Electrodynamic parameters of metamaterial-inspired slow-wave structures for miniature W-band traveling-wave tubes

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ABSTRACT

The development of miniature amplifiers based on a subterahertz traveling-wave tube (TWT) is relevant for a wide range of practical applications, for example, for the creation of high-speed wireless data transmission systems. The use of spatially-developed slow-wave structures (SWSs) for a miniature TWT makes it possible to obtain a high gain in a wide frequency band. In particular, a promising approach is the use of metamaterial-inspired SWSs.

In this paper, we present the results of design and simulation of SWSs, implemented as slots, which are periodically cut inside a metal plate located in a rectangular waveguide. In particular, we consider slots in the form of open rectangular rings and dumbbells. Analytical expressions for the resonant frequencies of the slots, as well as expressions for the effective dielectric and magnetic permeability of such media are obtained. Theoretical conclusions are in good agreement with the results of calculations of the electrodynamic parameters of SWSs by using COMSOL Multiphysics.

SWSs with operating frequencies in the range of 90-110 GHz have been developed. They exhibit the properties of double-negative metamaterial. The +1st spatial harmonic exhibits normal dispersion and TWT amplification is possible. In the operating range, the slow-wave factor is 4-6, which corresponds to the synchronism voltages not exceeding 15 kV. In addition, we designed input/output couplers with reflection loss not worse than –10 dB.

REFERENCES

1. *Paoloni C.* Sub-THz wireless transport layer for ubiquitous high data rate // IEEE Communications Magazine. 2021. Vol. 59, no. 5. P. 102-107.
2. *Duan Z., Shapiro M.A., Schamiloglu Ed., Behdad N., Gong Y., Booske J.H., Basu B.N., Temkin R.J.* Metamaterial-Inspired Vacuum Electron Devices and Accelerators // IEEE Trans. Electron Devices. 2019. Vol. 66(1). P. 207-218.
3. *Jiang S., Tang X., Huang S., Lyu Z., Wang Z., Tang T., Gong H., Gong Y., Duan Z.* Metamaterial-Inspired 0.22 THz Traveling-Wave Tubes With Double Sheet Beams // IEEE Transactions on Electron Devices. 2023. Vol. 70, no. 3. P. 1306-1311.