SKYWORKS®

APPLICATION NOTE

SKY65050-372LF: Low Noise Amplifier Operation

Introduction

The SKY65050-372LF is a high performance, low noise, n-channel, depletion mode pHEMT, fabricated from Skyworks advanced pHEMT process and packaged in a miniature 4-lead SC-70 package. The SKY65050 has a nominal noise figure of 0.65 dB (including input RF matching network loss) and a gain of 14 dB at 2.4 GHz. By changing external tuning components the SKY65050 can be used for many different applications ranging from 850 MHz up to 6 GHz.

This application note describes how to properly tune the SKY65050 for optimal noise figure and gain performance and provides suggested tuning networks for commonly used frequency bands.

Evaluation Board

The SKY65050 evaluation board is produced using 10 mil thick Rogers 4350B material. This ensures excellent board performance up to 6 GHz. FR-4 material may be used for lower frequency applications to reduce manufacturing costs. Low cost 0402 sized surface mount components are used to simplify handling and lower the overall cost of using the device. With the exception of the input high Q inductors, 0201 surface mount components may be used to further reduce component parasitics and overall footprint. Parasitic losses through the input traces and matching networks directly add to the overall measured noise figure. Excess trace length and component spacing should be eliminated to ensure the lowest possible noise figure

The PCB layout should be incorporated into circuit designs to ensure the accuracy between simulation and real world performance. Skyworks Solutions provides a circuit model, de-embedded scattering parameters, and noise parameters.

The Skyworks evaluation board is primarily designed for the 2.4 GHz RF matching network. Subtle changes will need to be made in order to properly accommodate the matching networks for other frequencies.

Biasing

The easiest and preferred method to bias the SKY65050 is by using a self-biasing resistor between the source lead and ground. This method eliminates the need for a second DC voltage supply and reduces board space and the number of external components. When current flows from drain to source through the resistor, the source voltage becomes biased above DC ground. The gate pin of the device should be left unbiased at 0 V_{DC}, thus creating the desired negative V_{GS} value.

For optimal noise performance, I_{DS} should be set to about 15 mA with a 27 Ω resistor. V_{DS} can range anywhere between 2 V and 5 V without affecting noise performance and device reliability. Increasing I_{DS} will increase the device noise figure, but will also increase $P_{1\ dB}$ and third order distortion performance.

LNA Design

Input

The input match largely dictates the overall noise figure of the device. For a wideband noise and input match, a shunt inductor and a series inductor are used. High Q Coilcraft CS series wire-wound inductors are used to minimize circuit loss. A high Q, low value DC block capacitor should be used on the input as well for optimal noise performance. Components with lower Qs may be used but may increase noise figure as a result.

For lower frequency operation, a small value feedback capacitor connected from gate to source is used. This capacitor shifts the frequency of operation down. This eliminates the need to use high value, lossy input inductors on the input to shift the frequency of operation.

Source Inductance

The SKY65050 has two source leads that must be well grounded for proper RF performance. The amount of source inductance has a large effect on in and out of band stability and gain. Adding source inductance to the device will improve low frequency stability and return loss, but at the expense of gain and high frequency stability. If too much source inductance is added high frequency gain peaking will occur and input return loss will become positive, indicating potentially unstable operation.

For the 2.4 GHz RF matching network, the source length lead should be approximately 25 mils. This length provides about 14 dB gain while still maintaining wideband stability. The source lead length should be increased for lower frequencies and decreased for higher frequencies. Adding the correct amount of source inductance will prevent oscillations at high frequencies.

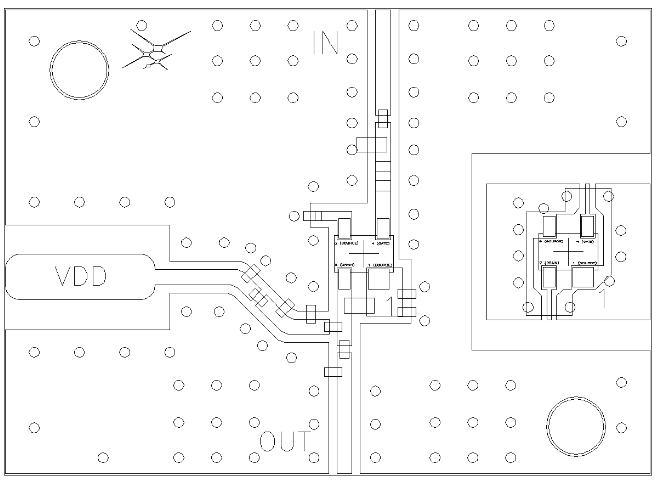

Figure 1. Skyworks Evaluation Board

Output

The output matching topology is typical for a RF amplifier consisting of an RF choke inductor and a DC blocking capacitor to isolate V_{DD} and the RF output from each other.

Resistive loading on the output can further improve stability, but at the cost of degraded output power and linearity. A small series or shunt resistor in the drain circuit will improve broadband stability. A low value shunt capacitor on the drain can also help remove high frequency instabilities.

Conclusions

The SKY65050 provides a low cost, high performance solution where sub 1 dB noise performance and high gain is required. Through the use of external components the device can be easily used for frequencies between 850 MHz and 6 GHz.

