

Security and eavesdropping in terahertz wireless links

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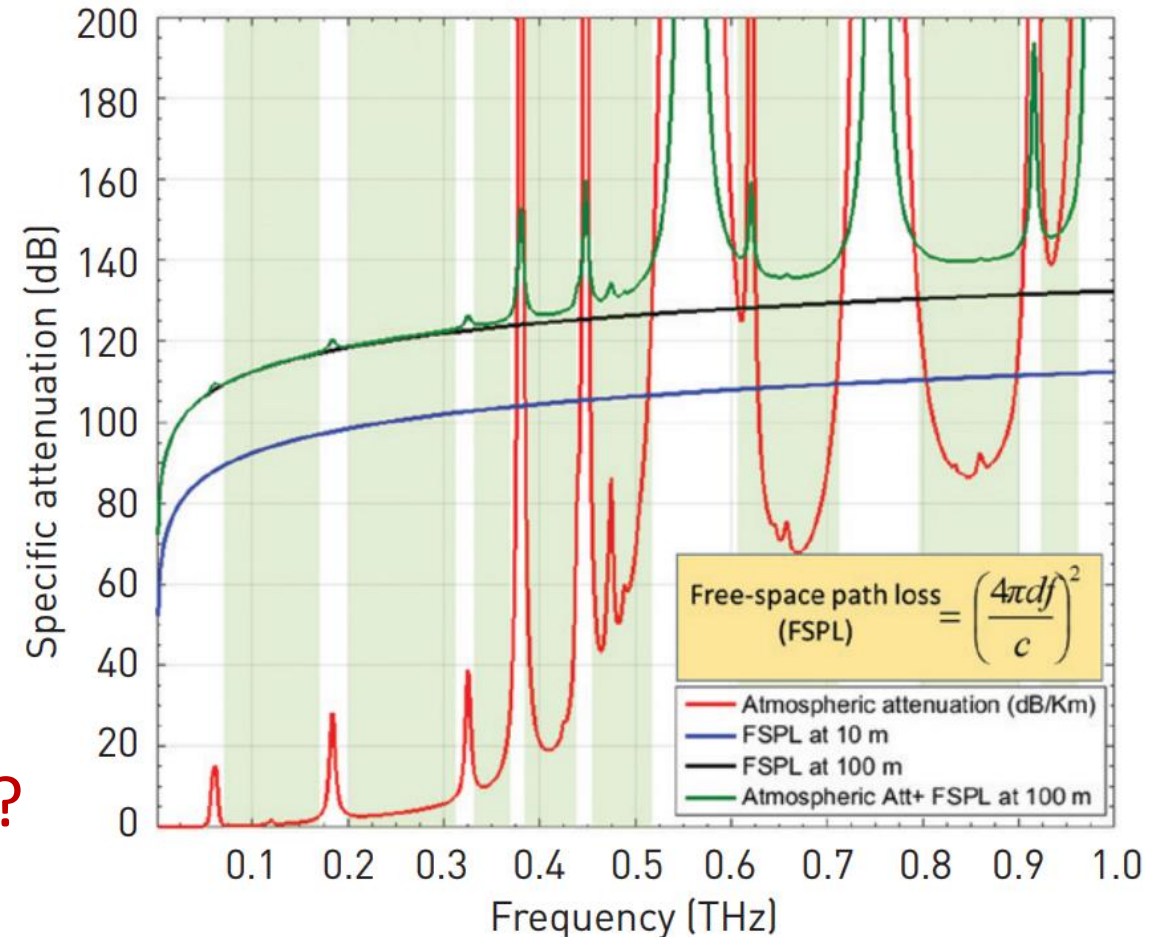
Ma, Jianjun, Rabi Shrestha, Jacob Adelberg, Chia-Yi Yeh, Zahed Hossain, Edward Knightly, Josep Miquel Jornet, and Daniel M. Mittleman. "**Security and eavesdropping in terahertz wireless links.**" *Nature* 563, no. 7729 (2018): 89.

