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Full Length Research Paper

A feed antenna for dielectric spheres lens in the Ka band

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In this paper, a feed antenna for dielectric spheres lens in the Ka band, which is a circularly polarized short dielectric rod antenna, is presented. The structure combines with circular polarizer and short dielectric rod antenna skillfully. The circular polarizer with dielectric septum realizes the circular polarization. The short dielectric rod antenna achieves the high gain. Compared with the long dielectric rod antenna, the short dielectric rod antenna in the design has realized miniaturization. The antenna is characterized by simple structure, manufacture and test easily. In addition, the performance of the antenna as a feed for the dielectric sphere lens antenna is also studied, whose simulated gain with a quarter wavelength choke is 20.369 dB and beam width is 16°, which show that the antenna is an excellent feed antenna.

Key words: Ka band, dielectric spheres lens, circularly polarized, short dielectric rod antenna, a quarter wavelength choke.

INTRODUCTION

In order to make full use of the limited frequency in modern wireless communications, multi-beam antenna, whose signal could cover wider range of area with high gain, and whose beam configurations can be adaptively adjusted according to the need, has been thoroughly studied and widely used. As a multi-beam antenna, dielectric spheres lens multi-beam antenna mainly be used in millimeter wave and sub-millimeter wave band. And the design of the feed antenna for dielectric spheres lens hold the balance in the whole design.

At present, the main feed antenna for dielectric spheres lens are: planar yagi antenna (Phillip et al., 2004), tapered slot antenna (TSA) (Bernhard et al., 2002), circular waveguide (Bo et al., 2009). In this paper a new type of feed antenna for dielectric spheres lens is presented: circular polarizer combined with dielectric rod antenna, which not only meet the performance but also realize the circular polarization. Circular polarized antennas play an important role in the communication system. Circular polarizer is an important part of circular polarized antenna waveguide feed system, whose performance have directly influence on the axis. In recently year, circular polarizer has been widely studied and discussed (Naofumi et al., 2000; Shih-Wei et al., 2004; Tian-ling and Ze-hong, 2006; Zhiru and Jin, 2009).

The dielectric rod antenna consists of a dielectric cylinder excited by a hollow waveguide. In order to reduce the reflection, the end part is generally conical. Dielectric rod antenna is usually traveling wave antennas. Its dielectric rod body part has much larger length than a wavelength and usually consists of 3 parts: feed gradient, rod body and end gradient. So, the long dielectric rod antenna is of great length. On the other hand, the short dielectric rod antenna, which refers to the length of the rod is little shorter than a wavelength, can satisfy the requirement of small size. The long dielectric rod antenna have been widely studied (Pramendra et al., 2008; Qiu and Wang, 2009), while the short dielectric rod antenna is mostly discussed before the 1980s (Watson and Horton, 1948; Kishk, and Lotfollah, 987). In recent years, few designs are reported in public papers. Moreover, the short dielectric rod antenna, which has the advantages of small size, highly-directivity, and adjustable direction diagram, has broad application prospect in microwave and millimeter waves (MMW) fuze. Therefore, it is necessary to study the short dielectric rod antenna.

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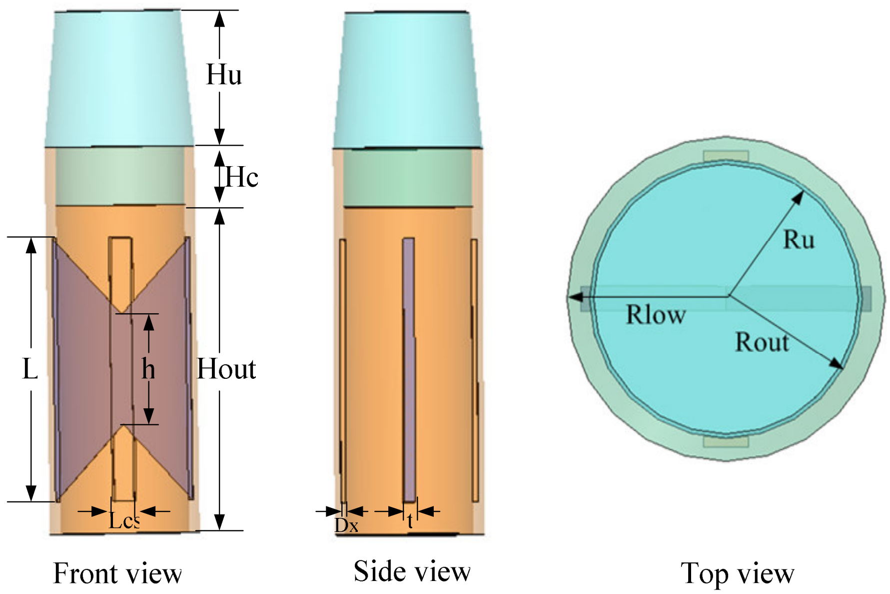


Figure 1. Schematic view of the circular polarizer with short dielectric rod antenna.

Table 1. Dimensions of the proposed antenna (unit: mm).

