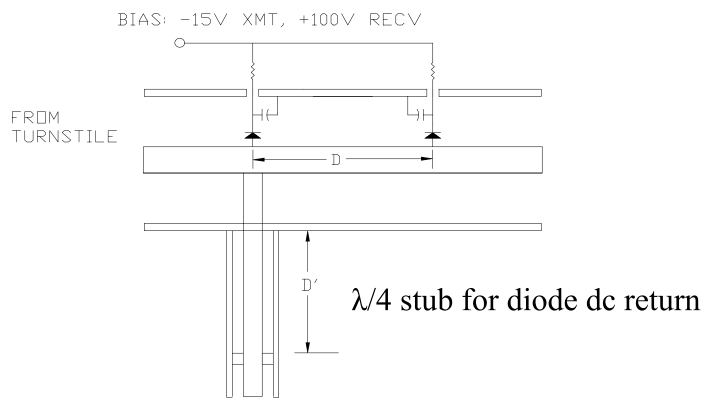
18. Receiver Protection

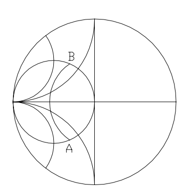
We can count on no more than about 25 dB of isolation from the turnstile junction. Therefore the pulse power leaving the turnstile's receiver port is about 2.5 MW - 25 dB = 7900 W. The job of the monoplexer is cut this feed through down to, say, 1 mW to prevent burning out, or severely overloading, the receiver. This implies a monoplexer attenuation of better than 69 dB.

18.1 430 Monoplexer - Theory of Operation



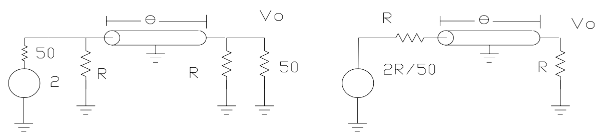
The monoplexer is shown above in simplified form. This device is put at the input to the receiver. When the diodes are forward biased, their resulting low impedance (about 1/10 ohm) shorts the inner and outer conductors of the coaxial feed line. This short reflects the leakage power from the turnstile (about 1 kW) to protect the receiver from burnout.

There are two diode "stations" along a 50-ohm line, separated by a distance *D*. Each station has 4 diodes to provide a better short. If a single diode station provided, say, 50 dB of isolation, then adding a second station a quarter wave from the first would increase the isolation to 2x50 + 6 = 116 dB. A quarter-wave separation provides the maximum isolation.



For receiving, the diodes are reverse biased. Their low resistance disappears but they still present a capacitance of about 2.1pF. Four diodes in parallel increase this to 8.4 pF which, at 430 MHz is a reactance of 44 ohms. This reactance, shunted across the 50-ohm produces a reflection coefficient shown as point *A* in the Smith Chart. Moving along the transmission line from point A, we arrive at point *B* (the mirror image of point *A* about the x-axis) where an identical station will bring us back to the center of the chart, i.e. eliminate the reflection. If the capacitance had been very small, point A would have been very near the y-axis. The separation on the chart would have been 180 degrees and the physical separation would have been 90 degrees - the separation that gives the best isolation when the diodes are in the transmit state. No compromise is made; the separation is determined by the angle between *A* and *B* so that there will be no mismatch on receive. For our 8-diode monoplexer, the separation is only 31 degrees.

We can analyze the circuit to determine the isolation as a function of the diode ON resistance and the distance between the diode stations. The equivalent circuit is shown below at the left. A simplified version is shown at the right.



The source is made to be 2 Volts so that the output voltage, Vo, will be 1 Volt when the resistors R are infinite in value (no attenuation). Since the R will be much less than 50, the circuitry to the left of the transmission line has a Thévinen equivalent voltage source of 2R/50 and an impedance of R. This Thévinen equivalent is shown in the simplified circuit. Again, since R<<50, we can ignore the 50 ohm load (the receiver) in calculating the output voltage. The output voltage can be calculated as follows: The cable and the resistor at the right-hand end present an impedance given by $Z = 50(R + 50\, j \tan\theta)/(50 + R\, j \tan\theta)$. The current flowing into Z is given by $I = (2R/50)/(Z+R)$. The power delivered to Z is given by $Pwr = |I|^2 \, Re(Z)$. This power is equal to $|Vo/R|^2 \, Re(R)$. Solving for $|Vo|^2$ we find

