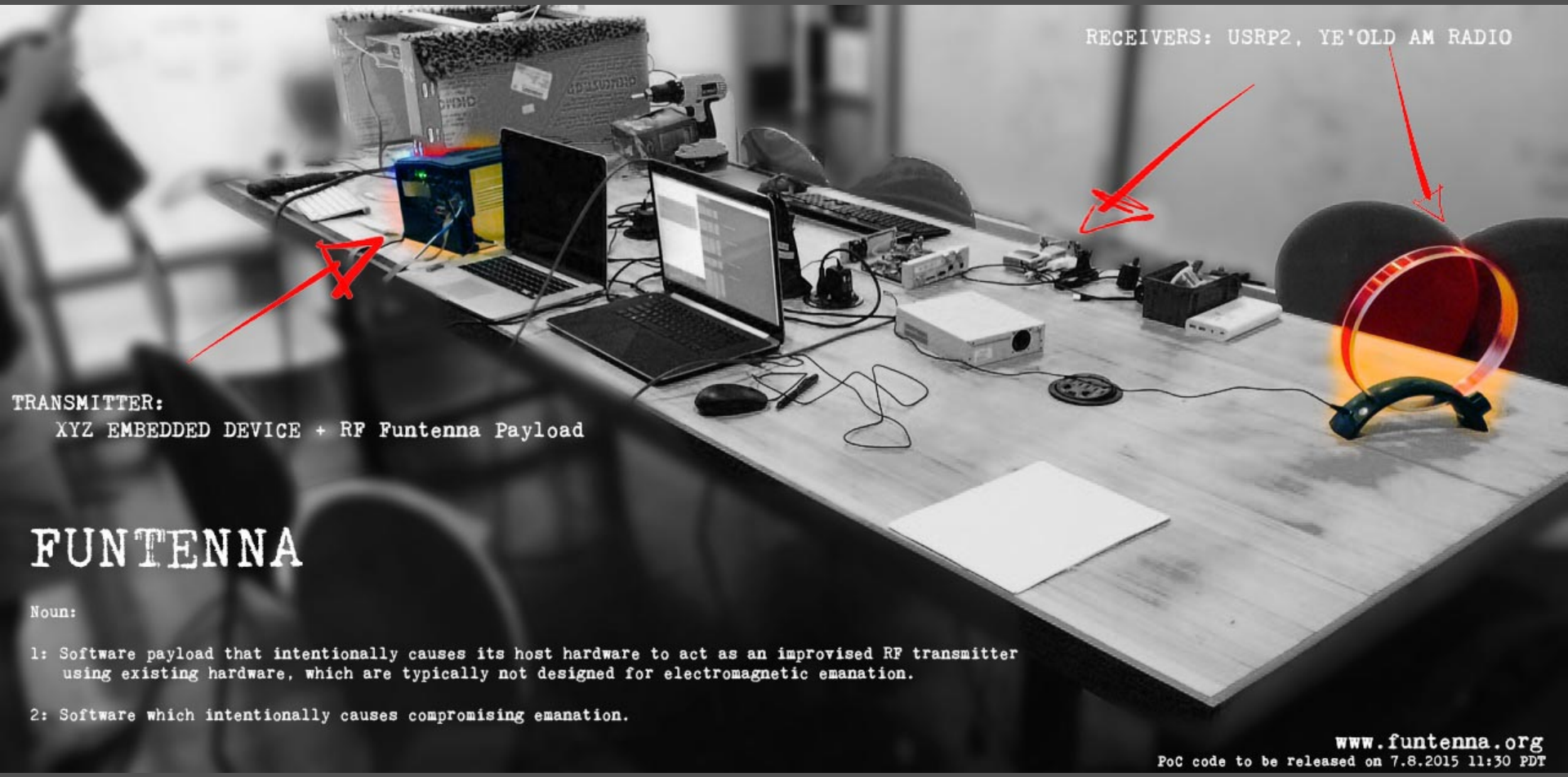
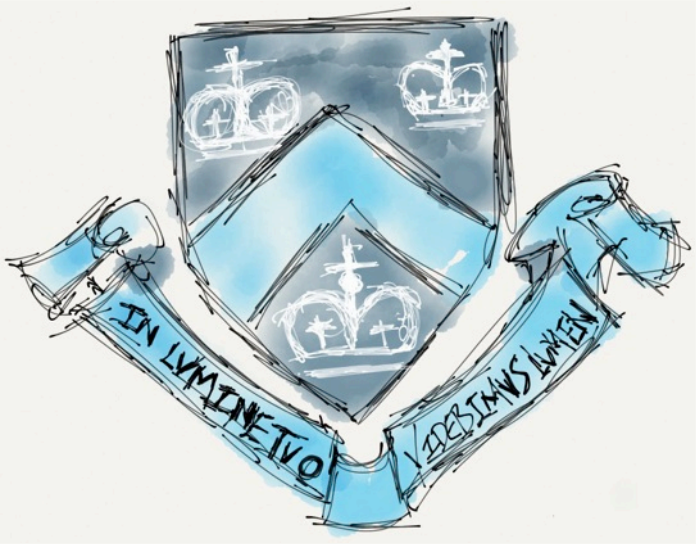


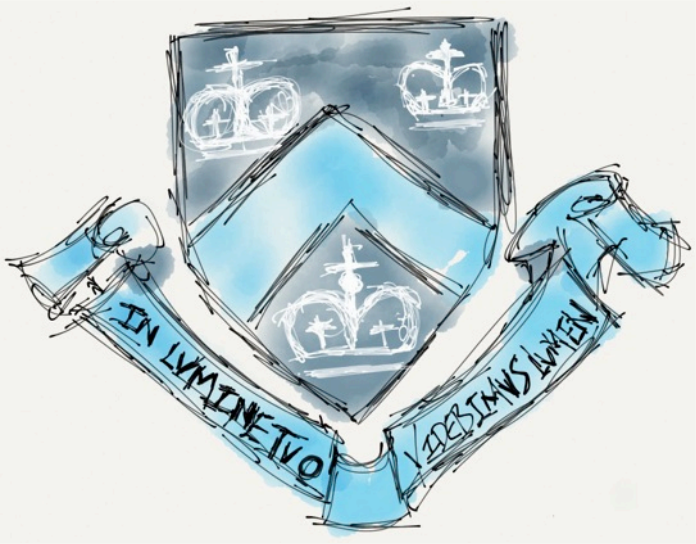
Ang Cui, PhD
a@redballoonsecurity.com

About me,

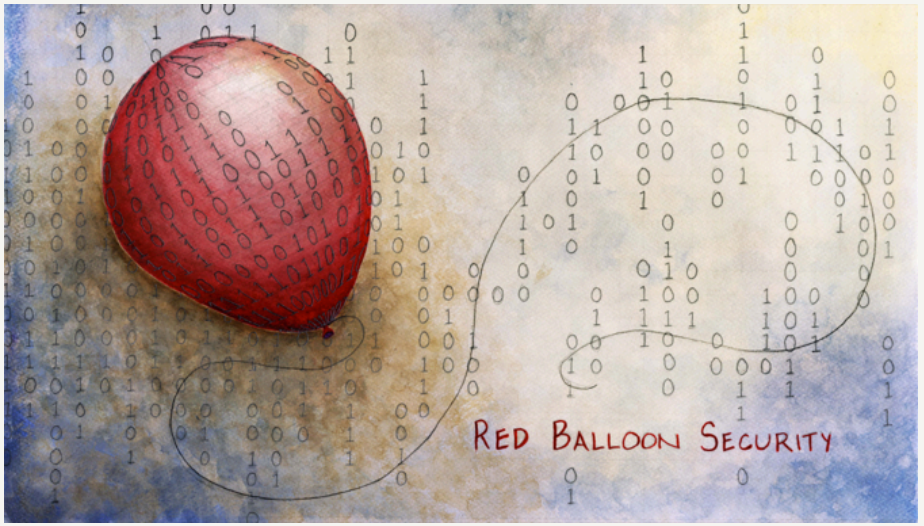


Columbia University

About me,



Columbia University



Red Balloon Security

Disclaimer

1. Research presented in this talk not funded by any government sources or Columbia University.

Disclaimer

1. Research presented in this talk not funded by any government sources or Columbia University.

2. Research presented not related to Red Balloon Security.

Disclaimer

1. Research presented in this talk not funded by any government sources or Columbia University.

2. Research presented not related to Red Balloon Security.

3. I only pretend to know how electricity works.

Boss Hardware

You are doing real science when you are using…

Boss Hardware II

You are doing real science when you are using…

You purchased this item on July 16, 2013.
View this order

Roll over image to zoom in

Geo-Phone Paranormal Research Tool

by Gen-El

11 customer reviews

List Price: $59.95
Price: $49.49 + $5.50 shipping
You Save: $10.46 (17%)

Note: Not eligible for Amazon Prime.

In Stock.
Ships from and sold by General Electromagnetics.

Estimated Delivery Date: Aug. 6 - 11 when you choose Standard at checkout.

- Ultrasensitive vibration detector

Boss Hardware II

You are doing real science when you are using…

Customer Questions & Answers

Have a question? Ask the owners here | Ask

Don't see what you're looking for? Submit your question to our community by clicking the 'Ask' button above.

0 votes

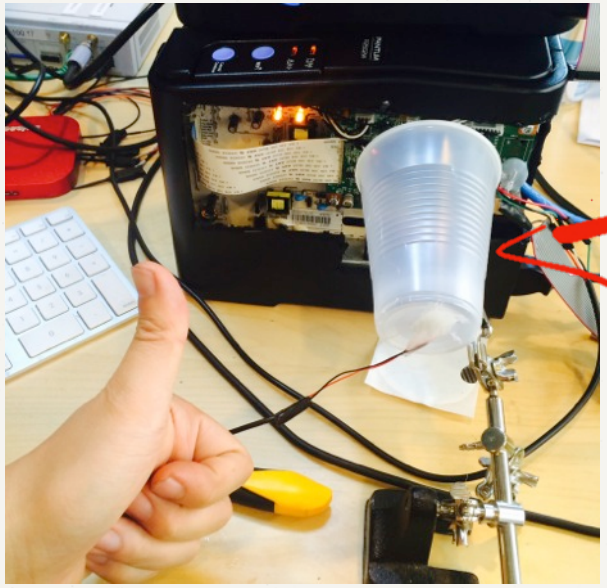
Geo pone converts noise into voices? have I got that right, and these voices are they Alive humans like your neighbors that you hear?

A: It hears through vibrations, you have to set it down on something and then hook either a recorder or headphones to it to hear anything. I thought it was something else when I bought it. I didn't want to have to hook something up to it to hear sounds. as for voices, I only tried it once and I think it picked up everything.

Sandra Labella answered on April 17, 2014

Boss Hardware II

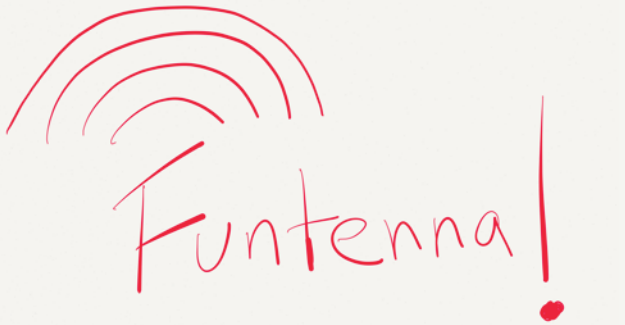
You are doing real science when you are using…



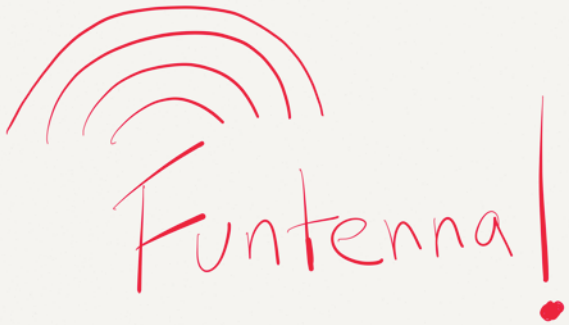
Homemade dog whistle detector
(in a cup)

Boss Hardware II

You are doing **real science** when you are using…

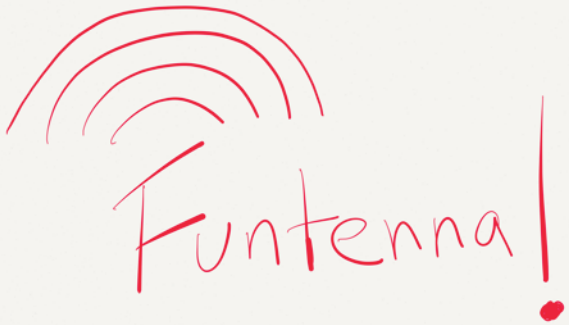


Noun:



Noun:

1: Malware that intentionally causes compromising emanation.



Noun:

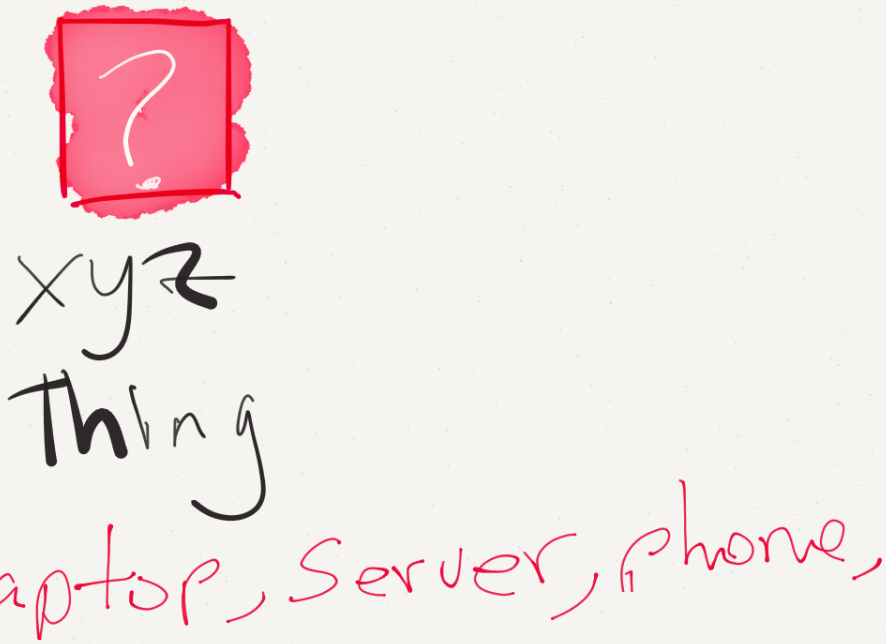
1: Malware that intentionally causes compromising emanation.

2: Software payload that intentionally causes its host hardware to act as an improvised RF transmitter using existing hardware, which are typically not designed for electromagnetic emanation.


?
xyz
Thing


?
xyz
Thing
Laptop


?
xyz
Thing
Laptop, Server,


?
xyz
Thing
Laptop, Server, phone,

xyz Thing

Laptop, Server, phone, router

xyz

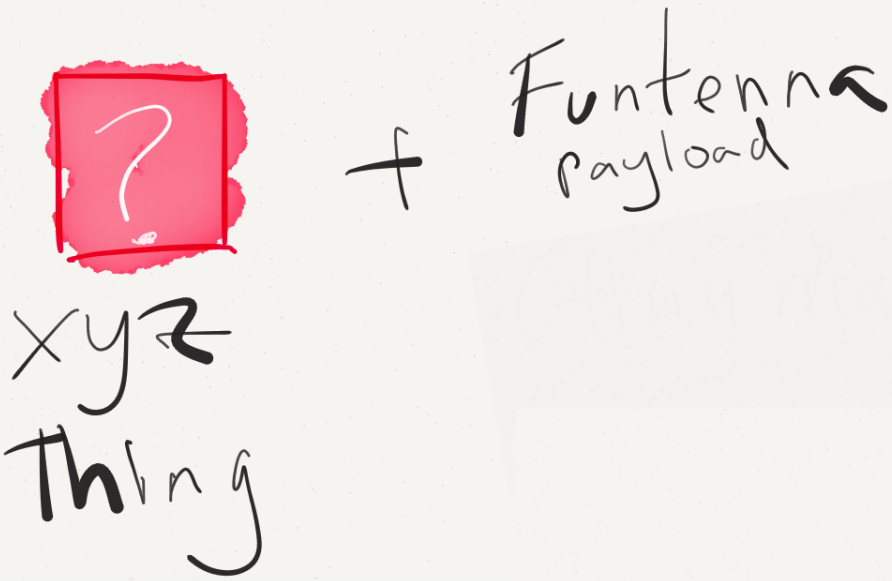
Thing

Laptop, Server, phone,
router, printer,

xyz

Thing

Laptop, Server, phone,
router, printer, TV, car, building, etc


?
+
Funtenna
payload
xyz
Thing

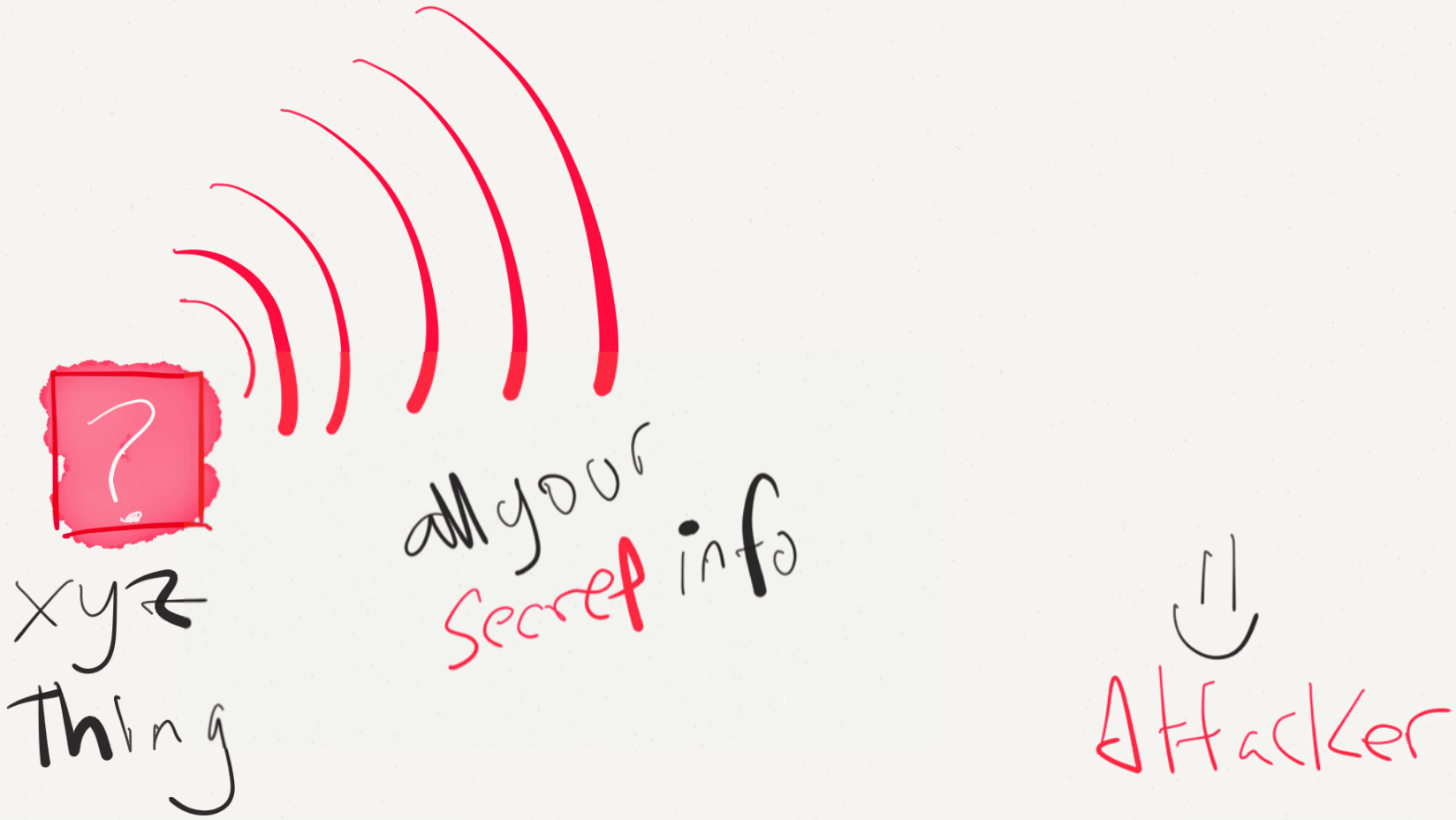
xyz Thing

+ Funtenna payload (tiny malware)


