Design and Development of Novel 3D Antennas for Weather and Tornado Sensing Applications

Anya Traille and Manos M. Tentzeris

THE use of Wireless Sensor Networks (WSNs), which consist of spatially distributed autonomous nodes, that communicate with each other, and a base station through multi-hopping, has recently grown tremendously as a technology. Although originally used for defense purposes, WSNs can be used for civilian purposes such as real-time monitoring and tracking of environmental conditions. The motivation for this paper is to use WSNs for the tracking of weather, specifically tornadoes. The design of the presented cubic antenna aimed in combining an omnidirectional radiation pattern, low weight, capability of having sensors packaged within the antenna structures, and efficient matching at 915 MHz (high power efficiency). The reason for using the UHF RFID band is that this antenna can be exploited for use as an RFID antenna for the tracking of position and velocity within a tornado. As will be demonstrated, a wide range of impedances can be realized by modifying the many design parameters inherent with using six sides as a basis for the antenna geometry. The cubic antenna design has the potential to be the first truly 3D ultra-low-cost solution for the realization of truly ubiquitous wireless sensing applications, especially when fabricated on flexible, organic Liquid Crystal Polymer (LCP) or paper.

The use of a cubic structure with integrated planar antenna structures has been studied for MIMO applications ([1]-[4]). These cubes have many antennas mounted on them with each one fed by a different port. In this case, isolation between ports is desirable. However, the use of a cubic structure with a single input where the planar antenna structures are intentionally coupled to improve radiation has not been previously published. The use of all six sides for one radiating structure allows for homogeneous radiation into 4π steradians in space.

In this paper, the design of a miniaturized, cubic antenna for use as the radiation part of an enclosed sensor in a wireless sensor node is proposed. A novel miniaturized 3D cubic antenna for use in a Wireless Sensor Network (WSN) and RFID's for environmental sensing is introduced. The antenna produces a truly omnidirectional pattern in both E-plane and H-plane, which allows for non-intermittent communication that is orientation independent. The frequency of operation lies in the UHF RFID band, 902MHz – 928 MHz (centered at 915 MHz). The ultra-compact cubic antenna has dimensions of 3cm x 3 cm x 3cm (27 cm^3), which features a length dimension of $\lambda/11$. The cubic shape of the antenna allows for "smart" packaging, as sensor equipment may be easily integrated inside the cube's hollow (or Styrofoam-filled) interior. The prototype fabrication was performed on 6 (planar) sides on Liquid Crystal Polymer (LCP) substrate, and then folded into the cubic structure. The geometry of the design is inspired by the RFID inductively coupled meander line structures, which are folded around the sides of the cube. Due to the large number of freedom degrees, this antenna concept may be easily reconfigured for many values of impedances and design parameters. Experimental data verify the simulation results. The optimized antenna is shown in Fig.1. The structures on the top and bottom of the antenna are identical, except that the bottom element has no excitation slot and is purely parasitic.

To account for the presence of a large number of water drops in clouds and tornados, we plan to replace the printed metallic strips of the folded dipole with plastic tubes with water solutions that could effectively operate as liquid antennas. In this way, no significant mismatches in the near-field would take place and the effective range of wireless links for weather and tornado monitoring could increase dramatically.

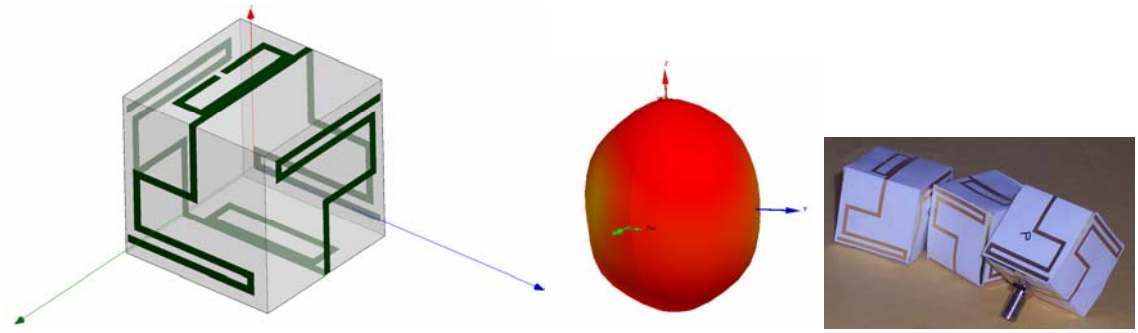

Fig. 1. Optimized 3D "Magic-Cube" Antenna: (left) topology, (mid) omni radiation, (right) prototype

As shown, the radiation pattern is almost truly isotropic with a slight E-plane tendency. The axial ratio is primarily above 5 in most directions, except where the cube edges occur and the axial ratio drops below 2, indicating that the polarization is largely linear except on the cube edges where the adjacent meander lines create an elliptical polarization

As a conlusion, the design, fabrication, and measurement of a cubic antenna with a nearly isotropic radiation pattern has been achieved. The antenna is matched to 50 Ω in the desired RFID band, and can be reconfigured to match almost any impedance. The cube can also be used for system-in-package technology, whereby the antenna provides housing for sensor electronics, providing the optimum solution for a WSN node. Using this technology, low-cost weather tracking may be realized, especially in turbulent scenarios, such as tornadoes.

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