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CHARACTERISTICS OF A DRIFT TUBE CAVITY WITH A STABILIZING STRUCTURE OF THE ANTIPODE TYPE

V. A. BOMKO, N. A. KHIZHNYAK, A. P. KLYUCHAREV, AND B. I. RUDYAK

Physico-Technical Institute, Academy of Sciences of the Ukr.SSR, Kharkov, USSR.

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The passband of a conventional drift tube linac structure has modes which lie uncomfortably close to the fundamental, operating mode. Methods which have been proposed to steepen the dispersion curve in the neighborhood of the operating point include multistem drift tubes, post couplers, crossbar structures and other techniques. The method described in the present paper is based on compensation of intermode interaction by suppression of the fields of interfering modes using posts mounted opposite to the drift tube stems.

A periodic structure in the form of a drift tube cavity is characterized by a spectrum of eigenfrequencies which indicate passbands.[1] Each of these bands represents graphically a dispersion curve drawn through the discrete points which determine frequencies of the modes, the distance between which depends on geometric characteristics of the structure and on the frequency location on the dispersion curve. In the ideal cavity there is *no* coupling between the modes. However, the appearance of a perturbation of any origin would lead to the appearance of mode relations which cause the shift of eigenfrequencies and the distortion of field distributions.

The presence of the drift tube in the cavity involves the emergence of intermode couplings. When tuning the accelerating structure there is practically always a known procedure of "flattening" of the operating mode field which depends on compensation of the resulting effect of intermode relations on the field distribution by using special tuning devices of a nonresonant type. Finally, one obtains a distribution of the operating mode field which is practically the same as that of the ideal cavity's field. However, the intermode coupling continues to affect the amplitude characteristics of the operating mode field; this is of importance especially for transition processes and local frequency detuning. That is why, in practice, one tries to diminish the intermode interactions by a wider separation of the frequencies of interfering modes and operating mode.

Lately, in connection with the development of stabilization methods for the field distribution in the drift-tube cavity a type of intermode relation compensation has been accomplished, which is based on providing a new dispersion band which is located symmetrically to the E_{01t} band relative to the operating mode frequency. With a sufficient accuracy in tuning this leads to a considerable growth of steepness of the dispersion curve.

Several types of accelerating structures are known, where some degree of compensation is attained. These are multistem structures,[2] post coupling structures,[3] and crossbar structures.[4] These are practically biperiodic structures. There are also known triperiodic[5] and multiperiodic accelerating structures.[6] The general drawback of this method of stabilization is the complexity of the construction and difficulties of tuning. Furthermore, this method does not allow or makes it too difficult to control the change of the field distribution sensitivity to the perturbing effects of tuning devices. However, the realization of the new method of heavy particle beam energy variation in linacs[7] has necessitated this control.

The stabilization method developed at the Kharkov Physico-Technical Institute is based on intermode interaction compensation by suppressing the fields of the interfering modes and removing their frequencies relative to the operating mode due to the choice of optimum coefficients of intermode relations of interfering E_{01t} modes and the fields of passive resonant devices. The main results of the field distribution stabilization by this method on LUMZI-10 have been already described in

Refs. 8 and 9. This method may be realized using as a stabilizing structure the conducting posts situated radially on the generating line opposite to that on which the drift tubes are mounted (Figure 1). Due to the obvious analogy this structure is called the "antipode structure."

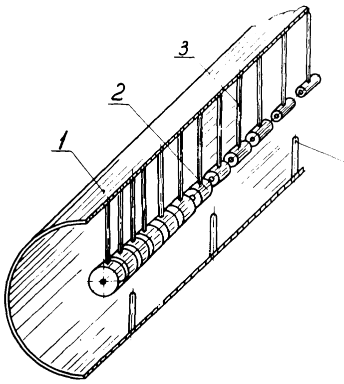

FIGURE 1 View of the accelerating structure with resonant stabilization arrangements of the antipode type.

This report presents the studies of the intermode coupling coefficient values for different conditions of a mentioned passive resonant device excitation which allows us to optimize the stabilization process of the operating mode field distribution.

1 THE INTERMODE RELATION COEFFICIENT

From the theory of the mode interaction in the cavity it is known that the coefficient of the intermode interaction relation is determined as a ratio of the maximum shift of the coupling frequencies relative to eigenfrequencies of interacting resonance systems at the coincidence point. This value is illustrated by a known Winn graph for a two-coupling system (Figure 2). As ω_1 and ω_2 approach each other, in a certain coupling frequency range there appear ω^+ and ω^- which move gradually from ω_1 and ω_2: the highest frequency becomes somewhat higher than the highest of the two, whereas the lowest frequency becomes lower than the lowest one of the partial frequencies. The shift increases as the partial frequencies approach and for $\omega_1 = \omega_2$ it reaches its maximum. In this case the frequencies of resonant terms (peaks) differ from each other by value of $\gamma_{12}\omega_1$ and each of them is shifted by $\gamma_{12}\omega_1/2$ from the position where it should have been at the coincidence point if there is no intermode relation.

