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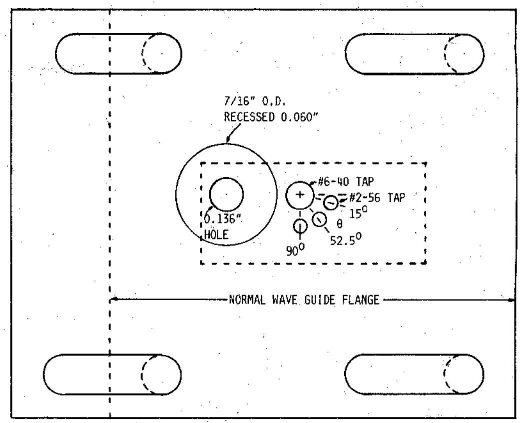

Fig. 1. Details of back plate with lateral adjustability.

Back Plate Mounted *X*-Band Lumped Element Gunn Oscillator[1]

ALEXANDER B. BERESKIN, FELLOW, IEEE

***Abstract*—A lumped *X*-Band Gunn oscillator, mounted on the waveguide back plate, provides full power output and tunability with provisions for altering the coupling to the waveguide in steps and/or continuously.**

Oscillator load variations can generally be expected to change both the frequency and amplitude of oscillation. In a cavity oscillator, a degree of control is obtained by interposing an iris between the cavity and the waveguide, thereby reducing the coupling between the oscillator and the load. Tuning screws, protruding into the cavity, can be used to adjust the frequency of oscillation.

The lumped element oscillator described in this paper does not use a frequency determining cavity and, therefore, other means have been devised to control the frequency of oscillation and the coupling between the oscillator and the load. These means differ substantialy from other lumped constant oscillators that have been described previously [1]–[5].

Fig. 1 shows details of a waveguide back plate on which the Gunn diode oscillator is to be mounted. This back plate is to be attached to the flange of an *X*-band waveguide at the transmitting end. When the back plate is removed from the waveguide, all of the oscillator's parts, both front and back, are readily accessible. The centered position of the waveguide and its flange are shown with dashed lines. The slotted back plate mounting holes make it possible to displace the back plate laterally, relative to the waveguide, by approximately 0.40 in.

The oscillator itself is shown in Fig. 2 and consists of a Gunn diode held in place by a chuck in the #6-40 tapped hole and a hairpin loop formed by a bare #24 tinned copper wire. The loop has a right-angle bend directly above the center of the #2-56 tapped holes and terminates flush with the surface of the back plate but does not contact it. The chuck is made by tapering the thread at the end and drilling and slotting the tip of the #6-40 copper screw. Tunability is provided by means of the #2-56

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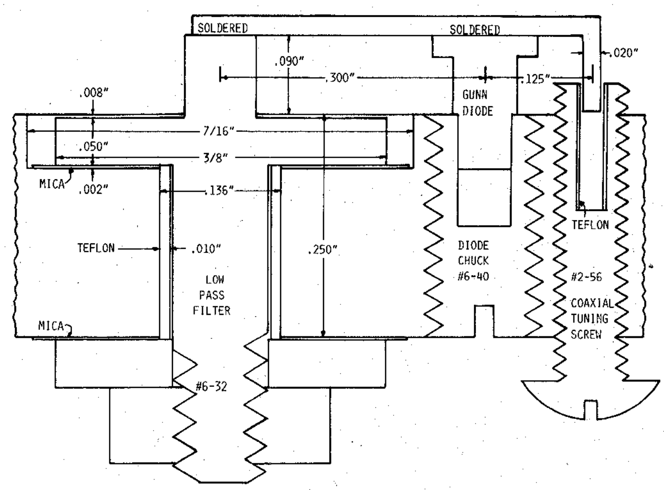

Fig. 2. Cross section of oscillator and low-pass filter ($\theta = 0°$).

