Automated Testing of a High-Power RF Microwave Tube*

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Abstract

This paper describes an automated procedure for testing the high-power klystron amplifiers used in the Ground Test Accelerator (GTA). To verify klystron performance, we have developed an automated test system using data-acquisition and control programs based on LabVIEW™, a program that can communicate with both an Allen–Bradley PLC5/15 controller over RS232 interface and with other devices that use the GPIB interface.

Three automated tests were developed and performed on the high-power klystron: swept-frequency, power-transfer, and VSWR. This paper describes the tests performed, presents test data on the GTA klystrons, provides block diagrams of the automated test facility, and characterizes all the capabilities for the automated test system. This test facility is being used by the GTA program to fully characterize the klystron amplifiers before they are commissioned.

I. INTRODUCTION

Shown in Figure 1 are the equipment racks of the high-power test stand, which uses the LabVIEW data-acquisition system because of its flexibility in programming and its ability to communicate with a wide variety of other controllers or instruments. LabVIEW is a virtual-instrument (VI) engineer workbench. LabVIEW itself provides some VIs and others can be created by a programmer using C language. LabVIEW communicates through a serial–port to RS232 devices such as Allen–Bradely programable controller and through a general-purpose interface bus (GPIB) to devices such as power meters. LabVIEW also has analog ports that can send a 0 to 10-V signal to an external device, such as a switch. The high-power test stand uses LabVIEW to monitor and record the status of safety interlocks and input/output parameters.

Currently, we perform three tests on the high-power amplifiers: swept frequency, power transfer, and voltage standing-wave ratio (VSWR). Each of these tests is carried out by a LabVIEW VI, which uses many other VIs that are integrated into the program when an operator initiates the main VI. The program then records data and fault conditions. Using these VIs, we have fully automated the test stand.

Figure 1 shows three test-stand equipment racks that can operate two high-power RF amplifiers. The rack on the left contains the Allen–Bradley Programmable Logic Controller (PLC) input/output cards and the display monitor, which is situated at the top of the rack. Just below the PLC is the AC distribution chassis, which contains the circuitry for the filaments and the focus coils. The next chassis contains the water-flow monitors for the high-power RF load. The next three chassis contain the solid–state RF driver amplifiers and the measuring circuitry. The middle rack contains the Vacion pumps, high-voltage power supply interlock circuitry, acoustic arc-detector circuitry, and a stack of solenoid supplies. The rack on the right contains all the instrumentation for the three tests. At the top of the rack are the stepper-motor controllers for the VSWR test. Three power meters permit the measurement of forward and reflected input power, forward and reflected output power, and forward and reflected power at the load. The microprocessor used in the test stand is a dedicated Macintosh IIfx.

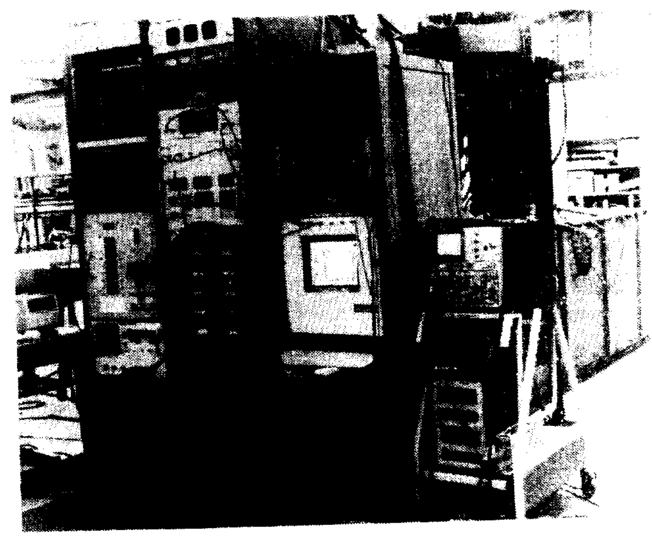

Figure 1. Equipment racks for the high-power test stand.

II. HIGH-POWER AMPLIFIER TESTS

All the data files generated by the three test have a generic format. The data file contains the test name, the time and date, the klystron tube's serial number, a number that indicates the cathode current setting, and a suffix that indicates the test type (*-px*=power transfer, *-fs*=swept frequency, and *-vswr*=Reike diagram). Along with the title information, the data file contains information on the cathode voltage (VC), modulated anode voltage (VM), cathode current

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(IC), and modulated anode current (IM), the filament voltage (FV) and current (FI), focus coil voltage (FCV) and current (FCI), operating frequency (F), pulse width (PW), and pulse repetition frequency (PRF). A typical header for this data is shown in Table 1 along with the units of measurement.

