Using the Elad FDM-DUO at 144 and 70MHz

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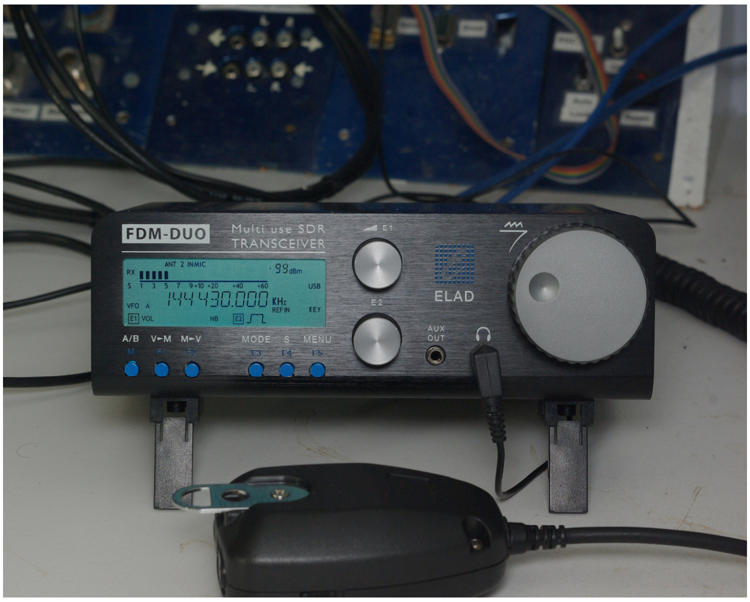
Introduction

The FDM-DUO is a modern software defined transceiver that offers full HF and 50MHz coverage with 5 watts output. On receive it uses direct RF sampling with the sampling rate F_S = 122.88MHz. The transmit signal is generated from a digital direct upconverter sampled at 368.64MHz. Frequency coverage can be extended to 165MHz by making use of alias products on receive, and the transceiver's tuning supports this. The higher F_S on transmit means that the generated RF is always below the Nyquist limit even when generating the maximum 165MHz



Above 54MHz (and also below 1.8MHz) a low power transmit signal at a level of 0dBm is available from a dedicated SMA connector on the rear panel. Transmit via this port is allowed at any frequency. To enable high frequency coverage, the lowpass filter has to be disabled via Menu Item 2, and the Transmission Output needs to be set to 0dBm via Menu Item 33. If CAT control is available, these selections can be done remotely.

Alias Products, Spurious responses and SINC(X)

For any given RF input frequency, F_{IN}, at a sampling rate of F_S the receiver also responds to many possible inputs. $N * F_S +/- F_{IN}$, these are called alias products. For 144MHz reception the receiver software LO needs to be set to a frequency of 144 – 122.88 = 21.12MHz so it then responds to an input at F_S + 21.12 = 144MHz. At 70MHz, the first alias is used by setting the LO to F_S – 70 = 50.88MHz. The software in the FDM-DUO recognises the need for using alias products and automatically sets the correct baseband point and sideband inversion for any specified RF input up to 165MHz

Since the receiver responds to all alias products, the wanted one has to be selected with a bandpass filter. Alias responses for 145MHz are shown in *Figure 1* by the vertical red lines. The green curve and dB signal levels illustrate another fact about using alias products. The amplitude of any product is reduced by an exact mathematically predictable level equal to

$$\text{Amplitude (dB)} = 20.\text{LOG}(|\text{SIN}(\pi.X) / (\pi .X)|)$$

X is the normalised frequency F_{IN} / F_S . The function is commonly referred to as SINC(X)

This means that at 145MHz receive gain is 17dB down over that of the fundamental 21.12MHz. At 70MHz it is a more respectable 5.3dB down. Although noise at the wanted alias frequency is also reduced by this amount, the receiver is also still seeing noise at the lower products with increased sensitivity.   The net effect of this is that at 144MHz the receiver ends up with an effective noise figure of around 30dB. At 70MHz it is more like 16dB

An added complication on the 144 – 146MHz band is that the first alias product lies in the range 99.76 to 101.76MHz which sits right in the middle of Band 2 FM broadcasting – the high powered station Classic FM lies in this band in the UK.

