

Design and Simulation of Bow-Tie Shaped Hexagonal Rings Quasi Fractal Antenna for Satellite Applications

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Abstract

Objective: To design a frequency reconfigurable fractal antenna for satellite applications. **Methods:** Using fractal geometries, a novel structure has been developed to operate the antenna at X (8-12 GHz), Ku (12-18 GHz) and Ka (26.5-40 GHz) bands. **Findings:** Frequency reconfigurable antennas are generally equipped with PIN diodes or MEMS switches etc., by controlling the switch conditions (ON or OFF) the proposed antenna can be operated either at X or Ku or Ka band. Various parameters of the antenna like reflection coefficient, gain, VSWR, radiation pattern, bandwidth were also determined. **Application:** This proposed antenna is compact in size and good impedance matching is achieved compared to existing antennas and hence it is very suitable to satellite applications.

Keywords: Frequency Reconfigurable Antenna, Quasi Fractal, FEKO, MEMS, MOM

1. Introduction

Reconfigurable antennas are the future antennas for wireless and satellite applications¹⁻⁷. The structure of the antenna is not changed, by using the electrical and mechanical methods we make the antenna to work under different applications i.e. the frequency, radiation pattern and other characteristics are changed. Reconfiguration makes a single antenna equivalent to multiple antennas with constant functionalities. Reconfigurable antenna with fractal shape can be used to radiate at high frequencies. Due to the self-similar property, many fractal shapes have been applied to antennas and array designs, including Koch, Hilbert, Peano, Minkowski, and Sierpinski⁶⁻¹², which demonstrates both compactness and multiband behavior. Therefore, the fractal antennas are very conducive to design reconfigurable antennas. Bow-Tie shaped hexagonal rings fractal geometries using RF-MEMS

switching elements were proposed for frequency-reconfigurable applications.

The proposed antenna structure radiates in frequency bands like X-band, Ku-band and Ka-band by changing the state of the switches.

2. Design of Frequency-Reconfigurable Bow-Tie Shaped Hexagonal Rings Quasi Fractal Antenna and Methodology

Figure 1 shows the geometry of the proposed Frequency Reconfigurable Antenna. The two arms of antenna are printed on top of the substrate. It is fed with coaxial cable which is converted by a micro strip transmission line. 'L' is the total length of the antenna arm, 'W' is the

width of the antenna arm, 'a, b' refers to the lengths of the hexagonal rings. Here we design the antenna for three order hexagonal rings that are connected with switches.

$$L = 12.5\text{mm}, W = 20\text{mm}, a = 2\text{mm}, b = 4\text{mm}$$

$$L_s = 30\text{mm}, W_s = 30\text{mm}, h = 0.256\text{mm}$$

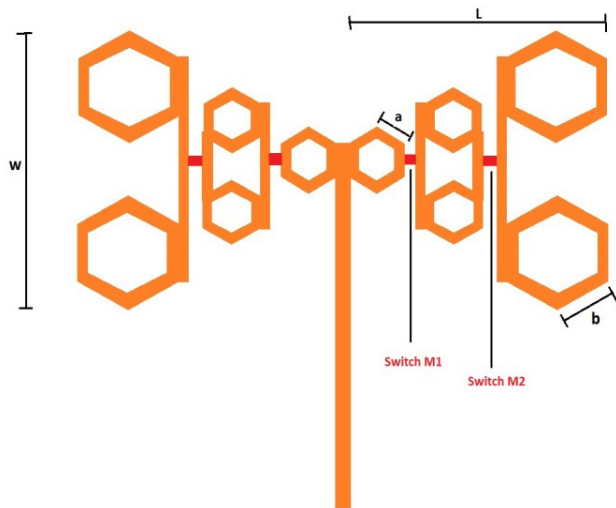


Figure 1. Bow-Tie shaped hexagonal rings quasi fractal antenna.

Reconfigurability is done through the switches (red color rectangles) M1 and M2 that connects the hexagonal rings. Switches are considered as ideal and its dimensions are 0.25 mm x 0.5 mm. Two switches on each side of the antenna can control three states of operation. Practical switch operations can be controlled by dc biasing voltage applied simultaneously¹³.

The proposed antenna is simulated using FEKO software version 2017.1 and the Electro Magnetic Field solver used is MoM (Method of Moments). If M1 and M2 both are in ON state, the antenna will radiate in X-band (11.02GHz). When M1 is in ON state and M2 is in OFF state the antenna will radiate in Ku-band (14.71GHz). When M1 and M2 both are in OFF state the antenna will work under Ka-band (27.5GHz). The top view of proposed antenna is shown in Figure 2. The radiating element is considered as PEC (Perfect Electric Conductor) material. The designed antenna is placed on a RT-Duroid 6002 dielectric substrate with dielectric constant (relative permittivity) of 2.96. The dimensions of the substrate are 30mm x 30mm x 0.256mm.

