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Rectangular-Spiral Fed Octagonal Microstrip Patch Filtenna for Wireless Applications

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High Gain, Wide Bandwidth, Filtration Characteristics and Compactness are the primary features of antennas which are of interest in many modern wireless applications. This paper presents design, simulation and analysis of a novel wide-band octagonal shaped microstrip patch antenna, co-designed with a rectangular spiral type resonating surface feed suited for wireless communication. The compact design of Filtenna gives minima at three different frequencies, 14.15 GHz, 21.6 GHz and 27.5 GHz, giving a wide passband of 14-28 GHz. The dimensions of the patch are less than 2mm for each side of octagon making it highly compact. The rectangular Spiral element coupled with the radiating patch increases the directivity and gain of the MPA. Both the elements share the same substrate of FR4 with a dielectric constant of 4.4 and dielectric thickness 0.8mm. The design is conceptualized and simulated using SONNET software. The Octagonal patch acts as a radiating element accompanied with rectangular spiral meander, providing filtration characteristics with improved bandwidth and multiple gain peaks making it suitable for wireless communication along with increased data rates, less distortion and lower return loss. This paper aims to investigate on the design of rectangular spiral fed octagonal microstrip antenna to achieve higher directive gain and radiation efficiency along with wideband frequency selective characteristics.

1. Introduction

The evolution of modern wireless communications systems has increased dramatically together with the demand for antennas which are miniaturized and low cost radiating structures. One way to miniaturize is to integrate required multiple functional circuitries into one device [1]. Wireless communication setup needs an antenna which acts as a transmitter or receiver, along with a bandpass filter which is able to select signals inside a specific bandwidth at a certain frequency and reject signals in another frequency region. This type of filter integrated with an antenna on single patch surface is termed as “Filtenna” [2].

Filtering antennas have been implemented in different forms including rectangular patch [3], [4], circular patch [5], patch array [6], Γ-shaped antenna [7], slot dipole [8], monopole antenna [9], inverted-L antenna [10], Yagi antenna [11], waveguide slot antenna [12], and dielectric resonator antennas [13].

One of the requirements for wireless antenna is that it should have omni-directional properties with circular polarization [14]. This can be achieved by using spiral structures, which have characteristics that are vital to wireless communications in many applications. Their wide-band characteristics accompanied with their low profile as well as their low cost make these antennas prime candidates for use in sensors and some mobile applications compare to other antennas as these provide dual band characteristics [15].

A novel wideband microstrip patch antenna co- designed with a rectangular spiral patch filter has been designed as shown in Fig.1 and simulated in this work. In the co-design approach presented here, the antenna filter is composed of a microstrip patch antenna and a filter, both of which share the same ground plane to reduce the size and the combination operates at three different resonant frequencies. Due to the circular polarization and the frequency selective characteristics at a relatively small size these designs are suitable for WLANs applications.

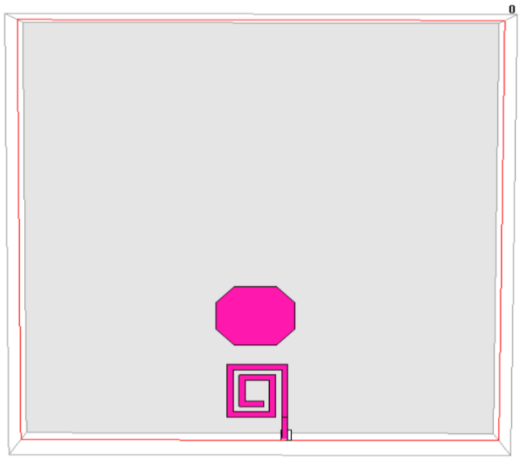

Fig.1: Rectangular Spiral fed Octagonal Microstrip Patch Antenna design using SONNET

2. Design Geometry

A. Design of Antenna

Dimensions, substrate selection and feed techniques are the important parameters that affect the antenna response. The dimensions of the antenna can be calculated from simple mathematical equations [16]. In this paper the co-design of antenna and filter is modified. The basic antenna designed is a octagonal patch antenna, dimensions of which are as shown in Fig.2. The optimized design parameters for the antenna with 50 Ω interface impedance are used accordingly to provide better bandwidth.