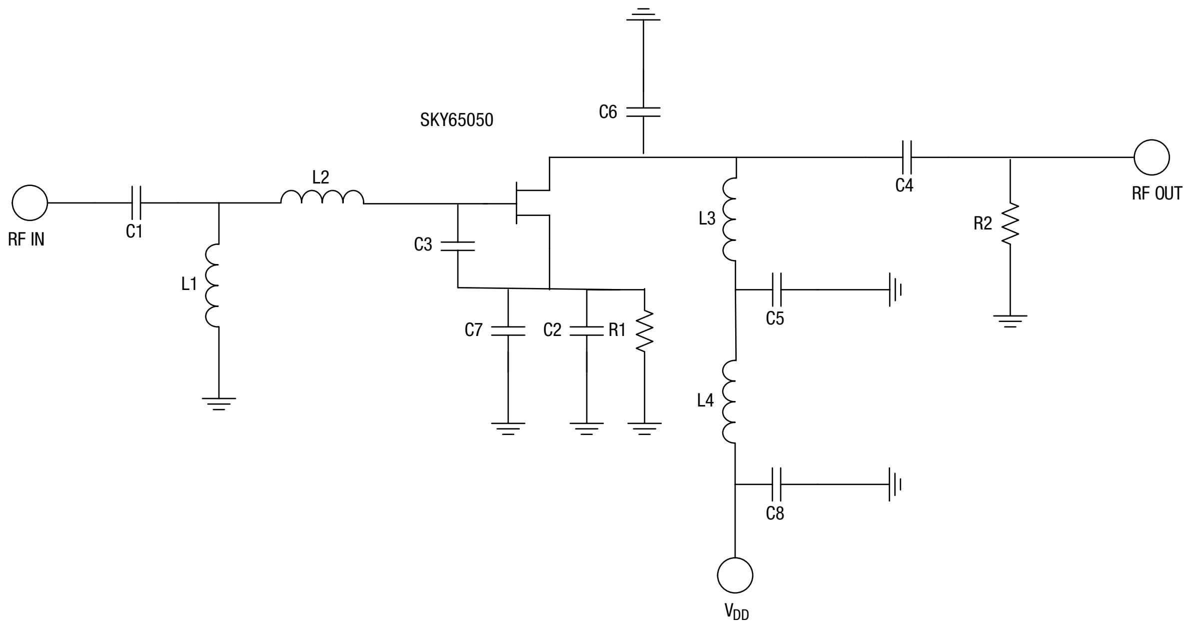

Figure 2. Recommended Schematic for 900 MHz Operation

Table 1. Recommended Components for 900 MHz Operation

Component	Value	Size	Manufacturer	Part Number	Notes
C1	30 pF	0402	Johanson	250R07S300JV4T	High Q
C2	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C3	0.5 pF	0402	Johanson	500R07S0R5BV4T	High Q
C4	15 pF	0402	Johanson	500R07S150JV4T	High Q
C5	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C6	0.2 pF	0402	Johanson	500R07S0R2BV4T	High Q
C7	1000 pF	0402	Murata	GRM1555C1H102JA01D	Place approx. 30 mils (0.762 mm) from pin 3
C8	1000 pF	0402	Murata	GRM1555C1H102JA01D	
L1	9 nH	0402	Coilcraft	0402CS-9N0XJL	High Q
L2	12 nH	0402	Coilcraft	0402CS-12N0XJL	High Q
L3	12 nH	0402	TDK	MLG1005S12NJ	
L4	27 nH	0402	TDK	MLG1005S27NJ	
R1	27 Ω	0201	Panasonic	ERJ1GEF27R0	
R2	150 Ω	0201	Panasonic	ERJ1GEF1500	

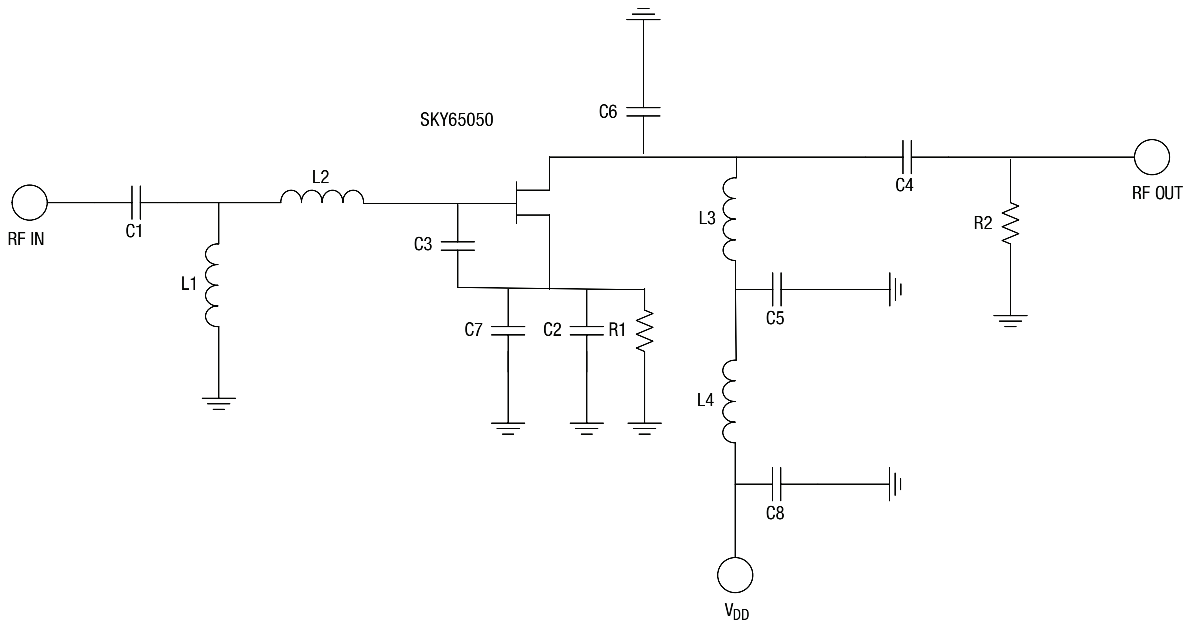

Figure 3. Recommended Schematic for 1 GHz Operation

Table 2. Recommended Components for 1 GHz Operation

Component	Value	Size	Manufacturer	Part Number	Notes
C1	30 pF	0402	Johanson	250R07S300JV4T	High Q
C2	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C3	0.5 pF	0402	Johanson	500R07S0R5BV4T	High Q
C4	15 pF	0402	Johanson	500R07S150JV4T	High Q
C5	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C6	0.2 pF	0402	Johanson	500R07S0R2BV4T	High Q
C7	1000 pF	0402	Murata	GRM1555C1H102JA01D	Place approx. 30 mils (0.762 mm) from pin 3
C8	1000 pF	0402	Murata	GRM1555C1H102JA01D	
L1	7.5 nH	0402	Coilcraft	0402CS-7N5XJL	High Q
L2	8.2 nH	0402	Coilcraft	0402CS-8N2XJL	High Q
L3	12 nH	0402	TDK	MLG1005S12NJ	
L4	27 nH	0402	TDK	MLG1005S27NJ	
R1	27 Ω	0201	Panasonic	ERJ1GEF27R0	
R2	150 Ω	0201	Panasonic	ERJ1GEF1500	

