PULSE NETWORK ANALYZER

D. L. Landt and R. J. Weber

Avionics Group,
Rockwell International Corp.
Cedar Rapids, Iowa 52498

ABSTRACT

A pulse network analyzer is described which, when added to an existing CW Analyzer, is capable of pulsed impedance and transmission measurements in time frames as narrow as 250 nanoseconds. The analyzer operates in a swept or fixed frequency mode from 0.5 - 12.5 GHz. Measurement results are presented on a GaAs, X-Band, IMPATT diode and a multistage, L-Band power amplifier.

INTRODUCTION

Recent trends in the microwave industry call for high-power, pulsed microwave amplifiers with greater bandwidths and improved stability. Proper design of these broadband amplifiers requires accurate characterization of pulsed power semiconductor devices. Turn-on behavior of these devices has not yet been adequately determined.

Most commercially available network analyzers operate essentially in a continuous mode with response rise times typically greater than 100 microseconds. These systems are not capable of resolving data in the 0.25 to 50 microseconds pulsewidth range which are typical pulse formats for many microwave pulsed-power devices.

Thermal restrictions on these pulsed power devices does not allow extending the pulsewidth to accommodate these 'CW' network analyzers.

Attempts to utilize these analyzers under pulsed conditions have been investigated, but have generally been unsuccessful due to the dependence of the amplitude response on the duty factor of the measurement pulse. (1, 2)

The pulsed network analyzer to be described overcomes these pulsewidth shortcomings and provides accurate pulsed signal measurements in time windows as narrow as 250 nanoseconds. The network analyzer can operate in a fixed or swept mode over a frequency range from 0.5 - 12.5 GHz. Thus, turn-on behavior of pulsed microwave devices can be studied with the aid of this analyzer. A CW network analyzer such as an HP 8505/8507 is used for calibration and display.

The analyzer was originally constructed for measurement of IMPATT device impedance characteristics during pulse operation. However, it can be used on any other pulse devices which are not capable of CW or long pulse operation.

The basic idea of the analyzer's operation, as shown in figure 1, is to first down-convert the rf signals at a frequency f_0 from the device under test to a fixed IF frequency, 50 MHz in this case. The amplitude and phase of these signals are determined and a CW signal of the same amplitude and phase is produced in the pulse to CW converters. The CW signals are then calibrated and displayed on a CW network analyzer using the standard procedure.

ANALYZER DESCRIPTION

A block diagram of the Pulsed Network Analyzer is shown in figure 2. The block diagram for a one-port measurement is shown but a two-port measurement system can be implemented by adding another coupler and switching the b channel signal. The analyzer uses the outputs of two signal generators which are locked 50 MHz apart. The 50-MHz offset signal is produced by the HP 8505 network analyzer. The upper signal generator at frequency f_0 supplies the test frequency for the device under test. This signal can be continuous or pulsed and at any power level desired provided that sufficient attenuation has been added after the coupler. The lower signal generator at f_0 - 50 MHz is split and provides LO drive to the down conversion mixers. The pulsed RF signals at f_0 from the couplers which represent the incident and reflected waves from the device under test are down converted to 50 MHz. These 50-MHz pulse signals thus contain the amplitude and phase information of the pulsed microwave signals. In the pulse to CW converters, the phase and amplitude of the pulsed signals are determined within the gate signal and the 50-MHz continuous signal from the HP 8505 is modified to be of the same amplitude and phase. The continuous 50-MHz signals are then processed in the HP 8505 network analyzer and displayed in the usual manner.

