METAMATERIAL STRUCTURES FOR UWB APPLICATIONS: A REVIEW

Manika Gupta[1], Beant Kaur[2], Garima Saini[3]

[1]Manika Gupta Department of Electronics and Communication Engineering, Punjabi University, Patiala
[2]Beant Kaur Department of Electronics and Communication Engineering, Punjabi University, Patiala
[3] GarimaSaini Department of Electronics and Communication Engineering, NITTTR, Sector 26, Chandigarh
Email: [1]manika3590@gmail.com,[2]sandhu.beant@gmail.com, [3]garimasaini_18@rediffmail.com

Abstract—In the recent years, wireless communication technology has shown a rapid growth. A low profile antenna that shows multiband characteristics with wide bandwidth coverage, allows high speed data transmission and can be easily fabricated in the housing of communication devices is required. The major drawback of conventional antennas is narrow bandwidth, lower gain and large size. Metamaterials is a promising future technology that provides ultra wide bandwidth and can be easily incorporated in various antenna designs. Metamaterials are unnatural materials which can be only engineered and shows properties such as negative permeability and negative permittivity. In this paper, a review on different types of metamaterials and their properties has been presented. It can be analyzed that metamaterials provide wide bandwidth coverage with low profile structure.

Keywords—Metamaterial; Wide bandwidth; Multiband; UWB; negative permittivity; negative permeability

1.Introduction

In February 2004, the Federal Communications Commission assigned 3.1-10.6 GHz band for Ultra Wideband (UWB) radio applications. At present time, mobile communication is advancing fast with the use of handheld devices [1]. The mobile communication holds WLAN approach with high data rate. UWB and multiband devices can be collaborated compactly to be hiding in the back cover of portable devices. Close studies have been carried out on fabrication of PIFA designs with different types of slots and loop structures on ground plane. Loop design is refined form for PIFA, hence resulting in miniature and easy feed antenna. PIFA including other internal antennas are generally designed to cover various communication bands GSM900 (880-960 MHz), GSM1800 (1710-1880 MHz), GSM1900 (1880-1990 MHz), UMTS (1920-2170 MHz), WiBro (2300-2390), LTE2300 (2305-2400 MHz), Bluetooth/WLAN (2400-2480 MHz), LTE2500/WiMAX (2500-2690 MHz), HiperLAN/2 (5470-5725 MHz) [2].

In this era, the amendments in telecommunication are distinguished by the use of compact, light and diverse handheld devices [3]. PIFA is a subtype of inverted F antenna (IFA) which consists of a radiating wire replaced by a shorting plate [4]. In IFA, the bandwidth increases with thickness and input impedance can be allocated to have a suitable value for impedance match using supplementary circuit [5]. The care is being concentrated on the high performance of antennas with simple construction, one such committed antenna which shoulders the high performance for mobile devices is planar inverted F Antenna (PIFA) [6].

PIFA is beneficial in many aspects such as reduced specific absorption rate (SAR) towards the head of the user, thus decreasing the electromagnetic power absorption and enhancing antenna output. Another boon is that the PIFA manifests adequate to high gain [7]. The only drawback of PIFA is its narrow bandwidth which is a major limitation in telephony communication. A simple remedy to reduce antenna size is by placing shorting plate near feeding pin but this result in narrow bandwidth. For mobile communication, PIFA is kept in the housing of the back cover of cellular devices exactly above the battery [8]. The problem arise in the fabrication of PIFA is to obtain the suitable frequency band for which PIFA height should be between 8-12 mm above ground plane. The large height of antenna makes the phone thick though the battery is very thin [9].

Recently, the experimental and theoretical study of metamaterials is on the increase [10]. In 1967, V. G. Veselago studied negative values of dielectric permittivity and magnetic permeability. Positive permeability and permittivity are the properties of conventional materials called as Double Positive (DPS) materials. Metamaterials are known as Double Negative (DNG) materials as they possess property of negative ε and μ. The subtypes of metamaterial structures include Split Ring Resonators (SRRs), Complimentary Split Ring Resonator (CSRRs), Square Spiral Ring Metamaterial Structuresand omega shaped structures [11].
In this paper, a conceptual study is performed on different types of metamaterial structures that are used to improve the bandwidth and gain of the conventional antennas. An overview on various technologies that enhances the bandwidth while maintaining a compact structure of antennas. Section II describes a review on various metamaterial structures adopted to obtain ultra wideband characteristics. The application and future scope of the metamaterial structures are highlighted in section III. Conclusion of the paper has been presented in section IV.

