The paper is organized as follows-
The former part of the paper presents a review of various EBG structures developed so far. The latter part describes various novel EBG geometries suggested by researchers. It also emphasizes the fact that inclusion of EBGs results in enhancement of Antenna performance to a greater extent.

II. EBG CONFIGURATIONS

The EBG configuration is categorized on the basis of their geometric arrangement and dimensions into 1-D, 2-D and 3-D EBGs. One-dimensional EBG structure is formed by arranging an EBG unit cell in one dimension to form a transmission line with two ports. Two dimensional EBG structures formed by arranging an EBG unit cell in two dimensions on a plane and one dimension, three dimensional EBG structures are formed by stacking different EBG layers to form a three dimensional structure.

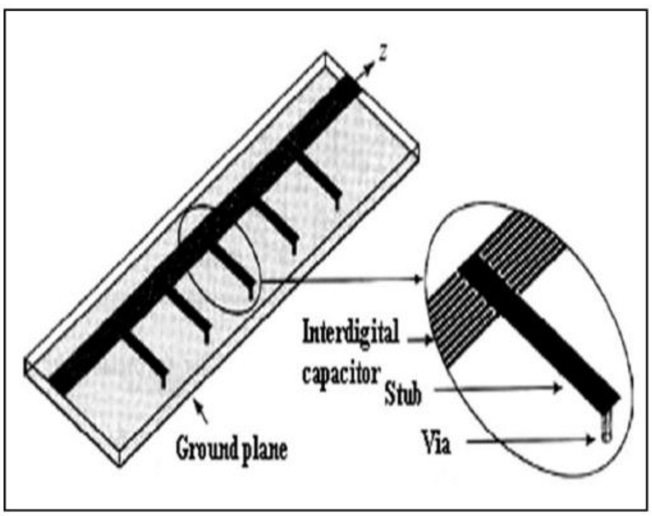

Figure 1. One-dimensional EBG structure. (*IEEE Trans.Microwave Theory Tech*., Volume 47, no. 11, 2085–91, 1999).

Figure 1 shows an example of one dimensional EBG structure which is used in a filtering application with two ports on either end of the EBG structure.

Figure 2 shows an example of two dimensional EBG structure formed by square patches, called mushroom like EBG structure

Figure 3 shows an example of a three-dimensional EBG structure, formed by laying metal strips vertically and horizontally in different layers to form a three-dimensional structure.

Two and three dimensional EBG structures exhibit some unusual properties in their band gap, when a plane wave is incident upon them, it is reflected without a phase reversal as shown in Figure 4 and they do not support surface waves, acting like a band-reject surface as shown in Figure 5.

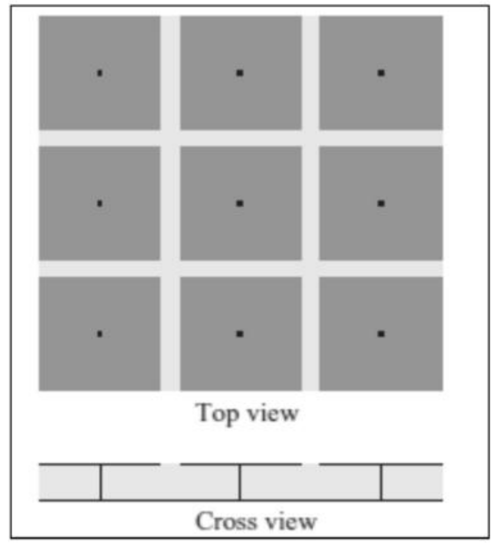

Figure 2. A two-dimensional EBG structure.

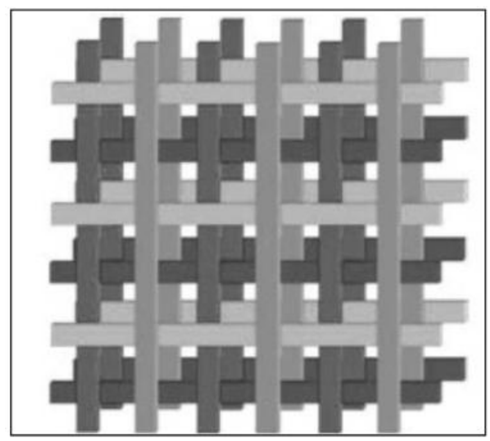

Figure 3. A three-dimensional EBG structure.

