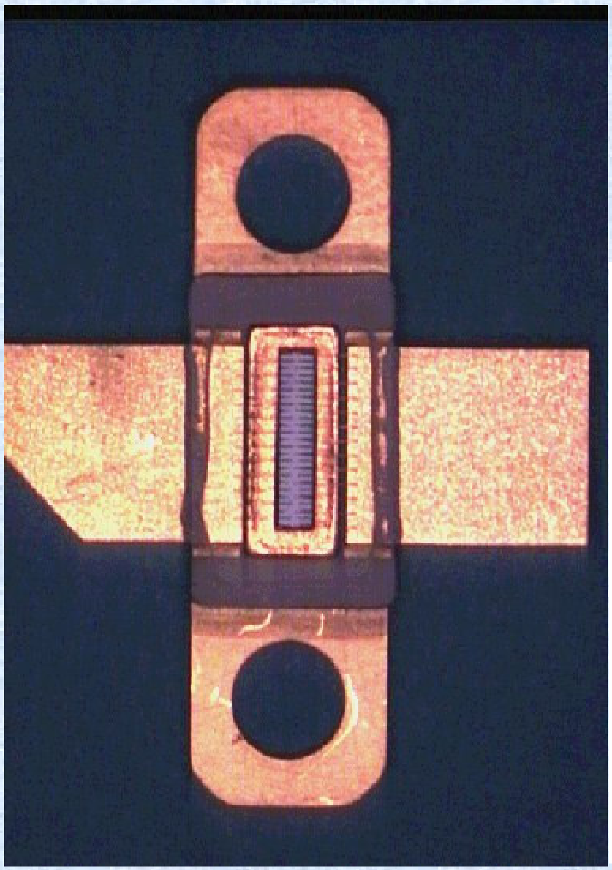
The Bodger's Guide to LDMOS Power Amplifiers

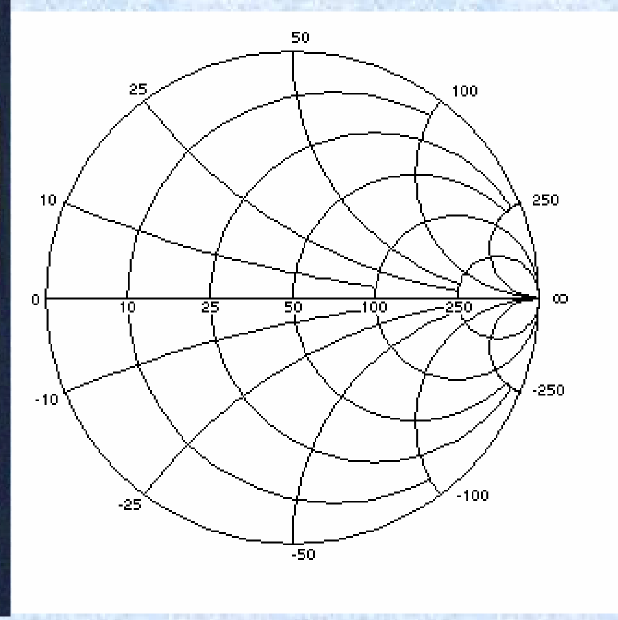
or

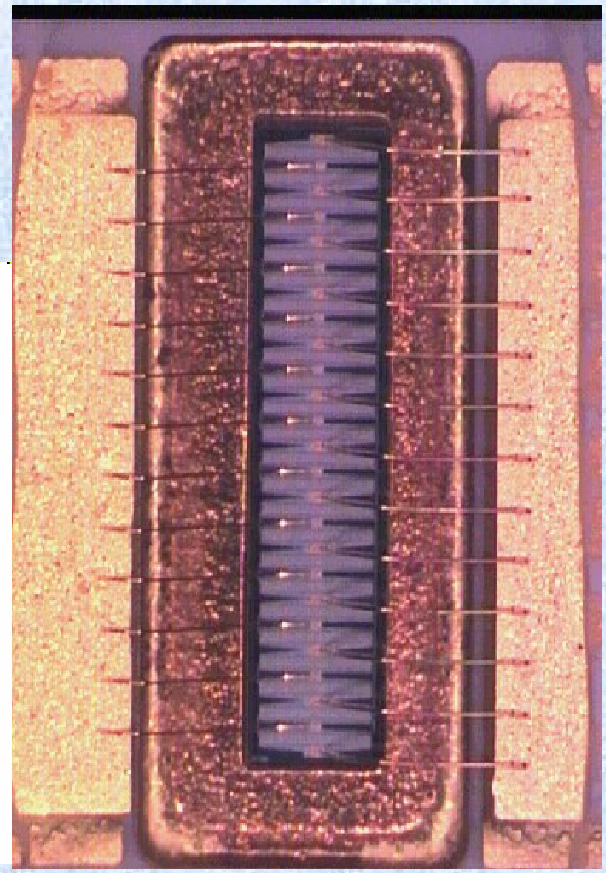
How to get serious SHF power without really knowing what you're doing!