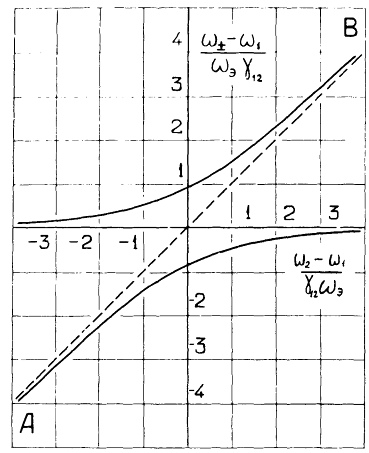

FIGURE 2 Resonant shift of the coupling frequencies relative to partial frequencies for a two coupling system.

In the case of resonance mode interactions of the accelerating structure and the antipode-type post system the coupling coefficient may be determined experimentally by a coupling frequency shift at the coincidence point.

The intermode interactions near the coincidence point are also characterized by the decrement of the resonance system damping $\alpha = 1/Q$, where Q is the quality factor. In the case when the intermode coupling coefficient γ_{EA} (E and A indices denote the mode belonging to the E_{01t} band and to the post of the antipode-type system, respectively) is sufficiently high as compared with the decrements α_E and α_A, the distortion of mode characteristics would be particularly high.

In practice, due to the number of the cavity mode t interacting with the post system fields, there are two cases of the relationships between the coupling coefficients and the decrements which are of interest. These are:

$$\gamma_{EA} > \alpha_E + \alpha_A \tag{1}$$

$$\gamma_{EA}^2 \ll \alpha_E \alpha_A \tag{2}$$

The second case is observed for the E_{010} mode having a high Q-value with $\alpha_E < \gamma_{EA}$ and $\alpha_A \gg \gamma_{EA}$. From the mode interaction theory for coupled systems it is known that only for a weak coupling the α_A increase would decrease the effect on the Q of the cavity at the coincidence point. If the coupling is not weak, then the decrement increase of the post resonance mode would deteriorate the Q-value of the cavity eigenmode.

2 THE CHOICE OF OPTIMUM CHARACTERISTICS OF STABILIZATION DEVICES

A stabilization system of the antipode type would have its optimum characteristics in the case when it ensures a minimum coupling coefficient between post resonances with the operating mode E_{010} and a highest one with interfering modes E_{01t} ($t > 0$). The coupling coefficient value of the two mentioned resonance systems will be in direct proportion to the number of the field components having the same direction. This corresponds to the case when the post is placed in the region of maximum density of radial components of electrical E_{01t} mode fields.

The question of the most favourable azimuthal position of the radial post was considered to some extent before. It was noted[11] that in the structure with coupling posts it is preferable to place them at an angle of 180° relative to each other and at 90° relative to the stems. This was required by necessity to ensure the minimum coupling between the posts and stems. At the same time, however, the frequency separation principle in the antipode type system is based on the effect of post interaction with interfering mode fields, therefore the necessity of obtaining the maximum coupling coefficient requires another approach to the coupling of resonance fields of the post-drift tubes-stem system with interfering mode fields.

Figure 3 shows the frequency dependence of the resulting modes on the length of a post placed in the node of a longitudinal electric E_{011} mode field for different angles relative to stems. Figure 4 shows the coupling coefficient value for the E_{011} mode versus the azimuthal post position relative to the stems. It is seen that the maximum of the interaction with this mode occurs for an angle of

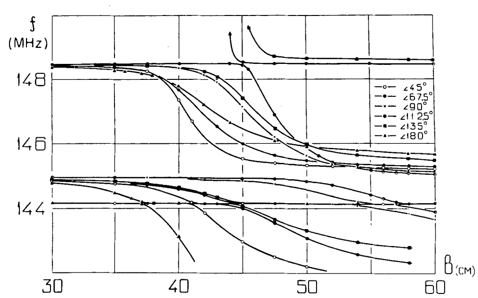

FIGURE 3 The frequency dependence of the resulting modes vs the length of post for different angles relative to stems.

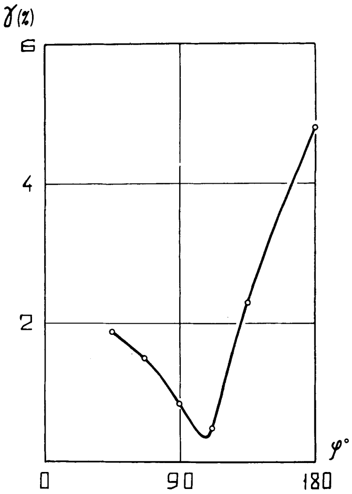

FIGURE 4 The coupling coefficient for the E_{011} mode vs the azimuthal post position.

180° and its minimum for 90°. At the same time the resonance for the E_{010} mode is observed for the longest post, therefore, it is impossible to obtain a high frequency separation at $\varphi = 90°$, whereas at $\varphi = 180°$ the maximum frequency separation is attained.