Transmitting at 144MHz the first alias occurs at 368.64 – 144 = 224.64MHz which is high enough to be removed with a simple lowpass filter. At 70MHz it sits at nearly 300MHz, also easily removed.

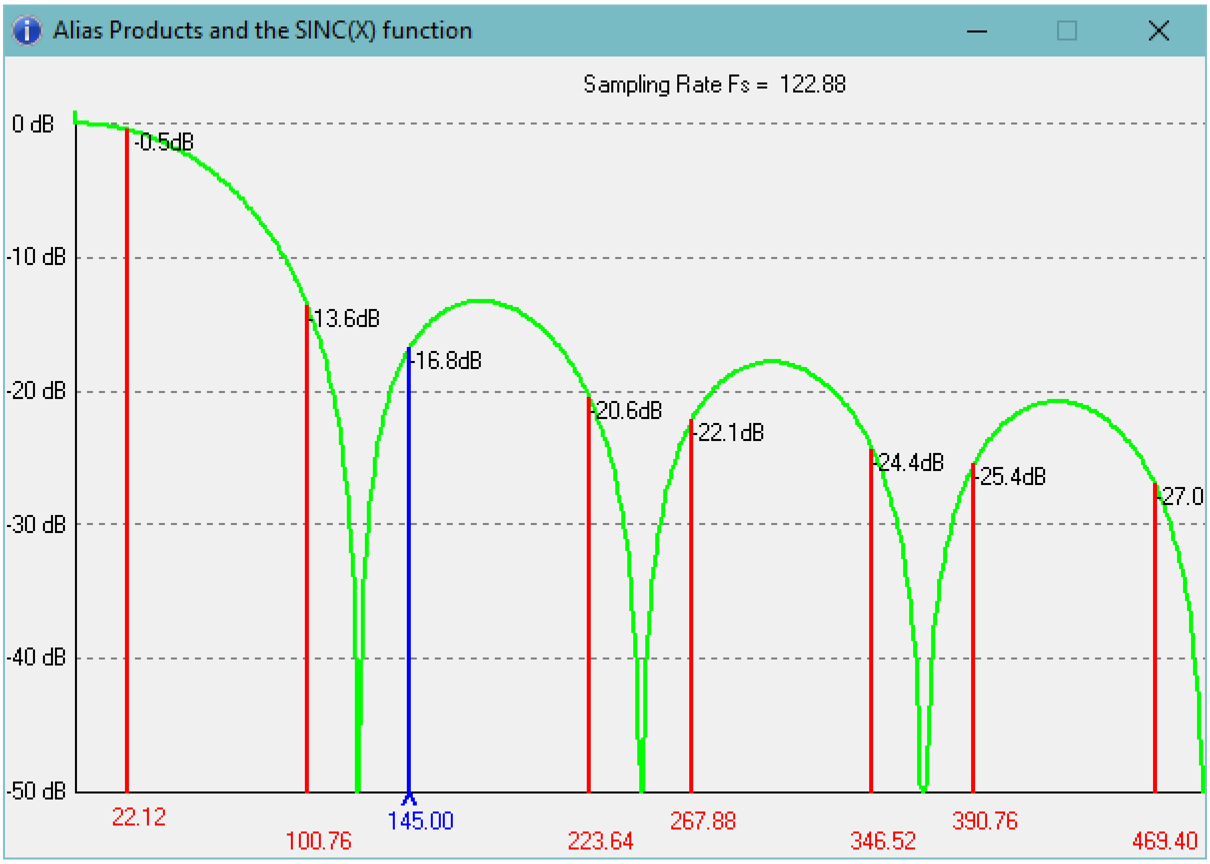


Figure 1   Alias frequencies and SINC(X) response for 145MHz operation

Interfacing Hardware

For receiving we therefore need a bandpass filter to pass just the wanted RF and reject adjacent alias responses, along with enough gain to overcome the receiver's SINC(X) response and noise figure. On 145MHz this means a gain of around 40dB is needed for weak-signal full sensitivity – and good rejection at 100MHz.   At 70MHz less gain will give full performance, but the bandpass filter needs to reject closer-in at 51MHz.

