Design and Applications of Subwavelength Negative Permeability Medium Elements from 0.3 GHz to 0.3 PHz

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The concepts and definitions of effective medium theory are valid if and only if the constituting elements are much smaller than the operation wavelength. A quantitative measure for subwavelength elements was given by calculating their electrical size. In the present study, we demonstrated μ-negative medium elements, whose electrical sizes range from λ/80 to λ/3. We specifically focused on 1 GHz [1-3], 3 GHz [1-5], 100 GHz [6-9] and 300 THz operation frequencies. Characterization was performed theoretically by using the LC-circuit models [10], numerically by using the full-wave solver CST and experimentally by using Network and Spectrum Analyzers. After the transmission based characterization, we have selected suitable elements for different applications. The permeability of the resonator based media can be controlled at will and the applications in the fields of radiation, enhanced transmission, tunable response, absorption, and negative refraction are promising. By utilizing the subwavelength resonance of the μ-negative medium elements we have designed electrically small antennas. A split ring resonator loaded monopole antenna and a two-dimensional spiral resonator array loaded patch antenna (Fig. 1) are characterized [4, 5]. Numerically, we demonstrated that complete transmission enhancement can be achieved by inserting the deep subwavelength resonators into the two-dimensional array of subwavelength apertures (Fig. 2) [3]. The multi-split resonators can be tuned by shorting their splits by means of photoconductive switches [3]. Negative refraction and superlens phenomena were demonstrated experimentally [6-9, 11]. Finally, the miniaturization of absorbers by using μ-negative slab instead of a PEC sheet was realized.

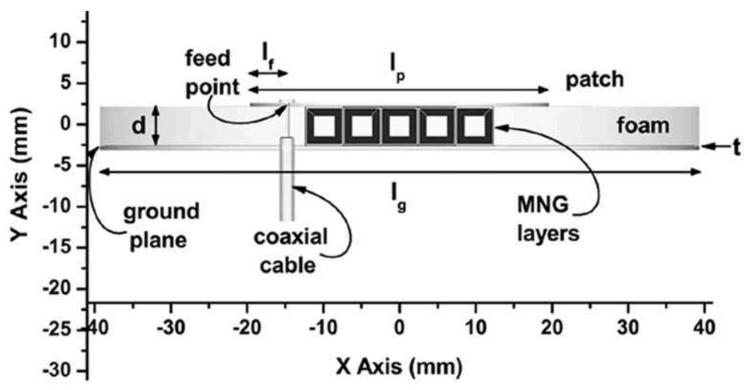

Fig. 1. Two-dimensional spiral resonator (SR) array loaded patch antenna

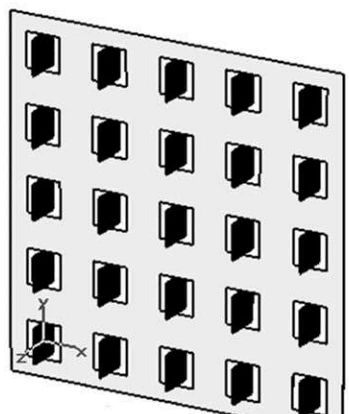

Fig. 2. Geometry of MSRR inserted hole array

References

[1] K. B. Alici, Filiberto Bilotti, Lucio Vegni, E. Ozbay, *Appl. Phys. Lett.* **91**, 071121 (2007).
[2] F. Bilotti, A. Toscano, L. Vegni, K. Aydin, K. B. Alici, E. Ozbay, *IEEE Trans. Microwave Theory Tech*. **55**, 2865 (2007).
[3] K. B. Alici, Filiberto Bilotti, Lucio Vegni, E. Ozbay, submitted, (2008).
[4] K. B. Alici, E. Ozbay, *J. Appl. Phys*. **101**, 083104 (2007).
[5] K. B. Alici, E. Ozbay, *Physica Status Solidi B,* **244**, pp. 1192-1196 (2007).
[6] K. B. Alici, E. Ozbay, submitted, (2008).
[7] K. B. Alici, E. Ozbay, *J. Phys. D: Appl. Phys.* **41**, 135011 (2008).
[8] K. B. Alici, E. Ozbay, submitted, (2008).
[9] K. B. Alici, E. Ozbay, “Observation of negative refraction by using a meta-prism at 100 GHz”,submitted, (2008).
[10] F. Bilotti, A. Toscano, L. Vegni, *IEEE Trans. Antennas Propag.* **55**, 2258 (2007).
[11] K. B. Alici, E. Ozbay, Photon. Nanostruct. **6**, pp. 102-107 (2008).