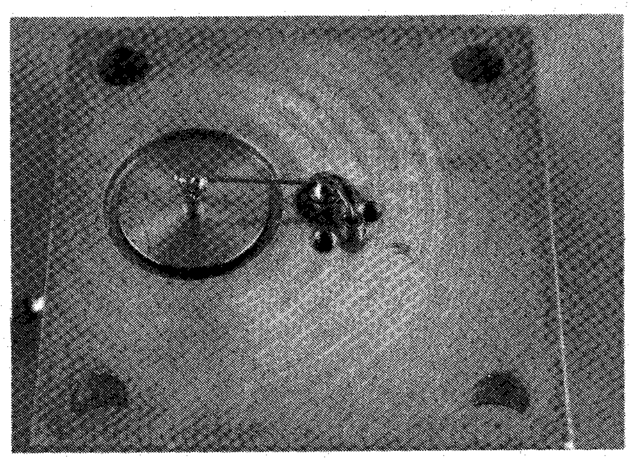

Fig. 3. Oscillator with coupling angle adjustability, $\theta = 52.5°$.

screw which has a central hole drilled in it and is lined with teflon sleeving obtained from teflon insulated hookup wire. As the #2-56 screw is made to engage the end of the hairpin loop it forms a coaxial variable capacitor with which the oscillator frequency can be varied continuously from outside the RF system.

Fig. 3 is a photograph of the active side of an oscillator with coupling adjustability but no lateral displacement adjustability. It is the one used for the tests of Figs. 5, 6, and 8. In practice the oscillator loop is formed by making a right-angle bend in the #24 wire and cutting the portion that engages the hollow tuning screw to the proper length. The bent tip of the wire is then fully engaged by the tuning screw and another bend is made at the center of the Gunn diode to direct the wire to the center of the low-pass filter. The wire is soldered in place at both the Gunn diode and low-pass filter positions and the excess wire, beyond the low-pass filter, is snipped off. The coaxial tuning screw now engages the tip of the resonant loop perfectly at all tuning positions. The electrical circuit associated with the oscillator is shown in Fig. 4(a).

The oscillator obtains its excitation by means of the extension of the hairpin-loop wire. This run of wire is approximately a quarter-wave long and forms the last element in the low-pass filter through which the dc power is supplied. The other inductive element in the low-pass filter is the conductor run between the two flat disk capacitors on the two sides of the back plate. The hole through which this conductor passes is lined with teflon and its length, including the effect of the teflon, is also approximately a quarter-wave. The shunting capacitors are formed by the two metallic disks which are insulated from the back plate with 0.002-in mica. These disks, including the effect of the mica, are approximately a half-wavelength in diameter.

The oscillator resonant loop can be made to couple into the waveguide by varying amounts depending on which of the #2-56 holes is used. The greatest coupling would result with the use of the hole at $\theta = 90°$ and zero coupling would result if a hole at $\theta = 0°$ were used. The coupling can additionally be varied continuously, using any of the #2-56 holes, by means of a lateral displacement of the back plate relative to the waveguide. The dc feed circuit does not couple into the waveguide because it is at right angles to the E-field.

All of the data reported here were obtained with the test circuit shown in Fig. 4(b). The attenuator was set permanently at 20 dB. After each circuit change the E-H tuner and the Mico wave meter were adjusted for a peak deflection of the power meter. This value was recorded and plotted on the curves. The frequency was calculated on the basis of the averaged value of five successive singularities resulting from the adjustment of the wave meter. In most cases, the deviations of the singularities from the averaged values were of the order of a few parts in ten thousand.

The data of Fig. 5 were obtained with a GE Type Y-2140C Gunn diode with the hairpin loop positioned over the $\theta = 15°$ #2-56 hole. At zero turns screw retraction, the screw just fails to contact the upper part of the hairpin loop. When the screw is retracted 4.5 turns it is approximately flush with the inside surface of the black plate. No further frequency variation results with additional retraction. The frequency curve has been drawn as a smooth curve through the average of the measured points. The points themselves are actually quite precise and deviate from the average due to a wobble in the tuning screw. The tuning range in this case was from 8.1 GHz to 11.6 GHz and the power output was between 5 and 8 dBm.