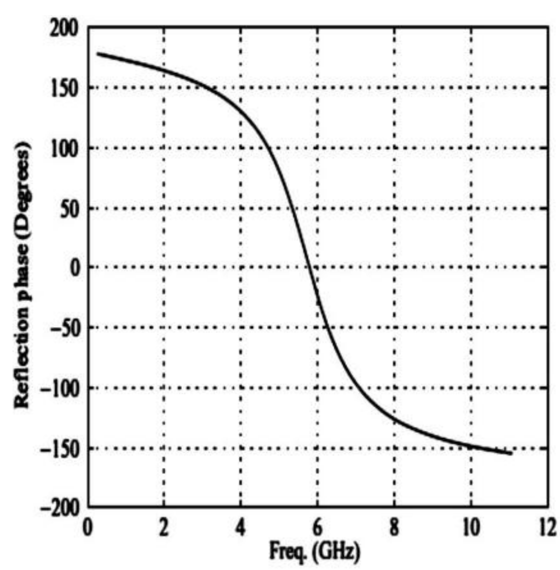

Figure 4. Reflection-phase from two-dimensional and three-dimensional EBG structures around their band gap.

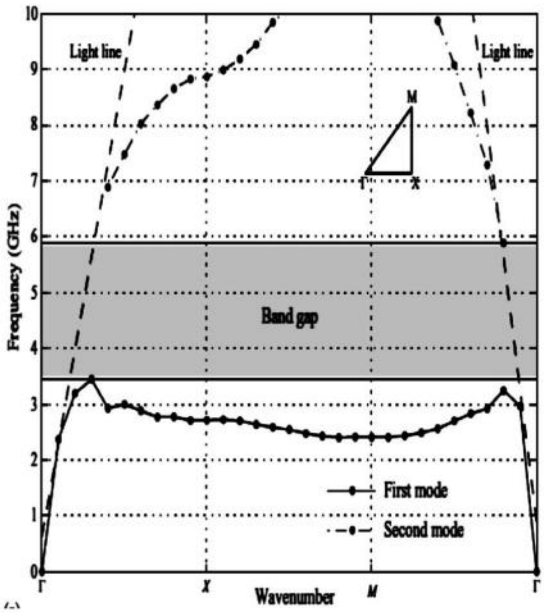

Figure 5. Surface wave band gap for two-dimensional and three-dimensional EBG structures.

One dimensional periodic structures can behave like a left handed material in one frequency band and behave like an EBG structure in another frequency band. So, a periodic structure can behave as one material in one frequency band and as another in another frequency band. Hence, it is not that easy to classify metamaterials. Due to their unique band-gap electrical properties, EBG structures can be classified as a special type of metamaterials.

III. DESIGN PROCEDURE

Design of the RSR EBG Structure: When the periodicity of EBG structure is small compared to the operating wavelength, it can be simply modeled as a parallel *LC* equivalent circuit. The capacitance *C* is determined by the fringing capacitance between neighboring metal patches, while the current flowing through the via and metal plate, can be modeled as inductance L. According to the lumped *LC* model of the conventional EBGs, the surface impedance can be calculated from the impedance of a parallel resonant circuit, and the resonance frequency of the EBG structure f_0 is calculated as follows:

$$Z = \frac{j\omega L}{1-\omega^2 LC} \qquad (1)$$
$$f_0 = \frac{1}{2\pi\sqrt{Lc}}$$

The inductance *L* and capacitance *C* are given by the following equations:

$$L = \mu_0 \mu_r h \qquad (2)$$
$$C = \frac{w\varepsilon_0(1+\varepsilon_r)}{\pi}\cosh^{-1}\left(\frac{a}{g}\right)$$

The bandwidth BW of bandgap can be determined by the surface capacitance *C* and inductance *L*:

$$\mathbf{BW} = \frac{1}{\eta}\sqrt{\frac{L}{C}} \qquad (3)$$

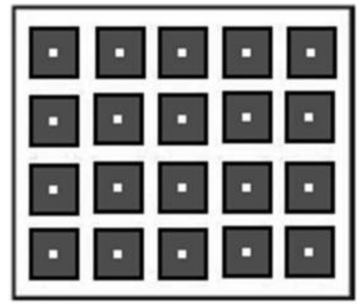

Figure 6. The mushroom-like EBGs [26].

