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Wideband Antenna with Reconfigurable Band Notched Using EBG Structure

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Abstract—A wideband antenna with band notch function using electromagnetic bandgap (EBG) structure is proposed. The antenna is capable of reconfiguring up to three band notch operation. Three EBGs are aligned underneath the feed line of the wideband antenna. The transmission lines over EBGs unit cells perform as a band stop filter. A switch is placed on each of the EBG structure, which enables the reconfigurable band stop operation. The simulated and measured reflection coefficients, together with the radiation patterns, are shown to demonstrate the performance of the antenna.

1. INTRODUCTION

Wideband communication systems are rapidly growing and attract a lot of attention due to the wide applications such as radar and short-range communication systems. However, due to their broadband operation, wideband antenna has the potential to be interfered by the existing wireless communication systems such as WIMAX, WLAN and C-band satellite communication systems. Several solutions have been attempted to overcome the interference problem, mainly by introducing band notch or band stop function to the wideband antenna design. In [1], a ultra-wideband antenna (UWB) with single band notch function using electromagnetic bandgap (EBG) structure is presented. A wideband planar monopole antenna with dual band notched characteristics is discussed in [2]. Dual band and triple band notched characteristics have also been discussed in [3–5]. However, the techniques used in [1–5] are applicable to only fixed single or dual frequency band. Recently, new techniques using reconfigurable notched function have been investigated. In [6], a reconfigurable slot antenna with band notch function is presented. A dual band notched UWB with triple band WLAN reconfigurable antenna has been discussed in [7]. Meanwhile, [8] proposes a UWB circular slot antenna with reconfigurable notch band function. In [9], a miniature UWB antenna with dual tunable band notched characteristics has been presented. Reconfigurable band notched antenna has also been discussed in [10–12]. However, none of the reported techniques use reconfigurable EBG to achieve reconfigurable notch function and capable of reconfiguring more than two band notches.

Therefore, in this paper, a proof of concept of the wideband antenna incorporated with reconfigurable EBGs is presented. The proposed antenna is capable of reconfiguring up to three band notch function. Three EBGs are positioned and aligned underneath the feed line of the wideband antenna. In the designated frequency, the EBGs function is to suppress the propagating of electromagnetic wave through the feed line. Hence, the transmission lines over EBGs acts as a band stop filter. To facilitate the switch between ON and OFF states, a switch is placed on each of the EBG structure to facilitate the band notch function. An average of 4 dB gain suppression is achieved for each band notch operation. More than three band notch frequencies can be reconfigured if additional EBGs are placed into the proposed antenna.

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2. ANTENNA DESIGN AND OPERATION

The geometry of the proposed antenna is depicted in Figure 1. Two layers of Taconic RF35 substrate with a thickness of 3.04 mm, permittivity of 3.5 and loss tangent of 0.0018 are used in the antenna design. The top view of the upper substrate of the antenna is the wine-cup shaped radiator. The radiator has a size of $a = 40\,\text{mm} \times b = 42\,\text{mm}$. The length of feed line is $c = 50\,\text{mm}$ with a width of 7 mm. Meanwhile, the geometry between the substrate layers shows the three EBG structures

