Can IoT Devices be Powered up by Future Indoor Wireless Networks?

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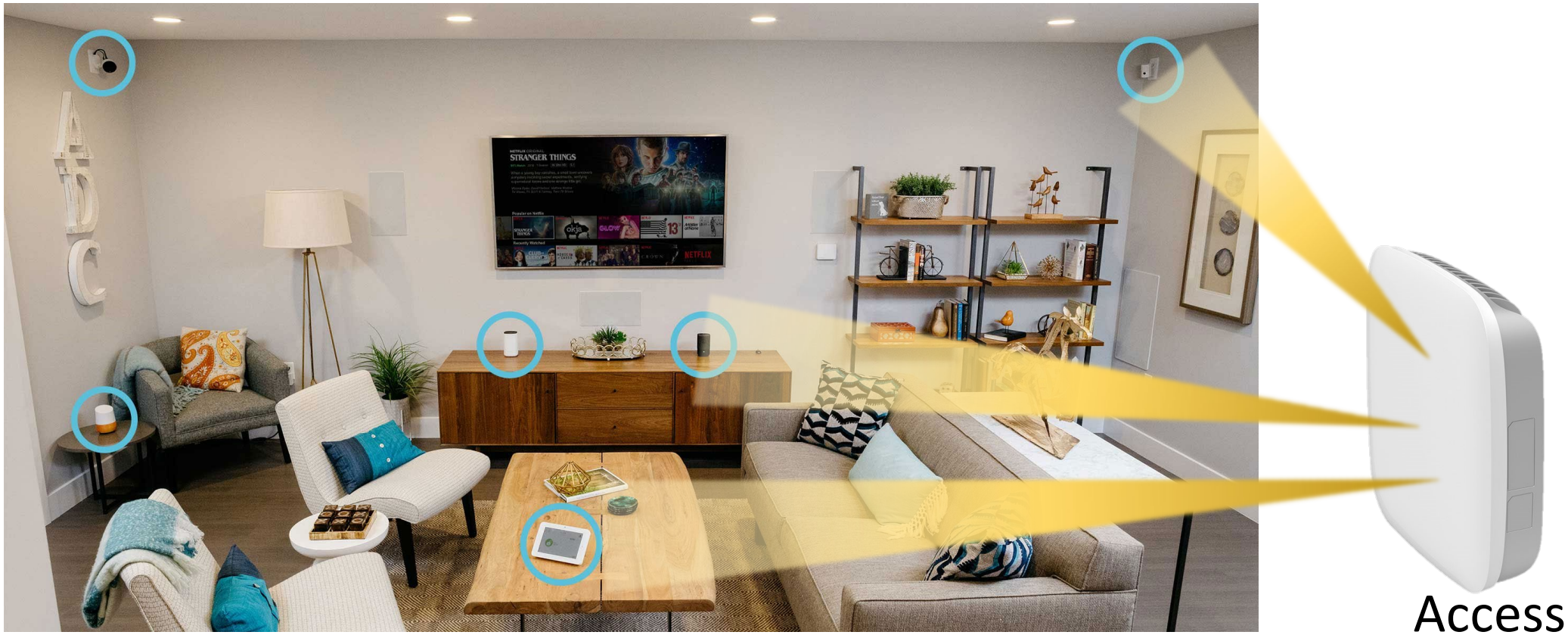
ICON LAB

Growth of Internet of Things

Techopedia

Problem: frequent battery replacement

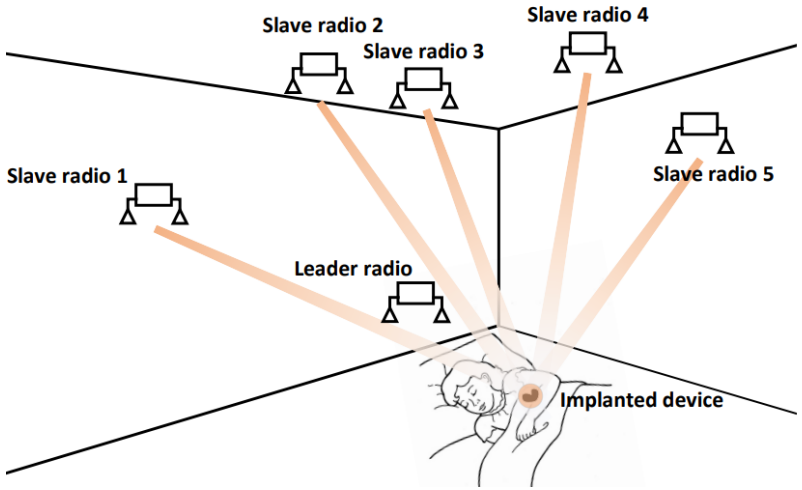
What can we do?



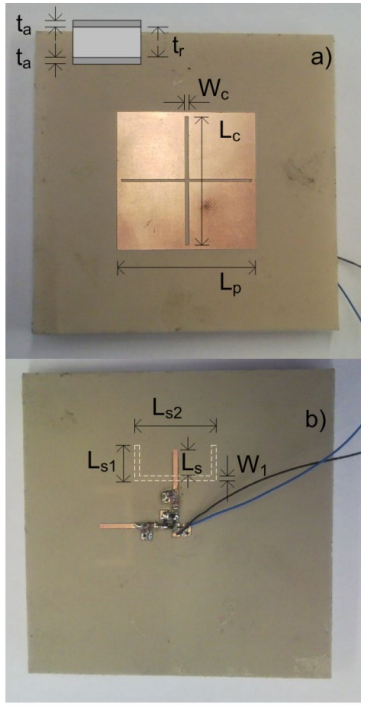
Access Points

Our idea: Access Point are mostly idle during nights, use them to transfer power to IoT device batteries

