A HIGH POWER PROTECTOR USING PIN DIODES

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PIN diodes are useful in high power switching applications because their microwave impedance is essentially a controllable conductance in shunt with a nearly constant capacitance. The diodes are made by diffusing heavily doped N+ and P+ layers into a π-type body. When reverse biased the R.F. impedance is determined by the π-region capacitance in series with a small resistance. If a forward bias current is applied, the π-region is progressively filled with carriers and the device becomes a conductance increasing to a maximum value of about 10 mhos. It is this high conductance which accounts for the high power rating of PIN diodes.

If stray reactances are neglected, a simple protector could be made by shunting a transmission line with a PIN diode. If this is followed by a second diode spaced a quarter wavelength from the first, it can be shown that the protection in decibels is approximately doubled. Similarly with three stages the protection is approximately tripled.

The switched protector to be described uses two commercially available diffused silicon PIN diodes (GA-53693) spaced a quarter wavelength apart in 36Ω ridge waveguide and has been designed to operate at 1350 Mc (Fig. 1). For such a configuration the fraction of incident power dissipated in the load is given by:

$$P = \frac{4Y_o^4}{|Y_1|^2 \cdot |Y_2|^2}$$

where Y_1 and Y_2 are the admittances of the two diodes when forward biased as shown in Fig. 2(a). Figs. 1 and 2(a) show a pair of lumped series capacitors used to tune out the inductances of the diodes; if these are stagger tuned, protection can be achieved over a broad band.

Two pairs of adjustable irises are used to shunt tune the diodes for minimum low level loss when in the reverse biased or capacitive condition. In this case stagger tuning is not necessary due to the broad banding effect of the quarter wave section. In the low loss condition the fraction of incident power reaching the load at midband is given approximately by $P = 1 - (G_1 + G_2)/Y_o$, where G_1 and G_2 are the conductances of the diode circuits at resonance as shown in Fig. 2(b).

The following performance figures were measured over a 10% band:

Protection	greater than 70 db	Fig. 3(a)
Low level loss	loss than 0.15 db	Fig. 3(b)

The bandwidth can be increased to 15% at the expense of protection which is reduced to 60 db. A three-stage protector could provide about 100 db of isolation with 0.2 db loss but there is little advantage in using this as the calculated peak power rating of the present device is only 100 kw. The peak power level is determined by voltage breakdown which is likely to occur either at the edges of the central ridge or within the first series tuned circuit where potential differences as large as 500 volts can appear. To date the device has only been tested with 10 watts of R.F. power.

The thermal power rating of the protector may be defined as 1000 watts of continuous R.F. or 2.5 watt-second pulses if the duration is shorter than the PIN thermal time constant of 2 ms. These limits were determined experimentally by Leenov* and agree closely with his calculated values.

*D. Leenov "Silicon PIN Diode as a Microwave Radar Protector at Megawatt Levels", Signal Corps Report #10, Bell Telephone Laboratories, Incorporated, December 10, 1962.

Several methods are available for switching the device but the essential feature is that 50 nanocoulombs are required to produce 60 db of protection over the band. Protection of at least 70 db can then be obtained with a hold current of 50 ma and finally a reverse bias of -30 volts (40Ω source impedance) can return the device to the low loss condition in 0.25 μsec (Fig. 4(a)).

If a faster return to the low loss condition is required, the forward hold current can be stopped well before the reverse voltage is applied. This is illustrated in Fig. 4(b) where it is shown that protection of at least 60 db can be maintained for a period of τ μsec by injecting an additional $60 \cdot \tau$ nanocoulombs. In this case the return to the low loss condition takes only 0.15 μsec and this can be further reduced by using a lower impedance voltage source. It is therefore possible to achieve switching times as low as 100 nsecs with control currents smaller than 0.5 amperes.

The results at 1350 Mc illustrated in Figs. 3(a) and 3(b) were obtained using GA-53693 diodes having the parameters shown in Fig. 2. At higher frequencies the 70 db of protection using forward biased diodes should still apply provided the bandwidth is restricted to 130 Mc. On the other hand the low level loss with reverse bias increases at a rate proportional to $(\omega \cdot C_{REV})^2$. For low loss at high frequencies it is therefore essential to use diodes with proportionately lower reverse bias capacitances. Recently, PIN diodes have been fabricated with capacitances of 0.5 μμf and at 10 Gc in 36Ω guide, two of these have a calculated low level loss of 0.2 db.

The protector has been designed primarily to safeguard varactor diodes in low noise parametric receivers. The emphasis has therefore been placed on achieving a lower loss than that which is obtainable using conventional T.R. tubes.

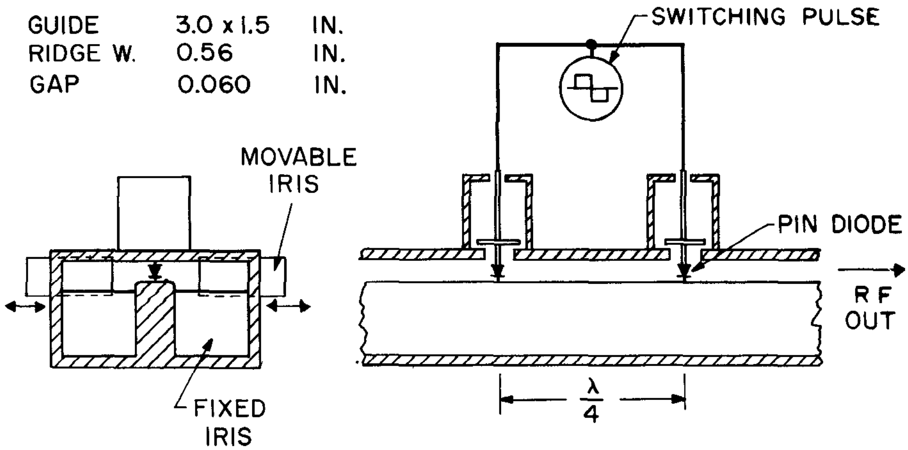

Fig. 1 Solid state switched protector.

