

Analyzing of the Feed Line and the Shroud Effects on a Reflector Antenna Performance

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Abstract

High gain, low sidelobe and backlobe levels are important parameters in the reflector antenna design. These parameters are being vital important for the antennas used in radar systems, especially in military applications. If the design of the reflector is made without considering the implementation stage, the characteristics mentioned above can not be provided. To manage this performance reduction, some improvements should be added to the design in the theoretical design stage. This paper propose two analysis for increasing the performance of a prime fed reflector antenna. The first analysis is choosing the true feedline mechanism and the second one is the effect of shroud usage. These analysis are made for an X-band waveguide fed prime focus reflector antenna. Numerical results and chosen design configuration are also presented in the numerical results section.

1.Introduction

In radar systems, suppression intentional or unintentional interference or radar clutter is directly related to the antenna sidelobe level [1]. Because of that, sidelobe suppression has become an important problem for the reflector antennas. In terms of sidelobe suppression, the generic axisymmetric single reflector antennas with simple feeds have four basic limitations, as discussed in reference [2]:

- Feed pattern shaping limitations
- Aperture blockage effects
- Spillover and edge diffraction effects
- Surface accuracy effects

In this study, two effects of four limitations mentioned above are examined. Analysing of feed line mechanism is done for aperture blockage effects. Shroud effect on antenna performance analysis is done for spillover and edge diffraction effects. Narasimhan talks about feed line effect as blocked area and blocking of the primary feed by the goose neck in [3] and also feed line effect is shown by calculating of antenna pattern with and without aperture blocking using GTD method. In this paper, five feed line mechanisms are examined and the best configuration is proposed. In addition to pattern calculation; gain, sidelobe and backlobe level values are presented for different mechanisms and different lengths.

The shroud design is an ideal performance raise factor for prime fed reflector antennas. It has been mentioned as absorber-lined tunnels in [1] and analysed with GTD in [3] and [4]. In addition the diffraction effects and the pattern calculations with and without shroud are shown in [3]. In this paper, the shroud effect on gain, sidelobe and backlobe level of a prime fed reflector antenna pattern is analysed for different shroud lengths. Chosen length of shroud is presented in section 4.

In the literature, there are some designs of X-band prime fed reflector antenna [5,6]. In this study, these designs are being improved by analysing both of the feed line and the shroud effects together. Thus, more effective reflector antenna design is obtained.

2.Feed Line Effect

The gain loss and high sidelobe level are observed in a prime fed reflector antennas because of aperture blockage. The feed antenna and the feed line mechanism cause this blockage effect. Choosing of waveguide line mechanism which carries the electromagnetic wave to the feed of the reflector, affects the reflector antenna performance directly.

Two main situations cause blockage in the prime fed reflector antennas:

- Primary pattern is distorted by feed line mechanism which belongs to feed antenna (horn antenna).

- Gain of the reflector decreases because of the reflector aperture blockage. The feed line has a corner reflector effect on the reflector aperture. Corner reflector effect increases the sidelobe level. Thus, secondary pattern (reflector pattern) distortion is observed.

The aim of this study is choosing the optimum feed line mechanism that distorts the primary pattern at least. Also this design provides the least gain loss and the lowest sidelobe level. Five different feed line configurations are examined to provide these requirements. The reflector diameter is 20λ in all analysis.

The waveguide feed line is gone around the reflector in the first and second configuration as shown in Figure 1. The first configuration is E-bend outside feed line. Waveguide length including E-bend radius, from feed antenna to reflector downside is 12λ . The second configuration is H-bend outside feed line. Waveguide length is same as the first configuration. As shown in numerical results in section 4, the second configuration is more advantageous. Thus the following three steps are made for H-bend feed line.

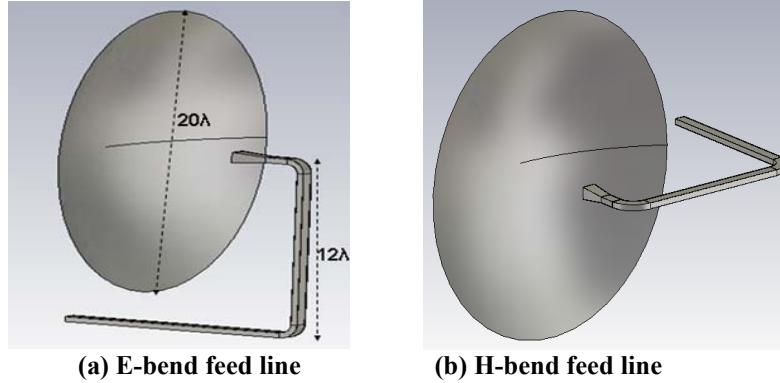


Figure 1. The configurations for the outside feed line design

After the selection of H-bend configuration, additional three different designs have been made as shown in Figure 2. H-bend cast miters are used in place of the bends in these three designs. Also, a hole made on the reflector surface for these three designs. But place of the hole on the reflector surface is changeable according to the design. The third configuration is sideward hole feed line. Optimum lengths of the waveguide line parallel to the reflector and waveguide line perpendicular to the reflector are determined. The fourth configuration is sideward hole offset feed line. The optimum values of three parameters are determined. These parameters are main parallel waveguide line, perpendicular waveguide line and offset parallel waveguide line. The fifth configuration is centered hole feed line. The difference between fourth and fifth configuration is place of the hole on the surface. The hole is made on the center of the reflector in the fifth configuration. Also, optimum values of three parameters, main parallel waveguide line, perpendicular waveguide line and surface parallel waveguide line, are determined. The three configurations are presented in Figure 2. Numerical results are presented in section 4.

