Braidio: An Integrated Active-Passive Radio for Mobile Devices with Asymmetric Energy Budgets

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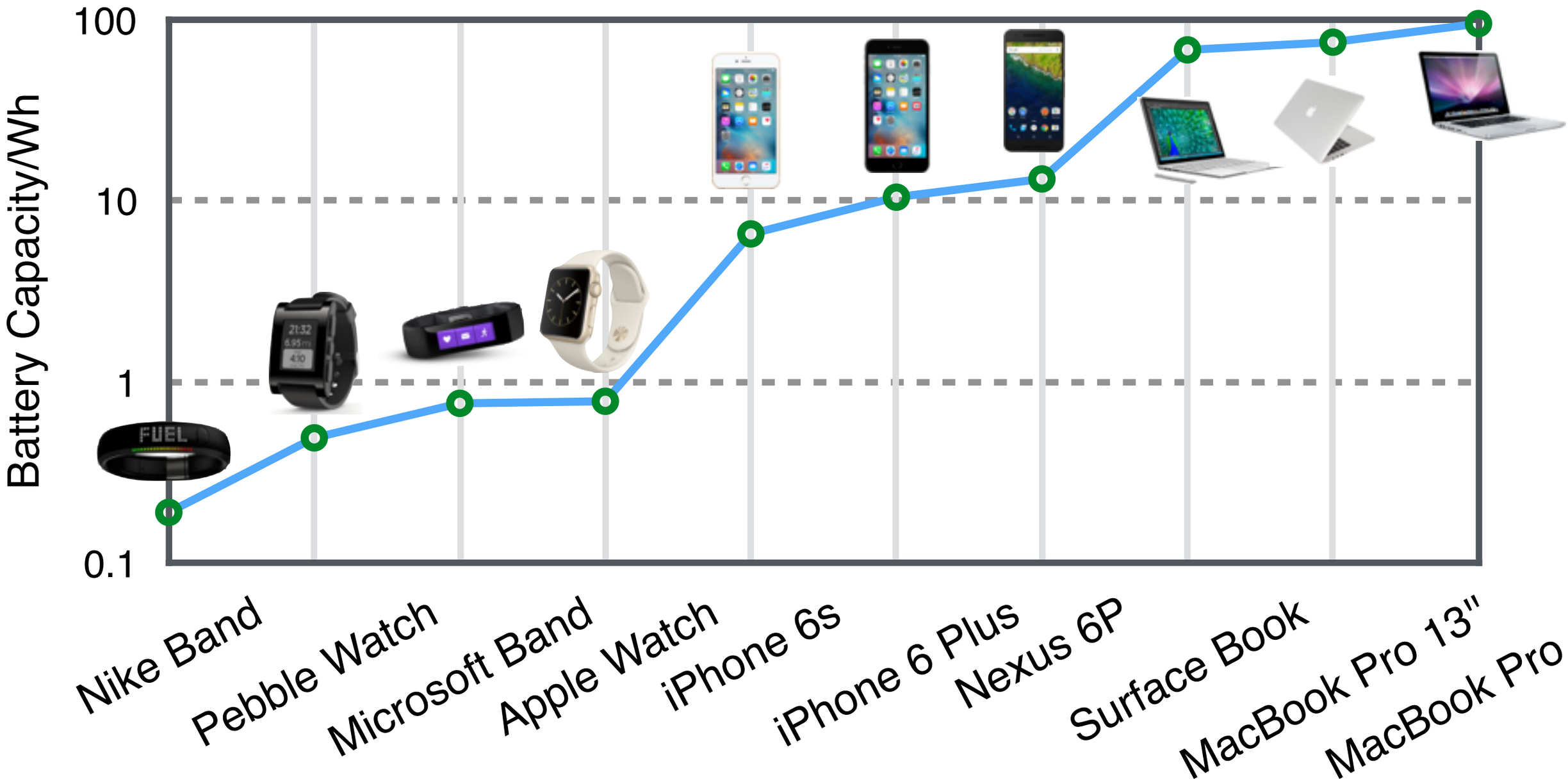
University of Massachusetts Amherst

Variability in battery capacity



Three orders of magnitude variation in battery capacity

Asymmetric battery lifetime

Sensor Data

50mW

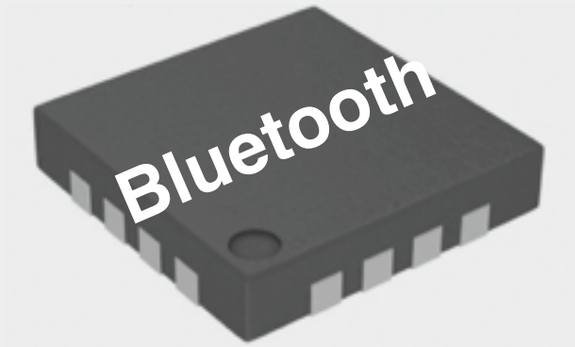
10%

50mW

90%

Devices with smaller batteries deplete far ahead of those with larger batteries

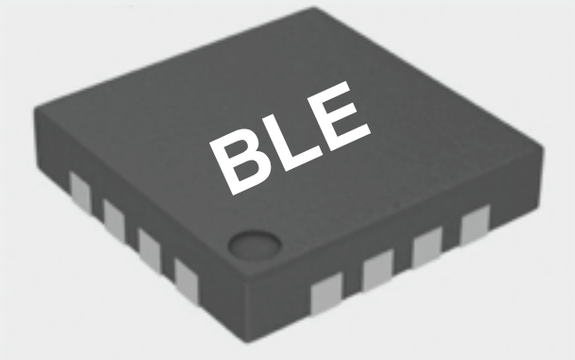
Symmetric power consumption



55~60mW

59~67mW

TX/RX
0.82~1.0



21~30mW

19mW

TX/RX
1.1~1.6

Can we design a power proportional radio?

Sensor Data

0.1mW

50mW

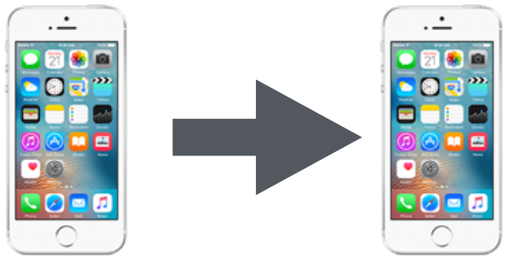
90%

90%

Can we create a radio which consumes power proportional to battery size?

Diversity of radio architectures

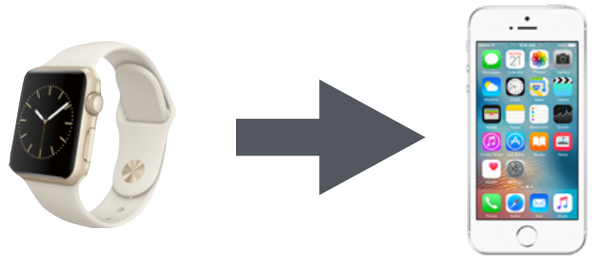
Active: Symmetric Radio



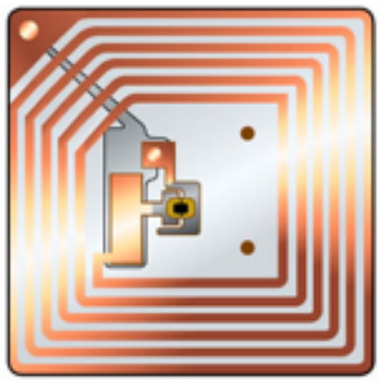
WiFi/ Bluetooth

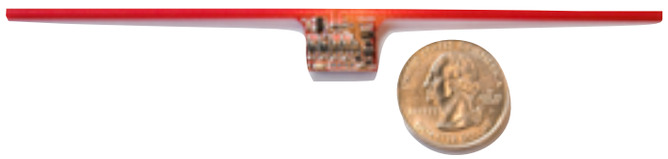
Bluetooth®

Backscatter: Low power transmitter

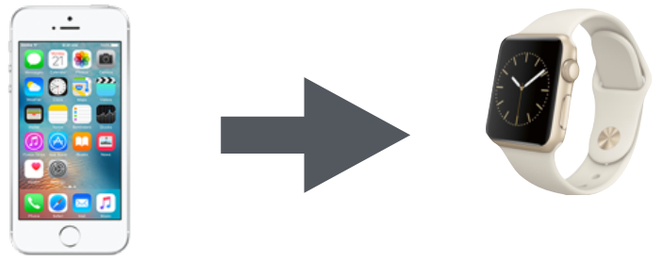


RFID Tag





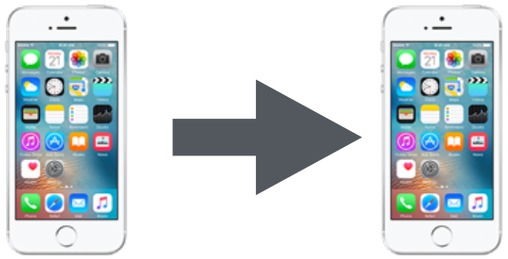
Passive: Low power receiver



AM receiver

Diversity of radio architectures

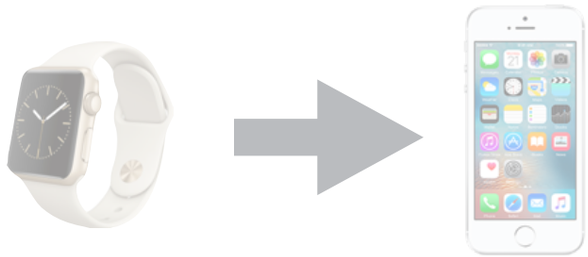
Active: Symmetric Radio



WiFi/ Bluetooth

Bluetooth®

Backscatter: Low power transmitter



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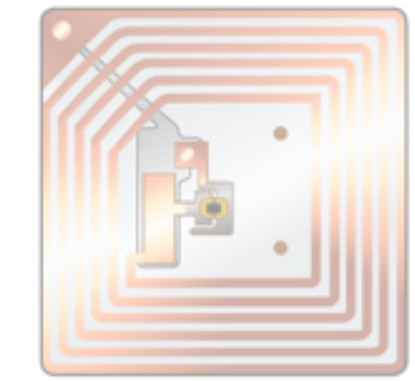
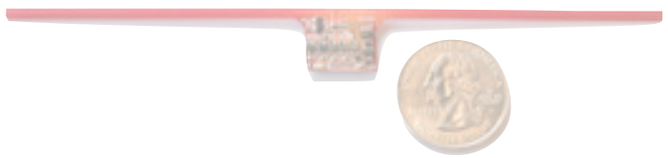
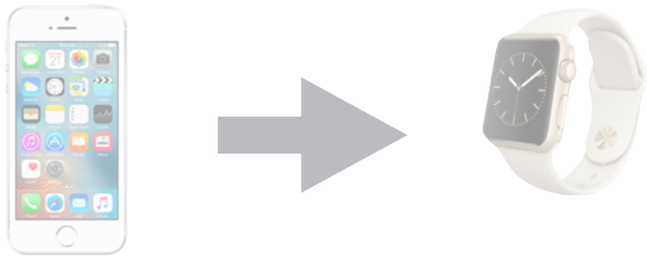




