An Electromagnetic Band Gap Structures for Ultra Wide Band Antennas.

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1. Introduction

A modern generation short-range wireless communications technology namely the Ultra Wide Band (UWB) systems, operates at an extremely wide range of frequencies from 3.1 GHz up to 10.6 GHz and allows high rate data transmissions. It can reach above 2Gbits/s with low power consumptions and have to be managed in a way that permits optimal spectrum usage at a limited transmits power of -41 dBm/MHz, as mandated by the FCC, ensuring protection of licensed services against potential interferences [1]. Given the identified bands and failure to comply with the regulations aforementioned, UWB systems could become a potential jammer for the numerous licensed services.

It is an option and will be much favourable if the UWB antenna has a capability to be 'tune' to work at a certain allocated band of frequencies and reject partially those unneeded ones, where, the radiating power will be reduced to a level that will not intrude any existing channels. In such a way, UWB systems will certainly not be a threat to the already operating applications. To accomplish this objective, the authors proposed an active and passive 2D Electromagnetic Band Gap (EBG) structure(s) that exhibit 'band stop' characteristics, that can be incorporated into UWB antennas and act as a 'band rejecter'.

1.1 UWB Antenna

Antenna designers have a bountiful of Wide Band (WB) and UWB antennas, already proposed to be used within these range of frequencies. The antennas are known for their wide impedance bandwidth and good omni-directional radiation patterns. Some antennas cover partially a certain band of frequencies but most design covers the whole range of the UWB spectrums [2, 3 and 4]. Although not regulated by the FCC, UWB antennas that possess bandwidth covering the whole range of the stated UWB frequencies could have an extra circuitry in order to avoid collisions or filter out some band of frequencies that might cause interferences. Alternatively, the use of antennas with band-rejection operation can relieve the requirements for the filtering electronics within the wideband devices. However, one-band-rejection operation is insufficient for future wireless communication. Thus, a tuneable band-rejection operation has become an important concern in this work.

An initial numerical design was done using user friendly CAD software [5]. After the optimal design was confirmed, models of these antennas and EBG structures were developed and constructed on an inexpensive Fire Retardant-4 (FR4) board, using wet etching techniques. The concept and the results were validated through measurements and found to be correlating well.

2. Electromagnetic Band Gap (EBG) Structures and Antenna Systems.

Research on the integration of EBG structures with antenna systems includes low profile slot antenna , multi-band EBG [6], application of EBG in cell phones [7], patch antennas with EBG crystals [8], to enhance bandwidth [9], planar inverted antennas PIFA [10], dipole with EBG [11], electronic beam steering [12], to reduce mutual coupling [13], and many more. Most of the objectives of the aforementioned research were to suppress surface waves and improve the radiation characteristics of the antennas involved.

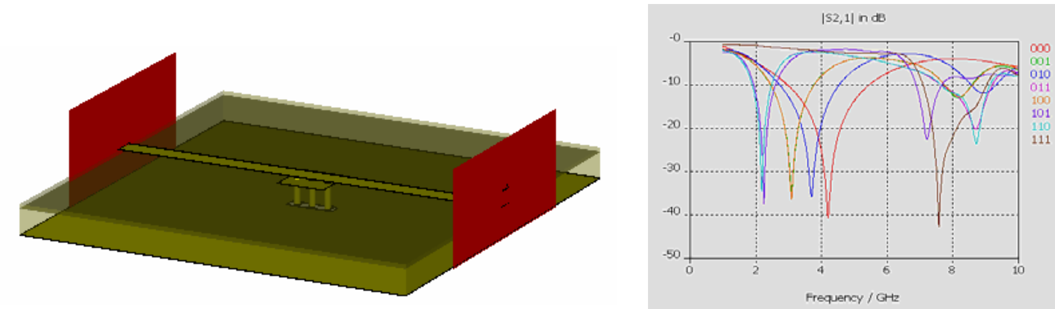
Consequently, in this work, the EBG structure(s) is/were positioned in between a feeding line and ground plane of transmission line feed UWB antenna, thus making it/them work as a band rejecter for the antenna itself. An experiment and test on a planar UWB 'transmission line feed' antenna using two layers of FR4 boards validates that this novel idea can be implemented and the objective can be achieved.

