## **THz Point-to-Point Links:**

## >100 GHz; >100 Gbps

Yinggang Li, Mikael Hörberg and Jonas Hansryd Ericsson Research, Ericsson AB Göteborg, Sweden March 7, 2019



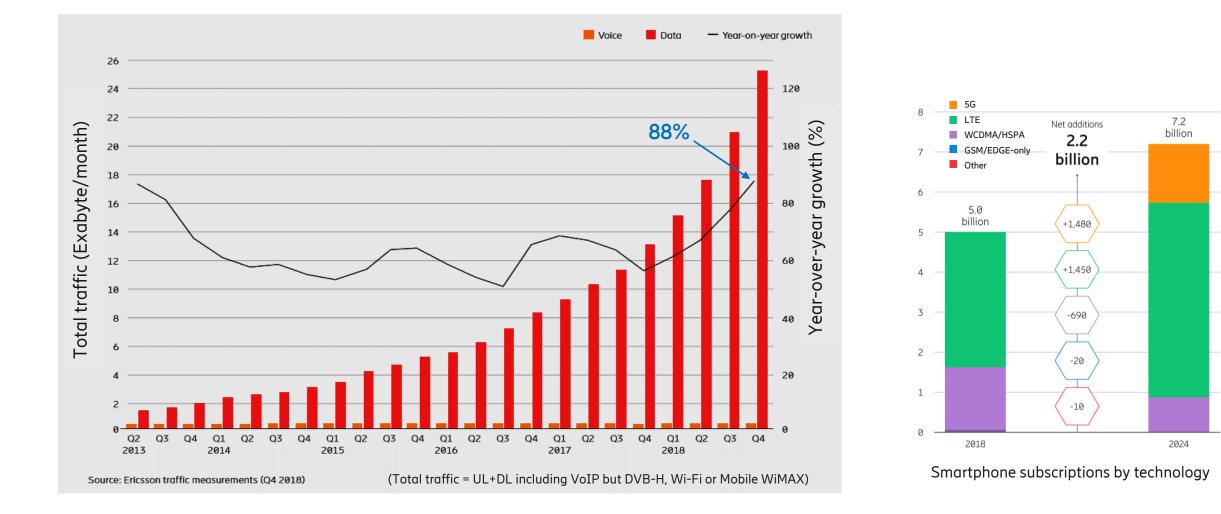
(Invited presentation at the 2nd THz Communication Workshop, Brussels Belgium)

#### Contents

- Background
- Spectrum Horizon
- Challenges
- Ex. D-band research and development
- Some future perspective



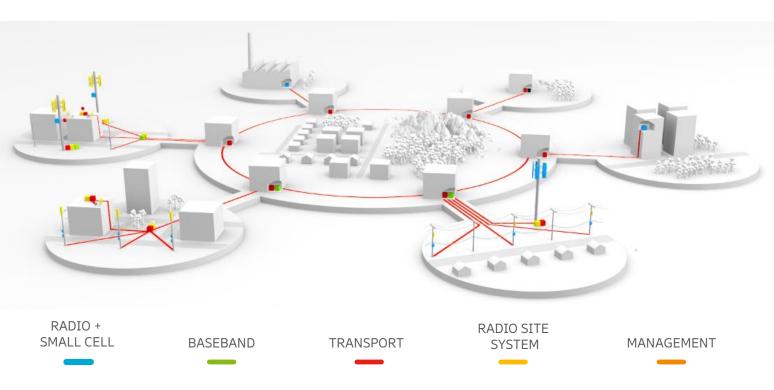
## Global mobile traffic growth (based on measurement):

