Viceroy Mk IV

KW Electronics Ltd.

Ca. 1964

Notes by Gwyn Griffiths, G3ZIL

Restoring a KW Viceroy Mk IV HF single sideband transmitter

Gwyn Griffiths

This KW Viceroy single sideband amateur band transmitter was bought via e-bay in November 2009. It is taken to be a Mk IV because an antenna change-over relay is fitted. While the front panel was in decent condition from the photographs and details on-line, the internals were rather poor. It was collected from Witney, Oxfordshire on our way back to Southampton from North Wales. The seller was a house renovator, and in a large shed at the back of the house they were working on were the remains of an extensive collection of elderly amateur radio equipment. At one time the equipment had been looked after, but from appearance, for some time the shed had been unheated, damp, and with mice as well. Clocking my interest in a Taylor Model 68 RF signal generator of late 1950s vintage, the seller accepted an offer of £10, and threw in a power supply for a KW Vespa Mk II with its cardboard cover for nothing.

Power Supply

Figure 1. Power supply unit removed from the case, in as received state, having brushed off the worst of the rust on the transformers and the smoothing chore, rear centre.

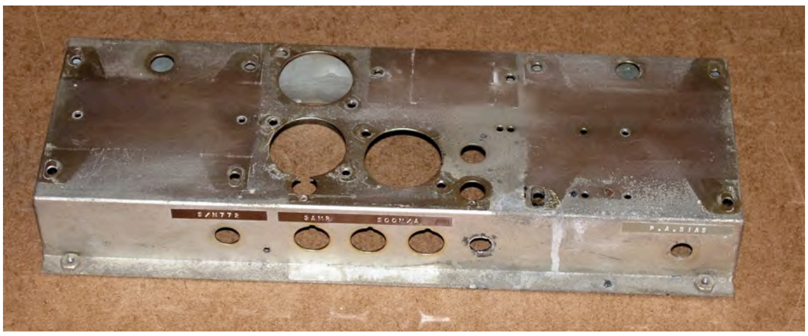

Figure 2. Power supply chassis stripped down completely, before bead-blasting.

The power supply was in fair condition, with no extensive corrosion, Figure 1. Given the simplicity of the wiring, and what I felt was the definite need to replace the high voltage capacitors, it was completely stripped down. This was, of course, after a circuit diagram had been drawn, as an exact correspondence with published circuits was not possible. For example, single diodes, not multiple, were used in each arm of the 750V supply. Careful notes were made of the transformer wiring colours.

Dismantling started with the “750V” tag strip, followed by the associated capacitors from their clips, the mains voltage selector panel, the “750V” transformer, mains cable and its tag strip, and then the three fuseholders. The rusted smoothing choke for the "350V" supply was removed, measuring 3H inductance and 75Ω resistance, marked with a 200mA maximum current. The details would be inscribed on the cleaned and repainted shroud. The "750V" transformer was dismantled, noting that green connected to the 200V tag on the voltage selector panel; yellow to 220V and red to 240V. The loose rust was cleaned off with a file and carbide paper. There followed treatment with Kurust rust converter from Hammerite, before spray painting with a grey aluminium primer, which mimicked the original finish. A silver paint was used on the metal clamp of the choke.

The wire loom to the transmitter chassis passed though a perished rubber grommet. A smear of Vaseline helped extract the wires. All the original grommets were replaced. The remainder of the wiring and tag boards were removed, and finally the "350V" transformer. This was given the same treatment as the 750V transformer.

With all components removed, Figure 2, the chassis was bead-blasted clean. A near original finish was achieved. All of the mounting hardware, the nuts, bolts, set-screws, voltage selector panel etc. were cleaned in an ultrasonic bath. Those that were rusty were first soaked in a citric acid-based cleaner (Hammerite Rust Remover Dip), and a dilute solution was used in the ultrasonic bath for a final clean.

The three high voltage electrolytics (two 50+50μF in series/parallel for the "750V" supply and a 32+32μF for the "350V" supply) were replaced with new F&T West German units rated at 500V. New 330K balancing resistors across the "750V" supply capacitors were also replaced as they had increased in value and were no longer equal. The electrolytic in the bias supply was replaced with a 47μF wire ended type.

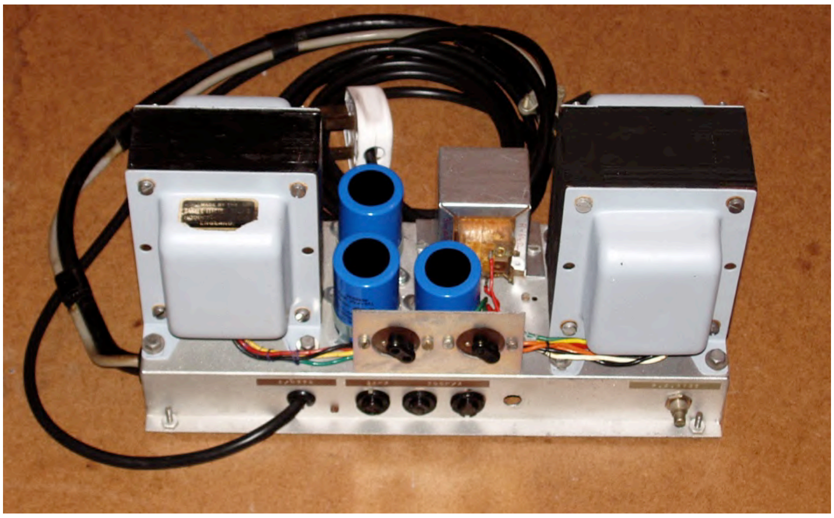

Figure 3. The restored power supply. The three capacitor cans in blue are new F&T West German units; also new is the mains cable.

Reassembly was straightforward using the photographs and my drawn circuit as reference, Figure 3. After careful double-checking the supply was switched on, and the voltages measured. All was fine.

As of 2018 the power supply has proven to be entirely reliable on the occasions that the transmitter has been in use.

The Transmitter – Pre-restoration checks

With the power supply rebuilt, the transmitter was tested as-is, as it is my custom to test before disassembly to ensure as far as possible that, when rebuilt, any faults or problems found were due to incorrect reassembly.

The test procedure generally followed the instruction manual[1], and comprised:

1. All valves and all crystals in place.
2. Visual check on all of the valve heaters glowing – found all OK, including the neon stabiliser on the VFO chassis.
3. On the Standby setting: check on the "350V" HT voltage in case it was being dragged low through excessive current consumption – found all OK.
4. 50Ω dummy load connected to aerial socket at rear, via a Hansen SWR meter.
5. Still in Standby mode, grid current was obtainable on all bands. Peakable with Mixer and Driver controls; peaks on Mixer input about where they should be on the front panel scale.
6. Move to Tune position, bias potentiometer on power supply adjusted to give PA anode current of just less than 50mA. Move to MOX, and with switch in Send position, adjusted to 50mA. All well with PA when HT applied with no drive.
7. Became obvious at this point that the glass in the meter was not properly attached. I've found this a common problem with elderly meters, where the original glue around the glass edges has become brittle. Note made to repair when stripped down.
8. Before applying drive, looking at the PA tune variable capacitor, at some positions the vanes were very close together. Note made to inspect when stripped down.
9. In Tune, with drive applied, output obtained on all bands.
10. Audio input to the microphone socket produces output as expected. Looks very good at this stage, strip down can begin.

The Transmitter Chassis

The upper surface of the transmitter was in rather poor shape (Figure 4 left). There were extensive rusty patches, and evidence of pitting in those areas. There was clear evidence that mice had been active on the upper chassis! This Viceroy transmitter unit comprises three chassis sections, in addition to the power supply: the single sideband generator unit; the VFO, oscillators and mixer to generate multiband signals and the PA, VOX and aerial change-over. Of the three sections on the upper side of the chassis, the PA was least affected, the VFO, oscillators and mixer being the worst. In contrast, the underside was in rather good condition throughout (Figure 4b). From the condition of the underside I felt there was no need to dismantle completely, as was done for the (simpler!) power supply,

[1] An electronic copy is available on the KW_Radios Yahoo Group at http://groups.yahoo.com/group/KW_Radios/files/

but would proceed to separate the three chassis sections, disconnect their interconnections, and clean, treat and paint the upper surfaces.

To dismantle the chassis, the screws between the front and side panel brackets were removed, and between the side panels and the chassis. The six 4BA set screws and spacer washers holding the L shaped bracket at the rear, across the three chassis units, were removed. All this metalwork, screws, nuts etc. were treated with Hammerite Rust Remover (citric acid based).

All knobs were removed. The microphone socket, a standard 4-pin type to include audio signal and PTT switch, was not original. This was clear from (a) the rather amateur wiring of the PTT contacts between the socket and the Send switch and (b) the scuff marks where the large nut at the rear of the socket had been tightened with a large spanner. This socket was removed, with the intention of replacing with a ¼" jack, as was in the original. To do this, the nut of the audio gain potentiometer had to be temporarily removed. An aluminium adaptor plate was made so that a ¼" jack socket could be fitted.

The chassis sections could now be removed separately.

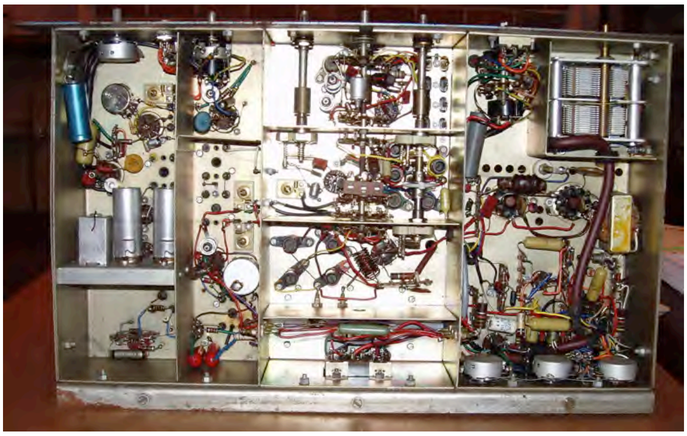

Figure 4. Left: As received, upper chassis, showing extensive corrosion of the plated steel especially on the centre section. Right: in contrast, the underside was in good condition, and did not need a rebuild.

The Sideband Generator Chassis

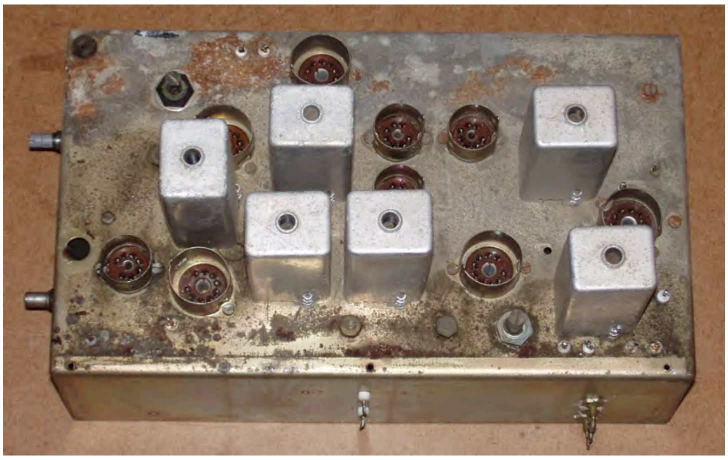

Figure 5. The sideband generator chassis, disconnected and ready for cleaning.

