An Advanced 2 Watt High Power Amplifier for CDMA 900 MHz System

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Abstract – **In this paper, an advanced 2 watt high power amplifier (HPA) for CDMA 900 MHz system is described. The results of this HPA – the linear gain of 30 dB, the gain flatness of 0.27 dB at the desired frequency range (895 MHz ~ 910 MHz), the input return loss of 18 dB, and the output return loss of 33 dB – are obtained. The output power of 39.74 dBm is measured at 0.42 dB gain compression. The back-off technique (BOT) and the pre-distortion technique (PDT) applied to improve the linearity of HPA. The improvement as 7.25 dB of Adjacent Channel Power Ratio (ACPR) is obtained by PDT.**

I. INTRODUCTION

The Increment of wireless communication customers and data causes the lack of the channel. The code division multiple access (CDMA) technology is used for the purpose of efficient use of frequency. The advantages of CDMA technology are large capability, high quality, security, and high efficiency.

The demands placed on high power amplifier (HPA), which are used in CDMA systems, are subsequently increasing in terms of bandwidth, output power, efficiency, and allowable level of distortion [1][2]. Especially, the linearity of HPA should be considered because the non-linearity of HPA causes interference to other radio users in CDMA systems. The linearity of HPA is described in terms of ACPR in CDMA systems. ACPR means the measurement of the degree of signal spreading into adjacent channels. Therefore, the ACPR must be measured in order to design HPA in CDMA system. In general, the several techniques such as back-off, feed-back, pre-distortion, pre-correction, and feed-forward are considered to remove the distortion. In this paper, PDT and BOT are used to improve the ACPR of 2 watt HPA.

II. DESIGN OF 2 WATT HPA

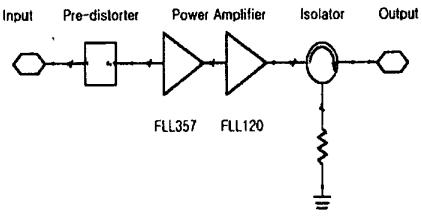
The 2 watt HPA requirements for CDMA repeater applications are summarized in Table I. This HPA is designed to satisfy the ACPR specification of CDMA system

TABLE I.
THE SPECIFICATIONS OF 2 WATT HPA FOR CDMA 900 MHZ SYSTEM

Parameter	Required Value	Unit
Frequency Range	895 ~ 910	MHz
Gain	30	dB
Gain Flatness	≤ 1 (Max)	dB
Output P_{1dB}	≥ 39	dBm
S_{11}	≤ - 14	dB
S_{22}	≤ -14	dB
V_{dd}	10	V
Current	3,000	mA

A 2 watt HPA consists of the power amplifier, the pre-distorter, and the isolator. The configuration of cascaded two stages is applied to satisfy the specifications. The pre-distortion technique improves the linearity of HPA, and the isolator compensates the output return loss of HPA.

It is very important to select the appropriate active device in HPA design. In this paper, the package type GaAs MESFETs are chosen in each stage considering the linearity and efficiency [2][4]. The FLL357ME and the FLL120MK (Fujitus compound semiconductor, Inc.) are used as the first and the second stage active devices. The *DC* bias points of FLL357ME and FLL120MK are shown that V_{ds1} = 10 V, I_{ds1} = 500 mA, V_{ds2} = 10 V, and I_{ds2} = 2,100 mA. Therefore, the total current consumption of *DC* bias is 2,600 mA. Each stage *DC* bias point should be set to operate in class A. Figure 1 shows the basic block diagram of the designed HPA.



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A 2 watt HPA is simulated by the advanced design system (ADS) design tool of Agilent Technology Inc. The non-linear models of active devices are not provided by the manufacturer. Therefore, the signal analysis and simulation is performed not by the large signal model but by the small signal model. The linear gain of 35.3 dB, the gain flatness of 0.36 dB, the input return loss of 20.4 dB, and the output return loss of 31.6 dB are achieved as simulation results. Even though the required total gain of HPA is just 30 dB, the gain should be more than 36 dB in order to meet the specification because there are insertion losses in the pre-distorter and the isolator.

The PDT is applied by the non-linear characteristics of the schottky diode. The PDT distorts the input signal of HPA to corrects both AM–AM and AM–PM distortions which are non-linearity of HPA. As a result, the linearity of HPA is enhanced by the PDT [5] – [7]. Figure 2 indicates the schematic diagram of PDT and figure 3 shows the measured small signal characteristics of PDT. The insertion loss of PDT at 900 MHz is 5.35 dB as shown in Figure 3. Figure 4 shows the small signal characteristics of the isolator, and the insertion loss of isolator is 0.66 dB at 900 MHz.

