Metamaterial-based Slow Wave Structure for Travelling Wave Tubes

Nil Apaydin*, Panagiotis Douris, Kubilay Sertel and John L. Volakis
Electroscience Laboratory, The Ohio State University, Columbus, OH, 43212

The advent of strong relativistic electron beams has led to the development of high power microwave sources. These devices generate high peaks of microwave power by transferring the kinetic energy in the electron beam to electromagnetic waves guided within a slow wave structure (SWS). Among these devices, traveling-wave tubes (TWTs) and backward wave oscillators (BWOs) are based on this principle, referred to as Cerenkov radiation. Strong interest also exists in employing the Cerenkov Maser (microwave amplification via stimulated emission of radiation) as a TWT due to its simplicity and tunability. This TWT is lined with a dielectric coating to slow down the electromagnetic waves. However, as noted by Shiffler *et al.* (Shiffler et al., IEEE Trans. Plasma Sci*.,* 2010), dielectrics become vulnerable to charging and surface breakdowns. A way to avoid charging is to employ purely metallic metamaterial-based slow wave structures that emulate the behavior of a dielectric liner.

Recently, printed slow-wave structures were developed (Locker et. al., IEEE Microw. Wireless Comp. Lett., 16, 12, 642-644, 2006) that support the same modes found in volumetric periodic structures. These modes were experimentally demonstrated using coupled dual transmission lines exhibiting group velocities 286 times slower as compared to free space (Apaydin et al., IEEE Trans. Microwave Theory Tech*.,* 60, 6, 1513-1518, 2012). That is, these printed metamaterial structures can be designed to have the same wave slow-down and field amplification properties without suffering from charging and surface breakdown.

In this paper, we exploit the concept of coupled lines to attain additional wave slow-down and therefore miniaturization in designing TWTs. Specifically, we insert smaller rings within ring-bar SWS to introduce inductive coupling in much the same way as done in the aforementioned coupled transmission lines. Initial simulations show that the phase velocity of the waves doesn't change with the inclusion of smaller rings. However, the interaction impedance of the SWS (a measure of how much the electron-beam energy is coupled to the electromagnetic wave) becomes constant over an octave bandwidth, whereas for regular ring-bar structures the mutual impedance decreases to half of its initial value at the highest operational frequency. Issues with dielectric charging are also avoided due to the purely metallic nature of the proposed slow-wave structures. At the conference, the specifics of the design and its advantages will be presented in more detail.