Miniaturized Antennas for Vehicular Communication Systems

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Abstract. This paper contains an overview on 3 antennas, whose properties are of interest for vehicular communications. The first one is a wide-band miniaturised antenna with a stable radiation pattern. The second one is a low-profile antenna inspired by high impedance surfaces. The last one is a helical-ring antenna, whose radiation is toward a half-space in circular polarisation without the use of a metallic reflector. For all of them, the basic principles and simulation results are presented. For the last one, a prototype is also analysed.

Keywords: Antenna · Miniaturisation · Wide-band

1 Introduction

In vehicular applications, antennas operate under several constraints. These constraints may concern RF properties, such as the bandwidth, the polarisation, and the radiation pattern. They may also concern the size, the shape and the weight. For example, for small vehicles as UAVs, the weight, the thickness and the presence of a ground plane, whose size is typically significant in terms of wavelength, are key-difficulties.

In this article, an overview on three antennas is presented in the context of vehicular applications. All of them are miniaturised antennas, i.e. they are small with respect to the wavelength. The first one is a wide-band antenna with a frequency-independent omni-directional radiation pattern [1]. The second one is thin and inspired from metamaterials [2]. The last one presents a half-space radiation in circular polarisation without using any metallic reflector or ground plane [3,4].

This article is organised as follows. For each antenna, the principles are explained and simulation results are presented. For the third antenna, a prototype is also studied both from simulation and measurement results.

2 Wide-Band Miniaturised Antenna with a Stable Radiation Pattern

2.1 Principle

To obtain a quasi omnidirectional radiation pattern for a wide frequency band, a disk-loaded folded monopole can be used [5,6]. Nevertheless, this solution yields

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a radiation pattern that is not stable over frequency, i.e. significant variations in the pattern appear in the upper part of the frequency band. An alternative solution is presented here [1]. Its structure allows to maintain the radiation pattern in the upper part of the frequency band. The antenna, presented in Fig. 1, comprises an upper disk, a smaller lower disk, six straight wires connecting both disks, and six helical wires connecting the upper disk to the ground plane. The feeding is realised on a wire located between the lower disk and the ground plane.

The radiation of this antenna corresponds to the combination of two modes: an unfolded-monopole mode and a transmission-line mode, both of which are equivalent to resonant circuits. The first mode is associated with the following elements of the antenna structure: the upper disk, the 6 straight wires and the lower disk. The second mode is associated with the upper disk and the helical-wire cage.

Taking into account both modes, a resonant circuit model can be found to determine the central frequency and bandwidth in terms of impedance matching. The analysis of the current on this antenna shows that to improve the radiation pattern stability over a large band-width, the number and the length of the helical and straight wires must be increased.

2.2 Simulation Results

In this section, the antenna of Fig. 1 is simulated using Feko. The dimensions of the structure are as follows. The upper and lower disks are of diameter 12 cm and 7 cm, respectively. Their distances to the ground plane are 5.5 cm and 1.5 cm. The wire diameter is 2 mm. The helix rotation is a quarter of a turn.

The simulation result gives a frequency band for this antenna going from 511 MHz to 1074 MHz, i.e. approximately one octave. In Fig. 2, the antenna gain pattern is displayed in the horizontal plane. As desired, the pattern remains omni-directionnal in all the frequency band.

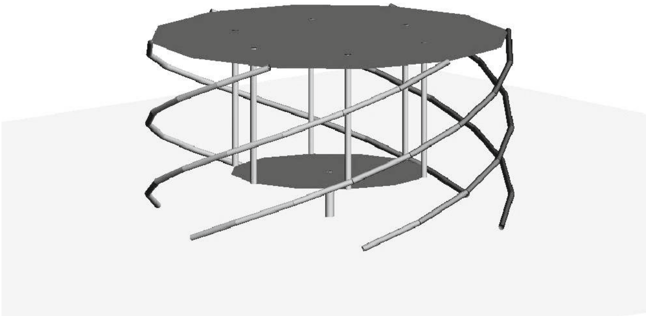

Fig. 1. Disk-loaded monopole with a 6-wires helical cage

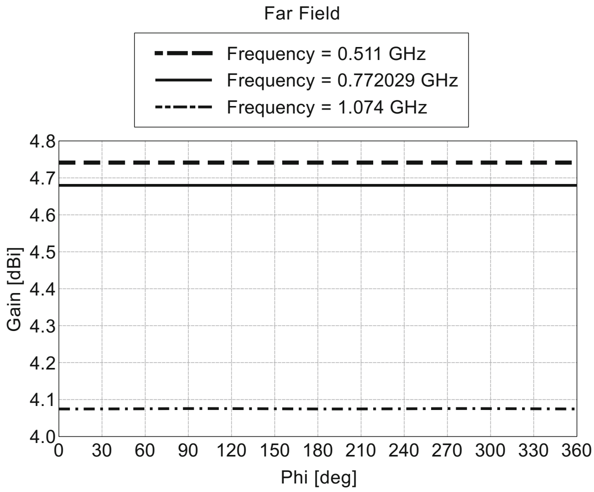

Fig. 2. Gain (dBi) in the horizontal plane of the disk-loaded monopole with a 6-wires helical cage

3 Thin Antenna Inspired by High Impedance Surfaces

3.1 Principle

For other types of applications in vehicular communications, the antenna thickness must be small. A way to realise low profile antennas is to use high-impedance surfaces (HIS). Indeed, any electric source placed parallel and close to such a surface has an optimal radiation. HIS are generally designed from periodic surfaces (metamaterials) for which the reflection coefficient is $\Gamma = +1$. In the design phase, the surface is generally assumed to have an infinite number of periodic cells so as to use Bloch-Floquet theory. In practical applications, only a small number of cells are however used due to size constraints.

