AN13584

Kinetis KW45 and K32W148 Loadpull Report

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Document information

Information	Content
Keywords	KW45, K32W148, Loadpull
Abstract	The purpose of the measurements is to monitor the supply current, the transmit power, and the harmonics level while the complex load seen by the DUT is tuned in amplitude and phase.

1 Introduction

1.1 Test purpose

The purpose of the measurements is to monitor the supply current, the transmit power and the harmonics level while the complex load seen by the DUT is tuned in amplitude and phase.

The automated impedance tuner MT982BL from MAURY MICROWAVE is used to make vary the DUT load.

The following pages describes the test set-up.

Characterizing the tuner covers the tuner stand alone and Test covers the load pull results on KW45/K32W148 device.

Test limitations: The harmonics rate depends on the DUT load value not only at the fundamental frequency but also at the harmonics frequencies. For the described measurements we control the load at the fundamental frequency but the return loss of the impedance tuner at the harmonics frequencies is not known.

1.2 Power and supply current summary Results

- VSWR = 1:1
  - The Tx power and supply current are almost constant versus the phase.
  - Delta Tx power is 0.23 dB and delta power consumption is 90 uA.
  - Power @SMA pin: +10.66 dBm for an EVK power consumption of 25.33 mA.
- VSWR = 2:1
  - The power varies from +8.89 dBm to +10.51 dBm depending on the phase.
  - Delta Tx power is 1.62 dB and delta power consumption is 2.6 mA.
  - Power @SMA pin: +10.04 dBm for an EVK power consumption of 25.95 mA.
- VSWR = 3:1
  - The power varies from +7.65 dBm to +9.81 dBm depending on the phase.
  - Delta Tx power is 2.16 dB and delta power consumption is 3.82 mA.
  - Power @SMA pin: +9.17 dBm for a EVK power consumption of 26.22 mA.

Overall results

- Power @SMA pin: from +7.65 dBm (min.) to +10.66 dBm (max.) +10.66 dBm @VSWR=1
- EVK Power consumption: from 23.24 mA (min.) to 27.06 mA (max.) 25.33 mA @VSWR=1

1.3 Conclusion

TX power level: Up to 2.1 dB variation with a poor quality antenna

Supply current: Significant extra consumption (~3.8 mA) with a poor quality antenna

Harmonics:

- H2 are more sensitive to poor quality antenna (out of ETSI limits on some cases)
- H3 are sensitive but within an acceptable range

2 Hardware setup — Characterizing the tuner

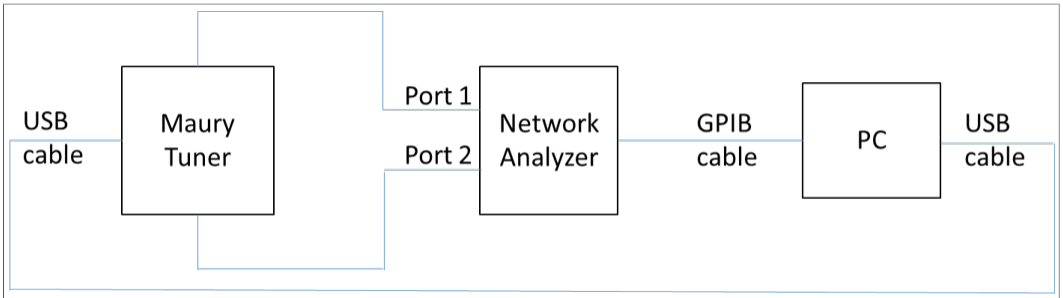

Figure 1. Hardware lab bench setup

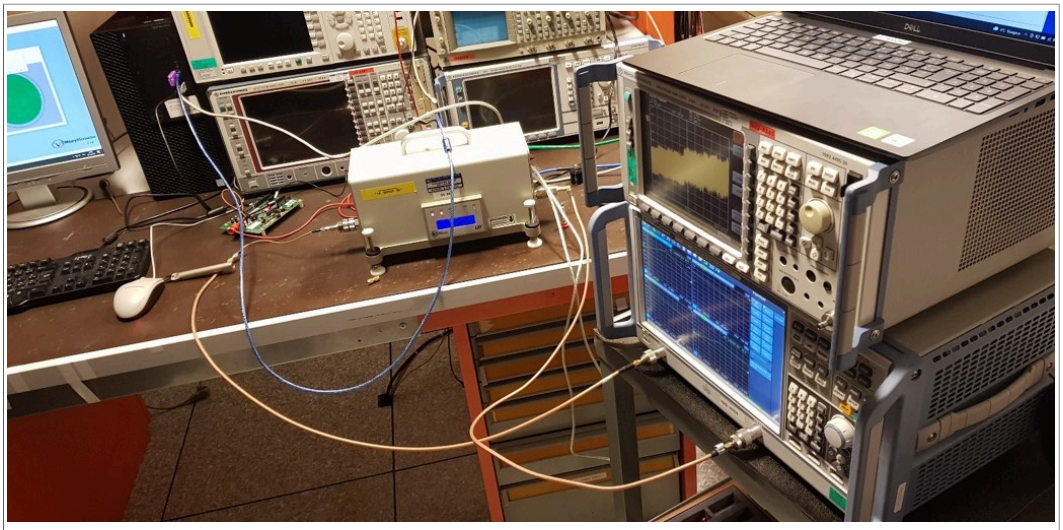

Figure 2. Hardware connection

2.1 Software lab bench setup

Launch the TCS software.

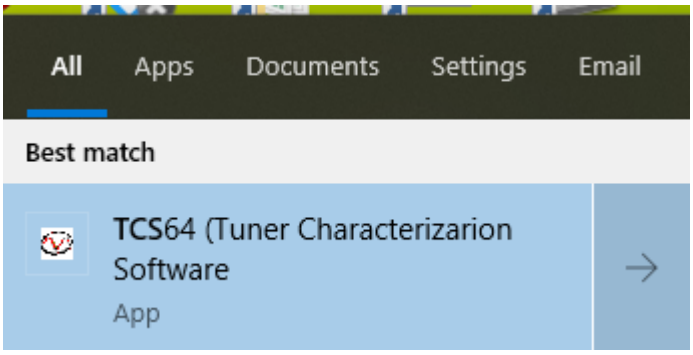

Figure 3. TCS software

The Tuner and the Spectrum are declared in the right way and ready to use.

