Quasioptical Patch Mixers at 35 and 94 GHz

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ABSTRACT

An innovative subharmonically pumped quasioptical mixer has been developed with a 4 GHz bandwidth at 35 GHz, nearly twice the bandwidth reported earlier. The design has been scaled to 94 GHz, and it is possible to scale the design to higher frequencies.

Quasioptical mixers are an important component for low cost applications combining the best aspects of microwave and optical technology at millimeter frequencies and beyond. Earlier work has developed low noise patch antenna quasioptical mixers at 35 GHz [1]. This work doubles the earlier 35 GHz bandwidth and extends the operating frequency to 94 GHz.

CIRCUIT DESIGN

This section will present our current design. The discussion that follows will explain how the design was developed, and how well the mixer performs. Our current design for the 35 and 94 GHz mixers, using the layout shown in Figure 1, can be scaled to 140 GHz. The figure shows the location of the patch antenna, the quarter wave transformer, the diodes, the grounding stubs, the LO port, and the IF port. The upper portion of the circuit is in microstrip, while the lower portion is in stripline because unwanted RF pickup can ruin the performance of the quasi-optical mixer. The 35 and 94 GHz mixers, shown in Figure 2, are limited in size by the LO and IF connectors.

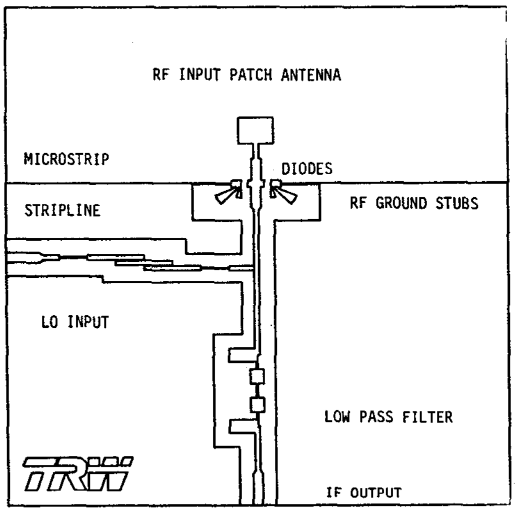

FIG. 1 Broadband 94 GHz quasioptical mixer layout.

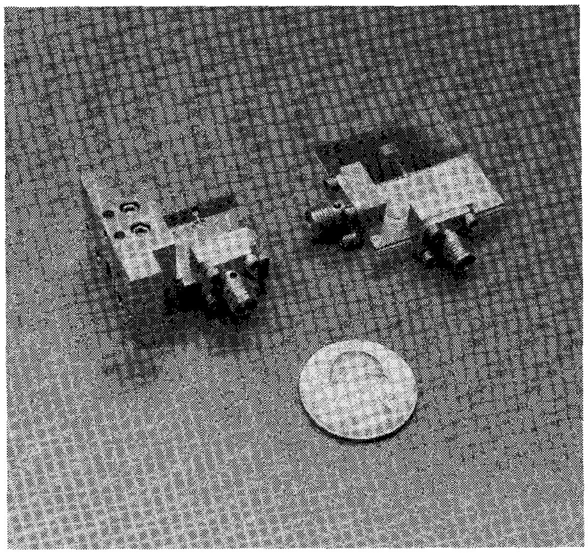

FIG. 2 Quasioptical mixers at 35 and 94 GHz showing scaling similarities.

A circuit model of the mixer, Figure 3, shows that matching the antenna impedance to the diode impedance is the greatest problem. The diode impedance can be calculated from the manufacturers data, while the antenna impedance can be determined from the transmission line model or a patch resonator model. Use of an increased number of transformer sections, or a coupled line transformer [2] will enable us to improve the match to the diodes. The patch antennas were designed using the standard transmission line model [3]. The patch antenna

