Application Report

SLAA525–September 2012

RF Matching Optimization Improves TRF3705 Performance

Wu, Bill and Hoppenstein, Russell

ABSTRACT

This Application Report reviews the RF matching technique, and discusses the optimization of RF port matching for improving the TRF3705 performance. The RF- and LO-port impedances and the default broadband matching circuit in the TRF3705EVM are also discussed. Two impedance optimization examples are provided for 350- and 2600-MHz bands.

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1 Impedance Matching for TRF3705 RF and LO Ports

The TRF3705 is a high-performance, superior-linearity device that is ideal for up-converting the baseband signal to RF frequencies of 300 MHz through 4 GHz. Its RF port input impedance varies widely across 400 to 4000 MHz as shown in Figure 1. Three markers showed impedance at 400 MHz, 1840 MHz, and 4000 MHz, respectively. The wide variation implies that it is impossible for one matching circuit to achieve an optimal performance across the whole frequency band. The suggested output matching circuit in the TRF3705 EVM as shown in Figure 2 provides reasonably good broadband performance across the frequency range of the device. It is possible to modify the output matching circuit to optimize both the return loss and other performance within a selected band.

The LO port matching does not have significant impact on the performance, except reducing the reflection loss and delivering more LO power into the modulator. LO port input impedance is shown in Figure 3.

Good RF port matching is usually preferred for better interfacing to the following stage and smaller reflection loss, but in RF modulator applications, the RF port matching could also affect other modulator performances. When there is a conflict between achieving a good RF matching and some important specification, the trade-off has to be made to balance the need for both. For the TRF3705, OIP3 is one of the most important specifications considered when we improve the RF port matching.

