

**Practical Smith Charts
Pacificon '14
by
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(ae6ty)

Objectives

Follow up to 'Introduction to Smith Chart Software'

- **Show more features of SimSmith**
- **Show more design techniques**
- **Provide additional time for questions**

I may go faster than you'd like: slow me down !

Who was just here? Who's used Smith charts before? Who's used SimSmith before?

First, lets review a few basic procedures so we don't get preoccupied with logistics.....

Procedure: Files

Most files can be loaded in two ways:

- **Click on button in SimSmith and navigate to file OR**
- **navigate to file and then click/drag it into SimSmith**

For example:

- **load in a circuit description**
- **load in a 'load' file**
- **load in a 'reference'**

Procedure: Display

The Smith chart has three display modes:

Path shows how components modify impedance

Sweep shows how frequency modifies impedance

Both....

**For sweeps, intermediate nodes are selected
using the menu.**

(10to50.ss)

Procedure: undo

SimSmith provides a limited undo.

click 'undo' to... well... undo something

click 'redo' to redo that thing

Use timeline to scan around the history

undo is not 'infinitely deep'

undo does not 'undo' library edits

Procedure: Library

A basic library is provided.

It contains circuit elements you want to save for a short time.

- Drag/Drop to add element to library**
- Drag/Drop to use library element**
- Drag/Drop to delete library element**
- Careful of putting Z components in library**

Procedure: Focus

SimSmith allows panning and zooming:

On the Smith chart:

zoom uses the wheel

zooms around cursor location

click/drag for pan

On SWR chart:

zoom used wheel

click/drag for pan

zooms around 'last clicked point'

Procedure: Sweeping

SimSmith allows multi variable sweeping. The variables to be swept are listed in the 'sweep menu'.

Any number of sweep variables are allowed.

The first sweep variable is the 'primary' one and it is used as the horizontal axis of the Square chart.

All combinations of all sweep variables are plotted. The maximum number of points plotted is controlled by file/preferences/maxSweepPoints.

Procedure: Preferences

The 'file/preferences' menu:

Controls various defaults and operating modes: e.g.

meters/feet

default sizes

power units

many others

Is 'user dependent', not 'project dependent': gets loaded only at startup.

Examples:

Now, lets look at some of the more advanced features of SimSmith.

The remainder of today will be a series of examples

While you may not see just how everything is done...

You will see what kinds of things can be done...

Again, feel free to slow me down !

Example: SnP files

**There is a standard file format called 'TouchStone'.
It is an industry standard.**

**These files are used to express the impedance of one
and two port devices across a range of frequencies.**

SimSmith can read and write both S1P and S2P files.

**S1P files are used to save the impedance seen by the
generator across the swept frequencies.**

These files can be used as loads or references.

Example: SnP files

The S2P file is used to record the impedance of two port devices at a set of frequencies.

SimSmith records the impedances at the generator and the load (looking right) across a set of frequencies.

do LC match of 80m antenna

write S2P file.

read back S2P file.

Example: SnP files

The S2P files can be used by the 'S' block.

The S2P files can be used by the 'Z' block.

Vendors often supply S2P files for their passive components.

Example: SnP files

For example:

S2P file used to measure passive component

- **Could be measured in ‘shunt’**
- **Could be measured in ‘series’**

Using it:

- **Could be using the passive in shunt**
- **Could be using the passive in series**

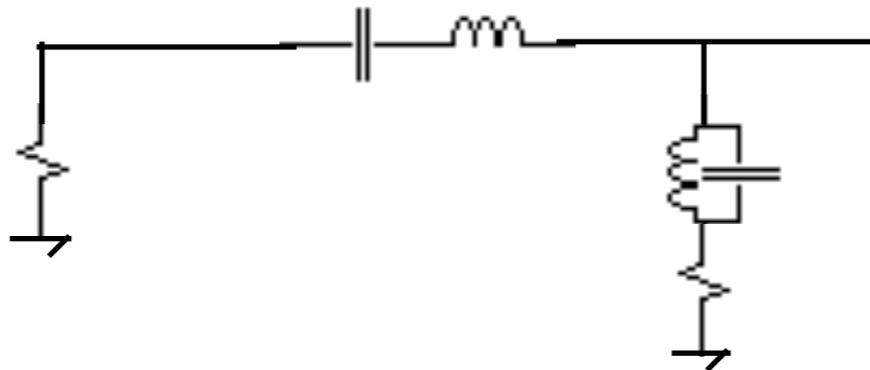
Use S block for shunt and series.

