Fujitsu develops GaN HEMT power amplifier featuring world's highest output in millimeter-wave W-Band

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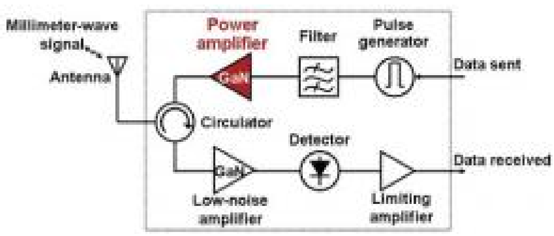


Diagram 1: Millimeter-wave W-band transceiver (example of impulse radio)

Fujitsu announced the development of a power amplifier using gallium nitride (GaN) High Electron Mobility Transistors (HEMT) that has achieved the world's highest output performance of 1.3W for wireless communications in the millimeter-wave W-band, for which widespread usage is expected in the future. The new amplifier will offer transmission output equivalent to approximately 16 times that of existing amplifiers that use gallium-arsenide (GaAs), thereby enabling W-band transmission ranges to be extended by approximately six times.

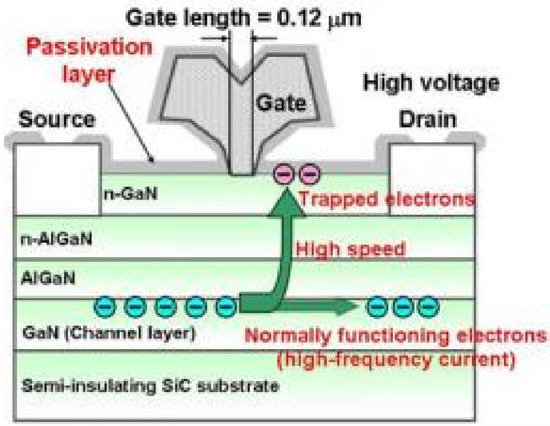
Fujitsu's new GaN HEMT-based power amplifier will make high-capacity wireless communications possible in regions in which it is unfeasible to lay optical fiber cables, in addition to ensuring high-quality communications in rain and under other conditions where the millimeter-wave signal is known to attenuate.

Part of this research was conducted under contract as part of the Research and Development Project for Expansion of Radio Spectrum Resources of Japan's Ministry of Internal Affairs and Communications. Details of the technology will be presented at the 2010 IEEE Compound Semiconductor IC Symposium (CSICS), to be held in Monterey, California from October 3-6, 2010.

In order to accommodate the demands for greater bandwidth resulting from increases in internet communications and expansions in mobile phone networks, optic fiber cables are being laid in nations throughout the world to create a high-capacity trunk-line system. This is problematic in areas with challenging topography, which has sparked interest in high-bandwidth wireless trunk lines that are capable of data transmission capacities in the range of up to 10 Gbps-on par with optical fiber cabling-as a way to bridge the "digital divide".

The millimeter-wave W-band is an effective band for use in wireless communications at a speed up to 10 Gbps, as it is readily available. Diagram 1 shows an example of a wireless transceiver that employs the millimeter-wave W-band. The power amplifier, located inside the transmission unit, is the key component for amplifying the millimeter-wave signal to the intensity required for transmission.

Up until now, Fujitsu and Fujitsu Laboratories have succeeded in producing 350 mW of power using power amplifiers that employ GaN HEMTs. The millimeter-wave W-band, however, experiences significant signal attenuation due to factors such as atmospheric absorption and rain, and there has been demand for high-output power amplifiers that can transmit a stable signal across distances ranging from a few kilometers to several tens of kilometers.



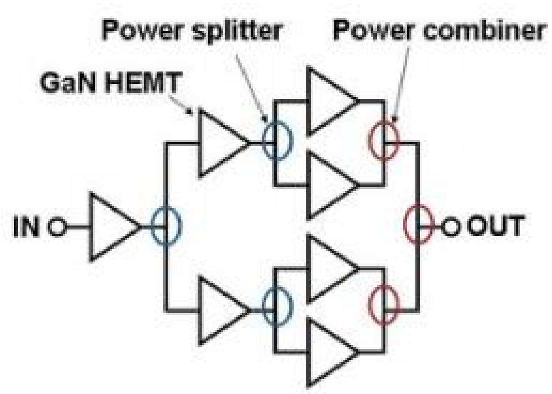
Cross-section diagram of millimeter-wave GaN HEMT transistor

In order to develop a millimeter-wave W-band power amplifier featuring high output, the following issues needed to be addressed.

