The Stabilization of Mixer Diode Performance Against L.O. Power Changes with Optimum DC Bias*

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Summary—The advantages of using a particular dc forward bias in maintaining receiver sensitivity for fairly large reductions in local oscillator power are experimentally verified. Definite improvement of performance is obtained over broad band operation where L.O. power level may vary considerably. For each of the mixer diodes investigated there is a particular optimum bias for each diode type where both the input signal level and local oscillator RF impedances as well as the IF impedance are practically stationary with respect to very large changes in local oscillator power level. At optimum bias, signal frequency RF and IF impedances were found to vary by only about ten per cent for L.O. power reduced from 1 mw to 1 μw. This results in considerably less reduction in tangential signal sensitivity over that obtained in the unbiased or overbiased condition.

Introduction

WHERE POWER, weight, complexity, and costs limit the availability of ample local oscillator power it is sometimes difficult to achieve and operationally maintain optimum receiver sensitivity. This is particularly so in very broad-band systems and /or where a single local oscillator is required to supply phase and amplitude correlated conversion power to several mixers.

An experimental investigation was conducted to determine how the characteristics of a mixer diode are affected by application of a forward dc bias while L.O. power level and operating frequency were varied.

Both a single ended and a balanced mixer were used in the investigations, each with several mixer diode types. The single ended mixer was a prototype design constructed for the experiments. The balanced mixer was a purchased unit that happened to be on hand. Both were designed for 50 ohm coaxial transmission line input.

The term "optimum bias" is used to designate that value of forward dc bias which results in RF and IF impedances which are most nearly stationary with respect to local oscillator power changes below a maximum of 1 mw per diode.

Presentation and Discussion of Data

Fig. 1–5 show the general characteristics of tangential signal sensitivity (TSS) as a function of applied L.O. power and dc bias. Every diode has the same general characteristic, but there is considerable variation between different types of diodes. At this point it is very important to note that neither the single ended mixer mount nor the IF or dc loads were optimized for a particular diode type, and therefore no conclusions can be drawn as to the relative performance of different diode types. In addition, during the course of measurements it was noted that for a particular diode type there was considerable difference, at zero bias, in the TSS vs L.O. power level characteristics for diodes whose front to back ratios differed appreciably. However, for the diodes within a type, if the diode was in good condition the optimum bias for each did not vary from the average enough to make a given "optimum" bias setting produce more than about 1 db difference in TSS from diode to diode over the complete range of L.O. power variation from 1 mw to 0.01 mw. On the other hand, if the front to back ratio deteriorates, the application of the proper dc bias in several cases showed that there was a greater improvement in going from zero bias to optimum bias than in the case of a diode in good condition. Samples for which the measured data shown in Figs. 1–5 are typical included one diode each of a matched pair plus one extra diode.

Fig. 6 shows the zero bias and optimum bias TSS vs L.O. power characteristic at 415 Mc/sec for the single ended mixer. Comparison with balanced mixer performance (IN416E diodes) at 1900 Mc/sec plotted in Fig. 7 shows that, independent of the diode type, mixer type, or frequency, the same general characteristic was observed. Note that the noise figure characteristic is presented along with the TSS characteristic in Fig. 7 to demonstrate the expected correlation between the two different methods of evaluation. The noise figures were not generally measured, however, because of the difficulty of staying within the AGC range of the noise figure instrument over large ranges in noise figure, and also because of large impedance variations for bias voltages not in the vicinity of optimum bias.

IF bandwidths were continually checked as the bias and L.O. power were varied. The only appreciable changes were for the zero bias condition or for biases well beyond optimum. No detectable change took place for any of the diodes used for biases in the vicinity of optimum over up to 30 db reduction in local oscillator power. However, in some cases, there was a difference in band pass characteristics in going from one diode to the next. This is the main reason why the TSS curves should not be interpreted as indicating that one diode performs better than another. In fact, most of the diodes used are not specifically recommended for use in the UHF region where most of the measurements were taken. By necessity the single ended mixer was a nominally high capacity design in order to provide ample

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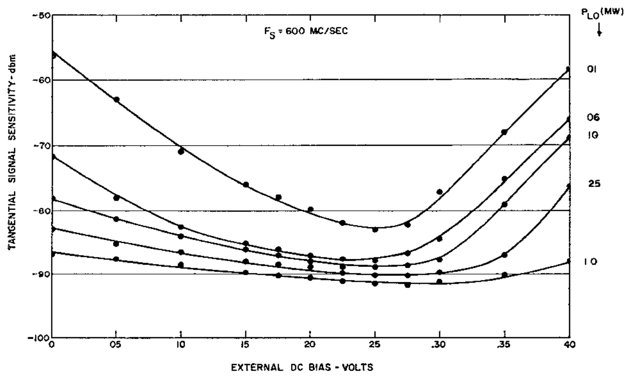

Fig. 1—TSS vs L.O. power—IN263 in single ended mixer.

