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A Dual Band Orthomode Transducer in K/Ka Bands for Satellite Communications Applications

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Abstract—This article presents the design, simulation and machining of a dual Orthomode Transducer for feeding antenna using waveguide technology. Linear orthogonal polarizations in common port are separated to single linear polarizations in other ports. This device is developed to work in K and Ka bands and could be exploited in satellite communications applications. Also, it is designed to provide good scattering parameters results experienced with simulation tools and real load laboratory measurement. The designed circuit exhibits important results with return losses less than 25 dB, insertion losses in theory of about 0.05 dB as well as a good isolation of 40 dB in both frequency bands of interest (19.4 GHz–21.8 GHz) and (27 GHz–32 GHz).

1. INTRODUCTION

The demand in terms of using technology and related services is increasing every day, and many applications in satellite communication, space crafts, radars, navigation systems and information sensing require the development of new and performing networks and devices. In microwave field the improvement of bandwidths in a variant band is a main parameter for industry and competitiveness. Some of the most used bands for this are K and Ka bands.

The guidance of the wave in a device is a determining factor in the definition of the used frequency. The general concept of antenna feed networks is based on waveguide technology. To make a microwave subsystem [1], we combine a variety of components and adapt their parameters to guide the wave properly. The most common architecture contains active and passive microwave circuits. Our case of study defines a device used in an antenna feed system which is an orthomode transducer presented in Figure 1. An orthomode transducer also known by polarization diplexers is a passive device that separates or combines signals with orthogonal polarizations within different frequency bands. In the design of broadband OMT, it is suitable to keep symmetry about both input polarizations to avoid generation of higher-order modes. Besides, most architectures which have been planned to answer symmetry conditions [2–7] result in considerable complexity compared with designs which are symmetrical about only one plane. This extra complexity presents an additional constraint to machining. Discussed configurations in literature classifies OMT in narrow-bands, broad-bands [4, 5] and multibands. In this work, we focus on dual bands OMT and describe a device symmetrical about only one plane which can be fabricated as split blocks assembly which requires no polarizing wires or septum.

Based on the new techniques of design and machining [2, 3, 8], performing circuits have been developed at many frequency bands and presented an interesting flexibility in terms of microwave parameters and mechanical constraints. With an accurate device design, simulation and analysis, a circuit was establised to show the estimated behavior of a feed assembly and intermediate components.

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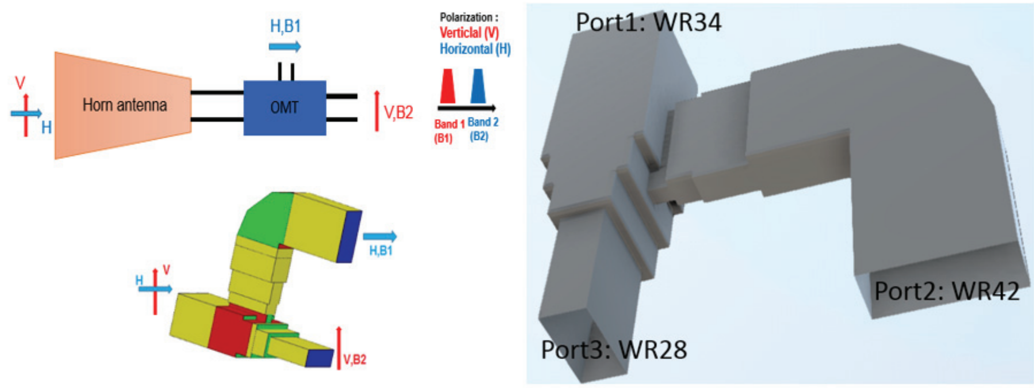

Figure 1. 3D view of designed OMT.

The parts of the device are designed and simulated using the commercial tools MICIAN microwave wizard and CST microwave studio. These tools help in optimization and present a very good agreement with estimated theory and experimental results.

This paper will describe the related concepts of the OMT design, simulation of the behavior by RF tools, mechanical design and comparison of measurements.

