High Gain and High Power Ku-band GaN HEMT for Satellite Communication

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In the satellite communication market, as the communication capacity and demand for mobile stations increase, the demand for higher output and smaller transmitters for satellite communication earth stations is growing. Mitsubishi Electric Corporation has developed a transmitter that operates at higher voltage and higher power density, using gallium nitride (GaN) with high dielectric breakdown voltage instead of the conventional gallium arsenide (GaAs). As part of our ongoing expansion of the lineup of amplifier devices for compact and high output transmitters, we have released a 70 W internally-matched GaN HEMT with the world's highest output (Table 1).

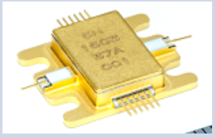
1. Characteristics of the 70 W Internally-Matched GaN HEMT

When developing the 70 W GaN HEMT, we focused on two concepts: using the same size package as the existing 50 W internally-matched GaN HEMT; and increasing the actual gain and output power compared with existing products. The purpose was to enable the amplifier output to be increased only by replacing the existing 50 W GaN HEMT used as the last stage amplifier with the 70 W GaN HEMT in a satellite communication earth station transmitter, while keeping the driver amplifier unchanged.

In order to increase the output power of a GaN HEMT, it is necessary to increase the gate width. However, increasing the gate width reduces the frequency (fk) required for converting the maximum stable gain (MSG) into the maximum available power gain (MAG) due to increases in the gate resistance (Rg) and source inductance (Ls) per gate width, thus decreasing the gain in the desired frequency band. Given this, we considered a method to improve fk involving reducing Ls per gate width by altering the chip layout. The transistor part of a GaN HEMT chip has a multi-finger structure in which source fingers and drain fingers are alternately arranged via gate fingers. As shown in Fig. 1(a), configuration source vias with which source electrodes are grounded are provided only on the gate side in the conventional layout. In such a configuration, an increase in the unit gate width (Wgu), meaning an increase in the distance to the source vias, causes Ls to increase at the source finger edges. In the new layout shown in Fig. 1(b), the source finger edges are connected, while source vias are added to the drain side.(1) In this layout, even at the edge of each source finger, Ls per unit cell can be reduced to approximately one-half of that of the conventional products. This is the result of making the distance to the source vias shorter than in the conventional layout and increasing the number of vias per unit cell from the conventional two to four. As a result, compared with fk = 14.8 GHz at Wgu = 88 μm using the conventional layout, a good fk value of 15.8 GHz has been achieved using the new layout even with a Wgu as long as 150 μm. This indicates that a sufficient gain can be expected in the Ku band when Wgu is long enough to downsize a chip.

Figure 2 shows graphs of the results of evaluating the input/output characteristic of the 70 W internally-matched GaN HEMT (MGFK48G3745) for the Ku band

Table 1 Ku-band GaN MMIC and GaN HEMTs

	MGFG5H 1503 (MMIC)	MGFK47G 3745A (Internally matched HEMT)	MGFK48G 3745 (Internally matched HEMT)	MGFK49G 3745 (Internally matched HEMT)
Appearance				
Size (mm)	13.8×16.4×3.2	21.0×12.9×4.5	21.0×12.9×4.5	24.0×17.4×4.3
Output power	20 W	50 W	**70 W**	80 W
Linear gain	20 dB	8 dB	**10 dB**	7.5 dB

