Inclined Slots on Broad wall of Ridged Waveguide

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Abstract— *A new inclined slot array on the broad wall of a single ridged rectangular waveguide is proposed. This paper presents slot array with similar inclination for all slots, slot array with different inclination and non-uniform length slots with different inclination on broad wall of a single ridged rectangular waveguide for vertical polarization. The co and cross polarization curves of the three designs are compared at different angles of observation.*

Keywords— Inclined Slots, Ridged Waveguide, Slotted Waveguide Array (SWA)

I. INTRODUCTION

Slotted Waveguide Arrays (SWAs) radiates through slots cut in broad wall or narrow wall of a rectangular or ridge waveguide. They are used for many applications because their designs are very simple; slots and feed system are on a single structure. There is no need for baluns or matching networks due to design simplicity. There are many advantages of slotted waveguide arrays(SWA).They have less weight and volume, high power handling, good reflection coefficient and high efficiency. Thus, SWAs are being used widely in many radar, navigation, communications and high power microwave applications [7].

The bandwidth of slotted rectangular waveguide array is very less. TE10 mode is the dominant mode in rectangular waveguide and it has a cut off wavelength of about 2a. Therefore dimensions of waveguide along x direction should be less than or equal to 2a where a is broad wall dimension. For a/b ratio equals two, next higher order mode will be TE20 or TE10. This will have cutoff wavelength equals either 2b or a, where b is narrow wall dimension and 2b=a. But dimensions of the waveguide is chosen such that only dominant mode can propagate. The ridge waveguide is made by adding conducting ridges on top and bottom wall of rectangular waveguide. An inward perturbation of the waveguide walls at a position of high E will lower the cutoff frequency. At the position of high H will raise the cutoff frequency. These ridges will lower the cutoff frequency of the dominant mode and will raise the cutoff frequency of the next higher order modes. Hence higher range of single mode of operation can be obtained using this technique. This results into higher bandwidth of operation.

David Y. Kim and Robert S. Elliott proposed a design procedure for longitudinal slot array on broad wall of waveguide having ridges on opposite broad wall[2]. The present paper presents inclined slot array on the broad wall of a single ridge waveguide in X-band**.** Ridged waveguide slot array has better performance compared to a rectangular waveguide broad wall slot array when the main lobe direction is off-broadside. This is because a ridged rectangular waveguide helps decrease the character impedance of guide and increases the bandwidth of operation as compared to a rectangular waveguide [6]. There are three designs proposed in this paper. The first two designs are equal length slots cut with same inclination and different inclination angles respectively. In third design the length of each slot is calculated using design equations given in [2] and the non uniform length slots are cut with different inclination angles.

II. WAVEGUIDE SLOTS

Waveguide slot radiates because an electric field is created at the slot aperture across the width of the slot. This is done by blocking surface current components on waveguide walls by creating an opening in waveguide walls. A slot will block surface currents on waveguide walls if there are traversal current components at the slot location on waveguide wall before opening the slot and direction of surface current components should be perpendicular to slots length. The current distribution on a single ridged rectangular waveguide walls for TE10 excitation can be seen in Fig 1. By seeing this current distribution it can be decided which type of slots can be opened on a ridged waveguide wall as radiating elements.

As it can be seen from the Fig 1 and 2, the surface current distribution for ridged waveguide is perpendicular to that of rectangular waveguide. So the offset broad wall slots with some offset from centerline of the waveguide will not block the surface current on the wall of waveguide since the slot length is not perpendicular to direction of current. Therefore the approach is to use inclined slot. Inclined slot due to some inclination will be able to block the surface current on the broad wall of waveguide. Since the slots are cut on top broad wall, the polarization of the array is mainly vertical; but a horizontal component is also present because of inclination of slot.

