GaN HEMT Supporting Multi-Carrier Communications for Ku-band Satellite Communication Systems

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Increasing information transmission capacity and speed is currently driving strong demand for Ku-band multi-carrier satellite communications. Low distortion characteristics (third-order intermodulation distortion, IM3, −25dBc or less) at wide offset frequencies are required for GaN power amplifiers, accordingly. With a newly developed matching circuit, the two GaN HEMTs introduced here achieve a low measured IM3 of less than −25 dBc at the maximum offset frequency (Δf) of 400 MHz while delivering a peak output power of approximately 70 W or 30 W.

1. Introduction

In recent years, gallium nitride (GaN) high electron mobility transistor (HEMT) power amplifiers have been increasingly used in transmitters for satellite communications. Mitsubishi Electric Corporation has been commercializing a Ku-band 70-W GaN HEMT (MGFK48G3745) as power amplifiers for single-carrier satellite communication earth stations.(1)(2) The current demand for further increase in the information transmission capacity and speed strongly requires GaN HEMT power amplifiers that can support multi-carrier communications. In such multi-carrier communications, it is very important to maintain low IM3 over a wide Δf range as well as to transmit high peak output power. This paper reports on two different power-classes (70 W and 30 W) of GaN HEMTs suitable for Ku-band multi-carrier satellite communications. The matching circuit featuring three different types of difference-frequency short circuits allows the GaN HEMTs to deliver a low IM3 of less than −25 dBc over a wide Δf range of up to 400 MHz.(3)

2. Ku-band 70-W GaN HEMTs for Multi-carrier Communications

Figure 1 illustrates the simplified schematic of the conventional output matching circuit used in a GaN HEMT (MGFK48G3745). For the conventional circuits, the resonance frequency in the low frequency band is set to approximately 5 MHz by the single short circuit placed near the drain bias circuit outside the package. Figure 2(a) shows the simulated impedance of the output matching circuit seen from the drain terminals of the FETs. Figure 2(b) shows the measured offset frequency (Δf) dependence of the IM3 for the above GaN HEMT under 14.125-GHz-band two-tone tests.

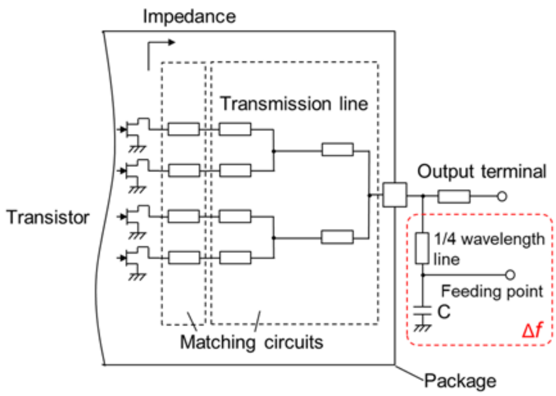
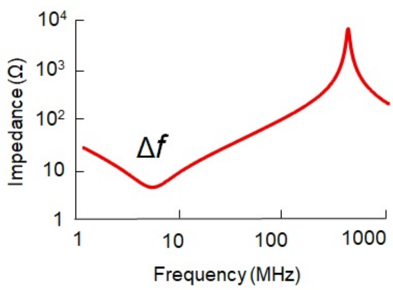
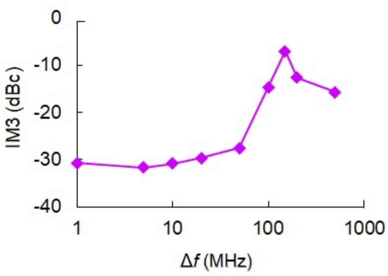


Fig. 1 Simplified schematic of conventional output matching circuit



(a) Simulated impedance looking into the conventional output matching circuit from all the drain terminals



(b) Measured **Δ**f dependence of IM3 characteristics for the conventional output matching circuit

Fig. 2 Simulated impedance looking into the conventional output matching network from all the drain terminals and measured **Δ**f dependence of IM3 characteristics for the conventional output matching circuit

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In the figure, Δf is the difference in the frequencies of two tones and the output power level per tone was 40 dBm. To realize low IM3 over a wide Δf of up to 400 MHz, we have adopted the output matching circuit shown in Fig. 3. The circuit features three different types of difference-frequency short circuits; two of which are embedded into a tournament-shaped output matching circuit inside the package and the rest is embedded into the drain bias feed placed outside the package. On the basis of our original analysis, the following three resonance frequencies were determined to be Δf1 = 157 MHz, Δf2 = 27 MHz, and Δf3 = 5 MHz.[3]

Figure 4 shows the inside micrograph of a Ku-band 70-W GaN HEMT (MGFK48G3745A) for multi-carrier communications. The difference-frequency short circuits use λ/4 lines and several nF wire-bonding-mount-type microchip capacitors. These circuits are deployed not only in the output matching circuit, but also in the input matching one to suppress the imbalance between the upper and lower IMD3.

