

A Millimeter Wave Backscatter Network for Two-Way Communication and Localization

Haofan Lu, Mohammad Hossein Mazaheri, Reza Rezvani, Omid Abari



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Emerging IoT Applications Constraints

- High datarate communication
- High resolution localization
- Low power consumption



Unfortunately, today's wireless systems cannot support these all together

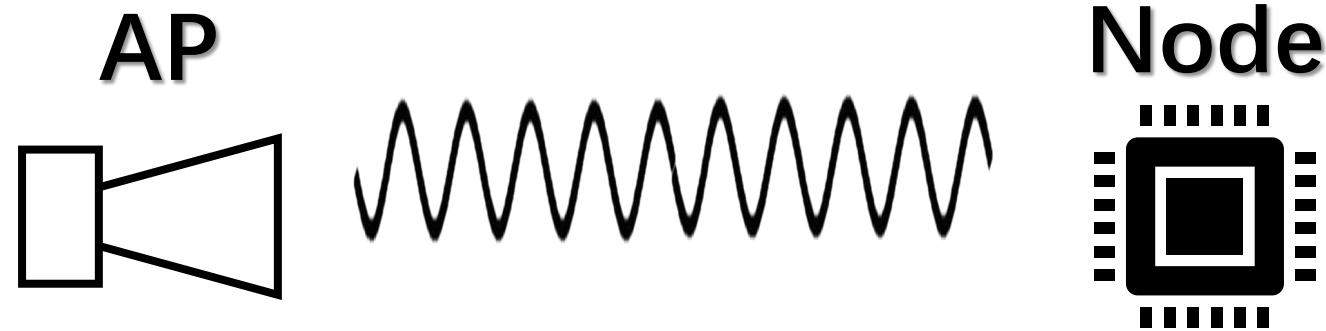
Millimeter Wave Technology

Large licensed and unlicensed bandwidth

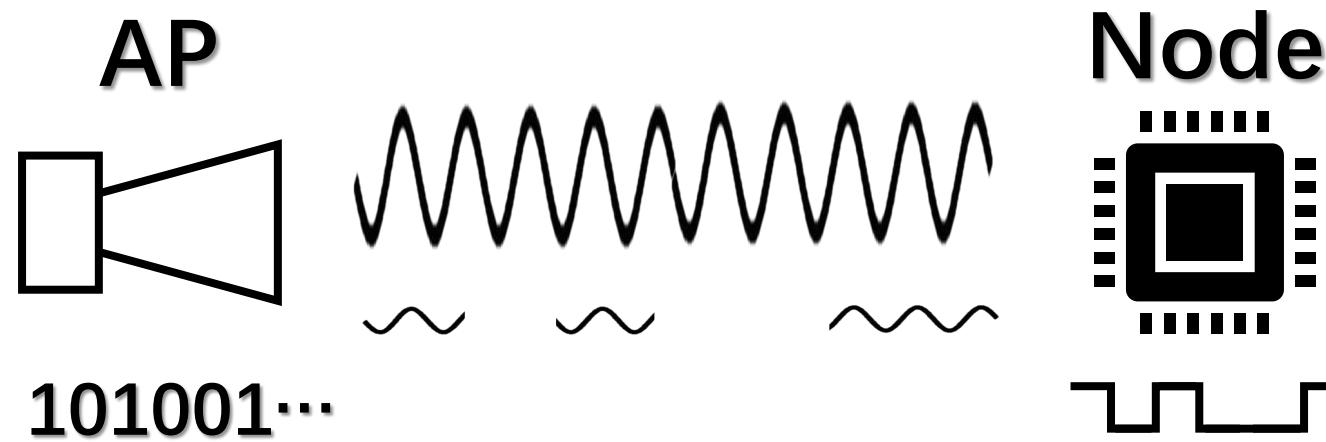
-  **High datarate communication**
-  **High resolution localization**
-  **Low power consumption**

Problem: Existing mmWave radios have high power consumption

Solution: mmWave Backscatter Technology

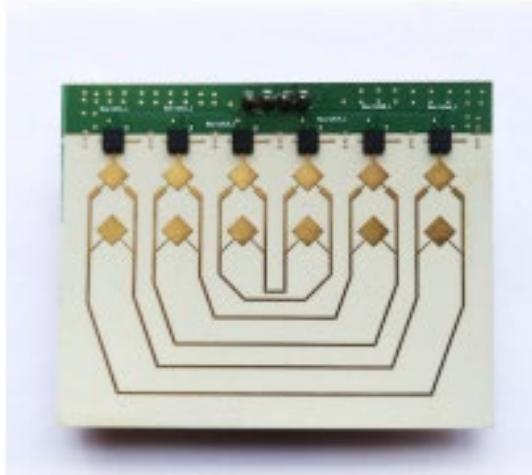


Solution: mmWave Backscatter Technology

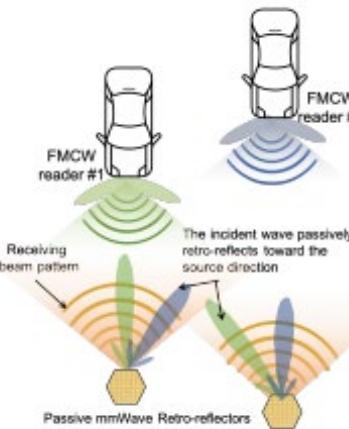


The Node can be very simple and power efficient

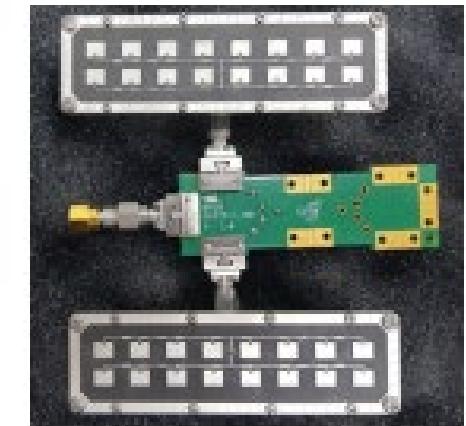
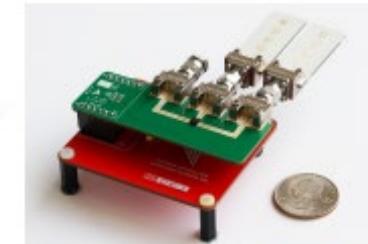
Past mmWave Backscatter Systems



mmTag
(HotNets'20 Sigcomm'21)



Millimetro
(MobiCom'21)



OmniScatter
(MobiSys'22)

Past work does not support **Downlink Communication**

This Paper

How can we design a mmWave backscatter system which supports uplink, downlink and localization?

MilBack

- The first mmWave backscatter system which supports localization, orientation sensing, uplink, and downlink communication.
- Proposed a novel beamforming technique and an orientation assisted modulation scheme.
- Built a prototype of MilBack and evaluated its performance in real-world scenarios.



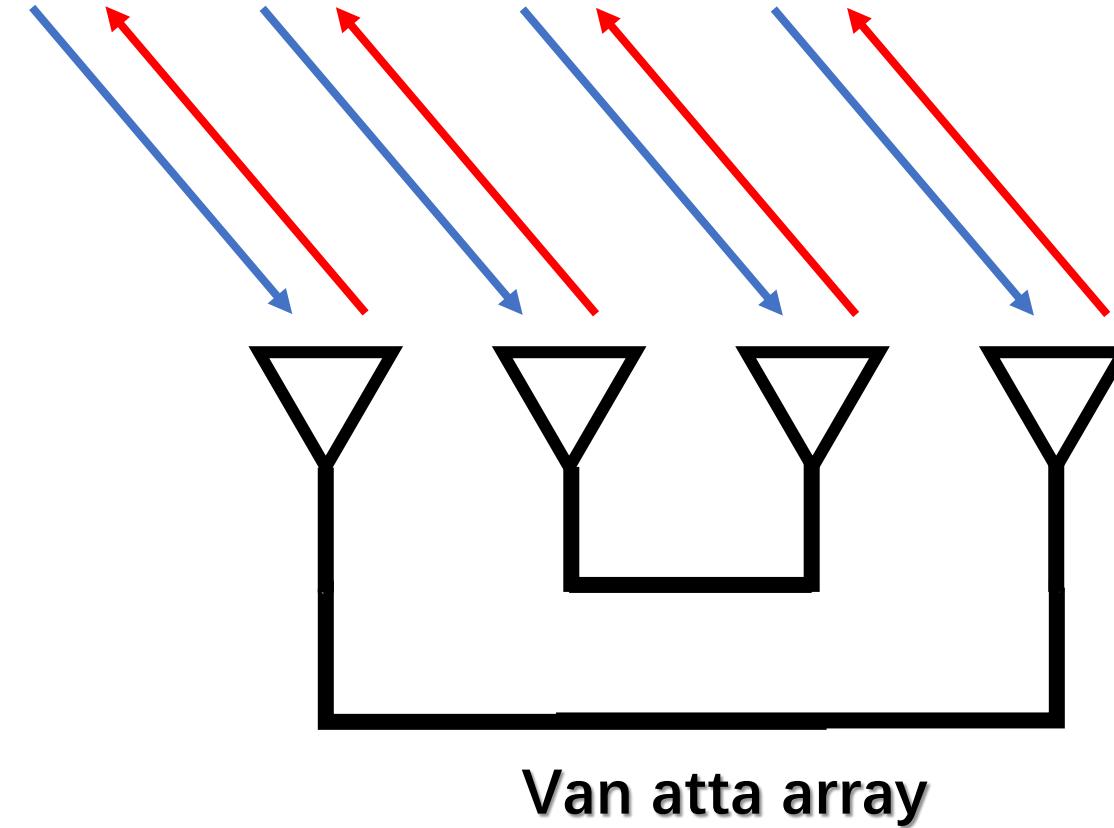
How to perform beamforming **passively**?

