More power from the TCS - is it worth it?

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The author's main station set up is the TCS TX/RX combination (fig. 1) feeding a dipole which is resonant on 3615 kHz. The TCS is rated to deliver 12 W AM from a plate and screen modulated 1625 (12.6 V version of an 807). Living some distance from the centre of gravity of 80 m AM operation, the modest output of the TCS leaves something to be desired. The transmitter has two 1625s in the PA compartment, the second being brought into service for CW operation; it seems reasonable to press both into service for AM operation with a resulting increase in output. This article explains how the modification can be carried out but also aims to evaluate critically its success. **Anyone intending to carry out modifications to the TCS is urged to have a full circuit diagram to hand and preferably a components placement diagram.**

Fig. 1. The author's TCS set up.

Bringing both 1625s into service

The double pole double throw AM/CW switch on the front panel serves a number of functions:

- One side switches directly the live heater supply either to the modulator valves or to the second 1625, thus ensuring that the modulator heaters are off when using CW.
- A small relay shorts the modulation transformer secondary on CW. In the AM position, the switch is used to earth the cold end of the relay coil, so allowing current to pass through the coil and open the contact to remove the short.
- In the CW position, the relay is de-energised shorting the transformer secondary, whilst the panel switch is used simultaneously to earth the cathode of the second 1625.

The simplest way of ensuring that both 1625s remain on when using AM or CW, is to short one side of the switch as illustrated in fig. 2.

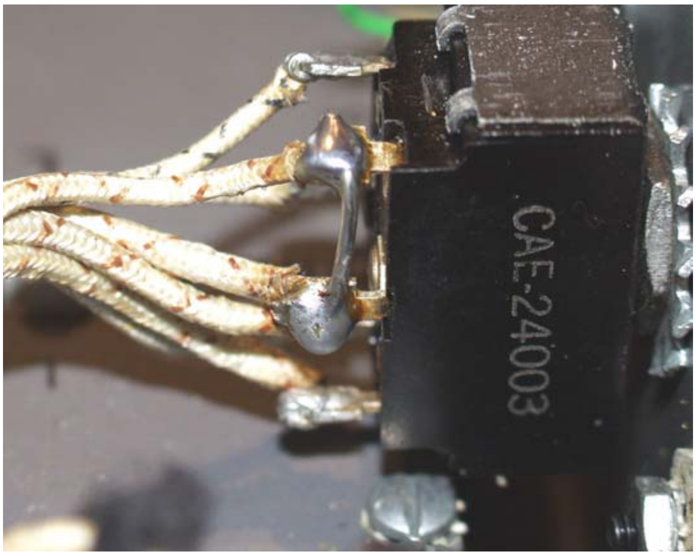

Fig. 2. Modification to AM/CW mode switch.

In principle, the 1625 cathode could be earthed by fitting a similar link on the other side of the switch, but the author decided instead to connect the cathode directly to the nearest earth point using 16 swg tcw, to ensure a low impedance connection.

With these modifications in place, the AM/CW switch still throws the relay thereby ensuring that the transformer secondary is shorted when using CW, and the modulator valve heaters are off.

Increasing the output of the modulator

As it stands, the modulator uses 2x1625 in class AB1. Push-pull audio drive is achieved using a high ratio carbon microphone transformer; the centre tap of this transformer is earthed and the windings connected directly to the output valve grids. Negative bias on the grids of 29 V is derived across the common cathode resistor. This potential is also used to drive the carbon microphone through two 470 Ω resistors in series, decoupled by a 2μF capacitor (C129 on the TCS circuit). This arrangement does not provide sufficient output to modulate the carrier sufficiently when both 1625s are active in the PA. The modulator output can be increased significantly by providing fixed bias.

Fixed bias for the grids can be derived from a simple voltage doubler powered from the 12.6 AC heater supply (Fig. 3). In the author's arrangement, this is stabilised using a 30 V Zener diode. This circuit also shows a second voltage doubler to derive a positive potential of 33 V, which is connected via two 470 Ω resistors to the original carbon microphone wiring.

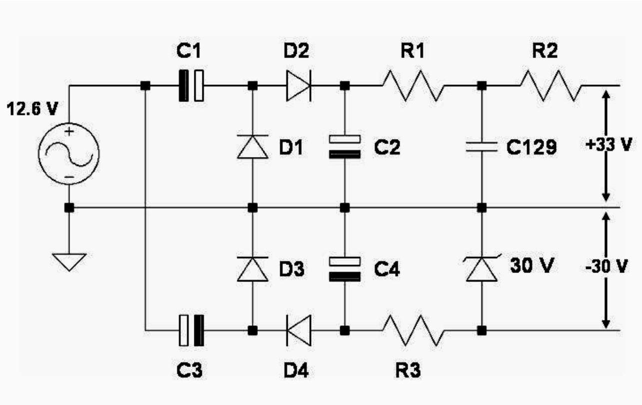

Fig. 3. Voltage doubler circuits to derive +33 V and -30V from the heater supply. C1-C4=1000 µF 40 V; C129=2 µF; R1=R2= 470 Ω; R3=1 kΩ; D1-D4=100 V rectifier; the zener diode is a 3 W type.