Existing wireless power transfer systems

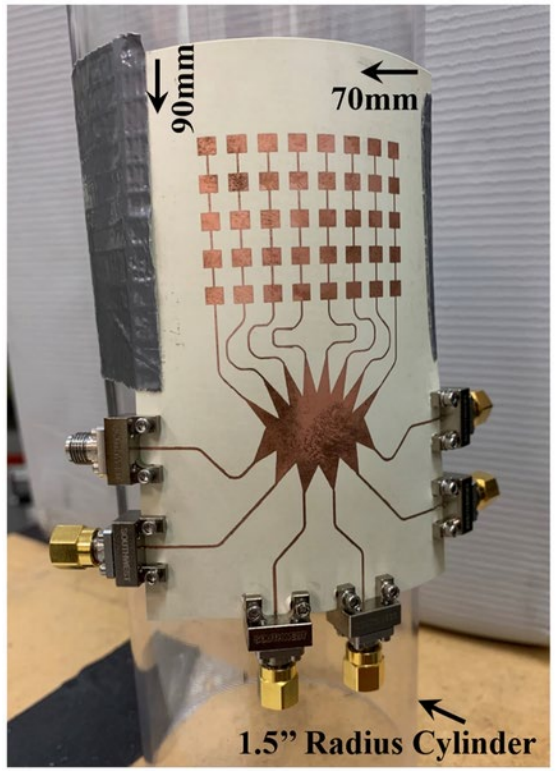


915 MHz
(X. Fan et al., 2020)



2.4 GHz
(G. Andia Vera et al., 2010)

24 GHz
(GuRu, 2017)

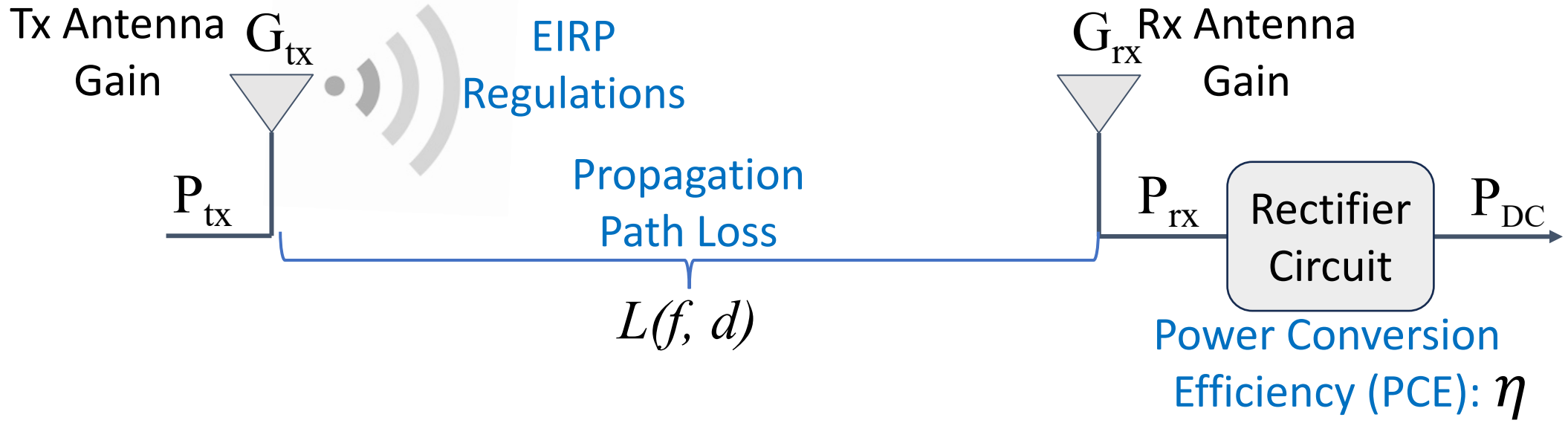


28 GHz
(A. Eid et al., 2021)

Which spectrum band serves better for wireless power transfer?

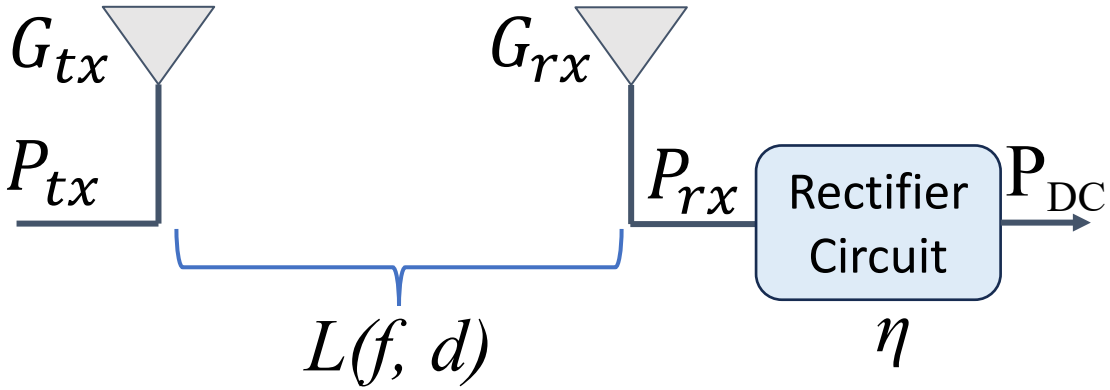
Which spectrum band serves better for wireless power transfer?

An End-to-End Evaluation



	Lower Frequency Bands (900 MHz, 2.4 GHz, and 5.8 GHz)	Higher Frequency Bands (≥ 24 GHz)
Path loss	Low	High
PCE	High	Low
Regulation EIRP	Low	High
Antenna Gain	Low	High

Link Budget Analysis



Received Power at harvester (dB):

$$P_{rx} = P_{tx} + G_{tx} + G_{rx} + 20log(\frac{c}{4\pi f d})$$

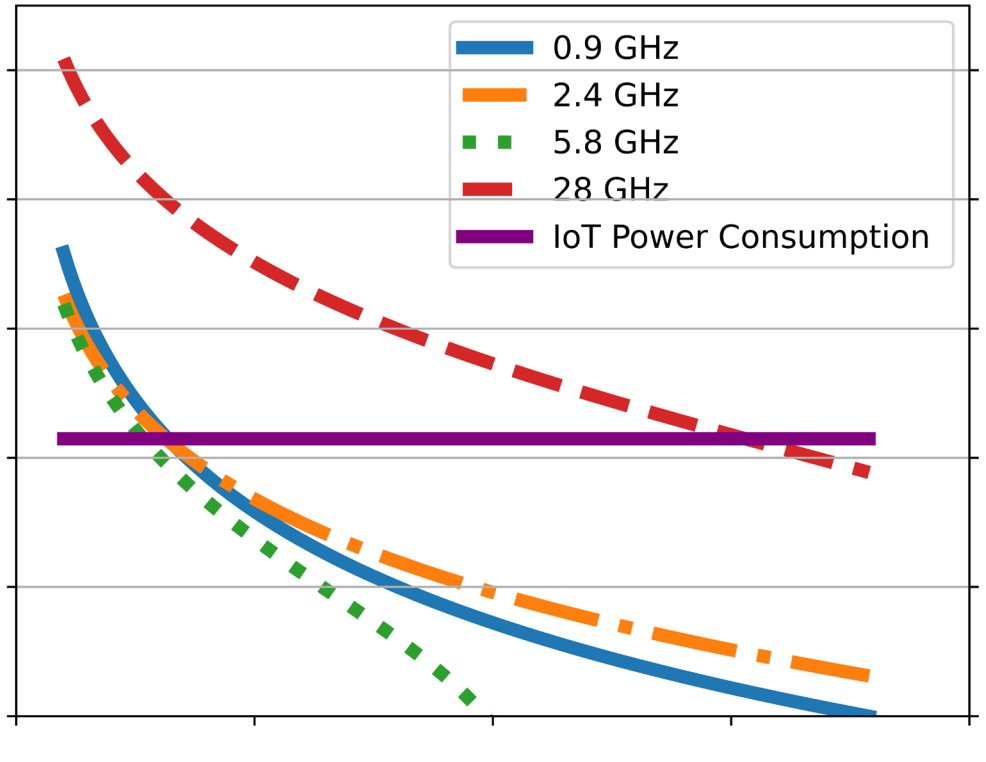
Harvester Antenna Gain (dB):

$G_{rx} = 10log(\frac{4A_e\pi f^2}{c^2})$, where A_e is the effective antenna aperture.