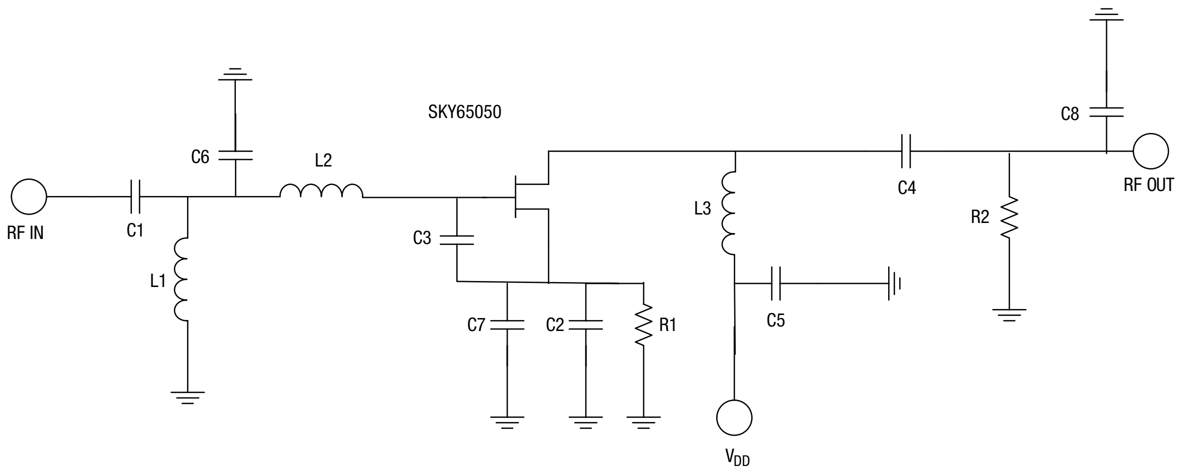

Figure 4. Recommended Schematic for 1.55 GHz Operation

Table 3. Recommended Components for 1.55 GHz Operation

Component	Value	Size	Manufacturer	Part Number	Notes
C1	30 pF	0402	Johanson	250R07S300JV4T	High Q
C2	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C3	0.3 pF	0402	Johanson	500R07S0R3BV4T	High Q
C4	15 pF	0402	Johanson	500R07S150JV4T	High Q
C5	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C6	0.5 pF	0402	Johanson	500R07S0R5BV4T	High Q
C7	1000 pF	0402	Murata	GRM1555C1H102JA01D	Place approx. 30 mils (0.762 mm) from pin 3
C8	0.7 pF	0402	Johanson	500R07S0R7BV4T	High Q, Placed 100 mils (2.54 mm) from R2
L1	5.6 nH	0402	Coilcraft	0402CS-5N6XJL	High Q
L2	3.3 nH	0402	Coilcraft	0402CS-3N3XJL	High Q
L3	8.2 nH	0402	TDK	MLG1005S8N2J	
R1	27 Ω	0201	Panasonic	ERJ1GEF27R0	
R2	180 Ω	0201	Panasonic	ERJ1GEF1800	

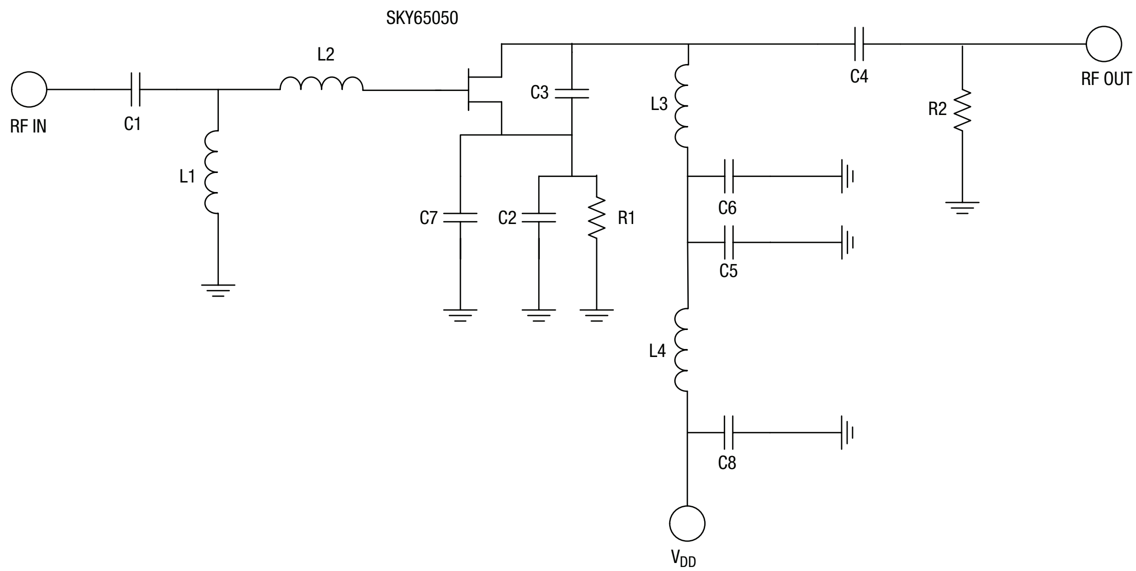

Figure 5. Recommended Schematic for 2.4 GHz Operation

Table 4. Recommended Components for 2.4 GHz Operation

Component	Value	Size	Manufacturer	Part Number	Notes
C1	33 pF	0201	Johanson	250R05L330JV4SK	High Q
C2	1000 pF	0201	Murata	GRM033R71E102KA01	
C3	0.5 pF	0201	Murata	GRM0335C1ER50C	
C4	15 pF	0201	Murata	GRM0335C1E150JD01	
C5	DNP	-	-		
C6	1000 pF	0201	Murata	GRM033R71E102KA01	
C7	1000 pF	0201	Murata	GRM033R71E102KA01	Place approx. 25 mils (0.635 mm) from pin 3
C8	1000 pF	0201	Murata	GRM033R71E102KA01	
L1	3.3 nH	0402	Coilcraft	0402CS-3N3XJL	High Q
L2	1.8 nH	0402	Coilcraft	0402CS-1N8XJL	High Q
L3	3.6 nH	0201	TDK	MLG0603S3N6C	
L4	27 nH	0201	TDK	MLG0603S27NJ	
R1	27 Ω	0201	Panasonic	ERJ1GEF27R0	
R2	180 Ω	0201	Panasonic	ERJ1GEF1800	

