U-4

LOW-NOISE 50-58 GHz MIXERS FOR SPACECRAFT RADIOMETERS

W. J. Wilson and A. L. Riley

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

SUMMARY

Reliable low-noise millimeter-wave mixers have been designed and built for the TIROS satellite microwave sounder radiometers. This mixer design features a balanced microstrip circuit using packaged diodes and fixed-tuned backshorts. System noise figures of less than 5 dB (DSB) were achieved in the 50-58 GHz frequency range.

INTRODUCTION

A requirement for space-qualified low-noise millimeter-wave mixers in the 50-58 GHz frequency range led to the mixer development described in this paper. These mixers will be used in the TIROS satellite microwave sounder radiometers. In each TIROS instrument, there will be four radiometers which will measure the atmospheric brightness temperatures at 50.3, 53.7, 54.9 and 58.0 GHz. These data are then used to estimate the earth's atmospheric temperature distribution on a global scale[1].

The mixer in each radiometer is driven by a Gunn diode local oscillator and operates double sideband with an intermediate frequency (IF) amplifier having a bandwidth of 10-110 MHz. The main design requirements for the mixer were low noise performance and high reliability during the spacecraft launch and subsequent 3-year orbital lifetime.

DESIGN

A schematic of the mixer circuit is shown in Figure 1 and a photograph of an assembled mixer and IF amplifier is shown in Figure 2. A balanced mixer design was chosen to reduce the low-frequency local oscillator (LO) noise in the 10-110 MHz IF band. To achieve low-noise and broadband performance, a crossbar-mixer circuit was used. The results of a recent analysis of crossbar mixers by Faber and Gwarek[2] were used to design the mixer and predict its performance. Other advantages of the crossbar mixer are low LO power requirements (<10 dBm), good RF/LO isolation and compact size.

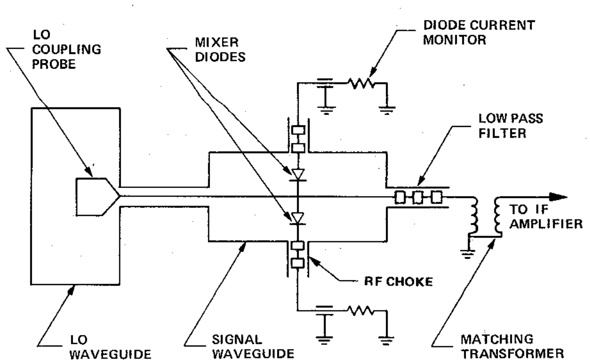

Figure 1. 50-58 GHz Mixer Schematic

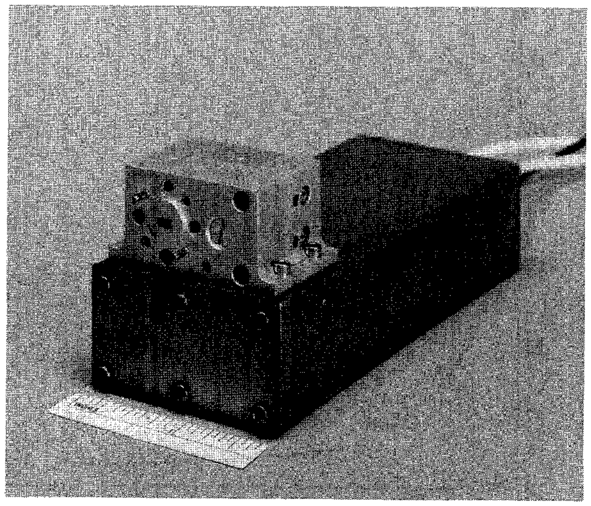

Figure 2. 50-58 GHz Space Qualified Mixer and IF Amplifier

The back section of an unassembled mixer is shown in Figure 3. Quartz microstrip circuits, .010" thick with titanium/tungsten gold metallization, were used for the diode, LO and IF circuits. This design provided low loss and excellent reproducibility and stability. The mixer circuits were designed by a combination of analytical and empirical techniques. A 2 GHz scale model was used to test the circuit structure in the signal waveguide by measuring the impedance at the diode location with a small coaxial cable. (Since the signal circuit is symmetrical, these measurements were done in half-height waveguide with only one-half the circuit structure.) The measured impedances and shunt diode reactance were used to compute the mismatch to the diode resistance determined from the results of Faber and Gwarek. The final millimeter-wave circuit, shown in Figure 3, was derived from model circuits optimized to produce the best impedance match to the diode over the required frequency range.

