A Compact Printed Spiral FM Antenna

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Abstract— In this work,a compact printed spiral monopole antenna operating in the FM frequency band (88–108 MHz) is reported. The antenna is printed on a 100 mm × 50 mm PCB layer providing more than 20 MHz bandwidth at −2 dB threshold and is easily fabricated with low manufacturing cost. The antenna was also measured and simulated on 900 mm × 900 mm ground plane which is representative of a vehicle roof

1. INTRODUCTION

Electrically Small Antennas (ESAs) are desired and essential for many applications and especially at lower frequencies such as in the HF and VHF bands. Nowadays, compact antennas have become standard for radio receivers on vehicles and mobile terminals which lead to new requirements for small, efficient and low cost designs. Good performance of a radio receiver is heavily depended on the antenna performance. A variety of FM antenna types have been reported for automotive and portable applications including, active [1] and short meander line monopoles [2], fractal Hilbert curve antenna [3], chip antennas [4], window-printed active antennas [5] and the shark type antennas [6].

The frequency range for the FM radio band which defined from FCC regulation is from 88 MHz to 108 MHz and the respective wavelength λ_0 for the centre frequency $f_0 = 98$ MHz is around 3 meters. The height of a quarter wavelength FM monopole antenna is around 750 mm. In order to reduce the size of the monopoles, helix antennas with a height of 80 mm are used for FM radio receivers. In this paper a compact spiraled monopole antenna is reported with an overall volume of 100 mm × 50 mm × 1.5 mm. A five element network matching circuit is embedded in orderto increase the bandwidth to more than 20 MHz. The antenna can be easily integrated into compact volumes, is low cost and easily fabricated.

2. COMPACT SPIRAL ANTENNA

The antenna was designed and printed on a 100 mm × 50 mm double sided FR-4 substrate ($\varepsilon_r = 4.3$, $\tan\delta = 0.025$, thickness = 1.5 mm) with copper metallization thickness of 0.035 mm (Figure 1(a)). The 67.9 mm × 50 mm metal ground plane is on the rear of the same PCB board. The antenna is fed by a 50 Ω microstrip line of 3 mm width which is connected to a SMA connector. The miniaturization is based on its spiral structure occupying a 33 mm ($0.01\lambda_0$) × 50 mm ($0.02\lambda_0$) area on the PCB board (Figure 1(c)). In order to improve the antenna bandwidth, a five element π-matching network circuit (Figure 1(b)) is added so that the impedance bandwidth of antenna can be wider, covering the frequency range of 31.5 MHz bandwidth at VSWR 8.5 : 1 (Figure 2). As shown in Figure 1(b) the matching network consists of two parallel capacitors of 68 pF and 82 pF, two serial inductors of 100 nH and 1.5 nH and a parallel inductor of 68 nH.

3. SIMULATED & MEASURED RESULTS

Figure 2 illustrates the measured S_{11} results of the final model and the simulated S_{11} results of the antenna with and without the matching network. The measurements were obtained using a Rohde & Schwarz ZVA 40 vector network analyzer. For the simulation model without the matching network the antenna resonates at 102.9 MHz with a −2 dB impedance bandwidth of 6.3 MHz. For the antenna with the matching network the simulation results indicate a −2 dB impedance bandwidth of 22.3 MHz (86.2–108.5 MHz), while for the measured design the impedance bandwidth at −2 dB threshold is 31.5 MHz (76.8–108.3 MHz).

The antenna was also measured and simulated on 900 mm × 900 mm ground plane which is representative of a vehicle roof (Figure 3). The spiral monopole (33 mm × 50 mm) is located on a metallic ground plane while the other part of the antenna with the microstrip line is located

