MEASUREMENT OF PHASE AND AMPLITUDE RESPONSE OF A GaAs MMIC BY ELECTROOPTIC SAMPLING

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ABSTRACT

Electrooptic sampling with a gain-switched semiconductor laser is used to measure the voltage gain and phase shift of a GaAs monolithic microwave integrated circuit (MMIC) low-noise amplifier over the 5-15 GHz frequency range. A new synchronization technique enables the phase response to be measured accurately.

Electrooptic sampling is a powerful technique for the noninvasive measurement of voltage signals within high-speed GaAs circuits (1). Although the best temporal resolution and voltage sensitivity in electrooptic sampling are achieved with high-power laser systems such as the pulse-compressed model-locked Nd:YAG laser (1), the gain-switched semiconductor laser (2) is suitable for many applications. The size and reliability of the semiconductor laser make it attractive for use in a practical electrooptic sampling system. Frequency-domain amplitude response measurements using electrooptic sampling have been performed with the mode-locked Nd:YAG laser (3) and the injection laser (4). In this work we extend the use of the injection laser to a wider frequency range and report a new technique (relative phase referencing) for synchronizing the electrooptic sampling system, which enables both the amplitude and phase response to be measured. We demonstrate voltage gain and phase shift measurements over the 5-15 GHz range on a GaAs MMIC low-noise amplifier.

The measurement bandwidth and voltage sensitivity achievable with the injection laser are sufficient for accurate characterization of GaAs MMICs. The 20 ps pulse duration of the gain-switched laser corresponds to a measurement bandwidth of about 20 GHz. By coating the optics and using differential detection, we have increased the received photocurrent to 27 μA to obtain a sensitivity of 0.5 mV/$\sqrt{Hz}$ (-53 dBm/Hz in a 50-Ω system), which is within 4 dB of the shot noise limit. At this sensitivity level, signals of -20 dBm or lower can be accurately sampled in one second or less. We have obtained phase resolution of less than 1 ° for a -10 dBm signal, which is also within 4 dB of the shot noise limit. Similar sensitivities should be obtained on non-electrooptic substrates using an external GaAs probe tip (5).

The electrooptic measurement of the phase response between two nodes of a circuit is complicated by extraneous variations in the phase relationship

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between the laser pulses and the signal being sampled. Even when the microwave synthesizers driving the laser and the circuit are operated from a single time base, the phase between the laser pulses and the electrical signal exhibits enough short term jitter and long term drift to affect the phase measurement. Additionally, the phase relationship between the two microwave synthesizers changes whenever the frequency of one synthesizer is changed. These phase variations must be accounted for in order to perform an accurate measurement of phase shift vs. frequency. We solve this problem by using a high-speed photodiode and a microwave mixer to generate a reference signal which is sensitive to fluctuations of the phase between the laser pulses and the signal being sampled. When the electrooptic sampling system is triggered by this relative phase reference signal, the phase fluctuations cancel out of the measured electrooptic modulation, since the fluctuations are present in both the electrooptic modulation and the reference signal.

We have performed frequency response measurements using the harmonic mixing technique (1) on a GaAs microstrip and on a packaged GaAs MMIC low-noise amplifier. The microstrip measurements (performed up to 18 GHz) clearly show the effect of standing waves on the transmission line. Fig. 1 shows the electrooptic measurement of the voltage gain and phase shift of the MMIC amplifer in the 5-15 GHz range. The solid lines show the amplitude and phase response measured electrooptically. Three overlaid sets of data indicate the scatter in the measurement, for a signal level at the input of -20 dBm. The dotted line in Fig. 1 shows the power gain measured at the wafer level, and the dashed line shows an electrical measurement of the power gain of the packaged circuit. The discrepancies in the measurements of amplitude response are probably due the frequency response of the package, which has not been characterized independently.

In summary, we have applied the gain-switched injection laser to measure the amplitude and phase response of GaAs MMICs and transmission lines by electrooptic sampling, up to 18 GHz. We have devised a phase referencing method which enables the phase response to be measured accurately, and we have measured the voltage gain and phase shift of a MMIC low-noise amplifier over the 5-15 GHz range.

We thank V.J. Zaleckas of AT&T and J. Wooldridge and R.G. Fleeger of Hughes Aircraft Co. for their encouragement and support. Hughes Aircraft supplied the MMIC circuits used in this work. This work was supported by the USAF Aeronautical Systems Division (contract number F33615-89-C-5712).

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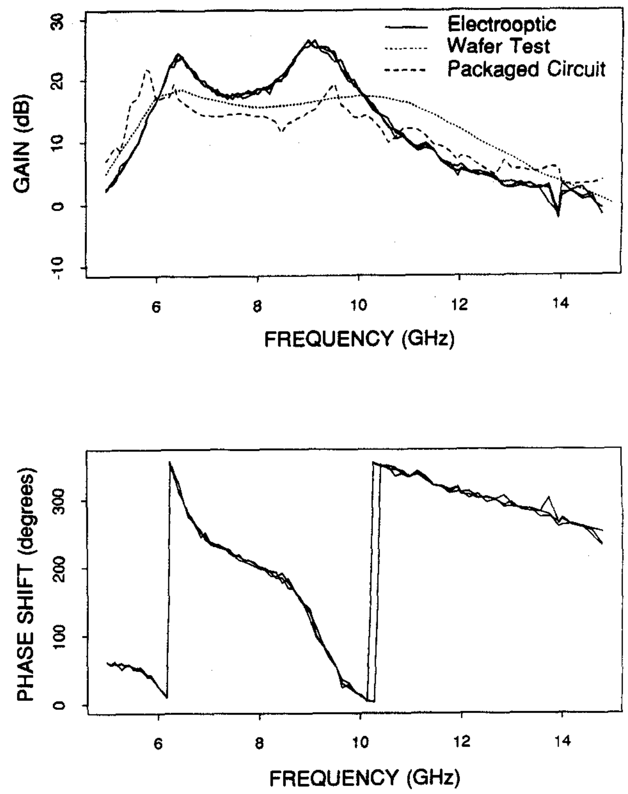

Fig. 1. Amplitude and phase response of MMIC low-noise amplifier