CHAPTER 2

LITERATURE STUDY

2.1 Introduction

Literature review is important in thesis writing for gathering necessary information to complete the project. This is to ensure the project can be done in efficient and practical way. Information gathered from books, journal, thesis, and website. All information filtered to get correct theory about antenna and EBG.

2.2 Antenna

An antenna is a device to transmit and receive electromagnetic waves. Electromagnetic waves are often referred to as radio waves. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. An antenna must be tuned (matched) to the same frequency band as the radio system to which it is connected, otherwise reception and/or transmission will be impaired.

2.3 Antenna Parameter

An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. There are several important antenna characteristics that should be considered when choosing an antenna for your application as follows:

i. VSWR and return loss
ii. Bandwidth
iii. Antenna radiation patterns
iv. Power Gain
v. Directivity
vi. Polarization

2.3.1 VSWR (Voltage Standing Wave Ratio)

The VSWR, which can be derived from the level of reflected and incident waves, is also an indication of how closely or efficiently an antenna's terminal input impedance is matched to the characteristic impedance of the transmission line. An increase in VSWR indicates an increase in the mismatch between the antenna and the transmission line.

Typically, most wireless communications systems operate with a 50 Ohms impedance, therefore the antenna must be designed with an impedance of close to 50 Ohms as possible. The antenna VSWR is then an indication of how close the antenna impedance is to 50 Ohms. A 1.0:1 VSWR would indicate an antenna impedance of exactly 50 Ohms. In many systems, the antenna is required to operate with a VSWR better than 1.5:1 To indicate how increased VSWR impacts overall system performance, The term dB is a logarithmic expression of the ratio between two signal levels. For the voltage, dB relationship is:

$$dB = 20\ log_{10}\ \frac{v_2}{v_1} \tag{2.1}$$

For the power, dB relationship is

$$dB = 10\ log_{10}\ \frac{p_2}{p_1} \tag{2.2}$$

2.3.2 Return Loss

It is a measure of the reflected energy from a transmitted signal. It is commonly expressed in positive dB's. The larger the value, the less energy that is reflected. Figure 2.1 illustrates return loss and it's effect on the original signal. In the top portion, the signal is injected upon the pair. As the signal travels down the pair portions of the signal are reflected back to the transmitter. These reflections are caused by impedance discontinuities in the channel. These discontinuities may be due to several things such as connectors, improper installation or handling or improper manufacture. Any energy, that is reflected, reduces the power of the transmitted signal

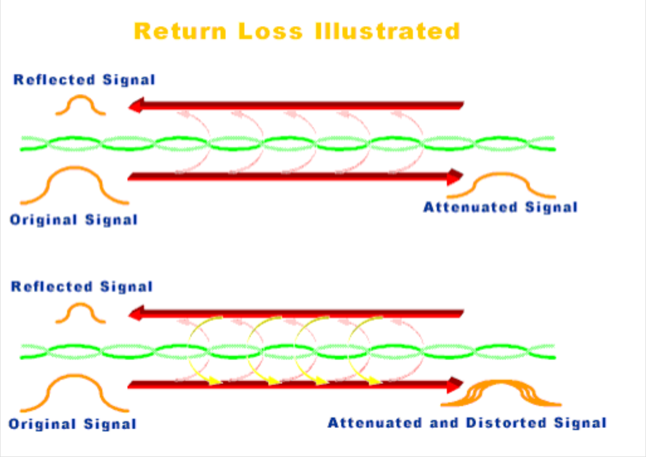

Figure 2.1 Illustration of return loss [6]

2.3.3 Bandwidth

The use of an antenna in transmitter or receiver system is always limited by its frequency region. In the frequency range of the antenna work is required to be able to work effectively in order to receive or emit waves in a particular frequency band.

Understanding must be able to work effectively is that the current distribution and the impedance of the antenna in the frequency range really have not changed much meaning [6]. So that the radiation pattern of the plan and the resulting VSWR is still not out of the allowable limit. Working frequency regions where the antenna can still work well call bandwidth antenna. An example of a working antenna at the center frequency of fc, but he also still be able to work well on the frequency f_1 (under F_C) to f_2 (above F_C), the wide bandwidth of the antenna is (f_1 - f_2). But when expressed in percent, then the bandwidth of the antenna is:

$$Bandwidth\ \% = \frac{f_2 - f_1}{f_c}\ x\ 100\ \% \qquad (2.3)$$

Bandwidth is expressed in percent as this is usually used to express the bandwidth antennas which possess a narrow band (narrowband). As for the bandwidth (broadband) are commonly used definition of the ratio between the upper-frequency limit of the lower-frequency.

$$Bandwidth = \frac{f_2}{f_1} \qquad (2.4)$$

An antenna is classified as a broadband antenna when the impedance and radiation pattern of the antenna does not undergo significant changes to f2 / f1> 1. Restrictions are used to obtain f_2 and f_1 is determined by the value of VSWR = 1.

There are several types of bandwidth among them:

- Impedance bandwidth, which is the frequency range in which the patch antenna is in a state matching with channel source. This occurs because the impedance of the antenna elements varies in value depending on the value of the frequency. This matching can be seen the value of the return loss and VSWR. Return loss and VSWR are still considered good is less than -9.54 dB. [7]

- Pattern of bandwidth, which is the frequency range in which the bandwidth, lobes, or gain, which varies according to the frequency meets a certain value. This value should be determined at the beginning of the design of the antenna so that the value of the bandwidth can be searched. [7]

2.3.4 Antenna Radiation Pattern

The radiation patterns of an antenna provide the information that describes how the antenna directs the energy it radiates. As stated earlier, an antenna cannot radiate bigger energy than delivered to its input terminals. All antennas, if 100% efficient will radiate the same total energy, for equal input power, regardless of pattern shape.

Antenna radiation patterns are typically presented in the form of a polar plot for a 360^0 angular pattern in one of two sweep planes. The most common angular sweep planes used to describe antenna patterns are a horizontal or azimuth sweep plane and a vertical or elevation (zenith) sweep plane. A graphical representation of these planes and a typical polar pattern are presented in Figure 2.2. Radiation patterns are generally presented on a relative power dB scale.

