Bandwidth Enhancement of 4GHz Probe Fed Rectangle Microstrip Patch Antenna with Diagonal DGS Technique for Wi-Fi Applications.

Satyanarayana R,
Research Scholar
Electronics JSS Research Foundation, UOM,
India.

Dr. Shankaraiah,
Professor E & C, SJCE
India.

Abstract
Microstrip antenna is extensively used in Wireless communication and Wi-Fi communications above 1GHz. The demand of increased wireless Wi-Fi communication applications, needs increase in bandwidth, gain and efficiency of microstrip antenna. Microstrip antenna is a low profile antenna but has narrow bandwidth, low gain and efficiency. In this paper a micro strip antenna is designed with 1.6mm, 3.2mm and 4.8mm FR-4 thickness substrate material. The bandwidth was found to be 140MHz, 240MHz and 400MHz. The bandwidth requirement for 4GHz Antenna for Wi-Fi communication is 600MHz(3.6 to 4.2GHz). Hence only with increasing thickness of antenna is not sufficient for Wi-Fi application. Therefore diagonal DGS (DDGS) technique is applied on 3.2mm thickness and 4.8mm thickness FR-4 antennas. This resulted in enhancement bandwidth of 1850MHz (1.85GHz) from 140MHz (1222%) and an radiation efficiency of 88.6% in 3.2mm thickness with DDGS and 1640MHz (1.64GHz) from 140MHZ (1071%) and an radiation efficiency of 78.6% in 4.8mm thickness with DDGS. Both meets the requirement of Wi-Fi application. But gain and S11 was found to be more in 3.2mm thickness with DDGS FR-4 antenna than 4.8mm thickness with DDGS FR-4 antenna. Hence 3.2mm thickness FR-4 with DDGS antenna provides low cost, simple solution for 4GHz Wi-Fi application.

Keywords: HFSS, Bandwidth, Micro strip Antenna, DGS, Wireless communication, Wi-Fi Application

1. INTRODUCTION
Antenna is a basic need in wireless and Wi-Fi communication. The microstrip antenna is widely used above 1 GHZ frequency in Wireless and Wi-Fi communication.

Microstrip antenna is designed using two layers of conductors and a dielectric material. The dielectric material is called substrate. The conductor on top side of substrate is called patch and another on bottom side of substrate is called as ground. The area of ground is larger than patch. The different types of patches are rectangular, square, circular and other shapes [1].

Microstrip antenna has a number of advantages. They are low profile, simple fabrication method, simple to interfacing of ICs. The working of microstrip antenna can be explained by various methods like Transmission line model and Cavity models[2]. It is used in aircraft, mobile, medical and satellite applications. The disadvantages of microstrip Patch Antenna (MPA) are less bandwidth and less gain. Various research groups are working on these issues. The bandwidth enhancement techniques are DGS, Dimensional change, use of different substrates etc[3-15]. More detailed bandwidth enhancement techniques are described below.

A probe fed U-slot MPA symmetrically located antenna, 3different design techniques of characteristics mode analysis is explained by the authors[16]. It was carried a on MPA with single layer ground substrate. It is explained with experimental data. The three methods are ResF, DI dimensional invariance and DI ResF. The ResF uses existence of four resonant frequencies. The DI method mainum invariance depends on property of dimensional invariance. The probe location optimization is required in ResF and DI dimensional invariance. In DI ResF, both the methods of ResF and DI Dimensional invariance features are combined. In this method with minimum or without probe location optimization, the bandwidth and performance enhancement are achieved. For rapid prototyping this method is better than ResF and DI. For critical electrical parameter like width, thickness, feed location and probe dimension to evaluate effect of dominant mode on U-slot MPA characteristics.