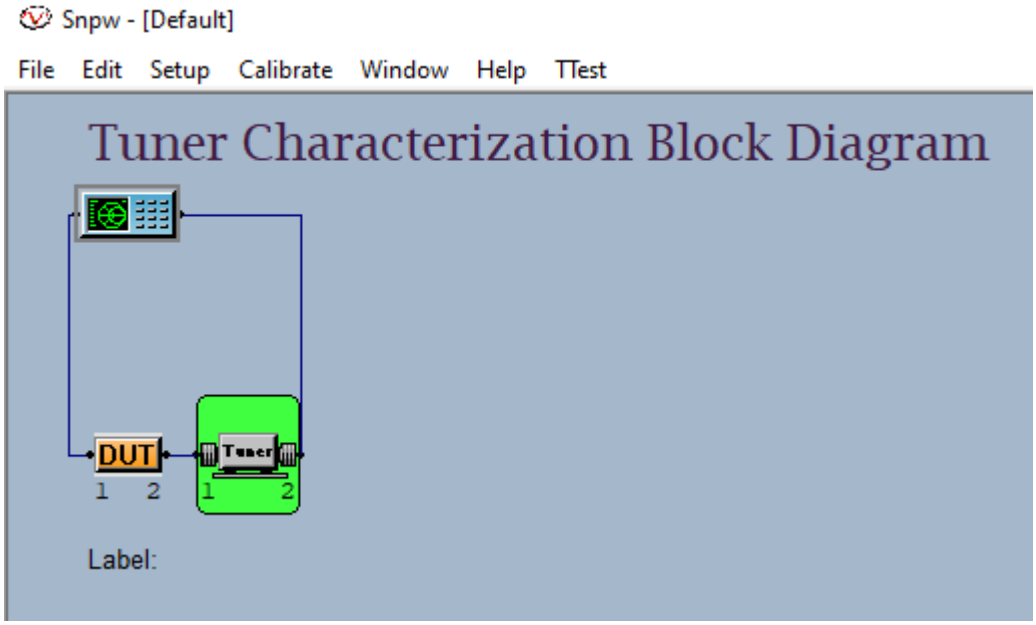

Figure 4. Tuner characterization block diagram

2.2 Characterizing the tuner

The tuner characterization is ready.

Verification step: Move tuner to one position: click right of the mouse, and then **Move Tuner**.

Check on Spectrum the S11 (for example):

- Real Amplitude = 0.621 dB
- Phase = 19.51°
- Ga = -2.58 dB

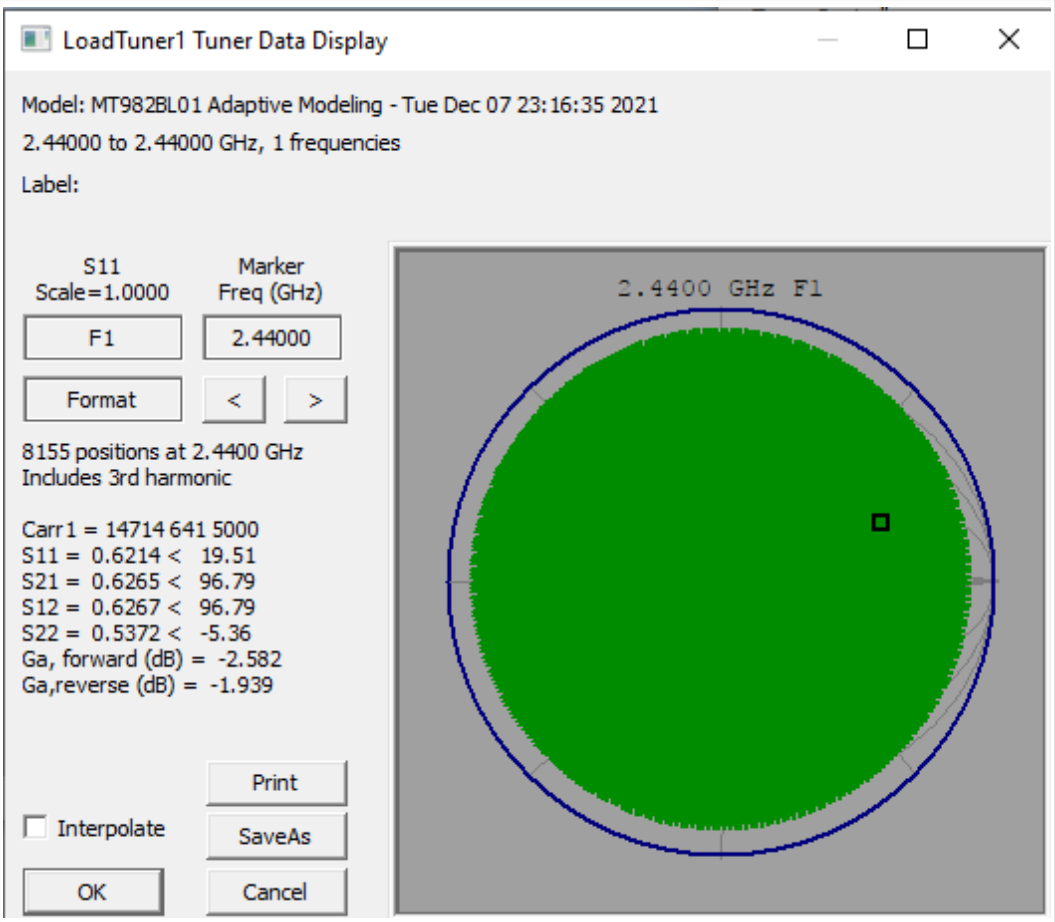

Figure 5. Characterizing the Tuner

2.3 DUT measurements

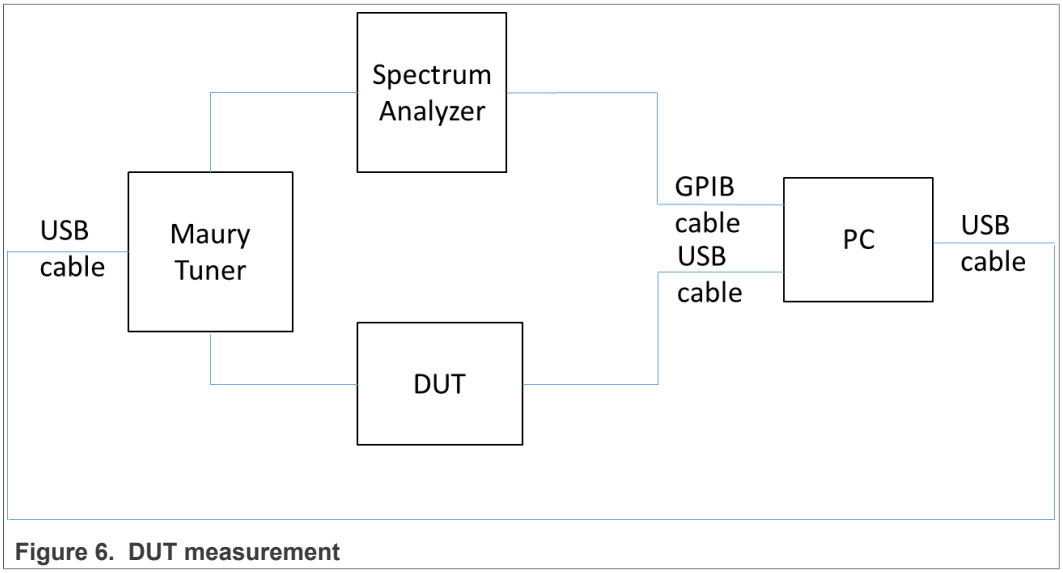

Figure 6. DUT measurement

Perform the following steps:

1. Click on the green tuner box, and the windows is opened, as shown in Figure 7.
   Verify that **Interpolate Impedance** is not selected (on the **Setup** tab) and **Tuner 1** is selected.

