International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 24 (2017) pp. 16017-16023

Pentagon Fractal Antenna for Above 6 Ghz band Applications

Ammar Nadal Shareef

Department of Sciences, Al-Muthanna University, Samawa, Iraq.

Ali. A.Seleh

Basra Oil Training Institute, Ministry of Oil, Basra, Iraq.

Amer Basim Shaalan

Physics Department, Al-Muthanna University, Samawa, Iraq.

Abstract

Bandwidth of the operating frequency of an antenna is an important parameter in antenna design. It is strongly related to the performance of data rate. Hence to get more data rates for mobile applications, much higher bandwidths are needed. Frequency bands lies above 6 GHz, characterized by more continuous frequency range than bands below 6 GHz. This gives more chance to meet these requirements. To this end Pentagon fractal antenna is proposed here. It has multiband behavior and very good gain and directivity with excellent efficiency which make it very suitable for above 6 GHz applications.

Key words: fractal antenna, pentagon fractal shape, microstrip patch antenna, above 6 GHz band, wireless communication systems

INTRODUCTION

Now a day communication systems uses multiband antennas to overcome its developing requirements. Wireless local area network (WLAN) and (WiMAX) have been vastly applied in mobile devices particularly in smart phones [1, 2]. The quick developments of wireless communication system have made antenna designs to focus on multiband and small simple structures that can be easy to fabricate.

Fractal shapes design has gathered these two limits, multiband and small size structure [3,4].Many designs were discussed in literatures considering antennas operate in c-band applications [5-7]. Fractal antennas studied include specific shapes, such as the Koch curve, Sierpinski triangle, Hilbert curve, Minkowski curve and Peano curve [8-11]. Pentagon fractal antenna representsa very good design to meet these two limits [12]. Frequency band above 6 GHz that might be suitable for future mobile communication services, regards as 5G (the 5th generation of mobile services). Fifth generation of mobile technology may include new ways of using mobile devices and completely new types of mobile devices [13]. According to the limited range of communication systems spectrum sharing above 6 GHz become easier [13]. This could be improved by the use of more directional antennas [13-16].

In the present work pentagon fractal antenna is proposed. It has four resonant points above 6 GHz band. Currently, there are some uses of this band (above 6 GHz) like satellite communications, fixed wireless links, defense, science, and the promising 5G applications [13].

FRACTAL SHAPE GENERATION

The pentagon fractal shape is generated by an iterated function system (IFS) process [3]. It begins with a pentagon initiatorP_0. In the second stage, there is five copies of the original pentagon are obtained when scaling down by a factor. Each one of the five pieces is translated from its position to five vertices of the large pentagon. After that, the large middle piece is subtracted from the small pieces. Fig.(1) shows the structure of the generator. Next iteration is obtained by repeating this processes on the new set P_1.So that the IFS for pentagon is given by the following equation [3,12, 17].

$$\left.\begin{aligned} I_1(x,y) &= (0.38x; 0.38y) \\ I_2(x,y) &= (0.38x+0.618; 0.38y) \\ I_3(x,y) &= (0.38x+0.809; 0.38y+0.588) \\ I_4(x,y) &= (0.38x+0.309; 0.38y+0.951) \\ I_5(x,y) &= (0.38x-0.191; 0.38y+0.588) \end{aligned}\right\} \ldots\ldots\ldots\ldots (1)$$

We can see that there are five maps for this IFS, with each ratio being greater than one. Therefore, the fractal dimension is [12]

$$D_f = \frac{\log(5)}{\log(\frac{2}{3-\sqrt{5}})} = 1.672 \quad \ldots\ldots\ldots\ldots (2)$$

