Design and Manufacture of a Diplexer for K/Ka Band Satellite Applications

H. Setti[*1], A. Tribak[2], A. El Hamichi[1], L. Yechou[2], A. Mediavilla[3]

Abstract— In this paper, a compact diplexer for satellite applications is presented. The diplexer is composed of an E- plane T-junction joined together with two filters based on inductive-iris. The overall bandwidth of the full diplexer is 45%. The filters channel Tx and Rx have a relative bandwidth of 14% and 8.3%, respectively. The insertion losses of the diplexer in the Tx-band [19-23 GHz] and in the Rx-band [29-31.5 GHz] are in the order of 0.1 dB, and the isolation between the two rectangular ports Tx and Rx is approximately 120 dB. A prototype K/Ka-band diplexer has also been fabricated. The measurements and simulations results found by Mician microwave wizard EM software are in very good agreement, that demonstrating the validity and manufacturing robustness of the proposed diplexer.

Index Terms— Diplexer, Waveguide filters, Bandpass filter, Low-pass filter..

1. INTRODUCTION

In satellite communications systems, the performance of diplexers is limited by electrical and mechanical constraints. Accurate automated design is required to avoid the need for any additional adjustment, which limits the maximum transmissible power and increases the cost of the device. From a mechanical point of view, a small size and a small volume are required. Diplexers are widely used for satellite communication systems since they allow the use of the same antenna for several frequency bands [1] - [6], therefore a significant reduction in mass and volume will be required. The success of emerging satellite communications systems for multimedia systems and broadband high-speed Internet access critically depends on the availability of cost-effective consumer terminals. The key elements for these terminals are subsystems and RF/Microwave components. One of the most critical components is the diplexer, which allows the use of a single antenna power supply to accomplish the transmission and reception function. A diplexer is a common device in communications systems, which divides a composite signal into its components to allow each part to be transmitted separately .

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The waveguide diplexers essentially consist of a three port junction closed by two filters, which select the Rx in port 1 and the Tx in port 2, while port 3 is the port of the antenna, according to figure 1.

For the best use of the junction in the realization of the diplexers, the port 3 must respectively be well matched with the ports 1 and 2 dedicated to Tx and Rx bands, respectively [7], [8]

In this paper, we present the design and realization of the diplexer based on a broadband E-plane T-junction in millimetric rectangular waveguide technology of high precision and lower cost. Two novel waveguide filters are utilized to design a compact diplexer. The first one is the low-pass filter that meets the K-transmission requirements, and the second one is a bandpass filter covering Ka-reception requirements. The diplexers are implemented in rectangular waveguide technology since, in comparison with other alternative solutions, it provides several advantages.

2. DIPLEXER DESIGN

In follows, we present the design of the diplexer based on a broadband E-plane T-junction in millimetric rectangular waveguide technology of high precision and lower cost. The main characteristic of the diplexer is the adaptation of the junction to three ports and especially the bandwidth reached.

The proposed diplexer consists essentially of an E-plane T-junction closed by two iris filters, which selects the signal Rx in the port 1 and the signal Tx in the port 2, while the port 3 is the commun port.

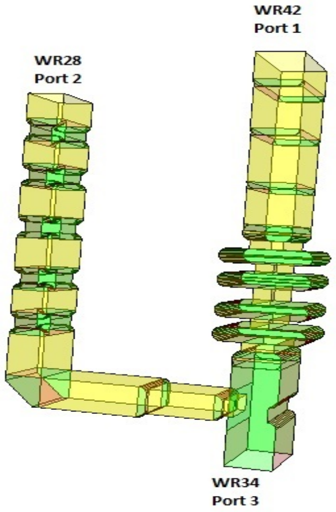


Fig.1. Diplexer based on the E-plane T-junction associated to two filters.

Figure 1 shows an internal view of the complete diplexer. As access to the diplexer ports, we used the rectangular waveguide WR42 in the low band Tx and WR28 in the high band Rx, and for the common port we used the standard rectangular waveguide WR34.

The duplexer is mainly composed of E-plane T-junction, filter Rx, and filter Tx. The filter Rx and filter Tx are different frequency (low-pass and band-pass) filter. Two filters connected with junction to form a compact waveguide duplexer. Filter Rx center frequency of 21 GHz, the fractional bandwidth of 8.3%; Filter Tx center frequency of 30 GHz, the fractional bandwidth of 14%. In-band insertion loss is less than 0.5 dB.

