An Ultralow Cross-Polarization Slotted Waveguide Chebyshev Array Antenna

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Abstract— an ultralow cross-polarization slot chebyshev array antenna in the narrow wall of ridge waveguide is presented. The normalized conductance obtained for untilted slot waveguide by concave and convex ridges. A slot array waveguide antenna was designed using ridges on its narrow wall and nine radiation elements having a frequency of 5 GHz by applied the normalized conductance of each radiating slot. It is shown that good performance can be achieved even for concave and convex ridges in waveguide. The antenna has the characteristics SLL= -20 dB and cross-polarization equivalent to -60 dB.

I. INTRODUCTION

The antenna which is used in the radar technology should be high power capability, inexpensive in terms of fabrication cost, high gain performance and low loss. The waveguide slot array antenna incorporates the above-mentioned features thus being an appropriate choice to be used in the radar technology and communications.

The edged slot waveguide array is widely used in radars and communication due to its simplicity. For this slot on narrow wall to radiate in the TE_{10} mode, it must interrupt the surface currents on the thin wall. To achieve this, the slots should be produced in a slant manner on the antenna wall which causes an increase in the level of cross-polarization and consequently the secondary beam of the antenna. This cross polarization coupled with the variation of the slot admittance with frequency, causes pattern deterioration and loss in array efficiency [1]-[2]. A strong cross-polarized component, which increases as the slot array scanned at an angle away from broadside, produces interference and jamming problems.

To decrease cross-polarization in the waveguide slot array antenna on the narrow wall of the waveguide is to change the fields inside the waveguide thus creating untilted slots in the waveguide.

Slant wires alongside the untilted slot present in [3]. Under this condition, the slant wires are excited by the radiation fields in the waveguide thus producing radiation in the slot. In addition, the untilted slot excited by a dielectric plate with conducting strip on both sides has been suggested [4]. In [5] the slot in excited by to compound iris which produced an inclination of the electric field as it passes the slot. Using a pair of shaped irises that flank the slot instead of the abovementioned wires or stripes in [6] the measured result for

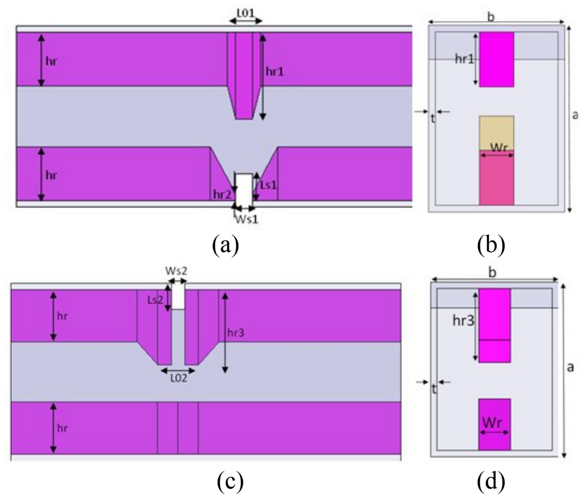


Fig.1 Dimension of proposed antenna (a) top view of convex double-ridge slot waveguide (b) side view of convex double-ridge slot waveguide (c) top view of concave double-ridge slot waveguide (d) side view of concave double-ridge slot waveguide.

16 element slot shows cross-polarization level less than -40 dB.

Based on the present authors literature review, it seems that most of the works reported on untilted slot waveguide antenna have been low efficiency and gain and this method encounters difficulty in the case of large-scale arrays. In [7], untilted slot uniform array antenna at narrow wall of double ridge reported, but design figures for tapering array have not report.

In this paper, the untilted slot array antenna on narrow wall of the ridge waveguide has been presented. Inserting the concave and convex ridges under the slots, the fields are changed in the waveguide in such a manner that the slot is capable of radiating without any angles and cross-polarization decreases. The normalized conductance curves are presented for design purposes. A slot array waveguide antenna was designed using ridges on its narrow wall in 5 GHz for 20 dB SLL. The proposed array is simulated by two established packages, named Ansoft HFSS and CST microwave studio. The former is based on the finite element method, and the latter on the finite integral technique.

