A DUAL-BAND POWER AMPLIFIER MODULE FOR KPCS/WCDMA APPLICATIONS ON A MULTILAYER LTCC SUBSTRATE

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Abstract - A compact power amplifier module (PAM) for Korean-PCS (KPCS)/WCDMA dual-band applications based on a multilayer low-temperature co-fired ceramic (LTCC) substrate is presented. All passive components which are required for the PAM are fully embedded in the substrate. The measured result shows that the PAM delivers a power of 28 dBm with a power added efficiency (PAE) of more than 30 % at KPCS band. The adjacent-channel power ratio (ACPR) at 1.25-MHz and 2.25-MHz offset is -44dBc/30kHz and -60dBc/30kHz, respectively, at 28-dBm output power. Also, the PAM for WCDMA band exhibits an output power of 27 dBm and 32-dB gain at 1.95 GHz with a 3.4-V supply. The adjacent-channel leakage ratio (ACLR) at 5-MHz and 10-MHz offset is -37.5dBc/3.84MHz and -48dBc/3.84MHz, respectively. The overall size of the LTCC substrate is only 6 mm × 4 mm × 0.8 mm.

1. Introduction

As the market for wireless communications grows, the demand for size reduction and full integration of RF modules increases. Among several multi-chip module (MCM) technologies such as MCM-L, MCM-C and MCM-D, a multilayer low-temperature co-fired ceramic (LTCC) has played a large role in mobile communications by accomplishing high levels of functionality in very small volumes. By adopting the LTCC technology, a large number of RF modules have been developed, allowing them to be compact and cost-effective solutions to overcome the problem of other technologies [1]-[3].

A multilayer LTCC technology enables RF modules to be reduced dramatically by taking advantage of the three dimensional flexibility. Compared to a conventional two dimensional PCB approach using discrete passive components such as chip capacitors and inductors, this technology allows higher density, reduced size, and lower cost. Furthermore, it would be very attractive to adopt the LTCC technology for multi-band operation both to meet the requirement of current trends of multi-band terminals and to further reduce the module size.

The aim of the work presented in this paper is to implement a dual-band power amplifier module (PAM) based on an LTCC substrate for Korean-PCS (KPCS) band and WCDMA band. The single-band PAM for KPCS band has been investigated, providing good performance with a total module size of 6 mm × 6 mm × 1.2 mm [3]. The PAM to be proposed here, however, is operating at dual band with more than 33% size reduction. The implemented LTCC substrate has 26 layers, including input and output matching networks, RF chokes, bypass capacitors to be replaced with external chip components on PCB.

2. Module Design

Before attempting to realize the 26-layer LTCC module, we investigated the sensitivity of each block such as input and output matching networks by varying values and location of external passive

ISBN: 89-86522-78-0 94460©KEES

components on two dimensional LTCC and/or PCB board. After that, the full three dimensional simulation of each block in the module for both bands was accomplished to approach the value obtained in two dimensional structure with the aid of CST Microwave Studio.

The proposed module was realized based on the conventional LTCC process. An LTCC green tape was prepared by tape casting with glass/ceramic mixed-powder (DuPont 9599). The thickness of the ceramic tape after co-firing is about 38 μm with 20 μm silver metallization on the surface layer and 10 μm in the buried layers. The dielectric constant of the substrate is 7.8 and loss tangent is about 0.003. Quarter-wave-length striplines and bypass capacitors at bias circuits for both bands were embedded in the substrate. In order to interconnect various layers of a ceramic substrate and conductors, vias were used. Furthermore, a large number of thermal vias and inner ground planes were also embedded to improve overall performance. The total size of the substrate is 6 mm × 4 mm, and the height of the substrate is about 0.8 mm. Three dimensional view of the LTCC substrate is shown in Fig. 1.

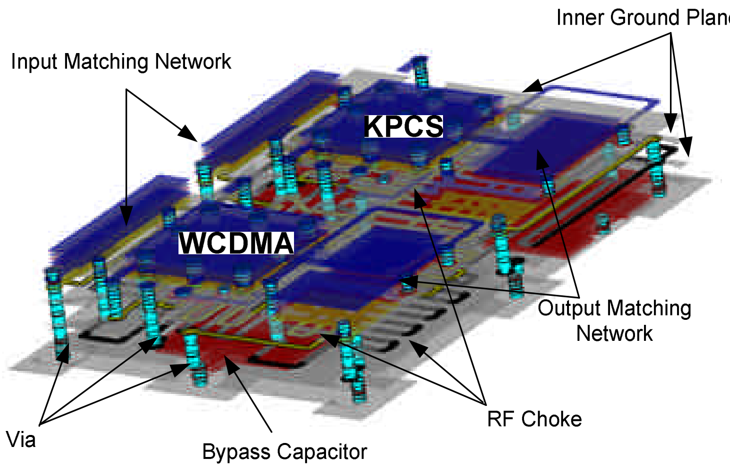


Fig. 1. Three dimensional view of the dual-band PAM.