The design procedure of the diplexer can be summarized in four steps: 1) Design of Low-pass filter function, 2) Design of bandpass filter function, 3) Design of E plane T-Junction, and 4) Combination of these three previous components and optimization process.

Figures 2 and 3 show an internal view and the dispersion parameters of two filters respectively. The two filters are well adapted, have return losses of the order of 40 dB in the case of the low band and 30 dB in the high band and insertion losses of the order of 0.05 dB in both bands. For the two Tx and Rx channels to come out on the same plane, we used a 90º E-plane bend with small bends that has a return loss of around 42dB and an impedance transformer at the output of the Rx low band filter for the final output of the Rx to be in standard waveguide WR28.

The device was designed and optimized using the conventional modal adaptation and FEM approach integrated into the Mician µwave wizard simulator.

The transmission filter of the diplexer must meet several constraints. It must allow the rejection of adjacent frequencies so as not to disturb the reception channel as little as possible. In addition, it must eliminate neighboring harmonic frequencies generated by the amplifiers so as not to interfere with the neighboring reception systems and thus meet the standards in force. As far as the reception chain is concerned, the duplexer's Rx filter must also satisfy antagonistic constraints: low loss, strong rejection.

*2.*1 Low-pass filter Function

The figure 2 presents the 3D view and S-parameters results of designed Low-pass filter in K-band. The filter is analyzed, designed, and simulated using Mician Microwave Wizard. This filter is designed for 8.3% bandwidth at 21 GHz.

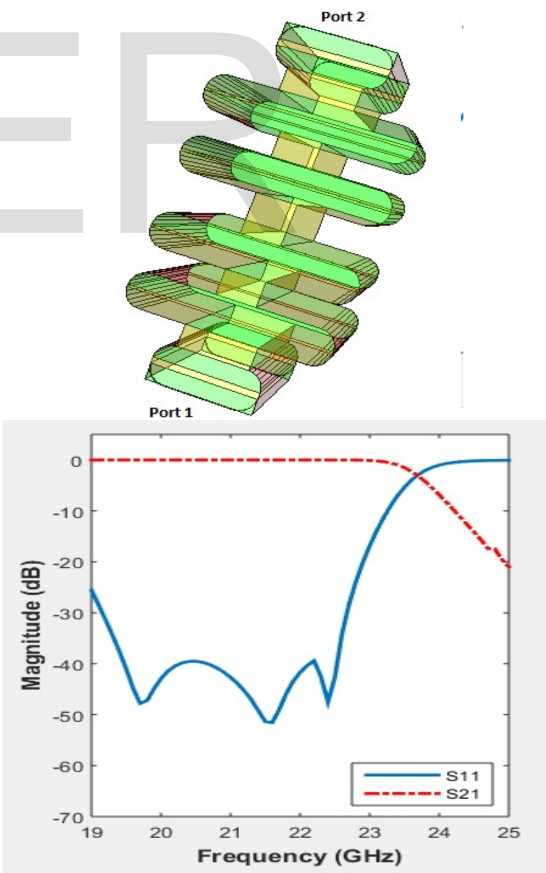


Fig.2. 3D view of Low-pass filter channel 1 (Tx)

2.4 Bandpass filter function

The layout and S-parameters of the channel for the higher band are presented in fig. 3. This filter has 14% bandwidth at 30 GHz.

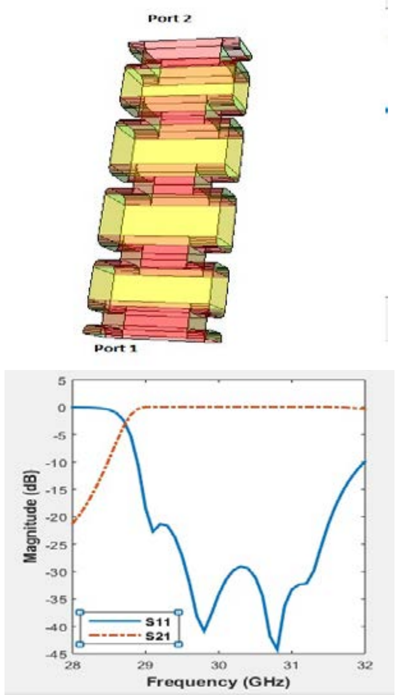


Fig.3. Band-pass filter channel 2 (Rx)

After designing two channels filter, the E plane T-junction is designed and analyzed. The optimization steps in the design of the diplexer are carried out by employing the Mician software which saves a tremendous amount of time .