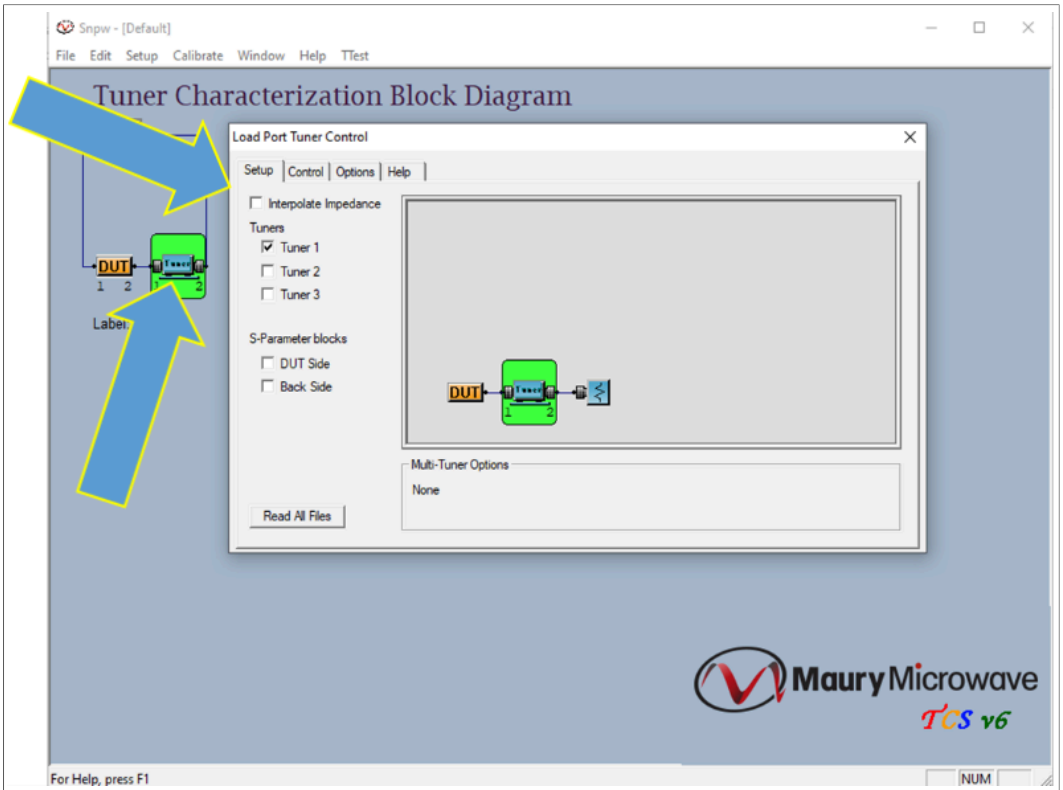

Figure 7. Selecting Tuner 1

2. Select the **Control** tab.
   Choose the **Target Mag** (VSWR) and **Phase** (°) values.
   Click **Apply** and then **Move Reflection**.
   Three markers (1:fund.; 2:H2; 3:H3) are represented in the smith graph.

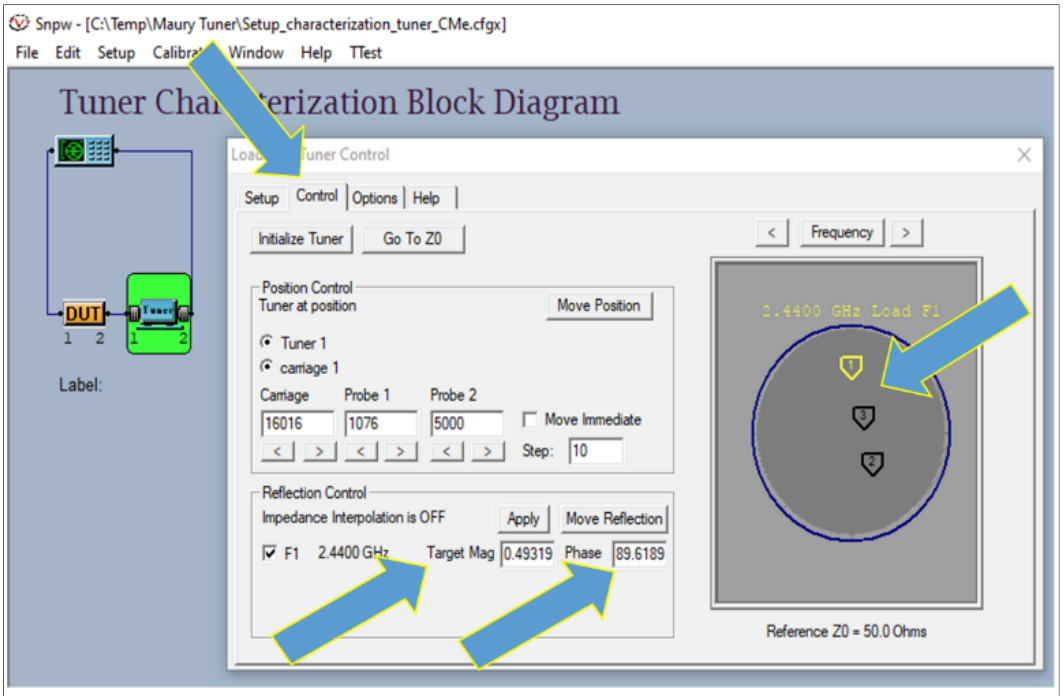

Figure 8. Selecting control

3. Click **Apply** and then **Move Reflection**. Go to the graph. Right-click the mouse and select **Show S-parameters**. Example setting values:
   - Target Mag: VSWR:1 ➔ 0 VSWR:2 ➔ 0.333 VSWR:3 ➔ 0.5
   - Phase: 0°, 45°, …

