the value corresponding to the selected reference point. This was realized by detecting the averaged intensity of the pulse sequence through the etalon, and by applying this signal in a feedback loop to control the temperature of the silicon chip. The control method relies on the average power staying constant during the measurement. The feedback signal was generated by modulating the pulse width of an external frequency generator by the detected average intensity, and by using a microcontroller to generate a current proportional to the width of the pulse. The microcontroller was programmed to perform all of the operations needed in the measurements. First, the transmission spectrum of the etalon (see Fig. 1) is scanned by applying a high heating current. During the scan, the average power of the laser should stay constant to avoid errors when the reference points are determined. The value for the transmission at the maximum and minimum points T_{max} and T_{min} are stored, and the desired reference point T_0 is calculated. We chose the reference point T_0 (see Fig. 1) according to $T_0 = (T_{max} + T_{min})/2$. The reference point at the positive slope and then at the negative slope are then searched and locked for the measurements. The time traces of the detected voltages from both slopes of the etalon fringe are transferred to the computer, and the time-resolved frequency chirp is calculated from Eq. (1). The whole measurement procedure takes about 2 min.

The performance of the device was tested by measuring the frequency chirp of a DFB laser that was modulated using a pseudorandom-bit sequence at the rate 2.5 Gbits/s. The time trace of the detected signal intensity for a 12 bit sequence "010110011101" and the corresponding time-resolved frequency chirp are shown in Figure 3. The average power of the modulated laser output was -0.8 dBm. The adiabatic part of the chirp varies linearly with the signal power, but there are also larger frequency transients present at the fast changes of the optical power. The detected time trace of the signal is an average of 64 values at each measurement point.

5. CONCLUSION

We have developed and demonstrated a simple and inexpensive device for measurements of the time-resolved frequency chirp in narrowband light sources used for telecommunication purposes. The device makes use of a solid silicon wafer as a frequency discriminator to convert fluctuations in the laser frequency into variations in the transmitted signal intensity. The transmission of the etalon is tuned by controlling the refractive index of silicon by changing the temperature of the chip. The FSR of 105 GHz allows frequency chirp up to ± 25 GHz to be measured with a time resolution of about 20 ps. The attractive features of the chirp analyzer include a broad wavelength range, insensitivity to mechanical vibrations, and to the polarization state of the light.

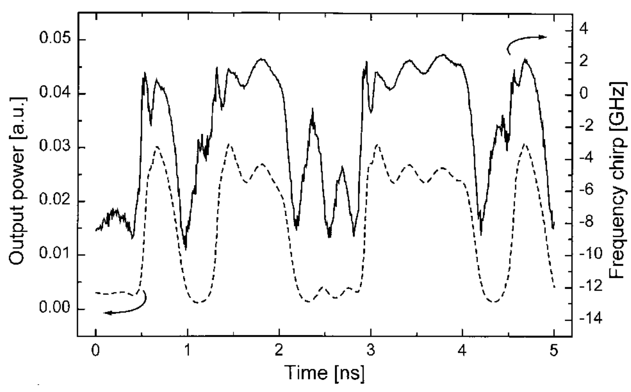

Figure 3 Time traces of the modulated laser output power and the measured frequency chirp for a DFB laser operating at 1.55 μm

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X-BAND BALANCED POWER AMPLIFIER USING NOVEL COUPLER WITH 50% POWER-ADDED EFFICIENCY

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ABSTRACT: *In this paper, we demonstrate an X-band balanced power amplifier using a novel microstrip line dc blocking impedance-transforming branch-line coupler (DCITBC). This novel coupler has the function of dc blocking, which can easily cascade two stages of an active circuit together. Therefore, we can reduce the cost and the circuit size. The measured power-added efficiency of this balanced power amplifier is 50% over the 9.8–10.2 GHz band, with an associated gain of 9 dB and 25 dBm output power. Additional important results are the superior performance of the harmonic suppression; the measured result shows a second harmonic below -40 dBc without an extra harmonic rejector.* © 1999 John Wiley & Sons, Inc. Microwave Opt Technol Lett 20: 192–195, 1999.