Highly directional THz links are expected to be more secure

- Higher band has higher attenuation, requiring more directional transmission
- Eavesdropping becomes harder
 - Harder to be in the narrow beam
 - Bulky THz device can block the beam
 - ➔ Alice and Bob choose another beam
 - ➔ The attack can be detected

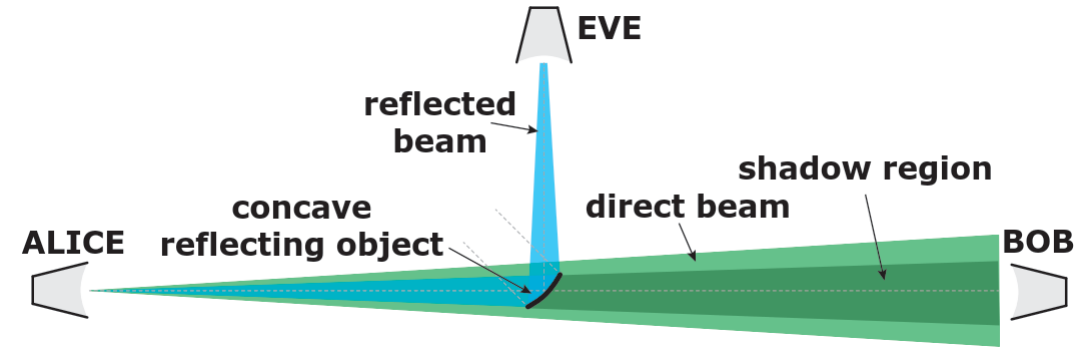
Is eavesdropping possible above 100GHz?

- Eve: What are the possible strategies? How effective is it?
- Bob: How to detect/react to an attack?



Prior work: Object scattering attack in the 60GHz

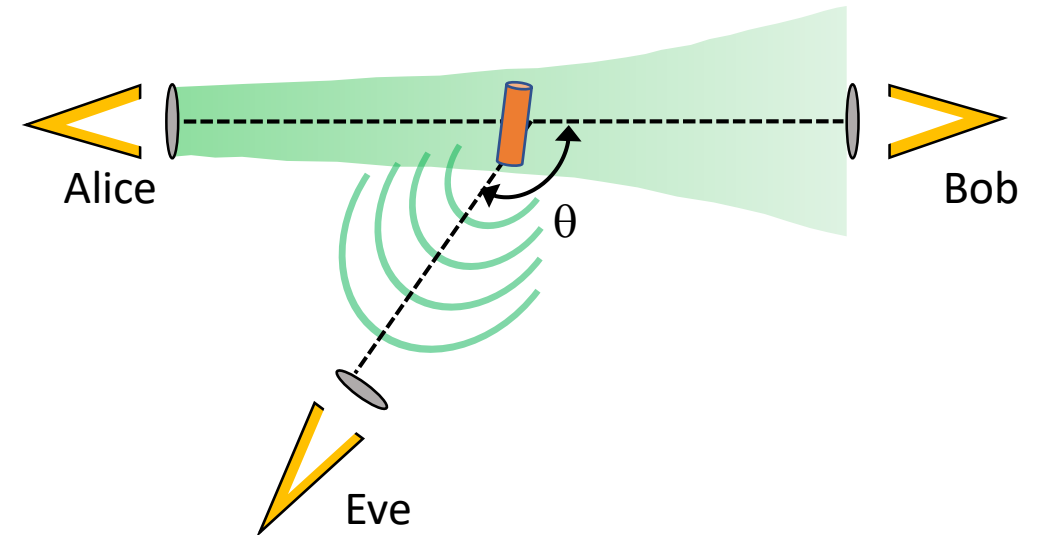
- Object materials
 - Metal is a good reflector
 - Reflectivity \propto reflection area, however, reflectivity come with high blockage
- Object location
 - Placing the reflector close to AP can potentially decrease the blockage (due to scattering) while maintaining good reflectivity
- Object shape
 - Plane object reflect signal to a specific direction
 - Round object (porcelain and metal cup) reflect signal to a wider range
 - Concave reflector focuses the reflected signal, but also poses high location precision on Eve
- Common devices can be good reflectors (laptops, iPhones)