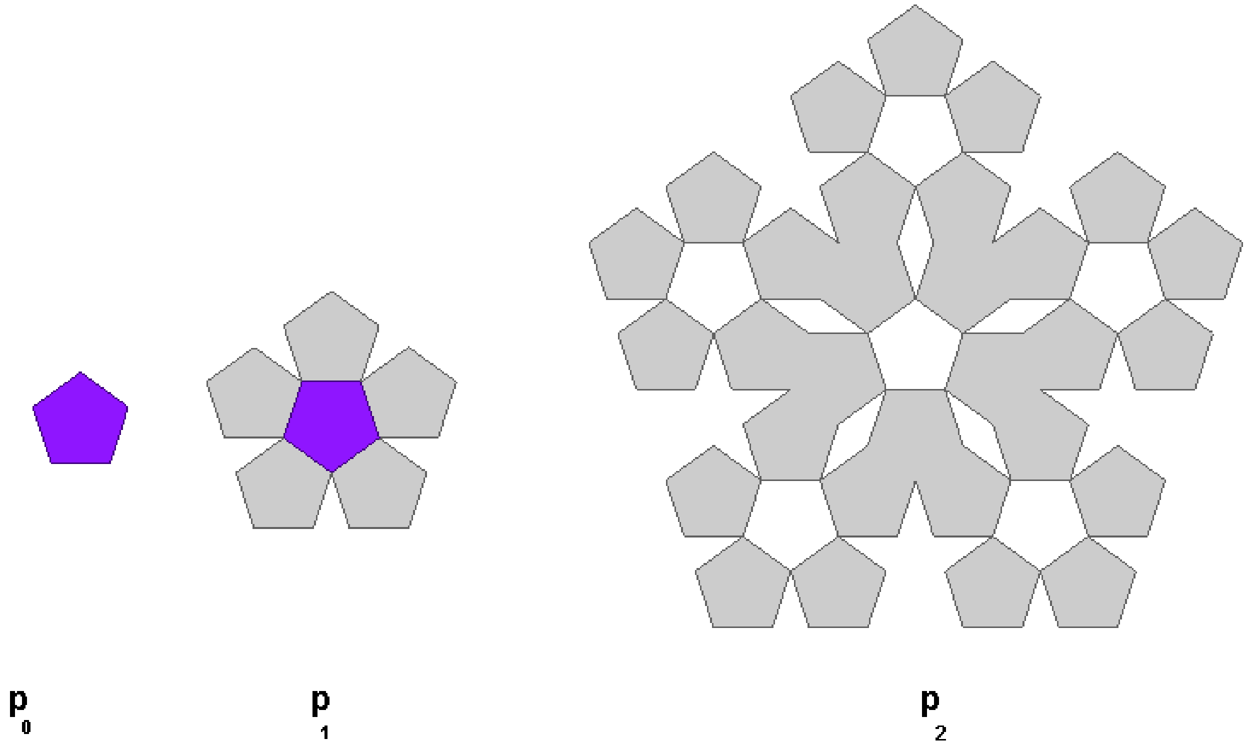


Figure 1: Pentagon generation

RESULTS AND DISCUSSION

Simulation of modified pentagon fractal antenna is done utilizing HFSS code. The modified shape is generated in the same way as the original one. The difference here is uniting the vertices of the five small copies with central one. This modification will allow current to flow across the antenna structure easily causing smoother field pattern. The computations for the S-parameter were performed in the frequency range (6.5–12.5) GHz. Computed scattering coefficient (S_{11}) with frequency are shown in Fig.2.