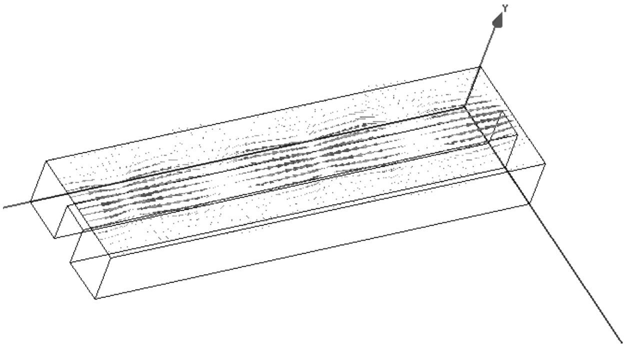

Fig. 1: Surface current distribution on the broad wall of ridged waveguide

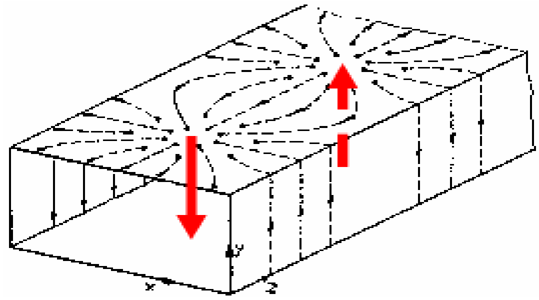

Fig. 2: Surface current distribution on the broad wall of rectangular waveguide

III. RESULTS

In the first design as shown in Fig. 3 all the slots are cut with same angle of inclination. All the slots have equal length which is λ0/2 where λ0 is free space wavelength. The free space wavelength is calculated for solution frequency in X-Band. The slot array is designed for center frequency of 9 GHz. So the resonant slot length is taken as 16.67 mm. The angle of inclination is 45°.

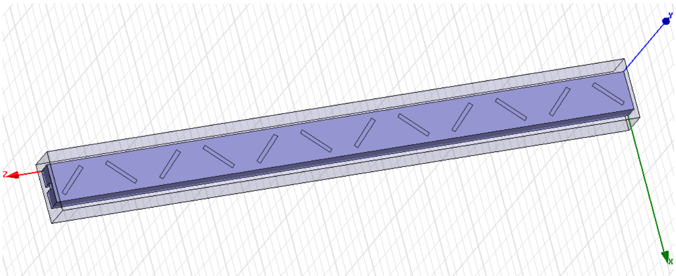

Fig. 3: Inclined Slots on ridged waveguide with same inclination

The co and cross polarization curves are observed with respect to θ for three different values of ∅ (angles of observations) at 45°, 90° and 135°. Since the slots are cut on top broad wall of the waveguide the co polarization is vertical polarization and cross is horizontal polarization.

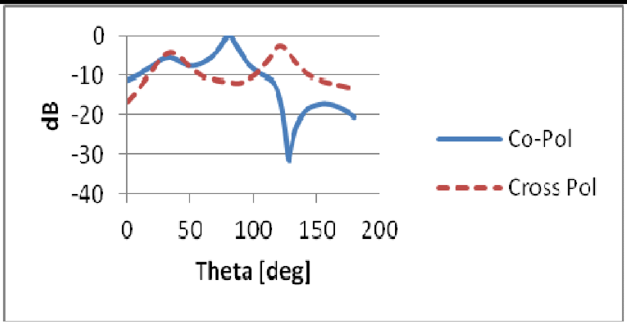

Fig. 4: Co and cross polarization curve for inclined slots with same inclination at ∅=45°

Fig. 4 shows the co and cross polarization curve for first design at ∅=45°. The ratio of co polarization to cross polarization in broadside direction is 11.5dB.

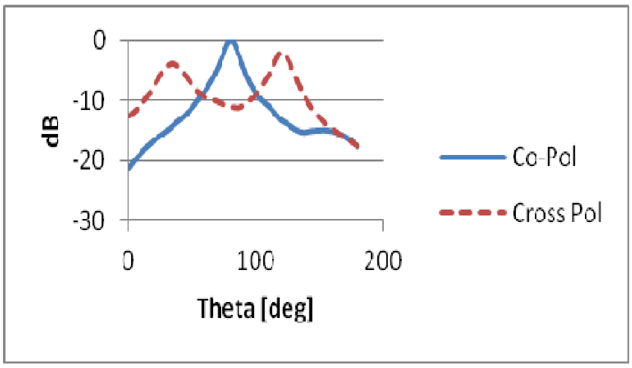

Fig. 5: Co and cross polarization curve for inclined slots with same inclination at ∅=90°

The co and cross polarization curve for inclined slots with same inclination at ∅=90° is presented in Fig. 5. The co to cross polarization ratio in main lobe direction is 11.02dB which is slightly less than the ratio at ∅=45°.

