A PERFORMANCE OF PEANO KOCH HYBRID FRACTAL ANTENNA FOR 2.4 AND 5.5GHZ APPLICATIONS

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Abstract - In this modernization, demand of wireless devices tremendously increased. The antenna is part and parcel component of every wireless electronic device. Thanks to hybrid fractal technology, single antenna can used for various applications. In this article, a hybrid fractal antenna is designed using Peano and Koch antenna. The performance of hybrid fractal antenna is scrutinized and anticipated with various antenna parameters to judge antenna behavior. The hybrid fractal antenna dimensions are 34x42 mm^2 and proposed antenna can operate 2.43 GHz frequency. This small size antenna has less than 2 value of VSWR at every resonant frequency. The proposed antenna is light in weight because it designed on FR4 epoxy material and cheaper in price. The current distribution and radiation pattern also demonstrate the omni directional radiation of electromagnetic waves. Max gain of 18dB at 2.43GHz at unlicensed band for Bluetooth application is achieved. Proposed antenna can also operate at 5.5GHz for Wi-Fi and WLAN application and 3G cellular communication (1.90-1.98GHz).

Keywords - Peano, Koch, GHz, VSWR, FR4

I. INTRODUCTION

In wireless communication, new types of antennas are explored by researchers. These antenna are immensely beneficial for Bluetooth, Wi fi, WLAN and other advance embedded system designs. In addition to this, fractal antenna is very wide area for research [1]and design different microstrip planner antenna which replaced traditional antennas[2][3]. Fractal type antenna was developed from two decades and there are multiple modifications are doing[4][5]. Given this, hybrid fractal antenna developed few years ago[6][7][8]. There are several antenna parameters which enriched by hybrid technique in fractal antenna. There are two well-known fractal properties which is space filling and self-similarity[9]. Both properties are essential for design effective antenna. The space filling property represents coverage ability of electrical conductor element on patch area[10]. Most popular fractal geometry peano has sound space filling because it helps to spread radiating element at every part of patch[11]. Similarly, hilbert and Moore fractal geometry have good proficiency of space filling[12]. In contrast, self-similarity described from zoom in or zoom out any part of fractal geometry. The self-similarity of Minkowski, Koch, Sierpinski carpet, Sierpinski gasket look similar image as iteration level decreased[13].

Besides this, iteration level also effect on radiating element of antenna because when antenna length increased, the fringing field lines from patch to ground are stronger as result radiating characteristics improves[14]. Substrate material is another essential aspect to enhance the performance of antenna[10]. The effective dielectric constant of substrate provide effective storage power so that electromagnetic field lines easily complete its cycle and radiate into free space. Thus, dielectric constant value should be as minimum as possible but not less than 2 otherwise electromagnetic lines started deteriorate[15]. It is beyond dough that if height of substrate increases EM waves become longer and it directly effect on performance of antenna.

The transmission line model calculate width and length of patch by using equations (1) and (2)[16]:

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

Where W is width of patch
c is velocity of light
fr is resonance frequency
ε_r is dielectric constant of substrate

The effective dielectric constant is varies in between 1 < ε_{reff} < ε_r . The expression for effective dielectric constant ε_{reff} is given as[10]:

$$\varepsilon_{reff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \quad (2)$$

Where ε_{reff} = Effective dielectric constant
ε_r = Dielectric constant of substrate
h = Height of dielectric substrate used under the patch

II. GEOMETRY STRUCTURE

The proposed antenna is designed by adding different fractal geometries to achieve hybrid geometry. Normally, utilization of different types of fractal geometries provides multiband response and compress the size of antenna. Peano fractal geometry was developed by Italian mathematician Giuseppe peano[17]. Peano fractal geometry is provides longer element on small area of patch. The plane filling fractal properties allows miniaturization of antenna

and self-similarity properties provides multiband antenna. So given this, peano curve provide benefits of space filing properties and Minkowski, Koch and Hilbert curve fulfill self-similarity properties[11][18]. The fusion of two fractal curves are illustrated below and radiation response of hybrid geometry is demonstrated as following:

Peano Koch Hybrid Fractal Antenna (PKHFA)

