

Analysis of Asymmetric Iris Excited Centered Slot Antenna on the Broadwall of Rectangular Waveguide

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Abstract. This paper presents the analysis of H plane iris excited broadwall centered longitudinal slot antenna in X band (9-11GHz). Radiation characteristics of centered slot with iris has been obtained with one port terminated by a matched load. Iris depth and thickness is optimized to 4mm thickness and 0.38mm depth ratio, giving the optimized realized gain of 4.8dB at 10GHz in both azimuth and elevation plane.

Keywords: H plane iris, Centered longitudinal slot, Radiation characteristics, X band, Realized gain

1. Introduction

In the modern day missile and airborne systems require fast and less weighty monopulse tracking components. For ease of tracking and fast switching flat plate antenna has been used with comparator. Slotted array antenna is the most widely used in flat plate antenna category. It is less weighty, planar and easy to swing in azimuth and elevation plane using gimbal. The conventional slots are placed on the broadwall of a rectangular waveguide with an offset from the center line of the broadwall. The theoretical analysis of radiation from an off center slot has been analyzed by Watson [1], Stevenson [2]. Slot analysis states that radiation from a slot is due to the perturbation of surface current in broadwall. Off centered slot thus gives enough radiation efficiency compared to a centered slot. Stevenson's analysis highlighted the solution of the field equations for single slot inside waveguide and halfspace. He solved the field continuity equations with Green's function for two different regions. Later Elliott showed the application of method of moment with Galerkin's technique in [3] for finding out the field solution in slot environment. With the formulation of Elliott's field equation Rengarajan [4] established the generalized field solution of a compound slot in broadwall. Using the solved field results he established the forward and back scattered coefficient which is useful to find out the scattering parameter values for waveguide in slot environment. He also used the solutions of a single slot to get the effect of mutual coupling in array environment [5]. Slot also has been used for coupling between two waveguides. Tiwari et al. [6] showed the effect of inclined slot over the coupling effect. The combination of inclined slot and radiating slots are used in the flat plate antenna.

In this paper a new type of slot antenna has been established. Slots cut on the broadwall do not radiate, but if the centered slot perturbs the surface current then the slot can be useful in radiation. With the above theoretical observation a centered slot antenna has been analyzed. Also in a large array environment slots at the end of the waveguide are placed almost at the center. So effectively those slots do not take part in radiation. This cause degradation in total gain. Those centered slots can be useful in radiation if we use an iris such that it shifts the surface current center line to sideways. By incorporation of this type of slots in planar slotted array antenna will give rise to bandwidth enhancement also.

2. Analysis of Centered slot

Longitudinal slots are analyzed using the field equivalence theorem which enables to derive the integral equation for the continuity condition of magnetic field at slots by using Green's function and unknown

electric aperture field. Generally the region of slots is divided in to three sub region. Fig 1 shows the field continuity equation solution region. With the solution of the field equation shunt equivalent circuit parameter for longitudinal slot is obtained.

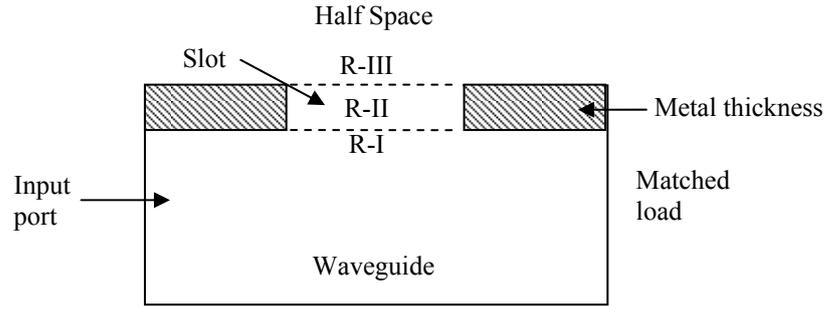


Fig 1. Waveguide – slot field equation region.

In the analysis we consider rectangular waveguide has two ports. One is input port and other port is matched. In this paper the above analysis of slot is performed in presence of a thick H plane iris placed in ‘L’ shape with slot in rectangular waveguide. Analysis of thin iris has been done analytically by Marcuvitz [7]. He also highlighted the variation of iris depth in the terminal plane susceptance calculation. From the field calculation the equivalent network model has been found out for a thin iris. Later he extends his theory for a thick iris having sharp edge and curved edge. With the presence of a single thick asymmetric iris the surface current patterns shifted to left of the center line of the broadwall. Hence broadwall slot can be used for radiation with shifted surface current density. Also thick iris has a variation of thickness which is already optimized in [8]. FEM analysis is used to find out the exact inductive and capacitive variation due to depth and thickness variation of iris. Here only the TE_{10} mode of propagation near the iris is considered. The iris slot model is shown in Fig 2. Here the slots have curved edge for ease of fabrication. Iris is taken with sharp edge though it has been seen in [8] that edge diffracted electric field effect can be minimized using the curved edge iris.

