Designing with the MAX2648 5GHz LNA for High-Frequency Stability

RF input and output matching networks are critical factors in determining the performance of a 5GHz LNA. This application note shows a simple method of using a microstrip capacitive element as part of output matching in order to assure stable operation of the MAX2648 at all frequencies. Individual applications will require slightly different matching networks, but the general principle can be applied to most cases. A small capacitive stub insures stability.

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The MAX2648 LNA has 17dB of gain and 1.8dB of noise figure in the band between 5GHz to 6GHz. Like all good microwave devices, The MAX2648 LNA has excellent high gain at high operating frequencies (up to 20GHz). As is well known, this class of amplifier can potentially oscillate at frequencies greater than 10GHz without appropriate microwave design techniques. This application note shows how the microwave matching should be done with the MAX2648 LNA to achieve the best possible performance and stable operation.

Design Considerations

Following are the factors we will consider when designing with this high performance microwave LNA:

- PCB material selection
- Component selection
- Power supply by-passing
- Input and output matching

PCB Material Selection

At 5GHz, the transmission line loss before and after the LNA is significant. The line loss at the LNA input is especially important since the loss is directly added to the noise figure of the LNA. A low-loss dielectric material is recommended for the PCB material. For example, MAX2648 EVkit uses 10mil thick Rogers 4350 "laminate over FR4 core" material. The laminate gives stable loss tangent for microstrip, while the FR4 board underneath provides a low-cost stiff backing.

Capacitor Selection

In order to achieve optimum noise figure, it is important to use high-Q capacitors for input and output matching circuit. Use of low-Q components will degrade noise figure. Experiments on MAX2648 EVkit have shown that this degradation in noise figure can be as much as 0.2dB when high-Q capacitors (such as ATC or Vitramon) are replaced by ordinary lossy capacitors (such as jelly-bean NPO types). These high-Q porcelain capacitors can be too expensive for high-volume product designs, so a good compromise between cost and performance would be GJ615 series from Murata.

Power Supply By-Passing

Power supply by-passing is essential at microwave frequencies to ensure stable high frequency operation. It is important to choose a capacitor such that the impedance of the capacitor is the lowest at the frequency one is trying to decouple. For example, a 1000pF capacitor is not a good choice for high-frequency decoupling since the lowest impedance for a 1000pF capacitor would likely occur below several hundred MHz. At 5GHz, the self-resonant frequency would make it look more like a lost inductor! So for high-frequency decoupling, a capacitor of typically less than 10pF should be placed close to the IC. Also, for low frequency decoupling, a 1000pF and 0.01uF capacitor combination is a good choice but they don't have to be located immediately at the IC pin.

Input and Output Matching

Because MAX2648 LNA is a high gain microwave device, it requires proper matching at the input and output for stable high-frequency operation. Run-of-the-mill smt capacitors and inductors typically have self-resonant frequencies below 6GHz. When designing with MAX2648, care should be taken to avoid using components with self-resonant frequencies below 6GHz.

To ensure high-frequency stability of the MAX2648, we have determined that a small capacitive stub should be incorporated at the output as part of the matching circuit. Placing inductive terminations at the output of the LNA (especially in series to the coupling capacitor) may result in high-frequency oscillations and should be avoided by careful attention to the layout. Since long transmission lines represent series inductance, use of capacitive stubs is suggested as a solution to compensate for the extra inductance seen by the device. The capacitive stub provides a good capacitor to ground at high frequencies where a lumped component would display properties of an inductor. In order to illustrate this point, one circuit simulation that shows a high-frequency oscillation is compared to another that shows no oscillation. Note that the component models used in the simulation are likely to be faulty at frequencies beyond their intended usage. Accurate high-frequency analysis is difficult in this case, but circuit simulations do show trends and could be a useful tool in predicting general circuit behavior.

Figure 1 is an ADS simulation plot showing an unstable circuit around 13.5GHz. The output match in this case uses all lumped components, as shown in the schematic below.

