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Abstract—This paper gives an overview of recent research on new application of Electromagnetic Band-Gap (EBG) structure antenna to integrate circuits and antennas. An important part of EBG antenna is the control of electromagnetic wave propagation and surface wave distribution over EBG substrate or board with periodic structure. Many compact and small periodic EBG’s structures have been design to solve antenna design problems such as Mushroom like EBG’s, Hair pin like EBG’s etc. In simple Microstrip Patch Antenna (MPA) have low gain, efficiency and bandwidth. This resolved by using MPA with EBG structure antenna and this antenna properties is to reducing the back radiation for better performance of antennas.

Key words: Micro Strip Patch Antenna, Printed Circuit Board, Vector Network Analyzer, Display

I. INTRODUCTION

The electromagnetic metamaterials are artificial materials which are control electromagnetic waves. In specific directions, the High impedance Electromagnetic Band-Gap (EBG) structures are used as an artificial media. Main EBG structures are periodic arrangement of dielectric element in one, two or three dimensions. In EBG structure microwave frequencies are conducted and this are used many properties like Zero reflection phase, Surface current suppression.

EBG has given an angle of incidence at some frequencies. These frequencies called partial band gap. At a specific band EBG does not allow for propagation in all directions so these frequencies called global band gap. The bandgap formation in EBG is in between macroscopic and microscopic resonances. The macroscopic resonance called Bragg or lattice resonance and microscopic resonance called Mie resonance. Depending upon structural characteristics one resonance mechanism used for designing antenna (single or multiple scattering resonances).

In High performance antenna design,

- A reflector which lacks edge current that radiate power into back hemisphere or radiations.

The main properties of EBG structures are the ability to guide and control electromagnetic wave propagation and surface wave suppression within the bandgap range which improves antenna performance by reducing back radiation. Because the period of an EBG structure must be a half-wavelength at the bandgap frequency and reduce their physical size becomes problematic when integrated with printed circuits and antennas. Although these EBG structure antenna are used to suppress unwanted surface waves.

This paper discusses various types of EBG structure antenna in section II. Section III describes review of some EBG structure papers. Finally section IV gives overall conclusion.

II. TYPES OF EBG STRUCTURE ANTENNA

A. Edge-located via

For simple modification to reduce the size of mushroom-like structure is to use edged-located vias, as shown in Figure (a). The purpose of moving the via position from the center to the edge is to increase the electrical path of each element shown in Figure 1(a). This edged-located configuration decreases resonant frequency of traditional mushroom-like structure by 20%.

The size can be reduced by using the structure shown in Figure 1(b). The design of compact structure is based on a miniaturized hairpin resonator. By combining edged metallic vias connecting to the ground plane and size reduction is approximately 40% is achieved.

B. Slot-Strip EBG Structure

The schematic of slot-strip EBG structure is shown in Figure 1(c), which is known as folk-like structure. Compared to the mushroom-like structure, this design has a more compact configuration. Each element of this EBG structure has a slot etched on one edge of the metal patch and a stretched strip connecting to the opposite edge.

These slots and strips provide additional gap length between the neighboring patches, leading to increase in capacitance of the equivalent LC circuit. Thus, resonant frequencies of LC circuits are reduced. The area occupied by each patch of the fork-like structure is reduced more than 40% compared to the mushroom-like structure.

Another slot-strip EBG structure mentioned is shown in Figure 1(d). Every four Folk-like patches are an isotropic configuration and a 41.6% size reduction is achieved compared to the mushroom-like structure.
C. Inter-digital Structure

Inter-digital capacitor was first introduced to enlarge the effective capacitance in microwave integrated circuits. It has been employed as a common technique to design compact EBG structure.

![Fig. 1(e): Examples of inter-digital EBG structure.](image)

III. REVIEW PAPERS

Different methods used for the microstrip patch antenna with EBG material design and their final results for improving performance of microstrip patch antenna as well as gain and related simulation software is given in these papers.

Dan Sievenpiper has given the theory of new type of metallic electromagnetic structure which has been developed that is characterized by having high surface impedance. Although it is made of continuous metal, and conducts dc currents, it does not conduct ac currents within a forbidden frequency band. Unlike normal conductors, this new surface does not support propagating surface waves, and its image currents are not phase reversed. Instead, any currents that are induced in the surface radiate efficiently into surrounding space. This new surface also reflects electromagnetic waves with no phase reversal, behaving as a kind of artificial magnetic conductor. The structure can be described using a lumped parameter circuit model, which predicts some of its electromagnetic properties. This unique material is applicable to a variety of electromagnetic problems, including new kinds of low-profile antennas [2].

