Wireless networking using conductive surfaces

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OF COMPUTER SCIENCE & ENGINEERING

Existing wireless technologies

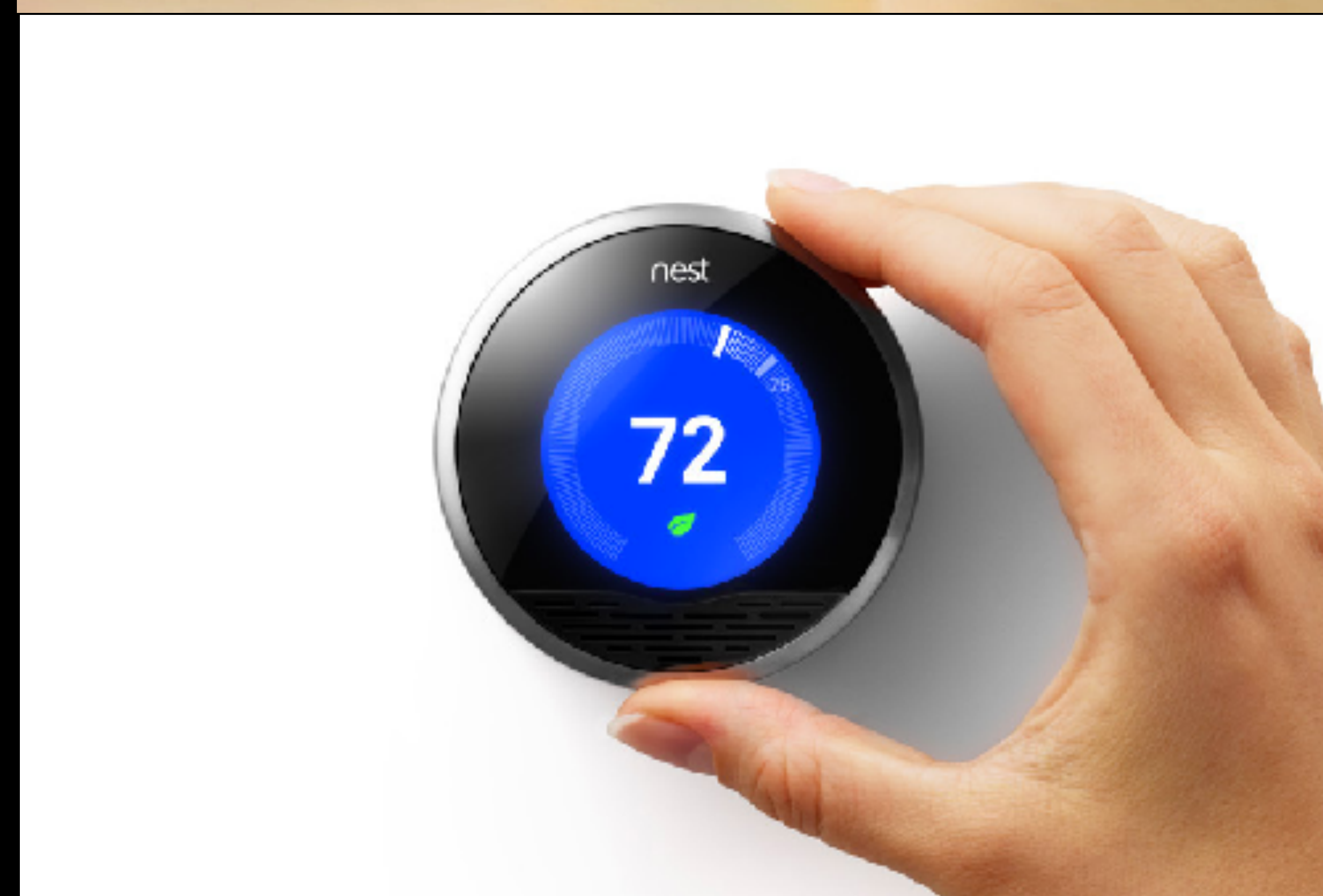
Ignore a large class of use cases

Devices often placed on common surface

Devices often placed on common surface

Shelves

Walls



Leveraging surfaces for communication

Can we achieve
high data rate
communication
when devices come
in contact with a
common surface?

Fundamental challenge

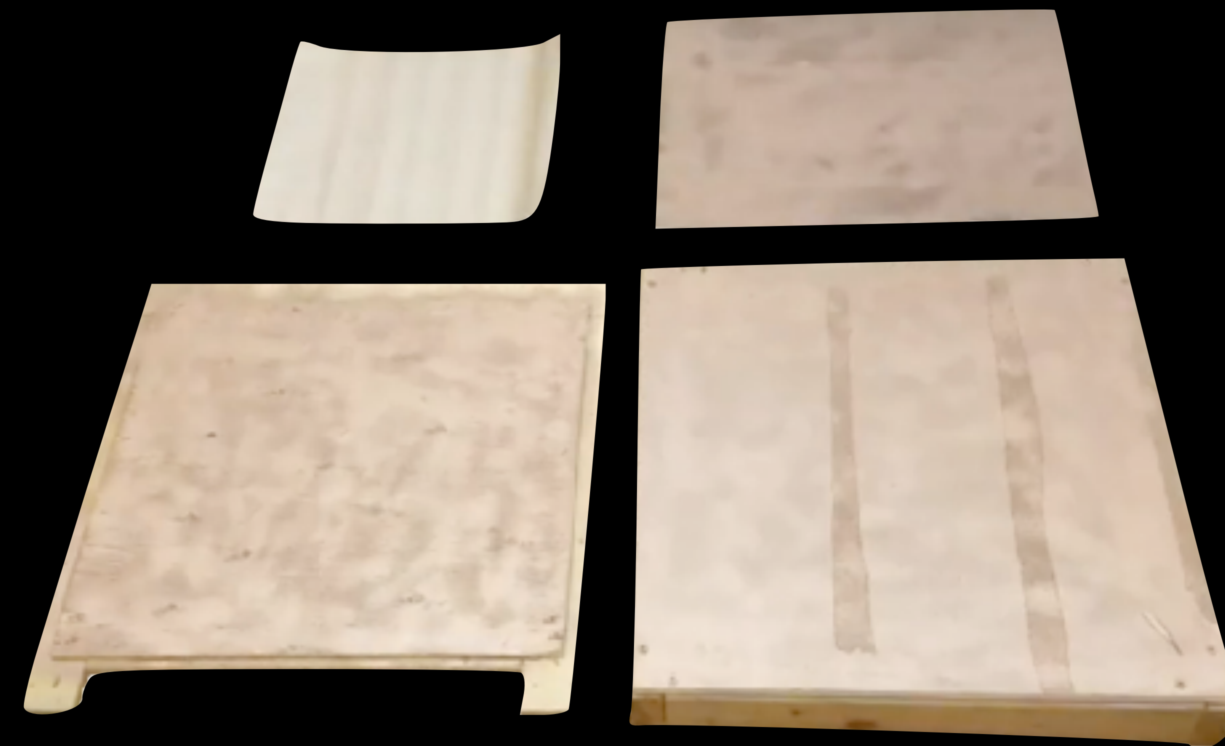
Wood

Sheetrock

Plastic

Common surface materials are not conductive

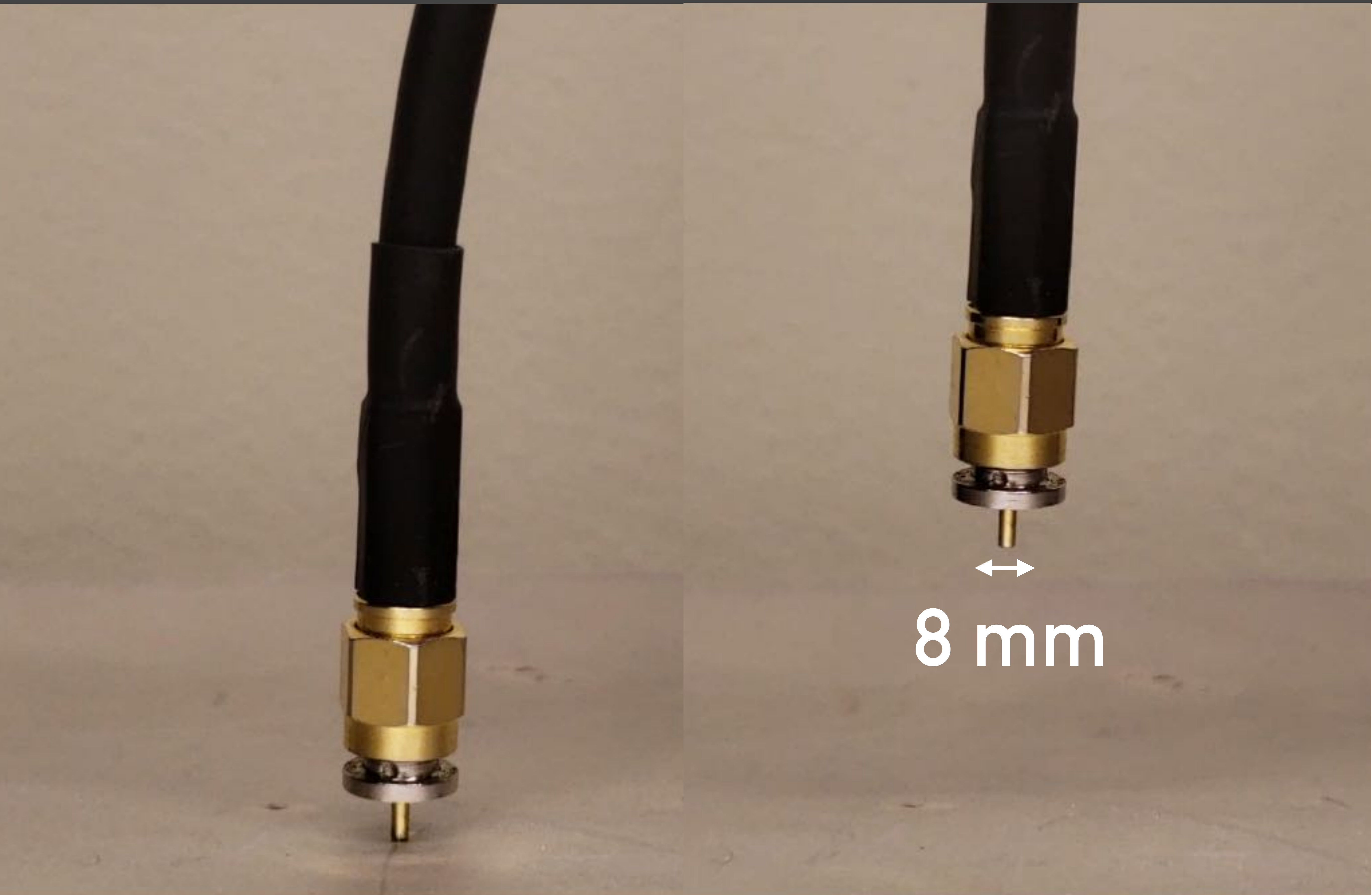
Our approach: conductive material



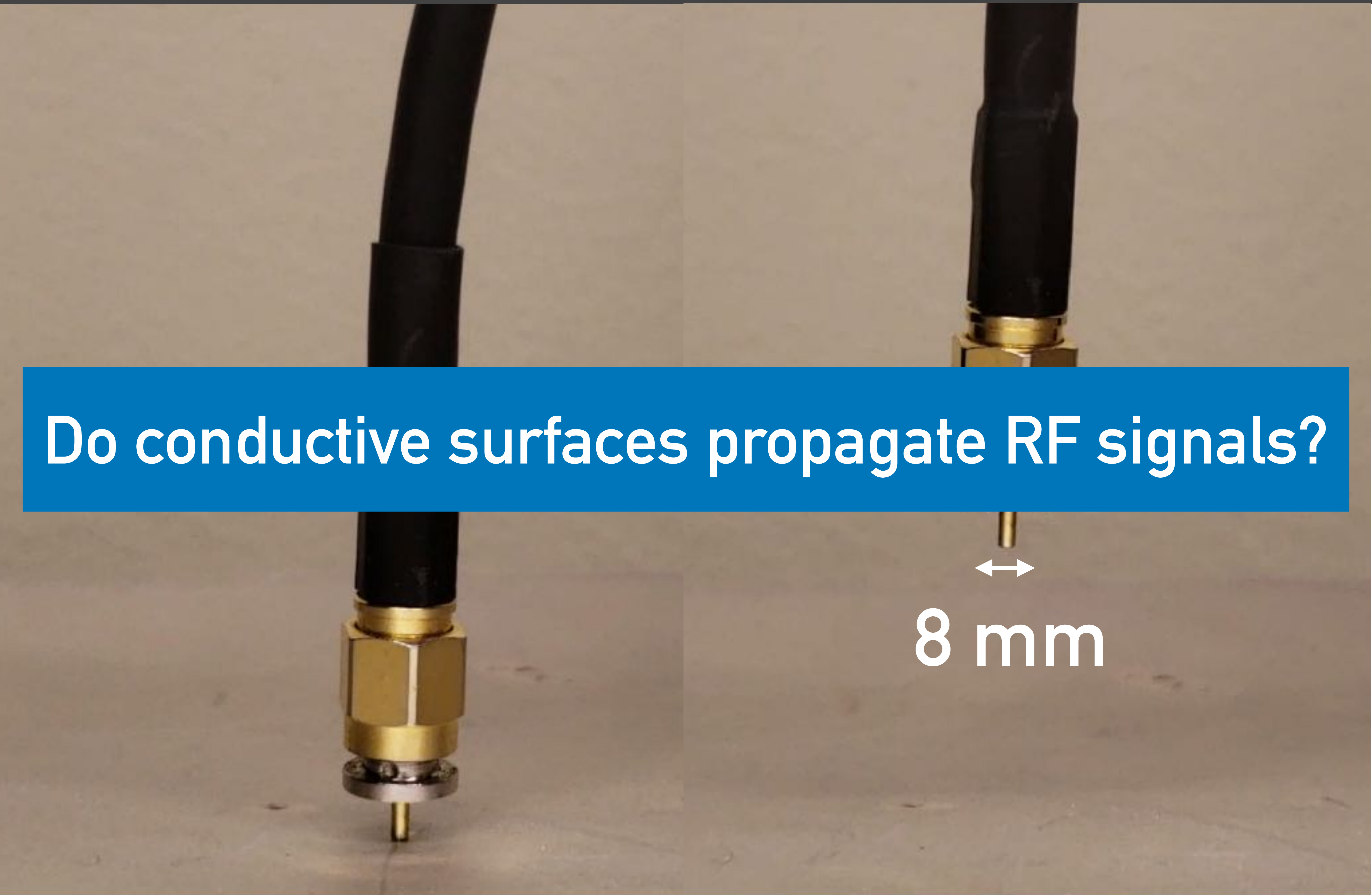
Our approach: conductive material

Materials can be used for wireless communication

Tiny contact point



Tiny contact point

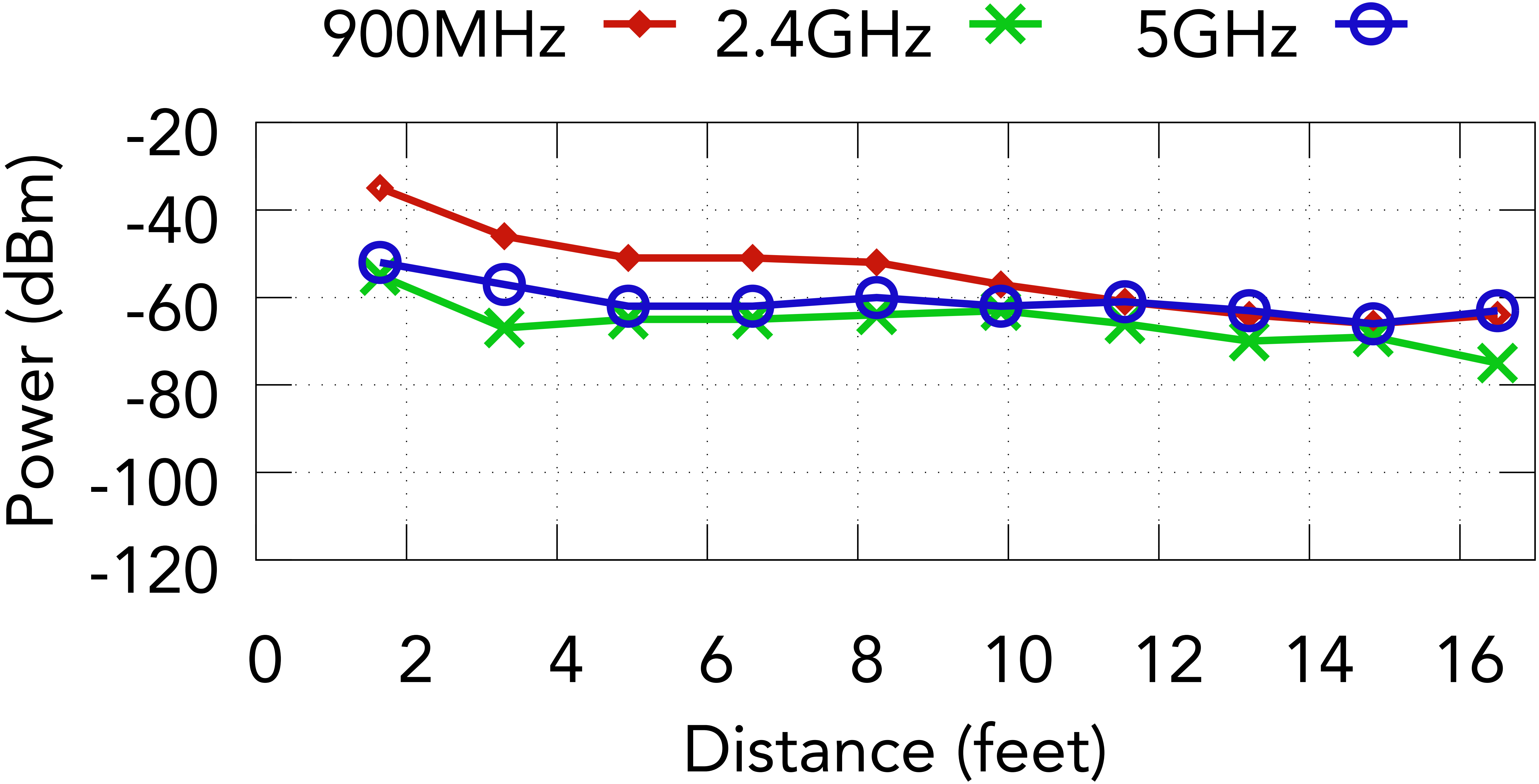


Do conductive surfaces propagate RF signals?