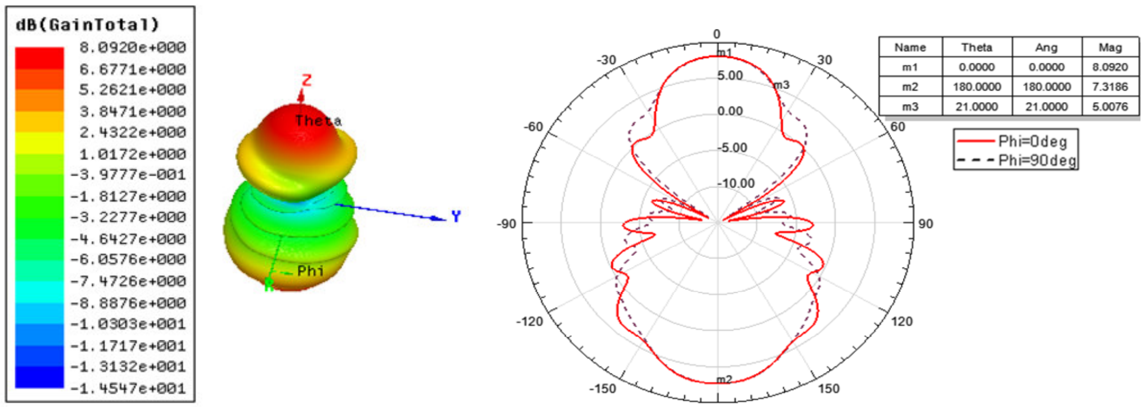
Parameters	Ru	Rout	Rlow	t	Hu	Hc	Hout	L	h	Lcs	Dx
Values	2.9	3.0	3.5	0.5	6.2	2.7	15.0	12.1	5.1	1.0	0.2

This paper skillfully assembles the circular polarizer and the short dielectric rod together to design a new type of antenna. Circular waveguide polarizer can achieve the requirements of circular polarization. The part of short rod antenna inserted into the waveguide medium is cylinder, plays the role of fixing dielectric rod antenna into the metal waveguide. While the exposed parts outside the metal waveguide, whose terminal is smaller and smaller, plays the role of guiding electromagnetic wave to radiate. Meanwhile, for being able to support the other antenna (such as dielectric ball), dielectric rod antenna terminal is of cone shape. The center frequency of the antenna is 35.4 GHz. The simulation results show that the combined antenna, which can be used both as an independent antenna and the feed antenna for dielectric spheres lens antenna, has the advantages of small size 24 mm × 7 mm × 7 mm, and low standing wave ratio, and perfect circular polarization.

ANTENNA DESIGN

Figure 1 shows the geometry and configuration of the proposed dielectric rod antenna. The material of the circular waveguide is set to copper and of the septum is FR4. The relative permittivity of the dielectric rod is 2.53. The detailed dimensions are depicted in Table 1. As expressed in Figure 1, a dielectric septum is inserted in the middle of the circular waveguide. An incident wave oriented at 45° relative to the dielectric septum is assumed, which can be decomposed into two equal orthogonal projections E_x and E_y, respectively, parallel and perpendicular to the dielectric septum. The two components then propagate through the septum region with little reflection due to the small septum discontinuity. In the septum region, propagation constant β_x of the E_x component is strongly perturbed by the dielectric septum because the electric field line is parallel to the septum. On the other hand, propagation constant β_y of the E_y component is weakly perturbed because the electric field line is perpendicular to the septum. As a result, this polarizer can be implemented by choosing a suitable septum length L so as to realize a 90° phase difference at the output port. As the result, circular polarized modes will be transmitted through the output port of the waveguide. The length L is determined by

$$\Delta \varphi = (\beta_x - \beta_y) \times L = 90^0 \quad (1)$$



(a) (b)

Figure 2. The simulated radiation pattern (a) three-dimensional (b) two-dimensional.

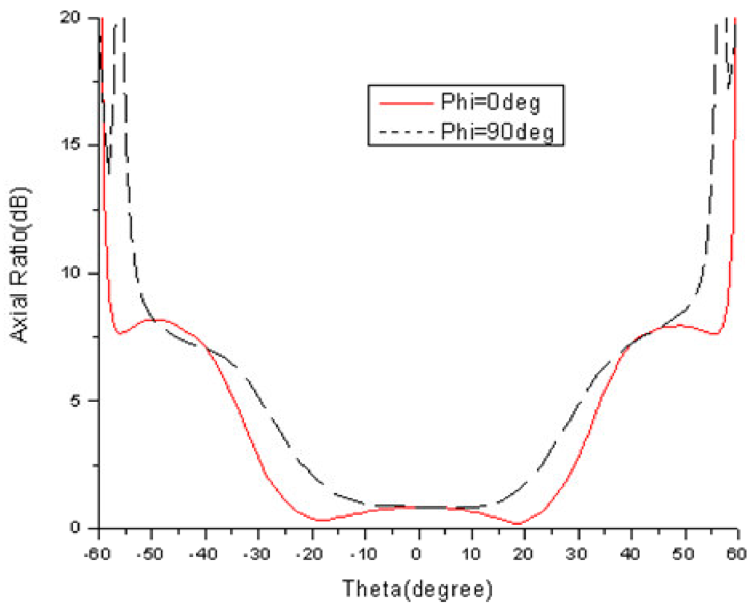


Figure 3. The enlarged axial ratio.

