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DESIGN OF AUTOMATIC TEST EQUIPMENT FOR DEVELOPMENTAL TWT'S.(U)
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DESIGN OF AUTOMATIC TEST EQUIPMENT

FOR DEVELOPMENTAL TWT'S

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DESIGN OF AUTOMATIC TEST EQUIPMENT FOR DEVELOPMENTAL TWTs

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INTRODUCTION

Modern TWT's operate over a very wide range of power levels and frequency. Measure of tube performance parameters therefore requires much equipment and time, as well as skilled personnel. Availability of these resources limits the amount and quality of testing that can be done. This report describes an automated system which can quickly, accurately, and fully test any TWT.

NEED FOR AUTOMATIC TESTING

Presently TWT's are tested manually using a setup similar to Figure 1. First, all of the couplers, filters, cables, sensors, and power meters are calibrated by a standards lab. Next, at each frequency, the appropriate hardware for measuring fundamental or harmonic power is connected, and power data is taken over several drive levels. Duty cycle for pulsed tubes is read off an oscilloscope. Since there is usually insufficient time to take complete data (transfer curves), often only the power at saturation and at small signal drive is measured. This raw data is then corrected for the calibration, and reduced to useful quantities such as small signal gain. All parameters are calculated and tabulated manually, with the inherent possibility of human error. Complete testing of a developmental TWT typically takes on the order of 20 hours.

The problems encountered with manual testing of TWT's can be overcome by a universal automated system. The system is configured to test any TWT, thereby eliminating setup time for microwave measurement gear. Test time is reduced by the use of a high speed small computer which controls all measurements. The system can minimize measurement error by automatically calibrating itself before each test session. Computer software can instantly reduce the test data into a meaningful form which can be utilized easily by the design engineer.