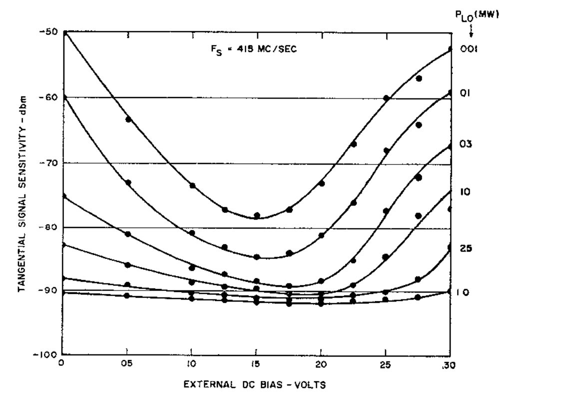

Fig. 2—TSS vs L.O. power—MA42IAR in single ended mixer.

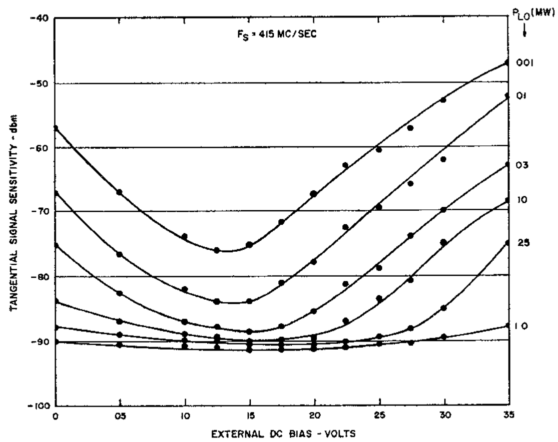

Fig. 3—TSS vs L.O. power—IN25A in single ended mixer.

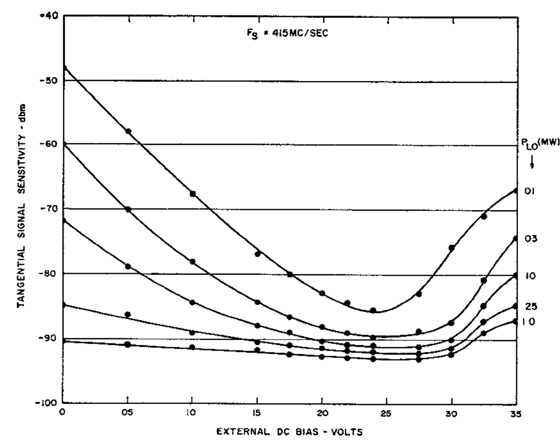

Fig. 4—TSS vs L.O. power—IN415E in single ended mixer.

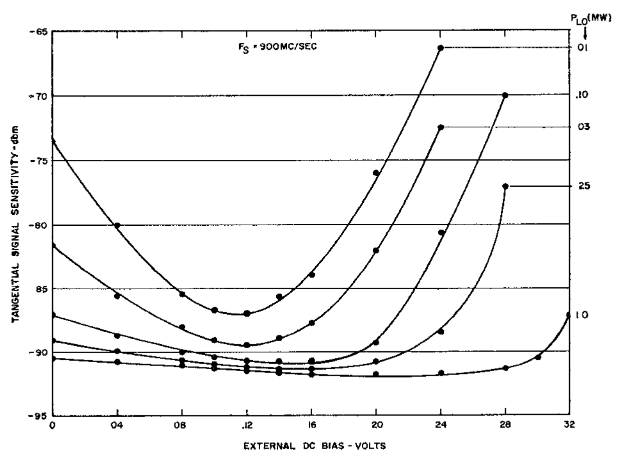

Fig. 5—TSS vs L.O. power—IN82A in single ended mixer.

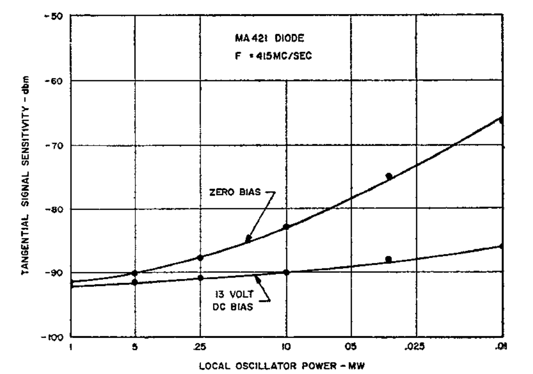

Fig. 6—TSS for zero and optimum bias-single ended mixer.

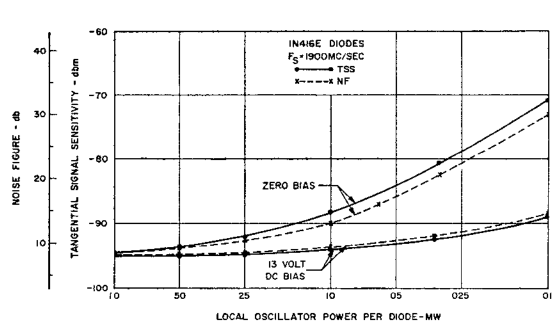

Fig. 7—TSS and noise figure for zero and optimum bias-balanced mixer.