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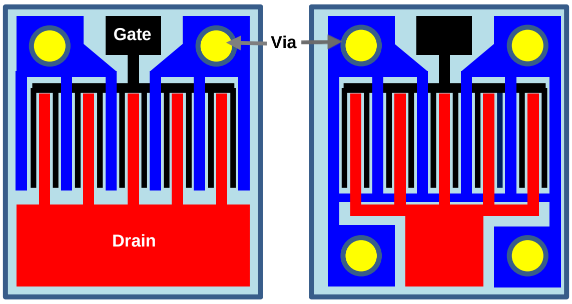
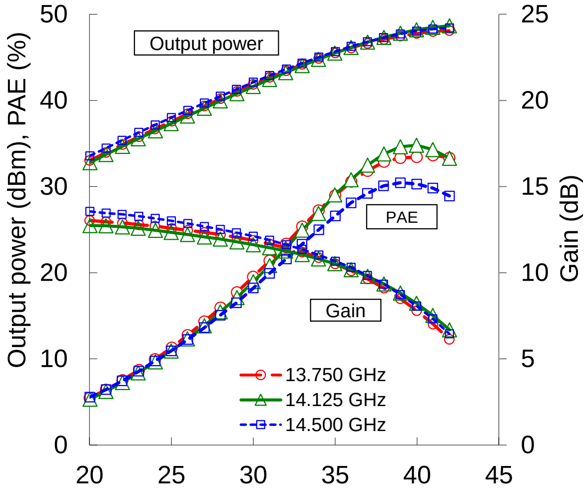
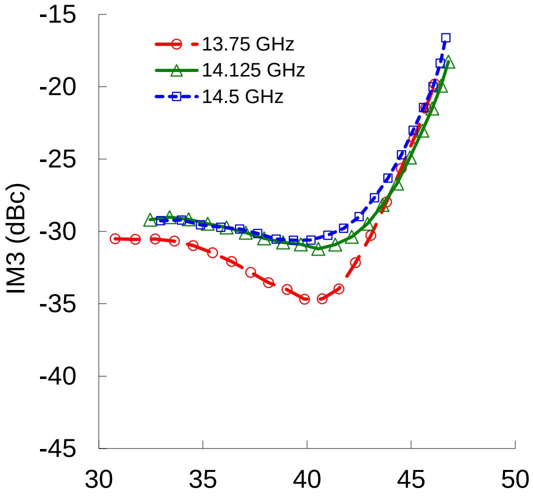


(a) Conventional layout (b) New layout

Fig. 1 Layouts of GaN HEMT Dies



(a) Input power (dBm)



(b) Total output power (dBm)

Fig. 2 RF and IM3 characteristics of Ku-band 70 W GaN HEMT (MGFK48G3745)

developed using the GaN HEMT chip described above. At a frequency of 14.125 GHz, the following favorable characteristics were obtained: saturated output power of 48.7 dBm (74.1 W), linear gain of 12 dB, and power added efficiency (PAE) of 35%. In addition, the output power (linear output power) that satisfied IM3 = −25 dBc required to secure the communication quality as a satellite communication earth station was 45 dBm. The new chip layout strikes a balance between a higher gain and higher output, and improves the output power by approximately 40% and the linear gain by 4 dB from the existing 50 W internally-matched GaN HEMT. This compact product achieves the world's highest level of output power and linear output power.

2. RF Characteristics When Combined with a 20 W GaN MMIC

While GaN HEMTs are highly promising for increasing the output and reducing the size of transmitters, they often involve 'soft compression', which is a phenomenon in which the gain starts to drop at a relatively low power output compared with the power output at which the saturated output power is reached. Soft compression is a problem when GaN HEMTs are arranged in a cascade to form a multistage amplifier. The soft compression of each stage GaN HEMT superposes on one another, lowering the gain linearity of the entire amplifier from an extremely low power output, resulting in significant deterioration of the strain characteristics such as IM3. In order to solve this problem, we have released a GaN MMIC (MGFG5H1503). The GaN MMIC comes with a built-in linearizer for the driver stage to improve the strain characteristics. A test with an amplifier integrated to the existing 50 W internally matched GaN HEMT (MGFK47G3745A) verified the improvement in strain characteristics.(2) Accordingly, we have produced a multi-stage amplifier using the cascade-connected GaN MMIC with the built-in linearizer and the new 70 W internally matched HEMT (MGFK48G3745).

Figure 3 shows a schematic view of the amplifier configuration and a photo of the amplifier. The input and

