Communication Infrastructures in Industrial Automation: The Case of 60 GHz MillimeterWave Communications

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Outline

- Motivations
- Characteristics of 60 GHz mmW communications
- Potentials of 60 GHz communications in automation
- Challenges
- Conclusions

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Motivations

- tight **time** and **data rate requirements**, long **duty cycles**
  - fast data exchange btwn central controller-distributed I/O modules ($\sim$ milliseconds)
  - real-time visualization or recording data transmission ($\sim$ Gb/sec)
  - higher data rates $\Rightarrow$ smaller duty cycle

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- lack of Gbps solutions with **strict real-time guarantees** [CMH10]

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  - safety-related data transmission (e.g. emergency stop)

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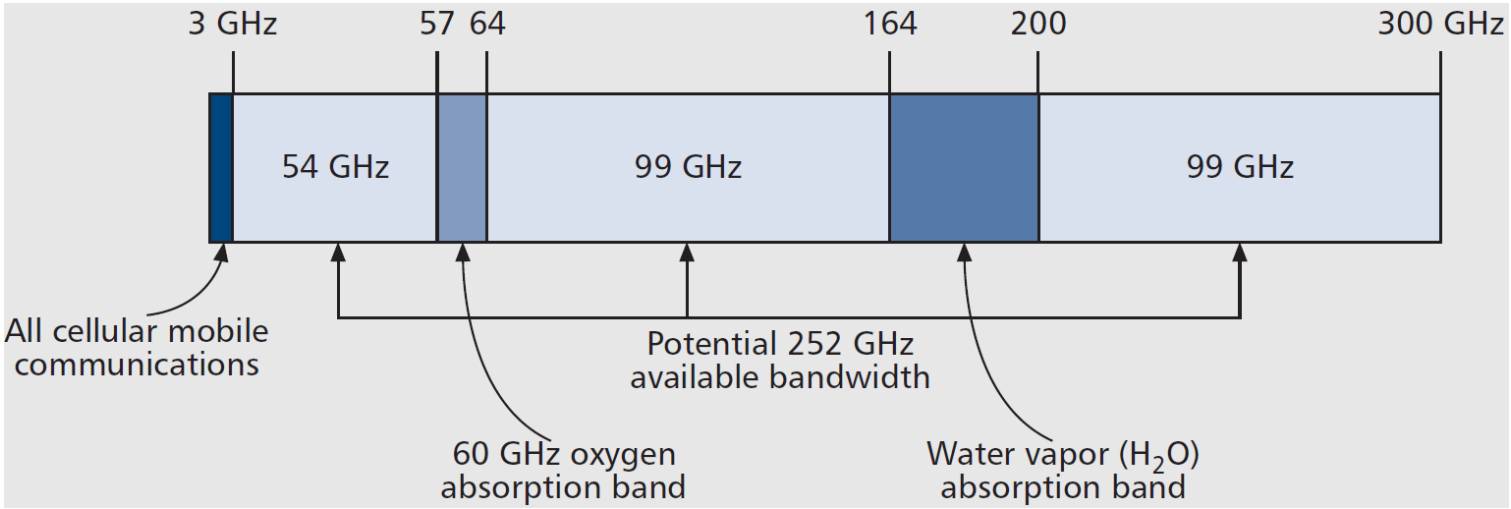
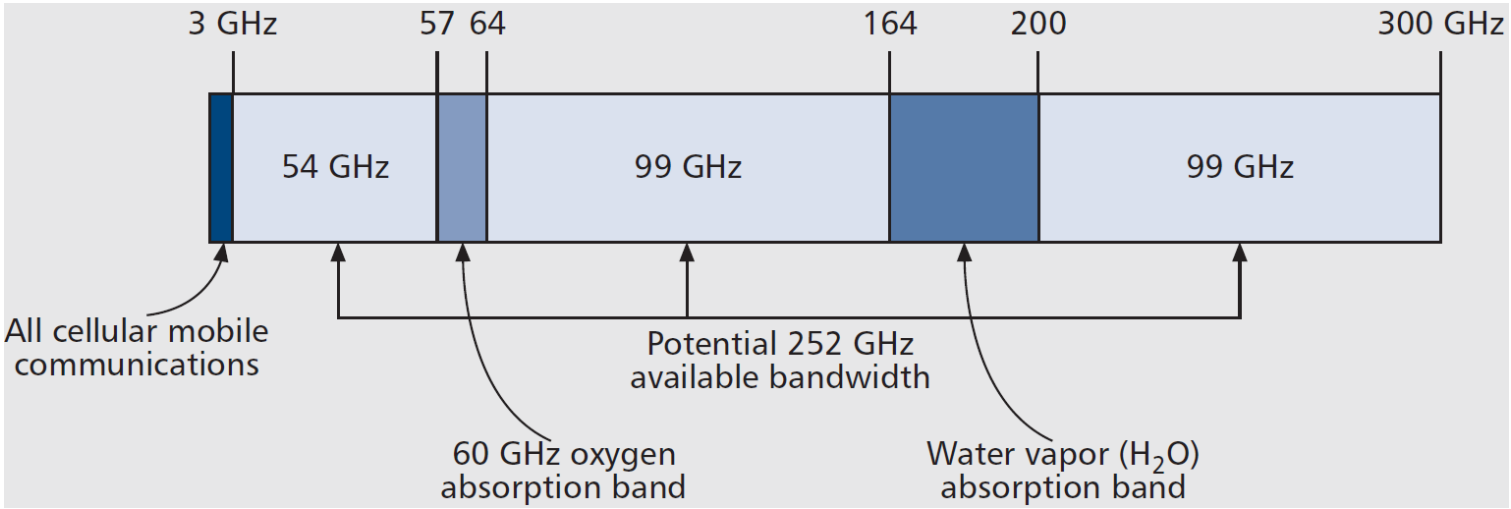


Figure: **Millimeter-wave spectrum, Source: [ZK11]**

- 3-300GHz spectrum $\rightarrow$ mmW bands (λ ranges from 1-100mm)

