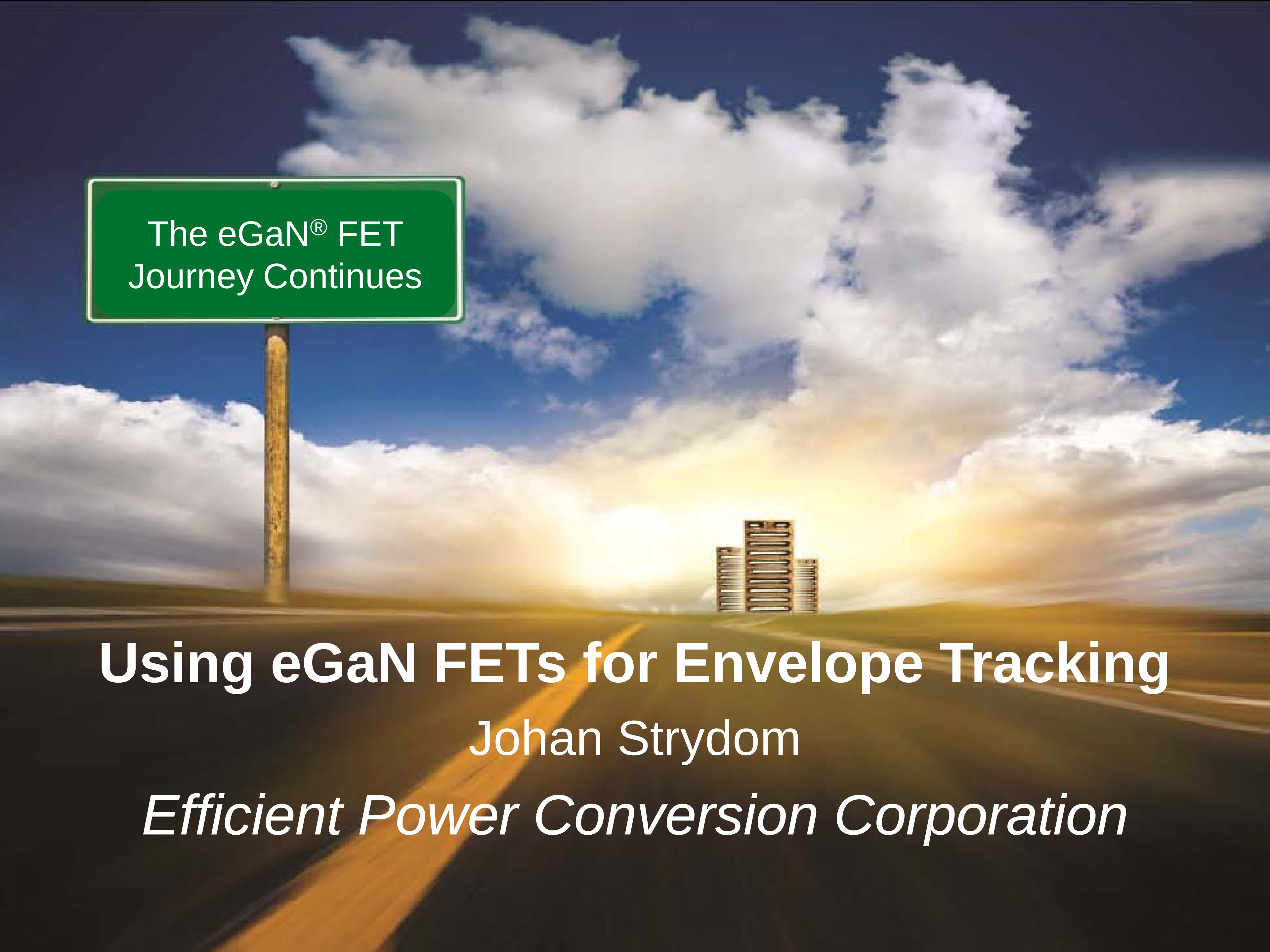


Using eGaN FETs for Envelope Tracking

Johan Strydom

Efficient Power Conversion Corporation

Agenda

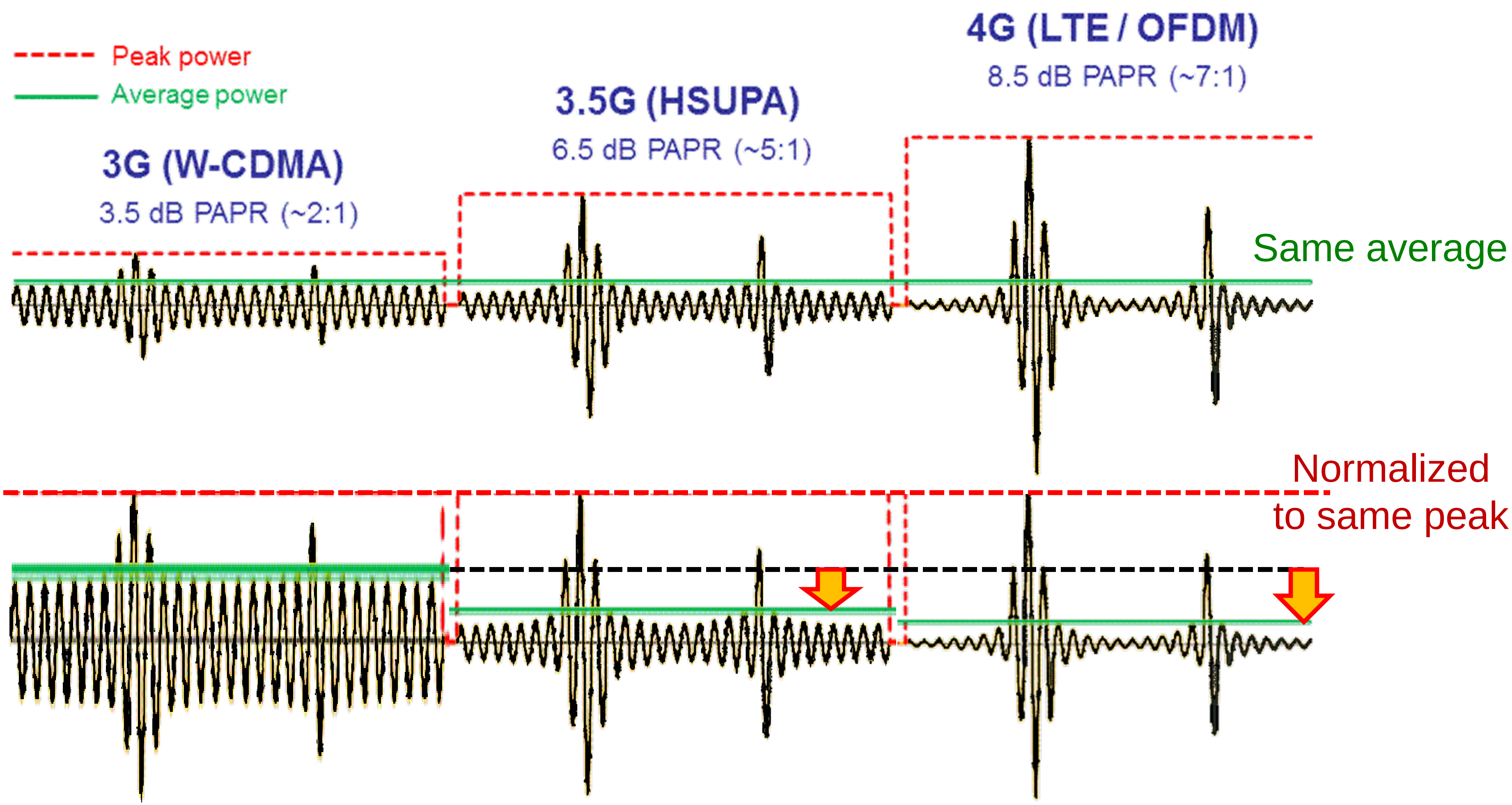
- **Overview of Envelope Tracking (ET)**
- **Example *eGaN*® FET Power Stage**
- **Opportunities in ET**
- **Conclusions**