VC kV	VM kV	IC A	IM mA	FV V	FI A	FCV V	FCI A	F MHz	PW ms	PRF Hz

Table 1. Typical data file header.

In addition, by using Cricket Graph as a post-processor tool, we were able to generate graphs at the conclusion of each test. This allowed us to quickly determine if the test was completed without a fault.

Power-transfer test

The power-transfer test allows us to calculate the efficiency, the gain, and the saturated power of the amplifier at different operating conditions. The operating conditions selected involved a fixed cathode voltage and three different cathode currents. The cathode voltage, filament voltage, filament current, solenoid focus coil voltage, and solenoid focus coil current were all set to the manufacturer's test specifications. By doing this, we could verify their test.

The LabVIEW power transfer VI is shown in Figure 2. The "font panel" allows us to input the klystron station number, a filename for data storage, input parameters for the signal generator, and the input parameters for the pulse generator. Once the test is completed we can view and verify the data on the graph that is generated at the end of the test.

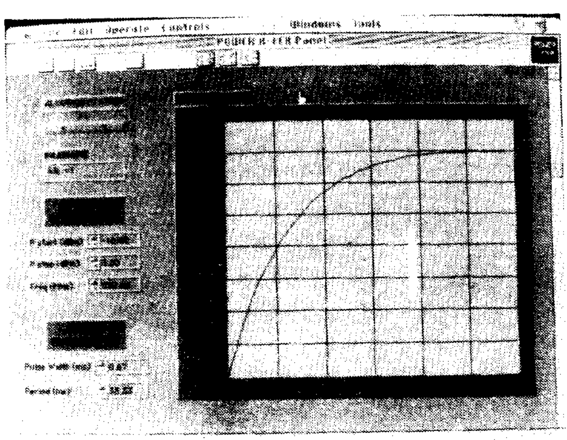

Figure 2. Power transfer virtual instrument.

The operating parameters for the klystron amplifier are shown in Table 2.

VC kV	VM kV	IC A	IM mA	FV V	FI A	FCV V	FCI A	F MHz	PW ms	PRF Hz
85.2	32.4	28.1	8	15.7	20.8	75.4	22.3	850	0.67	30

Table 2. Operating parameters for the klystron amplifier.

The test data follows the header shown in Table 3. The first column represents the input forward power (PIF), the second column is the output forward power (POF), the third column is the forward power going into the load (PLF). The remaining columns are the reflected power at each of these locations. All values are given in watts.

PIF (W)	POF (W)	PLF (W)	PIR (W)	POR (W)	PLR (W)
0	0	0	0	0	0
0.12	84 670	82 000	0.04	918	426
0.13	94 940	92 300	0.04	951	431
0.15	105 810	102 400	0.05	1034	438
0.16	118 560	114 900	0.05	1101	478
0.18	131 370	127 600	0.06	1158	460
0.21	146 660	141 600	0.06	1229	452
0.23	162 750	158 300	0.07	1329	480

Table 3. Power transfer data for the klystron amplifier

Based on the results of this test, the graph shown in Figure 3 was generated. It is important to note that the power output of the klystron matches the power going into the load. Thus, the load impedance matches the output impedance of the klystron.

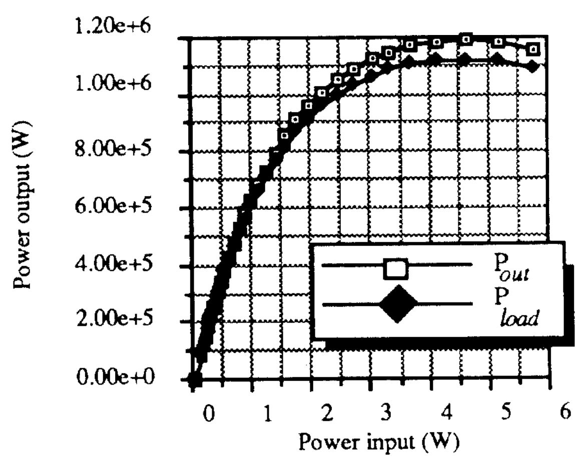

Figure 3. Power transfer of the klystron with cathode current of 28 A.

Swept-frequency test

This test is used to determine the frequency response of the amplifier at different drive levels. The header for the data file is basically the same as shown in Table 3. The only thing that changes is the organization of the raw data. The frequency is given in the first column, while the next five columns contain the forward and reflected output power. However, here each column includes a separate subcolumn for each tested drive level. The subcolumns for the klystron's forward power output (POF) are shown in Table 4.