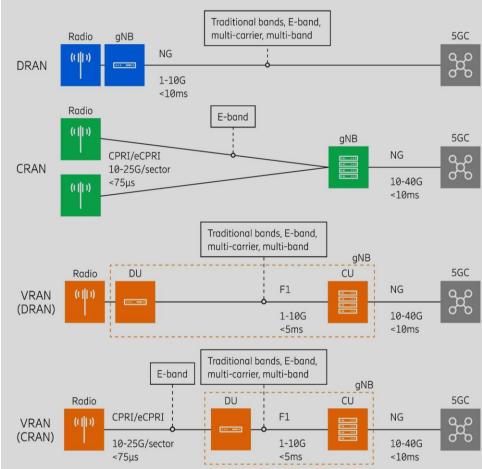


## Transport networks

#### Evolving in:

- Network dimensioning, architecture and topology
- Capacity





#### Future transport needs

Backhaul capacity per site in Distributed RAN

#### C2 (eCPRI) capacity in Centralized RAN

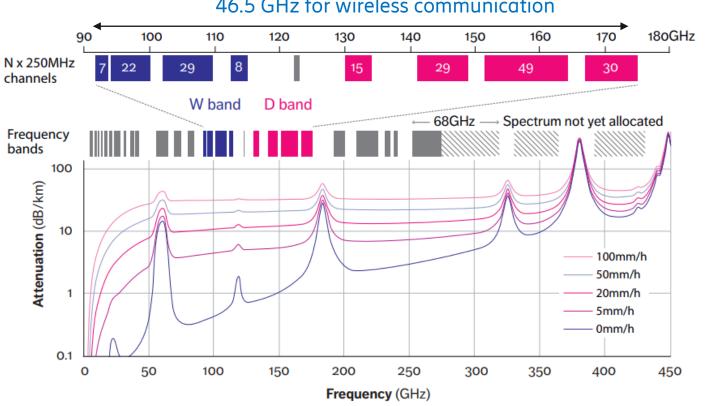
	2018 Low — high cap sites	2022 Low — high cap sites	Towards 2025 Low — high cap sites		2022 Low — high cap sites	2025 Low — high cap sites
Urban	150 Mbps — 1 Gbps	450 Mbps — 10 Gbps	600 Mbps — 20 Gbps	Massive MIMO (1 sector)	10 — 15 Gbps	15 — 25 Gbps
Suburban	100 Mbps — 350 Mbps	200 Mbps — 2 Gbps	300 Mbps — 5 Gbps	Massive MIMO (3 sector)	15 — 25 Gbps	25 — 40 Gbps
Rural	50 Mbps — 150 Mbps	75 Mbps — 350 Mbps	100 Mbps — 600 Mbps	Source Ericsson (20	18)	

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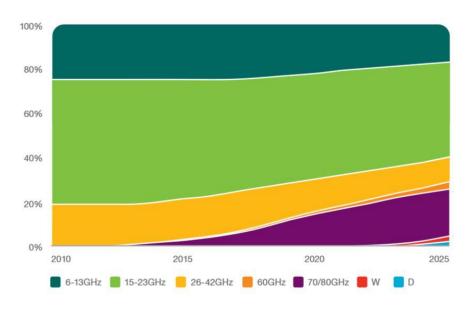
#### Spectrum Horizon