RFPA Standards

*Ref: www.open-et.org website

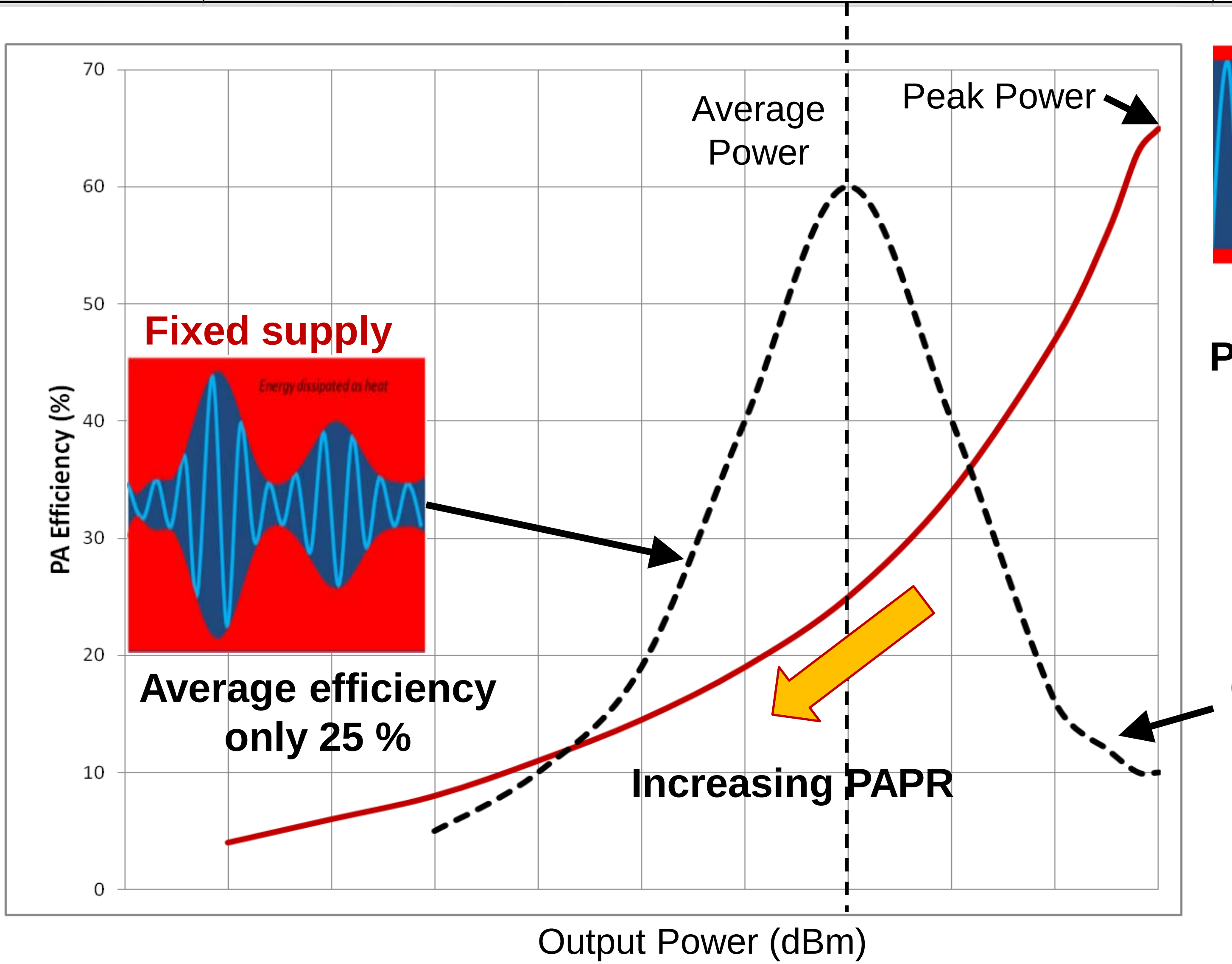
	Standard	Launched	Typ. Carrier BW (MHz)	Typ. Spectral Efficiency (bps/Hz)	Approx. PAPR(dB)
2G cellular	GSM	1991	0.2	0.17	0.0
2.75G cellular	GSM + EDGE	2003	0.2	0.33	3.5
3G cellular	WCDMA FDD	2001	5	0.51	7.0
Digital TV	DVB-T	1997	8	0.55	8.0
Wi-Fi	IEEE 802.11a/g	2003	20	0.90	9.0
WiMAX	IEEE 802.16d	2004	20	1.20	8.5
Wi-Fi	IEEE 802.11n	2007	20	2.40	9.0
3.5G cellular	HSDPA	2007	5	2.88	8.0
3.9G cellular	LTE	2009	20	8.00	10.0

