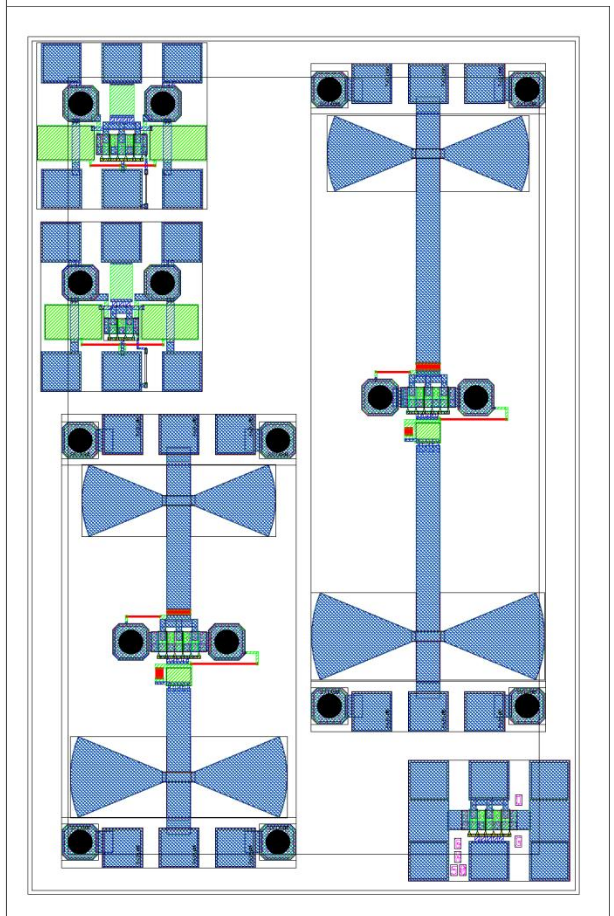
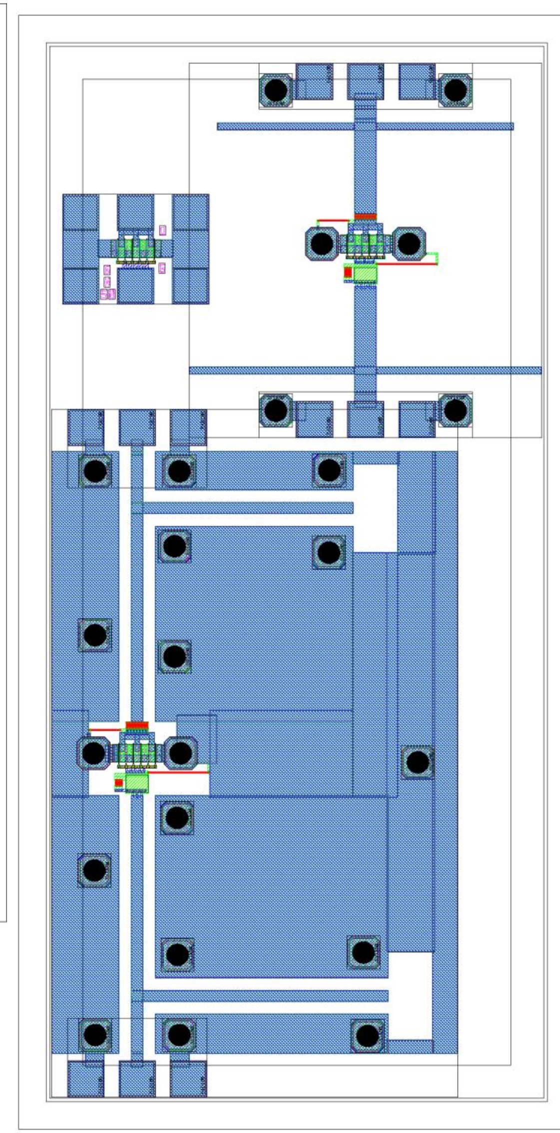
JHU Fall 13 MMIC Design Measured Results





PROJECTS F13

Image Reject Mixer–Nish Bhagat	**jhu13nb**
Low Noise Amplifier—Shaynee Contee	**jhu13sec**
Distributed Amplifier–Alan Doucette	**jhu13awd**
Low Noise Amplifier—Brad Greene	**jhu13bg**
Voltage Controlled Oscillator—Amy Kordovski	**jhu13ak**
Class F Power Amplifier 10G–Rajesh Madhavan	**jhu13rm**

Size-Location	C1: 1520um	C2: 1520um	C3: 1520um
R1: 3040um	JHU13LN4	JHU13LN2	JHU13LN3
R2: 2280um	JHU13LN1	JHU13WLT	JHU13AK
R3: 1520um	JHU13X4	JHU13X4B	JHU13BG2
R4: 1520um	JHU13SEC	JHU13NB	JHU13AWD
R5: 1520um	JHU1VCO	JHU13BG	JHU13RM

Designer	Die Label
John Penn	JHU13LN4
John Penn	JHU13LN2
John Penn	JHU13LN3
John Penn	JHU13LN1
Willie Thompson	JHU13WLT
Amy Kordovski	JHU13AK
John Penn	JHU13X4
John Penn	JHU13X4B
Brad Greene	JHU13BG2
Shaynee Contee	JHU13SEC
Nish Bhagat	JHU13NB
Alan Doucette	JHU13AWD
John Penn	JHU13VCO
Brad Greene	JHU13BG
Rajesh Madhavan	JHU13RM

Test PHEMTs: D6x25, D6x50, D4x20

Summary PROJECTS F13

Image Reject Mixer–Nish Bhagat jhu13nb

Mixer—Brad Greene jhu13bg2

Both mixer designs worked and were very broadband. It was difficult to get a good quantitative measurement and in the case of the 2nd mixer the LO drive maxed out as the conversion loss was still getting better. The conversion loss at 18 GHz looked better than 24 Ghz, probably because the significant cable losses were lower. Image Reject mixer shows 90 degree phase differences between +/- 10 to 30 MHz IF!

Low Noise Amplifier—Shaynee Contee jhu13sec

Low Noise Amplifier—Brad Greene jhu13bg

Both Low Noise Amplifier gains shifted down somewhat in frequency—typical at these high frequencies. This would probably match better with a full EM simulation of the layout, as is true of all these designs. NF measurement TBD.

Distributed Amplifier–Alan Doucette jhu13awd

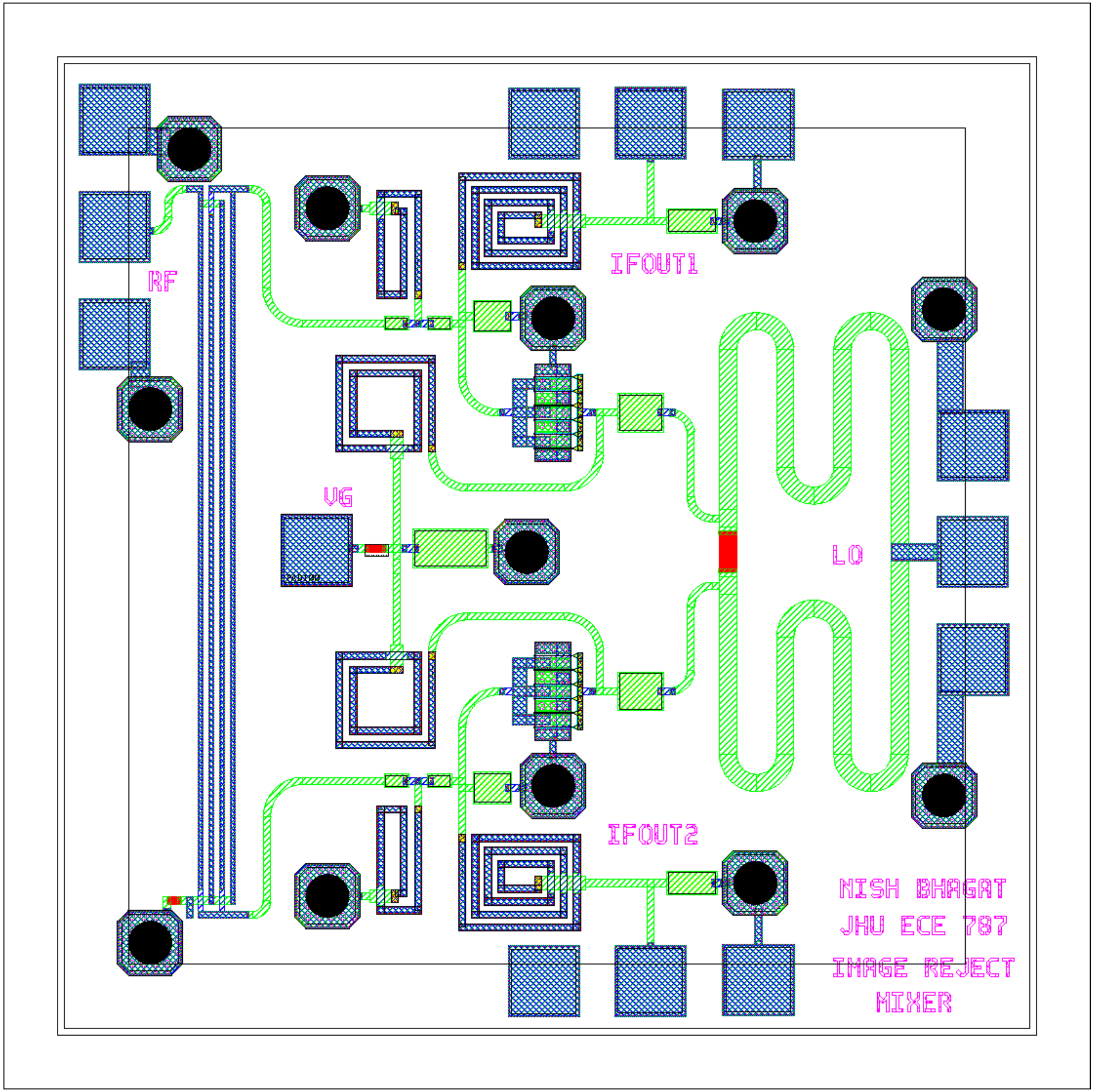
As with previous and current distributed amplifier designs, there were some marginal stability issues at high frequency. An EM simulation appears to show a better prediction of the stability issue which looks like it could be solved with some small resistors on the gate (or drain). Possibly a re-fab next year will fix the issue, but measurements show promising results if the high frequency stability can be resolved.

Voltage Controlled Oscillator—Amy Kordovski jhu13ak

Two VCO designs both oscillated around 20 GHz. Designs were intended for slightly higher 24 GHz, but EM simulations might help explain the difference.

Class F Power Amplifier 10G–Rajesh Madhavan jhu13rm

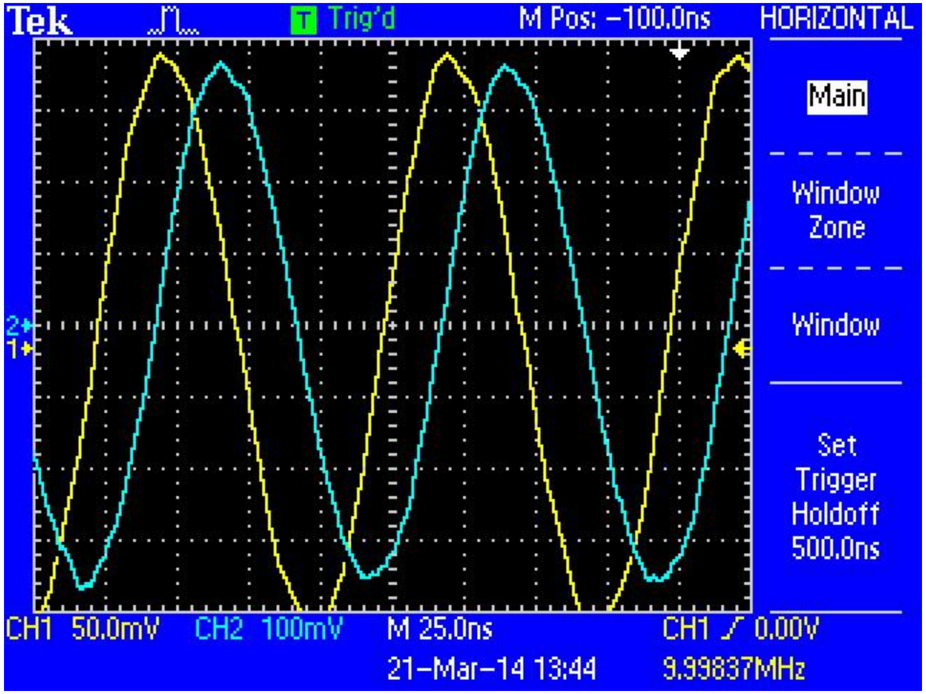
This amplifier had good efficiency at 10 GHz and it looks like the efficiency is still improving as the input signal generator drive maxed out.

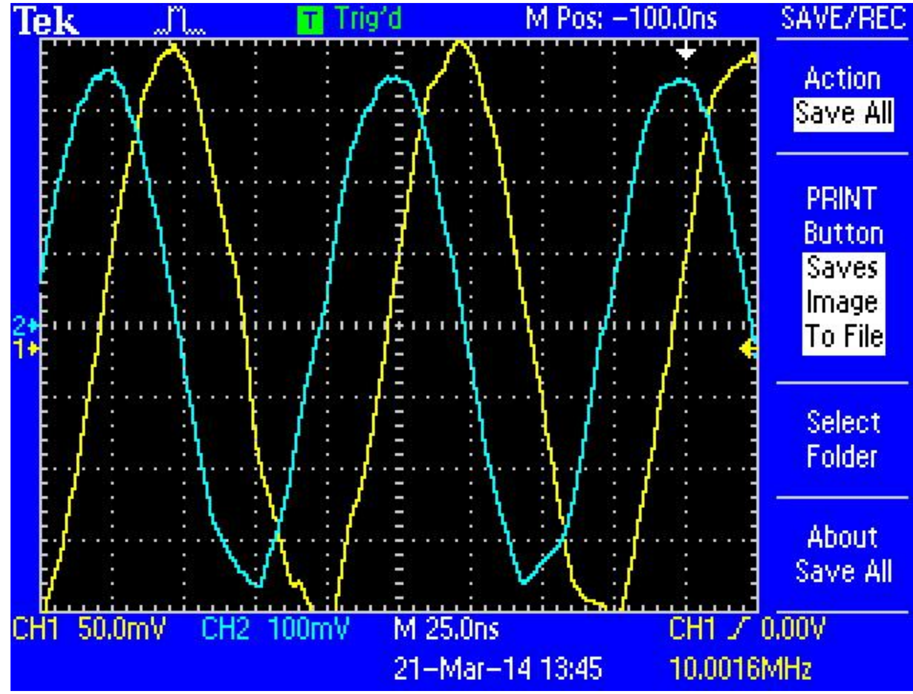


1) Nish Bhagat
   Image Reject Mixer

- *DRC (√)*
- *LVS (√)*
- *DC Current (√)*

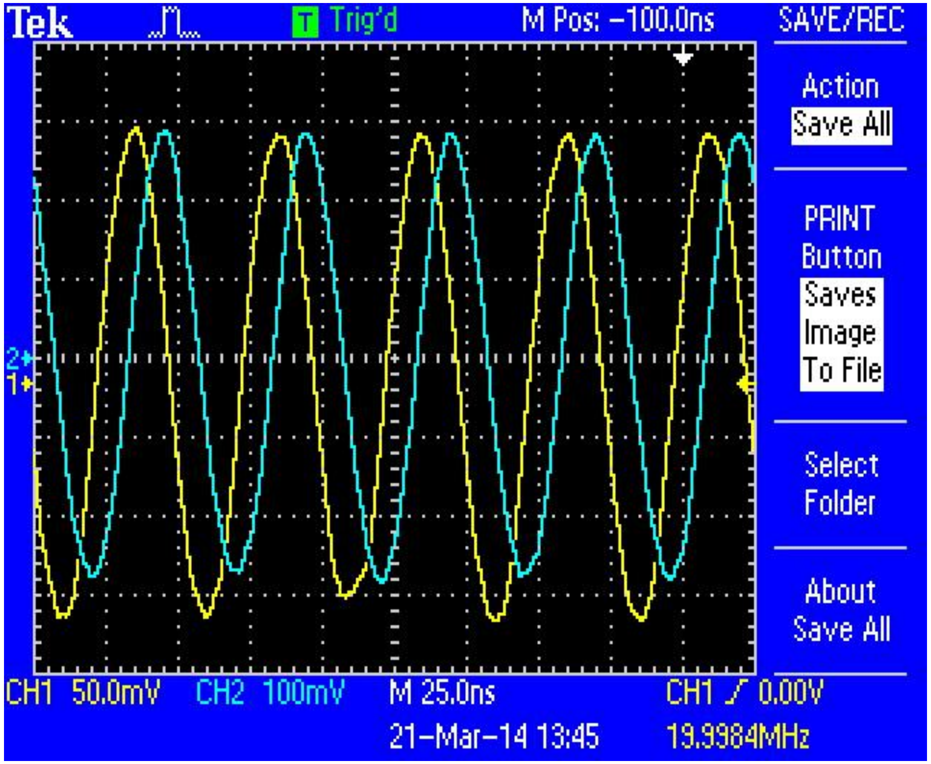
1) Nish Bhagat
Image Reject Mixer *24.1 GHz RF, 24.07-24.13 GHz LO, IF on Oscope; NOTE: +/-90 phase diff*

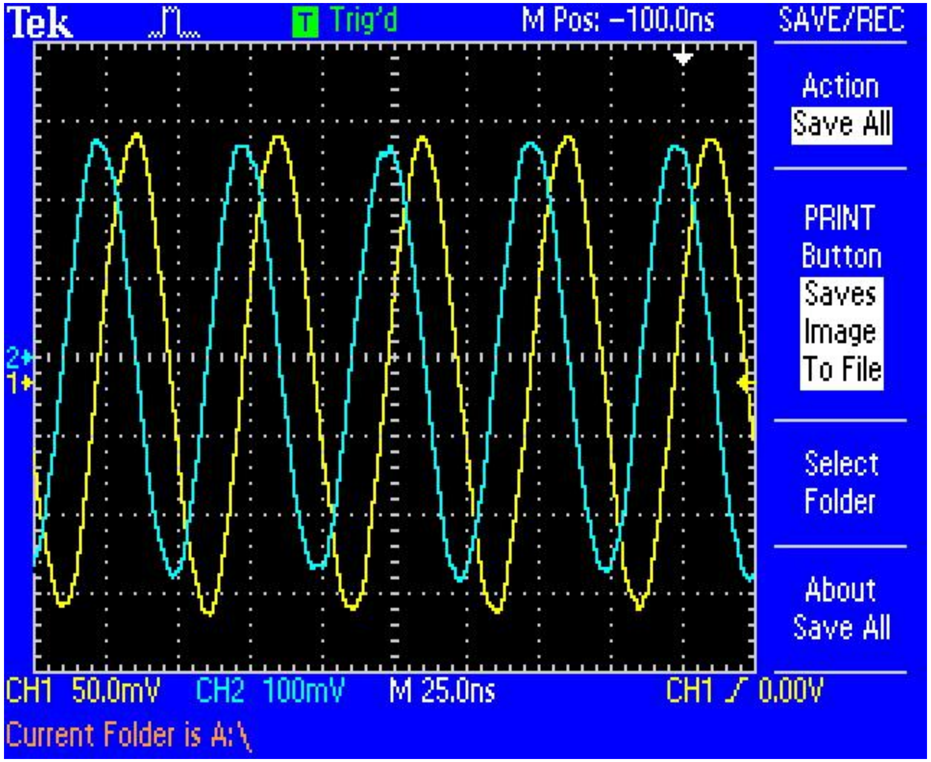




I,Q Phase differences for an IF of +/- 10 MHz
Impedance of Oscope? Some amplitude imbalance

1) Nish Bhagat
Image Reject Mixer *24.1 GHz RF, 24.07-24.13 GHz LO, IF on Oscope; NOTE: +/-90 phase diff*

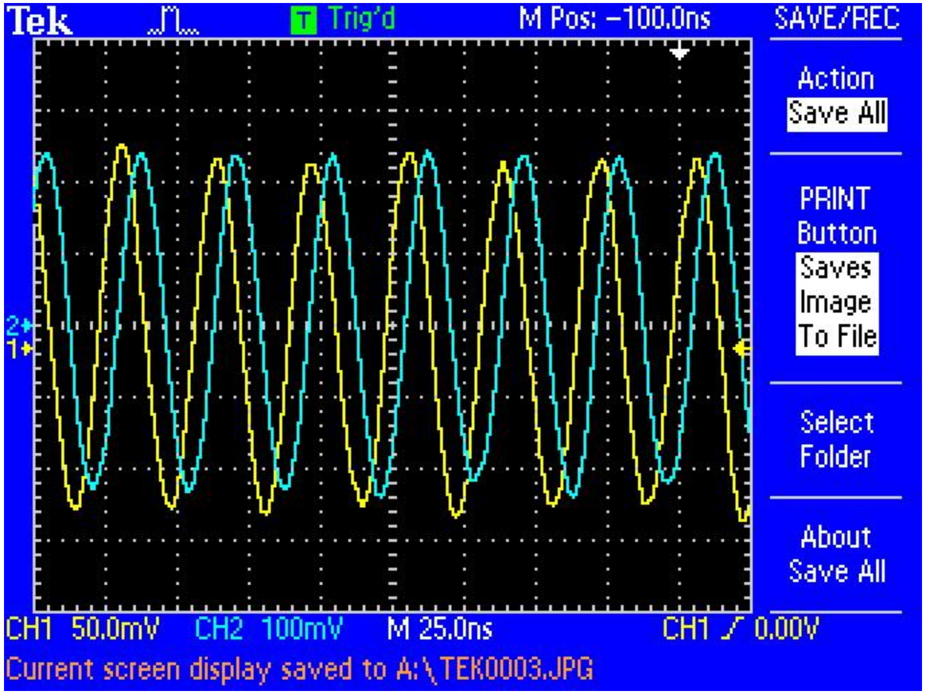


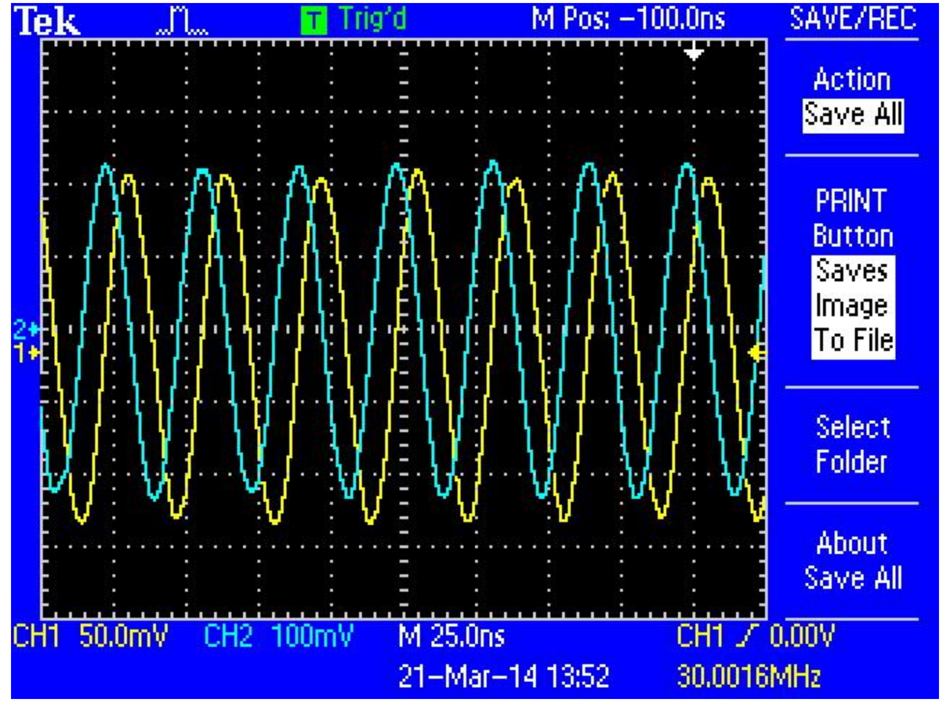


I,Q Phase differences for an IF of +/- 20 MHz
Impedance of Oscope? Some amplitude imbalance

1) Nish Bhagat

Image Reject Mixer *24.1 GHz RF, 24.07-24.13 GHz GHz LO, IF on Oscope; NOTE: +/-90 phase diff*





I,Q Phase differences for an IF of +/- 30 MHz

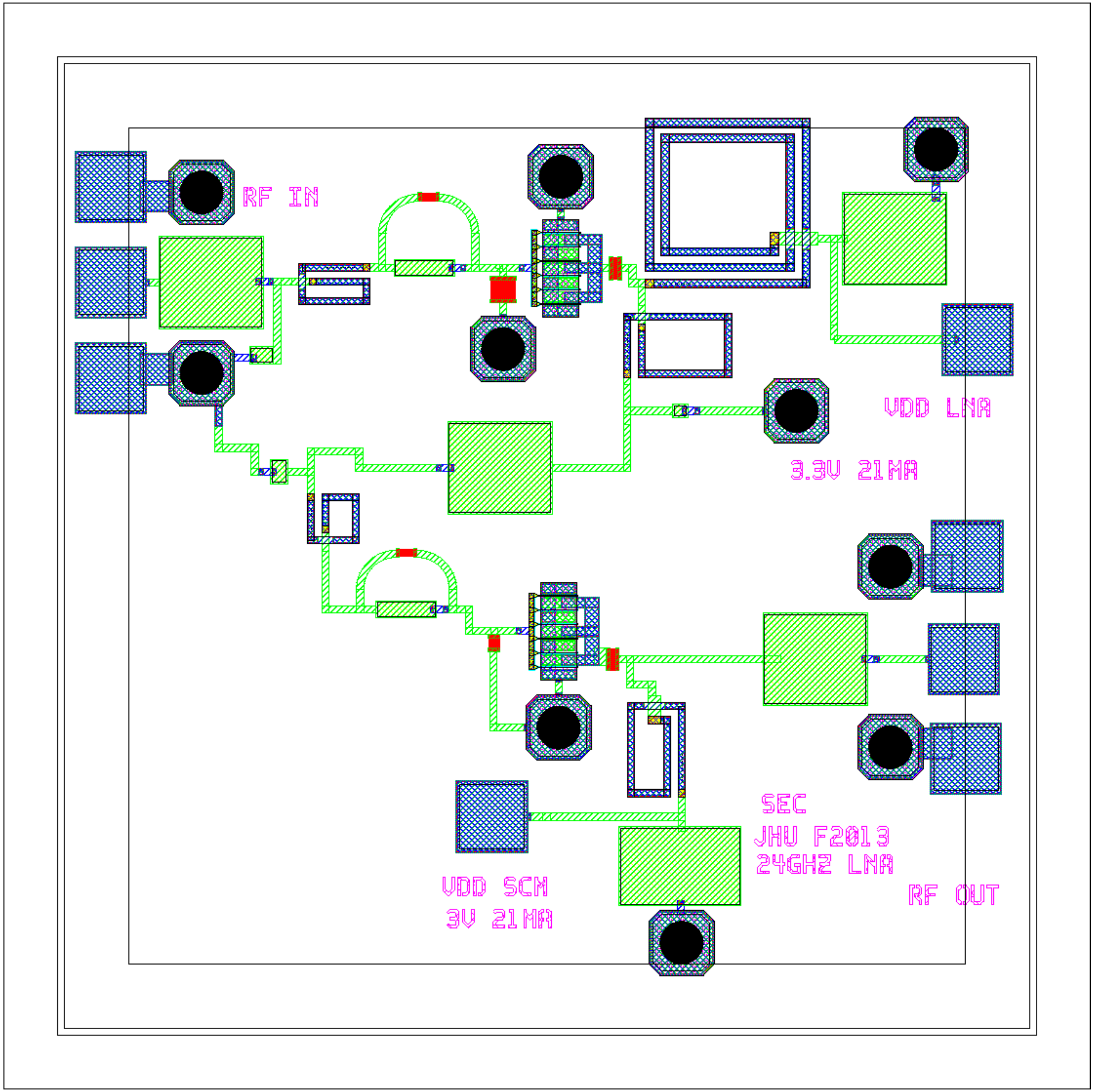
Impedance of Oscope? Some amplitude imbalance

1) Nish Bhagat

Image Reject Mixer *24.1 GHz RF, 24.0 GHz LO, 100Mhz IF*

Down Conversion					
LO 24.13G	**LO (corr)**	**IF (meas)**	**Loss (gair**	**Vt(best)**	**IF(MHz)**
-5	-10	-37.6	**-29.1**	**-0.2**	100.0
0	-5	-34.4	**-25.9**	**-0.2**	100.0
5	0	-31.3	**-22.8**	**-0.1**	100.0
10	5	-29.8	**-21.3**	**-0.1**	100.0
12	7	-29.6	**-21.1**	**-0.1**	100.0
14	9	-28.8	**-20.3**	**0.0**	100.0
16	11	-28.4	**-19.9**	**0.0**	100.0

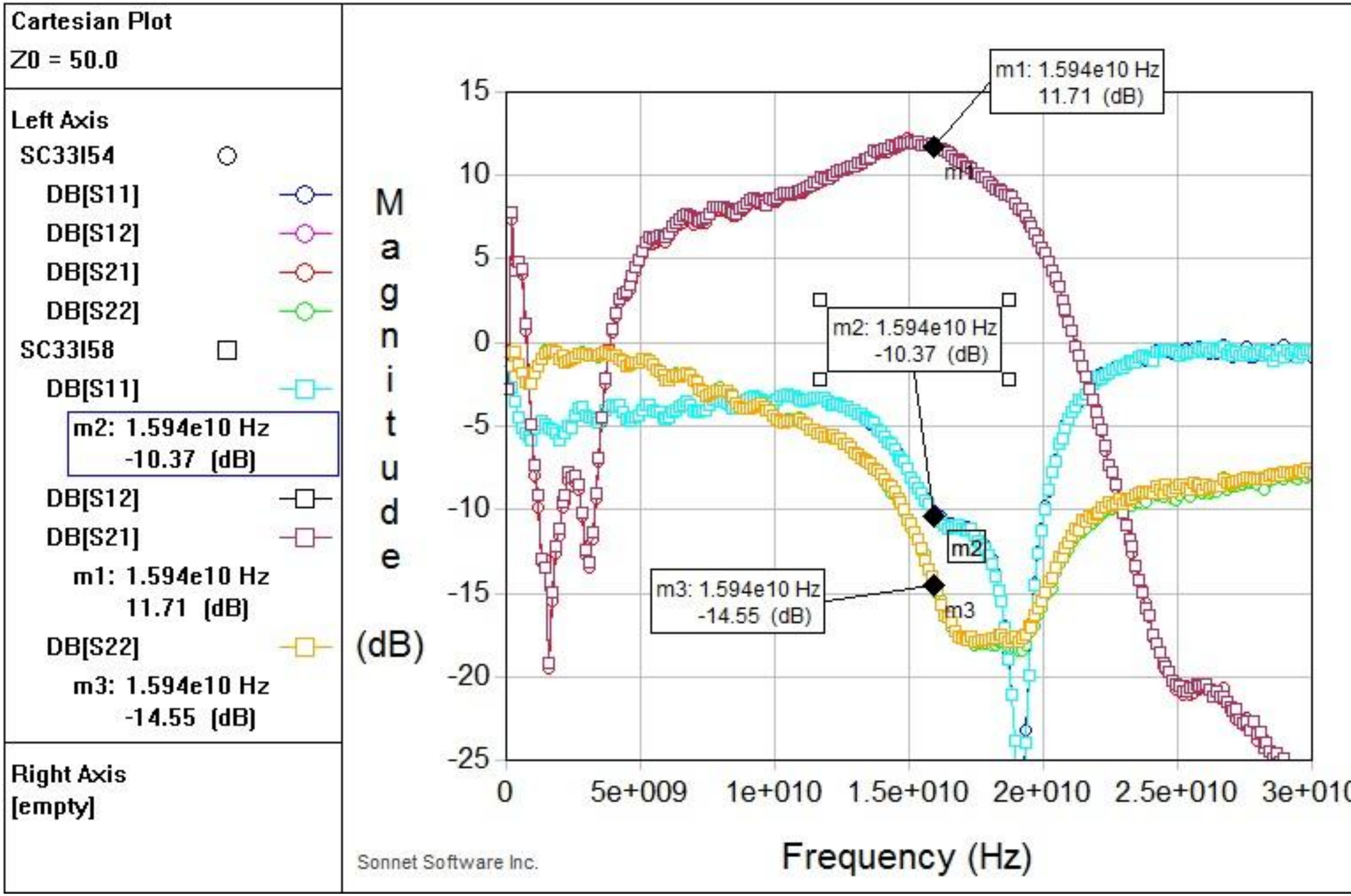
Good Mixing over a range of LO power, less negative V bias as LO power increases. calibration?



