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Optimization of Radiation Parameters for Monopole Antenna with Simple Geometry and Consequent Utilization for Multiband Applications

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Abstract: A new monopole antenna geometry with wideband characteristic is proposed in this work. The work addresses the problem of Gain and Directivity by cascading multiple geometrical structures as well as changing the material by which the geometrical structure is manufactured. By cascading simple structures it is possible to obtain the same directivity and gain provided by complex structures, retaining the portability of the antenna. The antennas capable of transmitting and receiving signals with high frequency are very important in portable high data rate applications. The parameters that characterize the perfectness of antennae are the source resistance of the excitation source that feeds the antennae, characteristic impedance of the transmission line that feeds the antennae, the geometry of the antennae itself, the Voltage Standing Wave Ratio, the Reflection Coefficient, the Directivity, Horizontal Gain, Vertical Gain, Total Gain, the magnitude of the electric field, efficiency, the current distribution and voltage distribution in the geometry of the antenna. The main parameters to be optimized for wideband portable application are the Gain, Directivity and Efficiency. The work addresses the second problem of efficiency by using stub or electrical networks as resonators. The stubs are designed by using impedances and admittances information provided by Smith chart at a particular frequency. The tool used for simulation is 4nec2 which stands for Numerical Electromagnetics Code. The frequency of operation used for analysis 300MHz. The wavelength in this frequency of operation is 1m.

Keywords: *Antenna Design, Reflection Co-efficient, SWR, Directivity, Gain.*

1. INTRODUCTION

An antenna is capable of transmitting and receiving signals with high frequency. Simply antenna is an electrical device which converts electrical signals into radio waves and vice versa. In transmission a radio transmitter transmit a high frequency alternating current to the antenna terminal and the antenna radiates the energy as electromagnetic radio waves from the current source. In receiver, an antenna obstructs some of the energy of an electromagnetic wave, to produce a very small voltage at its terminal that is applied to the receiver electronics, for amplification of the received signal to reconstruct the original signal.

Antenna design was depends on the transmission and reception of radio waves in all directions. The performance of the antenna is described by many parameters like gain, bandwidth, beam width, Voltage Standing wave ratio, radiation pattern etc. Gain is the parameter measures the degree of the directivity of the radiation pattern. Radiation pattern of the antenna denotes, in which direction the transmission range is higher and which direction the range is lower. Transmission ranges is technically named as major lobe, minor lobe and side lobe. Now a day's mirror reflector is used back side of the antenna, because to avoid the radiation to the unwanted direction. The reflector retransmits the radio waves to the transmission direction.

Dipole antenna is a prototyping antenna; it consists of two conductors arranged around an axis. Likewise the ultra wideband antenna technology is best optimistic solution for future communication system for high speed data rate and excellent immunity to path interference. Ultra wide band is also known as radio frequency technology; transmit data in binary form using extremely short duration pulses over a wide spectrum of frequencies. It transmit the information over a wide bandwidth above 450MHz. Circular disc monopole antenna, vertical disc monopole antenna, elliptical slot antenna and circular slot antenna are different antenna based on ultra wide bandwidth antenna design. UWB has ultra wide frequency bandwidth; it can achieve extremely high capacity as high as thousands of Mbps. It operates at low power transmission levels, and also provides high secure and high reliable communication.

UWB system is purely based on impulse radio features like low complexity. It does not modulate and demodulate the complex carrier waveforms, so it does not need the amplifier, mixer, filter, and local oscillator components. Impedance matching, radiation stability, high speed data rates, antenna cost, weight, size are the challenges facing the ultra wide band antenna design. In this work

2. RELATED WORKS

Mamadou Hady et al. [1] presented the two UWB Compact directive balance antipodal Vivaldi antennas (BAVA). UWB Antenna is considered as essential in microwave imaging systems. Better Impedance matching is achieved in this type of UWB antenna. Antipodal Vivaldi antenna assures the UWB requirements using FR4 substrate. Size reduction is one of the challenging processes for using low frequency, so UWB antennas are sizable. To reduce the coupling between antennas, Directivity improved when reducing the coupling between antennas.

Waseem Akram et al. [2] have been proposed multi strip monopole antenna for ultra wideband applications. The multi strip monopole antenna consists of various resonate frequency based six quarter wavelength strips to provide wideband width. Ultra wideband antenna is not affected to multipath fading. A rectangular slot is introduced to provide better bandwidth. Radiation pattern for monopole antenna is Omni directional an azimuthal plane and bidirectional in elevation plane.

Perfect magnetic wall condition (PWB) using Ultra wideband (UWB) antenna was described by Hyung-Seok Choi et al. [3]. Signal interference is removed by using step impedance resonator at 5GHz.By particle swarm optimization algorithm; the UWB antenna design is optimized. Embedded resonance slots in ground plane approach cannot control bandwidth and ripple. Two pole band-rejected UWB antenna based two resonators is used to avoid the flat skirt characteristics. UWB design based PSO algorithm is possible to adjust the band-stop frequency in UWB applications.

Ultra wideband antenna based bandwidth enhancement technique was proposed by R.Addaci et al. [4]. This design is capable to operate large frequency range based wide band characteristics. T shaped ground planes, meandered shorting strips, added parasitic elements, modified feeding structures, and modified elliptical antennas used to overcome the narrow bandwidth. Low profile planar antennas is validated on monopole antennas and its does not need any additional elements. The Low profile planar antenna not affects the antenna dimensions.

Asmi Pratiwi et al. [5] described the UWB Micro strip antenna based microwave imaging system for UWB Frequencies. This antenna is fetal detecting and monitoring system in dual band. Fetal monitoring is used to monitor the baby health condition during pregnancy. Fetal growth is derived from the reflected signal by using the principle of microwave imaging system. FR4-Epoxy material is used to design of UWB Micro strip antenna.

3. THE MONOPOLE ANTENNA

The monopole is the antennae with simple geometrical structure that can be used for portable applications. The existing antennae show poor directivity. The directivity can be improved by changing the geometry of the antennae, or increasing the quantity of current flowing through the antenna. The quantity of current flowing through the antenna is not changeable and so keeping the power fed to the antenna constant if we vary the geometry the directivity is also changed significantly. The simulation result of standard monopole antenna using Numerical Electromagnetics Code simulator is shown in Figure 1, Figure 2, Figure 3 and Figure 4 respectively.

From Figure 1 it is clear that maximum gain occurs in the direction for which theta is 55º. The gain is greatly reduced in other directions. So the existing structure is not good for omni directional transmission and reception. Even if used the gain of the receiving RF amplifier should be very high.

