Radio-frequency structures belong to the most important components of wireless communication systems. Their modern realizations have to fulfill rigorous specifications related operational parameters, environmental factors, or geometry constraints (resulting from, e.g., mobile character of the system). Determination of suitable topology (also referred to as synthesis) of such structures is a serious challenge. One of the reasons is insufficient performance of conventional solutions (that can be constructed based on a well-developed theory) from the standpoint of the imposed requirements. In practice, desirable functionality is predominantly achieved through manual modifications of standard radio-frequency components based on engineering experience. The obtained design solutions may (yet not necessarily) undergo further optimization using numerical techniques. This experience-driven design is often insufficient when construction of structures with unconventional properties is considered. Alternatively, component development procedure can be automated using suitable algorithms. The method exploits an universal computational models characterized by high flexibility in terms of attainable geometries. This flexibility stems from definition of model's topology using a set of interconnected characteristic points, or a composition of primitives (e.g., rectangles/voxels). The optimal design solutions are obtained using suitable algorithms that determine the geometries that fulfill the defined specifications based on the effects of mutual points/primitives allocation on the structure performance. Unfortunately, these methods require thousands of time-consuming computer simulations to converge, which limits their usefulness to design of relatively simple geometries. Regardless of the mentioned difficulties, the potential of unsupervised design for reducing engineering bias in the radio-frequency components generation is high. Development of the methods for fast and efficient components synthesis will not only promote generation of unconventional geometries with enhanced functionality in a manageable timeframe, but will also contribute to shortening of design cycles as compared to conventional techniques which (despite technology advancements) are still based on engineering experience.

The aim of the project is to develop efficient tools for automated design of complex radio-frequency structures with unconventional properties. The following tasks will be realized: (i) development of the methods for circuit architecture selection (suitable from the standpoint of requirements) which do not require engineering guidance, (ii) utilization of analytical models and machine learning for rapid optimization of the synthesized structures, (iii) development of nature-inspired methods for balancing complexity and diversity of the synthesized components, (iv) introduction of the methods oriented towards increasing immunity of the structures to fabrication tolerances, as well as (v) leveraging the potential of additive manufacturing technologies for fast, low-cost fabrication of prototype structures. Realization of the last task is important not only from the standpoint of fast experimental validation of the generated design solutions, but also utilization of readily available measurement data (obtained from the prototypes) to increase accuracy of the modeling tools used in the synthesis process. Introduction of the mentioned feedback will contribute to significant shortening of circuits development cycles (and hence reduction of their overall cost). Realization of the mentioned goals is therefore important both for research (development of new, efficient methods for components synthesis) and practical reasons (rapid circuits design and their low-cost experimental validation using in-house printed prototypes).

The most important expected outcome of the project will be a set of methods, tools, and algorithmic solutions dedicated to accurate, fast, automated synthesis of complex radio-frequency structures with high functionality and improved resistance to fabrication tolerances. Utilization of printing technologies will be of high importance for increasing the accuracy of the circuits modeling techniques and reducing components fabrication cost. The expected results of the project will go far beyond the current state-of-the-art and will define the new research directions on the unsupervised synthesis and cheap fabrication of complex radio-frequency components. The results will be of high importance not only for the development of microwave engineering, but also other disciplines where optimization of numerically expensive simulation models is and inevitable step of components synthesis. It is anticipated that utilization of the developed tools will enable generation of design solutions that are beyond the capabilities of contemporary techniques, which is of paramount practical importance.