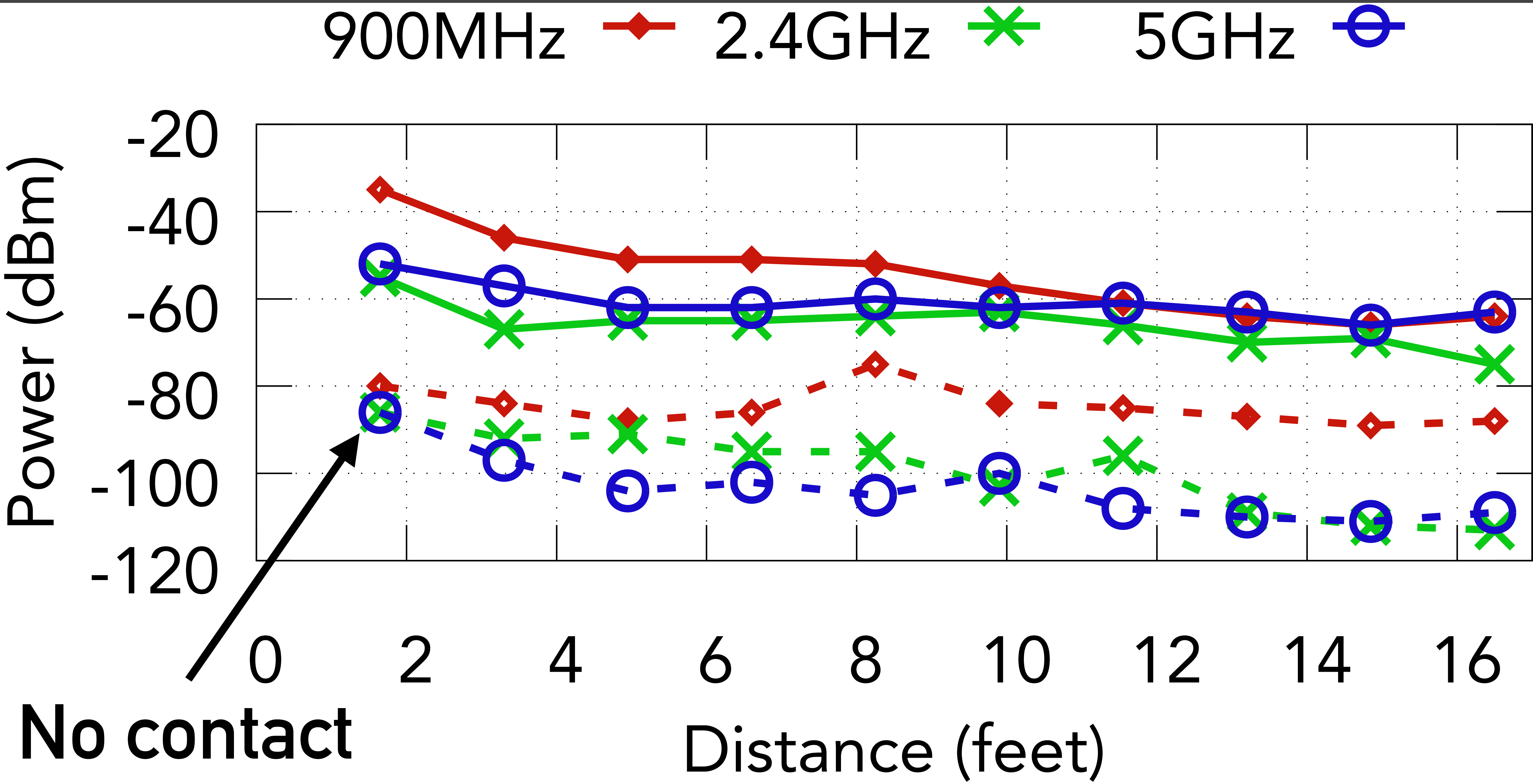
Surface MIMO testbed

16 feet

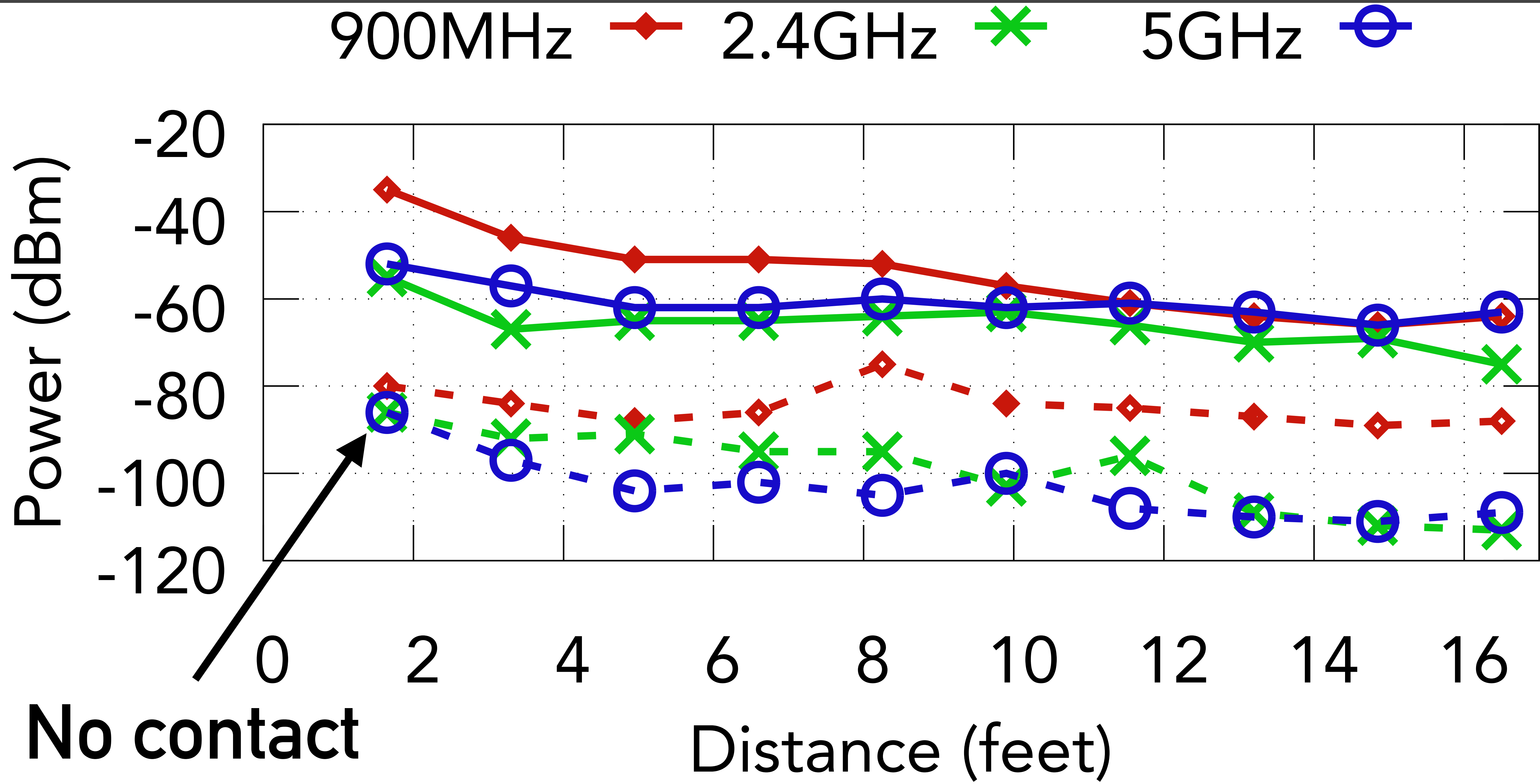
Do conductive surfaces propagate RF signals?



Do conductive surfaces propagate RF signals?

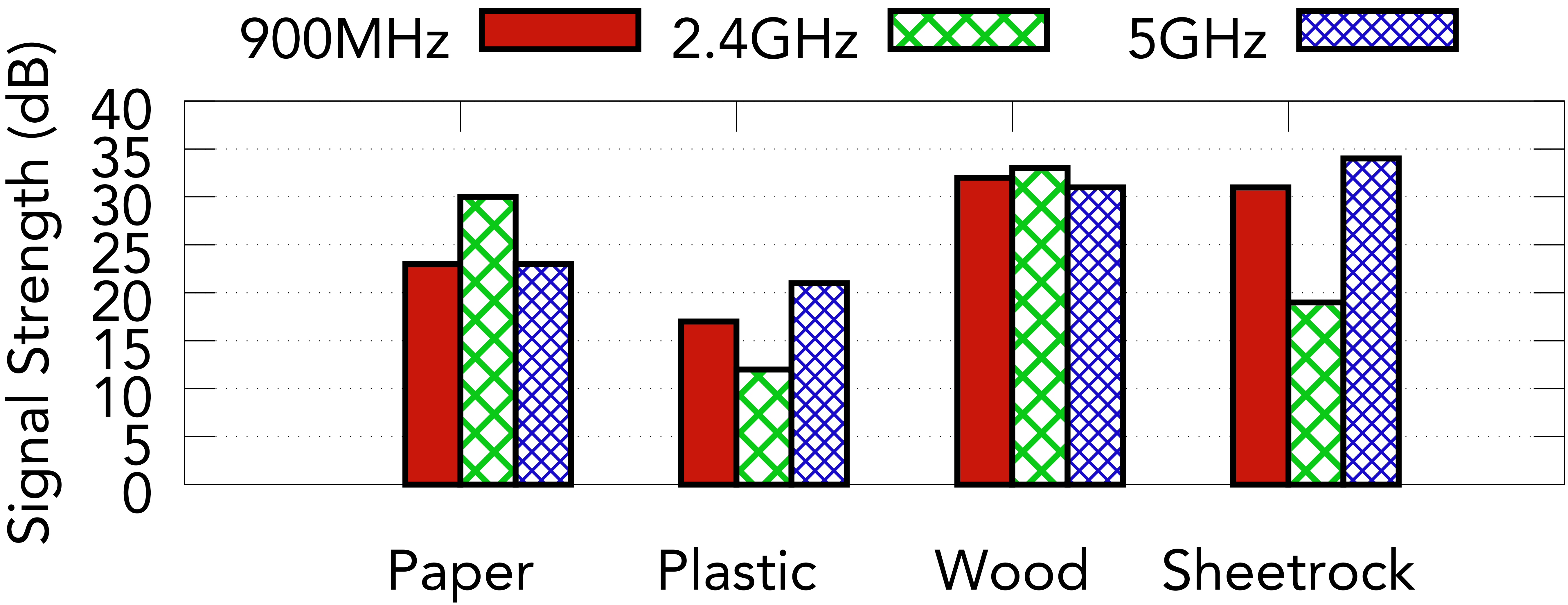


Do conductive surfaces propagate RF signals?



Communication is due to contact with the surface

Effect of substrate

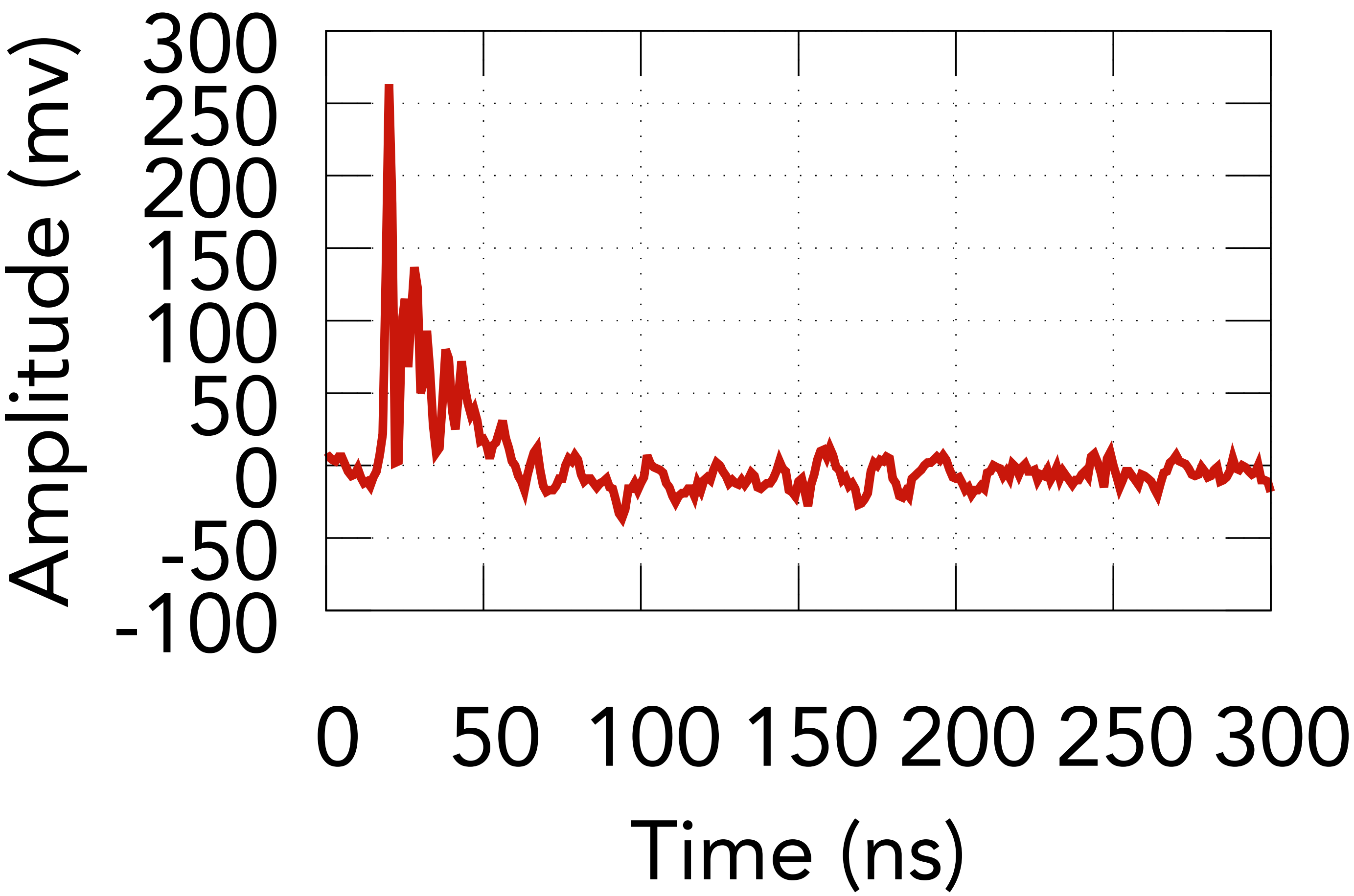


What happens with objects on the surface?

Without objects

With objects

What happens with objects on the surface?

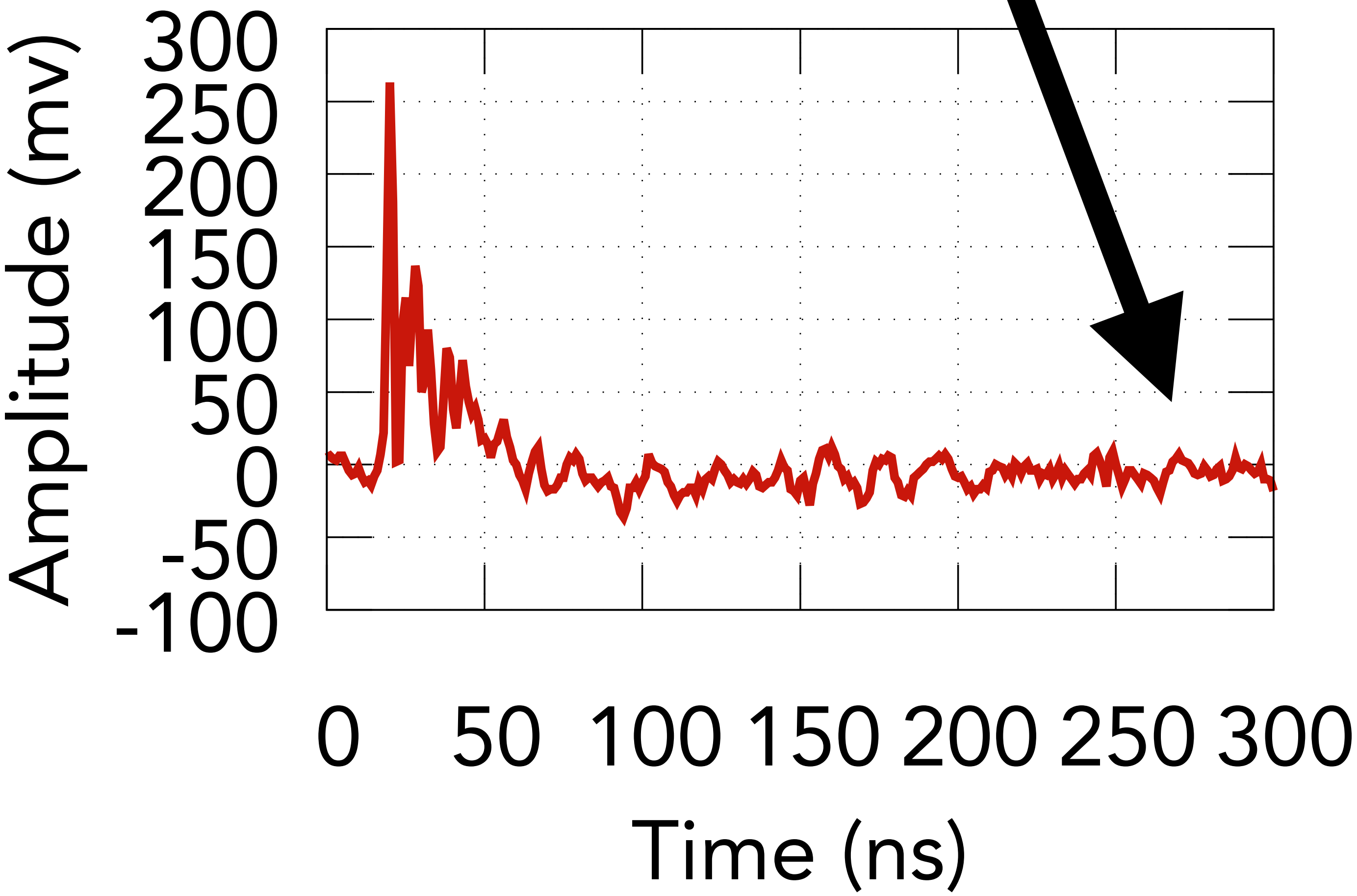


Without objects

With objects

What happens with objects on the surface?