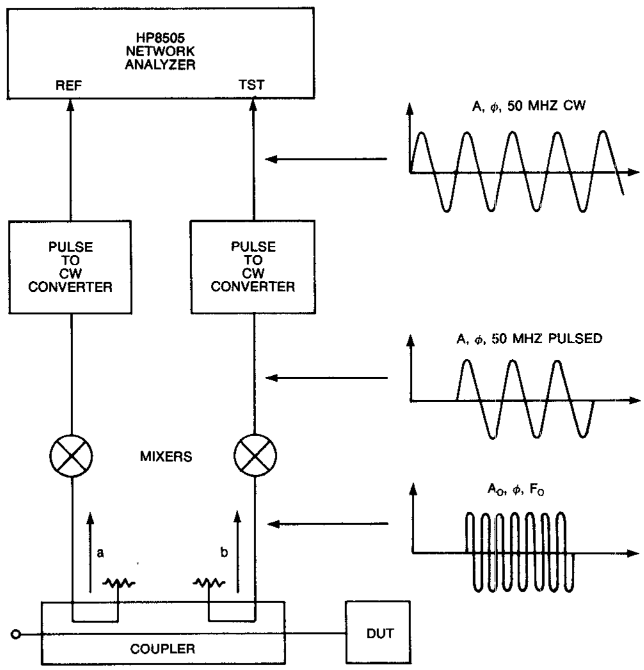

Figure 1. Basic Analyzer System.

Standard calibration procedures along with computer control and correction of the HP 8505 analyzer are thus possible.

Note that swept operation is accomplished by sweeping one of the CW microwave signal sources, the other source maintaining the locked 50 MHz offset frequency. Also note that 50 MHz is not a

