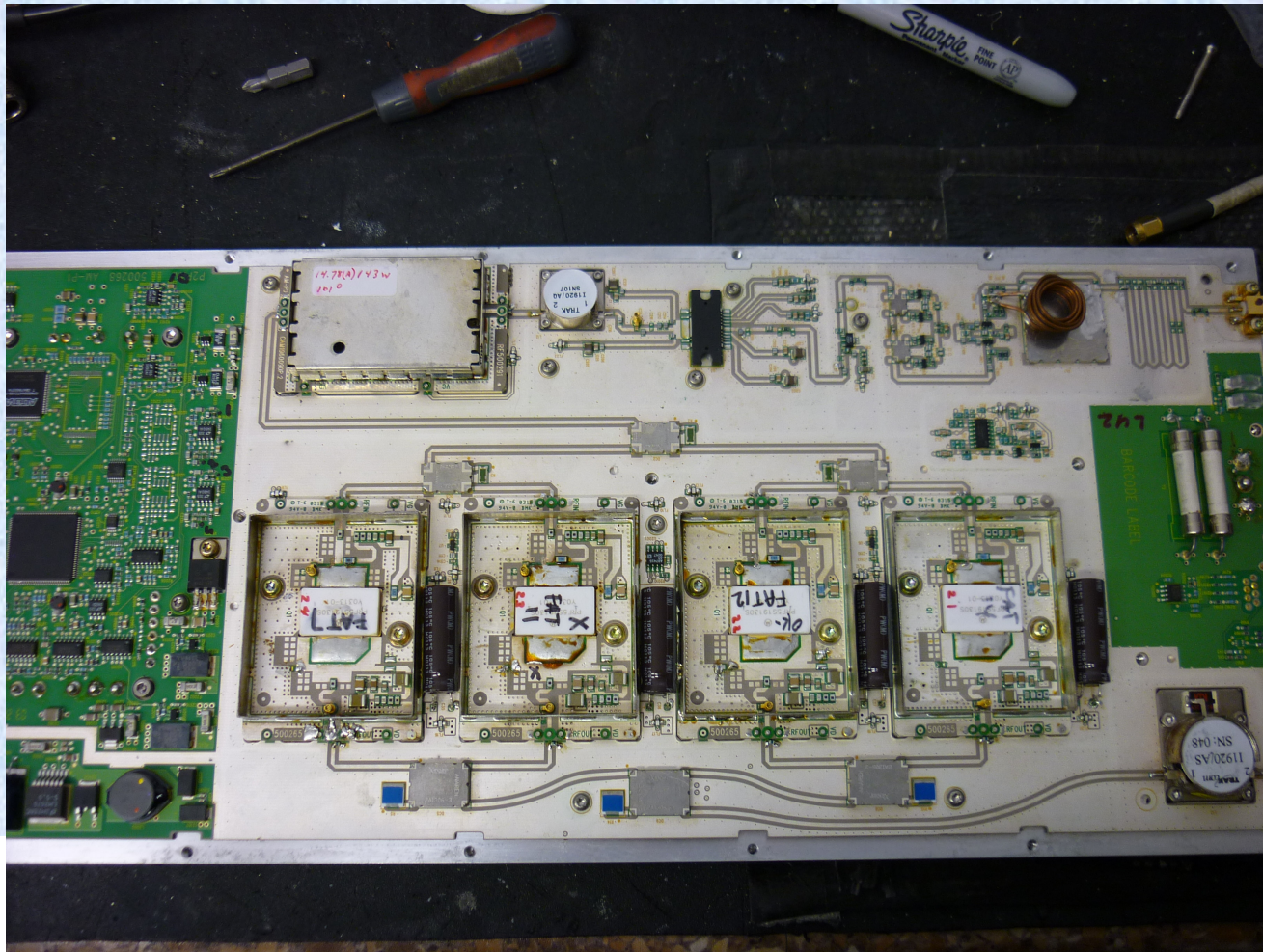


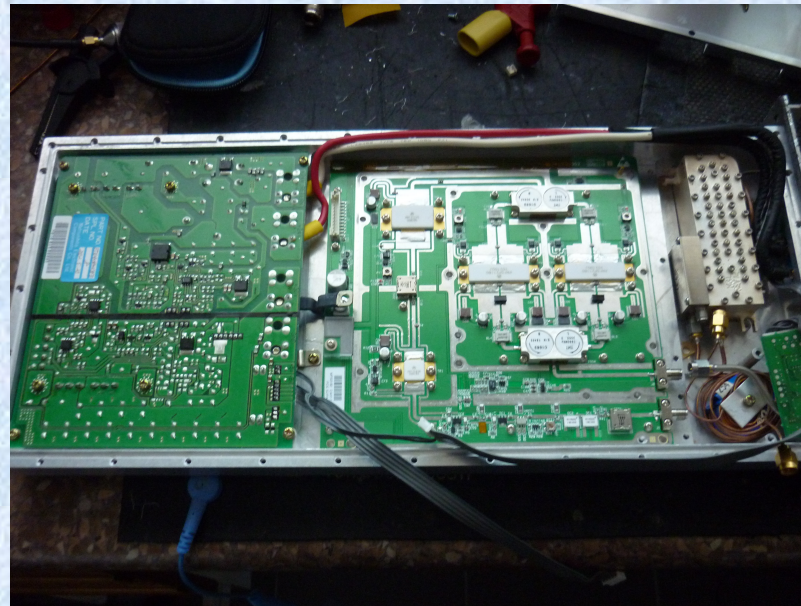
Modifying 1960MHz High Power Solid state Amplifiers for 13cm

John Worsnop G4BAO



Available amplifiers and their configuration

- Cellular, operating at 1960MHz or 2100MHz
- Original specification of 30 Watts per carrier, so a multi carrier CDMA amplifier typically had the potential for over 200 Watts in CW or SSB mode.
- Amplifiers such as the ILAM, IPAM, PKLAM and P2PAM looked good targets, along with a number of others from the Andrew Corporation
- Paper by R.L Frey WA2AAU first brought to my attention the possibility that 1960MHz amplifiers could be “stretched” up to 13cms.