The data of Fig. 6 show the degree with which the power output can be varied by changing the angle with which the oscillator loop couples to the fields of the waveguide. The $\theta = 15°$ curve in this case is the same as that in Fig. 5 except that the plotting variables have been changed. The frequency spans of these three curves do not coincide because a change in the coupling angle requires that the previous loop wire be unsoldered and discarded and a new loop soldered into place. The procedure is quite simple but no effect was made to keep these loops identical. Overall, it appears that any frequency span of about 1.4:1 could be achieved between 7.2 GHz and 11.6 GHz with this Gunn diode by properly sizing the loop. The effect of the coupling angle is quite obvious from this graph, the relative power outputs being proportional to the square of the sine of the angle θ. On the average, disregarding minor variations the 52.5° curve should be 4 dB below the maximum value and the 15° curve should be 12 dB below the maximum value. The 15° curve represents a substantial decoupling of the oscillator from the load. Obviously, any other convenient coupling angle could be designed into the system.

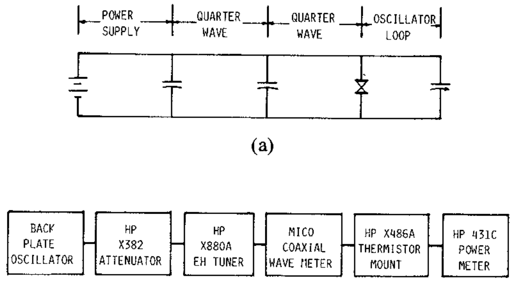

Fig 4. (a) Oscillator circuit. (b) Test circuit.

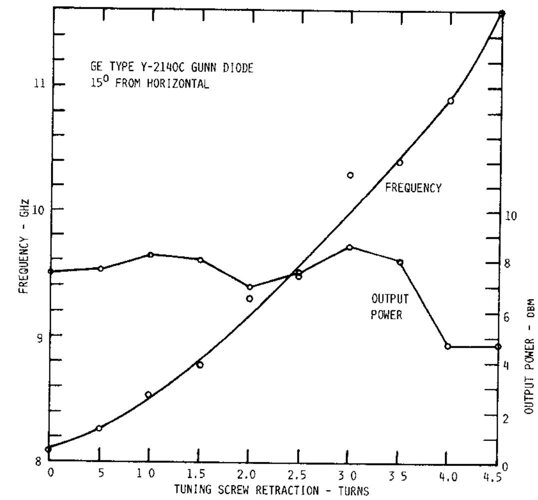

Fig. 5. Tuning characteristics.

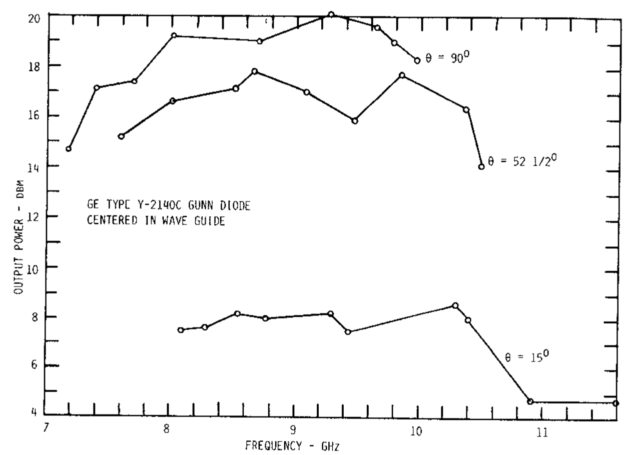

Fig 6 Coupling angle related power variations.

