Correspondence

Large Signal Operation of Microwave Transistors

Transistor amplifiers designed for small signal operation and near optimum noise figure in the microwave region have been reported by numerous workers [1]–[4]. As the transistors operate under small signal conditions, conventional characterization in terms of Y or other parameters may be used for circuit design. Accurate measurement of the parameters is somewhat more difficult than at lower frequencies; nevertheless, in principle and practice, the same techniques employed at lower frequencies to measure transistor parameters can be utilized in the microwave region [5].

Transistors designed with higher current and power dissipation ratings while maintaining performance capabilities well into the microwave region, are also becoming increasingly available. Single transistors capable of delivering 2 W output above 2 Gc are now available in the laboratory. It is desirable to utilize such transistors as oscillators and amplifiers where power output and efficiency are of prime importance. The maximum power output and efficiency from a given transistor is obtained under Class C operations (i.e., collector current flowing appreciably less than one-half cycle) and in general the parameters of the transistor under such large signal operation vary considerably from small signal values. This variance of parameters is not necessarily objectionable when it is possible to incorporate tuning adjustments in the amplifier or oscillator circuit. However, it is often undersirable, either from a fabrication or design philosophy viewpoint, to employ tuning adjustments in some circuit applications. Under such conditions it is necessary to obtain a knowledge of the transistor characteristics at various "levels" of large signal operation.

One method of obtaining the information desired in a form directly applicable to amplifier circuit design is shown in Fig. 1. Figure 1(a) represents a single stage test amplifier with the networks N_i and N_o being adjustable and capable of presenting a wide range of impedance variation to the transistor. These networks may be multistub tuners or an arrangement such as in Fig. 1(b) with a 3-dB hybrid and adjustable stubs. The latter network has the advantage of a complete range of impedance match possible and a direct correlation of the length of the tuning stubs S_1 and S_2 to the impedance seen by the transistor. The transistor under measurement is then operated in the test amplifier at various output powers and at the desired frequencies. The source and load admittances (or impedance) can then be determined either directly from the tuning stub positions or by VSWR measurements made looking back toward the source (or load) and referenced to the transistor terminals. Measurements made by the latter method as a function of output power for two silicon transistors in the common base configuration are shown in Figs. 2 and 3. A family of such curves over the frequency range of interest should provide information for the preliminary design of broadband power amplifiers.

One may question the validity of this method of characterization as no measure of stability is provided. Reverse gain measurements may be made, however, and it was observed that if the test amplifier is adjusted for maximum output at a given input power

Manuscript received May 6, 1965; revised August 23, 1965. This work was supported in part by the AF Avionics Lab., Res. and Tech. Div., AFSC

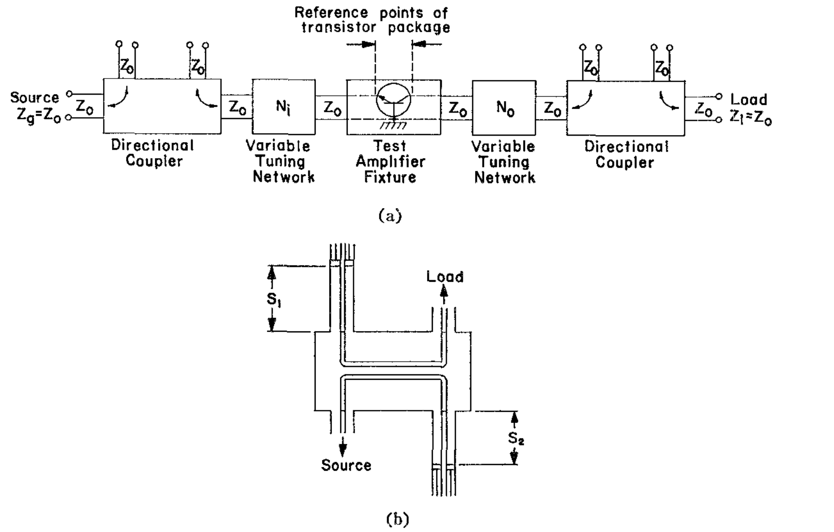

Fig. 1. (a) Block schematic of coaxial test arrangement for large-signal characterization of transistor; (b) Block schematic of coaxial 3-dB hybrid with adjustable shorted lines for use as flexible tuning network for N_i or N_o.

