**ABSTRACT:**

This research proposes a new antenna design for gain and bandwidth enhancement of the slotted bowtie microstrip antenna using the principle of partial substrate removal. This new design is a lightweight and compact one that is suitable for broadband communications due to its high gain and wide bandwidth. The slotted bowtie shape achieves the required wide bandwidth without increasing the microstrip size. This antenna was designed to achieve a bandwidth of more than 5 GHz. Furthermore, the gain of the bowtie antenna was enhanced by more than 2 dB due to the loss reduction in surface waves by using partial substrate removal. ANSOFT’s High Frequency Structure Simulator (HFSS) which is based on finite-element method (FEM) was used for the design and the simulation of the antenna. The standard antenna parameters such as gain, return loss, and radiation patterns were obtained and plotted.

**KEYWORDS:** Bowtie antenna, Broadband, High gain, HFSS, loss reduction.

**I. INTRODUCTION**

Printed slot antennas offer an attractive solution to compact, conformal, and low-cost designs of many wireless application systems [1] due to small size, light weight, low cost, good performance, and low profile [2]. In order to use slot antennas in broadband communication systems, the antennas must have wide bandwidth with suitable gain. These requirements are achieved by using slotted bow-tie antenna [3]. A slotted bow-tie antenna is preferred because of its basic geometrical structure, broadband characteristics, and number of applications when compared to a linear wire and a printed dipole antenna. Furthermore, they allow a considerable size reduction in compare to patch antennas that leads to lower operating frequencies without increasing the overall patch area [4].

It is known that the gain of a single patch antenna is generally low [1]. There are three types of losses i.e. conductor loss, dielectric loss and surface wave loss that lower gain of a patch antenna. The conductor loss depends on the quality of the materials. The dielectric loss is dependent on the loss tangent of materials and the quality of the substrate, while the surface wave loss depends on the permittivity of materials and the substrate thickness. Although better quality selection of conductor and substrate can reduce the conductor and dielectric losses and improving the gain of the antenna, the gain of the patch antenna can be further enhanced by suppressing surface waves [5].

In this research, the effects of partial substrate removal on the performance of slotted bow-tie microstrip antenna were investigated for antenna gain enhancements. The basic idea is
to improve the gain of a slotted bow-tie microstrip antenna by suppressing surface waves and reducing dielectric loss through partial substrate removal surrounding the antenna. This method is for ease of fabrication, which is considered a practical method to enhance gain and bandwidth of the antenna, and it’s a method used when the electric permittivity $\varepsilon_r$ of the designed antenna is low. [5].

Bow-tie slot antenna geometry was studied and designed for wideband operation. The related simulation and analysis are performed using ANSOFT’s High Frequency Structure Simulator (HFSS) which is based on finite-element method (FEM) which is considered the industry standard for antenna design and simulations.

II. ANTENNA STRUCTURE AND DESIGN

Several studies have demonstrated that the use of a partial substrate removal can enhance the gain of the antenna [5]. This method was applied and studied on the slotted bow-tie antenna. The bow-tie antenna designed is shown in Figure 1, where a substrate that has electric permittivity $\varepsilon_r=2.2$ and thickness $H1=1.57$mm was used. The antenna dimension as well as the feeding lines were designed and optimized to achieve input impedance matching to $50\Omega$. The antenna dimensions are given in Table 1.

![Antenna structure and design](image)

**Figure 1:** The antenna structure and design

**Table 1:** The antenna parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (mm)</th>
<th>Parameter</th>
<th>Value (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L1$</td>
<td>8</td>
<td>$W2$</td>
<td>1.2</td>
</tr>
<tr>
<td>$L2$</td>
<td>2.25</td>
<td>$W3$</td>
<td>5</td>
</tr>
<tr>
<td>$L3$</td>
<td>1</td>
<td>$W4$</td>
<td>3</td>
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<tr>
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<td>19</td>
<td>$H1$</td>
<td>1.57</td>
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<tr>
<td>$W1$</td>
<td>22.9</td>
<td>$H2$</td>
<td>1.2</td>
</tr>
</tbody>
</table>
III. SIMULATION RESULTS

The parameters of the antenna under study in this research are the substrate removal width $W_3$, $H_1$ which is the thickness of the substrate and the electric permittivity $\varepsilon_r$ of the substrate. Only one parameter is changed at a time during the analysis.

The effect of the substrate removal, $W_3$ equal 5mm, on the bandwidth, radiation pattern and gain of the slotted bow-tie microstrip antenna is shown in figures 2, 3 and 4.

![Comparison between with and without substrate removal](image)

**Figure 2:** The return loss with and without substrate removal.

![Antenna radiation pattern with and without substrate removal](image)

**Figure 3:** Antenna radiation pattern with and without substrate removal.
It’s clear that the gain was increased by more than 2dB which is considered as an excellent enhancement. Furthermore, the bandwidth with the presence of substrate removal was enhanced by 1.5 GHz. A better return loss can be obtained by optimizing the width of the substrate removal, \(W3\). A reduction of the return loss that reflects a good impedance matching and low VSWR was obtain as shown in figure 5.

Figure 5: Return loss for different values of \(W3\).
Figures 6, 7 and 8 show the return loss, radiation pattern and the gain, respectively, with the substrate removal width \( W_3 = 5 \text{mm} \) for different values of substrate thickness \( H_1 \). It’s clear that there is a slight effect on the radiation pattern and gain and larger effect on the return loss due to shifted in the resonance frequency of the antenna.

![Figure 6: Return loss for different values of \( H_1 \).](image)

![Figure 7: Antenna radiation pattern for different values of \( H_1 \).](image)
Figure 8: Antenna gain for different values of $H1$ at 10 GHz.

Figure 9 shows the return loss with $W3$ equals 5mm and $H1$ equals 1.57mm with relative permittivity $\varepsilon_r$ 2.1, 2.2 and 3.2. It can be seen clearly the effect of changing $\varepsilon_r$ on the resonance frequency of the antenna.

Figure 9: Return loss for different values of $\varepsilon_r$
IV. CONCLUSION

The technique of using partial substrate removal and its effect on the gain and bandwidth was applied on a slotted bow-tie microstrip antenna. The antenna was designed and simulated using HFSS software. The results obtained showed that by suppressing surface waves and reducing dielectric loss, the gain of the designed antenna has been enhanced by more than 2 dB with an increase of up to 1.5 GHz in the bandwidth. This new design is suitable for broadband communications applications.

V. REFERENCES