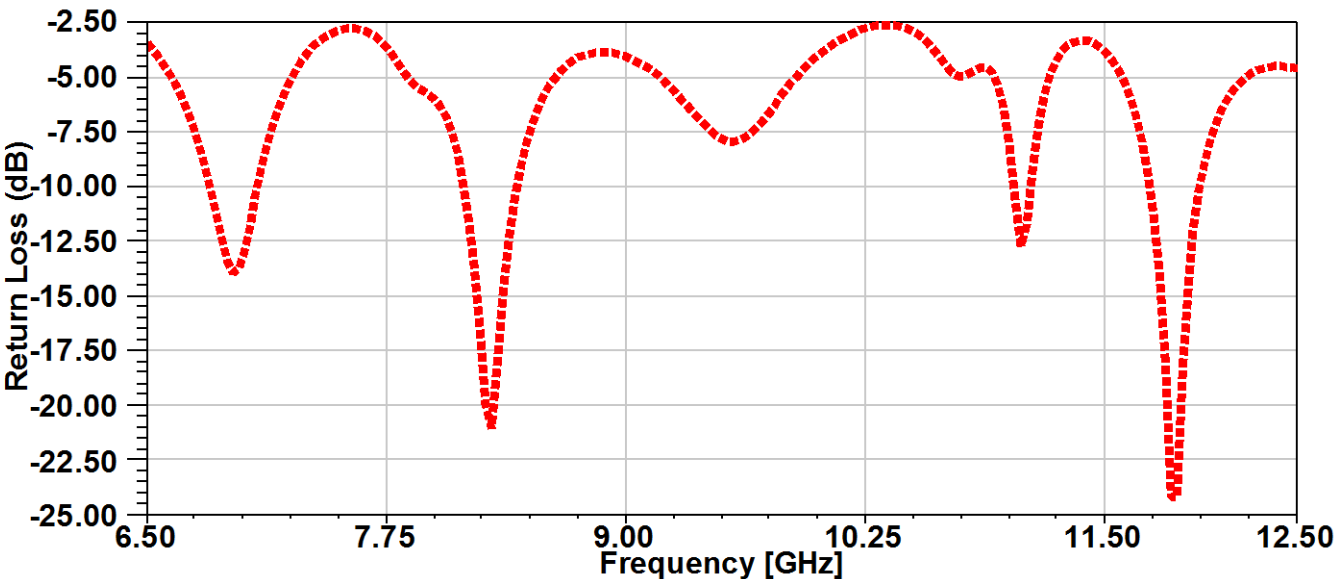


Figure 2: Scattering parameters (S_{11}) versus frequency

From Fig.3 we can see the variation of the computed voltage standing wave ratio (VSWR) with frequency.

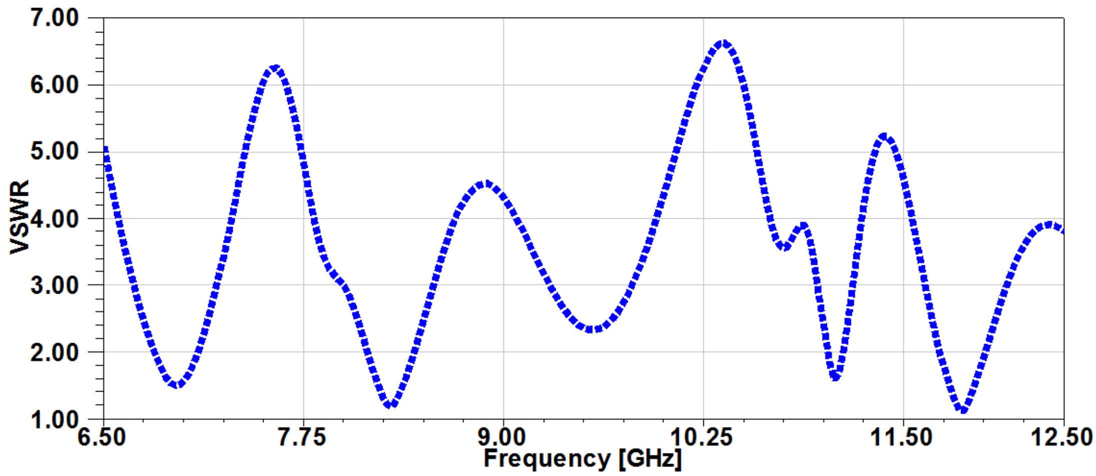


Figure 3: VSWR versus frequency

As seen from these two figures, there are four matching (VSWR< 2) frequencies with feeding point. The resistance of feed point is set to 50 ohm.

Fig.4. shows two dimensional radiation pattern for E-plane and H-plane of the four matching points. Smooth pattern is obtained due to the modification in the shape of the antenna. Uniting the edge of the connected elements led to more flow of currents across the antenna structure. This is cause more distribution of currents around the body of antenna which in turn affect the shape of field pattern.

