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 ECE 532

## Intro

Stability characterization is performed for the PHEMT transistor (SAV-541+). Simultaneous conjugate matching (SCM) is explored. Stability circles are simulated at 2.4 GHz and a resistor network is used to unconditionally stabilize the transistor.

### Simultaneous conjugate matching

When a transistor is unconditionally stable SCM may be implemented. A transistor may be only unconditionally stable in certain operating frequencies. In order to find these frequencies a frequency sweep is performed in ADS given an S2P file (see in references). Stability may be determined by the following equations:

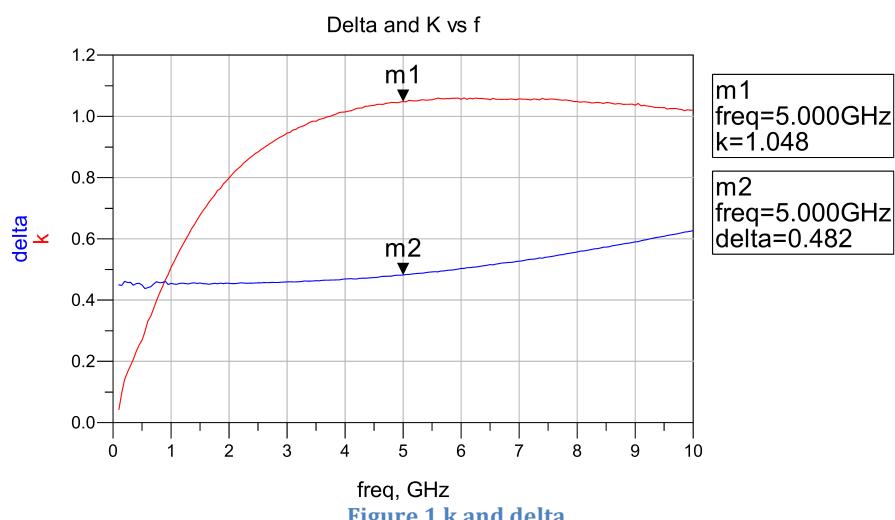
$$k = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} > 1$$

$$|\Delta| = |S_{11}S_{22} - S_{12}S_{21}| < 1$$

A plot of k and delta is constructed with the S2P file provided by the manufacturer as shown in Figure 1. The arbitrary frequency of 5GHz is chosen for further SCM analysis.

```
Eqn k=(1-mag(S(1,1))**2-mag(S(2,2))**2+(delta)**2)/(2.*mag(S(1,2).*S(2,1)))
```

```
Eqn delta=mag(S(1,1)*S(2,2)-S(1,2)*S(2,1))
```



Using ADS and the Smith chart tool a SCM network is constructed using ideal micro strip transmissions lines. The matching network schematic is shown in Figure 2 along with the S11 and S22 plots. As seen on Figure 3 the matching network provides an almost perfect match. A SCM match provides maximum power transfer.

