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Ku Band Linear Slot-Array in Ridge Gapwaveguide Technology

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Abstract— **A Ku band 4×1 linear slot array antenna design based on recently developed gap waveguide technology is presented. The complete antenna has been built using two parallel plates where the bottom metal plate has the guiding ridge and periodic pins and the top metal plate is smooth. The antenna feed network consists of power dividers has been realized on the bottom metal plate, and the radiating slots are placed on the top metal plate. Design and simulation results of the linear array show that it is possible to have a slot array antenna with 20 % bandwidth based on ridge gap waveguide technology.**

Keywords- Slot array antenna, corporate-feed, T-junction, Ridge gapwaveguide, Artificial Magnetic Conductor (AMC).

I. INTRODUCTION

Planer waveguide slot array antennas and microstrip patch array antennas have been used in many microwave applications since 1970s. Typical printed antennas can be compact and lightweight and offer low cost, but these types of antennas have low efficiency due to dielectric and conductive losses at high frequencies. Also, when a printed antenna array is built for high gain or multiple beam applications, the antenna efficiency decreases even more because of increased losses in the feeding network. The problems of unwanted surface waves are also associated with these type of printed antennas [1-2]. Rectangular waveguide slot array antennas do not suffer from the above disadvantages, and is therefore an attractive candidate for high frequency applications requiring high gain [2-4]. However, waveguide slot arrays have typically very complex feed networks under the radiating slots, and manufacturing costs are high at high frequency due to the requirements of electrically tight contacts between the slotted plate and the feed structure [5]. Apart from the cost of the waveguide array itself, the integration of high frequency MMIC with rectangular waveguide is very challenging at high frequencies [6-7].

The recently proposed ridge gapwaveguide technology [8-9] can be a real solution to above mentioned problems and can be applied very successfully to design good performance antennas at high frequency. The gap waveguide is realized using the parallel plate cut-off condition between a PEC layer (perfect electric conductor) and PMC layer (perfect magnetic conductor). So, the waveguide has a smooth upper metal surface and a lower surface with a ridge surrounded by bed of nails. The air gap between upper metal surface and the lower metal ridge is kept smaller than λ/4. With the help of this new gapwaveguide concept, it is possible to excite the local quasi TEM wave between upper metal surface and the ridge in such a way that this mode exists over a larger bandwidth without the presence of global parallel plate modes.

The low loss corporate feed network needed for an array can be built easily with the help of ridge gap waveguide concept with an inherent advantage of having no dielectric losses. Also the width of the line itself can be adjusted in a way that conductor losses can be reduced. The strip dimensions cannot be increased in normal microstrip feed lines because then the substrate supports surface waves, which is not present at all in gap waveguides. In addition, radiating slots can be placed conveniently on the top smooth metal plate of ridge gap-waveguide. There is also no requirement on good electric contact between the slotted plate and the feed structure. Thus, the ridge gapwaveguide slot antenna can be an attractive as well as cost effective solution for high gain and high efficiency applications.

Till now, there have been very few papers on gap waveguide antennas, except for horn antennas [11], the initial works in single hard-wall waveguide slot arrays [12] and the single slot design in ridge gapwaveguide [13]. Also, a multi-layer phase array antenna for automotive radar application has been presented in [14]. In the present paper we present a 4×1 linear slot array excited by ridge gapwaveguide. We consider fully radiating slots corresponding to using fully branched distribution network, i.e. a corporate-feed network. The spacing between the slots is kept at 17mm corresponding to about 0.85λ to avoid grating lobes.

II. ANALYSIS OF ISOLATION BETWEEN THE ELEMENTS

The periodic pin structure need for realizing the artificial magnetic conductor (AMC) is designed first. The dimensions chosen for this work are based on the design curves in [15] and corresponding dispersion diagram showing the parallel-plate stop band is presented in fig.1. After that, two ridge gap-waveguide structures with two radiating slot elements presented in [13] are placed side by side with only one row of pins spaced between the elements in order to measure the achieved isolation between the adjacent elements in the ridge gapwaveguide array. This is shown in fig.2. There is not enough room for more than one row of pins between the adjacent slot elements to maintain the spacing of about 0.85λ. Still, this one row of pins provides an isolation level of more than 20dB between the adjacent elements. The simulated isolation results are shown in fig.3.

