End-fire Microstrip Antenna with Negative Permittivity Substrate

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Microstrip antennas are a popular antenna choice for applications in vehicular technology and mobile communications because of their low-profile, low cost, and easy integrability into different surfaces. Typically, patch antennas have been designed to be broadside radiators; however, end-fire radiation patterns can also be achieved by exciting higher-order modes in the dielectric cavity. For example, a patch of length 0.5λ and width 0.25λ with a dielectric constant of $\epsilon_r = 4$ would support a TM_{20} mode, which radiates at end-fire. In this paper, we propose an alternative design that uses a negative permittivity substrate to achieve an end-fire radiation pattern without needing to excite higher-order modes in the cavity. With this design, the directivity of the antenna is improved, along with the impedance bandwidth, while maintaining a very low-profile antenna structure.

The negative permittivity substrate imposes a constant phase condition across the interior of the cavity, causing the cavity edge fields to produce a set of oppositely directed equivalent magnetic currents. The fields radiated from these currents destructively interfere at broadside, resulting in only end-fire radiation. Because the negative permittivity values are not large, the corresponding attenuation constant is small and the field exists throughout the patch area. The substrate is implemented using a vertical array of eight thin wires to produce an effective negative permittivity. The wire radius and spacing are adjusted to produce a permittivity close to -2, while the dimensions are adjusted, to get an input impedance over $50\ \Omega$ for an efficiency of 88%. The final directivity of the two-sided pattern was 3.8 dB with a bandwidth of 5.5%, operating at 10 GHz with a substrate thickness of 0.5 mm. Fig. 1 displays E-plane radiation pattern of the designed patch antenna.

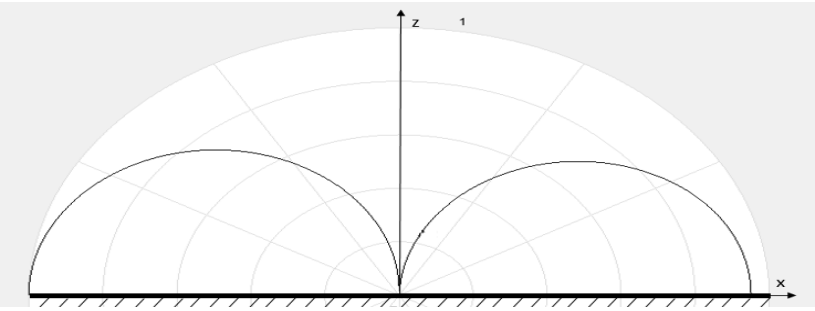

Figure 1. Normalized E-plane radiation pattern of the designed antenna.