2. OMT DESIGN

As Boifot has classified OMTs and waveguides based on symmetry of OMT in [4, 5], we will proceed with analog approach to ensure a dual-band operational behavior for our OMT but only with one symmetry plane. In theory, operational bandwidth of OMT has the constraint to be included between cutoff frequency of fundamental mode in all physical ports and cutoff frequency of the first higher mode. Our OMT is designed as explained: we will refer to the first physical port as the common square waveguide port with orthogonal modes, in which the TE10 mode and TE01 mode are numbers 1 and 2, respectively. Similarly, the axial and branching port will be referred as port 2 and port 3, respectively, in which only the fundamental mode is excited, and they are projected in the same plane to ensure design requirements. Figure 1 describes the OMT structure. In ports 2 and 3 normalized waveguides are used in EIA Standard, for instance WR42 (WG 20 in RCSC designation) for port 2, WR28 (WG 22 in RCSC designation) for port 3 and WR34 for rectangular waveguide in EIA Standard (square WG 21 in RCSC designation) for port 1 with fractional bandwidths (FBW) of 116.5% and 169.5% respectively for bands (19.4 GHz–21.8 GHz) and (27 GHz–32 GHz) and a return losses of 25 dB for the three ports and for both bands.

With Mician Microwave Wizard tool, the OMT is developed using blocs strategy calculating appropriate parameters for each bloc and respecting matching requirement, and the obtained dimensions lead to the design in Figure 1. Using the CAD Design, a typical flowchart is followed as explained in [8]; for and from the given specifications, a model of the OMT is obtained to master the synthesis of the waveguide structure. Next, an initial set of physical dimensions are determined based on simple circuits and/or simplified models. Once the complete physical model is generated, an MM simulation is performed to obtain S-parameters of the structure. The first response of the device using the initial dimensions will be relatively poor most of the time, since the original design did not take into account the higher-order mode interactions among different parts of the structure. Then, the simulated response is compared with the circuit model response, and an error or cost function is computed. Using an optimization routine, the dimensions of the device are adjusted to minimize the cost function. This process is repeated until the desired response is achieved.

The mechanical machining of the OMT is structured into a square box and divided into two spares machined separately. These spares are produced using Electrical Discharge Machining (EDM) also called wire erosion. In this process, a desired shape is obtained by using electrical discharges or sparks, and the material is removed from the workpiece by a series of rapidly recurring current discharges

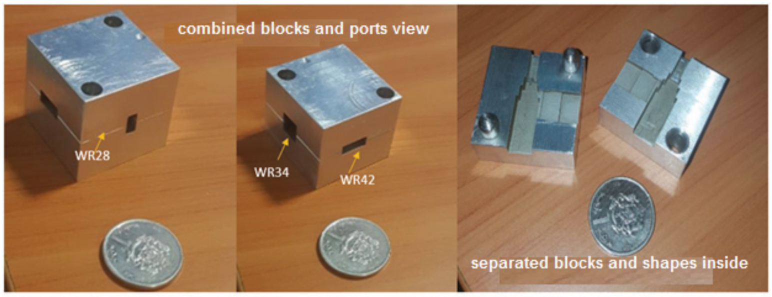

Figure 2. Machined OMT with EDM.

