Leaky-Wave Long Slot Antenna Design Using Ridged Waveguide

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Abstract—**In this paper a long slot ridged waveguide antenna is designed and simulated. Long leaky-wave slot antennas have high sidelobes in the far field patterns leading to reduction in their performance. To obtain better performance one way is use of a ridge in the waveguide. Through this method better sidelobe level can be achieved. The proposed design consists of a nonresonant slot which is longitudinally centered on the broad wall of a rectangular waveguide. The slot has a length of 20lambda and width of .08 lambda. With properly design of a ridge, the center-lined slot is exited and desired far field radiation pattern is achieved. The reflection coefficient of this design in about -27 dB at center frequency.**

Keywords- waveguide antenna; leaky-wave; nonresonant slot; broad wall; ridge

I. INTRODUCTION

Slotted waveguide antennas have been considered too much recently due to their good characteristics such as high gain, low side lobe level, low cross polarization and good efficiency. Such advantages make these type of antennas to be a good candidate for radar and telecommunication applications. Long leaky-wave slot antennas have been used in aerospace applications due to their narrow elevation beam width.

Much analysis has been performed upon resonant slot antennas cut on the broad wall of a rectangular waveguide. In [1], due to achieve low-average side lobe level, planar slot arrays was proposed. Wide width of these antennas limits the maximum scanning angle in the E-plane. This shortcoming has been overcomed by utilizing a ridge waveguide slotted antenna [2]-[4]. In[5], a wiggly-ridge waveguide has been introduced as a feed for linear arrays of center-line longitudinal slots. Wiggly-ridge waveguides are important due to illumination of slot offset, which improves side lobe level and cross polarization. A double-ridge waveguide with untilted slots cut on the narrow wall of the guide is presented in [6], [7]. Good cross-polarization is significant characteristic of these designs.

Straight longitudinal long slot leaky-wave antennas have several attributes, such as an elevation half-power beam width (HPBW). Also these type of antennas are among the easiest configuration of slotted waveguide antennas to fabricate. The uniform straight waveguide has a drawback that is, high level in innermost sidelobes. Balanis [8], showed that by

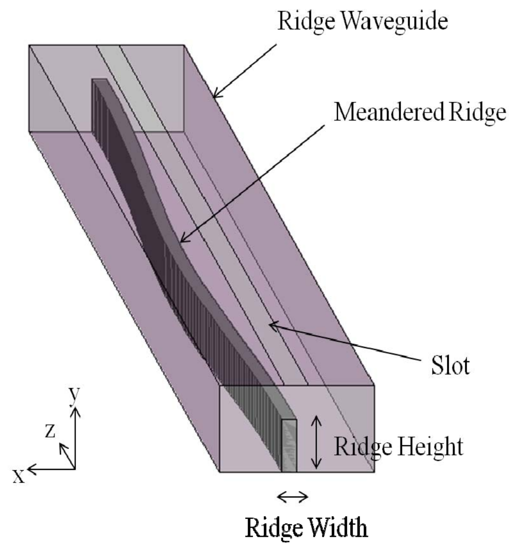

Fig. 1. meandered ridge slotted waveguide antenna

meandering a continuous long slot from waveguide centerline toward sidewall then back to centerline, better side lobe level can be achieved. However fabrication of this meandered long slot antenna is difficult.

In this paper we introduce a long slot leaky-wave ridged waveguide antenna. The straight slot cut on the broad wall of the rectangular wave guide and located in the centerline of it. Far field E-plane pattern of both antennas have compared and good side lobe level has achieved through this design. The simulated results are obtained through Ansoft HFSS.

II. ANTENNA DESIGN

Fig. 1 shows the proposed slot antenna. The radiating element consists of a long slot which longitudinally etched on the broad wall of a rectangular waveguide. The length and width of the slot are 20lambda and .08lambda respectively.

Due to radiation of slotted waveguide the slot must have an offset or inclination to the waveguide centerline. This causes a decadence in side lobe level. To decrease this side lobe the offset or angle of the slot can be removed. On the other hand to excit the slot, the current distribution must be intercept in position of it. To achieve this, one of the best method is applying a ridge inside the waveguide. Infact the ridge

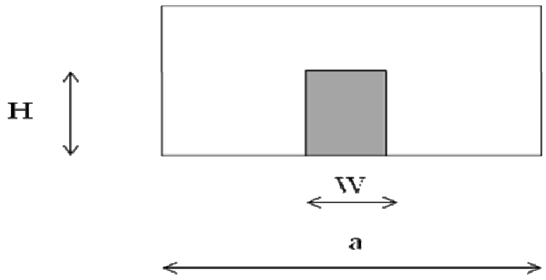

Fig. 2. Front veiw of the proposed antenna.

displaces the fields in the slot position which causes the slot to rediate. Through this method the offset or angle can be removed and good side lobe level can be achieved.