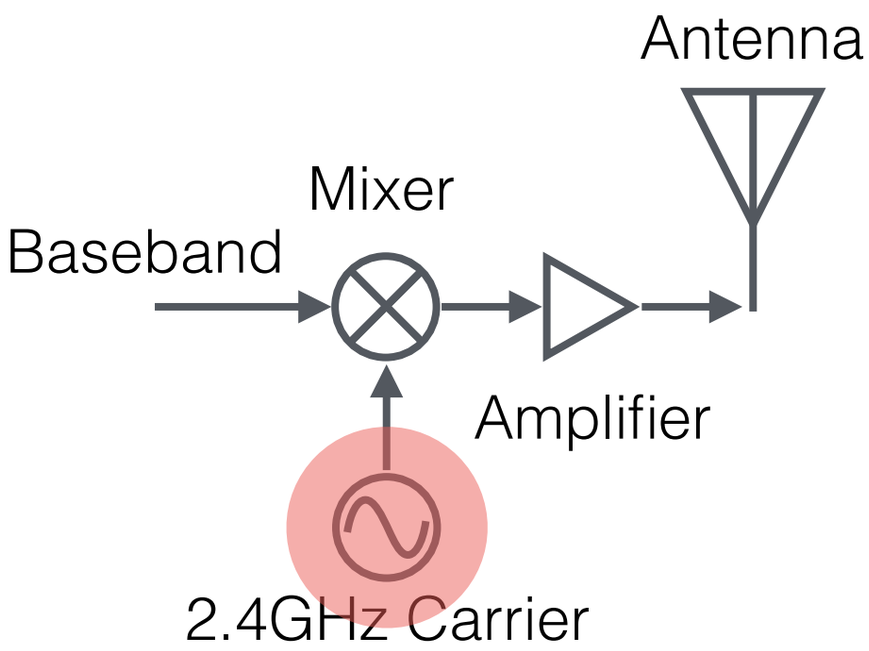
Passive: Low power receiver



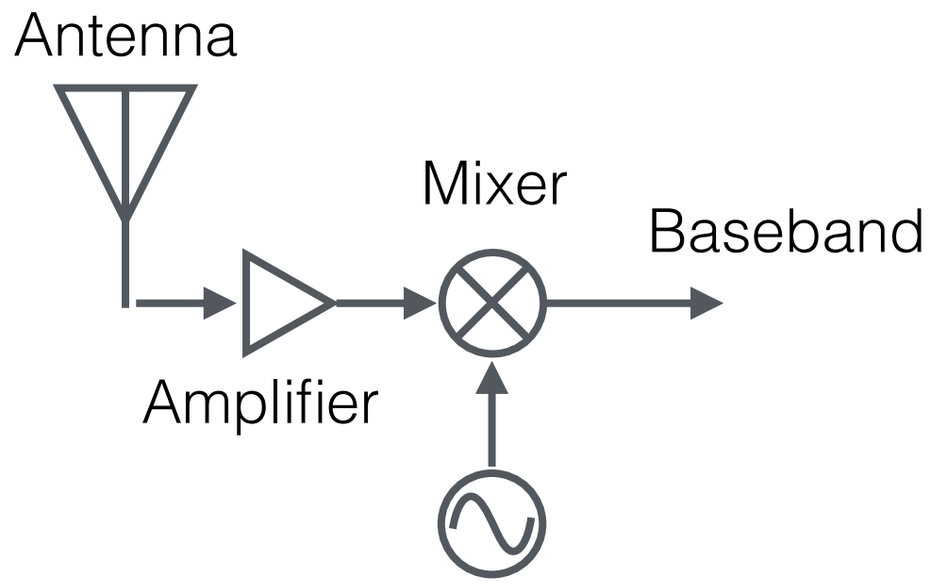
AM receiver

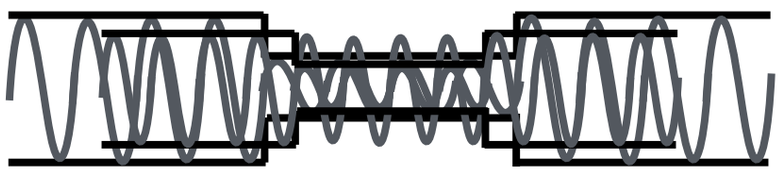
Symmetric active radio architecture

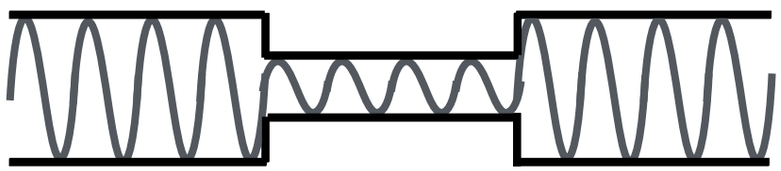
Active TX



Active RX



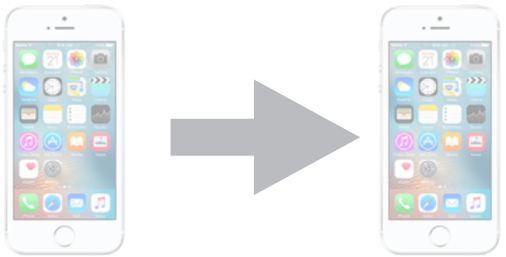




Similar power consumption at TX and RX

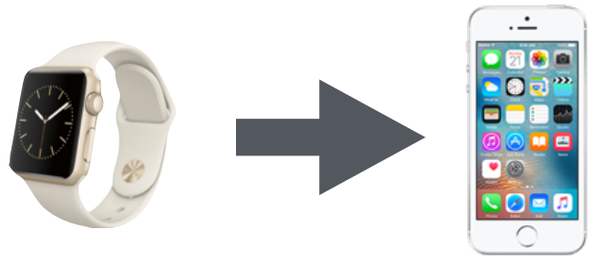
Diversity of radio architectures

Active: Symmetric Radio

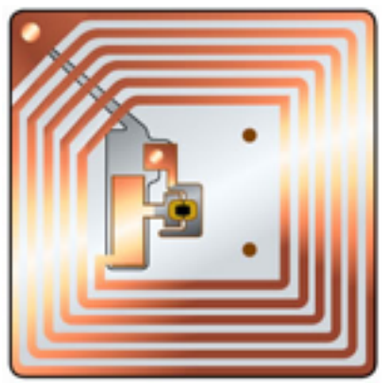


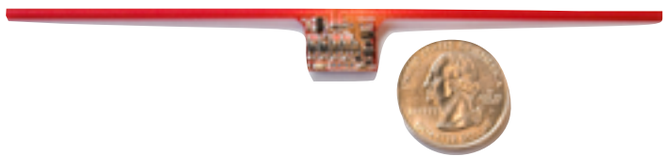
WiFi/ Bluetooth

Backscatter: Low power transmitter

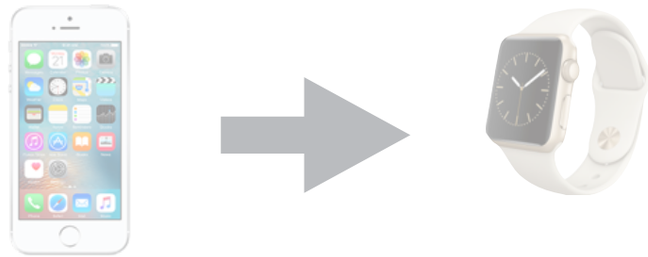


RFID Tag





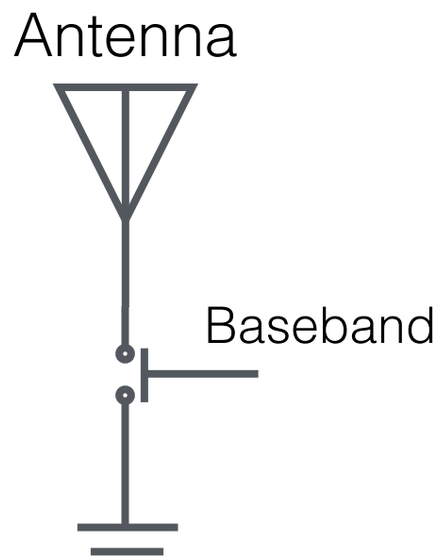
Passive: Low power receiver



AM receiver

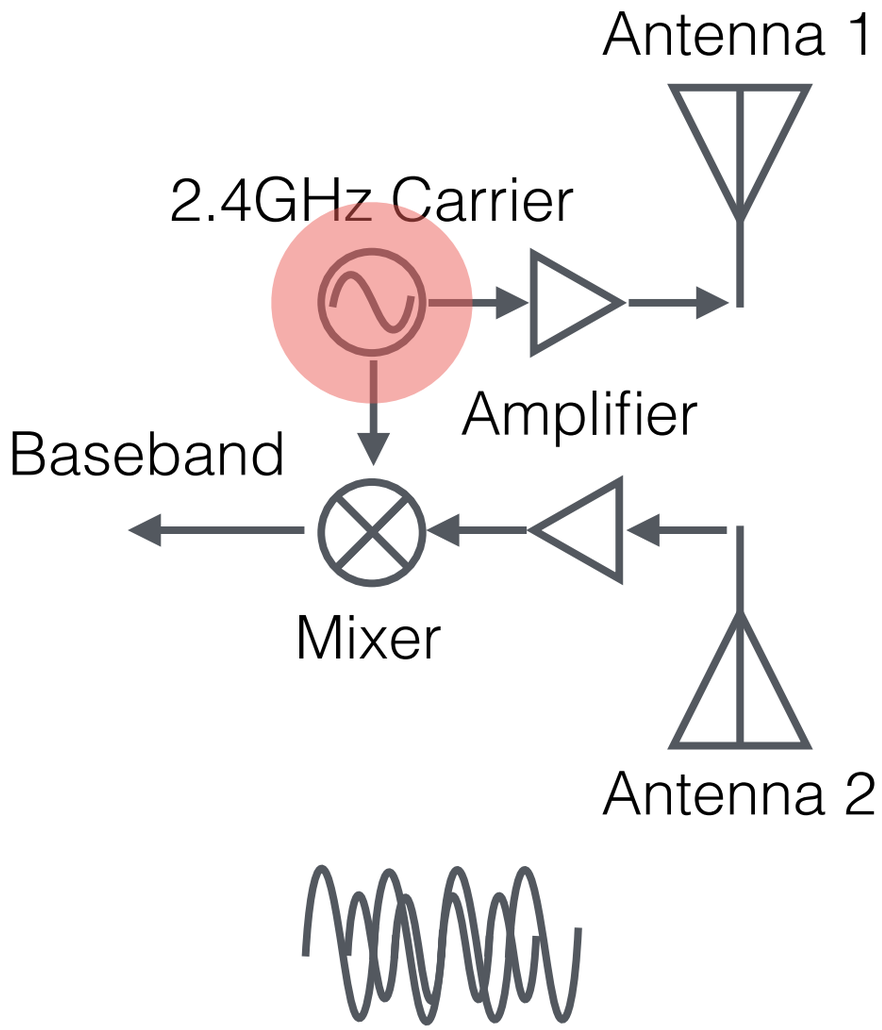
Backscatter reader architecture

Backscatter transmitter

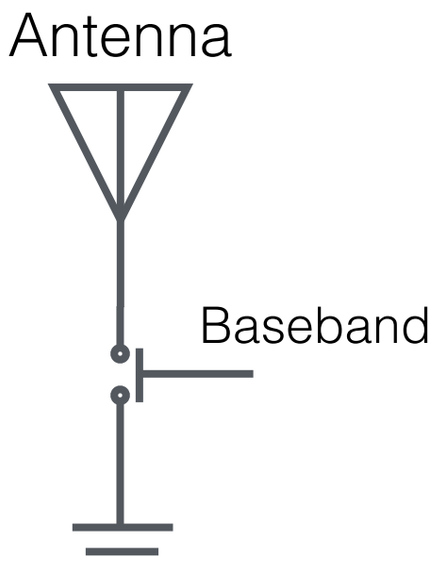


Backscatter reader architecture

Backscatter reader



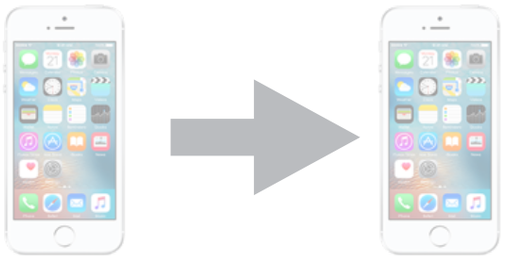
Backscatter transmitter



Much less power at TX but reduced range

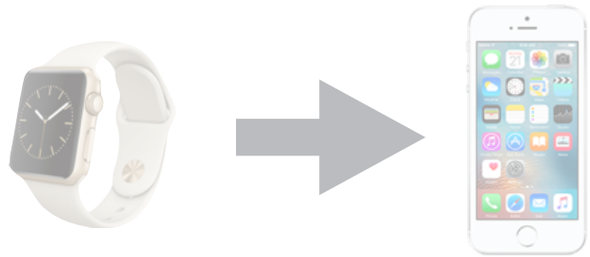
Diversity of radio architectures

Active: Symmetric Radio



WiFi/ Bluetooth

Backscatter: Low power transmitter



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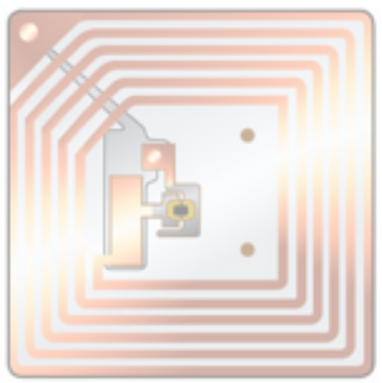
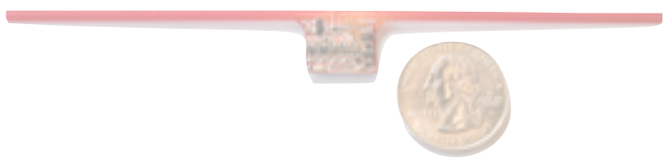
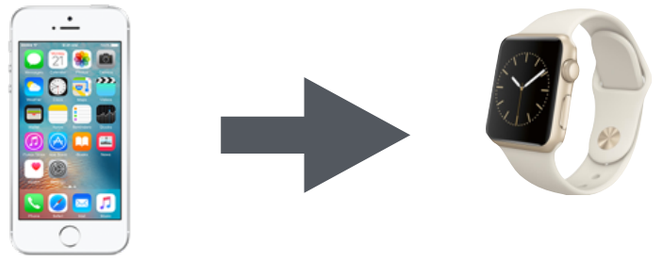