Characteristics: 60GHz mmW communications



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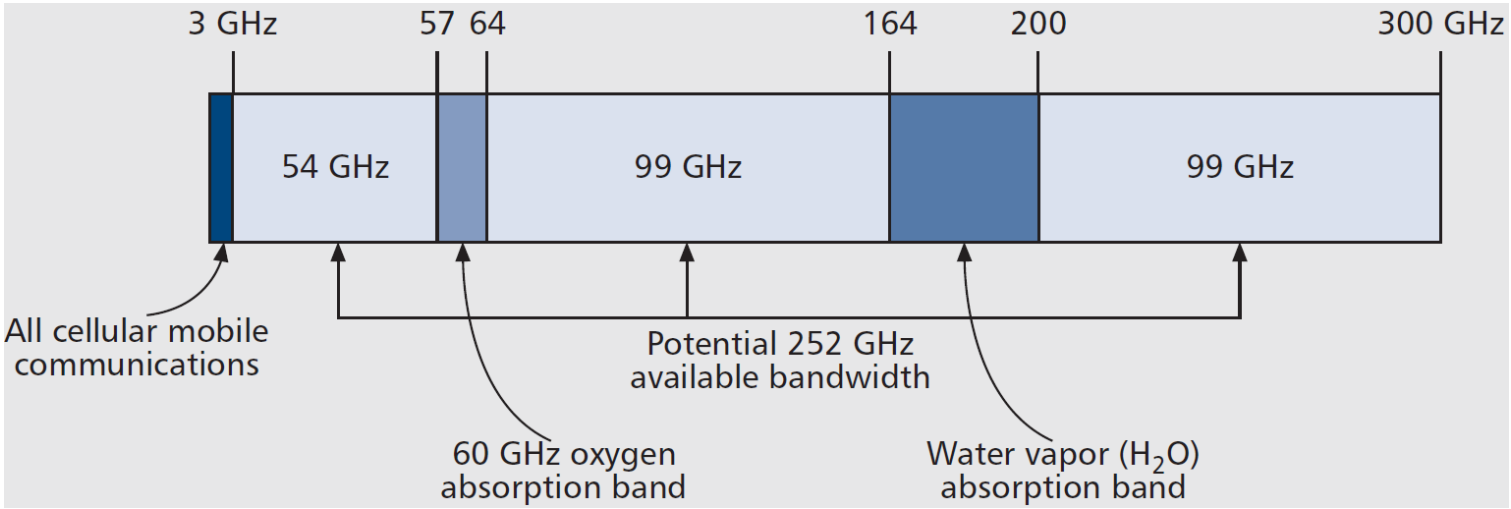

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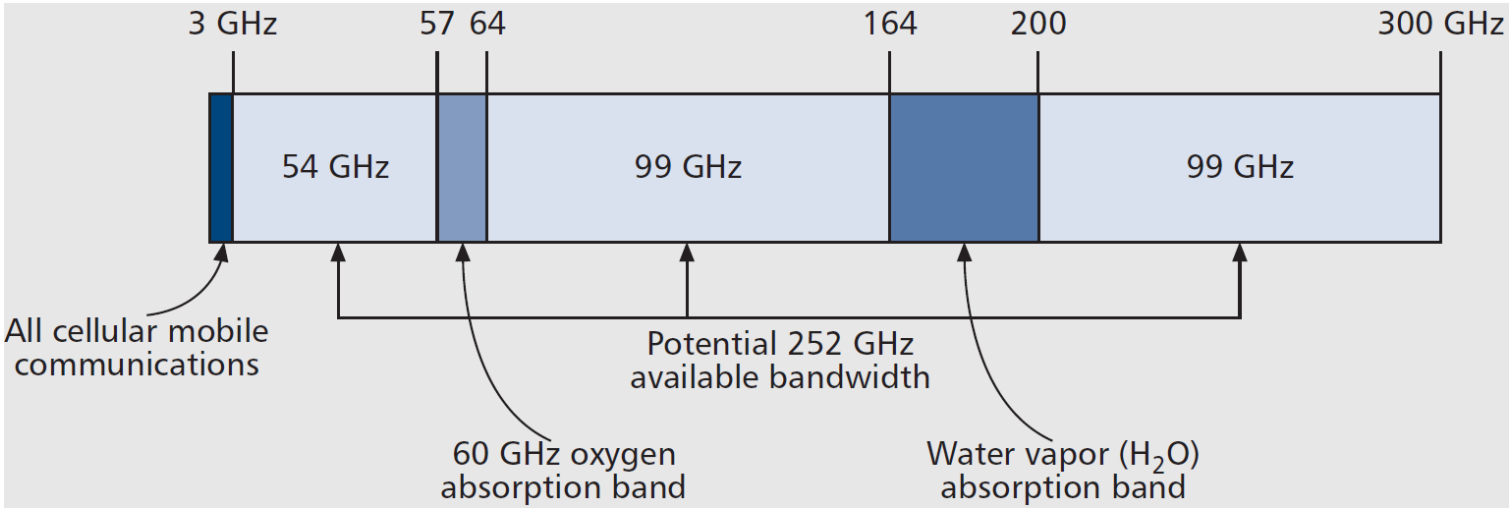

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- achievable data rates $>$ **2Gbps**

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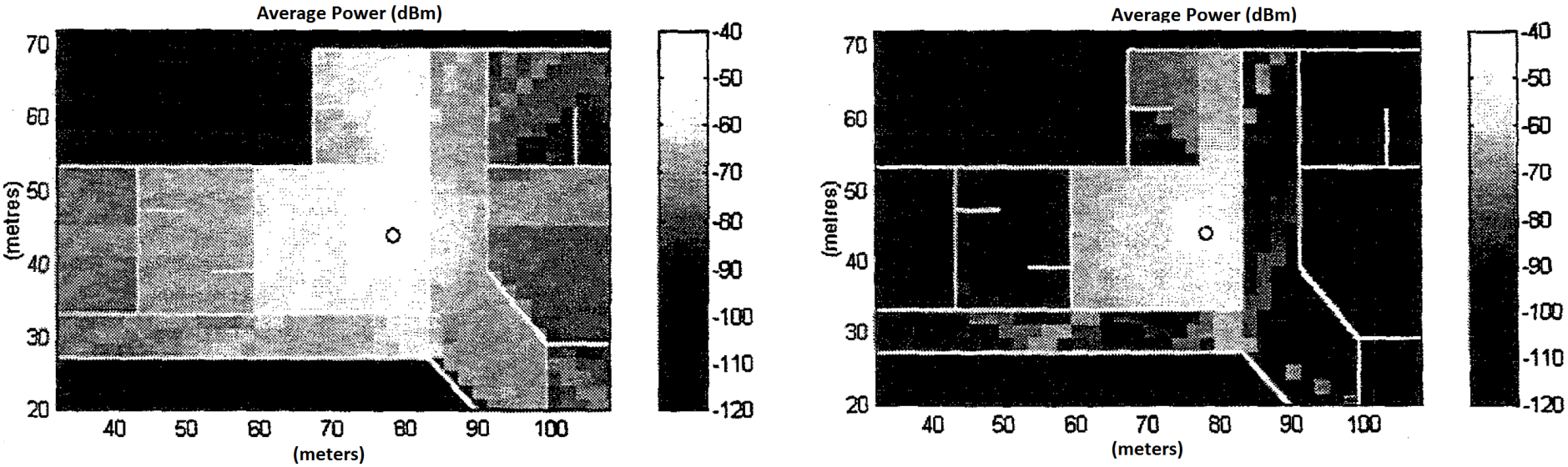

