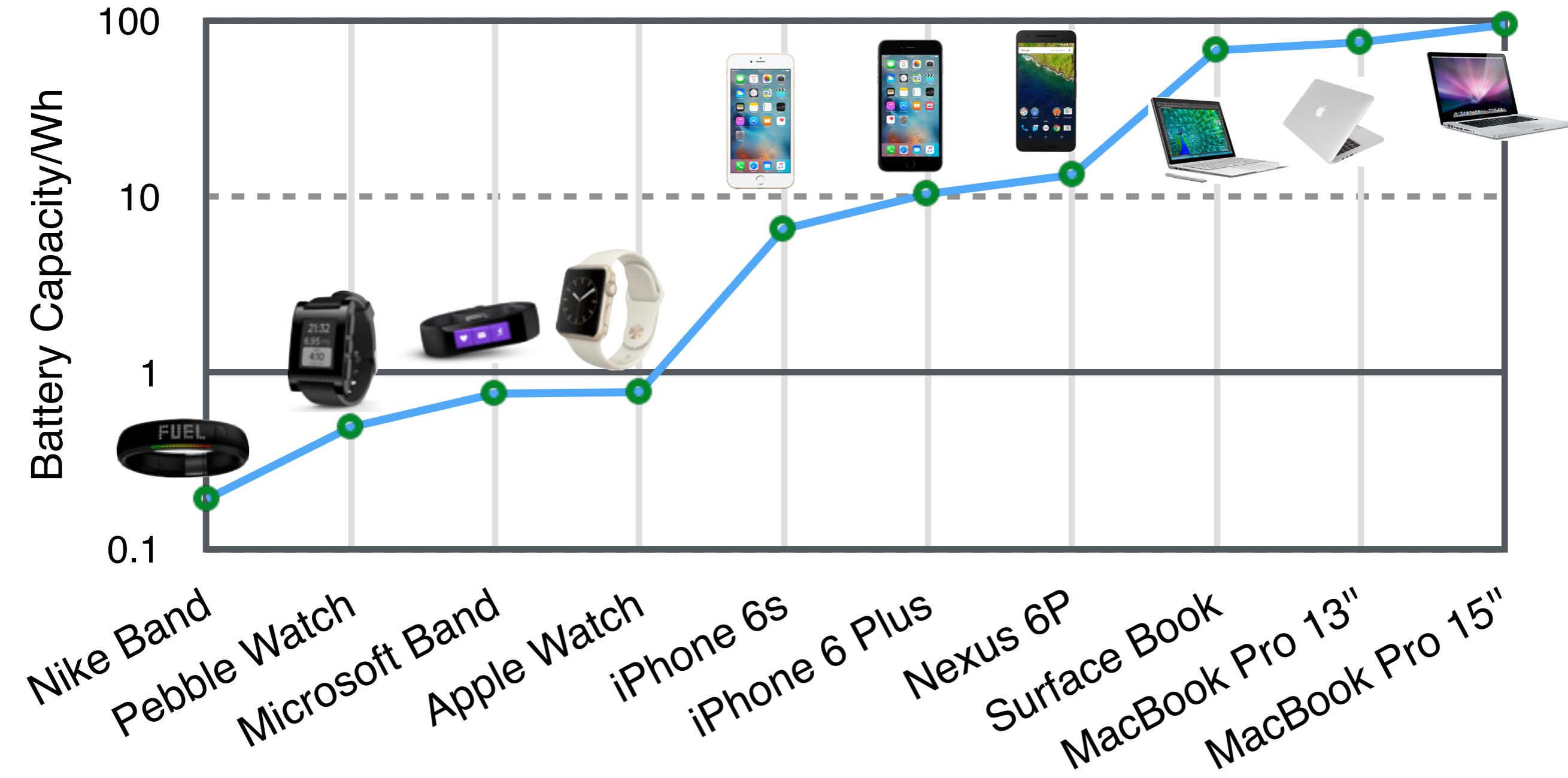


Braido: An Integrated Active-Passive Radio for Mobile Devices with Asymmetric Energy Budgets

Pan Hu, Pengyu Zhang, Mohammad Rostami, Deepak Ganesan
University of Massachusetts Amherst

Variability in battery capacity



Three orders of magnitude variation in battery capacity

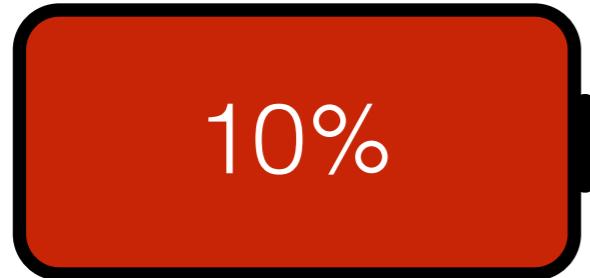
Asymmetric battery lifetime



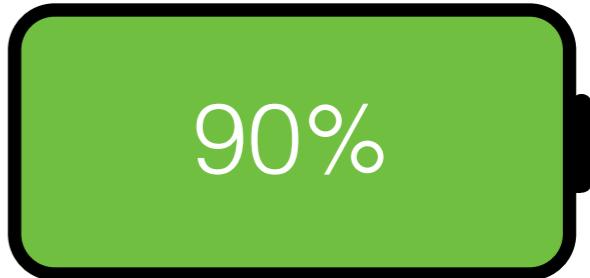
Sensor
Data



50mW

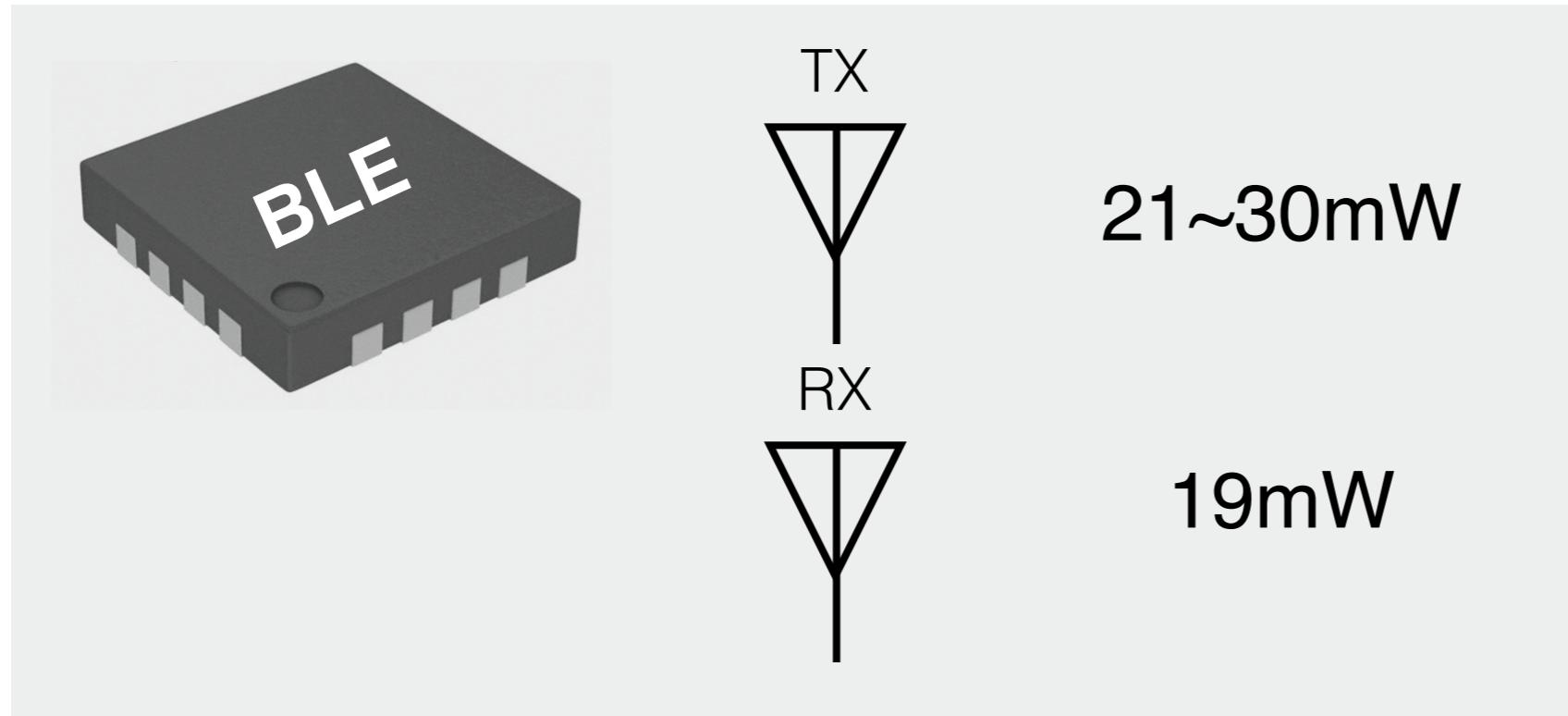
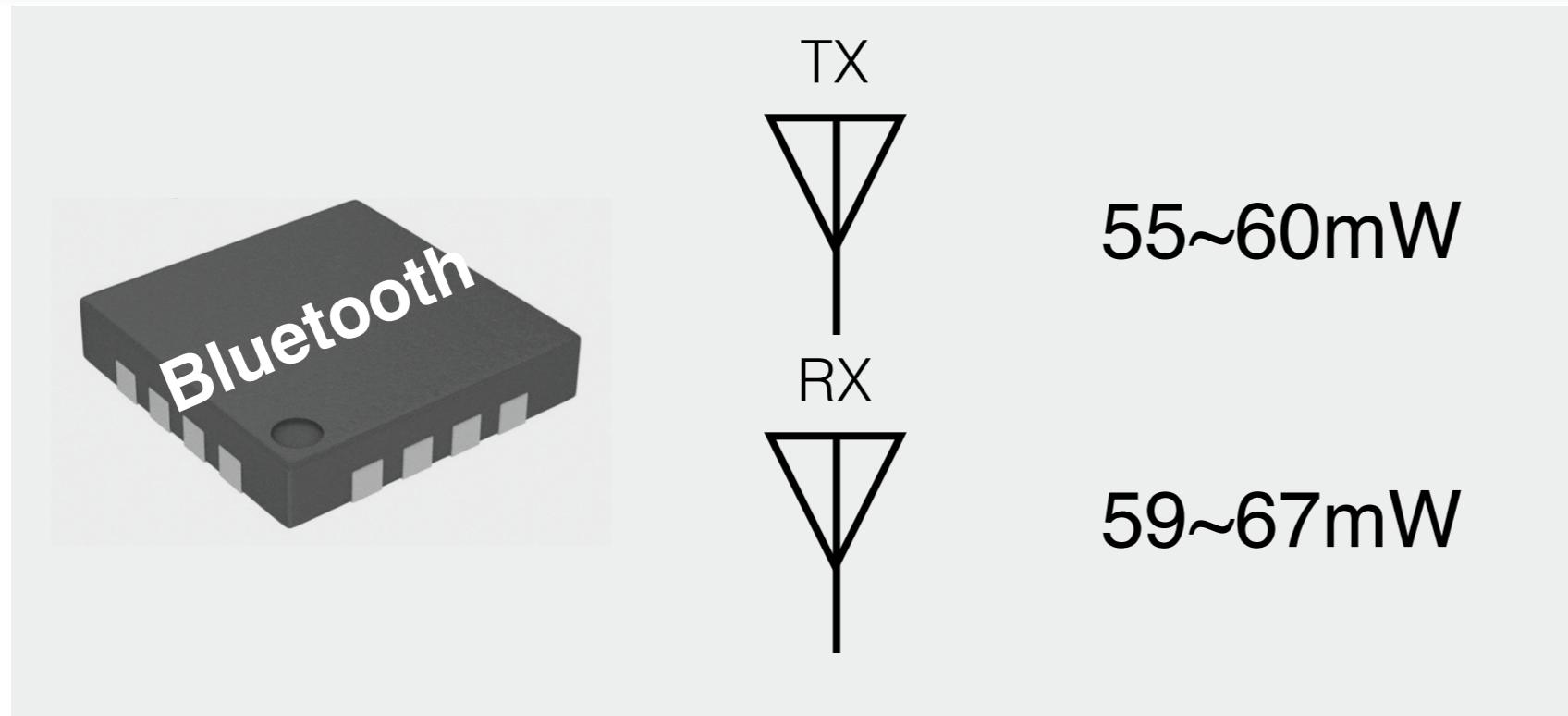