Eavesdropping threat still exists in 60 GHz

More directional beam in sub-THz

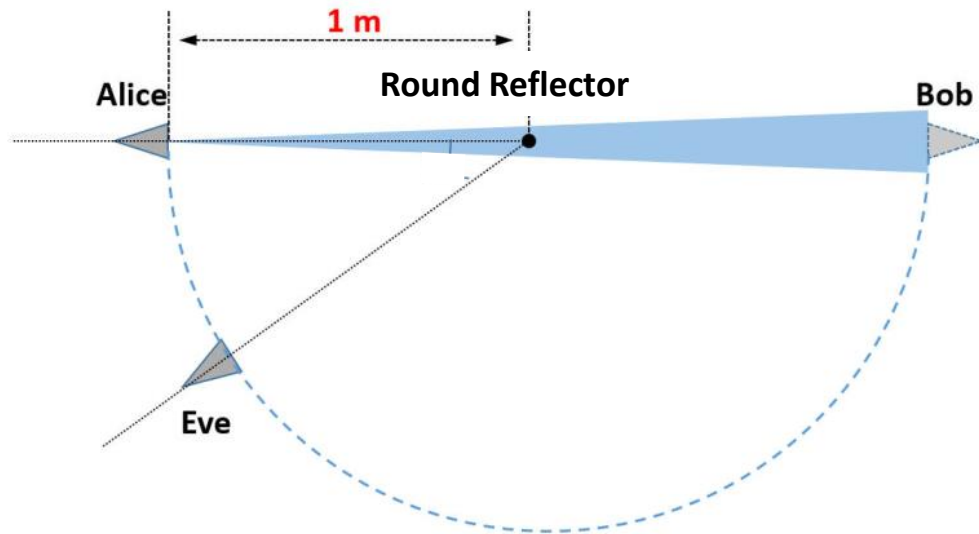
- HPBW at distance of 1m
 - 60 GHz: 12cm
 - 100 GHz: 7cm
 - 200 GHz: 4 cm
 - 400 GHz: 3 cm



- Require more delicate object placement
- Fewer object choices (size, shape, material)

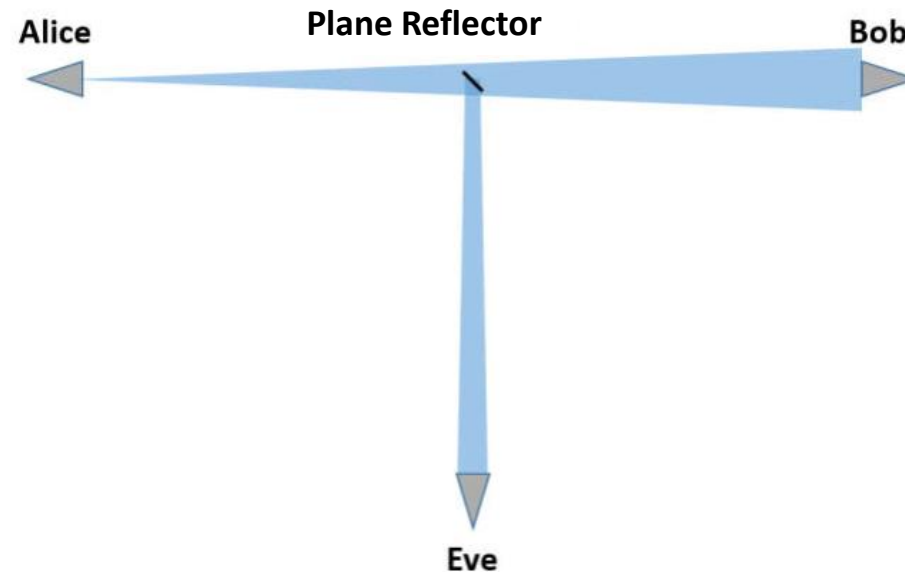
Sub-THz Experiment

- Cylindrical metal pipes
 - Diameter: 14 mm - 80 mm



- HPBW at distance of 1m
 - 100 GHz: 7cm
 - 200 GHz: 4 cm
 - 400 GHz: 3 cm
 - (Prior work 60 GHz: 12 cm)