Proposed hybrid fractal antenna is designed using two different types of fractal curved geometries which are Peano and Koch. Peano curve is plays an important role to achieve space filling property of patch antenna. The conductor path is tremendously increases which help to enhance the performance characteristics of antenna. Length of peano curve is rises with respect to iteration number. As represented in geometry, peano fractal curve implemented upto 3rd iteration level. The iteration level also enhance complexity of structure. In first iteration, initiator curve is sinusoidal square shaped. Moving toward second iteration, three set of initiator curves are arranges and fused with each other. Likewise, proposed peano geometry introduced by following same procedure in next iteration. Additionally, Koch curve originated from straight line initiator and triangles are added at one third part of every segment as illustrated in figure 1.

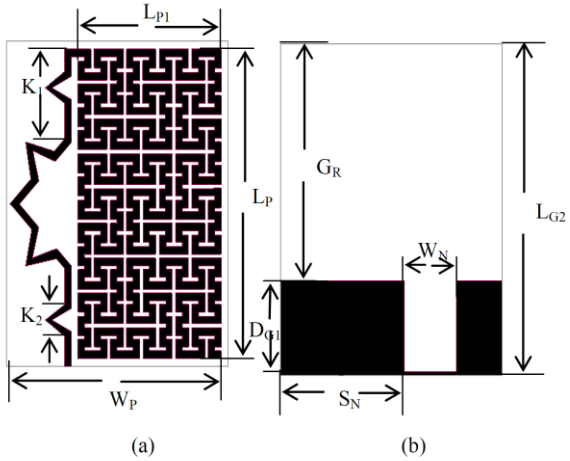


Figure 1 (a) Patch of proposed PKHFA (b) Defected ground of PKHFA

As discussed above the dimensions of proposed PKHFA are 34x42mm2 and FR4 epoxy material used for design prototype. The ground plane partially deflected with notch characteristics. Ground plane of antenna is analysis in HFSS. The notch in ground plane is analysis with far field radiation characteristics with gain scale.

The self-similarity of antenna is represented by D and it is observed by ratio of logarithmic of number of segments of curve to logarithmic of number of parts of curve as given below[9]:

$$D = \frac{\log(4)}{\log(3)} \qquad (3)$$

Parameters	Dimensions in mm
Peano geometry length (L_{P1})	22
Width of patch (W_P)	32.42
Length of patch (L_P)	40
Defected ground plane (D_{G1})	12
Length of reduced ground (G_R)	30
Notch width in ground plane (W_N)	8
Space between notch (S_N)	19
Length of ground plane (L_{G2})	42
Koch segment length (K_1)	11.61
Second iteration of Koch curve (K_2)	3.8

Table 1 Dimensions of Peano Koch Hybrid Fractal Antenna

Length of radiating element is essential factor which defines resonance characteristics of antenna. In case of peano curve, the length of patch perimeter is tremendously increased within limited space. Consequently, maintenance value of antenna gain and relevant impedance bandwidth of antenna[19].

$$L = h\left(\frac{N}{r}\right)^{i} = h\left(\frac{4}{3}\right)^{i} \qquad (4)$$

Initially, length of small peano curve has 10mm in length and 0.5mm is used as fused two peano curves. In single set of peano has 9 number of peano curves are used and 8 (9-1) number of joints are required each has 0.5mm long. It means length of one set is 94mm. Further, applying the third iteration of peano geometry length is become nine times (90%) increased. Because it has 9 set of peano sets and 4mm are used for conjunctions between every set i.e. peano geometry length is 94 x 9 + 4=850mm. Likewise, the Koch curve length is found 50mm long patch conductor at 2nd iteration of Koch curve. Finally, length of full hybrid Peano Koch curve is found 900mm.

III. EVALUATION OF ANTENNA PERFORMANCE

A. Reflection coefficient

The reflection coefficient of antenna described the ratio of amplitude of voltage reflected back toward tested antenna to amplitude of transmitted voltage[20]. Scattering parameters of proposed antenna is anticipated in figure 2. There are eight number of resonant frequencies which antenna radiate properly and return loss is -22.97dB at 1.98GHz, -14.80dB at 2.43GHz, -20.06dB at 5.54GHz, -18.39dB at 6.53GHz, -14.63dB at 8.15GHz, -12.62dB at 8.82GHz, -12.81dB at 10.11GHz and -13.32dB at 12.00GHz as demonstrated in figure 2.