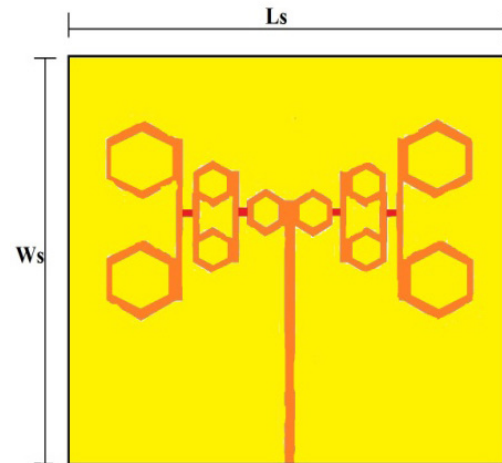


Figure 2. Top view of the BTSHRQFA with substrate.

3. Simulation Results and Discussion

The simulation of the bow-tie shaped hexagonal rings quasi fractal antenna is done with the FEKO software using MOM analysis.

Case-1: When Both Switches M1 and M2 are ON

When both switches M1 and M2 are in ON state, the antenna can work under X-band (8GHz-12GHz)¹⁴. Various parameters of the antenna are tabulated in following Table 1.

Table 1. Parameters of antenna under X-band

Frequency	Reflection coefficient	SWR	Gain	VSWR BW
11.02GHz	0.0069	1.014	1.27dB	0.67GHz

The antenna can radiate in X-Band at frequency of 11.02GHz with a S_{11} as 0.00696 as shown in Figure 3. For an antenna the effective reflection coefficient must be less than 0.33 and the SWR^{15,16} must be in between 1-2. Here we get the approximation results of the designed antenna up to those limits.

$$VSWR = \frac{1 + \Gamma}{1 - \Gamma}$$

Γ is the reflection coefficient that can be measured with help of voltages or the impedances of the antenna.

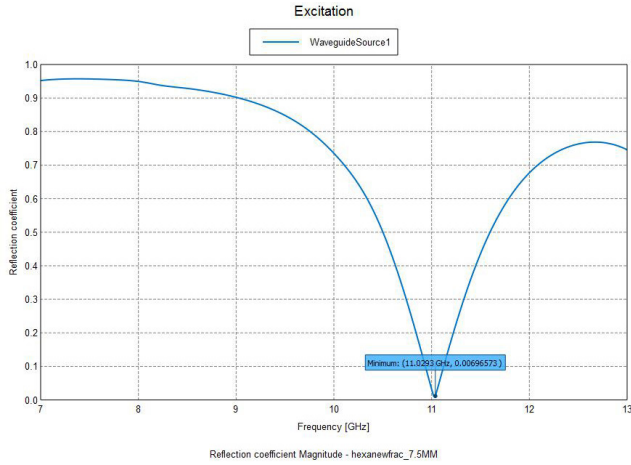


Figure 3. Reflection Coefficient of the antenna under X-band.

The directivity and the gain of the antenna is less, in order to increase the gain we may extend the design with help of some reflector materials or by decreasing the impedance matching. There are many chances to increase the directivity and gain of the antenna. The radiation pattern of the far fields in polar graph and standing wave ratio is shown in Figure 4 and 5 respectively.

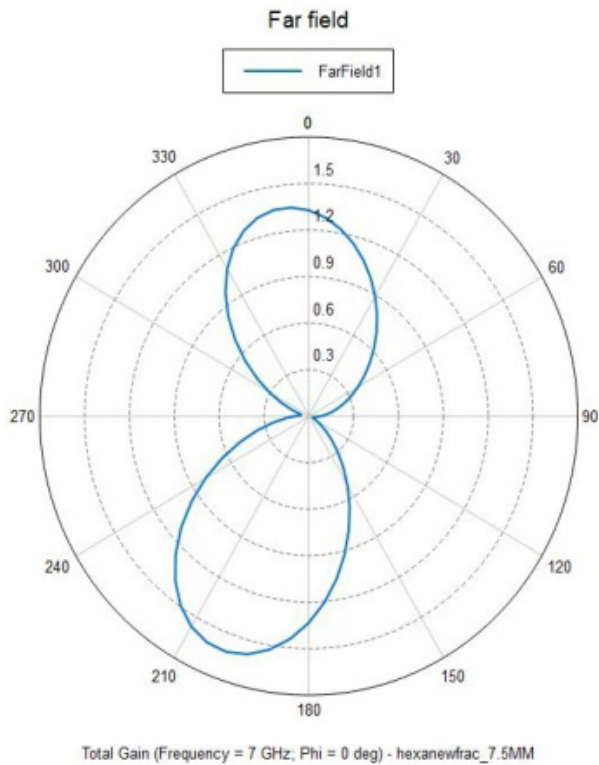


Figure 4. Far- Field radiation pattern in X-band.

