Design of Bow-tie Microstrip Antenna with Fractal Shape for W-Lan Application

A. C. Bhosale, V. U. Deshmukh

Vidya Pratishthan’s COE, Pune University, Maharashtra, India

Abstract

In this paper, we presented the design and analysis of Bow-Tie antenna on FR4 substrate, which is suitable for the WLAN-2.4GHz application. A novel Koch-like fractal curve is proposed to transform Ultra-Wideband (UWB) bow-tie into so called Koch-like sided fractal bow-tie dipole. The fractal bow-tie dipole can operate in multiband with moderate gain (3.5-7dBi) and high efficiency (60%-80%), which is corresponding to certain shape parameters, such as notch ratio α, notch angle φ, and base angles θ of the isosceles triangle. Compared with conventional bow-tie dipole and Koch-like fractal with the same size, this fractal-like antenna has almost the same operating properties in low frequency and better radiation pattern in high frequency in multi-band operation, which makes it a better candidate for application of WLAN and other communication systems. It’s well known that bow-tie antenna is a planar form of UWB finite biconical antenna. It is a practical angle-dependent frequency independent antenna. Because of its ultra-broadband, light weight, thin profile configurations, low cost and easiness of fabrication, reliability and conformability, bow-tie antenna has been widely studied and used in engineering applications. Also, the simple geometries make it compatible to be connected to planar feeding system in an integrated architecture. The novel Koch-like sided bow-tie dipole can behave both like multiband and UWB with conspicuous advantages over its conventional counterpart, printed dipole and Sierpinski gasket in dimension, bandwidth, gain and efficiency, which makes it a good choice for applications of UWB, PCS, WLAN, WiFi, WiMAX, and other communication systems. Details of the antenna design and simulated results return loss, Input impedance, Radiation Patterns, E-Field, H-Field and Current Distributions, VSWR are presented and discussed. The proposed antenna is simulated at 2.4 GHz using An soft HFSS-11.

Keywords
Bow-tie, Microstrip, FR4, UWB

I. Introduction

In recent years, microstrip antennas have been widely used in both theoretical research and engineering applications due to their light weight and thin profile configurations, low cost of fabrication, reliability, conformal structure and ease of fabrication. The bow-tie microstrip antennas have been designed for WLAN application, where the operating frequency is at 2.4 GHz. The bow-tie patch actually is the combination of imaginary image of two triangular patches which are fabricated in a single substrate. Fig. 1 shows the Bow-tie strips of a bow-tie microstrip antenna. Bow-tie microstrip antennas have become attractive candidates in the present day communication scenario due to their compact nature compared to rectangular patches. The ever increasing demand for compact wireless communication equipment explicitly necessitates research in compact antenna options and which sparked interests of many researchers worldwide in the field of bow-tie microstrip antennas. The bow-tie patch microstrip antenna as a compact one. Antenna has been proved to be an effective technique to design small, multiband and high gain antennas and low side lobe arrays. It is combination of antenna technology and fractal geometry. Fractal antenna geometry represents self-similarity and repeats itself in different dimensions filling the space effectively. It has shown many particular attributes in vast researches and applications as follows:

- Multiple electrical dimension, multiband or wideband, and ratio δ between adjacent resonant frequencies are approximately proportional to the fractal dimension D.
- Miniaturized and compact, filling space effectively.
- Self-loaded to 50Ω, auxiliary reactance and capacitance not needed.
- Mutual coupling between array elements can be reduced substantially.

Several typical fractal geometries such as Helix, Koch curve, Sierpinski carpet/gasket, Murkowski Ring, Hilbert curve and Mandelbrot tree have been employed for antenna design. The reason why there is no more novel fractal antennas emerged in recent years is mostly that fractal geometry is complicate and difficult to be constructed though its configuration rule is only virtually simple iteration. Fractal geometry which is suitable for antenna design is infinite and there must be better shape candidates among those geometries for antennas. Therefore, design and fabricating of fractal geometry is the premier topic of research of fractal antenna.

