9.2: BROADBAND PARAMETRIC AMPLIFIERS*

RAOUL PETTAI[+]

Micro State Electronics Corporation, Murray Hill, New Jersey

BERNARD B. BOSSARD

Radio Corporation of America, New York, New York

A criterion has been found for developing broadband parametric amplifiers of either reflection or upconverter type which are capable of large bandwidths with a minimum of external circuitry. The method to be described depends on the maximum utilization of the parasitic elements (R_s, L, C_o, C_c) of the varactor diode itself, plus certain simple experimental techniques which are easily applied. To illustrate the power of this method, a reflection type parametric amplifier has been developed with the following characteristics:

Signal Band	2000-3000 Mc/s
Gain	9.0 db
3-db Bandwidth	830 Mc/s
Noise Figure	2.1 db
Pump Frequency	12250 Mc/s

Figure 1 is a typical gain response of the device.

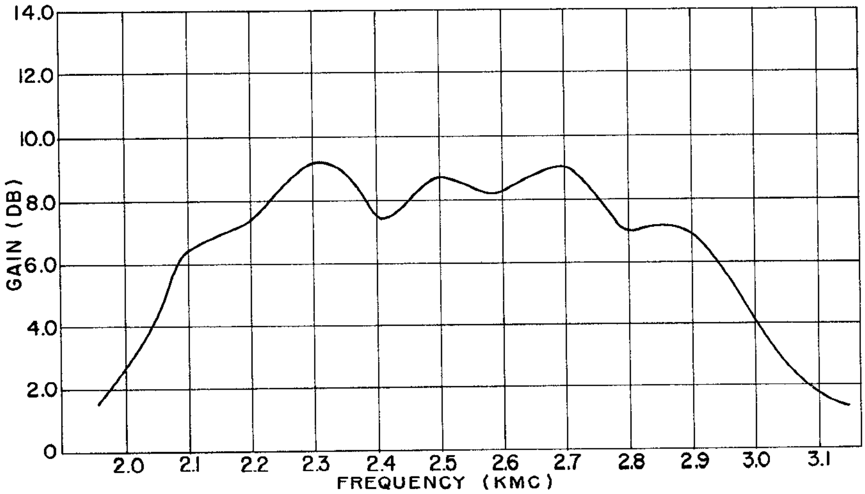

Fig. 1. Gain response of broadband parametric amplifier

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+Formerly with Surface Communications Division, R.C.A., New York, N.Y.

The technique is best explained by noting that a given varactor suitably mounted has a transmission characteristic which is a function of the geometry of the mount and of the elements (L, C_c, C_o, R_s) of the diode. Thus a diode terminating a transmission line (for example, the input line of a parametric amplifier) can be represented by the equivalent circuit of Figure 2, where the transformer permits the adjustment of the generator

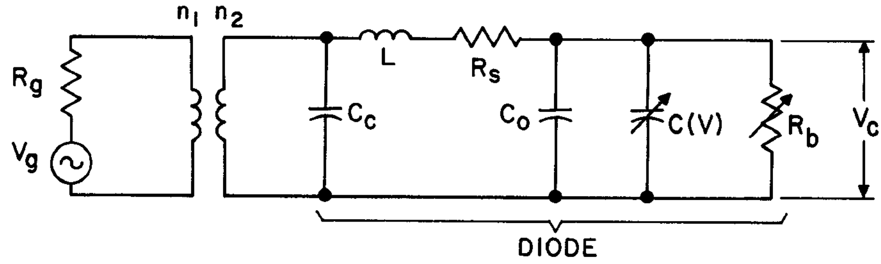

Fig. 2. Varactor diode terminating the input line.

impedance seen by the diode. The quantity of interest is now the ratio $|V_c/V_g|$ which can be looked upon as a measure of transmission of the input voltage to the variable capacitor $C_{(v)}$. As expected, this ratio is a function of the diode parameters (L, R_s, C_c, C_o), and its functional dependence on frequency and loading (i. e. the transformer ratio) is that of a tuned RLC circuit. Although a theoretical expression for $|V_c/V_g|$ has been derived, the voltage V_c can be more easily determined experimentally by observing the rectified output of the diode (in the mount) while sweeping the input signal over a band of frequencies. Since rectification is caused by the non-linear barrier resistance R_b, the maximum rectification implies (see Figure 2) a maximum voltage across the $C_{(v)}$. Figure 3 shows some experimental results obtained by the above technique. Two different transformer ratios were used. The response for the 50-to-7 ohm transformer is indeed seen to be more peaked than that of the other transformer. This method can, therefore, be used to rapidly check the diodes at hand and to find the unit with the most efficient transmission of V_g to $C_{(v)}$ over the given band of frequencies. Further adjustments can then be made by altering the transformer ratio.

In a similar manner the same varactor diode shunt mounted in waveguide (a typical idler circuit of a parametric amplifier) exhibits a two-port transmission characteristic which is generally of band pass type. It is significant that the extent and the location of the passband can be controlled by the type of the holding structure (Figure 4) and by varying the bias voltage (Figure 5). This transmission characteristic is easily measured by plotting the insertion loss or the VSWR of the diode-mount combination. It has thus been possible to find diode-obstacle combinations which exhibit extremely broad band pass type responses. A similar phenomenon has been described by DeLoach[1].