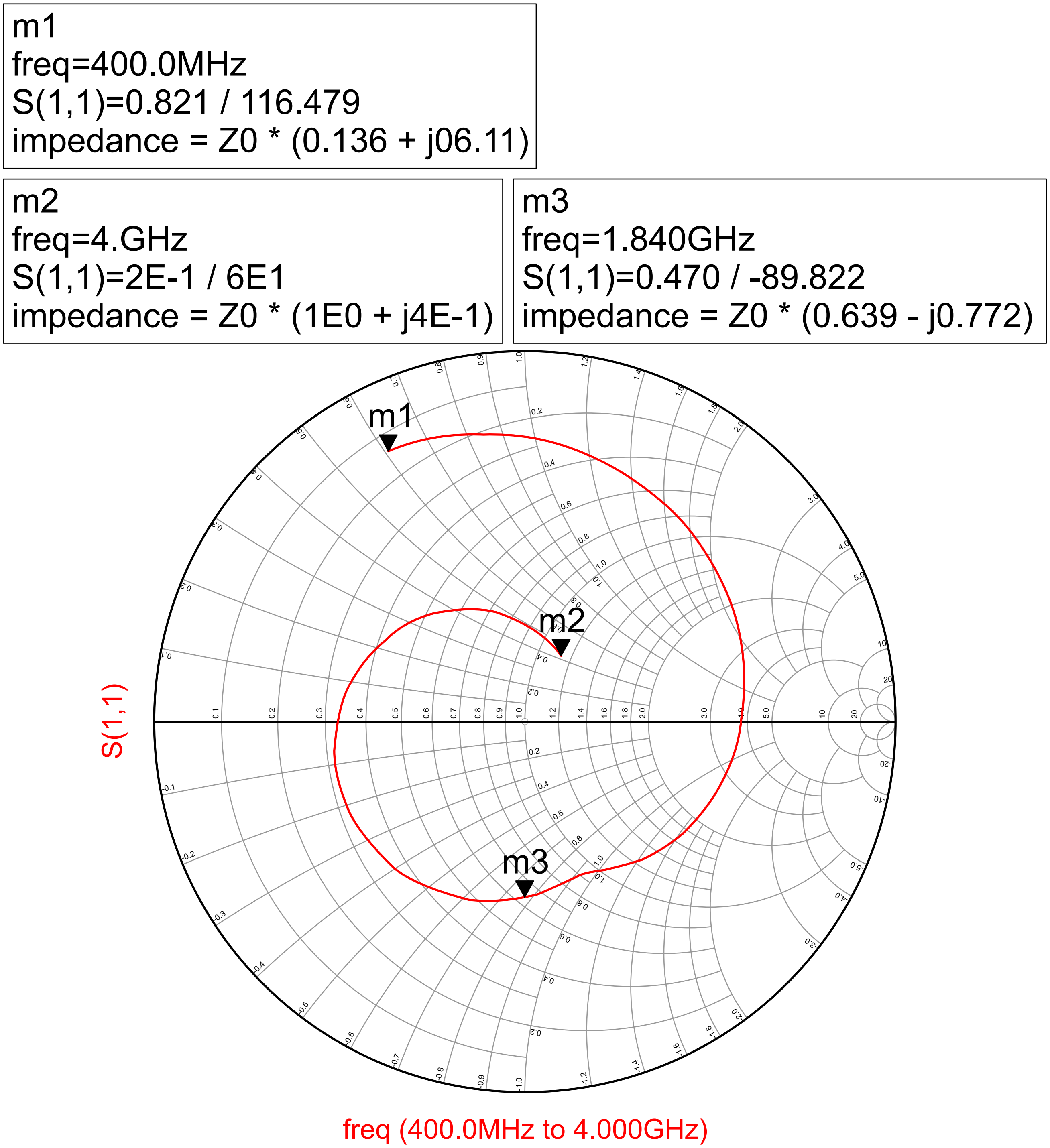

Figure 1. TRF3705 RF Port-Impedance Plot with LO Power and Vcc Applied

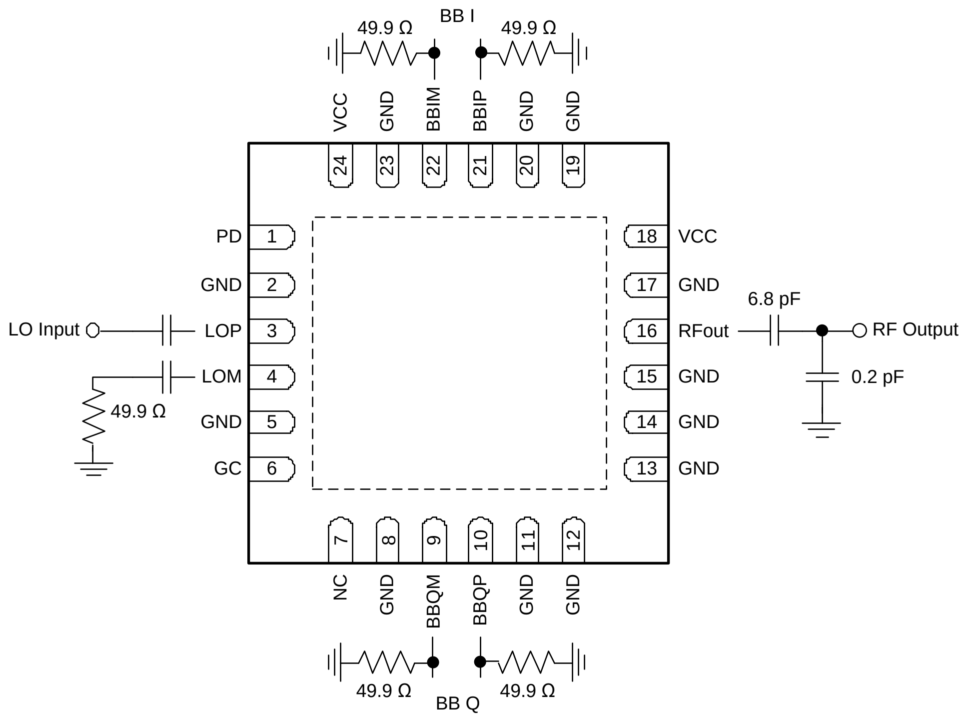

Figure 2. Suggested Broadband RF Port Matching Circuit in TRF3705EVM

m6
freq=1.840GHz
S(2,2)=0.227 / -91.894
impedance = Z0 * (0.889 - j0.426)

m4
freq=400.0MHz
S(2,2)=0.531 / -35.306
impedance = Z0 * (1.729 - j1.477)

m5
freq=4.000GHz
S(2,2)=0.400 / -146.785
impedance = Z0 * (0.459 - j0.240)

