Parasitic Modes Removal Out of Operating Mode Neighbourhood in the DAW Accelerating Structure.

V.G. Andreev, V.M. Belugin, S.K. Bain, I.V. Kravchuk, V.V. Paremonov
Institute for Nuclear Research of the USSR Academy of Sciences, Moscow

Summary
The disk and washer (DAW) accelerating structure/1/ finds its use in a number of new projects (PIGX, SBB etc.). It composes the main part of the accelerating structure of the meson factory now under construction in the Institute for Nuclear Research (INR), Moscow.

It is known/2,3,4/, that the parasitic modes with azimuthal (ϕ) field variations exist at the operating mode region. In this report different methods of the parasitic modes frequency shift are considered. The main attention is given to the resonant methods, which are the most efficient.

Introduction
The experimental/2,3/ and theoretical/4/ study of the structure shows, that existing in the operating mode neighbourhood parasitic modes have one azimuthal variation and belong to the bottom branch of EH modes of E type dispersion curve. This modes exist in the operating mode region practically for all β. The calculations/4/ show, that the parasitic modes with one ϕ-variation can be removed by the cavity radius decrease for β≥0.7, but this leads to the decrease of the shunt impedance at the operating mode. As it shown/5/ the shunt impedance drops when the cavity radius decreases.

Besides the modes with one ϕ-variation, the modes with three ϕ-variation, which are the EH modes of H type, can get into operating mode region/6/.

The proximity of the parasitic modes frequencies to the operating mode leads to the change of the resonant properties of the structure for the worse/2/ and can create hindrances for the automatic control systems. Therefore, the problem of the parasitic modes shift methods is important for DAW structure design.

Methods of Removal of the Parasitic Modes out of the Operating Mode Neighbourhood
To choose the method or some device for the parasitic modes removal we must to take into account the different factors. This device (or method) must satisfy to the following requirements.
1. To eliminate the influence of the parasitic modes on the resonant characteristics of the operating mode and to provide the normal functioning of the automatic control system it is sufficient to shift the parasitic modes out of the +15±20 MHz band relatively to the operating frequency fo (if fo=1000 MHz).
2. It must not lead to the considerable increase of the losses or to the noticeable shift of the operating mode frequency, and also not to disturb the azimuthal symmetry of the accelerating field.
3. It must not lead to the considerable distortion of the operating mode dispersion characteristics.
4. It must not complicate markedly the structure manufacturing.

Let's consider the different methods of the parasitic modes frequencies shift.

The Nonresonant Methods
The most simple method of the parasitic modes frequencies shift is the change of the periphery dimensions of the structure during the accelerating section tuning process. Calculations/5/ and experiments have shown, that the parasitic modes frequencies depend strongly from cavity radius R, disk radius Rθ, disk thickness Tθ and washer radius Rw (Fig.1). For example, calculated coefficient of the cavity radius R influence on the frequency EH11 of E type 0-mode for INR structure is equal -6.7 MHz/mm for β=0.7. But one must remember, that periphery dimensions affect also on the structure operating characteristics. In particular, correlation...
between $R_\theta$ and $R$ is chosen from the operation mode dispersion characteristic symmetry condition, and a large deviation of $R$ or $R_\theta$ from their calculated values causes distortion of this dispersion curve, what is undesirable, especially for cavities with a large number of cells. Besides, the change of dimensions affects on the frequencies of all parasitic modes of a given type, shifting a whole dispersion curve. If the parasitic modes exist lower and higher the operating frequency, then removing one parasitic mode we approach another one.

The frequencies of parasitic modes could be shifted by introducing of contrary pivots on the section bottoms and the nearest disks $/7/$ (Fig.2). The introducing of pivots does not affect on operating mode frequency and on operating dispersion curve symmetry at the operating mode region. In this way one can shift parasitic modes up to a few MHz, depending from the pivots length.

The Resonant Methods

The resonant methods allow to steer the parasitic modes frequencies more flexible. For this purpose let us introduce to the structure the resonant elements, which are not interact with the operating mode as well as with another modes of the operating type, but strongly interact with parasitic modes.