1. Transistor operating speed, or operating frequency, is determined by the speed at which electrons in the current pass directly beneath the gate electrodes. In order to operate a transistor at a high frequency, such as the millimeter-wave band, it is necessary to decrease the length of the gate electrodes. On the other hand, an effective method of achieving high power output is by applying high voltage to the transistor. When the GaN HEMT gate length is reduced and the transistor is operated at a high voltage, however, electrons dramatically increase in speed, and as a result, a portion of the electrons can leak from the current pathway (electron channel layer), reaching as far as the passivation layer, where they will accumulate. As a result, there is a reduction in the electrons contributing to high-frequency operation, or a loss in high-frequency current, thereby making it difficult to increase power output.

2. Power distribution within a power amplifier is performed by dividing the input signal among multiple parallel transistors in the power splitter circuit. After the signal is amplified by each transistor, it is combined

again using the combiner circuit, thereby enabling high-power output. At frequencies above 70 GHz, however, due to the interference of high-frequency complex signal distribution, the signal undergoes attenuation in the power splitter and combiner circuits, preventing the achievement of the desired power output. As a result, it was necessary to construct a power splitting and combination model for use in the millimeter-wave band, and develop a design that takes the complex signal distribution into consideration while enabling the desired output to be achieved.



Structure of millimeter-wave W-band amplifier

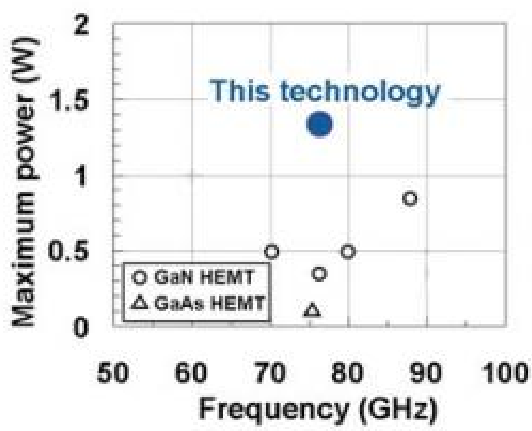
Fujitsu developed the following technologies in order to resolve the aforementioned issues.

(1) Optimizing the GaN HEMT passivation layer
After analyzing the reason why electrons escaped from the electron channel layer and accumulated in the passivation layer, Fujitsu traced the issue to the existence of defects in the crystallization of the SiN used as part of the passivation layer. By enhancing the layer's SiN composition and crystalline structure, Fujitsu was able to build a passivation layer with minimal crystalline defects, making it difficult for electrons to

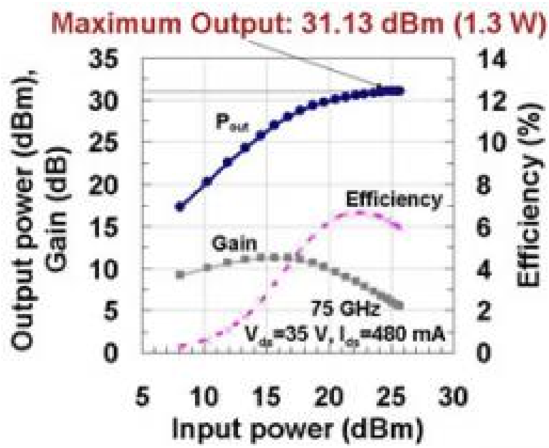
accumulate. As a result, the technology was successful in amplifying high-frequency current to over two times the power of existing technology.

(2) Building a power division and combination model through electromagnetic analysis

By performing electromagnetic analysis on the complex signal distribution of the high-frequency signal, based on the physical properties of the power splitter and combiner circuits, Fujitsu successfully designed a highly precise circuit that reduces signal attenuation in the two circuits. As a result, Fujitsu was able to increase design precision by roughly 15%.



Comparison with other millimeter-wave W-band amplifiers



Newly developed GaN HEMT amplifier's characteristics

The above technologies were employed to develop a power amplifier for use in millimeter-wave W-band wireless equipment. The newly developed amplifier achieves a maximum output of 1.3W, which, among GaN HEMT power amplifiers, represents the world's highest output in this frequency band using single integrated circuit.

Furthermore, the new technology achieves a transmission output equivalent to 16 times that of existing amplifiers that use GaAs. When employed in combination with the GaN HEMT receiver amplifier developed by Fujitsu last year, it is expected that transmission ranges will be able to be extended by approximately six times in comparison to transceivers that employ GaAs. This will enable millimeter-wave band wireless communications equipment to be deployed in a wider range of fields, while at the same time ensuring high-quality communications in which ample signal output can be obtained even when there is signal attenuation due to rain and other factors.

Source: Fujitsu