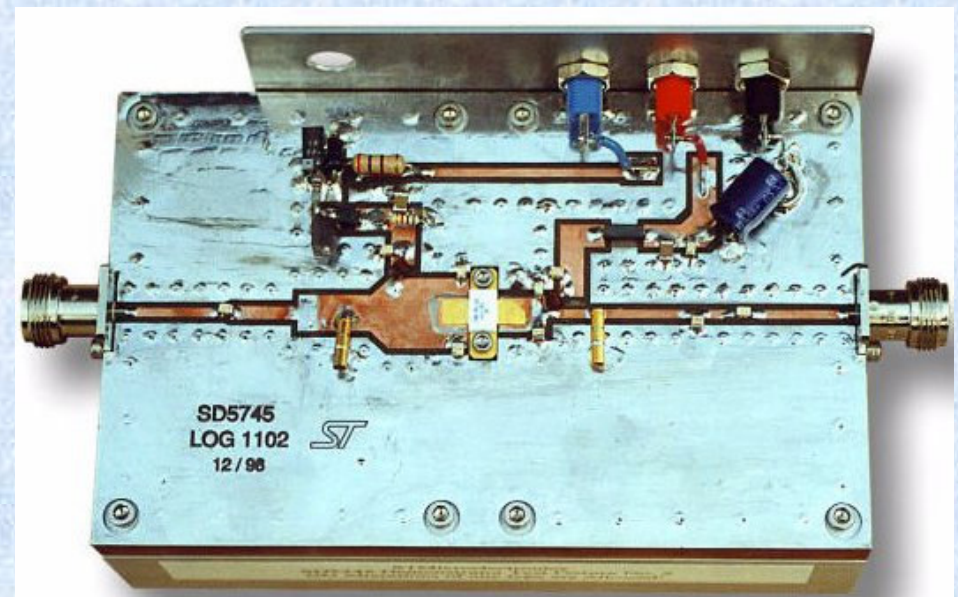


1960MHz vs. 2120MHz amplifiers (hard vs. easy!)

- Most 2120 Amplifiers work on 2320 without RF modifications, beyond simple retuning.
 - “Fix” the bias, provide a PTT line and off you go
 - Too Easy!! ☺
- I wanted to try moving a a basic RF design for 1.9GHz up to 2.3GHz
- But high power FETS are internally matched I hear you all say!
 - That’s a challenge, not a problem, and it’s only 400MHz after all!!
- For me, this has to be a cut and try approach, as I do not have the equipment to characterise the devices at 2320MHz.
- Time to call upon.....

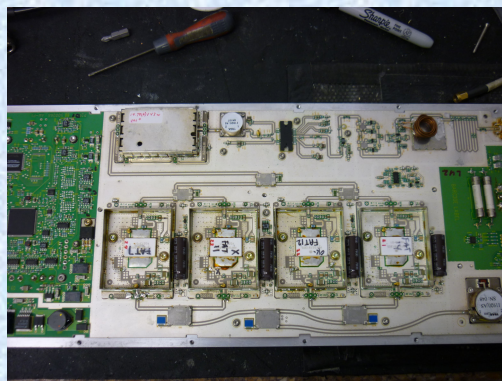
The Bodger's subroutine!