Key words: *power amplifier; balanced amplifier; coupler*

INTRODUCTION

In radar, communication systems, and phased-array antenna applications, high-power and high-efficiency amplifiers are required. Branch-line directional 3 dB couplers are used extensively in balanced amplifiers for power combining. The conventional branch-line coupler has quarter-wavelength lines with 50 Ω input/output impedances. The asymmetrical branch-line impedance-transforming coupler was first reported by Lind [1], and is used in balanced amplifier design by Gillick [2]. The dc block coupler was proposed by Buoli [3]. In this paper, we propose a coupler which has the combined advantages of the impedance-transforming coupler and the dc blocking coupler. We call this coupler the dc blocking impedance-transforming branch-line coupler (DCITBC). Applying this coupler to balanced amplifiers can reduce the required matching network, and can block the dc current between the two cascade stages.

The performance of an X-band high-efficiency balanced amplifier using this coupler is presented. For efficiency consideration, the level of harmonic distortion is a key issue. Here, to reduce the undesired harmonics, we terminate the output of the devices at lower reactances [4]. This balanced amplifier is attractive because of its excellent cascade ability, power-combining property, and good stability.

COUPLER DESIGN

A. Impedance-Transforming Branch-Line Coupler [1]. The conventional impedance-transforming branch-line coupler is shown in Figure 1. Its corresponding line characteristic for 3 dB coupling in terms of the termination impedances of the coupler port Z_{in} and Z_{out}, can be expressed as below:

$$Z_{c1} = Z_{\text{in}} \tag{1}$$

$$Z_T = \sqrt{\frac{Z_{\text{in}} Z_{\text{out}}}{2}} \tag{2}$$

$$Z_{c2} = Z_{\text{out}}. \tag{3}$$

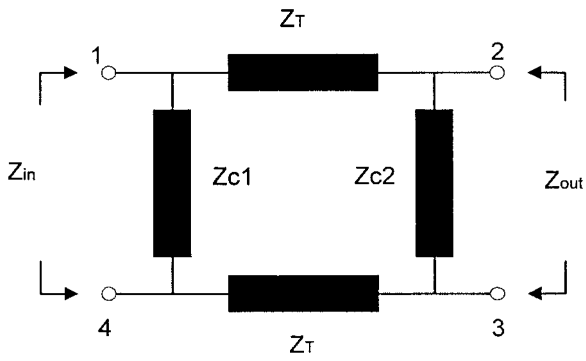

Figure 1 Impedance-transforming branch-line coupler

B. DC Block Branch-Line Coupler [3]. The dc block branch-line coupler (DBBC) has been demonstrated earlier [3], and used four coupler lines instead of all four ports in a branch-line coupler. The single branch line is equivalent to the couple line by the expressions shown below:

$$\frac{Z_e - Z_o}{2} = Z_c \tag{4}$$

$$\frac{Z''_e - Z''_o}{2} = \frac{Z_c}{\sqrt{2}}. \tag{5}$$

The equivalent circuit is shown in Figure 2. With this concept, the conventional branch-line coupler can be modified to be a dc block branch-line coupler (Fig. 3).

C. Novel dc Block Impedance-Transforming Branch-Line Coupler (DBITBC). We combine these excellent characteristics of the above two couplers to form a new hybrid, which follows by Eqs. (1)–(5). The measured small-signal performance of a 50 Ω coupler is shown in Figure 4. The direct and coupled responses show a good coupling balance of −3.5 dB and a return loss of −20 dB with a center frequency of 10 GHz. The size of the fabricated hybrid is 15 mm × 20 mm using RT/Duroid $\varepsilon_r = 2.2$ substrate.

BALANCED AMPLIFIER DESIGN

The power transistor used in single-ended amplifier design is the Mitsubishi MGF2407A. For high-efficiency applications, we design the power stage under class *AB* operation ($V_{ds} =$ 8 V, $I_{ds} = 35$ mA, about 20% I_{DSS}). The output impedance-matching circuit was designed to obtain maximum output