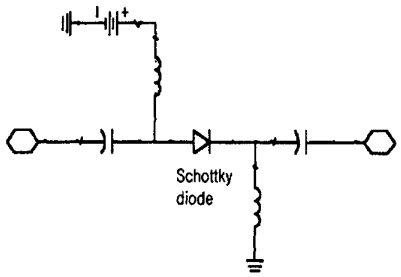

Figure 2. Pre-distorter

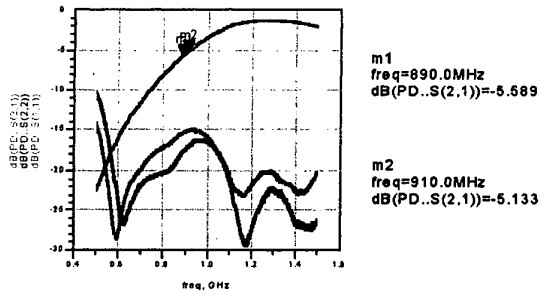

Figure 3. The small signal characteristics of pre-distorter.

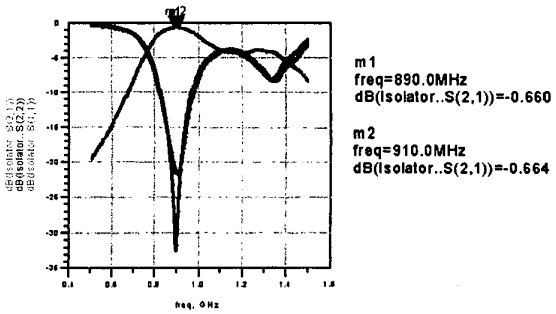

Figure 4. The small signal characteristics of isolator.

III. Implementation and Measurement

The small signal characteristics of the fabricated 2 watt HPA are measured by network analyzer. The gains of the simulation, the measurements with PDT and without PDT are shown in Figure 5. The simulated gain and the measured gain without PDT are 35.5 dB and 35 dB, respectively. The simulation is performed well, for there are 0.5 dB errors between the simulation result and the measure result without PDT. The measured gain with PDT is 30 dB because of the losses of PDT and the isolator. Even though the PDT has the insertion loss of 5 dB, it improves the linearity of HPA. The measured gain and the simulated gain from 890 MHz to 930 MHz are shown in Figure 6. The measured gain flatness with PDT from 895 MHz to 910 MHz is 0.27 dB.

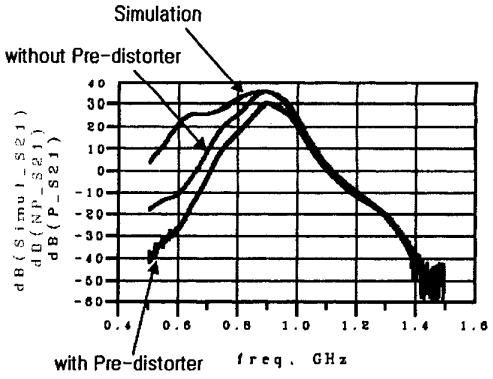

Figure 5. Gain of 2 watt HPA.

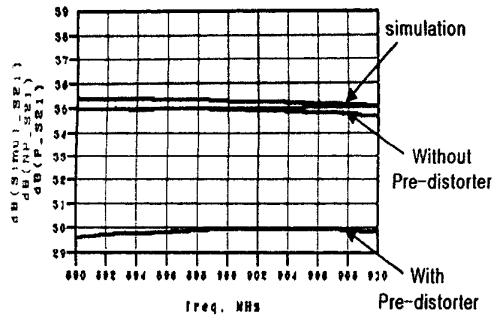

Figure 6. In-band gain of 2 watt HPA.

In many cases, the output matching network for maximum output power gives the bad output return loss, because the conjugate match yields P_{1dB} lower than that can be obtained by the correct power tuning. Typically, power transistors are the most expensive components in a module. Therefore a waste of performance of the power transistors can be translated directly into unnecessary cost [1][2]. In this paper, the power matching technique is taken for maximum output power. The input matching network of HPA is conjugately matched and the isolator is added behind the output network. The isolator is applied to compensate the output return loss. The input and the output return losses of HPA are scaled in dB in Figure 7. Even though the isolator has 0.66 dB loss, it decreases the output return loss of HPA.

