GaN powering 5G and beyond

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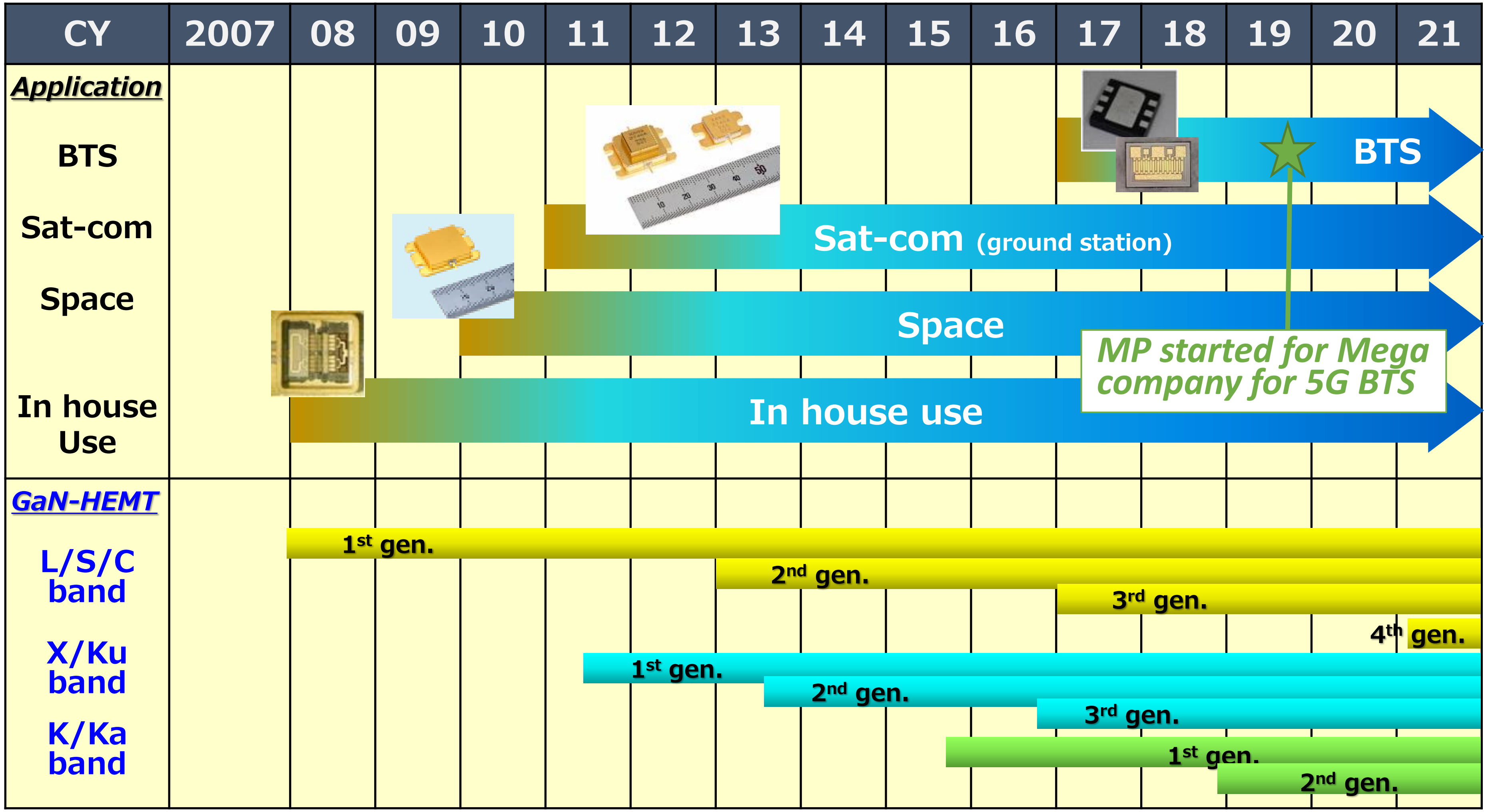
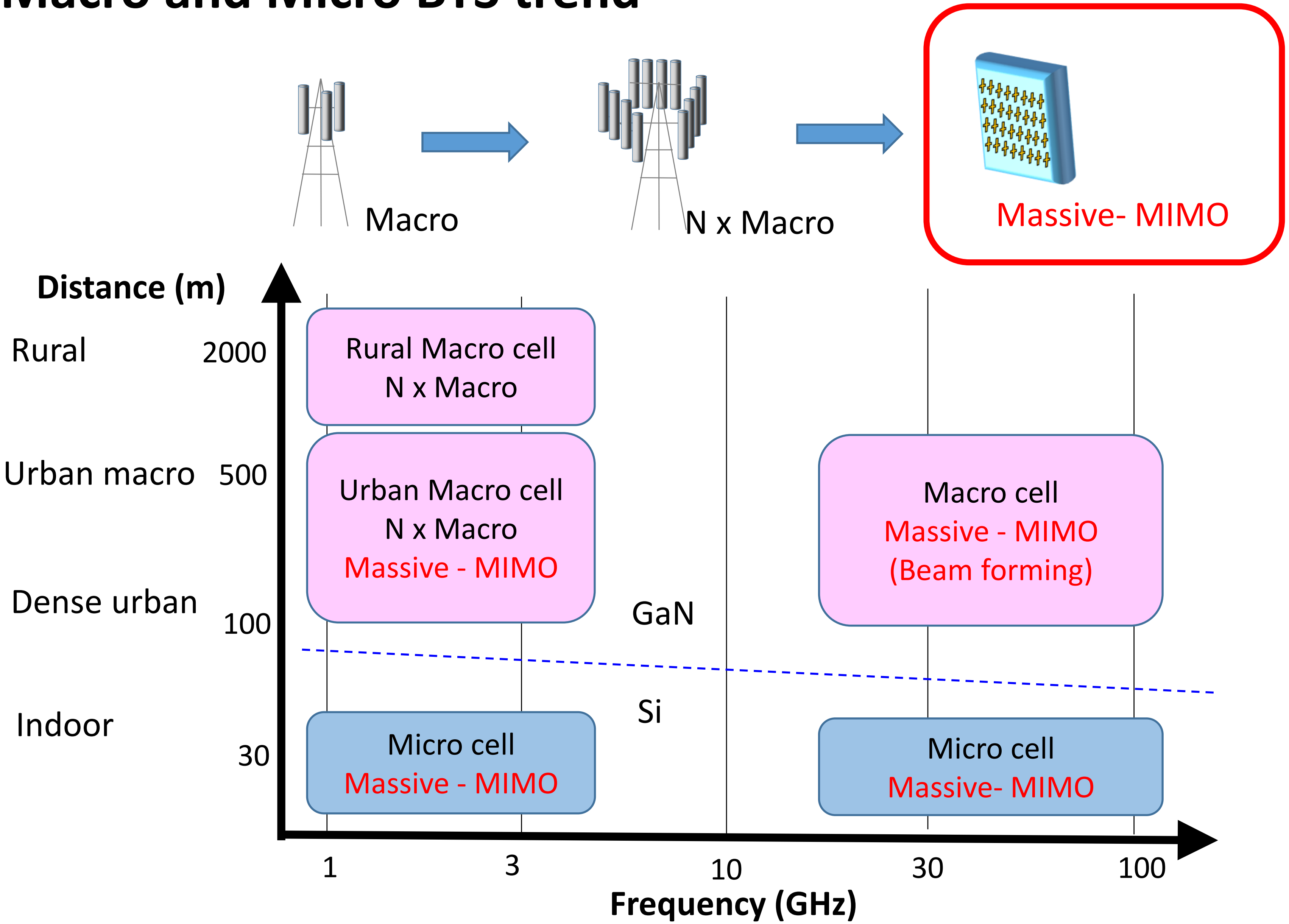
Mitsubishi GaN HEMT History