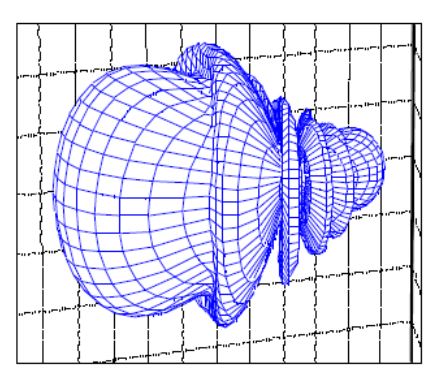

Figure 2.2 Antenna Radiation pattern [7]

2.3.5 Gain Antena

When the antenna is used in a system, usually more interested in how efficiently an antenna for transferring the power contained in the input terminals into radiation power. For these states, the power gain (or gain alone) is defined as the ratio of the intensity 4π times in a direction with the received power antenna, is given by:

$$G(\theta,\phi) = 4\pi \frac{U(\theta.\phi)}{P_m} \quad (2.5)$$

This definition does not include losses caused by an impedance mismatch (impedance mismatch) or polarization. The maximum price of the gain is the maximum price of the radiation intensity or maximum price of equation (1:22), so it can be restated:

$$G= 4\pi \frac{U_m}{P_m} \tag{2.6}$$

So the gain can be expressed as a function of θ and ϕ also can be expressed as a price in a certain direction. If no direction is determined and the price of power gain is not expressed as a function of θ and ϕ assumed as the maximum gain.

2.3.6 Antenna polarization

Antenna polarization is defined as the direction of the electric field vector radiated by the antenna in the direction of propagation. If the path of the electric field vector forward and back in a straight line to say linearly polarized. for example, the electric field of an ideal dipole.

If the electric field vector is constant in length but rotating around a circle path, said circularly polarized. Radian rotation frequency is w and happens one of two directions of rotation. If the vector rotates a counterclockwise polarization is called right hand (right hand polarize) and the so-called polarization clockwise left hand (left hand polarize). A polarized wave ellipse for right hand and left hand.

In general, the polarization in the form of the polarization ellipse, as shown in Figure 2.3 with a reference axis system. Waves that produce polarization ellipse was traveling wave moving along the z-axis can be to the left and to the right, and the instantaneous electric field vector E has components E_x and E_y direction along the x axis and the y-axis. Peak price of these components is E_1 and E_2.

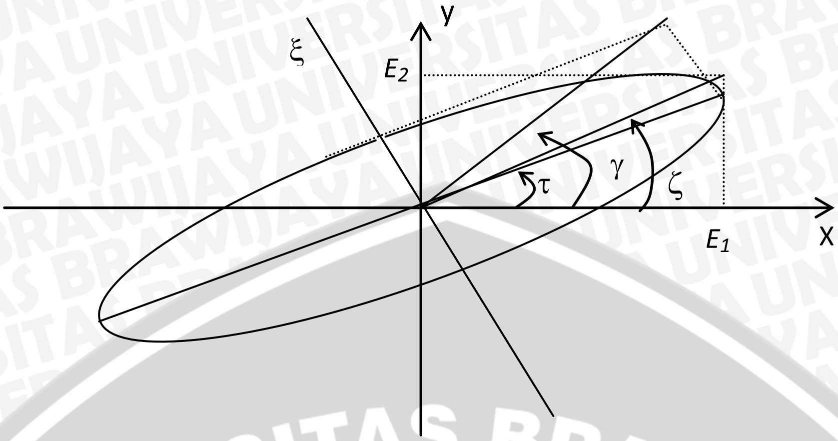

Figure 2.3 General picture of polarization [7]

2.4 Microstrip Antenna

Microstrip consists of two words, There are micro (very thin / small) and strip (bar / piece). Microstrip antenna can be defined as one type of antenna that has the shape of blades / pieces that have a very thin size / small. Microstrip antenna is very interesting because the load is light, easily customizable forms and fees low. This antenna can be integrated with field lines printed on the network and the active tool. This is the latest design in the world antenna. In its most fundamental form, a microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has groundplane on the other side as shown in Figure 2.4. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photos etched on the dielectric substrate.

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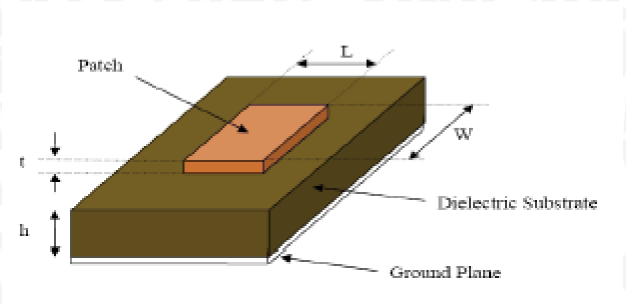


Figure 2.4 Parts of microstrip antenna [6]

To get a good microstrip antenna, a thick dielectric layer having a low dielectric constant as this gives better efficiency, greater bandwidth, and better radiation. However, this conFiguration causes a larger antenna size. In order to design a balanced microstrip antenna field, the dielectric constant used to be higher, thereby reducing the efficiency and produce a narrower bandwidth. Therefore, a balance must be achieved between the dimensions of the antenna and antenna performance. A thicker substrate increases the gain to some extent, but may lead to undesired effects like surface wave excitation: surface waves decrease efficiency and perturb the radiation pattern

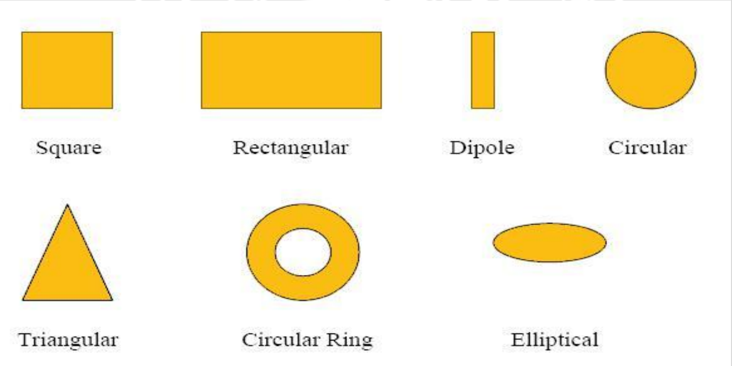


Figure 2.5 Shape of microstrip antenna [6]

Figure 2.5 shows variation of shape from microstrip patch antenna. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation [8]. However, such a conFiguration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence, a trade-off must be realized between the antenna dimensions and antenna performance.