The output power of 39.74 dBm is measured at gain compression of 0.42 dB. Table II shows measurement results of 2 watt HPA.

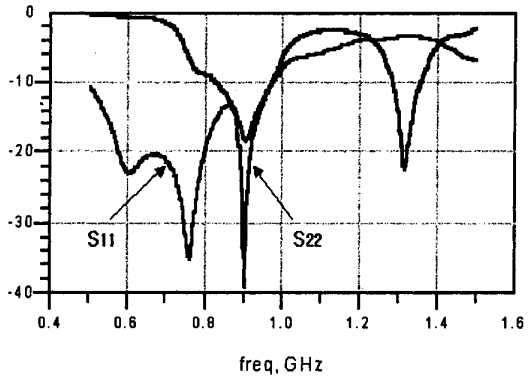

Figure 7. The input output return loss of 2 watt HPA.

TABLE II
MEASUREMENT RESULTS OF 2 WATT HPA.

Parameter	Measured Value	Unit
Frequency Range	895 ~ 910	MHz
Gain	30.35	dB
Gain Flatness	0.27	dB
Output P_{1dB}	39.74	dBm
S_{11}	- 18.37	dB
S_{22}	- 33.56	dB
Vdd	10	V
Current	2,600	mA

There are so many parameters to define the linearity of HPA such as the inter-modulation distortion (IMD), the third order intercept point (OIP3), ACPR, etc. The ACPR of HPA must be measured in order to use HPA in CDMA system [8][9]. ACPR measurements of 2 watt HPA with PDT and without PDT are shown in Figure 8. This HPA satisfies the conduction emission mask for CDMA 900 MHz system at 33 dBm output power with BOT. The ACPR improvement of 7.25 dB is obtained by using PDT at 33 dBm output power is shown in Table III. The fabricated 2 watt HPA is shown in Figure 9.

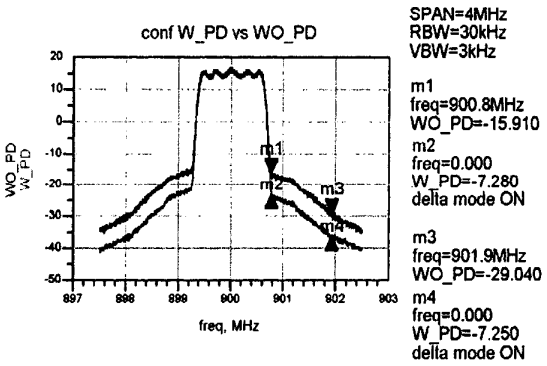

Figure 8. ACPR of 2 watt HPA.

TABLE III. ACPR IMPROVEMENT.

	900 MHz	Δ 750 KHz	Δ 1.94 MHz
Conduction Emission Mask	33 dBm	- 29 dBc	- 44 dBc
ACPR without Pre-distorter	33 dBm	- 31.5 dBc	- 45.3 dBc
ACPR with Pre-distorter	33 dBm	- 38.78 dBc	- 52.5 dBc
ACPR Improvement	0 dB	7.28 dBc	7.25 dBc

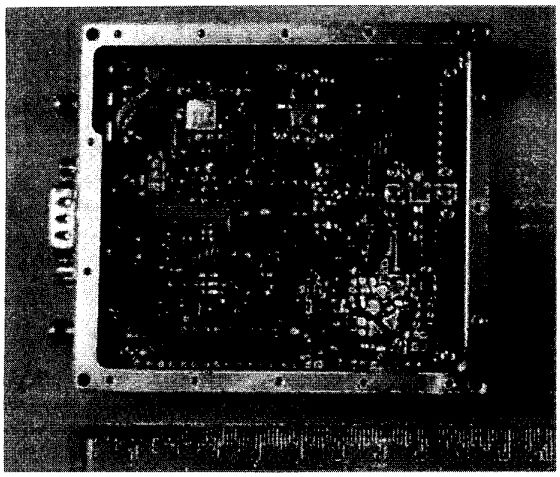

Figure 9. The fabricated 2 watt HPA.

IV. Conclusion

An advanced 2 watt HPA for CDMA 900 MHz system is designed, fabricated, and tested in this research. The input matching and output matching are considered for the conjugated matching and the maximum output power. BOT and POT are applied to improve the linearity of HPA. POT results in the improvement as 7.25 dB of ACPR. It satisfies the HPA specification of CDMA 900 MHz such as the conduction emission mask until the output power is up to 33 dBm. This technique makes it possible to shrink the size of HPA as 95 mm × 90 mm.

V. Acknowledgements

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VI. References

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