Gain and Bandwidth Considerations for Microstrip Patch Antenna Employing U and Quad L shaped Slots with DGS and Parasitic Elements for WiMax / WiFi Applications

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Abstract—In this research article, a microstrip patch antenna for Wireless Applications is presented. Stage by stage, the antenna is modified to achieve the desired wideband characteristics. The final proposed antenna is a combination of U and Quad L shaped slots with L shaped DGS and U shaped dual parasitic elements. Parameters S11, bandwidth and gain of the antenna versions during each stage are noted and steps are taken to improve these parameters. The end result is a wideband microstrip patch antenna working in the frequency range of 4.75 GHz to 6.15 GHz with a bandwidth of 1.40 GHz. The peak gain observed is about 7.24 dB at 5.64 GHz frequency. Simulations are carried out using HFSS software. The obtained results show that the proposed antenna can be extensively for WiFi (4.9 GHz to 5.9 GHz) and WiMax (5.3 GHz to 5.8 GHz) Applications.

Index Terms—Quad L slots, U shaped slot, DGS, parasitic elements, WiFi, WiMax.

I. INTRODUCTION

Increased demand is shown towards multiband operated antennas in the present day trends of the wireless systems. Even though the task of achieving this is difficult there is an increased scenario in terms of research going at various levels. Because of its advantageous features such as low profile, simple structure, and compactness, compatibility the monopole antenna has become an important contender in this aspect. Also, the monopole antenna has the unique advantage of integrating WiMax and WLAN applications onto one particular system [1]. On the other hand, one of the antennas that have the appropriate characteristics, namely the microstrip antenna.

It is a category of the printed antenna. A microstrip patch antenna consists of a dielectric substrate in between radiating and ground patches. In wireless communication, the MPAs are used in many applications. These antennas have many good features such as less weight, ease of manufacturing, low cost, and low profile. These antennas exhibit very low levels of radiating conditions and also they have a compact size. But conventional microstrip patch antennas have some drawbacks such as narrow bandwidth, low gain, and poor efficiency. [2] To obtain, multiband operation, over the years various techniques have been proposed such as slots in the ground plane or on the patch antenna, by adding strips or stubs to the reference patch [3]. Similarly, the inclusion of slots or slots on the ground plane or on the patch or implementing both on a simple broadband antenna is said to produce a multiband/wideband antenna. A split ring slotted patch has been used with step slotted shape defect on the ground plane. With the use of a split ring slotted patch, the size of the antenna is noted to be reduced and bandwidth is said to be also sufficiently improved [4-6]. It has been also analysed that the defected reduced ground plane provides better results in terms of bandwidth enhancement than a full ground plane structure. Defected ground structure (DGS) in microstrip antennas is frequently used as a strategy to reduce the size, reducing unwanted harmonics, improving the bandwidth, reducing the effects of mutual coupling in case of an array. DGS is simply a portion etched off from the ground plane of a particular microstrip antenna. The concept of DGS is also the same when it is applied to coplanar or coplanar waveguide (conductor-backed) that modifies or disturbs the current distribution which results in a stricter and limited excitation of EM through the substrate material.

While cutting slots in a patch, such as U-slot[7][8], E-shaped slot [9], and V-slot[10], and other shapes of slots [11-14] in addition to the single resonant frequency and an additional band resonating at other frequencies can be achieved with a wideband performance. Thus for a single antenna, dual-band frequencies with improved wideband characteristics can be obtained when compared to a normal conventional patch antenna. U-slot is a well-known method to broaden the bandwidth of microstrip antennas [15]. Other methods have also been used to achieve dual/multiband operations. Examples of these include making use of parasitic elements and multiple radiating elements as described in [16] and [17]. As antennas among other different categories, a microstrip antenna fed by strip-line employing wide-slot is mentioned in [18].

In this paper, the main aim is to increase the gain by maintaining the bandwidth to the maximum extent possible. Improvements are carried out at each point to provide better results. The antenna proposed is fed co-axially. The characteristics of the proposed antenna are analysed by ANSYS HFSS, which is a 3D full-wave electromagnetic field resolver for accurate and rapid design of high speed and high-frequency electronic components.
II. ANTENNA DESIGN STRUCTURE

A. Stage One – Conventional design

The proposed antenna as shown in Figure 1 is developed on the FR4 epoxy substrate with dielectric constant ‘4.4’. The loss tangent value for this material is ‘0.002’. The height of the substrate is considered to be ‘3 mm’. As per the dimensions of the patch which is 14.2 mm x 11.8 mm in terms of width and length, the initial conventional antenna is designed to work at 5 GHz frequency. HFSS is used as the simulation software in this case. The antenna dimensions and the parameters in this work are calculated using the equations as mentioned in [15]. The S11 plot and the gain plot for the conventional antenna can be seen in Figures 2 and 3.

