DESIGN AND PERFORMANCE OF A W-BAND BROADBAND FINLINE DIPLEXER WITH OVER 20 GHz BANDWIDTH

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ABSTRACT

This paper describes the design and performance of a contiguous 90- to 112-GHz diplexer using the integrated finline technique. State-of-the-art results of 1.5 dB insertion losses have been achieved. There is good agreement between the experimental results and those predicted theoretically; these results demonstrate a significant technological advance of millimeter-wave multiplexers using printed circuit techniques. Results of an extremely wideband H-plane tee with a VSWR of less than 1.4 over the full W-band (75 to 110 GHz) are also presented.

INTRODUCTION

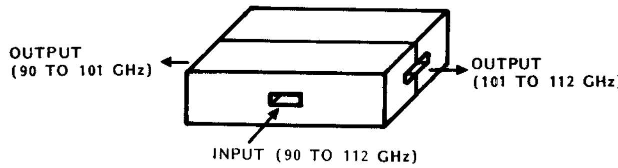
Rapidly increasing activities in millimeter-wave receiver technology have created strong interest in the development of wideband, low cost, low loss diplexers. Recently, a W-band narrowband non-contiguous diplexer with a guard band of 4 GHz was reported(1). Wideband contiguous diplexers are required for most practical channelized downconverters. This paper presents the design and performance of a contiguous broadband diplexer (90 to 112 GHz) using the integrated finline technique. Excellent results have been obtained with insertion losses of 1.5 dB in the 90- to 101-GHz channel, and 1.7 dB in the 101- to 112-GHz channel. The use of printed circuits offers the advantages of light weight, small size, and good reproducibility.

An H-plane tee plays an important role in the diplexer design; the broadband matching of this component has been difficult to achieve, especially at millimeter-wave frequencies. In this paper, an extremely broadband H-plane tee is reported over the 75- to 110-GHz range with more than 15 dB return loss.

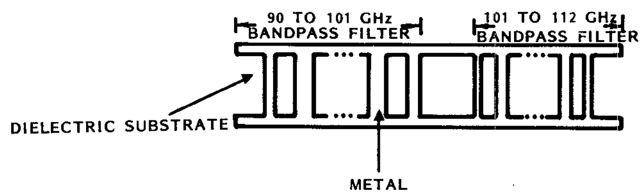
DIPLEXER ANALYSIS

In this section, the scattering matrix for the diplexer will be determined in terms of the S-matrices of individual components based on the multiport connection method(2). The diplexer shown in Figure 1 consists of two finline bandpass filters located in the two sidearms of an H-plane tee. A block diagram of the diplexer is illustrated in Figure 2.

Two-port networks A and B, representing channels A and B, respectively, consist of finline bandpass filters in cascade with waveguides as shown in



(a) H-PLANE TEE



(b) FINLINE BANDPASS FILTER CIRCUIT BOARD

Figure 1. Finline diplexer.

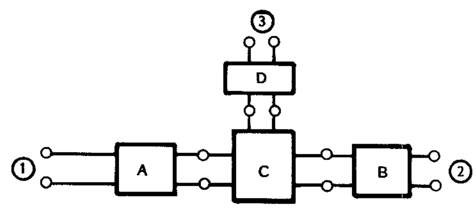


Figure 2. Block diagram of diplexer.

Figure 3. $A_1(B_1)$ and $A_2(B_2)$ are dielectric-slab-loaded waveguides of lengths $\theta_{A1}(\theta_{B1})$ and $\theta_{A2}(\theta_{B2})$, respectively. $A_3(B_3)$ and $A_4(B_4)$ are empty or dielectric-slab-loaded waveguides of lengths $\theta_{A3}(\theta_{B3})$ and $\theta_{A4}(\theta_{B4})$, respectively, and $F_A(F_B)$ is a finline bandpass filter, characterized by a scattering matrix $S^{F_A}(S^{F_B})$. The analyses of these filters are well established(3,4). Three-port component C, characterized by a scattering matrix S^C, stands for an H-plane tee-junction, and two-port component D, characterized by S^D, represents the main waveguide of length θ_D. The scattering matrix of the two-port component K (K stands for A or B) is given by

$$S^K = \begin{bmatrix} S_{11}^{F_K}\, e^{-2j(\theta_{K1}+\theta_{K3})} & S_{12}^{F_K}\, e^{-j(\theta_{K1}+\theta_{K2}+\theta_{K3}+\theta_{K4})} \\ S_{12}^{F_K}\, e^{-j(\theta_{K1}+\theta_{K2}+\theta_{K3}+\theta_{K4})} & S_{11}^{F_K}\, e^{-2j(\theta_{K2}+\theta_{K4})} \end{bmatrix}$$

