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Research Article

A RHCP Microstrip Antenna with Ultrawide Beamwidth for UHF Band Application

Yuan-zhu Liu, Shao-qiu Xiao, and Bing-zhong Wang

Institute of Applied Physics, University of Electronic Science and Technology of China, Chengdu 610054, China

Correspondence should be addressed to Yuan-zhu Liu; yuanzhuliu@vip.qq.com

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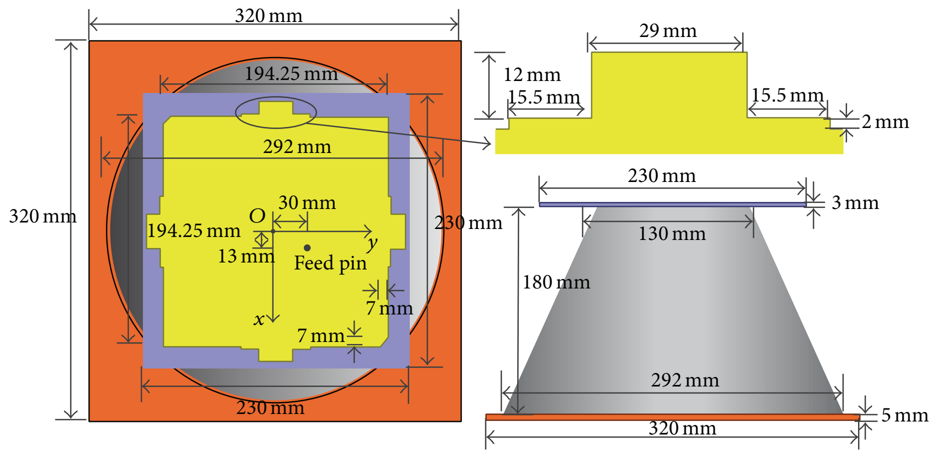
A novel right-hand circularly polarized (RHCP) UHF microstrip antenna with 3 dB beamwidth of more than 150° is presented in this paper. The 3 dB RHCP beamwidth can be broadened by utilizing a combined ground structure with a hollow truncated cone ground plane and a metallic rectangular plate. Optimizing the half-angle θ_c of cone and the cone height h_{cone}, a 3 dB RHCP beamwidth of more than 200° can be acquired, which is about 120° greater than its corresponding regular RHCP microstrip antenna. There is a good agreement between the measured results and simulated results for the proposed antenna operating in UHF band.

1. Introduction

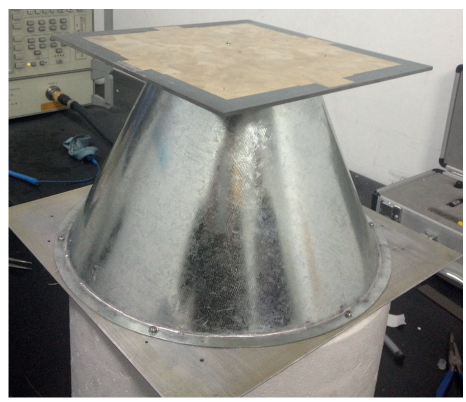
Circularly polarised (CP) microstrip patch antenna (MPA) is widely used in wireless communication and radar system due to its advantages of lightweight, low profile, ease of manufacturing, and conformation to the platform [1, 2]. However, it is difficult for the conventional MPA to realize ultrawide beam coverage which usually has more applications [3]. To increase the 3 dB CP beamwidth of the MPA, a lot of methods are applied. In [4], the proposed CP-MPA exhibits a 3 dB CP beamwidth of more than 110° by mounting a regular CP antenna on a three-dimensional square ground, which is about 30° greater than that of a corresponding regular MPA. However, the height of that proposed CP-MPA is more than 0.45 operating wavelengths (0.45λ). To obtain a wider beamwidth with lightweight and low profile, Nakano et al. use a folded conducting wall to reduce the height of the CP antenna to about 0.04λ and meanwhile provide a 3 dB CP beamwidth of about 106° [5]. In [6], a dielectric lens encapsulating at least a portion of the patch is used to increase radiation gain at low elevation angles. In order to further broaden the 3 dB CP beamwidth, we lay gradually variational metallic supporting platform under the antenna which will be an effective technique. Su et al. use a pyramidal ground structure and a partially enclosed flat conducting wall to broaden the 3 dB CP beamwidth up to 130° [7]. In this paper, we utilize a combined ground structure with a hollow truncated cone ground plane and a metallic rectangle plate to obtain a wider 3 dB CP beamwidth which is more than 150°. By optimizing the half-angle θ_c of cone and the cone height h_{cone}, a 3 dB RHCP beamwidth of more than 200° can be acquired, which is about 120° greater than its corresponding regular CP-MPA.