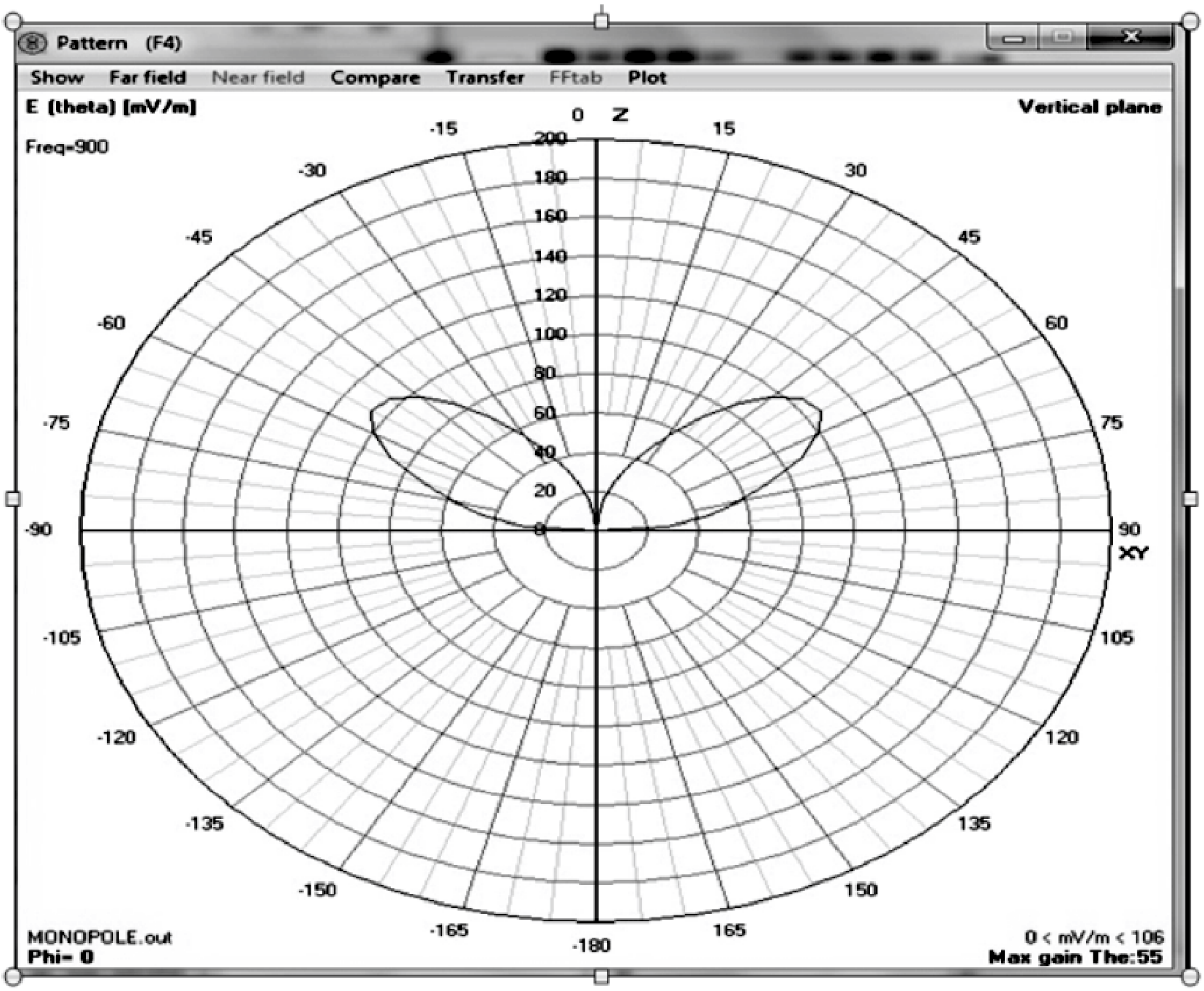

Figure 1: Electric Field of Existing Monopole Antenna

From Figure 2 it is clear that the SWR is high as 30. High value of SWR indicates that most of the power fed to the antenna is reflected back. This implies that most of the power is wasted due to losses in the lines and hence the overall efficiency comes down. So the antenna will not be suitable for portable applications.

Figure 3 indicates that the total gain varies with the angle theta. Figure 1 and Figure 3 show considerable similarity between them. Figure 3 also makes it very clear that the antenna can be only used for short distance communications. This has to be extended for long distance communications.

Figure 4 show the gain is constant over reasonable range of frequencies. The other disadvantages suppress this advantage and hence it needs to be overcome. The data for the plot in Figure 1 is tabulated in Table 1.

Table 1
Plot of Electric Field and Theta for Existing Monopole Antenna

S.No	*Theta^o*	*Electric Field(mV/m)*
1.	0	0
2.	45	100
3.	60	100
4.	80	40
5.	90	0