Young Ju Lee studied the applications of an electromagnetic bandgap (EBG) superstrate as a spatial angular filter for filtering undesired radiation by sharpening the radiation pattern. Two different defects, one introduced by the ground plane the antenna and the other produced by a row of defect rods with different dielectric constants in the EBG structure, are simultaneously used as key controllers of directivity enhancement. They are presented three applications of the EBG superstrate covering a class of patch antennas: i) a superstrate for dual-band dual-polarization; ii) a compact superstrate with wide directivity bandwidth; and iii) a cover for an array antenna to suppress its grating lobes. They are demonstrated that it is possible to achieve significant directivity enhancements of the antenna with cross-stacked rod EBG Superstrates, and that the EBG also help with the polarization isolation. A compact EBG superstrate design has been presented and EBG Superstrates that successfully suppress grating lobes [3].

Shau-Gang Mao has introduced the wave propagation along the finite-width conductor-backed coplanar waveguide (FW-CBCPW) with periodically loaded one-dimensional electromagnetic bandgap (EBG) cells. The full-wave simulation in conjunction with Fouquet’s theorem is employed to find the waves for characterizing the guided and leaky waves over a wide frequency range. The slow-wave propagation and backward-wave radiation for the periodic structure operating in the first pass band and the radiation leaky region were demonstrated, respectively. To characterize the Bloch impedance, a simple equivalent-circuit model that consists of lumped-element inductors and capacitors has established to find the analytical formula. Experiments were also carried out to validate the proposed theory for the periodic EBG structure [4].

Fei-Ran Yang has given the information of Mushroom-like electromagnetic band-gap (EBG) structures exhibit unique electromagnetic properties that have led to a wide range of electromagnetic device applications. The reflection phase feature of EBG surfaces is given when plane waves normally illuminate an EBG structure, the phase of the reflected field changes continuously from 180 to -180 versus frequency. One important application of this feature is that one can replace a conventional perfect electric conductor (PEC) ground plane with an EBG ground plane for a low profile wire antenna design [5].

Rebekka Porath has given an analytical theory for the eigenfrequencies and eigenmodes of shorting-post microstrip antennas (MPA’s). These antennas are seen as promising candidates for miniaturized mobile telecommunication handsets. In particular, it is given that the zero mode of the unloaded MPA plays a central role for reducing the lowest operation frequency of the loaded MPA. The theory allows a complete calculation of all relevant antenna parameters and can easily be extended to the case of multiple shorting posts [6].

Jodie M. Volakis has given the implementation of electromagnetic band-gap (EBG) structures with an inherently wide-band Archimedean spiral antenna. The EBG structure is designed to emulate a perfect magnetic conductor. The combination of technologies produces a low-profile and wide-band antenna. Utilization of an EBG structure offers an antenna height reduction of more than 69%, including the thickness of the EBG structure, compared to the traditional \( \frac{\lambda}{4} \) cavity backed implementation of spiral antennas. This allows the spiral antenna to maintain a considerable fraction (71%) of its designed inherent broad-band behavior with no loss to its directive gain [7].

Here J.M. Bell, M.F. Iskander has present a novel designs of a Dual-Band High Directive EBG resonator antenna that utilizes a single layer Frequency Selective Surfaces (FSS) as a superstrate. In this study, use a special configuration of square loop-array to design the FSS.
superstrate layer. They obtain the different operating frequencies by adjusting the distance of FSS from printed patch antenna and also the perimeter of square loops. The proposed structure presents more than 18dBi directivity enhancement at 11.25 GHz and 13.15GHz as compared to those of a patch antenna with 6 dBi directivity [8].

G. Shaker has introduced the EBG structures investigated for improving performances of numerous RF and microwave devices utilizing the surface wave suppression and the artificial magnetic conductor (AMC) properties of these special types metamaterial. The issues such as compactness, wide bandwidth with low attenuation level, tunability, and suitability with planar circuitry all play an important role in the design of EBG structures. The development of EBG structures is to be compatible with a wide range of wireless communication systems. A comprehensive review on various EBG structures such as three-dimensional, two-dimensional, and one-dimensional (3D, 2D, and 1D) EBG, mushroom and uniplanar EBG, and their successive advancement [9].

