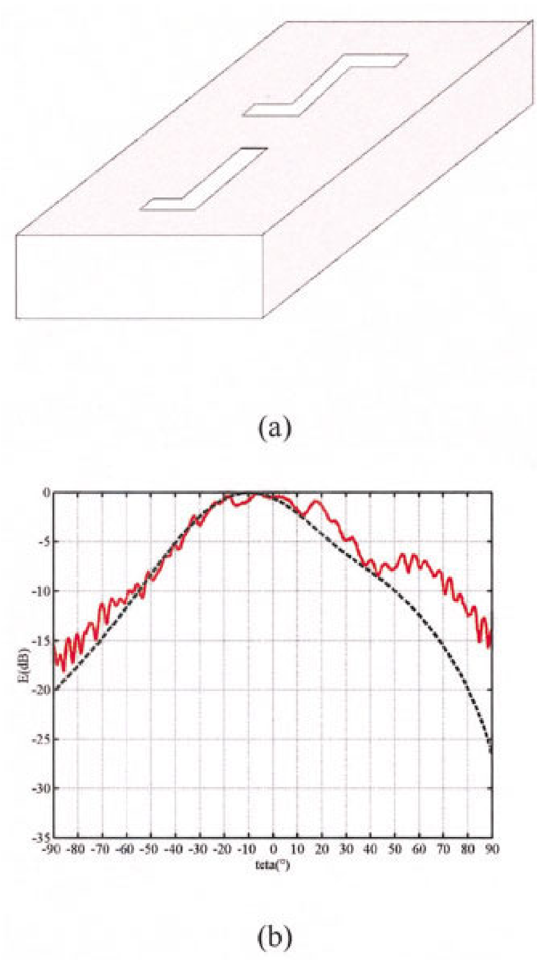

Figure 5 Another L-shaped antenna configuration (45°) and measured pattern at 12 GHz. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

VALIDATIONS

To validate the principle, four L-shaped dielectric-filled (ε_r = 1,15) slot-waveguide antennas [4] in the X band have been realized, with phase differences between the slots of antennas 1–4 0°, 180°, 90°, and 270°, respectively. Antennas 1 and 3 are depicted in Figure 3 (antennas 2 and 4 are the same but with the transversal slot inversed). Pattern results measured at 12 GHz are given in Figure 4 for both antennas, and are compared with CST patterns.

For these four cases, the beam offset are 0°, 20°, and ±30° for excitation phases of 0°, 90°, 180°, and 270°, respectively. The patterns are very difficult to measure due to diffraction and low-level radiation caused by the number of elements. However, good agreement between CST and measurements is obtained, and the results of both confirm the principle developed in the first part of this paper.

In addition, by properly modifying the slot geometry, 45°, 135°, 225°, and 315° can be obtained. In these cases, the slot is fed by two transversal slots which are C- and S-shaped. One of these antennas, depicted in Figure 5, illustrates the case where the slots are fed with a phase difference of 45°. The measured pattern has a beam offset of 10°.

PROSPECTIVE APPLICATIONS

By modifying the slot's geometry, 45° phase-current excitation can be achieved. This is very interesting for beam-scanning applications. Indeed, we can easily imagine an H-shaped slot with pin diodes at the slot's junctions, functioning as an interrupter to authorize (or not) the longitudinal slot's excitation. However, a method to feed PIN diodes one by one and, above all, separate DC from HF, needs to be found.

CONCLUSION

A new principle for slot-waveguide antennas for beam scanning has been proposed in this paper. This geometry offers advantages, especially for important beam offsets, such as coupling between slot and side-lobe-level reduction. Moreover, this paper proposes the application of this principle to particular beam offsets which have 90° increments. Both measured and simulated (according to CST Microwave Studio) results show good agreement in the patterns and confirm the principle. A final measurement, dealing with another phase excitation, shows the possibility to have 45° increments for phase excitation.

Several prospective applications are envisaged, such as array applications; however, the most interesting could be the H-shaped slot for active antennas.

REFERENCES

1. R.S. Elliott, An improved design procedure for small arrays of shunt slots, IEEE Trans Antennas Propagat AP-31 (1983).
2. S. Chainon and M. Himdi, A transmission-line model applied to shaped slot dielectric-filled antennas, Microwave and Optical Tech Lett, Vol 36, (2003), 306–310.
3. CST Microwave studio, ver. 3.
4. M. Himdi, S. Chainon, and J.P. Daniel, Technologie de mousses métallisées au service des antennes 2D et 3D, OHD, Le Mans, 2001, pp. 205–208 (in French).

