Tricks of the Trade

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In the last issue of *Signal* was described the Riz 500 kW OR500 K-02/A HF transmitter from 2006 **[1]**. One would guess that it was probably designed around the turn-of-the-century and came into production in 2002–2003. It was a late entry to the 500 kW HF market as other European manufacturers had introduced similar powered units as early as about 1975. From the European and USA manufacturers, Government Broadcast Agencies worldwide were enthusiastic purchasers of both 500 kW HF types and especially of the 600 kW MF/LF version. In Europe for example, Norway on 1314 kHz, Sweden on 1179 kHz, Orfordness, UK on 648 kHz, Luxembourg 236 kHz/1440 kHz, West Germany 183 kHz/1593 kHz/1539 kHz and Belgium 1512 kHz were at high-power for over-the-border transmissions for either Cold War propaganda or just general commercial entertainment. With the introduction of the Orban audio processor 9100A/B for LF/MF and the HF version 9105 and the cessation of jamming after the Cold War ended in 1989, it was found that 500 kW HF was no longer required and that 250 kW or even 125 kW would be satisfactory.

Efficiency considerations

With the emphasis in the mid-1990s towards better energy efficiency, the transmitter manufacturers were looking to develop improved designs. Later on, with the introduction of high power MOSFET RF transistors on a 48-volt rail there was the opportunity available to dispense with the valved penultimate RF stage and use a solid-state 5 kW RF module to directly drive the single TH558 RF output valve.

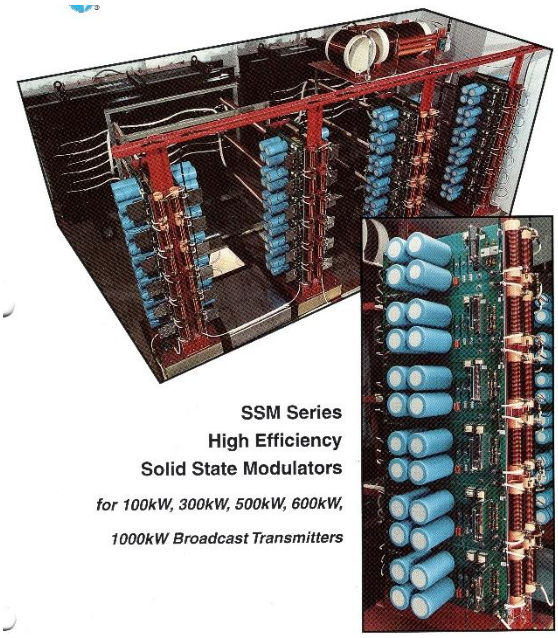

Figure 1. Continental Electronics Solid-State Modulators

In the meantime, Continental Electronics Corporation, CE Corp in the USA had made available to other manufacturers and broadcasters in general their SSM Series High Efficiency solid-state modulator **[2]** for OEM or retro-fitting to 100 kW through to 1000 kW broadcast transmitters (**Figure 1**). For example, four MCSL B6127, of the ten 500 kW senders at BBC Rampisham, were retrofitted in the early 1990’s as were the pair of 250 kW 198 kHz transmitters at Droitwich. The Atlantic 252 kHz commercial LF service from Eire would have been fitted from the start with the CE Corp SSM unit as it was a CE Corp transmitter.

Riz incorporated both the above, RF driver and modulator, in what was to be their last ever HF transmitter. In their usual fashion, they designed and made in-house everything including their own version of the CE Corp SSM unit. The SSM for 250 kW was a departure from their previous SSM for 500 kW. The 500 kW version was modelled on the CE Corp SSM in that the unit was external to the transmitter and, for transmitter sites that were having an upgrade, the concept worked well. The new transmitter unit could stand where the old one had been and what was the former modulation enclosure or as they say in the US, *the transformer vault* could be re-employed and contain the SSM and main HT transformer(s).

With the Riz 250 kW unit, clever design now meant that just one unit contained the RF components, the SSM and the main HT transformer. A small area was also required, as usual, to house the air-cooling and water-cooling plant.

For the RF output circuits the long tuned lines of the 500 kW version were gone being replaced by vertical, water-cooled, motorised tapped, coiled inductors.

