Optimized Design of Cylindrical Corner Reflectors for Applications on TV Broadband Antennas

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Abstract ─ The increasing of digital TV channels throughout the UHF band leads to use antennas with greater directive gain and improved response in higher bandwidth. For this purpose, in this paper an optimized design for a cylindrical corner reflector is presented. A comparative study between the radiation patterns in the UHF band for different commonly used reflectors is therefore carried out. Based on this study, a modified Yagi-Uda antenna with a cylindrical corner reflector has been suggested and implemented.

Index Terms ─ Antennas, TV Broadcasting Antennas, Reflector Antennas, Yagi-Uda Antennas.

I. INTRODUCTION

Antennas derived from the Yagi-Uda configuration are extensively used as general-purpose antennas in the UHF band. These types of antennas are composed by simple elements: driven element, reflector, and director element. [1]

Bandwidth is basically delimited by the reflector and feeder system. Director element is intended to increase the directivity of the antenna in the forward direction.

The reflector is a parasitic element that re-radiates impinged radiation, either from or going to the active feeder, into free space. Thus, it has a close relationship with the gain of the antenna.

For these purposes, reflectors are usually formed by equidistant wires, which are generally longer than the feeder element. Reflectors more commonly used in Yagi antennas are parabolic and corner reflectors.

The use of parabolic reflectors was introduced by Wheeler, presenting a wide study of the radiation characteristics, depending on the physical dimension. [2]

There are some variations of the parabolic reflectors. The parabolic cylinder is the most used of them in the UHF band. It provides a narrow beamwidth in the plane of the axis of reflector. The essential parameters in the design of this reflector are: diameter, D, and focal distance, f. The rest of parameters can be determined from them. When D > 4f a major efficiency is obtained in practice. [3-4]

Corner reflectors were introduced by Kraus [5]. They are formed by planar reflective sheets joined together forming an angle, α. Radiation pattern is a function of geometric dimensions: distance between vertex and feeder, s, and length, l, and height, h, of planar surface.

Investigations and improvements in the radiation patterns have been widely studied since the introduction of corner reflectors. [6,7,8]

A more complex reflecting structure is the Cylindrical-corner mix. It is composed by three conductive surfaces: two planes forming a corner reflector and the third one forming a cylindrical section. [9]

Design of this reflector is a more complex task than in the case of the conventional one. Multiple variables can influence an optimized design: radius of cylinder, aperture angle, position of the cylinder with regard to the corner panels and position of the feeder. In recent years, some studies on this topic have been carried out. Some of them have analyzed different feeding

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configurations [10] and others dealt with the performance of the reflector. [11]

With the aim of improving the performance of the Yagi-Uda antenna regarding the radiation bandwidth in TV applications, from 470 to 862 MHz, by means of the use of cylindrical-corner reflector, we have carried out an optimization study of the parameters of this kind of reflector. The results have been compared with the performance obtained with the rest of the most commonly used reflectors. From these facts, an improved implementation of the Yagi-Uda antenna based on the cylindrical-corner reflector is presented.

Programs based on the moment method, MoM, have been used in both processes, in the prototype design, and in the performance simulations. This well known method determines the element currents through numerical techniques. [12-13]

II. CONSIDERATIONS ABOUT FEEDER

In order to carry out the methodology on the comparative analysis and optimization for the reflector, a common feeder for all prototypes has been selected. Some different feeders have been studied with regard to directivity and radiation pattern: dipole, folded dipole, and different more complex configurations.

According to previous investigations, the feeder showed in Figure 1 has been chosen. The most important features of this feeder are summarized in the next paragraph: it is constructed by planar sheets of width equals to 0.5mm. It is connected through a balun 1:4. Length varies between approximately 0.54λ at the lowest frequency and 0.99 λ at the highest frequency of the bandwidth. Directivity gain is greater than 2dB with regard to simple elements.

The radiation pattern is symmetric as shown in Figure 2. Taking into account the whole involved variables, final prototype is shown in Figure 3 and its characteristics are: summarized in the next paragraph. Aperture angle of corner structure is 90º, elements uniform spacing of 5 cm, diameter of the cylindrical surface of 16 cm, distance between center of cylindrical surface and corner vertex is 5.5 cm, and gap between feeder and reflector is 6 cm.