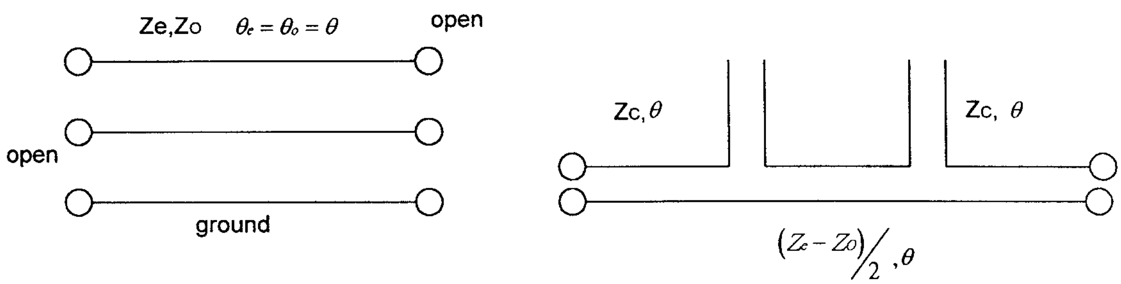

Figure 2 Coupled line equivalent to single line [3]

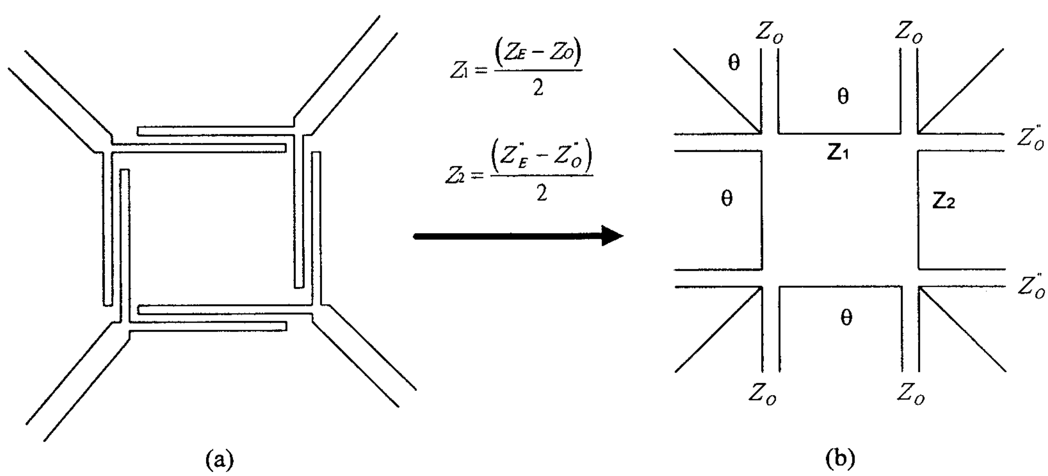

Figure 3 (a) Physical diagram of dc block branch-line coupler. (b) Single-line equivalent circuit

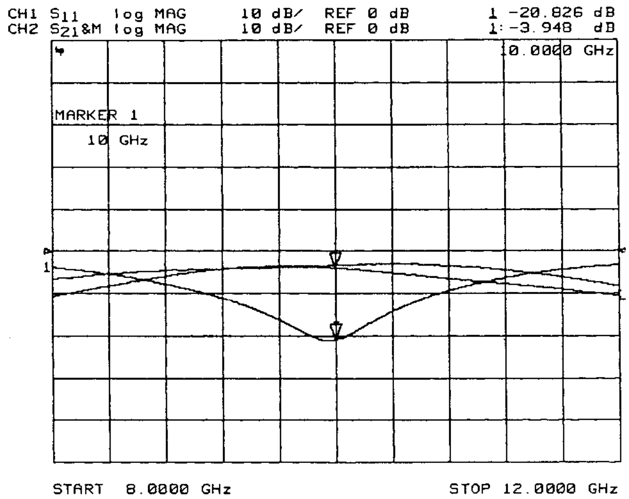

Figure 4 Measured small-signal performance of the coupler

power and high efficiency based on the nonlinear model device in the commercially available simulator EEsof Libra. An input impedance-matching circuit was implemented to provide good input return loss and flat gain response over the band of interest. For efficiency considerations, to reduce the undesired harmonics, we terminate the output of the devices at lower reactances [4]. One single-ended amplifier was designed using this method plus a transformer structure-matching circuit to tune the harmonic frequency. After finishing the single-ended amplifier design, we put together the two identical single-ended amplifiers with this new coupler as the complete balanced amplifier. Very little adjustment was necessary to obtain the desired response.

