ACM MobiCom 2012

Distinguishing Users with Capacitive Touch Communication

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Today is Safer Internet Day

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Protecting Your Device From The Dangers of...Toddler Hands

Whoops...Kid Accidentally Spends $1,400 on Mom's iPhone

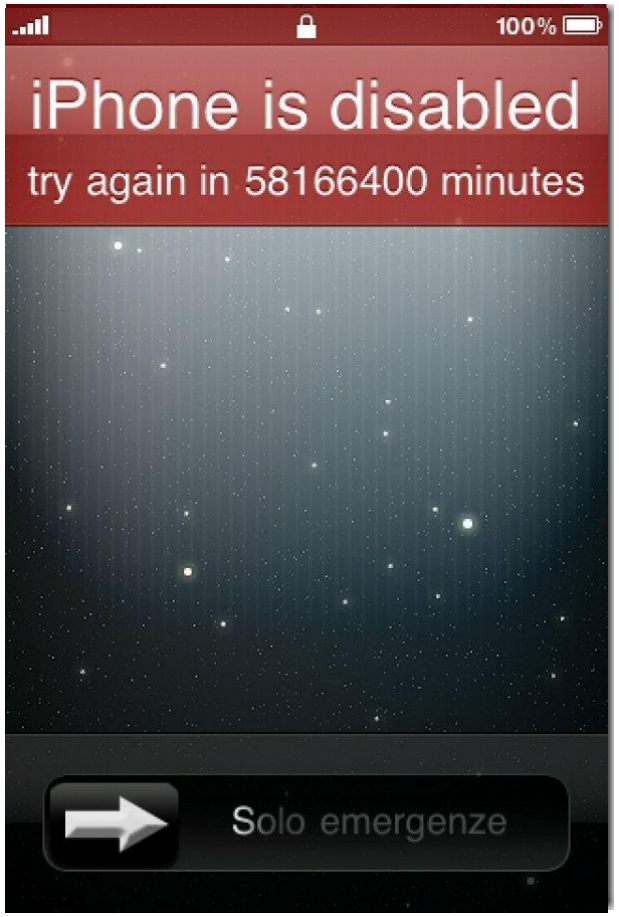
February 9, 2011

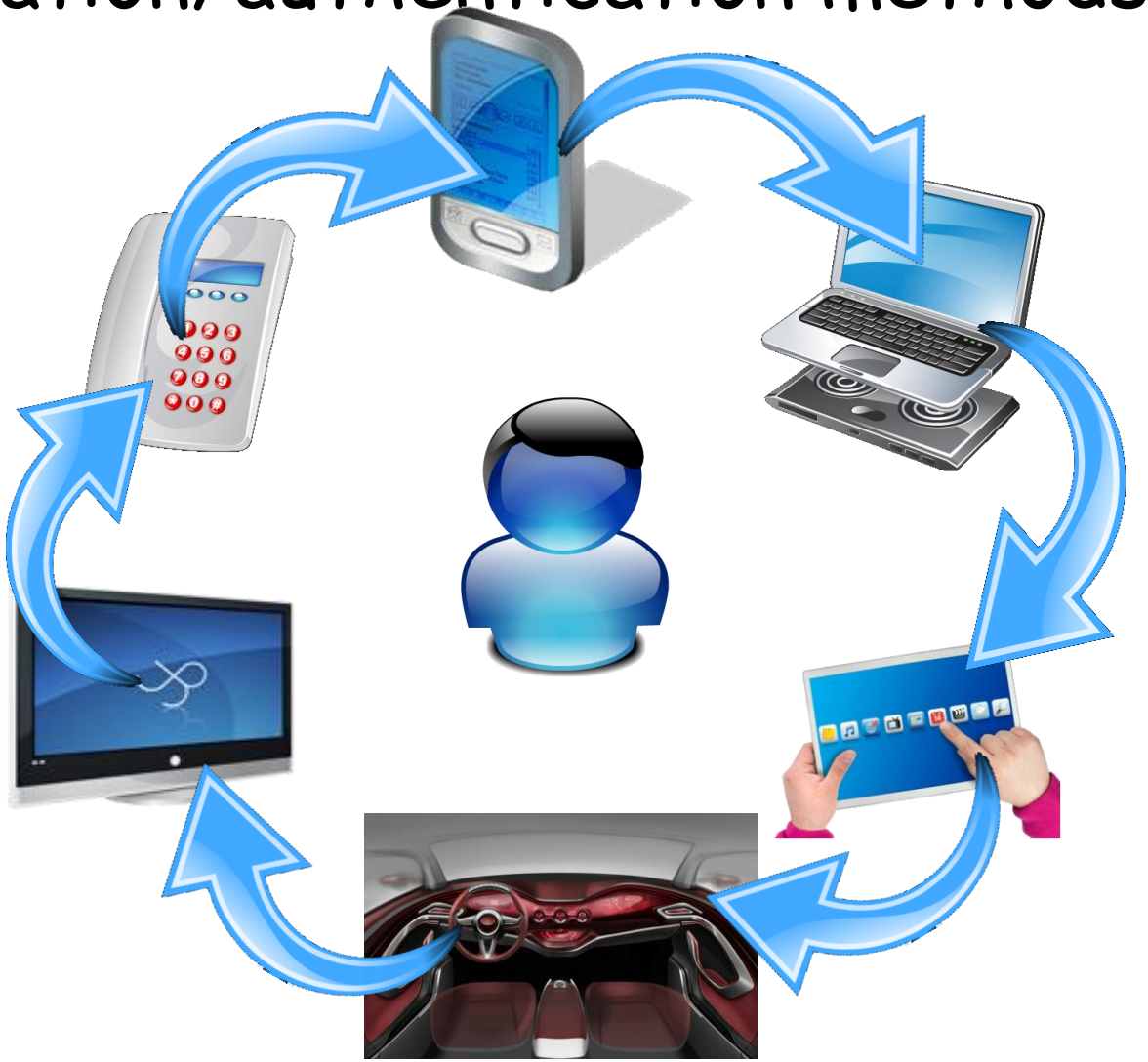
If only the phone knows who is interacting with it by itself ...

unknowingly had a veritable shopping spree in Smurfs' Village on her mom's iPhone. According to the *Washington Post*, Madison accessed the incredibly popular game (which is a FREE download in iTunes, by the way) and merrily played as it is to be played, racking up quite a bill in the process - $1,400 to be exact.