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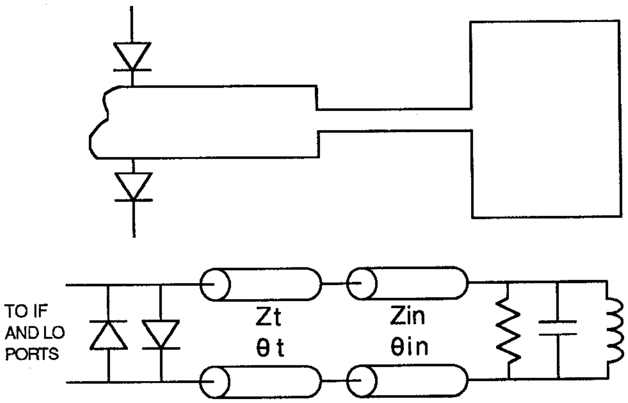

FIG. 3 Circuit model of the RF port of the patch mixer.

dimensions and input impedance were checked with a program using a cavity model solution [4].

Increasing the number of sections in the matching transformer will result in an additional benifit the antenna spacing from the stripline ground plane will be increased, thereby removing the unwanted nulls from the antenna pattern. Optimizing the waveguide to microstrip transition will improve the antenna resoponse by removing the large metal plane that interferes with the radiation pattern.

As a final step, we consider the selection of diodes. The diodes that we employed (Alpha DMK6606) were adequate for 35 GHz, but due to a cutoff frequency in the vicinity of 350 GHz, the mixer conversion loss suffers at 94 GHz by 1 dB. Selecting diodes that have a cutoff frequency ten times the operating frequency will improve the conversion loss of the 94 GHz mixer.

CIRCUIT LAYOUT AT 35 GHz

The earlier mixer design [1], shown in Figure 4, needed circuit opimization to achieve a broader bandwidth. The significant difference between the earlier layout and the current design is the absence of RF grounding stubs. The other two improvments, the IF filter and the DC block, contribute to circuit elements that can be fabricated with reasonable tolerances, as will be explained in the next section.

The radiation patterns of the 35 GHz mixer were well defined [1], and the bandwidth can be determined from the isotropic conversion loss shown in reference 1 to be about 2 GHz.

CIRCUIT OPTIMIZATION AT 35 GHz

To probe the circuit more closely, a mixer with no quasioptical elements was designed, (Figures 5 and 6) using only microstrip media. This approach isolated the problems of antenna interactions, conversion loss definition, impedance matching, RF grounding, and stripline media properties.

Starting with the earlier mixer layout [1] of Figure 4, and comparing to the final 94 GHz layout of Figure 1, a number of improvemnts that were introduced in the microstrip design of Figure 5 can be noted. First, the dc block of the early mixer could not be scaled up to 94 GHz, so

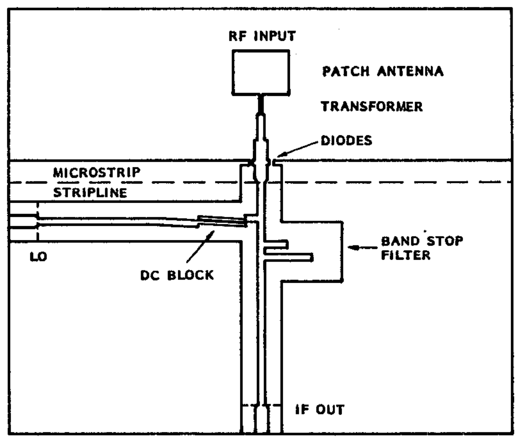

FIG. 4 Layout of early 35 GHz patch mixer.

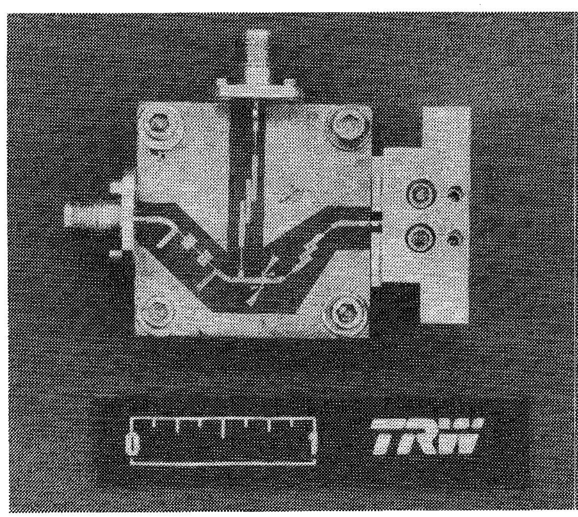

FIG. 5 Photo of the microstrip mixer, without the patch antenna, used to optimize the quasioptical mixer perfromance.