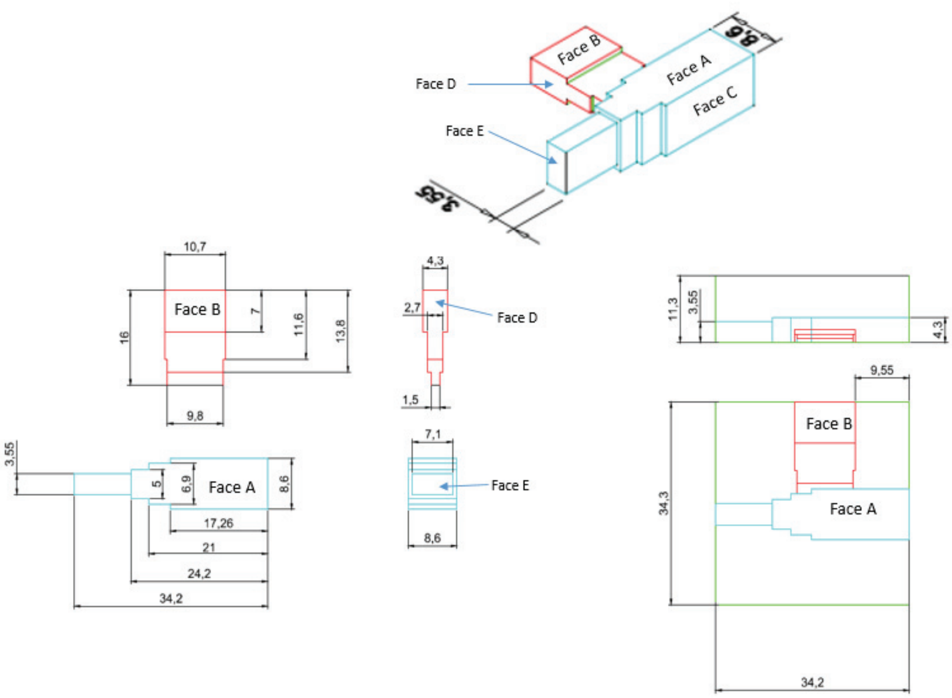

Figure 3. Functional design for the OMT model.

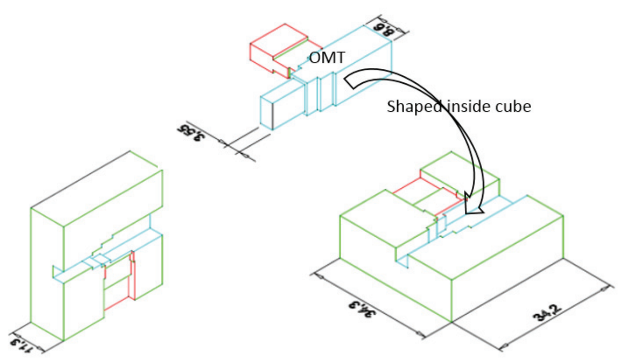

Figure 4. OMT shapes positions in 3D.

between two electrodes separated by a dielectric liquid and subject to an electric voltage. Figures 2, 3 and 4 show respectively the machined blocks and the shaped OMT into the square box and explore the functional design for the OMT model and the shapes positions in 3D.

3. SPECIFICATIONS

Table 1 shows the specifications of the OMT:

Table 1. Specifications of OMT.

Frequency (bands)	(19.4 GHz–21.8 GHz) (band1)	(27 GHz–32 GHz) (band2)
Return Loss	30 dB	30 dB
Insertion Loss	0.05 dB	0.05 dB
Isolation	40 dB	40 dB
Common port	Square Waveguide (dimension $a = 8.6$ mm from Rectangular WR34)	
Axial port	2 Rectangular Waveguides WR28 and WR42	

4. RESULTS AND MEASUREMENT

Using the geometry proposed in Figure 1, an OMT with the specifications of Table 1 is designed. The axial port is matched by using a waveguide transformer. In this case, four different waveguide sections are required. In principle, the bandwidth for the vertical polarization can be enhanced by using more waveguide sections in the transformer without complicating the final fabrication of the device. At the lateral port, the re-entrant stepped dimensions are adjusted to match the horizontal polarization in the desired frequency for wide bands. Moreover, an additional waveguide step is included to raise the matching of the lateral port. The full wave simulations are performed using Mician wave wizard, and to be sure from obtained results, we compare them using CST Microwave Studio for the same structure. The OMT is efficiently analyzed taking in a way that the full-wave analysis of the OMT is reduced to solve different problems for the higher frequency bands. In order to get accurate results, a different adaptive meshing at the desired frequency band is used for each problem.