- Metal plane reflector
 - Area: 1x1 cm² – 9x9 cm²



Metrics

- Blockage

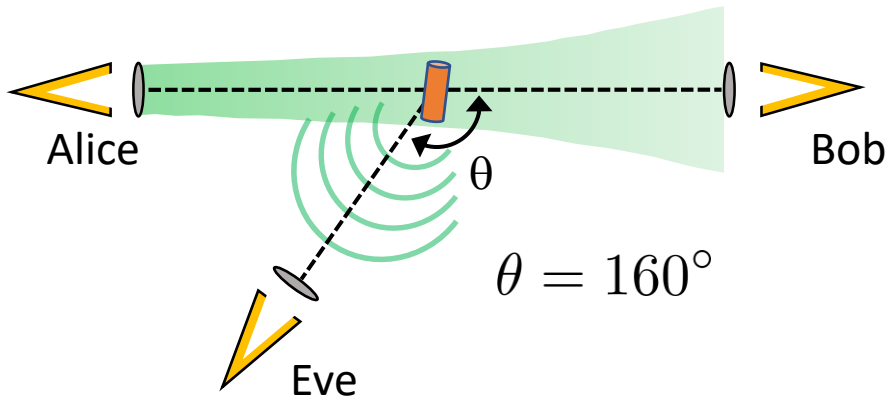
- $b = 1 - \frac{\text{SNR}_{Bob}^{\text{object}}}{\text{SNR}_{Bob}^{\text{no object}}}$

- Eve wants $b=0$ (no blockage, does not affect Alice-Bob transmission)

- Normalized Secrecy Capacity

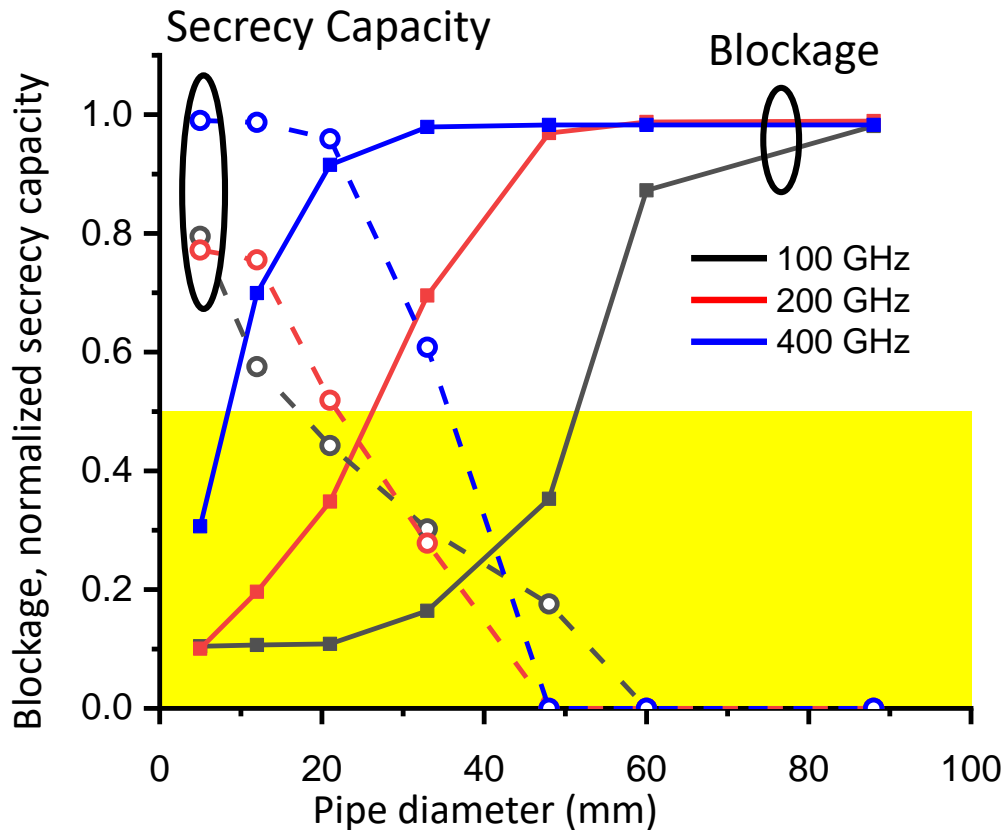
- $\bar{c}_s = \left[\frac{\log(1 + \text{SNR}_{Bob}) - \log(1 + \text{SNR}_{Eve})}{\log(1 + \text{SNR}_{Bob})} \right]^+$

