

# A 640 GHz Planar-Diode Fundamental Mixer/Receiver

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## ABSTRACT

The design and performance of a 640 GHz solid-state receiver using a fundamental planar-Schottky-diode mixer, InP Gunn diode oscillator, whisker-contacted Schottky-varactor-diode sextupler and folded-Fabry-Perot diplexer are reported. A best mixer noise temperature of 1640K DSB, conversion loss of 8.1 dB, has been achieved at room temperature at an IF of 8 GHz and the noise is below 2100K DSB from 1.5-11 GHz IF. Measurements employing a commercial 4-8 GHz Miteq amplifier and external bias T yield a double sideband receiver noise temperature below 3100K from 2-8 GHz with a best value of 2720K at 4 GHz. Measured local oscillator power was only 350 microwatts measured on a Keating acousto-optic power meter. These results are believed to represent the best reported performance for a room-temperature Schottky diode receiver at this frequency.

## I. INTRODUCTION

Low noise Schottky-barrier-diode based receivers have been employed for ground based, airborne and spaceflight radiometer applications for many years. Recent advances in device fabrication technology and circuit efficiency have enabled solid-state room-temperature radiometers based on waveguide mixers and multiplier chains to reach frequencies as high as 700 GHz [1-3]. In this short paper, the author's report on the design and performance of an all solid-state 640 GHz receiver utilizing a fundamental planar-diode mixer, an InP Gunn oscillator, a whisker-contacted varactor diode doubler/tripler combination and a folded Fabry-Perot diplexer. The receiver is intended for room-temperature aircraft and space borne applications and has state-of-the-art performance over a wide intermediate frequency range (1.5-11 GHz).

## II. PLANAR SCHOTTKY DIODE MIXER

The 640 GHz Schottky diode mixer utilizes a traditional full-height (320x160 micron) split-block waveguide configuration (Figures 1. & 2.). The planar Schottky diode is realized via Quartz-substrate Upside-down Integrated Device (QUID) processing [4-6] and is suspended across the center of the broad wall of the RF waveguide. Microstrip RF hammerhead blocking filters [7] are realized on both sides of the diode with a wire bond for a DC return on one side and for connection to a quartz suspended stripline impedance transformer on the other. The rectangular signal waveguide transitions first to square, using a variation of the transformer in [8], then to circular and finally to a dual-mode conical feedhorn [9] all machined directly into the split block. A simple BeCu spring finger backshort [10] is contained in the waveguide channel behind the diode. The quartz microstrip filter structure containing the T-anode Schottky diode is contained in a single mode cavity 125x125 microns in cross section. The diode itself sits on a 50 micron thick x 100 micron wide by 1000 micron long quartz substrate. A 200-to-50 ohm suspended stripline quartz impedance transformer is wire bonded to the end of the diode filter for IF matching and joining to a standard SMA tab launch connector.

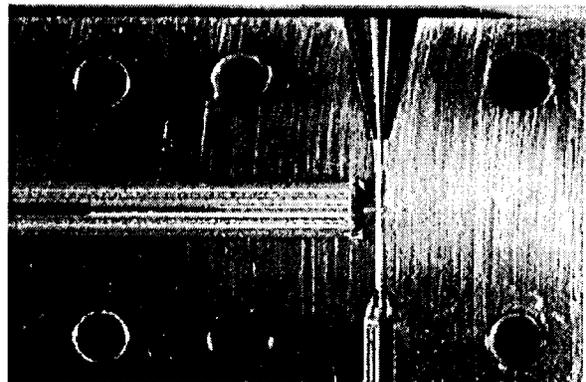
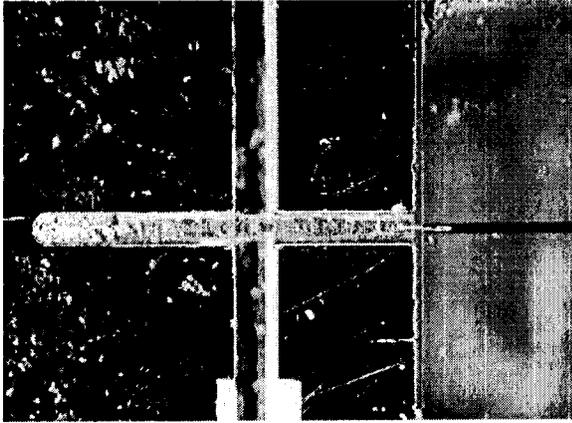


Figure 1: Photograph of 640 GHz mixer block (lower half) with horn, diode, backshort and IF filter.



