Evaluation of a Chinese 50 W Broadband RF Power Amplifier

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1. Background

As part of an increase in my home lab capability I sought a new or used broadband RF power amplifier, principally for use in LF/MF and lower-HF experiments. Having already constructed a number of Class D/E amplifiers for LF/MF transmission purposes, this time I wanted a linear amplifier with an output of at least 50 W, both for bench/field use and as a potential backup transmit PA (used in conjunction with appropriate external filters). Looking at professional broadband power amplifiers, which are often targeted at the EMC test community, it was clear they were financially unviable for my application, with eBay and test equipment vendors frequently quoting many thousands (or tens of thousands) of dollars for ~100 W amplifiers – often with a bandwidth much wider than I needed.

Putting the acquisition on hold and resolving that a custom-built approach would likely be needed, I then noticed a line of Chinese linear power amplifiers advertised as covering 100 kHz – 3 MHz with various power ratings up to 50 W. There is no brand on these devices but they are widely distributed on eBay and are recognizable by the fairly basic packaging and labelling. Deciding that it was worth investigating further, I bought a 50 W version for about USD 150.

2. The Chinese PA

Two external views of the PA are shown in Fig. 1, below.

Fig. 1. Views of the 50 W PA. This version has a 60 mm, fairly high speed, fan attached to the heatsink. The supply voltage is 48 VDC and the overall dimensions are 103 x 90 x 83 mm, excluding SMA connectors. Photographs copied from one vendor's eBay item page: https://www.ebay.com.au/itm/363985963936

The amplifier bandwidth is advertised at 3 MHz, with a gain of about 47 dB. The high gain is convenient for many applications, allowing the PA to be driven to full 50 W output from typical test sources or from the 0 dBm (1 mW) output of some amateur transceivers.

3. First Impressions and Tests

The external appearance and general construction of the amplifier were neat, similar to that expected from a good amateur construction job but falling short of true professional production standards. Applying 48 V power and an input test signal showed the PA is capable of more than 50 W CW but that the unit exhibits significant gain compression at this point. The power bandwidth of the amplifier is quite good, with essentially full output being obtainable from 50 kHz to 7 MHz, and useful performance from 20 kHz to beyond 10 MHz. The gain was close to the nominal 47 dB over the full-output bandwidth, with slow ripple at the < 1 dB level.

Since a number of my applications involve the 136 kHz (2200 m) and 475 kHz (630 m) amateur bands I inspected the performance more closely at those frequencies. I was initially puzzled to see a low-level artifact at 155 kHz and a second harmonic at 310 kHz (Fig. 2). These signals would be insignificant in most applications but they were uncomfortably close to 136 kHz for me, especially as I could see traces of very low-level intermodulation between my 2200 m test source and the 155 kHz artifact at some PA output levels. Further investigation and disassembly of the amplifier confirmed the signals originated in an XL7015 buck converter module (150 kHz nominal switch frequency) used to power the 12 V fan and the bias chain of the push-pull power devices. I was able to add a second stage of L-C filtering to the XL7015 output, resulting in significant attenuation of bias noise and PA artifacts. The output from the modified PA is shown in Fig. 2 and the fairly simple procedure for modifying the amplifier is described in Appendix 1.

