Ultra-Wideband GaN Doherty Power Amplifier for Next-Generation Wireless Base Stations

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We have developed the ultra-wideband Doherty power amplifier to support the drastic increase in communication volume in next-generation mobile communication. The amplifier is able to handle multiple bands in mobile communication by combining the technology of absorbing the parasites of the transistor or package into the λ/4 inverter with circuit technology for compensating the frequency dependency, in addition to the GaN transistor which effectively widens the bandwidth.

1. Background

To meet the drastic increase in communication volume in next-generation mobile communication, the amplifier used for the mobile communication base station must be able to amplify signals with large peak to average power ratio (PAPR) with high efficiency and over a broad bandwidth. Broadband, which can support multiple bandwidths, is effective for reducing the size and cost of the base station. The Doherty power amplifier is a useful technology[1][2] which efficiently amplifies signals with large PAPR. However, one problem of the Doherty power amplifier is that it generally has narrow band characteristics in configuration.

This paper describes the gallium nitride (GaN) transistor, which is effective for the Doherty power amplifier for broadband applications. In addition, we report the development of an ultra-wideband Doherty power amplifier which covers multiple bandwidths used in 4G/long term evolution-advanced (LTE-advanced) by combining the technology of absorbing parasites of the transistor or package into the λ/4 inverter with circuit technology for compensating the frequency dependency.

2. Circuit Configuration of Ultra-Wideband Doherty Power Amplifier

Figure 1 shows the circuit configuration of the Doherty power amplifier. Figure 1 (a) shows the conventional circuit and Fig. 1 (b) shows the proposed circuit. In an ideal Doherty power amplifier, the configuration has two amplifiers in parallel and a λ/4 transmission line connected to the main amplifier. This λ/4 transmission line causes load modulation according to the operation of the two amplifiers, resulting in highly efficient operation at back-off. In contrast, in the conventional circuit of the practical Doherty power amplifier, the matching circuit and the offset line are connected to the output side of the main and auxiliary amplifier. In general, a transistor consisting of amplifiers requires a matching circuit which includes parasitic reactance and adjusts the output impedance to 50Ω. In addition, the offset line is required for adjusting electric length to occur resistive load modulation and is connected after the matching circuit. The λ/4 transmission line is connected to the main amplifier after the offset line. On the other hand, in the proposed circuit, the equivalent λ/4 transmission line including parasites of the package and the transistor is connected to the current source of the main amplifier transistor (Part A in Fig. 1 (b)) instead of the matching circuit and the offset line. In addition, the frequency dependency compensating circuit is connected to the output of the auxiliary amplifier (Part B of Fig. 1 (b)).

Figure 2 shows the circuit of the equivalent λ/4 transmission line (Part A in Fig. 1 (b)) including parasites

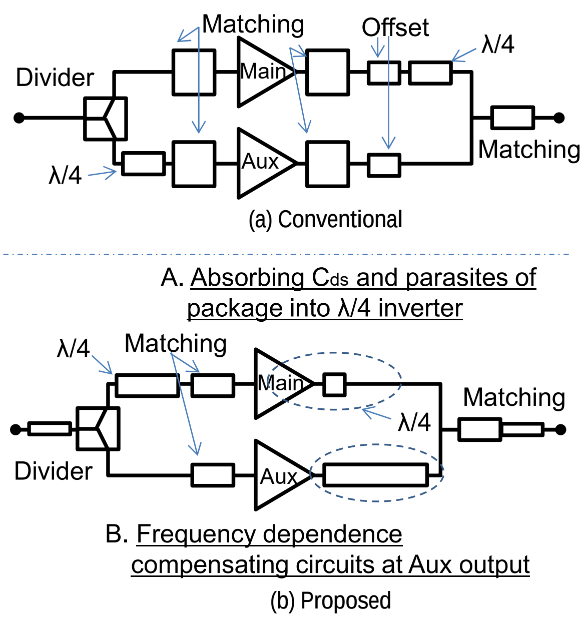

Fig. 1 Schematics of the Doherty power amplifier

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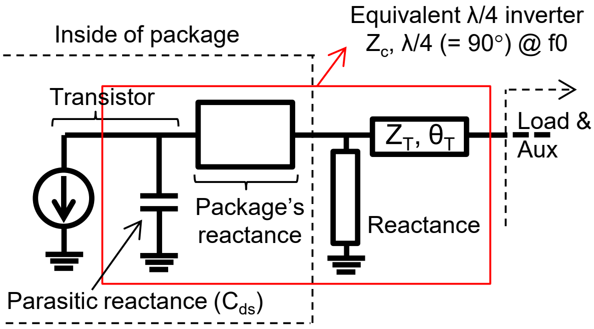

Fig. 2 **Schematic of the λ/4 inverter for absorbing the transistor output capacitance and reactance of package**

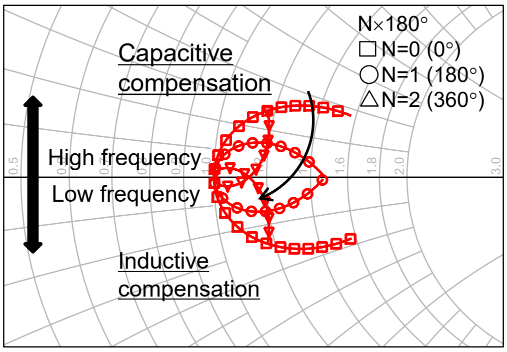

Fig. 3 Simulated frequency response of reflection at output terminal of the Doherty power amplifier