?
xyz
Thing


?
xyz
Thing


Attacker

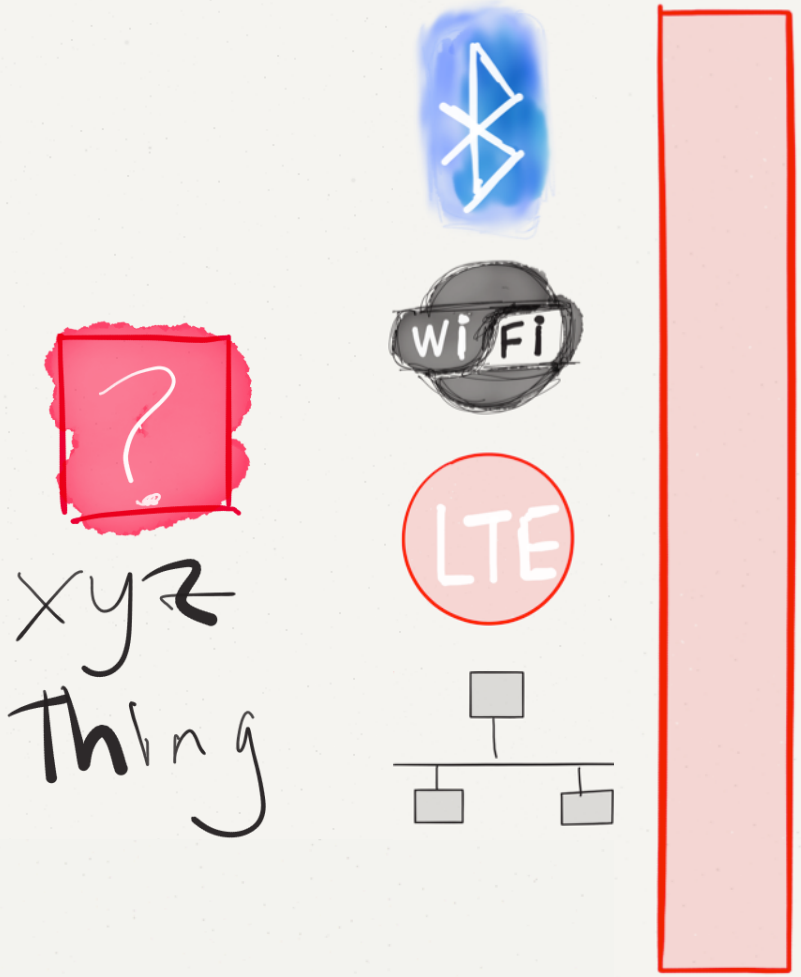

?
xyz
Thing
all your
secret info
Attacker


?
xyz
Thing

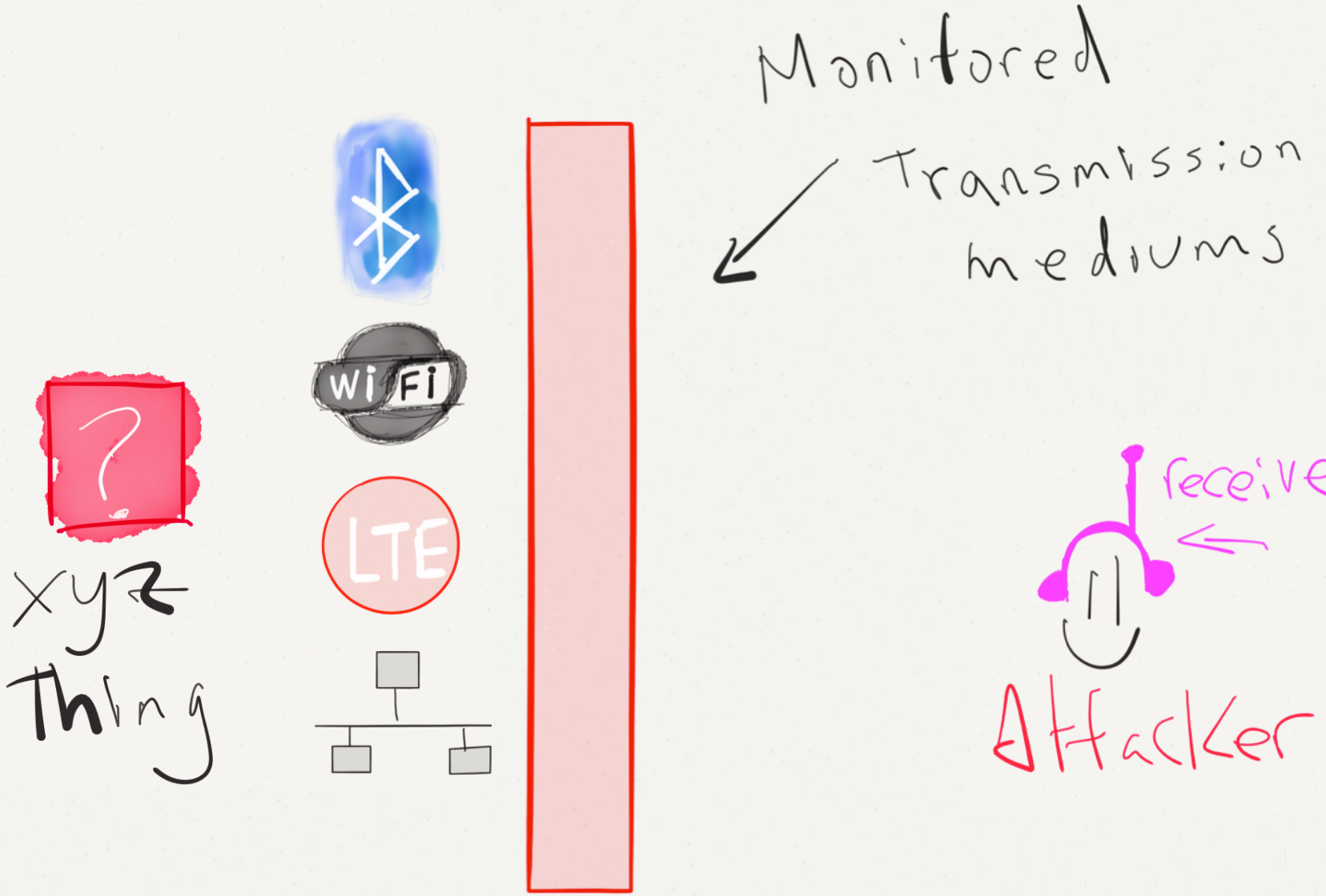

receiver
Attacker

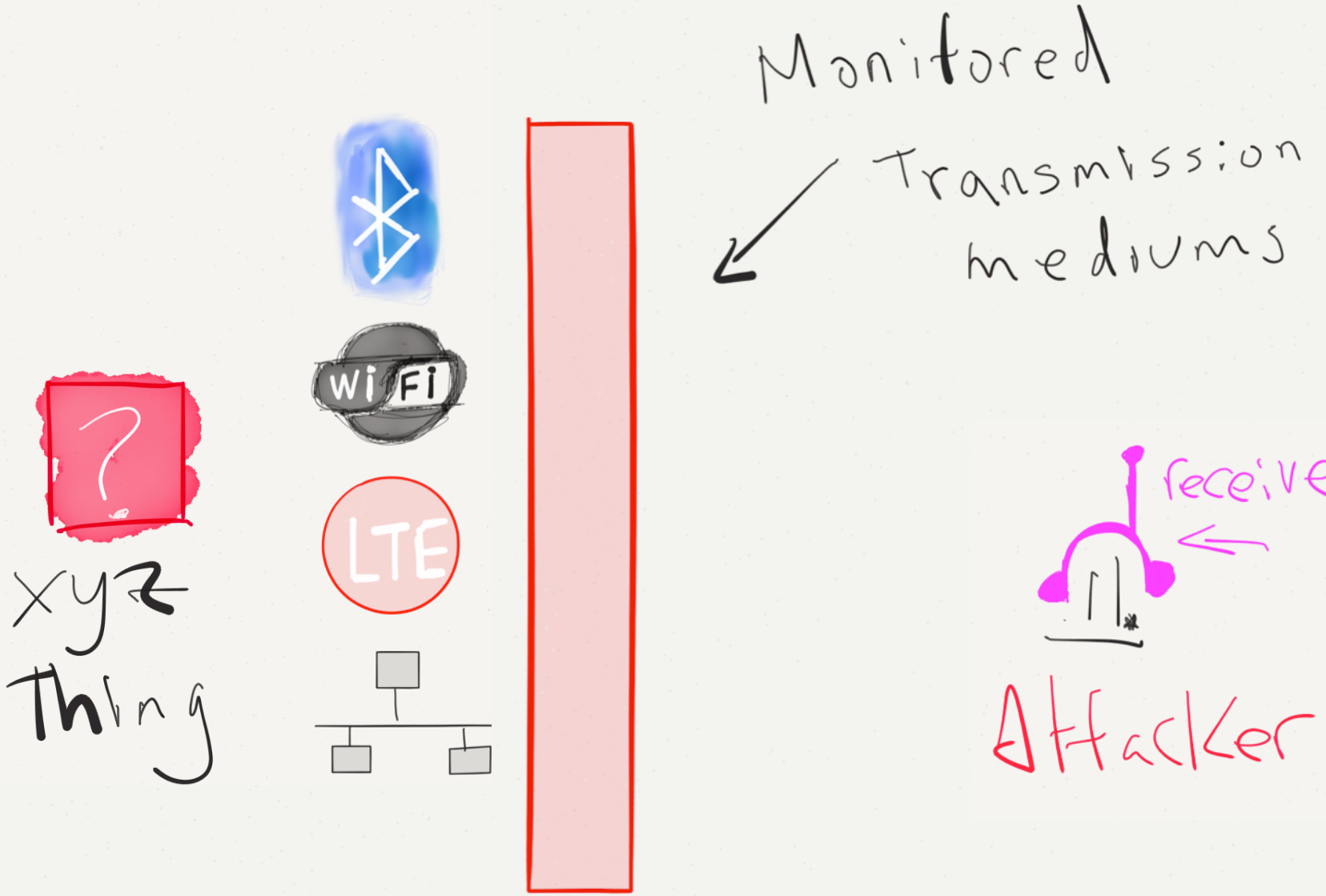

?
WiFi
LTE
xyz
Thing

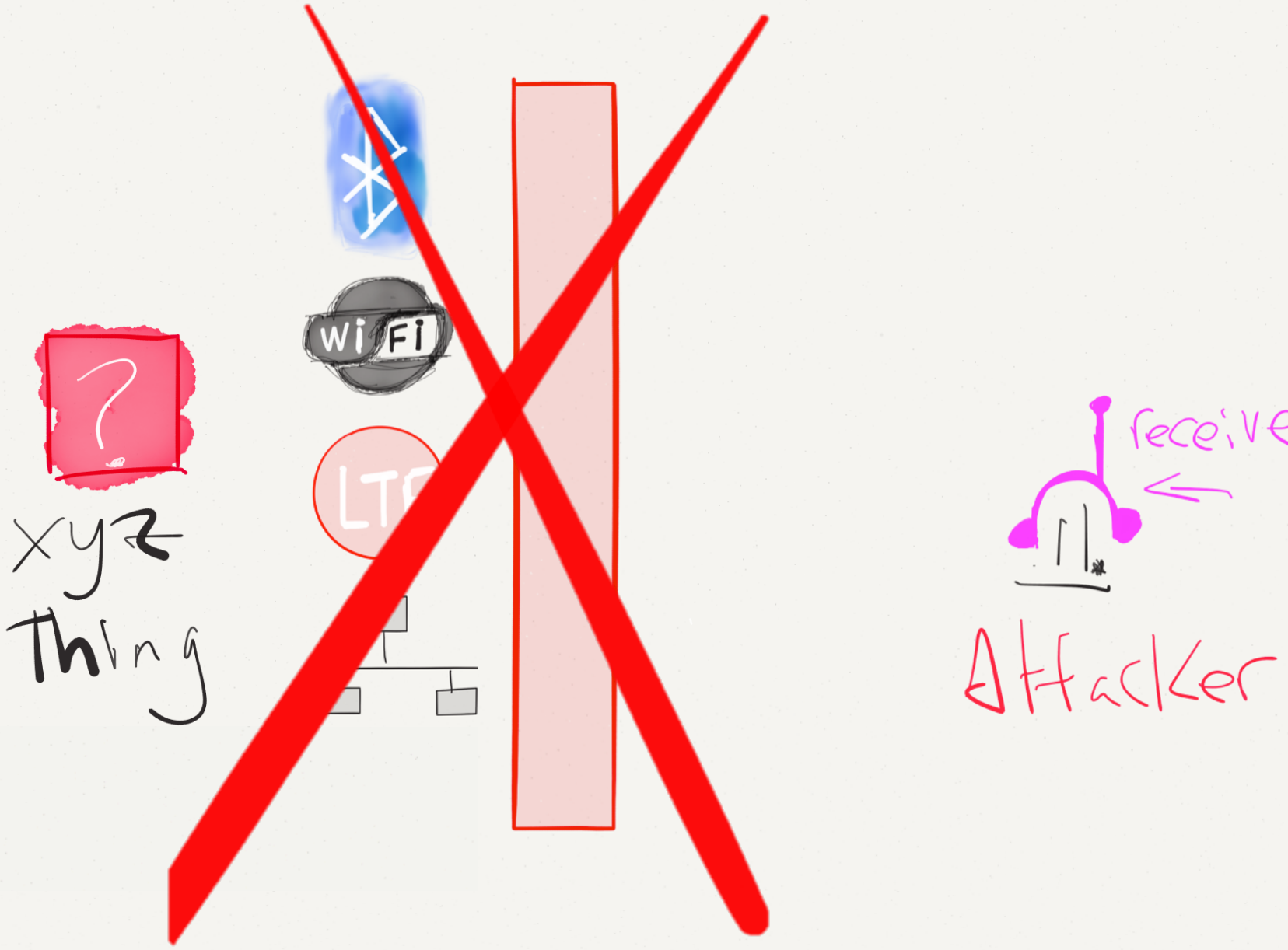

receiver
Attacker


?
xyz
Thing
Wi Fi
LTE


receiver
Attacker


Monitored
Transmission mediums
WiFi
LTE
?
xyz Thing
receiver
Attacker


Monitored
Transmission mediums
WiFi
LTE
?
xyz Thing
receiver
Attacker


?
xyz
Thing
WiFi
LTE
receiver
Attacker

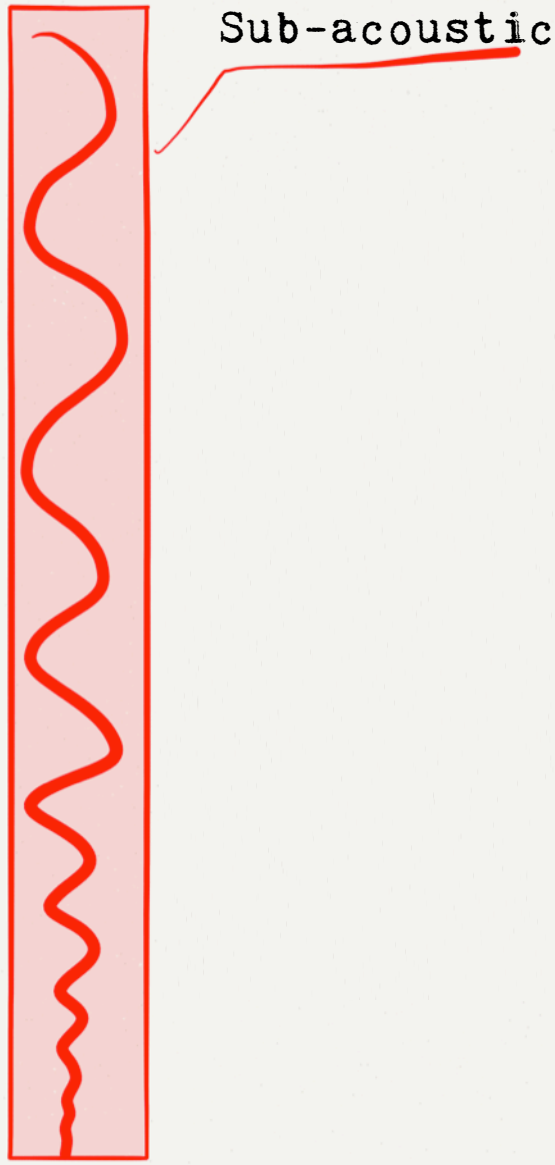
Transmission medium of the attacker's choosing

