A Compact Waveguide Ortho-Mode Transducer for Ku-Band Application

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Abstract— Ortho-mode transducers (OMTs) are key components in both dual-polarized antenna feed systems for telecommunication and radio-astronomy applications. The use of OMT has increased according to the growth of artificial satellites. In this paper, we have designed and developed a compact size, high-performance, single branched, Waveguide Ortho-Mode Transducer (OMT), operating in 17.0 - 17.25 GHz frequency band. Designed OMT has 3 physical ports but electrically it is a 4 port device. The square port of OMT supports two signals (modes) of same frequency, but polarizations are orthogonal. Achieved simulation return loss of both modes better than -15 dB and isolation is better than -60dB. Fabricated the OMT using CNC milling machine and measured all electrical parameters using Vector network Analyzer (VNA). Measured return loss is better than -15.0dB for straight arm (V-port) and -11.0dB for side arm (H-port) with an isolation of better than -37.0 dB between the Vertical and Horizontal ports.

Keywords— Ortho-mode transducers (OMTs), High Frequency Structure Simulator (HFSS), Vertical Polarization, Horizontal Polarization.

I. INTRODUCTION

The OMT is a polarization filter which separates orthogonal polarizations in same frequency. Ortho-Mode Transducer also known as the polarization diplexer is a device forming part of an antenna feed system and serving to combine or separate orthogonally polarized signals. Ortho-Mode Transducers are used in dual polarized VSAT (Very Small Aperture Terminal) and Satellite Earth Stations in low density populated areas of the country sides, radar antennas, radiometers and communications links. So instead of using two antennas for receiving two signals we can use only one antenna for receiving two signals by placing them orthogonally in polarization by using Ortho-mode transducer. An Ortho-Mode Transducer (OMT) is a device which separate or combine two independent signals of the orthogonal dominant modes within the same frequency band.

An OMT has three physical ports but electrically, it is a four-port device. The common port, usually square or circular waveguide cross-section, supports two independent signals of orthogonal modes and supplying them to the fundamental mode of the allocated single signal interface ports. An OMT maintained the good match at all electrical ports and high cross-polarization discrimination between the independent signals. The schematic view of an OMT as a four-port device shown in Figure 1.1.

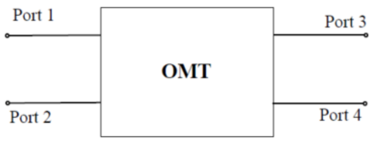

Figure 1. 1: Schematic diagram of an OMT

The common port of square waveguide support two orthogonal TE10 and TE01 modes and circular waveguide support two orthogonal TE11 and TE11* modes that provides two electrical ports. The scattering matrix of an ideal OMT is defined by

$$S = \begin{bmatrix} 0 & 0 & e^{j\emptyset 1} & 0 \\ 0 & 0 & 0 & e^{j\emptyset 2} \\ e^{j\emptyset 1} & 0 & 0 & 0 \\ 0 & e^{j\emptyset 2} & 0 & 0 \end{bmatrix}$$

The key building block of an OMT design is a branching region possessing a square or circular common cross-section, and at least two fundamental-mode junctions of rectangular waveguide. The standard OMT is shown in figure 1.2.

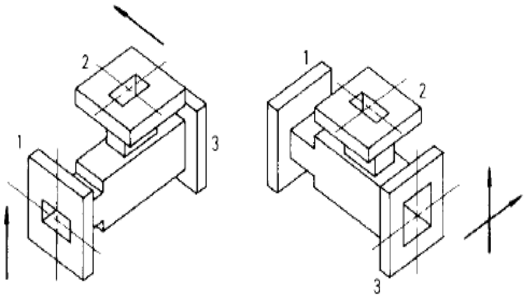

Figure 1. 2: Key building block of an OMT

II. DESIGN AND SIMULATION

A. *Design requirement*

Although the electrical and mechanical requisites of a design in respect to a microwave passive assembly depend on the specific application, the common figure-of-merit of a dual-polarized system are commonly low reflection losses measured through the use of a return loss measurement, high polarization purity related to an isolation, and compactness. Waveguide is best suitable transmission line to build a compact and reliable OMT. Waveguide walls are perfect electric conductor (PEC) so it has low coupling between two output ports. In the design of a waveguide OMT, a square waveguide supporting two orthogonally polarized signal is used as a common waveguide, and two standard rectangular waveguides can be connected to received/transmit two individual signals orthogonally polarized, respectively.