The Riz OR250 K-02/A transmitter

Overview

The DRM modulator is at the beginning of the chain. It generates two different signals: AF is sent to the Modulator Control Unit, RF is sent to the 5 kW Shortwave Amplifier to provide carrier.

The 5 kW amplifier delivers typically 3–4.5 kW which is then used to drive the output valve. The 5 kW amplifier is broadband and is not tuned.

The RF Power Amplifier runs in Class C using a Thales TH558 tetrode giving 250 kW output. Modulation is applied to the carrier by varying both the anode and screen grid voltage. The output of the PA is a tuned impedance-

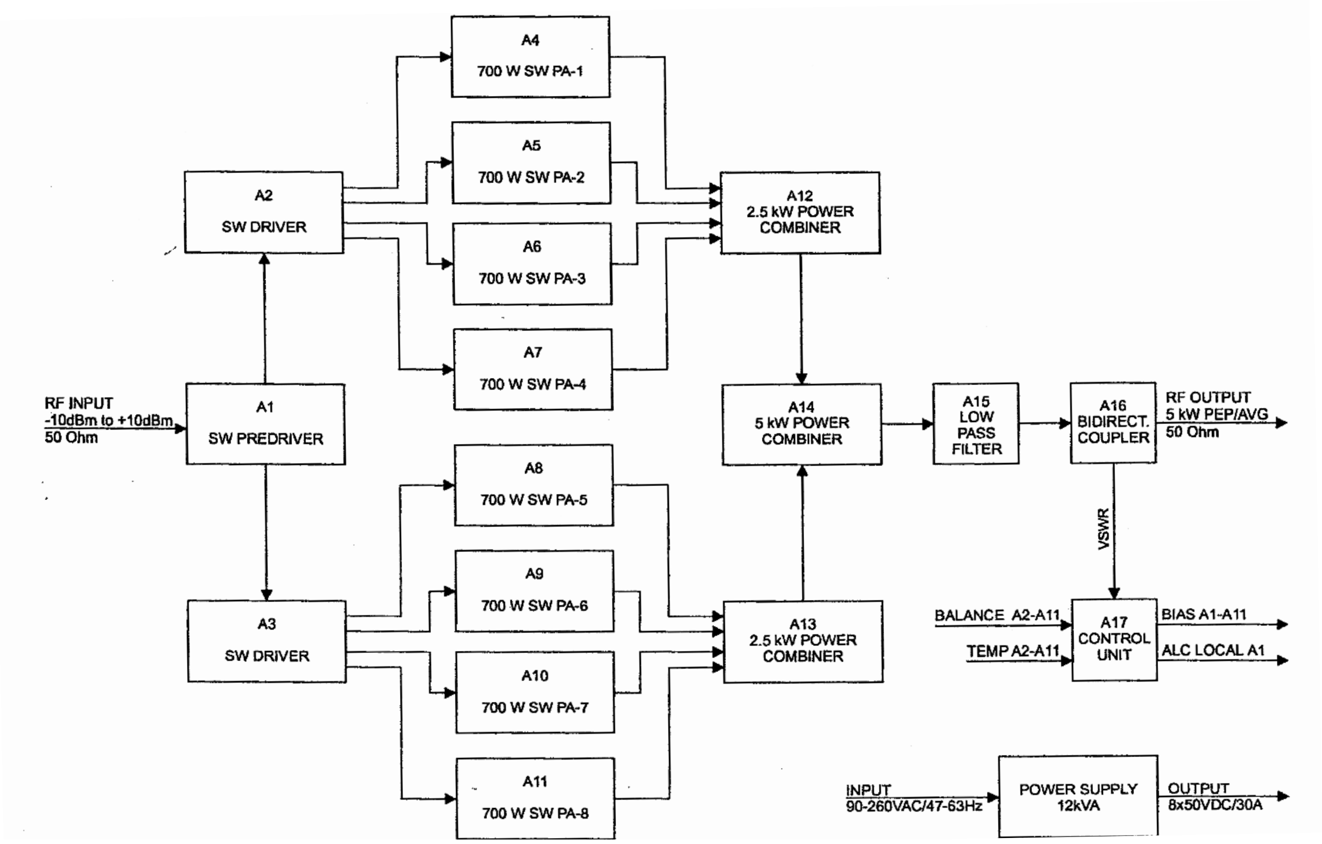

Figure 2. Block diagram of the Riz 5 kW solid-state RF driver

matching network providing the desired load impedance for the valve and a significant amount of harmonic attenuation. Any remaining harmonics between 40–300 MHz are attenuated in the VHF Low-Pass Filter incorporated in the 50 Ω output feeder.

