

ABSTRACT

This thesis presents the design and development of novel wideband filtering antennas that address key performance limitations in conventional filtering antenna systems, such as limited gain, narrow bandwidth, poor selectivity, and out-of-band reflection at the filtering antenna-port interface, design-level restrictions to trade between selectivity and phase linearity. By overcoming these challenges, the research paves the way for more flexible methodologies to design next-generation filtering antenna systems capable of sharp filtering, high-efficiency, multifunctional, and wideband operation. The thesis introduces and systematically analyzes two distinct classes of filtering antennas – a wideband circularly polarized (CP) microstrip-based reflectionless filtering antenna, and a class of evanescent-mode open-ended waveguide (EMOEW)-based wideband filtering antennas featuring all-pole and controlled transmission zero (TZ) designs.

In the first category, a complete theoretical and experimental framework is proposed for achieving simultaneous wideband CP radiation and selective but reflectionless filtering within a compact structure. A prototype CP filtering antenna is realized that integrates multiple advanced features in a single platform, high realized gain, wide operational bandwidth, high selectivity, even-order harmonic suppression, and reflectionless behavior, along with interchangeable dual-CP operation. These are made possible through the integration of a quadrature hybrid coupler (QHC), a defected air cavity, a radiating patch shared by two linearly polarized (LP) filtering antennas, and center-fed stub resonators. Furthermore, all-pole filtering, implemented using coupled resonator filter theory (CRFT), enhances the systems phase linearity and wideband suppression, while the QHC facilitates future extensions to multiband and full-duplex communication systems. Reflectionless behavior also enables seamless cascading and interference-free integration with other modules, saving those modules from malfunctioning and prospective damage due to reflected power interference.

In the second category, the thesis pioneers the design of wide-beam, wideband EMOEW-based filtering antennas, marking the first demonstration of such systems in the literature. A

novel methodology is introduced for embedding and independently controlling transmission zeros without degrading or altering in-band performance. Using a third-order trisection-based coupled-resonator topology, realized through embedded metallic posts in an EMOEW with very small length, the design enables a designer-defined trade-off between group delay flatness (phase linearity leading to low dispersion loss) and passband selectivity. Prototypes are manufactured by additive manufacturing (low corrosion material SS 316L with high melting point), utilizing laser power-bed fusion. The validation of the methodology is given through the measurement results of the manufactured prototypes. Moreover, the prototypes are rigorously evaluated through simulations to validate their high-power handling capability, on the basis of surface loss. Also, their performance stability is tested in simulations under extreme ambient temperatures, which proves their thermal robustness.

The proposed filtering antennas demonstrate significantly improved performance over existing designs in terms of realized gain, bandwidth, selective filtering, power-handling, and structural compactness. The microstrip-based designs are optimized for planar integration in portable and space-constrained platforms, while the compact EMOEW-based antennas offer wide angular coverage, monolithic 3D-printing compatibility (removes assembly losses), and high-power handling capability, making them ideally suited for radar front ends, synthetic aperture radar (SAR), and 5G/6G MIMO wireless infrastructure.

This work not only contributes multiple first-time implementations, such as reflectionless CP operation in microstrip and TZ control in EMOEW filtering antennas, but also establishes methodologies that are scalable, multifunctional, and system-level integrable. The work proposed architectures that are highly compatible with multi-band systems, phased arrays, and reconfigurable systems, making them promising candidates for next-generation communication, sensing, and defense technologies. This thesis lays the groundwork for future research in the direction of circulating filtering antennas, multi-band systems utilizing reflectionless units, and adaptive phased array system design with controlled dispersion loss and selectivity.