Transmission medium of the attacker's choosing

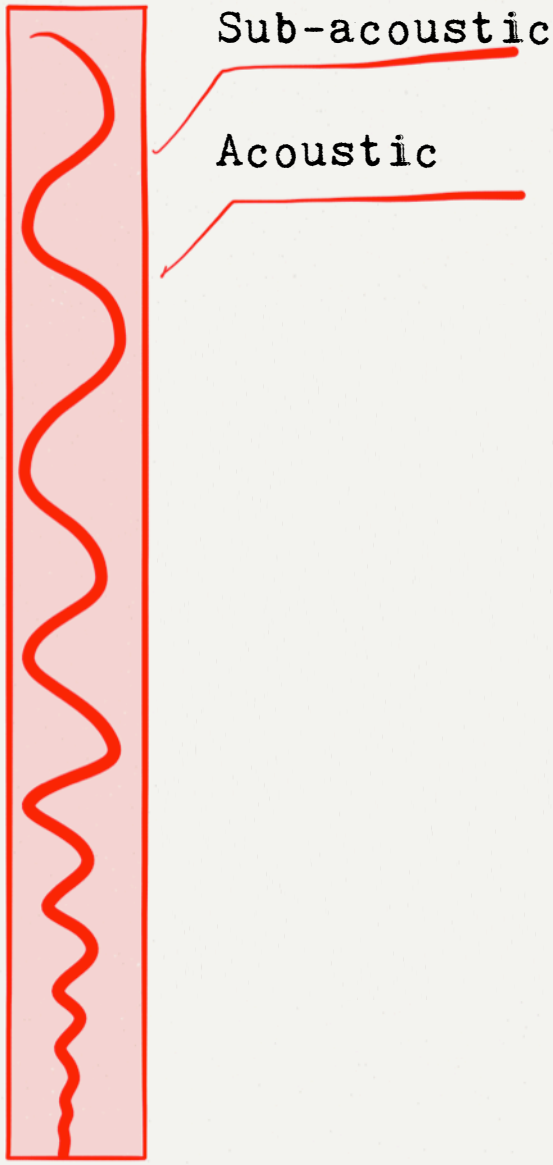
Where you don't monitor


?
xyz
Thing

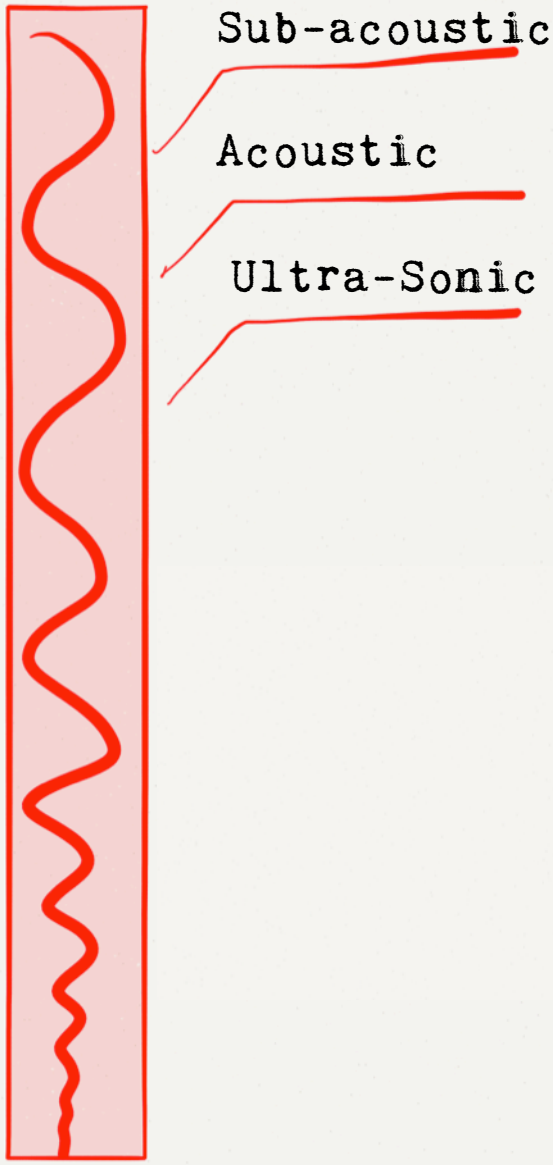

?
xyz
Thing


Sub-acoustic

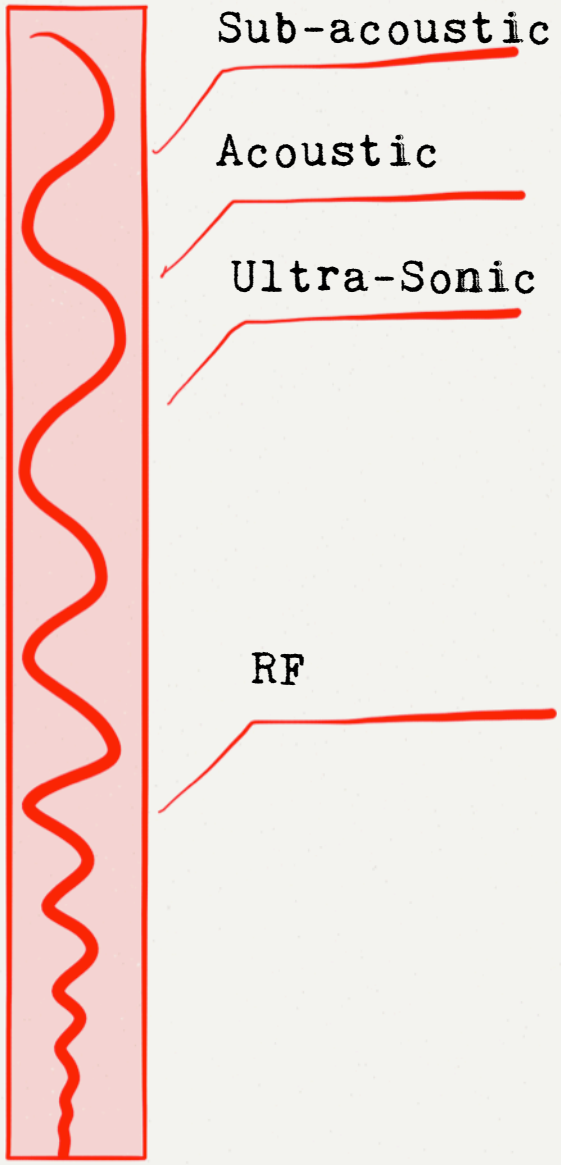

?
xyz
Thing


Sub-acoustic
Acoustic

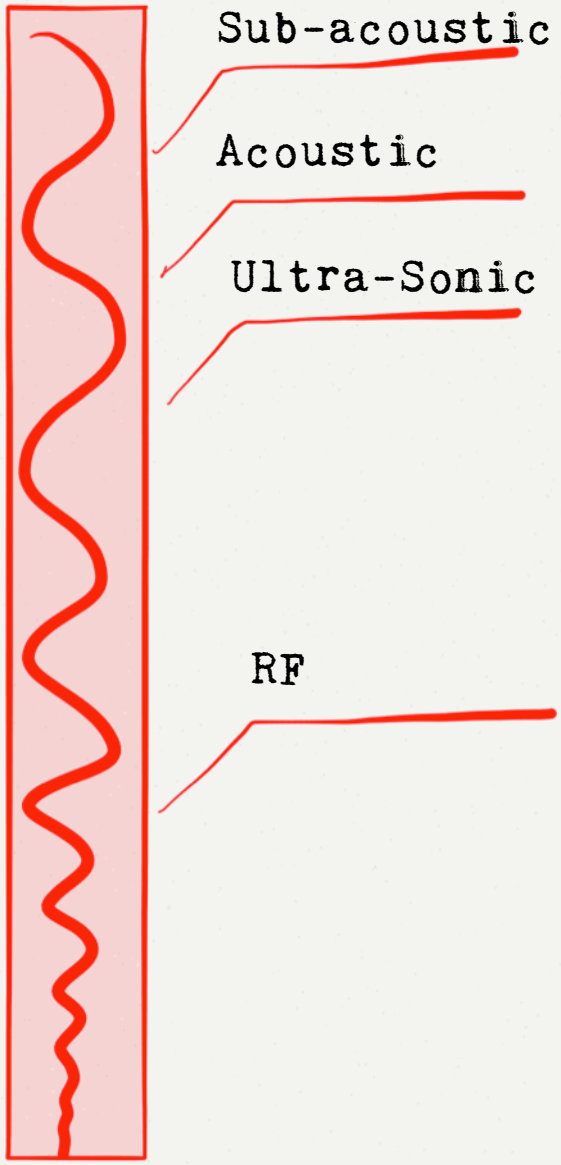

?
xyz
Thing


Sub-acoustic
Acoustic
Ultra-Sonic

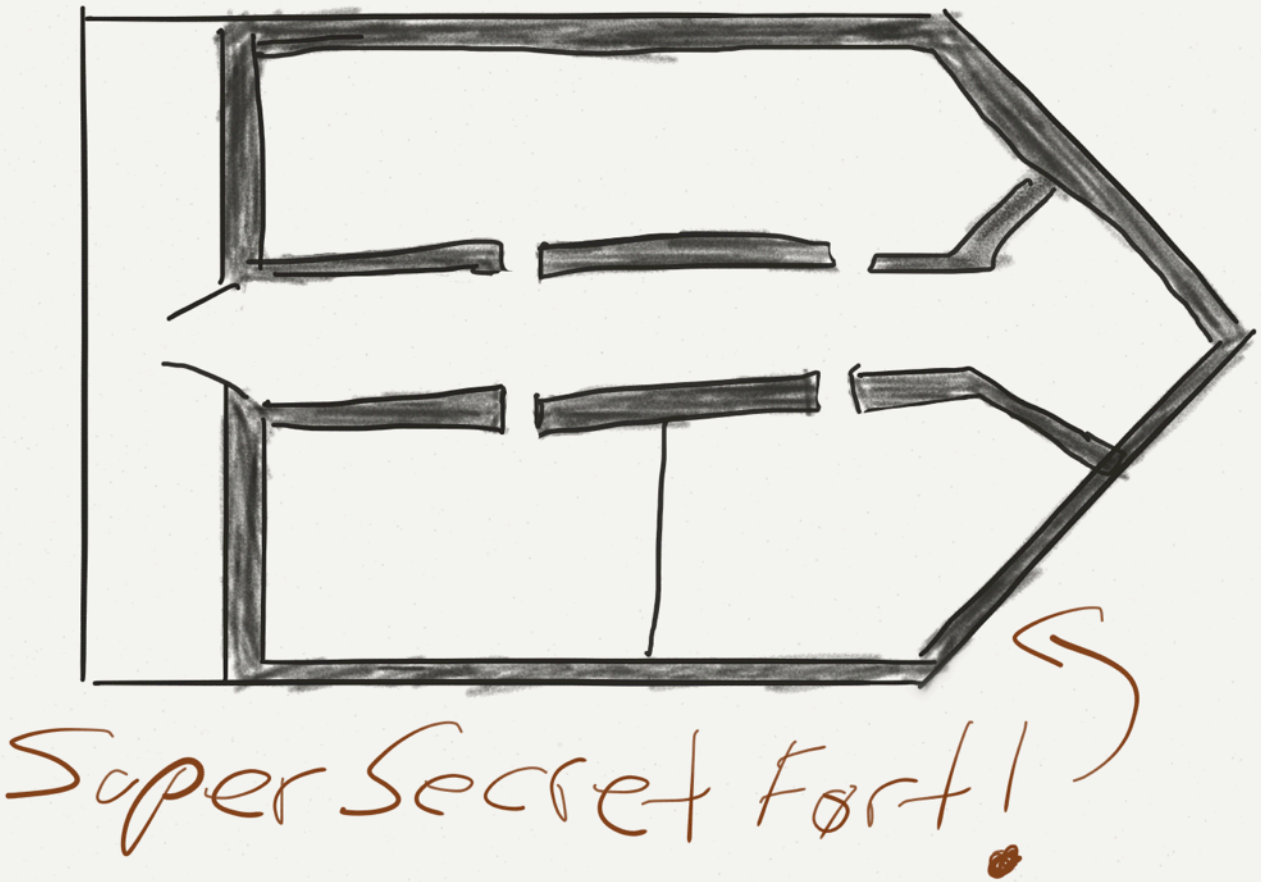

?
xyz
Thing

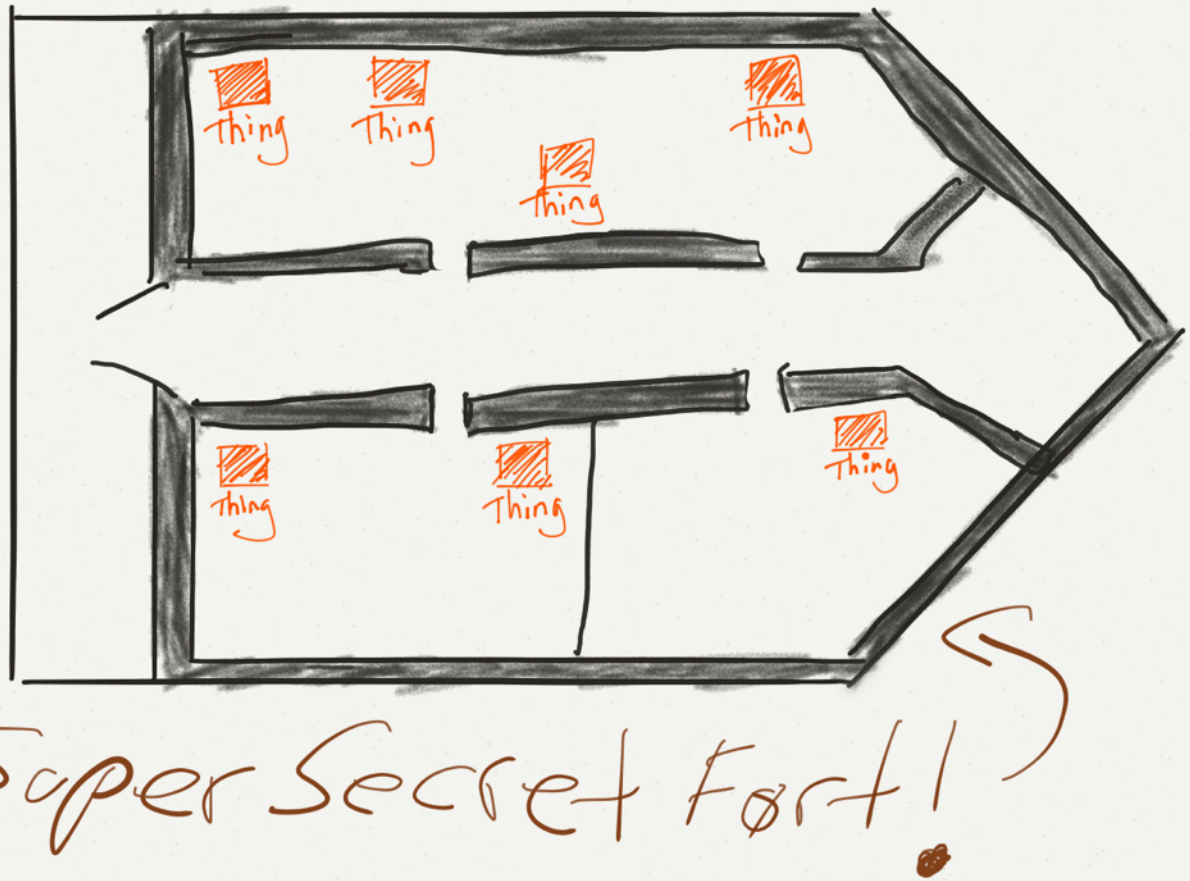

Sub-acoustic
Acoustic
Ultra-Sonic
RF

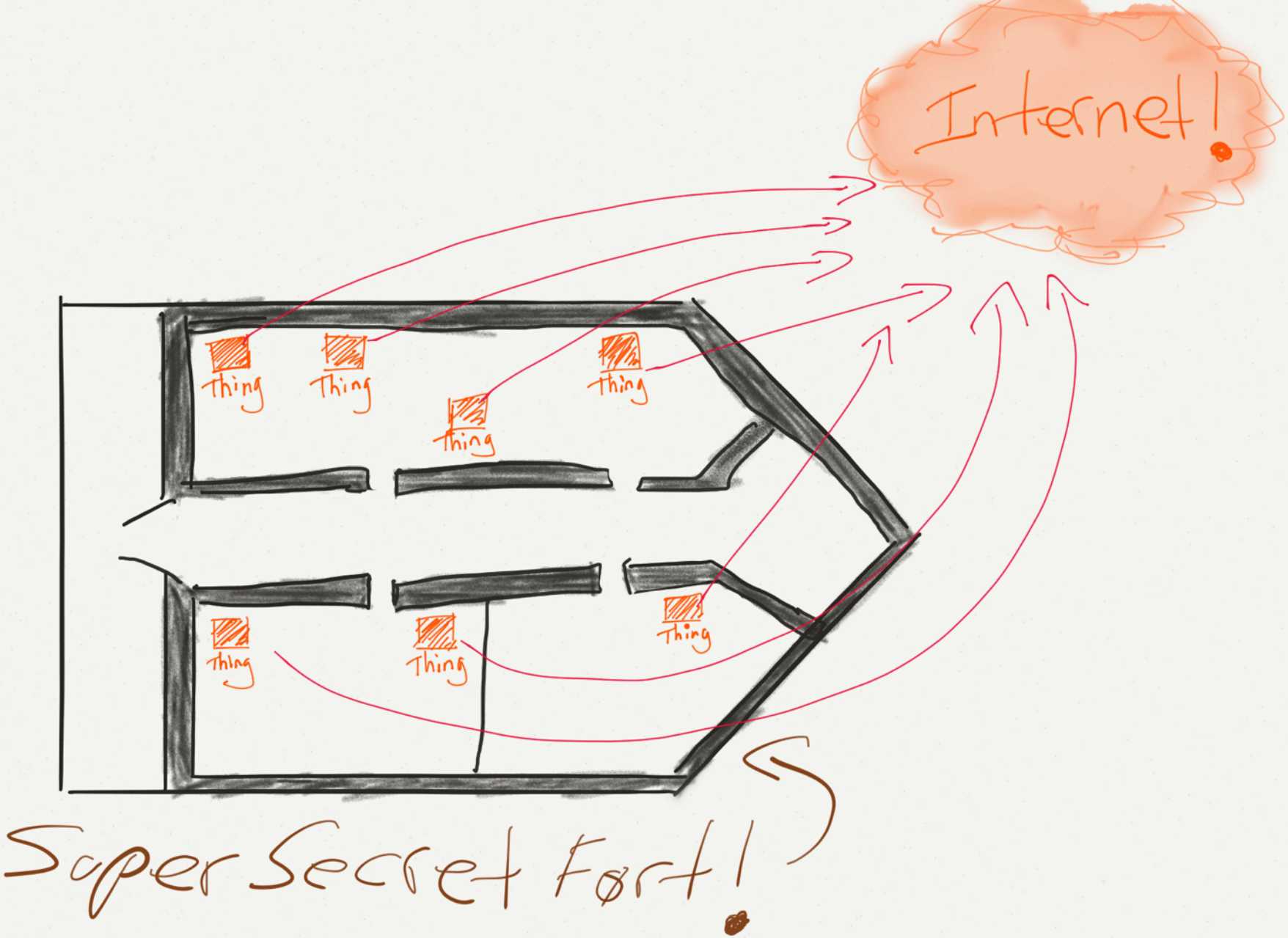

?
xyz
Thing


Sub-acoustic
Acoustic
Ultra-Sonic
RF

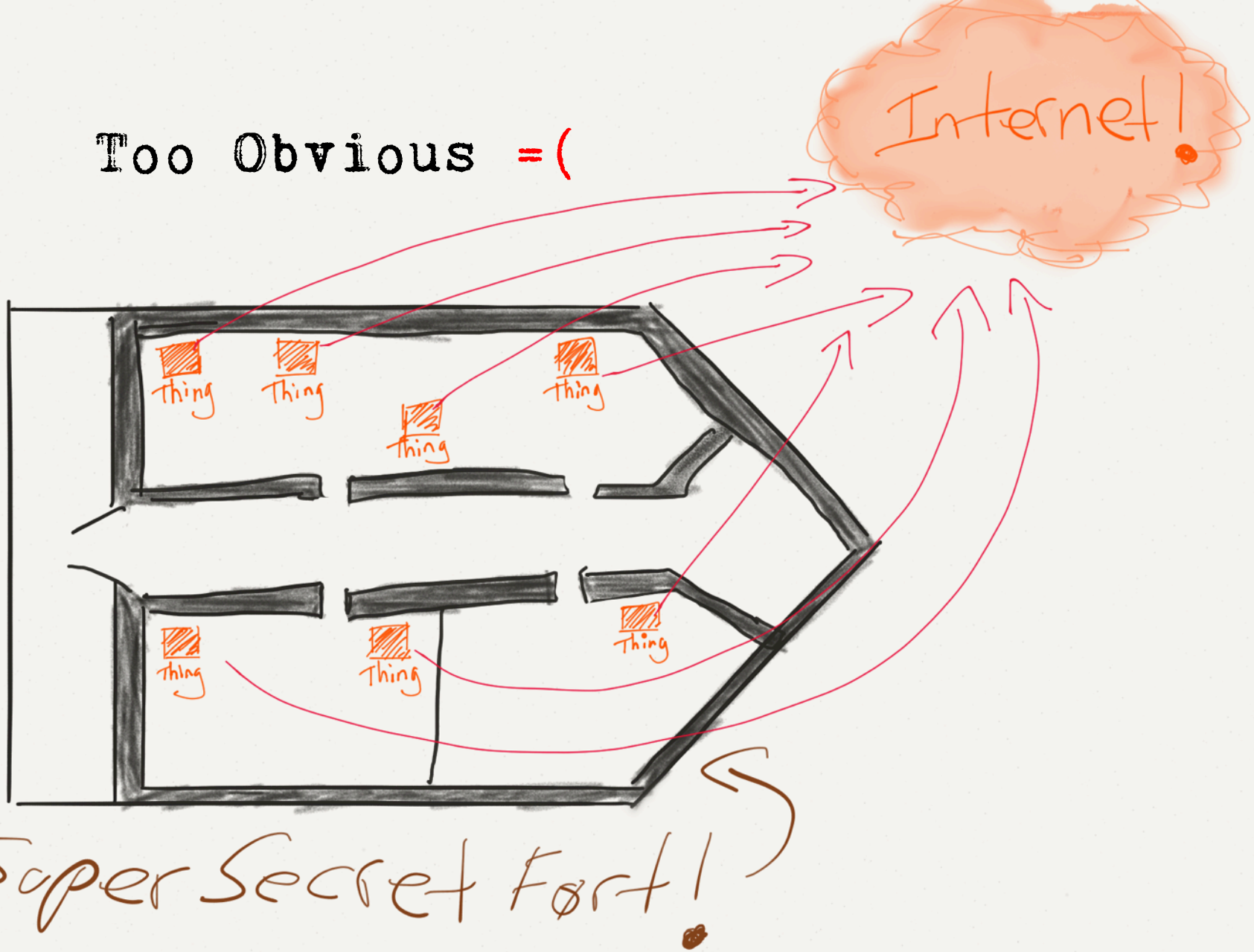

why?

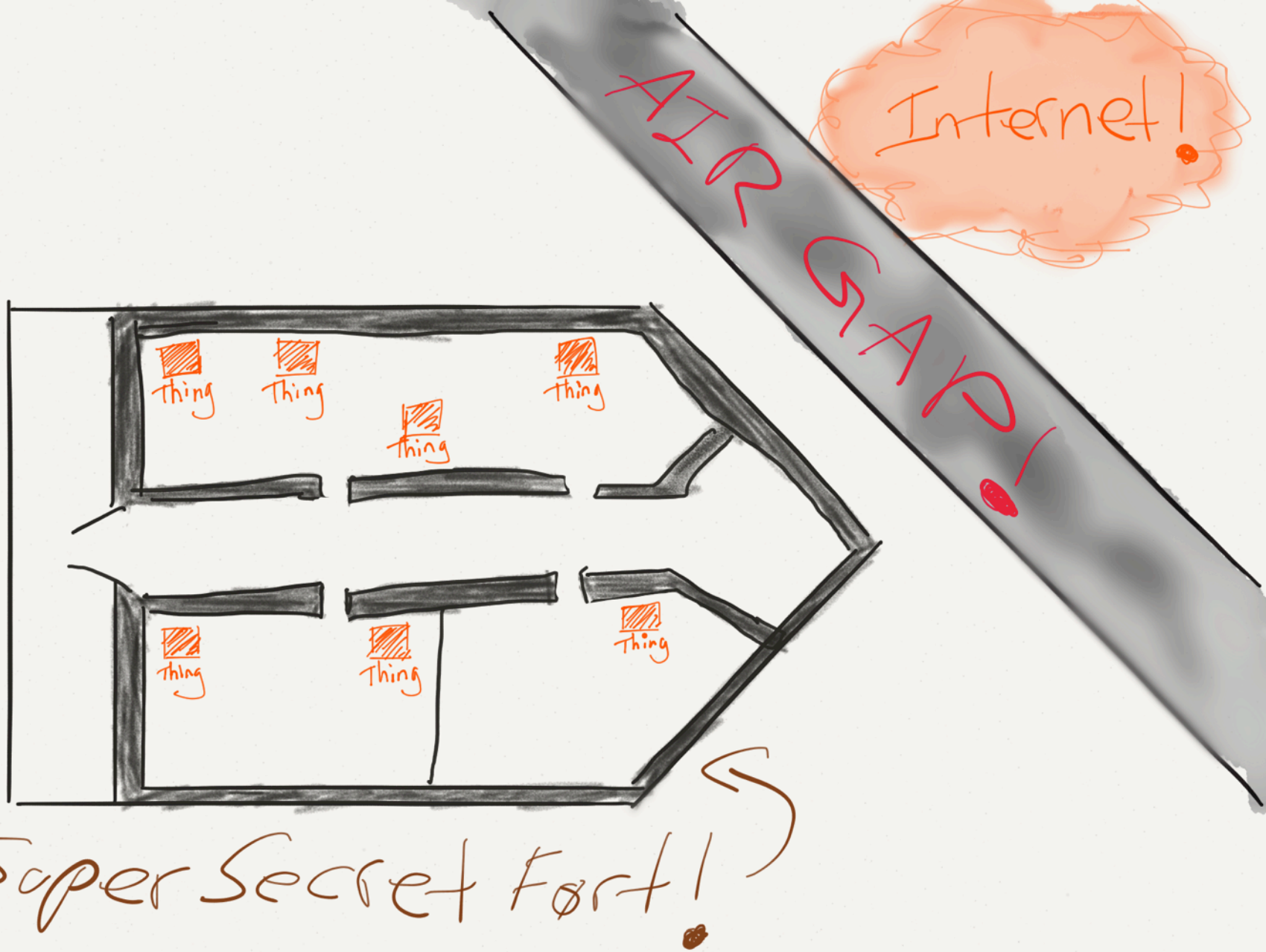

Super Secret Fort!


Internet!
Thing
Thing
Thing
Thing
Thing
Thing
Thing
Super Secret Fort!


Internet!
Thing
Thing
Thing
Thing
Thing
Thing
Thing
Super Secret Fort!

Too Obvious =(


Internet!
Thing
Thing
Thing
Thing
Thing
Thing
Thing
Super Secret Fort!

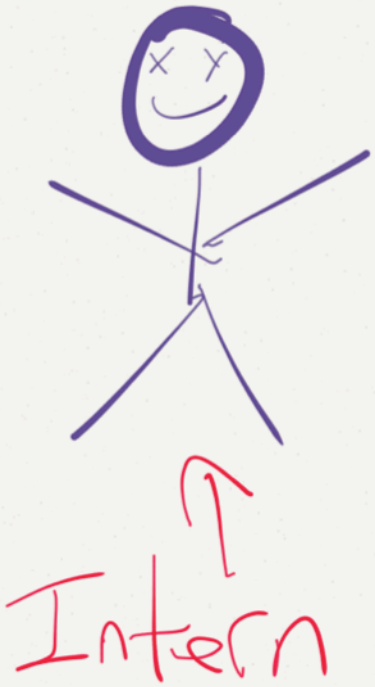

AIR GAP!
Internet!
Thing
Thing
Thing
Thing
Thing
Thing
Super Secret Fort!

Anti Super Secret Fort Technology

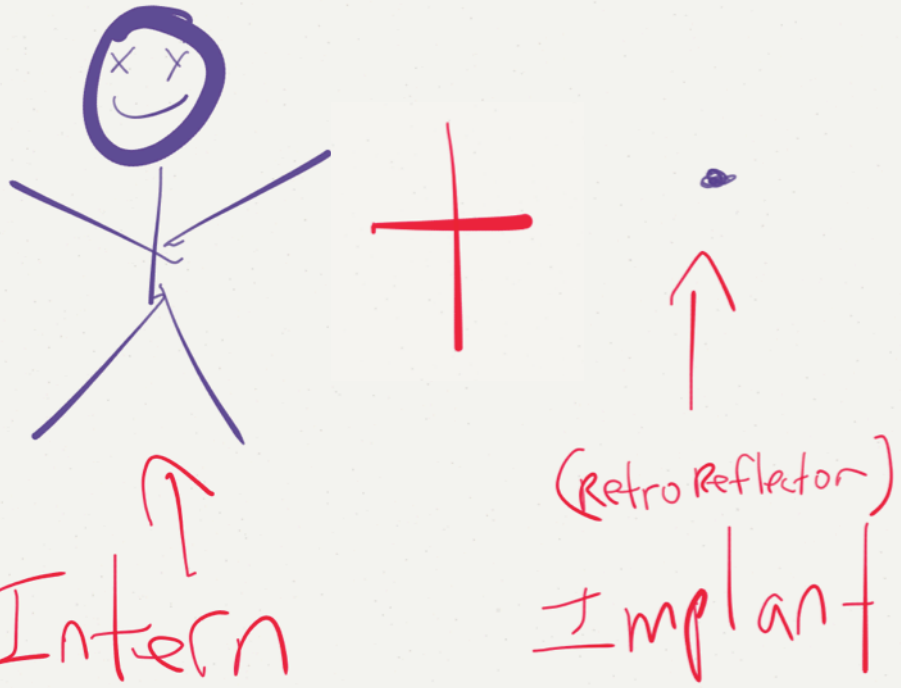
Anti Super Secret Fort Technology

Amazing Ninja Tech

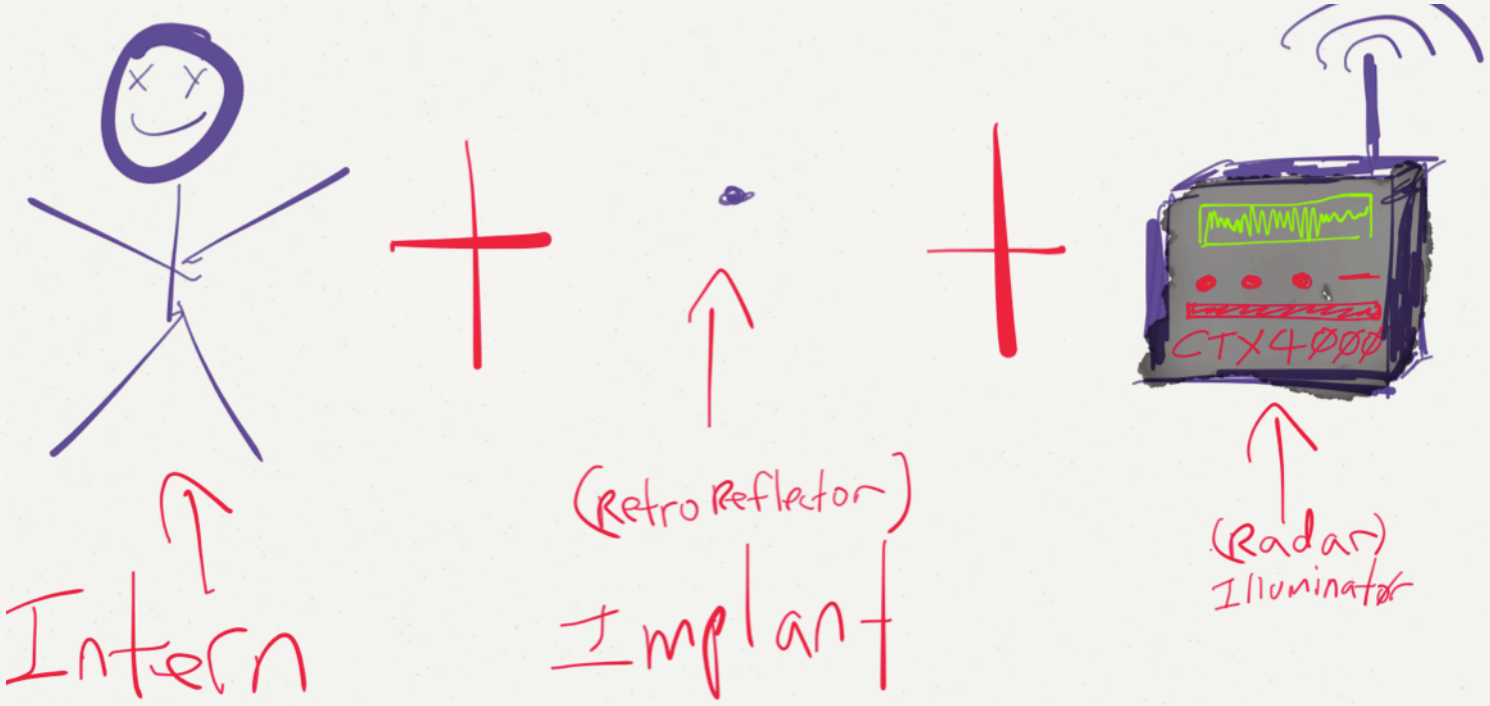
Anti Super Secret Fort Technology



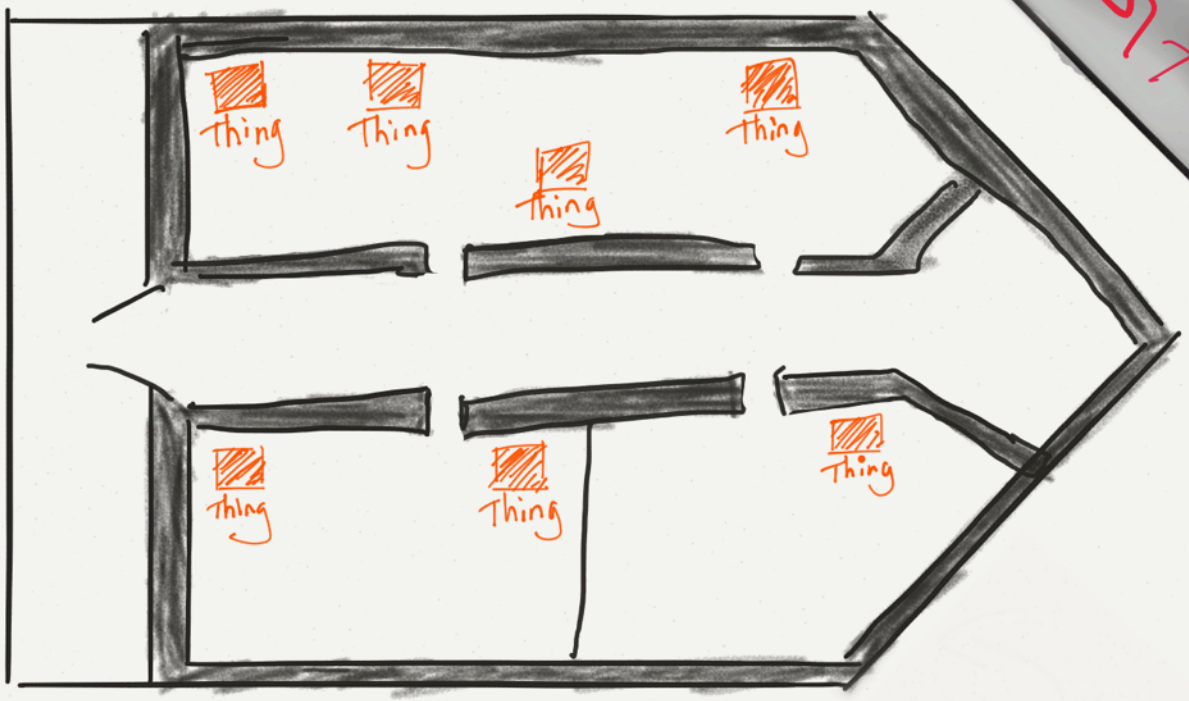
Anti Super Secret Fort Technology



Anti Super Secret Fort Technology



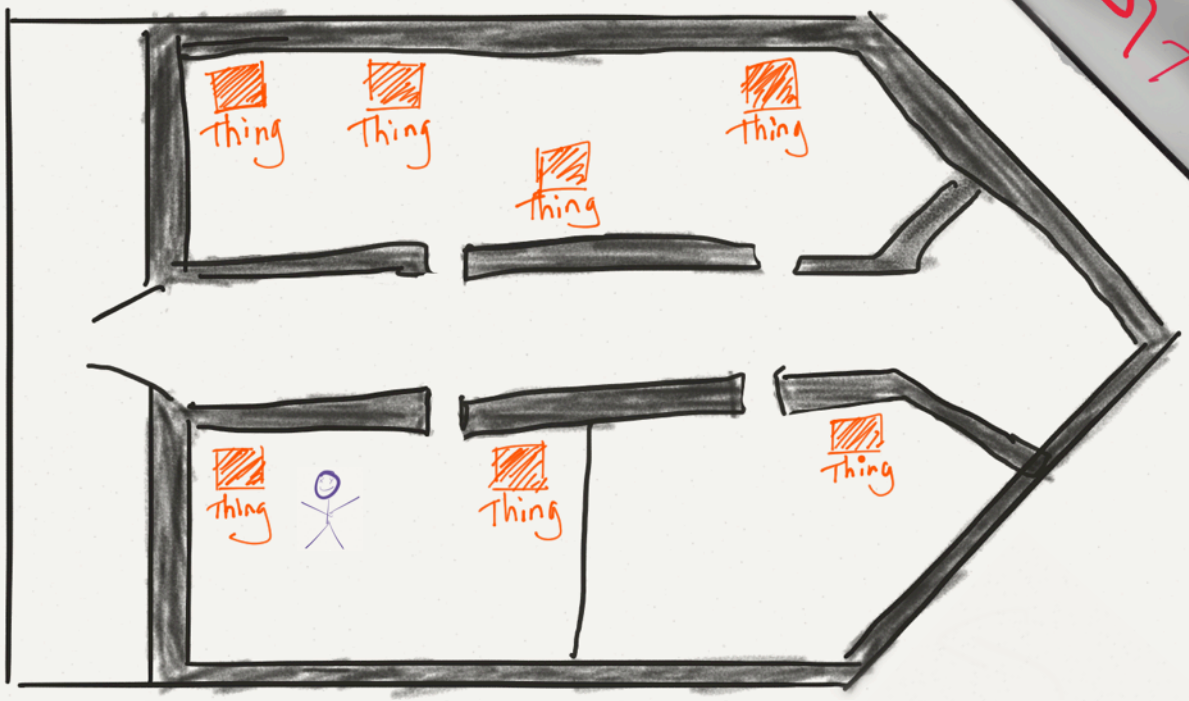
Step 1: Intern sneaks into secret fort



AIR GAP!

Internet!

Step 1: Intern sneaks into secret fort

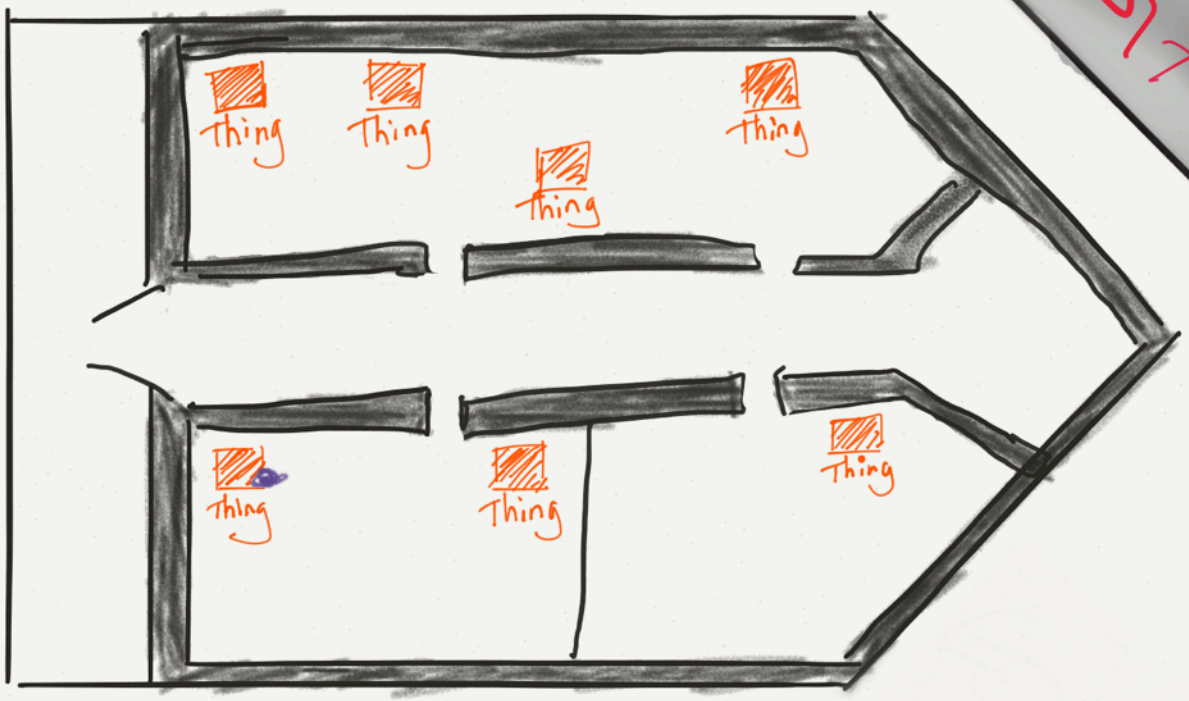


AIR GAP!