2. Antenna Configuration

The proposed right-hand circularly polarized (RHCP) MPA comprises ground layer, dielectric layer, patch layer, and metallic supporting platform shown in Figure 1. The square patch is printed on a grounded square substrate with thickness of 3 mm, relative permittivity of 3.5, and dielectric loss tangent of 0.001. The supporting structure under the grounded plane of the MPA comprises a metallic truncated cone with height of 180 mm (about 0.25λ) and a rectangular metallic plate with 320 mm × 320 mm. The truncated cone structure is made of sheet iron of thickness 0.1 mm and the rectangular plate is made of aluminium plate of thickness 1 mm. Figure 1(a) illustrates its detailed physical dimension. MPA is probe fed and adopts corner-truncated square patch with 7 mm truncated corners. The x-coordination and y-coordination of the feeding point are 13 mm and 30 mm, respectively, as shown in Figure 1(a). Four fine tuning branches are adopted for better matching, resonance



(a)



(b)

Figure 1: Configuration of the proposed RHCP antenna: (a) physical dimension (b) experimental prototype.

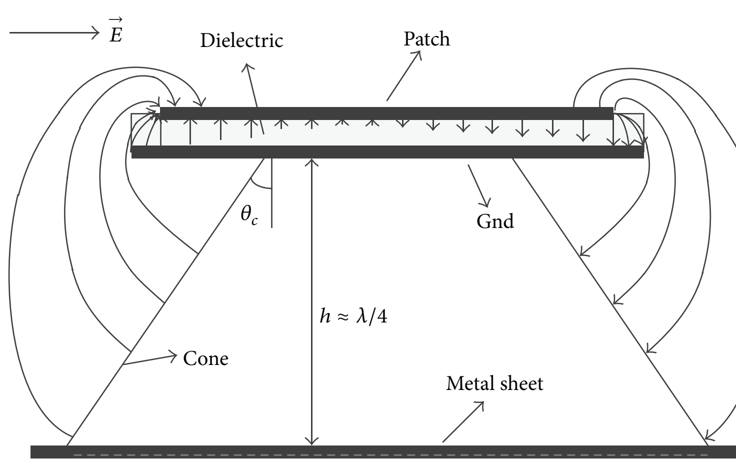


Figure 2: The electric field distribution diagram.

characteristic, and axial ratio (AR) at the centre frequency. The experimental prototype is shown in Figure 1(b). And all the simulated results in this paper are done by the electromagnet-ics simulation software HFSS14.0 based on the finite element method. Details of the proposed antenna design and the obtained experimental results are presented.

3. Antenna Analysis

Due to the existing truncated cone, the edge diffraction fields of the MPA shown in Figure 2 are changed. The reflection of the truncated cone ground plane leads to less backward radiation. Because of the angle between the grounded plane

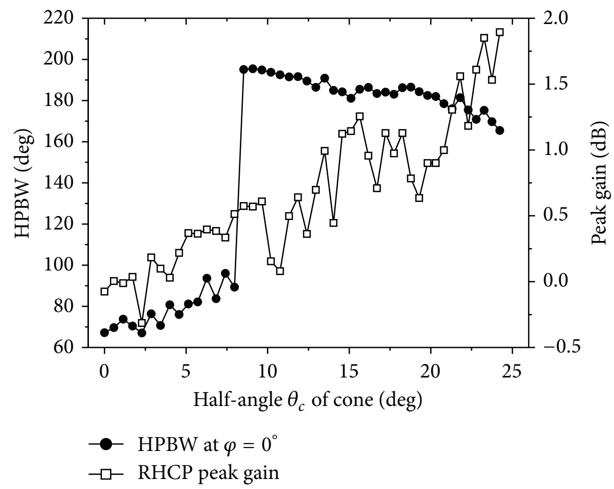


FIGURE 3: HPBW, peak gain versus half-angle θ_c of cone.

