III-6. A LOW NOISE FIGURE 94 GC GALLIUM ARSENIDE MIXER DIODE*

Richard J. Bauer

Advanced Technology Corporation, Timonium, Maryland

Until recently low noise figure mixer diodes for operation above 80 gc were very difficult to achieve and had short life times. This paper describes the procedures and results that evolved from a development program that eliminated these disadvantages.

The three major areas to be investigated in developing a low noise figure diode were selection of an intermediate frequency for minimum crystal noise ratio, selection of a semiconductor material that gave low conversion loss, and mounting the diode such that package parasitics have a minimal effect. (The term low noise figure in this discussion infers crystal noise figure, i.e., the product of the conversion loss (L_c) and the noise ratio. It is assumed that the noise figure of the IF amplifier, whether it be transistor, tunnel diode or TWT, will remain relatively constant through the low microwave frequencies.)

The semiconductor material finally chosen for this application was gallium arsenide with a mobility of 4100 cm^2/volt-seconds and a resistivity of 13.4×10^{-3} ohm-cm.

To minimize the effects of package parasitics the diode was constructed in a section of waveguide.

Forming the Diode. An interesting technique is being used for forming diodes. The whisker-crystal contact is made in an RF setup with the klystron square wave amplitude modulated at 1 kc. In addition a 60 cps curve tracer (Tektronix Type 575) is connected to the IF or detector port for forming the welded contact. When contact is established between the whisker and crystal, the curve tracer voltage is varied until a typical I-V curve appears on the scope. However, two curves are present, one from the 60 cps sweep of the curve tracer and one from rectification of the 1 kc modulated 94 gc signal (see Figure 1). The 1 kc curve is actually the sum of the rectified RF current and the current from the 60 cps sweep, i.e., the 60 cps curve can be thought of as being a family of various DC bias points for detection of the RF signal. Therefore, the greater the separation between the curves the better the rectification efficiency of the diodes. This measure of RF detection efficiency provides a qualitative measure of the device degradation due to the parasitic elements (spreading resistance and junction or barrier capacitance). By adjusting the contact pressure while applying the 60 cps diode forming voltage the resulting welded contact can be optimized for dual trace separation. To date a large variation in curve separation has been obtained for diodes with similar 60 cps traces. The conversion loss variation obtained on these diodes has correlated nicely with the amount of trace separation.

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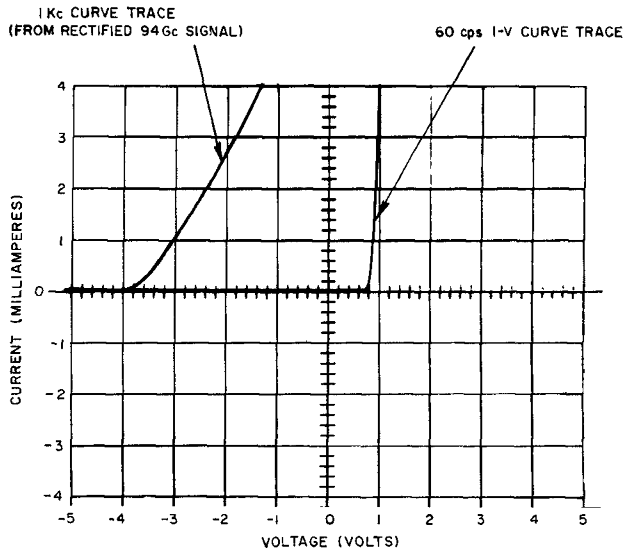

Figure 1. Dual Trace Characteristics of Mixer Diode

Crystal Noise Ratio. The advantages of using a high intermediate frequency with regard to crystal noise (including the local oscillator noise contribution) is well known (References 1, 2 and 3). Available local oscillator sources have extremely large noise sideband levels which substantially increase the effective noise ratio of the mixer diodes. Presently, the state of the art for the construction of conventional mixers is such that the usual method of local oscillator noise suppression by the use of a balanced mixer is not feasible. In addition to the impracticability of making pairs of crystals whose electrical properties at RF and IF are dynamically balanced, it would be very difficult to construct the required hybrid junctions. In an effort to establish the minimum intermediate frequency for a low noise figure mixer at 94 gc, crystal noise ratio measurements were made from 750 mc through 4 gc. By the term minimum intermediate frequency is meant that frequency at which the local oscillator noise becomes negligible in comparison to the crystal noise.