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

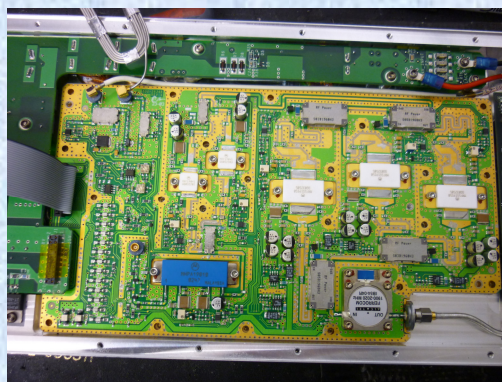


Amplifier Topologies

- Pallet amplifier

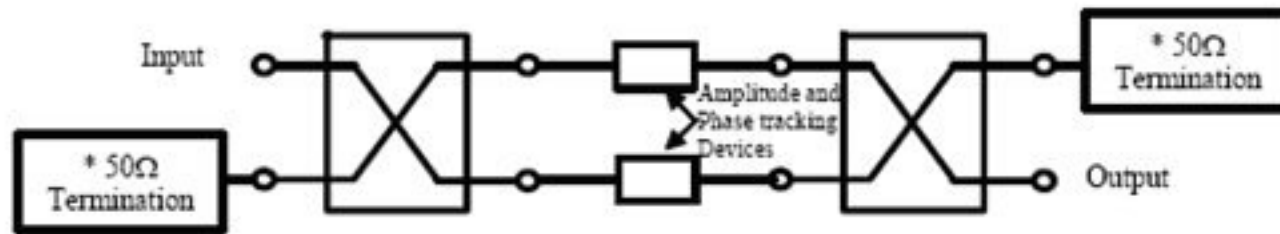


- “All in one” amplifier

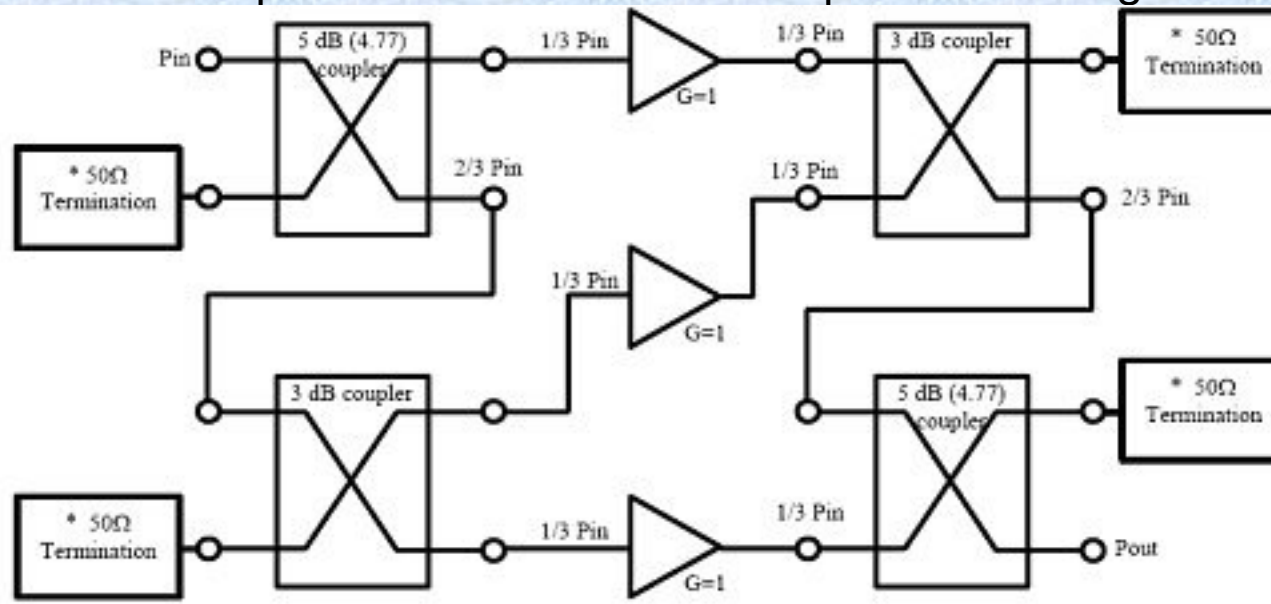


Amplifier Topologies

Two output devices with quadrature hybrid combining

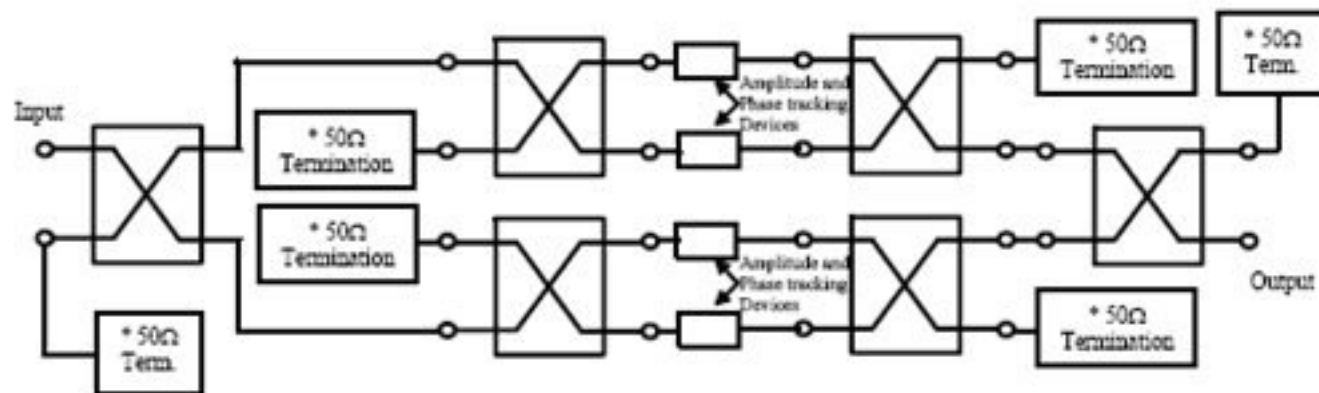


Three output devices with more complex combining

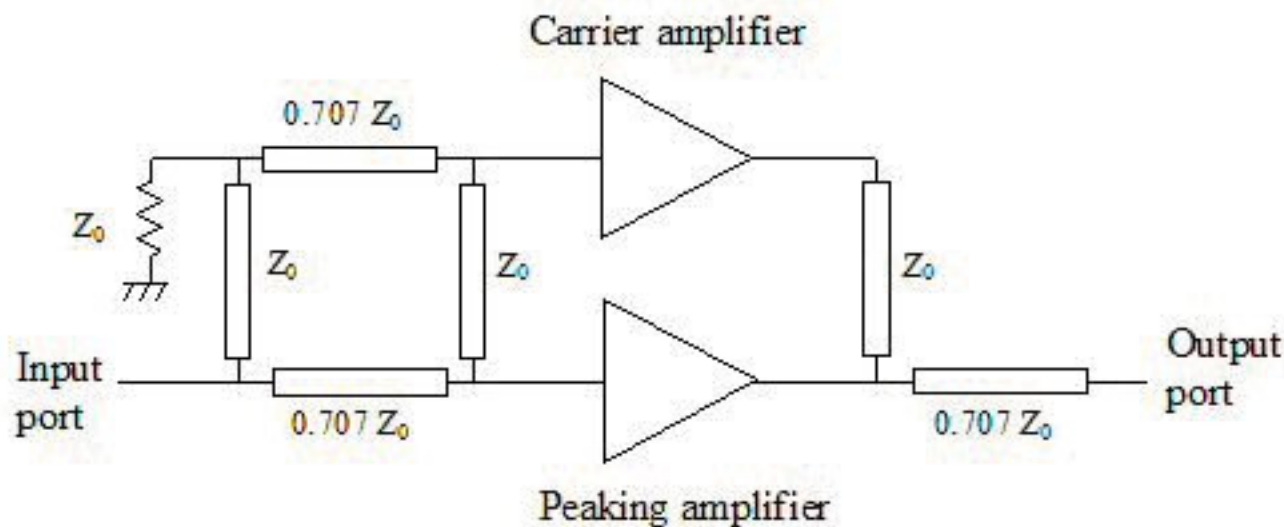


Amplifier Topologies

Four output devices with quadrature hybrid



Doherty output configuration



Which amplifiers should I attempt to modify?

- Relatively easy to re-match the devices, but
 - 1900MHz hybrid couplers hybrids often have a poor power and phase split at 2320MHz.
- Advantage of a pallet amplifier is that you can remove the pallet, work on it separately and re match it at 2320 MHz
 - Then carefully characterise the hybrids and either use them or replace them with ones that do work well at 2320MHz.

Which amplifiers should I attempt to modify?

- When the devices and hybrids are on the same PCB, you end up with a problem with “too many variables”
 - It becomes almost impossible to re match the whole amplifier in one go.
- Either avoid amplifiers that have a single PCB or take the approach of Frey, and separate out each device in turn and try to re match it.
 - It can then either be used as a lower power PA on its own, or multiple devices combined externally with in-band combiners.

