

Tricks of the Trade

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In ToTT this time is presented a classic Marconi Wireless Telegraph (MWT) MF transmitter design and, over the next few issues, the various technical innovations and novel features in this unit will be described. It probably featured the last of the ground breaking developments in valve MF transmitter design at the time when MWT Broadcast were at their zenith. Later valved transmitters were essentially repeats of this and earlier designs.

Early Days

Brookman's Park (BP) in Hertfordshire was the first of the BBC's Regional Transmitters and came on the air in 1929 with a pair of 50 kW Marconi MF transmitters for the National (T1), and Regional (T2), services. These were essentially low-level Heising-choke modulated transmitters with a Class B linear RF output stage. The overall efficiency was about 22%. The station was partially upgraded in 1939 with a 140 kW STC transmitter (T3), that carried the National service until the outbreak of War. After the War, T1 was a reserve for T3 right up until 1978.

The London Regional shall not have a full upgrade

After the War, the STC high-level modulated transmitter was firstly on 877 kHz, 356 m and then, after March 1950, on the familiar 908 kHz, 330 m Home Service allocation.

T2, the sturdy old 50 kW Regional, continued in use, firstly on 1149 kHz, 261 m and then on 1214 kHz, 247 m for the Light Programme.

Most of the other BBC MF sites had benefitted from wartime upgrades, for example Moorside Edge had a pair of MWT 150 kW transmitters for the 668 kHz then 692 kHz Home Service as well as an RCA 50 kW (BTA-50E) unit for the Light Programme on 1149 kHz then on 1214 kHz.

At Washford in 1948 were installed a pair of STC 100 kW CM10 transmitters for its single Welsh Home Service output on 804 kHz then 881 kHz.

Westerglen, like Washford, had an identical pair of STC 100 kW CM10's for the Scottish Home Service on 767 kHz then 809 kHz and, as at Moorside Edge, an RCA 50 kW on 1149 kHz then on 1214 kHz for the Light Programme.

Besides BP, the only other station using MWT early 1930's units for main service rather than reserve was Droitwich (series modulated, 150 kW, ex-5XX LF) on 1013 kHz then 1088 kHz for the Midland Home Service until 1961. A later exception was Moorside Edge where, in 1978, the 1931-vintage T2 had to be returned to regular service to cover the Radio One requirement on 1089 kHz until 1984.

On the sidelines in Chelmsford

By the late 50's, MWT's High Power MF Department in Chelmsford must have felt a little out of it having not supplied the BBC's domestic services with a high power MF transmitter since Daventry in 1950 and so were probably quite pleased when the BBC suggested a refit at Brookman's Park in 1961 to retire T2 to reserve service and replace with a more efficient unit.

The MWT BD228A

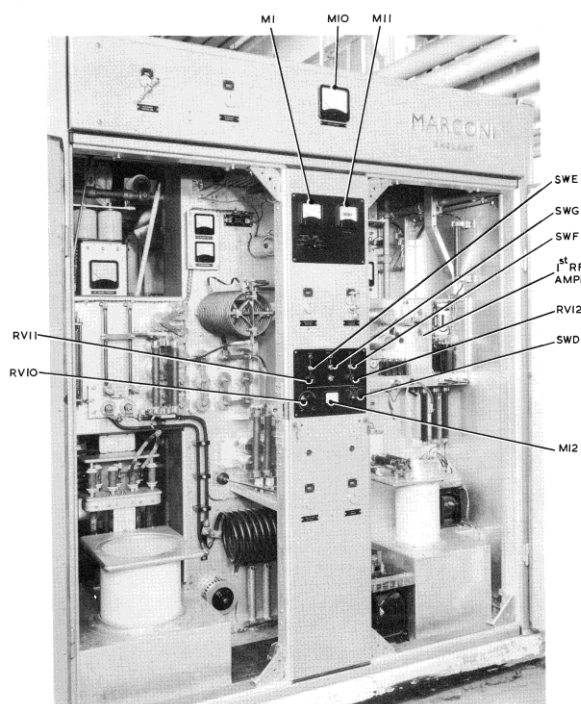


Figure 1. The RF cubicle of the BD228A. The final valve is missing from the socket for reasons of photographic clarity

The BD228A was the transmitter that MWT designed in 1960 and BP was to have the first! No doubt MWT thought that it was high-time that the BBC modernised its MF equipment and that they would be furnished with further orders.

It was promoted as "having an exceptionally high overall efficiency since the RF amplifier achieves a conversion efficiency of over 90%."

