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ELECTROMAGNETIC BAND GAP STRUCTURES EMBEDDED IN MICROSTRIP ANTENNA ARRAYS

BY

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Abstract. This paper explains the impact of electromagnetic band gap structures towards the improvement of gain of four element microstrip antenna array. The conventional four element microstrip antenna array is resonating at a fundamental frequency of 5.53 GHz. The gain and the mutual coupling values at the resonant frequency of 5.53 GHz are 6.81, –16.95, –14.22 and –17.30 dB respectively. The proposed antenna array with I-shape slot electromagnetic band gap structure in the ground plane and fractal patch electromagnetic band gap structure on the surface produces reduced mutual coupling of –38.42, –32.10 and –36.94 dB at 5.53 GHz. An enhanced gain of 9.42 dB is produced at 5.53 GHz. The proposed antenna array produces a virtual size reduction of 77.92% with sizable reduction in back lobe radiation. The dielectric substrate used is FR-4 glass epoxy with dielectric constant 4.2 and loss tangent 0.0245. The antenna arrays are designed using Mentor Graphics IE3D software and measured results are obtained using vector network analyzer.

Keywords: bandwidth, electromagnetic band gap structure, gain, microstrip array antenna, resonant frequency.

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1. Introduction

Antennas play an efficient role in modern communication devices and systems in creating a better transmission link between the transmitter and receiver. The type and performance of antennas depend on the excitation method and the transmission lines employed. The functioning of antennas particularly the microwave antennas is primarily based on electromagnetic theory. A proper and meticulous design of antennas is very much required to reduce the complexities involved in system performance and increase the efficiency of the rate of transmission and reception on the communication link. (Constantine A. Balanis, 1997).

In the microwave frequency range the most preferred transmission line employed is the microstrip line as the amount of parasitic inductance and capacitance produced is very much lesser than the normal lumped elements. The structure of microstrip antenna is similar to that of microstrip line. In its simplest configuration, a microstrip antenna is a printed type of antenna which is made of a dielectric substrate placed between the radiating patch and finite ground. These antennas are widely used in systems where high level of compactness, low cost, ease of fabrication and installation are the benchmarks. (Bahl & Bhartia, 1980). On the other side of the coin, they suffer from few demerits like narrow bandwidth and surface wave excitation particularly noticeable in multi element microstrip antennas. This has a serious consequence on the mutual coupling between the antenna elements. Hence an unusual procedure or approach or technique is very much required to be implemented to solve this detrimental problem. (Christos G. Christodoulu & Parveen F. Wahid, 2004).

Electromagnetic band gap (EBG) structures are band stop structures which are periodic in nature. They are capable of allowing or prohibiting the propagation of electromagnetic signals for all incident angles and polarization states. EBG structures have gained immense popularity and are being widely employed to give an appreciable decrease in interference between the individual antennas. These structures can be laid either on the ground plane or on the surface of the microstrip antennas. (Fan Yang & Yahya Rahmat-Samii, 2009).