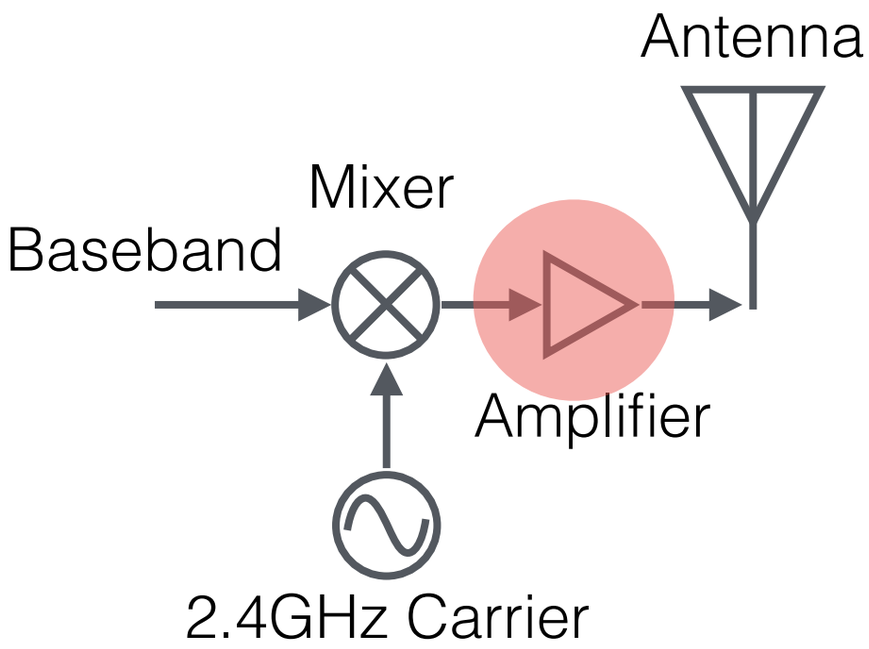
Passive: Low power receiver



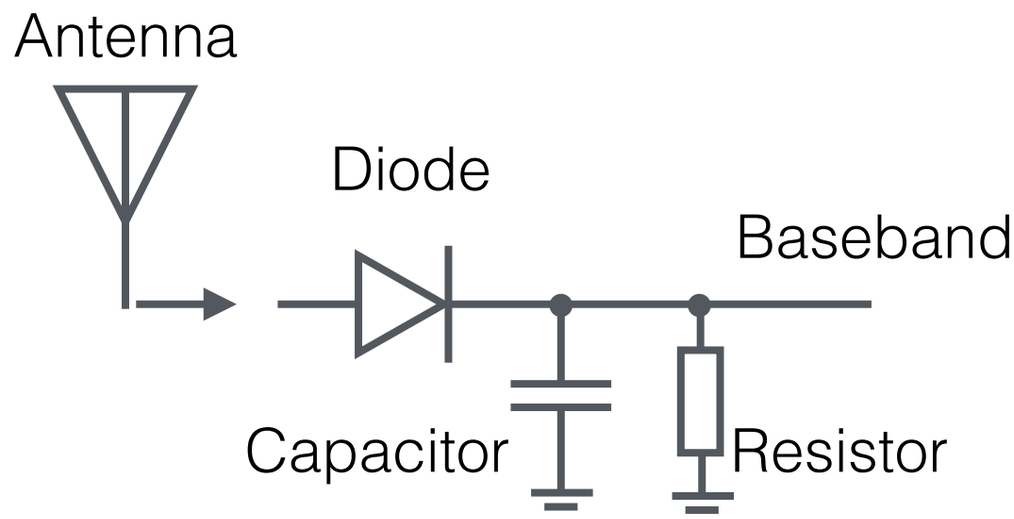
AM receiver

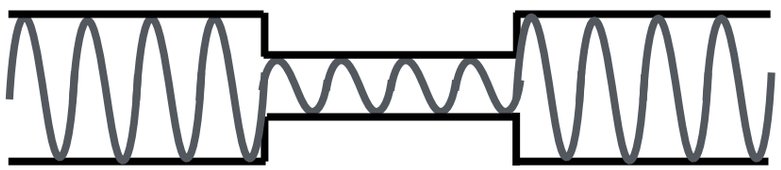
Passive receiver architecture

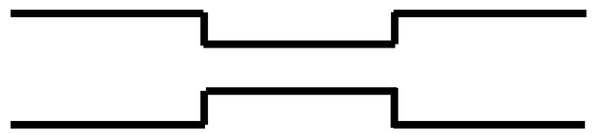
Active TX



Passive RX







Much less power at RX but reduced range

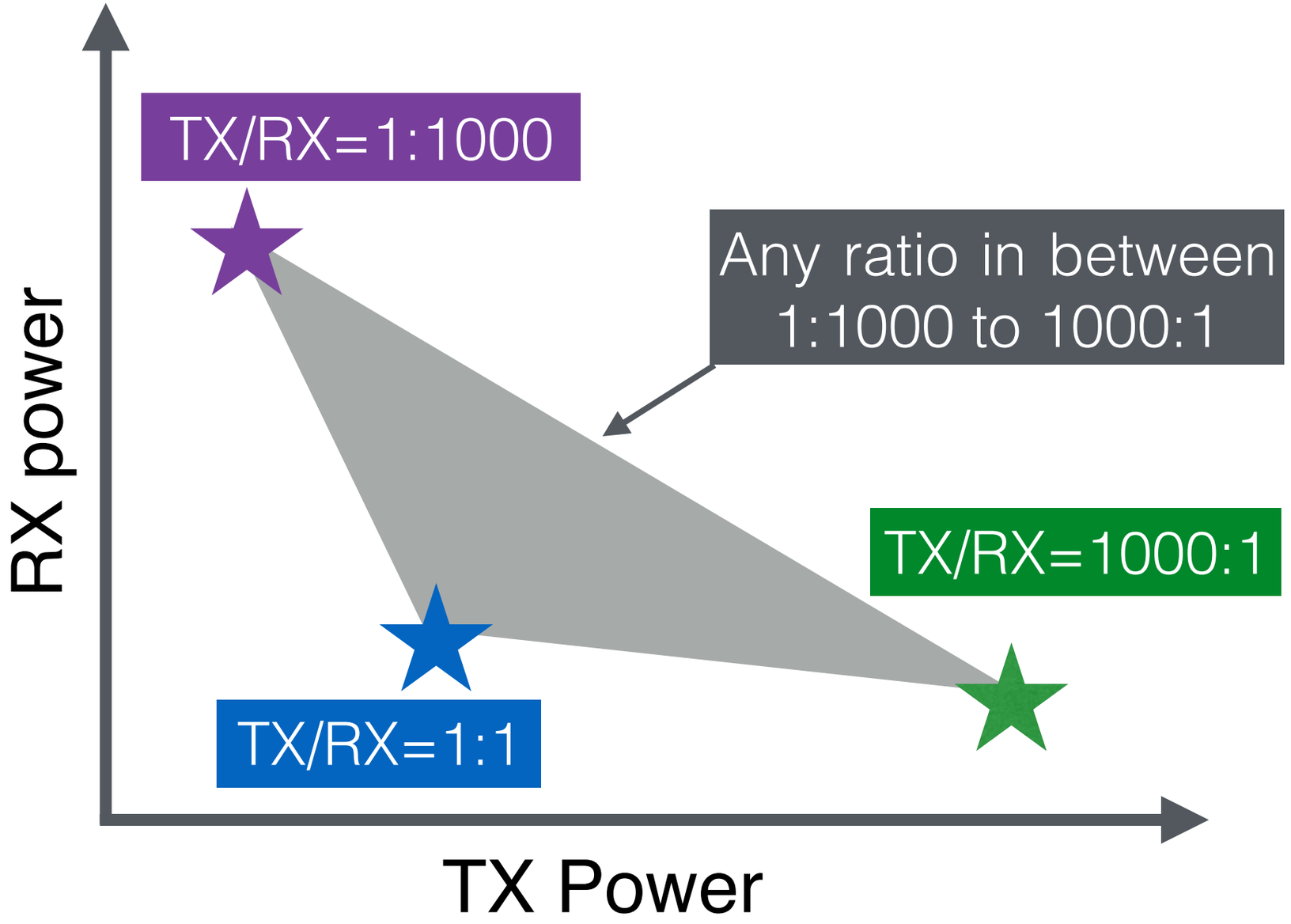
Power consumption of radios

Radio type	TX	RX	TX/RX
Active	20mW	20mW	1
Backscatter	20mW	0.02mW	1000:1
Passive	0.02mW	20mW	1:1000

Can we take advantage of these architectures?