John Worsnop G4BAO



Laterally **D**iffused **M**etal
Oxide **S**emiconductor



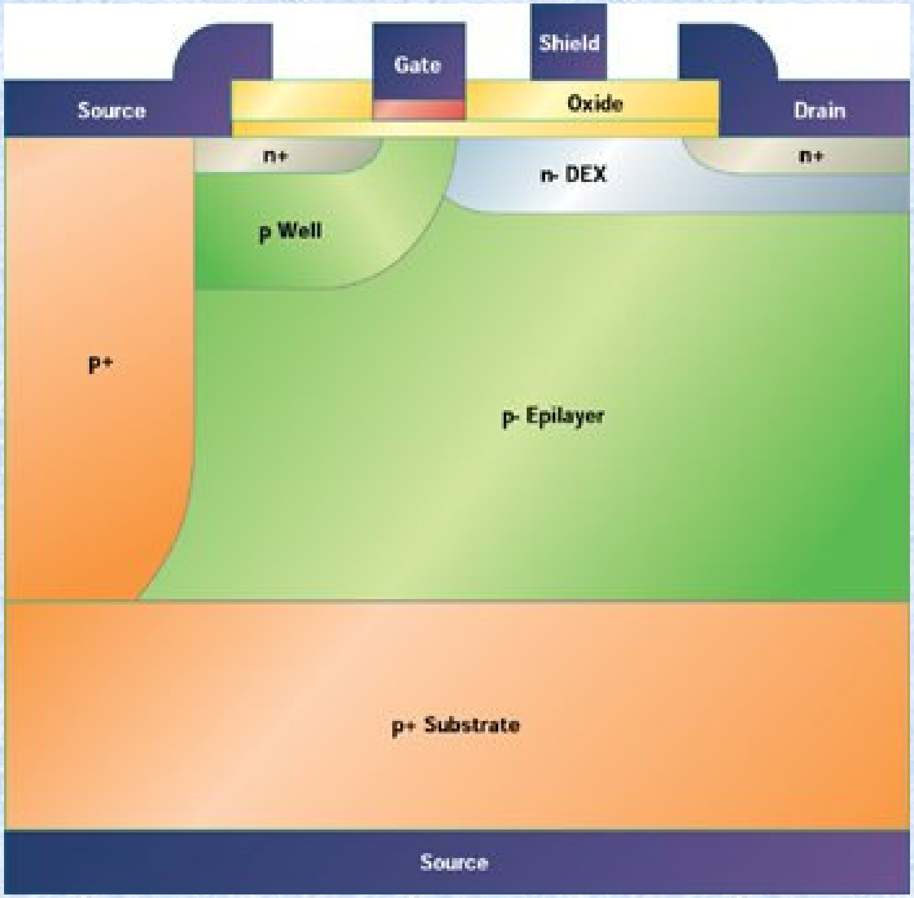


LDMOS for Bodgers

- Bodger – (noun)
  - A highly skilled itinerant wood-turner, who worked in the beech woods on the chalk hills of the Chilterns, in England
- Bodging (Br. Slang)
  - an inexpertly or roughly done job, typically in the field of DIY.

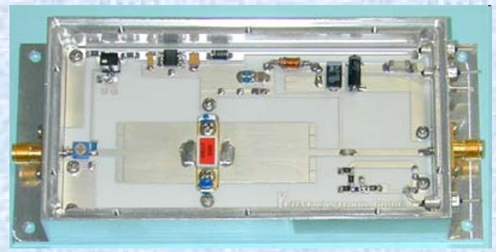
LDMOS for Bodgers

- Modified N-channel MOSFET.
- Three terminals of the transistor are accessible from the top of the chip.
- and source is at the bottom allowing direct connection to ground.
- No nasty beryllium oxide insulator needed.
- matching circuitry can be added within the transistor package.
- Devices that operate up to about 4GHz
- Vdd typically 28 or 50V.
- 100 Watt plus devices at 2GHz
- Simple positive gate bias circuitry.
- Hard to destroy in development.

