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Arrival of Composite Right/Left-Handed (CRLH) Structure

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One of the most exciting radio scientific research during the past 70 years can be in the birth and advance of metamaterial in the electromagnetic environment. Circa year 2000, John Pendry ignited investigation of negative index material and associated phenomena such as perfect lens [1]. The approach taken was to use wire meshes [2] and split rings [3] much smaller than the wavelength so that they exhibit effective permittivity and permeability. Many research groups follow this approach. The microwave community exhibited significant skepticism or even hostility.

On the other hand, Itoh group as well as Eleftheriades and Oliner have taken different approach [4-6]. All of them realized that an artificial transmission line obtained by interchanging the distributed series inductance and shunt capacitance can support the backward wave with phase and group velocities are anti-parallel and that this is equivalent to the propagation in the negative index material. Since transmission line can be broadband and low Q in contrast to the resonant structures used by Pendry's group, the approach by these three groups provides more useful and practical microwave components.

Furthermore, Itoh group introduced a concept of composite right/left-handed (CRLH) structure which has significant dispersion characteristics that provided opportunity of inventing and developing microwave components never before possible [7]. Some of the examples are small antennas based on negative order resonators [8], zeroth order cavity for antennas independent of size [9], dual band components [10] and harmonic output filters for Class-F high power amplifier [11]. Perhaps, one of the most unique components that was made possible is the leaky-wave antennas scannable from the backward to forward beam through the boresight [12]. This latter is made for the first time in microwave history. The CRLH concept is adaptable to higher frequency up to THz. Recently, the CRLH configuration was implemented to THz Quantum Cascade Laser (QCL) with efficient output in the form of coherent beam [13].

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