BROAD-BAND PUSH-PULL POWER AMPLIFIER

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ABSTRACT

This paper describes a broad-band push-pull amplifier. A new broad-band phase inverter which is necessary for constructing this amplifier is devised. The experiments on the amplifier are carried out at 5 - 18 GHz band. The bandwidth of 11 GHz and the output power of 1.85 W(32.7 dBm) are obtained.

INTRODUCTION

Many studies of a broad-band power-combining amplifier for microwave and millimeter-wave bands have been reported. To construct the amplifier using FET, a 3 dB, 90° hybrid couplers have been used so far. Since such amplifier operates as a class A amplifier, the current flows in FET when there is no signal, and when the power of the input signal becomes large, the nonlinearity of FET cannot be neglected and large distorsion of the signal occurrs.

As a way of obtaining high power-combining efficiency and of reducing the distortion, one may use a push-pull amplifier. The author has already reported this amplifier.1),2). This paper describes a broad-band push-pull amplifier. For this amplifier, a phase inverter which has a simpler structure and broader frequency characteristics compared with those of the phase inverter described in Ref. 1 is devised.

STRUCTURE OF A BROAD-BAND PUSH-PULL POWER AMPLIFIER AND EXPERIMENTAL RESULTS

Figure 1a shows the block diagram of a broad-band push-pull power amplifier. As seen from this figure, we have 0° and 180° phase angles at the drain and source of FET, and to each of these terminals, the input ports of the amplifiers are connected. A push-pull amplifier is formed by connecting the output ports of the two amplifiers to a phase inverter whose characteristics were reported in Ref. 1.

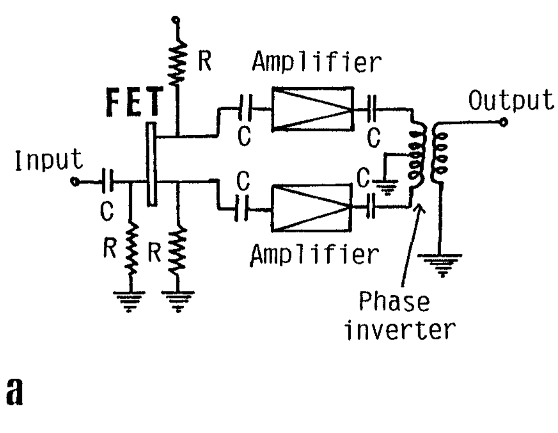

Fig. 1a Block diagram of the push-pull amplifier

The phase difference between the drain and source of FET which is used as a phase inverter in the input circuit becomes less than 180° as the frequency increases. Hence, we cannot use FET in a push-pull amplifier.

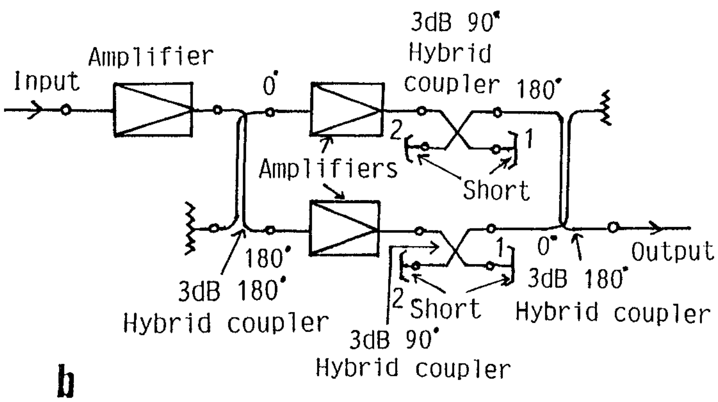

Fig. 1b Block diagram of the 5-18 GHz broad-band push-pull power amplifier

This problem can be solved if we use a hybrid coupler which maintains 180° phase difference over a wide frequency range. The author used 3 dB, 180° hybrid couplers in the circuit shown in Fig. 1b. In this circuit, the phase inverter used in the output circuit in Fig. 1a is also replaced by 3 dB, 90° and 180° hybrid couplers which have better frequency characteristics than those of the phase inverter.

