Miniaturized Circular Microstrip Patch Antennas with Conical Radiation Patterns

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Microstrip patch antennas (MPAs) have become an appropriate candidate for portable antenna systems, due to their compact and low profile configurations. Additionally, by changing the size of the radiating patch, flexibility in resonant frequencies and radiation patterns can be achieved. In particular, MPAs are capable of generating broadside and conical radiation patterns at their dominant and higher order TM_{n1} modes, respectively. Such conical shaped radiation patterns have numerous advantages in satellite communications, wireless local area network, tracking and guiding systems, and anti-jamming applications, where the null can be directed towards the source of the interference. However, the main issue with these higher order modes is that they require much larger aperture size compared with the dominant TM_{11} mode, whose radius is $0.293\lambda_d$ (R. Garg and et. al., 1995, *Microstrip Antenna Design Handbook*. Norwood MA: Artech House), where λ_d is the guided wavelength. For the higher order modes, the radius of the patch should be enlarged which has hindered its application in tightly-space antenna and array configurations. Previously, shorting vias were utilized for the miniaturization of the TM_{02} circular patch antennas (C. B. Ravipati and et. al, *IEEE Antennas Propag. Soc. Int. Symp.*, 3b, 2005). However, such shorting vias result in a three-dimensional structure, thus complicating the fabrication process. The size reduction of MPAs may also be realized through dielectric loading, as any increase in the permittivity can help reduce the guided wavelength of the antenna; however, high-contrast dielectric materials add a considerable mass to the antenna and increase dielectric losses.

In this paper, two compact circular patch antennas, one operating at the TM_{21} mode and the other at the TM_{31} mode, are introduced by applying a proper geometrical alteration to the patches, inspired by the respective surface current distributions of these modes. By judiciously placing radial slits on the patch where the surface currents are maximum, the current path is meandered, which consequently reduces the resonant frequency and thus miniaturises the patch size. In particular, it will be shown that the eigenvalue of the modes are reduced significantly. As a result, the proposed miniaturized patch antennas may readily be utilized in pertinent wireless applications, occupying much smaller aperture size than the conventional higher-order-mode circular patch antennas. The miniaturization is realized by placing four and six radial slits on the patches for the TM_{21} and TM_{31} modes, respectively, to elongate the current path and thus reduce the aperture size of the antenna. The effects of the slits on the size reduction, gain, and reflection coefficients are studied. It is found that the size of the patch can be controlled by changing the radial and angular dimensions of the slits. For the TM_{21} mode, a reduction up to 40% is achieved in the patch radius, which makes its aperture size equal to that of the conventional TM_{11} circular patch antenna. As for the TM_{31} mode patch antenna, a patch reduction up to 50% is realized. The corresponding results will be presented and discussed in the conference.