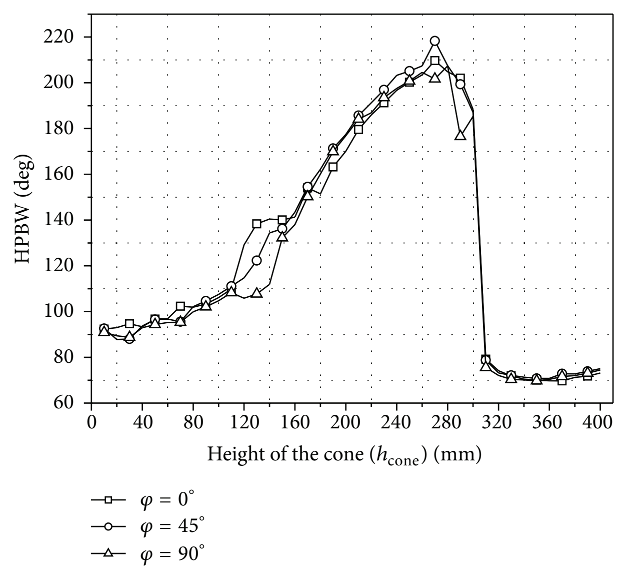


FIGURE 4: HPBW versus cone height.

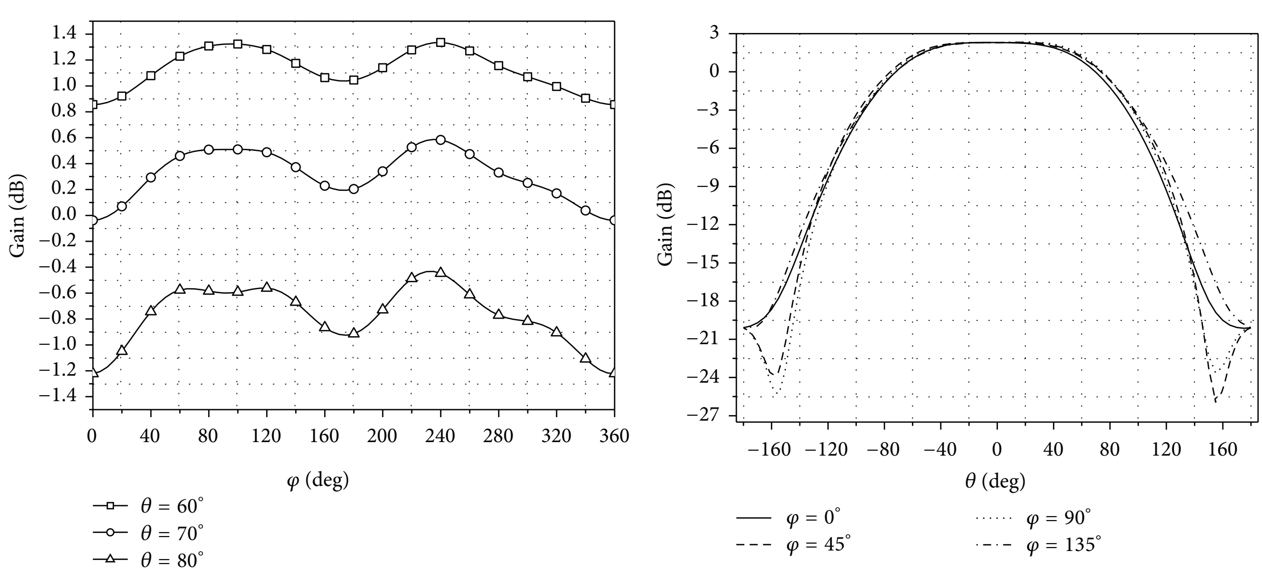


FIGURE 5: (a) Horizontal radiation pattern at low elevation angle; (b) radiation pattern for different φ.