© Smurfs' Village

Current identification/authentication methods

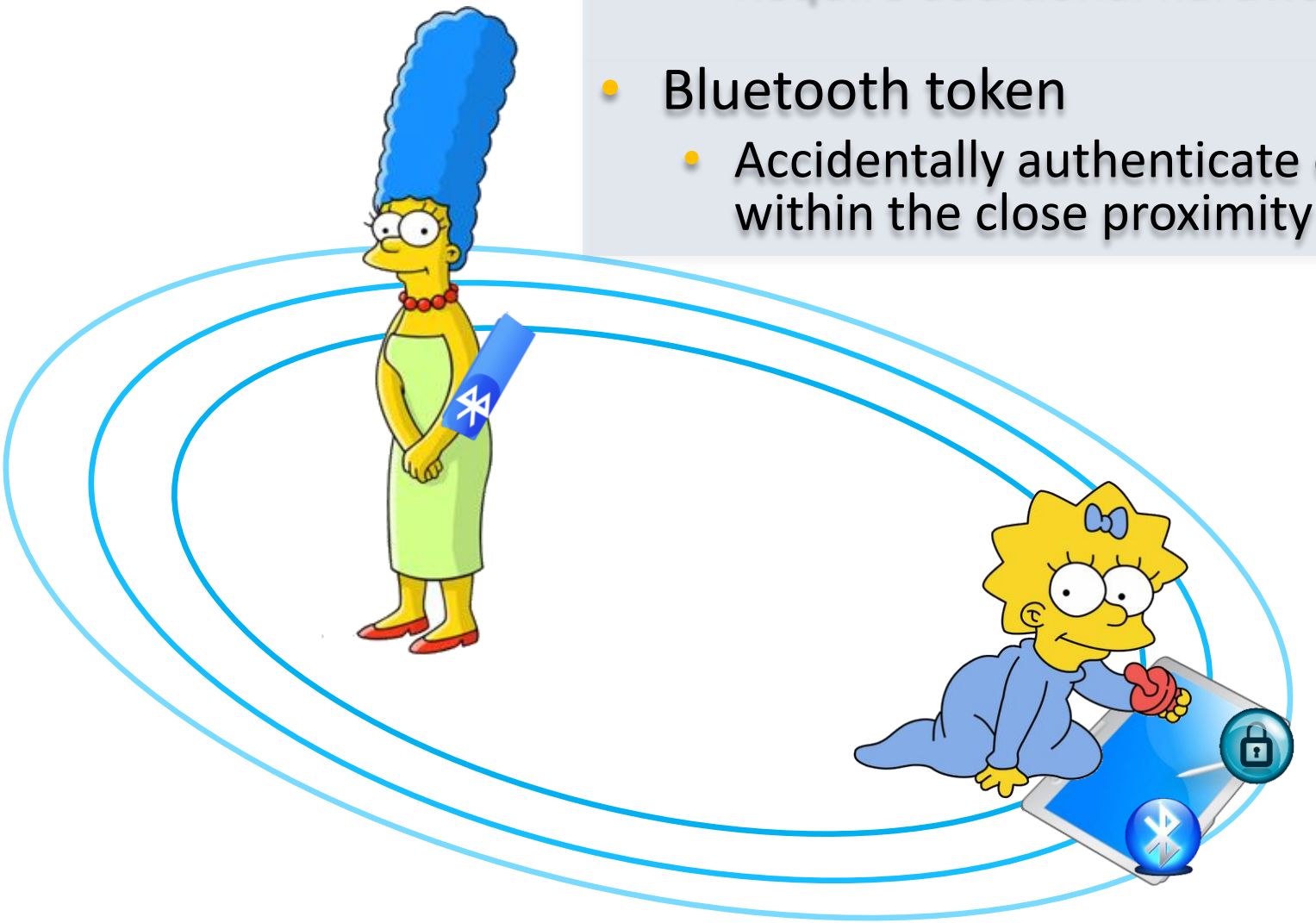




Users switch from one device to another more often

Other identification/authentication methods

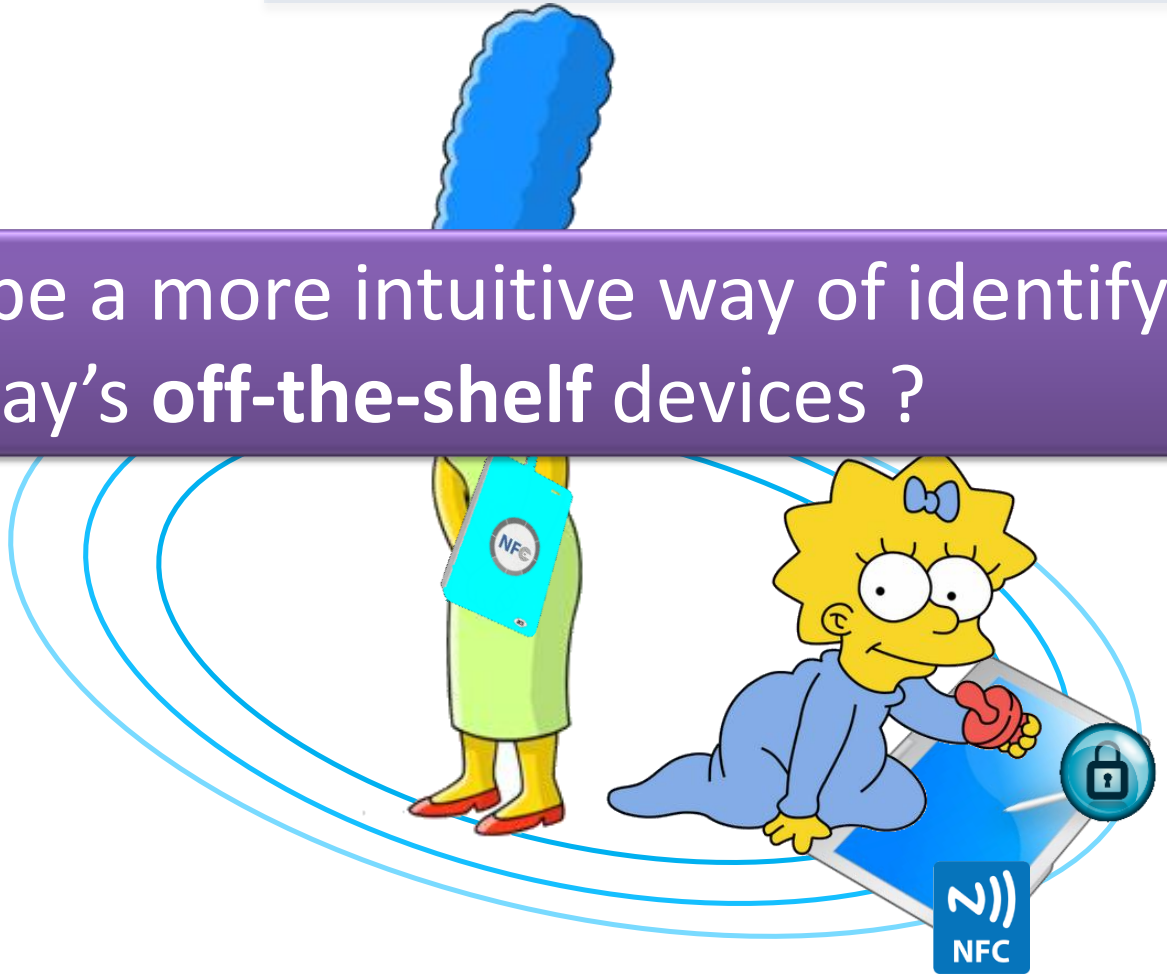
- Biometric based
  - Require additional hardware or space
- Bluetooth token
  - Accidentally authenticate devices within the close proximity



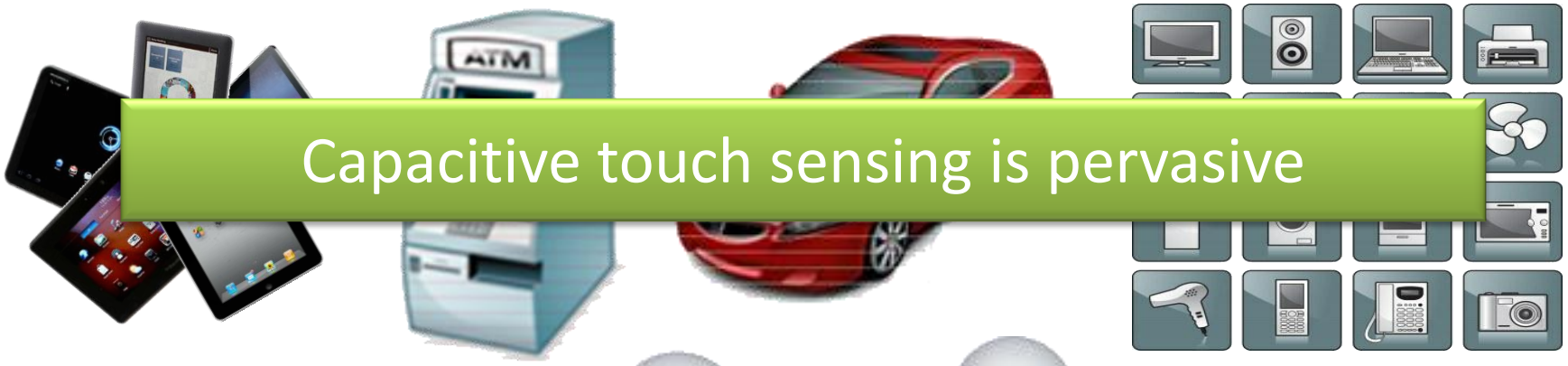
Other identification/authentication methods

- NFC-based methods
  - Require NFC hardware

What could be a more intuitive way of identifying users for today's **off-the-shelf** devices ?



Identifying users through their touches



Capacitive touch sensing is pervasive

Associating user identifier to touches

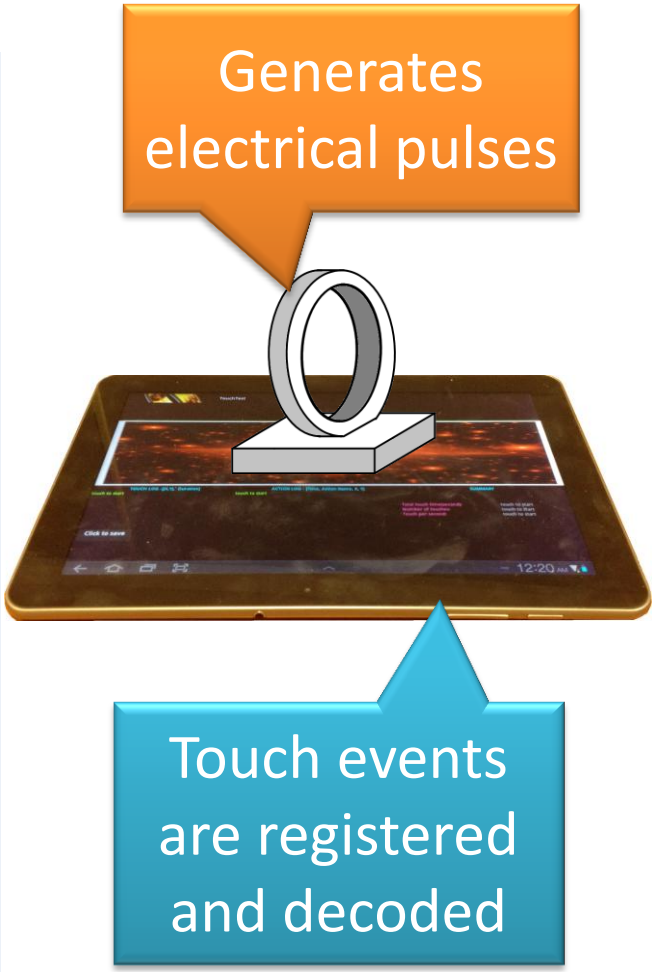
Capacitive Touch Communication

(Hardware token + Software decoder)

