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AUTOMATED MEASUREMENT SYSTEM FOR CHARACTERIZING POWER AMPLIFIER PERFORMANCE

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ABSTRACT

An automated test system is described which measures the transfer characteristics, frequency response, linearity, and dc characteristics of microwave power amplifiers. The system performs, in real time, a 24-carrier C/IM measurement at fixed amplifier output power for linearity tuning.

Summary

This paper describes an automated test system which we have been using for the development of C-band GaAs FET power amplifiers for satellite applications. Empirical tuning of amplifiers is often required because of limitations in device characterization data, variations in device parameters and variations in embedding network performance due to fabrication tolerances. This automated measurement system, which provides fast, accurate amplifier performance data, can improve the empirical optimization, allow experimentation over a wide range of tuning parameters, and provide more information on the relationships between parameters.

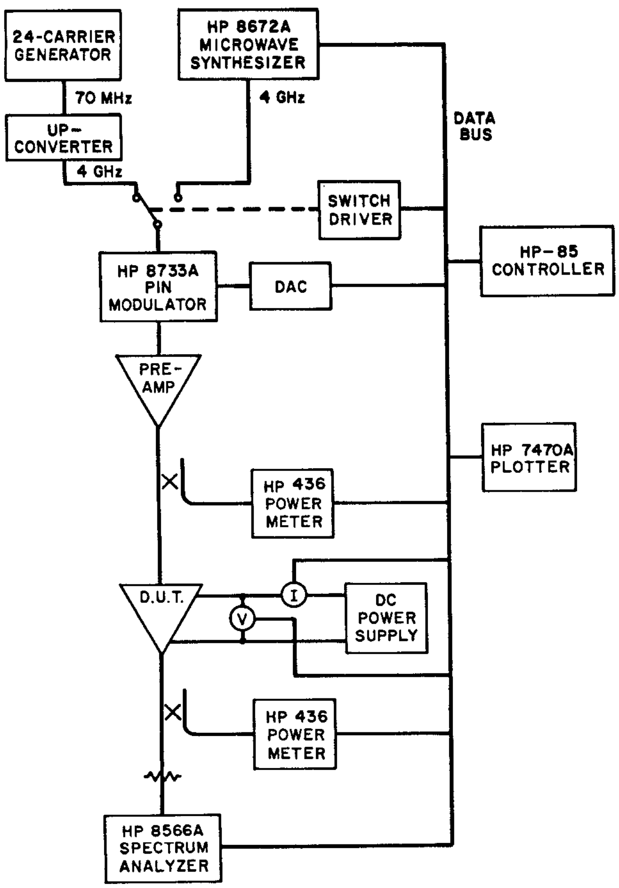

Figure 1 Block Diagram of the Measurement System.

System Description

The measurement system, shown in Figure 1, consists of RF equipment to provide a test signal to the device under test and to measure its response, dc equipment to provide and measure the bias for the device under test, a plotter for data output, and a desk-top computer for controlling the equipment. Two signal paths are shown in the figure, one for the RF and dc signals connected to the device under test, the other for instrument control and data transfer on the IEEE-488 bus connecting the equipment to the computer.

Either a single-carrier or multiple-carrier test signal can be selected with a computer-controlled switch. The single-carrier test signal is produced by a microwave synthesizer. The frequency can be adjusted, under program control over the 3.7-4.2 GHz range of our amplifiers with 1-kHz resolution. The multiple-carrier signal contains 24 carriers and has a bandwidth of about 34.5 MHz. It consists of twenty-three QPSK signals each modulated by a 1.76 Mb/s pseudorandom sequence plus an unmodulated carrier having the same power as the modulated carriers. The spectrum of the 24-carrier signal is shown in Figure 2.

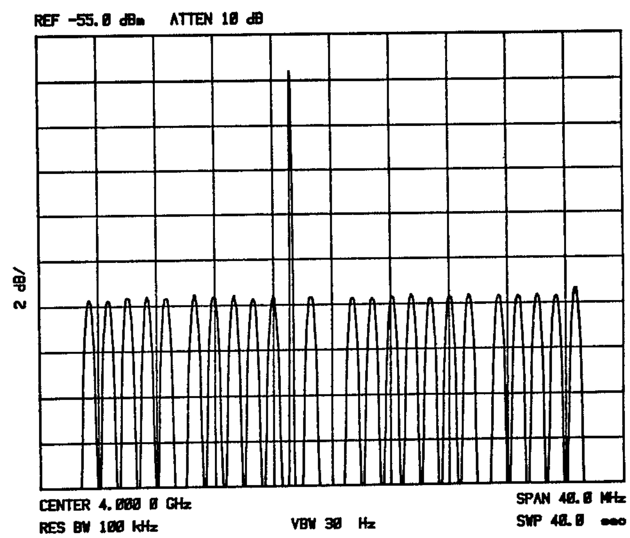

Figure 2 Spectrum of the 24-carrier test signal. One modulated carrier has been replaced by a unmodulated carrier with the same power.

