Source excitations of backward lateral and surface waves, surface plasmons and sub wavelength focusing in DNG layers

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When DNG layers are excited by a localized source, several wave modes are excited which are not present for ordinary dielectric layers. In this paper, we consider a line source exciting a semi-infinite and layered DNG medium. Fourier transform representations of the field are identical to those for ordinary media, except that close attention needs to be paid to the choice of the square root of the complex propagation constant. For a semi-infinite DNG medium, a choice needs to be made so that the imaginary part of the propagation constant is negative and the real part of the characteristic impedance is positive with $\exp(j\omega t)$ dependence, and this choice leads to the proper Riemann surface among four Riemann surfaces. This is the same as the Sommerfeld problem, except that the branch points and the poles for a DNG medium appear in the third quadrant, rather than the fourth quadrant as in the complex plane. The branch cuts and the poles in the third quadrant give rise to the backward lateral waves and backward surface waves, respectively. These poles and branch points exist only for certain values of μ and ε, and this can be expressed in the different regions of the $\mu-\varepsilon$ diagram.

It is known that Brewster's angle and the Zenneck wave are closely related. This can be explained by noting that the Zenneck wave pole is on the proper Riemann surface while Brewster's zero is on the next improper Riemann surface, and that the propagation constants along the surface are the same for both, but the phase front and the attenuation directions are different. For the backward surface wave, the phase velocity and the Poynting vector are in the same direction in free space, but they are in the opposite direction in the medium, and the total power is in the direction opposite to the phase velocity. A backward lateral wave due to a wave incident on the surface near the critical angle propagates in the negative direction with group velocity and is radiated at the critical angle. This is also related to the negative Goos-Hanchen shift of a beam wave.

When a wave is incident on a slab of DNG which is placed between the first and third medium, and if the refractive index of the first medium is greater than the third medium, a surface plasmon can be excited along the interface between DNG and the third medium. The surface plasmon can be forward or backward depending on the values of μ and ε. At this plasmon resonance, a sharp dip in the reflection coefficient occurs which may be used to measure DNG characteristics or the characteristics of the third medium. If the first and third media are free space, a sub wavelength focusing is possible when the refractive index of DNG is close to –1. However, this requires a large evanescent stored power which is highly sensitive to the deviation of the refractive index from –1.