Noise on channel

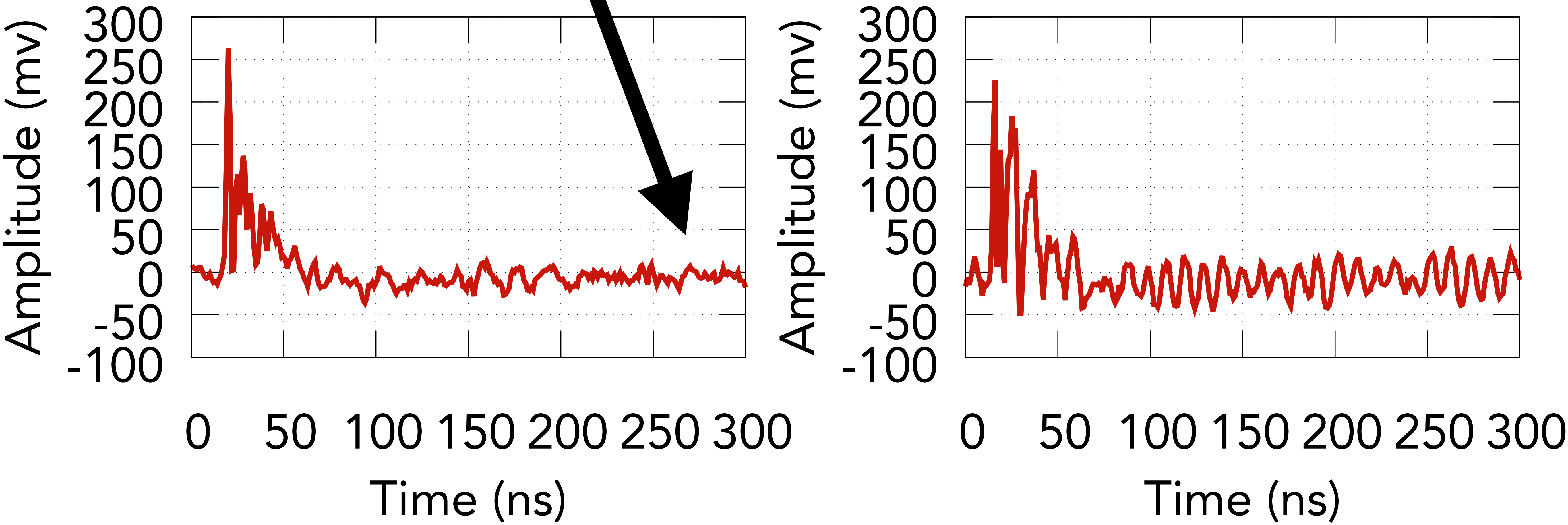


Without objects

With objects

What happens with objects on the surface?

Noise on channel

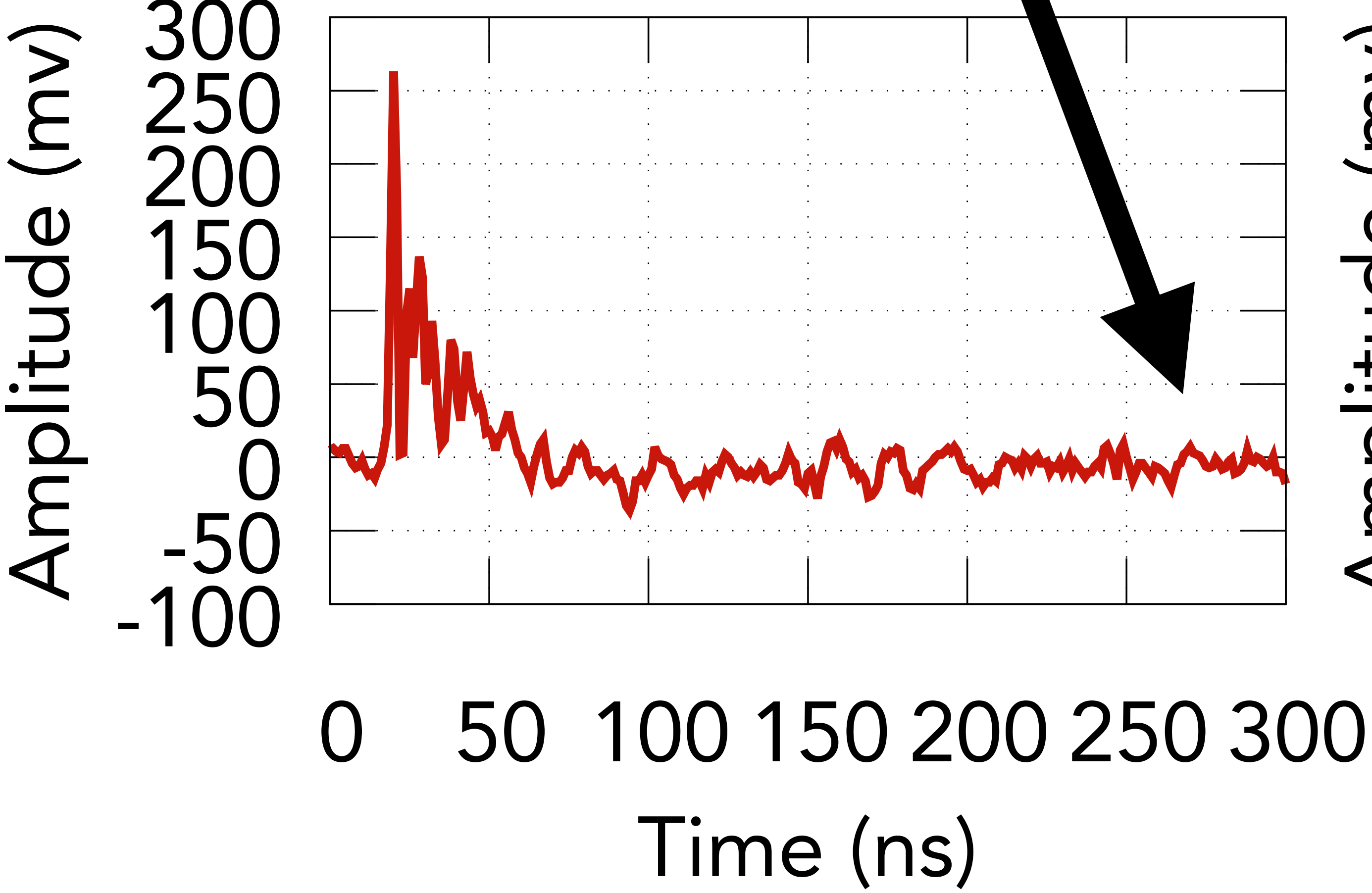


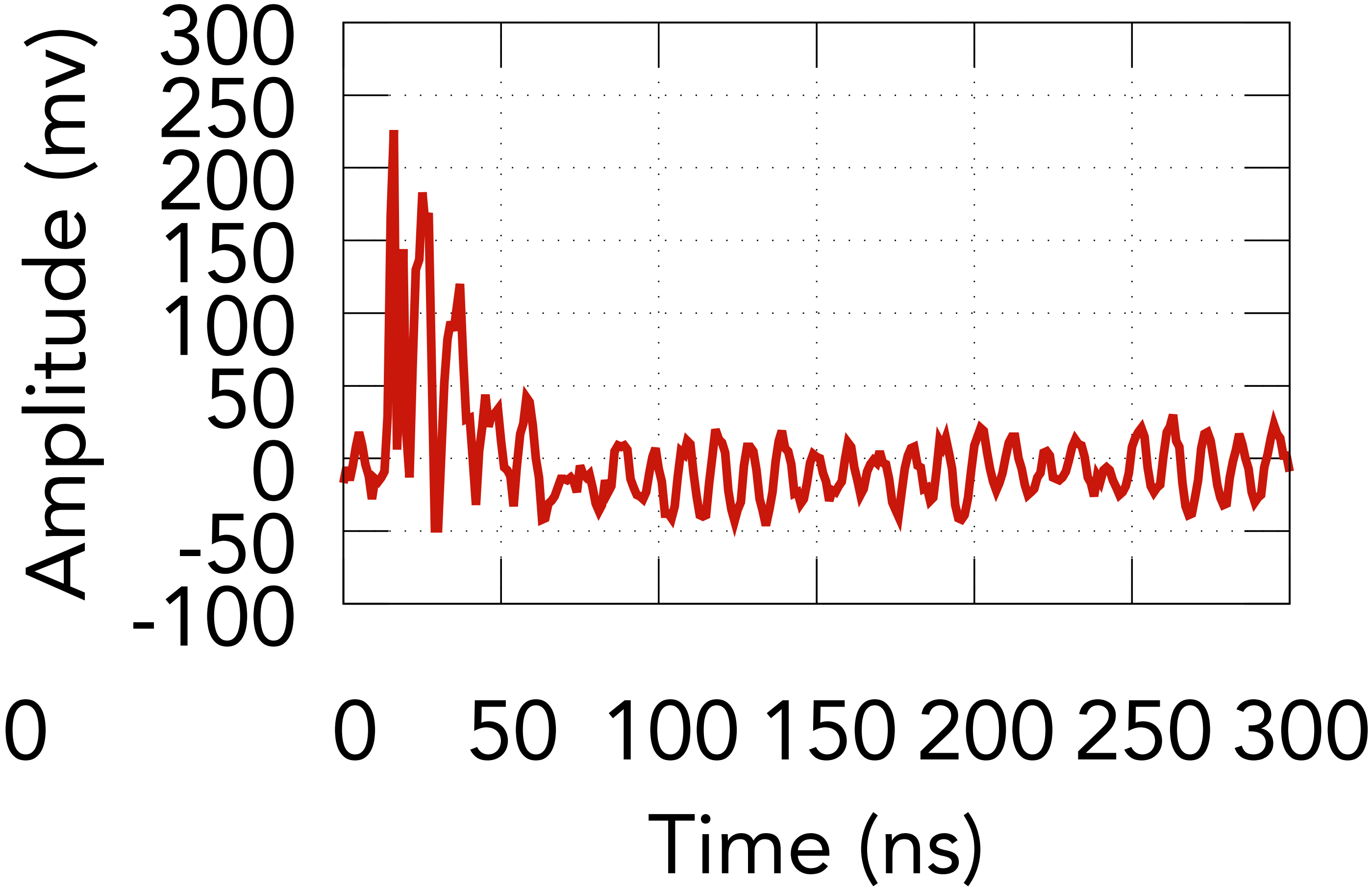
Without objects

With objects

What happens with objects on the surface?

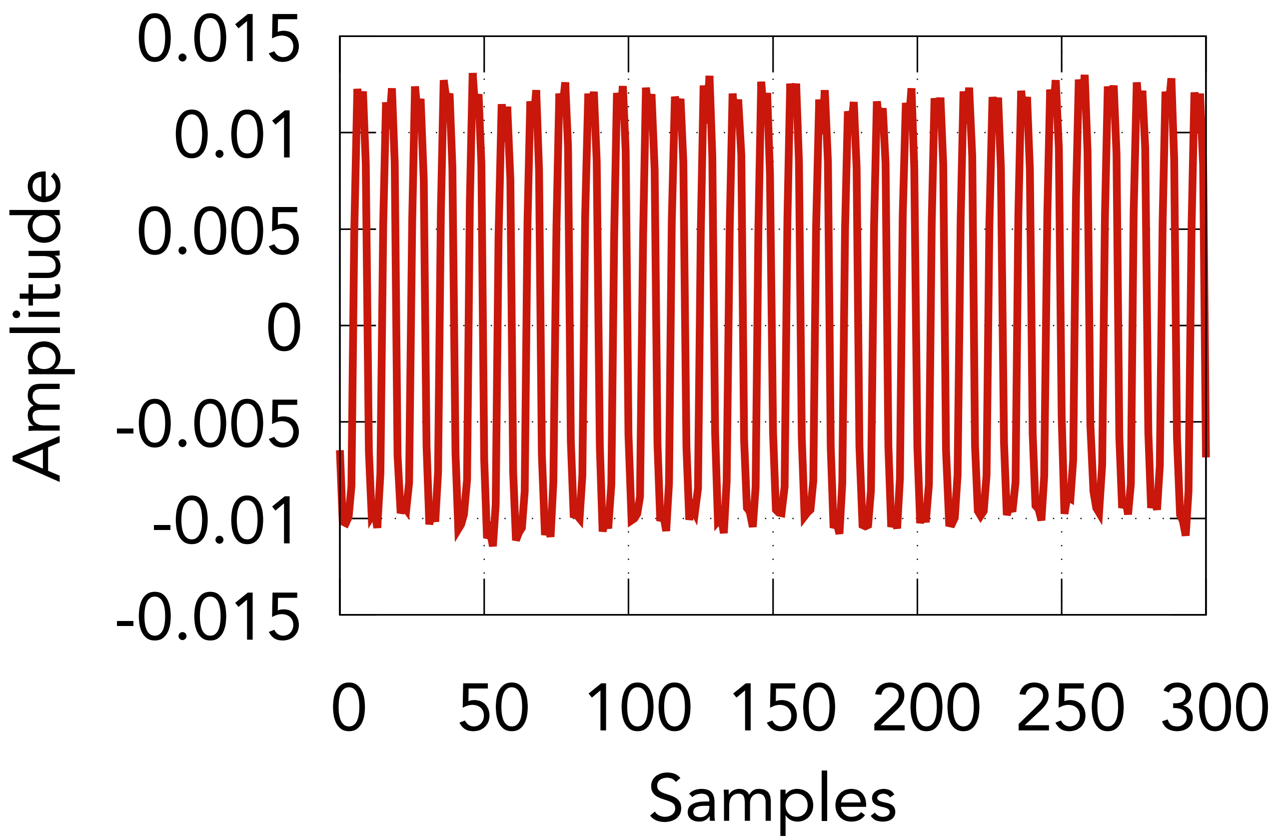
Noise on channel



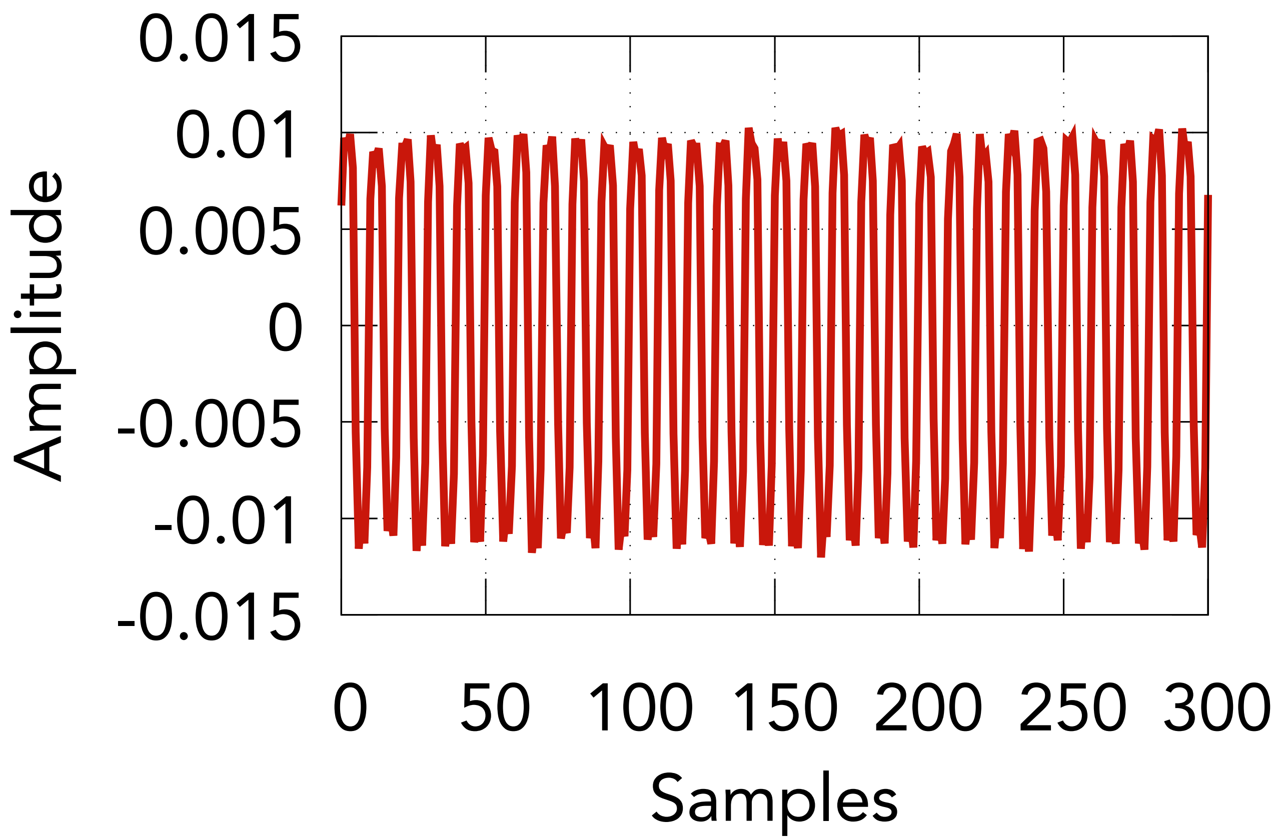


Delay spread addressable with OFDM cyclic prefix

Does grounding matter?