The circuits shown in *Figure 2a / 2b* for 144 and 70MHz are similar in all respects apart from filter component values.   The gain of around 40dB overall is probably excessive on the lower band where the SINC(X) response has not rolled off too much.   If this is problematical, attenuation can be added. Two PGA-103 broadband amplifier devices, each having around 21dB gain at VHF, provide the receive amplification with the bandpass filter placed between them.   A three section low pass filter on the input reduces the possibility of strong signals from cell phone base stations and Wi-Fi sources overloading the first device.   On transmit a single PGA-103 is sufficient to raise the 0dBm output from the DUO to 50 – 80mW. This level is more than enough to drive a small 'brick' PA module. A three section elliptic filter on the input removes the Tx alias product. The filter's zero is adjusted to place it over the alias frequency.

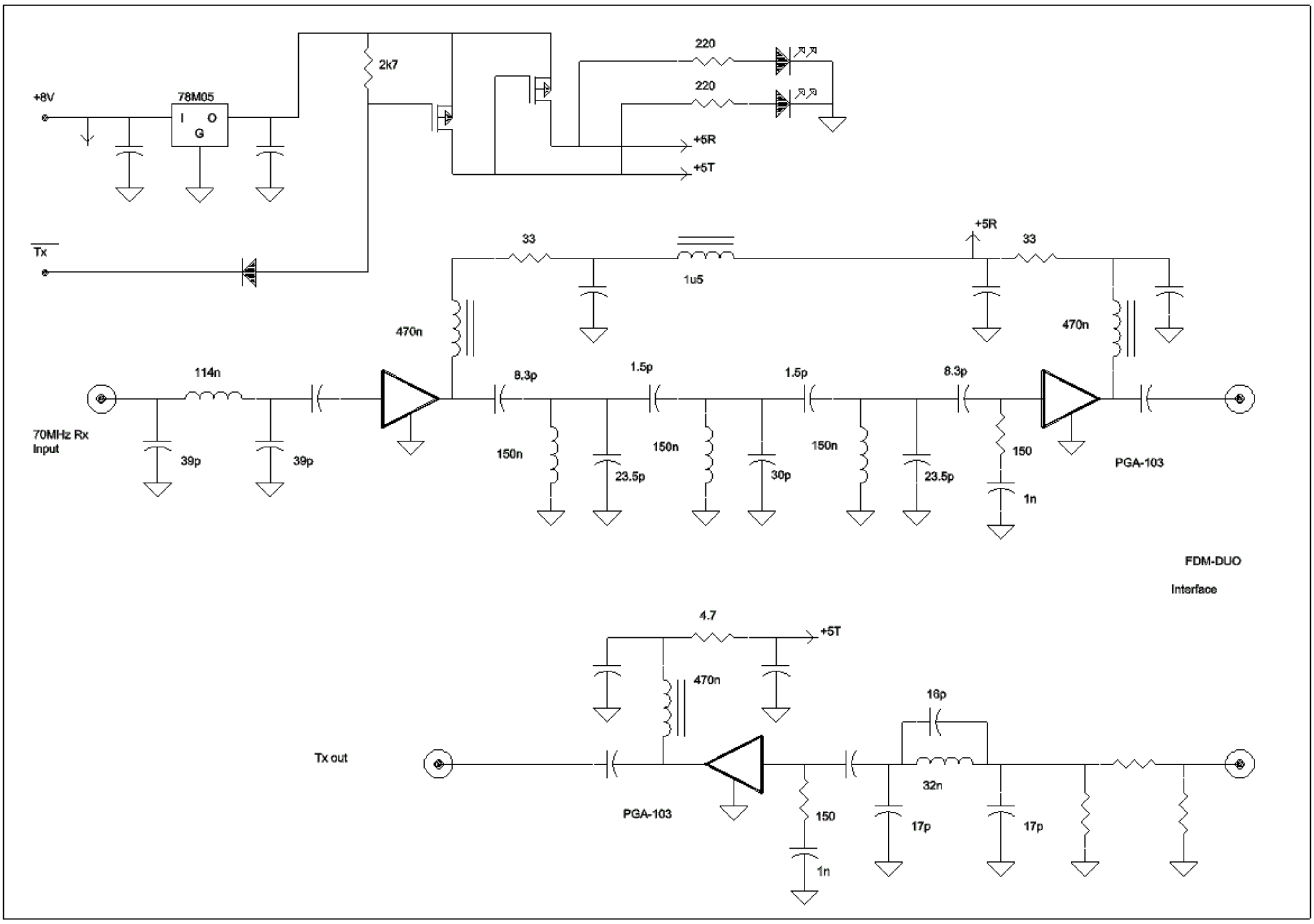


Figure 2a   Circuit Diagram of 70MHz VHF Adaptor module

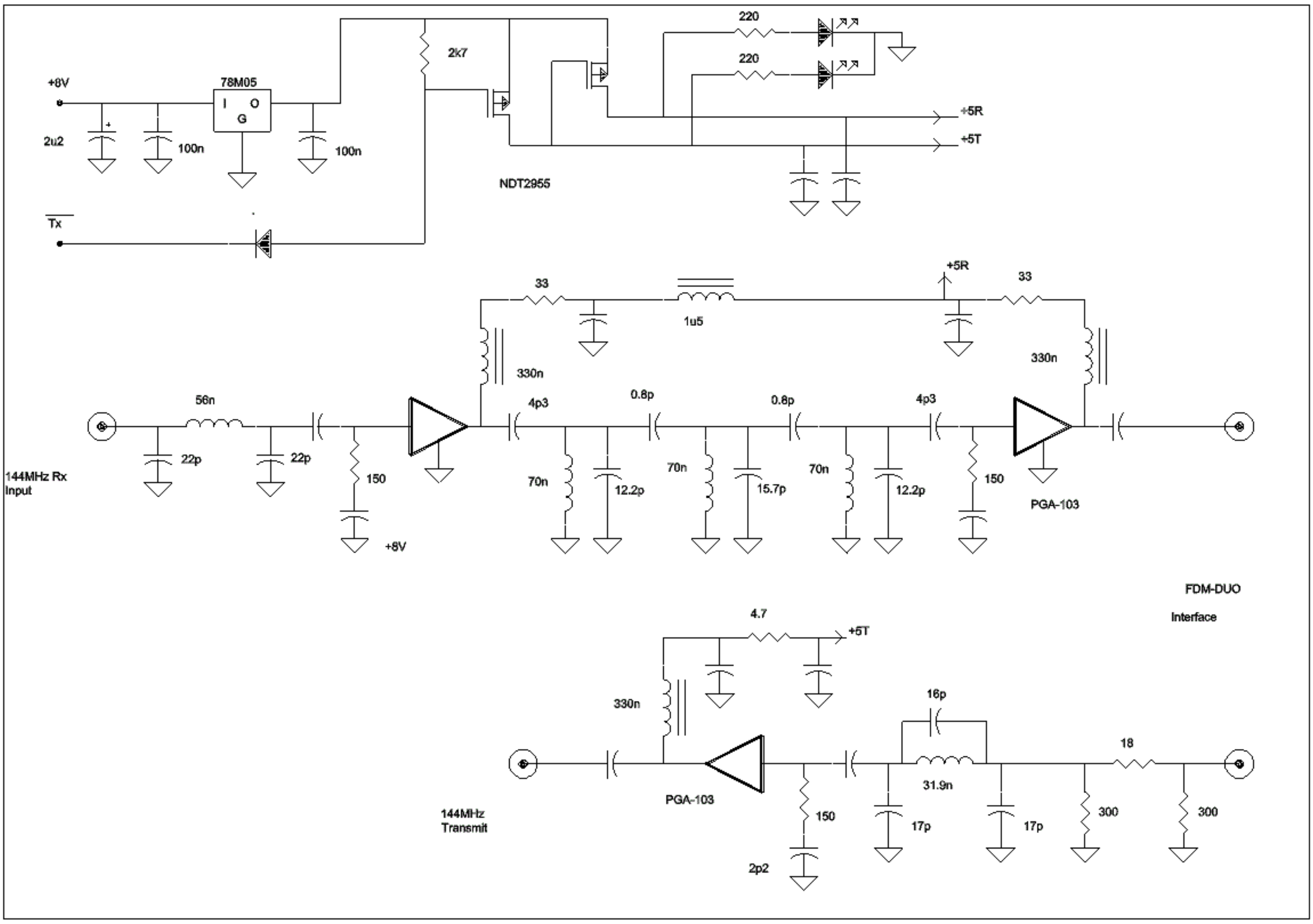


Figure 2b Circuit Diagram of 144MHz Adapter Module

Bandpass Filters on Receive

At 144MHz a three section top-coupled resonator centred on 145MHz provides the unwanted alias product rejection for the receive path. The predicted response shown in *Figure 3*. Nearly 80dB rejection at the troublesome 100MHz Band-2 alias *should* be possible. Without building the filter into a sealed and compartmentalised module this will probably be impossible to achieve, and a figure of nearer 70dB ultimate rejection due to leakage will likely be seen in practical implementations. As there is so much gain present in the Rx chain, there is no need to make this a particularly low loss filter so small air-wound inductors can be used. Using low-Q inductors does not significantly degrade the stopband response, but does tend to smooth out the passband and make simple "tuning for maximum smoke" easier. Tuning is performed by squeezing or stretching the coils to get the wanted response. If rejection of 100MHz is still insufficient, an additional bandpass filter can be inserted in the path to the Rx output. This will need to be in its own screened box.

At 70MHz, the alias at 50.9MHz is the most important one needing removal. This can be done with a three section top coupled design with bandwidth of 5MHz centred on 72MHz. The offset centre frequency means the 70 – 71MHz wanted part of the band lies at the bottom end of the passband. *Figure 4* shows the predicted response of this filter where is can be seen the rejection at 50.8MHz is around 75dB.   At this lower frequency, leakage should be lower than at 144MHz and in practice a figure of more than 70dB should be achievable.