The physical realisation of this circuit is shown in fig. 4. This tag board was made to fit the space occupied by the board carrying the original cathode resistor, the 20 kΩ screen grid resistor and the two 470 Ω resistors in series with the carbon microphone circuit. Careful unsoldering without cutting any wires, allows this to be replaced if required later. In this respect any of the changes referred to here are reversible. On the other hand, the modifications can be carried out without removing this board provided that the components of fig. 4 are located elsewhere, the modulator cathodes earthed, and the 470 Ω resistors disconnected from the original cathode circuit. Thus, wires carrying +33 V and -30 V can be run to the respective points in the TCS.

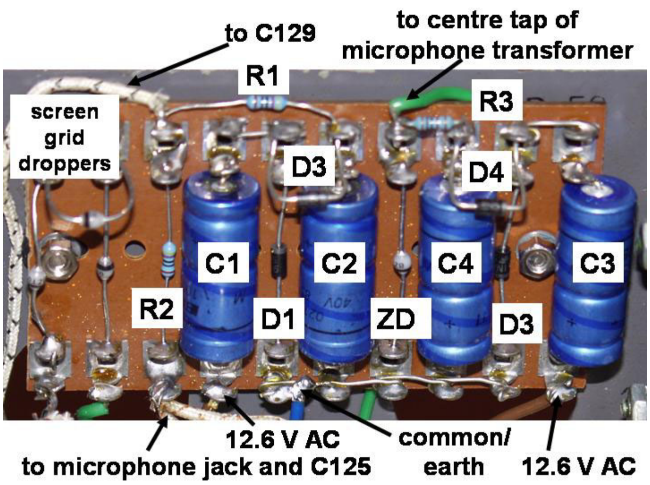

Fig 4. Physical realisation of the voltage doubler circuits in fig. 3 and the screen grid supply to the modulator. The bottom ends of C1 and C3 are both connected to the live side of the heater supply.

Included in fig. 4 are three (3 W) zener diodes in series to provide a dropper to power the modulator screen grids from the TCS HT supply. This method of feeding the screen grids with a 'stabilised' supply has aroused some interesting debate and the benefits or otherwise will be the subject of a future article. The TCS manual specifies a screen grid voltage of ~350V with 440 V on the anodes. The zener diodes should be selected to achieve this. The author's working conditions were 450 V on the anodes with 360 V on the screens. Under these conditions the theoretical output from the modulator should be in the region of 40 W.

Work to connect the microphone transformer is much more fiddly because it is concealed by the wiring loom (fig. 5) and is located just below the AM/CW relay. In the original transmitter, pins 1, 4 and 6 are connected together and earthed. For the modification described here it is necessary to disconnect pin 4 (the centre tap of the secondary) from the other pins and to connect it to the negative bias supply.

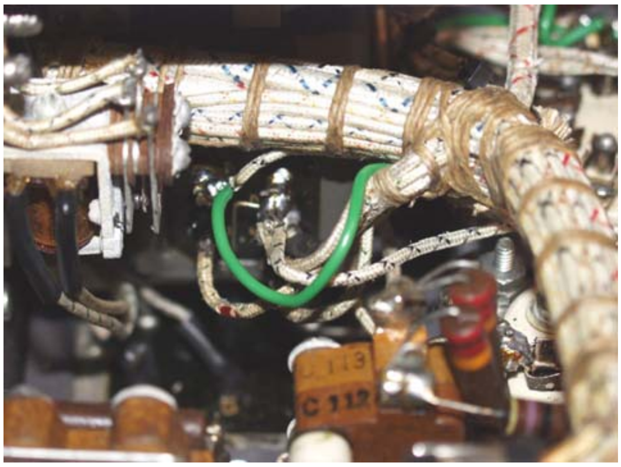

Fig. 5. The microphone transformer is concealed beneath the wiring loom.

