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# MODELLING OF MICROWAVE SLOTTED WAVEGUIDE FOR LTE SIGNAL DETECTION

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**Abstract-** Microwave Slotted Waveguide Antennas are Widely used for the detection of target or for aiming the target in aircraft, Ships & Submarines. Slotted Waveguide antennas are the first choice for the radar system in naval as well as in aircrafts. Slotted Waveguides have proven their efficiency in target detection having very low false target detection rate high probability of small target detection. Researchers have explored slotted waveguides for broad wall of the antenna but only some of the researches have explored narrow side of the antenna. In this Research slots are etched in the narrow side wall of the antenna to get high gain as compared to the previous structure and keep the side lobe levels below the threshold level without using any reflector or extra component with the waveguide model.

**Keywords:** Radiation Characteristics, Submarine, Aircraft.

## 1. INTRODUCTION

Regularly, electromagnetic energy is transmitted utilizing waveguide structure. Waveguides find wide application because of their reliability & robustness. One more advantage of utilizing waveguide structure is that the radiation loss is very low. Waveguides are generally employed in radar systems meant for Naval, Maritime, and Aircrafts etc. Slots are etched into the waveguide structure to operate it as an antenna for radar system. There are two walls in the waveguide structure namely broad wall and narrow wall. Many Researchers have analyzed broad wall structure for Radar Applications & thus lots of work is done on the broad wall structure to make it efficient for radar transmission system.

Only few Researchers have analyzed narrow wall waveguide structure to work as a radar antenna [1]. In this research narrow wall of the waveguide is chosen for analysis of the radiation pattern gain & cross polarization component. To work efficiently as a Radar Antenna waveguide must possess some characteristics like radiated energy must be focused at target, radiated back energy from the target only must be considered. It should have high gain and low side lobes because energy radiated in side lobes adds to the losses and reduces gain. Causes for side lobes are offset aperture of the waveguide structure and cross polarization component.

The designed model of waveguide is simulated in HFSS (High frequency software simulation) with the objective of getting optimum gain & reduced side lobe level. High level of side lobes results in falls target detection.

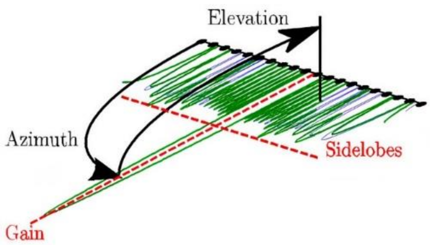


Figure 1. Suitable waveguide antenna radiation [1]

## 2. MATERIALS AND METHOD

Radar system which operates in X-band 8 to 12 Ghz. This radar system provides optimum gain for the low side lobes because energy radiated in side lobes adds to the losses and reduces gain. Causes for side lobes are offset aperture of the waveguide structure and cross polarization component. The designed model of the waveguide is simulated in HFSS (High frequency software simulation) with the objective of getting optimum gain & reduced side lobe level [2]. High level of side lobes results in the falls target detection whereas low side lobe levels help in determining the position of the target. A suitable waveguide reduces radiation in other direction while keeping gain high in main lobe. Aim of the research is to design a waveguide model which can be effectively employed in Maritime Radar system which operates in X-band 8 to 12 GHz [4].

### 2.1. Waveguide Modeling

Inclined slots are etched in the narrow wall of the waveguide with inclination of 45°. If the slots would be non-inclined structure would not radiate because it would not alter the flow of current and it would not be possible to employ it in radar transmission system. Inclination of slots is kept opposite to each other which results in addition of the axial component of the current and cancellation of radial component of the modeled in HFSS for frequency range of 8 to 12 GHz. This addition results in the high gain of the waveguide and increase in the probability of correct target detection [7].

Table 1. Designed structure parameters

| Parameters | Specification |
|---|---|
| Operating Frequency | 9 Ghz |
| Length of Slots | 16.67 mm |
| Width of slots | 2.4 mm |
| Slot spacing | 24.35 mm |
| Distance of last slot from | 12.18 mm |
| Inclination of the slot | 45° |

### 2.2. Design of Inclined Slot

Length of each slot is calculated as 16.67 mm with the width of 2.4 mm and slot spacing are calculated as 24.35 mm. Distance of the last slot from load is 12.18 mm.

