**The use of novel and alternative circutis` realization schemes as a way of power loss minimization**

*In this Chapter the use of novel and alternative realization schemes of circuits as a way of power loss minimization is studied. The realization of filters exploiting the periodic structures approach in which the filter is composed of identical, electrically small unit cells is considered. The proposed approach allows for obtaining very compact and high-performance circuits which in turn leads to power loss minimization. Moreover, further power loss reduction can be obtained by unit cell`s topology optimization and appropriate selection of realization technique.*

Filters are one of the basic building blocks of any communication system. Analysis and design of such components are subjects of intensive studies of scientific and industrial communities resulting in many different approaches and realizations being proposed. Among others, a periodic structures approach is a very attractive one allowing to reduce filter`s design to the design of a single UC which exhibits the desired frequency response. Order of such filter is dependent on the number *n* of cascaded, identical unit cells with a single unit cell being an electrically small structure. Usually, unit cells featuring right-handed (RH) character, which is a property of real materials, are designed and used. However, the left-handed (LH) medium have gained in recent years a significant interest and pose an attractive alternative to RH materials due to their unique properties, not available in a conventional medium. Although, there are no homogeneous materials having left-handed properties, the effectively homogenous metamaterial transmission lines composed of a finite number of elementary unit cells featuring left-handed character in microwave frequency range has been a subject of extensive research resulting in various realizations being proposed. On top of interesting phase properties of such artificial transmission lines, their construction and amplitude response is of great importance and well suitable for application towards filters realization. Properly constructed topology of such unit cell supported with the design methodology allows to provide all kinds of frequency selective response such as narrow- and wideband bandpass and bandstop.

In [1] the Authors have presented the structure realized as a finite number of periodically arranged unit cells composed of series capacitors and shunt inductors. Additionally, the Authors have described the properties of such a unit cell, which in contrary to the previously presented resonant structures e.g., [7], features broadband operation. However, the ideal L and C elements are not physically realizable and the realized L and C equivalents feature unwanted parasitic effects in microwave frequency range. In [8] the structure has been described being a composite right/left-handed transmission line in which the parasitic series L and shunt C elements have been included and the need for modeling these effects has been shown. Since then, different models and realizations of the unit cells have been proposed taking into account parasitic effects or taking advantage of them [9]-[11]. One of the solutions is the utilization of transmission lines or coupled-lines as unit cell elements. Attempts to incorporate coupled-line sections into the design of left-handed unit cells have been a subject of several papers. In [12] the Authors have proposed the CRLH unit cell composed of two coupled-line sections in SOS (shorted-open-shorted) and OSO (open-shorted-open) configurations. In [13], [14] the Authors have presented unit cells based on Schiffman ‘C’ section-like structures which feature left-handed character when the appropriate electrical length of a coupled-line section is selected. Also multiconductor transmission-line-based stubs have been investigated in order to realize an appropriate shunt impedance, or multi-finger structures which in specific frequency range can act as appropriate series and shunt impedances allowing to realize unit cells having composite right/left-handed character [15], [16]. However, in the mentioned structures a complicated technology process (bonding) is needed. A very broadband passband response can be obtained in CRLH structures by e.g. appropriate balancing of the left- and right-handed bands. From application perspective, such a feature can be used for realization of wideband filters required in e.g., UWB systems. UCs shown in [1] – [6] have been realized, mostly based on interdigital capacitors and shunt stubs, and analyzed using simplified, lumped elements based models which, however do not provide straightforward translation from model to physical realization. On the other hand, in [7] –[9] a different analysis approach is proposed e.g., in [7] the UCs based on series and shunt multiconductor transmission lines (TL) are presented, whereas in [8], [9] the Authors have proposed UCs based on series or shunt, coupled or uncoupled TL sections and/or lumped capacitors. The UCs are modeled and design formulas are derived from the TL theory allowing for better understanding of circuits` behavior and direct relation between the model and physical structure. On the other hand, in [1] a dual-composite right/left-handed (D-CRLH) unit cells (UC) have been introduced and characterized. The structures exhibit left-handed (LH) band at high frequencies, while the right-handed (RH) band is seen at low frequencies, moreover, they have inherently stop-band nature i.e. high attenuation between LH and RH bands exists. Therefore, D-CRLH unit cells can be of interest for realization of microwave components, e.g., bandstop filters. In [1]-[3] the Authors have proposed many D-CRLH unit cell models together with physical realizations of artificial transmission lines composed of such unit cells. However, the presented unit cells are modeled using ideal LC elements being easy to analyze on one hand, but featuring difficulties in straightforward translation into physical realization on the other.