For WR-62,

$$a = 15.748\text{mm}$$

$$b = 7.874\text{mm}$$

For operating centre frequency of 17.125 GHz

$$\lambda_o = 17.5\text{mm}$$

Guide wavelength, λ_g is given by

$$\frac{1}{{\lambda_g}^2} = \frac{1}{{\lambda_o}^2} - \frac{1}{{\lambda_c}^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1.4)$$

$$\lambda_g = 21\text{mm}$$

B. *Simulation*

Modeled the OMT using Ansys 3D structure simulator HFSS is shown in Figure 2.1. The dimensions of straight and side ports are equal to the standard WR-62. The common port is a square having length equal to the broad dimension of standard waveguide WR-62.The OMT length and impedance steps are used a variables and optimized to get desired results.

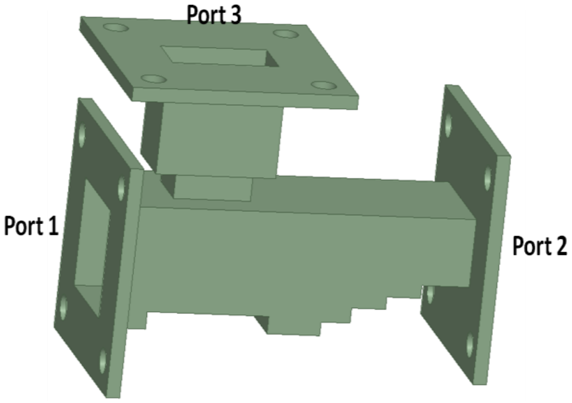

Figure2.1: HFSS Model of OMT

Port P1 is a square waveguide supports two orthogonally polarized TE10 and TE01 modes. Ports P2 and P3 are standard WR-62 waveguide, and both support TE10 dominant modes. Excitation of ports is shown in Figure 2.2.

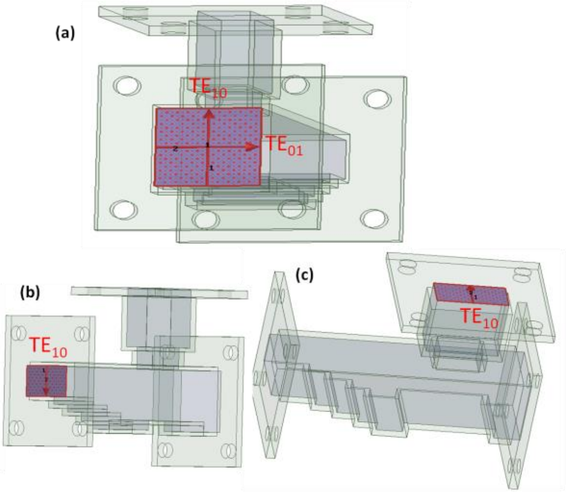

Figure2.2: Excitation of OMT structure designed in 3D EM software HFSS (a) Square waveguide port (b) Straight arm port (c) Side arm port

The simulated S-parameters are shown in Figure2.3. The output E-field vector when straight arm and side arm ports excited are shown in Figure 2.4 and Figure 2.5 respectively. The simulated radiation pattern (2D polar plot) is shown in Figure 2.6.

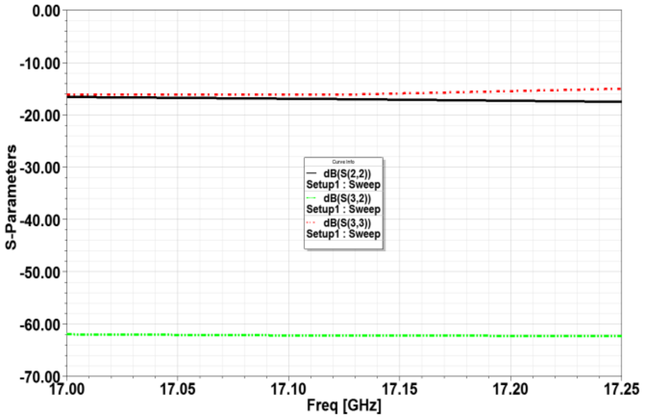

Figure2.3: Simulated S-Parameters (a) S22-Return Loss of straight port (b) S33- Return Loss of side arm (c) S32- Isolation