Figure: **Variation in Received Power with 32mW transmit power at 5.1GHz (left) and 60GHz (right), Source: [WAN97]**

- do not penetrate most solid materials $\rightarrow$ extra spatial isolation

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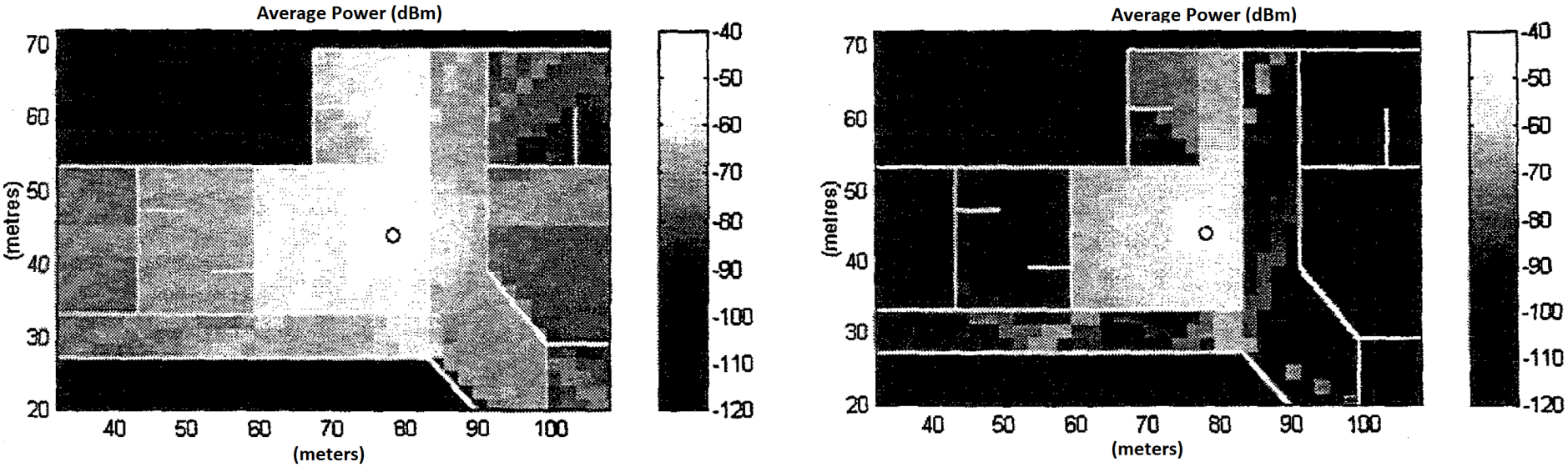

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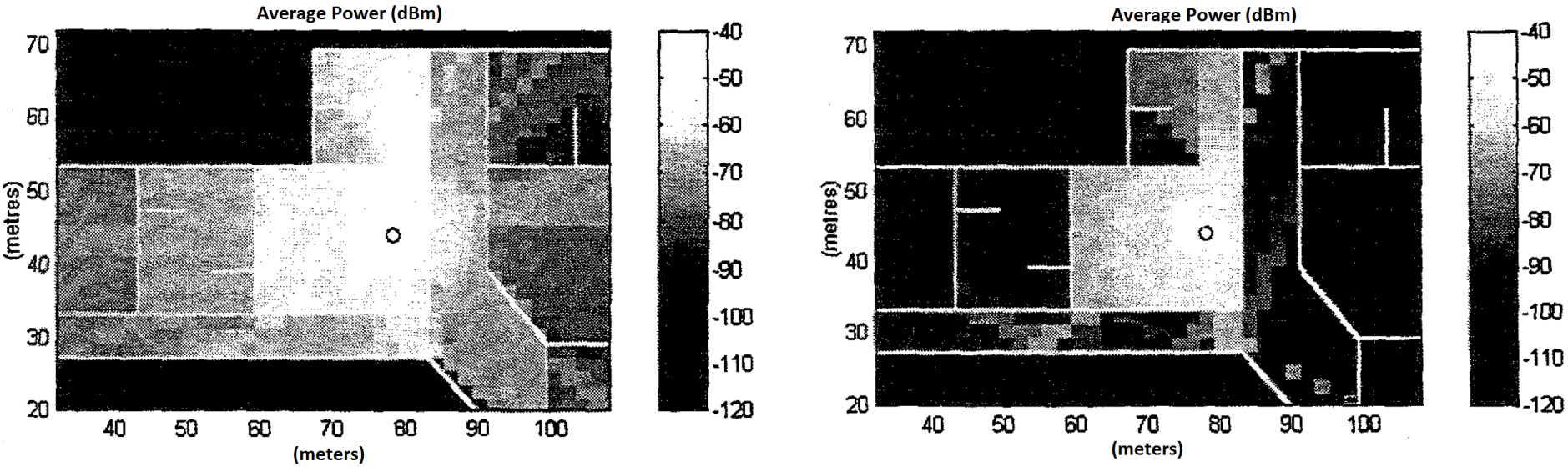