II. ANTENNA DESIGN

To decrease cross-polarization in the slot array waveguide, the slot angle should be removed. But, this slot

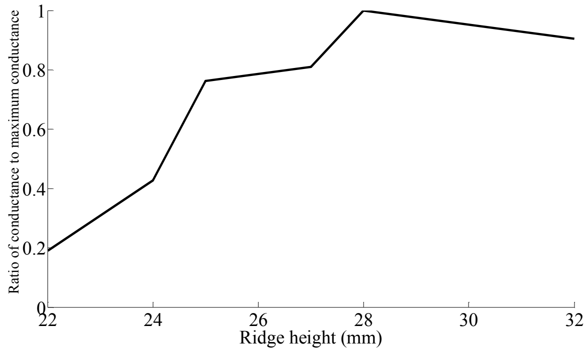


Fig.2 ratio of conductance of maximum conductance for different height of the concave ridge.

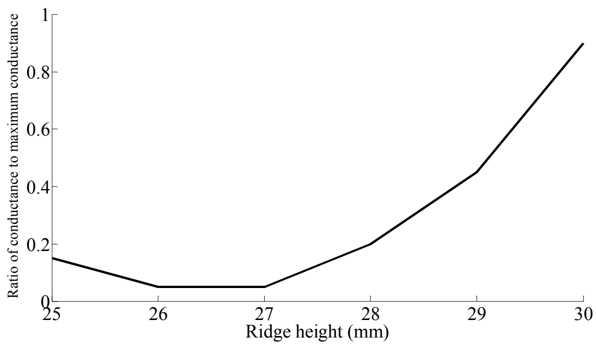


Fig.3 ratio of conductance of maximum conductance for different height of the convex ridge.

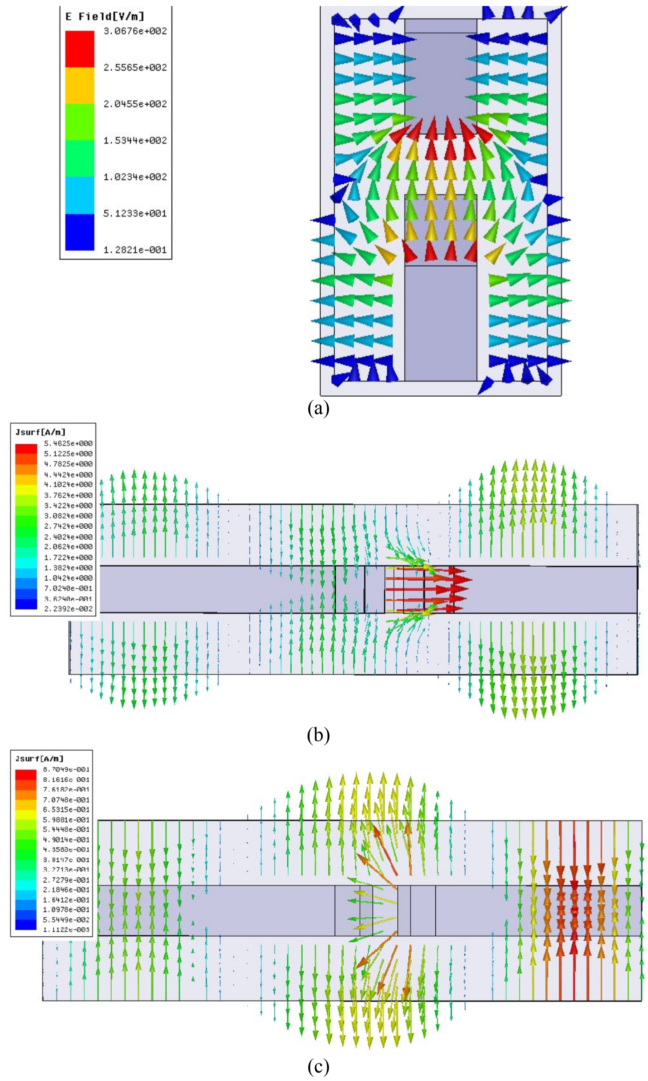


Fig.4. (a) E filed in narrow wall of double ridge waveguide, current distribution in narrow wall of angled distribution without slot (b) convex double ridge(c) concave double ridge.

does not intercept the current flow on the narrow wall and therefore does not radiate. Thus, the current distribution must be changed in the place of the slot so that the untilted slot radiates. One of the best methods where by appropriate field distribution is induced within the waveguide is to use ridges inside it.

