In the proposed project we will study experimentally and theoretically one-dimensional open systems such as microwave networks and quantum graphs.. The concept of quantum graphs is very important because they can be considered as idealizations of physical networks in the limit where the lengths of the wires greatly exceed their widths. A quantum graph consists of N vertices connected by B bonds. The vast majority of mathematical studies consider quantum graphs as closed systems, completely separated from the external world. Quantum graphs possess many interesting properties. The most unusual and famous one is isospectrality of graphs. It was proven that there exist differently shaped graphs that have the same energy spectra! In other words they are isospectral. In the real world, quantum graphs are open systems. They, for example, can be connected to the experimental system with leads that allow for measuring their properties. In the breakthrough research performed at the Institute of Physics of the Polish Academy of Sciences, it was shown that quantum graphs with and without time reversal symmetry may be experimentally simulated by microwave networks. Because microwave networks simulate quantum wires and many other structures, the results of the proposed research will deepen our knowledge of the properties of such systems, which are very important from the perspective of basic research as well as future applications.

In this project we will study properties of graphs and networks with and without time-reversal invariance, including non-Weyl and isoscattering ones. For non-Weyl graphs the number of resonances is lower than the one expected from the famous Weyl formula. Non-Weyl graphs have not been studied experimentally so far. Furthermore, our experimental investigations will go beyond the theoretical ones by including systems with broken time reversal symmetry and absorption. In the proposal we will also study isoscattering networks and influence of absorption and boundary conditions on their properties. Isoscattering graphs and networks are constructed from the isospectral systems by attaching to them a certain number of external leads. This important topic of mathematical and physical investigations was originated by the famous question of Mark Kac "Can one hear the shape of a drum?" which in the case of one-dimensional systems can be modified to "Can one hear the shape of a graph?". In this project we will introduce new isoscattering networks. Additionally, we will use a new measure of isoscattering to study properties of graphs and their dependence on boundary conditions and absorption. In the experiment a microwave network analyzer and flexible test port cables will be used to measure the scattering matrices of the networks. The experimental data will be analyzed and compared with the theoretical predictions.

Important investigations will be also performed in time domain. We will study the distribution of transit times through microwave networks simulating quantum graphs with and without time-reversal invariance. Recent theoretical investigations show that the distribution of transit times should depend on the graph properties such as connectivity of the bonds, their lengths and boundary conditions. We will attest these interesting properties experimentally. The distribution of transit times through microwave networks will be measured using a high speed waveform generator and a digital oscilloscope. In the project we propose the purchase of the required devices. In the analysis of time domain measurements a special attention will be paid to revealing, as complete as possible, information about the internal structure of the measured systems.

The implementation of this proposal will greatly contribute to expanding our knowledge on the properties of open one-dimensional systems. The obtained results will be published in prestigious scientific journals and will be presented at international conferences.