# Intelligent RF Power Module Using Automatic Bias Control (ABC) System for PCS CDMA Applications


**Tetsuo Sato** [*1] **Shigehiro Yuyama** [*2] **Akishige Nakajima** [*2] **Hideyuki Ono** [*2]

**Akiyoshi Iwai** [*3] **Eiichi Hase** [*3] **Chusiro Kusano** [*2]

*1 Sales and Marketing Division, Hitachi Semiconductor (America) Inc.
2000 Sierra Point Parkway, MS:190 Brisbane, CA 94005-1835

*2 Radio Frequency Device Engineering Dept. Multi Purpose Semiconductor Business Operation Semiconductor & IC Div. Jyousui Hontyou, Kodaira 187, Japan

*3 Communication Systems Research Dept. Hitachi Central Research Lab Kokubunji, Tokyo 185 , Japan



## Abstract

Intelligent RF Power Module accommodates advanced PHEMT(Pseudomorphic HEMT) die and a Automatic Bias Control (ABC) system Si die on a small ceramic substrate. This 3.5V RF Power Module has been designed for use in PCS CDMA applications. At PCS frequency of 1880MHz, the module attained 35% PAE at Po=28dBm.


## Introduction

Consumer demand, for lighter and smaller phones with longer talk time, is requiring RF Power Amplifiers to operate from a single Li-ion cell battery [1] .At 3.5V supply voltage, achieving high efficiency, good thermal and power supply stability, while satisfying low cost objective can be a daunting task[2].

However, the ABC Module accomplishes both technical and cost requirements, by utilizing advanced PHEMT technology and low-cost Silicon ABC system IC on a high density, multi-layer ceramic substrate. In addition, bias current through the power amplifier can easily be adjusted lower for higher efficiencies at lower power levels (Fig-1). For 1850 to 1910 MHz PCS CDMA applications, the ABC Module operates from 3.0 to 4.2V supply voltage and -30 to +100 degrees centigrade case temperature.

## ABC System Concept

Block diagram of ABC Module is shown in (Fig-2).
The module has 2 stage amplifiers. The amplifier die consists of three PHEMT devices--power output , driver and sensor.

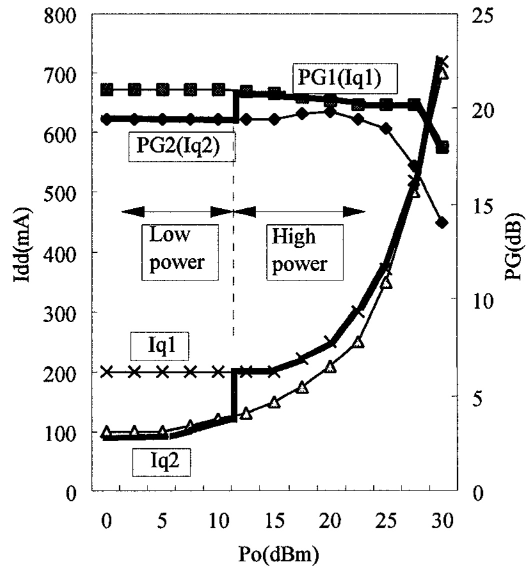


Fig-1 Bias Switching system

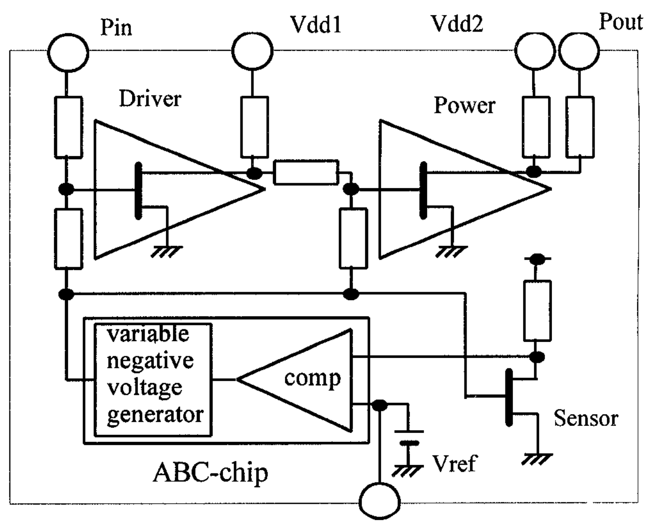


Fig-2 Block Diagram of ABC Module

The three PHEMT devices exhibit good thermal coupling. The ABC IC includes a current sensing comparator, and a variable negative voltage generator that consists of an oscillator, gain controlled charge pump circuit and a full wave detector. The oscillation frequency is 50MHz so that very little ripple filter capacitance is required. The sensor FET and ABC chip establishes a negative feed back loop and automatically adjusts gate bias voltages to both driver and output power FETs. This system does not require bias trimming process.