Architecture of radios

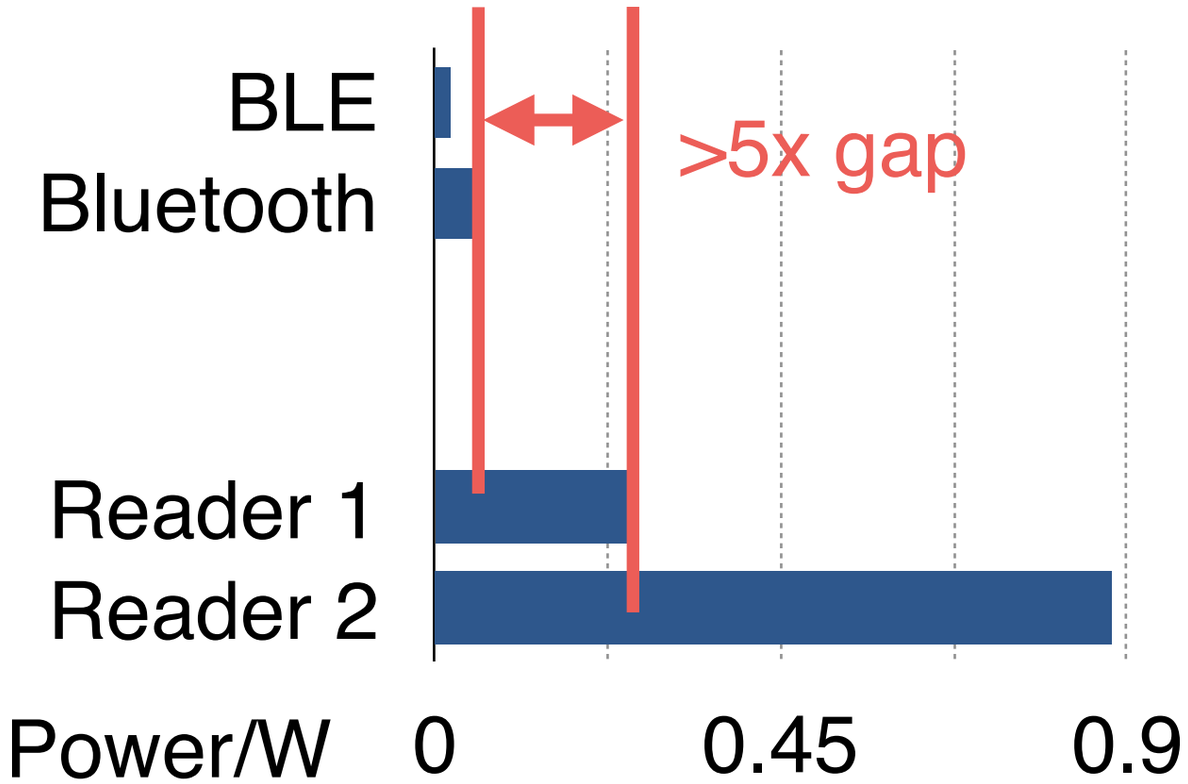
Achievable region



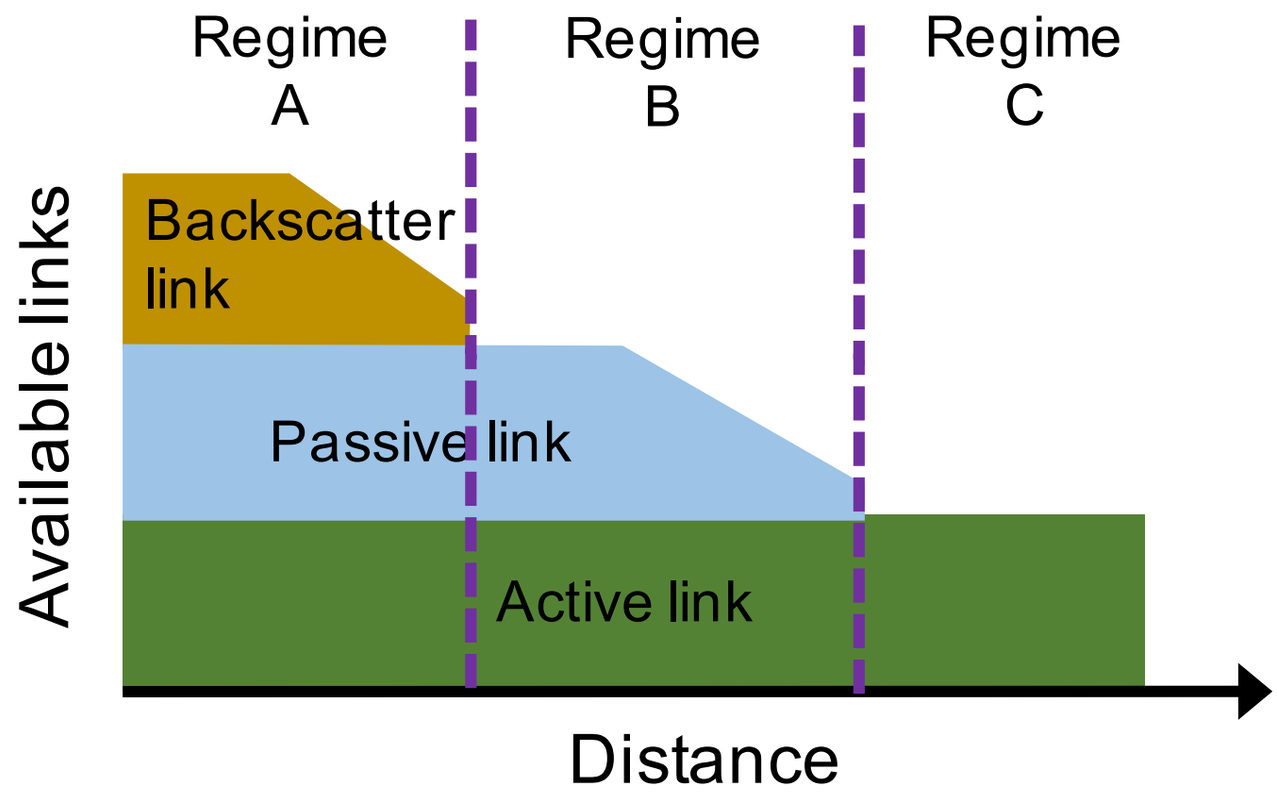
Available radio

Radio type	TX/RX
Active	1

Challenges in combining three modes

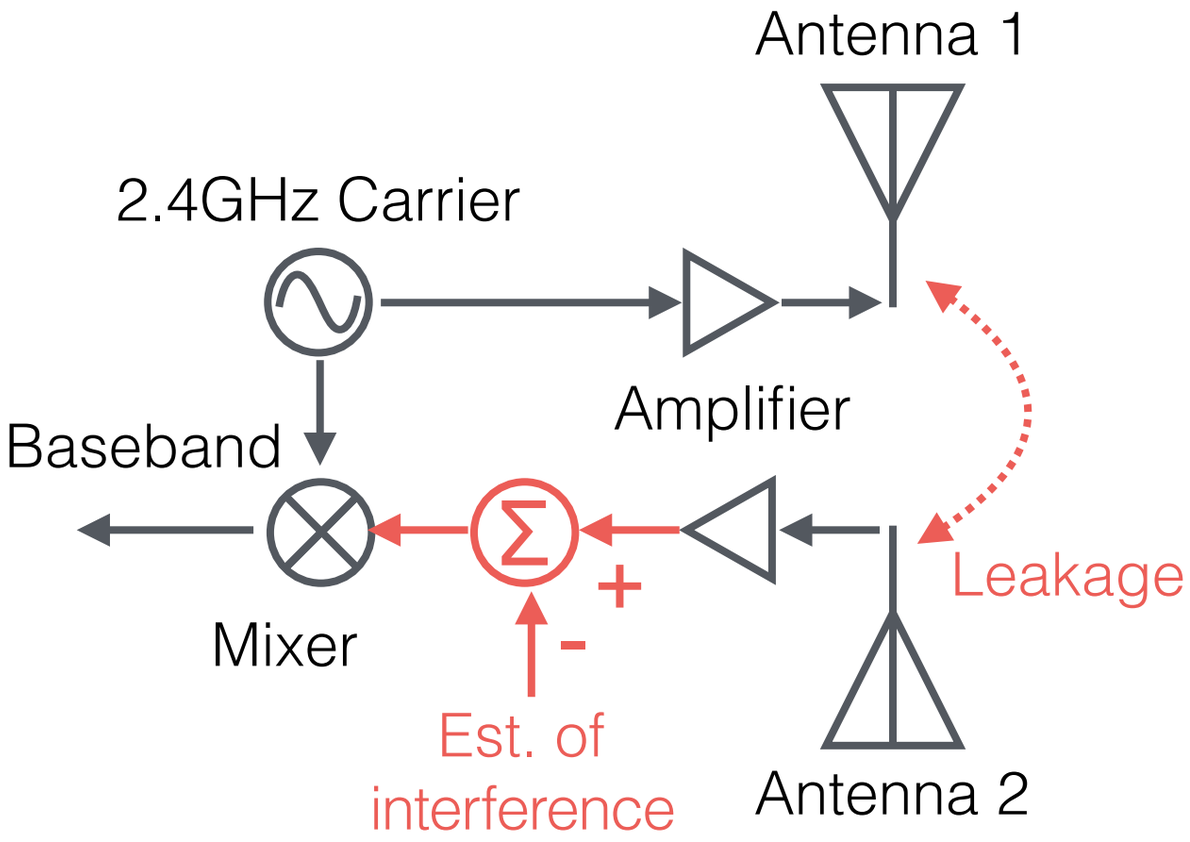


Backscatter RX consumes excessive power

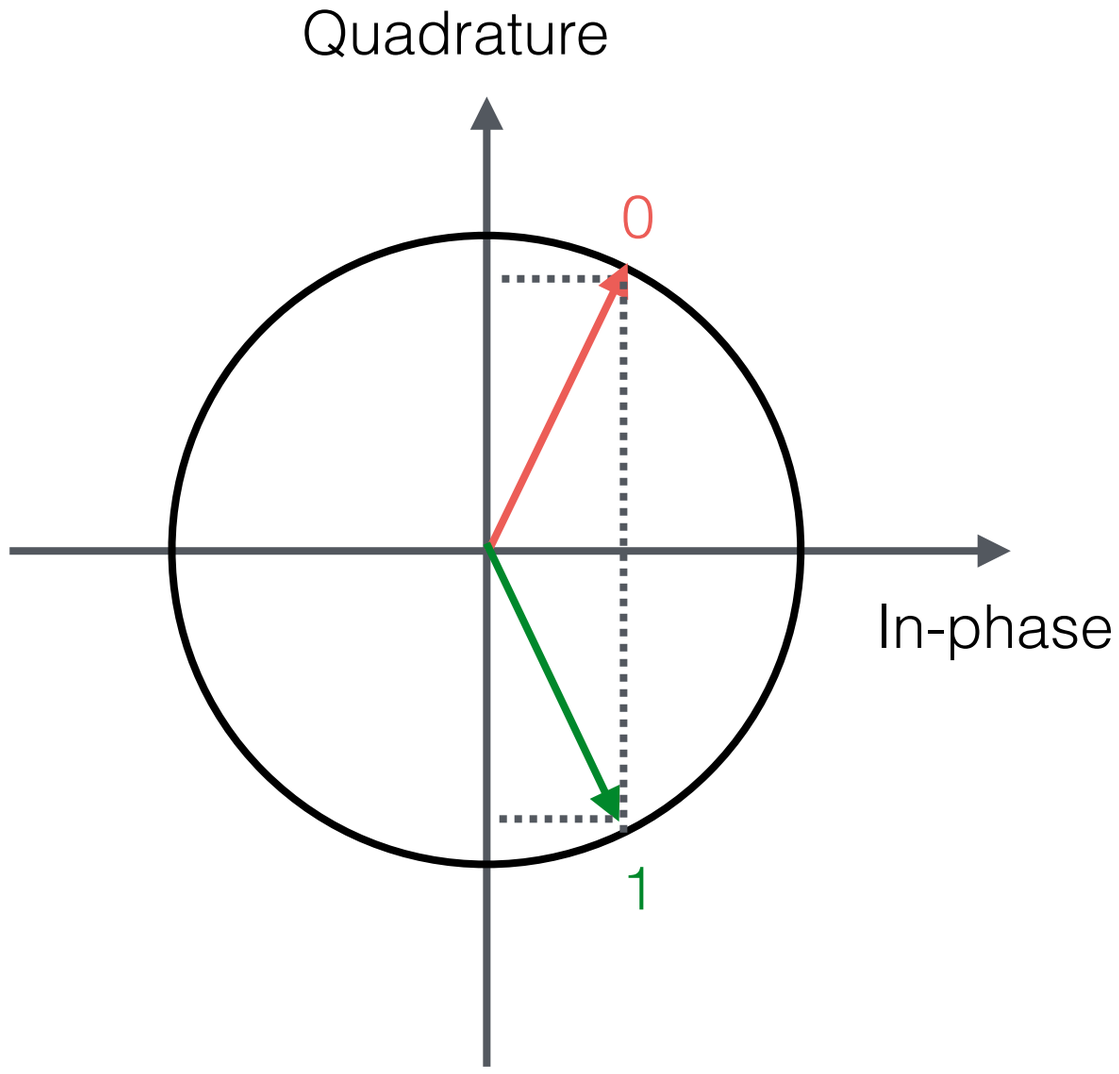


Different types of radios have different working ranges

Why is a Backscatter reader power hungry?