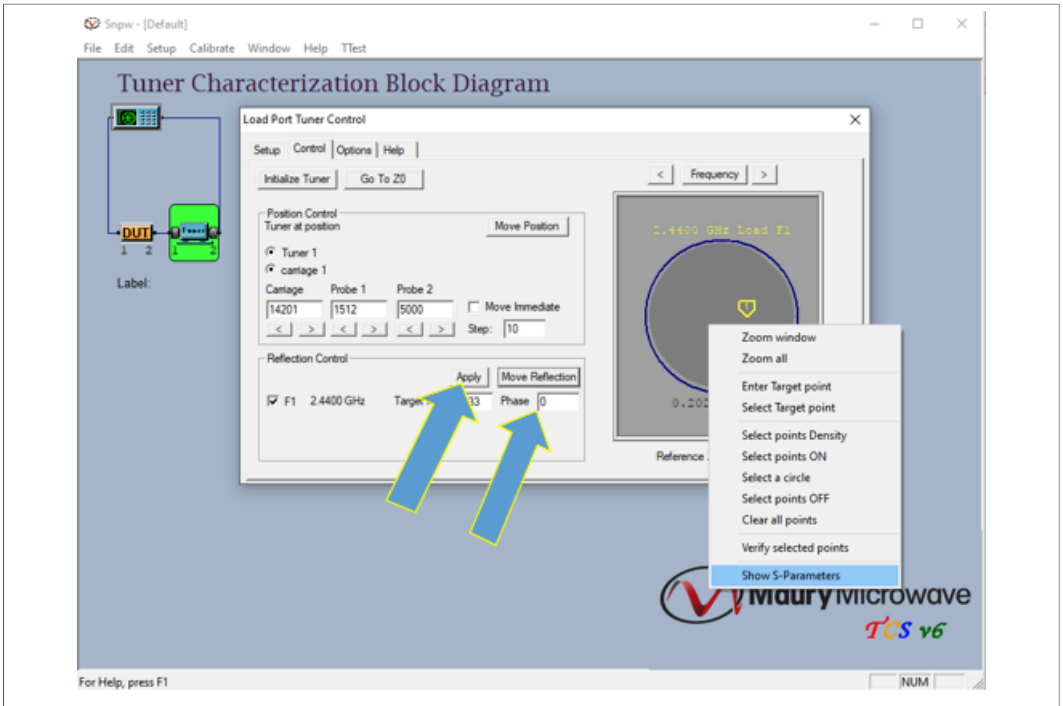

Figure 9. Clicking Apply

4. When the **Show S-parameters** is selected, the **Current Load Tuning Block** window is opened.
   Available information:
   Fund., H2 and H3 frequencies: S11, S12, S21, S22 values

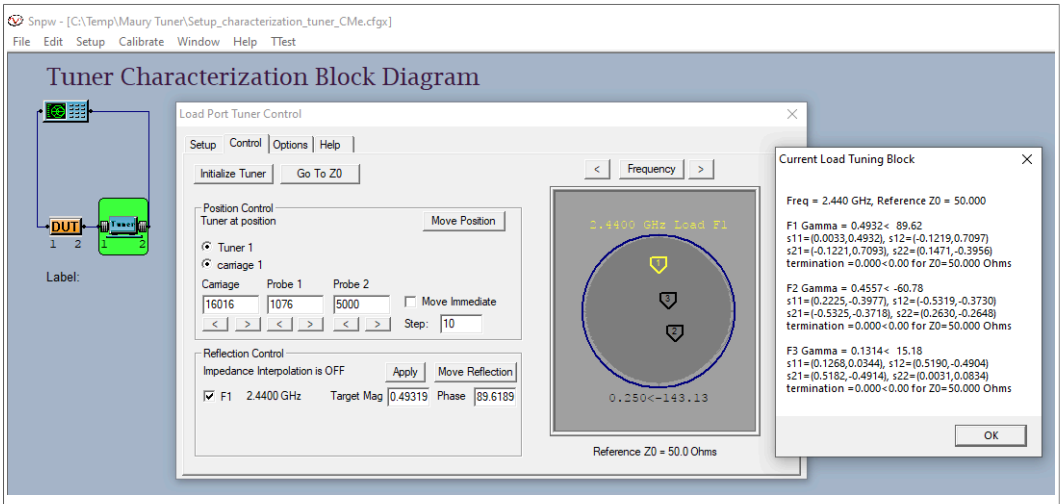

Figure 10. Opening Current Load Tuning Block

3 Test

3.1 Test conditions

Measurements have been done under the following conditions:

- Channel 19 (2440 MHz), continuous CW, Power level +10 dBm, Buck mode
- USB power supply (5.0 V), Temperature = room temperature
- Three values of VSWR have been tested:
  - 1.004:1 (return loss = 54 dB): very good return loss
  - 2:1 (return loss = 9.5 dB): corresponds to a ceramic antenna without matching
  - 3:1 (return loss = 5.8 dB): poor return loss

  For each value of VSWR the phase is varied from 0° to 315° by 45 ° steps.
- Spectrum analyzer settings for harmonics measurements
  - Reference amplitude : +12 dBm , RBW: 10 KHz, VBW: 30 KHz, Span 1 MHz, RF attenuation = 0 dB
- TX fundamental:
  - Center frequency 2.44 GHz/RBW 100 KHz / VBW 300 KHz / Span 10 MHz / Ref level 20 dBm /Trace average mode

$$Reflection\ Coefficient = \Gamma = \frac{Z_L - Z_S}{Z_L + Z_S}$$

Where

$\Gamma = Reflection\ Coefficient$

$Z_L = Load\ Impedance$

$Z_S = Source\ Impedance$

Figure 11. Test condition

3.2 Test results

3.2.1 Fundamental frequency

Fundamental frequency (2.44 GHz)									
VSWR=1.0	**=> RL=54dB**								
|ZL|	50.015 ohms	50.011 ohms	49.988 ohms	49.984 ohms	50.019 ohms	50.011 ohms	49.991 ohms	49.984 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
impedance (Ohms)	0.0111+0.0095i	0.0049+0.0098i	-0.0011+0.0117i	-0.0063+0.0151i	-0.0187+0.0003i	-0.0092-0.0058i	0.0015-0.0093i	0.0128-0.0098i	**delta**
TX power (dBm) @SMA	10.66dBm	10.43dBm	10.45dBm	10.55dBm	10.44dBm	10.49dBm	10.48dBm	10.49dBm	**0.23dB**
Vdd Current (mA)	25.33 mA	25.33 mA	25.33 mA	25.33 mA	25.24 mA	25.25 mA	25.25 mA	25.26 mA	**0.09 mA**
VSWR=2.0	**=> RL=9.5dB**								
|ZL|	99.665 ohms	100.337 ohms	100.340 ohms	100.344 ohms	100.341 ohms	100.346 ohms	99.656 ohms	99.666 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
impedance (Ohms)	0.3352-0.0019i	0.2332+0.2432i	-0.0078+0.3397i	-0.2417+0.2448i	-0.3414-0.0002i	-0.2469-0.2423i	0.004-0.3442i	0.2368-0.2362i	**delta**
TX power (dBm) @SMA	10.04dBm	10.34dBm	10.51dBm	10.10dBm	9.40dBm	8.89dBm	9.12dBm	9.59dBm	**1.62dB**
Vdd Current (mA)	25.95 mA	26.60 mA	26.40 mA	25.50 mA	24.40 mA	24.00 mA	24.01 mA	24.88 mA	**2.60 mA**
VSWR=3.0	**=> RL=6.02**								
|ZL|	149.504 ohms	150.490 ohms	150.493 ohms	149.498 ohms	149.495 ohms	150.513 ohms	150.511 ohms	149.483 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
Impedance (Ohms)	0.4961-0.0001i	0.3504+0.3427i	0.0033+0.4932i	-0.3489+0.3605i	-0.5054+0.0044i	-0.3617-0.3636i	-0.0062-0.5105i	0.3633-0.3685i	**delta**
TX power (dBm) @SMA	9.17dBm	9.44dBm	9.81dBm	9.17dBm	8.22dBm	7.65dBm	7.91dBm	8.63dBm	**2.16dB**
Vdd Current (mA)	26.22 mA	27.06 mA	26.88 mA	25.55 mA	23.88 mA	23.24 mA	23.48 mA	24.56 mA	**3.82 mA**