Internet!

Step 1: Intern sneaks into secret fort

Step 2: Intern physically implants target thing with retro-reflector

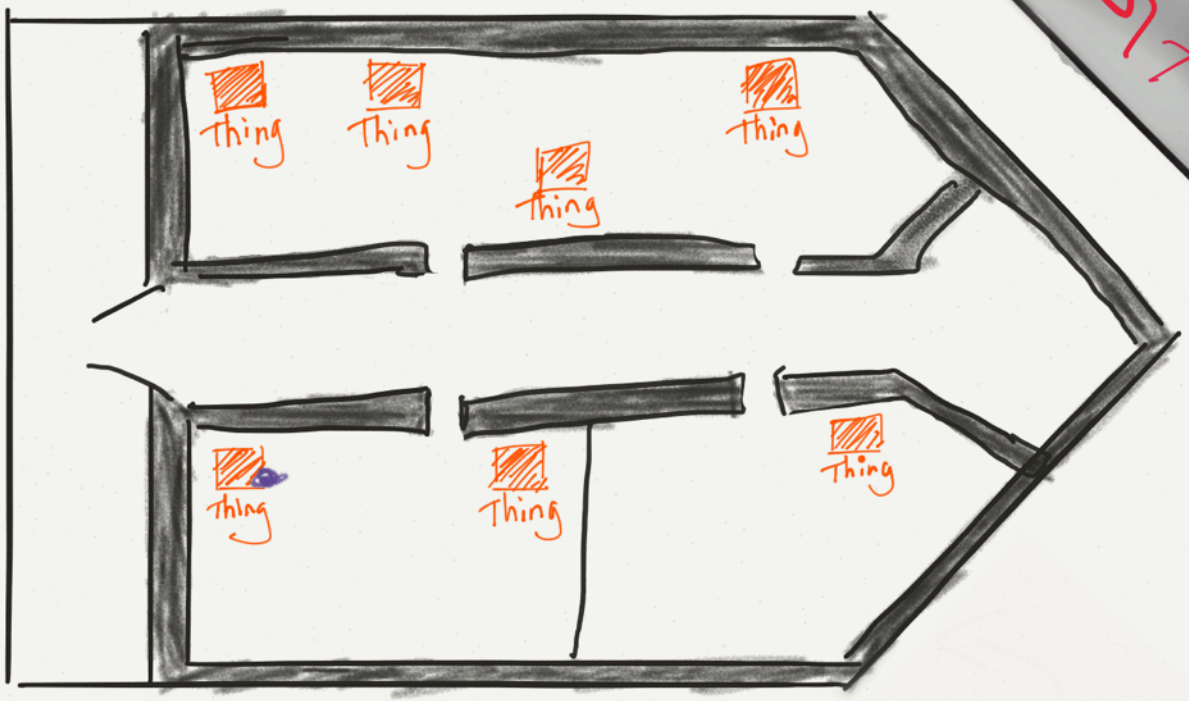


AIR GAP!

Internet!

Step 1: Intern sneaks into secret fort

Step 2: Intern physically implants target thing with retro-reflector



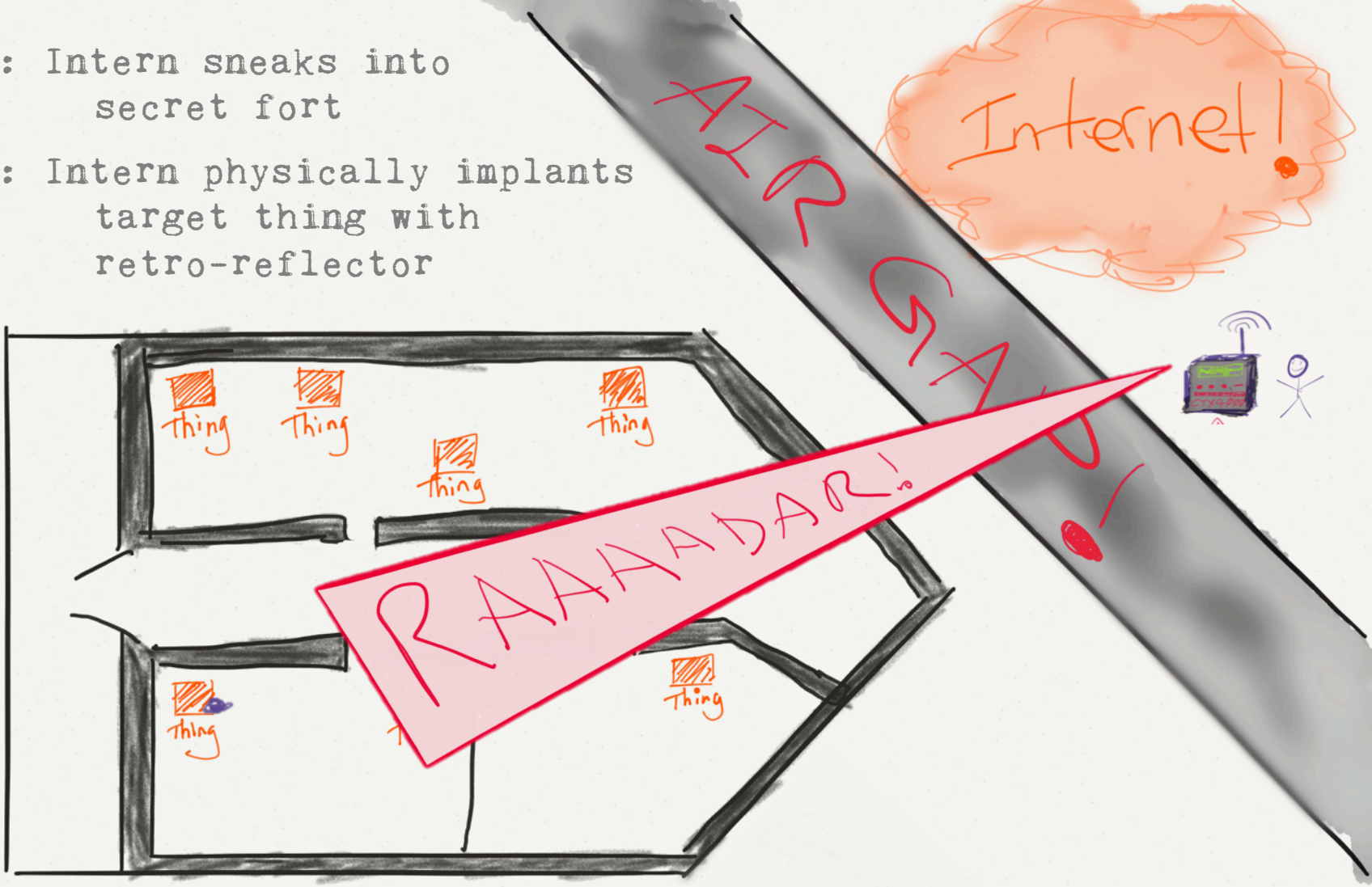
AIR GAP!

Internet!

Step 3: Continuous RF Illumination (CTX4k, etc) into secret fort

Step 1: Intern sneaks into secret fort

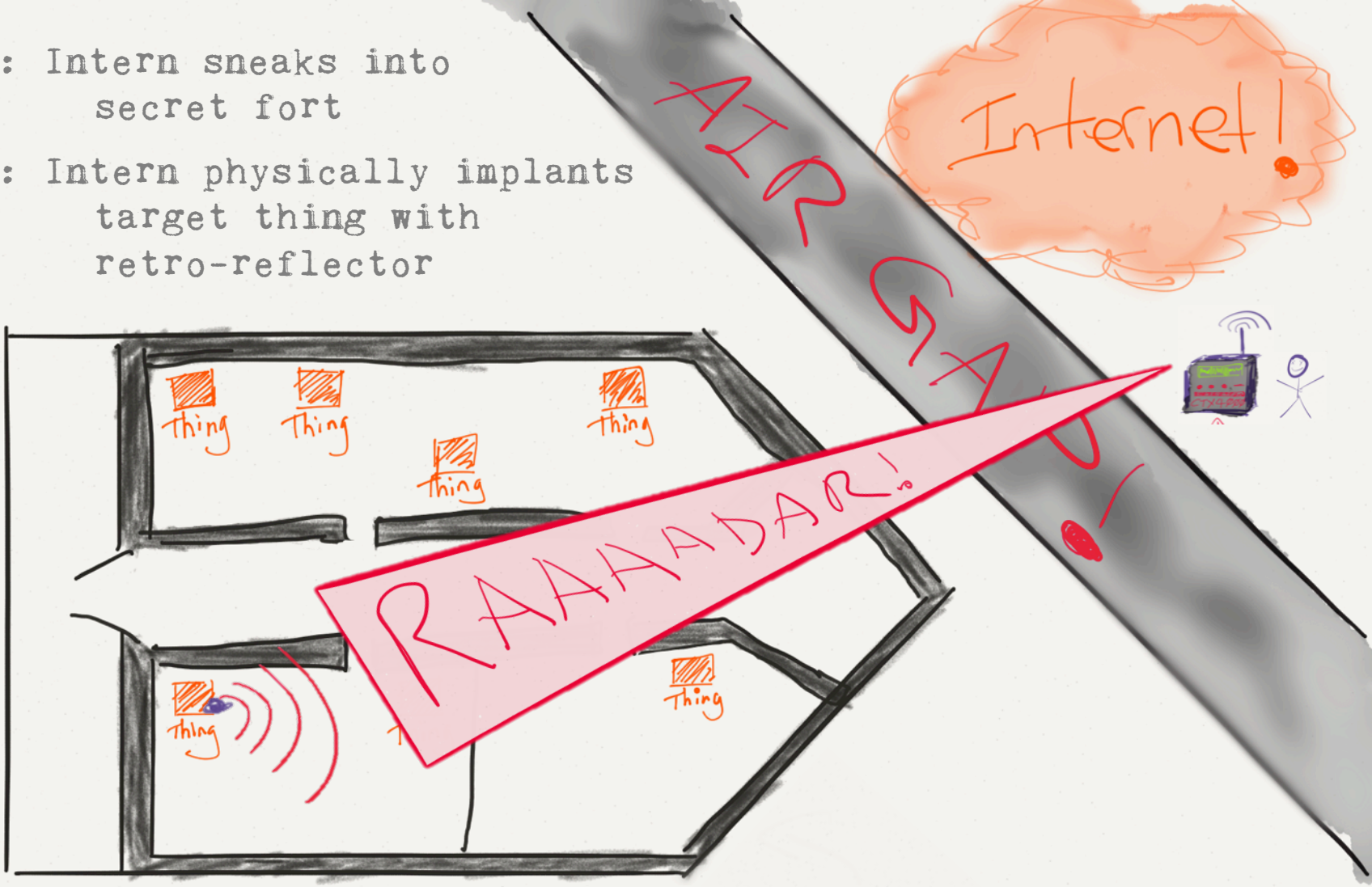
Step 2: Intern physically implants target thing with retro-reflector



Step 3: Continuous RF Illumination (CTX4k, etc) into secret fort, secret data comes out

Step 1: Intern sneaks into secret fort

Step 2: Intern physically implants target thing with retro-reflector



Step 3: Continuous RF Illumination (CTX4k, etc) into secret fort, secret data comes out

Good idea if…

Good idea if…

1: Infinite Interns

Good idea if…

1: Infinite Interns

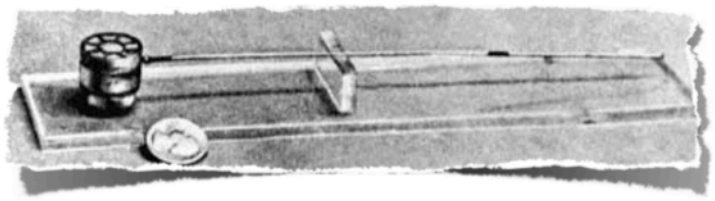
2: Not worried about leaving evidence behind
(see #1)

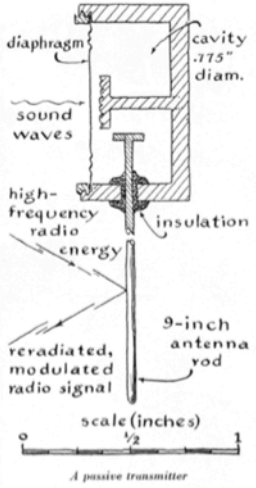
Retroreflector Technology

Retroreflector Technology

In Historical Context…

"The Thing"





(from Scientific American, 1968)

sites.apam.columbia.edu/courses/apph4903x/Great_Seal_Bug.pdf

Retroreflector
In Historical Context…

Way back when…

Retroreflector
In Historical Context…

Designed for this

Retroreflector
In Historical Context…

Phone

Phone

Deployed in the age of this

Retroreflector
In Historical Context…

office

Designed for this

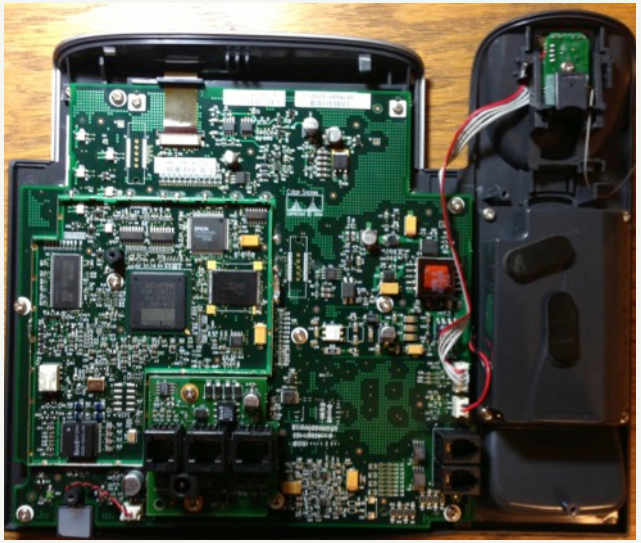
Retroreflector
In Historical Context…

office

office

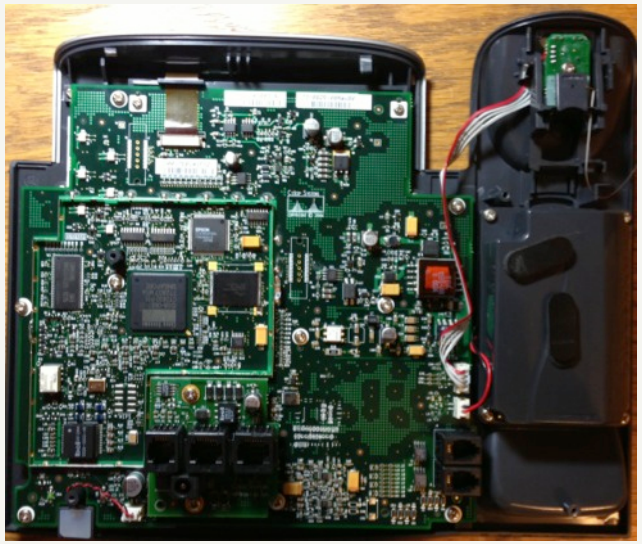
Deployed in the age of this

The Difference?



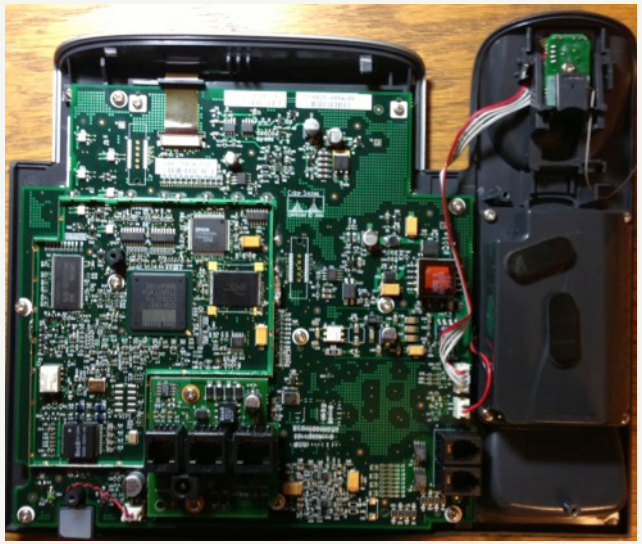
The Difference?

~ 50 Million Transistors



The Difference?

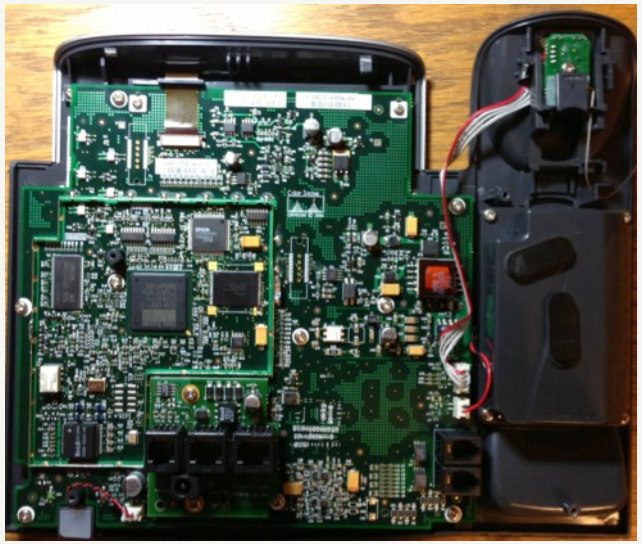
~ 50 Million Transistors
~ 1 Million Lines of Code



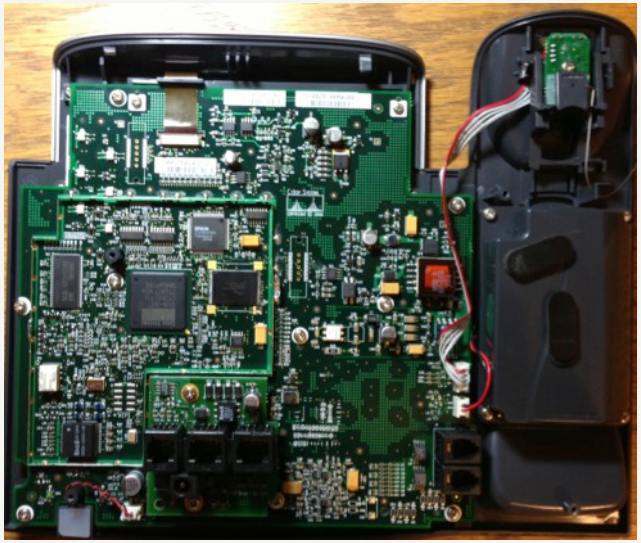
The Difference?

~ 50 Million Transistors
~ 1 Million Lines of Code

All-purpose computing hardware
Inside special-purpose packaging



Leverage This Difference



~ 50 Million Transistors
~ 1 Million Lines of Code

All-purpose computing hardware
Inside special-purpose packaging

And…


" Emanate like a "
scrub
Boss!

Leverage This Difference

And…

1. Exfiltrate using only software

Leverage This Difference

And…

1. Exfiltrate using only software
2. Exfiltrate using all the things

Leverage This Difference

And…

1. Exfiltrate using only software
2. Exfiltrate using all the things
3. Exfiltrate using arbitrary frequency range

Leverage This Difference

And…

1. Exfiltrate using only software
2. Exfiltrate using all the things
3. Exfiltrate using arbitrary frequency range

4. Evaporate when done

Part I

Compromising Emanations!

Part I

Compromising Emanations!

Part II

Firmware Shenanigans

Prior Art

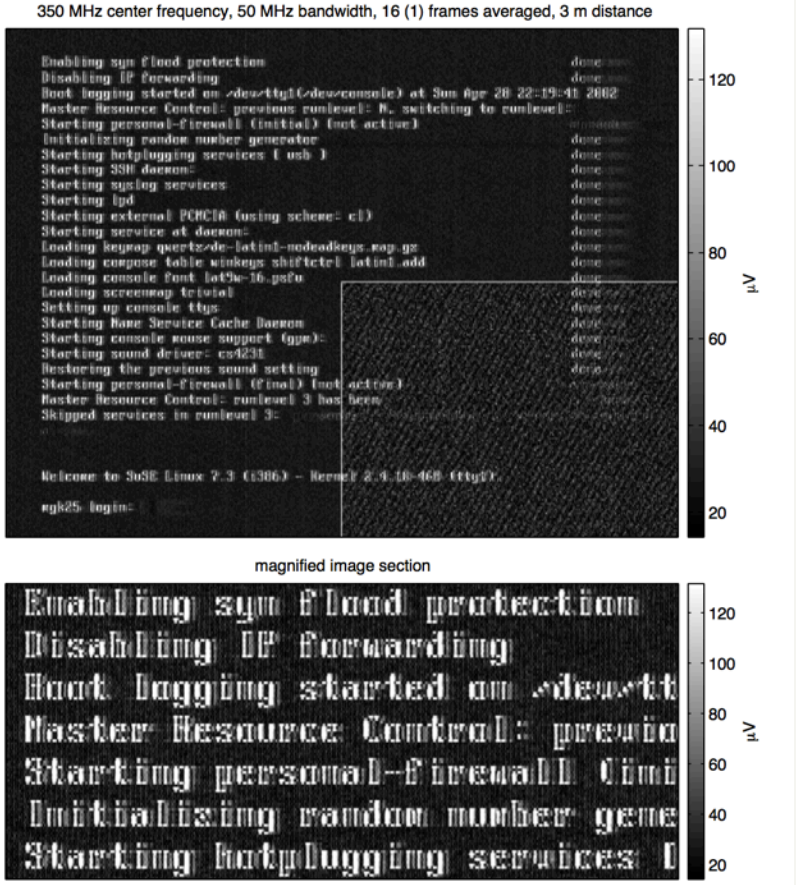
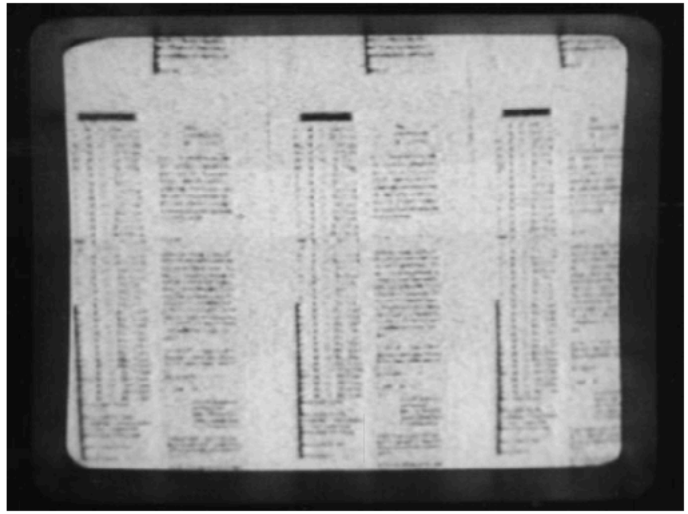


Fig. 1. Eavesdropped Linux boot screen visible on the LCD of a Toshiba 440CDX laptop (log-periodic antenna, vertical polarization).



Electromagnetic Eavesdropping Risks of Flat-Panel Displays

Markus G. Kuhn

University of Cambridge, Computer Laboratory,
15 JJ Thomson Avenue, Cambridge CB3 0FD, United Kingdom
http://www.cl.cam.ac.uk/~mgk25/

Prior Art

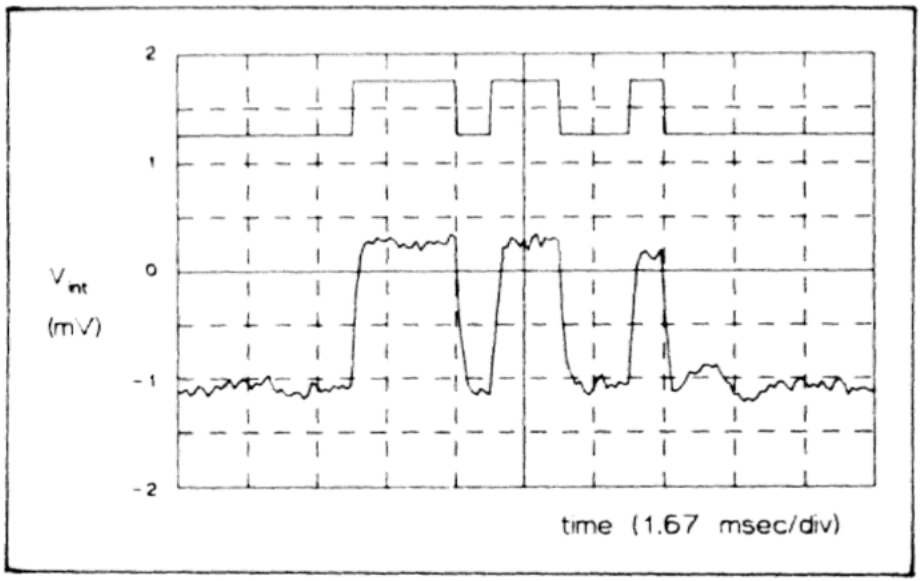


Fig. 4. Original and intercepted data signal at 7 m and 98 MHz (FM band).