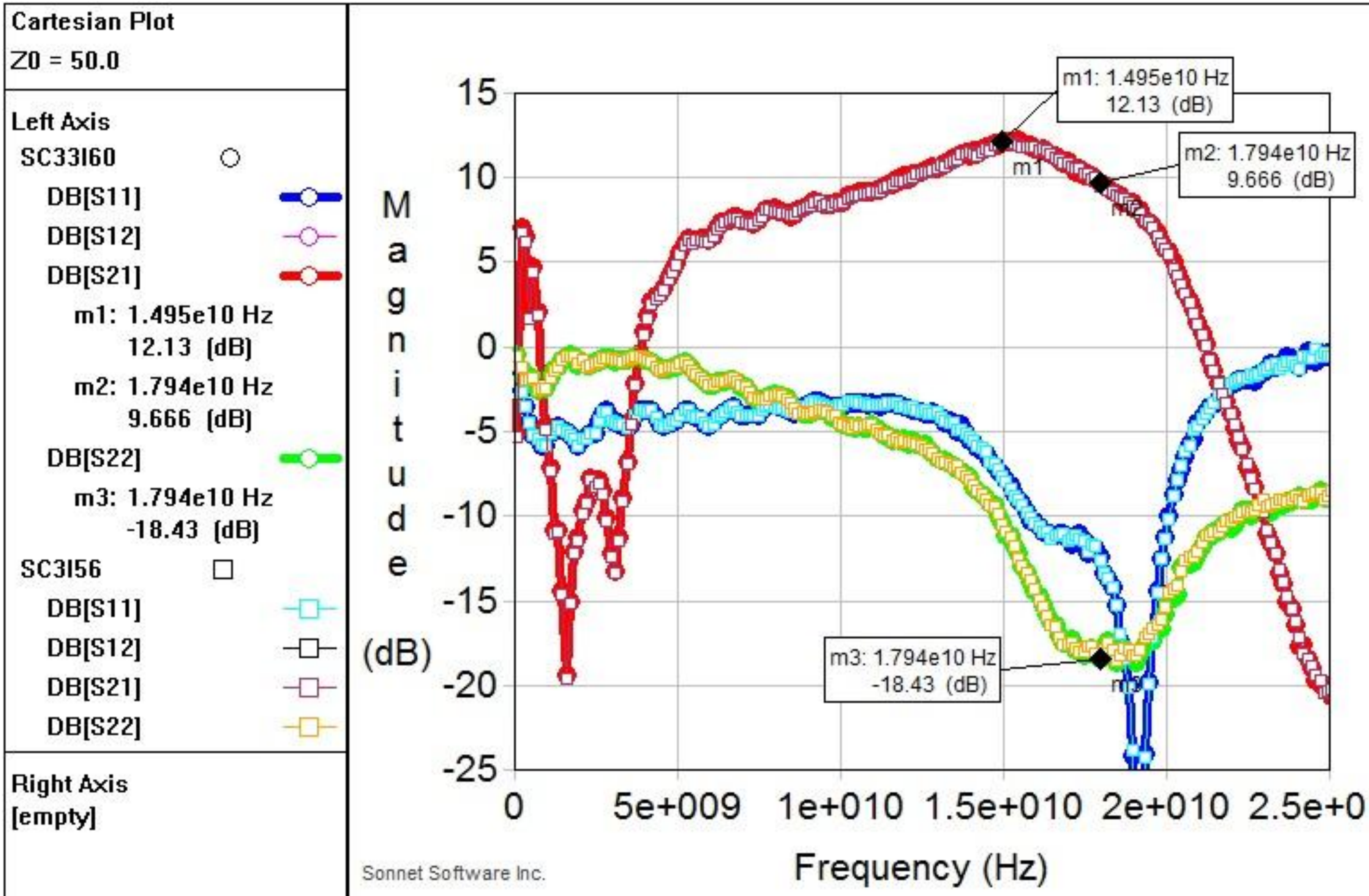
2) Shaynee Contee
Low Noise Amplifier

- *DRC (√)*
- *LVS (√)*
- *DC Current (√)*

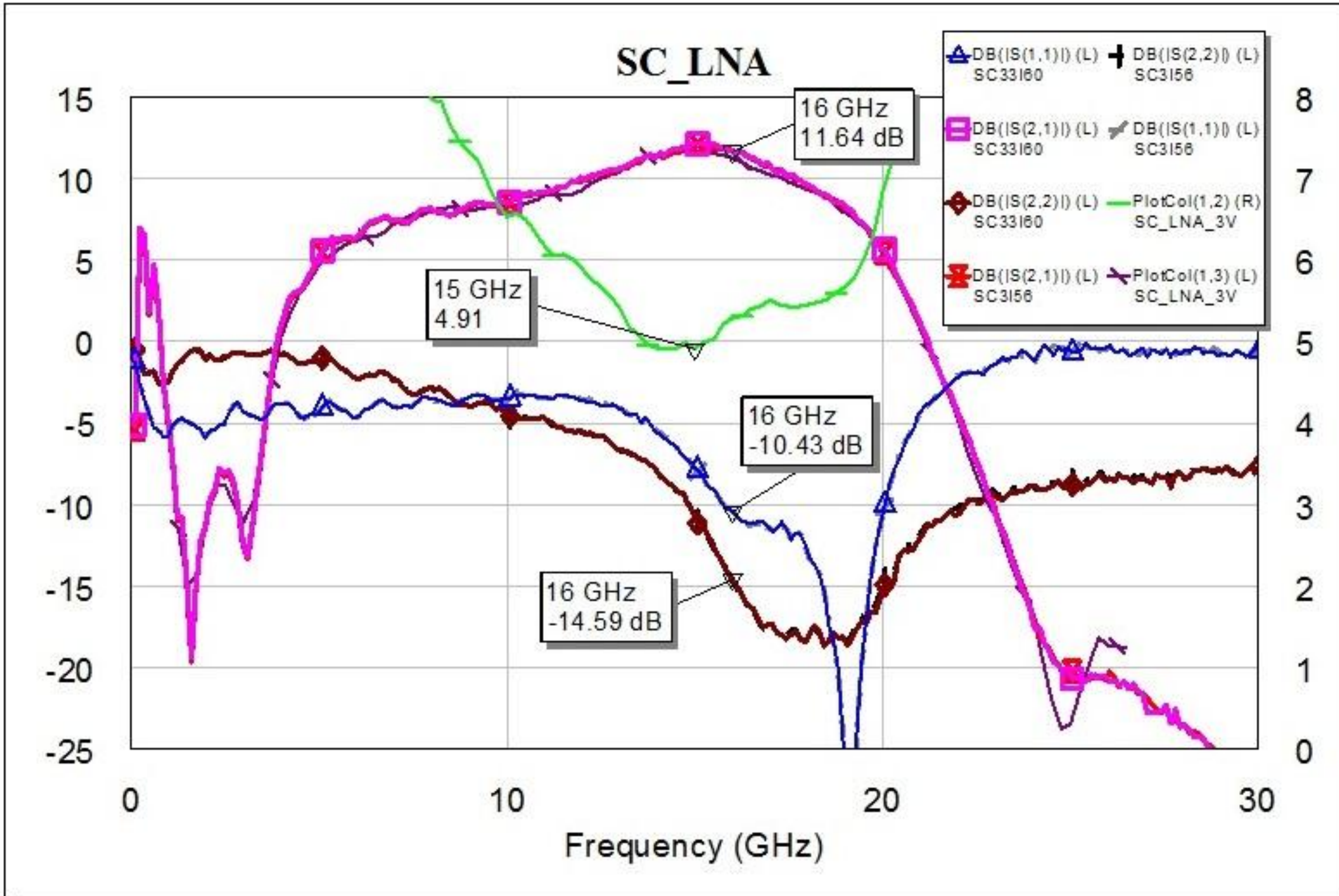
2) Shaynee Contee
Low Noise Amplifier 3.3V, 54mA Die #1; 3.3V 58mA Die #2 3/13/14

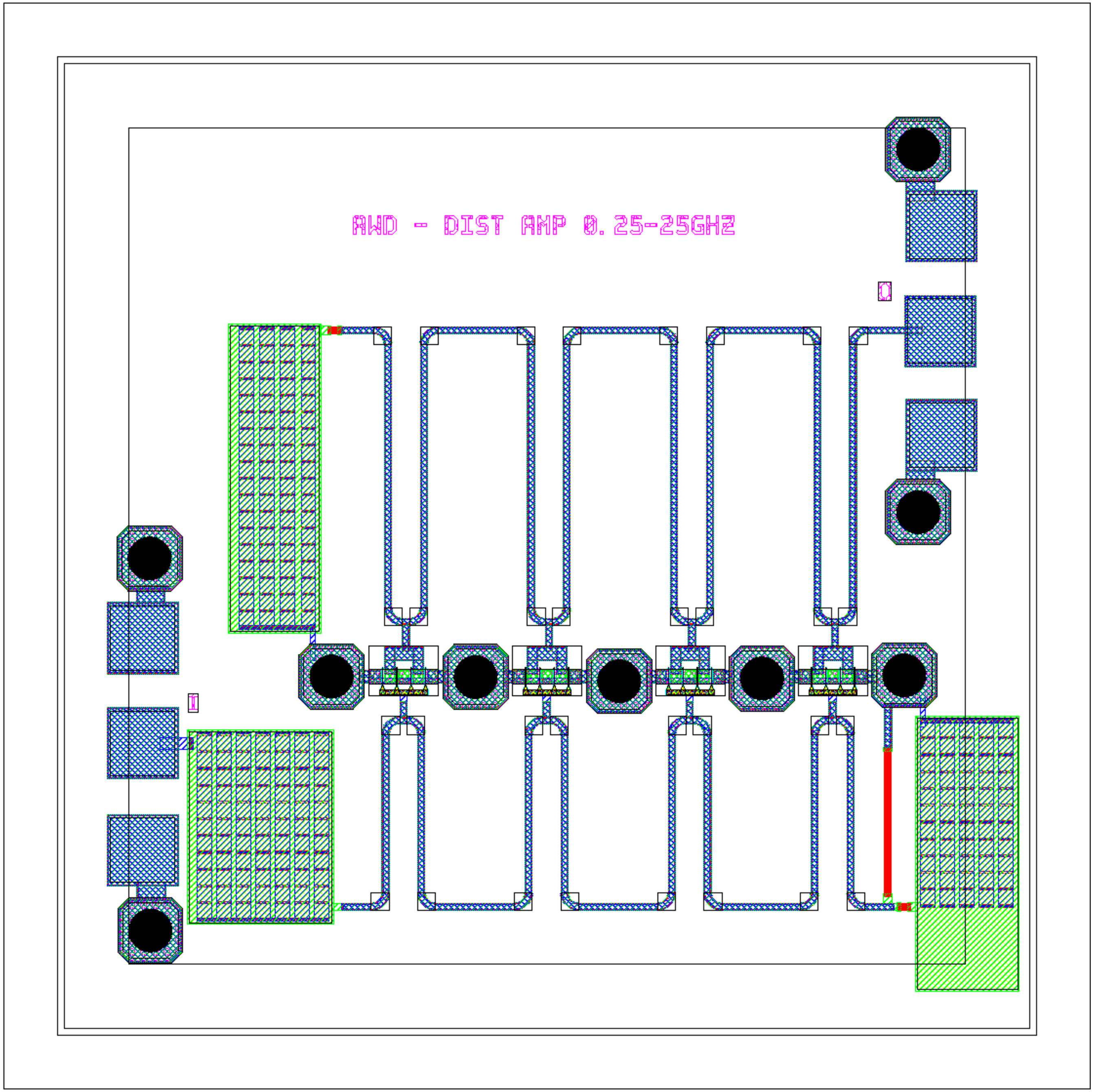


2) Shaynee Contee
Low Noise Amplifier 3.0V, 54mA Die #1; 3.3V 60mA Die #1 3/5/14



2) Shaynee Contee Added NF and Gain to 26.5 GHz to NWA measurements
Low Noise Amplifier NF measurements seem high by 1-2 dB ?

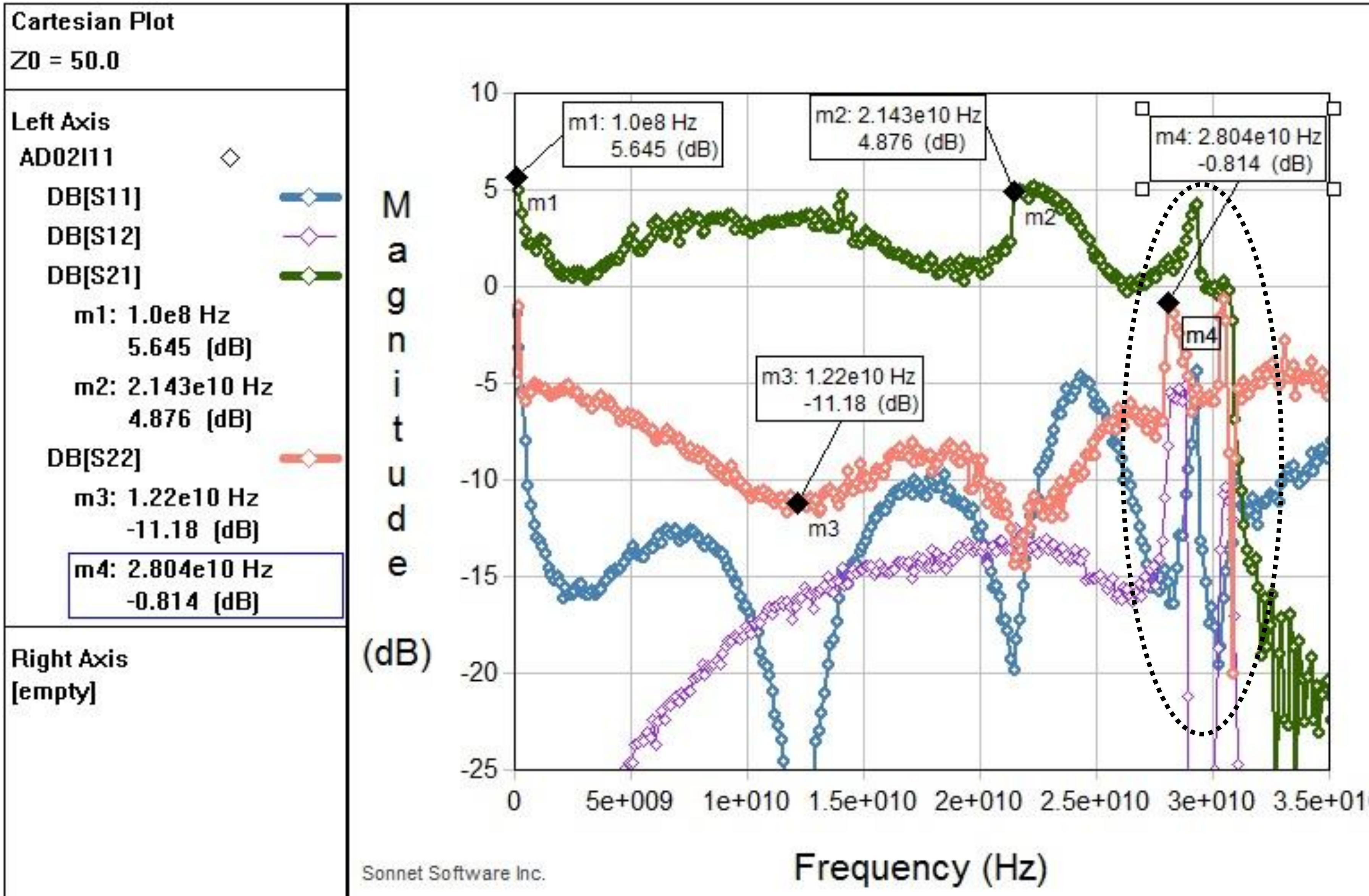




3) Alan Doucette
Distributed Amplifier

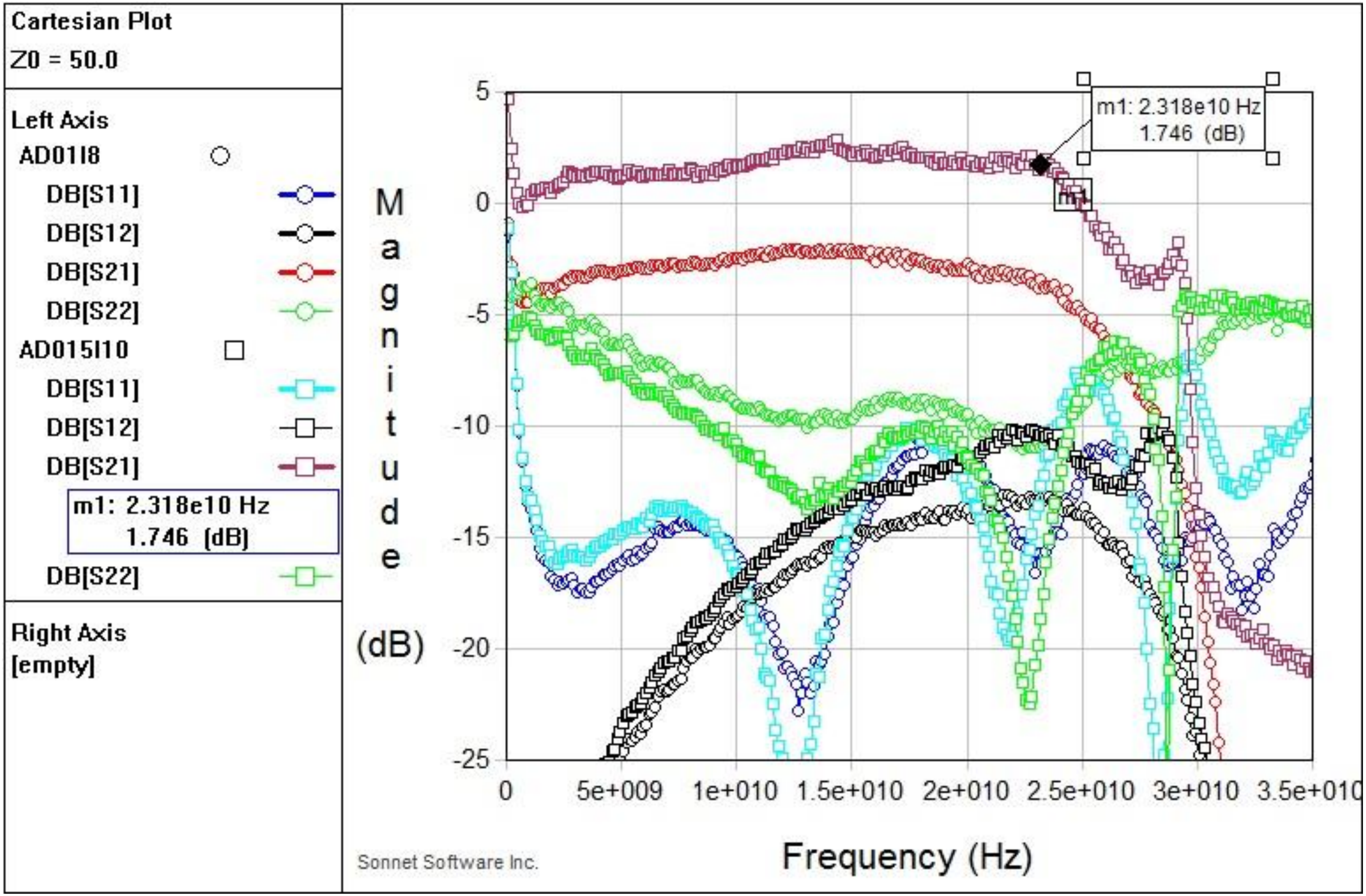
- *DRC (√)*
- *LVS (√)*
- *DC Current (√)*

3) Alan Doucette — 3/5/14
Distributed Amplifier — 0.2V at 11 mA; Stability problem ~30-35 GHz



3) Alan Doucette 3/13/14

Distributed Amplifier At low bias, broadband match looks great, then as gain approaches ~5dB (~0.2V), oscillations start at 30-35 GHz. Can drive amp into stable 1dB? compression



3) Alan Doucette

Distributed Amplifier At low bias, broadband match looks great, then around 5dB gain, oscillations start at 30-35 GHz. Can drive amp into stable 1dB? compression

3/13/2014											
				Loss 5 dB for thru at 10G, bias Tee 1.2dB at 10G							
10 GHz	Die#1	**AD Damp Fall13 TQP13**			Stability problem at ~30-35 GHz, driven slightly into compression (Stable!)						
Pin(SG)	**Pout(SA)**	**Pin(corr)**	**Pout(corr)**	**Gain**	**Vdd(V)**	**Ids(mA)**	**PDC(mw)**	**Pout(mw)**	**Drn Eff**	**PAE**	
-10.0	-12.40	-12.50	-8.70	3.80	0.20	10	2.0	0.13	6.7	3.9	
-11.0	-13.20	-13.50	-9.50	4.00	0.20	10	2.0	0.11	5.6	3.4	
6.0	5.20	**3.50**	**8.90**	**5.40**	**1.00**	**26**	**26.0**	**7.76**	**29.9**	**21.2**	
9.0	7.50	**6.50**	**11.20**	**4.70**	**1.50**	**32**	**48.0**	**13.18**	**27.5**	**18.2**	
10.0	8.90	**7.50**	**12.60**	**5.10**	**2.00**	**35**	**70.0**	**18.20**	**26.0**	**18.0**	
11.0	10.00	**8.50**	**13.70**	**5.20**	**2.50**	**39**	**97.5**	**23.44**	**24.0**	**16.8**	
12.0	11.20	**9.50**	**14.90**	**5.40**	**3.00**	**44**	**132.0**	**30.90**	**23.4**	**16.7**	

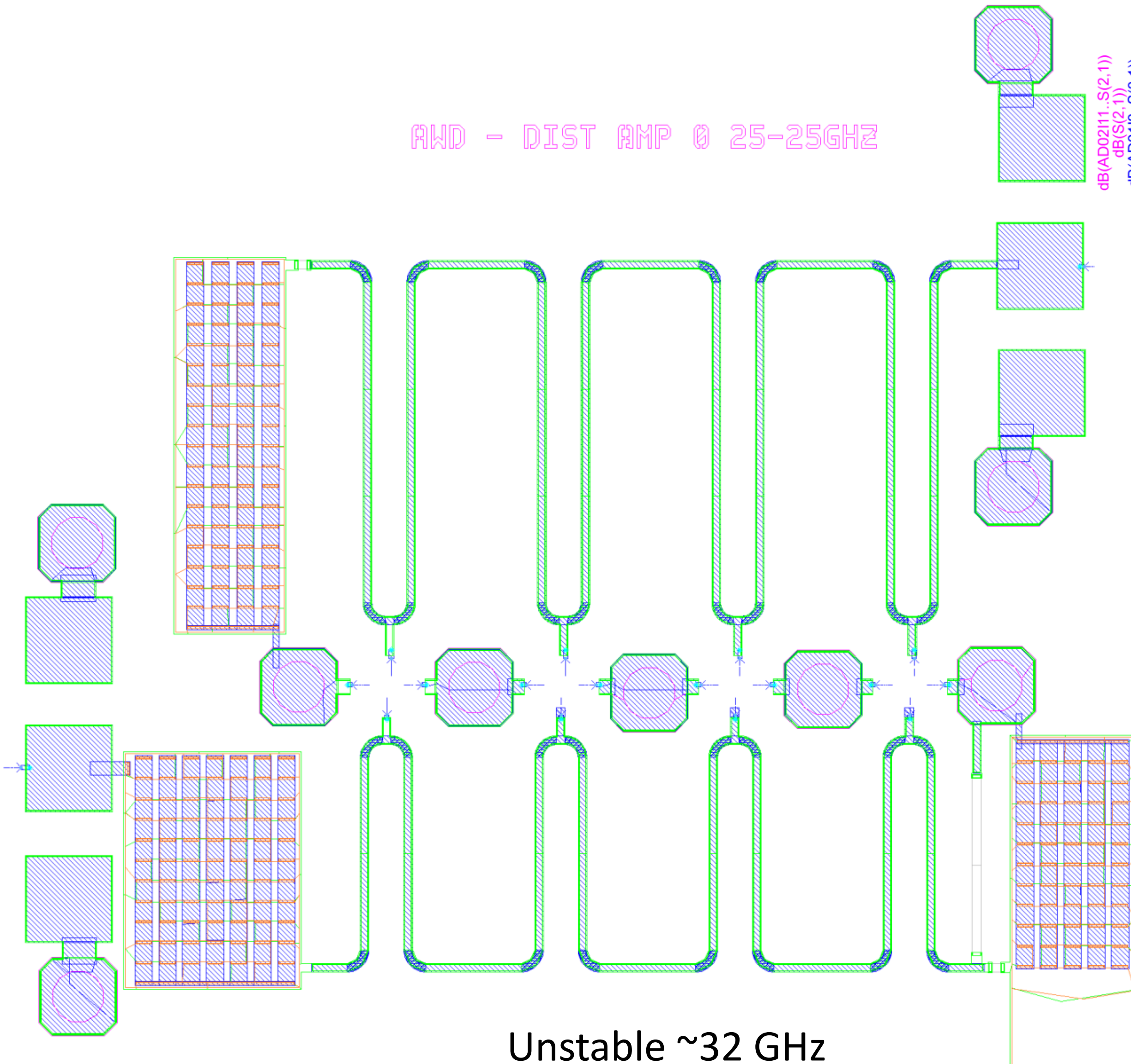
10 GHz input driven hard enough until oscillations quit. Results in about 5dB gain. Increased DC Bias, then increased signal at each point to maintain stability. An EM simulation of the actual layout may indicate the marginal stability problem at high frequency and a solution to stabilize the design.

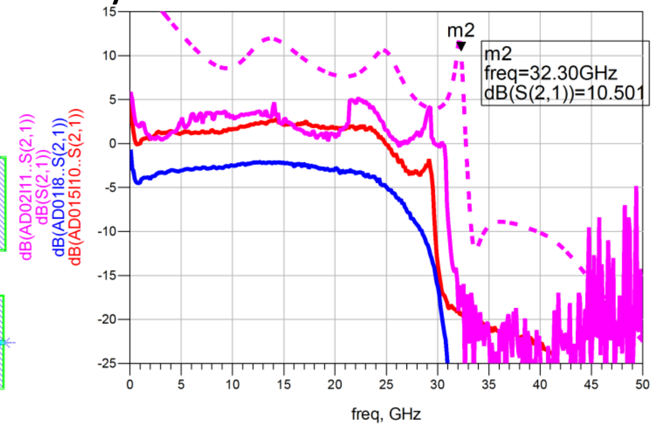
Note the fairly consistent gain (~5db) and efficiency (~17-21% PAE) where the amplifier showed gain and stability at increasing DC biases and signal levels.

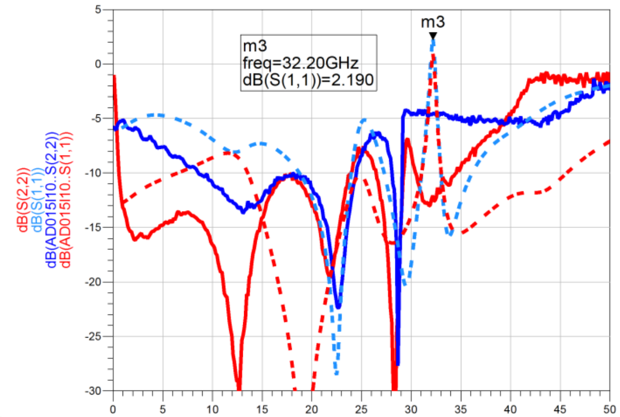
3) Alan Doucette

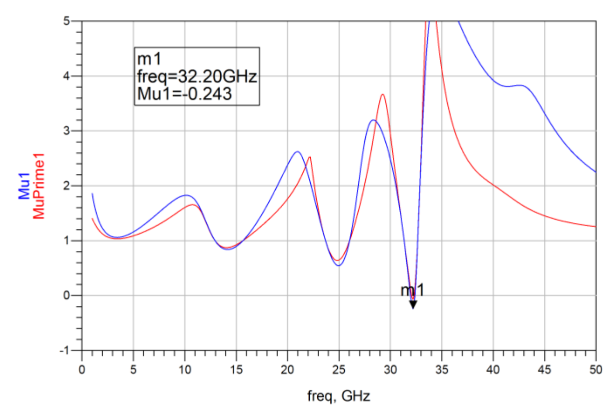
Distributed Amplifier   Momentum EM Simulation of Layout!

3V Sim; 0.15V Meas





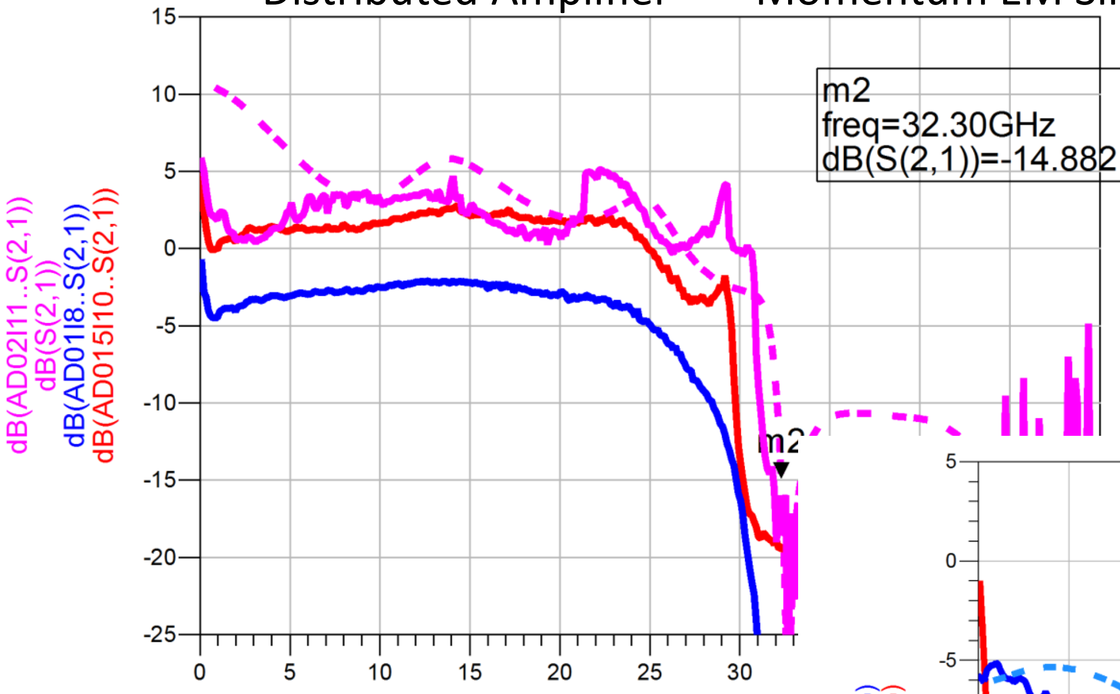




Unstable ~32 GHz

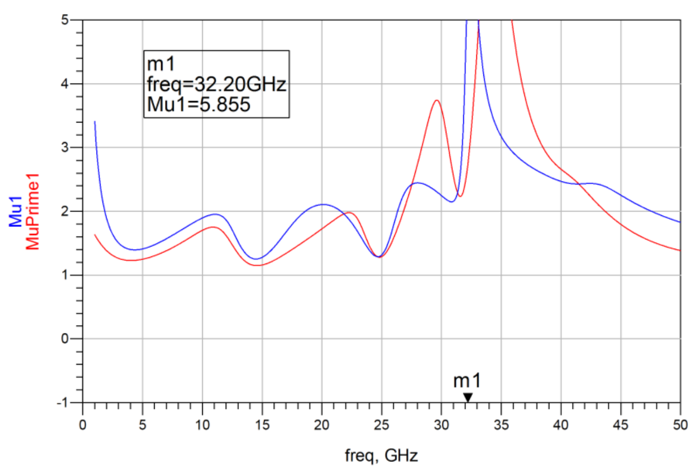
3) Alan Doucette

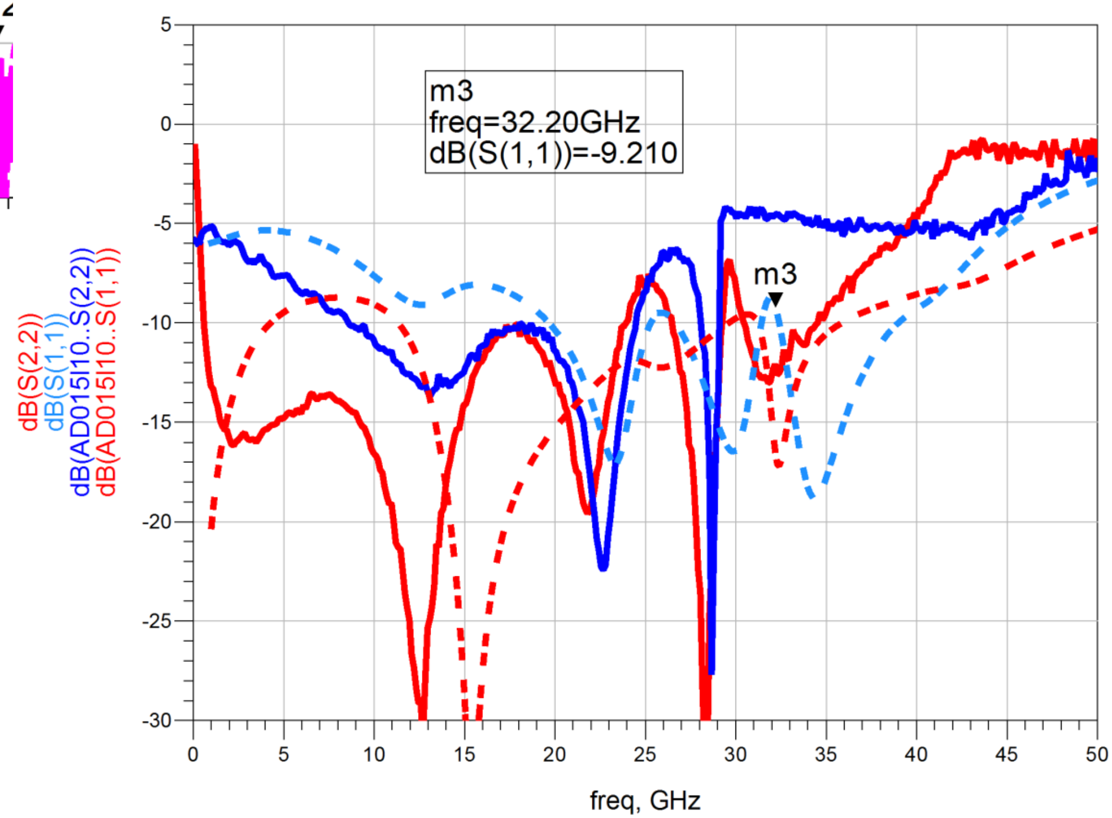
Distributed Amplifier Momentum EM Simulation of Layout!



0.2V Sim; 0.15V Meas

Stable at 0.2V Sim

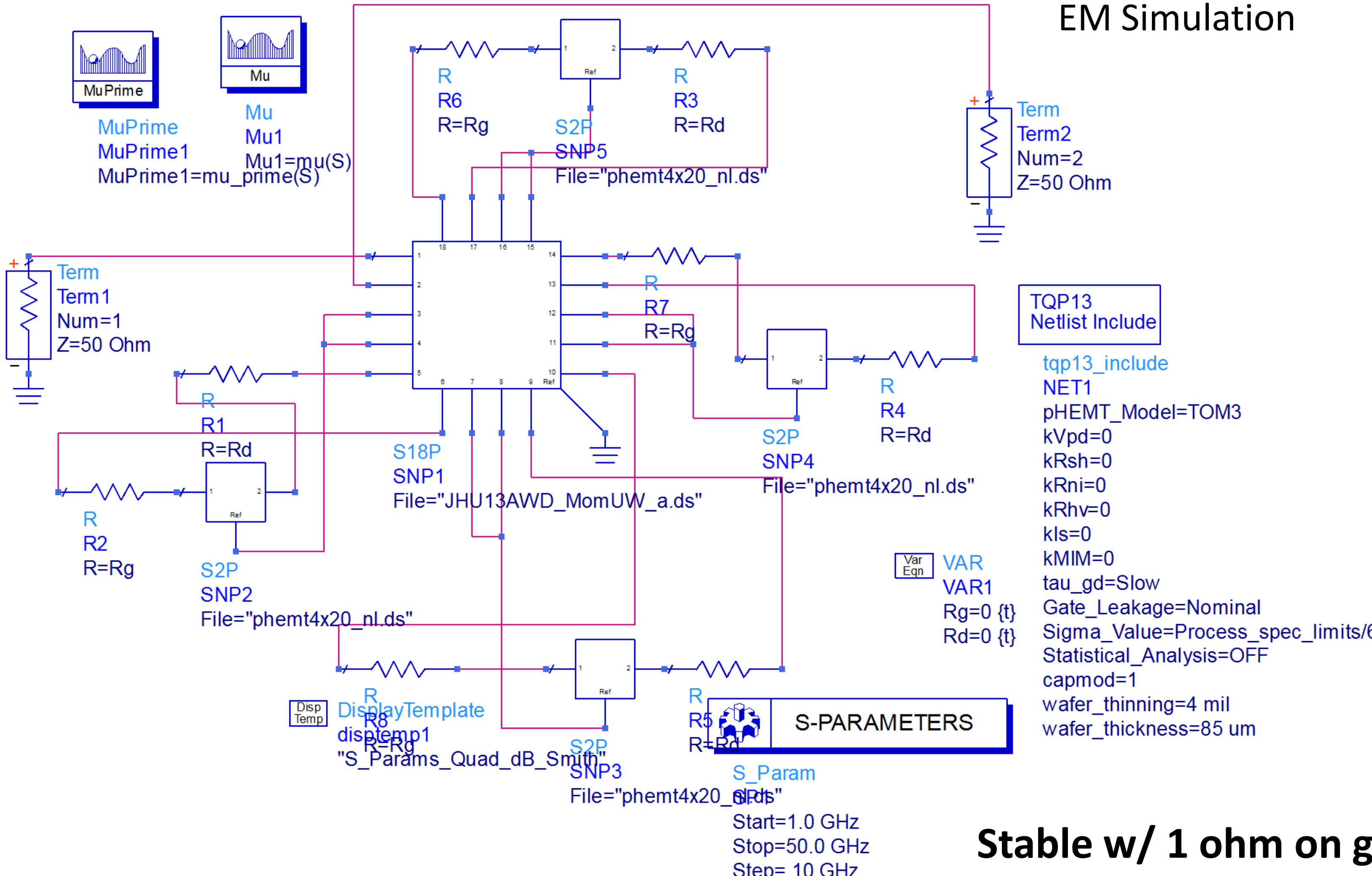




3) Alan Doucette

Distributed Amplifier   Momentum EM Simulation of Layout!

EM Simulation

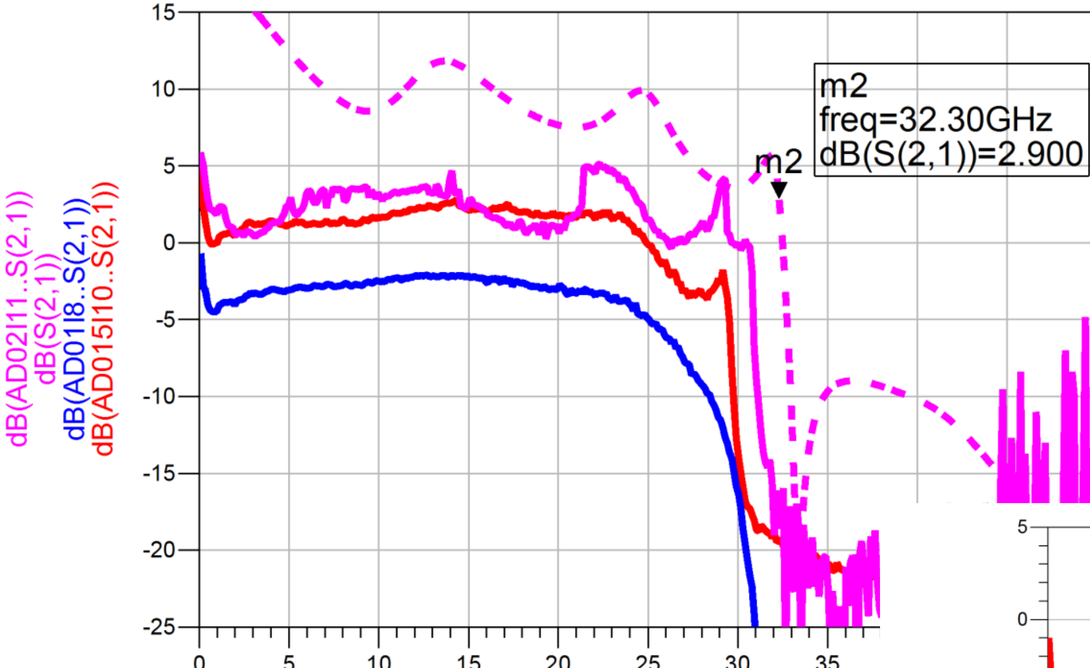


Stable w/ 1 ohm on gates
Or 3 ohms on drains

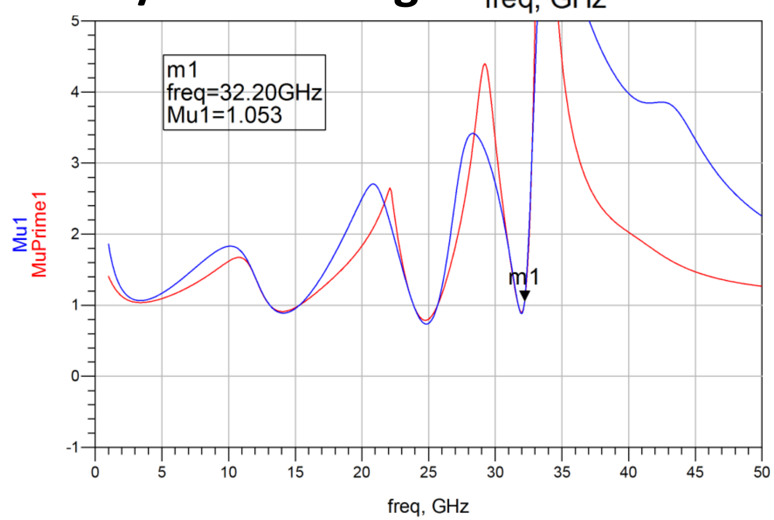
3) Alan Doucette

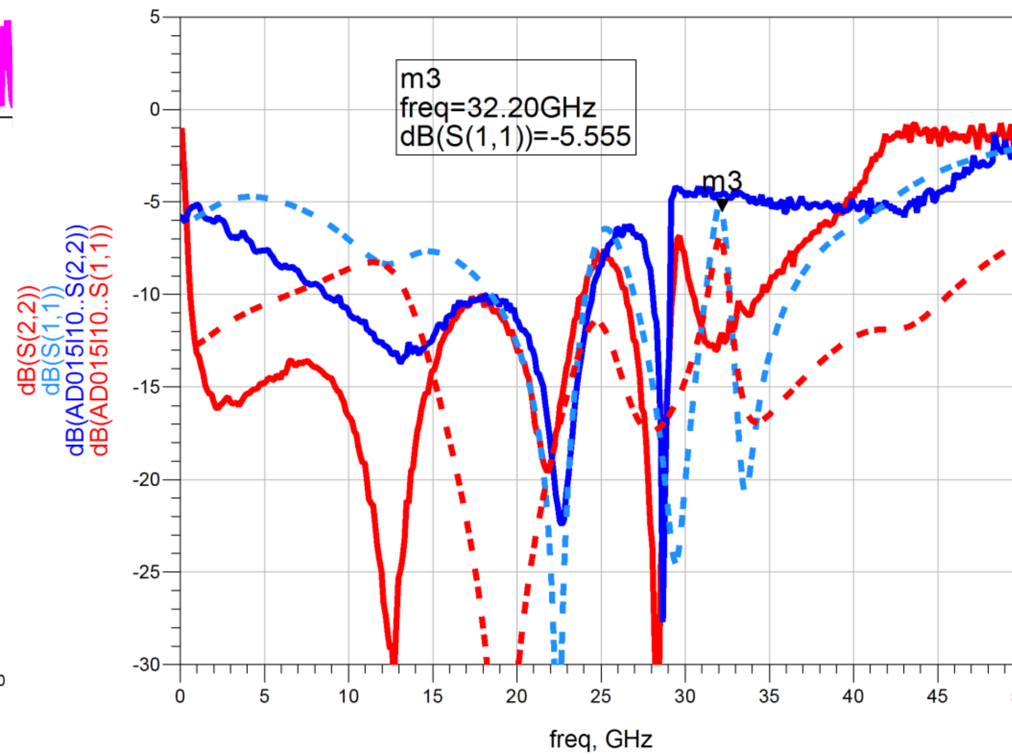
Distributed Amplifier Momentum EM Simulation of Layout!