Use ‘Z’ block for shunt and series.

Example: F block

The F block allows you to write an equation for the impedance transformation through the block. It provides parameter variables which are, of course, sweepable

Suppose we want to design a trivial duplexer of the form:



Example: F block

But, there are no SimSmith blocks which look like this:



For this simple case we could use the F block...

Equation: $|| (Rz + Ca | Lb)$

note 'not ideal due to losses'.

Example: F block

Here is a more advanced F block. It is a T pad attenuator with a variable loss:
(aDBtPad.ss)

Example: N block

Sometimes, the circuit is too complex for the F block.

In these cases, we can use the N block.

Note: N block is very general but very primitive.

Lets show the circuit for the duplexer 'down'.

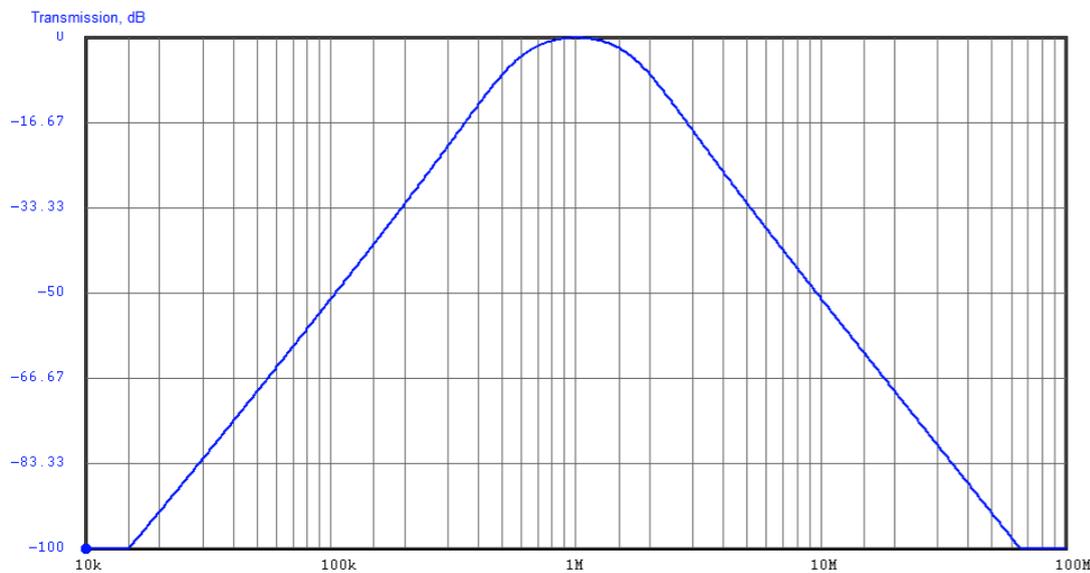
And show the ugliness.. It doesn't like 0 ohm resistors. If you use it, be on guard AND be vigilant for weird behavior (weirdnesses disappearing....)

Example: Filter Bandpass

Sometimes you want to examine the input impedance of a filter along with the transfer.

