Design of Multi-band Microstrip Patch Antennas Using Miniaturized 1D Metamaterial-Based EBGs

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One application of metamaterials is the realization of dual- or multi-frequency microstrip patch antennas (see, for example, D. Segovia-Vargas et al, "Quad-frequency linearly-polarized and dual-frequency circularly-polarized microstrip patch antennas with CRLH loading," *PIER*, Vol. 133, 91-115, 2013). In these structures, the strong left-handed dispersion of the metamaterial creates multiple resonances at different frequencies. Electromagnetic bandgap (EBG) structures, on the other hand, are typically used as antenna substrates or superstrates that employ their bandgap characteristics to produce multi-frequency operation (see, for example, A. Pirhadi et al, "Design of Compact Dual Band High Directive Electromagnetic Bandgap (EBG) Resonator Antenna Using Artificial Magnetic Conductor," *IEEE Transactions on Antennas and Propagation*, Vol. 55, 1682-1690, July 2007). This work introduces a 1D metamaterial- (MTM-) based EBG that employs the contradirectional coupling between a parallel-plate-waveguide-(PPW)-like mode and a left-handed coplanar-waveguide (CPW) mode to create a large bandgap. To illustrate the potential for this approach for multi-band operation, a microstrip patch antenna is loaded at its radiating edges with a uniplanar, miniaturized MTM-EBG. The nominal patch resonance is achieved in the MTM-EBG bandgap, and a lower-frequency resonance is achieved in the MTM-EBG passband. In addition to being uniplanar and easy to fabricate, these structures may be strongly miniaturized using lumped loading inductors and capacitors. Moreover, the MTM-EBG is accurately characterized using multiconductor transmission line (MTL) theory, which predicts its bandgap and passband behavior and enables a wide range of designs and applications. It will be shown how the MTM-EBG may be optimized to tune the patch resonances based on its dispersion, to improve impedance matching, and to mitigate degradation of radiation efficiency. Both full-wave simulation and experimental results will be compared to the predictions of the MTL theory to demonstrate both accuracy of the design process and limitations of the method.