140 GHz ALL SOLID STATE RECEIVER WITH SYSTEM NOISE FIGURE LESS THAN 6 dB DSB

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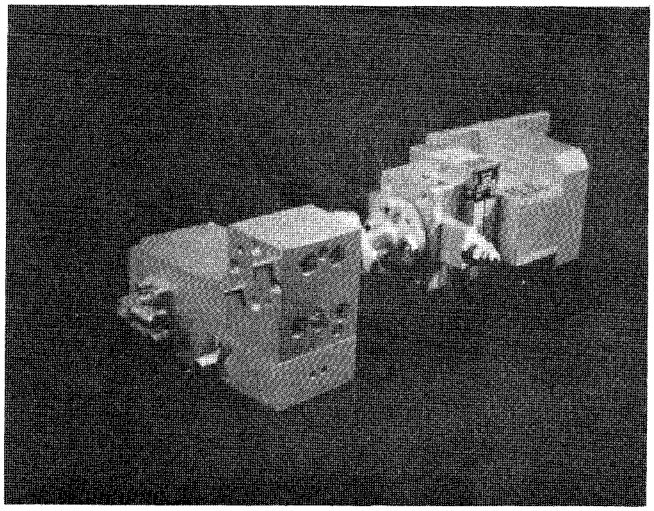
This paper describes implementation of beam lead GaAs diodes in a suspended stripline mixer at 140 GHz to obtain noise figures of less than 6 dB DSB. This compares quite favorably with previous commercial practice, where total receiver noise figures of less than 10 dB DSB were rarely obtained. These low overall noise figures were achieved over an instantaneous bandwidth of greater than 1000 MHz, while requiring only 3.5 mW from an integrated all solid state local oscillator source. Construction details for both the mixer-preamplifier and all the solid state L.O. source will be presented.

Introduction

A low noise all solid state receiver has been developed for use in the 140 GHz region of the spectrum. This receiver employs beam lead diodes in a suspended stripline medium to achieve noise temperatures of less than 860°K Double Sideband* over an instantaneous bandwidth of 2 GHz. Although similar in construction to previously described mixers, this is the first attempt to use beam lead mixer diodes at frequencies above 110 GHz. Local oscillator power is obtained through use of a tripler pumped by a gunn oscillator at 46 GHz. Only 3.5 mW of local oscillator power is required for optimum noise performance from the balanced stripline mixer.



PHOTOGRAPH OF INTEGRATED RECEIVER

Circuit Description

Stripline, commonly called suspended-stripline because of the symmetric air-gaps to either side of the dielectric medium, was used in the design of this mixer-preamplifier because it has lower loss and less excitation of higher order modes than many other available circuit media. Although similar to previously described stripline mixers[1,2,3] made using both beam lead and notch-front diodes, special attention had to be given to proper characterization of the beam lead microwave circuit model to insure proper operation at frequencies near 140 GHz. For this reason a scale model, operating near 6 GHz was constructed. Special attention was made to properly scale all known parasitic elements associated with the diodes and the bond-wires which form the embedding network.

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Scaling of the model structure to the frequency range near 140 GHz involved the use of single crystal quartz with an optical grade surface finish and a total thickness of nearly 0.12 mm to form the millimeter substrate. A standard photolithographically produced circuit metalization, consisting of 2.5 µm gold layer evaporated over approximately 200 Å of chromium was used to insure low loss operation at 140 GHz..

The IF matching network consists of a tuned network made using lumped elements in both series and shunt with the IF line in a Duroid microstrip medium. This matching network combines the IF outputs of the two mixer diodes and simultaneously provides dc bias input for each mixer diode. The first stage of the IF amplifier is a novel design, using a NEC 64580 bipolar device in a broad-band 100-1000 MHz low noise configuration, followed by a commercially available thin-film amplifier. RF to IF gain of 27 dB is obtained with a flatness of better than 1 dB peak-to-peak over the entire IF bandwidth of the mixer-preamplifier. GaAs mixer diodes with total capacitance of less than 0.025 pfd are used in the design.

The multiplier source was developed around the use of a commercially available Alpha DVE5033-14 GaAs varactor diode. This diode, with typical zero bias junction capacitance of less than 0.1 pfd and V_B greater than 15 V, was used in a waveguide cavity circuit first developed for application as a high power tripler from 15 – 45 GHz many years ago, and subsequently scaled to the 2 mm wavelength region. This tripler is pumped by a low noise gunn oscillator at 46 GHz. Approximately 75 mW is obtained from the gunn, generating a low noise local oscillator signal of approximately 4.0 mW at the mixer input flange including the losses of the isolator in the tripler input circuit. The noise level of this multiplier source was far less than that observed using a typical Varian klystron as the L.O. source for the mixer-preamplifier. In fact, a decrease in overall noise figure of greater than 2 dB was observed when operating the mixer with the gunn/multiplier source rather than with the Varian klystron. The multiplier was intentionally tuned for a rather broad operating bandwidth (several GHz) unlike in other applications where this multiplier has produced in excess of 15 mW over narrower bandwidths.

