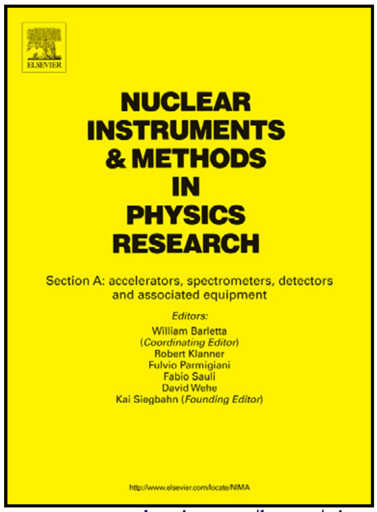

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Digital self-excited loop for a superconducting linac

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Abstract
A self-excited loop based RF control with signal processing carried out primarily in the digital domain, has been developed for the amplitude and phase stabilization of RF fields in the superconducting resonators of BARC-TIFR linac, having a resonant frequency of 150 MHz. The system employs direct sampling and the subsequent signal processing has been carried out in a Field Programmable Gate Array. The signal processing has all been carried out in the baseband using the in-phase and the quadrature components only. Limiter, one of the key elements of the signal processing, has been implemented as a feedback loop, which keeps the magnitude of its output constant without affecting the phase. Using a first order low pass filter with gain as the controller, good steady state and adequate dynamic characteristics have been obtained for the limiter. The paper describes the signal processing modules with emphasis on the analysis of the limiter. The test results with the BARC-TIFR linac are presented. The results are encouraging and establish the suitability of the signal processing scheme for this and similar systems.

Key words:
Digital self-excited loop, Digital Limiter

1. Introduction

Self-excited loop (SEL) is a very convenient architecture of the RF system for setting up and subsequently amplitude and phase locking of RF field in a superconducting resonator [1]. A number of implementations of SEL reported in the past are primarily analog in nature [2, 3, 4, 5]. Several advantages such as flexibility, stability, repeatability, ease of implementation of complex algorithms, built-in elaborate diagnostics etc., associated with a digital implementation coupled with the availability of high speed, accurate data converters and computational hardware has motivated the implementation of SEL based RF control in digital domain. Thomas Jefferson Laboratory, USA [6, 7] and S-DALINAC, Darmstadt Germany [8, 9, 10, 11], have successfully demonstrated an SEL based RF control for the superconducting resonators using digital technology. Both these laboratories have carried out the signal processing primarily in amplitude-phase domain. We have proposed an alternative implementation of the SEL, where all the signal processing is carried out in the in-phase – quadrature (I-Q) domain. Processing in I-Q domain without converting to amplitude and phase representation helps in keeping the time lag in the system to a smaller value. This is a very desirable feature in a feedback control application.

Encouraging results obtained with the computer model [12], which was developed to test this approach, have led to its implementation. In the initial phase the digital SEL was developed and tested with a normal-conducting test resonator at 12.5 MHz [13]. Subsequently the system has been developed for the superconducting quarter wave resonators of BARC-TIFR linac having a resonant frequency of 150 MHz. It is a continuous wave linac with very light beam loading [14]. Unloaded quality factor is about 7×10^8 with an average accelerating field of about 2.5 MV/m with 6W of dissipated power on the resonator walls. Resonant frequency variations are the main disturbance to the RF field stabilization. Loaded bandwidth of the amplifier-resonator system is increased to about 80Hz by the use of over-coupling. A 150W solid state RF power amplifier is set to deliver 50 W under free running SEL [15]. Existing RF control system of the linac, operational since 2002, is based on analog electronics [3].

This paper describes the basic set-up of the SEL, with hardware used to realize the SEL presented in brief. The digital signal processing modules of the SEL are explained with emphasis on the analysis of the limiter. The testing conducted in the lab and with the BARC-TIFR linac is presented and discussed. The description for most part is kept generic in nature and can be easily adapted for similar systems.

2. Implementation of SEL based RF control

Fig. 1 shows the basic set-up of the SEL retaining only the essential functionalities. The signal processing hardware is split in two modules. The analog module acts as an interface of the digital module with the rest of the system. Filtering and settable gain are the primary functions of the analog module. These features of the analog module help in reducing the noise, unwanted frequency components and lead to better utilization of the dynamic