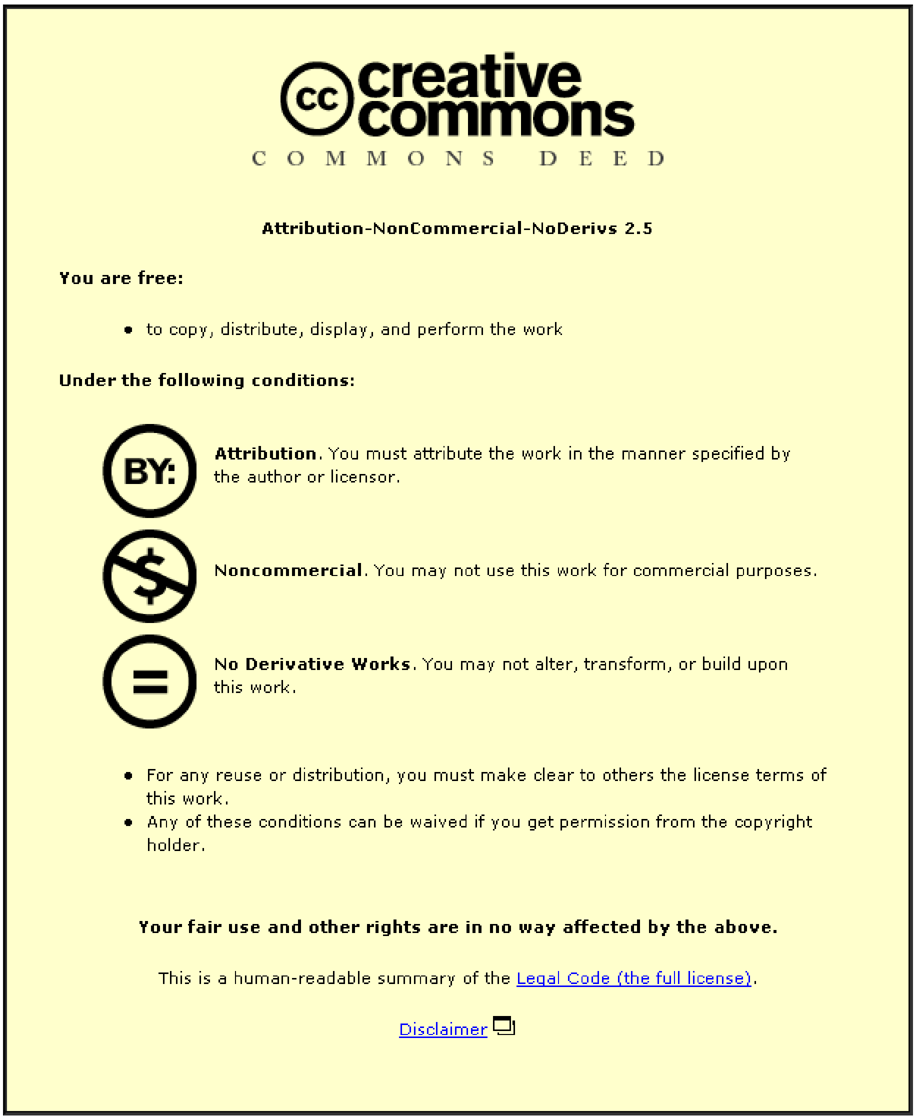

MEASUREMENT TECHNIQUES FOR POLAR ELECTROMAGNETIC BANDGAP STRUCTURES USING AN AIR SPACED MICROSTRIP LINE

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Abstract

The ability to accurately pinpoint with a high degree of accuracy the occurrence of the stop-band property in the newly engineered EBG materials is fundamental to their establishment. Measurement methods capable of achieving this have been proposed in literature but require intricate adjustments to suit particular requirements. In this paper we report on a repeatable measurement technique for characterising the bandgap properties of EBG structures using an air spaced microstrip line. The device constructed is simple, economical, robust and capable of quantifying the properties of a wide range of EBG materials. A tapered microstrip line transition is used to match a 50 Ω coaxial port. Simulation and measurement results using a Polar-EBG are presented to show the versatility of the proposed technique. In addition to this we demonstrate that by changing the orientation of the surface under test (SUT), transverse electric surface wave measurements can be carried out. This apparatus and measurement technique is particularly applicable to fabric based EBG materials where measurements are especially challenging.

