DISTRIBUTED UNIDIRECTIONAL MICROWAVE AMPLIFICATION

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Six .7-watt IMPATT diodes, directly coupled in tandem to a microstrip isolator have demonstrated electronic amplification and power accumulation at 9 watts input. Stub coupling of the diodes is also effective for higher gain per stage.

This is a progress report on the Distributed Unidirectional Microwave Amplifier (DUMA), described at the 1970 GMTT symposium[1]. Theory of the new ferrite devices employed has been published[2]. Further work on these ferrite components is reported in another paper submitted for this symposium[3].

In the DUMA, a microstrip field-displacement ferrite isolator is used. In this device, forward waves are concentrated along one edge and reverse waves along the other edge of the microstrip. Lossy material distributed along one edge attenuates reverse waves. Negative resistance diodes (Gunn effect or IMPATT diodes) are distributed in tandem along the other edge, giving gain for the forward wave. A basic advantage of the scheme is that the power in the line may be much greater than the power generation capability of any one diode when the impedance levels are properly chosen. Gain per diode may be quite low, but the power from each diode will accumulate in the line.

Two versions of the device have been analyzed, built and tested. One is a "direct-coupled" device in which the diodes are shunted directly across a low impedance line. The other uses a sequence of microstrip stubs to couple the diodes to the isolator. These schemes are illustrated in Figs. 1 and 2.

In the direct-coupled device, the isolator is a composite structure. A wide microstrip conductor is used, partly over ferrite, and partly over a ceramic substrate. Lossy material is applied on the ferrite side. The diodes are placed directly across the line in the ceramic region, through holes drilled in the line. The negative conductance of each diode, plus its susceptance, acts as a shunt element across the line. The perturbations at each diode location cause wave growth in the frequency range where the diodes are effective as negative resistances.

Figure 3 shows a photograph of a 6 diode DUMA of the direct-coupled type. Here, the ground plane is laminated into vertical slabs of copper, separated by thin dielectric sheets. This expedient was used to permit separate biasing of the individual diodes to equalize the DC currents. The diodes were spaced .150" apart. The isolator section was two inches long overall and had a loss of 2 dB when the diodes were removed. The diodes were HP type 5082-0400 with an average oscillator power capability of 0.6-0.7 watt. The isolator line impedance is estimated to be ~ 15 ohms. The diodes were allowed to draw 120 mA each at an average voltage of 97 volts.

This device was not intended to be a useful amplifier, but was designed purely as a test of the basic theory and principles involved. We wished to verify that the diode could operate efficiently in this environment, and to determine whether the predictions of broad bandwidth would be realized. Because of the relatively high loss of the isolator used, the net power loss in the isolator exceeded the power generation capability of all of the diodes at the maximum drive level of 9 watts. Thus, we could not obtain a net gain with 9 watts input, but our measurements indicated that the diodes did, indeed, add .5-.6 watts each to the line, on the average.

Figure 4 shows the net gain and the "electronic" gain as a function of frequency over a wide band at various input power levels. The small signal gain was maximum near the upper edge of the band. However, with large input signals, this region showed early saturation. At higher power levels, the useful band was found in the 9-10 GHz region. The high gain region in the upper frequency range is the result of proximity to the series-resonance of the diode's capacitance and inductance. At the lower edge of the band, the frequency is near or below the "avalanche-frequency" where the diode has only positive resistance.

The theory and the data indicate that it would be most desirable to use a large number of very closely spaced diodes, each of small capacitance, (and of necessity small power). This would raise the frequency of the series resonance and provide broad-band amplification whose gain-frequency characteristic would closely approximate the negative-conductance characteristic of the diode junction.

Amplifiers have also been built by coupling diodes to the isolator through short stub microstrip lines as shown in Fig. 2. This technique is more appropriate for lower power levels where higher gain (per diode) is desired. Several different stub networks have been tested successfully, at various frequencies from 6-11 GHz, with IMPATT diodes from various manufacturers.

Successful operation of a high-gain amplifier of this type requires that the junction between the isolator and the stub have some of the properties of a circulator. It has been found[3] that this situation can be obtained under special conditions of magnetization of the ferrite substrate. In this case we find that wave perturbations from the stub do not induce backward waves. Instead, the stub acts as a circulator inserted into the wave path of the isolator. It now appears that multi-stage amplifiers can be made in this way with many stubs, and many diodes.

Figure 5 shows a typical frequency response at various power levels for this type of stub-coupled amplifier, using a single diode.

ACKNOWLEDGEMENT

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REFERENCES

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3. M. E. Hines, "Ferrite phase shifters and multiport circulators in microstrip and stripline", (another paper submitted for this symposium).