RF choking at the low signal and L.O. frequencies used.

Figs. 8–11 show the TSS vs local oscillator power for two different diodes over a 7 to 1 frequency band in the prototype single ended mixer. For each diode a family of curves is presented, for different L.O. power levels, for zero bias, and for optimum bias.

It took two oscillators serving as local oscillators to tune over this range. To cover a comparable band in tuning range the power output of a single oscillator would generally vary by many decibels. The advantages gained by using optimum dc bias in such a case are self evident as one compares Figs. 8 and 9 or Figs. 10 and 11.

Upon examining Figs. 12 and 13, the reader will note that there is a particular bias region in the vicinity of 0.15 v bias where the VSWR at both the signal level and the L.O. level is practically stationary with respect to changes in L.O. power. Note that this is *not* the bias which gives the best impedance match *nor* optimum tangential signal sensitivity at full rated L.O. power. However, the additional increase in TSS obtained (at

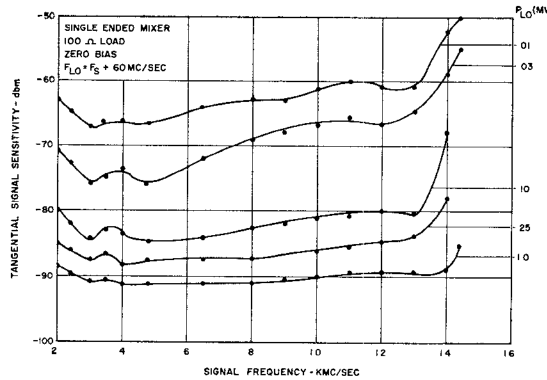

Fig. 8—TSS vs frequency for zero bias—IN25A.

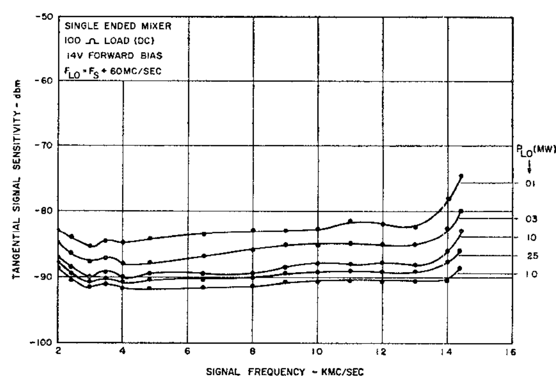

Fig. 9—TSS vs frequency for optimum bias—IN25A.

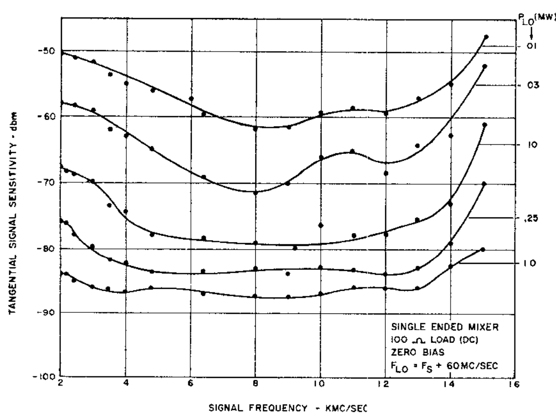

Fig. 10—TSS vs frequency for zero bias—IN263.

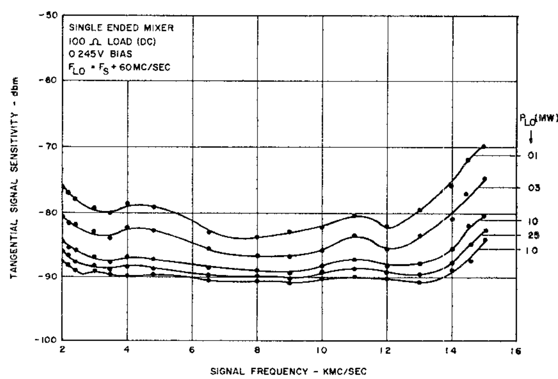

Fig. 11—TSS vs frequency for optimum bias—IN263.

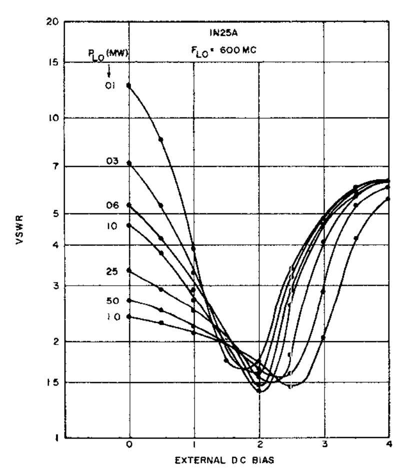

Fig. 12—VSWR at L.O. level.