Figure 12. Fundamental frequency

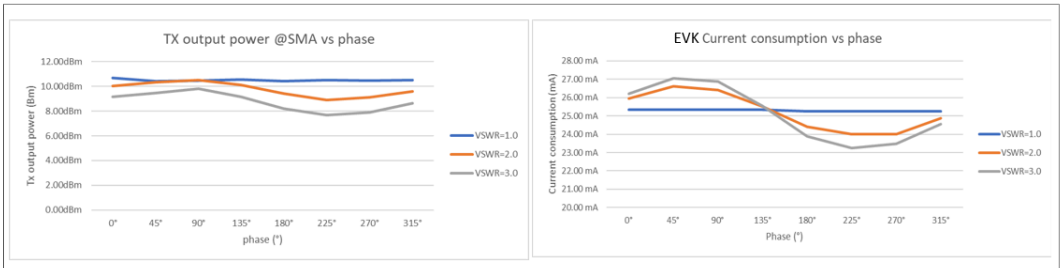

Figure 13. Fundamental frequency

3.2.2 H2 frequency

H2: Harmonic 2 frequency (4.88 GHz)									
VSWR=1.0	**=> RL=54dB**								
|ZL|	49.882 ohms	49.893 ohms	49.903 ohms	50.091 ohms	50.074 ohms	49.914 ohms	49.894 ohms	49.874 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
Impedance (Ohms)	0.118-0.0103i	0.1066-0.0106i	0.0968-0.0049i	0.091+0.0049i	0.0736+0.0001i	0.084-0.018i	0.1022-0.0282i	0.1228-0.0278i	
TX power (dBm) @SMA	-31.98dBm	-31.97dBm	-33.18dBm	-32.59dBm	-32.85dBm	-31.52dBm	-32.96dBm	-32.89dBm	
VSWR=2.0	**=> RL=9.5dB**								
|ZL|	50.340 ohms	100.188 ohms	99.676 ohms	50.404 ohms	50.318 ohms	100.248 ohms	99.638 ohms	50.413 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
Impedance (Ohms)	0.1144+0.3199i	-0.1882-0.0087i	0.1782-0.2703i	0.39+0.1051i	-0.0203+0.3173i	-0.2149-0.1241i	0.1923-0.3071i	0.4119+0.0278i	**delta**
TX power (dBm) @SMA	-32.51dBm	-34.47dBm	-35.53dBm	-39.08dBm	-35.96dBm	-31.21dBm	-26.96dBm	-29.64dBm	**12.12dB**
VSWR=3.0	**=> RL=6.02**								
|ZL|	50.448 ohms	150.341 ohms	149.544 ohms	50.529 ohms	50.450 ohms	150.412 ohms	149.502 ohms	50.532 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
Impedance (Ohms)	0.0542+0.4451i	-0.3374-0.0502i	0.2225-0.3977i	0.4996+0.173i	-0.1156+0.4344i	-0.3179-0.2614i	0.3247-0.3775i	0.5136+0.1382i	**delta**
TX power (dBm) @SMA	-36.02dBm	-35.85dBm	-37.46dBm	-39.57dBm	-36.50dBm	-31.91dBm	-25.26dBm	-28.94dBm	**14.31dB**