#### The W-band and D-band



#### 46.5 GHz for wireless communication

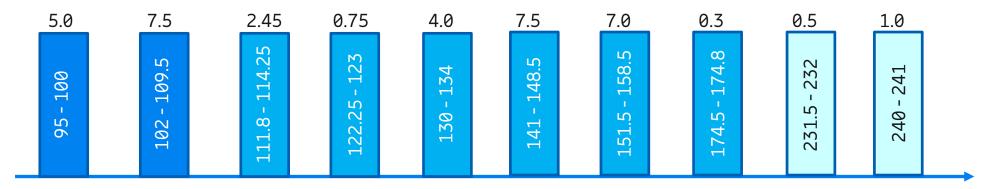


#### Deployment share per frequency (Source Ericsson 2017)

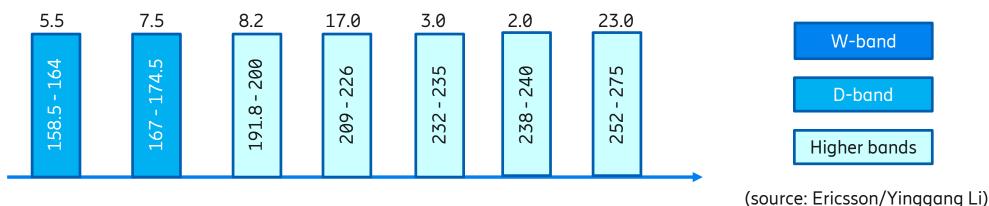
#### Source: Ericsson Technology Review 2017, https://www.ericsson.com/assets/local/publications/ericsson-technologyreview/docs/2017/etr-beyond-100ghz.pdf

## FCC Spectrum Horizon: up to 275 GHz proposed

#### (a) Bands based on rules similar to E-band (70/80 GHz), totally 36 GHz



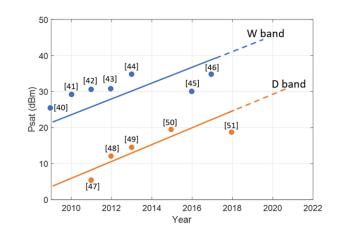
#### (b) Bands for licensed fixed wireless operations, totally 66.2 GHz

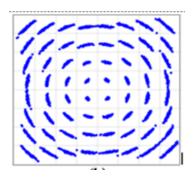


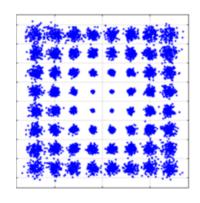
## Technical challenges when approaching sub-mmW:

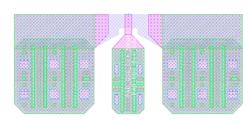
- Output power varies generally as  $1/f^{\alpha} \alpha = 2 \sim 3$
- Packaging becoming increasingly difficult

   if possible: integrate the antenna on-chip or in package
- Unwanted resonance modes may easily develop in MMIC substrate
- Modeling increasingly difficult at high frequency
- Phase noise increasing (typically 6 dB per frequency doubling)
- Receiver noise figure increasing
- → *General statement:* S/N degrades fast with frequency!

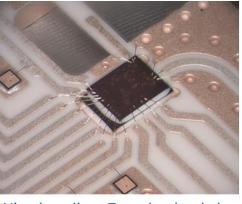








D-band RF pad, 30x60 µm<sup>2</sup>, challenging for wire bonding



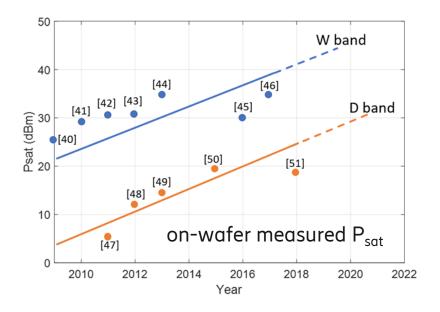
Wire-bonding, E-probe, backshort for transition, mmW substrate



# How to transfer the "precious" mmW power from MMIC to antenna port?

#### The solution must be:

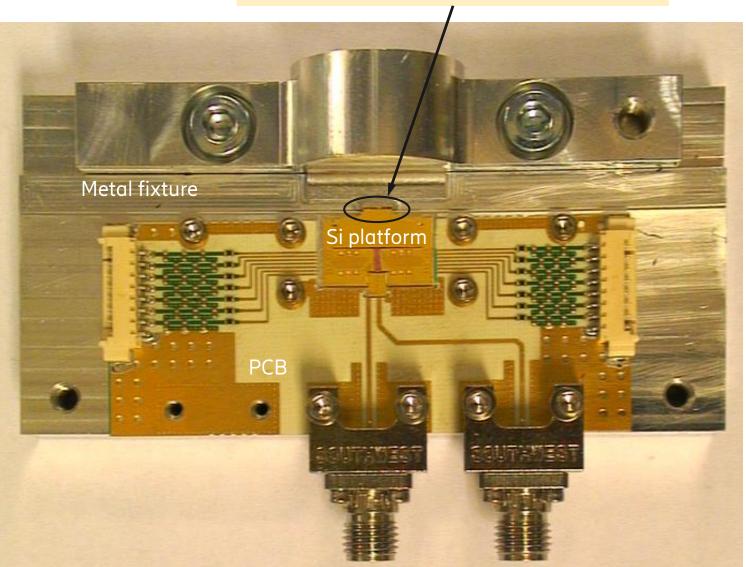
- Volume manufacturable
  - Automatically assembly, repeatability (yield), tolerance insensitive, etc.
- Commercially affordable



