ULTRA-HIGH SPEED DIODE SWITCH FOR 50 GHz BAND UTILIZING AVALANCHE BREAKDOWN OF VARACTOR DIODES

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This paper briefly reports on some of the results achieved with diode switches for 50 GHz band, which have been developed as transmitter-modulators for guided-millimeter-wave ultra-high-speed PCM communication systems.

When some kinds of varactor diodes are biased at a certain negative voltage, there appear an inductive reactance and a negative resistance at the junction due to the avalanche breakdown(1), giving higher cutoff frequency than what is measured under normal conditions. Diode switches of good electrical performances can thus be obtained even with varactors of relatively low cutoff frequency by utilizing this avalanche breakdown.

Silver-bonded Ge varactors GSB3C(2) of NEC were used in the experiment. Some of the electrical characteristics of the varactor are listed in Table I.

The diode holder whose cross-sectional view is shown in Fig. 1 had a reduced height of 1.40 mm at the waveguide portion, with reactance bars to be inserted from the sidewalls against the diode and a coaxial short plunger, primarily giving a series reactance to the diode. Two-section quarter-wave transformers were employed to match the holder to a standard waveguide of WRJ-500 (4.775 x 2.388 mm, I. D.). Because transmission-type operation was contemplated, the diode switch was adjusted and tested in a measuring circuit, the generator side as well as the load being matched to the WRJ-500.

Impedance adjustment was made with the reactance bars and the coaxial short plunger. The bias voltage was swept at 50 Hz while the transmitted power was detected and indicated on an X-Y oscilloscope, the input to the switch being +16 dBm at 48 GHz. The primary objective of the impedance adjustment was to obtain as high maximum attenuation as possible for insertion loss less than 4 dB. Attenuation was measured with a calibrated attenuator. A Model 125 pulse generator of EH Research Labs. was used to drive the switches. The modulated signal was detected by a cross-bar type detector and displayed on a Tektronix's type 661 oscilloscope.

Several classes of attenuation vs. bias voltage characteristic were obtained by proper adjustment(3), (4), and they can approximately be derived by a calculation on an equivalent circuit. One class gave first a maximum attenuation and then a minimum when negative bias was increased beyond the breakdown voltage. A second class gave first a maximum and then a minimum. But the performances of the switches of the two classes deteriorated as the input power increased beyond -10 dBm. A third class, therefore, was selected which gave a minimum attenuation for a positive bias and a maximum for a negative bias in the avalanche breakdown region with expectation that rectifying action of the diode would give good performances for an input power larger than +10dBm.

Performances of a typical switch are shown in Figs. 2-5. The diode had a breakdown voltage of about -10 Volts. For an input of +17 dBm at 48 GHz, an insertion loss of 3.5 dB was obtained with a maximum attenuation of 31 dB for a bias voltage of -15.3 Volts, the current being -6.3 mA.

Representative characteristics of the four switches finally constructed are as follows :

(a) a small variation of the bias voltage around the optimum value giving a maximum or minimum attenuation does not affect the attenuation much, easing some of the requirements to the baseband-pulse circuitry (Fig. 2),

(b) off(dB)-to-on(dB) ratios about 7-9 are obtained for an input power of +17 dBm at 48 GHz with varactor diodes whose cutoff frequency is around 150 GHz (Fig. 3),

(c) the ratio decreases rather slowly when the input power increases, showing possibility of switches for higher input power (Fig. 3),

(d) the switching time is less than 1 ns, which was one of the basic requirements (Fig. 5), and

(e) the operational frequency band is relatively wide (Fig. 4), etc.

GaAs bulk-effect devices are promising for driving the switch.

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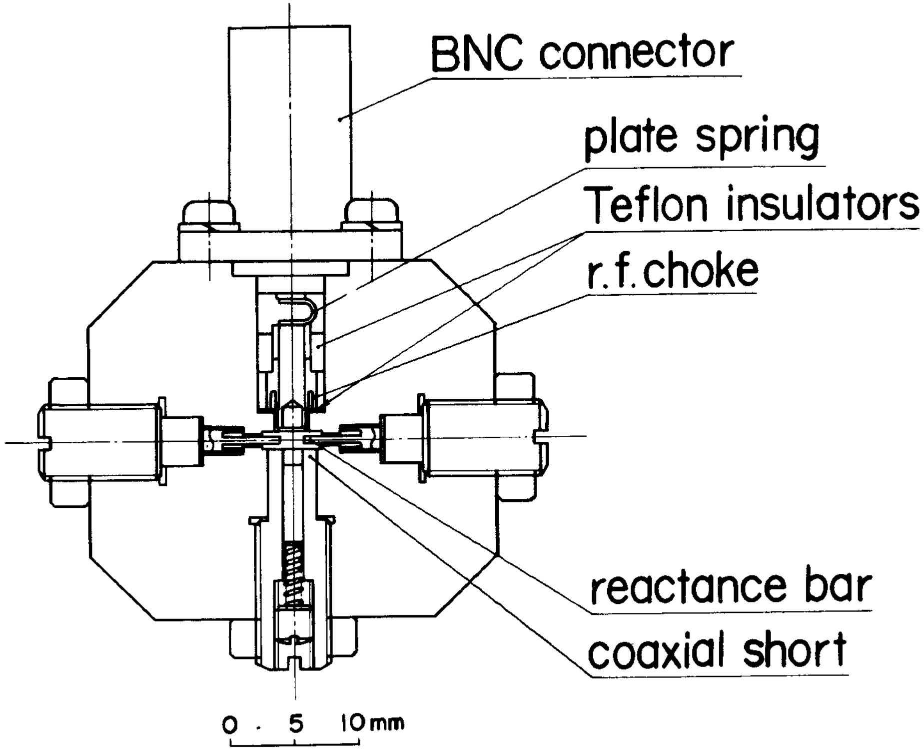