Figure 14. H2 frequency

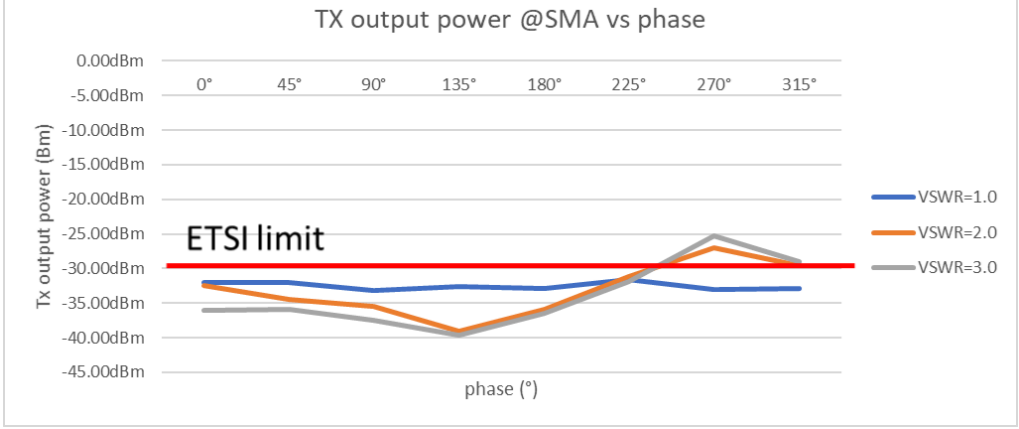

Figure 15. H2 frequency

3.2.3 H3 frequency

H3: Harmonic 3 frequency (7.32 GHz)									
VSWR=1.0	**=> RL=54dB**								
|ZL|	50.146 ohms	50.146 ohms	50.145 ohms	50.144 ohms	50.143 ohms	50.145 ohms	50.146 ohms	50.146 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
Impedance (Ohms)	0.1382+0.0471i	0.1385+0.046i	0.1377+0.045i	0.1367+0.0448i	0.1359+0.0443i	0.1375+0.0445i	0.1384+0.0455i	0.1384+0.0472i	
TX power (dBm) @SMA	-33.18dBm	-33.78dBm	-34.62dBm	-33.22dBm	-37.30dBm	-32.76dBm	-36.62dBm	-34.14dBm	
VSWR=2.0	**=> RL=9.5dB**								
|ZL|	50.139 ohms	50.143 ohms	50.135 ohms	50.145 ohms	50.132 ohms	50.140 ohms	50.148 ohms	50.129 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
Impedance (Ohms)	0.1304+0.0475i	0.1332+0.0508i	0.1255+0.0485i	0.1368+0.0477i	0.1214+0.0524i	0.1341+0.0387i	0.1353+0.0597i	0.1194+0.0495i	**delta**
TX power (dBm) @SMA	-35.12dBm	-35.80dBm	-35.55dBm	-33.81dBm	-35.14dBm	-32.76dBm	-32.16dBm	-34.11dBm	**3.64dB**
VSWR=3.0	**=> RL=6.02**								
|ZL|	50.159 ohms	50.130 ohms	50.131 ohms	50.155 ohms	50.108 ohms	50.159 ohms	50.147 ohms	50.103 ohms	
Phase	0°	45°	90°	135°	180°	225°	270°	315°	
Impedance (Ohms)	0.1531+0.0433i	0.1138+0.0629i	0.1268+0.0344i	0.1389+0.0678i	0.0987+0.0437i	0.1544+0.037i	0.1206+0.0848i	0.099+0.029i	**delta**
TX power (dBm) @SMA	-37.04dBm	-40.23dBm	-33.87dBm	-38.86dBm	-33.46dBm	-30.07dBm	-31.83dBm	-34.24dBm	**10.16dB**

Figure 16. H3 frequency

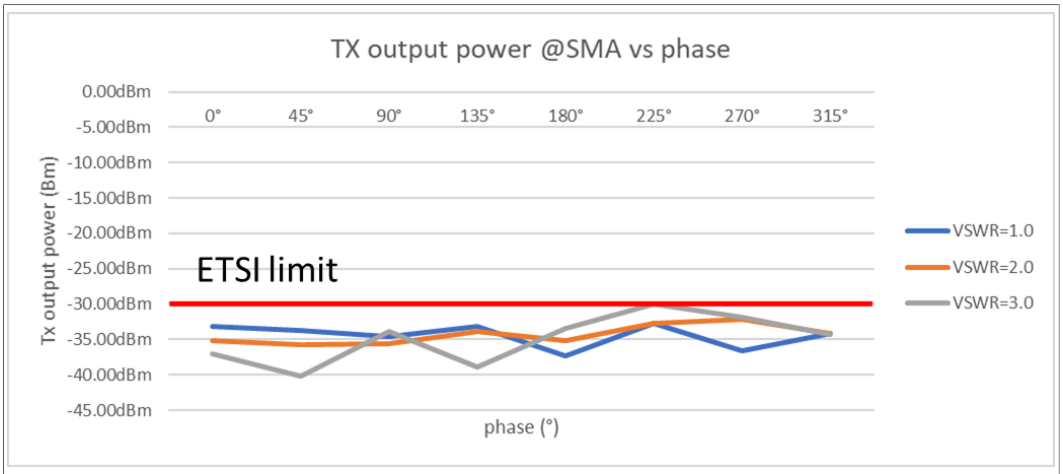

Figure 17. H3 frequency

3.2.4 Results

Power @SMA pin: +10.66 dBm (VSWR:1, phase 0°) for a power consumption of 25.33 mA

VSWR : 1, Phase : 0°										
Real/Im measured values										
Frequency (GHz)	S11		S12		S21		S22		S1p_Spectrum	
	Réel	Imag	Réel	Imag	Réel	Imag	Réel	Imag	Réel	Imag
2.44	0.0111	0.0095	-0.204	0.8258	-0.2043	0.8253	0.0131	0.8258	0.0178	0.02
4.88	0.118	-0.0103	-0.6468	-0.431	-0.6479	-0.4292	-0.0259	-0.0006	0.0363	-0.0843
7.32	0.1382	0.0471	0.5817	-0.4281	0.5811	-0.4291	0.005	0.1106	-0.0292	-0.0912
	S11 complex		S12 complex		S21 complex		S22 complex		S1p Spectrum complex	
2.44	0.0111+0.0095i		-0.204+0.8258i		-0.2043+0.8253i		0.0131+0.8258i		0.0178+0.02i	
4.88	0.118-0.0103i		-0.6468-0.431i		-0.6479-0.4292i		-0.0259-0.0006i		0.0363-0.0843i	
7.32	0.1382+0.0471i		0.5817-0.4281i		0.5811-0.4291i		0.005+0.1106i		-0.0292-0.0912i	

DUT Power Calculation					
Frequency(GHz)	Pout_Spectrum (dBm)	Current (mA)	Ga	Loss (dB)	Pout (dBm)
2.44	9.11	25.33	0.7	1.55	10.66
4.88	-34.06		0.62	2.08	-31.98
7.32	-35.94		0.53	2.76	-33.18

Figure 18. Result

3.2.5 Results

Power @SMA pin: +10.04 dBm (VSWR:2, phase 0°) for a power consumption of 25.95 mA

VSWR : 2,Phase : 0°										
Real/Im measured values										
Frequency (GHz)	S11		S12		S21		S22		S1p_Spectrum	
	Réel	Imag	Réel	Imag	Réel	Imag	Réel	Imag	Réel	Imag
2.44	0.3352	-0.0019	-0.1572	0.7756	-0.1575	0.7752	0.2663	0.1177	0.0178	0.02
4.88	0.1144	0.3199	-0.5971	-0.39	-0.5978	-0.3885	-0.2777	0.0107	0.0363	-0.0843
7.32	0.1304	0.0475	0.5387	-0.469	0.5381	-0.4697	-0.0021	0.0963	-0.0292	-0.0912
	S11 complex		S12 complex		S21 complex		S22 complex		S1p Spectrum complex	
2.44	0.3352-0.0019i		-0.1572+0.7756i		-0.1575+0.7752i		0.2663+0.1177i		0.0178+0.02i	
4.88	0.1144+0.3199i		-0.5971-0.39i		-0.5978-0.3885i		-0.2777+0.0107i		0.0363-0.0843i	
7.32	0.1304+0.0475i		0.5387-0.469i		0.5381-0.4697i		-0.0021+0.0963i		-0.0292-0.0912i	

DUT Power Calculation					
Frequency(GHz)	Pout_Spectrum (dBm)	Current (mA)	Ga	Loss (dB)	Pout (dBm)
2.44	8.55	25.95	0.71	1.49	10.04
4.88	-34.95		0.57	2.44	-32.51
7.32	-37.96		0.52	2.84	-35.12

Figure 19. Result

3.2.6 Results

Power @SMA pin: +10.04 dBm (VSWR:2, phase 0°) for a power consumption of 25.95 mA

