THE USE OF A SOLID STATE ANALOG TELEVISION TRANSMITTER AS A SUPERCONDUCTING ELECTRON GUN POWER AMPLIFIER*

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Abstract

A solid state analog television transmitter designed for 200 MHz operation is being commissioned as a radio frequency (RF) power amplifier on the Wisconsin superconducting electron gun cavity. The amplifier consists of three separate RF power combiner cabinets and one monitor and control cabinet. The transmitter employs rugged field effect transistors built into one kilowatt drawers that are individually hot swappable at maximum continuous power output. The total combined power of the transmitter system is 30 kW at 200 MHz output through a standard coaxial transmission line. A low level RF system is employed to digitally synthesize the 200 MHz signal and precisely control amplitude and phase.

INTRODUCTION

The Synchrotron Radiation Center (SRC) at the University of Wisconsin is developing a superconducting electron gun suitable as the injector for a future Free Electron Laser (FEL) [1]. The RF power required to run the electron gun is being provided by a used analog television transmitter. The transmitter was purchased through Transcom, Corporation from the KRXI-TV station located on Peavine Mountain, Nevada [2]. The system was verified to operate at the correct power and frequency and fully tested to 25 kW at the mountain site before disassembling and shipping the unit to the SRC. The transmitter was reassembled at the SRC facility inside of a custom built room to provide adequate air cooling, power input and radio frequency transmission to the superconducting electron gun cavity [3].

TRANSMITTER SYSTEM

The transmitter system is a solid state Platinum III Series HT-30HS analog unit manufactured by Harris Broadcast Communications Division. The system uses field effect transistors (FET's) built into 1 kW modular amplifier drawers that allow swapping in or out during full power operation [4].

The 30 kW system consists of four cabinets housing one computer control system, one driver amplifier cabinet and two high power 15 kW RF amplifier cabinets. The outputs of the cabinets combine with an outboard quadrature RF hybrid combiner that directs power through an RF circulator to the superconducting RF gun cavity [5]. All RF power is transmitted through standard coaxial transmission line. Figure 1 shows a front and back view of the transmitter system.

The entire system is powered with six Basler Electric 15 kW power supplies that operate on three phase 208V ac and deliver 50 volts dc at 300 amps. These units are used to power the RF amplifiers in each cabinet.

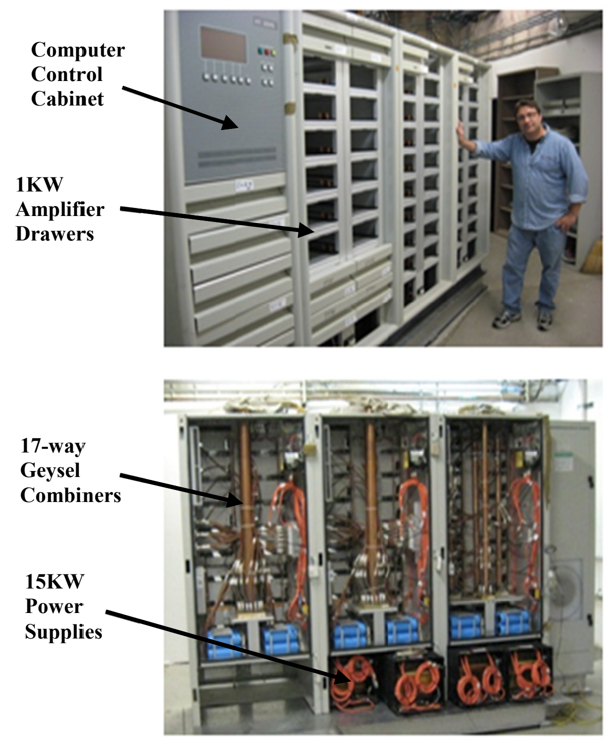

Figure 1: Front and back view of RF transmitter.

The amplifier driver modules contain two cascaded class A amplifier stages which drive a parallel class AB amplifier block. The drivers are used primarily to amplify the pre-amp outputs and drive the 1 kW RF power amplifier modules. The power amplifier modules are paralleled class AB blocks that are summed and then combined by a 17-way Geysel Network combiner [6]. This provides the total output of 15 kW of RF power from each amplifier cabinet. These in turn are combined with the 3dB hybrid RF combiner to make 30 kW of total RF output power. Figure 2 shows a basic block diagram of the amplifier chain.

The phase and gain of the combiner system is controlled with a mechanical phase shifter and the voltage standing wave ratio (VSWR) is monitored with

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directional couplers. Each individual amplifier cabinet has been successfully tested to 12 kW at the synchrotron facility at the time of this writing.

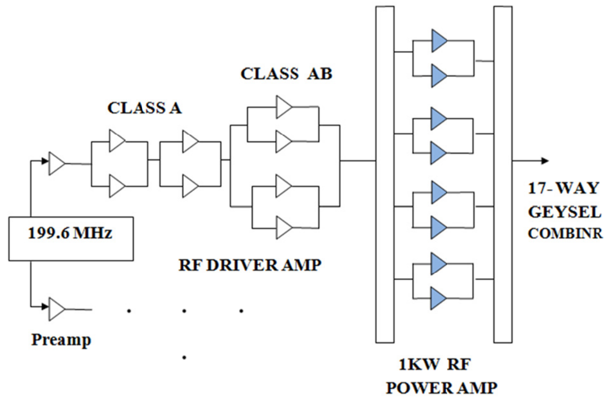

Figure 2: Block diagram of RF amplifier chain.