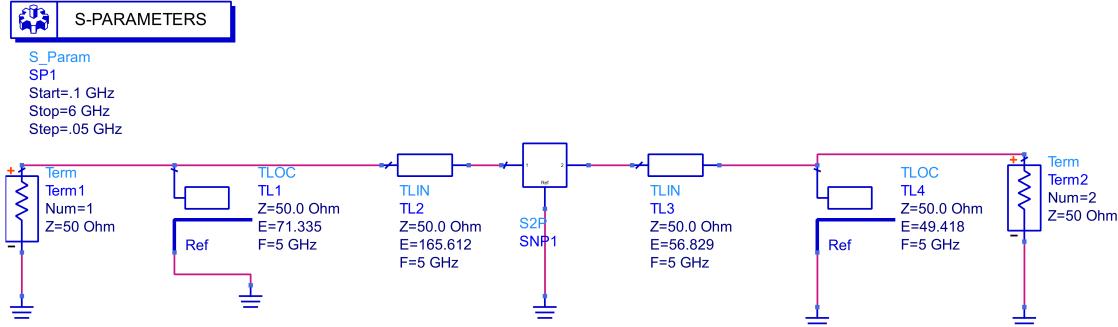


Figure 2 SCM schematic

Conjugate Match Input and Output

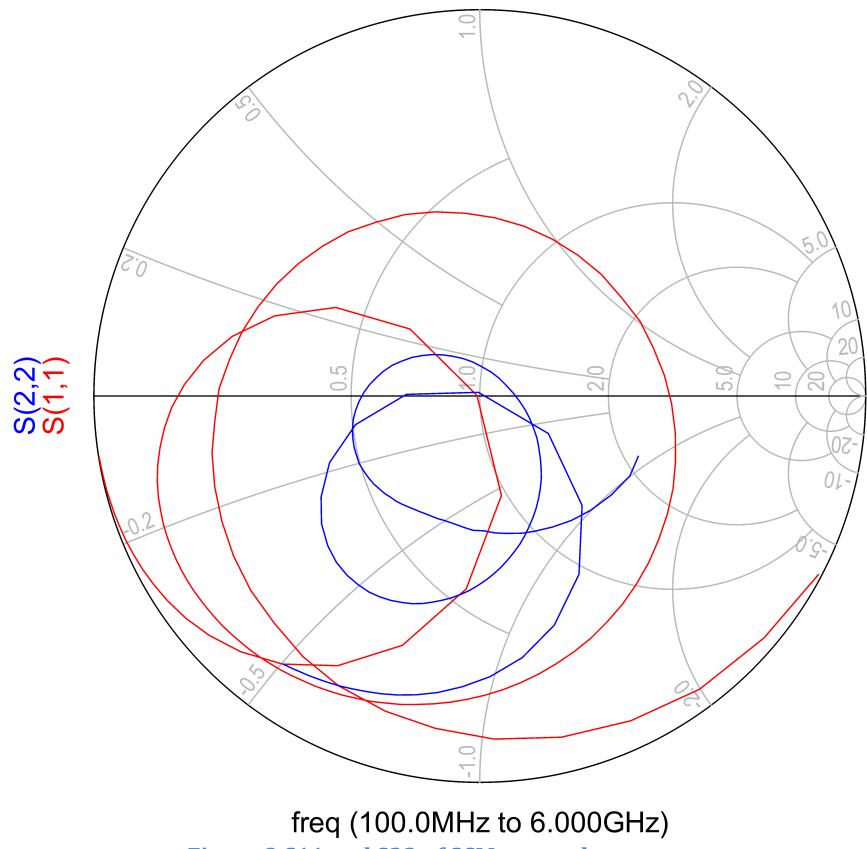
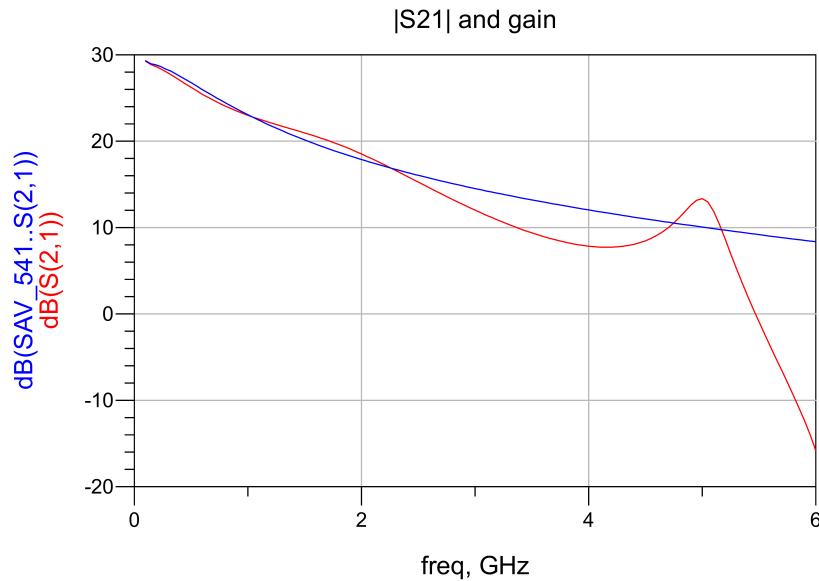