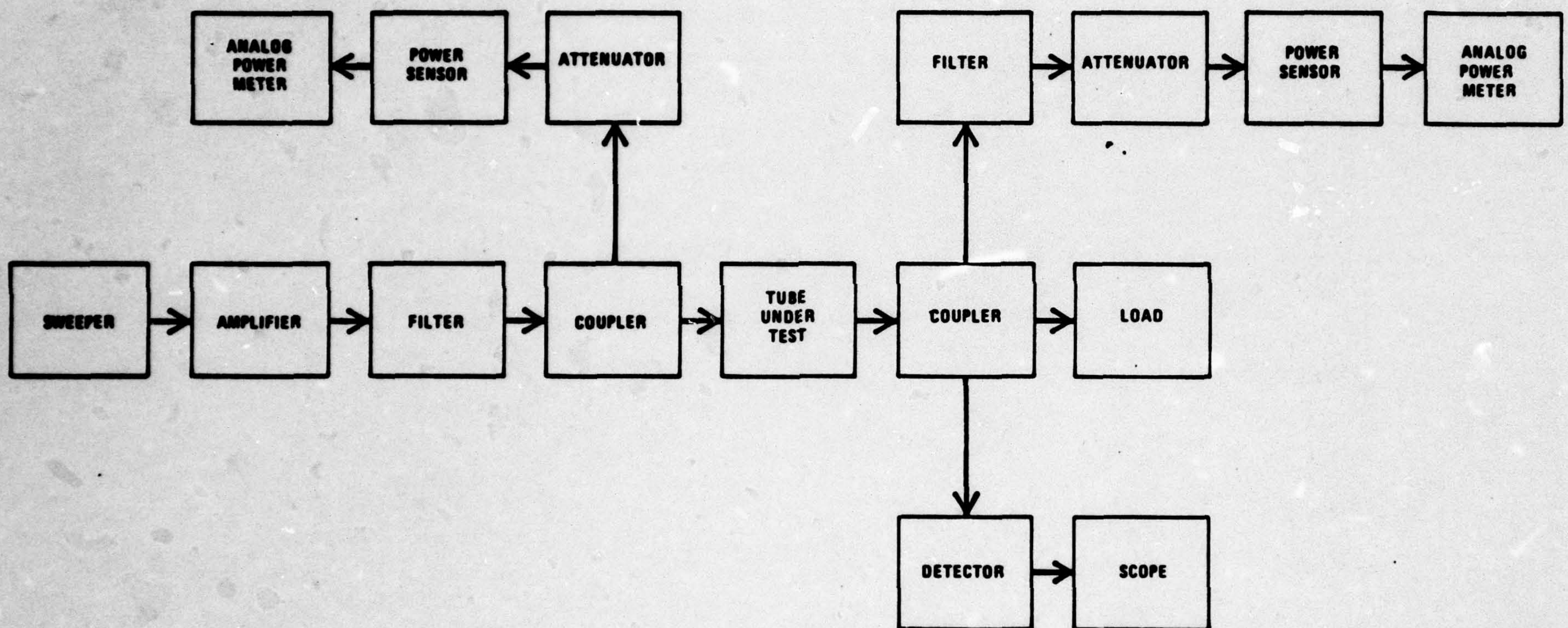

FIGURE 1. MANUAL TEST SETUP

Using these basic requirements, such a system was designed to be used on developmental TWT's. The next sections describe the design of the microwave hardware and the computer control.

MICROWAVE HARDWARE DESIGN

In order to test a TWT, two systems of microwave hardware are needed. First, a drive system must be designed to supply a microwave signal to the tube under test (TUT). Second, an output system is needed to measure the amplified output of the TUT. A common requirement of both these systems is the ability to cover the frequency range from 2-18.5 GHz. This allows testing of nearly any TWT presently built.

As shown in Figure 2, the first element of the microwave drive system is a sweep oscillator which operates from 2-18.6 GHz. This signal is then fed through a coax switch to one of two TWT amplifiers, depending on the drive frequency. The amplifiers provide 2 watts of power, which is needed in order to test high power TWT's. The amplifier output is then filtered to remove harmonics. The low pass filter network is shown in Figure 3. A directional coupler samples the drive signal to measure the power actually being supplied to the TUT. Last in line is a step attenuator, which provides a coarse (10 dB steps) adjustment to the drive power. Fine control (.1 dB steps) is accomplished by varying the sweep oscillator output. It is intended that the TWT amplifiers always be driven at near full power so that the power meter will always be in a high range. This maximizes the accuracy and speed of the power measurements. The dynamic range of the system is from 30 dBm to -50 dBm.

Figure 4 shows the design of the microwave output system. The TUT is connected to a coupler which samples the output of the tube. This signal must be controlled by the test engineer to insure that the CW power does not exceed 33 dBm, to protect the microwave hardware. The minimum power level that can be measured is -37 dBm, the limit of the power meter. The dynamic range of the output system is therefore 70 dB.