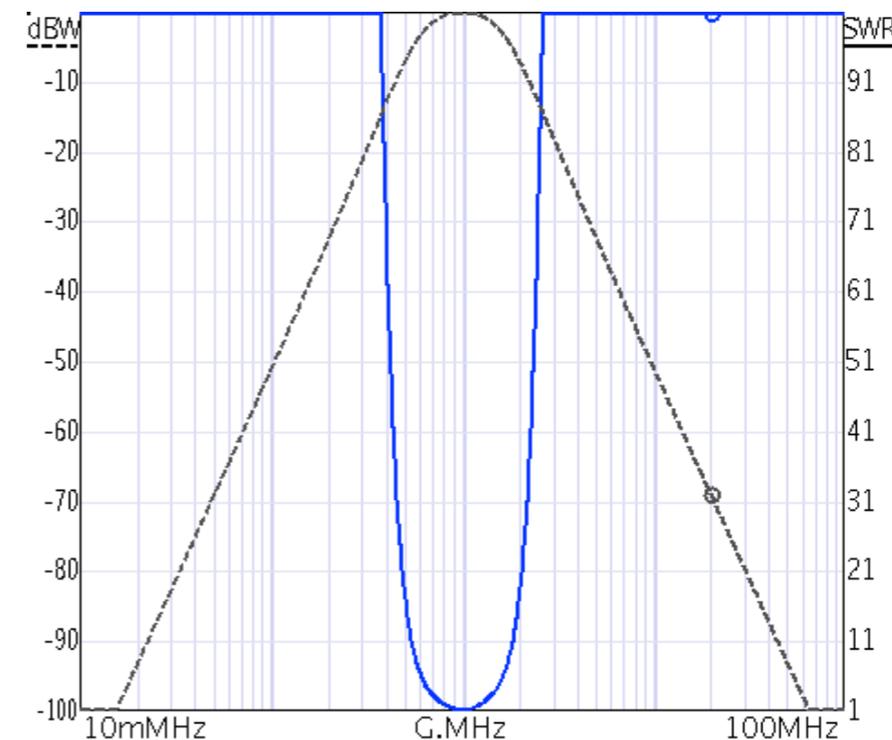
Here's a band pass filter transfer function:

Elsie



note 'log' scale on both...

SimSmith



Example: Transformers

SimSmith can model transformers in 4 ways:

transformer circuit element:

'almost ideal': primary inductance, perfect 'k'.

'coupled inductors': primary and secondary inductances with fractional 'k'.

F block:

$I^*(a^a)$ where argument a is turns ratio

N block:

'coupled inductors': two 'Ls' and a K line

Example: Transformers

As a circuit element:

set load value to, say, 10 ohms.

add transformer.

match up impedances.

notice primary inductance still there

set inductances to be 'BIG' to eliminate reaction

Show what happens with reduced 'k'.

That's why transformers are so 'non-ideal'!

Example: Transformers

In the F block: just $I*a*a$ for example

For the N block:

add L0

add L1

add K=1

Point out bug...

change $K=.9999999999$

Lesson: trust but verify the N block.

Example: F Block and Globals

F blocks (and N blocks) can access the parameters of other circuit elements.

For example, here are two back/back transformers where one is the inverse of the other: (Fblock.ss)

How can we use this?

Lets use it to explore the effects of a half wave transmission line with varying SWR.

Example: F Block and Globals

Lets look at the 'half wave length' transmission line.

In particular, how does it behave with impedances different that the transmission line. We've been taught that it "doesn't change the impedance".

Using two F blocks as transformers, lets see the effect of changing the SWR...

As we can see, as the impedance mismatch increases, the impedance is not preserved.

This is because of losses: see?

Example: Generator Models

The generator (G) element allows the user to specify the voltage out of the G model.

For evaluating 'impedances': who cares?

For evaluating power transfer: EVERYONE !

Generator element lets you write an equation for the voltage out.

Lets look at some examples:

Example: explicit V

The easiest Generator voltage equation is just a number, say “1”. In this case the generator will deliver 1 volt to the circuit.

Of course, you can use the parameter variables.

The next easiest to understand is the ‘fixedV’. When this is used, the generator will deliver ‘ $\sqrt{Z_0}$ ’ volts to the circuit. If the circuit presents an impedance of ‘ Z_0 ’ then the generator will be delivering 1 watt into the circuit.