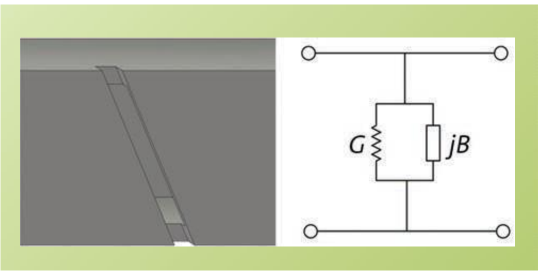


Figure 2. Inclined slot design [2]

Three models are simulated in HFSS for 2, 4 & 10 slots respectively. Gain & cross polarization component in each structure is observed. Radiation Pattern for the far field and near are analyzed waveguide structure is analyzed for the frequency band of 8 to 10 Ghz at the step size of 0.1 to get the resonant frequency. Return loss is observed for the frequency band of 8 to 10 Ghz to get the optimum frequency of radiation for waveguide structure. Modeled structure parameters are shown in the table measurements are calculated based on the waveguide.

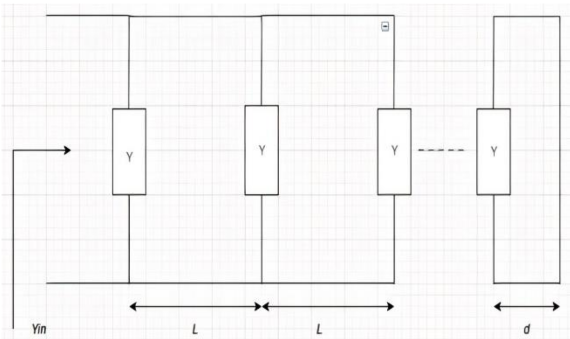


Figure 3. Slot distance calculation [2]

Mohammed Amanta K.S. Lubis et al. (2017) found the radiation characteristics of the narrow wall slotted waveguide antenna he found that when two narrow wall slotted waveguide antennas are connected to each other each having 32 slots using a flange connector a new waveguide is formed. This waveguide is simulated using CST Simulation software and tested for the radiation pattern & radiation characteristics.

They designed three antennas with and without flange connectors and observed gain and side lobe levels of the antennas & found that the side lobe levels are affected due to presence of flange connectors using UBR 100 flange connector along with WR90 waveguide having 32 slots and adding two waveguides make total number of slots as 64. This structure is able to achieve the gain of 23 dB Wave guide Antenna which has not incorporated flange connector shows better results foe side lobe levels as compared to the waveguide antenna having flange connector along with the waveguide structure.

Three such structures are designed and simulated in CST Software first antenna is designed with 64 slots than second antenna is designed with same number of slots and connected via flange connector than third antenna is designed and connected using flange connector trimmed flange connector is used to get the smooth front face of the antenna. They found that by increasing the array of the slots better results are found in terms of gain but side lobe level increases by adding flange connectors which is not desirable increase of the side lobe levels causes error in target detection and increases the probability of false target detection.

### 2.3. Inclined Slot Etching with Resonant Length

S. Murugaveni and T. Kathik (2014) designed a Slotted broad wall waveguide along with reflector. They simulated the structure in HFSS simulation software and design requirements are compared and they were able to get the gain of 16 dB with the help of reflectors they used a WR 90. Waveguide structure along with the Reflector circuit and 16 slots were etched into the broad wall of the waveguide antenna along with the TE10 mode of propagation designed mathematical mode is presented the structure is designed for the X band and the designed model is simulated using ANSYS HFSS simulation software for 9.4 GHz to get the gain and radiation pattern. 3D radiation pattern is presented with the return loss of greater than 10 dB Without reflector the structure has shown the gain of 16 dB but by adding the Reflector to the Waveguide structure having 16 slots in the broad wall of the waveguide the performance of the waveguide structure is enhanced to 22.5 dB. The horizontal mode of polarization is used and the guided wavelength for the structure is found to be 9.4 GHz [2]

Rashid Ahmed Bhatti et al. (2017) designed a planar waveguide structure for 9.37 GHz with many branch feed waveguide along with the main waveguide they used Taylor aperture to calculate Element weight for the side lobe levels of 25 dB in E Plane & H plane they used commercial CST Simulation software to simulate the structure and get the optimum results for the designed structure the surface current of the plane containing the planar array was shown feed point is kept at the center and as the distance from the center increases surface current decreases. Measured and simulated patterns are compared and the gain 0f 25.6 dB is found.

