MOBITEX PC CARD WIRELESS MODEM

Dr. S. Moghe, J. Stone, S. Stratmoen, S. Consolazio, K. Rausch, S. Geske, M. Patel
Northrop Grumman Corporation
Electronics & Systems Integration Division - Electronic Systems
600 Hicks Road
Rolling Meadows, Illinois 60008-1098, USA.

ABSTRACT

Northrop Grumman Corporation has developed a Type II extended PC card wireless modem that operates at 900 MHz over the nationwide Mobitex wireless data network and incorporates a conventional 14.4 kbps wireline modem, as well as cellular network access capability. The modem enables notebook computer and PDA users to send and receive electronic mail and data wirelessly. Gallium Arsenide (GaAs) monolithic microwave integrated circuit (MMIC) and Silicon application specific integrated circuit (ASIC) technology made it possible to implement complex high performance functions in a small size. A second generation modem using low temperature cofired ceramic (LTCC) and Ball Grid Array (BGA) packaging technologies is under development.

INTRODUCTION

There has been significant progress in the miniaturization of wireless devices over last few years. The development of a wireless type II PC card modem for notebook computers presents many challenges to product designers. The packaging of RF transceiver, baseband, and digital signal processing components in a credit card size is difficult because of coupling and interactions, thermal issues, and tight specifications on the RF subsystem. Northrop Grumman Electronics and Systems Integration Division has developed a wireless type II PC card modem using GaAs MMICs and high integration packaging technologies. This modem provides all receiver/transmitter functions in a small battery-powered package. The modem operates over the Mobitex wireless network to send and receive data; it also connects to wireline and cellular networks to send and receive faxes, data, and messages.

SYSTEM REQUIREMENTS

The requirements for wireless systems vary in terms of size, weight, cost and performance. The requirements for wireless Mobitex modems differ from those for other wireless devices, such as cellular phones and pagers. Mobitex modems require a minimum output power of 2 Watts effective radiated power (ERP), long battery life, and high receive sensitivity. The requirements must be met within the package constraints of a type II PC card outline. The most challenging requirement is the long battery life, which puts severe constraints on the modem standby, receive, and transmit currents. In a typical modem session, the standby, receive, and transmit times are 95%, 5%, and 1% respectively. With this profile, the transmitter power amplifier efficiency has the highest impact on the modem battery life. The transmitter current also determines if the modem can be used with the small handheld personal digital assistants (PDAs). Most PDAs do not have enough battery capacity to supply the surge current needed by the transmitter. For this reason, a rechargeable battery included in the modem is desired. Drawing modem power from the notebook computer would reduce the notebook's battery life considerably.

RADIO MODEM REQUIREMENTS

The requirements for wireless PC card modem receivers include low noise figure, high dynamic range, low power consumption, and low cost. GaAs MMIC RF front-end devices offer solutions to all of these requirements. Receiver dynamic range is limited by the RF sensitivity and the third order intercept point. High gain, low-noise amplifiers with typical noise figures of less than 2 dB can be achieved using reliable, commercially

0-7803-4603-6/97/$5.00 (c) IEEE

available ion-implant GaAs metal semiconductor field effect transistor (MESFET) processes. Receiver intercept points greater than -10 dBm are typically acceptable for many narrowband applications.

In today's portable wireless RF applications, the design trends are toward extremely low current +3V devices. Advanced biasing techniques are used to overcome the performance trade-off between intercept point and power consumption. The burden of maintaining long battery life in mobile communications products falls on the radio frequency integrated circuit (RFIC) designer.

The cost of GaAs MMIC chips is extremely volume-sensitive. As demand for GaAs IC volume continues to grow, the technology becomes more competitive with traditional silicon costs. Integrated circuit (IC) designers are faced with the challenge of integrating many circuit functions on a single chip in order to get maximum functionality from the available GaAs wafer real estate. Higher levels of circuit integration lead to more functionality in a given chip area and lower cost per chip.

GaAs MMIC technology is suited for RF wireless modem transmitter components due to its high efficiency and small size. High efficiency (>50%) power amplifiers are necessary in battery-driven mobile computing devices that require transmit output power of two Watts. The evolution of compact switched-capacitor networks allows negative gate bias to be implemented at reasonable cost. Sufficient bias filtering is required to reduce AM sidebands in the transmit output spectrum. A key advantage of MMIC technology is repeatable performance. Output power control is a critical requirement in portable RF systems. A power control range of 18 dB is required and methods of control vary in complexity.