2.5 Advantages and Disadvantages

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers.The telemetry and communication antennas on missiles need to be thin and conformal and are often in the form of microstrip patch antennas.[9].

i. Light weight and low volume.
ii. Low profile planar conFiguration which can be easily made conformal to host surface.
iii. Low fabrication cost, hence can be manufactured in large quantities.
iv. Supports both, linear as well as circular polarization.
v. Can be easily integrated with microwave integrated circuits (MICs).
vi. Capable of dual and triple frequency operations.
vii. Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from more drawbacks as compared to conventional antennas. Some of their major disadvantages discussed by [12] are given below:

i. Narrow bandwidth
ii. Low efficiency
iii. Low Gain
iv. Extraneous radiation from feeds and junctions
v. Poor end fire radiator except tapered slot antennas

vi. Low power handling capacity.

vii. Surface wave excitation.

Microstrip patch antennas have a very high antenna quality factor (Q). It represents the losses associated with the antenna where a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics. Other problems such as lower gain and lower power handling capacity can be overcome by using an array conFiguration for the elements.

2.6 Microstrip Antenna Parameter

2.6.1 Resonant Frequency

The resonance frequency of the microstrip antenna is given by

$$f_0 = \frac{c}{2Le\sqrt{\varepsilon_r}} \qquad (2.7)$$

Where *c* is the speed of light in vacuum. To account for the fringing of the cavity fields at the edges of the patch, the length, the effective length *Le* is chosen as

$$L_e = L + 2\Delta L \qquad (2.8)$$

The Hammerstad formula for the fringing extension is:

$$\frac{\Delta l}{h} = 0.412\,\frac{(\varepsilon reff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon reff-0.268)(\frac{W}{h}+0.8)} \qquad (2.9)$$

Where

(2.11)

$$\varepsilon reff = \frac{\epsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-\frac{1}{2}}$$

Where: ε_{reff} = Effective dielectric constant
εr = Dielectric constant of substrate
h = Height of dielectric substrate
W = Width of the patch

2.6.2 Bandwidth

The bandwidth increases as the substrate thickness increases (the bandwidth is directly proportional to h if conductor, dielectric, and surface-wave losses are ignored). However, increasing the substrate thickness lowers the Q of the cavity, which increases spurious radiation from the feed, as well as from higher-order modes in the patch cavity. Also, the patch typically becomes difficult to match as the substrate thickness increases beyond a certain point (typically about 0.05 λ0). This is especially true when feeding with a coaxial probe, since a thicker substrate results in a larger probe inductance appearing in series with the patch impedance. However, in recent years considerable effort has been spent to improve the bandwidth of the microstrip antenna, in part by using alternative feeding schemes.

Lowering the substrate permittivity also increases the bandwidth of the patch antenna. However, this has the disadvantage of making the patch larger. Also, because the $Q$of the patch cavity is lowered, there will usually be increased radiation from higher-order modes, degrading the polarization purity of the radiation.

2.7 Electromagnetic Band-Gap (EBG)

Electromagnetic bandgap structure defines as an artificial periodic (or sometimes not periodic) objects that prevent/assist the propagation of electromagnetic waves in a specified band or of frequency for all incident angles and all polarization states.

Electromagnetic bandgap materials are one of the most rapidly advancing materials in the electromagnetic arena. They have an ability to persuade the propagation of electromagnetic waves to a level that was not possible earlier [10].

Electromagnetic Band Gap (EBG) structures produced a wide variety of design alternatives for researchers working in the area of microwave and photonics. Focus is now towards on finding real applications combined with detailed modeling. Due to the incredible potential of EBGs, there are plethoras of applications in which they can be used. New companies have also started to exploit the commercial potential of this technology [9].

The electromagnetic bandgap (EBG) structures exhibit a bandstop behavior over a certain frequency range, in which the propagation of electromagnetic waves is prohibited. EBG structures can also be referred as Photonic bandgap (PBG) structures [12-13]. EBG materials have a wide range of applications in RF and microwave engineering. By using a periodic dielectric or metallic structure with periodicity value comparable to the wavelength, bandgap behavior is achieved [12]. EBG materials when used with microstrip patch antennas improve their radiation patterns, increase their gain, and reduce the sidelobe and back lobe levels [13]

2.7.1Types of EBG Structure

EBG structures are periodic in nature, which may be realized by drilling, cuffing, and etching of the metal or dielectric substrates. They may be formed in the ground plane or over the substrate. On the basis of dimensions EBG structures are categorised as one-dimensional (1-D), two-dimensional (2-D), and three-dimensional (3-D) periodic structures that satisfies Bragg's conditions, i.e., inter-cell separation (period) is close to half guided wavelength ($\lambda g/2$). They are capable of forbidding electromagnetic propagation in either all or selected directions [15]

2.7.1.1 3-D EBG

In the beginning, a 3D EBG was designed only. A successful attempt to obtain a 3D periodic dielectric structure was made at Iowa State University (ISU) [16]. It was called the woodpile structure as shown in Figure 2.6. Three-dimensional EBG crystals have periodicity along all the three dimensions and the remarkable feature is that these systems can have complete band gaps, therefore that propagation states are not allowed in any direction [17].

Although, a perfect 3-D EBG structure is required to block all waves in all directions, but then these structures are difficult to fabricate and integrate. From literature, we learned that 2-D EBG could be even more valuable. 2-D EBG structures are easy to fabricate and are capable of maintaining a similar control on the wave propagation in the structure as the 3-D structure.

