A New Balanced Amplifier using 6-Port Power Divider

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***Abstract* — A new balanced amplifier using the 6-port power divider[1] is proposed. The power divider used in this balanced amplifier has a totally planar structure, and needs no internal resistor and termination. The measured insertion loss of the 2-port back-to-back power divider/combiner for the balanced amplifier is around 0.7dB, which is a reasonable value at 10GHz. In power measurement, the 1dB output power compression point of the proposed balanced amplifier is twice that of the single-ended amplifier as predicted. The measured performances show that the proposed amplifier can be applied as a new balanced amplifier**.

I. INTRODUCTION

In general, balanced amplifier structures are often used in high power application, because the output power can be doubled by combining the power from two paths[2,3]. The Wilkinson divider, 90° branch hybrid, and the lange coupler are widely used in balanced power amplifiers. These divider/combiners require an internal resistor or termination. The resistor and termination have a critical limitation on the operating bandwidth and the magnitude of the output power that they can handle. The higher the operating power, the higher the power rating value is required to the termination. Furthermore, the internal resistor and termination require one more step in the fabrication process than the case in which they are not required.

Despite their problems, these kinds of dividers have been used widely because of their performance, simple design, and usefulness in power combining systems, especially in balanced power amplifiers. Here, we propose and add a new balanced amplifier using the totally planar power divider/combiner, which does not require any internal resistors and termination. The power divider/combiner for this new balanced amplifier is obtained from the 6-port power divider proposed in [1].

For the verification of the performances of the power divider/combiner section, we have measured the 2-port back-to-back power divider/combiner, and applied it to the proposed balanced amplifier. The measured S-parameters and power performances of the single-ended and the balanced amplifiers will be shown and compared in the following sections.

II. TWO-PORT BACK TO BACK POWER DIVIDER/COMBINER REFORMED FROM THE 6-PORT POWER DIVIDER

The power divider in [1], shown in Fig 1(a), has several advantages. First, it is possible to determine the dividing ratios and output ports arbitrarily. Therefore, we can design the divider with the desired dividing ratio at different output ports. Second, no internal resistors and termination are required, because this divider has a totally planar structure. Hence, it is very easy to design, fabricate, and measure the performance.

The measured performances of the 6-port divider in [1] showed us that the input power injected into port 2 is divided into port 1 and port 3, and the input power into port 5 is divided into port 4 and port 6. In other words, when the input port is port 2 or port 5, this 6-port divider acts like a 2-way power divider. At this time, port 2 is isolated from port 4,5,6, and port 5 from port 1,2,3. The measured performances of Fig 1(a) and detailed values of Z_1 to Z_5 are not issues of this paper and omitted here.

In Fig. 1(a), the output power ratio at port 1 and 3 is 1:1 when the input port is port 2 and Z_1 is equal to Z_2. The same situation goes for port 4 and port 6, that is, a 1:1 ratio when port 5 is the input port and Z_4 is equal to Z_5.

A 1:1 power divider which has two outputs of the same phase can be used as a power combiner which has two inputs of the same phase[4]. Therefore, this 6-port power divider can be used as a 1:1 2-way power divider and as a 1:1 2-way power combiner simultaneously by adjusting Z_1, Z_2, Z_4, and Z_5. When the input power at port 2 is divided into ports 1 and 3 by the ratio of 1:1, the divided power is injected into ports 6 and 4, respectively. The combined power appears at port 5. Hence, the 2-port back-to-back power divider/combiner can be defined as shown in Fig. 1(b).

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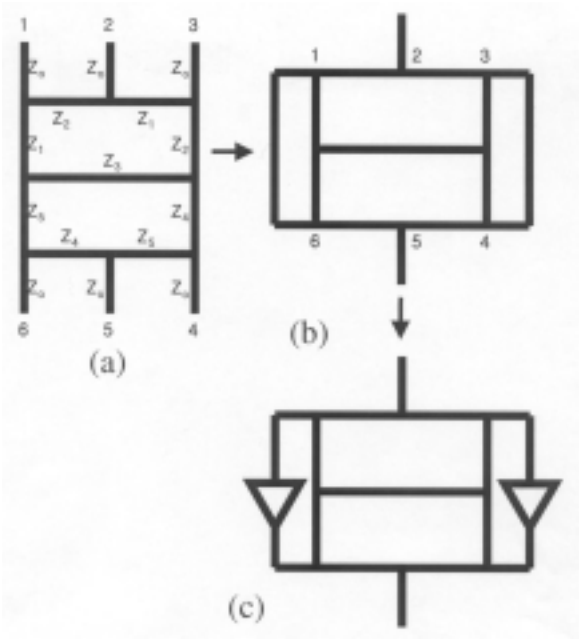
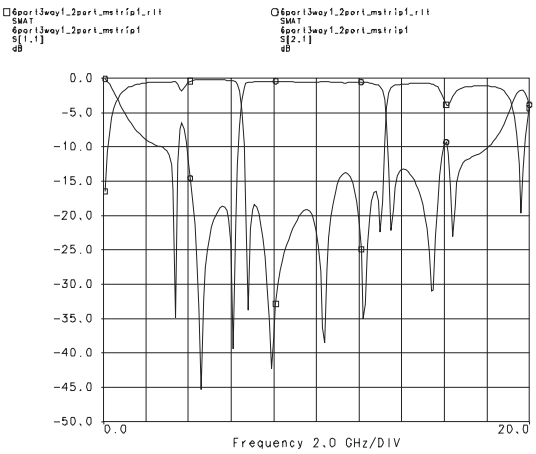