First, a sketch of the layout of the upper surface of the chassis was made, showing the valve locations, the locations of the crystals, and the wire colours to each of the connection posts, on the upper surface, and the six on the side of the chassis mating with the VFO and mixer chassis. A note was made of the cables through each of the two grommets. Particular care was taken to note the position of the two 435kHz crystals, as one is a series resonant type, and the other specified for operation with 30pF parallel capacity. A sketch was made of the wires that had to be unsoldered from the Net/Carrier Insertion potentiometer, and the screened cable to a tag strip on the underside.

The cleaning method employed was first, use a small brass wire brush with the inlet of the garage vacuum cleaner held close and a dust mask worn, second, emery paper, again with vacuum and dust mask, and then a gel Hammerite Rust Remover, applied with a small stiff brush or cotton buds. This was left in contact for an hour or so, and then cleaned off with clean water. The worse patches needed a second treatment. A Humbrol silver enamel paint was then used in several coats with fine emery between coats to help smooth out the pitting.

The VFO and Mixer Chassis

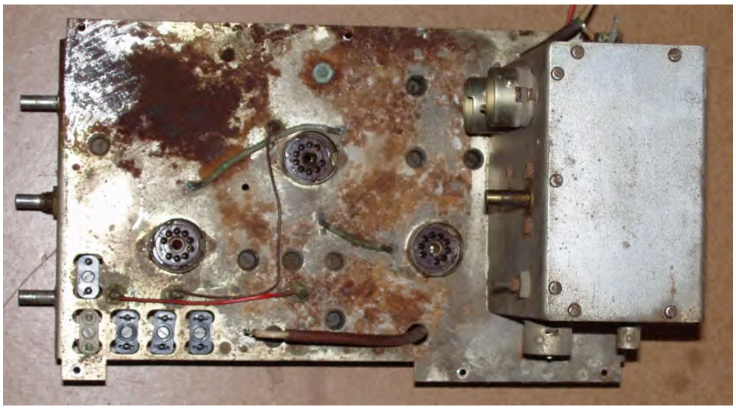

Figure 6. The VFO (upright box at right) and mixer chassis. This was the worst affected unit, especially top left.

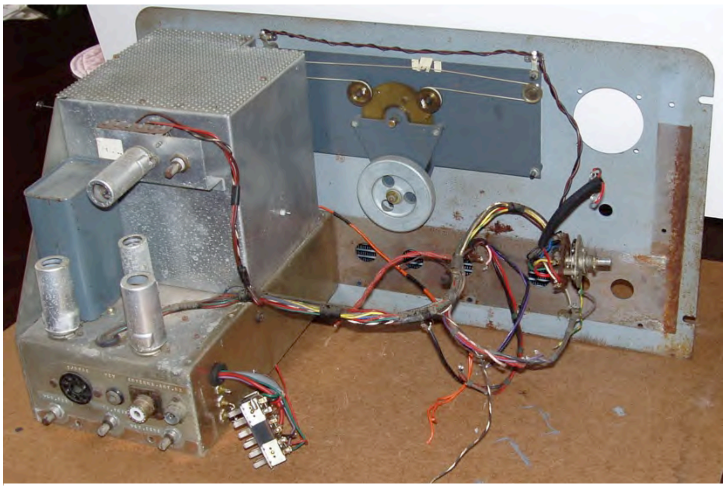

Figure 7. The PA chassis on the left before dismantling, showing the wiring loom after the VFO & mixer chassis and sideband generator chassis had been removed. The state of the back of the front panel is also visible.

As with the sideband generator chassis, a sketch was made of the layout at the outset. The flexible coupler to the main tuning capacitor was removed. While a note of the dial setting (3.9MHz) was made, the setting of the VFO tuning was inevitably moved during cleaning. A coax cable with its inner only connected to a feed-through on the side of the PA compartment was disconnected. The three self-tap screws connecting to the PA chassis were removed, one proved difficult and was left to soak with WD40. The wires to the PA chassis were unsoldered; the arrangement in the ‘power distribution’ screened compartment with the power supply connector was noted with care as several wires of the same colour passed through. The Jones power supply plug was then detached as wires from it went through a grommet to the PA.

The five crystals close to the front panel were removed, noting their positions: 4965kHz HC6U close to the panel, then a row of FT243 types, from the panel: 6000, 6250, 8025 and 8175kHz. All were cleaned in an ultrasonic bath. The chassis was cleaned, then painted using the procedure described above.

The PA Chassis

The PA chassis was in fair shape, Figure 7; also visible is the rust-stained rear of the front panel where the chassis and side plates had been in contact. The Eddystone 898 reduction drive mechanism and dial were in good condition. When dismantling this stage, care was taken around the drive cord to the pointer of the dial. The Jones plug can be seen with some of the wiring still attached.

The PA compartment gauze was removed, then the set screws from the front panel, except for the one by the PA Tune knob, followed by the screws to the side panel. The fixing nut for the PA Tune capacitor removed, allowing the tuning capacitor to drop away. The leads to the panel lights were cut close to the bulb-holder, and the Eddystone dial removed, with its fixing screws and spacer pillars.

The PA tuning capacitor could now be examined. A circlip that should have been in a slot on the shaft was missing. This meant that there was excessive play in the fore-aft direction, causing the near-short observed earlier. Having an exact spare capacitor available, the entire unit was replaced. (In January 2018 the capacitor had to be taken apart and re-tightened). The N750K ceramic capacitor to the feedthrough on the rear of the PA compartment was removed, followed by a bare wire from the neutralising trimmer to a feedthrough on the side of the compartment. The five self-tap screws holding the PA compartment screen to the chassis were then removed. After unsoldering the wire to a feedthrough, the small ALC chassis was removed. Next, the cover over the relay was removed, cleaned and repainted. The PL259 aerial socket was removed, noting the solder tag position, the corroded screws were treated, and the socket itself cleaned, followed by the same procedure for the octal auxiliary connector.

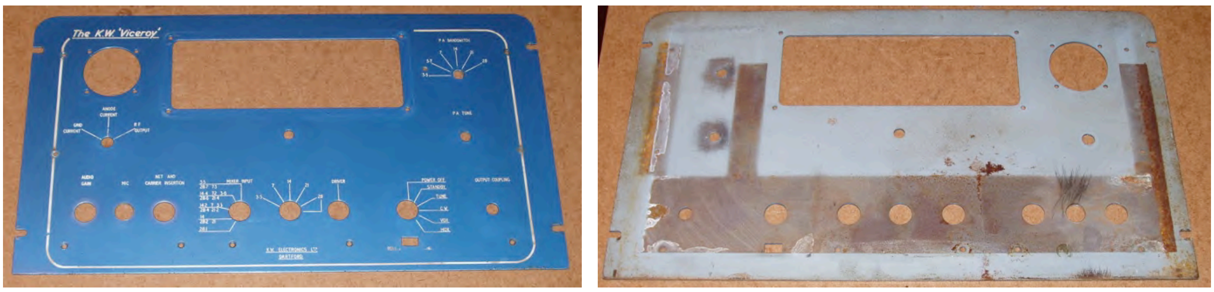

Figure 8. Left: the front panel and, right, the rear of the front panel before cleaning.

Rust stains on the rear of the front panel were removed first with emery paper on a small electric sander, followed by rust converter, and spray painted with a grey primer, Figure 8. All this was done with the front face resting on a flat surface on a sacrificial protective cloth. The front panel was cleaned with a kitchen cleaning product.

Reassembly and Test

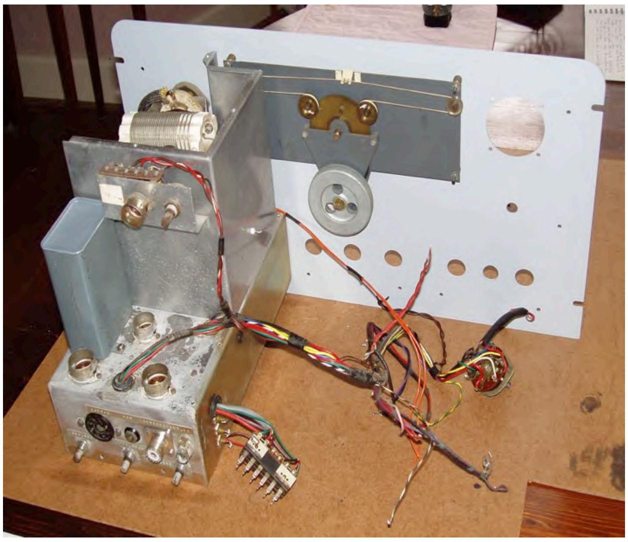

Figure 9. Reassembly: the painted panel, the Eddystone dial refitted, and the PA chassis cleaned and replaced.

The notes made during disassembly were used in reverse order to guide the reassembly. The original wiring loom was cleaned, ends of the wires were snipped and restripped; in almost all cases, there was more than sufficient length to do this while keeping the original layout. In a few places new wires were used.

The job had begun on 30 December 2009, and now, on 21 March 2010 the restored Viceroy was ready to test, Figure 10. With power on, and set to Standby, all dial lights and valve heaters were glowing. The rear coupler to the VFO tuning capacitor was slackened, and with the dial at 3.600MHz, the capacitor was turned independent of the dial shaft so that, with a slight carrier insertion, the correct frequency was read by a frequency counter. However, the mixer input knob was not at the correct point compared with the printed scale when at a peak at 3600kHz. The knob was slackened and adjusted so that the peak read correctly. Adequate indicated grid current could be achieved on 3.5, 7, and 21MHz, but was low on 14 and 28 MHz. However, on both these bands, there was enough drive to take the PA anode current to 200mA momentarily. On Tune, all was well, loading into a dummy load.

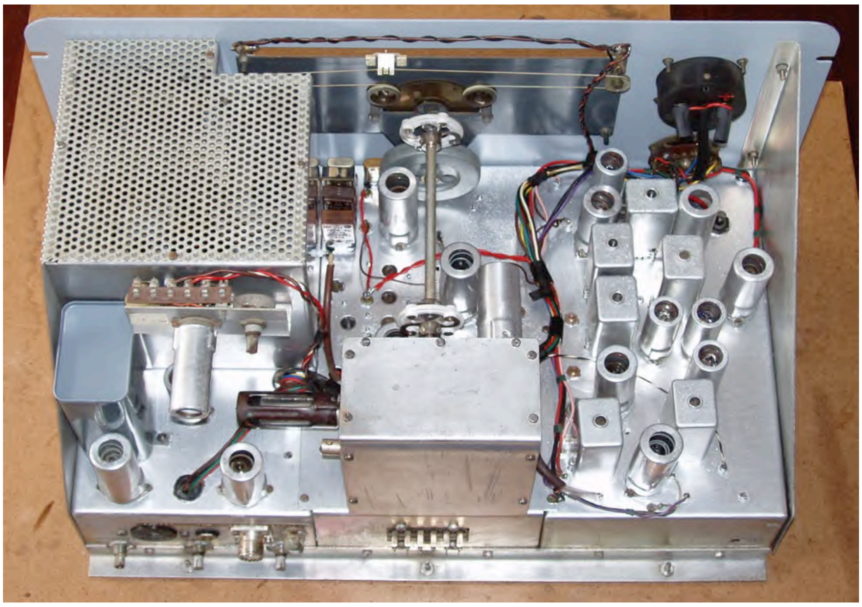

Figure 10. The KW Viceroy transmitter fully assembled after restoration. All valve and crystal screening cans have been cleaned using an ultrasonic bath.