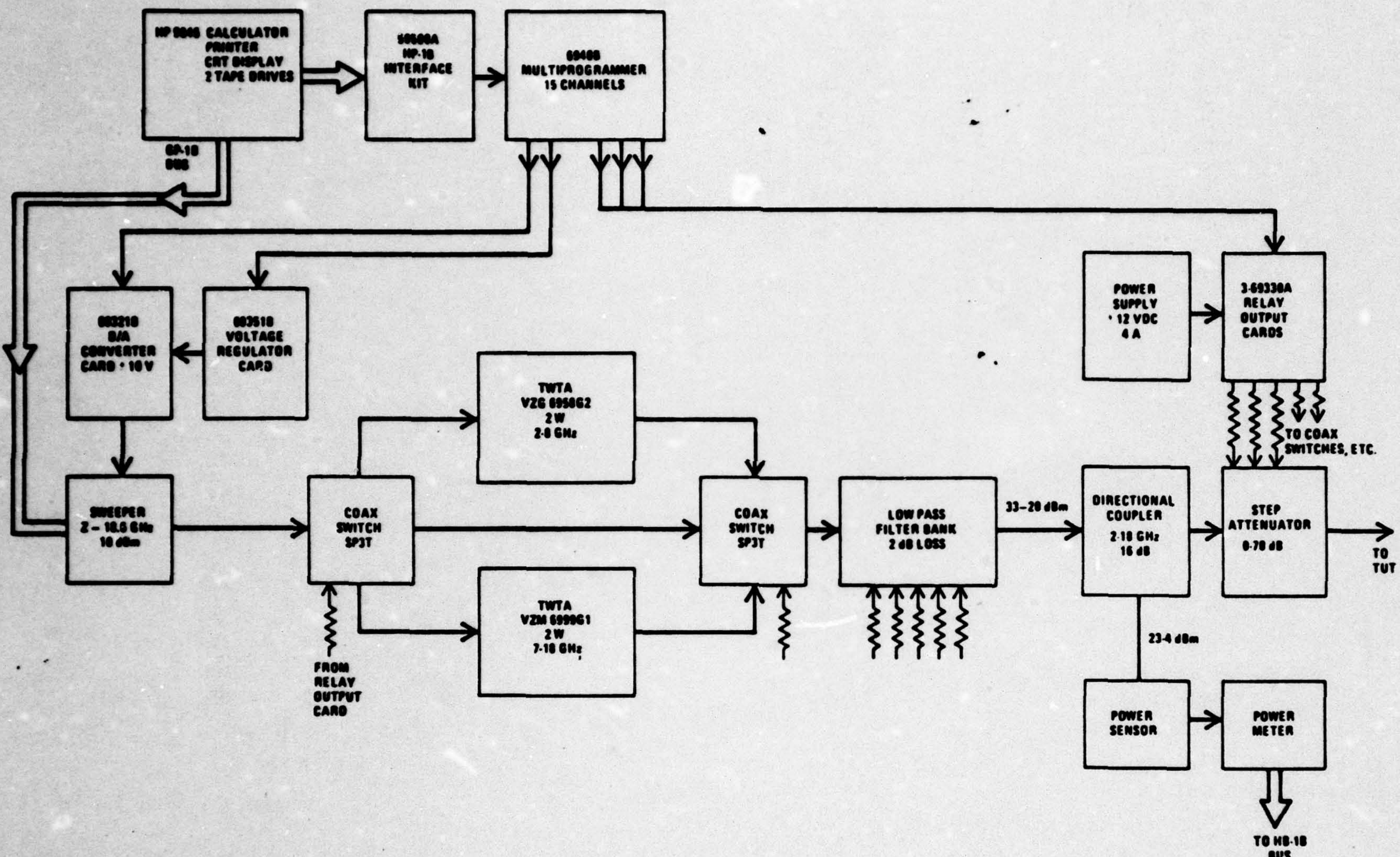

FIGURE 2. AUTOMATIC TEST – RF INPUT

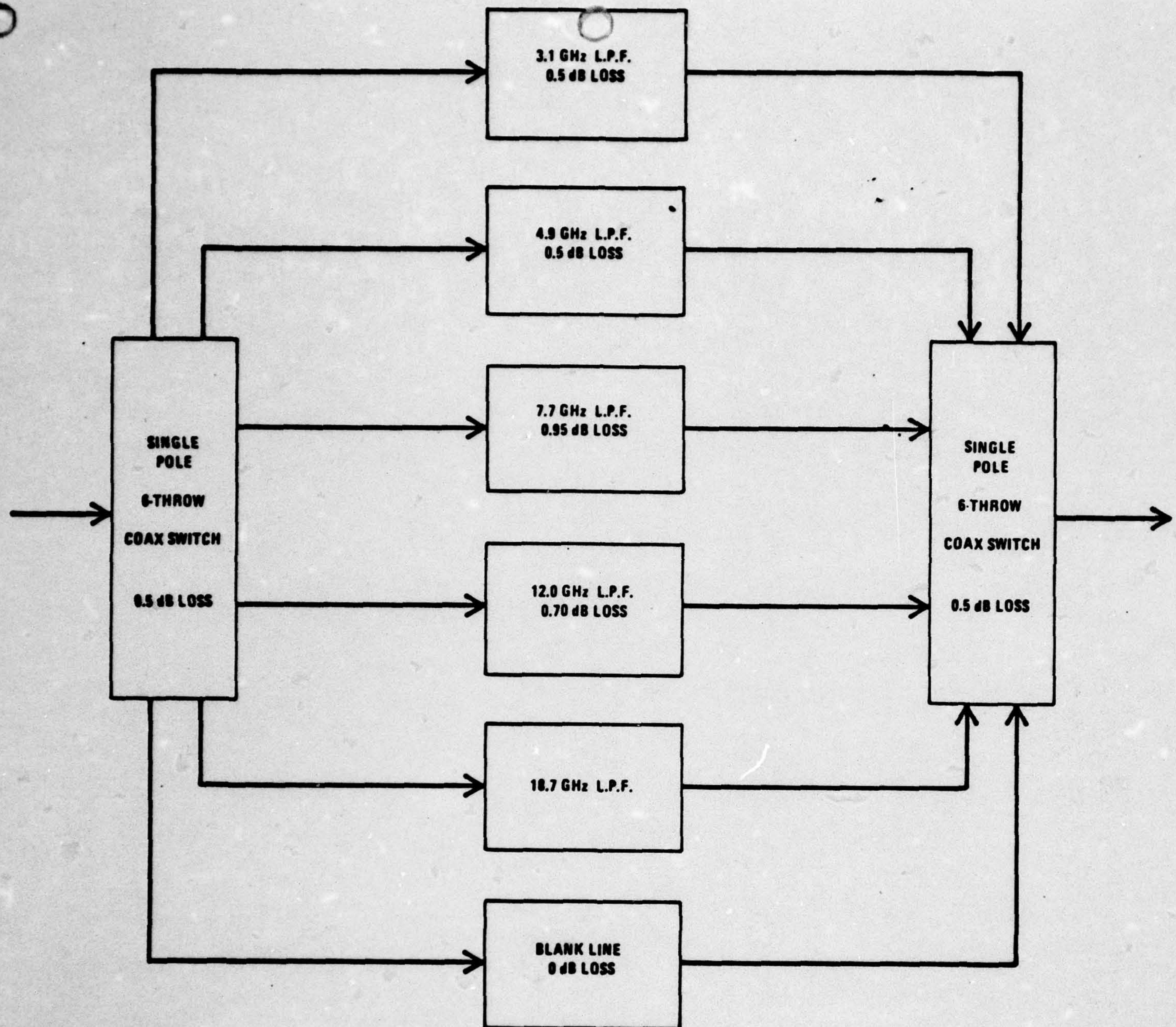

FIGURE 3. RF INPUT – LOW PASS FILTER BANK

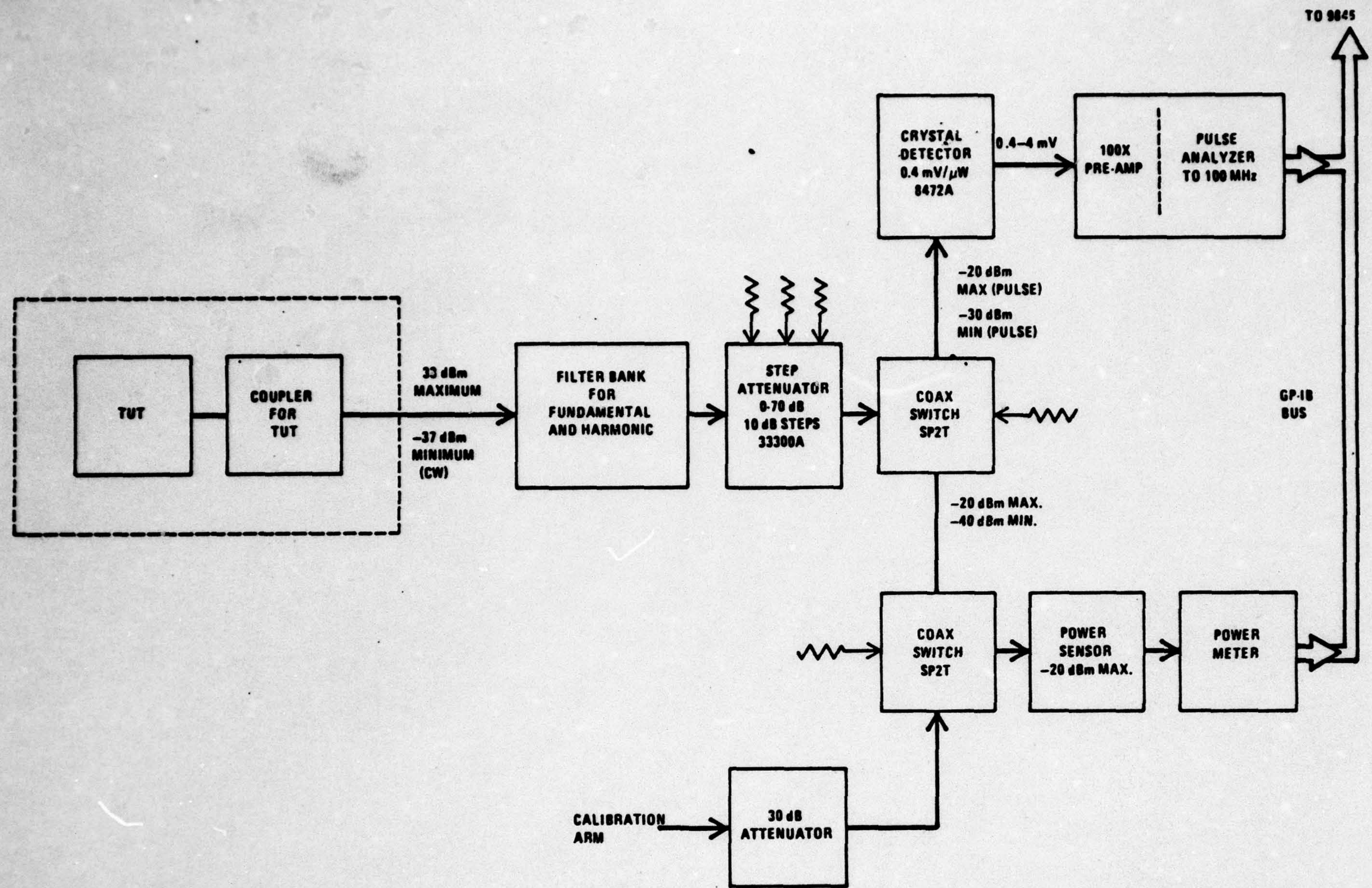

FIGURE 4. AUTOMATIC TEST – RF OUTPUT

The signal from the coupler is fed first into a filter bank, Figures 5 and 6, to remove either the fundamental or harmonic, depending upon what is to be measured. A step attenuator is then used to bring the signal down to a usable range, between -20 dBm and -40 dBm. The coax switch then branches the signal to either the pulse hardware or the power hardware.

The pulse hardware consists of a crystal detector and a pulse analyzer. The detector rectifies the pulsed microwave signal and sends its output through a pre-amp to the pulse analyzer. A pulse of 1 microsecond can be analyzed to determine pulse width, rise time, and fall time. Thus, the duty cycle can be measured accurately, which is necessary to make peak power calculations.

A low level sensor is used to make the average output power measurement. Again, as in the input, the signal level is controlled by the step attenuator to keep the power meter in an upper range, optimizing measurement accuracy and speed. A calibration arm is the alternate input to the output power meter. Calibration of both the input and output systems is based on the output power meter as a standard. The calibration arm (30 dB attenuator, coax switch, and power sensor) are first calibrated by an outside lab. Then, the output of the RF input system is connected to the calibration arm. A drive signal is then sent through the input system at selected frequencies. The input power meter and step attenuator are then calibrated by comparing readings on the two meters. Different attenuation steps are tested to find the exact frequency response of the RF input. Now, to calibrate the RF output, the RF input cable is connected to the main input arm of the RF output. As before, different frequencies are tested to find the calibration factor for each configuration of step attenuator setting and high or low pass filter. With this procedure, both the input and output systems can be calibrated internally, with a minimum of hardware changes.

