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Design of a Gap Waveguide Based Unit Cell for 1-D Beam Scanning Application at W-band

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Abstract

In this paper, we present a 1-D scanning slot array unit cell column based on ridge gap waveguide technology which can be a good candidate for wide scanning antenna applications at 100GHz. A parametric analysis of the proposed model is organized to demonstrate the merits and potential performance. Simulated data in terms of H-plane pattern and impedance bandwidth as well as the scanning characteristics has been investigated for the unit cell column of slot array. Also, design concerns regarding manufacturing issues and corresponding mechanical challenges have been taken into account while doing the electromagnetic design. The chosen unit cell which consists of a column of slot array works with 6-16% impedance bandwidth and achieves a scanning up to ± 60o in one dimension.

1. Introduction

Nowadays, more and more wireless communication applications are appearing at upper millimeter-wave (mm-wave) bands especially W-band which is promising for implementation of the beyond 5G or sixth generation (6G) of wireless networks. The gap waveguide technology which was first discussed in 2009 [1] has the advantages of low loss, high efficiency and ease of production and has been proven to be a desirable choice for high frequency applications. In the last ten years, many high-gain array antenna based on fully metal gap waveguide and PCB based gap waveguide has been proposed .

The gap waveguide technology can also be a good candidate for designing a multi-layer phased array antenna at mmWave due to its mechanical fabrication and assembly advantages. In particular, the ridge gap waveguide which allows propagation of quasi-TEM mode with shorter guide wavelength and less transverse dimension can be a better solution allowing for wider bandwidth and beam steering capabilities. In this paper, a 1-D scanning slot array unit cell based on ridge gap waveguide operating at 100GHz is evaluated and discussed in terms of H-plane pattern and impedance bandwidth as well as the E-plane scanning range. A parametric analysis of the proposed model is provided as a design guideline for future design of the high gain antenna array.

2. One Column of Slot Array as Antenna Unit Cell

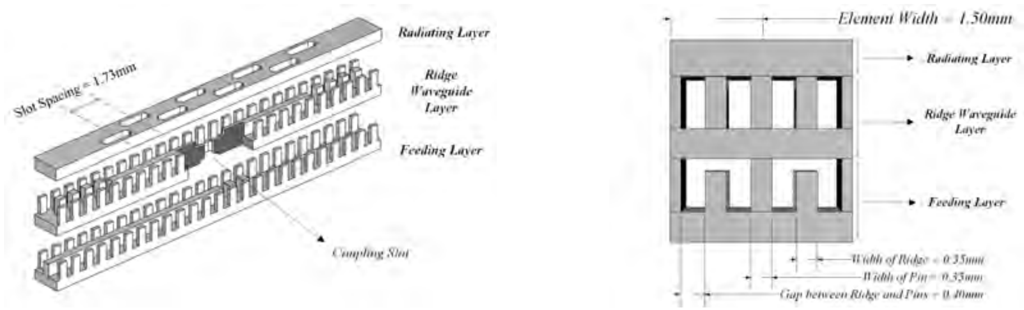

Figure 1. Exploded view of the proposed unit cell column (left) and sectional view of two columns with half wavelength (100GHz) element spacing (right) .

As is illustrated in Fig. 1, the proposed antenna element is composed of 3 layers. The radiating layer on the top contains a set of slots staggered on both sides of the axis of the middle ridge section. The ridge waveguide layer in the middle excites those radiating slots and is fed from the center via a coupling slot which helps to couple EM signal from the bottom feeding layer. And the coupling slot is tuned by the step structure together with the ridge of the feeding layer to achieve a better impedance bandwidth.

The implementation of the ridge gap waveguide has already provided a much less transverse dimension than a regular rectangular waveguide, and beside that, only 1 column of pins is placed between adjacent elements to further decrease the element spacing. However, limitation still exists due to the concerns of manufacturing difficulty and tight tolerance at higher mmWave frequency range such as W-band. Considering the commonly used CNC milling manufacturing process, the width of pins should be at least 0.3mm to ensure the structure robustness. Also, the least gap between all the structure should be

greater than 0.4mm to avoid the use of the drills with even smaller diameter, which could be much more expensive at this moment. Take the antenna structure shown in Fig. 1 as an example, the width of the ridge and pin are both 0.35mm and the gap between them is 0.4mm, which make the of element width and column-to-column spacing of 1.5mm, equivalent to the half wavelength at 100GHz. It is possible to further decrease the dimension to at least 0.45 wavelength, but even smaller dimension is not recommended due to the cost, fabrication time and the mechanical robustness point of view.
And it should be noted that, 1 column of pin rows may not provide perfect isolation between two ridges, but it usually provides over 25dB isolation which is considered to be good enough for phased array applications. The element mutual coupling will be dominated by coupling between radiation slots which happens on the top surface of the radiating layer.