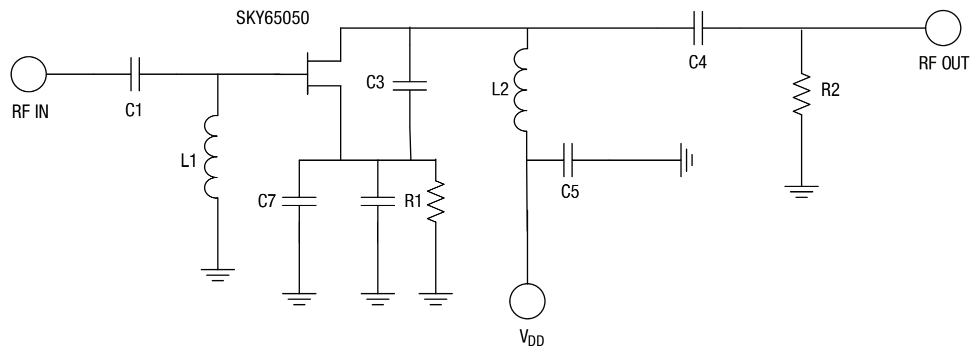

Figure 6. Recommended Schematic for 3.5 GHz Operation

Table 5. Recommended Components for 3.5 GHz Operation

Component	Value	Size	Manufacturer	Part Number	Notes
C1	30 pF	0402	Johanson	250R07S300JV4T	High Q
C2	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C3	0.3 pF	0402	Johanson	500R07S0R3BV4T	High Q
C4	15 pF	0402	Johanson	500R07S150JV4T	High Q
C5	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C6	1000 pF	0402	Murata	GRM1555C1H102JA01D	
C7	1000 pF	0402	Murata	GRM1555C1H102JA01D	Place approx. 5 mils (0.127 mm) from pin 3
C8	1000 pF	0402	Murata	GRM1555C1H102JA01D	
L1	2.2 nH	0402	Coilcraft	0402CS-2N2XJL	Placed approx. 20 mils (0.508 mm) from pin 4, High Q
L2	1.8 nH	0402	TDK	MLG1005S1N8J	
R1	27 Ω	0201	Panasonic	ERJ1GEF27R0	
R2	180 Ω	0201	Panasonic	ERJ1GEF1800	

Typical Performance Characteristics

V_{DD} = 3 V, Z_0 = 50 Ω, I_{DD} = 16 mA, T = 25 °C, includes 900 MHz matching network, unless otherwise noted

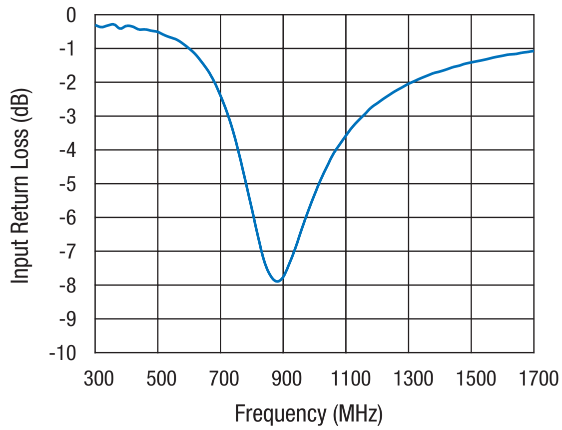

Figure 7. Input Return Loss vs. Frequency, dBm P_{IN} = -20

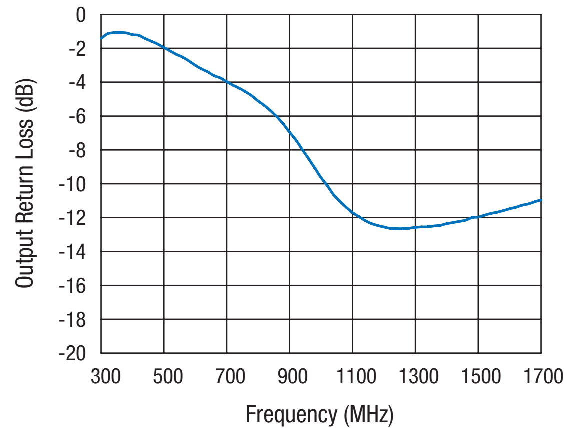

Figure 10. Output Return Loss vs. Frequency, dBm P_{IN} = -20

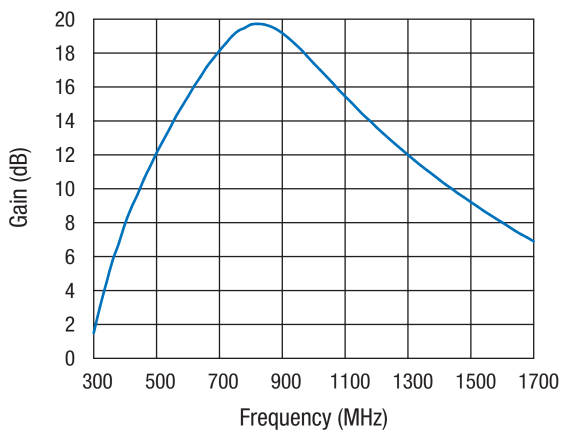

Figure 8. Output Return Loss vs. Frequency, dBm P_{IN} = -20

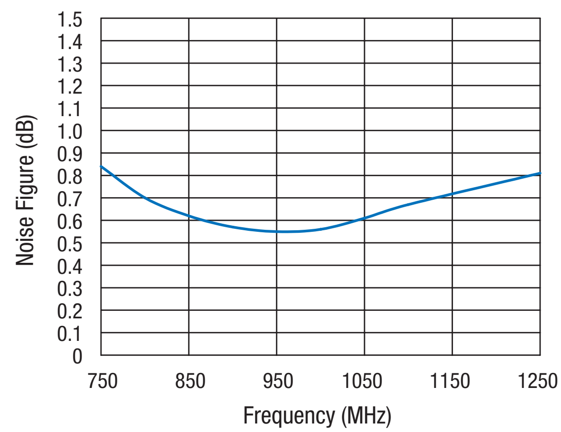

Figure 11. Noise Figure vs. Frequency, Input RF Connector Loss De-embedded from Measurement