The main characteristic of the diplexer is the matching of the junction to three ports and especially the bandwidth reached. Fig. 4 shows a 3D view of this junction, which is an E-plane T-junction with a scattering element located in the base of the junction to obtain a good matching.

The good adaptation of the different ports is obtained due to the scattering element located at input of the E-plane T-junction, as presented in Fig.4.

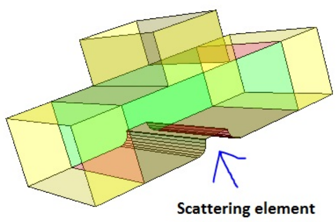


Fig. 4. 3D of E-plan T-junction view

The device was designed and optimized using the conventional modal adaptation and FEM approach integrated into the Mician µWave wizard simulator .

The transmission filter of the diplexer must meet several constraints. It must allow the rejection of adjacent frequencies so as not to disturb the reception channel as little as possible. In addition, it must eliminate neighboring harmonic frequencies generated by the amplifiers so as not to interfere with the neighboring reception systems and thus meet the standards in force. As far as the reception chain is concerned, the diplexer's Rx filter must also satisfy antagonistic constraints: low losses, high rejection, and others electrical and mechanical cretirias. The E plane T-junction is connected to filter Rx and filter Tx to consist a waveguide duplexer. Fig. 1 depicts the layout of the final diplexer. Through the simulation, the final parameters of duplexer need to be adjusted using optimization process in order to achieve the desired results.

3. FABRICATION AND MEASUREMENTS

According to the dimensions of the simulation design, the duplexer model is processing production. Assembled duplexer object as shown in figures 5.

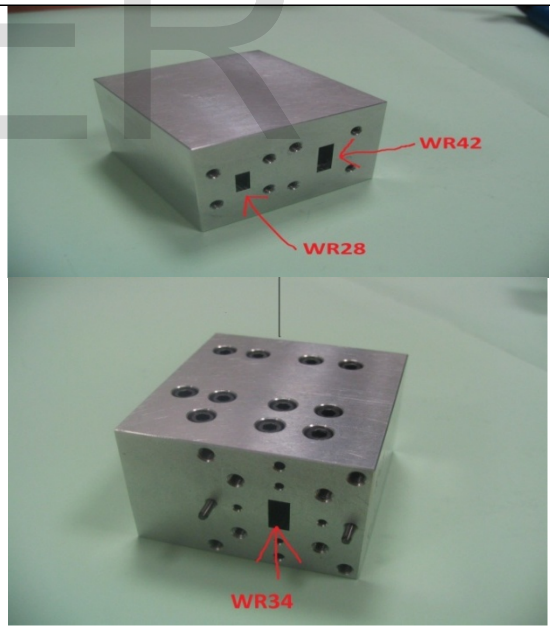


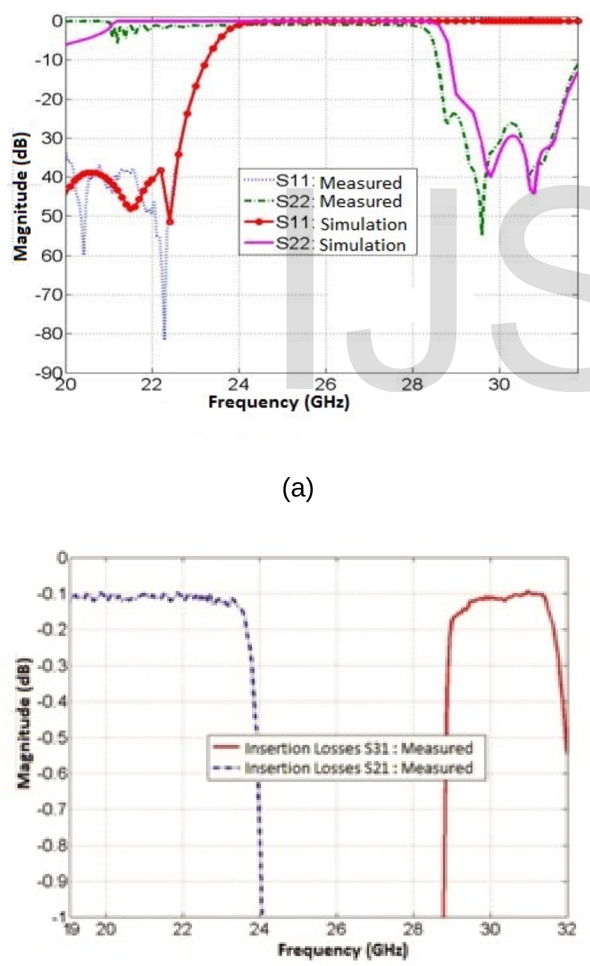
Fig.5. Photograph of the fabricated diplexer

