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MONOPOLE ANTENNA PERFORMANCE AT VARIED FEED POSITIONS

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ABSTRACT
Two simple monopole antennas mounted on finite ground planes are presented. The antennas designed to operate at 900 MHz and 1800 MHz respectively are simulated using High Frequency Structural Simulator (HFSS). The study reveals that variation in feed position from the edge of width of ground plane leads to slight increase in resonance frequency and return loss but decrease in antenna gain. An enhancement in gain can be achieved (up to 5% and 40 % for antennas tuned at 900 MHz and 1800 MHz respectively) when the feed is placed at the edge of the ground plane. On the other hand, an increase in bandwidth of 33.3% and 4% was observed when the feed is positioned at the center of the width of ground plane for 900MHz and 1800MHz tuned antennas respectively. Therefore for optimal monopole antenna performance, the choice of feed position should be made based on the application of interest.

Keywords: *Monopole Antenna, HFSS, Feed position.*

INTRODUCTION

A monopole antenna is a form of radio antenna consisting of a straight rod-shaped conductor, often mounted perpendicularly over some type of conductive surface called a ground plane. This antenna is resonant, where the rod functions as a resonator for radio waves with oscillating standing waves of voltage and current along its length (Gautam, 2008). The monopole antenna is an Omni-directional antenna with equal gain in all directions (Balanis, 1997). This property makes it attractive in many wireless applications, such as; medical, microwave sensors, Wi-Fi and wireless communication. Monopole antennas are employed in radio broadcasting at low frequency as most radiator antennas. They are also used with handheld radios such as walkie-talkies and cell phones. Recently, the antenna is proposed for use in radio-linked implantable medical devices. Examples of monopole antennas in use today are whip, helix and planar monopole.

Monopole antennas are half the size of their dipole counterparts hence they are attractive when a smaller antenna is needed. Antennas of older cell phones were typically monopole antennas with infinite ground plane approximated by the casing of the phone. In practice, monopole antennas are mounted on finite ground planes. This affects the properties of the monopole antenna, - the radiation pattern in particular. When monopole antenna is used on finite-sized ground plane, the resulting radiation pattern radiates in a skewed direction away from the horizontal plane. In general, the larger the size of ground plane, the more the radiation pattern approaches a maximum in the x-y plane. The rule of the thumb is that the diameter of the ground plane should be at least one wave length (Huang and Boyle, 2008).

Conventional monopole antennas have a very simple form consisting of a whip above a perfect ground plane (fig 1), an excellent radiation that has pattern uniformity in azimuth. They are usually operated with one-quarter wavelength (Saisset and Travers, 2009). The quarter-wave monopole however, requires large antenna height e.g. the height of monopole antenna is about 83mm when it is operated at 900 MHz for mobile communication (Owag, 2006). Hence they are mounted outside the communication system terminal.

To meet the cellular communication specification, different modified whip antenna types have been developed, (Kraus, 1998; Salah and Abousetta, 2003). These antennas had higher gain, wider frequency-bandwidth, low cost, omni-directional radiation pattern in the horizontal plane and compact size as compared with the classical whip antennas. Examples are helix, wound coil or folded loop and stepped and tapered monopole antennas. Multi system array with reduced gain in the direction of the user's head have been suggested to reduce the potential hazard of mobile phones. All the antenna proposed have a broadside power radiation in the direction of propagation i.e. in the opposite direction to the users head (Salah, 2009). Hence, performance of monopole antennas can be improved to make it more effective for wireless applications.

Many methods have been suggested for improving the performance of monopole antenna. Effect of ground plane shape and size on monopole antenna has been studied. (Kamal and Singhal, 2012; Saisset and Travers, 2009) In this study, the effect of feed position on the performance of monopole is investigated. The parameters of interest include: resonance frequency (F_R), return loss (S_{11}), bandwidth (BW), gain (G) and Electric field intensity (E) of the antenna.

