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Device Pairing at the Touch of an Electrode

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Device Pairing (I)

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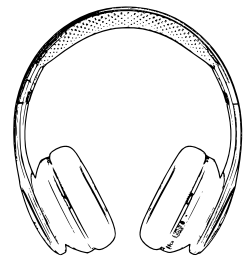
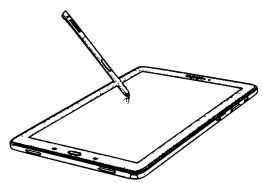
- Bootstrap secure communication
- Two un-associated devices derive a mutual secret
- No trusted third party
- Problem: Establish the identities of the devices

$\rightarrow$ **Device pairing protocol**





Device Pairing (II)

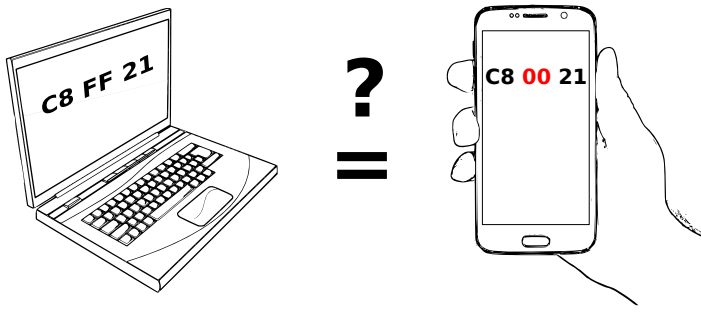
Most existing schemes either

- require physical assumptions on the communication channel

OR

- use an auxiliary channel
  $\rightarrow$ Security relevant decision

Near field communication



Short string comparison

Desirable Properties

- Minimal user interaction / Simple interface
- Action of pairing devices should be a natural task

Our Idea

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→ Two devices can be paired if
they are being held by the same human at the same time

→ Physical access to both devices implies ability to pair

Our Approach

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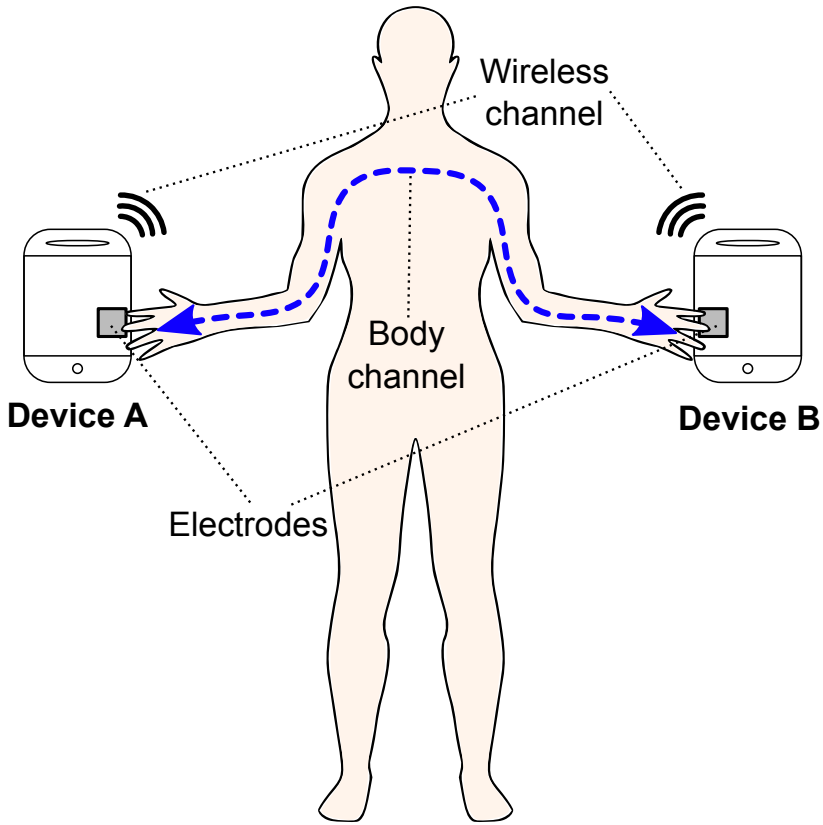
- Devices share two communication channels:
  - Unauthenticated wireless channel
  - **Body channel** via **capacitive coupling**
- Human touches an electrode on each device to establish data transmission



Intra-Body Communication

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Galvanic Coupling

- Induce alternating current into the body
- Small current propagates through human