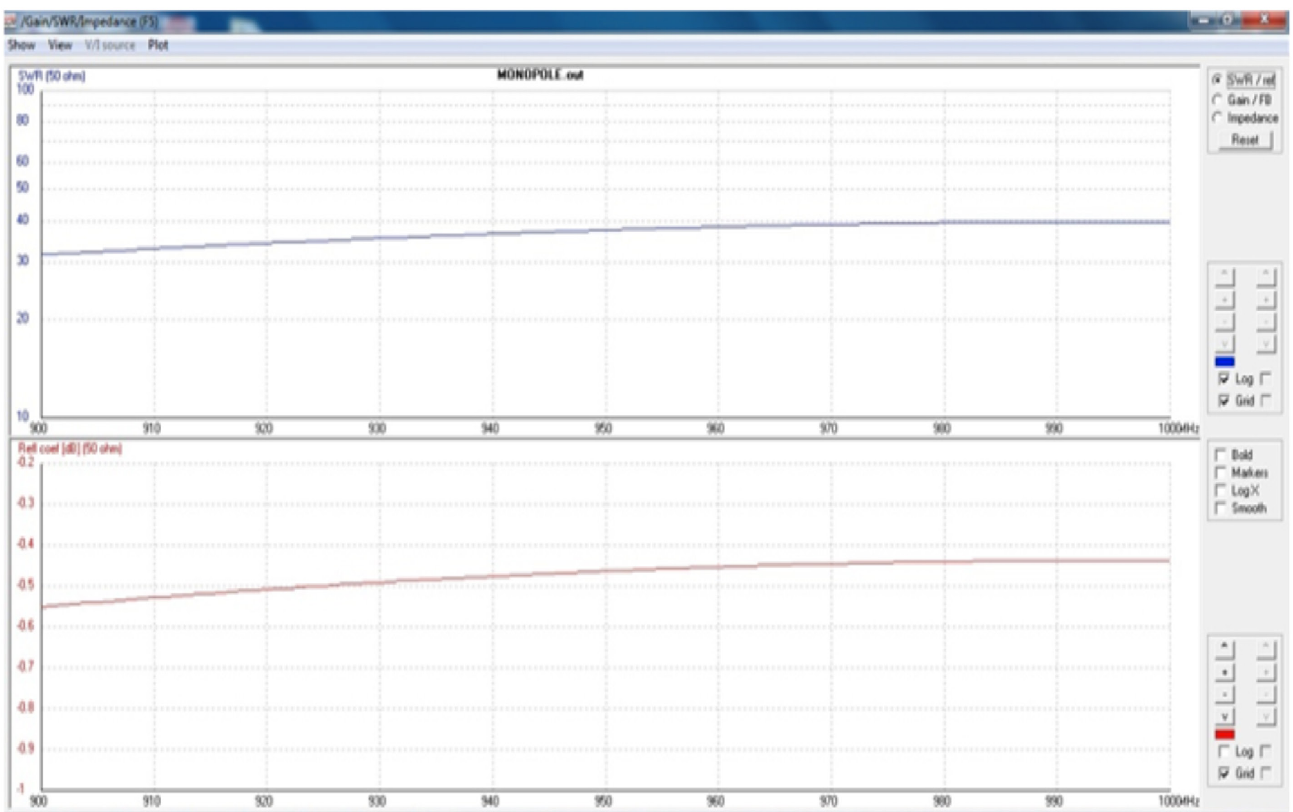

Figure 2: SWR and Reflection Coefficient of Existing Monopole Antenna

The data for the plot in Figure 2 is tabulated in Table 2.

Table 2
Standing Wave Ratio and Reflection Coefficient of Existing Monopole as a Function of Frequency

S.No	*Frequency(MHz)*	*VSWR*	*Reflection Coefficient*
1.	900	32	-0.55
2.	910	33	-0.54
3.	920	34	-0.53
4.	930	35	-0.52
5.	940	36	-0.51
6.	950	37	-0.50
7.	960	38	-0.49
8.	970	40	-0.48
9.	980	40	-0.45
10.	1000	40	-0.45

