Horn Array Antenna Design for Ku-Band Applications

Sezgin ORDEK, Ahmet KIZILAY

Electronics and Communications Eng. Dept., Yıldız Technical University, 34220
Esenler, İstanbul-TURKEY
sezginordek@gmail.com, akizilay@yildiz.edu.tr

Abstract

In recent years designing array antenna at microwave and millimeter wave frequencies for commercial and military purposes have become popular. The designed feed network causes losses. As frequency increases, losses caused by tangent losses of substrate and roughness of microstrip line increase drastically, especially in microstirp antenna array structures.

In this study, we benefited from bandwidth and extremely low loss characteristic of pyramid horn antenna during the design of this antenna, It was designed a rectangular waveguide that will operate between 14 and 14.5 GHz propagating with TE_{10} mode at the same time has sufficient small dimensions to be able to suppress higher order modes. The feed network consists of rectangular E-plane waveguide power dividers. To overcome grating lobe problems caused by distance between any unit elements that was selected for mechanical issues, it was used grid structure for every unit.

The antenna designed by using CST STUDIO SUITE that uses time domain computational electromagnetics.

1. Introduction

Horn antenna is one of the most common types of antennas used in microwave antenna types [1]. It was discovered at the end of 1800s. Since 1930s, it has been used in transmission lines and microwave waveguides. Their usage peaked during WW II. It has been published many publications about them during these years. Although it might found lots of study about horn antennas itself, it is not common to encounter studies about horn arrays [2,3,4].

Pyramid Horn antenna is one of the antenna types that consists of a flare and rectangular waveguide propagates at TE_{10} mode. The flare is used in order to increase directivity of antenna and to match impedance between waveguide aperture and free space [1].

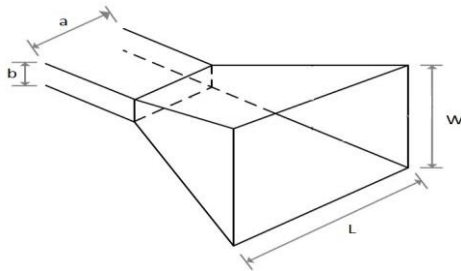Waveguide and horn antenna loss characteristic are low in the Ku-Band [5].

Fig. 1. Pyramid Horn

2. Horn Antenna Design

Designed unit horn antenna with grid structure on its aperture. The dimensions antenna are obtained via trial and error.
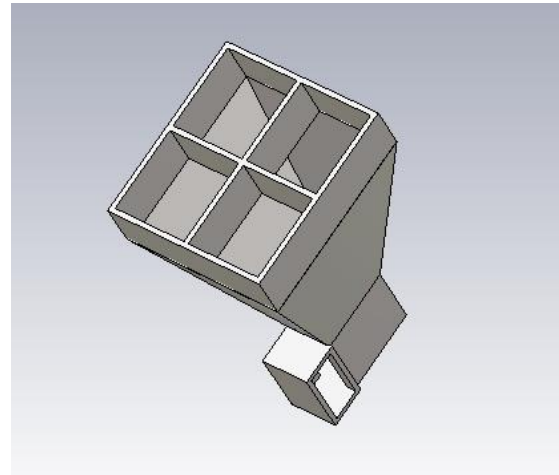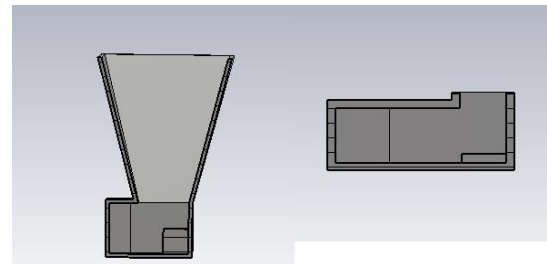

