Whisper in the Wire:
Voice Command Injection Reloaded

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Hack In Paris - 30/06/2016

WHO WE ARE

Chaouki Kasmi and José Lopes Esteves

- ANSSI-FNISA / Wireless Security Lab
- Electromagnetic threats on information systems
- RF communications security
- Embedded systems
- Signal processing

AGENDA

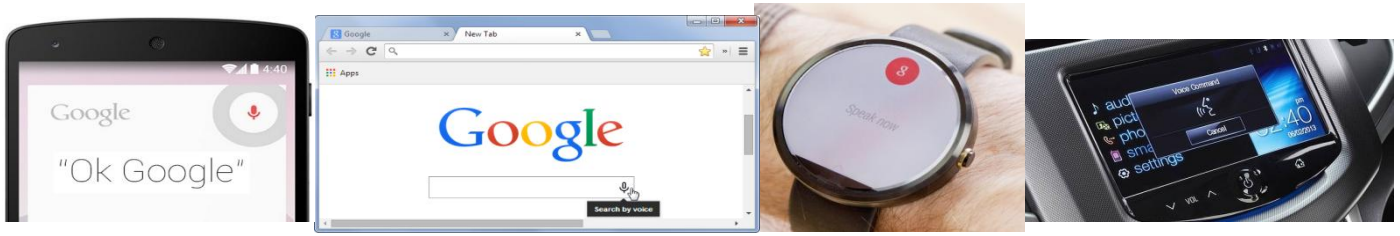
- Voice command interpreters
- Previous work: injection through headphones
- Back-door coupling: characterization
- Back-door coupling: exploitation
- Conclusion

Voice Command Interpreters

Your phone hears…

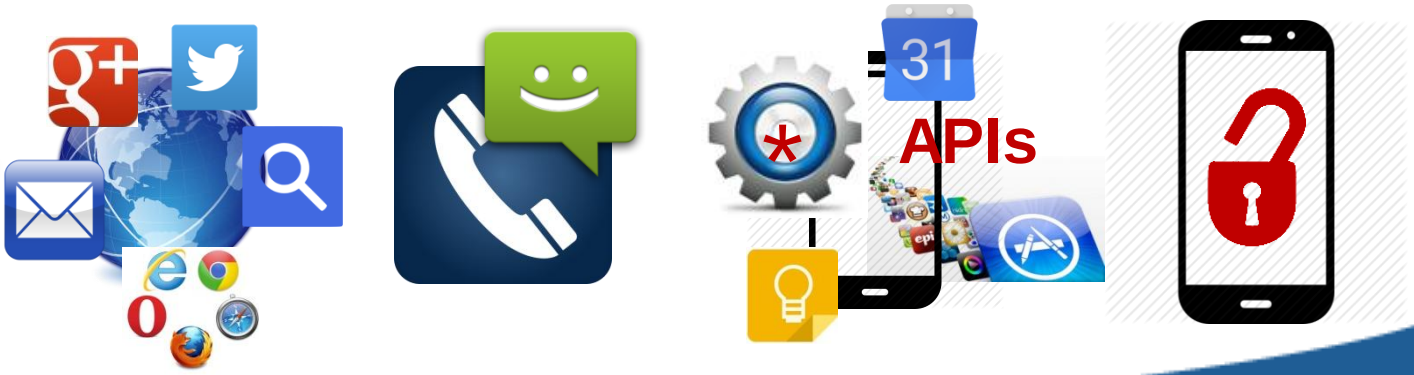
VOICE COMMAND INTERPRETERS

Where?



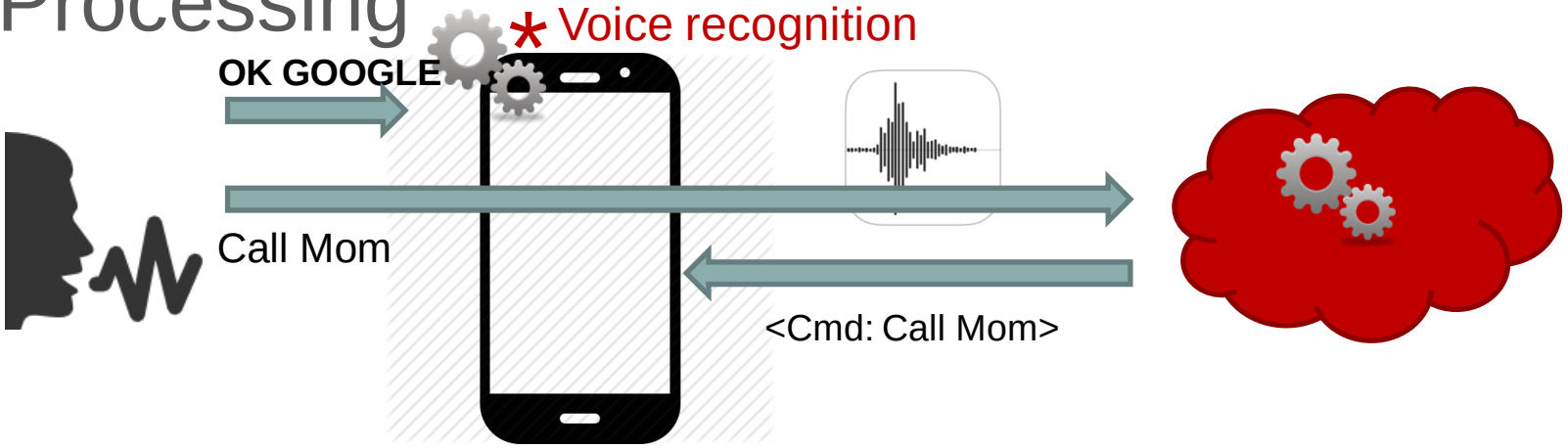
Who?

What?

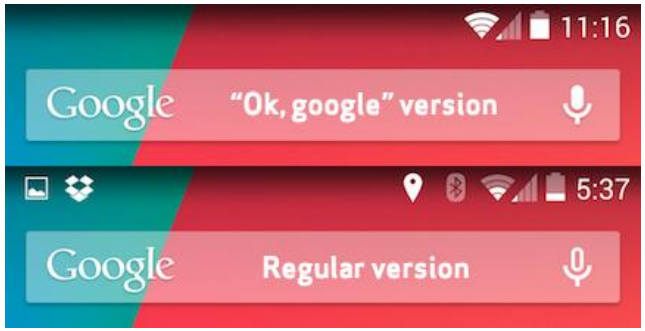


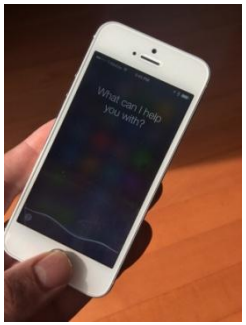
VOICE COMMAND INTERPRETERS

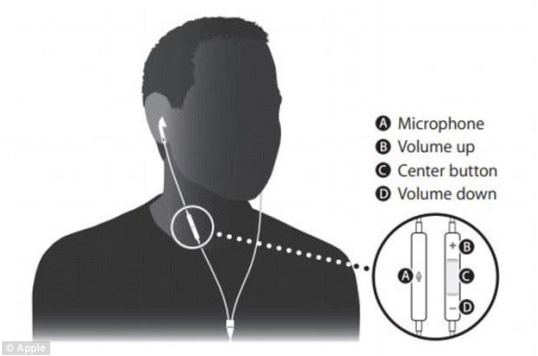
- Processing



- Activation







VOICE COMMAND INTERPRETERS

- Authentication
  - Depends on settings and OS
  - Voice recogniton available
  - Pre-auth commands can be limited
- E.g. Google settings