Since the ABC system constantly monitors and tracks the bias current, it offers excellent stability over temperature and supply voltage fluctuations. Bias current can also be easily changed by external control voltage. The switching speed is less than 10usec as shown in (Fig-3).

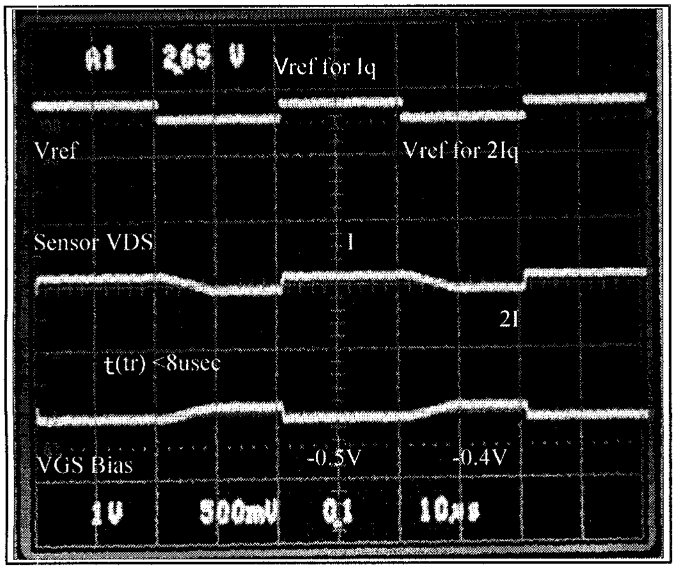


Fig-3 Bias Current Switching Time

## Manufacturing

Photograph of the ABC chip is shown in (Fig-4). Approximately 80 active devices and passive elements are fabricated into a 1.10mm x 0.90mm die using conventional 1.3um Si-Bipolar process. 0.5um gate length PHEMT are used for Power, Driver and sensor. Photograph of the ABC Power Module, for PCS CDMA application, is shown in (Fig-5). The module accommodates PHEMT, ABC IC, and all of matching components. Assembled multi-layer lead-less package dimension measures 11.0mmx 13.8mm x 1.8mm.

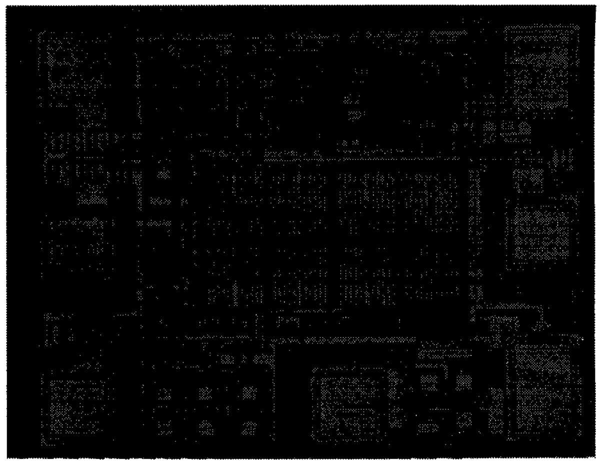

Fig-4 Photograph of the ABC chip

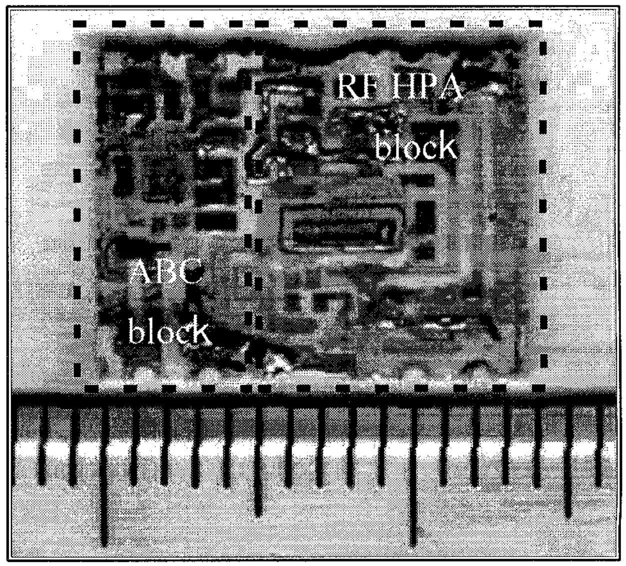


Fig-5 Photograph of ABC Module

## Test Results

Power gain versus output power characteristics is plotted in (Fig-7). The output P-1dB is greater than 29dBm, and gain variation over f=1850 to 1910MHz is less than 1dB. Performance was measured with CDMA modulated signal, Vdd= 3.5V, and at room temperature.