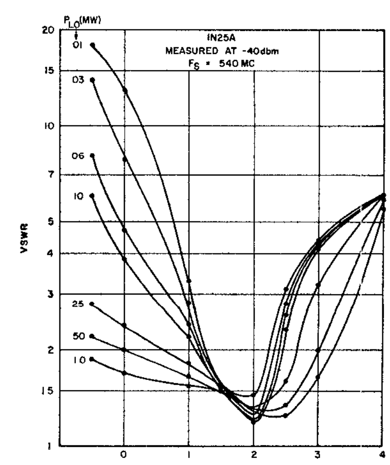

Fig. 13—VSWR at signal level.

1 mw L.O. power) by going to a higher bias was, in most cases, less than a decibel. Actually if one starts off with a higher L.O. level there is negligible difference between the TSS for zero bias and for optimum bias. It is only when L.O. power starts to fall off that the role of optimum bias control on signal sensitivity becomes outstanding.

Figs. 14 and 15 and Figs. 16 and 17 demonstrate the difference in RF impedance in going from 1 mw L.O. power to 0.01 mw L.O. power for the cases of zero bias and optimum bias for two diodes of different species in the same mount. Note that the input RF impedance of the mixer using the IN25A has an overall change of

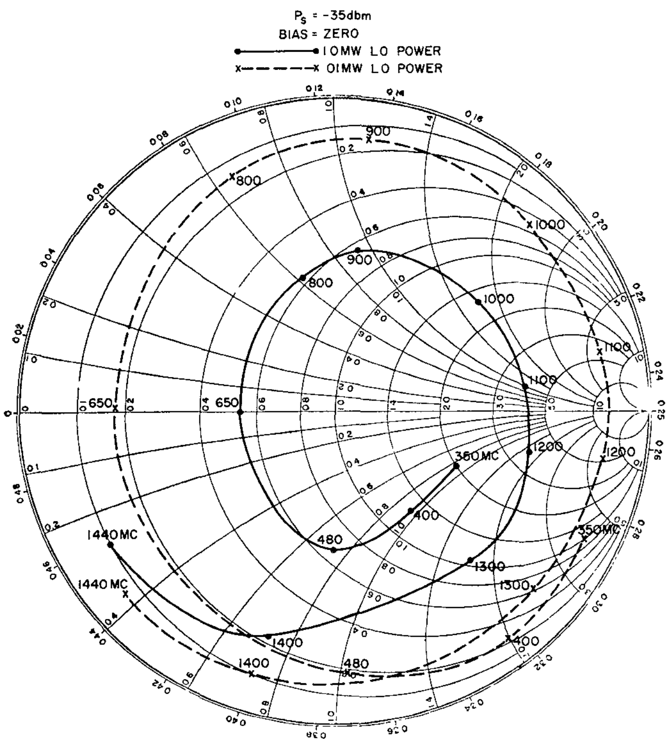

Fig. 14—Signal impedance at zero bias—IN25A.

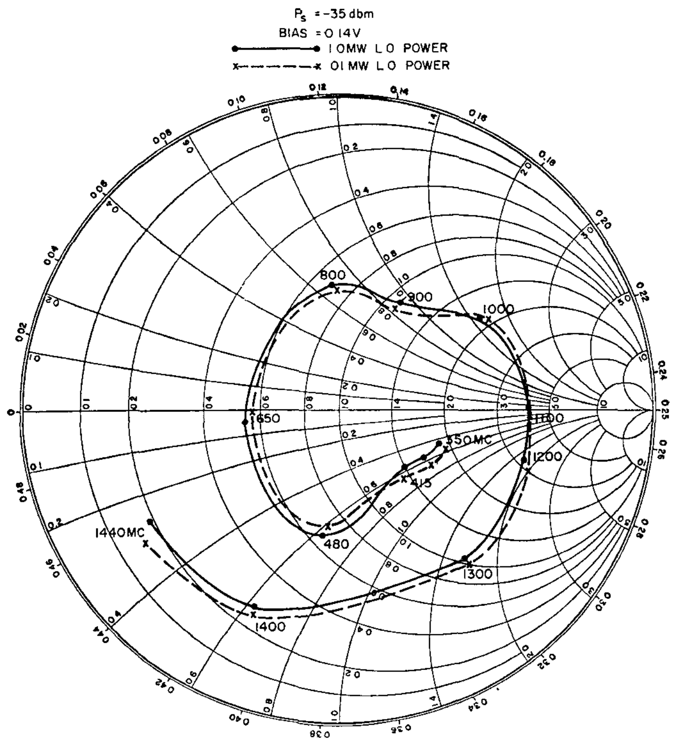

Fig. 15—Signal impedance at optimum bias—IN25A.