Fig. 2. A Unit Horn Antenna CST Model

Fig. 3. Section of Horn Antenna

This unit horn antenna has linear polarization in Ku band and also has good S11 values at operating frequency.
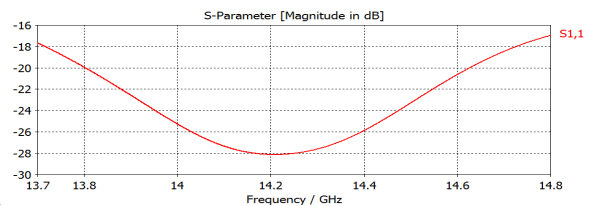
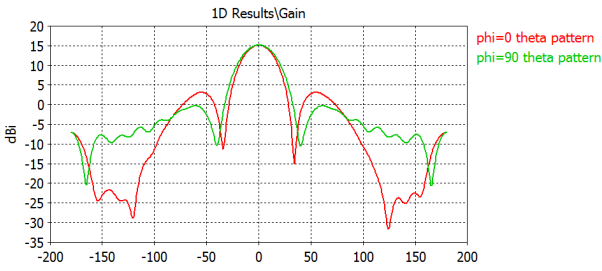**Fig. 4.** Unit Horn Antenna Return Loss Simulation Result

Fig. 5. Unit Horn Φ=0 and Φ=90 θ Pattern Simulation Result

As shown in Fig. 5 horn antenna that was simulated in CST has 14.25 dB gain in 14.25 GHz and a return loss less than -23 dB for whole frequency interval.

Flare dimensions of horn antenna can be found in table 1.

Table 1. Dimension of Horn Antenna

Variable	Dimension (mm)
W	32
L	35
h (Flare High)	40
h_1 (Grid High)	10
a	14
b	7

2. Array Antennas and Feed Network Design

An antenna array is basically a group of antennas that are placed in such way to get required necessary magnitude and phase in total. They are employed to achieve required radiation pattern and gain for the design. Array antenna pattern can be calculated by multiplying array factor with unit element pattern. In order to achieve highest directivity in planar antenna arrays, the amplitude and phase distribution should be uniform since uniformly distributed current gives highest directivity in aperture antenna designs [1].

2.1. Grating Lobe

In case of having a distance as more than a wavelength between unit antennas that has uniform phase distribution in any

antenna array unintended lobes which nearly have a radiation as strong as the main lobe appear in array factor. In array antenna these lobes becomes obvious in radiation pattern [1,3].

2.2. Waveguide Feed Network

The feed network of this array antenna consists of E-plane waveguide power dividers. E-plane waveguide power divider has two outputs equally in amplitude but 180 degree out of phase.
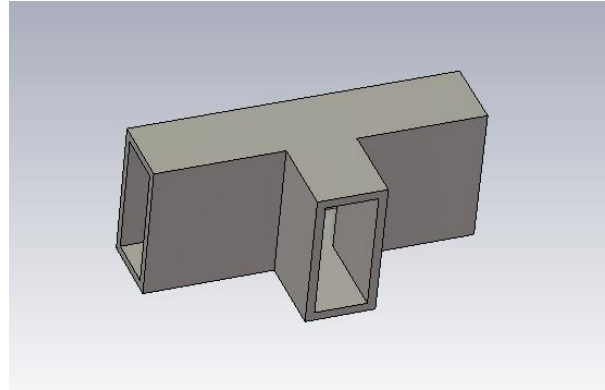

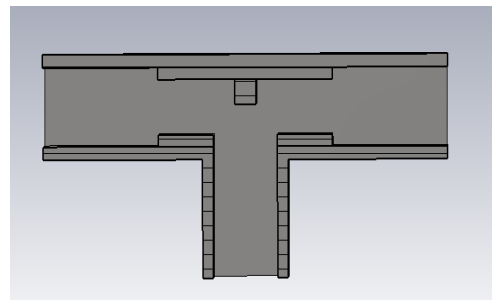**Fig. 6.** E-Plane Waveguide Power Divider
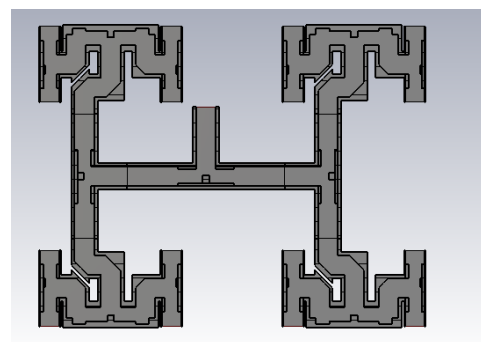