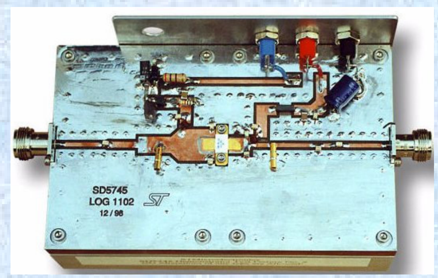


Amplifier Choices for Amateurs

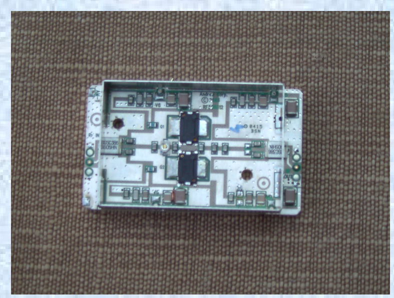
- **Buy one (£££)!**
  - » **image © DB6NT**



- **“Grow your own”**
  - » **Various kits available**

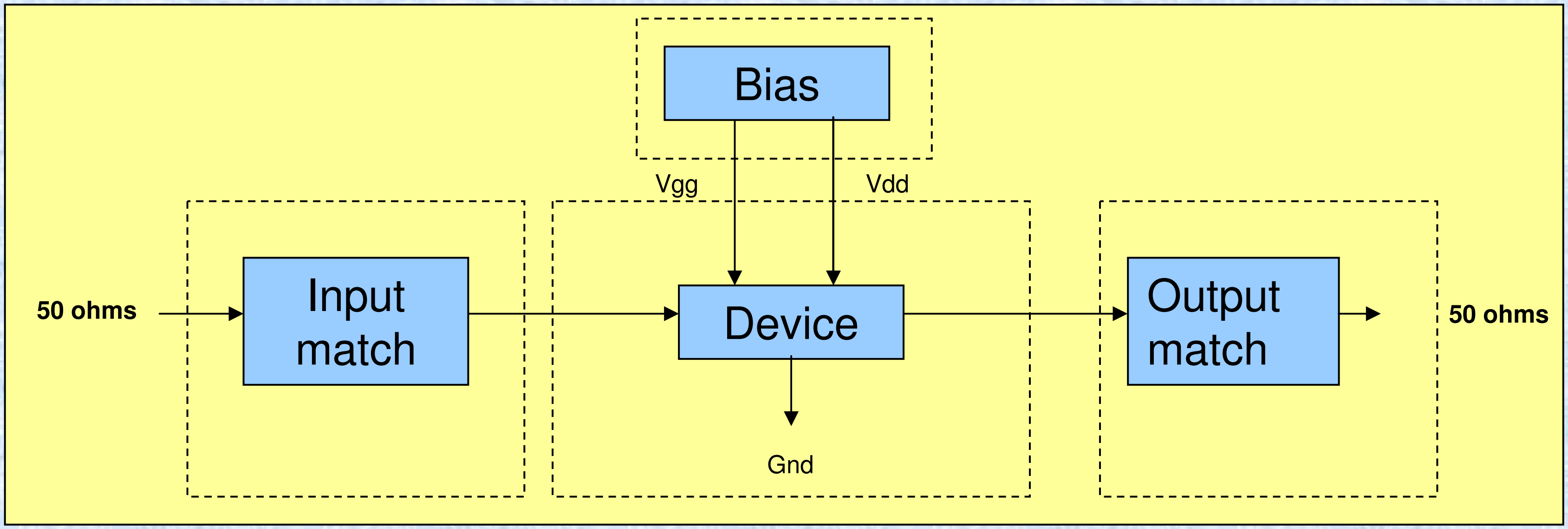


- **Modify surplus**
  - » **The Bodger’s choice**



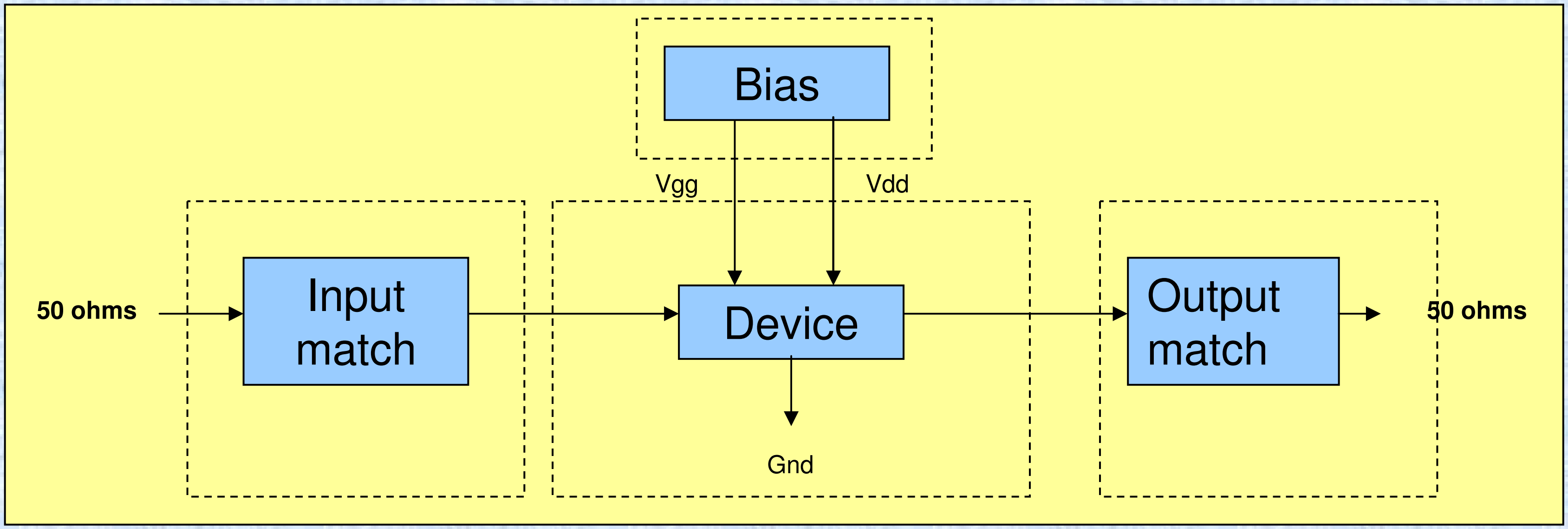
It's the impedances, stupid!