**Figure 3:** Close up picture of the 640 GHz mixer (lower half) showing the diode, RF filter, split rectangular waveguide and IF transformer (right).

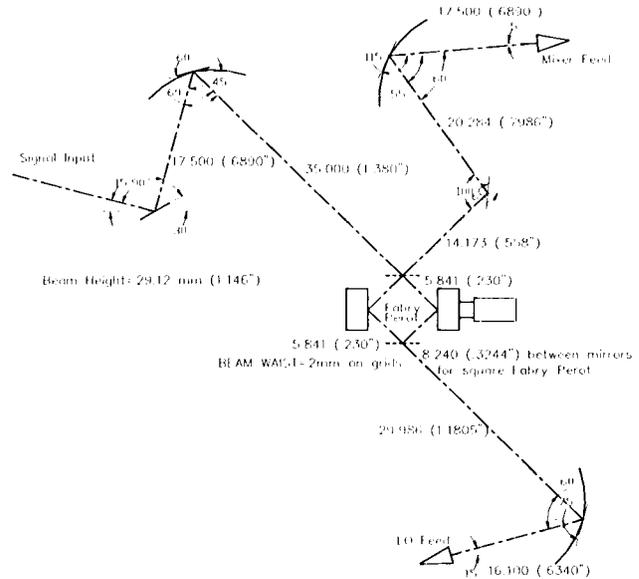
### III. VARACTOR DIODE MULTIPLIERS

Local oscillator power for the mixer is generated by two series connected whisker-contacted varactor diode multipliers. The first is a self-biased, fix-tuned doubler, the second a self-biased, fix-tuned tripler. Both the doubler and tripler have been reported upon previously [1]. The doubler is pumped by a Litton InP Gunn diode packaged in a custom cavity which produces 40 mW at 107 GHz. Unusual characteristics for the Gunn cavity include a specially designed resonator disk, a conical sapphire tuner and a built in isocoupler. The doubler and tripler are mechanically pinned together in a novel in-line waveguide arrangement [11]. The whisker-contacted diodes are from the University of Virginia and appear across the output waveguide of each multiplier. All tuners are fixed internally and bias is obtained through an external resistor which appears in series with the diode. At an input drive level of 40 mW the doubler produces roughly 10 mW at 214 GHz and from this the tripler produces approximately 420 microwatts at 642 GHz (measured using a Keating acousto-optic power meter). A separate dual mode horn, similar to that used on the mixer, is aligned to the tripler output waveguide. Special features of the multipliers include: a single input and output tuner (fixed), self biased operation, no isolators needed between multipliers, and compact rigid construction. The units are commercially available [11] and similar multipliers have been flight qualified for ODIN.

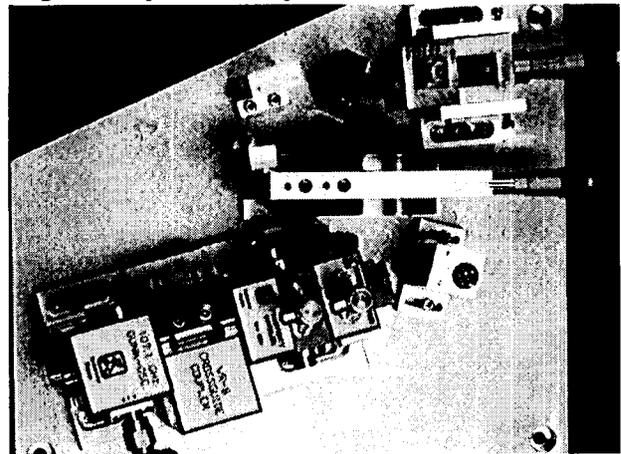
### IV. DIPLEXER

In order to couple LO and signal power into the mixer and at the same time provide LO noise filtering a folded Fabry Perot diplexer [12] was designed and

manufactured. The diplexer uses a very compact, simple mechanical configuration and unlike [12] uses two focusing mirrors, one of which is adjustable to peak the transmitted power at a particular frequency. The diplexer mesh uses standard Buckbee Mears electroformed nickel grids with 200 line per inch cells. Off axis ellipsoidal mirrors are used to provide beam waists on the LO and signal side of the diplexer at the mesh positions. Two flat folding mirrors and a third ellipsoidal mirror provide a high f-number beam for signal injection. The layout of the Fabry Perot and optical beam path for the receiver is shown in Fig. 3 and a photo of the complete front-end package is given in Fig. 4. Measured LO loss through the diplexer is less than 1 dB.