- ***Our GaN product designed and manufactured in Japan***
- ***Over 23 years GaN HEMT development (started in 1998)***

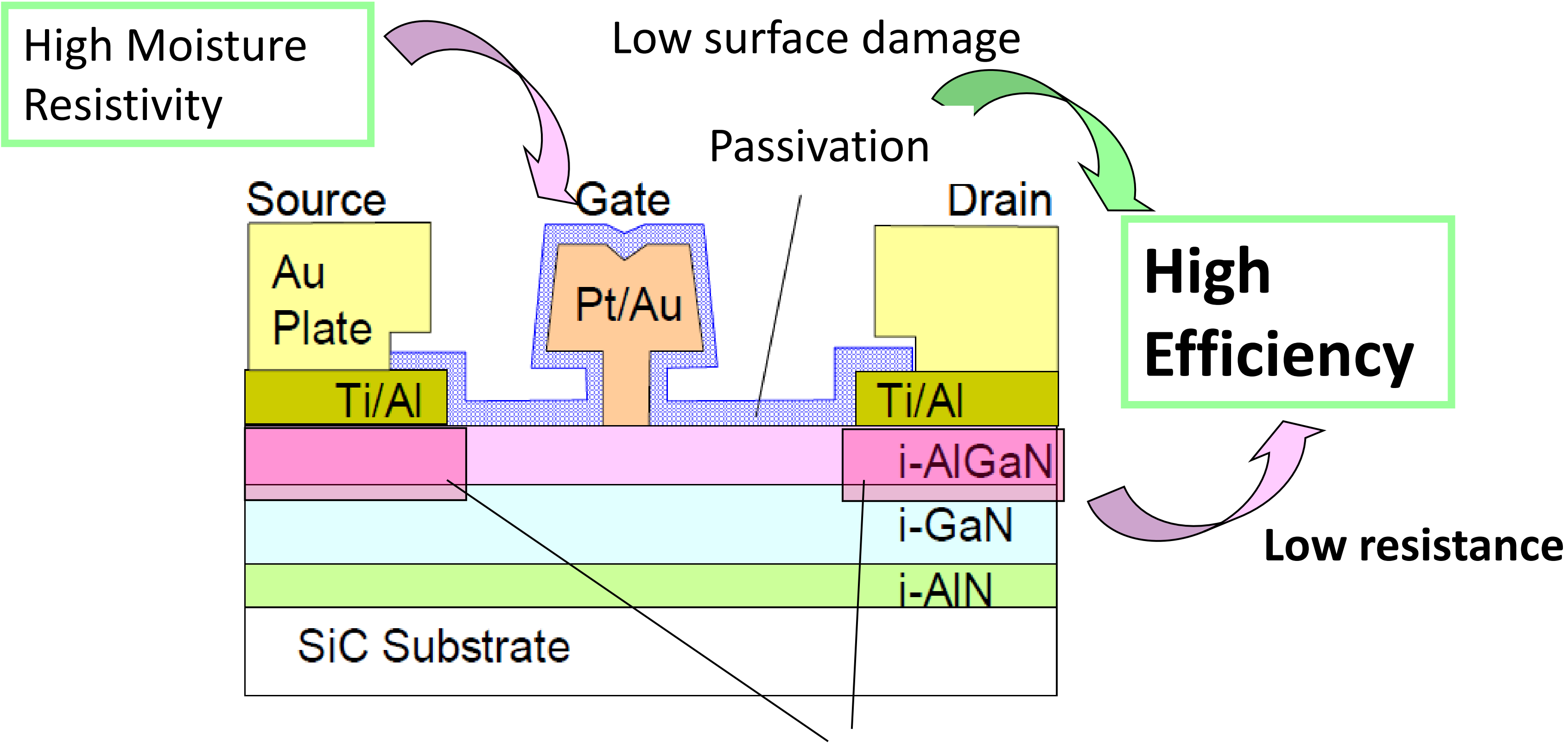


Macro and Micro BTS trend



GaN device is suitable from dense urban to rural

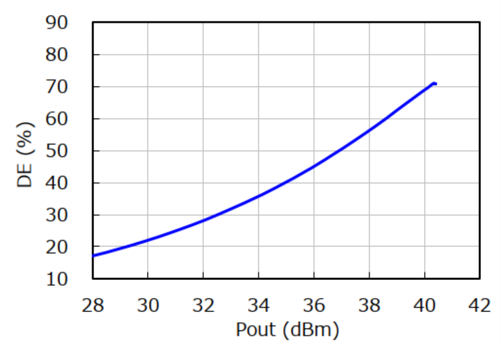
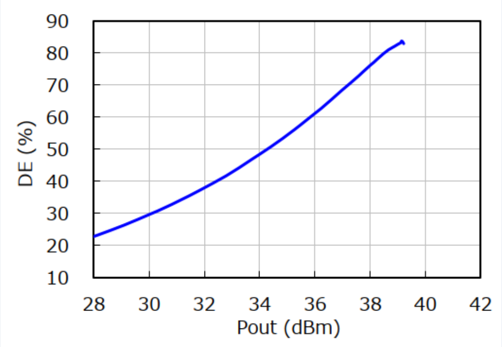
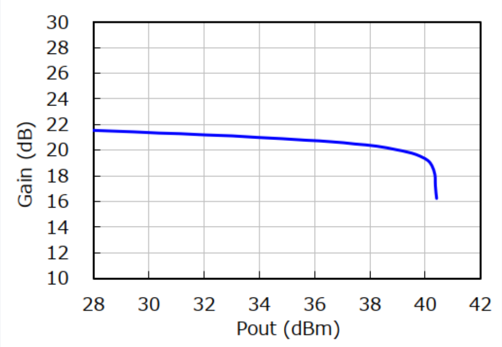
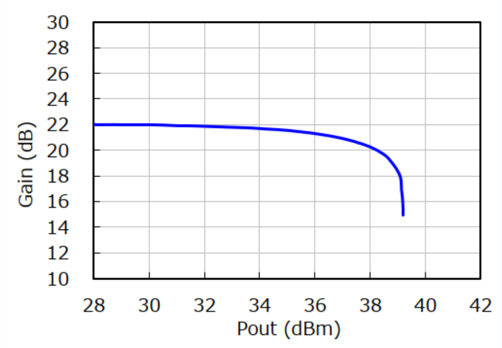
Efficiency: Mitsubishi GaN Technology



Heavily Ion implanted region realizes low ohmic resistance.