Design Consideration of Monopole Antenna

Monopole antenna consists of ground plane, a feed and a wire. The length (h) of monopole is given by (Saisset and Travers, 2009)

$$h = \frac{\lambda}{4} \quad (1)$$

where λ is the wavelength of the radiating wave. Figures 1(a) and (b) show the structure and design sketch of monopole antenna respectively. Where h, is height of monopole (wire) in mm, L_g, is the length of the ground plane, W_g, is width of the ground plane, feed, is distant of corner feed in mm. The resonance frequency is related to the height of the monopole from the equation (1) as.

$$f = \frac{c}{4h}$$

$$h = \frac{c}{4f} \quad (2)$$

where c is speed of light, and f is resonance frequency. The resonance frequency is read out from the return loss (S_{11}) curve. It corresponds to the frequency at which S_{11} is highest. It can also be obtained by the sum of upper frequency F_H and lower frequency F_L of acceptable operation band divided by 2. Mathematically,

$$\frac{F_H+F_L}{2} = F_c \quad (3)$$

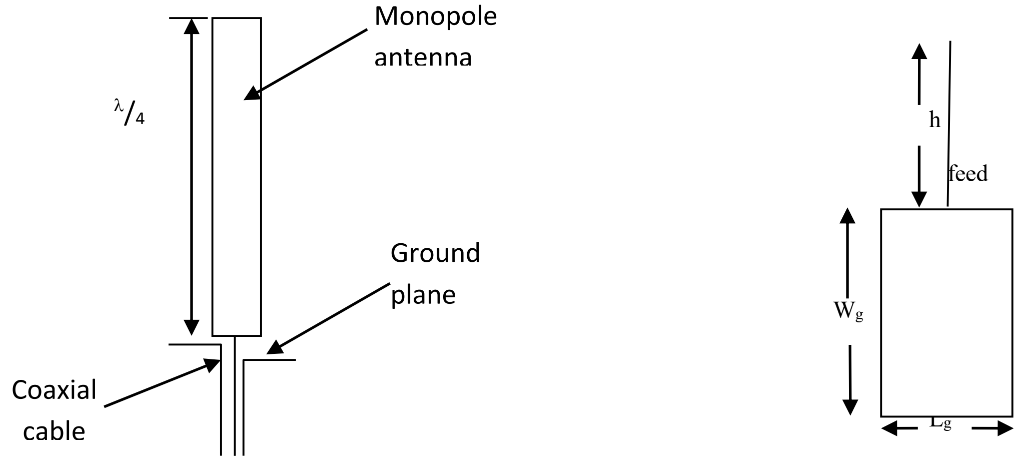

Fig. 1(a) $\frac{\lambda}{4}$ Monopole Antenna *(b) Basic monopole design*

The return loss (R_L) is defined as (Edling, 2012)

$$R_L(dB) = 10log_{10}\left(\frac{P_r}{P_i}\right) = -20log_{10}\left(\frac{E_r}{E_i}\right) = -20log\left|\frac{Z_L-Z_S}{Z_L+Z_S}\right| \quad (4)$$

where P_i is the incident power [watt], P_r is the reflected power [watt], E_i is the incident electric field, E_r is the reflected electric field, Z_L is the load impedance, Z_S is the transmissions line characteristic impedance. Return loss corresponds to the maximum S_{11} in the return loss curve. Bandwidth (BW) is obtained from the absolute bandwidth equation given as

$$BW = F_H\text{-}F_L \quad (5)$$

F_H and F_L corresponds to the upper and lower frequency when S_{11} = -10dB in the return loss curve.

MATERIALS AND METHOD

The materials used in this work include; a laptop and High Frequency Structural Simulator (HFSS). HFSS is a high-performance full-wave electromagnetic field simulator for 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It improves engineering productivity, reduces development time and better assures first-pass design success (Ansoft, 2010).