Harvested DC Power (dB):

$$P_{DC} = P_{tx} + G_{tx} + 10log(A_e) - 20log(d) - 10log(4\pi) + 10log(\eta)$$

Harvested Power vs Distance Simulation



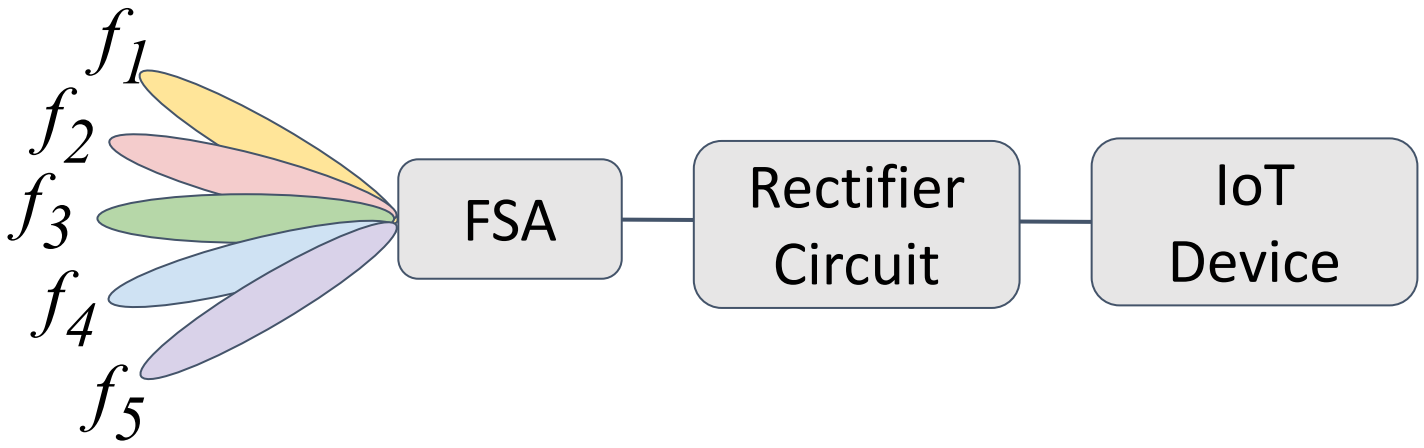
mmWave is a better candidate for wireless power transfer

How can IoT devices harvest energy from indoor mmWave access points?

Challenges #1: How to perform beamforming?

Conventional solution: active beamforming using phased array

Our solution: **passive** beamforming using *Frequency Scanning Antenna* (FSA)

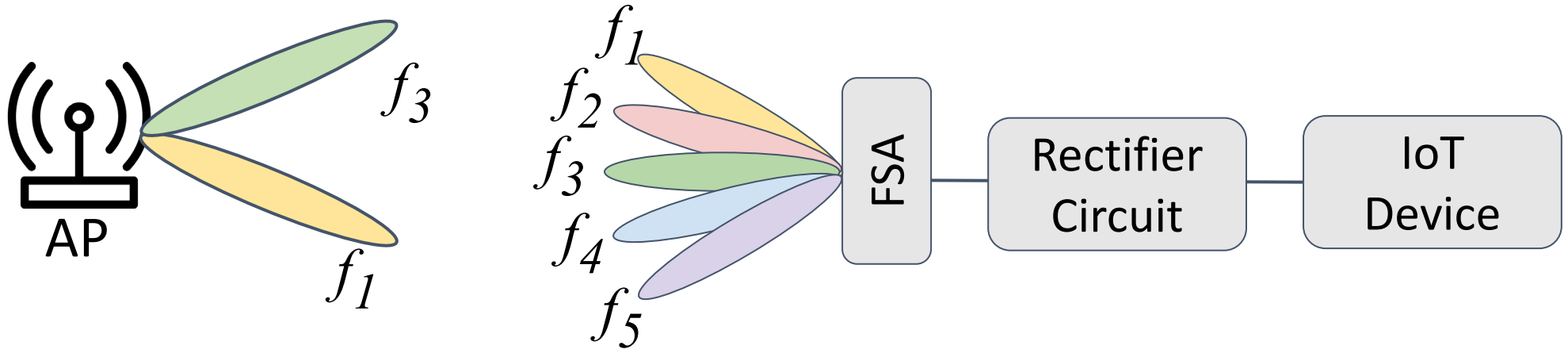


Advantages:

- Wide coverage angle
- Zero power consumption

Challenges #2: How to do beam alignment?

Goal: find the frequency and beam direction that align with the energy harvester

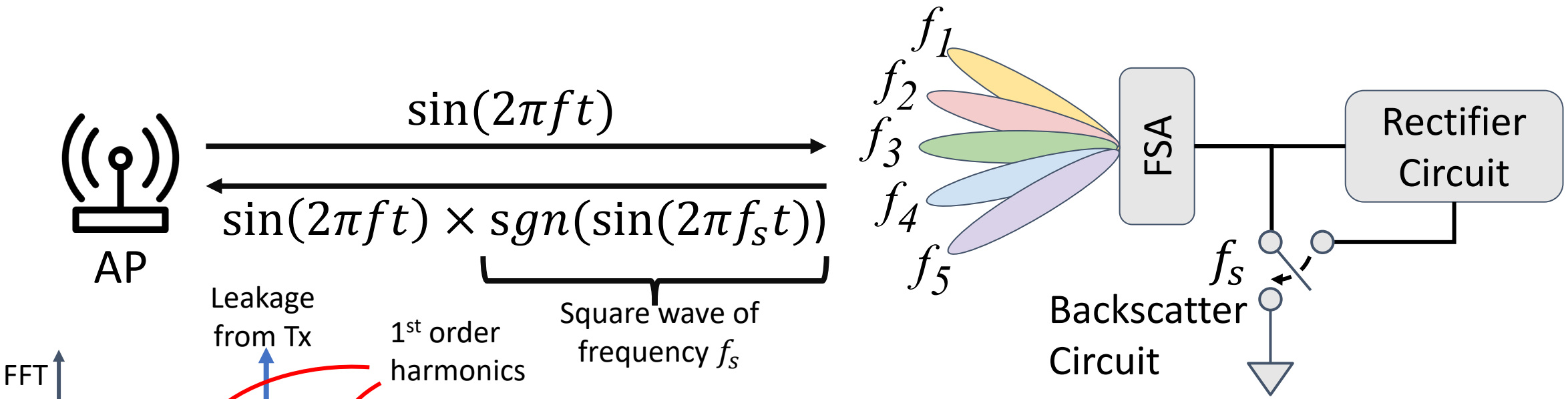


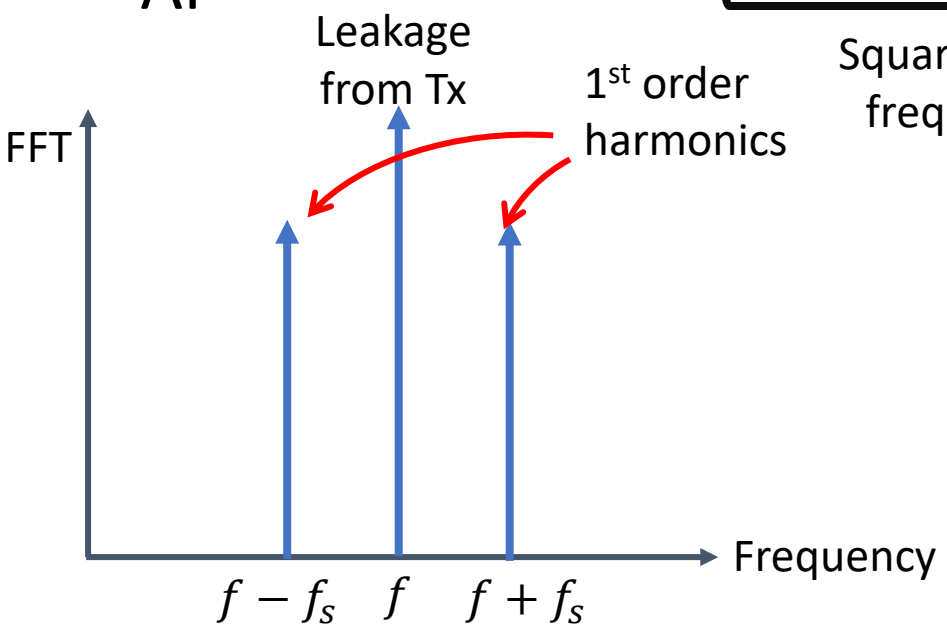
A naïve idea: use lower frequency radio to provide feedback to the AP

Problem: Additional power consumption to the IoT device

Challenges #2: How to do beam alignment?