- Power transistors are low impedance devices.
- Typically less than 1ohm, resistive and reactive
- You have to match them to 50ohms
- Matching circuits have a bandwidth



It’s the impedances, stupid!

- So the (Bodger’s) design process is:
  - Make the device look like 50 ohms in and out by transforming its impedances over the required bandwidth.
  - Make sure the impedance matching doesn’t make the amplifier unstable at other frequencies.



So we need the device datasheets, right?

- **WRONG!**
  - Fine if data is available for the frequency you need
- Most SHF LDMOS is designed for cellular radio.
  - 900MHz, 1.8GHz, 2.1GHz, **2.3GHz**
- So we're OK for 13cms then…but I want a 23cms PA.

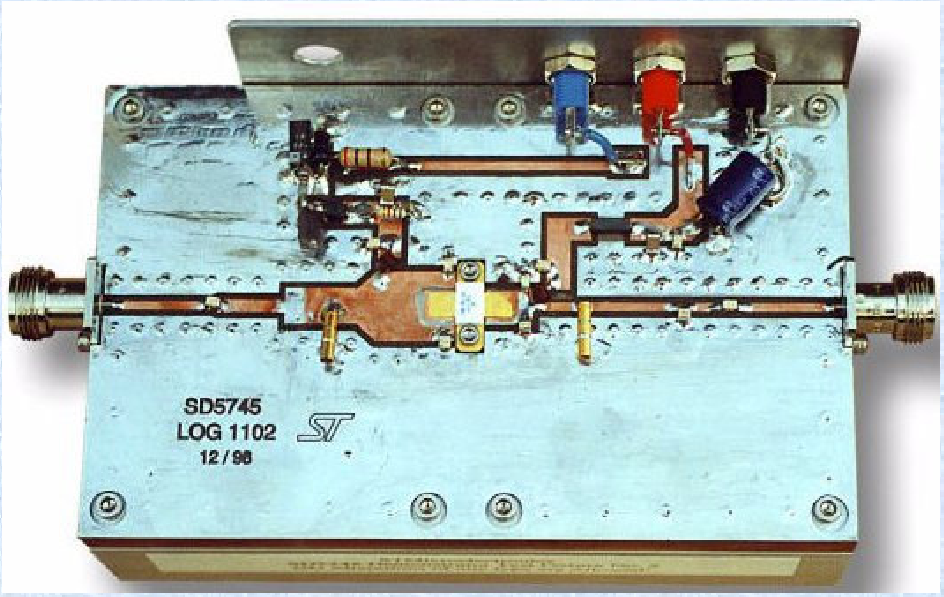
So we're stuck?

- Amateurs don't have the technology to measure device impedances.
- So let's call upon…………………..

The Bodger's subroutine!

Applicable to a "new" design or retuning surplus

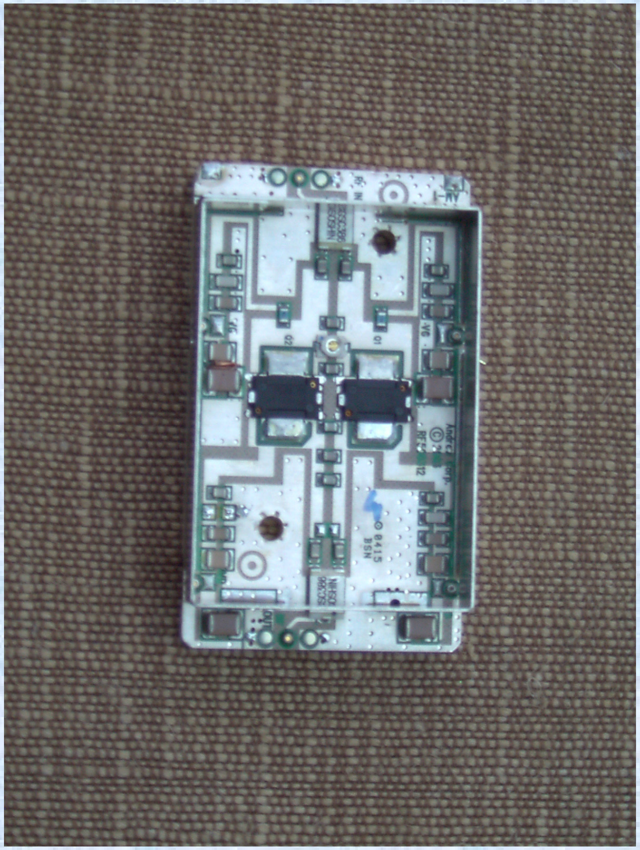
```
make intelligent stab at what
   you think might work
then
 repeat
        cut
        try
        optimise
 until working satisfactorily
end
```