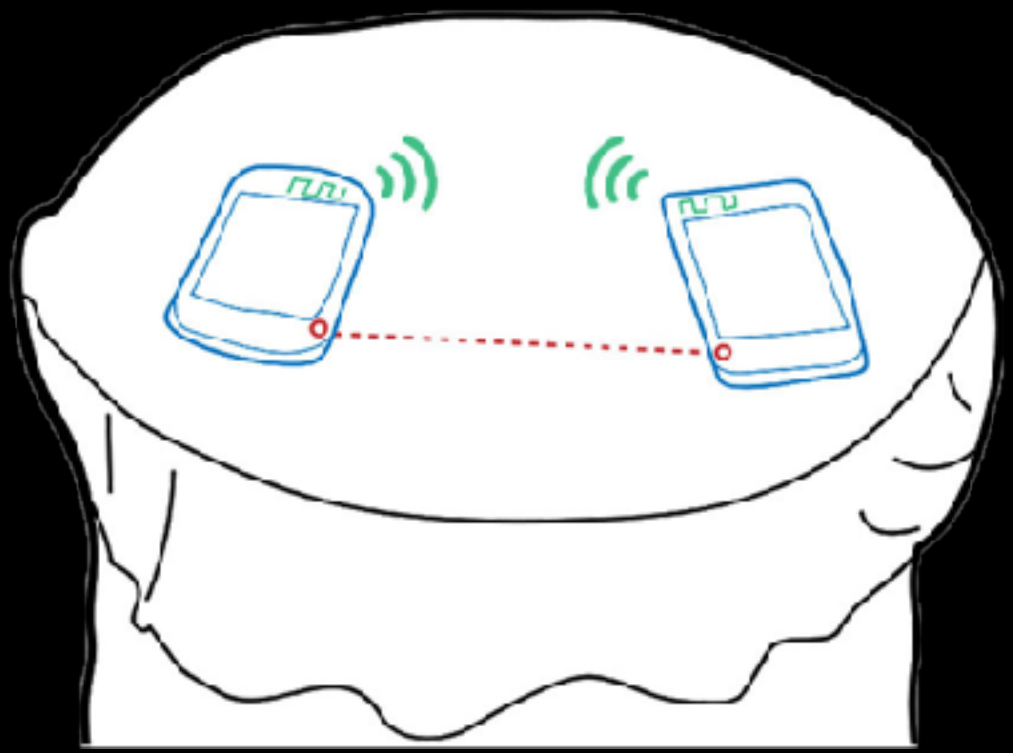


With ground



Without ground

Two new ways to communicate using surfaces



MIMO for single-antenna devices

Gigabit communication

Traditional MIMO

Transmitter

Receivers

Traditional MIMO

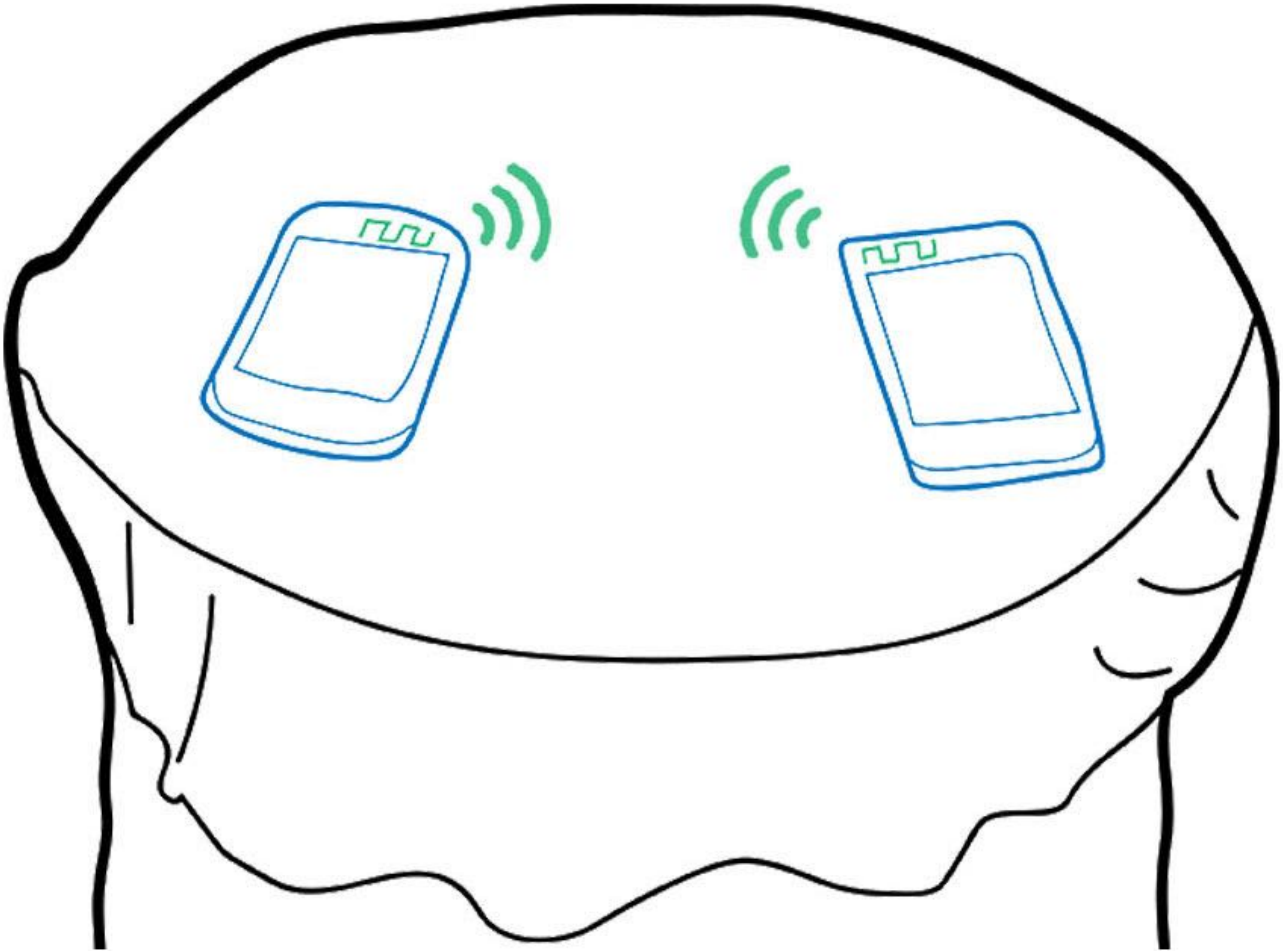
Transmitter

Receivers

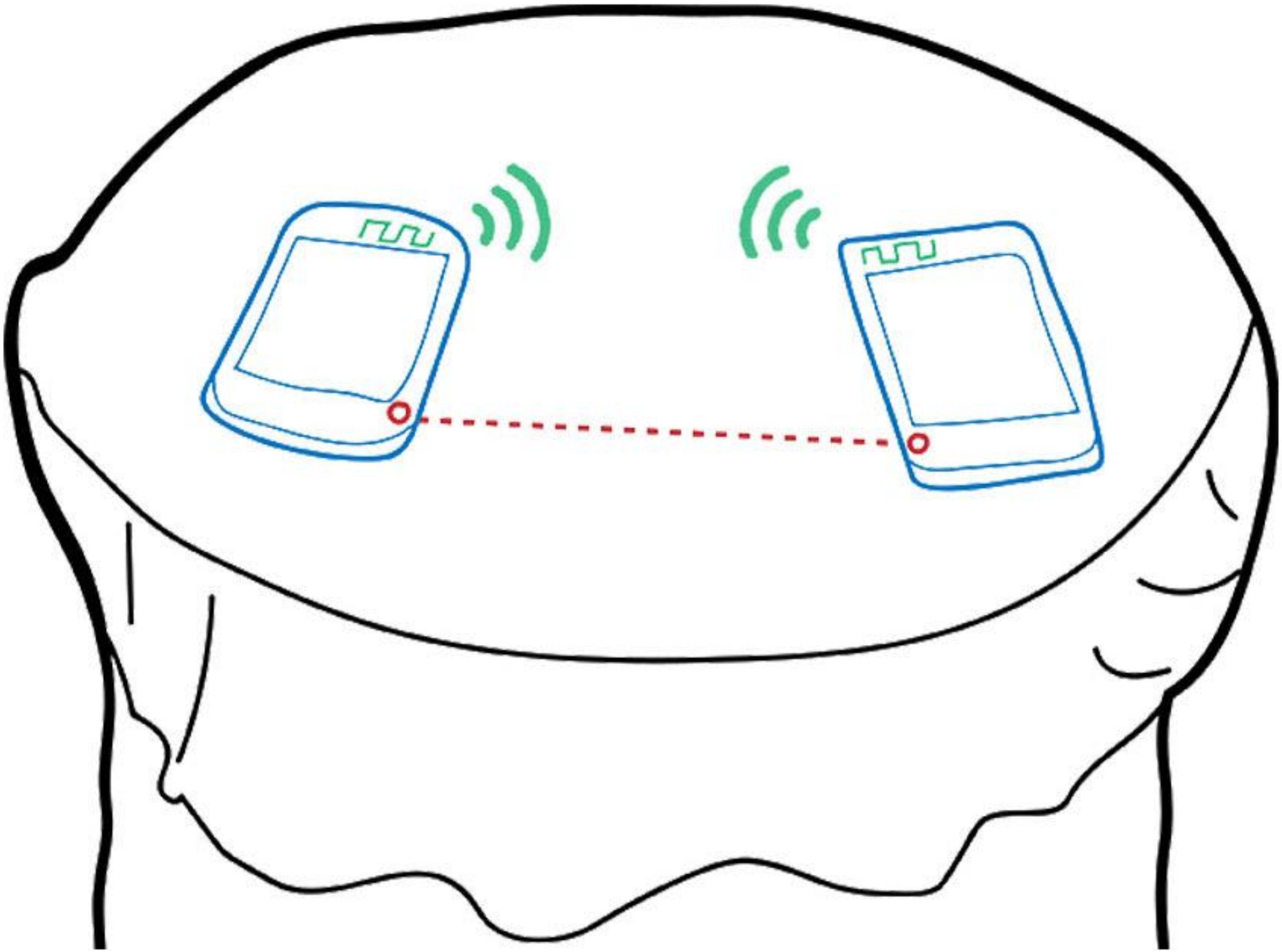
Key insight

Exploit surface as additional spatial path

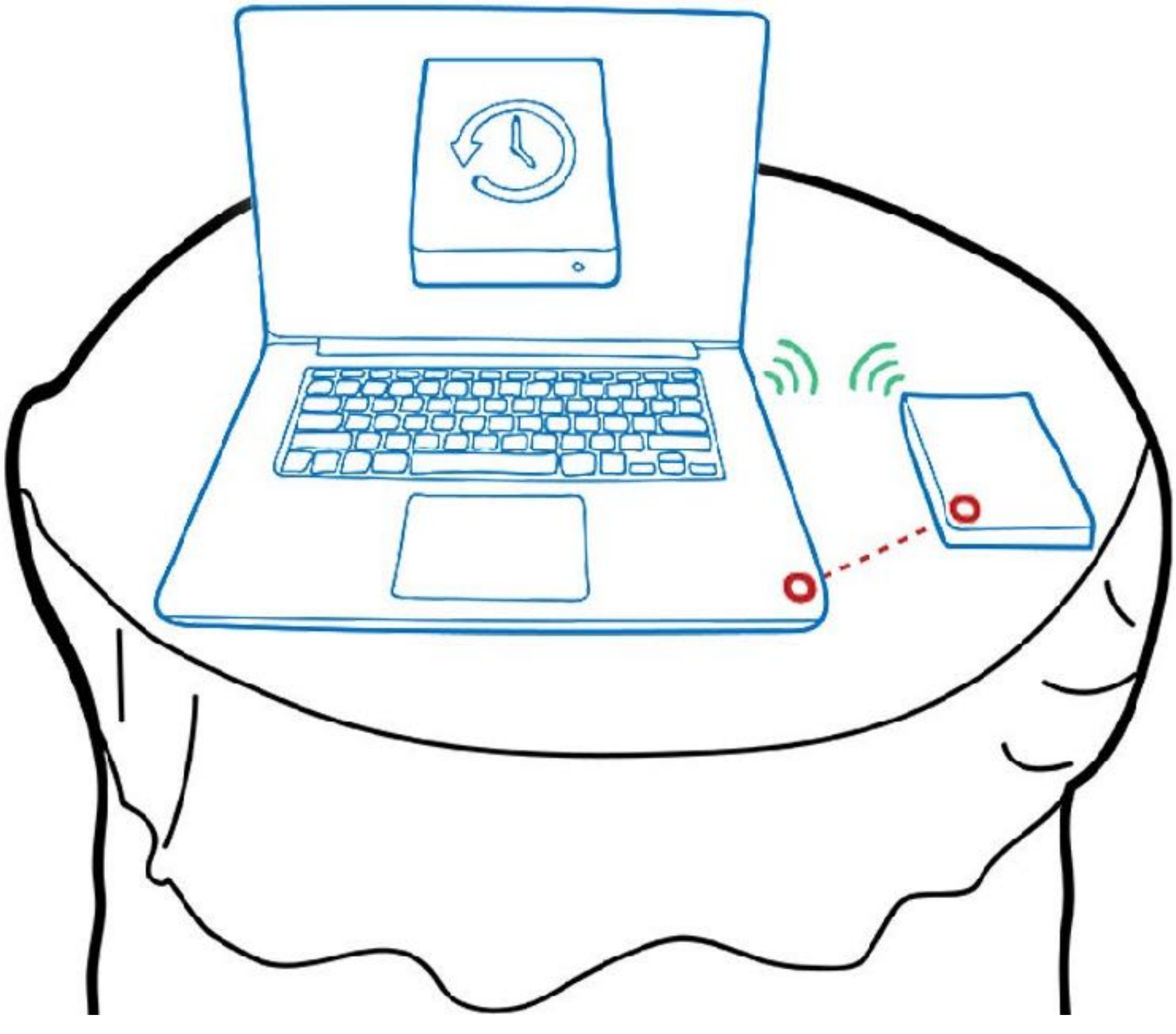
Surface MIMO



Surface MIMO



Surface MIMO



Traditional MIMO system

Traditional MIMO system

Too large for a mobile device

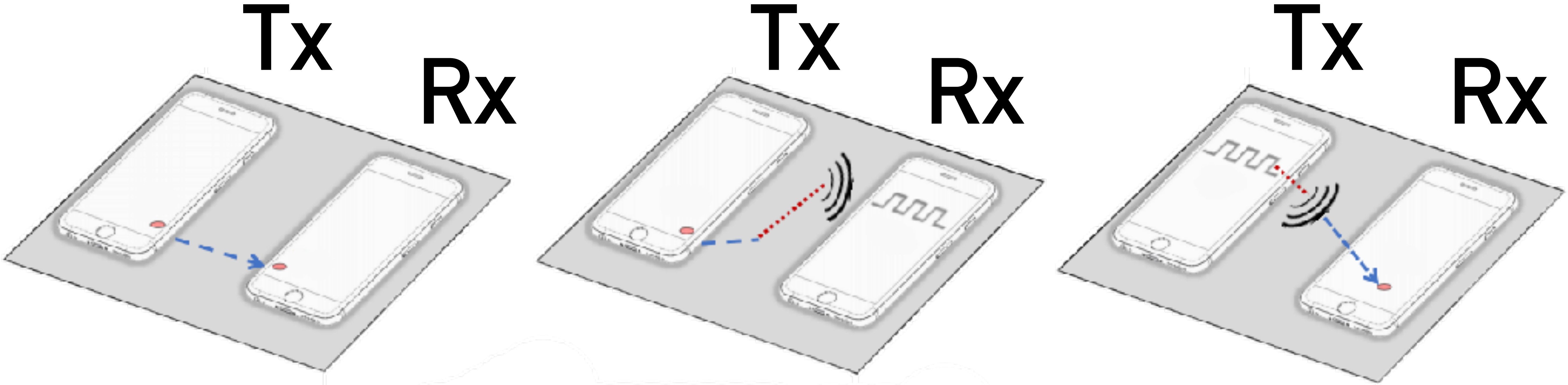
Traditional MIMO system

Streams become too correlated

Surface MIMO contact separation

Achieves MIMO with 1 cm separation

Propagation on surface is slower than over the air

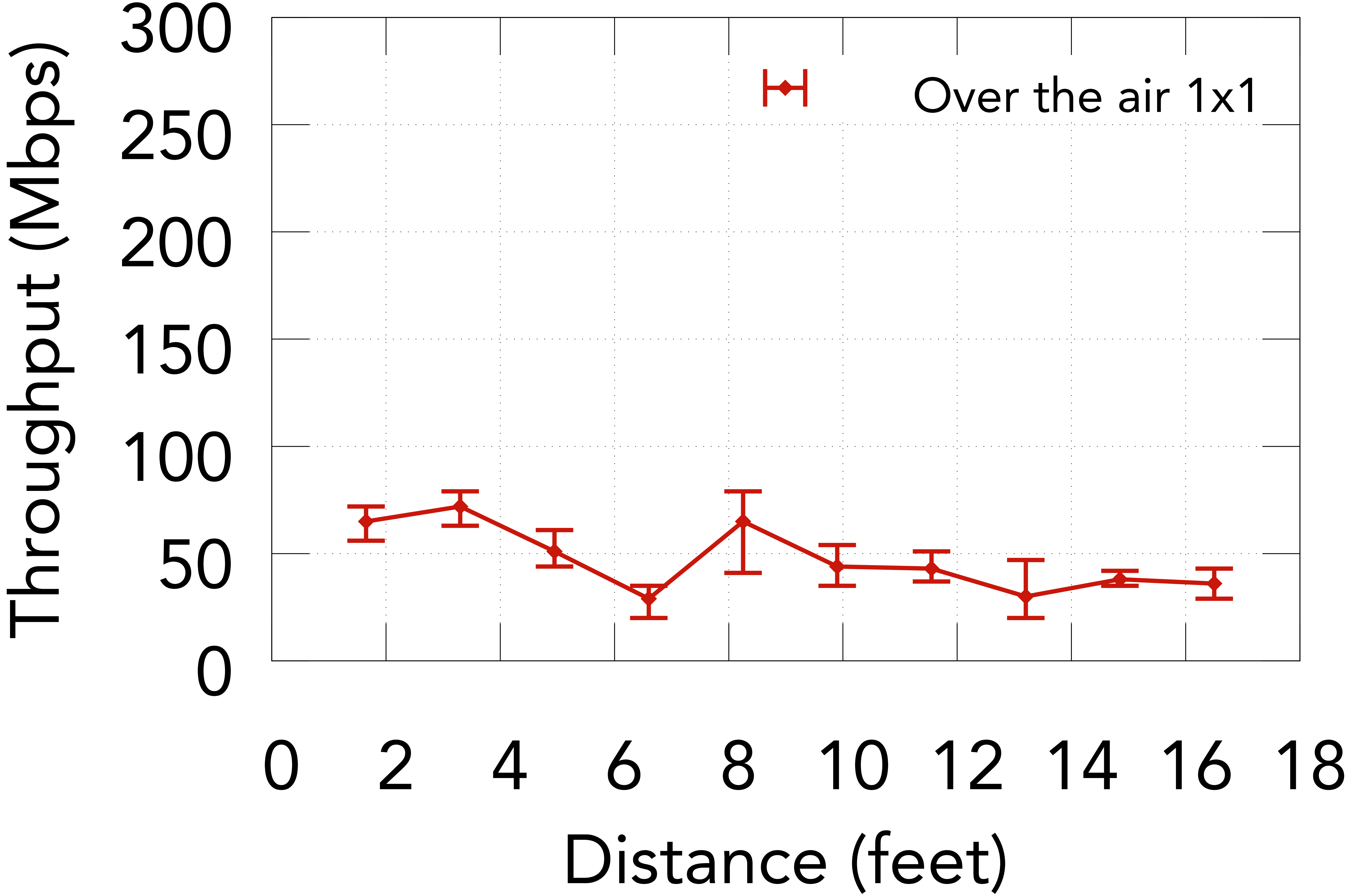


Surface channel creates additional spatial path

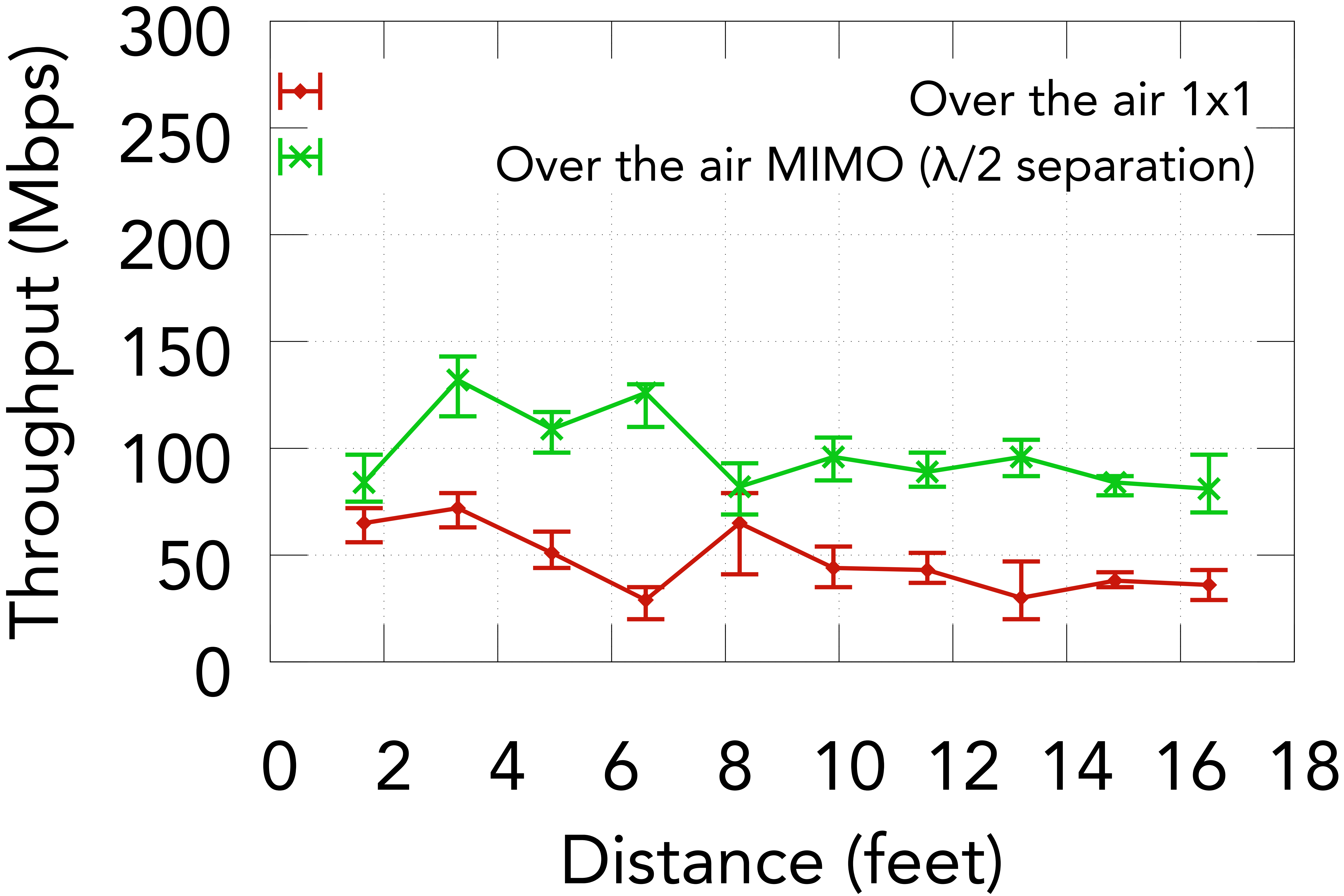
How well does Surface MIMO work in practice?

1. Over the air 1x1 system
2. Over the air MIMO system
3. Surface MIMO without objects
4. Surface MIMO with objects

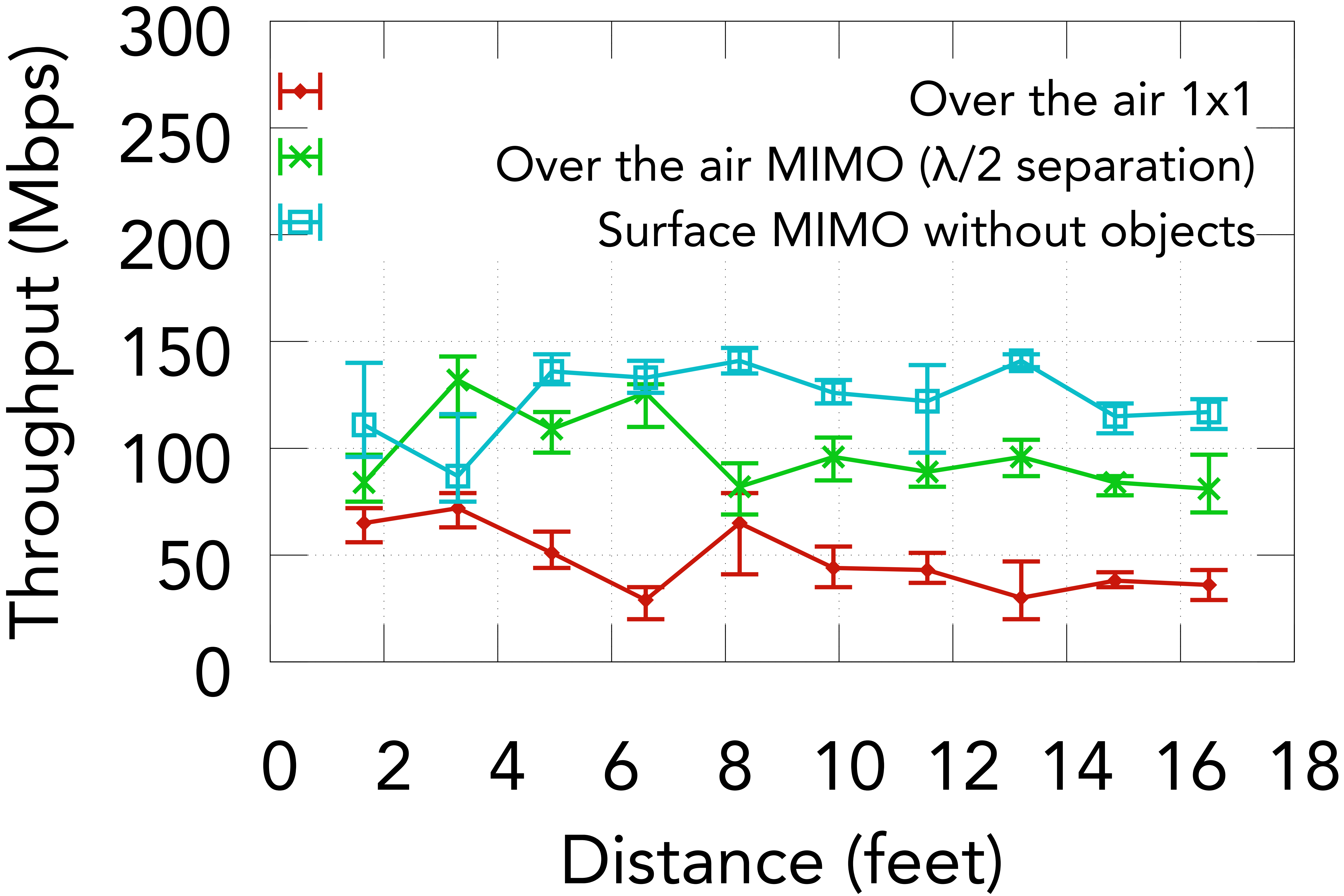
Throughput gains



Throughput gains



Throughput gains

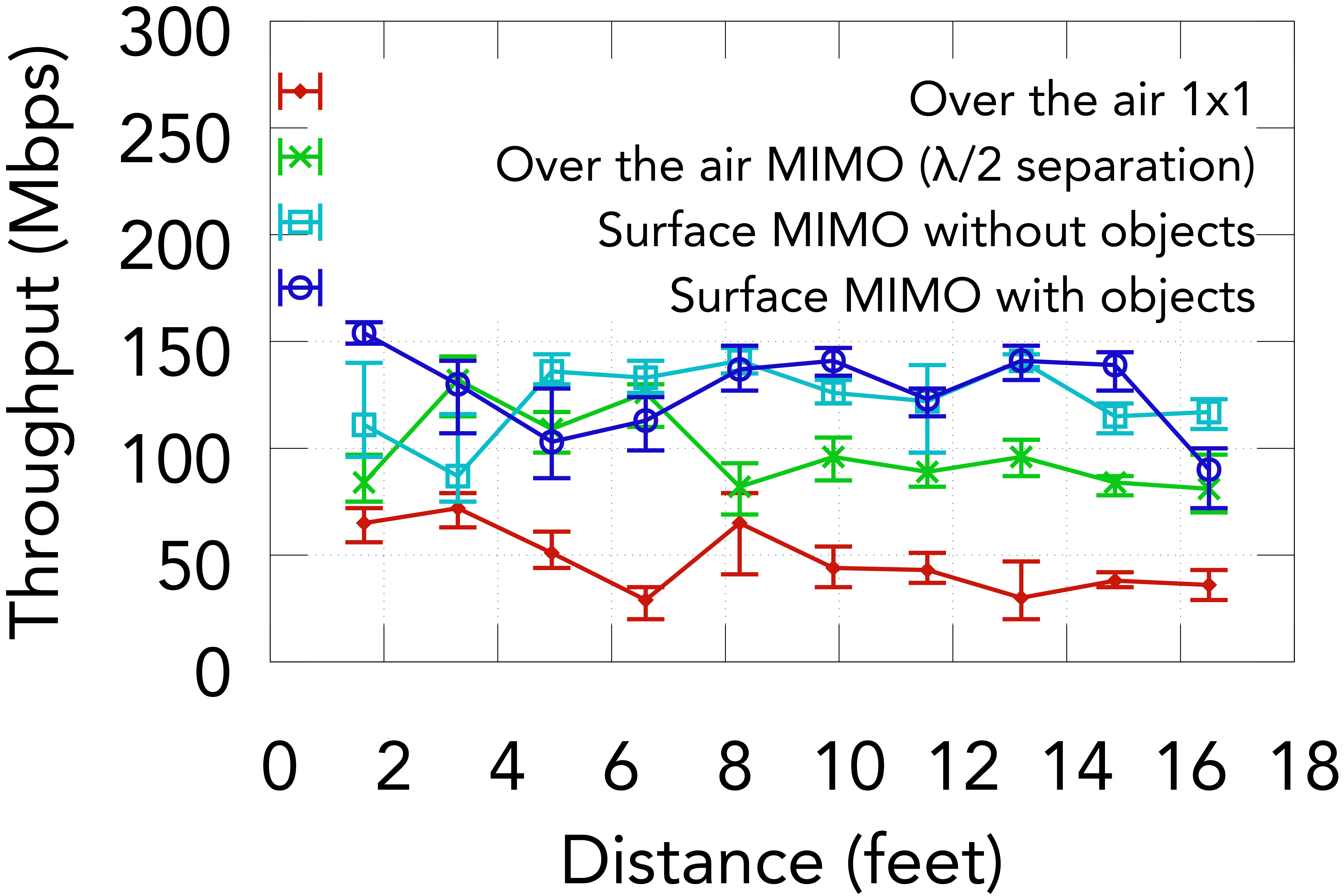


Why are we better than traditional MIMO?