3. Parametric analysis of the proposed model

The impedance and beam characteristics of the proposed antenna with different number of slots are discussed and investigation on the scanning performance of the array with different element spacing is given, which are shown in Fig. 2.

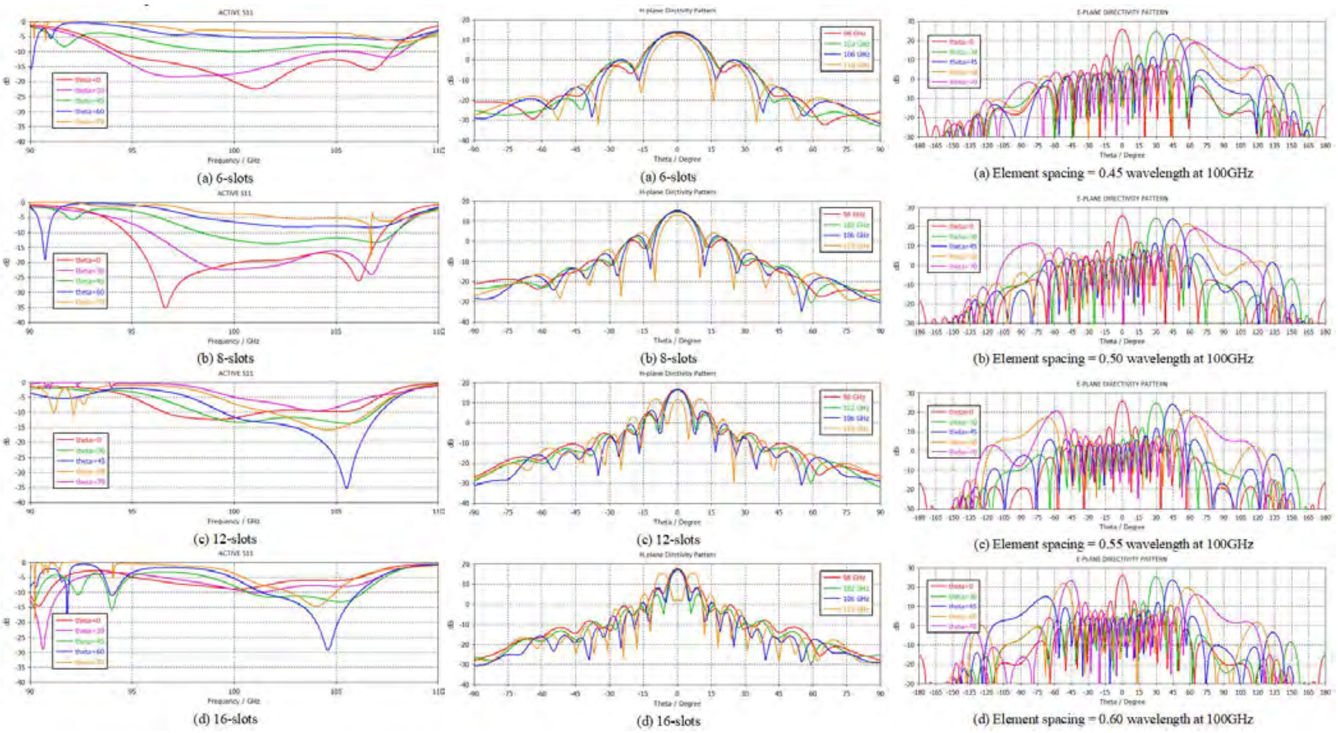

Figure 2. Active S11 of the unit cell with different number of slots at different scanning angles(left). H-plane Embedded Pattern of the unit cell with different number of slots (middle). E-plane pattern of the unit cell with different element spacing at different scanning angles (right).

6. Conclusion

In this paper, a 1-dimensional scanning slot array unit cell column based on ridge gap waveguide is discussed and demonstrated to have good potential to achieve good wide angle scanning performance and desirable bandwidth with specific mechanical tolerance robustness. Also, detailed simulation data is provided as a design reference for different requirements in terms of bandwidth and scanning performance. Future work will focus on further improvement of the proposed antenna array unit cell column such as using decoupling technique.

References

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