A SPIRAL ANTENNA BACKED ON PHOTONIC BAND GAP MATERIAL

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Ⅰ. INTRODUCTION

It is well known that the electromagnetic wave propagation in the photonic band gap (PBG) material is prohibited for a certain frequency band [1]. Thus the PBG material can be used as a reflector of radiator to enhance the directive gain and to suppress the surface wave mode. In general, dielectric PBG structures may be realized by drilling periodic holes in the dielectric, or etching periodic holes in the ground plane. The appearance of band gap mainly depends on the type of periodic element of the background. [2]

A traditional spiral antenna with unidirectional beam is performed by appropriately backing a cavity or conducting plate, or loading an electromagnetic wave absorber [3]. The former restricts the bandwidth of a wide band spiral radiator, and the latter results in a low efficiency due to the power dissipation. Besides, the spiral antenna fed by a coaxial line requires a broadband balun that will lead to the increment of antenna volume and lose the advantage of low profile. In this paper, a really low profile, broadband spiral antenna backed with PBG substrate and fed by coplanar strip (CPS)–coplanar waveguide (CPW)–coaxial line is reported.

By means of the PBG material replacing the traditional reflective cavity or ground plate, the performances of spiral antenna are certainly improved, the surface wave is restricted, the backward radiation is suppressed. The test results show that 1.15 times band coverage, 1.3dB gain enhancement, and 8.9dB F/B level improvement are benefited.

Ⅱ. DESIGN PRINCIPLES

2.1 Equiangular Spiral Radiator

Fig.1 shows a planar equiangular spiral radiator with two symmetric arms, which are composed with 4 equiangular spiral wires: $r_1 = r_0 e^{a\phi}$, $r_2 = r_0 e^{a(\phi-\delta)}$, $r_3 = r_0 e^{a(\phi-\pi)}$, $r_4 = r_0 e^{a(\phi-\pi-\delta)}$. Where r_0 is cut-off radius, a is spiral rate and δ is compensate angle [4]. The upper limit of frequency band f_{max} depends on r_0, but the lower limit of frequency band f_{min} depends on the maximum radius of spiral arms R. When $\delta = 90^0$ is utilized, the spiral antenna becomes self-compensatory with frequency-independent input impedance Z_{in}=188 *Ohms*.[5]

A designed sample of spiral radiator covers enough wide bandwidth (2-16) GHz with the geometric parameters $a = 0.221$, $\delta = 90^0$, $r_0 = \lambda_{min}/8$, and $R = \lambda_{max}/4$.

In practical applications, in order to form a unidirectional radiation pattern rather than bidirectional one, a spiral antenna backed a cavity or loaded absorber has been popularly used. However it results in frequency dependent or efficiency dropping. An ideal reflector behind the spiral radiator to form unidirectional pattern should be frequency-independent too within a required bandwidth. The PBG substrate can just provide this feature.

2.2 PBG Structure

Fig.2 shows a PBG structure with triangular-lattice of circular-holes. These holes are drilled into a substrate with sizes *190mm ×190mm ×1.27mm* and relative permittivity *10.2* , there are at least three rows of drilling holes extending outside the spiral area. The stop-band of this PBG structure is measured by means of S-parameters of a *50 Ω* microstrip line printed onto the same PBG substrates.

Fig.3 shows the frequency response of S_{21} for a *50 Ω* microstrip line on a PBG substrate with triangular-lattice of circular air holes. The sizes of period *6.35mm* , radius of hole *1.9mm* , and total number of holes (26 ×26) are designed. A distinctive stop-band (11.2-14.6) GHz is observed from that the transmission coefficient is less than -10dB, or (10.3-15.2) GHz band gap for-3dB transmission.

2.3 Feed Network

In general, a spiral antenna should fed by a pair of parallel wires, or fed by a coaxial line passed through a broadband balun. In this paper, a novel wideband balun from balanced CPS to unbalanced CPW, and then transferred to a SMA coaxial connector via a Chebybshev transformer is designed as shown in Fig.4. On the CPS side, two arms of spiral antenna with out-of-phase and equal amplitude is easy to be connected directly.

Ⅲ EXPERIMENTAL RESULTS

An experimental model is fabricated, the spiral radiator placed on the surface of PBG substrate, and the feed network was placed behind the ground plate of substrate. Fig.5 give its measured frequency response of VSWR⩽*2:1* on (8.1 - 15.4) GHz (*1.9:1* coverage). This frequency band is quite wider than the stop band of PBG. Fig.6 is the measured radiation pattern at *12.4* GHz (inside the band gap) with –27dB front-to-back ratio. Besides, the measured gain is 3.8dB. The measured VSWR response, front-to-back and gain of a traditional spiral antenna with a λ /4 spaced ground plate only (the height between spiral radiator and ground plate is about 6mm) are compared, it corresponds (8.7-14.6) GHz (*1.68:1* coverage), –18.1dB and 2.5dB, respectively. These results verify the advantages of a spiral antenna backed on a PBG substrate as follows: 1.15 times frequency band coverage, 1.3dB gain enhancement, and 8.9dB improvement in F/B level.