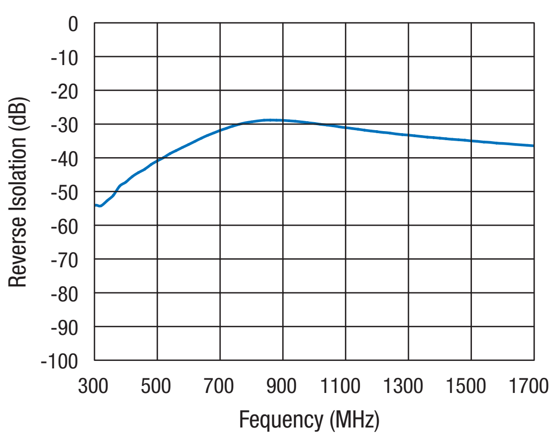

Figure 9. Input Return Loss vs. Frequency, dBm P_{IN} = -20

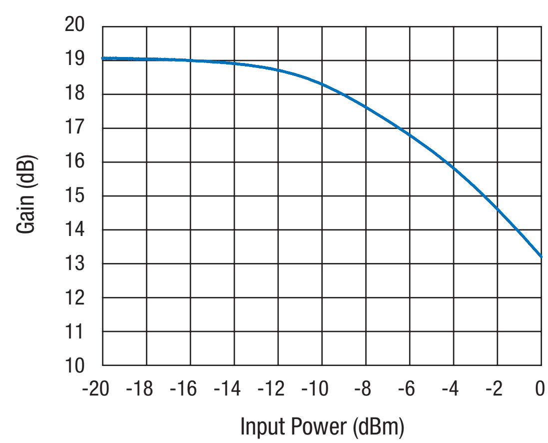

Figure 12. Gain vs. Input Power, F = 900 MHz

Typical Performance Characteristics

V_{DD} = 3 V, Z_0 = 50 Ω, I_{DD} = 16 mA, T = 25 °C, includes 1 GHz matching network, unless otherwise noted

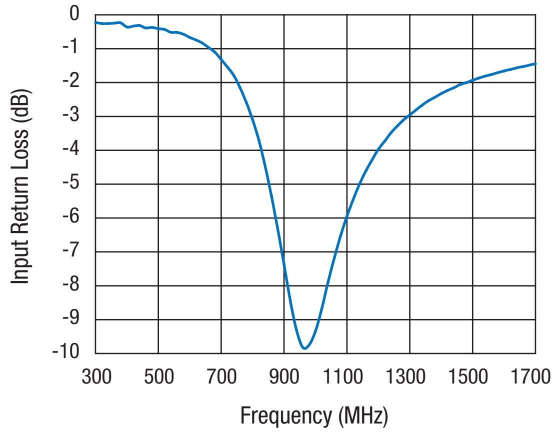

Figure 13. Input Return Loss vs. Frequency, dBm P_{IN} = -20

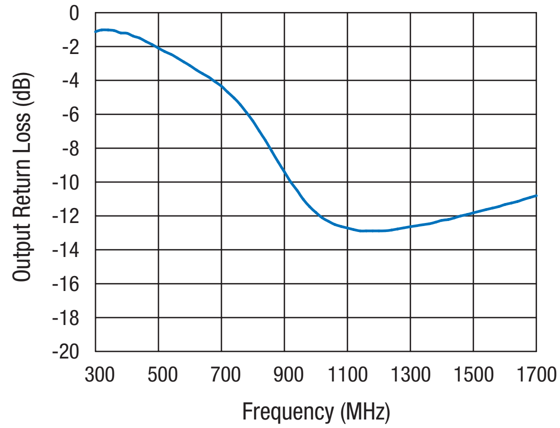

Figure 16. Ouput Return Loss vs. Frequency, dBm P_{IN} = -20

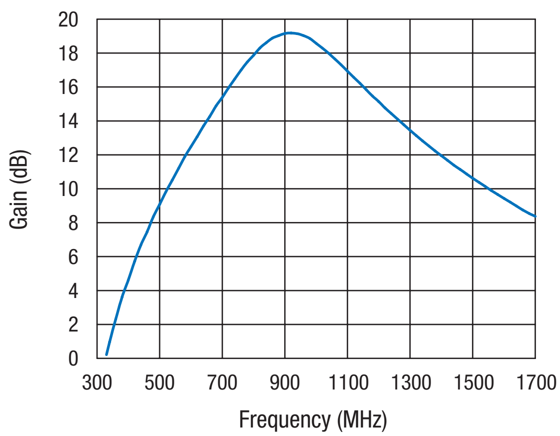

Figure 14. Small Signal Gain vs. Frequency, dBm P_{IN} = -20

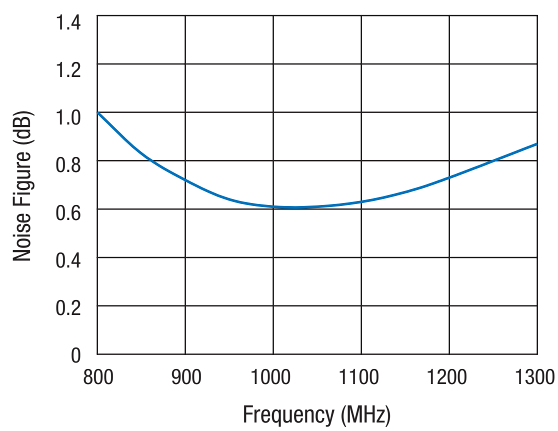

Figure 17. Noise Figure vs. Frequency, Input RF Connector Loss De-embedded from Measurement