The Threat of Information Theft by Reception of Electromagnetic Radiation from RS-232 Cables

Peter Smulders

Example: Acoustic Crypto-Analysis
Genkin, Shamir, Tromer

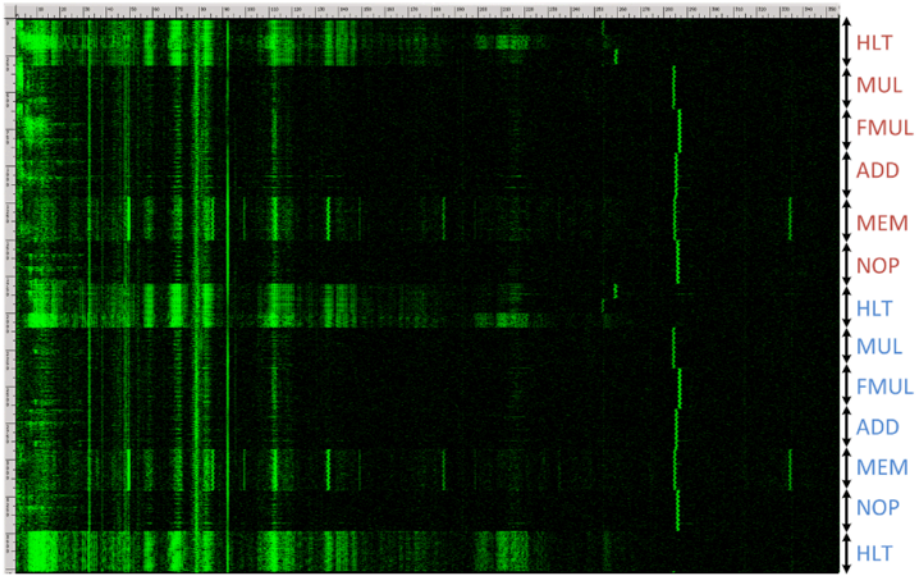


Figure 7: Acoustic measurement frequency spectrogram of a recording of different CPU operations using the Brüel&Kjær 4939 microphone capsule. The horizontal axis is frequency (0–310 kHz), the vertical axis is time (3.7 sec), and intensity is proportional to the instantaneous energy in that frequency band.

RSA Key Extraction via Low-Bandwidth Acoustic Cryptanalysis*

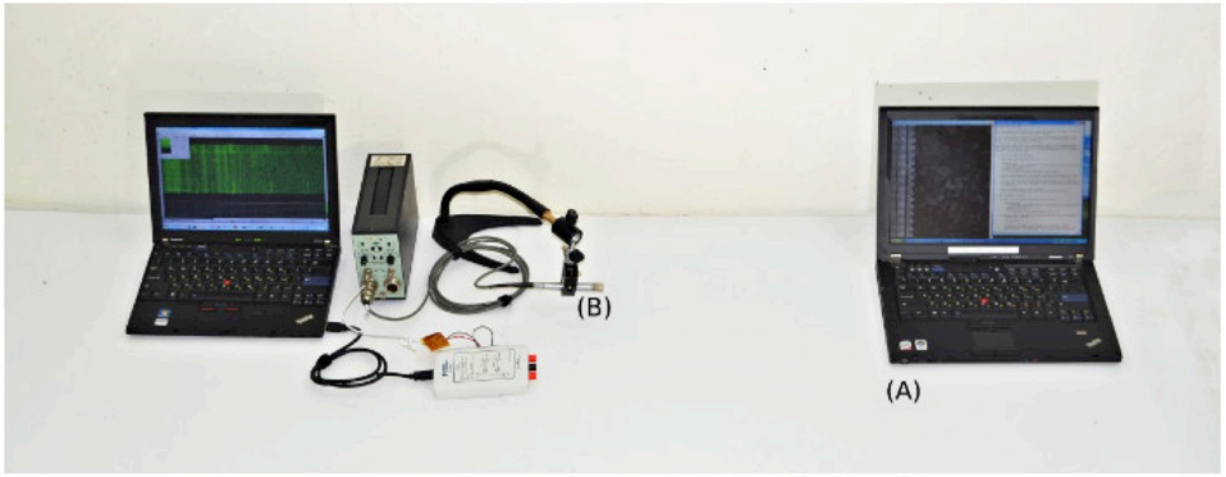
Daniel Genkin — Technion and Tel Aviv University — danielg3@cs.technion.ac.il

Adi Shamir — Weizmann Institute of Science — adi.shamir@weizmann.ac.il

Eran Tromer — Tel Aviv University — tromer@cs.tau.ac.il

December 18, 2013

Example: Acoustic Crypto-Analysis
Genkin, Shamir, Tromer



4 Meters!

RSA Key Extraction via Low-Bandwidth Acoustic Cryptanalysis*

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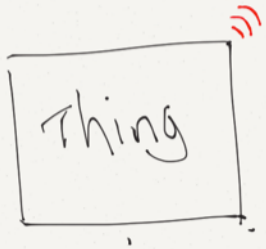
tromer@cs.tau.ac.il

December 18, 2013

Majority of Compromising Emanations Research

Majority of Compromising Emanations Research

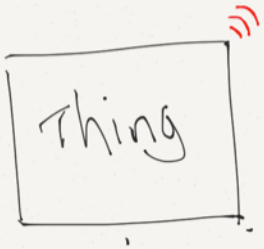
Faint, accidentally Leaked signal



Majority of Compromising Emanations Research

Big powerful receiver

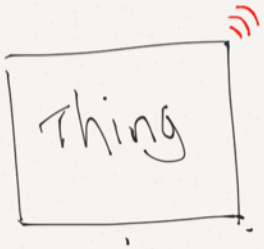
Faint, accidentally Leaked signal



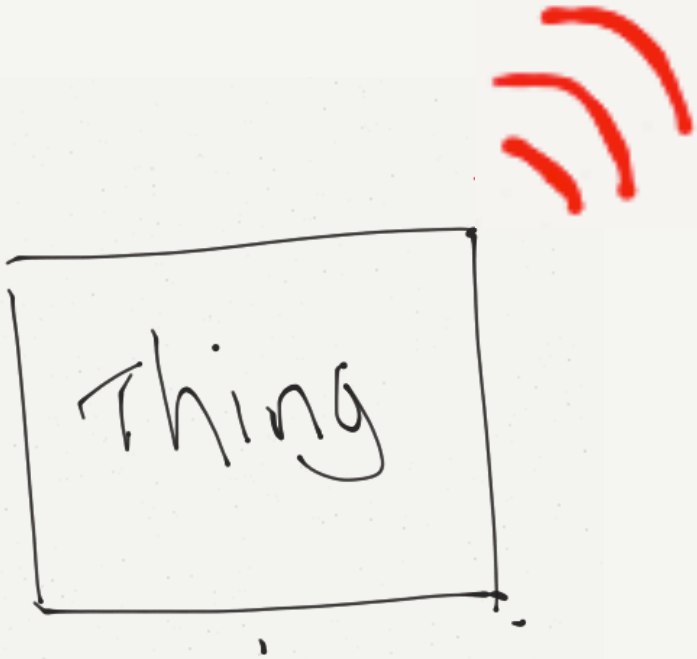
What if…

Big powerful receiver

Faint, accidentally
Leaked signal

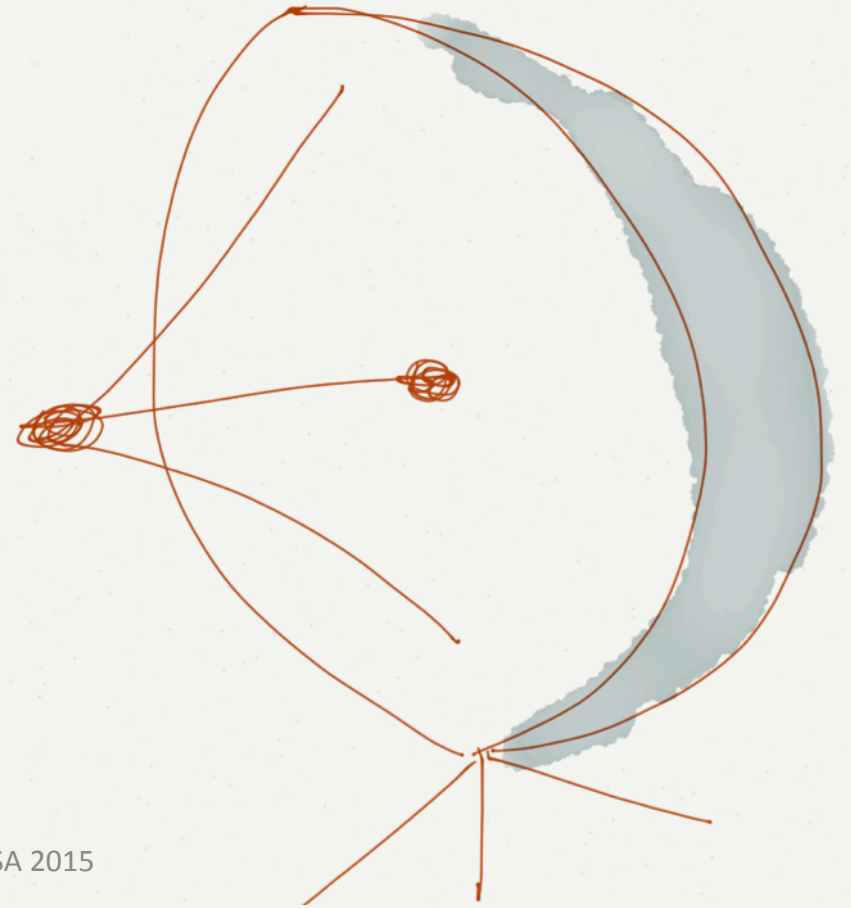


What if…

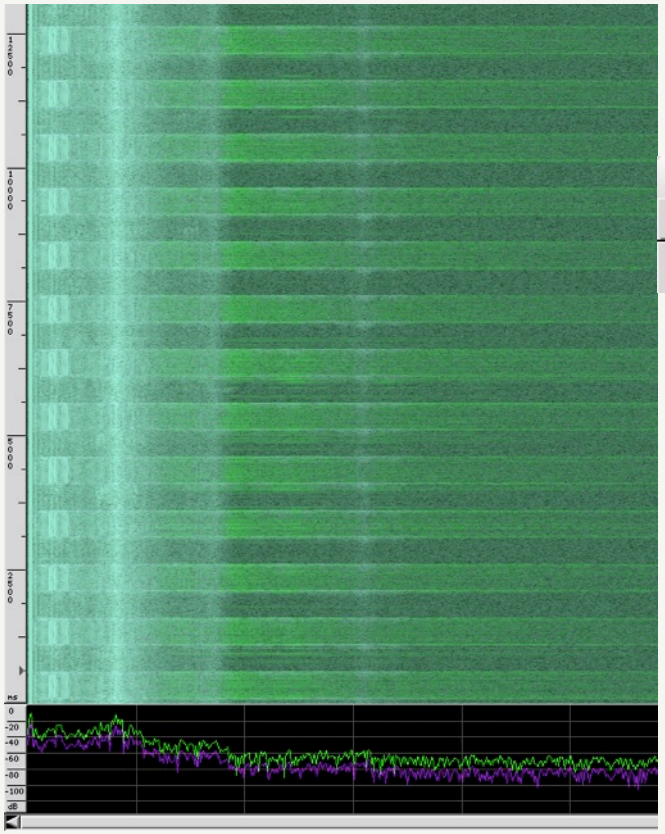


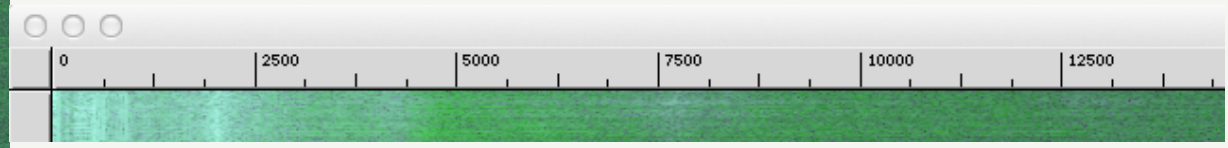
Loud, intentionally
generated compromising emanation

Big powerful receiver

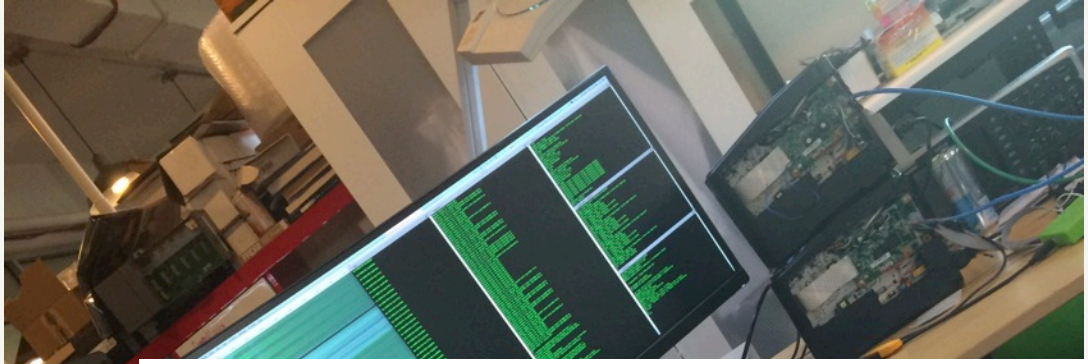


DEMO 1: Acoustic Funtenna Emanation





Sub 1khz emanation



Customer Questions & Answers

Have a question? Ask the owners here | Ask

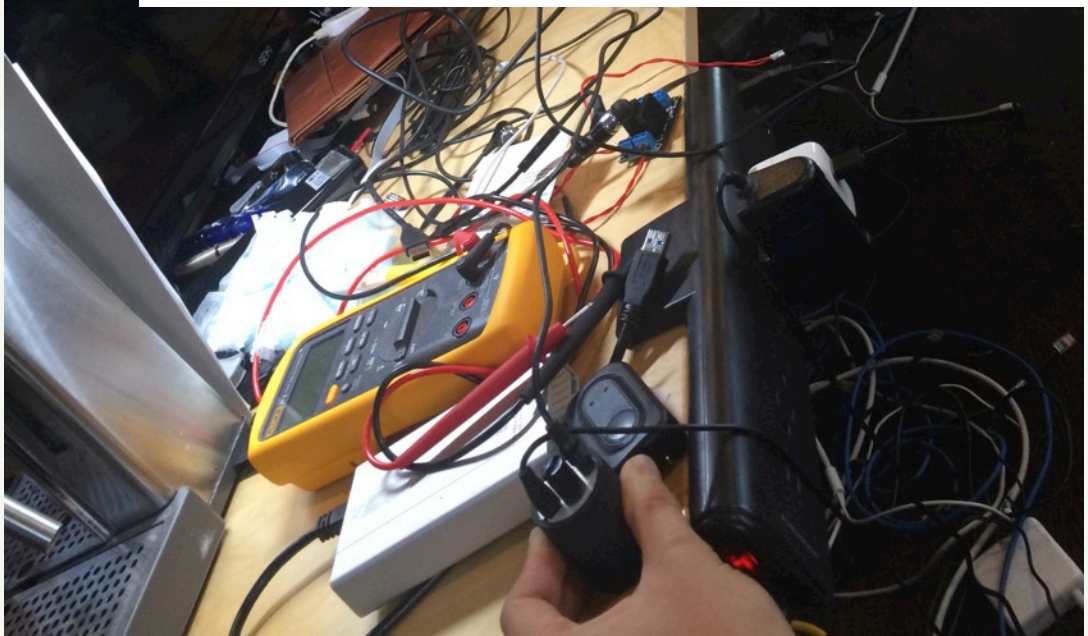
Don't see what you're looking for? Submit your question to our community by clicking the 'Ask' button above.

0 votes

Geo pone converts noise into voices? have I got that right, and these voices are they Alive humans like your neighbors that you hear?

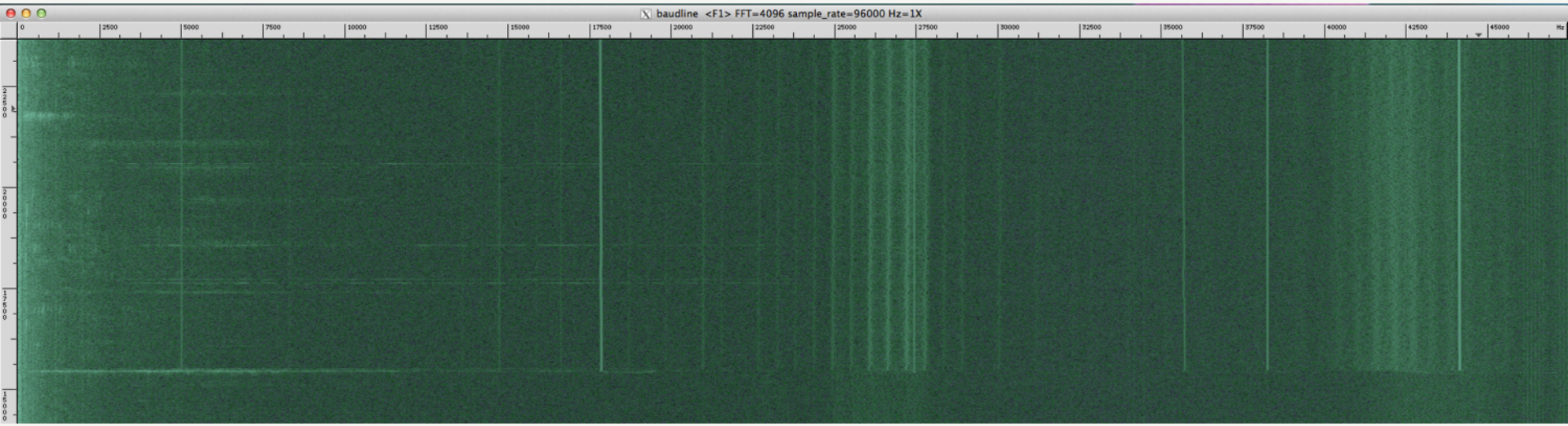
A: It hears through vibrations, you have to set it down on something and then hook either a recorder or headphones to it to hear anything. I thought it was something else when I bought it. I didn't want to have to hook something up to it to hear sounds. as for voices, I only tried it once and I think it picked up everything.

Sandra Labella answered on April 17, 2014

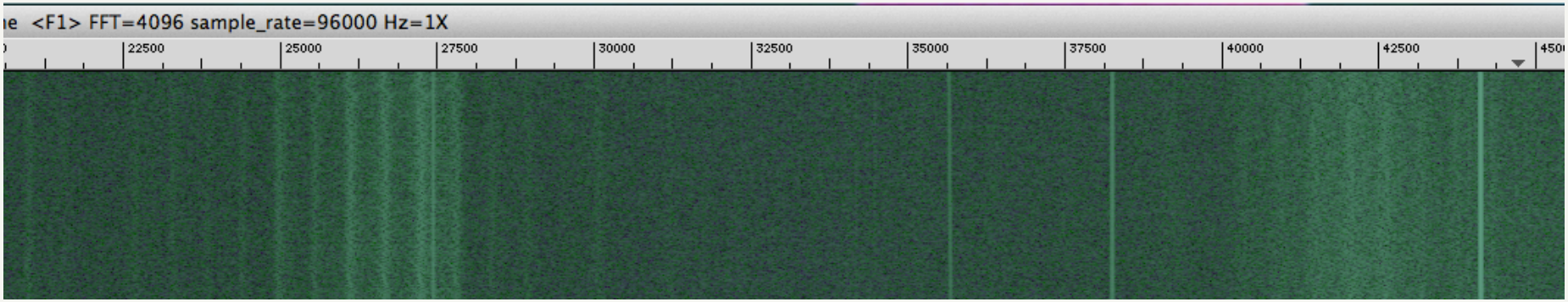


No, not like Alive humans

DEMO 1.5: Ultrasonic Funtenna Emanation



DEMO 1.5: Ultrasonic Funtenna Emanation



~27 Khz

~42 Khz

Soft Tempest: Hidden Data Transmission Using Electromagnetic Emanations

Markus G. Kuhn* and Ross J. Anderson

University of Cambridge, Computer Laboratory, New Museums Site,
Pembroke Street, Cambridge CB2 3QG, United Kingdom
{mgk25,rja14}@cl.cam.ac.uk

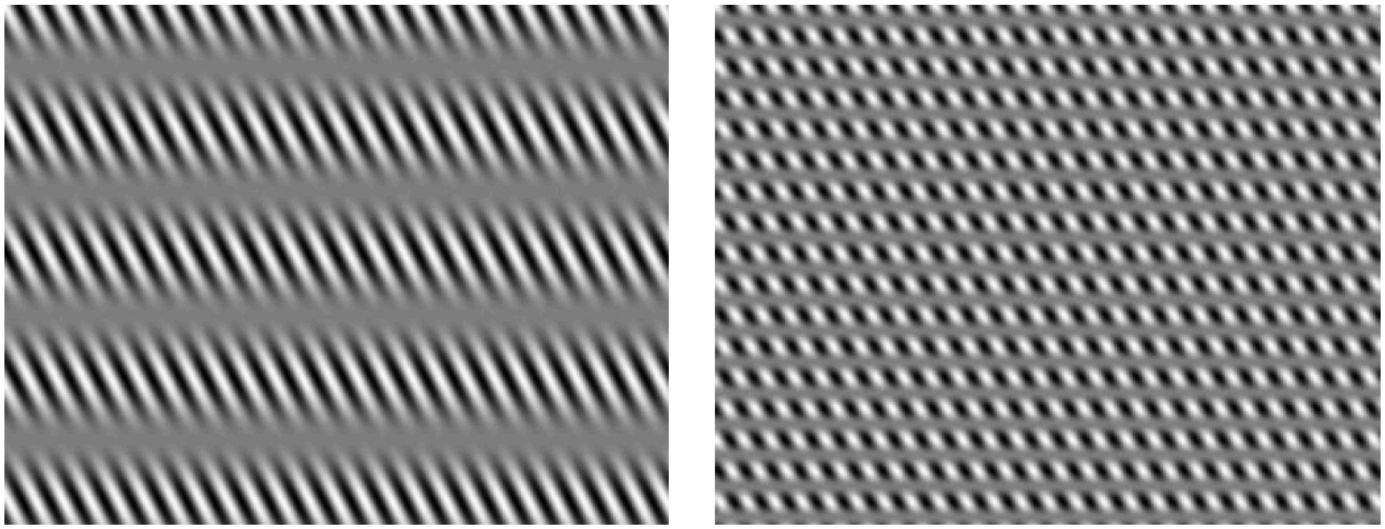


Fig. 1. Example screen contents that cause the authors' computer monitor to broadcast an $f_t = 300$ Hz (left) and 1200 Hz tone (right) on an $f_c = 2.0$ MHz carrier in amplitude modulation.