In the year 2013, Angelina M. Flashy *et al.* have designed and characterized microstrip circular antenna array to provide omni directional radiation pattern for C/X band radar applications. The antenna array is designed for dual bands 6.05,…,7 GHz and 9,…,10 GHz. For dual band operation, circular patch array is placed on both and bottom layers of the microstrip with larger rectangular patch placed on the bottom layer. The single sided antenna array is producing return loss of –20.19 dB at 5.5 GHz. In the case of double sided antenna array the return losses are –18.54 and –23.65 dB at 6.5 and 9.5 GHz respectively. The double sided antenna array is producing highest directivity and gain of 8.89 and 3.8 dB respectively. (Angelina M. Flashy *et al.*, 2013). In the year 2019, D. Nataraj *et al*. have presented the design of two element microstrip antenna array using dumbbell shaped DGS. The gain and bandwidth of the proposed antenna array are 1.94 dB and 100 MHz respectively. The size reduction obtained is equal to 79%. To design antenna without much degradation of performance, the patch radiator is modified keeping the physical volume of the antenna constant. The gain and bandwidth are enhanced to 4.14 dB and 120 MHz respectively. In this way the resonance frequency is shifted to 2.2 GHz, thus providing size reduction of 83% (Nataraj & Karunakar, 2019). In the year 2010, Elsheakh *et al*. have discussed the study of EBG structures loaded in the ground plane, their types, and their behavior in enhancing the performance of two element microstrip patch antenna arrays. The EBG structures employed are of two dimensional in nature and corporate feeding technique is used to feed the antenna array. The performances of square, circular, star, H and I shape EBG structures are compared. Highest bandwidth of 5.1% has been achieved using H shape EBG structure. Least amount of mutual coupling (S_{21}) of –30 dB and highest gain of 13.75 dB have been obtained in the case of star EBG structure. (Esheakh *et al*, 2010). In the year 1987, Eli Yablonovitch has exhibited that if a three dimensional periodic dielectric structure has an electromagnetic band gap which overlaps the electronic band edge, then spontaneous emission can be rigorously suppressed and also stimulated emission would be absent. There is periodic modulation along the laser axis and therefore a forbidden gap in the electromagnetic dispersion relation. (Eli Yablonovitch, 1987). In the year 2013, Hassan Elesawy *et al*. have designed and fabricated single, two and four element linear microstrip antenna arrays (E shape) using corporate feeding technique. Two parallel slots are cut to perturb the surface current path and enhance the bandwidth. The inter element spacing is 13.6 mm. The directivities of single, two and four element antenna arrays are 7, 9 and 12 dBi respectively. The corresponding maximum achievable gains are equal to 5, 7.5 and 11 dBi respectively. Bandwidths obtained are equal to 8, 11 and 16% respectively. The maximum values of antenna and radiation efficiencies are 80 and 88% (Hassan Elesawy *et al*., 2013). In the year 2019, Mahadu A. Trimukhe and Balaji G. Hogade have employed fractal and two via edge located (TVEL) EBG structures near the feed line to cause triple frequency band notch characteristics over WiMAX (3.3,…,4 GHz), WLAN (5.1,…,5.8 GHz) and satellite downlink communications (7.2,…,7.8 GHz) respectively. Structure with EBG is offering high efficiency and producing nearly omni directional radiation patterns proposed rectangular and circular EBG structures. (Mahadu A. Trimukhe & Balaji G. Hogade, 2019). In the year 2015, Mohamed I. Ahmed *et al*. have designed novel eagle shaped microstrip antenna array with eagle shaped EBG structure placed on the surface and in between the radiating patches. The measured results depict that a reduction in mutual coupling of 36 dB is achieved in the first band (1.68,…,2.65 GHz) and 22.1 dB in the second band (6.5,…, 8.86 GHz) due to the introduction of EBG structure. Moreover a size reduction of 80% is achieved. The bandwidths produced are equal to 31.5 and 30.4% respectively. Appreciable gains of 4 and 6.2 dB are also obtained. The better performance of proposed antenna arrays is further supported by high values of radiation and antenna efficiencies of 96 and 95% respectively (Mohamed I. Ahmed *et al*., 2015). In the year 2014, Mohammad Naser - Moghadasi *et al*. have designed 2 × 5 EBG structure to reduce mutual coupling between patch antennas of MIMO array. Two microstrip patch antennas are designed for resonance at 5.28 GHz. The conventional MIMO array is fed by coaxial feed and bandwidth is equal to 3%. The EBG structure is inserted between the two patch antennas and on the surface. Mutual coupling values without and with EBG structure are –22 and –43 dB respectively. By increasing the gap between the unit cells of EBG structure, the resonant frequency of proposed MIMO array is reduced. A gain value of 6.86 dBi is also produced. Moreover the EBG structure has reduced antenna current from 8.5 A/m to 3.9 A/m, so the coupling is reduced by 50%. However the antenna efficiency is reduced from 65 to 53%. (Mohammad Naser – Moghadasi *et al*., 2014). In the year 2018, Nilima A. Bodhaye *et al*. have demonstrated the improvement in the performance of microstrip patch antenna array using double I shaped slot DGS. By incorporating DGS in the two element microstrip antenna array, four resonant frequencies *i.e*. 2.48, 3.29, 3.57 and 5.51 GHz respectively are yielded. Improved bandwidths of 80, 90, 110 and 180 MHz are produced. The proposed antenna array is useful for wireless applications. (Nilima A. Bodhaye & P.L. Zade, 2018). In the year 2015, Niraj. R. Ada and Mayank. A. Ardashena have proposed the design of 2 × 2 microstrip patch array with 2 × 2 EBG substrate with respect to the rectangular ground plane. The material used for the substrate is Rogers _RO3010 with dielectric constant 10.2. The return losses of the antenna array with EBG are –48 and –42 dB at 3.5 and 7 GHz respectively. The overall bandwidth of the proposed antenna is 16%, which is double that of bandwidth obtained for conventional antenna. The gain of the antenna in the presence of EBG is 8.45 dBi which is greater than without EBG equal to 1.96 dbi (Niraj R. Ada & Mayank A. Ardashena, 2015). In the year 2018, N. Lakshmi Tejaswi and M.V.S. Prasad have depicted the enhancement in the performance of MIMO antenna using U shaped patch antenna. Stubs are placed in the U shaped patch antenna and DGS is etched in the ground plane. It is seen that the MIMO antenna is resonating at 2.5, 5, 7 and 9 GHz respectively. The antenna is yielding gains of 6.94, 6.2 and 8.225 dB at 5, 7 and and 9 GHz respectively. The proposed antenna is used in WiMAX communication systems (N. Lakshmi Tejaswi & M. V. S. Prasad, 2018). In the year 2018, Reefat Inum *et al* have proposed rectangular and circular EBG structures to investigate the antenna performance used in microwave brain imaging system. The return losses produced due to rectangular and circular EBG structures are –40.15 and –49.29 dB respectively. Using circular EBG is producing better bandwidth of 291.6 MHz compared to 275.5 MHz that due to rectangular EBG. Moreover gains of 6.7 and 6.06 dBi are obtained using circular and rectangular EBG. The specific absorption rates are equal to 0.922 and 0.695 W/Kg, which are lesser than maximum standard surface absorption rate limit of 1.6 and 2 W/kg, which ensures the safety of the considered microwave brain imaging system. (Reefat Inum *et al*., 2018). In the year 2017, Soumya Ranjan Mishra *et al*. have designed a 2 × 2 microstrip antenna array with DGS in the ground plane. The proposed array is producing 14 dB enhancement in the segregation between the co-polarization to cross polarization dissemination. The array is realized on RT8570 substrate. A minimum of 2 dB reduction in mutual coupling is achieved. Broadening of impedance bandwidth is also observed (Reefat Inum & Sheeja K.L, 2017). In the year 2016, Tao Jiang *et al*. have analyzed the performance of two element microstrip antenna array using periodic L-loading E-shaped EBG structure between the array elements. A mutual coupling reduction of 26 dB is obtained at 2.55 GHz in the presence of EBG structure. The L loading EBG structure has little effect on radiation pattern. The proposed structure also reduces the current effect on the adjacent antenna elements and hence can improve the decoupling between the adjacent antenna elements (Tao Jiang *et al*., 2016).