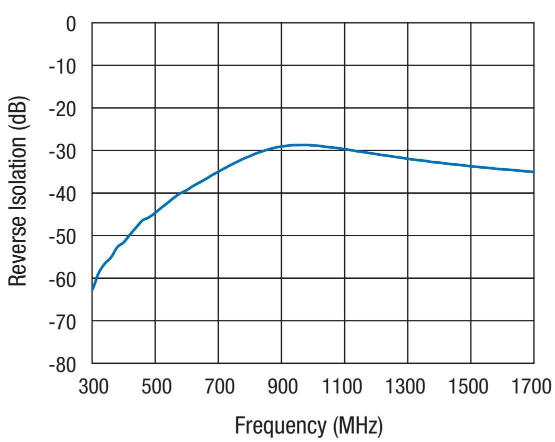

Figure 15. Reverse Isolation vs. Frequency, dBm P_{IN} = -20

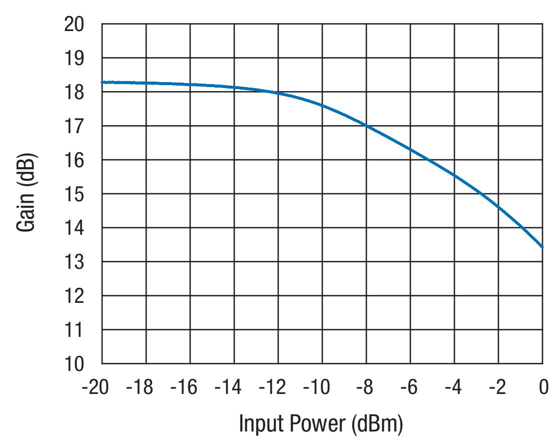

Figure 18. Gain vs. Input Power, F = 1 GHz

Typical Performance Characteristics

V_{DD} = 3 V, Z_0 = 50 Ω, I_{DD} = 16 mA, T = 25 °C, includes 1.55 GHz matching network, unless otherwise noted

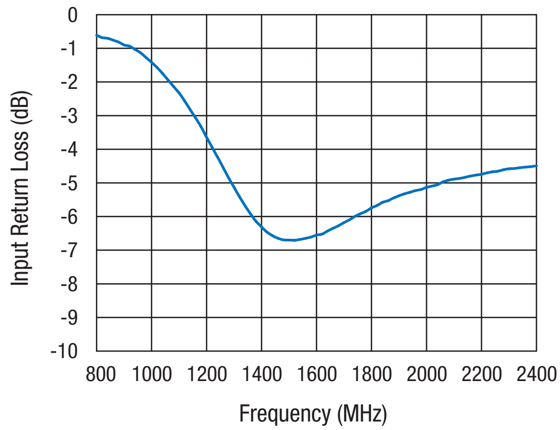

Figure 19. Input Return Loss vs. Frequency, dBm P_{IN} = -20

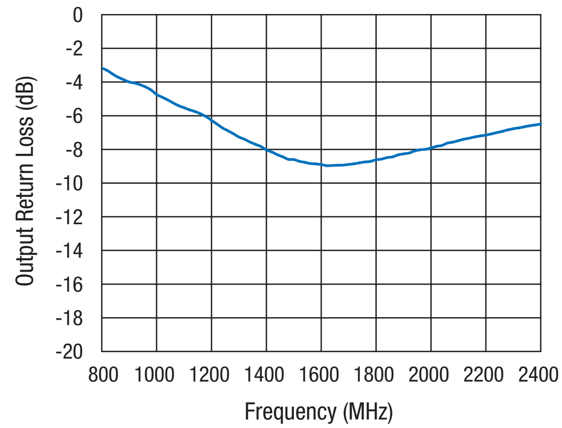

Figure 22. Output Return Loss vs. Frequency, dBm P_{IN} = -20

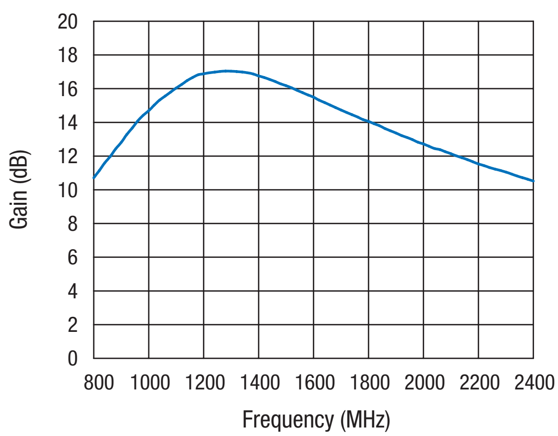

Figure 20. Small Signal Gain vs. Frequency, dBm P_{IN} = -20

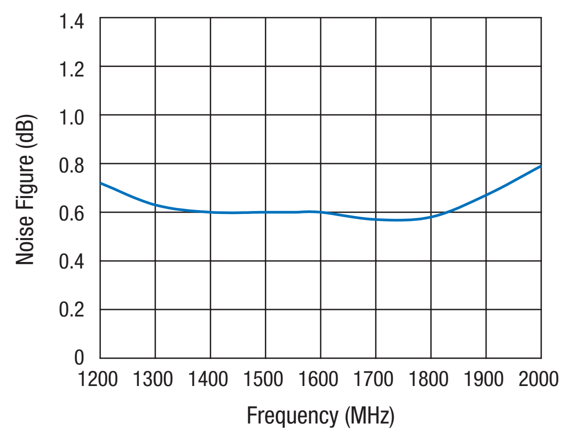

Figure 23. Noise Figure vs. Frequency, Input RF Connector Loss De-embedded from Measurement