The following weekend the transmitter was aligned as per the handbook. Overall, little adjustment was needed, except for the carrier balance, see below. Following Section 6 of the Manual, these are my short notes, where there are no notes, all was as per the Manual:

6-2 (2) Doubled checked that the transmitter side of R69 was temporarily shorted to chassis.

6-2 (3) The coax to the VFO box is an easy point to temporarily short this signal to chassis.

6-3 (3) Measured at 2.4V peak to peak, so ~0.8V rms as required.

6-4 (5) 1.4V was obtained at the junction of R9 and R10 of the audio amplifier; more than the 1V printed in the manual, and certainly more than the 0.6V pencilled in.

6-5 (1) Easier to get to was pin 7 of the 435kHz amplifier, while the cores of IFT1-3 were adjusted. The bottom core of IFT3 was the only one needing significant adjustment.

7-4 (4) 3.7V peak to peak (~1.2V rms) was obtained, the manual showed 1.5V.

9-4 (8) The adjustment potentiometer was right at one end and a proper dip could not be established. The matched diodes that plug in to a B7G socket were replaced with a pair from my original Viceroy.

The output signal with a microphone connected was fine when checked on a receiver. An octal plug was wired up to route the Anti-Trip and muting wires to my Star SR550 receiver.

The final test was on-air. And so it was real delight that on 2 April 2010 I made two contacts on 14MHz, with RW3XZ in Moscow, and SO8ZH in Lublin, Poland. Both stations reported a good signal quality. These contacts were made using my Mosley TA31jr 3-band trapped dipole in the attic, an aerial that dated back to 1967.

Refinishing the case

The wrap-around case was not too badly rusted; mild corrosion was limited to a few areas. The finish was a smooth grey, not a hammer tone finish. Given previous good experience from powder-coating specialists A1 Powder Coating at Woolston, Southampton, the case was taken to them for painting, in a colour very close to the original, Figure 11.

Figure 11. The restored Viceroy Mk IV with the original front panel and its powder-coated case.

Postscript

A KW Viceroy Mk IIIa was the first proper transmitter that I used as GW3ZIL in 1970. Previously, I had built a one-valve 7MHz crystal controlled CW transmitter with a 6L6 as CO and PA. This was rather neat, with, on one chassis, a power supply and the transmitter. There was an ex-WD meter for anode current, and output tuning was via a pi coupler circuit. There was no case, only a chassis and front panel.

Through the great generosity of my late father and mother, I joined the SSB generation, where, with the Viceroy (£100 second hand from the maker KW Electronics), a Star SR550 double conversion amateur band receiver (also second hand at £40), and a TA31jr three-band trapped dipole at a height of ~30’, I was able to “work the world” from an excellent site a few hundred metres from the sea at Holyhead, North Wales. My first logbook has gone missing over the years, but the second, from October 1970 onwards is still with me.

My Viceroy stayed with me for several years, but became neglected in the late 1980s/early 1990s when it lived in a damp garage. It was scrapped and dismantled some time after 1995, but most of the more useful components kept. In reality, it was probably in no worse shape than this example. I should have kept it, but *c’est la vie*, this one has been brought back to a respectable, working condition.

Update January 2018

Since the original restoration described above I've bought a suite of modern test equipment that has allowed me to revisit the Viceroy's alignment and performance. But it has also led me down a number of blind alleys, at least two of my own making. These are also set out below as a reminder!

Low power output - A Saga

This was a long saga with two blind alleys. Measurements with my Rigol digital oscilloscope showed that, even on 80 metres, I was only getting about 6W out for over 100W DC in. This conundrum was posted on the KW Yahoo Group as follows:

I've reached the point with head scratching and no solution ... To me, the problem appears (and I stress appears) to be down to something reducing the effective PA anode resistance to something like 700 ohms rather than the 2200 or so ohms that it should be.

Here are some other observations in no particular order:

1. *The capacitor to the ALC circuit has been disconnected - no change.*
2. *I've swapped the PA anodes RF choke for another Viceroy one I happened to have - no change.*
3. *The problem is there with the 6146s that I've had in the transmitter for years, and with the new Chinese 6146s that I've just fitted.*
4. *On "Tune" on 80m to a dummy load I cannot load to the 170mA / 140mA (off/on resonance) as in the handbook, best is 170/120.*
5. *Grid current puzzled me for a while, as I start to get grid current with the grids biassed at -67V when the drive at the grid is only about 48V peak to peak, so very far from driving the grids positive. Rather, at this level of grid drive there is an increase in the third harmonic content of the drive waveform from about -53dB re fundamental with the meter barely showing grid current to -41dB at 0.5mA grid current. I have convinced myself that this "grid current" is due to the assymmetric waveform rather than "real" grid current.*
6. *I've tried the "cold" method of checking the pi tank circuit, with a homebrew directional coupler connected across the loading capacitor fed by a tracking generator, a 50 ohm load, and looking at the output on the spectrum analyzer, and having fitted at 2200 ohm resistor from anodes to ground. I can easily get virtually zero reflected power. But, from the table below, I don't think the calculated load capacitor values line up with the position of the capacitor. This may be a clue ...*

The key measurements of the voltages at the grid of the 6CL6 driver (in blue, AC coupled) and the grid of the 6146B PA (in yellow, DC coupled) are in Figure 12 on 80 metres. PA grid current was being shown on the meter, but the PA grid drive was far from zero. However, the gain looked reasonable at ~57.

To cut a very long story short - Blind Alley No. 1- I'd damaged both of the Rigol scope probes on their x10 settings - in use here to minimise capacitive loading. In all probability I had used on too high a combined DC plus AC voltage and blown the capacitor (ca. 7pF) across the 9M resistor within the probe. This meant the probe was reading the correct DC voltage - as in the negative grid bias here, but was only reading some 30% of the AC RF voltage. So, in reality, the grid signal here ***was*** reaching zero. And, as power is proportional to V^2, 30% of voltage is some 10% or power, so, unknowingly, I was getting about 60W out.

All this came to light after I'd purchased high voltage a x100 probe ("2kV", 5pF and 100M). However, even that probe has quite a severe de-rating of DC+AC as a function of frequency, Figure 13.

With this new x100 probe, after aligning the 2nd mixer anode and driver anode coils, to be sure that the dual-gang 15pF "Driver" tuning was tracking, I could get 200V peak to peak at the 50 ohm dummy load on MOX on 80 metres. However, the output for each of the higher bands dropped away to nothing on 10. Then came my second Blind Alley.

Figure 12 80 metres PA grid voltage DC coupled in yellow and driver grid voltage AC coupled in blue. Why was there grid current being drawn when the PA grid voltage was nowhere near zero?

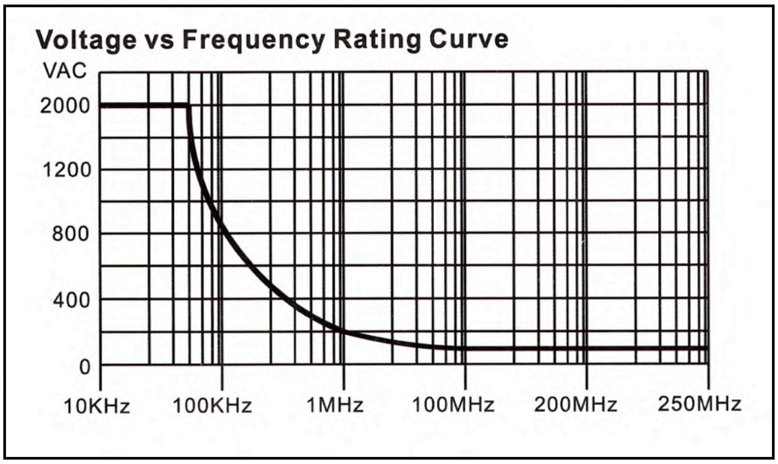

Figure 13 Voltage derating curve with frequency for the unbranded x100 scope probe. Note the curious frequency scale; best to rate the probe at 100V rms above 3MHz.

The output was dropping away because the drive to the PA grid was much reduced on the higher frequencies. With a signal generator input to the grid of the driver, measuring its amplitude there with a x10 probe, and measuring the voltage on the anode of the driver (after retuning to account for the presence of the x100 probe) the gain at 3.7MHz was ~66 but only 26 at 7.1MHz. Now gain should be given by the equation:

gain = gm * Q_{loaded} * $2\pi f$ L

where gm is the mutual conductance of the valve in A/V, in this case 0.008 (8mA/V, as measured on my valve tester; a new 6CL6 should be about 11mA/V). Q_{loaded} can be estimated from the ratio of the peak frequency to the -3dB full-width bandwidth measured using the Rigol DSA815. L, the coil inductance, was estimated by noting the resonant frequency with the driver variable capacitor fully open and fully meshed, taking the difference as 15pF, with the values of the other known capacitors and a calculated stray capacitance, and using a manual-inspection optimisation over the 80-40-20 metres.

The inductance values for 80-40-20 were: 29, 9.4, 2.3μH. Q_{loaded} for 80-40-20 calculated this way were: 12.7, 27.4, 29. The calculated gains were thus: 68, 93, 48 while the observed gains were: 66, 22, 11.

Why the discrepancy? It had to be that the measured Q values for 40 and 20 were too high, given that the gm would not change with frequency and that the coil values were reasonable and certainly not as far out as the measured gains would suggest. It struck me that I'd connected the signal generator to the grid of the driver, leaving the coupling link to the tuned circuit in the anode of the 2nd mixer in place. It was easy to disconnect the above-chassis shielded cable from the 2nd mixer cols to the driver grid and feed the signal generator only to the driver grid, with a 1mH choke to ensure a DC path from grid to chassis.

Now the measured Q_{loaded} for 80-40-20 were: 10.4, 9.6, 6.7. Using these values the calculated gains were: 57, 28, 11, much more in keeping with those measured. So, I've learnt to isolate a gain stage when making these measurements. But why was the Q lower than one would expect, and indeed, by inference, lower than the Q of the 2nd mixer tuned circuits? This took me quite a while to figure out, and the conclusion is embarrassing!