2. Materials and Methods

The conventional antenna array is designed at the frequency of 6 GHz. The height of the substrate is 1.6 mm. The conventional microstrip antenna array (CMAA) consists of four identical radiating patches fed by corporate feeding technique. Each of the radiating patches is rectangular in shape and the dimensions are 15.73 mm × 11.76 mm. The adjacent antenna elements are separated by a distance of $\lambda/4$, where λ is the wavelength calculated at the design frequency of 6 GHz. The schematic of CMAA is shown in Fig. 1. The feed and the quarter wave transformer have the dimensions of 6.52 mm × × 3.05 mm and 6.47 mm × 0.47 mm. The dimensions of the other parts of the schematic depicted in Fig. 1 are tabulated in Table 1.

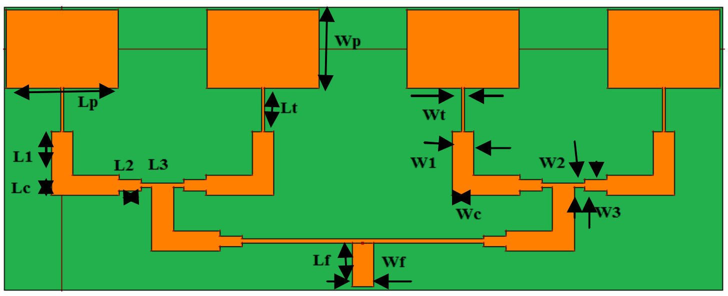


Fig. 1 − Schematic of CMAA.

All the parts and dimension values of CMAA are depicted in Table 1.

Table 1
Parts and Dimension Values of CMAA

Part	Value (mm)
Length of the patch (Lp)	15.73
Width of the patch (Wp)	11.76
Length of the quarter wave transformer (Lt)	6.47
Width of the quarter wave transformer (Wt)	0.47
Length of the 50 Ω line (L1)	6.52
Width of the 50 Ω line (W1)	3.05
Length of the coupler	3.05
Width of the coupler	3.05
Length of the 70 Ω line (L2)	6.54
Width of the 70 Ω line (W2)	1.62
Length of the 100 Ω line (L3)	6.56
Width of the 100 Ω line (W3)	0.70
Length of the feed line (Lf)	6.52
Width of the feed line (Wf)	3.05

By maintaining the same distance between the two adjacent antenna elements as $\lambda/4$, the parameter mutual coupling can be measured by exciting the four antenna elements separately as shown in Fig. 2. All the four antenna elements are assumed to be fed with the same amount of power.

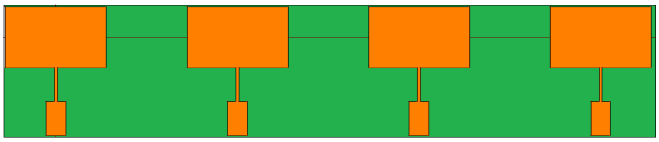


Fig. 2 − Schematic of setup of CMAA for mutual coupling measurement.

The proposed microstrip antenna array is designed by loading the EBG structures both in the ground plane and on the surface of CMAA. The EBG structure employed on the surface are in the same plane as that of the four rectangular radiating patches and placed between the adjacent radiating patches. The ground plane is replaced with a matrix of 4 rows and 9 columns of I shape slot EBG structure. On the other hand, the EBG structure integrated on the surface is a matrix of 5 rows and 2 columns of fractal shape patch. The unit cells of the EBG structures are depicted in Fig. 3.

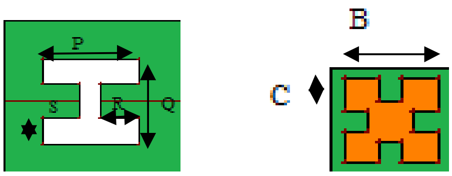


Fig. 3 − Schematics of unit cells of EBG structures.

In Fig. 3 the schematic on the left side depicts the unit cell of the EBG structure placed in the ground plane and the one on the right side depicts the unit cell of the EBG structure loaded on the surface. The dimensions of the unit cells shown in Fig. 3 are P = 9 mm, Q = 9 mm, R = 3.75 mm and S = 2 mm, B = = 9 mm and C = 1.5 mm respectively. The dimensions of the unit cell are selected on a trial and error basis.

The EBG structures employed to design the proposed antenna array are shown in Figs. 4 and 5. Fig. 4 depicts the EBG structure loaded in the ground plane and Fig. 5 depicts the EBG structure placed on the surface of CMAA.

