The Bodger's Guide to………………………………. LDMOS Power amps for 23cms

Introduction

- Bodger – (noun)
  - A highly skilled itinerant wood-turner, who worked in the beech woods on the chalk hills of the Chilterns, in England.

- Bodger (British. Slang)
  - Someone who carries out an inexpertly or roughly done job, typically in the field of DIY.

Many years ago when I worked in RF professionally I had a colleague who referred somewhat unkindly to some of his fellow design Engineers as "Bodgers," due to their innate ability to get a design to work reliably without really knowing why. In the software world, this dangerous technique is now more commonly referred to as "Hacking," and has been the downfall of many professional software systems over the years. While not something I would recommend to the professional design engineer who has to make hardware designs for use by the thousand or million, sometimes as a Radio Amateur one is sometimes forced in to "bodging" due to lack of information or just having something to start with that is close to one's needs but not quite there.

The technique can be summed up as:

```
Make an intelligent stab at what you think might work
then
      repeat
            cut, try, optimise
      until working satisfactorily"
```

I like to call this "the Bodger's Subroutine."

So, this is the Bodger's guide to LDMOS power amplifiers for 23cms. I'm sure professional designers will groan as they read this, but if the result is cheaper 23cm power, then, who cares?

The LDMOS Bodger's toolkit

All good Bodgers need tools.

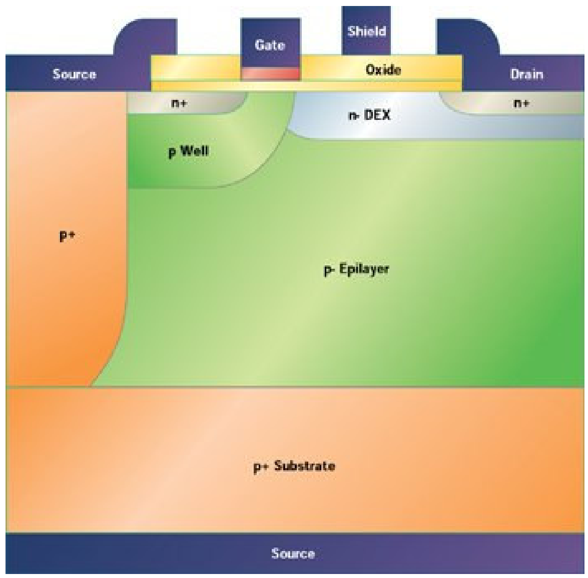
Along with a soldering iron, the basic tools are:

- a 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

LDMOS for dummies

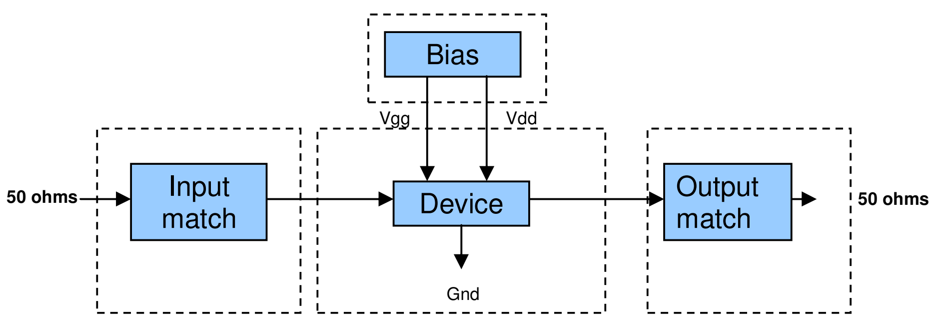
LDMOS stands for "Laterally Diffused Metal Oxide Semiconductor." It is modified N-channel silicon MOSFET. The tree terminals of the transistor are accessible from the top of the chip, and the source is at the bottom allowing direct connection to ground. This means that no nasty beryllium oxide insulator needed, and a good thermal path to the heatsink, and an electrical ground can be provided.



Matching circuitry can be added within the transistor package, and devices are available that operate up to about 4GHz with a Vdd of typically 28 or 50V. There are 100 Watt plus devices at for 2GHz, they require simple positive gate bias circuitry and they are hard to destroy during in development, making them idea for the Bodger.