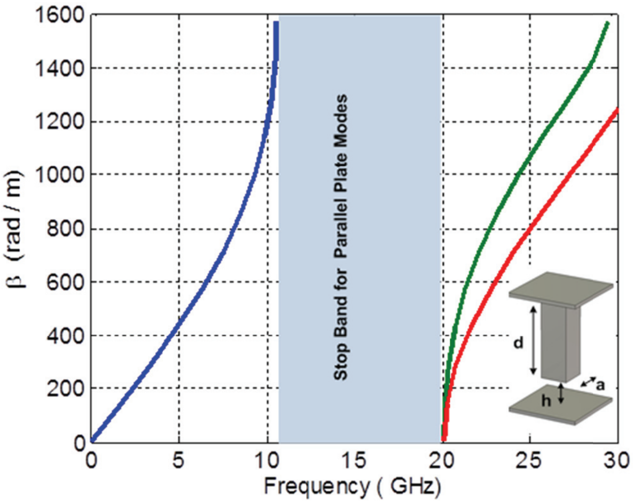

Fig. 1. Dispersion diagram for unit-cell of periodic metal pin structure; a = 2 mm, h = 1mm and d = 6mm.

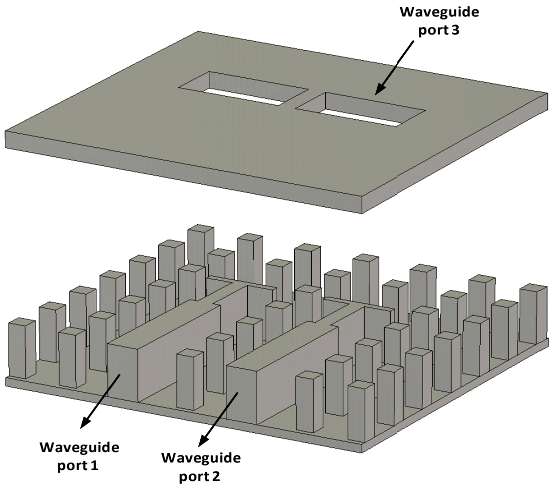

Fig. 2. Two slot elements separated by one row of pins

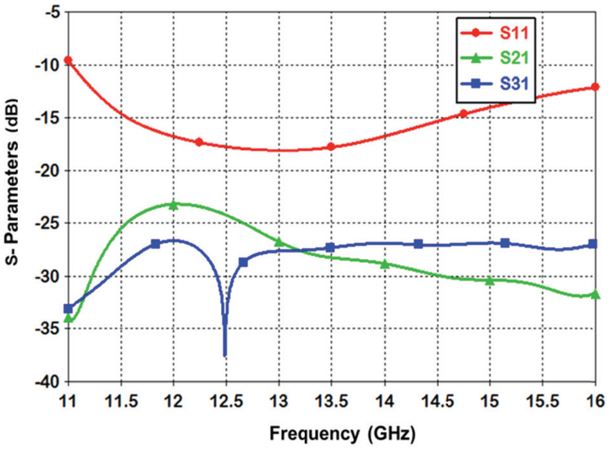

Fig. 3. Simulated isolation between two adjacent slots

III. LINEAR SLOT ARRAY DESIGN

The simple linear slot array design starts with the single slot presented in [13]. The single slot design is based on adding a T-section with the ridge just below the radiating structure. The single slot element is working within the frequency range 12-14GHz. The slot-length and slot-width are chosen to be 11.75 and 5.85 mm respectively. It is practically not possible to make sharp corners for each slot. But, at this point the effect of rounded corner is not considered and it is expected that at this frequency band the effect of the rounded corner will not be so severe. Also, four-way equal split power divider is designed in ridge gapwaveguide technology to work at the same frequency. The four-way power divider design is based on the single T- junction 3dB power divider presented in [13].