Capacitive Touch Communication

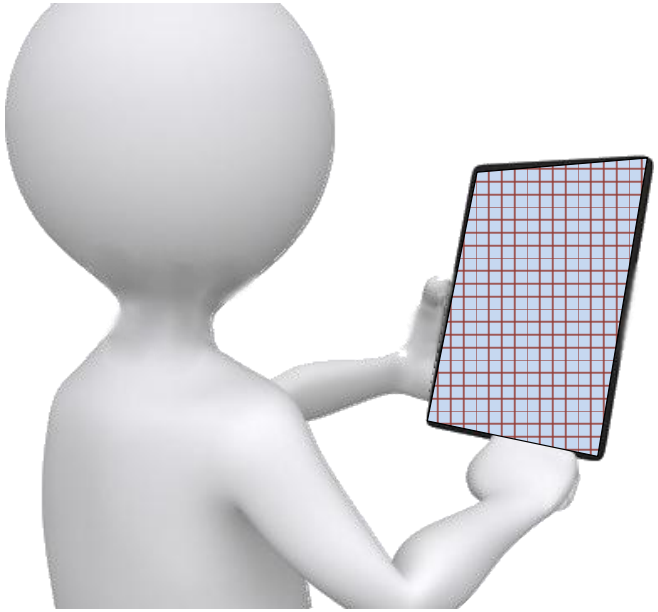
Overview

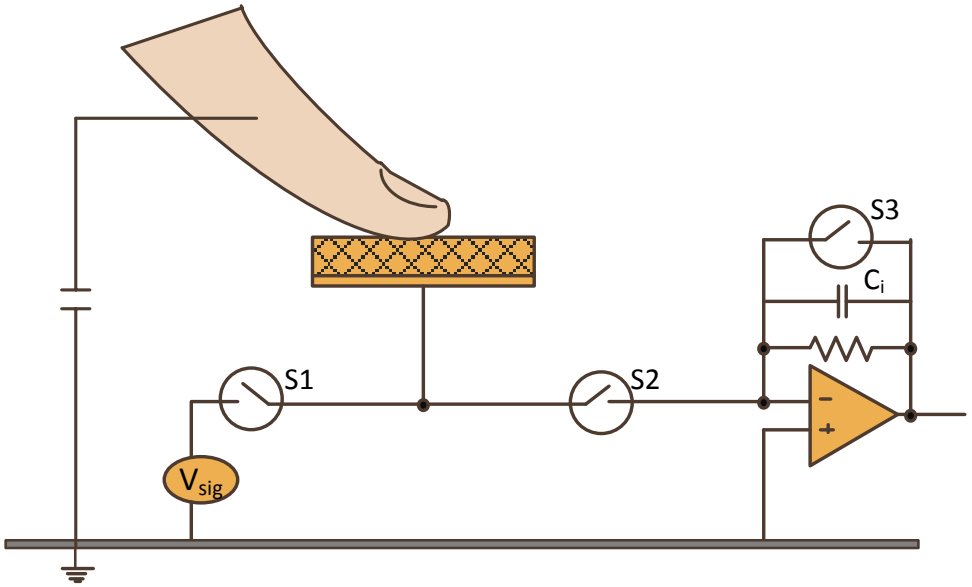
- A wearable hardware token
  - Generates electrical pulses
  - Spoofs the touch screen to create touch events
- Software decoder
  - Retrieves originally transmitted bits from the touch events
  - No modification to hardware or firmware of off-the-shelf devices



Creating Artificial Touches

Capacitive touch screen background



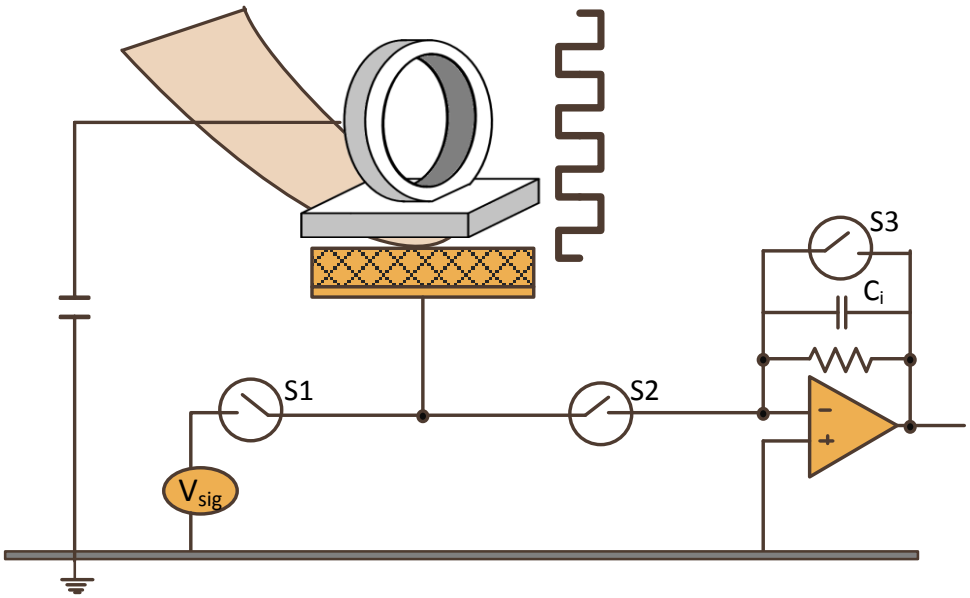


- Sensors measure the additional capacitance of a human body
- Array of conducting electrodes behind an insulating glass layer
- Structure of a touch event registered to the operating system

Timestamp	Event Type	Pointer ID	(X,Y) coordinates	Touch Size	Touch Amplitude

Creating Artificial Touches

"Spoof" the touch screen

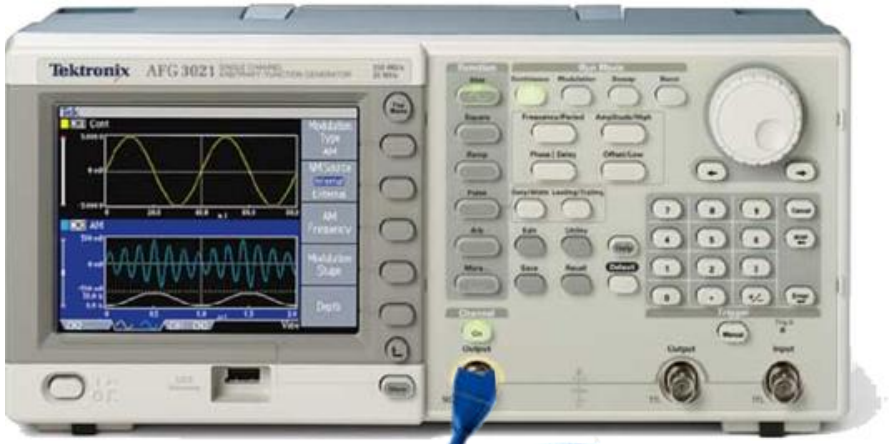


- Affecting the capacitance measurement by injecting signal to create artificial touch events

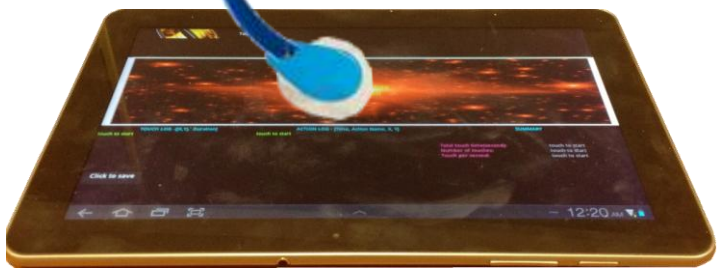
Creating Artificial Touches

Experimented with different signal sources

Tektronix AFG 3021



- Different waveforms
- Voltages: 1-20Vpeak to peak
- Frequency: 100Hz to 120KHz

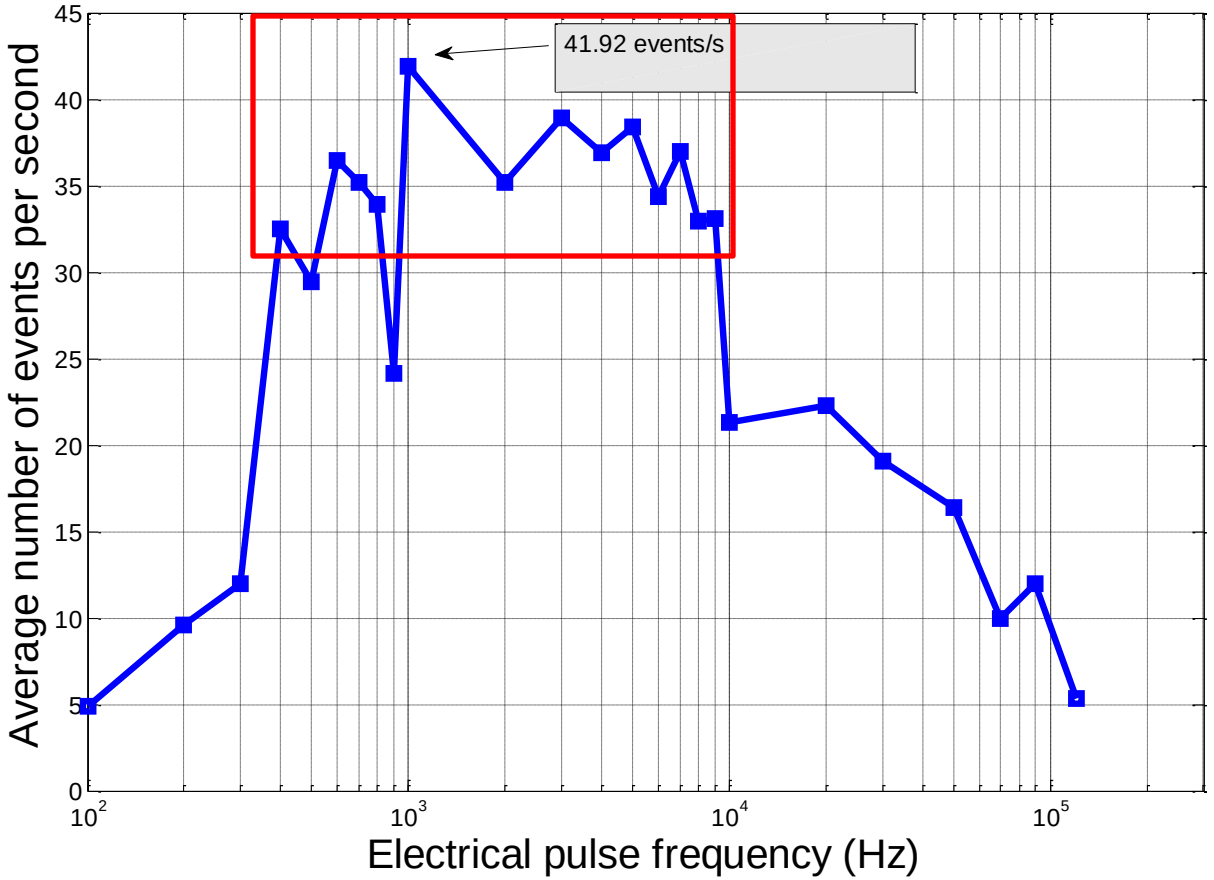


Samsung Galaxy Tab 10.1'