High Frequency → Severe Pathloss → Concentrate Energy



How to perform beamforming **passively**?

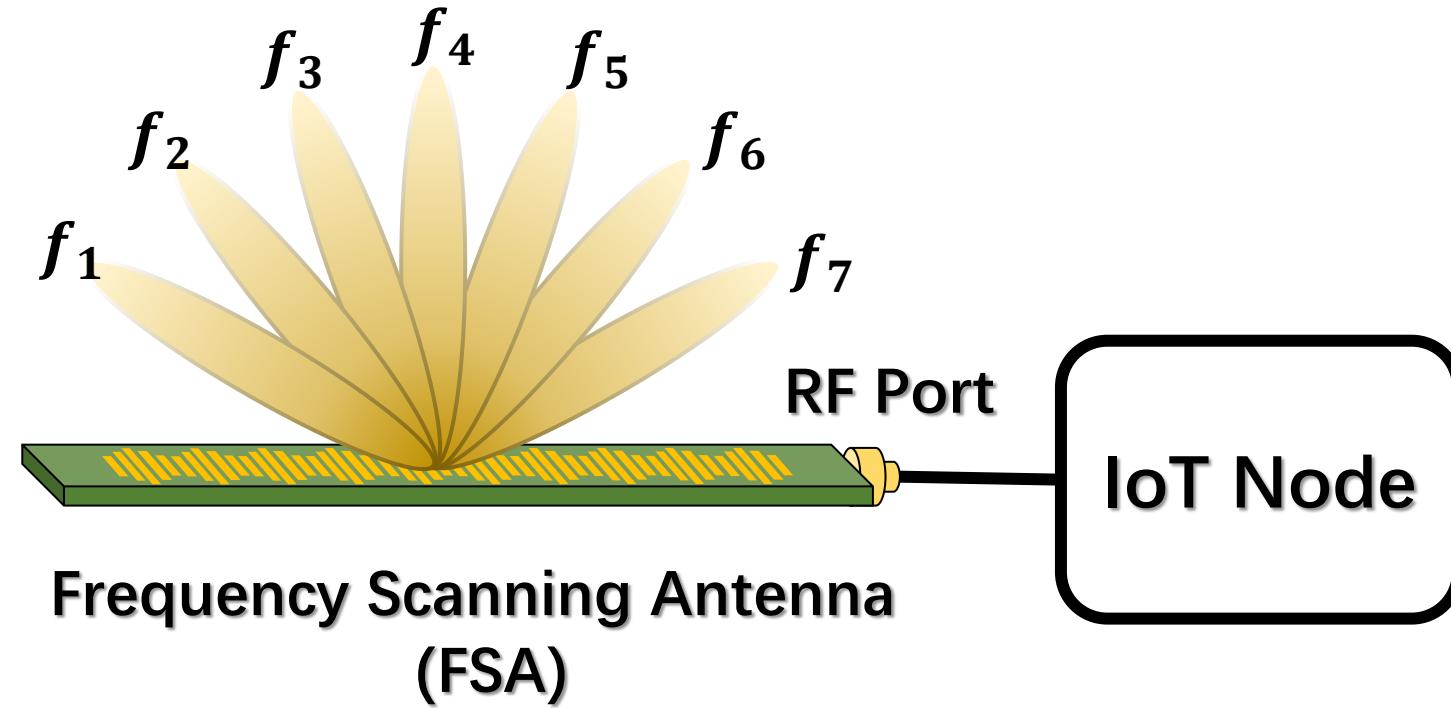
Past mmWave backscatter work uses Van atta array



Van atta array

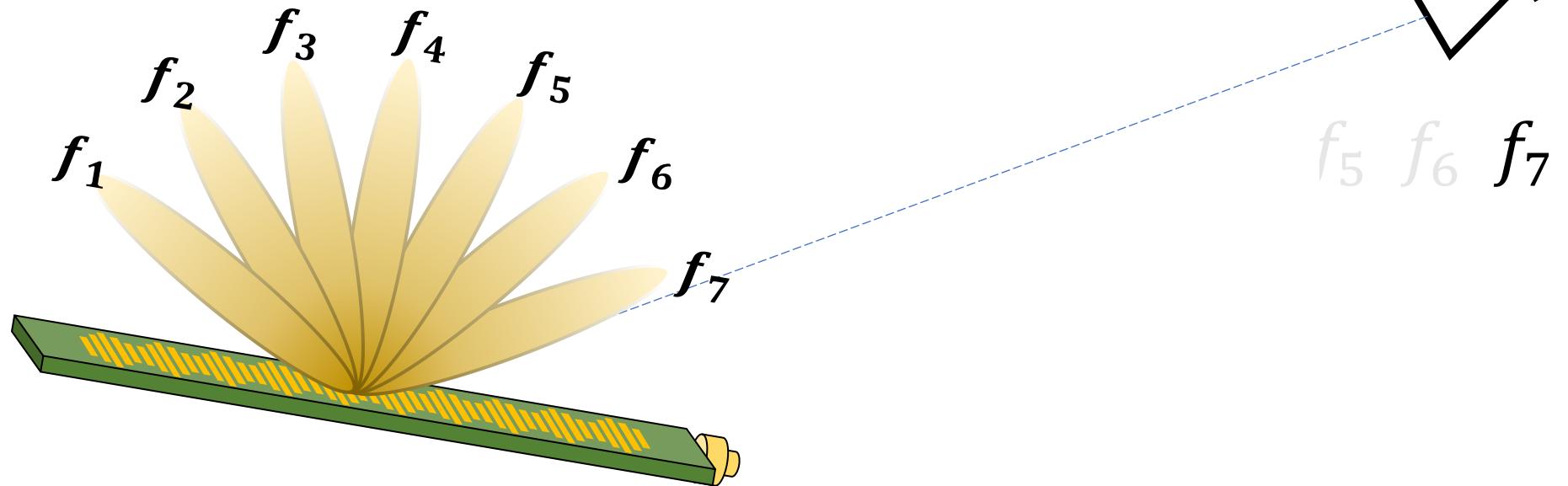
Van Atta cannot be used for receiving signal → No downlink