3. The Design and Construction of EBG Structures and UWB antenna

3.1 Electromagnetic Band Gap Structures

EBG structures in general, consist of a periodically arranged lattice of metal plates, connected to a solid metal sheet by vertical conducting vias. However, as minimum as one lattice of EBG structure, incorporated with a number of switchable vias, connected to pin diodes and ground plane, is introduced in this work to produce a tunable band gaps that act as a means to reject or stop a certain 'band of frequencies', effectively. It was intended to work within the UWB spectrum of frequencies, i.e. from 3.1GHz to 10.6GHz. The configuration of one of the proposed EBG structure(s) incorporated with switchable vias is as shown in Figure 1(a) below.

The design consists of a two layer substrates where the transmission line (feeder) and its radiating patch is on the top section of the first layer of the FR4 board of a thickness of 0.5mm, and the EBG lattice(s) is printed on the second layer (FR4 board) of a thickness of 1.6 mm. The main element of this EBG lattice is incorporated with vias that is connected with pin diodes that will short (the vias) to the ground plane when supplied with dc currents and plays an active part in the EBG design. These vias, with a radius of 0.4 mm, are positioned at different location within the EBG patch, accordingly. The vias were separated from the ground plane via a 1.5 x 6.0 mm^2 rectangular slot. The diameters/lengths of the square EBG structures under investigation are 3mm, 5mm, and 6mm. In this work, the 'narrow' band gap of the EBG structures shifts as the number of (grounded) vias is alternately shorted to ground, as shown in the simulated results in Figure 1(b). In this way, the frequencies to be rejected or filtered out can be selected accordingly.



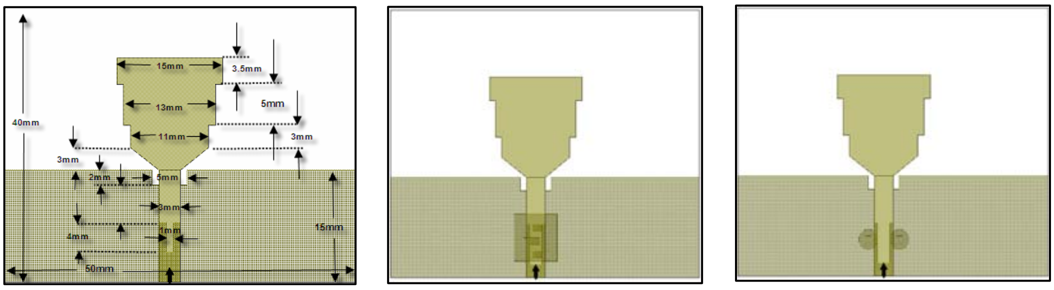
(a) (b)

Figure 1: (a) The geometry of the 6x6 mm^2 square EBG Lattice with three vias and a 50 Ohm transmission line. (b) The simulated results showing the various 'Band Gaps' shifting as the vias are shorted to the ground, alternately. The three digit numbers represent the pin-diodes conditions.

3.2 Ultra Wide Band Antenna and EBG Structures

Figure 2(a) shows the geometry of the novel Ultra Wide Band planar antenna without EBG structures. This antenna has a wide impedance bandwidth below -10dB from 3.1GHz to 10.6GHz and good Omni-directional radiation patterns. The design details consists of a two layer substrates where the main radiating patch is on top of the first layer of the 40 x 50 mm^2 FR4 board with a thickness of 0.5mm and is fed via a transmission line feed technique. The partial ground plane is printed on the bottom of the second layer (FR4 board) with a thickness of 1.6 mm, with length of

15mm and width of 50mm. Under the transmission line feed, the ground plane is modified and added with three staged slits, where, in such a way, the lower and higher range frequencies can be tuned for matching and optimization purposes. The relative permittivity/dielectric constant of the FR4 substrate is 4.7. Figure 2(b) shows the UWB antenna with a square EBG structure incorporated with three vias, located on the top section of the second layer, just below the transmission line feed, and Figure 2(c) shows the antenna with two circular EBG structures incorporated with a via at each EBG structure. Different shapes, sizes, active and passive configurations of EBG structures were studied for comparison purposes.