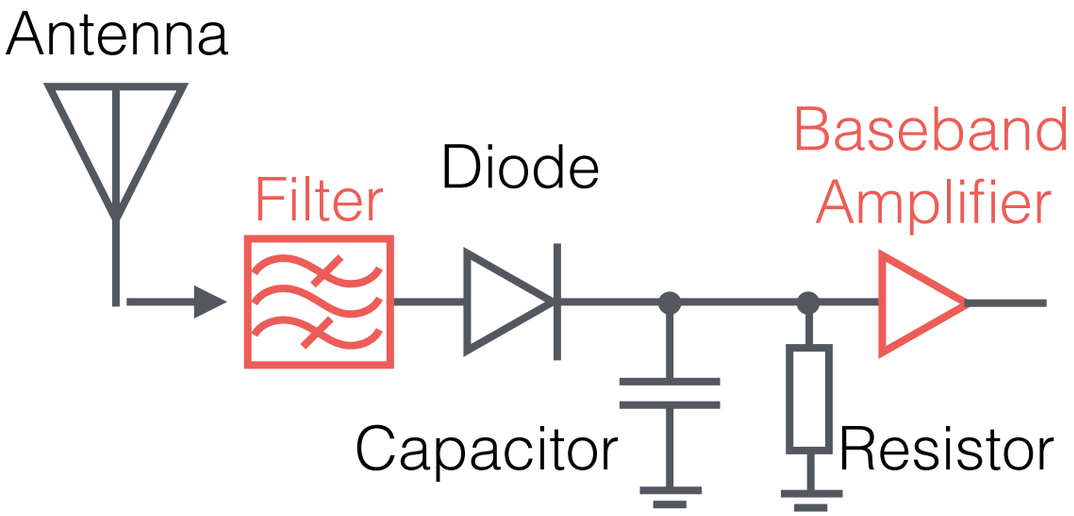


Self-interference cancellation

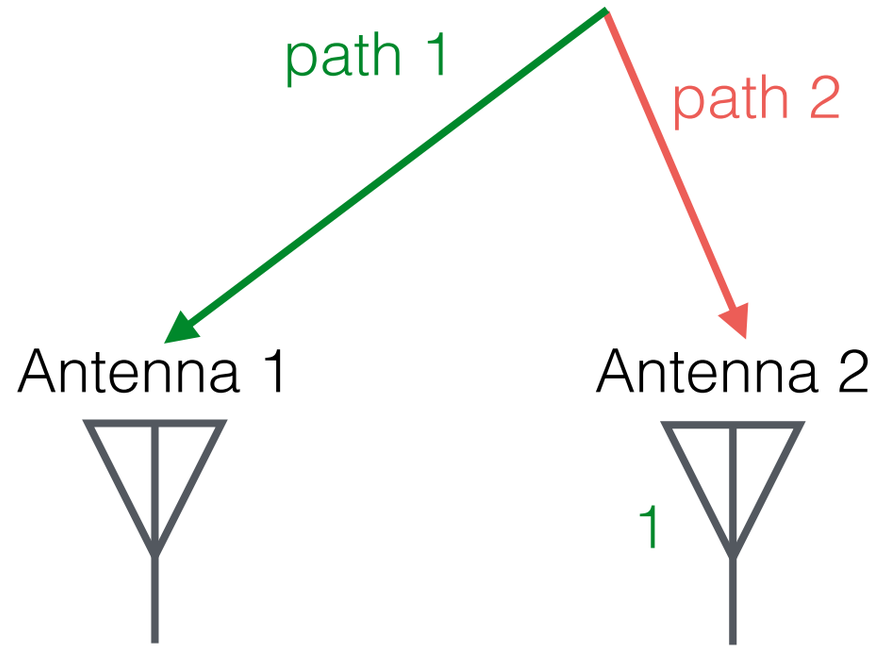


Active IQ Receiver

Reducing power of Backscatter reader

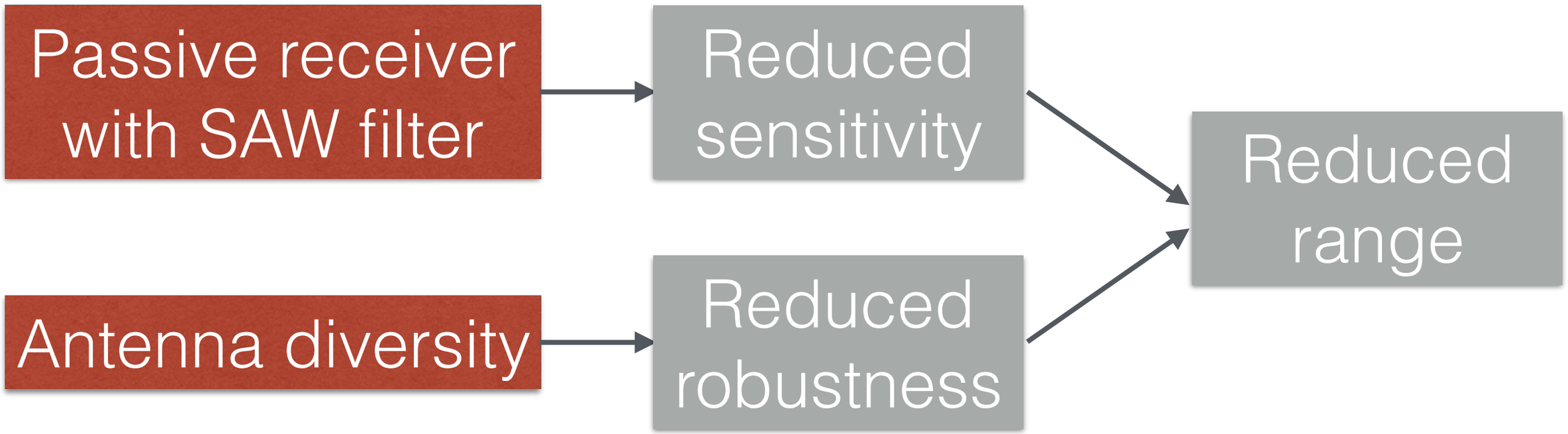


Passive receiver with SAW filter



Antenna diversity

Bradio Backscatter RX: Design Tradeoffs

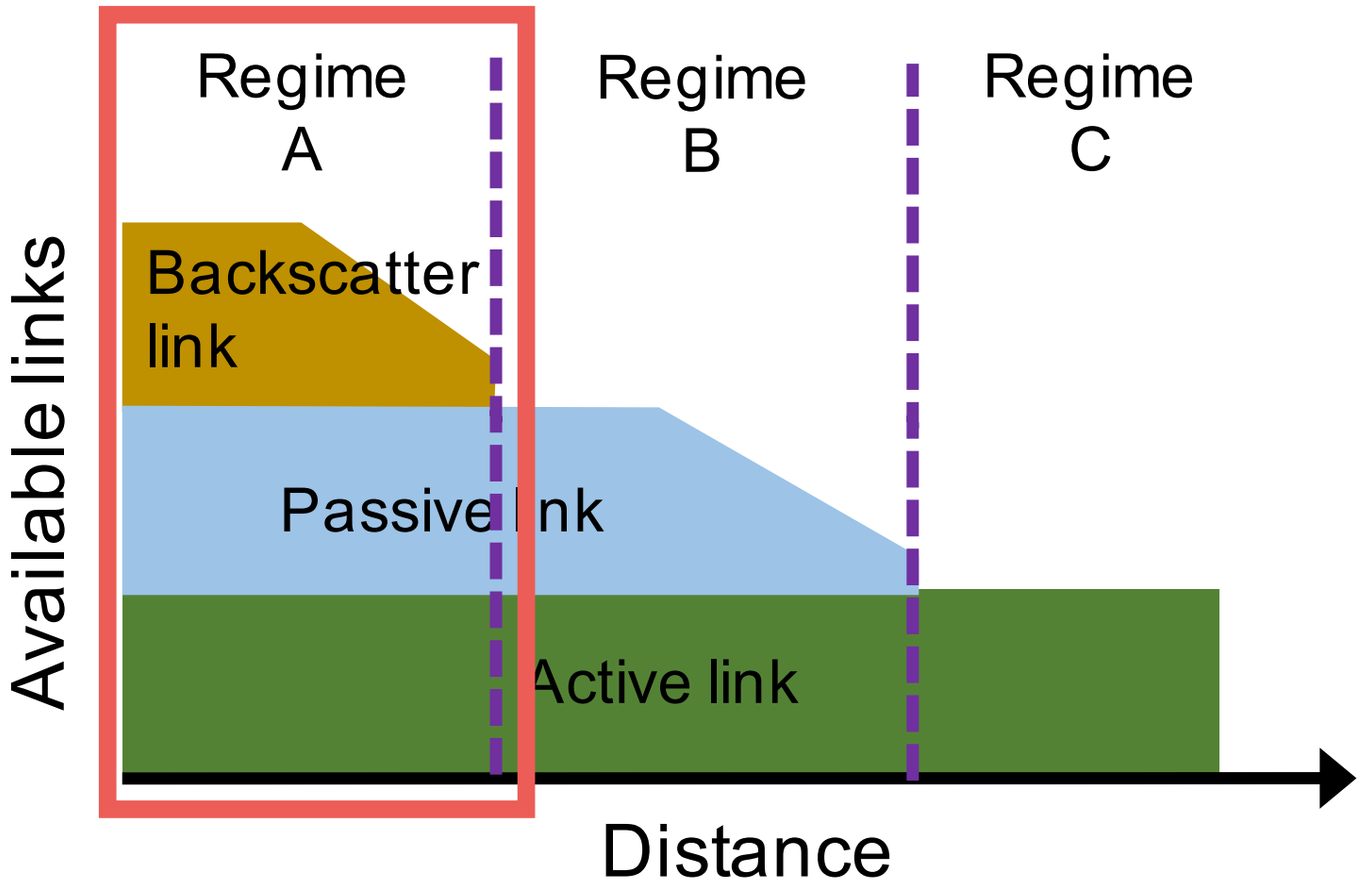


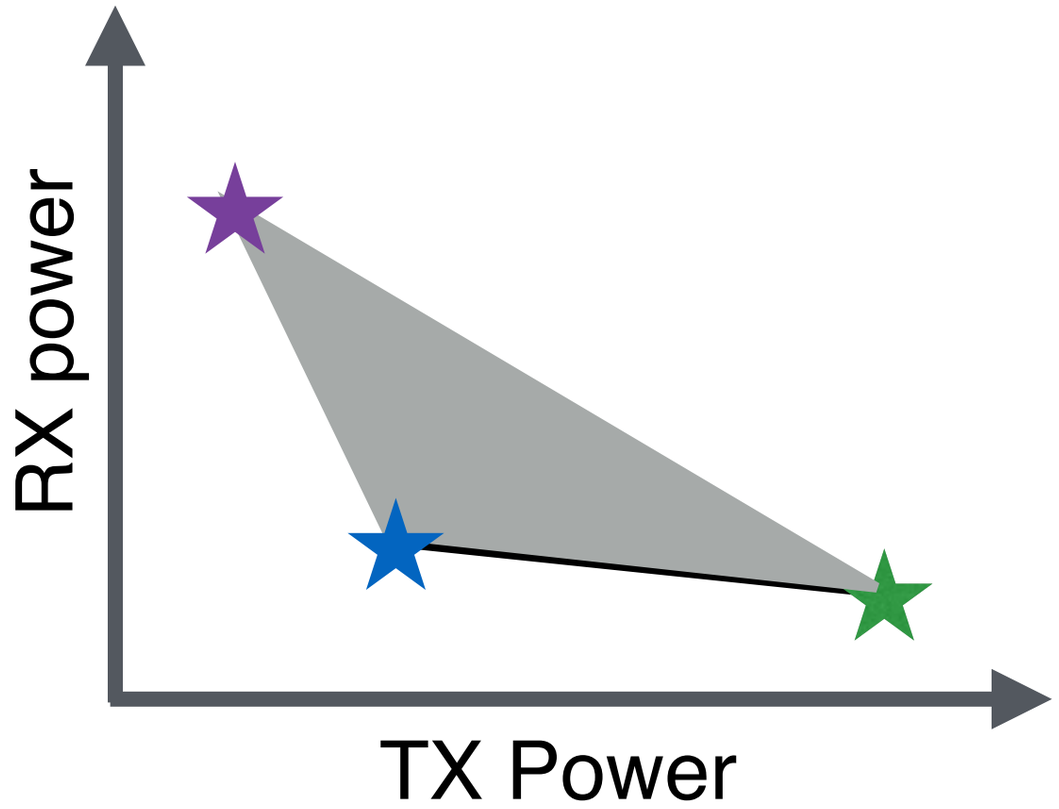
Active radio as a safety net

What if the Braidio backscatter mode fails?