Ⅳ. CONCLUSION

PBG material used as a frequency-independent reflector of spiral radiator in a specified bandwidth has been designed and tested. The multifold improvement in antenna performances: wider bandwidth, enhanced gain and lower backward radiation are verified for a low profile structure.

REFERENCE

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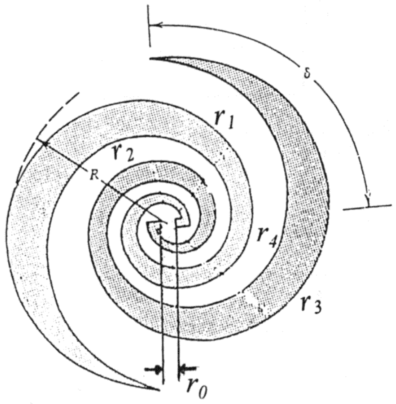

Fig.1 Equiangular spiral radiator

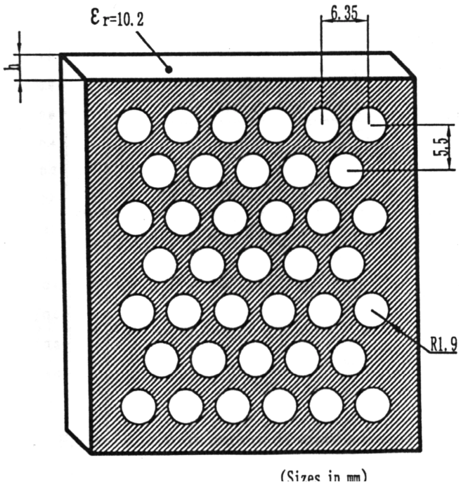

Fig.2 PBG structure

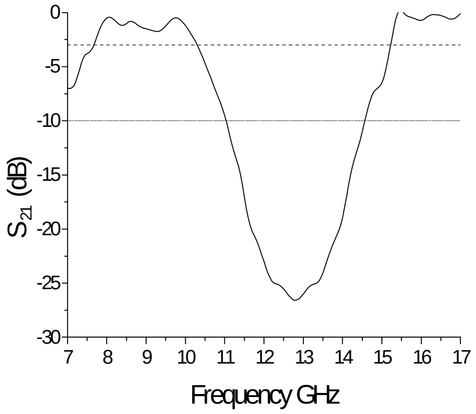

Fig3. Band-gap response of microstrip line

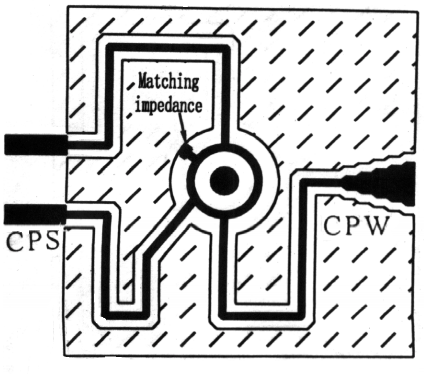

Fig.4 Wideband CPS-CPW balun

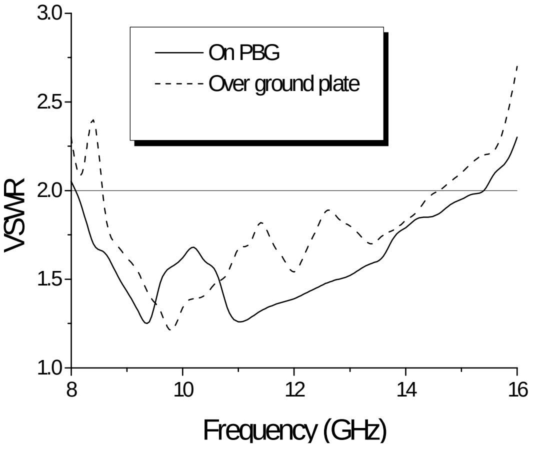

Fig.5 VSWR response of spiral antenna

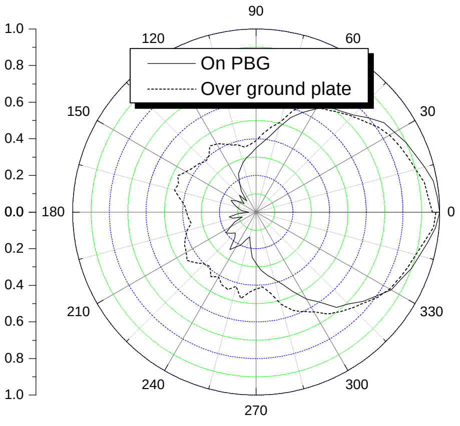

Fig.6 Radiation pattern of spiral antenna