HBT High Power Amplifier Modules for WiMAX CPE Applications

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1. Introduction

For WiMAX power amplifier applications, we have developed three models of heterojunction bipolar transistor (HBT) power amplifier modules, MGFS36EXXXX, which all have high output power and low distortion with a 50-Ω input/output interface. These modules have an average output power of 27 dBm and a gain of 33 dB in both the 2.3- and 2.5-GHz bands with an error vector magnitude (EVM) of 2.5%, and an average output power of 25 dBm and a gain of 30 dB in the 3.5-GHz band with an EVM of 2.5%.

2. Background

Worldwide interoperability for microwave access (WiMAX) covers mid- and long-distance areas and enables high-speed communications, and thus is a promising technology for the next generation of high-speed wireless communication systems. Although different countries have allocated various frequency bands, various systems are being developed concurrently for the corresponding frequency bands. In South Korea, for example, commercial service is already available. This communication system uses an orthogonal frequency division multiplexing (OFDM) modulation signal, which has an extremely high peak output power relative to the average output power, and thus needs a power amplifier having high saturation power and low distortion characteristics. In addition, WiMAX systems for customer premises equipment (CPE) applications will be installed in PC cards and mobile handsets, and thus need to be small, low cost and operable from a single power supply.

In response to these needs, Mitsubishi Electric has developed three models of high-output-power and low-distortion HBT power amplifier modules, MGFS36EXXXX, for the 2.3-GHz, 2.5-GHz and 3.5-GHz bands, using an indium gallium phosphide/gallium arsenide (InGaP/GaAs) HBT process that is well proven for fabricating mobile phone amplifiers. On a package measuring only 4.5-mm square, the amplifier module integrates a bias circuit including amplifiers and collector power supply line, as well as functions unique to the WiMAX power amplifier such as a step attenuator and output power detector circuit using Mitsubishi's proprietary AC-coupled stack type base-collector diode switch. In addition, the 50-Ω input/output interfaces eliminate the need for an external matching circuit and help make the overall system smaller and cheaper. The developed modules offer high output power and low distortion characteristics: the modules have an average output power of 27 dBm and a gain of 33 dB with an EVM of 2.5% in the 2.3-GHz band (MGFS36E2325) and 2.5-GHz band (MGFS36E2527), and an average output power of 25 dBm and a gain of 30 dB with an EVM of 2.5% in the 3.5-GHz band (MGFS36E3436).

3. Configuration of Power Amplifier Module

Figure 1 shows the schematic configuration of the newly developed power amplifier modules for the 2.3-, 2.5- and 3.5-GHz bands[1]. To achieve a gain of 30 dB or greater, a three-stage amplifier is employed; and a 0/20-dB step attenuator with its control circuit and an output power detector circuit are also integrated. The bias current to each circuit is shut down by turning off the reference voltage (Vref).

3.1 Step attenuator

The step attenuator consists of Mitsubishi's proprietary AC-coupled stack type base-collector diode switch (ACCS-DSW), which has a high permissible transmission power even when operating with a low bias current[2]. Figure 2 shows its circuit diagram. Under the same bias current conditions, the ACCS-DSW can improve the permissible transmission power characteristics by at least 6 dB compared to conventional diode switches. The distortion characteristics have been further improved by placing a diode linearizer at the input terminal, which compensates for the gain deviation at a high input power level.

This type of step attenuator makes it possible to insert an attenuator between the first and second stages of the amplifier, and to prevent a change in the input return loss and deterioration in the noise figure (NF) characteristics while the attenuator is being turned on and off.

The control circuit for the step attenuator is configured to allow a complementary signal to be output according to the control signal (0/3 V) input to the external control terminal (V_{cont}). A power supply switch transistor is added to the control circuit so that no current is consumed by the circuit while the Vref voltage is turned off.

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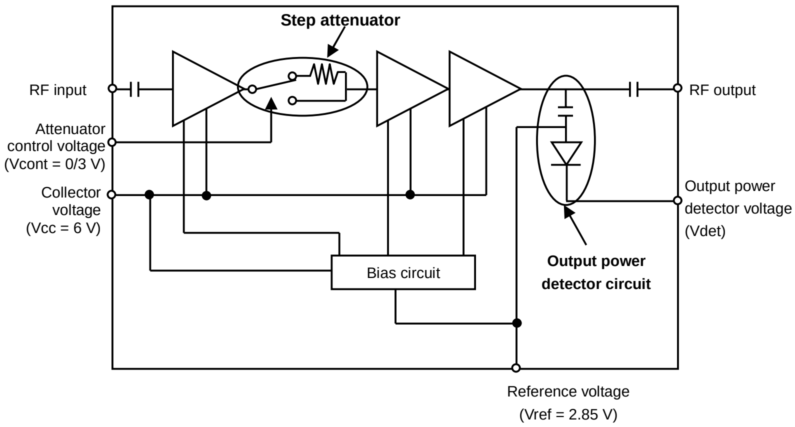


