Noise Reduction Techniques Used on the High Power Klystron Modulators at Argonne National Laboratory*

Thomas J. Russell
Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439

Abstract

The modulators used in the Advanced Photon Source at Argonne National Laboratory have been redesigned with an emphasis on electrical noise reduction. Since the modulators are 100 MW modulators with <700 ns rise time, electrical noise can be coupled very easily to other electronic equipment in the area. This paper will detail the efforts made to reduce noise coupled to surrounding equipment. Shielding and sound grounding techniques accomplished the goal of drastically reducing the noise induced in surrounding equipment. The approach used in grounding and shielding will be discussed, and data will be presented comparing earlier designs to the improved design.

I. MODULATOR PARAMETERS AND SYSTEM CONFIGURATION

There are five high power modulators used on the Advanced Photon Source injection linac at Argonne National Laboratory. The modulators are line type modulators incorporating command charge for regulation and control. The modulators consist of a monitor and control rack, high voltage power supply cabinet, charging choke cabinet, pulse forming network cabinet, klystron control rack, and pulse transformer tank. The configuration of these cabinets and racks is shown in Figure 1.

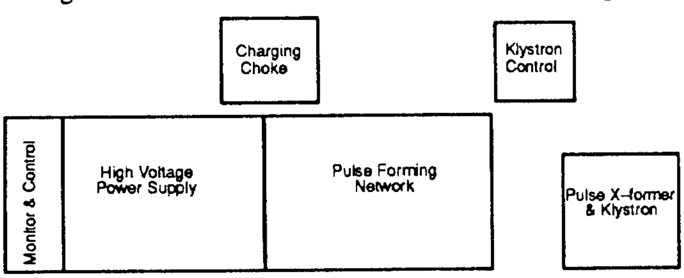

Figure 1. Basic layout of the modulator for the ANL APS linac.

The monitor and control cabinet contains the main control chassis, an interface to the main system computer, and an oscilloscope to locally monitor various wave shapes. All connections made from the monitor and control cabinet to other portions of the modulator are accomplished through fiber optic links. A limited number of connections are hard-wired to other portions of the linac system. These connections are limited to AC power and connection to the system safety system.

The high voltage power supply cabinet houses a 25 kV, 2 A DC power supply. The design incorporates a 480 V 3Ø variac driving a Δ-Y and a Δ-Δ stepup transformer. This configuration results in a 12-pole system and reduces the filter capacitor requirements. The filter capacitor is 14 μF at 30 kV. The high voltage power supply cabinet also houses the command charge deck. The command charge is accomplished through the use of an EIMAC 4CX15,000 tetrode, specially processed to behave as a series switch. The high voltage power supply cabinet also houses all the electronics for the pulse forming network.

The charging choke cabinet contains a 22 H charging choke, some dampening circuits, and the regulation diode with its associated load resistor. These components are contained in a 7-foot-high heavy-duty equipment rack which is connected to the high voltage power supply cabinet and the pulse forming network cabinet with RG-220 cable. Also contained in the pulse forming network (PFN) cabinet is a dump switch for the PFN and a voltage divider to monitor the PFN. Output from the PFN cabinet travels to a step-up transformer feeding the klystron through two RG-220 cables modified into a triaxial configuration.

The basic operating parameters of the klystron (Thomson CSF 2128) are given in Table 1. The design of the modulators was based on these requirements, and they were tested into a dummy load meant to represent these parameters.

Table 1
Klystron Parametric Requirements

Parameter	Required	
Beam Voltage	315	kV
Beam Current	315	A
Perveance	1.78	μ
Efficiency	35	%
Frequency	2856	MHz
Output Power	35	MW

The modulators were built and tested; Table 2 presents the data measured.

II. SPECIAL NOISE REQUIREMENTS

Because of the close proximity to other electronic equipment, special emphasis was placed on minimizing the electrical noise generated by the modulator. One modulator built by a commercial vendor was installed and tested in our linac test stand, but the level of radiated noise was unacceptable. In addition to anecdotal evidence (e.g. modulator control electronics

* Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W–31–109–ENG–38.

Table 2
Modulator Parametric Requirements and Achievements

Parameter	Required		Achieved	
Peak Output Voltage	20.5	kV	22	kV
Peak Output Current	4,820	A	4,990	A
Peak Output Power	100	MW	110	MW
Output Impedance	*4.25	Ω	**4.42	Ω
Transformer Step–up Ratio	1:15.3		1:15.3	
Pulse Width	5	μs	5	μs
Repetition Rate	60	pps	60	pps
Modulator Rise Time	<700	ns	<150	ns

*Measured at low voltage **Calculated by Ohm's Law

operating incorrectly, sparks between mating cabinet doors), several measurements were made. It was found that the behavior of much of the electronic equipment not associated with the modulators deteriorated when the vendor–supplied modulator was operating.