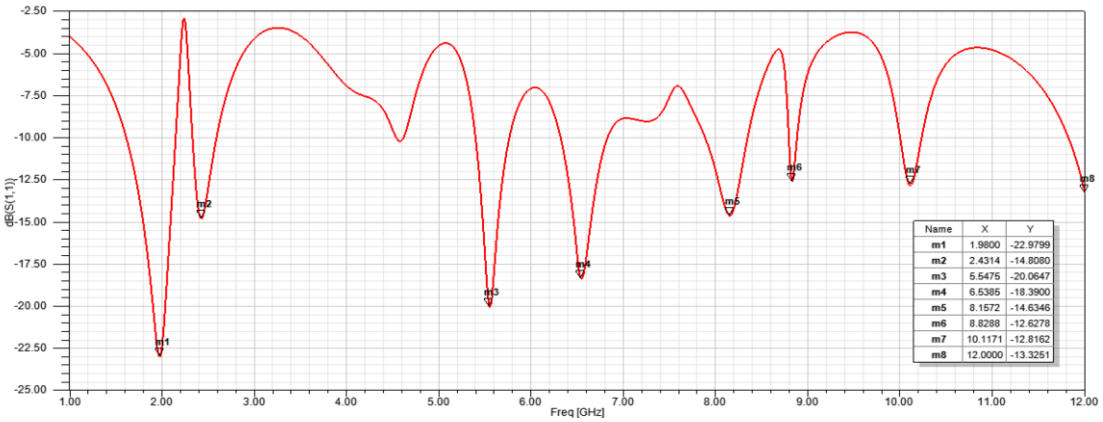


Figure 2 Reflection coefficient graph of proposed PKHFA

B. Feed position effect on scattering parameters

In proposed PKHFA, microstrip line feed used to in transmission line impedance matching which is 50Ω[3][16]. The feed transmission line connected at Koch side (KSF) as well as peano side (PSF). Both Koch Side Feed (KSF) and Peano Side Feed (PSF) positions are optimized within far field radiation pattern or reflection coefficient graph as delineated in figure 3. The partially defected ground surface implemented to enhance resonance bandwidth at relevant frequency band.

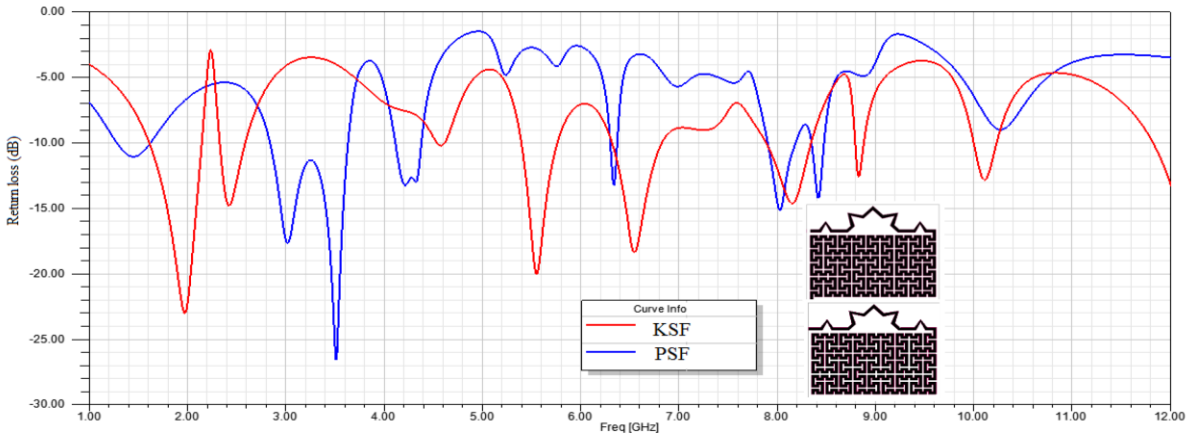


Figure 3 Effect of feed position on S11 parameters of proposed PKHFA

C. VSWR

The voltage standing wave ratio visualizes the impedance matching between source which provide energy and load[21]. Practically, the value of VSWR should be under two because it directly depends on reflection coefficient[6], [22]. The value of VSWR at every resonant frequency is obtained and value is acceptable as shown in figure 4.