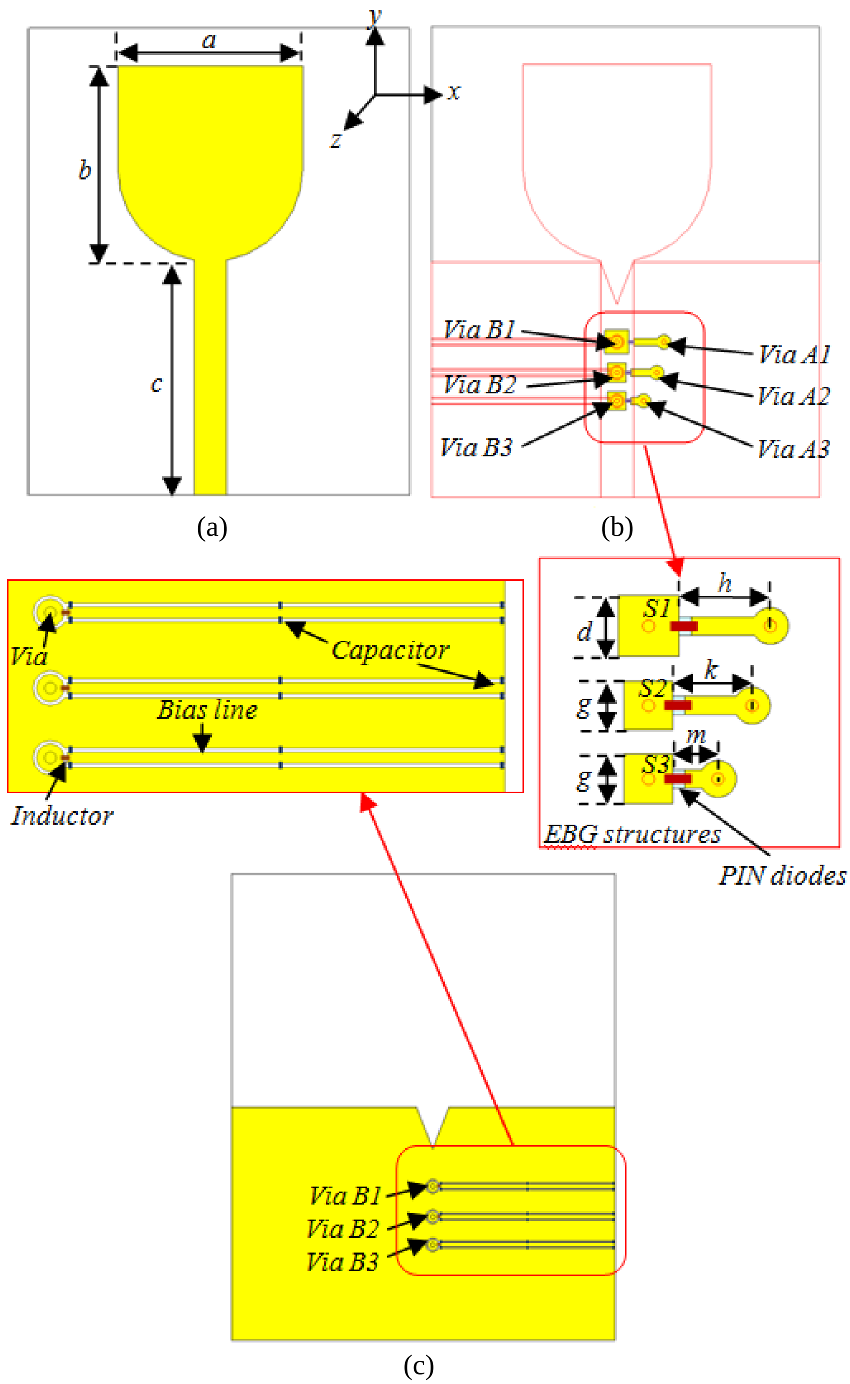

Figure 1. Geometry of the proposed antenna: (a) top view, and (b) in-between layers, (c) bottom view.

with different size of square patch and stub length are aligned underneath the feed line. The EBG structure is composed of mushroom-like structure designed by Sievenpiper [13]. This structure features a more compact structure than the other types of EBG structures such as dielectric rods and holes. The major characteristic of EBG structure is exhibiting band-gap feature in suppression of surface wave propagation at certain frequency range. EBG structure is frequently used in filter, subsequently improving the antenna performances such as gain and back radiation [14]. The proposed EBG structure is formed by a via-loaded metal patch where the geometry of the EBG are shown in Figure 2(a) and Figure 2(b) while the equivalent LC resonator of the EBG is shown in Figure 2(c). The resonant frequency of the EBG can be defined as $f_r = 1/(2\pi(L_1(C_1+C_2))^{1/2}$ [15]. The inductance, L_1 represents the current flowing through the via while the capacitance C_1 and C_2 is due to the coupling effect between the patch and ground plane and between the patch and the feed line, respectively. Thus, the approach to increase the inductance or capacitance will naturally result in the decrease of band notch frequency. In the design, the dimension of the square patch is $d = 5\,\text{mm}$ and $g = 4\,\text{mm}$ while the length of the stub is $h = 7.5\,\text{mm}$, $k = 6.5\,\text{mm}$ and $m = 3.7\,\text{mm}$, respectively. The width of the stub is 1.5 mm. The stubs are shorted to the ground plane using via A_1, A_2 and A_3.

