ANTENNA BEAM STEERING USING SECTORIZED SQUARE EBG

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Abstract

In this paper, a pattern diversity antenna using a switched sectorized square mushroom like electromagnetic band gap (EBG) surface is presented. A low profile antenna is integrated with an EBG whose band stop and band pass properties are changed by switching vias in and out of sectors. The propagation characteristics and pattern directivity have been analyzed using CST Microwave Studio (CST MWS). The antenna radiation pattern has been steered in multiple directions as surface impedance in each sectors has been altered. The radiation pattern has been directed towards the EBG sectors with lower surface and reflected from the high impedance surface of EBG. The concept of the directive antenna using mushroom type EBG has been achieved with lower profile with compared to monopole type of parasitic pattern directive antenna.

Keywords: *EBG, surface wave antenna, beam steering.*

I. INTRODUCTION

In mobile communication system, fast fading due to multipath has a significant impact on the overall system performance. The fading occurs when the signal arrive at the receiver over different paths with difference in amplitude and phase. The total signal vector at the receiver is taken from the vector simulation of all the received signals, which usually contain significant signals fade and pattern interference. The most popular technique to combat the signal fading is known as diversity [1-4].

Multiple incoming signals are combined properly in order to increase the probability and strength of the received signal. Various diversity types such as pattern, polarization, spatial, transmit/ receive, time and frequency diversity are commonly used to combat the signal fading in wireless communication. Further understanding of the diversity criteria will be useful for the research development.

Electromagnetic band gap (EBG) has been used to alter the surface characteristic of a diversity antenna [5] . Meta-material and electromagnetic surface design and development have contributed towards the evolvement of surface wave antenna which had effectively reduced the overall antenna size with total improvements in the overall performance.

Various designs and shapes of EBG structures have been implemented on the metal surfaces of dielectric substrates in order to stop and propagate the surface wave. Surface wave antenna (SWA) has been designed to make use of the surface wave propagation. The theories and experimental results on the SWA have been reported since the concept was introduced in the 1950's [6-12]. The SWA application has been investigated for low profile monopole like antenna [13-15] and the monopole-like dual-band SWA which has been realized in [16, 17] with the advantage of a low profile configuration. Leaky wave type antennas have been utilized for steering the antenna power pattern with a tunable EBG surface impedance [9, 10, 18-21].

The low profile surface wave antenna is suitable to be applied for vehicular applications in which the antenna design was always dictated by the vehicle style due to conformable requirement according to the vehicle metallic body. The distance from metallic body need to be kept to maximum as the closer distance could reduce the antenna efficiency and radiation pattern shape due to the effect of the surface current excitation. In [15, 20, 22], low profile antennas have been developed based on the high-impedance surface capability to shield the surface wave effect.

In this paper, the low profile surface wave beam steering antenna is designed and analyzed. The design is based on the previous design methodologies of pattern directive monopole antennas as published in [22-24]. Multiple monopole parasitic antennas that are placed around an excited monopole have been switched alternately to steer the beam. The beam direction has been determined by switching the parasitic antenna at the specific direction in order to receive the signal with the highest radiation power. This type of configuration requires multiple high profile antennas as monopoles have been used.

Beam steering surface wave antenna has been developed by utilizing the EBG and artificial ground plane characteristics that alternately reject and propagate the surface wave along the antenna or the dielectric plane. In this paper, a pattern diversity antenna using the switched sectorized EBG surface is presented. A low profile antenna is integrated with an sectorized mushroom-like EBG in which the band stop and band pass properties are changed by switching the pin vias in and out of the sectors. The circular EBG elements are arranged in the multiple sector and the pin vias on each sector of the EBG are switched in and out to steer the beam into that sector.

II. SQUARE MUSHROOM-LIKE SECTORIZED EBG

The sectorized square mushroom-like EBG has been simulated and analyzed to study its capability to control the power pattern directivity around the microstrip patch. A patch antenna that offers a monopole type radiation characteristic has been integrated with an EBG in order to achieve a low profile as well as a flexible directivity.