Cut off frequency of a rectangular waveguide without the presence of any slot or ridge is inversely proportional to the length of it. In other words to have a waveguide with cut off frequency of f_c the length of the guide must be

$$a = \lambda_c /2 \qquad (1)$$

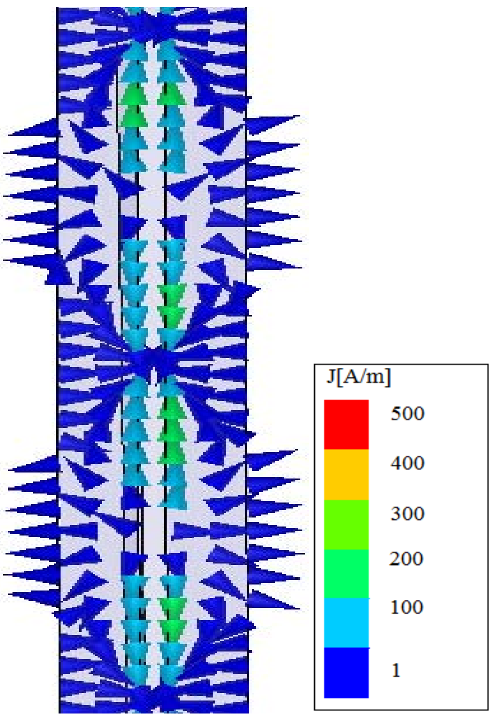

Fig. 3. Current distribution over upper surface of the waveguide.

TABLE 1. Designed size of the propposed antenna

Parameter	H	W	L	a
Size(mm)	6.8	2.14	857	22.52

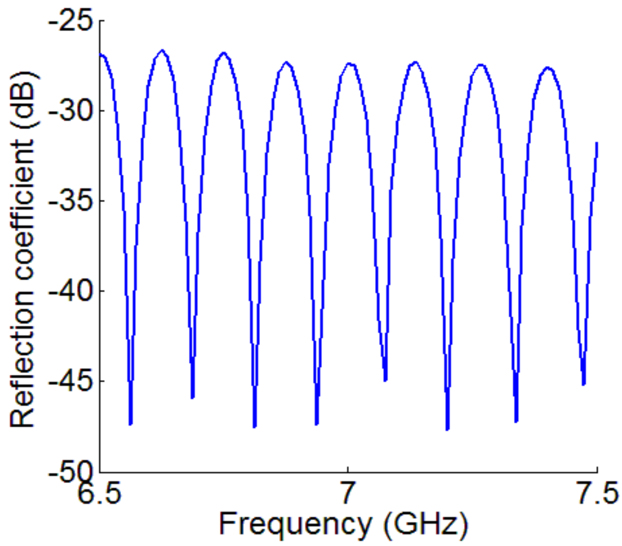

Fig. 4. reflection coefficient of the antenna.

where λ_c is cut off wave number of the guide. With the presence of a centerline situated slot without the ridge equation (1) is also valid. As mentioned before, not having inclination or offset the slot will no longer radiate. Due to intercept in the current distribution on the upper surface of the waveguide, bottom broad wall of the guide is ridged. Fig .2 shows the front view of the rectangular waveguide. As shown in this figure the ridge is defined by height of H and width of W. To have a good far field pattern with low side lobe level the size of both two parameters are important. In other words however the ridge causes radiation of the straight long slot but any change in the final calculated values of these parameters cause the slot not to be excited properly, and then the far field radiation pattern will have inner most sidelobes. On the other hand the contour of the meandered ridge is significant factor to achieve desired radiation pattern in the far field. The ridge is meandered such that it has maximum deviation in the center of the waveguide and has a sine squared curvature with a contour of

$$x = [.5+.12 \sin^2(\pi z/L)]a \qquad (2)$$

where L and a are the length and width of the antenna respectively.

Fig. 3 indicates the current vector over the upper surface of the waveguide at center frequency of 7 GHz. As shown in this figure the current distribution changes in place of the slot which causes the straight slot to radiate.

In the presence of ridge with proposed contour, the size of the structure reduces about 30 percent compared with the simple slotted waveguide to have the same cut off frequency. Decrease in dimention of the guide causes a wide scanning angle in the E-plane. Note that the dimension of the guide are chosen so that the dominant propagating mode at the center frequency of 7 GHz would be only TE10. The designed parameters are listed in table 1.