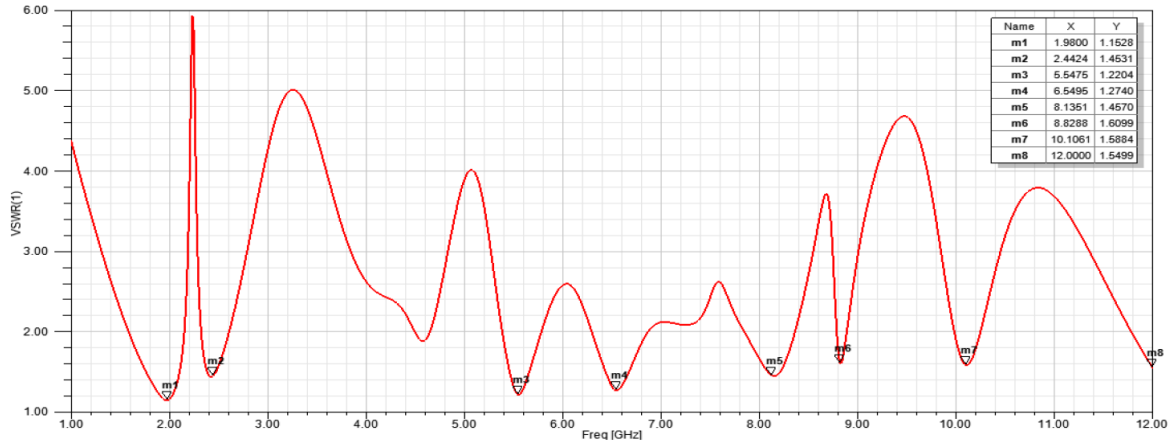


Figure 4 VSWR of proposed PKHFA

D. Gain

The gain defines as how much signal strength of electromagnetic wave is reached on particular direction[23]. 3-Dimensional gain is anticipated in figure 5 which is maximum value of gain is 18 dB at 2.43GHz resonant frequency.

