Photonic Bandgap Stacked Rectangular Microstrip Antenna for Road Vehicle Communication

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***Abstract*—A compact design of a stacked rectangular microstrip antenna with shorting post on slotted ground for road vehicle communication is presented in this letter. The antenna consists of a two stacked rectangular patches with a shorting post on a dielectric substrate micromachined with a rectangular lattice of holes on the ground plane. These lattices of holes act as electromagnetic band-gap structure which improves the antenna's efficiency. The whole structure is backed by a plane ground with a air gap of 8.5 mm.**

***Index Terms*—Photonic bandgap (PBG), shorting post, stacked rectangular microstrip antenna (SRMSA), PBG SRMSA.**

I. INTRODUCTION

ONE of the applications of intelligent transport system (ITS) is road vehicle communication system (VICS) that enhance traffic safety, smooth traffic flow and gives traffic information to drivers. It is desirable that car antennas for VICS have uniform level of received signals from below a beacon antenna at the shoulder of road to far away along the road. The radiation characteristics required for VICS are not sufficiently met with by the rectangular microstrip antenna (MSA) of TM_{01} mode, which are presently used as car antenna. A stacked rectangular MSA (SRMSA) with a shorting post had been used to improvise the radiation characteristics [1]. The radiation characteristics can be further improved by using a photonic bandgap (PBG) structure on one side of the substrate. This side of the structure is used as the ground plane as explained below.

Interest in the field of PBG structures has started in early 1990s. The PBG structure consists of a uniformly distributed periodic metallic pattern on one side of a dielectric slab which is capable of prohibiting the propagation of all the electromagnetic waves of certain band of frequencies [2]. Originally, the focus of most of the researches was in the optical regime [3], but as these structures are readily scaleable and applicable to a wide range of frequencies, over the years there has been an increasing interest in the applications of these structures in microwave and millimeter wave regions [4]. Extensive application of the PBG phenomena for practical uses both in optical regime and microwave and millimeter-wave is given in [5]–[7]. Applications of the PBG phenomena in microwave region improves the radiation pattern of antennas [4], increase the output power and efficiency of power amplifiers [8] as well as with the design of reflectors [9], broadband absorbers, and frequency selective surfaces.

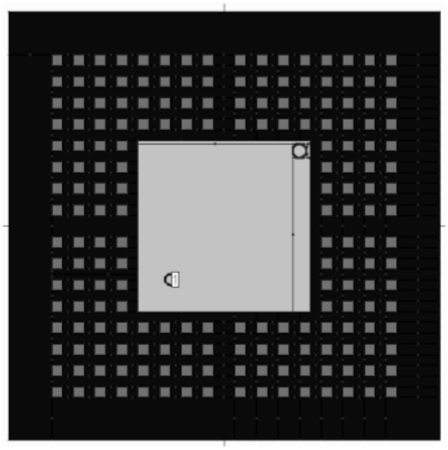

Fig. 1. Top view of the modified structure of SRMSA.

TABLE I
COMPARISON OF THE SRMSA AND PBG SRMSA

Antenna Design	Resonant Frequency (GHz)	VSWR	Radiation Efficiency (%)	Antenna Efficiency (%)	Gain (dBi)	Directivity (dBi)
SRMSA	2.57	1.15	77.02	76.23	3.46	4.64
PBG SRMSA	2.64	1.46	100	96.53	4.63	4.78

In this letter, a stacked rectangular MSA with a shorting post on a slotted PBG ground for VICS is proposed.

II. ANTENNA DESIGN

The antenna model used for VICS consists of two patch antennas and is installed above a particular height from the car antenna at the shoulder of road [1]. The design of the above antenna consists of two dielectric layers with stacked rectangular patches. A shorting post is used between the upper and the lower patch at a point (x_s, y_s). The width W and the length L of upper and the lower patches are 16 mm × 16 mm respectively. The relative dielectric constant and thickness of the two dielectric layers are ε_{r1}, h_1, and ε_{r2}, h_2, respectively. The shorting post diameter is d_s and is placed between the upper and lower patches.

The top view of the modified structure of the antenna is shown in Fig. 1.

On the bottom side of the lower patch a 40 mm × 40 mm square metallic ground plane has been constructed. Slots of 1 mm × 1 mm square holes spaced 2 mm apart forming a 14 × 14 matrix have been made on this ground plane. There are no slots

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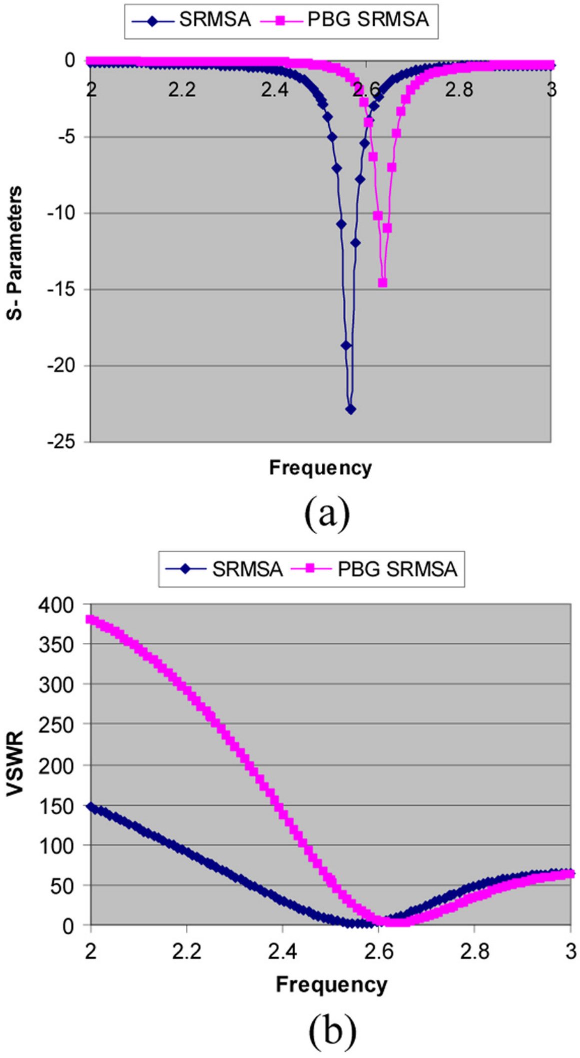


