Radiation Characteristics of Monopole Antenna Embedded in Low Effective Index of Refraction (n < 1) Wire Media

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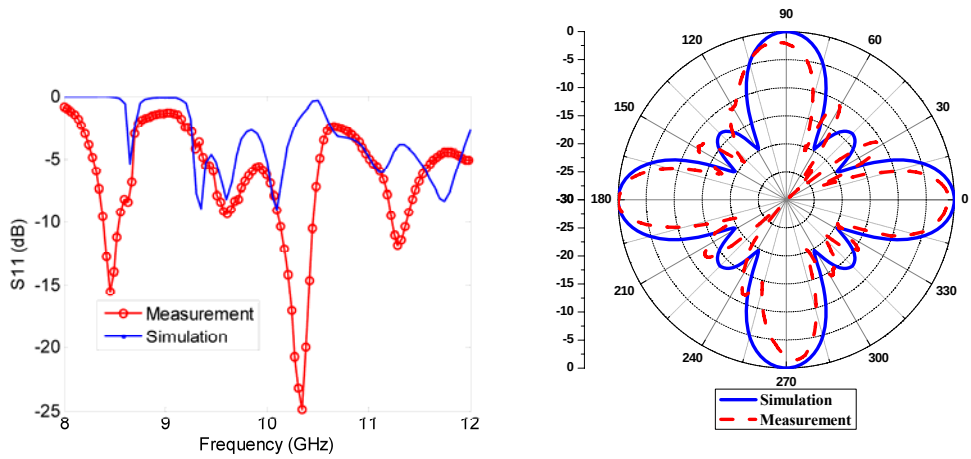
In this paper, a two-dimensional (2-D) metallic wire array is designed to be an effective medium with an index of refraction $n_{\text{eff}} < 1$. This type of wire array can be treated approximately as plasma with reduced electron density. The self-consistency of the plasma theory is verified. The geometry of the wire array is optimized by finite-element simulations and the effective medium parameters (ε_{eff}, μ_{eff}, and n_{eff}) of the wire array are extracted from the simulated scattering parameters. The extracted results confirm the low effective index properties of the wire array at frequencies just above the plasma frequency. To study the validity of using the wire array as an effective medium, a 2-D electromagnetic band gap (EBG) structure embedded in the wire medium is investigated. It is found that the first band gap of the 2-D EBG structure shifts to a higher frequency as expected when the vacuum region (n = 1) is replaced by the $n_{\text{eff}} < 1$ region.

A narrow beam monopole antenna is then realized by embedding the monopole within a metallic wire array. The 2-D wire array is designed to have $n_{\text{eff}} < 1$ at the monopole antenna working frequencies (8~12 GHz). The narrow beam effect due to the low refractive index of the wire media is demonstrated in both simulation and experiment. Measured antenna properties including return loss (Fig. 1a) and radiation pattern (Fig. 1b) are in good agreement with simulation results. This simple and straightforward antenna design methodology can be applied at any microwave frequency.



(a) (b)

Figure 1. (a) Measured (circles) and simulated (solid line) return losses of the monopole antenna embedded in the wire array. (b) Measured (dashed line) and simulated (solid line) broadside radiation patterns (normalized to 0 dB) of the monopole embedded within the wire array at 9.5 GHz.