- **From any screen:** You can say "Ok Google" from any screen on your device if the screen is on or the device is charging.
- **Always-on:** You can say "Ok Google" whether your screen is on or off on a Nexus 6, Nexus 9, or Samsung Note 4 device.
- **Trusted voice:** When you say "Ok Google" from a secure lock screen and we're able to recognize the sound of your voice, you can ask Google to do things for you or visit sites without having to unlock your device manually.

VOICE COMMAND INTERPRETERS

- Personalize keyword
- Carefully choose available commands (esp. Pre-auth)
- Limit critical commands
- Voice recogniton
- Enable feedbacks (sound, vibration…)
- Provide finer-grain settings to user

(a)flickr.com/photos/hikingartist

SECURITY

- Pre-auth actions (limited but still…): **auth bypass** [1]
- Cloud based: malicious server responses [2]
- Voice processing: privacy [3], biometric data
- Local attacks: malicious app voice sending commands by audio front-end [4][10], **audible obfuscated commands** [8]
- **Remote and Silent Voice Command Injection by Smart IEMI** [9]

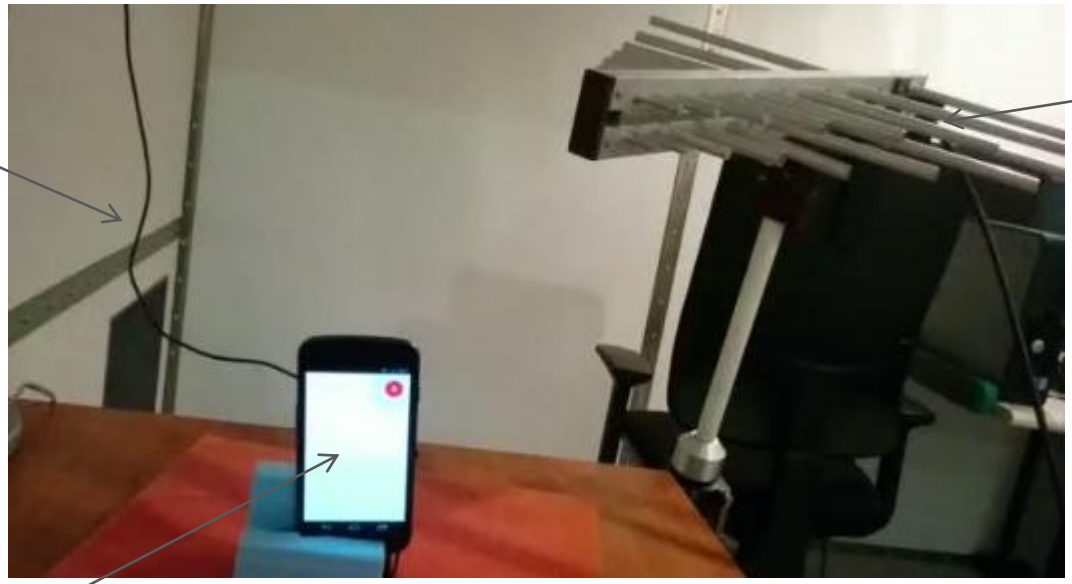
Previous work on remote voice command injection

[9] You don’t hear me but your phone’s voice interface does

Hack In Paris 2015

PREVIOUS WORK – TECHNIQUE [9]

- Voice command injection with a radio signal by front-door coupling on headphones cables

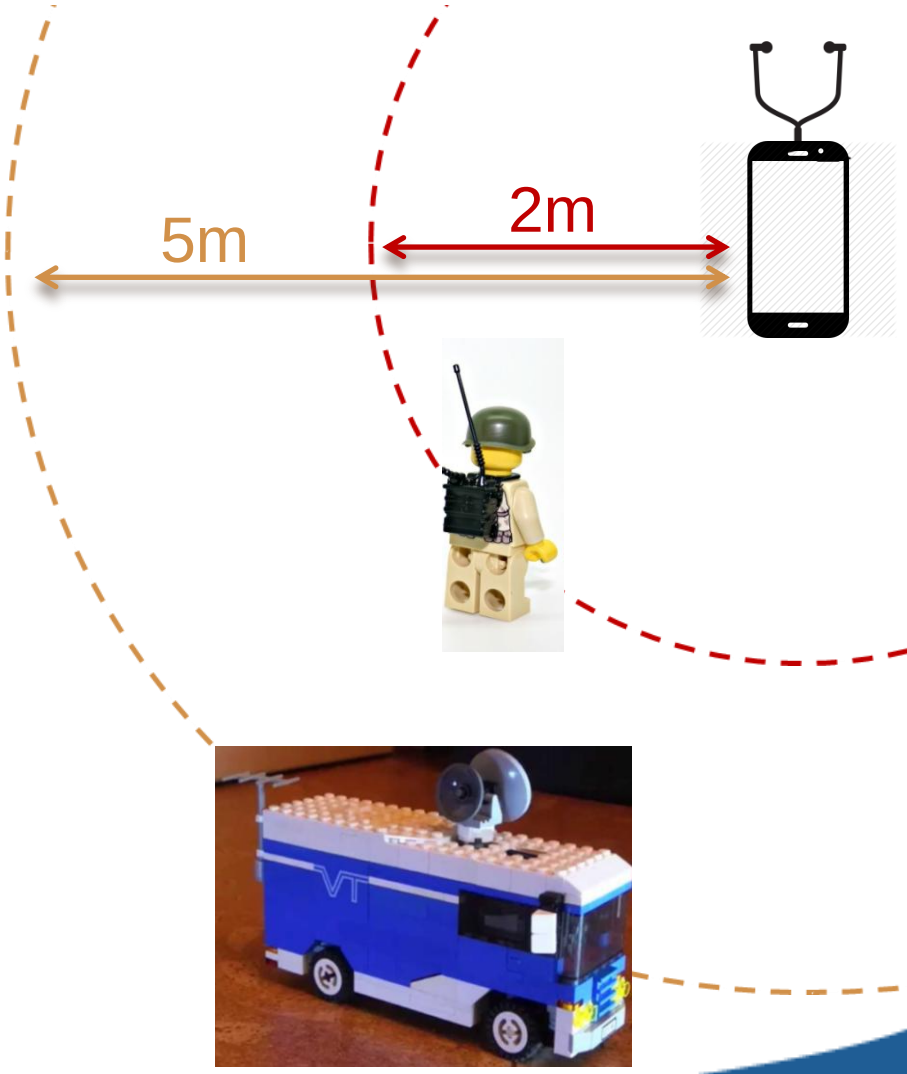


PREVIOUS WORK – IMPACT [9]