Fig. 7. E-Plane Waveguide Power Divider Section

Fig. 8. Feed Network for 4x4 Array Antenna
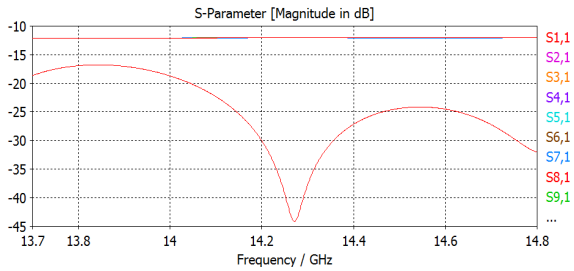
Fig. 9. S-Parameter for 4x4 Feed Network

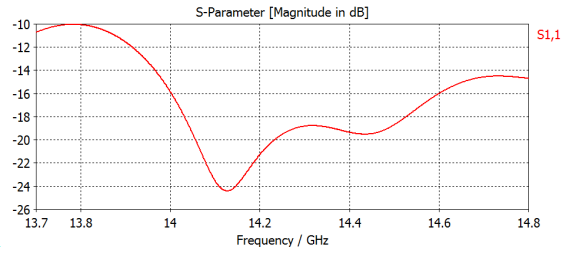## 2.3. 4x4 Horn Array Antenna Design

4x4 horn array antenna designed with feed was network in CST STUDIO SUITE. The unit elements have been fed uniform in phase and in amplitude. Every radiating element was fed with parallel feeding. Element spacing is 1.76λ along x axis and 1.61λ in y axis. According to array factor formula, grating lobe was expected to appear in radiation pattern but it has been suppressed because of using grid structure on horn antenna aperture design. The Array antenna has 27.5 dB gain and 7.4 degree HPBW (*Φ=0*) and 8 degree HPBW (*Φ=90)*. Use of grid structure not only helps to suppress grating lobes but only improves aperture efficiency.
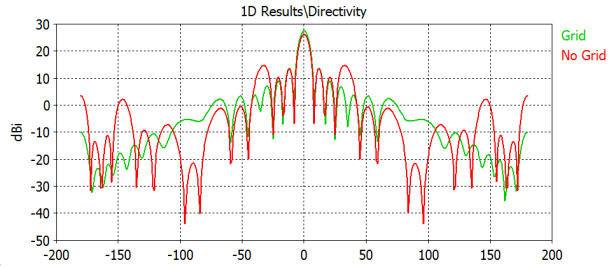

Fig. 10. 4x4 Horn Antenna Array

Fig. 11. 4x4 Horn Antenna Array Bottom View and Feed Network Section

Fig. 12. 4x4 Horn Array Antenna with Feed Network Return Loss Simulation Result

Fig. 13. 4x4 Horn Array Antenna with Grid Structure and without Grid Structure Directivity Comparison

Fig. 14. 4x4 Array Φ=0 and Φ=90 θ Pattern Simulation Result
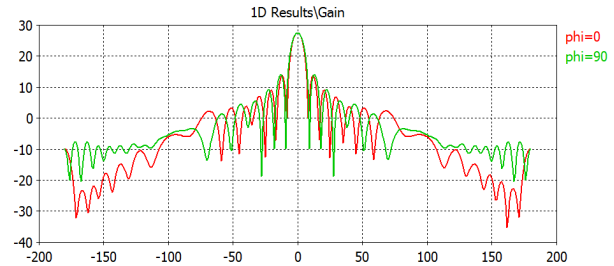
Table 2. Frequency vs Gain

Frequency (GHz)	Unit Element Gain (dB)	4x4 Array Gain (dB)
14	15	27.2
14.1	15.1	27.4
14.2	15.1	27.4
14.3	15.2	27.5
14.4	15.2	27.6
14.5	15.2	27.6

3. Conclusion

In this study, it was proposed a new design of a 4x4 antenna array that will operate between 14 and 14.5 GHz. Simulations were performed in a 3-D Electromagnetic Solver, CST STUDIO SUITE. In the first place a unit antenna was designed regarding

specifications and then antenna array was constructed by optimizing placement of aforementioned unit antennas by taking into account mechanical limitations. Moreover, a unique feed network was designed to be able to excite this antenna array properly. According to simulation results were performed on CST STUDIO SUITE, proposed design satisfies all required specifications in terms of gain, reflection coefficient and suppression of grating lobes.

7. References

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[5] A. Holy, M. Krihaly, H. Matzner, " A 1:8 Waveguide Feeding Network for Antenna Arrays", Microwaves, Communications, Antennas and Electronics Systems (COMCAS), IEEE International Conference 2011, pp. 1-4