Broad-Band 4-Sided Insulator Resonance Vibration Folded Fractal Antenna

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Abstract

This paper discusses the analysis of a two slot 4-sided Insulator Resonance vibrations FOLDED FRACTAL ANTENNA (FFA) for broadening of impedance Broad-Band in the proposed two-slot design, two 4-sided Insulator sections is used which is divided by a metal plane. With this plan, it is possible to excite two adjacent Vibrating frequencies. Utilizing the two-slot thin DM and skillfully varying its aspect ratio, an appropriate Foundation, s obtained that illustrates 76.8% impedance bandwidth (for S11 > 10dB) 3.32-7.46 GHz frequency.

Keywords: Insulator Resonance vibrations FFA, broadband, half size.

1. Introduction

The Insulator Resonance vibrations offer the advantages of small size, lightweight, low profile, and low cost. They have been demonstrated to be practical elements for FFA applications and have several merits including high radiation efficiency, flexible feed arrangement, simple geometry, and compactness [1, 2].

All the basic trigonometric shapes are already utilized in antenna design and their radiation mechanisms are well explored. And we also know that any arbitrarily random shape can pick up EM waves. So why not have a discipline in chaos. That means, using fractals as antennas may offer better radiation pattern and may also offer more controlling parameters to designer. Fractal antennas are multi-resonant and smaller in size. Qualitatively, multi-band characteristics have been associated with the self-similarity of the geometry and Hausdorff dimensions are associated with size. Research towards quantitative relation between antenna properties and fractal parameters is going on extensively.

Any variation of fractal parameters has direct impact on the primary resonant frequency of the antenna, its input resistance at this frequency, and the ratio of the first two resonant frequencies. In other words, these antenna features can be quantitatively linked to the fractal dimension of the geometry. This finding can lead to increased flexibility in designing antennas using these geometries. These results have been experimentally validated [1].

A fractal antenna’s response differs markedly from traditional antenna designs, in that it is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Normally standard antennas have to be “cut” for the frequency for which they are to be used and thus the standard antennas only work well at that frequency. This makes the fractal antenna an excellent design for wideband and multi-band applications. Various Fractal Types used in Antennas are shown below:

FFA application of Insulator Resonance vibrations was first proposed in the early 1980s [3]. Later, various investigations offer significant enhancements to parameters such as bandwidth, gain, polarization, or power coupling. Over last decades, various bandwidth enhancements techniques have been developed for FFAs [4].

FFAs are commonly available in 4-sided, cylindrical, and hemispherical geometries. 4-sided FFAs offer more design flexibility since two of the three of its dimensions can be varied independently for a fixed Vibrating frequency and known Insulator constant of the material [5].

In this paper, a two-slot 4-sided electric section in a suitable arrangement is used to enhance the bandwidth of FFA. This Foundation is composed of two 4-sided with different (size and permittivity) which are separated by a perfect E-plane [6]. Formerly, the overlap multi-slot FFA was developed to enhance pulping from the microstrip line [7, 8]. But the proposed arrangement emphasizes bandwidth broadening and size reduction of the FFA. The motivation or performing his investigations to attempt to design FFA’s that are sufficiently compact or user in broadband communications.

2. Half Size Ffa

Reduction of conventional FFA profile by approximately half has been done using an extra metallic plane in the FFA, which acts as an electric wall [9-11]. The added plane acts as a shorting post for the electric field and allows pan of the FFA to be removed, if certain field symmetry exists. The use of the metal plane can be likened to the shorting post used in patch FFAs to reduced heir length from M2 to M4 [9]. Because of the symmetry of EM field distribution in the main resonance frequency, we can slice the FFA into two halves by an infinite metallic plane perpendicular the conducting round plane. The field distribution in the other half in the main Resonance vibrations case, and we can...
expect the vibrating frequency to remain the same. In this case the size of the FFA is effectively reduced by half. Also, greater reductions (as high as 75%) in the size of the FFA can be obtained by utilizing sector Foundation [13]. However, the feed expected to need a iteration to give a good impedance etch or the half size design. This is the base of our idea to obtain size reduction and broad band width of operation to this purpose we consider Figure 1.