- Tracking
- Eavesdropping
- Cost abuse
- Reputation / Phishing
- Malicious app trigger/payload delivery
- Advanced compromising

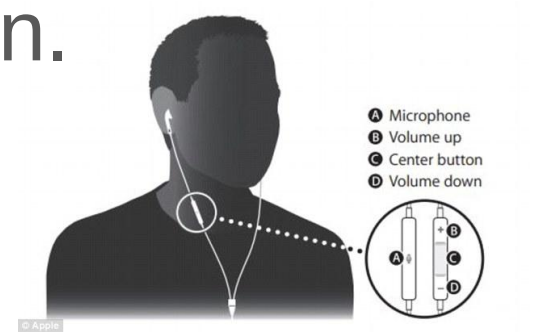
PREVIOUS WORK – RESULTS [9]

- Limitations
  - Antenna size (~30cm)
  - Emitted power
- E-field level
  - 28V/m at 100MHz
- Power level/range
  - 40W/2m, 200W/5m



PREVIOUS WORK – LIMITATIONS

- Headphones required : considered as the main limitation.



- Distance between source and target limited by the minimal required field.

- Activation conditions of the voice interpreters and exploitation impact depend on the settings

PREVIOUS WORK – LIMITATIONS

- Is it possible to overcome these limitations ?
- Maybe, if we change our attack vector

To ask questions without pressing the Home button, plug your device into power and turn on "Hey Siri." With iPhone 6s, iPhone 6s Plus, iPhone SE, and iPad Pro (9.7-inch) you can use this feature without plugging into power.

plug your device into power

- **From any screen:** You can say "Ok Google" from any screen on your device if the screen is on or the device is charging.
- **Always-on:** You can say "Ok Google" whether your screen is on or off on a Nexus 6, Nexus 9, or Samsung Note 4 device.
- **Trusted voice:** When ognize the sound of your voice, you can a your device manually.

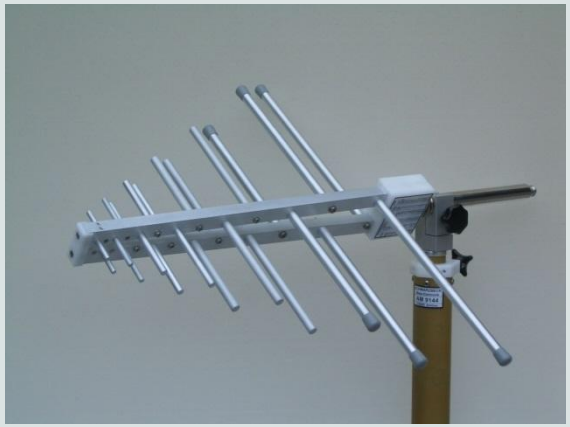
or the device is charging.

Analysis of back-door coupling mode to reach to the audio interface

Reaching the smartphones connected to the power network through the USB cable

ELECTROMAGNETIC WAVES I

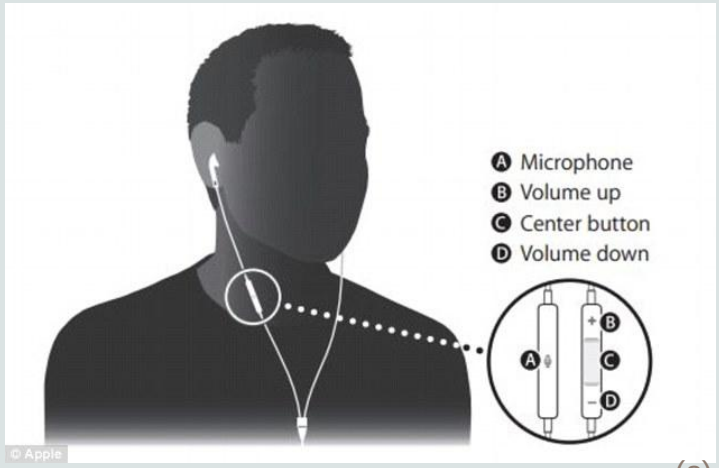
- EM waves propagation modes

Radiated	Conducted
 (a)	 (b)

(a)wikipedia.org (b)teseq.com

ELECTROMAGNETIC WAVES II

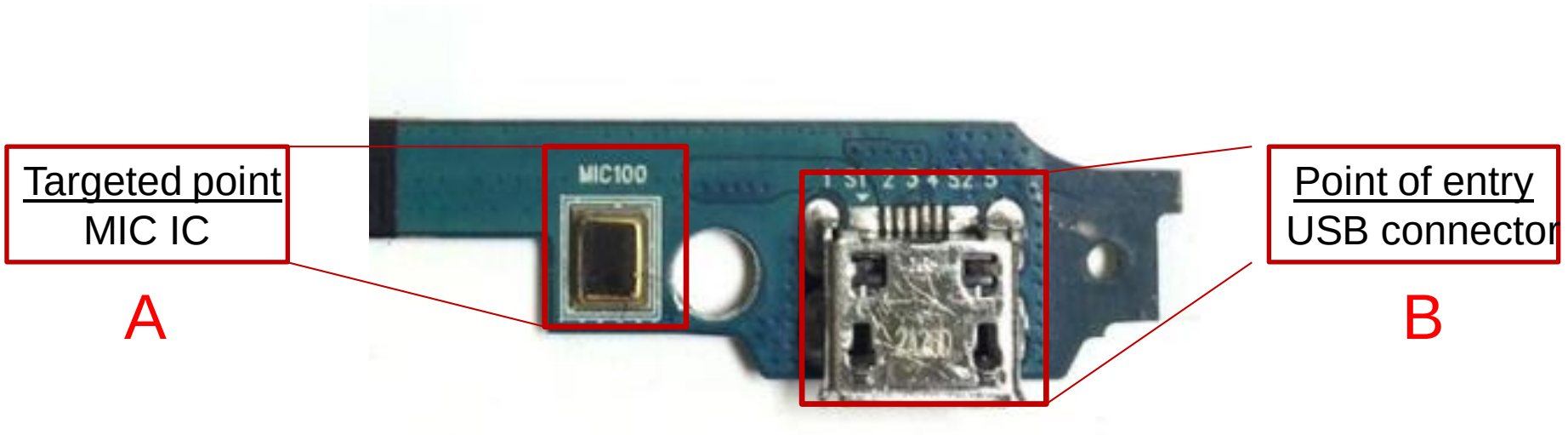
- EM waves coupling modes

Front-door antenna to antenna	Back-door antenna to cable
 (a)	 (b)

