# An Embedded On-Body Planar Antenna Using a Low Profile EBG Structure


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*Abstract*— This paper presents an embedded on-body planar monopole antenna using a low profile electromagnetic band gap (EBG) structure. The EBG structure consists of the series capacitance between an inter-digital slot and the shunt inductance through a via. Using the band-gap characteristic of the EBG array, a planar monopole antenna which has an isotropic radiation pattern could be mounted on the human body with low interference. The planar monopole has an advantage of miniaturization compared to the patch antenna which is usually used in on-body communication. By using the low profile EBG structure, the thin antenna is applicable to on-body communication systems.


## I. INTRODUCTION

Unobtrusive physiological monitoring, such as a wireless health patch adhered to the skin, requires antennas with a thin form factor capable of operating when mounted directly on skin [1]-[4]. However, once an antenna is placed on the body, the back radiation of the antenna causes interference between the antenna and the body, effecting the radiation pattern [5]. In previous work, several approaches have been proposed to resolve this degradation, including attaching a planar monopole antenna perpendicular to the body [1], creating a gap between the antenna and body [2], and utilizing a patch antenna with a shielding ground plane [3][4]. While these methods result in antennas that operate when on the body, the primary disadvantage is it is difficult to minimize the size of these antennas. As electronics continue to scale in size, with wireless sensors recently reported at the mm-scale, the antenna quickly dominates the area of a wireless health monitoring patch.

In this paper, an embedded on-body planar monopole antenna concept using a compact electromagnetic band-gap (EBG) structure is proposed. By incorporating the EBG structure, the planar monopole antenna can be mounted directly on the human body. Since this structure has a metal ground plane on the bottom layer, the back radiation of the antenna is suppressed [6]. In order to reduce the size of the EBG structure, an inter-digital capacitor at the edges is utilized. This produces a large capacitance in order to decrease the resonance frequency of the structure, and ultimately leading to size reduction of the structure. The side length of the EBG cell is only 0.03λ. Thus, the proposed structure can eliminate the back radiation on the body as well as reduce the size of the structure and the antenna.

## II. EBG STRUCTURE DESIGN

Fig. 1 shows the geometry of a 5x5 EBG array and the dimension of a unit cell of the EBG structure. The EBG structure is fabricated on a 0.025" thick RT/Duroid 6010LM which has a dielectric constant of 10.2 and dissipation factor of 0.0023. The parameters of the unit cell are: a = 10.5mm, b = 0.3mm, c = 0.5mm and g = 0.1mm.

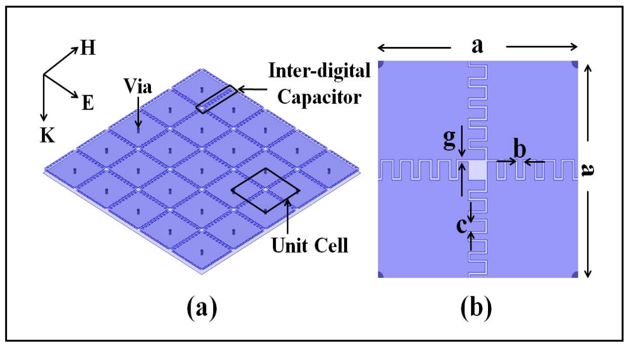


Figure 1. The geometry of EBG structure. (a) A 5x5 EBG array. (b) A unit cell model