ATMEL maXTouch

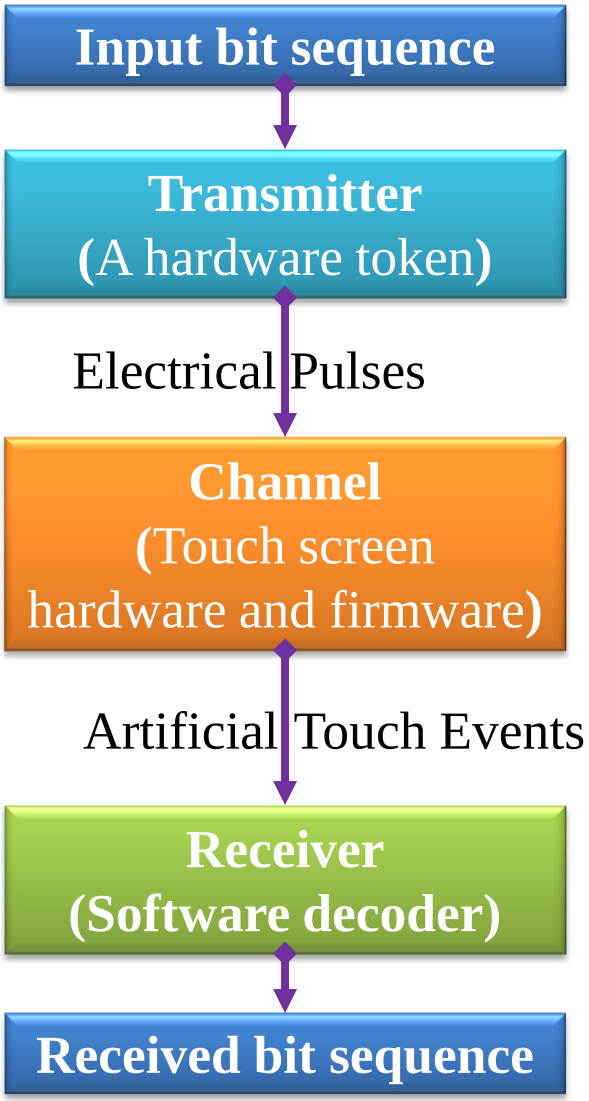
Creating Artificial Touches

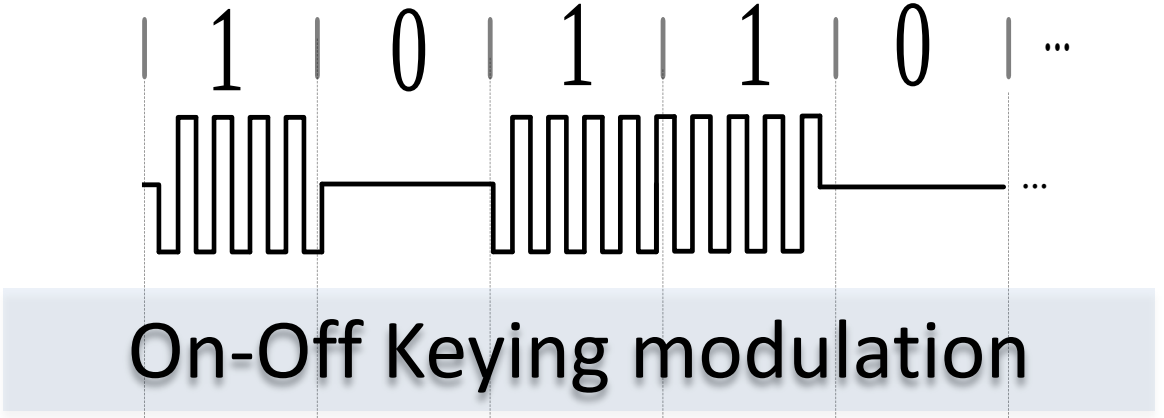
Experimented with different signal sources



Touch screen responses to 10 Vp-p square wave signals at frequency from 100Hz to 120KHz

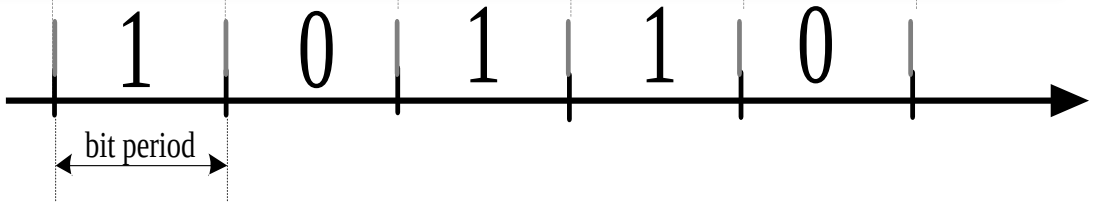
Encoding bits with touch events



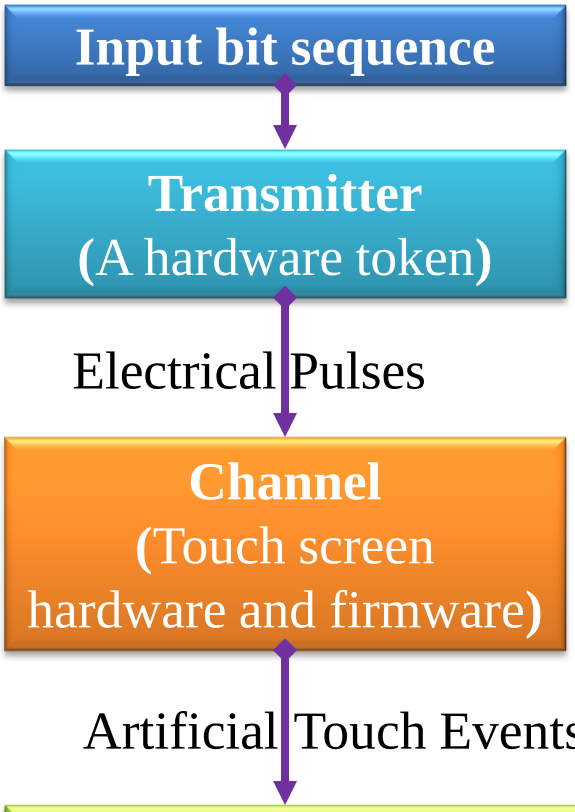


On-Off Keying modulation

Threshold-based demodulation



Encoding bits with touch events



On-Off Keying modulation

Threshold-based demodulation

- Unsynchronized
- Unknown processing delay
- Highly correlated channel
- Variable delay between symbols

- Low bandwidth

- Offline calibration to select thresholds
- Simultaneously synchronize and demodulate

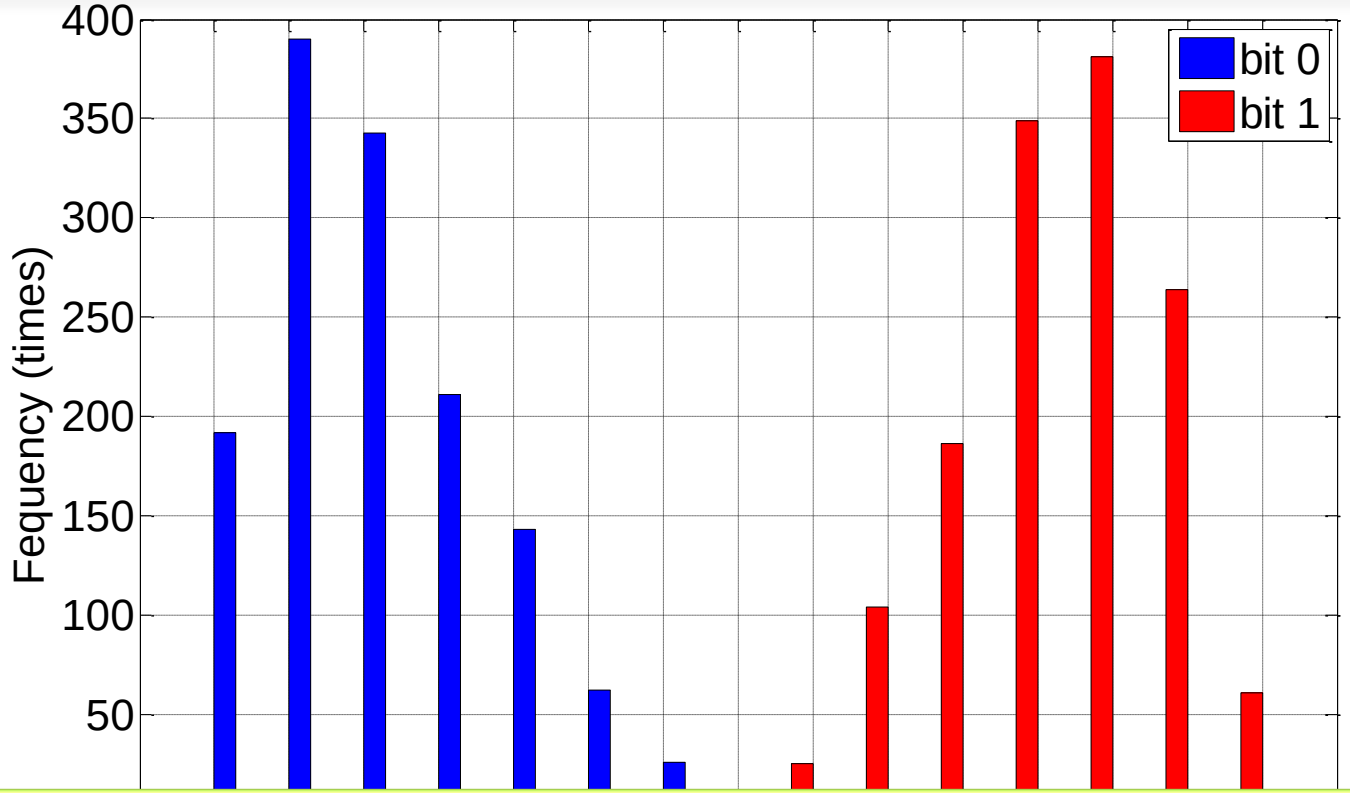
Offline Calibration

Determine number events for ***ones*** and ***zeros***

- Transmit a known bit sequence.
- Synchronize Tx and Rx using a sliding window:
  - The correct bit synchronization maximizes number of events in all **1**s and minimize that of **0**s
- Count the number of events in each bit 0s and 1s