(a)dailymail.co.uk (b)cdiscount.com

BACK-DOOR COUPLING PATH

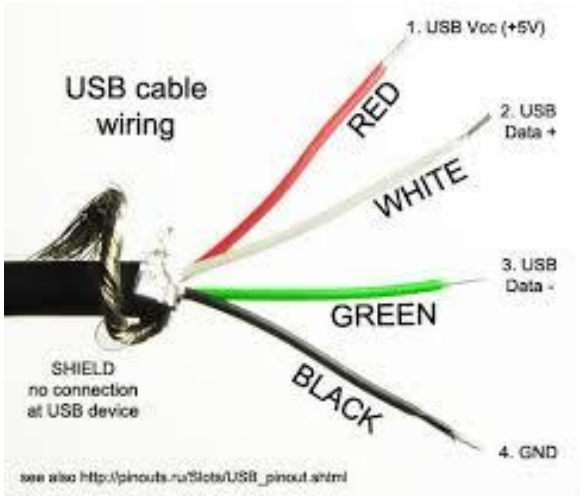
- Exemple of a target: Samsung Galaxy Nexus



Charging port part on the PCB

BACK-DOOR COUPLING PATH

- Target
  - USB cable (A)

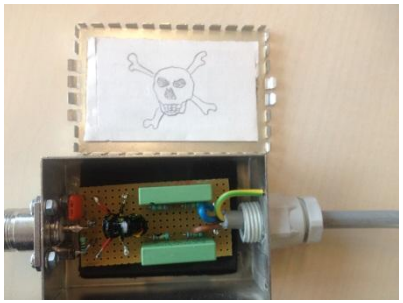


- Cable (A) connected to smartphones next to the smartphone microphone (B)
- Phenomenon (PCB teardown)
  - Isolation by-pass by parasitic coupling
  - A and B share the same Vcc and Gnd

BACK-DOOR COUPLING PATH

- Back-door coupling mode **exploitation**
  - Replace the antenna with an injection probe
  - Replace the antenna with a home-made coupler (PLC-like power circuit of PLC modems)
- Inject voice through conducted IEMI

Injection probe (teseq.com)



Home-made coupler

PLC: Power Line Communication

SIGNAL INJECTION [9]

- Experiments for injection validation

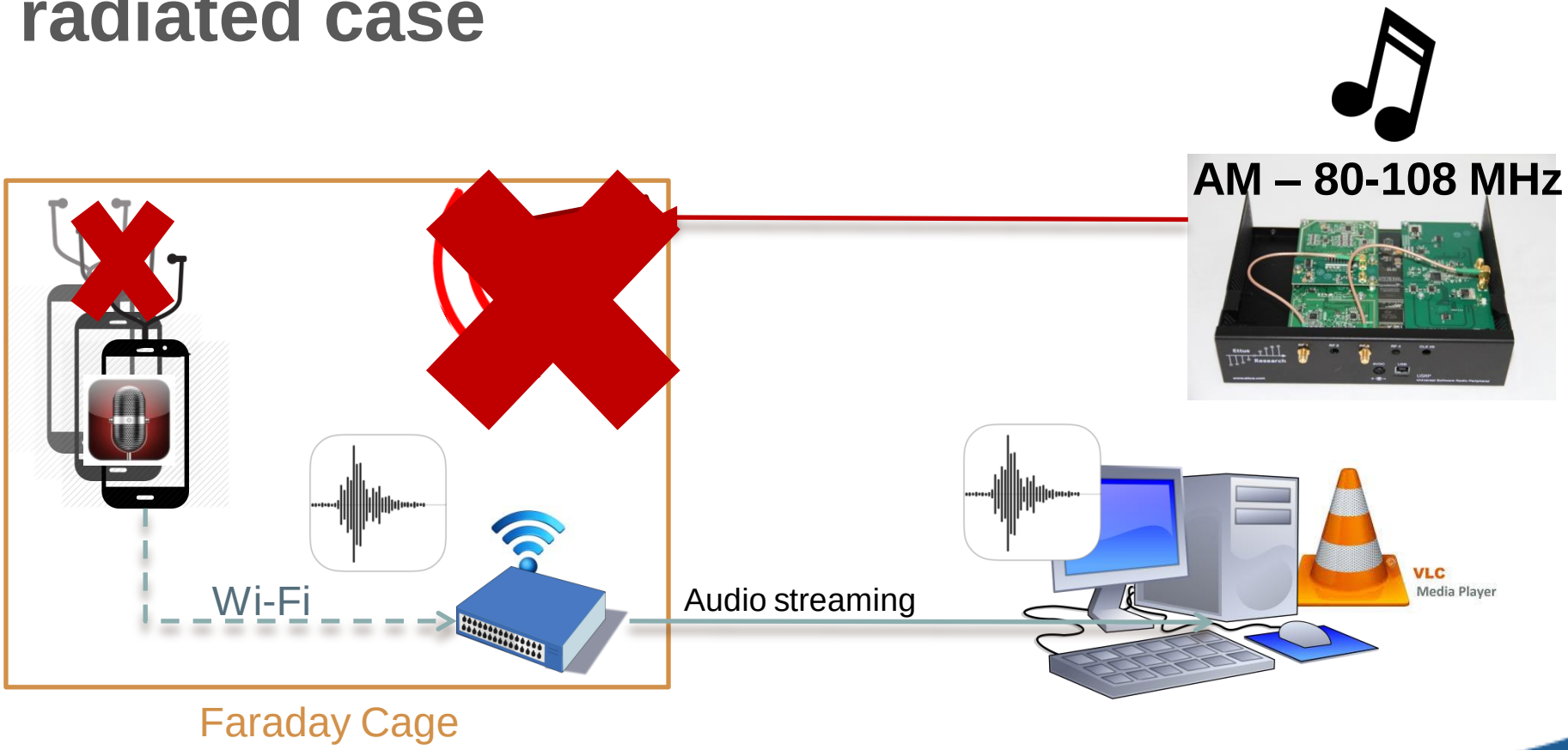
radiated case

Coupling frequencies = 80 - 100 MHz

SIGNAL INJECTION [9]

