Unstable Slower Branch of Fast Cyclotron Waves in Gyrotrons and BWOs

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Common existence of an unstable slower branch of fast cyclotron waves in gyrotrons and backward wave oscillators (BWOs) is analyzed numerically within the scope of linear treatment of beam-plasma systems. The dispersion relation including space charge mode and fast electron cyclotron mode for large orbit annular beam neutralized by ions in a BWO is calculated for various values of amplitude h of corrugation in the slow wave structure (SWS). It is shown that, as h tends to zero, conventional Cherenkov instability in the axial direction in the space charge mode vanishes, whereas Cherenkov instability in the azimuthal direction (CIAD) [1, 2] in the fast cyclotron mode survives to be unstable. This fact has not been known in plasma physics and gyrotron engineering. The CIAD can be another principle of cyclotron emission in addition to cyclotron resonance maser (CRM) instability in gyrotrons, when high-density neutralized beams are working.

Gyrotrons and BWOs are typical examples for high-power microwave sources. The former and the latter belong to the categories of fast and slow wave devices, respectively. Both devices have been developed independently, and they are considered to have no particular relationship with each other. However, they have a common similarity in structure: Both are operated in the passage of an electron beam streaming through a metal waveguide immersed in an axial magnetic field. The model of analysis for BWOs becomes identical to that for gyrotrons when the amplitude h of corrugation of the SWS in BWOs tends to zero. The electron beam in BWOs generally has more or less a small transverse velocity and resultant cyclotron motion, because the beam is conventionally produced by magnetically insulated diode in vacuum. Experimentally, cyclotron motions in the beam have existed in BWOs. Previously, sufficiently large axial magnetic field B_0 was assumed in the analyses on BWOs, and no effects of cyclotron resonance was taken into account, analytically. In recent years, however, analyses of BWOs with finite strength B_0 have been developed considerably [3]. Inclusion of finite B_0 has made analytical models of fast and slow devices borderless. In other words, the distinction between gyrotrons and BWOs became ambiguous near cyclotron resonance. Theoretical treatment of a combined Cherenkov-cyclotron resonance interaction is becoming possible in recent years, accordingly. In this paper, the author shows numerical examples of common existence of unstable slower branch of fast cyclotron wave in slow and fast wave devices.

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