GaN Chip RF Performance at 4GHz

fo=4.0GHz
Vd=50V
Idq=30mA/mm
Wgt : 1.2mm

	@Power matching	@Efficiency matching
Drain Efficiency -Pout		
Gain -Pout		

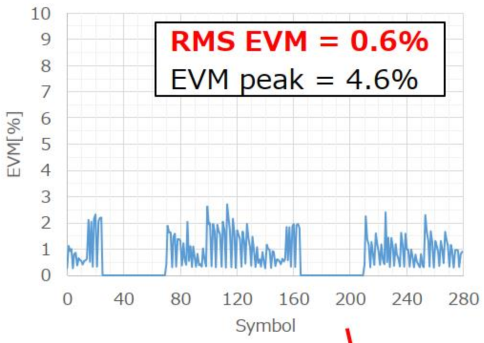
Drain Efficiency	Power density	Linear Gain
84% @Efficiency matching	***9W/mm*** @Power matching	***22dB*** @Efficiency matching

✓ *Our GaN HEMT has the best-in-class performance on Drain efficiency, Power density and Linear Gain.*

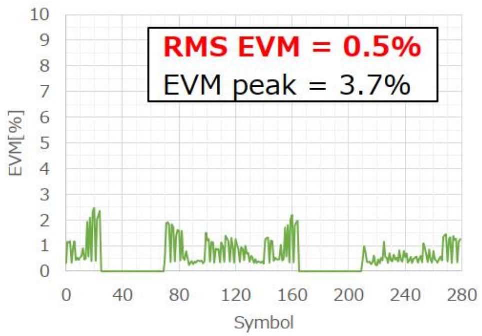
Highly Linear Performance of GaN HEMT

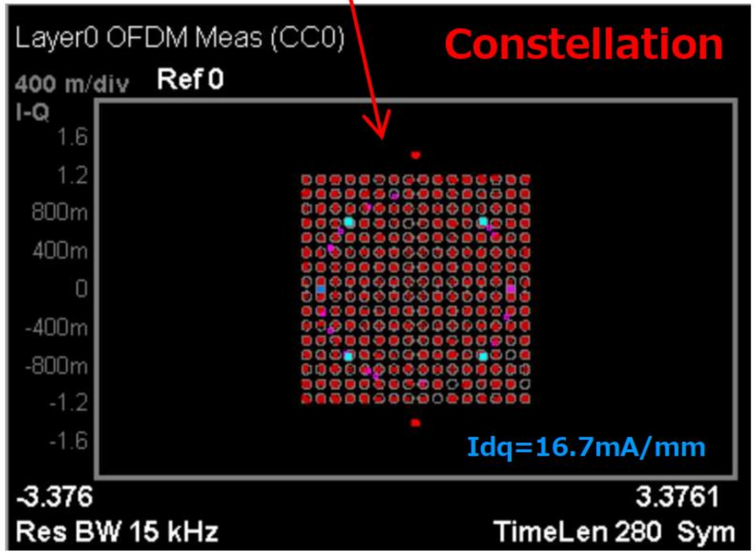
EVM (E-TM2.0a) with Idq dependency

Idq=16.7mA/mm

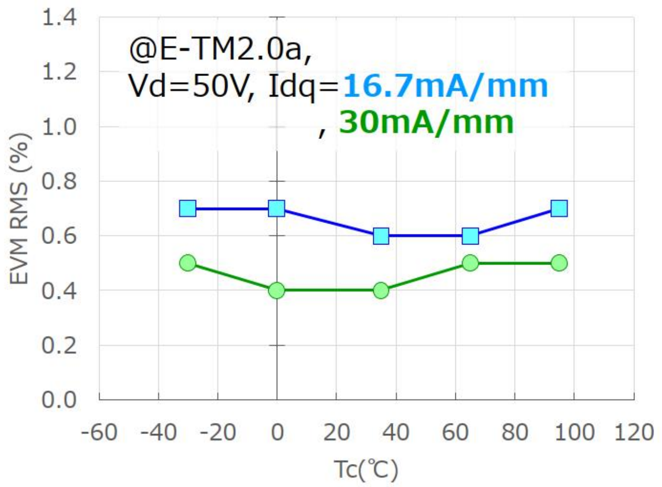


Idq=30mA/mm





EVM (E-TM2.0a) with Tc dependency



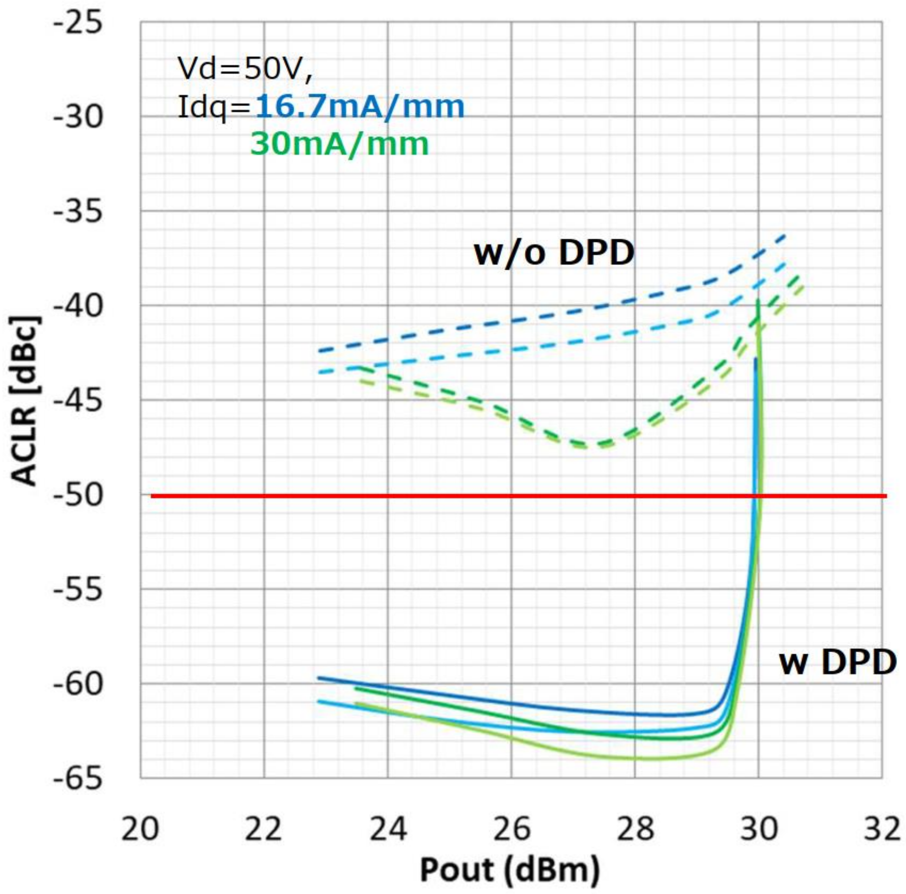
Sample : Wgt (Total gate width) : 1.2mm
Package : Metal flange package (Discrete type)
Measurement condition : **Test Signal : E-TM2.0a**
Freq.=2.14GHz, Vd=50V

Measurement equipment
Signal Generator : Keysight N5182B (MXG)
Signal Analyzer : Keysight N9020A (MXA)

Test Signal	Carrier Configuration	DL/UL config SSC cinfig	PAPR @0.001	CFR
E-TM2.0a (256QAM)	1 x LTE 1CC (20MHz)	3 / 8	15.4dB	Without

Our GaN HEMT has shown good performance in RMS_EVM comparable to LDMOS, keeping low RMS_EVM even at high temperature (Tc=100 deg C).

ACPR Performance of GaN HEMT



Sample : Wgt (Total gate width) : 1.2mm
Package : Metal flange package (Discrete type)
Measurement Condition : TDD, LTE, 256QAM,
BW=20MHz, PAPR=8.0dB
Freq.=2.14GHz, Vd=50V
Ta = 25 deg C

<u>Measurement equipment</u>
Signal Generator : Keysight N5182B (MXG)
Signal Analyzer : Keysight N9020A (MXA)

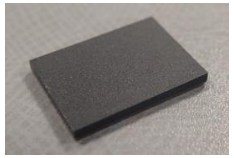
✓ *Furthermore, our GaN HEMT has achieved good ACLR which is less than -60dBc with DPD.*

Roadmap for 5G PAM

- Mitsubishi will lineup various PAM products having low distortion and higher efficiency in several frequency range and output power range with a small package in order to provide the best solution for customers.