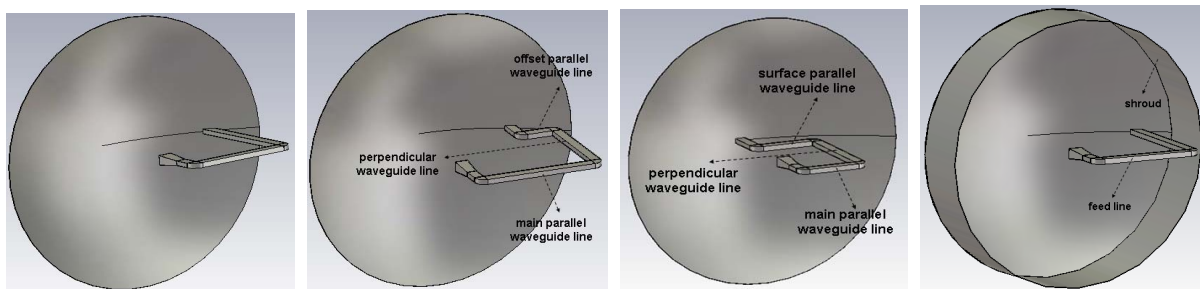


Figure 2. (a) Sideward hole feed line (b) Sideward hole offset feed line (c) Center hole feed line (d) The reflector antenna with shroud

3.Shroud Effect

Edge diffraction and spillover effects increase the sidelobe and the backlobe levels of a reflector antenna pattern. These effects on prime fed reflector antenna can be decreased by using designs with a shroud which one is shown in Figure 2. A prime fed reflector antenna surrounded by conductive shroud is an effective and low cost configuration to suppress the far-out sidelobes and the backlobe. Because of this conductive shroud, the aperture

field is changed and the electric field at the edge of the shroud is rapidly-varying [4]. The aim of this study is determining the optimum shroud length providing maximum gain, minimum sidelobe and backlobe levels. Also, effect of using shroud on reflector antenna performance is presented in section 4.

4. Numerical Results

The simulation results which are presented in this section are obtained by using a commercial electromagnetic problem solver called CST Microwave Studio. One of the simulation results is validated by a measurement result obtained by Spherical Near Field Measurement System in TÜBİTAK BİLGEM UEKAE (The Scientific And Technological Research Council Of Turkey-Center Of Research For Advanced Technologies Of Informatics And Information Security-National Research Institute Of Electronics And Cryptology).

4.1. Feed Line Results

The diameter of the reflector in the first design used for the feed line analysis is 20λ . The five configurations are analyzed. Results are presented in Table 1. In the second design, reflector diameter is 21.5λ . Optimization of lengths are done according to different optimization criterions and the last three configurations are analyzed in this design. Results are presented in Table 2.

Table 1. The simulation results of the first design (reflector diameter is 20λ)

	Gain	Azimuth Sidelobe Level	Elevation Sidelobe Level
No Feed Line	32.8 dB	-28.6 dB	-29.3 dB
E-Bend Outside	32.0 dB	-21.6 dB	-26.5 dB
H-Bend Outside	32.6 dB	-30.4 dB	-25.7 dB
H-Bend Sideward Hole	32.7 dB	-28.4 dB	-27.0 dB
H-Bend Sideward Hole Offset	32.7 dB	-27.0 dB	-27.5 dB
H-Bend Center Hole	32.5 dB	-24 dB	-23.2 dB

In the first design chosen configuration is H-bend sideward hole feed line. Selection criterions are the highest gain and minimum sidelobe level balanced in azimuth and elevation. This chosen configuration is worse than no feed line. However, choosing a feed line mechanism is an obligation to carry the electromagnetic wave. Because of that, the configuration is chosen which has the least corruptive influence on the antenna pattern. In the second design, chosen configuration is H-bend sideward hole feed line. The criterions are the highest gain and the lowest sidelobe level in azimuth and/or elevation. In E-bend and H-bend outside configurations, the gains are low and the sidelobe levels are high because of the electromagnetic interaction between reflector and waveguide line perpendicular to the reflector.