Fig. 2. (a) Simulated S-parameter of the SRMSA and PBG SRMSA. (b) Simulated VSWR of the SRMSA and PBG SRMSA. (Color version available online at http://ieeexplore.ieee.org.)

in the area just below the lower patch. The excitation for the antenna is given by a coaxial feed at (x_0, y_0) on the lower patch.

III. Results and Discussions

IE3D simulator based on the method of moments is used for the simulation of MSA and SRMSA [10]. The newly proposed PBG structure is compatible with microstrip circuits and can be easily implemented for practical uses. The various parameters of SRMSA and PBG SRMSA have been tabulated in Table I.

As seen from Table I, the frequency of operation for the SRMSA proposed by Noguchi [1] is 2.566 GHz. This has been increased to 2.636 GHz by introducing a PBG structure as shown in Fig. 2(a). From Fig. 2(b) it is seen that the voltage standing wave ratio (VSWR) has increased but is still in the acceptable range. This can be reduced by suitable choice of feed point.

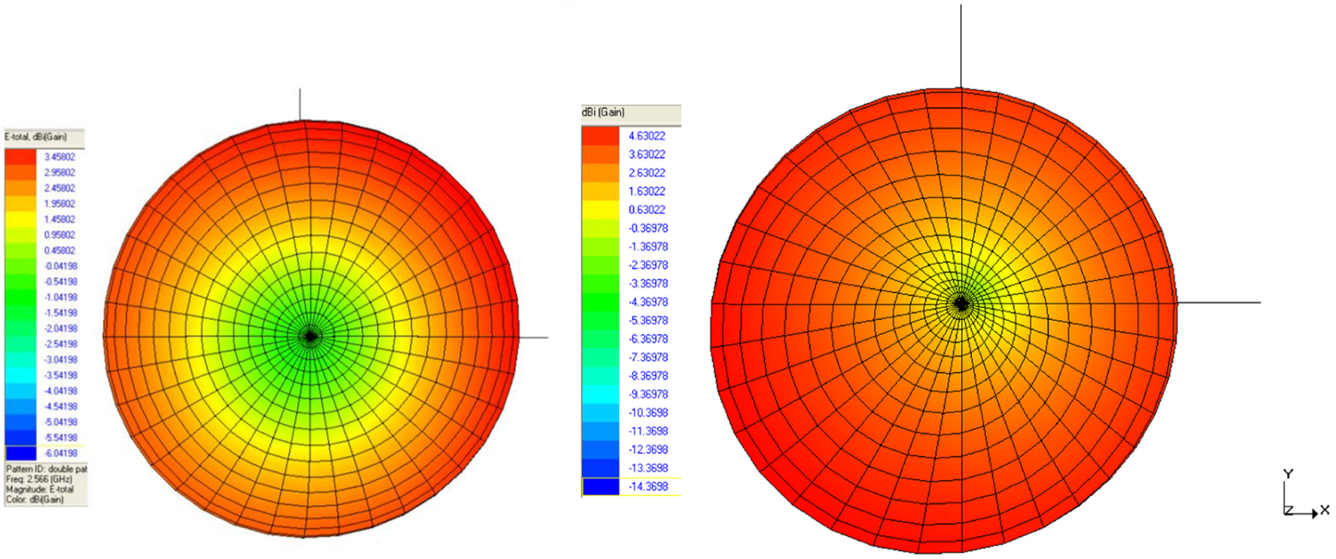
The radiation patterns for the SRMSA and PBG SRMSA have been shown in Fig. 3(a) and (b), respectively. The radiation efficiency of the PBG SRMSA is shown to be hundred percent. It is also observed that this structure has an improvement of around 20% in its antenna efficiency. Further there is 34% increase in gain and 3% increase in directivity as compared to the SRMSA antenna proposed in [1].

IV. Conclusion

It has been observed that by introducing the PBG structure the gain and the antenna efficiency can be improved considerably. The PBG structure suppresses the surface waves [4], which in turn increases the antenna efficiency.

There is slight change in gain and directivity because gain is a product of the efficiency and the directivity of the antenna. As the PBG structure improves the efficiency of the antenna which in turn improves the gain of the antenna.

In Table I, Column number 4 shows the radiation efficiency whereas column number 5 shows the total antenna efficiency. For the calculation of radiation efficiency no losses are taken into account, whereas in the case of antenna efficiency losses due to mismatch, ohmic and dielectric etc. are taken into account.



(a)

(b)

Fig. 3. (a) Radiation Pattern of the SRMSA. (b) Radiation pattern of the PBG SRMSA. (Color version available online at http://ieeexplore.ieee.org.)

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