50mW

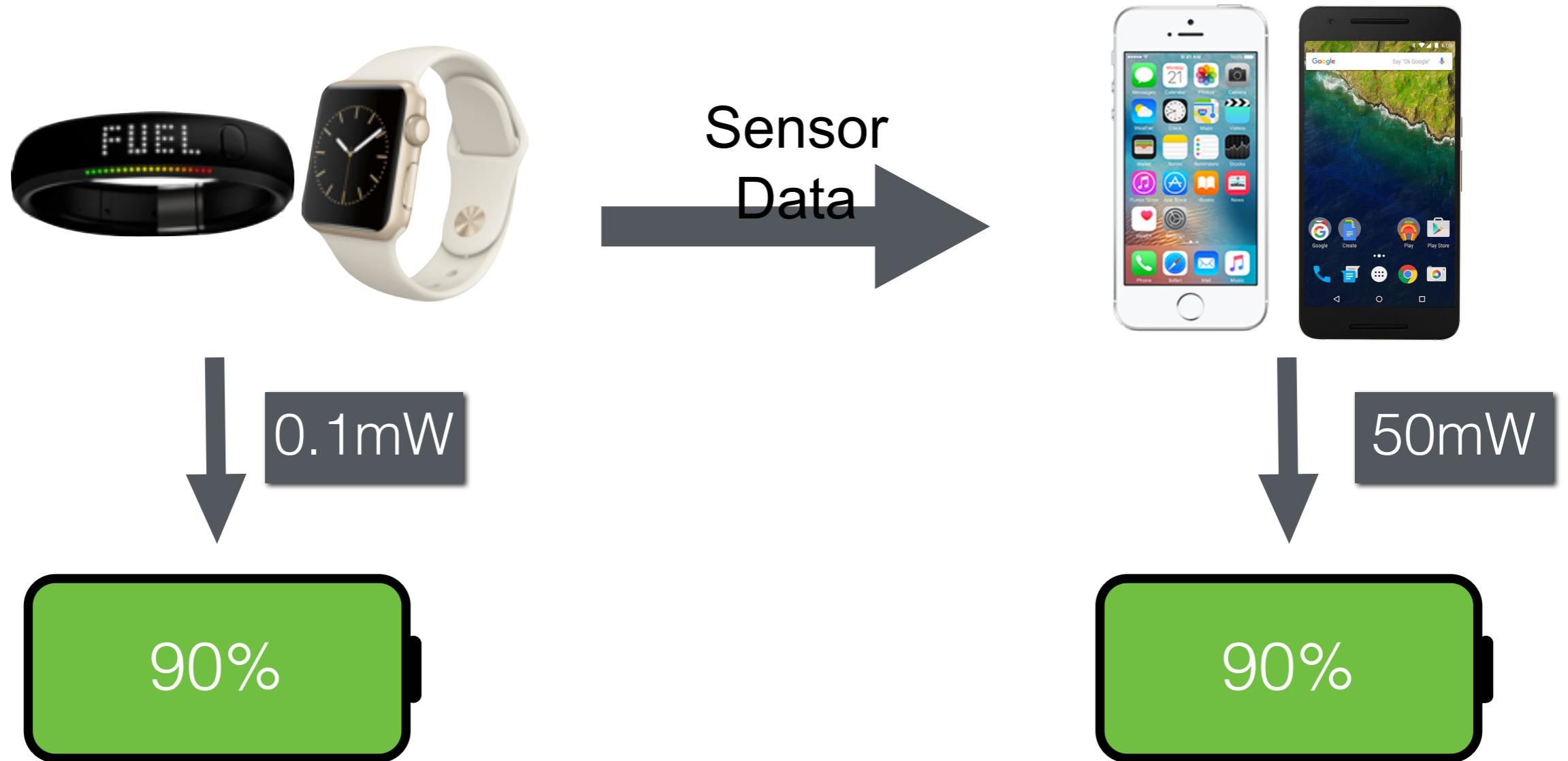


Devices with smaller batteries deplete far ahead of those with larger batteries

Symmetric power consumption



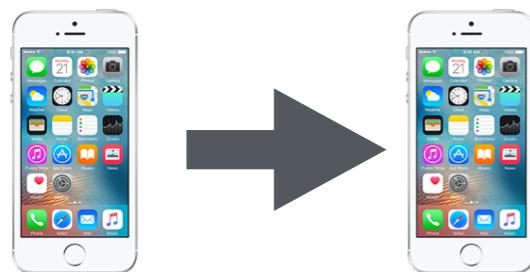
Can we design a power proportional radio?