Small size uniplanar WWAN tablet computer antenna, bandwidth improvement in paper[17] is carried out, using parallel resonant strip by the authors. The band of frequency covered is 824-960 / 1100-2170MHz. The antenna is fabricated by using 12X40 sq. mm FR-4 substrate. The structure is simple uniplanar structure with feeding strip, PR strip and shorter strip. By quarter wavelength resonant mode of shorter strip and addition resonant mode[18] by PR strip, the antenna wide band is formed. The area is 7X7 sq.mm. A parallel resonance of 1100MHz is achieved by PR strip. In the GSM and WLAN frequency band of 1.8GHz and 2.4GHz, bandwidth enhancement for a dual band circular patch is achieved. This uses a dual circularly symmetric-EBG structure. The CS-EBG structure[18] is simulated and fabricated. The measurements shows bandwidth improvement in both GSM and WLAN frequency band. The improvement is observed in 1.8 and 2.4GHz, front to back ratio are 5dB and

The author Satyanarayana R is a research scholar in JSS Research Foundation, S.J.C.E and Author Dr. Shankaraiah is Prof. & Head of E & C dept. S.J.C.E, Mysore.
7dB. The antenna gain improvement is 0.8dB. In the cross polarisation, there is a significant improvement is observed.

The authors in [19] explains that most of the literature describes about design optimization for RF application on size and shape optimization. The material optimization is very rare. Due to very less access to analysis tools, fabrication of non-homogeneous materials are not carried out much. The authors describes about material design of dielectric substrate and optimum topology. This is used for bandwidth improvement of simple MPA. For practical non-homogeneous substrate, the arbitrary dielectric constant material are used. Using FE-BI solid isotropic material (SIMP) with penalization is used[20]. Mathematically AU algorithm is proposed for Topology optimization. The SLP sequential linear programming is used to solve the non-linear optimization. With this 250% bandwidth achieved. The designed substrate is post processed using image process and fabrication using thermoplastic green machining.

The authors in [21] explains about aperture stacked patch radiation pattern. The patch shape of proposed antenna is designed to decrease effective propagation constant. By this higher order modes are eliminated. The bandwidth is improved from 68% to 76%, when compared with traditional antenna. Bandwidth enhancement of printed wide slot antenna with a parasitic patch is proposed in paper[22] and measured experimentally. Simple 50 ohm micro strip line is used for excitation of the antenna. This is compared with a square slot antenna as a reference. In square slot antenna, two resonant frequencies are found. The lower resonant frequency is decreased and higher resonant frequency is increased. By this method, the bandwidth is increased. This is achieved by inserting parallel patch into the centre of rotating square slot. By this broadband characteristics of wide slot antenna is obtained. The measurement shows that more than 80% in the frequency range of 2.23 to 5.35GHz. Omni direction stable radiation pattern is achieved with the bandwidth. In this structure ground area is smaller when compared to reference antenna.

Wideband MPA using L probe design is described in paper[23]. The air filled substrate with stacked between ground plane. This is designed for frequency of 2.5GHz centre frequency. The effect of design on performance is performed with parametric study. The simulation is carried out on CST microwave studio software. The bandwidth enhancement by L probe fed and parasitic elements. The patch is reduced and gain is enhanced by parallel slots. The performance improvement in bandwidth, VSWR gain and radiation characteristics is achieved. Simulation in bandwidth is 1.04% in the frequency range of 2.44GHz to 2.79 GHz. The value of VSWR is less than 2.

A broadside radiating planar, electrically using small Huygens antenna system that has large impedance bandwidth is described by authors [24]. The bandwidth is improved by including non-Foster component near field resonant parasitic elements. Parasitic elements met materials inspiring antenna. High quality and stable radiation performance characteristics are achieved. Ideal non-Foster components are included. Impedance bandwidth of approximately 17 times is achieved when compared to passive method. gain is 4dB, efficiency is 88% and FTBR is 26.95dB. The impedance bandwidth is maintained 10 times even after using negative impedance converter circuits are used. The peak gain is 3.74dB, radiation efficiency is 80% and FTBR is 28.01 dB. These values are comparable with ideal values.

A capactor fed resonator is designed by the authors. It is used to excite small bent planar monopole antenna. The bandwidth enhancement is tested at 2.4GHz and a bandwidth of 200MHz is obtained, with size of 18.6 X 24 sq. mm.

The bandwidth enhancement of horizontally polarised omnidirectional antenna is described by authors[25]. The proposed antenna designed with feeding network for printed dipole elements, etched slots, parasitic strips and director elements. The printed elements are placed in a square array. The antennas are fed by feeding network with uniform magnitude and phase. The radiation characteristics pattern is omnidirectional radiation. For improving bandwidth parasitic strips and etched slots are introduced. The gain is improved by using four director elements. The antenna is fabricated and measurements are carried out. Bandwidth of 84.2% (1.58-3.88 GHz). The variation in gain in the frequency range of 1.58-3.5GHz is 1.5dB. It is increased to 2.2 dB @ 3.8GHz. In the bandwidth range, the cross polarisation in the horizontal direction is less than -23dB.