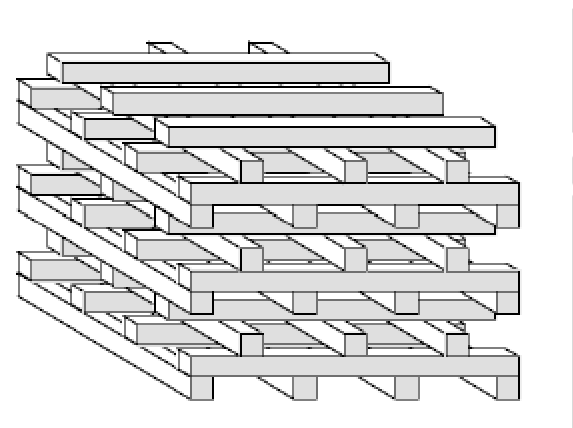


Figure 2.6 3-D EBG Structures [18]

2.7.1.2. 2-D EBG

These crystals have periodicity in two-dimensions and are homogeneous along the third direction, or we can say that, all variations happen in the two dimensions whereas everything is constant along the third dimension, thereby propagation is allowed along one axis of the crystal [17]. These 2-D EBG structures have substantial advantages in terms of compactness, stability, and fabrication, which make them more attractive for microwave devices [16].

One of the greatest advances in the development of these 2-D EBG structures in a microwave range has been their implementation in microstrip technology.

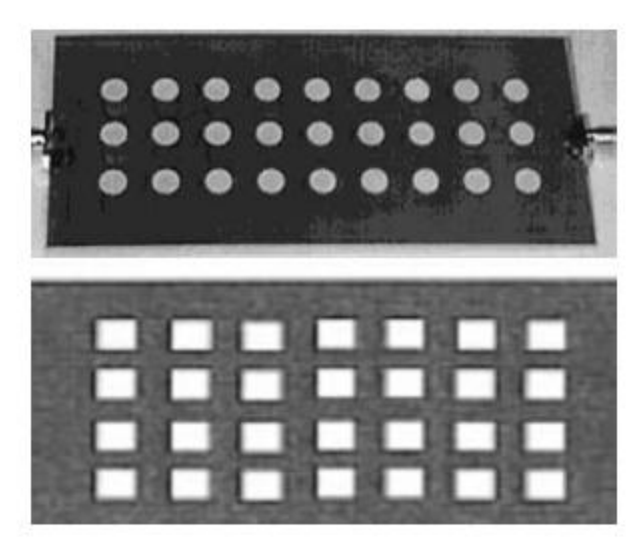


Figure 2.7 2-D EBG structures [19]

2.7.1.3. 1-D EBG

One-dimensional EBG structures can also be implemented in microstrip technology. 1-D EBG structures have periodicity of two different media along one direction only. These basic crystals exhibit three important phenomena: photonic band gaps, localized modes, and surface states. However, as the index contrast is only along one direction, the band gaps and bound states are limited to that direction.

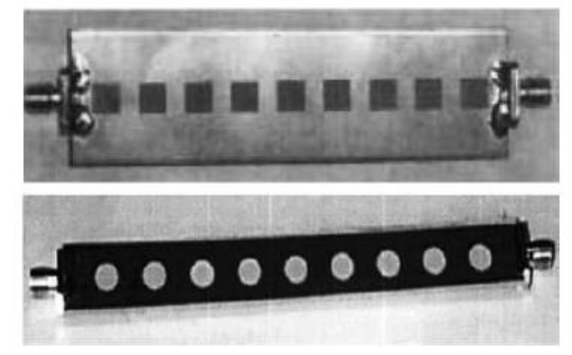


Figure 2.8 1-D EBG structure [18]

2.7.2 Planar EBG Structures

EBG technology represents a major breakthrough with respect to the current planar approaches, mainly due to their ability to guide and efficiently control electromagnetic waves. As the frequency increases, a planar structure that integrates the antenna, mixers, local oscillator, and all peripheral circuitry onto one single substrate becomes an attractive option.

Planar EBG’s are of particular interest at microwave frequencies due to ease of fabrication. These EBG’s are usually periodic in one and two dimensions. Planar EBG structures consist of uniformly distributed periodic metallic patterns on one side of a dielectric slab. They exhibit some interesting features such as distinctive passband and stopband, slow wave effects, low attenuation in the passband and suppression of surface waves when serving as the ground of planar microstrip circuit.

Several Planar EBG conFigurations have been reported in the literature like uni-planar designs without vertical vias, one and two dimensional EBG transmission line design etc. in which they used EBG basis points with different geometries, and shapes like circular shape, square, hexagonal, fork shape, plus sign and many more. In some planar devices, they create defects by creating a discontinuity in periodic pattern. For example, in a planar circular defect induced EBG structure with triangular lattice, they remove some circles or change their size for creating some discontinuity. Some of these types of EBG structures are shown in the Figure. 2.9.

