TELKOMNIKA, Vol.17, No.2, April 2019, pp.549~554
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v17i2.9205

K-band waveguide T-junction diplexer for satellite communication

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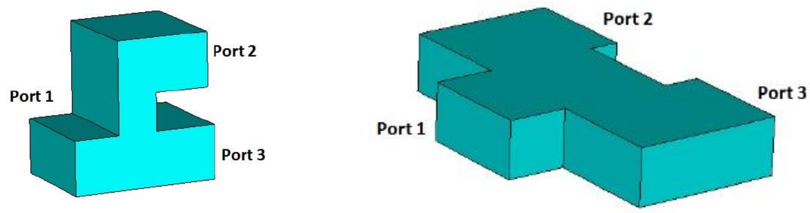
Abstract
Design and measurement of two waveguide diplexers on H-plane T-junction, are presented. The two diplexers structures consist of a waveguide H-plane T-junction and two waveguide obtained cavity filters. The two diplexers operate in the same frequency bands (17 GHz-19.5 GHz). The simulation results show that over the operating band of two filters, the return losses are better than 18 dB and insertion losses are lower than 0.05 dB. The proposed diplexers have been simulated using Mician µ Wave Wizard simulator based on the mode matching method (MMM). The diplexers have been validated experimentally and results are presented. Simulated and measured results show good agreement.

***Keywords**: diplexer, feed subsystems, T-junction, waveguide*

1. Introduction

Diplexers are the most reduced version of multiplexers, which are a combination of several devices: T-junctions and filters e.g. [1-6]. They are widely used in communication satellite applications. Although four filters (Band-pass, high-pass, low-pass, and stop-band [7-12]) have been designed to cover all possibilities of fulfilling specifications, only the two band-pass filters will be diplexed. The reason is that diplexing the other two filters is a more difficult task due to all the spurious responses excited, specially by the low-pass filter, and it is left for a subsequent work.There are two possibilities when deciding the configuration of the diplexer: using H-plane or E-plane junctions as shown in Figure 1 [13-16]. The filters used in both cases are the same: the only thing that changes is how they are placed in the diplexer.

The choise is made considering once again the cutoff frequencies of the different modes of propagation. In a H-plane junction as shown in Figure 1 (b), the width is at least twice the WR-75 width (a). Since cutoff frequency of TE_{10} is inversely proportional to the width, the fundamental mode starts propagating at lower frequencies and so do higher modes e.g. [17-19]. As a result, at the input port of the filters there is a great amount of undesired modes. However, with E-plane structures as shown in Figure 1 (a), the cutoff frequency of the fundamental mode is kept the same, since the width of the junction does not differ from the WR-75. As a result, an H-plane junction is used in the diplexer [20-21].



(a) E-plane (b) H-plane

Figure 1. Three port junction configuration

Received March 8, 2018; Revised November 15, 2019; Accepted December 18, 2019

The most adequate approach is to design the junction separately before joining the filters to obtain the whole structure. Before doing that, the main difficulties or challenges of the diplexer design, putting filters aside, will be explained so that the effort required to obtain a satisfactory response for the diplexer can be contextualized. Thus the common H-plane T-junction as shown in Figure 1 (a) is often used in front-end diplexer designs. Acceptable diplexer performance, however, seems possible only with reduced-Height T-junctions that require matching waveguide transformers to full-height technology at all ports [22-23]. Full-height H-plane junctions, without transformers, have only been used in manifold-type configurations, but they suffer from poor common-port return loss or spurious resonances [24-25]. Therefore, this paper presents the waveguide diplexer with 18 dB reflexion serving two operating bands (17.5 Ghz to 18.1 Ghz) and (18.1 Ghz to 19.1 Ghz). According to this design, a sample diplexer with simulation results is presented, whose out band rejection is more than 30 dB and the insertion loss is lower than 0.05 dB.