Measurements of radiated noise were made on the original design using a loop antenna input to an oscilloscope. The antenna and oscilloscope were terminated into 10 kΩ. The locations of the measurements are shown in Figure 2.

Our modulator design was engineered based entirely on coaxial principles. At any point where pulse currents flow, the return current path is coaxial about the conductor. This eliminates any magnetic loop antenna configuration which might radiate an interference signal. In order to assure that all the return current flowed through the coaxial configuration, it was necessary for the current path to be separated from ground.

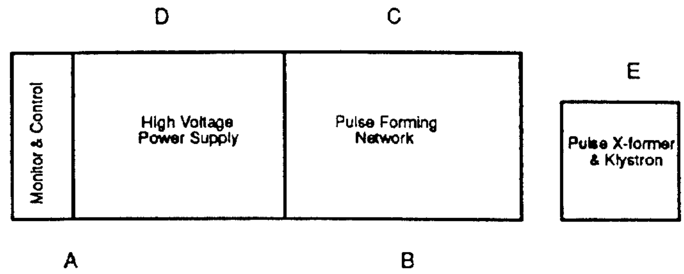

Figure 2. Locations of radiated noise measurements.

Therefore, all components were floating above ground by several 10's of volts. Figure 3 is an abbreviated schematic design for the improved shielding configuration.

III. TEST RESULTS

Tests were conducted on the improved modulator to compare the radiated noise to the original modulator design. Similar data was collected using the original design. The results of both measurements are shown in Table 3. The data is presented in power for simpler comparison to other data. It should be noted that while efforts were made to make the measurements as similar as possible, some differences in the testing exists.

IV. CONCLUSIONS

There has been a vast improvement in radiated noise on the high powered klystron pulsed modulators at the Advanced Photon Source. These efforts were made to improve operation of nearby sensitive equipment in the equipment gallery. Data clearly shows the improvement is on the order of 40 to 50 dB. Additionally, a simple test was made by the author using an inexpensive AM radio. With the modulator operating at full pow-

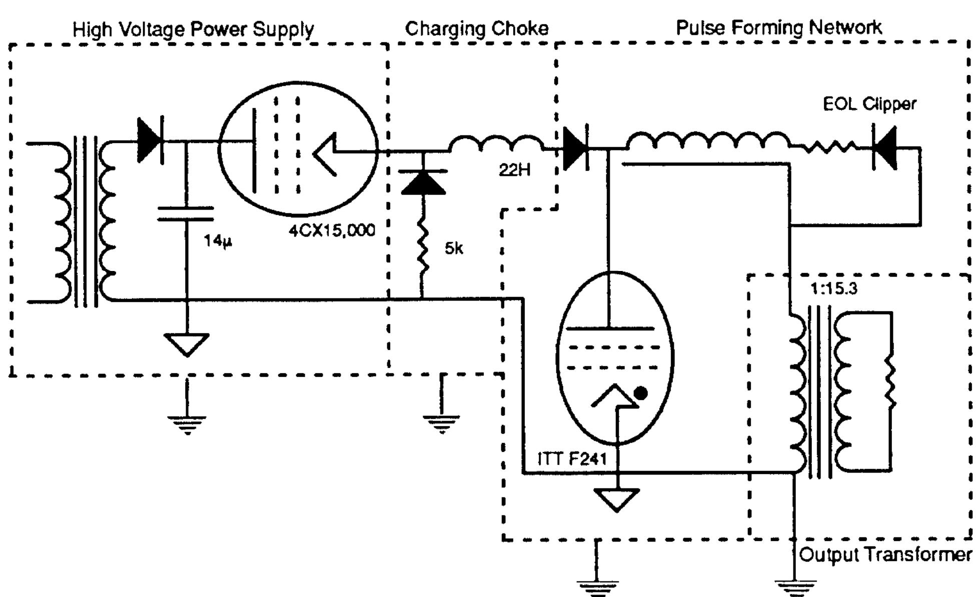

Figure 3. Abbreviated circuit design with grounds and shields.

er and full rep rate, noise was barely noticeable on the radio located three feet from the modulator.

V. ACKNOWLEDGMENTS

The author would like to thank many people in the design and construction of the modulator: Ray Fuja, for offering assistance and experience on numerous occasions; Matt Lagessie, Kevin Dunne, Rob Wright, and Mike Phelan and many others who, under a great deal of pressure, built five modulators in nine months; and Quentin Kerns of FNL for explaining the idea of a coaxial modulator.

Table 3
Measurements of radiated noise for both the original and improved design

Location	Original Design		Improved Design	
A	2.4	mW	0.12	μW
B	3.2	mW	0.02	μW
C	9.8	mW	0.16	μW *
D	0.8	mW	——	
E	20	mW	22	mW **

Notes:
*The test on the improved design was performed with the cabinet doors open while tests on the original design were made with the cabinet doors closed; therefore, actual results should be even better.
**Location E is directly next to the dummy load which was the same for both tests. No effort was made in shielding the dummy load; therefore, results should be similar.