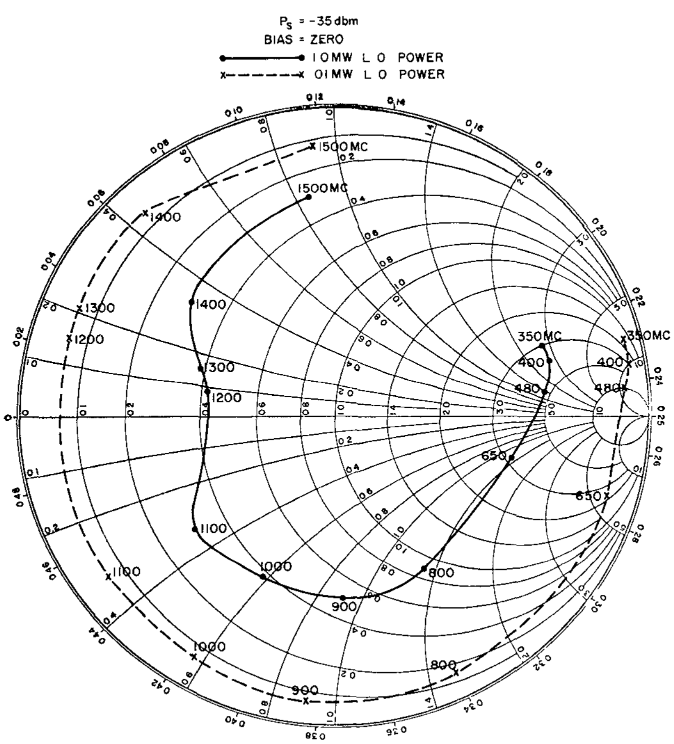

Fig. 16—Signal impedance at zero bias—IN263.

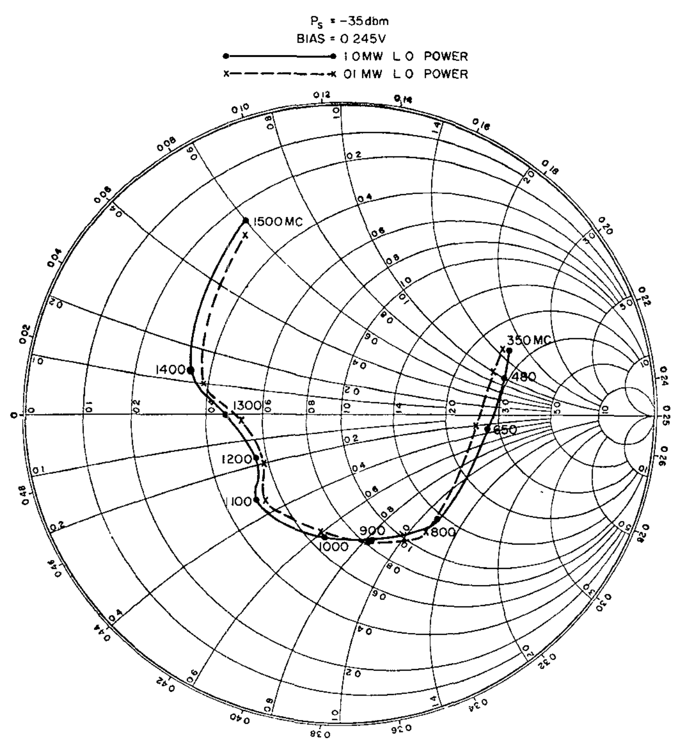

Fig. 17—Signal impedance at optimum bias—IN263.

phase from 350 Mc/sec to 1400 Mc/sec, roughly twice that of the IN263 over the same band.

Figs. 18–21 demonstrate the effect of dc bias on RF input impedance as a function of L.O. power over a bias range including the value of bias that is referred to as optimum bias. Note in Figs. 14 and 16 that only the magnitude of the RF impedance changes appreciably as the local oscillator power is changed, whereas for an applied dc bias both the magnitude and phase change except for a particular value of bias for which the impedance is stationary with respect to L.O. power changes. This optimum bias is independent of frequency

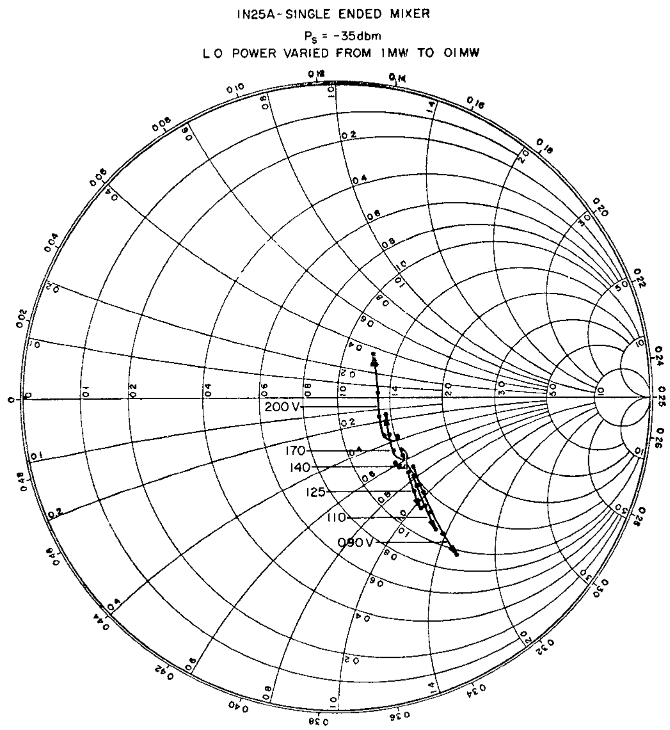

Fig. 18—Signal impedance as a function of L.O. power and bias 415-Mc diode no. 1.

