

# Upgradation in the Performance of Various Antenna Parameters by using the Concepts of Metamaterials

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## Abstract

A Rectangular Microstrip Patch Antenna with a size of  $94 \times 78 \times 0.787 \text{ mm}^3$  is put forward for IEEE 802.11 b/g/n applications where the performance of various antenna parameters is keenly improved by using Metamaterials. The Conventional Antenna is designed with the presence of Rogers RT Duroid 5870 Substrate with epsilon value of 2.33. In order to upgrade performance, EBG Structures in the form of Square Split Ring Resonator which is modified as previously been available is directly etched on the Ground Plane of Conventional Antenna. On this incorporation, we found that the Conventional Antenna which previously suffers from Narrow Bandwidth, Low Efficiency and Low Gain is sparsely enhanced where the Bandwidth was improved to +23.10%, Efficiency and Gain improved to a 17.15% and +51.35% respectively. In earlier works, the EBG Structures was attached to the radiating patch making it ineffective for modern day's applications but here the incorporation is done without disturbing the radiating patch and the EBG Structures are modeled in such a way where it tackles mutual coupling. So keeping in view with the desires of Wi-Fi (Wireless Fidelity) Applications certain technical issues need to be addressed where the designed prototypes fulfill them out.

**Keywords:** Antenna Parameters, EBG Structures, Metamaterials (MTM), Performance, Square Split Ring Resonator (SSRR), Upgradation

## 1. Introduction

In the current period of time, Wireless Communication Domain is one of the most growing utility where antenna designers have been showing their major vested interest. Because of the fact that antenna's play an evitable and important role for creating out better performance for all sorts of applications presently based in Wireless Communication. If certain ambiguities have been found between the antennas and frequency upon which they decided to work on it, then the foremost intension/motive behind the development of application is not fulfilled. The authors have chosen out ISM Band<sup>1</sup> as it is free to use, does not require the proposal of licensing. The application for which the antenna has been developed, completely meet designers demand or requirements.

Microstrip Patch Antenna is the special types of antennas that consist of a conducting patch of any planar or non-planar geometry on one side of the dielectric substrate with a ground plane on the very next side. A numerous number of different based geometries regarding the design has been available at different corners of various located streams but the authors has selected Rectangular Microstrip Patch Antenna as it resembles out with major benefits or features like dual and circular polarizations, dual frequency operation, frequency agility, broadband width, feed line flexibility, beam scanning followed up by the most interestingly property omni-directional patterning<sup>2</sup>.

Metamaterials defined as macroscopic composites having synthetic, three-dimensional, periodic cellular architecture designed to produce an optimized

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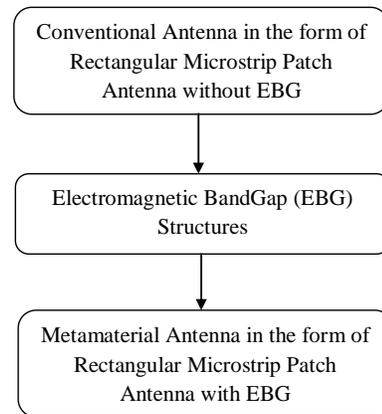
combination which is not available in the nature out of which two or more responses to that of the specific excitation<sup>3</sup>. Based on Wikipedia, Metamaterial, in general defined as a material which gains most of its properties mostly from the established structures, rather than directly from composition<sup>4</sup>. The above nature reflects out certain natures of Metamaterial to extent of different perspectives. Actually, these have been also defined as the macroscopic composite of periodic and also consideration of non-periodic structure, which functions out due to presence of cellular architecture and the chemical composition<sup>5</sup>.

Further it is segregated into various streams but the authors has mostly laid their focus on EBG Structures or EBG Metamaterials as they were predominantly defined as artificial periodic objects which prevent or assist propagation of electromagnetic waves in a specified band of frequencies, for all the incident angles and all polarization states<sup>6</sup>. They are very often realized as periodically arrangement of the dielectric materials and metallic conductors which suitably highlights the main objective. This feature has been taken into consideration by the authors and they want to grab the attention of research community by showcasing them out<sup>7-10</sup>. Here IEEE 802.11 b/g/n commonly acclaimed as the Wi-Fi or Wireless Fidelity where it establishes link through the air interface for creating out communication between them<sup>11</sup>.

