Circular Monopole Antenna Stability with Regard to Ground Plane Size

#Owais, Magnus Karlsson and Shaofang Gong
Department of Science and Technology, Linköping University
SE-601 74, Norrköping, Sweden
owais.owais@itn.liu.se

1. Introduction

Wireless communications for short range and high data rate require wideband operation that necessitates the demand for miniaturized, low cost and low profile antennas. Miniaturized planar monopole antennas provide wide impedance bandwidth for wireless personal area network applications [1]. Different monopole shapes have been considered and a lot of research has been made to improve the bandwidth and reduce the size by changing the antenna shape [2]-[4]. The radiator part has been the main focus of research to find a shape that provides wide bandwidth [3]-[4], as well on studying how the ground plane affects the bandwidth of antennas. Wide bandwidth has been obtained by bevelling the radiator [5] and use of a modified ground plane [6]. Planar monopoles with parasitic elements and slots give also a wideband [7]. It has been documented that the finite size of the ground plane is an important factor for the antenna performance [8]. Planar monopoles have a benefit of being low cost and compatible to printed circuit board (PCB) allowing compact design. Since the ground plane is coplanar with the antenna, it necessitates that its stability should not change when integrated in PCB with different ground plane size of adjoining circuits. To avoid pre-tuning and achieve cost effectiveness, system development requires a stable planar monopole antenna that can be integrated without depreciation of its performance. This paper studies in detail the effect of ground plane dimension, width and length, on the stability of the coplanar monopole antenna, by changing the ground plane size while keeping feedline and feedap constant. The parametric investigation supported by simulation and experimental results is conducted in this paper to give insights to the stability issue that have not been reported before.

2. Antenna Structures

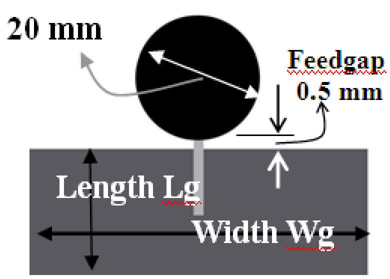

Figure 1: Geometry of Planar Monopole

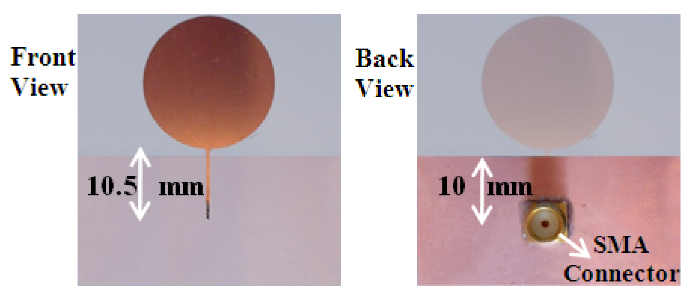

Figure 2: Front and Back view Planar Monopole

The configuration of the investigated planar monopole antenna is depicted in Figure 1. A circular planar monopole antenna of 20 mm in diameter composed of a conducting plate printed on a Rogers RO4350 [9] PCB of thickness 0.1676 mm, dielectric loss tangent of 0.004 and relative permittivity of 3.66. The antenna is in the same plane as the rectangular ground plane. The antenna is fed through a 50 Ω matched microstrip feedline via an SMA at the centre of the ground plane. The feedgap was kept constant at an optimized value of 0.5 mm for the maximum impedance bandwidth. The experimental set-up was designed from the viewpoint that ground dimension was the only variable. For this purpose the feedline length is kept at 10 mm and the feed-gap at 0.5 mm for all set-ups. When the length of the ground plane is increased the microstrip feedline length remains unaffected. Thus any change in antenna stability is attributed to the ground plane only.

3. Simulation and Experiment Results

The circular monopole antennas with ground planes of different sizes oriented in coplane with to the monopole axis were first studied by using the simulation tool HFSSv 10 [10]. Measurements were conducted using Rhodes and Schwartz ZVM vector network analyser. Measured results for VSWR are plotted against simulated results in each category represented by curve 4 as shown in Figures 4 to 6. In order to understand the ground plane effect, its dimensions were classified into three categories based on its widths Wg of 20, 40 and 60 mm, respectively. The ground plane length Lg is swept from 20 to 60 mm with a 20 mm step.

Table 1: Ground Plane Dimension for Category I, II and III

Width (Wg) mm	Length (Lg) mm	Width (Wg) Mm	Length (Lg) mm	Width (Wg) mm	Length (Lg) mm
20 Category I	20, case 1	40 Category II	20	60 Category III	20
	40, case 2		40		40
	60, case 3		60		60

3.1 Category I

As shown in Figure 3 the VSWR curve depicts that resonance frequencies, at the lower band, shift from 3 to 4.5 GHz and then to 5 GHz for every step increase in length, the overall deviation is about 2 GHz. At the upper band, resonance frequencies are stable at about 7.5 GHz.

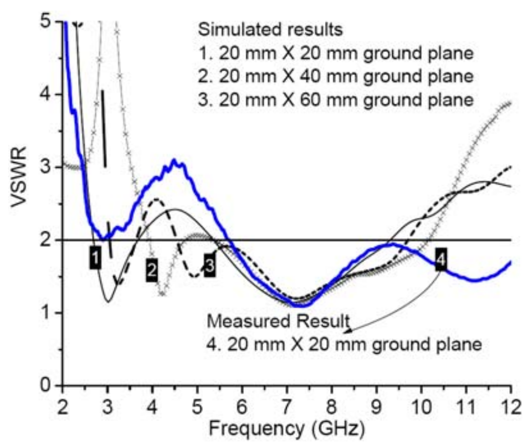

Figure 3: Simulated and Measured VSWR

3.2 Category II

In this category the resonance frequency variation from 2.9 to 3.6 GHz shown in Figure 4 stabilizes to a greater extent at the lower band with slight variation of 0.6 GHz, whereas the upper band gives a steady bandwidth with no resonant frequency shift.