- Experiments for injection validation

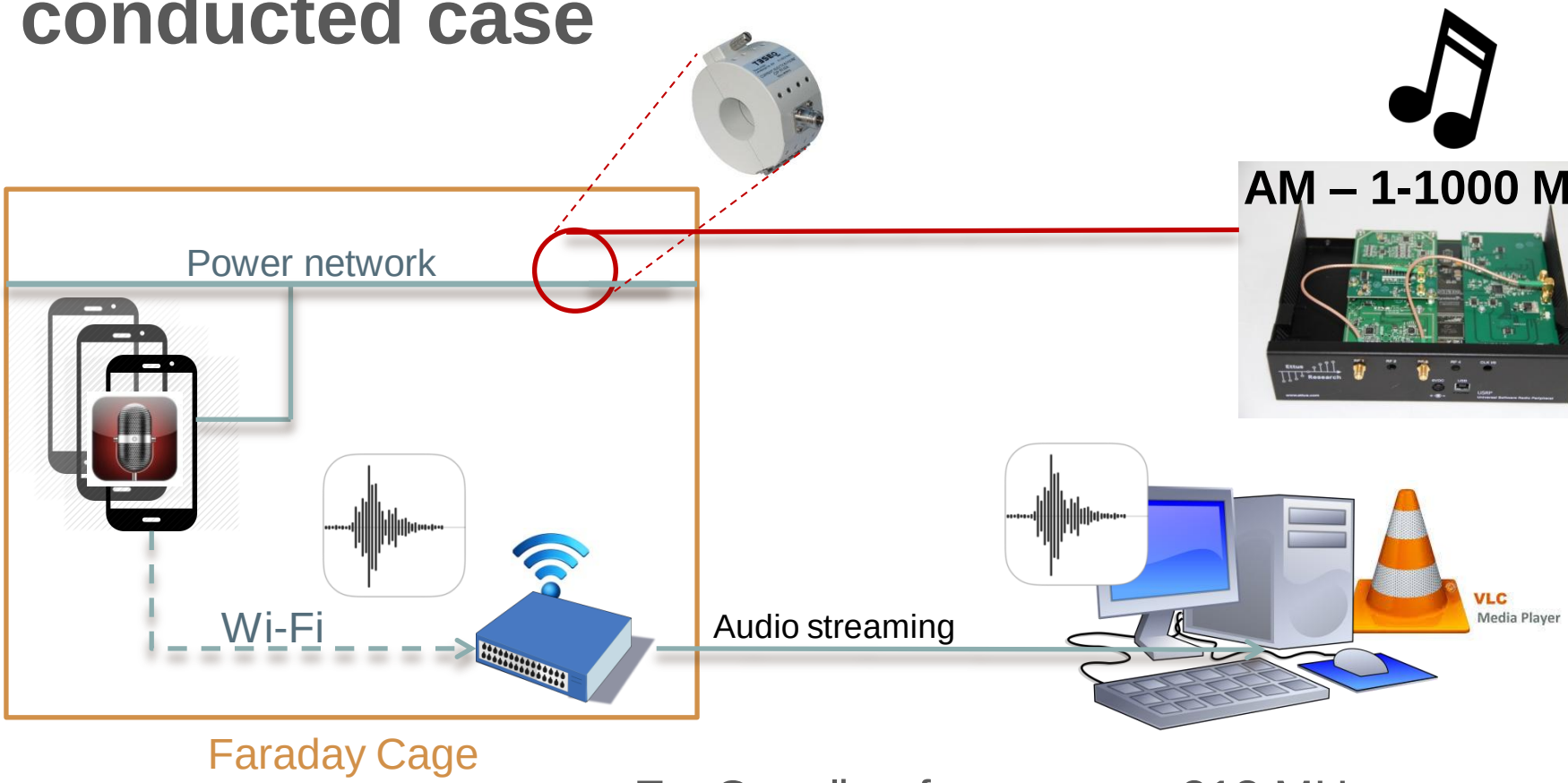
radiated case



SIGNAL INJECTION

- Experiments for injection validation

conducted case

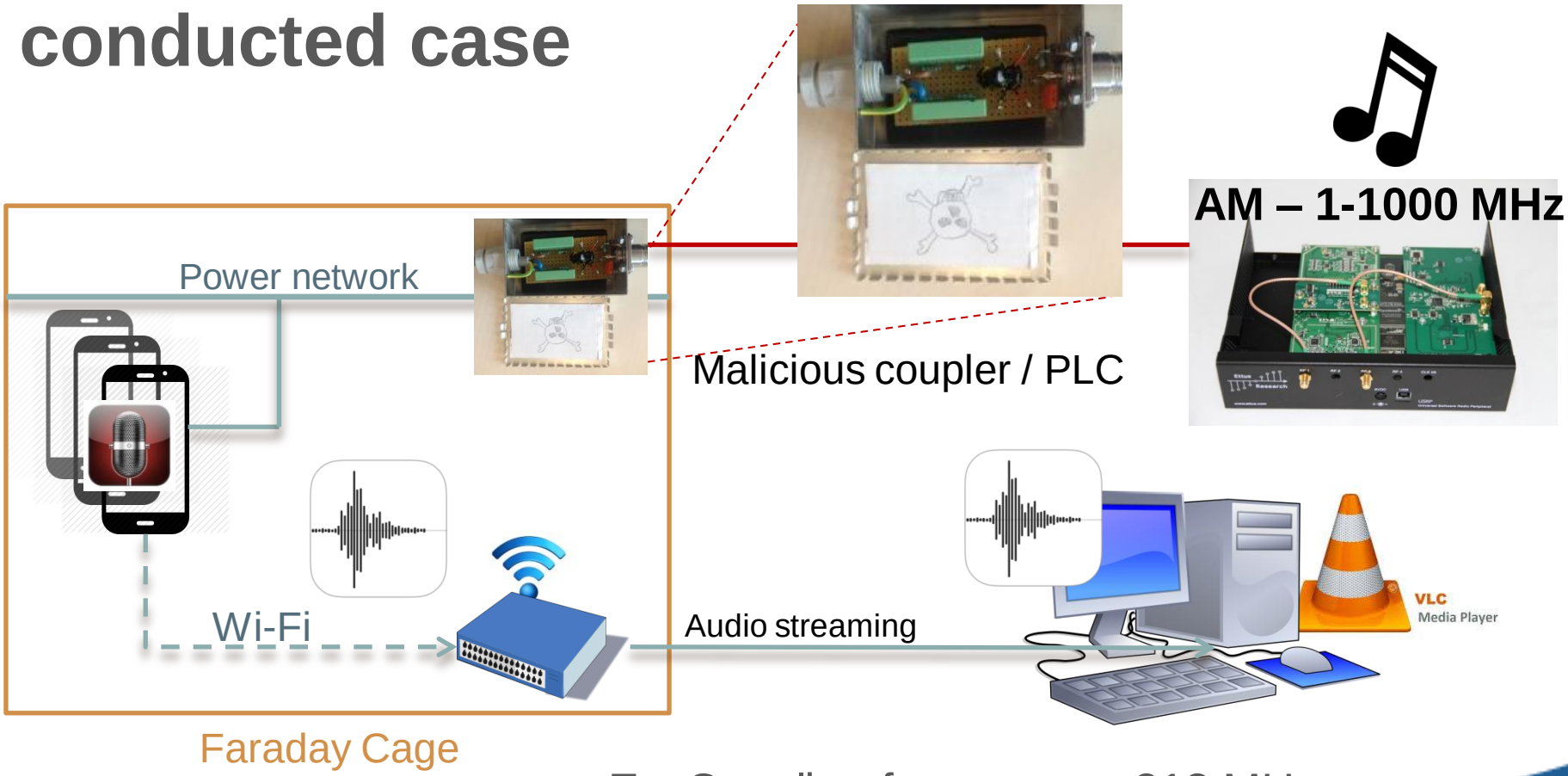


Ex. Coupling frequency = 218 MHz

SIGNAL INJECTION

- Experiments for injection validation

conducted case