Fig.1. Various Types of Fractals Used As Antenna

In this Foundation, the attentions focus on a type of FFAs that can offer different vibrating frequencies. Two half FFA due to their different permittivity and size, resonate in two different frequencies. These frequencies can be merged into a broad band [6].

By letting the two vibrating frequencies from the two slots are $f_1$ and $f_2$ with $f_1<f_2$ (for $a_1>a_2$), the continuous frequency band condition is fulfilled when

$$f_1 + \frac{\Delta f_1}{2} = f_2 - \frac{\Delta f_2}{2}$$

Where Deltaf is the 3-dB bandwidth of S11 curve. By choosing suitable values of $a_1$ and $a_2$ lengths such that (1) is satisfied, a broad continuous impedance bandwidth is achieved. For this purpose, the effects of $a_1$ and $U$ on the input impedance and consequently on matched bandwidth are investigated in the finite ground plane. Full wave analysis of the proposed FFA designs were performed using Ansoft HFSS™ [14] based on finite element method. In addition, the simulation results of CST microwave studio [5], based on finite integral technique, are provided to support our findings from HFSS software.

3. Foundation Designs and Implementation

Extensive implementation was carried out using the software in order to obtain optimal design parameters for the FFA. The initial dimensions of the radiating portions of the FFA were determined using the equations developed for the Insulator waveguide model (DWM) for 4-sided Resonance vibrations in free space [5]. Enforcing the magnetic wall the surfaces of the Resonance vibrations, the following equations are obtained for the dominant mode resonance frequency:

$$f_b = \frac{c}{2\pi \sqrt{\varepsilon_r}} \sqrt{k_x^2 + k_y^2 + k_z^2}$$

$$k_x = \frac{\pi}{a}, \quad k_y = \frac{\pi}{b},$$

$$k_z \tan(\frac{kd}{2}) = \sqrt{(\varepsilon_r - 1)k_z^2 - k_s^2}$$

where $k_x$, $k_y$, and $k_z$ denote the wave-numbers along the x, y, and z directions inside the DR, respectively. Then the appropriate dimensions of FFA parameters were determined with experimental patronization. In general, to achieve strong coupling, the FFA must be fabricated from high permittivity materials. However, to operate over a broad bandwidth, the FFA must have a low Insulator constant [1]. Previous work has shown the critical coupling is possible for FFA’s having a high value (20 or much) of Insulator constant [5]. In this work, for simplicity, material of two slots is similar and the Insulator constant of the designed DR (s) is 20. The microstrip feed line was 1mm broad and on a 0.33mm thick substrate with a relative Insulator constant, $\varepsilon_r=2.2$ give a characteristic impedance of 50Ω. Open circuit microstrip line is considered to excite the DR. To achieve the maximum coupling the FFA is placed at a distance $\gamma/2$ from the open end [5]. For this case the finest coupling and consequently the maximum bandwidth for AL:4.1db was achieved. The dimensions $(a^* \times d^*)$ of the proposed FFA are 10.5mm *6mm * 9.6mm that are equivalent to 0.192 $\gamma$, 0.11 $\gamma$, 0.176 $\gamma$ and $\gamma$. is the free space wavelength at the center frequency of 5.5 GHz. Additionally, the proper lengths of slots are obtained 4.8db, and 5.7db respectively he size of square round plane is assume to be 5db. To compare the effects of variation in lengths of the slots, different arrangement of these lengths were evaluated.

Equation (1) is satisfied in arrangement I and consequently broader impedance bandwidth is realized in this case. In arrangement 2, due to closeness of the two vibrating frequencies, the impedance bandwidth is limited to 16.8%. Likewise, arrangement3 has two separated bands, which offer 14.4 % band width totally.

The simulated results (HFSS software) have shown two Vi-
brating frequencies at 5.2GHz and 5.84GHz and impedance bandwidth at 5.01-6.01GHz, which illustrates more than 18.1% frequency bandwidth. The returns loss curves for two designs unit and two-slot Foundations, with the same dimensions are compared. Also, the results of the HFSS implementation are grossly confirmed by using simulation results from CST microwave studio with the same setup as mentioned above.

