

## Sub-wavelength waveguide loaded by a complementary electric metamaterial for vacuum electron devices

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We report the electromagnetic properties of a waveguide loaded by complementary electric split ring resonators (CeSRRs) and the application of the waveguide in vacuum electronics. The S-parameters of the CeSRRs in free space are calculated using the HFSS code and are used to retrieve the effective permittivity and permeability in an effective medium theory. The dispersion relation of a waveguide loaded with the CeSRRs is calculated by two approaches: by direct calculation with HFSS and by calculation with the effective medium theory; the results are in good agreement. An improved agreement is obtained using a fitting procedure for the permittivity tensor in the effective medium theory. The gain of a backward wave mode of the CeSRR-loaded waveguide interacting with an electron beam is calculated by two methods: by using the HFSS model and traveling wave tube theory; and by using a dispersion relation derived in the effective medium model. Results of the two methods are in very good agreement. The proposed all-metal structure may be useful in miniaturized vacuum electron devices. © 2014 AIP Publishing LLC.

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