1. Surface acts like an antenna
2. Multi path on surface is stronger than multi path over the air

Cluttered Surface MIMO testbed

Throughput gains



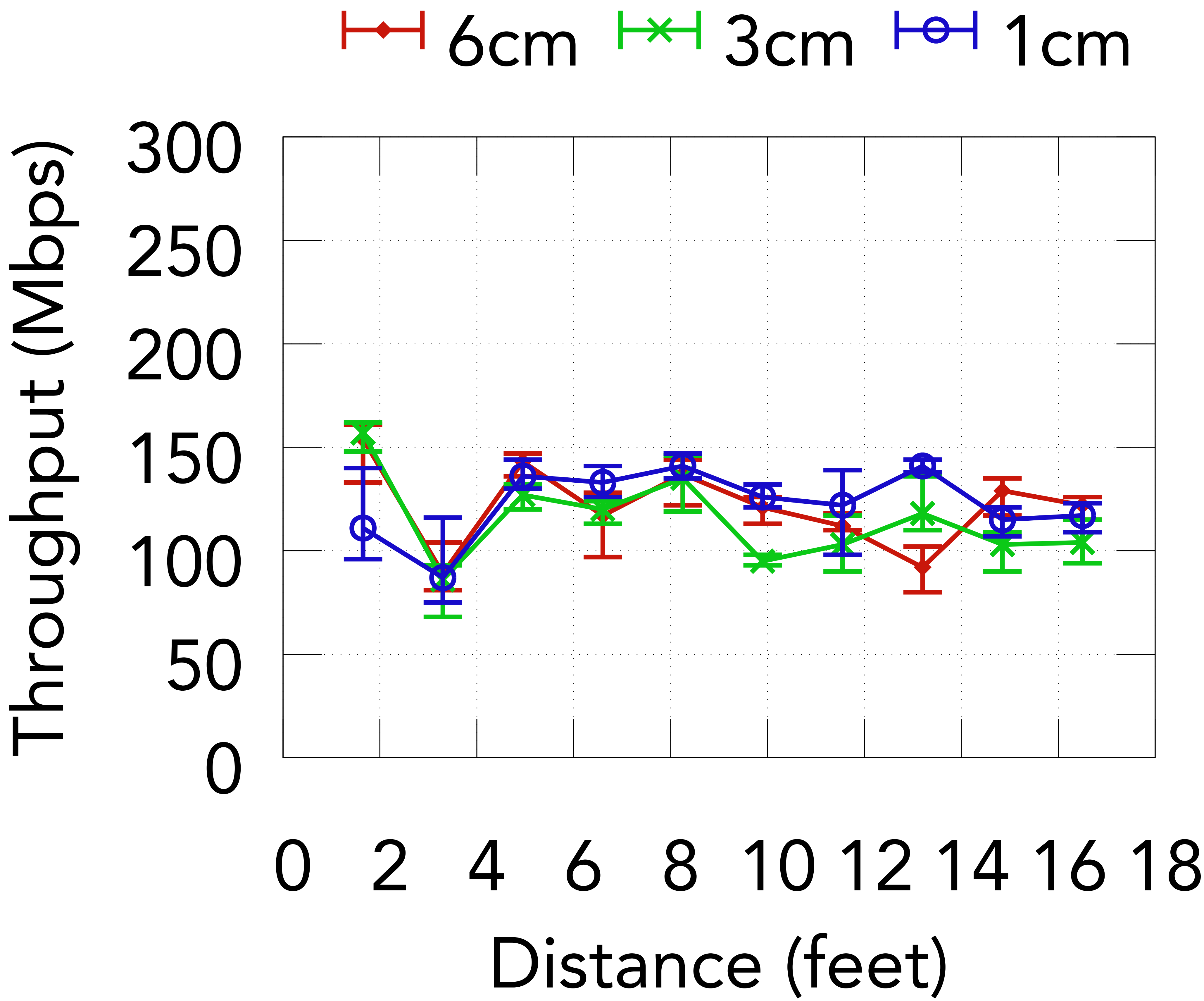
Throughput gains

	2x2 Surface MIMO gains
Over the air 1x1	2.6x
Traditional MIMO	1.2x

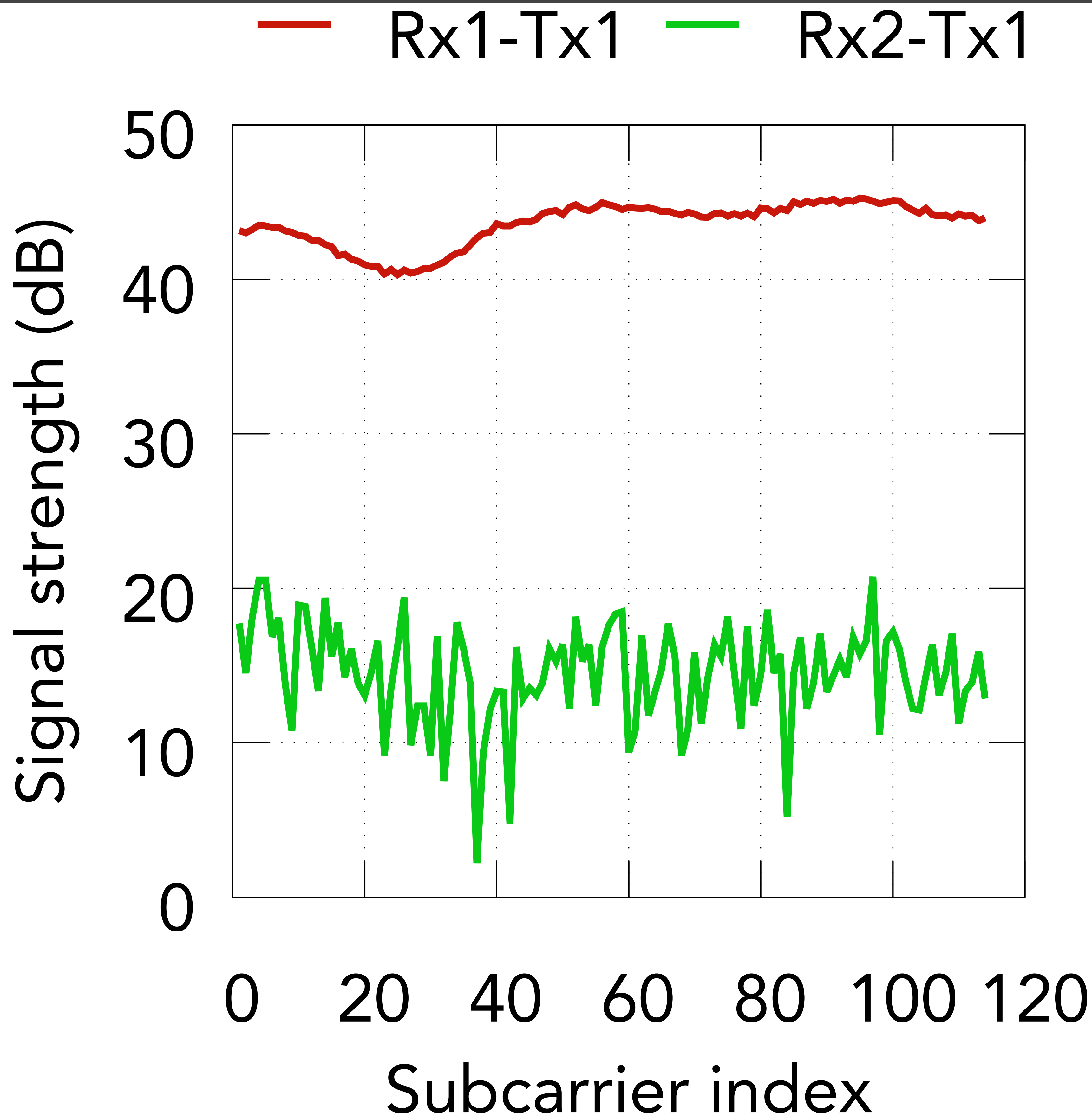
Throughput gains

	2x2 Surface MIMO gains	3x3 Surface MIMO gains
Over the air 1x1	2.6x	3x
Traditional MIMO	1.2x	1.3x