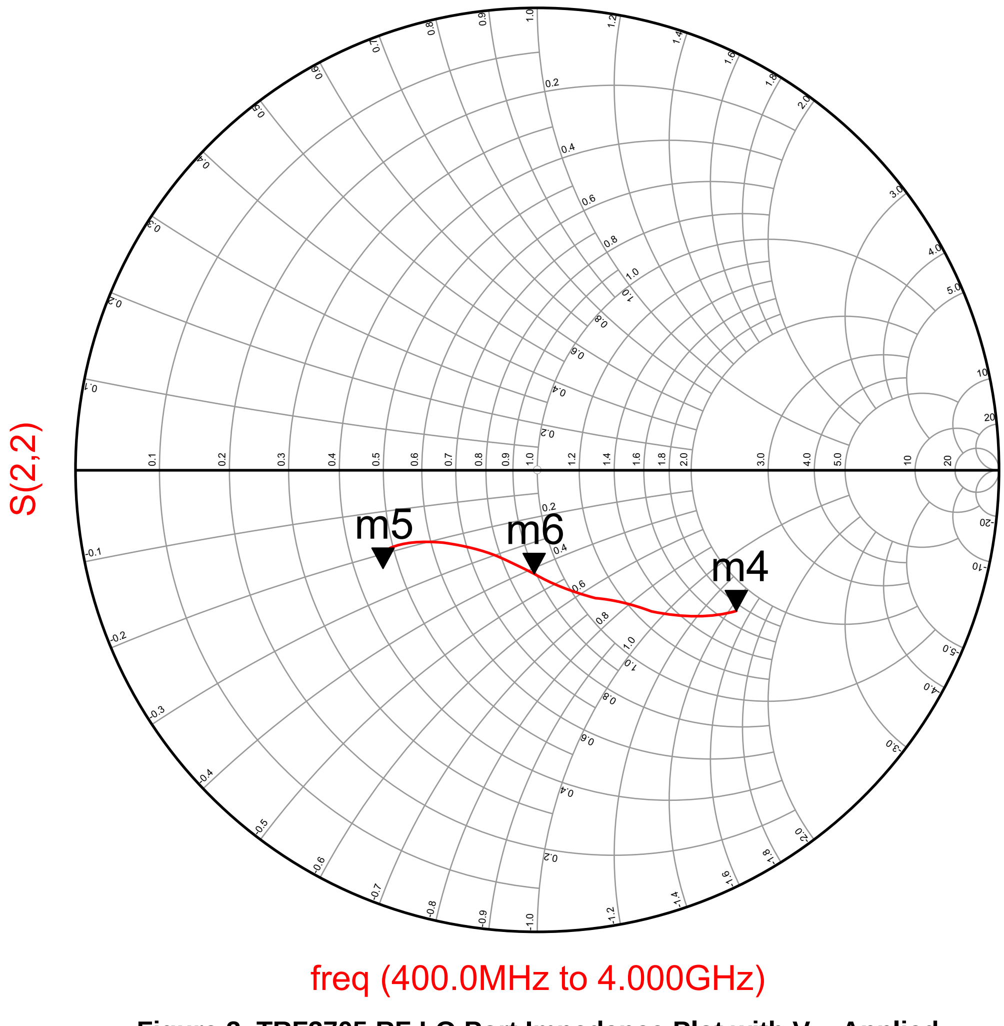

Figure 3. TRF3705 RF LO Port Impedance Plot with V_{CC} Applied

2 Basic Impedance Matching

For the best voltage standing wave ratio (VSWR), the output impedance of the previous stage should be the complex conjugate of the following stage. In some applications, they might not be complex conjugates of each other. Instead, the impedance of the following stage is determined to optimize a specified parameter, for example, the maximum output power or the maximum power-added efficiency (PAE) in the power amplifier, the low noise figure in the low noise amplifier. The optimal impedance is found experimentally through the load-pull technique.

In most wireless applications, the impedance matching is achieved using discrete components, such as inductor (Ind) and capacitors (cap), connected in series or shunt, or short transmission lines. Figure 4 is the overlapped Impedance Smith Chart and Admittance Smith Chart. The brown dotted curves are constant resistance (R) and reactance (X) where Z = R + jX, and the green dotted curves are constant conductance (G) and susceptance (B) curves, where Y = G + jB. The Smith Chart displays the normalized impedance or admittance, and at the central point, K, is the normalized impedance equal to one which represents a perfect impedance match. The impedance or admittance will be changed by connecting inductors, capacitors or transmission lines as summarized below:

- Increasing series inductance with a series inductor moves the impedance point clockwise, from A to B, along the constant resistance curve.
- Decreasing series capacitance with a series capacitor moves the impedance point counterclockwise, from C to D, along the constant resistance curve.
- Decreasing shunt inductance by adding a shunt inductor moves the admittance point counterclockwise, from E to F, along the constant conductance curve.
- Increasing shunt capacitance by adding a shunt capacitor moves the admittance point clockwise, from G to H, along the constant conductance curve.
- Increasing a transmission line length rotates the impedance clockwise around the center from I to J.

