A MIXER AND SOLID STATE L.O. FOR A 60 GHz RECEIVER

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SUMMARY

This paper describes the techniques evolved and the results obtained during the development of solid state RF components for use in the 50-70 GHz frequency range. The program is directed specifically toward the generation of a reliable, low noise, RF "front-end" for a 60 GHz radiometric receiver. The critical components of the "front-end" are the low noise (low conversion loss) mixer and the local oscillator. The mixer consists of GaAs Schottky barrier diodes of very high cut-off frequency; the local oscillator utilizes a silicon avalanche diode oscillator.

SCHOTTKY BARRIER DIODES

Schottky barrier diodes are particularly advantageous for millimeter wave applications because of the potential simplicity of their fabrication. A single evaporation or electroplating operation, performed through a suitable mask, will define the active area and provide the metallic surface for lead contact. The high mobility of GaAs has made possible the design of diodes with active regions of extremely low resistance. The design and fabrication of the semiconductor element is similar to the approach previously reported[1] and has resulted in GaAs diodes with a varactor frequency cut-off of nominally 800 GHz, as measured at zero bias and with a measurement frequency of 70 GHz.

The diode is a planar, SiO_2 passivated device. The GaAs chips used for the 60 GHz mixers are .015" x .015" x .004", and have an array of 5 micron diameter junctions spaced on 10 micron centers. The junction capacitance at zero bias is nominally .04-.05 pf and the series resistance falls in the range of 4-5 ohms.

MIXERS

An objective of this program was the development of 60 GHz mixers, but an indication of the quality of the diodes is to be had by noting that diodes of these same junction parameters, (both with a 20 micron over-lay bonding pad) have been used in an X-band, integrated circuit, image-enhanced mixer[2] which did yield a conversion loss of less than 3 dB (which value includes all input and output connector losses, and represents an improvement over previously reported values).

Figure 1 presents the conversion (transducer) loss of one mixer wafer as a function of L.O. drive power and bias voltage for converting from a signal at 68.8 GHz (L.O. at 70 GHz) to an IF of 1.2 GHz. The conversion loss curve is a plot of direct measurement data. It has not been corrected for input and/or output mismatches or other circuit losses. Yet a minimum conversion loss of between 5 and 6 dB can be regularly attained. The noise ratio of these diodes is very close to unity, as has been verified by direct noise figure measurements. Figure 2 is a photograph showing the double diode mounting scheme used to minimize the losses that would normally occur if the signal RF currents and/or L.O. currents had to flow through some form of RF choke or capacitive RF bypass. Note that in the holder shown, as long as the two diodes are reasonably well matched, there will be no fundamental signal or L.O. coupled out the pin by which the IF is removed. Because of the RF decoupling, the usual bypass capacitor is not needed and a very wideband IF match is easily attained. As was stated earlier, the junction capacitance at zero bias is about .05 pf (per diode). The series resonance of the composite diode at zero bias (as determined by transmission resonance and f_{co} measurements[3]) falls in the range of 60-70 GHz.

The diode holder with which the mixer measurements were made is shown in Figure 3. This is an RG-98/U waveguide mount with one of the mixer wafers in place. This mount is similar to the mount used for the avalanche diode oscillator measurements but with the addition of a cavity (on the side opposite to the wafer) which can be used for bias circuitry, IF matching, etc., depending upon the need.

SILICON AVALANCHE DIODE OSCILLATORS (ADO)

Silicon avalanche diodes are being analyzed and evaluated for use in waveguide circuits as millimeter wave oscillators and amplifiers. As in the previously discussed mixer configuration, a removable wafer package is used for diode mounting in the waveguide. This type of wafer package is particularly suitable for avalanche diode applications in the EHF microwave range as it conveniently provides a means by which a small, fragile semiconductor element may be embedded in a millimeter wave circuit, obtain sufficient coupling to the external load and maintain a low thermal impedance while concomitantly tolerating severe thermal expansion of the pertinent elements. The basic structure is a flat metal wafer (typically .800" x .250" x .100") with an iris (waveguide opening) which couples directly with a mating waveguide section for RF energy transmission to an external waveguide circuit. The ADO wafer is shown in Figure 4a (blown-up photo—50X—is shown in Figure 4b). In this figure can be seen the iris coupling to the diode structure, the heavy copper base heat sink (vertical metal cylinder) on which the diode is mounted, the beam diode contact (and bias lead) which enters the iris horizontally from above the diode for capacitive coupling of the waveguide impedance to the diode. In Figure 4b, the avalanche diode itself is the small dot contact between the conical section in the lower part of the iris and the horizontal beam which supplies the dc bias. The cylinder approaching the beam from the top of the iris is the tunable capacitive screw.

Figure 5 is a picture of the Westinghouse developed avalanche diode. The diode dimensions are 1.5 mils (38 microns) in diameter by 0.75 mils (19 microns) high. The junction is next to the metal (heat sink) surface. The pictures were taken with the Westinghouse scanning electron microscope, and show the extreme precision with which the junctions can be formed using standard etching techniques.