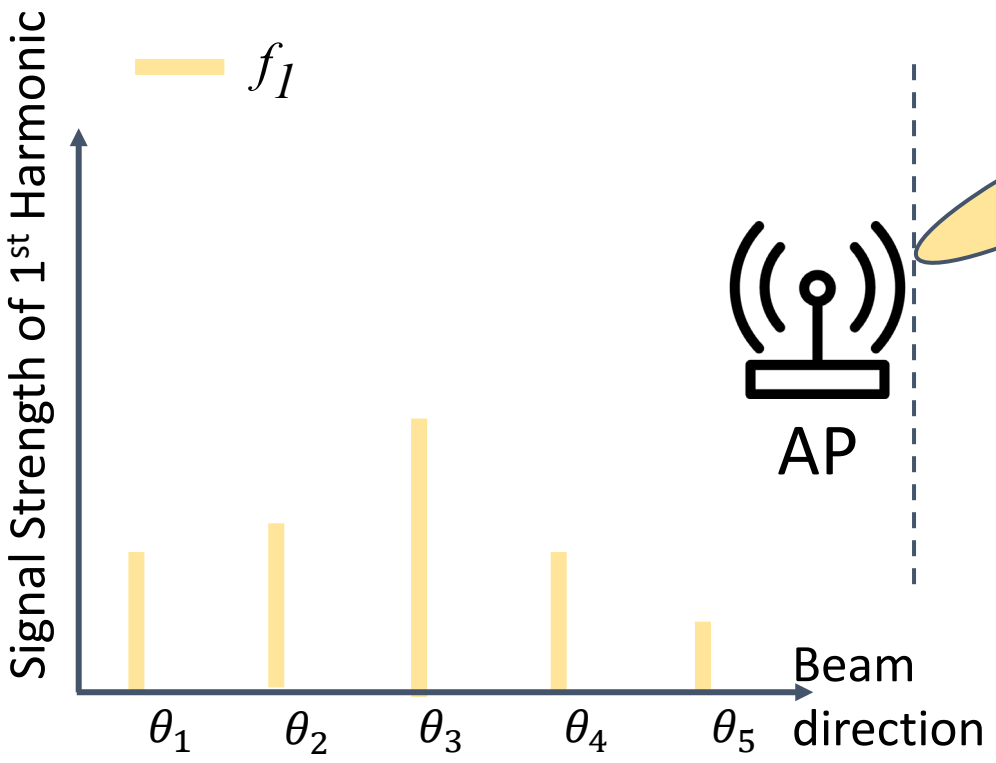
Our idea: use backscatter to provide feedback

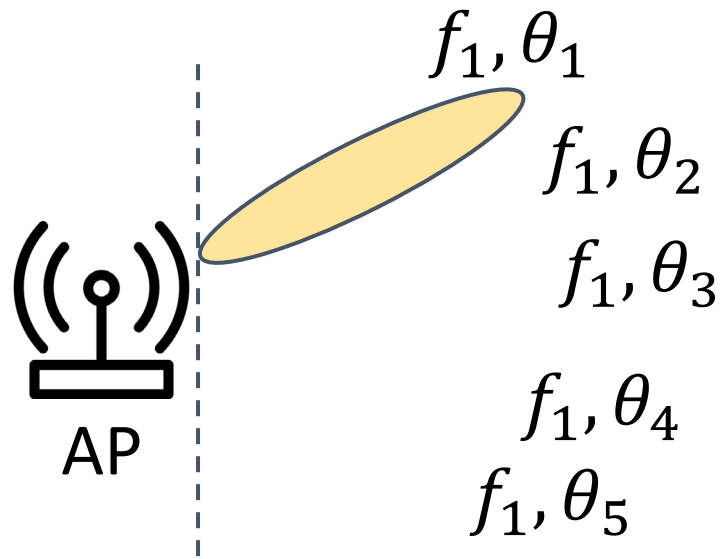


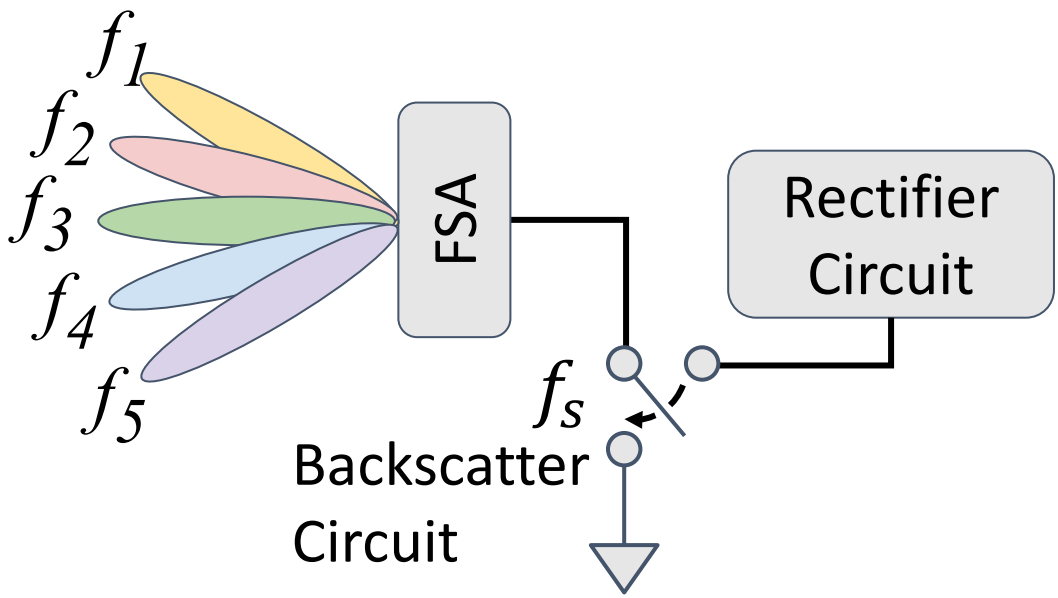


Key Observation:
The strength of the 1st order harmonics indicates the reflected signal strengths
→ Degree of alignment