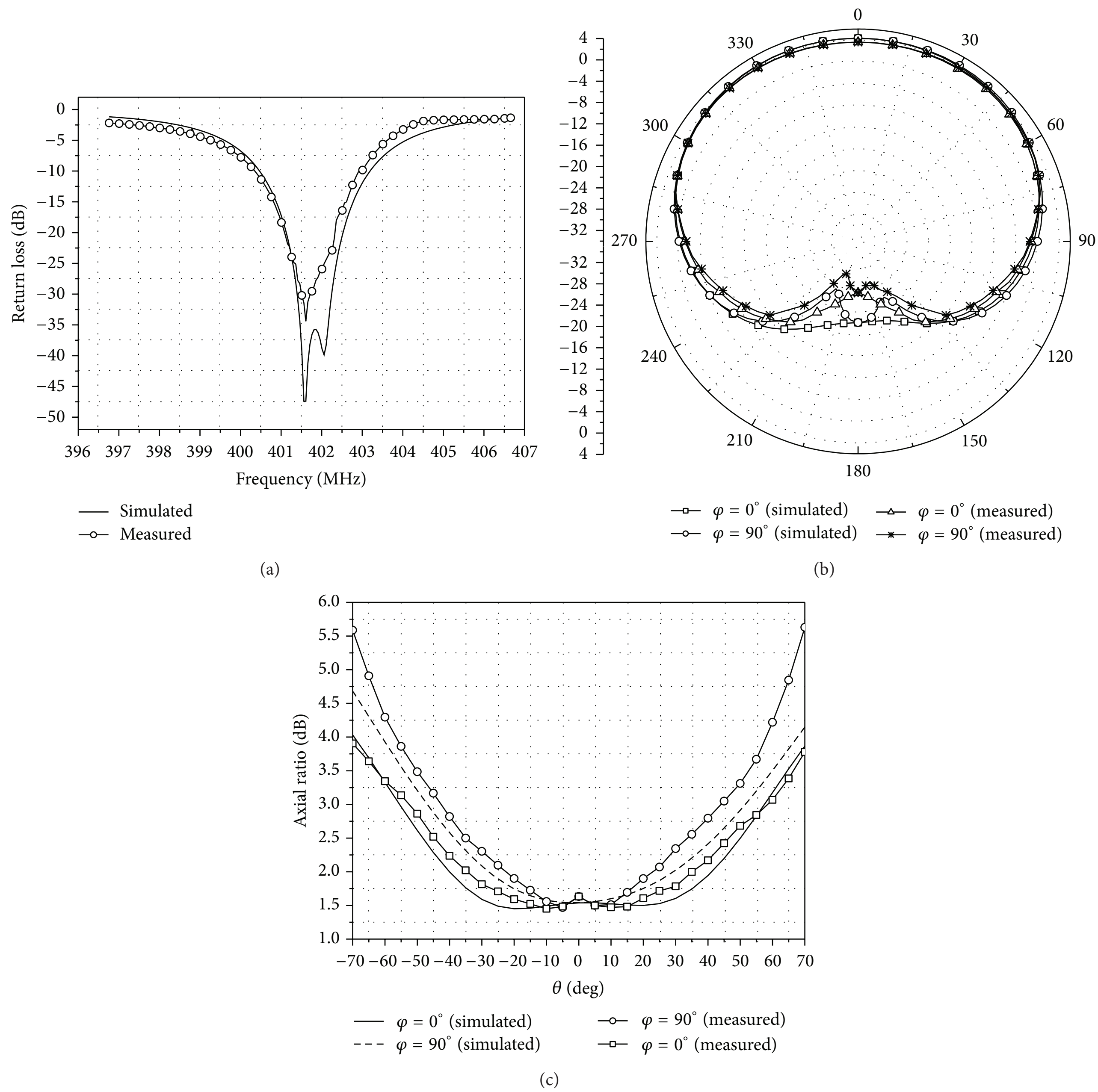


Figure 6: Antenna performance at f = 401.6 MHz: (a) return loss, (b) RHCP radiation pattern at $\varphi = 0^\circ$, $\varphi = 90^\circ$, and (c) axial ratio pattern at $\varphi = 0^\circ$ and $\varphi = 90^\circ$.