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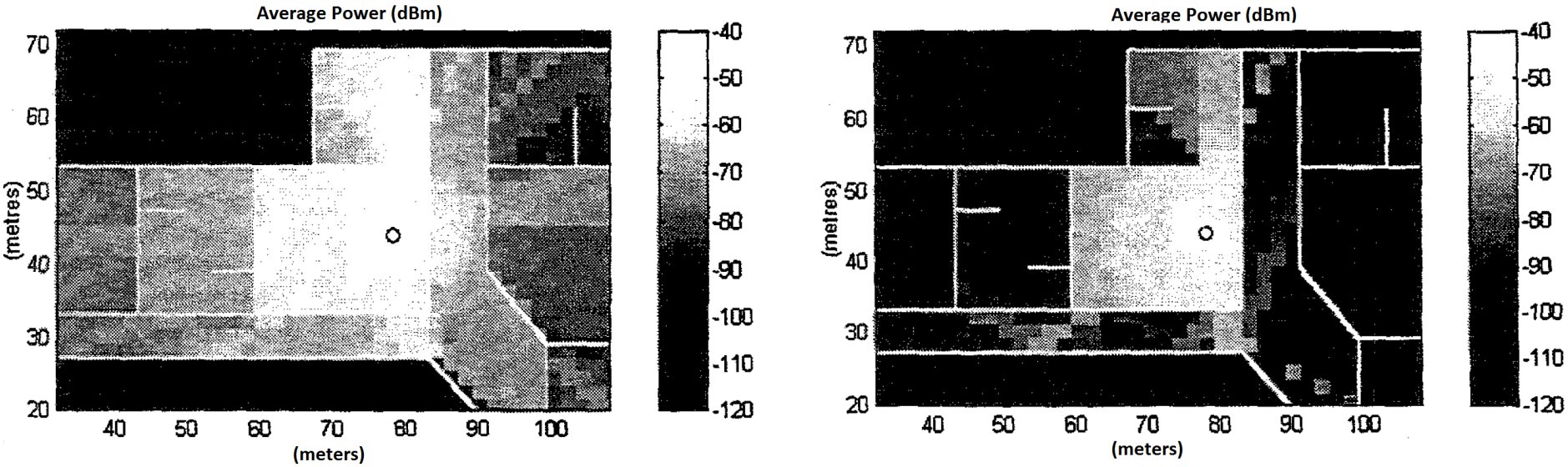

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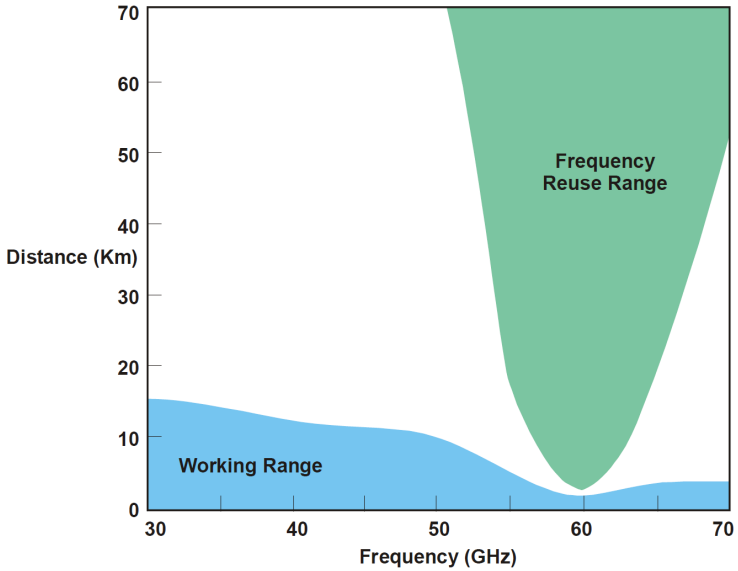

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- Oxygen absorption

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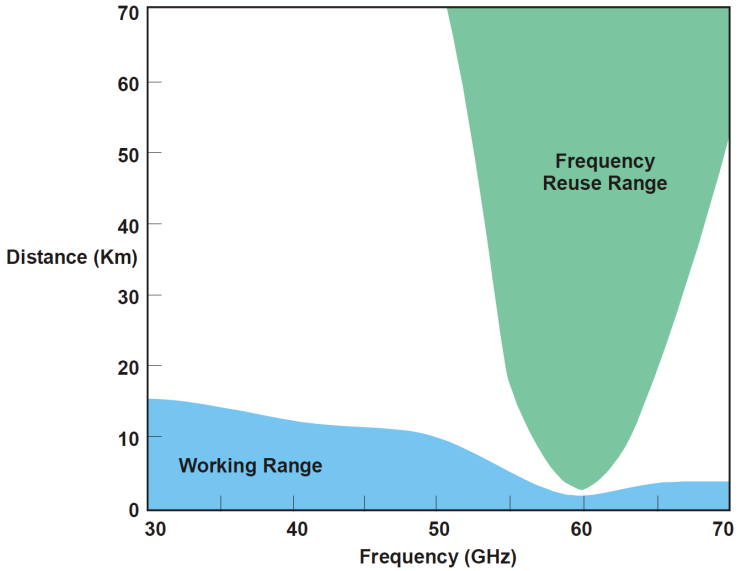

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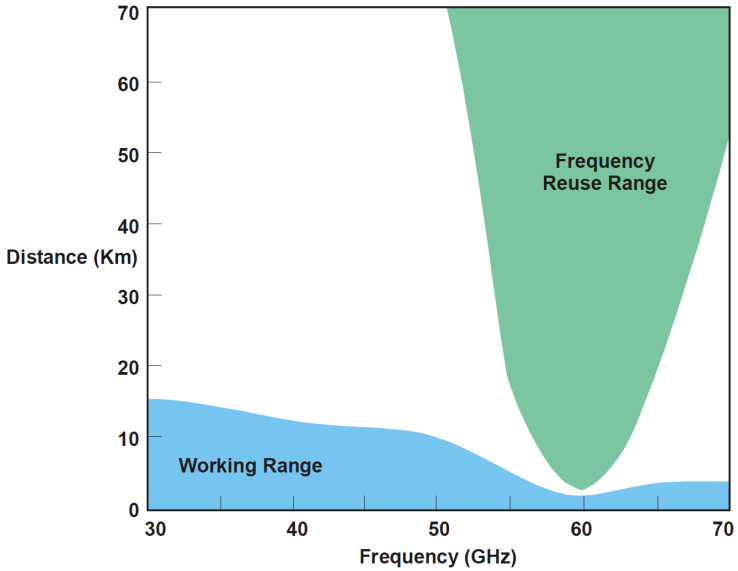