A probe in the LO waveguide is used to couple the LO signal into a 50 ohm microstrip line and to the signal waveguide and mixer. The mixer diodes are soldered on the diode microstrip circuit mounted across the signal waveguide. A unique diode tuning circuit was developed using the scale model. This circuit serves the purpose of adding increased flexibility to the diode matching and acts as an

0149-645X/83/0000-0187 $01.00 © 1983 IEEE

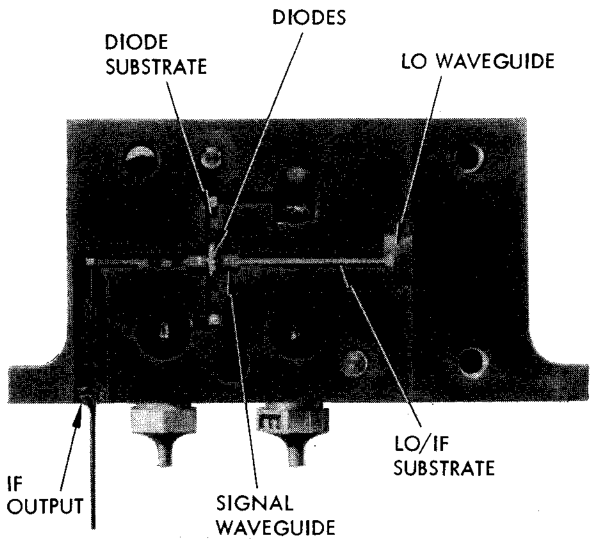

Figure 3. Back-half of 50-58 GHz Mixer

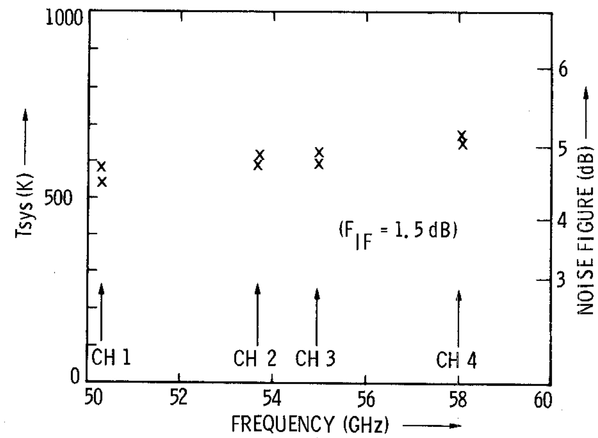

Figure 4. Measured System Noise Performance

RF choke circuit. This choke circuit is used to couple the diode bias current, by way of feed-through filters, to allow monitoring and control of individual diode current. The mixer diodes were made by Texas Instruments (MDX-623) and produced the required low conversion loss and low noise. These diodes are mounted in a very rugged package and have been previously space-qualified.

The IF signal is coupled from the diode circuit through an IF filter which blocks the LO and RF signal. The IF filter structure and location were designed, using standard transmission line analysis techniques, to tune the LO signal at the diode position. Following the IF filter, the output signal is coupled to a matching transformer and an IF amplifier. The transformer also provides a DC return for the diode current.

The mixer mount and microstrip circuits were broadband so that only the RF signal and LO backshorts required adjustment for each frequency. The signal and LO waveguides were stepped from rectangular to a circular cross-section and the fixed backshorts were counterbored plugs which screwed into the mixer mount. The position of the backshort was set by the depth of the counterbore. This configuration is similar to that used by Archer and Mattauch[3] at much higher frequencies and provides a very stable low-loss backshort.

RESULTS

Conversion loss and noise measurements of the mixer and its IF amplifier were made using room temperature and liquid nitrogen thermal loads with a calibrated IF radiometer system. An HP-85 computer system controlled a mirror switching between the thermal loads, read the output of the calibrated IF radiometer and then calculated the double sideband conversion loss, system noise temperature and mixer noise temperature. These results were displayed in real-time and were used to tune the mixer. With this system, we estimate that the conversion loss had a 3-sigma error ≤ 0.3 dB and the noise measurements had 3-sigma errors <50 K.

The results of our system noise measurements for eight of the flight mixers and IF amplifiers are shown in Figure 4. The conversion loss, including a feedhorn and the matching transformer, was measured to be 2.9 ± 0.2 dB (DSB) over the 50-58 GHz frequency range. As seen from Figure 4, the double sideband system noise temperature is <650 K from 50-58 GHz including a 120 K IF preamp noise temperature. This corresponds to a DSB system noise figure of <5 dB which is typical of the state of the art for room temperature radiometers. Dynamic and thermal environmental tests, simulating the launch and space environment, were performed and no degradation in performance was observed.

CONCLUSIONS

This paper has reported on the design of a reliable low-noise mixer in the 50-58 GHz frequency range with state-of-the-art performance. This mixer has been space-qualified and will be used in the TIROS satellite microwave sounder radiometers. Twenty-four mixers will be built for this spacecraft program.

REFERENCES

1. J. W. Waters, D. F. Kunzi, R. L. Pettyjohn, R. K. L. Poon, and D. H. Staelin, "Remote Sensing of Atmospheric Temperature Profiles with the Nimbus-5 Microwave Spectrometer," J. Atmos. Sciences, Vol. 32, No. 10, pp. 1953-1969, October 1975.

2. M. T. Faber and W. K. Gwarek, "Nonlinear-Linear Analysis of Microwave Mixer with any number of Diodes," IEEE Trans. Microwave Theory Tech., Vol. MTT-28, No. 11, pp. 1174-1181, November 1980.

3. J. W. Archer and R. J. Mattauch, "Low-noise, single-ended mixer for 230 GHz," Electron. Lett., Vol. 17, pp. 180-181, March 1981.