DESIGN OF TE_{21} MODE COUPLER IN Ka BAND FOR ANTENNA FEEDS

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Abstract

In this paper, a compact TE_{21} mode coupler is designed for tracking Low Earth Orbit Satellites. The tracking feed has to be employed to provide the error signal to servo systems feedback mechanism. The design incorporates the circular and eight rectangular waveguides with 13 asymmetric circular apertures on a single rectangular arm. The arrangement is small in size, good return loss, and VSWR. The designed configuration presents return loss is better than -30dB and VSWR around 1.06 over the entire frequency band (25.5-27GHz). The designed model is simulated and analyzed using CST.

Keywords: *Auto tracking TE_{21} mode coupler, coupling aperture, satellite communication.*

1. Introduction

The most important component for auto tracking feed mechanism is TE_{21} mode coupler. To communicate with satellite, large ground station antennas with narrow beams have been used. Various tracking methods have been employed in order to point these antennas. The most accurate is auto tracking mechanism. The direction to the satellites is called as bore sight axis, if the main beam is aligned to the axis of bore sight, the higher order modes are not excited. If the antenna is moved from the bore sight axis, higher order modes are excited and generate error signals. A composite error signal in Azimuth and Elevation planes is the input to a tracking receiver. The tracking receiver converts the RF error signal into the DC and separates the Azimuth and Elevation errors. The Azimuth and Elevation error DC voltages are given to servo amplifier and drive motor to position the antenna to the required satellite. By properly using coupling apertures [1], probe feeds or loop feeds excitation mode of TE_{21} can be achieved. The coupling apertures are the great choice for mode converters.

Four arm TE_{21} mode coupler,8 arm TE_{21} mode coupler design operating in various frequency bands are reported in literature. In the proposed model the higher order mode (TE_{21}) is employed with eight arm rectangular waveguide and asymmetric circular apertures for generating the composite error signal.

2. Principle of Operation

To originate the sum pattern for communication antenna utilize the TE_{11} mode with in the circular waveguide and to originate the difference pattern it employ the TE_{21} mode, for automatic tracking it combined with the TE_{11} mode These two modes generated by this pattern are shown in Fig 1[1]. According to the peculiar property of modes of waveguide, the sum pattern amplitude and phase are approximately constant, and to the angle deflecting from the bore-sight is proportional by the amplitude of the difference pattern, the phases of each side of the difference pattern are opposite within the small range near the bore-sight is Near the bore-sight with in a small angular area automatic tracking is performed. Sum beam is taken as reference. The angle and direction of local antenna bore-sight deflecting from the incoming wave is characterized by the strength and the phase of incoming wave received by the difference beam.