What I should have done far earlier was to sketch out all of the components that comprise the anode tuned circuit of the driver, including the valve and scope parameters. This is what I ended up doing and then using that circuit as the basis for a MacSPICE simulation. The circuit is more complex than one might think, Figure 14, and there is plenty of scope for the Q to be degraded if there is unwanted resistance in any of the components contributing to the tuned circuit. Note how the 15pF tuning capacitor is only about 25% of the total capacity across the tuned circuit. Also note that the 470pF HT decoupling capacitor and the 91pF feedthrough decoupler are in series with the frequency-determining capacitors. Therefore, if there were excessive loss resistance here the Q would be lowered. Note that the coupling capacitor from driver anode to PA grid is in series with the grid-cathode capacities of the 6146B valves - a total of 27pF. Together, these comprise some 50% of the resonating capacitance. Figure 14 shows where I've added nominal 1Ωresistors to represent losses, with those in circuit, the MacSPICE simulation is shown in Figure 15 (left), which shows a gain of about 51. My embarrassing realisation was that I'd added previously a 100 Ω resistor in series with the anode to grid coupling capacitor to measure the actual PA grid current. This was still in place, and it was not until now that I realised the importance of that path to the driver tuned circuit Q. The effect of the 100Ω resistor is clear in MacSPICE, Figure 15 (right) where the Q has dropped substantially and the gain has dropped to 15 from 51.

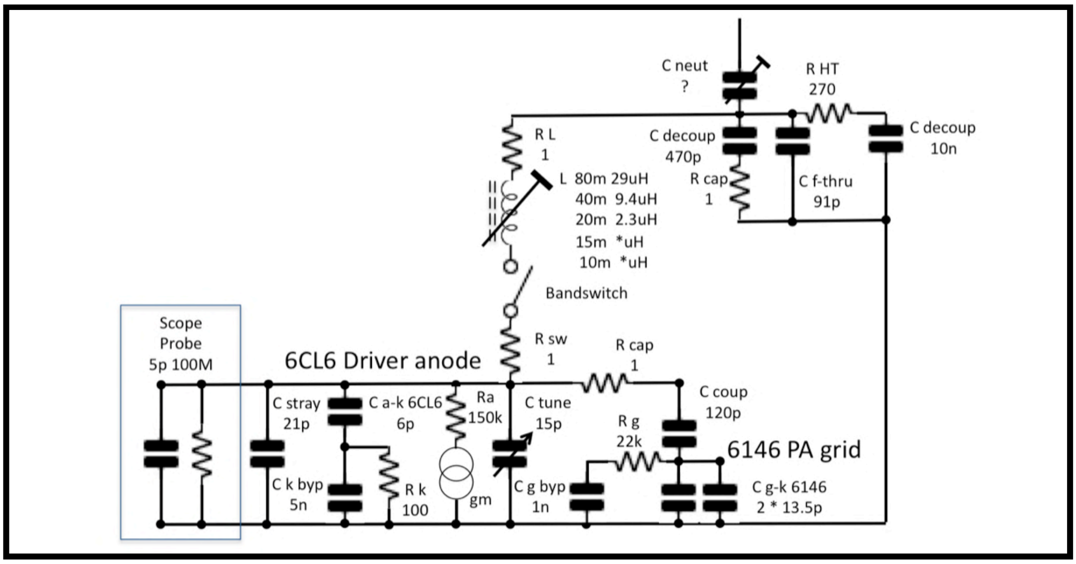

Figure 14 Circuit diagram of the driver stage tuned circuit components.

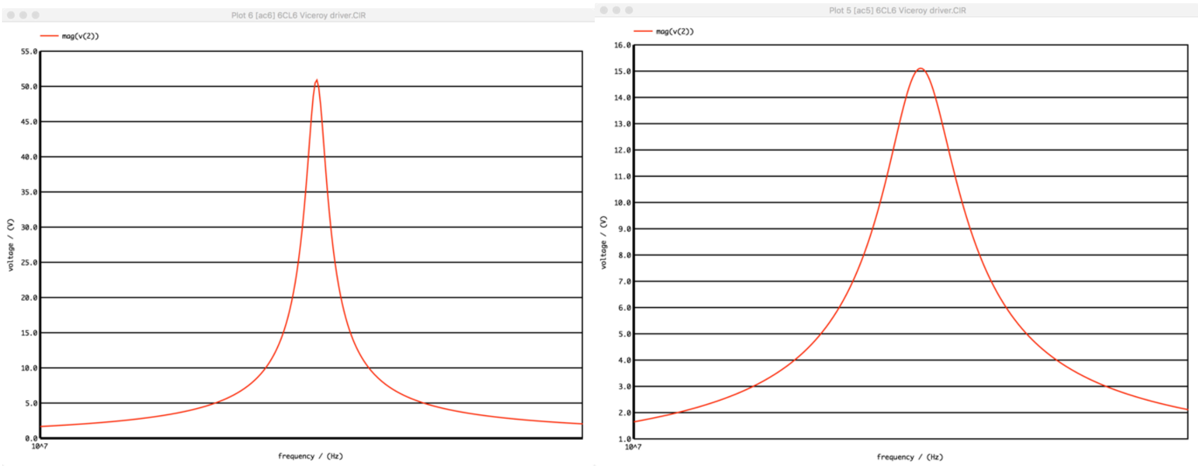

Figure 15 MacSPICE simulation of the driver-PA resonant circuit for 14MHz using the circuit topology of Figure 12. Left: with 1 Ω resistors. Right with 100Ω in series with the PA anode-grid capacitance.

Needless to say the resistor was removed forthwith! The measured Q_{loaded} values on 80-40-20-15 were now: 16, 24, 28, 27 - far more in keeping with expectations. I could not get the peak on 10 higher than 27.4MHz due to the added capacity of the test probe.

I found a new, unused 6CL6 on eBay (Thomson, Made in France) and with this valve, the peak-to-peak drive on 80–10 at the anode of the driver was: 240, 274, 280, 180, 120V. This was sufficient to provide 100W (~200V peak-to-peak) output into a 50W dummy load on 80–20, 81W on 15 and 50W on 10.

Microphone amplifier and cathode follower

With 50mV rms audio in to the front panel jack socket at 500Hz the level at V1a anode (half of a 12AX7) was 2V rms, a gain of 40. With the audio gain control fully CW the level from the cathode follower V1b at the junction of R9 and R10 was 0.57V rms, but distorted; the maximum level at which there was minimal distortion was 0.32V rms. The values in section 6.4 of the manual are rather curious, it calls for 1V audio input at 500Hz, and states that 1V

AC should be seen at the junction of R9 and R10; 1V input is far too high, and my measurements show that at 1V output there would be severe distortion.

Both the anode and cathode resistors of V1a have increased in value: R2 the anode resistor from 100k to 115k and R6 the cathode resistor from 2k2 to 3k1. The V1a anode voltage is 181V (cf. 160V in the manual) and the cathode is 1.66V (1.5V in the manual). From the ECC83 characteristic curves, one would expect a higher anode current at a bias of -1.66V, which suggests the emission of this valve is lower than when new. Consequently the observed gain of 40 is lower than the calculated gain of ~53.

The V1b cathode is at 1.7V, R8 the cathode resistor is 1k14 rather than 1k0; the components are so tight to the valve base that neither the anode voltage or the anode resistor can be measured.

The maximum undistorted audio level of 0.32V rms at the junction of R9 and R10 is reached with a whistle into the microphone at an audio gain setting of 12 o'clock. However, a gain setting of only 9 o'clock is needed to obtain whistle peaks of over 200mA on 80 metres. Hence distortion from the V1b cathode follower is not an issue in practice.

435kHz crystal oscillator

The 435kHz "carrier" crystal oscillator at the feed-through point "A" in Figure 16 (Right) was 35mV rms with the Carrier Insertion control fully CW. The frequency was 435.006kHz; no alternation was made to the carrier Phillips beehive trimmer C60, Figure 16 (Left).

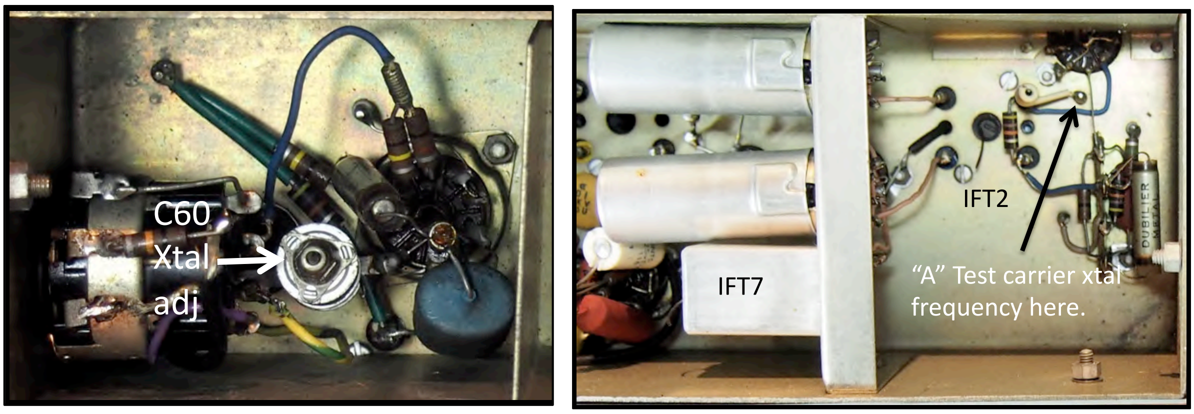

Figure 16 Component layout for (Left) 435kHz crystal oscillator. (Right) part of the crystal filter and part of the 435kHz IF amplifier top right with carrier test point, with Carrier Insertion control fully CW.

Diode shunt Balanced Modulator

Carrier suppression was only about 5dB soon after switch on. When trying to adjust the balance potentiometer with a screwdriver, it was stiff, the shaft sheared! It was removed and replaced with a 1kΩ potentiometer with a long plastic shaft that could be turned by hand (R12 in Figure 17). The potentiometer that was removed was sized solid, but it was not the original; it, and the two 470R resistors at each end, had been replaced at some time. The capacitive balance is adjusted using C28 in Figure 17.

Figure 18 shows the carrier suppression at over 40dB at the primary winding of the balanced modulator output transformer. The audio tone is from a 500Hz input to the microphone socket.

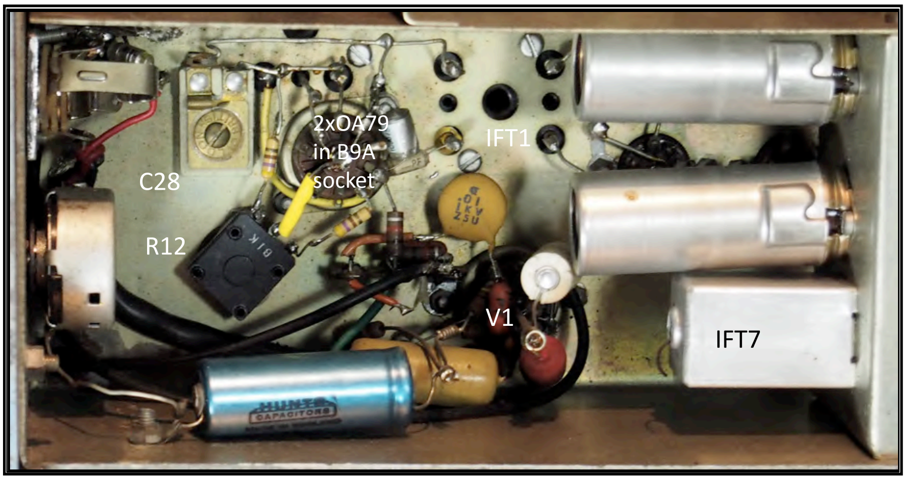

Figure 17 Component layout of the audio amplifier, the balanced modulator and part of the crystal filter. The circular screening cans on the sub-chassis at the right are the crystals from the extra half-lattice section.