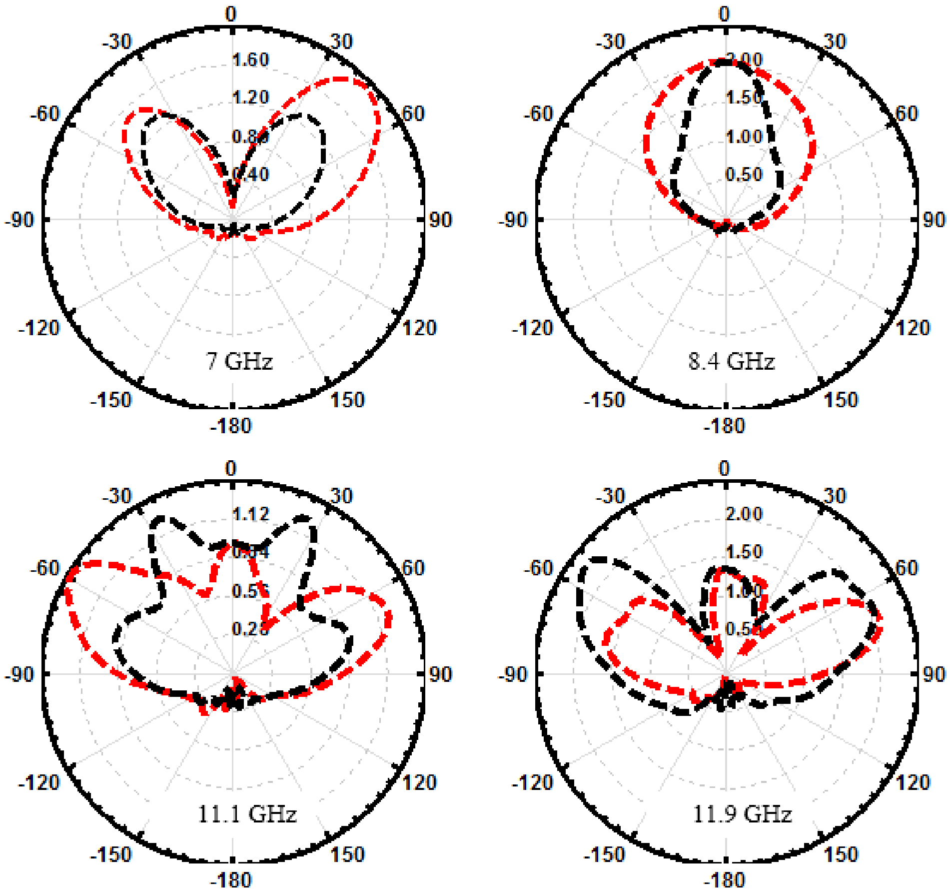


Figure 4: Radiation pattern field of the four resonant frequencies

Current distribution over the body of the antenna is illustrated in Fig.5. From the figure we can see that the current is concentrated around feeding point and cover all the structure body of the antenna. At higher frequencies it is reduced to the edges around the antenna body.