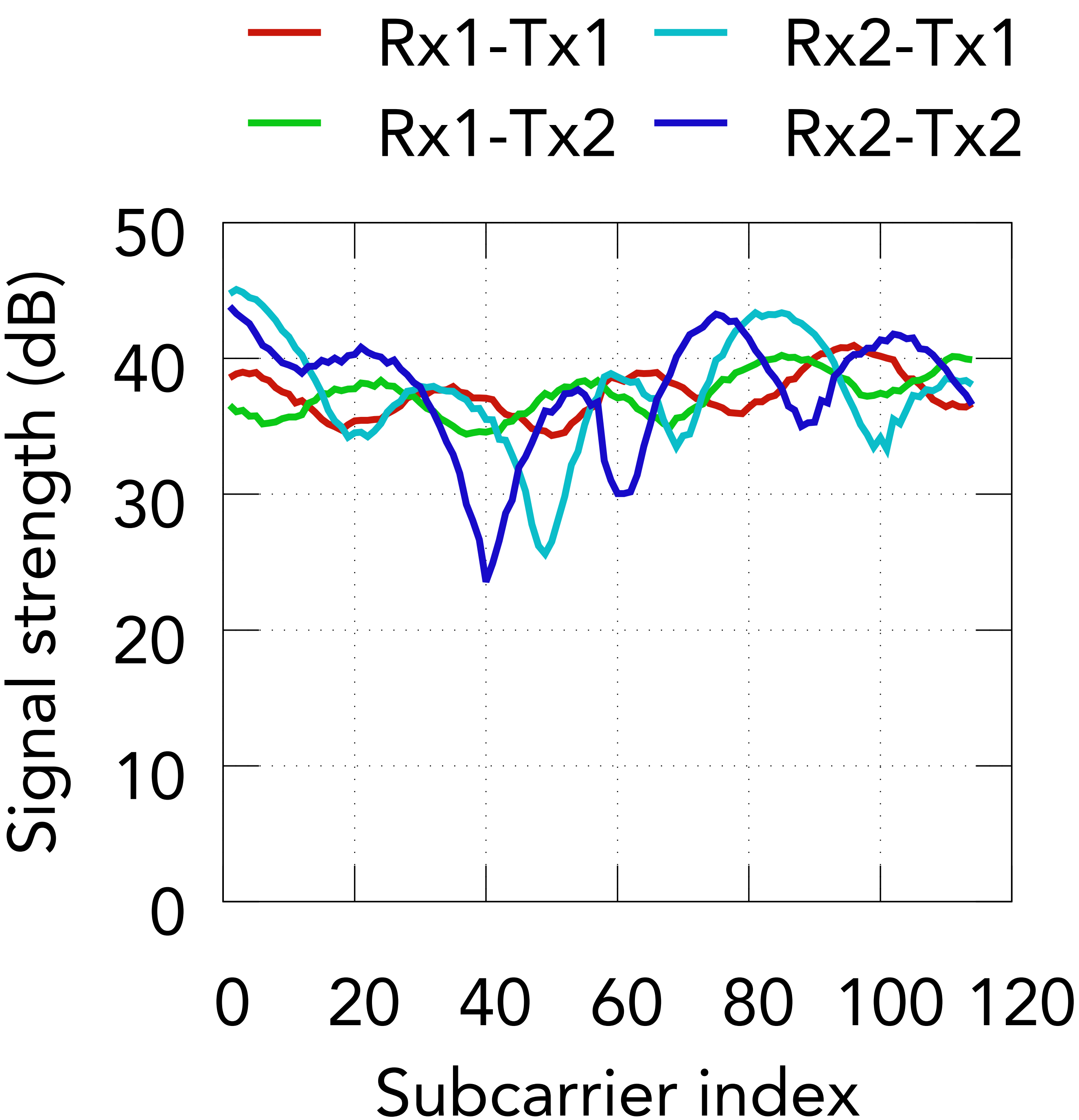
Contact separation



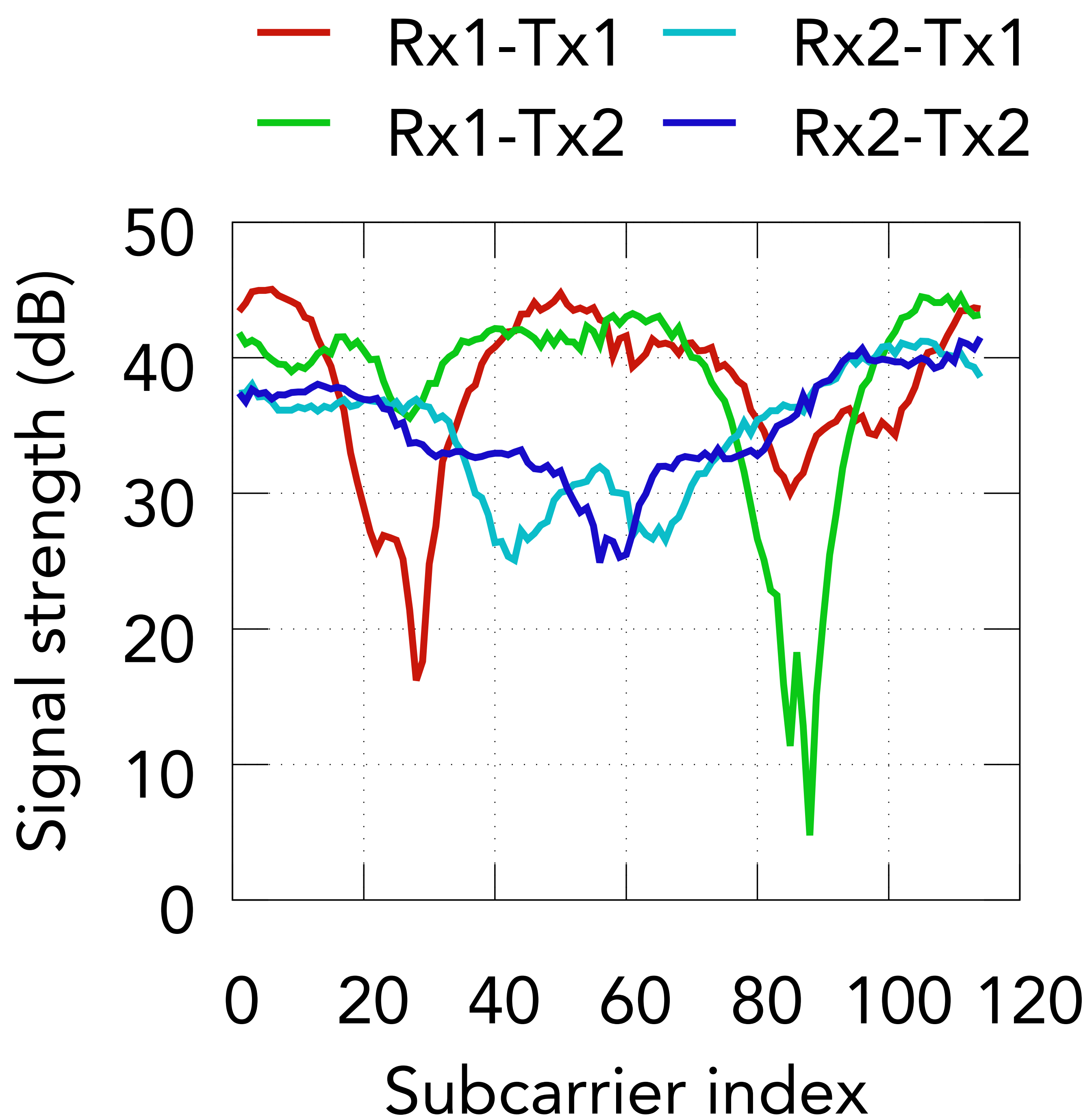
Channel state information



Channel state information

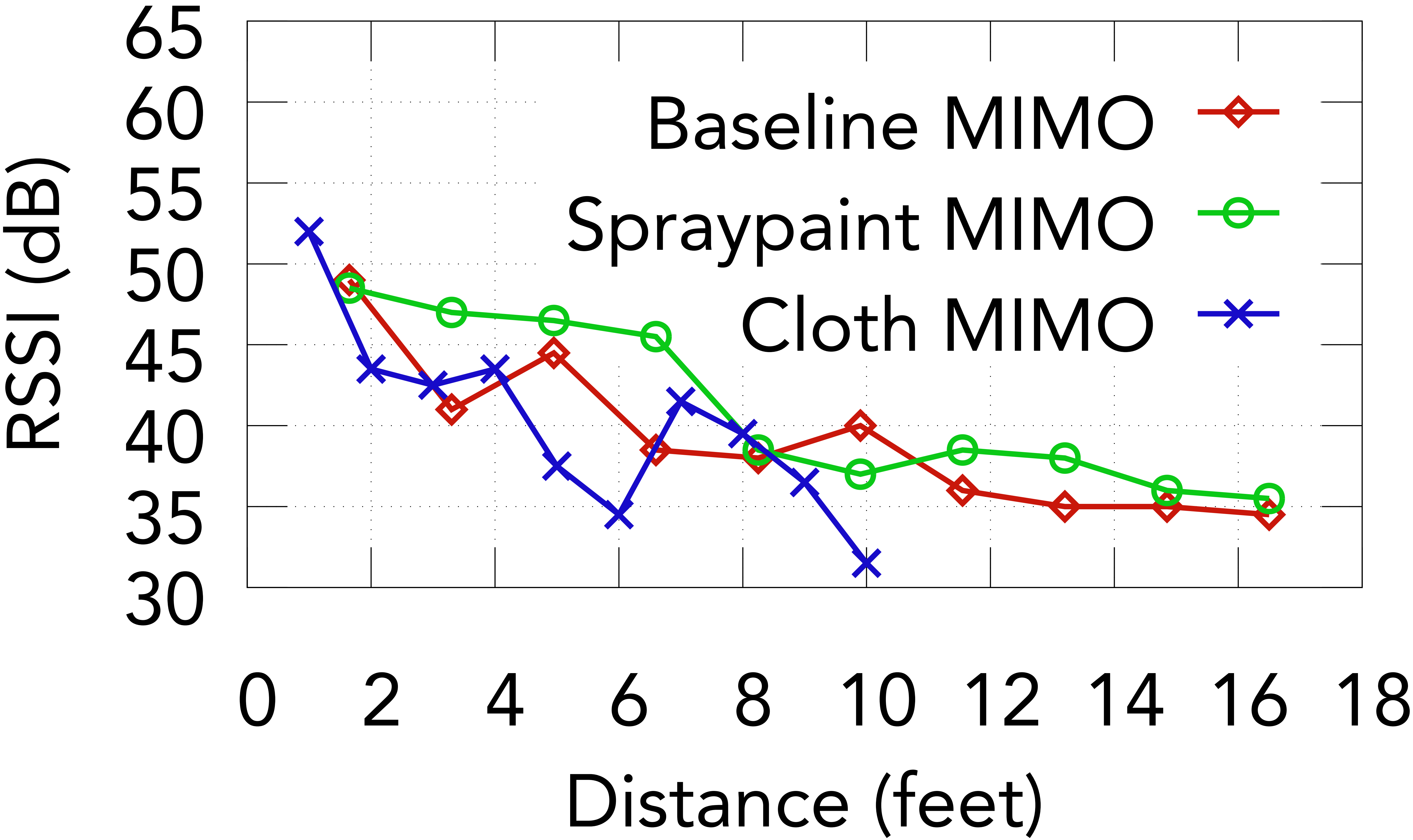


1 feet

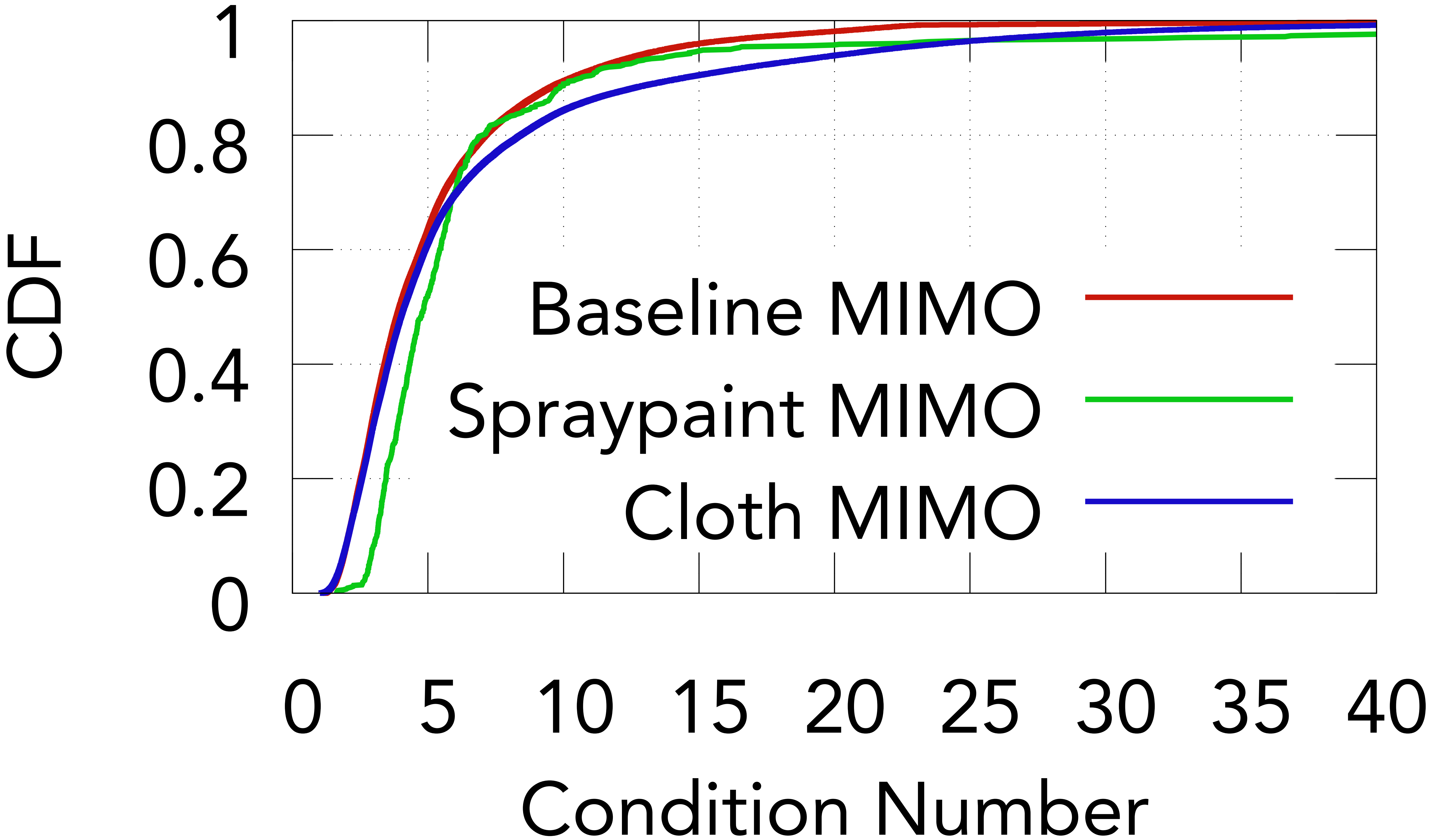


16 feet

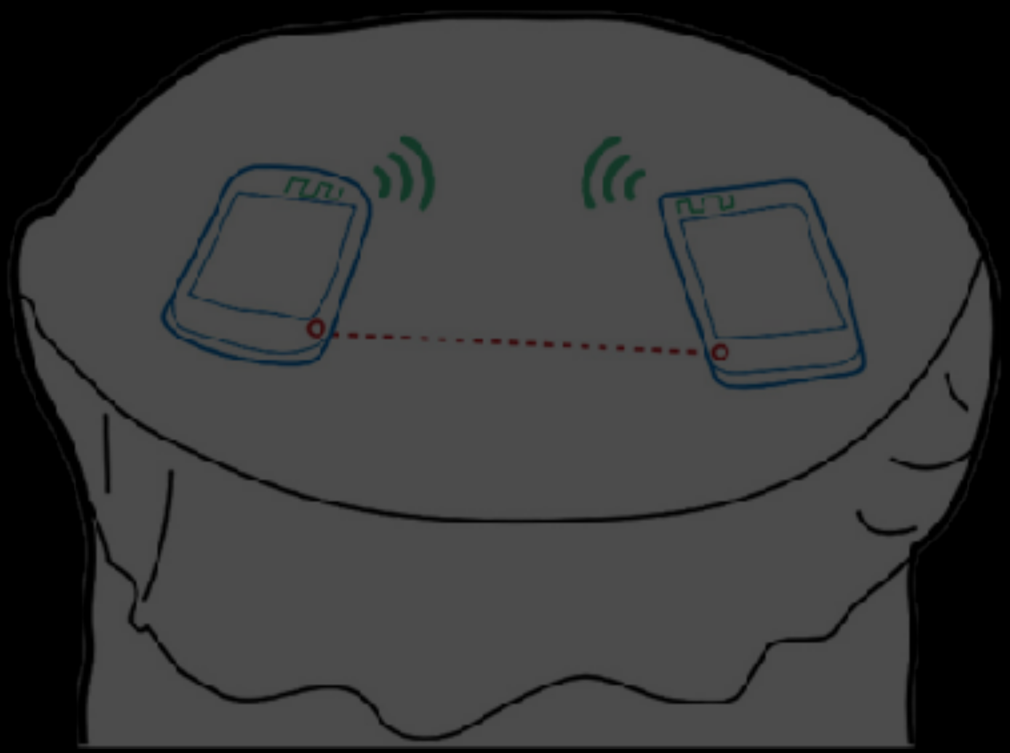
Received signal strength



Condition number



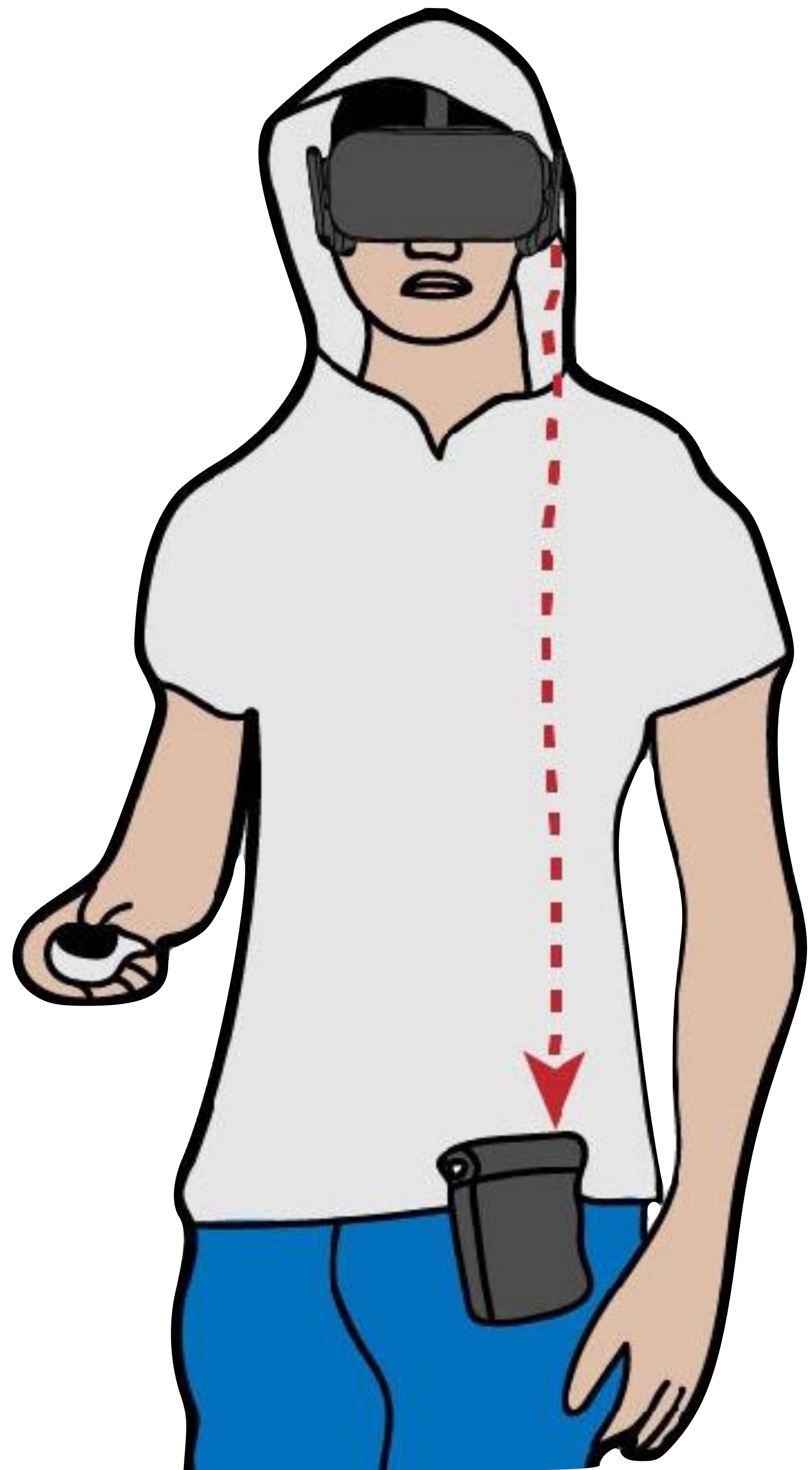
