A 17.5~ 20.5 GHz 30 W GaN HPA MMIC for Ka-band Satellite Communications

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***Abstract*—This letter presents a K-band high power amplifier (HPA) monolithic microwave integrated circuit (MMIC) for satellite communications. In pulsed condition, a peak output power is larger than 45 dBm in 17.5 ~ 20.5 GHz, with an power added efficiency (PAE) and gain up to 29 % and 22 dB.**

Keywords—Gallium nitride (GaN), high power amplifier (HPA), monolithic microwave integrated circuit (MMIC), Ka-band, Satellite.

I. Introduction

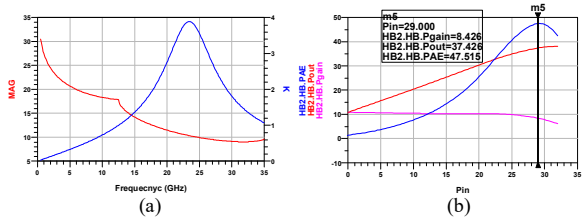
Recently, anytime, anywhere access to the Internet has become a basic daily life. It is not cost-effective to connect sparsely populated suburbs with rural and marine areas using only land-based networks. Various attempts to supplement this with satellite networks are being made by SpaceX, OneWeb, TELESAT, and Amazon.

Since a low mass, volume, and high efficiency are required for a satellite, a traveling wave amplifier (TWTA) has been mainly used in the prior art, but it is expensive and the manufacturers are very limited. In order to overcome this limitation, GaN-based SSPA has been studied recently, but it is difficult to replace TWTA because its output is less than 20 W compared to TWTA of 100 W or more[1]~[6].

In this paper, we report a K-band 30 W GaN MMIC high-power amplifier (HPA) designed and measured using a commercial 0.15 um GaN Foundry.

II. Design and Measurement

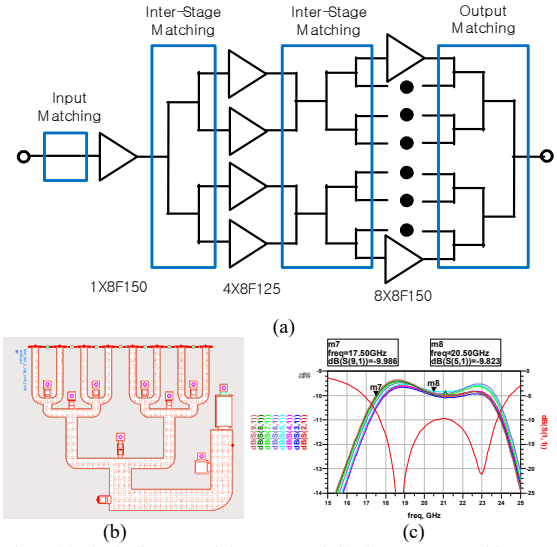
HPA is designed in 3-stage single-ended type. The unit FET used was evaluated to have a maximum output power of 37.4 dBm and a PAE of 47 % at optimum impedance. Fig.1 shows the simulation results of the unit FET. The unit FET is unconditionally stable with a stability factor (K) of 1 or more from 13 to 35 GHz, and the maximum available gain (MAG) is 11.5 dB at 20 GHz. Eight unit FETs were used for the final stage, four for the middle stage, and one for the first stage. Fig. 2 shows the block diagram of the HPA MMIC and the output matching circuit and simulation results. The output matching circuit is designed to have an insertion loss within 1 dB. Since satellite applications can be operated in CW mode, the final drain line width reaches 200 um considering the derating rule. The size of the designed MMIC is 4.55 x 2.2 mm^2.



(a) (b)

Fig.1. Simulation results of the unit FET (a) MAG & K and (b) Pout, PAE & Gain

Measurement of HPA was performed in pulse mode in Probe-Station. The pulse period was 1 ms and the pulse width was 30 us. Fig. 3 shows the GaN HPA MMIC being probed for measurement at the probe-station. Fig. 4 shows the measurement configuration connected to the output port of the GaN HPA MMIC for large-signal measurement. A 40 GHz GSG 250 um pitch probe, an RF cable, and a 30 dB high power attenuator are connected to the output port of the GaN HPA MMIC. One end of this is a GSG probe and the other end is 2.92 mm coaxial, so it's S-parameter was measured by "unknown thru" calibration method. The insertion loss of the measurement configuration connected to the output of the GaN HPA MMIC at a frequency of 20 GHz was measured to be 30.6 dB. Fig. 5 shows the small-signal S-parameter characteristics of the fabricated HPA. The measurement results agree well with the simulation, and the gain is about 25 dB at 20 GHz. Fig. 6 and 7 show the large-signal characteristics of the fabricated HPA. Figure 6 shows the output power, PAE, and gain as a function of input power at frequencies of 18, 19, and 20 GHz. Simulation and



(a) (b) (c)

Fig.2. (a)Block diagram of the HPA and (b) the output matching network and (c) simulation results of the output matching network.