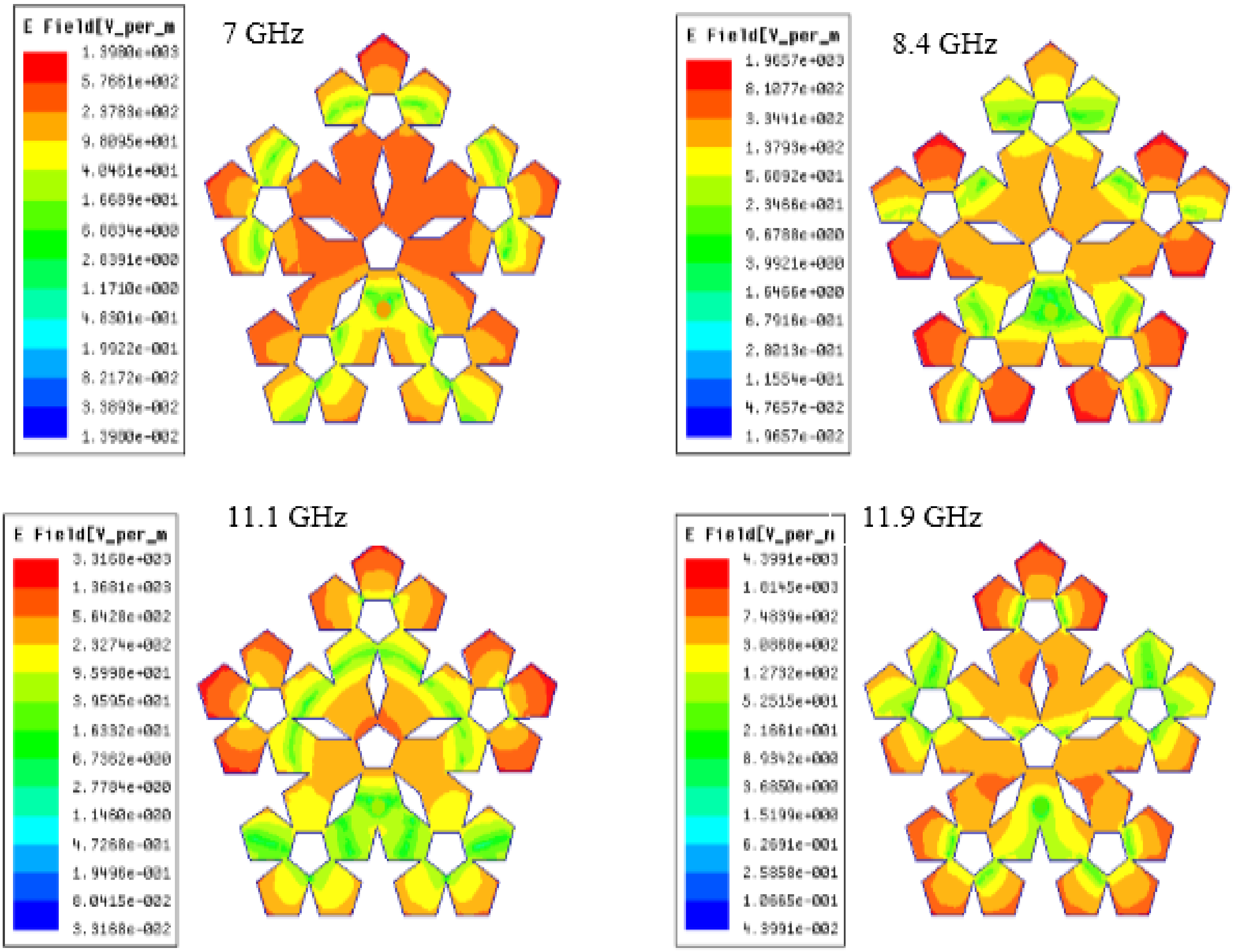
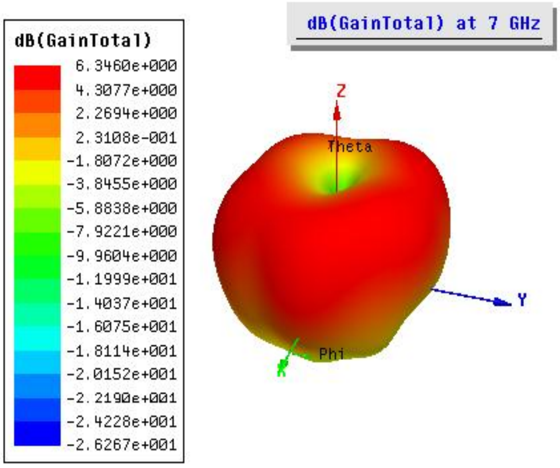
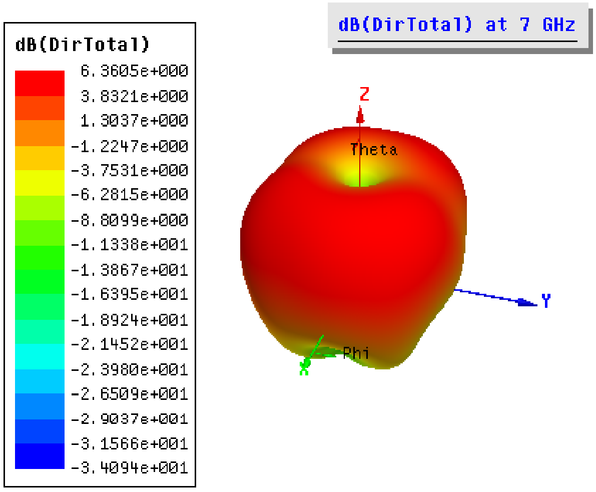
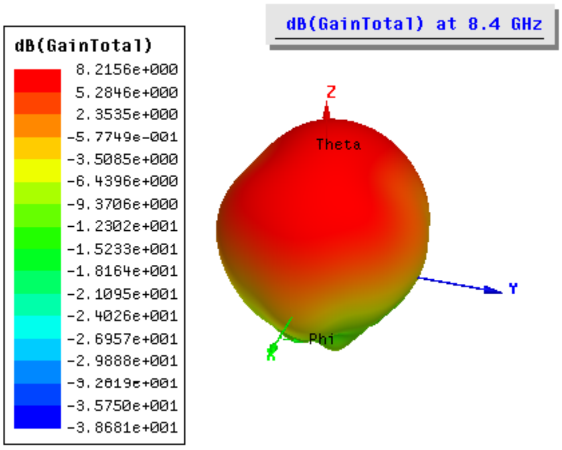