Where β_x and β_y can be approximated as (Stephen, 2006). The phase difference $\Delta\varphi$ is close to 90°, which means that the axial ratio is similar to 0 dB. In generally, when the axial ratio is less than 3 dB between the half power beam widths, it shows that the circular polarization property is good.

SIMULATION RESULTS AND DISCUSSION

The Ansoft HFSS software is used to simulate the model. The antenna works on the 8 mm band, the size of the antenna is only 24 mm × 7 mm × 7 mm. The radiation pattern shown in Figure 2 presents that the gain of the antenna is approximately 8.1 dB, which is 2 dB higher than the traditional circular horn antenna. The enlarged axial ratio (defined by value less than 3 dB between the half power beam widths) is shown in Figure 3. The simulation VSWR shown in Figure 4 is small, which indicates that the antenna is an excellent independent antenna.

Tables 2, 3 and 4 exhibit the impacts of various Rout, Ru and Hu have on the gain, the first side lobe level (FSLL), the half power beam width (HPBW) and the axial ratio. As shown, Rout has an important influence on the axial ratio. And the larger Rout is, the smaller the Gain or HPBW is.

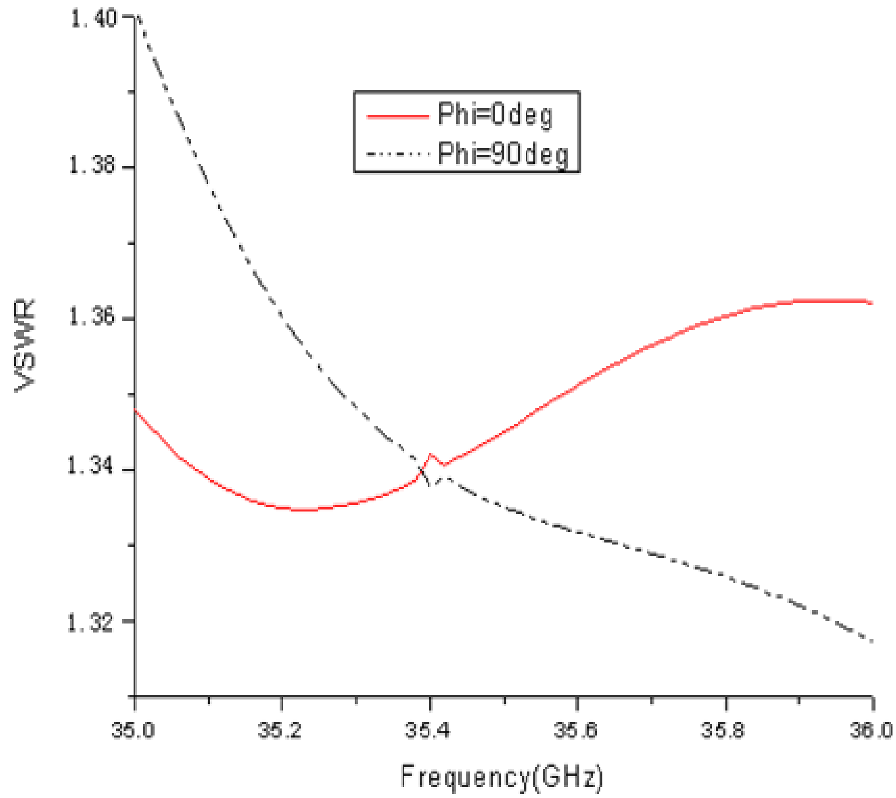


Figure 4. The VSWR.

Table 2. Rout --the radius of the circular waveguide.

Rout (mm)	Gain(dB)	FSLL(dB)	Axial ratio(dB)	HPBW(°)
2.9	9.2716	-14.0763	12.9344	48
3.0	8.0920	-14.1164	0.8834	42
3.1	7.9082	-12.0040	9.0276	40

Table 3. Ru-- the top radius of the cone.

Ru (mm)	Gain(dB)	FSLL(dB)	Axial ratio(dB)	HPBW(°)
2.8	7.9793	-13.9605	1.0530	42
2.9	8.0405	-14.1643	0.9267	41
3	8.0873	-14.2570	1.0309	41

Table 4. Hu--the height of the top cone.

Hu (mm)	Gain (dB)	FSLL (dB)	Axial ratio (dB)	HPBW (°)
6.1	8.0386	-13.1895	3.1132	44
6.2	8.0920	-14.1311	0.8834	42
6.3	8.1018	-13.6293	1.1749	40

Not quite the same, the larger Hu is, the larger the Gain or the smaller the HPBW is.