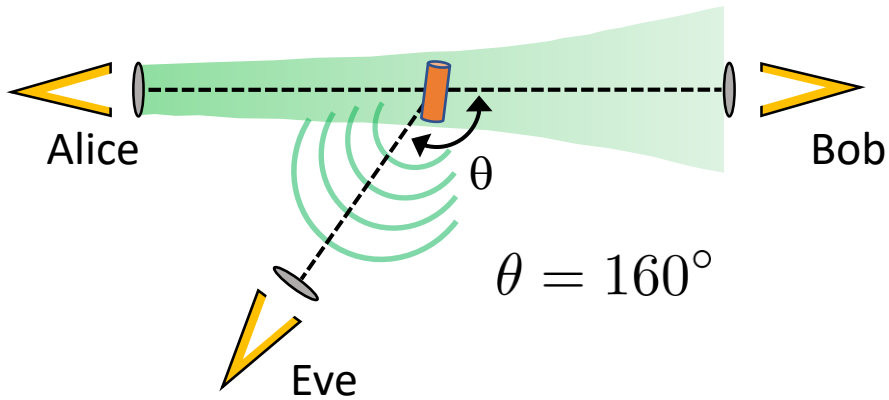
- Eve wants $C_s=0$ (no secure transmission between Alice and Bob)



Cylindrical metal pipes at the center of the beam

- Blockage depend on relative dimension of the beam and the object
 - Increases with the size of the scattering object
 - Increases with higher frequency (narrower beam)
- Normalized secrecy capacity
 - Decreases with the size of the scattering object
 - Increases with higher frequency
- Eve's goal: low blockage + low secrecy capacity
 - 100 GHz yes!
 - 200 GHz, 400 GHz no.





Cylindrical metal pipes off the center of the beam

moved off the center line by a distance equal to the radius

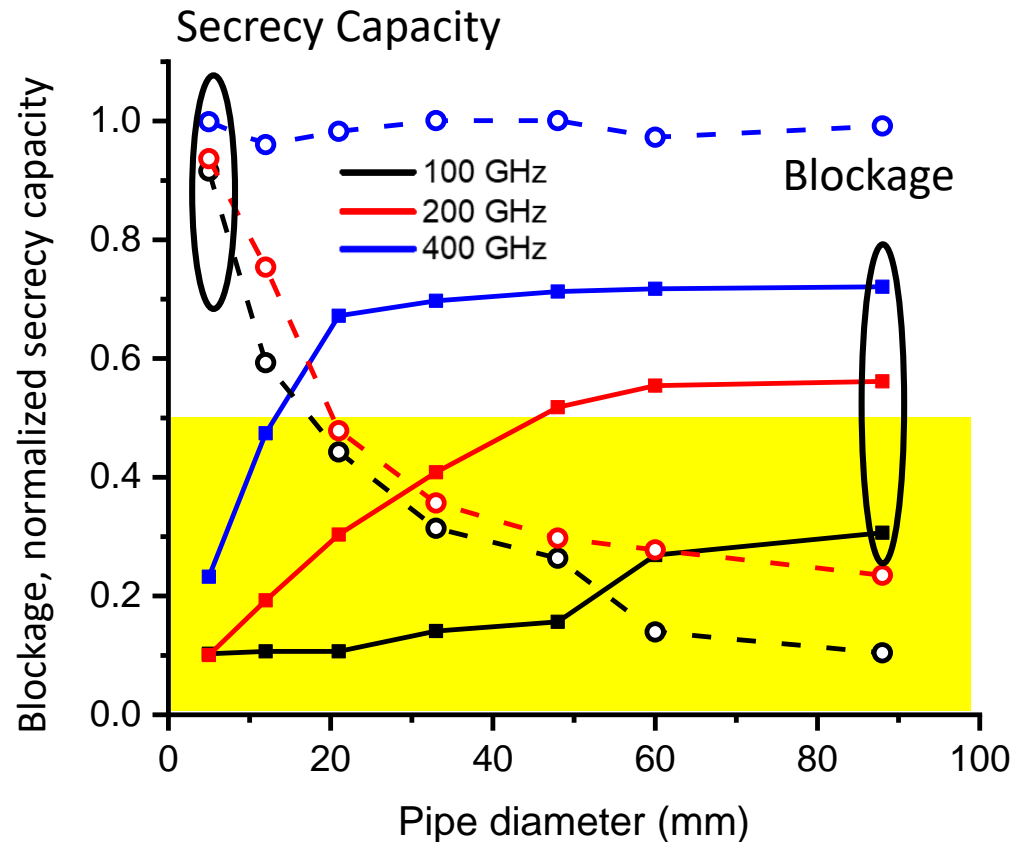
- Decrease blockage, but does not increase the scattering signal

