RF PULSED MEASUREMENTS AT THE TNK LINEAR ACCELERATOR-INJECTOR

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Measurements of RF pulse signals in megawatt circuits are an important problem of acceleration technique. Measuring circuits should not degrade WSVR in power transmitting channels or give rise to local electric field overvoltages. An especially developed set of tools including 2.8 GHz detecting unit blocks, vacuum directional couplers, phase detectors, and phase shifting lines is described. The set allows one to carry out non-intrusive RF signal measurements in the waveguide channel at up to 20 MW power level with an accuracy of some percents.

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1. INTRODUCTION

The industrial storage facility (TNK, Lukin State Research Institute for Problems in Physics, Zelenograd) includes an injector on the base of 80...100 MeV linear accelerator, and two storage rings: lesser 450 MeV and main 2.5 GeV. Linac is feed via the waveguide (90x45 mm) of ~15 meter length from KIU-53A klystron with an output power up to 20 MW at 2797.8 MHz [1,2]. RF measurement system is an element of the accelerator facility which controls the accelerator.

For RF accelerating devices operating in pulsed mode, the main requirements on measuring RF units are: measuring within wide dynamic range of signal amplitudes during facility operating from power-up time till normal operating regime; possibility to register fast processes; and constant "twenty-four-hour" device readiness. At TNK accelerator facility, an assembly of such RF measuring devices forms an RF control system, which elements are designed with consideration of the design of the linac, vacuum and gas waveguide sections including E- and H- types of turns, in which optical probes may be installed to register discharges in the waveguide and ceramic window.

2. RF MEASURING DEVICES

In the course of accelerator facility operating, measuring devices must be started in the certain order, specific for each facility.

Figure 1 presents a time chart, which clarifies the 20 MW RF operating system "linac-waveguide-Olivin klystron station. At RF measurements on linear accelerators, we prefer propagate RF signals from Rf source to RF rack via a cable. The rack is located near the control board. Units for RF pulse amplitudes, frequency, phase shift, etc. belonged to the same RF facility located in the protected room and having a common ground bus with RF rack crate, are located in the RF rack crate. RF measuring set is made in "Vishnya" standard with detector probe assemblies (DPA) for 6 channels and two phase detectors (PDA). The set also includes the master oscillator and special frequency 54-times multiplier, from which output 2.8 GHz frequency is applied after pulsed power amplifier to Olivin klystron station excitation. The pulsed amplifier power may be also used to test measuring devices.

RF power level measuring in the waveguide within the range of 0,1...20 MW and the corresponding field strength measurements in the linac accelerating cavities present difficulties in probes for incident and reflected wave fields creation for level drop by -60...70 dB. At the same time, it is problematically to avoid a sufficient error at attenuation constant calibration. Practically, at RF workbench, where RF power levels of 1...10 W are available, we can measure with calorimetric microwatt instruments attenuation rates down to -50 dB with several percents accuracy. Figure 2 presents the -50 dB waveguide directional coupler for incident and reflected waves; it corresponds to 10...200 W per pulse for derived incident wave power. A "cross" [3] is used to dump the power in the vacuum waveguide section 90x45 mm. The derived power is transferred through vacuum-proof waveguide-to-coax junctions and is applied to radio rack via phase-stable coaxial cable.

Two types of RF detectors are used for RF pulse amplitude measurements. Photo in Fig.3 shows a broad-band detector probe assembly for measured power level up to 1 W together with a special through-pass detector probe for 16x7 coaxial channel at 6D16D vacuum RF diode. In this detector, the measured power level amounts to 100 w at VSWR not worse than 1.05. Imaginary impedance compensation in the diode connecting point is realized by the parallel circuit (see Fig.4), in which $C_d=C_0$, $\omega L_d=2/\omega C_0$, where C_d and L_d are diode capacitance and its output inductance respectively.

Detector probe assembly contains three broad-band detector probes (DP) on the base of D608 semiconductor diodes for pulsed RF signal measurements and fast (~100...300 ns) processes registration during RF discharge in the linear accelerator or waveguide. Broadbandness of the DP is achieved by use of ~6 dB microstrip attenuator at the detector input ($W_{вх}$=50 Ohms) at VSWR not worse than 1.5 within the frequency range up to 5.6 GHz and also because of small (~20 pF) overall reduced capacitance at the video repeater amplifier input. Frequency bandwidth of the amplifier is ~100 MHz at input signal of ±4 V, $R_н$=50 Ohms.