All the tuneable elements in the RF PA are adjusted by stepper motor drives with follow-up potentiometers for presetting the desired positions for each frequency channel. Belt drive with or without reduction or isolating driving rods is used to couple them.

The following notes are courtesy of Peter Bairstow who was the VT Communications Training Officer at the time (2007) and are from both the Riz handouts and also the author's personal notes.

From Pen RF valve to solid-state drive

Prior to the OR250 most HF senders had incorporated a Pen RF valve as described in *Signal* **[1]**.

The block diagram in **Figure 2** shows the arrangement needed for a solid state driver.

The technique to achieve the considerable power output was not new as, in the early 1960s, the Englebrecht-Kurakawa, E-K, principles were first described.

Essentially, a signal enters the E-K 4-port setup, which is a 3 dB coupler, comprising the input port, two output ports and (usually) a 50 Ω (balancing) load port.

Two individual separate amplifiers, for example, can be connected to the two output ports with the resulting increased power outputted to a E-K 4-port unit in reverse, with now a single combined output and a balancing load.

Riz used a version of this where there are three stages of amplification as shown in the block diagram (**Figure 2**). The RF input signal in the range 3.2 MHz to 26.1 MHz is amplified in the SW Preamplifier/ALC, A1 unit to 2 Watts.

The second stage SW drivers A2 and A3 each deliver 4 x 20 W outputs.

The third stage comprises 8 output power amplifiers, OPAs, A4 through A11, each of 700 W.

Outputs from the OPAs are fed to the two SW power combiners 2.5 kW, A12 and A13, these feed into the 5 kW power combiner A14 and output at 50 Ω.

As is typical with Class AB1 amplification, the second harmonic is –30 dB and the third is –15 dB, not surprisingly, a low-pass filter, A15 and a bi-directional coupler for power and VSWR monitoring A16 are in use before the now cleaned-up RF power is sent to the grid circuit of the output valve. A17 is the control board for the unit. Eight switched-mode commercial power supplies giving a nominal 50 VDC at 30 A each, power the unit.

*The author recalls that much use was made of Englebrecht-Kurokawa configured amplifiers in BBC UHF low-power relay installations; these did occasionally fail, sometimes rather catastrophically and then the configuration was jokingly called Englebrecht-**Krakatoa**!*

The 250 kW RF unit

TH558 Grid

The output from the solid-state amplifier is fed to the G1 circuit of the tetrode valve V301 (**Figure 3**) . This circuit is