0149-645X/85/0000-0581 $01.00 © 1985 IEEE 1985 IEEE MTT-S Digest

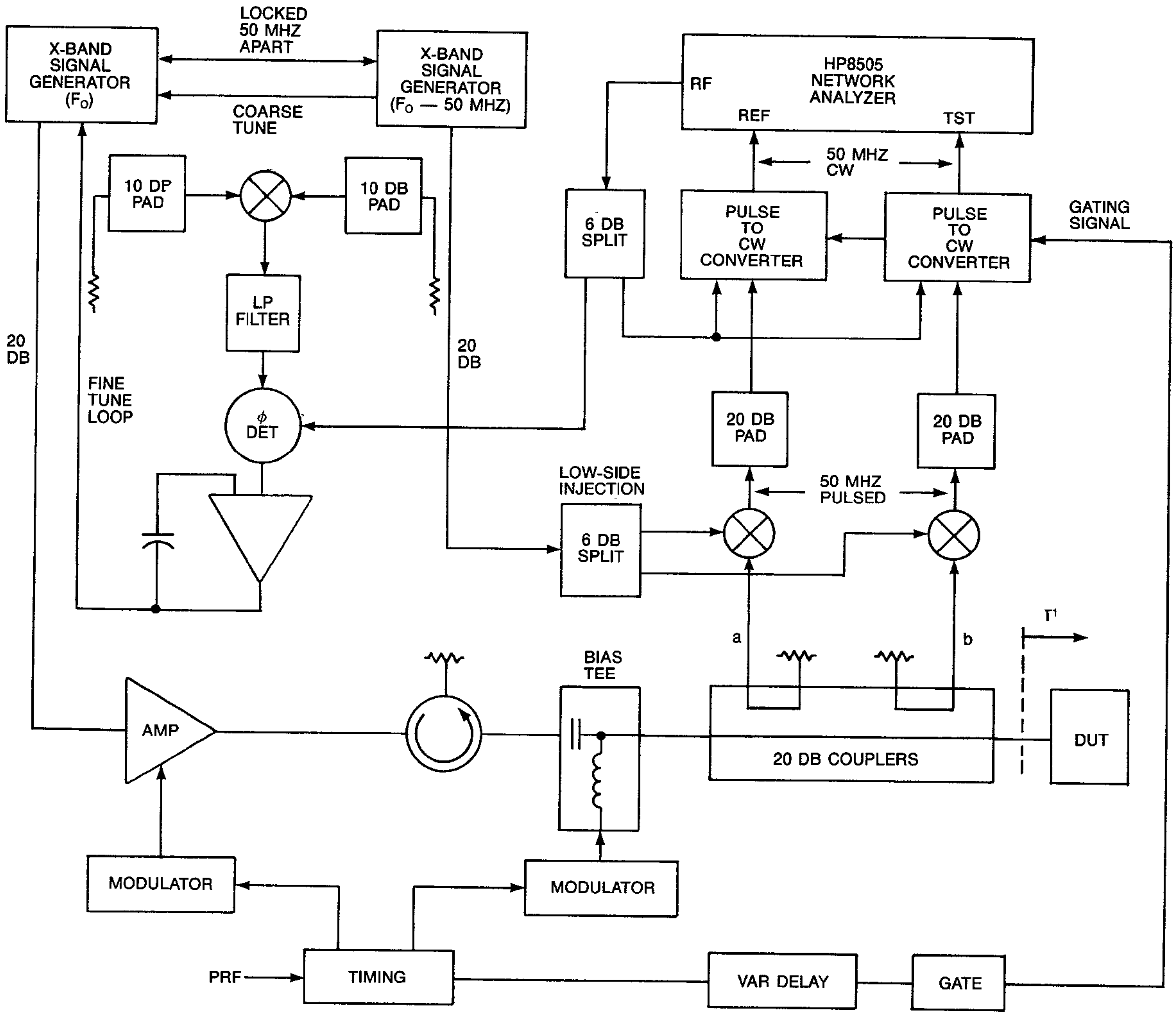

Figure 2. Pulse Network Analyzer.

unique frequency. It could be some other frequency within the range of the HP 8505.

PULSE TO CW CONVERTER DESCRIPTION

The most critical subsystem of the Pulse Network Analyzer is the pulse to CW converter circuits. A block diagram of one of these circuits is shown in figure 3. The function of the circuit is to determine the amplitude and phase of the incoming 50-MHz pulsed signal within a time window, and then by using this information, modify a 50-MHz continuous signal to exhibit an identical magnitude and phase.

Problems initially encountered in the design of these systems were fast loop responses, nonlinear saturation in the components, phase variation in attenuators and amplitude variation in the phase shifters. These problems have been minimized by using the unique multiloop design shown in the figure 3. The system contains two AGC loops and one true phase loop which interact simultaneously. Circuit operation is explained as follows:

The pulsed 50-MHz input signal with power levels in the range from -40 to -10 dBm is AGC amplified to +13 dBm with +7 dBm continuing on to the phase detector. The pulse response time of this AGC circuit is less than 0.5 microseconds over all the input power ranges.

The AGC loop control voltage from this unit is fed to a sample and hold circuit which maintains the amplitude information received from a selectable time window of the 50-MHz input pulse. This gate signal can be as short as 250 nanoseconds and can occur anywhere within, or on the leading or trailing edge of the input pulse. The lower limit on the time slot for sampling is limited by pulse feed-through from the sampling gate signal.

Output of the sample and hold controls an identical attenuator - amplifier gain block in the second AGC loop. Thus, the same gain and associated phase shift is introduced into the second AGC loop as was present in the first loop. The second loop attenuates a 50-MHz CW signal to maintain a 7-dBm output signal to the phase detector. Since the outputs of each loop are maintained at the same power level and each loop contains an identical gain block, the inputs to each loop track in absolute power level.

The 7-dBm outputs of each loop are applied to a phase detector which controls a phase shifter on the CW signal line. This phase loop locks the phases of the two 7-dBm outputs. Since each 7-dBm output signal has passed through identical gain blocks, each with the same overall phase shift, the inputs to each loop are phase locked independent of the absolute power levels. Thus, the CW output signal is amplitude and phase-locked to the pulsed input signal.