The curves in Figure 2 were constructed after averaging the results obtained on a number of low conversion loss (<12 db) diodes. As this figure indicates, the minimum intermediate frequency that should be used is approximately 2 gc. The basis for this statement is that in the region where the conversion loss reaches a minimum and is essentially constant, +3 to +7 dbm of local oscillator power, no significant improvement in crystal noise ratio is gained by going to a higher intermediate frequency than 2 gc. However, if a broad bandwidth intermediate frequency is desired, for example 1 gc, then a center frequency slightly higher than 2 gc should be used to insure that the low side of this frequency band has a low crystal noise ratio. For bandwidths up to 200 or 300 mc though a center intermediate frequency of 2 gc is sufficient.

Conversion Loss. Conversion loss measurements have been made on a number of diodes. Typically these diodes have a conversion loss of approximately 8 to 9 db. One of the diodes, however, was exceptional in that it had a conversion loss of 4.7 db.

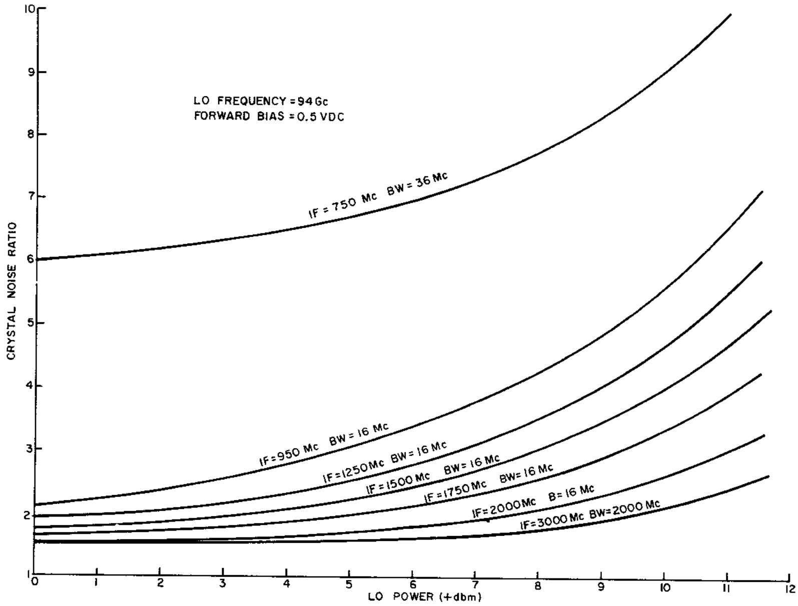

Figure 2. Crystal Noise Ratio versus Local Oscillator Power

In an effort to better understand the proper operating conditions for the mixer, a series of measurements were made on the 4.7 db conversion loss diode with various forward bias and local oscillator power levels. Figure 3 shows the family of curves that resulted from these measurements. As observed from this figure no measurements were made with a forward bias greater than 0.5 vdc. The reason for this is that experience has shown that the life time and stability of the diode is greatly reduced when operating at 0.75 vdc. With this consideration the optimum diode operating conditions appear to be 0.5 vdc forward bias with a local oscillator power of 5 milliwatts (+7 dbm).

Below +3 dbm of local oscillator power, the 0.5 vdc curve has a conversion loss slope of approximately 1 db per db of local oscillator power. This gradual increase in conversion loss with reduced local oscillator drive indicates the possibility of using a low level local oscillator drive while still maintaining a moderately respectable conversion loss.

