V-6. INTEGRATED BALANCED MIXERS FOR S- AND X-BAND

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This paper describes the approaches used and the results obtained in building integrated balanced microwave mixers at S- and X-band. It will describe the techniques used to make hybrid integrated circuits using "bilithic" Schottky diodes as the mixer diodes and discuss the merits of several mixer circuits.

With the development of good "chip" junction mixer diodes that do not require sensitive tungsten whiskers to make the rectifying junction, it has become possible to fabricate both hybrid and monolithic integrated mixers using these diodes and microstrip circuitry. The "bilithic" Schottky diodes are fabricated on epitaxial silicon or gallium arsenide by depositing the Schottky junction then covering the slice with a hard glass encapsulant several microns thick. Expanded contacts are made to the diode junction by etching a hole through the glass then depositing and bonding an enlarged contact over the glass (see Fig. 1). These diodes can then be used directly as the chip diodes in a hybrid mixer (see Fig. 2) or the microstrip circuit can be evaporated over the glass to make a monolithic-type mixer.

We find that on a given slice that the diodes made this way are sufficiently uniform so that it is not necessary to select matched pairs for local oscillator suppression. If very high isolation is required, this can be assured by carefully matching diode capacity and forward conductance at the anticipated operating point. Because chips can be prechecked, the yield of hybrid mixers is higher.

Presently, it has not been determined whether hybrid or monolithic will yield superior mixers. Because no compromise can be made in the noise figure of most mixers without damaging the performance of the receiver system, that mixer which gives the best noise figure will be used in almost all receivers.

Presently, the dielectric losses in alumina substrates are lower than that of high resistivity silicon (Fig. 3). Dielectric losses in the circuit add directly to the noise figure of the mixer. As the frequency of the mixer is increased, its size gets much smaller and the circuit losses due to dielectric and conductor losses tend to become less of a consideration. X-band appears to be the cross-over point.

Integrated mixers are made by evaporating and photoetching microstrip circuits on the glass or alumina substrates.

The two planar circuits used have been a hybrid ring and the 3-db hybrid coupler.

The hybrid ring is more easily fabricated and control is better. However, it is larger than the hybrid coupler and its bandwidth is nowhere as good.

The hybrid ring is used to make a standard ratrace mixer with local oscillator suppression obtained by symmetry. The I.F. ports are separated by $\lambda/4$ from the local oscillator port and $\lambda/2$ from the signal. Reverse diodes are not necessary as the polarity of the diodes can be easily reversed (see Fig. 3). RF isolation in the I.F. ports is accomplished by a bypass capacitor or choke and the d.c. return by a $\lambda/4$ high impedance line in the local oscillator port.

The hybrid coupler circuit requires precise control of the coupling coefficient. This is accomplished by evaporating a dielectric layer over the first line and precisely overlapping the second. For a 50-Ω line, the impedance of the overlapping lines must be $\approx$ 93 Ω.

Side coupling can be accomplished by narrow line spacing. For a 3.0 ± 0.2 db coupling coefficient, spacings of $\approx$ .00008 - .00012" are required. This is very difficult to accomplish repeatedly with present photoresist techniques. This problem may negate the use of 3-db coupled lines in most microstrip circuits.

With a hybrid circuit, the 3-db coupler spacing problem can be circumvented by going from microstrip into a balanced line for the coupler.

Care must be taken with microstrip lines to prevent radiation. A successful technique has been to design the body of the mixer such that its cavity has a resonant frequency above the operating frequency.

Several integrated mixers have been built. The most successful have been the hybrid ring types on alumina substrates.

These mixers have noise figures of 7 - 7.5 db in S-band with a 1.5-db I.F. The local oscillator power may be varied from 3 - 50 milliwatts with the noise figure remaining flat to 0.5 db. (This is characteristic of Schottky diodes, but its implications for superior dynamic range are obvious.) See Fig. 4. The mixers are built with 50-Ω in and out impedances. The signal input VSWR is less than 1.5/1 for a 25% bandwidth, and isolation between the signal and local oscillator ports is greater than 26 db at the design frequency and remains above 20 db across a 25% bandwidth.

Small size was not a design criteria of these mixers. The overall size of the mixer is $\approx$ 1.5 in^3 in S-band and 0.4 in^3 in X-band (Fig. 5). Substantial reductions could be made in their size with the use of folded line techniques, etc.

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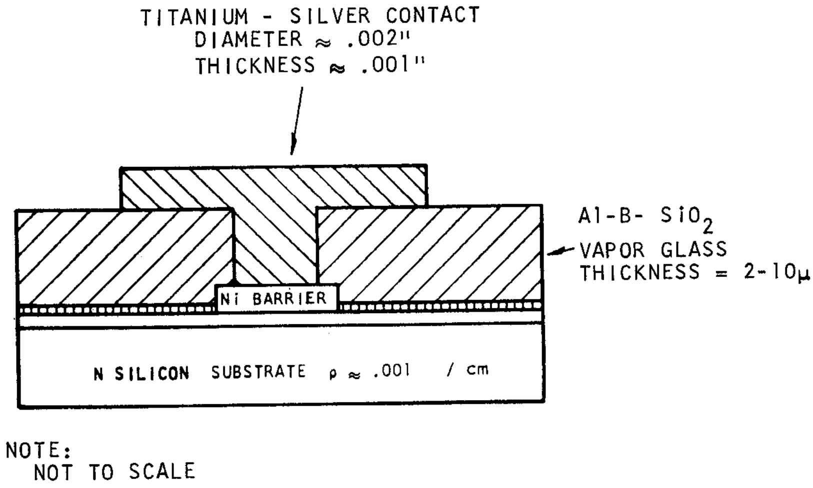