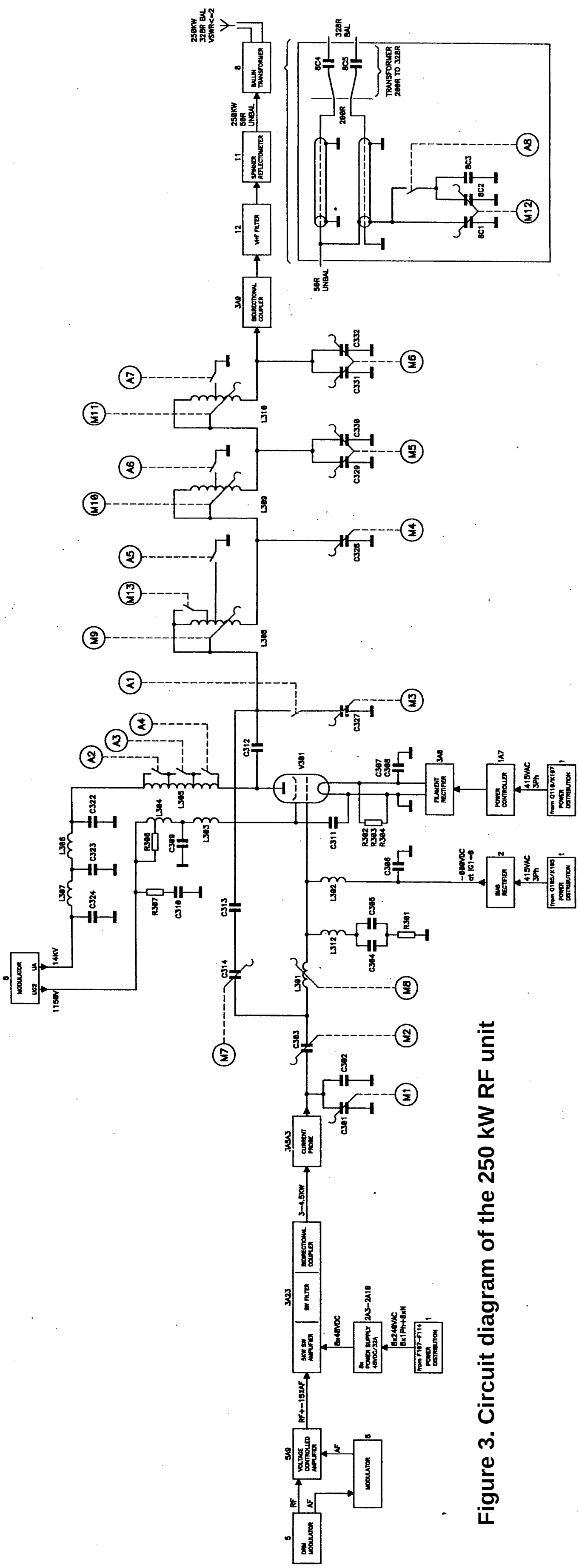

Figure 3. Circuit diagram of the 250 kW RF unit

tuned for minimum reflected power on the 5 kW amplifier. It is possible to achieve a VSWR of <2:1 over the whole frequency range.

The actual circuit is configured as a single π-network: C301, 1000 pF variable, in parallel with C302, 750 pF, then C303, 500 pF variable in series with L301 10 μH roller (**Figure 3**) and finally the input capacitance of V1 typically 450 pF. The load impedance of the π-network is determined by the input impedance of V1 in parallel with water-cooled resistor R301, 100 Ω. Water cooling is also applied to C303 and L301 (**Figure 4**).

Figure 4. Control grid input tuning L301 "Pancake" coil (horizontal roller coaster, with water cooled tap and coil.

The typical driver forward power required over the range is nearly 5 kW at 3.950 MHz and under 2 kW at the 21 MHz end. This is quite the reverse of most usual HF transmitters in the author's experience with the 75 metre band requiring just a sniff of drive power!

The TH558 itself

Figure 5. RF valve TH558 and C312 comprising 2 off 500 pF 55 kV components in parallel and neutralising capacitor assembly

V301, the Thales TH558 (**Figure 5**), is in the same configuration as in the 500 kW sender, being in grounded cathode, having a fixed G1 voltage and modulated G2 and modulated anode.

The socket contacts and base of V301 are cooled with forced air. The socket also contains the built-in screen grid bypass capacitor C311, 0.0283 µF (28.3 nF) ,with DuPont Kapton® polyimide film dielectric. Damping resistors R302–R304, all 300 Ω, are across the 23 VDC, 500 A filament supply.

The DC bias to G1 is –600 VDC and is filtered near the valve by L302, 20 µH and C306, 6800 pF.

The screen-grid voltage of 1150 VDC (on 250 kW plain carrier) comes from the modulator; it is filtered by L303 4.5 µH, L304 4.5 µH (tapped), C309 and C310 both 2000 pF, R306 and R307 both 50 Ω.

The anode voltage of 14 kV (on plain carrier) is also from the modulator. The anode RFC (**Figure 6**), just as in the 500 kW sender, is in three parts; L305 20 µH (tapped), L306 and L307, both fixed 20 µH with C322 and C323, both 1000 pF 30 kV and C324, 300 pF 60 kV. All components here, apart from L305 (**Figure 7**), are in screened, ventilated copper enclosures. Parts of L305 are shorted depending on operating frequency to avoid occurrence of potentially destructive spurious resonance(s) at a harmonic of the frequency.