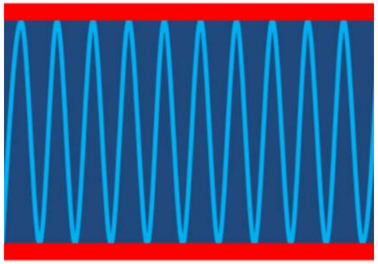
Peak to Average Power Ratio



Ref: Nujira.com website

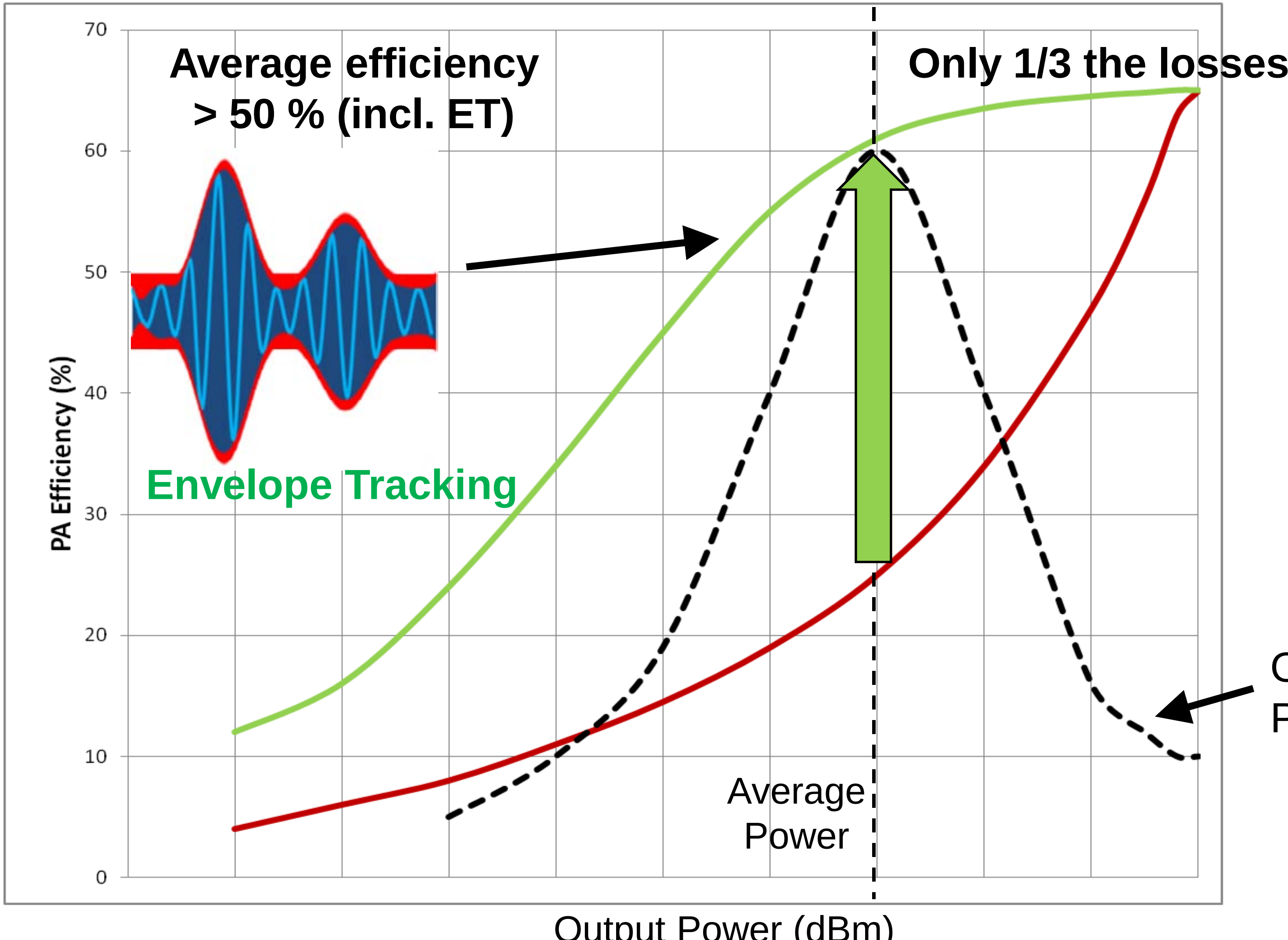
Effect of PAPR





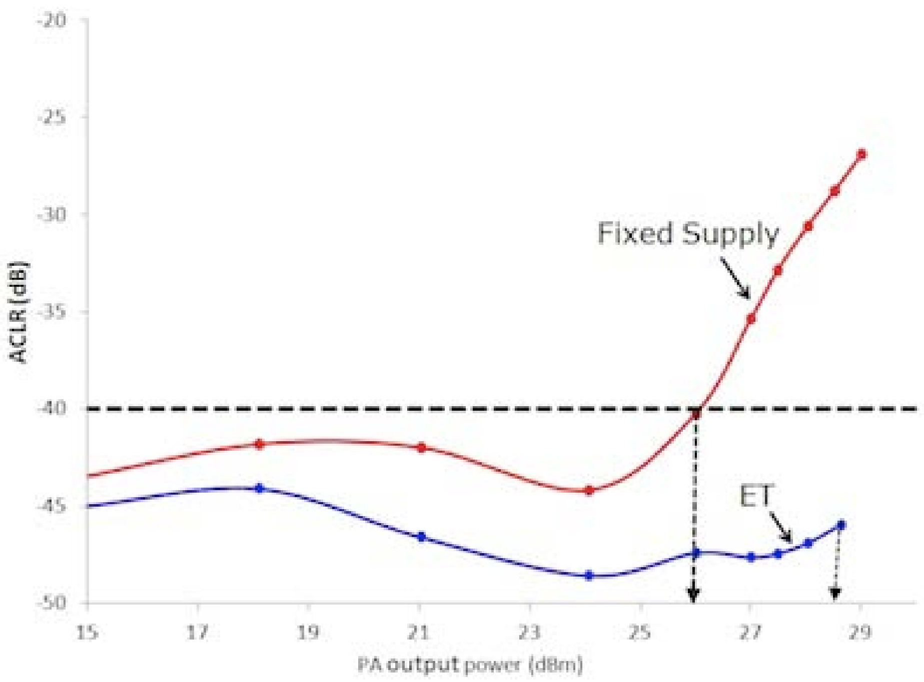
PAPR = 0dB
Peak efficiency up to 65%

Effect of ET

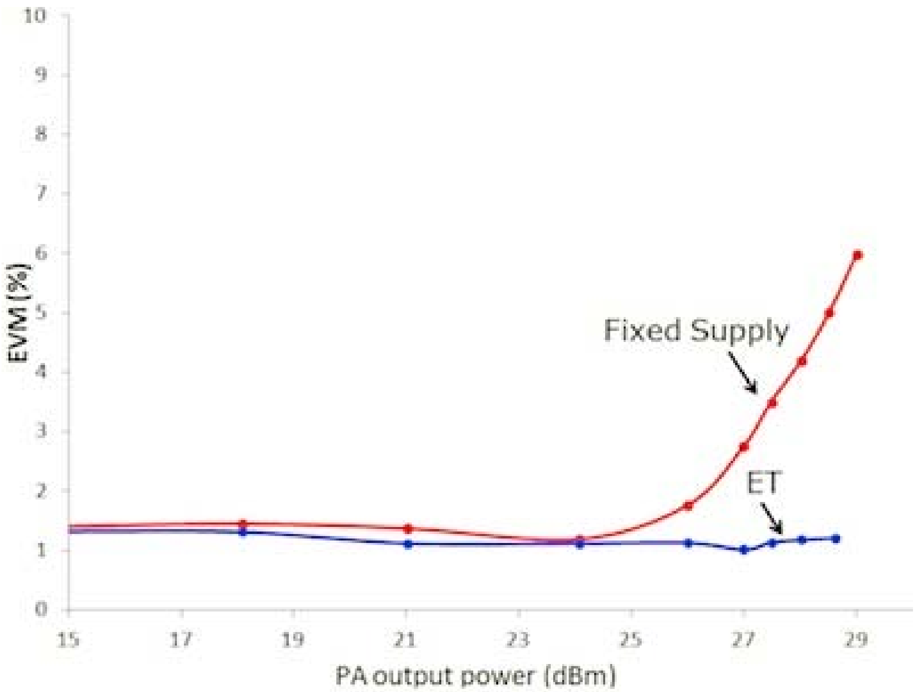


Average efficiency
> 50 % (incl. ET)
Only 1/3 the losses
Envelope Tracking
PA Efficiency (%)
70
60
50
40
30
20
10
0
Output
Probability
Average
Power
Output Power (dBm)

Linearity with ET



Adjacent Channel Leakage Ratio



Error Vector Magnitude

Envelope tracking can even improve the performance of RFPA

Gerard Wimpenny, Understand and characterize envelope-tracking power amplifiers, http://www.eetimes.com/design/microwave-rf-design/4233749/Understand-and-characterize-envelope-tracking-power-amplifiers#

RFPA Standards*

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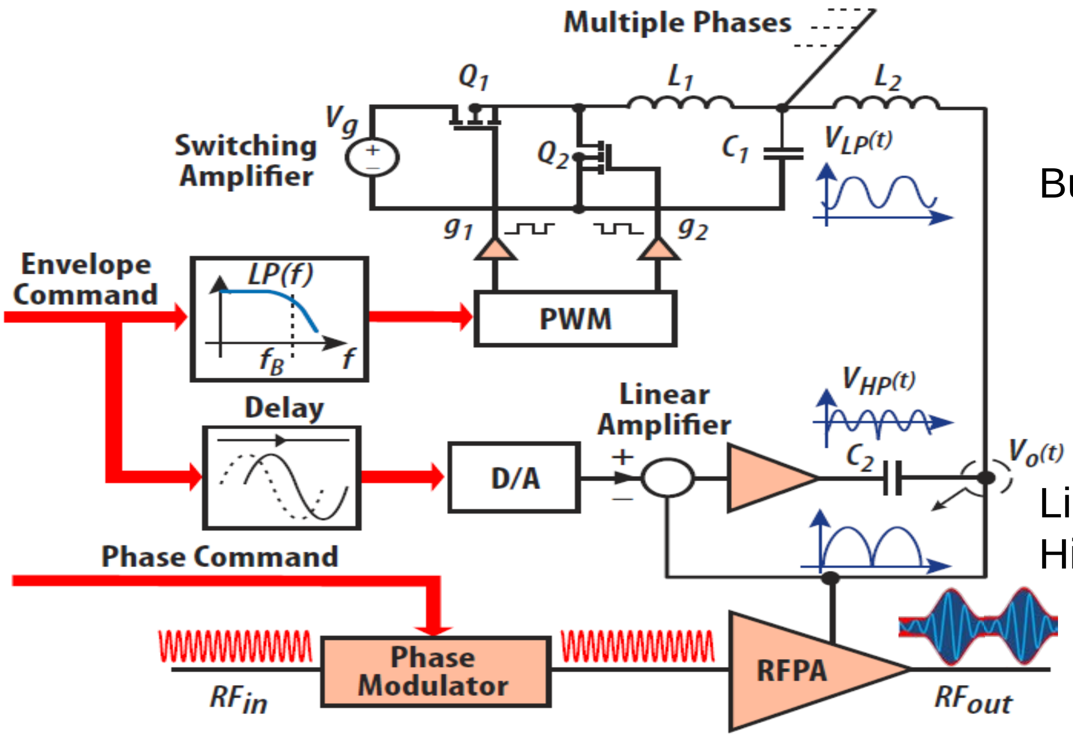
3.9G cellular	LTE	2009	20	8.00	10.0