A SiGe MICROMIXER FOR 2.4/5.2/5.7-GHz MULTIBAND WLAN APPLICATIONS

C. Y. Wang,[1] S. S. Lu,[1] C. C. Meng,[2] and Y. S. Lin[3]
[1] Department of Electrical Engineering
National Taiwan University
Taipei, Taiwan, R.O.C.
[2] Department of Communication Engineering
National Chiao-Tung University
Hsinchu, Taiwan, R.O.C.
[3] Department of Electrical Engineering
National Chi-Nan University
Puli, Taiwan, R.O.C.

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ABSTRACT: *A SiGe micromixer for 2.4/5.2/5.7-GHz multiband WLAN applications is demonstrated for the first time. Our experimental results show that the input return loss* $|S_{11}|$ *is below* -18 *dB from DC to 20 GHz with voltage gains of 32, 26, and 25 dB at frequencies of 2.4, 5.2, and 5.7 GHz, respectively. The wideband matching characteristic makes the micromixer very suitable for multiband applications. Input* $P_{1dB} = -14$ *dBm and* $IIP_3 = -6$ *dBm. Port-to-port isolation is also quite satisfactory. In addition, the single-to-differential input stage in the Gilbert micromixer eliminates the need for common-mode rejection.* © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 41: 343–346, 2004; Published onlinepublished online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20136

Key words: *SiGe micromixer; WLAN; multiband operation*

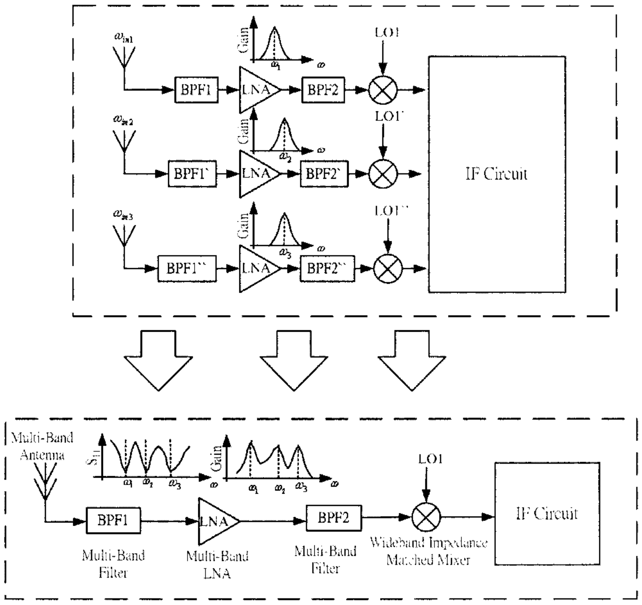

Figure 1 Concept of the concurrent multiband receiver

1. INTRODUCTION

Wireless communication has evolved into a world of multistandards and multiservices with operating frequencies in the 900-MHz/1.8-GHz/1.9-GHz bands for GSM, 1.5-GHz band for GPS, and 2.4/5.2/5.7-GHz bands for WLAN. Typical design strategies use different receive-transmit paths for different frequency bands. The primary challenge in designing multiband transceivers is how to increase the functionality of such communication systems while minimizing the number of additional hardware, such as antennas, filters, low-noise amplifiers, and mixers. Hence, it is desirable to combine two or more standards in one mobile unit [1, 2], as shown in Figure 1. Recently, a large number of efforts have been made to develop concurrent multiband antennas [3–5], filters [6], and low-noise amplifiers [7]. In heterodyne receivers such as RF2444 [8] or ISL3685 [9], the input impedance of a mixer has to be matched to 50Ω. Therefore, for 2.4/5.2/5.7-GHz multiband WLAN applications, a mixer whose input impedance can be matched to 50Ω at these frequencies is needed.

In this work, an integrated SiGe mixer, which can handle 2.4/5.2/5.7-GHz triple bands, is reported. Multiband input-impedance matching is accomplished by the parallel combination of a common-base transistor and a diode-connected transistor, which renders an impedance controlled by their transconductance. This is a variant of the Gilbert mixer called the micromixer [10]. Our experimental results show that the input return loss $|S_{11}|$ is below −18 dB from DC to 20 GHz with voltage gains of 32, 26, and 25 dB at frequencies of 2.4, 5.2, and 4.7 GHz, respectively.