High-level Class B modulation was employed. Air-cooling was used throughout and no under-floor ducting was needed for supplies, etc., so the unit could be sited on a solid concrete floor.

The performance was as detailed below:

- Frequency range: 525–1605 kHz
- Power output: 50 kW carrier
- Modulation capability: 100%
- Modulation rating: 40% modulation continuously and 100% for 10 minutes per hour at 400 Hz
- Output impedance: 300 ohms unbalanced at maximum SWR of 1.2 : 1
- RF harmonics and spurious output: less than 50 mW
- AF response: $\pm 1\text{dB}$ 50–7000 Hz, $\pm 2\text{dB}$ 30–10,000 Hz relative to 400 Hz at 75% modulation
- Harmonic distortion: from 100–4000 Hz less than 1.5% at 50% modulation, 3.0% at 90% modulation. From 30–100 Hz and 4–10 kHz less than 2.5% at 50% modulation, 3.5% at 90% modulation
- Noise level: -60dB relative to 100% modulation
- Power consumption: carrier 80 kW efficiency 62.5%, at 30% modulation 90 kW/ 59.5% and at 100% modulation 116 kW/61.5%.
- Carrier shift: less than 5% at 100% modulation.

Construction

The BD228A consisted of two cubicles, the left holding the modulator, main HT rectifier and auxiliary power supplies, and the right the RF stages. There was a small separate power distribution cubicle that contained the Automatic Voltage Regulator.

An interlocked separate room, the Smoothing Enclosure, contained the main HT transformer, modulation reactor, modulation transformer, modulation blocking capacitor, and the general smoothing components. 415 V, three-phase mains was employed for all the low power stages and 11 kV AC for the main HT transformer.

The air-cooling plant comprising fans and blowers with the requisite filters was provided. A 'Filtometer' was used to monitor for blockages in the air supply and was a regularly checked item. Flap switches detected total air fail, these were executive and would inhibit the HT in the event of loss of cooling air. The fans were manufactured by MWT's preferred supplier, The British Organ Blowing Company of Derby.

An interlock system, using Willmott-Breedon car ignition type keys, disabled all the HV supplies until all keys were placed in an operating panel. Thermal overloads, fuses, and miniature circuit breakers were the standard protection devices for current overloads, etc.

The RF Circuits

The circuit diagrams of the RF stages are shown as figures 4, 5, and 6.

RF Preamp and Penultimate RF (Driver) stage

A BBC designed COU-4 crystal drive (already described in Signal, January 2009) was the 4 W source of 1214 kHz into TR1, thence into the grids of the RF Pre-amp, a paralleled pair of TT21 valves (Figure 2).

The auxiliary HT supply of 2 kV was resistor-dropped to about 1000 V for the anodes, with screen grid feeds from further voltage droppers to about 300 V. The usual metering was provided for screen and cathode feeds by suitably placed shunts into MWT's standard 1 mA/100 ohm meters by Ernest Turner. RFC L3 and C5 (1000 pF) pass the RF into the grid of the Penultimate RF amplifier, a BR1131 triode by English Electric Valve Co. C8 and L5 are the anode tuning components for the TT21's.

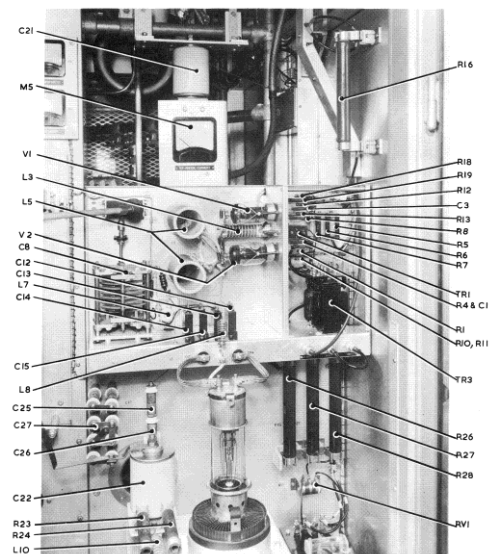


Figure 2. The RF Preamp with the two TT21s (on their sides) in the centre of the picture