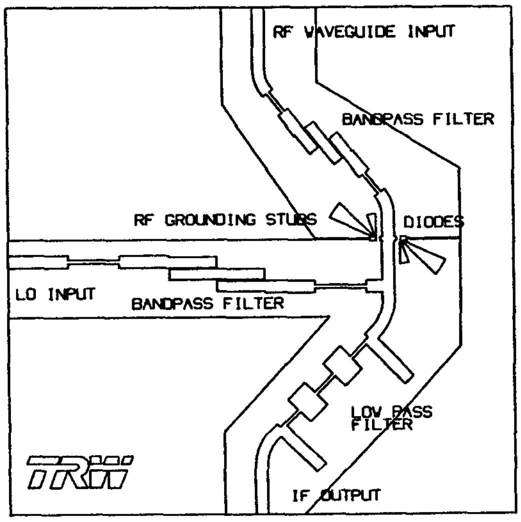

FIG. 6 Layout of microstrip mixer used to optimize the mixer perfromance.

an edge coupled filter was designed, using high impedance inverters to replace the tight coupling of the first and last sections. The sharper bandwidth of the edge coupled design (when compared to the DC block) simplifies the design of the mixer because it insures that out of band terminations are well known. For the low pass filter, the stub design of the early design was found to have less rejection than a low pass filter consisting of quarter wave lengths at the RF frequency and stubs at the ends for the LO frequency.

The most innovative feature of the optimized mixer, the quarter wave stubs at the LO and RF frequencies, serve to insure grounding of the diodes at high frequencies. The conversion loss of the microstrip mixer is plotted in Figure 7. Filter insertion loss and waveguide to microstrip losses have been subtracted from the data.

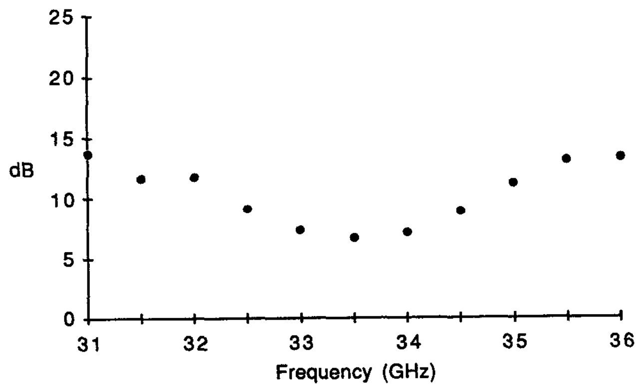

FIG. 7 Conversion loss of the microstrip mixer, used to optimize the mixer perfromance.

Using the improved circuit layout developed from the microstrip mixer, a 35 GHz mixer with the layout of Figure 1 was fabricated and tested. The end result of these improvements, a factor of two improvement in bandwidth, can be seen by comparing the earlier isotropic conversion loss of reference 1 to isotropic conversion loss of Figure 8. The maximum bandwidth is limited by the patch antenna, a neccessary consequence for any resonant antenna, as can be seen from a comparison of the mixer isotropic conversion loss (Figure 8) to the conversion loss of the microstrip mixer of Figure 7. The second feature of a quasioptical mixer, the radiation pattern, has already been optimized, as shown in reference 1.