**Figure 3.** Optical beam path for receiver front-end.



**Figure 4.** Complete 640 GHz receiver showing LO source (Gunn, isocoupler, multipliers) at top, diplexer in the middle and mixer at the bottom.

## V. MIXER/RECEIVER MEASUREMENTS

Characterization of the mixer and receiver was performed using two test sets: the first employing computer controlled chopped room temperature and nitrogen loads with a calibrated IF test system that removes IF mismatch to the output port of the mixer; the second, for receiver measurements, utilizes a Tektronix 2792 spectrum analyzer with a 3 MHz bandwidth and an HP437B power meter used as a detector on the IF output of the analyzer. The mixer test system contains a noise source, a series of low noise amplifiers which are switched in at different bands and a computer controlled input tuner to match the mixer to the test system at any IF frequency. A separate collinear Fabry-Perot filter can be inserted in the signal beam path and swept to perform accurate sideband ratio measurements (not performed in this measurement sequence). During mixer measurements the IF band was swept through the full available test set range (1.5-17 GHz). For the receiver measurements a commercial 4-8 GHz amplifier with a noise figure between 0.4 and 0.7 dB and gain of 23-25 dB was used (Miteq JS2). The resulting noise temperature and loss are shown in Figures 5 & 6. Note that the receiver data shown in Fig. 6 include a bias T and IF transformer. LO power at the mixer horn was measured to be 350 microwatts on a Keating meter.

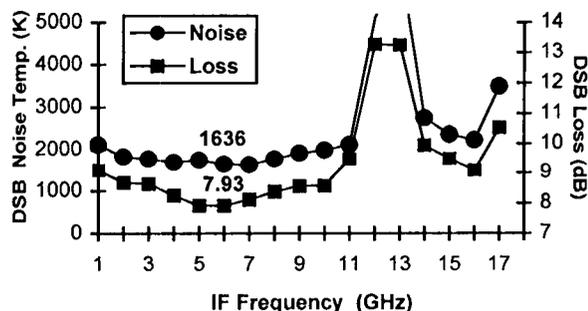


Figure 6: Measured mixer noise and loss at 640 GHz vs. IF frequency. The resonance at 13 GHz is due to the diplexer pass band. Available LO power is approximately 350 microwatts. The data shown was taken at a mixer bias of 0.7V and a diode current of 0.8 mA. Diode characteristics for the mixer are: anode = 0.4x2 microns,  $R_s = 7$  ohms, ideality factor = 1.31, saturation current =  $4 \times 10^{-14}$  A. There was some indication that the mixer was slightly LO starved as the mixer bias voltage was somewhat higher than usual and the mixer was clearly not saturated.

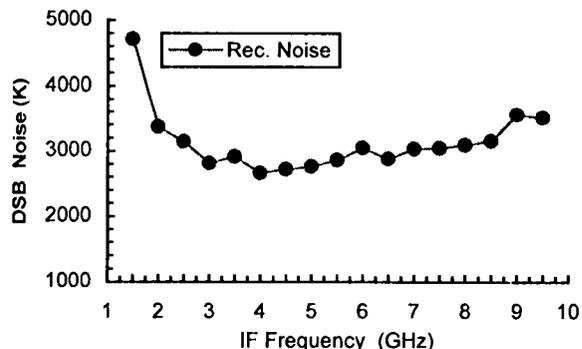


Figure 7: Measured receiver noise at 640 GHz vs. IF frequency using a Miteq 4-8 GHz packaged amplifier and external bias T.

## VI. CONCLUSION

A DSB noise temperature of 1640K at 8 GHz IF has been realized with a fundamental planar-diode mixer at 640 GHz. A full receiver noise temperature below 3200K DSB has been achieved over a band from 2-8 GHz using a commercial amplifier. The use of an all-solid-state Gunn driven multiplier chain and a compact folded Fabry-Perot diplexer has resulted in an extremely compact, robust radiometer package for applications at submillimeter wavelengths. The performance of this receiver front-end matches any previously reported room-temperature system. The receiver is intended for airborne operation in an experiment to measure the abundance and size of ice crystals in cirrus clouds [13].

## VII. ACKNOWLEDGMENT

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