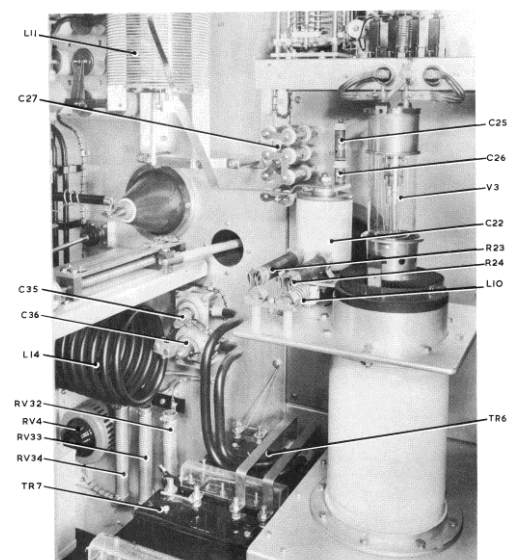


Figure 3. The Penultimate RF (Driver) stage

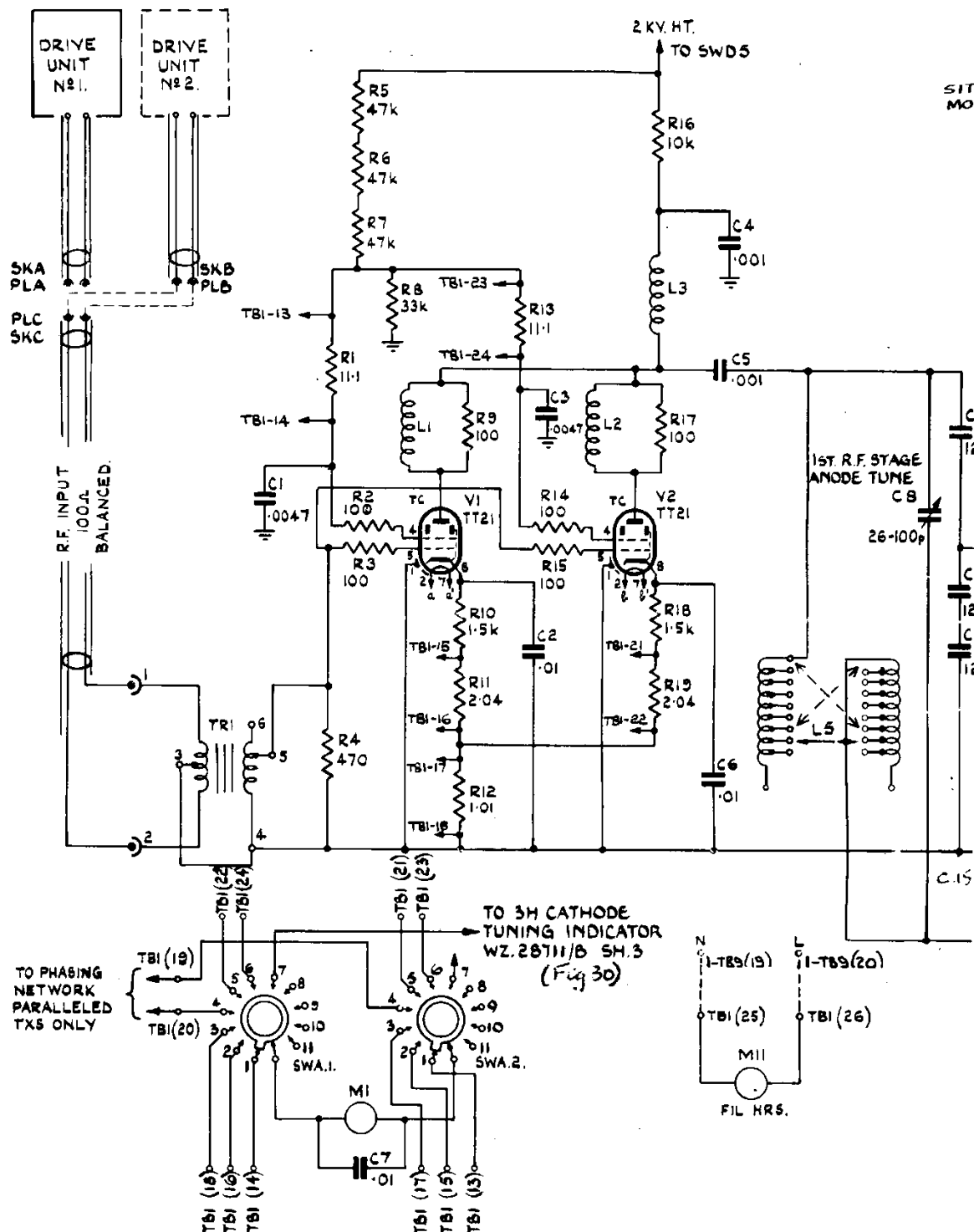


Figure 4. Circuit diagram of the RF Preamplifier stage

Neutralisation by C12, C13, C14, and C15 (all 1200 pF), with a tap from the RF output through C25 and C26 (both 50 pF in series), keeps the penultimate and the final stages stable. This is a necessity, as this design does not have the luxury of tetrodes or pentodes!

