AMPLITUDE AND PHASE DETECTOR
FOR
RADIO FREQUENCY MEASUREMENTS

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ABSTRACT

An module has been designed that may be used to demodulate amplitude and phase information in radio frequency systems. This design has been used on PLT and is currently in use on TFTR.

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Many radio frequency (RF) measurements require an amplitude detector followed by a low-pass filter which provides an analog signal suitable for digitizing. Often phase information is needed as well. This report describes a general purpose module that is used at the Princeton Plasma Physics Laboratory. The unit contains two identical amplitude detectors and a phase detector. A circuit that produces an output pulse if one of the channel amplitudes exceeds a preset percentage of the other channel amplitude is also included. This pulse may be used for protection in the event of high VSWR.

A module might be used to monitor forward and reverse signals from directional couplers between an RF source and an antenna. The forward power, reverse power, SWR and load impedance could be obtained in this manner. Additionally, the source could be shut down by a pulse generated as a result of high VSWR to extinguish an arc if one occurred.

A block diagram is shown in Fig. 1. The RF inputs are first amplified by a 50 ohm in/out feedback amplifier. The amplifier output drives both a limiter and a delay line. The limiter has three wideband stages and a 1 K ohm input impedance, which does not load the amplifier. The delay line is made of 50 ohm coaxial cable and is designed to have the same delay as the limiter. Thus, the limited and unlimited signals reach the double-balanced modulator at the same time. The limited signal drives the carrier port of the modulator and the unlimited signal drives the signal port. Since they arrive at the same time, they are in phase at the modulator regardless of the signal frequency. The modulator acts as a full wave synchronous detector and produces a D.C. output at its IF port that is proportional to the signal amplitude. The detected signal is then passed through a 100 kHz low-pass filter to remove the second harmonic generated by the detection process and further filtered by a 5 kHz low-pass filter for digitizing. Two filters are used in cascade to allow the high VSWR pulse to be produced rapidly.

Both channels' signal amplitudes are processed in the same manner. The limiter outputs are also connected to a phase detector. The B channel has an arrangement with a jumper on the printed circuit board that allows the phase detector to be driven by an external input if desired. When several signals are being compared to the same phase reference, a power splitter may be used to drive the external inputs. The B channel is then available for a separate power measurement.

The phase detector output is passed through a low-pass filter that cuts off at 400 Hz for digitizing. Detection is accomplished with a Motorola

integrated circuit type MC12040. The phase range is ± 360 degrees.

The high VSWR pulse circuitry operates on the amplitude signals at the 100 kHz low pass filter outputs. The A channel signal drives a threshold detector labeled "Power Detector" that has a preset comparison voltage, V_t . If the A channel signal exceeds V_t , a 50 μ sec oneshot is enabled. The A channel signal also drives a voltage divider that has an adjustable ratio. A ten-position rotary switch on the board can select ratios from 0 to 90% in 10% steps. The output of this divider is used as the comparison reference for another threshold detector labeled "VSWR Detector". The other input of the VSWR Detector is the B channel signal. If the B channel signal voltage exceeds the set percentage of the A channel voltage, a trigger pulse is sent to the 50 μ sec oneshot. Additionally, if the A channel voltage exceeds V_t , the oneshot will produce an output pulse. The oneshot pulse is buffered by a circuit designed for driving a light emitting diode. This feature may be used to send the pulse over a fiber optic link.

Two versions of this module have been built. The Group 501 version has no input amplifier and has an input VSWR of about 1.1:1 over most of its operating frequency range. The Group 502 has an input amplifier which provides gain, but degrades the input VSWR to 1.3:1 or so. Resistive pads are used in front of the amplifier units to improve the VSWR.

Typical Specifications (No input amplifier)

Nominal input power	0 dBm
Nominal input impedance	50 ohms
Compression point(1dB)	+6 dBm
Range for ± 1 dB linearity	501; +6 to -20 dBm 502; -12 to -38 dBm
Frequency response ± 1 dB	0.5 to 90 MHz
Output impedance	220 ohms
Phase detector gain	6 mV/degree
Frequency response, amplitude outputs	5 kHz to -3 dB
Arc detection time	3 μ seconds
Size	One wide NIM module
Power supply	+12 volts dc, 410 mA. & -12 volts dc, 60 mA.

The amplitude detector transfer characteristics for a 502 unit with 10dB pads on the inputs is shown in Fig. 2. The overall voltage gain is approximately one from -10 dBm to -50 dBm. The deviation from a straight line from -12 to -38 dBm input is shown in Fig. 3. At -12 dBm in the amplifier has -22 dBm at its input and -7 dBm at its output. This is approaching the compression point of the DBM, which is about -2. Linearity on the small signal side of the plot is controlled by the limiting range. The frequency response of the amplitude detector is shown in Fig. 4. The units are flat within ± 1 dB from 2 MHz to over 80 MHz.

The phase detector transfer characteristic is shown in Fig. 5. The data for this plot were taken at 47 MHz. The nonlinearity of this characteristic is shown in Fig. 6. The error is waveform induced and is smaller at lower operating frequencies. In typical operation the two input signals may be different amplitudes. Figure 7 shows the effect on measured phase as one of the inputs is varied from -16.5 to -56.5 dBm. At -36 dBm the limiters are starting to come out of limiting.

Fig. 1

Amplitude Detector Output vs Input, SN 02

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

PHASE SHIFT WITH UNEQUAL INPUTS

Fig. 7

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