The Monopole antennas at 900 MHz and 1800 MHz were designed based on transmission line model. The height of monopole antenna is calculated using equation (2). For f = 900 MHz, h = 8.33 cm = 83 mm and for f = 1800 MHz, h = 4.2 cm = 42 mm. The length (L_g) and width (W_g) of ground plane are chosen to be 100 mm and 40 mm respectively being the size of common handsets (Saisset and Travers, 2009) while the length of feed L_f is 20 mm.

The simulation of monopole at 900 MHz and 1800 MHz were run using the data obtained from the design. The simulation was done with the use of High Frequency Structural Simulator. With the understanding of the need for a fairly large ground plane, monopole antennas were simulated to resonate at 900 and 1800 MHz using a 100 mm by 40 mm ground plane which is the approximate size of recent cell phones. The effect of feed position is investigated. The feed location is varied from the edge to the center of the width of the ground plane (from 0 to 20 mm) at 5mm interval.

RESULTS AND DISCUSSION

The results showing the effects of feed position on monopole antenna resonance frequency, bandwidth, return loss, gain and electric field are presented in tables 1 and 2 for 900 MHz and 1800 MHz respectively. The return loss of simulated antenna with different feed positions are shown in figures 2a to 2e (for f = 900 MHz) and figures 3a to 3e (for f = 1800 MHz).

Table 1: Effect of feed position on performance of monopole antenna at 900 MHz

Parameter (mm)		**Variable**	**Results**				
L_g	W_g	feed(mm)	F_R (MHz)	S_{11}(dB)	BW(MHz)	Gain (dB)	E(dB)
100	40	0	860	-12.5	60	4.003	-
100	40	5	880	-12.5	70	3.915	21.32
100	40	10	875	-13.5	65	3.884	21.28
100	40	15	880	-14.0	80	3.943	21.46
100	40	20	910	-14.0	80	3.856	21.45