In this work, the performance of various antenna parameters of the Rectangular Microstrip Patch Antenna are keen to be upgraded out leaving behind all traditional problems or major hindrances. As in the earlier case, scope of improvement was performed with certain acceptance of reality<sup>12-13</sup> but in this present scenario, the authors are successful with most important motive of carrying improved performances in antenna parameters like Bandwidth, Directivity, Efficiency followed up by Gain and Power Handling Capacity. All of these facts have been possible by use of EBG Structures that acting as a Matching Networks with Rectangular Microstrip Patch Antenna<sup>14</sup>. By using them, the primary objective of the present form of work is illustrated out, citing for the fulfillment of at par specifications as required for the convergence of modern applications.

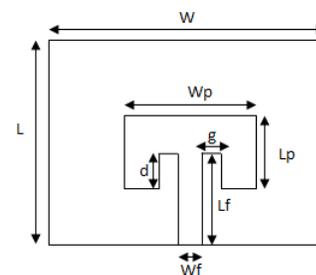
## 2. Design of Prototypes

The whole work includes follow-up of properly based procedural approach where it starts out right from designing out the Conventional Antenna, EBG Structures and finally incorporating both of them in a combined manner to form Metamaterial Antenna which is the final objective of the work as shown in Figure 1.



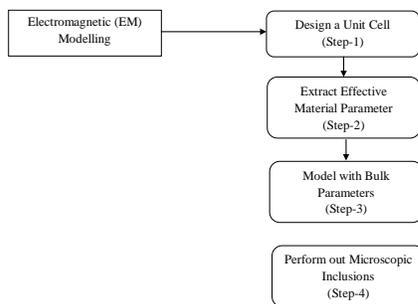
**Figure 1.** Schematic Diagram for Designing the Prototypes.

Rectangular Microstrip Patch Antenna is one of most fundamental structures are to be designed in a manner by following appropriate procedures. Before authors go for designing them, certain basis needs to be calculated by considering the dimensions consisting in general, Width of Patch ( $W_p$ ), Effective Dielectric Constant ( $\epsilon_{r_{eff}}$ ), Length Extension ( $L$ ), Patch Length ( $L_p$ ) with Inset Feed and presence of Ground with consideration for adding out the Substrate as in the Figure 2.



**Figure 2.** Basic Structure of Conventional Antenna.

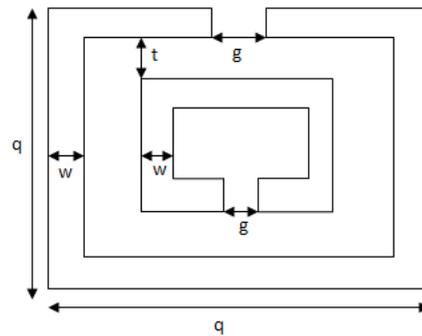
All the above constructional parameters are based on theoretical formulations, which can be taken from literature<sup>15</sup>. By following these steps it has been very much sure of achieving the appropriate constructional modeling dimensions. In order to comply with design layout, modeling parameters associated with them must be understood in a proper way. Their dimensions include  $W = 94\text{mm}$ ,  $L = 78\text{mm}$ ,  $W_p = 47\text{mm}$ ,  $L_p = 39\text{mm}$ ,  $t_m = 0.035\text{mm}$ ,  $h_s = 0.787\text{mm}$ ,  $W_f = 2.3\text{m}$ ,  $L_f = 32\text{mm}$ ,  $d = 12.7\text{mm}$ ,  $g = 1\text{mm}$  which is the case of Conventional Antenna i.e. is Rectangular Microstrip Patch Antenna without the presence of Electromagnetic Band Gap (EBG) Structures. Before going to the next i.e. Design of Electromagnetic Band Gap Structures<sup>16</sup>, we basically need to persuade for the Material Parameter Extraction<sup>17-18</sup> phenomena so as to achieve out the Computational Support to designed prototypes. This includes different approaches like Nicholson-Ross-Weir Method<sup>19</sup>, Lorentz Drude Model, Kramers-Kronig Relationship<sup>20</sup>. All these methods play a vital role in extracting the S-Parameters with the look of all the internal factors. By fortune of analysis, designed unit cells moreover exhibits out Negative Permeability and also the Negative Permittivity in a Frequency Spectrum i.e. for a particular frequency citing out for use in specific band application. Along with this, the modeling must be accommodated for the case of bulk material properties along with microscopic inclusions<sup>16</sup> as visualized in the Figure 3.