2. H-Plane T-Junction Diplexer Design

Two filters have different design requirements that need to be designed separately. Waveguide cavity filters are easy to be designed and fabricated so we chose this method to design the filters to meet the particular passband and rejection spefication demands. For the first filter whose operating band is 17.5 GHz to 18.1 GHz, we design six cavities to achieve the goal of 18 dB reflection and 30 dB out-band rejection. For the second filter has higher operating band of 18.4 GHz to 19.1 GHz we just need to use six cavities to get the same results. In order to make it easy to connect with the T-junction and other waveguide devices, we set the input and output ports of the two filters equal to the standard waveguide port. To finish the design of the diplexer we conbine the proposed H-plane T-junction and the two different filters together for further optimization. After the parameters optimization of the whole geometrie structure, the final 3D view of the diplexer is shown in Figure 2.

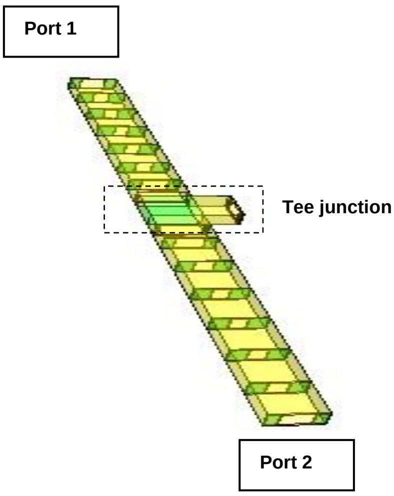


Figure 2. The 3D model of the diplexer

2.1. Simulation Results

The relative bandwidth of the full diplexer is around 2.8%. The filter Tx has a relative bandwidth of 2.53% and the filter Rx has a relative bandwidth of 2.6%. Figure 3 shows the computed optimized frequency response of the diplexer structure. The spefications of the proposed diplexer are given in Table 1. The simulation results of S11, S21, S31, S31, and S32 are shown in Figures 3 and 4, respectively. Filter 1 has a center frequency of 17.5GHz, bandwidth of 500 MHz. Filter 2 has a center frequency of 18.5 GHz, 450 MHz. The isolation between filter 1 and 2 is more tha 60 dB.

Table 1. Diplexer Specifications

Displexer	Specifications
Low-pass filter channel 1 (Tx)	17.45-18.15 GHz
Band-pass filter channel 2 (Rx)	18.45-19.2 GHz
Return losses in port 1 (Tx)	20 dB
Return losses in port 2 (Rx)	18 dB
Insertion losses	0.1 dB
Isolation between the two channels	60 dB

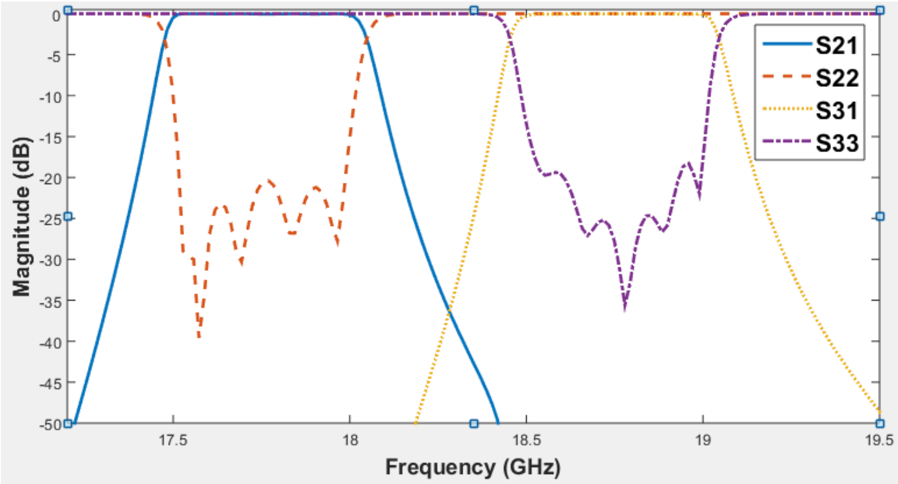


Figure 3. Simulation results of the diplexer's [S]-parameters in mician µwave wizard for K-Band