The test signal input power and the amplifier output power are measured with calibrated directional couplers and microwave power meters. A third power meter is also available for auxiliary measurements, such as the power at the isolated port of a hybrid combining network.

The C/IM measurements are made on the 24-carrier signal with a spectrum analyzer. The algorithm was designed to achieve low fluctuations in the measurement of the noise-like intermodulation signals and high speed for real-time operation during amplifier tuning. The routine makes direct measurements of the power of the unmodulated carrier in the 24-carrier test signal and the intermodulcation noise 250 kHz from that carrier. The measured carrier-to-noise ratio is corrected for instrumental effects and scaled to units of dB-Hz. The observed fluctuations in the C/IM values are less than 0.2 dB.

The 24-carrier measurement of linearity was chosen because it is fast and because its results are directly related to the capacity of a real service. Linearity information may be obtained from single-carrier gain and phase transfer measurements, but not in real time. Two-tone tests are fast, but their results are difficult to relate to broad-band measurements. The relationship between 24-carrier and noise power ratio (NPR) measurements is established.

The dc parameters are measured with a digital voltmeter (DVM). The voltage and current on the gate and drain of a device are routed to the DVM by a scanner. A scale factor is loaded into the DVM so that the measurements are displayed in convenient units, e.g., current in mA. The user can monitor any measured parameter.

Operating Modes

The system has two principal operating modes:

Tuning. This mode permits rapid amplifier tuning to optimize selected parameters. The system establishes an input signal of a type, frequency, and power level selected by the user, and it enables the user to monitor in real time the output power, gain, linearity and dc bias of the amplifier. The real-time measurement of amplifier linearity at fixed output power with the 24-carrier signal is a unique feature of the system.

Characterization. The system performs a set of measurements to characterize the performance of the amplifier. The user may select:

1. Transfer Characteristics, i.e., output power as a function of input power. The characteristic is measured over an input power range of 20 dB selected by the user for either a single-carrier or a multiple-carrier test single, or both.

2. Frequency Response The output power for a fixed input power selected by the user is measured at 25-MHz intervals over the frequency range of 3.7-4.2 GHz.

3. Linearity. The carrier-to-intermodulation noise ratio is measured for a 24-carrier test signal over the same range of input power as the transfer characteristics.

4. DC Parameters. The drain-source voltage, gatesource voltage, drain current, and gate current are measured, at the user's option, while any of the above tests are being conducted.

A typical characterization including transfer characteristics, linearity and dc parameters is performed and plotted in about 10 minutes.

System Output

The system also provides data storage and display. Immediately after completion of a test, a video display of the data is provided on the screen of the spectrum analyzer. Previous data can also be displayed for comparison. The data is stored on magnetic tape for later analysis and may also be plotted. Examples of the plots of transfer characteristics, linearity, and frequency response are shown in Figures 3-5.

