.16	1	\$ 0.16	>500	
FBI, FB2, FB3	Ferrite 1.5A, SMD	N/A	Ferrite, 1.5A	Emerson Network	142-0701-201	J500-ND	805	\$0.04	3	\$ 0.12	>500	
S3	SMA, Straight	N/A	SMA Connector	Penn Engineering	KFH-0420-BET	J500-ND	SMA	\$2.55	1	\$ 2.55	>500	
P1, P2, P3, P4	1/4-20 Bolt Insert	N/A	Electroplated Tin, 1/4-20	Galaxy Electronics	RTA-2	N/A	KFH	\$0.16	4	\$ 0.64	>500	
Printed Circuit Board	RTA v2.0	N/A	Double Sided, Solder Mask	Galaxy Electronics	RTA-2	N/A	N/A	\$7.00	1	\$ 7.00	>=300 (Note 3)	
Total Cost:									\$ 51.94			

* Parts only cost for a single polarization balun. Enclosure and connectors not included.
 * Price and availability verified on 1/16/2007
 Note 1: Part to be superseded by CM25016 Series
 Note 2: Part to be superseded by 9250 Series
 Note 3: Price provided 6/25/2007

B. Baseline Balun Design (LWDA) Bill of Materials

Bill of Materials Baseline LWDA Balun Design 1/24/2007

Designation	Value	Tolerance	Type	Manufacturer	Manufacturer's Part Number	DigicKey Part Number	Package Style	Unit Cost	Quantity	Extended Cost	Cost Bracket(L)
L1, L2	4.7 uH	10%	Inductor, Ceramic Core	JW Miller	PM1008-487K-RC	M9483TR-ND	PM1008	\$ 0.12	2	\$ 0.24	>2000
C1, C2	10 uF	20%	Tantalum Capacitor	Nichicon	F931E106MCC	493-2388-1-ND	SMT_C (6.0 x 3.2 mm)	\$ 0.52	2	\$ 1.04	>10
C3...C8	0.1 uF	10%	Capacitor, Ceramic, X7R	Panasonic - ECG	ECL3V81E104K	PCC1883TR-ND	1205	\$ 0.06	6	\$ 0.34	>4000
R1, R2	91 Ohm	5%	Resistor, 1/4 Watt	Panasonic	ERL1TYJ910U	PT91XCT-ND	2512	\$ 0.19	2	\$ 0.38	>1000
R3	51 Ohm	5%	Resistor, 1/4 Watt	Panasonic - ECG	ERLJF08J510V	P51ALCT-ND	1205	\$ 0.04	1	\$ 0.04	>1000
U1, U2	Galil-74	N/A	MIMC Amplifier	Mini-Circuits	Galil-74	Must Buy Directly	D7782	\$ 1.85	2	\$ 3.70	>1000
H1	HX62A	N/A	180 degree hybrid	Tale Tech, Corp.	HX62A	Must Buy Directly	SMB(5.59 x 3.81)	\$ 31.50	1	\$ 31.50	>500
D1	MBRS2040	N/A	Diode, Schottky, 40 V, 2A	ON Semiconductor	MBRS2040LT3G	MBRS2040LT3GOSCT-ND	SMA STR JACK	\$ 0.16	1	\$ 0.16	>500
S1, S2, S3	SMA Connector	N/A	SMA Connector, Socket	Linx Technologies	CONREVSMA008	CONREVSMA008-ND	NA	\$2.83	3	\$ 7.89	>500
Printed Circuit board	LWDA_PCB	N/A	Double Sided	Galaxy Electronics	LWDA_PCB	NA	NA	\$6.00	1.00	\$ 6.00	>=300
Total Cost:										\$ 51.29	

* Parts only cost for a single polarization balun. Enclosure and connector not included.

Appendix B. Cascade Analysis

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*****
*                               CASCADE ANALYSIS                               *
*                               Version 1.4A                                   *
*                               (c) 1997-2001 Dan McMahon                    *
*                               mcmahill@alum.mit.edu                         *
*****

Processing input file "-"

*****
*   Default Values Changed                                                 *
*****

    Input Resistance for each Stage = 50 Ohms
    Output Resistance for each Stage = 50
    Ohms
    Default Rho (for IIP3 calc.)      = 0

*****
*   Stage #1 "Gali-74"                                                    *
*****
    Power Gain= 25.10 dB, Voltage Gain= 25.10 dB
    NF= 2.70 dB
    Input Res. = 50 Ohms, Output Res. = 50
    Ohms
    IIP3= 12.90 dBm ( 59.89 dBmV), RHO= 0.00

    Total Power Gain          = 25.10 dB
    Total Voltage Gain        = 25.10 dB
    Total Noise Figure        = 2.70 dB
    Noise Figure from this stage only = 2.70 dB

    IIP3                      = 12.90 dBm
    IIP3 from this stage only  = 12.90 dBm

*****
*   Stage #2 "Gali-6"                                                    *
*****
    Power Gain= 12.20 dB, Voltage Gain= 12.20 dB
    NF= 4.50 dB
    Input Res. = 50 Ohms, Output Res. = 50
    Ohms
    IIP3= 23.30 dBm ( 70.29 dBmV), RHO= 0.00

    Total Power Gain          = 37.30 dB
    Total Voltage Gain        = 37.30 dB
    Total Noise Figure        = 2.71 dB
    Noise Figure from this stage only = 0.02 dB

    IIP3                      = -1.80 dBm
    IIP3 from this stage only  = -1.80 dBm

*****
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***** ANALYSIS OF THE 2 ELEMENT CASCADE IS COMPLETE *****

* Noise Figure Contribution Summary *

Stage	Noise Figure in the system	Possible Noise Figure Improvement
Gali-74	2.700 dB	2.689 dB
Gali-6	0.024 dB	0.013 dB

* IIP3 Contribution Summary *

Stage	IIP3 in the system
Gali-6	-1.800 dBm
Gali-74	12.900 dBm

* CASCADE ANALYSIS COMPLETE *