DEVELOPMENT OF INR LINAC BCT SYSTEM

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Abstract

New electronics of automatic BCTs system was developed to improve beam parameters measurements along INR Linac. BCT electronics details are described. The available results of beam pulse measurements are given.

INTRODUCTION

At proton beam acceleration process in initial part of INR linac from 750 keV to 100 MeV high level of interference and hum are produced in measuring channels on beam current transformers (BCT), preamplifiers (Preamp); cables between Preamps and Main modules of amplification (AMP) and calibration (CLB), that are installed in control room of initial part.

These low frequency (LF) and high frequency (HF) interference distort the BCT measurement results with single channel Preamp [1].

Besides that at time of proton acceleration in initial part, when beam from RFQ is accelerated from 750 keV to 20 MeV in first drift tube linac (DTL) tank, the amplitude of beam pulse is decreased from 23÷18 to 12÷10 mA approximately in process of the accelerating beam formation. But significant level of interference and hum don't permit to estimate with sufficient accuracy the rate of beam losses in first DTL tank and in another DTL tanks of linac initial part. Therefore, efforts were made to improve of resolution ability of BCT measuring system in initial part.

In the past two years system has been expanded with a new BCT on ferrite core and two differential Preamp circuits of two types, that enable to reduce interference and hum from high-power devices of linac.

Upgraded BCT system provides reliable and stable beam parameters representation along the linac in high level of activation of the equipment also.

THE STRUCTURE OF INITIAL PART BCT SYSTEM

Block-scheme of automated BCT system [2] for initial part of linac is shown on Fig. 1. The beam is injected from the RFQ in the initial part, which consists of five tanks (R1÷R5) of DTL type. After acceleration to 100 MeV, beam is injected into the main part of the linac, consisting of 27 accelerating sections of disk and washers (DAW) types.

BCT's and Preamps are installed on the exits of each DTL tanks excluding R2. Preamps are located in linac tunnel 1.5 m away from corresponding BCT. Analog pulse signals from Preamps are fed inputs of amplifiers (AMP) by RF cables. Generator of calibration pulses CLB is combined with appropriate AMP in common module MAC. All MAC's are installed in control room of linac initial part. CLB signals are fed to corresponding BCT. AMP output signals are fed on ADC inputs of corresponding servers (PC1÷PC5), installed in each of 5 sectors of linac. All ADC's are built into server computers of corresponding sectors of linac (PC1÷PC5). Servers are built into control system of linac (CSL).

The programs for data acquisition and processing are on the servers and remove the remnant distortions due to hum and interference. Processed data are transmitted into CSL. The final results of treatment are represented on computers of linac central control room.

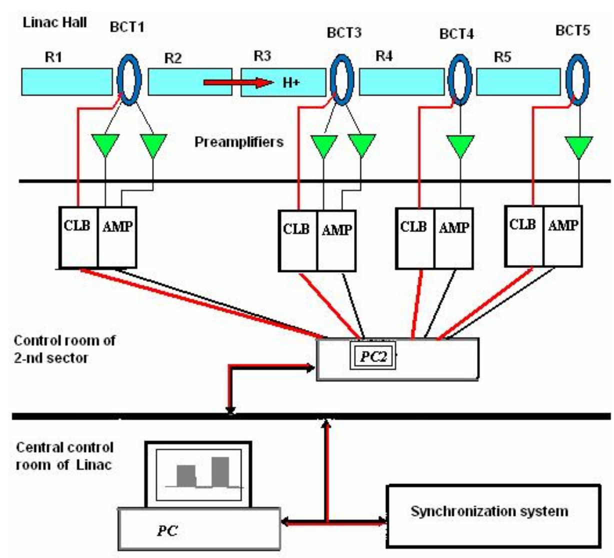

Fig. 1. Block diagram of automated BCT system of linac initial part.

BEAM LOSSES AND RADIATION CONDITIONS ON INITIAL PART OF INR LINAC

Currently, INR linac proton pulses have the 10÷12 mA pulse amplitudes, up to 200 μs pulse duration and 1÷50 Hz pulse repetition frequency. The beam amplitude formation is produced into first DTL tank.

RFQ, operating on the frequency of initial part 198.2 MHz, injects in R1 the beam of ions with 200 μs duration, consisting from $4*10^4$ bunches of 0.8 ns duration. The number of particles in bunches is decreased in R1 in process of formation of more short bunches at acceleration.