Figure 3 S11 and S22 of SCM network

With the matching network a comparison of power gain is made between the SCM circuit and the transistor without any matching network terminated with 50 Ohms. Figure 4 shows the power gain of both circuits.

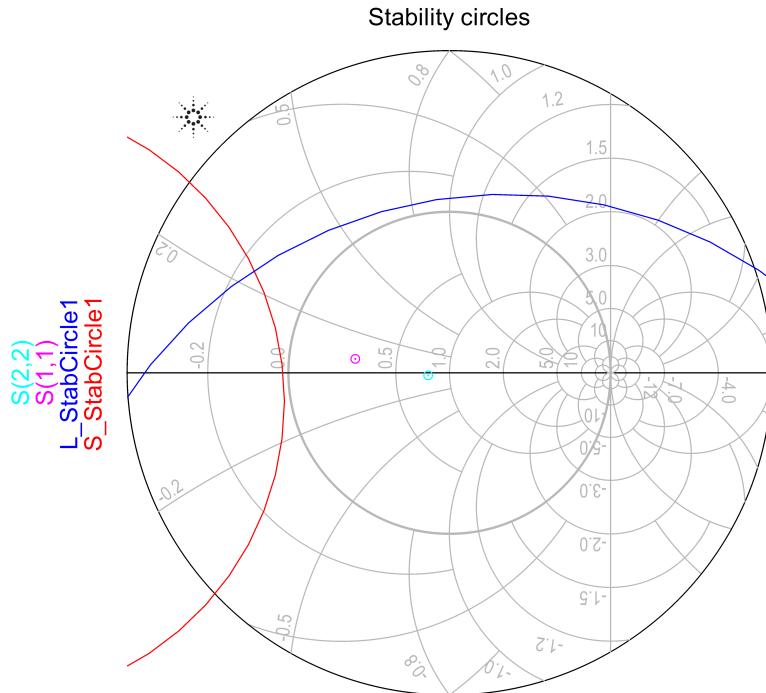


**Figure 4 intrinsic gain and SCM match gain**

Since SCM match guarantees maximum power transfer and the circuit is ideal (no losses) the gain of the transistor is increased by  $\sim 4\text{dB}$  @ 5GHz.

### Stability circles

In order to determine the region in which a transistor is stable, stability circles can be plotted on the Smith chart. The stability is dependent on the operating frequency and input/load impedance.



**Figure 5 Unconditionally stable transistor**

A transistor with a 50-Ohm source impedance and load termination may not be unconditionally stable. In order to make the transistor unconditionally stable resistors may be added in series or shunt to gate and drain. With ADS the input and output stability circles may be plotted. Using the tuning feature resistor values may be tuned to move the stability circles and make the transistor unconditionally stable.

As shown in Figure 5 the transistor was made unconditionally stable by moving the stability circles in such a way the load and source impedances may not cause instability. As seen S11 and S22 are less than unity in this configuration. Using this technique to achieve unconditional stability lowers the gain of the device since some power is now being dissipated on the resistors. The gain in this circuit was reduced by about  $\sim 2\text{dB}$  as shown in Figure 6.



Figure 6 gain comparison

## Stub Matching

Single stub matching is a useful technique because any impedance can be transform to any other impedance with two transmission lines. In this exercise a reflection coefficient of  $G_{in} = 0.644/172^\circ$  is transformed to 34 Ohms. For part 1 of the exercise ideal TL are used. Since substrate information is not necessary the TL will be described with electrical lengths. For both exercises the Smith chart tool has used (extra credit ☺).

