How the Power Rock Modulates

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The Continental Electronics 314R-1 Power Rock 1 kW transmitter (a.k.a. Rockwell-Collins 828C-1) was the second AM model that Collins sold to Continental when they got out of the broadcast transmission business. The first was the 828E-1 (a.k.a., 315R-1) 5 kW rig, that was produced in a large quantity (~1000 units). Both rigs used a 70 KHz pulse duration modulator (PDM) with a single modulator tube. The smaller Power Rock ran on single phase power, and was the last vestige of vacuum tube PDM transmitters, as no other broadcast manufacturer attempted PDM in a 1 kW rig with tubes, preferring either standard high level plate modulation using a pair of tubes with a transformer, or collector-modulation of transistors (like the Harris/Gates MW1).

In the little Power Rock, one 3-500Z triode was used as a switch tube, in series with the negative 8500 VDC power supply. As the duty cycle of the switch tube was varied in response to the program audio, the average (DC) value of the voltage at the plate of this tube varied at the audio rate. To derive this average, a low pass filter was required to filter out the 70 KHz component, leaving a time-varying DC (audio) component similar to what a high level plate modulation transformer would give (but with lower distortion and flatter frequency response). When the audio was removed, the PDM rested at 40% duty factor, which produced a 1 kW unmodulated RF carrier. This modulator is about 90% efficient, much higher than a class AB or class B push-pull high level modulation amplifier. It also used one less tube, and used the same tube type in the RF amplifier. It is important to note that this modulator will work properly with one brand of triode, and if it is changed from Eimac to Amperex tubes, for example, several components in the switch tube driver card must be changed. These compensate (predistort) the PDM pulses to maintain accurate pulse width from the switch tube even at very low duty factor with high negative modulation.

Because the Power Rock was marketed at the time that broadcast AM radio was promoting C-QUAM stereo modulation, it had very good audio performance, nearly flat out to 10 KHz, and without the typical LF tilt measured at the low end from capacitor and transformer-coupled circuitry. It was DC-coupled in the high power circuitry.

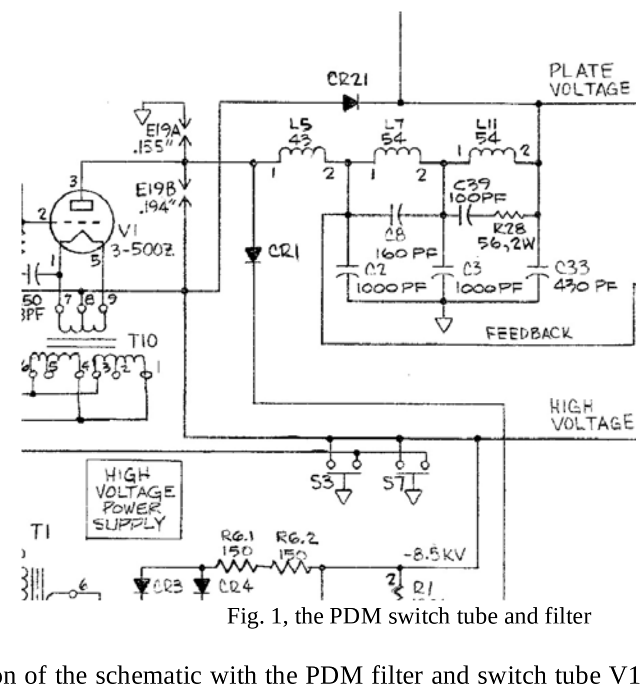
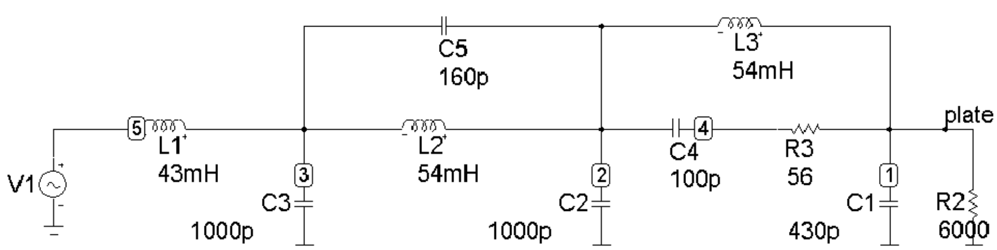