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Ions, lost during acceleration, produce in metal walls of ion guide neutrons and γ-quanta. Quantity of these background particles increased very rapidly with growing of energy of lost particles. Increasing of lost proton energy from 1 MeV to 20 Mev gives increasing of output of neutrons from ~10^{-7} to ~10^{-3} on single proton [3]. It is known from INR linac operating experience, that at standard adjustment of phases and amplitude of accelerating fields in next DTL tanks and DAW cavities, the losses of accelerated beam is decreased to average level less than 0.1 nA/m for 100 µA average proton current, but neutron background gradually increases at approximately constant beam losses along linac, due to growing of energy of lost protons from 20 to 209 MeV. The output of neutrons on single lost proton is increased from 10^{-3} to 1. And so, if in second half of R1 at growing energy from 10 to 20 MeV is lost ~10^{12} protons in 200 µs pulse then, in this case, will be produced ~10^{9} neutrons in single pulse or ~10^{5} neutrons/(1 cm^{2}s) on 1 m distance in 50 Hz repetition frequency. So radiation background on R1 output is comparable with this one on main part of linac [1], and it is need take into account for new preamplifiers constructions.

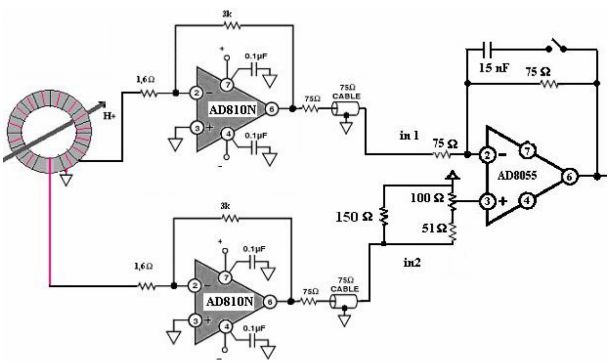

Fig. 2. Differential preamplifier for BCT1 with interference-hum suppression scheme.

FERRITE-CORE BCT AND PREAMPLIFIER DESIGN

The project of installation of isotope production facility on 20 MeV proton beam requires to develop a compact BCT that doesn't take the extra space between R1 and R2 and decreases the interference-hum level. This goal was achieved using new differential BCT1 located after R1 (fig. 2). The symmetric winding is wrapped around 65x40x9 mm M2500HMC ferrite toroidal core and tapped at the center. First type differential Preamp circuit is based on AD810N opamps. These chips are used in single channel Preamps and confirm operational reliability in more severe radiation background in INR isotope facility for the last 8 years [1].

The influence of ferrite core on the vacuum in the beamline was tested beforehand. It was determined that the core doesn't effect on vacuum. It also turned up that the induced activity remained at the same level after year and a half operation.

Inside diameters of the core and the beamline are 40 and 30mm correspondingly. BCT1 has additional screen protecting both particles and interference. Both halves of the winding consist of 100 turns of copper wire that is winded in the same direction. Center-tapping point and preamplifier common rail are interconnected. Opposite ends of the winding are connected to Preamp inputs. Signal currents on the inputs flow in the opposite directions. The resulting pulses on the outputs of two «current-to-voltage» converters have the opposite sign. The LF interference present in the ground wire and the interference on the output cables are of the same sign. Signals from the beam are summed in the main amplifier whereas LF interference is suppressed by subtraction. The less severe problem of HF interference elimination, however, remains in this construction. This interference is much smaller than LF hum but it considerably (by several times) increases the overall noise level. It is possible to suppress this interference by adjusting the balance of the main amplifier though, but it breaks the LF interference balance. Also we observed an interference of 5 kHz frequency that couldn't be suppressed due to lack of balance range. To overcome these problems more complicated second new circuit of differential Preamp (Fig.3) was designed and tested.

Either BCT or interconnection cables are subject to electrostatic noise pickup. The amplitude of LF hum on BCT1, BCT3 and BCT4 channels is comparable with the signal. It is possible to take advantage of differential connection scheme, as is shown on Fig.2, since BCT1, BCT3 and BCT4 have center-tapped symmetric winding. This method with second Preamp allows to suppress common-mode noise over than 20 dB (Fig.4).

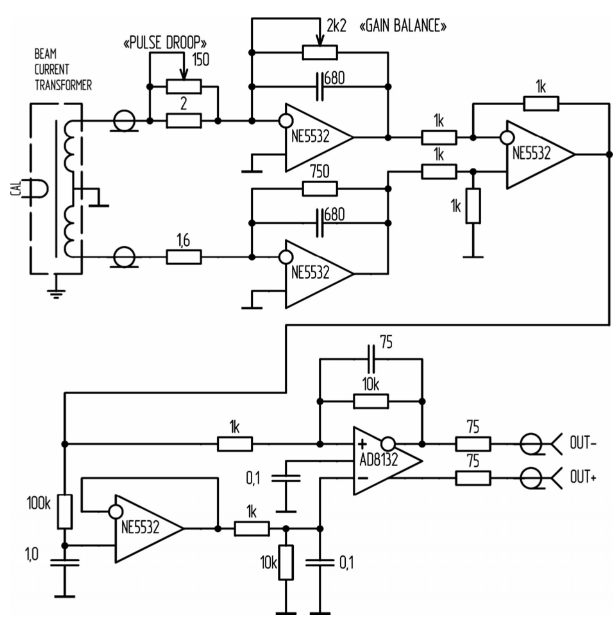

Fig. 3 Differential preamplifier circuit with pulse droop and gain adjustment capability.