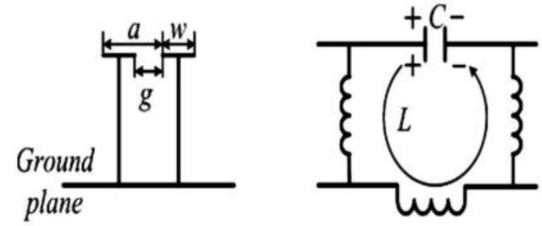

Figure 7. Geometry of the EBGs and Equivalent circuit diagram [26].

A fractal microstrip patch antenna is designed as a reference antenna, which is on a classical ground plane, as shown in Figure 8. The fractal patch is printed on a dielectric substrate with a relative permittivity of 2.65, thickness of h = 2 mm and size of $7a \times 7a$ mm^2.

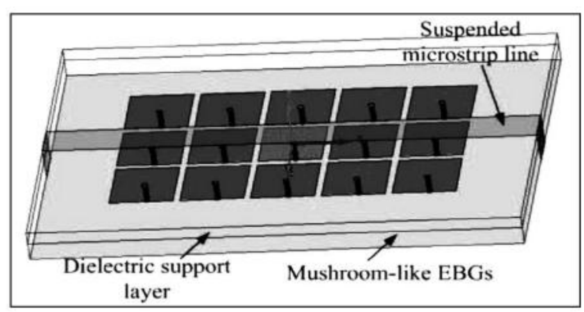

Figure 8. Geometry of 3 *x* 5 EBG arrays for the mushroom-like EBG array [26].

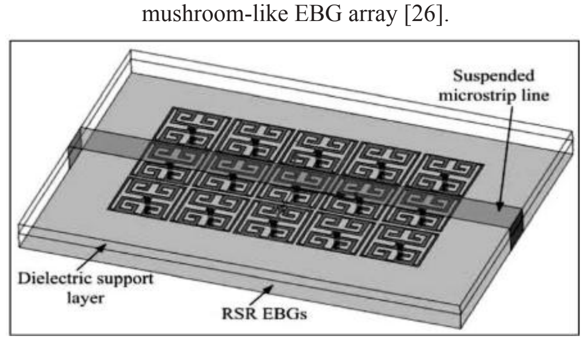

Figure 9. Geometry of 3 *x* 5 EBG arrays for the RSR EBG array [26].

The simulated S_{21} Parameters for the Mushroom shaped EBG array is shown below.

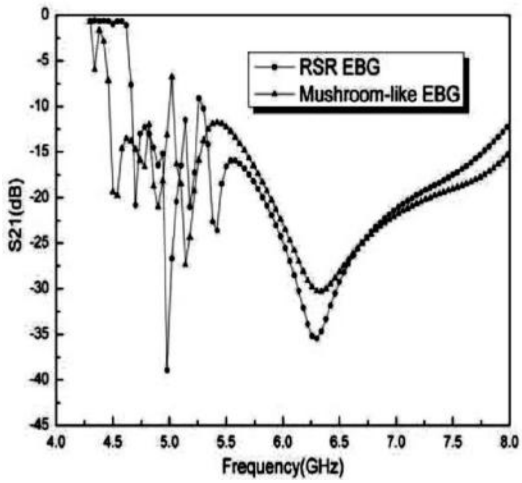

Figure 10. Comparison of simulated results of the EBGs [26].

As shown in Figure 10, the band gap range of RSR EBGs is approximately the same as the conventional EBGs, while the size of square patch of the conventional EBGs is $w_1 = 6.4$ mm, with the preservation of the other parameters. Therefore, the cell size of RSR EBGs is reduced about 30%, which is smaller than that of the conventional EBGs at the same operating frequency.