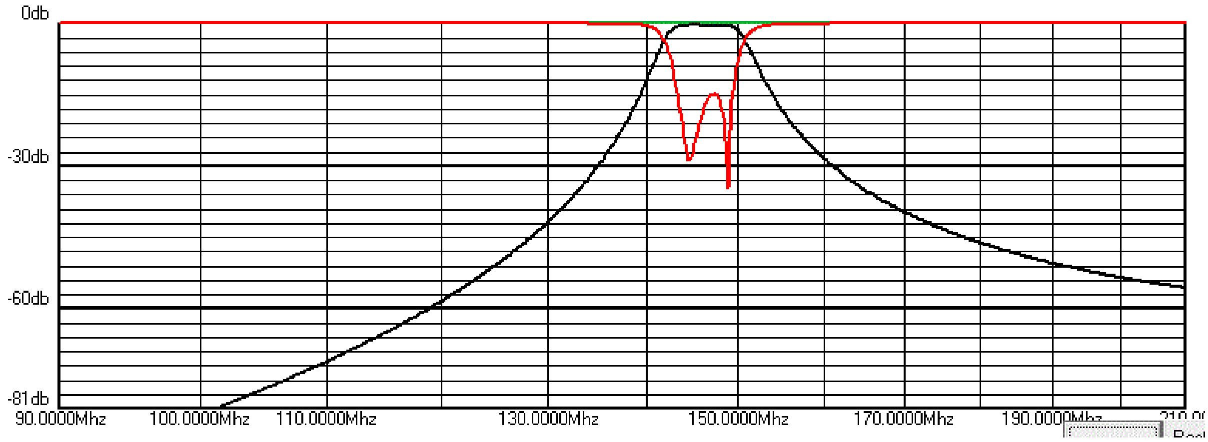


Figure 3   145MHz Filter Response

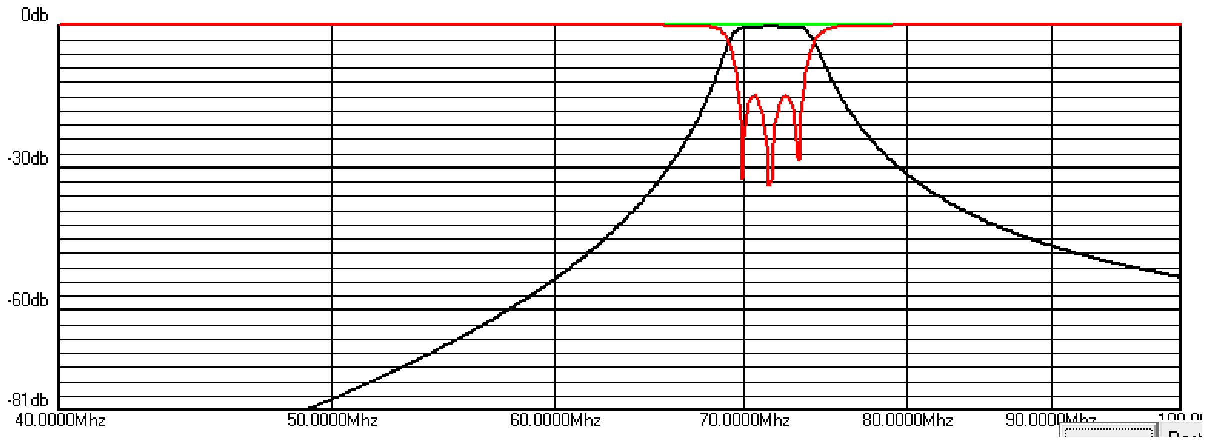


Figure 4   70MHz Filter response

Practical Designs

Two versions have been built, one for each band.   The 144MHz design shown in *Figure 5* was originally built with a 0.5 bipolar Watt PA on a PCB but the gain distribution proved to be all wrong, with too much interstage attenuation needed. So the PA was replaced with a module delivering 7 Watts.   A new PCB built to the diagrams in *Figure 2* was used for the 4m version.   This fed an old PA (not shown) taken from a now-defunct transverter for that band.