The table of operating data given in Table I represents the operation obtained to date. The prime objective of the program, that is to supply mixer L.O. power, has been well satisfied.

		Diode #1	Diode #2
Frequency	GHz	61	51
Output Power	mW	22	66
Input Power	W	1.5	4.8
Efficiency	%	1.5	1.4
Breakdown Voltage	V_b	19	19.5
Current Density	A/cm^2	6.2K	10K

Table I. ADO Operating Data

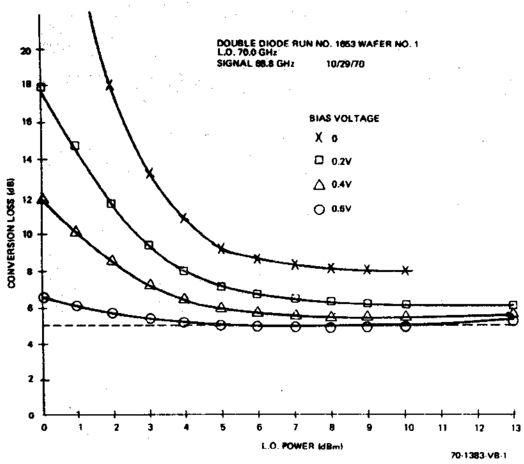

Figure 1 - Conversion Loss vs L.O. Drive and Bias

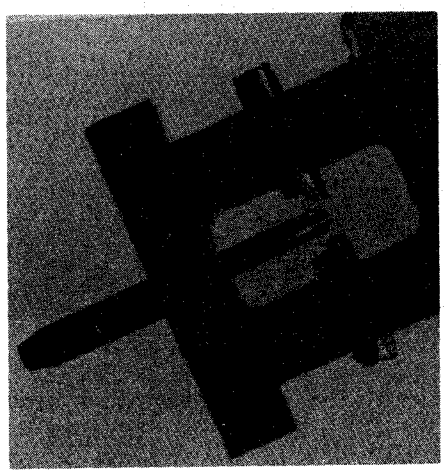

Figure 2 - Mixer Diode Mounting Configuration

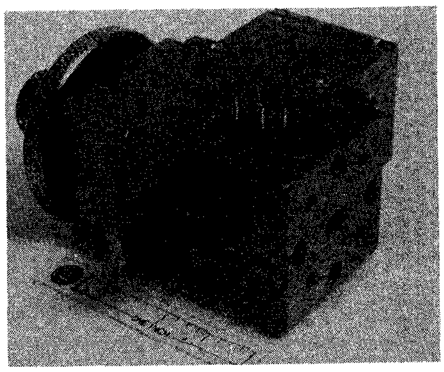

Figure 3 - RG-98/U Waveguide Wafer Diode Mount

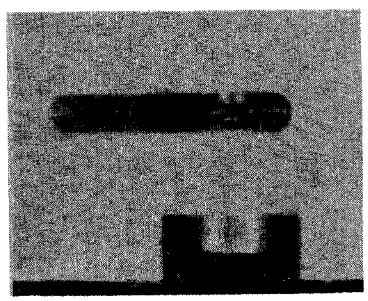

Figure 4a - 50-85 GHz ADO Wafer

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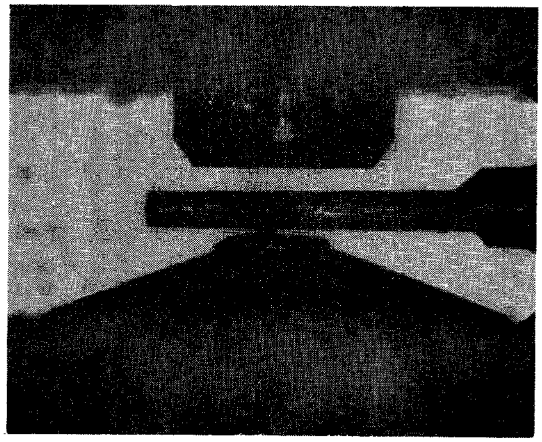

Figure 4b - Enlargement of Figure 4a Showing Details of Diode Mounting Configuration

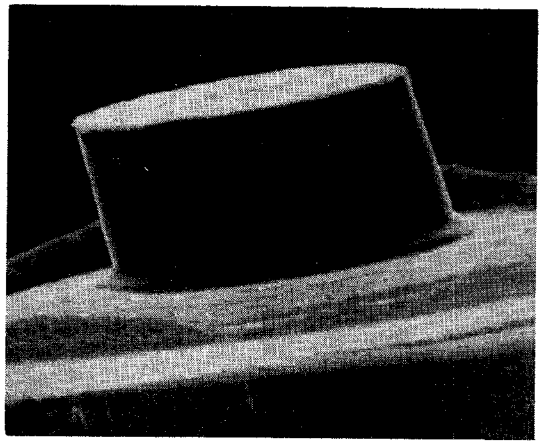

Figure 5 - Westinghouse Developed Avalanche Diode Mounted on A Heat Sink

Notes