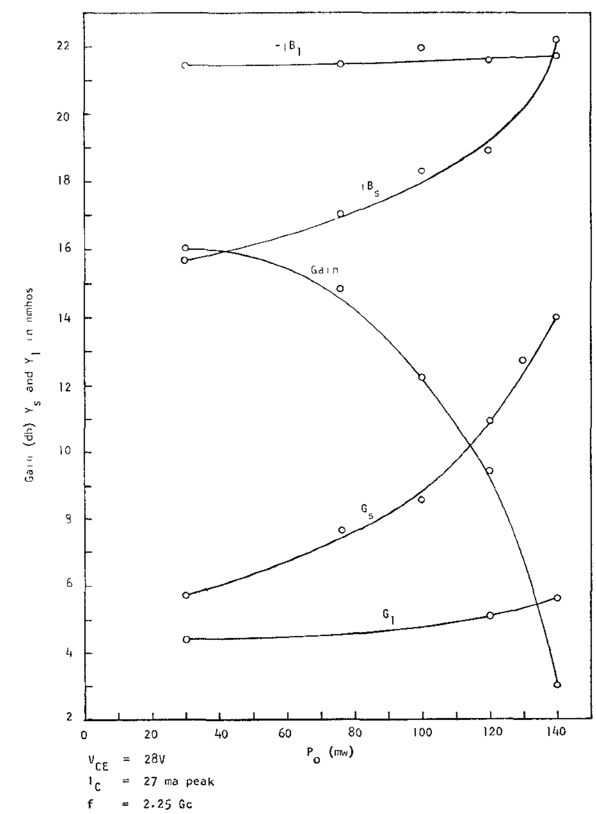

Fig. 2. Gain, Y_s, and Y_l vs. peak output power (20 μs, 5 kc pulsed) for AP1-B No. 66 silicon transistor

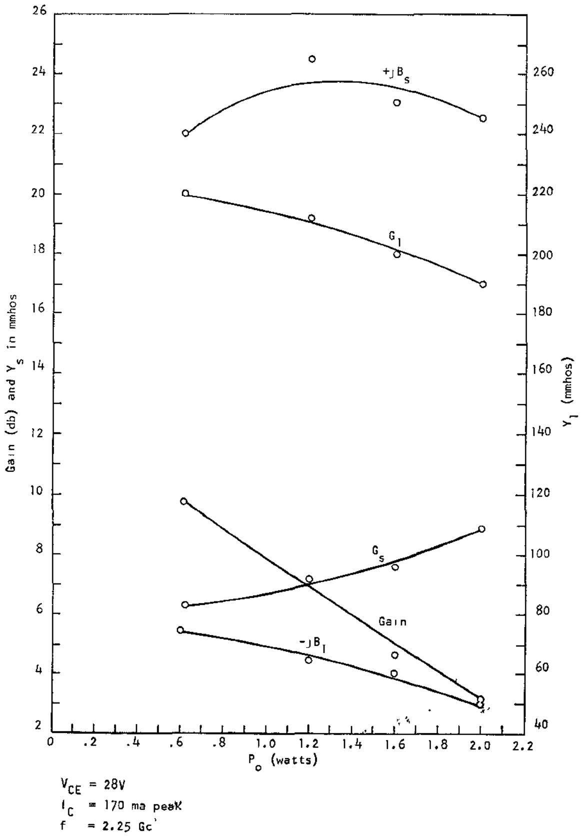

Fig. 3. Gain, Y_S, and Y_l vs. peak output power (20 μs, 5 kc pulsed) for A63-B No. 10 silicon transistor.

