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Realization of Ku-Band Ortho Mode Transducer with High Port to Port Isolation

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Abstract—Present paper describes the design, development and evaluation of a wideband, compact Ku-band orthomode transducer (OMT) for SATCOM application. It consists of a square waveguide output section, square waveguide to rectangular waveguide transition, straight waveguide port and an orthogonally coupled port. A tapered waveguide section has been used to couple the orthogonal RF (Radio Frequency) signal to the common port. The designed OMT has a transmit port with frequency band 13.75 GHz–14.5 GHz and a receive port with frequency band 10.95–12.5 GHz. Finite element method based ANSYS's High Frequency Structure Simulator (HFSS) EM software has been used for simulation and optimization of OMT. Measured reflection coefficients of OMT over transmission and reception frequency bands are better than −15 dB and −12 dB, respectively. Designed OMT has port to port isolation better than 45 dB against 30 dB isolation of conventional OMT available in market.

1. INTRODUCTION

An orthomode transducer (OMT) is one of the important components of antenna feeds used for satellite communications to separate the orthogonally polarized signals. OMT is also used in frequency reuse application having orthogonal polarizations. It can also be used to receive several satellite broadcast signals using single reflector antenna [1–4].

An OMT is one of the important subsystems of antenna feed for Ku-band SATCOM ground terminals. Ku-band SATCOM terminals use orthogonal polarized signals for transmission and reception purposes. Transmit and receive ports are utilized simultaneously in SATCOM system. High isolation between transmit and receive ports is required to avoid the saturation of receiver [5, 6]. Desired isolation between these two ports is achieved using OMT as well as Transmit Reject Filter (TRF). Besides providing isolation, it should also have wide band of operation and low insertion loss.

Several dual-band and multi-band OMTs in coupled waveguide, Fin line, planar and quad ridges waveguide configurations have been reported in the past [7–12]. The design of dual/multi-band OMTs is very complex as it should operate over wide band of frequencies, and port to port isolation should also be met. Conventional orthomode transitions from firms like M/s Swedish Microwave, A-info, Viasat, etc., being used in Ku-band SATCOM applications have port to port isolation of 30–35 dB.

Present paper describes the design, simulation, optimization and development of a Ku-band OMT with WR-62 port as transmit port and WR-75 as receive port. Coupling slot in tapered waveguide section has been optimized to achieve port to port isolation better than 45 dB and make it compact.

2. DESIGN & SIMULATION

Symmetrical or non-symmetrical transition in waveguide section produces many higher order modes. Almost all of the higher order modes produced in the waveguides are evanescent, and they do not

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propagate. However, uncompensated higher order modes store reactive energy and prevent broadband operation of the device. For broadband operation of OMT it is necessary to design a transition so that only even order modes are produced which are easy to compensate [13, 14].

Present OMT uses square waveguide as a common port to accept both vertical and horizontal polarizations simultaneously. Both TE_{10} and TE_{01} modes propagate in the square waveguide section. The square waveguide is connected to two rectangular waveguides (WR-75 and WR-62) using a tapered waveguide section direct port (WR-62) which produces vertical polarized signal, and coupled port (WR-75) provides horizontal polarized signal.

The coupled port is placed at centre, and it is perpendicular and symmetric to the longitudinal axis. Due to symmetry conditions, higher order modes generated for direct port are canceled at the common port and hence prevent the coupling of higher mode at direct port. Mode matching technique has been used in the tapered section to couple the maximum received power to the corresponding polarized ports.

For coupling of power orthogonal port has been cut in the tapered section. The position and size of the coupling slot has been taken in such a manner that only copolarized signal couples to coupled port, and the isolation between copolarized and crosspolarized signals remains better than 50 dB. Figures 1 and 2 show the sketch and CAD model of the designed OMT. Besides the size of coupling slot length (Ls) and width (Ws), the isolation also depends on the position of the coupling slot from the square waveguide section.

Full wave analysis of OMT is performed by modeling OMT on finite element method based ANSYS's HFSS EM software using proper boundary conditions.

The simulation of OMT is carried out over the frequency band 10.5–15.5 GHz. After initial simulation, a parametric analysis is done to optimize it for high port to port isolation and better reflection coefficient at each port using Quasi-Newton optimization techniques of HFSS. The dimensions of coupling slot and its position in tapered waveguide section are optimized for port to port isolation of better than 50 dB and simultaneously matching of the coupled as well as direct port over desired frequency band of operation.