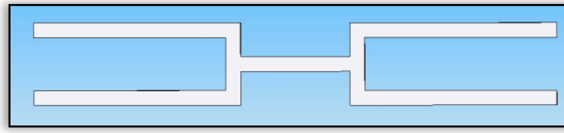
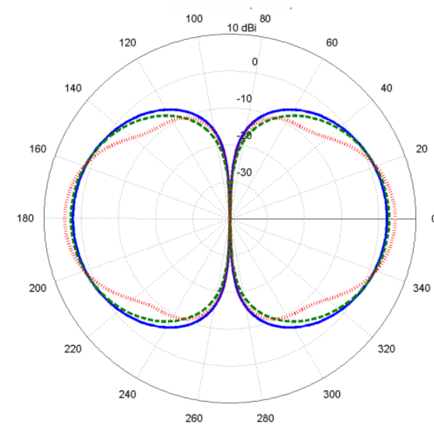
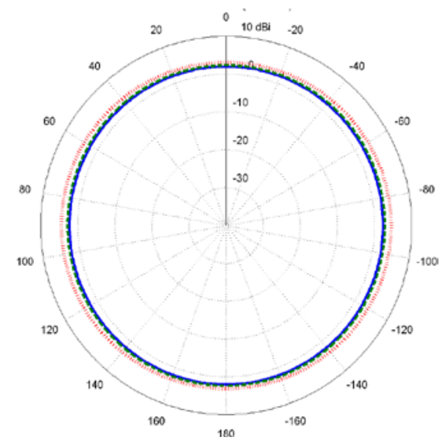


Fig. 1. Drawing of used feeder.



a)



b)

— 450 MHz. --- 600 MHz. ••• 900MHz.

Fig. 2. Radiation pattern of feeder: a) azimuthal plane, b) zenithal plane.

III. FORMATTING OF EQUATION, FIGURE, AND REFERENCE

The used methodology of optimization is founded on the steepest descent algorithm. It is based on a weighted function of diverse variables: gain, bandwidth, front to back ratio, VSWR, and impedance. The algorithm is carried out to determine the optimum position of every element of the antenna, mainly intersection angle and position, and dimensions of cylindrical surface, during the design process, as well as in successive improvement processes. Tables 1 and 2 show the comparative most significant results of simulation process in terms of gain for different frequencies.

Table 1: Gain of cylindrical corner reflector prototype for different configurations

Configurations		Gain (dB) for different frequencies (MHz)				
Angle	**Diameter (cm)**	**470**	**550**	**650**	**750**	**862**
90º	13	9.27	9.8	10.89	12.28	13.14
	19	9.07	9.41	10.16	10.96	11.07
120º	13	9.9	9.91	9.84	9.68	8.88
	19	8.97	8.63	7.51	5.84	6.74

Table 2: Gain of cylindrical corner reflector prototype for different configurations

Radii (cm)	Gain (dB) for different frequencies (MHz)				
	470MHz	**550MHz**	**650MHz**	**750MHz**	**860MHz**
16	9.14	9.59	10.54	11.65	12.21
13	9.27	9.8	10.89	12.28	13.14
9	9.12	9.7	10.86	12.31	13.35
6	8.99	9.58	10.73	12.3	13.32

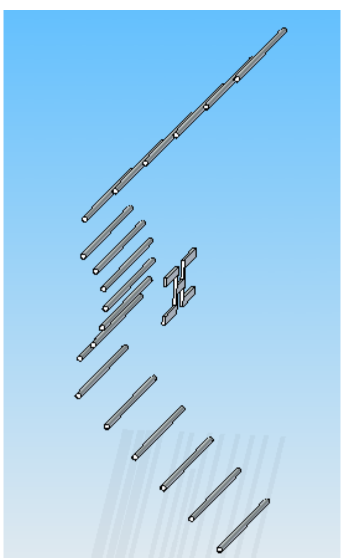


Fig. 3. Picture of prototype of cylindrical-corner reflector and feeder.

IV. DESIGN OF CORNER AND PARABOLIC CYLINDRICAL REFLECTORS

A comparative study between radiation characteristics of cylindrical corner reflector and radiation characteristics of corner of 90º, corner of 120º, and parabolic cylindrical reflectors have been made. In order to carry out a reliable comparative, every reflector has been designed and positioned in an optimum way, in relation to the best possible behavior of gain and directivity in each reflector. The process of optimization in every case is similar to the one explained in the previous paragraph. The obtained results are summarized in the following paragraphs.

A. Corner reflectors

Two corner reflectors, with intersection angles of 90º and 120º respectively, have been analyzed. Gain has been simulated with varying the following geometric parameters: dimensions of elements, inter-element spacing, distance between feeder and vertex, s, and length.