Using LDMOS devices

Power transistors are low impedance devices, typically less than 1ohm, resistive and reactive, to use them with antennas, you have to match them to 50ohms over your required bandwidth

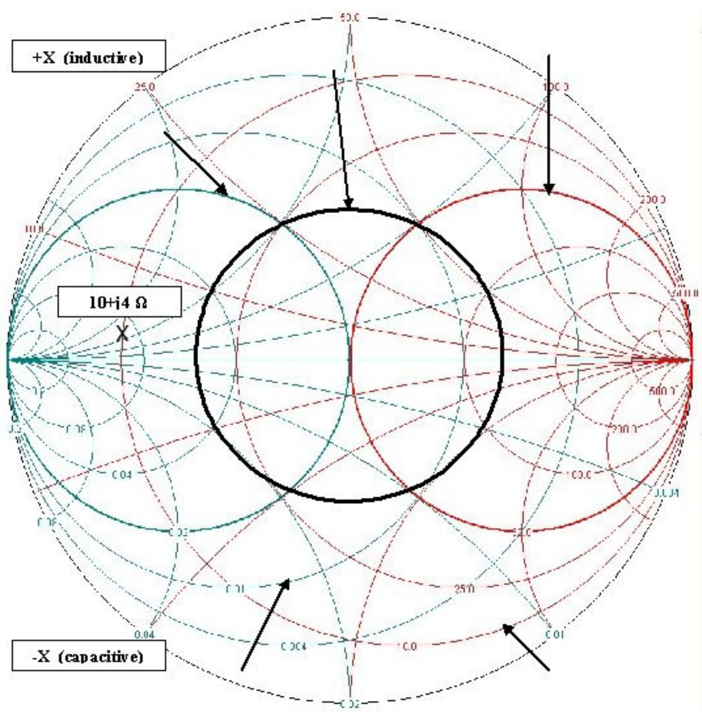


In a perfect world we just get the device datasheets for our frequency and design matching networks. This is fine if data is available for the frequency you need, but most SHF LDMOS is designed for cellular radio and that is around 900MHz, 1.8GHz, 2.1GHz, and 2.3GHz. So we're OK for 33 and 13cms then…but I want a 23cms PA. We therefore need to apply "the Bodger's subroutine"

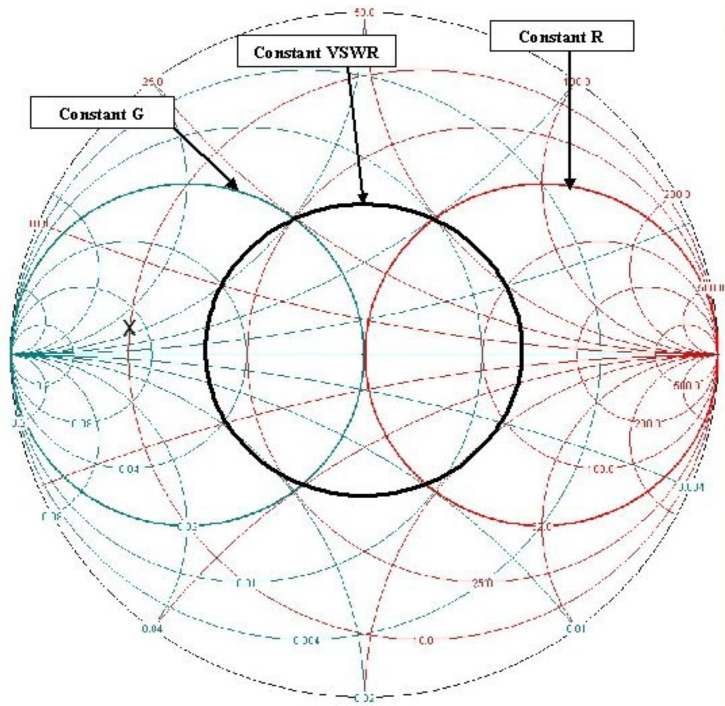
A brief aside on the Smith Chart

The chart below is called **an "Immittance" Chart. A** whole day could be given over to its usage, but basically it allows you to plot and manipulate complex impedances, admittances and line lengths. Hence matching networks can be designed.

It is usual to plot "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.



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



Simplified Example of the approach

Converting a 900MHz amplifier module when there is no impedance data for the device above 960MHz. The design will have to be "cut and try"

In general, look at the device datasheet and avoid devices that are internally matched as the really high power ones tend to be. The MRF9045 meets this criterion.

Looking at some photos and real hardware for other designs for this and similar devices (see DG0VE, G4HJW and DB6NT) and getting out my vernier callipers, it seemed that to match these devices at 23cms requires a pretty simple microstrip network with low impedance (i.e wide) lines on the input and output. Half a day playing with Appcad and my Smith chart programme allowed me to get a reasonable handle on the required matching circuit.