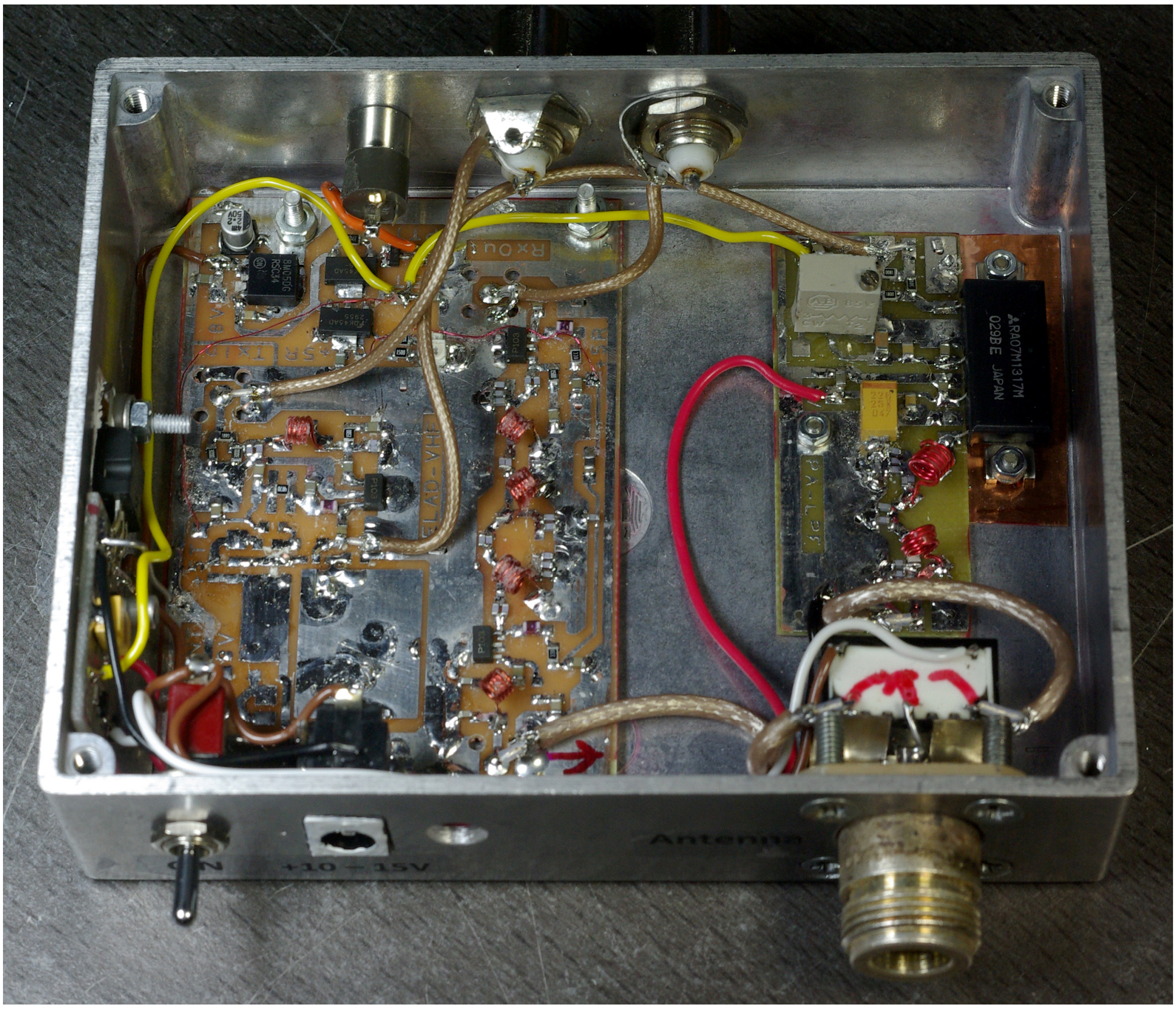


Figure 5   144MHz version using an older design of PCB.   7 Watt PA module