## Example, D-band transceiver modules for PtP links

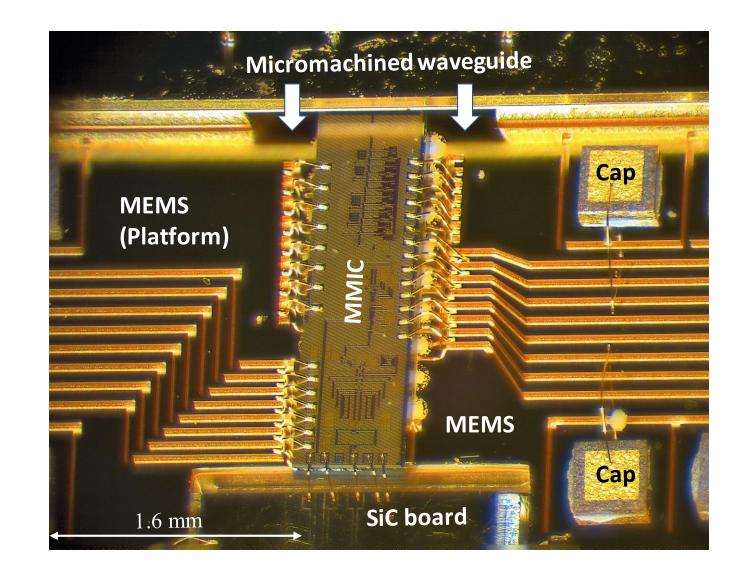
#### Micromachined chip-to-antenna transition

- M3TERA, a H20202 project
- PoC demonstrator: *D-band Tx/Rx module*
- MMICs in 130nm SiGe from Infineon (B11)
- Micromachined Si substrate as an heterogenous platform for system integration