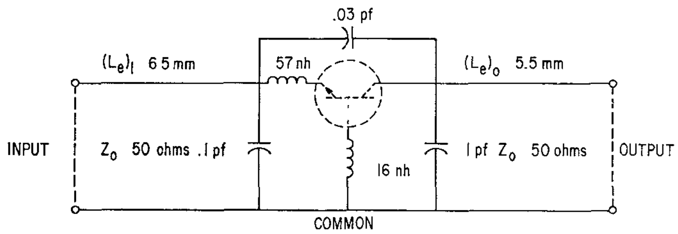

Fig. 4. Approximate equivalent circuit of T1-line package.

while maintaining a minimum of reflected power in the input, reasonably good input to output isolation was obtained and admittance measurements made at low power levels (small-signal) correlated closely with values calculated from small-signal Y parameters.

The measured source and load admittance in Figs. 2 and 3 are references of the terminals of the stripline package in which the transistors were packaged. The approximate equivalent circuit of this package is shown in Fig. 4 with the common-base configuration indicated. The internal inductances are somewhat lower than shown for the higher power transistor of Fig. 3 because of the method of lead bonding. The package reactances of this, or other typical microwave packages, can cause a considerable transformation between the admittance presented at the terminals of the transistor package and that seen from the transistor chip itself. For this reason, it is especially important with power transistors in the microwave range either to characterize the transistors in the packaging configuration in which they will be utilized in the circuit application, or to accurately know the package parameters so that suitable corrections can be made if the transistors are mounted in a different environment.

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A Four-Bit Latching Ferrite Switch

Introduction

Latching ferrites [1], [2] are rapidly advancing a new era of solid-state devices [3], [4]. These new devices require neither external magnets nor continuous drive current, and, in many applications, are far superior to those which utilize conventional biasing techniques. The resultant economy of weight and power supply requirements suggests the possibility of uses in a variety of microwave components such as circulators, switches, isolators, and digital phase shifters. Their fast-switching lightweight characteristics make them particularly suited to phased array and other systems.

This correspondence deals with a novel approach for combining polarized input signals through the use of latching ferrites. Vertical, horizontal, left-hand circular and right-hand circular polarized input waves are combined at a common output as shown in Fig. 1.[1] This is accomplished by proper selection of the bit states of a fast-switching, lightweight four-bit latching ferrite switch, the term bit being used to describe a single (90°) differential phase shift section. A transistorized power supply, and associated electronic driver, is used to select and transmit the commands necessary for the desired mode of operation.

Development of a 90° Bit

An experimental model of a 90° bit is shown in Fig. 2. It consists of a straight section of waveguide, with the toroid placed directly in the center and with the waveguide width reduced in the vicinity of the ferrite. The selection of material for the toroid can be obtained from the graph of Fig. 3. These data have been collected from previous empirical work with broadband ferrite circulators [5] and have been found to be applicable to phase shifters. One-piece toroids were formed by pressing the material around a mandrel. This technique has been found to be far less costly than the ultrasonic cutting method by which the final toroid was built up from shorter toroidal elements cemented together. Dielectric-stepped transformers of $K=10$ were designed, using techniques previously outlined by Cohn [6] and Vartanian [7], to match out the impedance of the air-filled waveguide to that of the loaded section which has a dielectric constant of $K=16$. A 0.010-inch diameter beryllium copper wire was used to pass the current pulse down the center of the toroid. To minimize RF magnetic coupling effects, it is essential that the wire travel a path parallel to the H plane from the toroid to the waveguide wall from which it emerges.

Initial test data indicated the presence of a sharp "spike" in both the VSWR and insertion loss characteristics. However these spikes were effectively suppressed through the use of cylindrical sleeves, made from a lossy material, and inserted into the waveguide walls through which the charging wires entered and emerged.

Manuscript received May 6, 1965; revised June 25, 1965.

[1] Since the waveguide supports only one mode, it should be understood that the actual conversion of the other various polarizations, to that one supported by the waveguide, takes place before they reach the switch.