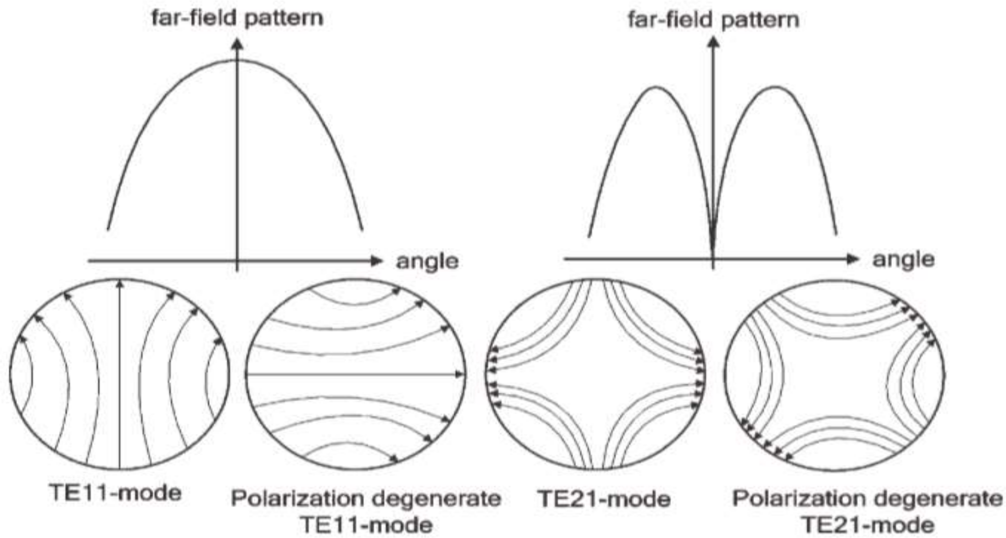

Figure 1.Two tracking modes and their patterns

The sum beam of antenna and difference beam of antenna can receive the signal when there is a angular difference between the axis of symmetry of antenna and the target. After processing these two signals can be used for automatic tracking.

3. Design of TE_{21} mode coupler

The design of TE_{21} mode coupler is shown in figure 2. Mode coupler is formed as a coupling line by circular waveguide and a coupled line by dominant mode rectangular waveguide. Dominant mode rectangular waveguide are placed on the periphery of circular waveguide at 45 degree angle to get composite error signals (LHCP and RHCP). With the size and spacing of small coupling apertures which is located in a common wall of waveguides, coupling between the waveguides are controlled.

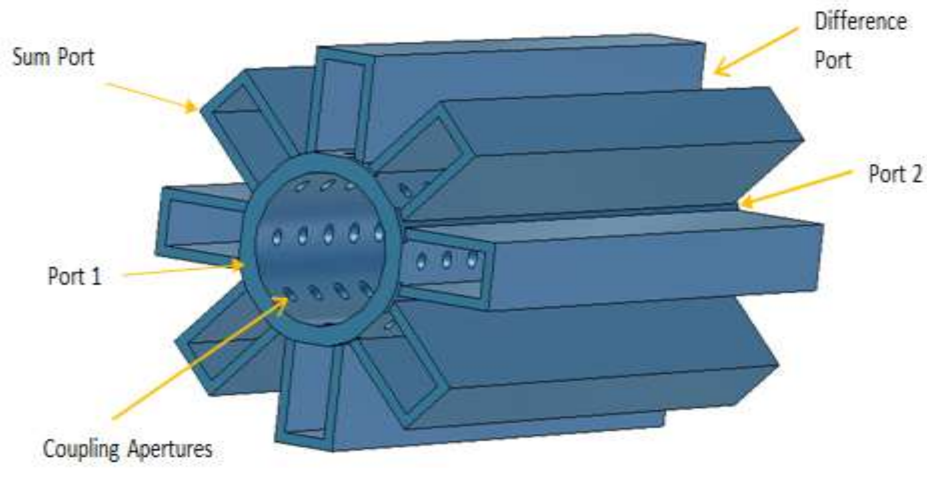

Figure 2. Structure of TE_{21} mode coupler

The mode coupler is composed of a circular waveguide and eight rectangular waveguides .The sum channel is on the left side and the difference channel is on the right side as shown in the figure 2. The channel network is shown in fig 3. In channel network opposite (0 &180,45&225,90&270,135&315 deg) couplings connected to magic -T to get combined signal (sum). And sum channel of magic-T's is again given to two magic-T's to get a composite error signal (LHCP and RHCP).The difference ports are terminated as shown in figure 3.