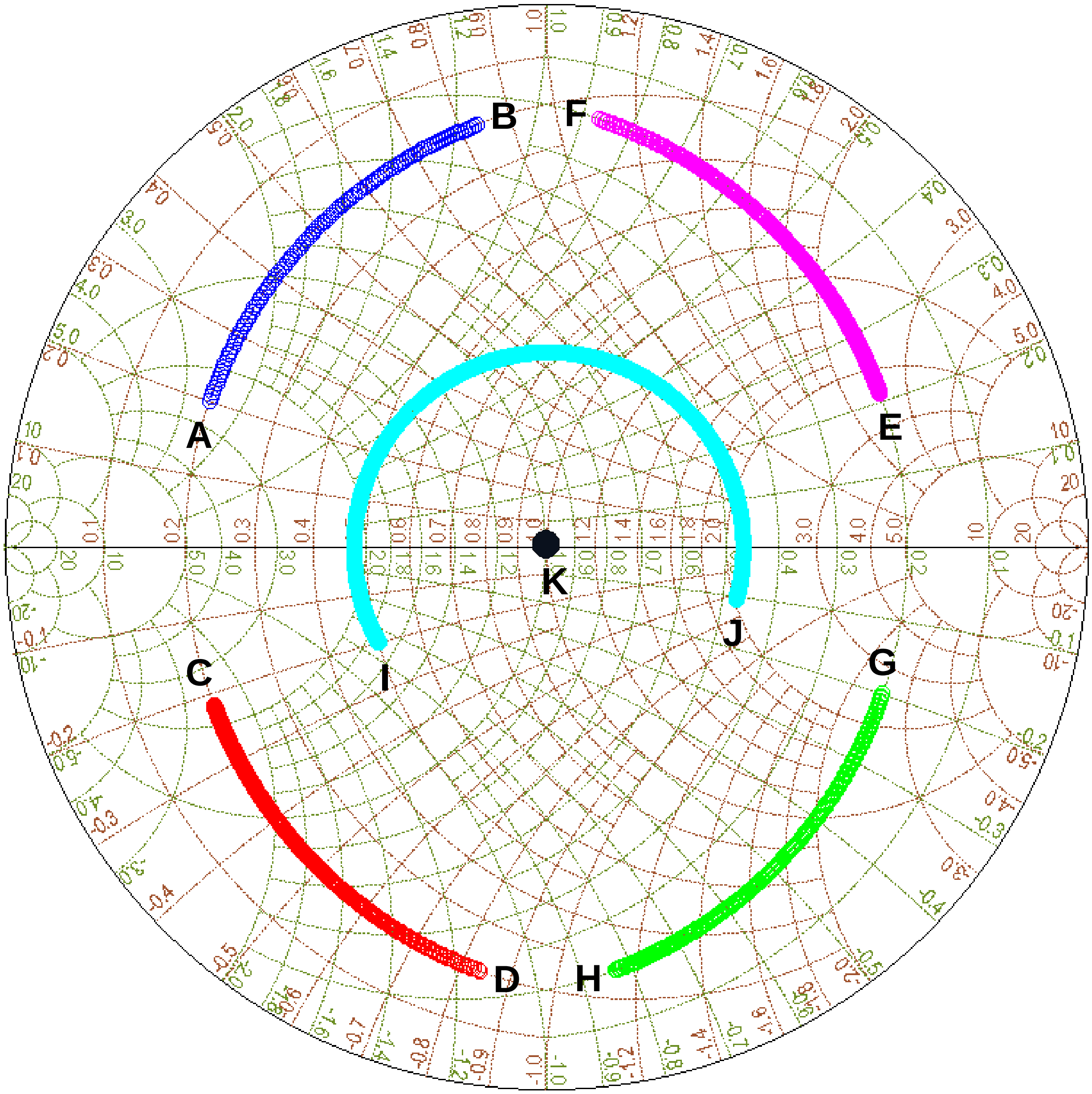

Figure 4. Overlapped Impedance and Admittance Smith Charts (Drawn by Agilent ADS)

In reality, an inductor or a capacitor has loss and parasitic capacitance and inductance. The loss and these parasitic parameters could be modeled in the simulation.

The following is a discussion about the constant Q-line. Every complex impedance point on the Smith Chart has a quality factor (Q) associated with it. The constant Q-line is overlaid on the Smith Chart as shown by the curve in Figure 5. The lower the Q is, the broader the bandwidth of the matching network. Adding a matching component moves the impedance point through a path to the new impedance point. Keeping the path short and close to the real axis helps achieving a broad bandwidth (Figure 5).