MMIC PAs were attached by wire bonding on top of the substrate. The PA provided by WAVICS Co. Ltd., was manufactured on an advanced InGaP HBT (Hetero-junction Bipolar Transistor) MMIC technology which can provide state-of-the-art reliability and temperature stability. This PA MMIC consists of two stages: a driver stage and a power stage. The two same PA MMICs were used for both bands with different values of passive components at matching networks which were embedded in the substrate. Each PA can be operated separately by turning Vref on/off, which was separately designed and had its own bypass capacitor. The photograph of the fabricated dual-band PAM is shown in Fig. 2.

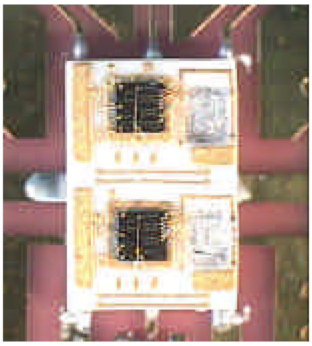
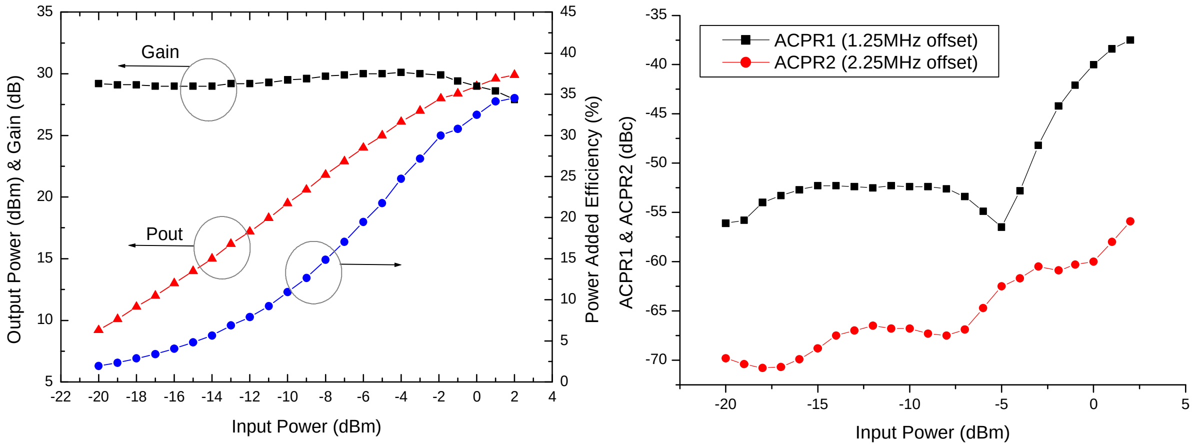


Fig. 2. Photograph of the farbicated dual-band PAM.

3. Experimental Result

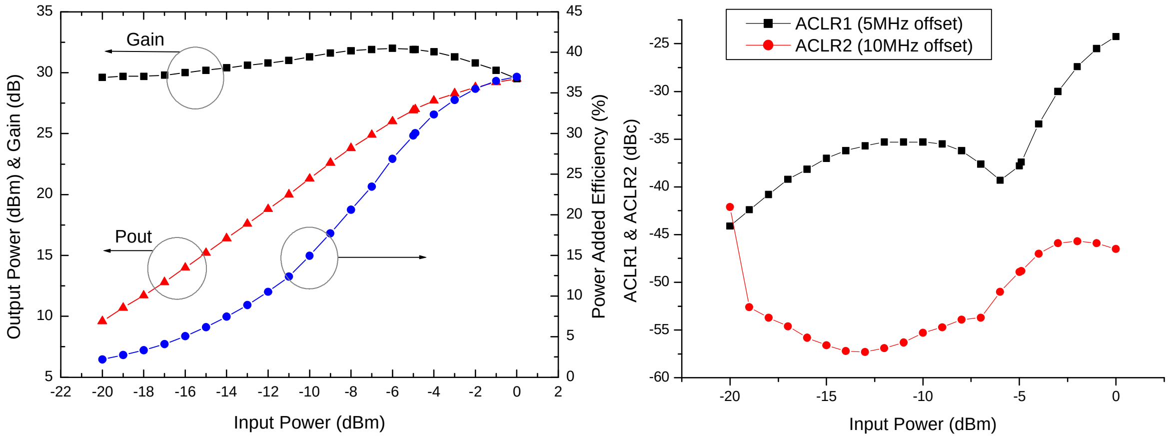
The implemented dual-band PAM was measured using E4432B signal generator, E4407B spectrum analyzer, and E4417A power meter. The measured performance of the PAM for KPCS band is shown in Fig. 3. The PAM exhibits an output power of 28 dBm and 30-dB gain at a center frequency of 1.765 GHz with a 3.4-V supply. A power added efficiency (PAE) of more than 30 % is obtained. The linearity performance of the PAM was measured under adjacent-channel power ratio (ACPR) measurement with a KPCS signal. The ACPR at 1.25-MHz and 2.25-MHz offset is -44dBc/30kHz and -60dBc/30kHz, respectively, at 28-dBm output power, as shown in Fig. 3 (b). The result can meet the stringent CDMA linearity requirement for an output power of up to 28 dBm.



