THE PERSPECTIVES OF APPLICATIONS OF THE FAST-ACTING VARACTORS WITH LOW LOSSES IN HIGH-CURRENT CYCLIC AND LINEAR ACCELERATORS

Konovalov V.A., Kuznetsov M.I., Murin B.P.,
Paramonov V.V.‡, Senichev Yu.V.‡

Moscow Radiotechnical Institute of the RAS, Moscow
‡ 'Institute for Nuclear Research of the RAS, 117312, Moscow

ABSTRACT

Main parameters of fast-acting varactors, based on magnetron diode, are described. Scope of problems in development of accelerators hardware, which can be solved with using varactors of this type, is considered. For example, application of the varactor for phase tuning in high power RF generator of 'regotron 'type, intended for burner-reactor linac, is discussed. Design parameters of fast-tunable RF station for booster and main rings of the Moscow Kaon Factory project, in which varactors are proposed as capacitive tuners, are given.

INTRODUCTION

In the development of the powerful RF hardware devices with controllable reactants are needed. Typical examples of application of such controllable devices in accelerator hardware are tunable accelerating cavities. Frequency of this cavity may be changed by changing either inductance, or capacitance. RF cavities with inductive (ferrite) tuners are now widely used. Mechanical varactors for capacitance changing are now used because their low reliability. First attempts to use magnetron as electronic varactor were made in the middle of 40-th [1]. RF losses were so high, that idea was not realized.

GENERAL PARAMETERS

In the development of accelerating RF stations for fast cyclic synchrotrons of the INR Kaon Factory project [2] in the MRTI was proposed [3] and developed fast-acting varactor with low RF losses, based on magnetron diode. Simplified scheme of the varactor is shown in Fig.1. As in usual magnetron diode, in the varactor originates electron cloud. Changing control voltage or bias magnetic field, one can change dimensions and position of the cloud between electrodes, so changing effective capacitance between electrodes. Special system in the varactor is intended for dumping of oscillations in the cloud, which results in reduction of RF power losses due to electron losses at electrodes. This varactor is practically inertionles device with enough wide range in capacitance changing due to changing in the electron cloud position.

Two varactors of different types are produced now, differing in capacitance range and maximum reactive RF power, which can be passed trough this varactor. Main parameters of these varactors are given in Table 1.

Varactors of the first type without bias solenoids is shown in Fig.2. Typical working characteristic of the varactor in coordinates bias field - control voltage is shown in Fig.3. Shaded region corresponds to high-quality working regime of the varactor. Sloped line in this region defines maximum value of reactive RF power, which can be passed trough varactor.

Plot of the dependence of the quality factor of the varactor vs bias magnetic bias field is shown in Fig.4 at nominal (middle) value of the voltage at anode. Reduction in the quality factor for $B \leq B_{min}$ is due to losses of electrons at anode, for $B \geq B_{max}$ - due to RF noise level increasing. For varactors with parameters, given in Table 1, the velocity of capacitance change is estimated as 10^{14} pF/sec.

Table 1. Main parameters of the varactors.

	Type 1	Type 2
Minimum capacitance, pF	100	40
Maximum capacitance, pF	160	120
Maximum control voltage, kV	25	50
Power of control circuit, kWt	3	5
Maximum RF voltage, kV	25	100
Maximum reactive power, MVA	40	200
Frequency range, MHz	20-100	20-80
Quality factor	2000	2000
Magnetic bias field Oe,	200	200
Life-time h,	10000	10000
Weight kg,	20	50

APPLICATIONS

Using varactors developed, one can construct powerful inertionles tuners for accelerating cavities, intended for fast-cyclic high current accelerators of Kaon Factory type or SSC boosters. Capacitance range is sufficient to provide working frequency changing near 30 %. Low RF losses in varactor allow reach accelerating voltage of order one-two hundreds of kV. In comparison with ferrite tunable cavity, varactor tunable one has such features as:

a) simple inertionles frequency tuning and small reactive power needed for control, smaller dimensions of the cavity along beam axis,
b) simpler cavity design,
c) simple handling of the station.

When varactors is used as the tuner in RF cavity, it allows solve enough simple such problems as:

1. cavity tuning in the range given.
2. fast detuning of the cavity far out of the working frequency range,
3. painting of the beam in longitudinal phase space according dependence given.
4. correction of the phase and value of the accelerating voltage.
5. active dumping of the betatron oscillations.
6. compensation in changing of beam loading due to empty buckets.

Working point of the varactor chooses depending on its functional purpose. To solve tasks 1,4,5, working point have to be selected in shaded region with low RF losses (see Fig.3). To solve task 3, working point have to be selected in the region of high noise level, tasks 2 and 6 - in the region of active load regime.

Both types of varactors developed are intended for usage in accelerating systems of INR Kaon Factory Project [2,3]. The varactor of first type is intended for cavities of main ring. Second type of the varactor, with wider capacitance range will be used for booster ring cavities. Design parameters of the stations for

main ring (energy 7.5-45 GeV) and booster ring (0.6-7.5 Gev) are given in Table 2.

Accelerating cavities with varactors as tuners are now ready for testing at full-scale RF stand. Construction of this stand is now near finish in MRTI. General view of the prototype cavity for booster ring together with varactor is shown in Fig. 5. Design of the cavity for main ring allows compare two types of tuners: varactor and ferrite with perpendicular bias field.

Table 2.
Design parameters of the accelerating stations for INR Kaon Project.