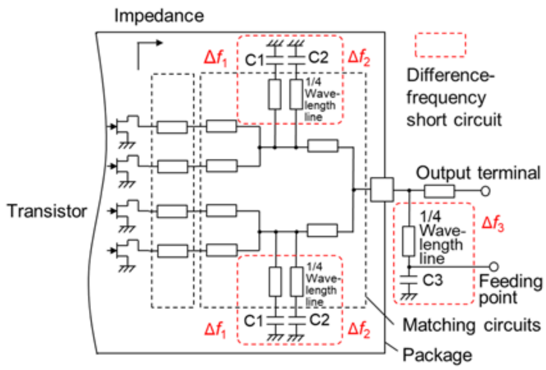


Fig. 3 Simplified schematic of output matching circuit supporting multi-carrier communications

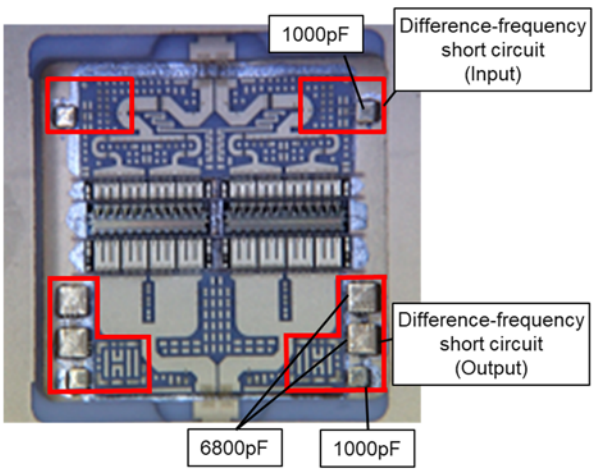
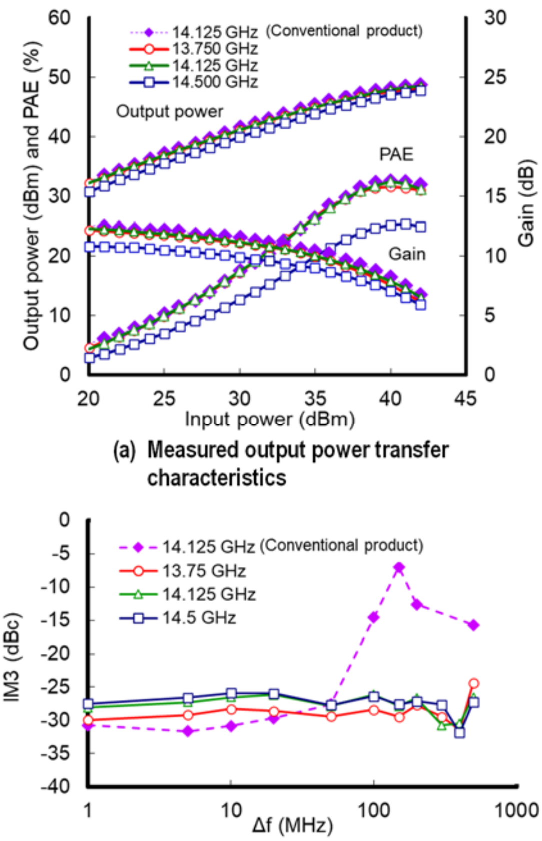


Fig. 4 Ku-band 70-W GaN HEMT (MGFK48G3745A) supporting multi-carrier communications



(b) Measured dependence of IM3 on Δf for the 70-W GaN-HEMT

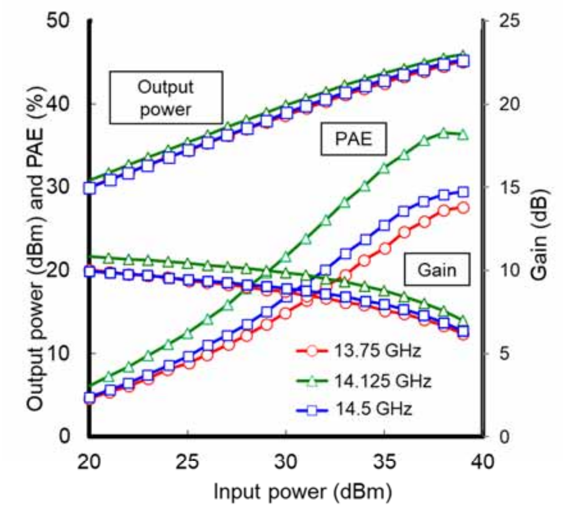
Fig. 5 RF and Δf dependence of IM3 characteristics of Ku-band 70-W GaN HEMT supporting multi-carrier communications