Figure 6. L307 and L306, part of the anode RFC, with the decoupling capacitors C324, C323 and C322

The TH558 with its tuned G1 input matching network to suit the 5 kW driver offers a grid impedance that is determined by the grid loading resistor R301 and the grid dissipation. C303 is precisely adjusted for exact tuning and correct load impedance; a phase detector produces an error voltage from the difference in phase between input RF voltage and input RF current which drives C303 to a zero error in phase shift.

Figure 7. L305 part of the final RFC. This is water-cooled

The output network

The output of V301 is to a tuned, triple π-network providing the desired resonant load impedance at the anode of V301 and a significant amount of harmonic attenuation. All elements of the triple π-network are preset to a given value for each operational frequency channel.

At the higher operating frequencies above 13.570 MHz (except for the 22 MHz band) the PA Tune capacitor C327, 1300 pF 55 kV variable is switched out of circuit and only the output capacitance of V301 is used in tuning. In this way, the resonant frequency of the parallel resonant circuit comprising C327, C312, 2 x 500 pF vacuum fixed 55 kV anode blocker (**Figure 5**), the stray capacitance of V301 and the inductance of connections is shifted higher.

The triple π-network has vacuum variable capacitors in shunt branches and inductors in series branches; all components are water cooled.

In this sender, the output inductors are vertical coils, L308 4.2 µH variable (**Figure 8**), L309 4.2 µH variable and L310 2.3 µH variable, all water-cooled, and each with a water-cooled coil tap (**Figure 9**). The 500 kW version used horizontal, paired inductors with a sliding short.

Each coil adds reactance in parallel with a capacitor connected each side. The magnitude and sign of these reactances depends on the operating frequency and the position of the inductor's moving coil contact. They can cause adverse effects to the tuning and amount of harmonic attenuation. Therefore, each inductor is equipped with a shorting arm (switches A5, A6 and A7) between one of its inactive upper turns and ground *via* the cabinet wall.

In addition, destructive spurious resonances can occur in the anode circuit; motor M13 (**Figure 8**) drives a switch on L308 to short out certain unused turns at the higher frequencies.

Each π-section performs transformation of impedance, from output to input, the impedance is first transformed from 50 Ω to 85 Ω then from 85 Ω to 220 Ω and finally from 220 Ω to 340 Ω, which is the nominal load for V301.

Figure 8. Close-up of L308, coupling capacitors and M13 motorised coil short

Figure 9. L310 in close-up showing water cooled variable coil tap, and edge of support structure for the assembly which has rounded feature to prevent flashover and is water cooled to prevent RF current burning the edges

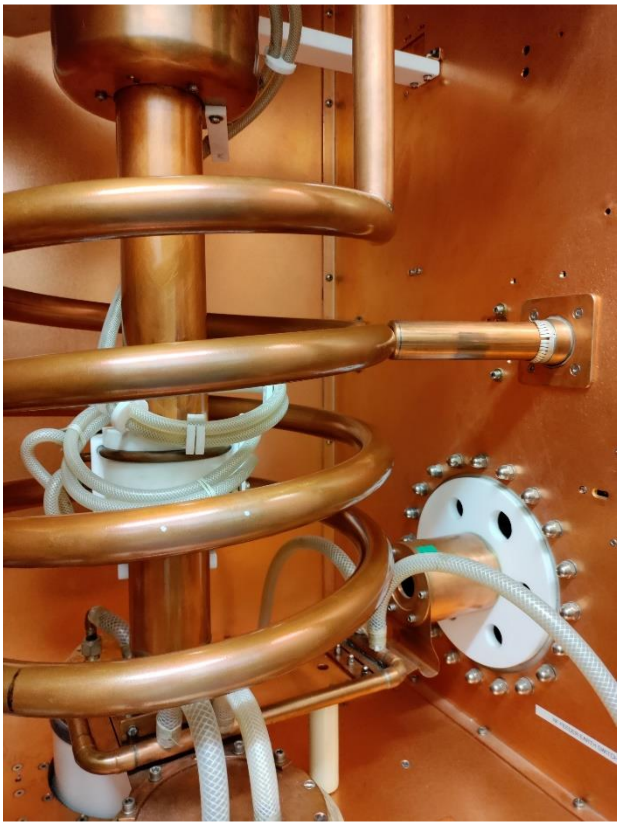

Figure 10. π-network output coil L310 showing A7 coil short in place and 9.25" diameter 50 Ω output feeder connection on right-hand side