B. Design of Filter

The filter used in this co-design is a microstrip bandpass Rectangular spiral filter. The specifications and the substrate properties are as stated in Table 1 and Table 2 respectively. It's used for theoretical and simulated study where the dimensions are in mm range. The layout of Rectangular Spiral Filter is as shown in Table 3 and its design dimensions are presented in Fig.3.

TABLE 1: SPECIFICATION OF THE ANTENNA

Center frequency(f_c)	14.15 GHz, 21.6 GHz, 27.5GHz
Bandwidth (BW)	14 GHz
Radiation Pattern	Omni-directional
Voltage Standing Wave Ratio(VSWR)	≤ 2
Return Loss (S11)	≤ -20
Line Impedance(Z_o)	50 Ω

TABLE 2: SUBSRATE PROPERTIES

Substrate	FR4
Dielectric constant	4.4
Thickness h (mm)	0.8
Top patch metal	Copper
Loss tangent (tan δ)	0.02

TABLE 3: DIMENSION OF RECTANGULAR SPIRAL MICROSTRIP PATCH

Height, h (mm)	2.54
Width, W (mm)	2.54
Gap, G (mm)	1
Inner radius, IR (mm)	1
No. of Turns	2

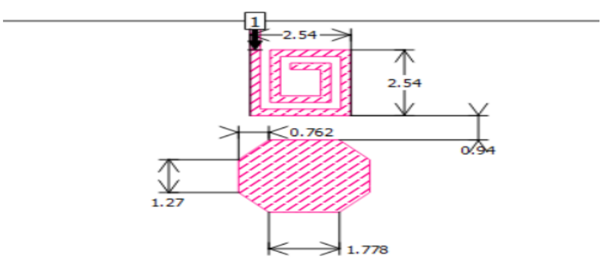

Fig-2: Dimensions of Octagonal Patch and Rectangular Spiral Filter as designed on

SONNET

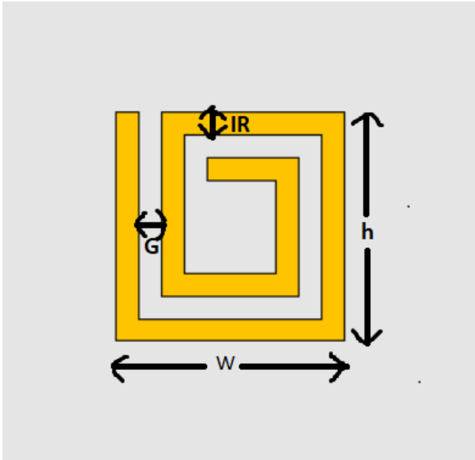

Fig.3: Rectangular Spiral Filter Design

C. Modelling and Simulation

The designing and simulation is performed using SONNET Software 13.56 [17]. This is a full wave simulator which works on the Method of Moments. It has been widely used in the design of MICs, filters, power dividers, antennas etc. It plots the S, Y, Z parameters, VSWR, Z_{in}, current density and gain of antennas.

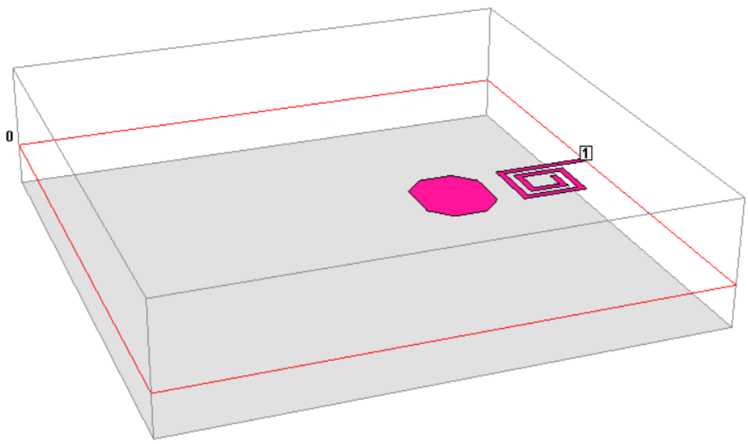

Fig-4: SONNET 3-D geometry view of designed Antenna

3. Result and Discussions

Full wave electromagnetic simulations were performed on EM Simulator (SONNET 13.56

Software). Due to better coupling between the antenna and the filter, three resonant frequencies appear that show the co-designed version has a better bandwidth. Fig. 2 shows the Sonnet geometry of this filtenna while Fig. 7 shows the Gain-Bandwidth result for the filtenna. During the design process several other substrates were simulated for drawing a comparative for better antenna performance with high gain and low return loss, Fig.5 and Fig.6 showcases the finding of the S_{11} graph for gain of Filtenna in case of Rogers RT-Duroid 5880 (ε_r =2.2) and Allumina (ε_r =9). S_{11} is greater than -10 db for patches designed on Rogers RT-Duroid 5880 and Allumina, thus these substrates were not preferred and FR4 shows good gain and low return loss value hence final design was made on FR4 as substrate.