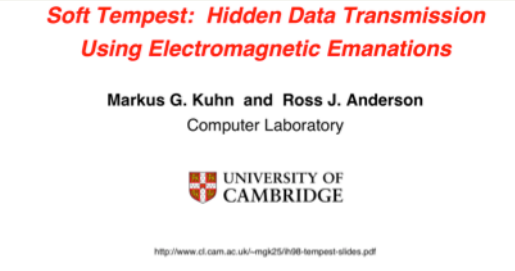
```
ModeLine "1152x900"  95  1152 1152 1192 1472  900 900 931 939
```

Soft Tempest: Hidden Data Transmission Using Electromagnetic Emanations

Markus G. Kuhn and Ross J. Anderson

Computer Laboratory

http://www.cl.cam.ac.uk/~mgk25/ih98-tempest-slides.pdf



Conclusions

→ Interesting field of study, mostly unexplored in the open literature

Probably not a new idea

But not discussed "in the open"

A decade later…

BitWhisper: Covert Signaling Channel between Air-Gapped Computers using Thermal Manipulations

Guri, Monitz, Mirski, Elovici

Distance: 40cm
Data Rate: 1-8 bits per hour

On Covert Acoustical Mesh Networks In Air

Hanspach & Goetz

Distance: 19.7 M
Data Rate: 20 bits per second

AirHopper: Bridging the Air-Gap Between Isolated Networks and Mobile Phones Using Radio Frequencies

Guri, Kedma, Kachlon, Elovici

Distance: 7 M
Data Rate: 60 bits per second

The next steps

The next steps

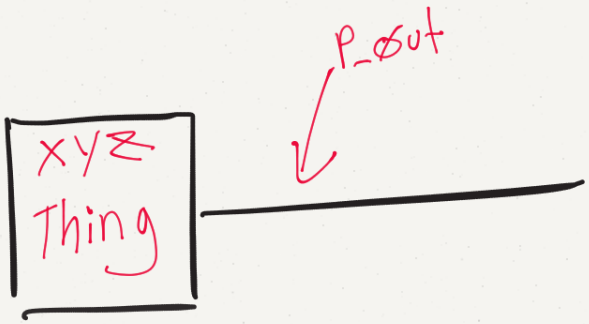
1. Generalize and Unify Methodology

The next steps

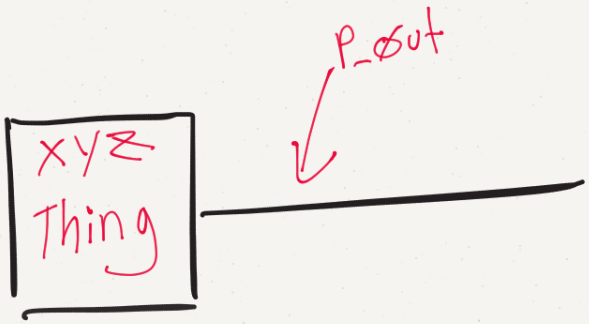
1. Generalize and Unify Methodology
2. **Minimize hardware dependencies**

Funtenna 101

Funtenna 101

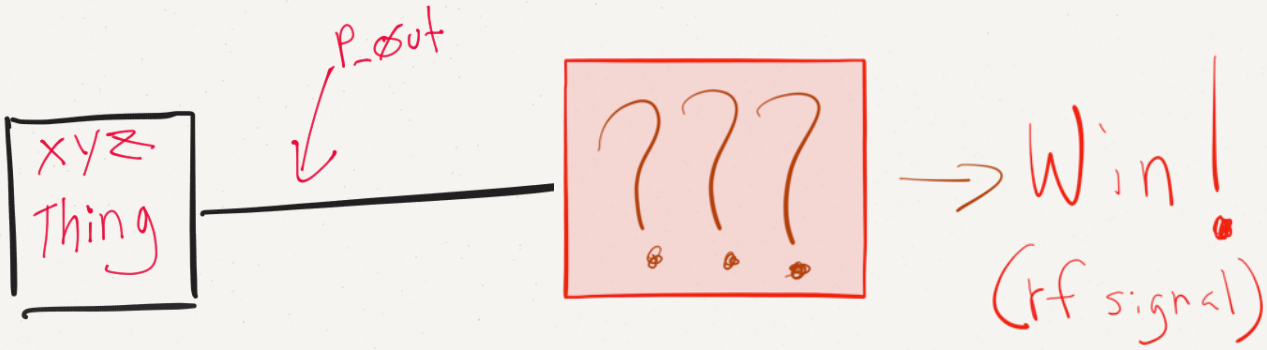


Funtenna 101



P_out: 0 1 0 1 0 1 0 1 0 1

Funtenna 101



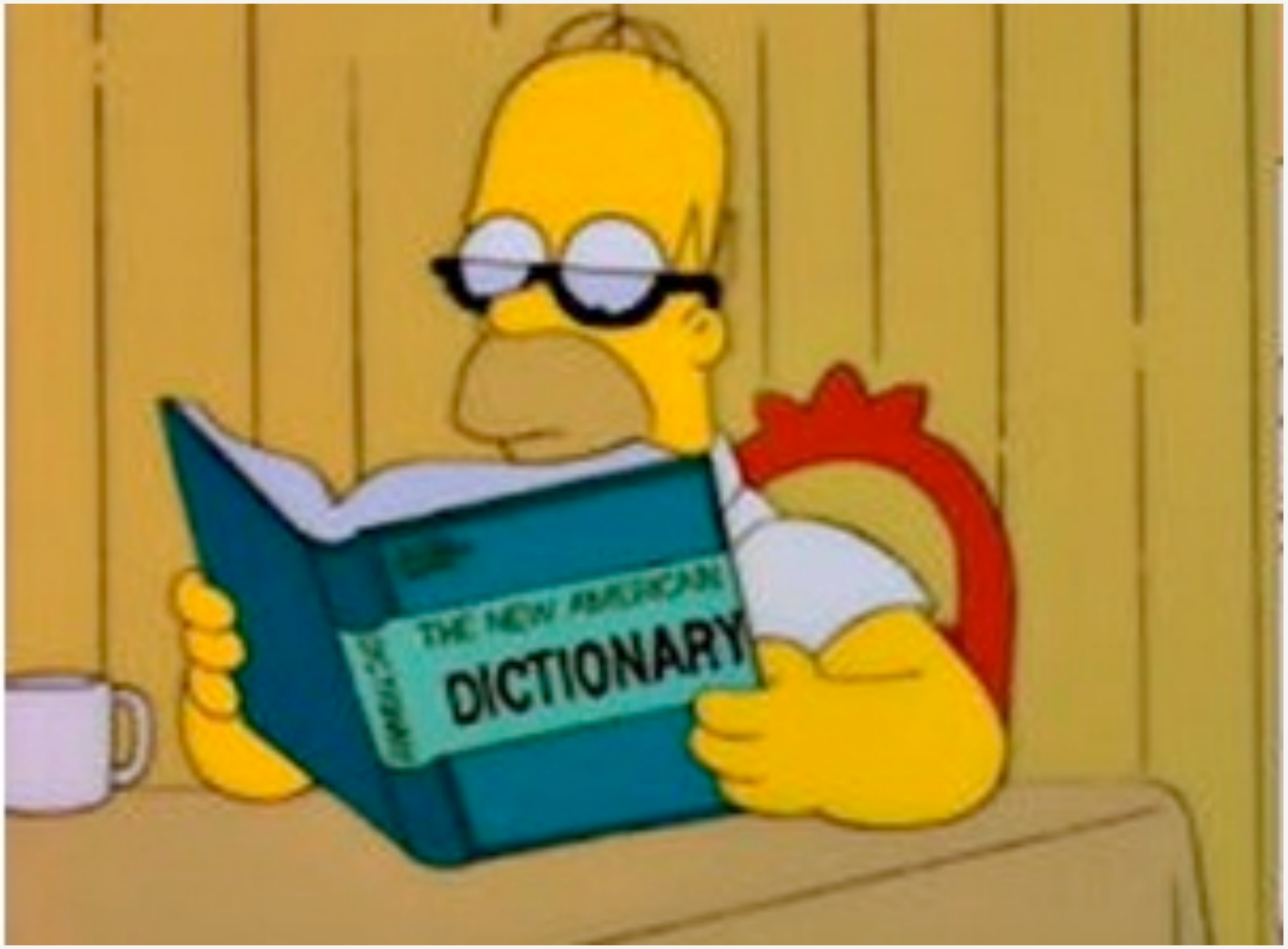
P_out: 0 1 0 1 0 1 0 1 0 1

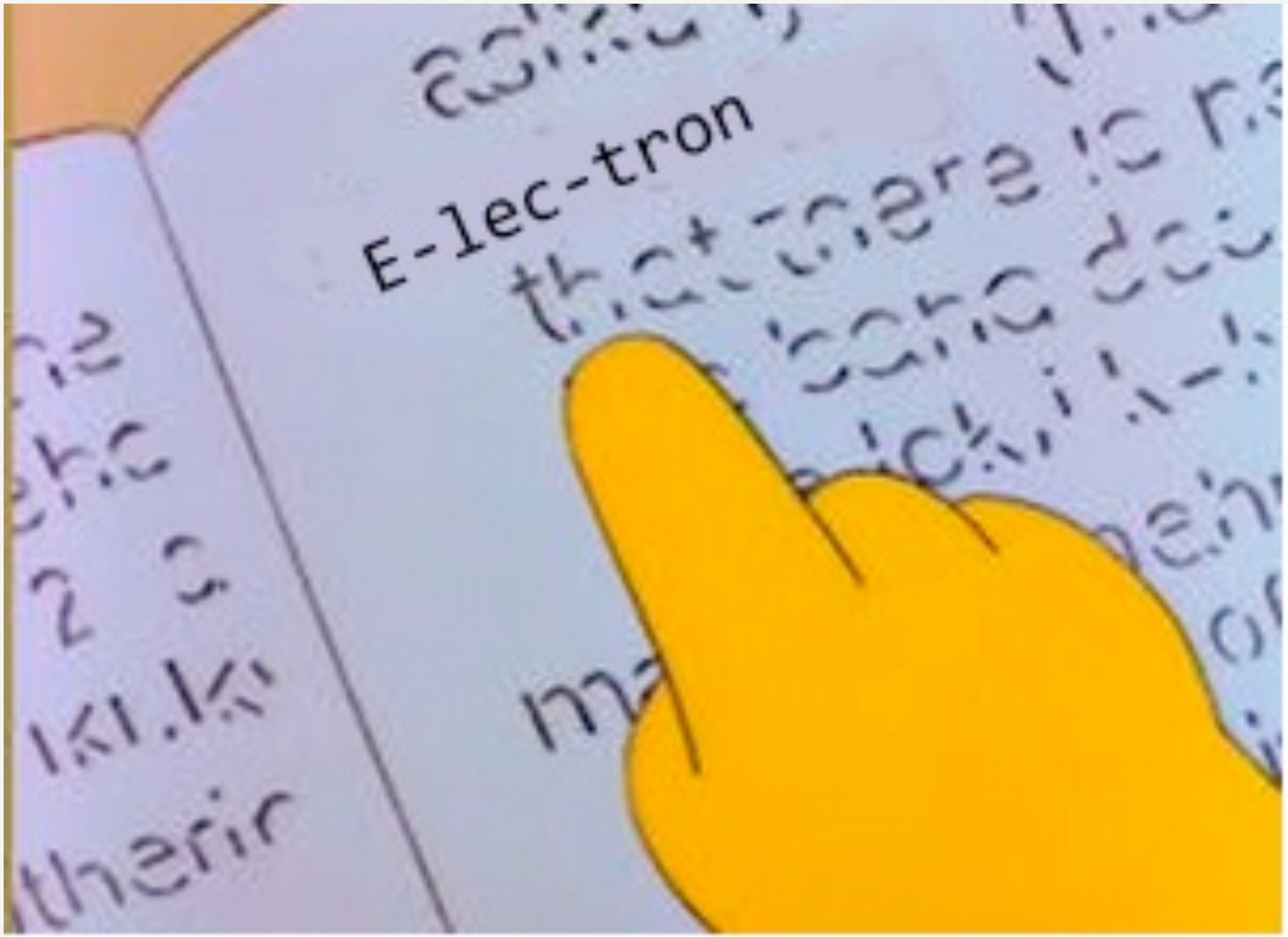

Advanced
SDR


Advanced
SDR


RADIO


Beginning
RADIO
VIA 9GAG.COM


DICTIONARY


E-lec-tron

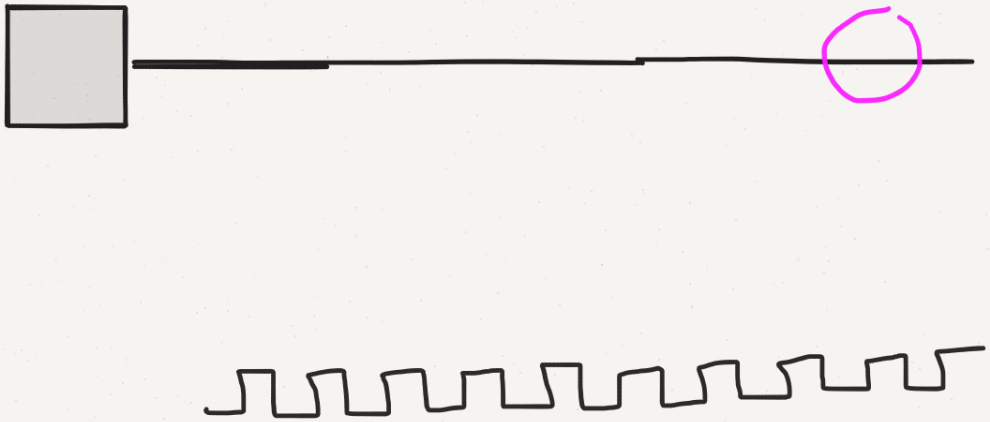
$$\nabla \times E = \frac{\partial B}{\partial t}$$

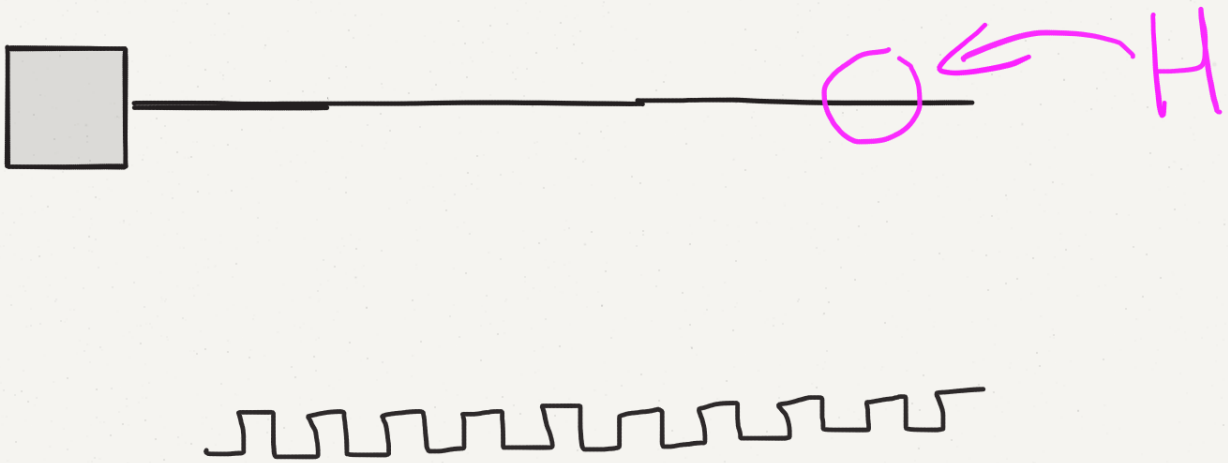
$$\nabla \times H = \frac{\partial D}{\partial t}$$

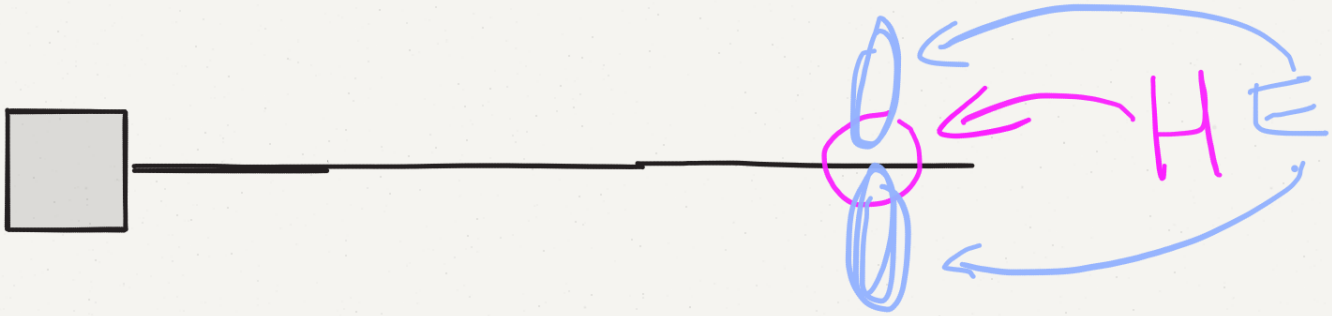
$$\nabla \cdot D = 0$$

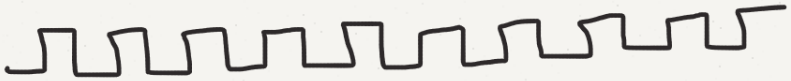
$$\nabla \cdot B = 0$$

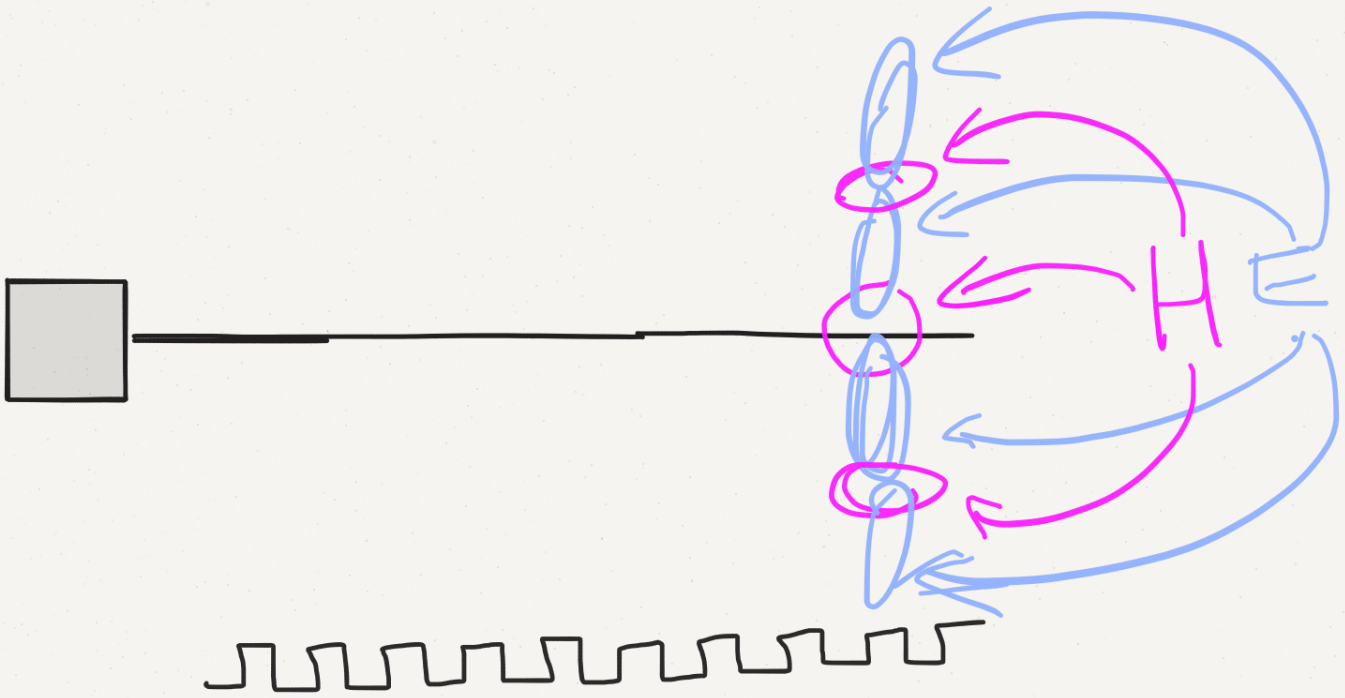
Maxwell's equations

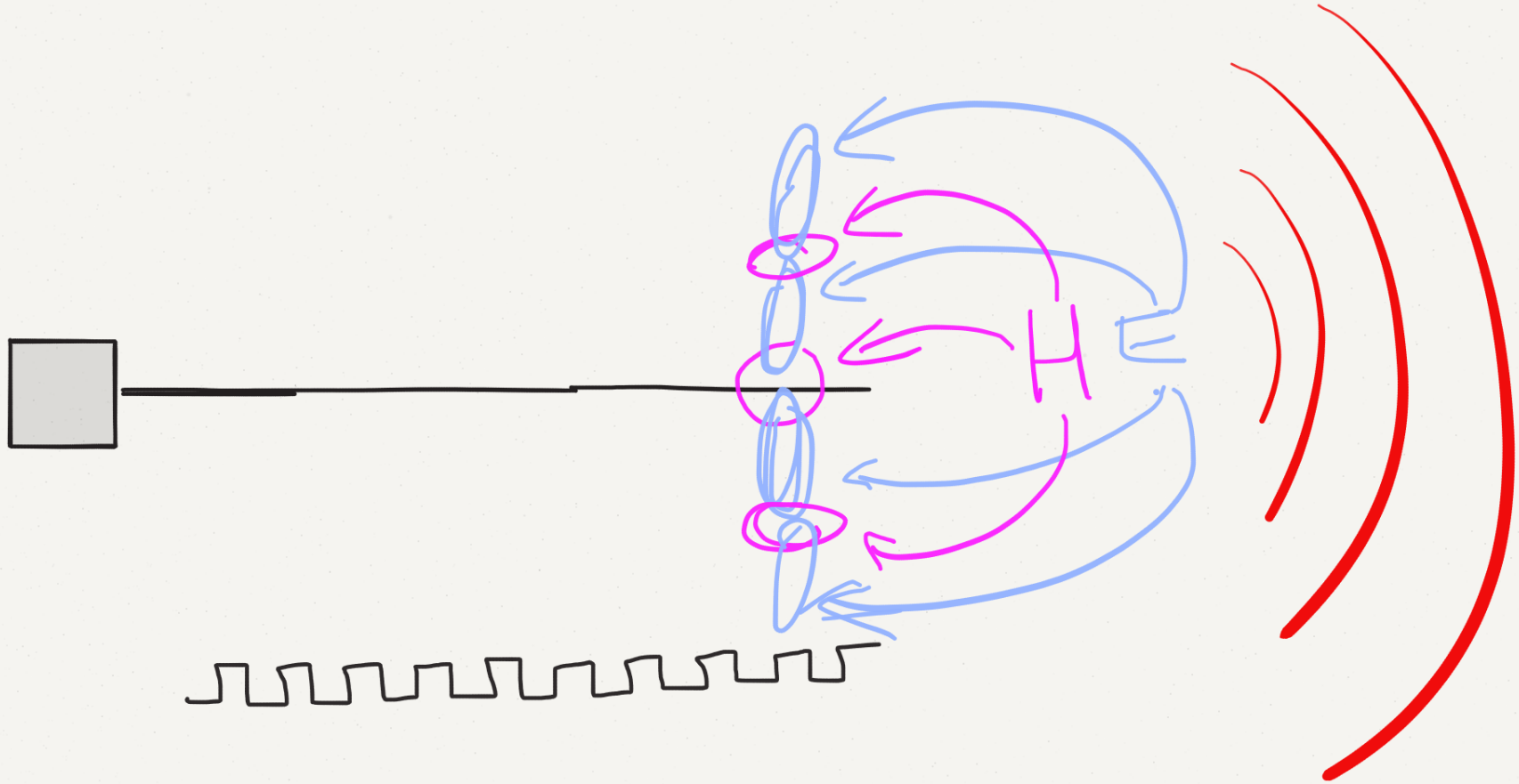


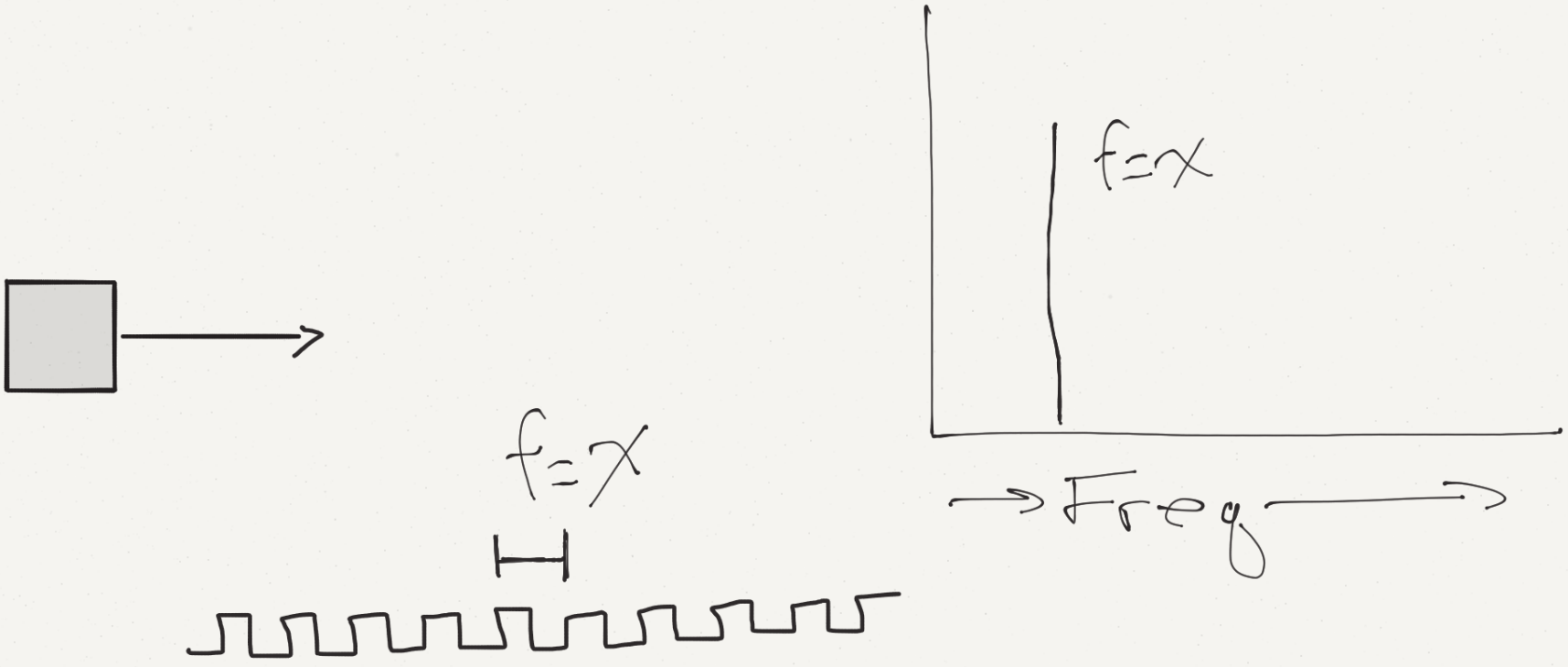

O
H

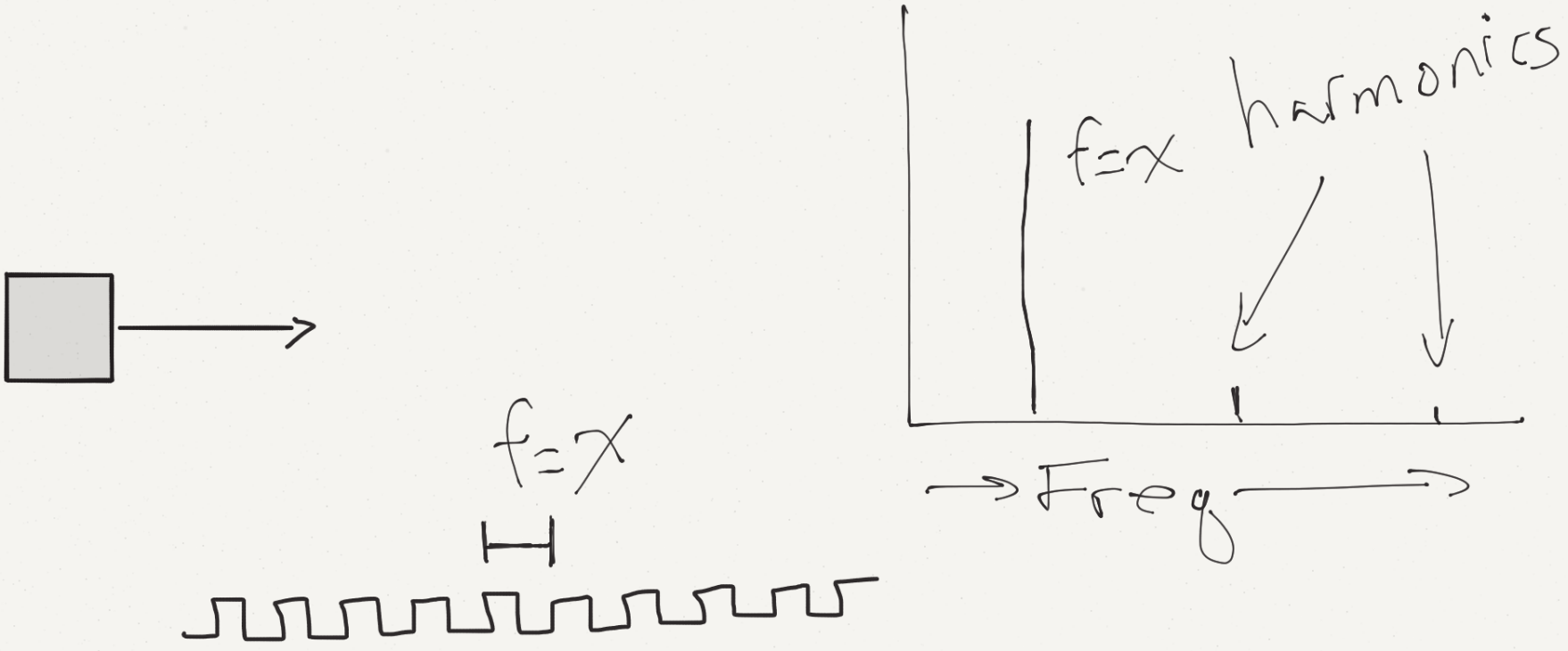

H
E




H
E


H
E


f=x
f=x
Freq


f=x
harmonics
f=x
Freq

Funtenna 102

Common Output Pins

- PWM (Pulse Width Modulation)
- GPIO (General Purpose Input Output)
- UART (Universal Asynchronous Receive Transmit)

Funtenna 102

Science!