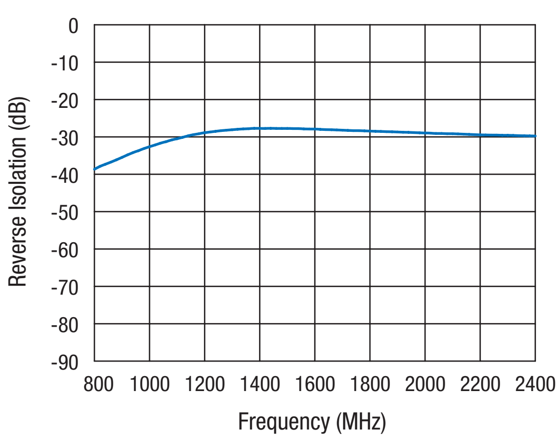

Figure 21. Reverse Isolation vs. Frequency, dBm P_{IN} = -20

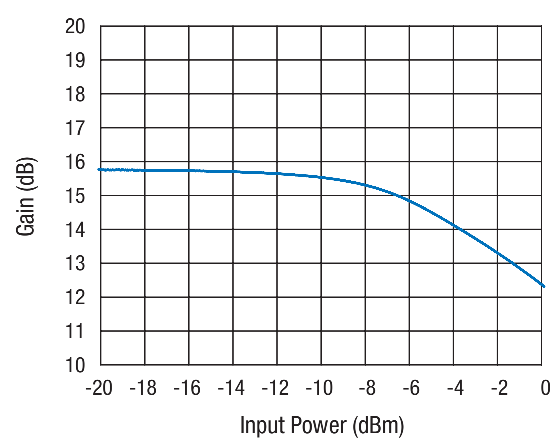

Figure 24. Gain vs. Input Power, F = 1.55 GHz

Typical Performance Characteristics

V_{DD} = 3 V, Z_0 = 50 Ω, I_{DD} = 16 mA, T = 25 °C, includes 2.4 GHz matching network, unless otherwise noted

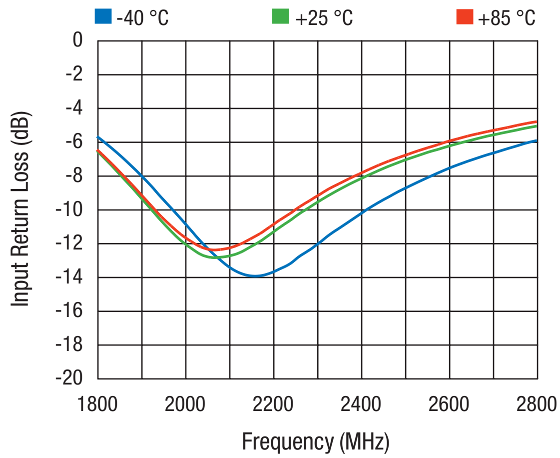

Figure 25. Input Return Loss vs. Frequency for Multiple Temperatures, P_{IN} = -20 dBm

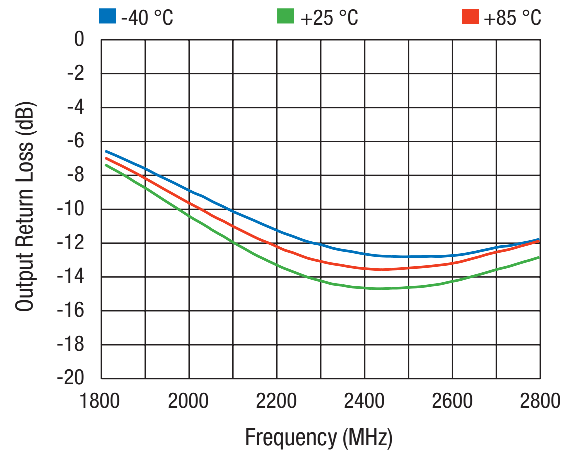

Figure 28. Output Return Loss vs. Frequency for Multiple Temperatures, P_{IN} = -20 dBm

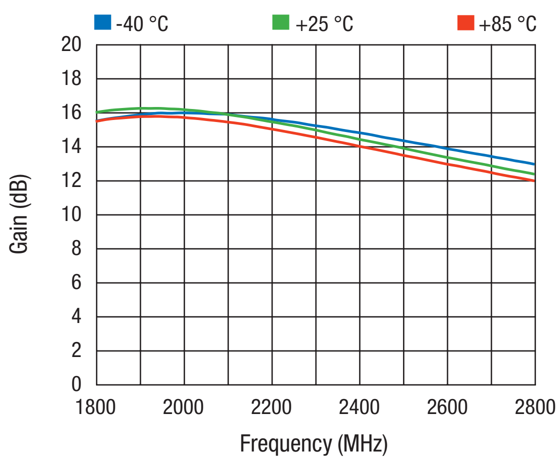

Figure 26. Small Signal Gain vs. Frequency for Multiple Temperatures, P_{IN} = -20 dBm

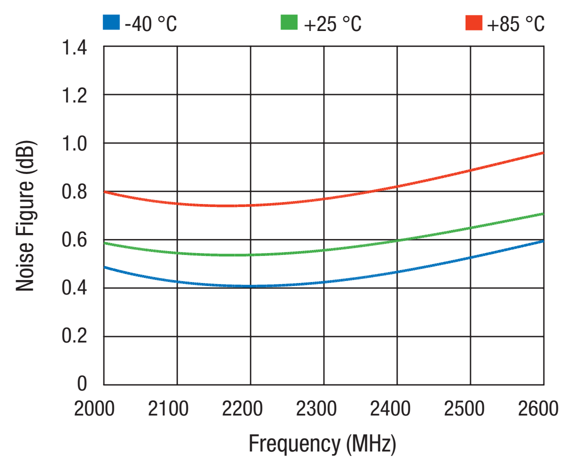

Figure 29. Noise Figure vs. Frequency for Multiple Temperatures, Input RF Connector Loss De-embedded from Measurement

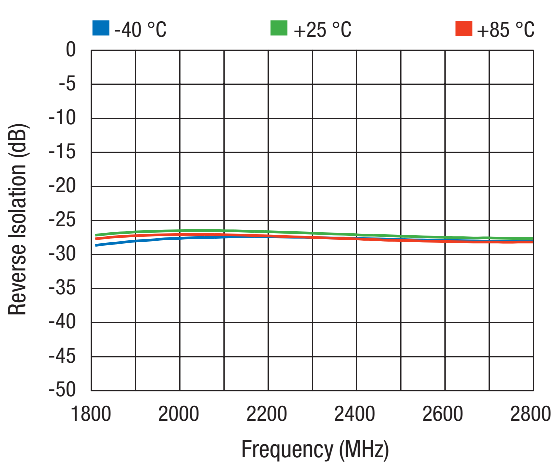

Figure 27. Reverse Isolation vs. Frequency for Multiple Temperatures, P_{IN} = -20 dBm