Effects of width, length and position of coupling slot in tapered waveguide section on the performance of OMT are analyzed. The effects of width and length of coupling slot on port to port isolation of OMT are shown in Figures 3(a) and 3(b). The length of coupling slot decides the frequency of RF signal to be coupled, and width of slot decides the bandwidth of RF signal. Ideally, the length of slot should be considered as $0.5\lambda_0$ with zero thickness (where λ_0 is operating wavelength of signal). Thickness of coupling slot (1.5 mm) and manufacturing tool radius (0.5 mm) are considered in the simulation. In the simulation, port to port isolation of 50 dB and reflection coefficient of better than -22 dB at transmit port and -12 dB at receive port have been achieved for desired frequency band with the slot length 13.6 mm and slot width 7.2 mm. The OMT can also be used as a feed antenna, and co-pole and cross pole radiation patterns of OMT at 14 GHz are shown in Figure 4. The isolation between co-pole and cross pole radiation patterns at bore-sight is 48 dB.

Optimized dimensions of optimized OMT are given in Table 1. All the dimensions mentioned in the table are labeled in Figure 2.

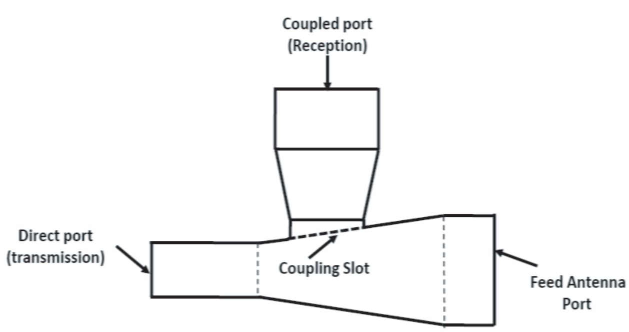


Figure 1. Sketch of orthomode transducer.

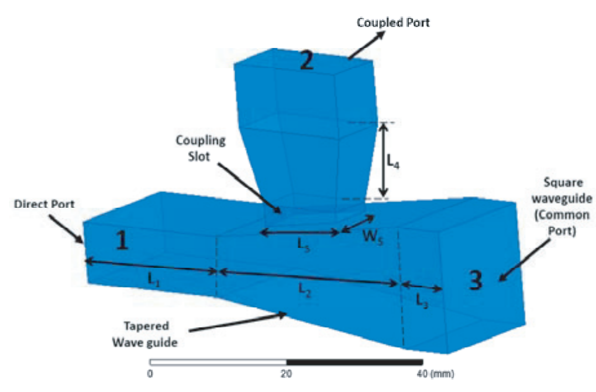
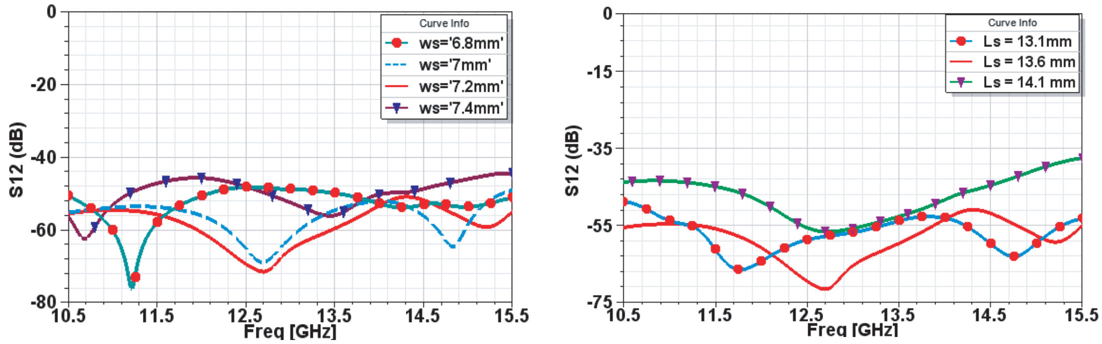


Figure 2. CAD model of OMT.



(a) (b)

Figure 3. Effect of coupling slot on port to port isolation, (a) width and (b) length.

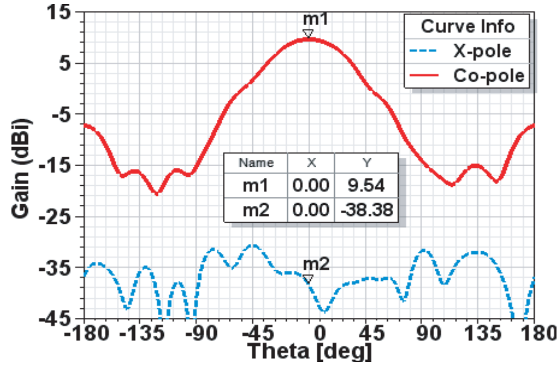


Figure 4. Co-pole and cross-pole radiation pattern at 14 GHz.