In proposed Foundation the impedance bandwidth have been increased over than 100%, in comparison with en-bloc Foundation without insulator plane. This two-slot FFA is proposed for WLAN systems [6]. With regard to IEEE 802.11 a standard a single-band FFA designed for this system should therefore work at center frequency 5481MHz and bandwidth 675MHz [6]. This plan is easily meeting this system requirement. Another advantage of the proposed Foundation is that it offers two optimum locations for FFA on the ground plane by readjusting the AL length after rotating the FFA in the feed line direction. In this case, by pivoting the FFA (i.e. exchanging the position of a1 and a2), the optimum return loss curve for ΔL: 6.1mm is obtained. In this condition, the bandwidth has slightly narrowed and has shifted to higher frequencies, and the vibrating frequencies have shifted to 5.34GHz and 5.90GHz. Also, the impedance bandwidth has shifted to 5.08-6.06GHz with 17.6% bandwidth. This bandwidth till satisfies the WLAN system specifications mentioned earlier. Afterward, the far-field radiation patterns of FFA Foundations were investigated. The resulting three dimensional (3-D) radiation patterns in center frequency band for unit and two-slot FFA are shown in figures 5 and Figure 6, respectively Figure 5: 3-D radiation pattern of two-slot FFA at 5.5GHz.

The unit slot FFA has a symmetrical pattern respect to x-z and y-z planes (figure. 2). In two slots Foundation due to the metal plane, radiation pattern has a main lobe in –X direction.
**Fig. 7.** Input impedance of two-slot FFA

![Input impedance of two-slot FFA](image)

**Fig. 8.** Simulated and measured radiation patterns of proposed antenna at 2.2 GHz

![Simulated and measured radiation patterns](image)

**Fig. 9.** Comparison of return loss of two-slot FFA

![Comparison of return loss](image)
4. Design of Broad-Band FFA

In this section, to obtain the better result the dimensions of FFA have been enhanced. Large improvements in bandwidth can be achieved by suitable selection of aspect ratio. For this reason, a scheme like what used for the cylindrical FFA is applied. A broad bandwidth is reported when this ratio equals to 0.329 [16]. Also in pervious works have been shown that thin transverse Foundation exhibit broader bandwidth. In fact, increase in b/d ratio results in an increase in the bandwidth. The Foundations with higher b/d ratios are evaluated and compared to the Foundations evaluated in the previous section. Also in the feed line, the far end of a microstrip line is terminated in an open circuit. The dimensions (a, d, and b) of this proposed FFA are l_0.8mm y 2.56mm y 12.8mm high which are equivalent to 0.1981 γ by 0.047γ by 0.2351γ high were L is the free space wavelength of 5.5 GHz. The optimum lengths of a; and a2 & a1 obtained 4.9mm, and 5.9mm respectively. A general expression linking the unloaded Q to the FFA basic geometric features is [9]:

\[ Q = \frac{2\pi}{\gamma} \frac{a}{d} \]

The real and imaginary parts of the impedance curve swing around 50 and 0 Ω, respectively, to provide acceptable impedance matching with the feed-line. For the optimum thin FFA, the simulated results with HFSS have shown matched impedance bandwidth at 3.32-7.46GHz band, that illustrate more than 76.8% frequency bandwidth is obtained. Good agreement between the two software implementation is obtained for the entire bandwidth. Aspect ratio, size, and bandwidth results from HFSS implementation for both of the designed FFA are provided.

The second scheme, the thin Foundation, occupies 41% less size compared to the first FFA. In our implementation we have found that with a constant size, the special b/d ratios of around 5 provide the broadest frequency bandwidth. Also, from a number of implementation we have found that CST microwave studio implementation generally predict broader frequency bandwidth than HFSS implementation with the same Foundation 3 Conclusion. In this work, a two-slot 4-sided FFA Foundation separated by a metal plane was introduced, and performance of this Foundation was analyzed. In comparison to an en-bloc FFA, this Foundation offers significant reductions in size.

Therefore, such a Foundation is a potential candidate for use in compact and broadband applications. The suggested thin FFA with a suitable aspect ratio, an impedance bandwidth of 3.32-7.46GHz is obtained, which is equivalent to a frequency bandwidth of as high as 76.8% (S11>-10dB).

5. References