Those elements could be the radial slits $/R/$, which are cut in the washers or in the disks and being tuned approximately to the operating frequency. For that the length of slits in the radial direction has been chosen near to $0.25\lambda_0$ (one end of the slit is open), where $\lambda_0$ - the operating mode wave length. However, the placement of the radial slits in the washers lead to the complication of the construction, since the washer has a channel for a cooling liquid. Besides, the placement of the radial slits in the region of the operating mode strong field is not advisable.

There are no cooling channels in the disks. They are placed for enough from the structure axial area in the region of the weak field of the operating mode. However, the disks radial size is not large enough. $R-R_\theta = 0.17\lambda_0$ at $\beta = 0.8$ and $R-R_\theta = 0.21\lambda_0$ at $\beta = 0.4$ for INR structure (similar values for the structure $/5/$).

Moreover it is not advisable to cut a whole disk radial size up to the cylindrical wall, otherwise the mechanical characteristics of the cavity deteriorate.

Let's consider the slit with a more complicated form (Fig.3) $/9/$, which is cut in the disks and consist of the radial part with a length $l_1$ and azimuthal part $2l_2$. We call it a combined slit.

The combined slit may be excited in a different modes. The main mode electric field has opposite direction in the halves of the azimuthal part of the slit (Fig.3a). The summary length of the radial $l_1$ and one half of the azimuthal part $l_2$ is near to a quarter wave length $\lambda/4$ of the main mode, i.e. $l_1, l_2 = 0.25\lambda_0$. The next mode electric field has the same direction in the both halves of the azimuthal part. The wave length of this mode $\lambda_1 = 4l_2$. For $l_1 = l_2$ we have $\lambda = 2\lambda_1$.

After the structure is excited, the conduction currents run on the side surface of the disk, and their distribution depends on the type of the exciting mode. We consider the summary surface current, which is equal to the sum of the conduction currents on both sides of the disk. When the operating mode is excited in the structure, the summary current is equal to zero and does not excite the combined slit. For other oscillations of the operating type the summary current has a radial component independent of $\varphi$ and the main mode of the slit is not being excited also.

For parasitic modes, which have field variations on $\varphi$ the summary current has the radial and azimuthal components, depending on radius $r$ and azimuth $\varphi$. In this case the summary current excites the main mode of the slit. The intensity of excitation depends on a slit placement, field distribution, type and polarisation of the parasitic mode. When the parasitic $0$ and $\pi$-modes are excited, the summary current in the structure without washer supports is equal zero. The supports disturb a uniformity of the field distribution along the structure for given parasitic modes, and the summary current differ from zero.

The Combined Slits in the Structure of INR Meson Factory
The combined slits are used for removal of the parasitic modes out of the operating mode neighbourhood in the main part of INR linac. The slits were cut in the disks before the tuning procedure. The slits dimensions have been chosen from conditions $\omega = 0.2\nu$. In this case main mode of slits proves to be tuned to the operating mode frequency. For effective removal of the parasitic modes out of operating mode neighbourhood a strong coupling of the slits with the parasitic modes must be produced. For this purpose three slits in each disk have been cut (Fig. 4). The placement of the operating and parasitic modes on the frequency axis before (Fig. 5a) and after combined slits introduction to one of the structure sections ($\beta = 0.4543$) is shown in Fig. 5. As it could be seen the introduction of the combined slits permits to clean up the parasitic modes out of a wide frequency band in the operating mode neighbourhood. The operating mode frequency is shifting weakly ($\sim 300$ kHz).

**Fig. 1** Half of the structure cell.

**Fig. 2** The structure cell with the contrary pivots (1), (2) - disk.

**Fig. 3** The electric field in the combined slit for the main (a) and the syn-phase mode (b).

**Conclusion**

The different methods of parasitic modes frequencies shift in the disk and washer structure are considered. The comparison indicates to preference of the resonant methods, which are more flexible and effective. The combined slits described may be used for the parasitic modes removal at any $\beta$.

**References**

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Fig. 4 The module of the INA structure with combined slits.

Fig. 5 The placement of oscillation modes before (a) and after (b) combined slits in a structure section.