**Figure 3.** EM Modelling involves Designing of EBG Structures/ Metamaterials.

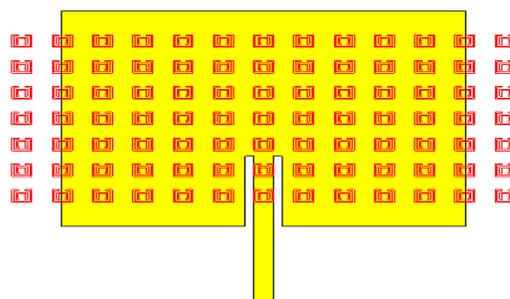
After performing out certain occurrences, Computational Techniques postulates can be further extracted or acquired out by using Full Wave Simulators or by a Electromagnetic Modeling to get the design of an Electromagnetic Band Gap (EBG) Structures like that of Square Split Ring Resonators (SSRR) with an modified form of structure's as

shown in Figure 4 and its extracted out results as shown in Figure 8.



**Figure 4.** Modified Form of EBG Structure coming under Metamaterials.

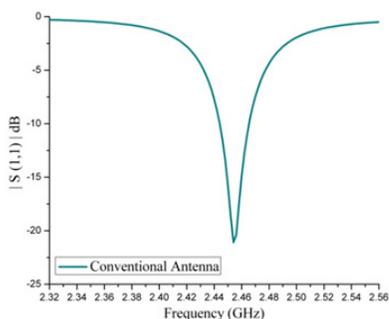
The dimensions of Square Split Ring Resonator (SSRR) are in precision with the application that includes out  $g = 0.3\text{mm}$ ,  $h_s = 0.25\text{mm}$ ,  $q = 2.2\text{mm}$ ,  $l_s = 0.14\text{mm}$ ,  $t = 1.5\text{mm}$ ,  $t_m = 0.035\text{mm}$ ,  $w = 0.2\text{mm}$  which is predominantly the case of Electromagnetic Band Gap (EBG) Structures as a constituent part of Metamaterials. After the design of Conventional Antenna and EBG Structures now we are looking forward towards the designing of Metamaterial Antenna as EBG Structures has been directly etched on the Ground Plane of Conventional Antenna. Basic care should be taken, while carrying the etching of EBG Structures as we have to maintain periodicity in between them. The dimensions of Metamaterial Antenna in the form of Rectangular Microstrip Patch Antenna with the presence of Electromagnetic Band Gap (EBG) Structures, involvement of Conventional with  $W = 84\text{mm}$ ,  $L = 78\text{mm}$ ,  $W_p = 47\text{mm}$ ,  $L_p = 39\text{mm}$ ,  $t_m = 0.035\text{mm}$ ,  $h_s = 0.787\text{mm}$ ,  $W_f = 2.3\text{mm}$  and the follow up by  $L_f = 32\text{mm}$ ,  $d = 12.7\text{mm}$ ,  $g = 1\text{mm}$  as shown out in Figure 5.



**Figure 5.** Structure of Metamaterial Antenna as EBG Structures is directly incorporated in Ground Plane of Conventional Antenna.

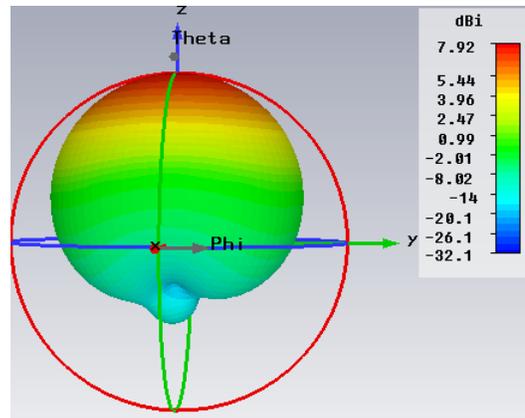
### 3. Exploration of Outcomes

After revealing out the prototype configuration through modes of Constructional Modeling, now it's been convergent to bring in extracted performance of Conventional Antenna, Electromagnetic Band Gap (EBG) Structures and Metamaterial Antenna which needs to go through the Full Wave Simulator and they are simulated by using CST-MWS. Further the effect of EBG on Metamaterial Based Antenna has been shown along with comparative analysis of both Conventional Antenna and Metamaterial Antenna. The results consisting of extracted results of various antenna parameters that include mainframe potentials like Bandwidth, Directivity, Gain, Power Handling Capability, Reflection Co-Efficient and inclusion of an Overall Efficiency for both the Conventional Antenna and Metamaterial Antenna.