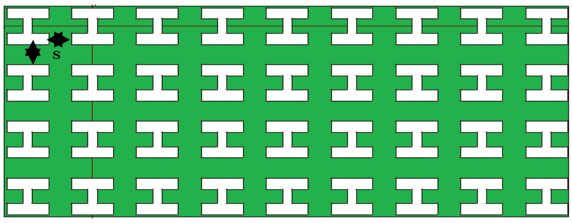


Fig. 4 – Schematic of I shape slot EBG structure.

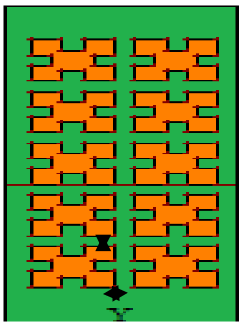


Fig. 5 – Schematic of fractal shape patch EBG structure.

In Fig. 4, S is the distance between the adjacent unit cells of the EBG structure and is equal to 5 mm along the *x*-axis and *y*-axis. In Fig. 5, the unit cells of the fractal patch EBG structure are separated by Y = 1 mm along the *x*-axis and *y*-axis.

Fig. 6 shows the schematic of the proposed antenna array.

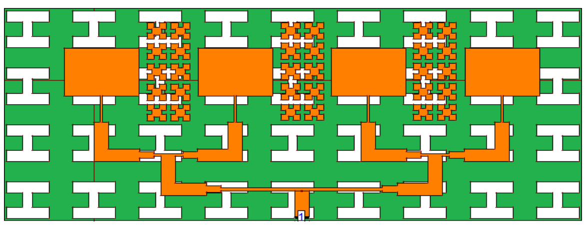


Fig. 6 – Schematic of proposed microstrip antenna array.

The parameter mutual coupling of the proposed antenna array is measured by loading the EBG structures mentioned in Figs. 4 and 5 in the ground plane and on the surface of the schematic shown in Fig. 2. The schematic of such a set up is depicted in Fig. 7.

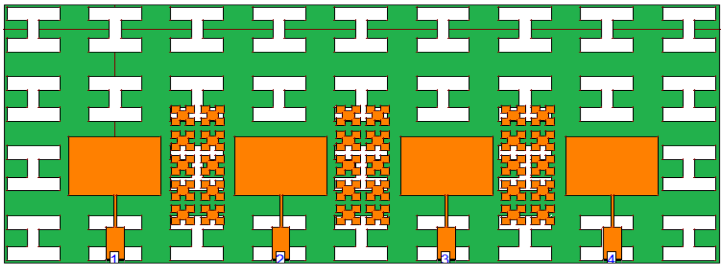
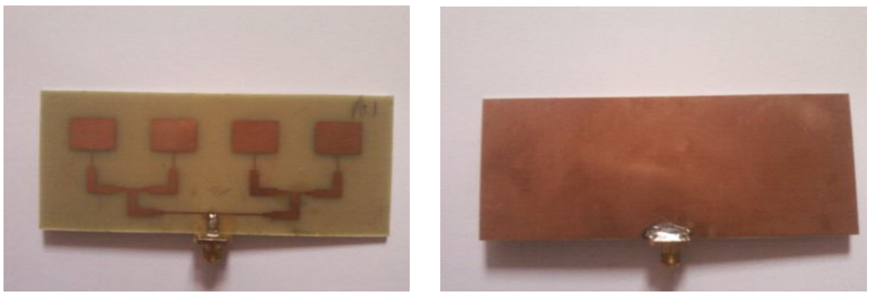


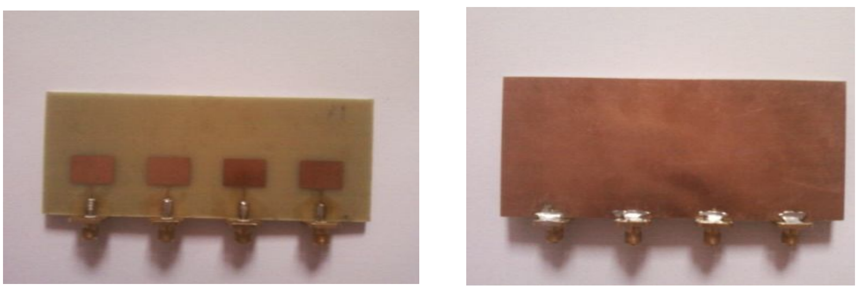
Fig. 7 – Schematic of setup of proposed microstrip antenna array
for mutual coupling measurement.

Figs. 8…,11 depict the photographs of the fabricated microstrip antenna arrays.



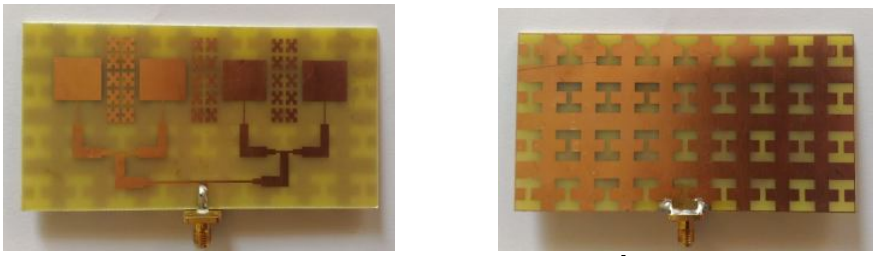
a *b*

Fig. 8 – Photograph of fabricated CMAA.
(*a*) Front view, (*b*) Back view.