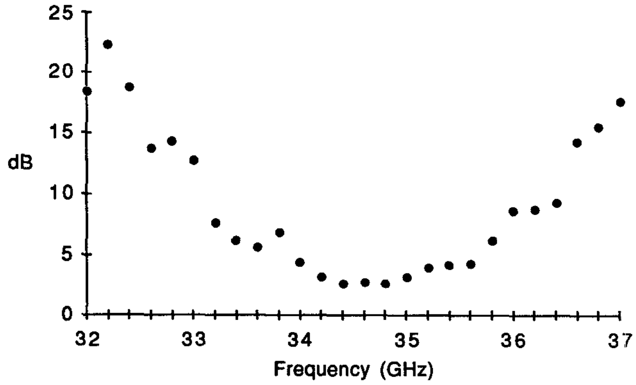

FIG. 8 Isotropic conversion loss of the 35 GHz quasioptical mixer demonstrating twice the bandwidth of the earlier design.

94 GHz MIXER

The optimized 35 GHz patch mixer design provided a perfect starting point for scaling to the 94 GHz mixer layout of Figure 1. By reducing the substrate thickness from 10 mils to 5 mils, by designing a new LO filter, and by optimizing a new low pass filter, we sucessfully scaled the mixer to 94 GHz.

The isotropic conversion loss of Figure 9 shows a very broad bandwidth with good conversion loss. Use of better diodes can improve the conversion loss by 1 dB. The mixer bandwidth, limited by the patch antenna resonance to 10%, provides sufficient bandwidth for many applications.

Scaling to 94 GHz resulted in a degradation in the radiation response shown in Figure 10. The deviation from a patch antenna response can be attributed entirely to the size of the connectors used to feed the LO and IF signals into the mixer, and to the close location of the antenna to the stripline upper ground plane.

CONCLUSION

The bandwidth of the earlier 35 GHz mixer designs [1] was doubled and the design was scaled to 94 GHz. The broadband 94 GHz mixer can be scaled to 140 GHz and beyond.

REFERENCES

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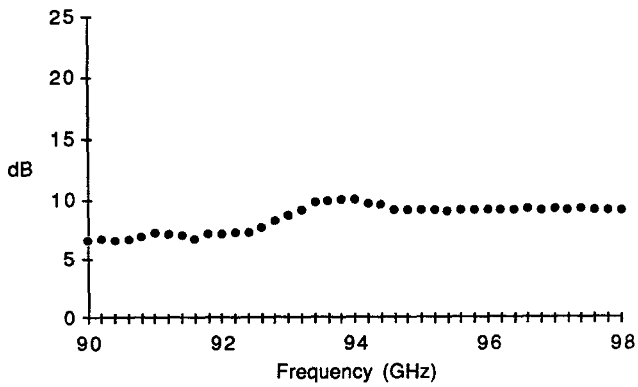

FIG. 9 Isotropic conversion loss of the broadband 94 GHz quasioptical mixer.

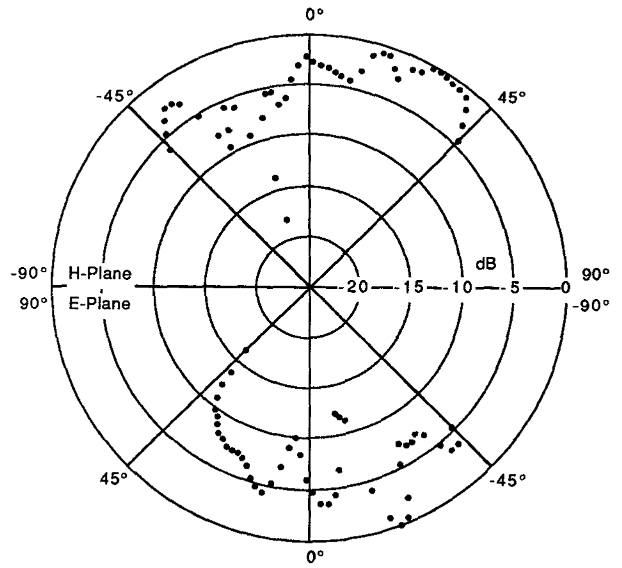

FIG. 10 Radiation pattern of 94 GHz quasi-optical mixer, showing effects of waveguide flanges.