EM Simulation



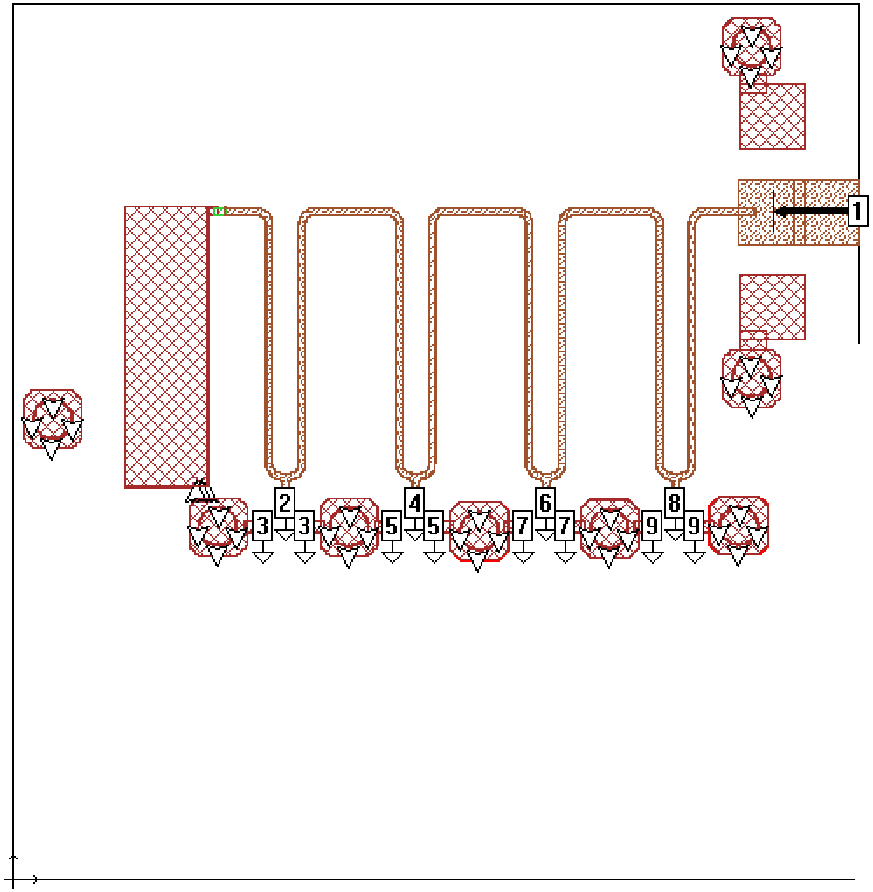
Stable w/ 1 ohm on gates





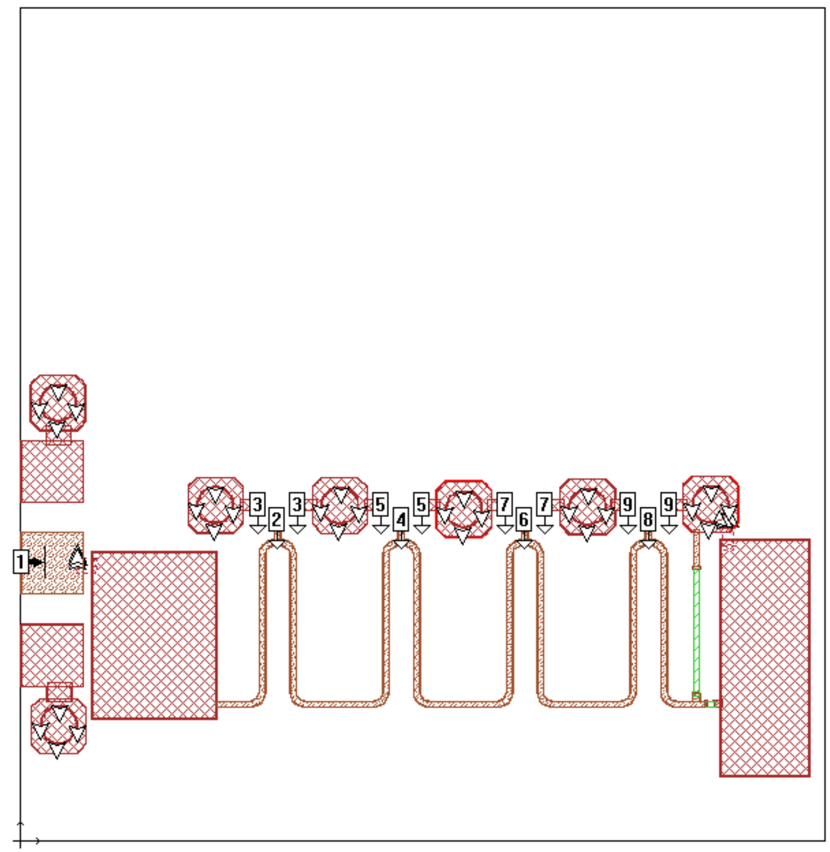
3) Alan Doucette

Distributed Amplifier   Sonnet EM Simulation of Layout!



EM Simulation
Drain/Gate

Simulate with 0.2V and 3V 4x20 PHEMT

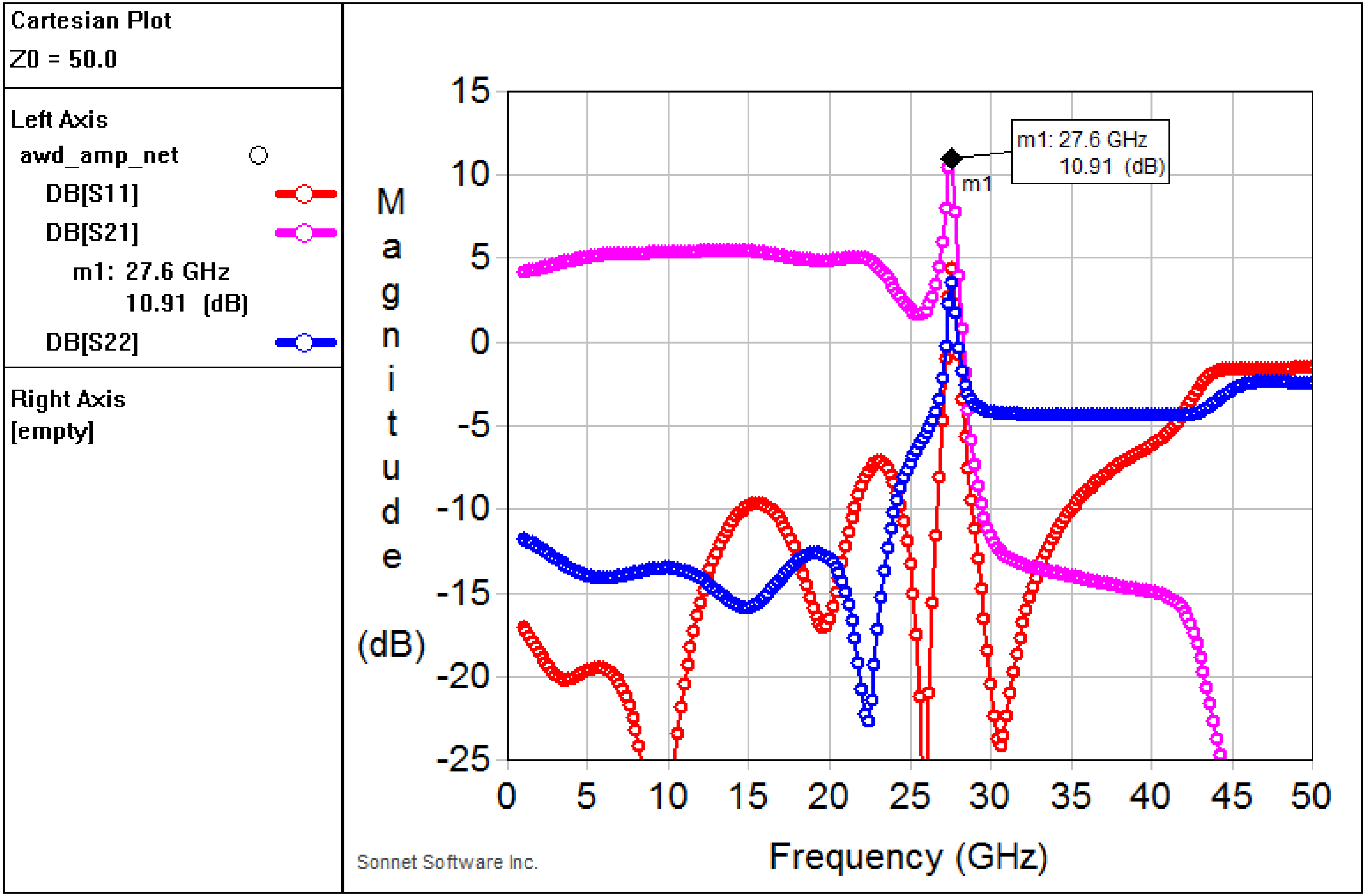


3) Alan Doucette

Distributed Amplifier Sonnet EM Simulation of Layout!

Simulate with 0.2V 4x20 PHEMT

EM Simulation

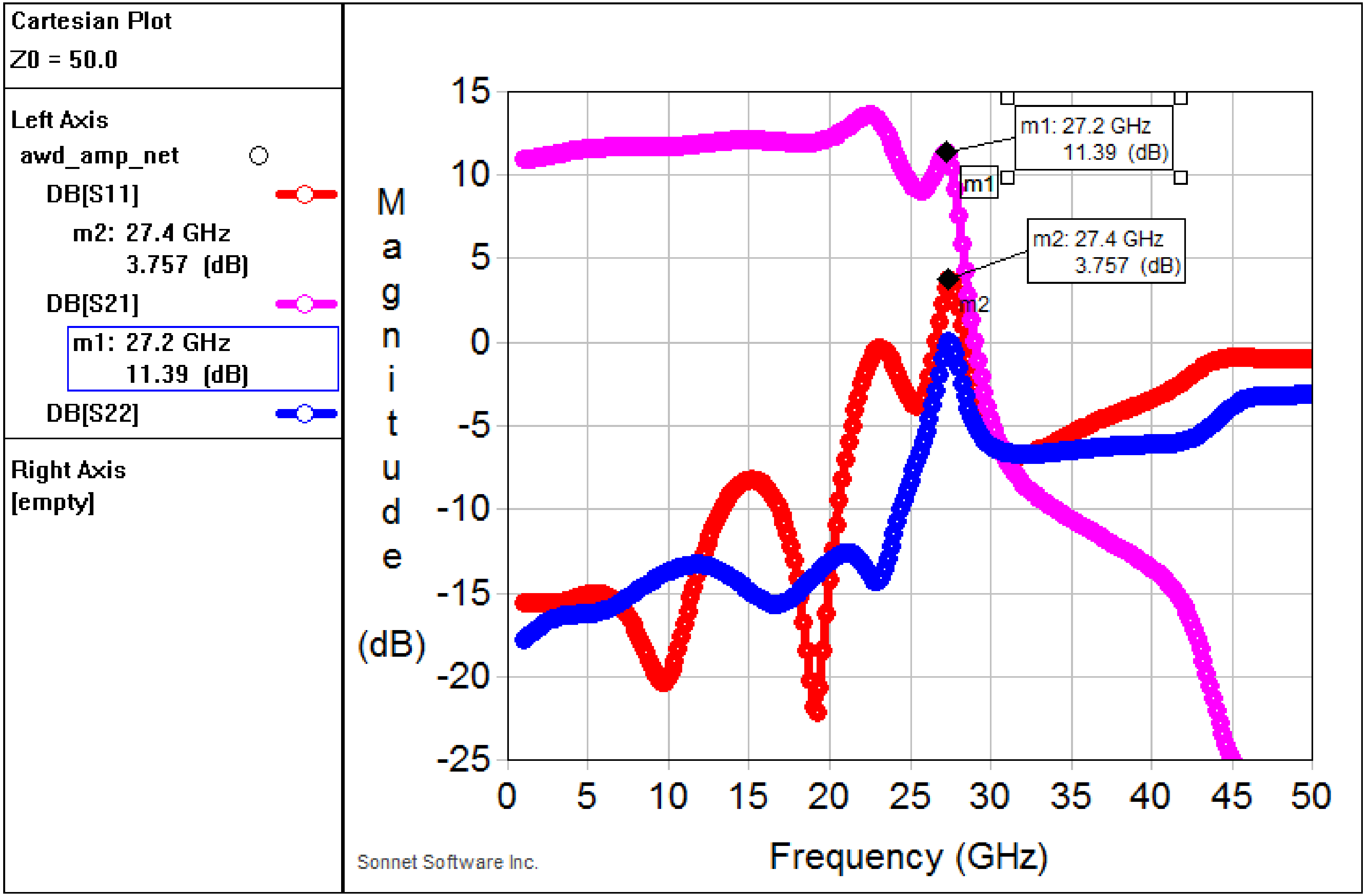


3) Alan Doucette

Distributed Amplifier Sonnet EM Simulation of Layout!

Simulate with 3V 4x20 PHEMT

EM Simulation

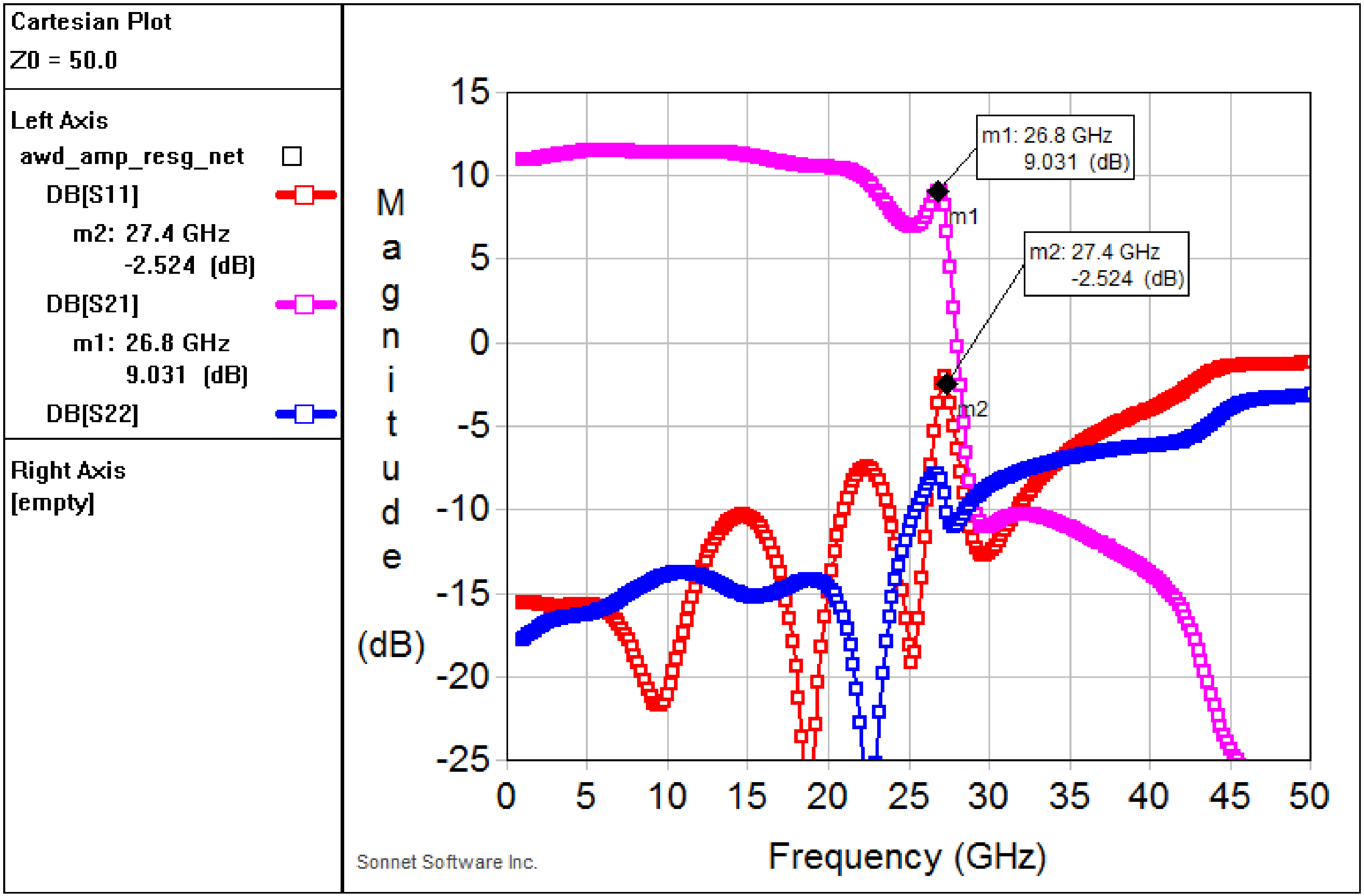


3) Alan Doucette

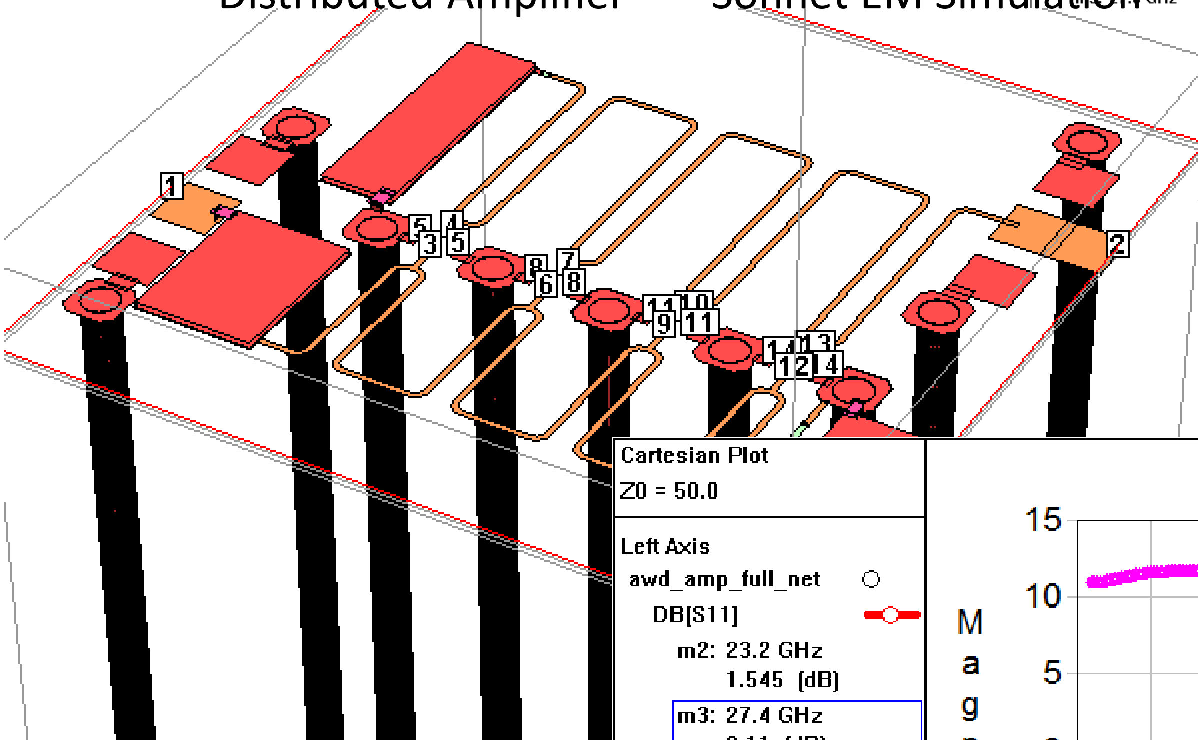
Distributed Amplifier   Sonnet EM Simulation of Layout!

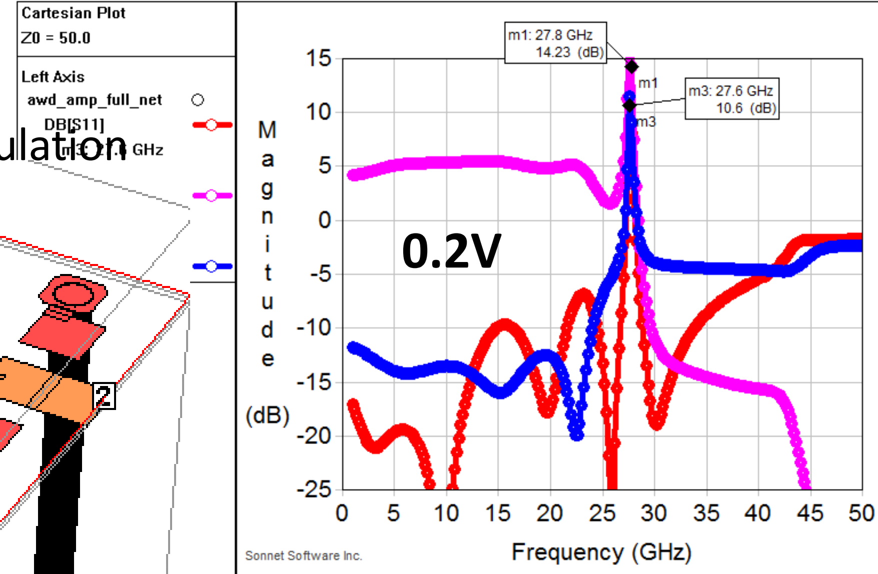
EM Simulation

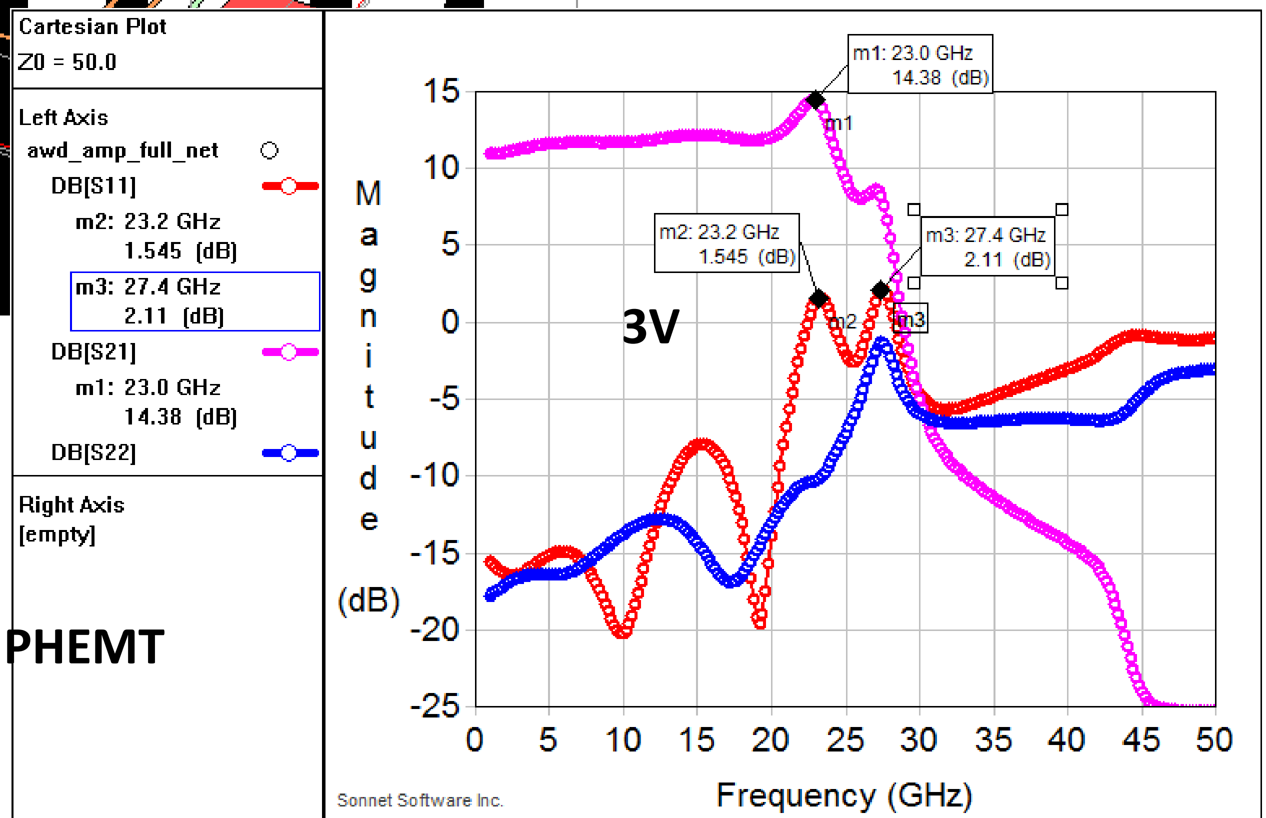
Simulate with 3V 4x20 PHEMT; Stable with ~6 Ωs on gates



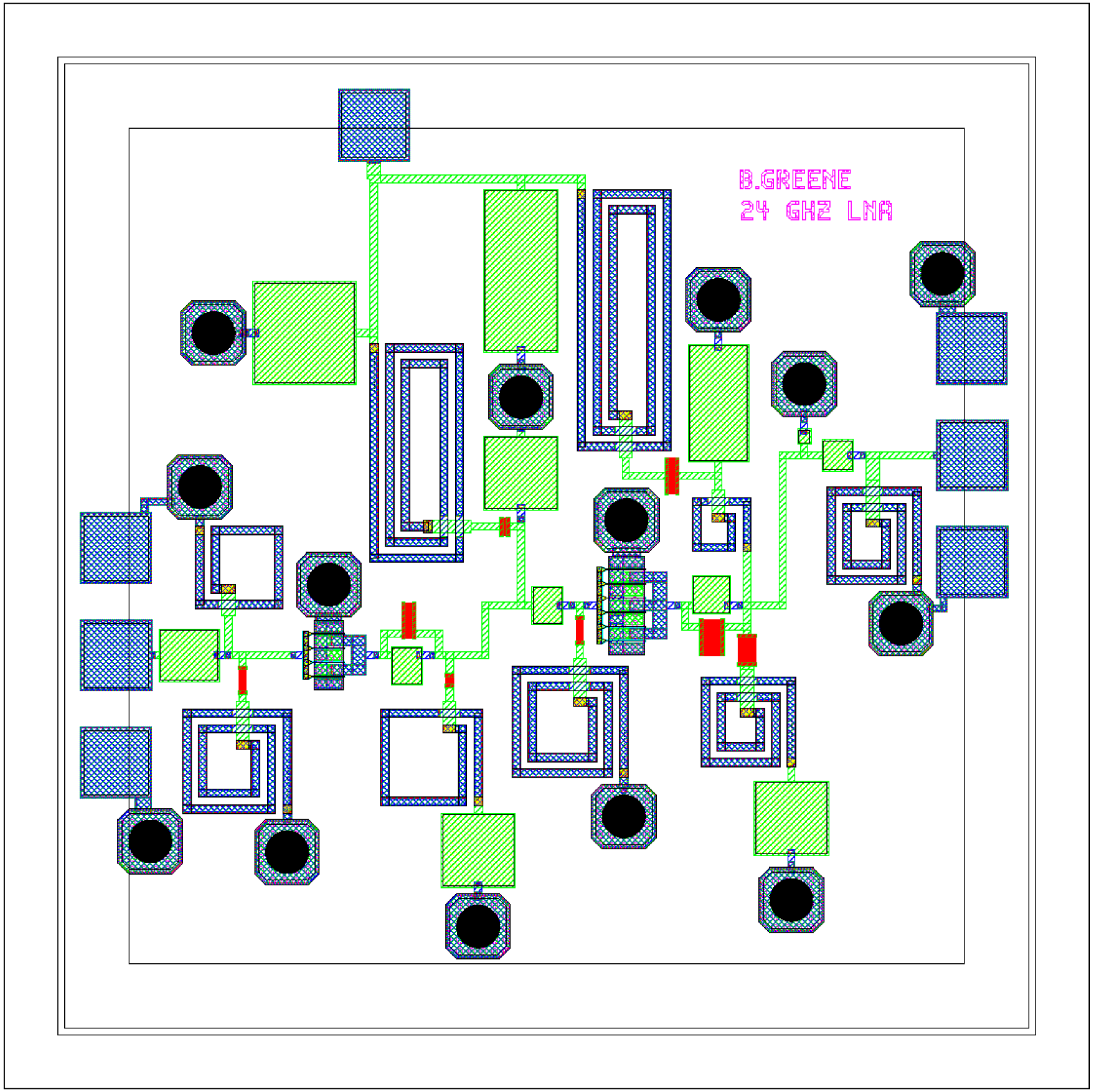
3) Alan Doucette Distributed Amplifier Sonnet EM Simulation







Simulate w/ 0.2,3V 4x20 PHEMT

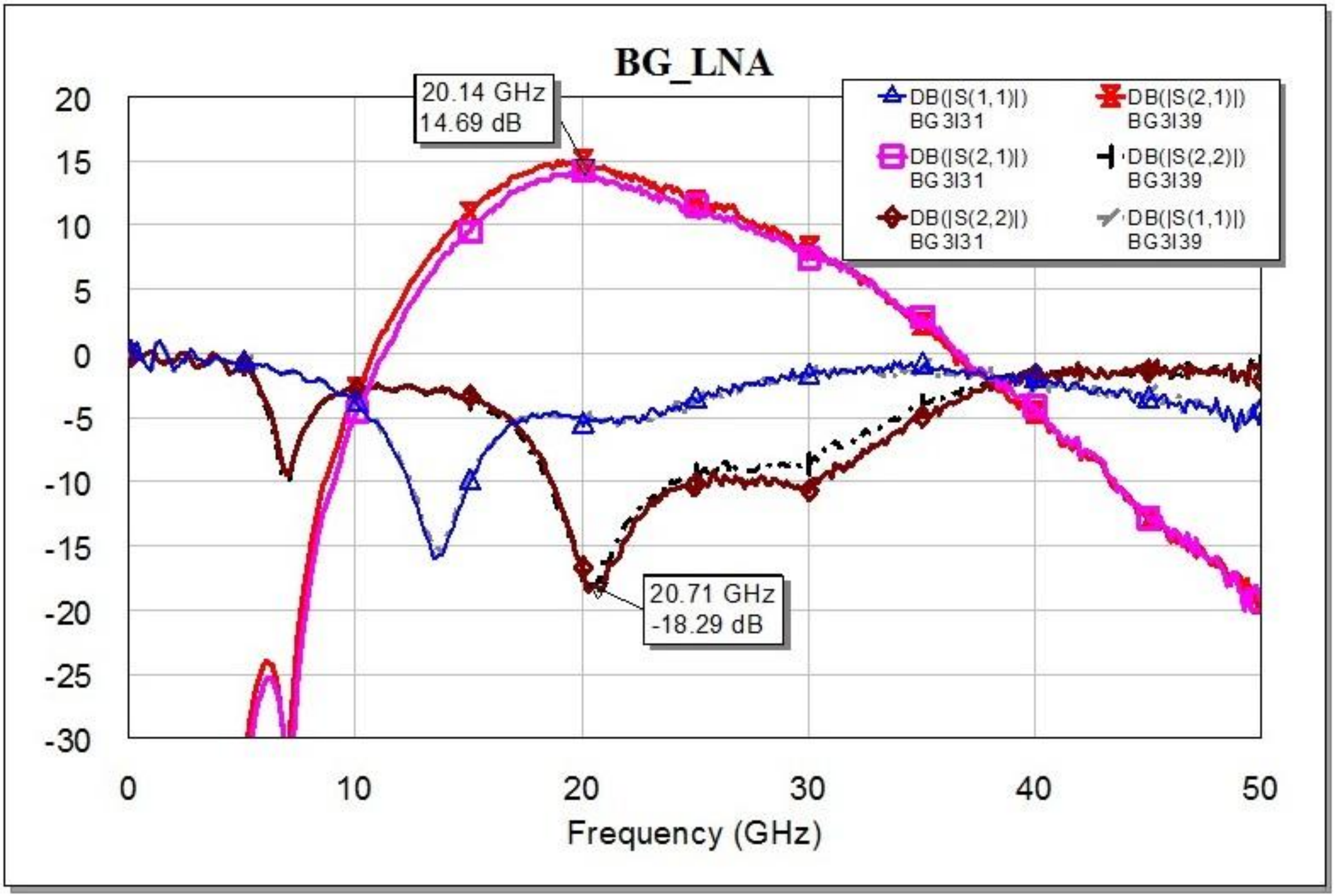


4) Brad Greene
Low Noise Amplifier

- *DRC (√)*
- *LVS (√)*
- *DC Current (√)*

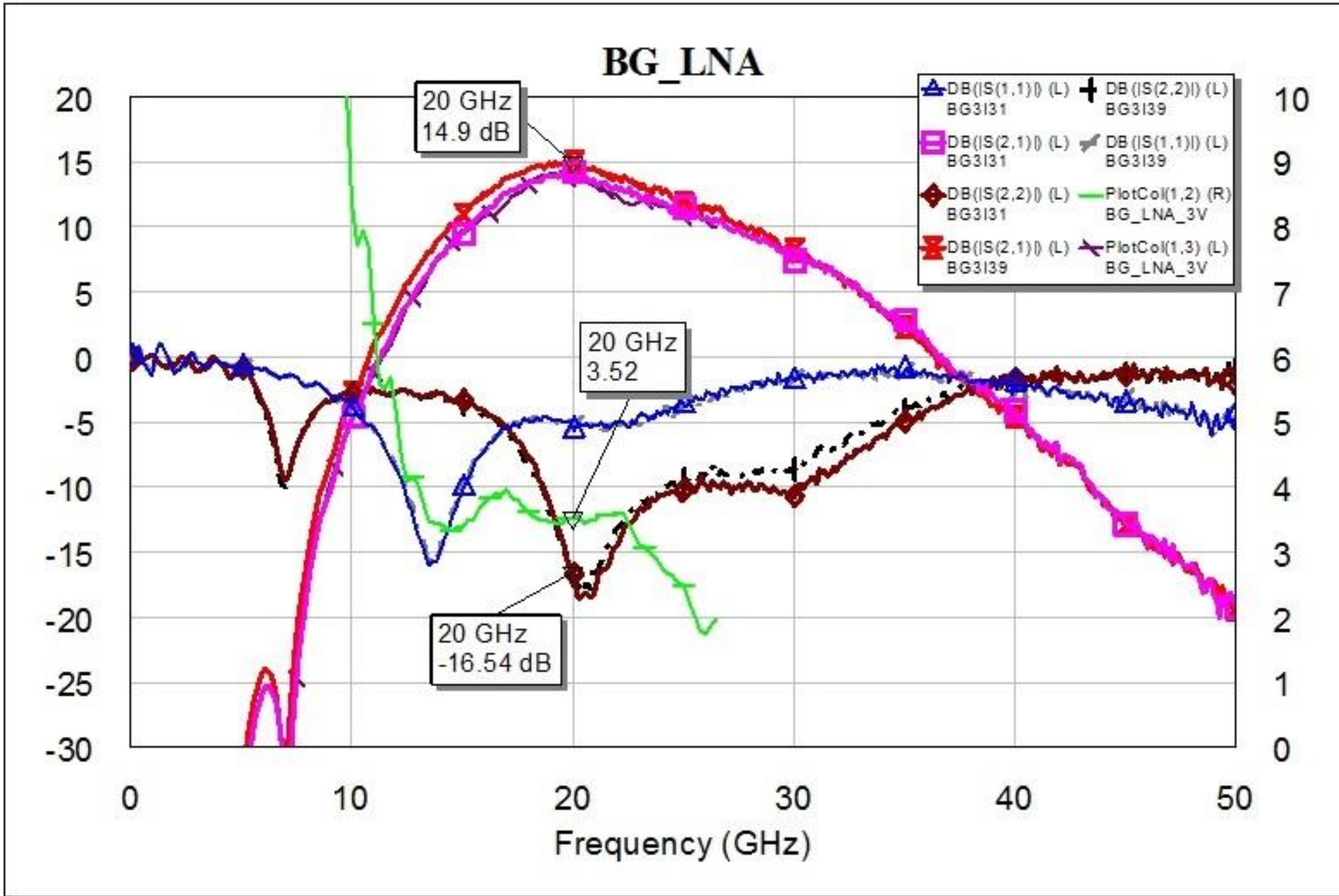
4) Brad Greene — 3/12/14

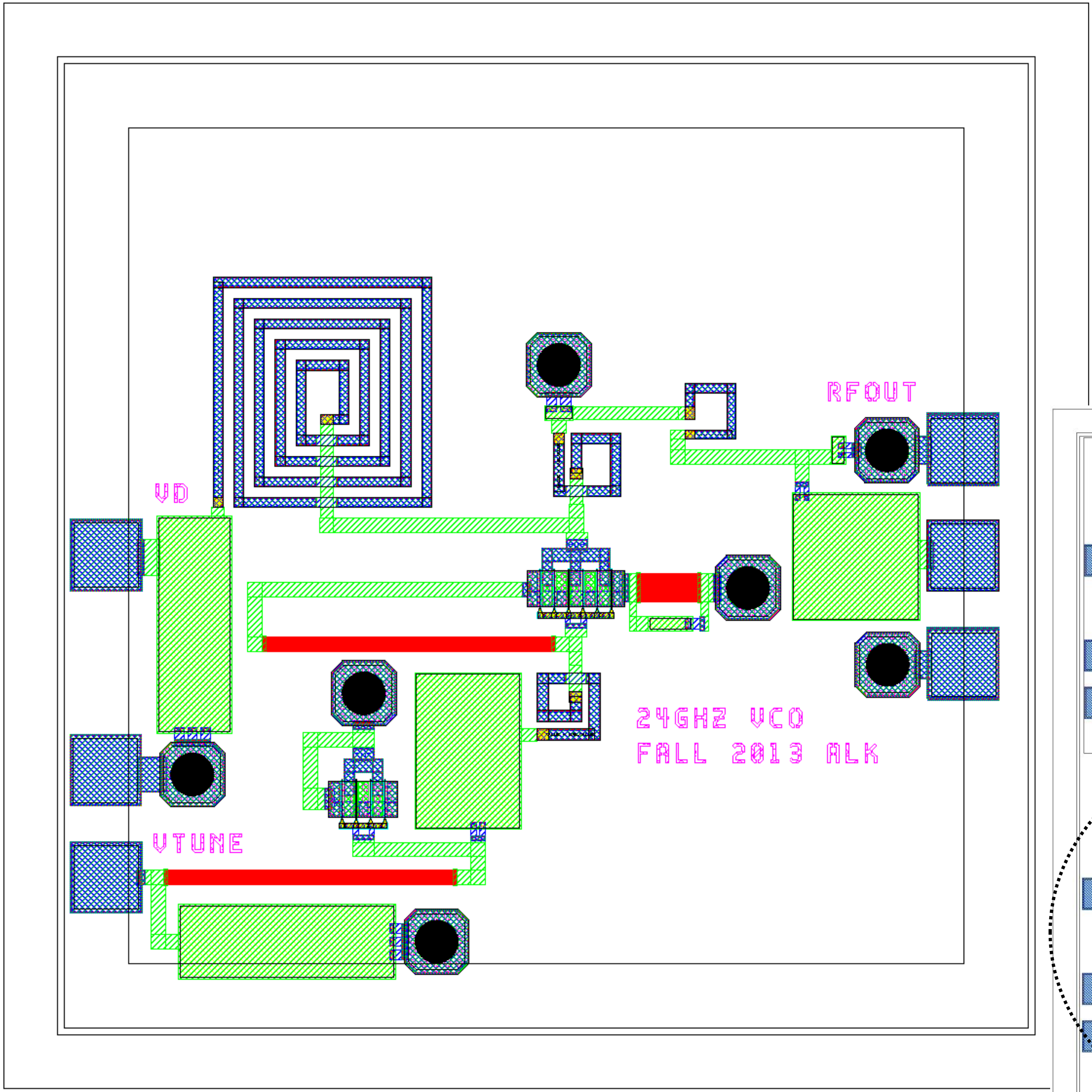
Low Noise Amplifier — 3V 31mA Die #1, 3V 39mA Die #2



4) Brad Greene — Added NF and Gain to 26.5 GHz to NWA measurements

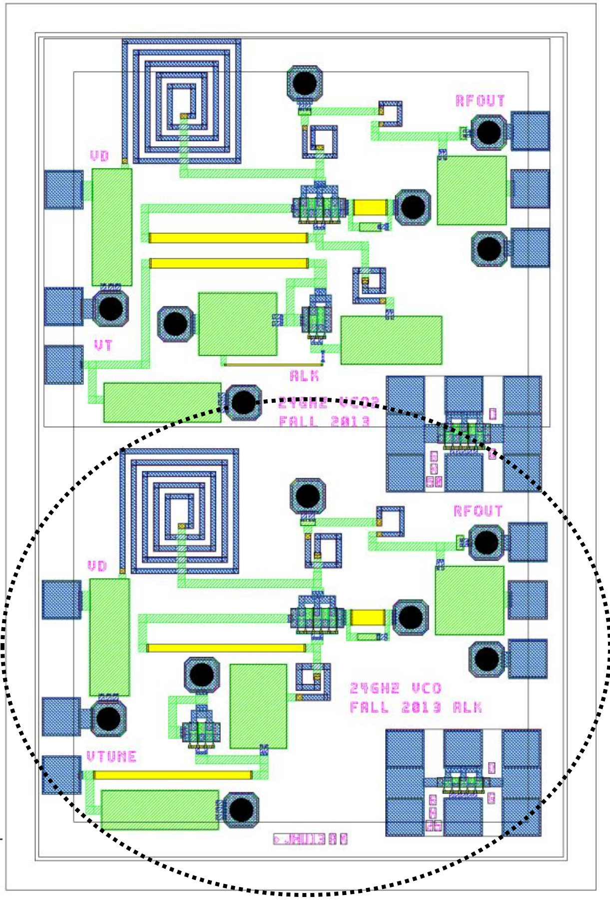
Low Noise Amplifier — NF measurements seem high by 1-2 dB ?