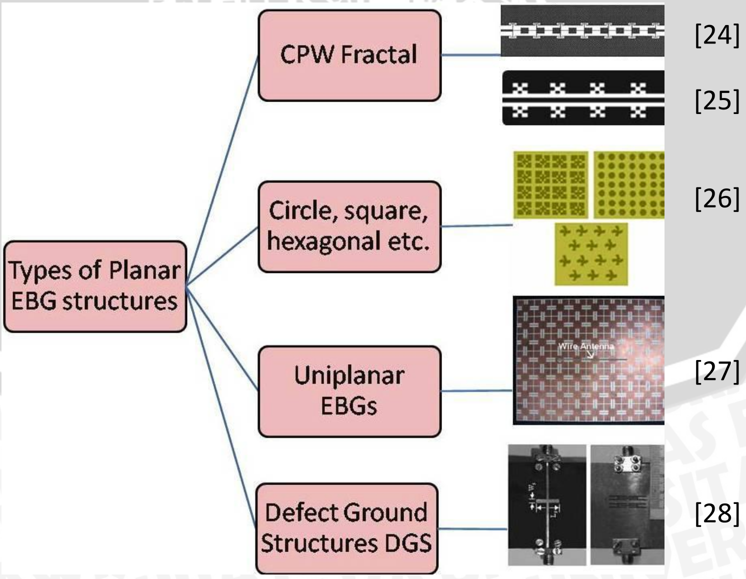


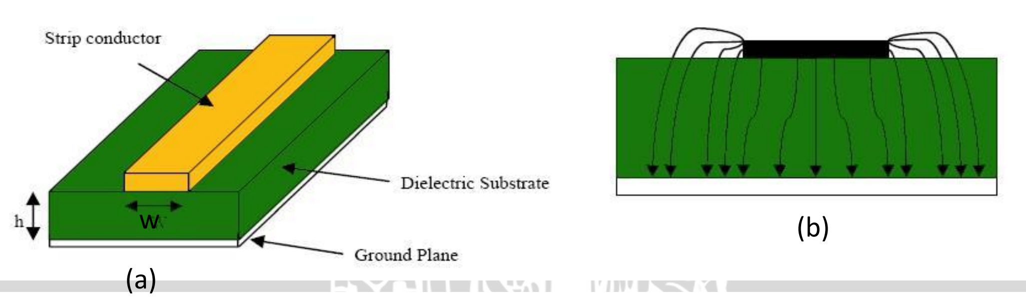
Figure 2.9 Classification of Planar EBG Structures

2.8. Methods of Analysis EBG Structure

The preferred models for the analysis of Microstrip patch antennas are the transmission line model, cavity model, and full-wave model [7] (which include primarily integral equations/Moment Method). The transmission line model is the simplest of all and it gives good physical insight but it is less accurate.

2.8.1 Transmission Line Model

This model represents the microstrip antenna by two slots of width *W* and height *h*, separated by a transmission line of length L. As shown in Figure 2.10 (a) The substrate and the air.



(a)

(b)

Figure 2.10 (a) Microstrip Line (b) Electric Field Lines [8]

Hence, as seen from Figure 2.10 (b) , most of the electric field lines reside in the substrate and parts of some lines in the air. As a result, this transmission line cannot support pure transverse-electric-magnetic (TEM) mode of transmission since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. based on formula 2.11 , The value of ε_{reff} is slightly less then ε_r because the fringing fields around the periphery of the patch are not confined to the dielectric substrate but are also spread in the air as shown in Figure 2.10 above.

2.8.2 Numerical modeling of EBGs

In this method, properties of wave propagation in periodic media can be fully described considering only one unit cell and applying periodic boundary conditions at its edges. Analysis of electromagnetic band gap structures is based on the Bloch-Floquet theorem [30] which describes the theory of wave propagation in infinite media consisting of the periodic repetition of the unit cell. The unit cell corresponds to the so-called first Brillouin zone which is the smallest polygon defined by the center axis of vectors connecting the points of a periodic lattice around the origin [31].

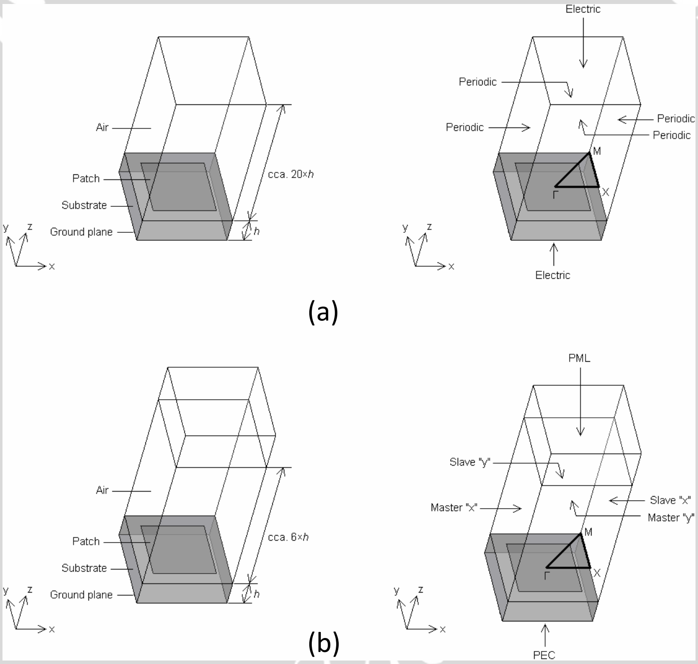


Figure 2.11 Dispersion analysis in CST MWS (a) and HFSS (b). The unit cell setup on the left, the applied boundary conditions with the irreducible Brillouin zone on the right. [31]

Figure 2.11 shows the unit cell setup of a periodic structure with a square lattice. The main differences between these two computational models in the considered software tools consists in the following fact. HFSS uses a perfectly matched layer (PML) to represent an infinite air layer above the unit cell, meanwhile CST MWS open boundaries are not allowed in combination with periodic walls, but only perfect electric conductor (PEC) or perfect magnetic conductor (PMC) boundary conditions can be applied. After many computers simulation in both the programs and comparing the obtained results with analytical and experimental considerations, the following rules for the correct surface waves dispersion diagram computation were stated:

i. In CST MWS, an airbox with the height of about twenty times the dielectric slab thickness has to be placed over the unit cell and the PEC boundary condition should be applied instead of the open boundary on the top of the model, see Fig. 2.11 (a).
ii. In HFSS, the height of the airbox about six times the dielectric slab thickness is sufficient and the PML boundary condition should be applied on the top of the model, see Fig. 2.11 (b).

2.9 Previous Work

2.9.1 2x1 Microstrip Array Antenna With Ebg Structure For Dual Band And Enhanced Bandwidth

Prashant R.T., et.al [21] propose two element rectangular microstrip array antenna (TRMSAA); the elements of this array are excited through simple corporate feed arrangement. This feed arrangement consists of matching transformer, quarter wave transformer, coupler, and power divider for better impedance matching between feed and radiating elements.