Auto load matching

Just as on the 500 kW sender, the final part of the π-network is active for continuous tuning on power when the antenna is connected. For this, two elements L310 (**Figure 10**) and C331/C332 both 1300 pF variable 55 kV are adjusted to compensate for varying antenna VSWR.

The advantages of this technique are that each element in the triple π-network, except for L310 and C331/C332, are equally and constantly loaded regardless of antenna impedance and spurious resonances on the anode of V301 do not depend on or are influenced by the actual antenna impedance.

Neutralising capacitor

Eagle-eyed readers may have spotted the neutralising capacitor C314, 2–5 pF variable and the series string C313 (20 pF) comprising four 80 pF 15 kV disc ceramics. It is a classic text-book configuration being connected between the grid and just after the DC blocker/output coupling 1000 pF capacitor. On certain of the four Riz 250 kW senders at Woofferton there are two-in-series EEV vacuum capacitors (**Figure 11**) of 50 pF value (25 pF) instead, as certain examples of the 80 pF ceramic door-knob types failed mechanically. Motor M7 drives the plate on the neutralising capacitor to a preset point.

The modulator

Unlike the 500 kW version, the modulator modules, the single Main HT transformer and 76 kHz filter components are incorporated in the transmitter cabinet itself, there is no need for a separate room other than that for the air handling and water cooling plant. There are 48-off 800 VDC modules for the anode supply and eight for the screen-grid supply (**Figure 12**). Two of the modules for both anode and screen grid are 'fine' types and provide half the nominal voltage of the 'coarse' types. A modulator control unit determines how many of the modules are 'fired' at the instants of the modulation cycle as the digitised audio samples dictate. These coarse and fine versions of the Riz Transmitter Company do not appear to have been incorporated in the CE Corp SSM unit.

Figure 11. Motorised C314 neutralising capacitor and fixed series pair of C313 comprising 2 x 50 pF 55 kV vacuum capacitors

Being in the digital domain the modulator is able to process audio and associated data or in fact just data, to the Digital Radio Mondiale, DRM standard and the sender runs at a maximum of 110 kW in that mode.

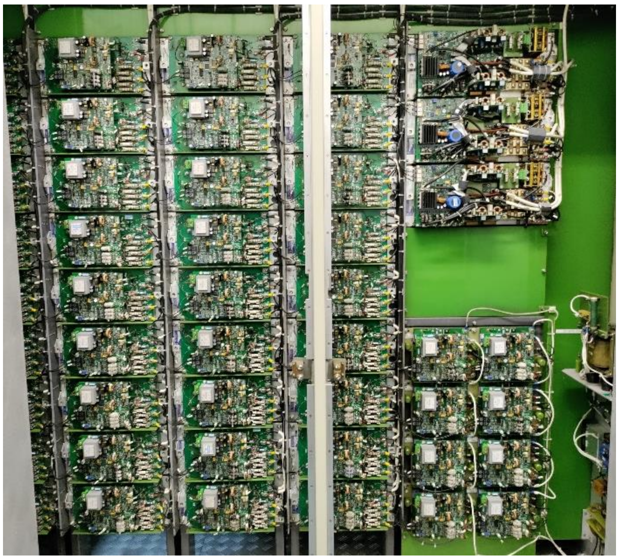

Figure 12. Part of the Riz modulator

Controlled carrier modulation

Mention has been made of controlled carrier modulation previously in *Signal* **[3]** where it is fully explained technically. Within the CE Corp promotional sales document, the front page of which has been shown as **Figure 1** above, there is a description of the concepts of Controlled Carrier Modulation, CCM.

The CE Corp default version of CCM is the same as the earlier AEG-Telefunken one, namely Dynamic Amplitude Modulation, DAM. Their description of DAM is in this first section.