*The Author has proposed and developed various novel, left-handed metamaterial inspired unit cells being constructed of mostly or solely coupled and uncoupled transmission line sections, exhibiting all kinds of frequency selective response. The results of the conducted research have been a subject of three journal papers published in IEEE Transactions on Microwave Theory and Techniqes, IEEE Microwave and Wireless Components Letters and Internatonal Journal of Electromagnetic Waves and Applications as well as two conference papers presented at Mediterranean Microwave Conference MMS`17 and accepted for 22st International Conference on Microwave, Radar and Wireless Communications MIKON`18, both under the auspice of Institute of Electrical and Electronics Engineers, which constitute the Chapter.*

*Novel metamaterial structures featuring left-handed (LH) and composite right/left-handed (CRLH) character are presented. The proposed unit cells utilize sections of coupled transmission lines. It is shown that by taking advantage of the coupling between transmission lines an additional degree of freedom is achieved, and therefore, the design process of artificial transmission lines is more flexible. The general behavior of each of the proposed circuits is presented and analyzed. Moreover, the design equations are formulated and the design process of each unit cell is described. The usefulness and validity of the proposed unit cells are illustrated and verified by the design and measurements of compact artificial transmission line sections utilizing the presented structures. Moreover, possible applications are discussed.*

*Following, an innovative approach for realization of artificial transmission lines featuring dual-composite right/left-handed character is presented. The circuits utilize a novel semi-distributed unit cell which is composed of sections of conventional transmission lines and a lumped capacitor. Such an approach allows for efficient modeling and convenient translation of model parameters (characteristic impedance and electrical length of transmission lines) into physical realization. Moreover, a single-layer microstrip realization is possible, making the unit cell attractive in practical applications. The proposed concept was experimentally verified by the design and measurements of an exemplary transmission line section and discussed in a context of possible applications in bandstop filters.*

*Moreover, the design of high selectivity, pseudo-highpass filters is presented. The proposed circuits utilize a novel semi-distributed-element composite right-left handed unit cell composed of sections of transmission lines and a lumped capacitor. By proper balancing the structure, a very broad operation band can be obtained. Moreover, a single-layer microstrip realization is possible making the unit cell well suitable for low-cost filter realization. The proposed concept was experimentally verified by the design and measurements of an exemplary pseudo-highpass filter.*

*Additionally, a realization of low-loss wideband bandpass filters utilizing a periodic structure approach is presented. The recently developed novel semi-distributed composite right-left handed unit cell is considered and adopted for the design of the proposed filters. It is shown that an appropriate balancing of the structure, i.e. selection of circuit parameters allows for achieving very broad passband. Moreover, a suspended microstrip technique is utilized to reduce total insertion loss of the circuit. The presented approach has been confirmed by realization of an exemplary low-loss wideband bandpass filter. Measured operation band is within 1.0 – 9.4 GHz with total loss ranging between 0.35 to 1.8 dB. The obtained results proved the applicability of the presented approach.*

*Finally, a novel wideband pseudo-highpass filter is presented. Wideband band-pass unit cells and periodic structure approach is utilized for realization of the filter. Low-losses and circuit properties` control are obtained by the realization of the unit cell using distributed elements only, i.e. transmission line stubs and a coupled-line section as well as the utilization of suspended stripline technique for circuit realization. Theoretical analysis of the unit cell as well as experimental results have been provided. An exemplary manufactured compact low-loss, four-unit-cell filter features 1 - 9 GHz wide fundamental passband with very sharp lower roll-off and minimal insertion losses of 0.24 dB. The obtained results confirmed the performance of the proposed approach.*