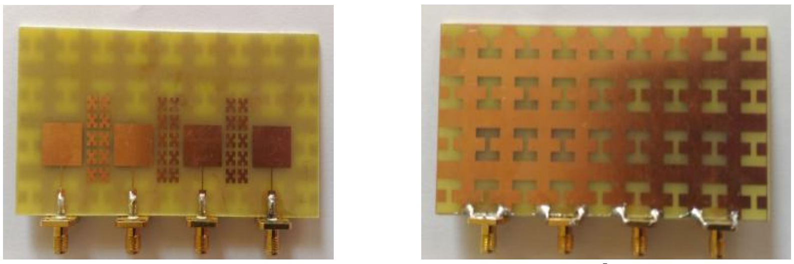
a *b*

Fig. 9 – Photograph of setup of fabricated CMAA for mutual coupling measurement.
(*a*) Front view, (*b*) Back view.



a *b*

Fig. 10 − Photograph of fabricated proposed microstrip antenna array.
(*a*) Front view (*b*) Back view



a *b*

Fig. 11 − Photograph of setup of fabricated proposed microstrip antenna array for mutual coupling measurement.
(*a*) Front view, (*b*) Back view

3. Results and Discussion

The performance of CMAA is compared with that of the proposed antenna array in terms of parameters – return loss, resonant frequency, bandwidth, mutual coupling, gain, forward power, backward power, front to back ratio and virtual size reduction. The parameter return loss is one of the most important parameters to examine the performance of microstrip antenna arrays. It is designated by the s-parameter S_{11}. The mutual couplings are represented by the s-parameters S_{21}, S_{31} and S_{41}. The plots of return loss and mutual coupling versus frequency of CMAA are depicted in Figs. 12,…,14 respectively.

The return loss and mutual coupling characteristics of the fabricated antennas are obtained by using German make Rohde and Schwarz (R&S) Vector Network Analyzer of ZVK model (10 MHz,…,40 GHz) and turn table arrangement. Initially the vector network analyzer is calibrated in the frequency range 1,…,7 GHz. The fabricated antenna CMAA shown in Fig.8 is employed to measure the return loss characteristics of CMAA. The fabricated antenna is connected to the port 1 (through the female type SMA connector of fabricated antenna) of the vector network analyzer. In the next step to measure the mutual coupling coefficient S_{21}, the transmitting element 1 of setup of fabricated antenna CMAA shown in Fig.9 is connected to port 1 of vector network analyzer and the receiving element 2 of fabricated antenna CMAA is connected to port 2 of vector network analyzer. To determine the values of mutual coupling S_{31} and S_{41} of CMAA, the receiving elements 3 and 4 are connected to port 2 of vector network analyzer. The same procedure is employed to determine the return loss and mutual coupling characteristics of proposed microstrip antenna array by using the fabricated antennas depicted in Figs. 10 and 11 respectively. The experimental setup used for the measurement of return loss and mutual coupling is shown in Fig. 15.

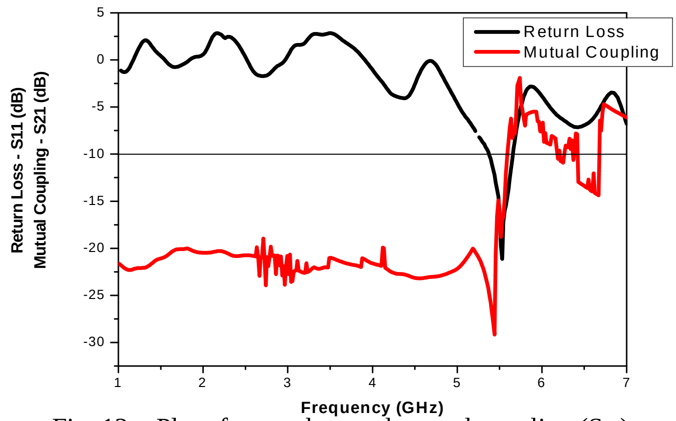


Fig. 12 – Plot of return loss and mutual coupling (S_{21}) *versus* frequency of CMAA.

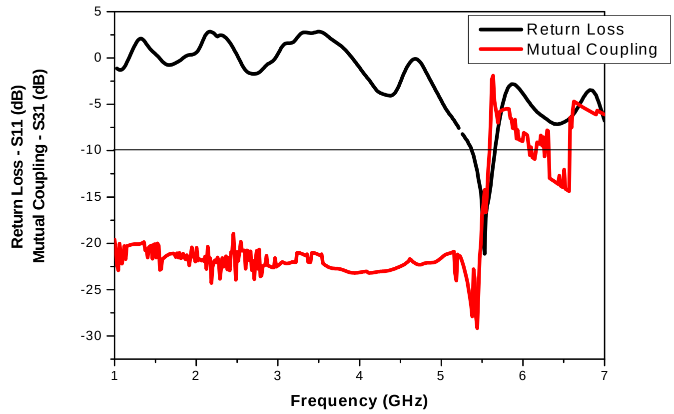


Fig. 13 – Plot of return loss and mutual coupling (S_{31}) . *versus* frequency of CMAA.

