Harmonically Loaded Active Integrated Antenna Using Characteristic Mode Theory

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Active integrated antennas (AIAs) are monolithic circuits in which an antenna is fully integrated with an active device. Such systems are useful in high-frequency applications where high efficiency and small size are crucial, especially in power combining applications. For optimum performance, the antenna and the active device's embedded structure are designed simultaneously. Since typical antennas are linear and passive devices, their frequency behavior at harmonics of their operating frequency is irrelevant for narrowband applications. However, the presence of a nonlinear device eliminates such assumption and harmonic properties gain paramount importance in the design process. Previous research and experiments have confirmed that harmonic loading of an active circuit such as a power amplifier or an oscillator has a significant effect on the performance of such devices at the fundamental frequency.

Commonly, to eliminate unwanted harmonic radiation, many authors have placed harmonic suppression filters between the antenna and the active core; however, such solution adds cost, circuit size and discontinuities. Other authors have used photonic bandgap structures, defected ground planes, circulator sectors, shorting pins, tuning stubs, slots and so on to suppress harmonic radiation.

This work proposes to use the theory of characteristic modes (CM) to systematically design AIAs not only for suppressing harmonic radiation but also for optimizing their output power, power efficiency and noise performance. In this paper, a self-oscillating AIA operating at a fundamental frequency of 900 MHz is designed to exhibit a set of harmonic loads computed to improve its radiated power at the fundamental frequency by at least 40%. Additionally, power efficiency and even phase noise improvements are reported. It will be shown that AIA design and loading using CM can be used such that the impedance profile seen by the active core at an arbitrary number of harmonics can be dialed so that optimum performance of the nonlinear system is reached.