Fig. 1, the PDM switch tube and filter

Figure 1 shows a portion of the schematic with the PDM filter and switch tube V1. The plate voltage wire at the top connected to the cathode circuit (CT of filament transformer) for a pair of 3-500Z triodes that were paralleled in the RF power amplifier. C33, the final mica capacitor in the filter, was actually mounted at the floating RF deck, bolted to ground. It served not only as a component in the filter, but as a RF bypass capacitor for the PA cathodes, as RF output is taken from the plate circuit of those tubes. By modulating the cathode voltage (negative HV DC), the plate was DC grounded, with only RF voltage present on the output RF network, and no blocking or coupling capacitor required. This lowered the peak voltage at the plate of the tube during positive modulation peaks, since there is no DC bias (the audio) at the plate. In addition, it minimized output capacitance across the switching modulator tube, which would be worse if a conventional 'totem pole' topology were used where the switch tube is in series with the plate of the RF PA. In that arrangement, the stray capacitance of the modulator filament transformer would be in shunt with the modulator (to ground). Excess capacitance across the switching device would raise power loss. One more advantage of this circuit was that it allowed the plate voltage and current meter circuitry to be grounded on one end. Forest Cummings received a patent on this topology in 1980 (US 4,187,167, found on my webpage). Harris had a similar patent for their MW5 and MW50 transmitters, which moved the ground to the negative lead of the HV power supply only, and floated both the switch tube and the RF PA tubes in series throughout. A thorough discussion of these PDM schemes can be found in George Woodard's chapter on AM Transmitters in the 1985 seventh edition National Association of Broadcasters engineering handbook.

As I mentioned earlier, with carrier and no modulation the PDM runs at 40% duty factor. The plate voltage out of the filter is around -3 kV DC, typical for a pair of 3-500Z triodes to produce one kW of RF. With 125% positive modulation, plate voltages is -6.75 kV and with 100% negative it is zero volts. CR21 and CR1 are high power diodes that are rated for fast recovery. CR1 connects back to the bottom (positive leg) of the power supply above the plate current meter shunt. Its purpose is to commutate the circuit so that there is no build up of positive voltage from the plate of the switch tube with respect to ground, due to the counter-emf developed by the first inductance of the filter, L5. When the switch tube is off, the magnetic field collapses in the inductor, and the currrent in this inductor flows through CR1. CR21 is another damper diode, that prevents the output of the filter from going more negative than the -8.5 kV power supply.

Forest Cummings designed the low pass filter starting with a Cauer design, then empirically improved it for best suppression of 70 KHz, while having the flattest audio passband. A Spice model of the passive circuit, along with amplitude and phase responses, is shown in figures 2 and 3.



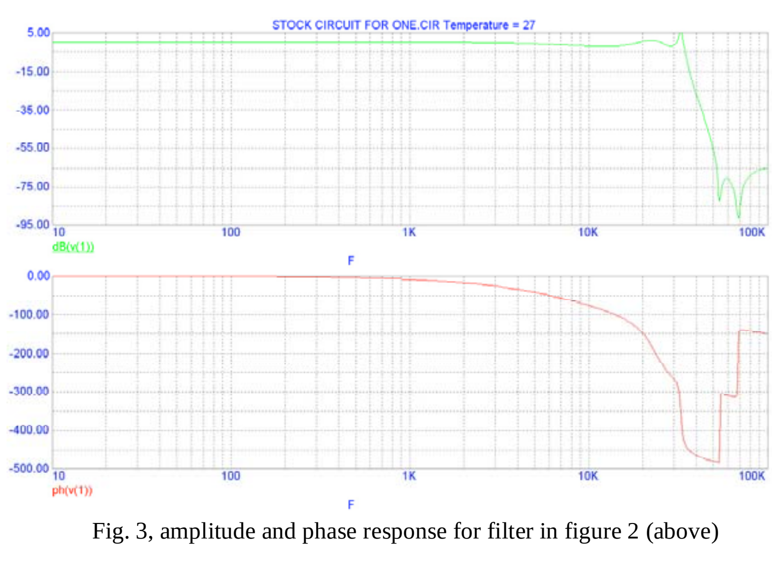


Fig. 3, amplitude and phase response for filter in figure 2 (above)

It is important to note that this filter will likely overshoot if driven with PDM having audio content with high frequency transient material. A mild bessel filter in the low level audio input stage is designed to prevent that. Computer optimization has demonstrated that a better filter could be made just by changing the capacitor values while leaving the inductors (the hard part to replace!). However, for amateur radio applications, just bandlimiting the incoming audio to 6 or 7 KHz would accomplish the desired result, leaving the PDM filter doing it's thing to suppress the 70 KHz switching carrier.