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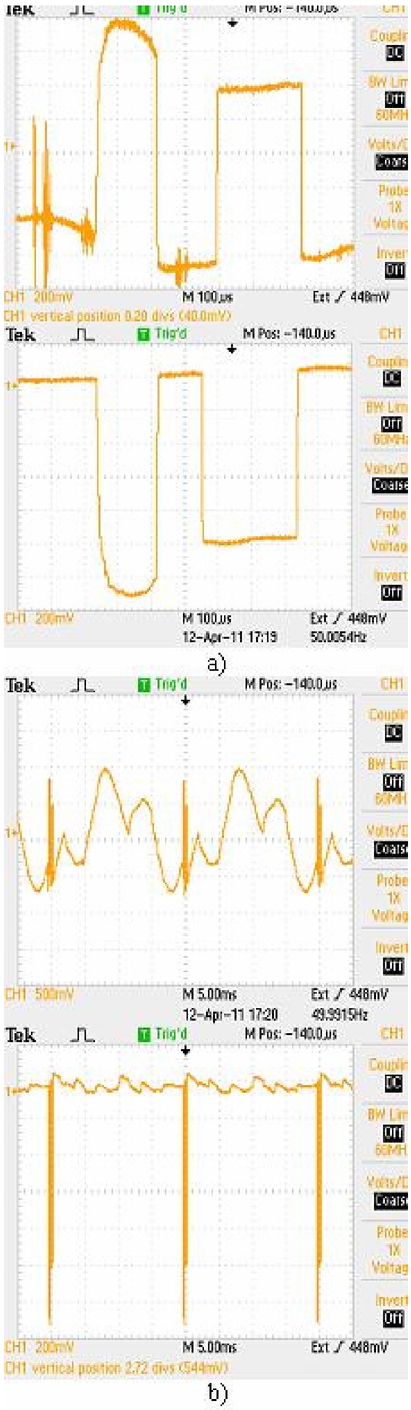

Fig.4. BCT oscillograms with single channel and differential preamplifiers.

BCT3 is connected to the new type of Preamp in the same manner as BCT1 is connected to Preamp shown on fig. 2. One of the input stages has variable input resistance which allows to set the pulse droop time constant of two channels close together. Furthermore it is possible to tune the feedback resistance if channel gain is mismatched for some reason. Pass band is limited to 350 kHz by the capacitor in the feedback in order to prevent self-oscillation of preamplifier and to cut off RF interference. The influence of balance mismatch in the main amplifier on LF hum suppression is eliminated by subtracting the interference in the second stage of this Preamp.

The resulting signal is fed to the output differential amplifier that drives two output coax cables symmetrically. The inverting input of the output stage is connected to biasing potential of integrating circuit with 100 ms time constant. Thus temperature and LF drifts of input stages are compensated. HF interference is additionally decreased by narrowing pass band to 100 kHz with capacitor in feedback.

Cables are connected to the main amplifier which further suppresses the interference induced on cables using the differential balance circuit as is shown on fig. 2.

RESULTS

Beam and calibration current source (CLB) pulses for single and differential preamplifiers of BCT3 are shown on Fig.4. The upper trace corresponds to single channel Preamp [1] and the lower trace corresponds to differential interconnection of BCT3 to the new Preamp circuit (Fig.3). This differential Preamp is less prone to LF and HF interference. It also produces a few times lower noise level because of decreased pass band.

The suppression of LF interference is shown on Fig.4b. The hum is decreased from 2 V to 50 mV by differential interconnection of the BCT. This residual hum is successfully eliminated in signal processing software [2].

CONCLUSIONS

New BCT1 and differential preamplifiers are suitable for the radiation environment of the initial part of INR linac.

BCT3 channel electronics allows to observe beam pulses without LF and HF distortions. The pulse droop and gain adjustment capability of BCT3 preamplifier allows for precise matching between input signals resulting in efficient interference suppression. The balancing circuit of main amplifier is now used for eliminating interference induced on the interconnection cables only. It doesn't impair the LF and HF interference suppression efficiency of BCT3 preamplifier anymore.

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