Dual Band Octagonal Microstrip Antenna Design Method for Energy Harvesting

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***Abstract*— A practical method to design dual-band octagonal patch antenna IS introduced. The antenna consists of an octagonal patch with a proximity coupling feed designed to radiate at 900 MHz and 1.8 GHz, respectively. The octagonal dual band patch antenna that is designed using the method introduced is then simulated with 3D FEM based electromagnetic simulator. The proposed antenna design can be used to harvest radio frequency (RF) energy from Wi-Fi and widely spread mobile networks. The simulated and analytical results are compared and good agreement is observed.**

Keywords—Microstrip, dual-band, antenna, Wi-Fi, octagonal, energy harvesting, radio frequency.

I. INTRODUCTION

The rapid growth of wireless systems and requirements of low-power integrated electronic circuits enabled extensive research to study various methods to power these systems and circuits by harvesting ambient electromagnetic energy [1].

Microstrip antennas have found widespread application for the last thirty years. Some of the applications of these antennas include mobile radio communication systems, satellite navigation receivers, satellite communications, direct broadcast radio and television, etc. The considerable interest in using and implementing microstrip antennas is due to their advantages over conventional microwave antennas in profile, cost, conformability, and fabrication. Nevertheless, the microstrip antennas typically suffer from narrowband radiation (a few percent of center frequency), low gain, tolerance problem and limited power capacity.

The development of microwave integrated technology and wireless communication systems require transceivers that can work in different frequency bands. Systems such as satellites, the global position system (GPS) are normally required to operate at two different frequencies. This stimulated development of devices including microstrip antennas to be able to operate in multi frequency band. Variety of methods has been proposed to obtain dual frequency operation. Among them, loading slits, loading the patch with shorting pins, using slots in the patch, using stacked patches, or using two feeding ports are the mostly exploited ones. The feeding technique for microstrip antennas based on the coupled-aperture concept is applied in order to achieve a large bandwidth. The technique consists of coupling energy from the strip-line though an aperture in the ground plane. The radiating element is isolated from the feed network by the ground plane, which minimizes

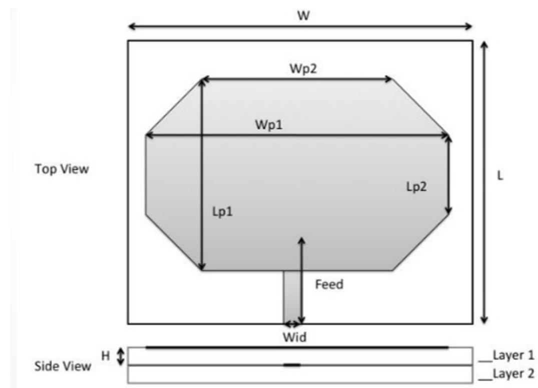

Fig. 1. Geometry of the octagonal patch antenna with the proximity feed

spurious radiation, and gives the designer the possibility to select independent substrate materials for the feed and the patch.

In this paper, a practical method to design and implement octagonal microstrip patch antenna that can operate in dual frequency band as shown in Fig. 1 is given for energy harvesting applications. The proposed method is simulated and verified with 3D FEM based electromagnetic simulator. Analytical and simulation results are compared and found to be in close agreement. A method such as the one introduced in this paper can be used to design dual band octagonal microstrip antennas in energy harvesting systems.

II. ANTENNA DESIGN

The geometry of the proposed octagonal microstrip antenna is modeled using the equations in [2] at two separate frequencies.

In Table I, W is the width of the patch, L is the length of the patch, del_l is the additional length on each end due to the fringing field along the widths, ε_r is the relative dielectric constant of the substrate, ε_{eff} is the effective dielectric constant, c is the speed of light in a vacuum, f is target frequency and h is the thickness of the substrate, l_{eff} is the effective length, g_1 is the conductance, g_{12} is the mutual conductance, r_{in} input impedance, $inset$ is the inset feed point distance, $Lg_{\min}$ is the minimum ground plane length, $Wg_{\min}$ is the minimum ground plane width, wid is the transmission line width, g is the gap between path and transmission line, respectively. The physical dimensions of the antenna for dual frequency operation are calculated and tabulated in Table I at 900MHz and 1.8GHz, respectively.