Two new ways to communicate using surfaces



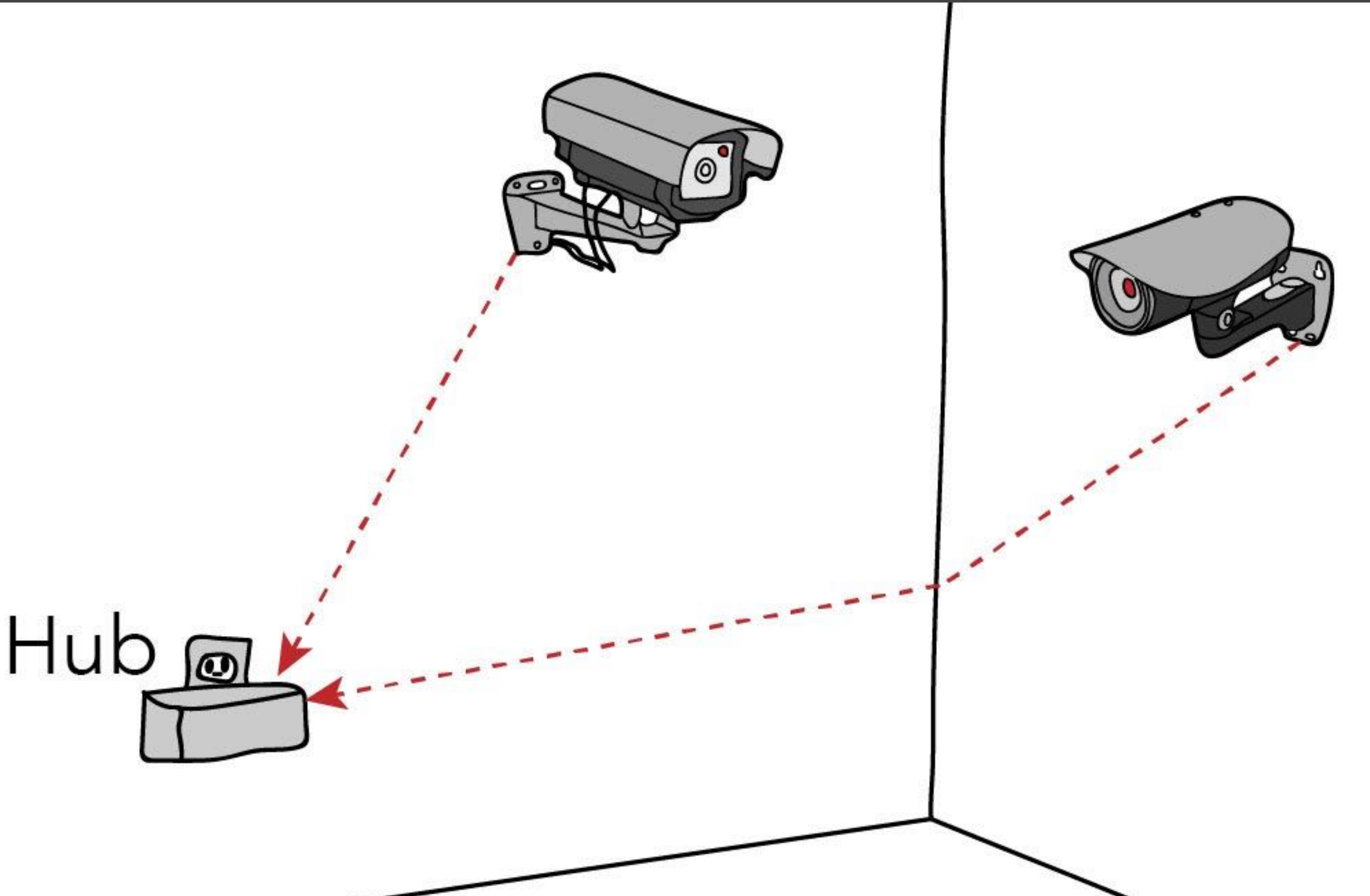
MIMO for single-antenna devices

Gigabit communication

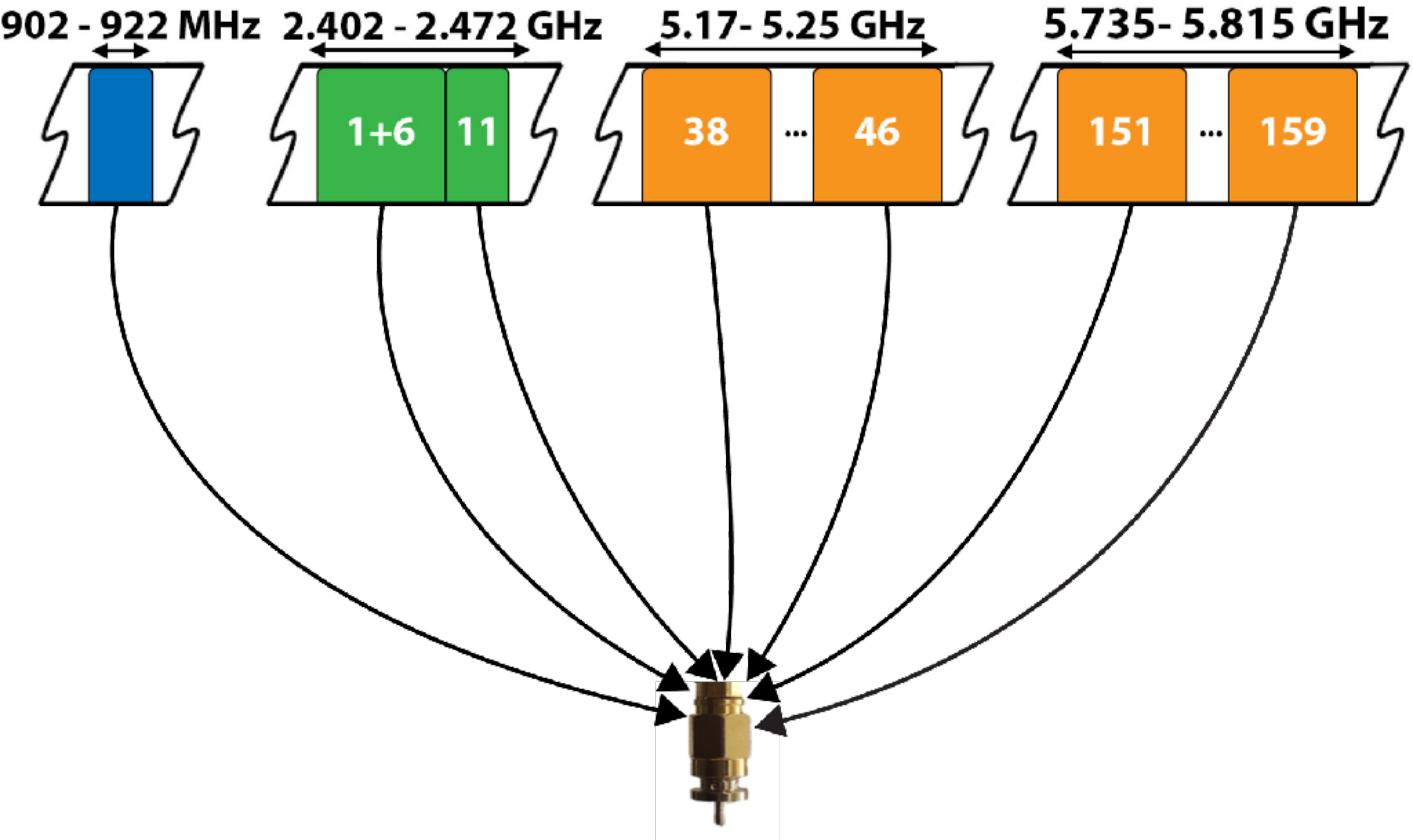
Gigabit surface communication



Gigabit surface communication



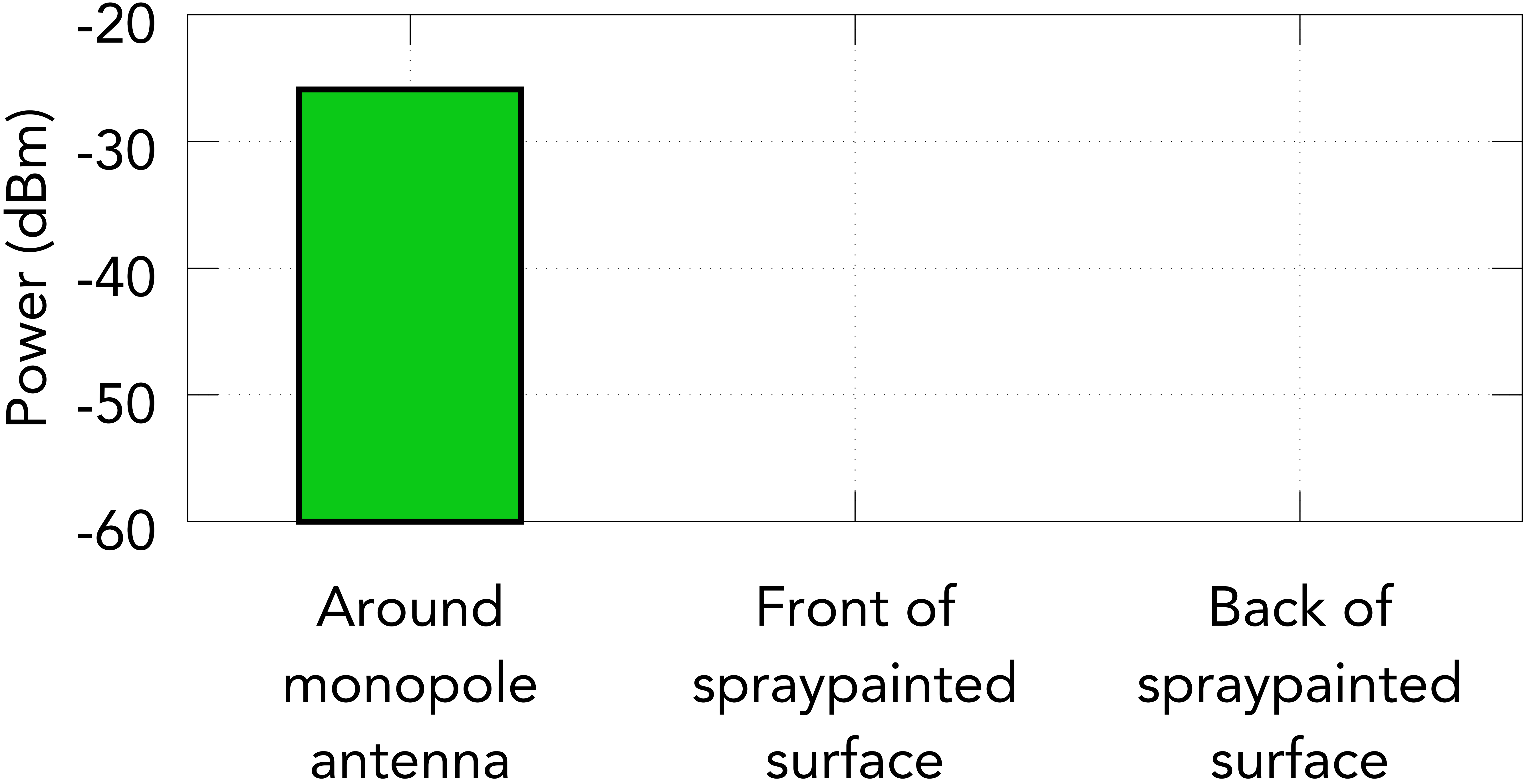
Stitching together ISM bands



Does the surface interfere with on air signals?