– Short transmission

– Two electrodes required

Surface Wave

- Similar to conventional RF transmission
- Uses body as a wave-guide

– Affected by external electromagnetic waves

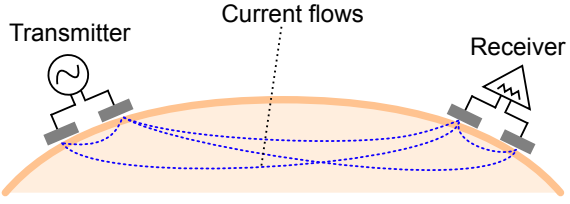
Capacitive Coupling

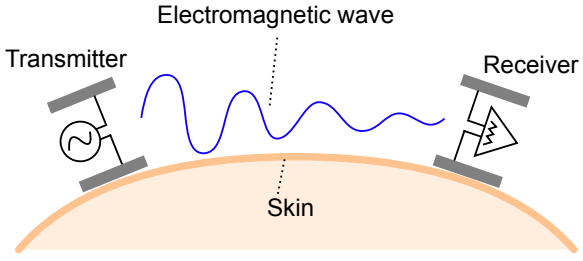
- Return path through the environment
- Electrostatic coupling to earth ground

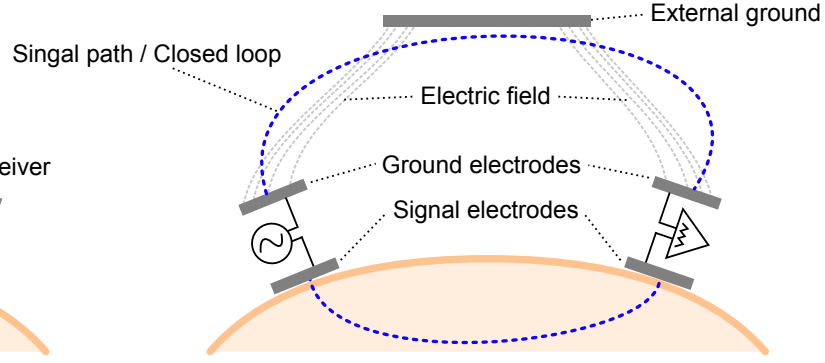
\+ Hand-to-hand communication

\+ One electrode

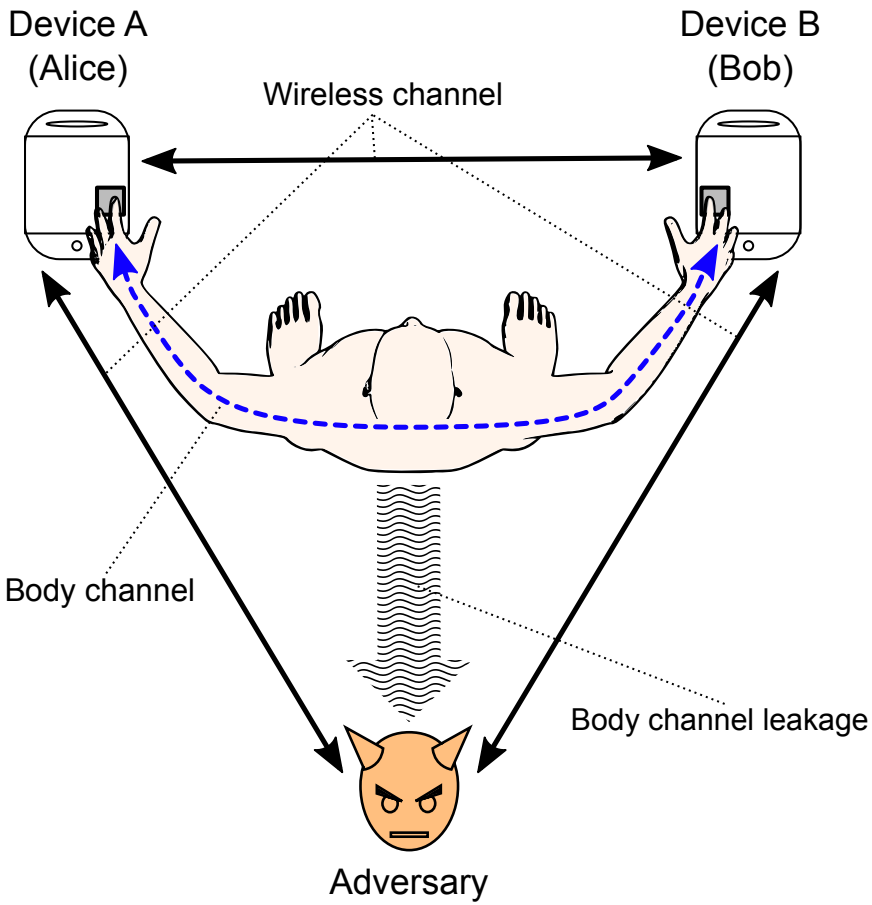
\+ Low electromagnetic interference







Adversary Model



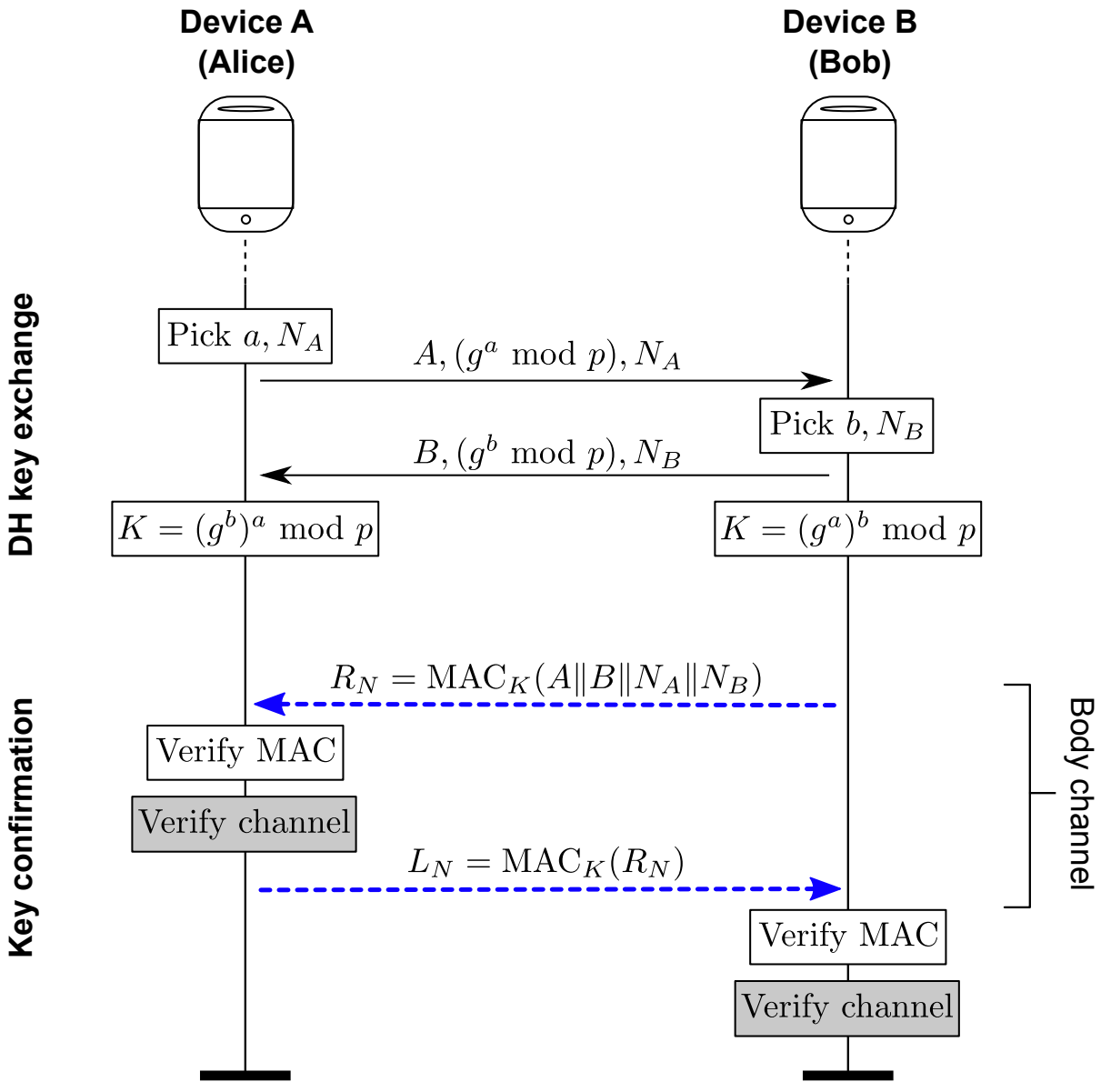
Attacker

- No physical access to devices
- Access to wireless channel
- Can listen on body channel