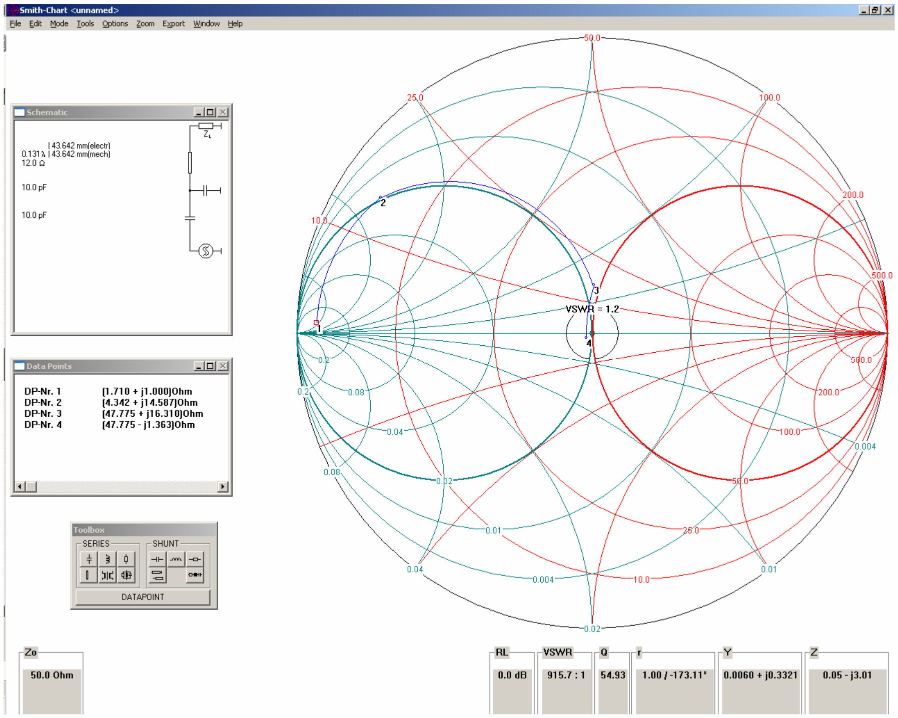
Using the Bodger's subroutine, either:

  - 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.

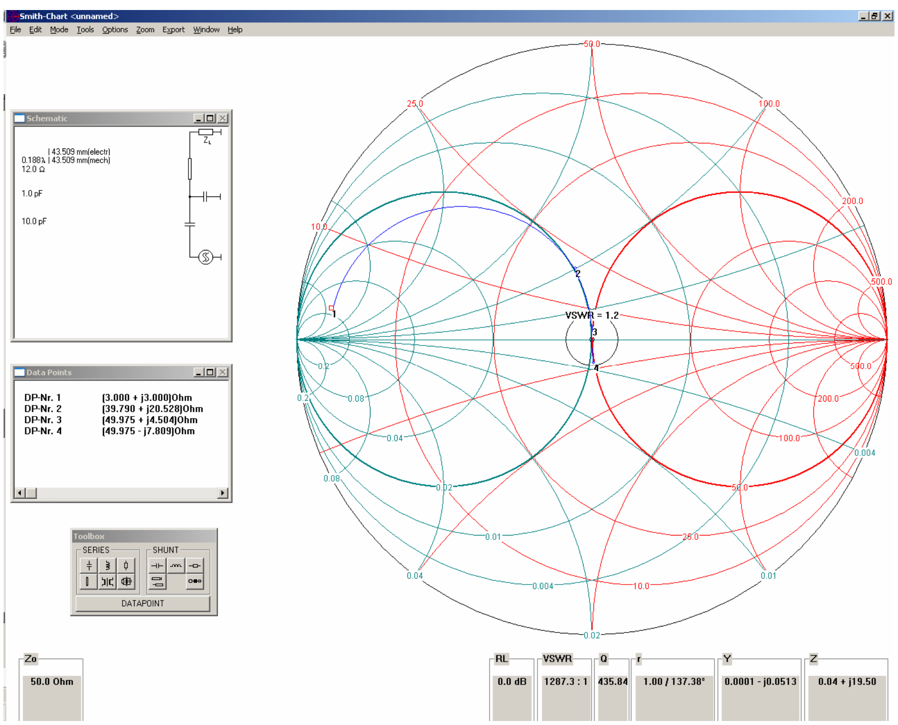
Simplified example - Reverse Engineering the 900MHz input match