Unusually for a power stage, the Penultimate RF is auto-biased with L7 being the RF blocker and R74 the bias resistor. The normal convention is to have a fixed DC supply as well. RFC L9 enabled the up-to-100% modulated HV feed of 8.5 kV to feed the penultimate

stage. Note the parasitic stopper components C160-C162, R100, R229, and R236 in the DC feed.

Into the final stage

The Penultimate stage is coupled to the Final via a pi arrangement consisting of C27, L11, and the circuit L12 and C28, which is arranged to be slightly capacitive and, as such, a capacitor element. L12 is tapped and provides a means of varying the coupling. C27 and C28 are multi-tapped to cope with any frequency in the MF band.

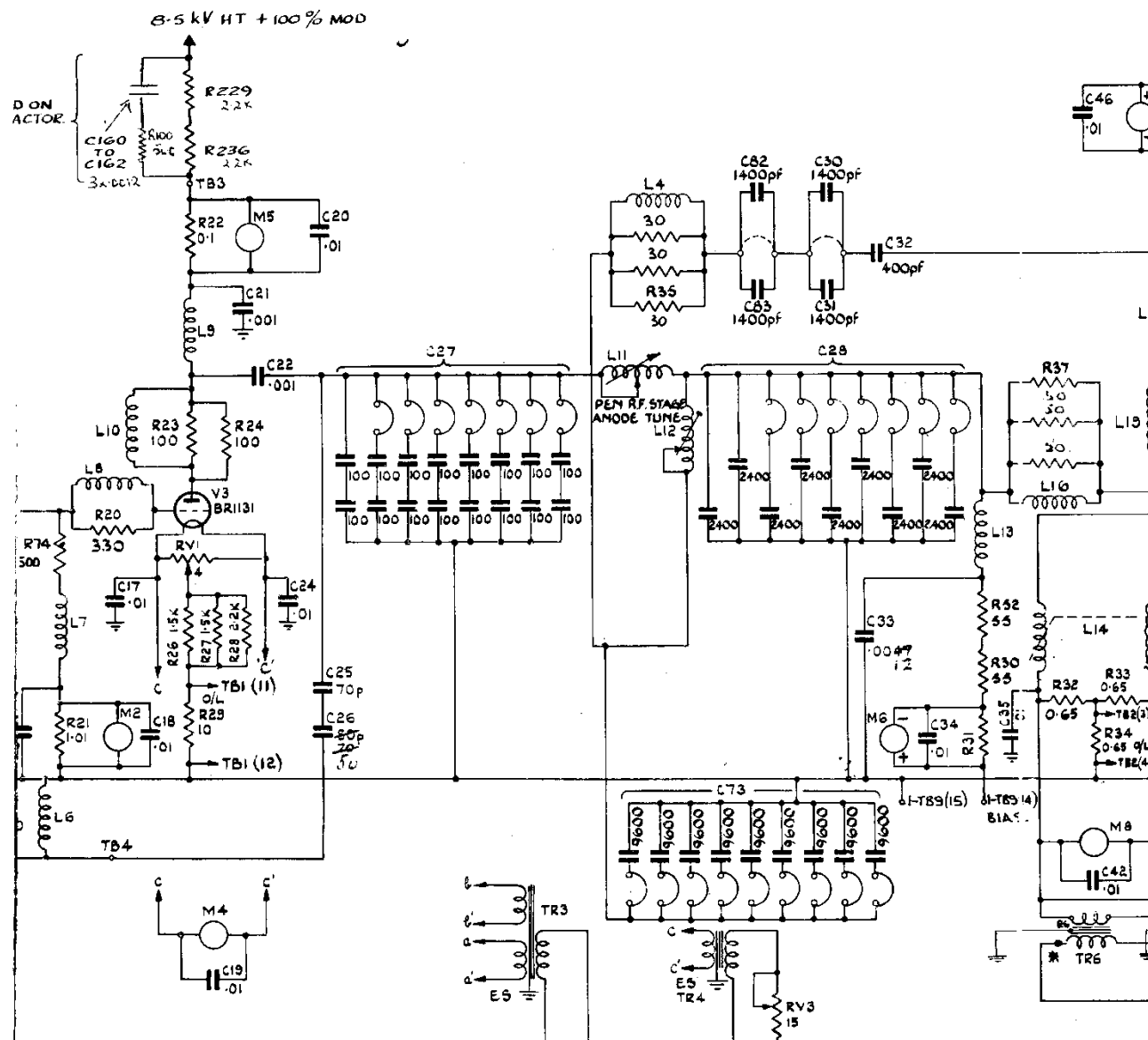


Figure 5. Circuit diagram of the Penultimate Stage

The Final Amplifier

Originally V4 was an EEV BR1151 triode, later the Siemens RS726, and a development of the BR1151, namely the EEV BR1161 was used. It is interesting to note that the AC filament voltage of the BR1151 was 13.5 V and, for the later tubes, it was 11 V. Unusually, the filament transformer is a pair of units with their primaries in series across 415 V and the secondaries in parallel. This AC feed is via a double-wound inductor, L14, for reasons to be explained soon.

Adjustable bias between -70 V and -145 V is provided on this stage via metering, an RFC, and anti-squegger components, R37 and L16.

The 8.5 kV modulated HV (again to 100%), is supplied from the modulator reactor, modulation transformer, and shunt capacitor arrangement through RFC L17 and a mysterious (for the time) piece of circuitry comprising L18 and associated capacitors. This was a third harmonic resonator and used a sulphur hexafluoride (SF_6) filled

variable capacitor as well as a string of seven frequency selectable 430 pF HV capacitors to achieve third harmonic (3f) resonance.

In addition to the 3f circuit in the anode, another was fitted to the cathode/filaments and comprised L15 and padder capacitors C38-C41 to enable initial coarse tune between 1.575-4.815 MHz with variable C37 to fine tune. The double-wound L14 was effectively an RFC in the filament supply, rather as would be employed on grounded grid designs.

From the anode was connected another anti-squegger (L19 and three 100 ohm resistors) up to the anode 3f section and out via the blocker capacitors C49 and C50. Here, the 50 kW went two ways, not only to the output circuit but also a fraction via C32 (400 pF), to a neutralising arrangement of a selection of four 1400 pF capacitors, then to another anti-squegger, L4 and damping resistor. This, in turn, led to the centre-point on the Penultimate RF stage tuning and coupling, with coupling to chassis by C73.

