Gain Enhancement of Slot Array for Base Station Using Cavity of Curved-Woodpile Metamaterial

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Abstract - **This paper proposes the gain enhancement of base station antenna for mobile phone by using the metamaterial structure associated with conventional slot array antenna. The new technique of cavity of curved-woodpile metamaterial on Electromagnetic Band Gap (EBG) structure has been utilized to improve the gain instead of increasing the number of slots on such an array. The proposed technique has the advantages of reducing the total length of slot array antenna but providing the higher gain. Furthermore, it provides the azimuth pattern covering 360° by using a triangular array configuration consisting of three panels of 1×4 slots array on each side of the triangle with the triangular PEC reflector for decreasing their back and side lobes. This idea has been verified by both the CST simulation software and experimental results. As the results, the prototype antenna achieves a high gain of 16.6 dB at 2.1 GHz.**

Index Terms — **Gain enhancement, base station antenna, slot array antenna, curved-woodpile metamaterial.**

1. Introduction

From the development of wireless communication system, the antennas were improved with new performances becomes currently necessary essential for the new services and networks of telecommunication. Microstrip antenna or MSA is an attractive choice for many modern communication systems because of its low profile, low cost, light weight, and versatile in terms of resonant frequency, polarization, pattern, and impedance [1]-[2]. Nevertheless, MSA has two important disadvantages of low gain and very narrow impedance bandwidth due to its resonant nature. The narrow bandwidth can be expanded by adding slot on ground plane and feeding by strip line above wide-slot ground plane [3].

Numerous new technologies have come out in the modern antenna design is the development of metamaterial, which has desirable electromagnetic properties that cannot be observed in natural material. In addition, the Electromagnetic Band Gap (EBG) structure is the one type of metamaterial, which has become a wondrous topic for antenna engineering to increase the antenna gain, minimize the side and back lobes, and reduce mutual coupling in array elements [4]-[5]. Therefore, from such advantages of EBG structure, this paper presents a triangular slot array antenna with cavity of curved-woodpile EBG structure and metallic reflector providing the high gain and beamwidth suitable for mobile phone base station.

2. Antenna and EBG Configurations

(1) Microstrip Slot Antenna Configuration

The microstrip slot antenna designed for utilizing in the UMTS band of 2.1 GHz and used be the initial prototype for our proposed antenna. The design of a slot is based on the transmission line model at 2.1 GHz and the desired bandwidth is around 1.92 GHz – 2.17 GHz as illustrated in [3]. From the simulated results, its gain at the operating frequency of 2.1 GHz is around 5 dB.

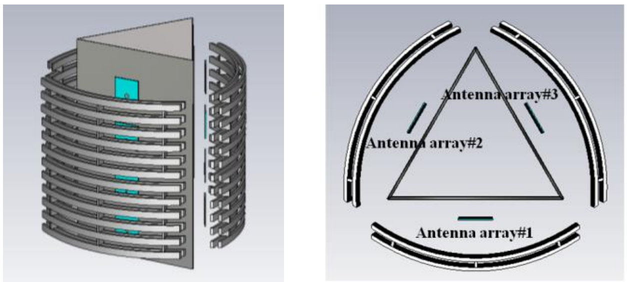
To improve gain and radiation pattern characteristics, a 1x4 microstrip slots have been arrayed with element spacing of 3λ/4 and added a PEC reflector with the size of 300×500 mm^2 behind each panel of slot array to control the radiation pattern as the directional antenna. The simulated result shows that its gain of each panel is around 14 dB.

(2) Curved-Woodpile EBG Configuration

From our study [6], we found that the equivalently resonant circuit of EBG structure is capable to enhance the gain of slot array antenna by installing such an EBG structure at front of the array panel. Therefore, this paper presents the proper structure of curved-woodpile EBG, which is applied from the planar and the cylindrical woodpile EBG, to reduce the half-power beamwidth, side and back lobes of the proposed antenna.

