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GaAs Components for 60 GHz Wireless Communication Applications

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Abstract: We have designed a low cost V-band transceiver chip set that is targeted for multiple applications. The chip set has enough versatility to support various modulation schemes and can be used in a simplex, half duplex or full duplex mode. The total size of 17 sq. mm means a small package and the high production and high reliability processes used ensures performance and yield margins.

I. Introduction

There has been a tremendous interest in utilizing the 60Ghz portion of the electromagnetic spectrum because of the wide bandwidth available, the propagation characteristics that allow high-density short-range links, and because of the short wavelength that allows very compact antenna structures. Key to bringing 60Ghz-based products to the market place is a low cost, repeatable, mass producible means of realizing the transceiver electronics. We describe here a MMIC chipset we have developed which provides a high performance but cost effective solution for implementing a full band (55 to 64 Ghz) transceiver suitable for a broad range of applications. Through extensive compaction, the total die area for the entire chipset has been shrunk to only 17 mm^2. These MMICs are standard off-the-shelf products and are fabricated in our proven high volume 0.1µm and 0.15µm GaAs HEMT production processes. [1-3]

II. Low Cost V-Band Transceiver

The block diagram of a half duplex transceiver implemented in our chip set is shown in Figure 1; only seven chips total (five chip types) realize the entire transceiver RF electronics. Full duplex transceivers can also be easily realized by substituting a power divider for the LO switch and deleting the T/R switch. This architecture has been used in the production of a low cost 60 Ghz module supporting > 155 Mb/sec data rates. The architecture shown in Figure 1 can support a range of constant envelope modulation formats such as FSK, TFM, and FM. More bandwidth efficient modulation schemes such as MPSK can be accommodated by utilizing frequency conversion rather than a frequency multiplication in the transmit LO chain.

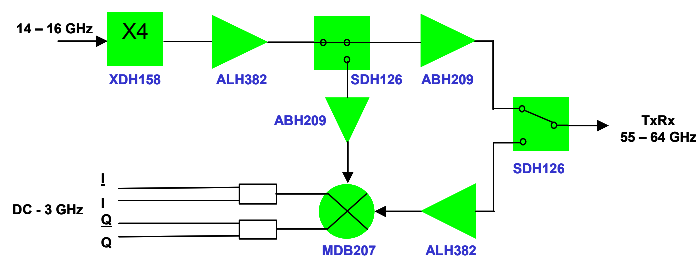

Fig. 1. V-Band Transceiver

IIIA. LNA/Down Converter

The ALH382 is an LNA that uses 0.1µm HEMT technology to achieve 3.5 to 4.5 dB noise figures from 55 to 65 Ghz. This single ended MMIC has four stages packed into a small 1.3 sq. mm area. The input return loss ≈ 10dB while the output return loss > 10dB. The gain across the frequency band is > 20dB. This MMIC can be biased with a single gate and a single drain. The output device size has been increased to 4f200 µm for a 12 dBm output P1dB. The noise figure statistics are included in Figures 2 and 3.

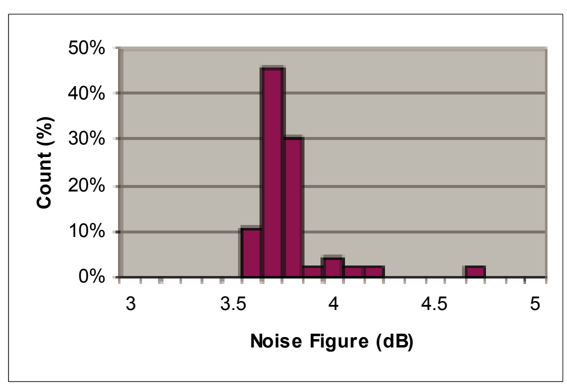

Fig. 2. ALH382Noise Figure Statistics @ 60 Ghz

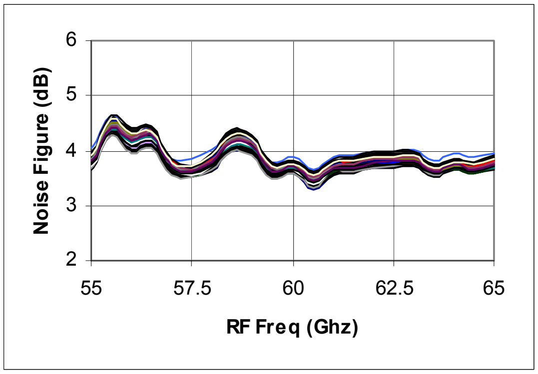

Fig. 3. ALH382 Noise Figure Vs. Frequency

TRW's 0.1µm HEMT technology has a high cutoff frequency of >110 Ghz for up to 4 volt operation. The 0.1µm process has been in production for over eight years and has been used to produce thousands of wafers. A photograph of the ALH382 is in Figure 4.