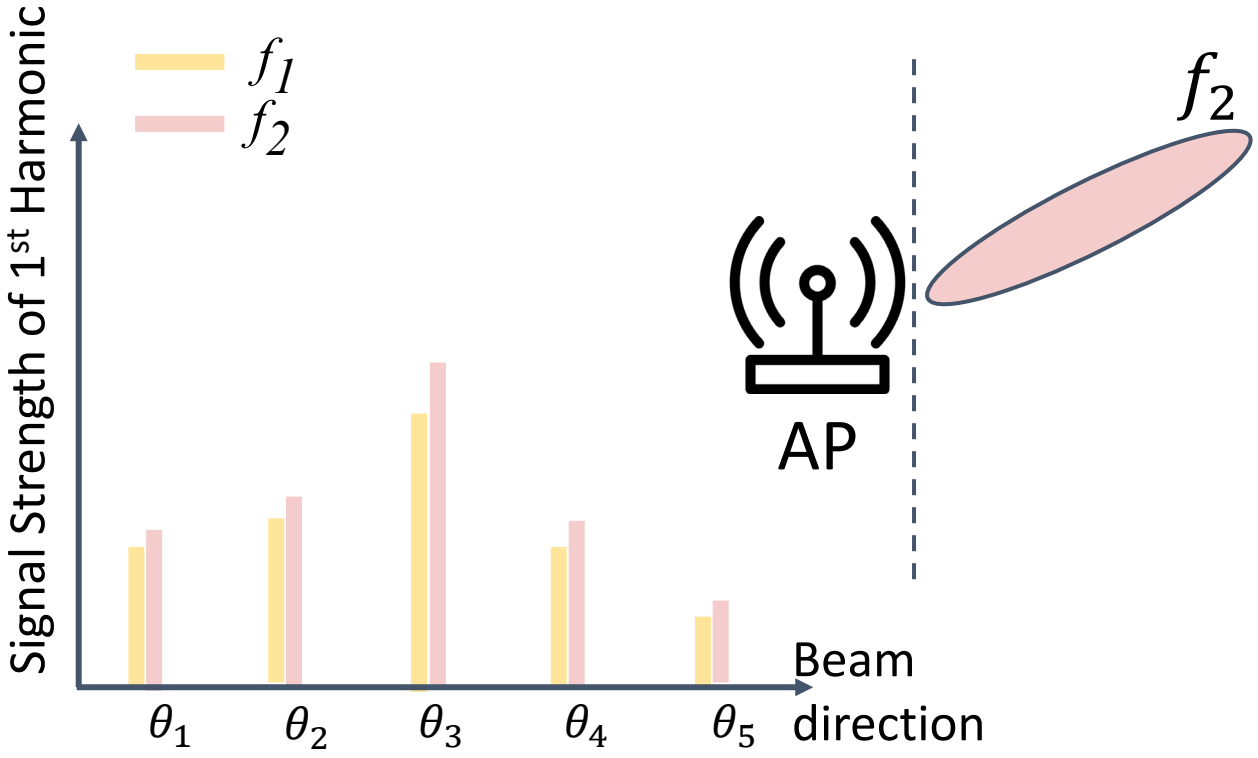
Beam Alignment Protocol

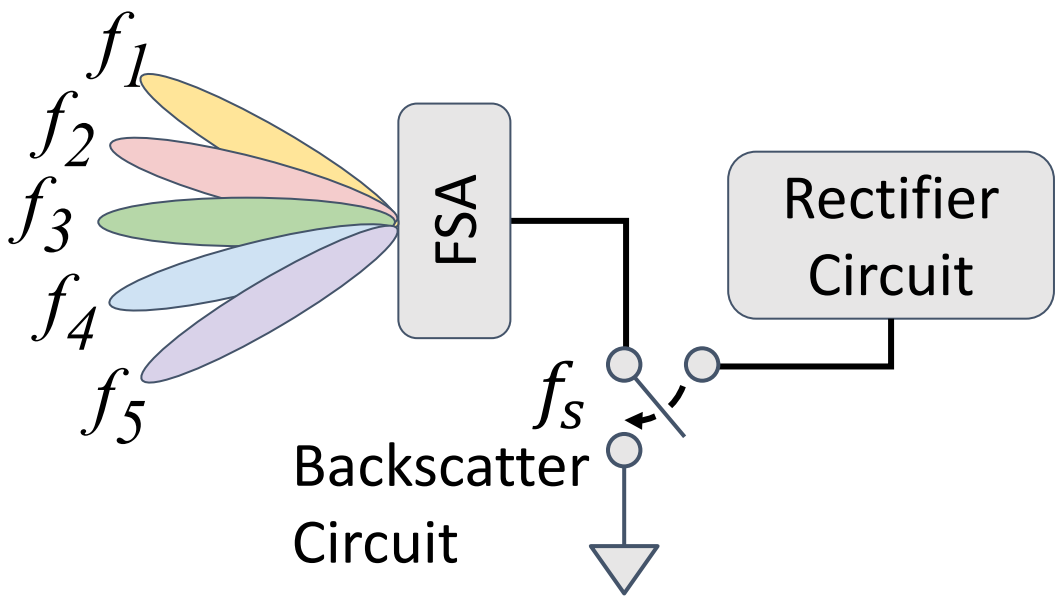






Beam Alignment Protocol





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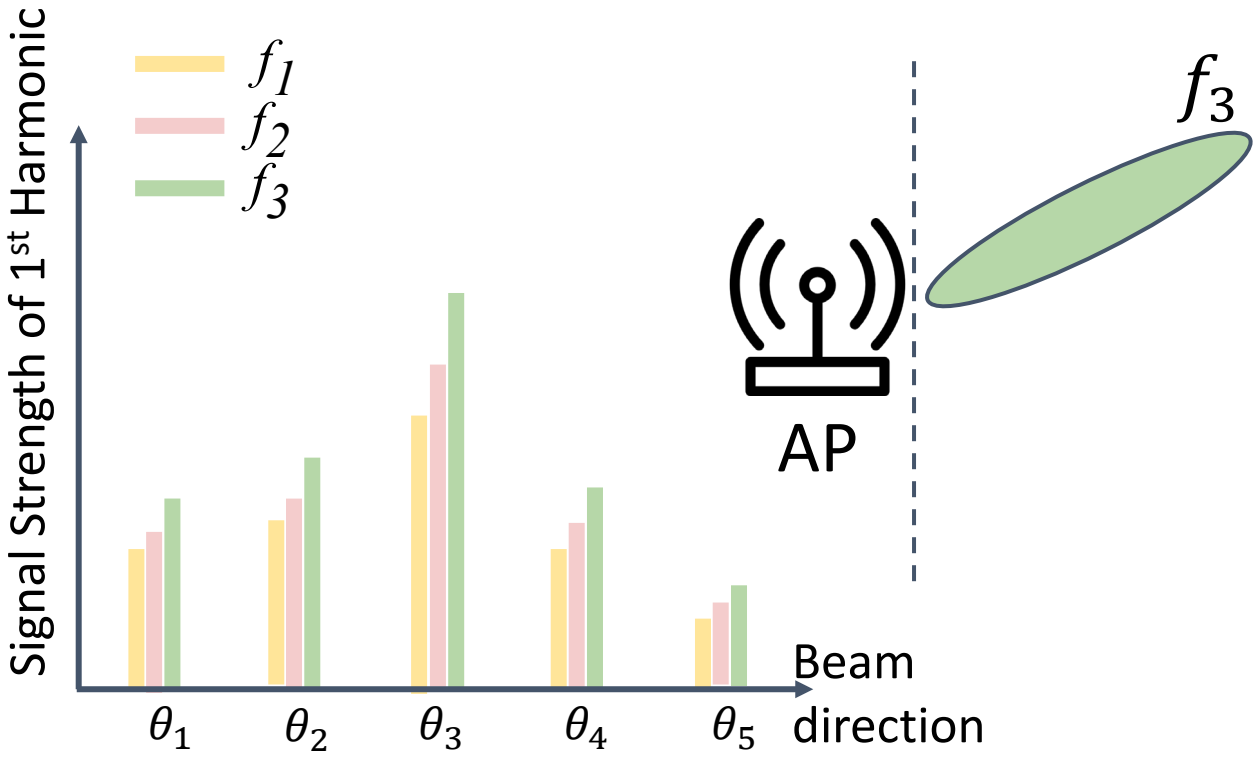