Table 1. Optimized dimension of OMT.

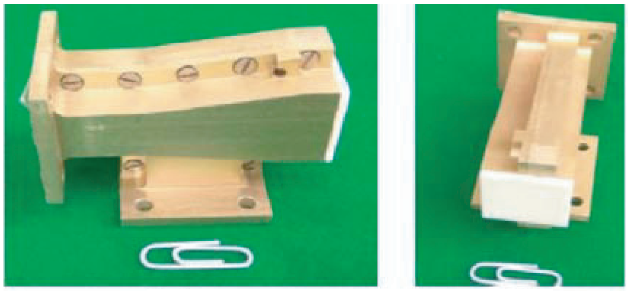
Parameter	Value
L_1	$1.12\lambda_0$
L_2	$1.35\lambda_0$
L_3	$0.38\lambda_0$
L_4	$0.58\lambda_0$
Ls	$0.52\lambda_0$
Ws	$0.22\lambda_0$

3. FABRICATION & MEASUREMENT

Photographs of developed OMT are shown in Figure 5. Aluminium alloy (IS736 24345 WP) is used for fabrication of OMT, and it is developed in two symmetrical parts using CNC milling machine. Fabrication tolerances of 36 microns have been maintained during machining of OMT. A teflon based radome is also used as a cap on the common port of OMT to protect it from outer environment.

Evaluation of developed OMT (VSWR and port to port isolation) has been carried out on Agilent vector network analyser. The comparison of simulated and measured port to port isolations, reflection coefficients at direct and coupled port and insertion losses are shown in Figures 6–8.

The measured port to port isolation is better than 45 dB over the band 10.8–15.5 GHz, and measured reflection coefficient at transmission and reception ports are better than −15.0 dB and −12 dB, respectively. The designed OMT is fabricated in two symmetrical parts, and transmit port is split from



(a) (b)

Figure 5. Fabricated ortho mode transducer, (a) side view, (b) front view.

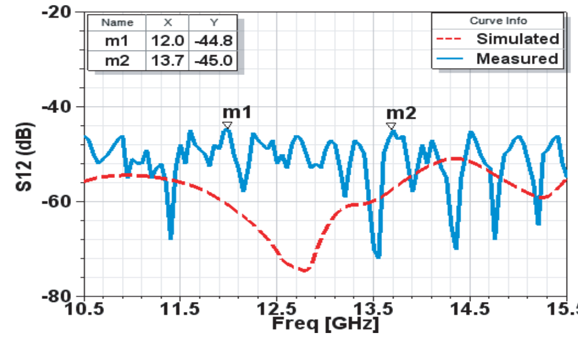
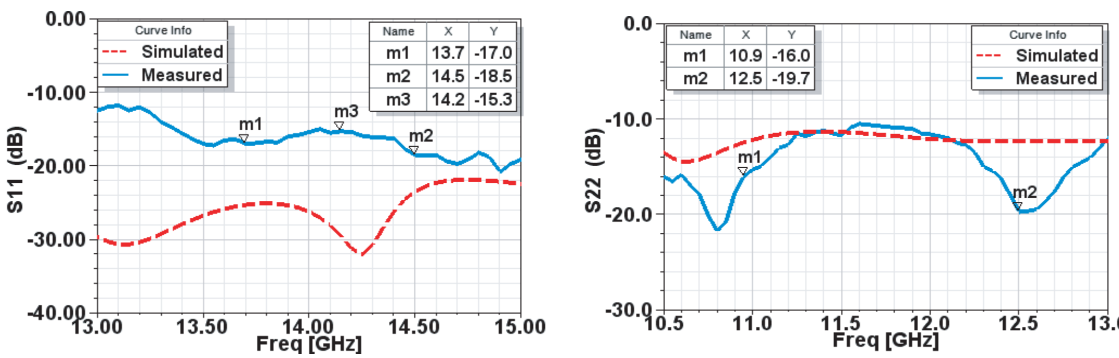


Figure 6. Port to port isolation of OMT.



(a) (b)

Figure 7. Reflection coefficient, (a) transmission port, (b) receive port.

