Enhancement of Bandwidth for Low-Profile Omnidirectional Zeroth-Order Resonant Antennas

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Abstract **–Low profile zeroth-order resonant antennas with monopole-like omnidirectional radiation in the horizontal direction with vertical polarization is proposed. It is composed of a rotationally symmetric mushroom structure including multiple metal patches and vias, a microstrip loop outside the patches, and a feed line connected to the outer loop. For comparison, conventional mushroom antennas with the same size is also simulated. It is found that the bandwidth of the proposed antenna is enhanced compare to conventional mushroom antennas without significant degradation of gain.**

Index Terms **—Mushroom structures, Zeroth-order resonance, Low-profile omnidirectional antennas.**

1. Introduction

In wireless communication systems, monopole antennas are fundamental and practically useful for omnidirectional radiation in the horizontal direction with vertical polarization, but with the height of quarter wavelength. Size and weight reduction of antennas has been strongly demanded, but simple miniaturization approach seriously suffers from narrow bandwidth and degradation of radiation gain. Low profile or electrically small antennas with bandwidths sufficiently wide for use have been developed and demonstrated [1]. Recently, possibility of the further reduction has been studied based on the concept of metamaterials, i.e., electromagnetic artificial structures composed of small elements compared to the wavelength.

Composite right/left handed (CRLH) transmission lines are useful and comprehensive concepts in designing metamaterials or in understanding physical meanings of new electromagnetic phenomena in metamaterials [2]. Zeroth order resonance manifests itself in CRLH transmission line-based resonators under some specific boundary conditions at frequencies where the guided wavelength is infinite, or the operation at Γ point in dispersion diagram [3]. One of the fascinating characteristics is that the resonant frequencies are independent of resonators' size. Therefore, zeroth-order resonators can be much smaller than the wavelength for miniaturization. However, it is well-known that the resonators have extremely narrow bandwidth resulting in the limitation of practical use for antenna applications.

Most of metamaterial-inspired small antennas radiates not only in the horizontal direction but also to the broadside direction. Planar-type low-profile antennas based on zeroth order resonance of mushroom structures or CRLH metamaterials provide omnidirectional radiation in the horizontal direction but not to the broadside direction [4], like monopole antennas. One approach to achieve wider band for the monopole-like radiation is a combination of various zeroth-order resonators with different operational frequencies [5]. However, each zeroth order resonator is composed of several unit cells and their total antenna size was proportional to number of the resonators.

In this paper, one approach to enhance the bandwidth for low-profile zeroth-order resonant antennas with monopole-like radiation is proposed without the size extension. From the numerical simulation results, proposed antenna clearly shows enhancement of bandwidth compared to the conventional mushroom antennas without serious degradation of gain.

2. Geometry

In Fig. 1, geometry of the proposed zeroth-order resonant antenna is shown, along with conventional mushroom antenna for comparison. The former is composed of a rotationally symmetric mushroom structure with multiple metallic patches and vias to form 2-D CRLH transmission

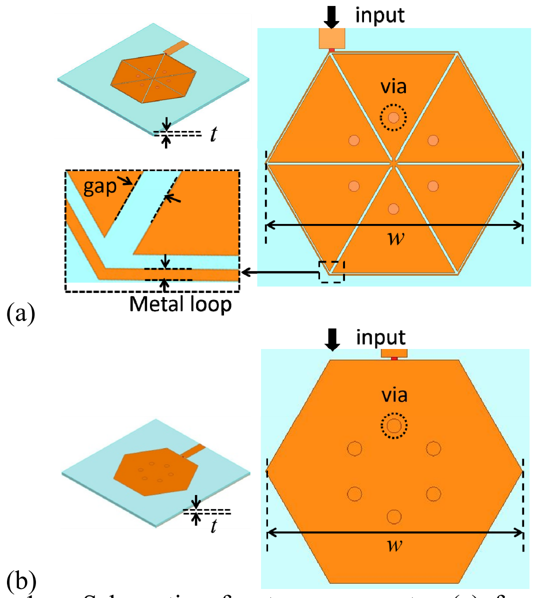
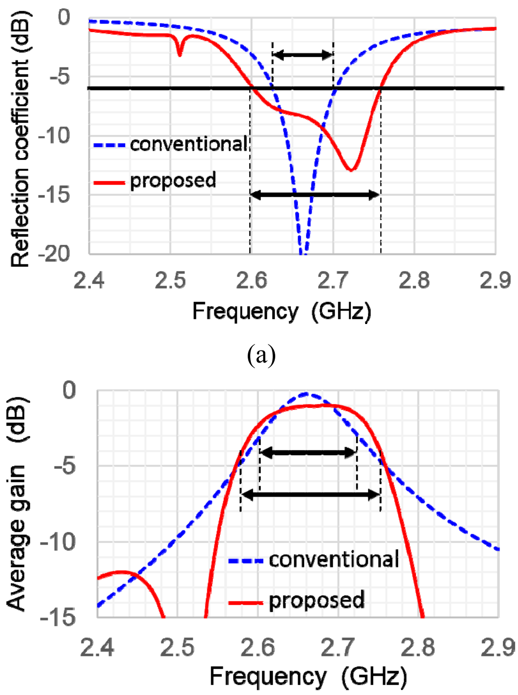