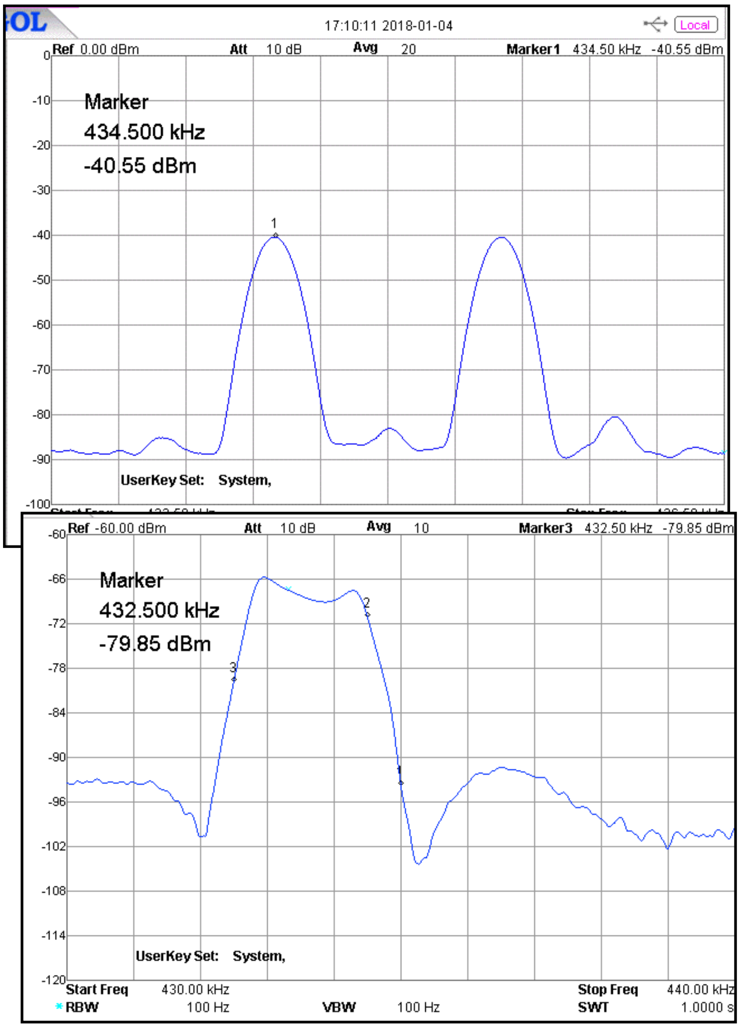

Figure 19 Spectrum - span 10kHz- showing lower sideband after crystal filter. Marker 1 is the carrier at 435kHz, marker 2 is 434.5kHz (500Hz audio) and marker 3 is at 432.5kHz (2500Hz audio). Note that with no physical connection to the circuit the signal level is low.

Crystal filter - upper sideband suppression

This Viceroy came fitted with the extra half lattice crystal filter - that is five crystals in all, together with a parallel tuned circuit, IFT7 (see Figure 17), whose tuning primarily affects the "sag" within the passband.

IFT1 and IFT2 had been tuned previously using the procedure in section 6.5 of the manual. Now, the Rigol DSA815 with tracking generator was used. The tracking generator output was fed via a 50Ω resistor to pin 6 of the 2xOA79 socket. The spectrum analyzer 50Ω input cannot be connected directly to the filter output and so the croc clip was placed on the body of the unnumbered 470k resistor at the grid of V2. This means that the levels are not right, but the shape should be correct. Only slight adjustments to IFT1, IFT2 and IFT7 were needed to give the passband shown in Figure 19.

Marker 2 is at an equivalent audio frequency of 500Hz and Marker 3 is at 2500Hz. Marker 1 is at the carrier, about 20dB below the level at 500Hz.

VFO

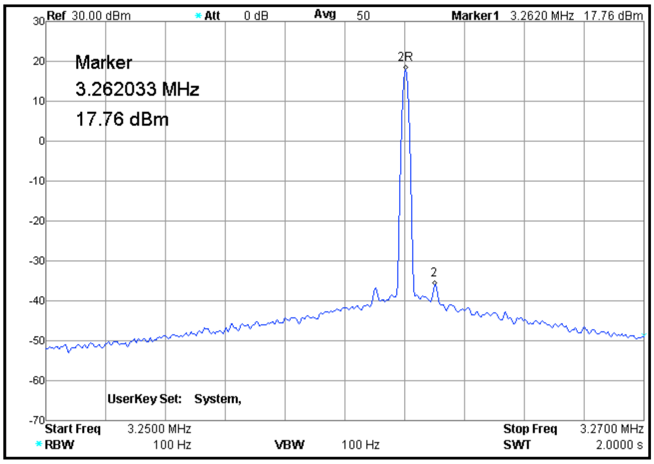

Figure 20 Close-in spectrum of the VFO output at a dial frequency of 3700kHz. The span is 20kHz and the spurs at 1kHz from the carrier are about 53dB down.

The frequency span of the VFO is 3065–3665kHz, which on 80m corresponds to 3500–4100kHz given the 435kHz IF carrier oscillator frequency. The adjustment at 3500kHz is by inductor L12 that has a threaded rod towards the front of the chassis. First, one must slacken slightly the lock nut; only slightly as the core is otherwise too loose. The core was adjusted to be correct at 3500kHz. At 100kHz increments, the error was 0, -3, -3, -1, +3, +2, +1; no further adjustment was made.

The level at the output was 1.88V rms (17.8dBm), the manual calls for 1.5V. The close-in spectrum is shown in Figure 20, where there are spurs at +/-1kHz at about -53dB below the peak. The source of these is not at all clear. The VFO waveform at the output is shown in Figure 21 (Left) and its spectrum (Right).

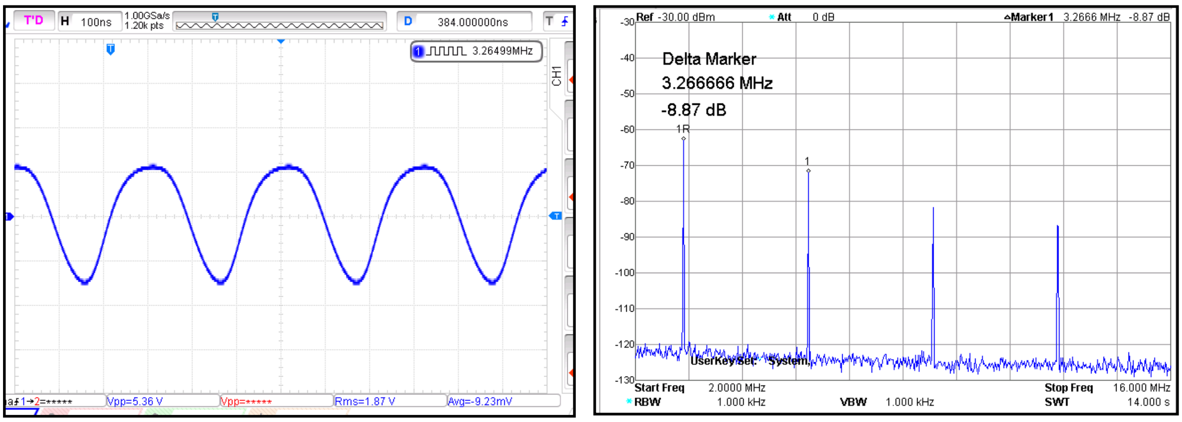

Figure 21 (Left) Oscilloscope waveform for the VFO output at 3.265MHz at 1.88V rms. (Right) spectrum from 2–20MHz for the VFO output, with the 2nd, 3rd and 4th harmonics present (relative only, not an absolute measurement).

First mixer

The first mixer, comprising the two triodes within V3 (a 12AT7), is in effect the second balanced modulator. The two RF signals into the mixer come from (a) the 435kHz IF amplifier V2 via a balanced "hot" ends of IFT3 into the grids and (b) the VFO into the centre tap of IFT3. Balance adjustment is by the potentiometer R22 and the 30pF beehive trimmer capacitor C27 (Figure 22). To provide the correct sideband for later amplification (on the 3.5MHz band), or frequency translation (7, 14, 21 and 28MHz bands), in the second mixer the output circuit comprising IFT4 and IFT6 must be tuned to the sum frequency on all bands *except* 7MHz where the tuning is to the difference frequency.

The first procedure, as described in section 8.3 of the manual, is to adjust top and bottom cores of IFT4 and IFT6 for maximum signal with the band set to 3.5MHz and the Mixer Tune and VFO frequencies set to 3700kHz. The result is shown in Figure 23 (left) after R22 and C27 were adjusted to minimise the component at the VFO frequency (marker 2). Disappointingly, the signal at the VFO frequency could not be reduced to less than 20dB below the wanted sum signal.

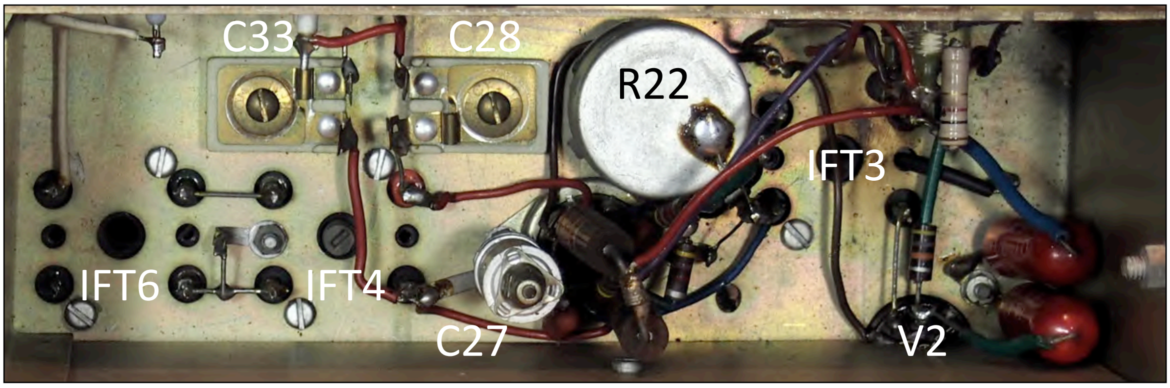

Figure 22 Component layout of the first mixer. R22 is adjusted from the top of the chassis.

With the 7MHz band selected three trimmer capacitors are switched into the tuned circuits, 110pF compression trimmers C28 and C33 are connected in parallel with the two fixed capacitors across the primary of IFT4 and the 110pF compression trimmer C34 is connected across C35 the Mixer Tune front panel control (and the series pair of C36 and C31). C34 is located within the 2nd Mixer sub-chassis, Figure 26. Figure 23 (right) shows over 45dB of VFO frequency suppression in this case.