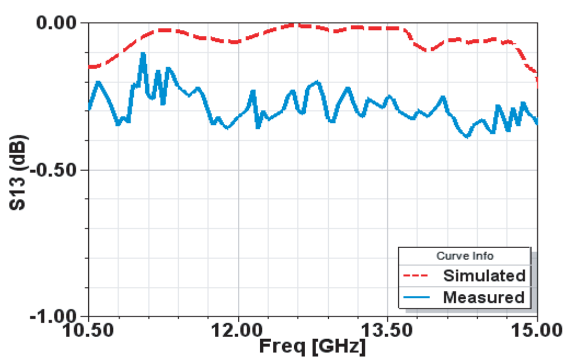


Figure 8. Insertion loss of OMT.

the middle of broad wall of waveguide while receive port is split from the middle of narrow wall of waveguide. At the centre of broad wall of waveguide, voltage is maximum, and current is minimum, so splitting from centre of broad wall does not affect the performance. On the other hand, at the centre of narrow wall of waveguide, voltage is minimum, and current is maximum, so splitting from centre of narrow wall disturbs the current distribution, hence it degrades the performance at receiving port. Thus performance of received port depends on the flatness of surfaces to be joint and screwing quality. Deviations in the measured results of OMT from the simulated values may be accorded to fabrication and integration tolerance.

4. CONCLUSION

A wide-band compact orthomode transducer has been designed, simulated, optimized and developed at Ku-band frequency. Measured results show very good resemblance with simulated values. Developed OMT has port to port isolation of better than 45 dB, and reflection coefficients of both Tx and Rx ports are less than −12 dB over the frequency band of operation. The realized OMT along with SATCOM feed will act asa very efficient feed for reflector antenna for satellite communication.

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REFERENCES

1. Jogelkar, H. P. and M. Singh, "A rectangular waveguide orthomode transducer" *International Journal of Electronics*, Vol. 47, No. 5, 515–517, 1979.
2. Dang, N. D., S. Kapartis, and D. J. Brain, "A wideband compact end-entry septum polariser OMT," *Int. Conference on Antenna & Propagation ICAP87*, Vol. 1, No. 274, 419–423, U.K., 1987.
3. Skinner, S. J. and G. L. James, "Wideband ortho-mode transducer," *IEEE Trans. Microwave Theory & Tech.*, Vol. 39, No. 2, 294–300, Feb. 1991.
4. Uher, J., J. Bornemann, and U. Rosenberg, *Waveguide Components for Antenna Feed Systems: Theory and CAD*, Artech House, Norwood, MA, 1993.
5. Rebollar, J. M., J. Esteban, and J. de Frutos, "A dual frequency OMT in the Ku band for TT&C applications," *IEEE Antennas and Propagation Society International Symposium*, Vol. 4, 2258–2261, Atlanta, GA, Jun. 1998.
6. Targonski, S. D., "A multiband antenna for satellite communications on the move," *IEEE Trans. Antennas Propag.*, Vol. 54, No. 10, 2862–2868, Oct. 2006.
7. Sharma, S. B., V. K. Singh, and S. Chakrabarty, "Multifrequency waveguide ortomode transducer," *IEEE Trans. Microwave Theory & Tech.*, Vol. 53, No. 8, 2604–2609, Aug. 2005.
8. Tao, Y. and Z. Shen, "Broadband substrate integrated waveguide orthomode transducers," *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 16, 2099–2108, 2009.
9. Soon, M. H., S. Choi, J. M. Kim, and B. Song, "Design of an orthomode transducer for use in multi-band antenna feeds," *PIERS Proceedings*, 1172–1176, Moscow, Russia, Aug. 18–21, 2009.
10. Tao, Y., Z. Shen, and G. Liu, "Dual-band ortho-mode transducers with irregularly shaped diaphragm," *Progress In Electromagnetics Research Letters*, Vol. 27, 1–8, 2011.
11. Dunning, A., M. Bowen, and Y. Chung, "Offset quad ridged ortho-mode transducer with a 3.4 : 1 bandwidth," *2013 Asia-Pacific Microwave Conference Proceedings (APMC)*, 146–148, 2013.
12. Fan, J., Y. Yan, C. Jin, D. Zhan, and J.-R. Luo, "Design of wideband quad-ridged waveguide orthomode transducer at L-band," *Progress In Electromagnetics Research C*, Vol. 72, 115–122, 2017.
13. Boifot, A. M., E. Lier, and T. Schaug-Pettersen, "Simple and broadband orthomode transducer," *IEE Proceedings Microwaves, Antenna & Propagation*, Vol. 137, No. 6, 396–400, 1990.
14. Boifot, A. M., "Classification of orthomode transducer," *European Trans on Emerging Telecommunication Technologies*, Vol. 2, No. 5, 503–510, 1991.