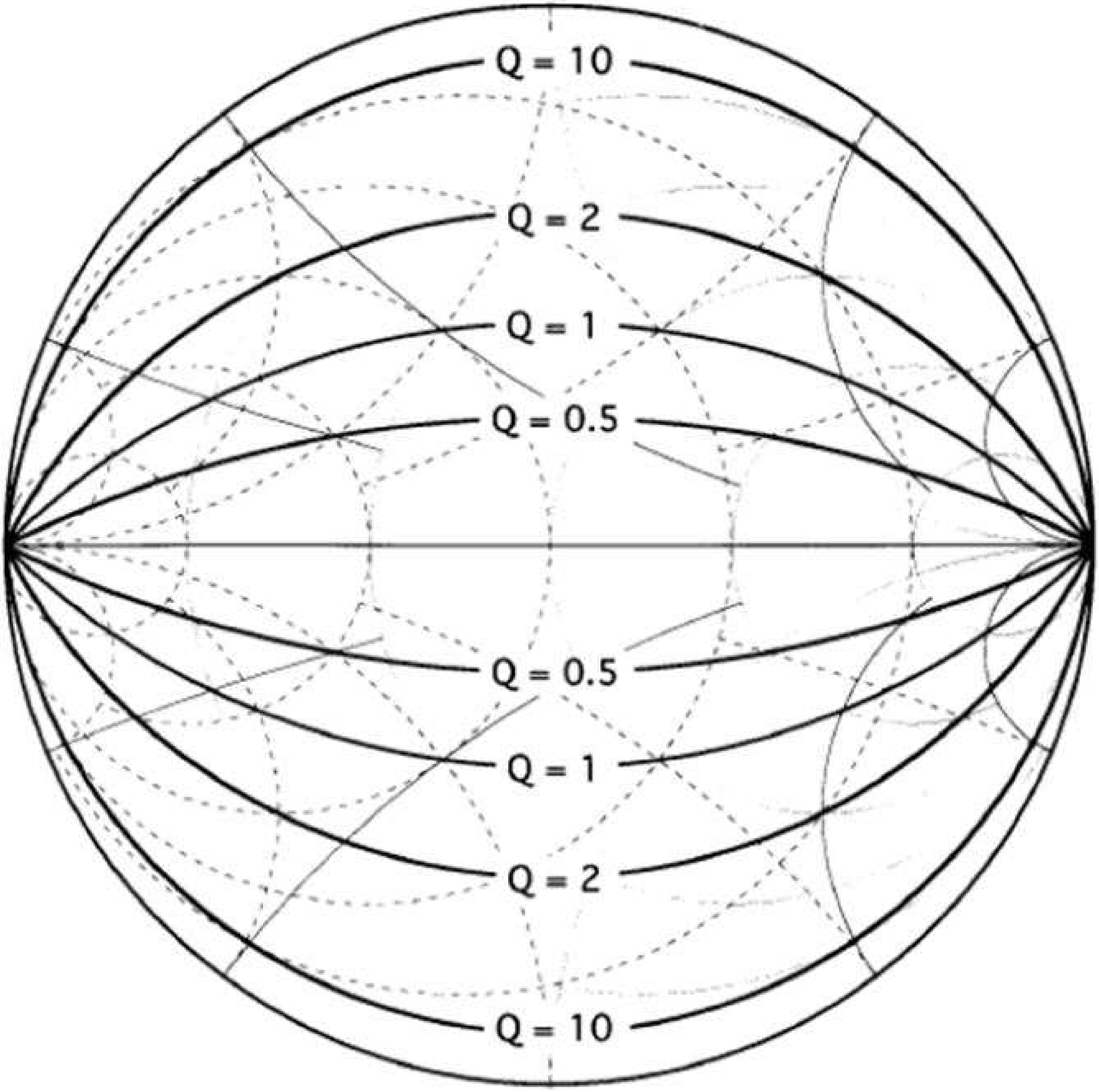

Figure 5. Smith Chart Overlapped with Constant Q-lines

3 Optimized Matching for 350-MHz LTE Band

Applying a different matching circuit improves the performance of the frequency from 300 to 400 MHz, as shown in Figure 6. Figure 7 - Figure 9 show significant improvements in the return loss, OIP3 performance, and the output power; comparing to the performance with the default broadband matching circuit.