## 3. SIMULATION RESULTS

HFSS Simulation Results for the designed model with two slots significant gain of 18 db with side lobe level of 15 db. Side lobe level seems to be high which should be reduced and to achieve that array is increased by increasing number of slots.

The distance of the last slot is kept 12.18 mm from the end of the waveguide so that the structure resonates Precarious section is underneath the important side fold level the chance of the amazingly planned layer in differential-condition based strategies knows about structure. With increase in the number of slots gain of the antenna will increase but it will also increase the cross-polarization component of the waveguide which causes side lobe levels to be very high and good amount of radiated energy is directed towards the side lobe level.

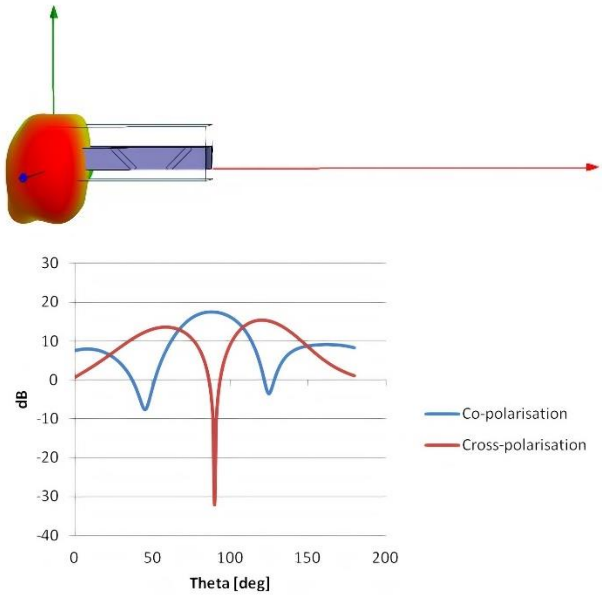


Figure 4. Modelled structure with 2 slots [HFSS Simulation Results]

HFSS for the designed model with four slots provides significant gain of 23 db with side lobe level of 18 db. Mohd Amanta, et al. (2017) Analyzed narrow wall slotted waveguide they combined two waveguide with the help of flange connector each having 32 slots and made a new waveguide of 64 slots to get the optimum gain and reduced side lobe level. The inclined slots must penetrate into the adjacent broad walls in order to radiate. These extended slot structures are kept semicircular to achieve high gain and reduce cross polarization component.

WR 90 waveguide is modeled in the simulation with 10 slots each slot is having opposite inclination to the next slot HFSS Results for the designed Waveguide with 10 slots shows the gain of 26 db. Gain achieved in the modeled design is better as compared to the previous findings by the researcher beside using some new component like flange connector or reflector. ANSYS HFSS simulation software for 9.4 Ghz to get the gain and radiation pattern.

3D radiation pattern is presented with the return loss of greater than 10 dB Without reflector the structure has shown the gain of 16 dB but by adding the Reflector to the Waveguide structure having 16 slots in the broad wall of the waveguide the performance of the waveguide structure is enhanced to 22.5 dB. The horizontal mode of polarization is used and the guided wavelength for the structure is found to be 9.4 GHz.