RF PIN diode BAR50-02V is positioned between the square patch and the stub. When the diode is in ON state, the square patch is shorted to the ground which acts as a band stop filter while in OFF state the band stop function is disable. Table 1 tabulates the diode configuration of the proposed antenna. At the designated frequency, EBG structures suppress the electromagnetic wave from propagating through

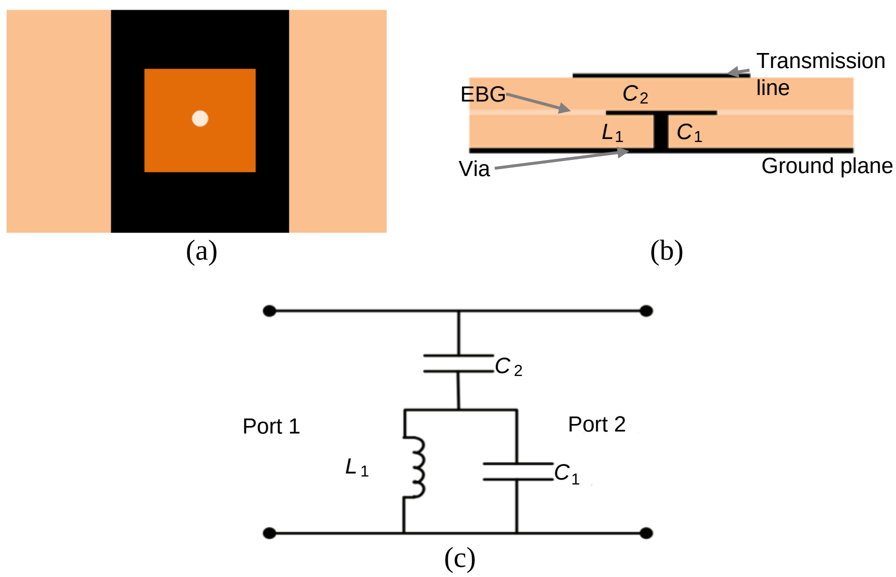

Figure 2. Geometry of EBG structure where (a) top view, (b) side view, and (c) equivalent circuit model.

Table 1. Diode configuration of the EBG structure.

Configuration	Diode state		
	S_1	S_2	S_3
Wideband	0	0	0
F_1	1	0	0
F_2	0	1	0
F_3	0	0	1

**0 =OFF, 1 = ON.*

the feed line. Hence, the transmission lines over EBG structures perform as a band stop filter operation. Method of suspended transmission line has been used to analyze the EBG structure [16, 17]. It is observed that the EBG can be reconfigured to three different band notch operations.

The bottom view of the proposed antenna as shown in Figure 1(c) shows the ground plane with the biasing circuit. The ground plane has a width and length of 82.5 mm and 50 mm respectively. To simplify the DC biasing of the PIN diode, the biasing circuit is inserted into the ground plane. EBGs are shorted to the ground plane using vias B_1, B_2 and B_3. The vias are connected to the "$+ve$" DC voltage while the ground plane is linked at the "$-ve$" DC voltage. Surface mount RF inductor with a value of 0.01 nH is placed between the vias and the bias line for suppressing the RF wave from going through the biasing circuit as shown in Figure 1(c). The width of the bias line is 1 mm with a slit width of 0.3 mm. Due to the effect of the slits separation, surface mount RF capacitor with a value of 100 pF is used to provide RF wave connection throughout the ground plane. Computer Simulation Technology (CST) microwave studio software is utilized to simulate the proposed antenna. The diode in the simulation is represented by the S-parameter of the BAR50-02V.

3. RESULTS AND DISCUSSIONS

The proposed antenna is fabricated and measured. Figure 3 shows the fabricated antenna. The simulated and measured reflection coefficients are presented in Figure 4 and Figure 5, respectively. Small discrepancies between the simulated and measured results of band notch frequency may be due to the parasitic effects of the PIN diodes which contribute to the shift of measured results to the higher frequency region. Table 2 summarizes the simulation and measurement performance of the proposed antenna with different diode configurations. The proposed antenna is capable to reconfigure the band notch operation to three different frequencies which are 1.82 GHz, 2.27 GHz and 2.58 GHz. The measured bandwidths of the band notched at F_1, F_2 and F_3 with -10 dB reference are 310 MHz, 240 MHz and 300 MHz, respectively.