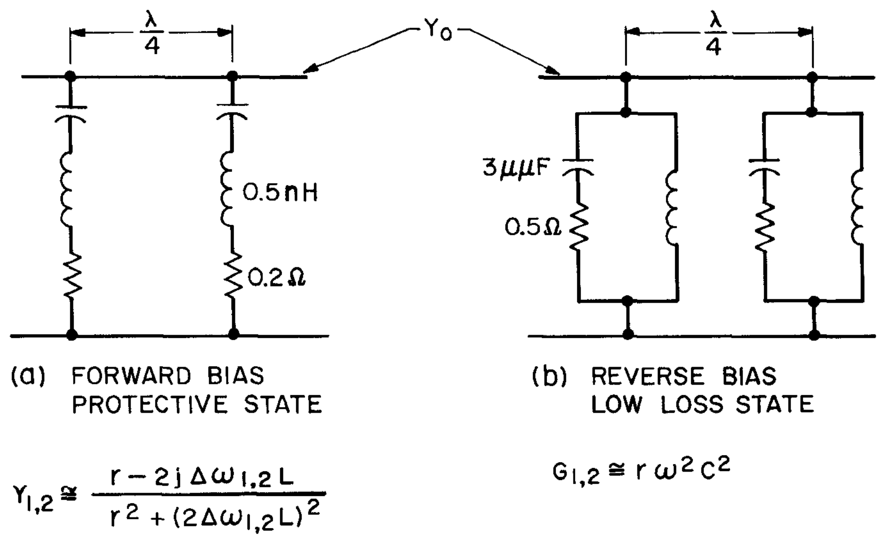

Fig. 2 Forward and reverse biased diode circuits.

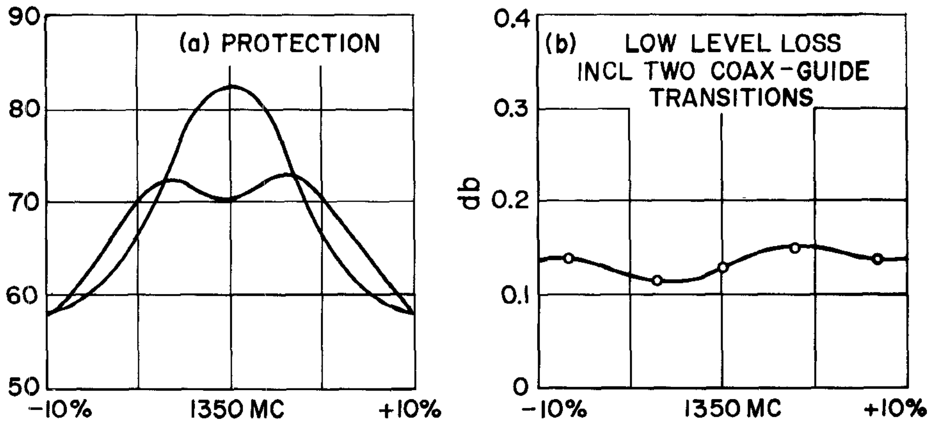

Fig. 3 Protection and low level loss vs frequency.

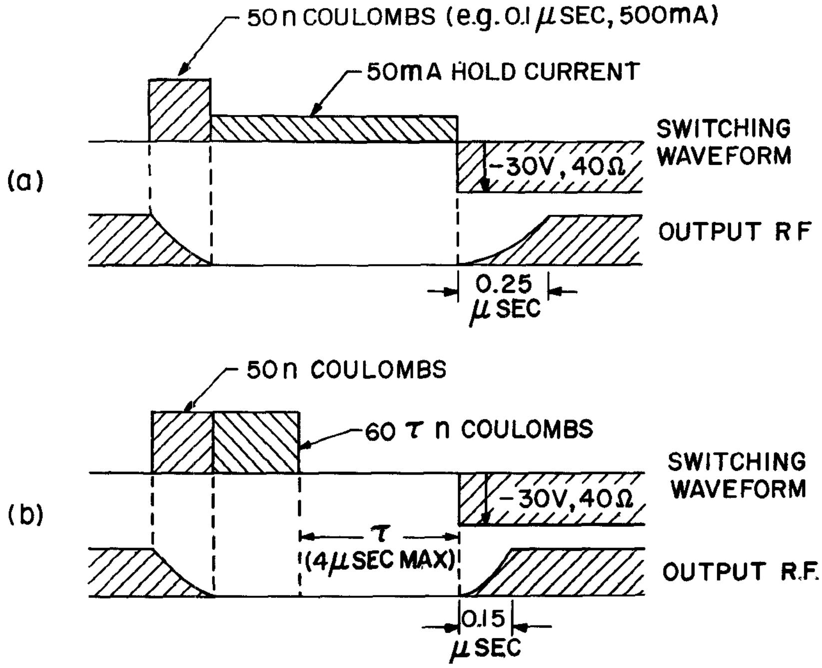

Fig. 4 Relations between output R.F. and switching waveform.

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