Case-2: Switch M1 is ON and Switch M2 is OFF

When the switch M1 is in ON state and M2 is in OFF state the antenna can radiate in Ku-band (12GHz-18GHz)¹⁷. The results of the antenna are listed in Table 2. The antenna can work under Ku-band effectively as the results are up to the good approximation. The reflection coefficient of the antenna under Ku-Band is 0.0503 as shown in Figure 6. This is less than 0.33 which is good approximation and has efficient working of the antenna, the SWR is shown in Figure 7, and the radiation pattern of the far fields in polar graph is shown in Figure 8.

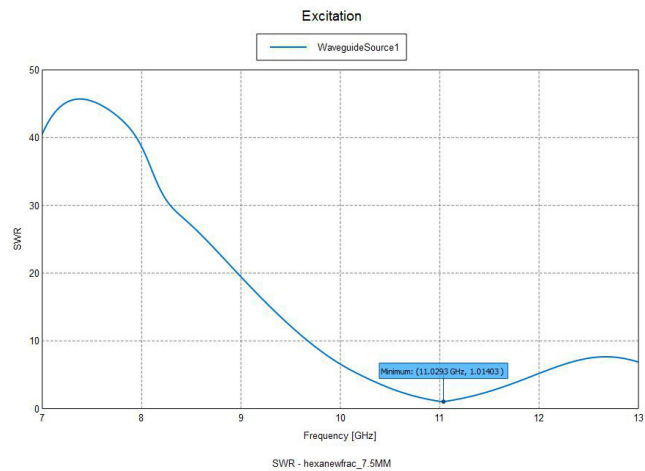


Figure 5. SWR of antenna under X-band.

Table 2. Parameters of antenna under Ku-band

Frequency	Reflection Coefficient	SWR	Gain	VSWR BW
14.71GHz	0.0503	1.106	3.7823dB	0.67GHz

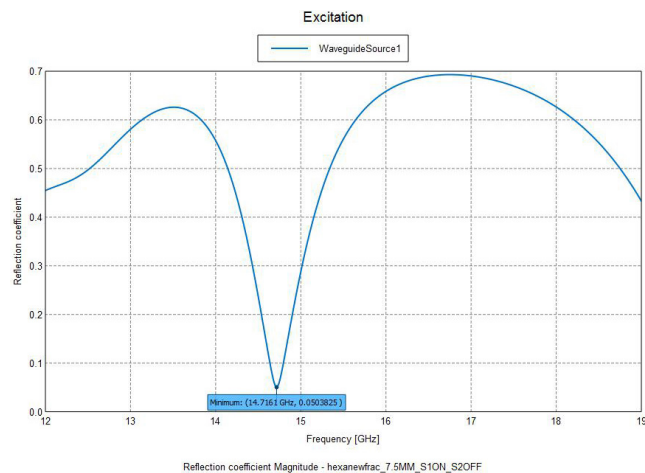


Figure 6. Reflection Coefficient under Ku-Band.

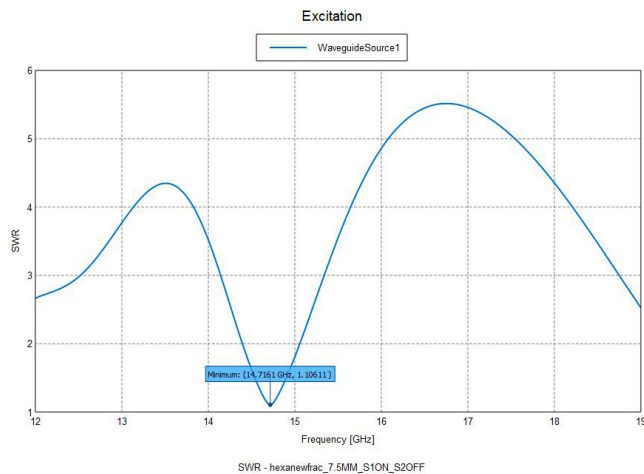


Figure 7. SWR of antenna under Ku-Band.