Example 1.7+j1 at 900MHz from datasheet

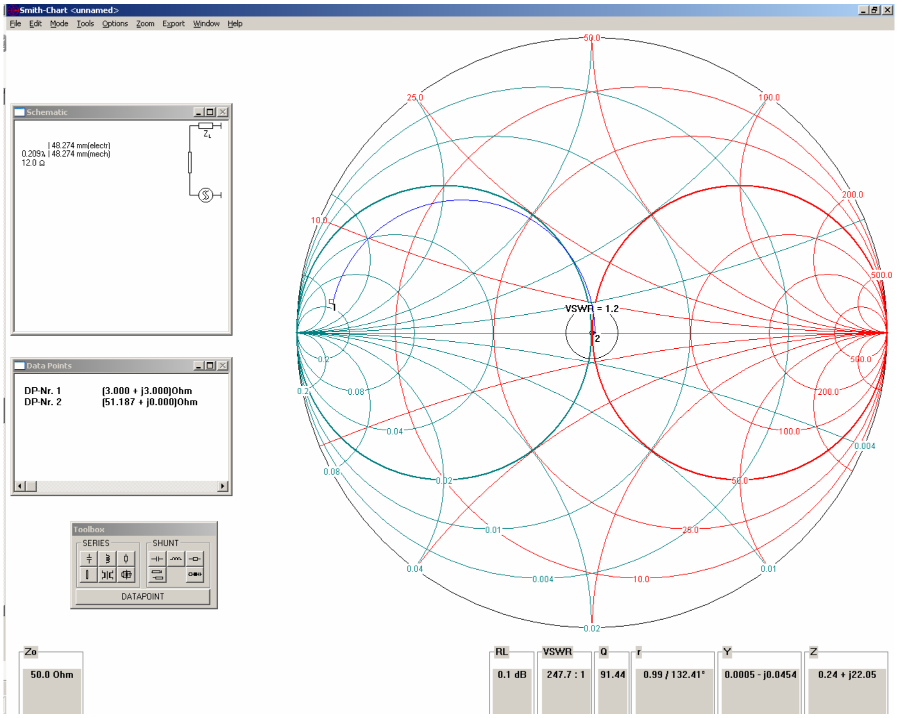
Matched at 900MHz with 0.131λ 12Ω, series, 10pF shunt, 10pF series



Now, 0.131λ = 0.188λ at 1296, Make an educated guess, and assume Zin changes to 3+j3. Let's see what C will have to do to rematch?



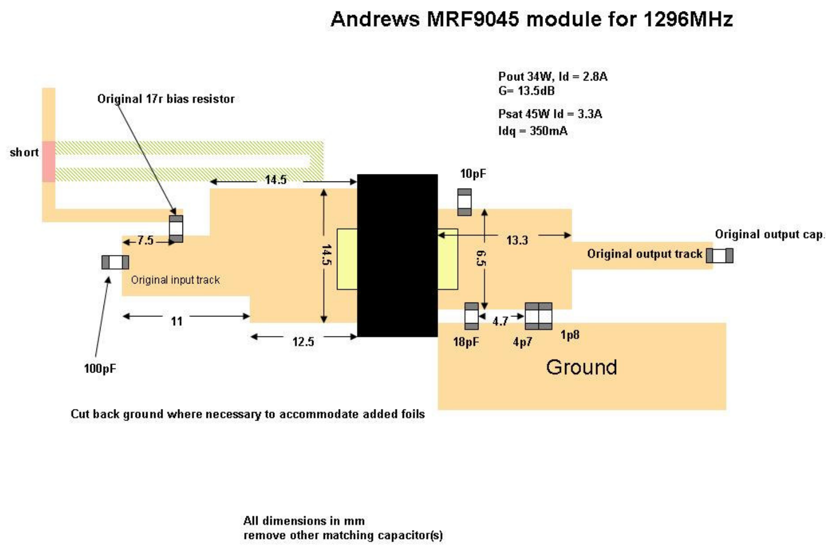
It needs to be around 1pF with the same series C of 10pF. Temporarily fit a trimmer, try it and see if the match really improves. (Actually C could be removed completely and the line lengthened to 0.209 λ and a larger DC block used.)



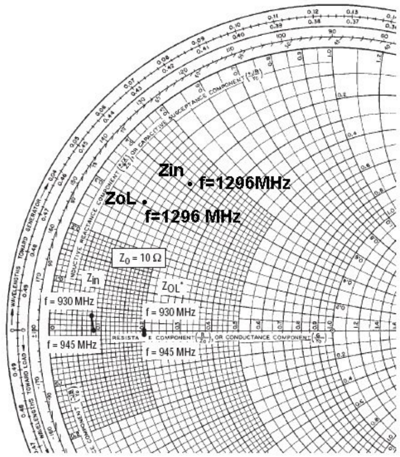
An Andrew Corporation 900MHz MRF9045 module

I removed all the existing components except the bias decoupling capacitors and the output capacitor and cut track and added copper tapes until I got a match and the correct output. Peeling off the existing copper microstrips is relatively easy with a sharp scalpel, but take care not to rip off too much insulation under the copper.

After much tweaking, I ended up with the following layout and performance.



Once you've come up with a working bodge you can measure the matching lines with vernier callipers and back – calculate to the device impedances at 1296MHz.



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.

"Measured" impedances

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