THE IMPROVED ANTENNA AND SIMULATION RESULTS

As shown in Figure 2, the disadvantage of this antenna is that its radiation pattern has a high back lobe level. This may has two reasons: the first is the unbalanced feed system leads to the leakage of the energy; the second is the septum resulting in energy loss. One of the known techniques to reduce the back lobe level of the radiation pattern is to use a quarter wavelength choke on the waveguide wall (Kishk and Lotfollah, 1987). The geometry and configuration of the improved antenna is shown in Figure 5, the material is set to copper and the detailed dimensions of the choke are indicated in the figure. As shown in Figure 6 - 8, the simulated results show that utilizing this approach the back lobe level reduces, on average, in excess of 2 dB. In addition, the directive gain of this dielectric rod with choke have somewhat increased. As shown in Figure 9, the peak gains of the proposed antenna illustrate stability in the given frequency range.

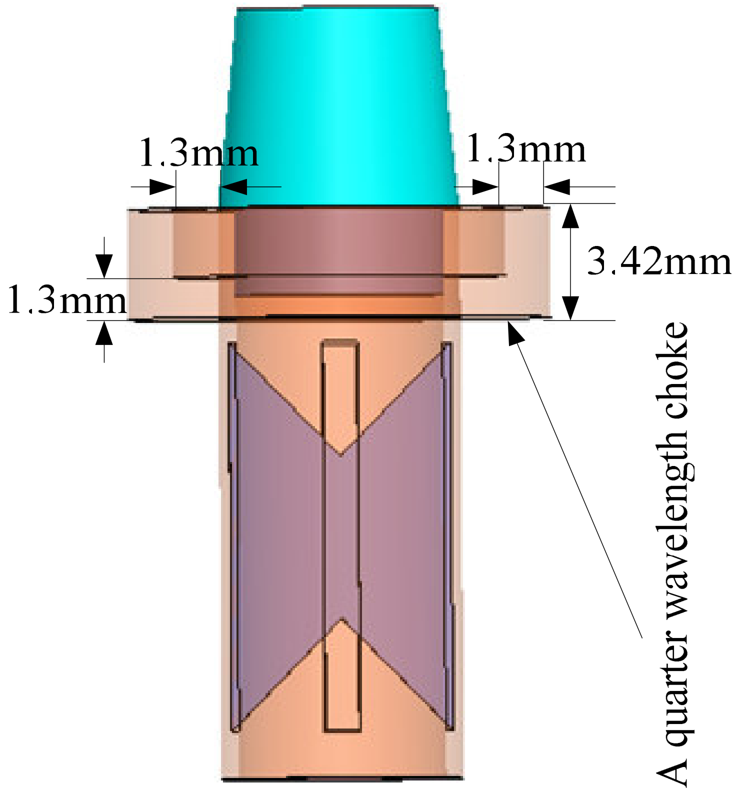


Figure 5. Short dielectric rod antenna with a quarter wavelength chokes.

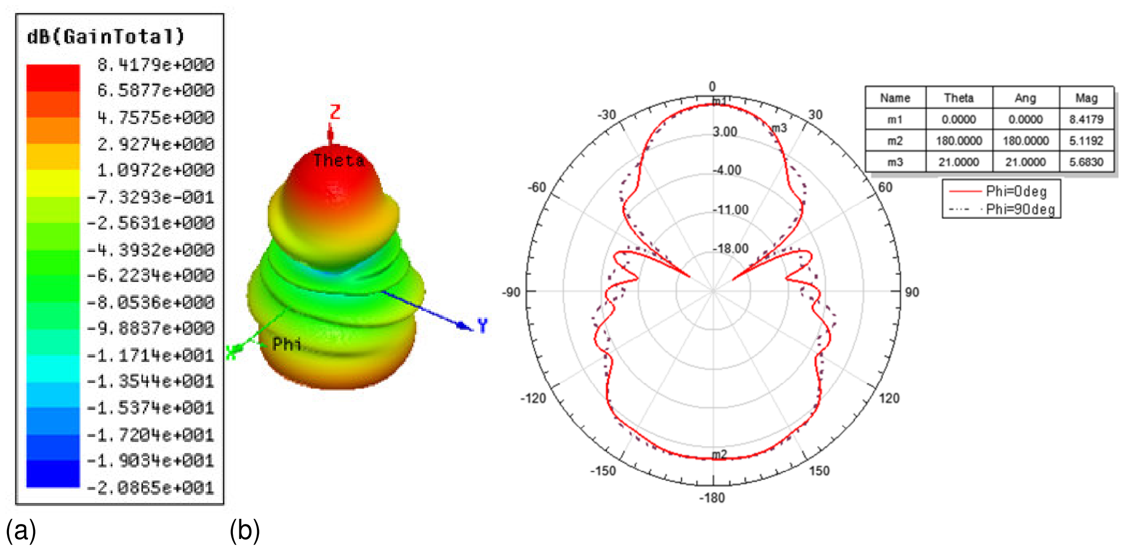


Figure 6. The simulated radiation pattern with choke (a) three-dimensional (b) two-dimensional.