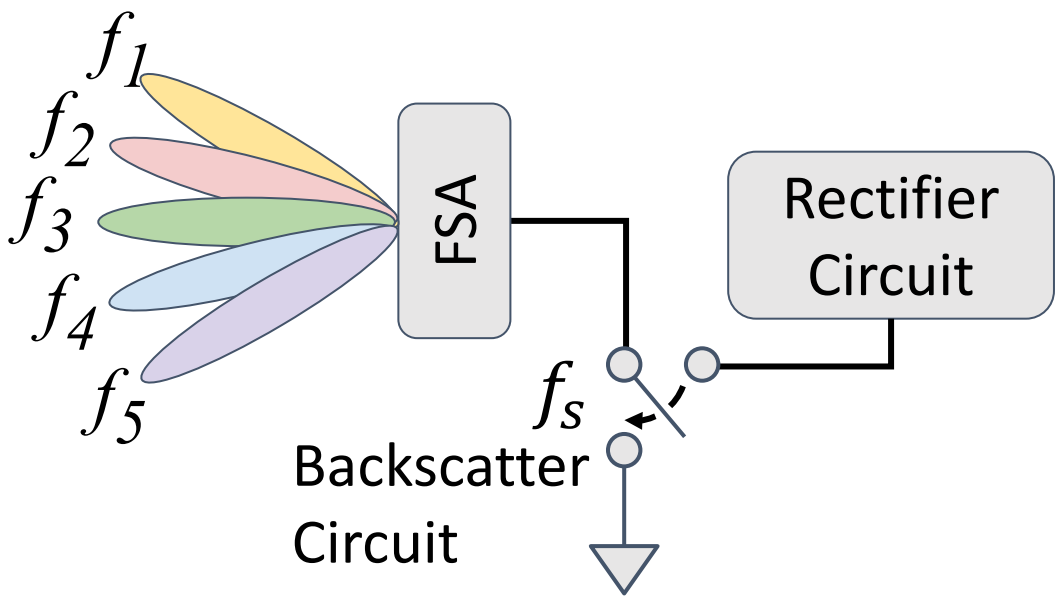

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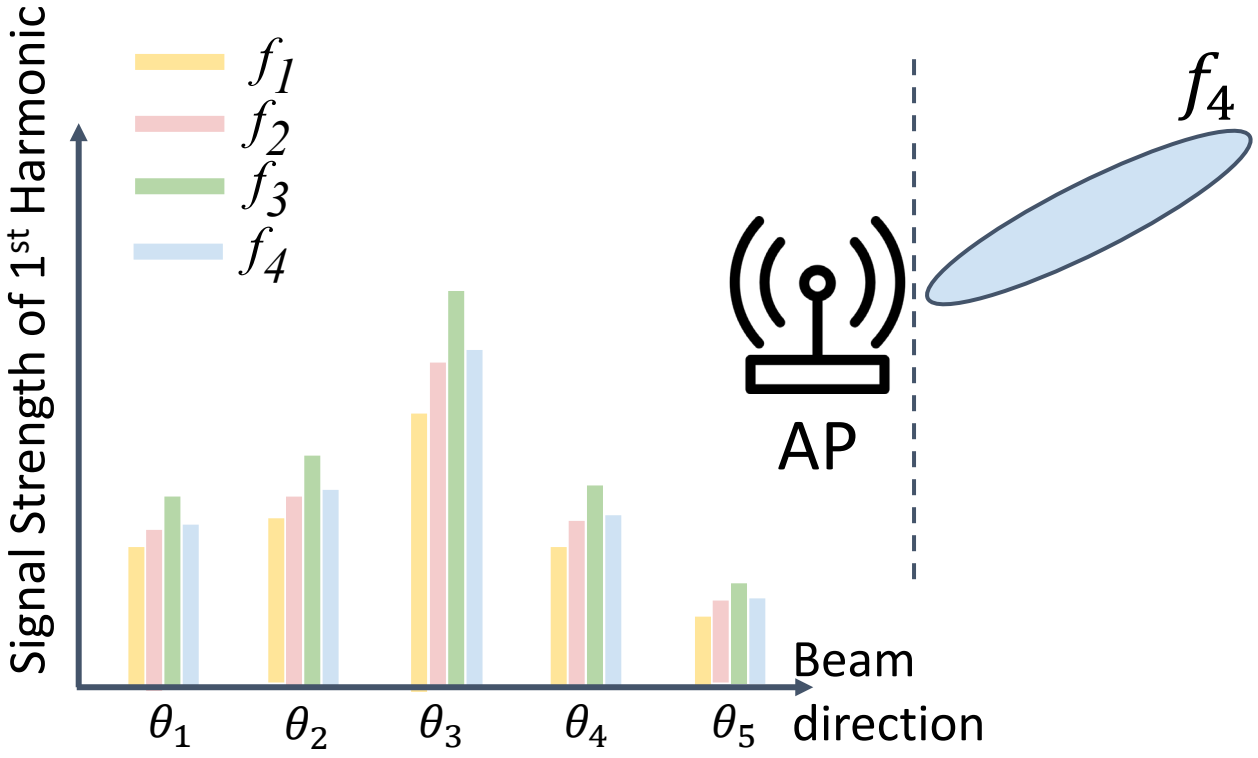