Introduction

Engineered materials have provided extraordinary electromagnetic behaviour fuelling a vast amount of interest in this area. Notable among these materials are Electromagnetic band gap (EBG) structures which have been extensively investigated in recent years. Numerous kinds of EBG structures have been proposed and applied to antennas and microwave circuits. EBG structures inherently behave as L-C resonant circuits with a pass-band and stop-band operation. Antennas operating within the stop-band region have their reflected waves in-phase with the incident waves. This occurrence together with the fact that surface waves are also suppressed, has led to the creation of low profile antennas, reduction of mutual coupling in antenna arrays and a host of other applications. EBG structures are often implemented using the mushroom geometry proposed by Sievenpiper [1] utilizing the plain square as the fundamental element of design. Although extremely instrumental to the understanding of these structures, the square patch was soon found to possess various limitations notable among which is the inability to lower resonant frequency without increasing the elementary unit cell size or thickness. Tse *et al.* [2] proposed the use of convoluted and interleaved elements to reduce bandgap frequency for fixed periodicity. From [2] a 55% reduction in resonant frequency as compared to the unit patch was realized. Toyota *et al.* [3] who targeted the operation of EBG surfaces for GSM frequencies explored the idea of increasing inductance by creating narrow slits on the patch and using high dielectric materials [4]. We recently demonstrated in [5] that polar curves and mapping functions can be used to design EBG structures with lower frequencies for fixed periodicities. With this novel structure – Polar-EBG it is possible to control the surface impedance on a point to point basis thereby rendering itself useful to a multitude of other applications. The ability to easily pinpoint with a high degree of accuracy the occurrence of the stop-band property of these newly engineered materials is fundamental to their establishment. Various measurement methods can be found in the literature for achieving this. Methods that use coaxial monopole probes, current loop probes, and flared parallel-plate waveguides (first proposed in [1]) form the baseline for TE and TM surface wave measurements. While these methods demonstrate the electromagnetic properties of EBG structures, various researchers have preferred to illustrate their designs by directly applying these materials to a given application. A popular example of this method can be drawn from low profile antennas [6] in which it is shown that an antenna can be brought very close to an EBG ground plane. In addition to these methods, the suspended microstrip is also employed to

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measure the bandgap characterisation of EBG structures [7]. The leading challenge in all these measurement methods is in tailoring them to suit a particular application or frequency range on which they are heavily reliant. Therefore, in this paper we propose the use of an air spaced-microstrip line based device for the bandgap characterisation of EBG structures. In this technique, the microstrip line can be described as exhibiting quasi-plane wave excitation. The key advantage of this technique is its ability to evaluate the bandgap characteristics of any EBG surface designed for any arbitrary frequency. Additionally, by correctly orienting the SUT, TE surface wave measurements can also be carried out.

Design

The apparatus constructed (Figure 1(a)) consists of a dielectric backed tapered microstrip line supported by screws at a height of 5 mm above the ground plane. The ends of the microstrip line are connected to a coax port. Figure 1(b) illustrates the topology of the microstrip line fabricated on FR4 substrate while Figure 1(c) shows the measurement setup incorporating the SUT. Initially using a microstrip transmission line calculator optimal values of W – microstrip width and dielectric spacing h were determined for operating frequencies up to 10 GHz and 50 Ω impedance match. In order to match the microstrip line to the coaxial port, various tapering configurations were investigated from which it was determined that the triangular taper provided the optimal match. Further optimization of the structure was undertaken to determine the optimal values of p and d whereby reflection is minimized and transmission is maximized.

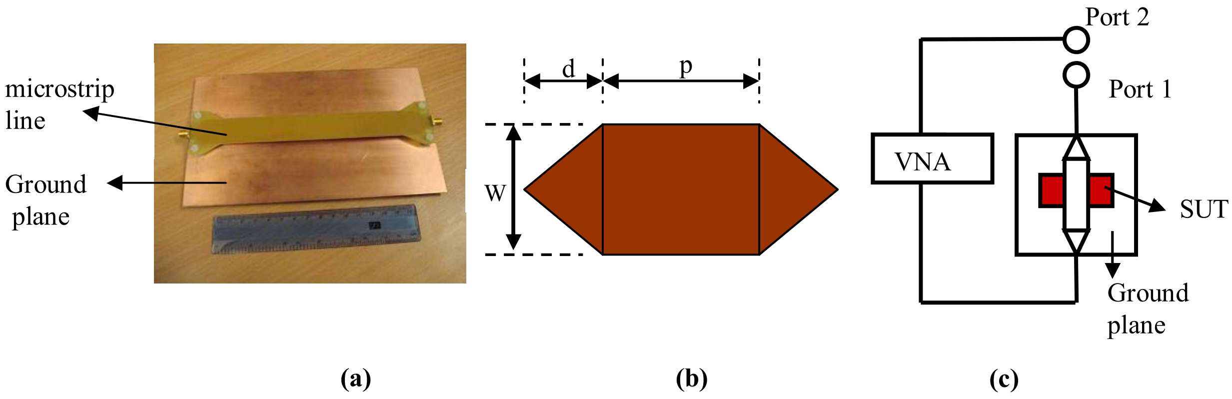
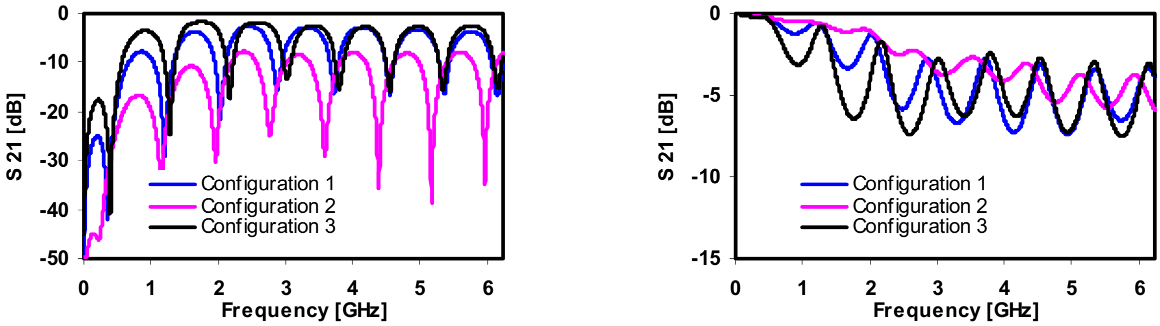