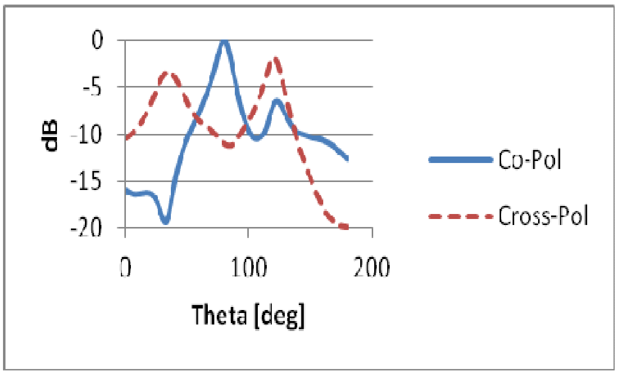

Fig. 6: Co and cross polarization curve for inclined slots with same inclination at ∅=135°

Fig. 6 depicts the co and cross polarization curve for design shown in Fig 3 at ∅=135°. The co to cross polarization ratio at ϴ=90° is 11.0dB. The ratio is almost same at three different angles for inclined slot array with same inclination.

The second design as shown in Fig. 7 consists of uniform slots i.e. slots with equal length but different inclination given by Table 1.

Table 1: Different Inclination for slots

Slot Number	Angle of inclination
1 and 12	10°
2 and 11	20°
3 and 10	30°
4 and 9	40°
5 and 8	50°
6 and 7	60°

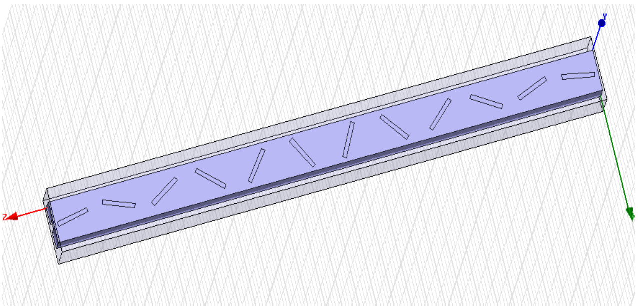

Fig. 7: Inclined slots on ridged waveguide with different inclination

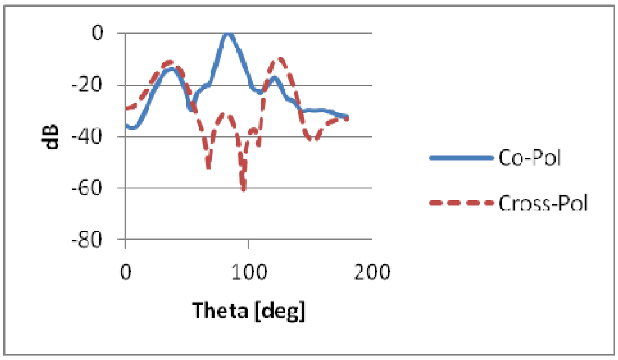

Fig. 8: Co and cross polarization curve for inclined slots with different inclination at Ø=45°

Fig. 8 shows co and cross polarization curve for inclined slot array with different inclination as shown in Fig 7 at Ø=45°. The ratio of co and cross polarization in main lobe direction is 31.72dB which is much better compared to design with same angle inclined slots.

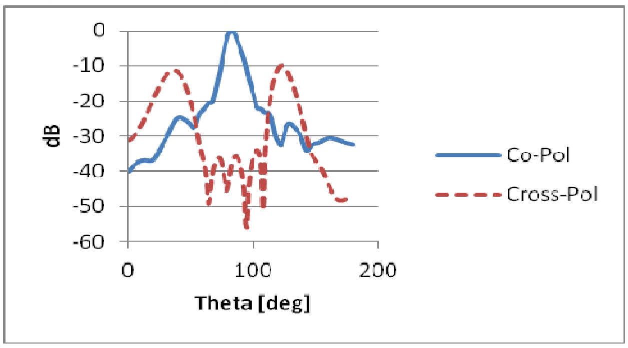

Fig. 9: Co and cross polarization curve for inclined slots with different inclination at Ø=90°

Normalized co and cross polarization curve for the second design at Ø=90° is shown in Fig. 9. The co and cross polarization ratio is 37.77dB which is better than the ratio at Ø=45°. The slot array with different inclination angles shows significant improvement in co and cross polarization ratio.