Fig.1. Cross-sectional view of the holder.

TABLE I. Electrical Characteristics of GSB3C.
($T_a = 25°C$)

Item		Condition
Forward Current I_F	100 mA (min)	$V_F = 1 V$
Reverse Current I_R	1.0 μA (max)	$V_R = 1 V$
Reverse Voltage V_R	6 V (min)	$I_R = 50 μA$
Capacitance C	0.3 pF (max)	$V_R = 0 V$
Cutoff Frequency f_c	140 GHz (min)	$V_R = 5 V$ $f = 6 GHz$

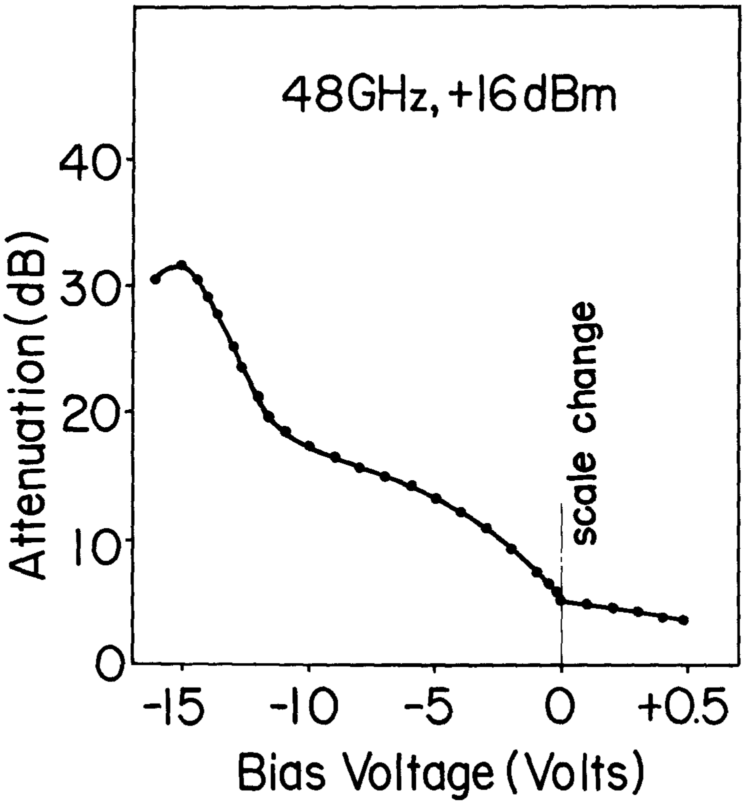


Fig.2. Attenuation vs. Bias Voltage.