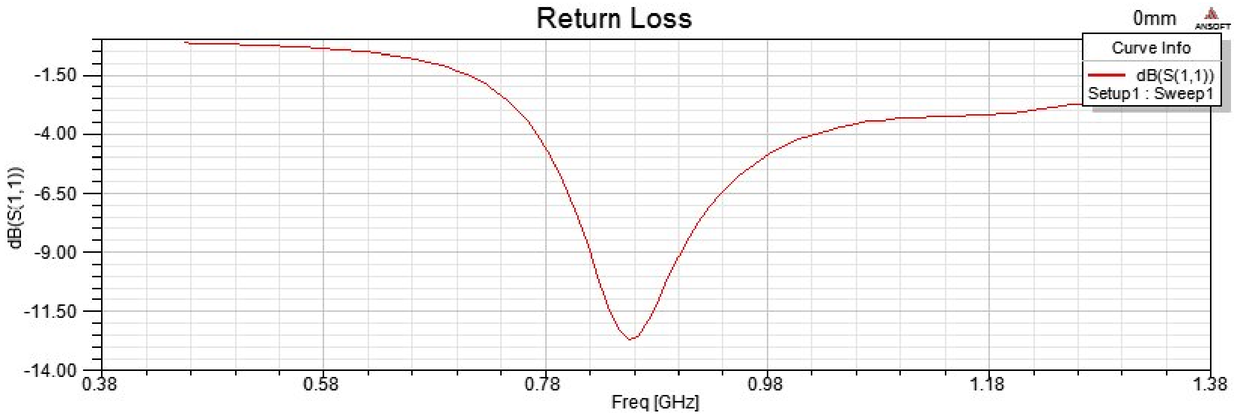

Fig. 2a Return loss of Monopole at 900 MHz with feed at 0mm

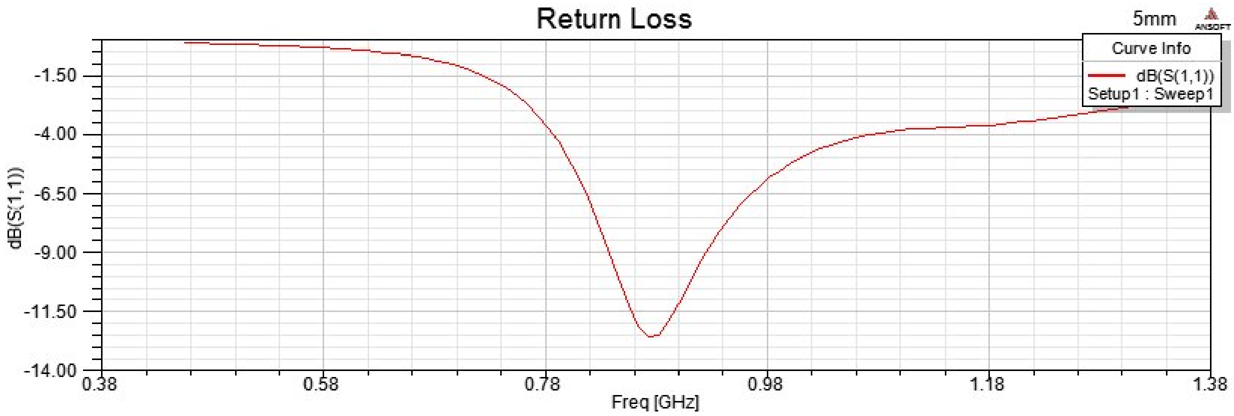

Fig. 2b Return loss of Monopole at 900 MHz with feed at 5 mm

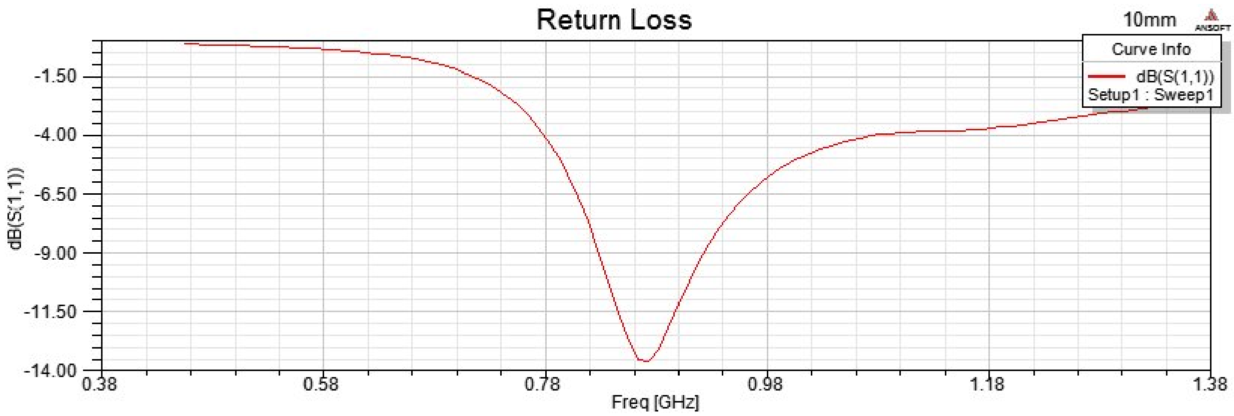

Fig. 2c Return loss of Monopole at 900 MHz with feed at 10 mm

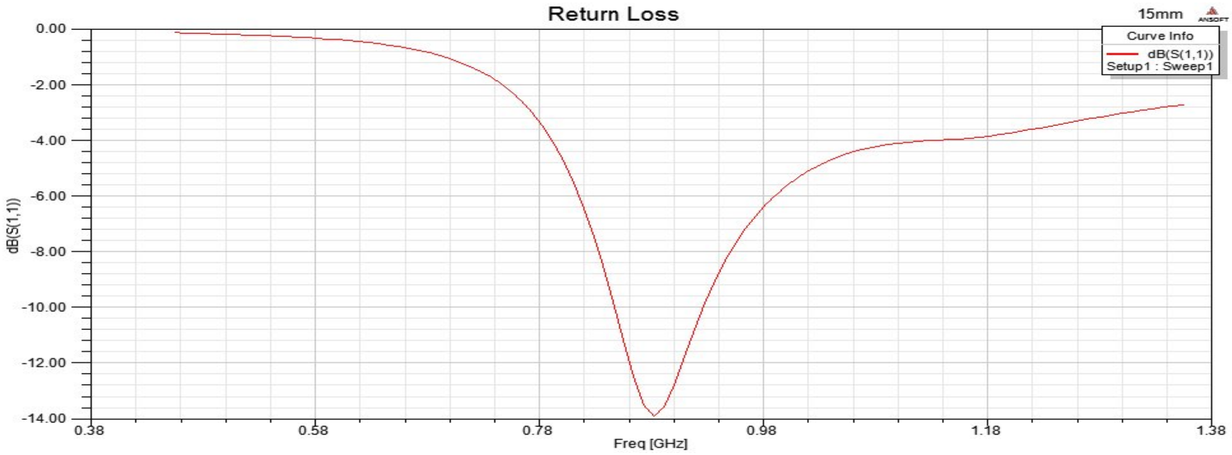

Fig. 2d Return loss of Monopole at 900 MHz with feed at 15 mm

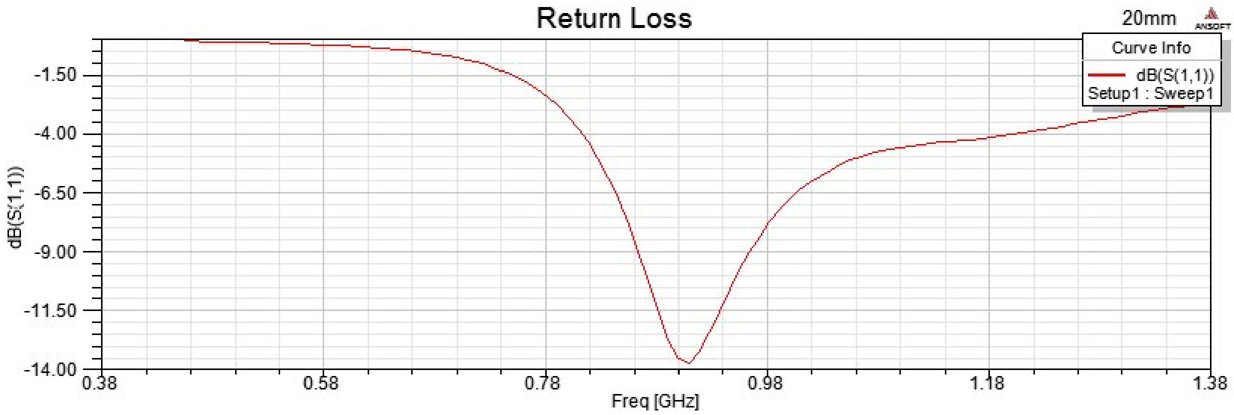

Fig. 2e Return loss of Monopole at 900 MHz with feed at 20 mm

Table 2: Effect of feed position on performance of monopole antenna at 1800 MHz

Parameter (mm)		**variable**	**Results**				
L_{gp}	W_{gp}	feed (mm)	F_R(MHz)	S_{11}(dB)	BW(MHz)	G(dB)	E(dB)
100	40	0	1750	- 8.0	-	7.87	24.86
100	40	5	1740	-18.5	270	6.78	24.39
100	40	10	1760	-15.5	260	6.76	24.38
100	40	15	1720	-16.0	260	6.90	24.41
100	40	20	1810	-16.5	270	5.67	23.35