CCM, a standard feature of the solid-state modulator maintains the carrier at a sufficient level to be 100% modulated by the incoming audio. In operation the input audio level is set so that 100% modulation is achieved on programme peaks with the transmitter carrier output at the full level. With this audio level setting and CCM enabled the carrier level will fall to a preset level in the absence of modulation and rise to a level compatible with the instantaneous peak level of the programme audio. The level to which the carrier will be reduced is adjustable at the front panel of the transmitter in 1 dB steps from 0 to 6 dB.

Activation or deactivation of CCM is also selectable on the front panel by a single switch and may be accomplished at any time without programme interruption.

CE Corp can also provide the Dynamic Radiation Compression System advocated by the British Broadcasting Corporation. This BBC form of CCM is essentially the inverse of the (DAM) *system first described above; in that full carrier is provided when no modulation is present and the carrier level is reduced as the level of the modulating signal is increased. In this form, the time constants are identical to the* (DAM) *system.*

The author has never before seen the CE Corp naming of the BBC system as DRCS but only the usual version as AMC, Amplitude Modulation Companding. Then again, CE Corp did not mention the AEG-TFK name of DAM, maybe there were copyright issues in those days?

CE Corp go on to say:

The primary reason to employ CCM is to effect a power saving without reducing listener satisfaction. Our tests and reports indicate that the use of CCM is virtually undetectable to the audience. In practice, actual power saving over non-CCM (DAM in their case) *usage is highly dependent by programme content, with talk programme resulting in greater power saving than most music programme.*

"CCM" was originally the umbrella term and indeed CE Corp labelled their switch CCM on and CCM off. Riz have done the same on their front panel but added inside the unit a second switch for DAM or AMC selection.

DAM or AMC?

Whilst the written description above of the two versions goes a little way towards explaining the systems, there is merit in actually adding in some numbers…

Considering first 6 dB AMC on a 250 kW transmitter.

We know that on a plain, unmodulated carrier of 250 kW, the peak envelope power (PEP) is also 250 kW. At 100%

regular AM the PEP is now four times that level, so that is 1 MW.

When the modulation level is increased the carrier level is progressively reduced and, at 100% modulation, the carrier is reduced to one-quarter, that is 62.5 kW.

A 100% modulated carrier of 62.5 kW results now in a PEP of 250 kW.

What is evident from this is that with 6 dB AMC, *any* modulation level *always results* in a PEP of 250 kW.

This is a useful technical concept as the strains and stresses of peak power on the output components or feeder and antenna are much reduced.

The strains and stresses of peak power…

Considering now the DAM system.

Again with a 250 kW transmitter and with a 6 dB setting; the regular AM carrier output would be reduced from 250 kW to 62.5 kW on plain carrier, which of course is 62.5 kW PEP.

As the modulation is increased, the carrier level increases as well such that at 100% modulation the carrier power is up to 250 kW and with the modulation the PEP is now four times that figure at 1 MW.

There is a very significant peak envelope power variation of 62.5 kW to 1 MW on this system and one wonders if the AGC range in the majority of receivers could adequately cope with this variation particularly on an HF service with the QSB having an effect as well. Early proponents of DAB sold the cost savings on the fact that the AGC would cope…

The BBC system of AMC (at 6 dB setting) maintains literally, a constant PEP so the receiver AGC has a much easier life.

Mention has been made of programme material and the cost savings. For DAM it would appear that, for non-Optimod processed speech-based material and classical music, they would exhibit the best power reduction over regular AM. Heavily compressed material would increase the power consumption.

For AMC to maintain the best cost savings then heavily-processed speech and even better, heavily processed continuous music would keep the carrier mostly at the –6 dB level compared to regular AM. For a HF broadcast service, heavy processing is almost always used and AMC will win out in the power efficiency stakes especially with music content.

To conclude… the accountants are happy with CCM, the design engineers are happy with CCM and the operational engineers are much happier with AMC (less peak voltage) but who loses?

It is only when a simple AM demodulator is used, such as a transmitter monitor, that the audio differences become apparent. There is no AGC incorporated on these monitors, often just a DC-biased Shottky diode and audio-pre-amplifier to 600 Ω balanced output to a power amplifier and speaker, that the volume differences are noticed. DAM shows the greatest variation with AMC the least, but it is obvious that AMC is a lot quieter than regular AM. Cynically, one could say that the listeners are being sold short!