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

Diversity of radio architectures

Active:
Symmetric
Radio

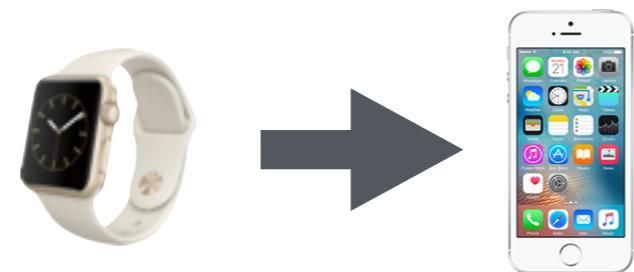


WiFi/
Bluetooth

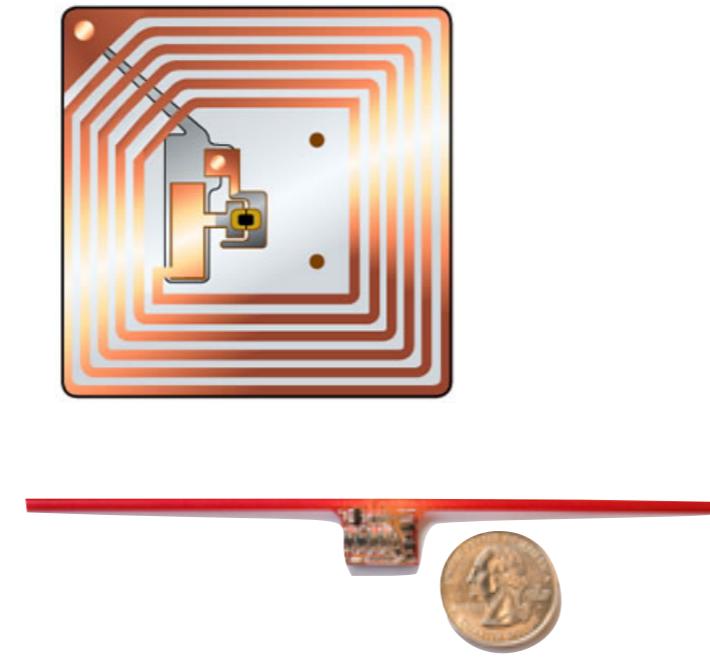


Bluetooth®

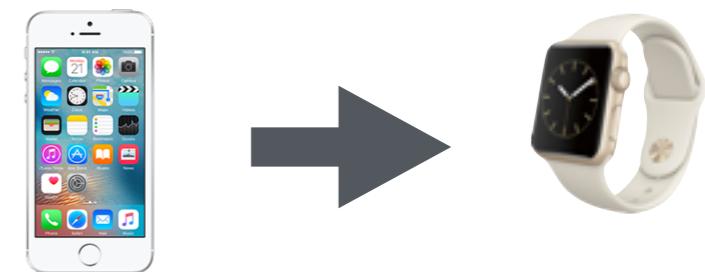
Backscatter:
Low power
transmitter



RFID Tag



Passive:
Low power
receiver

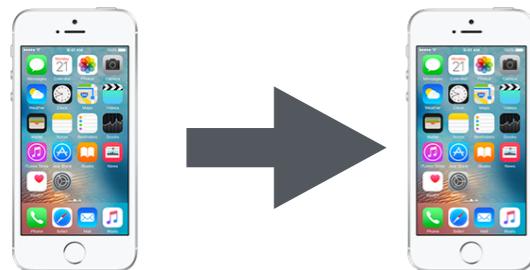


AM receiver

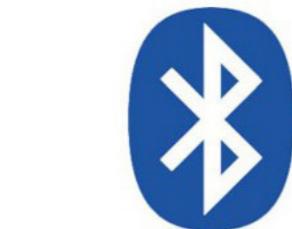


Diversity of radio architectures

Active:
Symmetric
Radio

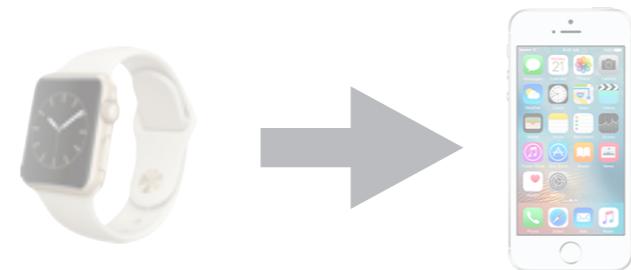


WiFi/
Bluetooth

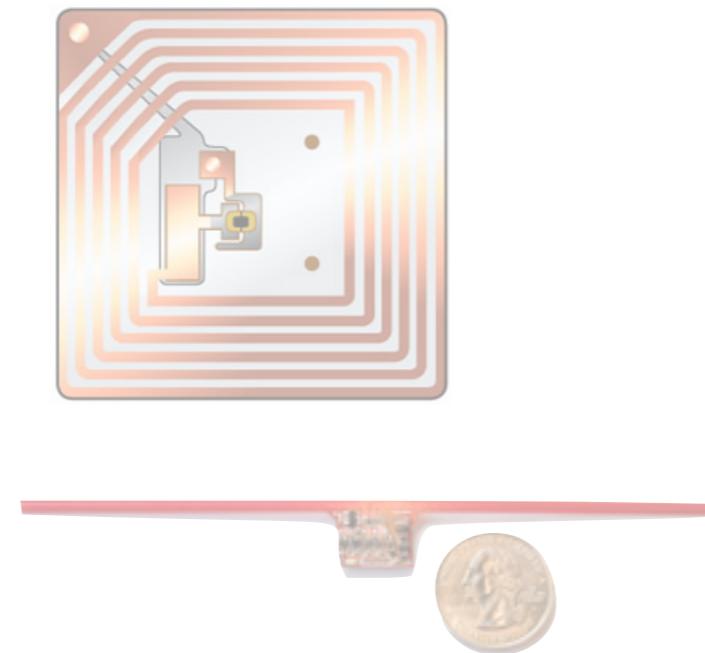


Bluetooth®

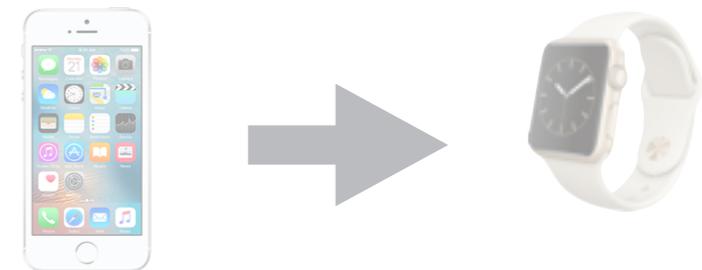
Backscatter:
Low power
transmitter



RFID Tag



Passive:
Low power
receiver

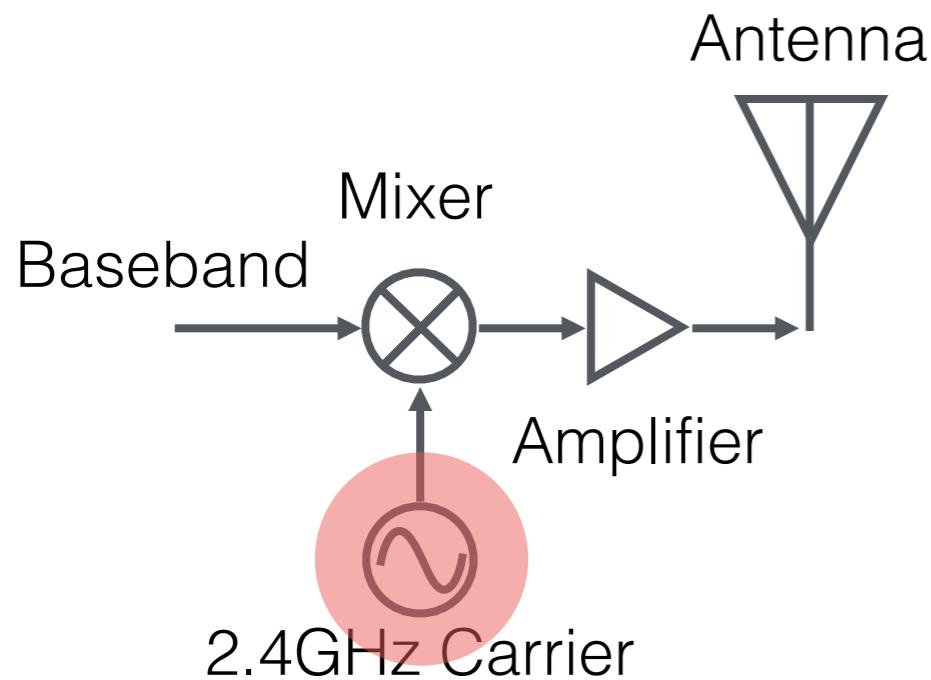


AM receiver

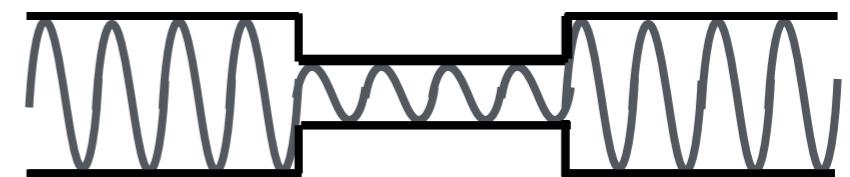
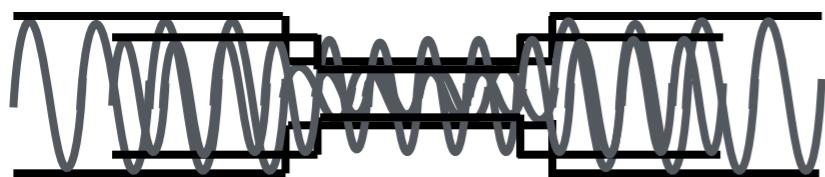
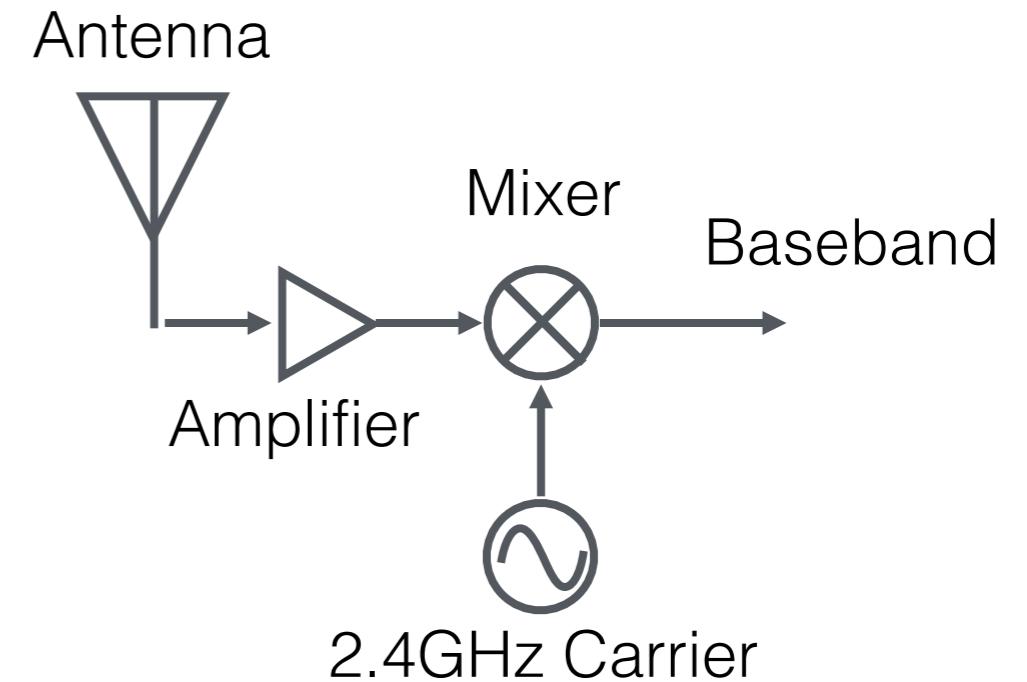