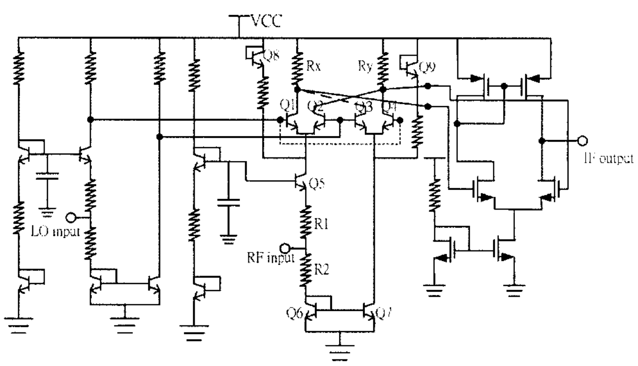

Figure 2 Schematic of the SiGe double-balanced Gilbert micromixer

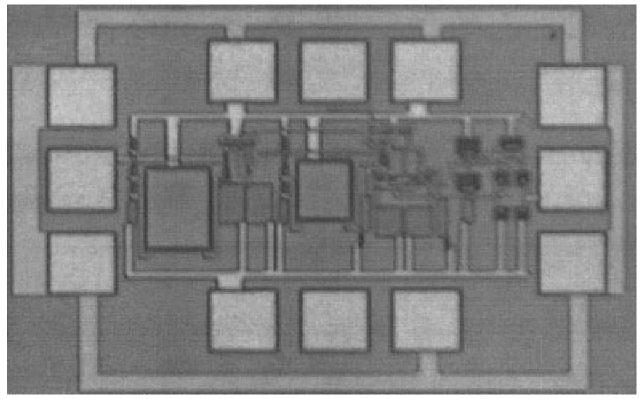

Figure 3 Die photo of the SiGe double-balanced Gilbert micromixer

2. CIRCUIT DESIGN

The schematic of our SiGe multiband micromixer is depicted in Figure 2. A single-to-differential stage is constructed with Q5, Q6, and Q7 and two resistors, R1 and R2. The common-base-biased Q5 and common-emitter-biased Q7 provide equal but out-of-phase transconductance gain when Q6 and Q7 are connected as a current mirror. The common-base configuration possesses good frequency response while the speed of the common-emitter-configured Q7 is improved drastically by adding the low-impedance diode-connected Q6 at the input of common-emitter-configured Q7. Thus, the single-to-differential stage, as shown in Figure 2, is very suitable for high-frequency operation.

The single-to-differential stage used in this paper not only turns a single-ended signal into two balanced signals, but also facilitates the input-RF impedance matching [1, 2]. The resistance at point-RF input (see Fig. 2) is equal to the parallel combination of the R1-Q5 branch and the R2-Q6 branch. The resistance of the R1-Q5 branch is the sum of R1 (24Ω) and $1/g_{m5}$ (69Ω), where g_{m5} is the transconductance of Q5. The resistance looking into the R2-Q6 branch is the sum of R2 (24Ω) and $1/g_{m6}$ (69Ω), where g_{m6} is the transconductance of Q6. Therefore, 50Ω at point RF input can be achieved by choosing appropriate biases of Q5, Q6,

