DESIGN OF POLYGONAL SLOT ANTENNA WITH TAPERED STRIP-FED MONOPOLE FOR UWB APPLICATIONS.

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Abstract—A compact wide-slot antenna with microstrip-fed monopole for ultrawideband (UWB) application. The monopole is composed of an elliptic patch connected to a trapezoid one. The radiator patch is attached to a 50-Ω microstrip feed line by a smoothly tapered line to enhance the wideband matching. A hexagonal slot is etched from a finite ground plane placed on the other side of the substrate. The antenna has compact physical structure and is designed on standard FR4 substrate. EM Simulation indicates 163% of fractional impedance bandwidth varying from 2 to 20 GHz for VSWR less than 2.

Index terms—Planar monopole, radiator patch, slot antenna, tapered line, ultrawideband (UWB) antenna.

I. Introduction

There has been a rapid development in ultrawideband (UWB) wireless communication technology. Thus, UWB antenna designing has become a hot topic to attract researchers attention, both in academic and industrial points of view worldwide. The Federal Communications Commission (FCC) prescribed the frequency spectrum of 7.5 GHz (3.1–10.6 GHz) for commercial ultrawideband applications in 2002 [1]. Since then, UWB technology is expected to revolutionize prevalent communication systems. Meanwhile, low cost, low weight, small shape, low transmission power, and omni-directional radiation pattern should also be considered, particularly in portable cases. Among various types of microstrip antennas, planar monopole does not require balanced feeding structure and can be implemented in a smaller area compared to equivalent planar dipole, hence it would be a competitive choice to be handled in UWB systems if we could overcome its inherent drawback of narrow bandwidth. Some researchers suggested common alternatives such as using a large ground plane and thick substrate to widen the bandwidth. Using planar wide slot would be another feasible and effective technique due to its likely benefits such as wideband radiation performance, easy fabrication, and bidirectional radiation. In addition, a larger near magnetic field component rather than an electric one in wide slots results in reducing coupling to adjacent slabs if not desired. Round slots with round radiator patches have lately been reported in [2]. In [3] and [4], semiround slots with circular patches are being used. Some others used fork-shaped stubs to excite semicircle slot like in [5]. Reference [6] employed a polygon slot and beveled T-stub to fulfill the FCC’s expectation. Another open-slotted slot with a substrate of 40 × 40mm provides band-notch function demonstrated in [7] to achieve 2.6–13.6 GHz bandwidth. In [8], the authors obtained 111.7% using a via hole to connect the patch and feed, but the response is sensitive to hole dimension and place.

In this paper, we present a new wideband planar geometry for UWB antennas. First, smoothly tapered transition is employed to effectively obtain impedance matching over the band of interest. Also, bent junctions, round patch end, and modified microstrip feeding structure are utilized to enhance bandwidth. A hexagonal slot is inserted symmetrically on the ground plane just in front of the patch for electromagnetic (EM) coupling augmentation. By choosing a proper wide size for the slot, we realized the optimal design with successful increment of 10 dB measured bandwidth up to 163% from 2 to 20 GHz. The substrate area is only 30 × 30 mm, which can be considered as a compact antenna with respect to most of the others. Although supporting the lower UWB range is commonly obtained with larger dimensions, the advantage of this structure is the ability of supporting both lower range and higher range functions, despite a small size.

II. Antenna Structure and Parameters

The geometry of the proposed hybrid antenna, as depicted in Fig. 1, consists of a patch mounted on the top layer of a famous FR4 epoxy substrate with dielectric relative permittivity of 4.6 with thickness of 1.6 mm and a hexagonal-shaped slot etched from a square conducting ground plane on the other side. The ground plane is located in the xy plane in $L_x \times W_x = 30 \times 30$ mm surface. The top-layer patch itself includes a main radiator patch, feed line, and wideband matching. The radiator patch acts as an open-circuit load at the end of the transmission line. The structure is fed by a centered 50Ω- microstrip line by way of another narrow smoothly tapered matching line. Any attachment between feed line slabs is applied tapered in order to give another degree of
freedom for matching, in addition to reducing reflection caused by sudden changes in line width. The primary sharp trapezoidal patch is improved by an elliptical end substitution as well. The junction between the radiator element and feed line is the most critical segment of design. An optimal adjustment of this section can increase the upper frequency and decrease reflection in higher band due to small reflection theory.