Symmetric active radio architecture

Active TX



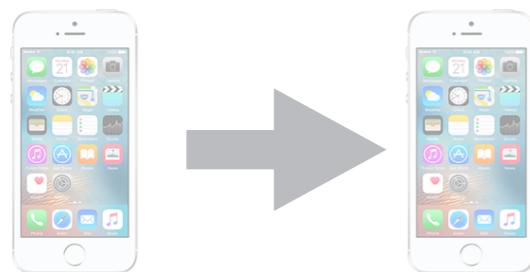
Active RX



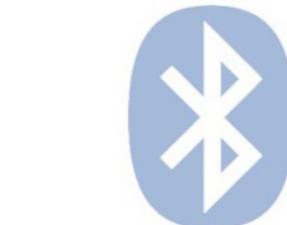
Similar power consumption at TX and RX

Diversity of radio architectures

Active:
Symmetric
Radio

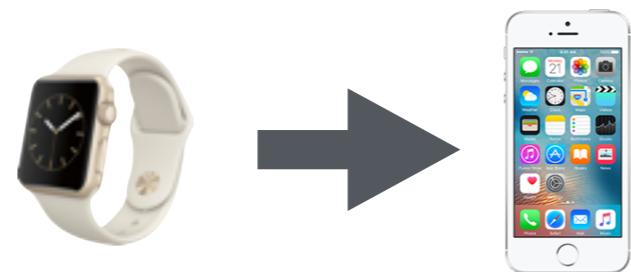


WiFi/
Bluetooth

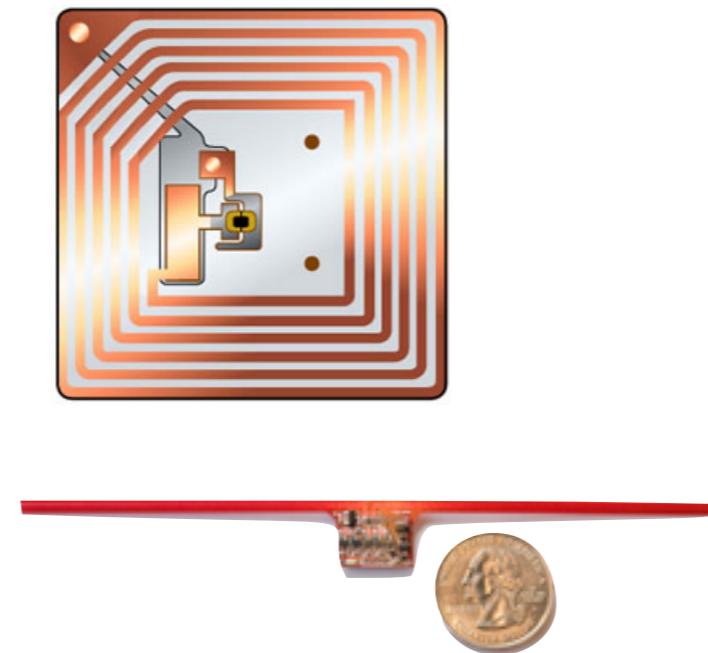


Bluetooth®

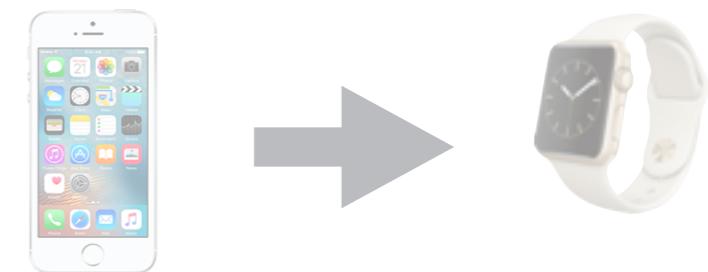
Backscatter:
Low power
transmitter



RFID Tag



Passive:
Low power
receiver

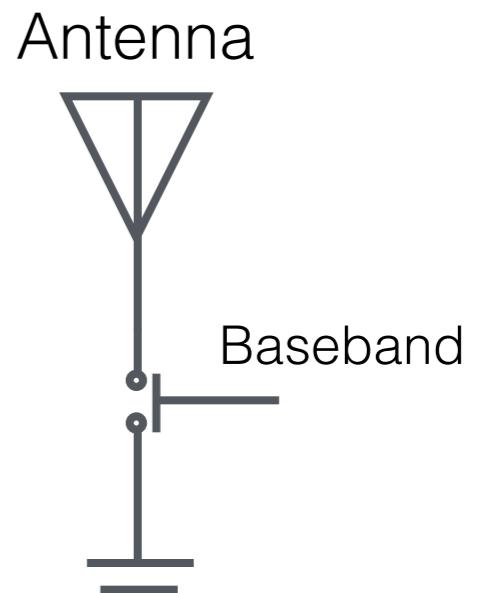


AM receiver



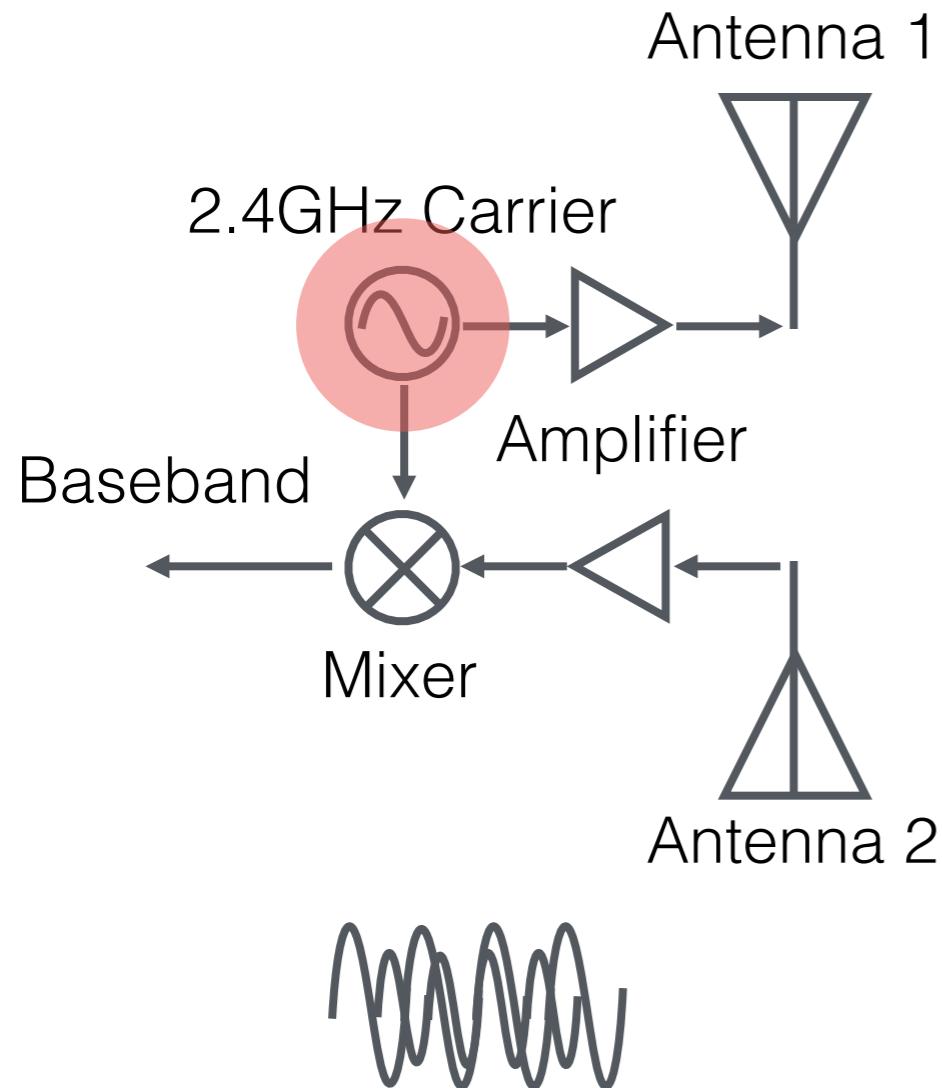
Backscatter radio architecture

Backscatter transmitter

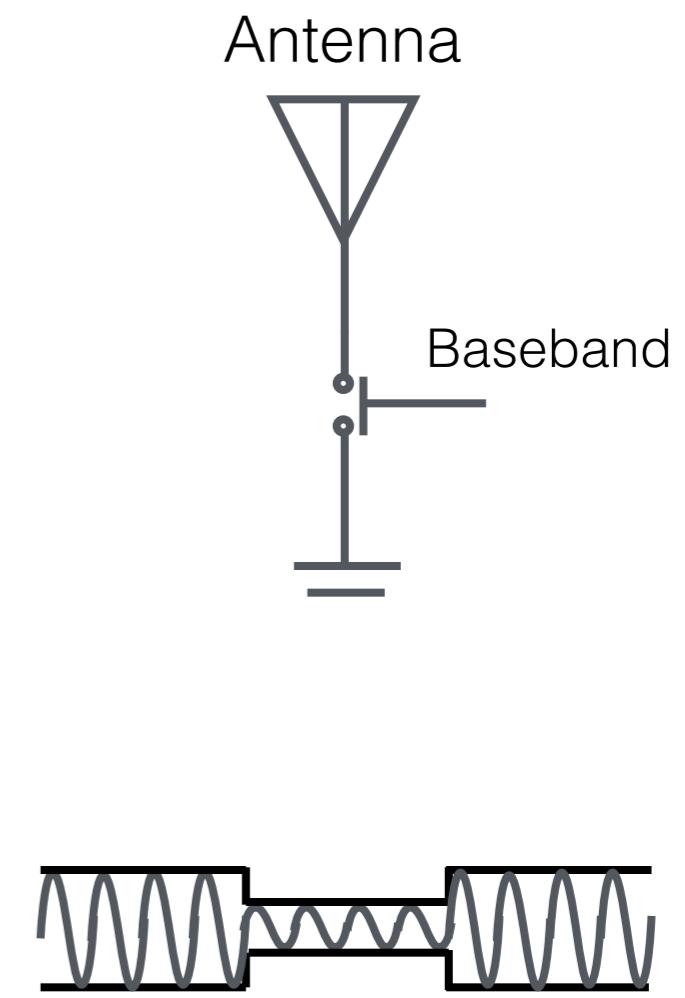


Backscatter radio architecture

Backscatter receiver



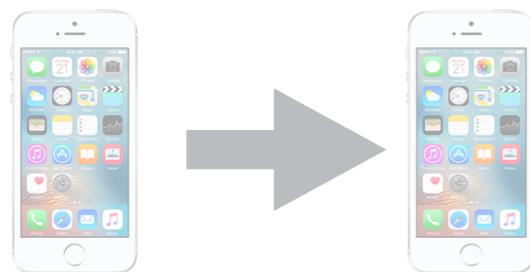
Backscatter transmitter



Much less power at TX but reduced range

Diversity of radio architectures

Active:
Symmetric
Radio

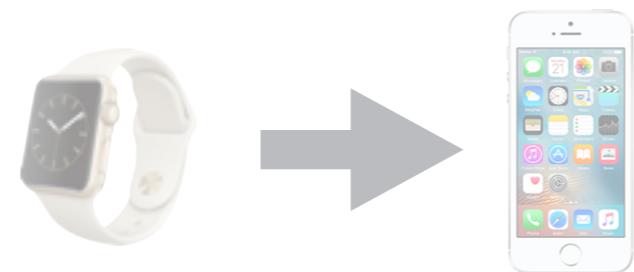


WiFi/
Bluetooth

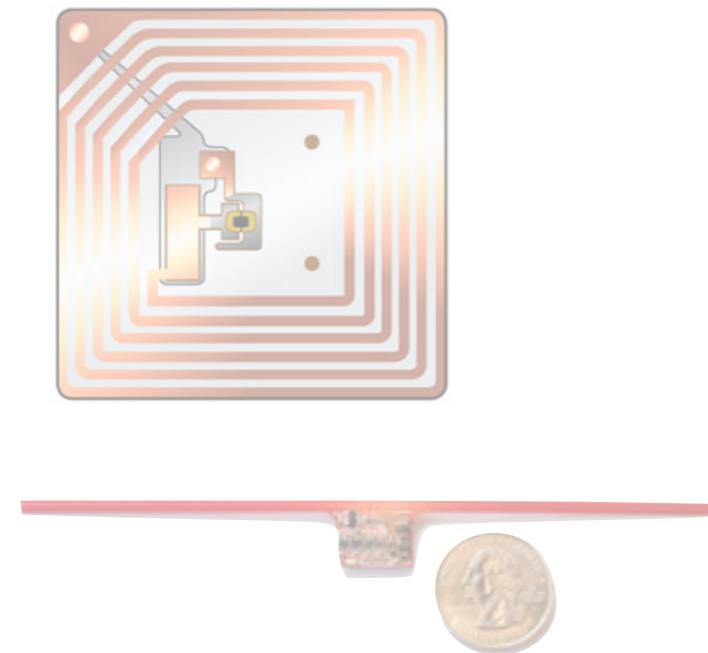


Bluetooth®

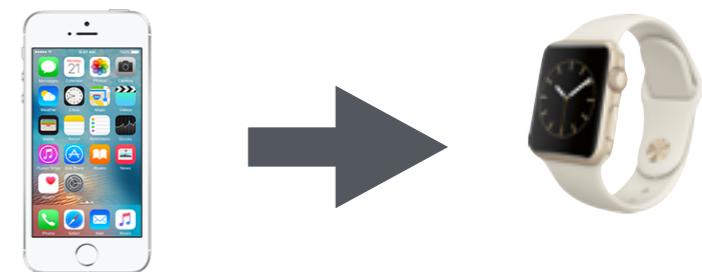
Backscatter:
Low power
transmitter



RFID Tag



Passive:
Low power
receiver

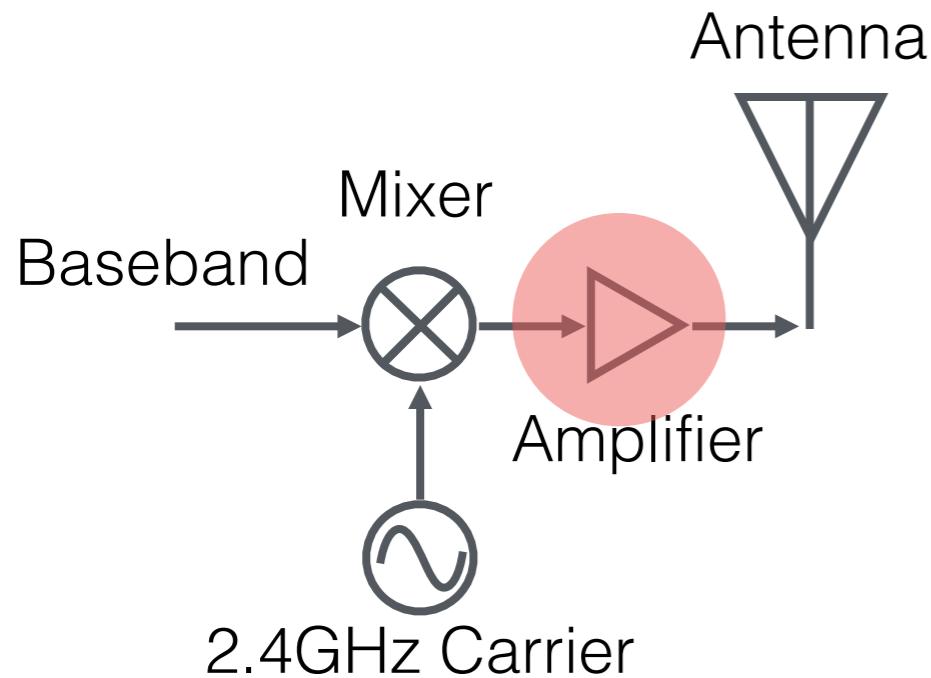


AM receiver

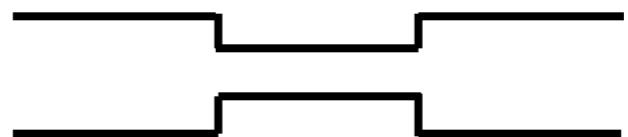
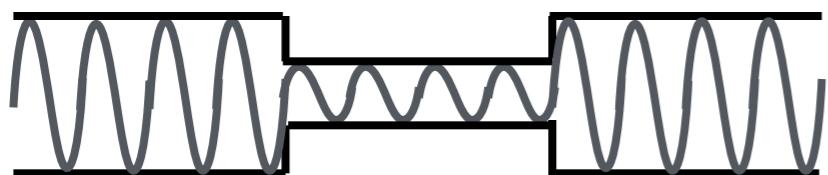
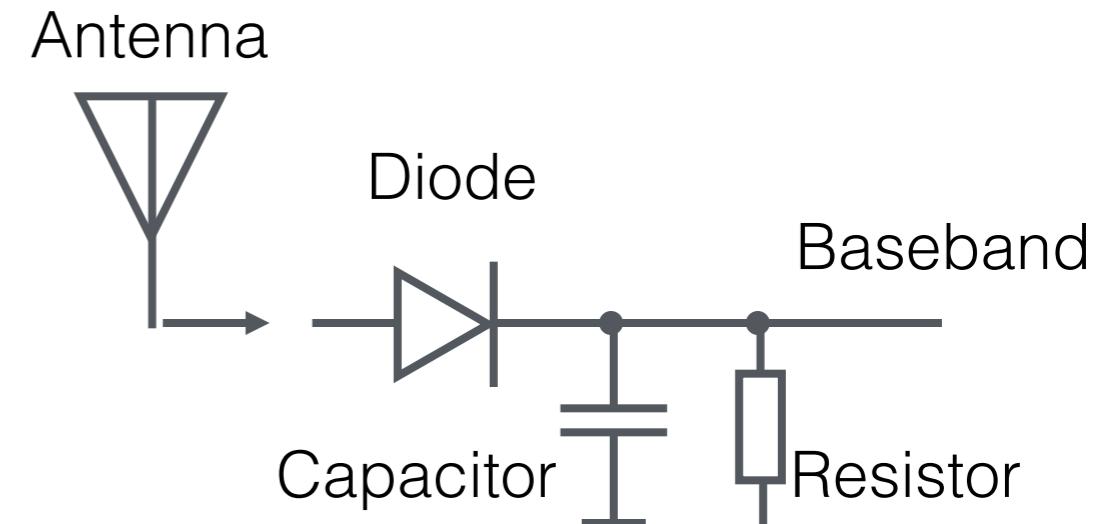