Figure 6 shows the measured gain of the proposed antenna at different diode configurations. The gain varies from a minimum of -3 dBi to a maximum of 4 dBi. As observed, each configurations of band notch operation are capable to decrease the gain of the proposed antenna to 5.3 dB, 3.2 dB and 4.0 dB

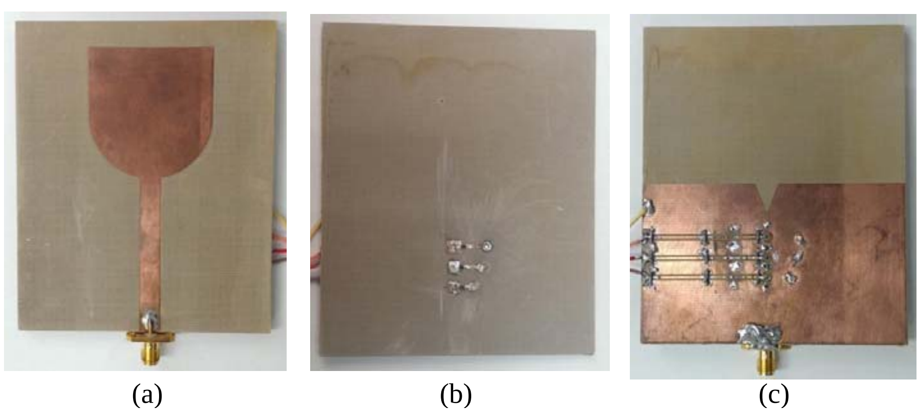

Figure 3. Fabricated proposed antenna where (a) top view, and (b) between layers, (c) bottom view.

Table 2. Simulated and measured band notch frequency.

Configuration	Simulated (GHz)	Measured (GHz)
F_1	1.65	1.82
F_2	1.98	2.27
F_3	2.33	2.58

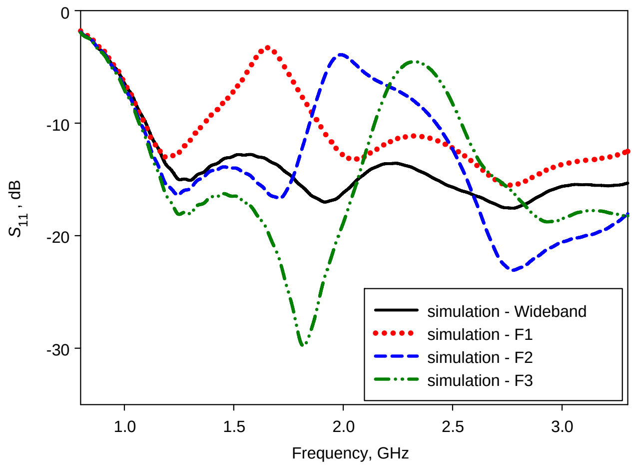

Figure 4. Simulated return loss, S_{11} results.

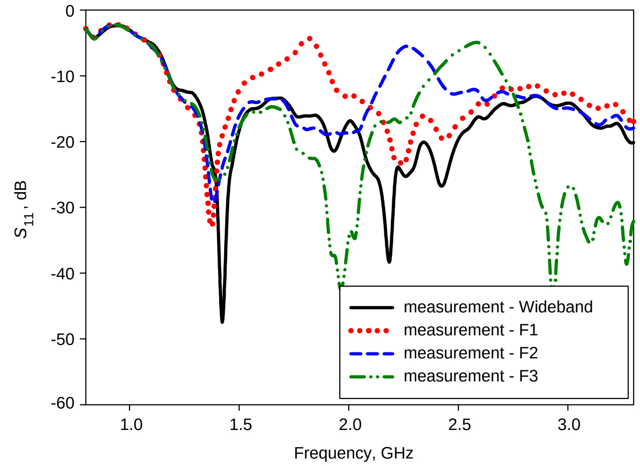

Figure 5. Measured return loss, S_{11} results.