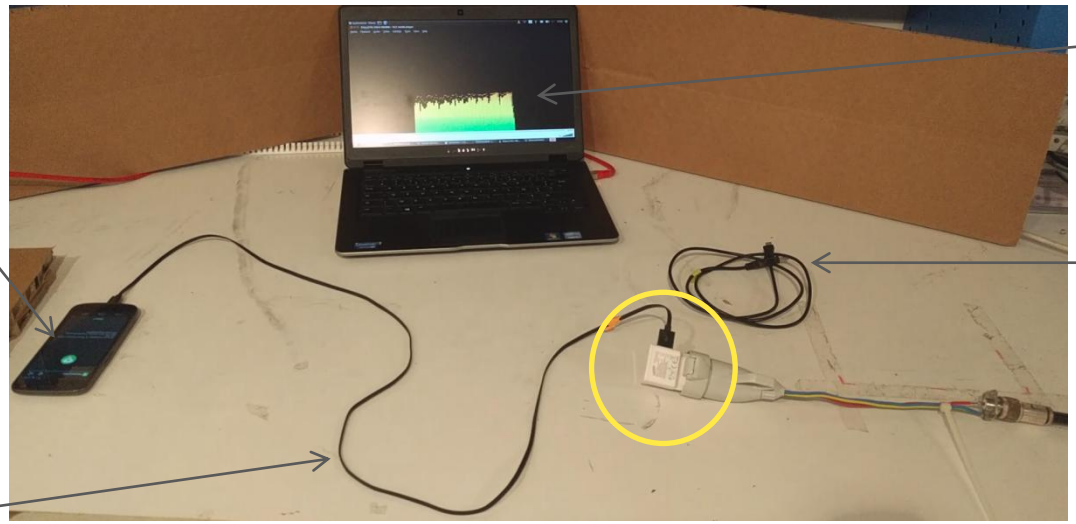


Ex. Coupling frequency = 218 MHz

TARGET CHARACTERIZATION

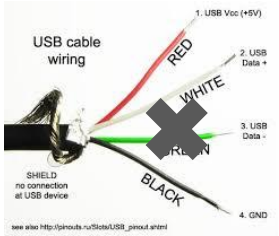
- Analysis of conducted interference bypassing the power charger of devices **offline**
  - Direct injection on devices under tests with a specific test fixture (common-mode injection P-N)