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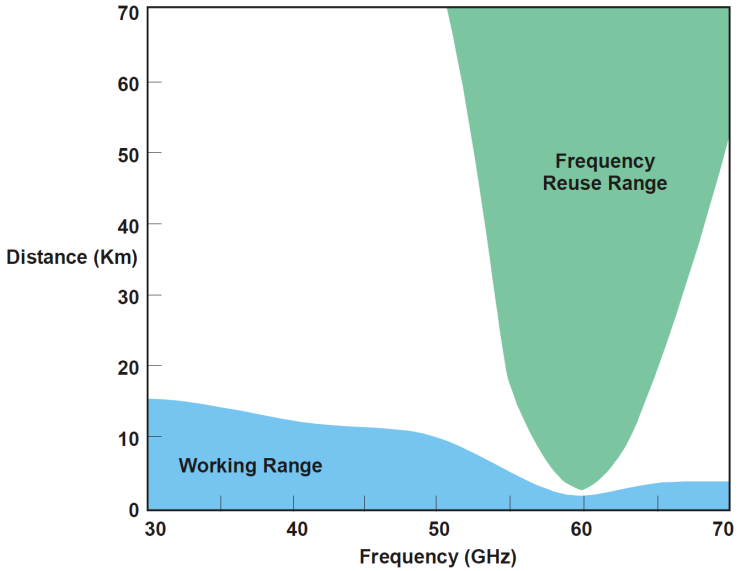

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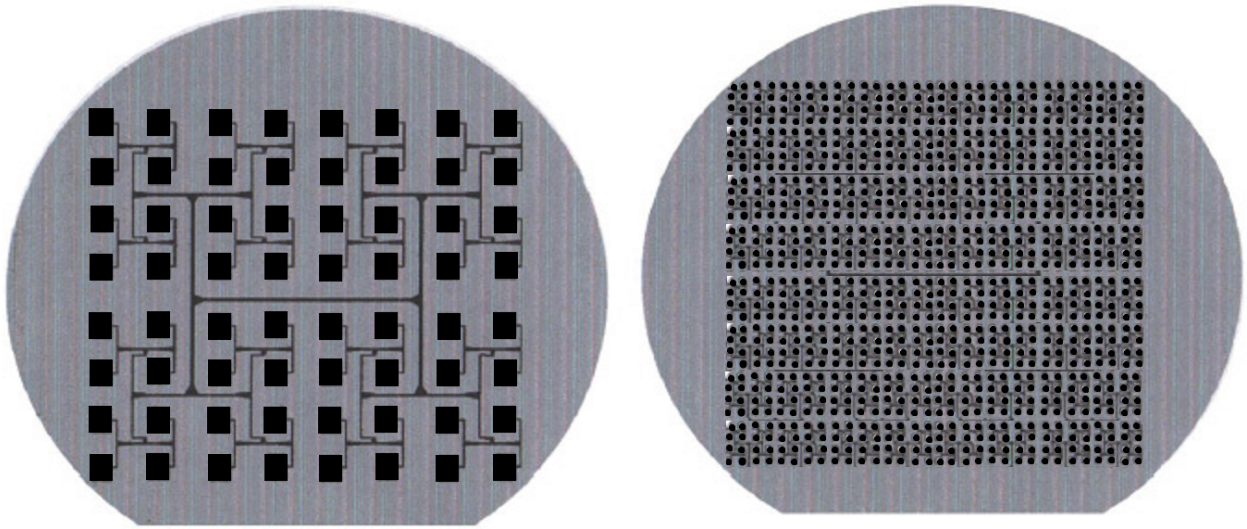

X - band, 64 antenna elements

V - band, 1024 antenna elements

Figure: **Wafer-scale antenna: 64 elements in 8-12GHz (left) and 1024 elements in 50-75GHz (right), Source: [Moh06]**

- (antenna dimension) $\propto \lambda$

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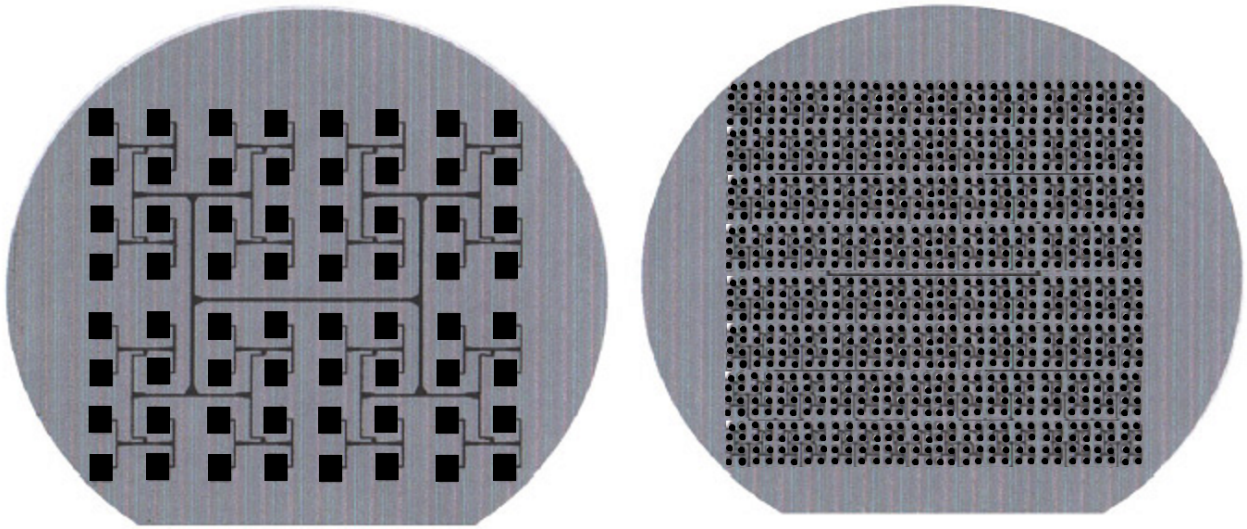