1. Around a monopole antenna
2. In front of the spray painted surface
3. Behind the spray painted surface

Does the surface interfere with on air signals?



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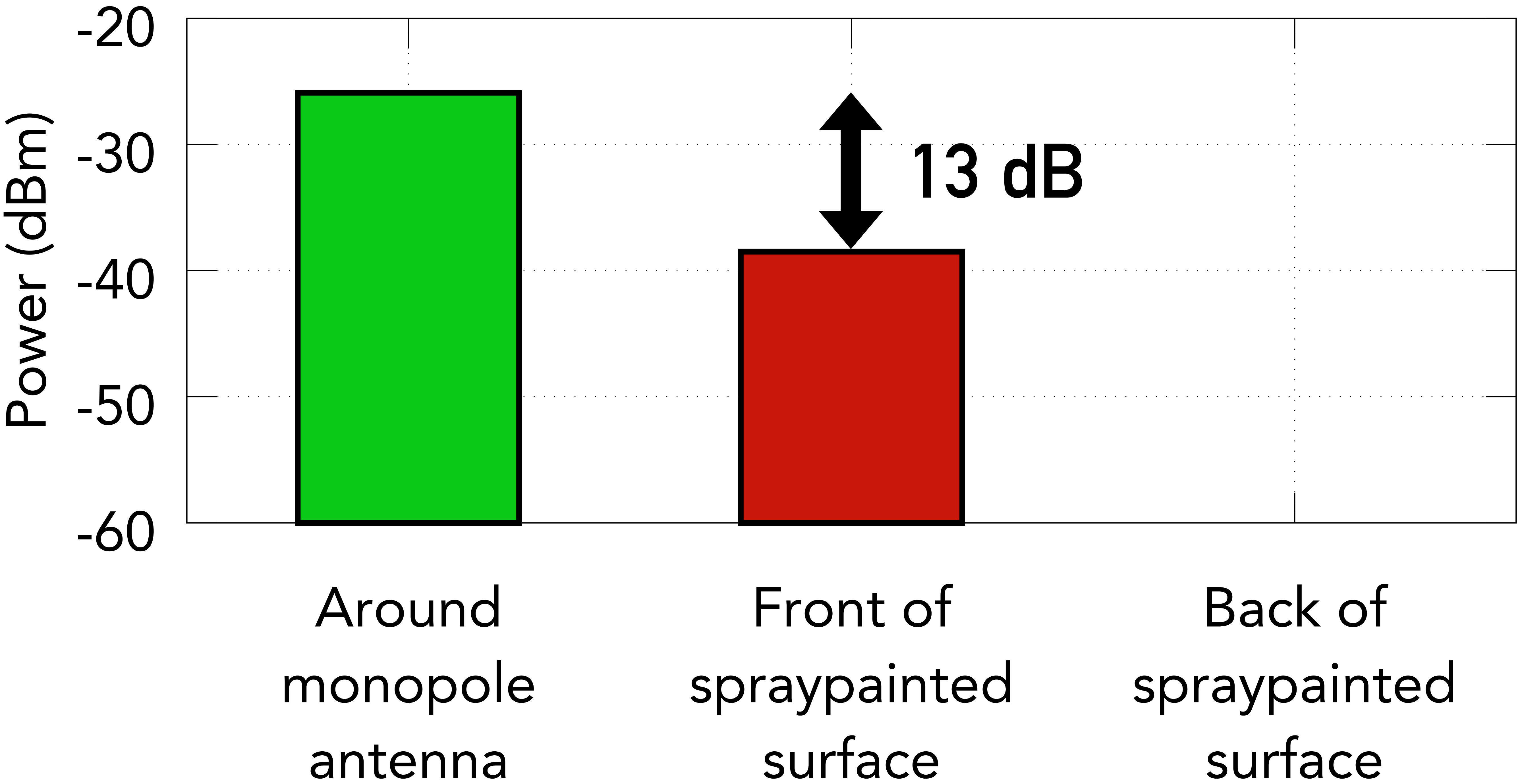

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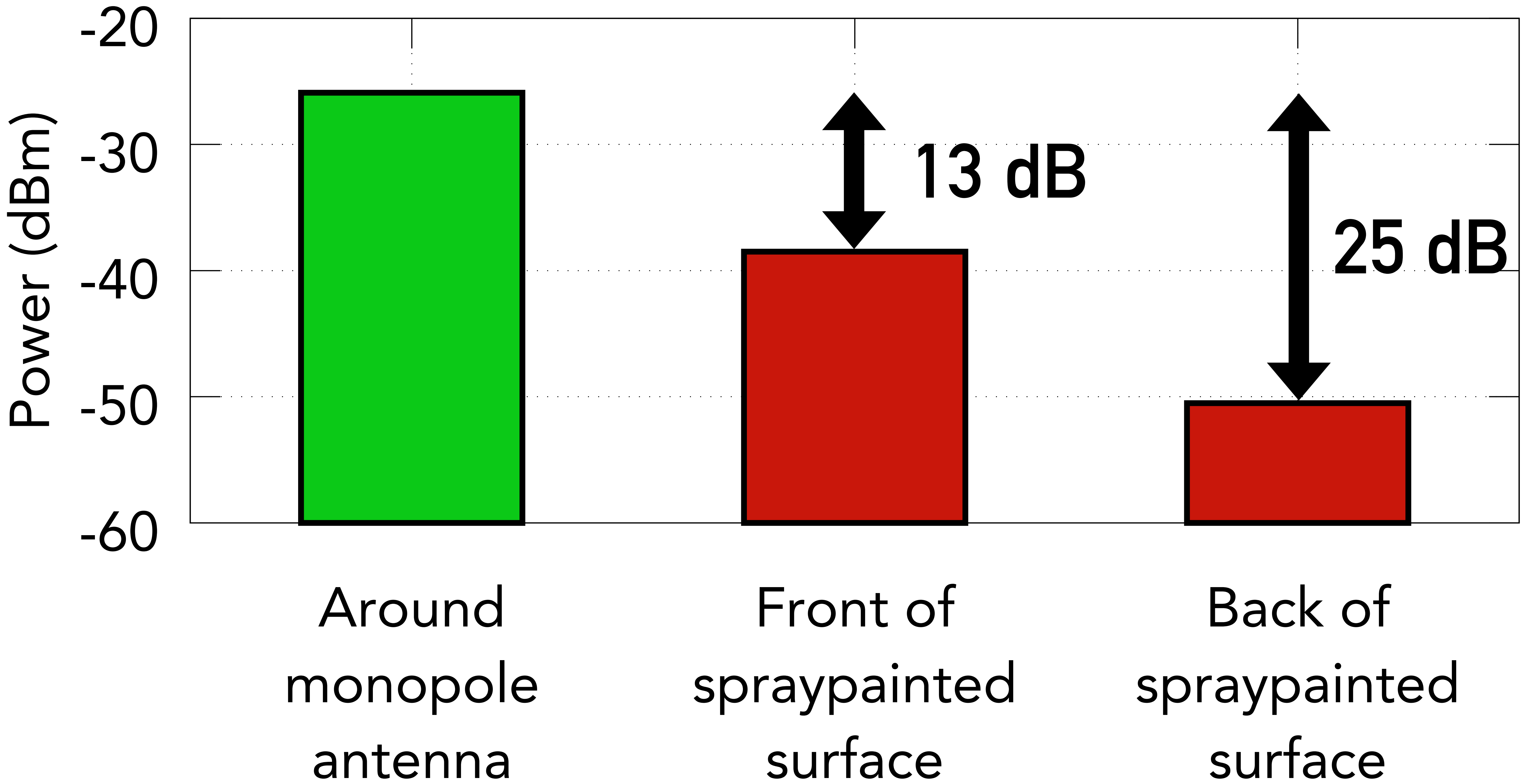
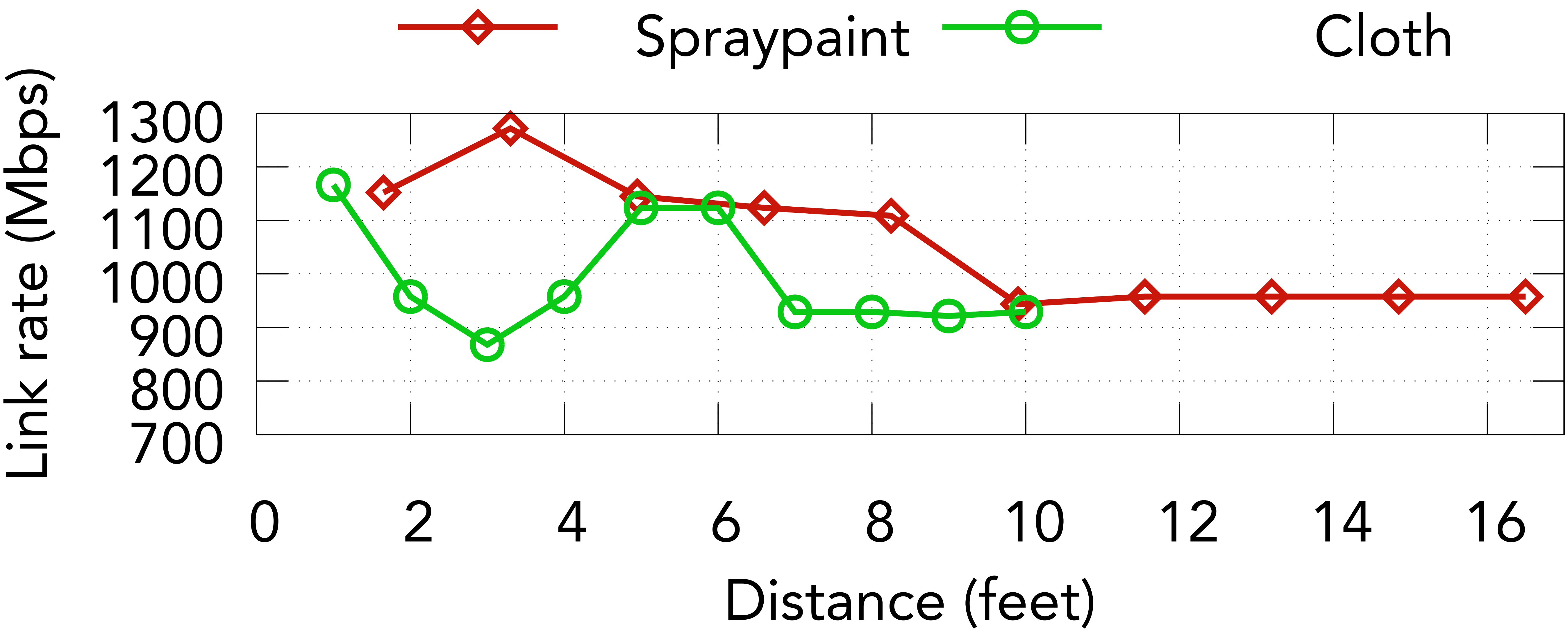


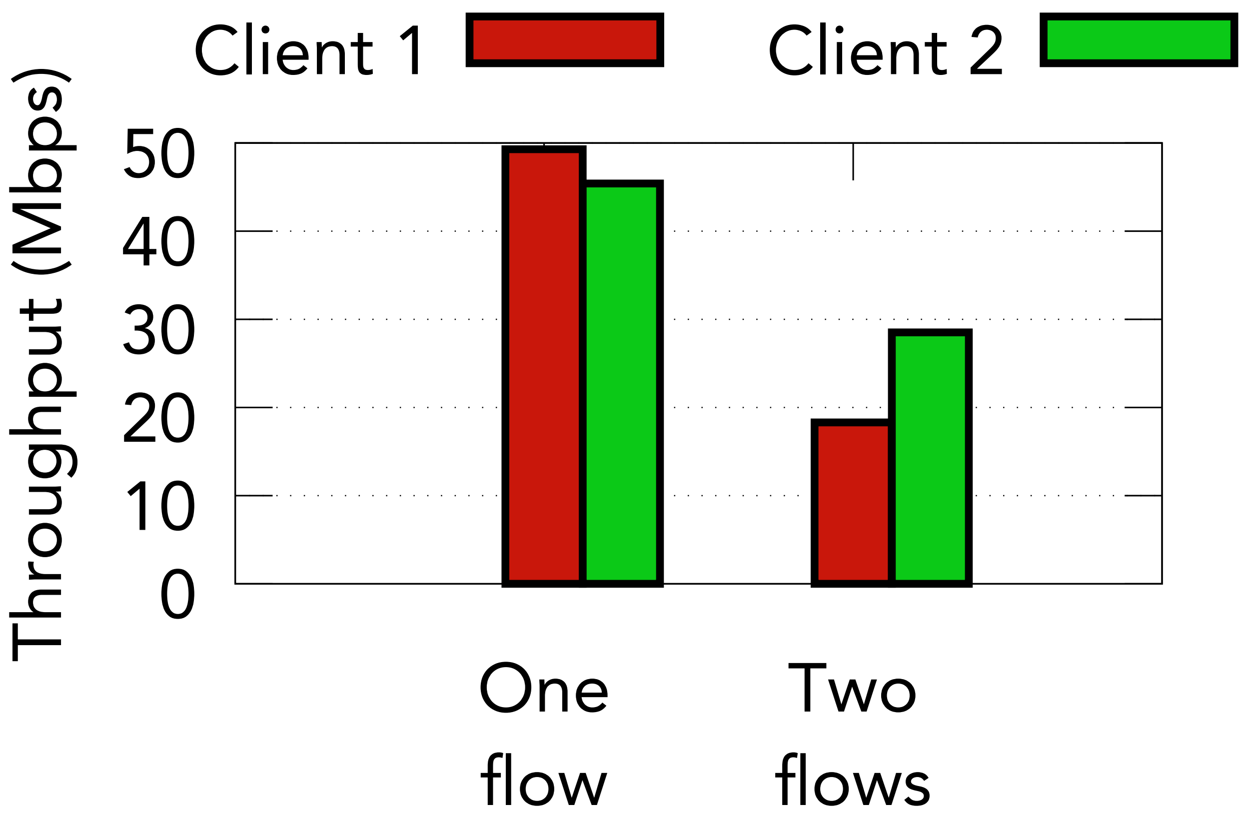
Less over the air interference

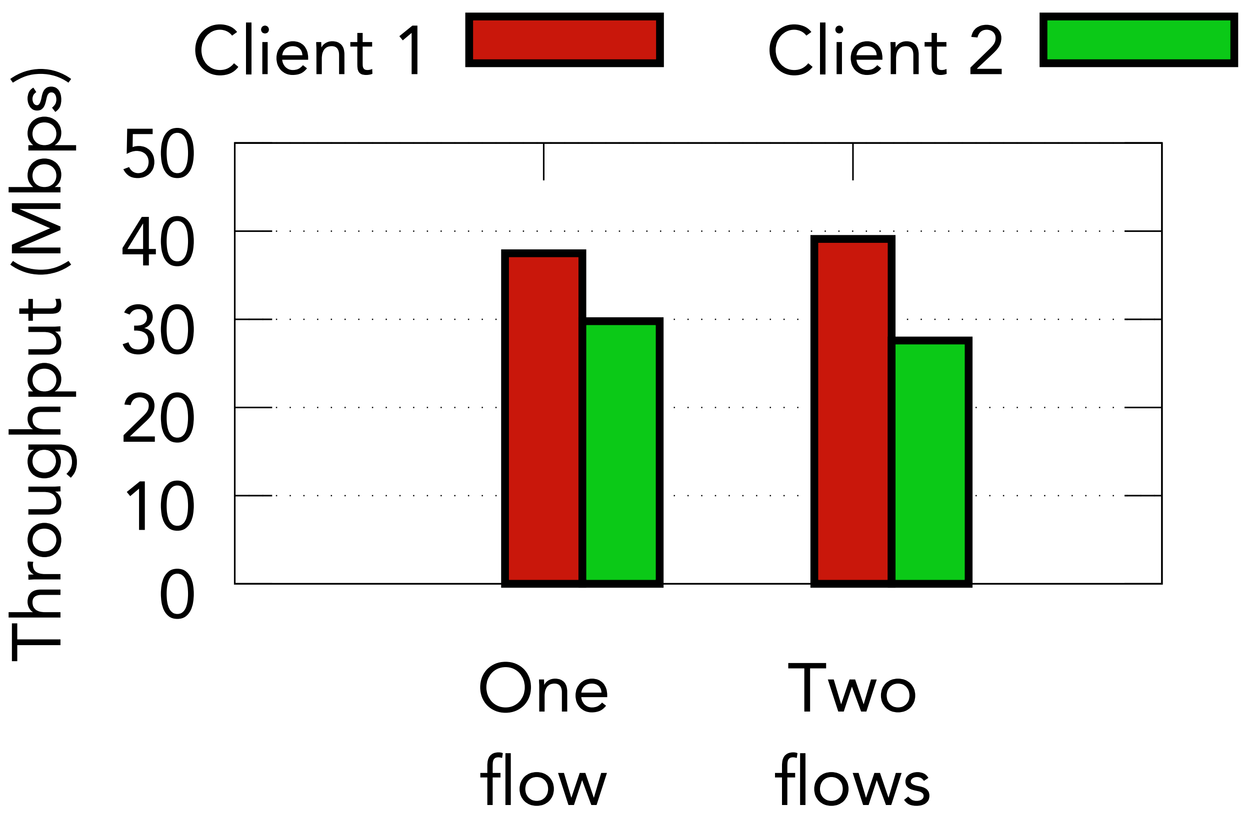
What capacity can we achieve?



Link rates of 776 Mbps - 1.27 Gbps

Can we share the surface?





Same channels

Different channels

Conclusion

- Detailed characterization of conductive paint and cloth for communication
- Enable MIMO communication between small devices via conductive surfaces
- First communication design to support Gbps data rates over surfaces