The minimal separation of "s" is determined by the impedance of the system and the maximal value is defined by the antenna directivity and by the appearance of side lobes. In Table 3, the main parameters of the selected corner reflectors are shown.

Table 3: Parameters of corner reflectors

Parameter	90º Corner reflector	120º Corner reflector
Diameter of elements	0.6 mm	
Inter-element spacing	No homogeneous, increasing from vertex. From 0.08λ to 0.18λ at central frequency of UHF band.	
Distance between feeder and corner vertex, s	18.5 cm	14.5 cm
Distance between vertex and last element	1.74s	2.15s
Length of elements, l	57 cm	

Variations of gain of 120º corner reflector versus the frequency of the UHF band for different values of "s", are shown in Table 4.

Table 4: Gain of corner reflector with intersection angle of 120º

s (cm)	Gain in dB for frequencies in MHz				
	470MHz	550MHz	650MHz	750MHz	860MHz
14.5	9.14	9.59	10.54	11.65	12.21
16.5	9.27	9.8	10.89	12.28	13.14
18.5	9.12	9.7	10.86	12.31	13.35

B. Parabolic cylindrical reflector

The parameters which define the radiation response of the parabolic cylindrical reflector are: dimensions of elements, diameter of cylinder, D, inter-element spacing, and focal distance, f. Tables 5 and 6 show directive gain as function of frequency for different focal distances.

Table 5: Directive gain of parabolic cylindrical reflector versus frequency for several focal distances

f(cm)	Gain in dB for different focal distances				
	470MHz	550MHz	650MHz	750MHz	860MHz
18	7.2	7.28	7.37	6.03	2.01
14	7.26	7.55	8.04	8.83	7.93
12	7.2	7.54	8.12	8.7	8.87

Table 6: Directive gain versus frequency for focal distance of 12 cm

f/D (cm)	Gain in dB for different f/D values				
	470MHz	550MHz	650MHz	750MHz	860MHz
0.25	8.89	9.46	10.39	11.63	12.02
0.3	8.48	8.98	9.81	11.05	11.22
0.4	7.86	8.29	9	9.86	10.1
0.53	7.2	7.54	8.12	9.07	8.87

In Table 7, the most significant characteristics of parabolic cylindrical reflector prototype are shown.

Table 7: Parameters of parabolic cylindrical reflector prototype

Parameter	Parabolic Cylindrical Reflector
Diameter of elements	0.6 mm
Focal distance, f	12 cm: From 0.18λ at lowest frequencies to 0.34λ at highest frequencies of working bandwidth
f/D	0,25

V. COMPARATIVE STUDY OF THE REFLECTORS

A comparative study of the directive gain and radiation pattern characteristics in UHF band for four different reflectors, corner of 90º and 120º, parabolic cylindrical and cylindrical corner, is implemented. The used prototypes for this comparative have been designed in accordance with the criteria exposed in previous paragraphs. Figure 4 plots the directive gain as a function of the frequency in range of the UHF band for TV applications.

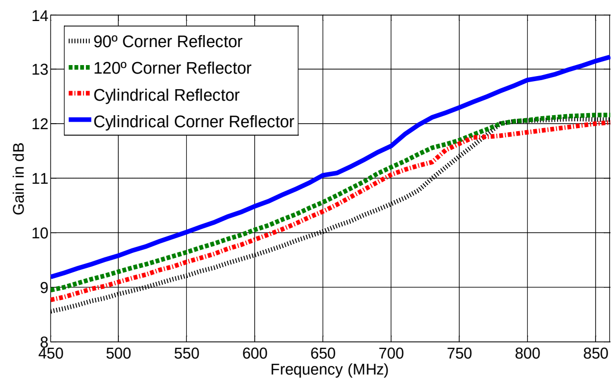


Fig. 4. Directive gain for different prototypes.

For low frequencies, all the reflectors have comparable responses. Nevertheless for higher frequencies, the cylindrical corner reflector has better gain, enhancing the antenna response in the upper frequencies of the UHF band.

Radiation patterns for frequencies of 750 and 850 MHz are plotted in Figures 5 and 6. Where the half-power beamwidth decreases for high frequencies of the band and the side lobes have been improved for cylindrical corner reflector in relation with the other reflectors.