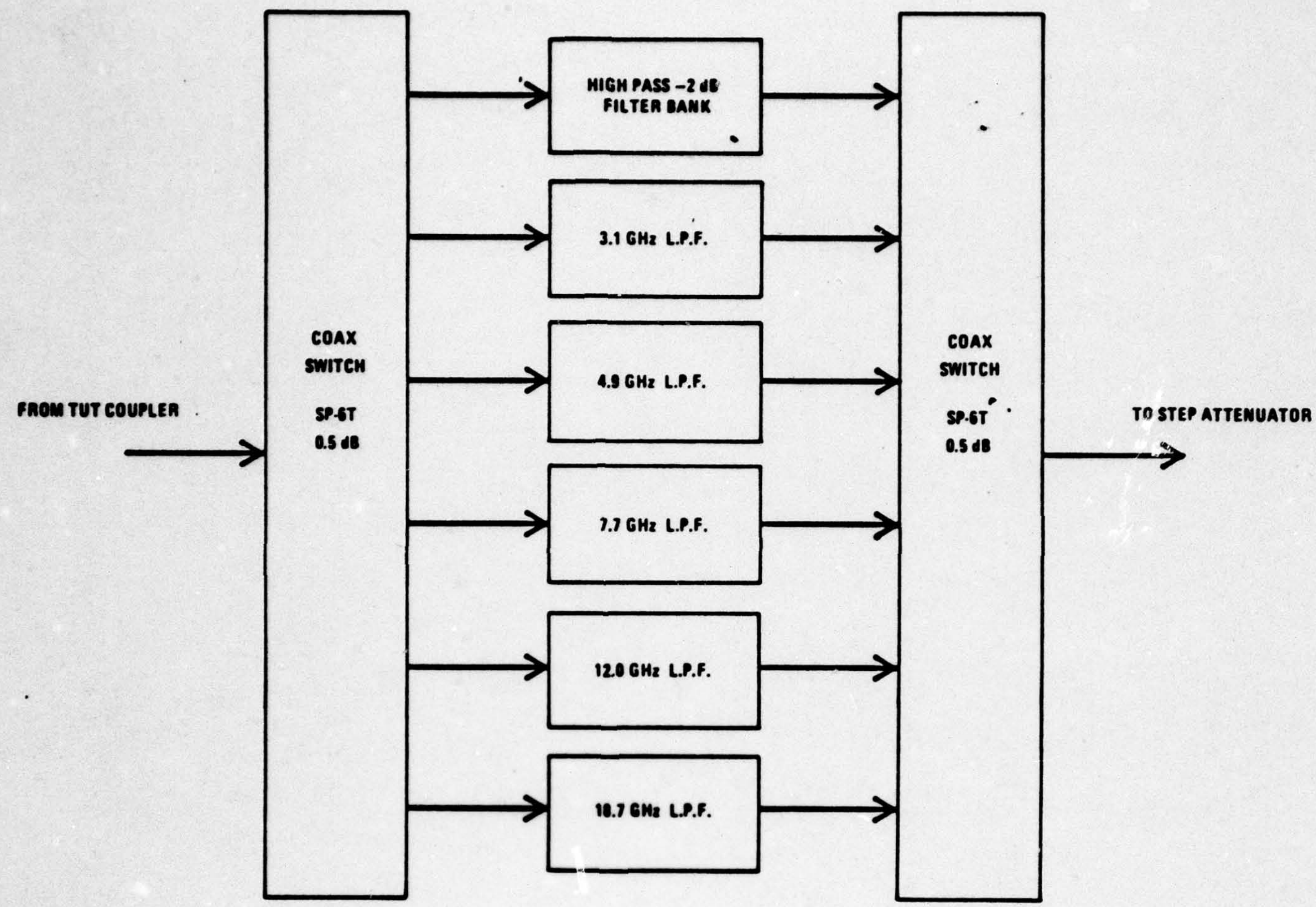

FIGURE 5. RF OUTPUT – LOW PASS FILTER BANK

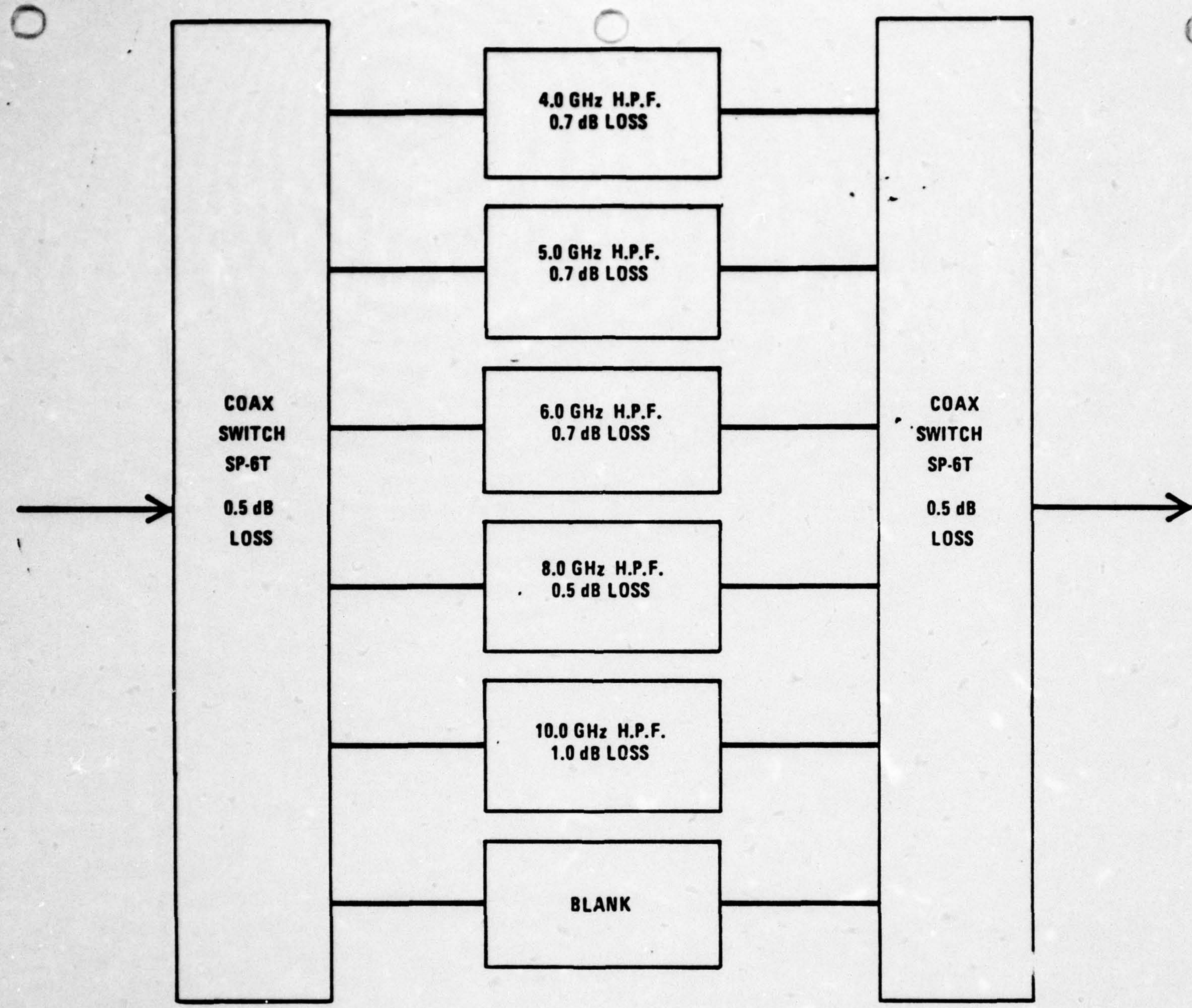

FIGURE 6. RF OUTPUT — HIGH PASS FILTER BANK

COMPUTER CONTROL DESIGN

In order to have a computer control and monitor a "real world" system, there must be a two-way information channel between the system and the computer. The IEEE-488 Interface Bus, also known as GP-IB (General Purpose Interface Bus), provides this necessary link. Commands can be sent by the computer to instruments on the bus, which can in turn send data back to the computer. Interfacing details, such as handshaking, are automatically taken care of by GP-IB. This makes programming the controlling computer very simple, and allows the user to concentrate more on the central purpose of the program. GP-IB compatible instruments are now widely available, and are used exclusively in this system.