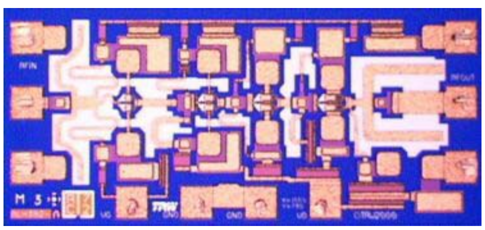

Fig. 4. ALH382

The down converter function is implemented using a MDB207 MMIC. This chip can be used as an I/Q down converter, or can be configured as an IR down converter with the addition of an off chip IF hybrid. The double balanced mixers are realized using microstrip Marchand balans. The conversion loss ranges between 9.5 to 10.5 dB from 57 to 64 Ghz on each port. With an LO signal of 15 to 17 dBm, the image rejection is > 30dB. A photograph of the mixer is included in Figure 5.

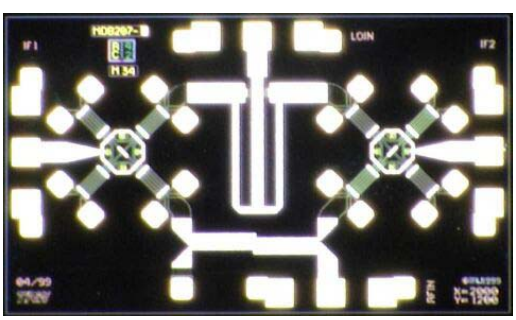

Fig. 5. MDB207

IIIB. SPDT Switch

The SDM126 MMIC is a SPDT switch fabricated in the 0.15µm HEMT process and is used for the transmit/receive selection. A shunt configuration with λ/4 device separation is utilized to achieve the desired isolation and over 15 dBm power handling capability. Featuring an insertion loss of < 1.5 dB from 55 to 63 GHz, the output port-to-port isolation is ~ 30dB. The overall layout and die size of the 2.4 mm^2 was a compromise between the desire to minimize die area while not degrading isolation from coupling between the output ports. The insertion loss and isolation are plotted in Figures 6 and 7. A photograph of the MMIC is included in Figure 8.

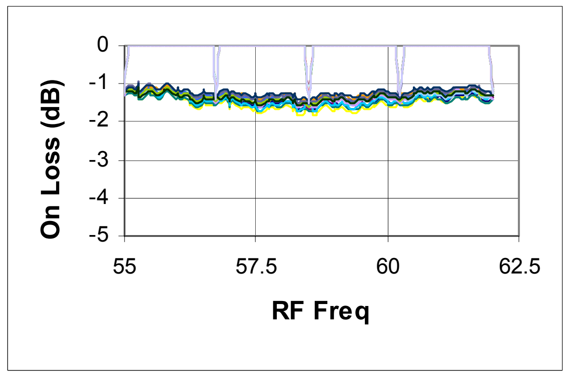

Fig. 6. Insertion Loss, SDH126

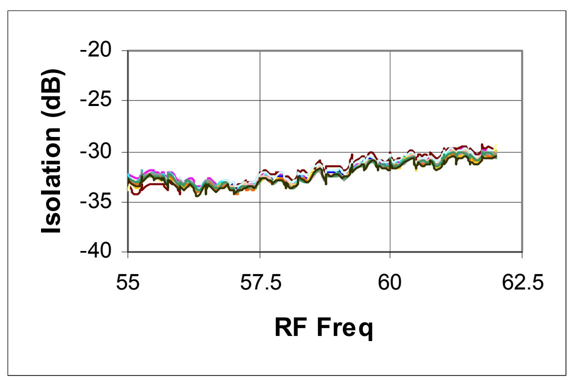

Fig. 7. Output Port-Port Isolation, SDH126

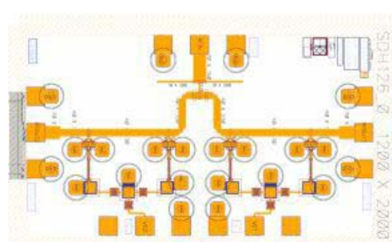

Fig. 8 SDH126-0

IIIC. X4 Multiplier

The X4 multiplier (XDH158) is a compact 1.5 sq. mm MMIC that multiplies a 14 to 16.5 GHz signal at a 4 dBm level to 56 to 66 GHz with a conversion loss of about 8 dB. The multiplier section draws about 14 mA at 1.5V on the drain while the integrated amplifier uses 114mA at 4V. The rejection of the other harmonics excluding the third is > 20dB. This part is fabricated using the well-established space qualified 0.15 µm HEMT process. A photograph showing the XDH158 is shown in Figure 9

