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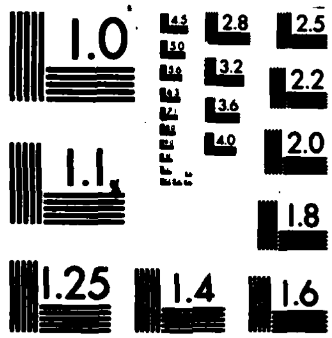

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FOREIGN TECHNOLOGY DIVISION

THEORY OF THE TWO-FREQUENCY OPERATING MODE OF TRAVELING-WAVE TUBES OF THE "O" TYPE

by

B.Ye. Zhelezovskiy, V.V. Mashnikov

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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THEORY OF THE TWO-FREQUENCY OPERATING MODE OF TRAVELING-WAVE TUBES OF THE "O" TYPE

B.Ye. Zhelezovskiy, V.V. Mashnikov

This report gives results of the analysis of harmonics of the electron beam of a traveling-wave tube with the simultaneous introduction into the input of two high-frequency signals of different amplitudes and frequencies. The examination of the indicated question is interesting from the viewpoint of interpreting the general problem of multifrequency operating modes of SHF [microwave] devices. There is special interest in the development of approximation methods of analysis, which permit obtaining simple analytical relations convenient for engineering calculations. One of the methods of this kind (expansion of stream function in double Fourier series) was used in work [1].

To solve the problem, we used the expansion of the stream function in Fourier series according to a certain fundamental frequency Ω, which is multiple to frequencies of external signals:

$$\omega_1 = \lambda_1\Omega;\ \omega_2 = \lambda_2\Omega.$$

The expression of frequencies ω_1 and $\omega 2$ in terms of Ω permits conducting the expansion of the current grouped in the field of two traveling waves in series according to harmonics of the fundamental frequency and thereby obtaining by a quite simple method the expression for harmonics of the stream of combined frequencies. Since the statement of the problem and basic calculation relations, to a significant degree, are analagous to those conducted in [1], then by introducing the fundamental frequency, as was indicated above, and performig the expansion of the stream in Fourier series, it is easy to obtain

$$
\begin{array}{l|l}
i_k = 2I_0 \left\{ \sum_{p=1}^{\infty} (-1)^p J_p(kX_1) J_0(kX_2) \cos p\Psi_1 + \right. & k = p\lambda_1 \\
+ \sum_{q=1}^{\infty} (-1)^q J_p(kX_1) J_q(kX_2) \cos q\Psi_2 + & k = q\lambda_2 \\
+ \sum_{\substack{p=1 \\ q=1}}^{\infty} (-1)^p J_p(kX_1) J_{2q}(kX_2) \cos [2q\Psi_2 \pm p\Psi_1] \pm & k = p\lambda_1 \pm (2q)\lambda_2 \\
\pm \sum_{\substack{p=1 \\ q=1}}^{\infty} J_{2p-1}(kX_1) J_{2q-1}(kX_2) \cos [(2q-1)\Psi_2 \pm (?p-1)\Psi_1] - & k = (2p-1)\lambda_1 \pm \\
 & \pm (2q-1)\lambda_2 \\
\left. - \sum_{\substack{p=1 \\ q=1}}^{\infty} J_{2p}(kX_1) J_{2q-1}(kX_2) \cos [(2q-1)\Psi_2 \pm 2p\Psi_1] \right\} & k = 2p\lambda_1 \pm \\
 & \pm (2q-1)\lambda_2
\end{array}
\quad (1)
$$

Here I_0 is the constant component of the current;

$J_{p,q}(kX_1)$ - the Bessel function of the 1st kind;

$X_n = \frac{\mu_n}{\lambda_n}\sqrt{(\cos\rho\varphi_{on} - 1)^2 + (\rho\varphi_{on} - \sin\rho\varphi_{on})^2}$ - the grouping parameter;

$\mu_n = \frac{E_n x}{2V_0\rho\varphi_{on}}$; $\varphi_{on} \frac{\omega_n x}{v_0}$ - absolute transit angle;

$\Psi_n = \mathrm{arc\,tg}\frac{\cos\rho\varphi_{on} - 1}{\rho\varphi_{on} - \sin\rho\varphi_{on}}$; $\rho = \left(1 - \frac{v_0}{u_0}\right)$ - parameter of dissynchronism;

Each of the sums is distinguished from zero only with the fulfillment of the appropriate condition of "sampling," which stands on the right.

By means of expression (1), in principle it is possible to analyze any combination harmonic of the current. It is easy to show that in the case of one signal ($X_2=0$), the obtained expression concurs with the corresponding expression for the stream of a one-frequency mode.

Some of the results of the analysis are given on graphs of figures 1-4.

Figure 1 shows the dependence of the relative amplitude of the stream of the difference frequency on the grouping parameter X.

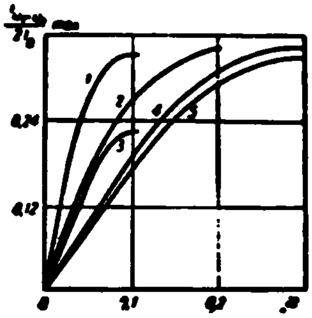

Fig. 1.