2. Various Metamaterial Designs

2.1 Split Ring Resonators(SRRs)

Metamaterial structures have split ring resonator structures for negative permeability and a thin wire element for negative permittivity. It is a latest design and is formed by two concentric metallic rings with a split on opposite sides. Slits induces the magnetic resonance and concentric rings separation space behaves like capacitive elements. This resonant behaviour supports larger wavelength even more than the rings dimension. Also, with smaller wavelengths metamaterials have applications up to terahertz frequencies.
In this paper, different slit widths of split ring resonators have been reported. The metamaterial comprises of concentric rings of copper on a kapton substrate (ε=3.2). The region between the circles i.e., d= 0.3 mm with a width of w= 0.4 mm, inner circle radius r = 1.4 mm, side a= 6 mm, in order to have the structure diameter of 5 mm. In the analysis, the effect of resonance of three types of gaps has been studied. After experiments, it has been verified that SRRs supports miniaturization of devices with smaller circle diameters even lesser than the wavelengths. Fig. 1 describes the geometry of proposed antenna [12].

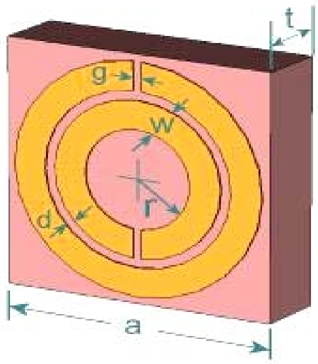

Fig. 1 Geometry of Split Ring Resonator [12]

3.2 Complimentary Split Ring Resonator (CSRR)

The metamaterial structures provides favourable features such as multiband operations controlled radiation properties, miniaturization, low spectral power density, low cost, high data transmission rate and can be used for ultra wide band applications. Complimentary Split Ring Resonator (CSRRs) is used for enhancing the characteristics of metamaterial antennas. These structures can be modelled as LC circuits and can be used for improving impedance matching and bandwidth.
In this paper, an ultra wide band antenna using metamaterial structure has been proposed. The unit cell of metamaterial structure consist of two capacitance loaded strips (CLSs), gapless ring and split ring. An impedance bandwidth from 3.07-19.91 GHz can be obtained from the proposed antenna. The proposed antenna consisting of metamaterial structure has a compact size of 0.28λ * 0.19λ * 0.02λ. Also, the antenna provides high gain of 8.57 dBi, efficiency of 85.42 %,

omnidirectional radiation pattern and VSWR less than 2. Hence, the proposed antenna covers 146.56 % fractional bandwidth and is properly matched to UWB frequency range. The metamaterials structure provides simplicity and compactness and potentiality to the proposed antenna for UWB applications. Fig. 2 describes the geometry of proposed antenna [13].

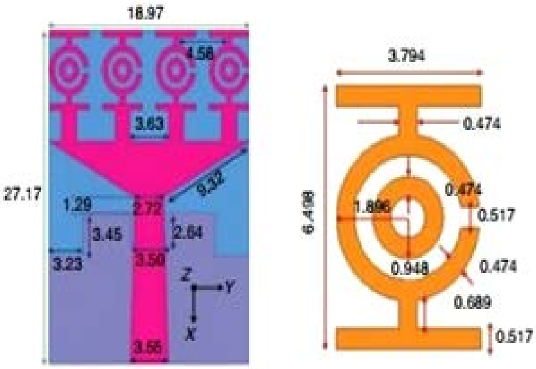

Fig. 2 Geometry of Complimentary Split Ring Resonator [13]

3.3 Square Spiral Ring(SSR)

The metamaterials have novel properties such as negative permeability, negative permittivity and negative refractive index. Printed Yagi antennas have low cost of fabrication, compact size, and low cross polarization and high radiation efficiencies. These antennas provide wide band performance which can be achieved using stepped impedance coupled structure and dual resonant driver.