Running up the Amplifiers

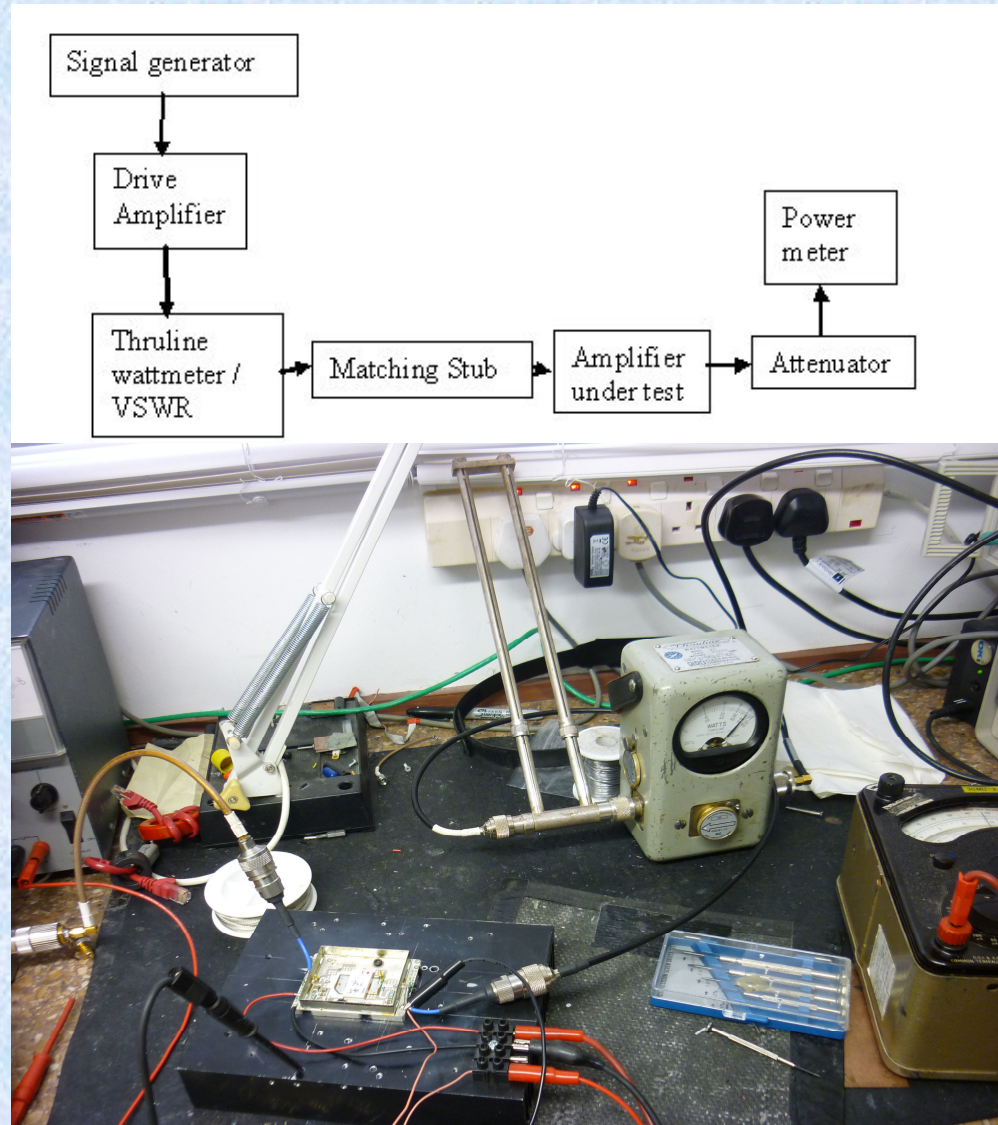
- Check out the unmodified amplifier
 - In most cases, the amplifier will default to a standby mode where the device gates are biased off.
 - Checking the gate voltages of the PA stages will quickly determine this.
 - If the voltages are above 3V, the devices are on and you will see a large supply current,
 - 2.4 volts or less, the devices are off and the main supply will be a few hundred mA.

Running up the Amplifiers

- Analyse the existing design
 - Measure all the matching capacitor values, measure the microstrip lines and work out their impedances and lengths, using the freeware “QUCS” (Quite Universal Circuit Simulator)
- Model the amplifier circuit to get a handle on the original design.
 - Allows you to play with the matching networks and analyse the results before “cutting copper” to guide you to a quicker solution.
- Bias up the Amplifier(s)
 - Direct connection of Drain to 28V via Ammeter, plus fuse/current limit
 - Simple regulated gate supply – set to I_{dq} as per device datasheet for Class AB

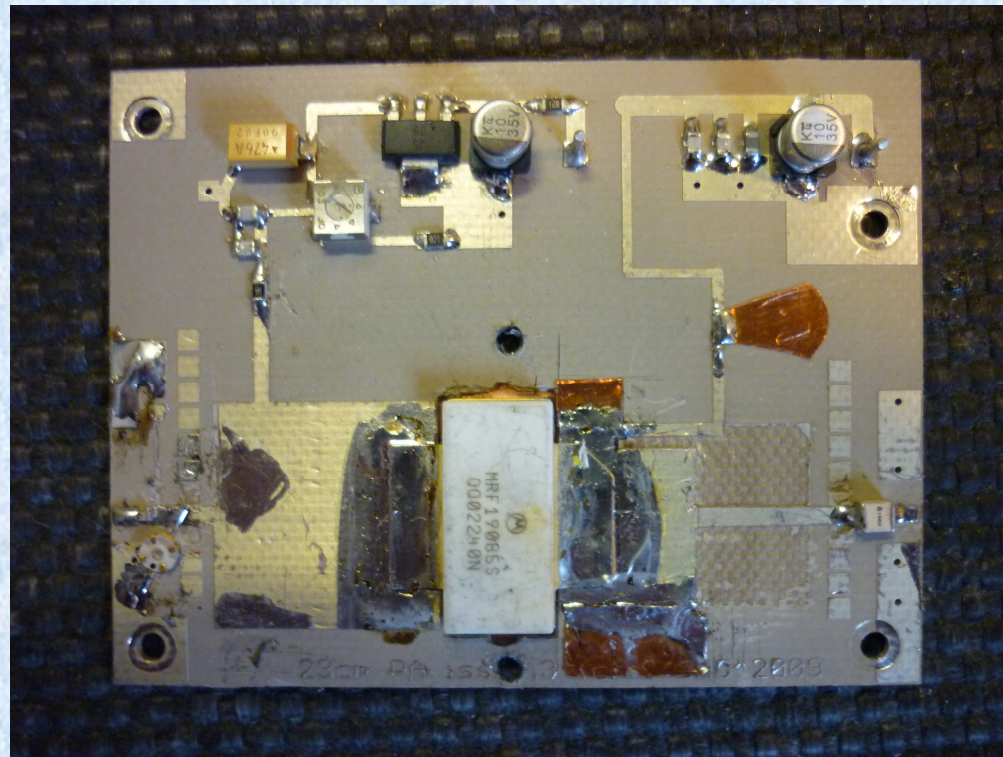
Tuning procedure

- Test setup
- First test at operational frequency
 - Start with low drive!
- Initial input matching of whole amplifier
 - using an external 2 - stub tuner
- Then work on tabbing output match for best efficiency
- Once done, remove stub and tab input for a match
- A note on the use of trimmers for matching