The OMT is developed to answer the need of antenna feed chain, and it can be combined with a polarizer and other circuits. The choice of dimensions and orientations is derived from a variety of

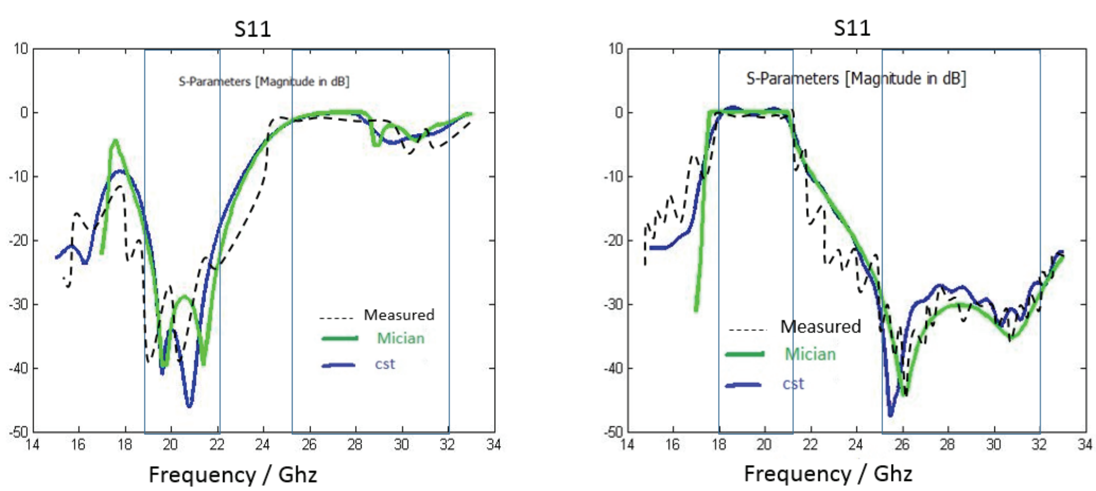

Figure 5. Reflection coefficient S_{11} measured and simulated at both operating bands.

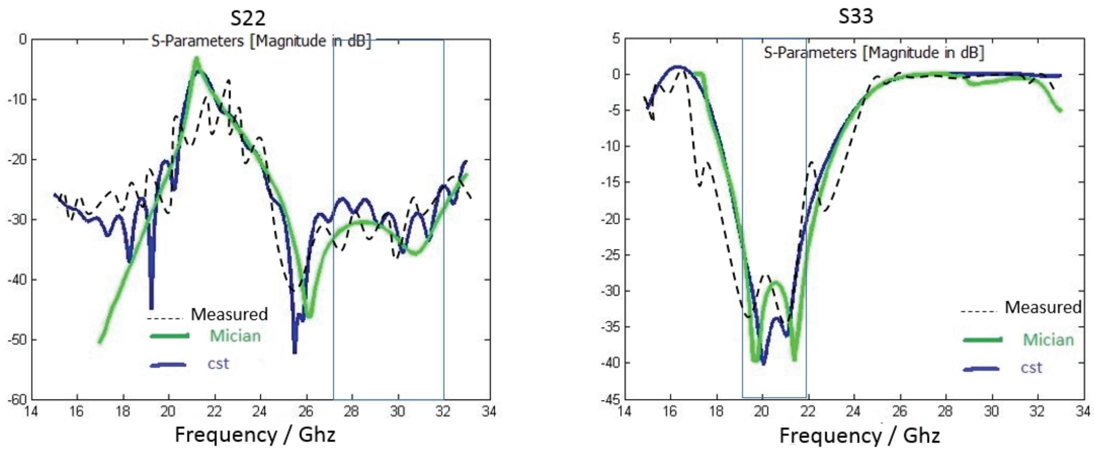

Figure 6. Reflection coefficients S_{22} and S_{33} at both operating bands.