Some photos are included in figures 4 and 5, of the actual components in the PDM filter for a 314R-1 transmitter. The upper diode has been replaced as it had been shorted. The original CR1 was a Semtech diode, 17 kV 1 Amp, CEC part number 353-6599-020. This diode had a 250 nS recovery time at 0.25 Amps. A 10 Amp 18 kV stack of 50 nS diodes replaced it, seen as the cylindrical "doorknob" diodes at the top of the photo.

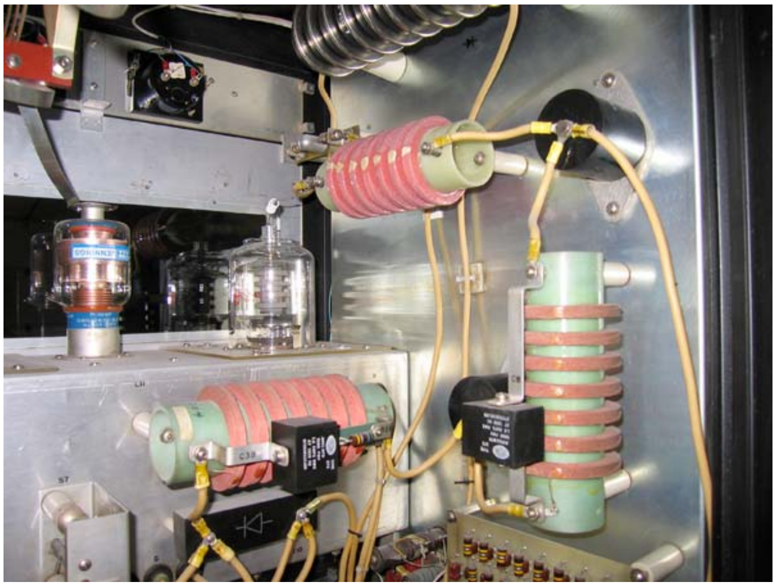


Fig. 4, showing V1, L5, L7, L11, C2, C3, C8, C39, CR21 and R28

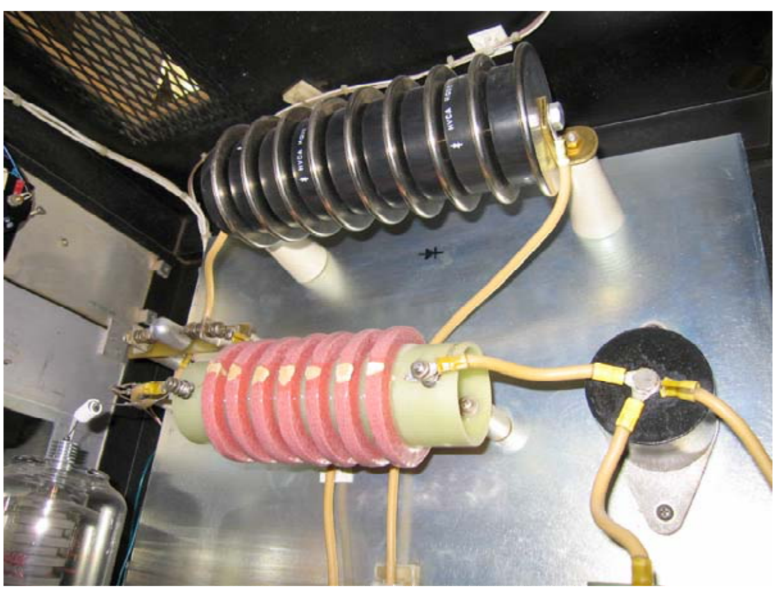


Fig. 5, showing L5, C2 and the new CR1 diode at the top

This transmitter will modulate at 9 KHz with a tone at 90% without overloading. However, when pushed to beyond 95% negative, PDM 'nipples' can be seen on the RF carrier as it approaches cutoff. The predistortion circuit on the switch tube driver card (mentioned earlier) attempts to correct for the problem of extremely low duty factor PDM. Simply stated, a problem in PDM systems is that the small capacitance at the modulator switch and filter input ‘smears’ the narrow pulses of low duty factor. Because they are not translated through the switch tube with high fidelity, the resulting audio B+ becomes distorted. It is nonlinear distortion, unlike harmonic distortion of audio. Various schemes have been used to improve this, such as reducing the amplitude of the narrow pulses. I won’t go into further details of how it works, but Forest Cummings’ patent is on my webpage (US 4,140,980). The low level audio circuitry had a modulation controller that maintained peak modulation levels in proportion to the HV power supply level as it could vary with line voltage fluctuations (US 4,199,723). The audio input circuitry also had negative and positive modulation clippers.