Figures 5(a) and (b) show the measured output power transfer characteristics and the measured dependence of IM3 on Δf for the 70-W GaN-HEMT, respectively, under a 24-V drain voltage and a single-tone CW signal condition, where the measurement frequencies are at 13.75, 14.125, and 14.5 GHz. Figure 5 also compares the characteristics with and without difference-frequency short circuits. As can be seen in the figures, the 70-W PA achieves a peak output power of 48.6 dBm (72.4 W) at 14.125 GHz while maintaining a linear output power of over 40 dBm and an IMD3 of –26 dBc. Over the frequency range from 1 MHz to 400 MHz, IMD3 is successfully suppressed to less than –26 dBc. Thus, while maintaining the low IM3 required for multi-carrier communications, the 70-W GaN HEMT achieves high output and high gain characteristics similar to those of the conventional single carrier GaN HEMT product.

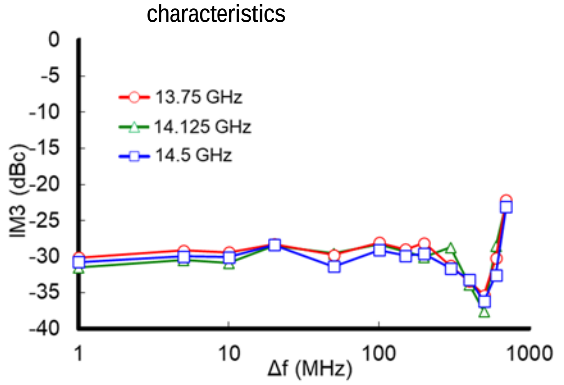
3. Ku-band 30-W GaN HEMTs for Multi-Carrier Communications

Regarding the output power levels of power amplifiers for satellite communications, there is a demand not only for higher-power products, but also for relatively low-power products. This is because for small earth stations, products with various output power specifications are commercially used depending on the size and cost of the stations. This time, we have also developed a Ku-band 30-W GaN HEMT (MGFK45G3745A) for multi-carrier communications to address the need for relatively low- power products. Regarding the package, the same packages as those of the Ku-band 70-W GaN HEMTs were used considering the compatibility. Inside the package, only one GaN HEMT chip is used; the chip is the same that as used for the 70-W GaN-HEMT (Fig. 4). The matching circuit design for the 30-W GaN-HEMT was the same as that previously described for the 70-W GaN-HEMT.

The measured output power transfer characteristics and the measured dependence of IM3 on Δf for the 70-W GaN-HEMT are shown in Figs. 6(a) and (b), respectively, under a 24-V drain voltage and a single-tone CW signal condition. A peak output power of approximately 46.0 dBm and a linear gain of higher than 10.8 dB are achieved at 14.125 GHz. Over the same frequency band, the PA offers a peak output power larger than 45.2 dBm and a linear gain of over 10.0 dB. Figure 6(b) shows the IM3 characteristics at a single-carrier output power level of 36.3 dBm, indicating that an IM3 of less than –26dBc is well suppressed at offset frequencies from 1 MHz up to 500 MHz. The measurements reveal that the 70-W GaN HEMT achieves high output and high gain characteristics while the low IM3 required for multi-carrier communications is maintained.



(a) Measured output power transfer characteristics



(b) Measured dependence of IM3 on **Δ**f for the 70-W GaN-HEMT

Fig. 6 RF and **Δ**f dependence of IM3 characteristics of Ku-band 30-W GaN HEMT supporting multi-carrier communications

4. Conclusion

Regarding the use of power amplifiers for Ku-band satellite communication earth stations, we have commercialized Ku-band 70-W GaN HEMTs (MGFK48G3745A) supporting multi-carrier communications with Δf of 400 MHz and Ku-band 30-W GaN HEMTs (MGFK45G3745A), which is a lower output model similar to the 70-W GaN HEMTs. These HEMTs feature our original, low-distortion matching circuit design. The package size is the same as that of packages for the already commercialized 70-W GaN HEMTs (MGFK48G3745). The addition of these Ku-band GaN HEMT products to our lineup will help reduce the size of satellite communication earth stations and increase the information transmission capacity and speed.

Acknowledgement

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References

(1) Tetsuo K., et al.: High Gain and High Power Internally Matched GaN HEMT for Ku-band Satellite Communications, Mitsubishi Denki Giho, 91, No. 5, 293–296 (2017)
(2) Hiroaki M., et al.: Ku-Band GaN HEMT Amplifier with 100W Output Power, Mitsubishi Denki Giho, 87, No. 2, 113–115 (2013)
(3) Yoshioka, T., et al.: A Ku-band 70-W Class GaN Internally Matched High Power Amplifier with Wide Offset Frequencies of up to 400 MHz for Multi-Carrier Satellite Communications, 2020 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium, BCICTS (2020)