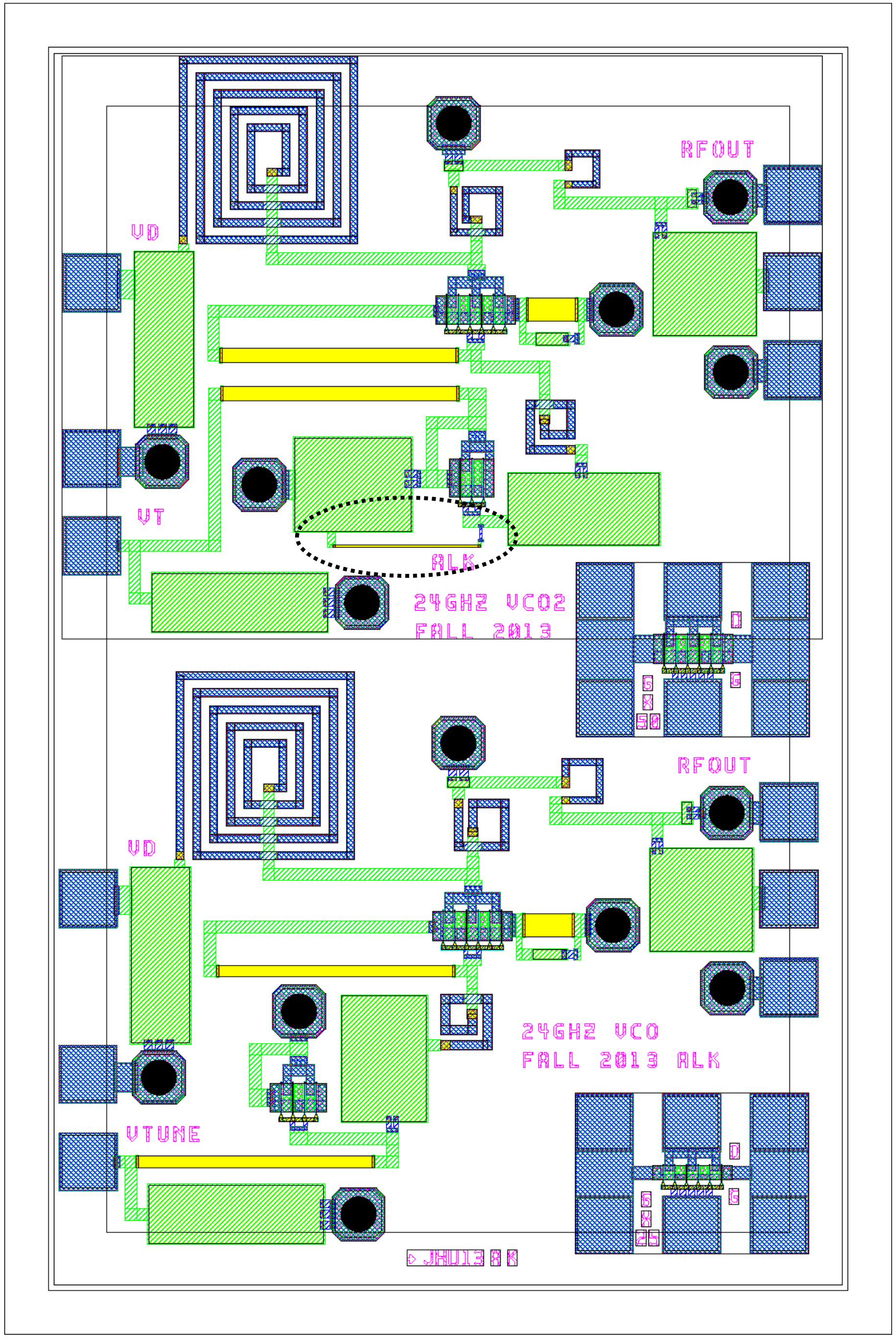




5) Amy Kordovski
Voltage Controlled Oscillator

- *DRC (√)*
- *LVS (√)*
- *DC Current (√)*





5) Amy Kordovski

Voltage Controlled Oscillator V2 (Top), Original Version (Bottom)

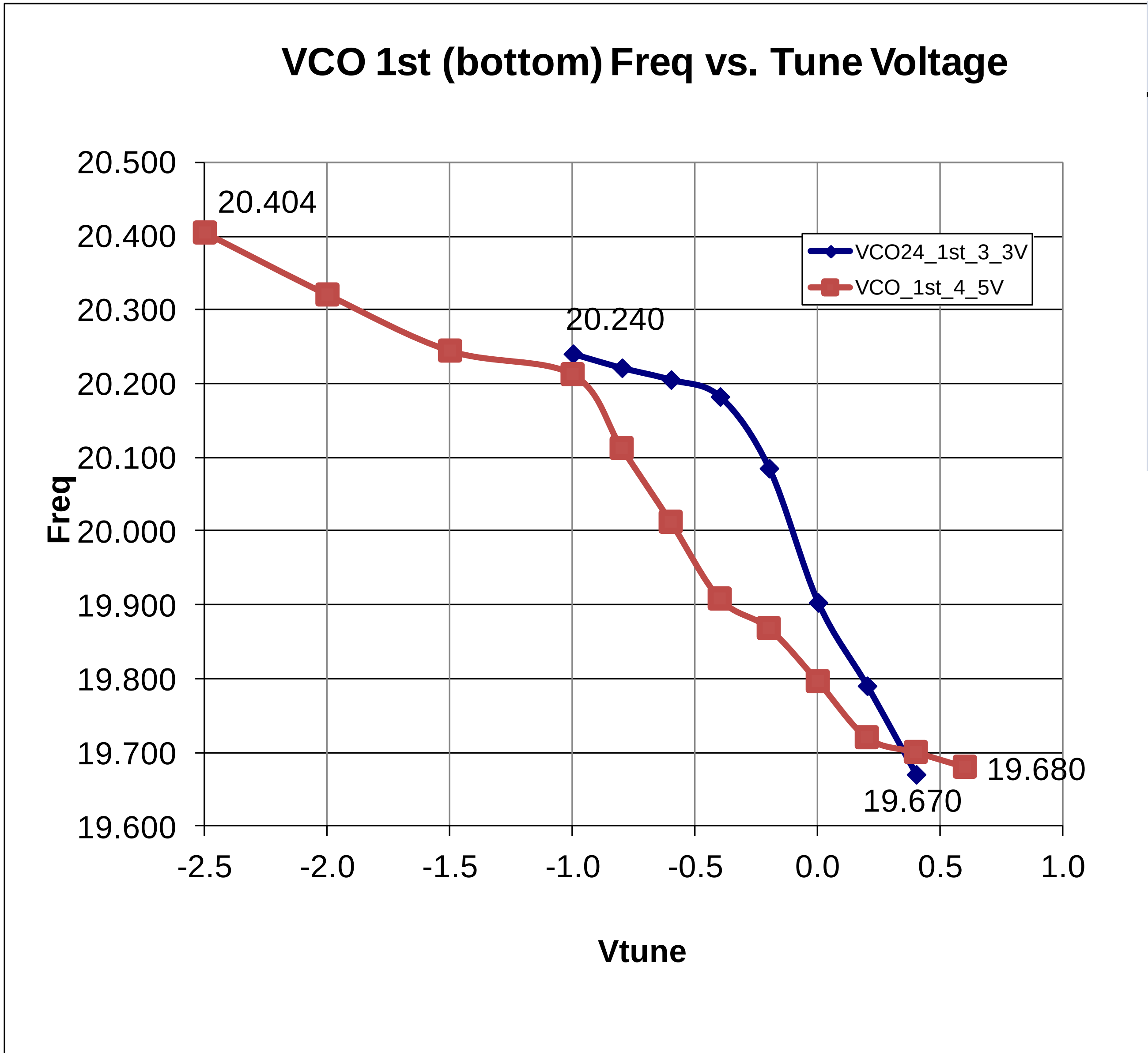
- *DRC (√)*
- *LVS (√)*
- *DC Current (√)*

Added 3.5K resistor to provide DC reference to varactor voltage. Original Layout was DC isolated by capacitors.

Also Note that the varactors are DC biased oppositely in the two designs. Varactors typically vary most when reverse biased, thought there is some variation with these diodes for small positive voltages before the diode starts to forward conduct. In the following measurements it "appears" that the tuning voltage swaps polarity but it is really just the reversing of the varactor DC connections. Both VCO designs oscillated near 20 GHz.

5) Amy Kordovski

Voltage Controlled Oscillator 1st Tuning Range measured at 3.3V (3/7/14) and 4.5V (3/27/14)



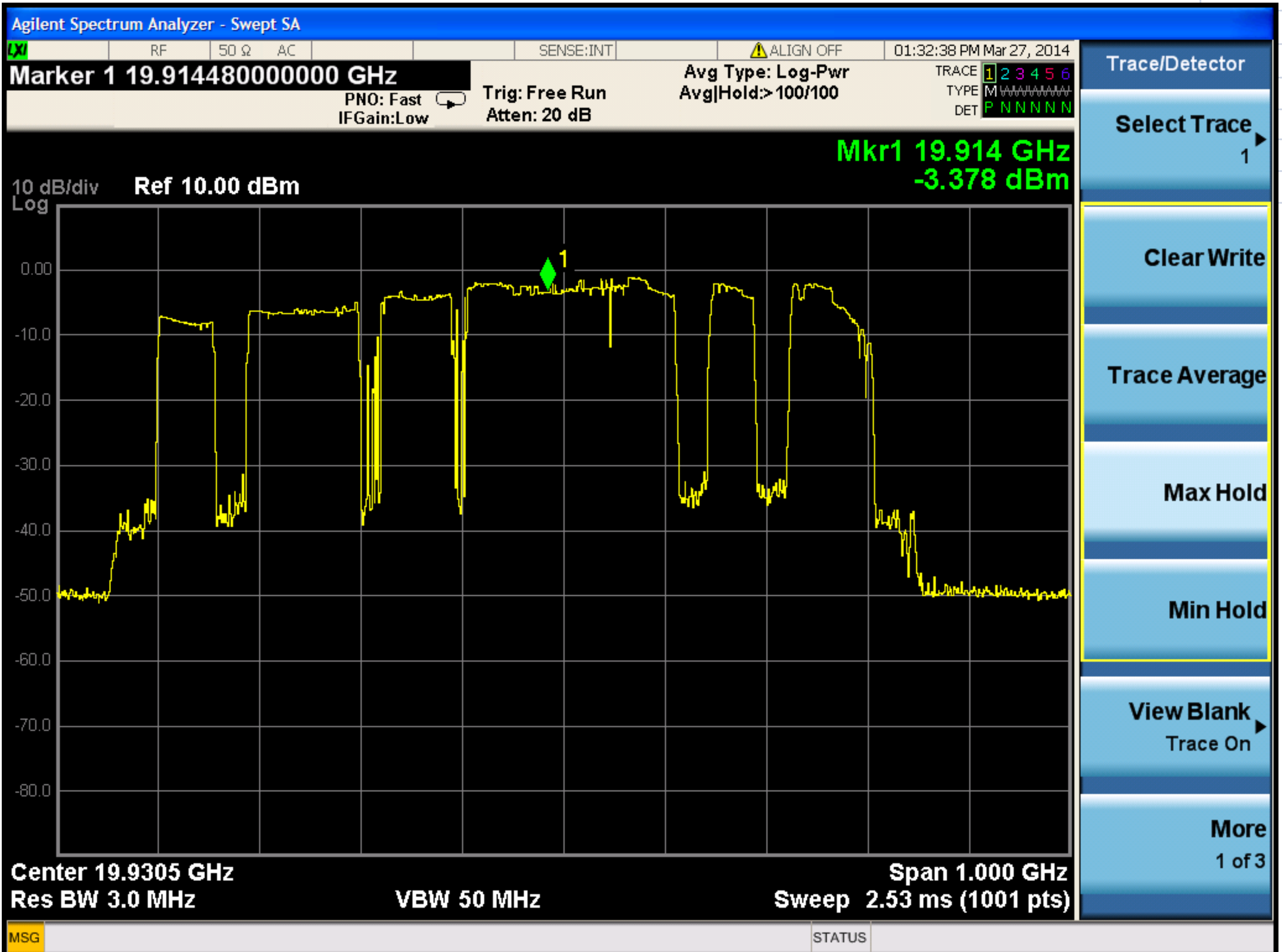
3/27/2014		~3.5-4dB cable loss	
Bottom 1st V	**4.5V at 28mA**		**Die #1**
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**
-2.5	**20.404**	2.3	**6.3**
-2.0	**20.320**	2.6	**6.6**
-1.5	**20.244**	3.1	**7.1**
-1.0	**20.212**	3.5	**7.5**
-0.8	**20.112**	2.6	**6.6**
-0.6	**20.012**	3.5	**7.5**
-0.4	**19.908**	2.6	**6.6**
-0.2	**19.868**	2.6	**6.6**
0.0	**19.796**	0.7	**4.7**
0.2	**19.720**	-1.2	**2.8**
0.4	**19.700**	-1.7	**2.3**
0.6	**19.680**	-1.4	**2.6**

Bot VCO	**3.3V at 18mA**		**Die #1**
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**
-1.0	**20.240**	-2.4	**1.1**
-0.8	**20.221**	-1.7	**1.8**
-0.6	**20.205**	-1.2	**2.3**
-0.4	**20.182**	-1.0	**2.5**
-0.2	**20.085**	-1.6	**1.9**
0.0	**19.903**	-2.6	**0.9**
0.2	**19.790**	-3.7	**-0.2**
0.4	**19.670**	-5.0	**-1.5**

5) Amy Kordovski

Voltage Controlled Oscillator 1st Tuning Range measured at 4.5V (3/27/14)

3/27/2014		~3.5-4dB cable loss	
Bottom 1st V	**4.5V at 28mA**		**Die #1**
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**
-2.5	**20.404**	2.3	**6.3**
-2.0	**20.320**	2.6	**6.6**
-1.5	**20.244**	3.1	**7.1**
-1.0	**20.212**	3.5	**7.5**
-0.8	**20.112**	2.6	**6.6**
-0.6	**20.012**	3.5	**7.5**
-0.4	**19.908**	2.6	**6.6**
-0.2	**19.868**	2.6	**6.6**
0.0	**19.796**	0.7	**4.7**
0.2	**19.720**	-1.2	**2.8**
0.4	**19.700**	-1.7	**2.3**
0.6	**19.680**	-1.4	**2.6**

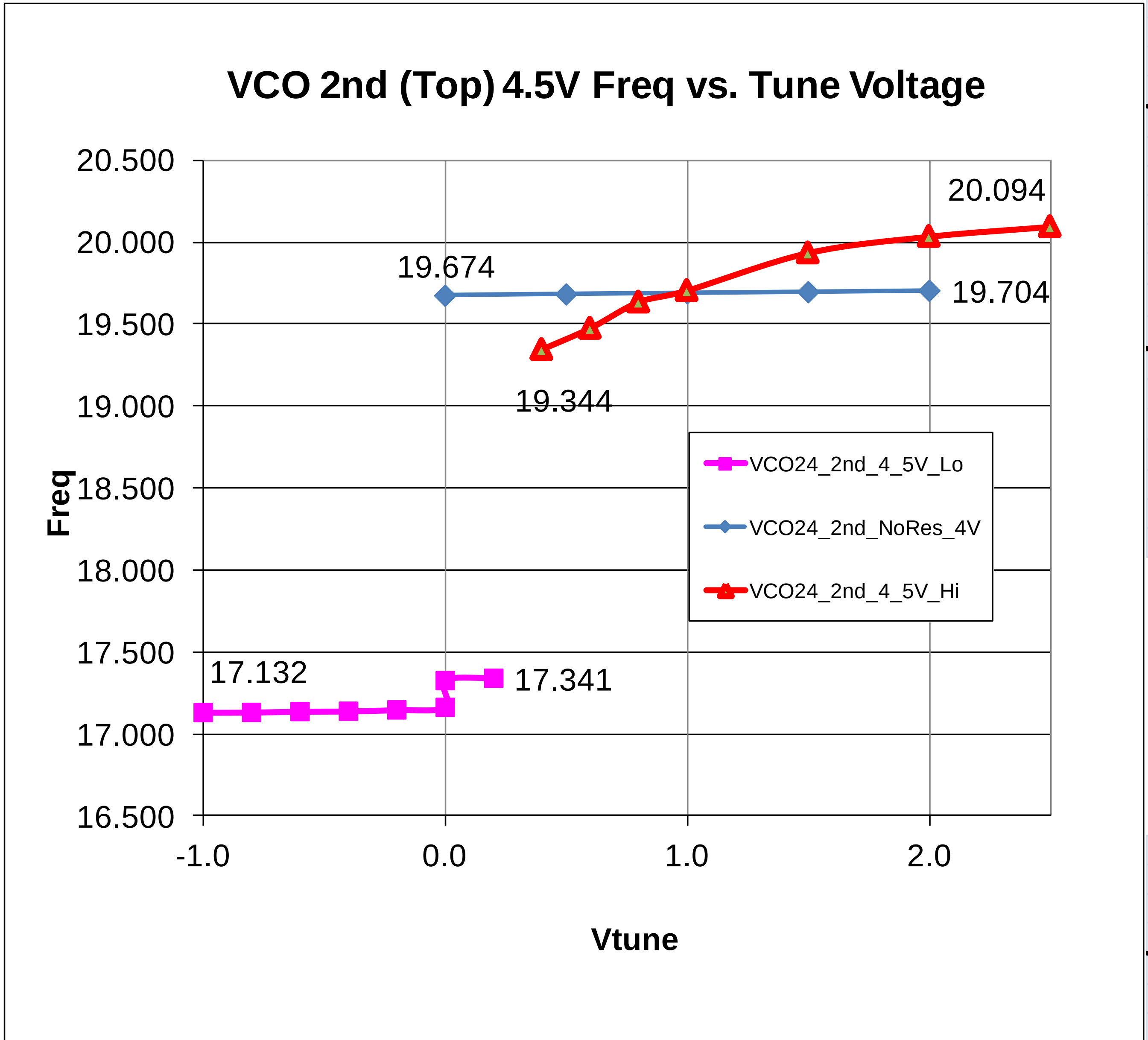


725 MHz

Tuning range

5) Amy Kordovski

Voltage Controlled Oscillator 2nd Tuning Range measured with and without resistor at 4.5V (3/27/14)



3/27/2014			
With Resistor		~3.5-4dB cable loss	
Top 2nd VC	**4.5V at 26mA**		**Die #2**
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**
-1.0	**17.132**	7.4	**10.9**
-0.8	**17.133**	7.4	**10.9**
-0.6	**17.138**	7.3	**10.8**
-0.4	**17.140**	7.3	**10.8**
-0.2	**17.148**	7.2	**10.7**
0.0	**17.164**	7	**10.5**
0.0	**17.327**	6.8	**10.3**
0.2	**17.341**	5.5	**9.0**
0.4	**19.344**	-1.4	**2.6**
0.6	**19.474**	-1.4	**2.6**
0.8	**19.634**	0.4	**4.4**
1.0	**19.704**	-0.8	**3.2**
1.5	**19.934**	3.2	**7.2**
2.0	**20.034**	2.7	**6.7**
2.5	**20.094**	3.1	**7.1**

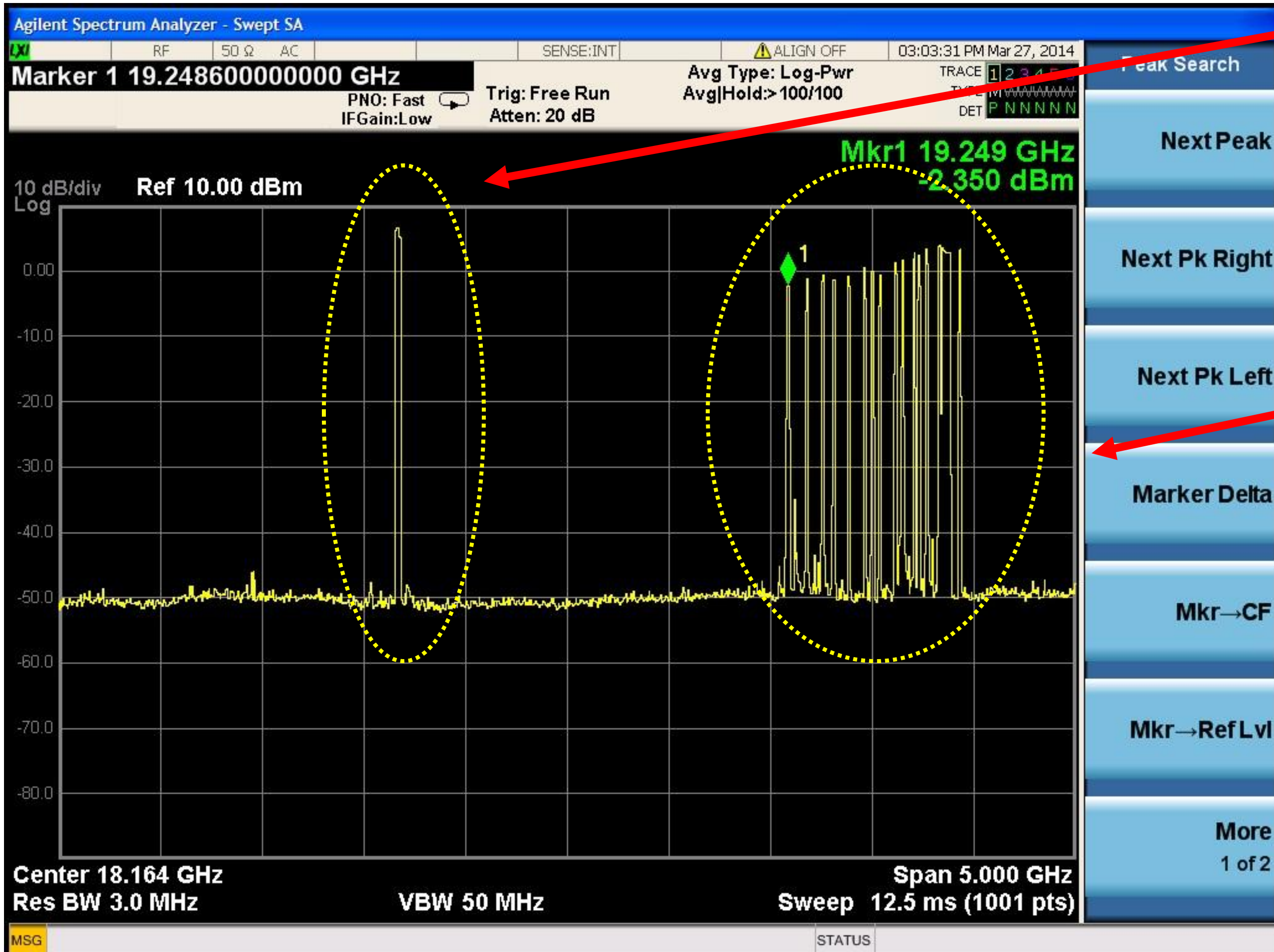
3/27/2014			
Removed Resistor		~4dB cable loss	
Top 2nd V	**4V at 29mA**		**Die #1**
VBias (V)	**Freq (GHz)**	**Pout(ms)**	**Pout(corr)**
0.0	**19.674**	-1.3	**2.7**
0.5	**19.682**	-1.3	**2.7**
1.0	**19.689**	-1.2	**2.8**
1.5	**19.696**	-1.3	**2.7**
2.0	**19.704**	-1.4	**2.6**

3/27/2014			
Removed Resistor		~4dB cable loss	
Top 2nd VC	**4.5V at 31mA**		**Die #1**
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**
0.0	19.719	0.0	**4.0**
1.5	19.779	1.2	**5.2**
2.0	19.787	1.0	**5.0**

5) Amy Kordovski

Voltage Controlled Oscillator 2nd Tuning Range measured with and without resistor at 4.5V (3/27/14)

2nd Design seemed "bi-stable" with a lower frequency (17GHz) with little tuning range, and a high frequency (20 GHz) with a good tuning range. Without the DC reference Resistor there was a very, very small tuning range but only for positive bias voltages. Varactors are typically reverse biased.



3/27/2014			
With Resistor		~3.5-4dB cable loss	
Top 2nd VC	4.5V at 26mA		Die #2
VBias (V)	Freq (GHz	Pout(ms)	Pout(corr)
-1.0	17.132	7.4	10.9
-0.8	17.133	7.4	10.9
-0.6	17.138	7.3	10.8
-0.4	17.140	7.3	10.8
-0.2	17.148	7.2	10.7
0.0	17.164	7	10.5
0.0	17.327	6.8	10.3
0.2	17.341	5.5	9.0
0.4	19.344	-1.4	2.6
0.6	19.474	-1.4	2.6
0.8	19.634	0.4	4.4
1.0	19.704	-0.8	3.2
1.5	19.934	3.2	7.2
2.0	20.034	2.7	6.7
2.5	20.094	3.1	7.1

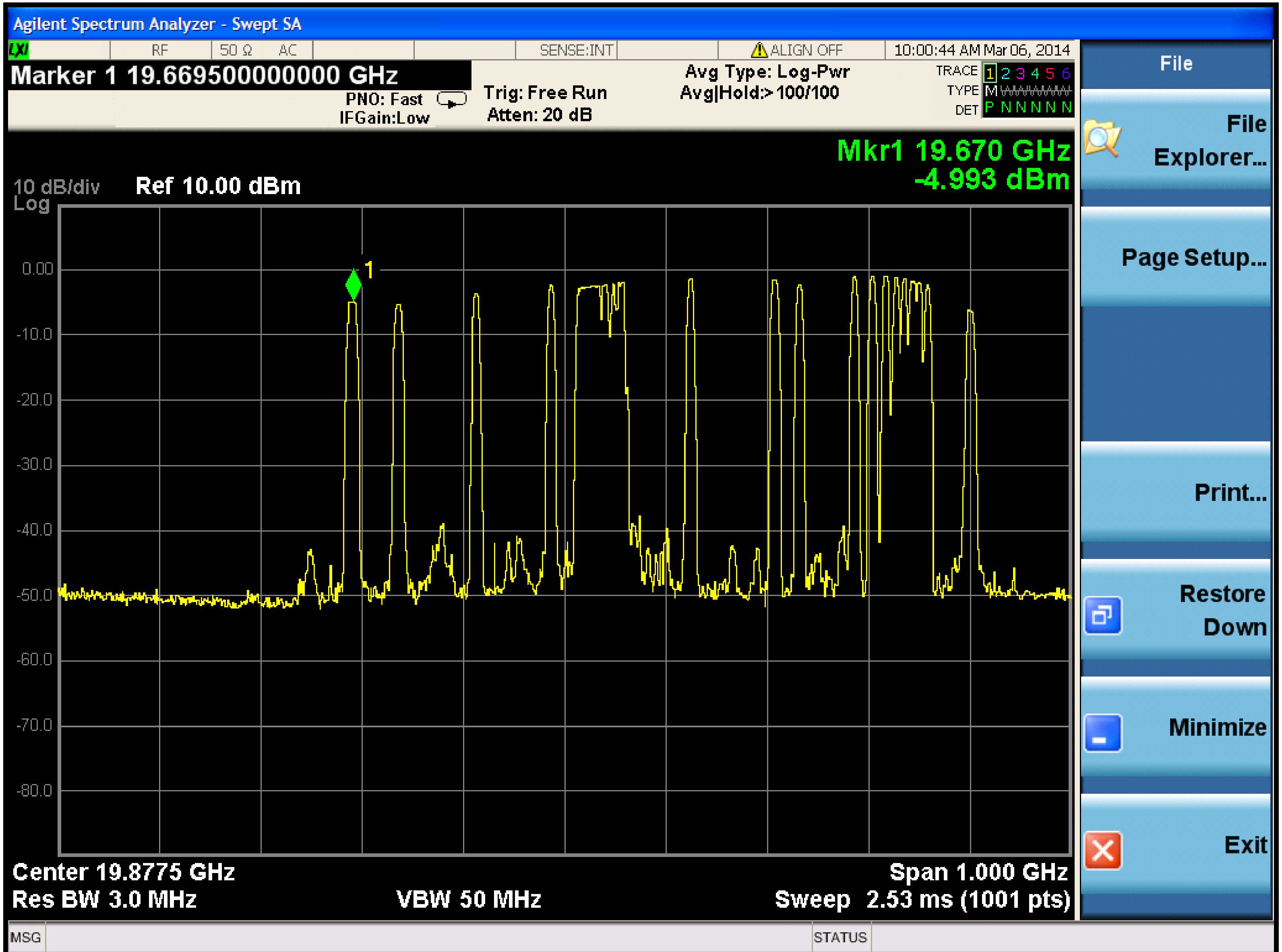
750 MHz Tuning range

3/27/2014			
Removed Resistor		~4dB cable loss	
Top 2nd V(	4V at 29mA		Die #1
VBias (V)	Freq (GHz)	Pout(ms)	Pout(corr)
0.0	19.674	-1.3	2.7
0.5	19.682	-1.3	2.7
1.0	19.689	-1.2	2.8
1.5	19.696	-1.3	2.7
2.0	19.704	-1.4	2.6

30 MHz tuning

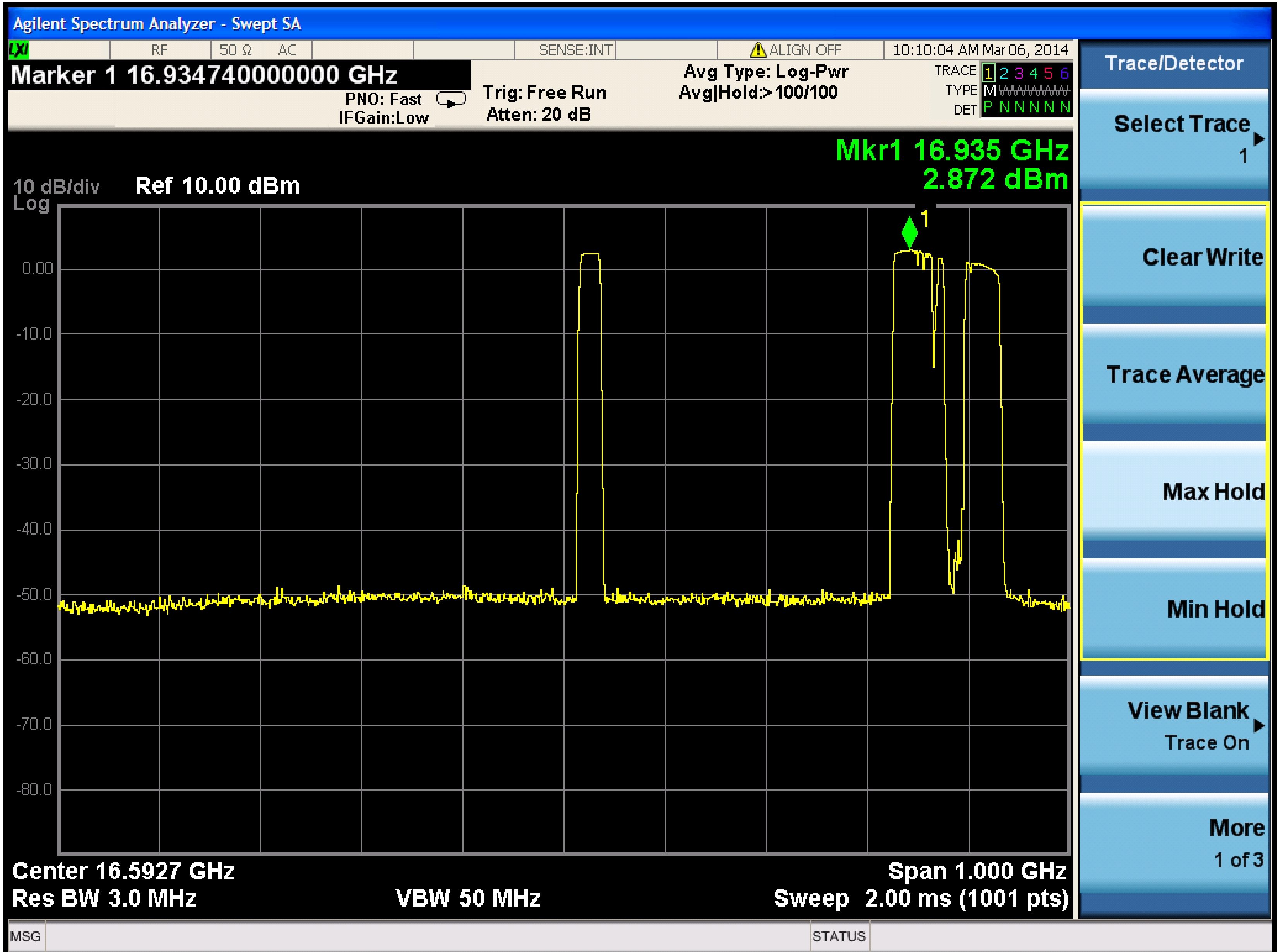
5/8) Amy Kordovski

Voltage Controlled Oscillator V1 Bottom 19.67-20.24 GHz tuning range



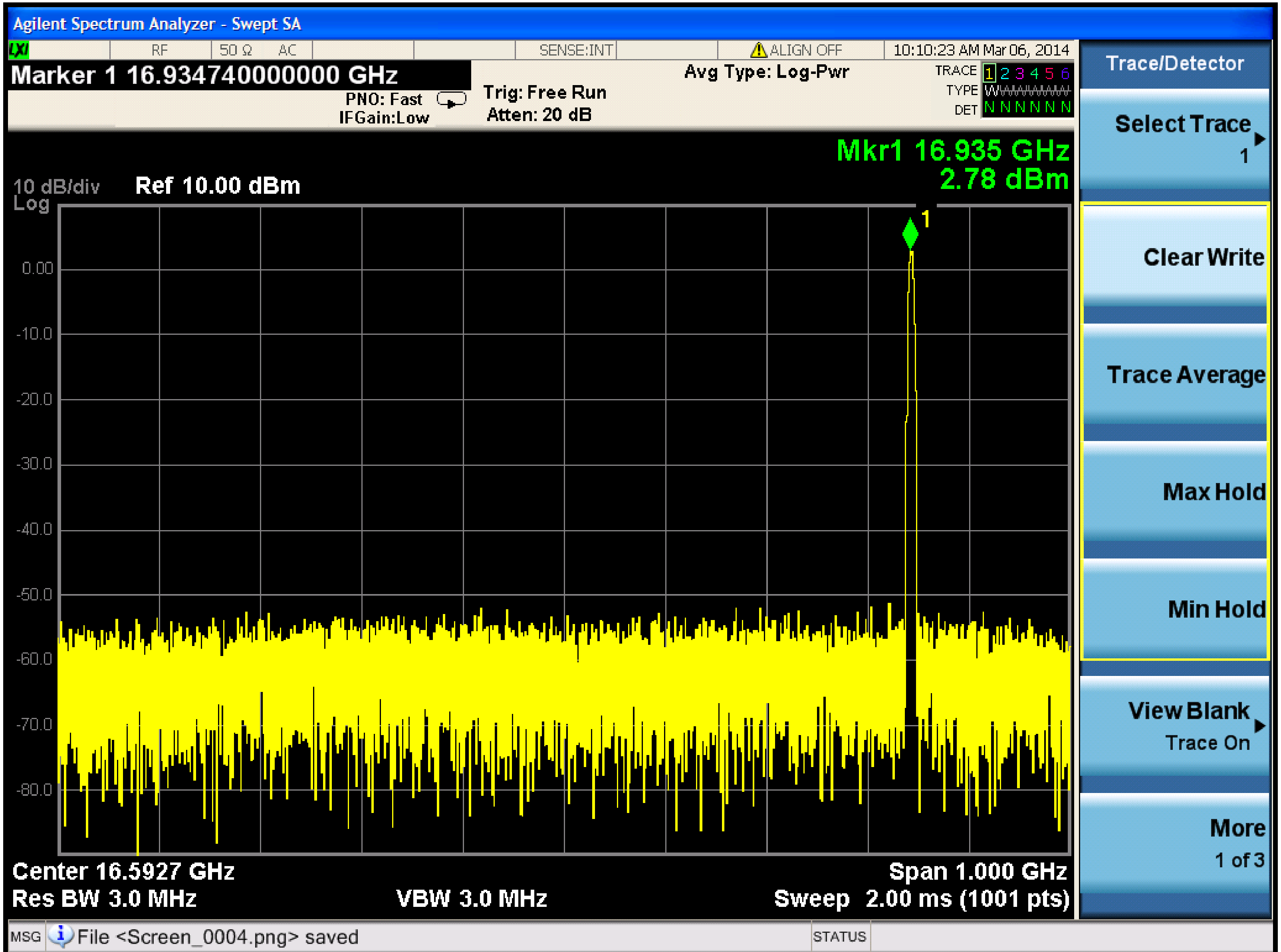
5/8) Amy Kordovski

Voltage Controlled Oscillator V2 Top 16.6/16.94 GHz bi-stable tuning range?