TABLE I. CALCULATED PARAMETERS

Param.	Frequency	
	900 MHz	***1.8 GHz***
W	71.7219 mm	35.8610 mm
ϵ_{eff}	9.3079	8.9509
del_l	0.6916 mm	0.6853 mm
l_{eff}	54.6289 mm	27.8538 mm
L	53.2457 mm	26.4832 mm
$g1$	0.1397 siemens	
$g12$	4.0307e-4	4.0403e-4
r_{in}	554.1945 ohm	553.6109 ohm
$inset$	21.4522 mm	10.6684 mm
$Lg_{\min}$	62.8457 mm	36.0832 mm
$Wg_{\min}$	81.3219 mm	45.4610 mm
wid	1.3974 mm	
g	0.3592 mm	0.1832 mm

The geometry of the configuration of an antenna that was designed is shown in Fig.1. In this design, two dielectric substrate layers are stacked together [3]. On the first top layer, the octagonal patch is etched. The second layer is the feed layer with a proximity coupling feed between the bottom and the ground plane. The material used for the dielectric is Rogers TMM 10i with a dielectric constant ε_r of 9.8 and thickness of 1.6 mm. $Lp1$ and $Wp1$ are the optimized values of length and width at the lower frequency, 900 MHz, and $Lp2$ is the optimized values of length at the higher frequency, 1.8 GHz. The length of the proximity feed coupling is obtained using Optimetrics in Ansys HFSS simulation by varying the physical dimension from 10 mm (value obtained from 1.8 GHz) to 21 mm (value obtained from 900 MHz). The optimized values found with HFSS for 900 MHz and 1.8 GHz operation are given in Table II. The method is also repeated for dual frequency band operation at 900MHz and 2.4GHz and given in Table II.

TABLE II. ANTENNA OPTIMIZATION PARAMETERS

Param.	Frequency	
	1.8 GHz	***2.4 GHz***
$Lp1$	53 mm	53 mm
$Lp2$	35 mm	29 mm
$Wp1$	73 mm	73 mm
$Wp2$	55 mm	49 mm

III. SIMULATION RESULTS

The antenna performance is studied by ANSYS Electronics Desktop 2017. The simulated return loss of the proposed octagonal antenna with the calculated physical dimensions using formulation is depicted in Fig 2. The graph shows the maximum return of -6.6357dB and 6.9307dB at the resonant frequencies of 940 MHz and 1.82 GHz, respectively. The proposed antenna is then optimized using the method described and simulated. The return loss of the optimized octagonal antenna is depicted in Fig 3. The graph shows the maximum return of -21.5574dB and -20.3761dB at the resonant frequencies of 900 MHz and 1.76 GHz, respectively. The improvement is around 15dB with optimization method proposed.

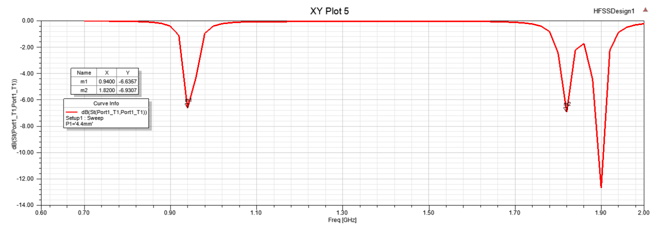

Fig. 2. Return loss of the proposed octagonal antenna for 900 MHz & 1.8 GHz.

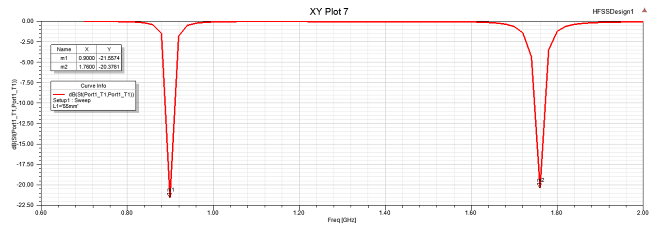

Fig. 3. Return loss of the optimized octagonal antenna for 900 MHz & 1.8 GHz.

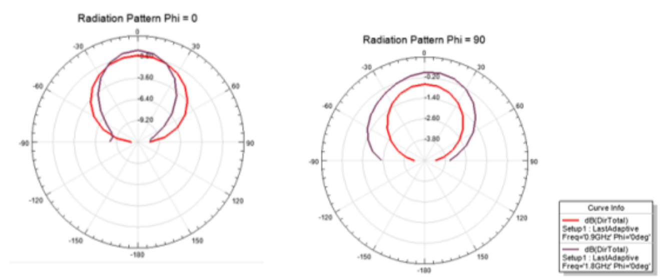

Fig. 4. Simulated directivity of the optimized antenna for 900 MHz & 1.8 GHz on XY and XZ planes.

The directivity of the optimized octagonal microstrip patch antenna on XY and YZ planes are illustrated in Fig. 4.

IV. CONCLUSION

In this paper, a practical method for dual-band microstrip octagonal antenna design for energy harvesting application has been given. The proposed method is verified via 3D electromagnetic simulator. The results of the analytical methods for antenna are found to be in agreement with the simulation results. The proposed method includes calculation of the physical dimensions and optimization with electromagnetic simulator. The octagonal microstrip antenna that is designed to execute dual frequency operation in the frequency band of GSM, PCS and Wi-Fi technologies can be used for energy harvesting applications. The antenna has an proximity coupling feed and double-layer microstrip patch structure.

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