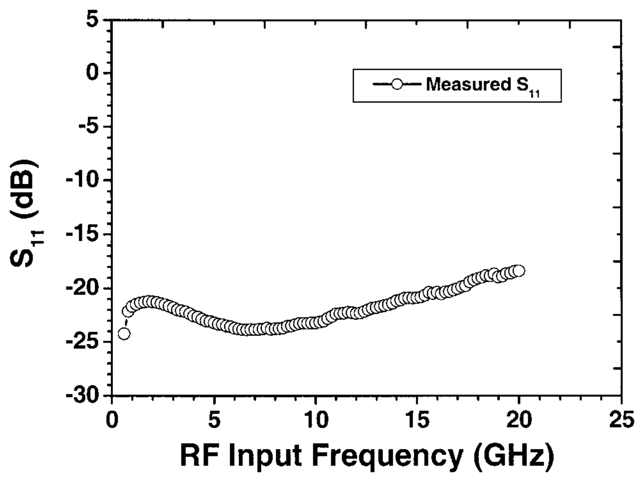

Figure 4 Input-matching characteristics of the SiGe micromixer

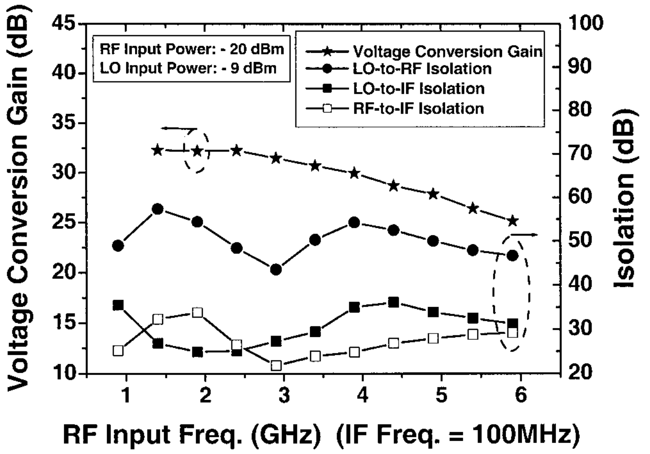

Figure 5 Voltage-conversion gain and isolation characteristics as functions of RF frequency of the SiGe micromixer

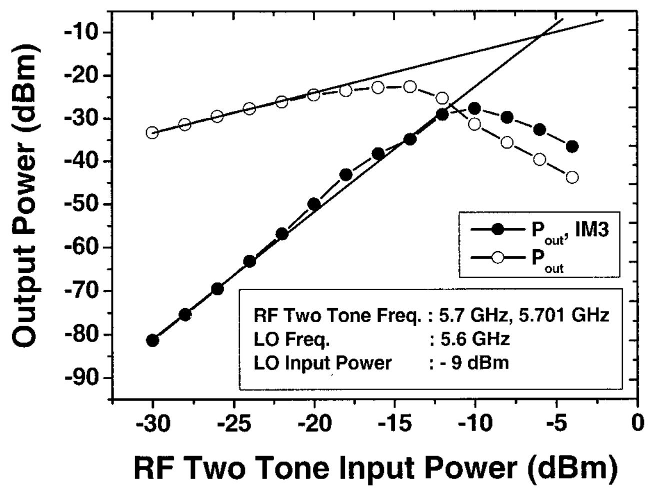

Figure 7 Third-order intermodulation characteristics of the micromixer

and Q7. Note that the bias current source in a conventional Gilbert mixer contributes noise and deteriorates the common-mode-rejection ratio rapidly at high frequency. In contrast, the single-to-differential input stage in the Gilbert micromixer renders good frequency response and eliminates the need for common-mode rejection necessary in a conventional Gilbert mixer.

The current-injection-bias technique [12] (see Fig. 1) is applied to enhance the conversion gain of the mixer. To be specific, two diode-connected transistors (Q8 and Q9) function as current sources and supply part of the DC current to the single-to-differential stage. Because of the current injection from Q8 and Q9, the DC tail current of the Gilbert quad (Q1, Q2, Q3, Q4) can be reduced; hence, large load resistors (Rx, Ry) can be used, which results in higher voltage conversion gain of the mixer. The single-to-differential technique is also applied in the LO input, and a CMOS differential amplifier is used to convert the differential IF signal to the single-ended signal.

3. RESULTS AND DISCUSSION

The micromixer is implemented using the 0.8-μm SiGe BiCMOS process. The die photo of the fabricated SiGe micromixer is shown

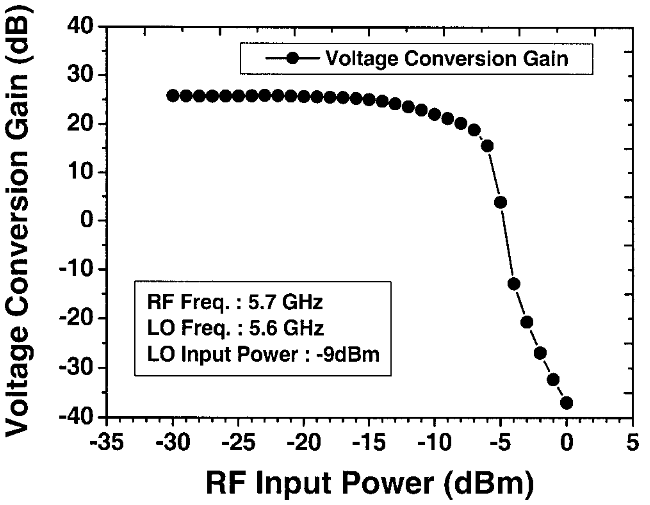

Figure 6 Conversion gain of the SiGe HBT double-balanced Gilbert micromixer as a function of RF-input power

in Figure 3. On-wafer measurement is performed, and the supply voltage is 3.3 V.