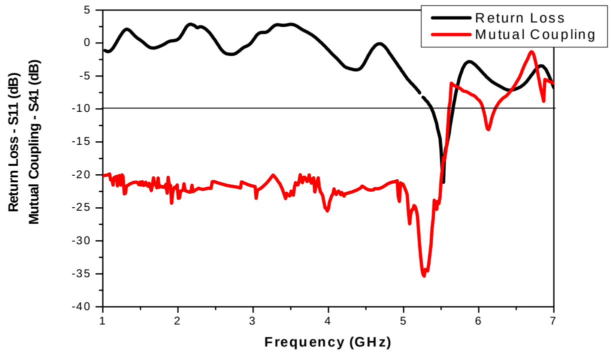


Fig. 14 – Plot of return loss and mutual coupling (S_{41}) *versus* frequency of CMAA.

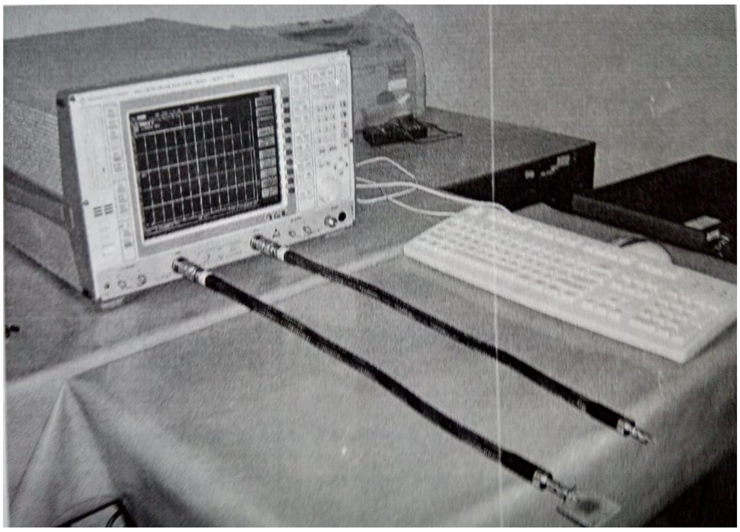


Fig. 15 – Photograph of experimental setup to measure return loss and mutual coupling.

From Figs. 12,…,14, the CMAA designed at the frequency of 6 GHz, is resonating at the fundamental frequency of 5.53 GHz with a return loss of –21.06 dB. Resonant frequency is measured as the frequency at which the return loss is least between the points where the return loss graph is crossing the –10 dB value. The other important parameter that can be extracted from the return loss graph is the bandwidth. It is calculated by subtracting the lower frequency from the upper frequency where the return loss crosses –10 dB value. The CMAA thus possesses a bandwidth equal to 273 MHz. The bandwidth (%) is calculated by using:

$$\frac{\text{Bandwidth}}{\text{Resonant frequency}}\times 100\%. \tag{1}$$

Hence the bandwidth (%) of CMAA is equal to 4.89%. From Figs. 12,…,14, the experimental values of mutual coupling (S_{21}, S_{31} and S_{41}) measured at the resonant frequency of 5.53 GHz are equal to –16.95, –14.22 and –17.30 dB respectively. These values of mutual coupling are considered to be very severe. More importantly, the return loss and mutual coupling graphs are crossing each other at the resonant frequency of 5.53 GHz. This has a serious effect on the interference between the transmitting antenna 1 and each of the receiving antennas 2, 3 and 4, which leads to improper transfer or loss of electromagnetic waves from the antenna 1 to antennas 2, 3 and 4 respectively.

After the EBG structures are loaded in the ground plane and on the surface of CMAA, the following variations in the plots of return loss and mutual coupling of proposed antenna array are observed as depicted in Figs. 16,…,18.

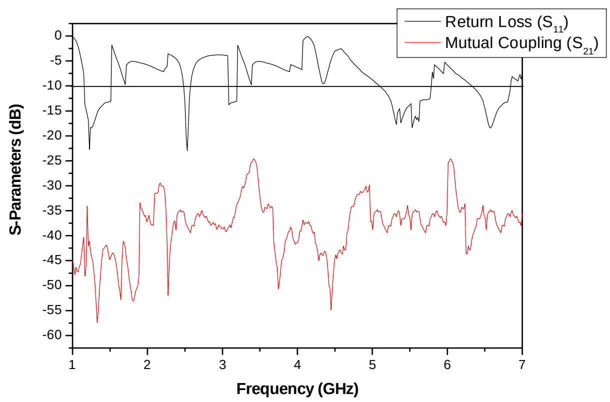


Fig. 16 – Plot of return loss and mutual coupling (S_{21}) *versus* frequency of proposed microstrip antenna array.

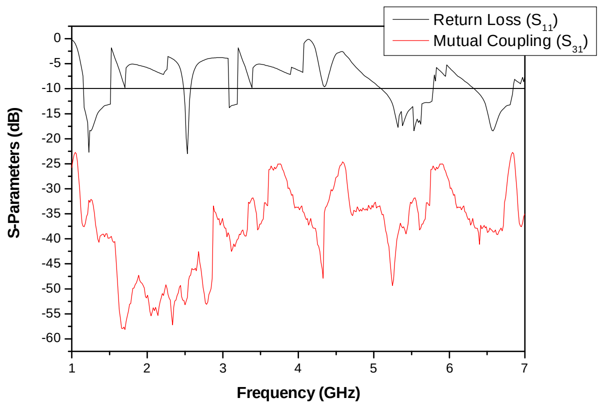


Fig. 17 – Plot of return loss and mutual coupling (S_{31}) *versus* frequency of proposed microstrip antenna array.