Main line-up	*Operating Frequency*	*PAE*	*ACLR*	*Linear Gain*	*PKG size*	*Schedule (CY)* ('21 Q4 – '23 Q4)
8W PAM *For narrow band*	*3.4-3.6G or 3.7-4.0G*	*48% (target)*	*-52dBc (@20 MHz)*	*30dB (Typ.)*	*10x6mm QFN*	TS Available → ES '22/1H → CS/MP '22/2H
8W PAM *For wide band*	*3.4-3.8G*					
16W PAM *For narrow band*	*3.4-3.6G or 3.7-4.0G*				*10x8mm QFN*	TS '21/Q4 → ES '22/Q2 → CS/MP '22/Q4
16W PAM *For wide band*	*3.4-3.8G*					TS '22/Q2 → ES '23/Q1 → CS/MP '23/Q3

PAM: power amplifier module



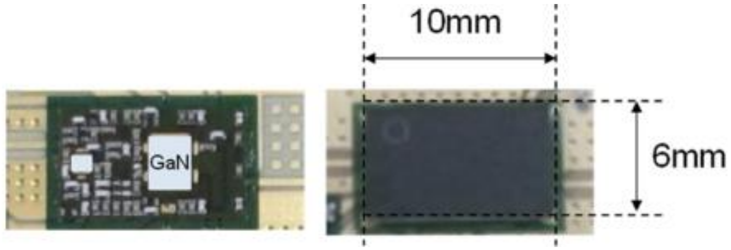
**TS : Test Sample*
ES : Engineer Sample (Design fixed)
CS : Customer Sample (Reliability confirmed)
MP : Mass Production

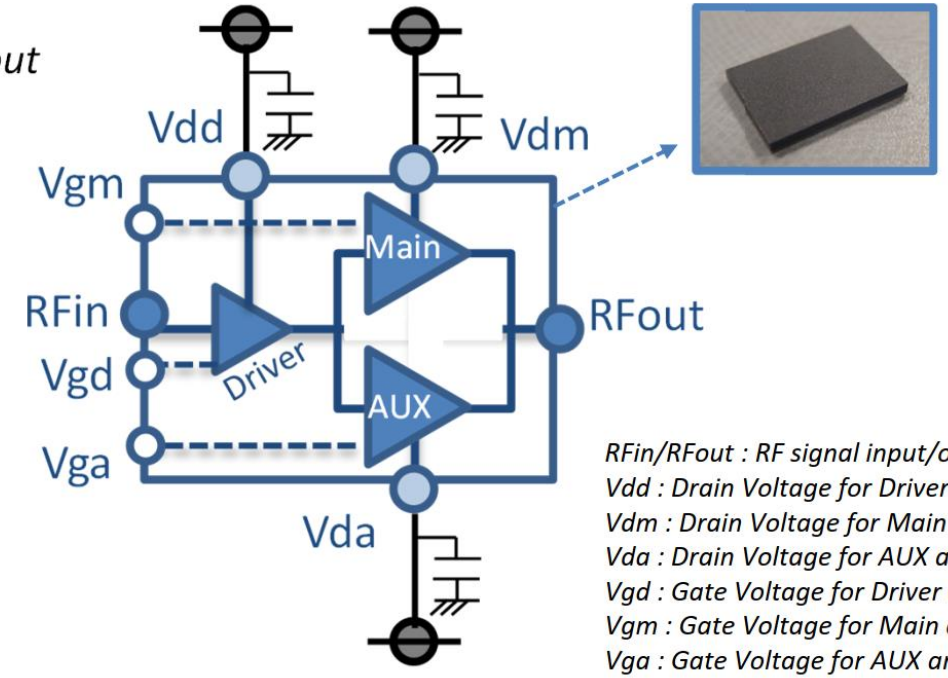
Wideband Compact GaN PAM

- Designed for sub6 band (3.4-3.8GHz, 3.7-4.0GHz) with TDD and FDD NR m-MIMO BTS
- Wideband signal bandwidth (200MHz) in a small package layout (10x6mm, or 10x8mm)