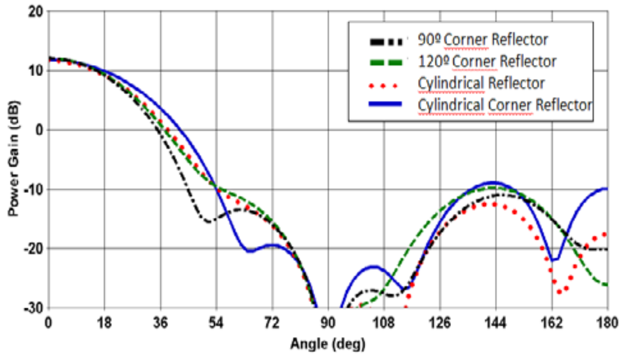


Fig. 5. Radiation pattern for 750MHz.

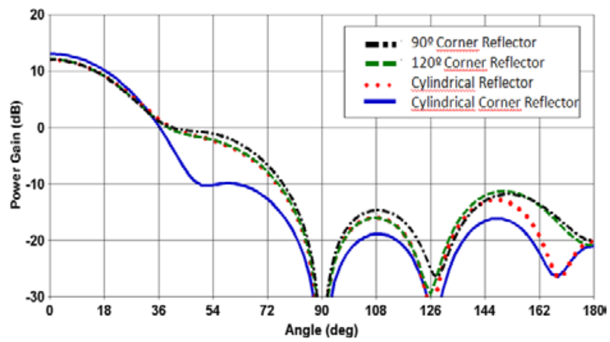


Fig. 6. Radiation pattern for 850MHz.

The directivity is improved in the case of cylindrical corner in relation with the rest of reflectors. This conclusion can be also deduced from Figures 7 and 8. In these figures, half-power beamwidth is represented for the azimuthal and zenithal plane, respectively.

As it can be observed from these figures, cylinder corner reflector presents the best response in all radiation characteristics.

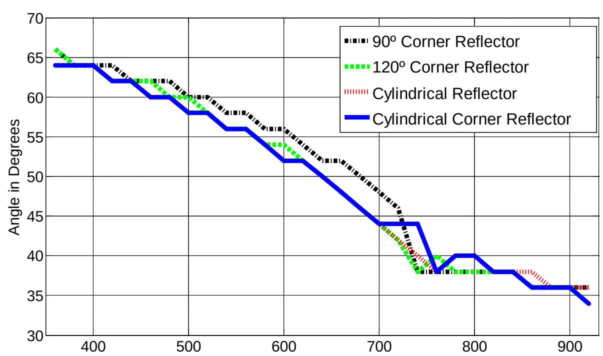


Fig. 7. Half-power beamwidth for the azimuthal plane.

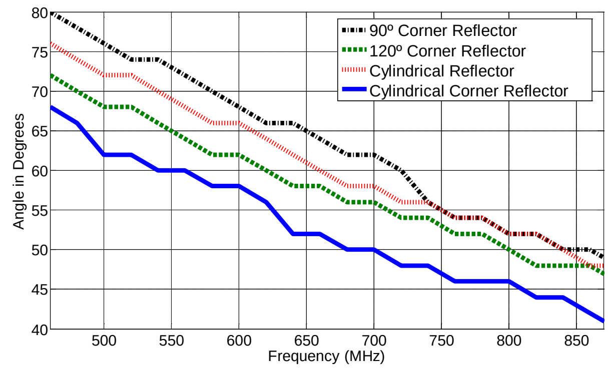


Fig. 8. Half-power beamwidth for the zenithal plane.

VI. IMPLEMENTATION OF YAGI-UDA BROADBAND ANTENNA

Based on the previous design of feeder and cylindrical corner reflector, an implementation of a modified Yagi-Uda antenna is carried out. To control the impedance of the antennas in the complete bandwidth, antenna design have been optimized with passive elements. A rhombic structure with twelve pairs of director elements of 12.2 cm, has been implemented. The distance between elements for each couple is 2.4 cm. See Figure 9.

Fig. 9. Picture of optimized antenna

Directive gain and voltage standing wave ratio (VSWR) as a function of frequency in the UHF band are shown in Figures 10 and 11, respectively for the optimized antenna.