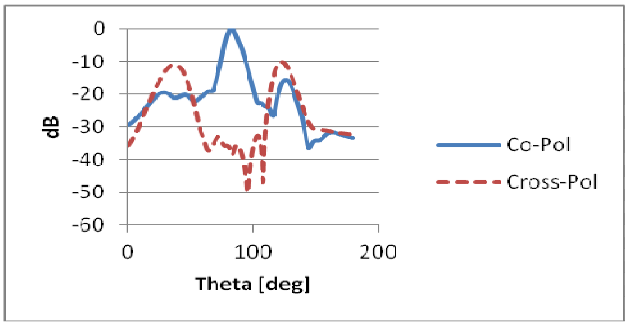

Fig. 10: Co and cross polarization curve for inclined slots with different inclination at Ø=135°

Fig.10 illustrates co and cross polarization curve for the second design at Ø=135°. The co and cross polarization ratio is 37.93dB which is the best of all designs.

In the third design, non uniform length slots are cut with different inclination. The slot lengths for non-uniform slots are calculated using the design expressions given in [2]. The slots are cut at different offsets from center line of the waveguide.

The slot length, offset and inclination for slot array at 9 GHz is given in Table 2

Table 2: Different Inclination for non- uniform length slots

Slot Number	Offset from center line	Slot Length	Angle of inclination
1 and 12	1.06mm	16.32mm	10°
2 and 11	1.10mm	16.42mm	20°
3 and 10	1.19mm	16.63mm	30°
4 and 9	1.21mm	16.81mm	40°
5 and 8	2.08mm	16.89mm	50°
6 and 7	1.85mm	17.04mm	60°

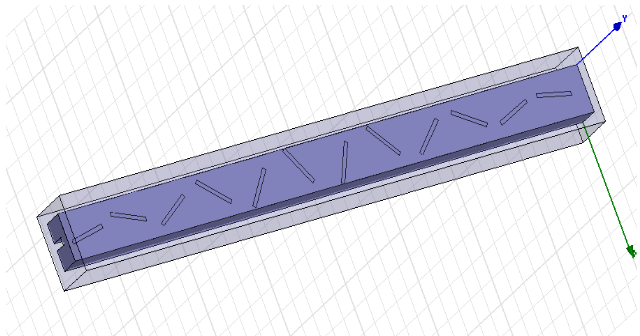

Fig. 11: Non-uniform slots on ridged waveguide with different inclination

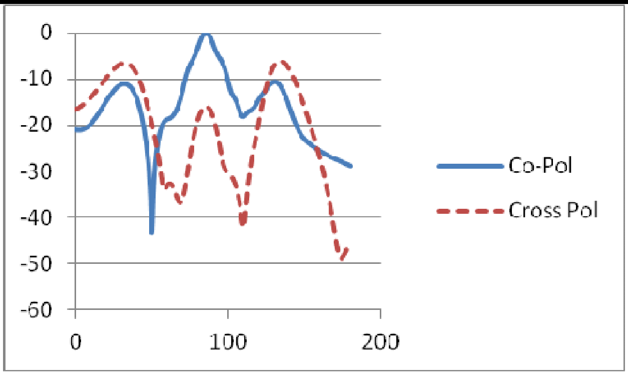

Fig.12: Co and cross polarization curve for non-uniform length slots with different inclination at Ø=45°

Fig. 12 depicts co and cross polarization curve for non-uniform length slots with different inclination as shown in Fig. 11 at Ø=45°. The co and cross polarization ratio in broadside direction is 16.04dB. The ratio is decreased for non uniform length slots.

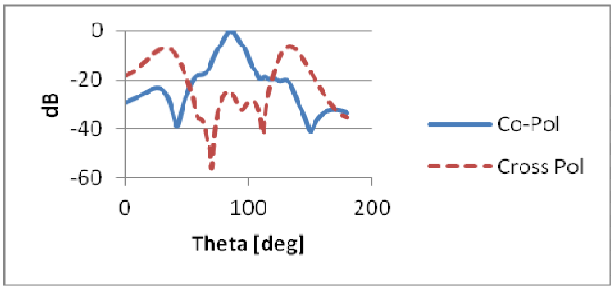

Fig. 13: Co and cross polarization curve for non-uniform length slots with different inclination at Ø=90°

Co and cross polarization curve for the third design at Ø=90° is presented in Fig. 13. The co and cross polarization ratio is 25.15dB. The ratio is better than the ratio at Ø=90°.