Fig .4 shows the reflection coefficient of the proposed antenna. As shown in this figure, the antenna has reflection

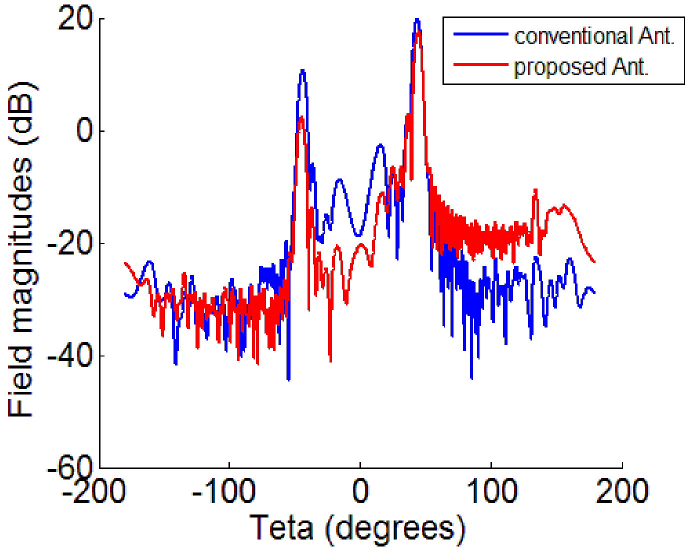

Fig. 5. E-plane patterns of proposed antenna and conventional one.

coefficient of -27.5 dB at center frequency. Note that the antenna is simulated at a frequency of $f=1.5f_c$.

Fig. 5 shows the far field radiation pattern of both proposed antenna and conventional one. The proposed antenna has a gain of 19 dB and HPBW of about 5 Degrees. The maximum gain of the proposed antenna occurs at the angle of 44 Degree. It can be found from this figure that with proposed antenna the second beam at -44 Degree is about 10 dB better than conventional one.

III.CONCLUSIONS

A long slot leaky-wave ridged waveguide antenna is presented. With a meandered ridge with a sine square curvature the straight long slot is carefully excited. The antenna is designed at frequency of 7 GHz and has reflection coefficient of about -27 dB at the center frequency. Through this design far field radiation pattern with better side lobes is achieved. The proposed antenna has HPBW of about 5 Degrees and gain of 19 dB at the angle of 44 Degree.

REFERENCES

[1] Sembiam R. Rengarajan, Mark S. Zawadzkr, and Richard E, "Waveguide-Slot Array Antenna Designs for Low-Average-Sidelobe Specifications," IEEE Antennas and Propag. Magazine, vol. 52, no. 6, December 2010.

[2] D. Y. Kim and R. S. Elliott, "A design procedure for slot arrays fed by single- ridge waveguide," IEEE Trans. Antennas Propag., vol. 36, no. 11, pp. 1531–1536, Nov. 1988.

[3] W. Wang, S.-S. Zhong, Y.-M. Zhang, and X.-L. Liang, "A broadband slotted ridge waveguide antenna array," IEEE Trans. Antennas Propag., vol. 54, no. 8, pp. 2416–2420, Aug. 2006.

[4] S.-S. Zhong, W. Wang, and X.-L. Liang, "Compact ridge waveguide slot antenna array fed by convex waveguide divider," Electron. Lett., vol. 41, pp. 1151–1152, Oct. 2005.

[5] M. Moradian, M. Khalaj-Amirhosseini, andM. Tayarani, "Application of wiggly ridge waveguide for design of linear array antennas of centered longitudinal shunt slot," Int. J. RF Microw. Comput. Aided Eng., vol. 20, no. 6, pp. 593–602, Nov. 2010.

[6] A. Mallahzadeh, S. Mohammad ali nezhad, "Untilted Slot Array Antenna at the Narrow Wall ofthe Waveguide Using Double-Ridge," Int. J. RF Microw. Comput. Aided Eng., vol. 20, no. 6, pp. 699–710, Nov. 2010

[7] A. Mallahzadeh, S. Mohammad ali nezhad, "An Ultralow Cross-Polarization Slotted Waveguide Chebyshev Array Antenna," EUCAP-2011, Rome, pp. 1953-1956, April 2011.

[8] Frank L. Whetten, and Constantine A. Balanis, "Meandering Long Slot Leaky-Wave Waveguide Antennas," IEEE Trans. Antennas Propag., vol. 39, no. 11 , Nov 1991.