Passive radio architecture

Active TX



Passive RX



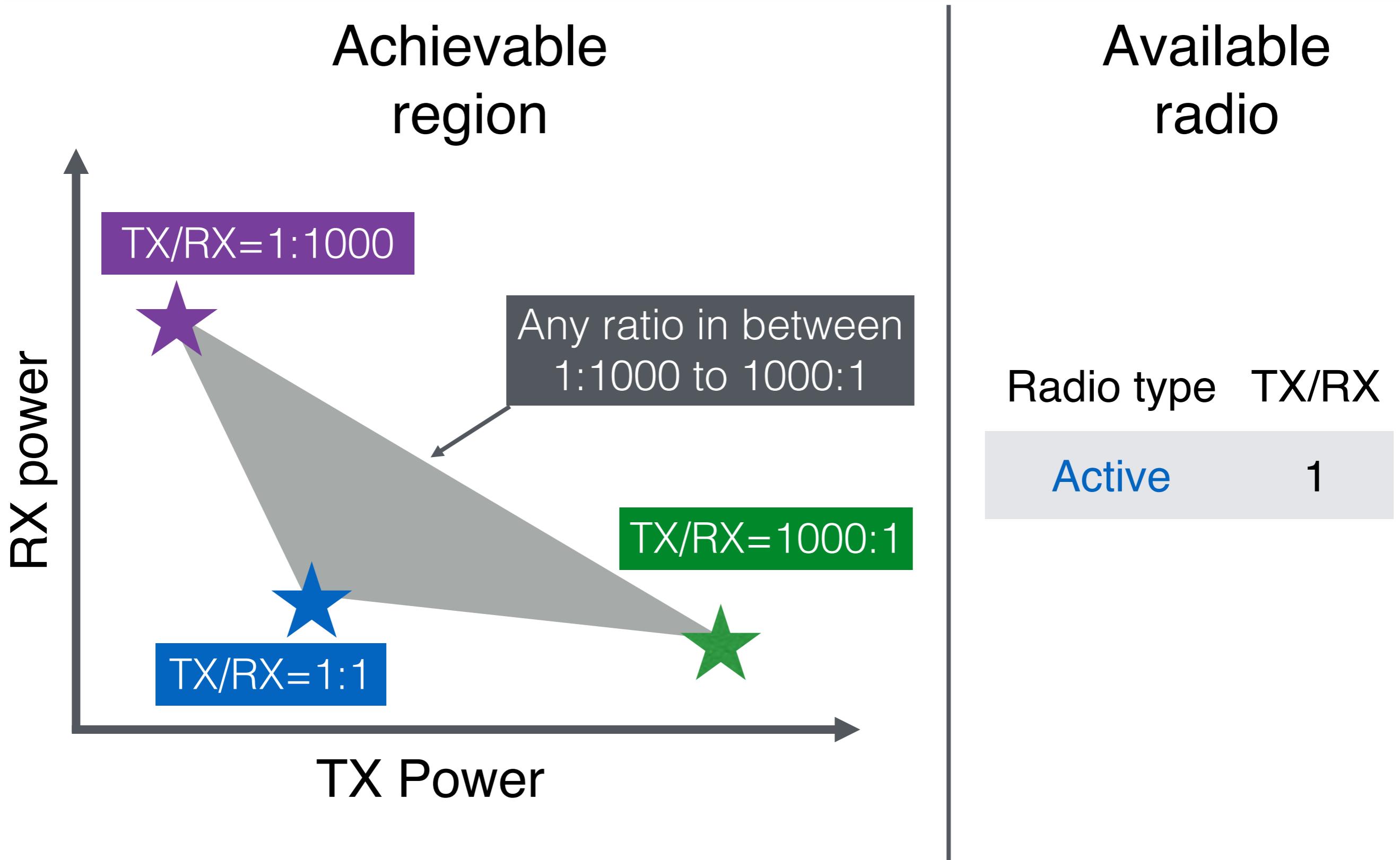
Much less power at RX but reduced range

Power consumption of radios

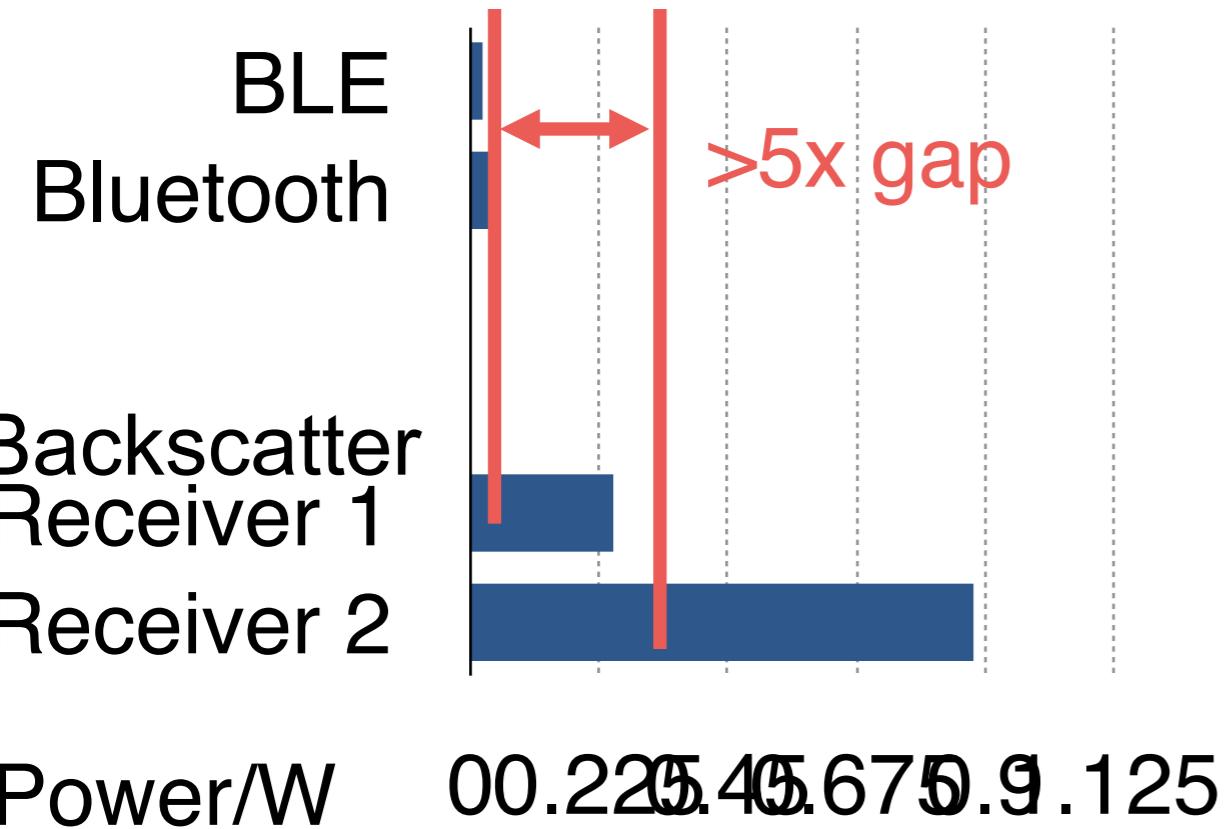
Radio type	TX	RX	TX/RX
Active	20mW	20mW	1
Backscatter	20mW	0.02mW	1000:1
Passive	0.02mW	20mW	1:1000

Can we take advantage of these architectures?

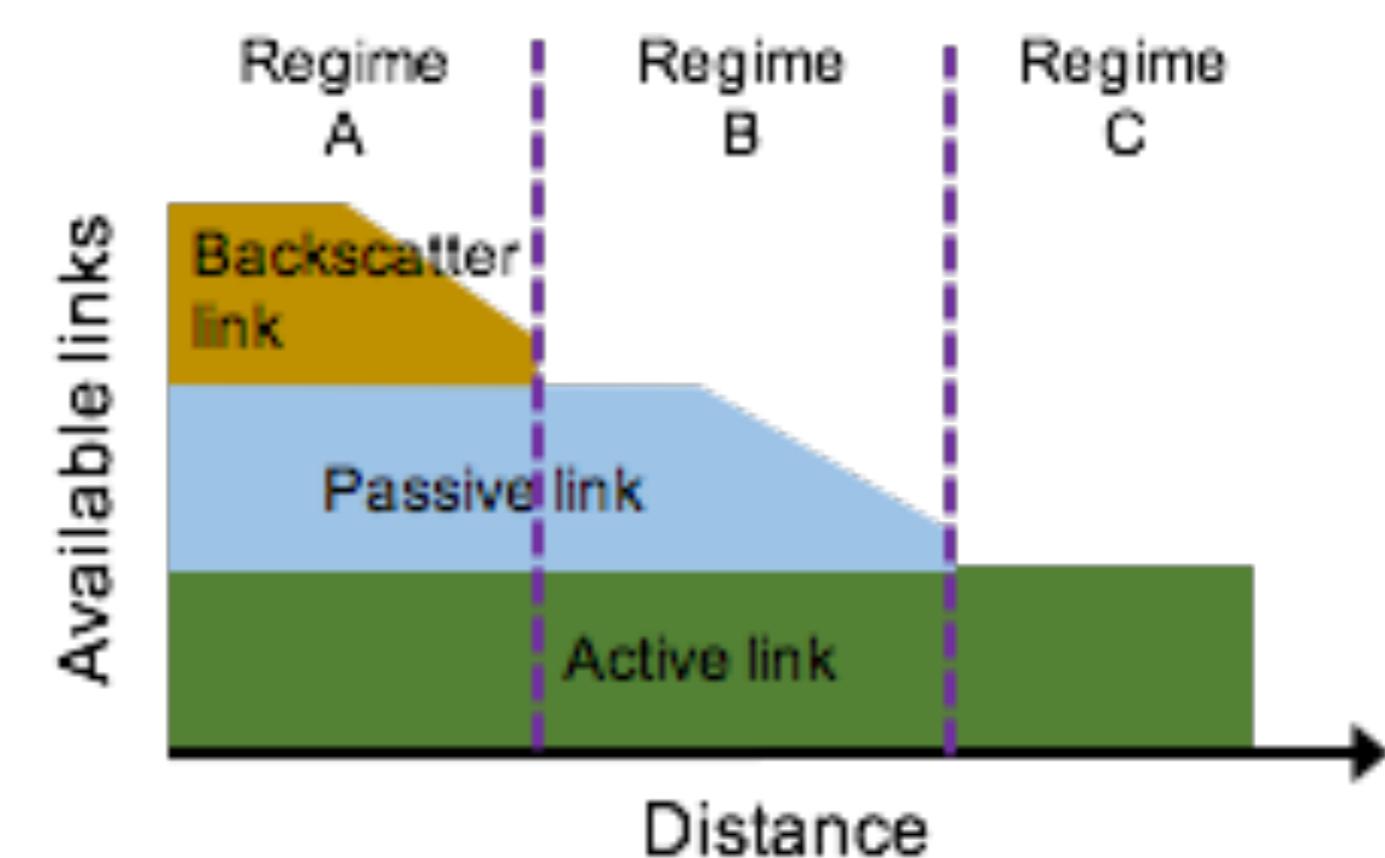
Architecture of radios



Challenges in combining three modes

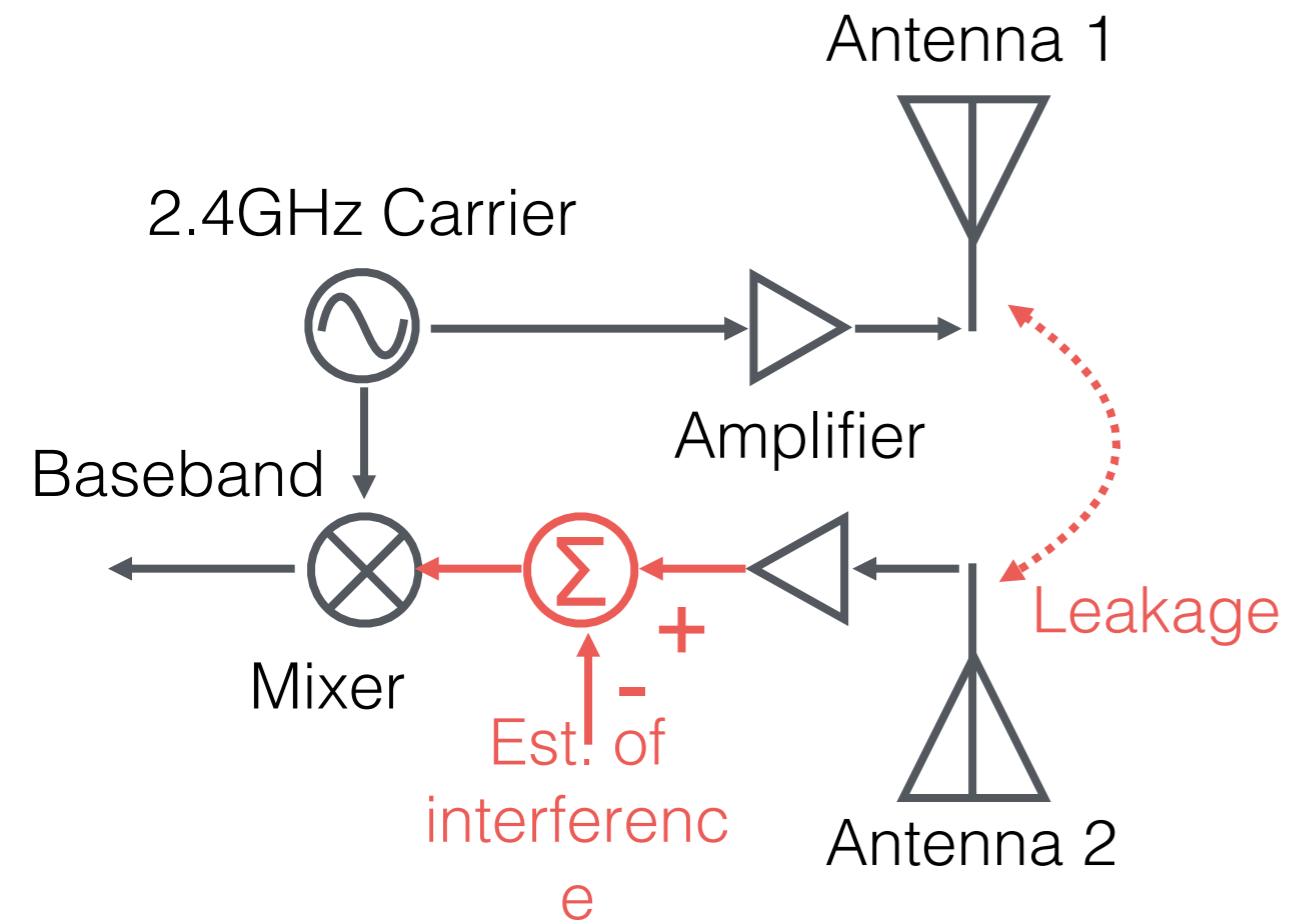


Backscatter RX consumes excessive power

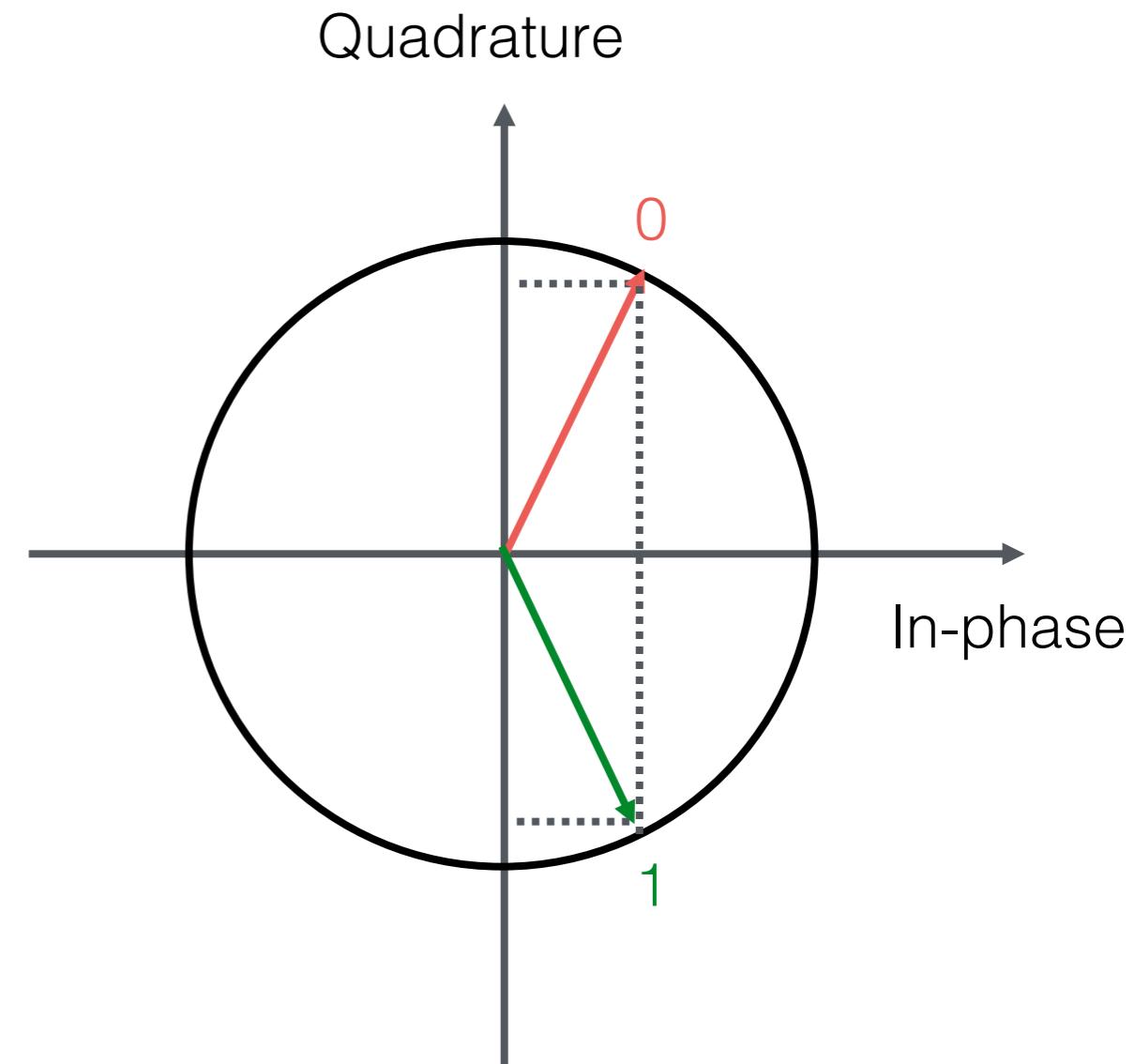


Different types of radios have different working ranges

Why is a Backscatter reader power hungry?