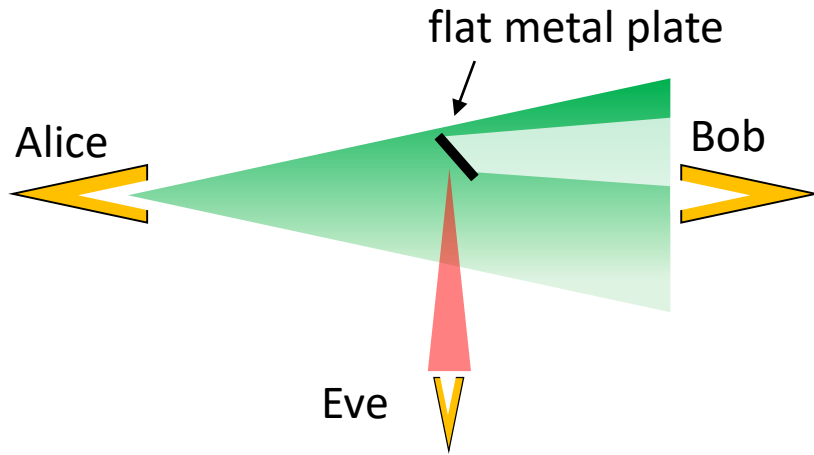
- Normalized secrecy capacity

- 100, 200 GHz: Decreases with the size of the scattering object
- 400 GHz: Remains high regardless of the size of the object

- Eve's goal: low blockage + low secrecy capacity

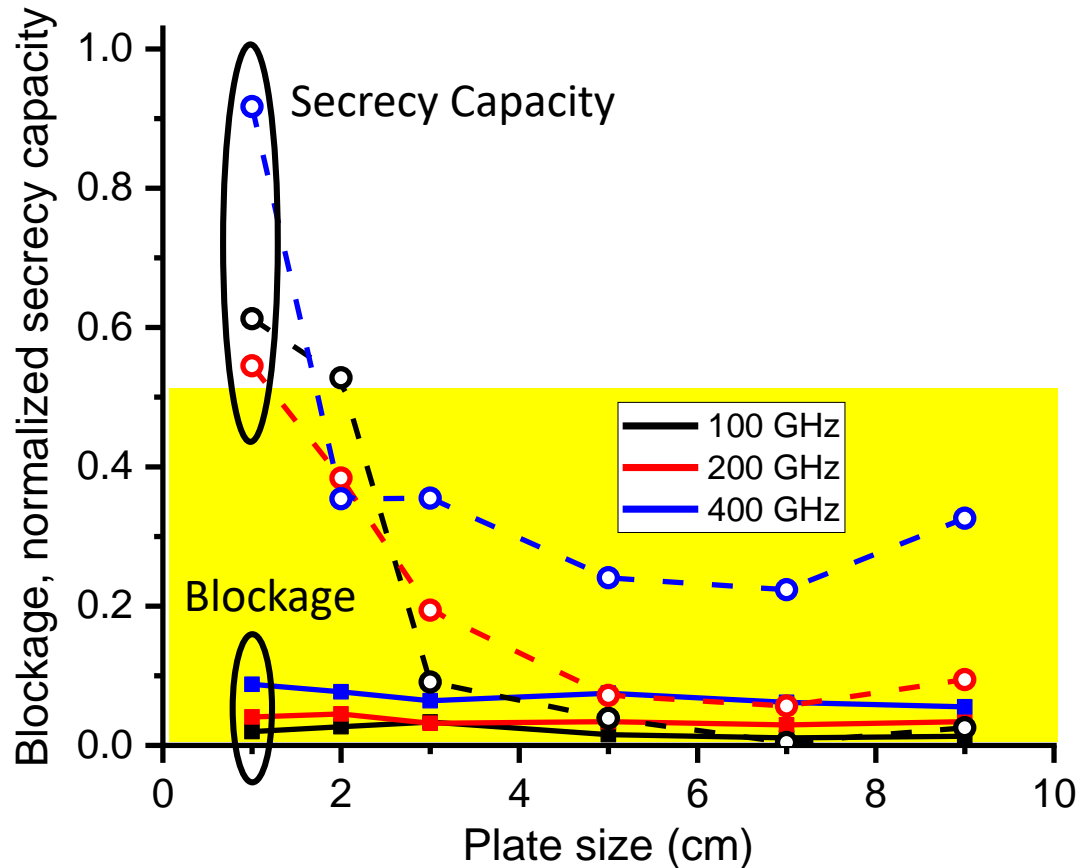
- 100, 200 GHz yes!
- 400 GHz no.