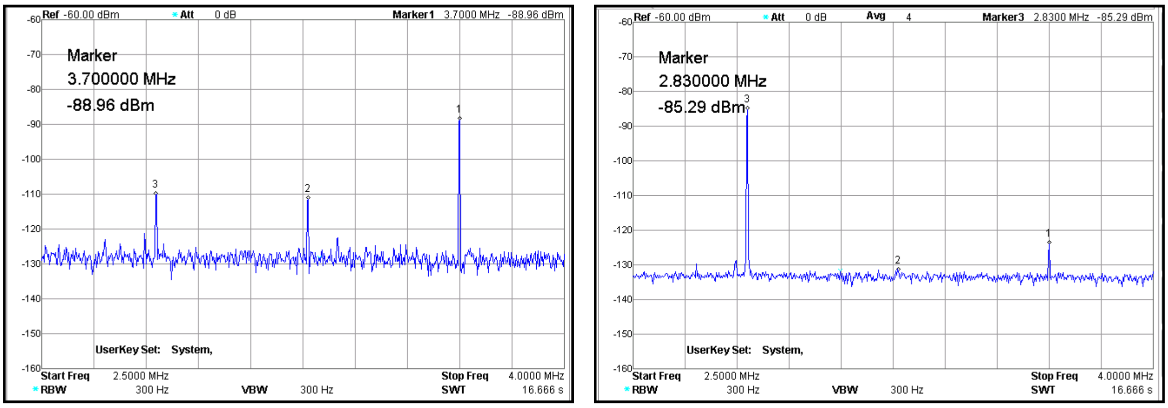

Figure 23 Output of the 2nd balanced modulator taken with the DSA815 croc clip over the body of C36 attached to the Mixer tuning capacitor. (Left) 3.5MHz band selected, with IFT6 tuned to the sum (3700kHz) of the VFO frequency (3265kHz) and the 435kHz crystal oscillator (this is also the configuration for 14, 21 and 28MHz bands). (Right) 7.0MHz band is different; IFT6 is tuned to the difference frequency of 2830kHz in this example. I've not been able to find out why the VFO and sum frequency suppression is better in this case.

Peaking for the correct mixer product was quite straightforward with the spectrum analyzer, but could be trickier using only valve voltmeter (as in the manual) if the cores and trimmers were way out. The sum and difference products are sufficiently far apart that measurements of the period on an oscilloscope would be sufficient to make sure the correct signal was being peaked. With a x100 scope probe the levels at the Mixer Input tuning capacitor were 2.6V rms at the sum frequency of 3.7MHz and 2.1V rms at the difference frequency of 2.83MHz for the 7MHz band.

Crystal Oscillator for the Second Mixer

The crystal oscillator, V12, an EF80, generates the appropriate frequencies for the second mixer, V4. The anode tuned circuit is a bit of a compromise in that a single inductor (L4) is used with a low impedance coupling winding to the cathode of V4. To tune the primary to the correct frequency, there are trimmer capacitors and a core-tuned inductor for the 10m band frequencies. The Table below lists the relevant details (frequencies in kHz), and the layout is shown in Figure 24.

Band	Xtal freq	Holder	Mult	Adjust	Out Vrms	Tuned freq	Mixer: CO-Input=Output
7	4965	HC6U	2	C76a	4.5	9930	9930-2830=7100
14	6000	HC6U	3	C77	6.6	18000	18000-3700=14300
21	6250	FT243	4	C78	3.6	25000	25000-3700=21300
28a	8025	FT243	4	L10		32100	32100-3700=28400
28b	8175	FT243	4	L10	2	32700	32700-3700=29000

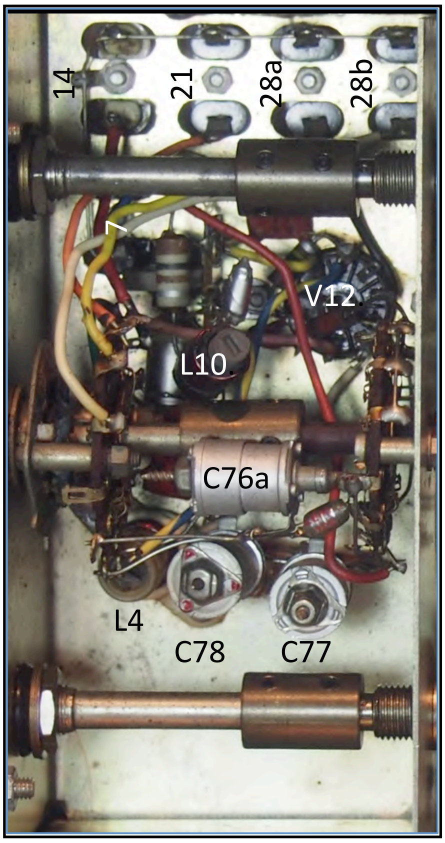

Figure 24 Component layout of the crystal oscillator for the second mixer.

The manual states that the initial adjustment is that of L4 for maximum output (on a valve voltmeter) at V4 cathode (test point "A" in Figure 26) on the 28MHz band-switch setting. There is no mention in the handbook of how to adjust L11. In practice aligning this stage was the most difficult, it is quite possible to tune the outputs to the wrong harmonics. This was especially true for the lower frequency 28MHz band (8025kHz crystal). The wanted 32100kHz output was difficult to achieve, the highest amplitude output was at 16050kHz, then 24075kHz; there was minimal output at 32100kHz, even after L10 was adjusted, and different combinations of L4 and L10 tuning tried. The waveform at Figure 25a (left) was the best that could be achieved; the 32100kHz component is about 0.5V rms. It is not surprising that the drive on 28MHz is down compared with the other bands.

The waveform for the upper 28MHz band was better, Figure 25 (centre). This suggests that the problem is a sluggish 8025kHz crystal. This was confirmed when a 8050kHz FT243 crystal was inserted, and the output was 2.2V rms, Figure 25a (right).

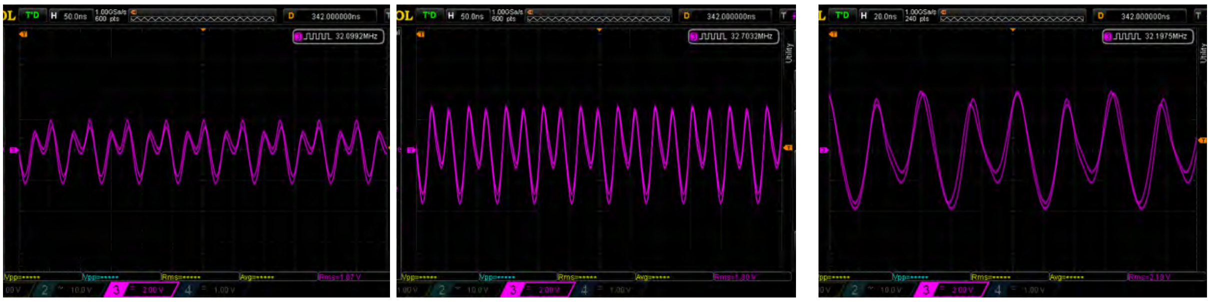

Figure 25a Oscilloscope traces for (left) lower 28MHz band with original 8025kHz crystal, the wanted 32100kHz signal is weak, (centre) original 8175kHz crystal for the upper 28MHz band, (right) temporary test with a 8050kHz crystal showing a decent 2.2V rms (note the scale here is 20ns per division not 50ns as for the other two).

Later, a 8025kHz FT243 crystal was found and bought on eBay, on a gamble that it might prove more active. Indeed that was the case! Figure 25b (left shows the spectrum of the original crystal (as for Figure 25a (left)) and (right) the replacement crystal showing about a 10dB higher level at the wanted 32.1MHz.

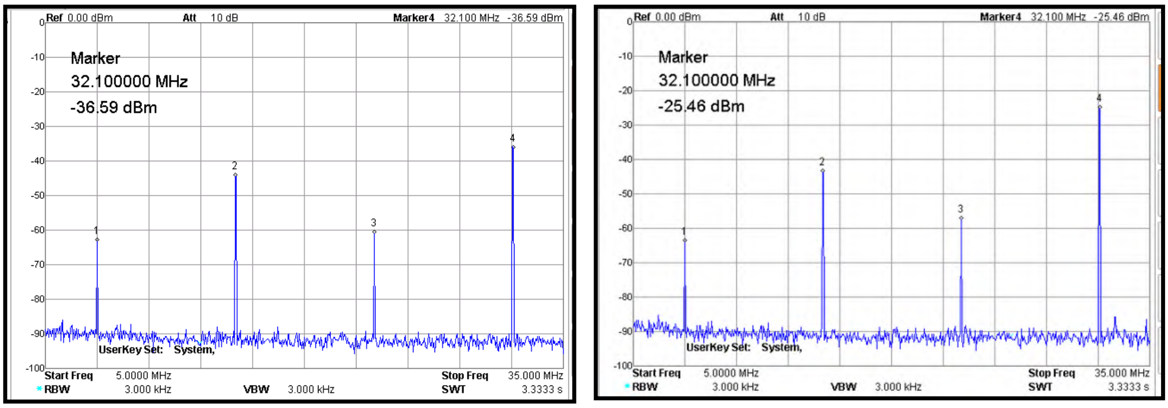

Figure 25a Spectrum from 5–35MHz for the 8025kHz FT243 crystal for the lower part of the 28MHz band where the 4th harmonic at 32100kHz is the wanted signal: (left) original crystal with the time series shown in Figure 25a (left) and (right) a replacement crystal showing an 11dB higher output at 32100kHz.

Second Mixer

Section 8.6 of the manual has the output of the second mixer measured at the grid of the driver V5, test point "A" in Figure 27. With a x100 scope probe at this test point, and the variable capacitors set as in the manual, peaking the coils, Figure 26, was straightforward. For this, I used the Carrier Insertion to provide a signal rather than an audio tone.

However, I swapped to using a 500Hz audio signal to the microphone socket at 1mV rms, with the audio gain fully CW, to measure the signal at the grid of the driver on each band. This gives a reference level for me to return to in the future. Note that with the Viceroy on Standby using the audio input path requires the negative bias on the IF amplifier and first mixer to be removed by shorting the "valve" side of R69 as per the manual, section 6.2.2, shown as point "B" in Figure 28. The voltages obtained are in the table below.

Figure 26 Component layout of the second mixer sub-chassis.