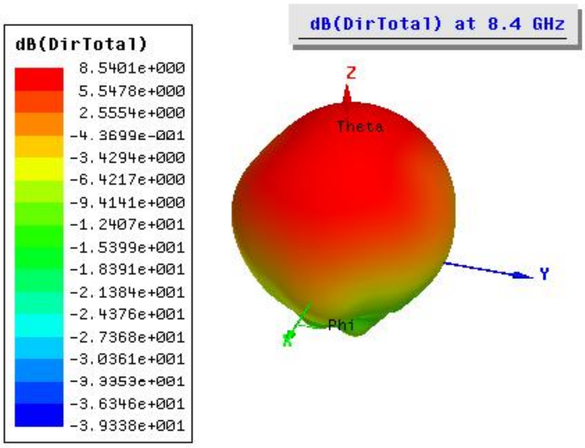
Figure 5: Current distribution over antenna body

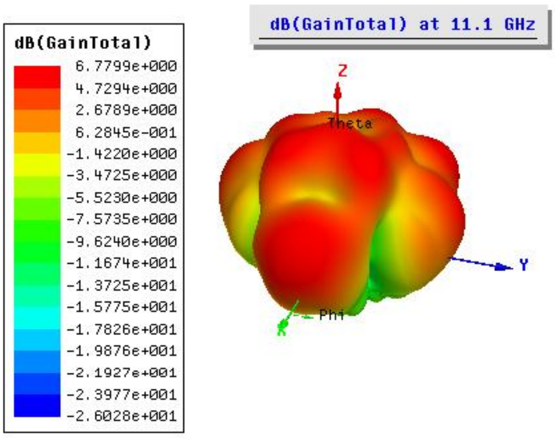
In addition to the above properties, gain and directivity is computed using HFSS code. Modified pentagon model has high gain and directivity at all resonant frequencies illustrated in Fig.6.

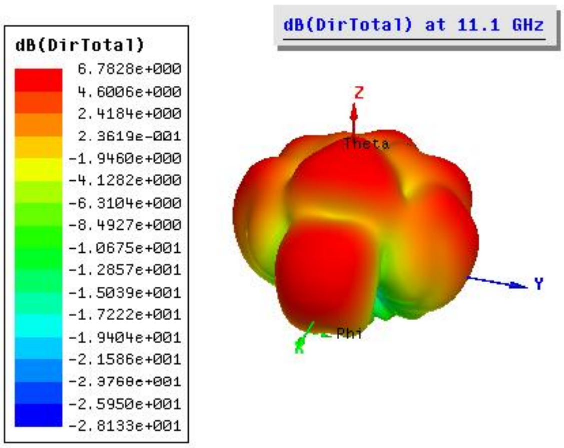

dB(GainTotal) at 7 GHz
dB(GainTotal)
6.3460e+000
4.3077e+000
2.2694e+000
2.3108e-001
-1.8072e+000
-3.8455e+000
-5.8838e+000
-7.9221e+000
-9.9604e+000
-1.1999e+001
-1.4037e+001
-1.6075e+001
-1.8114e+001
-2.0152e+001
-2.2190e+001
-2.4228e+001
-2.6267e+001
Z
Theta
Y
Phi
X


dB(DirTotal) at 7 GHz
dB(DirTotal)
6.3605e+000
3.8321e+000
1.3037e+000
-1.2247e+000
-3.7531e+000
-6.2815e+000
-8.8099e+000
-1.1338e+001
-1.3867e+001
-1.6395e+001
-1.8924e+001
-2.1452e+001
-2.3980e+001
-2.6509e+001
-2.9037e+001
-3.1566e+001
-3.4094e+001
Z
Theta
Y
Phi
X


dB(GainTotal) at 8.4 GHz
dB(GainTotal)
8.2156e+000
5.2846e+000
2.3535e+000
-5.7749e-001
-3.5085e+000
-6.4396e+000
-9.3706e+000
-1.2302e+001
-1.5233e+001
-1.8164e+001
-2.1095e+001
-2.4026e+001
-2.6957e+001
-2.9888e+001
-3.2819e+001
-3.5750e+001
-3.8681e+001
Z
Theta
Y
Phi
X