MEASURED RESULT

A. Single-Ended Class AB Power Amplifier. The measured small-signal performance of a single-ended power amplifier shows that, over the design band, the return loss was better than 10 dB, and the small-signal gain is about 9.5 dB. The measured output spectrum distribution of this single-ended power amplifier shows that the *P*1 dB is about 22 dBm.

B. Balanced Power Amplifier. A photograph of the fabricated balanced amplifier is shown in Figure 5. The measured small signal of the complete balanced amplifier exhibits an even

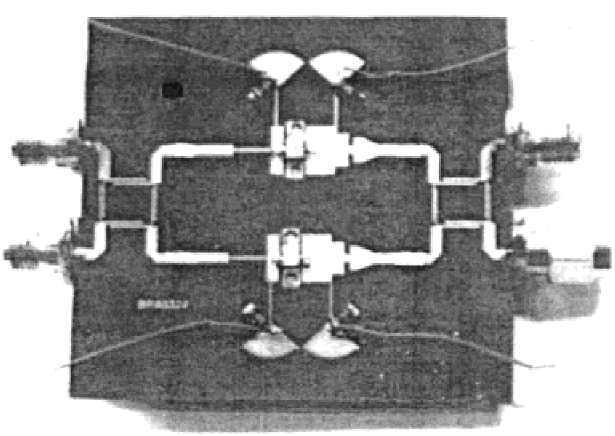

Figure 5 Photograph of the fabricated balanced amplifier

better return loss, which is less than −20 dB. The power performance of the balanced amplifier is shown in Figure 6. It has achieved a *P*1 dB of 25 dBm. The efficiency performance of the balanced amplifier is shown in Figure 7, which exhibits 50% peak power-added efficiency.

The performance of this balanced amplifier was compared with that of a single-ended amplifier in the above results. Overall, the output power doubled and the gain dropped about 0.5 dB. This is attributable mainly to losses in the DBITBC used for power combining. The second-harmonic suppression of this balanced amplifier is shown in Figure 8. The level is below −40 dBc.