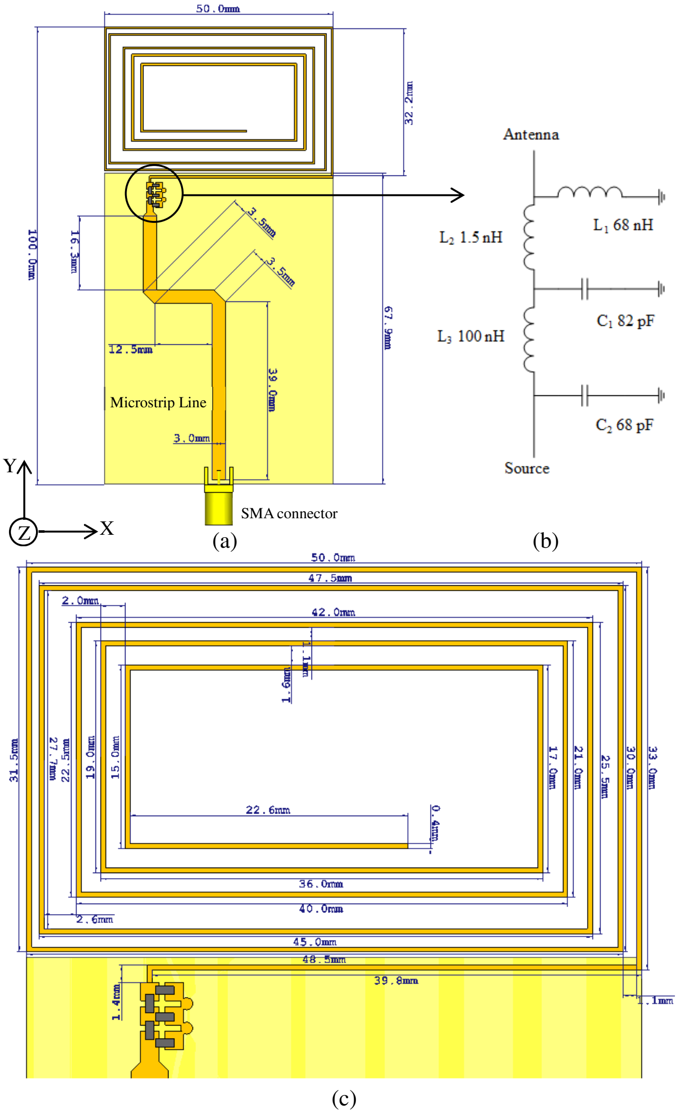

Figure 1: (a) Antenna general view, (b) π-matching network, (c) spiral monopole.

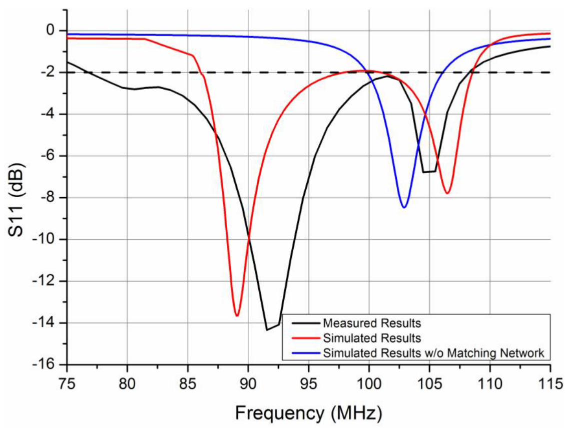

Figure 2: Simulated and measured S_{11} results.

below it. In Figure 4 the simulated and measured results are depicted. The antenna resonates at 91.5 MHz with a −2 dB bandwidth of 30.5 MHz (77.3–107.8 MHz) which is compared to the results in Figure 2. The simulated results provide a −2 dB bandwidth of 18 MHz (83–101 MHz).

In Figure 5 the simulated z-x and x-y plane radiation patterns at 98 MHz are illustrated.

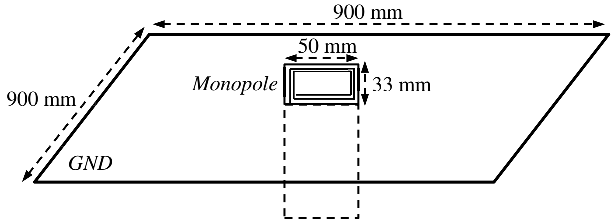

Figure 3: The FM antenna on large ground plane.

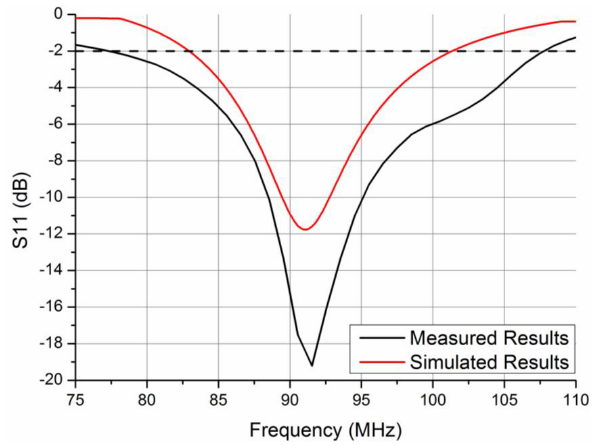

Figure 4: Simulated and measured results with the antenna on a large ground plane.

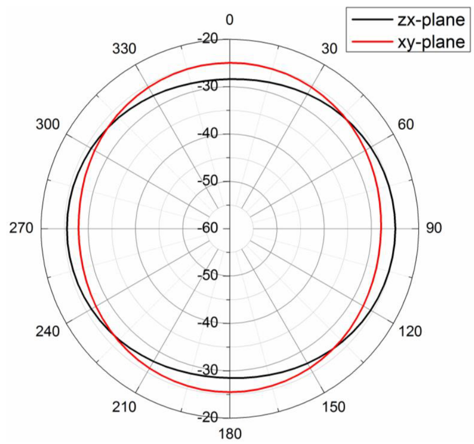

Figure 5: The simulated Phi (φ) components for the zx and xy-plane at 98 MHz.

The patterns are illustrated both in 10 dB/division scaled plot. The Phi (φ) component provides omnidirectional characteristics in both planes. The simulated maximum realized gain and total efficiency is -24.9 dBi and 2% at 98 MHz respectively.

4. CONCLUSIONS

In this work, a compact spiral FM monopole antenna is described. The proposed antenna is an electrically small antenna ($< 0.037\lambda_0$) offering a 32% fractional bandwidth (-2 dB) over the centre frequency ($f_0 = 98$ MHz) and covers the whole FM frequency band (88 MHz–108 MHz). The antenna is low cost, easily fabricated with omnidirectional radiation characteristics suitable to embed into housing. The antenna still operates with a decent wide bandwidth on large sized ground plane which makes it usable for automotive and vehicle applications.

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