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Various Multi-Frequency Antenna Design Techniques: A Review

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***ABSTRACT:** The paper addresses the requirement for multi banding in Micro Strip Antennas (MSAs), which has been identified as a significant research problem in antenna engineering in the twenty-first century. Statistical analysis/methods: Antennas have had to meet new demands in terms of bandwidth, gain, size, and efficiency as a result of wireless applications that support multiband standards. Recent efforts by a number of researchers around the world to achieve multiband geometry have resulted in the development of new and innovative antenna designs, which are presented in this paper. Findings: This paper provides an overview of different techniques for designing compact, multiband planar antennas for wireless devices and applications. The theoretical concept of achieving a multi-frequency antenna, as well as related design issues, has been discussed in general and briefly. For illustration purposes, design examples, some of which have been published in literature, are presented. This review also includes recent methods such as EBG/AMC, SRR/CRR, FSS, and DGS.*

***KEYWORDS:** Antenna Design, Multi-Frequency, Techniques Used For Designing Antenna, Local Multipoint Distribution Systems (LMDS).*

1. INTRODUCTION

In recent years, wireless technology has undergone significant changes in terms of frequency of allocation, operational standards, device size, and techniques to improve and enhance the performance of wireless systems. With the introduction of new wireless standards that are not only compact but also multi-functional, the demand for wireless devices has skyrocketed. One of the most important components of these wire-free devices is the antenna. Due to the shrinking of hand-held devices, small and lightweight antennas that may be readily incorporated into RF packages are required. As a result, the need for antennas that can cover several homogeneous and heterogeneous wireless communication bands on a single platform has skyrocketed. With numerous wireless standards introducing multi banding capabilities, antenna engineers are faced with the difficult job of developing antennas that are efficient, conformable, and compact, have a low profile and cost, and have enough bandwidth to handle many bands[1].

The fast growth and revolution of wireless technology has resulted in increased demand for integrated components, such as antennas. Because antennas are one of the most important components of integrated low-profile wireless communication systems, antenna shrinking is required to achieve the best design. Other wireless antenna applications, such as Wireless LAN, Worldwide Interoperability for Microwave Access (WiMAX), and some next-generation wireless technologies, are hoped to run at the same time[2]. Various researchers presented the fundamental geometry and configuration of the U-slot antenna in 1995 as a single-layer, single-patch wideband linearly polarized microstrip patch antenna. However, in microstrip patch antennas, the U-slot was primarily utilized for bandwidth improvement rather than creating a band notch, and it has been shown that the U-slot method may be used to build patch antennas with dual and multi-band characteristics. The research on the U-slot patch antenna shown that it can be used for both wideband and multiband (dual and tripleband) applications. Integrating numerous bands for wireless technologies such as AWS (Advanced Wireless Services), GSM (Global System for Mobile), and different WiMAX and WLAN bands running at several frequency ranges is much more difficult. Even with low bandwidths, designing multi-band microstrip patch antennas is difficult. In this case, patch antennas with appropriately constructed holes or slots are helpful[3].

In general, the microstrip patch antenna is an essential component of communication systems that need properties such as small size, low weight, simple manufacturing, and broad bandwidth. The copper substance or a perfect electric conductor is used to make the microstrip patch antenna (PEC). Geometries include circular, rectangular, triangular, elliptical, square, ring, cone, and other shapes. Nonetheless, rectangular and circular forms are the most frequent. The patch antenna's size is determined by the substrate's constant dielectric material. A smaller antenna is caused by a higher substrate dielectric constant. Faster data speeds, greater density connections, and reduced latency are all features of the 1G/2G/3G/4G and 5G generations. With right-angled isosceles, a compact patch feeds a square microstrip. Koch fractal antenna design on the edges is appropriate for applications in the U-wide frequency range. The antenna is mounted on a 60 x 55 x 1.59 mm3 FR4- epoxy (r = 4.4) substrate. The antenna operates at 4.3, 5.0, 6.1, 7.4, 8.9, and 9.2 GHz, however its bandwidth and gain are restricted[4].