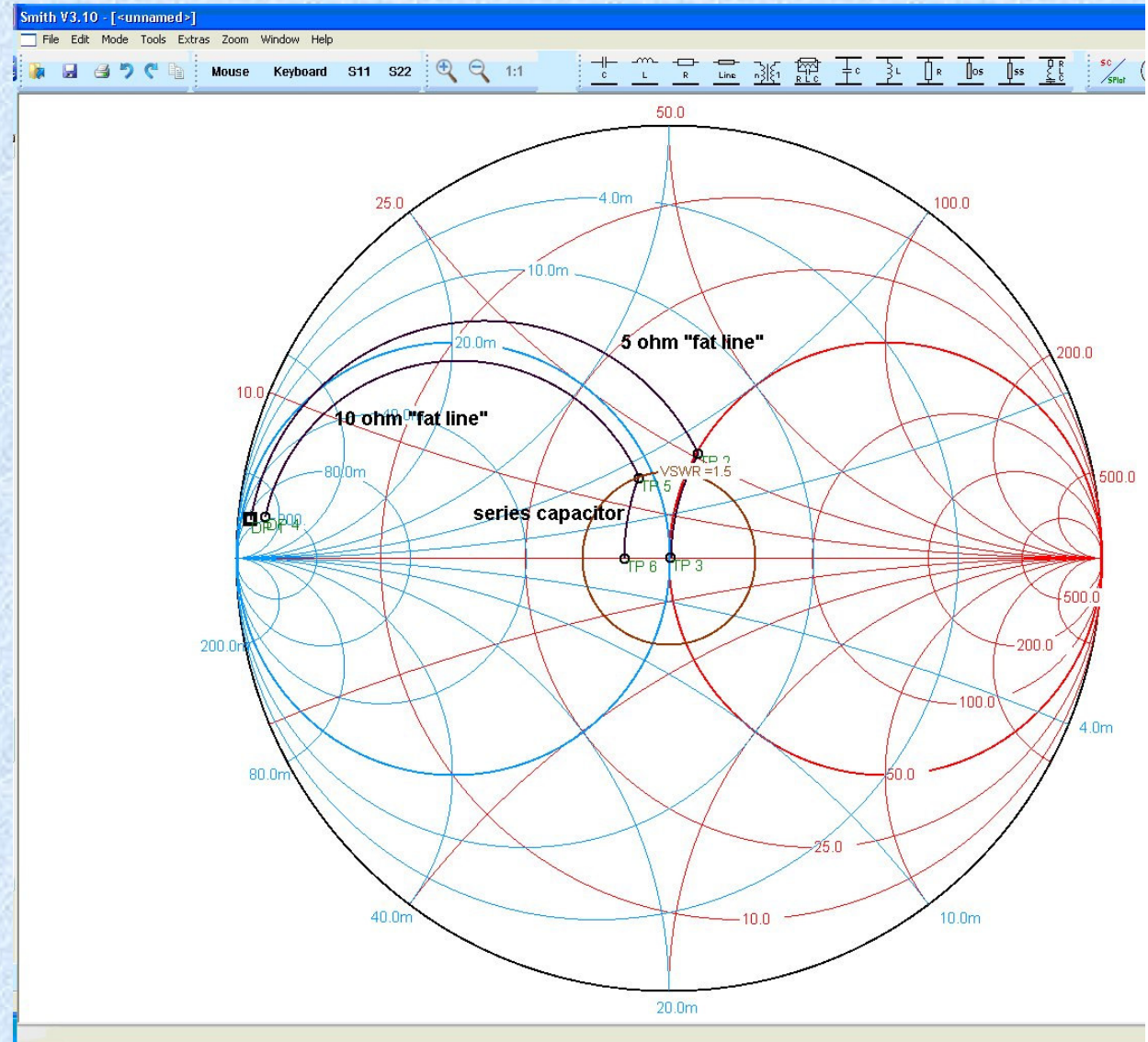
The “Fat Line and Capacitor” input network

- “Standard” input matching approach
 - series, low impedance microstrip in the order of 0.2λ , from the gate, followed by a series or shunt capacitor.
- If you plot some typical device impedances on a Smith Chart, you will see why.



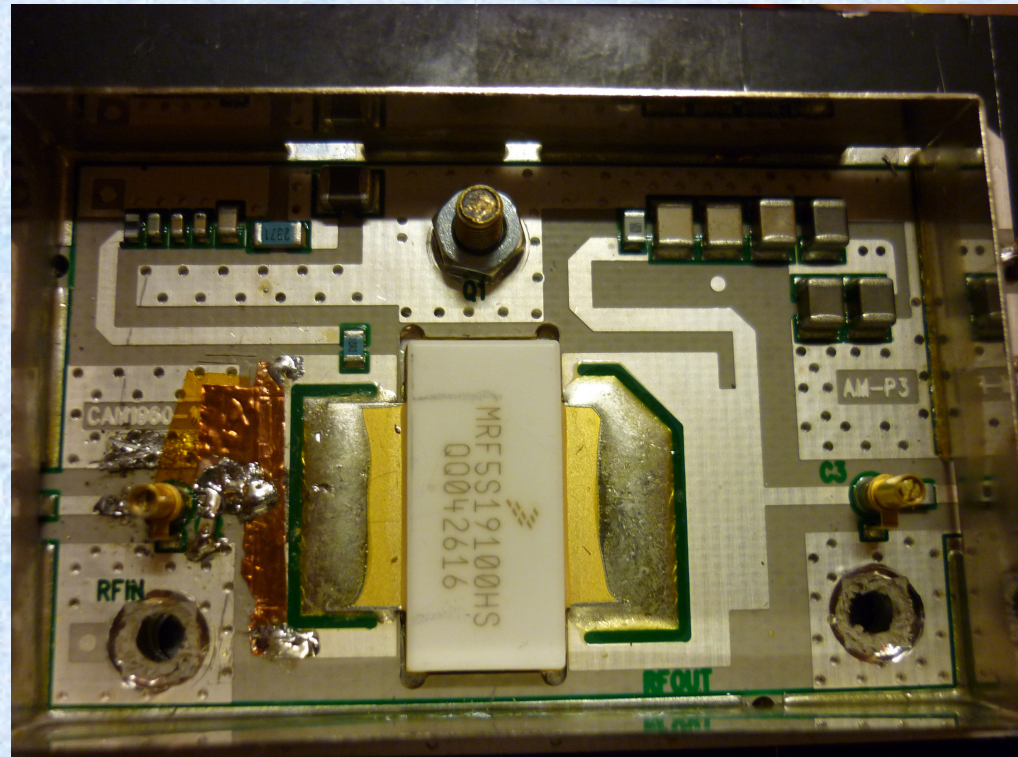
The “Fat Line and Capacitor” input network