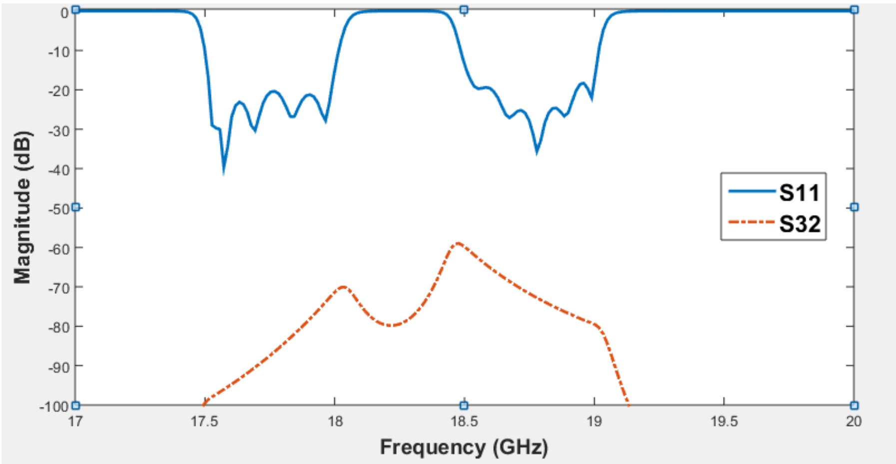


Figure 4. Isolation between two channels (2 and 3) for K-band H-plane T-junction diplexer

3. Design and Fabrication of H-Plane T-Junction Diplexer

3.1. Diplexer Design

The proposed diplexer is composed of two waveguide filters combined with a H-plan T-junction. The Tx-filter whose operating band is 17.5 GHz and 18.1 GHz, we design six cavities to achieve the goal of 18 dB reflection and 30 dB out-band rejection. The second filter has higher operating band ranging from 18.4 GHz to 19.1 GHz. We just need to use six cavities to get the same results. To finish the design of the diplexer we combine the proposed H-plane T-junction and the two different filters together for further optimization. After a slight parameters optimization of the whole structure. Figure 5 presents the 3D model of the proposed K-band H-plane T-junction diplexer.

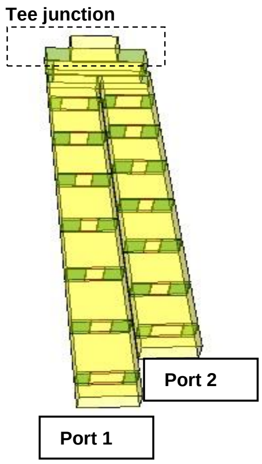


Figure 5. The 3D model of the diplexer

3.2. Simulation Results and Measurement

At the end of work, we will compare results of our diplexer designed be µWave wizard software and fabricated H-plane T-junction diplexer. The insertion losses obtained of 0.1 dB as shown in Figure 6, and the return losses in the order of 23 dB as shown in Figure 7.

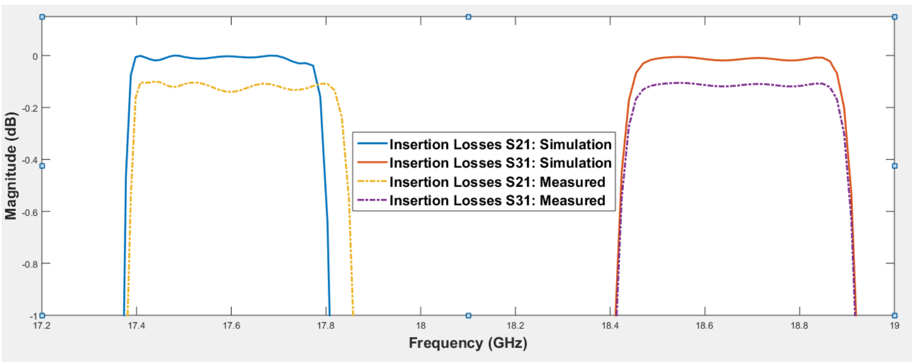


Figure 6. Simulation and measurement results of diplexer's insertion losses for H-plane T-junction diplexer

