Broadband Nonmagnetic Non-Reciprocity in Time-Varying Transmission Lines (TVTLs)

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Non-reciprocity in passive components is traditionally achieved with magnetic material such as ferrite. Such components are often bulky and narrowband. Another drawback of magnetic components is that they are not compatible with the current integrated circuit (IC) technology. On the other hand, active non-reciprocal components using transistors suffer from poor noise performance and power handling capability.

Recently, non-reciprocity obtained through time-modulation to the material property has received great attention (Z. Yu and S. Fan, IEEE J. Sel. Topics. Quantum Electron., 16, 459–466, 2010; R. Fleury, D. L. Sounas, C. F. Sieck, M. R. Haberman, and A. Alu, Science, 343, 516–519, 2014; N. A. Estep, D. L. Sounas, J. Soric, and A. Alu, Nat. Phys., 10, 923–927, 2014; S. Qin and Y. E. Wang, IEEE MTT-S Int. Microw. Symp. Dig., 1–3, 2013; S. Qin, Q. Xu, and Y. E. Wang, IEEE Trans. Microw. Theory Techn., 62, 2260–2272, 2014). The modulation can potentially offer non-reciprocity with minimum compromise to other circuit performances such as noise and power handling. This presentation will focus on the development of time-varying transmission lines (TVTLs) for RF front-ends. A TVTL can be implemented by distributing a finite number of variable shunt capacitors along a normal transmission line with their capacitances modulated by a traveling carrier wave. It leverages on the additional dimension of traveling wave modulation to break the space-time symmetry for non-reciprocity and the intrinsic noise-free property in the parametric conversion. Non-reciprocity over a multi-octave frequency band is observed in the experiment. The TVTL-based component also offers superior noise performance that is comparable to the state-of-the-art low-noise amplifiers and yet with good power handling capability. Such component can be thus placed in the first stage after the antenna to prevent interference from the transmitter while enhancing the receiving signal to the receiver over a same, broad frequency band in a full-duplex radio. Besides serving for circulators, the novel properties of TVTLs can be also utilized to form superior RF components such as integrated, broadband isolators, low-noise mixers and frequency-tunable filters.