Fig. 1. Schematic of antenna geometry (a) for the proposed zeroth order resonant antenna, and (b) for conventional mushroom antenna for comparison.



(a)

(b)

Fig. 2. Comparison of simulated reflection coefficients and radiation gains of the proposed and conventional zeroth order resonant antennas. (a) Reflection coefficient. (b) Averaged gain of vertical polarized component in the horizontal direction.

line ring that is symmetric around the normal axis at the center, as shown in Fig. 1(a). Another micrstrip ring is placed coaxially and outside the mushroom patches with a small gap. Capacitive couplings between neighboring mushroom patches are kept weak in order to achieve multiple resonant frequencies in the vicinity of parallel resonance in shunt branch of the CRLH transmission line, resulting in broadening the bandwidth. However, coexistence of multi-resonant modes often excites out-of-phase current flows among neighboring mushrooms in the antenna, which causes destructive interference of radiated waves, and results in serious degradation of gain. To avoid out-of-phase resonances among mushrooms, we propose to place microstrip ring outside the patches and to keep their capacitive coupling strong. In addition, mushroom patches are set to be directly connected at the center for their in-phase resonance. The 50-Ω microstrip line for feeding was connected to the microstrip ring at an intermediate position between two mushrooms through a capacitor for impedance matching. In Fig. 1(b), conventional mushroom antenna with six vias is shown for comparison. To keep their antennas' size and operational frequency the same in Fig. 1, configuration of the vias was optimized.

3. Numerical Simulation

With the use of commercial 3-D full-wave electromagnetic field solver based on finite element method, HFSS ver. 13, ANSYS, reflection coefficient at the input port and radiation characteristics of the two antennas in Fig. 1 were numerically investigated. Various configuration parameters used in the numerical simulation are as follows; the thickness and dielectric constant of the dielectric substrate are 1.6 mm and 2.2, respectively, number of the mushroom cells in a whole patch was six, i.e. the shape is regular hexagon with the side length of 24 mm. The distances of gaps between neighboring patches and another gap between mushroom structure and microstrip ring are both 0.5 mm.

For both the two designed structures in Fig. 1, parallel resonance occurs at 2.65 GHz due to a combination of patch capacitance and via inductance. The radiation characteristics show the monopole-like omnidirectional patterns in the horizontal direction with vertical polarization and not to the broadside direction. In Fig. 2(a), simulated reflection coefficients at the input port is shown for two cases, and Fig. 2(b) represents radiation gains of vertically polarized component that is averaged over the azimuthal direction on the horizontal plane. From the numerical simulation results in Fig. 2, the typical mushroom antenna in Fig. 1(b) shows bandwidths for -6-dB return loss and for 3-dB gain are 75 MHz and 127 MHz, respectively, whereas the proposed antenna in Fig. 2(a) represents the corresponding bandwidths with 157 MHz and 177 MHz. Therefore, the bandwidths of the proposed low-profile mushroom zeroth-order resonant antenna are clearly enhanced compared to conventional mushroom antennas without serious degradation of the gain.

Conclusion

The enhancement of bandwidth for low-profile, omnidirectional, and vertically-polarized zeroth-order resonant antennas was proposed. The antenna was composed of a rotationally symmetric mushroom structure including multiple metal patches and vias, a microstrip ring outside the patch, and another microstrip line for feeding. For comparison, conventional mushroom antennas with the same size was also simulated. It was found that the bandwidth of the proposed antenna was almost twice the bandwidth of conventional mushroom antennas without significant degradation of gains.

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