This is because the ridges within the waveguide displace the fields in relation to their form and position. Thus, in double ridges waveguide the fields are confined within the ridges. For this purpose, one can make use of the ridge inside the waveguide to induce appropriate levels of current in the untilted slot so as to generate appropriate radiation levels with the least cross-polarization fields.

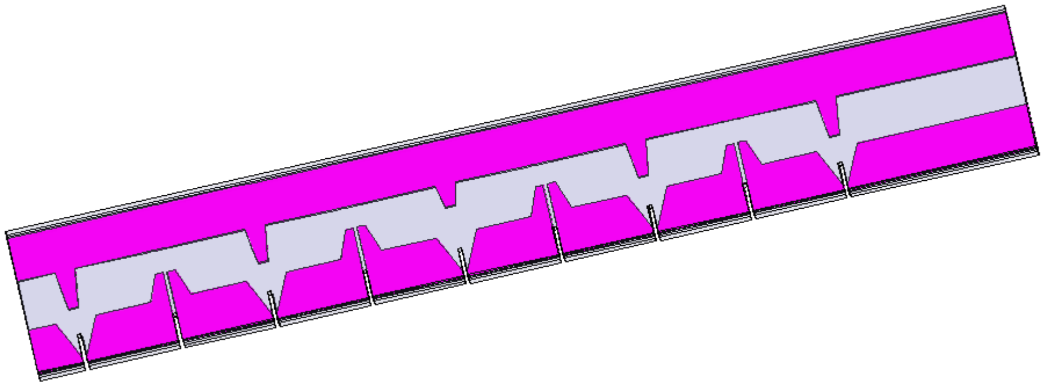
Figure 1 shows the proposed configuration and the dimensions as the appropriate alternative for tilted slot

waveguide antenna where anuntilted slot has been cut in the narrow wall of the waveguide. Double ridge on the narrow wall of the waveguide is placed under the slot. The length of the slot, similar to that of dipoles, is about $\lambda/2$. As shown in Fig.1, the field between two ridges starts is moving; depending on the convexity or concavity of the ridges in the place of the slots the field moving towards the slot radiating with the untilted slot.

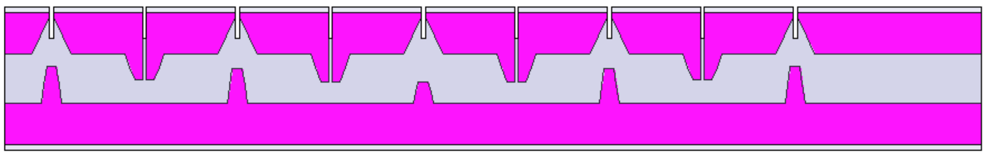
The untilted slot waveguide antenna is equivalent to a shunt impedance circuit. The various height of the concave and convex ridge causes the slot to have various normalized conductance. For the slot to be in the resonance condition the susceptance should be equal to zero. In Fig. 2 and 3, the ratios of conductance of maximum conductance for different height of the concave and convex ridges are shown.

To better understand the behavior of the waveguide slot antenna, the distribution of electric fields and the currents distribution on the surface of the waveguide are shown in Fig.4. Fig.4 (a) shows the distribution of electric field on the side of the waveguide without slots. As can be seen, most of the fields reside between the double ridges.

Fig. 4 (b) shows the current distribution in the narrow wall of the convex double ridge waveguide for the dominant mode.



(a)



(b)

Fig.5. Configurations of the (a) front and (b) top view of designed array.

Hence, the untilted slot can interrupt the direct current distribution.Fig. 4 (c) shows the current distribution in narrow wall of the concave double ridge waveguide for the dominant mode. Thus, the untilted slot can interrupt the direct current.

III. ANTEENA ARRAY DESIGN

For the slots to be in the resonance condition each should reveal a resistance load. Calculating normalized conductance and susceptance for the slots on the basis of the lengths of the slots one can find the optimal length for the slots where normalized susceptance equals zero (i.e. $\lambda_0/2$). The slots are spaced λ_g / 2 .The distance between centers of slot and S.C end waveguide wall is the half wavelength at the frequency of 5 GHz as the $\lambda_g/4$ line is short circuited.

Fig.5 shows the front view of the designed antenna array of nine chebyshev resonant untilted slots in a double ridge waveguide.