of the MPA and the conical surface, the contribution of the reflected wave to the forward radiation concentrates at the low elevation angle, and then a wide beamwidth is achieved. To study the effects of the shape of the platform on the beamwidth, we analyze the relationship between the half power beamwidth (HPBW), peak gain, and half-angle θ_c of cone, as shown in Figure 3. In this case study, the height and the top diameter of the truncated cone are fixed to be 180 mm and 130 mm, respectively. Obviously, increasing the half-angle θ_c of truncated cone, the influence of the reflected wave on the forward radiation is gradually strengthened which results in the decrease of the maximum radiation gain and the increase of the antenna gain at low elevation angle, and then the radiation beam at low elevation angle will be included in the domain of 3 dB RHCP radiation beam at some θ_c. All of the above can explain why the main beam has mutation at $\theta_c = 8.5^\circ$, in which the beamwidth suddenly changes from 90° to 195°. From Figure 3, we can observe that when $\theta_c \geq 8.5^\circ$, the beamwidth declines slowly, and the maximum beamwidth presents at $\theta_c = 9.7^\circ$ where the 3 dB RHCP beamwidth is about 195°. The antenna peak gain ranging from −0.5 dB to 2 dB exhibits a rising tendency when θ_c is increasing. Figure 3 shows that the low elevation angle gain and beamwidth can be effectively controlled by changing the θ_c.

In order to further study the effects of the truncated cone to the beamwidth, the influence of the cone height is analyzed in this paper where the top diameter and bottom diameter of the truncated cone are 130 mm and 292 mm, respectively. Figure 4 illustrates the relationship between the HPBW and the cone height. From Figure 4, we can observe that the beamwidth increases with cone height h_{cone} ranging from 90° to 210° for different φ, and when $h_{\text{cone}} \geq 300$ mm, the HPBW suddenly falls to a stable value which is about 70°. This is because the contribution of the reflected wave to the forward radiation is gradually shifting to low elevation angle, and the low elevation angle beam will be excluded from the main beam at some h_{cone} ($h_{\text{cone}} = 300$ mm), which results in the mutation shown in Figure 4. After the mutation, the supporting platform has little effects to the forward radiation for the case of increasing the h_{cone} which comes out as a stable value of beamwidth. However, when the h_{cone} is tending to 0 mm, due to the existing metallic rectangular plate which is larger than the ground of the MPA, the contribution of reflected wave to forward radiation is still at work which can explain why the beamwidth increases from 90°. Figure 4 depicts that the HPBW can be further broaden to more than 200° by changing the cone height h_{cone}. To obtain the hemispherical pattern coverage, low elevation angle radiation pattern and different φ-plane radiation are presented to show the antenna performance. Figure 5(a) shows the horizontal radiation pattern at low elevation angle, and we can observe that the horizontal gain range are less than 0.8 dB, 0.6 dB, and 0.5 dB at $\varphi = 80°$, 70°, and 60°, respectively. The HPBW variation is less than 8° as is shown in Figure 5(b).

4. Simulation and Measurement Results

A RHCP-MPA with $\theta_c = 24.2°$ is designed and experimented in this paper. Figures 6(a) and 6(b) show the measured and simulated return loss and RHCP radiation pattern for the designed antenna at the operating frequency of 401.6 MHz, respectively, and the corresponding axial ratio pattern is given in Figure 6(c). The measured antenna gain is about 1.5 dB. From Figure 4, we can find that the 3 dB RHCP beamwidth is 152° and the 3 dB AR bandwidth is 89° for the proposed RHCP-MPA. And the simulated and measured results are in good agreement.