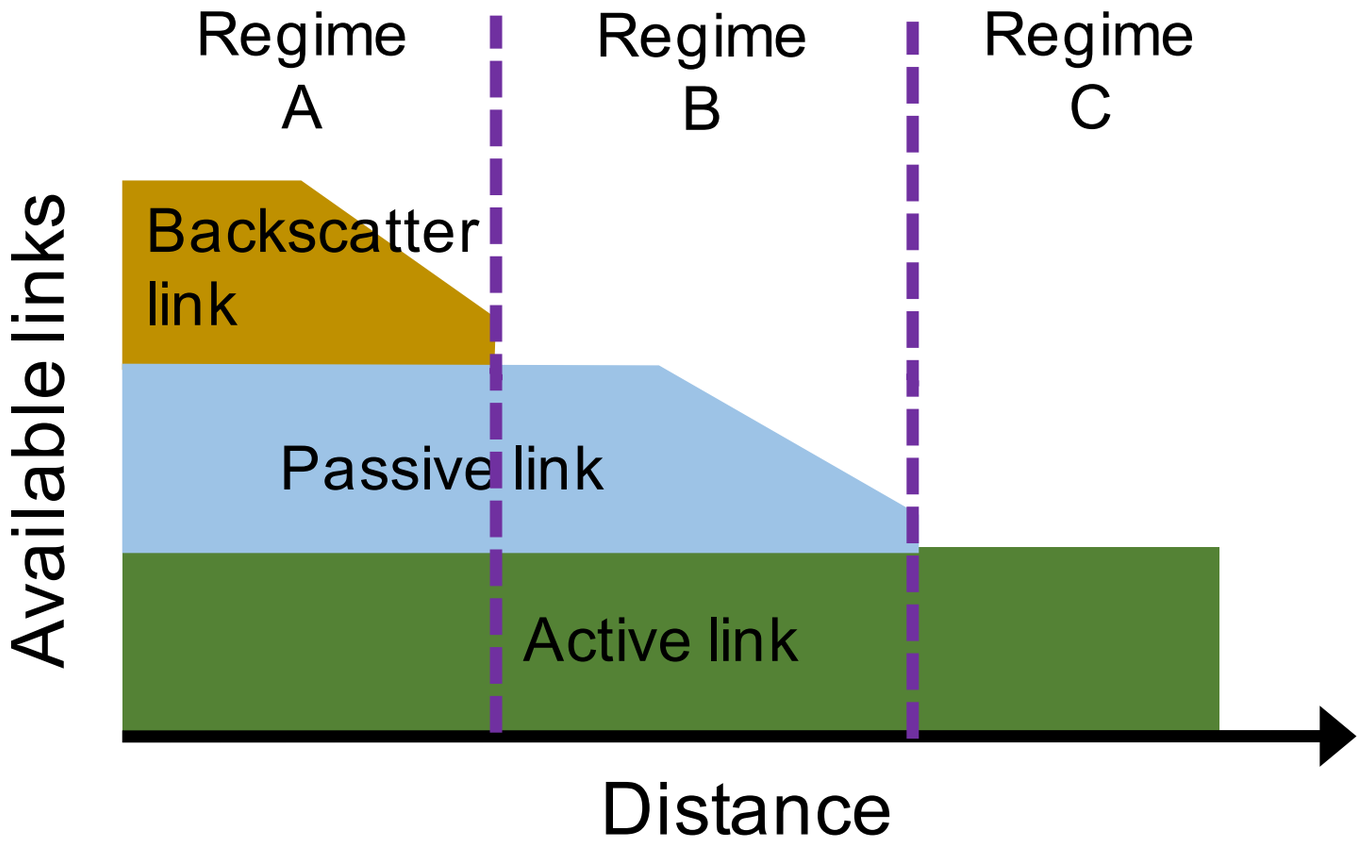
Active radio as safety net

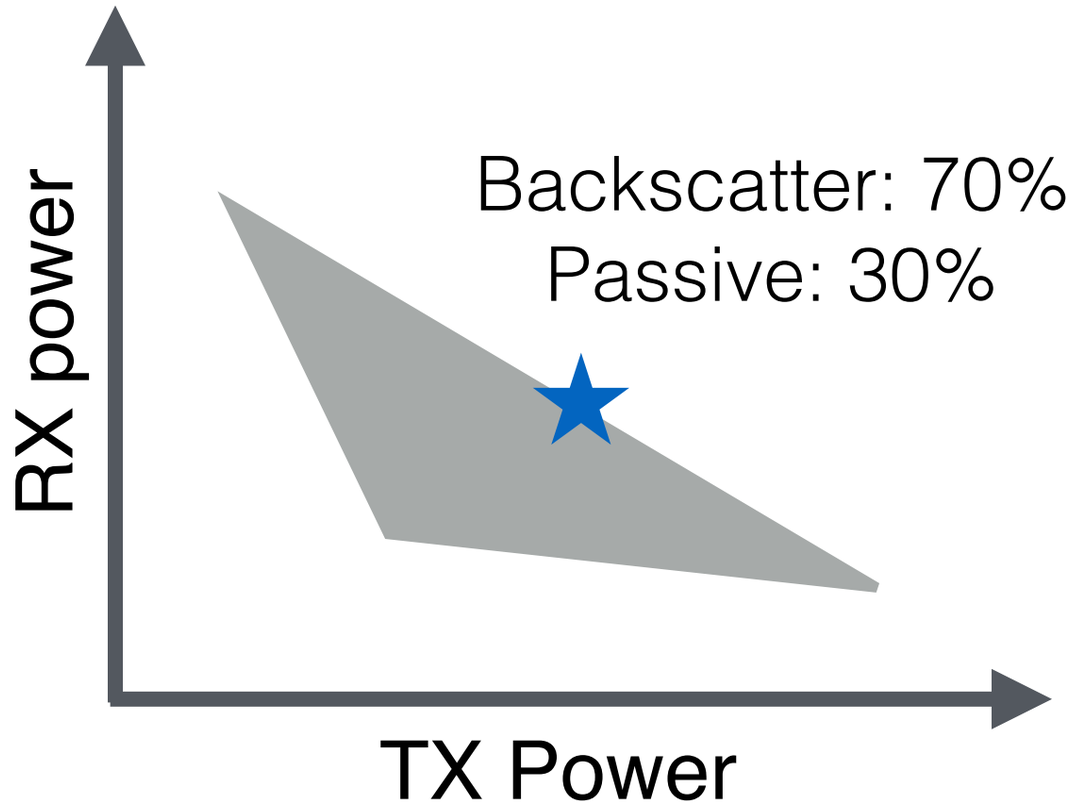
Challenge #2: different working ranges





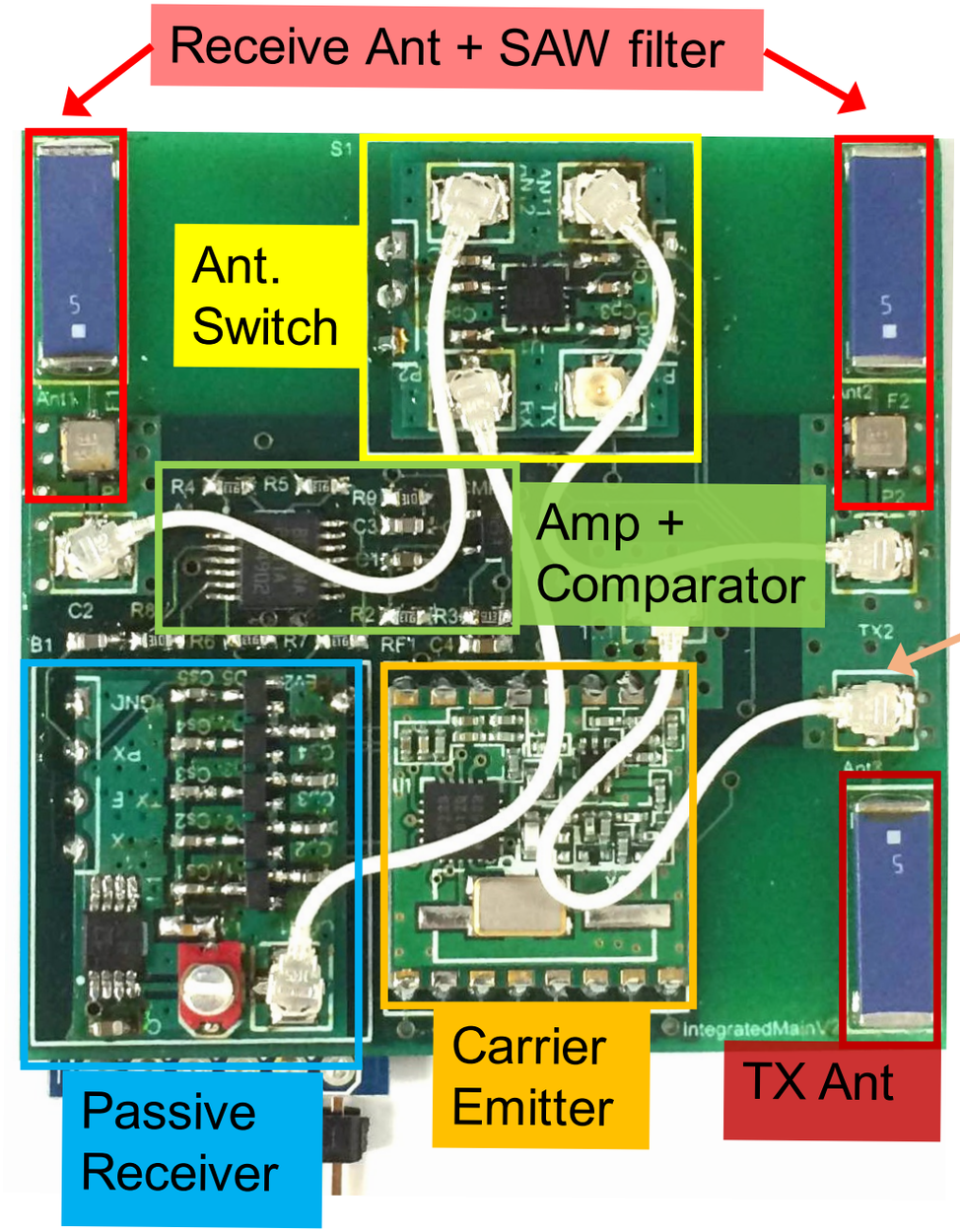
Challenge #2: different working ranges



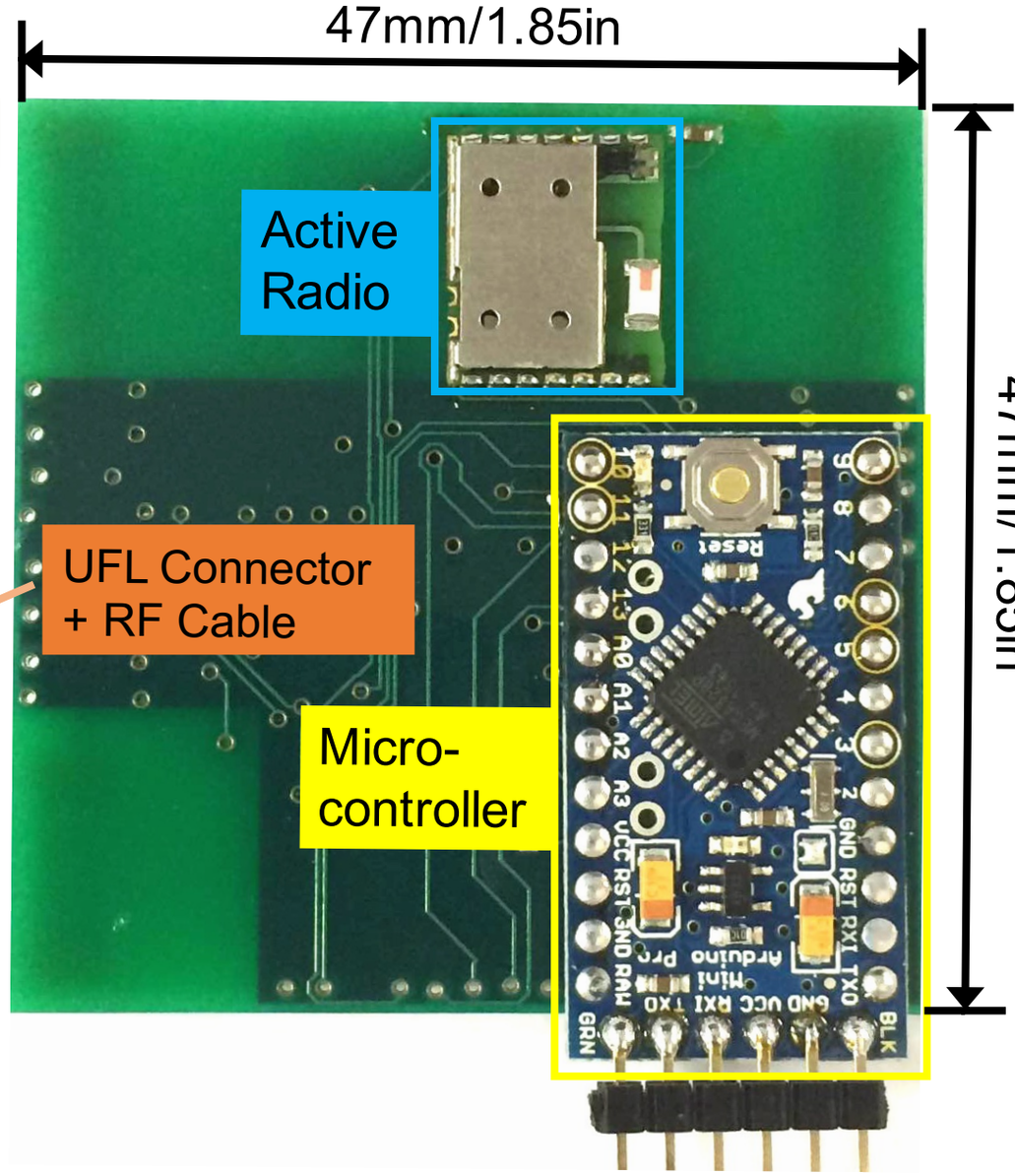


Braidio multiplexes across modes based on SNR of each link and battery levels to achieve desired power ratio.