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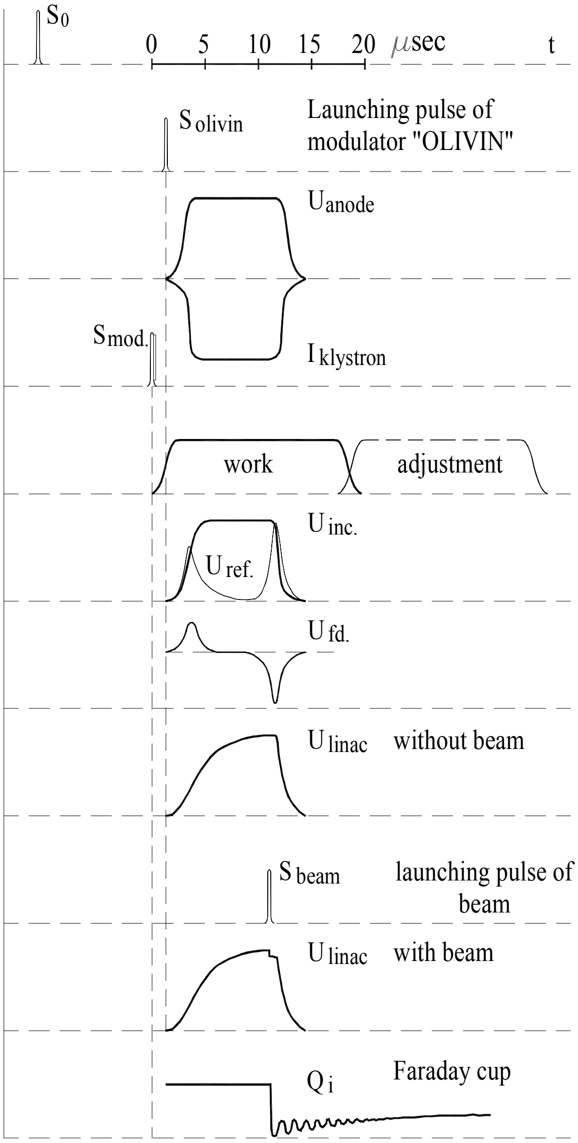

S_0 – Start of the charging device for "Olivin" modulator power source

S_{olivin} – Start of the "Olivin" modulator

Uanode – klystron anode pulse amplitude
$I_{klystron}$ – cathode current pulse of KIU-53 klystron

S_{mod} – Start of radio rack RF amplifier modulator

RF pulse shape of KIU-37A klystron:
"work"- normal mode, "adjustment"- start of the RF amplifier modulator is delayed relative to "Olivin modulator start

Uinc and Uref – incident and reflected wave voltages at linac input. Slot directional coupler -50 dB (cross) is installed into 90x45 mm waveguide channel.
U_{fd} – shape of phase shift between U_{inc} and U_{linac}.

Ulinac – envelope of field rise in linac structure. Inductive probe is placed into the central cavity of the linac structure (regime without beam).

S_{beam} – Beam start.

Ulinac – envelope of field rise in linac structure with beam loading.