In the limiting case, this yields a procedure to design thin antennas from a given basic structure [2]. Firstly, the basic structure is periodized, i.e. considered to be one cell of an infinitely periodic surface. Then, by simulation, the periodized structure is optimized so as to behave as a HIS. Finally, only two or three cells are used to obtain the antenna.

An example of application of this method is illustrated in Fig. 3. The basic structure is a rectangular metallic plate placed on top of a ground plane. The periodization method is firstly applied. Then, only two cells are kept.

3.2 Simulation Results

The final size of the rectangular plate is 67 mm × 55 mm. The gap between the two plates is 1 mm. The plates are 6 mm above the ground plane. For such dimensions, the antenna has 100 MHz of bandwidth centered at 1.575 GHz. In Fig. 4, the radiation pattern of this antenna is displayed.

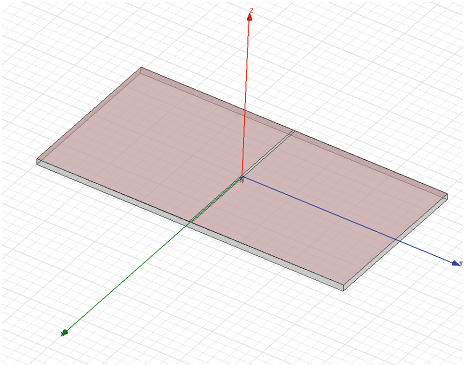

Fig. 3. HIS inspired antenna

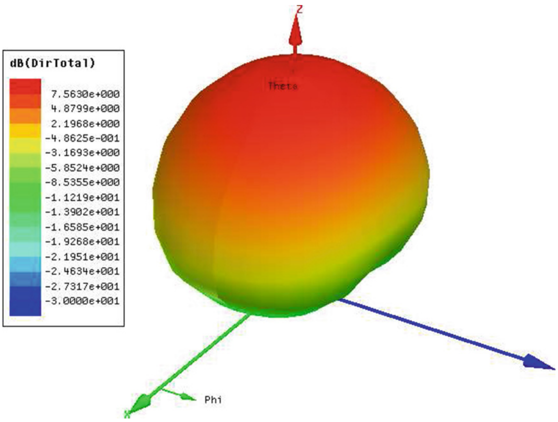

Fig. 4. Directivity pattern (dBi) of the HIS inspired antenna

4 Helical-Ring Antenna

4.1 Principle

With both previous antennas, the presence of a metallic ground-plane is assumed. For small vehicular applications as UAVs, this ground plane is an issue because of its weight and size. An antenna whose radiation is oriented toward a half-space without any large planar metallic structure would therefore be of interest. Besides, for numerous communication applications, e.g. SatCom, circular polarisation is also desirable. Theoretically, a half-space radiation in circular polarisation can be achieved by combining 2 elementary electric dipoles and 2 elementary magnetic dipoles. Two of the dipoles can be obtained from a straight helix antenna [7,8]. Thus, to combine the four dipoles, two straight helices must be used. This can be done relying on a helical ring structure [3,4] as illustrated in Fig. 5. The direction of the circular polarisation is defined by the handedness

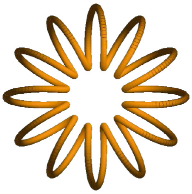

Fig. 5. Helical ring

of the helix. Note also that the direction of the radiation can be electrically switched frontward or backward by modifying the feeding.

4.2 Example of Application

In Fig. 6, a prototype of helical ring is presented. The helix has 4 turns. The right-handed helical ring has an outer diameter of 38 mm, an inner of diameter 5.5 mm, and height of 13 mm. The antenna is fed so that the radiation is directed upward.

Fig. 6. Picture of the prototype

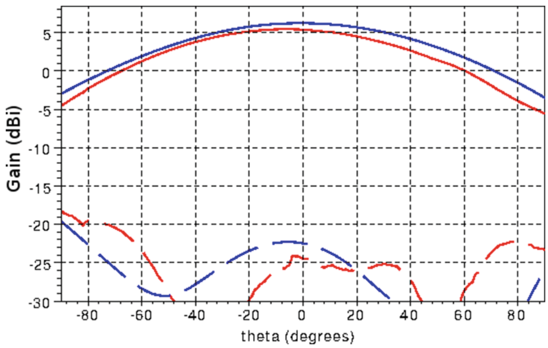

Fig. 7. Helical ring gain pattern (dBi): RHCP measurement (red line), RHCP simulation (blue line), LHCP measurement (dashed red line), LHCP simulation (dashed blue line). (Color figure online)

Both in simulations and measurements, the antenna central frequency is of 1.575 GHz with a 2:1 VSWR bandwidth of 21 MHz. In Fig. 7, the measured and simulated radiation patterns are compared in the upper half-space. The matching between simulation and measurement is acceptable. Besides, the purity of the right-hand circular polarisation (RHCP) is very good for any elevation angle.

5 Conclusion

In this article, three antennas have been presented. They offer properties that may be useful for vehicular communications. The first one combines a reduced size and a radiation pattern which remains the same regardless of the frequency. The second one is low profile. The last one radiates toward a half-space in circular polarisation without using any metallic reflector.

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