Our idea: use Frequency Scanning Antenna
in mmWave backscatter communication

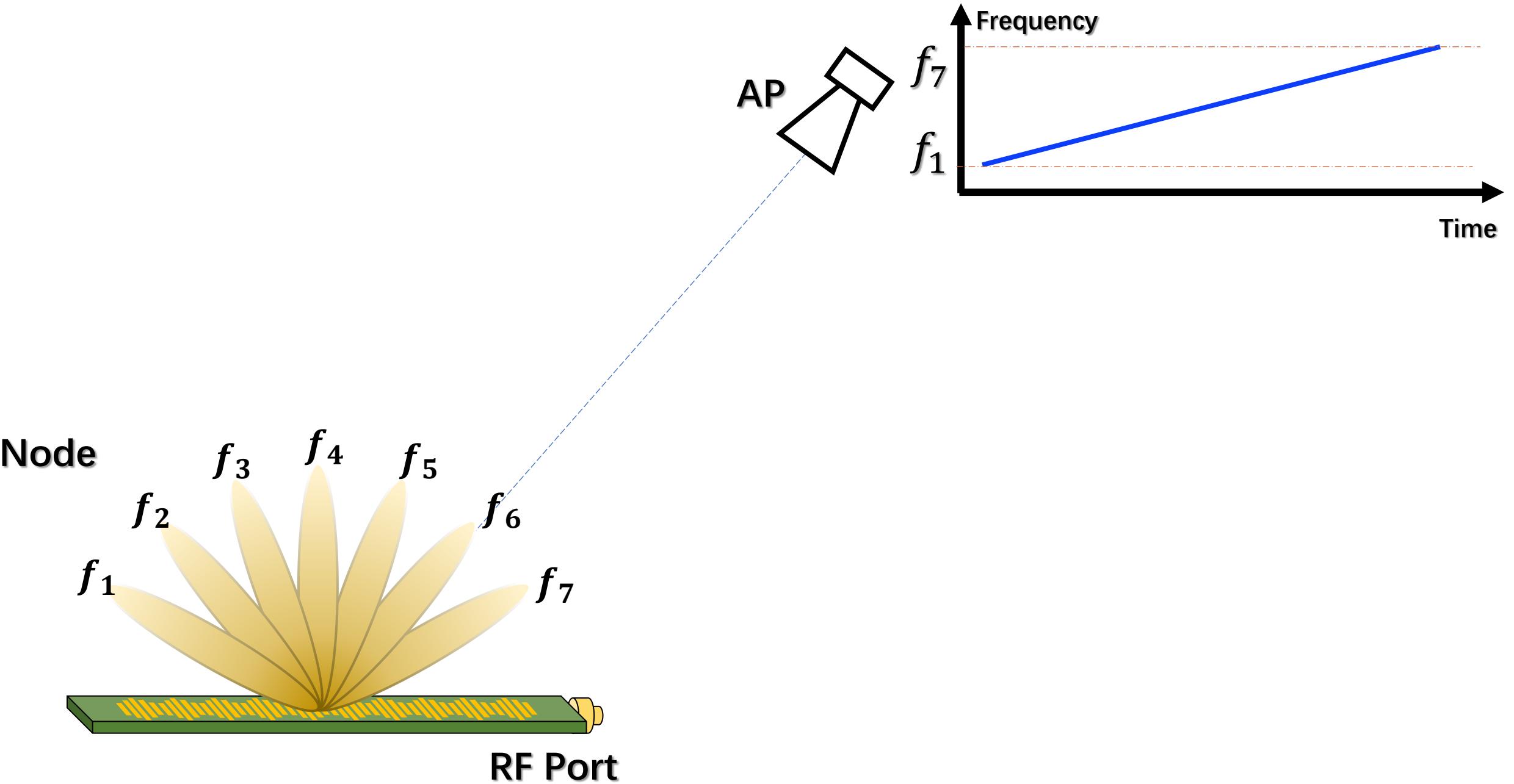


Our idea: use Frequency Scanning Antenna in mmWave backscatter communication

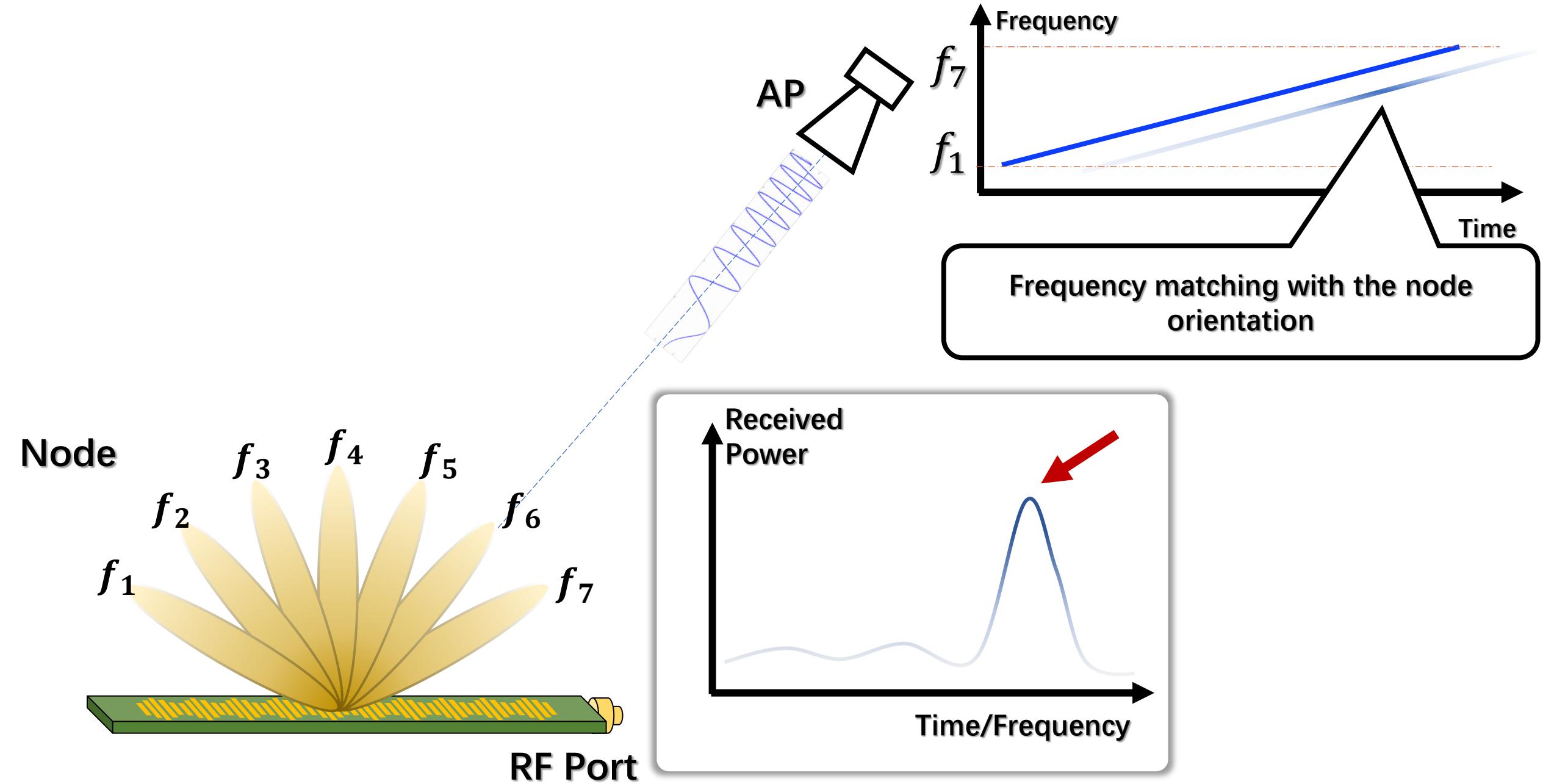
AP needs to figure out the node's orientation to pick the right frequency



How to estimate orientation of node?



How to estimate orientation of node?

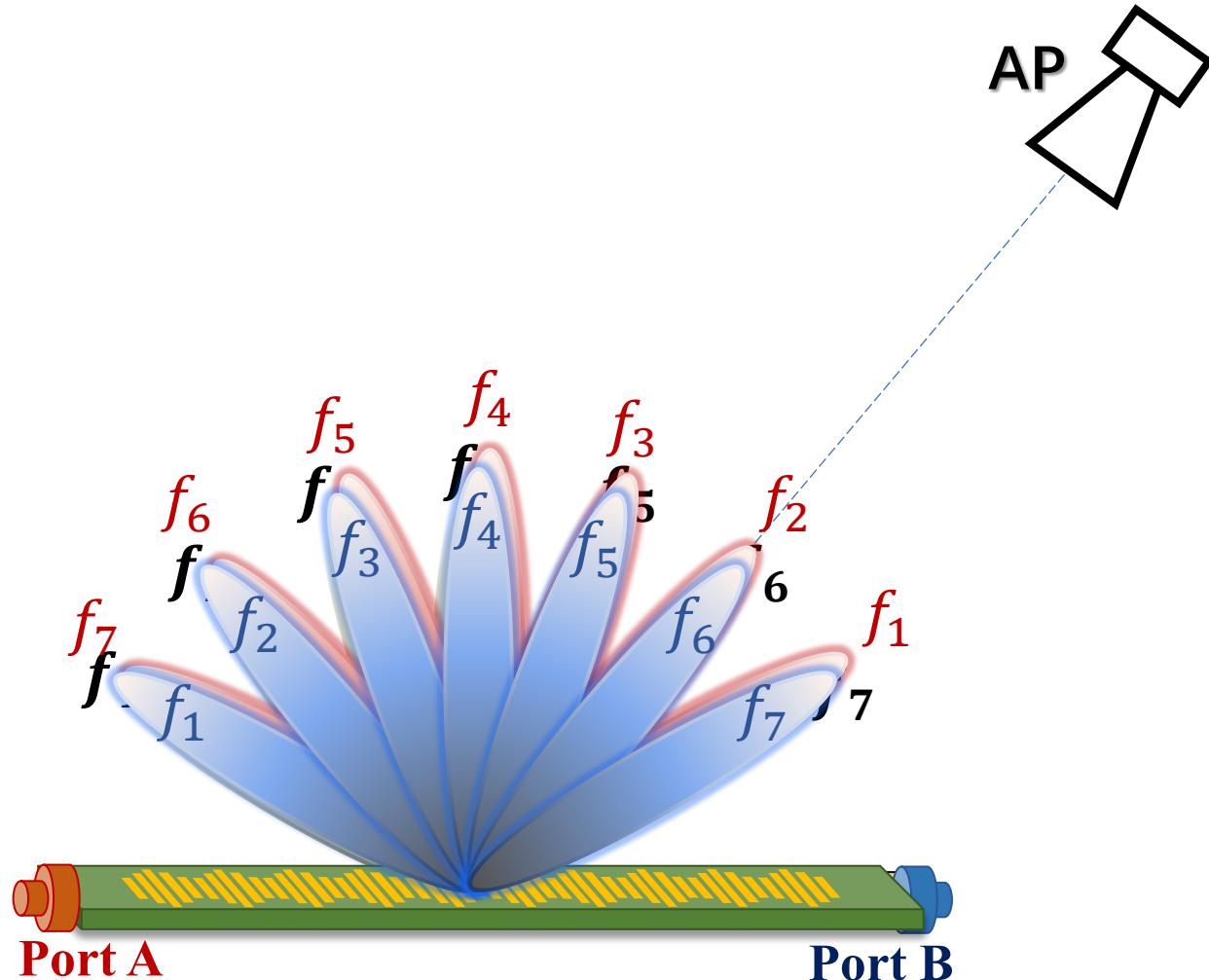


How to enable two-way communication?