Table 2. The simulation results of the second design (reflector diameter is 21.5λ)

	Gain	Azimuth Sidelobe Level	Elevation Sidelobe Level
H-Bend Sideward Hole	33.0 dB	-32.6 dB	-27.1 dB
H-Bend Sideward Hole Offset	32.9 dB	-33.5 dB	-26.8 dB
H-Bend Center Hole	32.5 dB	-31.0 dB	-24.7 dB

The feed line mechanism blocks the electromagnetic wave propagation from the feed antenna and the reflector antenna aperture in the region of the highest density of electromagnetic energy in the H-bend center hole configuration. Thus, the gain decreases and the sidelobe levels increase. The offset parallel waveguide line couples to the reflector surface in the H-bend sideward hole offset configuration. This causes the gain to drop and the sidelobe level to raise. In considering of all of these comparisons, explanations and the numerical results, the best feed line mechanism is the H-bend sideward hole feed line. In the meaning of the best configuration, the length of the parallel waveguide line is 2.1λ in the first design and it is 6.1λ in the second design. The first design has been implemented and measurement results is presented in Figure 4.

4.1. Reflector with Shroud and Measurements Results

The first design mentioned in the feed line results section is used for the shroud analysis. After the selection of the H-bend sideward hole mechanism as the length of 2.1λ , the shroud analysis has performed for this design. Optimum shroud length is found as 3.4λ . Shroud length is varied from 0.1λ to 10λ in this optimization.

Highest gain criterion is performed for optimization. The patterns of the reflector antenna with and without the shroud are presented in Figure 3. This design has been implemented and measurement result is presented in Figure 4. After the implementation and measurements, the shroud analysis has performed again. But the optimization of the shroud length is performed with different criterions which are highest gain, lowest sidelobe level and return loss values, highest front to back ratio and flatness of beamwidth. Optimum shroud length is found as 2.5λ . Shroud length is varied from 0.1λ to 10λ in this optimization.

The measurement has been done with the Spherical Near Field System in TÜBİTAK BİLGEM UEKAE. In comparison of Figure 3 and Figure 4, the far-out sidelobes and backlobe of the reflector antenna are suppressed with using the shroud. Before the shroud, backlobe level is -35 dB. After the shroud, backlobe level fall to -50 dB. The simulation and the measurement results are compatible. But in the measurement, the sidelobe level is 3 dB higher than the simulation. However backlobe level of the reflector is better than the simulation in the measurement as seen in Figure 4. Outside of the -165° and $+165^\circ$ interval can not be measured because of the capability of the measurement system. After the implementation and the measurement, the shroud length is optimized as 2.5λ . The sidelobe level is decreased about 2.5 dB and the far-out sidelobes are more suppressed with this optimization. The closest sidelobes to the main lobe are become thanks to feed line. Because the feed line acts as a corner reflector near the main lobe of the reflector antenna.

5. Conclusion

In this study, five different feed line mechanism and the shroud analyses are obtained by optimizing to provide high gain, low sidelobe and backlobe levels. For the implementation stage of the reflector antenna the best design configuration is presented. The feed line configuration is selected, which make the least distortion to the primary pattern of the feed antenna and make the least blockage to the reflector antenna. For an X-band feed horn, there is no need for any handle mechanism thanks to above design. Above 15 dB improvement for the backlobe level is provided by the shroud design. Above 32 dB gain, below -26 dB sidelobe and -50 dB backlobe level are provided by using proposed design. The far-out sidelobes and backlobes of the reflector antenna are suppressed.

In the future works, the shroud will be covered by an absorber. Thus, the sidelobe levels of the reflector will be more suppressed with this study. Another future work is to perform other available sidelobe suppression techniques and also to find new sidelobe and backlobe suppression techniques for the reflector antennas.

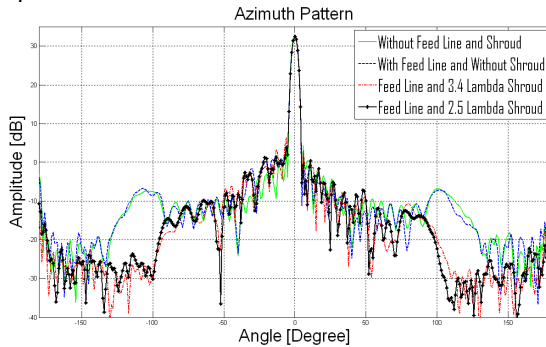


Figure 3

Feed line and shroud effects on reflector antenna patterns

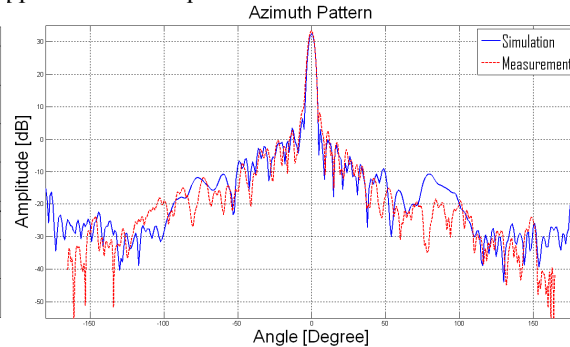


Figure 4

Comparison of the simulation and measurement results

6. References

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