To achieve better antenna performance, these small antennas are developed utilizing time-domain electromagnetic and circuit modeling methods and optimized using parametric analysis. The antenna systems developed in this way are utilized in real wireless communication systems including IEEE802.11a WLAN, IEEE802.16 WiMAX, Bluetooth Industrial-Scientific-Medical (ISM) devices, GSM, and Local Multipoint Distribution Systems (LMDS)[5]. Micro Strip Antenna (MSA) is the best option for such systems because of its tiny size, low profile, conformability, and cost effectiveness. MSAs for wireless applications are increasingly focusing on improving these characteristics and developing multiband antennas. In the literature, several methods for antenna downsizing with multiband functionality have been proposed [6]. The goal of this article is to provide a thorough overview of the different methods and designs for small multiband microstrip antennas. We primarily refer to the commonly referenced articles out of the vast amount of research done in this area.

2. DISCUSSION

Various techniques used for design of an antenna are discussed below:

2.1 *Slot Loading:*

Slotting is the process of removing a section of the patch in a particular pattern to alter the micro strip antenna's resonant properties. Cutting slots allows the surface currents on the metal radiating patch to disperse, resulting in multi-banding. Compactness, bi-directional radiation patterns, and multiband performance are additional features. The author created a triangular monopole printed antenna in 2006, which was supplied by a coplanar waveguide with three slots cut into it to disperse surface currents. The addition of slots on the two equilateral sides of the triangular antenna alters the current flow's path length, resulting in multibanding.

2.2 Notch Loading

Notch loading is a form of reactive loading in which a notch is carved parallel to the current lines in the metal radiator. The notch adds series inductance and capacitance to the original resonant circuit, causing the main patch and the notch7 to interact strongly. The notch may be used to reject undesired bands, create wideband antennas, and introduce numerous resonances, among other things.

The effects of the band-notching slit in the PIFA structure are used to cover three broad bands in WLAN/ WiMAX. The slit creates a notched band at approximately 4 GHz by acting as a quarter-wavelength resonant structure. Additionally, at a frequency of 3.5 GHz, it generates an extra resonance. The length of the notch may be reduced, causing the notched band to move to higher frequencies[7].

2.3 Loading of Lumped Elements

Passive (inductors, capacitors, and resistance) components may be added to micro strip antennas to improve radiation resistance, narrow the impedance band width, and decrease size. It also generates numerous resonances and changes the antenna's emission pattern. Each kind of loading has its own set of benefits and drawbacks. The antenna9's Q factor is lowered as a result of the resistive loading. By adjusting the frequency separation between two radiating modes, inductive or capacitive loading may induce broadband and multiband operations, as well as make antennas more compact by lowering the frequency of higher resonant modes to a lower value10. The chip capacitors are utilized across unequal-length slots on a square patch, significantly altering the current distribution [8].

2.4 Micro Strip Antennas with Short Circuits

Multiple bands with various resolutions need the same input impedance, polarization, and radiation properties in certain applications. Short circuit micro strip antennas may achieve the same resonant properties while halving their size. The zero-potential plane of the micro strip antenna is short-circuited using a shorting wall or plate in the fabrication of a shorted micro strip antenna. Which lowers antenna size while maintaining a resonant trace length, resulting in an increase in bandwidth.

A single shorting pin may be used to create a small and electrically adjustable antenna, while two shorting pins can make it multiband or broadband. For example, in11, the designer creates a circular patch with two shorting pins separated by an angle, resulting in multi-band functioning. The frequency may be changed over a broad range by adjusting the shorting pin position11. Broad banding is achieved when the feed is inserted on the x-axis (=0) with a frequency range of 1.9-2.9 GHz.

2.5 The Use of Fractals to Introduce Multiple Resonances

Fractals are irregular or broken forms with Self-Avoidance, Simplicity, and Self-Similarity properties. These are self-similar structures that are replicated at multiple scale sizes, resulting in the same perspective at various scales. Cohen, who designed an antenna utilizing fractal structures, showed how to decrease antenna size without sacrificing performance and accomplish multibanding or wide banding at each band using fractals. Antenna geometry was suggested in 2013 utilizing a space-filling curve, with each subsequent stage consisting of four copies of the preceding one, joined with extra segments. In theory, antenna resonance frequency is inversely proportional to antenna size, thus as the number of iterations increases, the antenna lengths and resonances change, resulting in multiband capability [9].