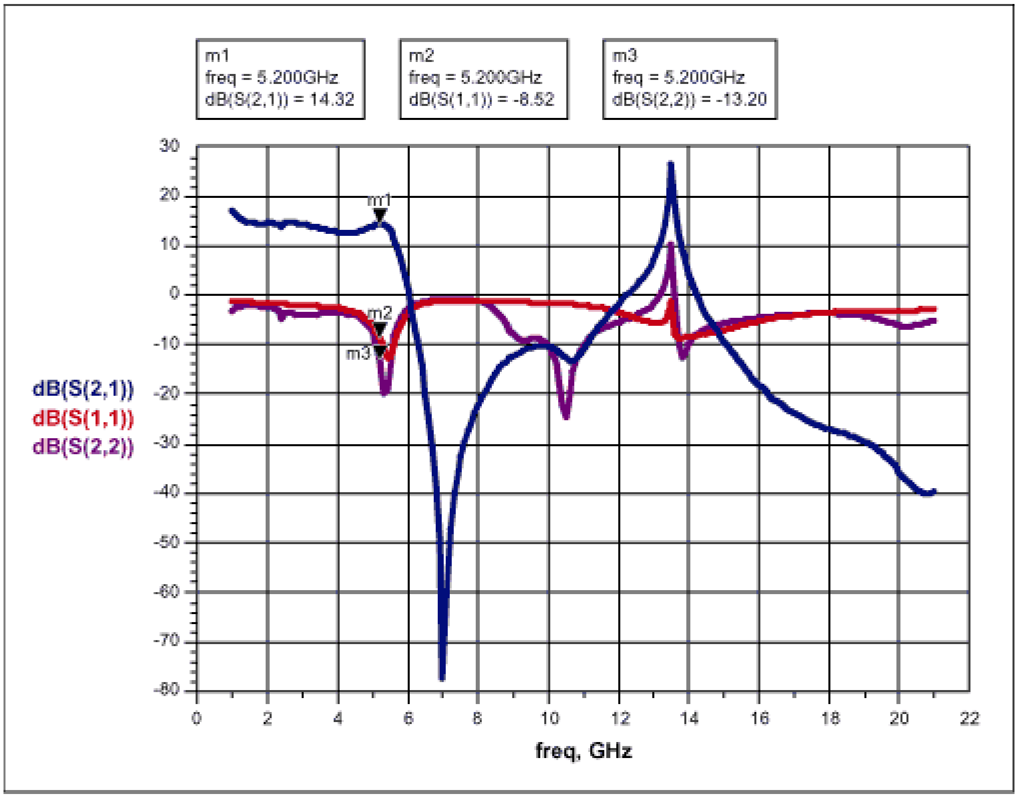

Figure 1. ADS simulation with lumped matching components

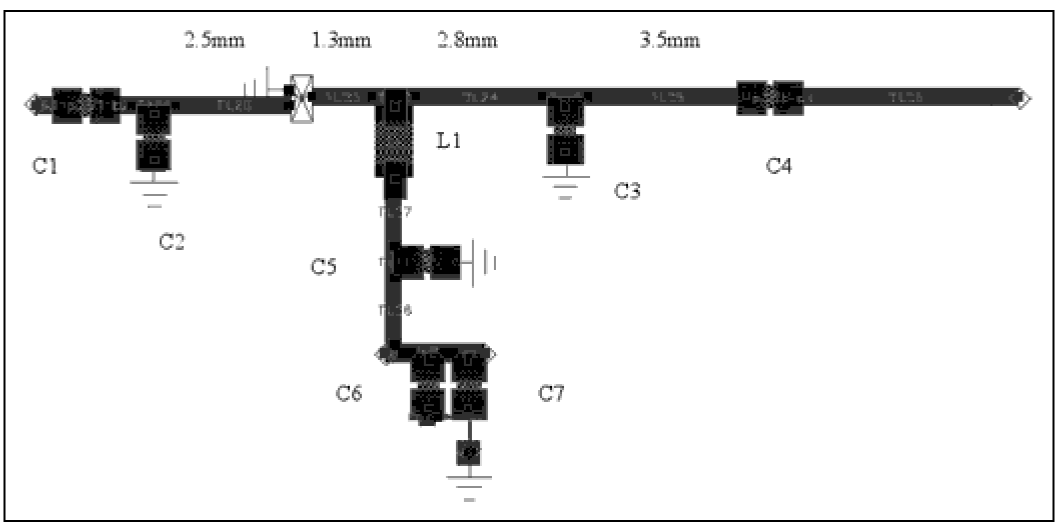

Figure 2. Input and output match layout (50Ohm line is 0.4mm)

C1	2pF
C2	0.5pF
C3	0.5pF
C4	2pF
C5	1.5pF
C6	1000pF
C7	0.01uF
L1	6.8nH

Figure 3 shows the results of using a capacitive stub implemented by placing a wider microstrip section in the output trace. The capacitance can be approximated by using the formula