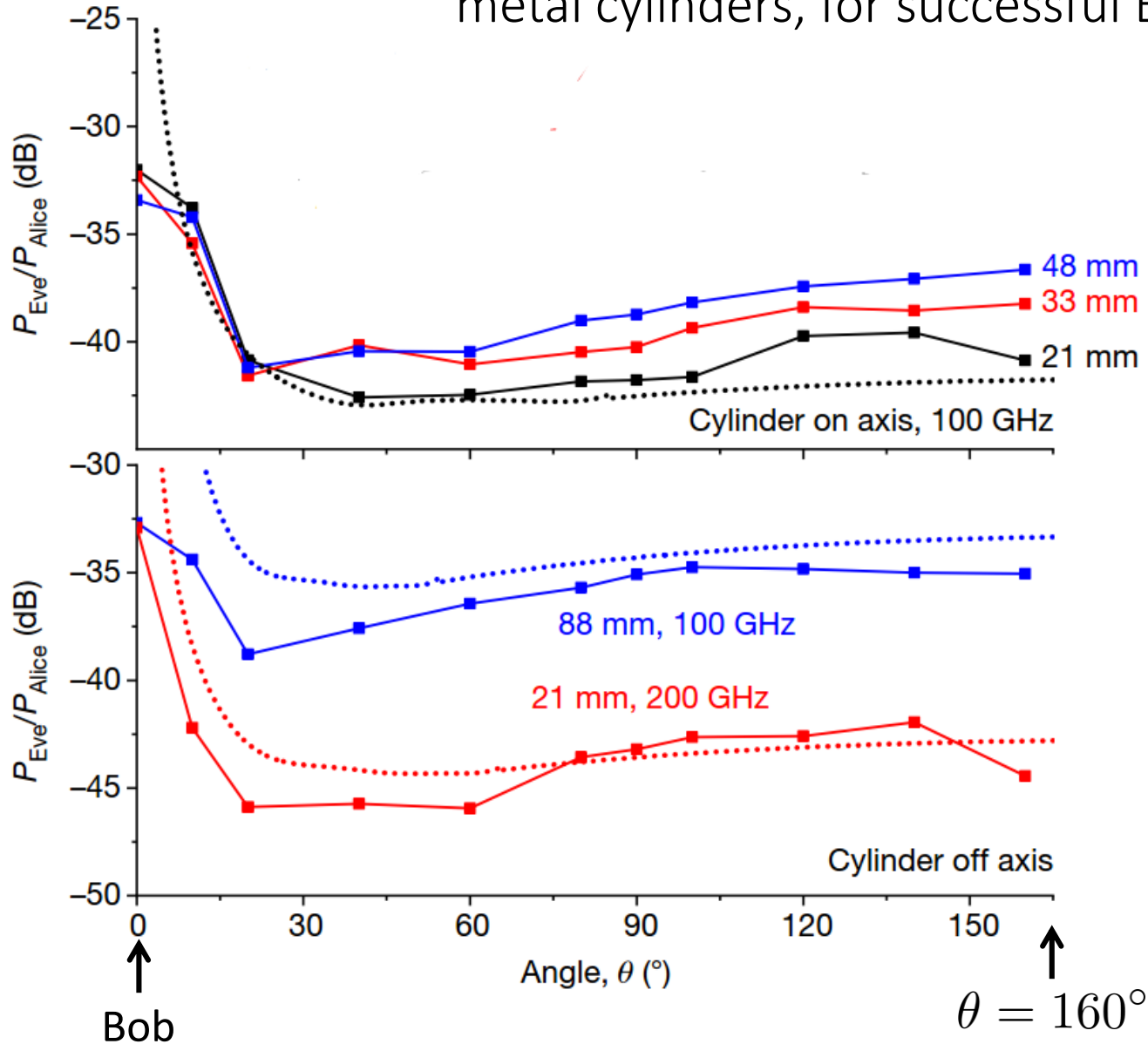
Off-axis flat metal plate

- Blockage almost zero
- Lower secrecy capacity
- Eve's goal: low blockage + low secrecy capacity
 - Achieves even for 400 GHz
 - Requires precise eavesdropping location at 90°