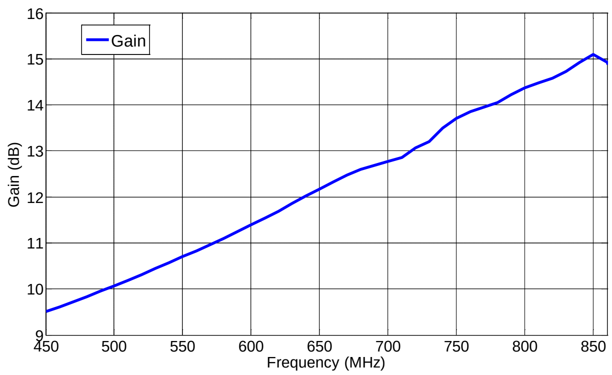


Fig. 10. Obtained directive gain for the antenna.

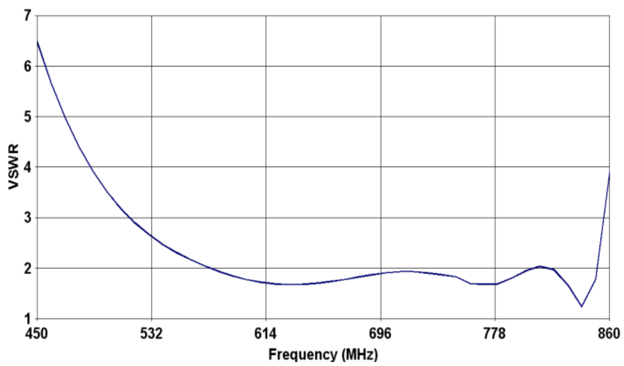


Fig. 11. Obtained VSWR for the antenna.

These figures show how the directivity gain is nearly 15dB for upper frequencies, and greater than 9.5 dB for lower frequencies. The values of VSWR lead to bandwidth of nearly one octave.

Radiation patterns for different frequencies and for azimuthal and zenithal planes are plotted in Figures 12 and 13.

In order to evaluate the performance of the designed antenna, these previous characteristics have been compared with two widely known digital TV antennas. They are formed by similar feeders and 120º corner reflectors. The first antenna is a conventional Yagi-Uda with 14 director elements. The second antenna has the same passive elements with a rhombic structure. A comparative graphic of VSWR and radiation pattern for horizontal and vertical plane are respectively shown in Figures 14, 15, and 16.

From the measured and calculated results it can be seen that the side lobe level of the designed antenna is better than the other kinds of compared antennas.

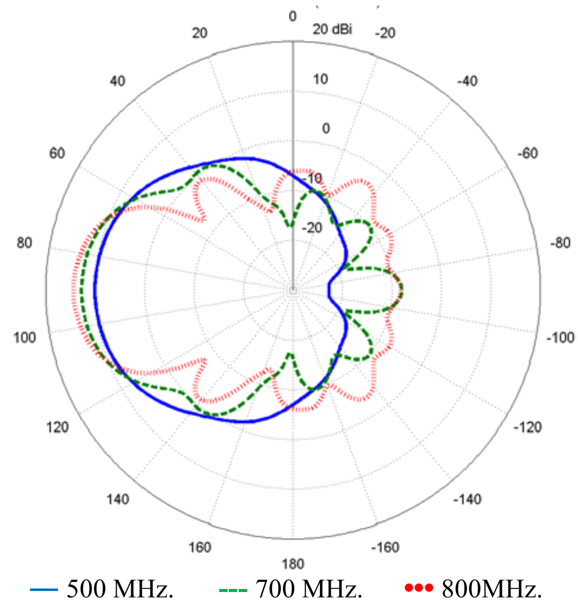


Fig. 12. Radiation pattern for optimized antenna in zenithal plane.

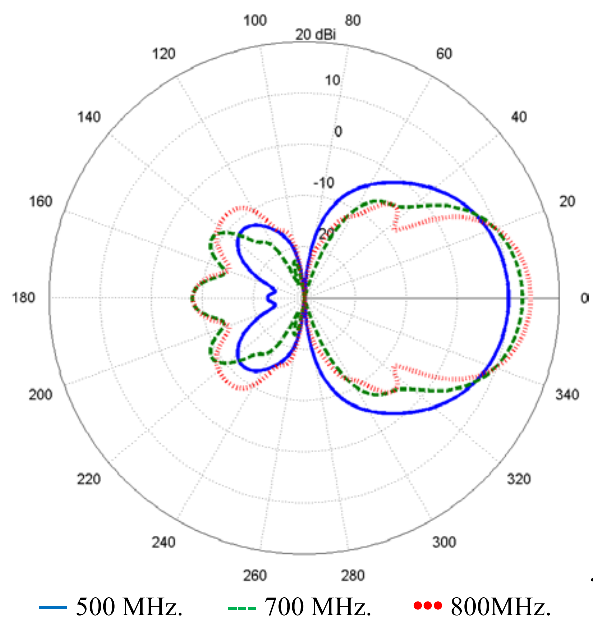


Fig. 13. Radiation pattern for optimized antenna in azimuthal plane.