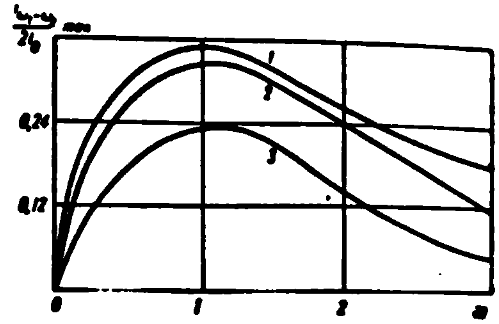

Fig. 2.

Fig. 1. Dependence of the relative amplitude of the current of difference frequency on the grouping parameter X: 1- ν=0.1, ρ=0; 2 - ν=0.3, ρ=0, ρ=0.01; 3 - ν=0.1, ρ=0.01; 4 - ν=0.4, ρ=0; 5 - ν=0.4, ρ=0.01.

Fig. 2. Dependence of maximum value of current of difference frequency on parameter $\kappa = X_2/X_1$: 1 - ν=0.1, 09; 2 - ρ=0.2-ν=0.9, ρ=0.01; 3 - ν=0.1, ρ=0.01.

With complete synchronism (ρ=0) the maximum of the reduced current of difference frequency reaches a full defined value of 0.337 for any relations of frequencies $\nu = \omega_2/\omega 1$ and is shifted with the approach of parameter ν to unity in the direction of large values of the grouping parameter. When ν=1 on the finite length of the region of interaction, the stream of the difference frequency is absent.

When there is a certain dissynchronism between the phase velocity of the waves and speed of the electron beams (ρ=0.01), the lowering of the maximum of the current of difference frequency is observed; and the assigned ρ corresponds to a certain relation of frequencies in which this decrease is minimal. Thus value ρ=0.01 corresponds to ν=0.3, in which $\frac{i_{\omega_1-\omega_2}}{2I_0}$ =0.336, i.e., is approximately equal to the maximum value of the stream with complete synchronism.

It is interesting to note that the maximum of the current of difference frequency is reached in the case of the equality of amplitudes of the applied signals and drops with departure from the value of κ equal to unity. Here the value of the achievable maximum of the current of difference frequency for the fixed ν depends on the magitude of the parameter of dissynchronism (Fig. 2). It should also be noted the good concurrence of results of the calculation with results of work [1]. For amplitudes of first harmonics of the reduced streams of frequencies ω_1 and ω_2 (1), we can write

$$\frac{i_{1\omega_1}}{2I_0}=J_1(X_1)J_0(\kappa X_1)\cos\Psi_1; \tag{2}$$

$$\frac{i_{1\omega_2}}{2I_0}=J_0(\nu X_1)J_1(\nu\kappa X_1)\cos\Psi_2. \tag{3}$$

Here κ=X_2/X_1. Results of the calculation conducted according to formulas (2) and (3) with the optimal parameter of dissynchronism are shown on graphs of Figs. 3 and 4. From the graphs (Fig. 3) it follows that the higher the amplitude of one of the signalss exceeds the amplitude of the other signal, the larger the value of the first harmonic of current of the smaller signal. At defined values of the ratio of amplitudes of external signals (κ=0.1), a sharply marked suppression of the smaller signal takes place. It should also be noted that a similar dependence is observed for different relationships of frequencies, and the large values of ν (close frequencies) correpsond to smaller values of κ at which the suppression is observed.

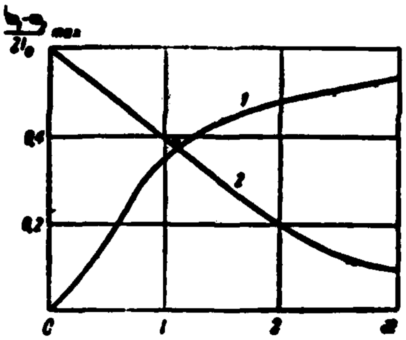

Fig. 3.

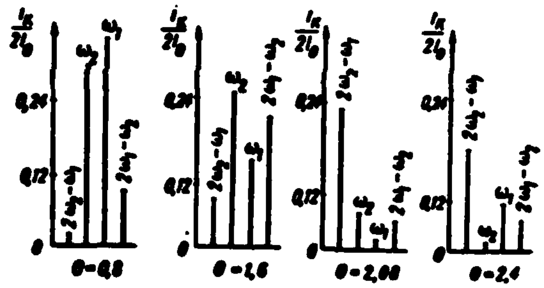

Fig. 4.

Fig. 3. Dependence of the maximal value of amplitude of the first harmonic of frequency current ω_1 and ω_2 on parameter κ: 1 - $\frac{I_{1\omega_1}}{2I_0}$; 2 - $\frac{I_{\omega_2}}{2I_0}$.

Fig. 4. Spectrum of combination frequencies $\left(\Theta = \frac{\Omega\tau}{\omega_0}\right)$.

Calculation of spectra of combination frequencies given on Fig.

4 shows that the amplitude of signals of different frequencies considerably depend on the length of the region of iteraction. It is easy to see that by means of sampling of the appropriate value of the transit angle, it is possible to achieve both a considerable superiority of the amplitude of one or another signal above the amplitude of other harmonic components of the grouped current and the partial and full suppression of any of its harmonics.

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Referencecs

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