Our idea: Two port FSA and Orientation Assisted Quadrature Frequency Modulation (OAQFM)

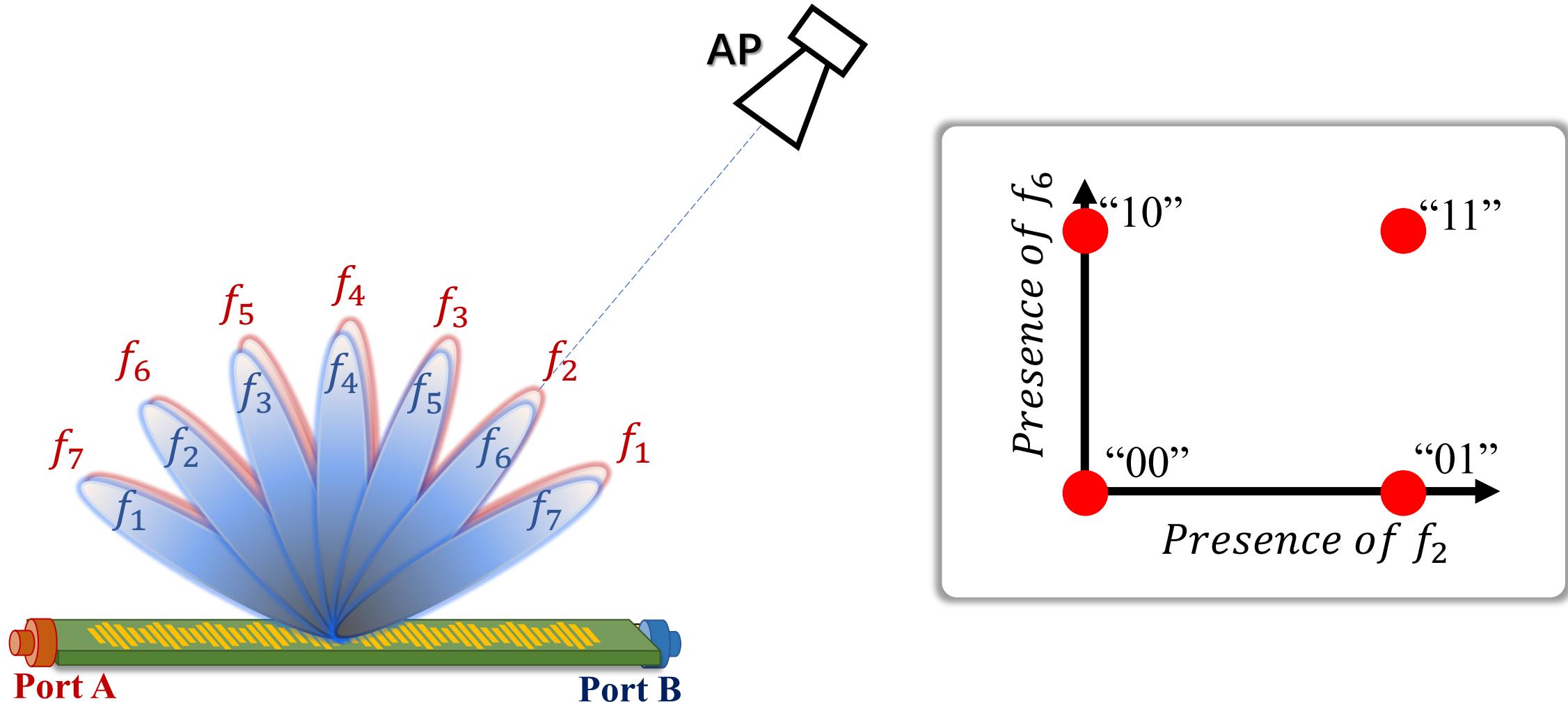
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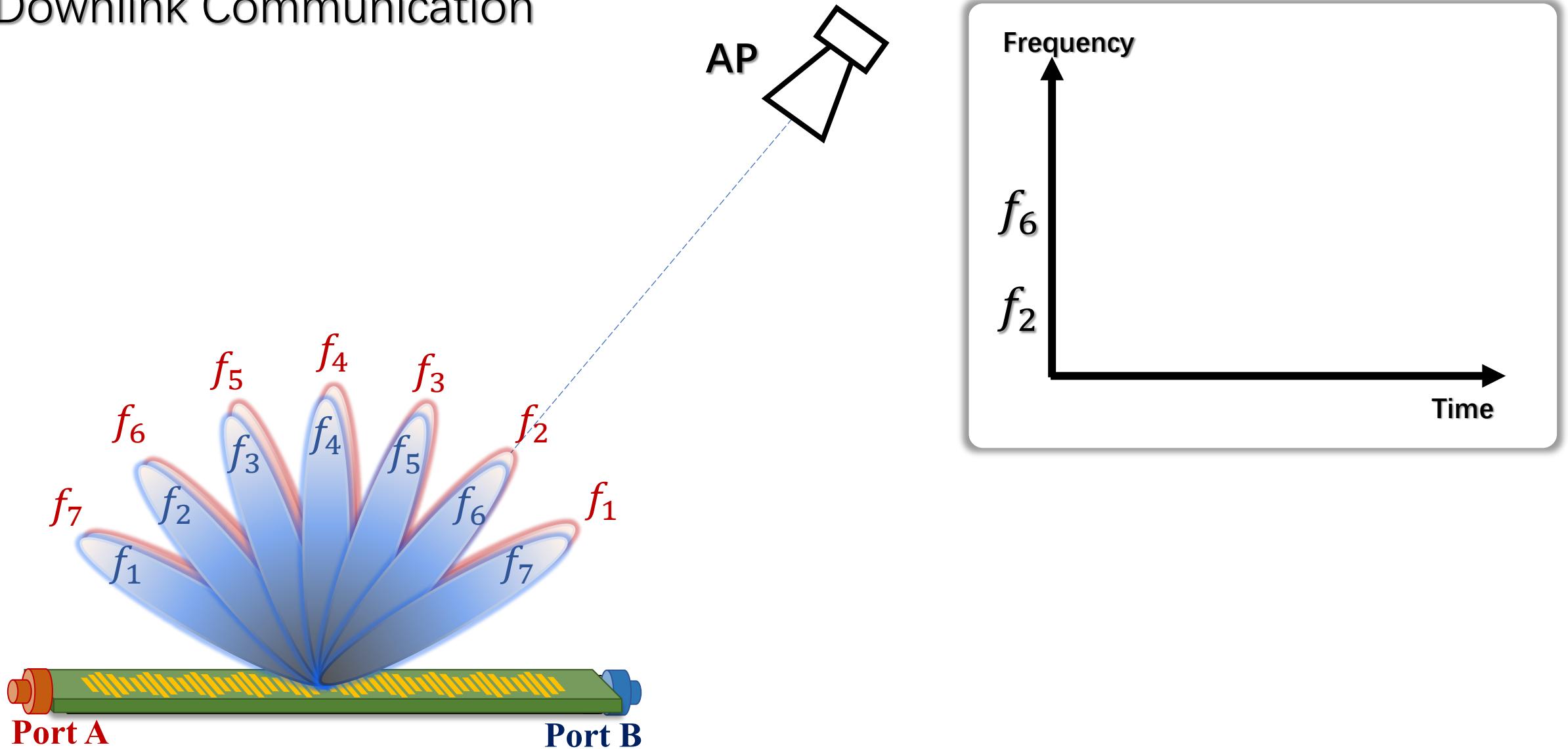
How to enable two-way communication?

Our idea: Two port FSA and Orientation Assisted Quadrature Frequency Modulation (OAQFM)



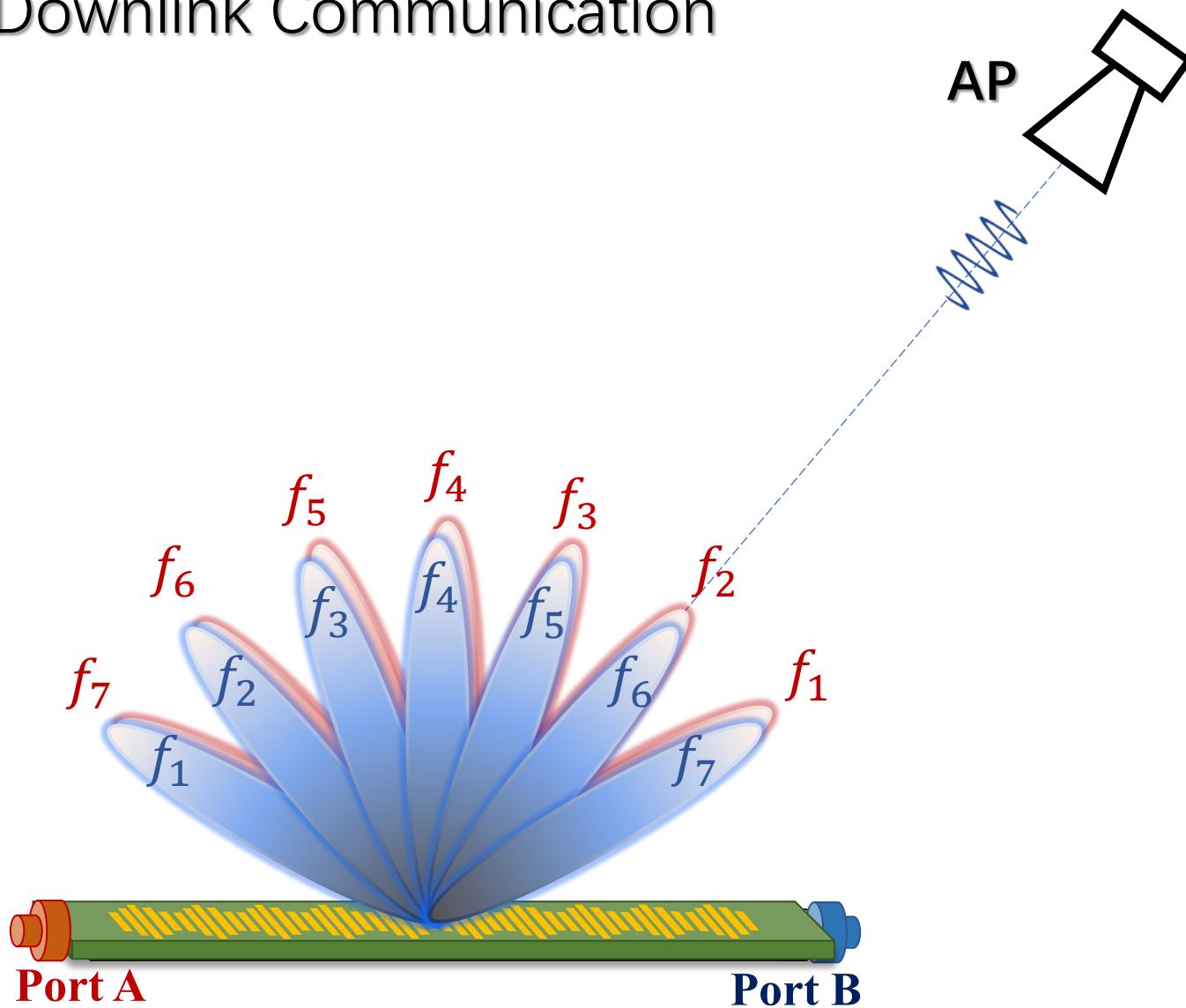
How to enable two-way communication?