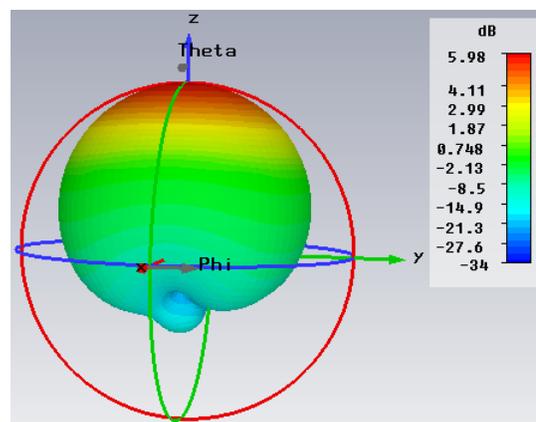


**Figure 6.** Reflection Co-Efficient of Conventional Antenna resonating at 2.45 GHz.

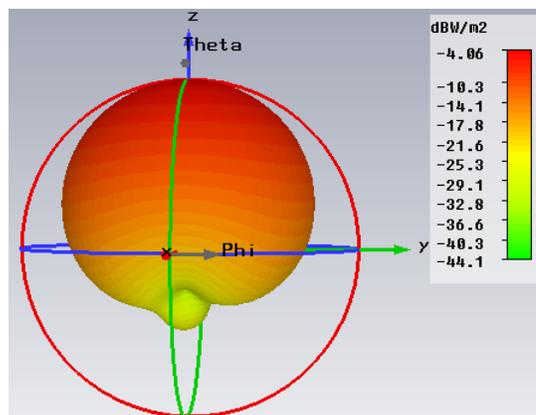
Here, the source free modes play a vital role regarding the behavior of proposed prototype. On account of which these modes been extensively studied out in a much better way for carrying out the computational analysis. The Bandwidth can be calculated by taking differences of frequencies at -10 dB reference line taken as a standard as shown in Figure 6. The authors have also showcased other aspects of results shown in Figure 7, Figure 8 and also in Figure 9 respectively.



**Figure 7.** 3D Plot of Directivity of Conventional Antenna.

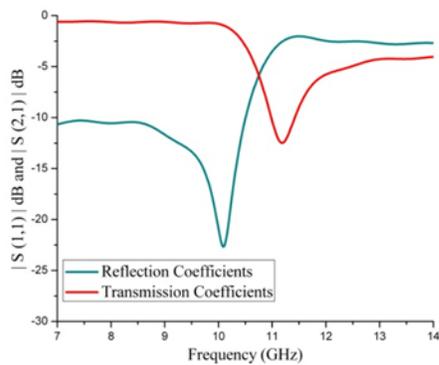


**Figure 8.** 3D Plot of Gain of Conventional Antenna.

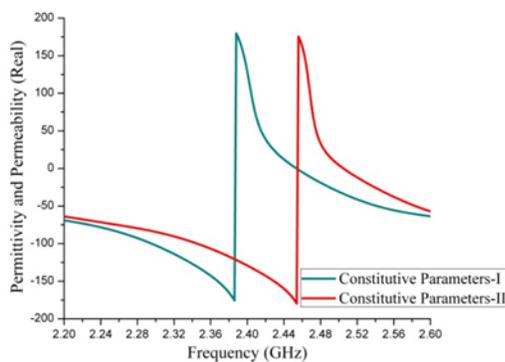


**Figure 9.** 3D Plot of Power Pattern of Conventional Antenna.

After explaining earlier counterparts, the author’s main focus has shifted towards obtaining out the behaviour of EBG Structures as a form of Square Split Ring Resonator. At the time of designing them, there is also a consideration for the standard dimensions of Square Split Ring Resonator which has optimized using the Mathematical Approaches as explained earlier and as shown in Figure 10. As obtaining out, an additional structure which affects out Electromagnetic Waves as a prescribed definition of EBG Metamaterials, the focus has been shifted to find the behaviour at the Wi-Fi Range. This has presumed to an another scope where the behaviour of Electromagnetic Band Gap (EBG) Structures wil come under the shed of Effective Electromagnetic Parameters that highlights the mainframe definition of Metamaterials as shown in Figure 11.