It’s well known that bow-tie antenna is a planar form of UWB finite biconical antenna. It is a practical angle-dependent frequency independent antenna. Because of its ultra-broadband, light weight, thin profile configurations, low cost and easiness of fabrication, reliability and conformability, bow-tie antenna has been widely studied and used in engineering applications. Also, the simple geometries make it compatible to be connected to planar feeding system in an integrated architecture. In this paper, a new Koch-like fractal curve is designed and introduced into modification of the typical bow-tie antenna. The novel Koch-like sided bow-tie dipole can behave both like multiband and UWB with conspicuous advantages over its conventional counterpart, printed dipole and Sierpinski gasket in dimension, bandwidth, gain and efficiency, which makes it a good choice for applications of WLAN, WiFi, WiMAX, and other communication systems.

II. Antenna Design

Fig. 1 shows the dimensions of the microstrip bow-tie antenna. α is the side length and θ is the angle of the equilateral triangle. L1,
The resonance frequency is given by
\[ fr = \frac{Kmn}{2\pi\sqrt{\varepsilon_r}} \]  
(1)

\[ fr = \frac{2C\sqrt{m^2 + mn + n^2}}{3a\sqrt{\varepsilon_r}} \]  
(2)

Where
fr is the resonance frequency
Kmn is the resonating modes
m and n are number of modes
C is the velocity of light in free space.
a is the side length of the bow tie strip

\[ a_{\text{eff}} = a + \frac{h}{\sqrt{\varepsilon_r}} \]  
(3)

Where a_{\text{eff}} - Effective side length
h - Height of substrate
\( \varepsilon_r \) - Dielectric constant

Above equation (1) & (2) is used Design of Bow-Tie Microstrip Antenna. Fig. 2 shows the HFSS generated bow-tie antenna with the specifications applied to the design. Following are the design data for Bow-tie Antenna Designing,

A. Design Data
Height of the substrate = 1.58 mm
Arm Length=17.1 mm
Feed line inner width = 1 mm
Substrate Dimension along X-axis=40 mm
Substrate Dimension along Y-axis=60 mm
Design Frequency = 2.4 GHz
\( \theta = 45^0 \)

For this antenna we use FR4 substrate whose Dielectric constant is \( \varepsilon_r = 4.7 \). The bows are connected to the microstrip feed line and the ground plane through a stub and mitered transition to match the bow-tie with the 50 \( \Omega \) feed line.

III. Results
The return loss and VSWR are computed using Ansoft HFSS and they are shown in fig. 3 and fig. 4. The return loss of -9.95db and the VSWR= 1.11 are obtained at 2.45 GHz from the simulated results. As per theory VSWR ≤ 2 is required & return loss is up to -20 db minimum required. Smith chart indicates the impedance is resistive, inductive & capacitive. The Smith plot for the proposed antenna is shown in fig. 5. The rms of 0.1073 and bandwidth of 1.9192 is obtained from the results. The 3D gain is shown in the fig. 6. The co-polarized (E\Phi) and cross-polarized (E\theta) far-field radiation patterns for the proposed antenna is computed at 2.45 GHz. Fig. 7 shows the radiation patterns of the bow-tie antennas. The input return loss is shown in figure 3 with the simulation result for angle \( \theta = 45^0 \) with a return loss=-9.95db at the operating frequency of 2.45 GHz, L2, W1 and W2 are the dimensions of the matching network.

Fig. 2: The HFSS Generated Bow-tie Antenna

Fig. 3: Return Loss at \( \theta=45^0 \)

Fig. 4: VSWR at \( \theta=45^0 \)

Fig. 5: Input Impedance at \( \theta=45^0 \)
The BW from measurement & simulation result nearly 3%. The radiation patterns give the good agreement between the simulated and the measured results. The shifting of the frequency is due to the substrate of FR4 which has dielectric constant between 4.0 and 4.7. In this design the dielectric constant is 4.7. The shifting of the frequency is also from the fabrication process of hardware.