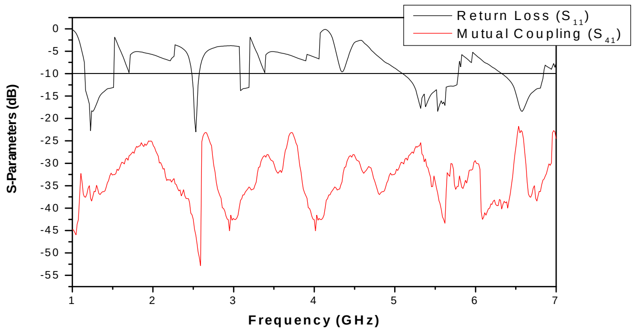


Fig. 18 − Plot of return loss and mutual coupling (S_{41}) *versus* frequency of proposed microstrip antenna array.

Figs. 16,…,18 depict that the proposed microstrip antenna array is resonating at five frequencies – 1.219, 2.533, 3.071, 5.53 and 6.56 GHz respectively. It produces bandwidth at the corresponding resonant frequencies equal to 346, 108, 107, 704 and 526 MHz respectively. Thus the overall bandwidth (%) of the proposed antenna array is equal to 56.83 % as against 4.89% of CMAA. As the value of bandwidth (%) of proposed microstrip antenna array is greater than that of CMAA, proposed microstrip antenna array is a better antenna than CMAA in terms of parameter bandwidth.

From Figs. 16,…,18 the measured values of mutual coupling (S_{21}, S_{31} and S_{41}) at the resonant frequency of 5.53 GHz are equal to –38.42, –32.10 and –36.16 dB respectively. In addition the plots of return loss and mutual coupling of the proposed antenna array are no more overlapping at the resonant frequency of 5.53 GHz. Hence the amount of interference between the transmitting antenna 1 and receiving antennas 2, 3 and 4 is minimized in proposed microstrip antenna array. Therefore, proposed microstrip antenna array is a better candidate than CMAA in terms of mutual coupling.

The parameter Gain is calculated by:

$$G = 20\log_{10}\left(\frac{4\pi R}{\lambda}\right) + 10\log_{10}\frac{Pr}{Pt} - Gt, \tag{2}$$

where: *Pt* is the transmitted power; *Pr* – received power; *R* – distance between the transmitting and the receiving antennas; λ – wavelength at the resonant frequency of 5.53 GHz; *Gt* – gain of the transmitting antenna; *Gt* – given by:

$$Gt = 10\log_{10} Gs, \tag{3}$$

$$Gs = \frac{2\pi ab}{\lambda^2}, \tag{4}$$

where: *a* and *b* are the length and width of the standard pyramidal horn antenna used as the transmitting antenna. The dimensions *a* and *b* are equal to 24 and 14 cm respectively. The distance between the transmitting antenna (standard horn antenna) and the receiving antenna is given by:

$$R \geq \frac{2D^2}{\lambda}, \tag{5}$$

where: *D* is the larger dimension of the transmitting antenna equal to 24cm. The value of *R* = 71.86 m.

The transmitted and received powers in the case of CMAA are equal to 8.7 μW and 12.414 nW respectively. Substituting the parameter values in equation 1), the gain of CMAA is equal to 6.81 dB. In the case of the proposed antenna array, the corresponding powers are equal to 8.7 μW and 22.64 nW respectively. Substituting the parameter values in equation 1) the proposed antenna array produces a better gain equal to 9.42 dB. Therefore, by employing the EBG structures, the gain of CMAA is increased by a value of 2.61 dB. Hence the proposed microstrip antenna array is a better candidate than CMAA in terms of gain.

The CMAA and the proposed microstrip antenna array are resonating at fundamental frequencies equal to 5.53 and 1.21 GHz as shown in Figs. 12,…,18 respectively. The proposed microstrip antenna array is resonating at a lesser fundamental frequency compared to CMAA. This accounts to virtual size reduction (%) determined by using equation The virtual size reduction produced by proposed microstrip antenna array is calculated by:

$$\frac{f_1 - f_2}{f_1} \times 100. \tag{6}$$

Hence the virtual size reduction produced by proposed microstrip antenna array is equal to 77.92 %.

Fig. 18 shows the radiation properties of the microstrip antenna arrays designed in the form of a radiation pattern. The forward power is calculated at the angle of 90^0 and the backward power at the angle of 270º.

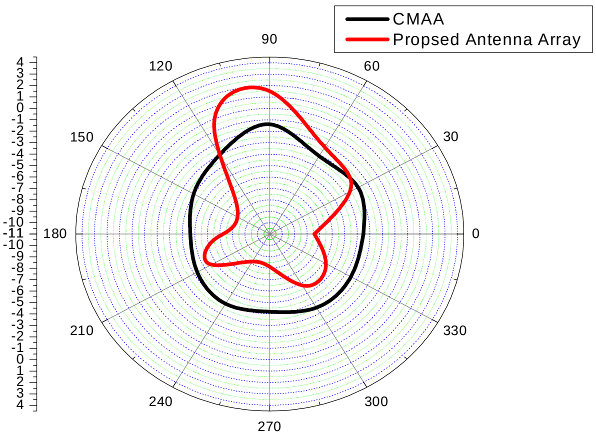


Fig. 19 − Plots of radiation patterns of CMAA and proposed microstrip antenna array.