Downlink Communication

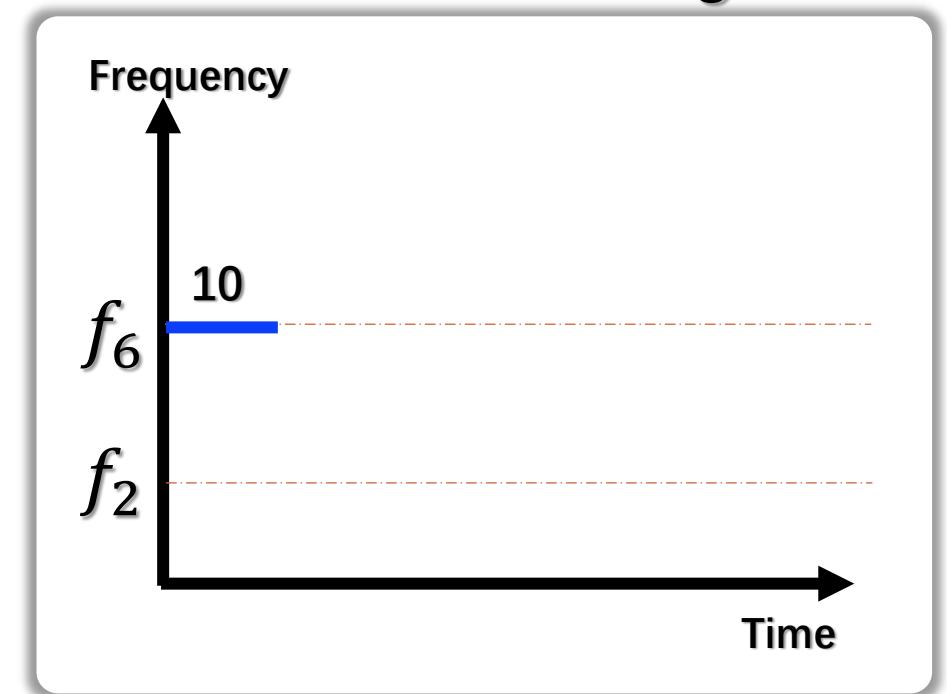


How to enable two-way communication?

Downlink Communication

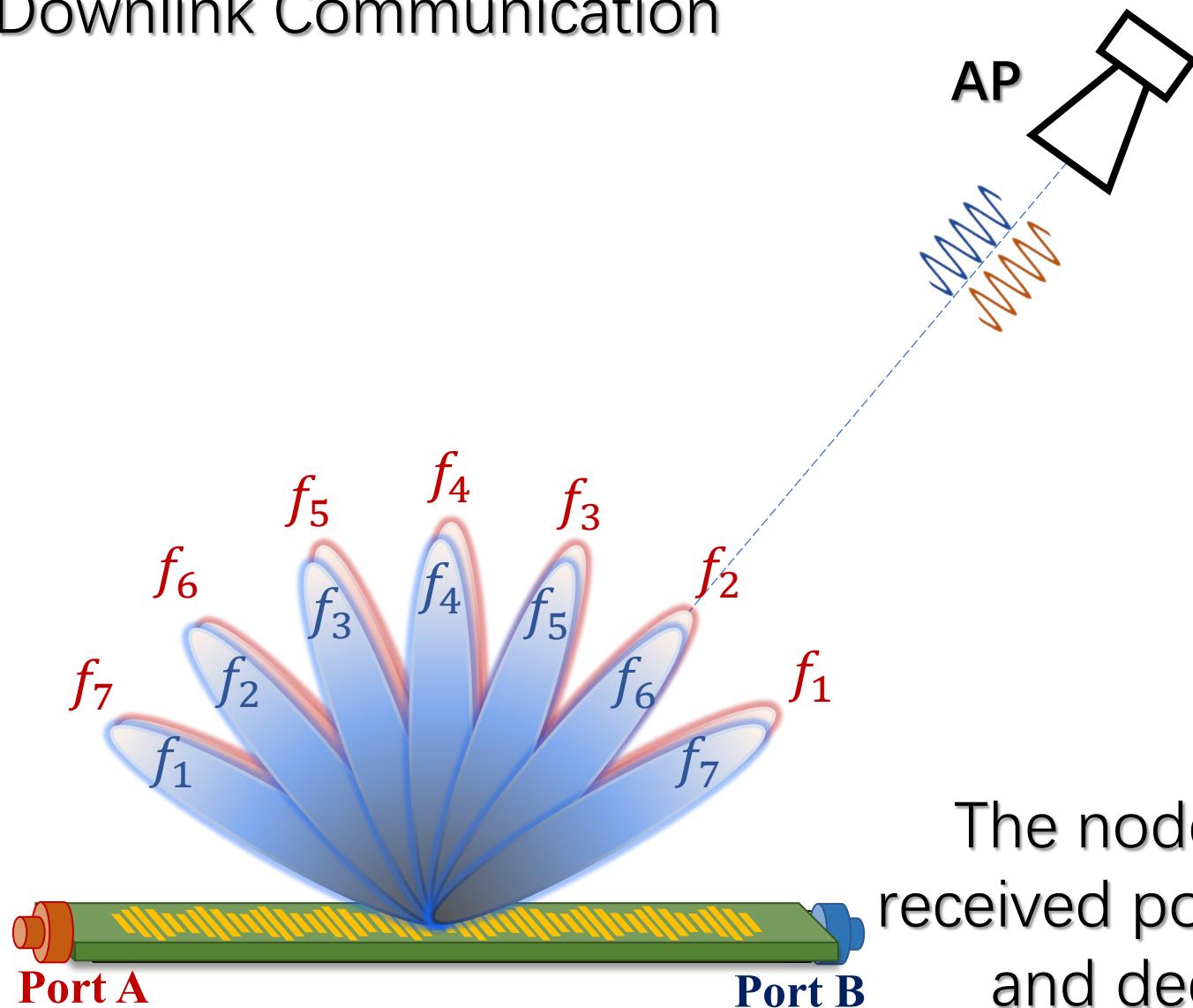


AP transmitted signal

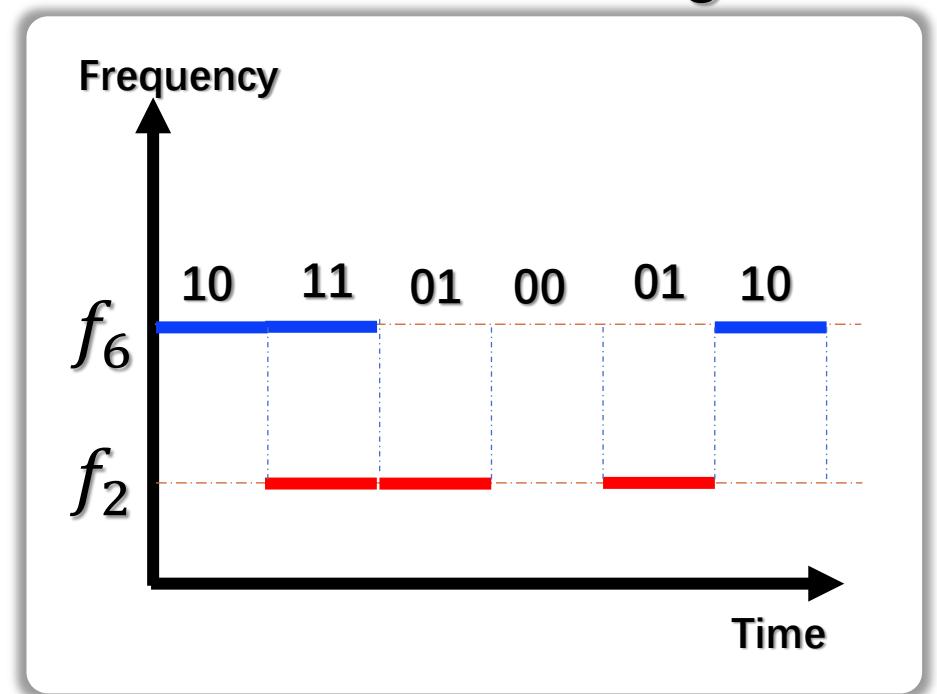


How to enable two-way communication?