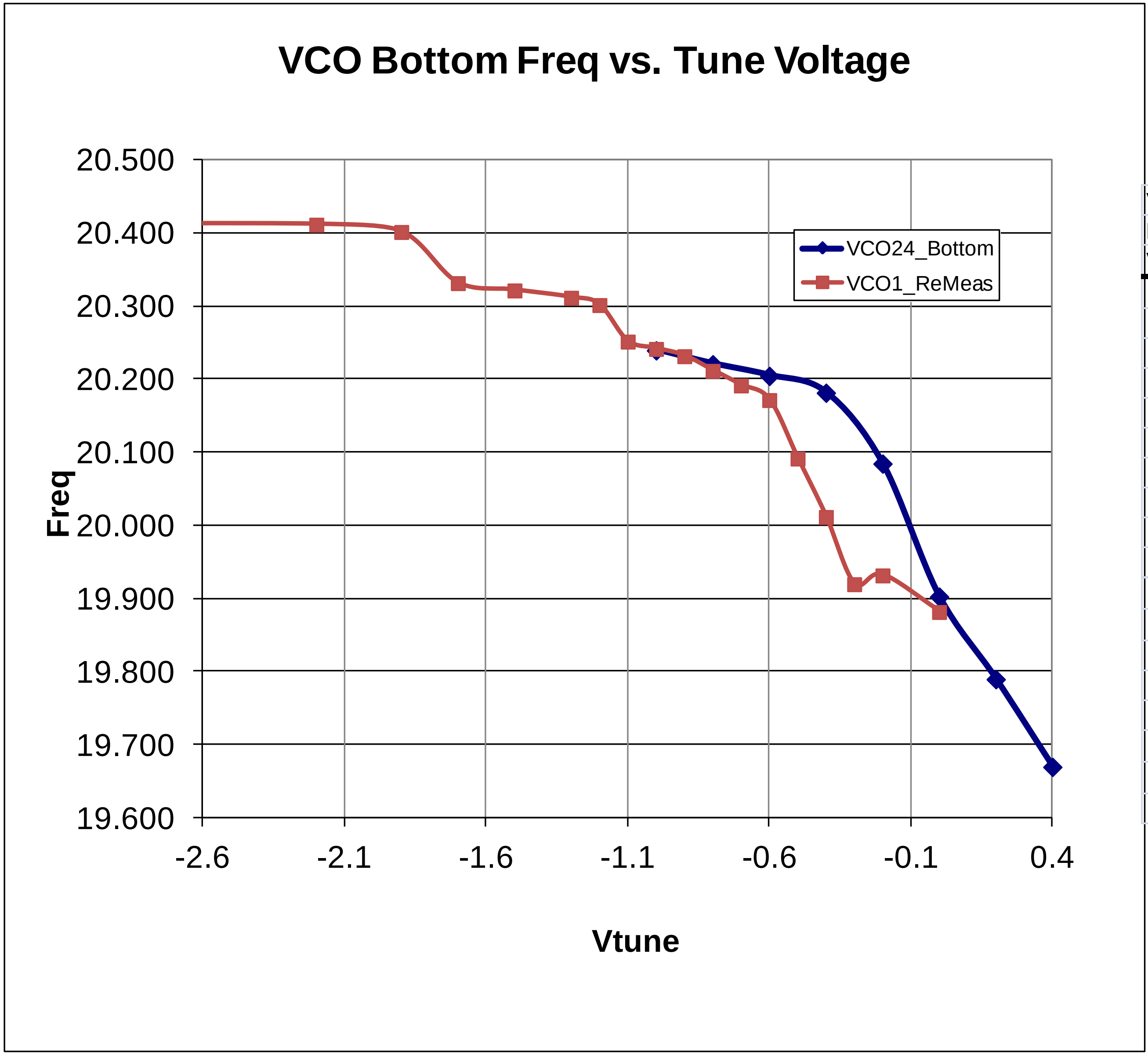
5/8) Amy Kordovski

Voltage Controlled Oscillator V2 Top 16.6/16.94 GHz bi-stable tuning range?



5/8) Amy Kordovski

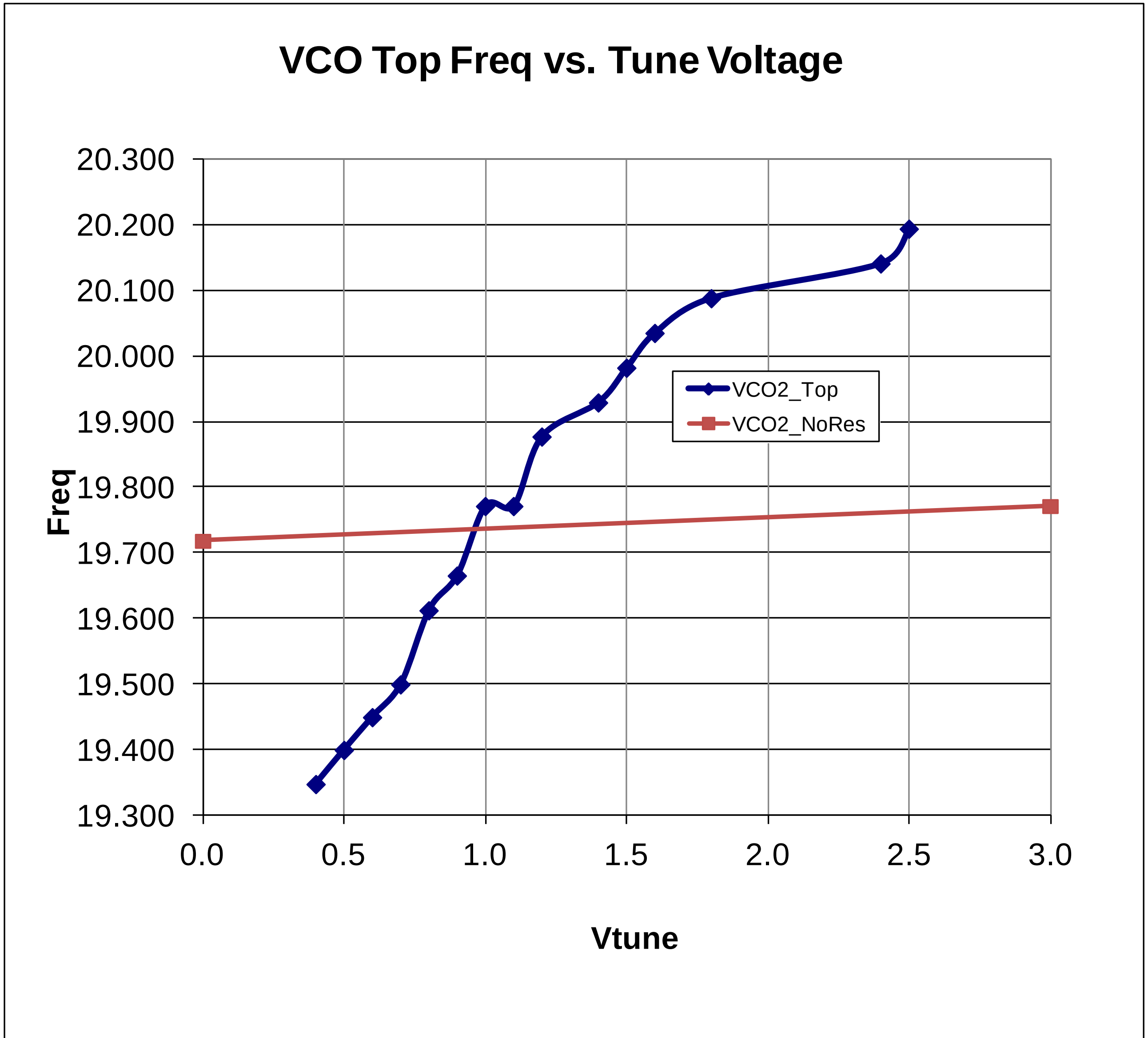
Voltage Controlled Oscillator Re-measured “Bottom” #1 VCO over larger voltage tuning range



VCO1			
Bot VCO	**4.5V at 29mA**		**Die #3**
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**
0.0	19.882	0.9	**4.4**
-0.2	19.932	1.7	**5.2**
-0.3	19.920	2.5	**6.0**
-0.4	20.012	1.4	**4.9**
-0.5	20.092	1.8	**5.3**
-0.6	20.172	2.8	**6.3**
-0.7	20.192	2.8	**6.3**
-0.8	20.212	2.7	**6.2**
-0.9	20.232	2.5	**6.0**
-1.0	20.242	2.4	**5.9**
-1.1	20.252	2.5	**6.0**
-1.2	20.302	2.8	**6.3**
-1.3	20.312	2.7	**6.2**
-1.5	20.322	2.2	**5.7**
-1.7	20.332	1.7	**5.2**
-1.9	20.402	2.0	**5.5**
-2.2	20.412	1.6	**5.1**
-3.3	20.412	0.8	**4.3**

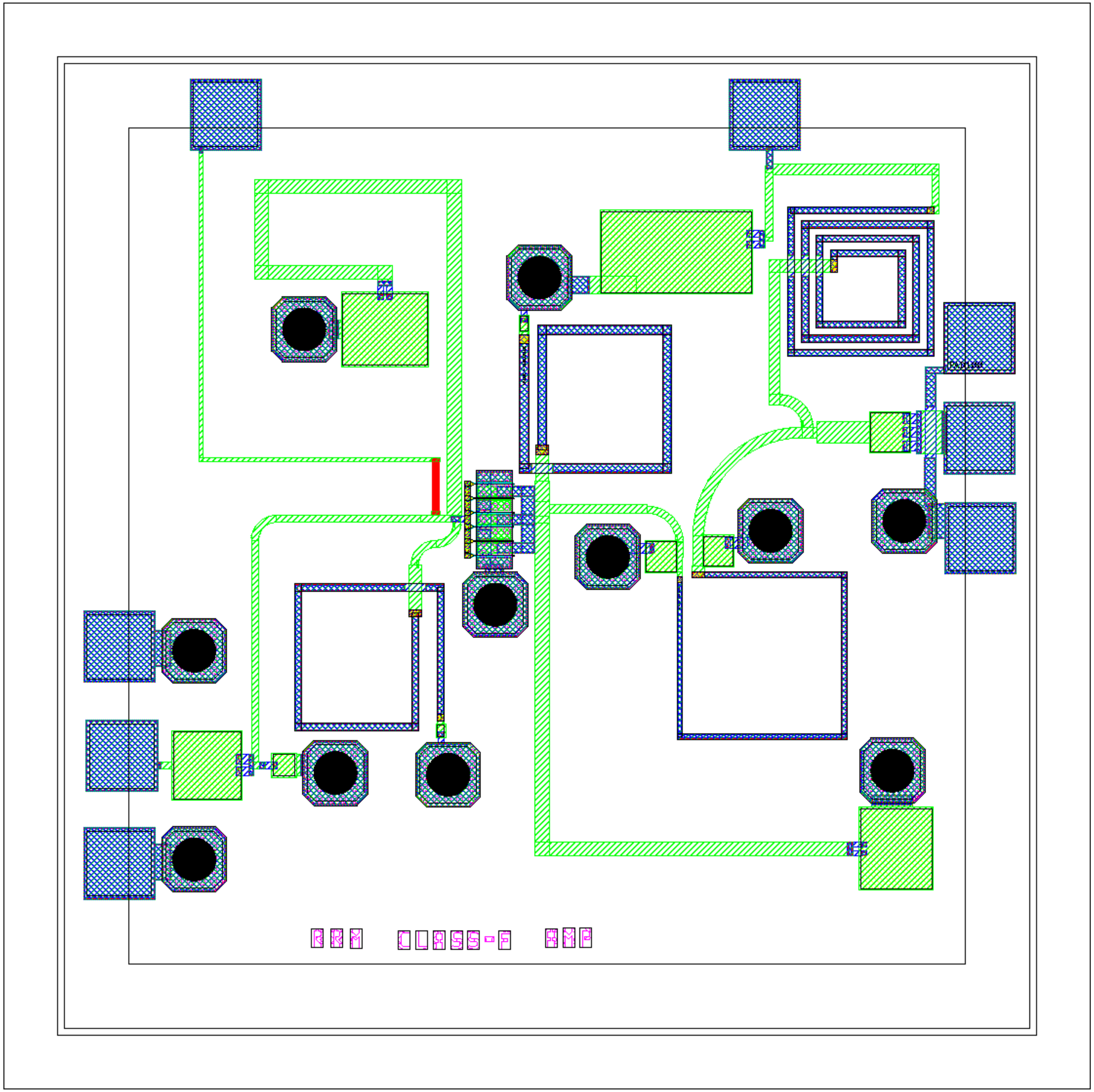
5/8) Amy Kordovski

Voltage Controlled Oscillator Re-measured “Top” #2 VCO over larger voltage tuning range



Re-Measured 4/17/14			
Two Stable Frequencies!			
Top VCO	**4.5V at 24mA**		**Die #3**
VBias (V)	**Freq (GHz)**	**Pout(ms)**	**Pout(corr)**
0.0	17.017	6.2	**9.2**
0.4	19.348	-2.0	**1.5**
0.5	19.400	-2.7	**0.9**
0.6	19.450	-2.5	**1.0**
0.7	19.500	-2.4	**1.1**
0.8	19.613	-1.4	**2.1**
0.9	19.666	-2.0	**1.5**
1.0	19.772	-0.2	**3.3**
1.1	19.772	-0.5	**3.1**
1.2	19.878	1.0	**4.5**
1.4	19.930	2.3	**5.8**
1.5	19.983	2.2	**5.7**
1.6	20.036	1.7	**5.2**
1.8	20.089	2.0	**5.5**
2.4	20.142	1.7	**5.2**
2.5	20.195	2.9	**6.4**

Broke Airbfridge--small tuning range			
Top VCO	**4.5V at 24mA**		**Die #3**
VBias (V)	**Freq (GHz)**	**Pout(ms)**	**Pout(corr)**
0.0	19.719	-3.0	**0.5**
3.0	19.772	-1.0	**2.5**



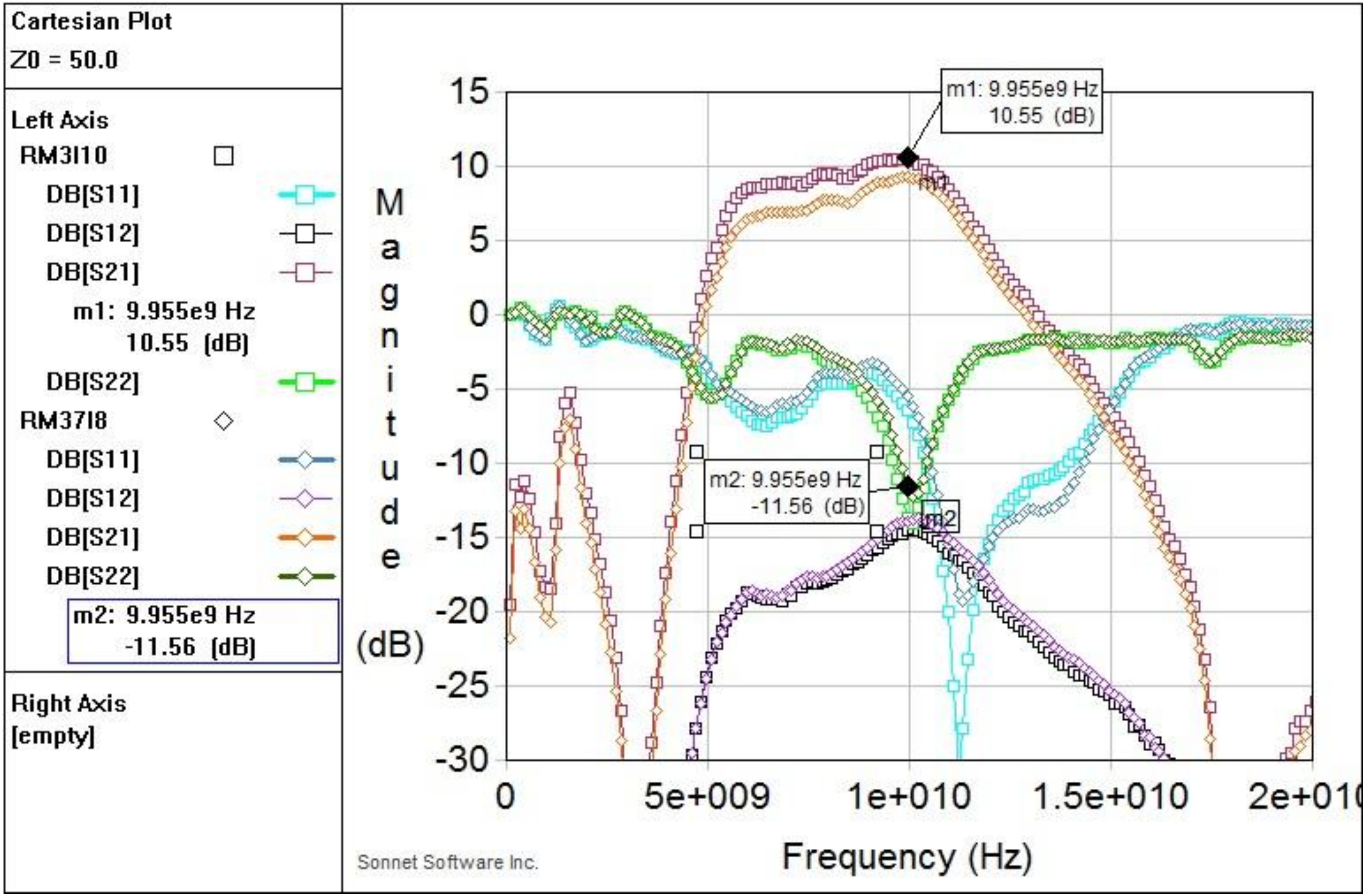
6) Rajesh Madhavan

Class F Power Amp 10G

- *DRC (√)*
- *LVS (√)*
- *DC Current?*

6) Rajesh Madhavan 3/13/14

Class F Power Amp 10G 3V 10mA Die #1, 3.7V 8mA Die #2



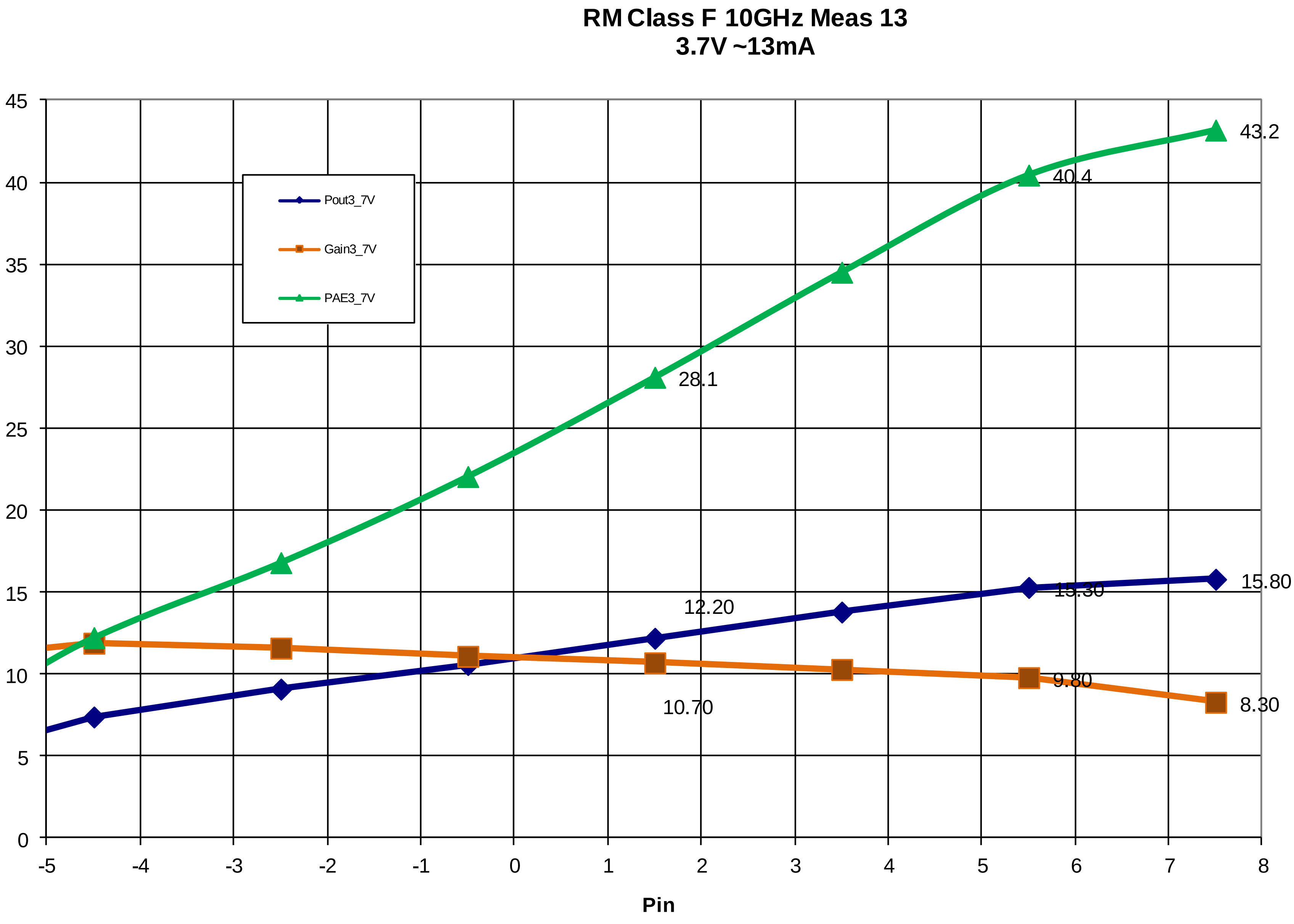
6) Rajesh Madhavan 3/7/14

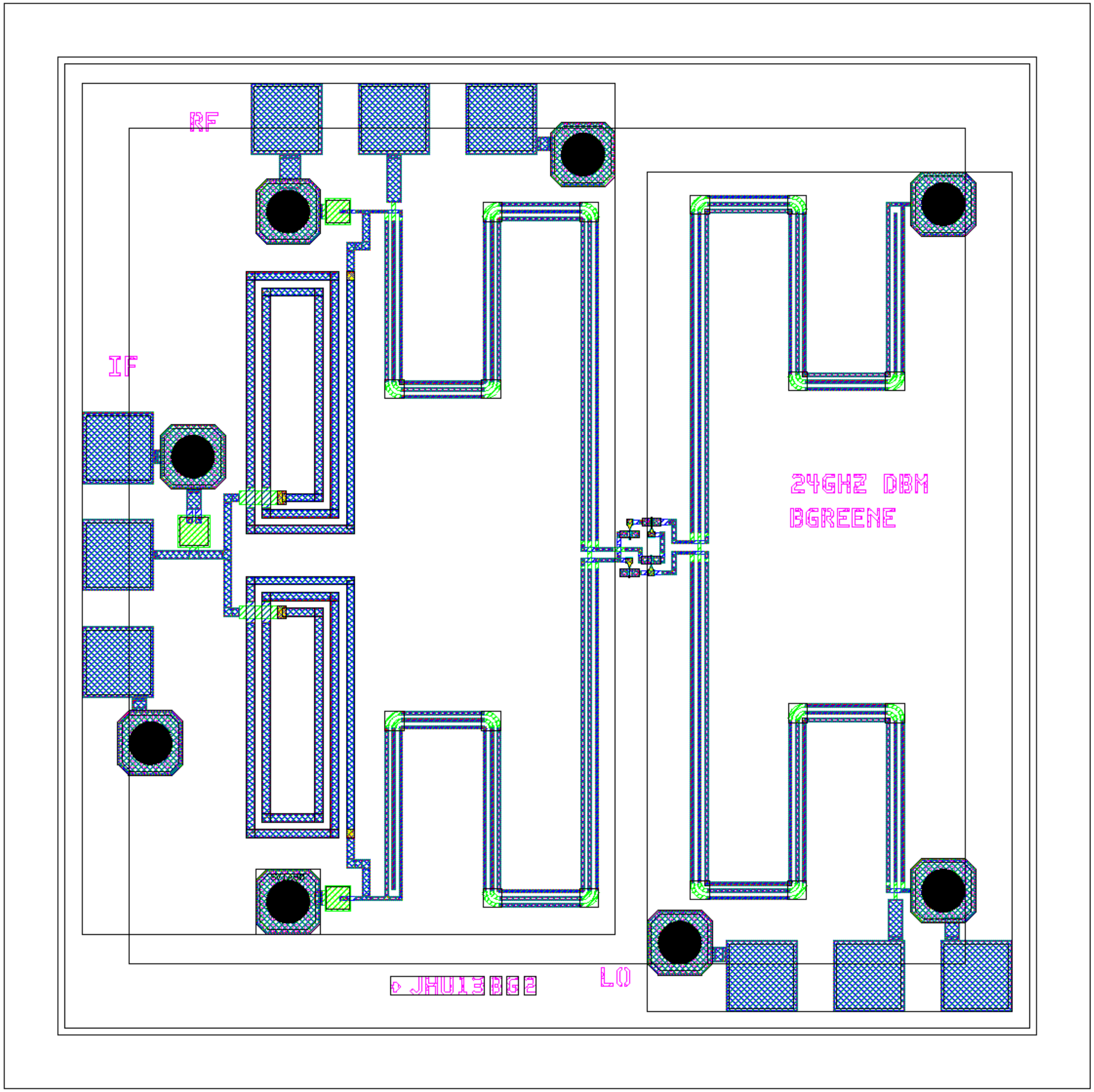
Class F Power Amp 10G 3.7V 8mA Die #1 Note low 2nd harmonics, good efficiency!

JEP 10 GHz Class F Amp 3.7 V Rajesh M												
3/7/2014												
				Loss 5 dB for thru at 10G, 8dB at 20G								
10 GHz	Die#1	**RM PA Fall13 TQP13**				3.7V ; 7 mA		vg=-0.2V				
Pin(SG)	**Pout(SA)**	**Pin(corr)**	**Pout(corr)**	**Gain**	**I1(3.7V)**	**PDC(mw)**	**Pout(mw)**	**Drn Eff**	**PAE**	**Pout2X(SA)**	**Pout2X(cor**	**dBc2X**
-10.0	-4.10	-12.50	-1.60	10.90	13	39.0	0.69	1.8	1.6	-54.5	-50.5	48.90
-5.0	-1.03	-7.50	2.67	10.17	14	42.0	1.85	4.4	4.0	-44.0	-40.0	42.67
-2.0	3.70	-4.50	7.40	11.90	14	42.0	5.50	13.1	12.2	-37.6	-33.6	41.00
0.0	5.40	-2.50	9.10	11.60	15	45.0	8.13	18.1	16.8	-33.2	-29.2	38.30
2.0	6.90	-0.50	10.60	11.10	16	48.0	11.48	23.9	22.1	-29.9	-25.9	36.50
4.0	8.50	1.50	12.20	10.70	18	54.0	16.60	30.7	**28.1**	-27.1	-23.1	35.30
6.0	10.10	3.50	13.80	10.30	21	63.0	23.99	38.1	34.5	-24.0	-20.0	33.80
8.0	11.60	5.50	**15.30**	**9.80**	**25**	**75.0**	**33.88**	**45.2**	**40.4**	-22.5	-18.5	33.80
10.0	12.10	7.50	**15.80**	**8.30**	**25**	**75.0**	**38.02**	**50.7**	**43.2**	-21.9	-17.9	33.70

6) Rajesh Madhavan 3/7/14

Class F Power Amp 10G 3.7V 8mA Die #1 Good Efficiency ~43%! 2nd Harmonic is very low!



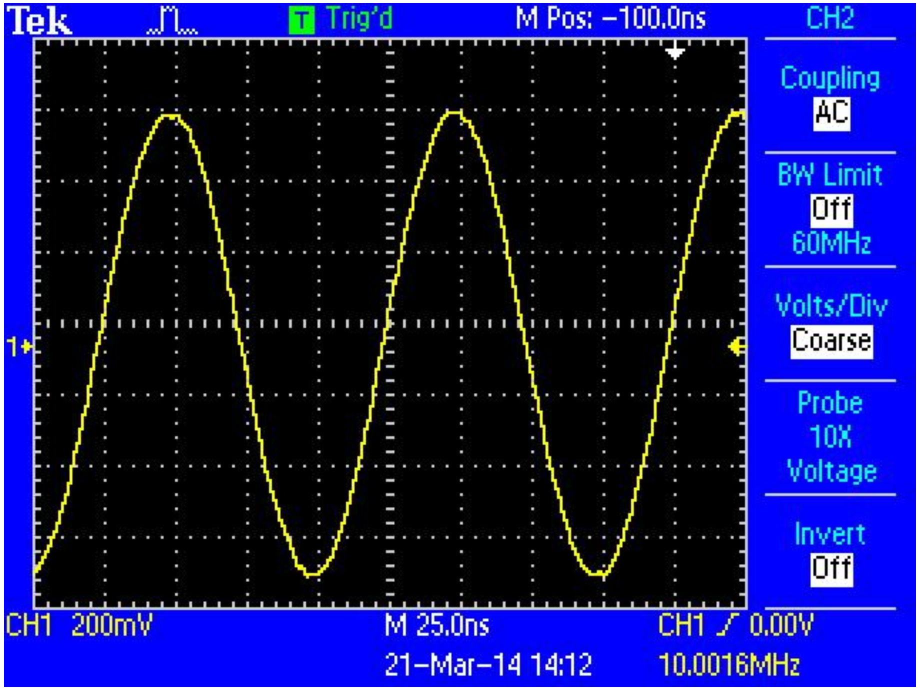


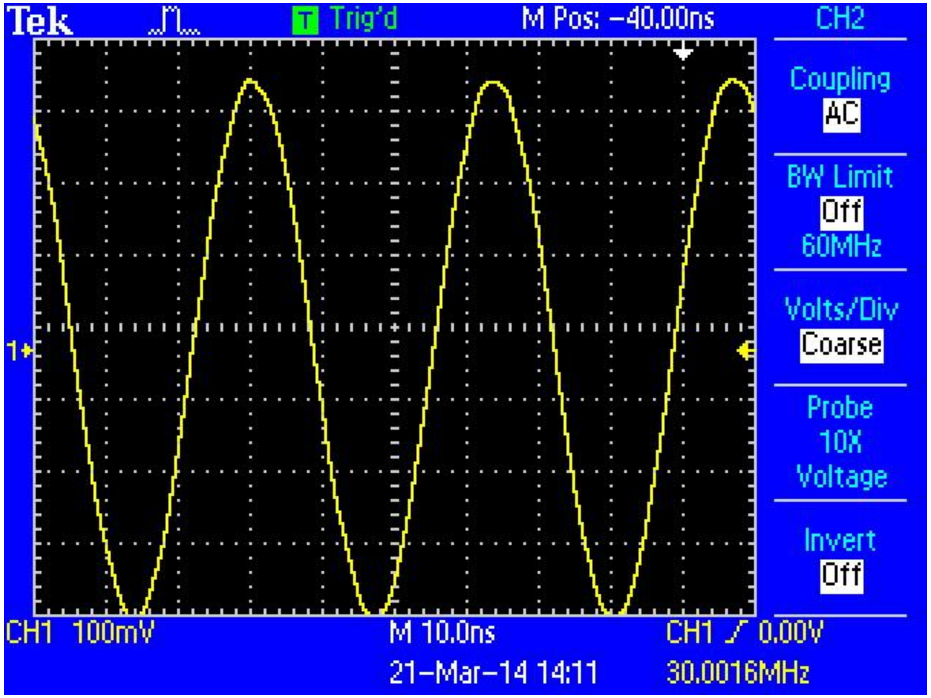
7) Brad Greene Mixer

- *DRC (√)*
- *LVS (√)*
- *DC Current (√)*

7) Brad Greene

Mixer *24.1 GHz RF, 24.0-24.13 GHz LO, 10-100Mhz IF*



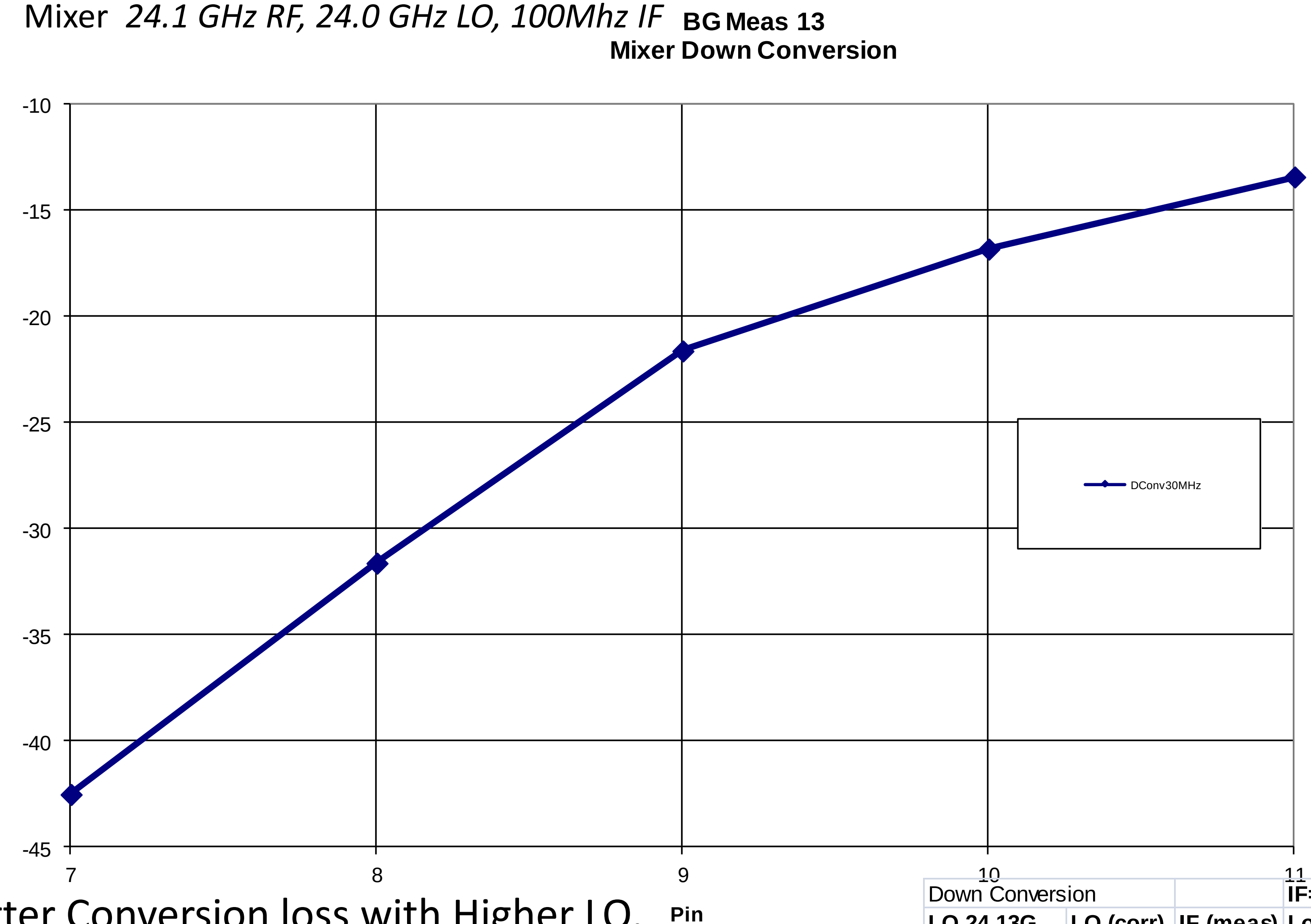


10 Mhz and 30 Mhz IF on Oscope
60 MHz Scope BW? Impedance?
8510/RF – Losses 2 Cables, 2 Probes, 8510

8510 freq	Meas	Pwr8510	Loss
24.1	**-13.0**	0.0	**13.0**
24.1	**-10.1**	5.0	15.1
26.1	**-12.9**	0.0	12.9
26.1	**-17.3**	-5.0	12.3
26.1	**-22.0**	-10.0	12.0

7) Brad Greene

Mixer *24.1 GHz RF, 24.0 GHz LO, 100Mhz IF*



Better Conversion loss with Higher LO.