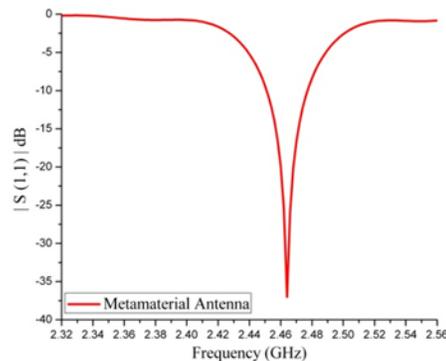


**Figure 10.**  $S_{11}$  and  $S_{21}$  of SSRR taken as a part of Metamaterials.

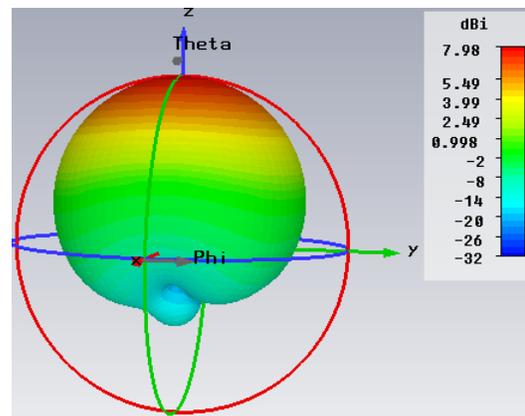


**Figure 11.** Effective Electromagnetic Parameters of SSRR at the Required Frequency.

Coming to the later phase of work, where after getting out all internal behaviour instances of the Electromagnetic Band Gap (EBG) Structures or formerly correlated as Electromagnetic BandG ap Metamaterials in the form of Square Split Ring Resonator, then the authors look forward about the characteristics of the various antenna parameters of Metamaterial Antenna in the form of the Rectangular Microstrip Patch Antenna with the presence of Electromagnetic Band Gap (EBG) Structures as constituent parts of Metamaterials as shown in Figure 12, Figure 13, Figure 14 and Figure 15 respectively. It covers out all the essential antenna parameters that can be illustrated.



**Figure 12.** Reflection Co-Efficient of Metamaterial Antenna Resonating at 2.46 GHz.



**Figure 13.** 3D Plot of Directivity of Metamaterial Antenna.

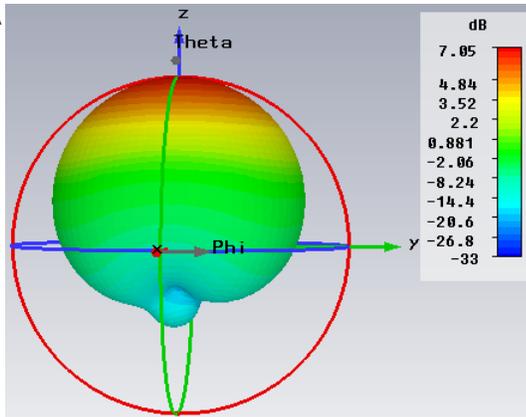


Figure 14. 3D Plot of Gain of Metamaterial Antenna.

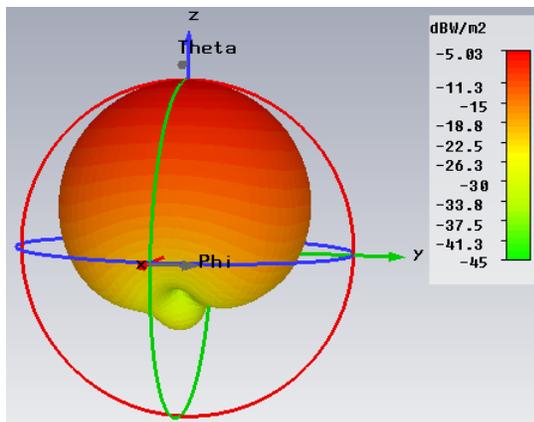


Figure 15. 3D Plot of Power Pattern of Metamaterial Antenna.