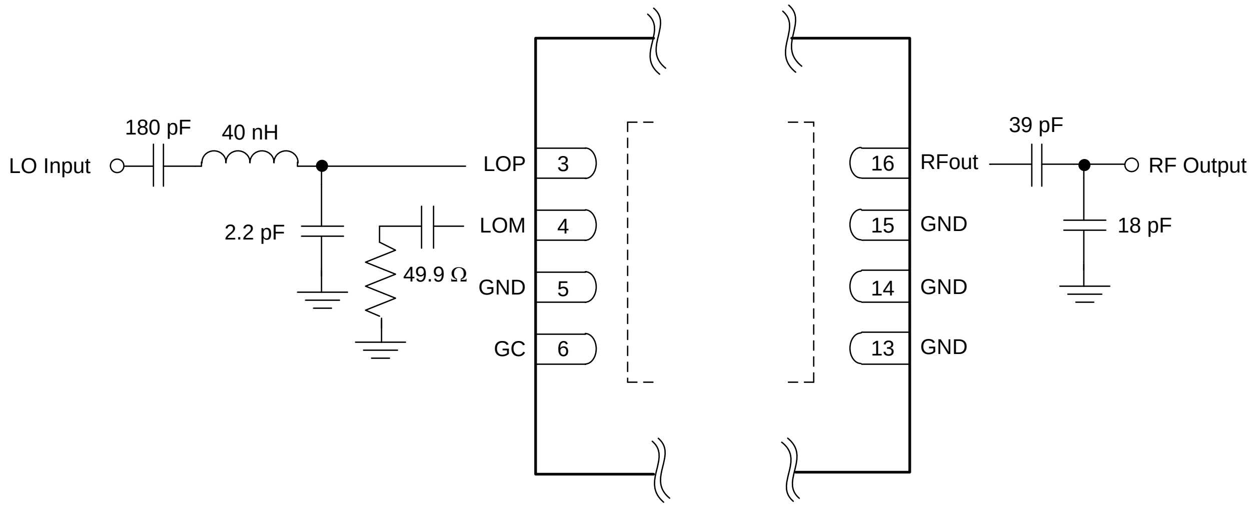

Figure 6. Optimized Matching Circuit For Operation Centered at 350 MHz

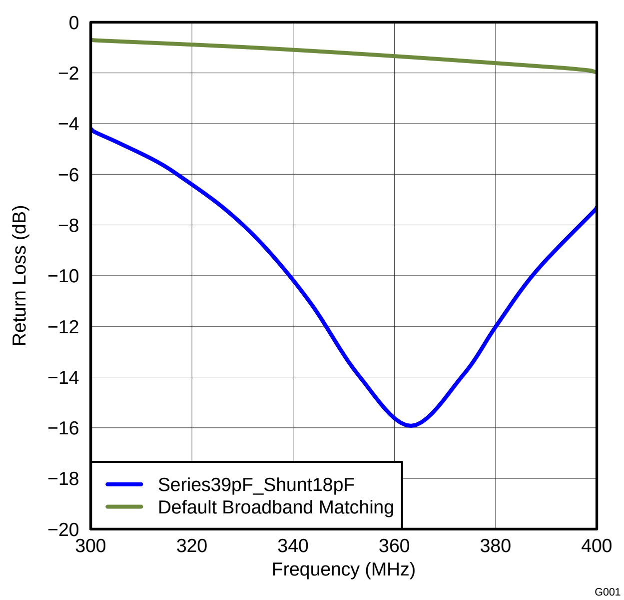

Figure 7. Measured RR Port Return Loss with the Optimized Impedance and Default Broadband Matching Circuit

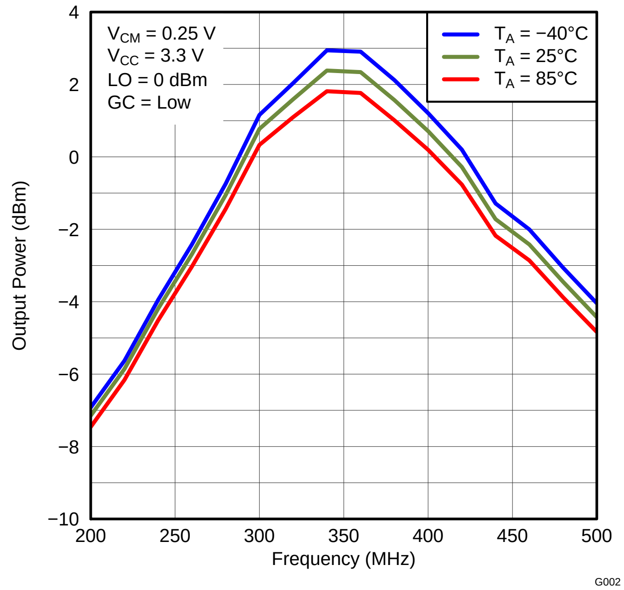

Figure 8. Output Power with the Optimized Matching Circuit Centered at 355 MHz

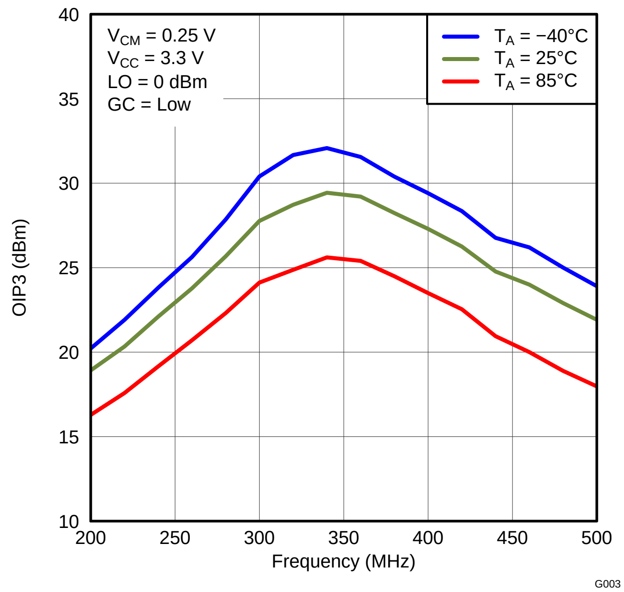

Figure 9. OIP3 with the Optimized Matching Circuit Centered at 355 MHz

4 Optimized Matching for 2600-MHz LTE Band

A second optimized matching circuit, as shown in Figure 10, improves the performance for the 2600-MHz LTE band. Figure 11 - Figure 12 show an improved return loss, flatter output power, and more than 1-dB OIP3 improvement across the band.

For this case, the impedance is not fully optimized for the best return loss. The load-pull experiment identifies this optimal impedance as shown in Figure 12 for balancing the return loss, output power flatness, and OIP3.

