**Introduction of emerging materials and manufacturing technologies for low-loss circuits realization**

In this Chapter the application of emerging materials and manufacturing technologies for the realization of low loss microwave circuits in strip transmission line technique is considered and discussed. Application of various 3D printing technologies and dedicated materials were subject of this study. The results of the conducted research have been a subject of one journal paper submitted for *IEEE Transactions on Microwave Theory and Techniqes* and three conference papers presented at *International Conference on Electrical, Electronisc and System Engineering ICEESE`17* and *Electronic Components and Technology Conference ECTC`18*, both under auspice of *Institute of Electrical and Electronics Engineers,* which constitute the Chapter.

The applicability of additive manufacturing with conductive Polylactic Acid (PLA) based filament for realization of low-loss suspended microstrip microwave circuits is investigated. Filament is used to 3D print case which serve three major functions: provides mechanical enclosure and support for the circuit, provides appropriate elevation of the thin laminate with circuit mosaic over the ground plane and can potentially serve as the ground plane. The influence of the bulk conductivity of the utilized filament on total losses within the structure has been studied. Moreover, an exemplary transmission line hosted in Fused Deposition Modelling (FDM) 3D printed case has been manufactured and measured. Graphene-enhanced PLA material having volume conductivity of ≈ 166 S/m has been used yielding total loss of ≈ 0.14 dB/cm/GHz while reference case with copper foil ground plane yields total loss of ≈ 0.04 dB/cm/GHz.

Following, the realization of microwave circuits in suspended microstrip structure with a 3D printed conductive enclosure is presented for the first time. An example of a low-pass filter with a cut-off frequency of 2.5 GHz was designed, manufactured and measured. A Fused Deposition Modeling (FDM) type 3D printing and a conductive copper-based filament recently developed by Multi 3D were employed to realize an enclosure serving both mechanical and electrical purposes. The influence of the ground plane conductivity on the total loss within the circuit was studied, and requirements for the conductive material properties were established. Moreover, the impact of the print parameters as well as the connection between microstrip line and SMA connectors was investigated. The obtained measurements proved that the proposed approach is of potential use for circuits and systems operating within low GHz frequency range.

Moreover, an application of additive manufacturing technologies for realization of multilayer microwave circuits in microstrip transmission line technique is presented for the first time. An example of a second-order cascaded loops directional filter allowing to separate 2100 MHz LTE band was designed in suspended microstrip with three metal layers, manufactured using a combination of PolyJet 3D printing with UV cured VeroWhitePlus polymer material and magnetron sputtering of copper, and assembled out of two parts using a “lego-like” process. The obtained results for the manufactured circuit confirmed that the proposed approach is of potential use for circuits and systems operating within the microwave frequency range.

Finally, a novel approach for the realization of high-performance coupled-line directional couplers in suspended stripline technique is proposed taking advantage of recent development in 3D printing technology. A third degree of freedom is introduced to a 2.5D structure allowing to combine the advantages of strip-transmission-line techniques, for which the circuit can still be considered as a quasi-planar structure, with the 3D printing flexibility of air layer thickness variation limited only by technological constraints. It is shown, that the proposed approach is well suitable for the realization of low-loss circuits, where tight coupling and superior performance are required, as well as compactness. Moreover, it is shown that compensating elements, often required to improve couplers` performance, can easily be realized as a combination of a circuit mosaic and ground plane integrated 3D structures allowing for better circuit volume utilization. An example of a 3-dB coupled-line directional coupler operating within the ISM 5.8 GHz band is designed, manufactured and measured for experimental verification. The obtained results confirm the applicability of the proposed approach.