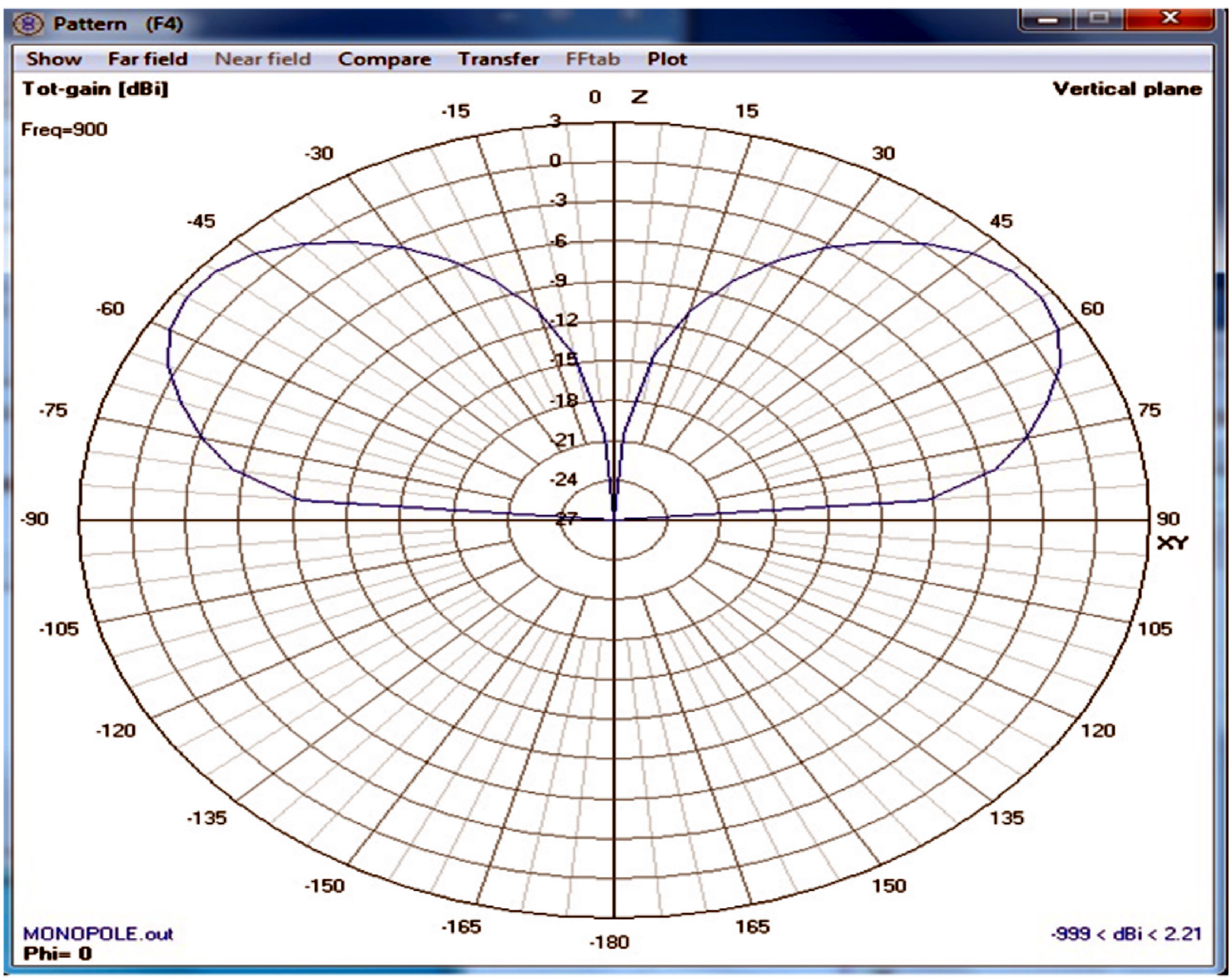

Figure 3: Total Gain of Existing Monopole Antenna

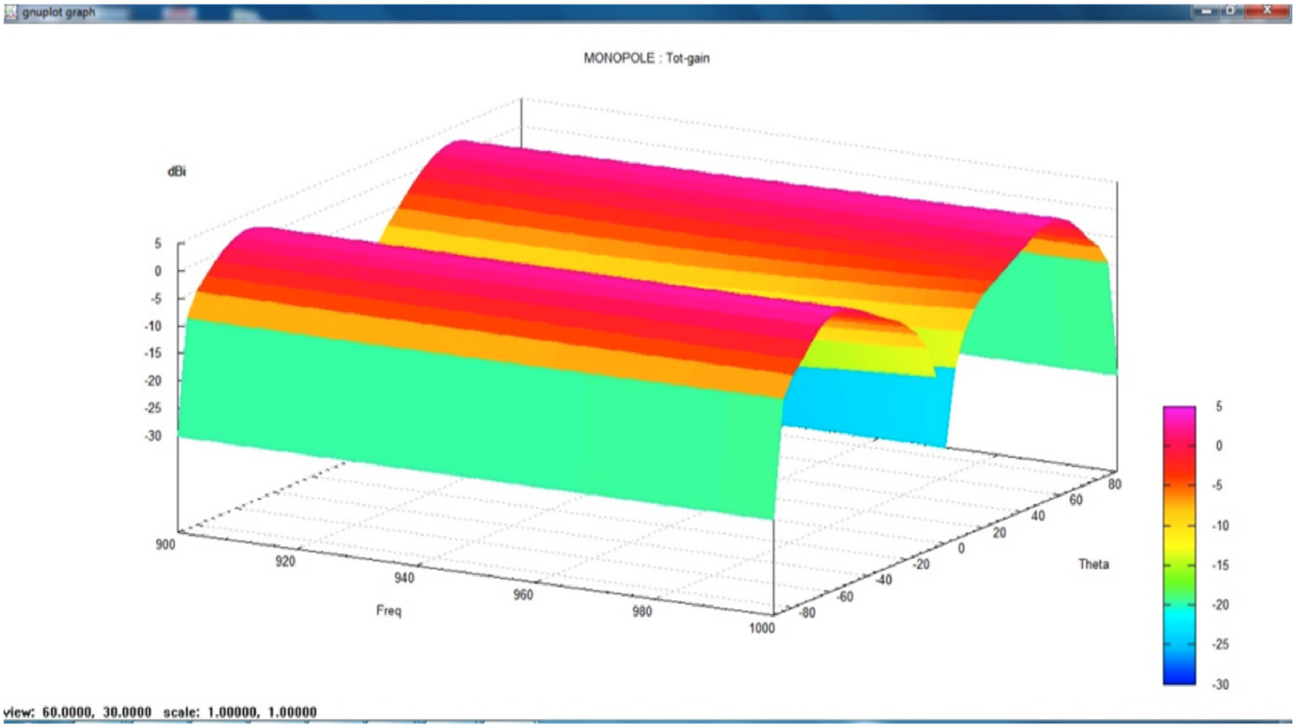

Figure 4: 3D Total Gain of Existing Monopole Antenna

4. STRUCTURE AND DESIGN OF MULTIBAND MONOPOLE ANTENNA

A monopole antenna is a type of radio antenna, it consist of a straight rod shaped conductor mounted on a ground plane. The monopole antenna contains two sides, one side of the antenna feed line is connected to the lower end of the antenna, and the other side is connected to the ground plane. Earth is used as the ground plane of the antenna. The monopole antenna is a resonant antenna, the functions of rod as open resonator for radio waves, changing the standing waves of voltage and current along its length. The antenna length is determined by the wavelength of the radio waves. Like a dipole antenna, the monopole antenna has omnidirectional radiation pattern. It radiates the radio signal in all azimuthally directions perpendicular to the antenna, but the radiated signal varying with elevation angle. At very high frequency (VHF) and ultra high frequency (UHF) antenna needed a smaller size ground plane. So artificial ground plane are used to mount the antenna above the ground plane.

Figure 5 shows the structure of the monopole antenna. Height of the antenna is denoted as L, and the width of the antenna is denoted as d. The straight rod antenna is mounted on the ground plane surface. The radiation pattern of dipole antenna is same as monopole antenna, but the only change is impedance. The impedance of the monopole antenna is one half of the dipole antenna. Quarter wave monopole antenna (L = 0.25*) the impedance is half of the half wave dipole antenna. So, Zin = 36.5 + j21.25 ohms. Dipole antenna requires + V/2 and –V/2 voltages applied to its end of the antenna to drive a current. But monopole antenna needs only + V/2 voltage applied between the top end and ground plane of the antenna to drive the same current. Monopole antenna uses finite ground plane. The finite sized ground plane affects the properties of monopole antenna. Radiation pattern and impedance are affected by the ground plane. The radiation pattern radiates in a skewed direction, it changes the horizontal plane direction.