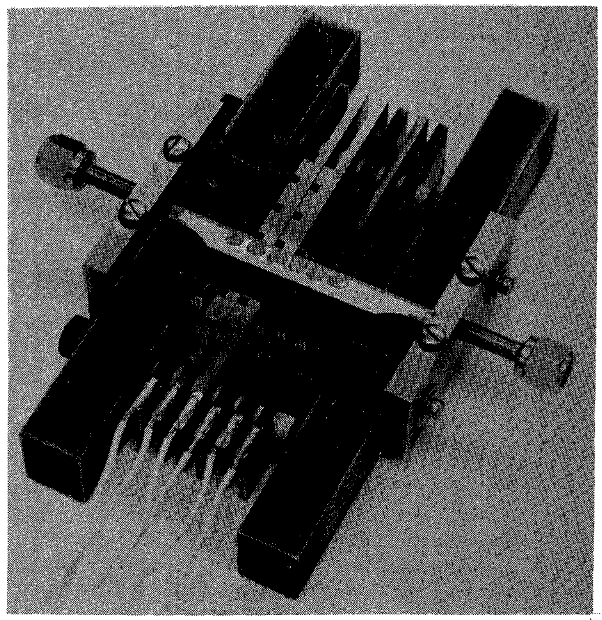

Figure 3. Photograph of the six-diode DUMA amplifier. The lossy film was removed for clarity.

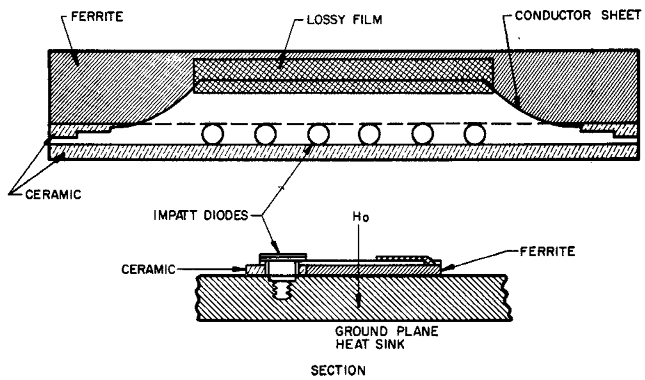

FIGURE 1 DIRECTLY COUPLED DUMA AMPLIFIER IN FERRITE MICROSTRIP FORM

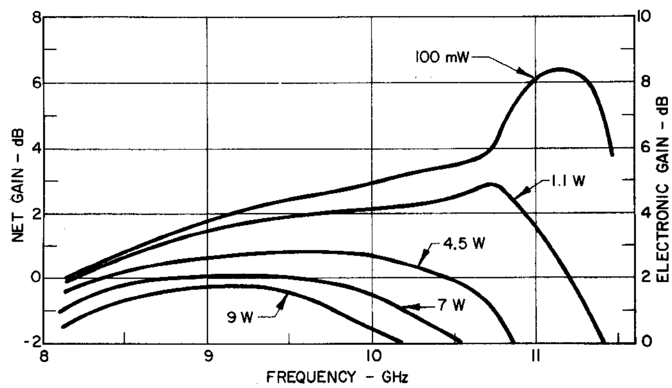

FIGURE 4 NET GAIN AND "ELECTRONIC GAIN" OF THE SIX DIODE DUMA, FOR VARIOUS INPUT POWER LEVELS.

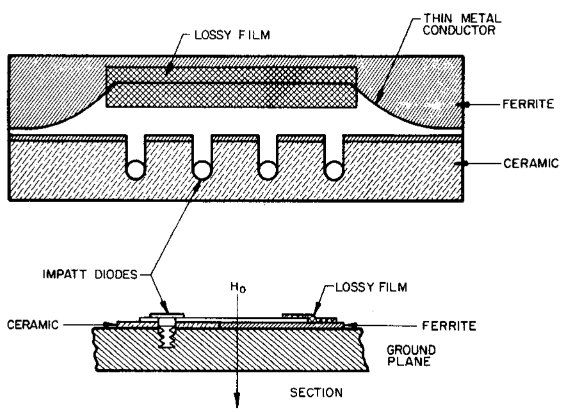

FIGURE 2 STUB-COUPLED DUMA AMPLIFIER

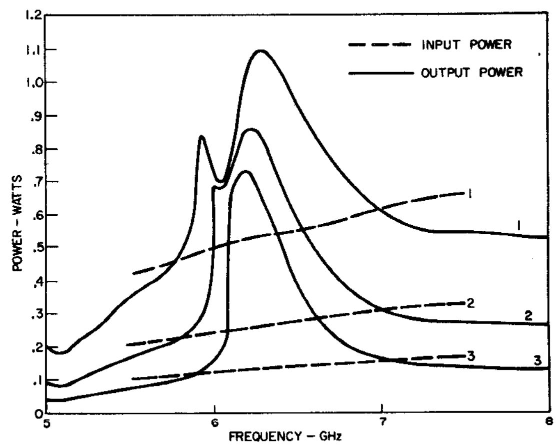

FIGURE 5 OUTPUT POWER AND INPUT POWER (3 CASES) AS A FUNCTION OF FREQUENCY FOR A SINGLE DIODE STUB-COUPLED AMPLIFIER IN THE DUMA CONFIGURATION.