<Block diagram>

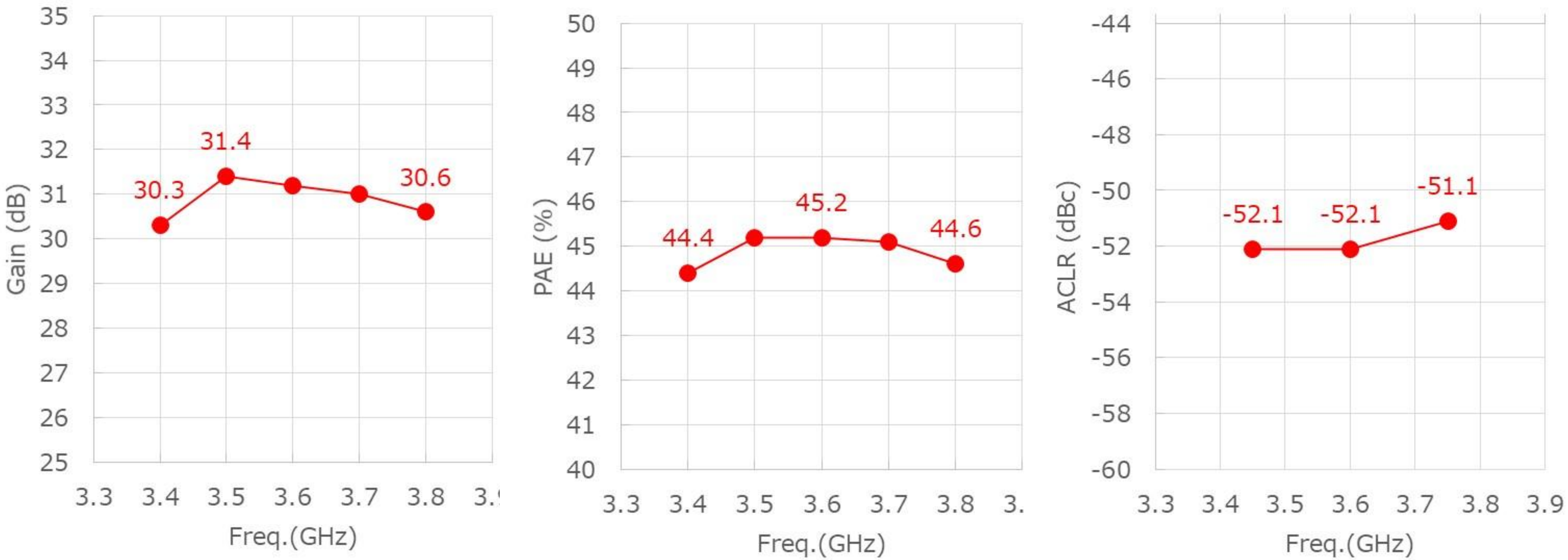
- ✓ *2-stage Doherty amplifier structure*
- ✓ *GaN HEMT amplifier with 48V*
- ✓ *50ohm impedance matching in RFin/RFout*





RFin/RFout : RF signal input/output
Vdd : Drain Voltage for Driver amplifier
Vdm : Drain Voltage for Main amplifier
Vda : Drain Voltage for AUX amplifier
Vgd : Gate Voltage for Driver amplifier
Vgm : Gate Voltage for Main amplifier
Vga : Gate Voltage for AUX amplifier

RF Performance of PAM (BW=100MHz)



Gain (*)	PAE (*)	ACLR (*) @FDD,BW=100MHz	EVM (**)
30.3~31.4dB	44.4~45.2%	-51.1~-52.1dBc	1.3%

(*) @Vd=43V, FDD, Pave=39dBm, BW=100MHz, National Instrument DPD
(**) @Vd=43V, TM3.1a, Pave=39dBm, Keysight DPD, 3.6GHz, PAPR=7.5dB

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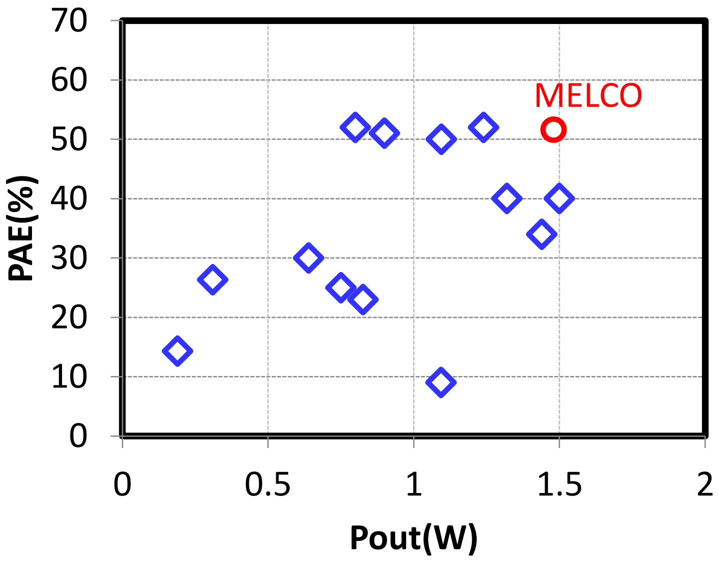
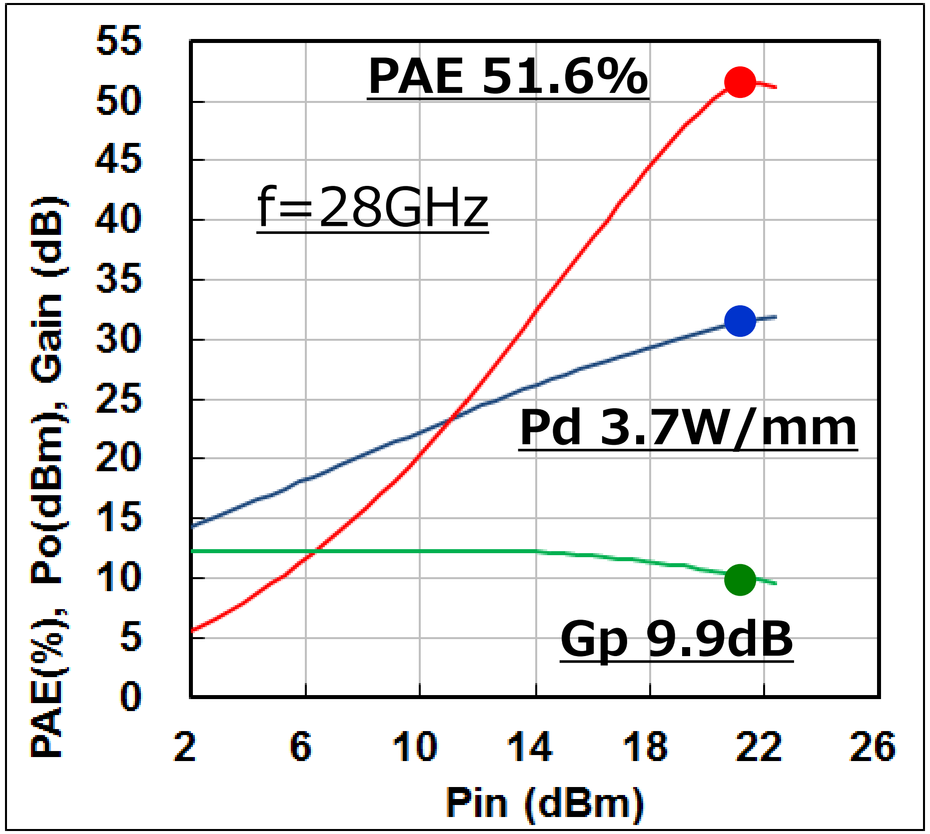
Millimeter wave 0.15um GaN Technology