The amplitude tracking loops use current controlled attenuators with only five degrees of phase shift for 50 dB of range and with response times of less than 10 nanoseconds. The continuous 50-MHz

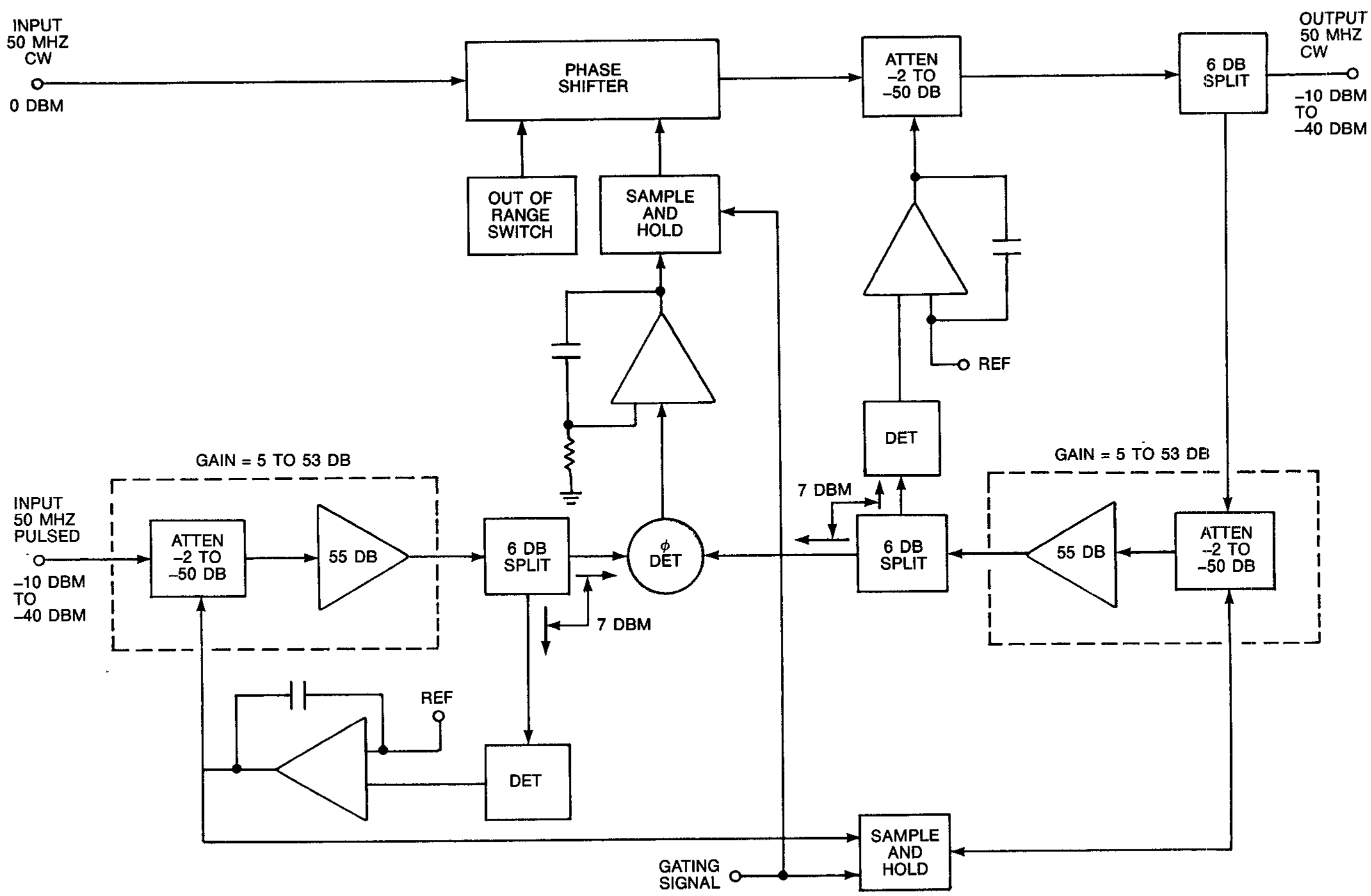

Figure 3. Pulse to CW Converter.

signals are derived from the differential tracking of two of these attenuators resulting in less than two degrees phase error over a 30-dB range. For a 30-microsecond pulse at 1 percent duty and a 1-microsecond sample window the CW signal tracked the input signal within 0.2 dB over the -40 dBm to -10 dBm input signal level. The phase tracking loop uses three hybrid coupled varactor phase shifters with 720 degrees of range at 50 MHz. Implemented into the phase loop is an "out of range" switch which automatically resets the phase loop to the center of its range if an upper or lower phase limit occurs.

