Tricks of the Trade

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Last time in ToTT we had looked at the developments in AM transmitter engineering from the late 1960s and into the 1970s, particularly with regard to the advances in pulse modulation techniques, a development that was to be a fortunate business opportunity for those manufacturers who had encompassed this technology. They were able to capitalise on the sudden increase in the cost of energy and thus the operating cost of high-power transmitters following the 1973 Oil Crisis. Together with the fact that international tensions had escalated with the Middle Eastern situation and the seemingly never-ending East-West Cold War, MF high-power cross-border broadcasting was on the upsurge, as was the HF power struggle against the Soviet-bloc jamming. For the transmitter manufacturers, there were good markets to be explored with sales and supplies, mainly to Government procurements of ever more powerful 600 kW LF and MF (often paralleled to 1200 kW) and up to 500 kW HF senders. Those units that exhibited high energy efficiency would be sales successes against the older 'gas-guzzling' designs if the accountants were 'on the case'.

PANTEL

AEG-Telefunken had their first generation, 100-250-500 kW PANTEL PDM (**Figure 1**) and RF auto-tune design by the early 1970s and installed nine 500 kW SV2500 units at the brand-new Deutsche Welle site at Wertachtal, southern Germany. Five of the units were operational in time for the Munich Olympics in 1972. This site was a good shop window for Western and extremely wealthy Middle-Eastern Governments who were evaluating what to purchase, either for power upgrade at older installations or for brand-new installations. By 1987, six of the later AEG-TFK S4005 were added. Some west European state broadcasters had purchased the 600 kW AEG/TFK PANTEL MF; the countries included Norway, Sweden, Germany and the UK at Orfordness for 648 kHz.

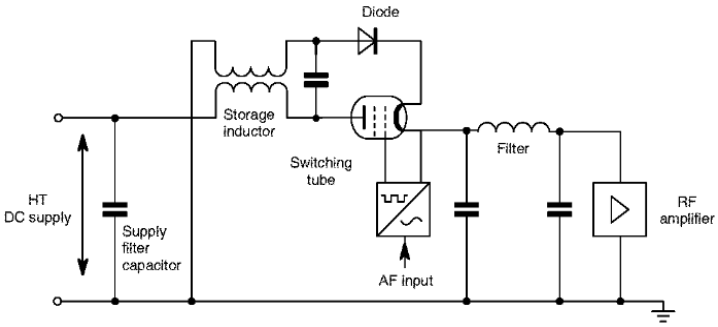

Figure 1. Basic circuit diagram of the Pantel series-PWM system

PANTEL involved the use of a regular 500 kW valve for the RF section and a similar valve in the switching modulator.

UK Developments

In the UK, Marconi Communication Systems Ltd., MCSL, was a little slower off the mark in not having a high-power PWM design for sale until about 1981 but the design of the RF section had already been proven in the B6124 300 kW auto-tune senders in Nigeria, Thailand, UAE, Switzerland, Cyprus and Woofferton, UK between 1979–1981. It was with the B6127, a 500 kW HF sender introduced in 1981/2, that they had caught up with the other manufacturers.

The 300 kW proven RF design was carried over to 500 kW and **Figure 2** shows a section of the B6124 output circuit. For the final RF stage, 54 mm copper pipes with elbows were configured as water-cooled inductors with pneumatically-operated, water-cooled shorting switches strategically placed to suit the various preset HF ranges between 3.9 and 26 MHz. The output circuit comprised a π-section from the output valve to a central 185 Ω coaxial section and then a second π-section to either a 50 Ω output for coaxial feeders or, at most legacy sites with 320 Ω balanced feeders, a 75 Ω coaxial output into a 4:1 switched and tuned Pawsey stub balun. Within the 185 Ω section were mounted the forward and backward power couplers for both monitoring and executive trip action in the event of high VSWR.

Figure 2. 54 mm copper pipes with elbows were configured as water-cooled inductors in the B6124

The 5–10 kW penultimate RF stage used a similar range-switched inductor of 22 mm pipe with smaller water-cooled crosshead switches.

The contact surfaces on all these switches, both on the penultimate stage and final, suffered burn-ups; checking and refurbishment/replacement were an on-going task.

