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Design and Simulation of Crescent Monopole Antenna for 4G LTE Application

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ABSTRACT

A Crescent shaped monopole antenna for 4G LTE Application is proposed .The design parameter were investigated using HFSS software package. The HFSS microwave studio is used to obtain the reflection coefficient and input impedance of the investigated antenna. The crescent antenna geometry is composed of a circular radiating patch with a smiling slot, and it occupies a small size of (l)*(w)*(h) mm^3.An antenna prototype has been manufactured and it is characterized in terms of return loss, VSWR and radiation pattern measurement in rogers substrate .The return will be minimized in terms of 4G LTE applications. The performance of the investigated methods is compared using MATLAB software.

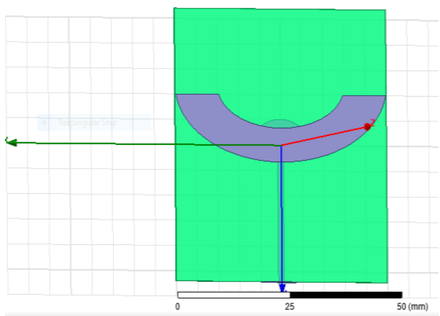
Keywords: Return loss, VSWR and Radiation pattern.

1. INTRODUCTION

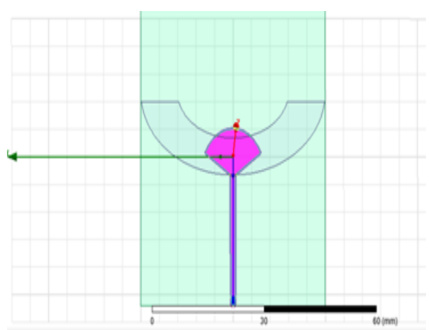
The main goal of the project is to propose the use of crescent monopole antennas at 4G LTE applications. The ability of crescent antenna is to reduce the return loss and increasing the bandwidth .Due to this antenna performance gain and directivity also increased. The input impedance and reflection coefficient can be obtained. The radiation pattern, VSWR, and return loss will be analyzed using HFSS software. Extensive progress has been achieved in the field of UWB systems, since its adoption by the federal communications commission "FCC" in 2002 [1]. To comply with all of these requirements the micro strip antenna has been nominated. However, due to its narrow bandwidth, many solutions have been introduced, such as using different shapes of the patch that can accommodate multimode surface current waves, which in turn lead to resonating at multiband frequencies and finally widen the impedance bandwidth across the entire UWB range. Among the proposed broadband antenna shapes are; a triangular monopole [2], circular and elliptical disc monopoles [3]-[4]. Another technique was through applying the self-complementary principle to the circular disk and ring monopole antennas [5]-[6], respectively. Impedance matching (IM), is an earlier efficient technique that can be used for either widening the impedance bandwidth of antennas [7], or improving the resonance at some desired frequencies [8]. Accordingly, IM has witnessed tremendous research activities on antennas of various technologies. For instance; the alternation of impedance due to the effect of human body or hand in mobile communication terminals, has been investigated through; suggesting an adaptive antenna impedance matching system [9]-[10]. Despite of all of the benefits of IM on antennas, but unfortunately IM hasn't been used widely in designing of UWB antennas, for instance; a tunable wideband matching network has been used along with a circular planar monopole antenna to cover a frequency range of 1.8 ~ 7 GHz [11], while in many studies the circular planar monopole antenna has been designed even to exceed the UWB range [5],[12].Another technique to enhance the bandwidth was using a triple feed configuration connected to the lower edge of planar square monopole antenna. This method helps to excite more uniform surface current on the planar monopole antenna [13-15].

2. ANTENNA DESIGN

The designed crescent monopole antenna is shown in Fig. The lower edge frequency, is an important parameter of the planar monopole antenna since it controls the start of the operation band. The front and back view of the crescent antenna is shown in figure 1.1 and 1.2.



(a) Figure 1.1 Front view-Radiating structural design having Crescent shape



(b) Figure 1.2 Back view - Swastic shaped structure

3. AREA OF ARC

The area the arc-shaped monopole can be found as: Area of arc=area of outer sector - area of inner sector;

$$Area = 0.5\prod (r_1^2 - r_2^2) \ldots\ldots (1)$$

Band Lower Edge Frequency

Keeping the height same of both the configurations as L, so that frequency of both the monopoles and crescent is the same.