Figure 1: (a) Geometry of an air spaced microstrip line (b) Top view of tapered microstrip line (c) Schematic of measurement setup

Figure 2 shows the return loss and transmission coefficient results for various values of p and d simulated in the TLM based commercial solver MicroStripes v7.5. The optimal values found for the triangular tapered microstrip line were p = 180 mm and d = 10 mm with a microstrip width W = 24 mm and substrate spacing h = 5 mm. The ground plane dimensions adopted herein are 200 × 100 mm.



(a) (b)

Figure 2: (a) Return Loss (b) Transmission Coefficient (i) Configuration 1: d = 46 mm , p = 108 mm (ii) Configuration 2: d = 10 mm, p = 180 mm (iii) Configuration 3: d = 25 mm, p = 150 mm

Measurement Results

Standard network analyser (VNA) return loss measurements were carried out on the Polar-EBG surfaces with unit cell dimensions of 7.5 × 7.5 mm and gap widths of 0.75 mm, 0.5 mm and 0.25 mm and also a mushroom structure of periodicity 7.5 mm and gap width 0.5 mm. The samples were made on a Taconic TLE-95 of dielectric constant 2.95 and substrate height of 3.18 mm. A Full 2-port calibration procedure was implemented at ports 1 and 2 (Figure 1(c)) with the microstrip apparatus forming part of the transmission line from the VNA. The S_{21} results obtained using the air spaced microstrip line apparatus and those obtained using coax monopole probes (Figure 3) show good agreement with the latter showing the presence of the bandgap more evidently. The bandgap region obtained through measurement is compared to numerical values derived using equations determined in [1] for the resonant frequency (w_0) and bandwidth (*B.W.*).

$$\omega_0 = \frac{1}{\sqrt{LC}} \quad \text{and} \quad B.W. = \frac{\Delta\omega}{\omega_0} = \frac{1}{\eta}\sqrt{\frac{L}{C}} \tag{1}$$

Overall, the results obtained using the air spaced-microstrip line are closer to the numerical values than the coax monopole results. The difference in bandgap width between the two measurements can be attributed to presence of multiple interference which results from occurrences of multiple signal paths when coax probes are used for measurements. Figure 4 shows the results obtained when the surface under test is oriented 45^0 to the microstrip line and shows the bandgap clearly. The effect of the ripples in Figure 2(a) are negated by making the designed apparatus part of the transmission line terminating in port 1. As no post-processing of the measurement data is required, the air-suspended microstrip line technique makes the portrayal of the bandgap of EBG structures very straight forward.

