Cross-band microstrip diplexer design

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ABSTRACT

A large span ultra-broadband microstrip planar structured diplexer are presented. Firstly, this paper describes the general steps for designing filters based on the synthesis of N+2 coupling matrices, based on microstrip lines. Secondly, this paper implements a dual-way frequency combing of C and X band satellite downlink signal based on a cross-finger filter structure and a microstrip T-junction. Finally, the diplexer was tested for practical processing. The diplexer operates in the frequency range of 3.7GHz-4.2GHz and 7.25GHz-7.75GHz, with in-band insertion loss better than 1.6dB and 2.6dB respectively, return loss better than 15.6dB and 15dB respectively, and passband isolation greater than 60dB. The test results are consistent with the simulation results and meet the design specifications

Keywords: diplexer; cross-finger filter; N+2 coupling matrix

1. INTRODUCTION

Microwave diplexers not only perform screening of electromagnetic signals, but can also combine two signals of different frequencies into one or split one signal into two[1]. Compared to waveguide cavity diplexers, microstrip diplexers have the advantages of small size, easy processing, easy integration, easy design, etc[2][3].

The idea of the ultra-wideband microstrip diplexer studied in this paper is to first design a two-channel filter based on the diplexer's specifications, and to design a microstrip cross-finger filter for the C and X bands that meets the specifications using a microstrip cross-finger structure and a filter synthesis method based on an N+2 coupling matrix. The ideal diplexer circuit is then designed by means of circuit synthesis. The filter parameters as well as the phase at both ends of the T-junction are then modified by joint field-circuit simulation. The results are finally optimised by electromagnetic field simulation to complete the design of the microstrip line ultra-wideband diplexer.

2. FILTER DESIGN AND SIMULATION

The function of the ultra-wideband diplexer designed in this paper is to synthesise or split the downlink signals of C and X-band applications for satellite communications. The design specifications are shown in Table 1.

Table 1. diplexer indicators.

Passband Frequency	Isolation	Insertion Loss	Return Loss
3.7-4.2GHz 7.25-7.75GHz	＞50dB	＜3dB	＞15dB

The diplexer indicator is first split to split it into a two-channel filter with the following filter design indicators.

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Table 2. diplexer indicators.

Passband Frequency	Insertion Loss	Return Loss
3.7-4.2GHz	＜2dB	＞18dB
7.25-7.75GHz		

Firstly, the structure of the filter is determined. There are various structures of microstrip line filters: comb line filters, hairpin filters, cross-finger filters, etc. According to the filter index, the cross-finger filter can be selected for the design.After analysis, a 5th order Chebyshev filter is used to achieve this,and according to the conversion relationship between the coupling matrix and the *k*-converter [4], k_{ij} can be obtained.

$$bn = bw / f_0 \quad k_{01} = M_{01} \cdot \sqrt{bn} \quad k_{5L} = M_{5L} \cdot \sqrt{bn} \quad k_{ij} = M_{ij} \cdot bn$$

The microstrip line filter and diplexer designed in this paper uses a Rogers 5880 board with a dielectric constant of 2.2, a dielectric board thickness of 0.508mm, a dielectric copper cladding thickness of 0.035mm, a microstrip line width of 50Ω line width of W=1.525mm and a metallised through-hole radius of r of 0.35mm. Based on the above theory a simulation model is built as shown in Figure 1, with two The structure of the channel filter is the same, with five resonators staggered and grounded through a circular metalised via-hole. The S-parameter curves for the two channels are shown in Fig. 2 .

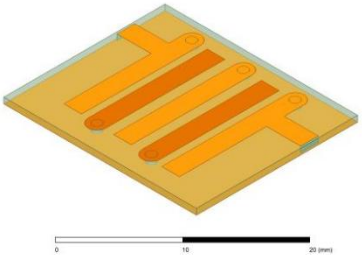

Figure 1. Bandpass filter 3D simulation model

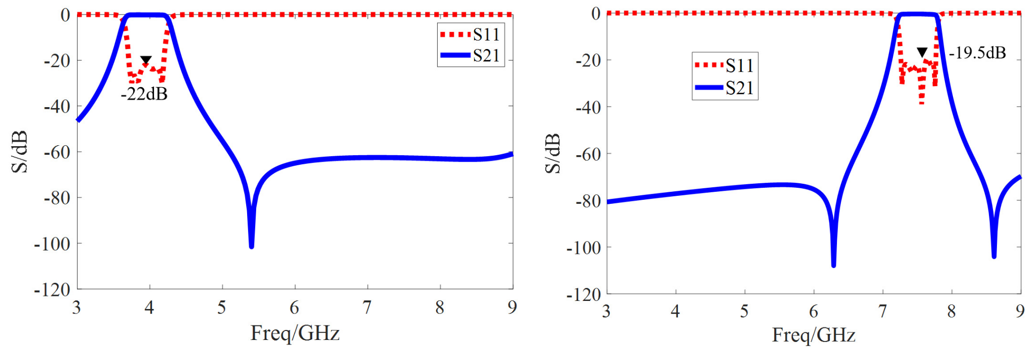

Figure 2. Simulation measurement results of compact SDGR triplexer

As can be seen from Figure 2, the insertion loss of the C-band filter is better than 0.4dB and the return loss is better than 22dB; the insertion loss of the X-band filter is better than 0.76dB and the return loss is better than 19.5dB, meeting the set targets with a margin.