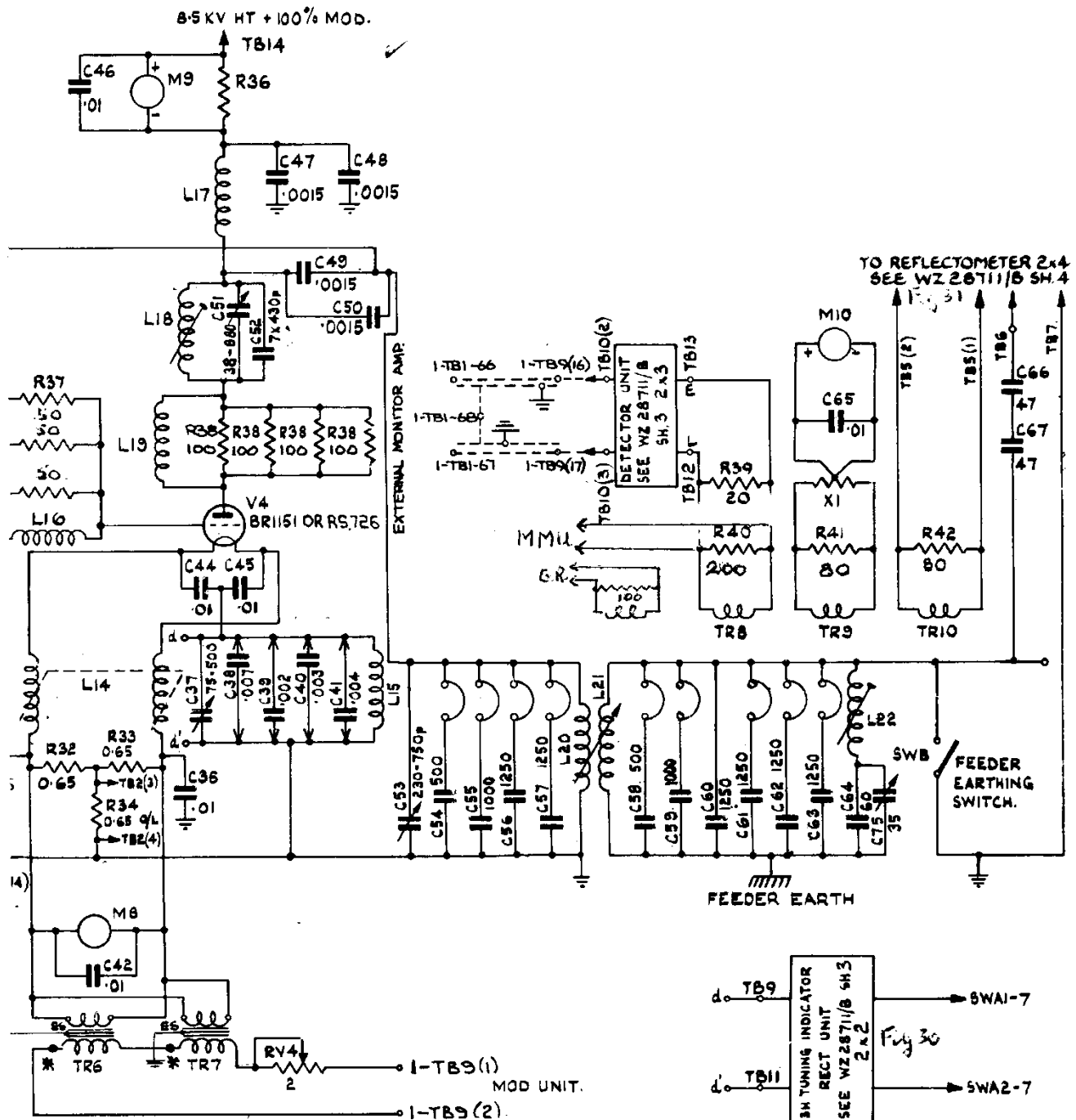


Figure 6. Circuit diagram of the Final Amplifier

The taming of the pressurised beast

Have you noticed so far just how many anti-squegger components are employed in this transmitter? This is not the norm at MF! It would appear this beast took some taming!

The output circuit was quite conventional with two parallel tuned circuits and variable coupling coil. The circuitry was unbalanced, so provision of a series second harmonic

tuning trap with L22, C64, and C75 was easy to accomplish.

The anode tune capacitor C53 was a pressurised nitrogen-filled device. 'White Spot' nitrogen was specified at a pressure of 15-25 kg/cm². 20 kg/cm² Equates to 283 psi! A handwritten note in red ink in the BP BD228A handbook warns, "These pressures should be treated as dangerous".

At this time vacuum variable capacitors were not available.