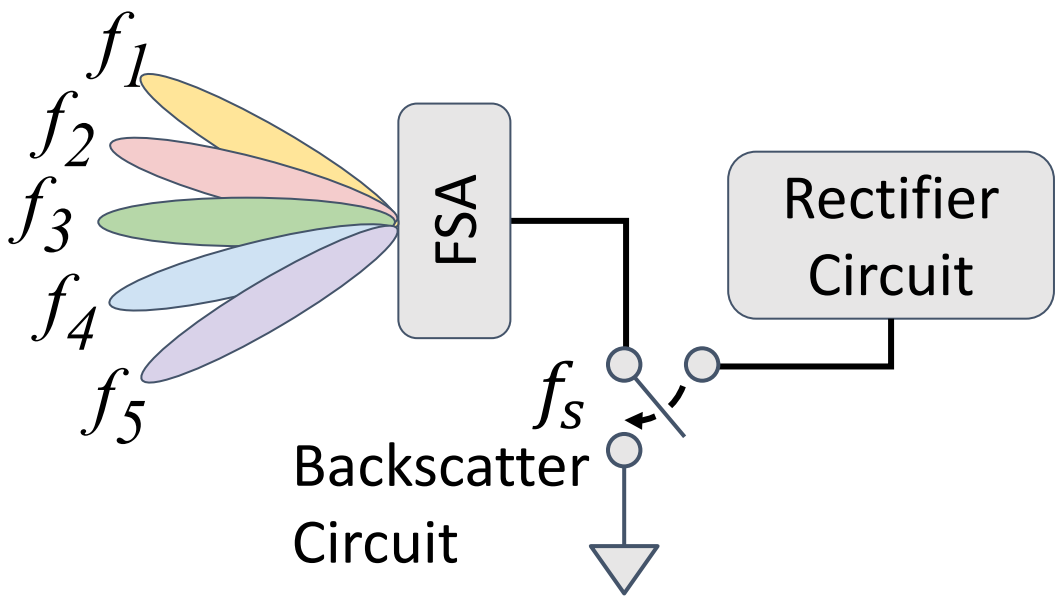

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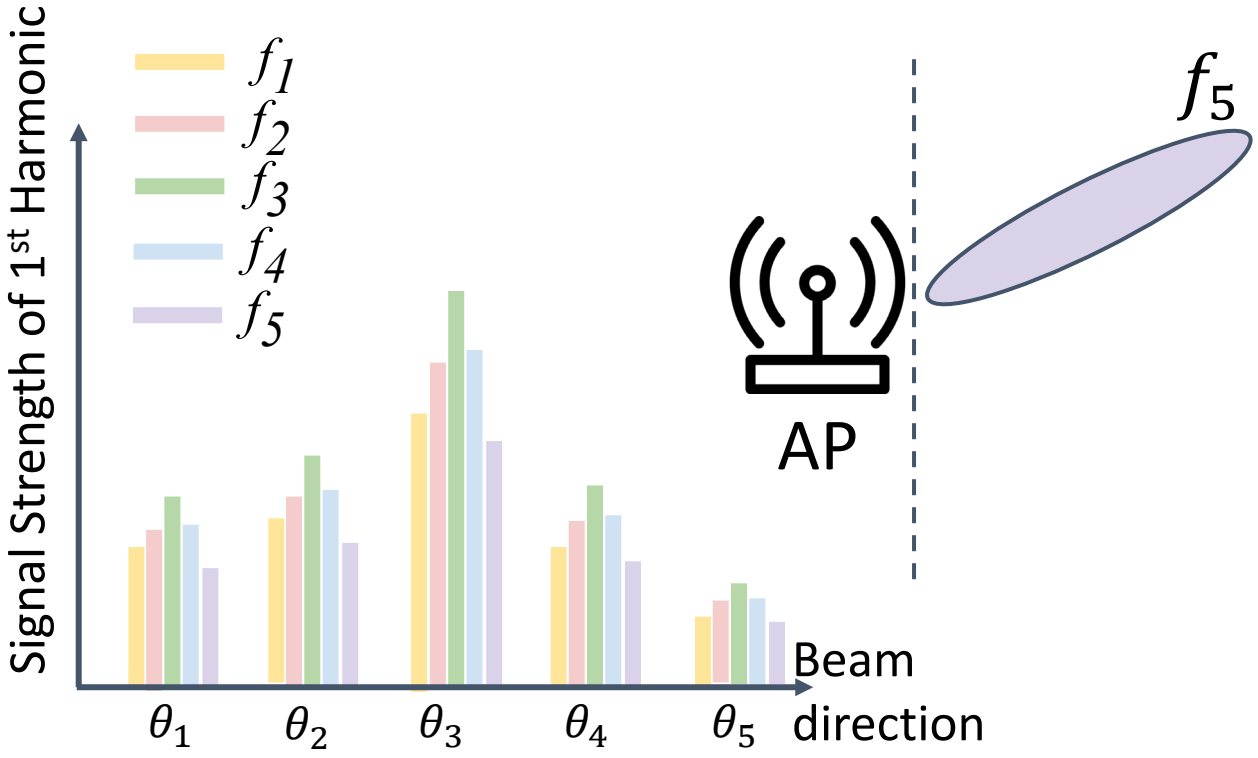