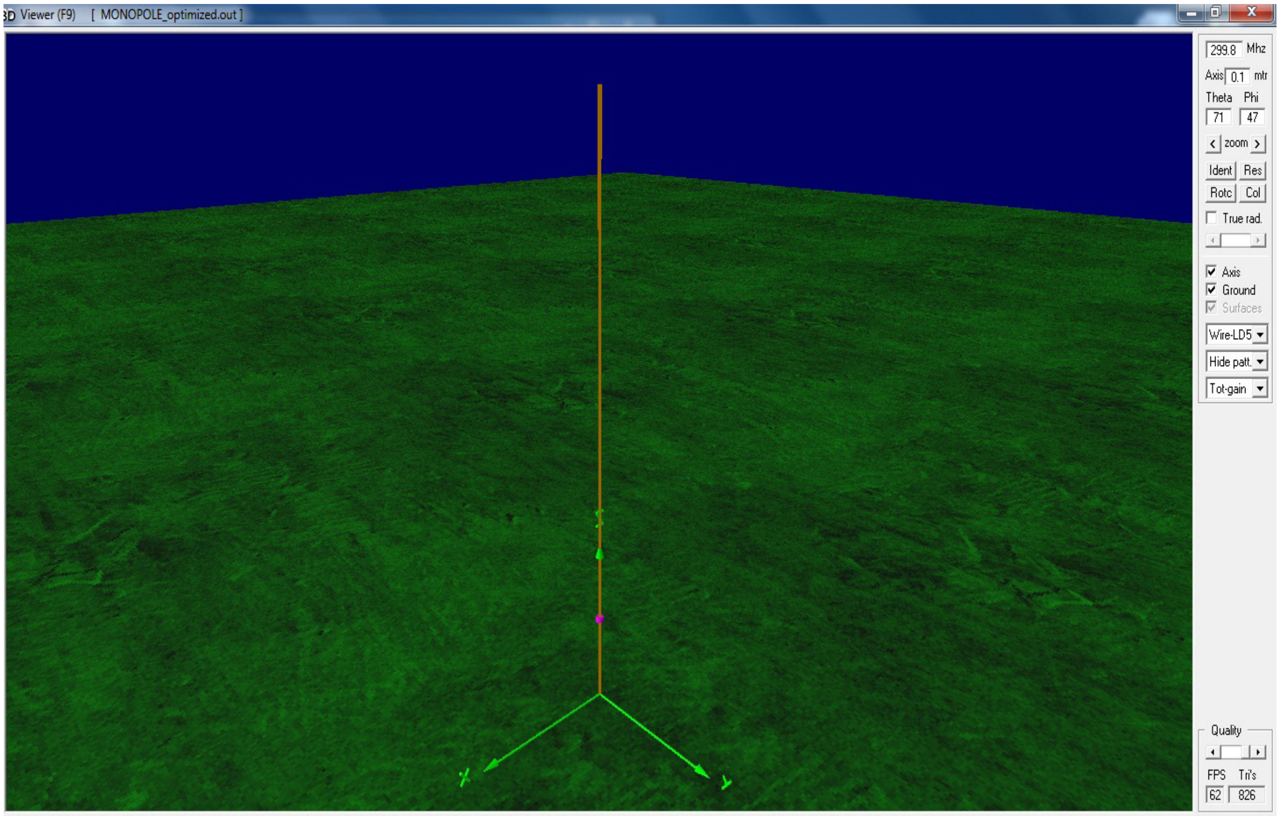

Figure 5: The Designed Monopole Antenna

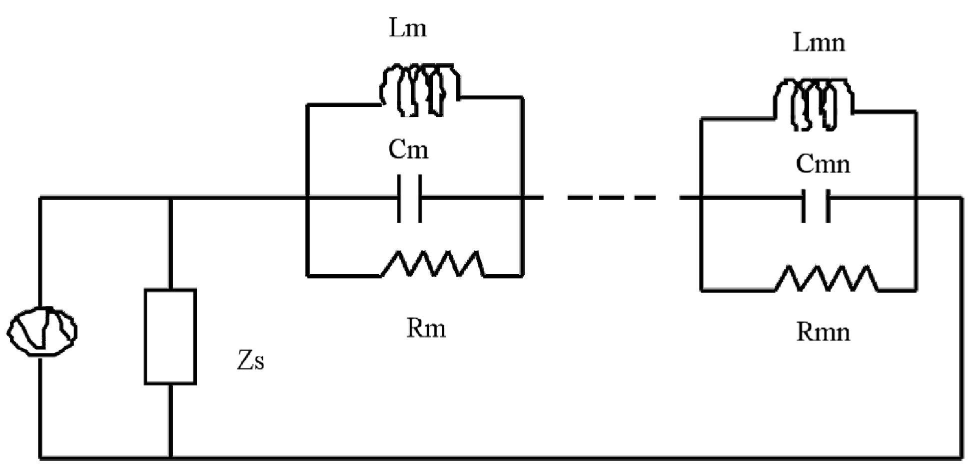

Figure 6: Equivalent Circuit of UWB Antenna

Figure 6 show the equivalent circuit of the ultra wide band antenna with short stub. Each resonances of the antenna are represented by RLC parallel resonant circuit. Zs is the impedance of the short stub; it operates as parallel impedance to the UWB monopole antenna. It is possible for impedance matching by adjusting the parameter of the stub. Impedance matching in the lower frequency is improving the performance of the antenna and also achieves wideband characteristics of UWB monopole antenna in small size and using a short stub for impedance matching.

For example the design of dual band monopole antenna according to the calculation is illustrated. The two monopole antennas are placed in parallel to feed for impedance matching. The longer monopole of length L_1 = 83.5mm is the radiating element for GSM band (frequency range is 900MHz) and the shorter monopole of length L_2 =31.5mm is the radiating element for ISM band (frequency range is 2.4 GHz). The gap between the ground plane and the top feed is 0.7mm. The gap is maintained constantly for processing of antenna. The thickness of the metal in all surface of the antenna is 0.5mm. One of the important parameter of the antenna is width, selecting a matched bandwidth that can be used for communication. Based on the substrate used in the antenna design, the radiation pattern, bandwidth and dimensions are changed.

The antenna is designed and configured using Numerical Electromagnetics Code simulator. Finally the antenna simulation is run for multiple antenna lengths and the optimum length for which most of the parameters of the antenna are good enough is found. It is at this length the SWR of the antenna becomes close to 1 and operates at maximum efficiency.

5. SIMULATION RESULTS

From Figure 7 it is clear that the lobes of the electric field of the proposed antenna are flat. The maximum gain occurs around the direction with theta = 45º. This makes the fact clear that the antenna can be used in a wide range of directions. The Figure 7 clearly shows that the gain of the antenna is same and highest over a range of directions. The data in the Figure 7 is tabulated in Table 3.

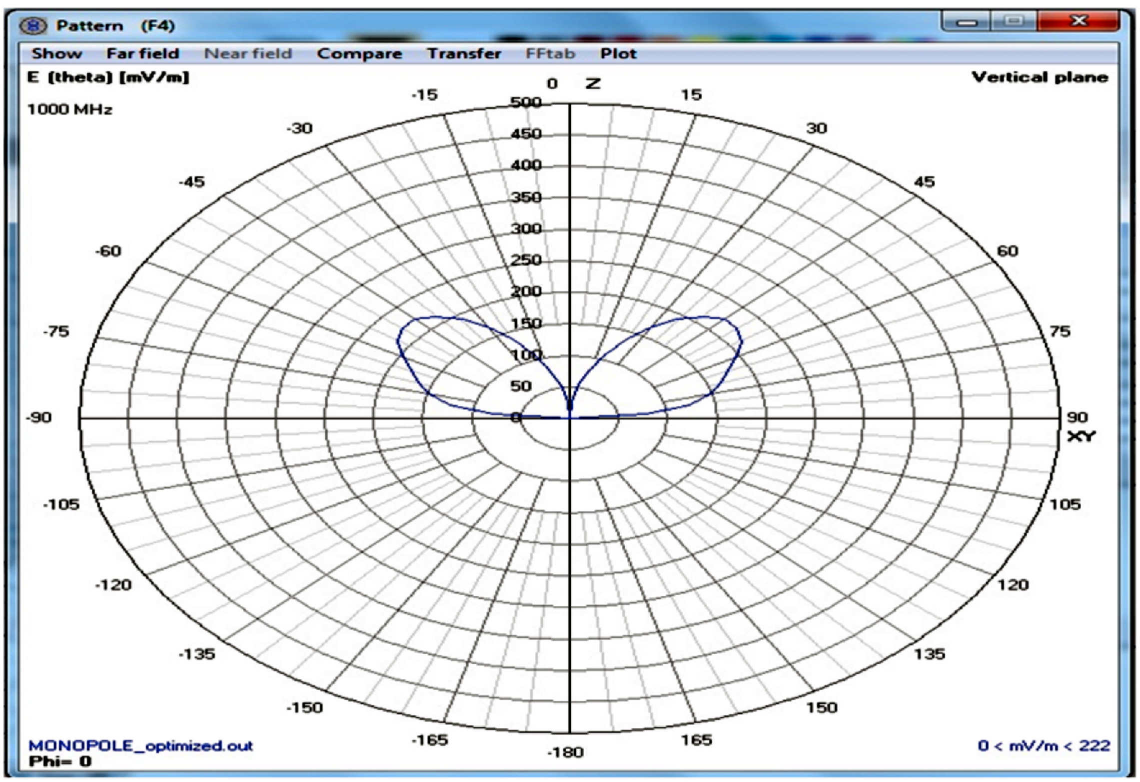

Figure 7: Electric Field of Proposed Monopole Antenna

From Figure 8 it is clear that the SWR is very close to 1. It implies that most of the power fed into the antenna is radiated by the antenna and the reflected power is almost zero. Since the reflected power is zero the antenna does not require matching stubs or special impedance matching networks. The antenna is also suitable for broad range of frequencies with very less reflected power. The data in the Figure 8 is tabulated in Table 4.