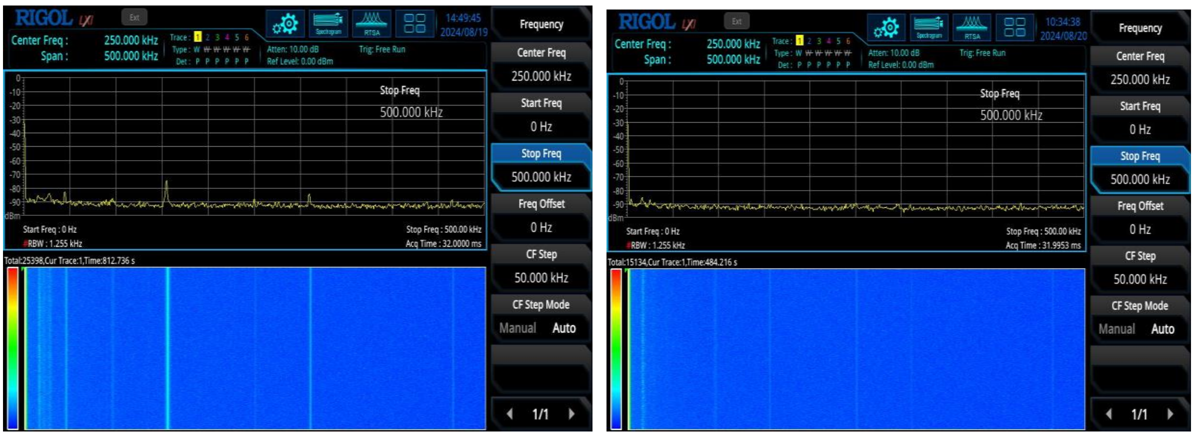

Fig. 2. (Left) Unmodified PA, with input terminated. (Right) PA internally modified with additional L-C network added to XL7015 power converter module. 0 dB corresponds to +50 dBm (100 W).

With the XL7015 modification in place no intermodulation effects from the switching noise are evident at any level. Results in the remainder of this report are from the modified amplifier.

The internal construction of the PA is good, at least in terms of the main PCB (see Appendix 1). Two push-pull power devices (probably FET's) mounted on the heatsink are evident, with a transistor driver stage. Point-to-point soldering is visually rough, but electrically adequate. The XL7015 module is mounted with tinned copper wire and stabilized with a white goop compound, departing from good construction standards.

4. CW and Two-Tone IMD tests

The harmonic output of the PA is fairly conventional for a low-cost solid-state amplifier with a push-pull topology. Fig. 3 shows the 630 m output at full output and 5 W. For CW and most data applications the PA is usable at the rated power, assuming adequate output filtering.

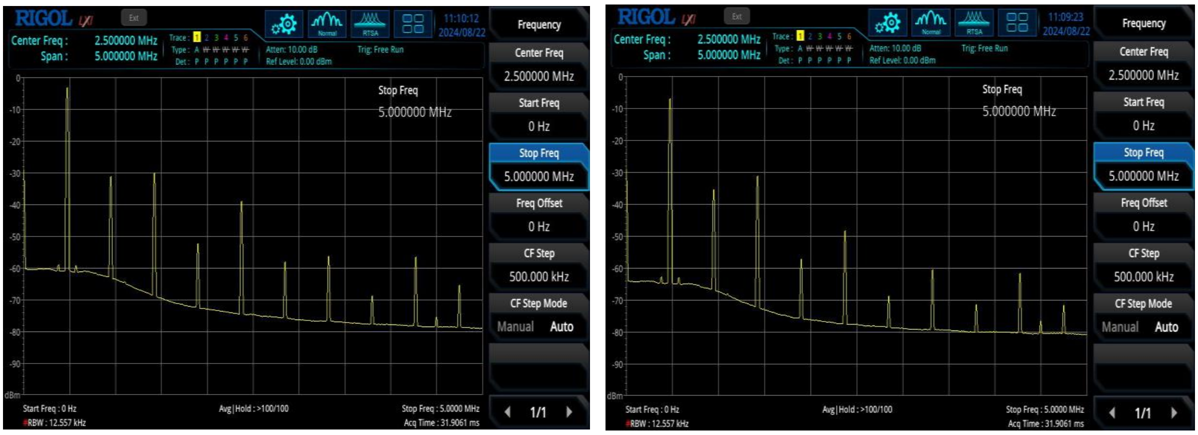

Fig. 3. (Left) PA 630 m CW output at 50 W. (Right) Output at 25 W. Low-level artifacts around the fundamental are from the test synthesizer. 0 dB corresponds to +50 dBm, or 100 W.

Since this is a linear amplifier with a high gain it is relatively straightforward to examine the intermodulation distortion using two bench RF signal sources, a hybrid combiner, and some care in preserving port isolation. Fig. 4. shows indicative 80 m IMD plots, using two non-identical synthesizers. The LF and MF characteristics are similar to the 80 m plots.