and T/R Switching

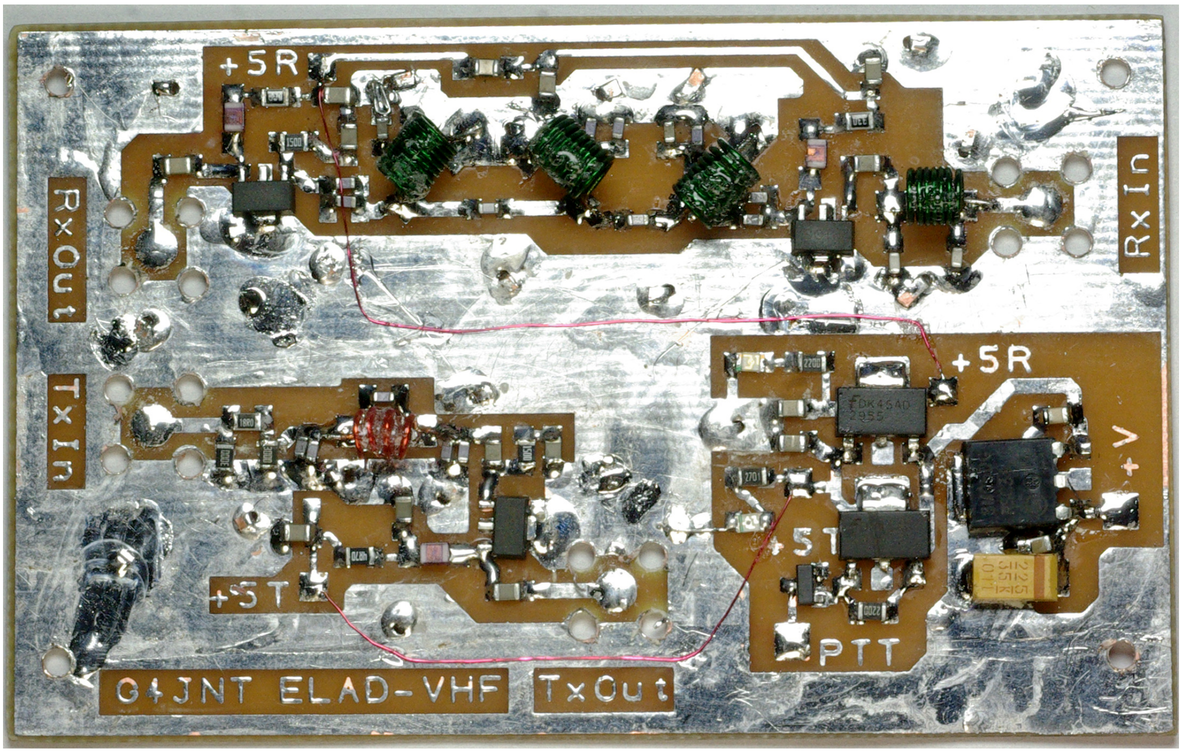


Figure 6   Later design of PCB with the 70MHz version