The family of curves in Figure 3 is representative of gallium arsenide-phosphor bronze diodes. As mentioned above, however, the minimum conversion loss value of 4.7 db does not represent a typical mixer diode. To use these curves for a typically "good" diode the minimum conversion loss point of 4.7 db should be shifted up to 8.5 db.

Diode Structure. Figure 4 shows a photograph of one of the experimental diodes. The diode is formed in a section of RG-99 waveguide to minimize the effects of package parasitics. The semiconductor wafer is mounted to the center conductor extension of the coaxial connector. After a good mixer diode has been obtained via the technique described above a differential screw tool jig, for adjusting the diode's contact pressure, is removed and the integral diode-waveguide section of the mount is sealed with dry nitrogen. A 0.001 inch mica window is used to seal the waveguide port. Sealing the diode in dry nitrogen has greatly increased the life time of these diodes.

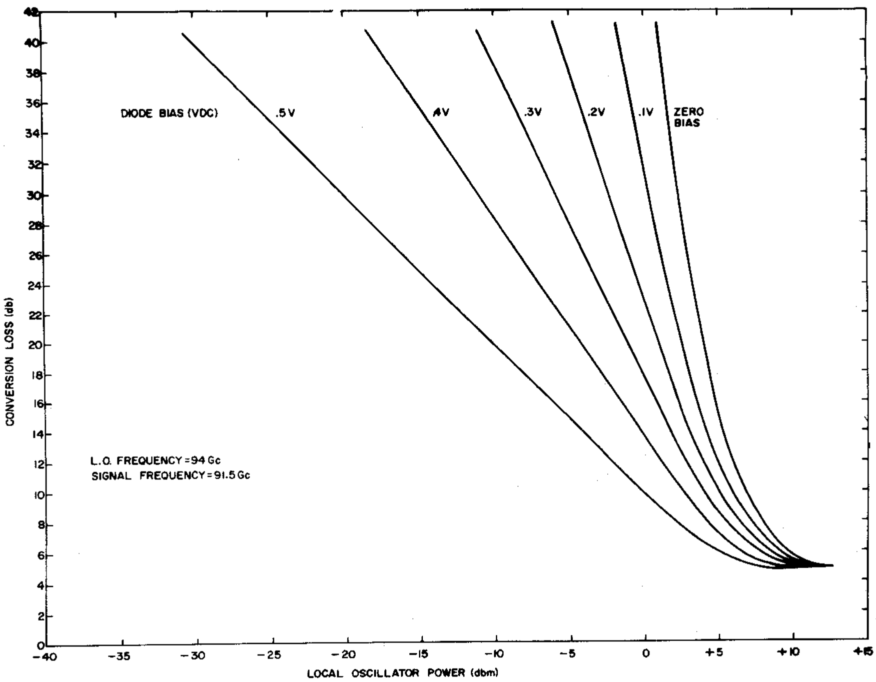

Figure 3. Conversion Loss versus Local Oscillator Power and Bias

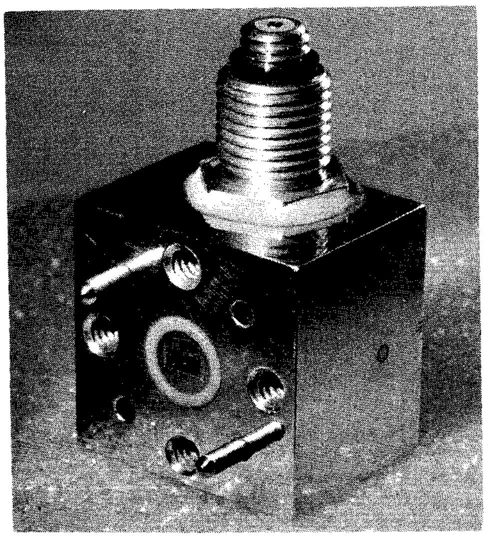

Figure 4. Sealed 94 gc Mixer Diode with UG-387 Flange Mounting

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