	Booster	Main ring
Frequency range, MHz	33.03-41.36,	41.36-41.64
Max accelerating voltage, kV	77.05,	130
R/Q, Ohm	22.5,	20
Varactor capacitance, pF	40-120,	100-160
Cavity length, mm	860	1100

Now under consideration is the possibility of using varactors for phase control of accelerating fields in high-current linear accelerators. Solution of this problem will allow RF power dividing at high level and will lead to reduction of delay-time in fast feedback system. This scheme of construction of RF generator becomes especially important if syperhigh-power RF sources like regotron [4] with average RF power of order 5-10 MWt will be used in linear accelerators.

SUMMARY

Fast acting varactor with low RF losses may be used for wide variety of problems in the powerful RF hardware design. Its features in large tuning range, low losses, fastactivity in additional with low production costs make it attractive in comparison with another devices, which are used in accelerator hardware.

REFERENCES

1. Buneman G., CVD, Rep. Mag. n.30, 1943
2. Golubeva N.I. et al., Accelerating complex of the INR Kaon Factory. 12-th Particle Accelerators Allunion Meeting. 1990, Moscow (to be published)
3. Ivanov Yu.D. at al. Particularities in the development of RF stations for INR Kaon Factory project. ibid.
4. Murin B.P. at al., Superhigh-high RF regotron-type generator for linear accelerators with high mean current. Atomic energy industry radioactive waster handling problems. MRTI, Moscow, 1991, p. 77-88.

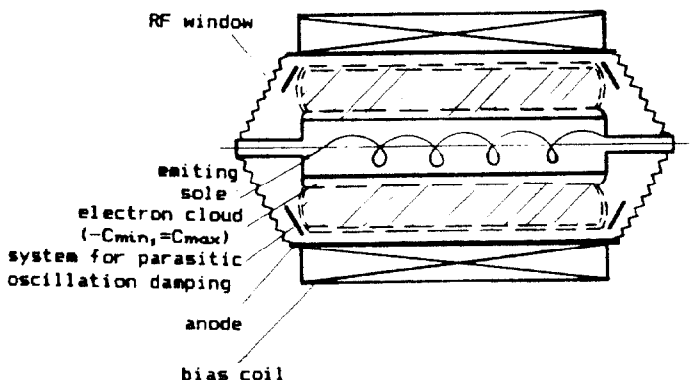


Fig.1 Scheme of the varactor.

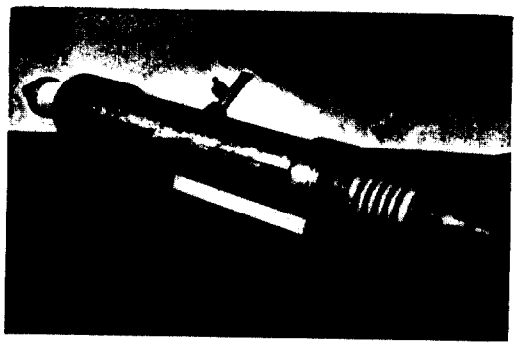


Fig.2 Appearance of the varactor.

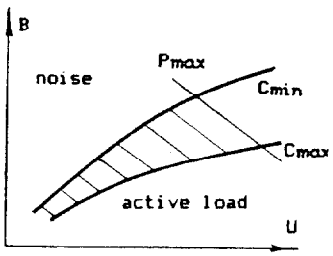


Fig.3 Performance diagram of the varactor.

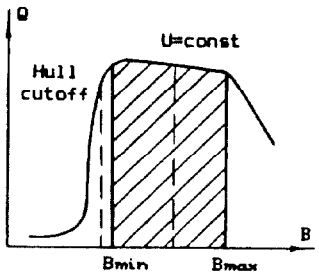
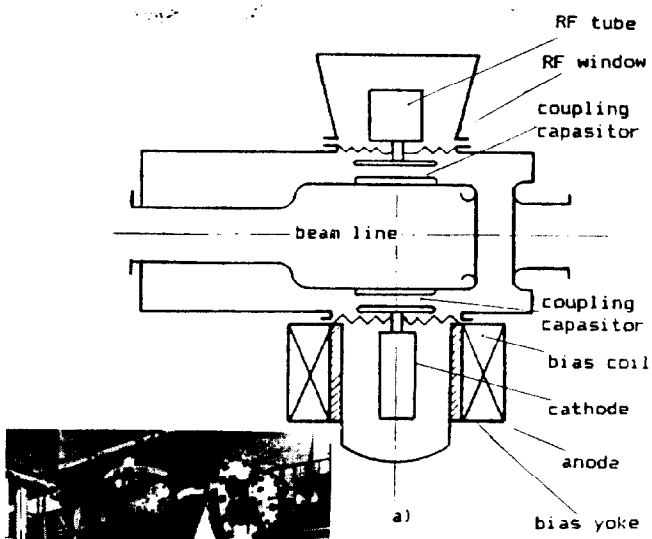


Fig.4 Variation of quality factor of the varactor.



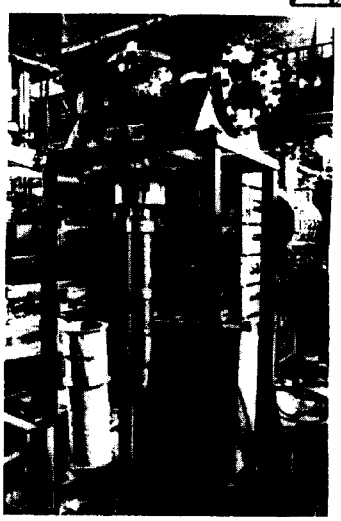


Fig.5 Varactor tunable accelerating cavity.