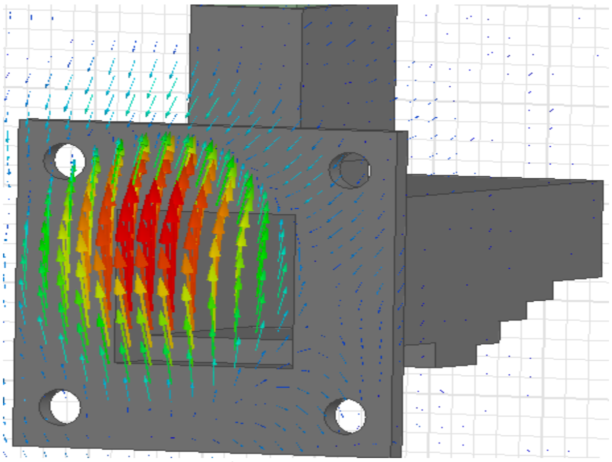

Figure2.4: Output E-field Vector when Straight port excited

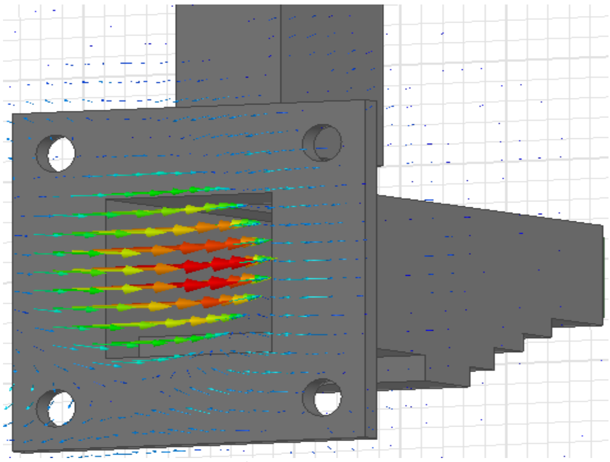

Figure2.5: Output E-field Vector when Side port excited

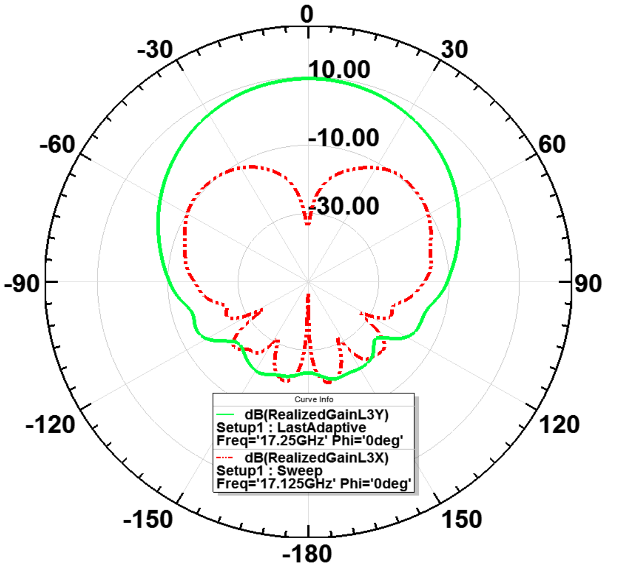

Figure2.6: Simulated Radiation Pattern (a) Co-Polarization (3Y) (b) Cross-Polarization (3X)

III. EXPERIMENTAL RESULTS

The OMT has been fabricated from aluminium in two pieces and joined together using silver epoxy. The fabricated model is shown in Figure 2.7.

Figure 2.7: Fabricated Model of OMT

All measurements of the OMT were performed using a Vector Network analyzer (VNA). The measured return loss of straight (V-port) and side (H-port) ports of the OMT are shown in Figure 2.8 and Figure 2.9 respectively. The isolation between V-port & H-port ports is shown in Figure 2.10.