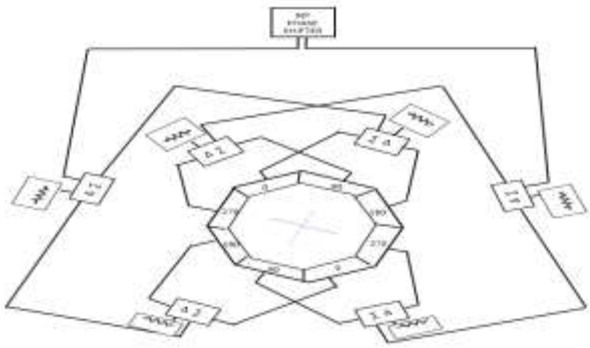

Figure 3. Block diagram

The explored model of TE_{21}mode coupler will work from λL to λH .To propagate TE_{21} mode, with respective to cut off frequency the circular waveguide R [2] is selected, which denotes radius of circular waveguide. R range is

$$\lambda L / 2.06 < R < \lambda H / 1.64$$

The circular waveguide diameter is selected as 14.38mm.The inner wall of rectangular waveguides are 8.636mm and 4.318mm. The length of a waveguide l is 70.65.Wall thickness for Ka band is 1.015.

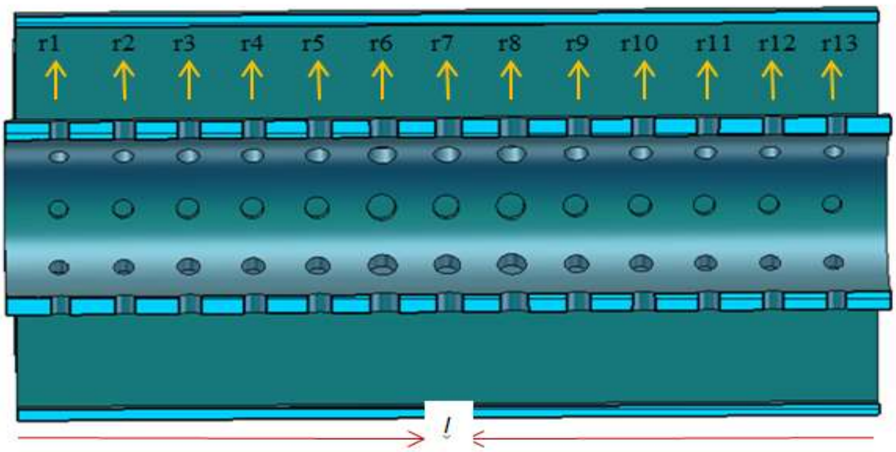

Figure 4. Cross-sectional view of mode coupler

Circular coupling apertures are placed on common wall of two waveguides. The cross sectional view of mode coupler is shown in figure 3.The left side of the mode coupler shows circular waveguide as port 1 and right side as port 2.To optimize, many sensitive parameters should be adjusted. Parameters like length of circular waveguide, spacing between the apertures, diameters of the apertures. The optimised diameter of the coupling apertures is shown in Table I

Table 1.Dimension of Coupling Aperture

Apertures No:	Coupling aperture diameter of (mm)	Spacing between Apertures
r1	1.6	1.7
r2	1.7	3.75
r3	1.9	3.60
r4	1.9	3.50
r5	2	3.45
r6	2.4	3.20
r7	2.20	3.10
r8	2.1	3.10
r9	2	3.20
r10	1.9	3.45
r11	1.8	3.55
r12	1.7	3.65
r13	1.6	3.65

The design is simulated using CST MICROWAVE STUDIO (MWS). Using frequency domain solver, the accuracy and efficiency of microwave studio is established for simulating 8 arm TE_{21} mode coupler.

4. Simulated results and discussions

Return loss shows the loss of signal which is reflected by the discontinuity in the transmission line. The return loss of circular waveguide of input port is demonstrated in figure 5. The input port of composite mode coupler return loss is more than -30dB over the desired frequency bands.