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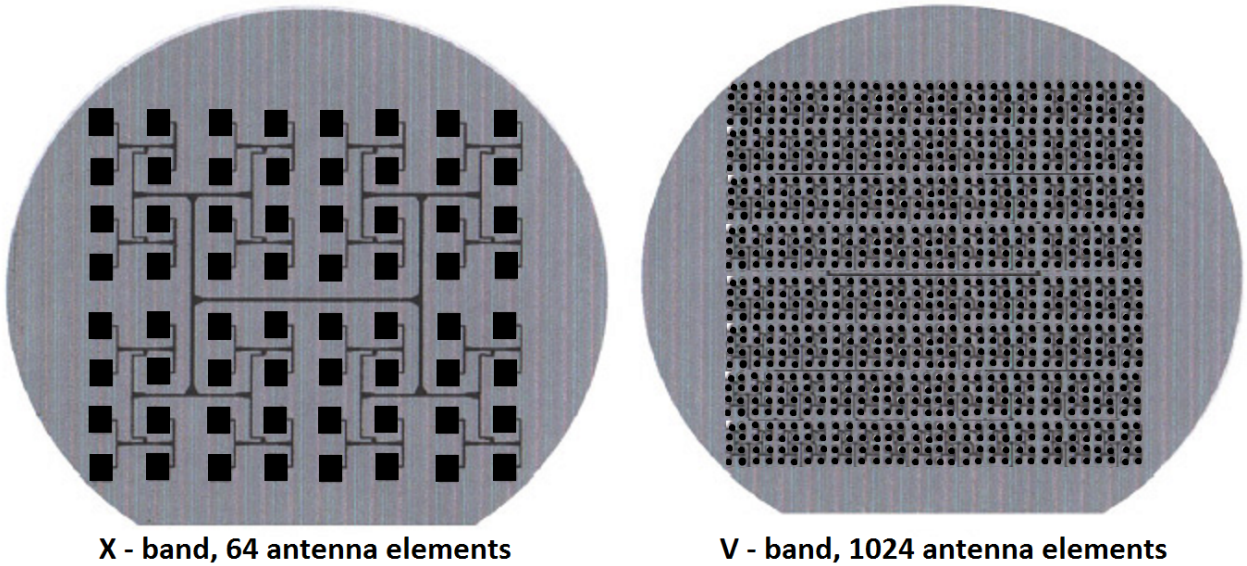

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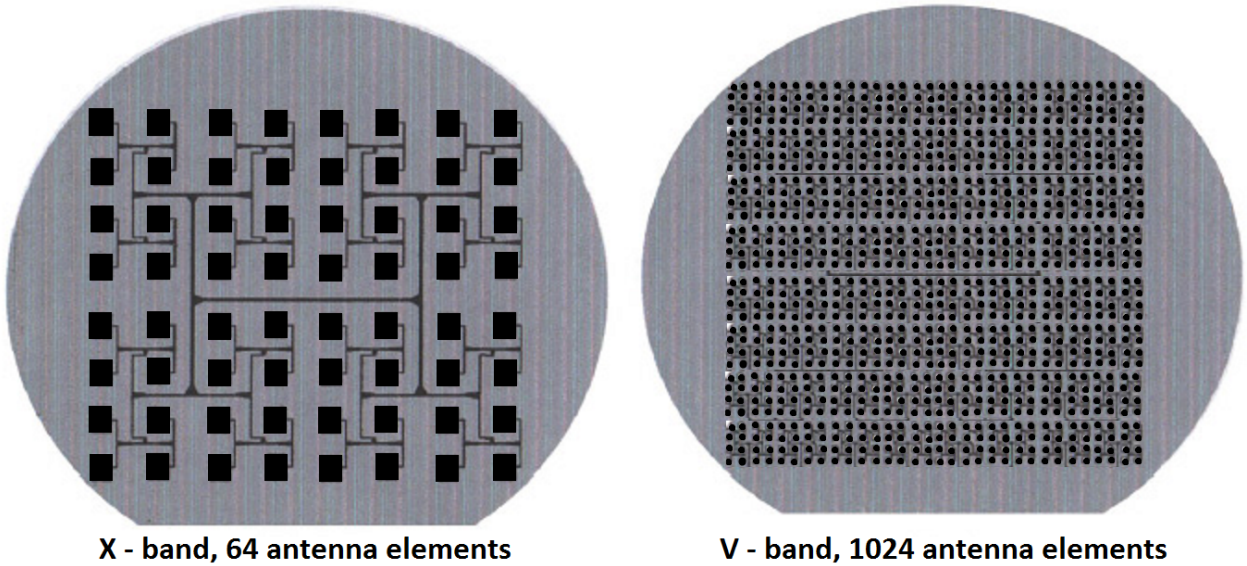

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- MIMO $\rightarrow$ SDMA $\rightarrow$ (point to multipoint communication)

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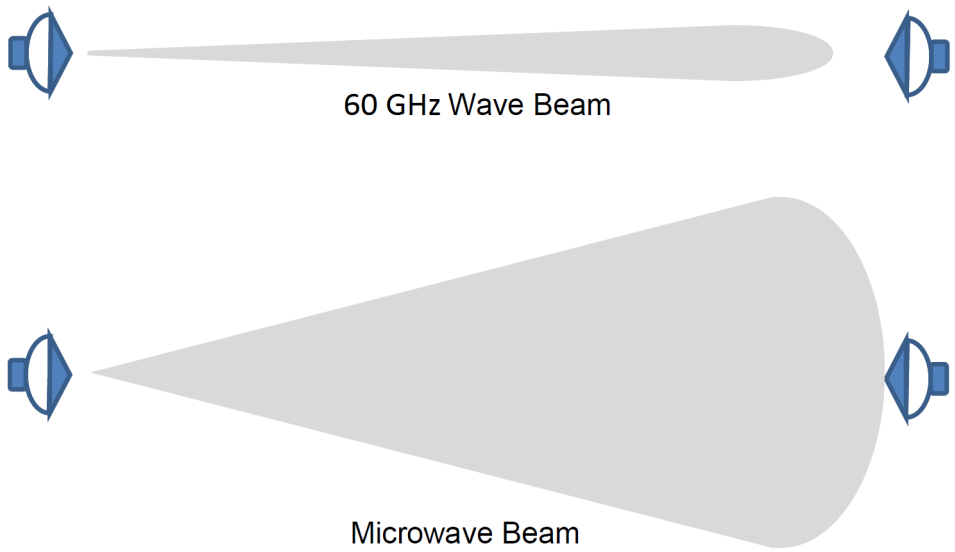