Downlink Communication



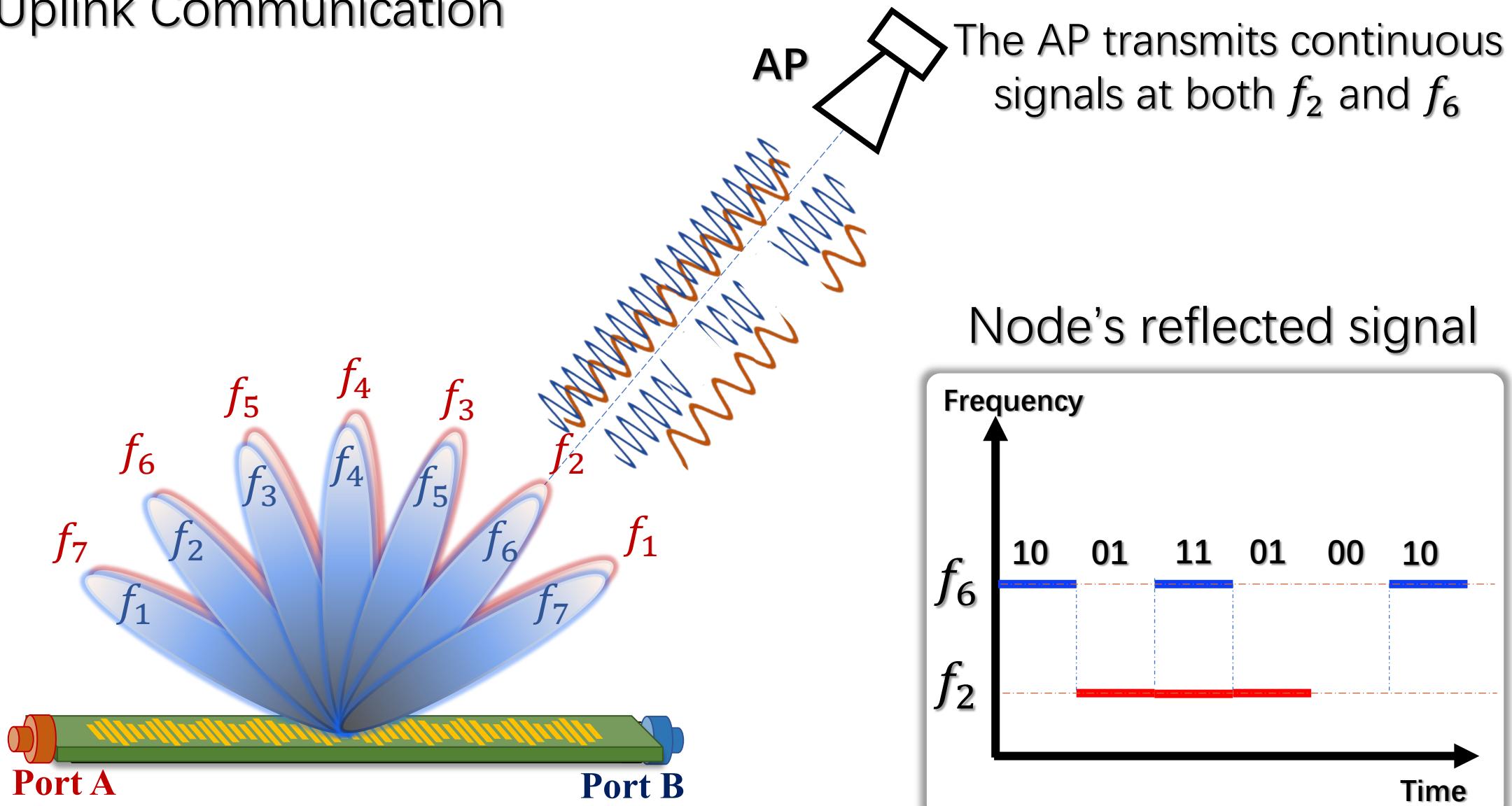
AP transmitted signal



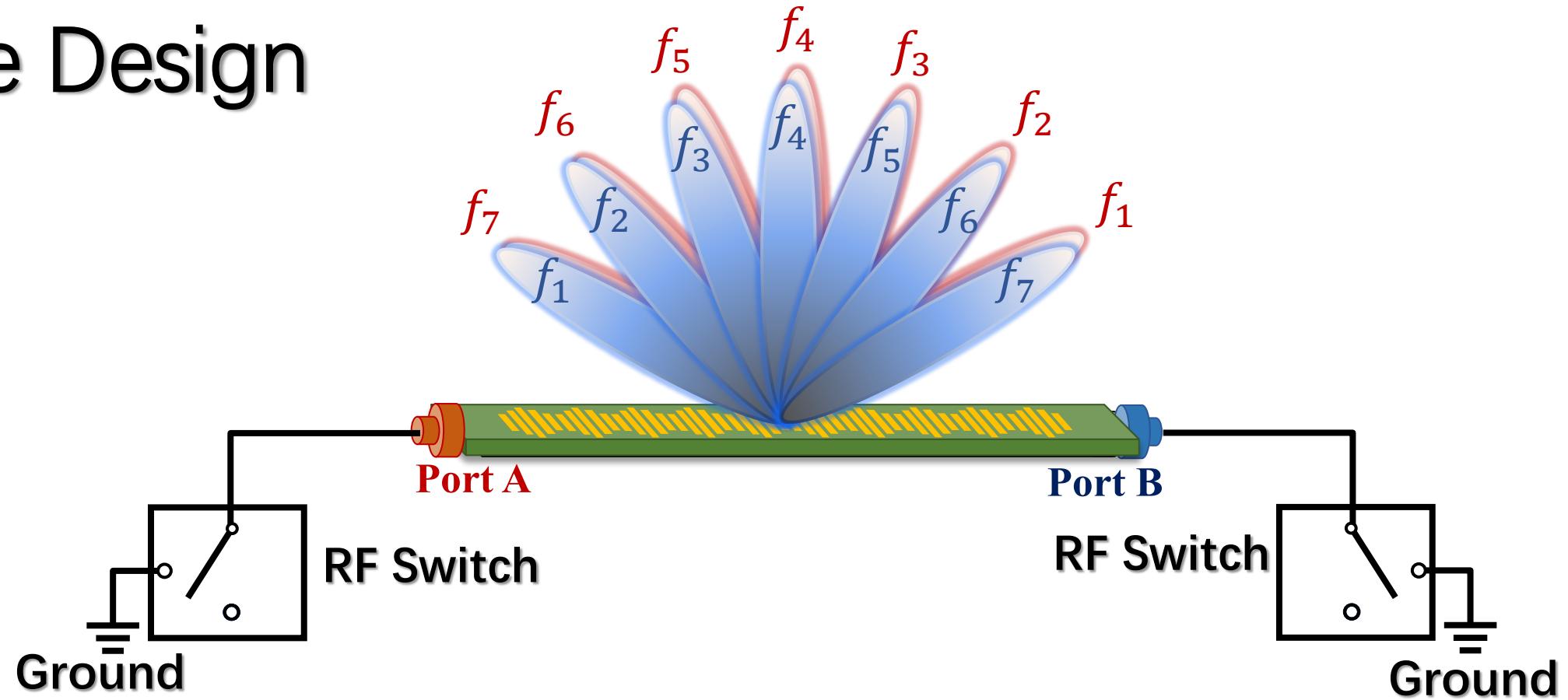
The node measure the received power at each port and decode the bits

How to enable two-way communication?

