THE REFLECTION AND TRANSMISSION CHARACTERISTICS OF THE WAVEGUIDE WITH STEP DISCONTINUITIES IN MILLIMETER-WAVE

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In this paper, mode transitions inside the waveguides with step discontinuities are studied. These transitions are applied to design the corrugated horn antenna directly connected with band pass filter (BPF) in millimetre wave regime. The used rectangular waveguide at the input port is a WR-22 standard waveguide for the frequencies from 40.5GHz to 43.5GHz. The RF system used for transmitter and receiver requires wide beam width and wide bandwidth characteristics for coverage and return loss, respectively. Also the antenna needs the high front-to-ratio in radiation pattern.

1. Introduction

The transmission characteristics of $H_{01,}$ the lowest mode of the circular waveguides in the conical horn antenna has been investigated by many researchers. Especially, the scattering characteristics from circular to rectangular waveguides, the scattering characteristics from square waveguide to rectangular waveguides with rounded corner, the 2-port scattering characteristics at the waveguide junction with elliptical cross section have been studied from many years ago and are well-known as the simple structures in the electromagnetic scattering of the microwave and millimetre wave engineering. These structures can be applied to the resonator filters, coupler inducing the coupling between waveguides, feeding part of the antenna radiator, and power divider/combiner. Generally, in the case of final-stage duplexer and rectangular waveguides of final-stage band pass filter in RF transceiver systems, the signal transmission and electromagnetic scattering characteristics from rectangular waveguide to circular waveguide are very important. The transition phenomena from rectangular waveguide to circular waveguide can be analysed by modal-analysis using mode-matching technique with boundary conditions at the junctions [2]. In addition, GSMT(Generalized Scattering Matrix Technique) by assuming cascaded connection can be used [2]. In this paper, the radiation and reflection characteristics from the conical horn antenna in series with rectangular waveguides with different cross sections such as rectangle and rounded-corner rectangle are studied. As a canonical structures inducing mode conversion, the transmitted characteristics of rectangular-to-rectangular, circular-to-rectangular and rectangular-to-rounded-corner-rectangular are reviewed. Finally, the requirements and measured results of conical horn antenna applicable to millimetre-wave are listed for verification of manufacturing process.

2. Mode Conversion

From the field representations of existing each mode at the junction between waveguides, the scattering coefficients of each mode can be decided by enforcing the boundary conditions. The field in each region can be represented by summing the travelling wave and reflected one as followings [1] :

$$E_I = \sum_{m=1}^{M} \left(A_{\mathrm{Im}} e^{-j\beta_m z} + B_{\mathrm{Im}} e^{j\beta_m z} \right) \underline{e}_{\mathrm{Im}}$$

$$H_I = \sum_{m=1}^{M} \left(A_{\mathrm{Im}} e^{-jb_m z} - B_{\mathrm{Im}} e^{jb_m z} \right) \underline{h}_{\mathrm{Im}}$$

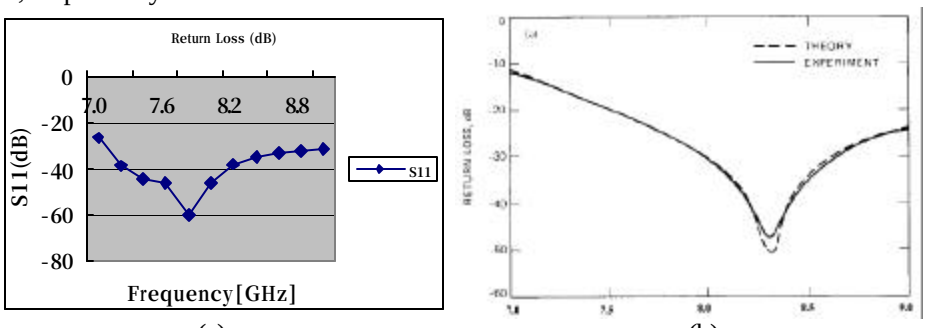
$$E_{II} = \sum_{n=1}^{N} \left(A_{In} e^{-jbnz} + B_{In} e^{jb_n z} \right) \underline{e}_{In}$$

$$H_{II} = \sum_{n=1}^{N} \left(A_{In} e^{-jb_n z} - B_{In} e^{jb_n z} \right) \underline{h}_{In}$$

where M is dependent on the convergence of the field and maintains large enough value. $\underline{e}_{\mathrm{Im}}$ and $\underline{h}_{\mathrm{Im}}$ are normalized vector function for m-th mode in region I, respectively.