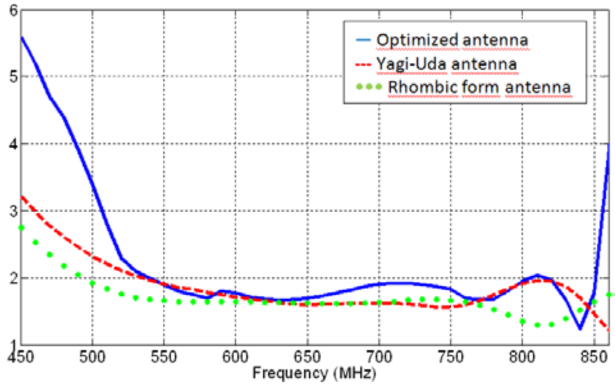


Fig. 14. VSWR.

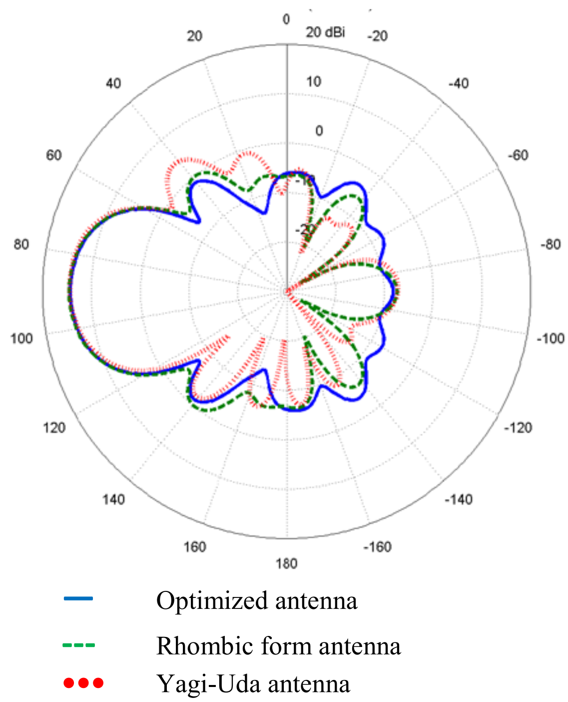


Fig. 15. Radiation pattern in zenithal plane.

VII. CONCLUSION

The design of cylindrical corner reflector has been optimized taking into account the bandwidth response for the application on broadband antennas in UHF band. Comparison with the three most used reflectors in the market, corner of 90º and 120º and parabolic cylindrical reflectors, has been made. The results show a significant enhanced directive gain in the UHF bandwidth. This cylindrical corner reflector design has been used in an implementation of broadband Yagi-Uda antenna.

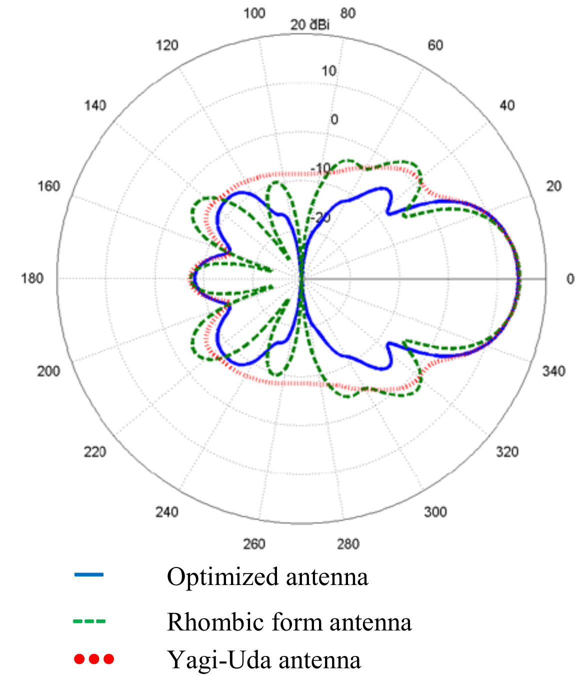


Fig. 16. Radiation pattern in azimuthal plane.

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