Matching the RF output

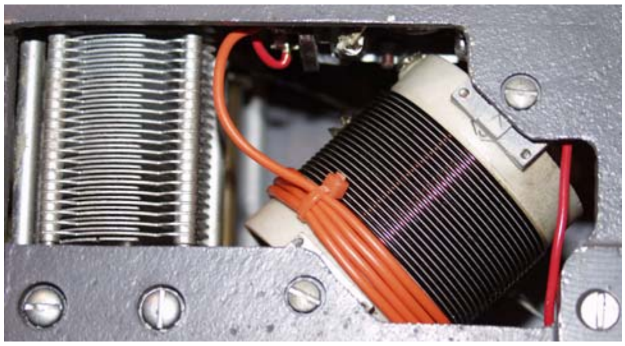

Fig. 6. Fixed coupling link around cold end of the PA tuning coil.

With the single 1625 in circuit the author has had no problem in loading the PA to 80-90 mA input at 420 V on the anodes. However, with both valves in circuit it is difficult to load to more than 110 mA. A number of other TCS users have experienced similar difficulties. This has been overcome by winding a fixed 4-turn link using PVC coated wire as illustrated in fig. 6, and taking one end to earth with the other directly to the change over relay. In this way, the matching circuits within the TCS are bypassed.

When used on 80 m, the TCS is excited at half the frequency, followed by a frequency doubler. In Issue 27 of the VMARS Newsletter (February 2003), Richard Hankins draws our attention to the tendency for spurious emission to be radiated from such a transmitter, and indeed the TCS is potentially good at this. The problem is exacerbated by the tank circuit proposed here, and part of the development described here included the building of the simple band pass filter shown in fig. 7. The circuit should be self-evident from the picture. Component values are similar to those given in Newsletter 27, but the construction is different in so far as the inductors are 16 turns 18 swg ecw on T-106-2 Amidon powdered iron torroidal cores, and the input and ouput are link coupled through 4 turns of PVC coated wire. Since the author's 80 m operation is restricted to 3615 kHz, it was decided to simplify the construction using mica compression trimmers (750 pF for the main tuning components) to provide a single frequency solution. The coupling trimmer is a relative low capacitance postage stamp trimmer that was available. The whole thing goes nicely into an Eddystone diecast box. This has now been in service for well over a year and has not required re-adjustment, so it is very stable.

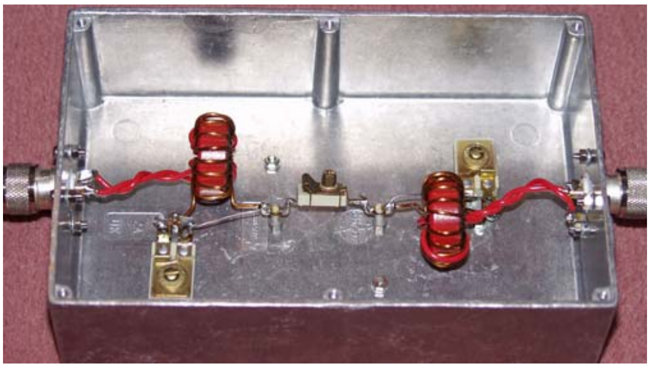

Fig. 7. Bandpass filter used in conjunction with the TCS transmitter.

A particular advantage of including the bandpass filter is that it serves as an ATU, working to some extent as a 'Z-match'. One could take a 'balanced' output from this instead, but the author was using it to couple to a resonant dipole hence the coaxial connector.

Tuning is simple if an RF ammeter is available, because one simply adjusts the trimmers, and dips the PA for maximum antenna current. The author's RF ammeter (seen in front of the TCS receiver in fig. 1) will be the subject of a future article. However some caution is required. First, the author strongly advises that the RF ammeter inside the TCS is shorted whilst initial adjustments are being made to avoid excessive current being drawn through this meter and causing it to burn out. It is possible to load the TCS into the filter itself without anything coming out at the other end, resulting in high current between the TCS and the filter. Secondly, whilst tuning the filter into a resonant antenna is easy, the adjustment into a non-resonant load, e.g., a dummy load or a non-resonant antenna requires that the output is monitored using an absorption wavemeter. The author was able to tune the filter onto a harmonic without realising it!

In operation at 40 W though the filter, its components remain cool suggesting that it has low loss. Feeding a signal source through the filter into a calibrated receiver indicates that the filter response is at least 60 dB down at harmonics and at half the pass frequency.

