Waves in Gradient Transmission Lines: Physical Fundamentals, Mathematical Basis and the First Experiments

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Gradient transmission lines (TL), characterized by heterogeneous continuously distributed capacitance and/or inductance are shown to possess the unusual non–local heterogeneity-induced dispersion in the microwave spectral range. This strong artificial dispersion, both positive and negative, is determined by the shapes and sizes of distributions of capacitance and inductance along the TL. To optimize the regimes of microwaves propagation in these structures the series of new exact analytical solutions of telegraph equation for gradient TL are obtained beyond of the scope of any assumptions concerning smallness or slowness of variations of fields or impedances along the line. These solutions visualize the formation of flexible non – Fresnel reflectance/ transmittance spectra of TL, formed due to interference of forward and backward waves, occurring on the discontinuities of gradient and curvature of spatial distributions of impedance inside the line. The heterogeneity – induced dispersion is shown to provide the weakly attenuated tunneling regime for effective energy transfer in the microwave spectral range by evanescent and antievanescent modes in the gradient TL.

Formation of heterogeneity–induced dispersion in the gradient transmission line is verified by the experimental measurements of transmittance for the fundamental *TEM* mode propagating in the coaxial waveguide through the gradient plastic porous diaphragm. The variable ratio of plastic - filled and air - filled parts in each cross – section of diaphragm mimics the gradient distribution of impedance along the line. The theoretical and experimental transmittance spectra for *TEM* mode in the waveguide loaded by gradient impedance are fitted well.

The drastic influence of gradient dielectric diaphragms located inside the waveguide on the propagation of TE_{11} and TM_{11} degenerated modes in this waveguide is examined by means of exact analytical solutions of Maxwell equations for the different distributions of dielectric permittivity in the diaphragms. The possibility to use this effect for filtration of degenerated TE_{11} and TM_{11} modes with the same frequencies is illustrated.

The non – locality stipulated dispersive phenomena in the gradient transmission lines are presented as the newly shaping microwave counterpart of general wave structures, developed recently for optical and acoustical wave fields in the artificial heterogeneous media (A.B. Shvartsburg and A.A. Maradudin, “Waves in Gradient Metamaterials”, WSPC, 2013).