Fig. 1 Configuration of power amplifier module

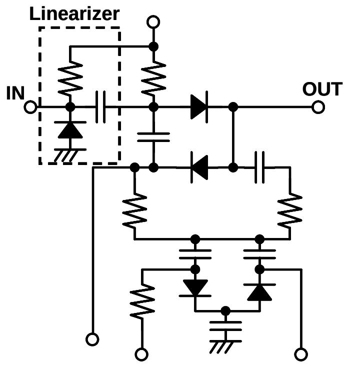


Fig. 2 Circuit diagram of step attenuator

3.2 Output power detector circuit

A diode detector circuit is used as the output power detection circuit. The circuit is designed to provide a change in the detector output voltage (Vdet) of at least 1 V when the output power level changes from 7 to 27 dBm. This detector circuit is biased directly by the Vref terminal via a resistor, and thus can also be shut down by turning off the Vref voltage.

4. Basic Characteristics of Power Amplifier Module

Figure 3 shows a photograph of the WiMAX power amplifier module. A small module size of $4.5\times4.5\times1.0$ mm^3 common to all the 2.3-, 2.5- and 3.5-GHz bands has been achieved. The InGaP/GaAs HBT process was used to fabricate the monolithic microwave integrated circuit (MMIC) power amplifier, which is mounted on the module. Figure 4 shows the measured frequency characteristics of the 2.5- and 3.5-GHz band modules with the attenuation being switched on or off and a power supply voltage of 6 V. The 2.5-GHz band power amplifier module exhibited a linear gain of at least 28 dB and an attenuation of 19 dB at frequencies between 2.5 and 2.7 GHz, and maintained an input return loss of 10 dB or greater regardless of whether the attenuation was turned on or off. The 2.3-GHz band module exhibited nearly the same characteristics. Meanwhile, the 3.5-GHz band power amplifier module also exhibited a linear gain of at least 27 dB and an attenuation of 21 dB at frequencies between 3.4 and 3.6 GHz, and showed similar input return loss characteristics as the 2.5-GHz band module, maintaining an input return loss of 10 dB or greater regardless of whether the attenuation was turned on or off.

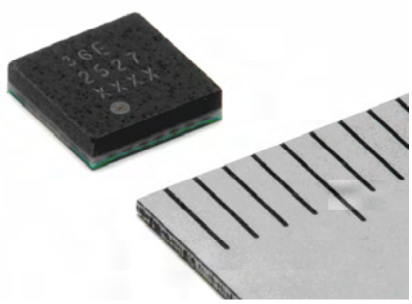
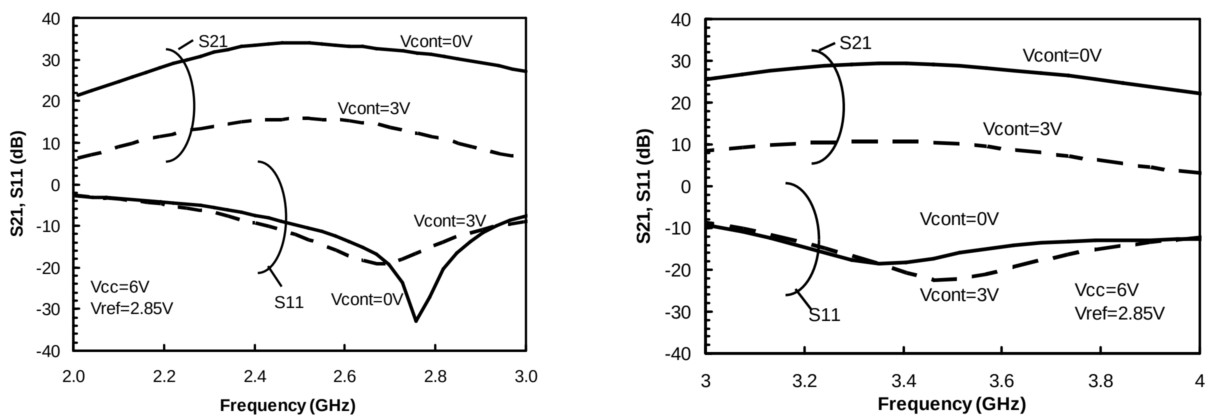


Fig. 3 Photograph of module

Figure 5 shows the measured output-power dependencies of the gain, efficiency and EVM of the 2.5- and 3.5-GHz band modules with the attenuation being turned on or off and using the IEEE802.16-2004 compliant 64 QAM-OFDM modulation signal. The power



(a) 2.5-GHz band module

(b) 3.5-GHz band module

Fig. 4 Frequency characteristics when attenuation is turned on or off
Attenuation off (Vcont = 0 V), Attenuation on (Vcont = 3V)

supply voltage was 6 V and the reference voltage (Vref) was 2.85 V. When the attenuation was turned off, the 2.5-GHz band module exhibited a power gain of 33 dB, an EVM of 2.5%, and an efficiency of 12% with an output power of 27 dBm at frequencies between 2.5 and 2.7 GHz. The 2.3-GHz band module has nearly the same characteristics. The 3.5-GHz band module exhibited a power gain of 30 dB, an EVM of 2.5%, and an efficiency of 11% with an output power of 25 dBm at frequencies between 3.4 and 3.6 GHz. The 2.3-, 2.5- and 3.5-GHz band modules have all achieved high power gain and low distortion characteristics. When the attenuation was turned on, the output power that satisfied EVM = 2.5% was a sufficiently high value of 12 dBm or greater with all three power module models.