- A change in device impedance just requires a line width change and a different series capacitance to re match.
- This is how “Tabbing” or “Snowflaking” works!



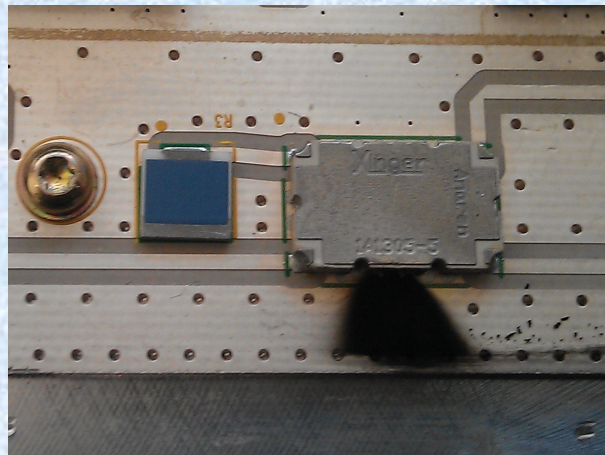
The “Fat Line and Capacitor” input network

- Many 1960MHz amplifiers, re match to 2320MHz by widening/lengthening the existing “fat line,” followed by a series or shunt trimmer before the 50 ohm line to the input connector.
- Interactively adjust the width and length of the fat line for a dip in the input vswr with the trimmer at 2320MHz.
- This will usually coincide with maximum power output.



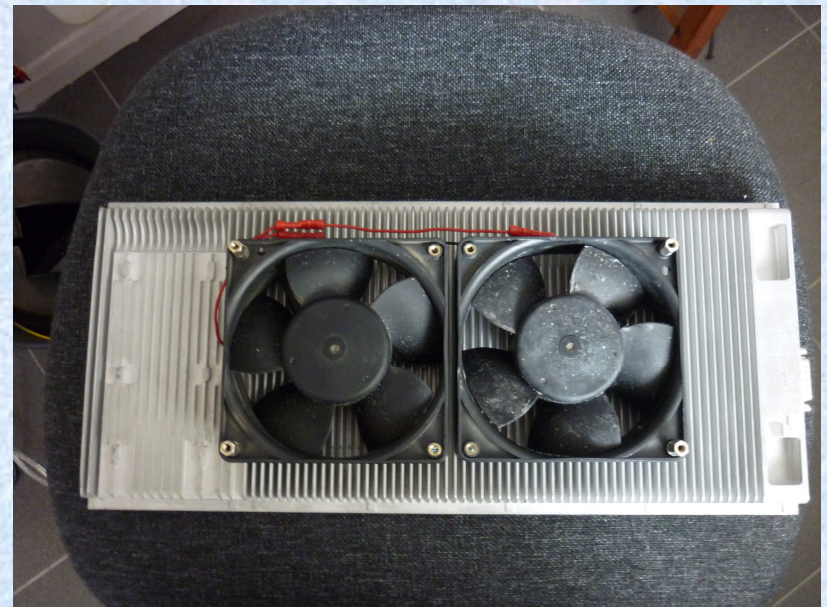
Combiners and Isolators - Pitfalls

- **Isolators** - Lose directivity
 - power dissipated in reverse power load = an increase in loss
 - at the 200Watt level this can be risky
 - Often better to bypass the output isolator and fit an external one that is for the correct band
 - especially if you plan to run full duty cycle JT modes.
- **Combiners** – Power rating, poor phase and amplitude match
 - if they are used significantly “out of band” the combining will be poor
 - power will be reduced, and in extremis the combiners will be destroyed
 - Check temperature of the coupler relative to the rest of the PCB
 - 100 Watt Combiners can fail in spectacular fashion if they are run at 250 Watts output for any significant time!



