Observation of negative refraction and subwavelength focusing in metamaterials

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We report a true left-handed (LH) behavior in a composite metamaterial consisting of periodically arranged split ring resonator (SRR) and wire structures. The magnetic resonance of the SRR structure is demonstrated by comparing the transmission spectra of SRRs with that of closed SRRs. We confirmed experimentally that the effective plasma frequency of the LH material composed of SRRs and wires is lower than the plasma frequency of the wires. A well-defined left-handed transmission band with a peak value of -1.2 dB (–0.3 dB/cm) is obtained. We also report the transmission characteristics of a 2D composite metamaterial (CMM) structure in free space. At the frequencies where left-handed transmission takes place, we experimentally confirmed that the CMM structure has effective negative refractive index. Phase shift between consecutive numbers of layers of CMM is measured and phase velocity is shown to be negative at the relevant frequency range. Refractive index values obtained from the refraction experiments and the phase measurements are in good agreement. The experimental results agree extremely well with the theoretical calculations. The influence of periodicity, misalignment, and disorder on the magnetic resonance gap of split-ring resonators (SRRs) which are essential components of left handed-metamaterials (LHMs) is also investigated. The resonance of a single SRR which is induced by the split is experimentally demonstrated by comparing transmission spectra of SRR and closed ring resonator. Misaligning the SRR boards do not affect the magnetic resonance gap, while destroying the periodicity results in a narrower band gap. The disorder in SRR layers cause narrower left-handed pass band and decrease the transmission level of composite metamaterials (CMMs), which may significantly affect the performance of these LHMs. We employed left-handed materials (LHM) as negative index materials and experimentally investigated focusing behavior of such lenses. A point source is embedded inside the LHM lens. We have shown that it is possible to focus electromagnetic (EM) waves by using planar configuration of lenses that are constructed by using two-dimensional LHMs. Flat lens behavior is observed at 3.89 GHz, where EM waves are focused both along lateral and longitudinal directions. At 3.77 GHz, where the reflection is measured to be minimum, the focusing effect occurred at the surface of the LHM with a spot size of 0.16λ. We have been able to overcome the diffraction limit with slab-shaped LHM superlens.