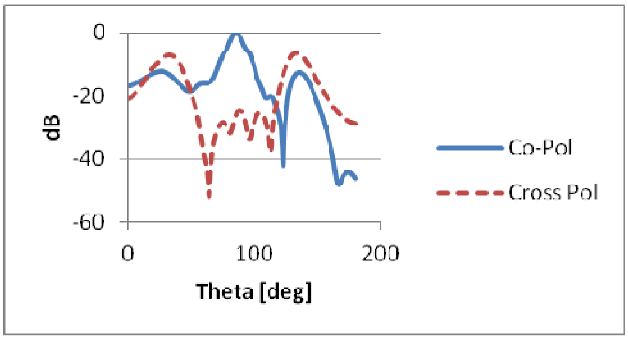

Fig. 14: Co and cross polarization curve for non-uniform length slots with different inclination at Ø=135°

Fig. 14 shows co and cross Polarization curve for the third design at Ø=90°. The co and cross polarization ratio in main lobe direction is 26.34dB. Non-uniform length slots with different inclination give better co and cross polarization ratio than slots with same angle of inclination.

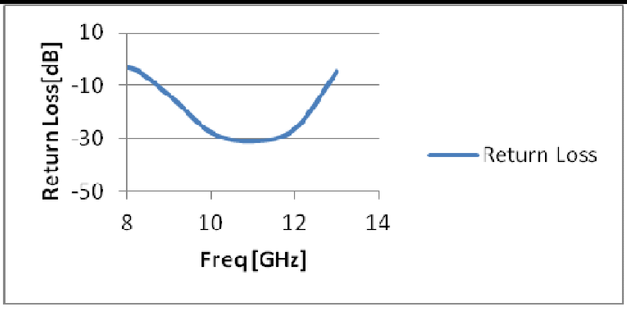

Fig. 15: Return loss versus frequency curve

Fig. 15 illustrates return loss versus frequency curve for second design. The return loss is less than -10 dB in the frequency range 9 to 12GHz.

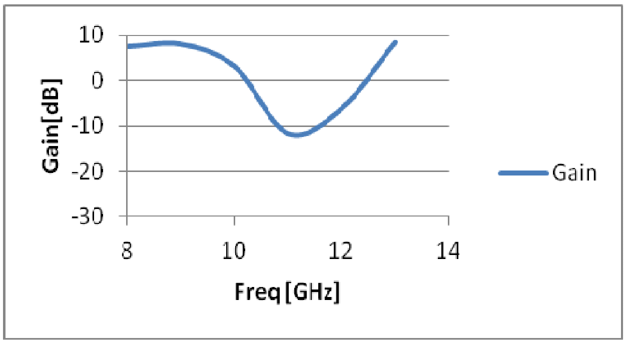

Fig. 16: Gain versus frequency curve

Gain versus frequency curve for the second design is shown in Fig. 16. The maximum value of gain is 8dB at frequency 9GHz.

The ratio of co and cross polarization for the three designs at three different angles is compared in the Table 3.

Table 3: Comparison of co and cross polarization ratio

Design	**Ø = 45**	**Ø = 90**	**Ø = 135**
Slot array with same inclination angle	11.544 dB	11.0241 dB	11.0001 dB
Slot array with different inclination	31.7234 dB	37.7737 dB	37.9369 dB
Non-Uniform slot array with different inclination	16.0427 dB	25.1518 dB	26.3472 dB

By comparing the co and cross polarization ratio at three different angles as given in Table 3, it can be inferred that equal length slot array with different inclination gives the best result of all three designs. Inclined ridged wave guide slotted waveguide array can be used for vertical polarization for broad side radiation i.e., φ=90°. The same waveguide array can also be used for dual polarization by considering the angles of observations along φ=45° and 135°.

IV. CONCLUSIONS

Three different slot arrays on the broad wall of single ridged rectangular waveguide are designed and the ratio of co and cross polarization at three different angles is compared. The slot array with equal length slots and different inclination angle gives the best result of all the three designs. Such arrays have applications in dual polarized slotted waveguide arrays which are used in radar, navigation, communication and high power microwave applications.

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