Phase Modulation of Microwave Signals Using Point Contact Germanium Signal Diodes

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A forward-biased point contact germanium signal diode placed inside a waveguide section along the E-vector is found to introduce significant phase shift of microwave signals. The usefulness of the arrangement as a phase modulator for microwave carriers is demonstrated. While there is a less significant amplitude modulation accompanying phase modulation, the insertion losses are found to be negligible. The observations can be explained on the basis of the capacitance variation of the barrier layer with forward current in the diode.

It is well known that point contact diodes can be used as waveguide switches[1-5]. But the action of a point-contact diode in the forward-bias condition as a phase shifter of microwave signal is not mentioned in literature. In this communication, we report the properties of such a simple and effective electronic phase modulator at microwave frequencies. It essentially employs a single-point contact germanium signal diode which is placed inside a waveguide section along the E-vector. The phase modulating property is established to be primarily due to the phase-shift effect introduced by the forward-biased diode. Even though the conspicuous phase modulation is accompanied by a less significant amplitude modulation, the insertion losses are found to be extremely negligible. The use of this phenomenon for phase modulating microwave signals with different waveforms for communication purposes is demonstrated. The arrangement can also be used as a continuously variable electronic phase-shifter in UHF and microwave lines.

The phase modulator set-up consists of a single-point contact germanium signal diode (OA79) shunted across an X-band waveguide section along the E-vector when the waveguide supports TE_{10} mode. The variations of the phase and amplitude of microwave signal with forward-bias current through the diode is monitored by a network analyser (Hewlett Packard 8410C). The effect of applying a modulating signal across the diode is also studied under both near- and far-field conditions. For far-field measurements, the modulated signal is transmitted by a pyramidal horn and received by another similar horn at a distance greater than $\frac{2D^2}{\lambda}$ where D is the maximum aperture of the horn.

The nature of the variation of phase angle with forward-bias current is shown in Fig. 1. With a single diode, the phase shift is as much as 80° for a current of 12 mA. The maximum insertion loss is found to be only less than 1 dB. VSWR measurements show that matching is improved considerably under forward bias condition. The phase shift can be increased by periodically loading the waveguide with diodes. It is

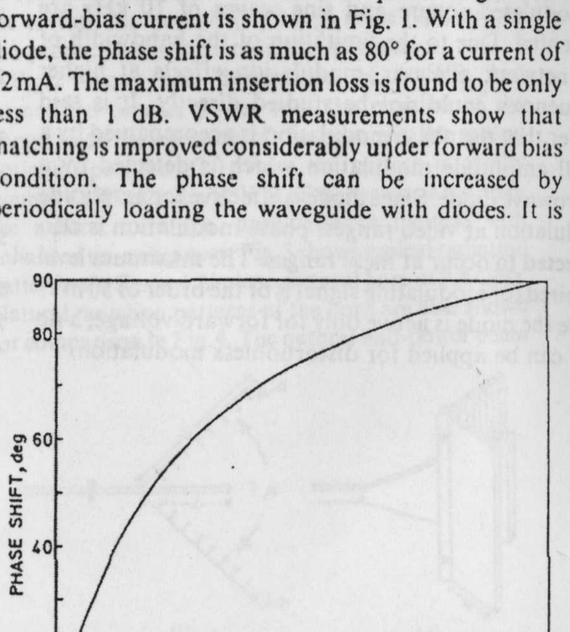

Fig. 1—Phase shift produced by the diode versus the forward current

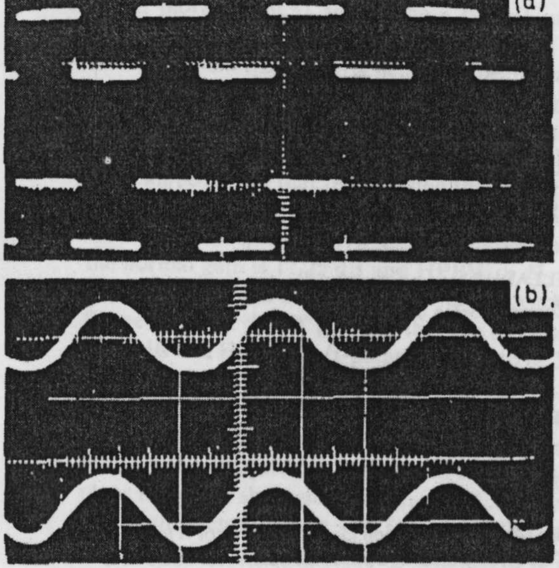

Fig. 2—Phase demodulated waveforms: (a) 10 kHz square waves; and (b) 10 kHz sine waves (Modulating signals are shown above for comparison.)

found that maximum phase shift occurs for anti-resonant spacing and minimum for resonant spacing.

In Fig. 2[(a) and (b)], photographs of phase demodulated square and sine waves of 10 kHz are presented. Due to the limitation of the bandwidth of the network analyser, modulation effects at higher frequencies could not be studied directly. It is said earlier that the phase modulation is accompanied by a small amplitude modulation which is detected by a microwave diode. Since diode is effective for amplitude modulation at video ranges, phase modulation is also expected to occur at these ranges. The maximum level required for modulating signal is of the order of 50 mV. Since the diode is active only for forward voltage, a dc bias can be applied for distortionless modulation.

An ordinary p-n junction diode can act as a phase shifter in reverse-bias condition only[6]. But a point-contact diode virtually produces no phase change in reverse-bias condition. It is found to be active as a phase shifter only when a forward voltage is given. Compared to PIN modulators, point-contact modulators are simpler, inexpensive and more readily available.

Since the capacitance of the metal semiconductor contact, which essentially forms a Schottky barrier layer, increases with the forward bias[7], the equivalent susceptance also increases with bias current, thus increasing the resultant phase variation.

In conclusion, a point-contact diode can be used as an effective, simple and low-cost phase modulator. However, its use is not restricted to microwave frequencies alone. The arrangement described here may find extensive practical uses in communication, antenna applications, electronic scanning, etc.

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