MILLIMETER WAVE MULTIPLEXER WITH PRINTED CIRCUIT ELEMENTS FOR THE 88 TO 100 GHZ FREQUENCY RANGE

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ABSTRACT

An 88 to 100 GHz contiguous triplexer that uses printed circuit elements has been developed and demonstrates the practicality of millimeter wave multiplexers. The triplexer is composed of an E-plane, 7-pole, dual band-pass filter, a common junction diplexer and two H-plane quadrature hybrids. The filter and hybrid circuit elements are printed on metal cards. This multiplexer technology is extendible to 140 GHz.

INTRODUCTION

There is an emerging need for high performance multiplexers for millimeter wave channelized receivers. The practicality of such receivers has been advanced with the development of an 88 to 100 GHz contiguous triplexer that uses printed circuit elements. The triplexer demonstrates that high quality performance, simple fabrication and assembly, small size and low cost can be achieved at millimeter wavelengths.

DISCUSSION

The configuration of the 88 to 100 GHz triplexer is shown in Figure 1. It consists of a hybrid coupled dual band-pass filter that passes the 92 to 96 GHz portion of the input frequency band and a common junction diplexer for separation of the remaining band into the 88 to 92 GHz and 96 to 100 GHz channels. This sequence of channel dropping provided a 4 GHz guard band between the channels to be seprated in the common junction diplexer and thereby minimized channel interaction effects.

The work to be reported with the 88 to 100 GHz triplexer both enhances and extends previously reported multiplexer results in the 26 to 60 GHz range (ref. 1 to 4) in which cascaded sections of printed element, hybrid coupled filters were used for the channelization process. The present work extends multiplexer realization to 100 GHz, and includes the development of a common junction diplexer that provides a means to simplify multiplexer construction and reduce its size for the channelization process. The common junction diplexer is used in combination with hybrid coupled filters. This approach is advantageous in the millimeter waveguide bands where a large number of channels may be involved. As compared to multiplexing by use of only hybrid coupled filters, the combined approach provides for smaller size and lower channel loss by eliminating many hybrids. This multiplexer technology is also significantly less mechanically complex and less costly then a waveguide cavity type millimeter wave multiplexer that has been reported (ref. 6). Performance characteristics of the multiplexer technology over a temperature range of -54 to +95°C will also be reported.

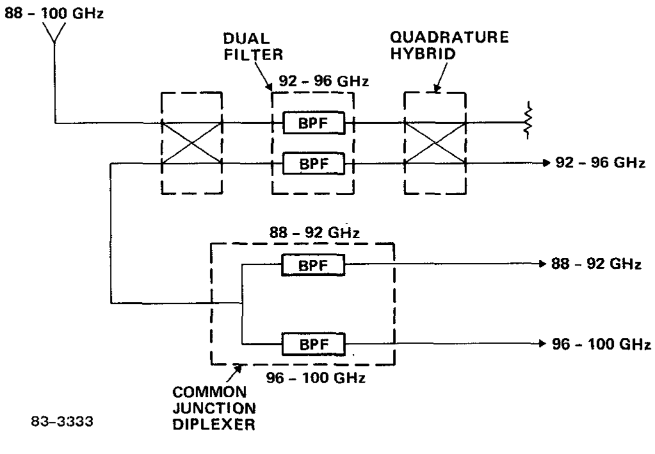

Figure 1. Block Diagram of Printed Element 88 to 100 GHz Triplexer

The triplexer shown in Figure 1 used E-plane filters and H-plane (broadwall) qudrature hybrids couplers. The band-pass filters were printed on 1 mil thick copper cards and were designed for 7-pole, 0.1 dB ripple Tchebycheff response. The design follows the procedure described in ref. 2 which is based on Knoishi's model (ref. 5). The all metal printed cards offers about 50 percent higher Q than a metal clad dielectric backed card (ref. 7) and was a key factor in maintaining low passband loss (1 dB) at 100 GHz. The hybrid was printed on a 3-mil thick copper card and consisted of a 2 x 10 array of coupling apertures.

The filter and hybrid cards were printed by standard photolithographic and chemical etching techniques. Typical printed filter and hybrid cards, from batch processed sheets, that were used in the millimeter triplexer are shown in the right side of Figure 2. Filter and hybrid cards used in