The height of concave and convex ridges of x_n(n=1, 2… 9) which control the conductance and excitation level of each slot, are determined from the resistance curve described in figures 2 and 3.The designed parameters for 20 dB SLL are listed in table 1.

The optimal antenna parameters for resonance at 5 GHz are set as follows: a=22.86mm, b=10.16mm, t=1.27mm, Wr=4mm, Hr=15.24mm, Ws=1.27mm.

TABLE1. DESIGNED SIZE OF HEIGHT OF CONCAVE AND CONVEX RIDGE AT CHEBYSHEV ARRAY FOR SLL=20 DB

	X1,9	X2,8	X3,7	X4,6	X5
Height(mm)	30	25.7	29	26.3	24

based on the normalized conductance of each slot the array is designed neglecting the mutual coupling. The array was designed so that to have a normalized input admittance of y=1 at the operational frequency.

It has to be mentioned that the presence of the ridge within the waveguide causes the wavelength of the design frequency to be shorter as compared with the simple waveguide. To calculate λ_g, HFSS software and the following formulae were used:

$$\gamma = \alpha + \beta \quad (1)$$

$$\lambda_g = 2\pi / \beta \quad (2)$$

The simulation of the designed array was done using Ansoft HFSS and CST Microwave Studio software.

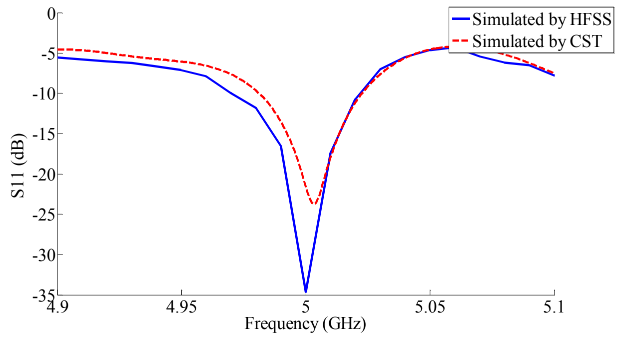


Fig.6.The reflection coefficient designed array antenna with HFSS and CST.

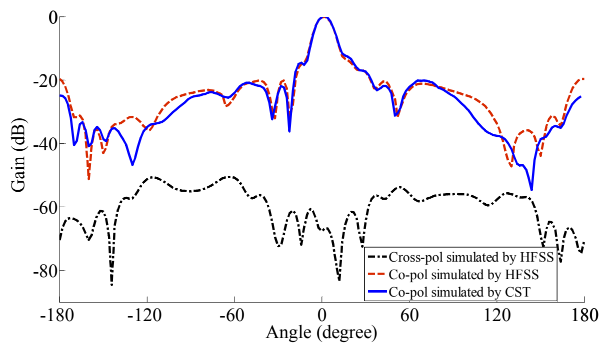


Fig.7. Simulated co and cross polarization of H-plane radiation pattern of the array with HFSS and CST.

IV. RESULT

The calculated input reflection coefficient is shown in Fig.6. the reflection coefficient is less than 30 dB at design frequency.

Fig.7 shows the H-plane radiation pattern of the array. The simulation results show that cross polarization level is -60 dB below the main lobe. The cross polarization in proposed structure is omitted in some extent and improvement of the cross polarization is -40 dB and a side lobe level of about -20 dB. There is good agreement between simulation results from HFSS and CST software for reflection coefficient and radiation pattern.

The radiation efficiency of untilted slot array exceeding 0.995 at 5 GHz. which is improved 0.15 efficiency of tilted slot array antenna this good radiation efficiency is due to the use of the ridge into waveguide. The radiation efficiency is obtained by calculating the total radiated power of the slot array antenna with HFSS over the 3-D spherical radiation first and then dividing that total amount by the input power of 1watt.

The peak gain of untilted slot array over the 5 GHz is 15 dBi, which is developed 2 dBi peak gain of tilted slot array antenna.

V. CONCLUSIONS

A novel array antenna composed of untilted slots in the narrow wall of the ridge waveguide, with significantly improved cross-polarization, is presented. The proposed structure works by inserting a convexity or reducing the concavity of one of the ridges of the double-ridge waveguide. The linear array consists of nine chebyshev resonant untilted slots in the double ridge waveguide at the frequency of 5 GHz. The simulated results show that the antenna has an excellent cross-polarization smaller than -60 dB and a side lobe level of about -20 dB.

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