As shown in (Fig-8), efficiency of 35% is achieved at the Po=28dBm output power, Vdd=3.5V,and at f=1880MHz.

In addition, (Fig-9) which shows adjacent channel power rejection (ACPR) at +/-1.25MHz offset, demonstrates that ACPR is less than -45dBc for output power levels less than 28dBm.

0-7803-4471-5/98/$10.00 (c) 1998 IEEE

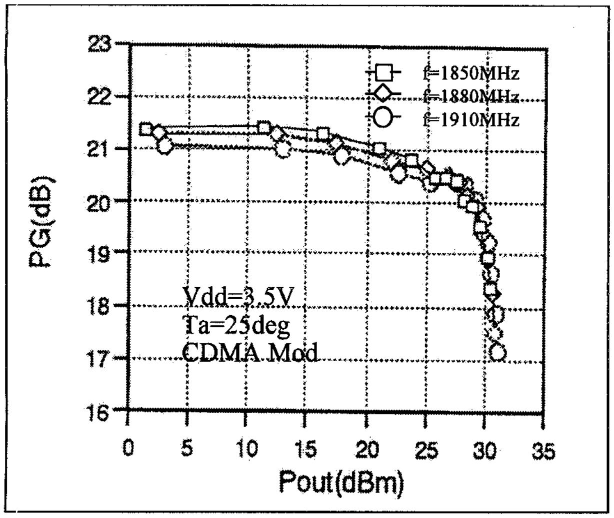


Fig-7 Power Gain vs. Output Power

ABC system uses negative feed back technology to monitor and control PHEMT bias current. Thus, the module is able to achieve excellent stability over temperature and supply voltage fluctuation. As shown in (Fig-10), the power gain at Vdd=3.0V is nearly identical to the gain at Vdd=3.5V. Even at Vdd=3.0V, the ABC Module is able to maintain greater than 27dBm of output P-1dB, and gain variation over 1850 to 1910MHz is still less than 1dB. Therefore, ABC Module is ideally suited to operate from a single Li-ion cell battery. (Fig-11) shows power gain variation versus Tc. Power gain variation is defined as the difference between power gain at low output power (0dBm) and power gain at high power (28dBm). Gain variation is less than 0.95dB over Tc=-30 to 100 degrees centigrade.