Offline Calibration

Determine number events for ones and zeros



- ~~Offline calibration to select thresholds~~
- Simultaneously synchronize and demodulate

Minimum Distance Demodulation

Simultaneously synchronize and demodulate

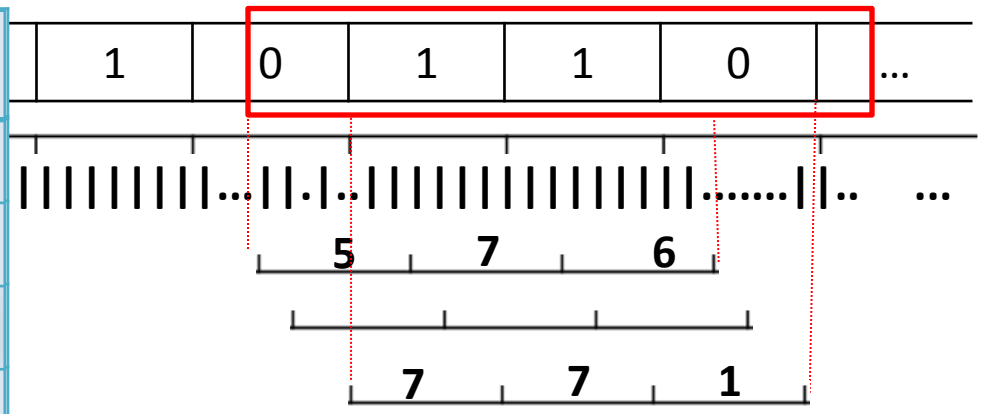
- Assumption:
  - All possible messages are known
- Demodulation:
  - Try all possible starting points
  - At each starting point, compute the correlation between the event sequence and all messages
  - Select the message and starting point that give the highest correlation (decoded message)

Example

Message = 011

Possible Messages = {001, 011, 111}

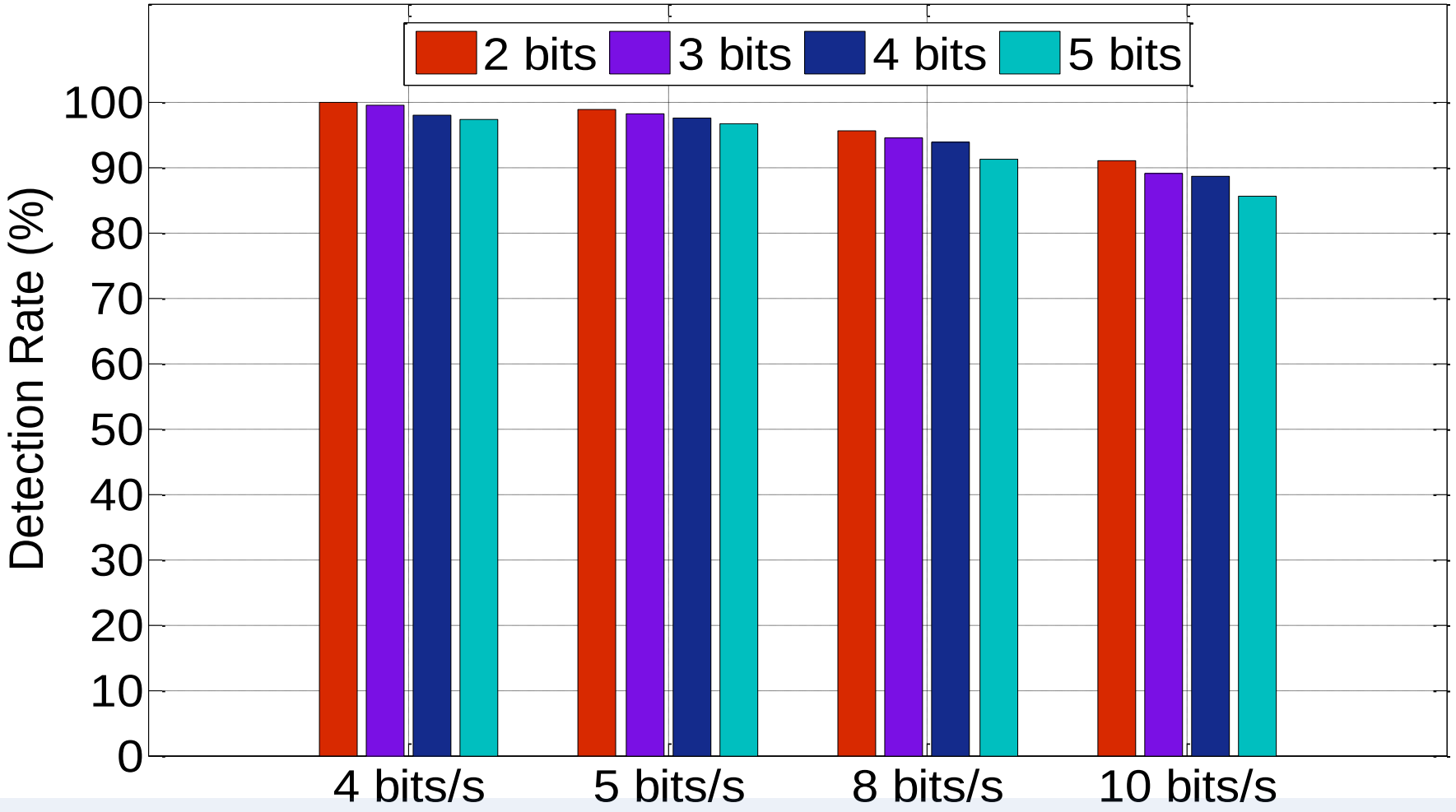
Starting Position	001	011	111
1	11	5	2
...	...	...	...
202	18	0	6
...	...	...	...



Evaluation with Function Generator

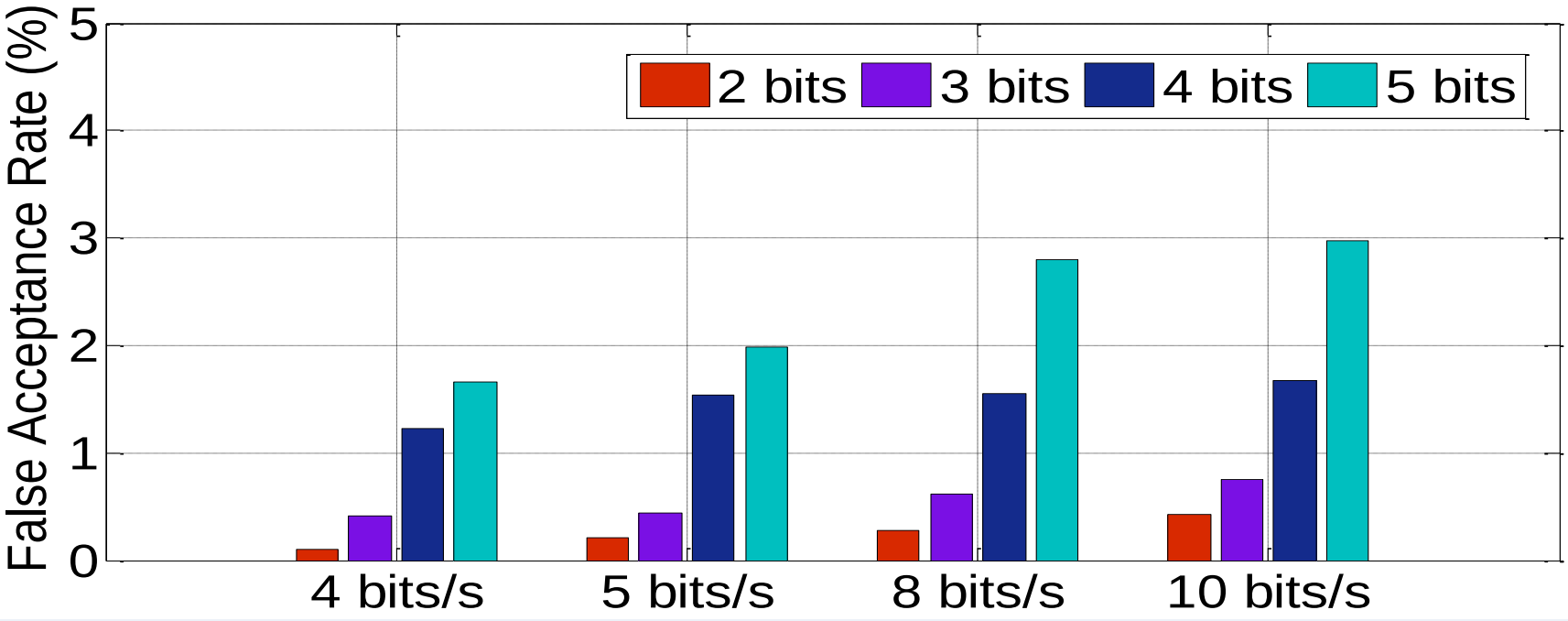
- Metrics:
  - Detection Rate & False Acceptance Rate
- Methodology:
  - Messages with length of 2-5 bits.
  - Repeatedly transmitted 5000 times for each message