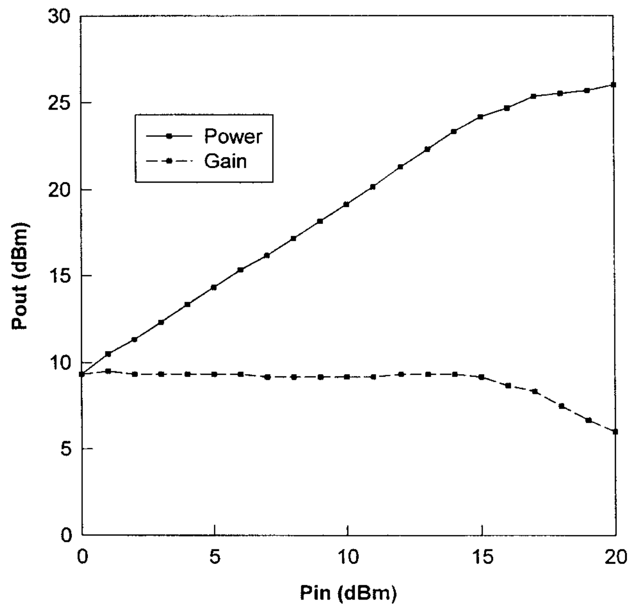

Figure 6 Measured power performance and gain of balanced amplifier at 10 GHz

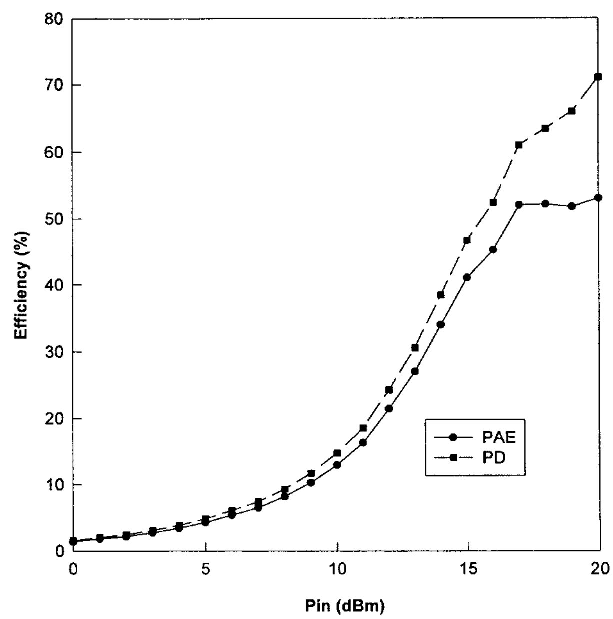

Figure 7 Efficiency performance of the balanced amplifier

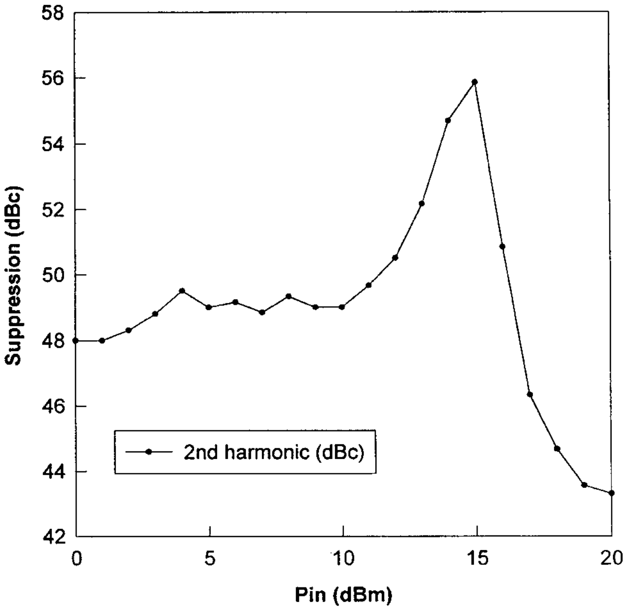

Figure 8 Output second harmonic versus input power of the balanced amplifier

CONCLUSION

A novel coupler with the function of impedance transforming and dc blocking is used in an *X*-band balanced amplifier. The measured result has 25 dBm output power, with associated gain 9 dB and 50% power-added efficiency. This coupler used in a microwave circuit can reduce the cost of the dc blocking capacitor and the circuit size. Therefore, it is suitable for MMIC applications.

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FEEDING NETWORKS FOR SINUOUS ANTENNAS

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ABSTRACT: *Two experimental versions of feeding systems for broadband antennas are described in this paper. Tapered transmission lines are used in the design of one, and the conventional type of baluns in the second. These feeding systems are employed to feed four-arm sinuous antennas in order to allow good impedance matching and good electrical characteristics over more than one octave. Experimental results of input impedance and radiation patterns are also given.* © 1999 John Wiley & Sons, Inc. Microwave Opt Technol Lett 20: 195–200, 1999.

Key words: *sinuous antenna; balun; dual-polarized antenna; tapered lines; microstrip/slot-line transition*

INTRODUCTION

There are numerous devices [1–3] which are suitable for transforming a balanced to an unbalanced transmission line over a wide range frequency. These devices have been used to feed broadband dual-arm antennas like spiral antennas [4].

The sinuous antenna used [5] is a planar broadband (2–18 GHz) antenna. The practical bandwidth is limited by photoetching, feed point considerations, and impedance-matching devices.

In this paper, two feeding systems are described and developed in order to meet the request of a wideband feeding device for the four arms constituting the sinuous antenna. Moreover, the feed has to include a broadband balun in order to match the balanced antenna to the unbalanced coaxial transmission lines. The four arms of the sinuous antenna can be fed in order to show dual linear polarization or a dual circular polarization. In the latter case, the use of a 90° hybrid is requested to produce the phase shift between two pair of arms.

We also present the experimental results which verify the concept and show a fairly good radiation pattern in more than two octaves.

A. Sinuous Antenna. The basic geometry of the sinuous antenna is shown in Figure 1. It is formed of four identical sinuous arms printed symmetrically on a thin dielectric at intervals of 90° around a central axis. To analyze this type of antenna, a simple method has been developed based on the wire model [6].

The antenna used was fabricated on a 40 μm thick Teflon substrate. A small hole was cut at the center, to pass the feed terminals to the antenna. The input impedance of the sinuous antenna used here is about 300 Ω over the entire bandwidth.

FEEDING NETWORK

In the following paragraphs, two feeding networks are proposed for the development of the sinuous antenna. In each case, it uses two microstrip printed baluns on the same dielectric substrate of two-sided copper-clad printed board.

Figure 1 Four-arm sinuous antennas