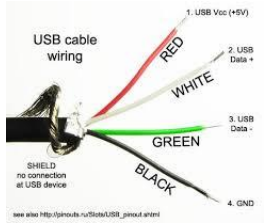
target with Wireless Mic



Monitoring with VLC

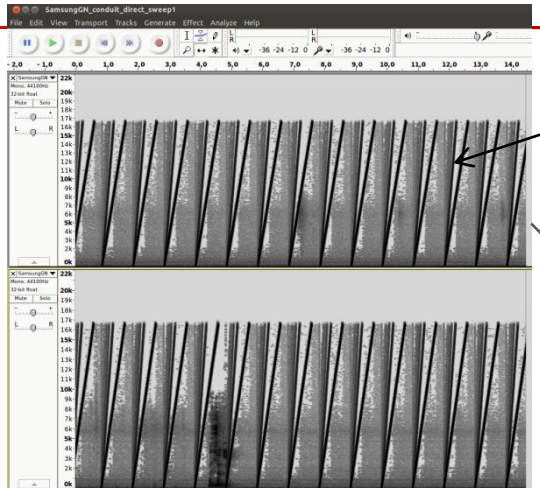
USB cable with data link





USB cable without data link

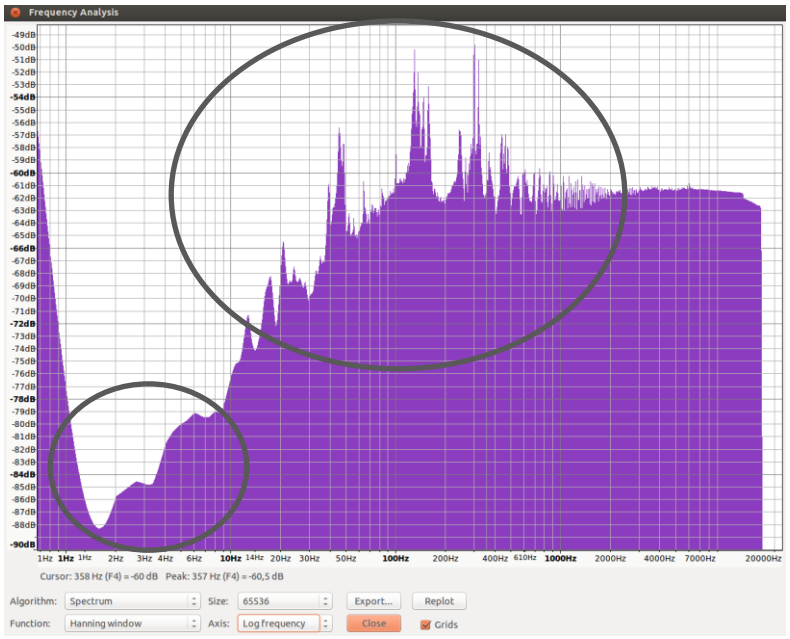
TARGET CHARACTERIZATION

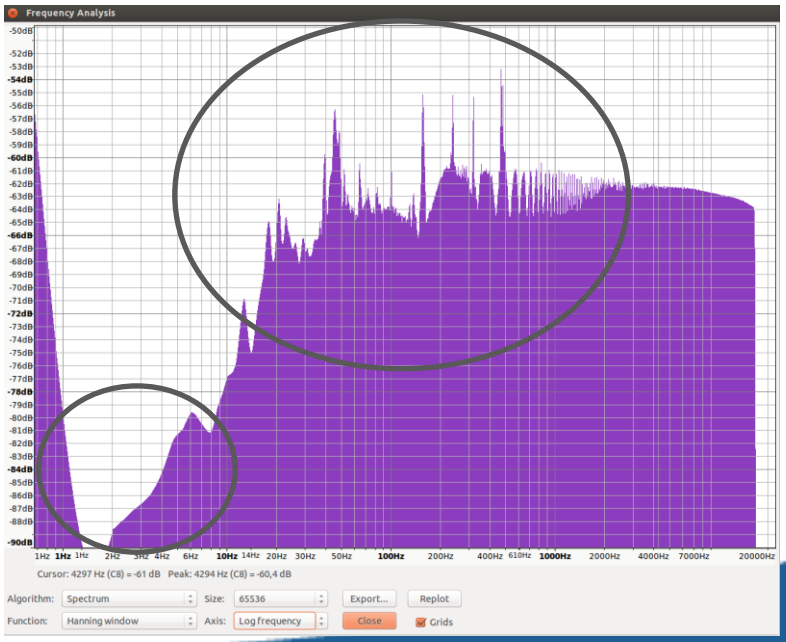


AM modulation
sweep: 0.01 – 20 kHz
fcw = 218 MHz

USB cable
without data link

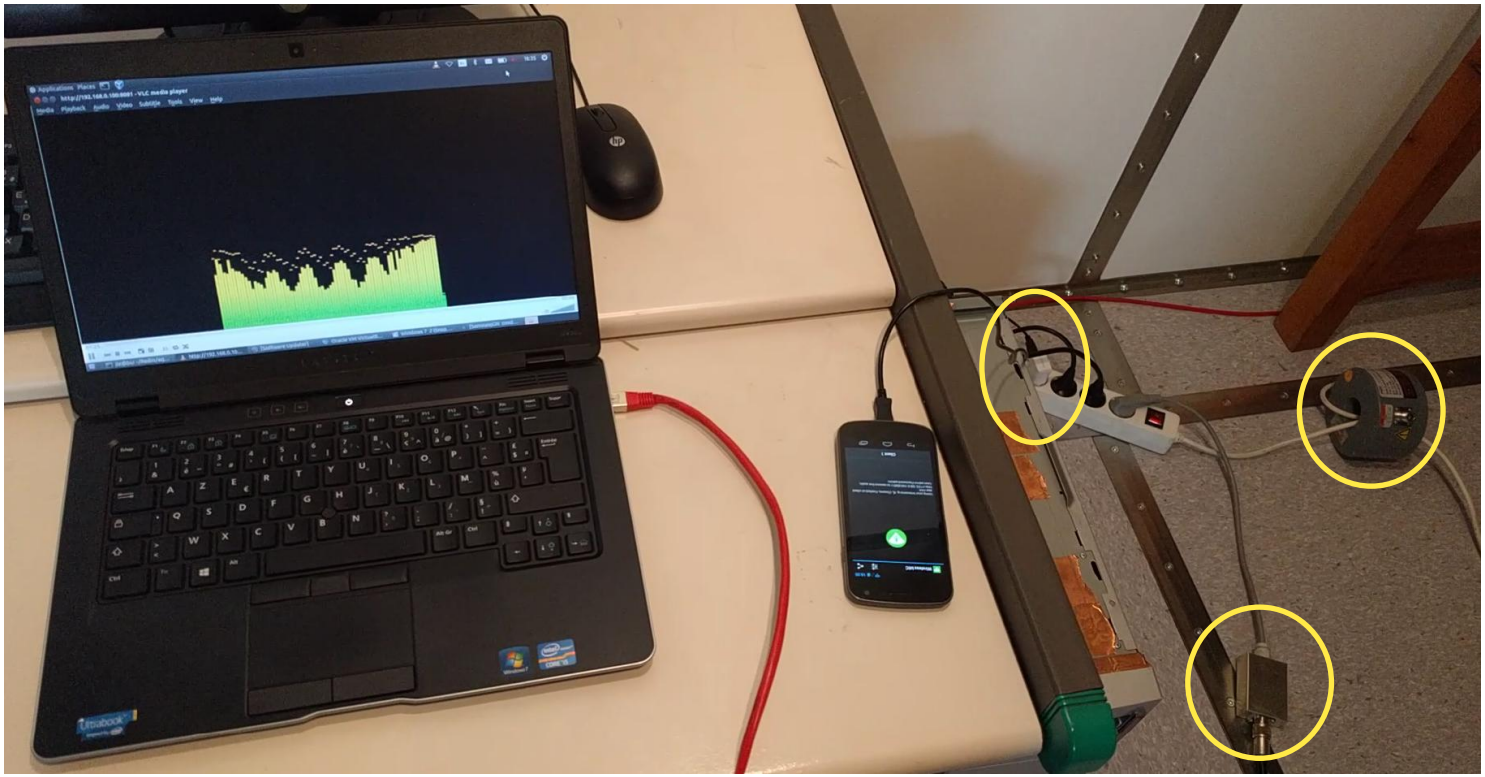
USB cable
with data link





TARGET CHARACTERIZATION

- Analysis of conducted interference bypassing the power charger of devices **online**



TARGET CHARACTERIZATION

- Preliminary results
  - Audio signal can be injected through the power network when:
    - Devices are charging through the LV network
    - Devices are charging through USB interfaces of a computer
    - **Interpretable by voice command interfaces ?**
  - Power injected
    - < 500 mW !
    - **Enough to get voice signal interpreted and command executed ?**

Exploitation of back-door coupling mode to inject voice commands

Controlling the smartphones connected to the power network through the USB cable

EXPLOITATION SCENARIOS

- Analysis of conducted interference by-passing the power charger of devices on-line

- Considered scenarios
  I. Charging through the power network
  II. Charging through the USB port of a computer connected to the LV network
  III. Direct injection through malicious USB charging device

SCENARIO I

- Charger on power network

(a)

(b)

(c)