$$|Vo|^2 = |(2R/50)/(Z+R)|^2 \, |R|^2 \, Re(Z)/Re(R)$$

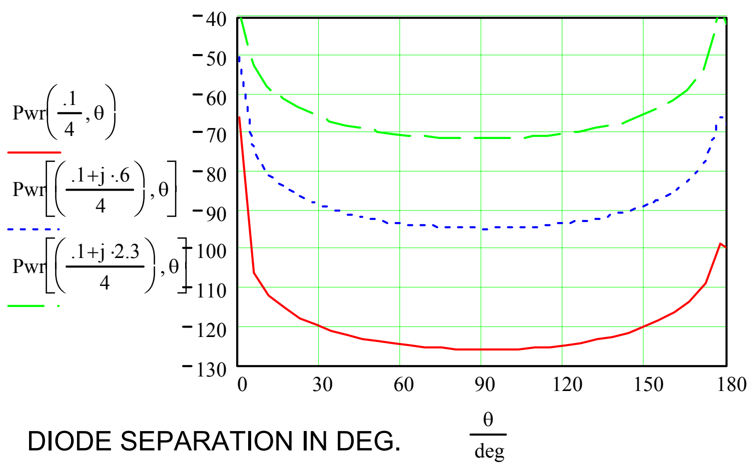
where $Z = 50(R + 50\, j \tan\theta)/(50 + R\, j \tan\theta)$. In this formula, the value of R can be complex, to include diode reactance. The attenuation is given simply by $10\log(|Vo|^2)$ and is plotted below in dB vs. diode station separation for three values of R.

file:430mpxr2.mcd

$$\theta := 0, .1 .. 4$$

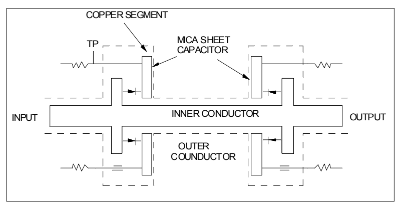
$$Z(R,\theta) := 50 \cdot \left(\frac{R + j \cdot 50 \cdot \tan(\theta)}{50 + j \cdot R \cdot \tan(\theta)} \right) \qquad Pwr(R,\theta) := 10 \cdot \log\left[\left(\left| \frac{\frac{2 \cdot R}{50}}{R + Z(R,\theta)} \right| \right)^2 \cdot \frac{(|R|)^2}{Re(R)} \cdot Re(Z(R,\theta)) \right]$$

ISOLATION IN dB



DIODE SEPARATION IN DEG.

When the diode impedance is taken as 0.1/4 + j0 (four diodes of 0.1 +j0 ohms in parallel, as at each end of our 8-diode monoplexers), the theoretical isolation reaches 120dB. If we add 0.6 ohms of reactance to each diode, corresponding to the 630pF bypass capacitors (metal segment plate with mica insulation), the isolation drops to 88dB. The measured value, however, is about 66 dB. As shown in the third curve, this is the value we would expect to measure if each diode had a reactance of 2.3 ohms. This corresponds to an inductance of only 0.85nH, which could be attributable to the 1/4" length of the stud-mounted diodes. It could also be attributable to the fact that the diodes don't directly contact the center conductor of the coaxial line. Instead, at each diode station, the center conductor becomes a thin disc, i.e. a radial transmission line. The diodes contact the disk at a radius that is about twice that of the center conductor. This section of radial transmission line might account for the apparent reactance.



We have nodocuments describing the original monoplexer design, which was done at Sylvania in Waltham Ma. Did the designer take into account the radial transmission line and attempt to resonate out its impedance by carefully selecting the thickness of the mica insulation in the bypass capacitors?

18.1.1 Monoplexer power handling capability

The monoplexers should be able to withstand an incident wave of 50kW cw, and maybe up to 800kW with a 6% duty factor. Power handling is determined by the input diode station, where four diodes in parallel short the input line. If the incident power is P_{INC}, the current through the short will be
given by $I^2_{RMS} = 4\ P_{INC}/Z_0$ where Z_0 is the impedance of the line (50 ohms) and the factor of 4 is due to the fact that the reflected wave produces a current equal to the incident current. Each diode, when forward biased, has an RF resistance of 0.1 ohms, so the resistance of the four diodes in parallel is 0.025 ohms. The maximum average power dissipation of each of these stud-mounted diodes is 25 watts, for a total dissipation of 100W. Putting this together, we have $.025\ I^2_{RMS} = 100$ or $.025(4\ P_{INC}/Z_0) = 100$, from which $P_{INC} = 50{,}000$ cw or $50{,}000/.06 = .83$MW when pulsed with a 6% duty factor..