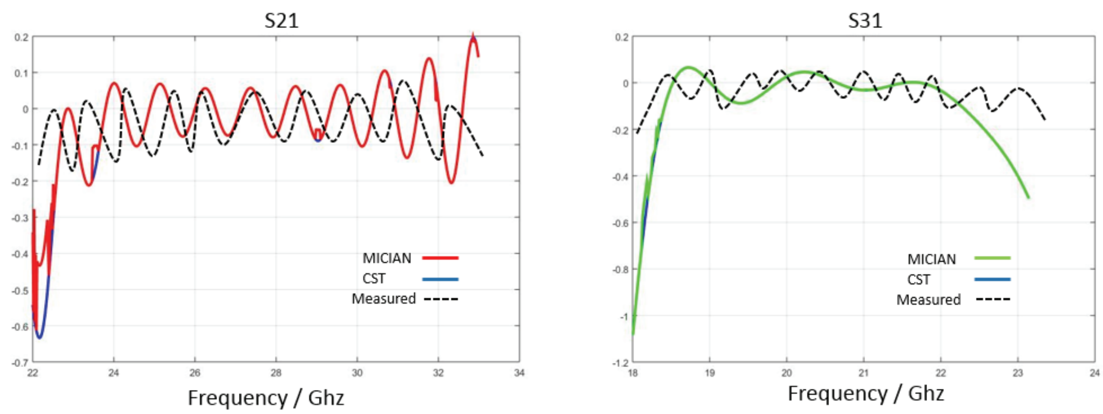

Figure 7. Insertion loss coefficients S_{31} and S_{21}.

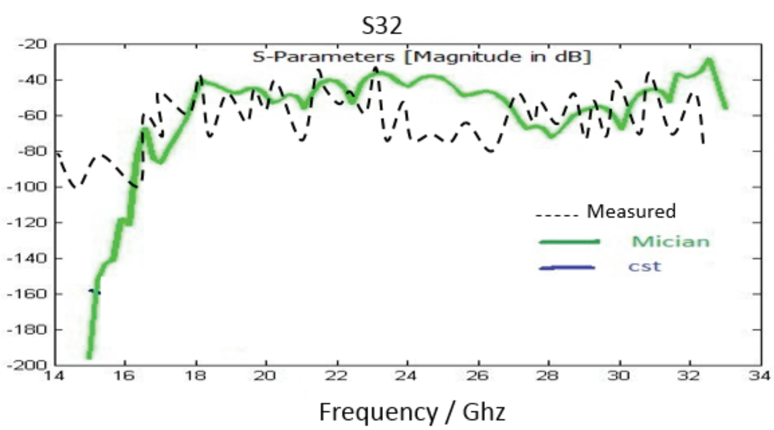

Figure 8. Simulated and measured isolation for all band.

applications in literature [9]. The measurement has been performed with VNA network analyzer, and ATRL calibration is carried out in both frequency bands of interest.

The simulations of the scattering parameters of the OMT are performed for every port with respect of specifications and optimization parameters. In Figure 5, the simulation of reflection coefficient S_{11}

at both operating bands is presented. Return loss for port 1 can be appreciated around 25 dB for the bands (19.4 GHz–21.8 GHz) and (27 GHz–32 GHz), and the same result is obtained for the return loss simulation for ports 2 and 3 presented in Figure 6. In correlation with the analysis of these parameters and modes, it is important to mention other effects of other higher order modes (TE12 in port 2 and TE20 in port 3) that can be excited in the frequency range of the operation bands of the OMT but not in the full range at once. Another parameter which is insertion loss is measured with a value of 0.05 dB in bands of interest as shown in Figure 7.

The isolation, defined as the transmission between the rectangular waveguide single ports, is well in dual bands and presented in Figure 8. The isolation values gap between Mician and CST (value of CST is about 170 dB and not presented in Figure 8) simulation is due to the methods used by every software for calculation, and the one of Mician is considered the reference and is in accordance with experimental results.

5. CONCLUSION

A dual-band OMT for waveguide feed networks has been designed and machined. To be sure from the circuit performances, we did the experiment and took measures of parameters in laboratory. The device compact structure provides return losses better than 25 dB at every waveguide port, an insertion loss about 0.05 dB as well as a good isolation and maintains strong electrical performances and robustness. Moreover, optimized and achieved results through the use of waveguides technology help to develop complete antenna feed for satellite communications and wide fields of applications.

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