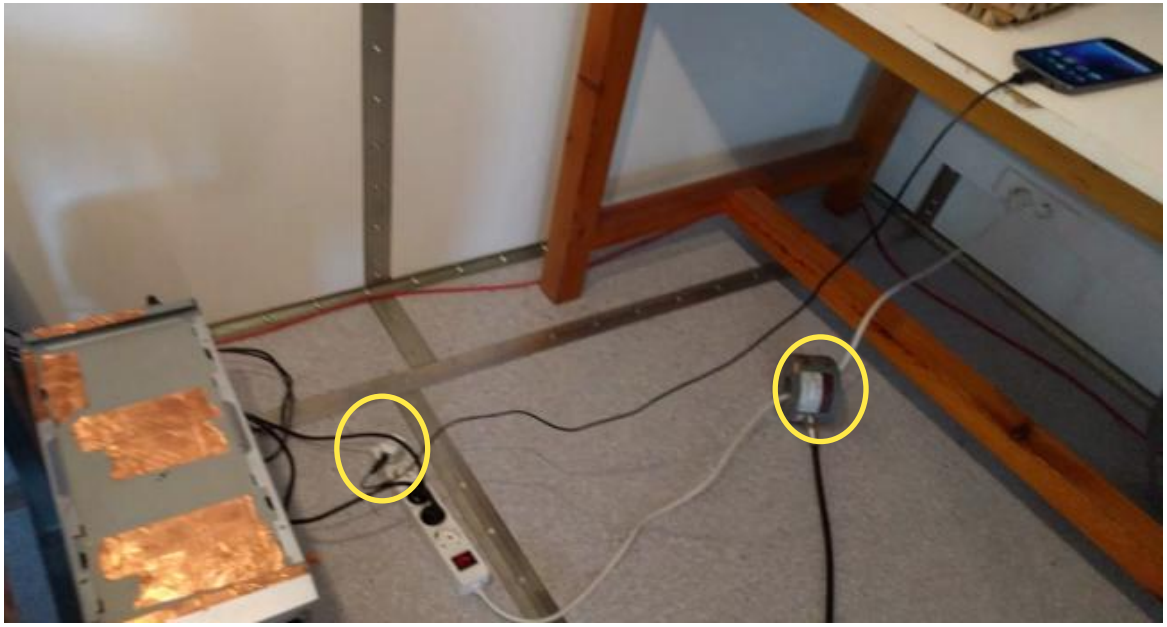
(a)extremetech.com (b)phys.org (c)treehugger.com

SCENARIO I

- Target connected to the power network
  - With standard USB charger
- EM waves propagation path
  - Point of injection: the power network
  - By-pass transformers of the charger
  - By-pass high-pass filters of the charger
- Audio
  - Quality have to be high enough to be processed

SCENARIO I

- Demo



SCENARIO II

- Charging through USB on a computer connected to the power network

(a)

(b)

(a)makeuseof.com (b)istockphoto.com

SCENARIO II

- Target connected to a computer's USB port
- EM waves propagation path
  - Point of injection: the power network
  - By-pass transformers of the computer
  - By-pass high-pass filters of the computer
- Audio
  - Quality high enough to be processed
- Computer and peripherals should not be disturbed if possible

SCENARIO II

- Demo

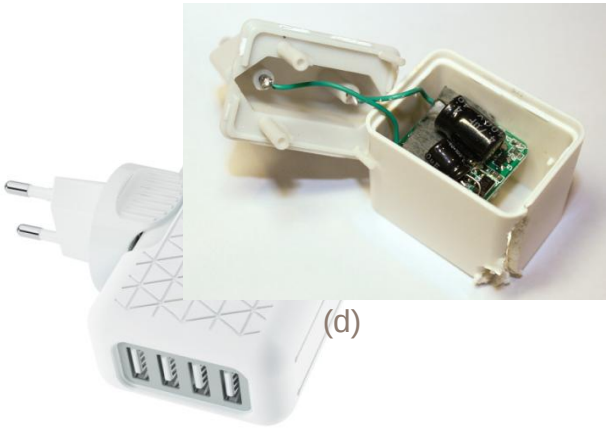
SCENARIO II

- Demo

SCENARIO III

- Custom malicious charging device

(a)



(d)

(b)

(c)

(a)Samy Kamkar © (b)pinterest.com (c)intomobile.com (d)media.cdnws.com

SCENARIO III

- Less propagation and filtering issues
- Phone model/brand can sometimes be determined by cable shape (Apple)
- Try different frequencies until feedback of keyword recognition

- **Demo:**
  - Injection in the USB cable, behind the charger

RESULTS

- Successful voice command injection
  - Target charging directly from the power network
  - Target charging through a computer
  - Audio signal processed by remote servers
  - Command executed by the target
- Computer still running
- No real impact of the type of USB cables
  - Charge only / charge + data
  - Some minor differences (Spectral analysis)

LIMITATIONS

- Power network
  - Topology
  - Devices connected
- Chargers
  - Frequency response
  - Filtering and signal degradation
- Target phone
  - PCB characteristics
    - Unexpected coupling interface with some devices…
  - Audio input sensitivity and filtering

Conclusion

CONCLUSION

- Longer distance to reach the targets
  - Power network is a good propagating structure for EM waves
  - Power emitted is less than the one required for the radiation case (< 500 mW)
- Source can have limited size
  - PLC-like transceiver
- No need for headphones
- Reachable targets: devices charging

PLC: Power Line Communication

CONCLUSION

- We proposed two remote voice command injection techniques:

	Radiated attack	Conducted attack
Coupling path	Front-door	Back-door
Propagation path	Air	Power lines
Pre-requisite	Headphones cable with microphone	USB cable
Required power	40W (2m) / 200W (5m)	0.5W (>10m)
Source size	Backpack (SDR + CPU + amplifier + battery + antenna)	PLC coupler / Charger
Target type	Outdoor mobile	Indoor stationary

PLC: Power Line Communication

CONCLUSION

- Both front-door and back-door coupling paths exploited
  - Remote and silent voice command injection
- **Smart IEMI can be an efficient attack vector against information systems**
  - Not limited to DoS
  - More and more affordable (SDR…)
- Take it into account for risk analysis
- Carefully choose voice command settings

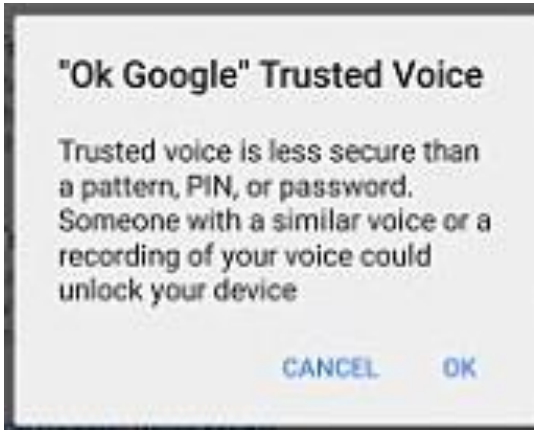
CONCLUSION

- Voice command interface is evolving:
  - Default settings are more secure
  - More activation options (opt-in for pwn)
  - Voice recognition available
  - Authentication/unlock mandatory for some privacy critical commands
- But also:
  - Increasing scope of possible actions
  - Users get used to it and will slowly move away from security towards usability
  - Voice recognition not mature

Appendix:
Reloaded Voice Command Injection

ON VOICE RECOGNITION

- Voice recognition on keyword for authentication is not mature yet
  - Only keyword analyzed
  - Command can be any voice
- Simple audio replay attack example:
  - Get voice samples from the victim
  - Forge a sample reconstructing the keyword
  - Play it to unlock the phone
- **Demo**



Thank You

We thank the manufacturers and the editors for their interesting feedback

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[2] Applidium, *Cracking Siri*, GitHub, 2011

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[10] AVG, *How an app could use Google Now to send an email on your behalf*, YouTube, 2014

QUESTIONS ?

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