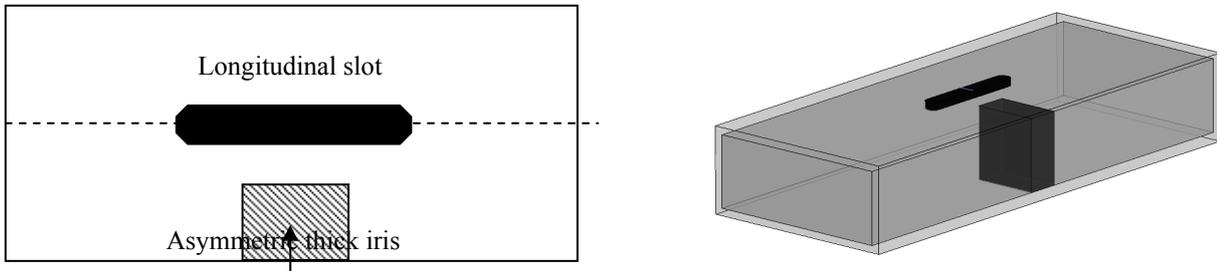


Fig 2. Structural layout of centered slot antenna with iris (a) Top View (b) 3D view of slot antenna

The equivalent circuit of the above structure is shown in Fig 3. A longitudinal slot is represented by a shunt circuit with G and jB . Equivalent circuit representation has been highlighted by Oliner [9]. Thick iris has the equivalent circuit of combination of capacitive and inductive reactance. Though if we take the effect of edge diffraction then the equivalent circuit parameter for iris will change. Here we use to transform the whole circuit in to a ‘T’ equivalent model. The overall effect has a transformer which has been used to highlight the modal conversion of field due to iris in slot. Overall input capacitive and inductive impedance value can be obtained using the 1 and 2.

$$j \frac{X_a}{Z_0} = \frac{Z_{12}}{Z_0} = \frac{2S_{12}}{(1-S_{11})^2 - S_{21}^2} \quad (1)$$

$$-j \frac{X_b}{Z_0} = \frac{Z_{11} - Z_{12}}{Z_0} = \frac{1+S_{11} - S_{21}}{1-S_{11} + S_{21}} \quad (2)$$

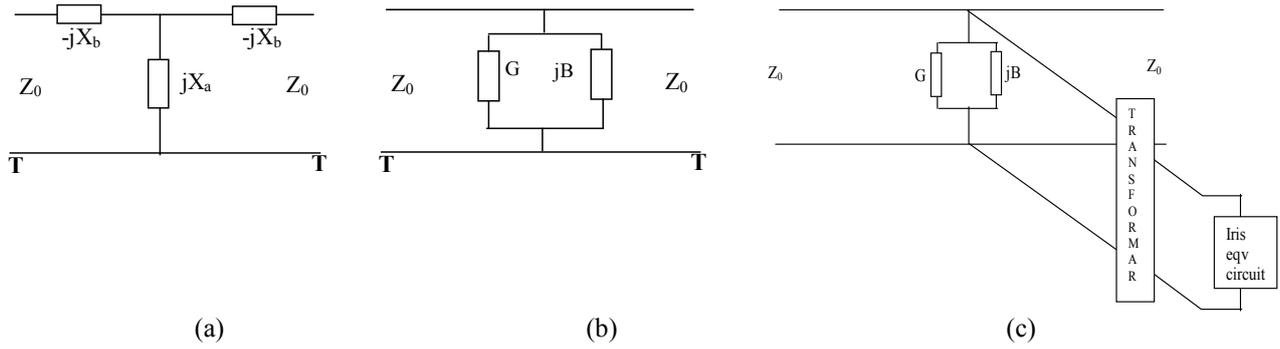


Figure 3. Equivalent circuit model of

(a) thick iris in waveguide, (b) longitudinal slot in broadwall and (c) Iris with slot in rectangular waveguide

3. Results and Discussion

Finite element method based simulation technique using ANSOFT HFSS™ is used to analyze the iris excited slot antenna in a WR90 rectangular waveguide with wall thickness of 1mm. Input and output matched loads are de-embedded on to the terminal plane. Here for ease of calculation the de-embedding length is multiple of λ_g from the terminal plane of slot. Slot length is chosen to be 14mm and width of 2mm which is designed to resonate at 10GHz. Iris thickness and depth is parametrically varied. Height of the iris is kept constant though for better return loss one can optimize the height of the iris. In general broadwall longitudinal slots are placed at a distance of $\lambda_g/4$ from the short circuit output port. Slot antenna has been simulated within 9-11GHz frequency range. Azimuth and elevation plane realized gain plot are shown in Fig 4 and Fig 5, which is studied for variation of thickness and depth.