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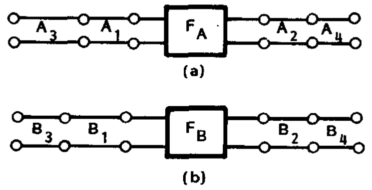

Figure 3. Schematic of (a) network A
(b) network B.

The scattering matrix, S, of the diplexer can now be obtained by applying the multiport connection method(2) to the diplexer network considered in Figure 2, and is given by

$$S = S_{pp} + S_{pc}(\Gamma - S_{cc})^{-1} S_{cp}$$

where

$$S_{pp} = \begin{bmatrix} S_{11}^A & 0 & 0 \\ 0 & S_{22}^B & 0 \\ 0 & 0 & S_{22}^D \end{bmatrix}$$

$$S_{pc} = \begin{bmatrix} S_{12}^A & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{21}^B & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{21}^D \end{bmatrix}$$

$$S_{cp} = \begin{bmatrix} S_{21}^A & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & S_{12}^B & 0 \\ 0 & 0 & S_{12}^D \end{bmatrix}$$

$$S_{cc} = \begin{bmatrix} S_{22}^A & 0 & 0 & 0 & 0 & 0 \\ 0 & S_{11}^C & S_{12}^C & S_{13}^C & 0 & 0 \\ 0 & S_{21}^C & S_{22}^C & S_{23}^C & 0 & 0 \\ 0 & S_{31}^C & S_{32}^C & S_{33}^C & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{11}^B & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{11}^D \end{bmatrix}$$

and

$$\Gamma = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

DIPLEXER DESIGN AND PERFORMANCE

The finline bandpass filters used in the diplexer were seven-pole, 0.1-dB ripple Chebyshev filters, and were realized on a 0.127-mm (0.005-in.) thick Duroid substrate. These filters can be analyzed individually using the technique described in (3). For the H-plane tee, tremendous reflections occur when power is sent toward the junction from any of the three arms because of the severe geometrical discontinuities characterizing each junction. These reflections may be reduced or substantially eliminated by the incorporation within the junction of suitable reactance, such as metal rods or plates. If these tuning elements are disposed in a sufficiently symmetrical manner, the original shunt character of the junction can be preserved. The H-plane tee used in the diplexer has been matched by using a cylindrical post located in a symmetrical plane inside the junction. The measured return losses at the common port and insertion losses from this port to sidearm ports are shown in Figures 4 and 5. In Figure 4, the curves show the return loss at the common port before and after the matching device was added. An insertion loss of 0.5 dB and VSWR of less than 1.4 over the 75- to 110-GHz frequency range have been achieved. It can be seen that an extremely good balance has been obtained for the junction. A cross-section of the matched H-plane tee is illustrated in Figure 6. The same technique can also be used to design very wideband H-plane tees in other frequency bands. The diplexer was constructed using two finline bandpass filters and the H-plane tee. The performance of the diplexer is shown in Figure 7. Insertion losses of 1.5 and 1.7 dB were achieved in the 90- to 101-GHz and 101- to 112-GHz channels, respectively. The measured band-edge frequencies of any channel are within 1 percent of the crossover frequency. Stopband attenuation of more than 25 dB apart from 0.8 and 1.3 percent of the crossover frequency for the higher and lower channels, respectively, has been achieved. Good agreement between the measured and calculated results has also been observed. A photograph of the diplexer is shown in Figure 8.