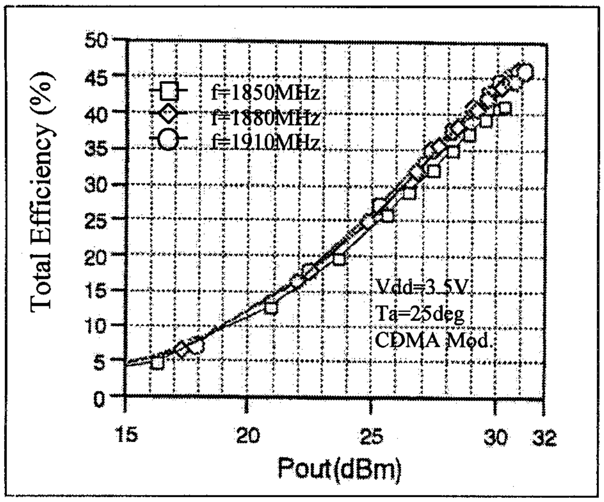


Fig-8 Efficiency vs. Output Power

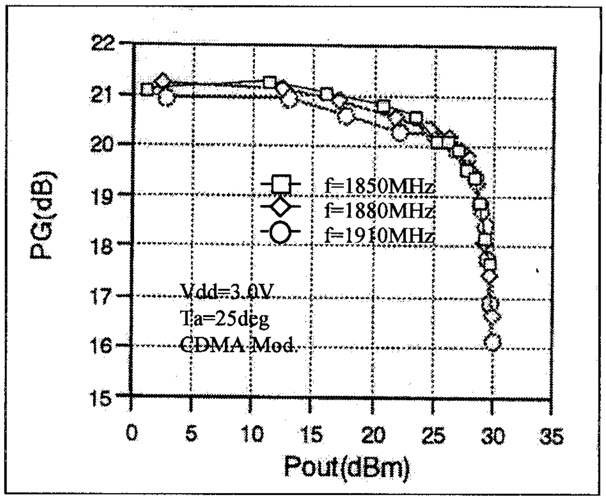


Fig-10 Power Gain vs. Output Power

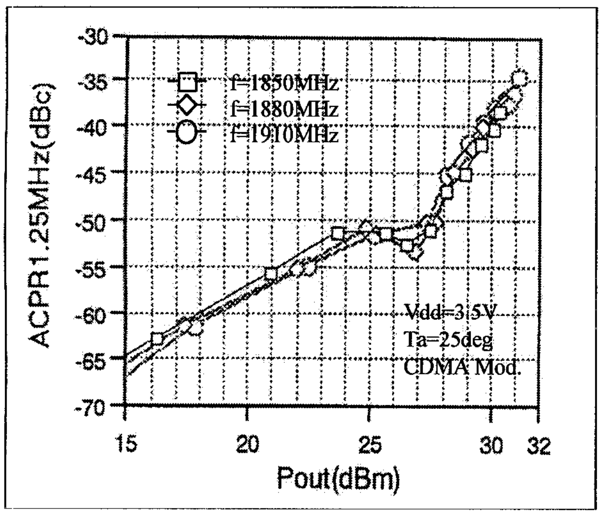


Fig-9 ACPR vs. Output Power

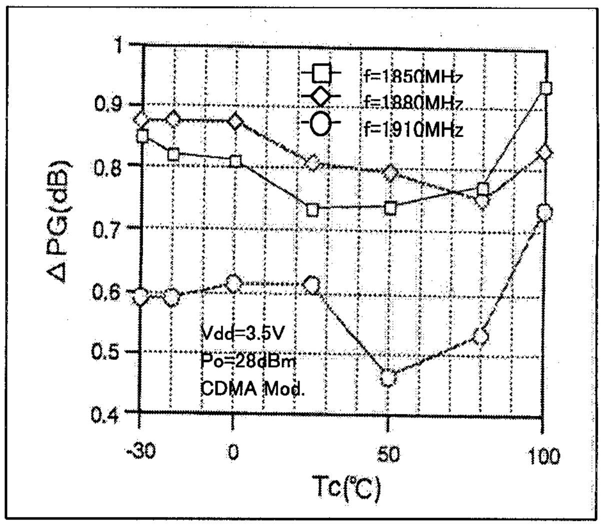


Fig-11 delta PG vs. Tc

0-7803-4471-5/98/$10.00 (c) 1998 IEEE

## Conclusion

We have developed RF Power ABC Module for PCS CDMA applications. The module was assembled with 0.5um gate-length PHEMT and Si ABC system IC, and all of the matching components in a small 0.27cc multi-layer ceramic package. ABC Module works from positive 3.0 to 4.2V supply voltage and achieves excellent power gain, linearity under wide temperature and supply voltage fluctuation. It attained 28dBm output power and 35% efficiency from a 3.5V supply voltage. (Tab.-1) summarizes the characteristics of ABC Module. This Intelligent RF Power ABC Module can also be used for TDMA and other systems applications.

Tab.-1 Characteristics of ABC Module

| | |
|---|---|
| **Operating frequency** | **1850-1910 MHz** |
| **Supply voltage** | **3.0-4.2 V** |
| **Output power** | **28 dBm** |
| **Power gain** | **21 dB** |
| **Total efficiency (at Po=28dBm)** | **35 %** |
| **Adjacent channel power rejection 1.25MHz offset** | **-45dBc** |
| **Adjacent channel power rejection 2.25MHz offset** | **-55dBc** |
| **2nd harmonics** | **-34dBc** |
| **3rd harmonics** | **-63dBc** |
| **Gain variation over frequency** | **+/-0.5dB** |
| **Gain variation over supply voltage** | **1.2dB** |
| **Gain variation over case temperature** | **0.95dB** |

## Acknowledgment

We wish to thank Dr. M. Nagata, Mr. S. Shimada, Mr. S. Ueda for their technical suggestion. We thank Mr. K. Kamegaki, Mr. K. Yamazaki, Mr. T. Hirano for Si-chip mask preparation. We thank Mr. S. Kudou, Mr. M. Maruyama, Mr. S. Moriyama for their P-HEMT Module device and circuit design work. We wish to thank Mr. P. Patterson, Mr. I. Ho for their encouragement.

## References

( 1 ) Silicon RF GCMOS PERFORMANCE FO PORTABLE COMMUNICATIONS Eddie Speas et al IEEE Radio Frequency Integrated Circuits Symposiu 1997 p153

( 2 ) A 2W,65% PAE SINGLE-SUPPLY ENHANC EMENT-MODE POWER PHEMT FOR 3V PC APPLICATIONS Der-Woei Wu et al. IEEE-MTT-International Microwave Symposium Digest 1997 p1319