Dispersion Shaping of Double-Ring-Bar Slow-Wave Structures for Traveling Wave Tubes

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High power RF sources are used in many applications. Several devices (Cerenkov Maser, Traveling Wave Tubes, Magnetrons, and Couples Cavity Resonator) have been developed and used widely. However, most of these devices are bulky and there is a need for miniaturization. Focusing on Traveling Wave Tubes (TWTs), wave slow down methods have recently been pursued to couple the electron beam's kinetic energy into a radio frequency signal and amplify it. To do so, various structures (tape helix, contra-wound helix, ring-bar structures, and sloped ring-bars) have been used within the waveguide for wave slow-down and for more efficient electron beam to waveguide coupling. Among these approaches, helical structures are less dispersive but are associated with low interaction impedance, leading to lower gain. By contrast, the Ring-Bar Structure (RBS) within the TWT waveguide is associated with higher interaction impedance at the expense of lower bandwidth due to dispersion. Therefore, the ring-bar structure is attractive provided its bandwidth can be increased.

In this paper, a new Double Ring-Bar Structure (DRBS) for S-Band (2-4 GHz) TWTs is proposed and studied. A focus is to reduce dispersion and therefore increase bandwidth. We found that the double ring-bar increases the interaction impedance significantly. The increase is about two times higher than that in previous single ring-bar structures and nearly 6 times higher than that of helical TWTs. However, as noted, the ring-bar structure leads to narrower bandwidths due to dispersion. The most common technique to reduce dispersion in conventional RBS is to include a metallic vane loaded with dielectric support rods. These dielectric rods promotes additional wave slow-down and reduce interaction impedance. Other dispersion reduction techniques include use of longitudinal metal rods, conducting fins, discs etc.

In this paper, several techniques are considered to reduce the dispersion in DRBS enhanced TWTs. A technique is also proposed to improve dispersion by introducing metal vane placed around a slow-wave structure. Also, a complete full wave analysis will be presented and used to study dispersion, phase velocity, interaction impedance, and E-field profile, among others, for the proposed slow wave structures. A Particle in Cell (PIC) analysis will be also provided to obtain verification of the final design's operation.