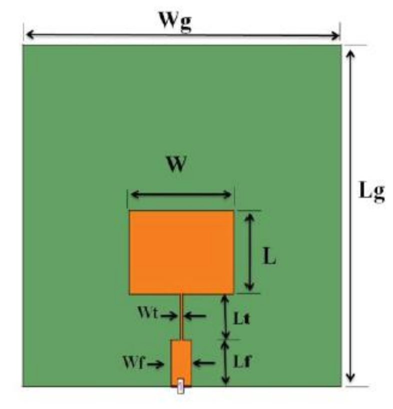
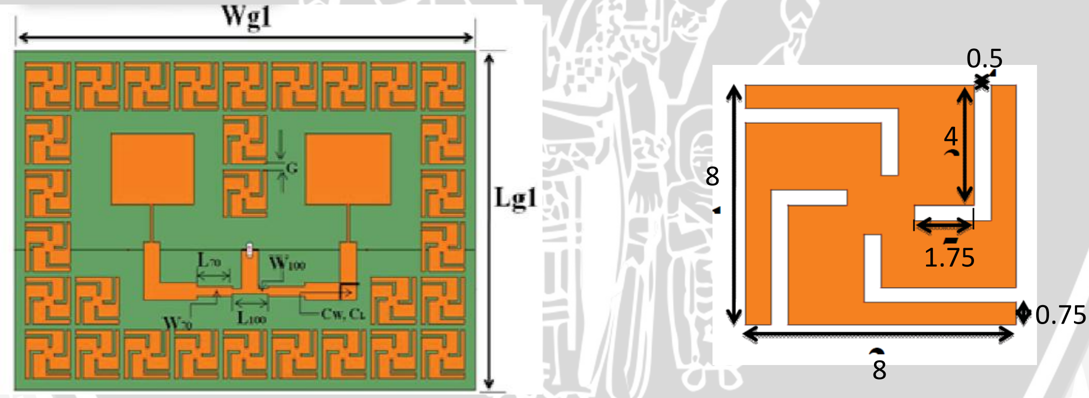


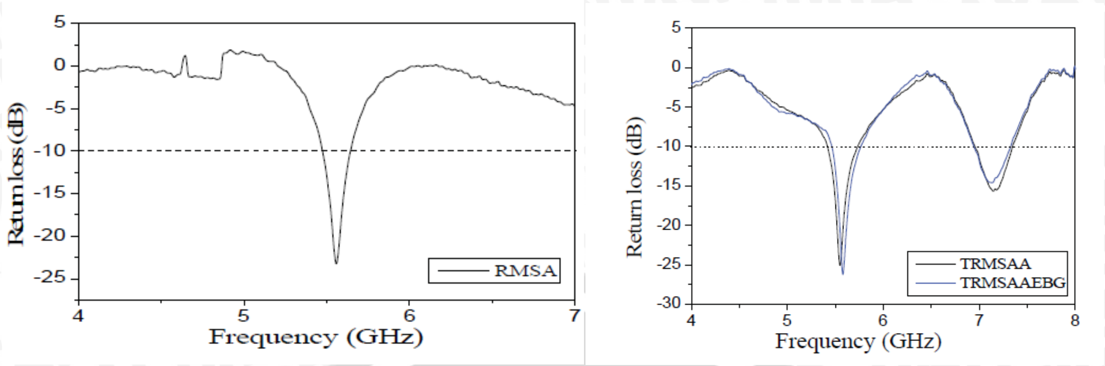
Figure 2.12 Conventional rectangular microstrip antenna [21]

Next, implementing slotted EBG lattice around the TRMSAA by maintaining all the dimensions same as that of the TRMSAA and the Fig 2.12 depicts the two element rectangular microstrip array antenna with EBG (TRMSAAEBG). A total amount of 30 elements of EBG has been used. The Fig. 2.13 shows the one element of the EBG.



(a) (b)

Figure 2.13 (a) Rectangular microstrip array antenna with slotted EBG lattice (b) Geometry of EBG slot structure [21]



(a) (b)

Figure 2.14 Experimental return loss versus frequency of (a) RMSA (b) TRMSAA and TRMSAAEBG [21]

Antennas with array are resonating with dual frequency points. Fig. 2.14 shows the comparison of experimental bandwidth of TRMSAA and TRMSAAEBG is found to be 330MHz and 390 MHz (5.945% +5.454%) and 290 MHz and 380 MHz (5.197%+5.322%) respectively, which is 8.342% wider compared to conventional rectangular microstrip antenna.

2.9.2 Enhancement of Microstrip Monopole Antenna Bandwidth by Using EBG Structures.

D. N. Elsheakh, et. al [22] make a modification to antenna shape to gain the best result. First a conventional shape of rectangular antenna is proposed. The conventional shape of rectangular microstrip patch antenna shown in Fig. 2.15(a) has the radiator dimensions of 12x24 mm and rectangular groundplane with dimensions equal to 35x35 mm. In this design, the antenna fundamental resonance frequency was found to be at 5 GHz. The ground plane size is reduced to 15x35 mm in Fig. 2.15(b). A semicircular ground plan with radius R_g = 15 mm was used as shown in Fig. 2.15c). As a last step, circular shapes for both the radiator and the ground plane with radii of R_r = 12 mm for the antenna and R_g = 15 mm for the ground plane are used as shown in Fig. 2.15(d). The microstrip feed line length f_l = 16 mm, and width

f_W = 1.9 mm. The antenna is printed on FR4 substrate with ε_r = 4.7 mm and thickness 3.2 mm (0.034 λ0)

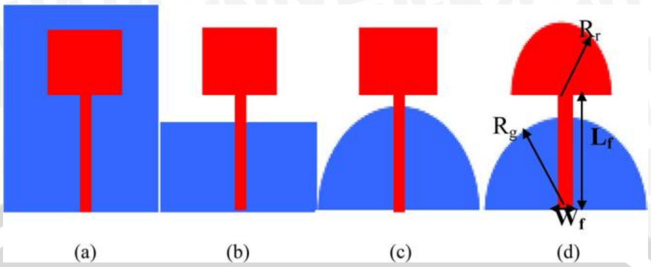


Figure 2.15 Steps toward the final design of proposed umbrella shaped monopole patch antenna.[22]