(a) (b)

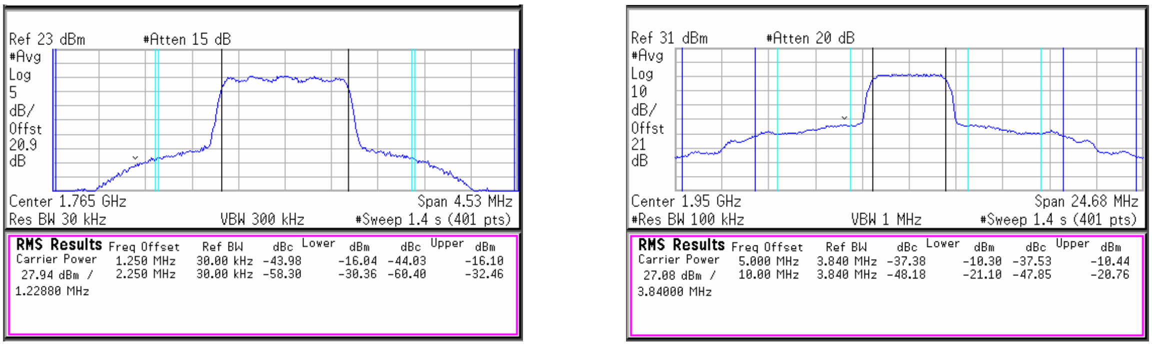
Fig. 3. Measured performance of the PAM for KPCS band.
(Supply voltage: 3.4 V and *f*o: 1.765 GHz)

The PAM for WCDMA band was also measured as shown in Fig. 4. The result of the PAM shows an output power of 27 dBm and 32-dB gain at a center frequency of 1.95 GHz with a 3.4-V supply. The PAM fulfilled the 3GPP WCDMA adjacent-channel leakage ratio (ACLR), resulting in a ACLR of -37.5dBc/3.84MHz and –48dBc/3.84MHz at 5-MHz and 10-MHz offset, respectively, at 27-dBm output power, as shown in Fig. 4(b). The output spectrums of the KPCS PAM at 28-dBm output power and the WCDMA PAM at 27-dBm output power are illustrated in Fig. 5.



(a) (b)

Fig. 4. Measured performance of the PAM for WCDMA band.
(Supply voltage: 3.4 V and *f*o: 1.95 GHz)



(a) (b)

Fig. 5. The output spectrum of the PAM. (a) KPCS at 28-dBm output power (b) WCDMA at 27-dBm output power.

Table 1. Summary of measured performance.

	KPCS	WCDMA
Output Power (dBm)	28	27
Power Gain (dB)	30	32
PAE (%)	30	30.1
2^{nd} Harmonics (dBc)	-35	-37
Supply Voltage (V)	3.4	3.4
ACPR1/ACPR2 (dBc)	-44/-60	-37.5/-48

The measured performance of the module for both bands is summarized in Table 1. As can be seen in this table, linearity and efficiency for both bands are high enough to meet the specification of KPCS and WCDMA bands.

4. Conclusion

A fully integrated dual-band power amplifier module for KPCS and WCDMA bands incorporating a multilayer LTCC substrate is demonstrated. All passive components are fully embedded, and the overall size of the substrate is 6 mm × 4 mm × 0.8 mm. The measured results show that the PAM delivers a power of 28 dBm with a PAE of more than 30 % at KPCS band. The ACPR at 1.25-MHz and 2.25-MHz offset is -44dBc/30kHz and -60dBc/30kHz, respectively, at 28-dBm output power. Also, the PAM for WCDMA band exhibits an output power of 27 dBm and 32-dB gain at 1.95 GHz with a 3.4-V supply. The ACLR at 5-MHz and 10-MHz offset is -37.5dBc/3.84MHz and -48dBc/3.84MHz, respectively at 27-dBm output power. Therefore, the dual-band PAM offers good performance with very compact size.

Acknowledgement

This work was supported by the Ministry of Information and Communication of Korea through Electro-0580 project.

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