A single layer micro strip antenna with micro strip line feeding is designed for bandwidth improvement and harmonic suppression. Lambda /4 micro strip line resonator is designed and fed to micro strip patch using proximity coupling method. There are two resonances, one due to patch another due to Lambda /4 non-resonating resonators. The proposed antenna does not require electrically thick substrate. This makes it low profile and attractive property, due to Lambda /4 resonator and capacitor feeding method [26]. Due to this feeding scheme harmonic motions of higher order harmonics are suppressed very much. Prototype antenna is fabricated for operating at 4.9GHz. Prototype measurements are carried out and compared with traditional antenna. The bandwidth is 2.7 times wider than traditional in-set fed reference antenna. Also spurious harmful radiation of higher order radiating modes are suppressed very much.

A circular symmetric HIS (High impedance surface) used in ground plane of designing two-arm spiral antenna. Spiral arm antenna was simulated and performance was found measured. It was found that due HIS circular periodicity use, gives 16% and 11.3% more operating and fractional bandwidth. The gain of the antenna increased 2.5dB when compared circular HIS with rectangular HIS ground plane [27]. The measurements were carried out and compared with simulation results. The results were found to be comparable.

The author in the paper [28] describes the about use of metamaterial to modify single band patch antenna into double band antenna. The simulations are carried out using CST microwave simulation software. The purpose of optimization of two frequencies instead of single frequency is increase the bandwidth. The patch operates in two frequencies 2.0009 and
2.498GHz. The return loss S11 is -31.4dB and -19.2dB. The bandwidth is 35 and 99MHz. For single band return loss S11 is -10.11dB. The meta material structure is used with split rings for the conversion of single band into two bands. The authors explains in the paper[29] about bandwidth enhancement using Defected Ground structure (DGS) [30] of a rectangular micro strip patch antenna. The design frequency of antenna is 2.4GHz. The bandwidth of the reference antenna is 67MHz. Then the RMPA is designed using DGS technique. A U shaped DGS is done, then E shape and shape DGS is carried out to improve the performance. The performance is improved. This is compared with reference RMPA. The bandwidth is increased from 67MHz to 302MHz with fr = 2.4GHz. This band is suitable for various WLAN applications. HFSS Tool is used for simulation. The authors describes in the paper[30] the method of improving impedance bandwidth using proximity coupling of optically transparent meshed patch antenna. The antenna configuration is solar panel compatible. The proposed antenna is has 3different sizes of meshed elements antenna. This enhances bandwidth 2.5 times the single meshed element antenna.

Compared to these methods the proposed method is simple, low cost and gives better results. A 4GHz rectangular micro strip patch antenna (RMPA) is designed with FR-4 substrate. The performance of the RMPA is simulated. To enhance the bandwidth, the thickness of dielectric is changed to 3.2mm and 4.8mm. To get a wide bandwidth for Wi-Fi application, a diagonal DGS is introduced on 3.2mm and 4.8mm FR-4, 4GHZ RMPA. The 4GHZ RMPA is designed and simulated using HFSS. The bandwidth VSWR and other performance parameters are simulated and compared with that of reference FR-4 antenna. The organisation of this paper is as given here. Introduction and literature study are described in section 1. Section 2 gives Design, feeding of RMPA and proposed Probe feed antenna design. Section 3 describes modelling and simulation of RMPA and diagonal DGS RMPA using HFSS and simulation results. Section 4 gives brief comparison of reference RMPA and 3.2mm, 4.8mm diagonal DGS RMPA and results are discussions. Section 5 describes conclusion and future work. Acknowledgements are given in Section 6.

2.0 DESIGN OF PROPOSED ANTENNA
Rectangular micro strip patch MPA configuration is most widely used as shown in Figure 1. The mathematical model of RMPA can be explained using models of Transmission Line and Cavity [2].