The input return loss $|S_{11}|$ is below -18 dB from DC to 20 GHz, as shown in Figure 4, thus indicating a very wideband matching characteristic. The characteristics of voltage-conversion gain as a function of RF frequency with a fixed IF frequency of 100 MHz and a fixed LO power of -9 dBm are plotted in Figure 5. The conversion gain is 32, 26, and 25 dB at frequencies of 2.4, 5.2, and 5.7 GHz, respectively. The isolation characteristics of the mixer are also shown in Figure 5. The LO-IF isolation is 26, 32, and 30 dB at frequencies of 2.4, 5.2, and 5.7 GHz, respectively. The LO-IF isolation achieved is better than the previous value of 27 dB at 5.7 GHz obtained using a conventional Gilbert mixer [11]. The LO-RF isolation is 48, 48, and 47 dB at frequencies of 2.4, 5.2, and 5.7 GHz, respectively. The RF-IF isolation is 25, 28, and 29 dB at frequencies of 2.4, 5.2, and 5.7 GHz, respectively. Clearly, isolation characteristics of the micromixer are quite satisfactory.

The characteristics of conversion gain versus RF input power (RF frequency of 5.7 GHz) with a fixed LO power of -9 dBm (LO frequency of 5.6 GHz) are shown in Figure 6. From this figure, an input P_{1dB} of -14 dBm is obtained. Finally, two-tone intermodulation measurement is performed and the results are shown in Figure 7. Clearly, an $IIP_3 = -6$ dBm is obtained.

4. CONCLUSION

In this paper, a micromixer is demonstrated using SiGe BiCMOS technology for multiband WLAN. The intrinsic wideband-matching characteristics of the micromixer make it very suitable for multiband applications. Conversion gains of 32, 26, and 25 dB at frequencies of 2.4, 5.2, and 5.7 GHz are obtained, respectively. Good isolation and linearity are also achieved.

ACKNOWLEDGMENTS

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REFERENCES

1. T. Antes and C. Conkling, RF chip set fits multimode cellular/PCS handsets, Microwave RF, 35; (1996), 177–186.

2. S. Wu and B. Razavi, A 900-MHz/1.8-GHz CMOS receiver for dual-band applications, IEEE JSSC 33 (1998), 2178–2185.
3. Z.D. Liu, P.S. Hall, and D. Wake, Dual-frequency planar inverted-F antenna, IEEE Trans Antennas Propagat 45 (1997), 1618–1625.
4. H. Miyake, S. Kitazawa, T. Ishizaki, T. Yamada, and Y. Nagatomi, A miniaturized monolithic dual-band filter using ceramic lamination technique for dual mode portable telephones, IEEE Microwave Millimeter-Wave Monolithic Circ Symp Dig (1997), Denver, CO, 789–792.
5. H. Hashemi and A. Hajimiri, Concurrent multiband low-noise amplifiers-theory, design and applications, IEEE Trans Microwave Theory Tech 50 (2002).
6. RFMD RF2444 data sheet.
7. Intersil ISL3685 data sheet.
8. B. Gilbert, The MICROMIXER: A highly linear variant of the Gilbert mixer using a bisymmetric Class-AB input stage, IEEE J Solid-State Circ 32 (1997), 1412–1423.
9. J. Durec and E. Main, A linear class AB single-ended to differential transconverter suitable for RF circuits, IEEE MTT-S Dig (1996), San Francisco, CA; 1071–1074.
10. L.A. MacEachern and T. Manku, A charge-injection method for Gilbert cell biasing, IEEE Canadian Conf Electrical Computer Eng 1998, 365–368.
11. W. Durr, U. Erben, A. Schuppen, H. Dietrich, and H. Schumacher, Low-power low-noise active mixers for 5.7 and 11.2 GHz using commercially available SiGe HBT MMIC technology, Electron Lett 34 (1998), 1994–1996.

A WATT-LEVEL 2.3-GHz GaAs MESFET POWER AMPLIFIER WITH GAP-COUPLED MICROSTRIP-LINE MATCHING TOPOLOGY

C. C. Meng[1] and W. Wang[2]
[1] Department of Communication Engineering
National Chiao Tung University
Hsinchu, Taiwan, R.O.C.
[2] Department of Electrical Engineering
National Chung-Hsing University
Taichung, Taiwan, R.O.C.