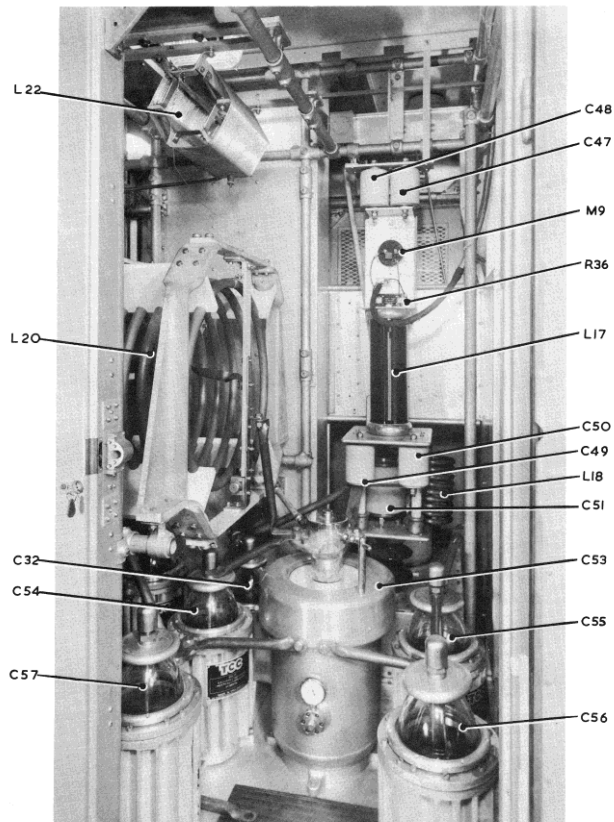


Figure 7. Final RF anode circuit

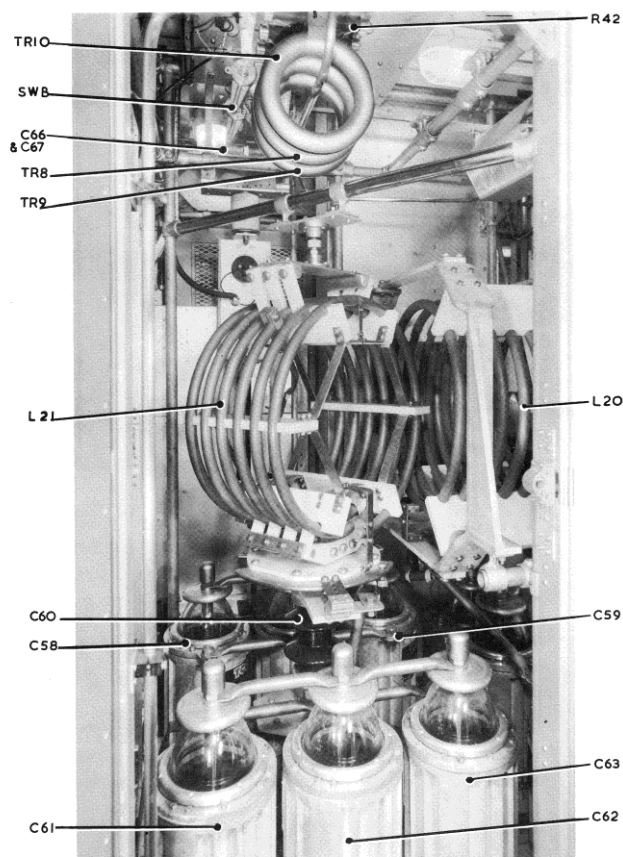


Figure 8. Output circuit

Mr V J Tyler of MWT and the RCA BTA-5T 5 kW MF Transmitter

As was often the case, the Marconi Company were leaders in ground-breaking developments and it was an engineer, Mr V J Tyler at MWT who, around 1957, invented and then patented jointly with MWT the use of Third Harmonic Resonators as a means of increasing the efficiency of a regular Class C RF stage. In the trade it was always (confusingly) known as 'Tyler Mod' even though it refers only to RF circuitry!

The technique was not only employed in the BD228A but also abroad by RCA in, for example, their 5 kW MF transmitter, the BTA-5T. They acknowledged the patented invention by Vic Tyler of MWT.

Rather than offer a plagiarised description of the technical theory of the Tyler system, the author has edited a section of an RCA 'Broadcast News' article of March 1960 written by I R Skarbek.

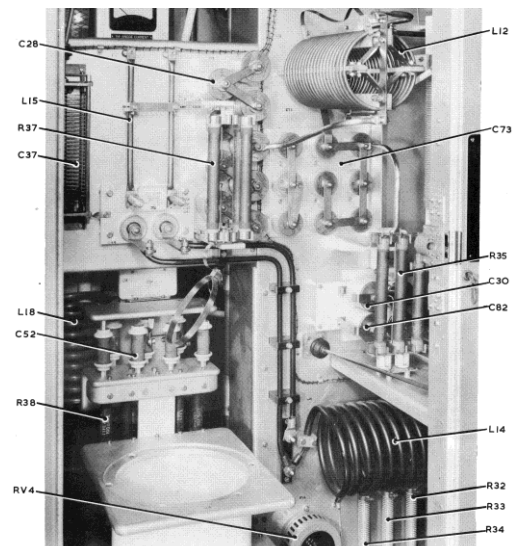


Figure 9. 3rd Harmonic cathode and anode circuits. The final valve is missing from the socket for reasons of photographic clarity

The high-efficiency plate-modulated power amplifier uses a single tube to deliver the nominal 5 kW, with 5.5 kW power output capability at 90-92% plate power conversion. The circuit arrangement is very similar to a conventional class C amplifier except for the presence of two resonators L1 and C1 for the plate, and L2, C2 for the cathode (Figure 10). In fact, the new high-efficiency stage behaves so much like the conventional class C stage that, with the resonator shorted or mis-tuned, the PA tube returns from the high-efficiency to the conventional class C operation. This characteristic is very useful in the initial tune-up of the transmitter. For the moment, it will be helpful in making a detailed comparison.

In both systems, the angle of the tube current conduction is restricted to that portion of the cycle wherein the instantaneous plate current is high and the instantaneous plate voltage low, corresponding to a low anode dissipation at a relatively high-power output. In class C operation, however, the waveform is sinusoidal and is substantially rounded off. Therefore, a large portion of the

power is lost in the anode, resulting in an average efficiency of about 70%. The new system provides corrective means for maintaining a flat waveform near the peak, resulting in 90% average plate efficiency.