Forward power input (PIF)					
F (MHz)	PI1 (W)	PI2 (W)	PI3 (W)	PI4 (W)	PI5 (W)
850	0.999	2.018	3.015	4.06	5.04
Forward power output (POF)					
845	39 870	80 450	120480	162250	199320
845.2	44 960	90 420	134610	182310	223390
845.4	50 800	102 350	152460	205930	252410
845.6	57 760	116 670	172780	232920	284150
845.8	65 960	133 000	197330	263160	320840
846	75 360	151 720	223740	298440	359700
846.2	85 290	173 240	255640	338440	407300

Table 3. Swept-frequency data for the klystron amplifier.

It is important to note that the swept-frequency program is linked to the power transfer program. The power transfer program determines the saturated drive and output power, and the swept-frequency program uses this information to determine the five different drive levels. This was done to prevent overdriving the amplifier. Thus, the swept-frequency program is programmed to do five frequency curves at five different drive level, one being at the saturated power level as illustrated below.

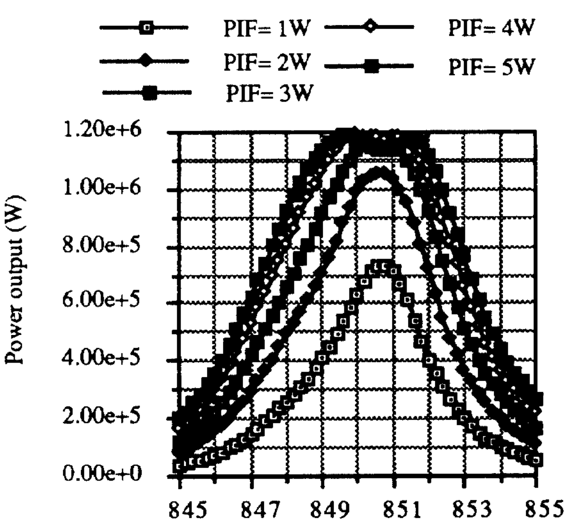

Figure 4. Frequency sweep of the klystron with cathode current at 28 A.

VSWR test

The VSWR test is conducted using a mismatch (tuner) section, which is located between ht output power coupler and the coupler located before the load. Each tuner is evenly spaced apart at approximately 30°. Each test LabVIEW calculated the VSWR by measuring the reflected and the forward power and then adjusting the position of the tuner using a stepping motor.

The VSWR test data file contains six sets of power transfer data. One power transfer test is performed for each tuner. A sample of a data file is shown in Table 5.

PIF (W)	POF (W)	PLF (W)	PIR (W)	POR (W)	PLR (W)
VSWR #1					
0	0	0	0	0	0
0.444	447 300	416 600	0.13	8200	843
0.498	510 000	471 200	0.148	9210	949
0.559	562 700	519 400	0.155	10 140	1021
0.628	612 400	564 700	0.171	11 000	1107
0.703	660 600	607 800	0.182	11 760	1145
0.794	712 900	653 200	0.198	12 630	1208
0.886	766 900	704 700	0.224	13 580	1293

Table 5. Sample of the data file for the VSWR test.

The graph shown in Figure 5 shows a Rieke diagram for the klystron amplifier. (VSWR #1 stands for tuner #1 on the mismatch section.

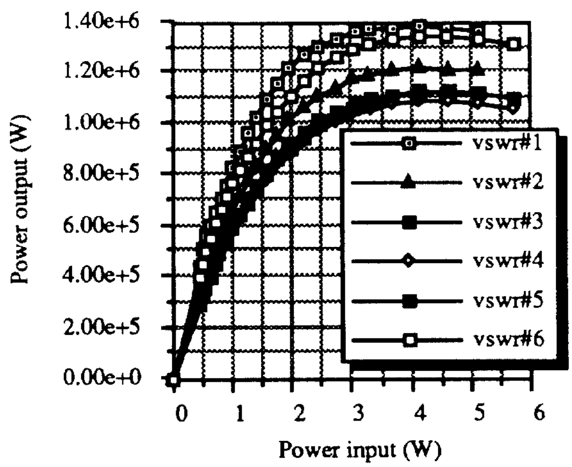

Figure 5. Rieke diagram of the klystron with the cathode current at 28 A.

III. CONCLUSION

With the automated high-power amplifier test stand, full characterization of a high-power amplifier at several operating conditions can be completed in one day. The test stand has allowed the 12 GTA klystrons to be accurately tested in a timely manner. The data from the test stand has also allowed our group to refine our models of the amplifiers.