From Figure 9 it is clear that the total gain has significantly increased in the proposed antenna design. The peak gain is around -3 dBi for the existing design where as the gain has increased to -1dBi in the proposed design. Greater the gain, the antenna can be used for longer communication range without the need for powerful RF amplifiers.

From Figure 10 it is clear that the proposed antenna design retains the advantage of the existing antenna which is the gain is constant over a range of frequencies.

Table 3
Plot of Electric Field and Theta for Proposed Monopole Antenna

S.No	*Theta^o*	*Electric Field(mV/m)*
1.	0	0
2.	52	225
3.	60	200
4.	80	100
5.	90	0

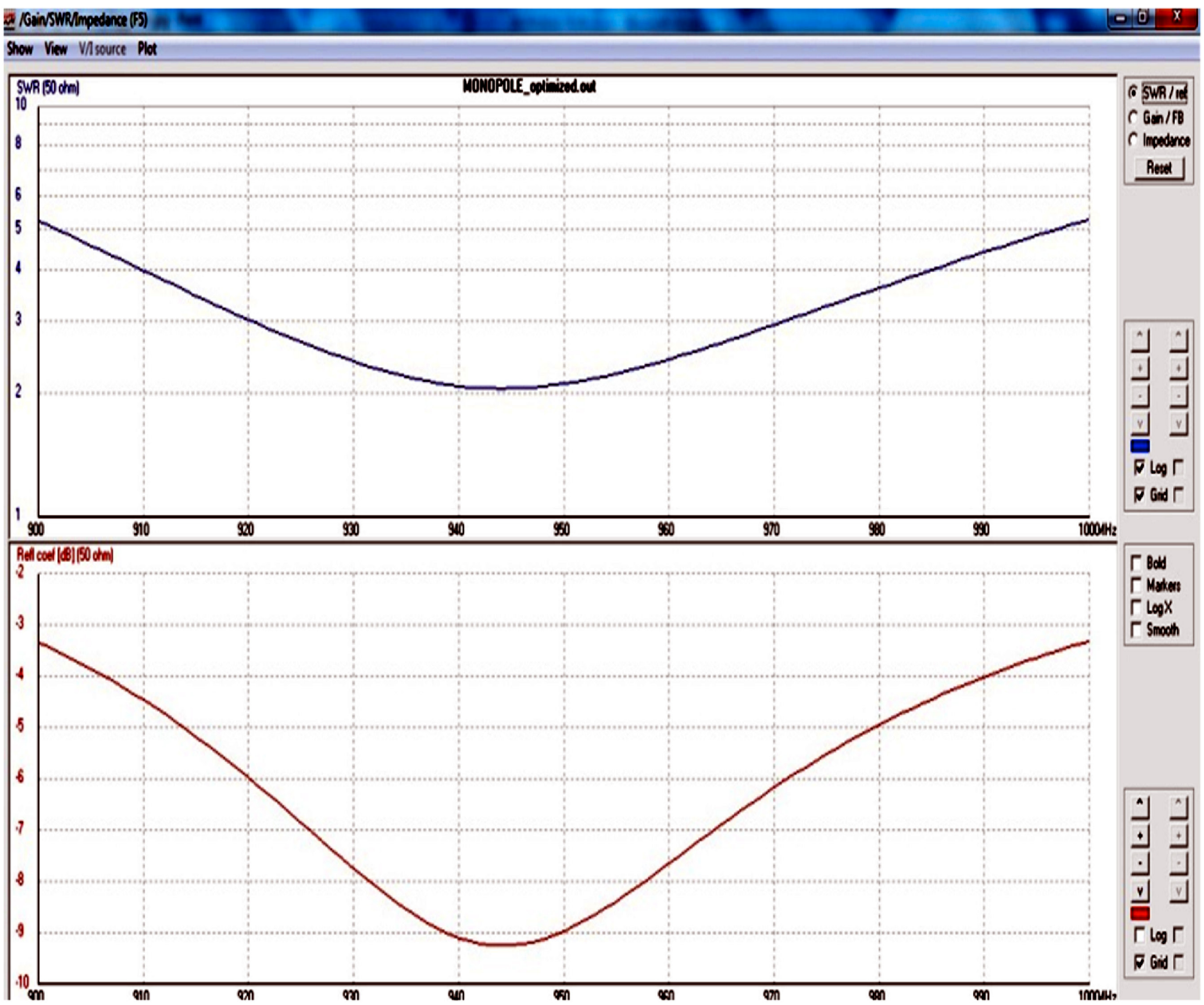

Figure 8: SWR & Reflection Coefficient of Proposed Monopole Antenna

Table 4
Standing Wave Ratio and Reflection Coefficient as a Function of Frequency

S.No	*Frequency(MHz)*	*SWR*	*Reflection Coefficient*
1.	900	5	-3
2.	910	4	-4
3.	920	3	-6
4.	930	2	-8
5.	940	2	-9
6.	950	3	-9
7.	960	3	-8
8.	970	3	-6
9.	980	4	-5
10.	1000	5	-3.3