AS THE FEED FOR THE DIELECTRIC SPHERE LENS ANTENNA

Taking account of the gain of the dielectric spherical lens and the simulation memory of the computer, the permittivity ε_r = 2.53 and the radius 21 mm of the lens are selected. The simulation models are shown in Figure 10

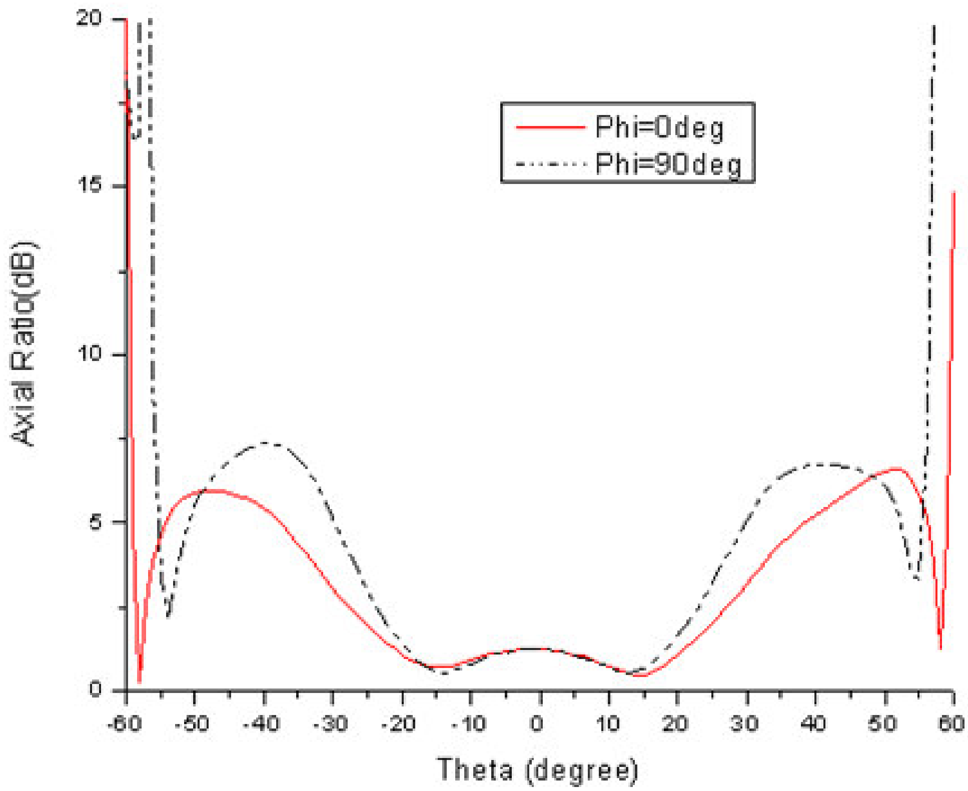


Figure 7. The enlarged axial ratio with choke**.**

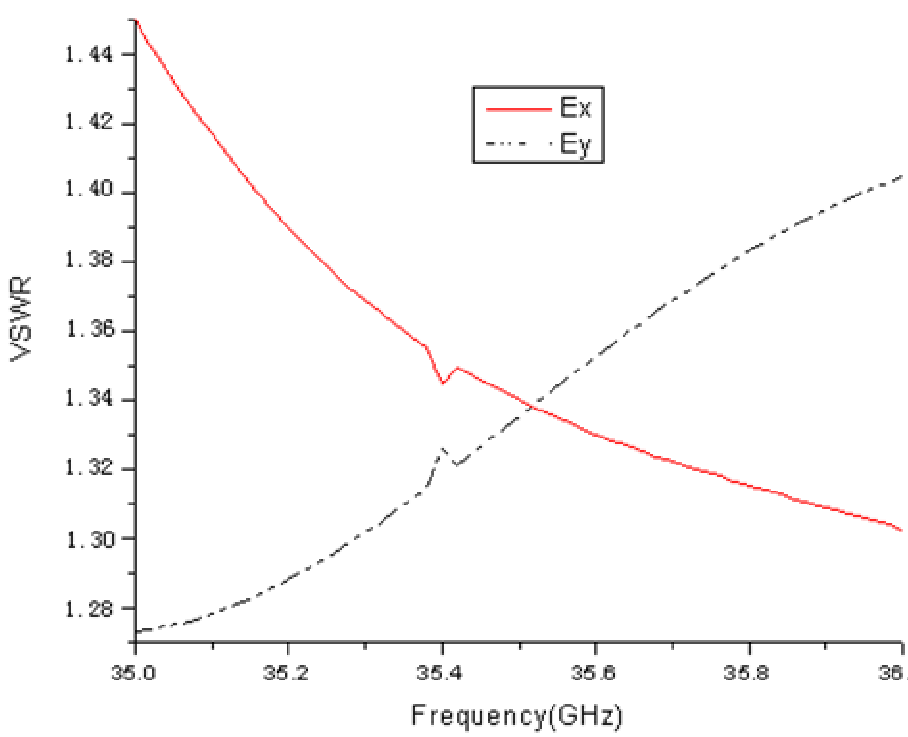


Figure 8. The VSWR with choke.