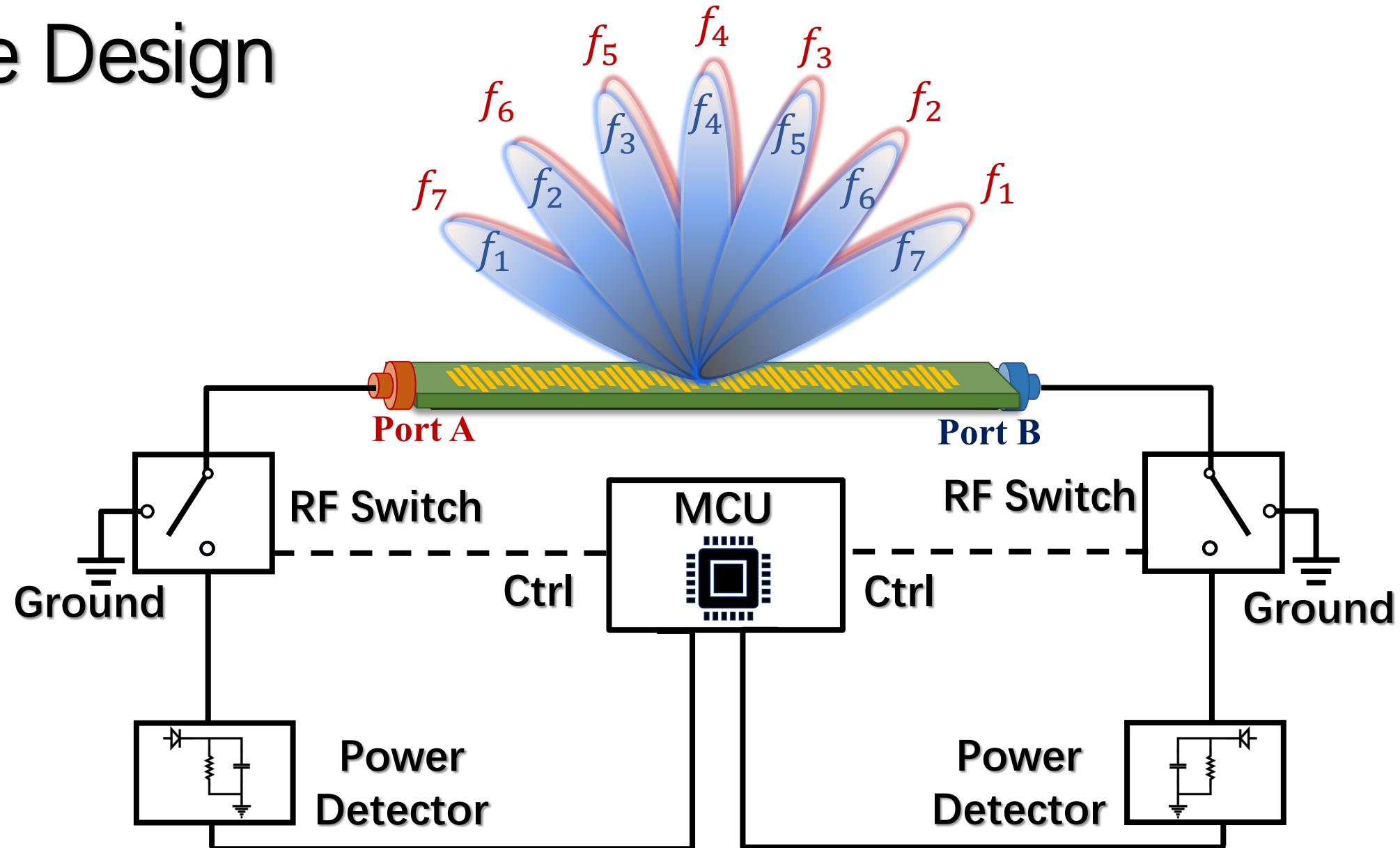
Uplink Communication



Node Design



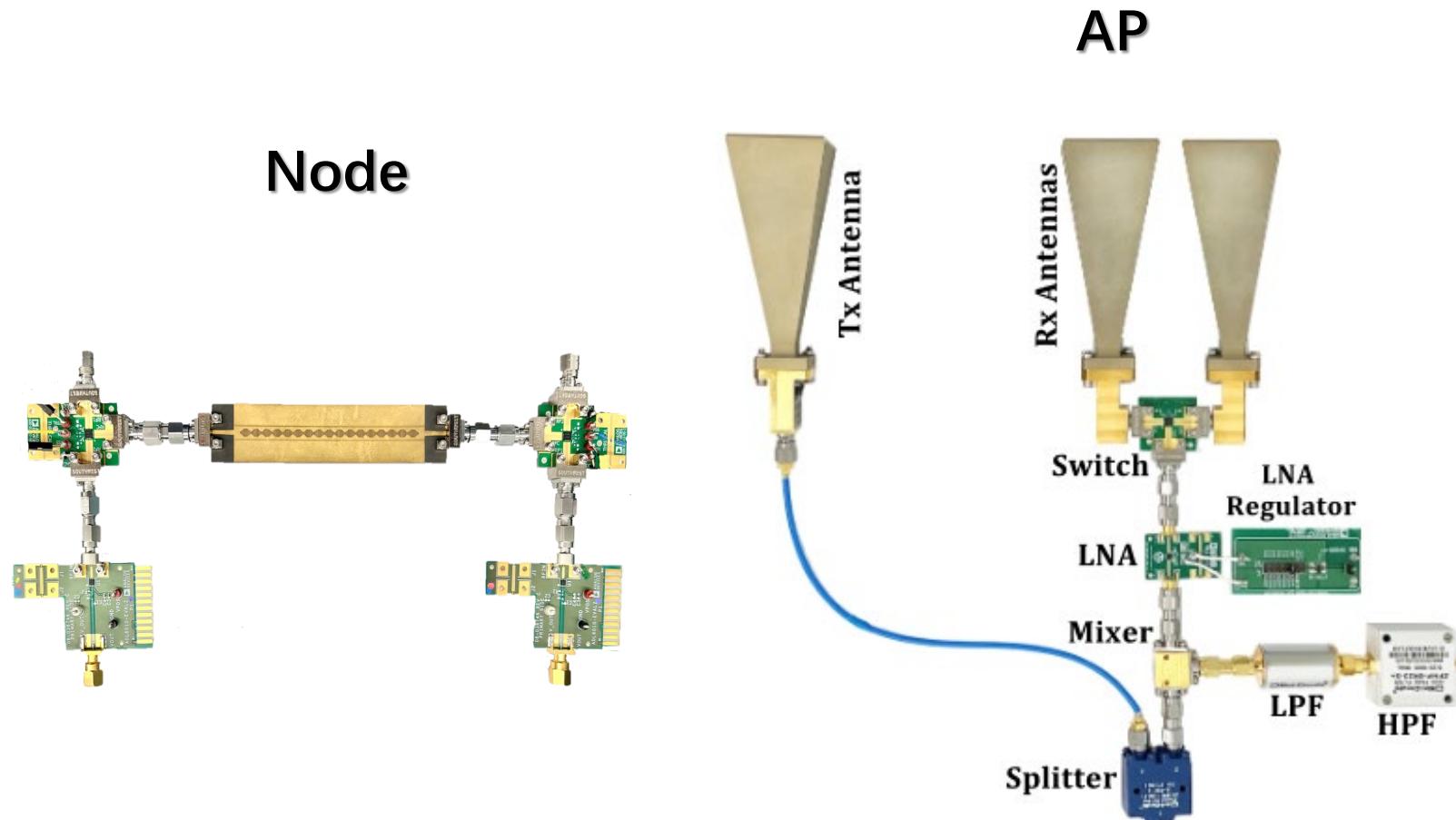
Node Design



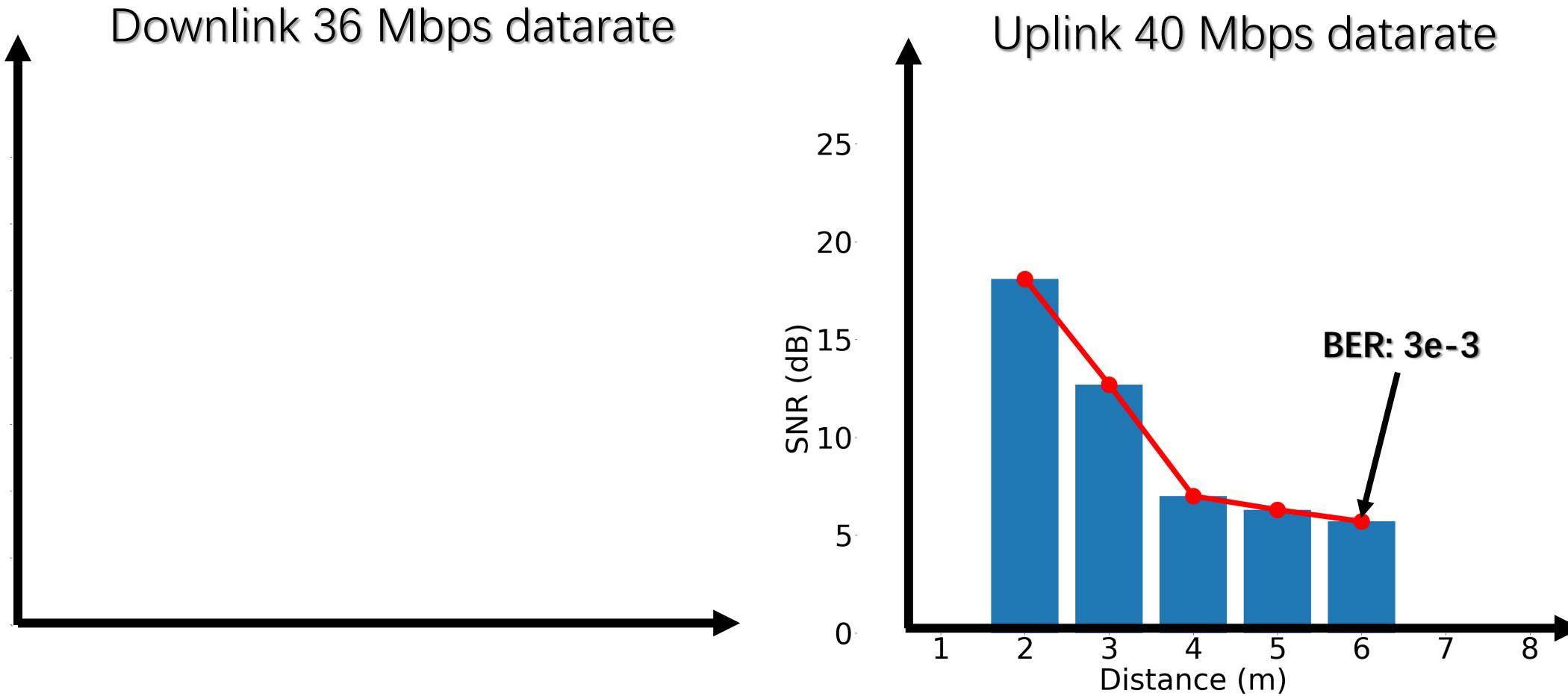
Our Design is simple, low-power and low-cost