Angular distribution of power received by Eve

metal cylinders, for successful Eve ($b < 0.5$ & $c_s < 0.5$) cases

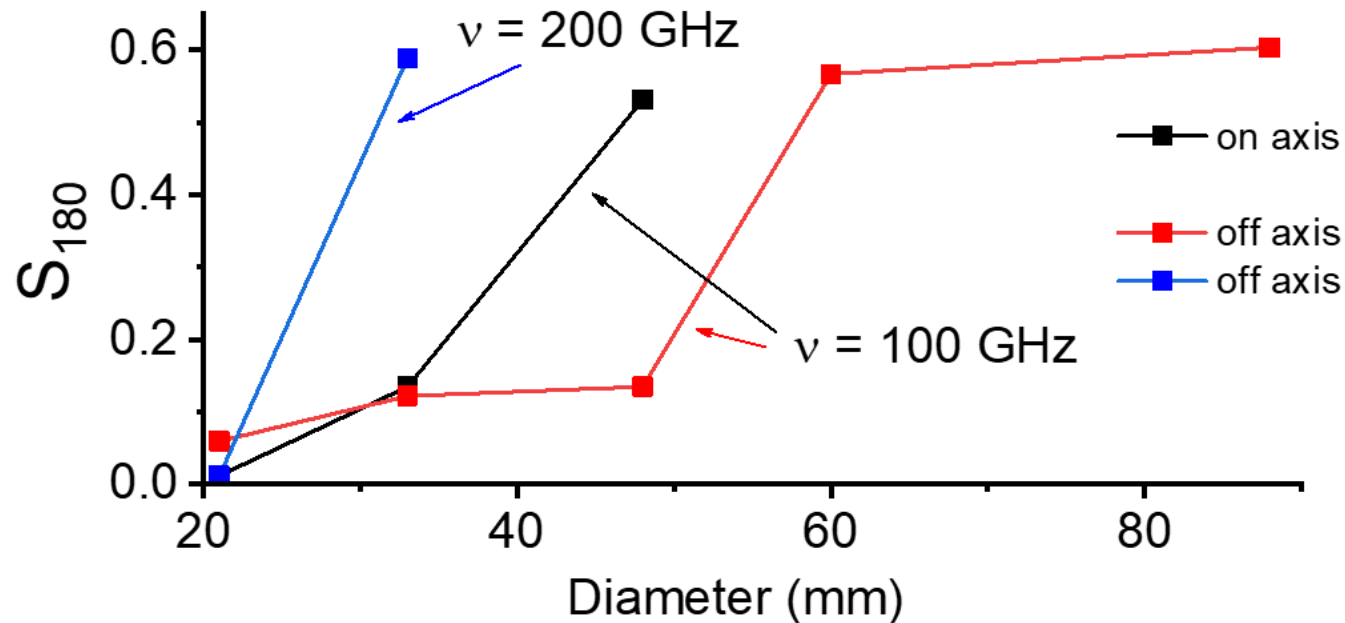


- Dotted curves: numerical computations
- Scattering signal increases with increasing cylinder diameter
- Eve has the freedom to place her receiver in many different locations

Countermeasure: Give Alice the ability to monitor

Back scatter detection

- Change in back scatter power: potential attack



$$S_{180} = \left| 1 - \frac{\text{SNR}_{\text{Alice}}^{\text{no object}}}{\text{SNR}_{\text{Alice}}^{\text{object}}} \right|$$

- S_{180} increases with pipe diameter
- Off-center object reduces S_{180} (compare 100 GHz on axis and off axis)
- Higher S_{180} with higher frequency (compare 100 and 200 GHz off axis)
- However, S_{180} for metal plate is generally low (not shown here)

Conclusion

- Higher frequency is more resilient to eavesdropping
 - **Object size:** too large causes high blockage, but too small doesn't reflect enough signal for eavesdropping
 - **Object shape:** Cylinders → Plate to focus scatter signals, but restrict Eve's position
 - **Object location:** on axis → off axis to reduce blockage and back scatter
 - **Being detected:** Both Bob (via blockage) and Alice (via backscatter) are more likely to detect Eve at higher frequency
- However, eavesdropping is still possible even for 400 GHz
 - Plate + off axis