Implementation of Braidio

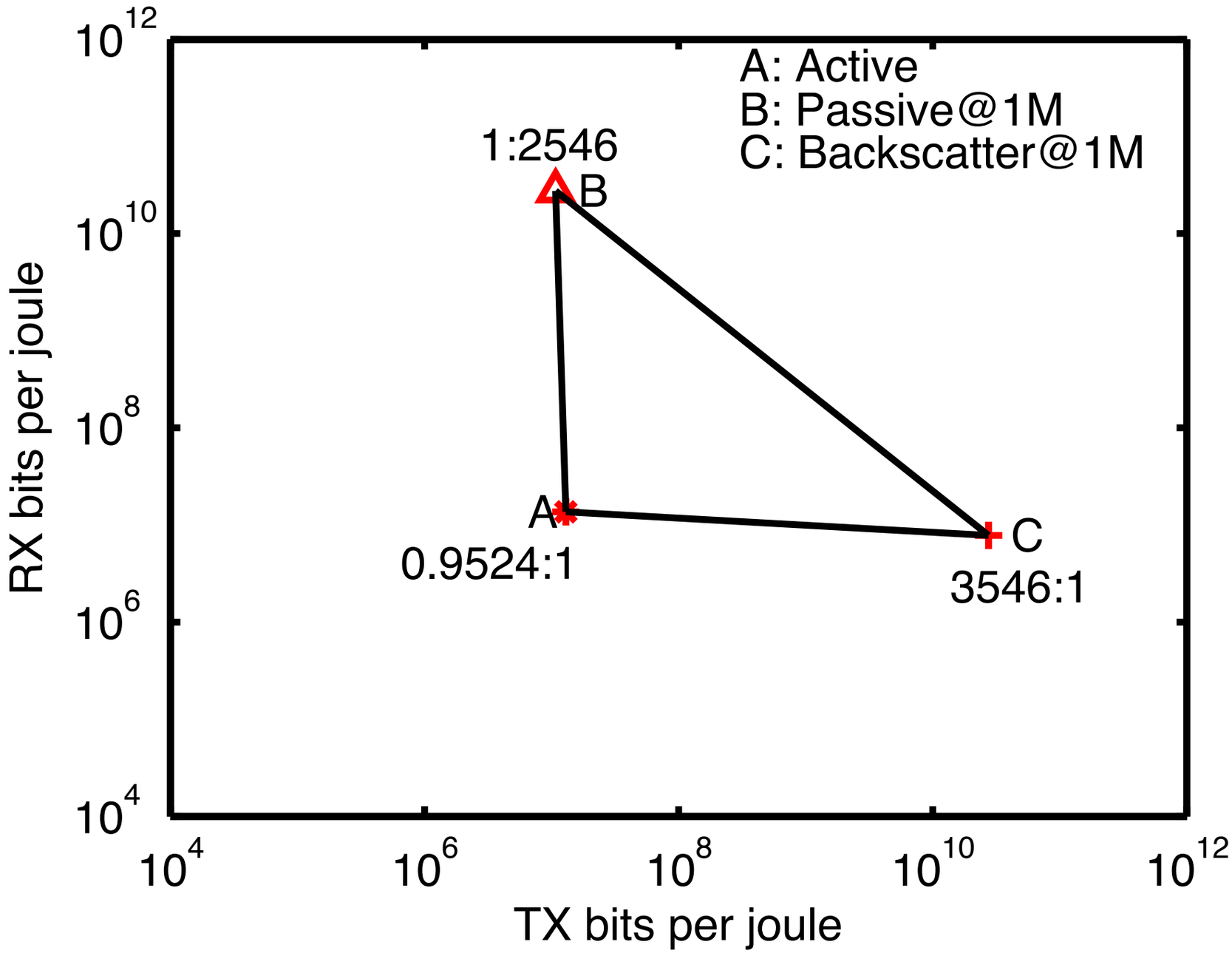


Top Layer

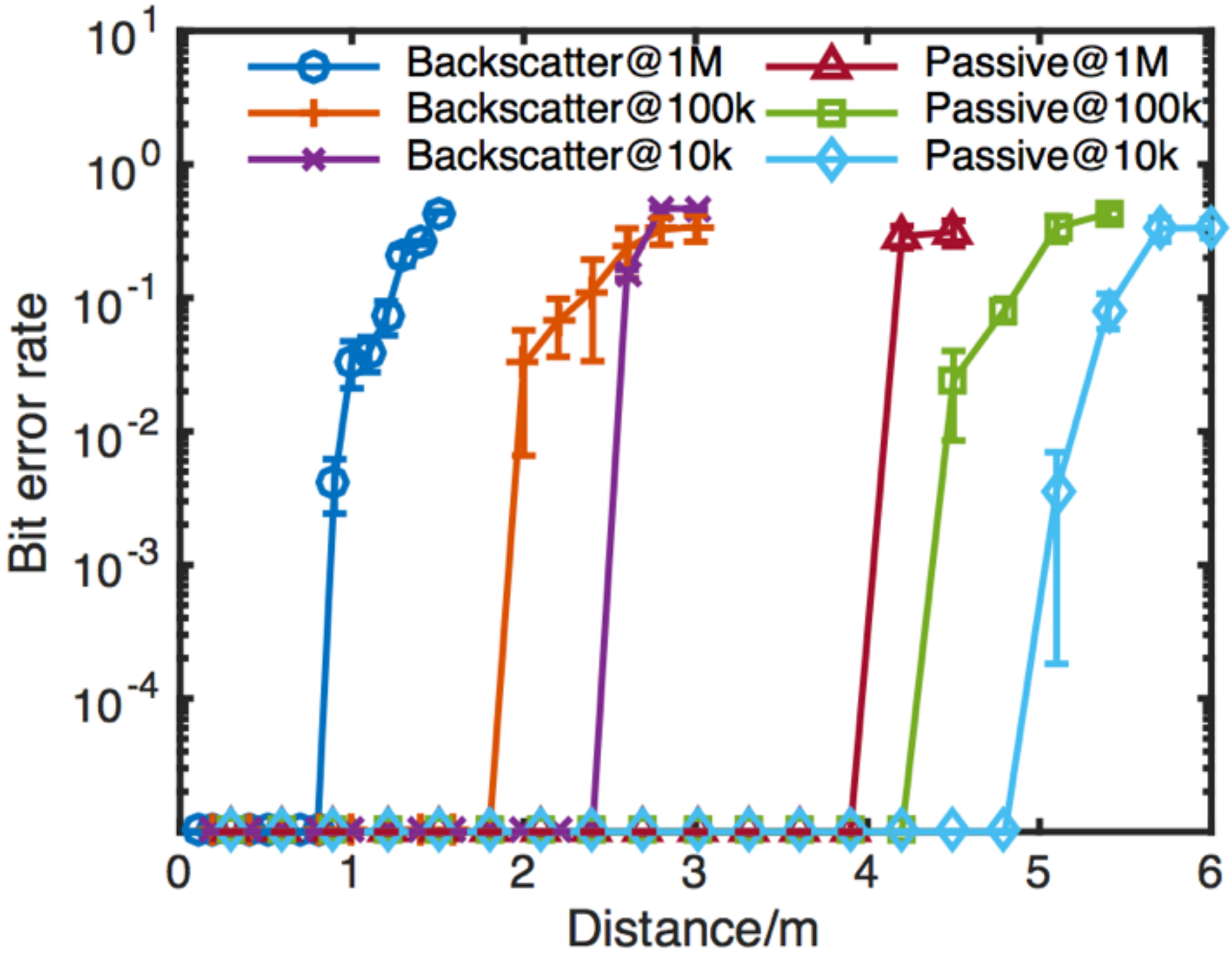


Bottom Layer

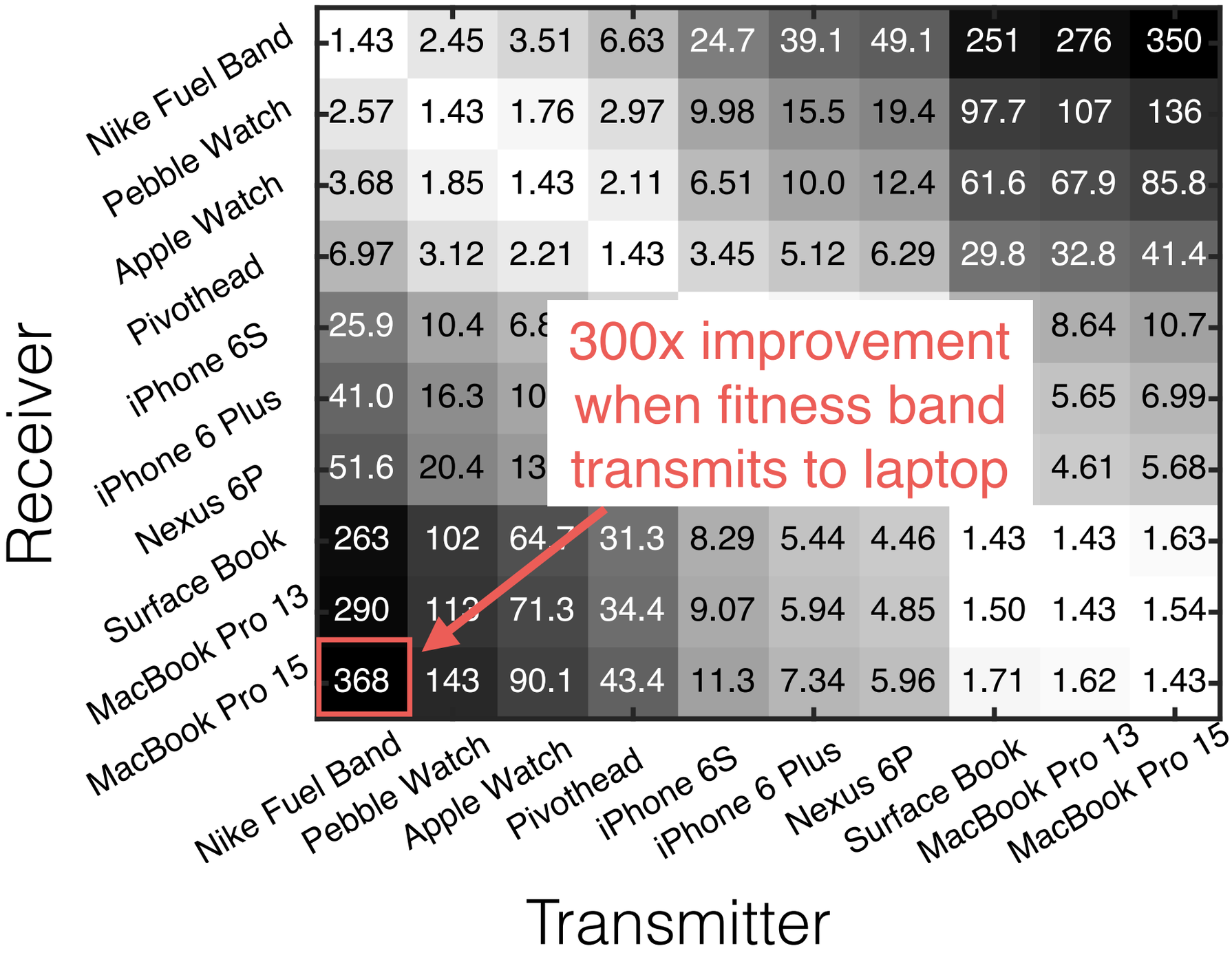
Braidio: Achievable power ratios



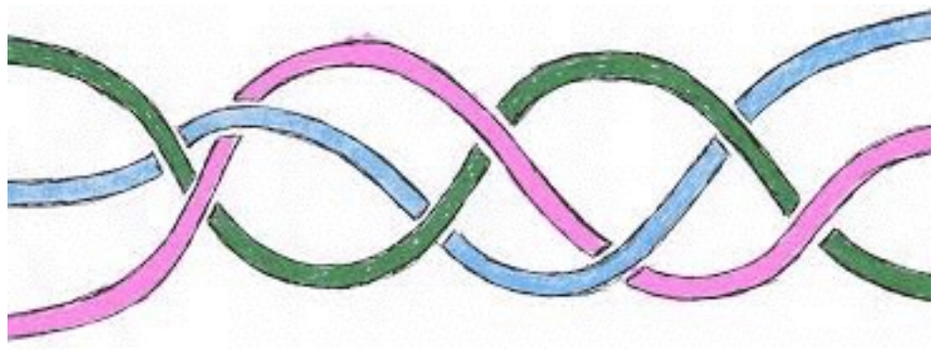
Braidio: Operating distance



Braidio: Performance gain over active radio



Conclusion

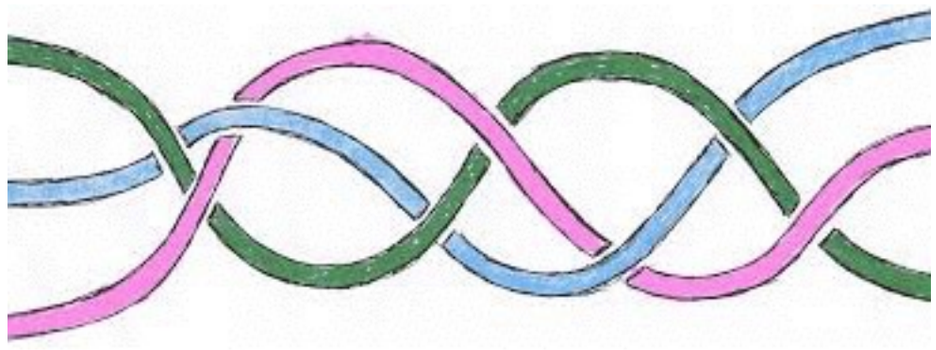


Active
Backscatter
Passive

Braidio: A novel power-proportional radio that can deal with asymmetric energy budgets on mobile devices.

Thank you

Conclusion

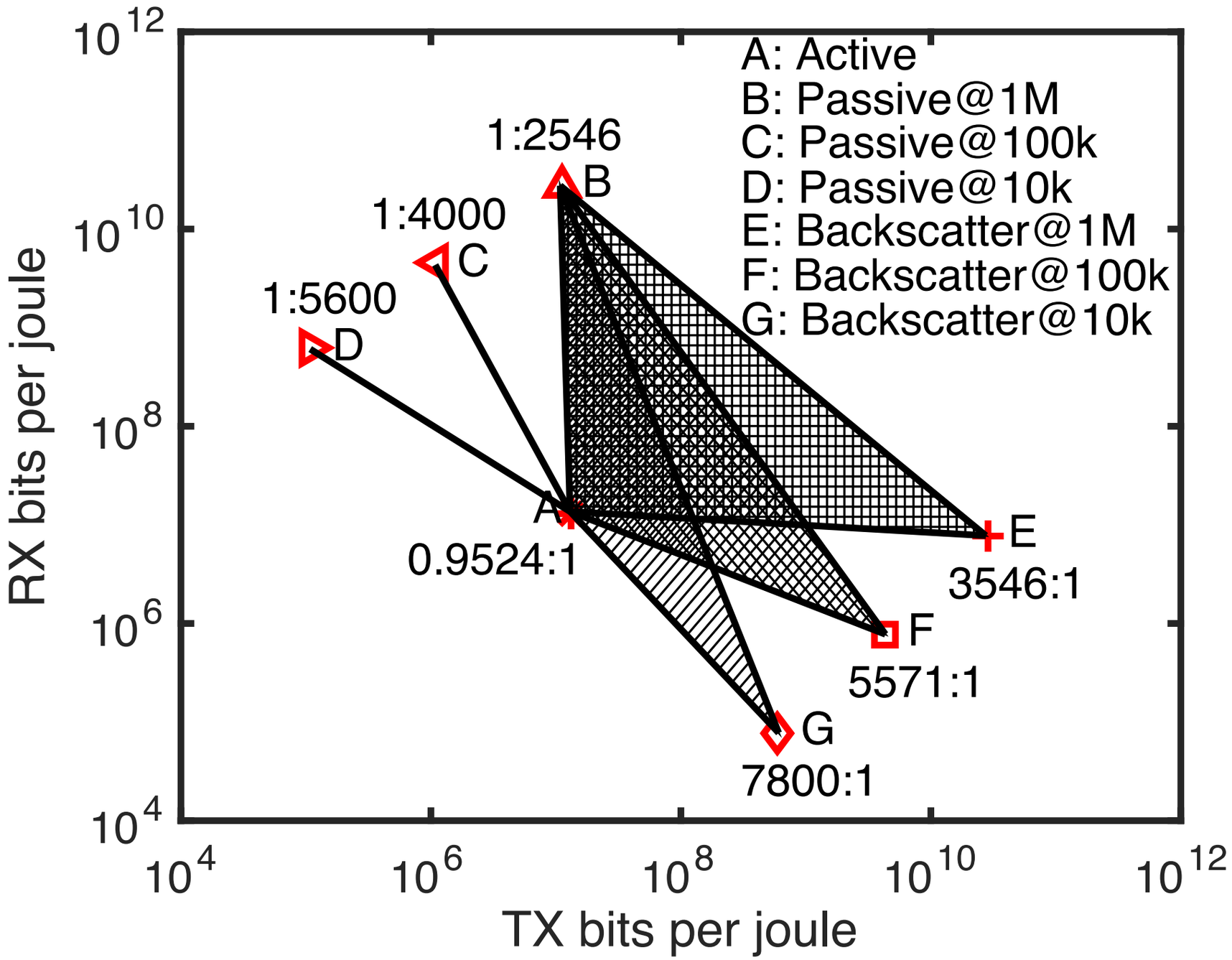


Active
Backscatter
Passive