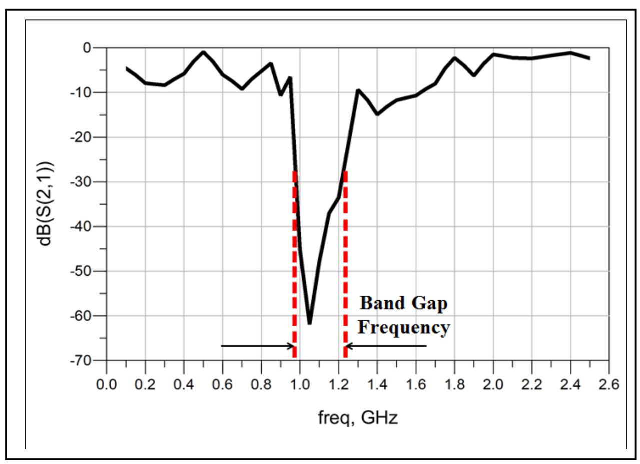


Figure 2. Simulated S21 of a 5x5 EBG Array

The structure consists of the series capacitance between the inter-digital slot and the shunt inductance through the via in Fig. 3. The capacitance and inductance determine the resonance frequency of the EBG structure at which the surface wave is suppressed. The proposed EBG structure has a band-gap frequency range between 1.0 GHz to 1.2 GHz, as shown in Fig. 2

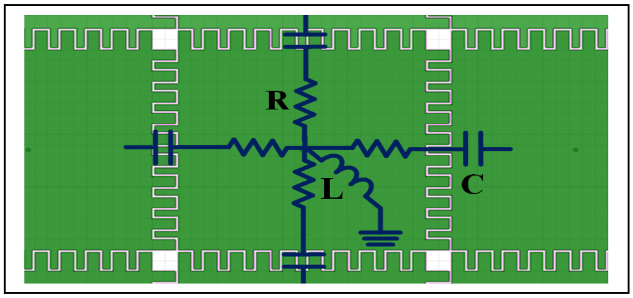


Figure 3. An equivalent circuit with lumped elements

## III. Body Network Application

A human body model is used in order to simulate the performance of the antenna when in close proximity to the skin [7]. When a planar monopole antenna is placed on the EBG structure, its surface wave is suppressed at the band-gap frequency, and the radiation pattern changes as the back radiation pattern is eliminated. In Fig. 4, the geometry of the antenna on the EBG structure and its radiation patter is shown. Compared to the radiation pattern without the EBG array, the pattern of the back radiation is much smaller. This characteristic makes it possible to place the planar monopole antenna on the body without interfering with the radiation pattern.

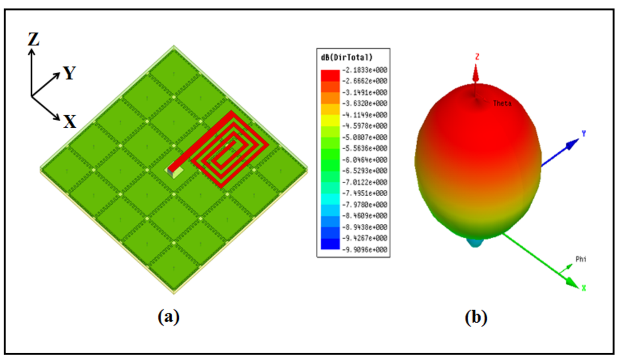


Figure 4. (a) A planar monopole antenna on the EBG array. (b) The directivity of the antenna

To verify the effectiveness of the EBG structure, we compare simulation results of antennas on the body with three different situations; (a) the planar monopole on the EBG structure, (b) the planar monopole without the EBG structure and (c) the patch antenna on a ground plane. As shown in Table I, the performance of the monopole antenna without the EBG structure is significantly deteriorated by the body interference. On the other hand, the monopole antenna on the EBG structure shows good agreement with the off-body case. The result of the patch antenna is not affected much by proximity to the body due to the higher directivity of this antenna. However, the patch antenna occupies much more area compared to the monopole antenna. This would be particularly problematic when operating at low frequency, such as within one of the 400MHz MedRadio bands.

Table I. Simulation Results of the directivity

| | **(a) Monopole without EBG** | **(b) Monopole with EBG** | **(c) Microstrip Antenna** |
|---|---|---|---|
| Off-Body | 0.33 dBi | -0.67 dBi | 3.49 dBi |
| On-Body | -14.2 dBi | -1.71 dBi | 1.37 dBi |
| Antenna Dimension | 5 x 15 mm² | 5 x 15 mm² | 22 x 45 mm² |

## IV. Conclusion

For on-body wireless communication, antennas are required that are immune to body interference in order to eliminate the back radiation of the antenna. By using the low profile EBG structure, the planar monopole antenna would be applicable for an on-body network, resulting in a smaller total volume for low-frequency wireless communication.

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