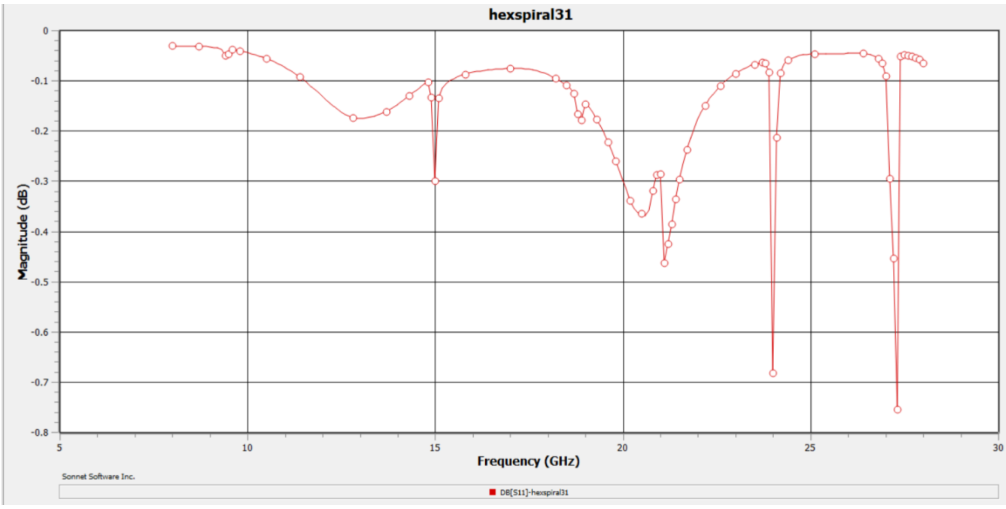

Fig-5: S11 graph for Gain of the Filtenna with Substrate as Rogers RT Duroid 5880