The data of Fig. 7 were obtained with an ALPHA DGB6835D

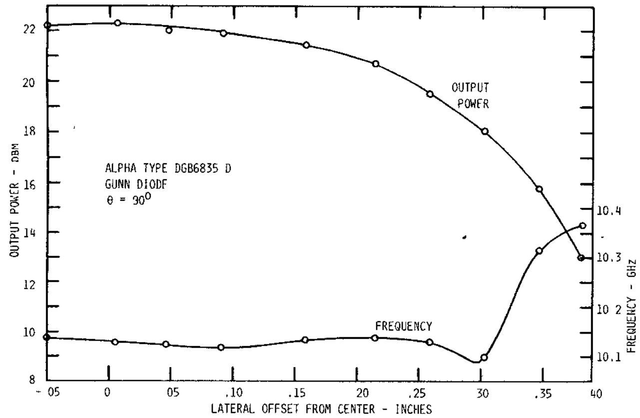

Fig. 7. Lateral offset related power and frequency variations.

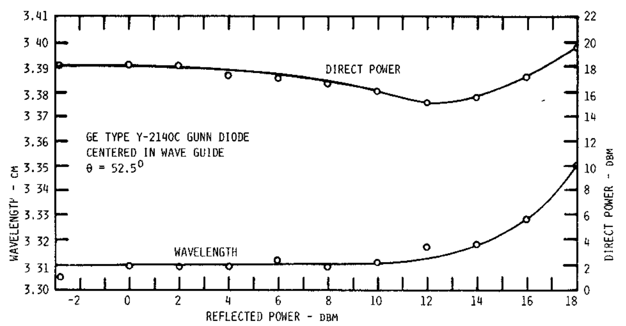

Fig. 8. Oscillator pulling characteristics.

Gunn diode with a $\theta = 90°$ coupling angle and a fixed tuning screw position. The variable in this case was the lateral position of the oscillator loop within the waveguide. At 0.300-in lateral offset from the center, the loop is 45 electrical degrees from the side wall of the waveguide. The square of the sine of 45° corresponds to half-power which is reasonably close to the value obtained. At 0.380-in lateral offset from the center, the loop is 21 electrical degrees from the side wall of the wave guide. The square of the sine of 21° corresponds to a power 9 dB below the maximum. This is also reasonably close to the value obtained. The finite dimensions of the Gunn diode and the resonant loop make it unreasonable to expect any closer agreement.

A minor variation of the frequency is observed as the back plate is moved laterally from the center. A substantial variation results as the resonant loop approaches the side wall of the waveguide. Of course, for any lateral setting of the back plate the tuning screw could be readjusted for the precise frequency desired.

The maximum power outputs obtained from the two Gunn diodes agree well with the manufacturers' specifications and in both cases correspond to about 3 percent efficiency.

The pulling characteristics of the oscillator are shown in Fig. 8. This data was obtained by connecting the oscillator of Fig. 3 directly to a waveguide system consisting of two HP-X752C directional couplers, an *E-H* turner and a resistance card load. The reflected power was adjusted by variation of the *E-H* tuner ahead of the resistance card load. The highest three reflected power readings were obtained with a flat brass plate in place of the resistance card load. At 10-dBm reflected power, the direct power was 16 dBm and the magnitude of the reflection coefficient was 0.50. Below this value the wavelength was essentially consistent and the direct power varied only about 2 dB. Varying the angle θ, or displacing the oscillator laterally, is equivalent to changing the diameter of the iris on a cavity oscillator.

The use of a coaxial tuning screw is a very simple and convenient method of adjusting the frequency. A lock nut on the tuning screw could be used to provide a fixed frequency setting. Varactor tuning could also be provided as described in several previous papers.

Operational circuits frequency follow the oscillator with an adjustable attenuator in order to provide a precise operating level for the circuits that follow. The circuit presented here renders the attenuator unnecessary. A level slightly higher than the required value can be established by choosing the right coupling angle, and the precise operating level can be established by a lateral motion of the back plate.

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