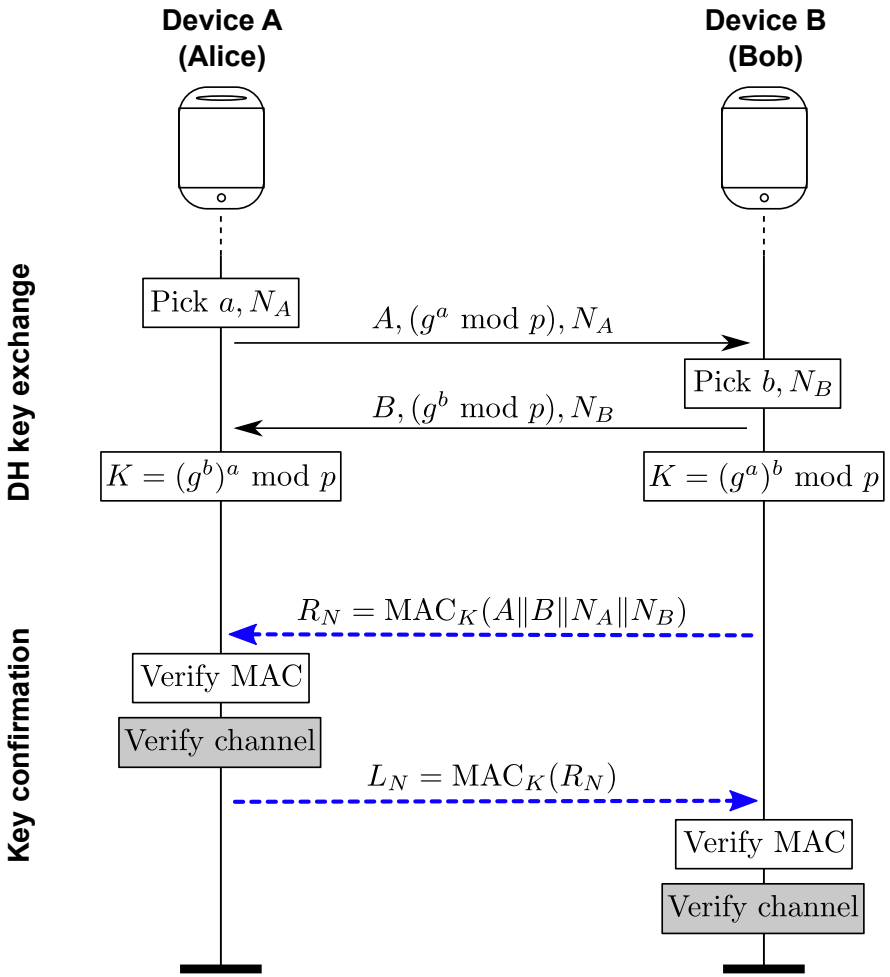
Body Channel

- Devices extract channel properties
- Read-only to external transmitter

Pairing Protocol



Security Guarantees



Remote Pairing

- Attacker can establish key
- Key confirmation fails as body channel is read-only

MITM Attacks

- Not feasible if body channel is inaccessible
- Injection on body channel fails

The Body Channel

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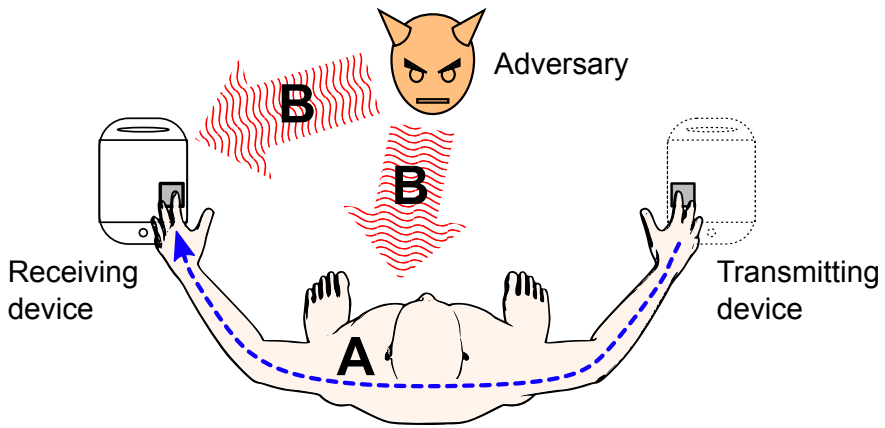
- Security of the pairing protocol relies on read-only property
- The receiving device needs to be able to distinguish between