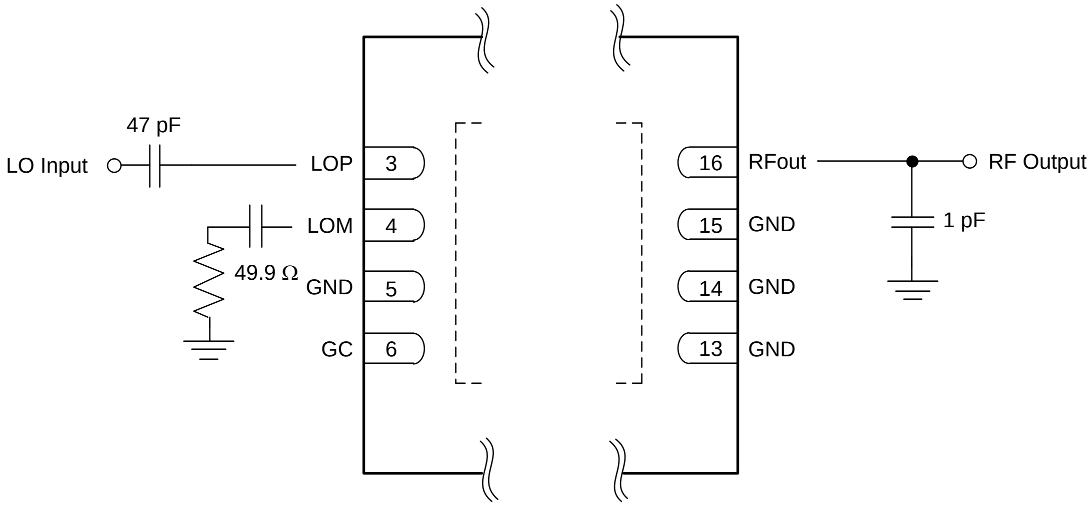

Figure 10. Optimized Matching Circuit for Operation Centered at 2600-MHz Band

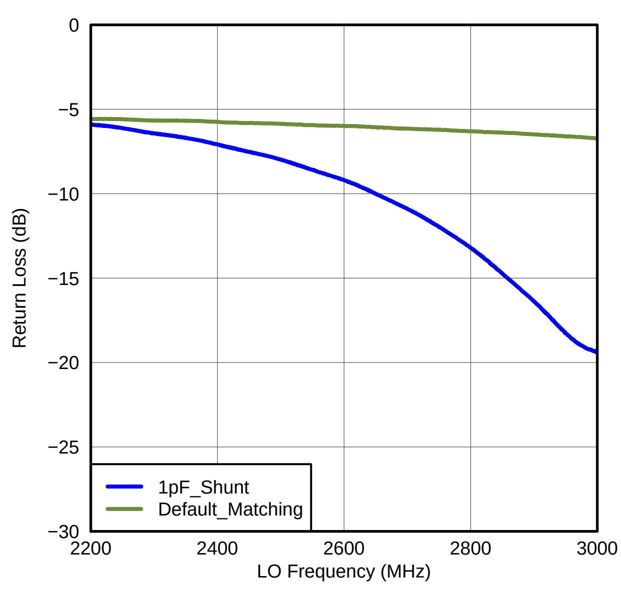

Figure 11. Measured RF Port Return Loss with the Optimized Impedance for 2600-MHz Band