- Up to 20 MHz Carrier bandwidth required
- Required ET supply BW about 5x higher than carrier BW

*Ref: www.open-et.org website

Envelope Tracking Supply

- **ET power supply topologies vary**
  - Open loop boost – full BW required
  - Closed loop linear-assisted Buck*



Buck ~ 10% Bandwidth
~ 90% Power

Linear AMP ~ 10% Power
Highest 90% of Bandwidth

*V. Yousefzadeh, et. Al, Efficiency optimization in linear-assisted switching power converters for envelope tracking in RF power amplifiers, ISCAS 2005

1300 W DVB* – 8 MHz BW and 8 dB PAPR

Linear-assisted Buck for ET

- 4 phase x 1 MHz Buck with up to 800 kHz band width

45 Vin, 22 Vout/ 15 Aout (Avg)

Alt. Buck option for ET (Push frequency)

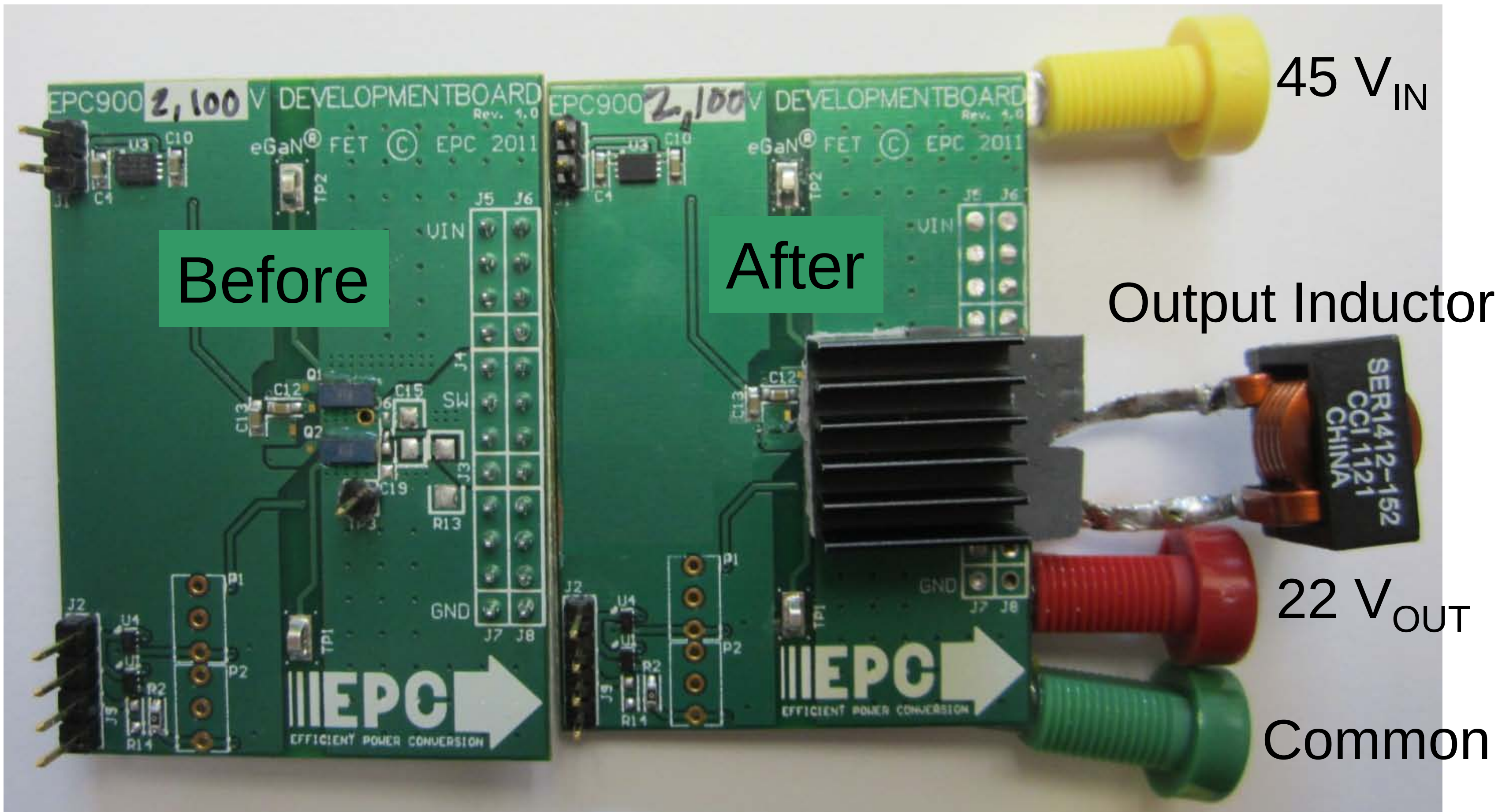
- 10 phase x 4 MHz Buck with up to 8 MHz band width

45 Vin, 22 Vout/ 6 Aout (Avg)

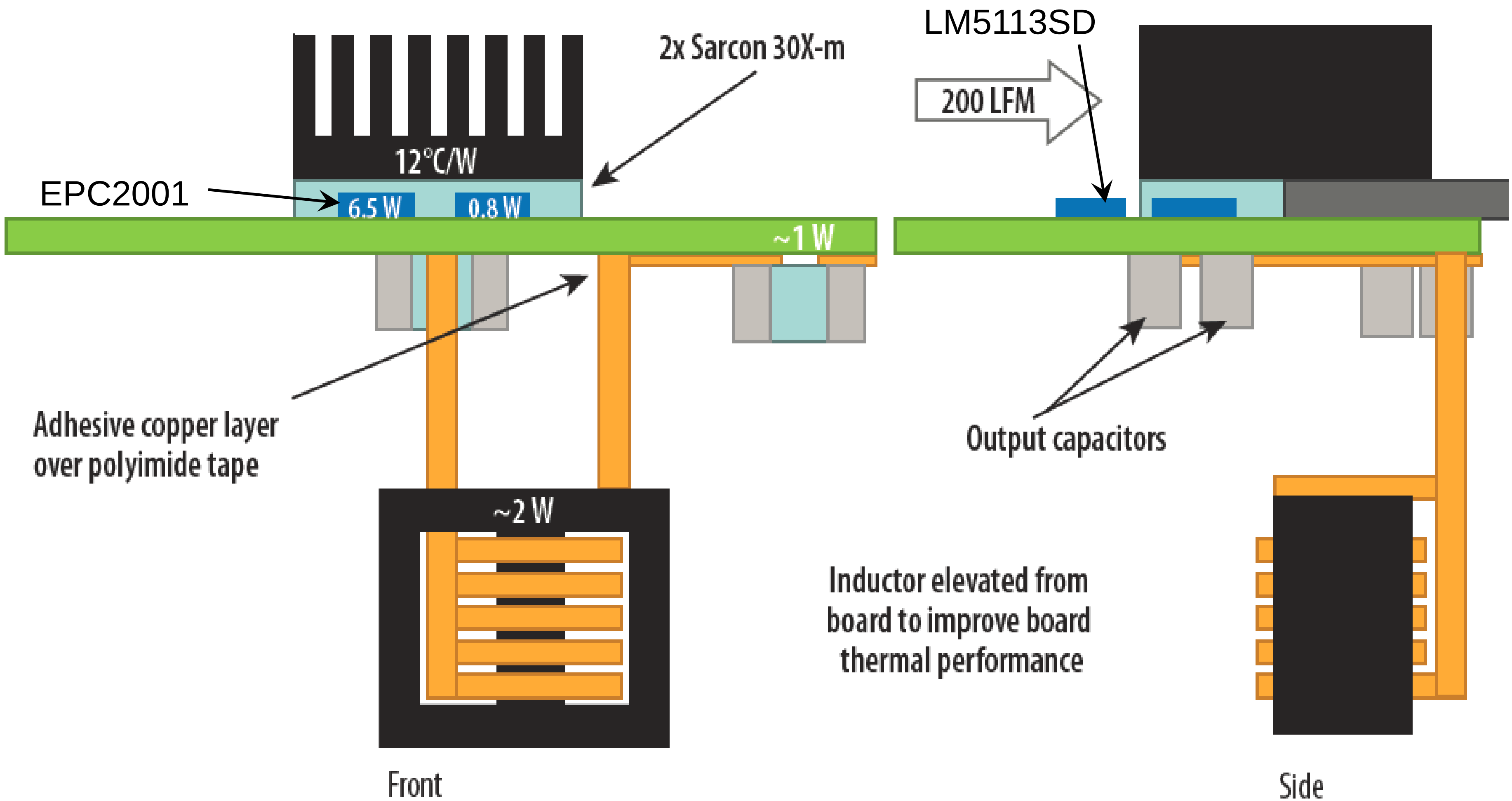
*Representative of a high power ET buck in HV LDMOS, such as that implemented by ET specialist Nujira.