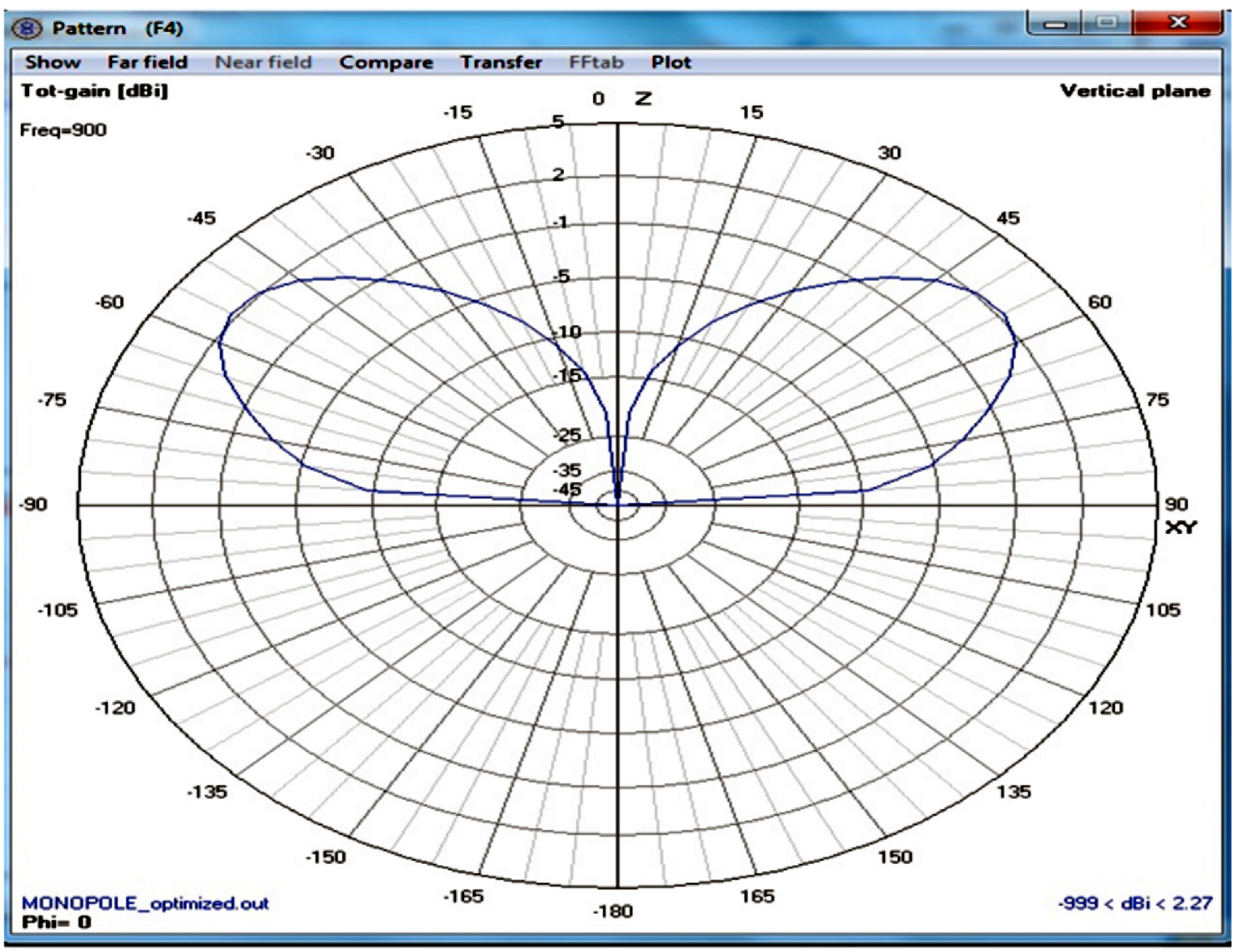

Figure 9: Total Gain of Proposed Monopole Antenna

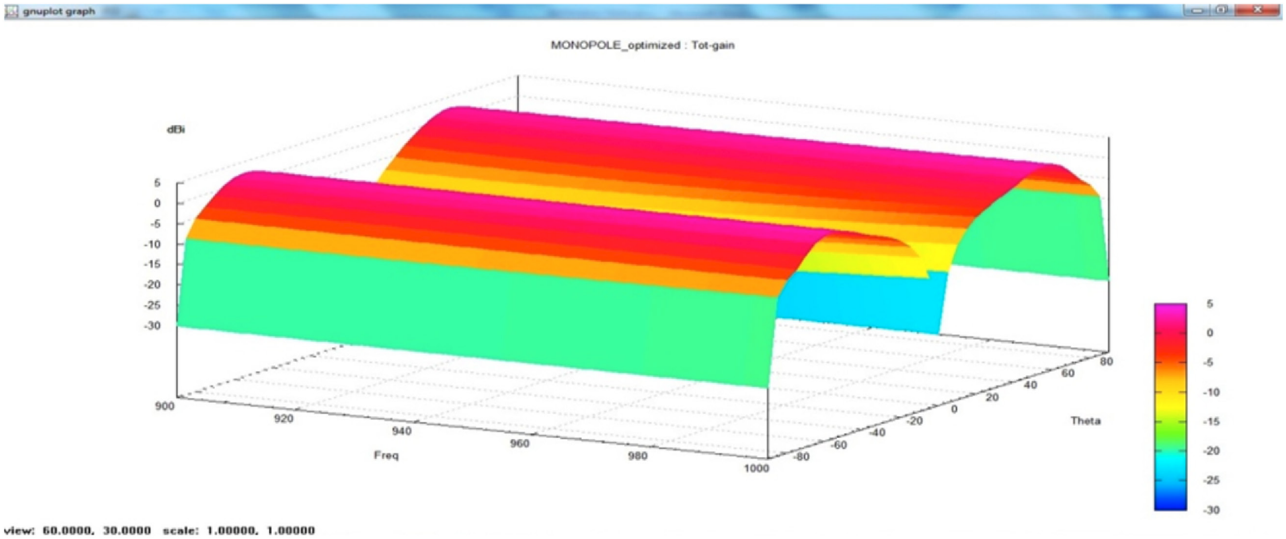

Figure 10: Total 3D Gain of Proposed Monopole Antenna

The Figure 11. *a* and 11.*b* shows the magnitude and phase of the current distribution on the structure of the antenna. The simulation is done using the Numerical Electromagnetics Code. The current is maximum at the point where the antenna is driven using a voltage source and reduces to zero at the open end of the antenna.