The LDMOS Bodger’s toolkit

- Along with a soldering iron, the basic tools are:

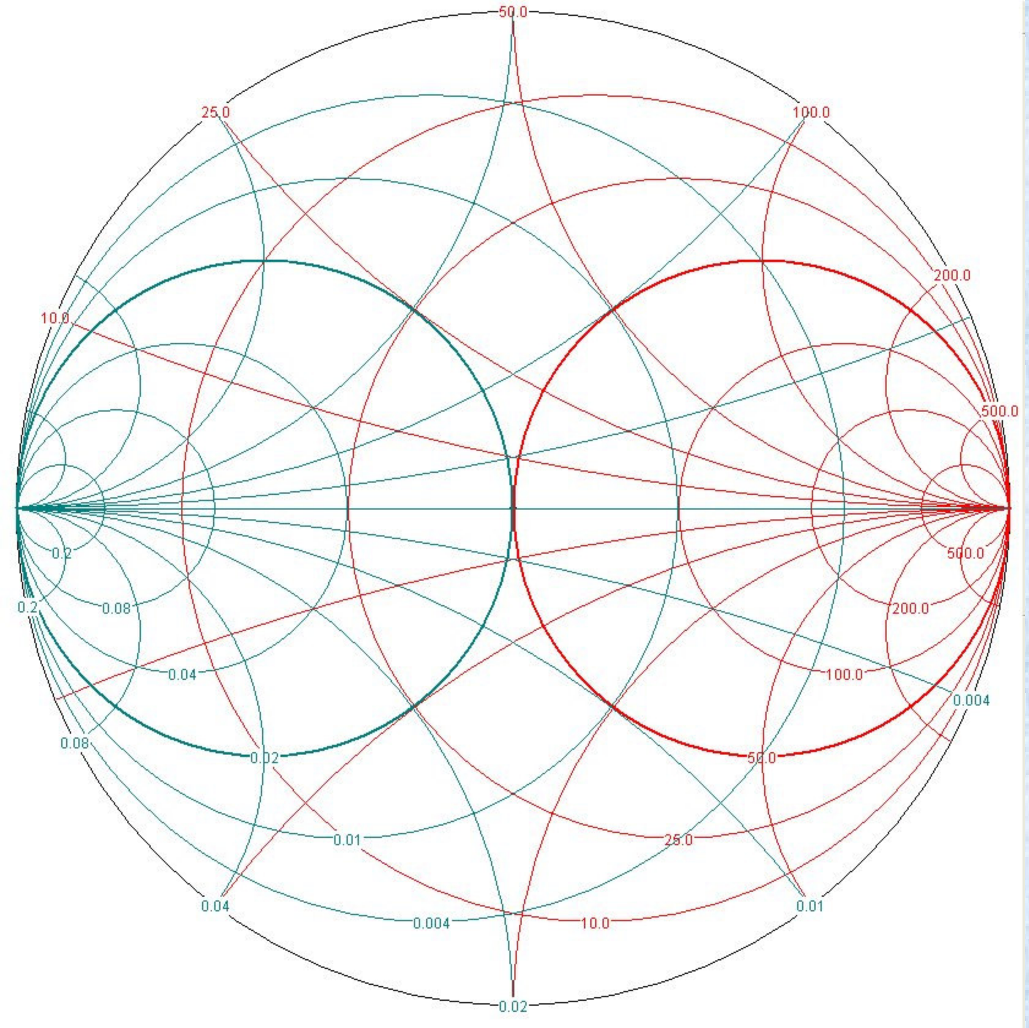
- pair of cheap vernier callipers
- a roll of adhesive copper tape
- a sharp scalpel
- a roll of plastic insulation tape
- a Smith Chart program
- “Appcad” program