Transmission Line model is s most accurate for thin dielectric substrates. Fundamentally Transmission model represents the RMPA by two slots, separated by low impedance Zc transmission line having length of L. Mathematical model of RMPA using Transmission model is described here. In this analysis the resonating frequency fr, Substrate dielectric material dielectric constant and dielectric material thickness or height h of dielectric substrate material are known. The design parameters W - RMPA Width and L- Length are calculated [2].

2.1. Feeding techniques, Calculation of feed point
There are two types of feedings for MPA as given below.

1) Contact feeding.
2) Non-contact feeding.

In contact feeding there are 2 methods. Line feeding and Probe feeding. In Non- contact feeding Aperture feeding and Proximity coupling feeding are well known methods.

The simple method is microstrip line feed. In this line feeding we have 3 types. They are given below.

1) Centre feeding
2) Off-set feeding
3) In-set feeding

This method provides good impedance matching without use of additional matching device.

The second method is probe feed for RMPA. This method very popular method frequently used for feeding microstrip patch antenna.

The third method is Aperture coupled method of feeding RMPA. It is also known as Electro-magnetic coupling. The advantage of Electro-magnetic coupling is low spurious feed radiation, higher reliability, easy matching of impedance.

Proximity coupling technique for RMPA is fourth method. The advantage of Proximity coupled / indirect feed is less spurious feed radiation. The matching of impedance simple with good reliability. Up to 13% bandwidth can be obtained. The fabrication is tedious process which also requires alignment.

In proposed RMPA, Probe feed is used. The location of probe are calculated as per formulae given in [2]. Then probe position is optimized for optimum performance.

3.0. SIMULATION AND TESTING
Design of FR-4 microstrip antenna is modelled and simulated by HFSS is shown in Figure 2. This reference antenna has single layer substrate of FR-4 material with thickness of 1.6mm. This antenna has resonating frequency of 4.07GHz and bandwidth of 140 MHz and maximum gain of 2.8dB
To improve bandwidth the thickness is increased to 3.2mm. The resonating frequency and bandwidth with 3.2mm is found to be 3.87GHz and 244MHz. Then thickness of substrate is increased to 4.8mm. The resonating frequency with 4.8mm is found to be 3.84GHz and bandwidth is 400MHz. The requirement of 4GHz RMPA for wireless communication Wi-Fi application is 600MHz (3.6 to 4.2GHz). To meet the requirement diagonal DGS method is adopted.

Figure 4 shows the MPA S11 of reference antenna of FR-4 with thickness 1.6mm. The value of S11 is -32.54dB. The bandwidth is narrow and is 140MHz. The resonating frequency is 3.87GHz for 3.2mm FR-4 without DDGS. The value of S11 is -27.315dB. The bandwidth is 244MHz. But it is still less than the requirement. The resonating frequency of 4.8mm without DDGS is shown in Figure 5 and it is 3.87GHz and S11 is -27.315dB. The bandwidth is 400MHz. But it is still less than the requirement.

Figure 5 shows the S11 characteristics of 3.2mm thickness substrate. Figure shows the MPA S11 of proposed antenna of FR-4 with thickness 3.2 mm. The value of S11 is -27.31dB. The S11 characteristics of 4.8mm thickness is shown in Figure. The resonating frequency is 3.84GHz. The value of S11 is -20.56dB. The bandwidth is 400MHz. This is still 200MHz less than requirement of 600MHz.
Figure 6 shows the MPA S11 of proposed antenna of FR-4 with thickness 3.2 mm with DDGS. The value of S11 is -49.67dB. For meeting the bandwidth requirement, a diagonal DGS method is used in both 3.2mm and 4.8mm thickness. Figure 6 show the S11 characteristics of 3.2mm thickness with diagonal DGS technique. The value of resonating frequency is 4.01GHz and S11 is -49.67dB. The bandwidth is found to be 1.85GHz and it meets the requirement.

Figure 7 shows the S11 characteristics of 4.8mm thickness with diagonal DGS antenna. The resonating frequency is found to be 3.77GHz and S11 is -19.13dB. The bandwidth is found be 1.64GHz and meets the requirement.

Figure 8 shows the VSWR characteristics of reference Antenna. The value of VSWR at resonance is 1.18.

Figure 9 shows the VSWR of FR-4,3.2mm MPA.

Figure shows the MPA VSWR of proposed antenna of FR-4 with thickness 3.2 mm. The value of VSWR is 1.13.