Figure: **Beam comparison**

- narrow beams

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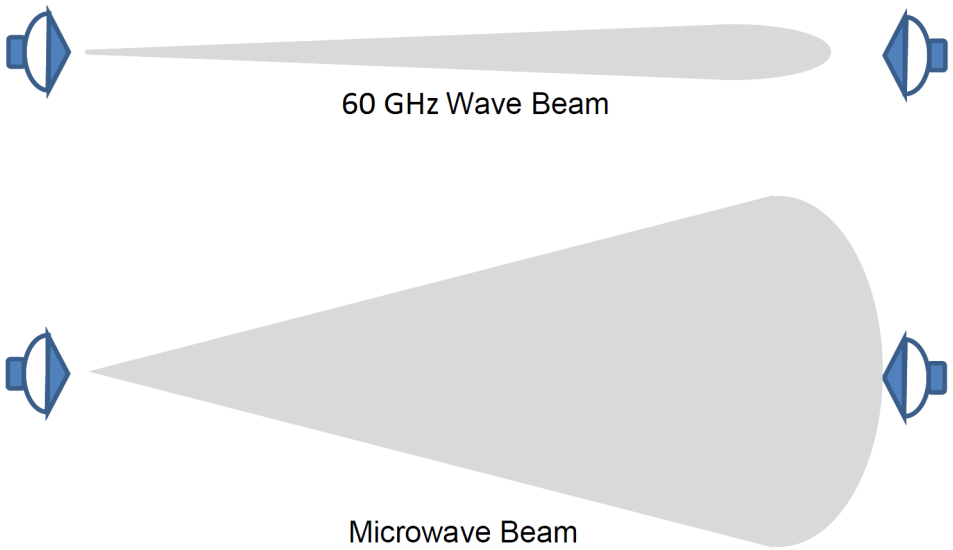

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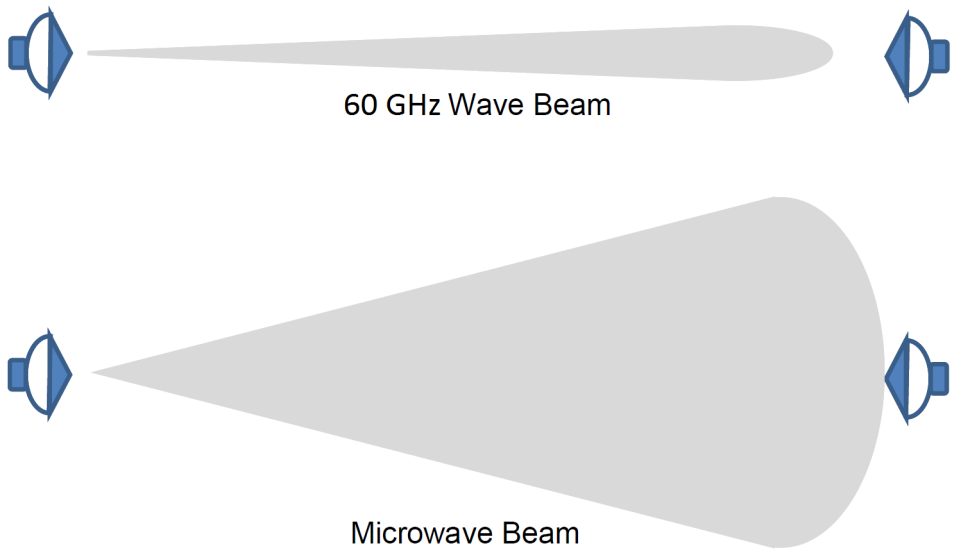

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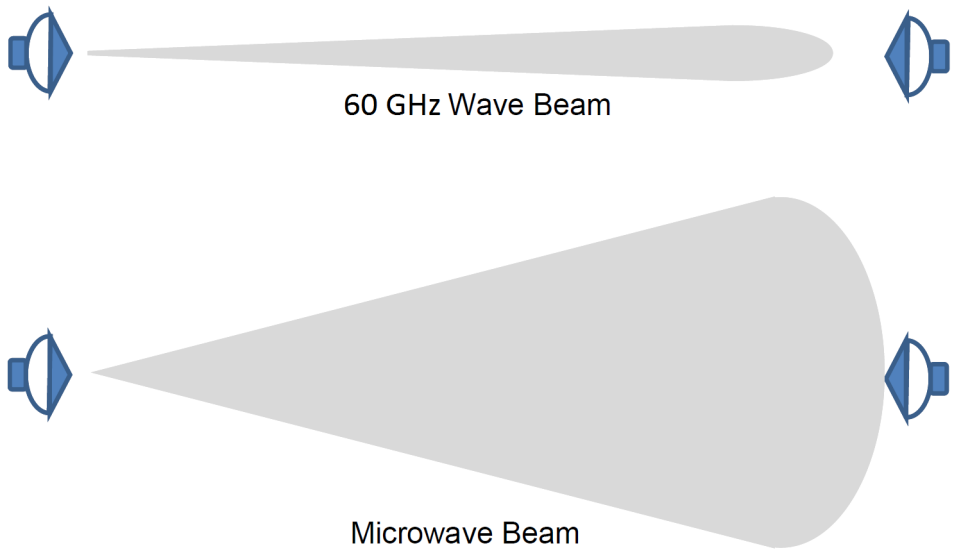