3. DIPLEXER DESIGN AND SIMULATION

If two filters are directly cascaded to design a diplexer, there will be a conductance residual effect at the connection and, due to the mismatch, the two end channels will affect each other, resulting in a significant degradation of the performance of both end channel filters. Therefore, a matching network is required to make the two channel filters well connected, thus eliminating the effect between the two end ports[5]. Figure 3 shows a schematic diagram of the diplexer structure, consisting of two channel filters and a matching network between them.

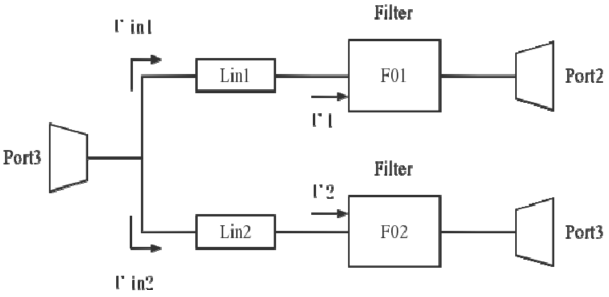

Figure 3. diplexer construction schematic

In accordance with the above theory, the equivalent circuit model of the diplexer is first established, and the ideal diplexer circuit model-level coupling matrix is obtained through circuit simulation. Based on the coupling matrix and circuit model, the overall diplexer simulation model is established as shown in Figure 4. At the beginning of the simulation, the 3D model is modified several times in combination with the comparative duplex time delay method to obtain results that are roughly close to the ideal circuit response curve, and finally combined with HFSS's own optimisation tools, the ideal simulation results can be obtained as shown in Figure 5.

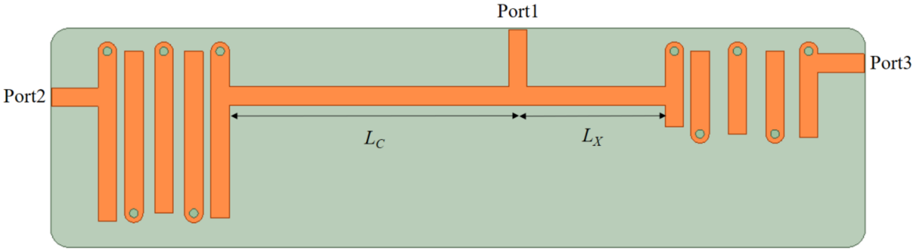

Figure 4. Simulation test results of ultra-wideband triplexer based on suspended microstrip line

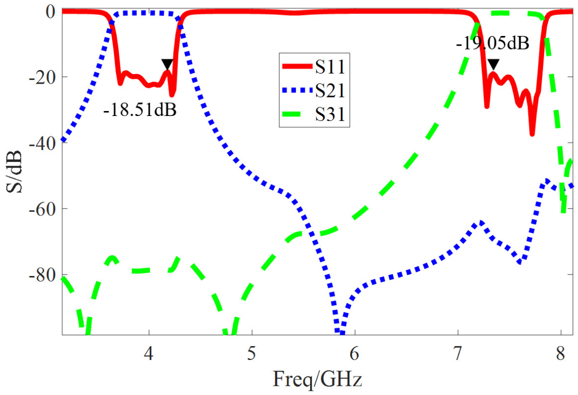

Figure 5. Simulation test results of ultra-wideband triplexer based on suspended microstrip line

As can be seen from the simulation results, the minimum return loss in the diplexer passband is 18.51dB, the maximum insertion loss is 0.99dB and the minimum isolation between passbands is 60.42dB.

4. DIPLEXER MEASUREMENT RESULTS

In order to improve the working stability of the microstrip diplexer, a shielded metal housing with silver-plated aluminium was designed. In order to strengthen the structural solidity and reliability, the dielectric substrate is glued to the metal housing with conductive adhesive, the total length of the microstrip diplexer with the metal housing is 7.82 mm, and the three SMA joints are welded with a hard lap process.