2.1. Larger circular to smaller circular waveguide

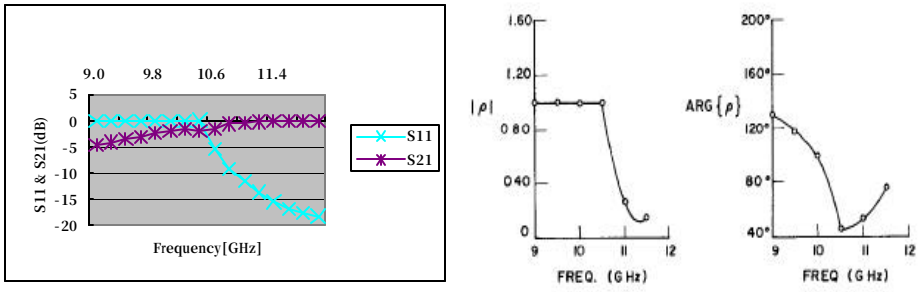
The following example shows the reflection characteristics from circular to circular waveguide with step discontinuities in series of multiple circular waveguides. The used parameters in Fig. 1 are shown in Ref. [2] and the radii of multi-step discontinuities are 34.77, 32.2, 28.85, 26.97, 26.39[mm] from left to right, respectively.



(a) (b)

Fig.1. The return loss of transition from circular to circular waveguides with multi-step discontinuities (a) simulation results (b) Fig. 3 in [2]

2.2. Larger to smaller rectangular waveguide



(a) (b)

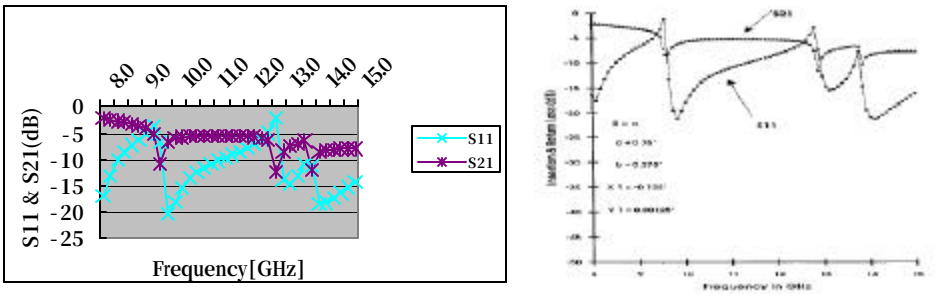
Fig. 2. The reflection and transmission characteristics from larger rectangular waveguide to smaller rectangular waveguide (a) simulation results (b) Fig. 3 in Ref. [9]

Fig. 2 shows the transition from larger to smaller cross section in waveguides at X-band. The dimensions in Fig. 2 are 2.285*1.005[cm] and 1.428*0.650[cm] in [9], respectively.

2.3. Circular to rectangular waveguide

To ensure the convergence of the S-parameters in the junction between the circular and retangular waveguides, the number of modes, N_m^i used in the input port of rectangular waveguide is N times that of circular waveguide in the output port in proportion to the ratio of relative area [3]. The number

of modes used for the simulation at the input and output port are 3 and 19, respectively. Fig.3 shows that the fluctuation of S_{21} with offset at the junction of two waveguides is more severe than that of S_{21} without offset.



(a) (b)

Fig. 3. S-parameter with offset at the junction between circular and rectangular waveguides (a) simulated results (b) Fig. 3 in [3]

The size and radius of the rectangular and circular waveguides in Fig. 3 are 0.75*0.375[in] and 0.75[in] listed in [3]

2.4. Junction with different cross sections

There are many literatures dealing with the variety of waveguide junctions such as rectangular-to-elliptic, circular-to-elliptic, elliptic-to-elliptic, rectangular iris in circular waveguides. In order to improve the reflection performances maintaining the linear polarization, the rounded corner-rectangular waveguide as an intermediate medium is inserted between two waveguides.