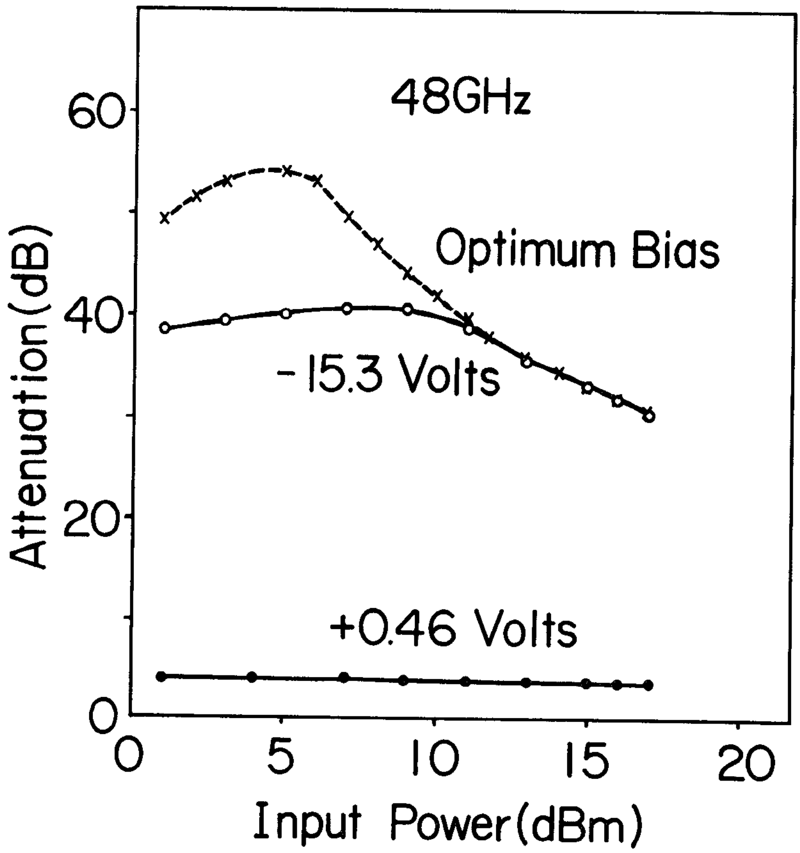


Fig.3. Attenuation vs. Input Power.

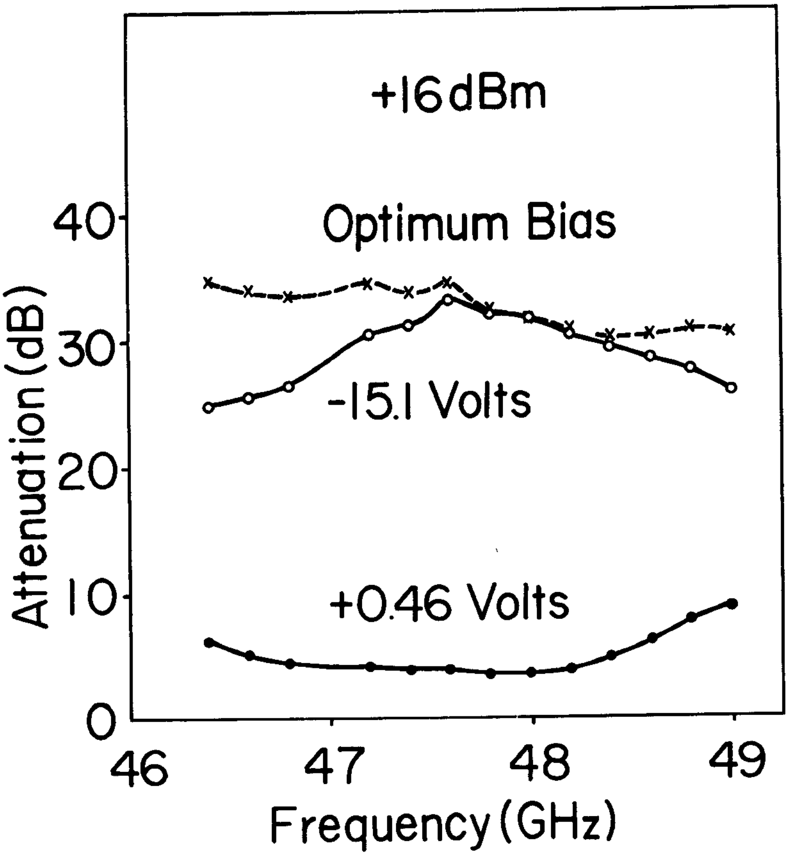
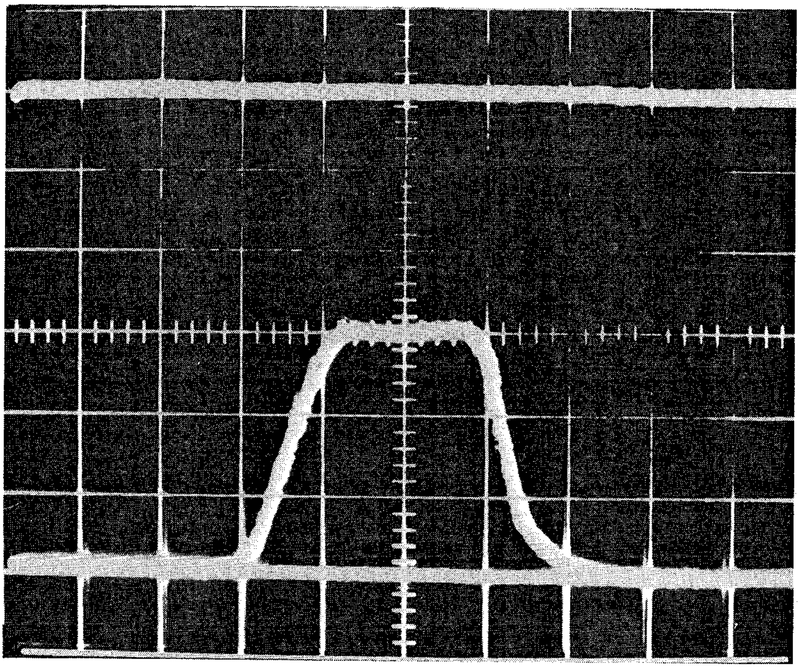


Fig.4. Attenuation vs. Frequency.



f = 48GHz, P = +17dBm
V: 10mV/div., H: 1ns/div.

Fig.5. Detected Pulse Waveform.