Evaluation with Function Generator



- Bit period gets smaller as the data rate increases

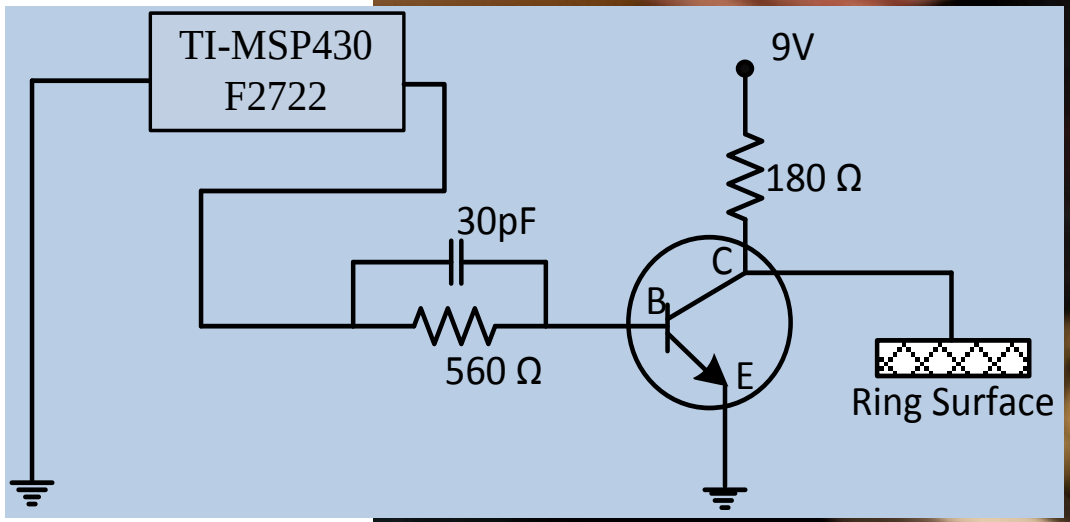
Evaluation with Function Generator

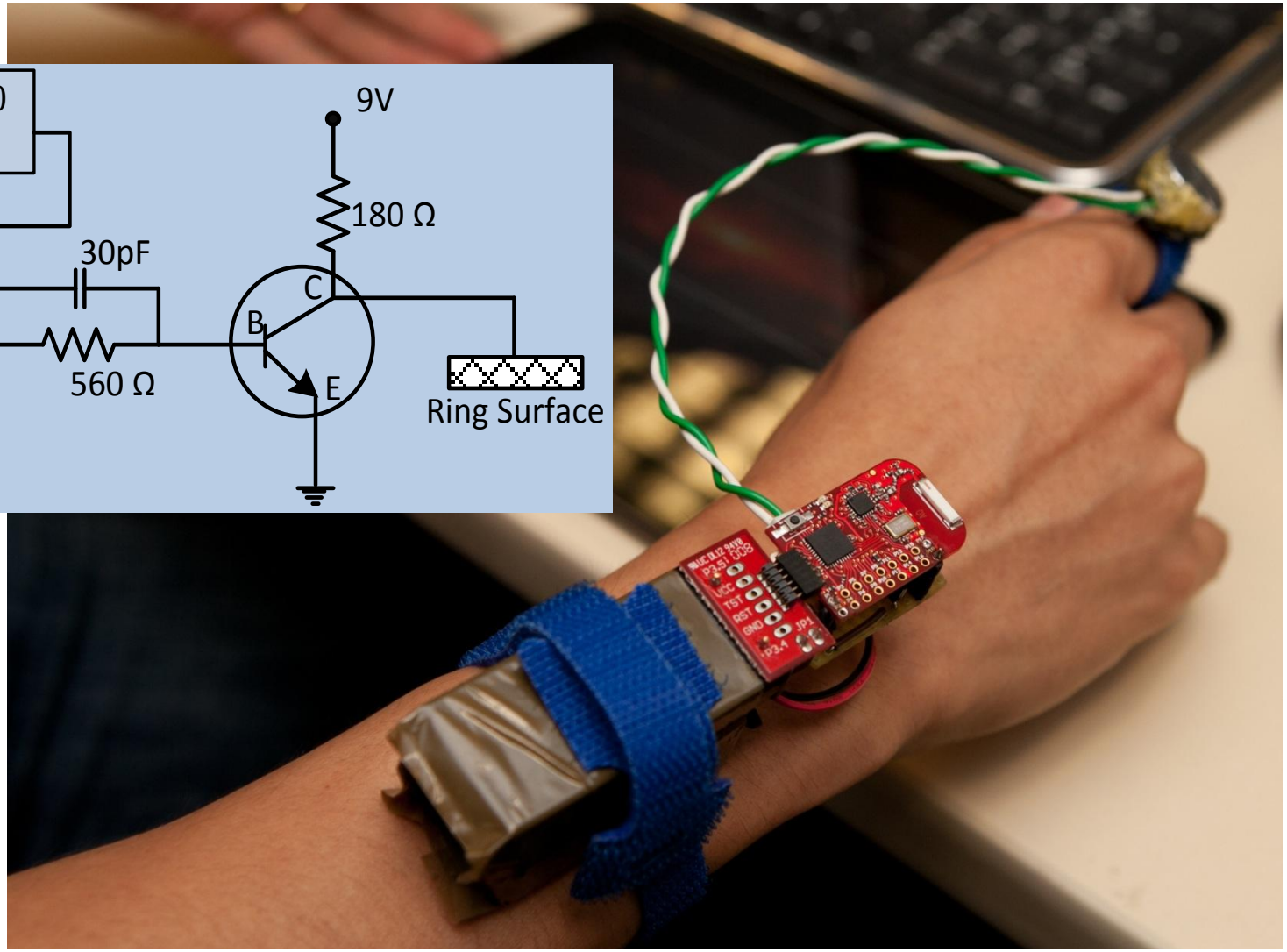


- Bit period gets smaller as the data rate increases

Prototype

Building a wearable hardware token





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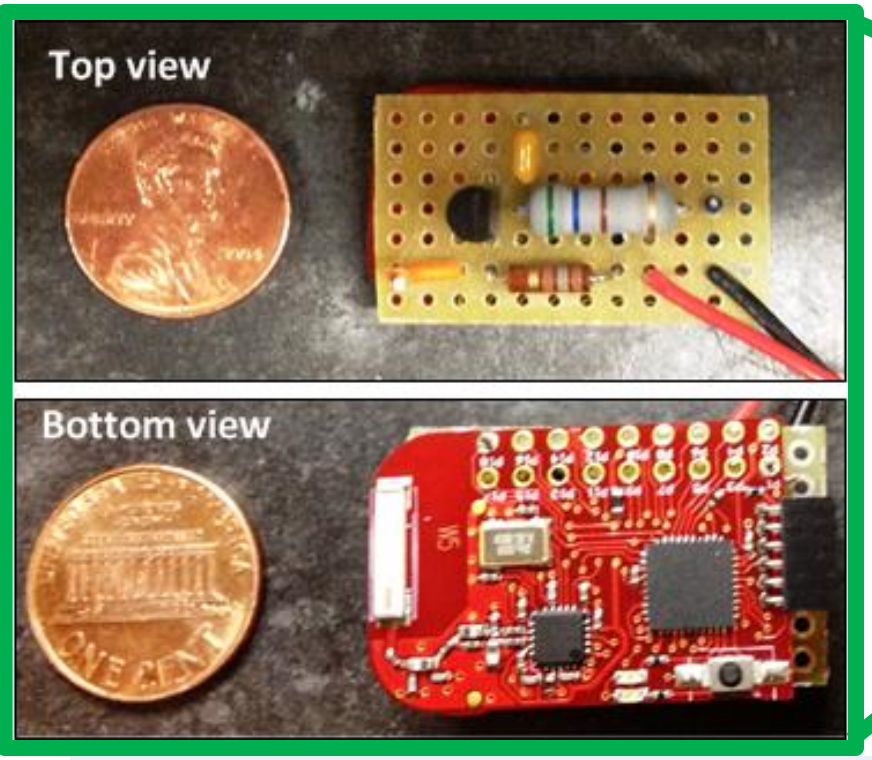
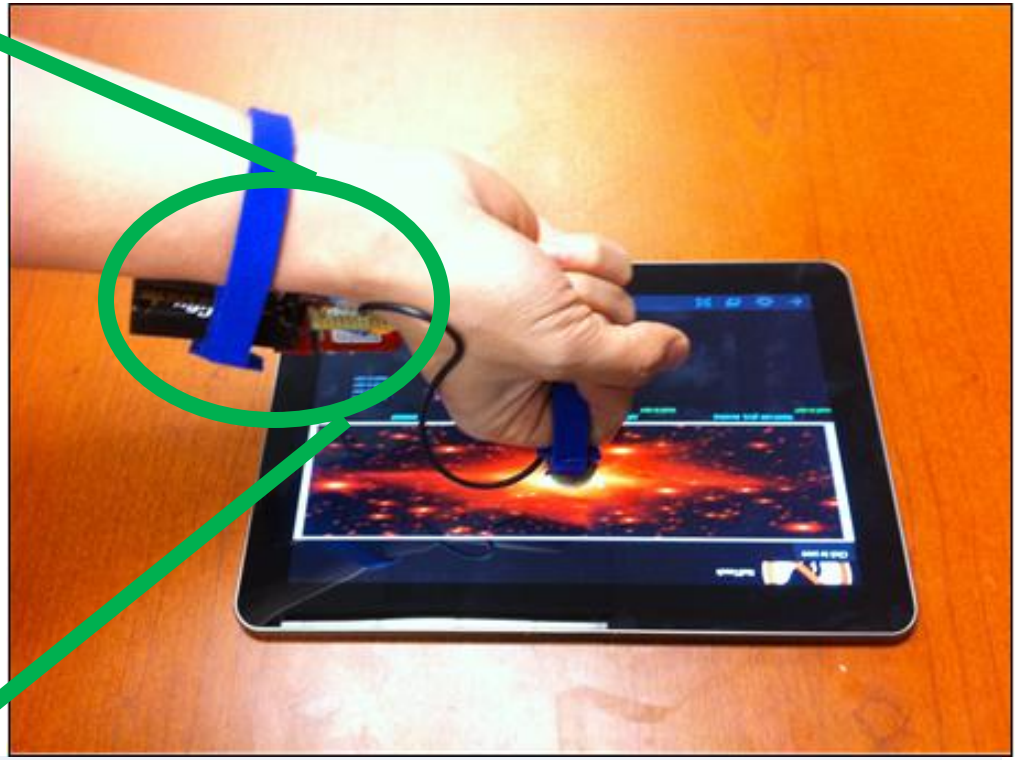
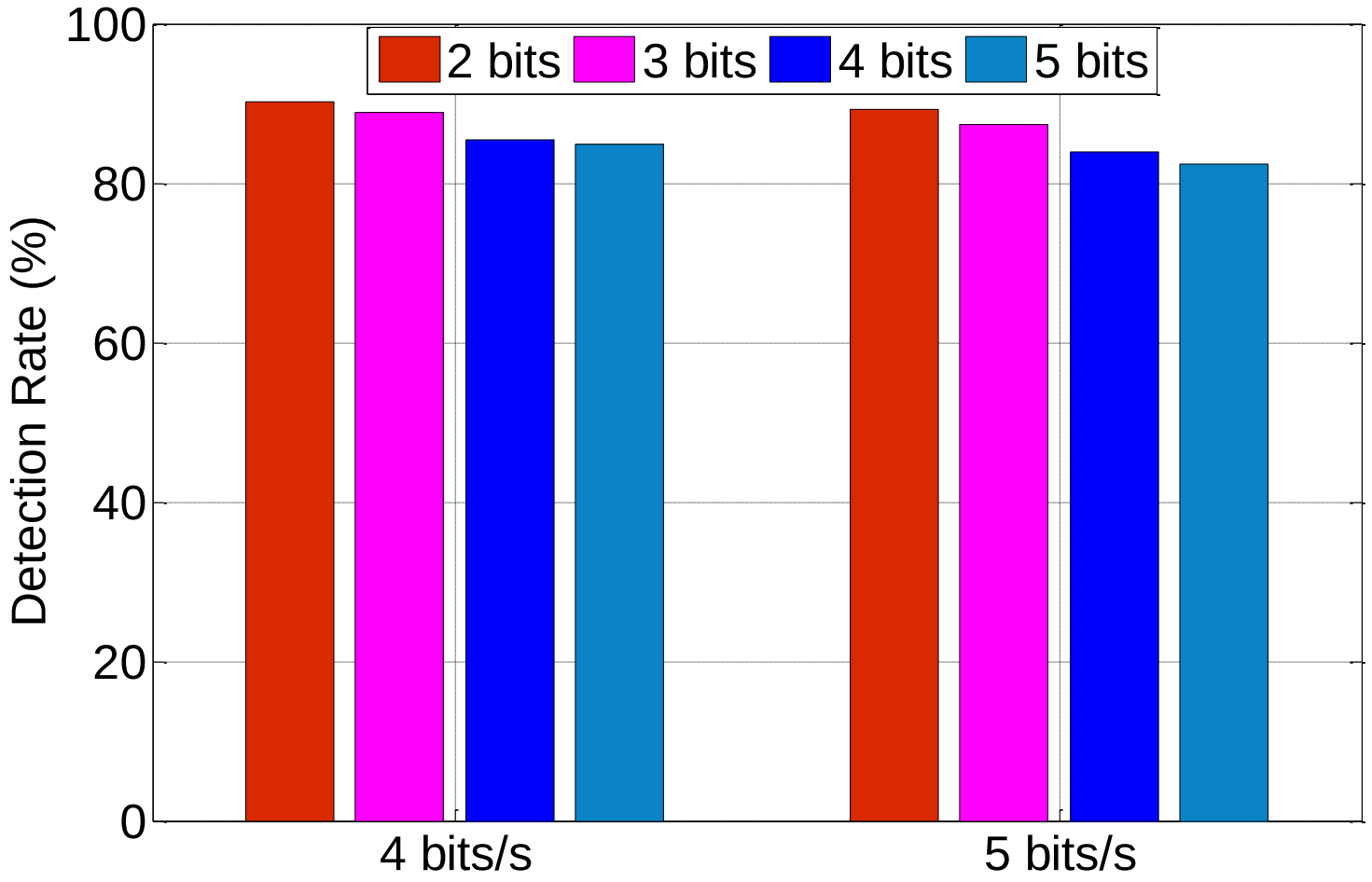




- The ring generates pulses with longer rise time
- Contact point is not as good as of the AFG electrode

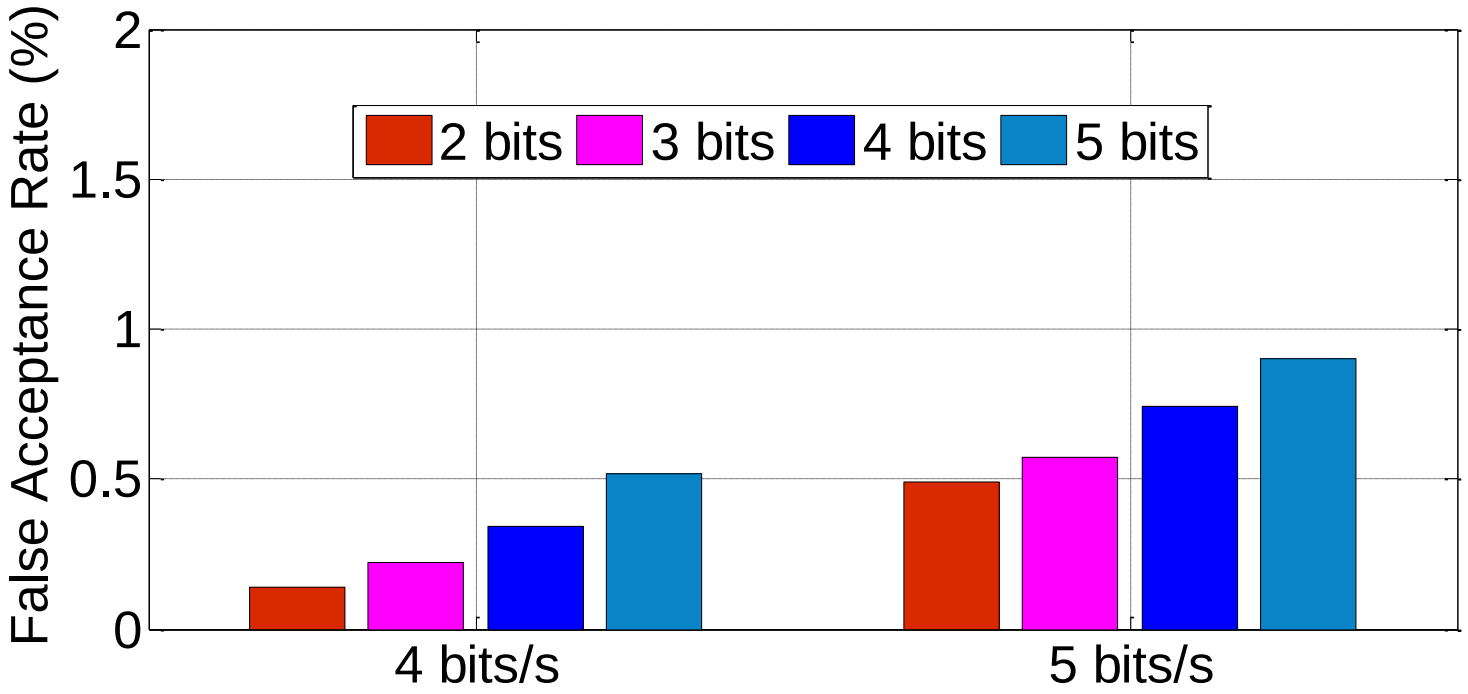