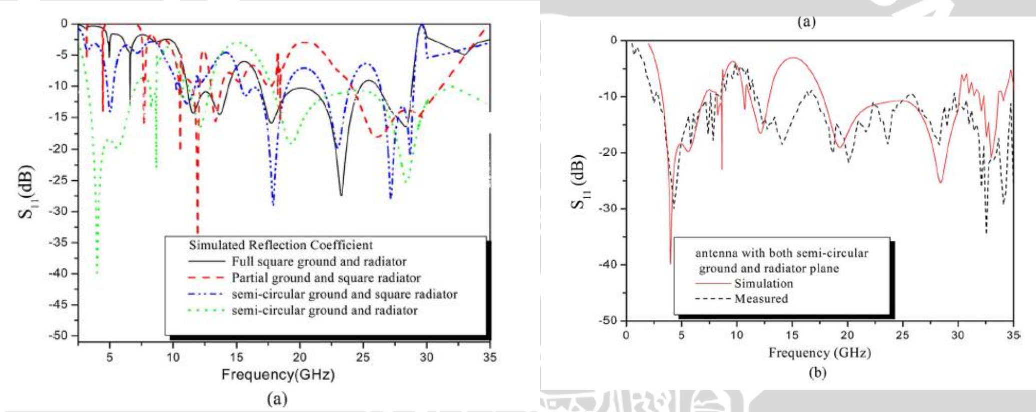


Figure 2.16 S_{11} versus frequency for various design options. (a) Simulated results and (b) comparison between simulation and measurement for the proposed antenna. [22]

Figure 2.16 shows the result of antenna simulation from the proposed antenna. This final design for the basic antenna shows UWB characteristics in Fig. 2.16. but with bandwidth discontinuities in the bandwidth from 7 to 10 GHz and 12.5 to 17.5 GHz.

Embedded circular and square patches in a periodical EBG structure are shown in Fig. 2.17a) and (b), respectively, and the side view is shown in Fig. 2.17(c). The optimization process includes embedded circular and square patches dimensions as well as antenna parameters such as gain, bandwidth, and radiation efficiency. The Measured antenna is shown in Fig. 2.17(d).

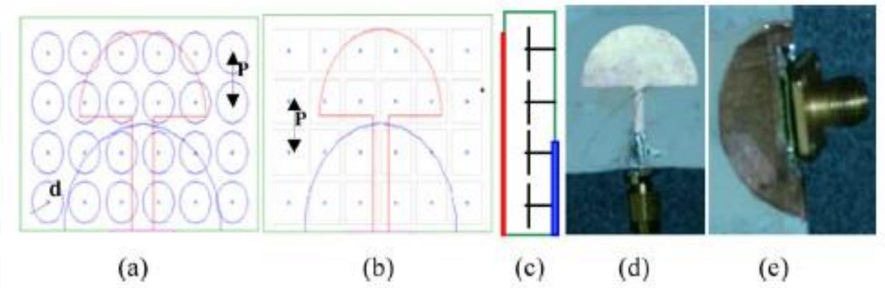


Figure 2.17 The proposed antenna with embedded EBG: (a) circular EBG, (b) square EBG, (c) side view of EBG structure, (d) Measured radiator monopole antenna, and (e) ground plane on back of the substrate. [22]

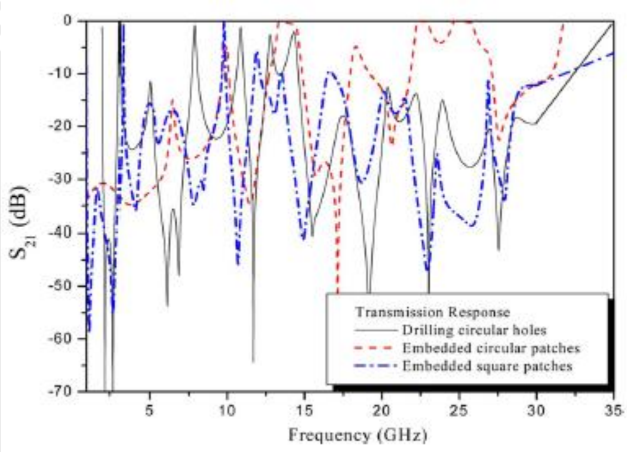
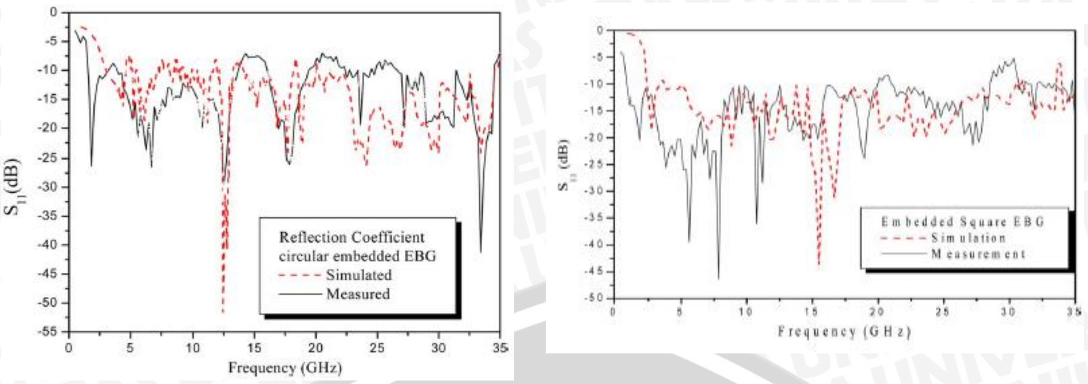


Figure 2.18 Transmission coefficients s21 versus frequency for different EBG design options. [22]

Figure 2.18 shows the result of EBG simulation. These results were obtained by calculating the transmission coefficient of a 50-ohm microstrip transmission line placed on the top of a substrate with either square or circular EBG structure or circular holes. From Figure 2.18., it is seen that each of these embedded structures has a different effect on the bandwidth of the microstrip line. The square EBG structure provides the best bandwidth as may be seen from transmission coefficients comparison shown in Figure 2.18.



