Magnetless Nonreciprocal Devices Based on Angular Momentum Biasing

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Reciprocity is a fundamental principle in electromagnetics, stipulating that signal transmission between two points in space is the same for both transmission directions. Breaking this symmetry is important on various practical occasions, including the protection of lasers from spurious back-reflections and the design of circulators for full-duplex systems. Nonreciprocity is conventionally achieved through magnetic biasing, but the challenges related to integration of this approach on chip have recently created a lot of interest in developing magnetless nonreciprocal devices. In this context, our group has introduced the concept of angular momentum biasing, according to which strong nonreciprocal response as in conventional nonreciprocal devices can be obtained if the static magnetic biasing is replaced with angular momentum biasing effectively generated in a circuit through spatiotemporal modulation, e.g., modulation of three symmetrically resonators with signals of equal amplitude and phases 0, 120 and 240 deg. In this talk, we will present our recent progress in this direction and show how we can design angular-momentum magnetless circulators with metrics satisfying the requirements of practical applications. We will show how we can eliminate intermodulation products by employing a differential architecture based on two circulators with 180 deg phase shifted modulation, allowing to improve insertion loss and reduce the modulation parameters. We will also discuss the problem of matching and show how bandwidth can be significantly extended by adding passive networks at the circulator ports. We will show results for other practically important metrics, including linearity, noise and power consumption, and discuss how they can be improved. Furthermore, we will present an analytical theory for the proposed devices, which is very useful for their efficient design, and show experimental results of different implementations of the proposed circuits on printed circuit boards. Our results will demonstrate that angular-momentum biasing is a practically attractive approach for various applications, including full-duplex systems, RFIDs and radars, and also amenable to different implementations, including PCB, integrated circuit and MEMS, creating exciting opportunities for fundamental and applied research.