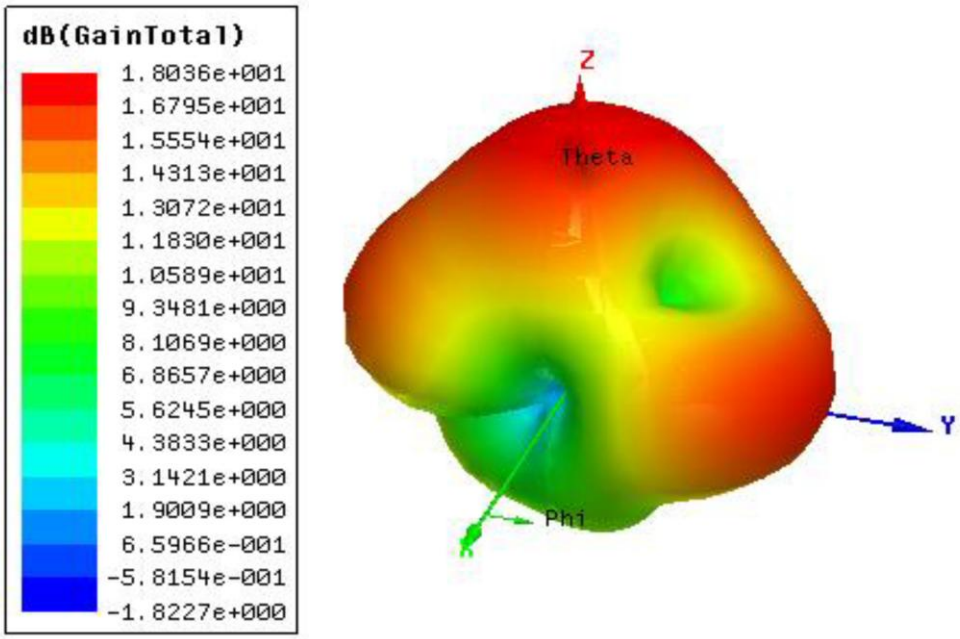
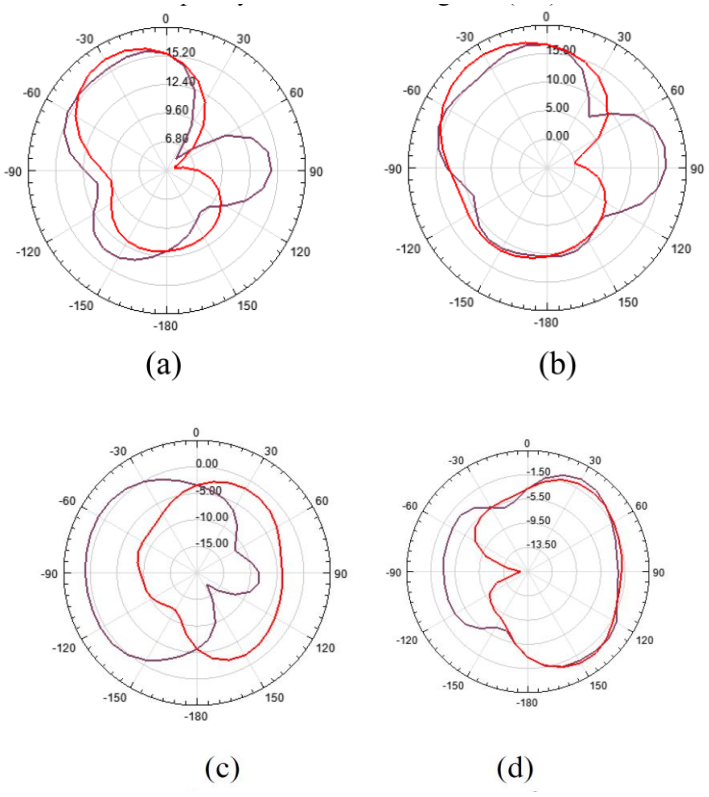


Figure 5 Maximum gain of proposed PKHFA at 2.43GHz

E. Radiation pattern

The two dimensional radiation pattern delineated with gain scale in figure 1. The radiation characteristics of proposed hybrid fractal antenna is obtained at 0 degree and 90 degree. The red line in figure 1 indicates 0° angle also known as azimuth angle On the other hand, 90° angle shows in black line called as elevation angle. The proposed antenna radiates electromagnetic waves in almost omni directional at every resonance frequency as exhibited in figure 6(a-h).