CONCLUSIONS

The design and performance of a W-band broadband (90 to 112 GHz) finline diplexer have been presented with state-of-the-art results. An extremely wideband (75 to 110 GHz) H-plane tee has also been

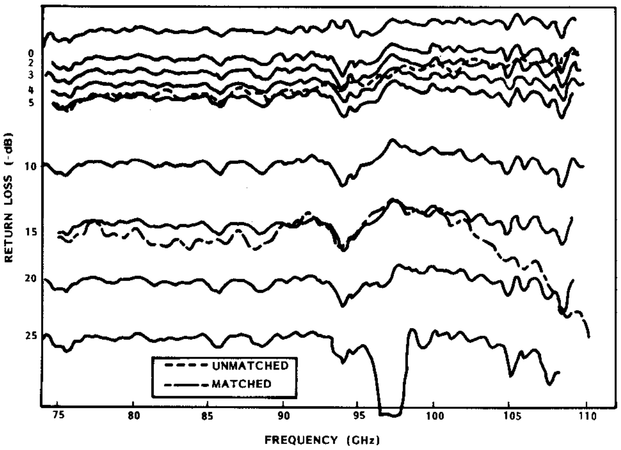

Figure 4. Measured return loss at common port of an H-plane tee.

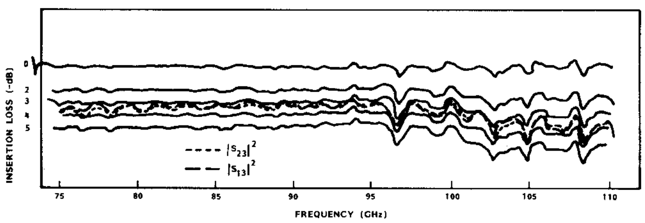

Figure 5. Measured insertion losses from common port to sidearm ports.

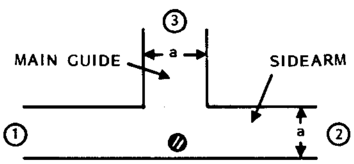

Figure 6. Cross-section of matched H-plane tee.

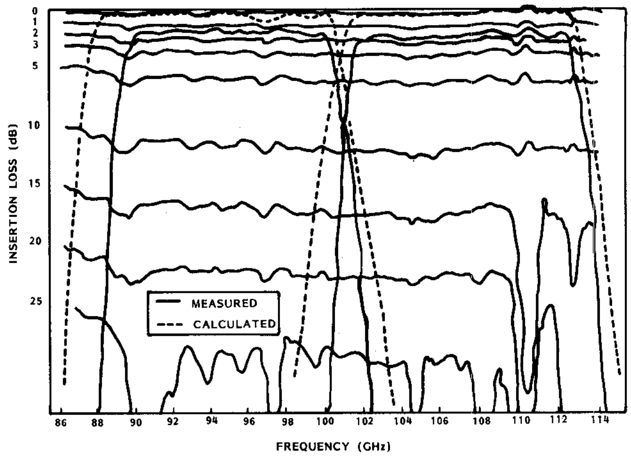

Figure 7. Transmission loss response of diplexer.

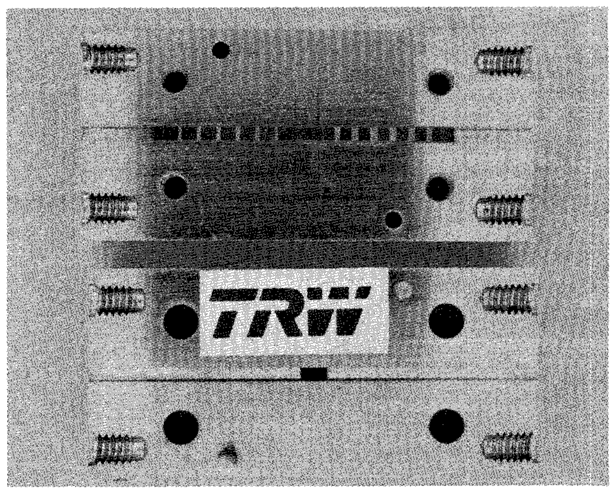

Figure 8. Photograph of diplexer.

developed. The results represent a significant advance in the development of low cost, low loss diplexers. The diplexer together with other high performance broadband components(5) demonstrate the practicality of wideband, high performance, low cost millimeter-wave channelized receivers.

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