Fig.1 The proposed balanced amplifier and power divider/combiner
(a) The 6-port power divider
(b) 2-port back to back power divider/combiner
(c) Configuration of the proposed balanced amplifier

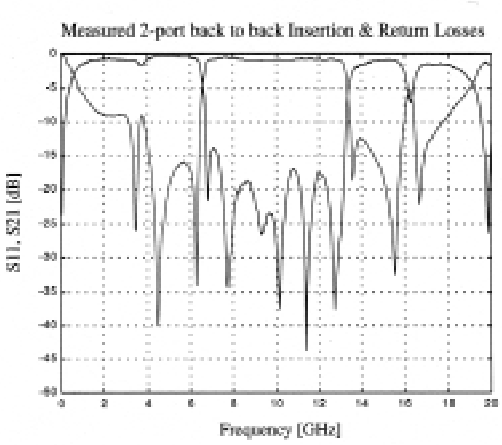
It is very easy to realize the circuit and measure it, because the structure of the circuit in Fig. 1(b) is a totally planar structure. The predicted performances and measured results of this circuit over 0~20 GHz are shown in Fig. 2. Elliptic Band Pass Filter characteristics with a very broad bandwidth over 60% are observed. The measured in-band insertion loss is around 0.7dB, and the reflection coefficient is about 20dB. From the measured data, the loss of one power divider or combiner is about 0.35dB. Although this loss has occurred due to the combination of the divider/combiner section and extra length of line, a careful design and fabrication process will allow us to reduce it.

III. New Balanced Amplifier

Fig. 1(c) shows the configuration of the proposed balanced amplifier using the 2-port back to back power divider/combiner. The electrical lengths of the left and right paths are exactly the same. Hence, this power divider/combiner and two identical single-ended amplifiers compose a balanced amplifier[2,3]. Since the proposed balanced amplifier includes a totally planar power divider/combiner, no resistors and termination are required in the power dividing/combining section. Therefore, this balanced amplifier can handle high power without high power termination and internal resistors.



(a)



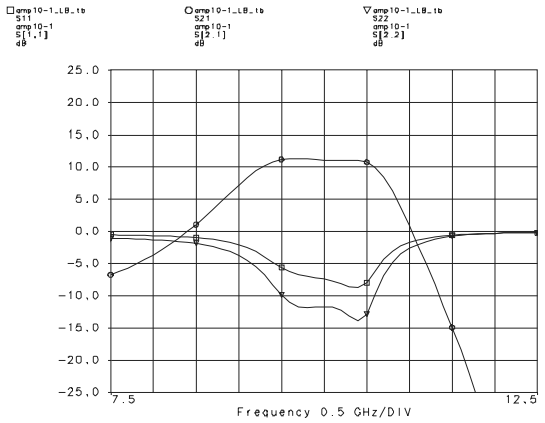
(b)

Fig. 2 (a) The predicted performances and (b) the measured results of the 2-port back to back power divider/combiner

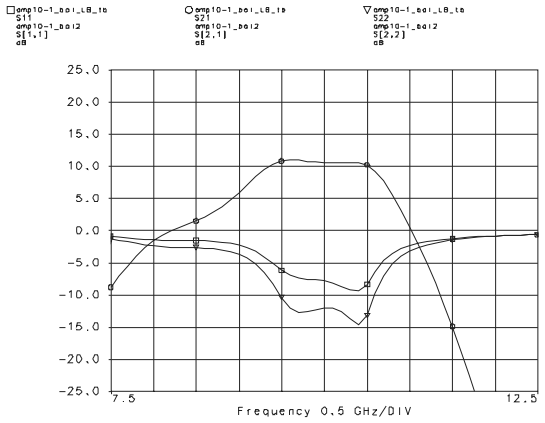
The single ended amplifier used in the proposed balanced amplifier has been designed using a general purpose HEMT device for the X-/Ku-band and a widely used microwave substrate. 10GHz was chosen as the center frequency, because it is simple to design, fabricate, test, and compare its performances using the in-house

equipment and facilities. Two identical single ended amplifiers and the 2-port back to back divider/combiner reformed from the 6-port power divider compose the proposed balanced amplifier.