15 A_{OUT} / 1 MHz Single ϕ Buck

- **Modified an EPC9002 development board**



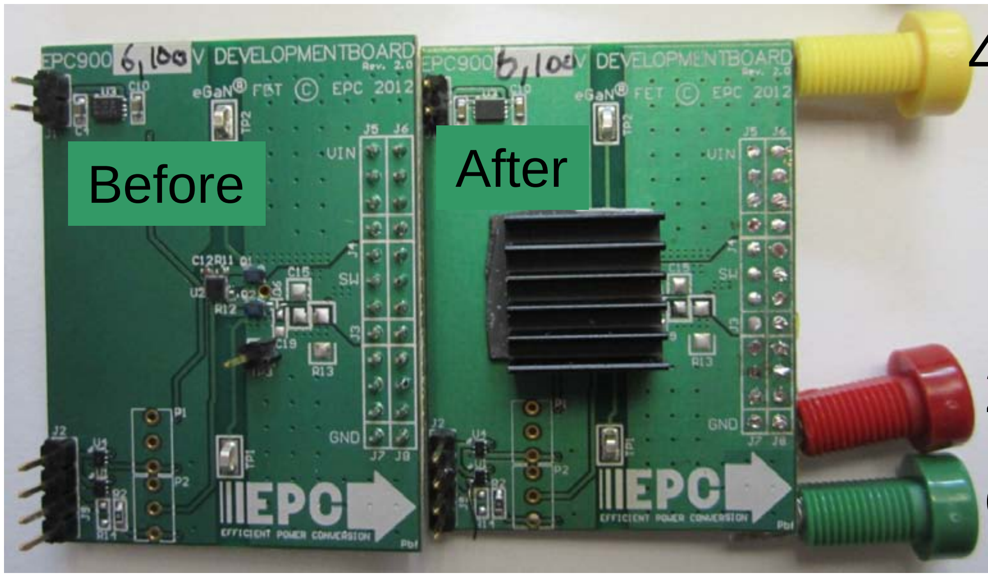
15 A / 1 MHz Single ϕ Buck

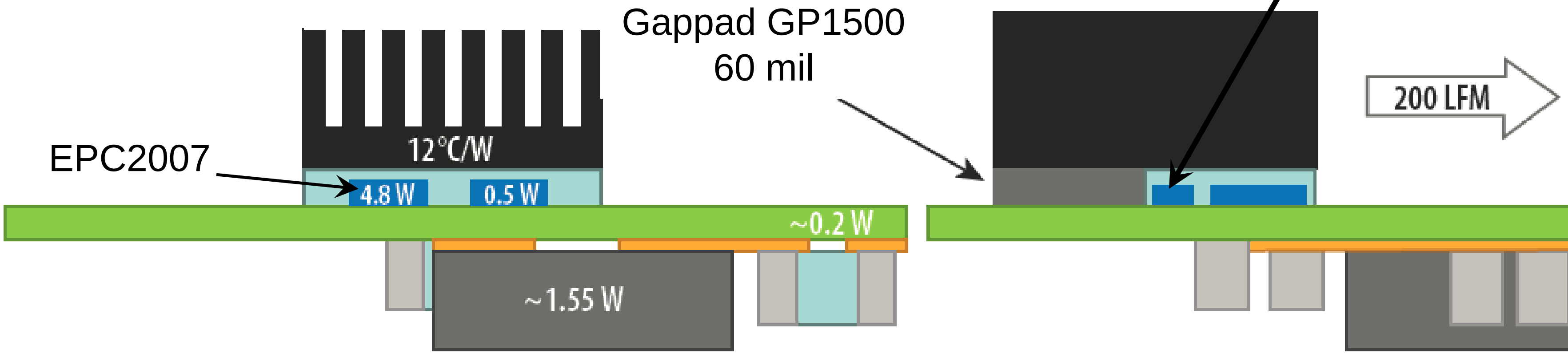


45 V to 22 V, 15 A, 1 MHz buck converter using EPC9002

6 A_{OUT} / 4 MHz Single ϕ Buck

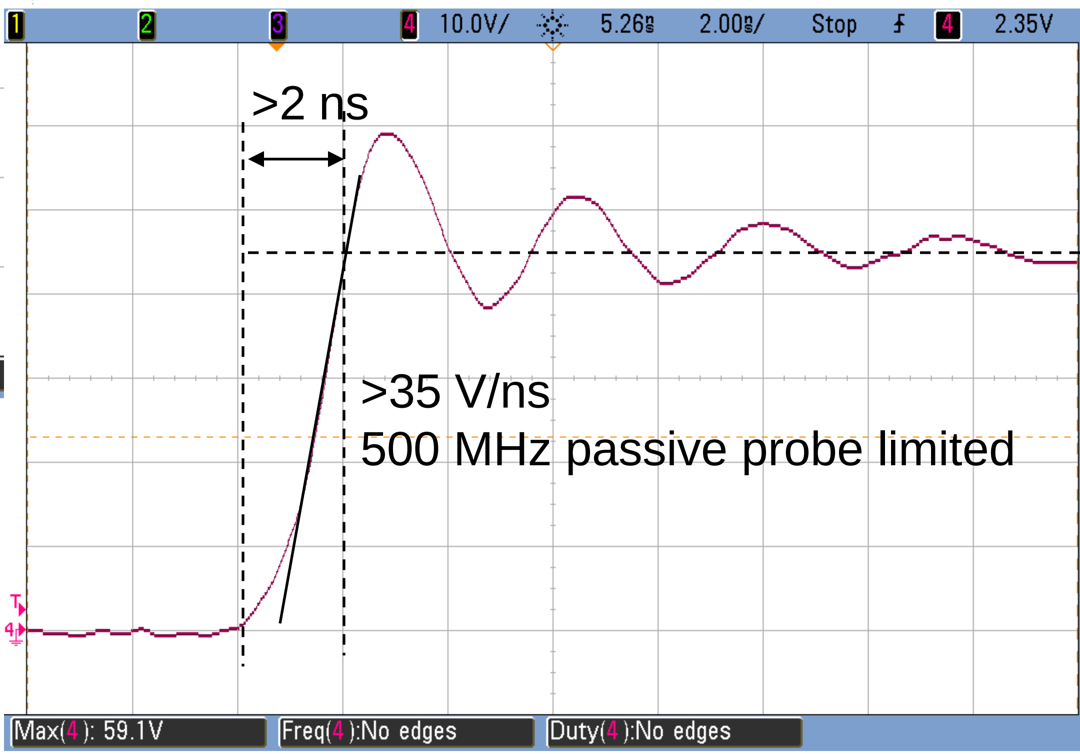
- **Modified an EPC9006 development board**



