A Literature Review of Multi-Frequency Microstrip Patch Antenna Designing Techniques

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Abstract: Proposing compact antennas that integrate different wireless standards is a vital topic of research. Looking at the work done in past few years, the call for multi-frequency antennas have increased enormously. In this review paper, various design techniques for modeling a multi-band antenna are discussed and compared. Antenna parameters such as impedance bandwidth, gain, radiation pattern etc are also discussed.

Keywords: Microstrip, Multi-band, Parasitic Elements, Stacked Patches, Spiral, Fractal

I. INTRODUCTION

Numerous antennas for different purpose already exist, but the thirst of excelling in this expanse has no end. In the always growing and developing communication systems and the application areas along with the obvious requirements of small size, less weight, better performance, ease of integration and low cost, miniaturized multiband antennas are in great demand. Multiband antennas symbolize a single antenna with multiple resonant frequencies with different applications customized as per user requirement and hence are of utmost importance in modern communication systems.

Many techniques have been projected for the designing of multi-frequency radiating elements, the great majority of which are microstrip antennas. The general characteristic, of almost the entire, of the multiband printed elements is that their designing generally is initiated from an ordinary patch shape which is then perturbed. On the basis of the approach of the shape perturbation, the multiband microstrip antennas can be bifurcated in categories

- Printed elements with integrated slits or slots. [1-10]
- Patches with several radiating elements inductively coupled or/and conductively connected [11-16]
- Patches of specific shape as conductively connected cross dipoles[17], the bowtie[18-19], and the spiral [20-22]
- More than one stacked patches [23-29].

Another separate category comprises the fractal microstrip antennas [30-38].

Need of study

The rapid evolutions in the wireless communication industry stipulate novel antenna designs with the purpose of being used in more than one frequency bands and allow size reduction, thus reducing the number of antennas required for various applications. So, the design of small antennas that work on multiple frequencies as per requirement is of great significance. Before directly starting with the designing of such antenna it is better to have knowledge about the various approaches. This paper presents brief review of all the techniques discussed above that enhance multi-band characteristics along with examples, pros and cons; and hence provides a succinct material for beginners in the field.

II. LITERATURE SURVEY

1) Slot or Slit Loaded Multiband Microstrip Antenna

The procedure of slot cutting the printed antenna surface, besides the broadening of the bandwidth has been proved effective in driving the patch to multi-frequency operation. Various slot shapes have been proposed for the texturing of the patch; some indicative results are presented in papers [1] to [10]. Paper [1] proposes a high gain wideband monopole antenna. The regular rectangular patch was transformed into multiple monopole radiators by introducing a number of slits at the far radiating edge. The bandwidth is enhanced by using partial ground plane while placing in suitable slits at the radiating edges improved the return loss and bandwidth as well. Figure 1 depicts the basic geometry of the proposed patch as well as ground. High gain of up to 13.2dB and a wider impedance bandwidth is achieved than an earlier reported design. As substrate, FR4 Epoxy with dielectric constant 4.4 and loss tangent 0.02 has been used. Being simulated using HFSS as a 3D electromagnetic field simulator, good agreement has been found involving the simulated and measured results.

The proposed design is suitable for GSM, GPS, DCS, PCS, UMTS, WLAN/ HiperLAN/IEEE 802.11; Bluetooth, WiMAX & LTE applications.
2) **Multiple or Parasitic Patches**

A different move towards designing of a multiband printed antenna is to employ more than one element of different size which resonates at different frequencies. An indicative structure is proposed in [11] and shown in Figure 2. This paper presents a WCDMA/WLAN antenna which is a combination of a planar monopole, a T-shaped element, and a parasitic element, which results in two distinct operation bands as well as enhanced radiation due to the parasitic element. The overall area of the design with FR-4 substrate is 58 x 65 mm$^2$ with a thickness of 1 mm. The radiating patch consists of two parts: the main patch which is a planar monopole with 10 x 18 mm$^2$, and two side patches on left and right of main patch with dimension 4 x 2 mm$^2$. Antenna with the parasitic element here is the FR4 superstrate, which shift the S11 response to a lower frequency without increasing the size of the radiating patch. The proposed antenna can operates in 1920-2170 MHz WCDMA, 2400-2497 MHz WLAN, 5150-5350 MHz WLAN, and 5725-5825 MHz WLAN bands.

Some other multi-frequency designs based on this concept is indicated in [12]-[16].

3) **Patches of Specific Shapes**

According to the previous works of researchers it can be observed that there are some specific patch patterns or shapes which have the inbuilt tendency of showing multi-frequency characteristics. Conductively connected cross dipoles [17], Vivaldi antennas, Bow-tie patches, spiral shapes are some of them.