In a recent piece in the broadcast trade magazine *Radio World,* that is published on-line in the USA, the author was surprised to see that the CCM systems (DAM and AMC) are now being hailed as something quite extraordinary! It may be worth writing a piece for RW adding in some math (as they would say) about the system as it was a little light on technical detail but, as one would expect, it was heavy on hype and saving money! Quite why it has taken so long for this to surface over there is a mystery, though to be fair the CE Corp SSM modules, for example, have not been available for transmitters running as little as 50 kW

The last throw of the dice

One would guess that most in VMARS are aware of the gradual cessation of MF services for the domestic market in the UK over the last few years. A major loss was the high-power Absolute nationwide service on 1215 kHz along with its low power relays, then the main Northern Ireland 100 kW 1341 kHz Radio Ulster service followed by many of the ILR directional city coverage services for the 1152 kHz and 1548 kHz operators. Many local services for both BBC and ILR have closed as well.

What remains at present, are the BBC high power services of Radio Five Live on 693 and 909 kHz, the regional BBC Scotland 810 kHz, national BBC 198 kHz LF and Radio Wales 882 kHz now down from 100 kW AMC to 10 kW regular AM at Washford.

The commercial operator Talksport continues with high power on 1053 kHz and 1089 kHz.

With the cessation of the 1215 kHz services, there were available on the sites, redundant Harris DX-50 solid-state transmitters; these exhibit excellent efficiency, approaching 80% even in regular AM and some have been wavechanged and placed into service on 693 kHz and 909 kHz. Being regular AM 50 kW transmitters, not AMC and having at 100% modulation, a PEP of 200 kW they were an attractive proposition.

The reason for this was that the 40-plus-year-old 150 kW and 100 kW transmitters they replaced, had been used on 6 dB AMC for a good few years previously. 150 kW AMC would mean a 37.5 kW carrier at 100% modulation with, of course, a PEP of 150 kW; similarly the 100 kW AM sender then on 6 dB AMC would also be now only 100 kW PEP.

These 150 kW and 100 kW transmitters were combined Marconi B6034 50 kW Doherty types. These have the carrier valve and peaking valve in the output stage.

On a single B6034, the 4CX35000C carrier valve is biassed to give, *in regular AM,* a maximum of 50 kW output on plain carrier. When modulated the carrier valve sets the negative peaks of modulation down to zero, while the peaking valve adds in the positive peaks.

With many of these sites being on 6 dB AMC for some years previously, it was discovered that only the carrier valve needed to be in service as now the PEP is 50 kW and, as at 100% modulation the carrier is dropped to 12.5 kW, the peaking valve has no contribution to make. The 4CX35000C peaking valve could be disconnected electrically from its socket thus saving filament supplies, *etc*. so aiding overall efficiency and spares holding.

Conclusion

One would have to conclude that, in the end, the accountants have won out assisted by the fact that, over a near 100-year reign of service, the AM mode is coming to a close. With the digital modes of DAB and on-line delivery and near perfect studio to listener quality, the power-hungry mode has been overtaken.

It is only on over-the-border HF transmissions that there is some time left, especially in troubled times where the VHF/FM delivery can be killed overnight by the host Government cessation of a licence to transmit in a 'foreign' country or a block placed on internet access.

The rationale of HF broadcast being "Crisis Driven Radio" appears to be as valid now as ever.

References

1. D Porter G4OYX. Tricks of the Trade. *Signal* 2024, **72** (August), 45-49.
2. Continental Electronics Corporation. SSM Series. High Efficiency Solid State Modulators for Broadcast Transmitters. Sales Document 2M/3-92.
3. D Porter G4OYX. Tricks of the Trade. *Signal* 2008, **6** (January), 17-19.

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"Build your new transmitter kit". This is the latest 250 kW Riz Sender 93 being installed at Woofferton. It was previously in use at the BBC Far East Relay Station at Singapore from 2012 to 2023 as Sender 107 . Before that it was Sender 61 at Skelton in Cumbria from 2007. So it is much travelled!