The process of resonance transformations of fields and different mode frequencies in the interaction with the antipode-type system was studied on the LUMZI-10 cavity. Figure 5 shows the

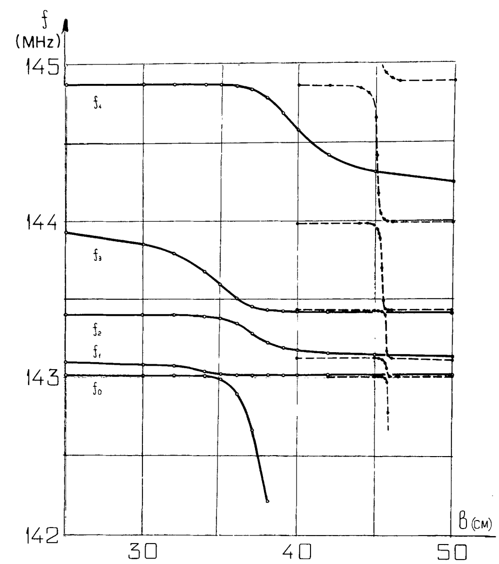

FIGURE 5 The frequency behavior of the resulting modes vs the depth of one post immersion along the radius, b.

frequency behaviour of the resulting modes as a function of the approach of the cavity mode eigenfrequencies and those of the post system. The required frequency difference was obtained by changing the depth of the post immersion along the radius *b*. The solid curve illustrate the case when one post is placed at a point equidistant from the end walls of the cavity and the dashed curves show the case when the post is in the immediate vicinity of the end wall.

The width of the resonance interaction is not large for even modes. A particularly small deviation of the coupling frequencies from partial ones is observed for zero-type modes. A higher interaction is observed for the modes with odd t. It is seen that the process of unfolding the coupling frequencies is observed for all modes of the E_{01t} spectrum. However, the post found in the maximum to longitudinal components, interacts weakly.

A more complicated process is observed for a larger number of posts. Figure 6 shows an analogous dependence for seven posts introduced into the cavity at the same depth in the positions corresponding to the nodes of the E_{01t} mode. A succession of seven E_{010} mode transformations is observed. This is explained by the fact that the posts are placed opposite to the accelerating structure with a changing length of drift tubes, therefore their resonance characteristics were different. The right-hand part of Figure 6 shows the formation of the E_{01t}-type mode frequency spectrum which is much more extensive than the initial one. In this case the coupling frequencies are approaching very slowly as they move from the resonance. This fact is a very important feature of this stabilization method since it does not put forward any rigid requirements for the accuracy of frequency tuning post resonant systems. It is also seen that by changing the post length within this range it is possible to control over a wide range of steepness of slope of the dispersion curve thus changing the stabilizing effect of the antipode system (Figure 7). Furthermore, in this case there is no danger of "overcompensation" as well as formation of "stopbands." The described method is technically simple and it provides a high efficiency.

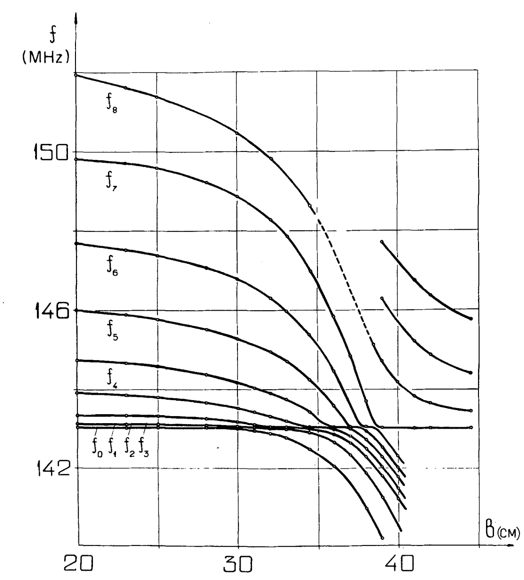

FIGURE 6 The frequency behaviour of the resulting modes vs length of the 7 posts.

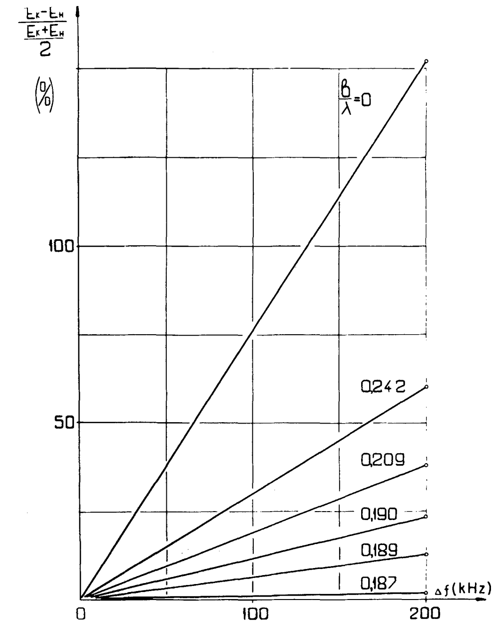

FIGURE 7 The field stabilizing effect of the antipode system for different post length.

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