Figure 10, Figure 11 shows the VSWR characteristics of 3.2mm thickness with diagonal DGS. The value of VSWR is found to be 1.28. Figure 10 shows the VSWR characteristics of 4.8mm thickness with diagonal DGS technique. The value of VSWR is 1.3. In all Figures the value of VSWR are almost same and less than 2. The Acceptable value of VSWR is less than or equal to 2. Hence VSWR is acceptable in all cases.
The 3D total gain of reference antenna is shown in Figure 12. The value of gain is 2.8dB. Figure 13 shows the gain of 3.2mm thickness RMPA. The value of gain is 3.4dB. The Figure 14 shows the gain of 4.8mm thickness. The value of gain is 3.36dB. The gain 3.2mm and 4.8mm is more than 1.6mm thickness. But gain of 3.2mm and 4.8mm are almost same. The Figure 13 shows the gain of 3.2mm thickness with diagonal DGS technique. The value of gain is 2.6dB. Almost same as reference antenna.

Figure shows the MPA Gain of FR-4 with thickness 3.2 mm with DDGS. The value of gain is 2.6dB. From comparison the bandwidth and efficiency is enhanced by 1071.43%, 6.25% of proposed 4.8mm thickness with DDGS FR-4 RMPA. The proposed RMPA has better performance Enhancement and meets 4GHZ Wireless Wi-Fi application.

Figure shows the MPA Gain of FR-4 with thickness 4.8 mm with DDGS. The value of gain is 1.8dB. This value is 1dB less than reference antenna.

Figure shows the MPA Directivity of reference antenna of FR-4 with thickness 1.6mm. The value of directivity is 4.3 dB. Figure 16 shows directivity of reference MPA. The value of directivity is found to be 4.2. Figure 17 shows the directivity of proposed MPA, the value of directivity is 3.02 dB. There is almost 1dB difference in directivity proposed RMPA.
Figure shows the MPA Directivity of proposed antenna of FR-4 with thickness 4.8mm. The value of directivity is 3.02 dB.

Figure shows the MPA radiation pattern of proposed antenna of FR-4 with thickness 3.2 mm with DDGS. The radiation pattern is hemisphere.

Figure shows the MPA radiation pattern of proposed antenna of FR-4 with thickness 4.8 mm with DDGS. The radiation pattern is hemisphere. 2.8dB gain and hemisphere. The impedance in all cases is matched and equal to 50 ohms. It is found to be acceptable.

### 4.0. COMPARISON OF RESULTS

The comparison of reference RMPA (1.6mm FR-4) and 3.2mm thickness FR-4 with DDGS RMPA, 4.8mm thickness FR-4 with DDGS RMPA are described in this section.

#### 4.1 Performance Comparison of Reference and 3.2mm thickness with DDGS Proposed Antenna

The comparison of FR-4 reference and proposed RMPA with shown in Table 2.

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Parameter</th>
<th>Reference RMPA</th>
<th>Proposed RMPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Resonance Frequency</td>
<td>4.07GHz</td>
<td>4.01GHz</td>
</tr>
<tr>
<td>2</td>
<td>S11</td>
<td>-32.54dB</td>
<td>-49.67dB</td>
</tr>
<tr>
<td>3</td>
<td>Bandwidth</td>
<td>140MHz</td>
<td>1850MHz</td>
</tr>
<tr>
<td>4</td>
<td>Gain</td>
<td>2.8dB</td>
<td>2.6dB</td>
</tr>
<tr>
<td>5</td>
<td>Input impedance</td>
<td>50 ohms</td>
<td>50 Ohms</td>
</tr>
<tr>
<td>6</td>
<td>Radiation pattern</td>
<td>Hemisphere</td>
<td>Hemisphere</td>
</tr>
<tr>
<td>7</td>
<td>VSWR</td>
<td>1.18</td>
<td>1.28</td>
</tr>
<tr>
<td>8</td>
<td>Efficiency</td>
<td>73.68%</td>
<td>86.6%</td>
</tr>
</tbody>
</table>
The comparison of FR-4 reference and proposed RMPA with 4.8mm thickness with DDGS is given in above Table 2. From comparison, it is found resonance frequency is of reference and proposed 4.8mm thickness DDGS RMPA almost same near the design frequency of 4GHz. There is improvement of -17dB of S11 at 3.77GHz. Efficiency of proposed RMPA is 86.6% when compared with reference antenna’s 73.68%. It is 15% more than reference antenna. From comparison the bandwidth, S11 and sensitivity is enhanced by 221%, 53.1% and 17.8% in proposed 4.8mm thickness with DDGS FR-4 RMPA. The proposed RMPA has better performance enhancement and meets 4GHz Wireless Wi-Fi application.