0.15um GaN device technology:

at 28GHz, top class 51% PAE and 9.9dB Gain were exhibited.



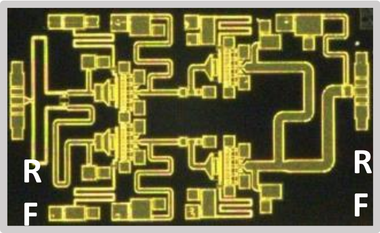
f=28GHz Measured Load-pull data



※Wgt=0.4mm,Vd=24V,Idq=50mA/mm

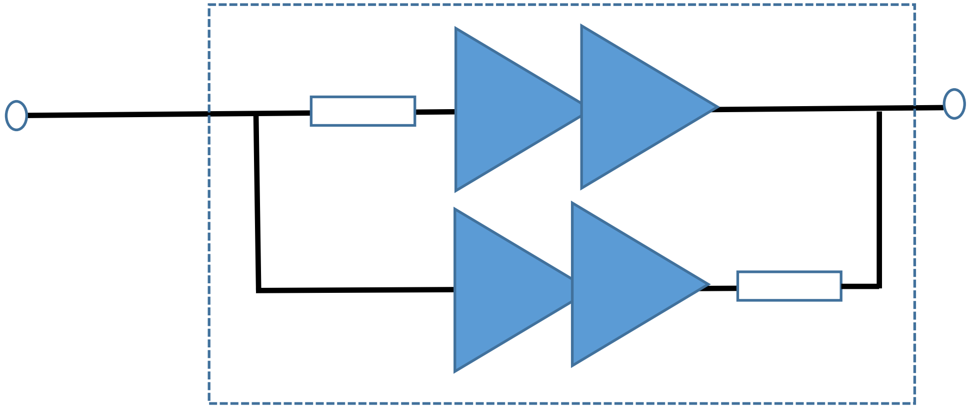
A Ka-Band High Efficiency Doherty Power Amplifier MMIC using GaN-HEMT for 5G Application
K. Nakatani et al.,2018 IEEE MTT-S International Microwave Workshop Series on 5G Hardware and System Technologies (IMWS-5G) , 2018

2-stage Doherty MMIC for 5G



■Fabricated by Mitsubishi’s 0.15um GaN-on-SiC technology

28GHz 2-stage MMIC was fabricated with 0.15um GaN



2 stage MMIC design target and measured results

	Results
Frequency (GHz)	28.5-29.5
Saturation Power (dBm)	35.6
Linear Gain (dB)	16
PAE@8dB Back off (%)	19~20
Vdd (V)	24

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Summary

- GaN HEMT based PA solution is enabling high performance 5G massive-MIMO deployment worldwide
  - High power efficiency: energy consumption and thermal handling
  - Very wideband signal bandwidth with excellent linearity performance
  - Compact PAM design minimize the challenging footprint requirement

- At mmWave frequency, GaN based Doherty PA solution can offer high power (1~30W), wideband (more than 3GHz) and high power-efficiency (10 ~ 20% (Back off), 50% (Saturated)

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