As shown in Fig. 1b, we use a broad-band amplifier of 0.5 W for the excitation, and the output terminal of this amplifier is connected to the input terminal of the 3 dB, 180° hybrid coupler. To each of the output terminals with 0° and 180° phase angles of the hybrid coupler, a broad-band amplifier is connected, and these amplifiers are followed by the two 3 dB, 90° hybrid couplers. The terminals 1 and 2 of these hybrid couplers are short circuited, which is equivalent to connecting filters at these terminals. The operation of these filters is identical with that of the filter used in the phase inverter described in Ref. 1. However, the filter obtained by short-circuiting the terminals 1 and 2 of the 3 dB, 90° hybrid coupler has broader frequency characteristics than those of the filter used in Ref. 1. It is thought that grounding the terminal 1 is equivalent to grounding the midpoint of the secondary side of the phase inverter shown in Fig. 1a. To construct the push-pull amplifier, the output terminals with the phase angle 0° of the two 90° hybrid couplers are connected to the terminals with the phase angles 0° and 180° of the 180° hybrid coupler. The operating frequency range of the two push-pull power amplifiers and broad-band power amplifier used at the exciting part is 6 - 18 GHz, and they are the products of Fujitsu with the output power of 0.5 W.

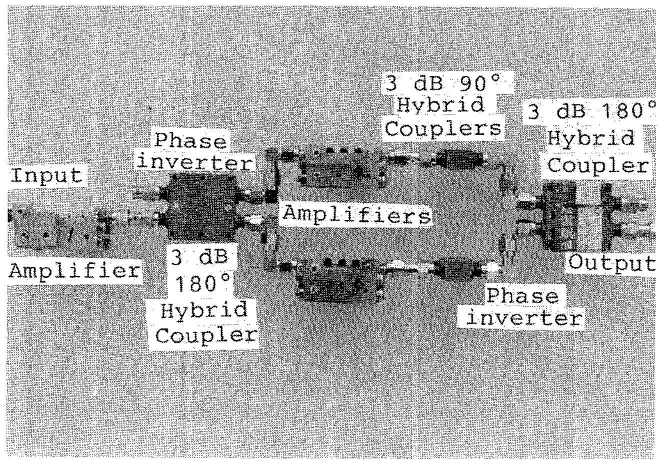

Fig. 2 Photograph of the broad-band push-pull power amplifier shown in Fig. 1b

Figure 2 is a photograph of the constructed broad-band push-pull power amplifier of Fig. 1. The bias voltage of the exciting amplifier was so chosen that it operated at class A, whereas the push-pull amplifiers operated at class AB_2. Figure 3 shows the frequency characteristics of the push-pull power amplifier. The phase difference of the two power amplifiers is shown in Fig. 3a. We see that the phase difference becomes larger than 10° when the frequency exceeds 16 GHz. As described in detail in Ref. 1 , the phase angles of S_{21} should be the same to construct the