Marconi 500 kW B6127 with PULSAM

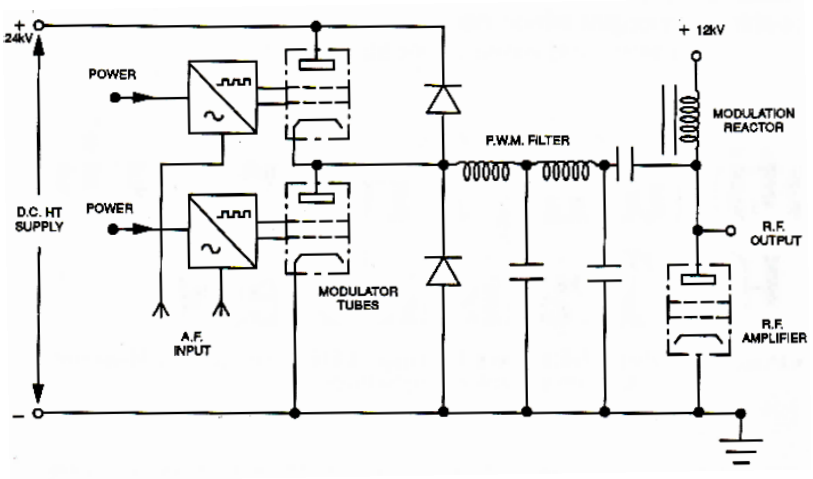

Figure 3.Circuit diagram of the MCSL PULSAM modulator

The PULSAM modulation system combined the benefits of PWM and Class B such that, in effect, the duty of the modulator is limited to the processing of the sideband information only. In this system, the switching valve peak anode current is half that required for series PWM systems and the mean anode currents are much lower. It is possible, therefore, to use two relatively small tetrodes instead of one large valve, thus reducing stray capacitance and minimising power losses at low modulation levels. As such, the modulator switching valves are each about one quarter the electrical size of the RF modulated amplifier and are substantially smaller than those required for an equivalent Class B modulator. Although each valve requires a string of diodes, their rating is approximately a tenth of that required for a series system; these diodes are not highly stressed and need only be air cooled. The single wound storage inductor is relatively small as it only carries AF current and, by ingenious design with ferrite cores, an even smaller inductor is possible. **Figure 3** shows the MCSL circuit.

The sub-modulator driving the tetrodes is completely solid state and does not require to be located on a high-voltage platform. It processes the audio and switching frequencies to produce pulses whose width is proportional to the sinusoidal modulating frequencies. These pulses are applied to the two switching tetrodes which operate in push-pull. The storage inductor and low-pass filter remove the switching frequency to a level well below that required to keep within the limits for spurious radiation. The resultant audio waveform is capacity-coupled to the RF PA. With this system, which is analogous to regular analogue Class B, there is no restriction to full modulation on positive and negative peaks and spurious radiation does not present a problem.

Much of the above section was from the MCSL B6127 sales brochure and, while is it true and accurate, the references to “series (PWM) systems” and the ability of this PULSAM technique to absolutely fully positively and negatively modulate to 100% as well as the improved specification for non-radiation on spurious switching frequency output were direct pointers at the deficiencies in the rival AEG-TFK PANTEL system.

What was not quite so heavily publicised in the MCSL literature was the size and rating of the required modulation blocking capacitor and the fact that an expensive modulation reactor ~5 H at 50 A (AF choke) was also needed. There is also the (not so) small matter of two HV power supplies and typically for HF these would be 12 kV at 50 A for the 500 kW RF PA and a 24 kV one for the modulators.

Four B6127 senders numbered 45–48, were installed at BBC Rampisham as part of the mid-1980’s audibility programme and commenced service in 1987. They joined four AEG-TFK S4005 senders numbered S41–S44 installed at the same time. It was the only 500 kW HF site the BBC ever had. By 1992 or so, another two 500 kW, again from MCSL, senders were added and they were type B6128 bringing Rampisham’s sender complement to ten.

Marconi 300 kW B6126 and 500 kW B6128 with Advanced PULSAM

As an introduction, the piece in Signal issue 38 **[1]** from Ewan Fenn, G3RTF is reproduced below.

The Advanced PULSAM modulator is a variation on the classic series modulator. The valve is mounted on a low-capacity box which houses the power FETs. These are used to drive the control grid and the screen grid with constant current feeds and a third electronic switch provides the PWM drive to the control grid. At carrier the valve is driven with a mark-space-ratio of approximately 50:50 and consequently the DC potential is half that of the HV supply.

With increased modulation the on period becomes longer and the off period shorter. In the trough of modulation the duty cycle is reversed. The cathode of the valve is at high potential with respect to ground and therefore requires a highly-insulated filament transformer. This is constructed on a similar principle to the toroidal transformers on mast lighting to reduce its stray capacity to a minimum and had to pass about 10 kW of filament power. A similar construction is used for the bias and screen transformers. Control signals are fed to the valve and monitoring signals are sent back by means of fibre-optic cables providing very good electrical isolation and having high noise immunity.

Just a single 24 kV HV supply is required and there is no need for modulation reactors or mod-blocking capacitors (**Figure 4**) so, for MCSL, this was a cheaper transmitter to build and offer to market.

Six B6126 were installed at Daventry by 1987 with a further four at the new-build site at Skelton C. A pair were installed at the British East Mediterranean Station, BEMRS in Cyprus, a pair at the BBC Indian Ocean Relay Station, IORS in the Seychelles with a further pair at the East Asia Relay Station, EARS in Hong-Kong. It was fast-becoming the standard BBC 300 kW HF unit. All these 300 kW

B6126 installations are now out of service. Rampisham is also closed and the senders scrapped.