Results

The coupling and matching arrangement described above allowed the transmitter to be matched into a 50 Ω load with the PA running 180 mA at 440 V in the CW position, and 160 mA at 420 V in the AM position. The reduction in PA current on switching to AM was the result of the resistance of the modulation transformer reducing the voltage on the anodes of the 1625s. It is estimated, from the RF current, that the output is in the region of 40 W, a good improvement on the original configuration. The microphone transformer is fed by a transistorised amplifier with an electret microphone insert. The unit draws power from the carbon microphone supply. The circuit is currently available on the website of G3XFE (www.christopher.morgan1.btinternet.co.uk/index.htm) and is attributed to G0DRT (Peter Quested). It produces 2 V peak to peak audio which is transformed into a measured 60 V peak to peak at the modulator grids. The modulation is definitely upward with a healthy increase (~25 %) in antenna current as one speaks. Signal reports are very favourable, the audio is said to sound much louder and the only negative comment being that the modulation sounds a little 'forced'. A recording of a transmission forwarded by e-mail from Dave (GW4GTE) confirmed this, but it was pleasing to hear loud and apparently nice sounding modulation. On this basis, it seems, therefore, that the modification has been worthwhile.

Fig. 8 shows a tone modulated signal (calculated from the heights of the peaks and depths of the troughs apparently to be approximately 70% modulated) just before clipping occurs. Increasing the amount of audio beyond this point does not increase the peak power but causes considerable distortion and clipping as illustrated in fig. 9. These traces are consistent with the reception reports.

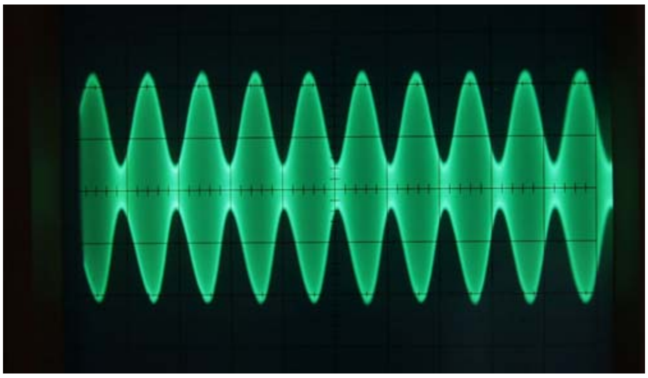

Fig. 8. Modulated waveform showing maximum depth of modulation (~70%) before clipping occurs.

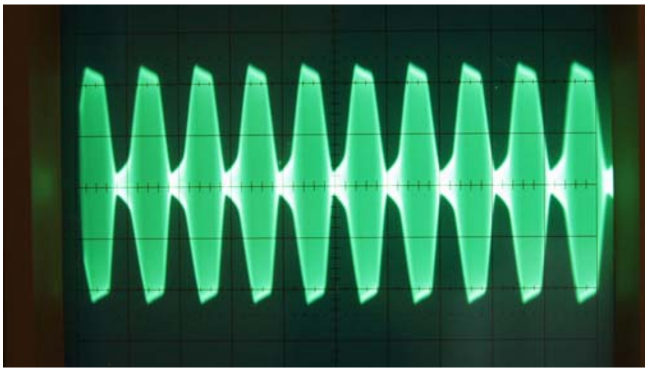

Fig.9. Modulated waveform when audio drive is increased beyond that used to obtain fig. 8.

Critical appraisal of success

Whereas the modification has definitely resulted in an increase of carrier power, an important question is whether there is a corresponding increase in sideband power. Using the carrier as the reference level, the peak RF voltage reached in the trace shown in fig. 8 was 1.5 x carrier. Hence, if the carrier power was 40 W, the corresponding sideband power was 2.25 x 40 = 90 W.

Fig. 10 confirms that if only one of the 1625s in the PA is active, 100 % modulation can be achieved (and there is plenty of spare audio available); if the output with only one 1625 is 20 W carrier, then the peak sideband power would be 80 W. Thus, the inclusion of both 1625s provides only limited benefit whilst modulation is linear. The apparently 70 % modulated carrier illustrated in fig. 8 is the result of unsymmetrical modulation with the troughs being slightly deeper than the peaks are higher, relative to the carrier level.

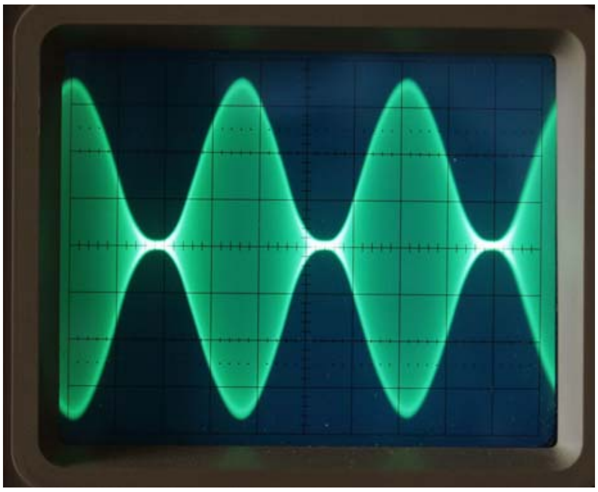

Fig. 10. 100 % modulated waveform when only one 1625 is active in the PA. The audio signal was an 800 Hz tone from a loudspeaker and the waveform therefore represents the entire transfer characteristic of the microphone and modulator.