Because of the use of beam lead semiconductors, shock and vibration, as well as military temperature profiles do not impair the performance and noise figure of this receiver in any way.

Performance

The mixer preamplifier was tuned up using a swept source at 138 GHz. This swept source consisted of a broadband doubler driven by a BWO oscillator near to 70 GHz. No attempt was made to level the sweep, although it was fairly flat as measured with a power meter over the entire bandpass of interest. In Figure 1, a scope photograph of the mixer-preamplifier bandpass with the local oscillator centered at 138 GHz clearly illustrates the broadband nature of the mixer to IF amplifier matching circuit. The only tuning adjustments were the two backshorts which coupled each stripline element to the short-slot hybrid junction used as the RF combining circuit. These backshorts were *fixed and epoxied in place before all the data illustrated in this* *paper was taken.* Final tuning adjustments were made using a signal to noise meter and a pulsed noise source, as well as an IF radiometer to fully characterize the mixer.

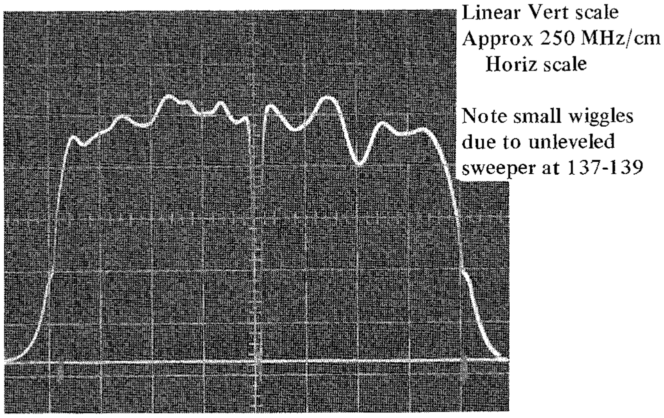

FIGURE 1 SCOPE PHOTOGRAPH OF MIXER-PREAMPLIFIER BANDPASS – L.O. IS CENTERED AT 138 GHz

The noise figure was measured using a calibrated noise source. This source agreed directly with hot-cold load measurements. The noise figure data is graphically illustrated in Figure 2. As is evident, the measured noise figure is flat with 0.2 dB much the same as the mixer bandpass. These measurements have been verified using hot-cold radiometer techniques in other laboratories.

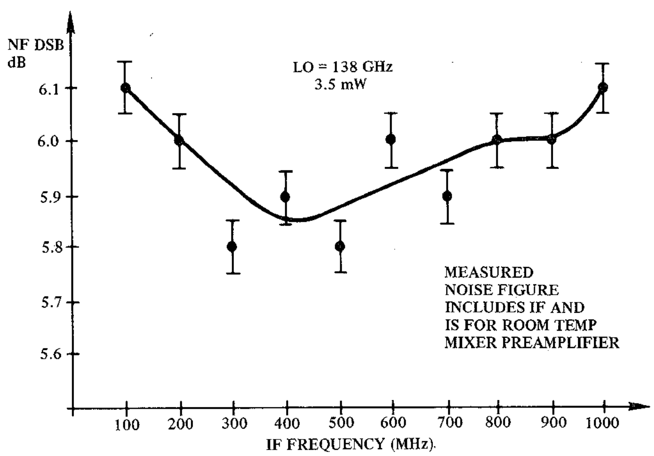

FIGURE 2 NOISE PERFORMANCE OF RECEIVER

In Table 1, below we summarize the measured noise performance of the mixer-preamplifier when pumped by the TRG Gunn/Multiplier source at 138 GHz. Since the two mixer sidebands were measured to be equal to within a few tenths of a dB, we have taken them to be exactly equal in the analysis which led to Table 1. Expressing the mixer temperature as a single sideband quantity with the signal and image band of essentially equal contribution, provides the extrapolated value of

$$T_m \text{ (SSB)} = 760°K$$

for a room temperature mixer. Of course this value includes the effect of RF loss in the hybrid junction and stripline elements, as well as IF losses which are *not* subtracted as is the custom in some papers in the literature.

It should be pointed out that the MIXER temperature, known in the literature as T_m[4] is very low for this room temperature mixer, comparing favorably with room temperature mixers at 94 GHz and below.

TABLE 1

PARAMETER	SYMBOL	VALUE	UNITS	ESTIMATED ERROR
Total Receiver Noise Figure	T_R	5.8 812.5	dB DSB K DSB	±0.2 dB ±20 K
IF Preamplifier Noise Figure	T_{IF}	1.5 120.0	dB K	±0.1 dB ±10 K
Mixer RF to IF Conversion Loss	L_s	5.9	dB SSB	±0.2 dB
Mixer Temperature	T_m	380	K DSB	±30 K

Conclusion

The use of beam lead diodes at 140 GHz has been demonstrated in a balanced mixer preamplifier. This receiver when pumped by an all solid state Local Oscillator source at 138 GHz provides less than 6 dB DSB noise figure with an associated mixer temperature of 380 K DSB.

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