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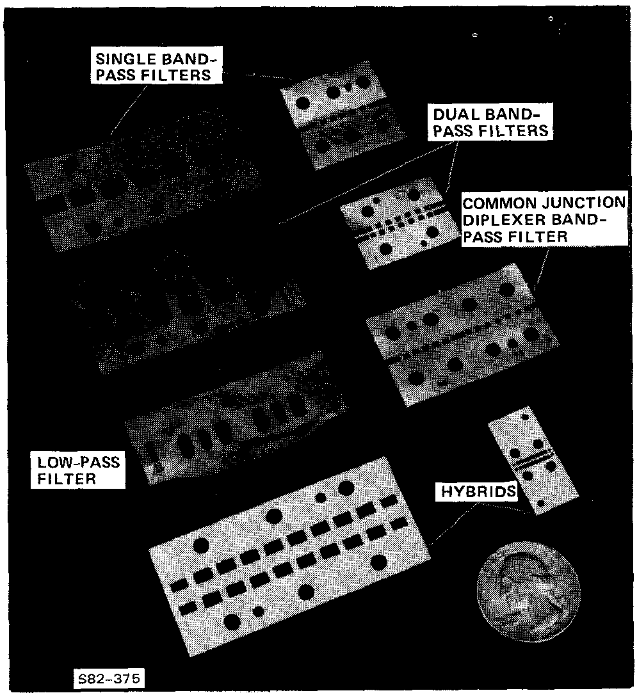

Figure 2. Typical Printed Filter and Hybrid Cards for Microwave and Millimeter Band Multiplexers

a K-band (18 to 26 GHz) multiplexer are shown in the left side of the figure. This figure illustrates the broad frequency range (18 to 100 GHz) over which this technology has been used and the relative size of the filter and hybrid elements at microwave and millimeter wavelengths. Our experience has shown that filters can be realized with smaller size in the microwave region by use of other transmission mediums, such as suspended substrate stripline, but with a tradeoff on performance. Comparative measurements in Ka-band (26 to 40 GHz) of E-plane and suspended substrate filters showed that suspended substrate filters exhibited approximately 0.4 dB higher passband loss and 50 percent higher frequency/temperature sensitivity ($\pm$18 ppm/°C). Dimensional constraints and mode problems make transmission mediums such as suspended substrate stripline impractical for filters and hybrids in W-band (75 to 110 GHz). However, the all metal E-plane filters and H-plane hybrids have remained a viable approach through the microwave region and have exhibited mode free, high quality performance and fabrication simplicity to 100 GHz. Based on the results obtained with the triplexer, it is projected that this multiplexer technology is usable to 140 GHz.

Beryllium copper was used for the K- and Ka-band filter and hybrid cards, but pure copper was used for the millimeter triplexer cards because of its lower dissipative loss. Triplexer filter cards fabricated from beryllium copper exhibited 0.8 dB higher loss than cards fabricated from pure copper. The 92 to 96 GHz dual band-pass filter element shown in Figure 1 was printed on a common card and was assembled in a housing with a common broadwall. A dual filter assembly is shown in Figure 3. The filter card is self jigging on dowel pins in the housing. The simple mechanical form, fabrication and assembly at millimeter wavelengths is noteworthy. The quadrature hybrid and common junction diplexer were of similar constructional form. The hybrid was one half the volume of the dual filter assembly shown in Figure 3. The hybrid was split along the H-plane and its printed card with coupling apertures formed the common broadwall between parallel waveguide sections.

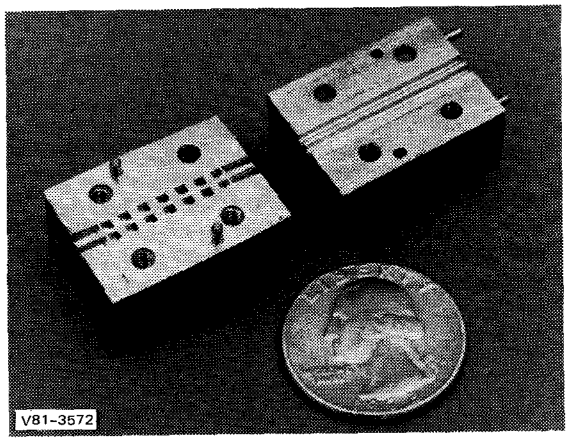

Figure 3. MM Wave Dual Band-Pass Filter

A diagrammatic representation of the common junction diplexer and its filter card is shown in Figure 4. A printed filter card is shown in Figure 2. The filter card contains two 7-pole band-bass filters that are suitably spaced from each other to minimize their interaction.

The performance of the band-pass filters is typified by the measured performance of a 96 to 100 GHz filter shown in Figure 5. The average midband insertion loss was 1 db and return loss was 15 to 30 dB over the 4 GHz passband. Out of band rejection was greater than 40 dB to the measurement frequency limits of 90 to 104 GHz.

The swept response of the triplexer over the 91 to 104 GHz frequency limits of a sweep generator is shown in Figure 6. The average passband loss was 2 dB in the 92 to 96 GHz channel, which is the combined loss of the dual filter (1 dB) and the input and output hybrids (0.5 dB/hybrid). The average passband loss of the 96 to 100 GHz channel was 2.5 dB which comprises the loss of the common junction diplexer and two passes through the input hybrid. Channel response in the 88 to 92 GHz band is not shown in Figure 6 due to sweeper limitations, but its response was similar to that shown for the 96 to 100 GHz channel (complementary common junction diplexer channels).