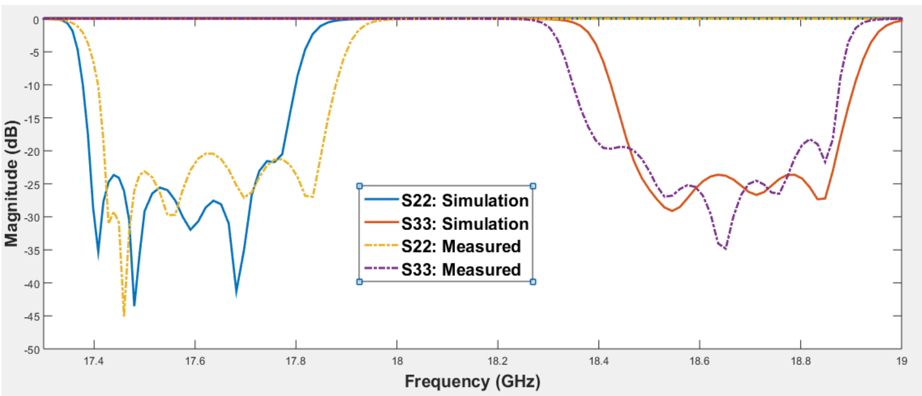


Figure 7. Simulation and measurement results of diplexer's reflexion coefficient for H-plane T-junction diplexer

The isolation between the transmission and reception ports of the H-plane T-junction diplexer is of the order 60 dB in the entire working band as shown in Figure 8.

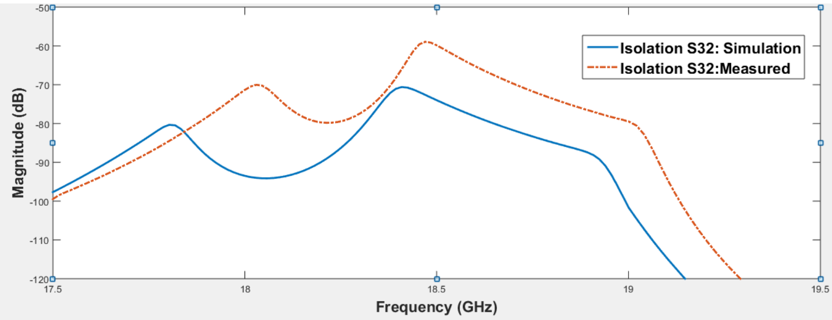


Figure 8. Simulation and measurement results of isolation between two channels (2) and (3) for H-plane T-junction diplexer

Both the simulation and measurement results are presented in Figures 6, 7 and 8 for easiness of comparison. It is clear from that there is good agreement between the simulated and measured results. We observe from the previous results that there is a small difference between the simulation results and the measurement results. We explain this difference by the errors on the variations of the dimensions during manufacture because obtaining a good precision when one goes up in frequency is difficult for the mechanical fabrications.

4. Conclusion

In this paper, the design procedure of two diplexers for K-band system has been presented. The first diplexer contains an H-plane T-junction and the second contains an H-plane T-junction. Finally, a comparaison between two designs has been made. Another comparaison with measurement diplexer has also been made. The return losses obtained are in the order of 23 dB. The insertion losses of 0.1 dB and the isolation between the transmission and reception ports of the E-plane T-junction diplexer are of the order of 60 dB in the entire working band.

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