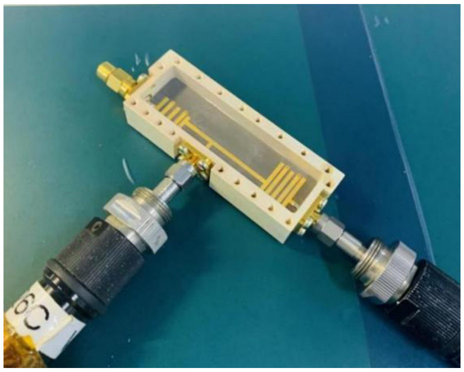

Figure 6. Physical photo of the microstrip diplexer

The test environment was set up and the S-parameters and VSWR were tested by a vector network analyser N5230A. Figure 7 show the physical test results of the low frequency passband and high frequency passband of the microstrip diplexer respectively. Analysis of the test results showed that the X-band passband insertion loss was slightly larger, which was found to be related to the oversized hard lap solder joint of the SMA connector. The passband range of the ultra-wideband microstrip diplexer did not show any deviation, and the indicators met the working requirements of the diplexer, which can verify the correctness of the simulation design.

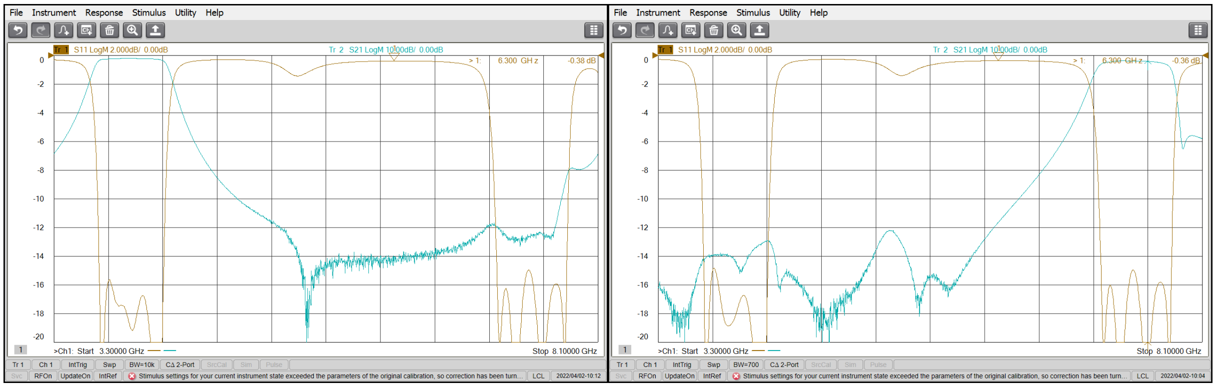

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Figure 7. Measured filter curves

The overall measured results for the microstrip diplexer are shown in Figure 10, where the isolation between the two passbands is greater than 60 dB. Comparing the measured results with the simulated junction, as shown in Figure 8, it can be seen that they are in general agreement.

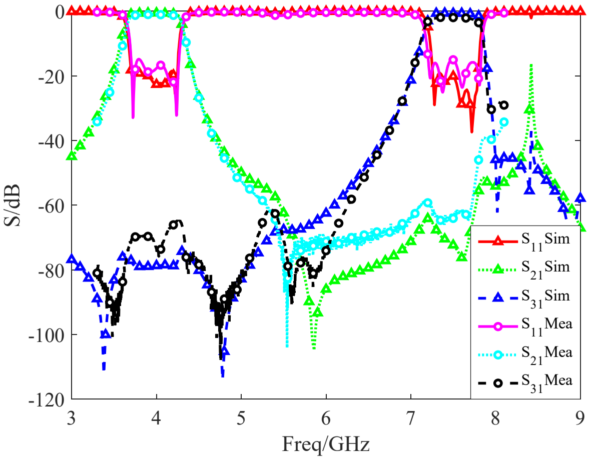

Figure 8. Comparison of simulated and measured results of microstrip diplexers

5. CONCLUSION AND OUTLOOK

Firstly, according to the N+2 coupling matrix synthesis, the coupling matrix of the filter is obtained synthetically, and the two-channel filter is designed by resonant frequency, coupling coefficient simulation through the cross-finger structure to achieve the coupling matrix. Secondly, according to the diplexer theory, the equivalent circuit model is established, and the ideal diplexer circuit response is obtained by optimising the phase and coupling matrix at both ends of the T-junction, and the joint field and circuit simulation is carried out step by step according to the theoretical parameters to determine the physical parameters of the diplexer. The final model is built on HFSS for final optimisation, and the simulation results of the ultra-broadband microstrip diplexer fully meet the specification requirements and have the advantages of large relative bandwidth, high isolation and low insertion loss, providing feasibility for the design of high-performance diplexers. Afterwards, a test environment is built to physically verify the correctness of the theoretical design, and some problems arising from the test are analysed.

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