5. Conclusion

The ultrawide beam coverage of a RHCP corner-truncated antenna with a truncated cone ground plane and a metallic rectangular plate has been studied experimentally for operation in the 401.6 MHz UHF band. Employing the technique of laying gradually variational supporting platform under the MPA, the 3 dB RHCP beamwidth of a new MPA can be broadened effectively. The proposed antenna has a 3 dB RHCP beamwidth of 152°, which is about 70° greater than the conventional MPA and its RHCP gain is about 1.5 dB. By optimizing the shape of the metallic supporting platform, we can broaden the 3 dB RHCP beamwidth up to 200°, which is very suitable for applications of ultrawide beam coverage.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

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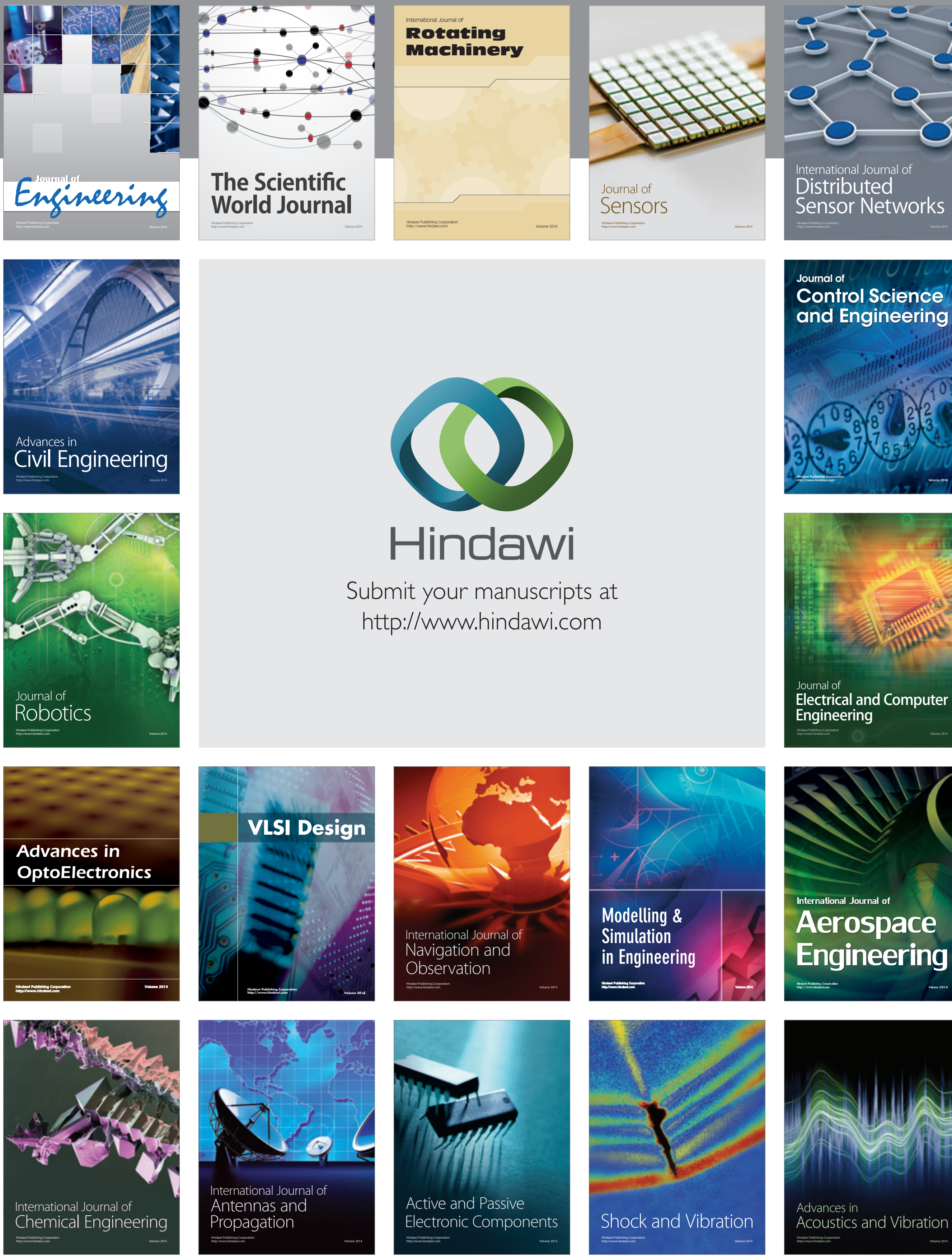
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