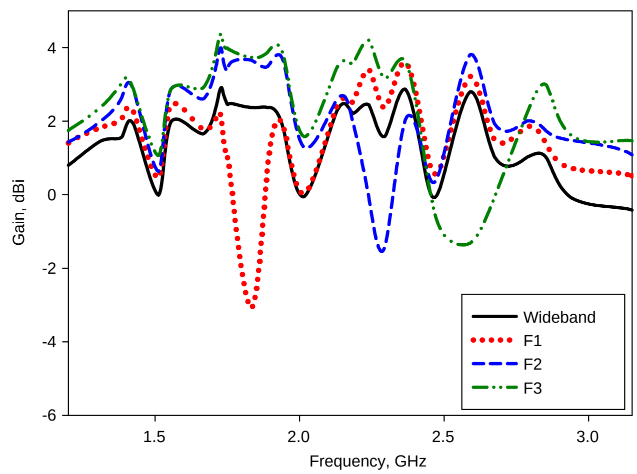

Figure 6. Measured gain results.

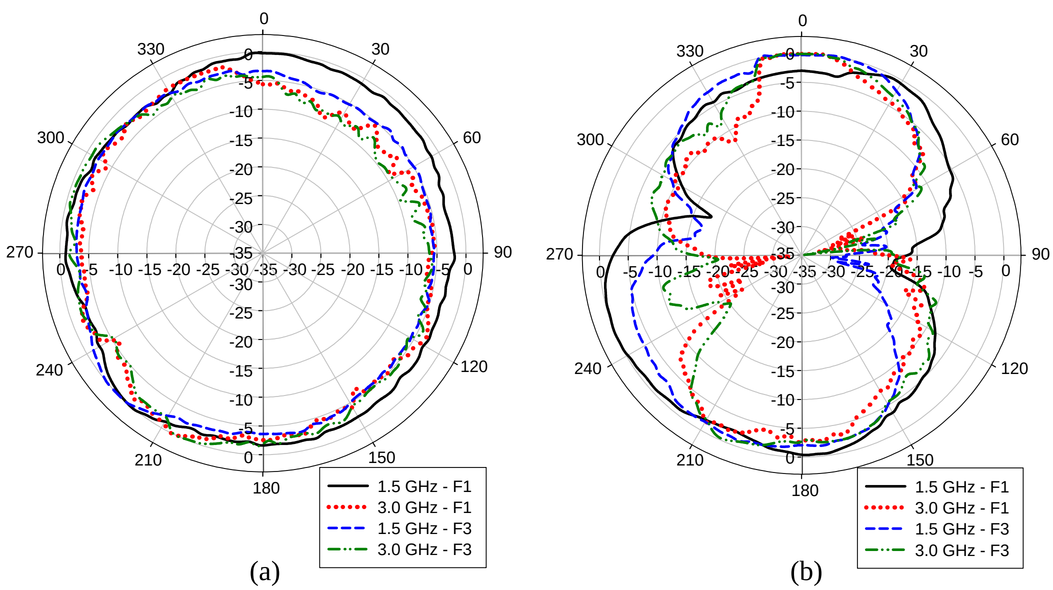

Figure 7. Measured radiation pattern, (a) *H*-plane and (b) *E*-plane.

for F_1, F_2 and F_3, respectively. Meanwhile, the measured radiation pattern of the proposed antenna at F_1 and F_3 configuration are shown in Figure 7. Figure 6(a) and Figure 6(b) show the radiation pattern in H plane and E plane, respectively. The radiation patterns are measured at 1.5 GHz and 3.0 GHz. As observed, the radiation patterns are omni-directional at both configurations. It is also shown that the EBG gives minimum effect towards the radiation pattern characteristic of the proposed antenna. No major changes of radiation pattern at different frequency bands of F_1, F_2 and F_3.

4. CONCLUSIONS

A wideband antenna with band notch reconfigurability is presented. EBG structures are incorporated into the wideband antenna to produce band notch operation. By proper tuning of the band notch operation of the EBG structures, three band notch frequencies can be reconfigured. The proposed antenna can be used in UWB systems that requires the function of band rejection to avoid interference with other existing wireless services.

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