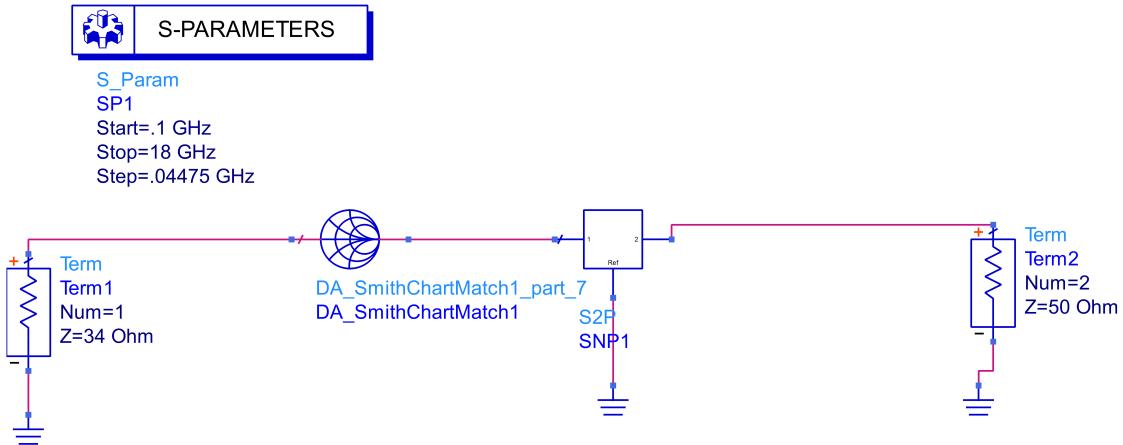


Figure 7 ideal TL matching network

Using the Smith chart tool a single stub matching network the input impedance was transformed to 34 Ohms. As seen on figure 8 the reflection coefficient is  $\sim 0$ .