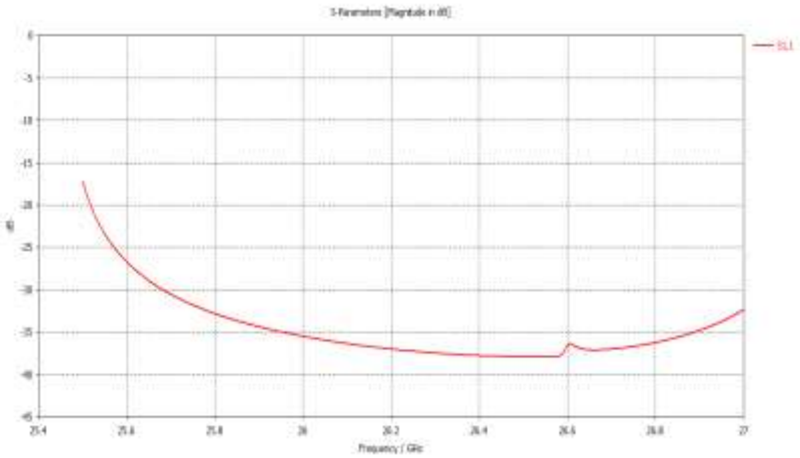

Figure 5. Input Port return loss characteristic at 25.5-27GHz

Figure 6 demonstrate the return loss characteristics of output port. The output port of composite mode coupler return loss is more than -30dB over the entire frequency bands.

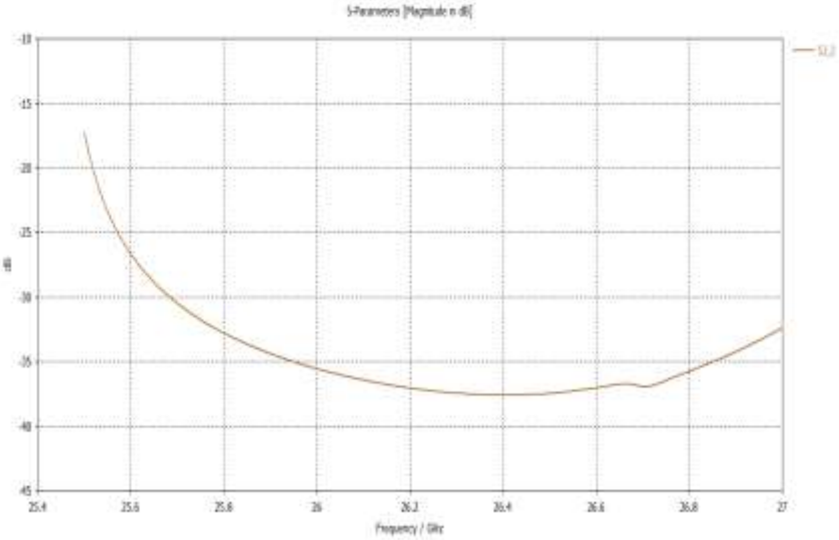

Figure 6. Output Port return loss characteristic at 25.5-27GHz

The sum port (Port3-Port10) characteristics of composite mode coupler are presented in figure 7. Port 3 of design mode coupler return loss is better than -34.5dB over the desired frequency band. The compact design of mode coupler port 4 return loss is better than-34.5dB over 25.5-27GHz. The sum channel Port 5 return loss is better than -36.5dB.The design model sum channel mode coupler port 6 return loss is better than -35dB.The Port 7 return loss is better than -36db. The port 8 return loss is better than -36.5db. The Port 9 return loss characteristics is better than -36.5db. The Port 10 return loss is better than -36.5dB.

