TWO NOVEL SOURCES OF VARIABLE FREQUENCY MICROWAVE ENERGY

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Variable Frequency Microwave (VFM) technology, developed by "Lambda Technologies," is successfully used in Industry and other applications [1, 2]. This technology requires variable frequency source of microwave energy that is not a simple task. The electronically adjustable microwave generators such as backward wave oscillators (BWOs) have very low efficiency and can not be used for commercial heating.

Unlike a traveling-wave tube (TWT) in which an electron beam and an amplified wave move in the same direction, a BWO is an electron device in which an electron beam and an electromagnetic wave excited by this beam move in opposite directions. The BWO provides a maximum power at the output adjacent to the gun, while the maximum modulation of the electron beam is achieved near the collector. This is why BWOs have a low efficiency.

The BWO efficiency can be increased significantly by the electron beam modulation in the electron gun [3]. Such device has a feedback circuit between the slow-wave structure and electron gun. This feedback circuit is designed as an electrodynamic structure, which transmits traveling-wave electromagnetic field from the output of the oscillator to the electrode which provides modulation of electron emission from cathode. This modulation results in the electrons bunching at the entrance of the slow-wave structure that in its turn at east doubles the efficiency.

The BWO efficiency can be increased also by adding an additional section of a slow-wave structure, operating in the forward wave mode [4]. The second section in BWO was used earlier for operation in the regime of frequency multiplication [5]. For that purpose, parameters of the additional section were chosen to operate in the backward wave mode at a multiple frequency. The beam, over-modulated in the first section, transforms its energy into RF radiation mostly in the second structure.

The analysis of a two-section BWO in which the first section operates as a beam modulator and the second section converts the dc energy of the modulated beam into the microwave energy at the output of the device is presented in this paper. The first section, operating in the backward wave mode, is loaded at both ends by matched severs, while the second section is connected to the matched output. The input end of the second section can also be loaded by a sever.

Parameters of a slow-wave structure (SWS) forming the first section and the RF beam current are chosen to obtain the optimum modulation of the beam at the output of the first section. Parameters of the SWS forming the second section are chosen to provide the optimum interaction with the modulated beam at the forward wave mode. Results of calculations based on the non-linear analysis [6] allow one to optimize parameters of both sections of the considered device. It is found that in the case of a small space charge (Pierce's gain parameter $C = 0.059$), the maximum amplitude of the first harmonic J_1 in the beam current at the end of the first section can be achieved when the normalized length of this section $2\pi CN$ is equal to *2.06*, and the relative value of electric field intensity E_z is equal to *1.2,* while $J_1 = 1.3\ J_0$. Here, N is a number of the slow waves at the first section. Note that the normalized length mentioned above exceeds the starting length equal to *1.98*, but is significantly smaller than the length corresponding to the maximum power, which is equal to *2.7*.

It is found in this paper that the best efficiency of the offered BWO-TWT device can be achieved at relatively low intensity of the field at the BWO section output ($E_z = 0.3$). In this case, the maximum field at the TWT section output achieves *3.3* for Pierce's velocity parameter b equal to *1.6*. It follows from this that the maximum theoretical efficiency of the offered oscillator fourfold exceeds the maximum efficiency of a conventional BWO (*32%* in comparison to *8.4%*).

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