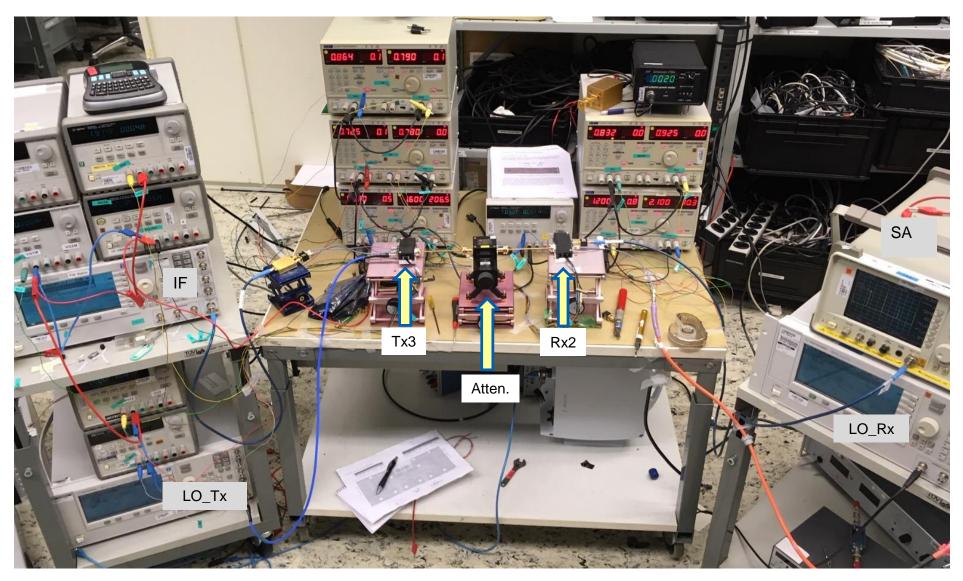


#### Heterogenous integration based on micromachined Si substrate

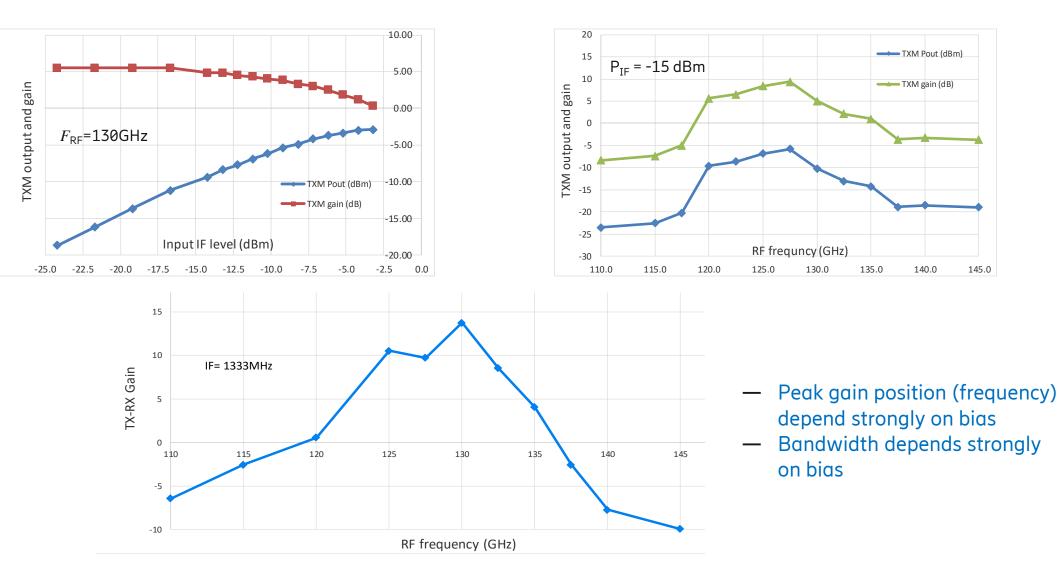
- Micromachined low-loss Si waveguide
- Non-gavanic transition between MMIC and the waveguide
- Embedded components, e.g. BPF, duplexer and phase shifters



#### Link test setup



#### CW test



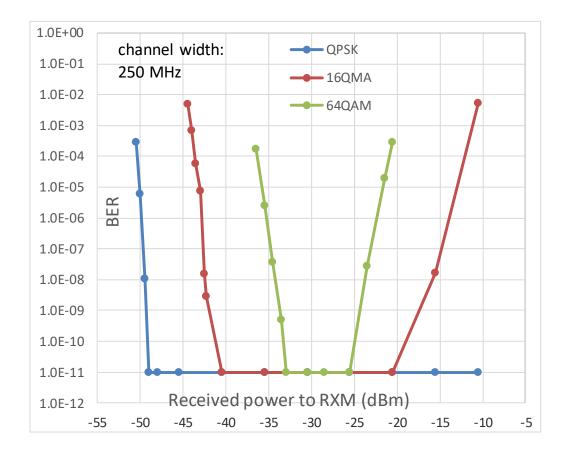
#### Real-time data transmission based on Ericsson's Modem