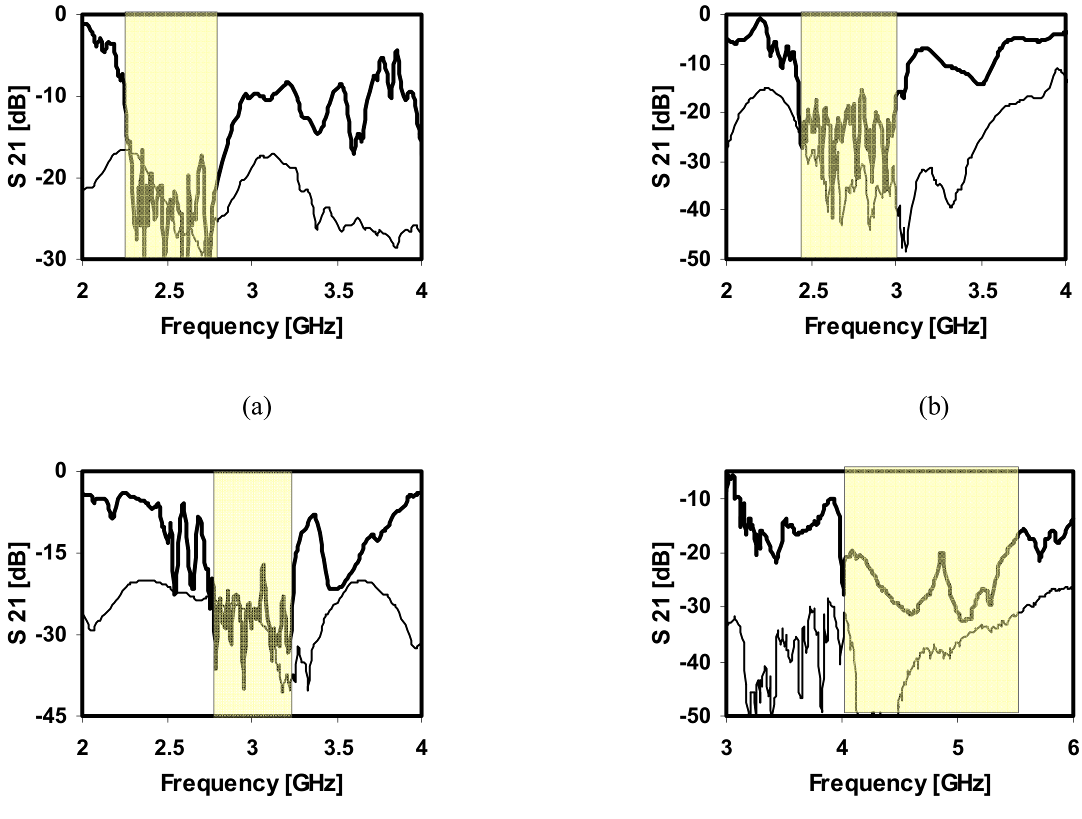
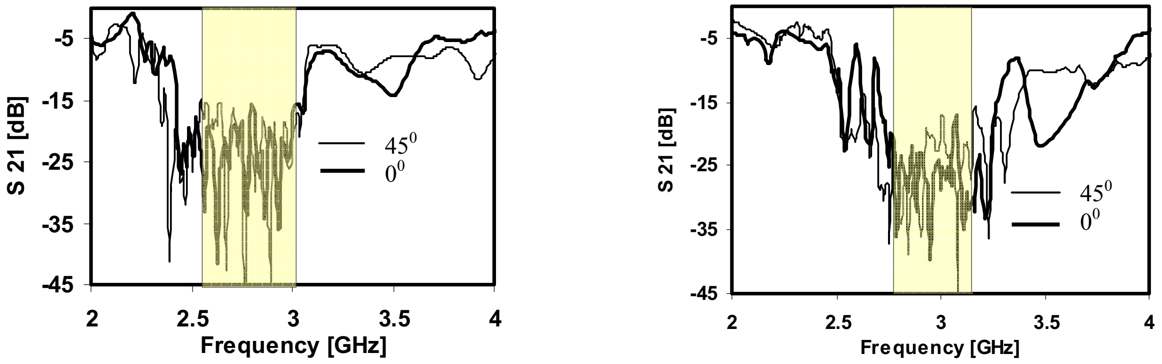


Figure 3: Comparison of bandgap regions based on measurement results using air spaced microstrip line (thick Line) and a pair of coax monopoles (thin line) (a) gap width 0.25 mm (b) gap width 0.5 mm (c) gap width 0.75 mm (d) mushroom structure. The coloured region shows the bandgap as numerically determined using equations proposed in [1]



(a) (b)

Figure 4: Measurement results using air spaced microstrip line showing strong correlation between results obtained for different angles of orientation for a Polar-EBG (a) gap width 0.5 mm (b) gap width 0.75 mm

Conclusion

In this paper a rapid technique for characterising the bandgap properties of electromagnetic bandgap structures has been proposed. Using measurement results it has been shown to accurately demonstrate the bandgap feature of these structures. The air spaced microstrip line apparatus has been found to show the presence of a bandgap more clearly as it reduces the amount of external interference unlike the coax monopole probes. In addition to this, it is more versatile as no new strip has to be specially designed for each new EBG surface. Although successful, this technique still requires fine tuning and this forms part of our future work.

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