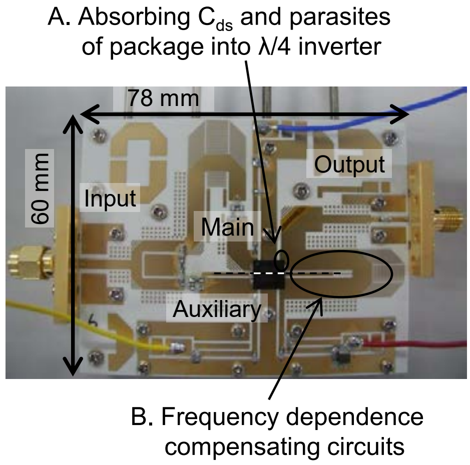

Fig. 4 Photo of the assembled ultra-wideband GaN Doherty power amplifier

of the package and the transistor. By combining parasites of the package and the transistor in Fig. 2 with the external circuit of the package, an equivalent λ/4 transmission line which has a characteristic impedance of Z_c and electric length of λ/4 at a certain frequency can be created. Since many Doherty power amplifiers include matching circuits and offset lines, the electric length from the current source of the transistor to the combining point of the main amplifier and auxiliary amplifier is larger than λ/4 wavelength or it has circuit elements for eliminating parasites. In contrast, our configuration directly connects the λ/4 transmission line to the current source of the transistor. The matching circuit or offset line is not connected as in the conventional circuit and the Doherty circuit can be configured with a broad bandwidth.

The frequency dependency compensating circuit (Part B in Fig. 1 (b)) compensates the frequency dependency of the λ/4 transmission line loaded on the main amplifier. This circuit is configured by including the package of the auxiliary amplifier and parasites of the transistor, and it has an electric length that is an integer (N) multiple of the λ/2 transmission line (λ/2) viewed from the current source of the auxiliary amplifier. The characteristic impedance and electric length are set to values so as to eliminate the frequency dependency of the λ/4 transmission line on the main amplifier. Figure 3 shows the simulation result of the frequency dependency of the reflection characteristic from the output terminal to the Doherty power amplifier. The electric length of the frequency dependency compensating circuit shows the simulation result of 0, λ/2×1 (180°) and λ/2×2 (360°). The frequency dependency compensating circuit is capacitive on the high-frequency side and inductive on the low-frequency side. This shows that impedance is concentrated on the real impedance axis. In the case of λ/2×2, the reflection coefficient is 0.14 or less over 20% of the fractional bandwidth and it is mostly matched with the broad bandwidth.

3. Measurement Result of Ultra-Wideband Doherty Power Amplifier

Figure 4 shows the manufactured ultra-wideband GaN Doherty power amplifier. Mitsubishi Electric's MGFS39G38L2 with two GaN high electron mobility transistors (HEMT) was used for the transistor of the Doherty power amplifier. In the Doherty power amplifier in Fig. 4, the upper path is the main amplifier and the lower path is the auxiliary amplifier.

Figure 5 shows the output power of the ultra-wideband Doherty power amplifier and the measurement results of the drain efficiency frequency characteristics. For the input signal, the LTE downlink signal with the bandwidth of 20 MHz and PAPR of 7.5 dB was used. Both the output power and efficiency in the figure are the maximum values, achieving ACLR = −50 dBc. In the broad bandwidth of 3.0–3.6 GHz, the drain efficiency of 45.9–50.2% is achieved, showing that this amplifier covers the multiple bandwidths of 4G/LTE-advanced.

4. Conclusion

We proposed a frequency dependency compensating circuit and ultra-wideband Doherty power amplifier incorporating parasites of the package and transistor into the output combiner. Prototype production

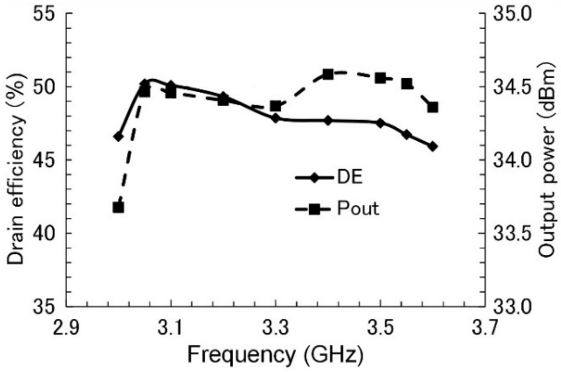

Fig. 5 Measured frequency dependencies of drain efficiency and output power

confirmed that this GaN Doherty power amplifier operates with a drain efficiency of 45.9–50.2% with the LTE signal in the 20 MHz bandwidth after satisfying −50 dBc by ACLR at the operating frequency range of 3.0–3.6 GHz.

This amplifier technology will enable the reduction of the number of transmitter amplifiers or power consumption, thus reducing the total cost of ownership of base stations.

5. References

(1) Xia, J., et al.: High-Efficiency GaN Doherty Power Amplifier for 100-MHz LTE-Advanced Application Based on Modified Load Modulation Network, IEEE Trans. Microw. Theory Techn., 61, 2911–2921 (2013)

(2) Özen M., et al.: Symmetrical Doherty Amplifier with High Efficiency over Large Output Power Dynamic Range, IEEE MTT-S International Microwave Symp. (2014)