2.6 Magnetic Conductors Man-Made

The AMC surface is made up of tiny conducting patch elements that are shorted to the ground separately, forming a magnetic ground plane. The image currents will be in phase with the patch current15 as a result of this. These AMC patch components interact with one another to produce parallel resonance to the radiating patch, resulting in a significant increase in gain and impedance bandwidth. The size of the shorting pins was reduced by increasing the AMC

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patch inductance. In 2017, a multiband low-profile antenna based on Artificial Magnetic Conductors (AMC) is developed for automotive applications. The dual-band AMC is used as a ground plane in a wideband printed circular disc monopole antenna, resulting in a low-profile, multiband, and platform-tolerant antenna system [10].

An Electromagnetic Band-Gap (EBG) structure with four spiral-shaped arms was proposed by authors as a replacement for the traditional ground plane of MPA. The authors demonstrated that changing the length and breadth of the spiral ground plane alters inductance and capacitance, resulting in numerous bands, smaller antennas, and improved antenna gain[11].

2.7 Structures with an Electromagnetic Bandgap (EBG)

Electromagnetic band gap structures are manufactured periodic components that prohibit or help EM waves propagate in a certain frequency band for all polarization states and incidence angles. It has a frequency range with very high surface impedances, which causes it to function as a filter. The inductor L is formed by the current flowing through the vias, while the capacitor is formed by the gap effect between neighboring patches in the corresponding LC circuit.

2.8 Ground Plane Structures That Have Been Affected (DGS)

DGS is made up of periodic or non-periodic flaws etched under the ground plane's planar transmission line (e.g., micro strip line, coplanar, etc.). By altering line capacitance and inductance, it changes the shield current distribution and limits it to the perimeter of the perturbation. A unit DGS (dumbbell) consists of two rectangular regions etched in the ground plane linked by a slot. The DGS can generate a stop band, as well as a slow-wave effect and high impedance.

To enhance the performance of a micro strip antenna, several types of slots with various associated area shapes may be carved underneath the planar Transmission line in the ground plane.

2.9 Split Ring Resonators (SRRs)/Complementary SRRs

A single cell Split Ring Resonator (SRR) is a man-made structure that resembles metamaterial. The goal of SRR is to generate the required -magnetic response in various kinds of metamaterials up to 200 terahertz in frequency. SRRs are made up of two concentric metallic rings with slits on opposing sides. To provide strong magnetic coupling between the transmission line and the rings at resonance, SRR may be etched in the back side of the substrate, beneath the slots. The actual portion of magnetic permeability becomes positive below the resonant frequency in SRR, while it becomes negative above the resonant frequency. This characteristic may be combined with another structure's negative dielectric constant to create negative refractive index materials.

Size reduction, wide banding, and multi banding are all done using SRRs in MSA. On a FR-4 substrate, the author develops a dual-band electrically small antenna (ESA) utilizing a tiny ring and two concentric SRR. The extra capacitance provided by the connection between two split-ring resonators and the tiny ring lowers the resonant electrical length. The side gap of the SRR stores a significant quantity of electric field energy, which is represented as resonator capacitance. The gap separation of the SRRs and the circumference of the ring antenna may be utilized to adjust the dual-band ESA's resonant frequencies. The lower band is represented by the outer SRR, whereas the high band is affected by the length of the inner SRR[12].

3. CONCLUSION

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Various kinds of micro strip antenna design methods and micro strip antenna designs are described, as well as novel ways for making the micro strip antenna a low-profile, compact multiband antenna. Different kinds of antenna components and their connection to enhanced qualities with their distinct geometrical properties are given to demonstrate the characteristic features of multiband micro strip antennas. The microstrip antennas are shown to be extremely helpful for commercial and military wireless applications in this article. The area of antenna engineering is very difficult since the effectiveness of the transmitting and receiving antennas determines the efficiency of the whole communication system, therefore it is expected to see a lot more creative development in this sector.

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