Example: transMatch

The third easiest to understand is the 'xMtch' option. In this case, the generator will adjust the voltage as necessary to deliver 1 watt into the circuit regardless of the impedance.

This is useful when exploring losses in the circuit itself or when modeling a transmit amplifier which contains a tuner.

(drag match around and show constant 1 watt.)

Example: useZo Generator

Finally comes 'useZo'. This case is unique in that the generator is assumed to have an internal resistance of Z_o ohms. The voltage delivered to the circuit is adjusted so as to model this internal resistance with an internal voltage twice that of 'fixedV'.

The result is a generator which will deliver 1 watt into a perfectly matched circuit and less than 1 watt with other impedances.

Drag match around and show lower power except at 50 ohms.

This is useful for exploring filters and the 'maximum transfer theorem'.

Example: Q curve driven matching

Suppose you want to design a match of 10 ohms to 50 across a wide frequency range.

You can do this using the 'Q' curves.

Lets start with a Q of '4' which is quite high.
Lets match a 'bad' load of, say $3.5 - j7$.

Here is a frequency sweep: `q4example.ss`

Example: Q curve driven matching

If we change the Q curve to 2 and stay below it, we get a match which looks like....

And if we change the Q to 1 and stay below it we get:

looking at all 3 examples using 'reference'...

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Example: Two Port Matching

The fundamental function of SimSmith is to facilitate the match of a complex load to a real impedance.

However, there are times when you might want to match a complex load to a complex impedance.

Suppose your load is $75+j25$ ohms and your generator has an internal impedance of $12+j15$ ohms. How can SimSmith be used to do this match?

Example: Two Port Matching

First, remember that if the generator has an internal impedance of $12+j15$ ohms then we want our circuit to have an impedance of $12-j15$ ohms.

Where is this on the chart?

Add Z block to get 'back to the origin'.

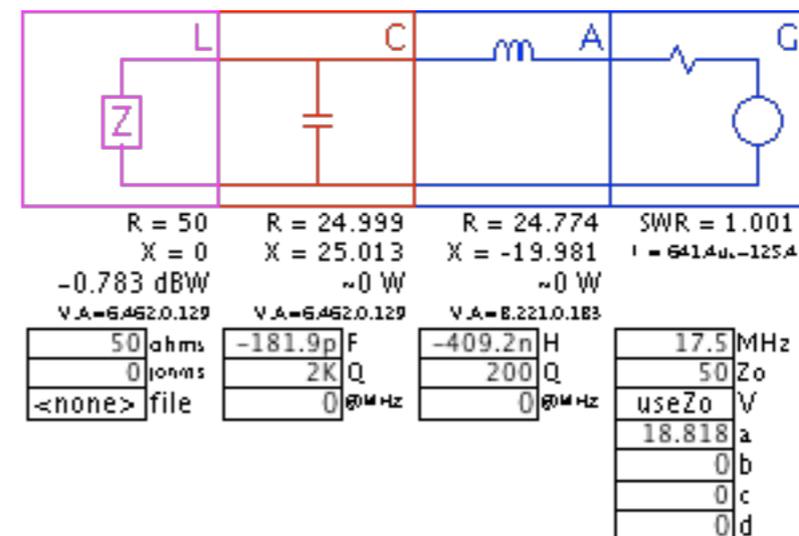
Now, set load to $75+j25$... adjust circuit. Note that the impedance before the Z is $12-j15$ just as desired.

Example: Reverse Operation

SimSmith can operate in 'reverse' by using negative component values.