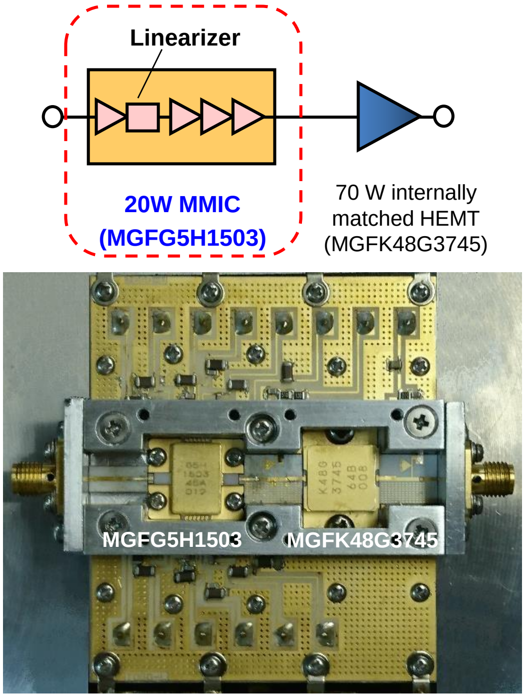
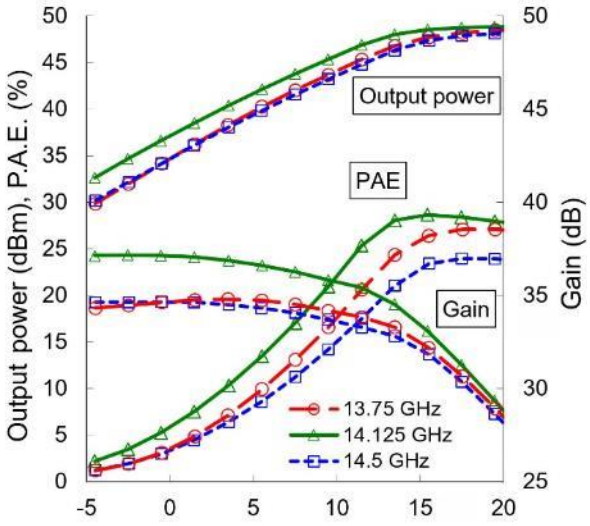
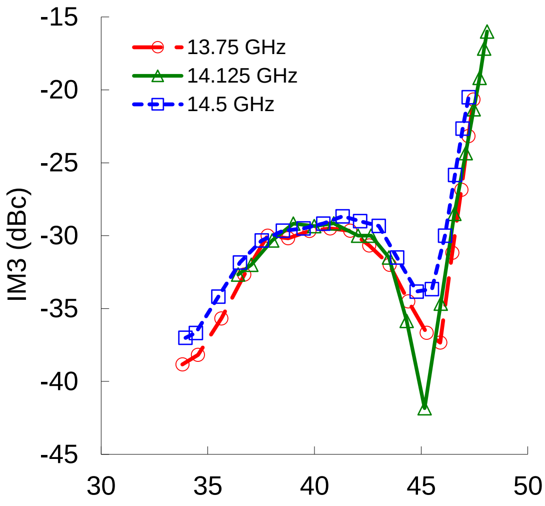


Fig. 3 Two-stage amplifier of MGFG5H1503 and MGFK48G3745 (MGFK48G3745)

output terminals and the devices are connected using 50 Ω lines on an alumina substrate. Resin substrates with bias circuits are arranged on both sides of the alumina substrate, while an aluminum heat sink is provided on the underside of the alumina substrate to suppress the temperature increase of the GaN HEMT during operation. Figure 4 shows the results of evaluating the input/output characteristics of the amplifier. At a frequency of 14.125 GHz, the saturated output power was 48.7 dBm (74.1 W), linear gain was 37 dB, and power added efficiency was 28%. The linear output power satisfying IM3 = −25 dBc was 47 dBm, an improvement of approximately 2 dB from the linear output power when a 70 W HEMT alone was operated. The use of the GaN MMIC with a built-in linearizer in the driver stage has suppressed the deterioration in strain characteristics due to soft compression, which is a disadvantage of GaN HEMT multistage amplifiers, achieving high linear output power with a GaN HEMT multistage amplifier.



(a) Input power (dBm)



(b) Total output power (dBm)

Fig. 4 RF and IM3 characteristics of 2-stage amplifier

3. Conclusion

We have added a 70 W internally matched GaN HEMT (MGFK48G3745) to our lineup of amplifying devices for Ku band satellite communication earth stations. The new product, with the same package size as the existing 50 W GaN HEMT, offers the world's highest level of output power. With this new product, our range of Ku band GaN devices will help increase the output power and reduce the size of transmitters for satellite communication. We will keep expanding our lineup of power amplifiers by developing devices that can operate at even higher output power and in diverse frequency bands.

The developed product uses part of our achievements in the Innovation Commercialization Venture Support Project of the New Energy and Industrial Technology Development Organization (NEDO).

References

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