VSWR : 3, Phase 0°

Real/Im measured values

Frequency (GHz)	S11		S12		S21		S22		S1p_Spectrum	
	Réel	Imag	Réel	Imag	Réel	Imag	Réel	Imag	Réel	Imag
2.44	0.4961	-0.0001	-0.1097	0.7075	-0.1099	0.7073	0.4062	0.1328	0.0178	0.02
4.88	0.0542	0.4451	-0.5572	-0.3545	-0.5577	-0.3536	-0.3463	0.0946	0.0363	-0.0843
7.32	0.1531	0.0433	0.523	-0.4902	0.5226	-0.4906	0.0118	0.1148	-0.0292	-0.0912
	S11 complex		S12 complex		S21 complex		S22 complex		S1p Spectrum complex	
2.44	0.4961-0.0001i		-0.1097+0.7075i		-0.1099+0.7073i		0.4062+0.1328i		0.0178+0.02i	
4.88	0.0542+0.4451i		-0.5572-0.3545i		-0.5577-0.3536i		-0.3463+0.0946i		0.0363-0.0843i	
7.32	0.1531+0.0433i		0.523-0.4902i		0.5226-0.4906i		0.0118+0.1148i		-0.0292-0.0912i	

DUT Power Calculation

Frequency(GHz)	Pout_Spectrum (dBm)	Current (mA)	Ga	Loss (dB)	Pout (dBm)
2.44	7.5	26.22	0.68	1.67	9.17
4.88	-38.7		0.54	2.68	-36.02
7.32	-39.8		0.53	2.76	-37.04