Here is an example. Suppose we want to know the range of impedances which can be matched to 50 ohms by a particular L network with a given range of values for the L and C. Here is the circuit:

the 50 ohms of the Load can be matched to a range of values at the Generator

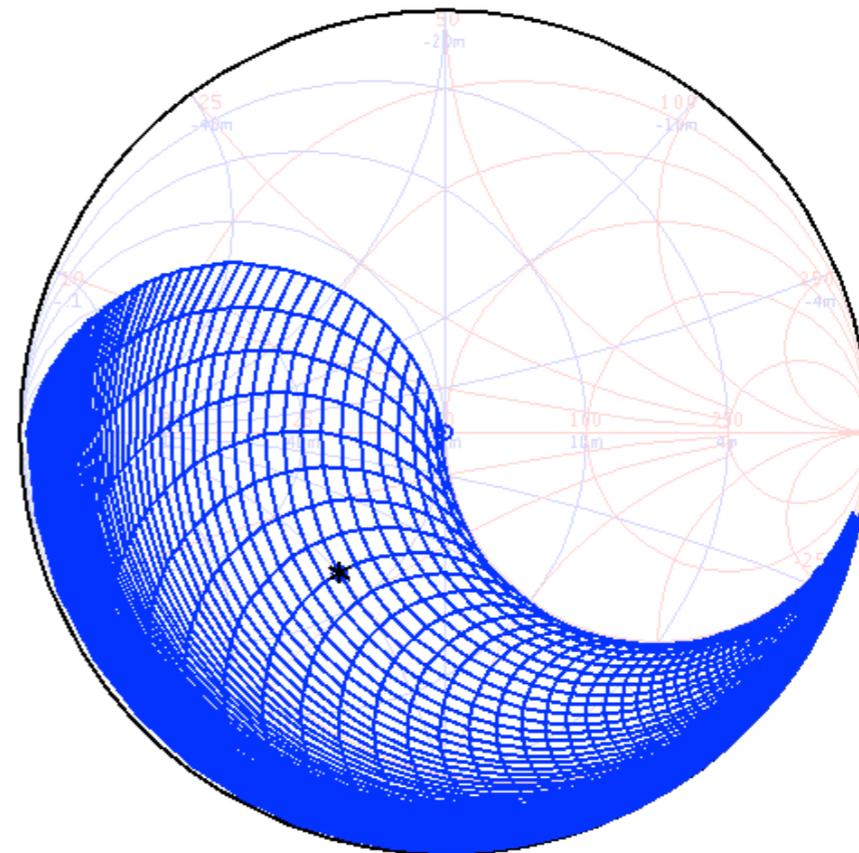


Example: Reverse Operation

Here the Smith chart where the L and C values are swept across a range of 'negative' values:

All the blue area can be matched to 50 ohms using
 $45\text{n} < L < 4.5\text{u}$ &
 $20\text{p} < C < 2000\text{p}$

| numPnts | | from | to | name | sweep |
|---------|-----|------|-------|-------|-------|
| 25 | lin | 10 | 30 | G.MHz | n |
| 100 | log | -20p | -2n | C.F | y |
| 100 | log | -45n | -4.5u | A.H | y |



Example: Reverse Operation

This computation can be done with both L networks simultaneously using F blocks (bothLs.ss)

F block for 'load'

F block for L

F block for C

Notice missing range. show plots at different L.ohms

Example: Maximum Power

Here's a fun example of maximum power transfer. Suppose we have a generator with a complex internal impedance.

We can write a Generator voltage equation which takes this internal impedance into account:
($Z_{ThevComplex}$)

Example: Maximum Power

Now, lets sweep the variables 'L.ohms' and 'L.johms'.

Now, lets look at the power being delivered to the load:

Now we can click on the peak of delivered power...

And see that it is the 'complex conjugate' of the Generator impedance just as predicted.

Example: N Block.

Here is an interesting example of using the N block.

Lets compare the Guanella and Ruthroff 4 to 1 baluns.