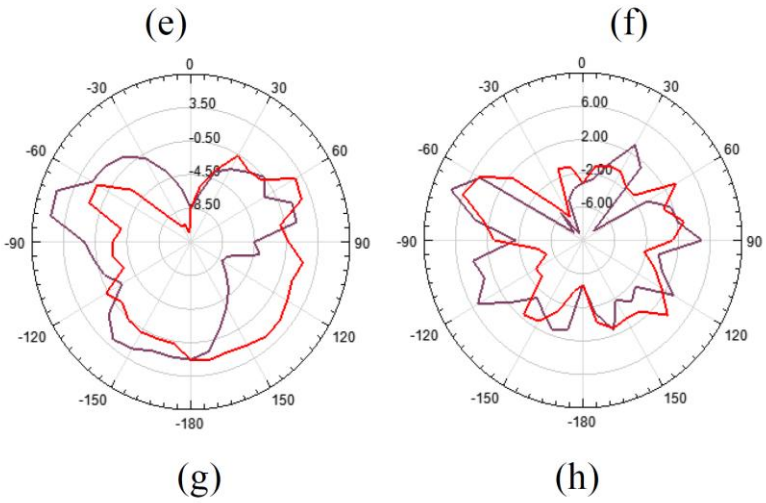
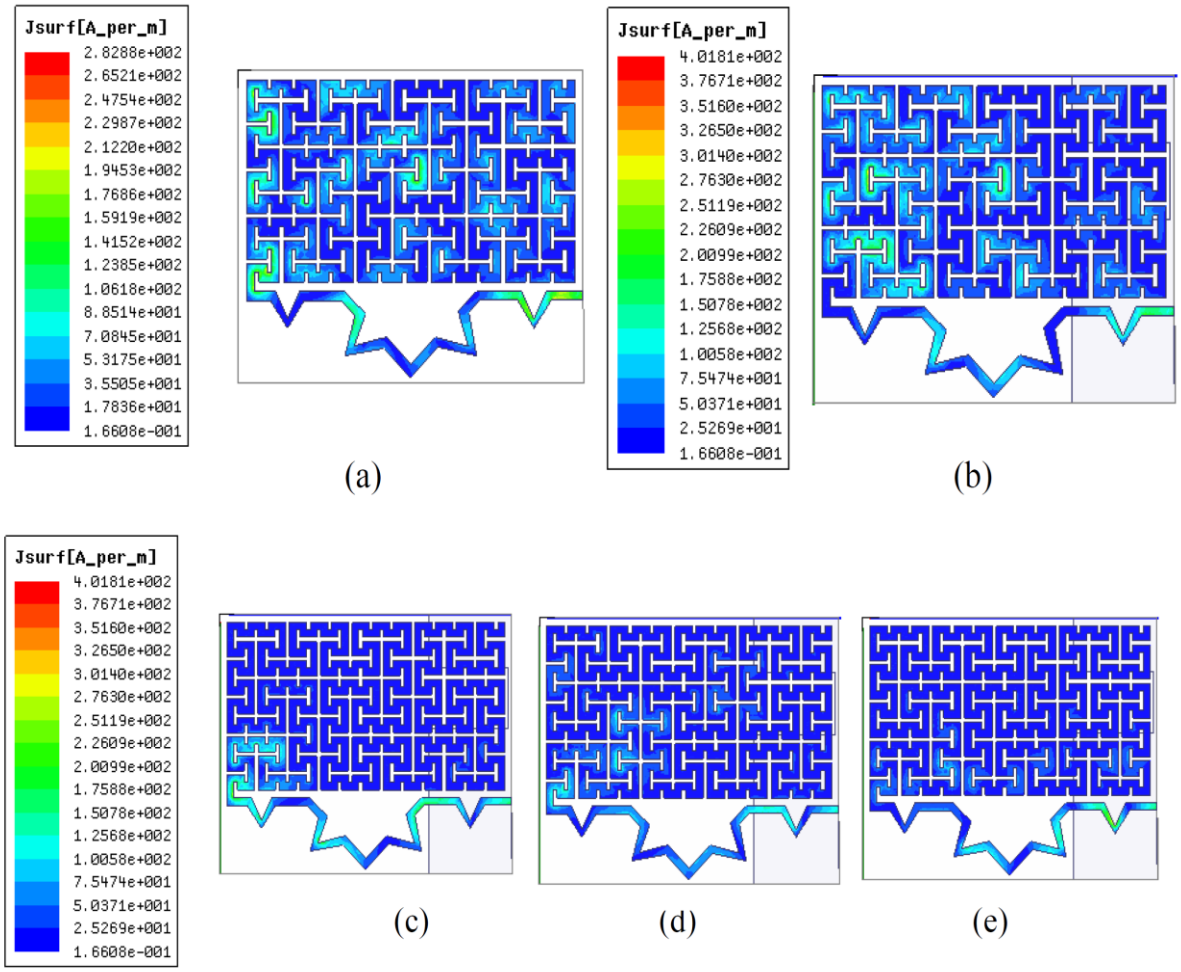


Figure 6 Radiation pattern of proposed PKHFA at resonant frequencies 1.98GHz, (b) 2.43GHz, (c) 5.54GHz, (d) 6.53GHz, (e) 8.15GHz, (f) 8.82GHz, (g) 10.11GHz, (h) 12.00GHz

F. Current distribution

The surface current distribution depicts the patch surface current distribution on various corners and edges of patch antenna[10][24]. The value of current distribution is different at various parts of patch. The minimum current density is anticipated at around peano curve and value is 282. In contrary, maximum surface density recorded 401 near feeding position as represented in figure 7(a-h).