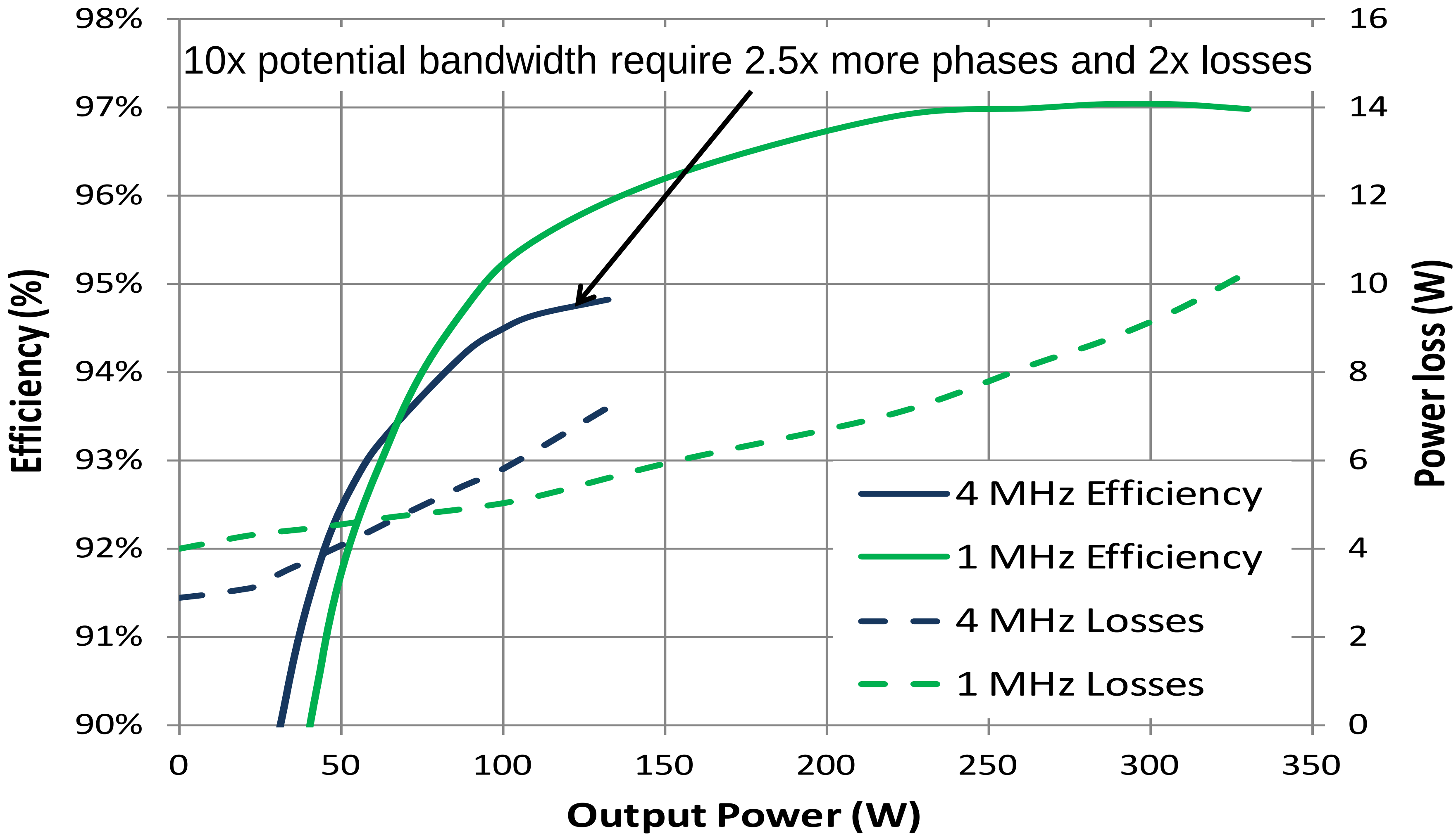


Switching Waveforms

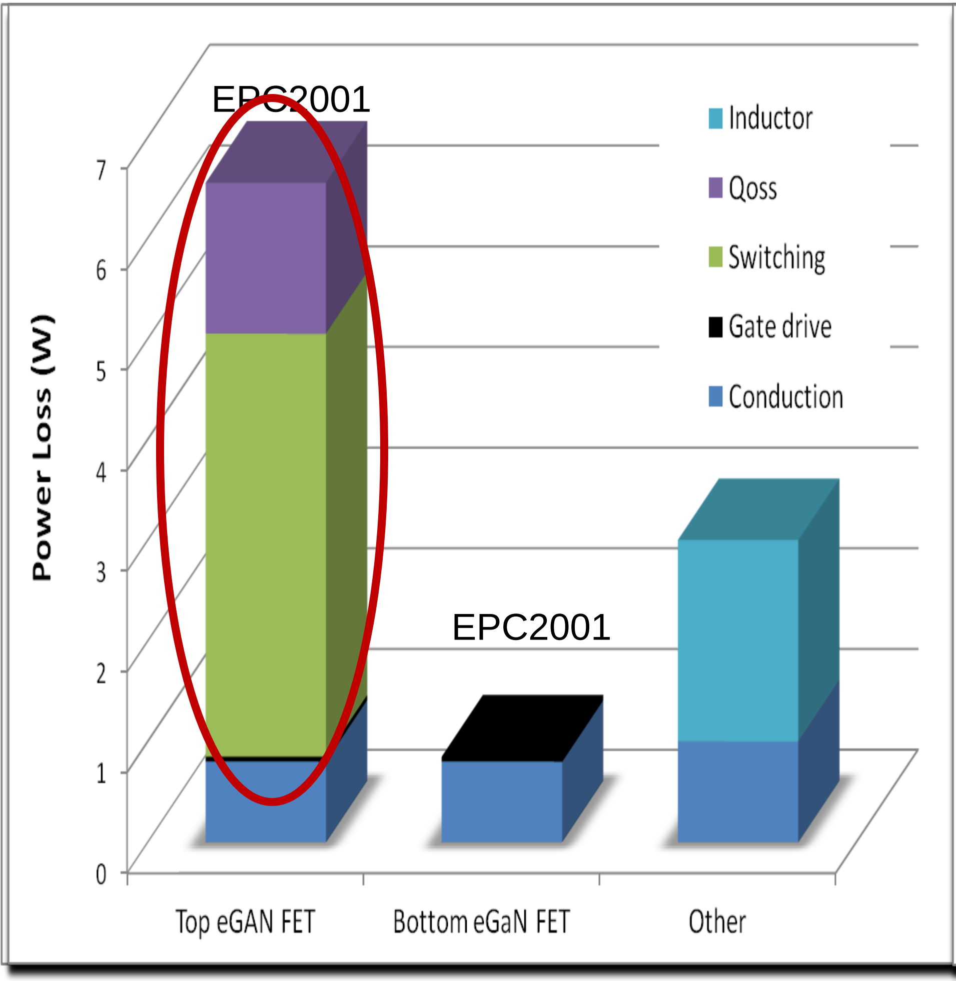
EPC9006 @ 2 A / 4 MHz



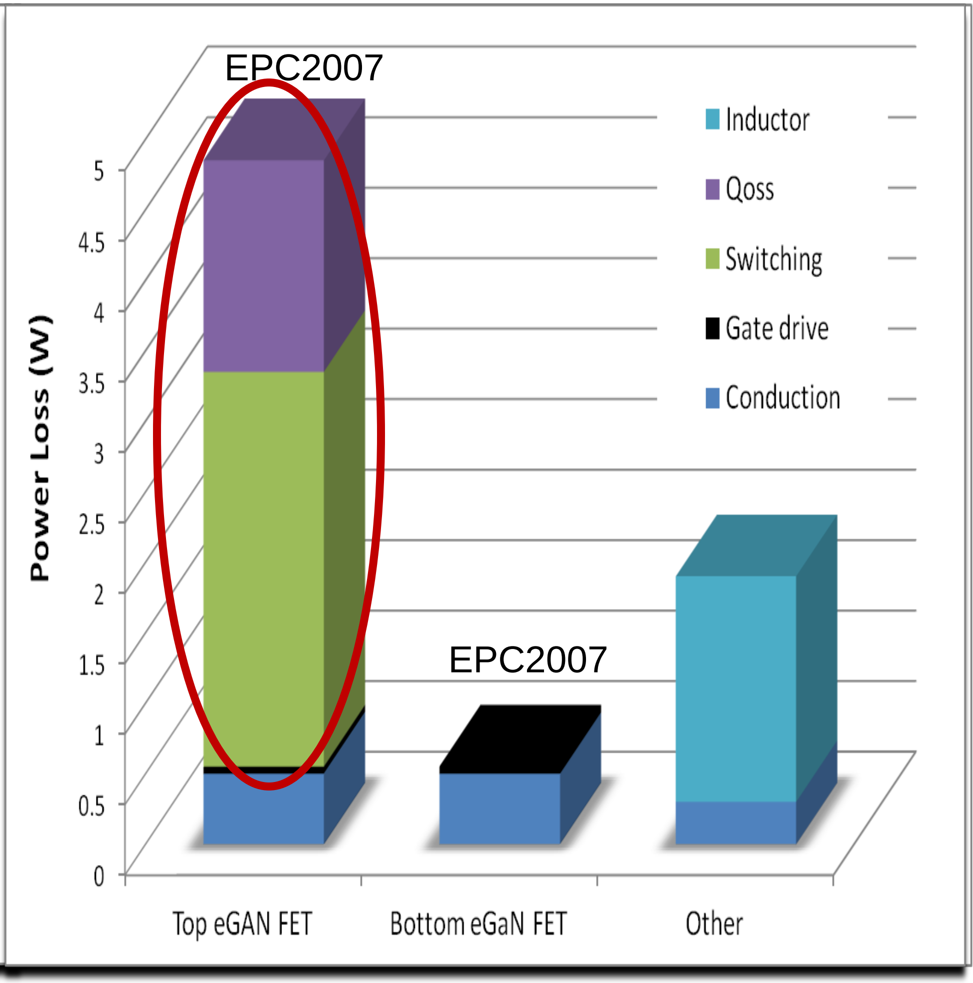
Efficiency Results



Loss Breakdown



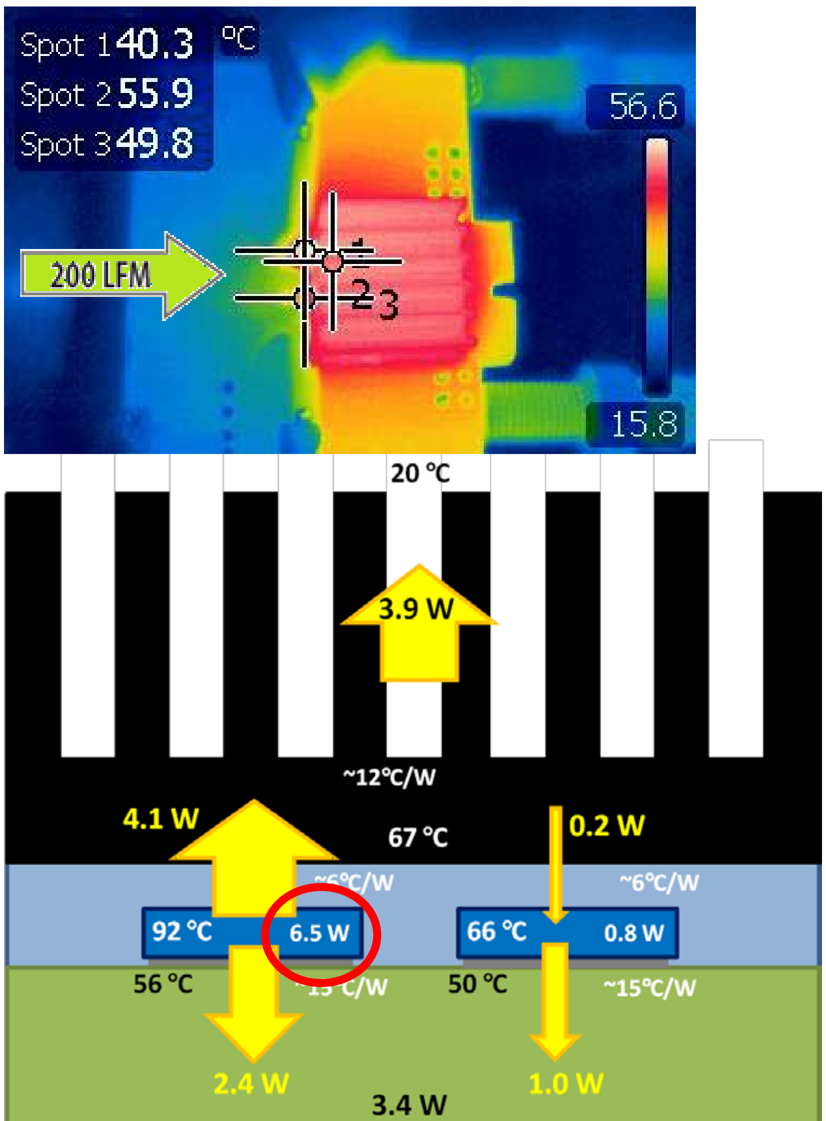
1 MHz EPC9002

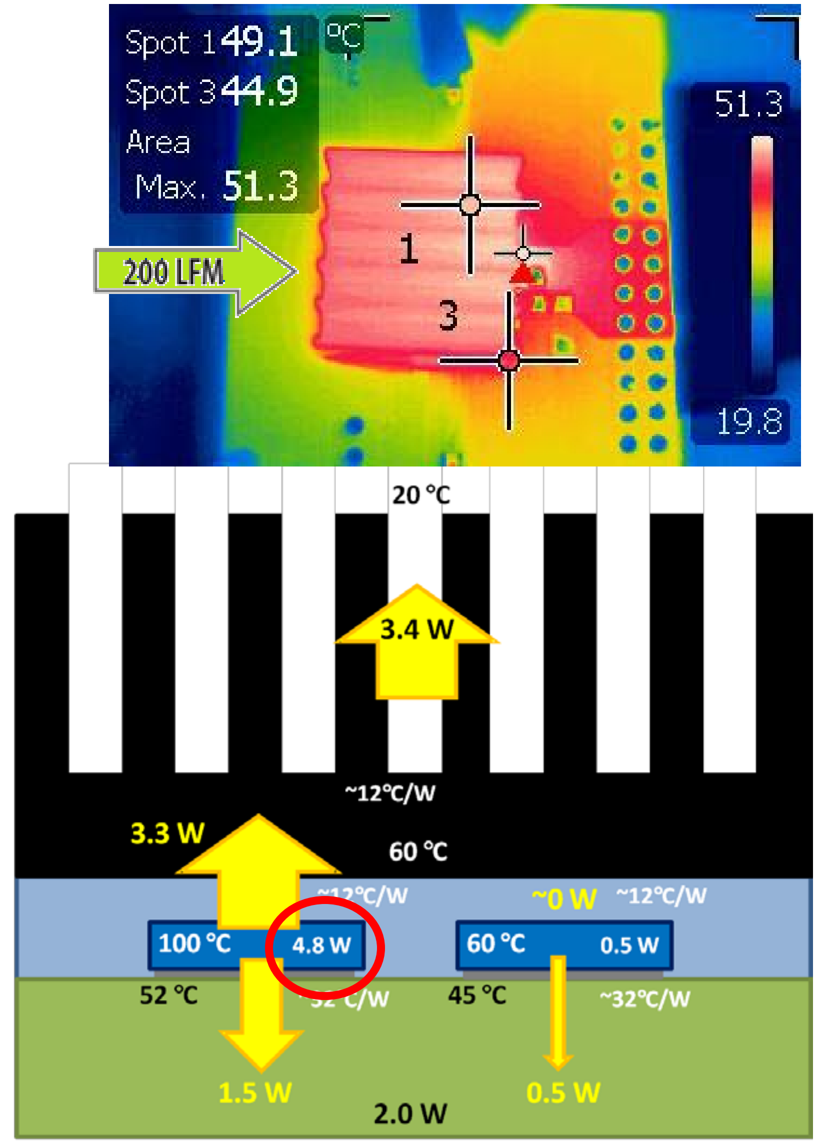


4 MHz EPC9006

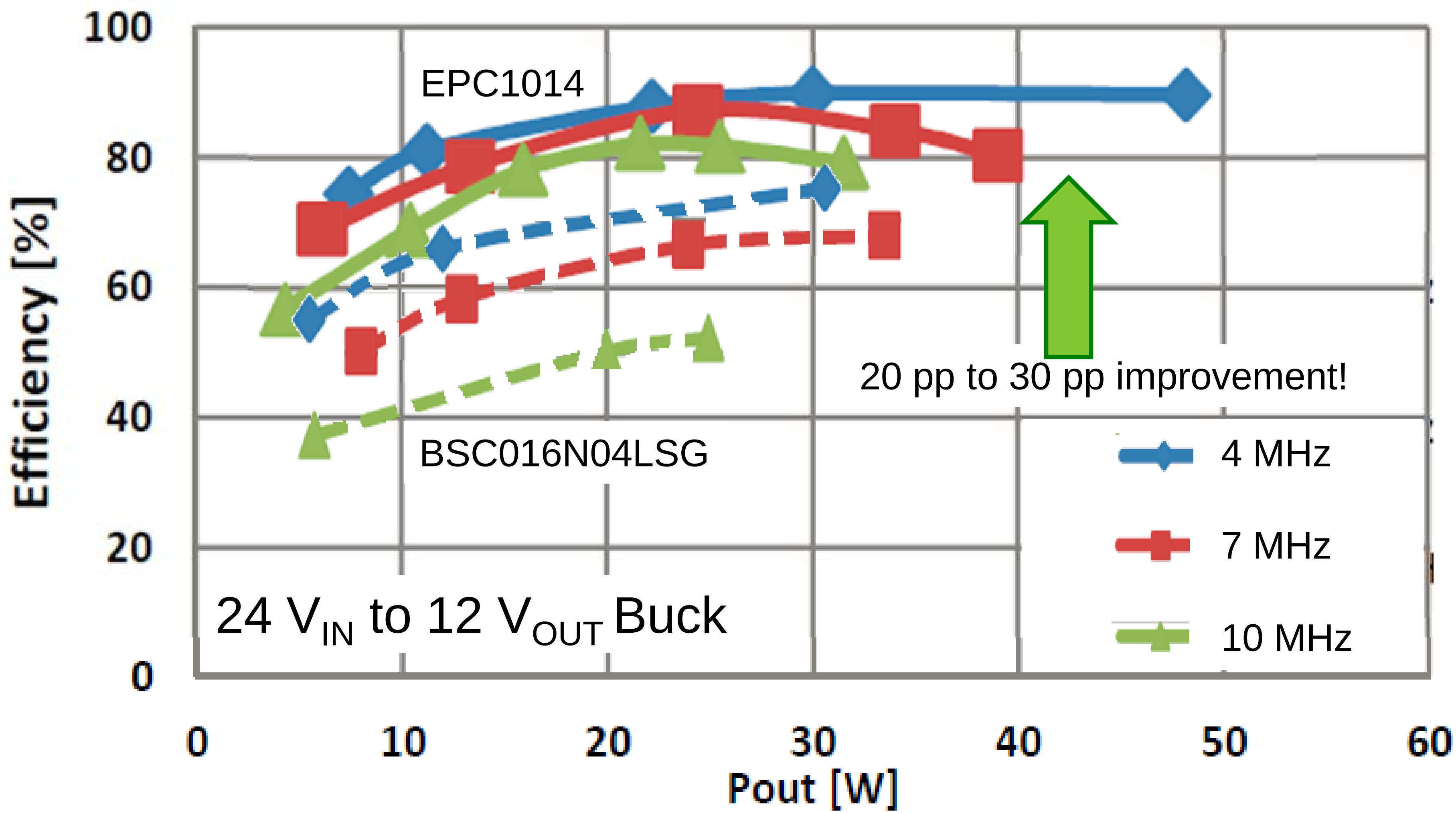
Future die size optimization possible

Thermal Results





Lower Voltage ET Results*



*D. Čučak, et. al, "Application of eGaN FETs for highly efficient Radio Frequency Power Amplifier", CIPS 2012