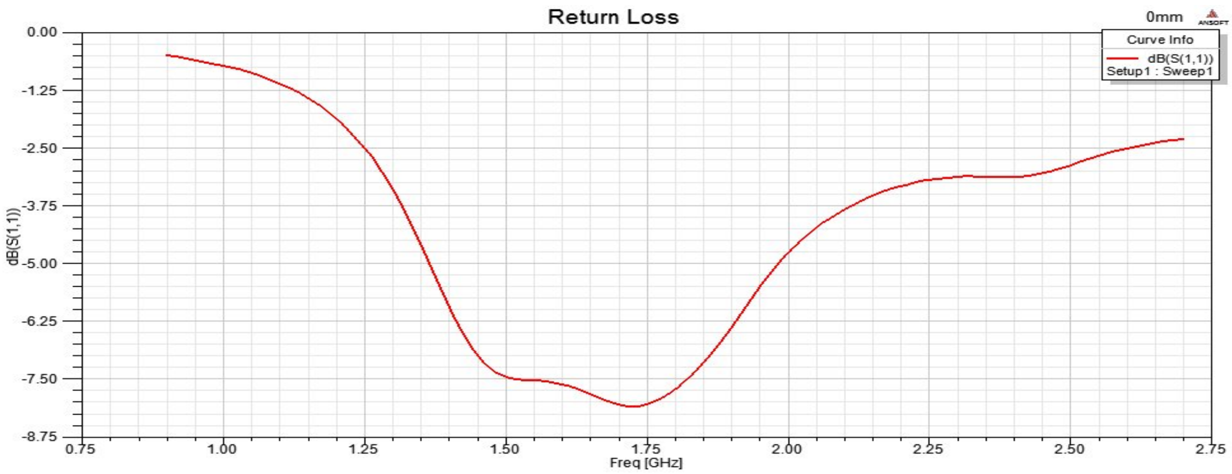

Fig. 3a Return loss of monopole at 1800 MHz with feed at 0 mm

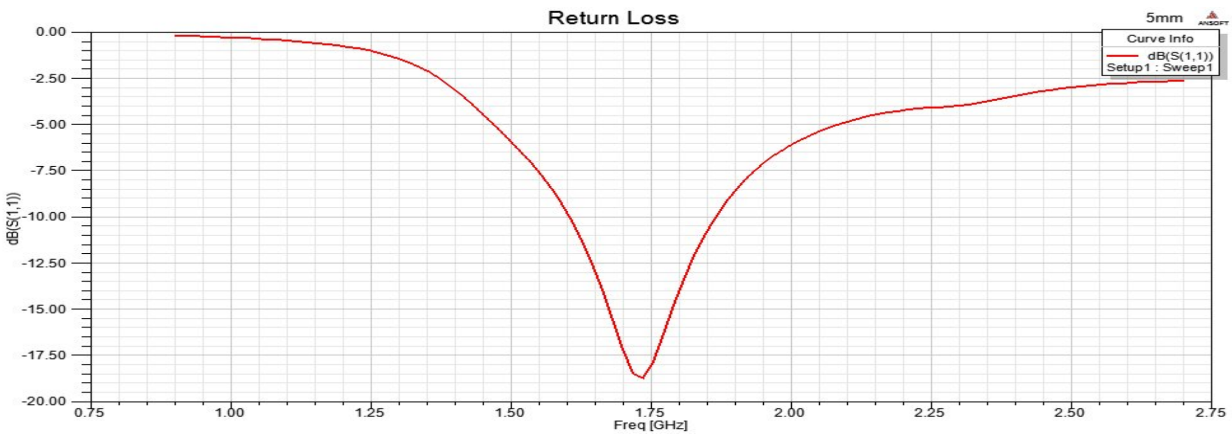

Fig. 3b Return loss of monopole at 1800 MHz with feed at 5 mm

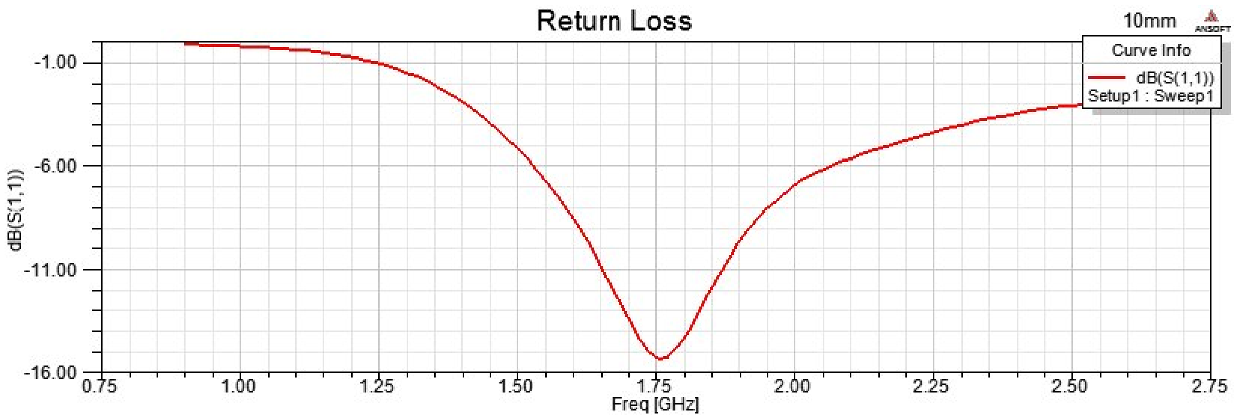

Fig. 3c Return loss of monopole at 1800 MHz with feed at 10mm

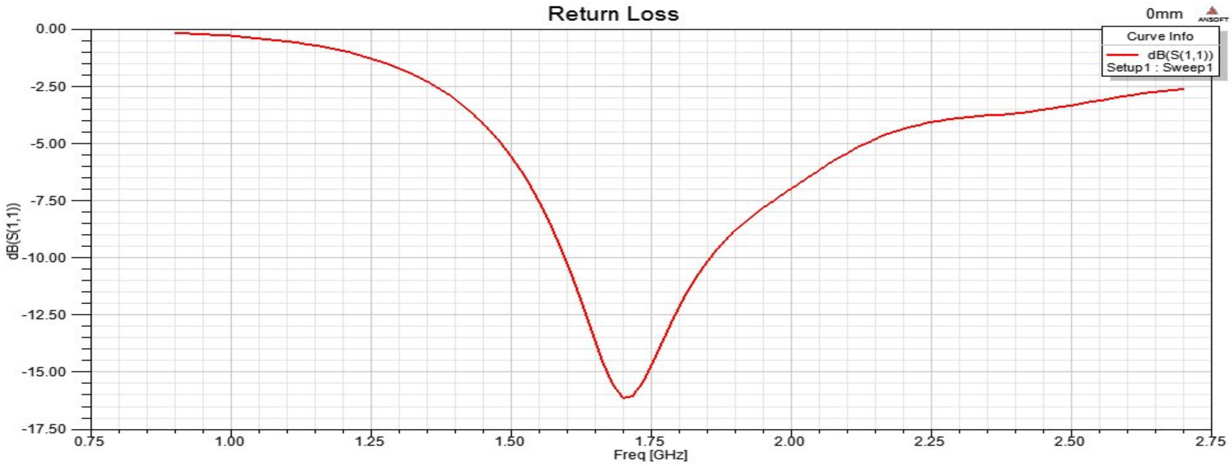

Fig. 3d Return loss of monopole at 1800 MHz with feed at 15 mm

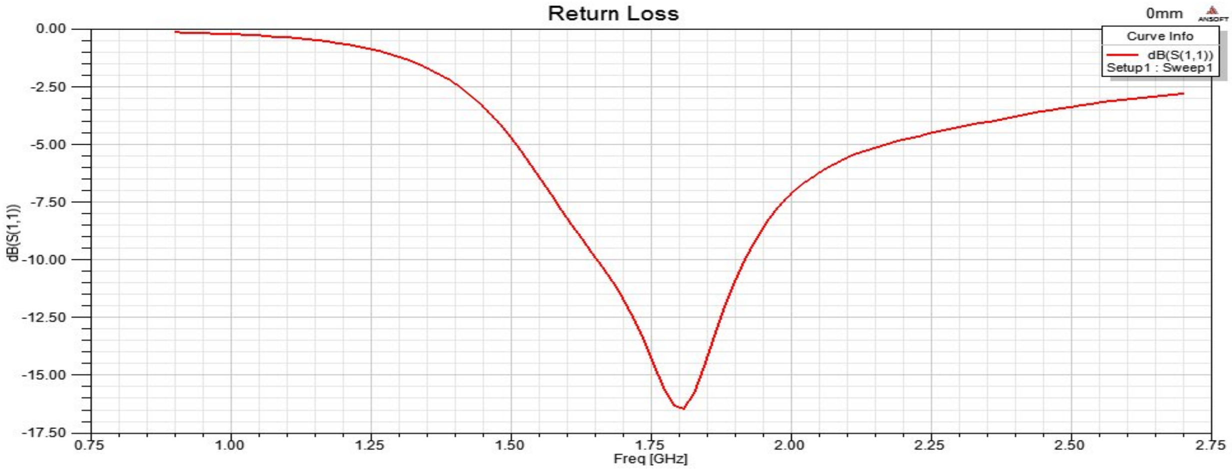

Fig. 3e Return loss of monopole at 1800 MHz with feed at 20 mm

The resonance frequency is the smallest when the resonating distance over the ground plane is largest for monopole antenna simulated to operate at 900 MHz (i.e. 0 mm when the feed is placed at the upper corner of the ground plane). At this configuration, the gain is high but the bandwidth is low. However for monopole at 1800 MHz, with simulated frequency of 1750 MHz at 0 mm, the gain is also high but the bandwidth was not determined because the S_{11} is less than the acceptable value of – 10 dB. The low return loss may be as a result to losses due to signal absorption and reflection by the ground plane.