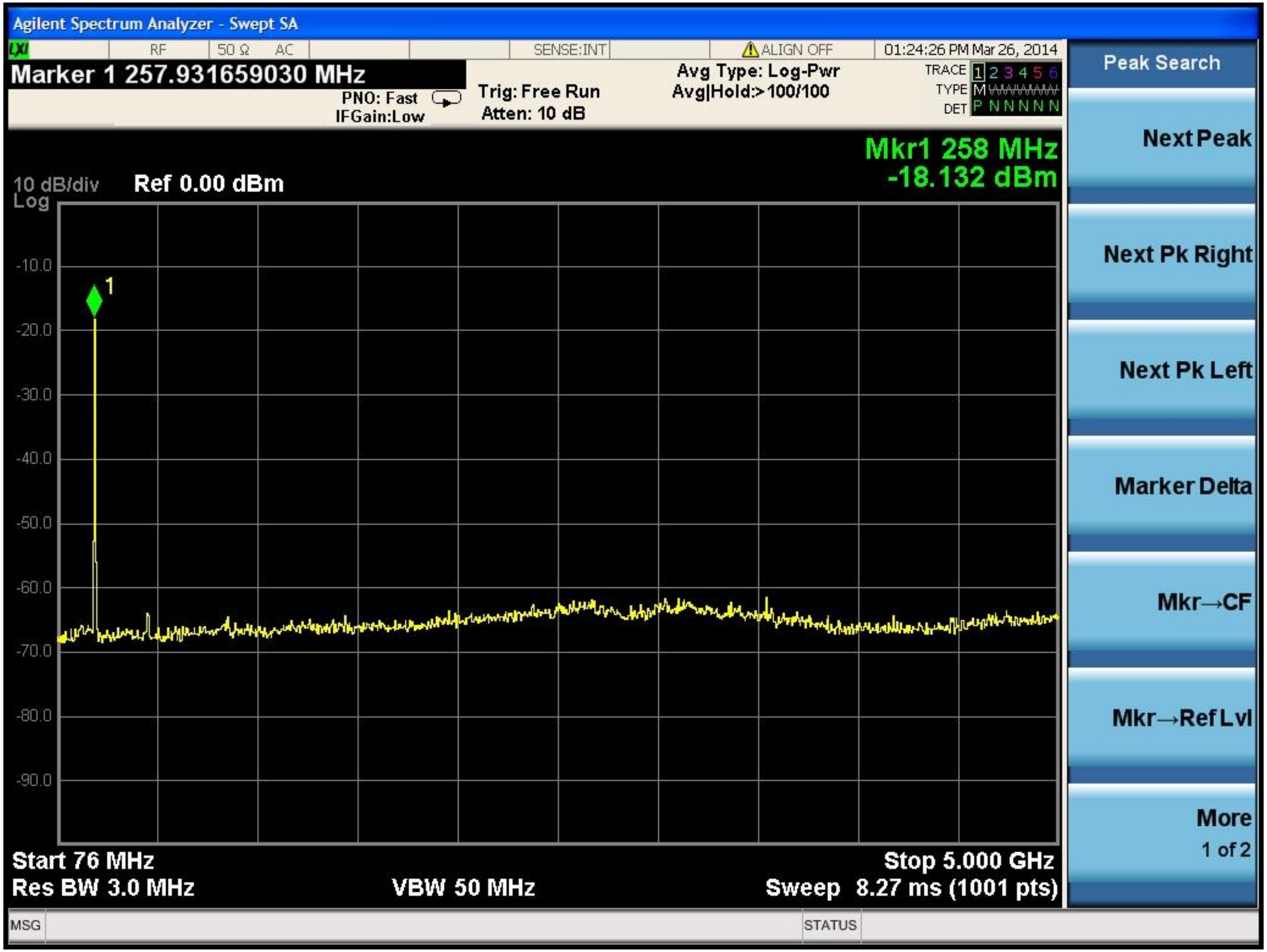
LO quit at +16 dBm, +11 dbm at MMIC?

Calibration?

Down Conversion			IF=30 MHz
LO 24.13G	**LO (corr)**	**IF (meas)**	**Loss (gain**
12	7	-51.0	**-42.5**
13	8	-40.1	**-31.6**
14	9	-30.1	**-21.6**
15	10	-25.3	**-16.8**
16	11	-21.9	**-13.4**

7) Brad Greene

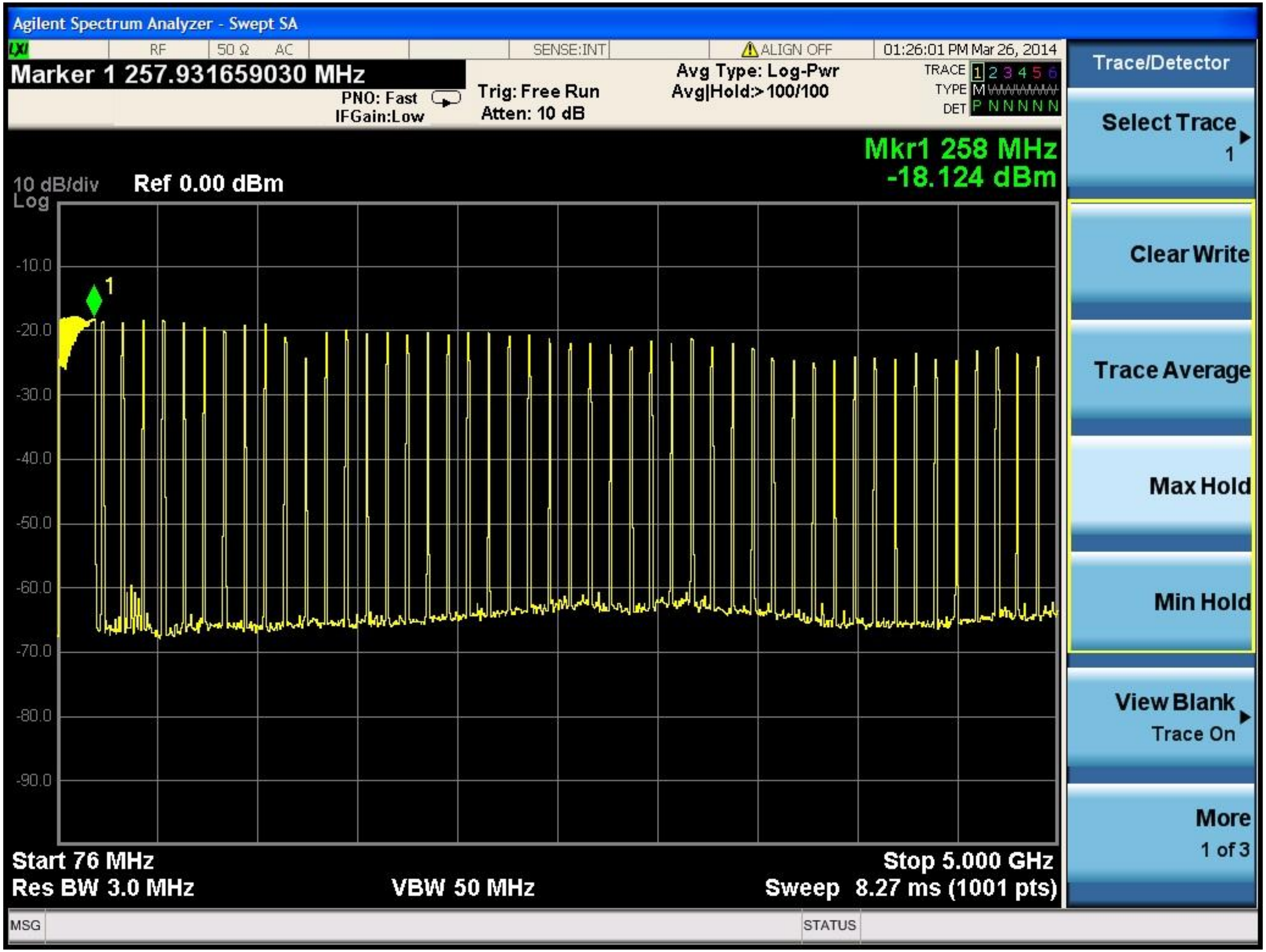
Mixer *18.1 GHz RF, 18.0 GHz LO, 260Mhz IF*



Better Conversion loss with Higher LO. 18 GHz

7) Brad Greene

Mixer *18.1 GHz RF, 18.0 GHz LO, 260Mhz IF*



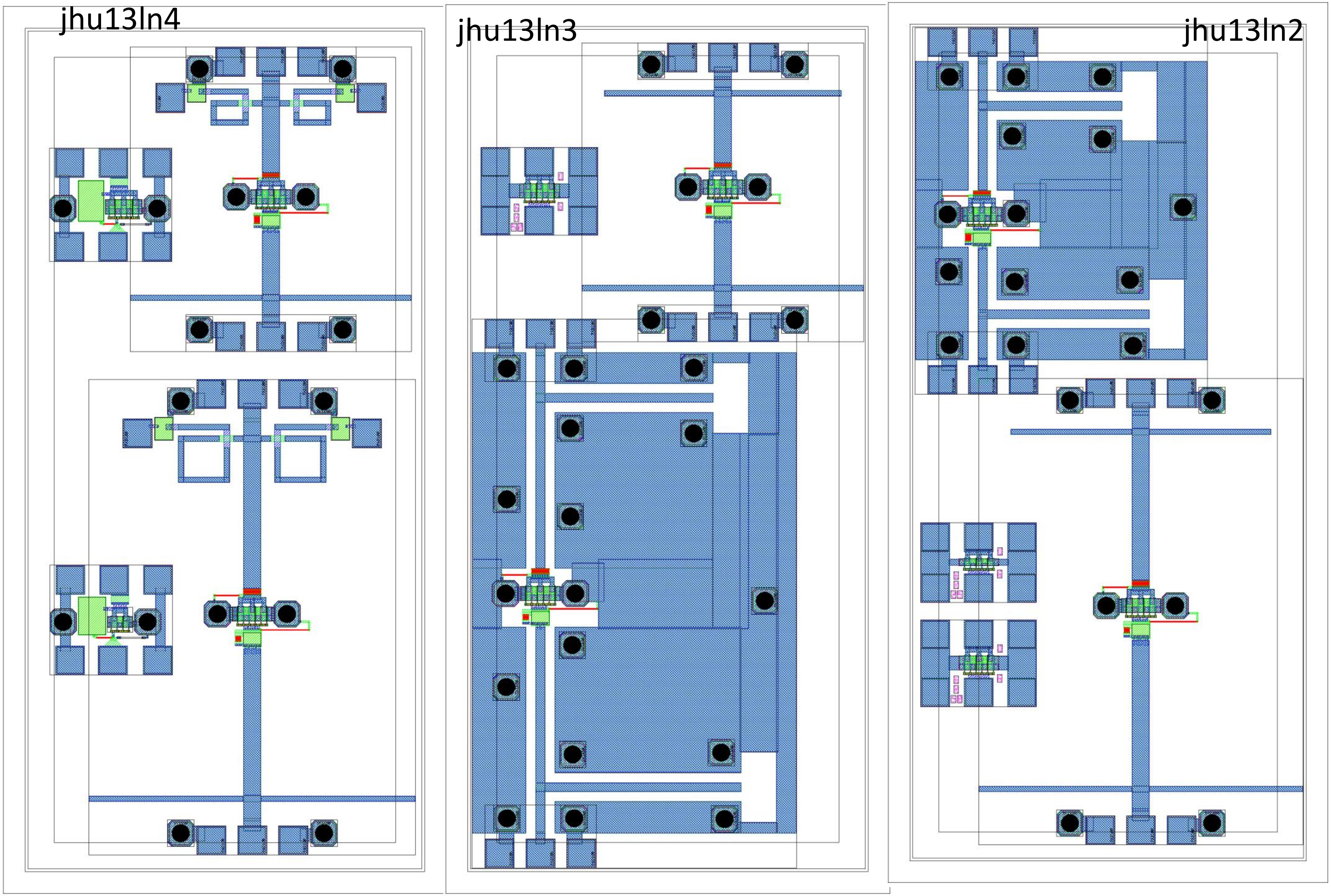
Better Conversion loss with Higher LO. 18 GHz

7) Brad Greene

Mixer *24.1 GHz RF, 24.0 GHz LO, 10M-5G IF*

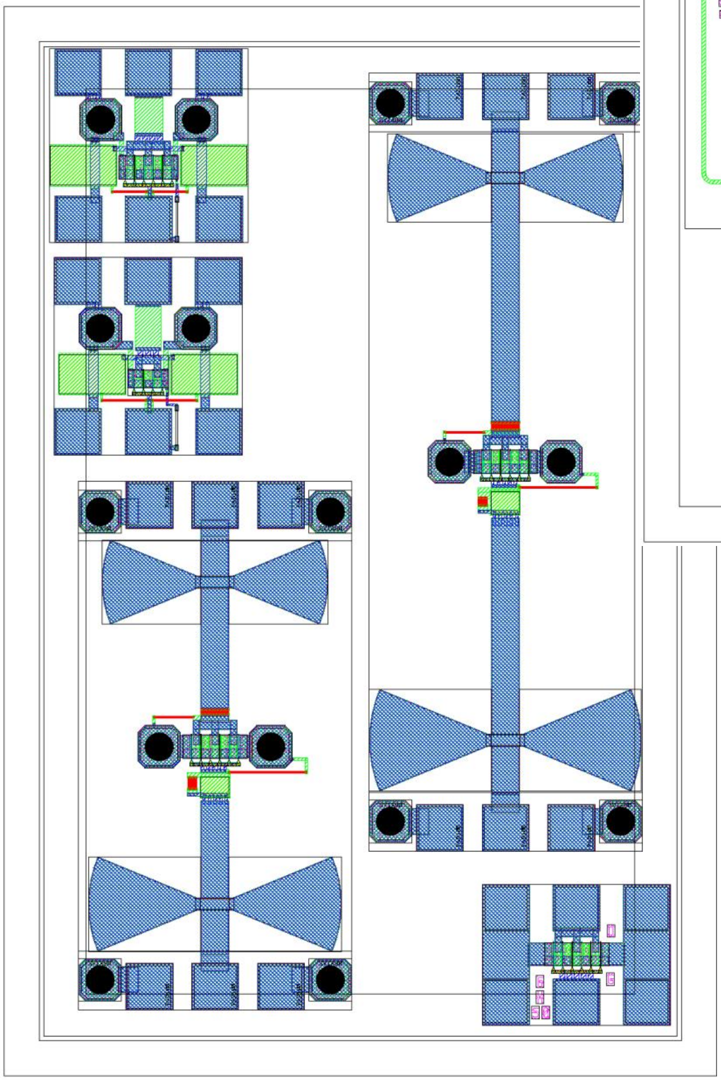
Better Conversion loss with Higher LO. 24 GHz, More Ripple

JEP Other Projects

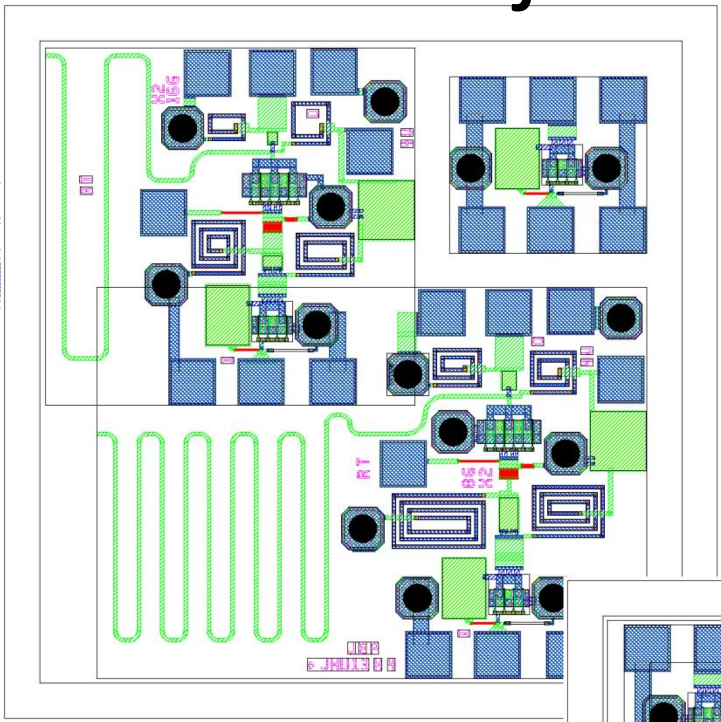


JEP Other Projects

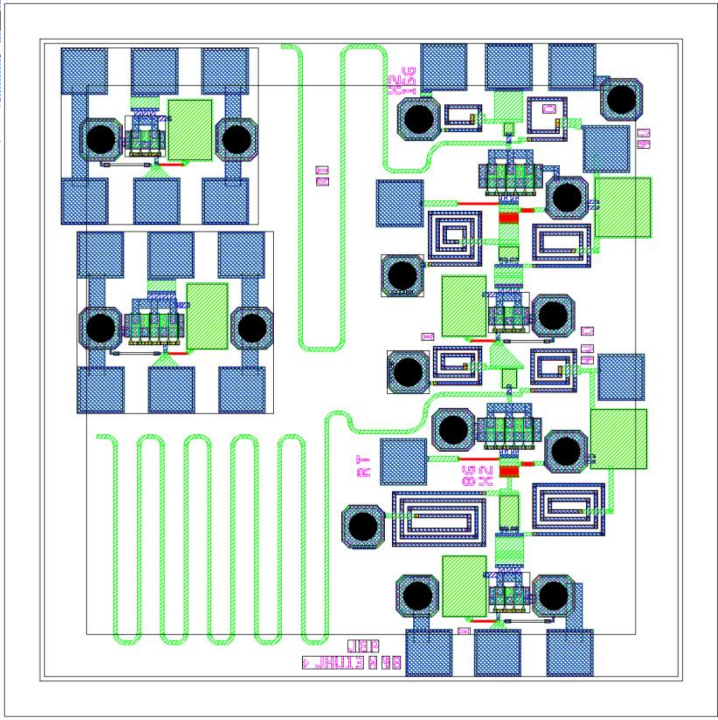
jhu13ln1



jhu13x4

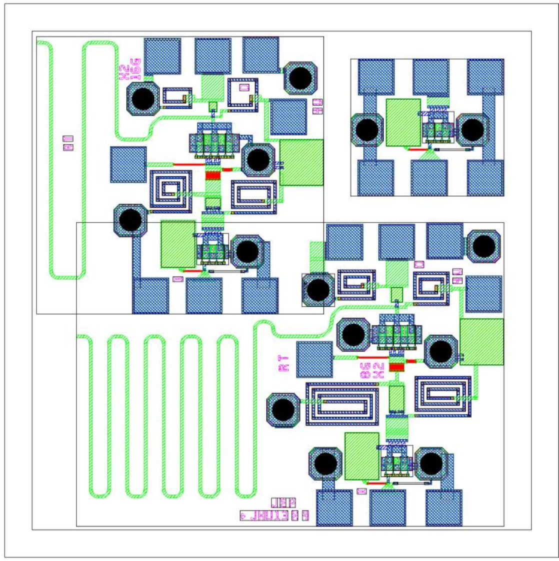


jhu13x4b



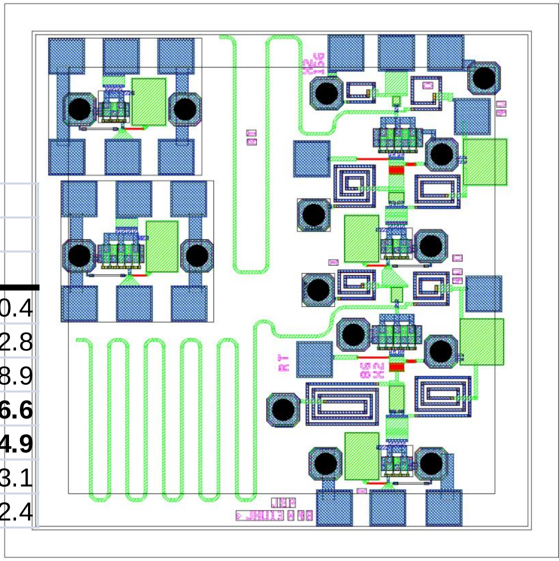
JEP '12 Frequency Doublers-Rev '13

The '12 8-16 GHz and the 16-32 GHz Frequency Doublers were modified to add the broadband feedback amplifier as a driver to reduce conversion loss. The 4x38 feedback amplifier was used to reduce DC power consumption, vs. the 6x50 amp. For the 8-16GHz doubler, conversion gain of 6dB was 12 dB better than the previous 6dB conversion loss. For the 16-32 GHz doubler, conversion loss improved from the previous 12 dB to 6 dB. Note the gain of the Feedback Amp is much less at 16 GHz, than 8 GHz.



Jhu13x4-2 Doublers

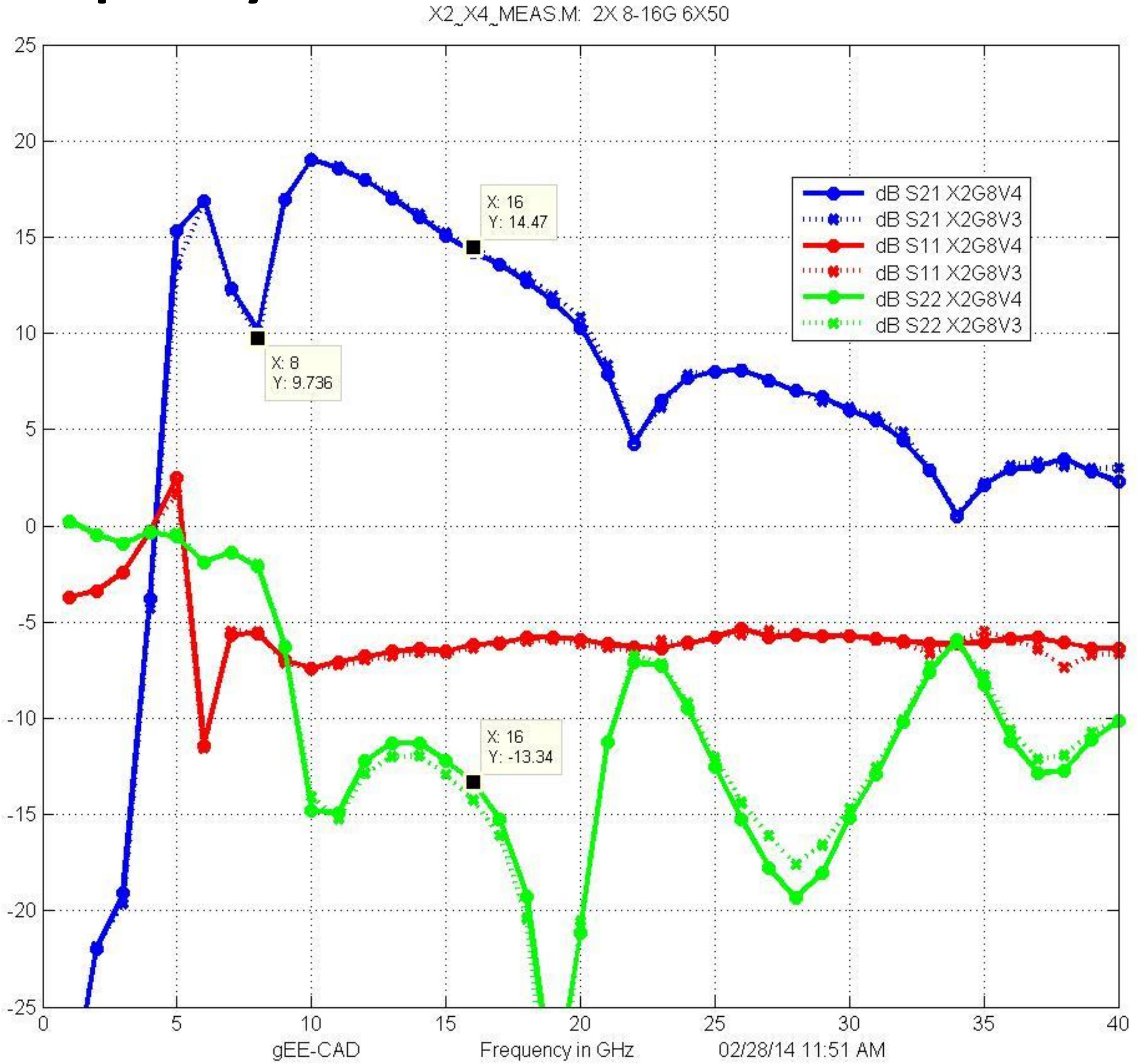
Jhu13x4b-1 Quadrupler



41415		16.0 GHz							
Doubler 8-16G		**3V at ~55mA, vg=-1.5v**				**Die #1**			
Pin(SG)	**Pin(A)**	PoutX1(ms	PoutX2(ms	PoutX3(ms)	**Pout(corr)**	**Pout2X(cc**	**Pout23(co**	Cnvloss	dBc
-10.00	**-12.4**	-5.80	-14.2	-29.4	**-3.4**	**-11.2**	**-24.8**	-1.2	-7.8
-8.00	**-10.4**	-4.10	-9.7	-22.5	**-1.7**	**-6.7**	**-17.9**	-3.7	-5.0
-6.00	**-8.4**	-2.60	-5.9	-17.4	**-0.2**	**-2.9**	**-12.8**	**-5.5**	-2.7
-4.00	**-6.4**	-1.20	-3.3	-13.2	**1.2**	**-0.3**	**-8.6**	**-6.1**	-1.5
-2.00	**-4.4**	-0.10	-1.9	-9.3	**2.3**	**1.1**	**-4.7**	**-5.5**	-1.2
0.00	**-2.4**	0.50	-1.4	-6.6	**2.9**	**1.6**	**-2.0**	-4.0	-1.3

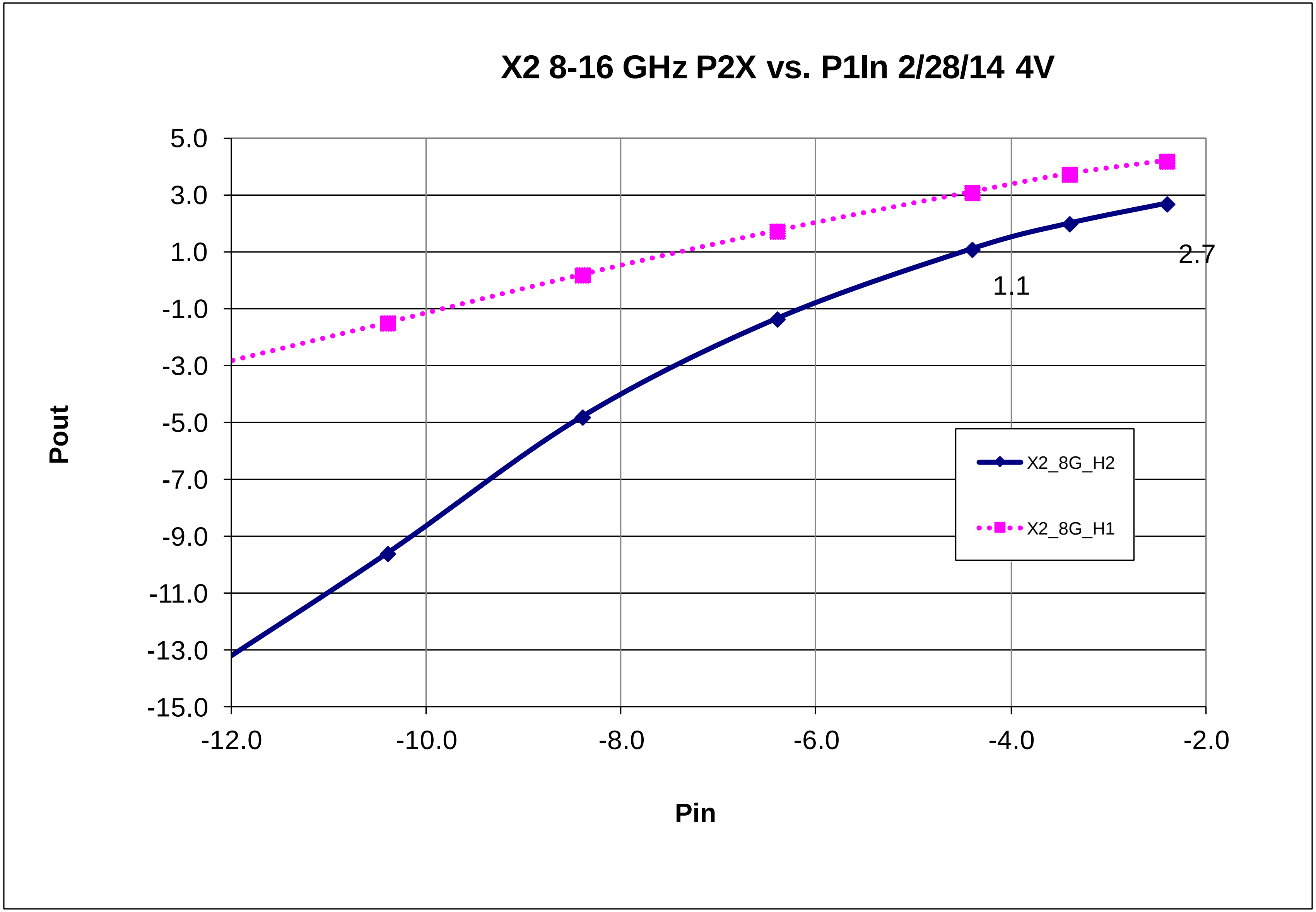
3/11/2014		**16.0 GHz**							
Doubler 16G		**3V at ~56mA, vg=-1.5v**			**Die #2**				
Pin(SG)	**Pin(corr)**	**PoutX1(ms**	**PoutX2(ms)**	**PoutX3(ms)**	**Pout(corr)**	**Pout2X(cc**	**Pout3X(cc**	**Cnvloss**	**dBc**
-5.00	-8.4	-10.78	-32.3		-7.4	-27.8		19.4	20.4
0.0	-3.4	-6.10	-20.0	-28.7	-2.7	-15.5	-22.4	12.1	12.8
2.0	-1.4	-4.49	-14.4	-22.6	-1.1	-10.0	-16.3	8.6	8.9
4.0	**0.6**	**-3.08**	**-10.7**	**-18.1**	**0.3**	**-6.3**	**-11.8**	**6.9**	**6.6**
6.0	**2.6**	**-2.07**	**-8.0**	**-14.1**	**1.4**	**-3.5**	**-7.8**	**6.1**	**4.9**
8.0	4.6	-1.50	-5.6	-10.9	1.9	-1.2	-4.6	5.8	3.1
9.0	5.6	-1.28	-4.7	-9.7	2.1	-0.3	-3.4	5.9	2.4

JEP '12 Frequency Doublers-Rev '13



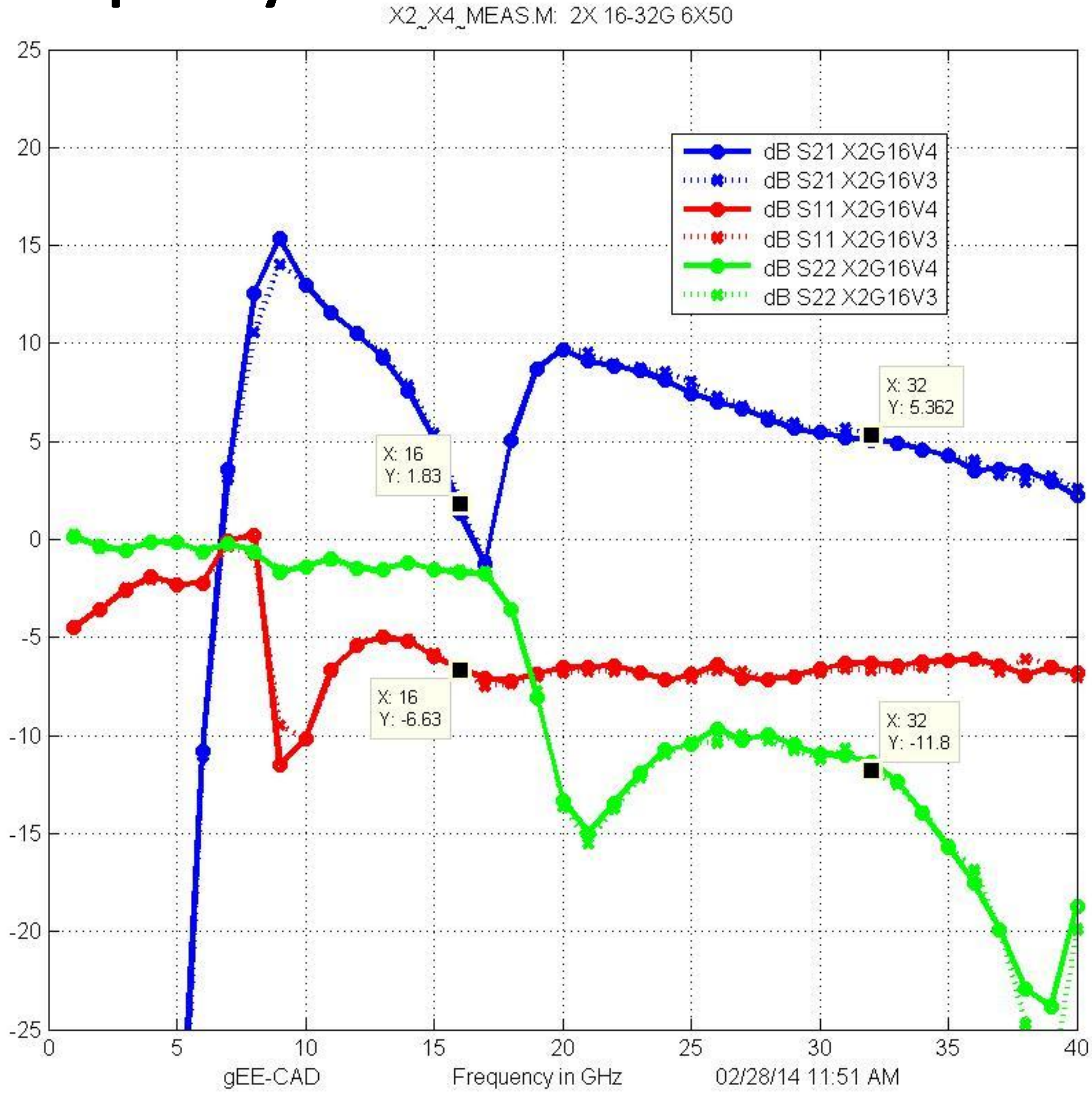
Jhu13x4-8 to 16 GHz Doubler S-Parameters, Note Null in Fundamental (S21 at 8 GHz)

JEP ‘12 Frequency Doublers-Rev ‘13



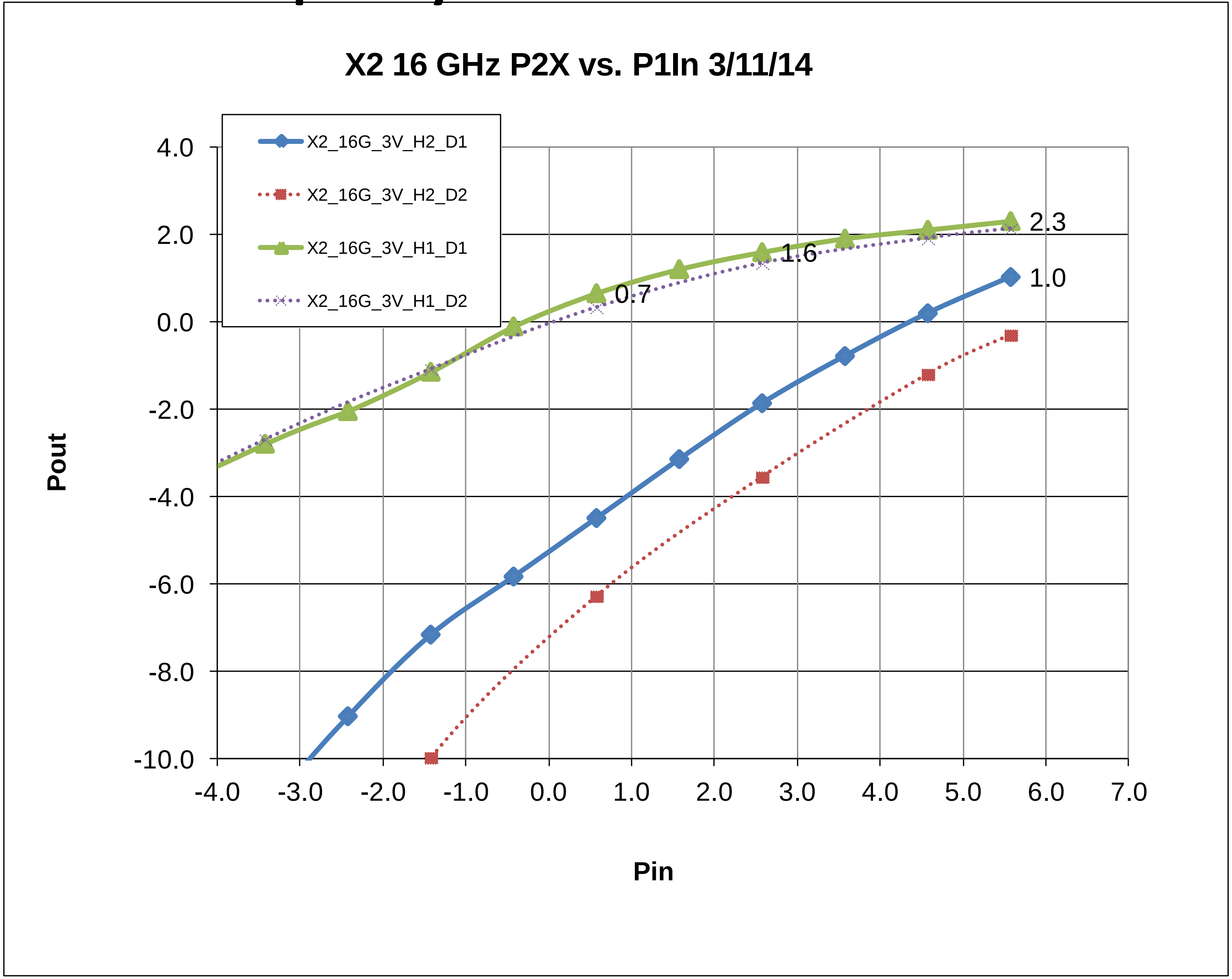
Jhu13x4-8 to 16 GHz Doubler, Fundamental (Magenta) and Second Harmonic (Blue)

JEP '12 Frequency Doublers-Rev '13



Jhu13x4- 16 to 32 GHz Doubler S-Parameters, Note Null in Fundamental (S21 at 16 GHz)