The method employed to measure the radiation pattern of the antennas in the present research study is the turn table method. The experimental set up for the radiation pattern measurement is depicted in Fig. 19.

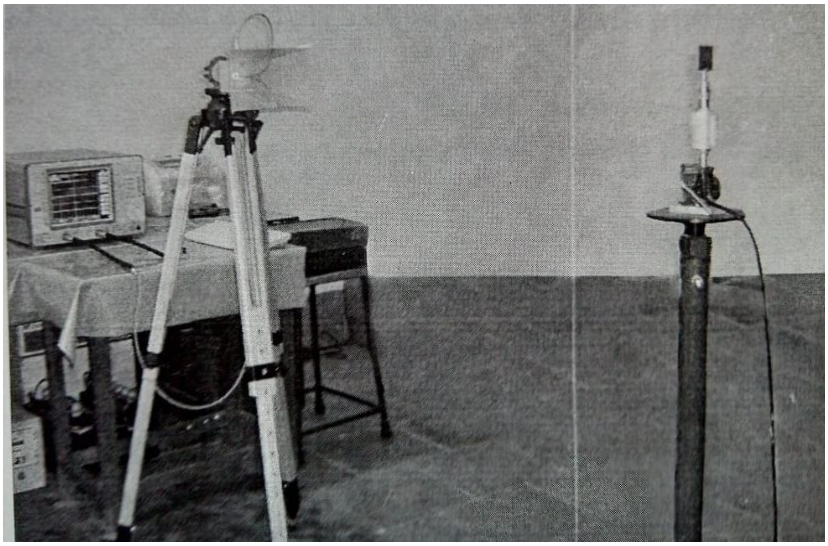


Fig. 20 − Photograph of experimental setup to measure radiation pattern.

In the arrangement shown in Fig. 20, two antennas are placed facing each other and then keeping the position of transmitting antenna fixed, the receiving antenna is rotated around its axis to change the angle of rotation in steps of few degrees. For each position of the receiving antenna, the corresponding power is read in the power meter. The DUT is connected in the receiving mode and the reference antenna (standard pyramidal horn antenna) fed by vector network analyzer is connected in the transmitting mode. The distance between the transmitting and receiving antennas is determined by using equation (5).

From Fig. 18, the amount of backward power radiated by CMAA and the proposed antenna array are –4.5 and –8.3 dB respectively. Hence with the introduction of EBG structures, the back lobe radiation of CMAA is reduced considerably to –8.3 dB. This shows that the proposed antenna array is radiating lesser power in the undesired direction compared to CMAA. This shows that the proposed microstrip antenna array is a better radiator than CMAA in terms of backward power.

The forward power is measured in order to judge which antenna is radiating better in the desired direction. The measured forward powers of CMAA and the proposed antenna array are –2 and –1.4 dB respectively. This depicts that the proposed antenna array is a better radiator than its competitor in the desired direction. The parameter Front to Back ratio (FBR) is determined by subtracting the power radiated in the undesired direction from the power radiated in the desired direction. Hence the FBR values of CMAA and the proposed antenna arrays are 2.5 and 6.9 dB respectively. This confirms that the FBR value of the proposed antenna array is greater than CMAA by 4.4 dB. Hence proposed microstrip antenna array is a better antenna than CMAA in terms of FBR.

To summarize, as proposed microstrip antenna array is performing better than CMAA in terms of bandwidth, mutual coupling, gain, forward power, backward power, FBR and virtual size reduction, hence proposed microstrip antenna array is a better candidate compared to its opponent *i.e.* CMAA.

4. Conclusion

This paper investigates the behaviour of CMAA without and with EBG structures. The CMAA and the proposed antenna array are designed and fabricated and measured results conclude the capability of EBG structures. The proposed antenna array is yielding a high gain of 9.62 dB. The radiation characteristics of CMAA are enhanced in the wanted and unwanted directions as depicted by the parameter values of forward power, backward power and FBR. Additionally, the proposed antenna array is giving tremendous virtual size reduction of 77.92% and better bandwidth of 56.83%. Therefore, the proposed antenna array is a superior performer than CMAA.

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STRUCTURI BAND GAP ELECTROMAGNETICE INSERATE ÎN ARII DE ANTENE MICROSTRIP

(Rezumat)

Lucrarea explică efectul structurilor electromagnetice de tip *band gap* în vederea îmbunătățirii câştigului unei arii de antene microstrip cu patru elemente. Varianta convențională a acestui tip de antene are o frecvență fundamentală de rezonanță de 5.53 GHz. Câştigul şi valorile cuplajului mutual la frecvența de rezonanță sunt de 6.81, –16.95, –14.22 şi, respectiv, de –17.30 dB. Soluția propusă furnizează valori reduse ale cuplajului mutual de –38.42, –32.10 şi –36.94 dB la frecvența de 5.53 GHz, cu un câştig suplimentar de 9.42 dB. Antena propusă oferă o reducere a dimensiunilor de 77.92%, cu reducerea semnificativă a radiației lobului posterior. Pentru realizare s-a folosit un substrat dielectric de tip FR-4 din sticlă epoxy, având constanta dielectrică 4.2 şi tangenta unghiului de pierderi de 0.0245. Aria de antene a fost proiectată folosind programul Mentor Graphics IE3D, iar rezultatele măsurătorilor au fost obținute cu ajutorul unui analizor de rețea vectorial.