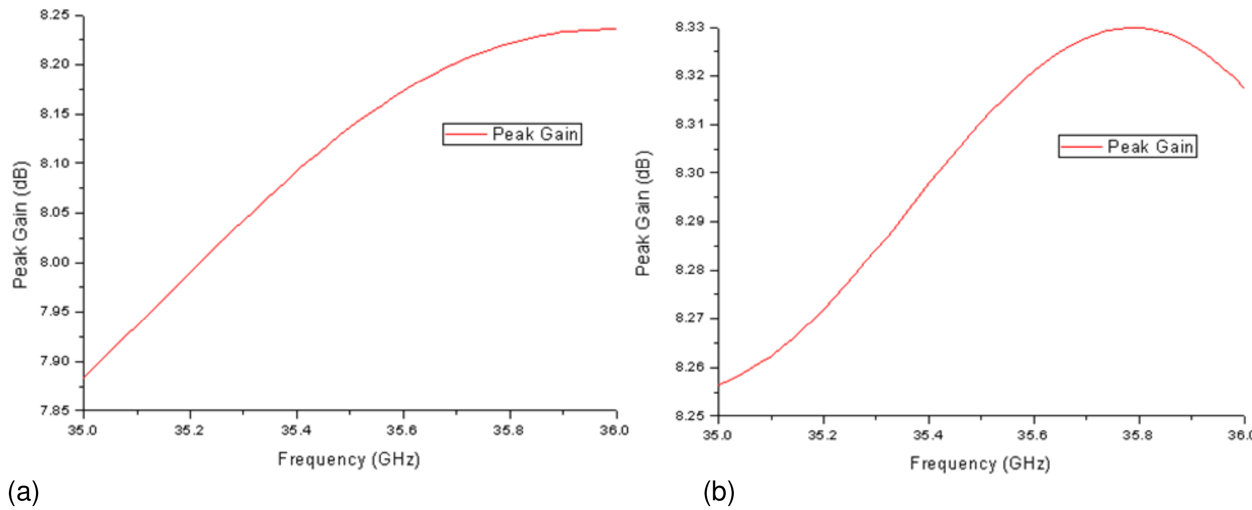


Figure 9. The peak gains of the proposed antenna (a) without choke (b) with choke.

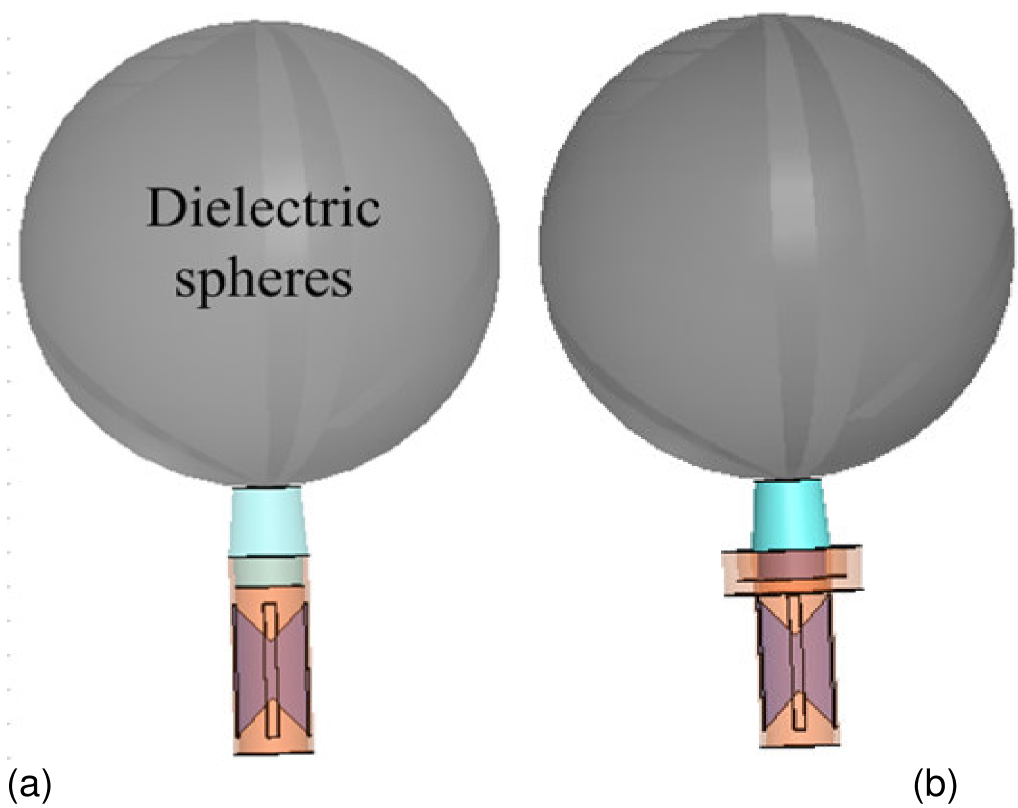
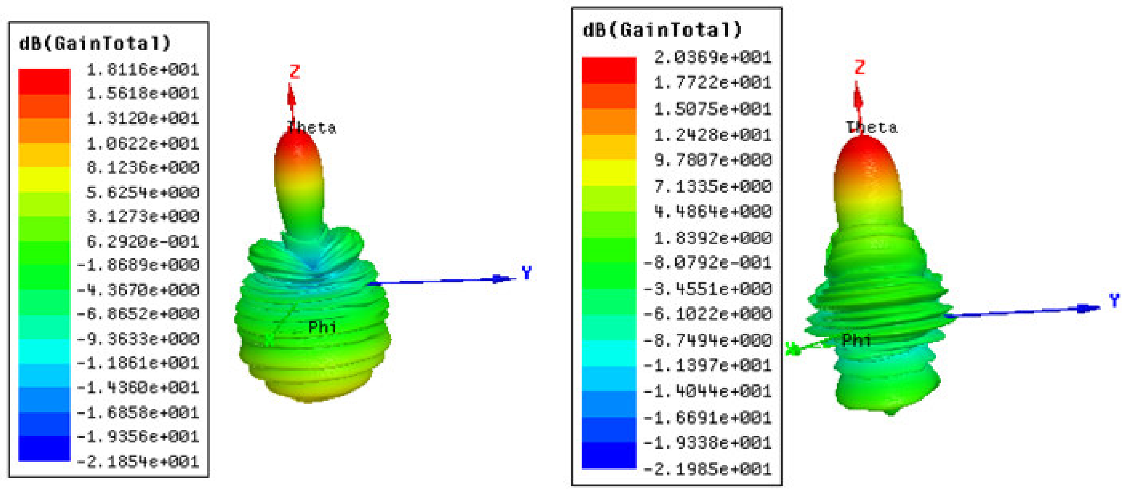