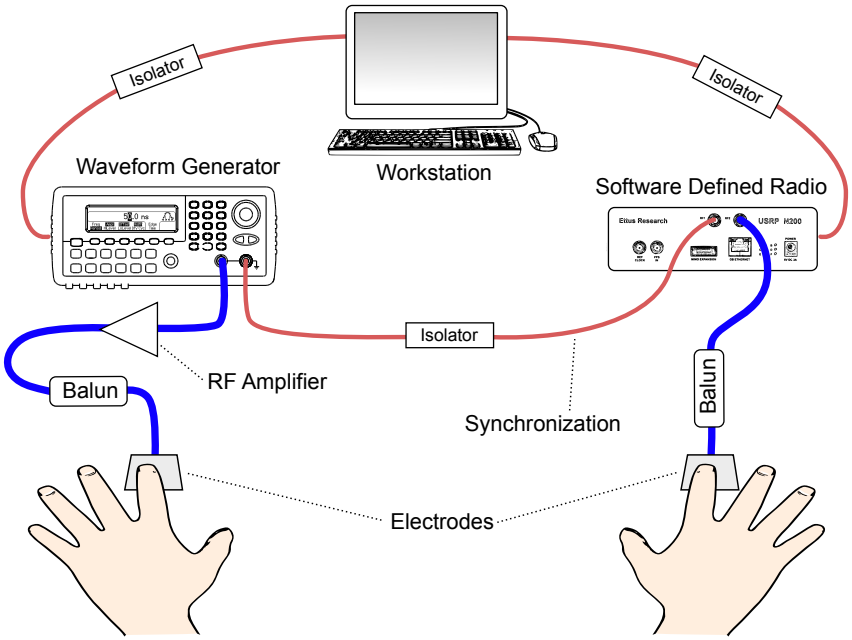
A. Messages from another device being held by the person

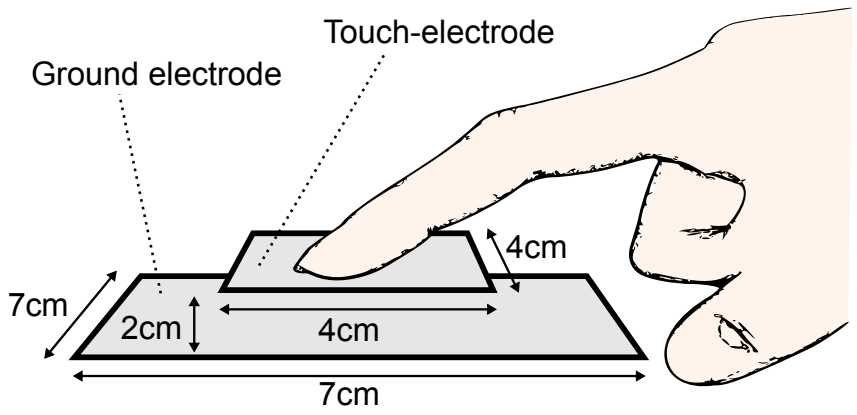
B. Messages from an external source



- We experimentally verify this property

Implementation / Setup





Proof-of-concept for body channel transmitter and receiver

Frequency bandwidth	0.5 MHz - 3.5 MHz
Sending power	5 milli-Watts
Sender voltage	3 Volts (pp)
Current through body	∼10 micro-Amperes

→ Miniaturized version can be manufactured as single chip

Body Channel Transmission

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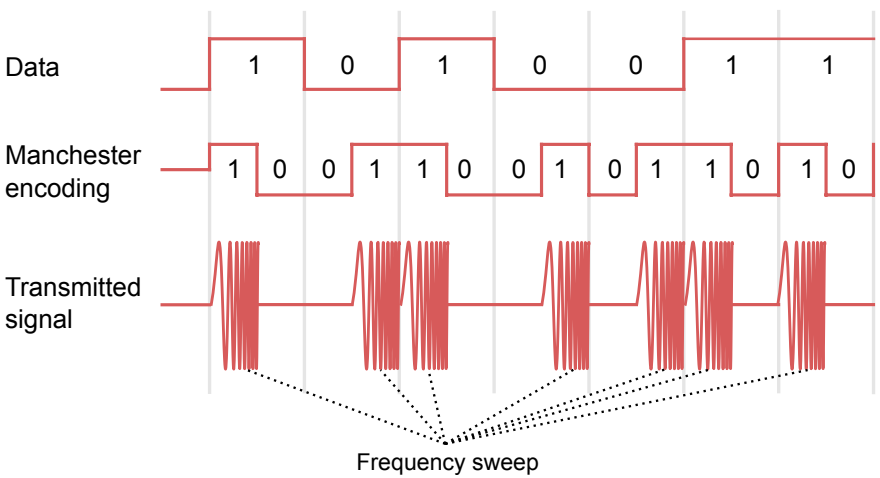
Encoding and Modulation