Opportunities in ET

eGaN FET switching times not limiting factor

– <1 ns delay / <2 ns switching time.

Bandwidth will be limited by loop delay

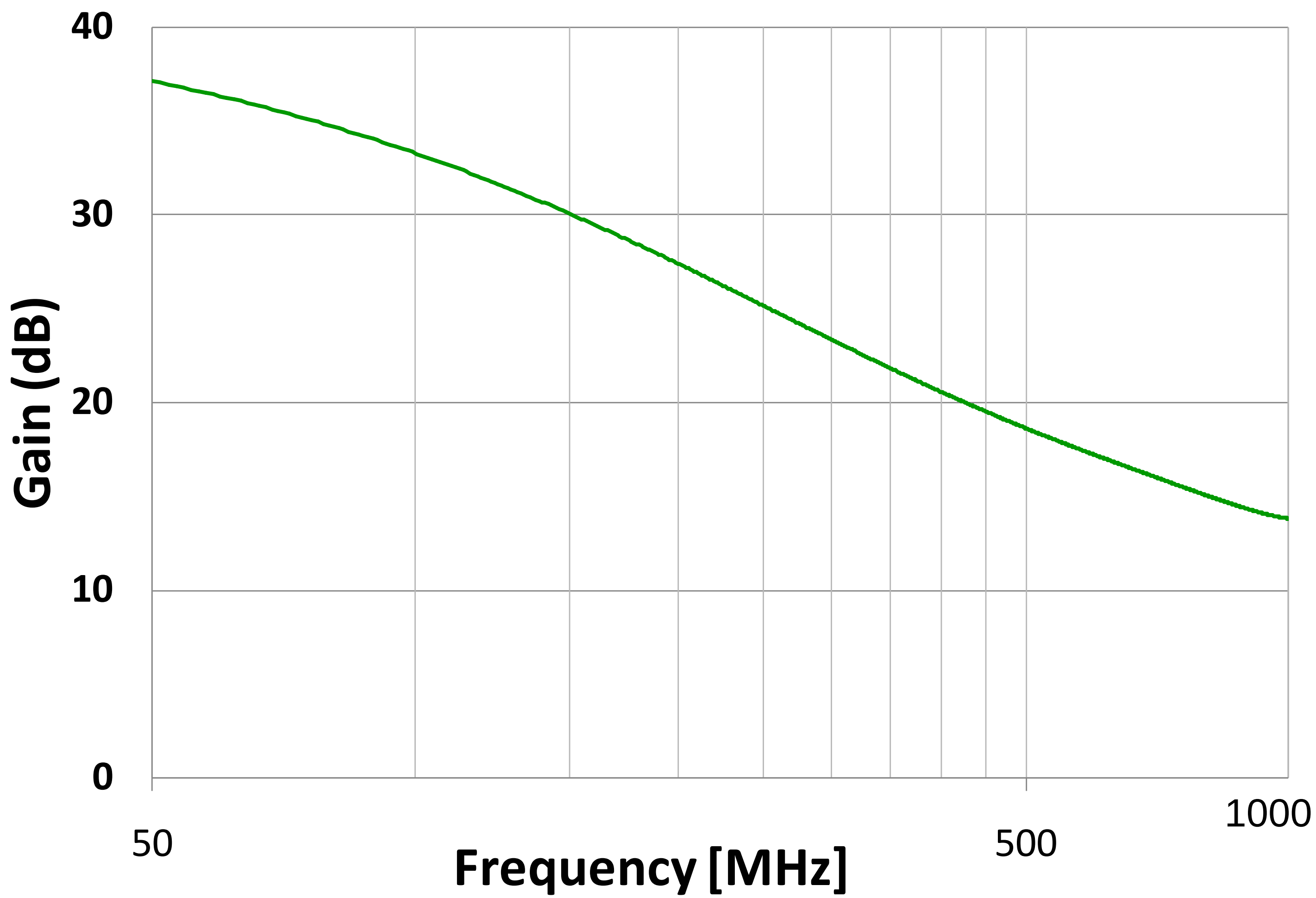
– e.g. 20MHz BW require <12ns loop delay (90º)

Linear assisted buck ‘cleans up’ Buck distortion.

– Relaxes controller delay requirements

eGaN FET suitable as LDMOS replacement for Linear regulator

EPC 2012 Maximum Gain vs Frequency 200 V eGaN FETs



Conclusion

- **eGaN FETs are an enabling technology for ET**
  - Low charge reduces delay and switching times
  - Thermally possible - with double sided cooling
- **Results are representative, but not optimized**
  - Improve inductor selection
  - Improve thermal design
  - Reduce high side peak device temp by reducing low side device size to reduce Q_{OSS} losses
- **Power and # of phases application specific**

EFFICIENT POWER CONVERSION

The end of the road for silicon…..

is the beginning of the eGaN FET journey!