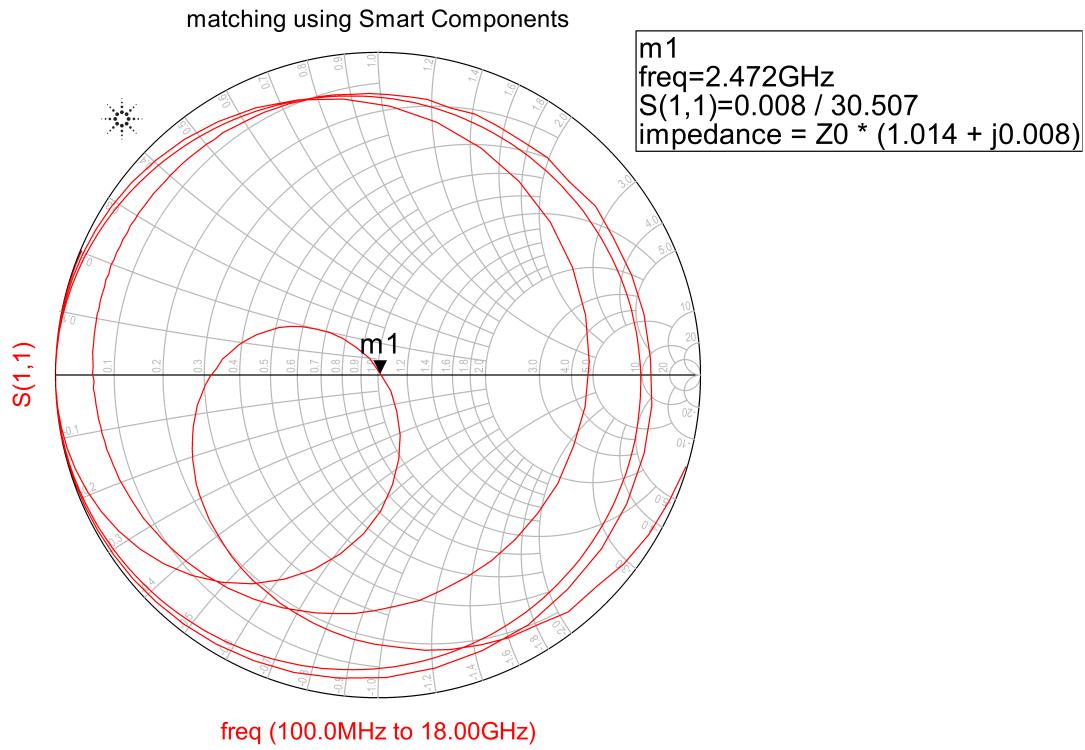


Figure 8 S11 of ideal matching network

In order to realize this circuit with actual transmission lines physical dimensions are necessary. Using the Smith chart tool (see screen shots in references) and the LineCalc tool TL were synthesized. As shown in Figure 9 the physical dimensions of the TL are shown.

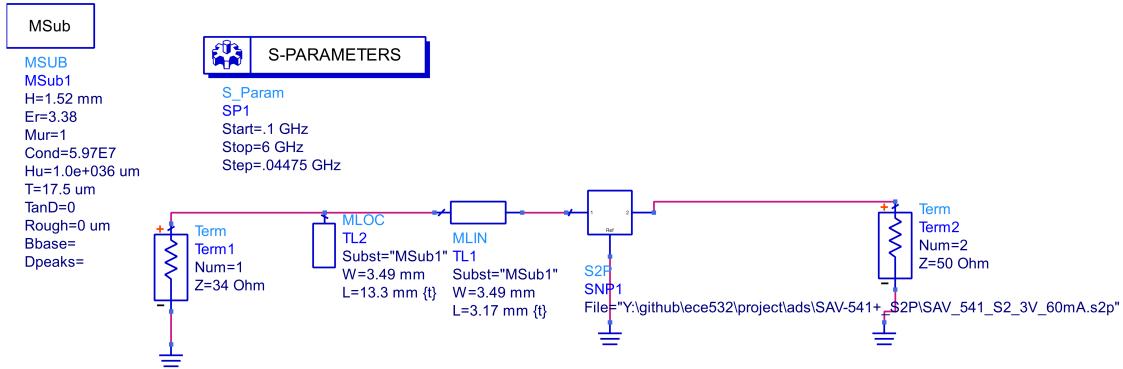


Figure 9 matching network

Figure 10 shows S11 of the above schematic. As shown the input reflection coefficient is  $\sim 0$  indicating a perfect match.

## New knowledge

This week involved activities with software only. It was very useful to learn some of the more advanced features of ADS. I found the Smith chart tool very useful and convenient, although I still like to do these problems by hand.

## References

Files from manufacturer  
 SAV\_541\_S2\_2V\_80mA.s2p  
 SAV\_541\_S2\_3V\_60mA.s2p

Microwave transistor amplifiers (2nd ed.): analysis and design by Guillermo Gonzales  
 Prentice-Hall, Inc. Upper Saddle River, NJ, USA ©1996

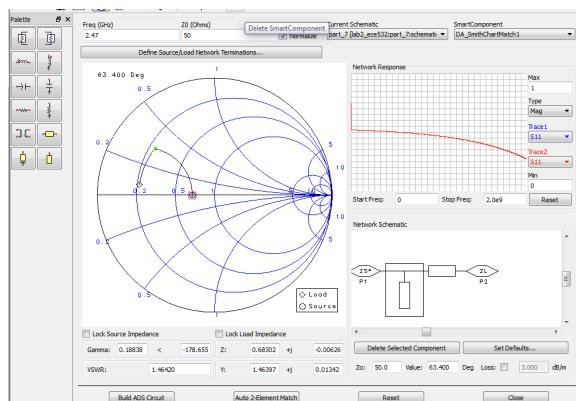


Figure 10 Smith chart tool (for reference only)