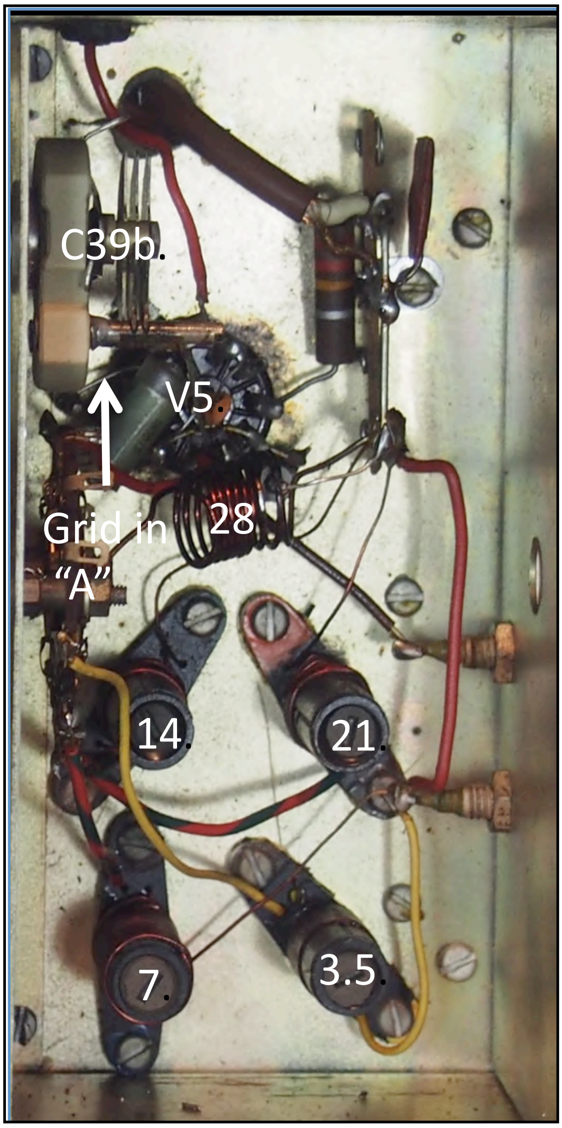

Figure 27 Component layout of the driver sub-chassis.

Band / frequency	Driver grid (V) rms	Driver Setting
3.7	0.73	
7.1	1.1	
14.3	3.9	
21.3	4.3	at 11:30 o'clock. NOT 2:30 o'clock which is 25MHz.
29.0	5.1	at 12:30 o'clock. NOT 2:30 o'clock which is 32.7MHz.

My next step was to move the scope probe to the grids of the PA, point "A" in Figure 28, and to retune the second mixer coils now that there was no additional loading at the driver grid.

Driver

Section 8.7 of the manual deals with Driver alignment; using the grid current meter setting to peak the coils for each band, Figure 27. Note that the 28MHz coil is self-supporting air-cored and is adjusted by squeezing or expanding the turns. **Caution!** This coil is in the anode circuit, and so is at HT potential of ~260V. My practice is to use two plastic blades to set the coil.

My practice was now to use a x100 scope probe of adequate RF voltage rating at the grid of the PA, test point "A" in Figure 28. This gets the coils for bands 3.5–21MHz close to correct, and one can be sure of peaking the correct frequency. Note that this cannot be done for the 28MHz band as the adjustment on the coil is insufficient to bring the circuit to resonance with the added capacity of the scope probe. The voltages on the PA grid for 3.5–21MHz are shown in the table below; note that with the bias at -54V grid current began at 37V rms.

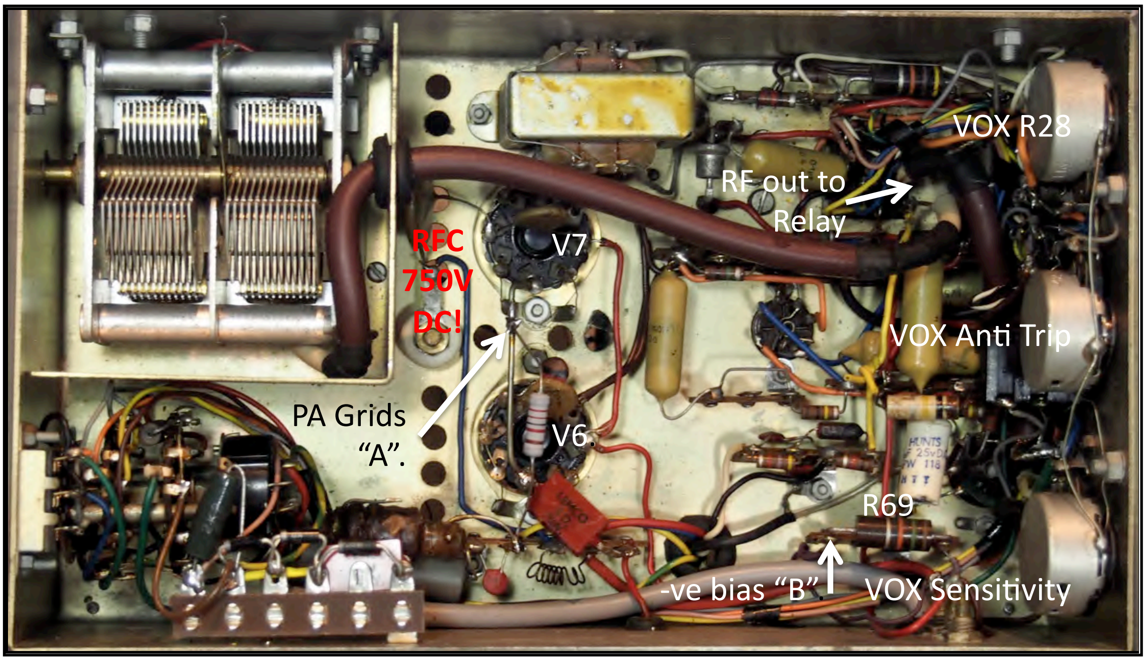

Figure 28 Component layout of the PA and VOX sub-chassis.

Band / frequency	PA grid (V) rms
3.7	46
7.1	49
14.3	72
21.3	63

ALC

In my early investigations on low drive I'd thought there might have been an ALC problem, which I isolated for the time being by removing the 6AL5 ALC double diode V13. Now it was time to investigate. The ALC circuit was the same in both of the circuit diagrams available on the web, but the reading of ALC out on this Viceroy did not make sense given the circuit:

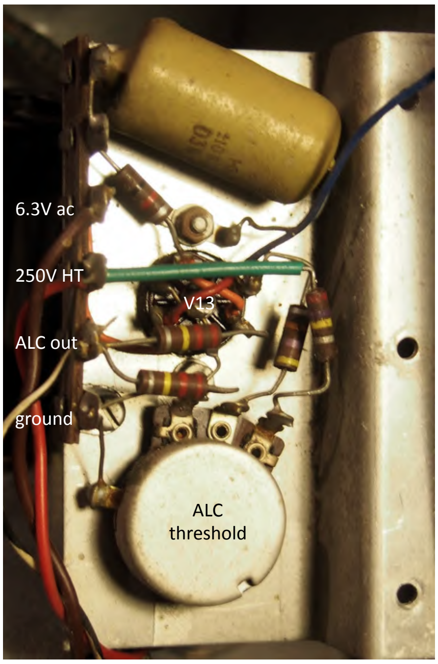

Figure 29 Component layout of the ALC sub-chassis that is normally screwed to the outside rear of the PA compartment.

1. On Standby the ALC out was at -27V instead of zero (irrespective of the position of the ALC potentiometer - as it should be with no drive). This suggested (a) that my ALC circuit must be different, with a negative fixed bias on V2 in Standby, probably switched off in Carrier Insert or on any of the transmission/tune modes, as is the bias to the first mixer V3 and (b) the circuit around the potentiometer must be different so that the fixed bias is not shorted to ground.
2. On Tune, there was a DC ALC out voltage present from just a few volts RF output irrespective of the setting of the potentiometer.

The ALC sub-chassis, Figure 29, was detached from the PA compartment and the circuit worked out, Figure 30, together with the ALC circuit at the grid of the 435kHz amplifier V2. This circuit makes sense of the observations, but only if the 270k resistor from the 250V HT line to the potentiometer was a very high resistance or open circuit. In fact, it was open circuit.

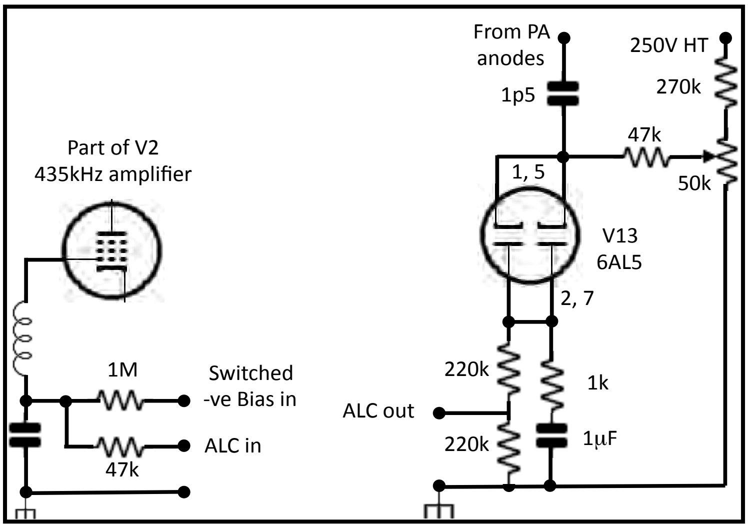

Figure 30 ALC circuit as in my MkIV Viceroy.

With this arrangement the ALC control varies the cut-in threshold for the ALC by varying the positive stand-off voltage on the cathodes of the diodes. The "slope" of the PA anode voltage to ALC voltage is fixed. In the Viceroy MK III circuits on the web the cut-in threshold is fixed (as .03 of the HT voltage by the 220k and 6k8 resistors), but the "slope" is set by the ALC control. I have set the potentiometer to give 14V stand-off voltage (~0.05 of the HT voltage).

The wiring of the ALC potentiometer is such that fully CCW is with the wiper at 0V, hence maximum ALC, with no stand-off. This is the exact opposite of the effect of the control in earlier circuits, where fully CCW is no ALC. This is an important point!

The table below gives the RF output voltages (rms) at the antenna connector, with a 50Ω dummy load, for four settings of the ALC potentiometer with the transmitter set to "Tune".

V ALC	Vpot=18	Vpot=14	Vpot=7	Vpot=0
0	30.0	23.0	11.5	0
-0.4	32.4	25.5	12.8	1.6
-1.7	36.5	32.0	18.5	6.8

Performance against specification

VFO frequency stability

The brochure describes the VFO stability as "*Better than 100 cycles after warm-up*". The measurements in Figure 31, taken from cold in a room temperature of about 20˚C with an Apollo Black Star 100 counter, show a drift to -120Hz followed by a rise to +53Hz in the first 30 minutes, followed by a rise in frequency of 130Hz in the next hour, levelling of to 29, 13 and 0Hz in subsequent hours. This is followed by a slow rise, but no more than 20Hz per hour. This is an excellent performance and meets the specification.

