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Input Impedance Characteristics of Barrier Structures

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Abstract—In this article we consider the general peculiarities of input impedance characteristics. The analytical expressions for the input impedance characteristics have been obtained for the typical wave barrier structures. We present the dependences of the input impedance on the energy for the quantum-mechanical structures and on the frequency for the case of electromagnetic and acoustic structures. Additional conditions to the known ones of resonance transmission and of resonance wave localization, which occur in barrier structures, have been found.

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INTRODUCTION

Layered barrier structures are used in various scientific and engineering applications and form the basis of nanoelectronics. The resonance transmission (in particular, the wave tunnel effect with transmission coefficient equal to unity) is of prime importance for these structures [1]. Inasmuch as in the case of conventional tunnel effect the transmission coefficient is very small quantity, resonance and conventional tunnel effect modes combination in signal processing devices provides the maximum ratio of signals in the transmission and suppression frequency bands.

Resonance waves localization, which takes place in the dispersive medium bounded on two sides by semi-infinite reactive media, belongs to important resonance effects in the wave structures either. The terms "dispersive" and "reactive" medium correspond to the ones given in [2]. In the reactive medium a wave number is imaginary, which results in the absence of wave propagation and its magnitude reduces exponentially without energy dissipation.

The resonance transmission, as well as the resonance localization are caused by the formation of resonance standing wave in the structure.

Double-barrier structures (DBS) are widely used in various engineering fields. Quantum-mechanical DBS with resonant electron tunneling [1] is the basic structure of nanoelectronics. DBS is the basis of the resonant tunneling diode with an *N*-shaped current-voltage characteristic and the negative differential resistance [3]. Resonant tunneling through the DBS is utilized for electromagnetic [4, 5] and acoustic [6] waves. Optical microresonators are designed based on DBS [1, 7].

The quantum-mechanical double-well structure (DWS) with double-well potential is of considerable interest [8, 9]. DWS is used for the simulation of quantum-mechanical systems with two states (two-state systems) [10]. In connection with the development of quantum informatics the DWS is of particular importance, because its lower and upper states, the so-called energy eigenvalues are similar to the "0" and "1" values of a bit in classical informatics.

Traditionally barrier problems are solved using the join of solutions at the boundaries, which is obtained from the continuity conditions for the function characterizing the wave and for its derivative [1]. In the case of an approach based on the wave impedance of the medium, in particular, for the quantum-mechanical problems [11, 12], the boundary conditions are taken into account automatically, which greatly simplifies the simulation. In many cases the solution is analytical. This approach applies the theory of transmission lines for the analysis of structures, which allows one to combine the simulation of structures based on the barriers and wells, for example, based on the potential wells for quantum-mechanical waves.

The models development for the structures is actual for the applied micro- and nanoelectronics, which provides an opportunity to pass directly to the synthesis, analysis and designing of signal processing devices based on the mathematical techniques developed for radio engineering circuits.