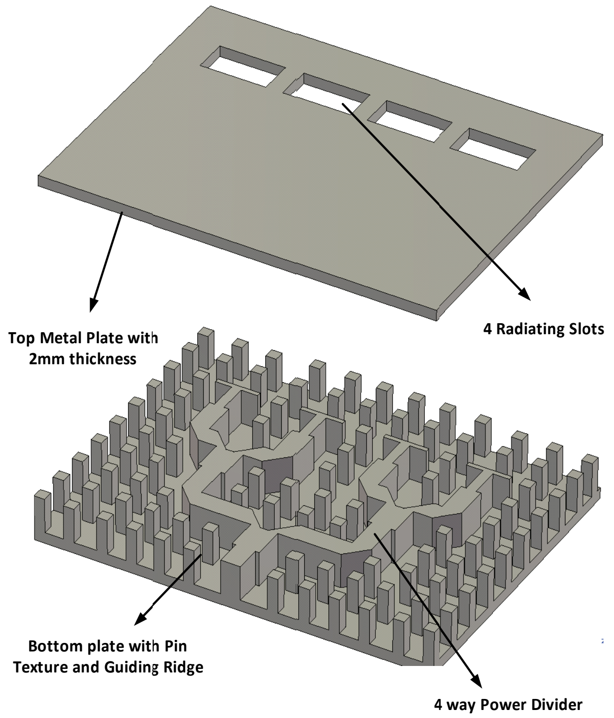

Fig. 4. Linear array in gap waveguide technology

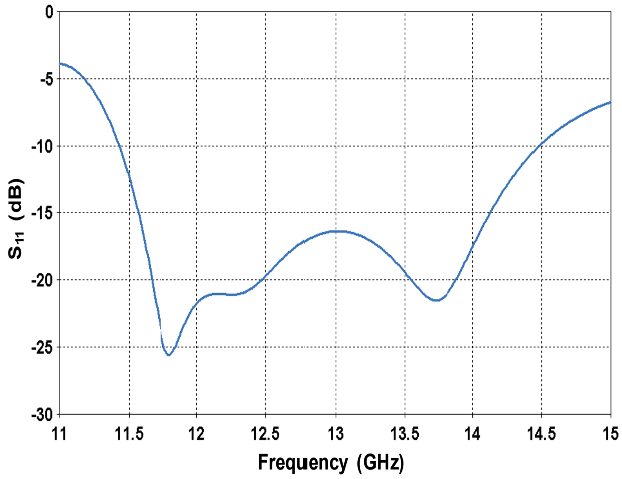

Fig. 5. Simulated return loss for the linear array

The linear array is designed for a fixed beam in mind. So, the element spacing can be kept 0.85λ to avoid grating lobes and all the slot elements are excited with equal amplitude and phase. The complete array is shown in fig.4 and it is designed to operate in 12-14GHz frequency range. As shown in fig.4, the bottom plate with ridge and texture pin structure holds the feeding network for the array. On top is placed a smooth metal plate with four radiating slots at a distance of 1 mm from the bottom plate. It is important to mention that- no electrical contact between the radiating layer and bottom feed layer is needed in this ridge gapwaveguide array which is a significant advantage of this technology. The simulated reflection coefficient for the linear array is shown in fig. 5 and simulated radiation patterns are shown in figure 6(a) and 6(b).