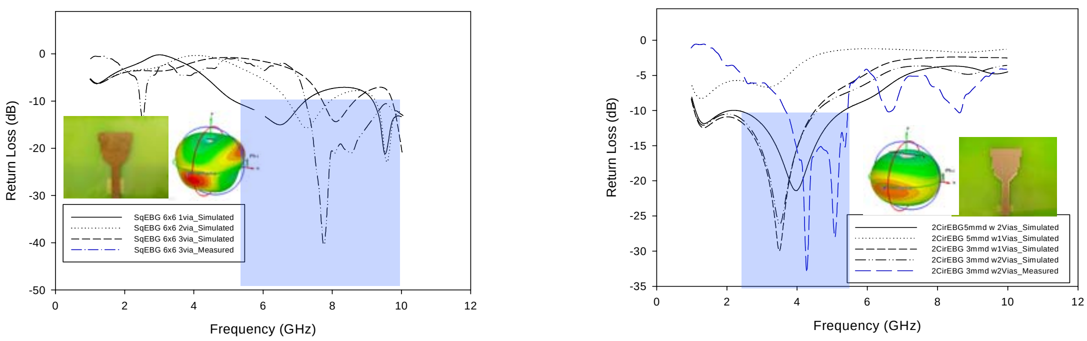


(a) (b) (c)

Figure 2: The geometry of the Ultra Wide Band planar Antenna (a) without EBG structure (b) incorporated with a square lattice and three active vias and (c) incorporated with two circulars lattice with vias at each EBG structure.

4. Results and Discussions

As expected, the EBG structure rejects the targeted band of frequencies effectively when incorporated under the feed lines of the UWB planar antenna. Figure 3 (a) shows the simulated and measured results of a 6x6 mm^2 square EBG structure with three vias inserted at a particular positions respectively. The result shows that the square EBG structure could reject the lower band of frequencies. Figure 3(b) shows two 3mm diameter circular EBG structures rejecting the higher band of frequencies, effectively. The radiation patterns are maintained, similarly like those without EBG structures.



(a) (b)

Figure 3. Simulated and measured results showing the Square EBG structure when (a) inserted with different numbers of vias at different position rejecting the lower band of frequencies and (b) rejecting the higher band of frequencies. The blue region determines the frequency band of the UWB antenna.

It was also observed that there is a slight difference in term of 'Band-gap's bandwidth' between a square and a circular EBG structures. A square EBG lattice reject about 30% more compared to a Circular EBG lattice. This also gives the idea that, in order to reject a larger band of frequencies, a square EBG lattice is more suitable than a circular lattice. In the fabrication, a 6x6 mm^2 square lattice incorporated with three vias was used to reject the lower band frequencies and two 3mm diameter circular lattice, with one via each, was used to reject the higher band frequencies. The ‘oscillating’ pattern (measured) at the higher frequencies in figure 3(b) is due to the high tangential loss (0.019) of FR4 board. This effect is reduced when using Taconic board (Tan Loss of 0.0019).

5. Conclusion

A novel active and passive 2D square and circular Electromagnetic Band Gap structure(s) that exhibit ‘stop band’ characteristics have been incorporated into an UWB planar/patch antenna and have been proven acting as a ‘band rejecter’ to reject band of frequencies within the UWB spectrum of frequencies. Models of the UWB antenna and EBG structures was developed and constructed on an inexpensive Fire Retardant-4 (FR4) board, using wet etching techniques, to validate the concept. As expected, the EBG structure rejects the band of frequencies effectively when incorporated into the UWB planar antenna. The EBG structure(s) were initially simulated and measured using the method of suspended transmission line and their results were validated through fabrication and found to be very promising and correlating well.

Acknowledgments

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