Additionally, more geometries have been investigated into. These are listed below

a) *Elongated mushroom electromagnetic band-gap (EMEBG) structure*

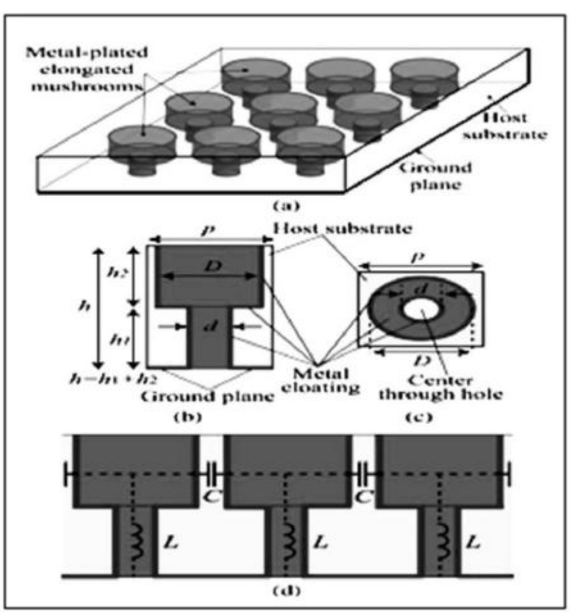

Figure 11. Elongated-Mushroom (EM)-EBG structure.
(*a*) Perspective view.
(*b*) Cross sectional view of the unit cell. (*c*) Top view of the unit cell.
(*d*) Simplified circuit model [27]

b) Hexagonal shape EBG structure:

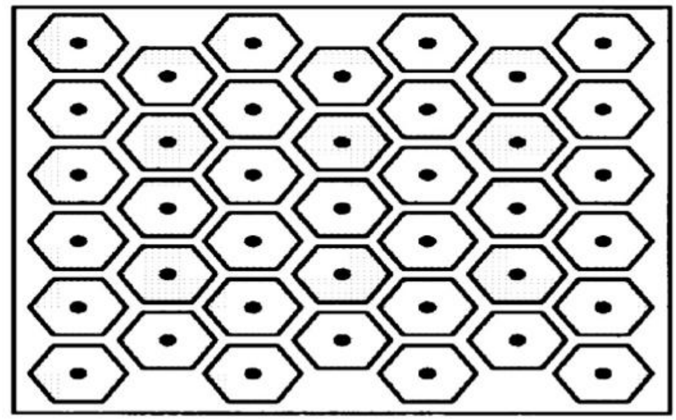

Figure12. Hexagonal shape EBG structure.

c) Fork like EBG structure

The schematic of a fork shaped EBG structure is shown in Figure 13(a).The gray section in Figure13 represents the metallic periodic structure, which is etched on a dielectric substrate. It comprises of several identical elements with each element consisting of a square metal patch with a slot etched on it as shown in Figure 13(*b*).

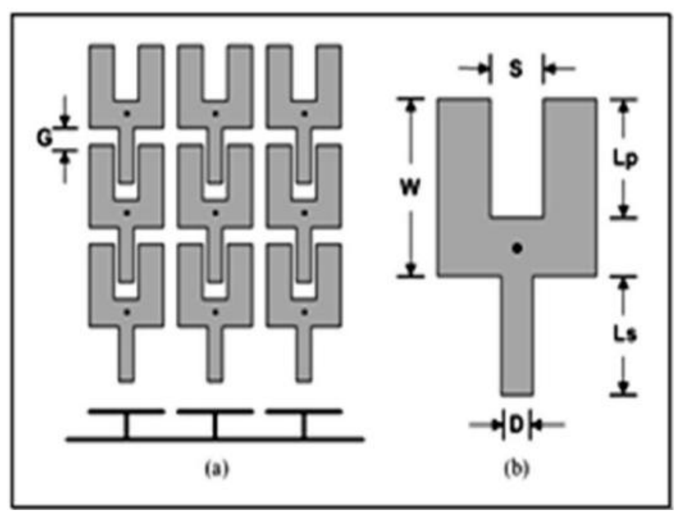

Figure 13. (*a*) Configuration of the fork-like EBG structure. (*b*) Details of one unit of the fork-like EBG lattice [27].

IV. CONCLUSION

From the illustrations and design procedure results, it is established that implementation of Antenna design and other microwave circuits using EBGS results in a phenomenal enhancement in the structural design and overall improvement in the performance of these circuits.

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