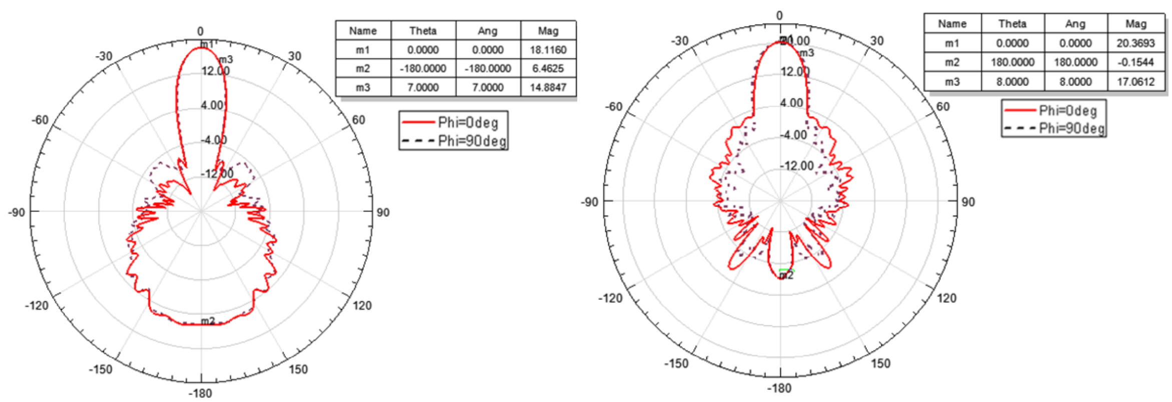
Figure 10. The circularly polarized short dielectric rod antenna feed for dielectric sphere lens antenna (a) without choke (b) with choke.

for both cases with and without choke. The simulation radiation pattern shown in Figures 11 and 12 show that the gain of the antenna without and with choke are 18.116 and 20.369 dB, respectively. And the beam widths are separately 14 and 16°. More importantly, the back lobe level of the antenna with choke becomes very small, which is only -0.15 dB, compared with the antenna without choke 6.46 dB. In addition, the enlarged axial ratio and VSWR are shown in Figure 13 and 14, respectively. Figure 15 demonstrates the stable peak



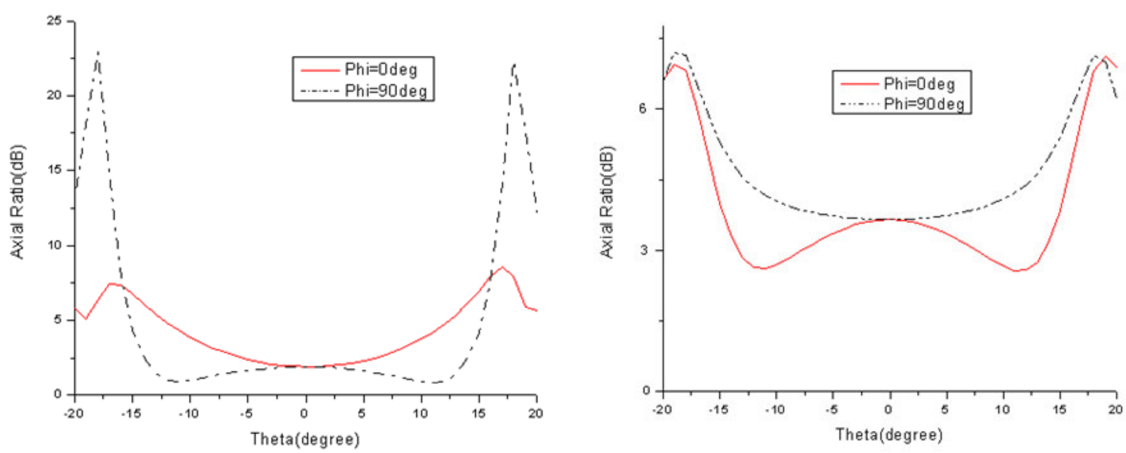
(a) (b)

Figure 11. The three-dimensional simulated radiation pattern (a) without choke (b) with choke.