$$2\pi r\,L = W\,L \ldots\ldots (2)$$

Which gives

$$r = W/(2\pi) \ldots\ldots (3)$$

Where, r is the equivalent radius of the cylindrical monopole antenna. For cylindrical monopole antenna the resonant length L is given as

$$L = 0.24\,\lambda\,F \ldots\ldots (4)$$

Where

$$F = (L/r)/\,(1 + L/r) = L/\,(L + r) \ldots\ldots (5)$$

Combining (3) and (4), the wavelength λ is obtained as:

$$\lambda = (L + r)/\,0.24 \ldots\ldots (6)$$

Therefore, the lower band edge frequency fL is given by:

$$fL = c/\,\lambda = 0.24\{c/L\}\ \{L/\,(L+r)\} \ldots\ldots (7)$$

Taking all the dimensions in cm for the suspended configuration

$$fL = 7.2/\{L + (W/2\pi)\}\ GHz \ldots\ldots (8)$$

But the monopole is fabricated on a substrate, thus

$$fL = 14.4\,\pi/\,(2\pi\,L + W)k\ GHz \ldots\ldots (9)$$

Where k is the correction factor, k=1.15 for FR4 substrate with ε_r = 4.3 and h = 0.159 cm [1, 5].If one includes the effect of feeder length p then equation (7) can be re-written for fL as

$$fL = 7.2/\ \{\,(L + p) + 0.159W\}\ k\ GHz \ldots\ldots (10)$$

According to the idea of equivalence, the surface area of cylindrical monopole is made equal to the area of the arc. For a cylindrical monopole antenna, the length L is usually chosen as quarter of the resonant wavelength. Therefore the band lower edge frequency fL is given by:

$$fL = C/\lambda_L = 7.2/(L + a)GHZ \ldots\ldots (11)$$

Where L is the length in centimeters, a is the effective radius of the equivalent cylindrical monopole antenna in centimeters, and c is speed of light. The monopole is fabricated on substrate, and if one includes the effect of feeder length p then Eq. 11 is modified as:

$$fL = C/\lambda_L = 7.2/[(L+a+P)*k]\ GHz \ldots\ldots (12)$$

Where k is a correction factor.

To investigate the performance of the above-suggested formulations; effect of L on the value of fL in Eq.12, six antennas were analyzed using the HFSS software. In the simulations of the antennas, an rogers substrate of 1.6 mm thickness, ε_r of 4.3, and dielectric loss tangent of 0.025 was assumed. The parameters of the designed antennas are listed in table 1.

Table 1. Parameters of the Monopole Antenna

	r_1	r_2	W	L		T
Antenna1	25	24.4	0.67	50	54	0.5
Antenna2	24.5	23	0.65	49	53	0.5
Antenna3	24	22.6	0.64	49.5	53.5	0.5
Antenna4	23.5	22.1	0.63	48	52	0.5
Antenna5	22	21.5	0.62	48.5	51.5	0.5
Antenna6	21	20	0.61	47	50	0.5

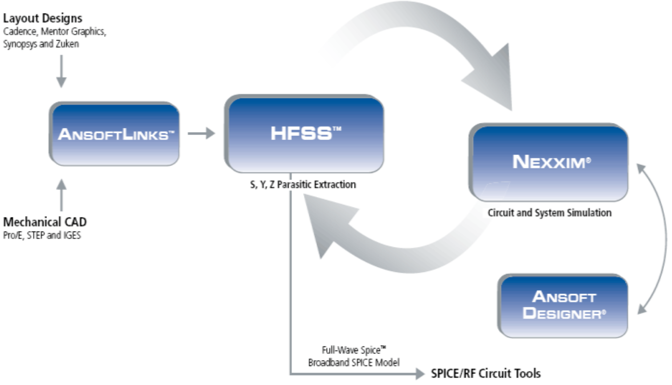
4. PARAMETER STUDY AND RESULTS

The total antenna length of x axis L=50mm and y axis L=54mm will be around 9 GHz. The basic antenna is fabricated on a rogers substrate of size 50mmX54mm with ε_r=4.3, thickness h=0.5mm .this antenna is fed using a polyline of width 0.675mm above the ground plane. The radiation pattern, VSWR, return loss will be analyzed using HFSS software.

I. HFSS Software Analysis

HFSS can simulate the electromagnetic fields, currents and radiation in an arbitrary 3D structure composed of metals, dielectrics, magnetic materials etc. Based on three-dimensional finite element method (FEM) it is widely used in the industry for RF- antenna, and circuit design. HFSS is the industry-standard software for S-parameter and full-wave SPICE extraction and for the electromagnetic simulation of high frequency and high-speed components. HFSS is widely used for the design of on-chip embedded passives, PCB interconnects, antennas, RF/microwave components, and high-frequency IC packages. HFSS improves engineering productivity, reduces development time, and better assures first-pass design success. The latest release of HFSS delivers significant productivity gains to Microwave/RF engineers and expands electromagnetic co-design to a new segment of engineers working in the areas of RF/analog IC and multi-gigabit designs as well as EMI/EMC.