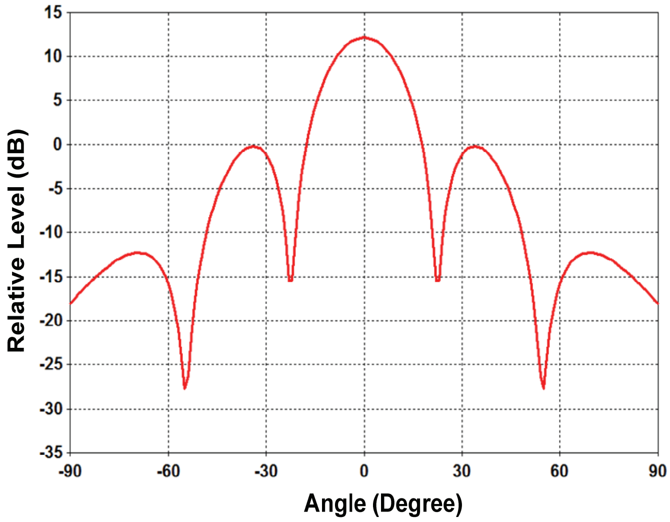

Fig. 6 (a). Simulated H-plane pattern of the linear array at 13GHz

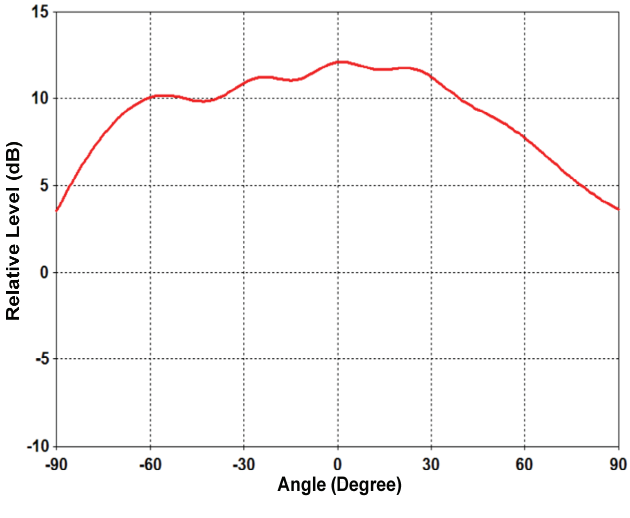

Fig. 6 (b). Simulated E-plane pattern of the linear array at 13GHz

The simulated S-parameter value in fig.5 shows good impedance bandwidth from 11.5-14.5 GHz with a relative bandwidth of more than 20% around the center frequency of 13GHz. The simulated radiation patterns shown in fig.6 are also quite acceptable. As expected, the array has more directive beam and symmetric pattern in H-plane. In H-plane, the first side-lobe is 12.8 dB lower from the beam peak value which is also common for uniform arrays. On the other hand, in E plane the beam is wider and is not really symmetric as the slots are close to the edge on one side. In E-plane, there is a possibility of back radiation as the slots are close to the edge. This is shown in the 3D far field pattern in fig.7. But the level of back radiation can be improved by adding 2 or 3 corrugations being quarter wavelength deep at the lowest frequency of operation. These corrugations are not included in this work but will be incorporated in the final design. The simulated directivity value is 12.4 dBi and the simulated total efficiency is -0.12 dB at the center frequency of 13GHz. The radiation efficiency and total efficiency for the antenna over the band of interest are plotted in fig.8. It is needed also a transition from ridge gapwaveguide to the standard coaxial SMA connector for measurement of the entire antenna. This transition can be a simple interface consisting of steps in ridge which allows the Quasi TEM mode to convert to a groove gapwaveguide mode (similar to that of standard rectangular waveguide mode). Then we can connect easily with a SMA connector with an extended center conductor.

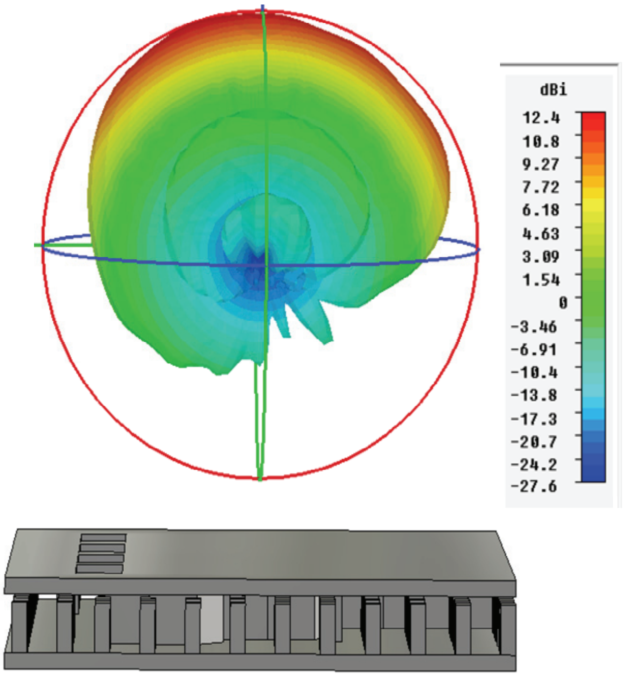

Fig. 7. Simulated 3D radiation pattern and possible back radiation at 13GHz.

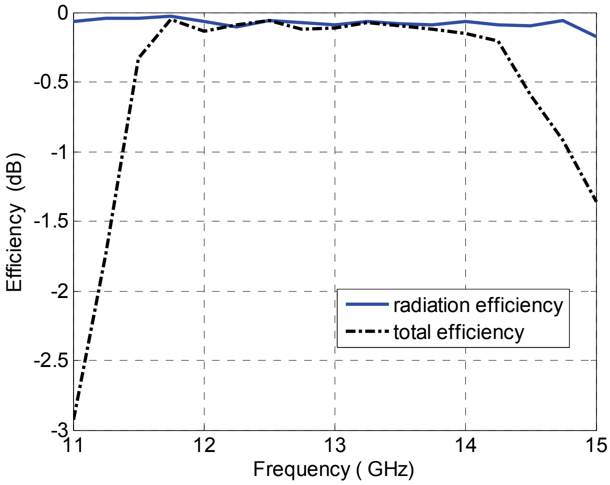

Fig. 8. Simulated radiation efficiency and total efficiency for the linear array.

IV. CONCLUSION

We have presented a linear slot array antenna based on ridge gap waveguide technology. The low-loss corporate feed network is designed on the bottom metal plate with guiding ridge and periodic pins, and above the ridges there are radiating slots in the top metal plate. These two parts of the ridge gapwaveguide antenna can be manufactured separately and there is no need for an electrical contact between these two parts, thus making it much simple and lower cost to manufacture. The simulated S-parameters and radiation patterns show promising results for the linear array at Ku-band from 11.5-14.5 GHz. Though presented at Ku band, ridge gapwaveguide technology is very suitable for this type of single layered corporate feed array antenna even at millimeter-wave frequency range. Measured results for the designed linear array will be presented at the conference.

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