Funtenna 102

Science!

For each

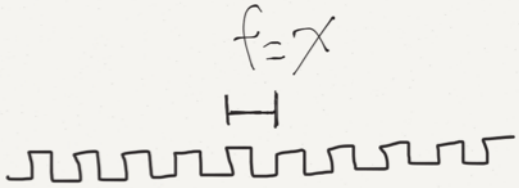
- PWM
- GPIO
- UART

Funtenna 102

Science!

For each

- PWM
- GPIO
- UART



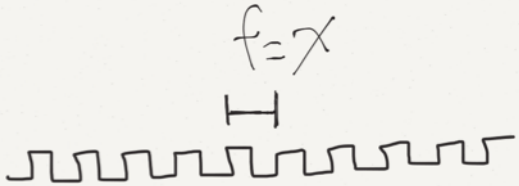
Funtenna 102

Science!

For each

- PWM
- GPIO
- UART

1. Possible values for f
2. Optimal values for f



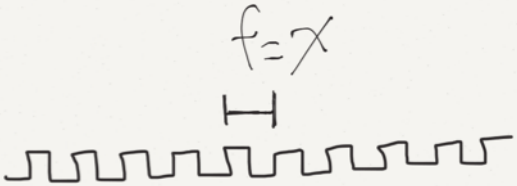
Funtenna 102

Science!

For each

- PWM
- GPIO
- UART

1. Possible values for f
2. Optimal values for f



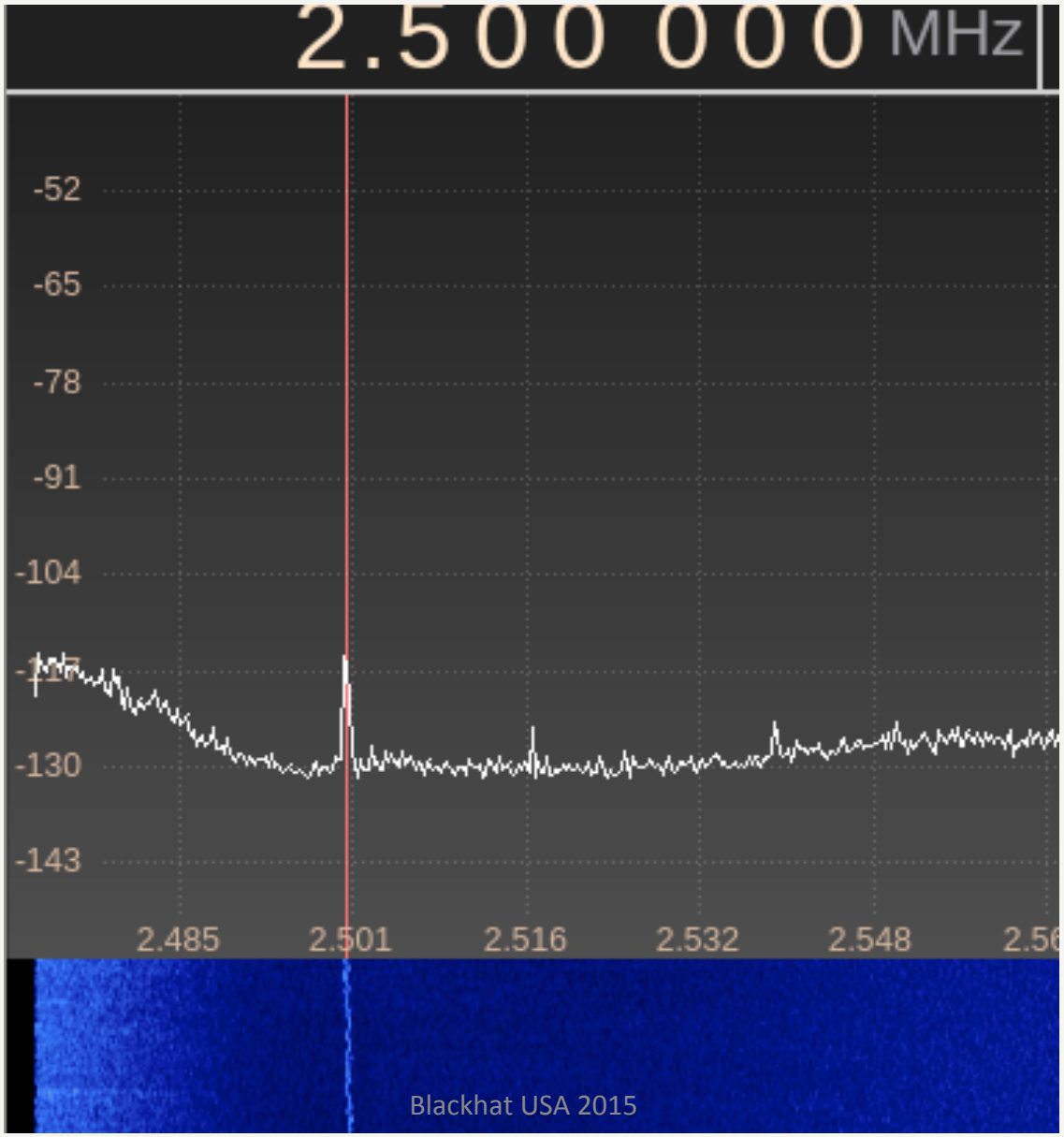
For each radiator length

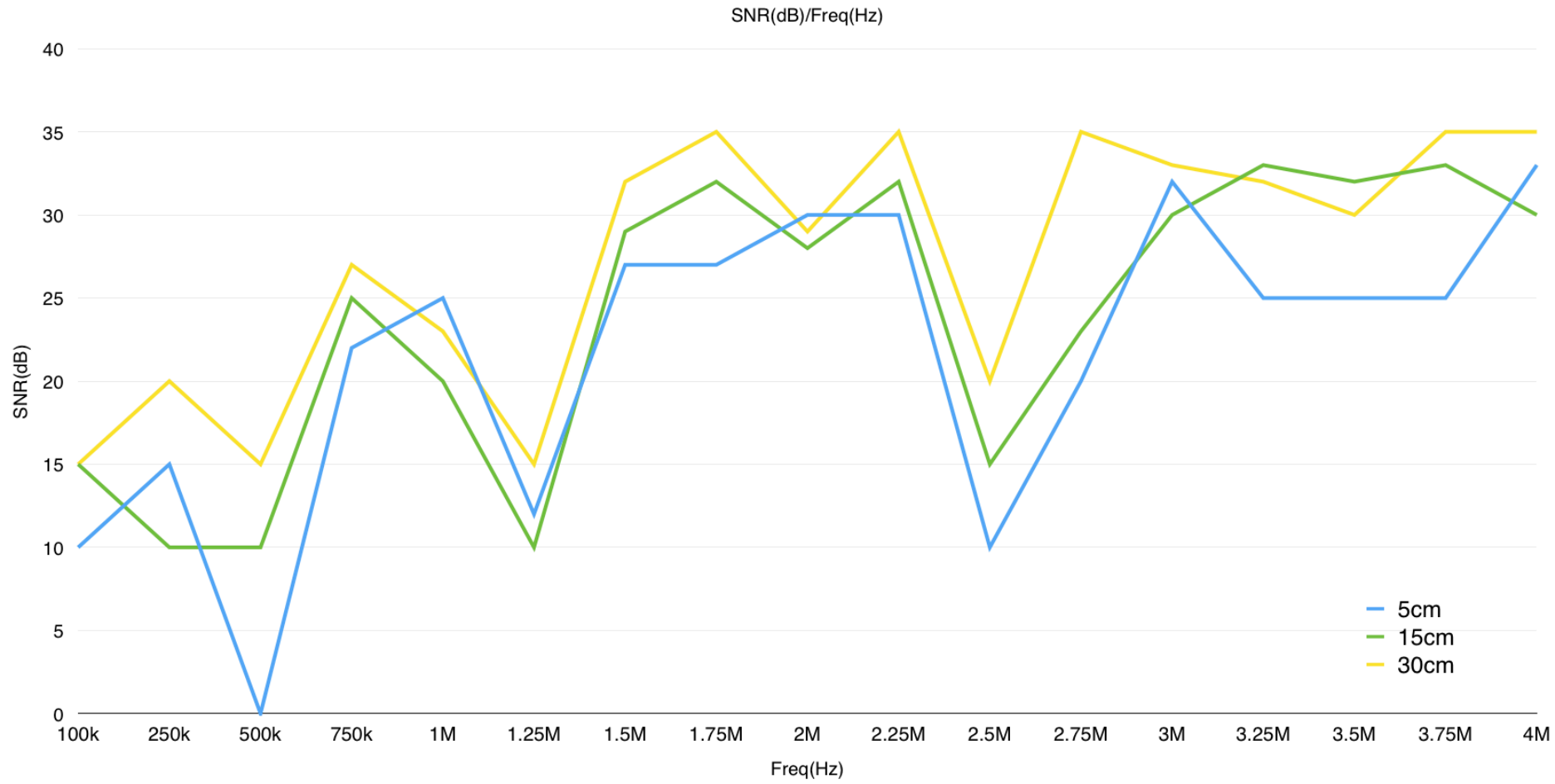
- 0cm
- 15cm
- 30cm

Experimental Setup

- "Faraday" Cage
- Buspirate (transmitter)
- USRP2 & BasicRX Board (receiver)

For example,
30cm radiator, f=500khz, harmonic signal @ 2.5mhz





Full raw dataset available at www.funtenna.org

Funtenna 102

Data Analysis…

Possible values for f

Optimal values for f

Optimal length of radiator

Funtenna 102

Data Analysis…

Optimal length of radiator

Anything > 0, longer better…

Funtenna 102

Data Analysis…

Possible values for f

PWM: 10khz - 4mhz

GPIO: 10khz - 5mhz

UART: 10khz - 4mhz

Funtenna 102

Data Analysis…

Possible values for f

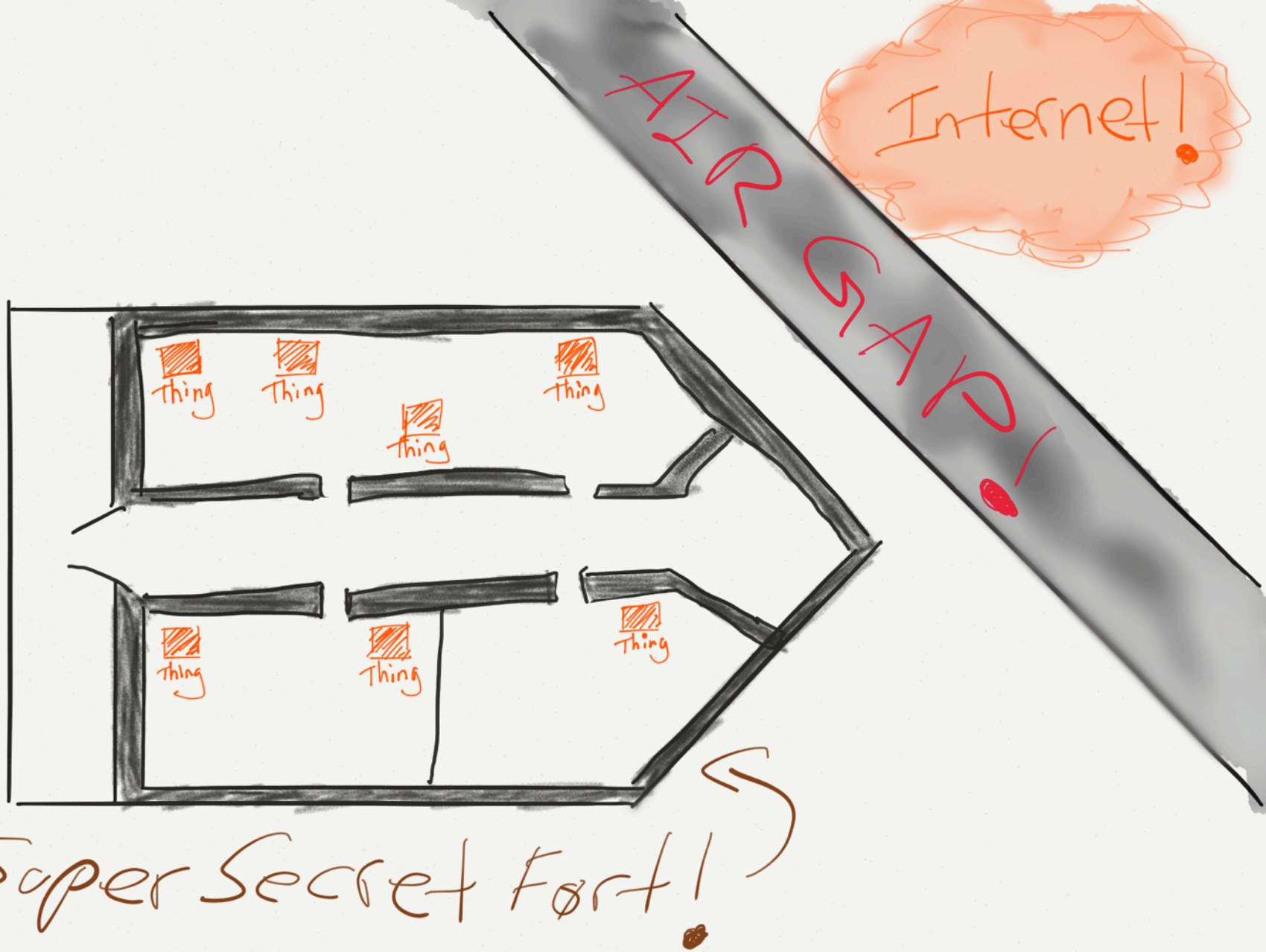
PWM: 10khz - 4mhz

GPIO: 10khz - 5mhz

UART: 10khz - 4mhz

Optimal values for f

120Mhz - 205Mhz


AIR GAP!
Internet!
Thing
Thing
Thing
Thing
Thing
Thing
Super Secret Fort!

AIR GAP!

Internet!

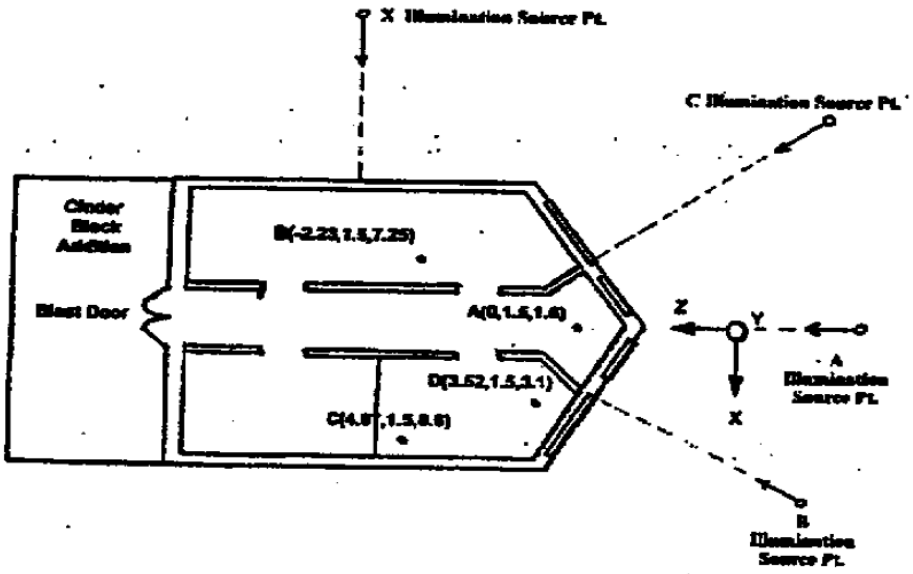


Figure 2. Diagram of Building 12500 at the A-15A Site on Elgin Air Force Base,

Super Secret Fort!

Measurement of RF Propagation into Concrete Structures over the Frequency Range 100 MHZ to 3 GHz

by

Clayborne D. Taylor
Samuel J. Gutierrez
Steven L. Langdon
Kenneth L. Murphy
William A. Walton, III

Phillips Laboratory/WSM
3550 Aberdeen Ave. SE
Kirtland AFB, NM 87117-5776

ISBN 97814613786l7

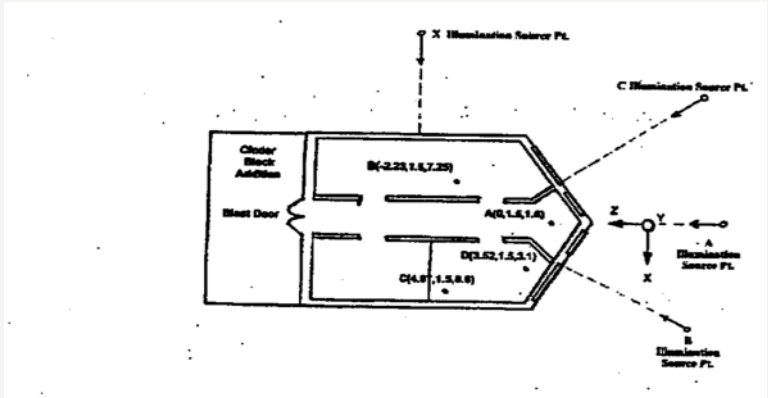


Figure 2. Diagram of Building 12500 at the A-15A Site on Elgin Air Force Base,

Say you wanted to Funtenna out of a
2-ft reinforced concrete structure

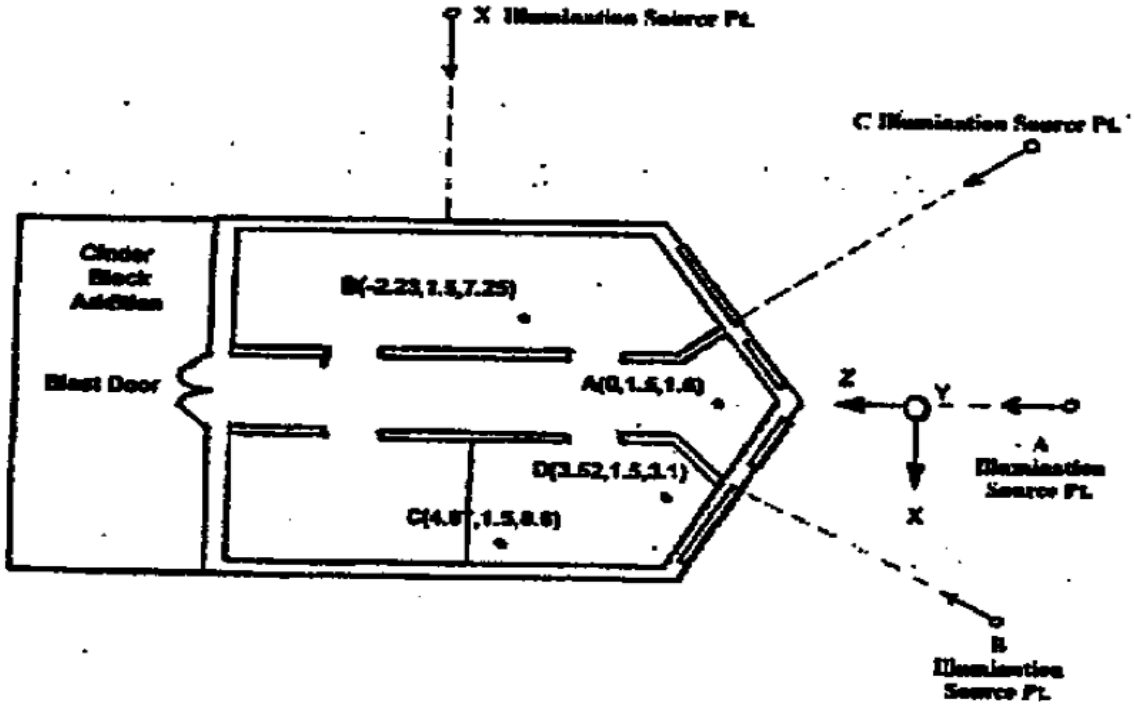


Figure 2. Diagram of Building 12500 at the A-15A Site on Elgin Air Force Base,

ISBN 9781461378617

Say you wanted to Funtenna out of a
2-ft reinforced concrete structure

ISBN 9781461378617

structures. For two-feet thick concrete walls, the measured attenuation above 200 MHz appears to increase with an increase in frequency. And for frequencies near and below 100 MHz, rebar attenuation becomes significant and seems to affect the magnetic field more than the electric field penetration. In the frequency range between 120 and 205 MHz the attenuation is often less than 20 dB. For four-inch and eight-inch thick walls the attenuation is much less (see Table 3).

F <= 100Mhz, bad for magnetic field penetration

F >= 200Mhz, bad for electric field penetration

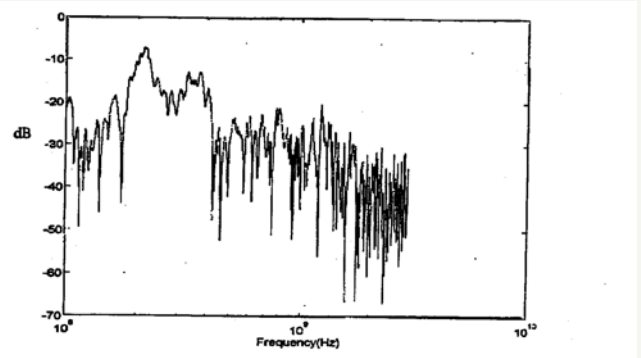


Figure 5. The internal electric field (E_z) at measurement point B relative to the incident electric field for illuminating source point X.

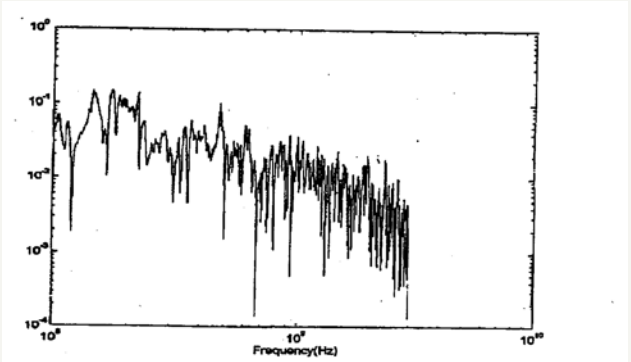
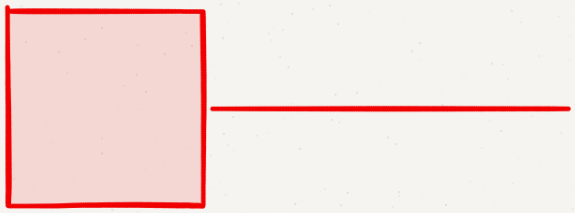
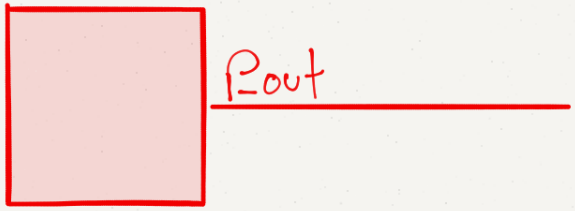


Figure 4. The internal magnetic field (H_z) at measurement point B relative to the incident magnetic field for illumination source point X.