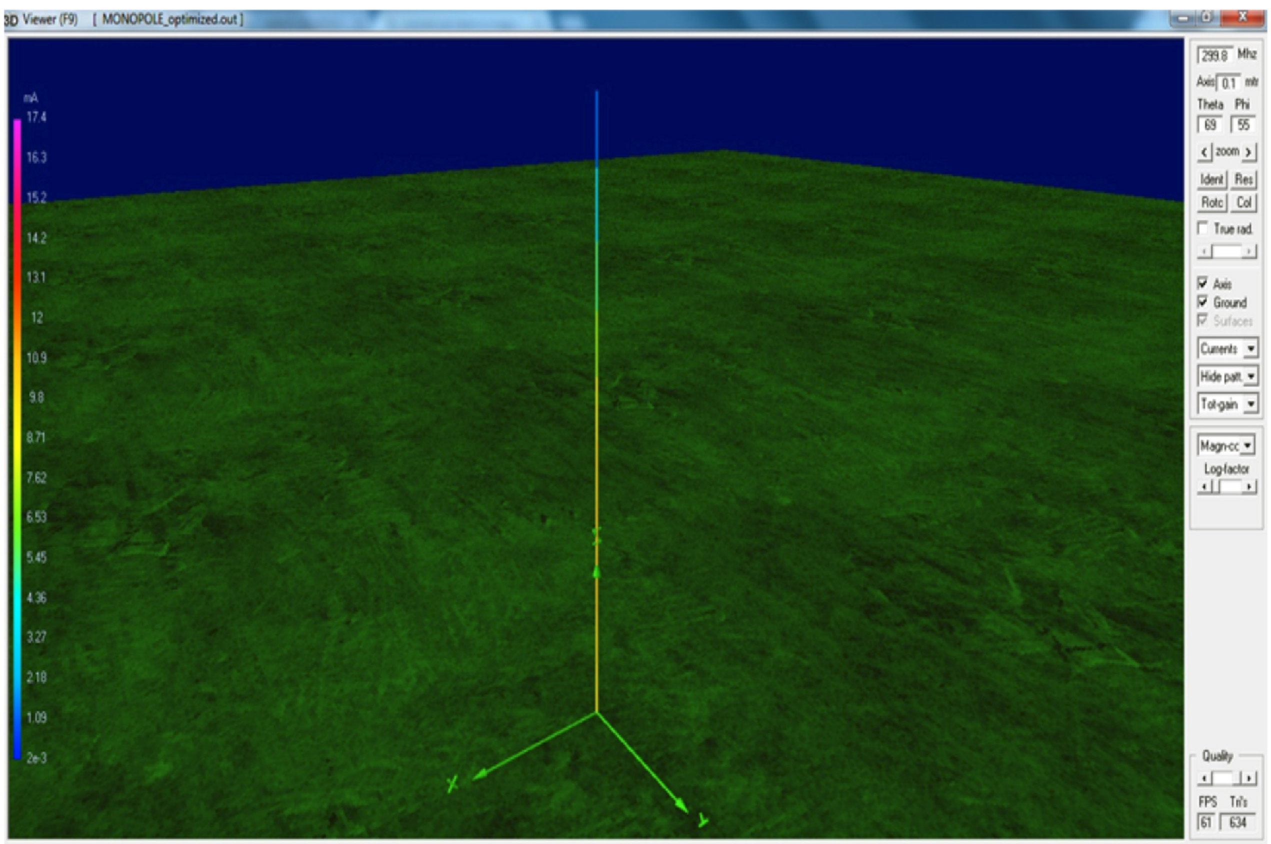

Figure 11: (*a*) The Magnitude of the Current over the Length of the Antenna

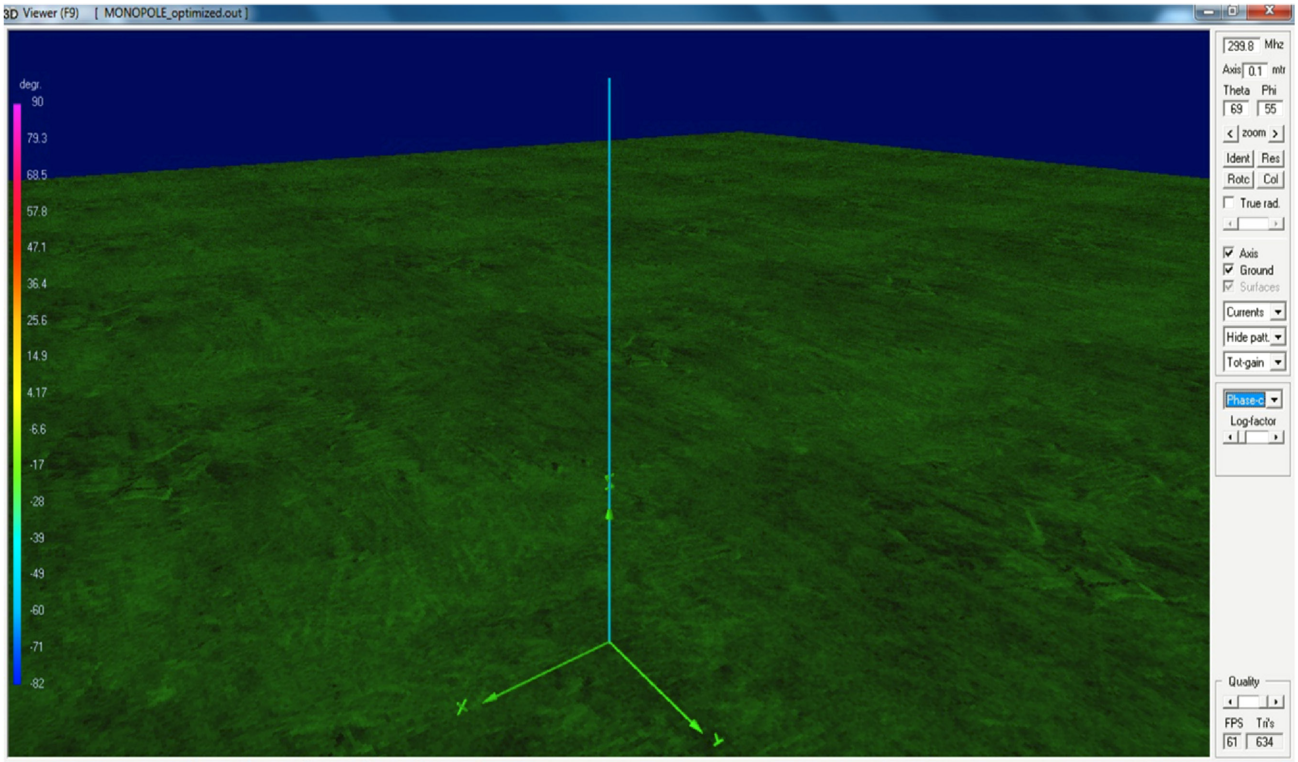

Figure 11: (*b*) The Phase of the Current over the Length of the Antenna

Table 5 summarizes the parameters of the designed antenna.

Table 5
Parameters of the Proposed Antenna Design

S.No	*Parameter*	*Value for Existing Monopole*	*Value for Proposed Monopole*
1.	Mid Band Frequency	500 MHz	500 MHz
2.	Bandwidth	1GHz	1 GHz
3.	Gain(max)	2.21 dBi	2.27 dBi

6. CONCLUSION

The simulation results using Numerical Electromagnetics Code clearly show that the existing antenna design has drawbacks like limited directivity, gain, and efficiency. These drawbacks severely affect the antennas use to portable applications. The simulation result from Numerical Electromagnetics Code of the proposed antenna clearly show that the lobe of the electric field of the proposed antenna is flat compared to the existing antenna design. Hence the proposed antenna design has high gain over a range of directions. This makes it possible to place the transmitting and receiving antennas within a certain range to the maximum extent possible. The SWR of the proposed antenna design has come down to nearly 1 making the reflected power nearly zero. Hence as already discussed most of the input power is radiated by the antenna. The total gain of the antenna has been increased by -2dBi.

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