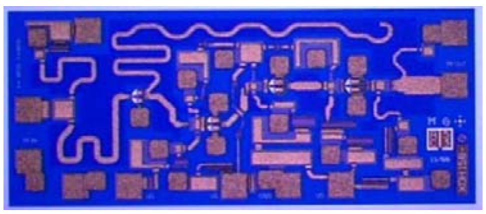

Fig. 9. XDH158 x4 Multiplier

IIID. Power Amplifier

The ABH209 is a power amplifier fabricated in TRW's 0.15 µm HEMT production process. The balanced two stage configuration has linear gain of 13 dB from 55 to 65 Ghz. The linear power is > 16 dBm over the whole 55 to 65 Ghz. The saturated power is > 18dBm. The MMIC is a mere 2.7 square mm in size and takes 110 mA at 5 volts for maximum power. The ABH209 has been used as a LO driver as well as the PA for the block diagram. The gain plot and statistics are included in Figures 10 and 11 while the photograph of the chip is shown in Figure 12.

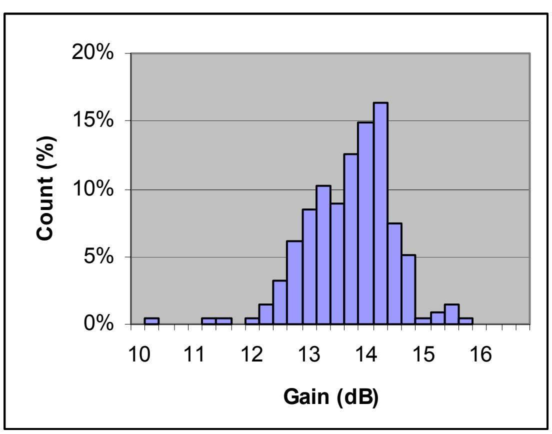

Fig. 10. ABH209 Power Amplifier Gain at 60Ghz

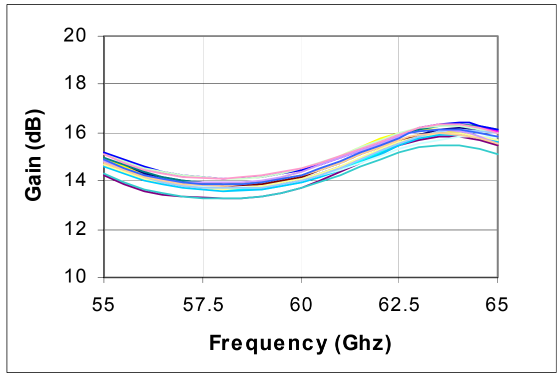

Fig. 11. ABH209 PA Gain Vs. Frequency

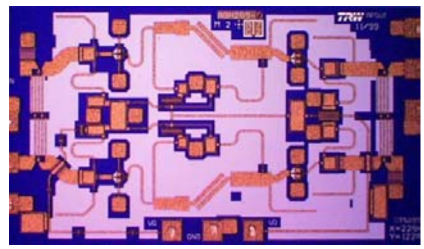

Fig. 12. ABH209 Power Amplifier

IV. Demonstrated Production Capability

Key to the success of many of the 60 Ghz transceiver applications are a high yield, repeatable MMIC chipset. Through design focused achieving robust performance against specifications and ongoing processing efforts directed toward repeatable high performance, we have achieved a chipset, which has demonstrated excellent producibility in volume. An example of this is the production history of the ALH382 LNA. Shown in Figure 3 is a plot of noise figure versus frequency for MMICs from a typical wafer; performance versus frequency is highly repeatable from part to part with noise figures better than 4.5 dB achieved across the entire 55 to 65 Ghz band. Figure 2 shows a histogram of noise figure at 60 Ghz for the same wafer; average noise figure is less than 3.8 dB with most all of the parts measuring less than 4.2 dB. Another example is the production history for the ABH209 power amplifier shown in Figure 11 is the gain versus frequency for MMICs from a typical wafer, and Figure 10 that shows a histogram of the gain at 60 Ghz for several hundred parts. In production, gain is typically 13 to 14 dB across the 55 to 62 Ghz band with the minimum gain specification of 10 dB exceeded on a vast majority of the parts.

VII. Summary

The success of a wide range of products utilizing 60 Ghz portion of the spectrum is dependent on a low cost, mass producible solution for the transceiver electronics. We have presented a MMIC chipset which provides a cost effective solution for a wide range of transceiver architectures; an example half duplex transceiver was presented which is implemented with 8 chips total (5 chip types) with a total die area of only 17 mm^2. Low cost, volume production has been demonstrated through robust designs and utilization of proven high volume, high reliability [4] 0.1 and 0.15um GaAs HEMT MMIC processes.

Acknowledgements

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