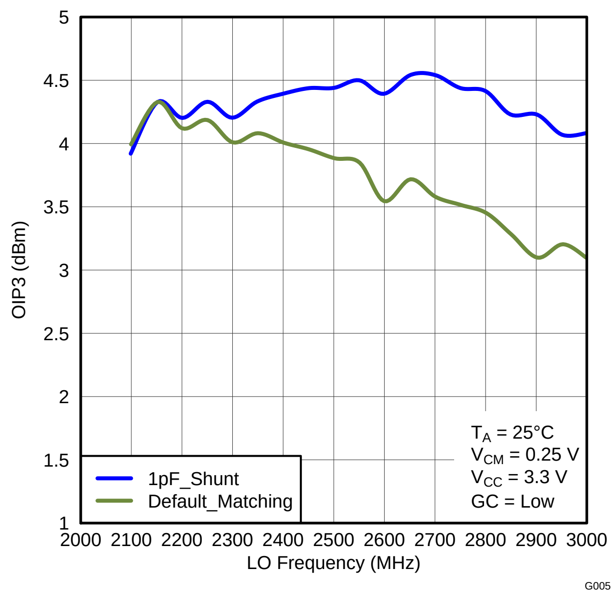

Figure 12. Output Power with the Optimized Matching Circuit at 2600-MHz Band

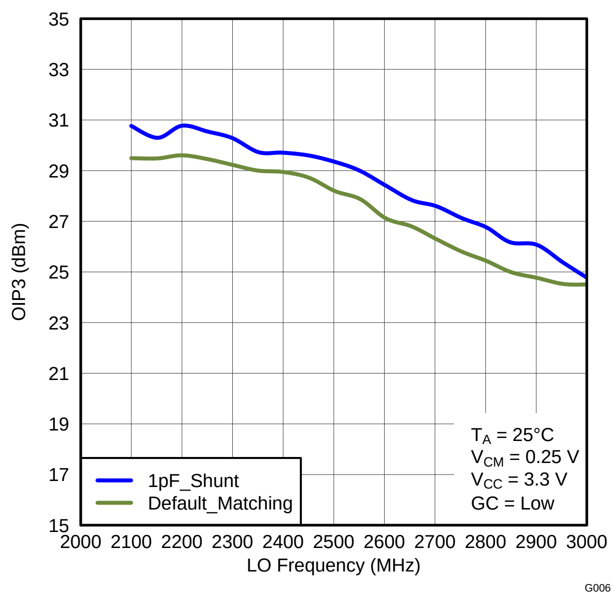

Figure 13. OIP3 with the Optimized Matching Circuit at 2600-MHz Band

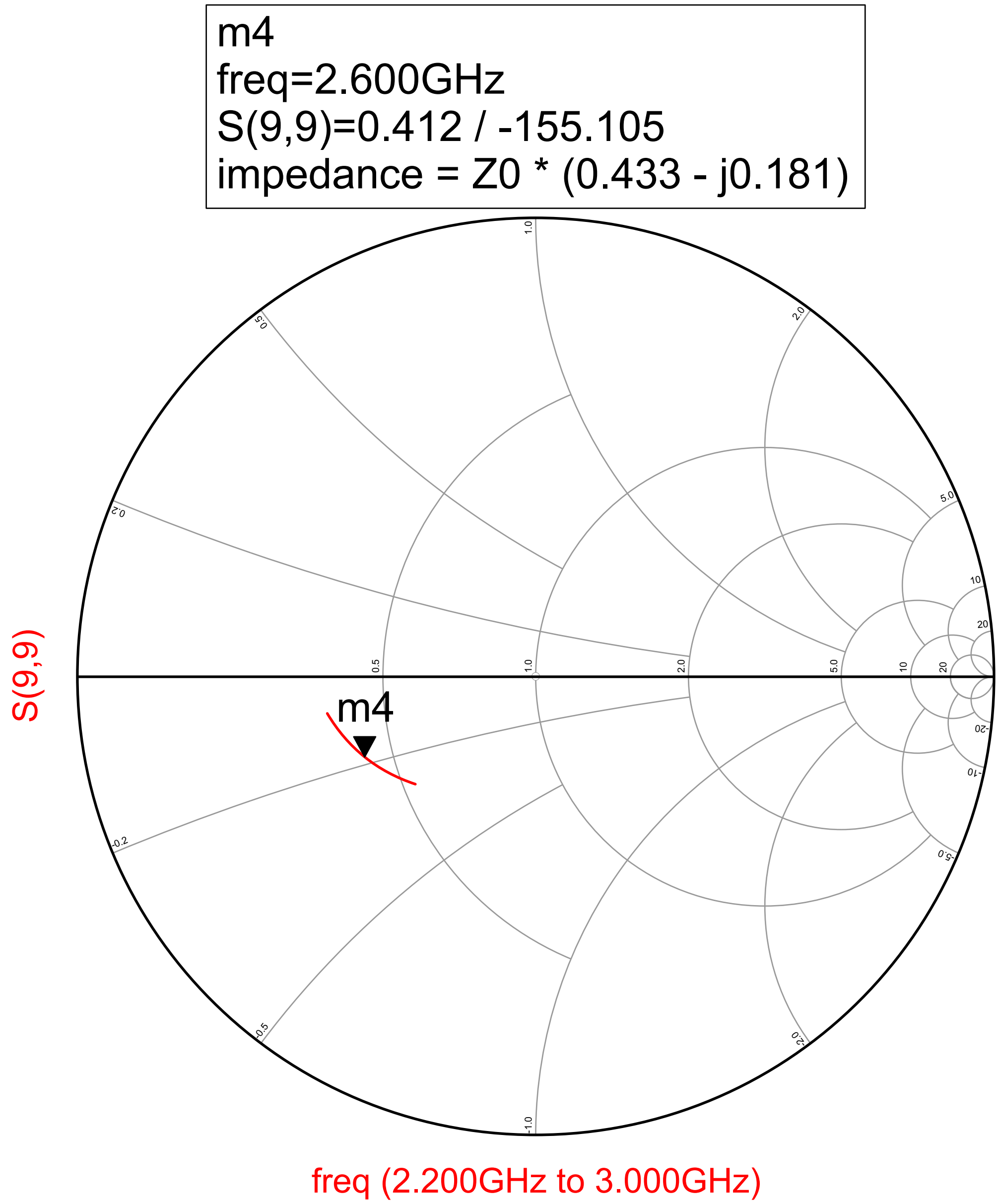

Figure 14. Optimized Load Impedance at RF Pin, Centered at 2600 MHz

5 Conclusion

This application report reviewed the RF matching technique and discussed how RF port matching improved TRF3705 performance. Two impedance optimization examples were provided for 350- and 2600-MHz bands.

6 Reference

Vizmuller, Peter, *RF Design Guide: Systems, Circuits and Equations*, Artech House, Norwood, Mass., 1995.