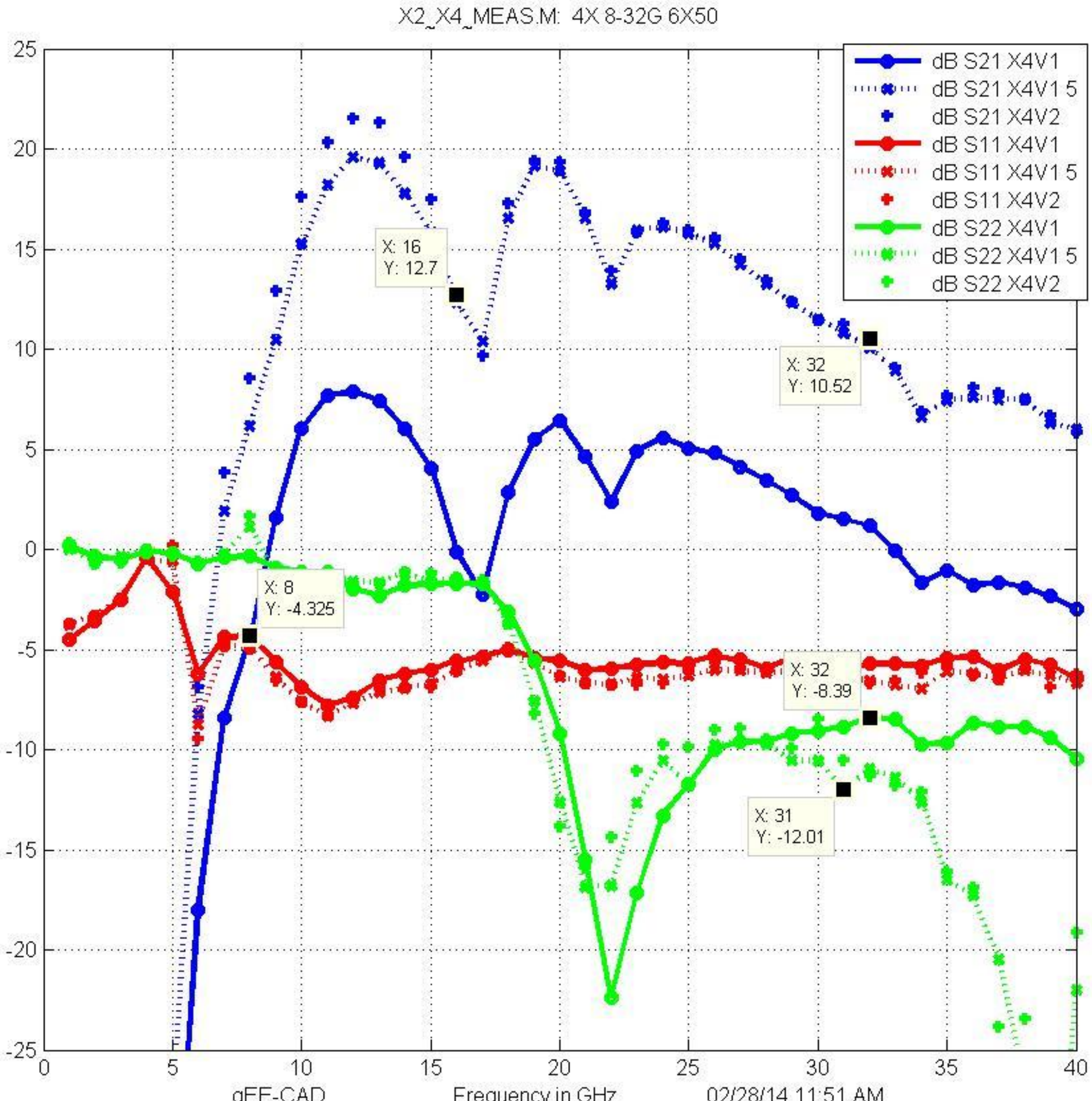
JEP '12 Frequency Doublers-Rev '13



Two Measured Die: Best-Solid

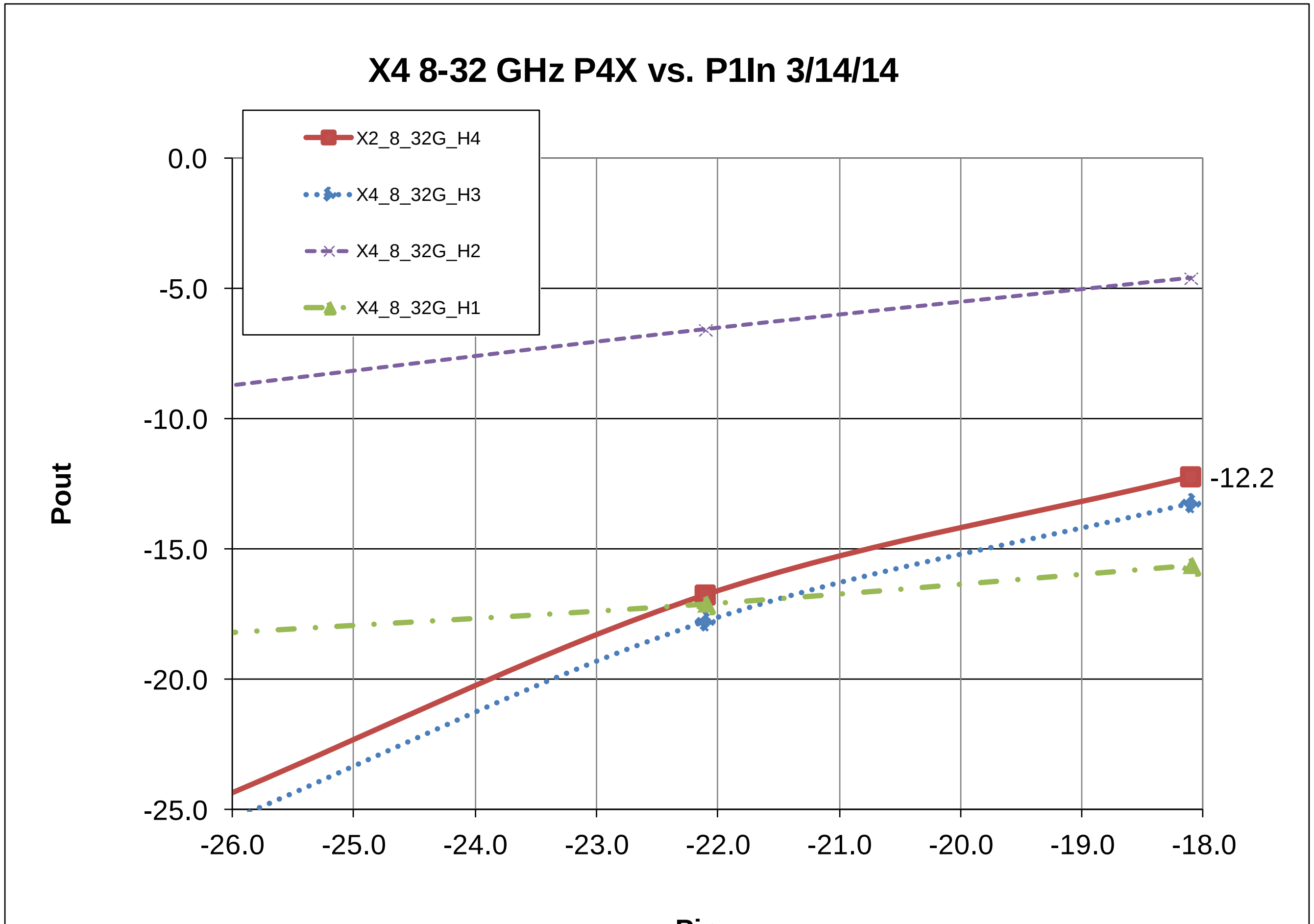
Jhu13x4-16 to 32 GHz Doubler, Fundamental (Green) and Second Harmonic (Blue)

JEP Frequency Quadrupler '13



Jhu13x4b- 8 to 32 GHz Quadrupler S-Parameters, Note Null in Fundamental (S21 at 8 GHz)

JEP Frequency Quadrupler '13

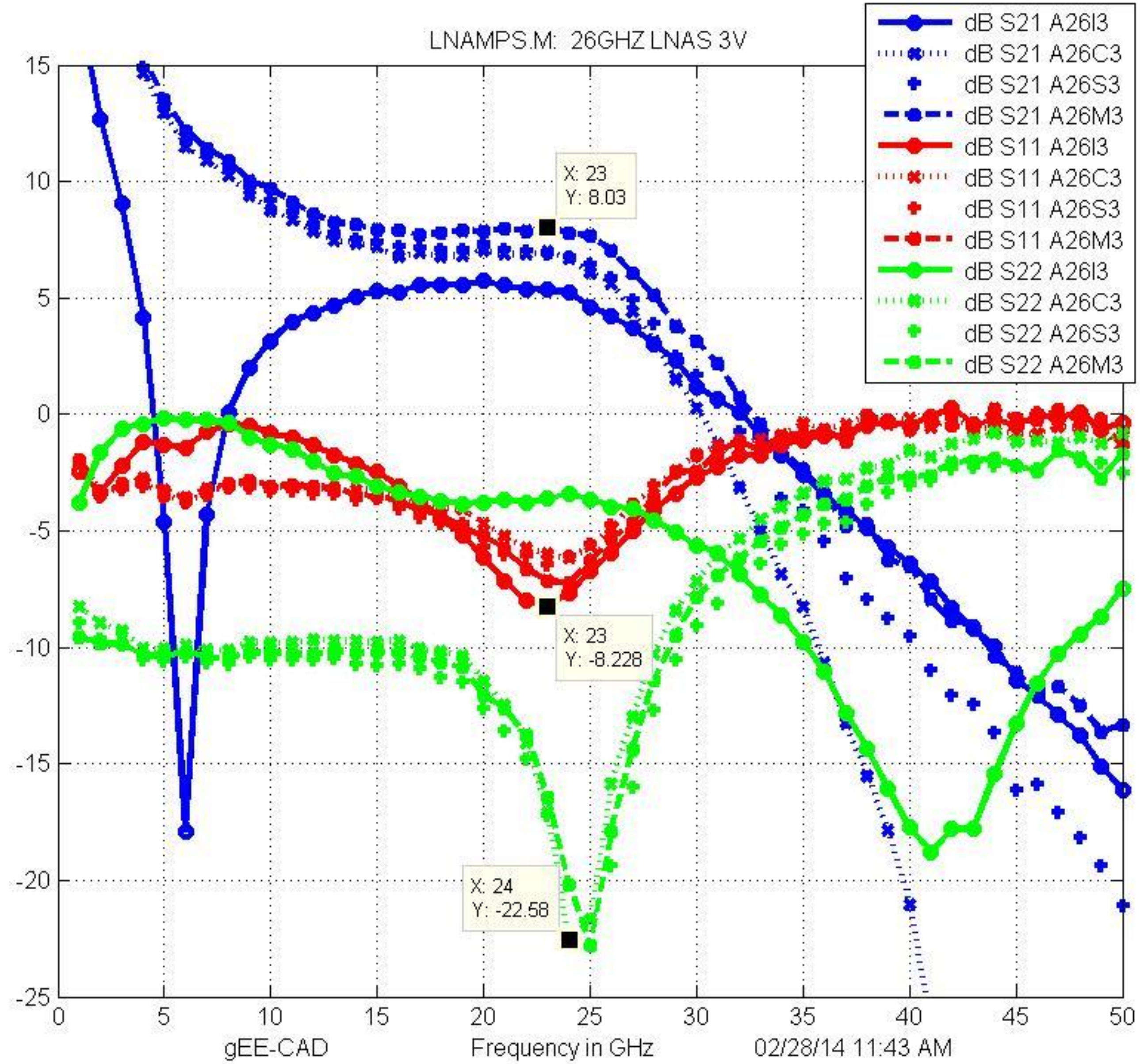


Strong 1st Harmonic, but Conversion Gain at 32 GHz of about 6dB! Best efficiency at 1V VDS1, 1.5V VDS2, both VGS1=VGS2=-1.5V. With two feedback amplifiers, only -20 to -16 dBm 8GHz input is needed for 6dB more output at 32 GHz.

3/11/2014		8-32.0 GHz								
Quadrupler 8-16-32G		**1V at ~27mA, vg1=-1.5v; 1.5V at 37mA, vg2=-1.5v**				**Die #1**			**32GHz!**	
Pin(SG)	**Pin(corr)**	**PoutX1(m**	**PoutX2(ms)**	**PoutX3(ms)**	**PoutX4(ms)**	**Pout(corr)**	**Pout2X(co**	**Pout3X(co**	**Pout4X(co**	**Cnvgain**
-24.00	-26.1	-9.56	-20.05	-12.2	-29.0	-18.2	-8.8	-25.6	-24.6	1.6
-20.00	**-22.1**	-9.30	-18.93	-10.0	-21.2	-17.1	-6.6	-17.8	**-16.8**	**5.4**
-16.00	**-18.1**	-8.32	-17.45	-8.0	-16.7	-15.6	-4.6	-13.2	**-12.2**	**5.9**

Jhu13x4b-8 to 32 GHz Quadrupler, Fourth Harmonic (solid) and 1st, 2nd, 3rd Harmonics

JEP 26 GHz LNA (Variations)



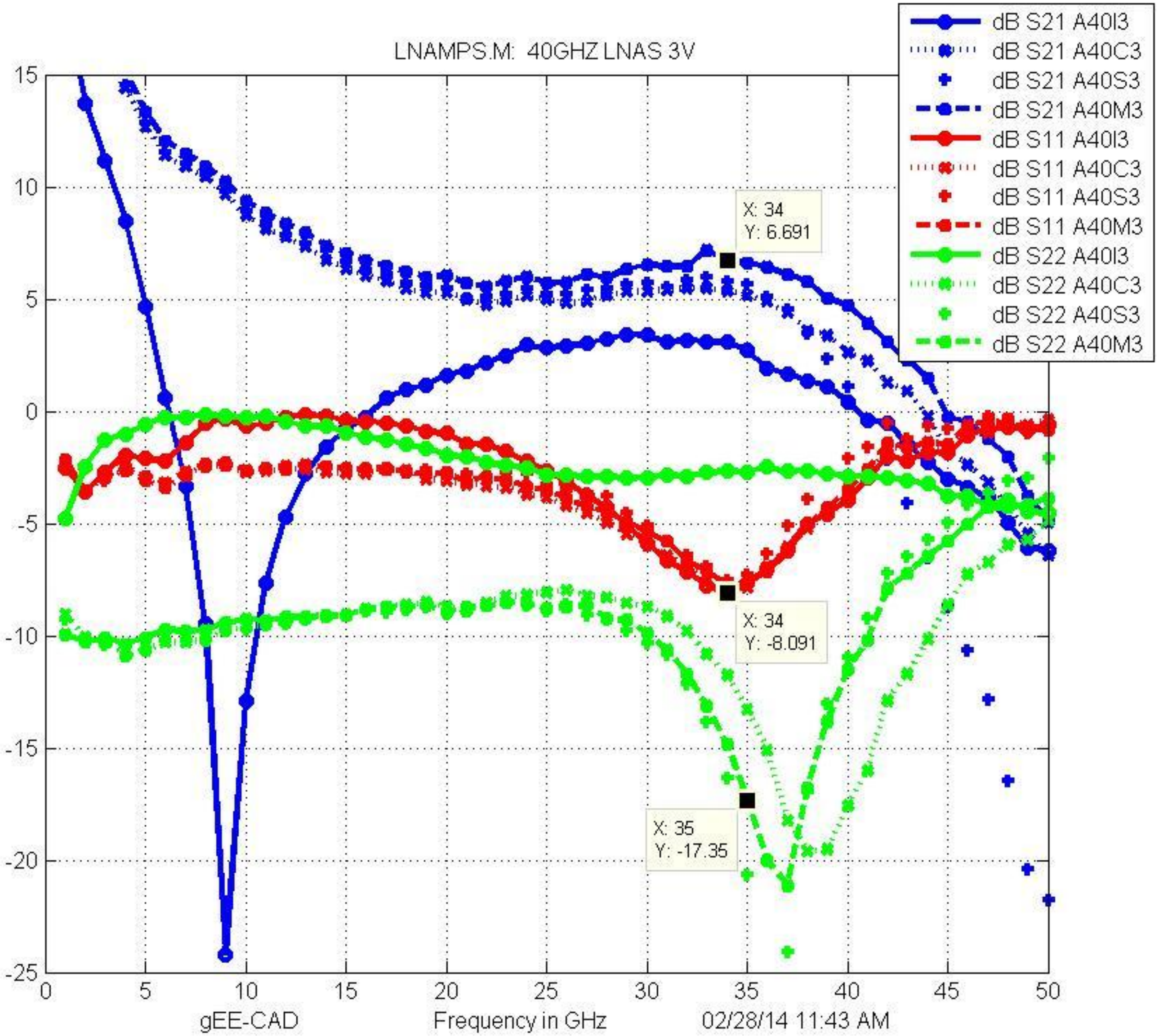
<u>Jhu13ln1-4</u>

Various comparable simple distributed matching circuits.

1) Stub
2) Radial Stub
3) Coplanar (Stub)
4) Spiral inductor (cap to gnd)*

*Model Issue? Try EM?

JEP 40 GHz LNA (Variations)



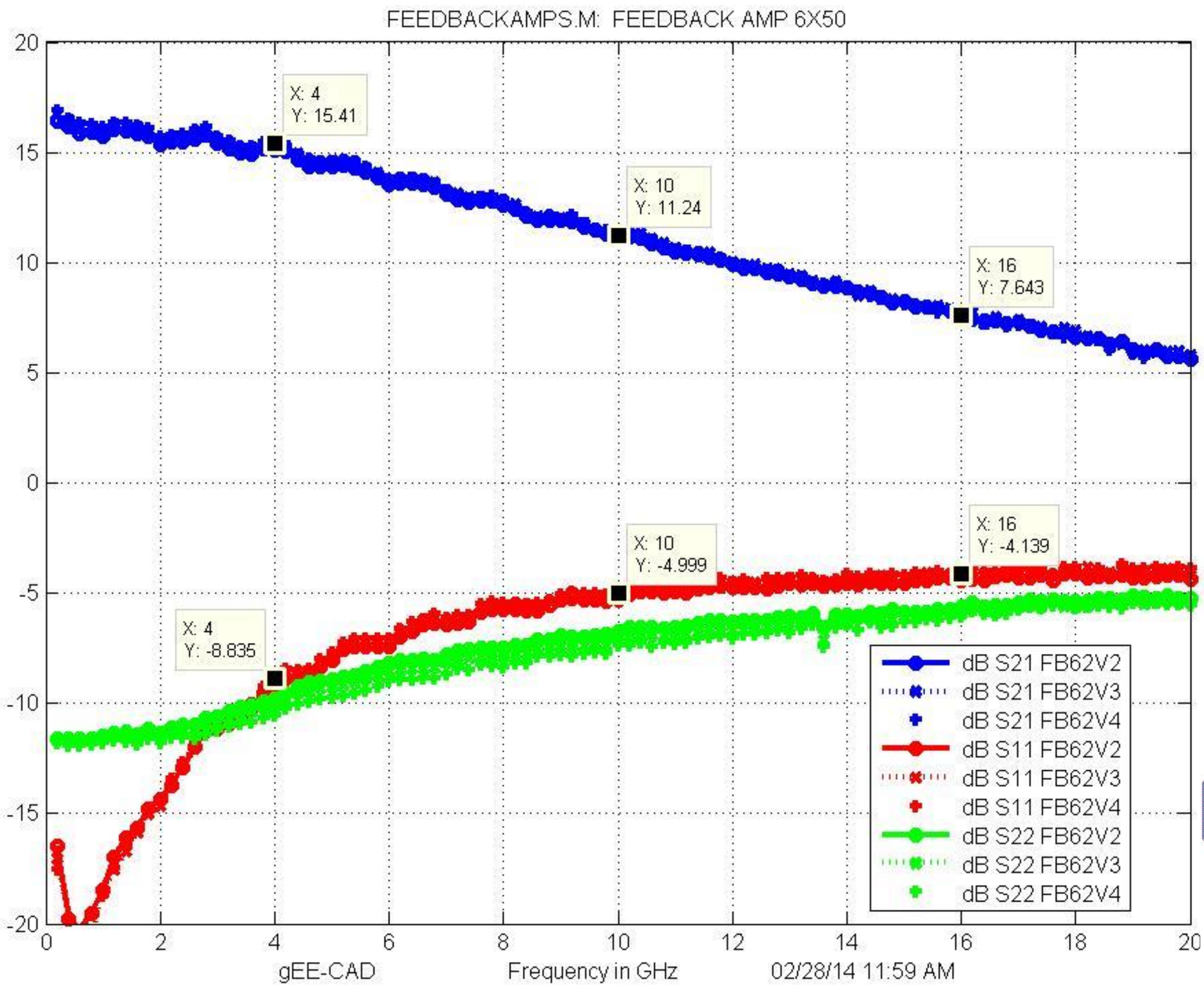
Jhu13ln1-4

Various comparable simple distributed matching circuits.

1) Stub
2) Radial Stub
3) Coplanar (Stub)
4) Spiral inductor (cap to gnd)*

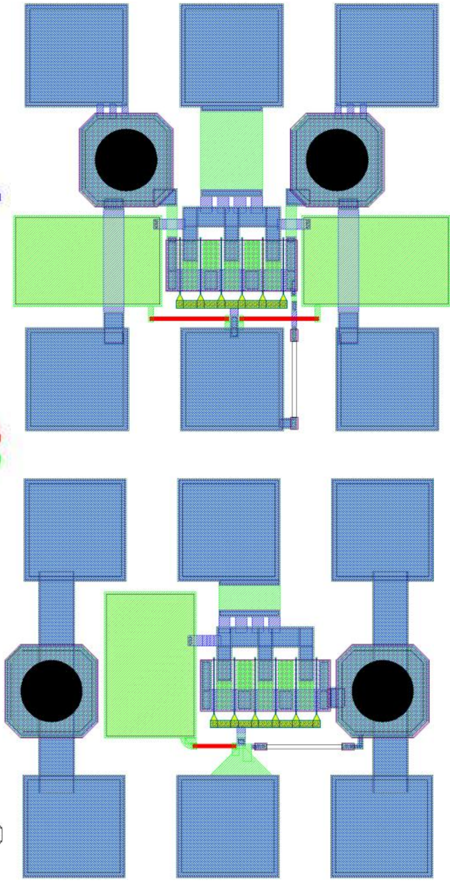
*Model Issue? Try EM?