SUPERCONDUCTING ELECTRON GUN

A niobium superconducting RF electron gun cavity has been manufactured by Niowave for the University of Wisconsin . The cavity is a quarter wave structure with a resonant frequency of 199.6 MHz [7, 8]. A peak accelerating gradient of 40 MV/m is required along with an unloaded Q of $3x10^9$. The cavity is cooled with liquid helium to 4.2 K inside of a custom designed helium vessel and cryostat.

RF is transmitted to the cavity through a uniquely designed coupler and klystron type ceramic window feed-through. The coupler is designed to allow RF into the cavity and electron bunches to travel outward. In addition, a pulsed laser is aimed down the coupler tube and focussed onto a cathode located at the nose cone tip inside the cavity. The laser is used to liberate electrons from the cathode which are then accelerated by the RF field inside the quarter wave structure [9]. Figure 3 shows a layout of the electron gun cavity.

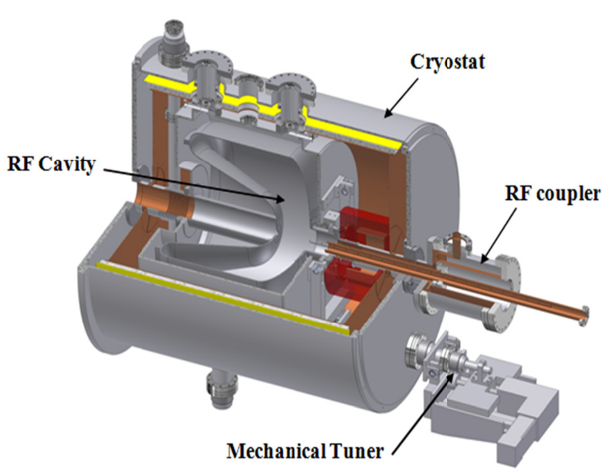

Figure 3: Superconducting RF electron gun.

LOW LEVEL SYSTEM

A new low level radio frequency (LLRF) system was developed and supplied by Jefferson Laboratory to produce the 199.6 MHz signal and precisely control the amplitude and phase of the superconducting electron gun cavity [10]. The system uses a probe antenna in the gun cavity as a feedback signal to monitor and control the amplitude and phase.

A stepper motor and actuator are used to coarsely tune the cavity close to resonance before the system can lock the operational gradient of the cavity to a reference signal. This occurs with a digital self excited loop (SEL) algorithm that is programmed into an Altera field programmable gate array (FPGA). Once the cavity is at its desired gradient, the LLRF system switches to generator driven resonator (GDR) mode to keep the cavity very close to the reference [11].

These operations are performed inside a field control chassis (FCC) and a separate stepper motor control chassis. The FCC unit synthesizes the 199.6 MHz cavity resonant frequency by mixing signals from two Rohde & Schwarz SMA100A low phase noise signal generators [12]. The two signal generators are phase locked together and are set to 149.7 MHz and 79.84 MHz with the latter being split to drive a high repetition rate laser. These

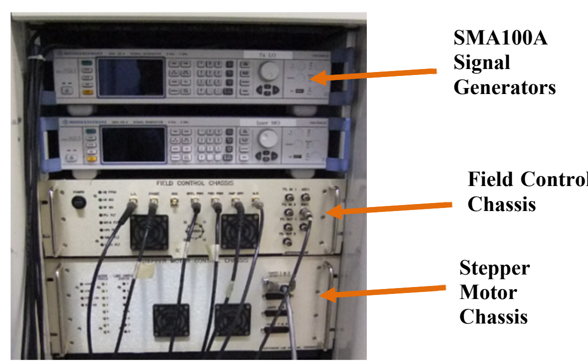

Figure 4: LLRF system installed in control rack.

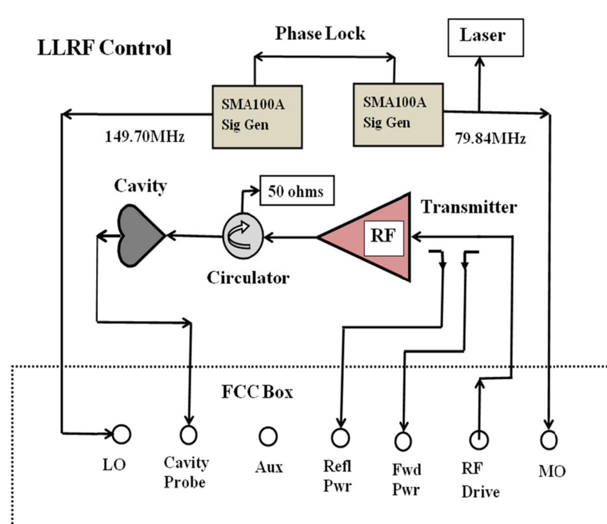

Figure 5: LLRF system block diagram.

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signals are input to the FCC box which produces the cavity drive signal that is fed to the RF transmitter amplifier chain. The FCC box receives feedback signals from the cavity probe and forward and reflected power signals. These signals along with interlocks are used to operate and control the entire RF system. Figures 4 and 5 show a picture and block diagram of the LLRF system.

SUMMARY

A solid state analog television transmitter is being used as a superconducting RF electron gun power amplifier at the University of Wisconsin Synchrotron Radiation Center (SRC). The system was purchased from a television station in Nevada and was reassembled and tested in Wisconsin. It is currently being commissioned as the power amplifier for a unique superconducting RF cavity gun design. The system is capable of producing 30 kW of power at 200 MHz and is controlled by a custom designed LLRF system produced by the Jefferson Laboratory.

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