The significance of the transmission characteristics and passbands just described lies in the fact that by operating the parametric amplifier

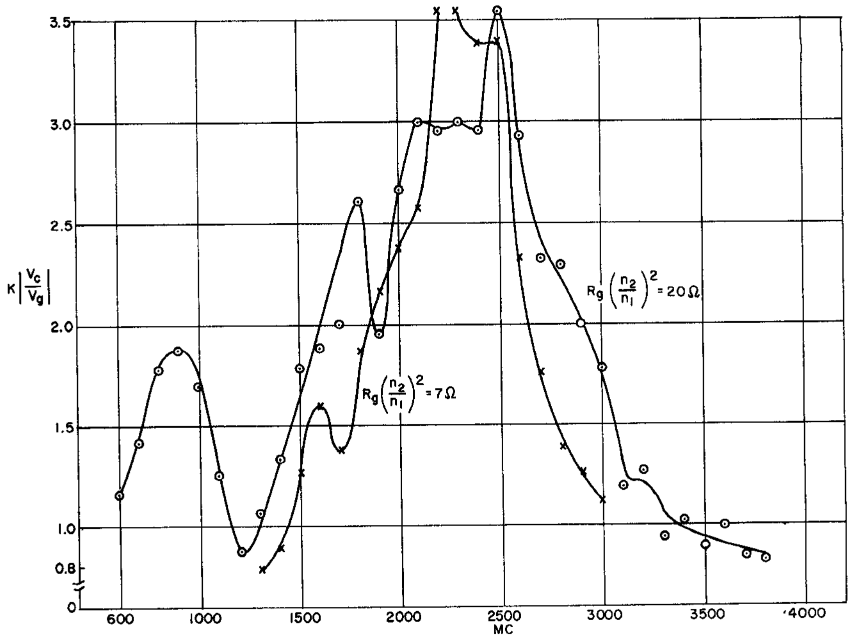

Fig. 3. Experimental results for $K\left|\frac{V_c}{V_g}\right|$

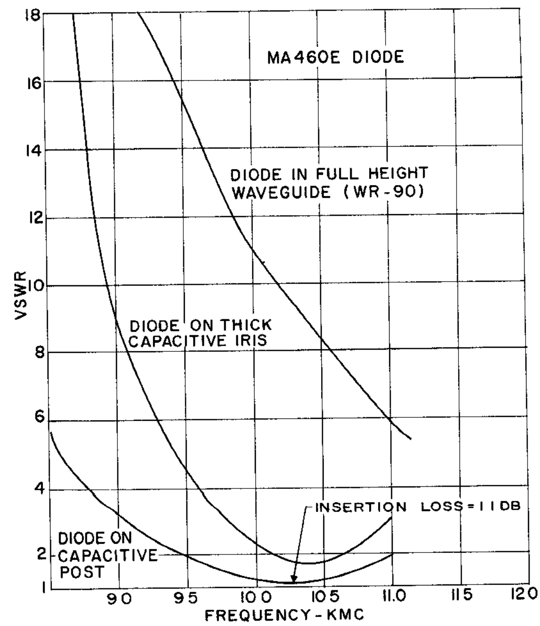

Fig. 4. Effect of obstacle on diode passband.

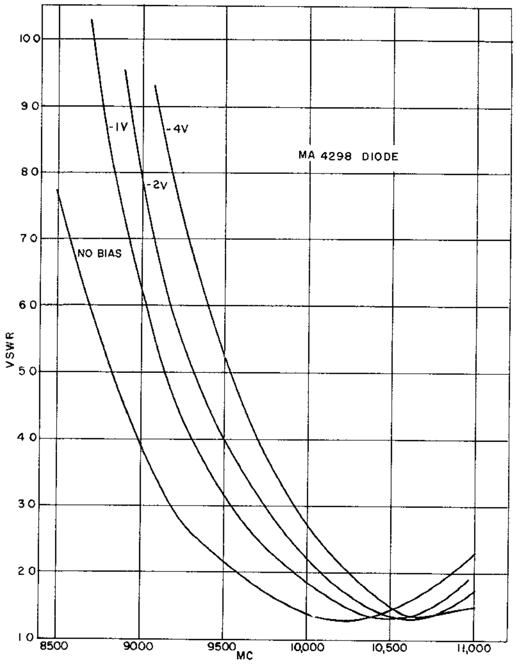

Fig. 5. Effect of bias voltage on diode passband.

within the bands where maximum transmission occurs, large gain-bandwidth products can be achieved. It has been possible to develop non-degenerate gain-bandwidth products approaching 3300 Mc/s (20 db of gain with 330 Mc/s of bandwidth at S-Band). Several reflection type parametric amplifiers have yielded amplification (2-5 db) over bandwidths approaching 2000 Mc/s (2 to 4 Mc/s).

It is felt that a useful criterion has been found which allows the designer of a parametric amplifier or upconverter to make a better evaluation of the various structures and diodes at hand. Because of the number of different parameters influencing the gain of a paramp, the existence of passbands at the operating frequencies is not a sufficient condition for optimum performance. Their existence does, however, appear as a necessary condition in broadband applications.

1. B. C. DeLoach, Jr., "Waveguide Parametric Amplifiers," 1961 Solid State Conference Digest, 24-25 (Feb. 15, 1961).