Fei-Ran Yang, Yahya Rahmat-Samii has given the applications of a mushroom-like EBG structure on antenna designs. Based on its unique band gap features, two main applications of this EBG structure are presented. One is to utilize the EBG structure as a ground plane to build a low profile antenna. This idea is validated by a curl antenna on the EBG surface whose height is reduced compared to an ordinary curl antenna on a PEC surface. The other is to integrate the EBG structure with patch antenna and array on high dielectric constant substrates to improve their performance. A 3.24 dB gain increase, 15 dB back radiation reduction and 8 dB mutual coupling reduction are obtained. Our observations suggest that the electromagnetic band-gap (EBG) structures have potential applications in wireless communications [10].

T. H. Liu, W. X. Zhang, M. Zhang and K. F. Tsang has written a novel on spiral antenna backed on photonic bandgap (PBG) material. It consists of a spiral radiator, a PBG substrate and a feed network and exhibits a wider frequency bandwidth, larger ratio of front-to-back radiation level, and higher gain than a traditional spiral antenna with \( \lambda/4 \) spaced ground plate. It has been given that a patch antenna with a fractal boundary exhibits localized modes. The localization effect produces an electric current density that is mainly concentrated in certain regions at the boundary. The result is that the microstrip fractal boundary antenna behaves as an array of antennas. When the localized modes are properly in phase, a broadside pattern is obtained and the directivity increases in comparison with the directivity of the antenna at the fundamental frequency [11].

S. Bashir, M. Hosseini, R. M. Edwards, M. I. Khattak, L. Ma has proposed a novel paper presents a low profile antenna based on the properties of a non-uniform electromagnetic bandgap (NU-EBG), i.e. a non-uniform high impedance surface (NU-HIS). The structure, referred to as Flexible EBG Inverted-L (FEBGIL) antenna, is an efficient wearable antenna incorporating a planar inverted-L element adjacent to some non-uniformly spaced high impedance elements. While the bandwidth is approximately 10% at 1.85 GHz, the overall electrical size is quite small providing an ideal condition for the antenna to be worn on biceps (upper arms) [12].

Nacer Chahat, Maxim Zhadobov, Ronan Sauleau, Kourokh Mahdjoubi has discussed a brief review of a new dual-band wearable textile antenna designed for body-centric communication. The antenna is fully characterized in free space and on the body model, with and without an electromagnetic band gap (EBG) substrate. The band gap array consists of 3 x 3 elements and is used to reduce the interaction with human issues. With the EBG back reflector, the radiation into the body is reduced by more than 15 dB. Increases of 5.2 dB and 3 dB gain are noticed at 2.45 GHz and 5.5 GHz, respectively. The results are presented for the return loss, radiation pattern, efficiency, and specific absorption rate [13].

RongLin Li, Gerald DeJean, Manson M. Tentzeris, J. Papapolymerou, J. Laskar has introduced the techniques for the surface-wave suppression are related to periodic structures, such as photonic bandgap (PBG) or electromagnetic bandgap (EBG) geometries, which require complicated processes and considerable area. A compact soft-surface structure consisting of a square ring of short-circuited metal strips is employed to surround the patch antenna for blocking the surface-wave propagation thus, alleviating the effect of the edge diffraction and hence improving the radiation pattern. Since its operating frequency is determined by the width of the metal strip (about a quarter guided wavelengths), the compact soft-surface structure is suitable for a substrate with arbitrary thickness and dielectric constant [14].

Tian Hong Loh has given the design approaches and the applications of mushroom-like High Impedance Surface Electromagnetic Band Gap (HIS-EBG) metamaterials in antenna engineering. The techniques for developing HIS-EBG metamaterials that are wideband and compact in size using an electrically tunable approach. A tunable HIS-EBG structure is represented by a novel analytic equivalent transmission line circuit model for surface wave propagation. The analytical and numerical simulations and a parametric study on the effects of patch width, gap width, substrate thickness and substrate permittivity are presented [15].

Rudy Diar has developed a magnetically loaded artificial magnetic conductor (AMC) providing enhanced bandwidth. The design has been carefully given to align the high impedance and surface wave bandgap frequency bands. The demonstrated result is greater than four times improvement in bandwidth relative to a conventional stomacher of the same thickness. The use of magnetic loading in AMC structures for bandwidth enhancement has been successfully demonstrated. More than a factor of four increases in reflection phase bandwidth is achievable with a magnetically loaded AMC compared to a conventional foam core AMC. Using the Mag-AMC it is possible to build an antenna to instantaneously cover the UHF LOS frequency band in a depth of about 1.5” [16].

IV. CONCLUSION

In this paper, a novel of EBG structure has been introduced with their properties. The mushroom-like patches structure is more expensive than the other types that are observed by given different types of EBG structure comparison in section II. In review paper EBG theory is given in detail.
REFERENCES