Expected shape of voltage on CF FOC 1 capacitor

Fig.1. Time chart of the "linac-wavaguide-Olivin"RF system operation

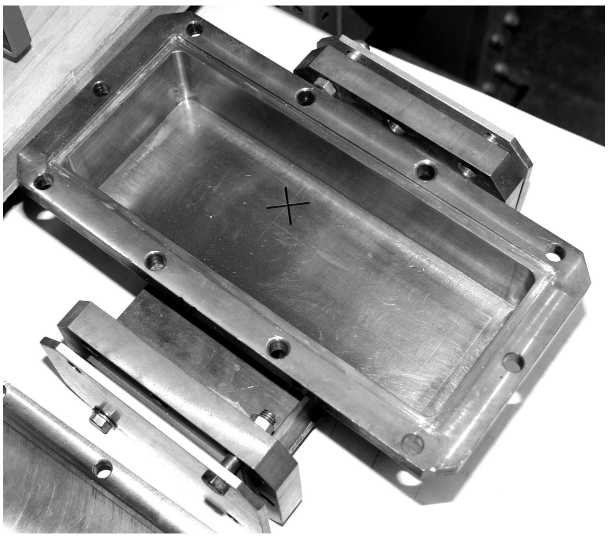

Fig. 2. Waveguide directional coupler

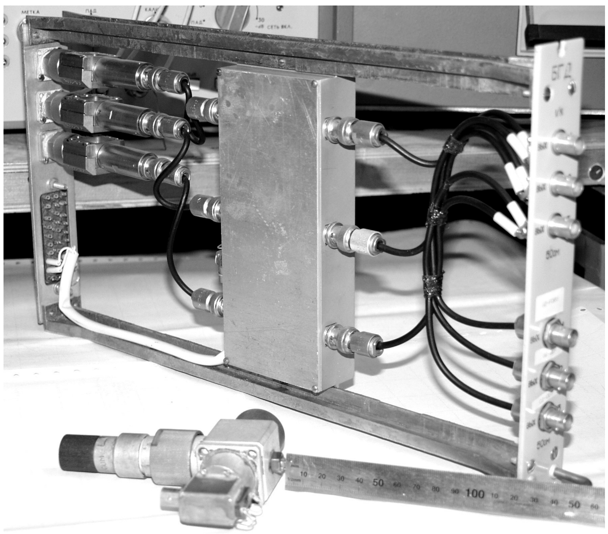

Fig.3. Broad-band detector probe assembly with "special" detector probe for pulsed power up to 100 W

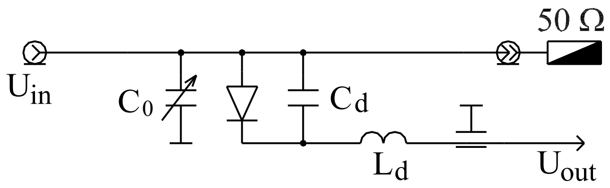

Fig. 4. Special detector probe circuit

Fig.5. Phase detector assembly

Phase detector assembly (see Fig.5) includes two phase detectors, either consists of a phase detector itself, phase shifting line (PSL), RF cables, and pulsed signal repeater ($R_н$=50 Ohms). In this variant, phase detector is assembled on the microstrip board made of Flan-5 with thickness of 1.5 mm on the base of 3 dB bridge. Bridge RF inputs are made on RF connectors. RF signal on a certain input pass through the phase shifter. Signals from bridge outputs are detected by 2A201A RF diodes, which are connected in circuit with different polarities, are summarized on the balance resistor and then transmitted to a broad-band repeater (the signal shape U_{fd} is shown in Fig.1). VSWR of inputs is ≤1.25 within the frequency range 2800 ±50 MHz. The phase shifter is a phase shift line of telescopic type. The line is set in motion by the screw with 0.75 mm lead, which results in 2.57° per turn. Phase shift line VSWRs are not worse than 1.07. The maximal power at PDA outputs is ~0.6 W. Phase detector sensibility is ~8-10 mV/degr for optimal linac tune zone, when the reflected wave in the waveguide Uref is minimal (see Fig.1).

3. CONCLUSIONS

The control system for TNK accelerator-injector has been created. It includes the set of detecting devices, directional couplers, phase shifters, and phase detectors, providing operation of the auto frequency turning and linac temperature stabilization systems.

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ИЗМЕРЕНИЕ ИМПУЛЬСНЫХ СВЧ СИГНАЛОВ НА ЛИНЕЙНОМ УСКОРИТЕЛЕ ТНК

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Измерение высокочастотных импульсных сигналов в устройствах с мегаваттными уровнями мощности является важной задачей ускорительной техники. Измерительные цепи не должны ухудшать КСВН в трактах передачи мощности и создавать локальные перенапряжения электрических полей. Описана специально разработанная на частоту 2.8 ГГц элементная база, состоящая из блоков детектирующих устройств, вакуумных направленных ответвителей, фазовых детекторов, фазосдвигающих коаксиальных линий, обеспечивающая не возмущающие измерения СВЧ сигналов в волноводном тракте и линейном ускорителе с уровнем мощности до 20 МВт с точностью не хуже нескольких процентов.

ВИМІР ІМПУЛЬСНИХ НВЧ СИГНАЛІВ НА ЛІНІЙНОМУ ПРИСКОРЮВАЧІ ТНК

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Вимір високочастотних імпульсних сигналів у пристроях з мегаватними рівнями потужності є важливою задачею прискорювальної техніки. Вимірювальні ланцюги не повинні погіршувати КСВН у трактах передачі потужності і створювати локальні перенапруги електричних полів. Описана спеціально розроблена на частоту 2.8 ГГц елементна база, що складається з блоків детектуючих пристроїв, вакуумних спрямованих відгалужувачів, фазових детекторів, фазозсувних коаксіальних ліній, що забезпечує виміри НВЧ сигналів без збурення у хвилеводному тракті і лінійному прискорювачі з рівнем потужності до 20 МВт із точністю не гірше декількох відсотків.