FIG. 1. BILITHIC SCHOTTKY BARRIER

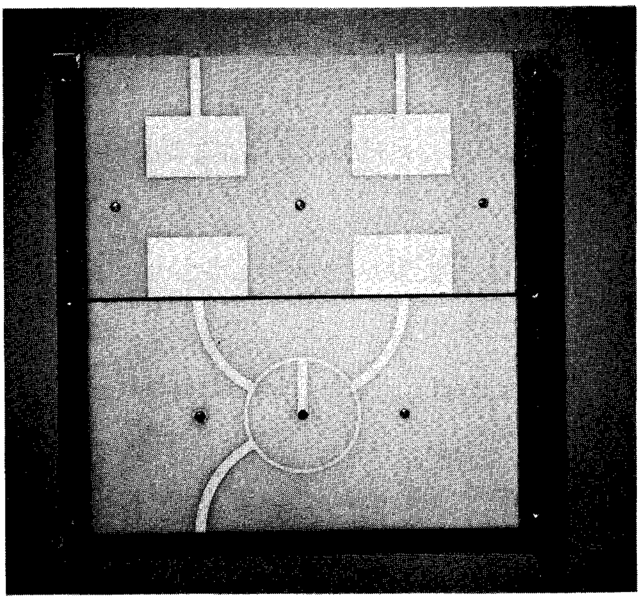

FIG. 2. PHOTOGRAPH OF BALANCED INTEGRATED MIXER

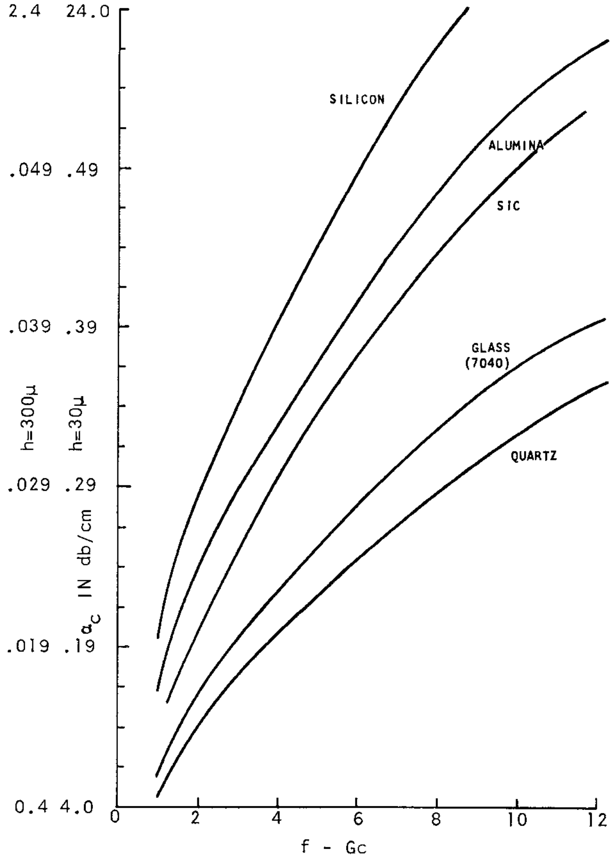

FIG. 3. CONDUCTOR LOSSES WITH VARIOUS DIELECTRICS

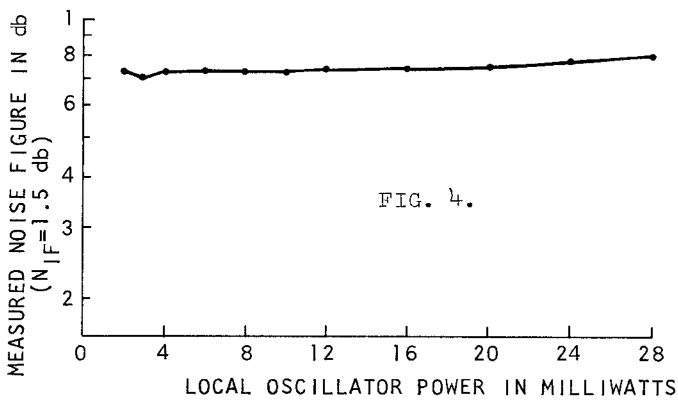

FIG. 4.

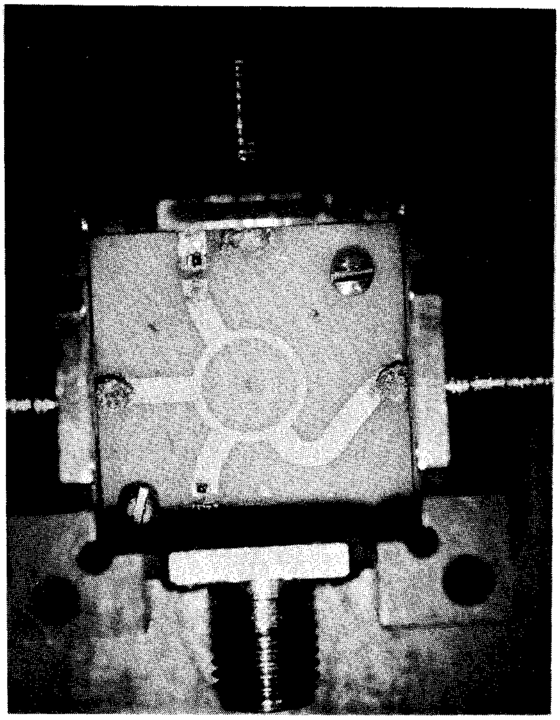

FIG. 5. X-BAND INTEGRATED MIXER