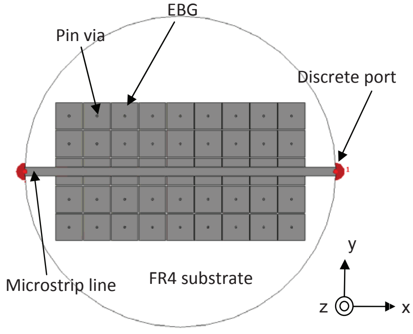


Figure 1: Microstrip transmission line to measure EBG surface mutual coupling

The EBG has been designed on a double sided FR4 with a thickness of 3.2mm and a dielectric constant of 4.3. The optimization of the EBG dimensions has been implemented using the microstrip transmission line technique which measuring the surface mutual coupling within two edges as shown in Figure 1. The width of the transmission line is determined as 6.2 mm, which has been calculated using CST MWS to achieve matching with the 50Ω input impedance. A couple of 50Ω discrete ports have been connected at both edges of the transmission line for calculating the EBG surface mutual coupling.

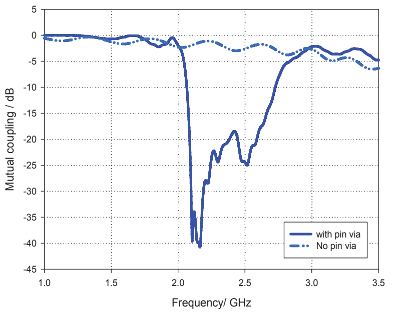


Figure 2: Mutual coupling for a square EBG using microstrip transmission line.

The EBG surface mutual coupling, as shown on Figure 2, represents the band gap characteristics for the EBG with optimized parameters that covers the antenna operating frequency of 2.2GHz. The optimization of the EBG dimensions has determined the width and length as 19.4mm with a 0.5mm gap between the elements. The mutual coupling for the EBG structure illustrates the enhancement in EBG surface mutual coupling when the pin vias are removed. Additionally the results when the pin vias are inserted illustrate that the EBG structure rejects the surface wave propagation. Hence, the structure characteristics can be easily altered by alternately switching the pin vias in and out.

A. Antenna Beam Steering Using Sectorized EBG

The EBG capability to control the radiation pattern directivity around the antenna has been analyzed by arranging in sector for the 4-rows of the square EBG with 2 rows are at the underneath of patch antenna. The sectors have been arranged in six sectors around the circular dielectric substrate as shown on Figure 3. The sectors have been denoted as A to F to simplify the method of acknowledging the radiation pattern direction. The EBG structure, which is placed at approximately 25mm from the centre of the substrate, has been designed on a 3.2mm thick FR4 substrate with an overall circular diameter of approximately 223 mm.

The microstrip patch forms the basis of the antenna discussed here and has an omni-directional pattern in azimuth at about 30° above the ground plane. The circular patch antenna, which was designed to operate at 2.2 GHz with a diameter of 115 mm has been placed at the middle of, and at a height of 3mm above, the EBG surface. A metal pin with a diameter of 1mm has been used to connect the patch antenna to the coaxial discrete port located below the dielectric substrate.