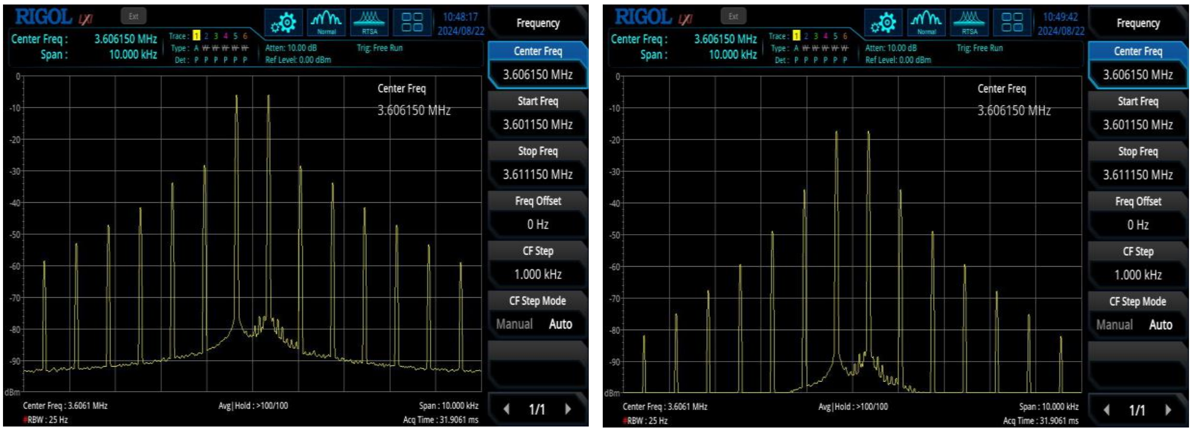

Fig. 4. (Left) Two-tone 80 m IMD at about 50 W PEP, with two non-identical synthesizers used as RF sources for each tone. Very low-level spurii on the upper-frequency tone are signal generator artifacts. (Right). IMD at 5 W PEP. 0 dB corresponds to +47 dBm (50 W) CW output.

The PA is undistinguished as a linear amplifier, with IM3 at about -23 dBc at full power (equivalent to -29 dB with respect to PEP). Higher-order products are very prominent and the common interchange between high and low-order relative levels is evident as power output is varied. Still, with major manufacturers having sold amateur transceivers with similar characteristics, the general behaviour is not unknown. My applications, fortunately, do not require very good linearity but it's worth knowing that the PA and filters could, at a pinch, be used in a low-power 630 m SSB role in Australia and other jurisdictions where that mode, in bandwidth-restricted form, is allowed.

5. Realization of a Bench Power Amplifier

Despite its shortcomings I concluded that the Chinese PA was useful in the bench amplifier and stand-by LF/MF transmitting roles. For a measurement environment use of a linear power supply is preferable and I had both a suitable 48 VDC, 3A supply and a vented instrument case in which to house it and the amplifier. The PA has no fixing lugs and, while it is feasible to drill and tap its aluminium enclosure, I resorted to my pilot's accessory approach of strong Velcro. The instrument case is only just high enough, with the PA fan being a snug fit against the case's removable top. The front panel is very simple with a power switch and mains indicator, a 48 V supply LED monitor, and BNC input and output bulkhead connectors cabled to SMA connectors to suit the amplifier. Fig. 5 shows the assembled system.

Fig. 5. (Left) Assembled bench power amplifier using a spare Schroff instrument enclosure. (Right) Internal view of the enclosure showing the 48 VDC 150 W linear power supply and PA. The power supply is secured via rear studs and the PA is mounted using strong Velcro.

Appendix 1. Fitting an Additional L-C Filter to the PA Buck Converter

For reference, I refer to the heatsink and fan side of the PA as the “top”. To access the amplifier internal circuitry remove all four screws on the input connector side of the PA case. Remove the input SMA connector mounting nut and washer. Remove the two bottom screws on the output connector panel. Remove the bottom of the case by sliding it towards the input connector. A general view of the PA internal arrangement is shown in Fig. A1-1.

Identify the XL7015 buck converter module (preset to 12 V) mounted vertically, and note its positive output is closest to the amplifier PCB with the ground (common) at the top. There are two connections to the positive the terminal: a red flying lead to the 12 V fan and a tinned copper wire going to the amplifier bias network. The idea is to remove the tinned copper wire and insert an additional L-network filter between it and the XL7015 positive output.

The L-network filter consists of a 47 μH choke and a 470 μF electrolytic capacitor (16 V or 25 V working). Solder the choke between the bias supply tinned copper wire and the XL7105 module’s positive terminal and, observing polarity, solder the capacitor between ground and the bias wire. Fig. A1-1 shows my approach to fitting the choke and pushing the new capacitor and XL7015 slightly inwards, allowing the protrusions on the sliding case bottom to clear the capacitor.