After establishing the stable conclusive approach, it has been necessary to study out the effects of the changes in mainframe parameters of Electromagnetic Band Gap (EBG) Structures as Square Split Ring Resonator on Metamaterial Antenna. Here the parameters indulges criterion out in case of parametric study where the author's found variations in different aspects of Reflection Co-Efficient Curves which resonates out at different frequencies ranging from 2.46 GHz to 2.48 GHz including out 2.47 GHz where it achieves a variation from -36.9975 dB, -41.824 dB and -43.2037 dB respectively. With this virtue, authors had noticed that all of the observations had been coming under IEEE 802.11 b/g/n Standard as in Figure 16.

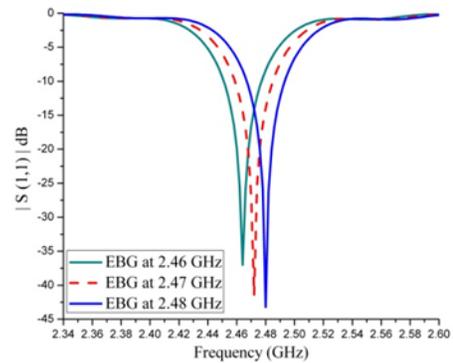


Figure 16. Parametric Comparison of EBG on Metamaterial Antenna.

In last part of the present work, the comparative analysis between the Conventional Antenna and Metamaterial Antenna has been carried out where the extracted results are witnessed in the form of Pictorial Comparison and Tabular Comparison as in Figure 17 and Table I. It is noteworthy to mention that Metamaterial Antenna outsourced the Conventional Antenna with different aspects of Antenna Parameters. The authors have taken reference as Conventional Antenna resonating at 2.45GHz which is the start for IEEE 802.11 b/g/n Standard with the presence of Metamaterial Antenna resonating at 2.46GHz. All these major facts have been tabulated which highlights the mainframe briefings of the work as in Table-I with its upgradation in Table II.

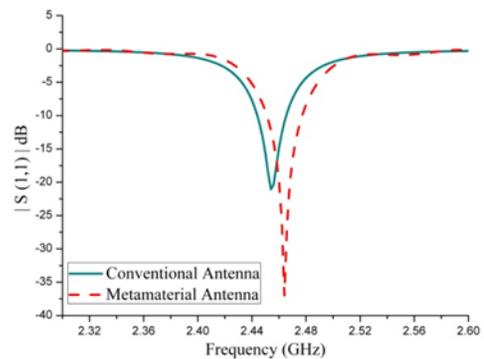


Figure 17. Comparison between Conventional Antenna and Metamaterial Antenna.

**Table 1.** Comparison of Various Antenna Parameters

Parameters	Conventional Antenna (2.45 GHz)	Metamaterial Antenna (2.46 GHz)	Percentage Change
Area	7332mm <sup>2</sup>	6552mm <sup>2</sup>	-28.82%
Bandwidth	21.2MHz	26.2MHz	+23.10%
Directivity	7.900dBi	7.989dBi	+1.126%
Efficiency	2.025dB	3.065dB	+51.35%
Gain	5.983dB	7.045dB	+17.75%
Power	4.063dBW/m <sup>2</sup>	5.034dBW/m <sup>2</sup>	+23.89%
Reflection-Co-Efficient	-21.07 dB	-36.99 dB	+75.55%

**Table 1.** Upgradation of Conventional Antenna

Parameters	Conventional Antenna	Metamaterial Antenna
Bandwidth	Narrow	Improved to +23.10%
Gain	Low	Improved to +17.15%
Efficiency	Low	Improved to +51.35%

## 4. Conclusion

From above the authors has tried to grab the attention with a link or motive that Metamaterials has not only been a unit of Scientific Research but can be strived forward towards the designing of Engineering Applications. With lieu of this, it brings into existence a path where we can look forward into ways of achieving out main potentials in the field of Antenna Design Engineering. In other sense, these Metamaterials has created an era where we could find out the right direction in converting out findings in the lab into applicable industry designs for the specific areas. Also the authors has laid down the stress that Antenna's also plays an important role with the help of Electromagnetic Band Gap (EBG) Metamaterials, the end products can be modernised to go for specifically demanded applications based on Wireless Communication Domain.

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