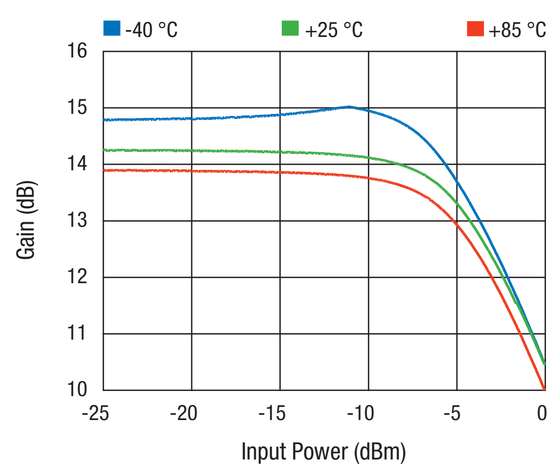

Figure 30. Gain vs. Input Power, F = 2.4 GHz

Typical Performance Characteristics

V_{DD} = 3 V, Z_0 = 50 Ω, I_{DD} = 16 mA, T = 25 °C, includes 3.5 GHz matching network, unless otherwise noted

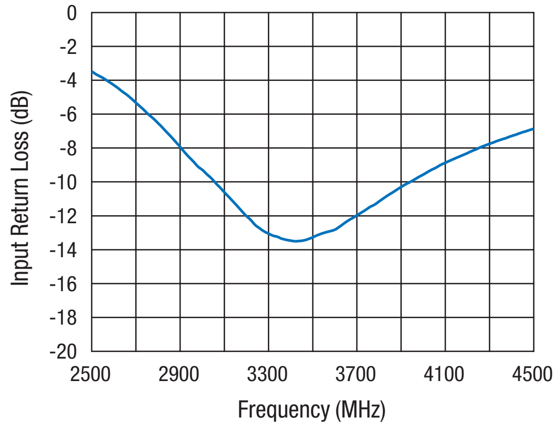

Figure 31. Input Return Loss vs. Frequency, dBm P_{IN} = -20

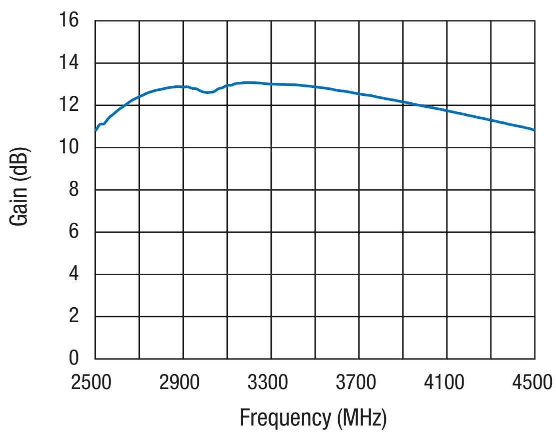

Figure 32. Small Signal Gain vs. Frequency, dBm P_{IN} = -20

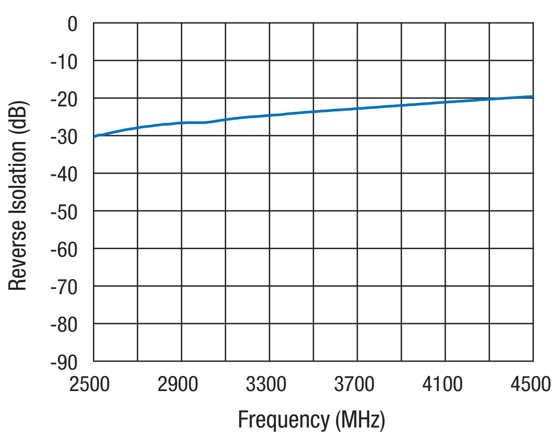

Figure 33. Reverse Isolation vs. Frequency, dBm P_{IN} = -20

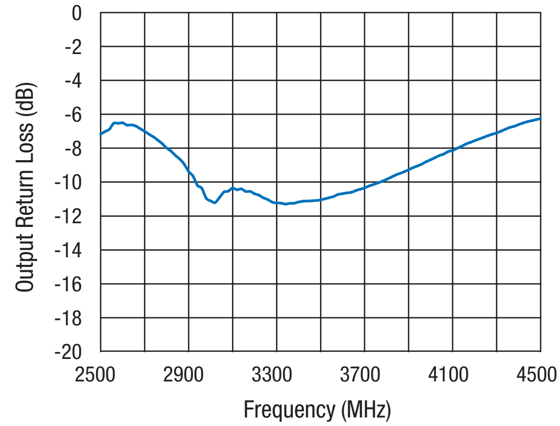

Figure 34. Output Return Loss vs. Frequency, dBm P_{IN} = -20

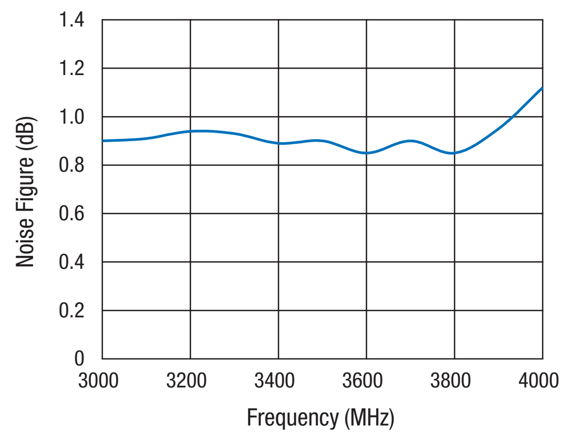

Figure 35. Noise Figure vs. Frequency, Input RF Connector Loss De-embedded from Measurement

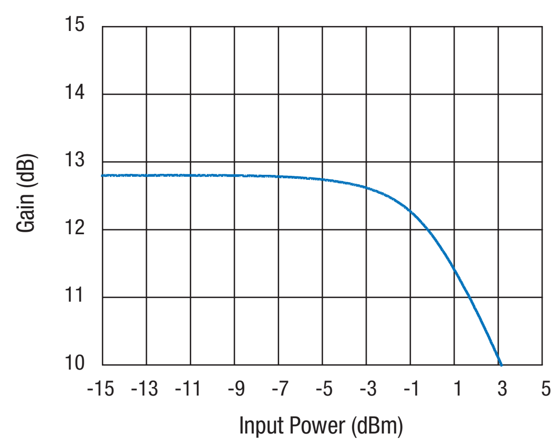

Figure 36. Gain vs. Input Power, F = 3.5 GHz