3. Simulated Results and Discussions

The triangular array of three panels of 1×4 slots array with PEC reflectors and curved-woodpile EBG structures to form the antenna beam directed to around the base station tower was simulated by CST Microwave studio software as shown in Fig.1. Such a triangular array configuration consists of 1×4 slots array on each side of the triangle while the cavity of curved-woodpile EBG is used to cover an angular sector of 120° of user area. From the simulated results, the reflected power (S_{11}) of this proposed antenna covered 1.92 GHz – 2.17 GHz, which are wide enough and can be well utilized for 3G mobile phone base station. From the normalized radiation patterns at 2.1 GHz, it notes that in the azimuth plane, its radiation pattern can cover 360° of user area as shown in Fig.3. Also, the gains, bandwidths and HPBWs of each four-element slot array on each side are shown in Table I.



(a) Perspective View (b) Top View

Fig. 1. The configuration of antenna system model.

4. Experimental Results and Discussions

The triangular array of three-panel prototype has been simulated with the CST Microwave studio software and fabricated and tested for validating the proposed concept. Fig. 2 shows photograph of the fabricated antenna. Its geometry consists of a triangular array configuration consisting of three panels of 1x4 elements of slot antenna arrays with PEC reflector to decrease their back and side lobes, while the cavity of curved-woodpile EBG structures of each panel exhibits as the bandgap characteristics at 2.1 GHz. The simulated and measured radiation patterns of the proposed antenna are shown in Fig. 3. The further studies of this proposed antenna have focused on its gain, bandwidth, and HPBW as shown in Table I. A good agreement is obtained between calculated and measured results. With such features, we can summarize that this antenna is suitable for a mobile phone base station.

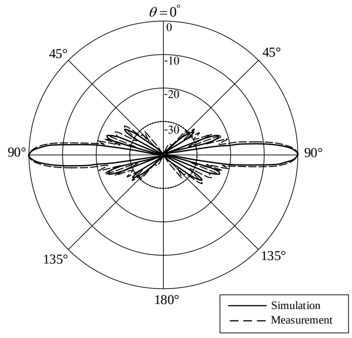
TABLE I

Results of Simulation and Measurement.

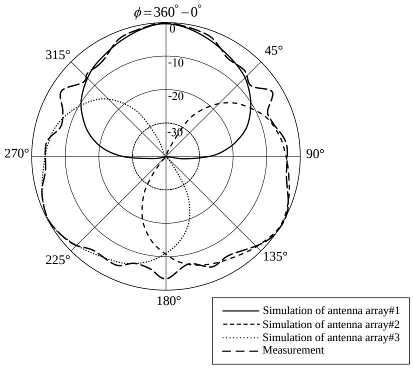
Antenna	Gain (dB)		Bandwidth (%)		HPBW AZ:EL	
	Simulation	Measurement	Simulation	Measurement	Simulation	Measurement
Antenna array#1	17.2	16.7	18.9	19.3	62.6°:8.6° (7.3:1)	63.2°:8.9° (7.1:1)
Antenna array#2	17.1	16.6	19.1	19.3	62.8°:8.6° (7.3:1)	63.4°:8.9° (7.1:1)
Antenna array#3	17.1	16.5	18.9	19.3	62.8°:8.6° (7.3:1)	63.5°:8.9° (7.1:1)

(a) Front view (b) Side view

Fig. 2. The prototype of the proposed antenna.



(a) E-plane



(b) H-plane

Fig. 3. The radiation patterns of this proposed antenna.

5. Conclusion

The gain enhancement of slot array by using the cavity of curved-woodpile EBG is presented. From the results, this proposed antenna provided the directive gain on each side increasing around 3 dB when such proper EBG structures were added, while its length of array was not enlarged. Additionally, an omnidirectional radiation pattern in the horizontal direction according to our requirement was obtained with a high average gain of 16.6 dB. With reference to these curves, a good agreement between predictions and measured data can be observed. Therefore, this proposed antenna accords to the requirements and is appropriated for a mobile base station.

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