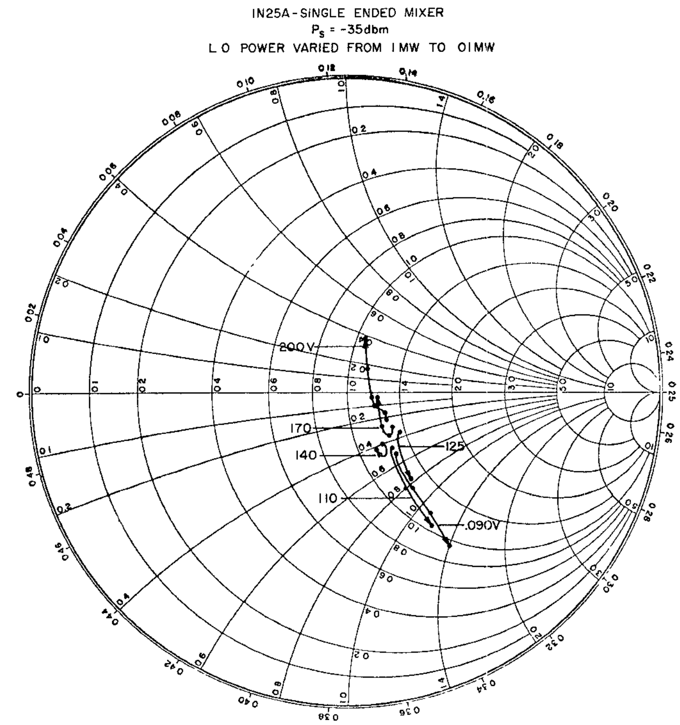

Fig. 19—Signal impedance as a function of L.O. power and bias 415-Mc diode no. 2.

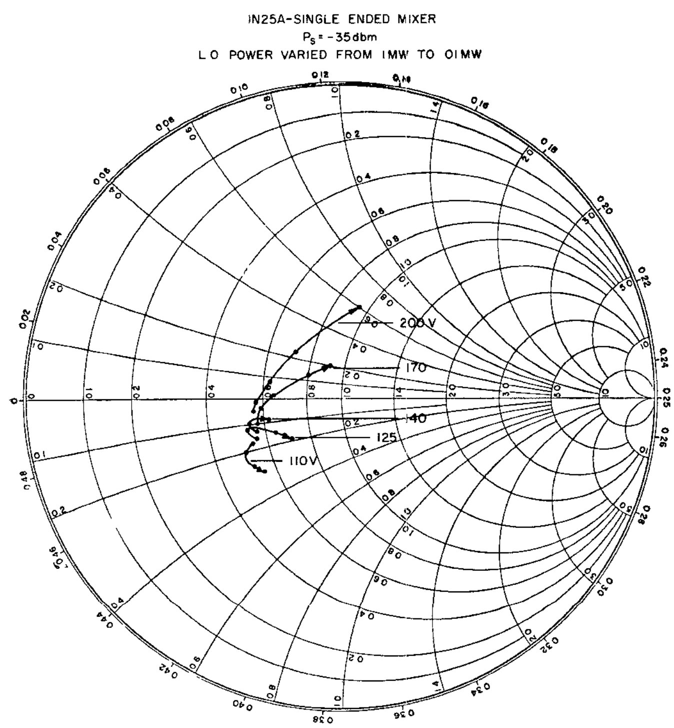

Fig. 20—Signal impedance as a function of L.O. power and bias 540 Mc.

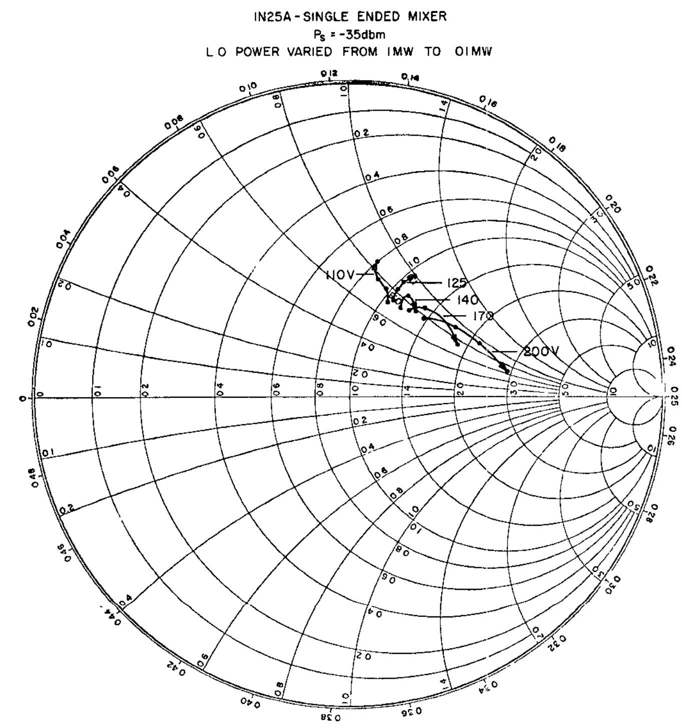

Fig. 21—Signal impedance as a function of L.O. power and bias 900 Mc.