Prototype

Building a wearable hardware token



Prototype

Building a wearable hardware token



- Can be improved with better hardware design
- Trading data rate for DR and FAR by ECC

Possible applications

- Parental control applications
  - Sharing devices with your children/spouse
  - 2-3 bits to be transmitted
- Weak authentication
  - Pincode level (i.e ~13 bit of entropy)

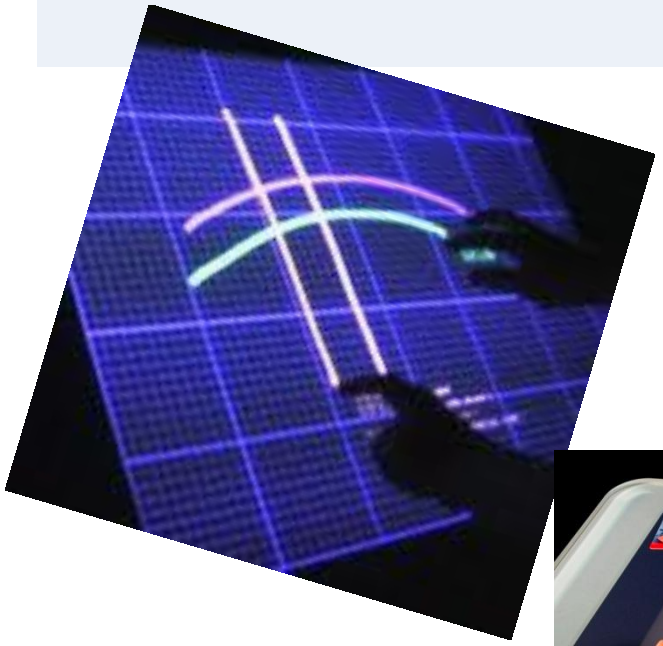
Parental control

Possible applications

- Distinguishing different types of tokens
  - Board games on touch screens
  - Different coloring styluses
  - A few bits to be transmitted