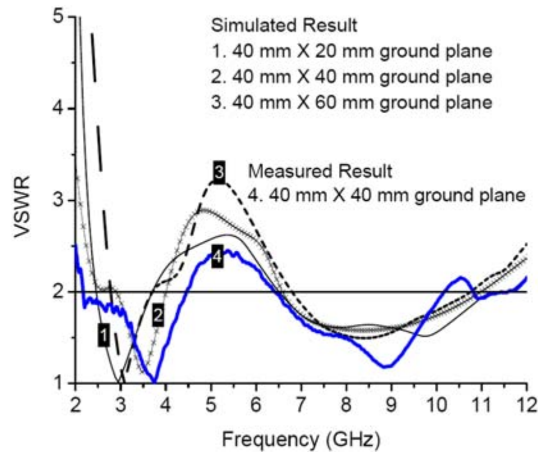

Figure 4: Simulated and Measured VSWR

3.3 Category III

The VSWR pattern, shown in Figure 5, shows that the resonant frequency variation in both upper and lower bands gets insensitive to the length variation, resulting in a stable performance. The E plane radiation pattern shown in Figure 6, simulated at 7.5 GHz, exhibits a pattern typical to monopole antennas [1].

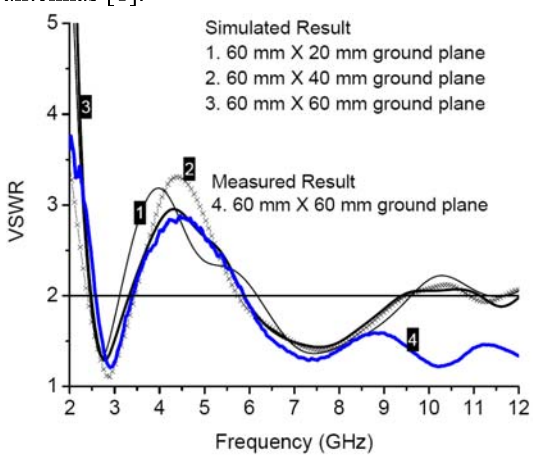

Figure 5: Simulated and Measured VSWR

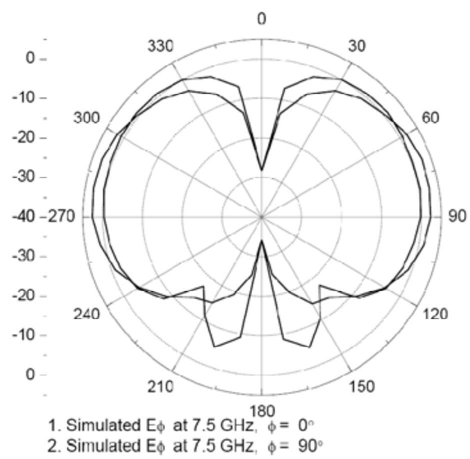

Figure 6: Simulated Radiation Pattern

4. Comparison of Simulated and Measured Results

The source of discrepancies between simulated and measured results shown in Figures 3-5 can be attributed to manufacturing tolerances. Moreover the SMA connection was not included in simulation which is an added source of difference. However, good agreement can be observed.

5. Discussion

The very first case of Category I in which the width and length of the ground plane are equal to the antenna diameter has a current distribution in anti-symmetry with the radiator. Theoretically a new ground plane of an infinite size may be inserted midway between the two anti-symmetrical radiator and ground plane without disturbing the field. This whole arrangement can be viewed as a monopole antenna on infinitely large flat ground plane. However, the radiator is circular and the ground plane square; it can be viewed as the near approximation of the above assumption. As the length is increased to 40 and 60 mm, the above described hypothesis is no longer applicable. The resonances of the antenna shift as the current distribution on the ground plane changes. The stability of the antenna is susceptible to variation in the ground plane length. If a Category I antenna is integrated into PCB. The increased ground plane size changes the antenna performance. This category can be characterized as insufficient ground plane dimensions. In category II and III when the width of the ground plane is about or greater than half wavelength at the lowest resonant frequency, sufficient coupling between the ground plane and the antenna occurs. As a result, the antenna becomes more stable, even after increasing the length.

The dimensions of the ground plane are critical to the performance of monopole planar antennas. Current concentration is high when the ground dimensions are small and has pronounced effect on the antenna performance compared to that with a large ground plane. The width of the antenna is an important parameter as the capacitive electric field coupling between the antenna and the ground plane takes place. The capacitive coupling is the function of the gap distance and ground plane width. Therefore, it serves as an antenna resonant tuning circuit. As the feed-gap is kept constant while the width is varied, at the width less than half wavelength, insignificant coupling results in shifting of resonant frequencies with variation in length and hence unstable antenna performance. However, the bandwidth of the antenna becomes insensitive to length variation, when it is at least quarter wavelength or more, and the width greater than half wavelength at the lowest resonant frequency.

6. CONCLUSION

Circular monopole antenna stability has been studied with regard to the ground plane dimension. It has been shown that the resonant frequencies and the impedance bandwidth are drastically affected when the antenna ground plane has a width less than half wavelength at the lower resonant frequency. The effect is more pronounced on the lower band of operation while the upper band remains relatively stable. The sensitivity of the antennas to ground plane length reduces significantly when its width is larger than half wavelength and length is equal or less than quarter wavelength of the lowest resonant frequency, because of the sufficient coupling between the antenna and the ground plane.

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