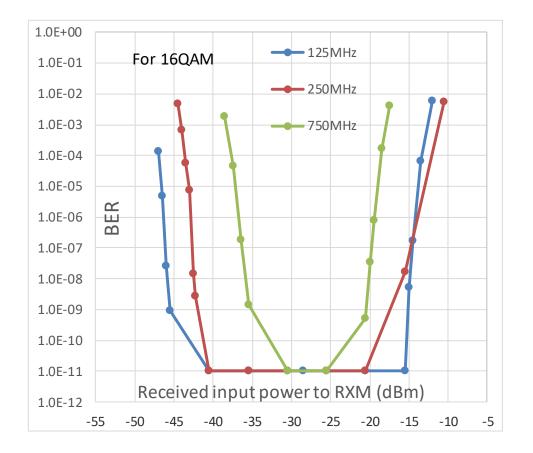
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Modem Monitor							
Equalizer							
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Group Delay (3[symbols]/div)							
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Save Equalizer Coeff							
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1	-Receiver Informatio	Lock Indicators			
	Int AGC Gain	4.6 [dB]			AGC
	Ext AGC Gain/Pwm:	8.8	17.6 [%]		Timing
	Ext. Back Off [Input/Inban	d] -12.0 [dB]	-16.6 [dB]		
	MSE [Norm/Rad/Worst]	-25.0 [dB]	-24.3 [dB]	-24.9 [dB1	Preamble
	Res Phase Noise:	1.5 [deg]			FEC
	ACMB Profile:	10 [64QAM]			Cock
	ACMB Engine (Rx):	Enabled			
	ACMB Engine (Tx):	Enabled			Network
	Symbol Rate:	222.000 [MBaud]			
	Decimation Ratio	0.082223			ACMB Engine
	LDPC Decoder Stress:	N/A			Enable ACMB Set
	Total Freq Correction	-144 010 288 [H	z]		
	PSAM Freq Correction	-4 [Hz]			Local 10 -
	Freq. Correction	-144 010 284			
Ì	Transmitter Informa	ition			Remote 10 -
	ACMB Profile:	10 [64QAM]			Inc Local+Remote
	Symbol Rate:	222.000 [MBaud]			Dec Local+Remote
	Interpolation Ratio	21.621643			
	Freq Correction	0 [Hz]			Acquire Parameters
	Gain Correction	4.5 [dB]			Acquisition Last used
	Symbol Time Factor	1.000000			Spectral Inv Last used
	Actual Bit Rate	1129.635 [Mbps]			Mode:
	Remote MSE/RPN:	Remote LOL	Remote LOL		Last Acquire SUCCESS Error:
					Acquire

#### Measurement results

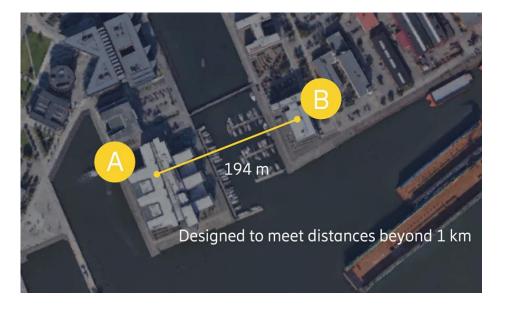




# 100 Gbps microwave link is not a dream any more today but a reality!

- Demonstrated by Ericsson in Gothenburg, Feb. 2019
- Based on Ericsson's existing commercial product
- Line-of-sight MIMO plus H/V
   polarization





#### **Purposely removed!**

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## Looking forward

- > 100 GHz
  - Short-term: W- & D-band
  - Longer term: towards sub-mmW (275 GHz)
- > 100 Gbps
  - Microwave solutions available today to meet the need for 5G towards 2025
  - 100 Gbps for beyond 5G towards 2030 (Tbps from even longer-term perspective ?)
- Compact and simplified site solution for MIMO and highgain antennas towards sub-mmW
- Challenges with THz MMIC interconnect and packaging
  - Heterogenous system integration
  - Antenna-in-package and SiP

# Continuous and sustained research effort is necessary to commercialize the mmW-THz spectrum



Perspective for future D-band LoS-MIMO