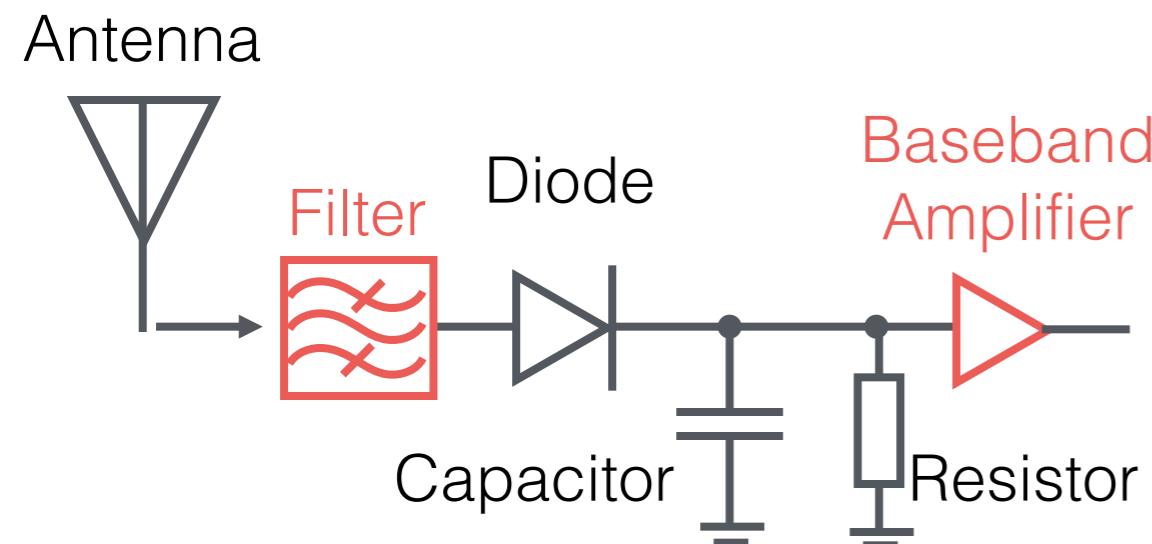


Self-interference cancellation

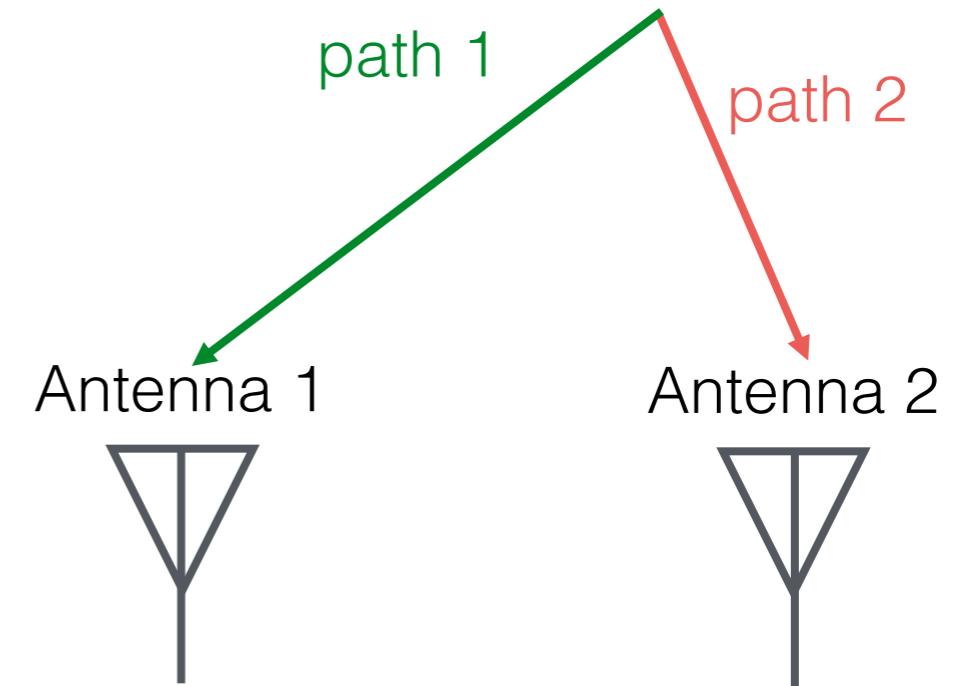


Active IQ Receiver

Reducing power of Backscatter reader

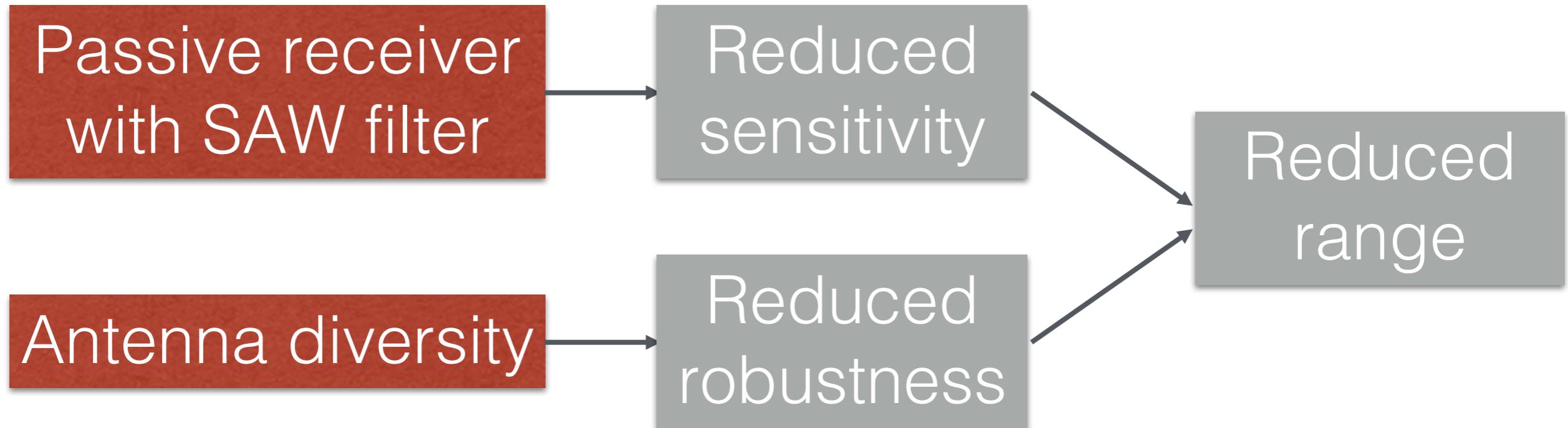


Passive receiver
with SAW filter



Antenna diversity

Bradio Backscatter RX: Design Tradeoffs



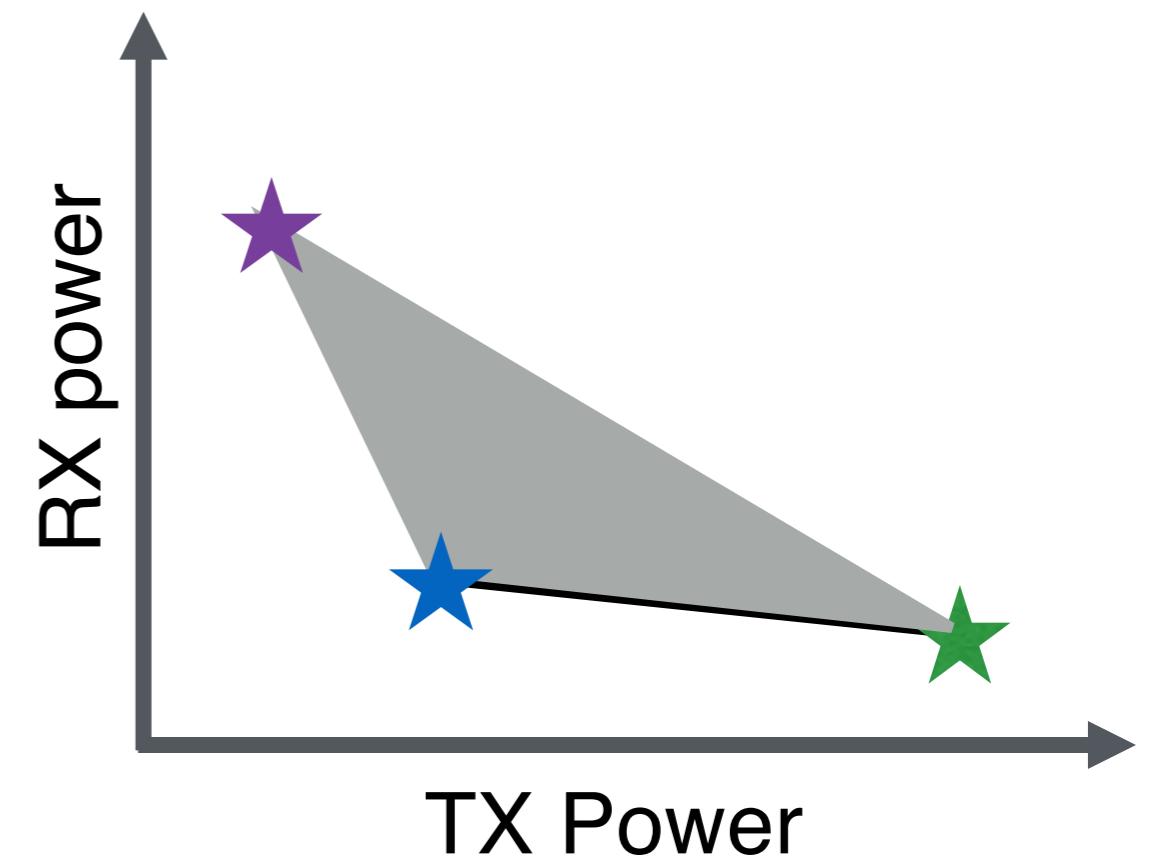
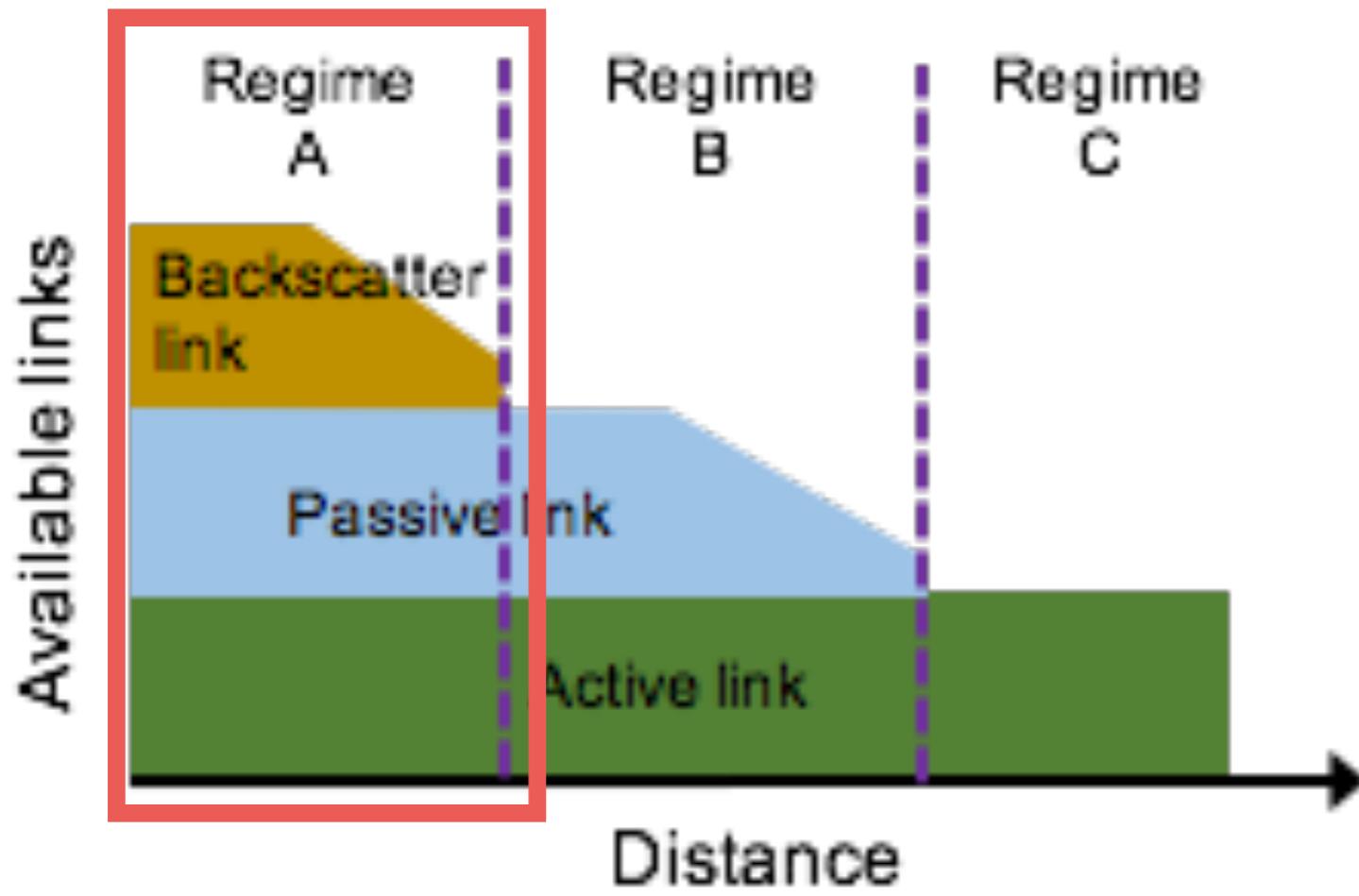
Active radio as a safety net