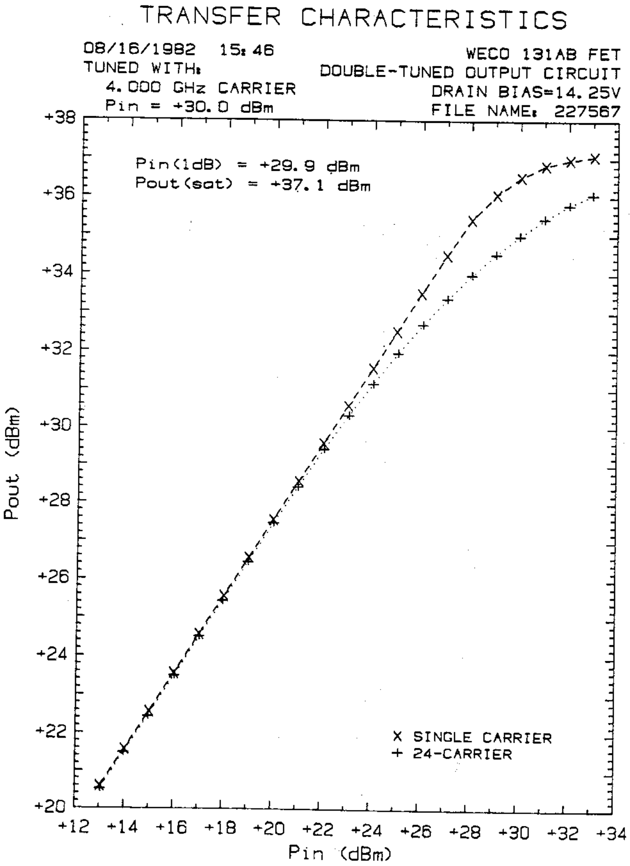

Figure 3. Transfer characteristic plot produced by the measurement system. The amplifier being tested contained a single Western Electric GaAS FET with an 8-mm gate length.

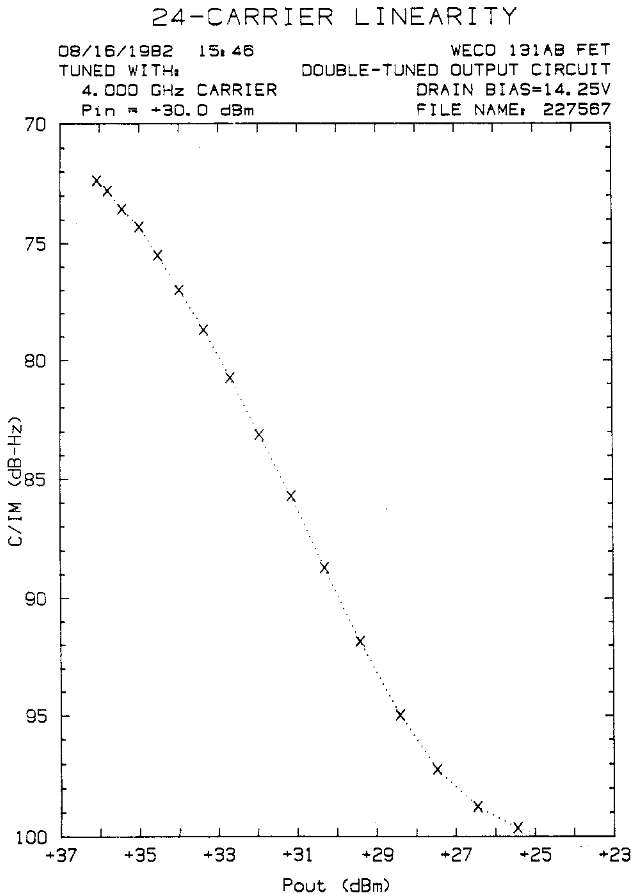

Figure 4. The 24-carrier linearity measurement results for the same amplifier measured in Figure 3.

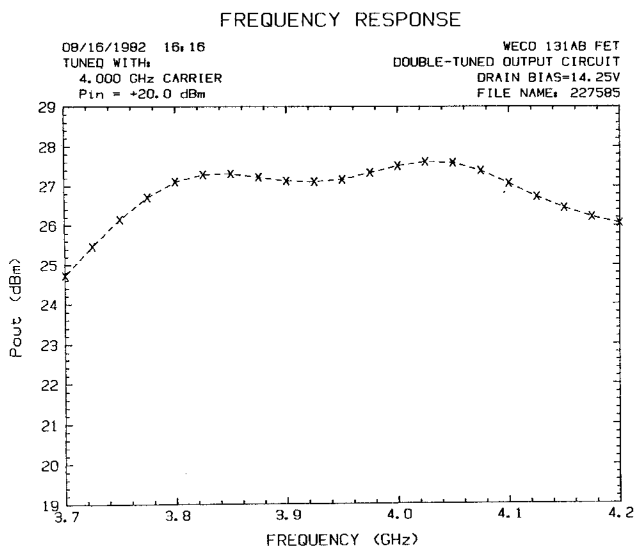

Figure 5. The frequency response plot for the amplifier of Figure 3.

Conclusions

Although this system was designed for our development of C-band satellite amplifiers, it can be used for any C-band amplifier and, with some changes in the test equipment, for amplifiers covering a wide range of microwave frequencies. Devices other than amplifiers could be measured on the system. Hardware changes are easily made, and the (mostly) modular design of the computer program makes possible modifications to accommodate hardware changes or the introdoction of new functions. The features of the system make it useful for both amplifier development and production.