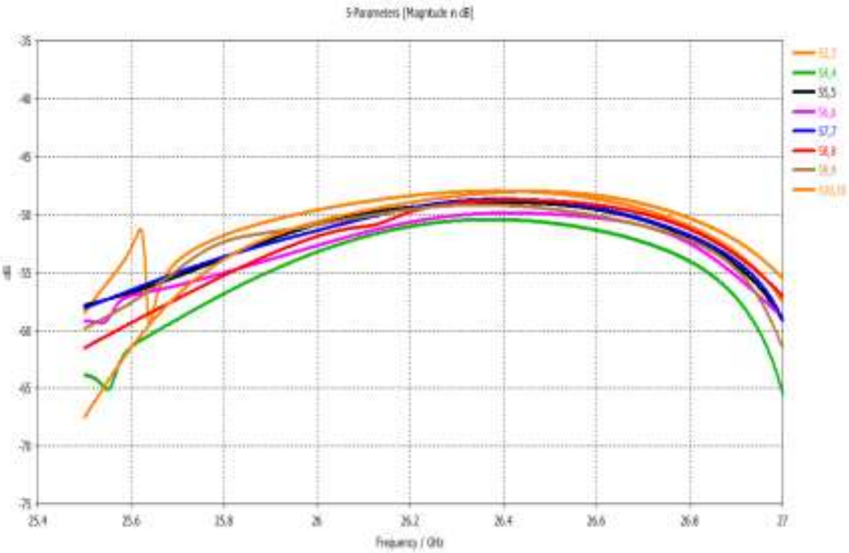

Figure 7. Return loss characteristic of sum ports at 25.5-27GHz

The difference port (Port11-Port18) characteristic of composite mode coupler is presented in figure 8. Port 11 of design mode coupler return loss is better than -48dB over the desired frequency band. The compact design of mode coupler port 12 return loss is better than-50dB over 25.5-27GHz. The sum channel Port 13 return loss is better than -49dB.The design model sum channel mode coupler port 14 return loss is better than -50dB.The Port 15 return loss is better than -48db. The port 16 return loss is better than -48db. The Port 17 return loss characteristics is better than -48db. The Port 18 return loss is better than -48dB.

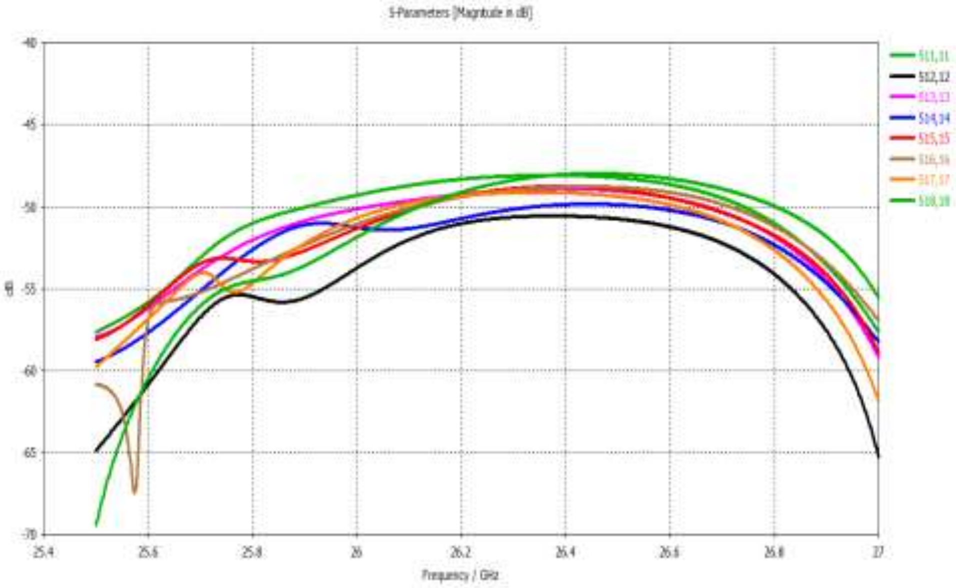

Figure 8. Return loss characteristic of difference ports at 25.5-27GHz

VSWR shows how well the antenna is matched by the transmission line. VSWR should be greater or equal to 1. VSWR=1 shows the transmission line is perfectly matched by the antenna. VSWR at input Port is depicted in figure 9. It shows the VSWR is less than 1.03 over the desired frequency band.