What if the Braudio backscatter mode fails?

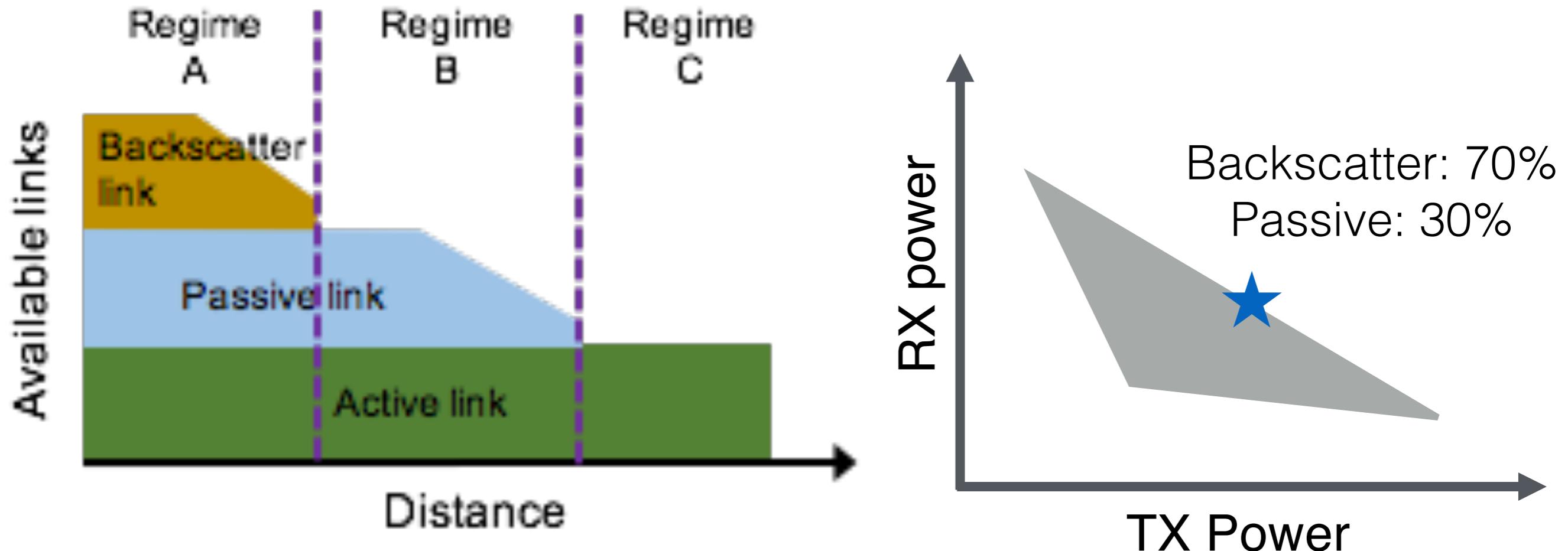


Active radio as
safety net

Challenge #2: different working ranges

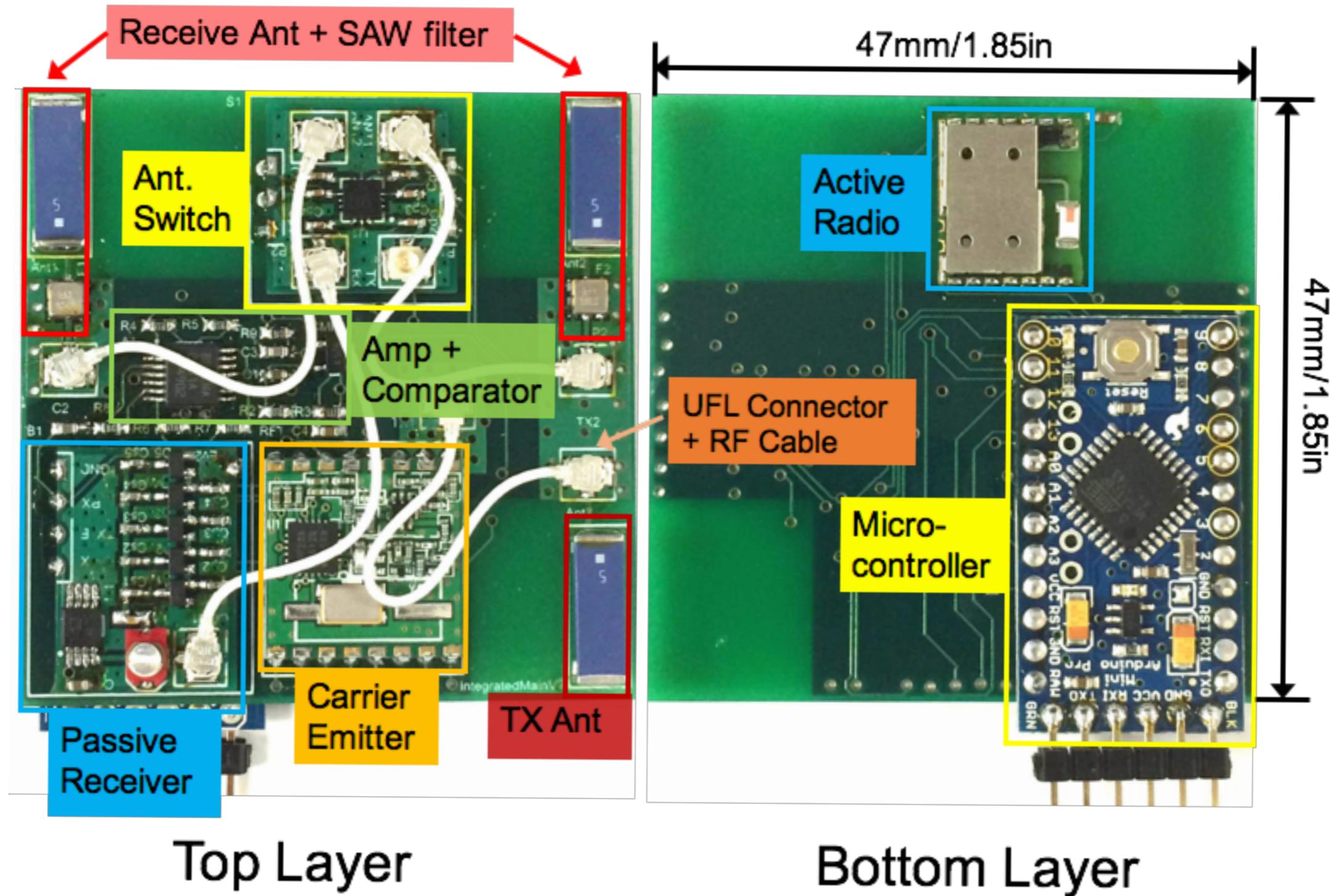


Challenge #2: different working ranges

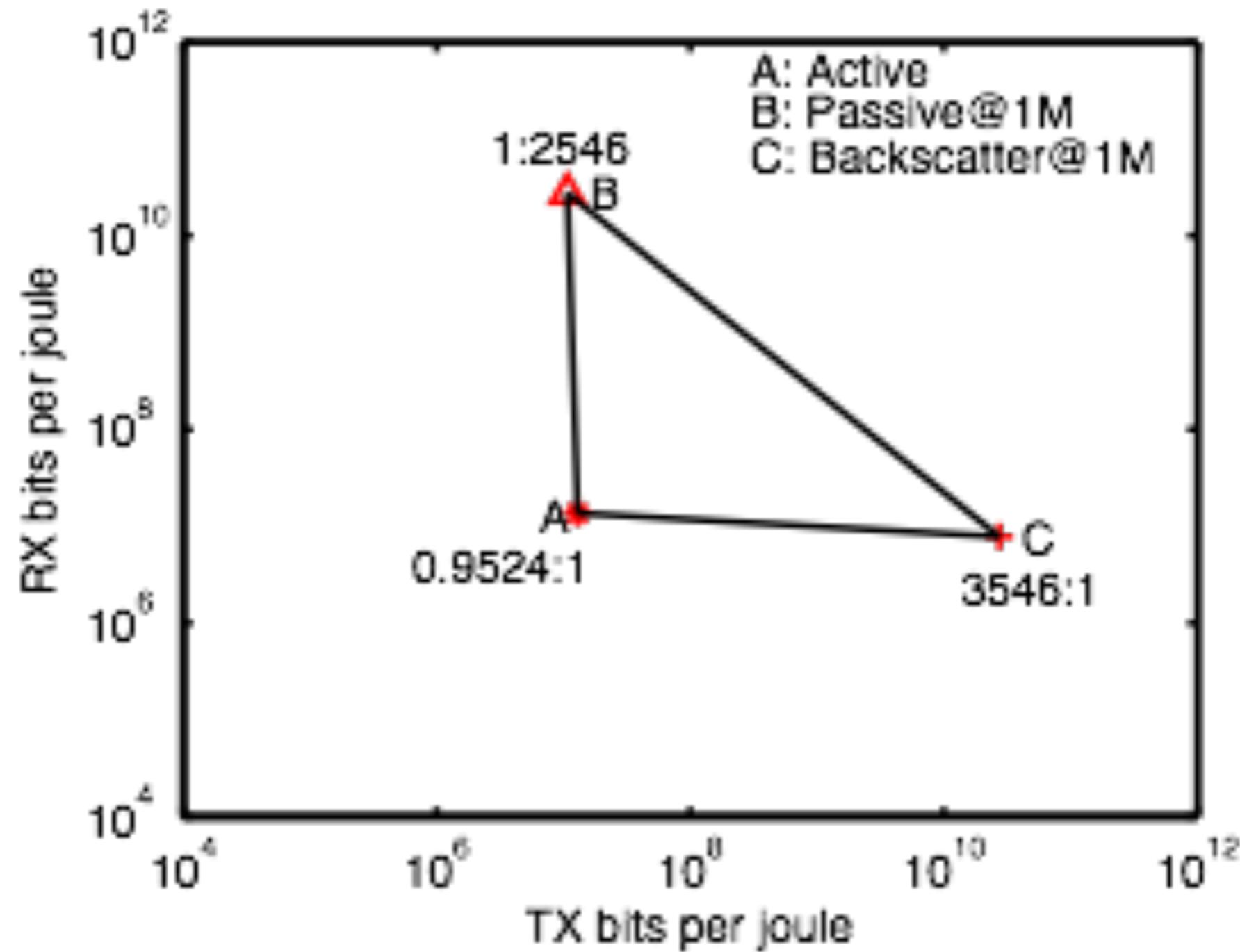


Braido multiplexes across modes based on SNR of each link and battery levels to achieve desired power ratio.