The obvious question is why the sideband power is limited to 90 W and the RF output becomes severely distorted when attempts are made to increase the modulation with both 1625s active. Tests eliminated the following:

- Saturation of the inductors in the band pass filter.
- Insufficient RF drive to the PA.
- Insufficient drive to the modulator output valves.
- Too great a voltage swing on the modulator valve anodes causing non-linear behaviour.

With respect to the last of these possibilities, when both 1625s were active, the modulator anode voltage swung 300 V peak to peak. When only one 1625 was active, this value was 400 V peak to peak. Thus, it is concluded that sufficient voltage swing was not being realised with both 1625s active.

Other reasons for the non-linear behaviour include saturation of the modulation transformer by the higher DC component feeding the PA, and the mismatch between the modulator and the PA when both 1625s are active. The author's attention was drawn to the latter by the apparently anomalous voltage swings on the modulator anodes.

Valve data for a pair of 807s operating in class AB1 with 450 V on the anodes and actually V_{g2}=300 V and V_{g1}=-31V indicates a peak current of 72 mA per valve and a plate to plate impedance of 6.8 kΩ. When the PA is running at 160 mA with 420 V on the anode, the modulating impedance is 2.625 kΩ. Since the modulation transformer is 1(ct):1, the maximum current of 72 mA flowing in the primary will also flow in the secondary and thereby develop 184 V across the load (which is the two PA valves). This is sufficient to modulate the PA to 50%, as is observed in practice.

As the modulator grid voltage swing is increased beyond this point, the audio waveform cycle duty increases without increase in peak power, and so the average RF power increases; in the author's situation, this exceeded significantly the 22.6 % increase in average RF power associated with 100 % modulation.

Conclusion

The modifications described in this article have made the author's TCS more effective but it must be recognised that any advantage with respect to communication is not due to an increase in side band power but due to clipping of the audio waveform. Nevertheless, signal and audio quality reports have been very encouraging. There is some benefit from the higher carrier power in so far as it helps to squash QRN which pervades 80 m.

As a main station transmitter, the author's TCS holds its own alongside the medium powered transmitters heard on 80 m. There are now few people who the author can hear but cannot work. However, the clipped waveform does stand a risk of creating splatter and whilst this aspect has not yet been checked, no unfavourable reports have been received.

The author's TCS had been used in this mode for at least 6 months with no apparent detriment to the modulation transformer, though the case does become much hotter as may be expected. Nevertheless, VFO stability is as good as ever.

Any reader wishing to learn more about the TCS is also referred to Issue 25 (October 2002) of the VMARS Newsletter in which Mike Hoddy (G0JXX), describes the units, their history, and personal reflections.

Postscript

So, was it all worthwhile? The author will leave that for the reader to decide with ample evidence to sway one way or the other. Regardless of other merits and demerits, the PA coupling arrangement works very well with one PA valve or two, and avoids the intermittent or high resistance contact at the slider of the loading coil resulting from the continual use of a small portion of the track. Similarly, the band pass filter surely is mandatory at a time when we should be paying more attention to spurious emissions, and particularly those which are modulated.

This postscript is being written whilst concluding a QSO with Colin, G4DDI, located at Thorpe Camp Museum on the occasion of the opening of the museum's radio station. With only one 1625 in the PA, 'broadcast quality' audio is reported from the other end and, suffice to say, the TCS is back in its original configuration with the author now looking towards the merits of using his 4 x 811 linear to boost this signal. But that will be another story!

Acknowledgement

The modifications described in this article were inspired during a QSO with Mike, G4EJM, who had previously modified his TCS successfully. The author is, therefore, indebted to him for advice, but any errors or omissions in this article are entirely those of the author. The author is particularly grateful to Richard Hankins for suggesting that the modifications be assessed critically for their impact on side band power, a fact which few colleagues on the air have considered when working on their TCS transmitters. This not only caused the author to re-think his original claims regarding the benefits of this modification to the TCS, but serves as an important lesson to anyone trying to get a 'quart' out of any other 'pint pot'. Thanks are also due to Dave (GW4GTE) for providing a recording of the author's signal, and to many others who have given reports and helped with tests.

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