HFSS as a part of the Ansoft product family



II. MATLAB Software

MATLAB (matrix laboratory) is a high performance language for scientific and technological calculations. It integrates computation, visualization and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. It is a complete environment for high –level programming, as well as interactive data analysis. Some typical applications are

- System simulations ,
- Algorithm development,
- Data acquisition, analysis, exploration, visualization, as well as
- Modeling, simulation and prototyping.

MATLAB was originally designed as a more convenient tool(than BASIC,FORTRAN or C/C++)for the manipulation of matrices .it was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects after-wards ,it gradually became the language of general scientific calculation, visualization and program design. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computations. It received more functionalities and it still remains a high-quality tool for scientific computation .mat lab excels at numerical computations ,especially when dealing with vectors or matrices of data .it is a procedural language ,combining an efficient programming structure with a bunch of predefined mathematical commands .while simple problems can be solved interactively with MATLAB ,its real power is its ability to create large program structures which can describe complex technical as well as non-technical systems .MATLAB has evolved over a period of years with input from many users .In university environments ,it is the computational tool for introductory and advanced courses in mathematics ,engineering and science. In industry, MATLAB is the tool of choice for highly productive research, development and analysis.

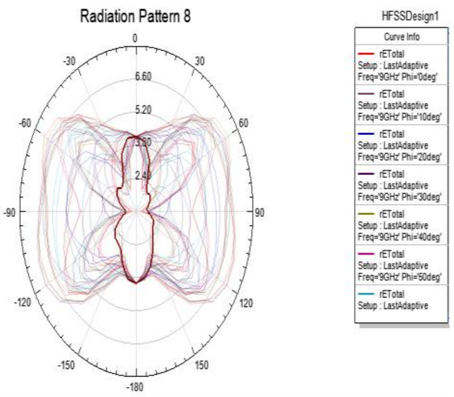


Figure 1.3 Radiation Pattern of the Proposed System

5. SIMULATIONS RESULTS AND DISCUSSION

A.RADIATION PATTERN

In the field of antenna design the term radiation pattern (or antenna pattern or far field-pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. It can be described as “a mathematical function or graphical representation of the variation of the power radiated by an antenna as a function of the direction away from the antenna”. We can also say that the radiation pattern is a graphical or directional dependence of the relative strength of the radio waves transmitted from or received by the antenna or any other source. The plot is typically shown as a three dimensional graph or as a separate graphs in vertical or horizontal plane. It is basically depicted on a linear scale or in Db. The radiation pattern of the designed antenna is shown in figure 1.3.

B.VSWR

Impedance mismatches in a radio-frequency (RF) electrical transmission line cause power loss and reflected energy. Voltage standing wave ratio (VSWR) is a way to measure transmission line imperfections.

The mathematical formula is given in equation 14

$$VSWR=1+\Gamma/1-\Gamma…….. (13)$$

For this antenna the VSWR is mathematically calculated as-1.252.

C. RETURN LOSS

In telecommunications, return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. Example for return loss is shown in figure 1.4

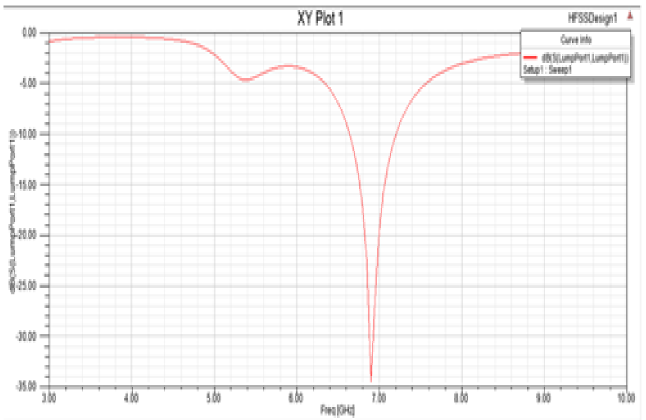


Figure 1.4: Simulated reflection coefficient versus frequency plots of Crescent shape MPA with and without defected ground structure.