and of phase and magnitude of the nominal impedance. That there is considerable phase change of the diode impedance itself, over a broad band, independent of the mount, is apparent when comparing the impedance phase spread of Figs. 14 and 15 with Figs. 16 and 17 (two different diodes in the same mount). The impedance loci in Figs. 18–21 are each for a given bias for a variation in L.O. power from 1 mw (the "tail" of each curve) down to 0.01 mw (the tip of the arrow-head of each curve). Very careful impedance measurements are necessary to show the nature of the RF impedance as optimum bias is approached.

In Fig. 22 an impedance characteristic is displayed which demonstrates what appears to be an internal diode series resonance at about 960 Mc/sec. The admittance of the shunt stub (the only major contributor to mixer RF reactance other than the diode itself, since the RF choke was very good in this region) is very small and capacitive at this frequency. In observing tangential signal sensitivity it was found that a reduction of about 3 db occurred at this frequency, even though, it will be noted, the input VSWR was nearly unity. This happened for both the optimum bias and unbiased conditions. This "absorption hole" as one might term it, demonstrates why, in mixer design, one should monitor all the pertinent characteristics at close frequency intervals.

In the balanced mixer there was no large deterioration in RF impedance matching as L.O. power was dropped; however, the noise figure and tangential signal sensitivity deteriorated in the same general way as in the single ended mixer. Neglecting the condition that the diodes were different and the frequencies quite different, the observed result of less spread in TSS for the balanced mixer can be at least partially attributed to the fact that, for zero bias, the RF impedance of the balanced mixer does not change appreciably with reductions in L.O. power whereas in the single ended mixer much greater changes take place.

It was also noted that for each diode in the single ended mixer there was a bias level, always higher than optimum, where the noise envelope observed on the oscilloscope went to a definite minimum for zero RF local oscillator and signal input. The bias was generally at or near the value that gave the best signal level impedance match. For the IN25A this was about 0.2 v. (See Fig. 13.) No such minimum in noise envelope was observed on the balanced mixer-preamplifier combination.

The striking effect that optimum bias has on stabilizing IF impedance against L.O. power level variations is demonstrated in Figs. 23 and 24 for the IN25A and IN82A, respectively. For the normal method of operation (zero bias) note the rapid increase in R_p and ΔC_p as L.O. power drops off, compared to the optimum bias case with the same diode in the same mount with the same passive RF, IF and dc circuit parameters. For both diode types it will be noted that the R_p varied by

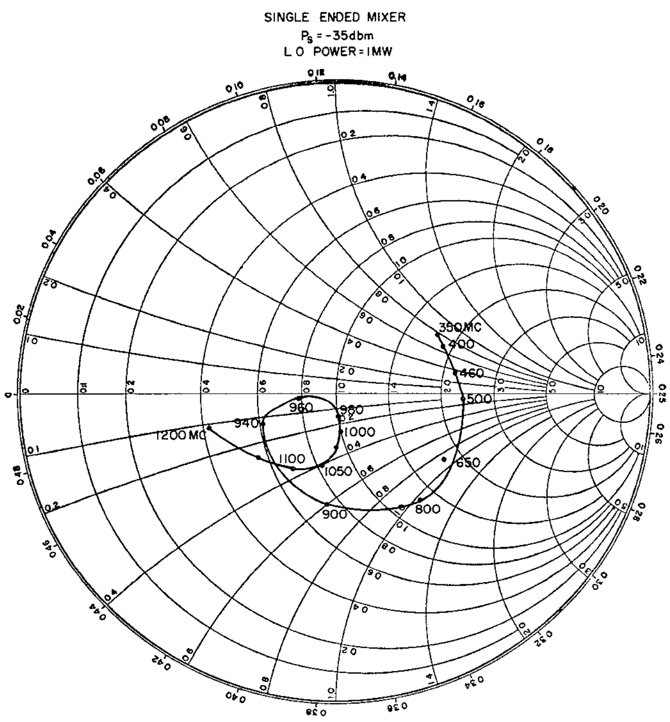

Fig. 22—Signal impedance showing diode resonance.

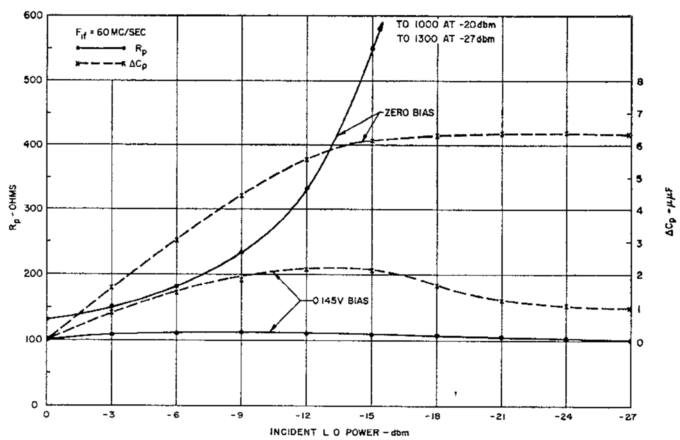

Fig. 23—IF impedance IN25A in single ended mixer.