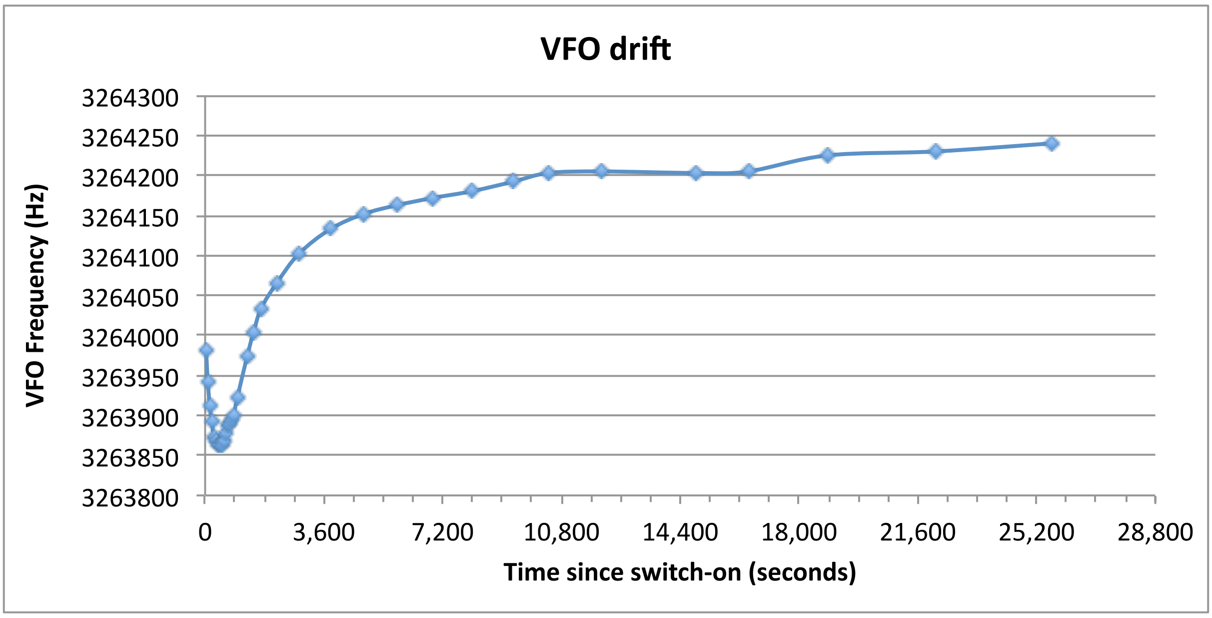

Figure 31 VFO frequency stability measured with an Apollo Black Star 100 frequency counter beginning at 15:38 and ending at 22:45 on 29 January 2018.

Carrier and unwanted sideband suppression

With the extra half-lattice crystal filter as fitted to this Viceroy the specification has the carrier suppression as at least 45dB and the unwanted sideband at least 50dB at 2kHz. Figure 32 shows the spectrum +/-5kHz centred on 3700kHz with a 2kHz audio tone into the microphone socket, and with the anode current on Tune set to 100mA The DSA815 probe was placed over the insulation of the coax cable to the antenna socket.

The observed carrier suppression was -57dB and the unwanted sideband at -58dB, both exceeding the specification.

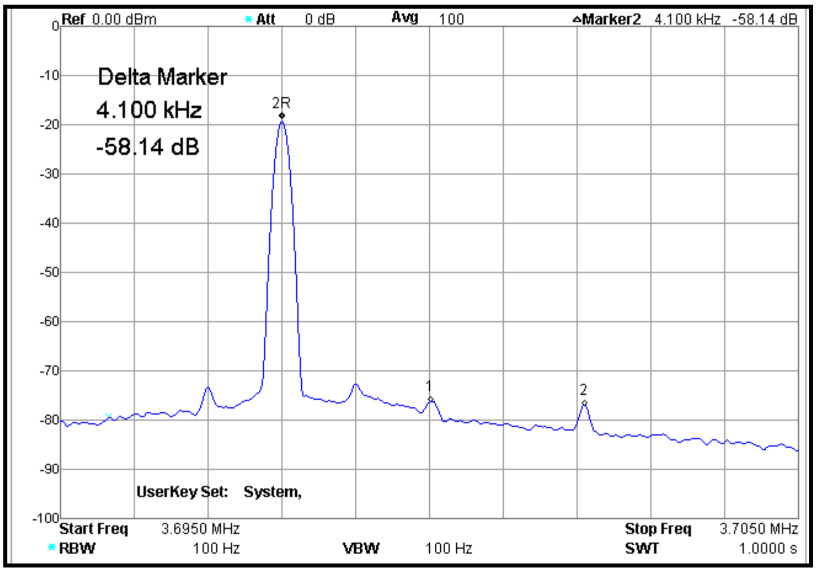

Figure 32 Spectrum of +/-5kHz around 3700kHz with a 2kHz audio tone to the microphone socket. Marker 1 is the carrier, marker 2 is the unwanted sideband. Note that there are spurs at 1 and 3kHz, but both are over 50dB down. The absolute values are not relevant; the connection was by capacitive pick-up.

Spurious outputs

The Viceroy specification does not cover spurious outputs. The spectra below were obtained using a DSA815 with a probe clip over the top of the insulation on the inner conductor of the coaxial cable at the antenna socket. This will likely have introduced a frequency-dependent factor, but it is a safe way to operate - there is also a 50 ohm 20dB attenuator at the front end of the analyzer. Hence the figures do not represent absolute amplitudes, but should give a fair indication of relative levels.

80m

Not surprisingly, the 80m band has the least complex spectrum of spurious responses, Figure 33; this is because there is no frequency translation in the second mixer. Point 3R is the wanted signal at 3700kHz, with its second harmonic at point 1 at 7400kHz 44.5dB down, and the third harmonic at point 3 at 47dB down. Point 2 at 435kHz below the wanted signal is at the VFO frequency of 3265kHz and is 42dB down; this is from imperfect balance at the first mixer. See Figure 23 (left) where I was unable to get a better VFO suppression than -20dB; the additional 22dB suppression seen in Figure 33 must come from the tuned circuits after the first mixer.

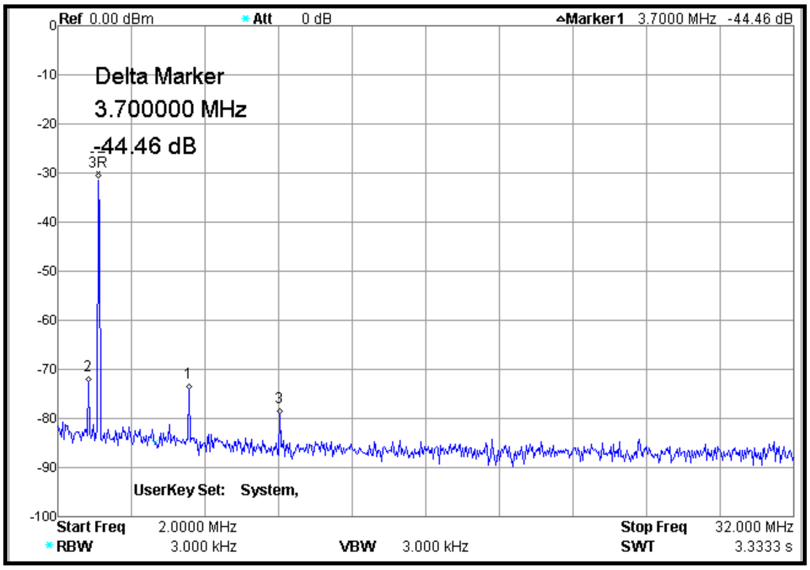

Figure 33 Spectrum of the Viceroy output at a dial frequency of 3700kHz, showing substantial second and third harmonics and the VFO frequency.

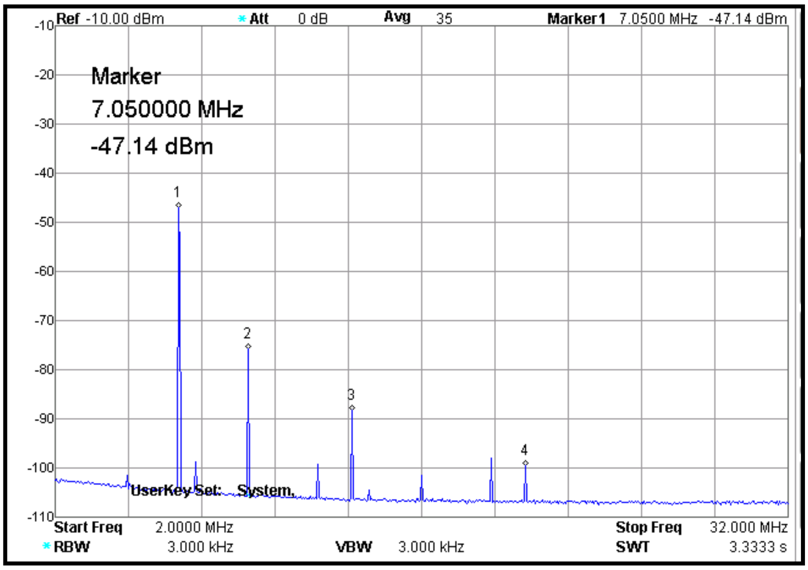

Figure 34 Spectrum of the Viceroy output at a dial frequency of 7050kHz, showing substantial second and third harmonics and harmonics of the second mixer crystal oscillator.

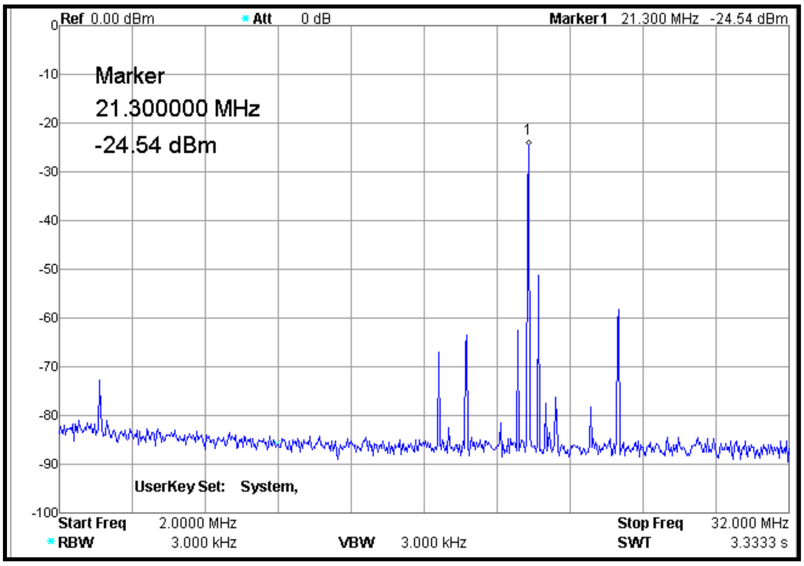

Figure 35 Spectrum of the Viceroy output at a dial frequency of 21300kHz, nine significant suprii within +/- 4MHz.

40m

On 40m, because of the second mixer, there are more unwanted frequencies present than on 80m. Figure 34, taken at a PA anode current of 100mA, has the wanted output at 7050kHz, marker 1; its second harmonic, marker 3; and third harmonic, marker 4. The peak just below marker 4, and at about the same amplitude, is the fourth harmonic of the second mixer 4965kHz crystal oscillator for 40m, its third harmonic is ca. 10dB lower, just above the noise floor HF of marker 3, and the second harmonic is marker 2.

15m

On 15m the spectrum has more close-in peaks than on 40m with nine spurii within +/- 4MHz and the VFO frequency is also present, Figure 35.

It is hard to know whether these spurious responses were there in the Viceroy from new, or whether small changes in valve operating conditions (e.g. bias points, screen voltages) due to component aging could be contributory factors to this poor performance.