$$C = \frac{\varepsilon_r \varepsilon_o \text{Area}}{d}.$$

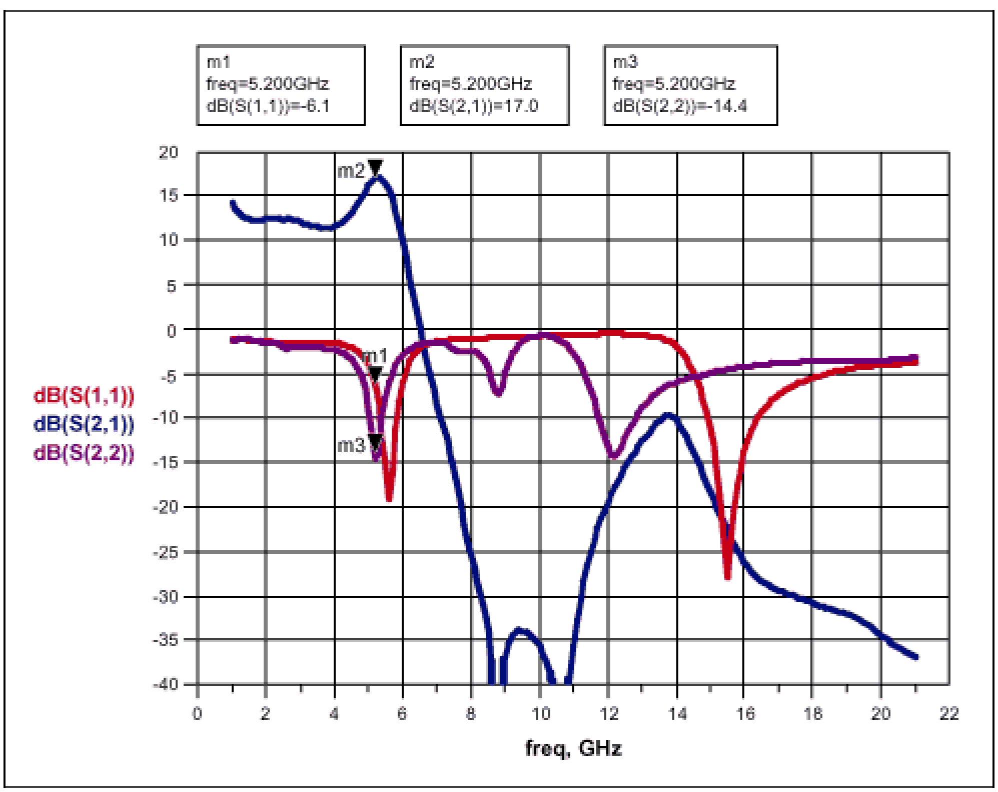

Figure 3. ADS simulation with output capacitive stub

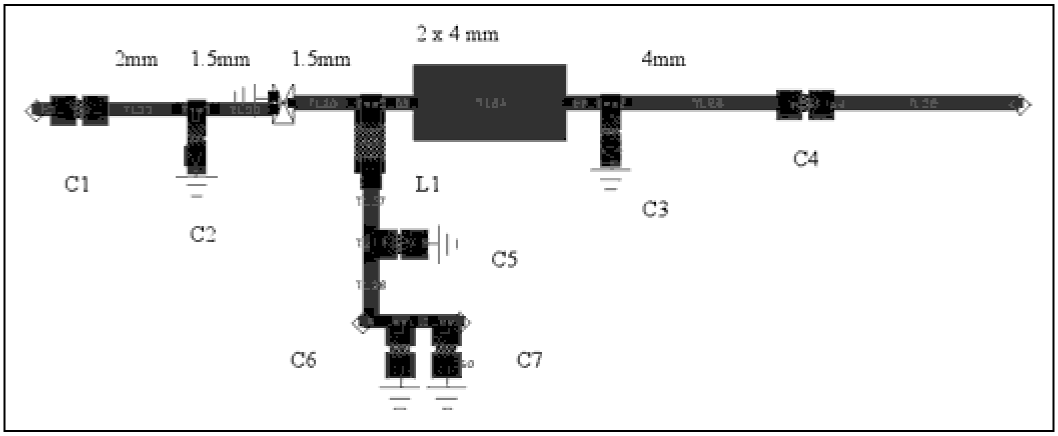

Figure 4. Layout showing 2mm x 4mm stub (50Ohm line is 0.4mm. Individual microstrip section lengths are noted above.)

C1	2pF
C2	0.75pF
C3	0.5pF
C4	2pF
C5	1.5pF
C6	1000pF
C7	0.01uF
L1	6.8nH

A microstrip that is about 2mm x 3.5mm in size with dielectric constant of 4.1 and substrate thickness of 0.2mm gives roughly 1.27pF in capacitance, neglecting fringing effect. A shunt capacitor to ground is added for ease of tuning. Location of input and output shunt capacitors should be adjusted as needed to attain optimum noise figure and gain.

Conclusion

Input and output matching networks are critical factors in determining the performance of a LNA. This application note showed a simple method of using a microstrip capacitive element as part of output matching in order to assure stable operation of the MAX2648 at all frequencies. Individual applications will require slightly different matching networks, but the general principle can be applied to most cases.

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