Metamaterials with low effective permittivity for directive antennas

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In this talk we describe our theoretical and numerical work, as well as our experimental results concerning the design of directive antennas. One of the aims is to obtain antennas much more compact than classical solutions. Another interesting feature is that these antennas can be excited by a single feeding device (patch, monopole). Such antennas could be useful for microwave telecommunications.

The behavior of the antenna presented in this talk is based on the properties of a stack of metallic grids, which can be considered as a photonic crystal, a grating, a metamaterial, a complex media, depending on the reader's habits. As well known, these grids have filtering properties. First, they completely filter the low frequencies that cannot propagate inside (low frequency bandgap). We are mainly interested in the small frequency range associated with the transition between the low frequency bandgap and the allowed propagating solutions. Several studies have shown that in this frequency range where the wavelength is much greater than the period of the periodic media, the metamaterial can be homogenized in a material whose relative permittivity has a behavior governed by a plasma frequency in the microwave domain: $\varepsilon_{eff} = 1 - \omega_p^2 / \omega^2$. Of course, using this expression, one can check that the low frequencies see the metamaterial with a negative permittivity, i.e. a pure imaginary optical index, and so the only solutions are evanescent waves. But this expression also tells us that for frequencies just a little bit larger than the plasma frequency, the relative permittivity stays between 0 and 1, and the same is valid for the optical index. In this case where the metamaterial has an effective optical index which can be close to zero, one can expect ultrarefraction phenomena. This remarkable property is the key idea which governs the behavior of the antenna.

The two-dimensional case is used for the preliminary studies. We show that, for thin wires, many properties can be derived from the two-dimensional model. Three-dimensional codes based on Harrington's wire approximation allow us to get a more realistic model, but lead to very large numerical systems.