### III. Bow-Tie Microstrip Antenna with Fractal Shape

#### A. The Fractal Shape

This proposed fractal bow-tie antenna consists of a couple of isosceles triangles with Koch-like sides. A small isosceles triangle is cut off from centre of each side of the initial isosceles triangle, then the procedure iterates in the tips of two sides of each angle of the notched triangle while a smaller one protrudes from middle of equilateral sides of each isosceles-triangular notch of last iterative. The iterative procedure itself proceeds, forming the novel fractal bow-tie geometry, as shown in fig. 1(a)-1(f). The conspicuous discrepancy between Koch-like curve and Koch curve is that the former is turn-left and turn-right tortoise-walking as the latter is only turn-left one. The antenna was fully parameterized modelled and simulated with Ansoft HFSSTM v.13. The parameters’ symbols and meanings are as follows: θ is base angle of the initial isosceles triangle, φ is base angle of each iterative isosceles-triangular notch, ν is rectilineal base side length of the isosceles dipole triangle, ι is half length of base side of the initial isosceles-triangular notch, α is the ratio of side length of initial iterated isosceles triangles to the base side length of iterated isosceles notches of Kn-iterated Koch-like sided isosceles triangle, as shown in fig. 1(b),1(f) and formula (1), μ is height of the isosceles triangle dipole.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Simulated Result</th>
<th>Measured Result</th>
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</thead>
<tbody>
<tr>
<td>Return Loss</td>
<td>-24.45 dB</td>
<td>-16 dB</td>
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<tr>
<td>VSWR</td>
<td>1.11</td>
<td>1.39</td>
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<tr>
<td>Smith Chart</td>
<td>54.4Ω</td>
<td>48Ω</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>45 MHz</td>
<td>50 MHz</td>
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</tbody>
</table>

Fig. 6: 3D Gain at θ=45°

Fig. 7: Radiation Pattern at θ=45°

Fig. 8: E-field distribution at θ=45°

Fig. 8: Fabricated Hardware of Bow-tie Microstrip Antenna

Fig. 9: The HFSS Generated Fractal Bow-tie Antenna

Fig. 10: Radiation Pattern
Table 3: Results of Fractal Bow-Tie Microstrip Antenna

<table>
<thead>
<tr>
<th>parameters</th>
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<th>Measured Result</th>
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</thead>
<tbody>
<tr>
<td>Return Loss</td>
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<tr>
<td>VSWR</td>
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<td>1.45</td>
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<td>SMITH Chart</td>
<td>56.58Ω</td>
<td>52Ω</td>
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<tr>
<td>Bandwidth</td>
<td>55MHz</td>
<td>65MHz</td>
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</tbody>
</table>

Table 4: Comparative Results of Fractal Bow-Tie & Conventional Bow-Tie Microstrip Antenna

<table>
<thead>
<tr>
<th>parameters</th>
<th>Measured Result</th>
<th>Measured Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Loss</td>
<td>-16 dB</td>
<td>-18.40dB</td>
</tr>
<tr>
<td>VSWR</td>
<td>1.39</td>
<td>1.45</td>
</tr>
<tr>
<td>SMITH Chart</td>
<td>48Ω</td>
<td>52Ω</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>50 MHz</td>
<td>65MHz</td>
</tr>
</tbody>
</table>

These are the comparative results which indicate fractal antenna gives better result than conventional Bow Tie antenna. In fractal antenna Bandwidth is enhanced and gain is also increased. In conventional bow-tie antenna also gives 3% bandwidth change between simulated and fabricated results.

IV. Conclusion

The BW from the measurement and simulation result is nearly 3% with a return loss more than 20 dB. The angles of the bow-tie microstrip antennas do not affect its return loss. As long as the design of the matching network is correct, the desired return loss can be obtained. In fractal Bow-tie antenna bandwidth increases as compared to conventional Bow-Tie Microstrip antenna.

V. Acknowledgment

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References


Amol Bhosale received his B.E. degree in Electronics and telecommunication engineering from College of Engineering, Malegaon (BK), Baramati, in 2008 from Pune University. The M.E. degree pursuing in Digital System from VPCOE, Baramati, Pune University.