Figure 20. Result

3.2.7 Results given by IVCAD: Pout

Table 1. IVCAD SW

	Pout
minimum	7.94 dBm
VSWR = 1	**10.47 dBm**
maximum	10.62 dBm

Table 2. TCS SW

	Pout
minimum	7.65 dBm
VSWR = 1	**10.66 dBm**
maximum	10.66 dBm

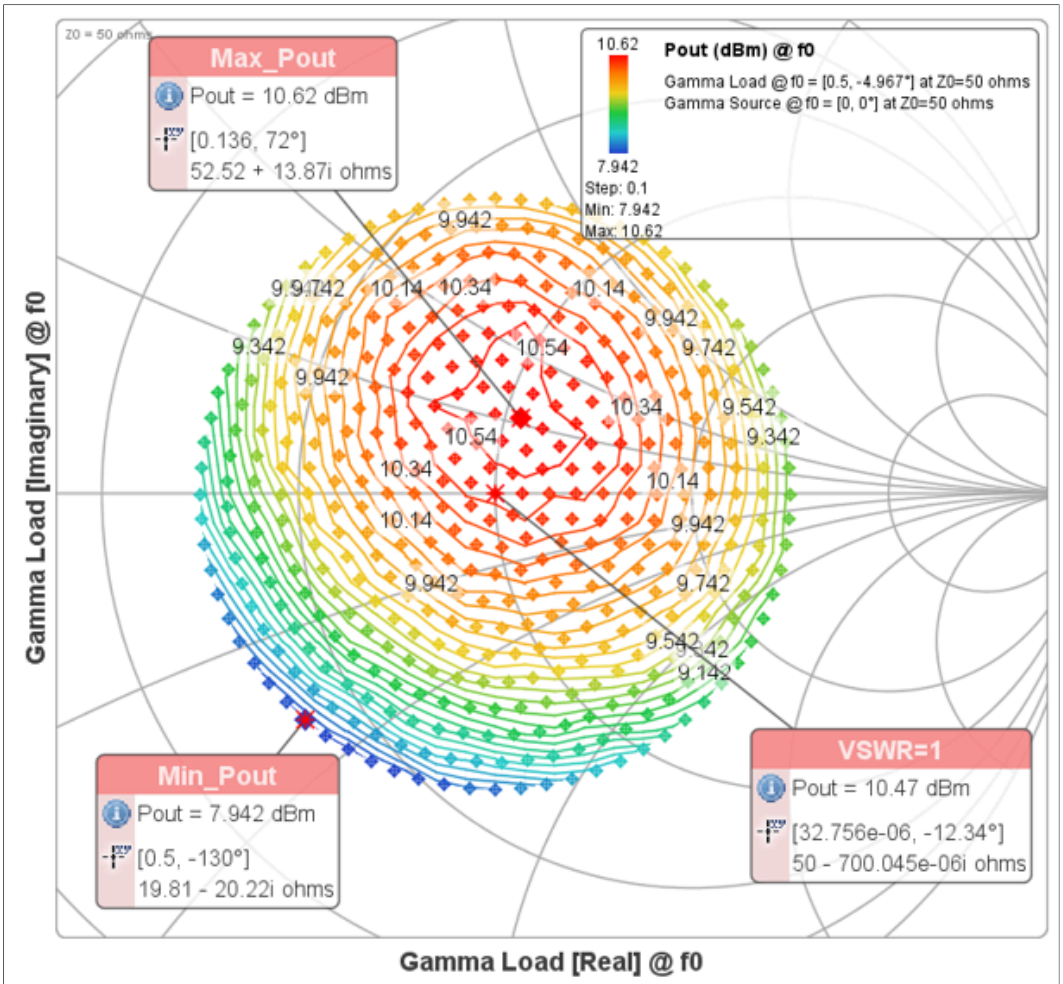

Figure 21. Results given by IVCAD: Pout

3.2.8 Results given by IVCAD: Iout (EVK)

Table 3. IVCAD SW

	Iout
minimum	23.33 mA
VSWR = 1	25.38 mA
maximum	27.13 mA

Table 4. TCS SW

	Iout
minimum	23.24 mA
VSWR = 1	25.33 mA
maximum	27.06 mA

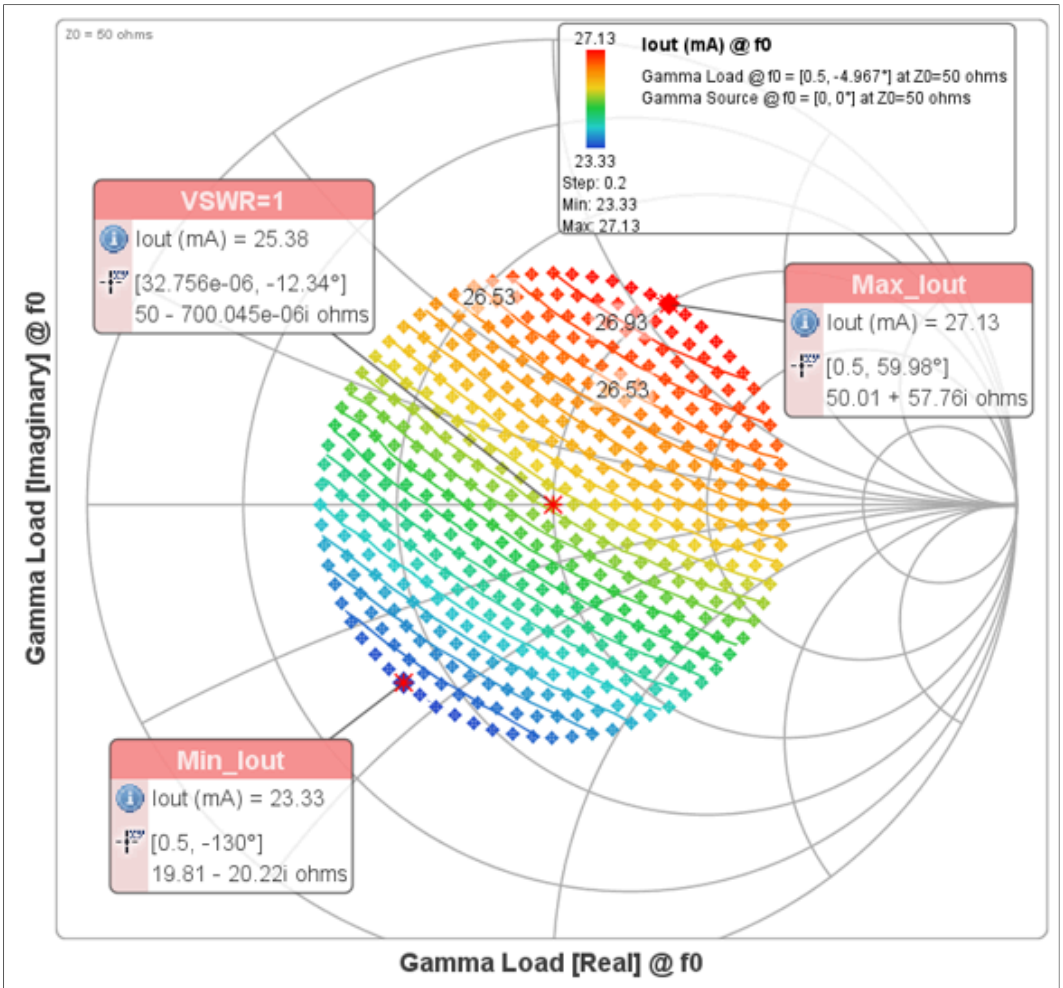

Figure 22. Results given by IVCAD: Iout (EVK)

3.2.9 KW45/K32W148: delta Pout vs VSWR

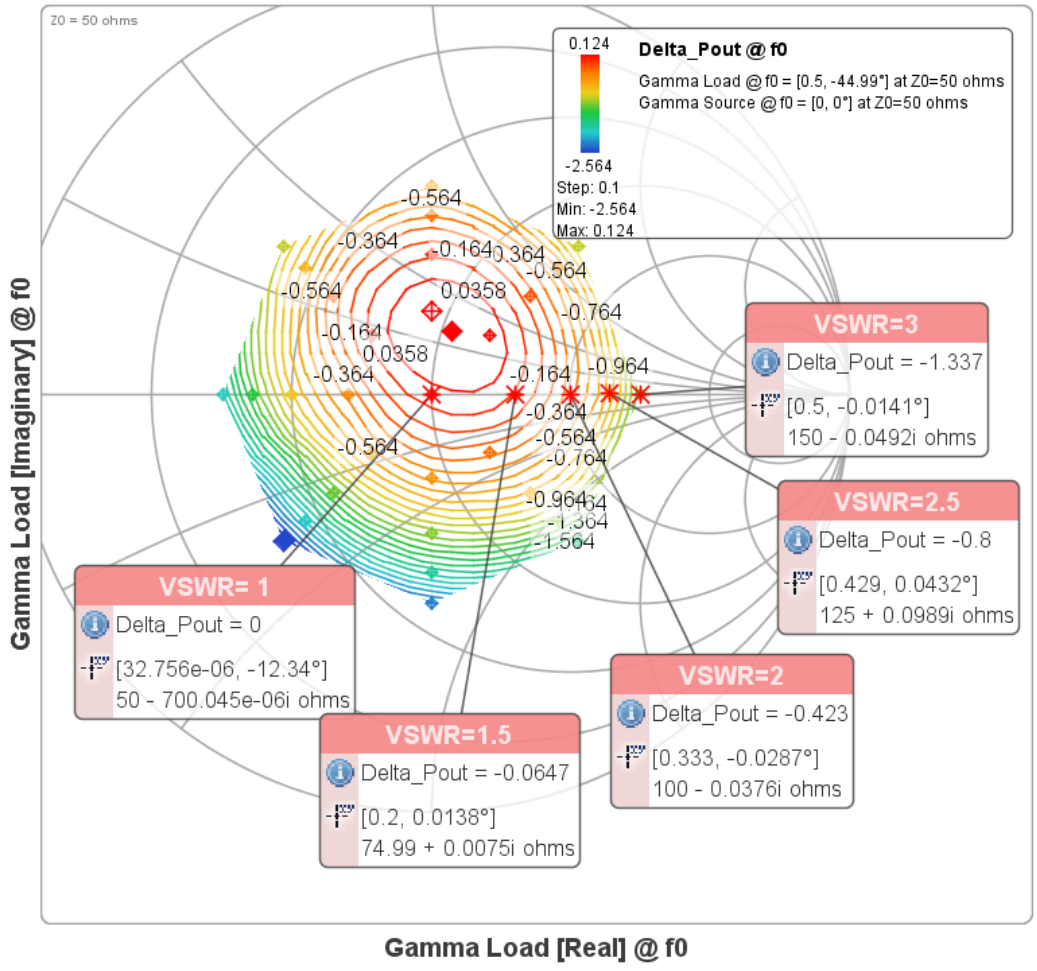

Figure 23. delta Pout vs VSWR

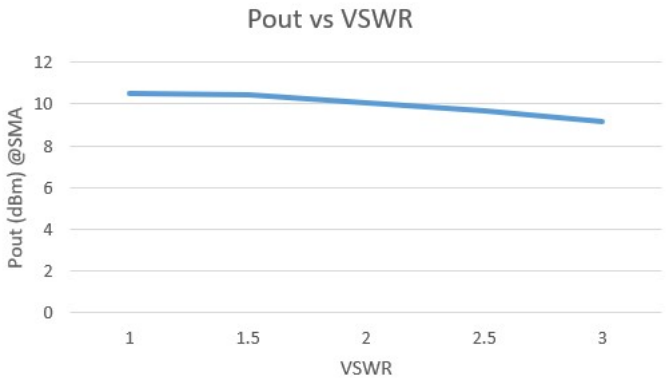

Figure 24. delta Pout vs VSWR

4 Revision history

Revision number	Date	Substantive changes
0	24 August 2022	Initial release

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