ANALYZER UTILIZATION

The Pulse Network Analyzer was used to measure the pulse impedance of a fully-biased, X-Band, GaAs IMPATT diode. The measurement was performed in a setup similar to that shown in figure 2. The diode was placed in a fixture containing a 50-ohm tapered line. The taper ends at the 50-mil diameter top cap of the IMPATT diode. Independent tests of this taper and transition indicated a VSWR of less than 1.3 up to 12 GHz. A gold-plated brass diode was used to set the amplitude and phase reference on the HP 8505.

The IMPATT diode was operated in a standard weather radar transmit pulse format of 30 microseconds pulsewidth and 1 percent duty. The sample window width in this case was 1.0 microsecond and could be positioned to any portion of the 30 microseconds bias pulse. During these measurements, the diode was operated in a nonoscillatory, small-signal mode with an input signal incident on the diode of less than -10 dBm.

The diode admittance obtained at a frequency of 9.34 GHz is plotted on the chart in figure 4. The two curves represent admittances obtained at 10 and 25 microseconds into the 30 microseconds bias pulse and clearly shows the impedance variation due to heating. Each curve gives the measured admittance of the diode as the pulse current was increased from 0.1 to 1.0 amps. Note that the magnitude of the small signal equivalent parallel resistance is on the order of -10 ohms. This was larger than expected and it is believed that this resistance collapses to the large-signal level of -1 ohm as the signal magnitude increases. Further work is planned to measure this effect by increasing the incident signal level to the diode.

The Pulse Network Analyzer was also used to measure the phase and amplitude of the forward transmission of a JTIDS power amplifier. Bit errors were occurring on the leading edge of the JTIDS data burst and the 8-stage power amplifier was suspected as the cause of these errors. To determine the source of the problem, the pulse network analyzer was set up for a transmission measurement and connected to the JTIDS PA. Two L-Band signal generators were phase-locked using a circuit similar to that shown in figure 2.

The sample gate was set to a pulse width of 200 nanoseconds and positioned approximately 1000 nanoseconds into the PA pulse. The system was then calibrated for an S_{21} of unity at an angle of zero degrees. The results of the experiment are shown in figure 5. Note that as the gate pulse was walked toward the start of the PA pulse, the amplitude of S_{21} dropped smoothly to zero and the phase of S_{21} remained nearly constant. The maximum measured phase-shift deviation of -8 degrees was not large enough to account for the bit errors and it was concluded that the missing data bits were not occurring in the PA, but instead at some other point in the system.