In this paper, a Square Spiral Ring (SSR) metamaterial Yagi antenna has been proposed. The antenna is rested upon Rogers 5870. The antenna provides a wide bandwidth from 2.38 GHz to 2.51 GHz when centred at 2.54 GHz and 2.92-3.36 GHz when centred at 3.06 GHz. A peak gain of 10dBi can be observed from the proposed antenna. The performance parameters are achieved due to SSR metamaterial structures imposed on Yagi antenna. These antennas find their applications in WiMAX, WLAN and Wifi. Fig. 3 describes the geometry of proposed antenna [14].

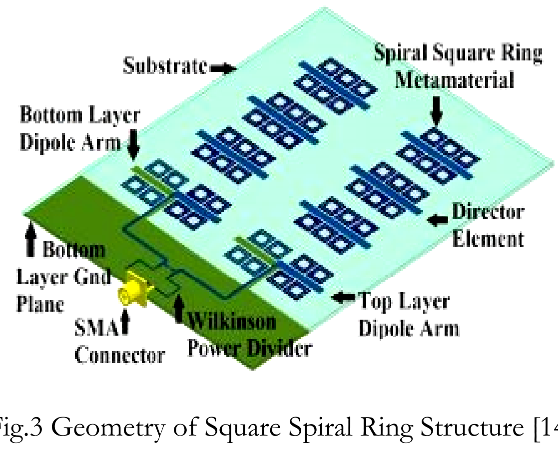

Fig.3 Geometry of Square Spiral Ring Structure [14]

3.4 Omega Shaped Metamaterial

Radio frequency identification is used as an auto identification technique to identify items books, animals, books etc. In 1960, the RFID uses RADAR and radio frequency (RF) frequency for communication and for tracking the movement of enemies. The RFID antenna can be easily designed using rectangular antenna because of low cost of production and

compact size. But these antennas suffer a major disadvantage of narrow bandwidth which can be overcome by using various metamaterial structures.
In this paper, a rectangular patch antenna with dimensions 14.2857 * 11.1897 mm^2 has been proposed. The antenna is designed using Taconic RF-35 substrate having permittivity of 3.5. In order to improve various performance parameters of the antenna an omega shaped is introduced on the rectangular patch. With the introduction of metamaterial structure, the return loss of the antenna increases to -20.20 dB. Also, the radiating bands of the proposed antenna increases from 3-5. The radiation pattern and the gain of the antenna is also improved using metamaterial structures. Hence, the antenna can be efficiently used in RFID devices. Fig. 4 describes the geometry of presented antenna [15].

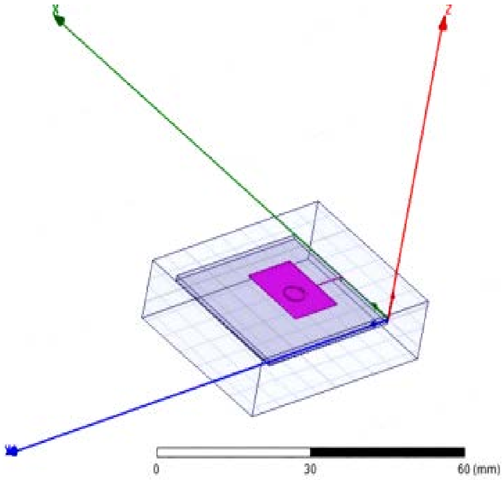

Fig.4 Geometry of Omega Shaped Structure [15]

3. Applications and Future Scope

The metamaterial structures find their application in optical sensing and super resolution imaging, elctro optical dynamic control of light, light harvesting for solar cell technology, electromagnetic cloaking etc.
The future scope of metamaterial structures is to design invisible cloaks. Although, it is a long term process but steps have alredy been taken in the desired direction the metamaterial structures bends the light in unusual ways, following the surface boundary of the material and follows the same path as it went in [16].

4. Conclusion

Planar inverted F antenna have various applications in communication systems. Although it has advantages such as compact size, easy fabrication and reduced SAR, it suffers from major disadvantage of narrow bandwidth and gain. Use of metamaterials is one such remedy which can enhance the performance parameters of antenna such as bandwidth, gain, efficiency etc. these structures can be designed on the substrate and the ground plane. By using metamaterials the antenna gain can be increased from 1.5 dB-7 dB and the size can be reduced to half of its original dimensions with ulta wideband coverage.