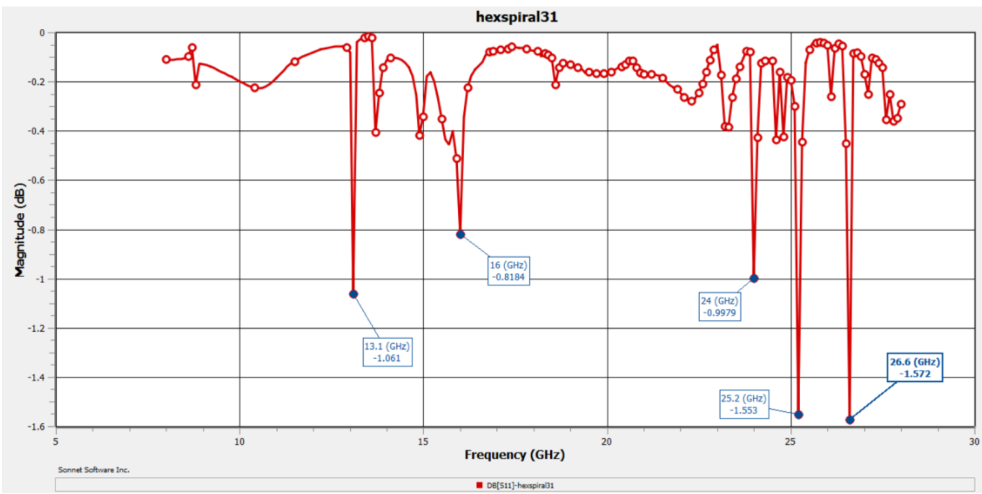

Fig-6: S11 graph for Gain of the Filtenna with Substrate as Alummina

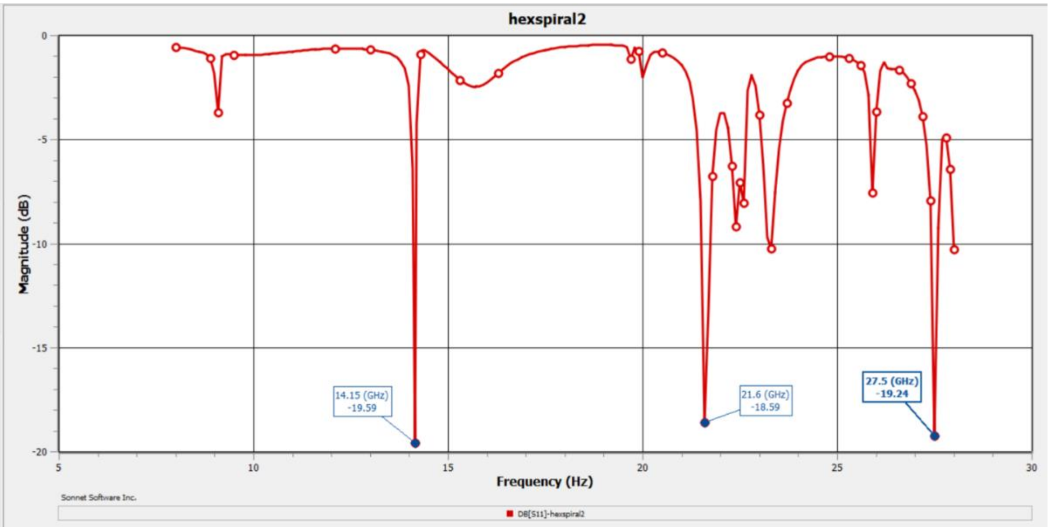

Fig-7: S11 graph for Gain of the Filtenna with Substrate as FR4

Based on the result shown in Figure 7, the simulation result gives 19.59 dB of return loss (S11) at 14.15 GHz, 18.59 dB of return loss at 21.6 GHz and 19.24 dB of return loss at 27.5 GHz. The frequency is being shifted by 2.4% to the right.

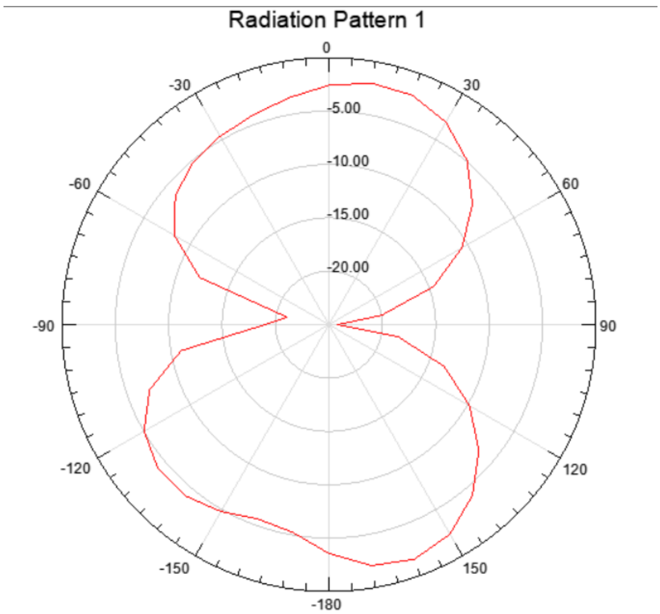

Fig-8: Radiation Pattern for Filtenna with Substrate as FR4

In Fig-8, the 2D radiation pattern is exhibited for the final design realized for the MPA with FR4 as substrate, at a specific orientation of theta 90° in the XY direction. The pattern is observed at a frequency of 14.15 GHz.

4. Conclusions

In the past decade, because of its low profile, small size and low manufacturing cost, the microstrip filters and antennas have found to be in significant demand for commercial applications. Especially in the area of satellite communications, Wireless & WLAN applications and future 5G and 6G communications the demand for microstrip antennas will be more evident. It is believed that this small size antenna will continue to boost the Communication systems further with larger bandwidth and single structure compensating multiple components requirements.

The structure presented above combines filtering and radiating functions simultaneously. The proposed system can reduce the size and cost of the communication system by combining two systems components into one. Thus we see that the co design approach is helpful in reducing the size of microwave circuits: combining two important devices into a single. Obviously, due to better coupling between the antenna and the filter, three resonant frequencies appeared. This shows that the co-designed version has a better bandwidth and the structure combines filtering and radiating functions simultaneously. Compensation such as DGS and vias for discontinuities can be applied to get better results in terms of reflection and radiation.

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