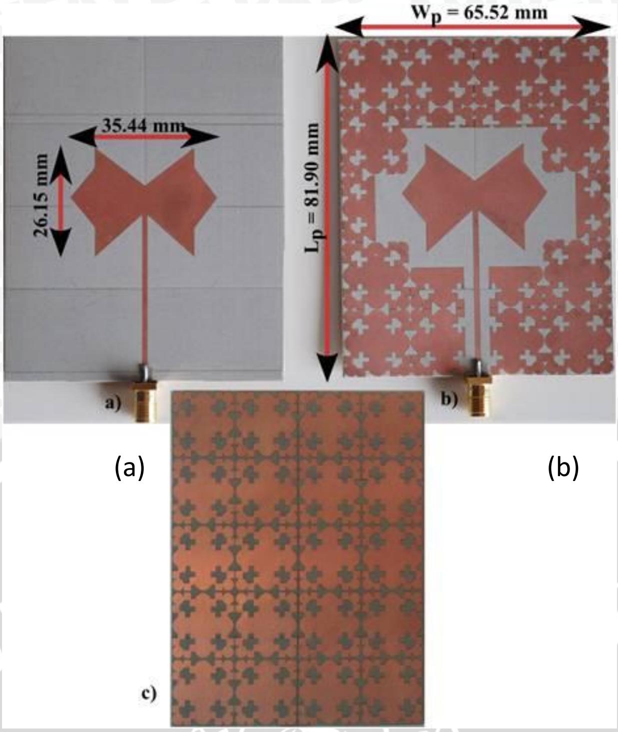
(a) (b)

Figure 2.19 Comparison between simulated and measured reflection coefficient for (a) umbrella monopole antenna with embedded circular EBG patches.(b) umbrella monopole antenna with embedded square EBG patches. [22]

The comparison between simulation and measurement of reflection coefficient of both embedded EBG are shown in Fig. 2.19 (a) and 2.19 (b) , respectively. From these Figures, it may be noted that not only improvement in the bandwidth was achieved, but also the antenna size was reduced to about 34% from that of the basic half circular monopole antenna without EBG. This gives more than 60% size reduction higher than published in by 10%.

2.9.3 on the Bandwidth Enhancement of Patch Antenna Using EBG/AMC Structures

Ramona Cosmina Hadarig, et.al [23] propose two methods of bandwidth enhancement from microstrip patch antenna. First method is EBG then AMC structures. The antenna was fabricated on a dielectric substrate, ROGER3010, with relative dielectric permittivity, εr=10.2, loss tangent 0.0025 and a thickness of 1.27 mm is used. The dimension of proposed antenna is shown in Figure 2.20. Suspended transmission line and unit cell method were been used to analyzes the characteristic of the EBG (as in Fig. 2.21) and AMC structures (as in Fig.2.22) respectively.



(a)

(b)

(c)

Figure 2.20 Manufactured prototypes: a) Patch antenna, b) Patch antenna−EBG, c) Planar AMC [23]

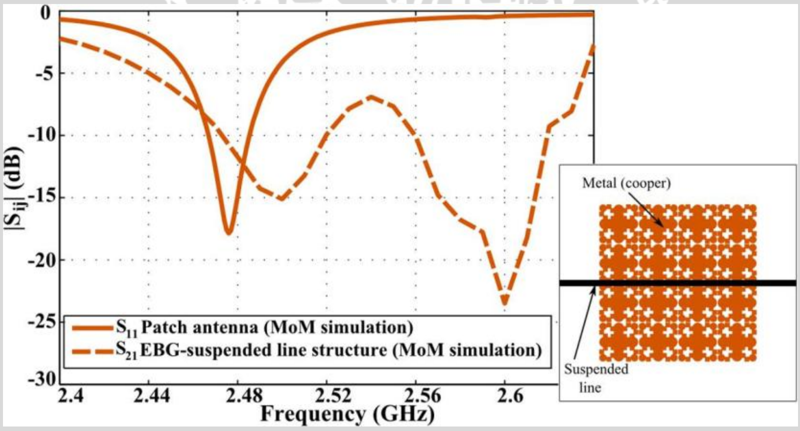


Figure 2.21 Resonances to be coupled in order to achieve bandwidth enhancement. Schematic of suspended line above EBG surface (top view) [23]

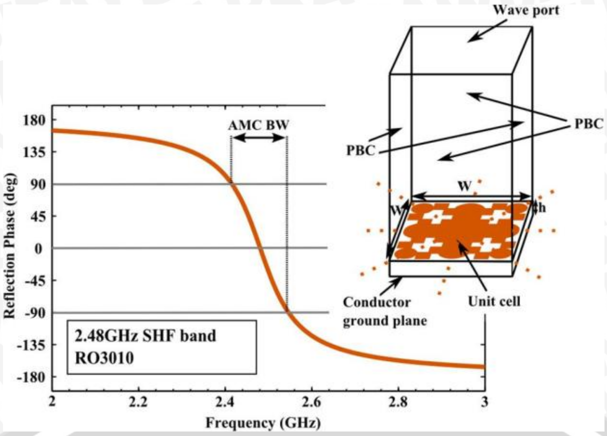


Figure 2.22 Phase of the reflection coefficient on the AMC surface (simulated). Reflection phase simulation set-up, [23]

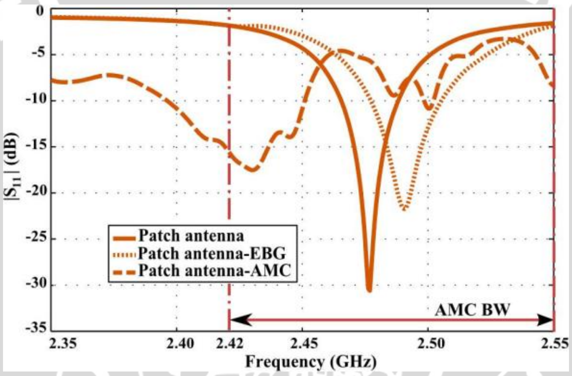


Figure 2.23 Phase of the reflection coefficient on the AMC surface (simulated). Reflection phase simulation set-up, [23]

Figure 2.23 shows the bandwidth of the patch antenna surrounded by one row of EBG cells and AMC structures. EBG structures increases 50% bandwidth of the antenna. For patch antenna with AMC structure has wider bandwidth than the patch antenna without AMC structure, the resulting prototype bandwidth increases to 46 MHz, meaning a 100% broader bandwidth.