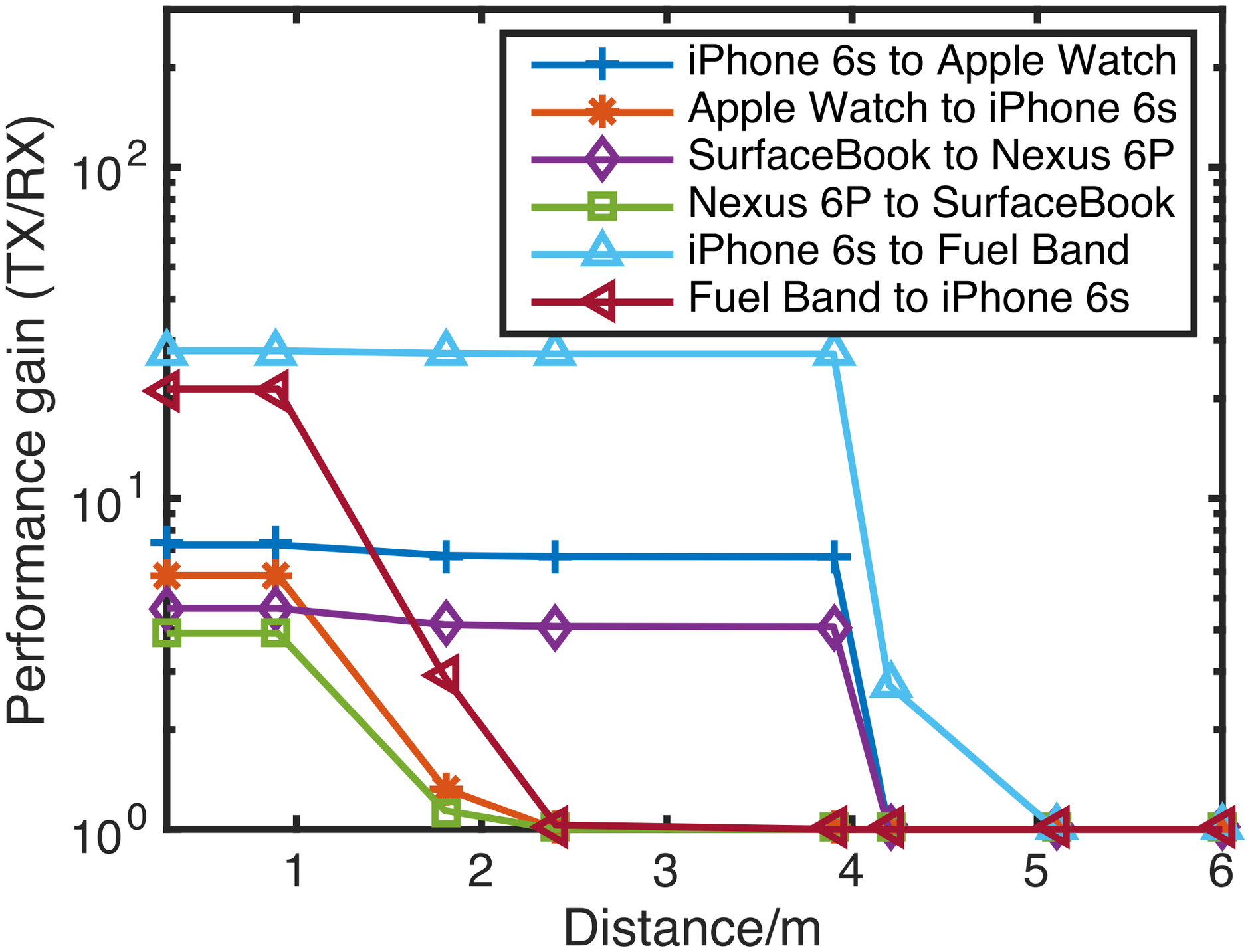
Braidio: A novel power-proportional radio that can deal with asymmetric energy budgets on mobile devices.

Thank you

Backup


A: Active
B: Passive@1M
C: Passive@100k
D: Passive@10k
E: Backscatter@1M
F: Backscatter@100k
G: Backscatter@10k
1:2546
B
1:4000
C
1:5600
D
A
0.9524:1
E
3546:1
F
5571:1
G
7800:1
RX bits per joule
TX bits per joule
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}

Backup


iPhone 6s to Apple Watch
Apple Watch to iPhone 6s
SurfaceBook to Nexus 6P
Nexus 6P to SurfaceBook
iPhone 6s to Fuel Band
Fuel Band to iPhone 6s
Performance gain (TX/RX)
10^2
10^1
10^0
1
2
3
4
5
6
Distance/m