The fabricated prototype of the diplexer for K/Ka band is shown in fig. 5. The measurements have been carried out in the [19–32 GHz] band. Fig. 6 and fig. 7 show the measurements of reflection and transmission coefficients for both frequency bands (Tx [19-23GHz]; Rx [29-31.5GHz]), as well as isolation. The amplitude of the reflection coefficient (return losses) measured in port 1 Tx is around 40 dB and in port 2 Rx is around 30 dB, the insertion losses of the diplexer in the Tx band and in the Rx band are in the order of 0.1 dB. The isolation between the two rectangular ports Tx and Rx is about 120 dB. The diplexer specifications are shown in the table 1.

TABLE 1
DIPLEXER SPECIFICATIONS

Low-pass filter channel 1(Tx)	18-23.8GHz
Band-pass filter channel 2(Rx)	28.8-32GHz
Return Losses in port 1 (Tx)	40 dB
Return Losses in port 2 (Rx)	30 dB
Insertion Losses	0.1 dB
Isolation between the two chennels	120 dB

2.4.3



(a)

(b)

Fig. 6. Reflection and transmission coefficients of the diplexer in the two frequency bands of (Tx / Rx). (a) reflexion coefficient. (b) Insertion losses.

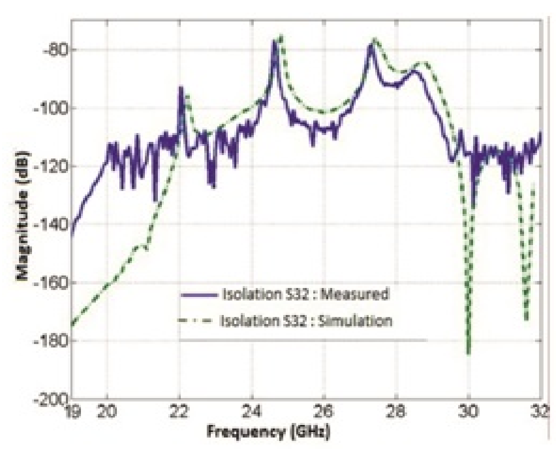


Fig. 7. Isolation between the two channels of the diplexer.

In addition, the tolerance of the mechanical manufacturing has been taken into account in the design phase, for this we have been interested in the sensitivity of the diplexer in the two frequency bands of interest (Tx / Rx) by varying slightly the dimensions of the geometry of ± 0.05mm.

Mechanical fabrication of the diplexer has been done in parts. The first part consists of the E plane T-junction plus the low-pass filter channel which are divided into two blocks according to their horizontal half-plane. The second part contains only the high-pass filter which has been manufactured as an independent body, and it is then screwed to the main body formed by the two blocks of the first part. The measurement results are in good agreement with simulation one, as shown in figs. 6 and 7.

4. CONCLUSION

In this paper, a very compact diplexer for K/Ka bands has been presented, based on filtering structure. The proposed diplexer is designed by combining low-pass and bandpass responses. The designed diplexer benefit from this very compact size, which makes it especially attractive for satellite applications, where compact hardware is nedded to reduce mass and volume. A high performances wideband K/Ka band prototype has been manufactured in clam-shell configuration demonstrating the validity of the novel diplexer configuration. Finally, the very close agreement achieved between simulations and measurement fully validates the novel diplexer configuration proposed in this paper.

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