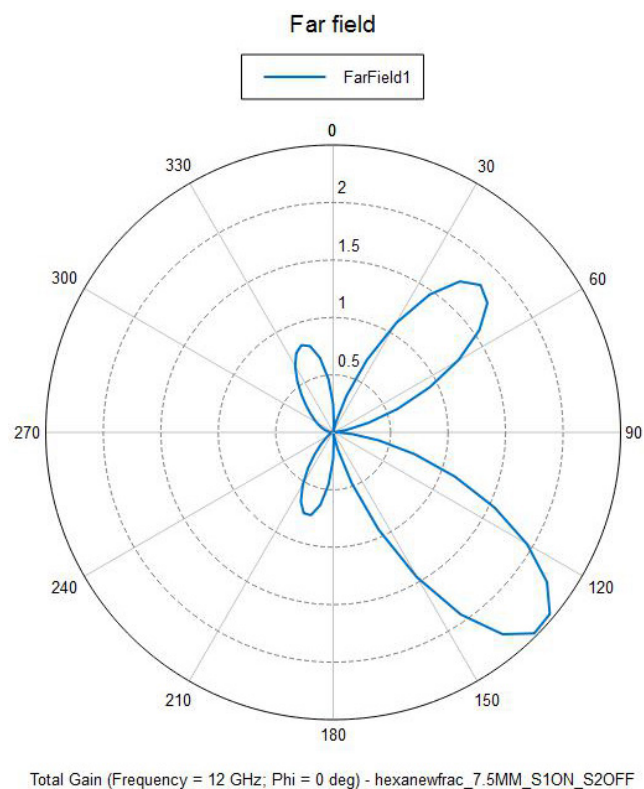


Figure 8. Far Field radiation pattern under Ku-band.

Case-3: When M1 and M2 both are in OFF State

When both the switches M1 and M2 are in OFF state the antenna can work under Ka-Band (26.5-40GHz)¹⁸. The parameters of the antenna are listed in the Table 3. The Reflection Coefficient of the antenna under Ka-Band is 0.21 which is good to approximation can be shown in

Figure 9. The SWR bandwidth can be measured by the SWR measurement curve that is shown in Figure 10.

Table 3. Parameters of antenna under Ka-band

Frequency	Reflection Coefficient	SWR	Gain	VSWR BW
27.5GHz	0.21	1.55	2.25dB	0.74GHz

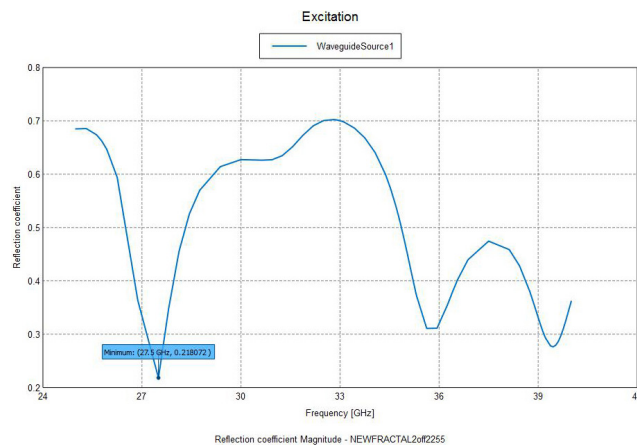


Figure 9. Reflection Coefficient of antenna under Ka-Band.

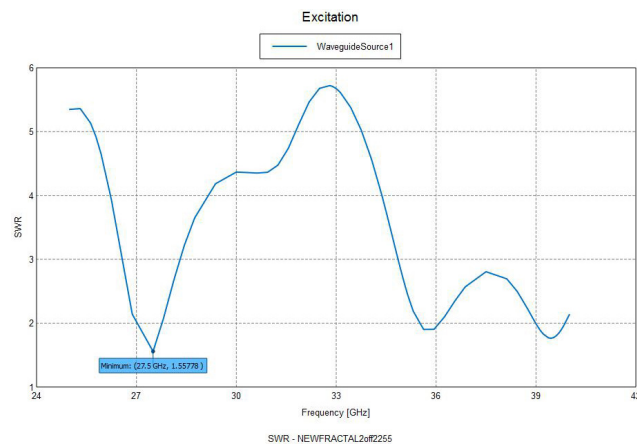


Figure 10. SWR of antenna under Ka-Band.

4. Conclusion

Bow-Tie shaped hexagonal rings quasi fractal antenna using Frequency Reconfiguration has been proposed in this study. The designed antenna can radiate in X-Band (8GHz-12GHz), Ku-Band (12GHz-18GHz) and Ka-Band (26.5GHz-40GHz) effectively with less power loss. Reconfiguration technique can be done with MEMS switches which help for the frequency reconfiguration by changing the length of the antenna.

5. References

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