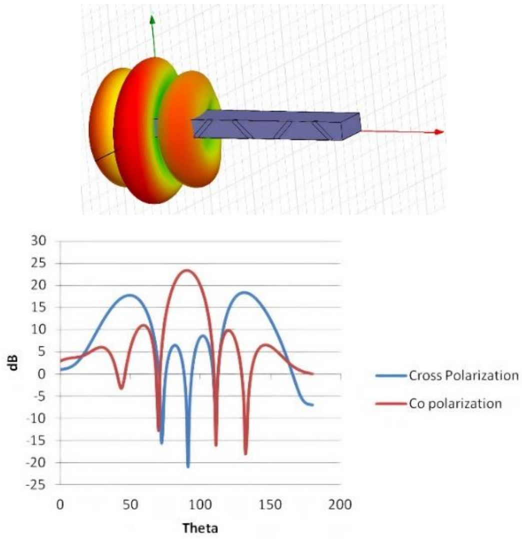


Figure 5. Modelled structure with 2 slots [HFSS Simulation Results]

The inclined slots must penetrate into the adjacent broad walls in order to radiate. These extended slot structures are kept semicircular to achieve high gain and reduce cross polarization component. WR 90 waveguide is modelled in the simulation with 10 slots.

Rashid Ahmed Bhatti et al. (2017) designed a planar waveguide structure for 9.37 GHz with many branch feed waveguide along with the main waveguide they used Taylor aperture to calculate Element weight for the side lobe levels of 25 dB in E plane & H plane they used commercial CST Simulation software to simulate the structure and get the optimum results for the designed structure the surface current of the plane containing the planar array was shown feed point is kept at the center and as the distance from the center increases surface current decreases. Measured and simulated patterns are compared and the gain 0f 25.6 dB is found. Less Complex method is employed in this research as compared to the complexity employed by other researchers which provide robustness to the structure along with the high gain. High gain improves the target detection probability and reduces the probability of false target detection.

The inclined slots must penetrate into the adjacent broad walls in order to radiate. These extended slot structures is kept semicircular to achieve high gain and reduce cross polarization component. WR 90 waveguide is modelled in the simulation with 10 slots each slot is having opposite inclination to the next slot HFSS Results for the designed Waveguide with 10 slots shows the gain of 26 db. Gain achieved in the modelled design is better as compared to the previous findings by the researcher beside using some new component like flange connector or reflector. With increase in the array of slots gain is increased also semicircular cutting into the adjacent broad wall add to the gain of the antenna.

Higher gain is achieved as compared to latest finding by Mohd Amanta et al. found the radiation characteristics of the narrow wall slotted waveguide antenna he found that when two narrow wall slotted waveguide antennas are connected to each other each having 32 slots using a flange connector a new waveguide is formed.

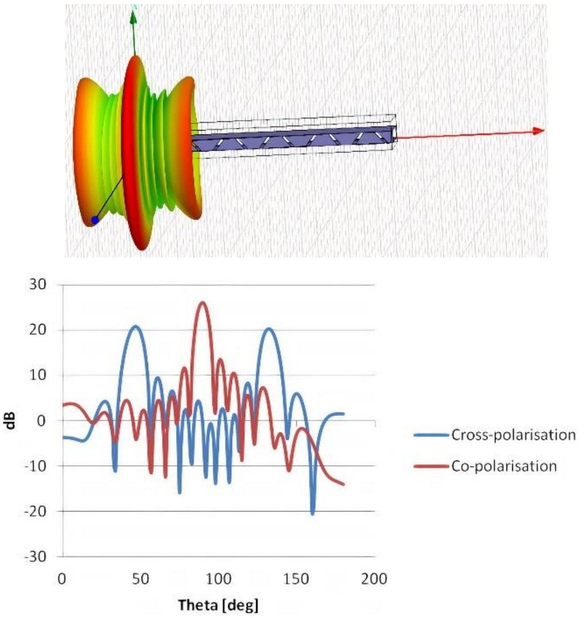


Figure 5. Modelled structure with 2 slots [HFSS Simulation Results]

This waveguide is simulated us pattern & radiation characteristics [9]. They designed three antennas with and without flange connectors and observed gain and side lobe levels of the antennas & found that the side lobe levels are affected due to presence of flange connectors using UBR 100 flange connector along with WR90 waveguide having 32 slots and adding two waveguides make total number of slots as 64. This structure is able to achieve the gain of 23 dB Wave guide Antenna which has not incorporated flange connector shows better results foe side lobe levels as compared to the waveguide antenna having flange connector along with the waveguide structure.