Possible applications

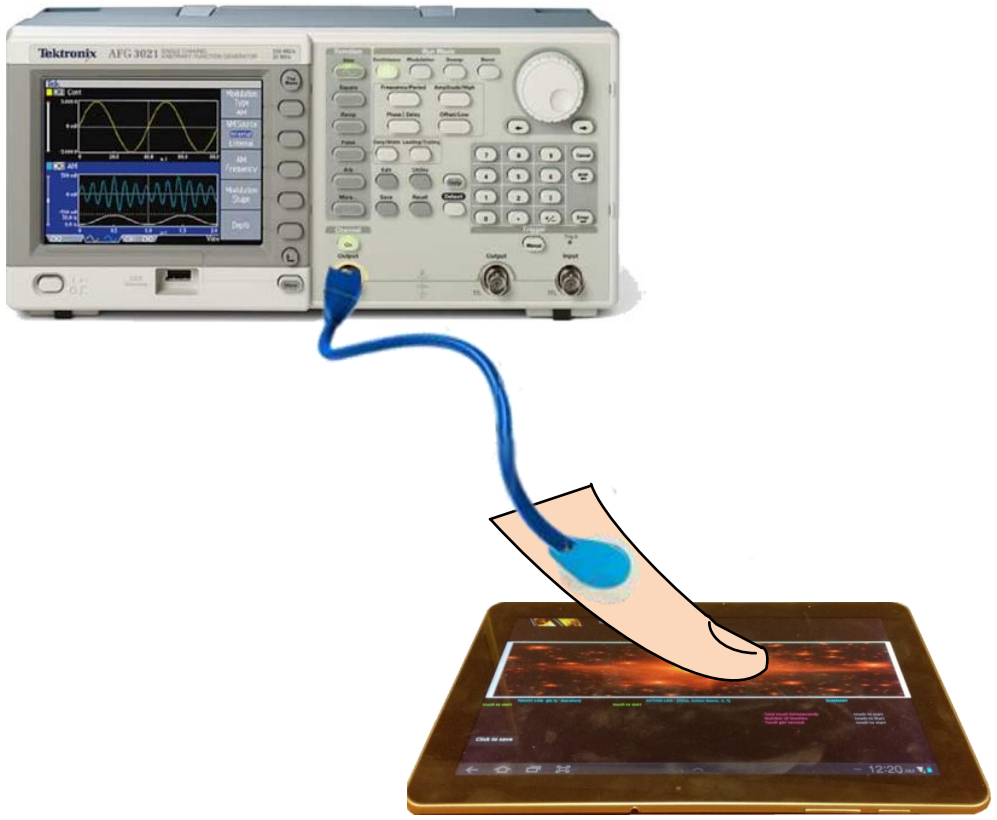
- Multi-user games/collaboration
  - 1-2 bits to be transmitted



Transmitting through a finger

- The electrode in contact with a human finger

Tektronix AFG 3021

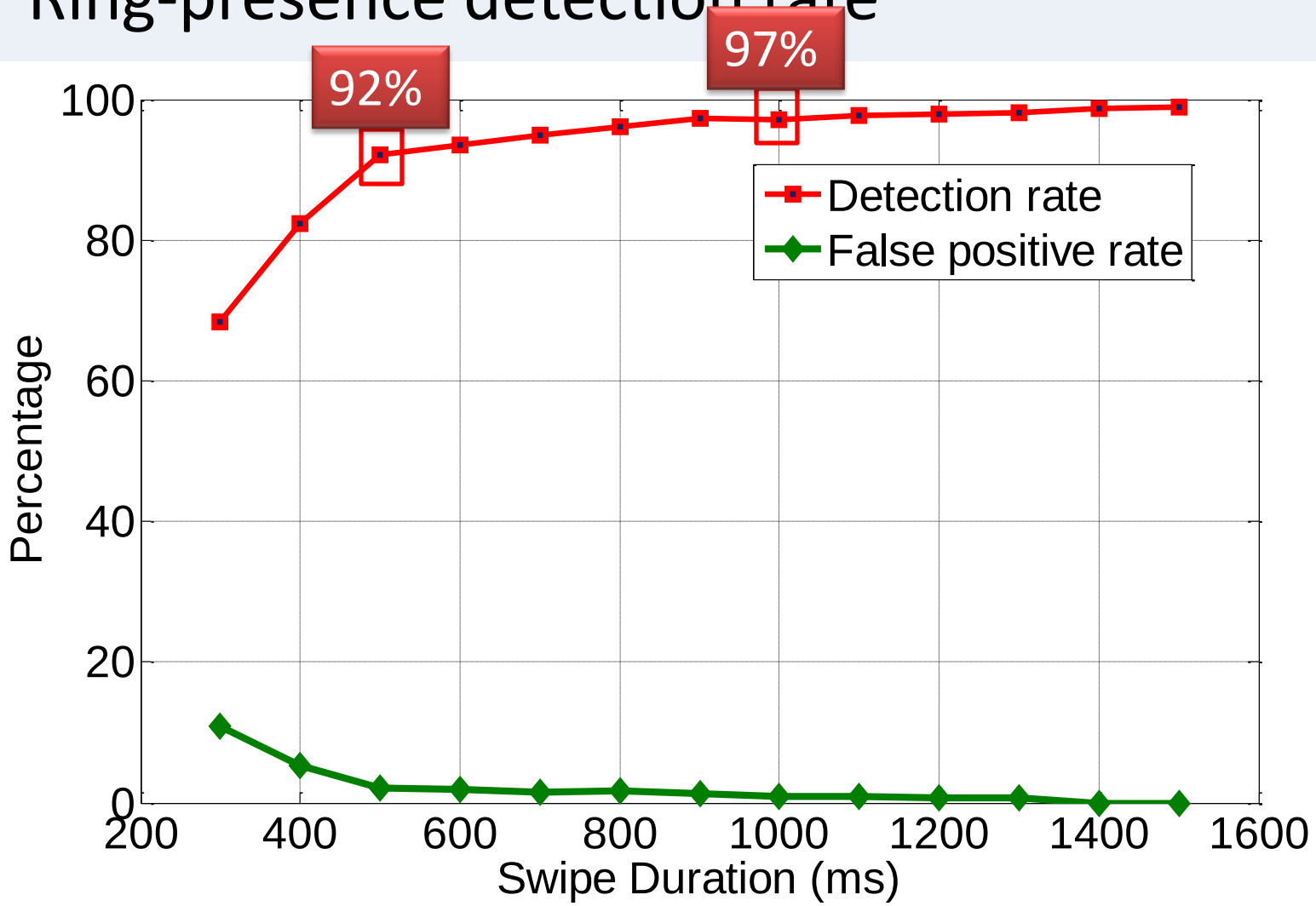


Samsung Galaxy Tab 10.1'

- Detecting the presence of the ring when the user swipe

Transmitting through a finger

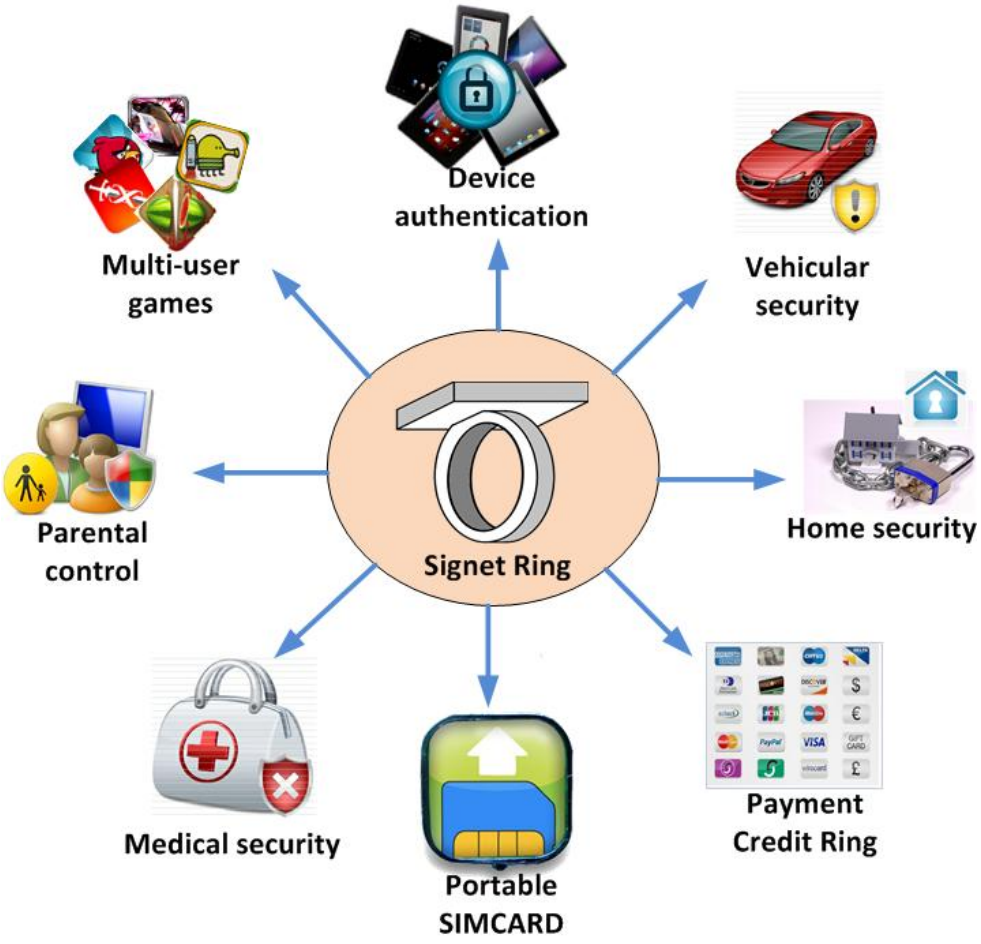
- Ring-presence detection rate



Conclusion

Capacitive Touch Communication

Thank you !



Demo video is available on YouTube at:

http://tinyurl.com/8nc65ro