Microwave components such as coax switches and step attenuators are not directly controllable through GP-IB. To overcome this problem, a general purpose interface device is used, the Hewlett-Packard Multiprogrammer. The Multiprogrammer is GP-IB compatible, so it can communicate with the computer. Using this device, analog outputs can be sent to a large number of system components simultaneously. The form of the output depends upon what kind of interface card is used. Fifteen different cards can be used in the Multiprogrammer, each having up to twelve separate outputs. Three relay actuator cards are used to control the solenoid switches in the step attenuators and coax switches. Also, one digital-to-analog converter card (D/A card) provides a voltage to control the output level of the sweep oscillator.

The controlling computer used is a Hewlett-Packard 9845 calculator-based system. The programming language is an enhanced BASIC. 62 kilobytes of of core storage are available for programs and data, along with two 217 kilobyte cartridge tape drives for permanent storage. The core memory will be able to store 2500 data measurements and 1000 calibration points. For instance, a data run of 50 frequencies and 50 drive levels could be stored in the active (immediately available) core. This could later be transferred to a cartridge tape. Each tape could contain 20 such data runs, and the calibration table that was used to correct the measurements.

The system measurement time is less than one second. Included in this is time to set the drive frequency and power level, and measure the output power. The two slowest operations are the switching of the step attenuators (50 ms), and waiting for the power sensors to settle (100 ms). Thus, a complete run of 2500 data points would take about 40 minutes. A less detailed test run of 300 data points (e.g., 20 frequencies and 15 drive levels) would take only 5 minutes.

SOFTWARE DESIGN

Computer programs (software) are an integral part of this automated test system. In this system, two programs perform all the necessary functions to test a TWT. The first program is responsible for controlling all the hardware, doing the calibration, and collecting and storing the measurement data. Inputs to this program will be the tube identification, operating conditions, and the range of frequencies and power levels to be tested.

Reduction of basic measurement data is done by the second program. After using the data measurement program, the engineer now uses the computational program to calculate tube parameters and display them. Options available are shown in Table 1. In addition to this list, the same dependent variables could be displayed with Ew as the independent variable instead of frequency (e.g., P_{SAT} vs E_w @ fixed frequency). Also, combinations of options could be simultaneously displayed.

Presentation of TWT characteristics can be in two forms: tabular or graphic. Tabular format permits accurate data to be displayed when exact calculations are required. Graphic presentation of data allows for quick analysis of the TUT by the design engineer. CRT displays of data in either form can be copied onto 8-1/2 x 11" hardcopy for inclusion in reports or engineering test files.

TABLE 1: TWT PARAMETER DISPLAY

	Dependent Variable	Independent Variable	Fixed Parameter
1.	Small signal gain (SSG)	Frequency	E_w, i_w
2.	Saturation power (P_{SAT})	Frequency	E_w, i_w
3.	Fundamental power (P_F)	Frequency	P_{in}, E_w, i_w
4.	Harmonic power (P_H)	P_{in}	Frequency, E_w, i_w
5.	P_H	Frequency	P_H @ rated power, E_w, i_w
6.	Harmonic ratio (P_F/P_H)	P_{in}	Frequency, E_w, i_w
7.	Beam efficiency	Frequency	P_F @ saturation, E_w, i_w
8.	Overall efficiency	Frequency	P_F @ saturation, E_w, i_w
9.	P_{in} @ saturation	Frequency	E_w, i_w
10.	P_{in} @ rated power	Frequency	E_w, i_w
11.	Saturation compression	Frequency	P_F @ rated power, E_w, i_w
12.	P_F	Frequency	P_{in} @ 1 dB compression, E_w, i_w

SUMMARY

It has been shown that there is a definite need to have TWT's tested automatically. There is equipment presently available which facilitates automation of microwave testing. A prototype system design was described which integrates microwave hardware, computer hardware, and program software.

A system using this design is being constructed at Varian. Programming is also being done to control the microwave hardware and evaluate the data collected. This system will be used to test development helix TWT's.

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