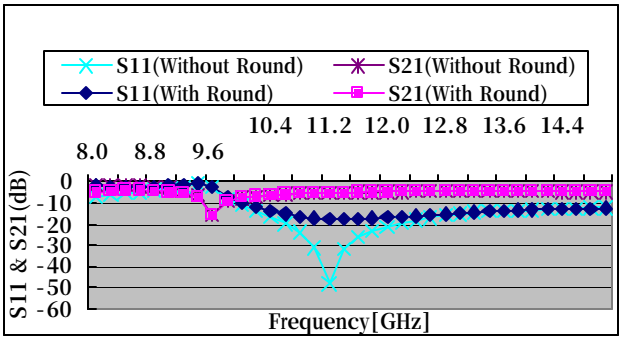


Fig. 4. S-parameter with rounded-corner rectabgular waveguide at the junctions as an intermediate medium

3. Antenna requirements and experimental results

The requirements of millimetrewave antenna at 40GHz have many differences according to the situation whether it is designed for fixed/mobile, outdoor/indoor unit and base station/subscribers.

Table 1. The requirements of transmitter antenna for wireless multimedia services

Parameter	Tx. Antenna
Frequency	40.5~43.5GHz
Azimuth Beamwidth	30degree
Elevation Beamwidth	30degree
Gain	>15dBi
Side-lobe Level	<-20dB
Polarization	Linear
Antenna Type	Conical Horn

The size of the manufactured antenna is 36.7(height)*29.86[mm](outer diameter) and the input port of the antenna is connected with WR-22 standard rectangular waveguide. The return loss has been

measured by using 37393C Network Analyzer of Anritsu.

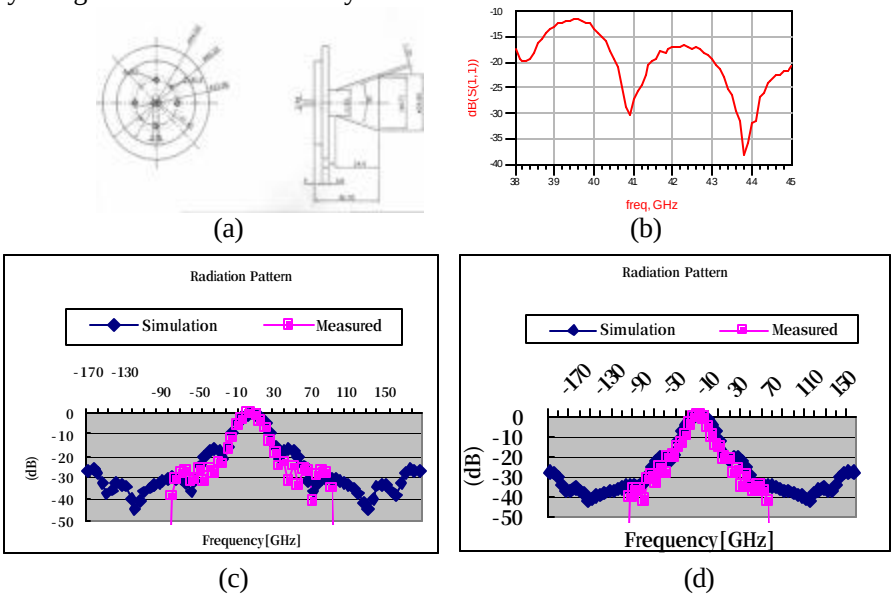


Fig. 5. The design and the measured results of conical horn antenna (a) design (b) return loss (c),(d) radiation pattern

4. Conclusion

The available conical horn antenna as base station antenna in millimetre wave regime has been studied by measuring the reflection and radiation characteristics and comparing between the simulated and measured data. The requirements of this antenna have been described. To accomplish easy easy transition, improve the reflection performance from WR-22 standard rectangular waveguide to conical horn antenna, and reduce the effects of the higher-order mode caused by step discontinuities, the corner-rounded rectangular waveguide is inserted between the standard waveguide as an input port and the conical horn antenna as an output port. We have shown that the transition performance at the junctions can be improved by inserting intermediate medium.

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