In [18], a 50 ohm CPW fed Bow-Tie antenna loaded with slits for multiband operation is discussed (Figure 3). The antenna is printed on a FR4 substrate having relative permittivity of 4.4, with an overall dimension of 100x100 mm. It was concluded by the developer that larger is the slot length $W_s$, lower is the cut-in frequency. The antenna covers many modern wireless systems (GSM, PCS, UMTS, DCS, and UWB) rejecting the WLAN frequencies. [19] Proposed another bow-tie shaped multi-band design.
A suitable alteration of the ordinary printed spirals shapes, especially that of the rectangular shaped, has been proved to be successful for multi-band performance. Two shorted spiral patches were proposed in [20], both of them having an overall size of 17×25mm as shown in Figure 4. The substrate used is 10-mm foam and a thin layer of 0.508–mm Taconic TLC30 (εr = 3.0) was used to etch the copper conductor of the patches. The track width was 1.2 mm and the gap width was taken 1 mm for both the configuration. The size of each ground-plane was 4cm×4cm. A dual band operation was obtained in both the cases at frequencies smaller than 1GHz. A reduction in resonant frequency by factors of 6.5 and 10.0, respectively, is achieved by using these two configurations when compared with a standard microstrip patch antenna. This frequency reduction further corresponds to a decrease in dimension by a factor of 111 and 261, respectively.

Another spiral configuration was presented in [21] incorporating smaller number of bend and the corners were also truncated which accounted for smooth current flow. Electromagnetic band gap (EBG) structure is used as defected ground plane structure in [22]. Two spiral-shaped defected ground structure (DGS) cells with each of the cell composed of spiral with four arms were used in the design.

4) Multiple Stacked Patches
A multi-frequency microstrip patch antenna comprising a driven patch along with a plurality of parasitic elements that are placed underneath the driven patch is proposed [23]. The multi-stacked structure consisting four parasitic patches and one driven patch (Figure 5) has been designed numerically using the commercial IE3D MoM-based code. This proposal has been experimentally tested also. The total antenna height is 15.6 mm. The antenna features five operating band with center frequencies 1.63GHz, 1.81GHz, 1.95GHz, 2.09GHz and 2.28GHz having similar gain varying from 1.1 to 1.4 dBi.

More configurations based on stacked patches concept were proposed in [24]-[29] and studied.
5) Fractal Antennas

The fractal technique is based on the scheming of the antenna by duplicating an initial radiating structure in either arbitrary or regular scales for obtaining the desired operational characteristics. These self-similarity properties of the produced configurations are rendered into their electromagnetic behavior and the higher stages of developed fractal geometries would have, for illustration, the feature of multi-frequency operation. In [30], a Koch loop monopole was proposed to resonate at the bands of 2.45GHz and 5.25GHz to serve an 802.11b/g WLAN system. In this case, the generator was an equilateral triangle.

The configuration proposed in [31] was successfully used to build a tri-band microstrip antenna for GPS, DCS1800 and 2.7GHz. The generator square patch had a side length of 78.25mm and substrate used had a dielectric constant of 1.046 and height 6mm. The desired performance was obtained by the configuration shown in Figure 6 which came from the combination of four patches of the first stage, slightly overlapped. Two probes were used for feeding and further the operation was enhanced by using two pins.

![Figure 6: Fractal Antenna Layout a) Square patch modified via the first stage inverse van Koch fractal curve b) Final structure produced by the union of four fractal elements [31]](image)

[32]-[38] proposed multi-band designs based on various fractal types such as Sierpinski carpet fractal modeling, Sierpinski gasket fractal modeling, Hilbert curve and other fractals of different shapes.

III. CONCLUSION AND FUTURE SCOPE

A variety of techniques for modeling a multi-frequency microstrip patch antenna were studied and discussed. Most easy and commonly used scheme is cutting of slots. While some special shapes such as bow-tie, Vivaldi antenna or spiral patterns have inbuilt multi-frequency tendency; multiple parasitic patches are also used to achieve the target frequencies. Other techniques are using stacked patches or some of the fractal concepts with proper concern. More work can be done in future by integrating some of these techniques together resulting in much better operational characteristics that overcome shortcomings of individual techniques.

Limitations and implications of the study

The paper discuss about various methods to obtain multi-frequency characteristics and their merits and demerits. It serves only as a foreword. Slot cutting method is easy to implement but has poor radiation patterns and gain. These things are improved in the other methods like stacked patch, parasitic coupling or fractal curves but they are a hard job to implement as prototype. Hence, this study can be used by research scholars to get a nutshell about the basic concepts of multi-frequency field, compare various techniques and select as per their requirement.

IV. REFERENCES


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