JEP BroadBand Feedback Amps

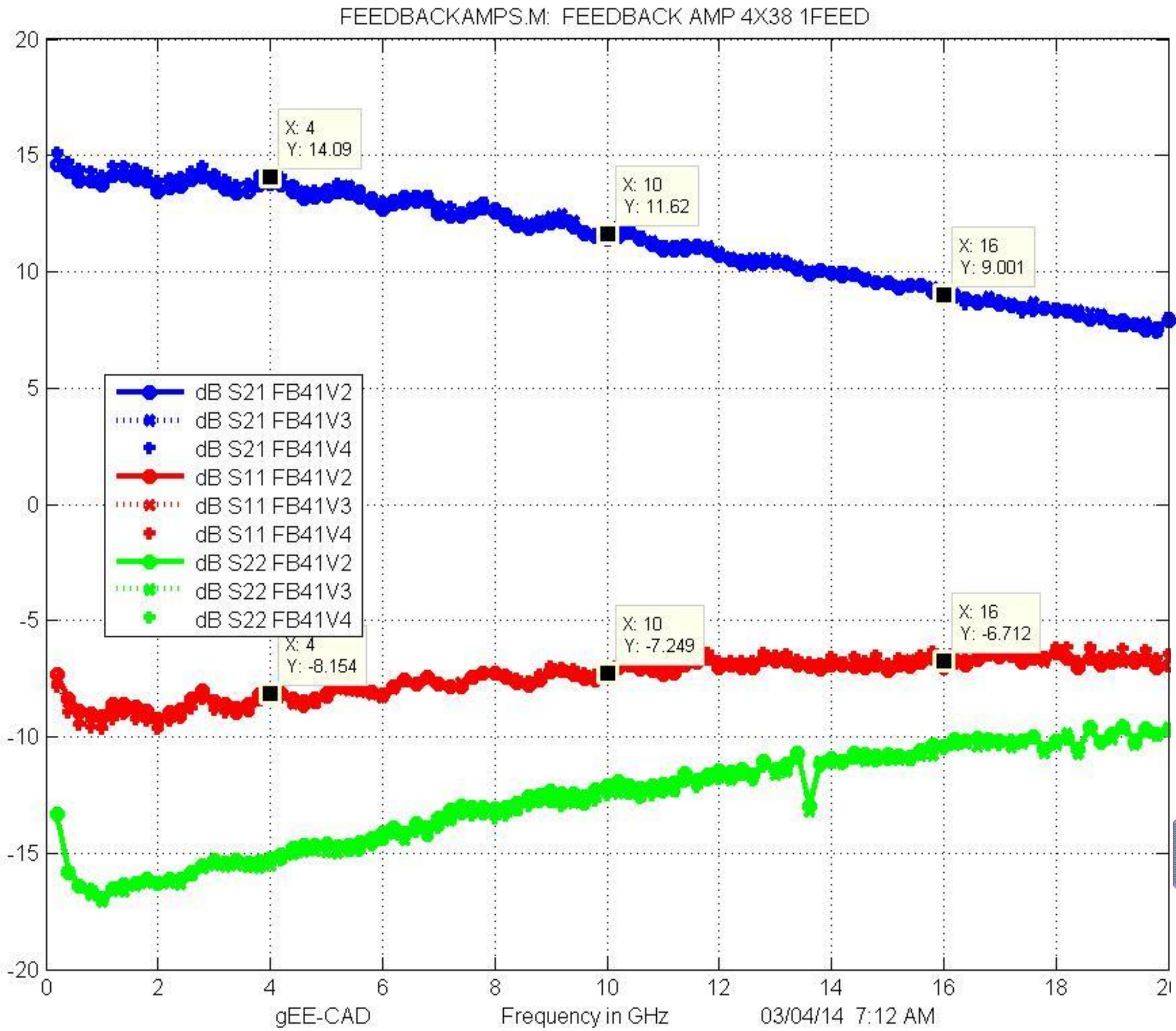


Jhu13ln1&4

6x50 FeedBack Amp

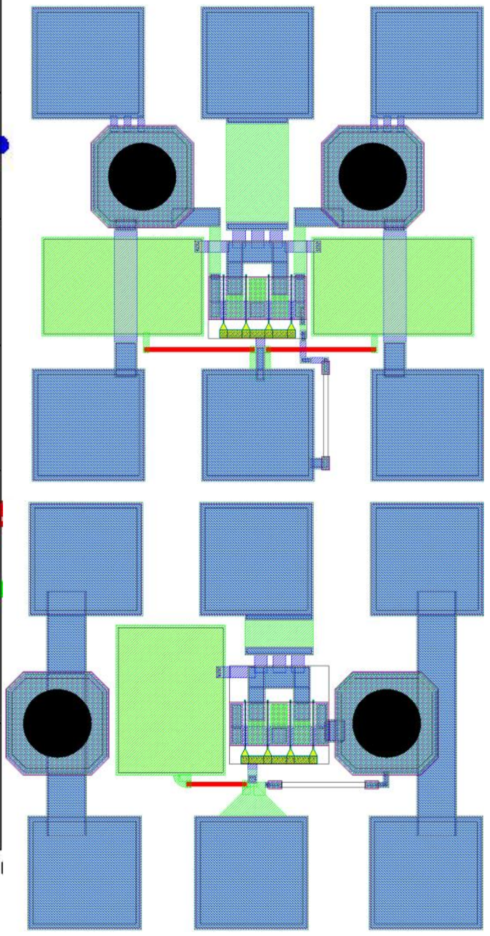


JEP BroadBand Feedback Amps



Jhu13ln1&4

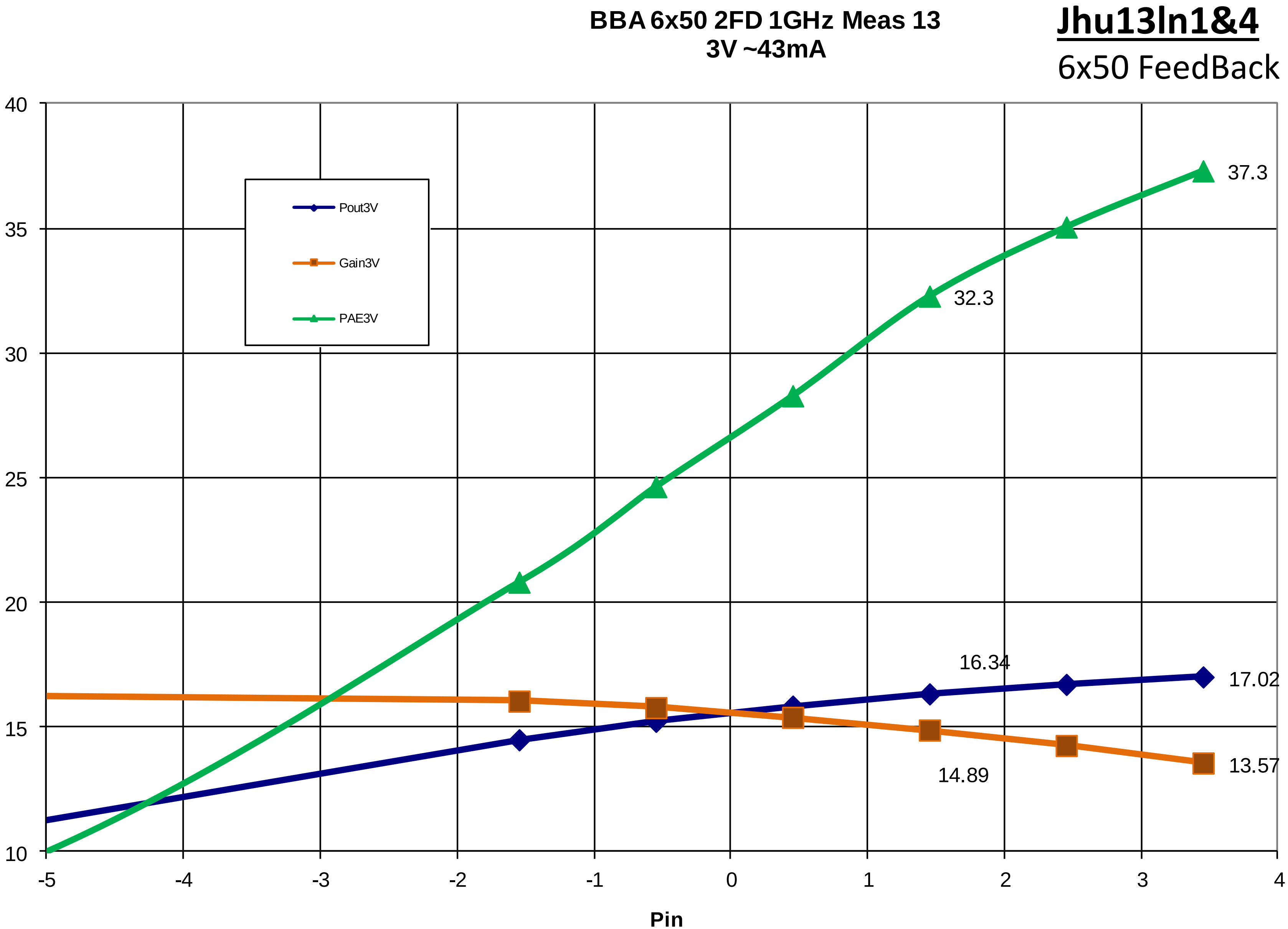
4x38 FeedBack Amp



JEP BroadBand Feedback Amps

Jhu13ln1&4

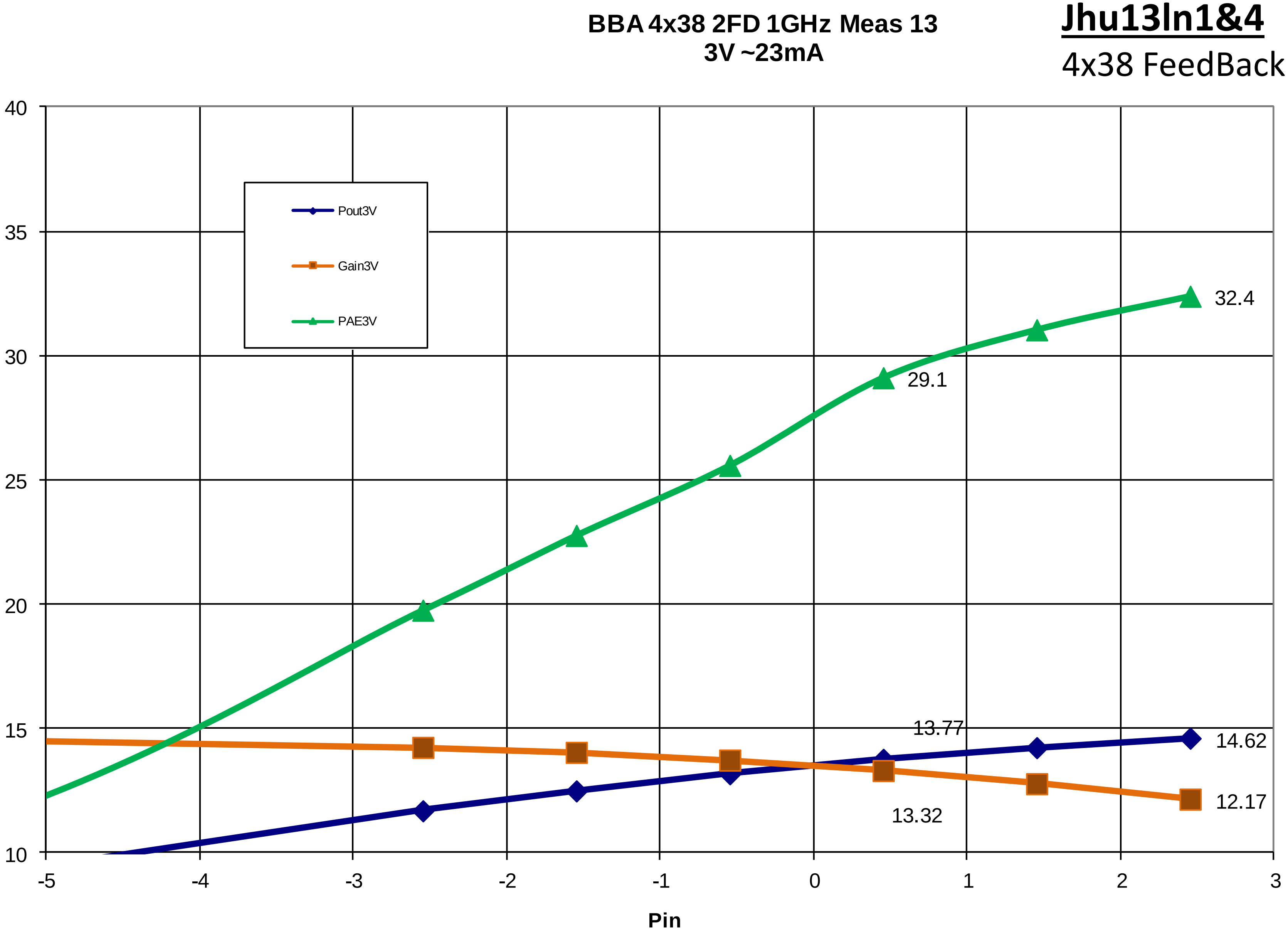
6x50 FeedBack Amp



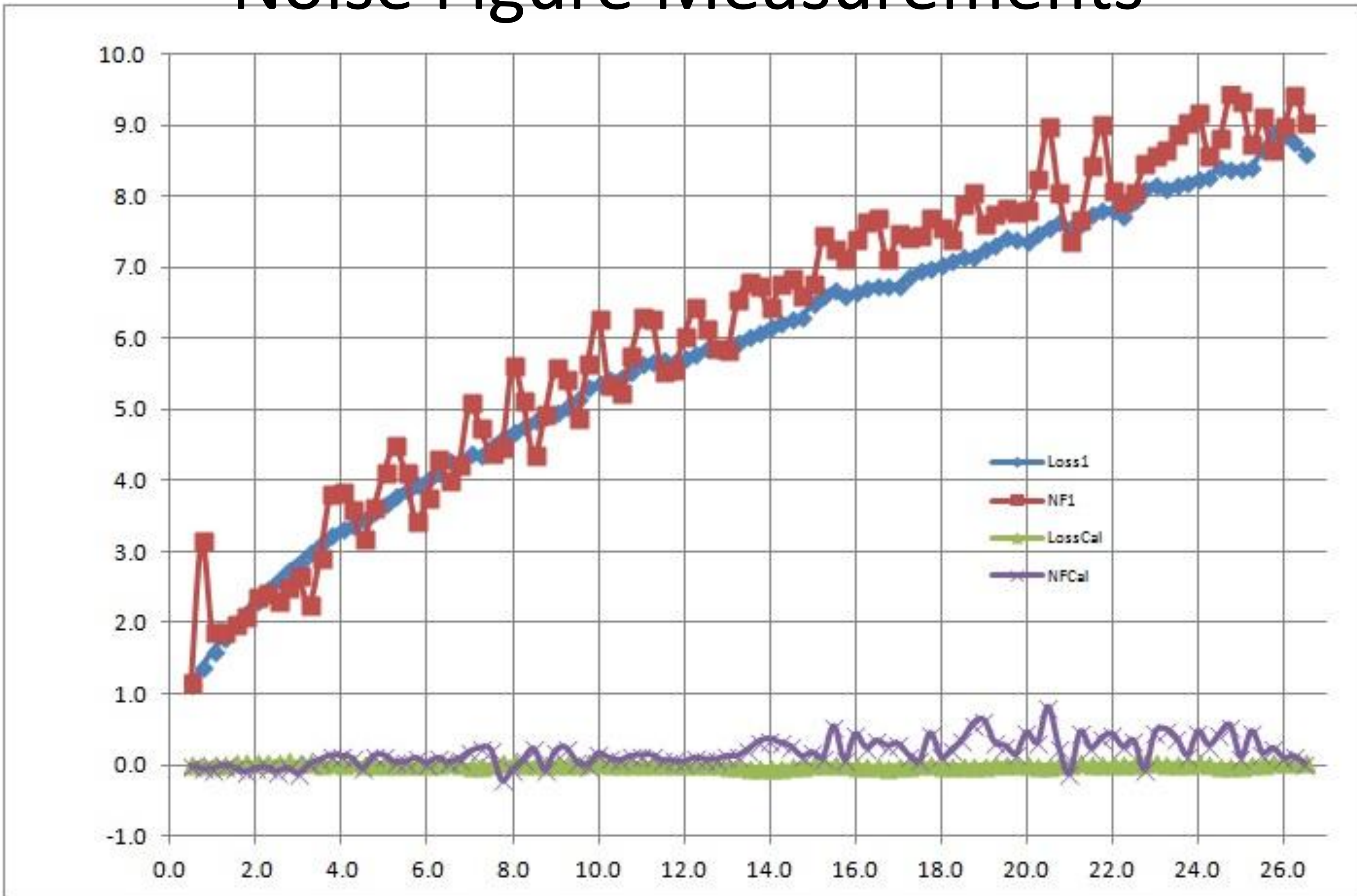
JEP BroadBand Feedback Amps

Jhu13ln1&4

4x38 FeedBack Amp

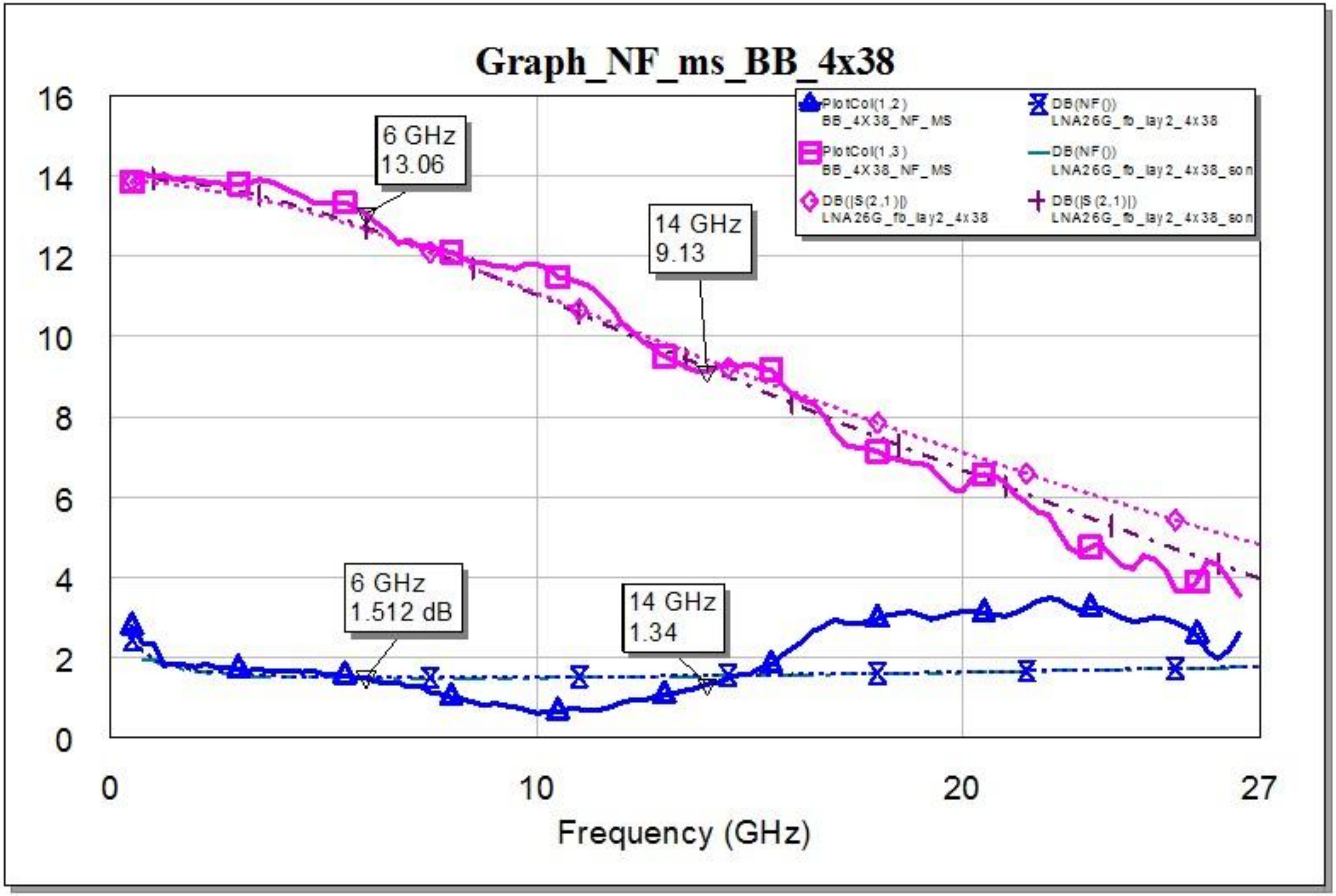


Noise Figure Measurements



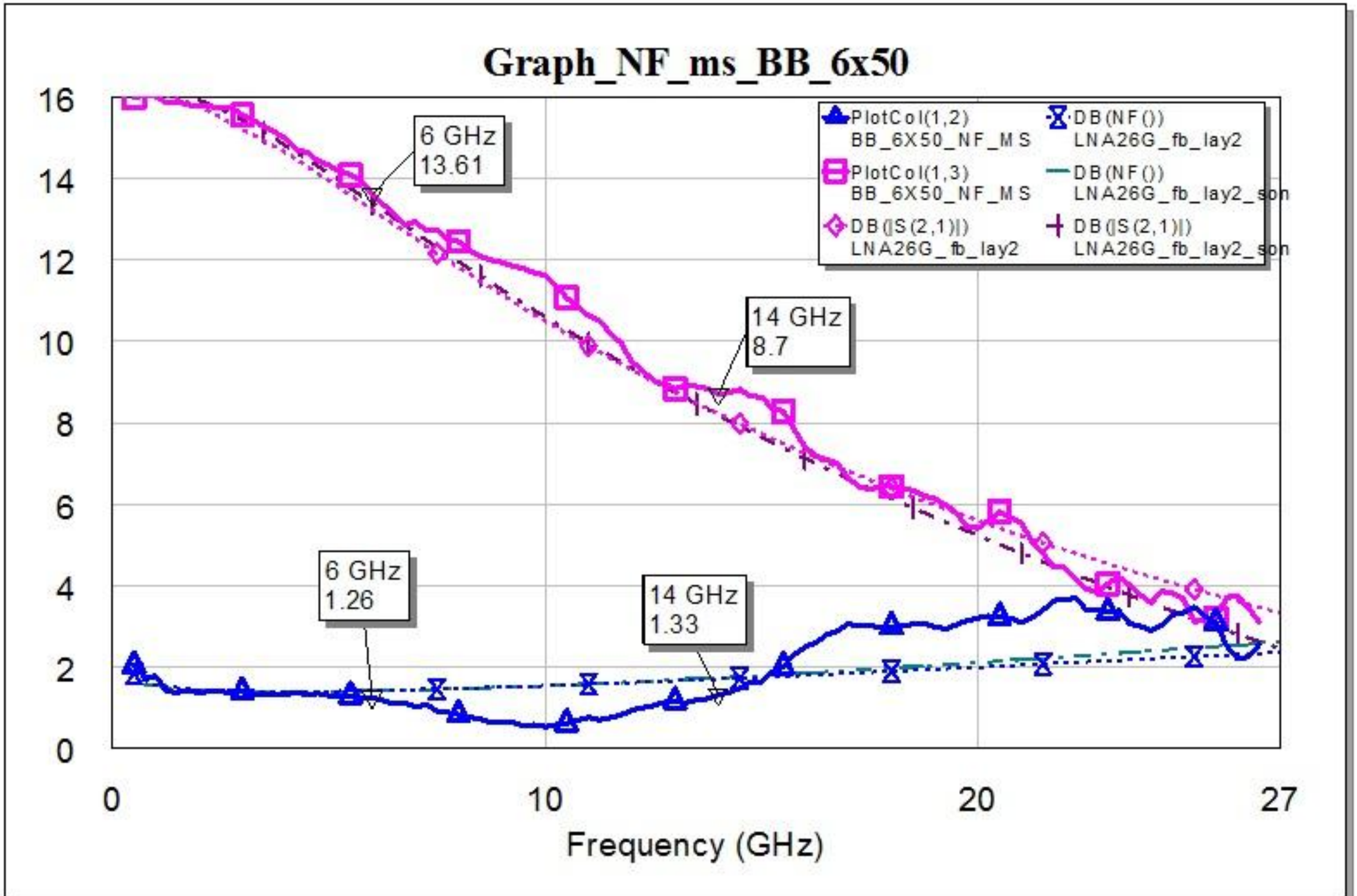
Gain and NF of "Cal" and two cables plus two GSG probes to 26.5 GHz

Noise Figure Measurements



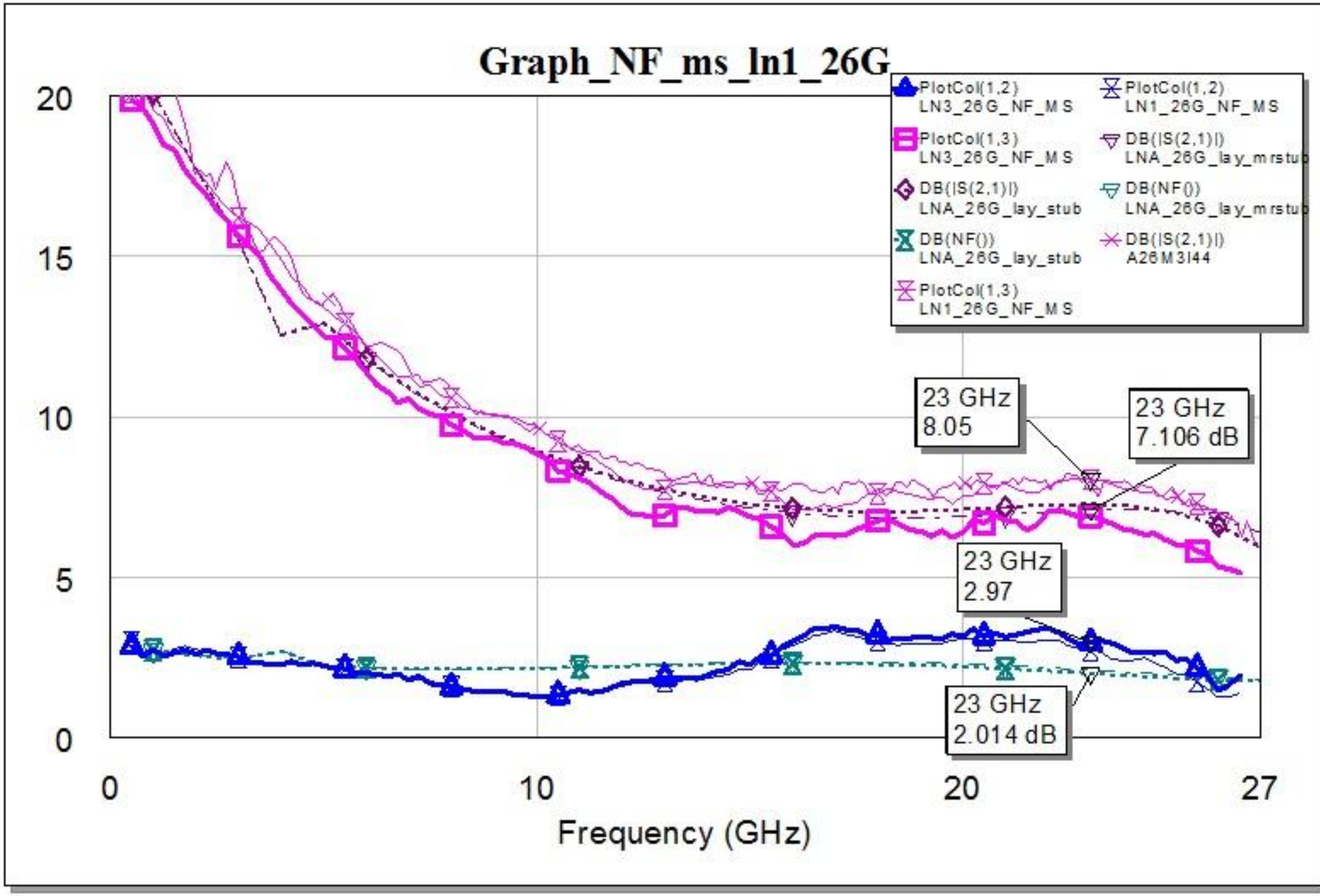
Gain and NF – Simulation versus Measured for 4x38 Broadband Feedback Amp

Noise Figure Measurements



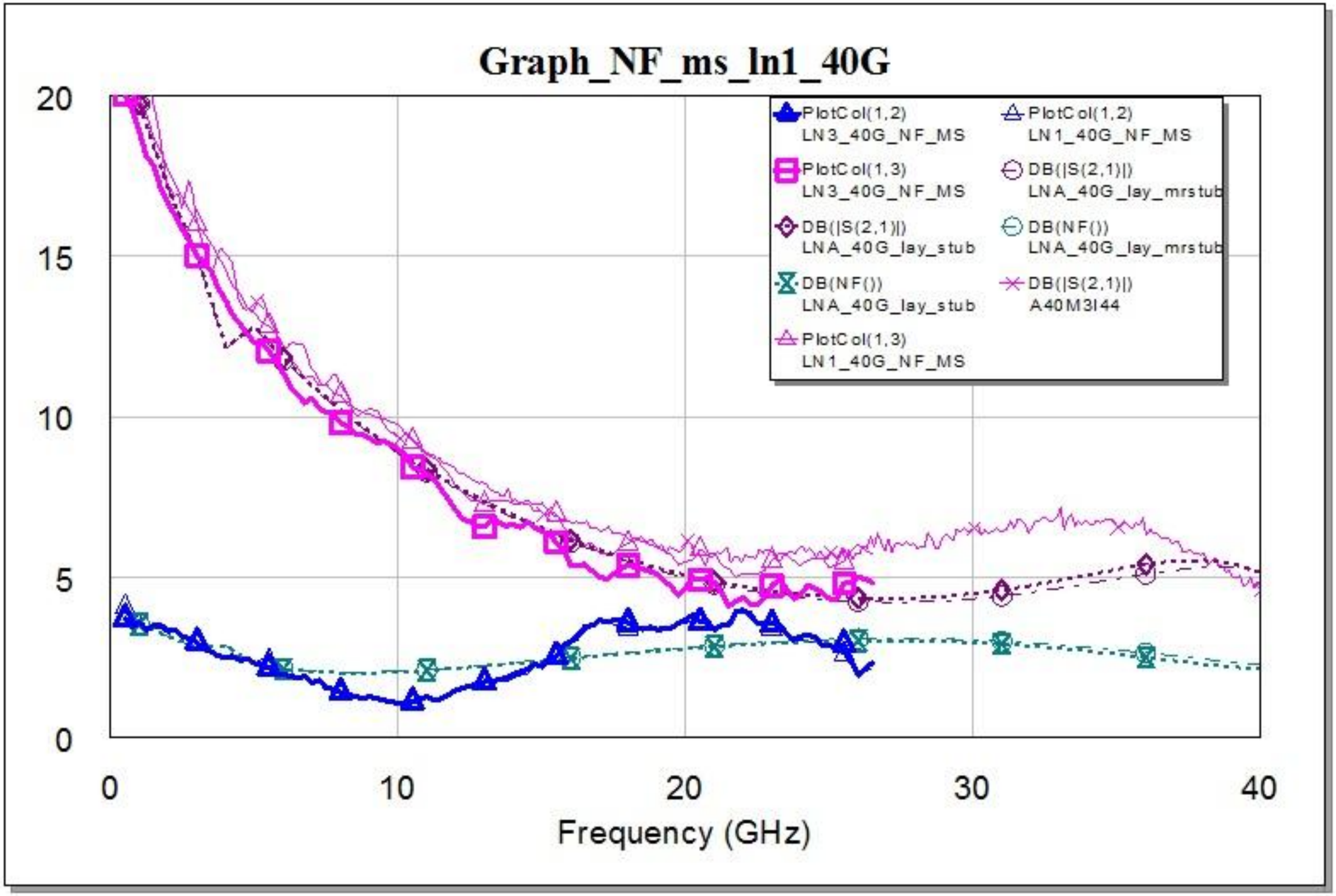
Gain and NF – Simulation versus Measured for 6x50 Broadband Feedback Amp

Noise Figure Measurements



Gain and NF – Simulation versus Measured for ~26GHz Low Noise Amp

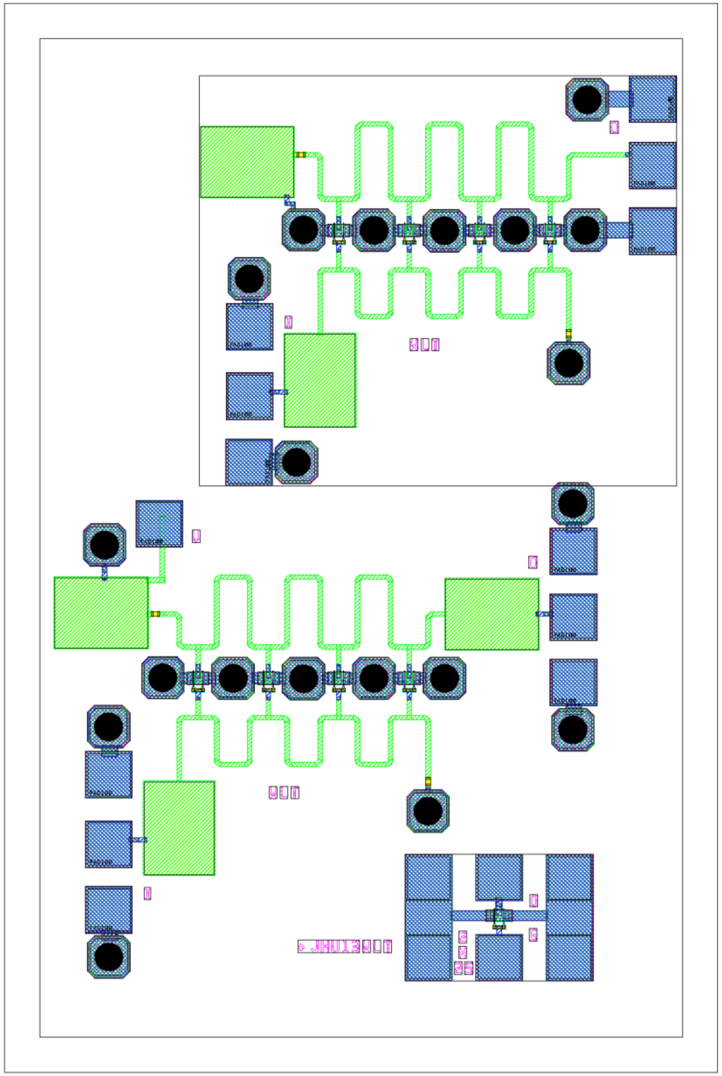
Noise Figure Measurements



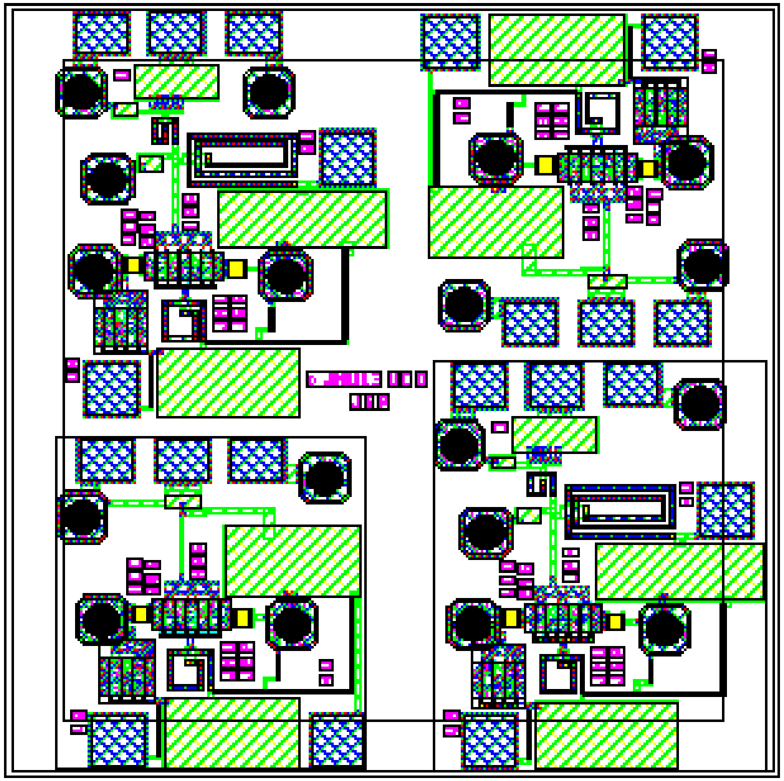
Gain and NF – Simulation versus Measured (to 26.5 G) for ~40GHz Low Noise Amp

Other Projects

jhu13wlt

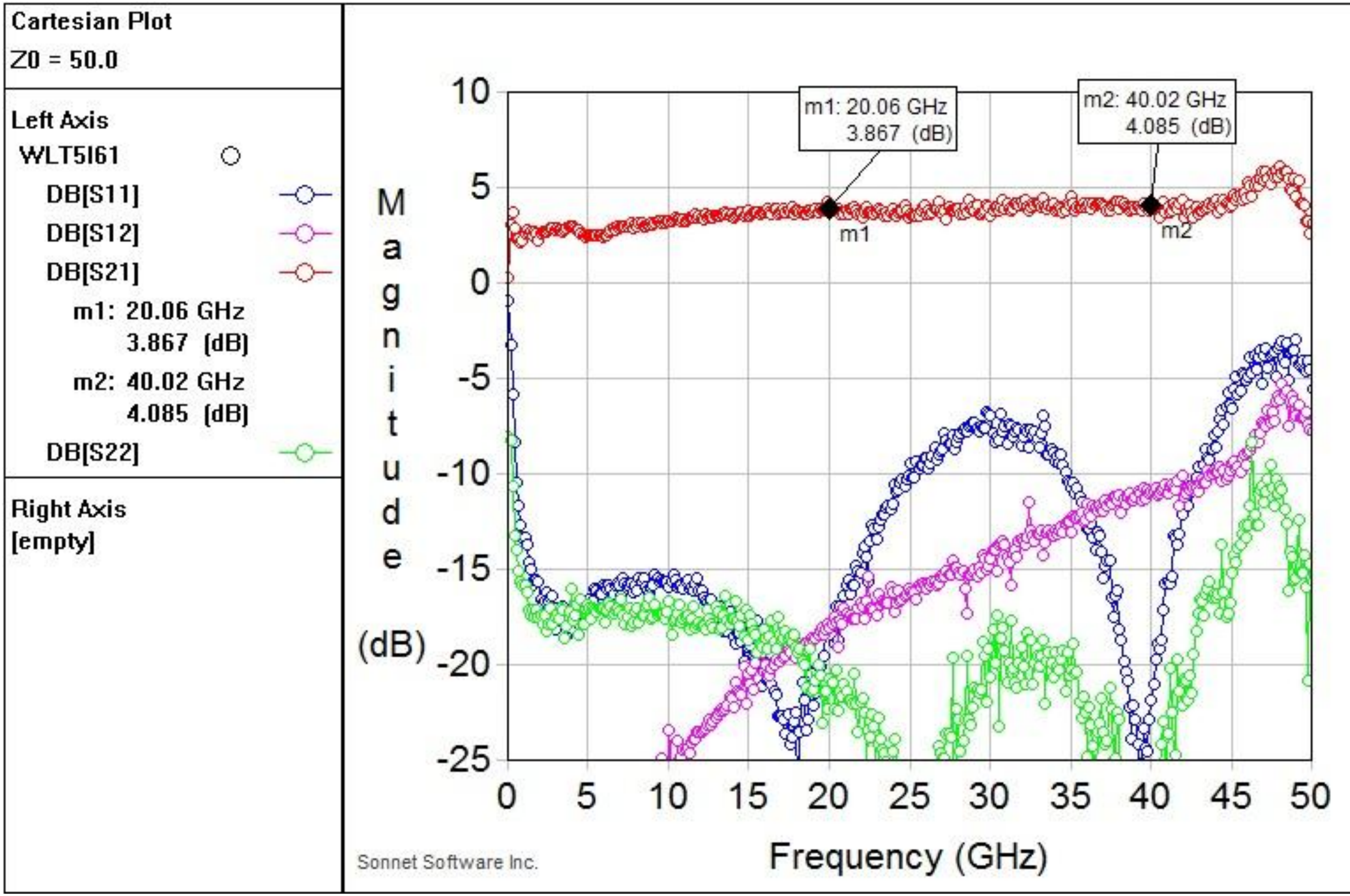


Jhu13vco
Re-tuned



Jhu13wlt
5V 61mA

WLT Distributed Amplifier



Jhu13vco Re-tuned 24GHz VCOs

Slight Modifications to '12 24 GHz VCO Output Matching Circuits to increase robustness of oscillation. High Pass vs. Low Pass Quarter Wave Lumped Element Transformer on output. Similar Tuning Range to '12 Versions. Better, more consistent Output Powers '13.

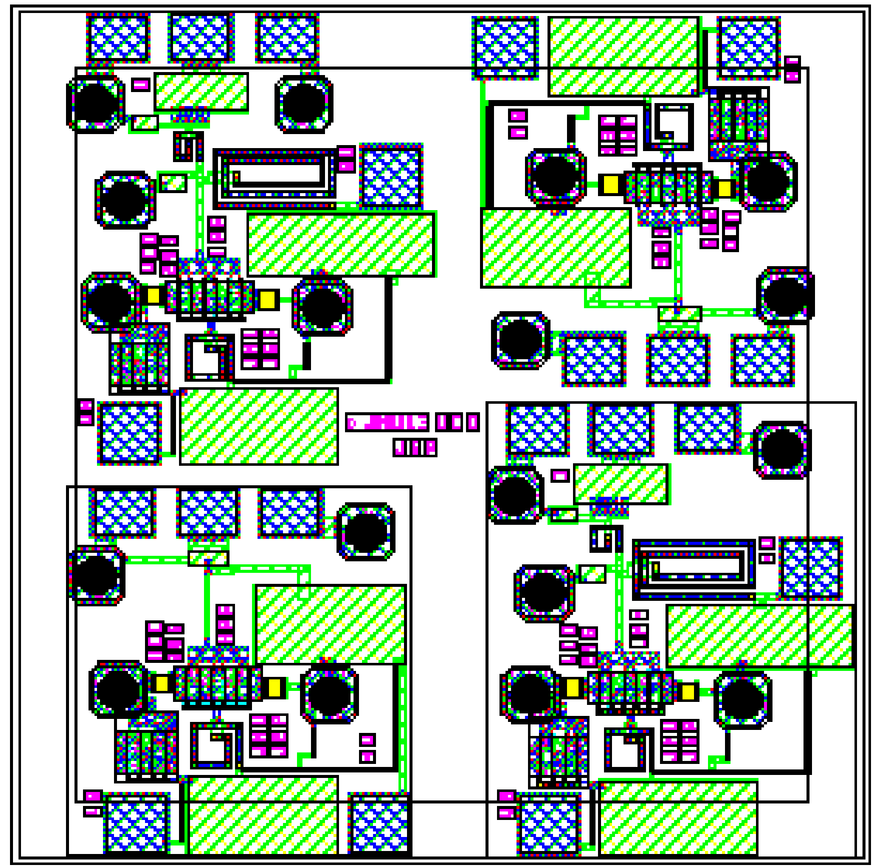
HPF VCO	3V at 21mA		Die #1	UR
VBias (V)	Freq (GHz	Pout(ms)	Pout(corr)	
-0.8	23.645	0.0	**4.5**	
-0.5	23.660	0.5	**5.0**	
0.0	23.883	0.3	**4.8**	

HPF VCO	3V at 21mA		Die #1	LL
VBias (V)	Freq (GHz	Pout(ms)	Pout(corr)	
-0.8	23.550	0.4	**4.9**	
-0.5	23.649	0.0	**4.5**	
-0.3	23.663	0.0	**4.5**	
0.0	23.879	0.0	**4.5**	

LPF VCO	3V at 20mA		Die #1	LR
VBias (V)	Freq (GHz	Pout(ms)	Pout(corr)	
-0.8	22.295	2.0	**6.5**	
-0.6	22.503	2.5	**7.0**	
-0.4	22.593	3.0	**7.5**	
-0.2	22.789	2.7	**7.2**	
0.0	22.799	2.7	**7.2**	

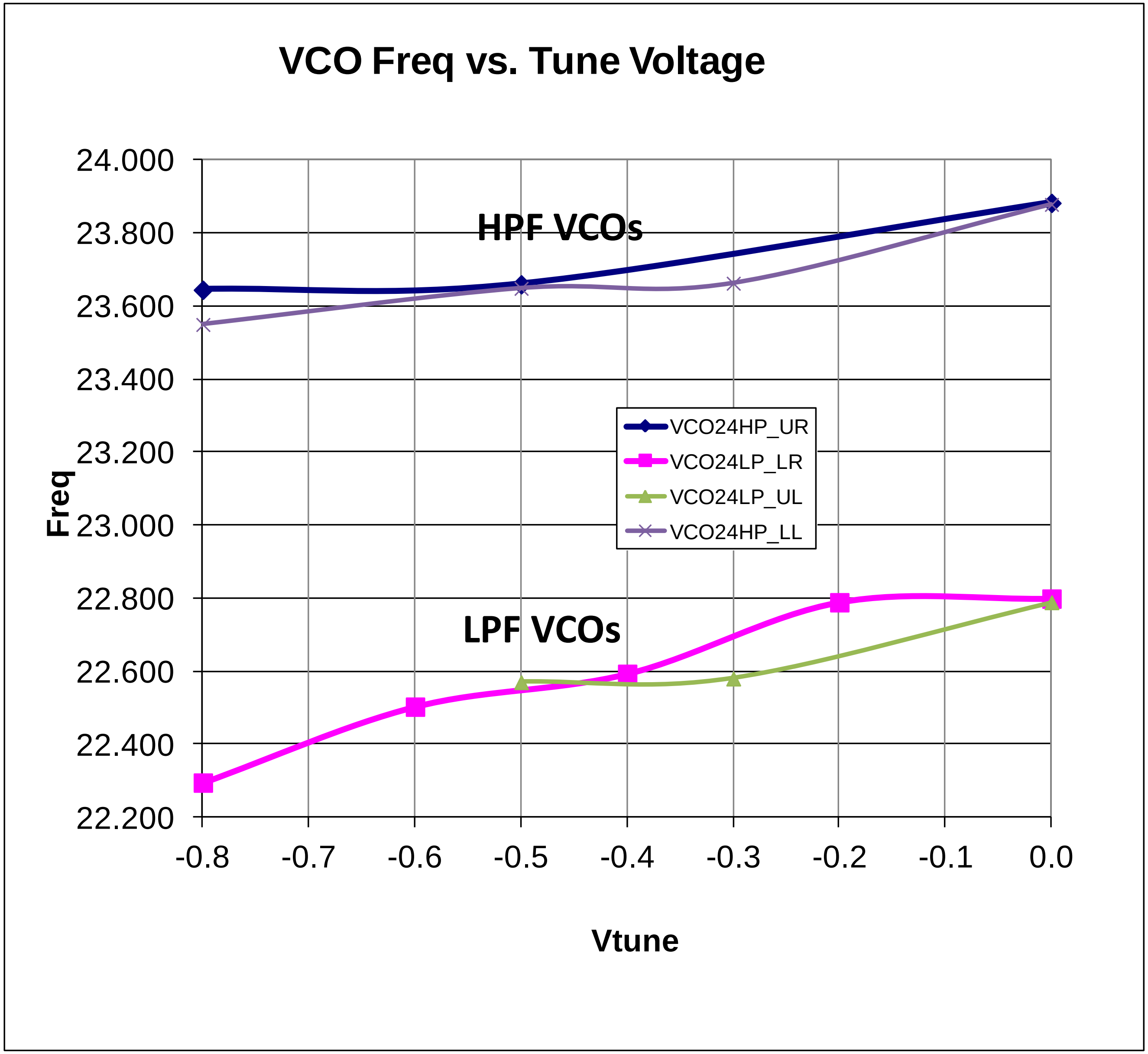
LPF VCO	3V at 20mA		Die #1	UL
VBias (V)	Freq (GHz	Pout(ms)	Pout(corr)	
-0.5	22.570	2.6	**7.1**	
-0.3	22.580	2.8	**7.3**	
0.0	22.789	2.2	**6.7**	

LPF-UL **HPF-UR**



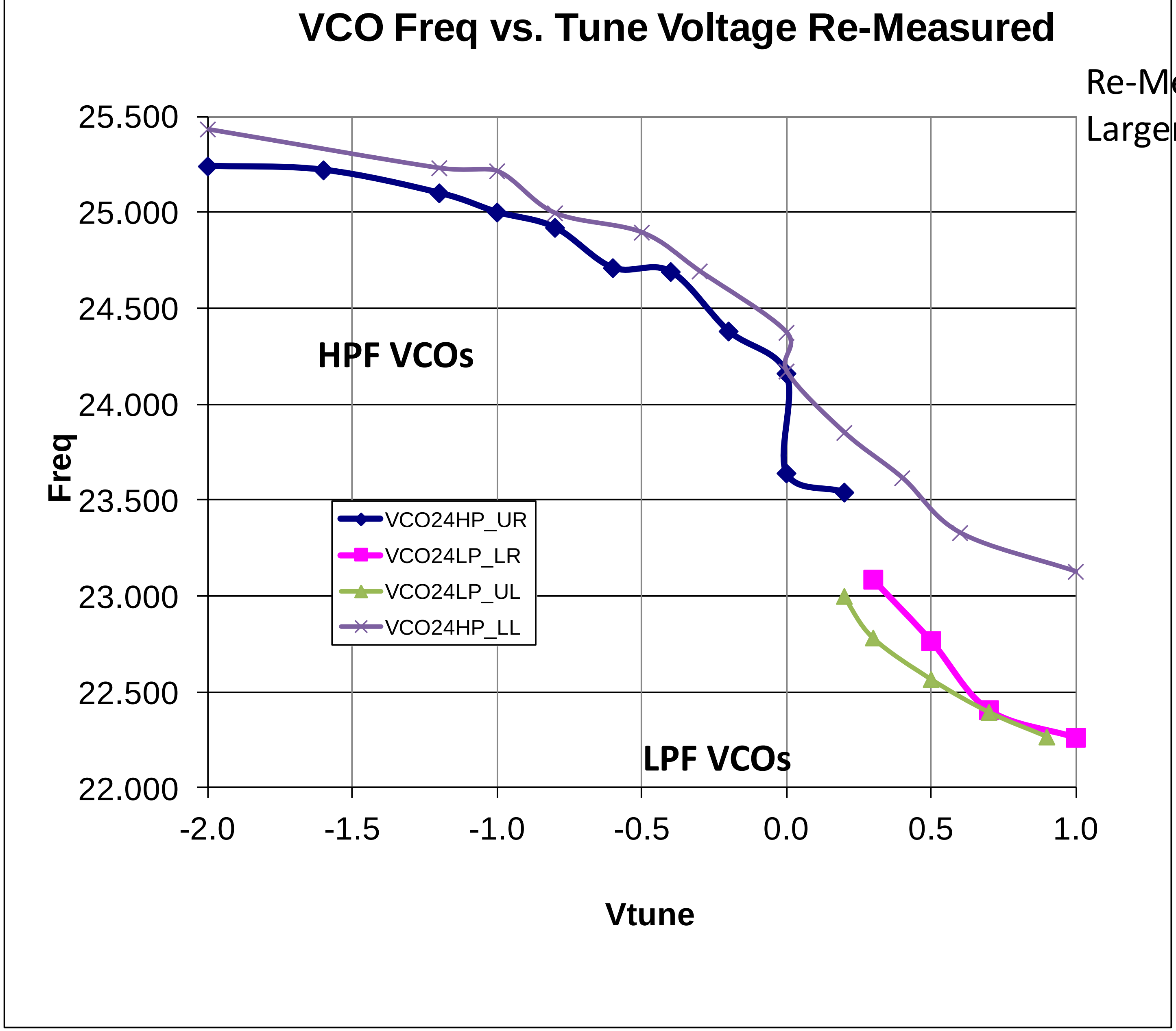
HPF-LL **LPF-LL**

Jhu13vco Re-tuned 24GHz VCOs



Slight Modifications to '12 24 GHz VCO Output Matching Circuits to increase robustness of oscillation. High Pass vs. Low Pass Quarter Wave Lumped Element Transformer on output.

Jhu13vco Re-tuned 24GHz VCOs



Re-Measured over Larger Tuning Range

Jhu13vco Re-tuned 24GHz VCOs

Re-Measured over Larger Tuning Range

HPF VCOs

Re-Measured 4/17/14				
HPF VCO	**3V at 15mA**		**Die #1**	LL
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**	
-2.0	25.434	0.9	**5.4**	
-1.2	25.232	-0.2	**4.3**	
-1.0	25.216	0.1	**4.6**	
-0.8	24.997	0.6	**5.1**	
-0.5	24.896	1.7	**6.2**	
-0.3	24.694	-2.2	**2.3**	
0.0	24.374	0.0	**4.5**	
0.0	24.172	-1.3	**3.2**	
0.2	23.852	-1.3	**3.2**	
0.4	23.616	-1.3	**3.2**	
0.6	23.330	-1.0	**3.5**	
1.0	23.128	-1.0	**3.5**	
HPF VCO	**3V at 15mA**		**Die #1**	UR
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**	
-2.0	25.241	-0.9	**3.6**	
-1.6	25.221	-0.7	**3.8**	
-1.2	25.101	-1.3	**3.2**	
-1.0	25.001	-0.1	**4.4**	
-0.8	24.921	0.7	**5.2**	
-0.6	24.711	-2.5	**2.0**	
-0.4	24.691	-2.1	**2.4**	
-0.2	24.381	-0.6	**3.9**	
0.0	24.161	-0.6	**3.9**	
0.0	23.641	0.0	**4.5**	
0.2	23.541	1.0	**5.5**	

LPF VCOs

Re-Measured 4/17/14				
Positive voltages only for oscillation!				
LPF VCO	**3V at 15mA**		**Die #1**	UL
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**	
0.2	23.000	-0.4	**4.1**	
0.3	22.783	-0.2	**4.3**	
0.5	22.567	0.9	**5.4**	
0.7	22.395	0.7	**5.2**	
0.9	22.267	-0.39	**4.11**	
Positive voltages only for oscillation!				
LPF VCO	**3V at 14mA**		**Die #1**	LR
VBias (V)	**Freq (GHz**	**Pout(ms)**	**Pout(corr)**	
0.3	23.087	0.0	**4.5**	
0.5	22.767	0.2	**4.7**	
0.7	22.407	0.8	**5.3**	
1.0	22.263	-0.5	**4.0**	