PACKAGING REQUIREMENTS

The current packaging technology trend in cellular phones, pagers, and other high volume, cost-sensitive applications is to use plastic packages mounted to a soft board substrate with a solder reflow process. Newer packaging technologies like chip-on-board (COB) and ceramic and laminate substrate BGAs are finding acceptance in some of the more demanding wireless systems that require smaller size. Mechanical performance and thermal heat management requirements play a critical role in the choice of packaging technology. Cellular phones and wireless PC card modem applications require high transmitter power, up to 2 watts, thus posing significant thermal constraints. This condition worsens as the trend toward higher levels of monolithic microwave functional integration continues.

MMICs with high levels of integration continue to present significant challenges to packaging engineers. An important consideration in selecting the appropriate packaging technology for a system application is the change in electrical performance, before and after packaging a device, caused by the package parasitics. These performance changes must be understood and accounted for in designing a system. The number of input/output (I/O) leads is also an important consideration in the choice of a packaging technology. Current discrete devices typically require 2 to 6 I/Os, including RF, DC, and ground connections. The higher functionality monolithic ICs currently used in many systems require 10 to 20 I/O connections. Many of these I/Os require high isolation for acceptable electrical performance. In this modem design, low integration MMICs in plastic packages are used in the first generation design, whereas the high integration MMICs are used in the BGA transceiver module.

PC CARD MODEM DESIGN

A complete wireless modem assembly is shown in Figure 1. The main circuit card contains a microprocessor, memory, DSP functions, switching power supply, receiver IF section, wireline phone interface, and the battery. The power supply operates from a 3.3 Volt $LiMnO_2$ battery, which fits into the extended portion of the PC card and delivers sufficient power for the 2 Watt ERP transmitter section. The battery is rechargeable from the host computer or an external battery charger. The RF transceiver circuit card is attached to the main board with a flexible wire connector and folds over the main board. Figure 2 shows the top side of the RF transceiver board, which uses standard multilayer printed wiring board (PWB) technology. The RF module contains

0-7803-4603-6/97/$5.00 (c) IEEE

a combination of Northrop Grumman MMIC technology and standard integrated components forming a half-duplex transceiver. Miniature active and passive RF components were used to meet the small size objective. The challenge was to package all the RF circuitry and most of the IF circuitry in a 1"x 2" PWB and still meet all the electrical specifications. The receiver sensitivity has been measured at -111 dBm at 12 dB signal-to-noise ratio (SNR).

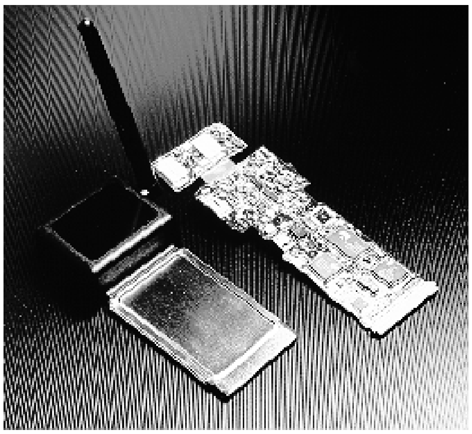

Figure 1: Wireless Modem and Circuit Card Assemblies

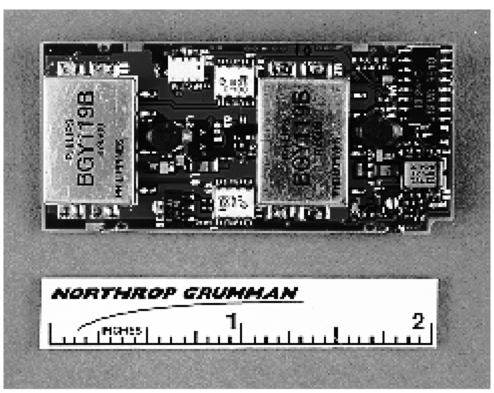

Figure 2: Front Side of the First Generation RF Transceiver Module with Off-the-Shelf Components

A second generation 900 MHz modem has been developed. It features higher levels of MMIC integration and advanced packaging techniques that will further reduce the recurring cost of the RF module. A photograph of the complete Northrop Grumman RF transceiver MMIC chip set packaged in a laminate-based Multi-Chip Module (MCM-L) is shown in Figure 3. Four MMIC chips [Low Noise Amplifier (LNA)/Downconverter, Voltage-Controlled Oscillator (VCO), Buffer Amplifier and Power Amplifier] and supporting circuitry are contained in a 0.8"x 0.8" BGA package. The BGA assembly features low cost multilayer laminate PCB technology on a 15 x 15 array of collapsible solder balls designed for high volume production reflow. The main advantage of BGA technology over conventional technology is smaller size, lower cost, and better electrical performance. The design and layout were carefully optimized to meet critical electrical specifications, such as isolation, adjacent channel rejection, noise figure, phase noise, etc.