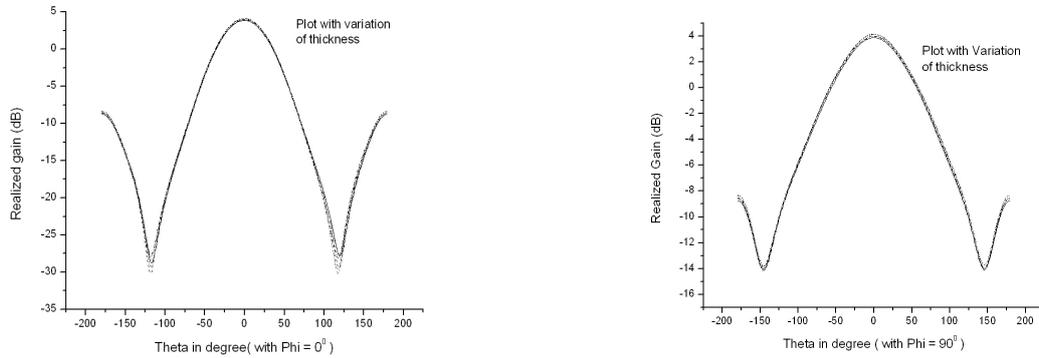
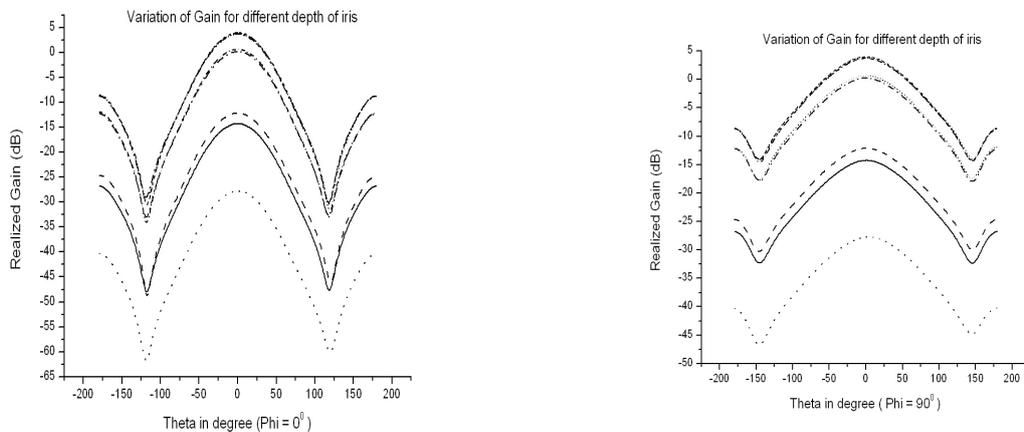


Figure 4. Realized gain variation with variation of thickness for 0.4mm depth ratio of iris.



Variation of S_{11} (dB) is studied with the above two parameters namely the thickness and depth of iris. Plot of S_{11} (dB) is shown in Fig 6. As the slot is analyzed in travelling wave environment hence the return loss is optimized to a better result. Depth optimization is done on the basis of radiation pattern in both planes. It has been observed that with lower depth of iris gives better S_{11} characteristics.

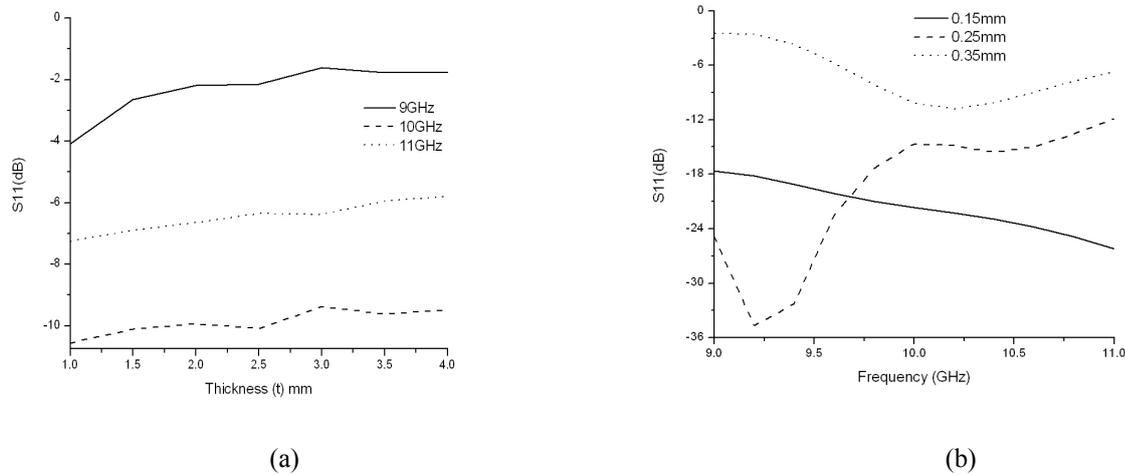


Figure 6 S_{11} (dB) plot for iris dimension. (a) Variation of thickness of iris for different frequency (b) variation of depth of iris

4. Conclusion

FEM simulation results show the optimum depth and thickness of iris for designing the centre slot antenna. Variation of thickness does not contribute any considerable change in radiation pattern. Though one should avoid thick iris for weight reduction. Variation of depth gives optimized depth for good amount of radiation efficiency. Here we choose sharp edge thick iris though the effect of edge diffraction in sharp edge can be minimised using curved iris and that will be more useful in final slot analysis. For a slot array environment iris has to be placed in either side of the slot to adjust the phase of each slot excitation.

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