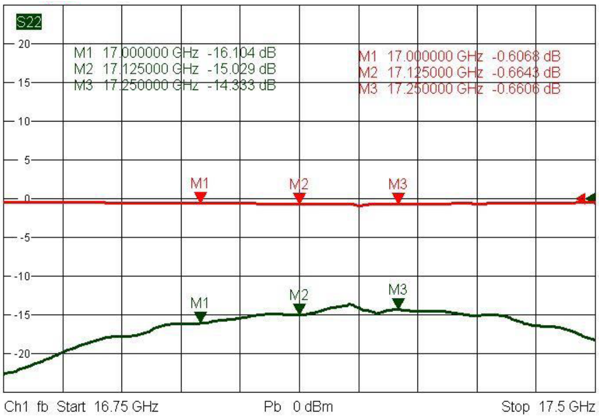

Figure2.8: Measured Return Loss of Straight Port

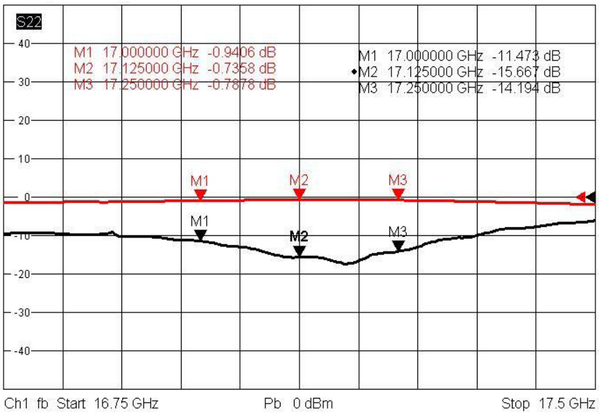

Figure2.9: Measured Return Loss of Side Port

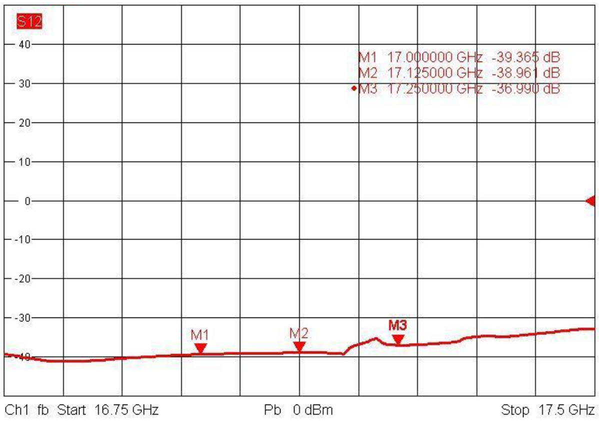

Figure2.10: Measured Isolation between straight and side arms

The comparison between simulated and measured results are shown in Table 2.1. The measured value of isolation is better than -36dB in the band of frequency of operation.

Table2.1: Simulated Vs Measured

Parameters	Simulated result	Measured result
Return Loss (V-port)	-22.5 dB	-15.0 dB
Return Loss (H-port)	-17.0 dB	-11.4 dB
Isolation (V & H ports)	-60.0 dB	-36.99 dB
Insertion Loss (V- V ports)	-0.08 dB	-0.6 dB (including WG-SMA Adaptor)
Insertion Loss (H- H ports)	-0.12 dB	-0.94 dB (including WG-SMA Adaptor)

CONCLUSION

Designed and developed a compact size, high-performance, single branched, Waveguide Ortho-Mode Transducer (OMT), operating in 17.0 - 17.25 GHz frequency band using 3D software HFSS. Achieved simulation return loss of both ports better than -15 dB. Studied about the generation of higher-order modes and impairment of isolation between vertical and horizontal ports of OMT. Achieved isolation is better than -50dB and cross-polarization is better than -30dB using 3D EM s/w HFSS. Fabricated the OMT using CNC milling machine and measured all electrical parameters using Vector network Analyzer (VNA). Measured return loss is better than -15.0dB for straight arm (V-port) and -11.0dB for side arm (H-port) with an isolation of better than -37 dB between the Vertical and Horizontal ports. The degradation of isolation value from simulation to measurement was attributed to fabrication errors as it was machined in two parts and joined using silver epoxy.

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