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ABSTRACT: *A one-stage hybrid power amplifier integrated with gap-coupled microstrip lines for impedance matching is demonstrated in this work. The gap-coupled microstrip line amplifier module realized here can provide 15-dB power gain, 33.5-dBm output power, and 42% power-added efficiency (PAE) at 2.3 GHz. The demonstrated topology is suitable in monolithic IC technology, especially in the millimeter-wave frequency because the gap-coupled microstrip lines can be easily compacted into small size.* © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 41: 346–348, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20137

Key words: *MESFET; power amplifier; microstrip lines*

1. INTRODUCTION

Recently, demand for high-level integration in microwave monolithic integrated circuits (MMICs) has increased and become more important. The off-chip band-select filters are often too bulky for integrated-circuit technology. Typical microwave and millimeter-wave transceivers still consist of MMIC chips and off-chip filters to achieve maximum performance. The potential of integrating devices and filters in integrated-circuit technology is thus attractive for cost reduction [1]. In this work, a GaAs MESFET power amplifier with gap-coupled microstrip-line matching structures has been developed. The gap-coupled microstrip lines serve as impedance transformations and also provide DC blocking. Chip capacitors are inserted into the gaps to optimize the matching design for the desired band-pass amplifier response. The amplifier demonstrated provides 15-dB gain and 33.5-dBm output power at 2.3 GHz. The power-added efficiency (PAE) at maximum output power is 42%. The gap-coupled microstrip lines can be easily compacted into a serpentine shape and thus the amplifier topology demonstrated here is very suitable for millimeter-wave monolithic integrated circuits.

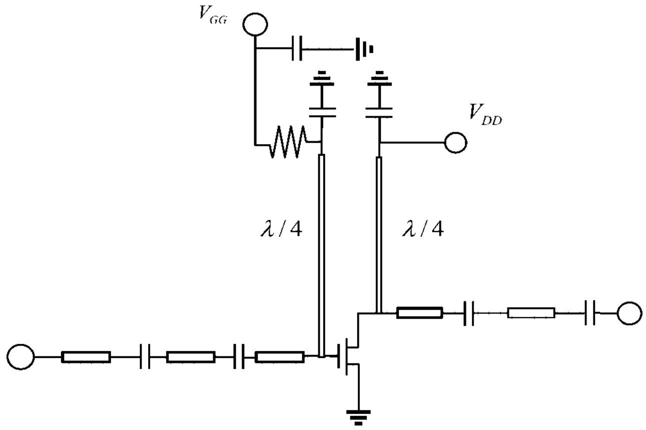

Figure 1 Schematic of the gap-coupled microstrip-line power amplifier

2. CIRCUIT DESIGN

Figure 1 illustrates the schematic of a one-stage GaAs MESFET power amplifier with gap-coupled microstrip lines for impedance matching and transformation. A load-pull measurement is used to obtain the optimum load impedance for maximum output power and the packaged device's S parameters are also measured for power-amplifier design. A gap-coupled microstrip-line topology is simple and thus used for impedance matching. In other words, the gap-coupled microstrip lines not only have band-pass characteristics, but also provide the input and output impedance matching of a power amplifier. The band-pass nature of a gap-coupled matching network also helps increase the stability of a power amplifier because such a device is prone to low-frequency oscillation and the gain mismatch at low frequency increases the stability. There are two design parameters in gap-coupled 50Ω microstrip lines: the lengths of the microstrip lines and the capacitors inserted in the gaps. A conventional power-amplifier design methodology is adopted here; the input impedance matching is optimized for power gain and the output impedance matching is optimized to obtain maximum output power [2, 3]. The input equivalent-circuit of a MESFET device is close to a series-RC circuit and thus the capacitor is absorbed into the gap-coupled microstrip line-matching circuit [4, 5]. The output equivalent-circuit for maximum power-impedance matching is close to a parallel-RC circuit and the effect of the parallel capacitor is negligible at the frequencies of interest. Quarter-wavelength RF chokes are used at bias gate and drain terminals. The stability factor K is large than 1 and the B factor is larger than zero for all the frequencies in order to prevent undesired oscillation in the amplifier design.

3. EXPERIMENTAL RESULTS

A photograph of the fabricated power amplifier is shown in Figure 2. A standard microwave ceramic package is used to package the