(a) (b)

Figure 12. The two-dimensional simulated radiation pattern (a) without choke (b) with choke.



(a) (b)

Figure 13. The enlarged axial ratio (a) without choke (b) with choke.

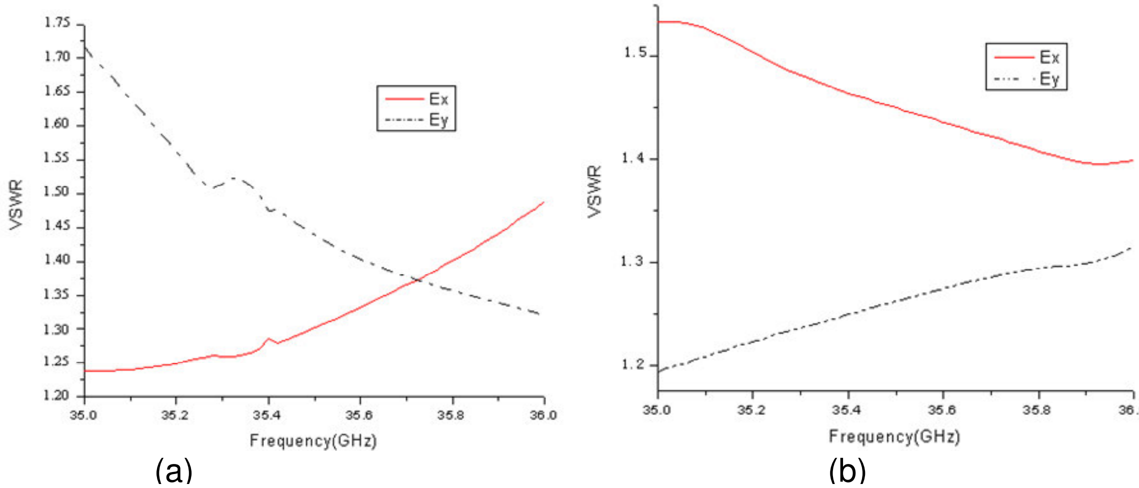


Figure 14. The VSWR (a) without choke (b) with choke.

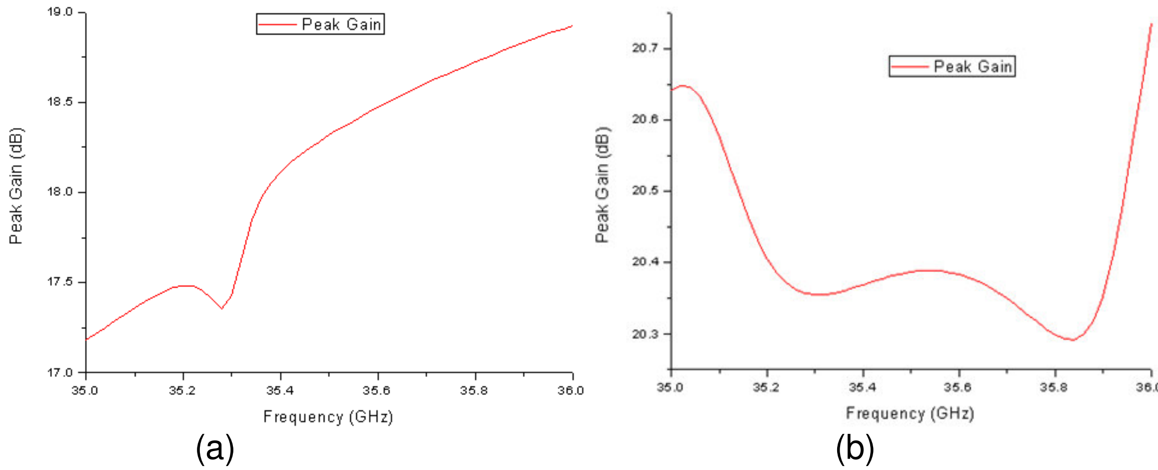


Figure 15. The peak gains of the spherical lens antenna (a) without choke (b) with choke.

gains of the spherical lens antenna without and with choke in the given frequency range. The simulation of the spherical lens takes a very large computer memory, while the computer configuration of working group can not meet the requirement, some points (Mosallaei and Rahmat-Samii, 2001; Boriskin and Nosich, 2002), in design of spherical lens antennas can not be in-depth discussion and research. It is only hoped that this part will provide an idea to the relevant researchers.

CONCLUSION

The design of a circularly polarized short dielectric rod antenna, which can be used as an independent antenna and a feed antenna for dielectric spheres lens antenna, has been presented in the paper. The simulation results show that the design is reasonable and feasible. This kind of antenna has a simple and compact structure which can be easily manufactured and large-scale produced. The results, such as the gain, the axial ratio, the bandwidth etc, show the antenna is a good feed antenna.

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