dB(DirTotal) at 8.4 GHz
dB(DirTotal)
8.5401e+000
5.5478e+000
2.5554e+000
-4.3699e-001
-3.4294e+000
-6.4217e+000
-9.4141e+000
-1.2407e+001
-1.5399e+001
-1.8391e+001
-2.1384e+001
-2.4376e+001
-2.7368e+001
-3.0361e+001
-3.3353e+001
-3.6346e+001
-3.9338e+001
Z
Theta
Y
Phi
X


dB(GainTotal) at 11.1 GHz
dB(GainTotal)
6.7799e+000
4.7294e+000
2.6789e+000
6.2845e-001
-1.4220e+000
-3.4725e+000
-5.5230e+000
-7.5735e+000
-9.6240e+000
-1.1674e+001
-1.3725e+001
-1.5775e+001
-1.7826e+001
-1.9876e+001
-2.1927e+001
-2.3977e+001
-2.6028e+001
Z
Theta
Y
Phi
X


dB(DirTotal) at 11.1 GHz
dB(DirTotal)
6.7828e+000
4.6006e+000
2.4184e+000
2.3619e-001
-1.9460e+000
-4.1282e+000
-6.3104e+000
-8.4927e+000
-1.0675e+001
-1.2857e+001
-1.5039e+001
-1.7222e+001
-1.9404e+001
-2.1586e+001
-2.3768e+001
-2.5950e+001
-2.8133e+001
Z
Theta
Y
Phi
X

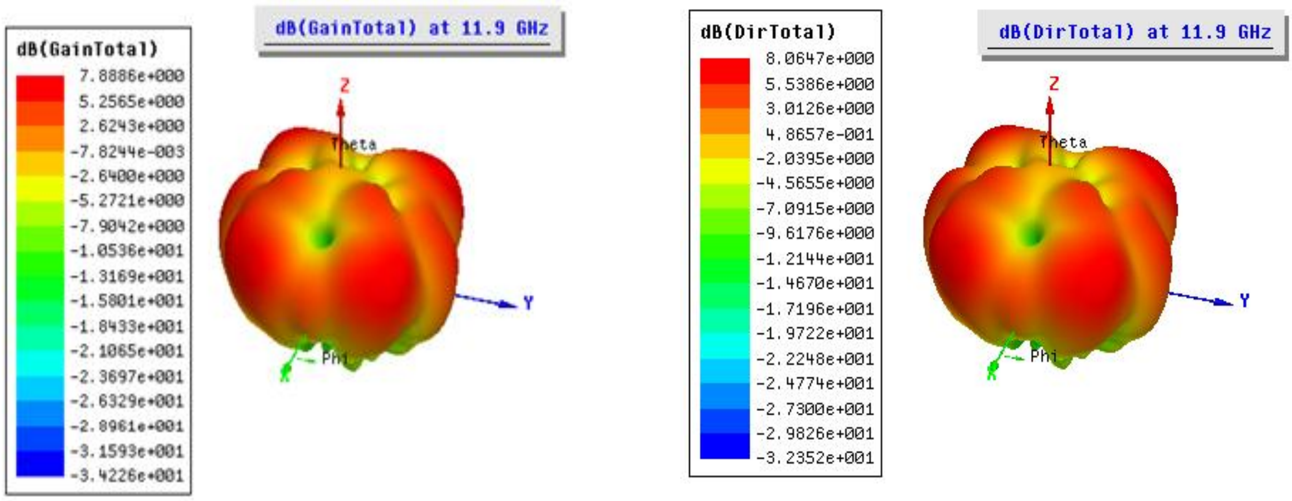


Figure 6: Gain and Directivity of the four resonant frequencies

The radiated efficiency of the proposed antenna is also calculated using the following equation [18].

$$e = \frac{G}{D} \quad \ldots\ldots (3)$$

Where e is the radiated efficiency, D is the maximum directivity, and G is the maximumgain. All these parameters are listed in Table.1.

Table 1: Parameters of Pentagon fractal antenna

Frequency (GHz)	Return loss (dB)	VSWR	Directivity (dB)	Gain (dB)	Input Impedance	Efficiency %
7	*-13.7*	*1.5*	*6.36*	*6.34*	*42.5*	*99*
8.4	*--21.08*	*1.2*	*8.54*	*8.21*	*46.6*	*96*
11.1	*-12.7*	*1.6*	*6.78*	*6.77*	*48.6*	*99*
11.9	*-24.1*	*1.1*	*8.06*	*7.88*	*48.7*	*97*

CONCLUSION

In the present work modified pentagon fractal antenna is proposed to work in the frequency range (6.5-12.5) GHz. Utilizing from fractal geometry in designing the shape of the antenna and uniting the vertices of the shape elements has acquired this model very good properties like small area, low profile, high gain and directivity, and very good matching at four different frequencies. Besides, very high efficiency which makes this antenna is applicable in different areas like fixed wireless links, defense, science, and smart phones through the promising applications of 5G technology.