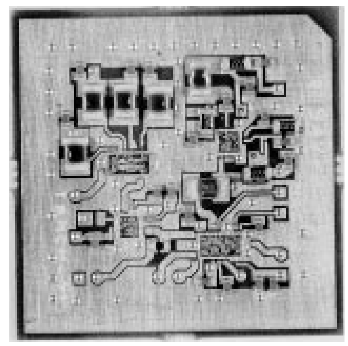

Figure 3a: Second Generation MCM-L RF Transceiver (size reduction due to BGA)

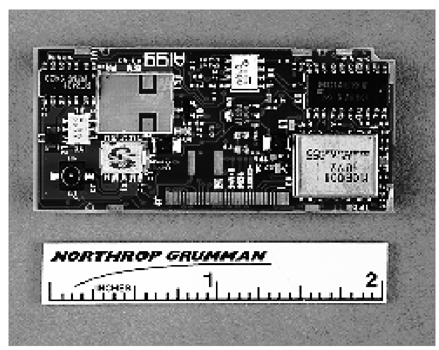

Figure 3b: Back Side of the First Generation RF Transceiver Module with Off-the-Shelf Components (Showing Size Comparison)

Figure 4 shows a block diagram and photograph of the receiver MMIC used in the BGA multi-chip assembly module. The receiver MMIC is fabricated using an ion implanted MESFET process, is small in size (0.050" x 0.100"), and consequently has high yield (> 80%). The receiver chip draws low receive current (25mA), has a -7 dBm input 3rd order intercept point, and operates on

0-7803-4603-6/97/$5.00 (c) IEEE

a single 3 volt power supply. It also has a LNA bypass switch for overload capability. The receiver chip and the RF module can be used for both Mobitex and half duplex Cellular Digital Packet Data modem applications. Figure 3 shows that the current RF module can be reduced in size by a factor of more than two by using the BGA technology. Figure 5 and Table 1 show the measured data of the BGA module. The BGA transceiver shows good receiver conversion gain and noise figure. The detailed performance summary shown in Table 1 meets the performance requirements for the PC card modem.

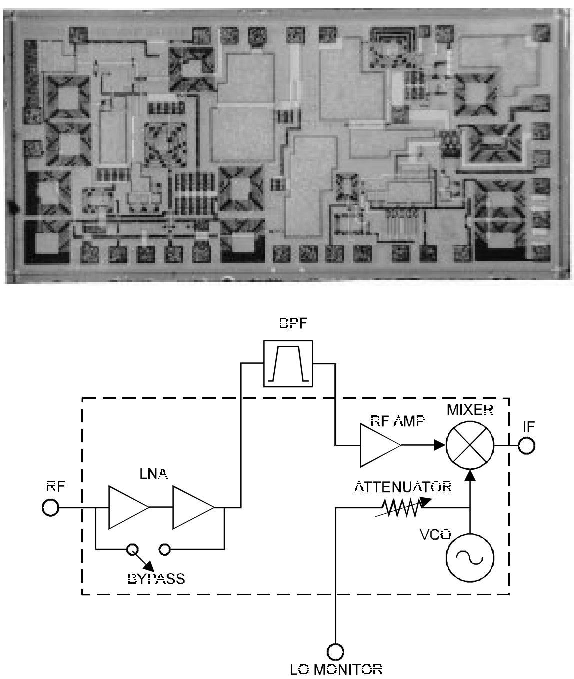

Figure 4: Block Diagram and the Photograph of the Receiver MMIC Used in the Laminate BGA Module.

CONCLUSION

A wireless PC card modem for the RAM Mobitex data network at 900 MHz has been developed using off-the-shelf MMIC and discrete technologies; the modem shows good performance. The next generation modem, using higher integration MMIC and BGA packaging technologies, demonstrates that further improvement in size, cost, and performance can be achieved.

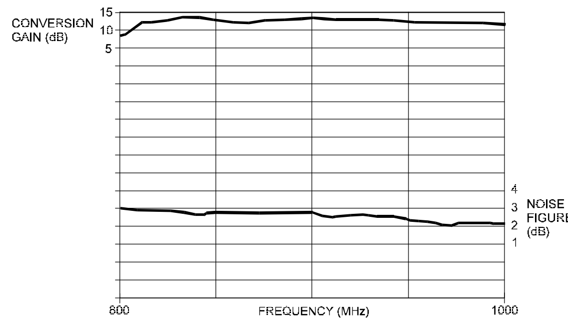

Figure 5: RF Transceiver Measured Conversion Loss and Noise Figure

Table 1. Measured BGA Performance Summary	
Parameter	**Measured Data**
RX Frequency	935-941 MHz
TX Frequency	896-902 MHz
Conversion Gain	14 dB
Noise Figure	3 dB
Input 3rd Order Intercept Point	-7 dBm
RX Current	25 mA
TX Current	1200 mA
Output Power	+33 dBm