The fabrication experience and performance obtained with the 88 to 100 GHz triplexer indicate that is is feasible to extend this multiplexer technology to 140 GHz.

Frequency/temperature performance of the triplexer filters has not been measured. However,

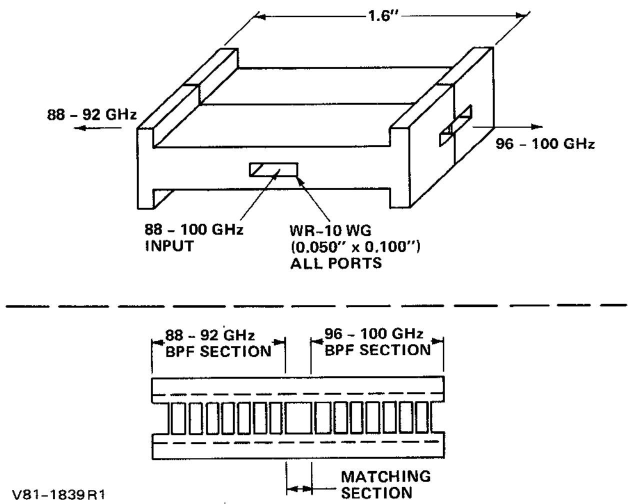

Figure 4. MM Wave Common Junction Diplexer

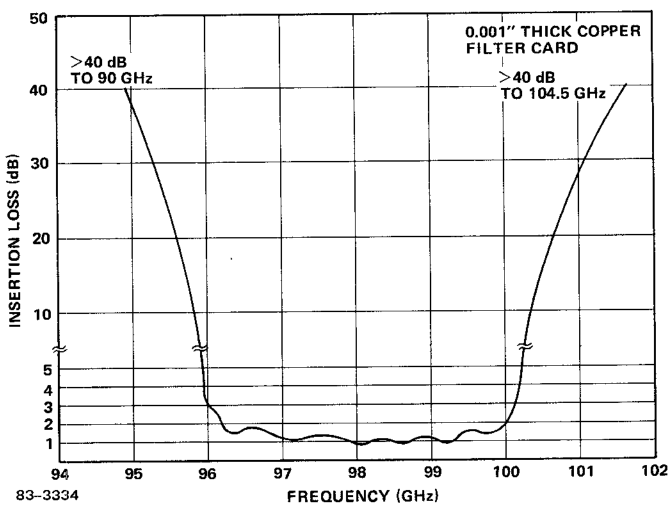

Figure 5. Printed E-plane Band-Pass Filter Measured Performance

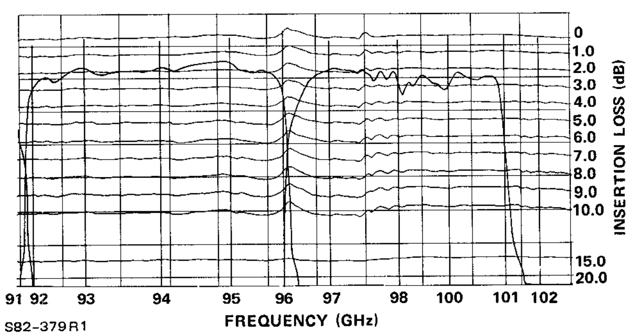

Figure 6. Swept Frequency Response of Millimeter Wave Triplexer

performance should be comparable to the measured performance of printed filters of a similar design for the 18 to 40 GHz range which exhibited a frequency/temperature sensitivity of ±12.5 ppm/°C over a temperature range of -54 to +95°C. Amplitude tracking between individual multiplexers in this lower frequency range was within ±0.3 dB and the variation in crossover frequency between units was within ±25 MHz. The close tracking performance and good frequency/temperature stability was the result of the printing of the multiplexer circuit elements and the absence of any adjustable tuning elements, technology features that were also in the 88 to 100 GHz triplexer.

SUMMARY

The design and performance of an 88 to 100 GHz triplexer has been described. The basic components comprising the triplexer are a common junction diplexer and a hybrid coupled channel dropping filter. The use of printed filter and hybrid circuit elements has reduced multiplexer fabrication to a simple and low-cost level, while providing a high level of performance and small size at millimeter wavelengths. The results obtained indicate that the technology is extendible to 140 GHz. The practicality of channelized receivers at millimeter wavelengths has been advanced by the reported triplexer technology and should have wide application in the emerging needs for receivers in the millimeter bands.

ACKNOWLEDGEMENTS

This work was performed at the Eaton Corporation AIL Division in Melville, NY, under the direction of J. Whelehan and G. Irvin. Technical consultation was provided by J. Taub. Technical assistance was provided by A. Cooley and J. Pfeifer.

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