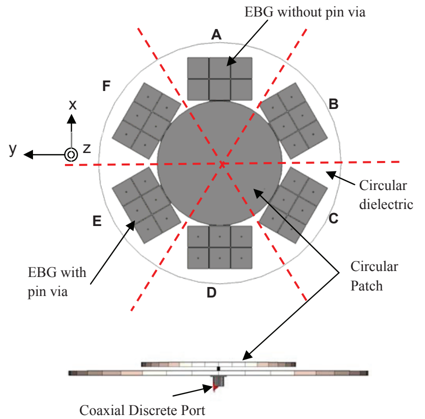


Figure 3: Patch antenna at the centre of an EBG

The EBG capability to steer the antenna radiation beam has been analyzed by alternately switching the EBG sector surface characteristic. As mention earlier, pin vias have been switched in and out at particular sector/s to control the beam direction. For instance, to direct the pattern towards sector A, pin vias at the sector have been switched out, whereas pin vias have been switched in for the rest of the sectors. As a result, the mutual coupling has been enhanced in sector A and reduced in the other sectors. Therefore, the surface wave has propagated towards sector A and reflected from the rest of the sectors. Figure 4 presents the antenna reflection coefficient, where it can be noticed that matching has been achieved at an operating frequency of 2.2 GHz with an approximately a -10dB bandwidth of 13.7%.

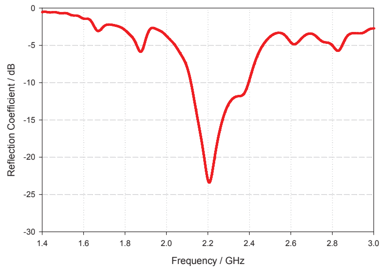
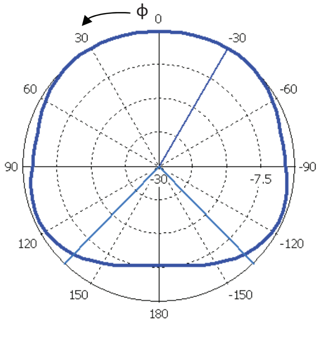


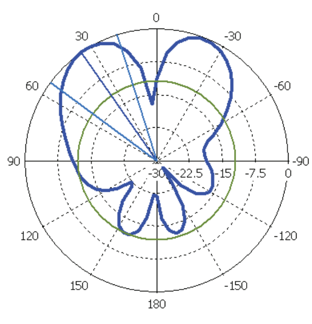
Figure 4: Reflection Coefficient for the Patch Antenna

B. Antenna Radiation Pattern Result

Figure 5(a) shows the phi-plane power pattern at theta=60°, which is directed towards sector A with the maximum gain increases by approximately 7.5dB. The elevation pattern, shown in Figure 5(b) also indicates that the antenna power radiation was radiated towards sector A at theta=30°.



(a) Phi(theta=60)



(b)Theta(phi=0)

Figure 5: Antenna Power Pattern at 2.2GHz for sector A without pin vias.

The simulation results for the antenna with the sectorized EBG expose that the 4 rows of 19.4mm square EBG in sector has shown its capability to control the direction of the radiation pattern when pin vias have been switched in and out at each sector. The power pattern has been directed towards the EBG sector without pin vias due to the higher mutual coupling across this surface, whereas, the EBG structure with inserted pin vias has introduced a lower mutual coupling, which has reflected the surface wave radiation accordingly.

However the phi-plane radiation pattern in Figure 5(a) shows that the both side lobe has been marginally reduced by approximately 2dB with compared to the maximum gain. This means that there a high power that has been radiated towards the side of the antenna or/and to the other sectors, which is actually not desired. This problem can be attributed to the square EBG shape, which cannot perfectly forms a circular sector as there are spaces within the sectors. Another possible source of this problem is the limited number of EBG elements underneath the antenna. This has caused some degradation on the EBG capability to properly control the propagation of surface waves. The radiated power towards other EBG and the neighboring sectors has been illustrated by the only slightly reduction of the side lobes.

III. CONCLUSION

A beam scanning antenna has been demonstrated that uses a band gap surface to switch sectors of the EBG elements on and off using vias. The patch antenna was integrated with a square EBG consisting of circular cells arranged in 6 sectors. Simulations show that the radiation pattern can be scanned by switching the EBG sectors increasing the gain by about 8 dB.

The concept of steerable pattern directive surface wave antenna has been realized by utilizing the sectorized square EBG. The switching pin vias in each sector are likely to introduce parasitic effects.

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