4.1 Performance Comparison of Reference and 4.8mm DDGS Proposed Antenna

The comparison of FR-4 reference and proposed 4.8mm thickness with DDGS are shown in Table 3.

TABLE III
PERFORMANCE COMPARISON OF REFERENCE AND 4.8MM DDGS PROPOSED RMPA

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Parameter</th>
<th>Reference RMPA</th>
<th>Proposed RMPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Resonance Frequency</td>
<td>4.07GHz</td>
<td>3.77GHz</td>
</tr>
<tr>
<td>2</td>
<td>S11</td>
<td>-32.54dB</td>
<td>-19.13dB</td>
</tr>
<tr>
<td>3</td>
<td>Bandwidth</td>
<td>140MHz</td>
<td>1640MHz</td>
</tr>
<tr>
<td>4</td>
<td>Gain</td>
<td>2.8dB</td>
<td>1.8dB</td>
</tr>
<tr>
<td>5</td>
<td>Input impedance</td>
<td>50 ohms</td>
<td>50 Ohms</td>
</tr>
<tr>
<td>6</td>
<td>Radiation pattern</td>
<td>Hemisphere</td>
<td>Hemisphere</td>
</tr>
<tr>
<td>7</td>
<td>VSWR</td>
<td>1.18</td>
<td>1.3</td>
</tr>
<tr>
<td>8</td>
<td>Efficiency</td>
<td>73.68%</td>
<td>78.26%</td>
</tr>
</tbody>
</table>

The comparison of FR-4 reference and proposed 4.8mm thickness with DDGS are given in above Table 3. From comparison, it is found resonance frequency is of reference and proposed 4.8mm thickness DDGS RMPA 3.77GHz, is less but acceptable. The proposed antenna S11 is -13dB of less than reference RMPA. The bandwidth is 11.7 times more than reference RMPA. The minimum required bandwidth is 0.6GHz and achieved bandwidth is 1.64 GHz. The bandwidth is enhanced by 11.7 times. The gain is 1dB less in proposed Antenna. The directivity and Radiation pattern are comparable. Input resistance and SWR are same. The input resistance is 50 ohms. The VSWR of reference RMPA is around 1.18 and the VSWR of Proposed RMPA is 1.3 is and it is good matching of antenna with transmission line. Efficiency of proposed RMPA is 78.26% when compared with reference antenna’s 73.68%. It is 6.25% more than reference antenna.

5. CONCLUSION

Rectangular microstrip patch antenna (RMPA) is designed with 1.6mm, 3.2mm and 4.8mm thickness FR-4, but the bandwidth is 140MHz, 240MHz and 400Mz respectively. The requirement of bandwidth for 4GHz antenna for Wi-Fi application is 600MHz (3.6 to 4.2 GHz). Hence diagonal DGS technique was adopted on 3.2mm and 4.8mm thickness antennas. The bandwidth, S11, efficiency of 3.2mm thickness with DDGS is found be 1850MHz (1.85GHz), -49.67dB and 86.66% and meets the requirement of Wi-Fi application. The bandwidth, S11, efficiency of 4.8mm thickness with DDGS is found be 1640MHz (1.64GHz), -19.13dB and 78.26% and meets the requirement of Wi-Fi application. But gain of 3.2mm thickness with DDGS RMPA is more than 4.8mm thickness with DDGS RMPA. Hence we can conclude 3.2mm thickness with DDGS RMPA is more suitable for 4GHz Wi-Fi application. The Future work RMPA bandwidth enhancement can be extended for various shapes of microstrip patch with other types of feed methods, different shapes of slots and different substrate materials.

6. ACKNOWLEDGMENT

We thank University of Mysore, Dr. Hallappa Gajera of Hemagangothri Dept. of PG Hassan Mysore University, JSS Research Foundation and Sri Jayachamarajendra College of Engineering, Mysore for encouragement and support.