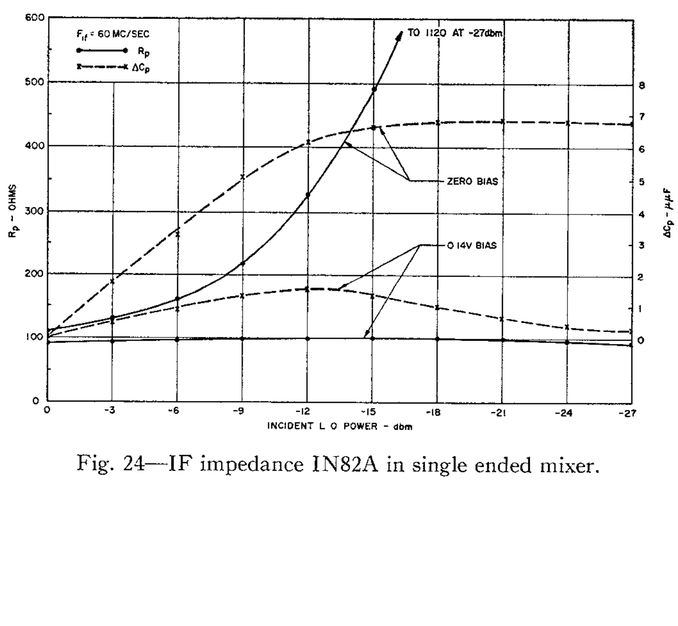

Fig. 24—IF impedance IN82A in single ended mixer.

10 per cent or less over the 27 db range in incident local oscillator power level. The total change in shunt capacity over the same range operating in the optimum bias condition was also considerably less than in the zero bias condition.

The general characteristic of reduction of signal sensitivity by decreasing or increasing the bias from the optimum condition, as is demonstrated in Figs. 1–5, points to another possible application of the biased mixer diode. Although not shown in these figures, the application of a backward bias (negative values of the abscissas in Figs. 1–5) causes a smooth decrease in signal sensitivity as the bias goes through zero into the negative region. These same trends hold at high signal levels, that is, the bias controls either the high signal level or low signal level conversion loss. If the mixer diode has a positively or negatively polarized feedback AGC type of signal applied when operating at optimum dc bias, or a negatively polarized feedback signal when operating at zero dc bias, signal limiting could be achieved at the input to the first IF stage. This could be done only at high signal levels; otherwise the reduction in signal to noise ratio would deteriorate low signal level performance. However, at high incident signal levels a reduction of S/N is tolerable. Thus at high signal levels this type of automatic signal limiting would serve as a supplementary adjunct to a conventional AGC, the automatic signal-limiting bias being developed at a lower level, say after only a few stages of amplification. This would keep the lower level amplifiers from saturating at high incident RF signal levels and thereby extend the effective AGC range. Whether the signal distortion introduced by the accompanying changes in equivalent mixer R_p and C_p would be more or less than that caused by amplifier saturation would have to be determined.

Conclusions

The experimental observations disclosed that:

1) The optimum bias for a particular type of diode varies little from diode to diode within a type.
2) The optimum bias is independent of signal or L.O. frequency.
3) There is a large tolerance, percentagewise, in the vicinity of optimum bias where the resultant tangential signal sensitivity is reduced by only about 1 db for 10 db reduction (from rated values) in local oscillator power.

These results lead to the inference that the use of optimum dc bias as a control feature in mixer design applications should be quite practical.

One to five specimens of several diode types, chosen merely because they were available, all demonstrated that a particular dc bias makes the RF and IF impedances practically stationary with respect to local oscillator power changes. These results suggest to the author that this may be a universal characteristic of mixer diodes that, to his knowledge, has not been heretofore observed.

Acknowledgment

The author wishes to extend his appreciation to Dr. W. H. Watson, who, though not having witnessed the experiments, has shown active interest in the significance of the experimental observations.

Phase, Attenuation, and Impedance Characteristics of Coaxial Transmission Lines with Thin Tubular Conductors*

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Summary—**The phase, attenuation, and impedance characteristics of coaxial lines are discussed in some detail, stressing the improvements which can be obtained by removing conductor material that is not effective in the main part of the frequency interval for which the line is used. The ensuing attenuation is higher for the low frequencies but lower for the high frequencies, in comparison with the solid conductor line. The corresponding phase (that is, total phase minus the constant delay) is substantially more linear than for solid conductor lines in the frequency interval of interest. The real part of the characteristic impedance is more independent of frequency than for the solid conductor case. The reactive part of the characteristic impedance increases faster for low frequencies, but can be very nearly represented by a pure capacity, thus enabling a more ideal and simple line termination with lumped elements.**

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