References

[1] F. N. M. Redzwan, M. T. Ali, M. N. Md. Tan, NF. Miswadi, "Design of Tri-Band Planar Inverted F Antenna (PIFA) with Parasitic Elements for UMTS2100, LTE and WiMAX Mobile Applications," IEEE I4CT 2015, pp. 550-554, April 2015.
[2] Y. Hong, J. Lee, J. Choi, "Design of a Multi-Band Antenna for 4G Wireless Systems," The 8th European Conference on Antennas and Propagation (EuCAP 2014), pp. 597-600, 2014.
[3] N. Kumar and G. Saini, "A Multiband Pifa with Slotted Ground Plane for Personal Communication Handheld Devices," vol. 7, pp. 70 –74, 2013.

[4] F. N. M. Redzwan, M. T. Ali, M. N. Md. Tan, NF. Miswadi, "Design of Planar Inverted F Antenna for LTE Mobile Phone Application," IEEE Region 10 Symposium, pp. 19-22, 2014.
[5] S. Saini, S. Singh, N. Kumar, "A review of various of planar inverted F antenna (PIFA) structures for wireless applications," International Journal of Electrical and Electronics Engineering, special issue 1, vol.1, pp. 63-65, 2015.
[6] J. Tsai, Y. Chen, C. Wu, "Dual-Band Planar Inverted-F Antenna for Application in ISM, HYPERLAN, UNII, and WiMAX," Microwave Conference Proceedings (APMS), pp. 1340–1342, 2012.
[7] N. Kumar, G. Saini, "A Novel Low profile Planar Inverted-F Antenna (PIFA) for Mobile Handsets," Int. J. Sci. Res. Publ., vol. 3, no. 3, pp. 3–6, 2013.
[8] H. I. Hraga, C. H. See, R. A. Abd-Alhameed, D. Zhou, S. Adnan, I. T. E. Elfergani, F. Elmegri, P. S. Excell, "PIFA antenna for UWB applications with WLAN band rejection using spiral slots," In Antennas and Propagation (EUCAP), Proceedings of the 5th European Conference, pp. 2226-2229, IEEE, 2011.
[9] C. Chiu, Y. Chi, S. Member, "Planar Hexa-Band Inverted-F Antenna for Portable Device Applications," IEEE Antennas andWireless Propagation Letters, vol. 8, pp. 1099–1102, 2009.
[10] H. Attia, M. M. B. Suwailam, O. M. Ramahi, "Enhanced Gain Planar Inverted-F Antenna with MetamaterialSuperstate for UMTS Applications", PIERS Proceedings, pp. 494-497, 2010.
[11] Anisha, S. Thomas, A.K. Prakash, "A Survey on Microstrip Patch Antenna using Metamaterial," International Journal of Advanced Research in Electrical Electronics and Instrumentation Engineering, Vol.2, issue 12, pp. 6289-6294, 2013.
[12] P. J. Castro, J. P. L. Neto, "Experimental Study on Split-Ring Resonators with Different Slit Widths," Journal of Electromagnetic Analysis and Applications, pp. 366-370, 2013.
[13] M. M. Islam, M. T. Islam, M. Samsuzzaman, M. R. I. Faruque, "ComapctMetamaterial Antenna for UWB Applications", Electronics Letters, vol. 51, pp. 1222-1224, 2015.
[14] O. M. Khan, Z. U. Islam, Q. U. Islam, F. A. Bhatti, "Multiband High Gain Printed Yagi Array using Square Spiral Ring Metamaterial Structures for S-band Applications," IEEE Antennas and wireless propagation letters, vol. 13, pp. 1100-1103, 2014.
[15] S. Bhattacharjee, R. Saha, SantanuMaiti, "Metamaterial Based Patch Antenna with Omega Shaped Slot for RFID System," IEEE International Conference on Advances in Engineering and Technology Research, pp. 1-5, 2014.
[16] A. Kumar, N. Kumar, S.C. Gupta, "Review on Microstrip Patch Antennas using Metamaterials," International Journal of Engineering Research and General Science, vol.2, issue 4, pp. 678-682, 2014.