Fig. 3 and Fig. 4 show the predicted and measured S-parameters of the single-ended and balanced amplifier, respectively. The single-ended amplifier has very flat gain and good return losses over the 9.5~10.5GHz band in their predicted and measured performances. The gain and return losses of balanced amplifier are still reasonable, although the losses in the power divider/combiner section are included. No attempts were made to tune or optimize the performances during S-parameter measurement.

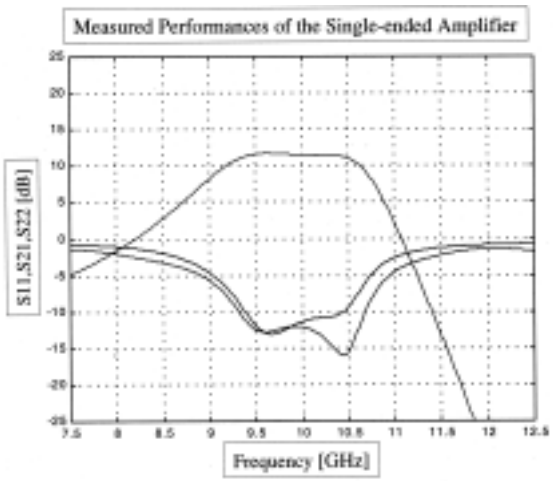


(a)

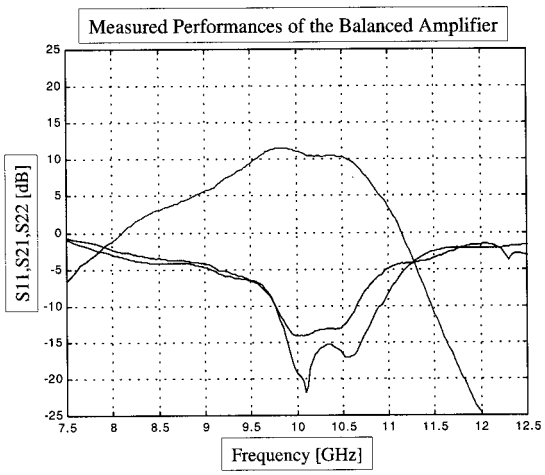


(b)

Fig. 3 Predicted S-parameters of (a) the single ended amplifier and (b) the balanced amplifier



(a)



(b)

Fig. 4 Measured S-parameters of (a) the single ended amplifier and (b) the balanced amplifier

Although the used HEMT device was not a high power device of Watt-level, powermeasurements have been performed for the comparison of the output power from the single ended and balanced amplifiers. Fig. 5 shows the measured P_{in}-P_{out} characteristics of the single ended and balanced amplifiers at 10GHz. The P_{1dB} of the balanced amplifier is higher than that of the single-ended amplifier by almost twice as was expected. The measured output power of the balanced amplifier is quite acceptable because there is a finite loss in the power divider/combiner. It has been verified that the output power capability has been increased by twice than single ended amplifier through the power measurement.

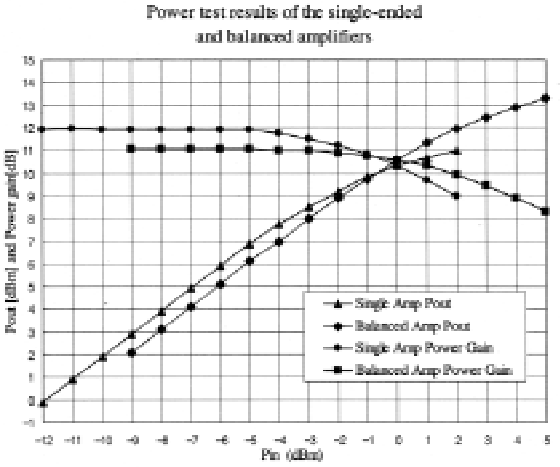


Fig. 5 Measured power performances of the single ended and the balanced amplifiers (Fo=10GHz)

IV. CONCLUSION

A new balanced amplifier which makes use of the 6-port power divider as a 2-port back to back power divider/combiner has been proposed. This balanced amplifier adopts the broadband power divider/combiner, which has a totally planar structure without any internal resistors and termination. The measured insertion loss of the back to back power divider/combiner was 0.7dB at 10GHz. The gain of the balanced amplifier was slightly less than that of the single ended amplifier due to the loss in the power divider/combiner. However, the output power of the balanced amplifier was twice that of the single-ended amplifier. The proposed balanced amplifier can be applied for high power amplifiers because of simple design, planar structure, and verified performances.

ACKNOWLEDGEMENT

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