Evaluation

We built MilBack's node and AP using off-the-shelf components

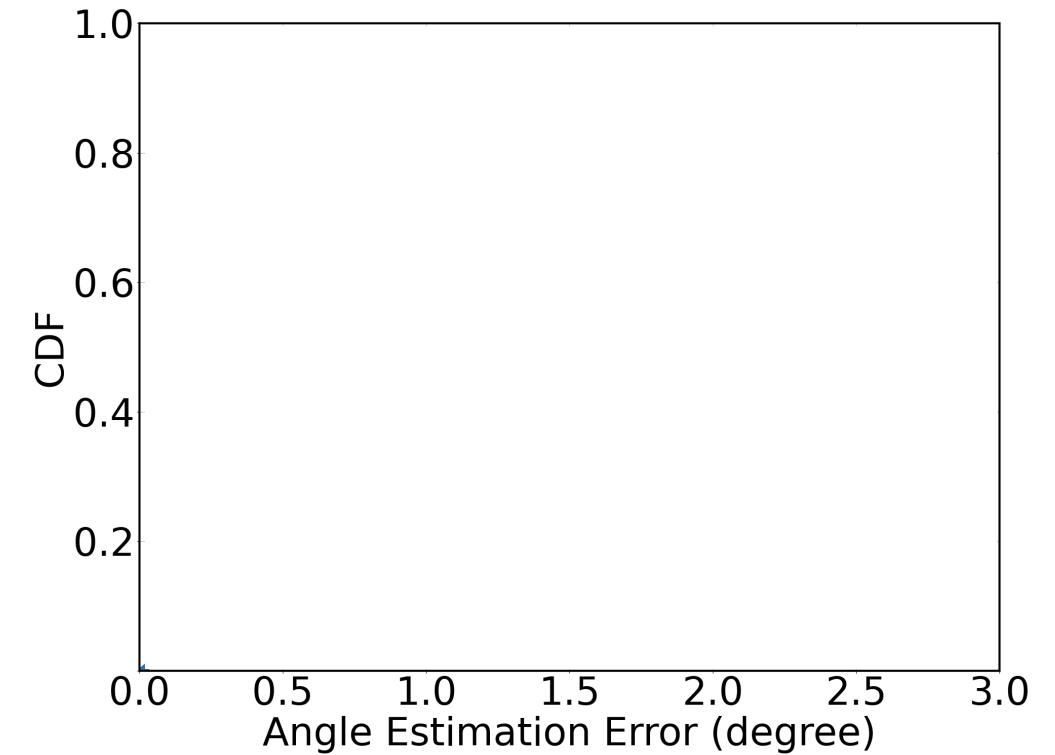
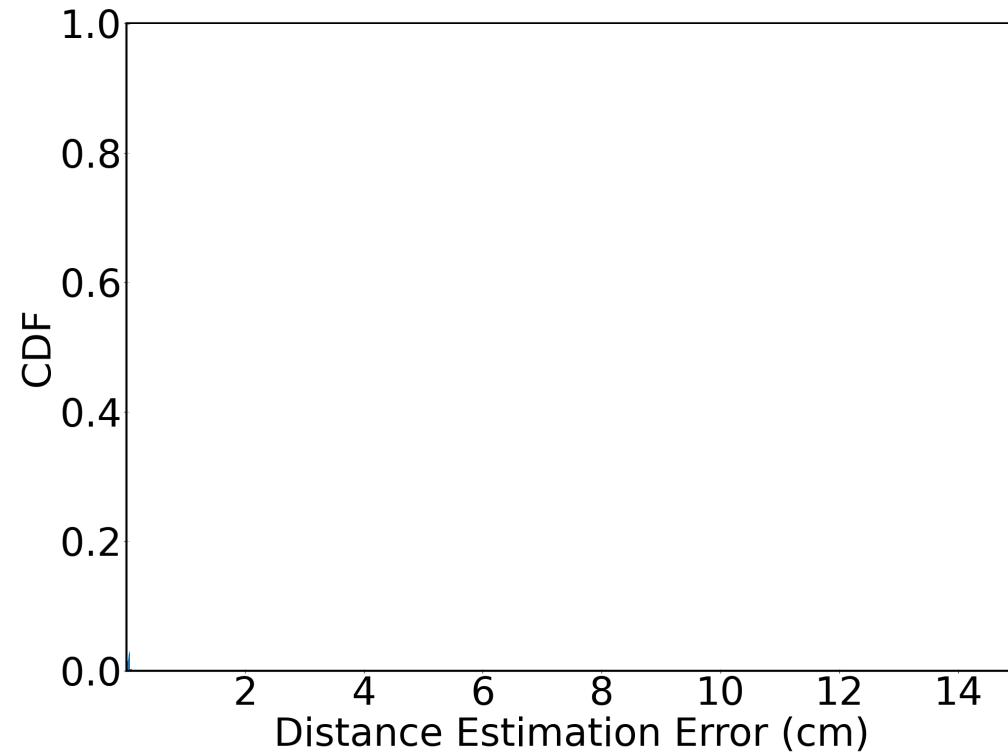


Downlink and Uplink Communication



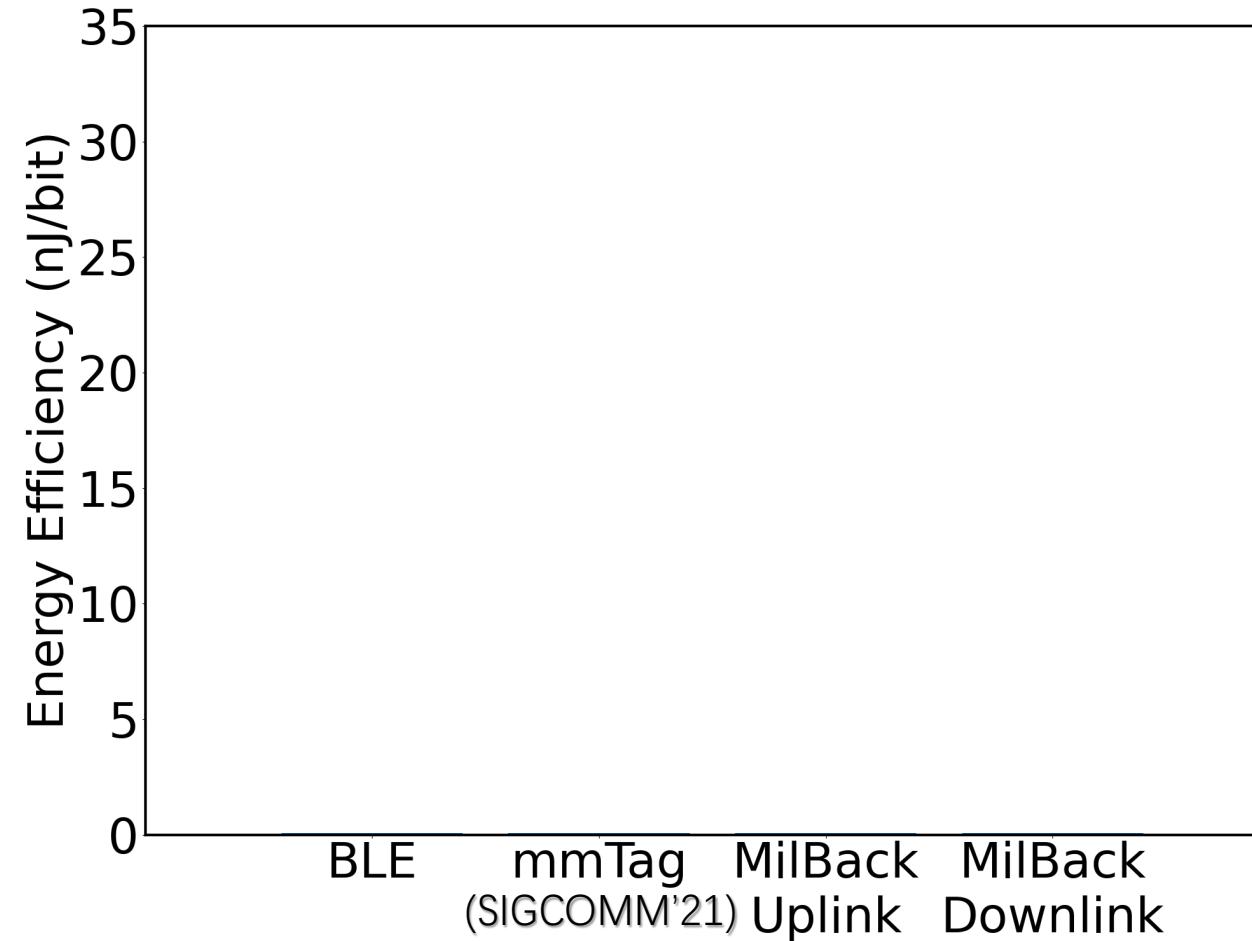
MilBack supports both uplink and downlink communication

Localization



MilBack localizes the node very accurately

Power Consumption



MilBack has very low power consumption

Conclusion

-  **First mmWave backscatter system which supports uplink, downlink communication and localization all together**
-  **Novel passive beamforming technique and orientation assisted modulation scheme**