and of course, something to bodge

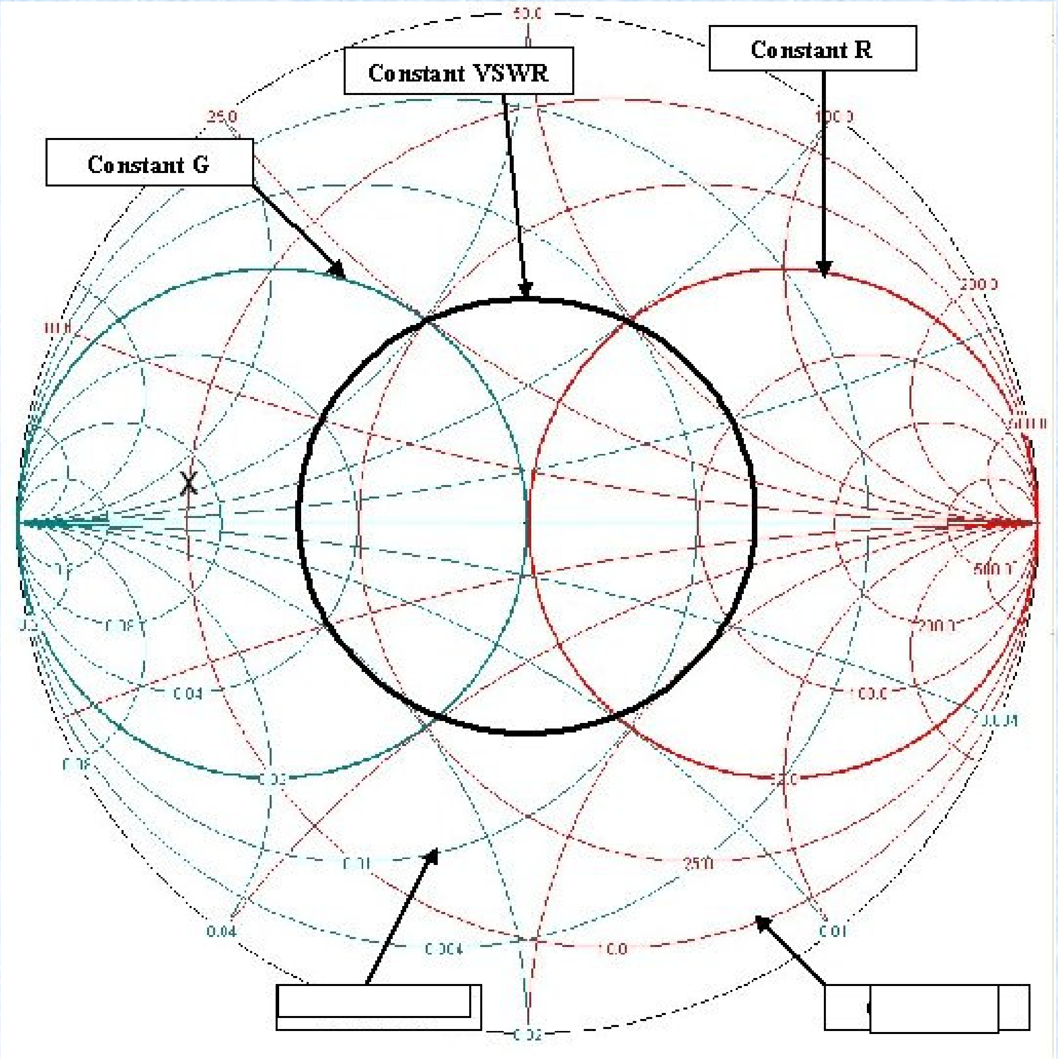
A brief aside on the Smith Chart

- **"Immittance" Chart**
- A whole day could be given over to its usage
- It allows you to plot complex impedances, admittances and line lengths.