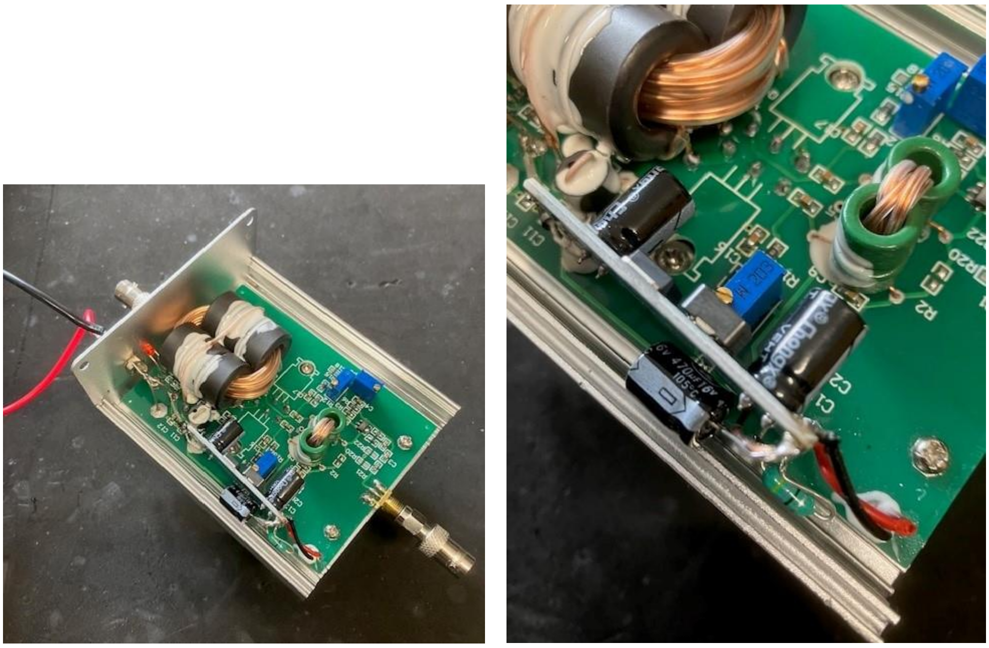

Fig. A1-1. (Left) General view of the PA interior with the new filter fitted. The XL7015 power converter module is the vertical PCB at the lower middle. (Right) Detail of L-network filter fitted to the power converter. The choke (green body, visible against case aluminium) and capacitor (pushed inward to clear the channels in the PA case) are visible.

The reduction of switching noise in the PA output is illustrated in Fig. 2. A more sensitive measurement, taken with the spectrum analyzer pre-amp enabled, is shown in Fig. A1-2. The extra XL7105 filtering reduces the switching noise by at least 15 dB at 155 kHz.

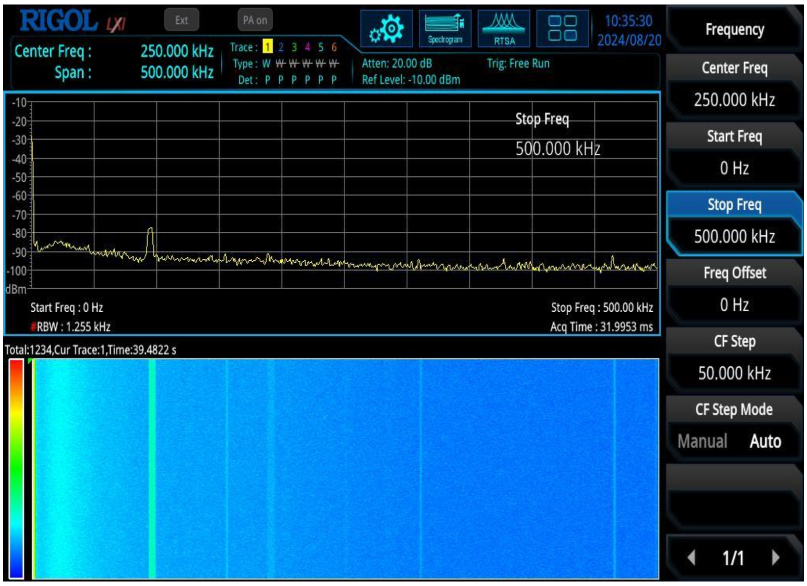

Fig. A1-2. More sensitive LF spectrum taken with the extra PA filtering in place. Scales are as for Fig. 2. Features unrelated to the switching noise at 155 kHz and harmonics are generated in the test environment or equipment.