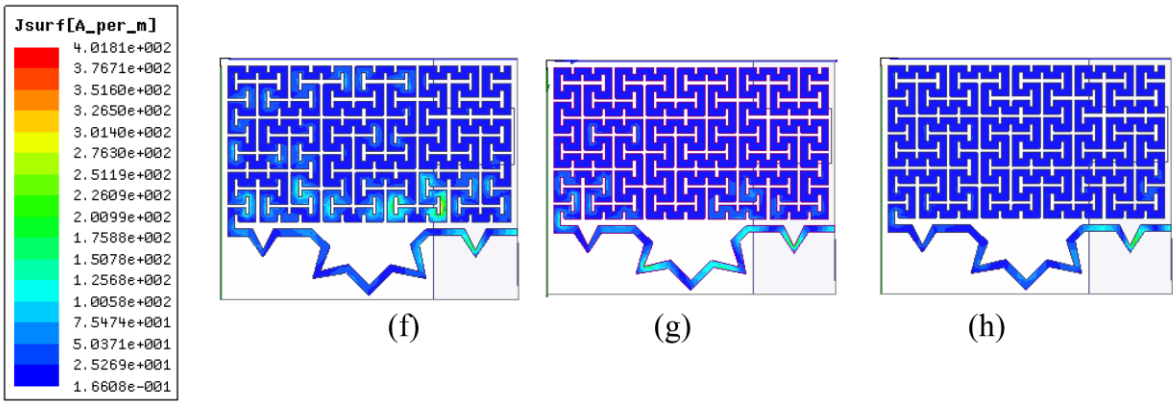


Figure 7 Current distribution of proposed PKHFA at resonant frequencies 1.98GHz, (b) 2.43GHz, (c) 5.54GHz, (d) 6.53GHz, (e) 8.15GHz, (f) 8.82GHz, (g) 10.11GHz, (h) 12.00GHz

G. Smith chart

The impedance of antenna comes in immensely handy to determine the antenna characteristics with respect to frequency range[25][26]. Figure 8 illustrated the impedance matching between source and load with scattering parameters. There are two scale lines real and imaginary axis. Both represent the level of impedance match properly when both scattering parameter line cross value 1 or near to one.

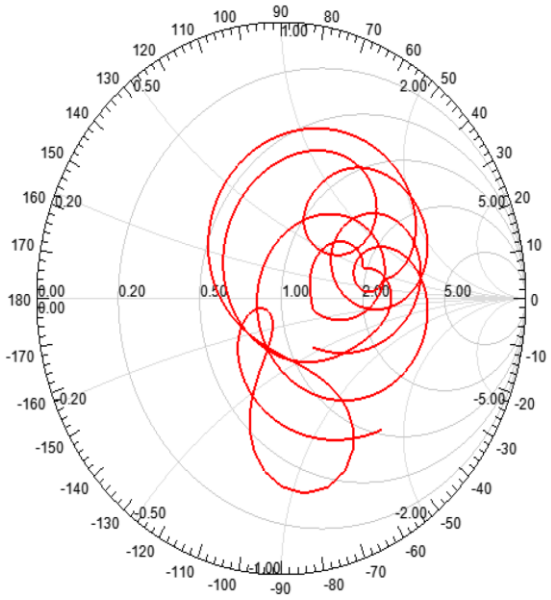


Figure 8 Smith chart of proposed PKHFA

IV. CONCLUSION

It is concluded from the overall analysis the performance of hybridization of Koch and peano curves. The proposed antenna has maximum gain 18dB at 2.43GHz which pays a rich dividend for various applications because it is unlicensed band and very useful for Bluetooth application. Moreover, proposed antenna can operate at 5.5GHz which is also free band for Wi-Fi and WLAN applications and 3G cellular communication (1.90-1.98GHz). Apart from this, minimum scattering value is -22.97 dB at 1.98GHz frequency and antenna is small in size 34x42mm^2. Proposed PKHFA can operate in L, S, C and X band applications with acceptable value of gain at every resonant band. It is found form the overall conclusion that peano curve helps to increase length of patch conductor and antenna become multiband in behavior, the Koch curve provides good value of gain at resonance frequency.

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