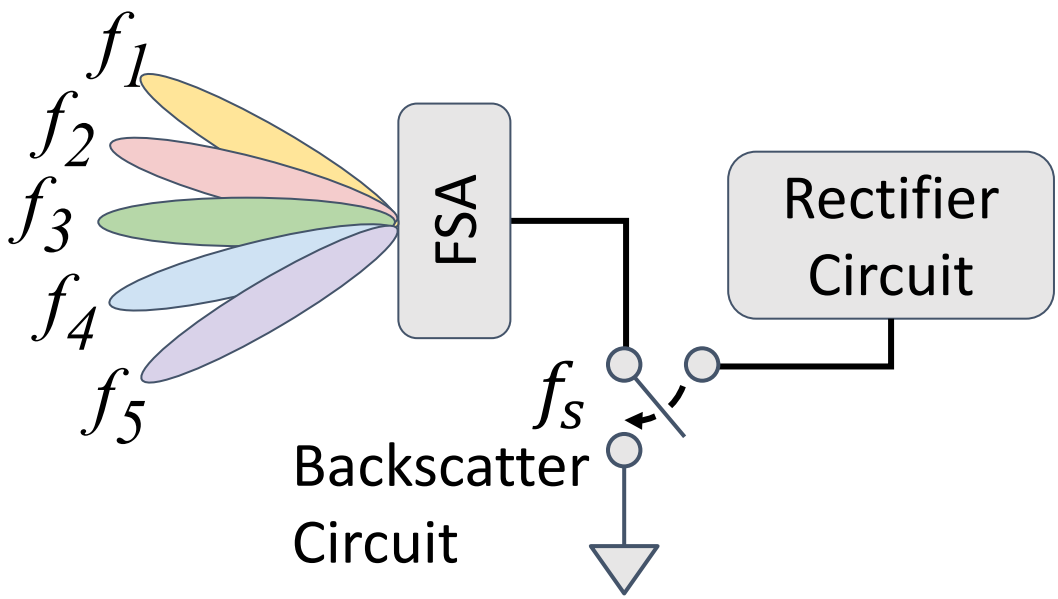

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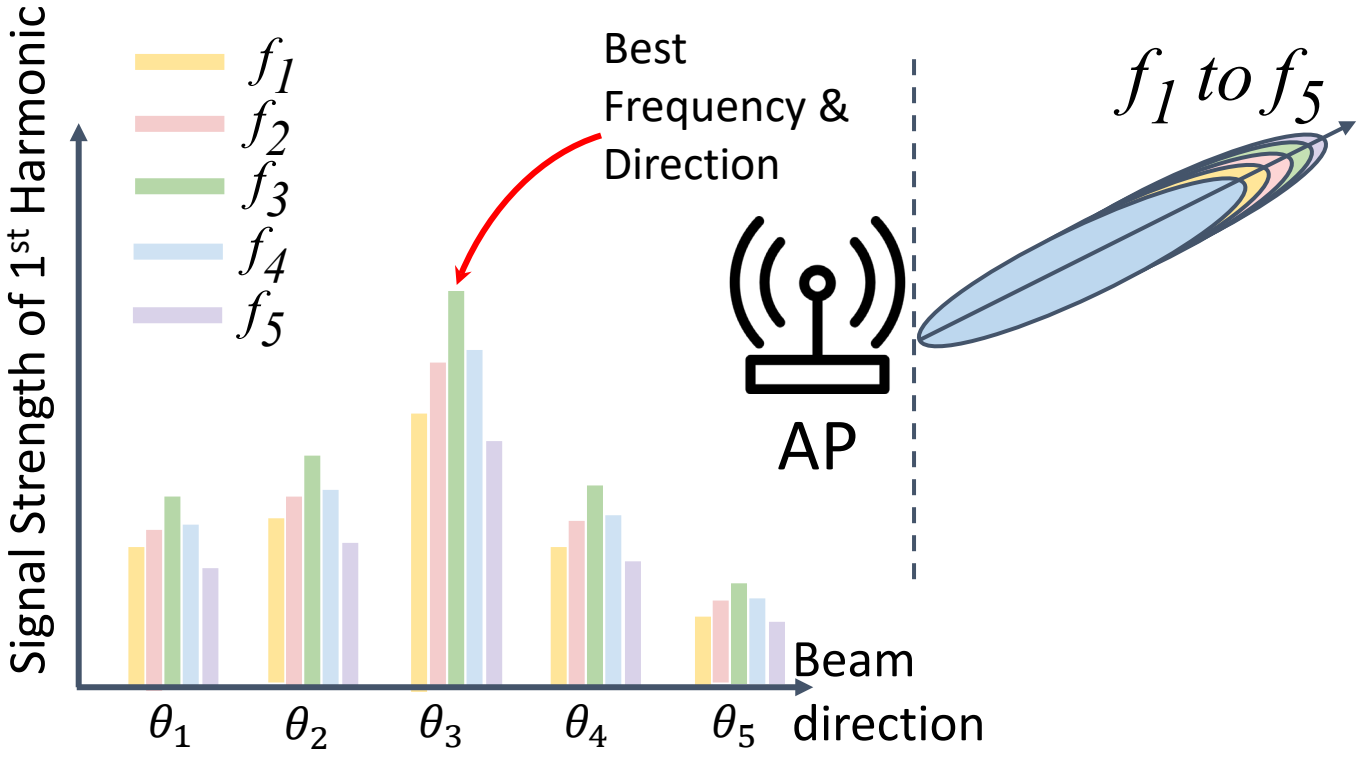
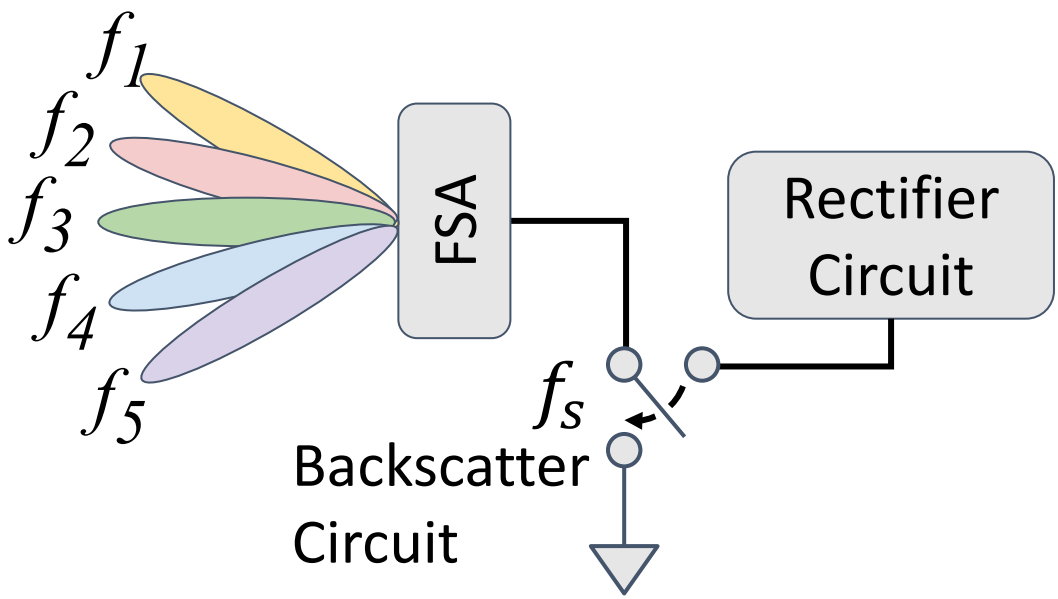
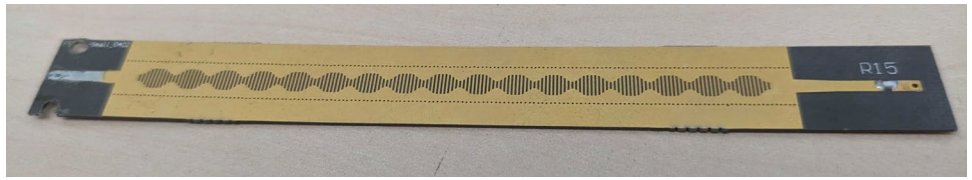


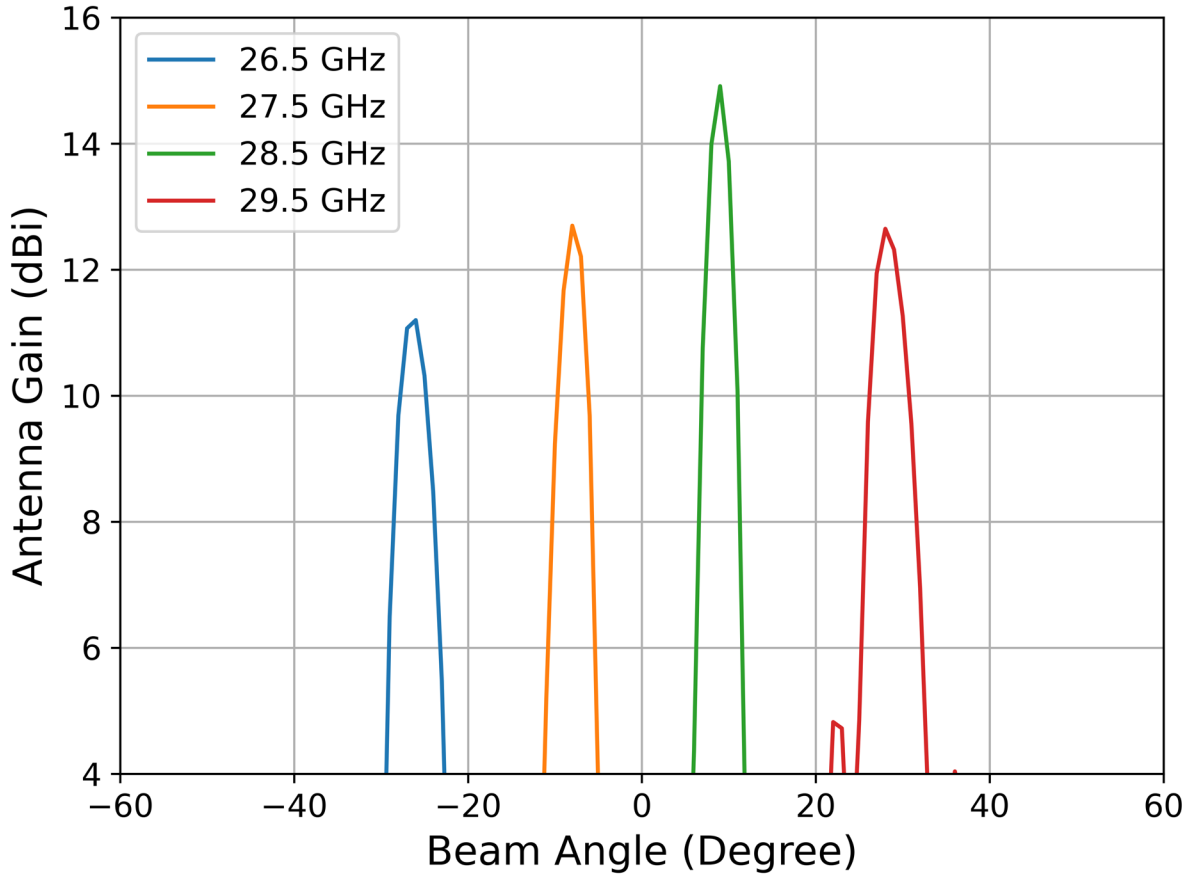


Evaluation

Our FSA Design



$110 \times 7 \times 0.5\ mm$



Our FSA design has high antenna gain and wide coverage angles

Harvest Power vs Distance Measurement

Our system can power up IoT sensor from more than 12 meters

Conclusion

- Investigated the feasibility of different frequency bands for wireless power transfer and shows mmWave is the best candidate

- Proposed a mmWave energy harvesting system and a beam-alignment protocol based on passive beamforming and backscatter technique