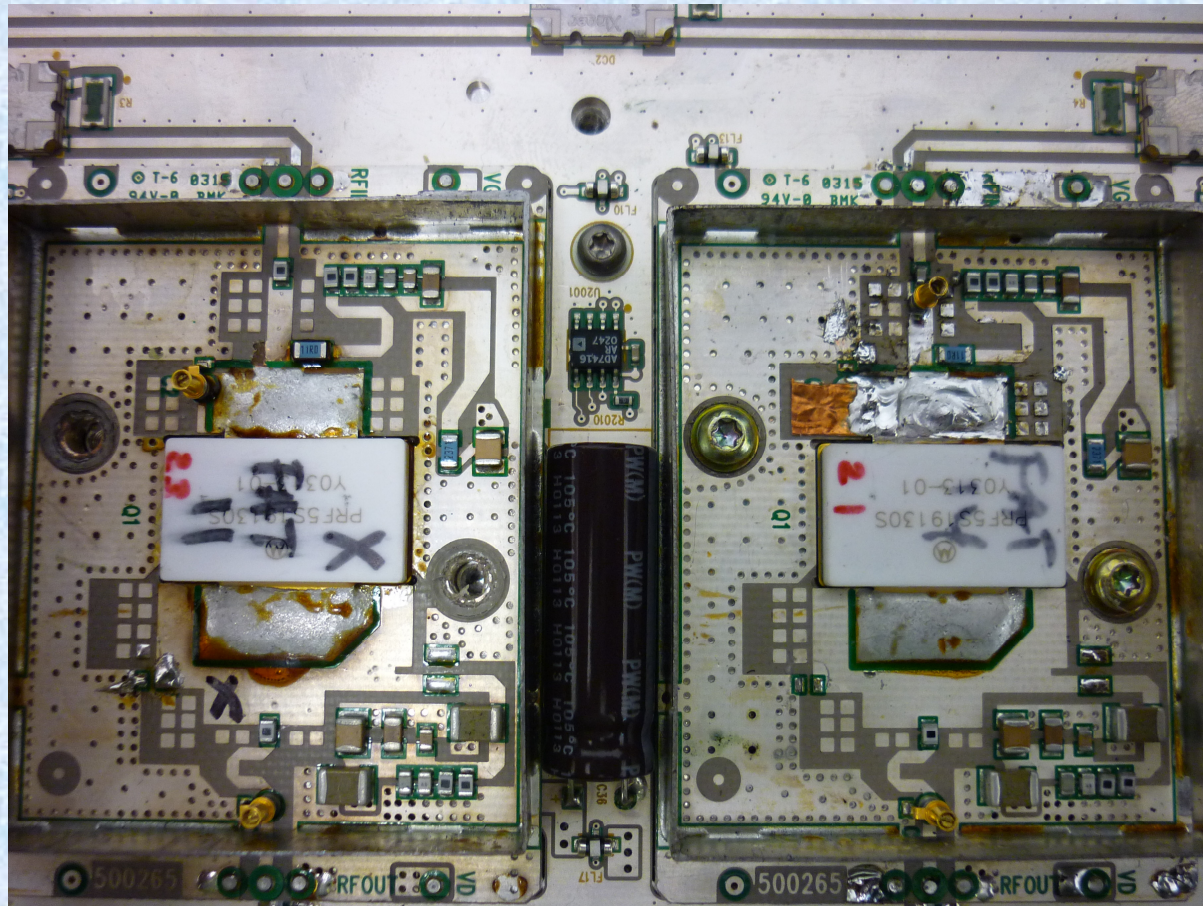
Thermal Considerations

- **Consequence of re banding internally matched devices**
 - drop in DC to RF conversion efficiency.
- **Often overall efficiency of less than 40%**
- **Heat sinking designed for forced air cooling in large racks.**
- **I fit two 5 inch muffin fans to the heatsink, and run them continuously with the excellent fan controller board kit provided by W1GHZ**



Some examples and results

- Andrew P2PAm pallets

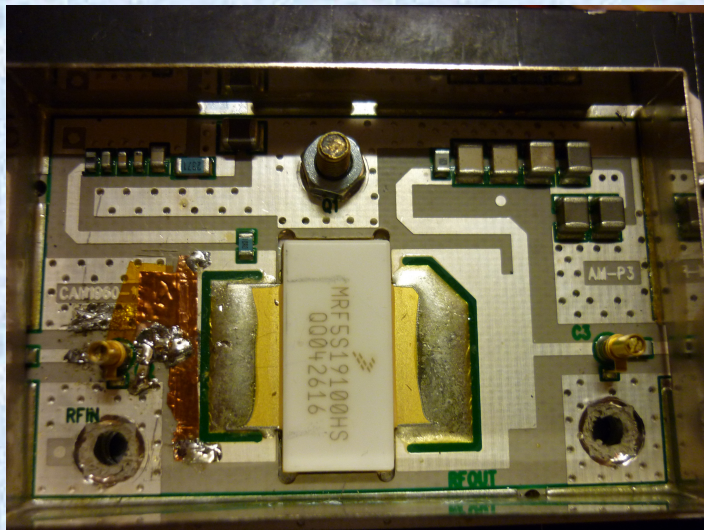
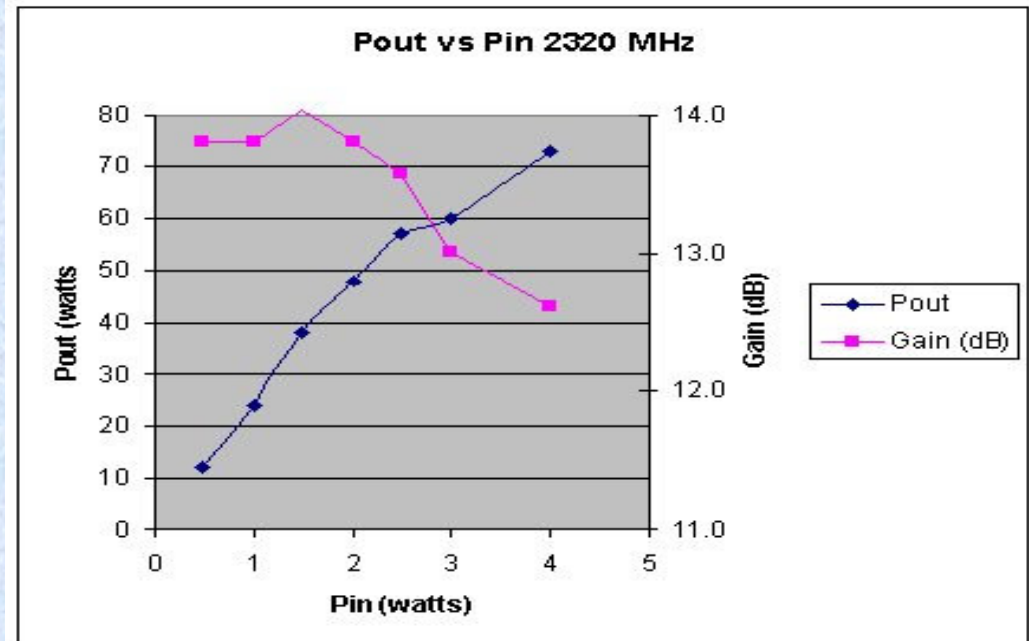
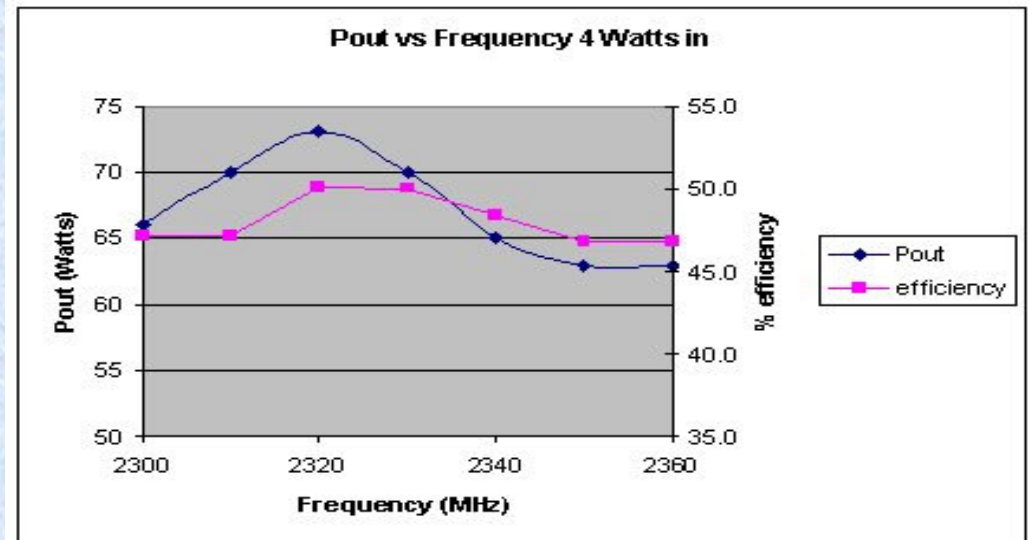