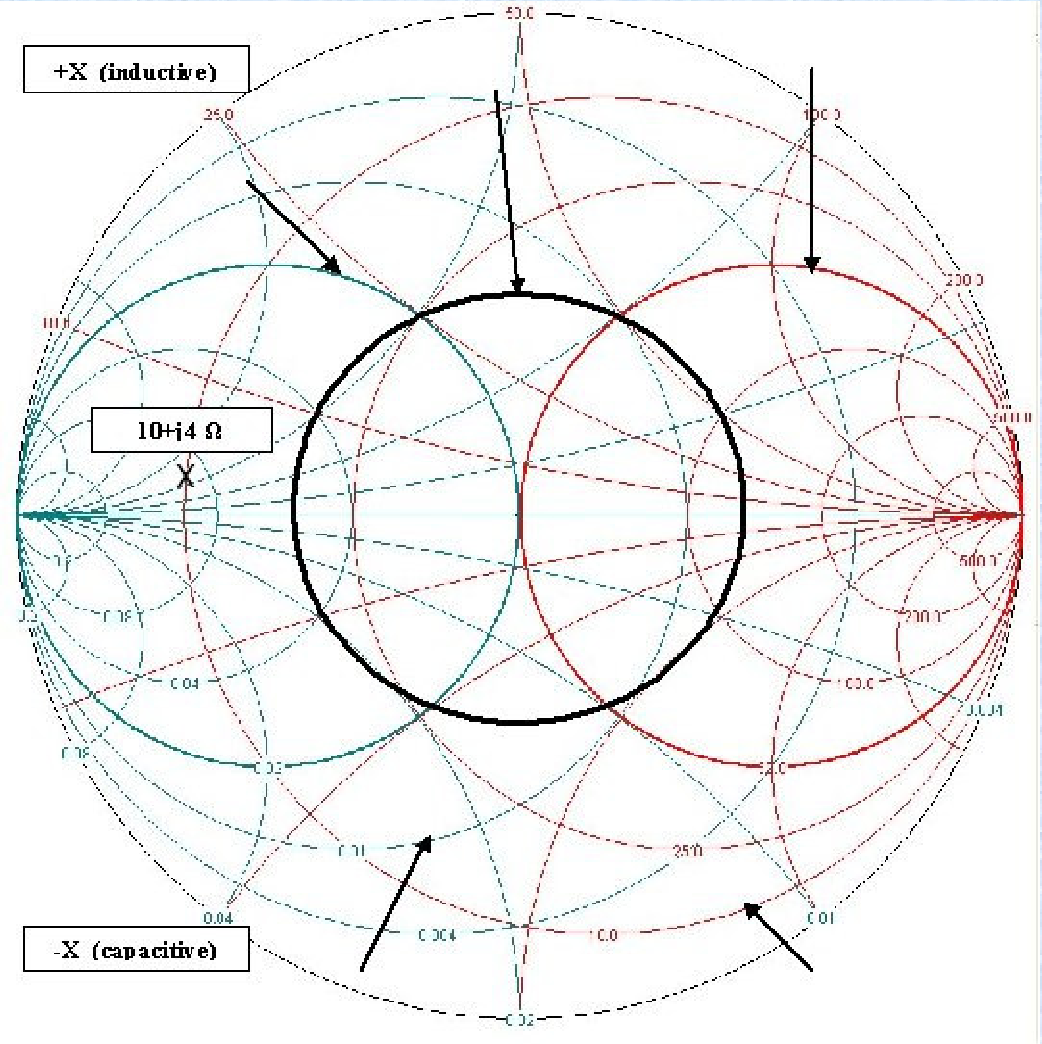
A brief aside on the Smith Chart

- Series L or C moves you along constant R circle
- Shunt C or L moves you along constant G circle.



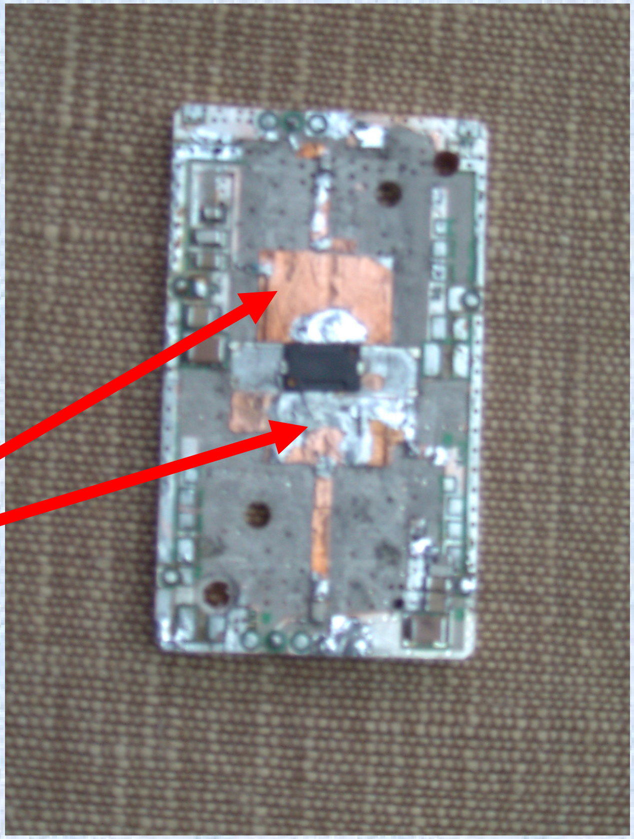
A brief aside on the Smith Chart

- Usually use "normalised" impedances,
  - i.e (actual Z)/Zo
- Positive reactances (Inductive) are in the upper half of the chart
- Negative reactances (Capacitive) are in the lower half of the chart
- Impedance can be plotted directly