Three such structures are designed and simulated in CST Software first antenna is designed with 64 slots than second antenna is designed with same number of slots and connected via flange connector than third antenna is designed and connected using flange connector trimmed flange connector is used to get the smooth front face of the antenna. They found that by increasing the array of the slots better results are found in terms of gain but side lobe level increases by adding flange connectors which is not desirable increase of the side lobe levels causes error in target detection and increases the probability of false target detection.

They employed CST Simulation software and tested for the radiation found the gain of 23 db by combining two waveguides with each having 32 slots. Flange connector was used to combine two waveguides & to get the array of 64 slots [1].

S. Murugaveni, T. Karthick (2014) designed a Slotted broad wall waveguide along with reflector. They simulated the structure in HFSS simulation software and design requirements are compared and they were able to get the gain of 16 dB with the help of reflectors they used a WR 90. Waveguide structure along with the Reflector circuit and 16 slots were etched into the broad wall of the waveguide antenna along with the TE10 mode of propagation designed mathematical mode is presented the structure is designed for the X band and the designed model is simulated using ANSYS HFSS simulation software for 9.4 Ghz to get the gain and radiation pattern.

3D radiation pattern is presented with the return loss of greater than 10 dB Without reflector the structure has shown the gain of 16 dB but by adding the Reflector to the Waveguide structure having 16 slots in the broad wall of the waveguide the performance of the waveguide structure is enhanced to 22.5 dB. The horizontal mode of polarization is used and the guided wavelength for the structure is found to be 9.4 GHz They used the reflector along with the waveguide and achieved the gain of 22.5 db & gain without reflector was found to be 22.5 dB [3].

Advantage of this designed model is that no any extra component is employed while designing the waveguide like reflector used by S. Murugaveni & T. Karthik. While Mod Amanta et al. employed a flange connector to combine two waveguides each having 32 slots to get the array of 64 slots which increases the complexity of the structure. It reduces the robustness of the antenna which is the primary requirement of the radar applications in aircraft, submarines & naval radar. The designed model for the waveguide provides good results in terms of gain as compared to the gains achieved by Mohd Amanta which is 23 dB & S. Murugaveni & T. Karthik achieved the gain of 22.5 dB whereas in the designed model gain of 26 dB is achieved with the simple structure having only 10 slots.

Adding semicircular cutting into the adjacent sides of the waveguide increases the resonate length to 16.65 mm which helps in achieving the higher gain. But a disadvantage of adding extra length is that side lobes level increase to 20 dB which is acceptable but here it opens new path for the researcher to reduce the side lobe level to minimum value.

Waveguide can be analyzed for the rectangular cutting into the adjacent walls of extending to get resonant length.

Table 2. Simulation result parameters

| Parameters | Specification |
|---|---|
| Gain achieved etching 2 Slots | 18 dB |
| Gain achieved etching 4 Slots | 23 dB |
| Gain achieved etching 10 Slots | 26 dB |
| Resonant Length | 16.65mm |
| Return Loss | >10 |

Gain of 18 dB is achieved with only two slots & Resonant Length of 16.65 mm along with side lobe level of more than 15 dB. With increase in array number of slot increase to 4 and gain of 23 dB is achieved which is high gain with only 4 slots and side lobe levels are of 18 dB. By etching 10 slots in the narrow wall of the waveguide and allowing these inclined slots to extend to the neighboring sides in semicircular shape provides the high gain of 26 dB. Most important advantage of this structure is that optimum gain is achieved without adding any extra element or increasing the complexity of the structure. Thus, this research results in robust waveguide model with high gain and low complexity.

## 4. CONCLUSIONS

Designed structure provided high gain as compared to the previous finding by the researchers without employing any additional component like flange connector or reflector. Gain of 26 dB is achieved with 10 inclined slots in narrow wall of WR 90 waveguide with slot length extending to the neighboring broad walls with semicircular cutting. Robust structure of the waveguide is more prone to wear & tear of the antenna which makes it suitable to be used in aircraft, submarines and naval radars.

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## BIOGRAPHIES

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