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Resonant Antennas Based on Coupled Transmission-Line Metamaterials

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Abstract

A novel microstrip patch antenna topology is presented for achieving a dual-band response with arbitrarily closely spaced resonances. This topology is based on a coupled transmission line structure in order to take advantage of the separation in propagation constants for parallel (even-mode) and anti-parallel (odd-mode) current modes. Applying a metamaterials inspired design approach, periodic reactive loadings are used to design the underlying transmission line to have specific propagation constants necessary to realize a desired separation between two resonant frequencies. Using a single probe feed for a finite coupled line segment, both even-and odd-mode resonances can be excited to radiate efficiently at their respective design frequencies. The efficiency of the odd-mode radiation is enhanced by separating the two lines, while strong coupling is maintained by inserting a series of narrowly-separated thin loops between them. Several example resonant antenna designs, in

the 2.45 GHz band, are presented.

The directivities of these microstrip patch antennas are enhanced by optimizing the physical length of the resonant structure. For a resonant antenna obtained by cascading several unit cells of reactively loaded microstrip segments, dispersion analysis is employed for the unit-cell design. Maximum directivity is achieved by choosing the overall physical length to be slightly less than a half wavelength in free space at the design frequency. This gain optimization is applied to three coupled-line antennas, as well as a single resonance patch. Excellent agreement is observed between simulated and measured responses across all designs.

The potential of loading the coupled line structure with active components is also explored. Varactor diodes are placed on coupled-line structures in two configurations. In one configuration, both resonant frequencies are affected. In the other configuration, only the odd-mode characteristics are reconfigured. In this way, the resonant frequency of either one or both modes can be adjusted by applying a DC bias voltage to the varactor diode loading elements. Two antennas, one employing each of these topologies, were designed and fabricated. Control of the resonant frequency over the predicted range through applying a bias voltage is observed with the fabricated prototypes.

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