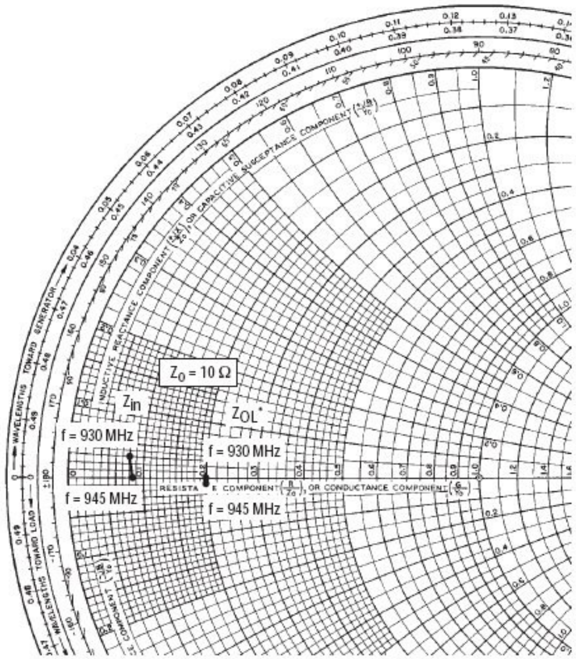


Something to Bodge for 23cms

- 900MHz Cellular base station amplifiers
- Look at the device datasheet.
  - Avoid devices that are internally matched.
  - Really high power ones tend to be.
- Using the Bodger's subroutine, either:
  - strip off all matching and try again from scratch using sticky copper foil.
    - Use a "T" step from very wide down to typically 7 -9 ohm line on input.
    - 5-7 ohm line on output, and trim length starting at 0.25λ
- or
  - Use existing lines and try to move input match then Pout up in freq in stages by changing capacitor values.



Freescale MRF9045



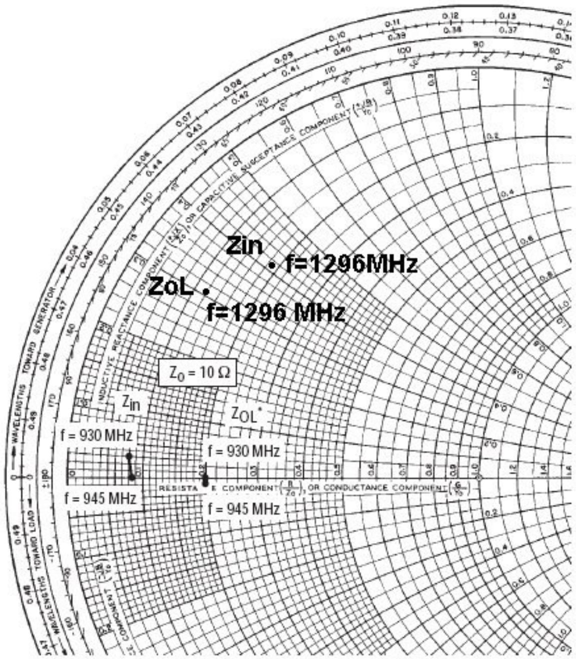
$V_{DD} = 28$ V, $I_{DQ} = 350$ mA, $P_{out} = 45$ W (PEP)

f MHz	Z_{in} Ω	Z_{OL}^* Ω
930	0.81 + j0.25	2.03 – j0.09
945	0.85 + j0.05	2.03 – j0.28

Z_{in} = Complex conjugate of source impedance.

Z_{OL}^* = Complex conjugate of the optimum load impedance at a given output power, voltage, IMD, bias current and frequency.

Freescale MRF9045 1296MHz



V_{DD} = 28 V, I_{DQ} = 350 mA, P_{out} = 45 W (PEP)

f MHz	Zin Ω	ZoL* Ω
1296	1.9+j4.1	1.2+j3.1

Z_{in} = Complex conjugate of source impedance.

Z_{OL}* = Complex conjugate of the optimum load impedance at a given output power, voltage, IMD, bias current and frequency.

"measured" impedances

Reverse Engineer the existing input circuit

- Determine the board thickness and material
  - Find a 50ohm line and measure its width (say 1.8mm)
  - Use Appcad to work out εr
- Measure Ls, Cs and microstrip lines
  - Scale line lengths by 1296/900
- Plot on your Smith Chart
  - Assume that Zin increases from 900-1296 and see which way the final match goes
- Iterative process
  - Change a C based on above see if amp matches better at 1296.

Reverse Engineer the existing input circuit

Example 1.7+j1 at 900MHz from datasheet

- Matched with 0.131λ 12Ω, series, 10pF shunt, 10pF series

- 0.131λ = 0.188λ at 1296
- Assume Zin changes to 3+j3 and see what C will have to do to rematch

Do's and don'ts

- DO try and avoid shunt capacitors (losses)
- DO Watch the output capacitor's rating and type.
  - 100Watts in to 50 ohms means that 1.4 Amperes of RF is flowing.
- DO try and avoid trimmers except when "bodging".
  - Shunt capacitors have high currents as well
- DO recycle as much of the original amplifier as you can
- DON'T bother trying internally matched devices.
- DON'T put too much gate bias voltage!
- DON'T use standard FR4 board material for new designs.
  - At even 30 Watts it cooks!

Acknowledgements

- LDMOS pictures – ST Microelectronics
- "Smith" program Prof. Dellsperger Univ of Berne
- Appcad program