Figure 6 shows the measured output voltage from the detector circuit. Both the 2.5- and 3.5-GHz band modules have achieved a sufficient change in the detector output voltage (Vdet) of 1 V or greater when the output power level is changed from 7 to 27 dBm.

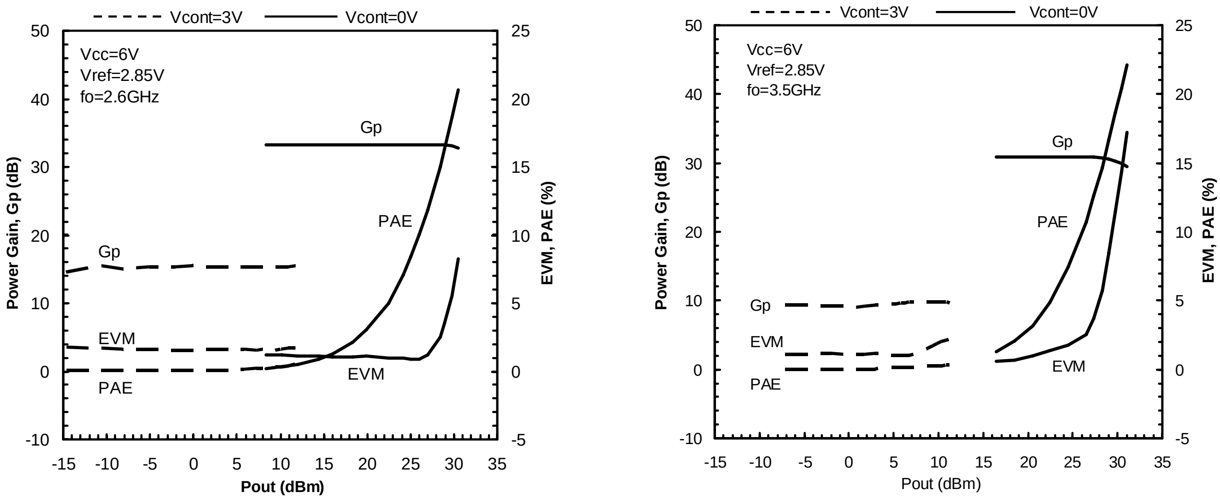
The basic characteristics of these three models of power amplifier modules (MGFS36EXXXX) are summarized in Table 1. These modules will be useful for developing small, low-cost handsets.

We will continue to develop products with even higher output and efficiency.

References

(1) Miyo Miyashita et al., “Fully Integrated HBT MMIC Power Amplifier Modules for Use in 2.5/3.5-GHz-Band WiMAX Applications,” IEICE Technical Report, ED 2007-220.

(2) K. Yamamoto et al., “A 0/20 dB Step Linearized Attenuator with GaAs-HBT Compatible, AC-coupled, Stack Type Base-collector Diode Switches,” IEEE International Microwave Symposium Digest, pp. 1693-1696, 2006.



(a) 2.5-GHz band module

(b) 3.5-GHz band module

Fig. 5 Large signal characteristics when attenuation is turned on or off
Attenuation off (Vcont = 0 V), Attenuation on (Vcont = 3 V)

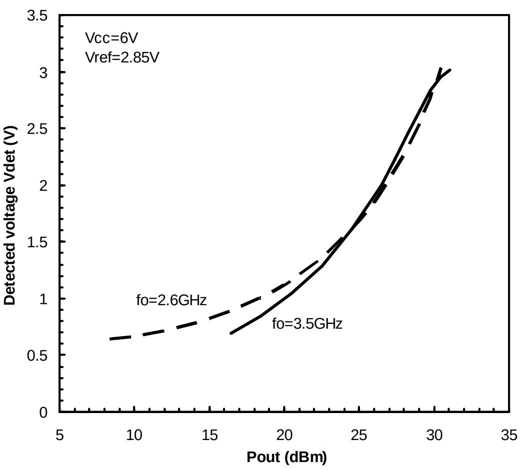


Fig. 6 Measurement result of detector output voltage

Table 1 Basic characteristics of power amplifier modules for WiMAX CPE applications

Characteristics	Measurement conditions	MGFS36E2325	MGFS36E2527	MGFS36E3436A	Unit
Operating frequency	Vcc=6V Vref=2.85V IEEE802.16 signal input	2.3 – 2.5	2.5 – 2.7	3.4 – 3.6	GHz
Power gain		33	33	30	dB
Efficiency		11	12	11	%
Output power (EVM = 2.5%)		27	27	25	dBm
Input return loss		10	10	10	dB
Detector output voltage		2	2	2	V
Attenuation		16	19	21	dB
Total collector current		760	700	700	mA
Module size		4.5mm × 4.5mm × 1.0mm			