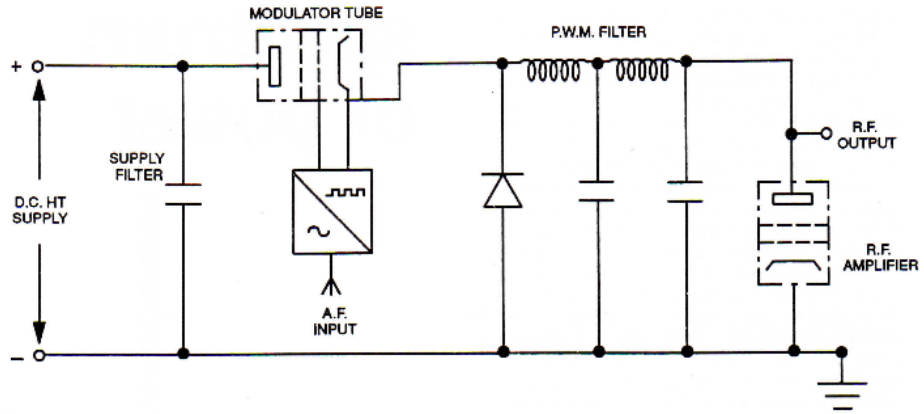

Figure 4. Circuit diagram of the Advanced PULSAM modulator

Operations were generally satisfactory as the RF section was almost a direct copy of the B6124 units that had been in use since 1981 so the transmitter staff were aware of what could go wrong. It is fair to say that, on the B6124, cooling blockages and RF contact burn-ups were the bane of the transmitter engineers' lives however, on the B6126 and B6128, there were additional problems arising from the addition of modulator grid box. Much time was spent at Daventry with an American specialist contractor, Verity Smith, in ironing-out the cooling problems and his work there and the lessons learnt benefitted all the MCSL-equipped sites.

Chicken and egg?

The FETs and associated complex circuitry in the HV-isolated grid box proved to be affected by flash-overs within the PWM valve and resultant repairs and fault-finding were tricky because, after a session replacing the many FETs, the engineers did not want to risk another, possibly instant, catastrophic failure arising from what could be a suspect valve or perhaps failing FETs in the first place that caused the tube to flash over.

Woofferton was a favourite place for suspect TH537 valves to be sent to be tried in the B6124 benign final RF amplifier slot after being under suspicion in the PWM slot at Rampisham.

Back-to-basics?

The B6124 was the earlier design of an auto-tune MCSL sender and used plate and screen modulation with a pair of tetrodes in Class AB1 with a conventional modulation transformer, *etc*. Despite its overall poorer efficiency, modulation-wise it has proved to be a more reliable system and the solid-state driver stages for the modulator valves required much less maintenance and repair over the years compared to the PWM types. These stages would probably have been essentially fault-free if some design engineer at MCSL in 1977 had not parked a pair of 180 W wire-wound resistors in the same crate adjacent to the successive series transistor 'beanstalk' stages. Even in stand-by operation between transmission times they were dissipating about 100 W each. This normally resulted in the electrolytic capacitors drying out with consequent decoupling and coupling problems and the need for replacement of 'crunchy' insulation on wiring within.

Many a time were the senders at Woofferton covering, that is taking service that was really scheduled, for Rampisham, Daventry and Skelton C whilst urgent repairs, usually to PWM modulators, were being undertaken on their (at the time) new senders. The author is reminded of the time, during a particularly heavy session of cover at Woofferton for Rampisham that, upon being rung up for more, the Duty Engineer at Woofferton who answered the telephone as "Rampisham B", was overheard by some senior management who were on site and received a gentle reprimand for being facetious.

The LF variant of the B6126, the B6042, was installed at Droitwich in the mid-1980s as a replacement for the ex-Ottringham wartime 2 x 200 kW, 200 kHz/198 kHz LF transmitters that had been (re)installed in 1962. The two 250 kW B6042 with a Bridged-Tee combiner are still in use though there has been considerable consternation in the UK general and technical press after reports that the last pair of Thales TH573 output valves were allegedly in use and that the 198 kHz service would stop when they did. In actual fact, further supplies are still available from Thales in France but they are to special order so maybe a one-time final purchase needs to be, or has been, effected by the BBC's domestic transmission contractor Arqiva.

The Advanced PULSAM fix

With the on-going failures and often lengthy time-consuming repairs in the Advanced PULSAM modulators, the BBC took steps with MCSL to effect permanent repairs to upgrade the system and consequent reliability.

What transpired was a replacement programme using a modulation system from the USA that had originally been invented by the Brown-Boveri Company in Switzerland in the mid-1970s. This was a win-win situation in effect as it substantially lowered both the number of valves and the amount of filament and auxiliary power supplies in use. As a result, the efficiency of the transmitting plant was improved and the operational energy and staff costs lowered.

Progress to maximum efficiency

How maximum efficiency was engineered and what the result was at MCSL/GEC-Marconi Communications when they incorporated it in what was to be their last-ever 500 kW HF sender, the B6132 will be explored next time. There are first-hand accounts of the unit from the Lead Engineer Ewan Fenn, G3RTF and other staff.

Reference

1. D. Porter G4OYX and E. Fenn G3RTF. Tricks of the Trade. *Signal* 2016, **38** (February) 24-28.

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