- On-off keying of manchester-encoded data
- Frequency sweep during "on"-periods
- Sweep allows to characterize the channel



Throughput and Error rate

- 500 bit/s (on-period is 1ms)
- Transmitting two 56bit MACs takes 224ms
- Measured bit error rate is below 10^{-6}

User Safety

- Very little current flow through body
- $<$ 12 micro-Amperes
- Much weaker than e.g., body composition scales

Body Channel Characteristics

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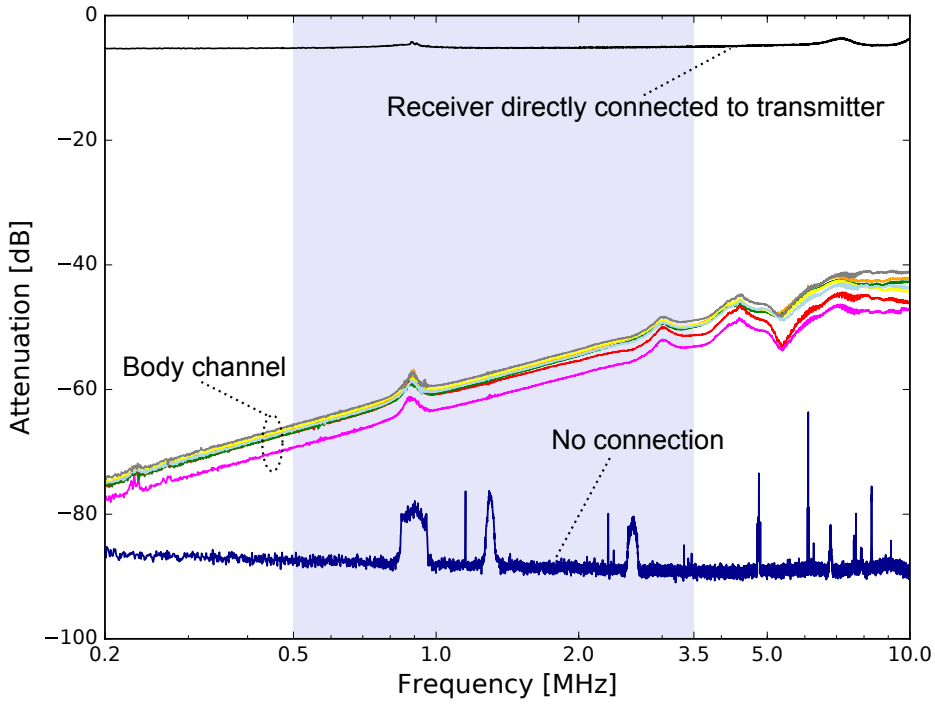
- Energy transmitted on body channel is lost due to
  - Capacitive coupling
  - Body is not perfect conductor

→ Sweeps are attenuated depending on frequency

→ **Most specific frequencies between 0.5 MHz and 3.5 MHz**



Experimental Analysis

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We verify the read-only property in two ways:

1. Can messages be *classified* according to their origin?
2. Can messages be *injected* into the body channel?

Evaluation

Classify attenuation patterns generated by the frequency sweep

Two classes

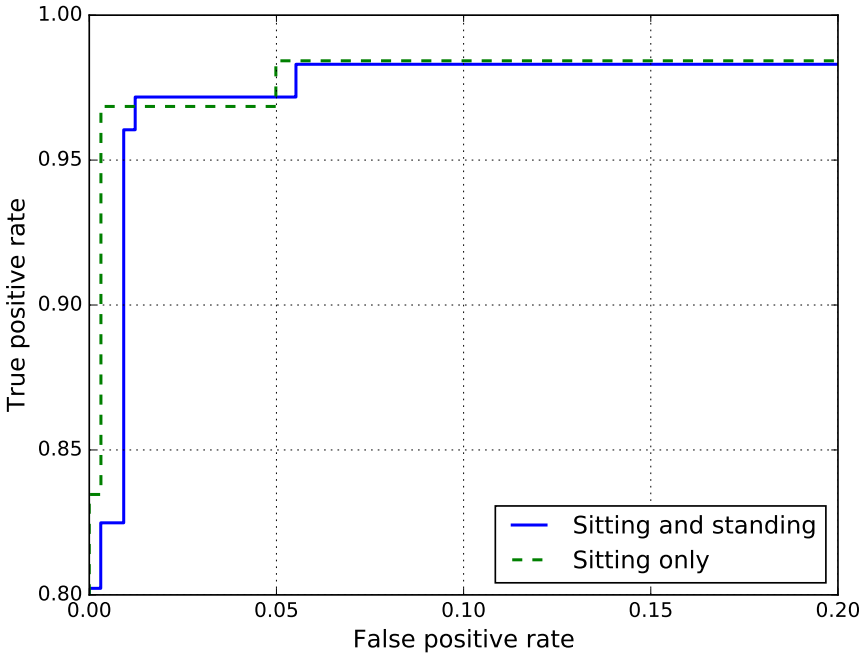
- Intended use of body channel
- Injection attempts