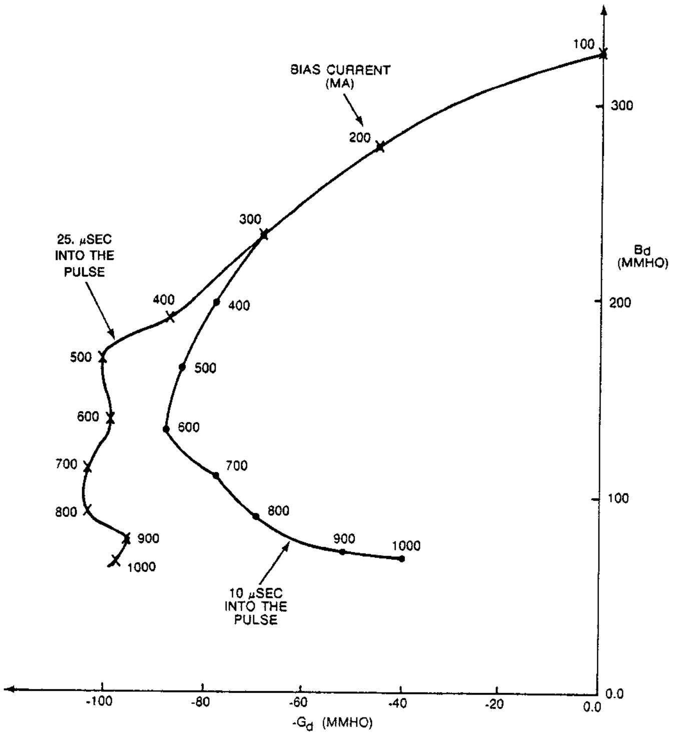

Figure 4. Diode Admittance, 9.34 GHz.

POSSIBLE FUTURE ENHANCEMENTS

One modification of the Pulse Network Analyzer to be implemented this year is to replace the down-conversion mixers with broadband sampling heads. This will improve measurement accuracy versus frequency and extend the frequency range to 18 GHz.

Millimeter wave pulse analyzers using this scheme should be feasible by increasing the 50-MHz baseband signal to 1 GHz. A phase-locked HP 8505 can still be used as the display device since it will operate up to 1.3 GHz. The Si MOSFET sample and hold circuit can be altered by using smaller Si MOSFETS or GaAs MESFETS biased for high on-off ratios.

CONCLUSION

A swept frequency pulse network analyzer has been described which operates in the 0.5 to 12.5 GHz frequency band. This analyzer is capable of measuring the changing pulse characteristics of microwave semiconductor devices by using a variable gating signal. Repetitious impedances with durations as short as 250 nanoseconds can be measured with this system.

REFERENCES

(1) T. Apel and R. Weber, "Large-Signal Pulse Network Analyzer Operation", 1984 IEEE MTT-S International Microwave Symposium Digest, pp. 517-519.

(2) T. Apel, "RF Power Device Characterization Accomplished Through Direct and Indirect Techniques" MSN, Sept. 1984, pp. 115-134.

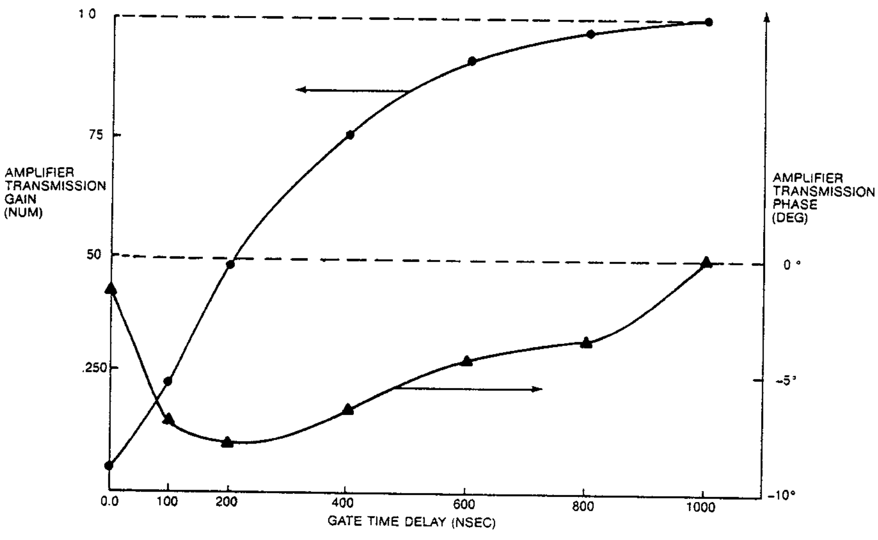

Figure 5. JTIDS Power Amplifier, Transmission Characteristics.