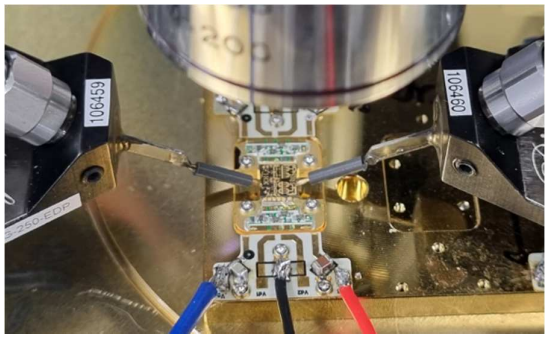
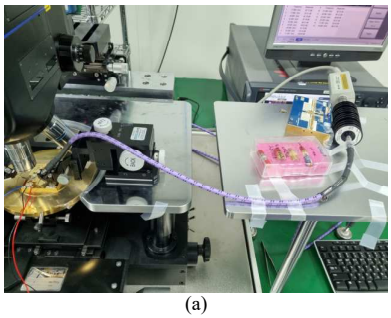
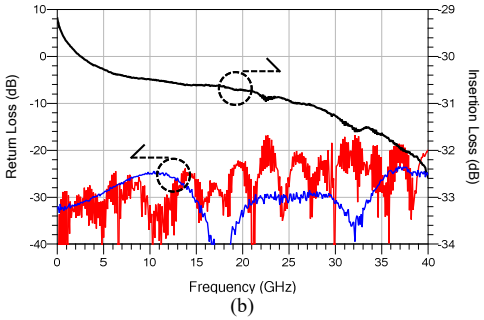


Fig.3. GaN MMIC HPA measured at probe-station.

measurement results for output power (Pout), power addition efficiency (PAE) and power gain at an input of 24 dBm were compared in fig. 7. The measurement results agree well with the simulation, and at a frequency of 17.5 to 20.5 GHz, the Pout is 45 dBm or more, and the maximum is 46.1 dBm, and the power addition efficiency is 23 % or more, and the maximum is 34 %. As shown in Table I, previously reported GaN HPA MMICs at K-band have high PAE but the highest output power is 43 dBm (20W) and the highest power density is 2153 mW/mm^2.



(a)



(b)

Fig.4.(a) Measurement configuration connected to the output port of the GaN HPA MMIC and (b) it's S-parameter characteristics.

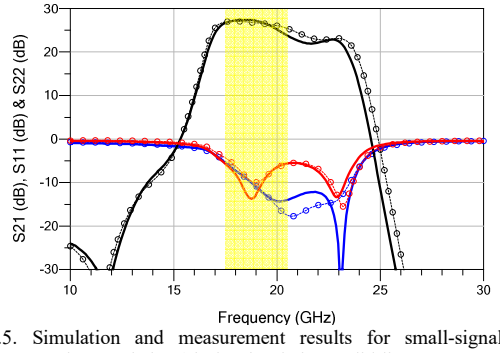


Fig.5. Simulation and measurement results for small-signal S-parameter characteristics (circle: simulation, solid line: measurement, black: S21, blue: S11, red: S22)

TABLE I. STATE OF THE ART : GAN HPA MMIC AT K-BAND

Year/Ref.	Frequency (GHz)	Pout (dBm)	PAE (%)	Gain (dB)	Size (mm^2)	Pout/Size (mW/mm^2)
This Work	17.5~20.5	45~46.1	23~34	26	4.55x2.2	3159~4070
2016 [1]	18 ~ 19	40	28~32	20	3.5x4.5	635
2017 [2]	19.5 ~ 22	42~43	26~33	35	4.8x2.5	1321~1663
2019 [3]	17 ~21	39.8~40.8	33~38	22	4.0x3.4	702~884
2021 [4]	17.3 ~ 20.2	40.5~42.5	30~42	25	5.0x4.4	510~808
2021[5]	17.3 ~20.2	39~42	30~42	24	5.0x4.5	353~704
[6]	17 ~20	42~42.5	27~36	31	2.95X2.8	1919~2153

III. CONCLUSION

According to the authors' knowledge, the presented K-band GaN MMIC HPA achieved the world's highest 30 W output power, which is at least 10 W higher than other MMIC HPAs reported in K-band.

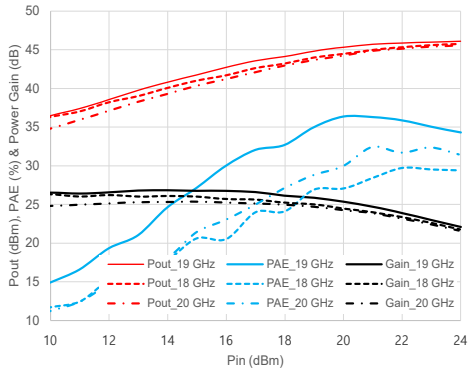


Fig.6. Pout, PAE and power gain vs. input power at 18, 19, 20 GHz.

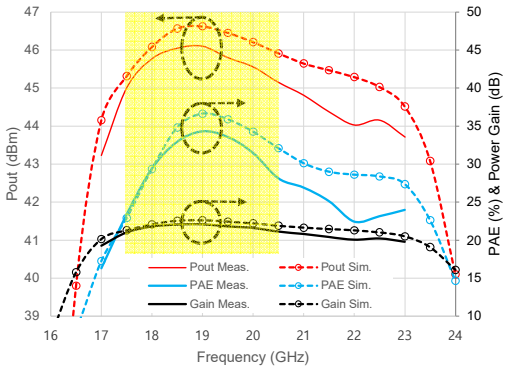


Fig.7. Simulation (circle) and measurement (solid line) results for Pout, PAE and Power Gain at input 24 dBm.

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