Signal injection

- Different emitters
- At varying distances

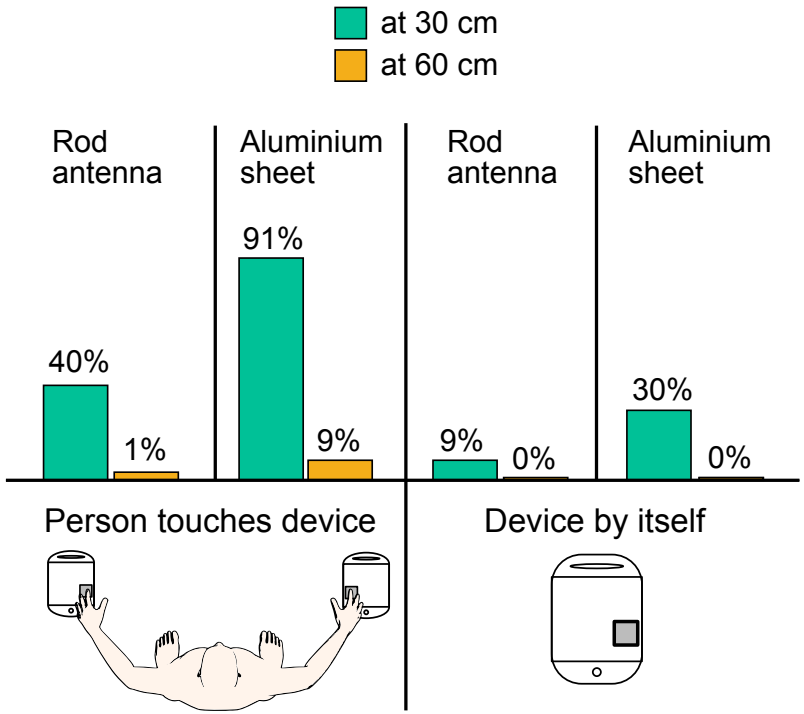
Classification

Receiver operating characteristic for body channel receiver



→ External sources can be detected with high probability

Injection attempts and success rates



→ External source needs to be close to receiver and carry large capacitance

External Signal Injection

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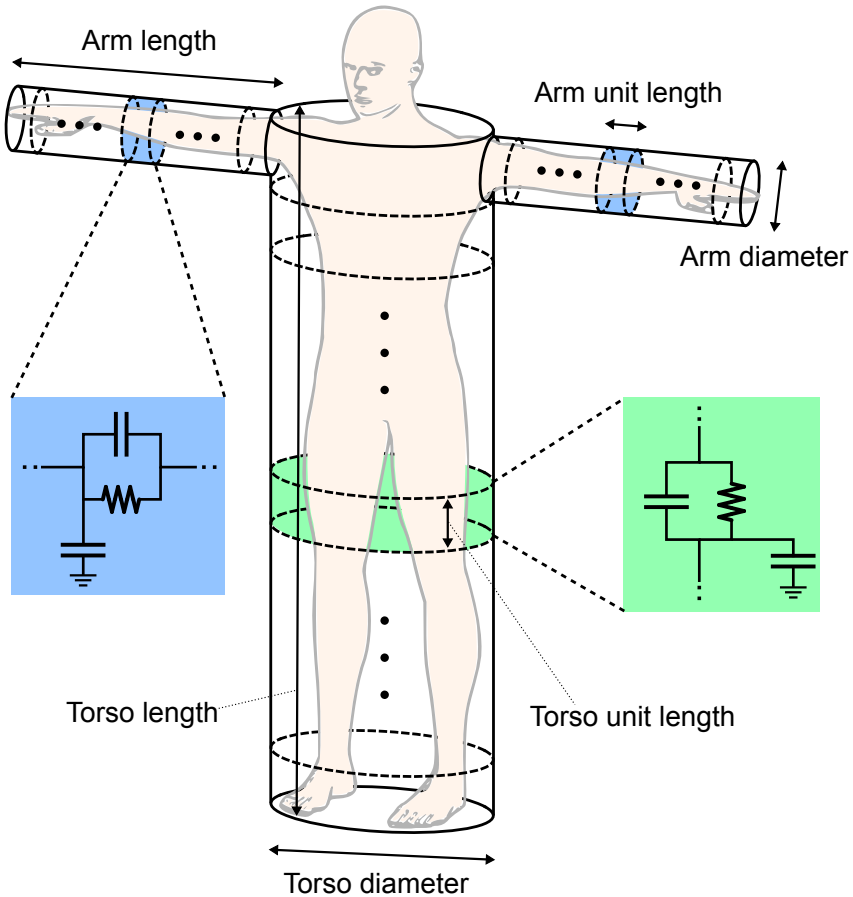
Human Body Model

- Simulate injection from near field
- Approximation with three cylinders
- Dielectric properties of human tissues

→ Receiver and transmitter can be attached anywhere on body



Read-only assumption holds if there is 50cm between body and adversary

Conclusion

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1. Novel approach to device pairing using intra-body communication
2. Pairing becomes natural and straightforward
3. Body channel is read-only if there is at least 50 cm between body and signal source
4. Small form factor and low manufacturing cost

Questions and Discussion

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Thank you!

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External Signal Injection

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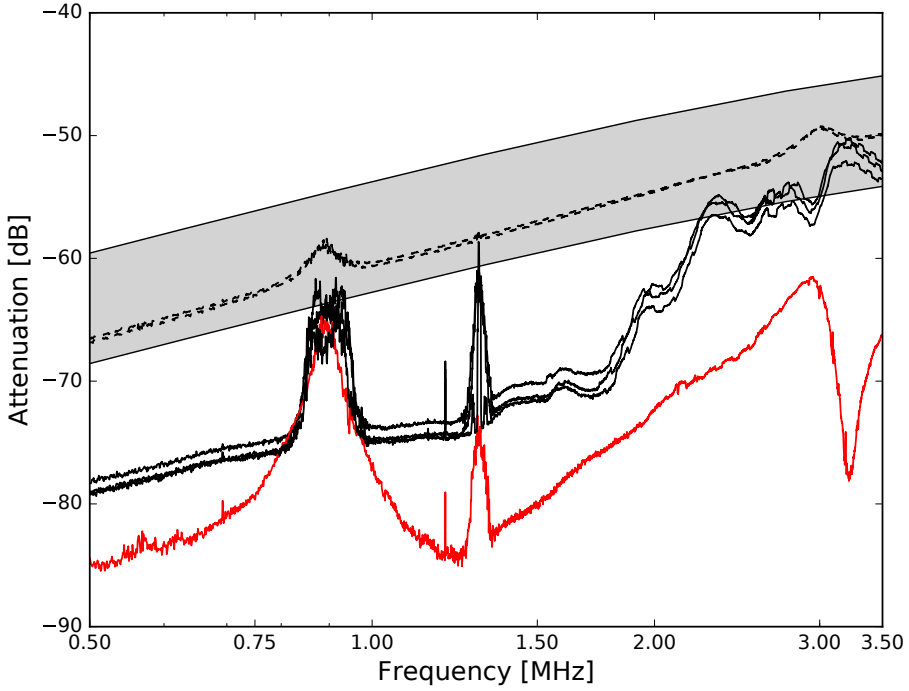
External Source

- Has to match body channel characteristics
- Attacker can not measure attenuation pattern of external transmitter
- Capacitive coupling only works in near field
- High capacitance and/or highly directional antenna with high output power needed

Injection with aluminium sheet



- Pattern changes significantly if sheet is 5 cm further away from body

→ Attenuation pattern is volatile