Figure 1. Configuration of the proposed prototype.

The etched ground plane acts like a slot to radiate the energy perpendicular to the plane of antenna. Also, placing a ground plane will suppress the back radiations and enhance the gain. Furthermore, its substantial capacitive behavior results in negation of inductive nature of the patch. Actually, this combination can excite different harmonics compared to the conventional ones due to generating traveling wave rather than standing. Although the primary range of the antenna size is estimated according to those represented in [7] and [8], they have been redesigned based on simulation results.

III. Antenna Design

There are several significant parameters that affect impedance matching. Fig. 2 shows how the slot dimensions can influence the performance of the antenna. It can be seen that the Return Loss resemble each other totally, and changing the longitudinal slot parameter (L5) does not affect the first resonance and low cutoff frequency, while it has noticeable impact on high frequency behavior of the antenna.

By looking across the whole spectrum in Fig. 2, it is noticed that the lateral slot parameters (W5, W6, and W7) do not play any critical role in harmonics and antenna performance, both in low frequency and high frequency function. Moreover, the antenna Return Loss for different radiator patch sizes evaluated by EM Simulation is plotted in Fig. 3 to investigate their effect on antenna behavior.
Figure 2. Computed Return Loss against frequency for different slot dimensions. (a) L5. (b) W5. (c) W6. (d) W7.

Figure 3. Computed Return Loss against frequency for different radiator patch dimensions.

Table 1. Dimensions of the Proposed Antenna

<table>
<thead>
<tr>
<th>Parameter</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value(mm)</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>10</td>
<td>20</td>
<td>14</td>
</tr>
</tbody>
</table>

IV. Simulated Results

A. Return Loss and VSWR

The designed monopole antenna was simulated. Fig. 4 and 5 illustrates the simulated Return Loss and VSWR curves for optimal design against frequency. This figure demonstrates the extremely wide operating range from 2 to 20 GHz ascribed to overlapping of three major resonant frequency harmonics around 6, 12.5, and 19 GHz and some other sub-resonants closely distributed across the spectrum. It is seen that the antenna covers the entire UWB band according to the FCC thoroughly and has the ability to be used in the 5.2–5.8-GHz band for WLAN and 5.5-GHz for WIMAX applications. The numerical calculation is confirmed by stimulated data. The structure is simulated with EMDS utilizes finite integration technique for EM computation.

Figure 4. Simulated Return Loss of antenna with optimal design parameters.

Figure 5. Simulated VSWR of antenna with optimal design parameters.
B. Gain

The peak antenna gains at different frequencies are also simulated and revealed in Fig. 6. The 5.5 dB maximum gain is observed at about 16 GHz. The average gain is obtained near 3.7 dB. Therefore, the radiation gain of the antenna remains almost constant throughout the frequency band.

![Figure 6. Simulated gain of the proposed antenna against frequency.](image)

VI. Conclusion

A compact wide-slot antenna with tapered feeding structure is designed. The proposed antenna has the frequency band of 2 to over 20 GHz for VSWR less than 2.0, which has a bandwidth increment of 163% with respect to the previous similar antennas. The structure can support both lower-range and higher-range functions despite compact size. This antenna covers the 5.2–5.8-GHz WLAN bands and 5.5-GHz WIMAX band. As a design role, any longitudinal parameter in the slot, feed, or patch can affect input matching more than lateral ones, especially in higher frequencies. Simulation results show that the proposed antenna can be a good candidate to be used in personal and mobile UWB applications due to compactness and other proper features.

REFERENCES