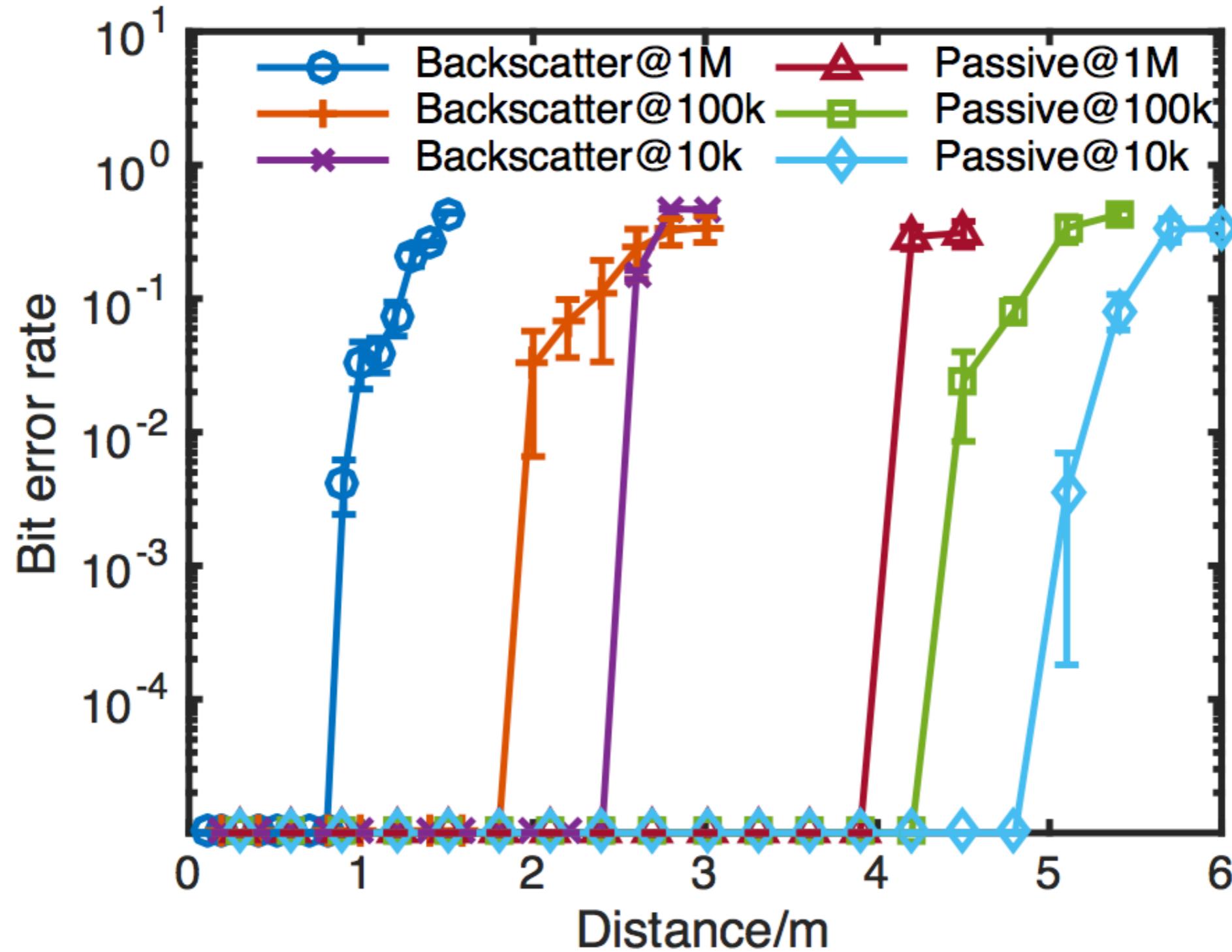
Implementation of Braudio



Braido: Achievable energy ratios



Braido: Operating distance

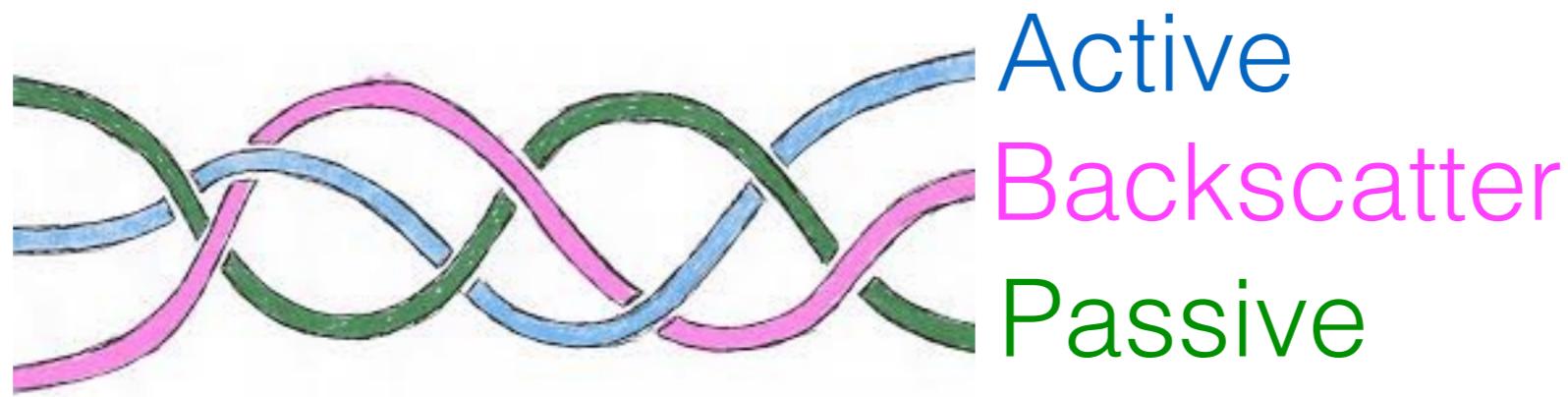


Braido: Performance gain over active radio

Receiver	Nike Fuel Band	Pebble Watch	Apple Watch	Pivothead	iPhone 6S	iPhone 6 Plus	Nexus 6P	Surface Book	MacBook Pro 13	MacBook Pro 15
Transmitter	1.43	2.45	3.51	6.63	24.7	39.1	49.1	251	276	350
Nike Fuel Band	2.57	1.43	1.76	2.97	9.98	15.5	19.4	97.7	107	136
Pebble Watch	3.68	1.85	1.43	2.11	6.51	10.0	12.4	61.6	67.9	85.8
Apple Watch	6.97	3.12	2.21	1.43	3.45	5.12	6.29	29.8	32.8	41.4
Pivothead	25.9	10.4	6.1	6.1	8.64	10.7	10.7	10.7	10.7	10.7
iPhone 6S	41.0	16.3	10.1	10.1	5.65	6.99	6.99	6.99	6.99	6.99
iPhone 6 Plus	51.6	20.4	13.1	13.1	4.61	5.68	5.68	5.68	5.68	5.68
Nexus 6P	263	102	64.7	31.3	8.29	5.44	4.46	1.43	1.43	1.63
Surface Book	290	112	71.3	34.4	9.07	5.94	4.85	1.50	1.43	1.54
MacBook Pro 13	368	143	90.1	43.4	11.3	7.34	5.96	1.71	1.62	1.43
MacBook Pro 15										

>300x improvement
when fitness band
transmits to laptop

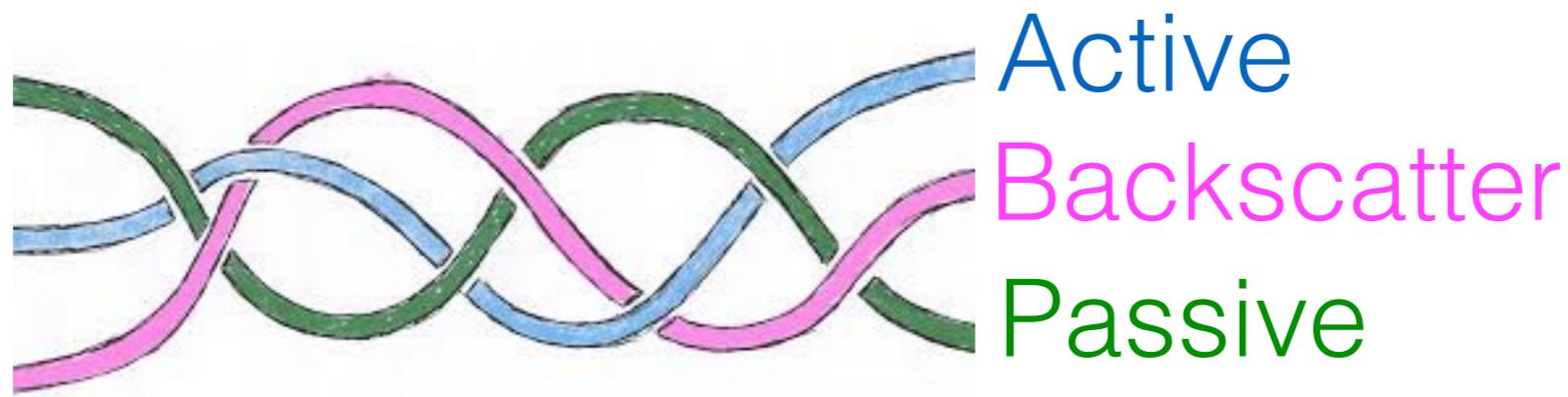
Conclusion



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

Thank you

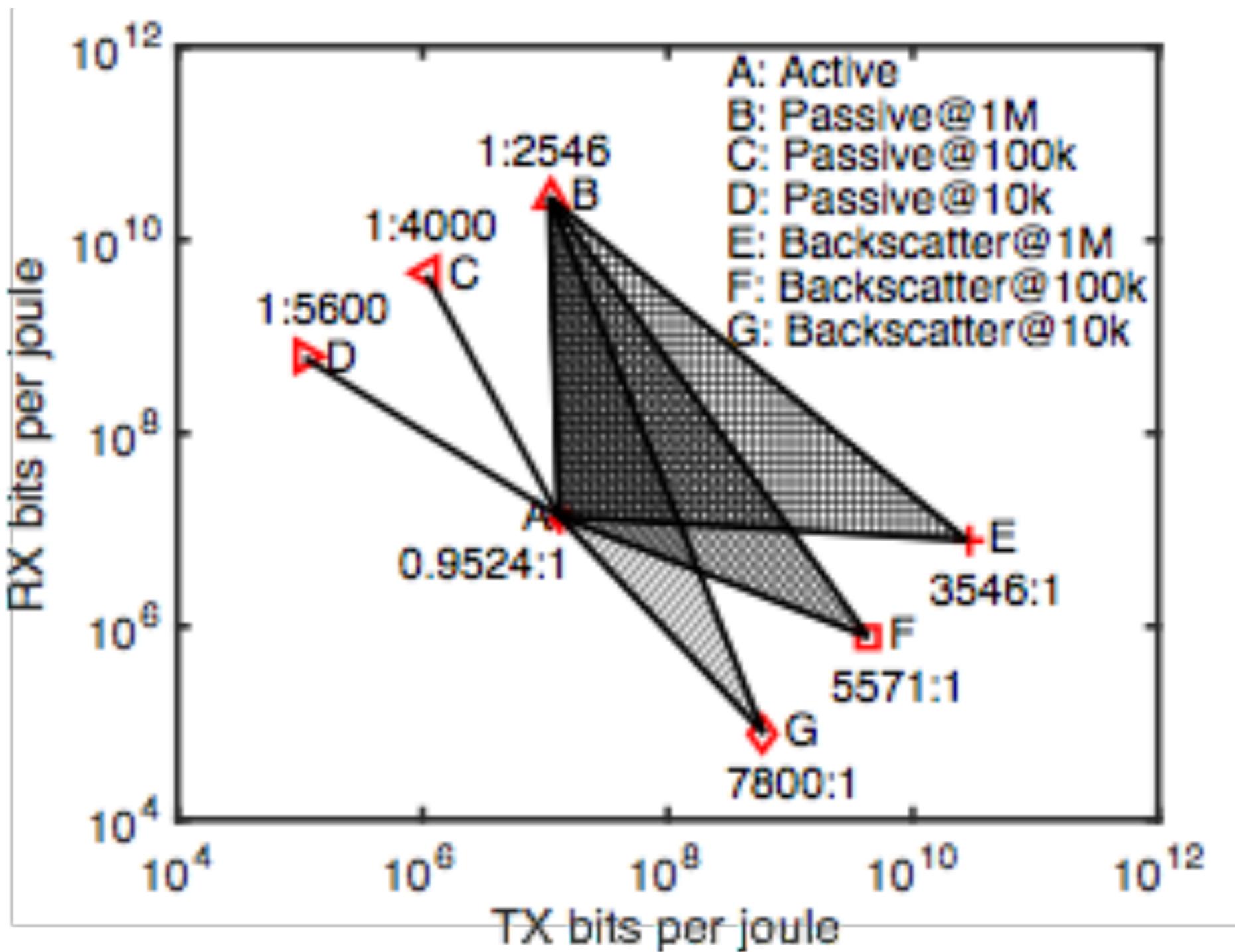
Conclusion



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

Thank you

Backup



Backup