REFERENCES

[1] Sarkar, Debdeep, KushmandaSaurav, and Kumar VaibhavSrivastava. "Design of a novel dual-band microstrip patch antenna for WLAN/WiMAX applications using complementary split ring resonators and partially defected ground structure." *Progress in Electromagnetics Research Symp. Proc., Taipei*. 2013.

[2] Krzysztofik, Wojciech J. "Modified Sierpinski fractal monopole for ISM-bands handset applications." IEEE Transactions on Antennas and Propagation 57.3 (2009): 606-615.

[3] Krzysztofik, Wojciech J. "Take advantage of fractal geometry in the antenna technology of Modern Communications." Telecommunication in Modern Satellite, Cable and Broadcasting Services (TELSIKS), 2013 11th International Conference on. Vol. 2. IEEE, 2013.

[4] Shaalan, AmerBasim. "Design of fractal quadratic Koch antenna." Systems Signals and Devices (SSD), 2010 7th International Multi-Conference on. IEEE, 2010.

[5] Attia, Hussein, and Omar M. Ramahi. "EBG superstrate for gain and bandwidth enhancement of microstrip array antennas", 2008 IEEE Antennas and Propagation Society International Symposium, 07/2008.

[6] Shaalan, AmerBasim, and AmmarNadalShareef. "Gain Enhancement of Fractal Shape Antenna using Metamaterial Cover." International Journal 2.11 (2014): 880-887.

[7] Attia, Hussein, et al. "Enhanced-gain microstrip antenna using engineered magnetic superstrates." IEEE

Antennas and Wireless Propagation Letters 8 (2009): 1198-1201.

[8] Azad, Mohammed Z., and Mohammod Ali. "A miniaturized Hilbert PIFA for dual-band mobile wireless applications." IEEE Antennas and wireless propagation letters 4.1 (2005): 59-62.

[9] Vinoy, K. J., and Arnab Pal. "Dual-frequency characteristics of Minkowski-square ring antennas." IET microwaves, antennas & propagation 4.2 (2010): 219-224.

[10] Puente, C., et al. "Variations on the fractal Sierpinski antenna flare angle." Antennas and Propagation Society International Symposium, 1998. IEEE. Vol. 4. IEEE, 1998.

[11] Shareef, AmmarNadal, and AmerBasimShaalan. "Fractal Peano Antenna Covered by Two Layers of Modified Ring Resonator." International Journal of Wireless and Microwave Technologies (IJWMT) 5.2 (2015): 1.

[12] Muhi, Malek AH, and Mohammed AZ Habeeb. "Modeling and Simulation of Sierpinski Pentagon Fractal Antennas." Journal of Al-Nahrain University 16.4 (2013): 106-166.

[13] Spectrum above 6 GHz for future mobile communication. (2015, January 16). Retrieved from

https://www.ofcom.org.uk/consultations-and-statements/category-2/above-6ghz

[14] Vettikalladi, Hamsakutty, Olivier Lafond, and Mohammed Himdi. "High-efficient and high-gain superstrate antenna for 60-GHz indoor communication." IEEE Antennas and Wireless Propagation Letters 8 (2009): 1422-1425.

[15] Krzysztofik, W. J. "Terminal antennas of mobile communication systems–some methods of computational analysis." (2011).

[16] Salous, S. "Multi-band multi-antenna chirp channel sounder for frequencies above 6 GHz." Antennas and Propagation (EuCAP), 2016 10th European Conference on. IEEE, 2016.

[17] Falconer, K.J., Fractal Geometry: Mathematical Foundations and Applications, Chinchester, New York: John Wiley & Sons, 2nd ed., 2003.

[18] Shaalan, Amer Basim. Simulation of Fractal Antenna Properties Using Fractal Geometry. Diss. Ph. D. Thesis, Al-Mustansiriyah University, 2002.