The return loss of the designed antenna is shown in figure 1.5

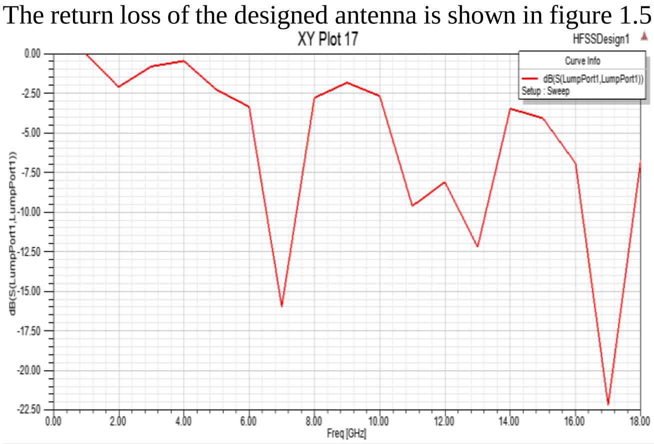


Figure 1.5: Return Loss of the Proposed System

The mathematical formula is given in equation (14)

$$RL= -20\log(\Gamma) \ldots\ldots\ldots.. (14)$$

For this antenna the return loss is mathematically calculated as -19Db

D. GAIN AND DIRECTIVITY

Gain:

It is relative measure of an antennas ability to direct RF energy in particular direction. It is defined as how much power is transmitted in the direction of peak radiation to that of an isotropic source. Mathematically it is be represented in equation (15)

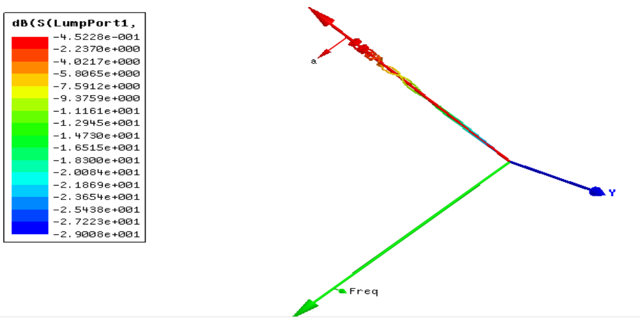
$$\text{Gain} = 4\Pi U/P_{in} \ldots\ldots.(15)$$

U=Radiation intensity

P_{in} =total input power

Directivity:

It measures the power density the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator (which emits uniformly in all direction) radiating the same total power.



E. REFLECTION COEFFICIENT

In physics and electrical engineering the reflection coefficient is a parameter that describes how a whole lot of an electromagnetic wave is pondered by an impedance discontinuity in the transmission medium. It is equal to the ratio of the amplitude of the reflected wave to the incident wave, with each expressed as phasors. If the ratio of V_{max} to V_{min} is infinite, then the magnitude of the reflection coefficient is 1, so that all power is reflected. Hence, this ratio, known as the Voltage Standing Wave Ratio (VSWR) or standing wave ratio is a measure of how well matched a transmission line is to a load.

The mathematical formula is given by

$$\Gamma=VSWR-1/VSWR+1$$

For this antenna the reflection coefficient is mathematically calculated as 8.912

F. INPUT IMPEDANCE

The input admittance (1/impedance) is a measure of the load's propensity to draw current. The source network is the portion of the network that transmits power, and the load network is the portion of the network that consumes power. The transmission lines that connect the antenna to the transmitter or receiver circuits have a characteristic impedance (z) of 50 ohms. To avoid the reflections the input impedance of the antenna is designed at 50 ohms. Antennas are made with 300ohms and 75ohms and many other impedances too.

6. CONCLUSION

A small size micro strip-crescent shaped antenna for 4G LTE operation is proposed and successfully implemented. The proposed antenna design is simple, and its performances have fulfilled the requirement set by 4G LTE communications. LTE (Long Term Evolution Advanced) is a 4G Wi-Fi broadband technology developed with the aid of Third Generation Partnership Project (3GPP), LTE provides significantly increased peak data rates, with the potential for 100 Mbps downstream and 30 Mbps upstream, reduced latency, scalable bandwidth capacity, and backwards compatibility with existing GSM and UMTS technology. Simulation results reveal that the above mentioned section of the proposed system provide a return loss very less due to crescent shaped monopole antenna.

7. FUTURE SCOPE

Future work can be carried out for the development of a crescent antenna array as a directional system with high gain for high quality communication link.

The radiation pattern effect is more in case of HFSS software compared to MATLAB software. Since this type of antenna can be mounted on the 5G mobile system and underground water testing, it is essential to study the reflection coefficient characteristics of the crescent monopole antenna to understand its probable usage in the defense sector, as the minimal reflection coefficient characteristics helps reducing the return loss of being measured.

Moreover, the designed crescent monopole antenna finds application in wireless personal communication systems and indoor wireless communication; hence it becomes imperative to study the effect antenna radiation on the human body.

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