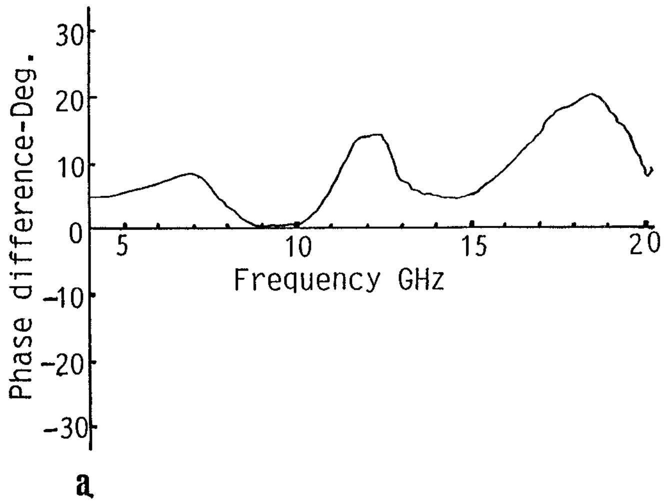

Fig. 3a Phase difference of two power amplifiers

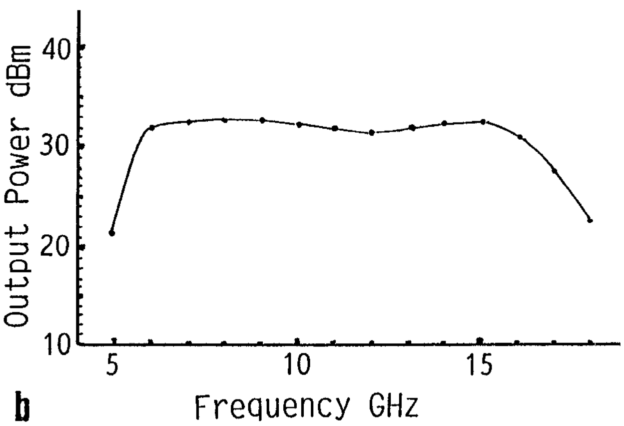

Fig. 3b Frequency characteristic of the broad-band push-pull power amplifier

push-pull amplifier. But it is quite difficult to have the same phase angle over the wide frequency range.

Figure 3b shows the frequency characteristics of the push-pull amplifier for the phase-angle difference of Fig. 3a. We see that the output power is 1.85 W(32.7 dBm) and the bandwidth is 11 GHz. In the range of 6 - 11 GHz, the phase difference is from 0° to 13.5° and, for this difference, the output power has flat characteristics with the maximum of 1.85 W. Since the phase difference is about 13.5° around 12 GHz, the output power slightly drops to 1.5 W(31.8 dBm). Above 16 GHz, the phase difference exceeds 10°, and as a result, the output power is less than 1.85 W. As seen from the above results, we can construct a push-pull amplifier using two amplifiers if the difference S_{21} between the phase angles of the two amplifiers is less than 10°.

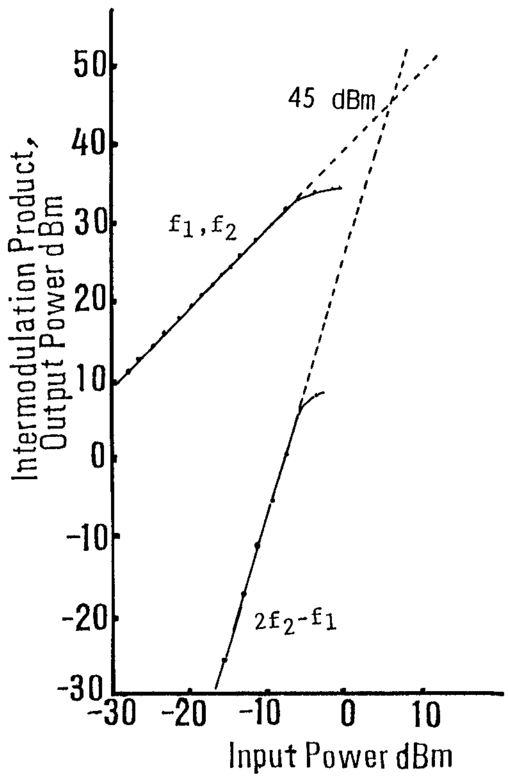

Fig. 4 Output power and third order intermodulation production versus input power at the center frequency(f_1=10 GHz, f_2= 10.010 GHz)

Figure 4 shows the measured results of the input-output characteristics and third order intermodulation distortion of the push-pull power amplifier. The measurement was done with a spectrum analyzer by injecting into the amplifier the fundamental signal at 10 GHz and the signal with the same level but at frequency shifted by 10 MHz. The intercept point was 45 dBm.

CONCLUSION

A broad-band push-pull power amplifier has been described. To construct this amplifier, a broad-band phase inverter was devised by using commercially avaiable 3 dB, 90° and 180° hybrid couplers. It was shown that we could construct a broad-band push-pull power amplifier if the difference S_{21} between the phase angles of the two power amplifiers is less than 10°.

ACKNOWLEDGEMENT

The author is grateful to Fujitsu Co. for providing broad-band amplifiers.

REFERENCES

1) S.Toyoda "Microwave Band Push-Pull power Amplifiers. Trans., IEICEJ, Vol J72-C-I No. 2 PP. 101-109 February 1989.

2) S.Toyoda "Power Combining System Using Two Push-Pull Power Amplifiers" Thirteenth International Conference on Infrared and Millimeter waves Vol. 1039. PP. 53-54 5-9 December 1989.