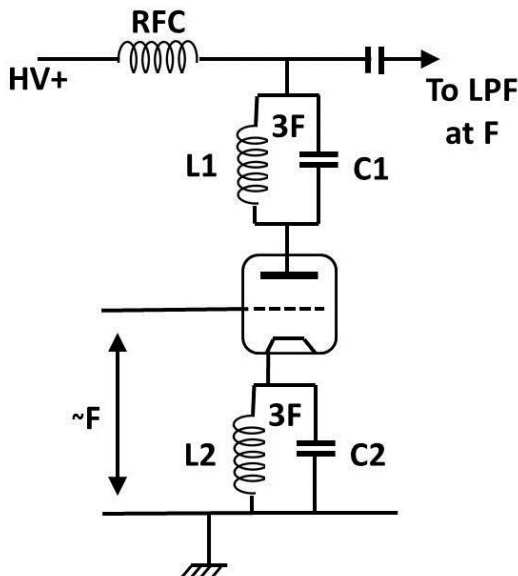


Figure 10. Third harmonic tuned circuits in the anode and cathode of the final amplifier

The wave shaping is effected by two LC parallel resonant circuits, one located in the plate and the other in the cathode circuit of the power amplifier tube. Both are adjusted to resonate at the third harmonic of the carrier frequency (Figure 10).

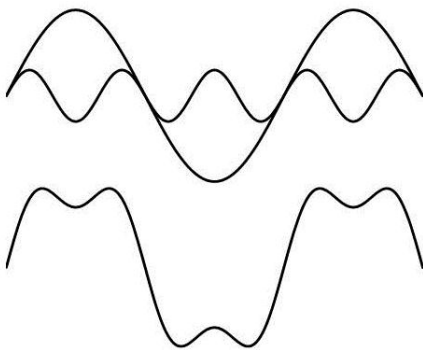


Figure 11. Harmonic addition (lower trace) of the plate voltage and the oscillatory voltage from the third harmonic L-C circuit (upper traces)

When the amplifier tube is driven, the harmonic component of the grid input power sets up and maintains circulating current within each resonator. Since the resonator is designed to store high kVA, the total voltage supply at the plate is composed of the usual DC plate supply and the superimposed oscillatory potential equal to the voltage build-up across the resonator. This oscillatory voltage, being at the third harmonic, vectorially adds twice to, and subtracts once from, the fundamental, producing a flat top waveform (Figure 11). When the cathode resonator is adjusted to resonate at the third harmonic, the instantaneous grid-to-cathode potential modifies the cathode emission to approximate a rectangular pulse (Figure 12).

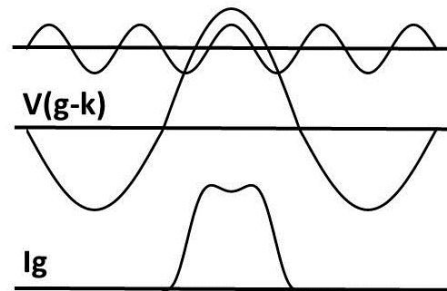


Figure 12. With the cathode resonator at the third harmonic (top trace), the grid to cathode voltage (middle trace) modifies the cathode emission to produce a rectangular pulse of grid current (lower trace)

Improved efficiency

In the BTA-5T transmitter, adjustment of the plate resonator improves the efficiency by 6 to 8%. Subsequent adjustment of the cathode resonator improves the efficiency by an average total of 20% above conventional class C operation.

Improved tube performance

The energy stored within the resonator modifies the instantaneous current voltage waveform of the conventional class C amplifier to reduce its amplitude and broaden the top. For the same power output this means not only a reduction in the plate dissipation, but also considerable reduction in peak-plate to plate-peak grid current and operation at a much lower cathode emission. As the result of the high-efficiency operation, the BTA-5T transmitter employs only one PA tube, an RCA type 5762. It is worthy to note that plate dissipation in the new system is comparable to the filament power consumption of the old.

Conclusion

As can be seen, the combination of the two resonators makes for a substantial increase in efficiency. Later was coined the general term, 'Class D', to more accurately describe Tyler Mod. For LF and MF operation on fixed frequency, it is attractive even though the initial set-up is fairly complicated; however any further adjustment is not normally required. The technique can be applied to HF senders but for those (and that is most) on a varying frequency schedule, any complex tune-up requirements are best avoided.

Regrettably for MWT, the BBC only bought the one BD228A, preferring to employ for later upgrades, starting in the early 1970's, an internal BBC design, the 'Willis 50 kW Doherty'. However, the BD228A was in the MWT catalogue for many years and it even had a cosmetic makeover in the early 70's. It was replaced with the introduction of the more efficient B6034 50 kW Doherty in 1977.

Next time in ToTT we will continue with this MWT TX and look at the modulator which, like the RF, it is not conventional!