• Before

After

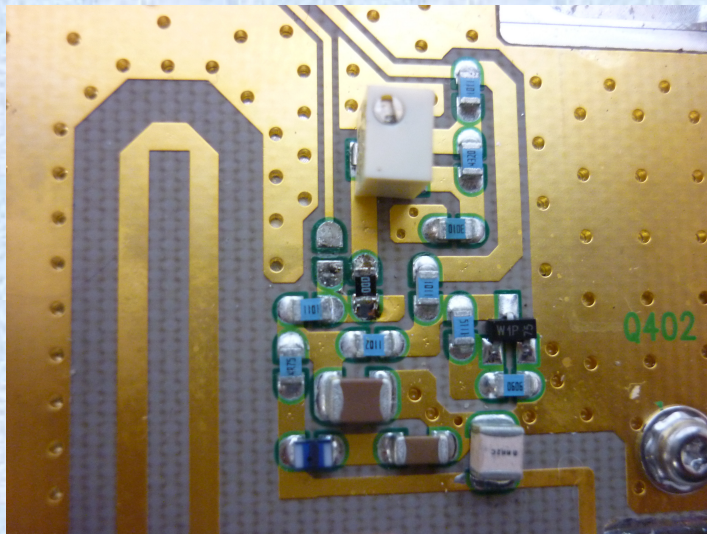
Some examples and results

- **Andrew P2PAm pallets**
 - 130 W 1900MHz device
 - Close to 75W out for 4W in @2320
 - 12 – 13dB gain
 - Close to 50% efficiency

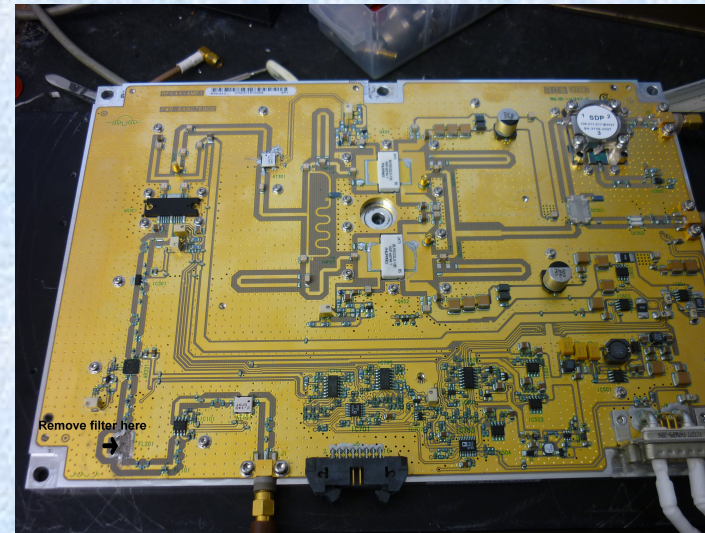
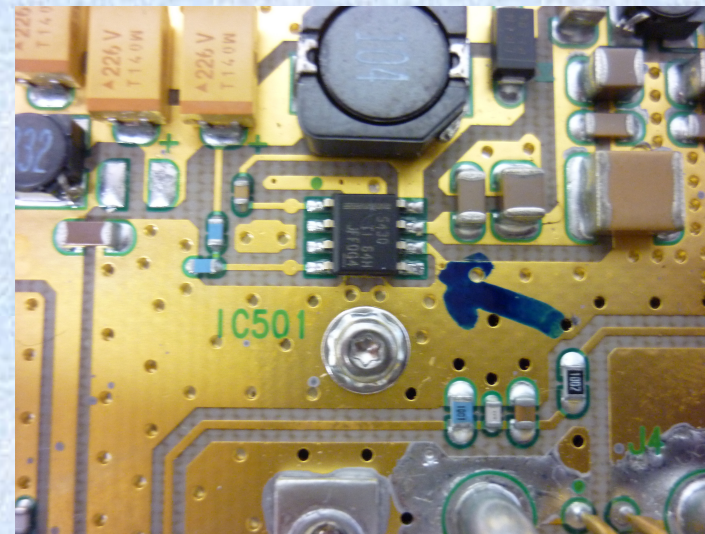


Some examples and results

- An easy one!
 - A small 100 Watt 2.1GHz Doherty Amplifier
 - No RF mods



- Connect up the test bias pots and set the bias



- Slap it on a heatsink,
- pull this low to disable – you're off!

Do's and don'ts

- All these amplifiers need forced air cooling or a MUCH bigger heatsink when run in CW mode!!
- 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.
- Avoid trimmers at the output except when “tabbing”
 - Shunt capacitors have high currents as well
- DON'T apply too much gate bias voltage or drive!

Acknowledgements

- W2AAU for the inspiration to try
- F1JRD, GW4DGU, G4DDK, G4HJW, for advice and encouragement
- G4DZU for his Appendix on the ILAM
- The writers of QUCS
- Phillip Hagar Smith (1905–1987) and his wonderful chart!
 - Even if you don't understand how it works, make the effort to learn how to use it!
 - When asked why he invented this chart, Smith explained: - :*"From the time I could operate a slide rule, I've been interested in graphical representations of mathematical relationships."*