B. Stage two – Inclusion of double U slot parasitic elements and U Shaped Slot

To the basic conventional design, to excite dual resonant frequencies, U shape slot is cut on the body of the conventional patch. The dimensions and the position of the U-slot are optimized for better results. The dimensions are taken to be 7.2 mm x 3.6 mm (width x length) along the outer slot dimensions and 6.2 mm x 2.6 mm along the inner slot dimensions. U shape slot is considered for achieving wideband performance. To improve the wideband characteristics of the antenna, two identical parasitic elements in the shape of U are considered [15]. Two resonant frequencies are excited using this variation along the patch. One at 4.93 GHz with S11 value of -16.11 dB and a bandwidth range of 0.45 GHz (4.75 GHz to 5.2 GHz) and the resonant frequency at 5.88 GHz with S11 value of -25.83 dB and a bandwidth range of 0.50 GHz (5.7 GHz to 6.2 GHz). The S11 plot is shown in the comparison plot of Figure 2. The gain in this case, is 7.63 dB at 4.93 GHz frequency and 6.28 dB at 5.88 GHz frequency, respectively. The gain plot in this case, is shown in Figures 4 and 5.
III. CONCLUSION

A microstrip patch antenna is designed and simulated. The design is performed in three stages where modifications are done for the antenna at each stage to improve the S11, gain, and bandwidth parameters. Initially, a conventional antenna is designed to operate at 5 GHz frequency. In order to achieve dual-band characteristics, U shape is cut on the patch surface. At this stage, the antenna resonated at two frequencies 4.93 GHz and 5.88 GHz with 7.63 dB and 6.28 dB. The following stage is to make the antenna operate at wideband frequencies, covering the frequencies achieved in the previous stage. This is achieved with the inclusion of L shaped DGS which made the antenna to realize wideband characteristics covering the frequency of 4.75 GHz to 6.12 GHz with a bandwidth of around 1.40 GHz. The gain, in this case, was achieved at a peak value of 5.35 dB in the bandwidth region. As a final stage in the process, to achieve more gain while sustaining the bandwidth to the maximum extent possible, quad L shaped slots are cut on the surface of the patch. This improved the gain in the bandwidth region with peak value up to 7.24 dB at 5.64 GHz while preserving the bandwidth (4.75 GHz to 6.15 GHz). Therefore, the proposed antenna can be extensively used for WiFi (4.9 GHz to 5.9 GHz) and WiMax (5.3 GHz to 5.8 GHz) Applications.

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C. Stage three – Proposed inclusion of L shaped DGS and Quad L – shaped Slots

The previous version of the antenna is made to resonate at two frequencies of 4.93 GHz and 5.88 GHz with decent gain. The bandwidth offered at these center frequencies is 0.45 GHz and 0.50 GHz. As a third stage in the design, the idea is to excite the antenna with improved wideband characteristics covering both the center frequencies observed in the previous version of the antenna. To achieve this, an L – shaped slot is cut on the ground. This antenna with the inclusion of defected ground structure that contained L shaped slot along the left and bottom edges of the ground improved the impedance bandwidth of the overall antenna. The improved bandwidth is observed to be covering the frequency range of 4.75 GHz to 6.15 GHz which is 1.40 GHz. This is shown in the S11 plot of Figure 2. The gain is computed along the bandwidth covered region of the S11 plot. It is observed that the gain is achieved over 4 dB till 5.35 GHz after which a decline is seen. The peak gain observed in this case is 5.35 dB at 5.66 GHz frequency.

As a final step in the design process, steps are taken to improve the gain further while protecting the bandwidth achieved already to the maximum extent possible. This is done by cutting four L shaped slots along the four corners of the patch antenna. The dimensions of the L shaped slot are optimized to achieve better results, which are 2 mm x 2 mm along the outer dimensions and 1.5 mm x 1.5 mm along the inner dimensions of the slot. This inclusion of quad L shaped slots to the antenna, improved the gain while limiting the bandwidth not to be decreased. Therefore, for the same bandwidth of 1.40 GHz (4.75 GHz to 6.15 GHz), an improved gain is seen with the introduction of quad L shaped slots. The final gain is seen to be well over 6 dB for the frequency values up to 5.64 GHz with a peak gain of 7.24 dB after which a decline is seen. The gain comparison plot for the antenna with the above discussed two variations is seen in Figure 6.
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