The bandwidth is highest when feed is located at 5 mm and 20 mm (for 1800 MHz frequency) and at frequency of 900MHz, maximum bandwidth of 80MHz was obtained at 15mm and 20mm positions. The simulated antenna at operating frequency of 1800 MHz gave wide bandwidth of the range of 260 MHz to 270 MHz more than three times the bandwidth at 900MHz

As the distance of feed from the edge of the ground plane increases, the value of gain drops slightly at both frequencies however monopole at 1800MHz produced higher gain. The variation of return loss and electric field intensity did not follow any particular trend. When the feed was connected to the middle of the ground plane, the monopole exhibited the highest resonance frequency at both 900 MHz and 1800 MHz with highest level of loss and minimum gain. For monopole at 900 MHz, the best results were obtained when the feed was placed at the center of the width of ground plane which gave the best resonance frequency (910 MHz), highest bandwidth (80 MHz) and return loss of – 14 dB while for monopole at 1800 MHz, feed position of 5 mm gave the best result with resonance frequency of 1740 MHz, bandwidth of 270 MHz and return loss of – 18.5 dB.

CONCLUSION

In conclusion, this paper presents the simulated analysis of monopole antenna that was an effective ultra-high frequency radiator with varied feed position. The simple monopole antennas were tuned at 900 and 1800 MHz resonant frequencies at different feed positions. The results reveal that feed position can affect performance of Monopole antennas. There was significant effect on the resonance frequency suggesting that feed position can cause slight detuning of the antenna. All but one of the antennas provided sufficient return loss of more than -10 dB hence, the position of the feed does not affect the matching of the antenna. Feed located at the center (20 mm) of the width of ground plane resulted in 33.3% increase in bandwidth for monopole tuned at 900 MHz and 4% for that tuned at 1800 MHz. Meanwhile, gain can be enhanced up to 5% and 40% for 900MHz and 1800MHz respectively by positioning the feed at the edge of the ground plane. This implies that for an optimal monopole performance in a particular application, trade - off has to be made between gain and bandwidth. The results obtained reveal that the simulated monopole can be employed in wireless communication (GSM 900 and DCS 1800), implantable medical devices (ISM 900) with proper shielding.

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