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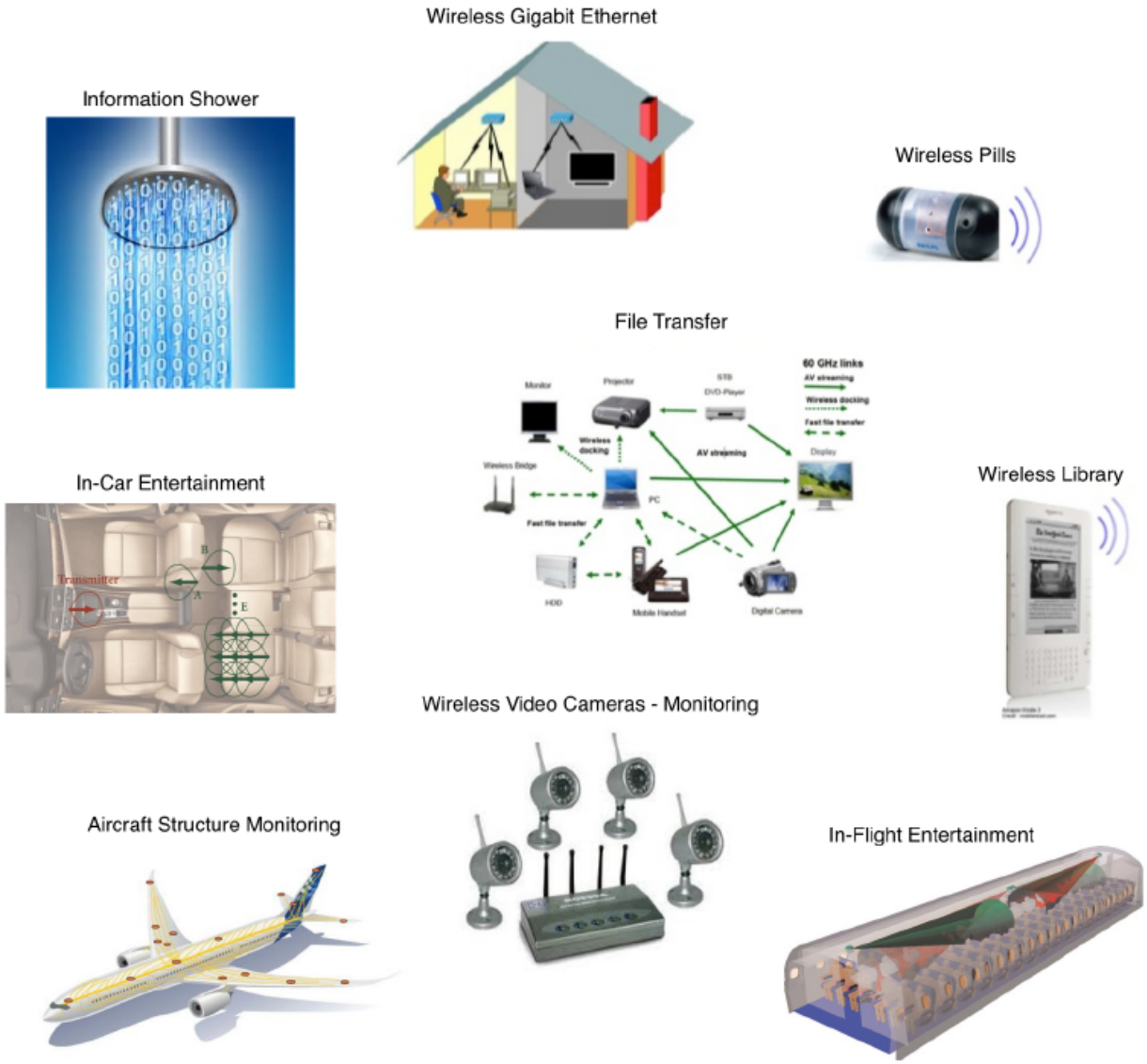

Figure: **60GHz applications in general**

Potentials: 60 GHz commun. in automation

- tight **time** and **data rate requirements**, long **duty cycles**
  - fast data exchange btwn central controller-distributed I/O modules ($\sim$ milliseconds)
  - real-time visualization or recording data transmission ($\sim$ Gb/sec)
  - higher data rates $\Rightarrow$ smaller duty cycle

- lack of Gbps solutions with **strict real-time guarantees** [CMH10]

- **coexistence** without interference
  - e.g., radio interference mainly has an effect on telegram transmission delay
  - new radio systems should ensure parallel operation with already existing systems (WISA, WirelessHART)

- **scalability and extensions**
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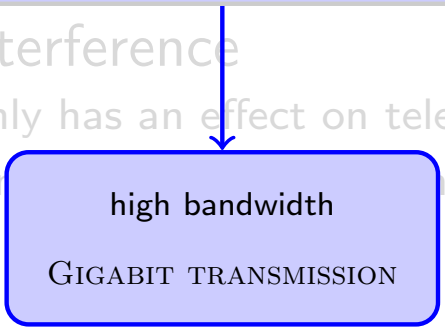

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narrow beams

O_2 absorption

interference immunity

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DENSE DEPLOYMENTS

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sophisticated beamforming techniques

EXPLOIT MULTIPATH DIVERSITY

beam steering mechanisms

SEEK FOR AN LOS ACCESS POINT

FEC

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Challenges

- $\uparrow$ directivity $\Rightarrow \downarrow$ angular separation of multipaths $\Rightarrow \downarrow$ DoF gain
  - presence of many obstacles $\rightarrow$ natural solution
  - omni directional antennas (recall: there is spacial decoupling)
  - switched-beam antennas, cylindrical/spherical array antennas

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- O_2 absorption, solid walls $\Rightarrow$ attenuation
  - higher transmission power
  - higher beamforming gains with multiple antennas
  - dense deployment of access points (AP)$\rightarrow$ maximize diversity
  - APs with multi-beam maneuvering capabilities

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- ISI: equalization, OFDMA

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  - higher transmission power
  - higher beamforming gains with multiple antennas
  - dense deployment of access points (AP)$\rightarrow$ maximize diversity
  - APs with multi-beam maneuvering capabilities
- ISI: equalization, OFDMA
- baseband signal processing
  - analog domain signal processing
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Challenges

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- blend many technologies $\Rightarrow$ new signalling protocols
  - video tracking with high resolution $\rightarrow$ unidirectional 60GHz communications

Conclusions

- unlicensed operation – FREE !!
- Gbps data rates
- supports coexistence with old technologies
- inherent interference free operations, high frequency reuse, high densities
- small profile
- mature technology, e.g., CMOS
- reliability: links with "five nines" of availability if desired
- 60GHz: A PROMISING TECHNOLOGY → BLEND INTO EXISTING TECHNOLOGIES USED IN FACTORY/PROCESS AUTOMATION

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Thank you

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