REFERENCES

[6] Gullu Kiziltas ; Pschoudokis ; and Norboru kikruchi;


[12] Hong-Yin Zhang ; Fu-Shun Zhang ; Fan Zhang,Tian Li ; and Chao Li ( 2017), Bandwidth Enhancement of a Horizontally polarized omnidirectional Antenna by adding parasitic Strip IEEE Antennas & Propagation Letters Vol. 16


[18] Petropoulos Ioannis ; Abd-Alhameed ; Raed A; Jones; Stephen; and Voudouris, Kon-stantinos ; ( 2013 ), Development of an antenna system for a relay-based wireless network. Simulation and measurement of antenna systems for relay based wireless network, covering the backhaul and access links and applying beam forming technology, University of Bradford.

[19] Hemant Suthar; Debdeep Sarkar; Kushmanda Saurav; and Kumar Vaibhav Srivastava; (2015), Gain enhancement of microstrip patch antenna using near zero index metamaterial (NZIM) lens, Twenty First National Conference on Communications (NCC)


[22] Ming-Chun Tang;Ting Shi; and Richard W.Ziolkowski; (2017) , Electrically Small, Broadside Radiating Huygens Source Antenna Augmented With Internal Non-Foster Elements to Increase Its Bandwidth, IEEE Antennas and Wireless propagation letters , volume. 16

[23] Runbo Ma ; Jianguo Yan; Yifan Bai; Liping Han; and Qingsheng Zeng ; (2016), Small Bent Planar Monopole Antenna with Capacitive-fed Resonator to Enhance Bandwidth, IEEE conference 978-1-4673-8762-0/16

[24] Hong-Yin Zhang ; Fu-Shun Zhang; Fan Zhang; Tian Li ; and Chao Li ; (2017), Bandwidth Enhancement of a Horizontally Polarized Omnidirectional Antenna by Adding Parasitic Strips. IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 16

[25] Jin-Dong Zhang ; Lei Zhu ; Qiong-Sen Wu ; Neng-Wu Liu ; ,and Wen Wu ; (2016), A Compact Microstrip-Fed Patch Antenna With Enhanced Bandwidth and Harmonic Suppression, IEEE TRANSACTION ON ANTENNAS AND PROPAGATION, VOL. 64, NO. 12

[26] Mikal Askarian Amiri ; Constantine A. Balanis ; and Craig R.; (2017) Gain and Bandwidth Enhancement of a Spiral Antenna Using a Circularly Symmetric HIS, IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL.16


[28] Tursunjan Yasin; and Rejhan Baktur; (2017) , Bandwidth Enhancement of Meshed Patch Antennas Through Proximity Coupling, IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 16
[29] Adeline Mellita ; Chandu DS; and S S Karthikeyan ; (2016) , Gain Enhancement of a Microstrip Patch Antenna Using a Novel Frequency Selective Surface IEEE conference 978-1-4673-8983-3/16


Authors Biography

R.Satyanarayana received B.E degree in Electrical and Electronics Engineering from Mysore University, Karnataka, India in 1997. He Received M.Tech in VLSI Design & Embedded systems from Visvesraya Technological University in 2012. Currently he is Research Scholar of Electronics in SJCE, JSS Research Foundation under Mysore University. He has more than 15 years industrial experience and more than 7 years teaching experience. His area of interests are Embedded system Product and Software Testing, Analog VLSI Design and implementation, Antennas and Propagation, EMI / EMC Design & testing and Microstrip Antennas.

Dr. Shankaraiah received his B.E degree in Electronics and Communication Engineering from Mysore university in 1994. M.Tech Degree in Digital Communication systems from Mysore university 1997. He completed his Ph.D under the guidance of Prof.P.Venkataraman Dept. of ECE, IISC Bangalore. He has investigated a transaction based on QoS,Resource Management scheme for mobile communication. He has more than 20 years of teaching experience in Engineering. He published more than 30 papers in national and international journals and conferences. He is reviewer and Chair for many conferences. His research includes Bandwidth Management, Quality of service ( QoS) management, topology management and Energy Management for Hybrid wireless superstore environments. He is a Life member for India society for Technical Education (LMISTE). Presently working as Professor and Head in the department of E & C of Sri Jayachamarajendra College of Engineering, Mysore, Karnataka India.