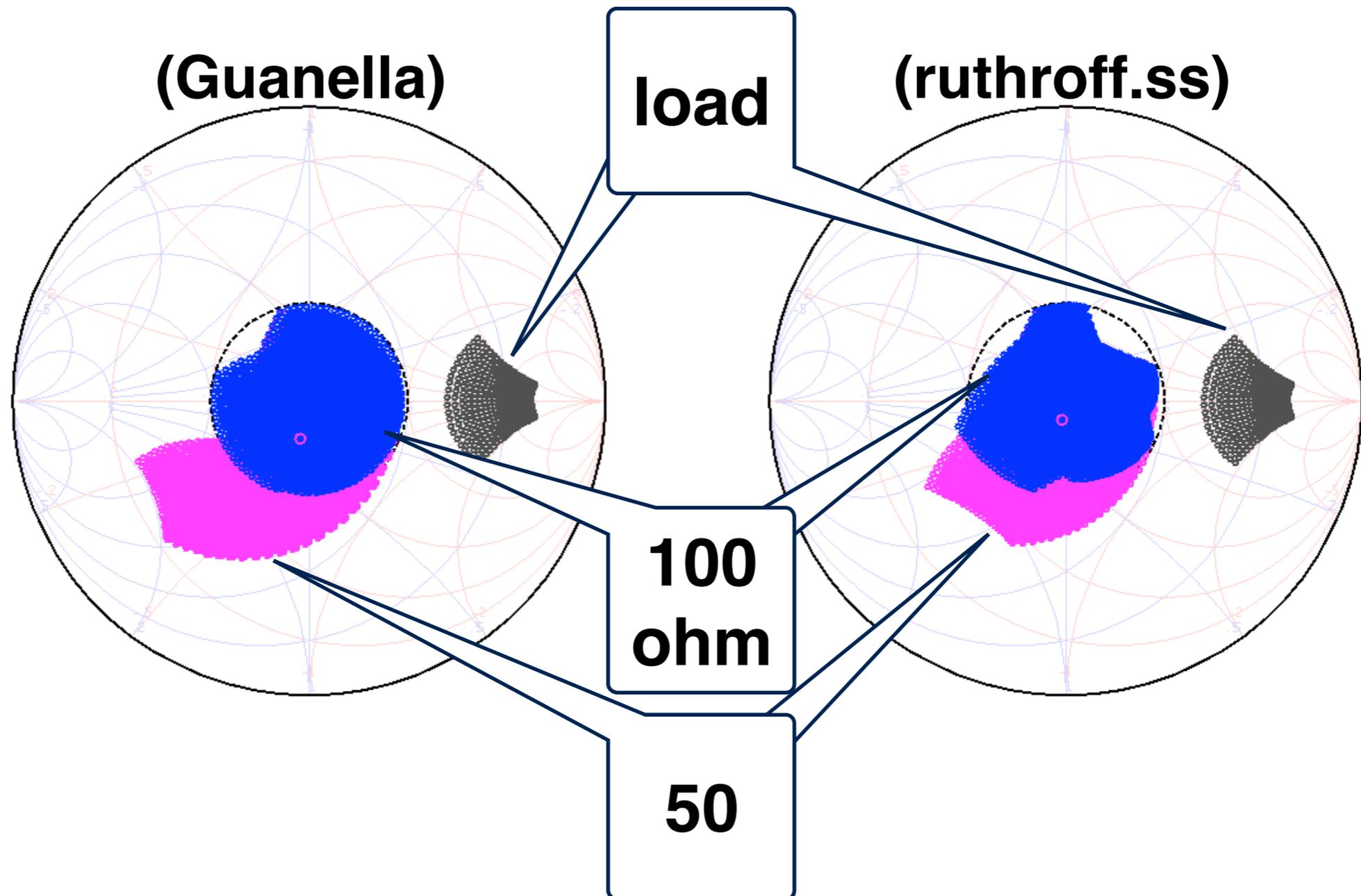
Of particular interest is their ability to match a range of load impedances down below 2 to 1.

(Guanella.ss)

Not how it isn't so good when Z_o isn't 100.

Example: Balun Comparison

Now lets look at the Ruthroff balan.



Wrap Up

Smith charts can be used to explore a wide variety of circuit behaviors.

With basic operation, SimSmith can be used to synthesize and analyze most basic circuits.

With the more advanced features and operator ingenuity, SimSmith can be used to explore many fundamental principles of electronic engineering.

Thank you....