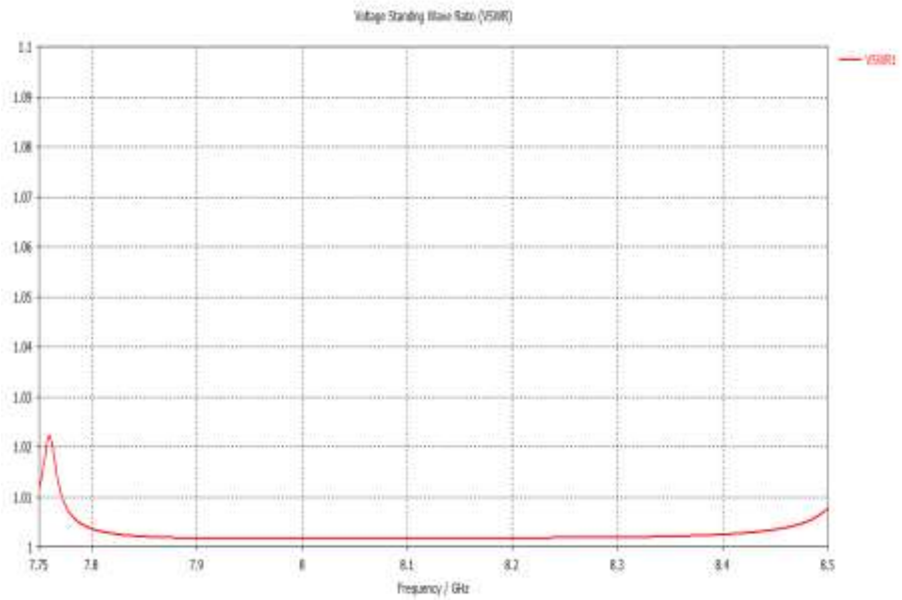

Figure 9. Simulated VSWR at input Port 1

VSWR at output Port is depicted in figure 10. It shows the VSWR is less than 1.03 over the desired frequency band.

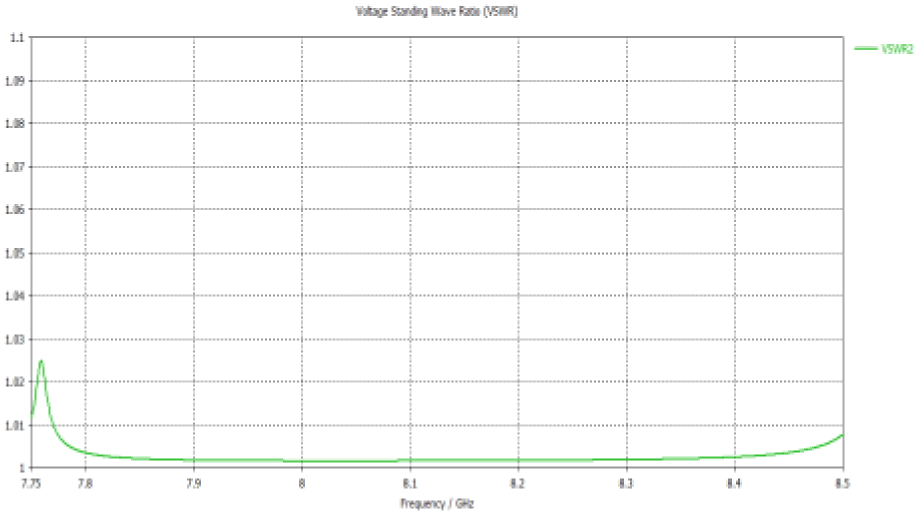

Figure 10. Simulated VSWR at input Port 2

5. Conclusion

In this work, a compact design of TE_{21} mode coupler is designed and simulated at frequency range of 25.5-27GHz.The model is designed as eight arm rectangular waveguides which is placed on the periphery of circular waveguide with equal distance with 13 coupling apertures on a single rectangular arm. Asymmetric circular apertures are designed to meet the objective. The proposed model is appropriate in Ka band for satellite application. The acceptable return loss and VSWR is achieved over the desired frequency band.

Acknowledgments

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