Generalized Funtenna Algorithm

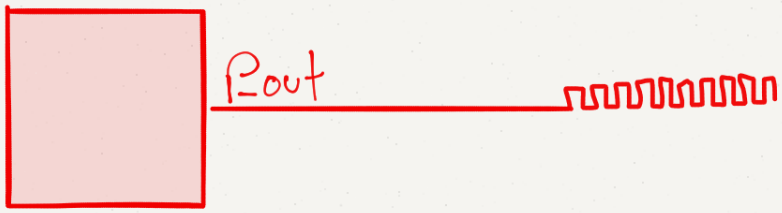


Generalized Funtenna Algorithm



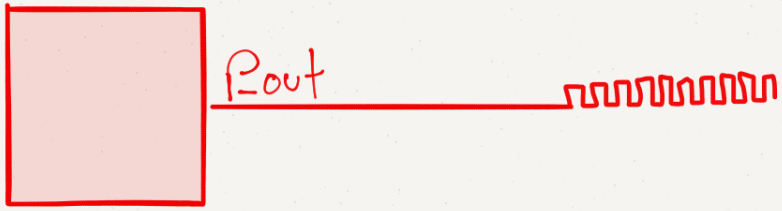
P_out → 1
Delay(t1)
P_out → 0
Delay(t1)

Generalized Funtenna Algorithm



P_out → 1
Delay(t1)
P_out → 0
Delay(t1)

Generalized Funtenna Algorithm



P_out → 1
Delay (d_1)
P_out → Ø
Delay (d_1)
] f = X

Generalized Funtenna Algorithm

Do "Symbol Duration" Times

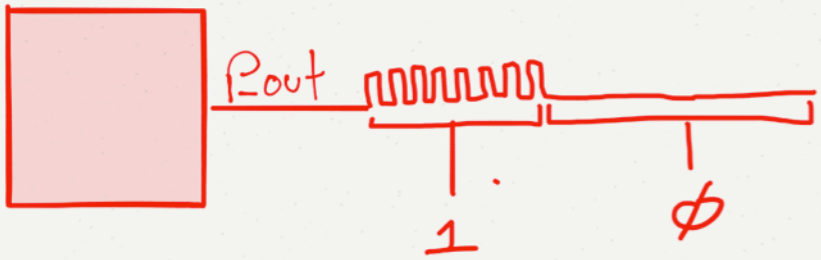
P_out → 1
Delay(d1)
P_out → Ø
Delay(d1)

] f=X

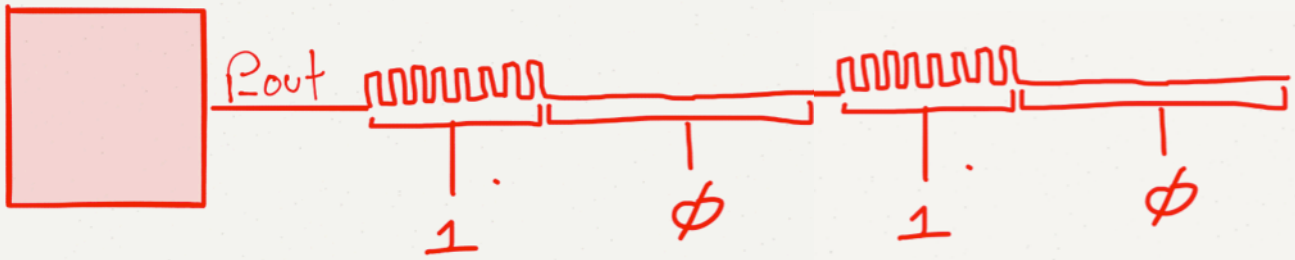
Generalized Funtenna Algorithm

- ASK (Amplitude Shift Keying)
- FSK (Frequency Shift Keying)
- OOK (On-Off Keying)

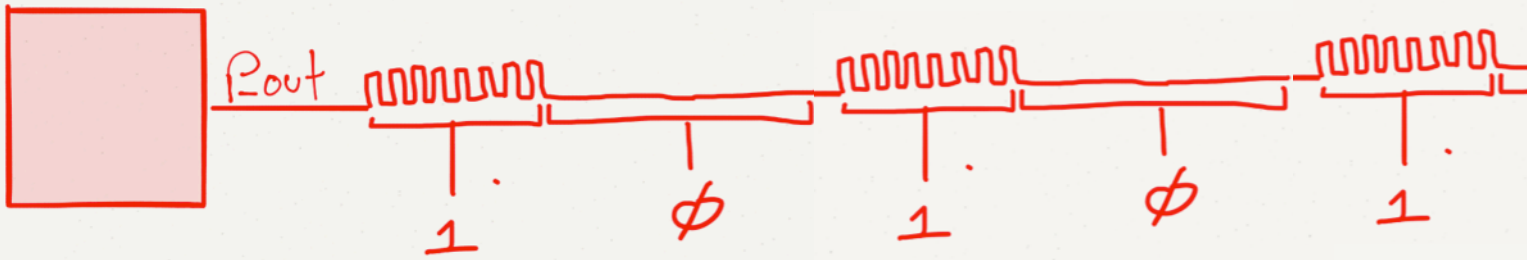
Generalized Funtenna Algorithm
Amplitude-Shift Keying



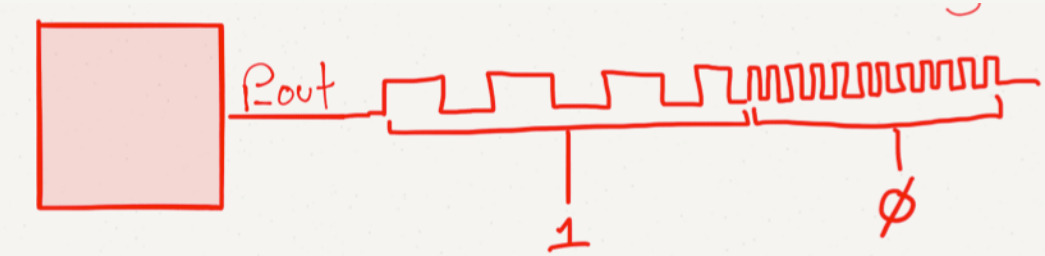
Generalized Funtenna Algorithm
Amplitude-Shift Keying



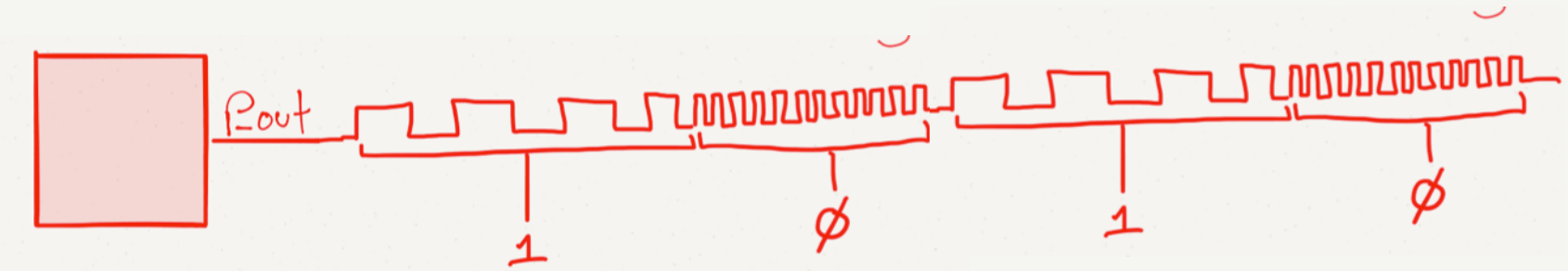
Generalized Funtenna Algorithm
Amplitude-Shift Keying



Generalized Funtenna Algorithm
Frequency-Shift Keying (sort of)

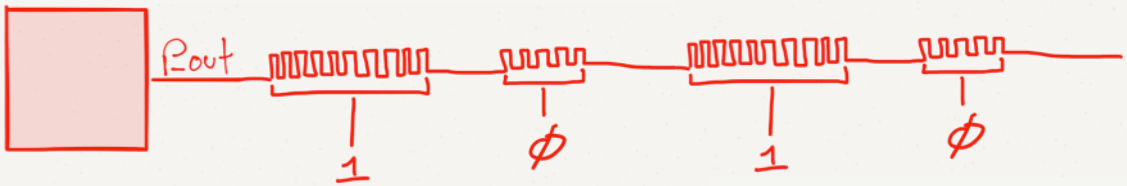


Generalized Funtenna Algorithm
Frequency-Shift Keying (sort of)

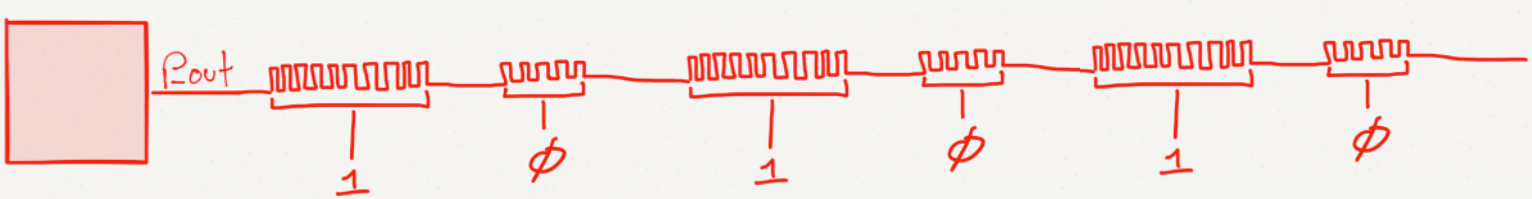


Generalized Funtenna Algorithm
On-Off Keying

Generalized Funtenna Algorithm
On-Off Keying



Generalized Funtenna Algorithm
On-Off Keying



Funtenna In Practice

Funtenna In Practice

Pantum P2502W Wireless Monochrome Laser Printer

★★★½☆ 113 reviews

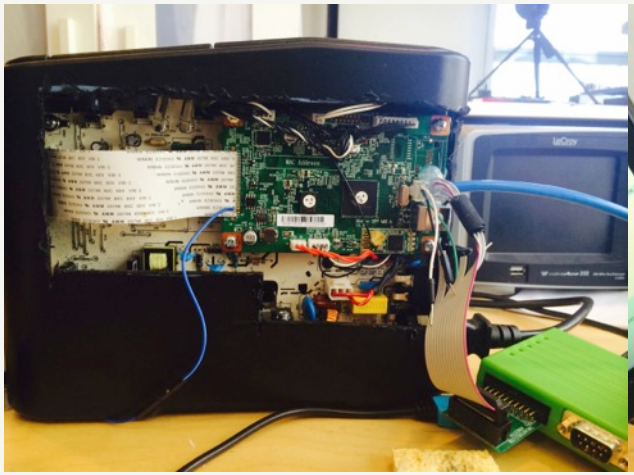
Stores

Newegg.com	Free shipping, no tax - **$39.99**
eBay	Free shipping, no tax - **$53.00**

View all stores and prices »

Funtenna In Practice

Pantum P2502W Wireless Monochrome Laser Printer

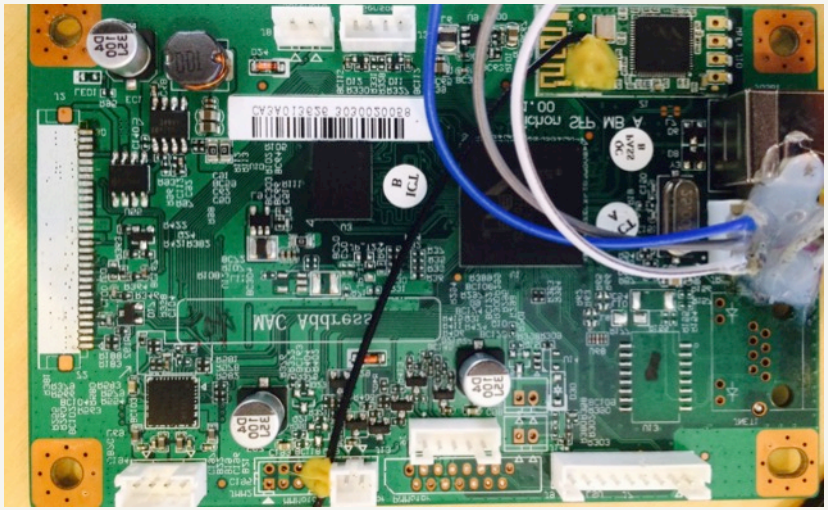


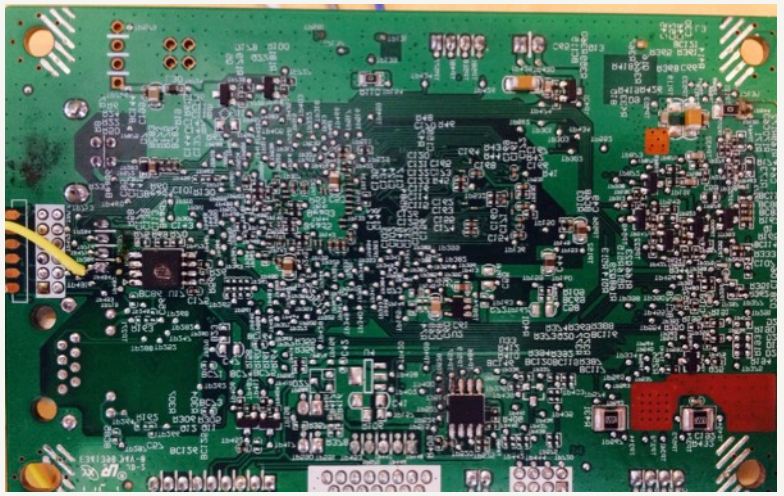
1. Cheap
2. Typical ARM SoC
3. GPIO (lots)
4. PWM
5. UART
6. JTAG

Funtenna In Practice

Pantum P2502W Wireless Monochrome Laser Printer

The Controller Board



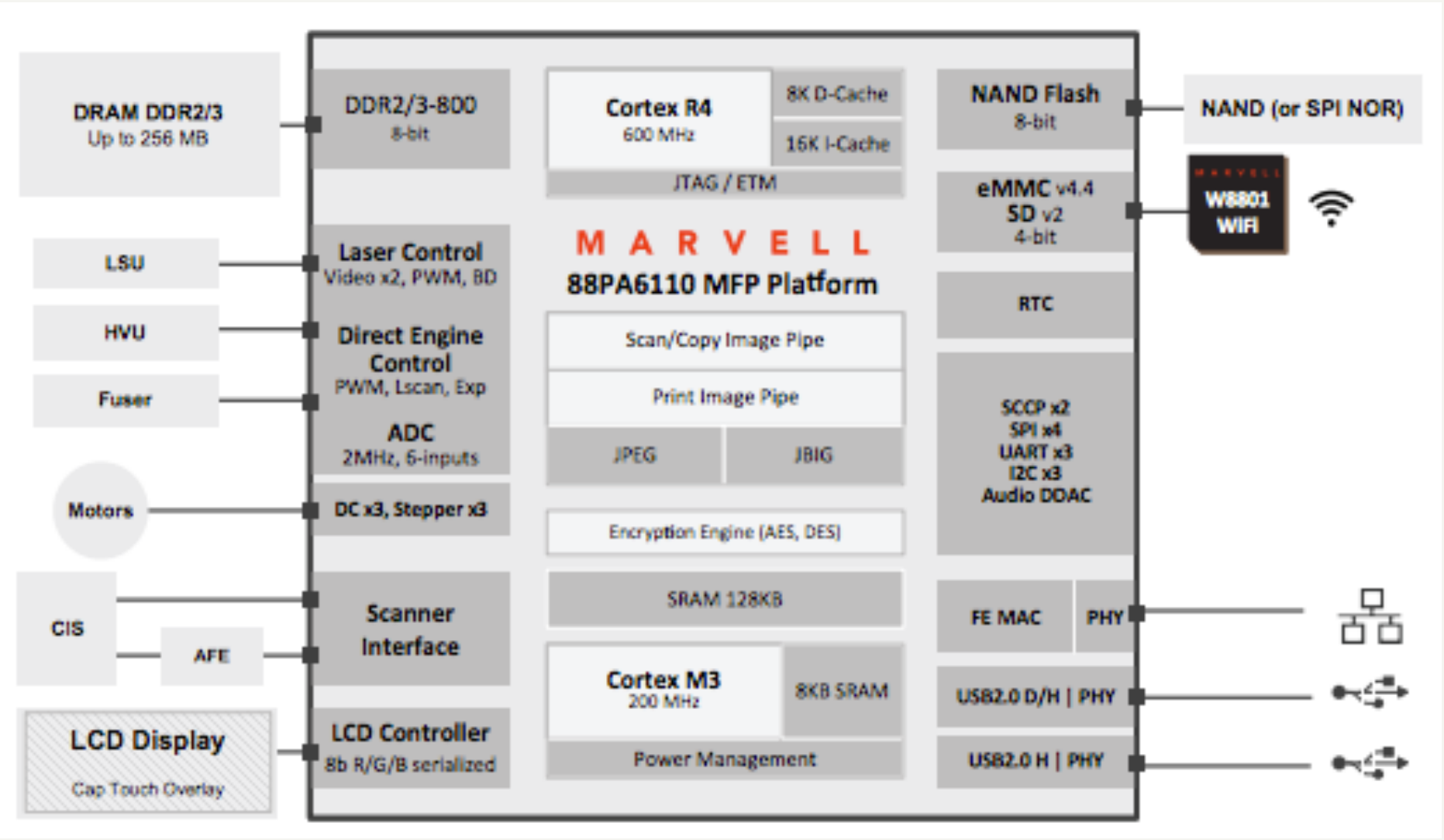


Funtenna In Practice

Pantum P2502W Wireless Monochrome Laser Printer

The SoC

Marvell 88PA6110



The product brief
http://www.marvell.com/printers/assets/Printer_88PA6110-01_pb_FINAL.pdf

Funtenna In Practice

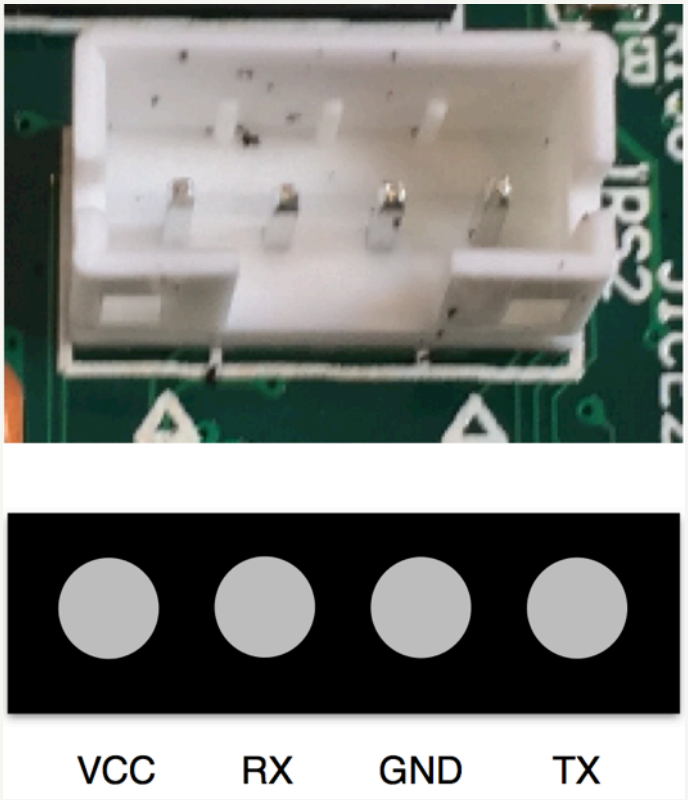
Pantum P2502W Wireless Monochrome Laser Printer

Hardware Triage

Funtenna In Practice

Pantum P2502W Wireless Monochrome Laser Printer

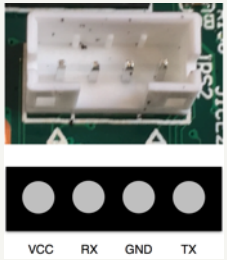
Hardware Triage

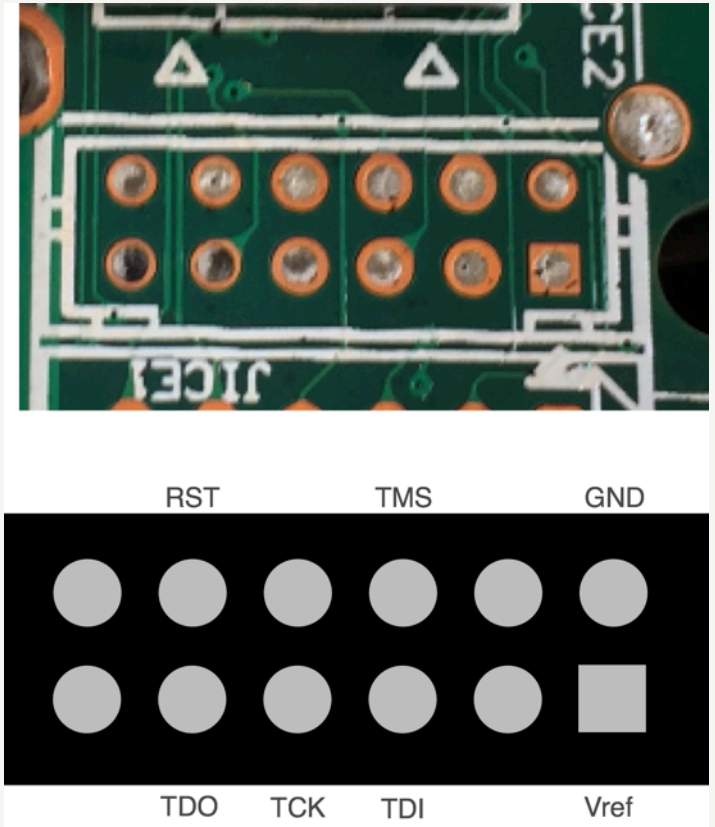


Funtenna In Practice

Pantum P2502W Wireless Monochrome Laser Printer

Hardware Triage





Funtenna In Practice (PWM)

Pantum P2502W Wireless Monochrome Laser Printer

13Khz PWM

Funtenna In Practice (PWM)

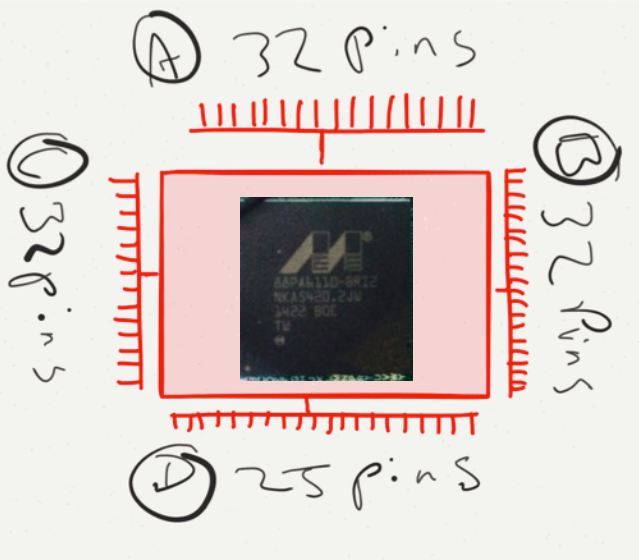
Pantum P2502W Wireless Monochrome Laser Printer

13Khz PWM

No love -(

Funtenna In Practice (GPIO)

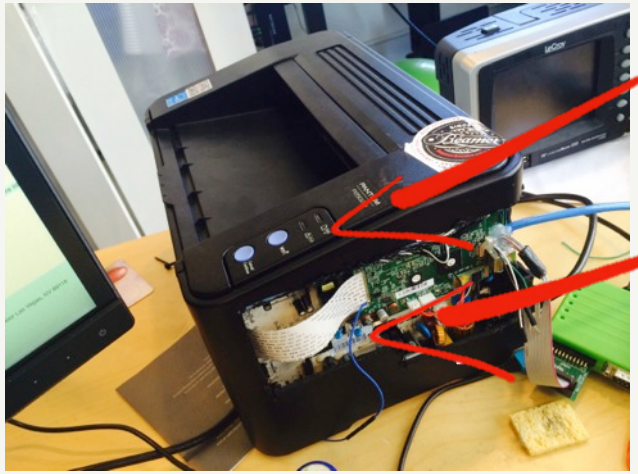
4 GPIO Banks, 121 pins in all



Funtenna In Practice (GPIO)

Input pins: Buttons, few sensors, switches

Funtenna In Practice (GPIO)



Output pins: LEDs, Engine Control, Power Control, Fuser Control, Toner Control and lots more!

Funtenna In Practice (GPIO)

Which pin to flip?


" Emanate like a "
scrub
Boss!

Funtenna In Practice (GPIO)

Which pin to flip? Every pin, at the same time!

Funtenna In Practice (GPIO)

OFF

On

Which pin to flip? Every pin, at the same time!

0x20 - Pin OFF
0x24 - Pin On

GPIO Bank A – Memory Mapped Control Registers

Funtenna In Practice (GPIO)

```
.equ all_p1mp, 0xffffffff
.equ gpio_bank_a_off_addr, 0xFD040020
.equ gpio_bank_b_off_addr, 0xF8040020
.equ gpio_bank_c_off_addr, 0xF8041020
.equ gpio_bank_d_off_addr, 0xF8042020
_loopy:
    LDR     R5, =all_p1mp
    LDR     R1, =gpio_bank_a_off_addr
    LDR     R2, =gpio_bank_b_off_addr
    LDR     R3, =gpio_bank_c_off_addr
    LDR     R4, =gpio_bank_d_off_addr
```

Funtenna In Practice (GPIO)

```
.equ all_p1mp, 0xffffffff
.equ gpio_bank_a_off_addr, 0xFD040020
.equ gpio_bank_b_off_addr, 0xF8040020
.equ gpio_bank_c_off_addr, 0xF8041020
.equ gpio_bank_d_off_addr, 0xF8042020
_loopy:
    LDR     R5, =all_p1mp
    LDR     R1, =gpio_bank_a_off_addr
    LDR     R2, =gpio_bank_b_off_addr
    LDR     R3, =gpio_bank_c_off_addr
    LDR     R4, =gpio_bank_d_off_addr
```

```
    STR     R5, [R1, #0x4]
    STR     R5, [R2, #0x4]
    STR     R5, [R3, #0x4]
    STR     R5, [R4, #0x4]
```

All Pins on

Funtenna In Practice (GPIO)

```
.equ all_p1mp, 0xffffffff
.equ gpio_bank_a_off_addr, 0xFD040020
.equ gpio_bank_b_off_addr, 0xF8040020
.equ gpio_bank_c_off_addr, 0xF8041020
.equ gpio_bank_d_off_addr, 0xF8042020
_loopy:
    LDR     R5, =all_p1mp
    LDR     R1, =gpio_bank_a_off_addr
    LDR     R2, =gpio_bank_b_off_addr
    LDR     R3, =gpio_bank_c_off_addr
    LDR     R4, =gpio_bank_d_off_addr
```

```
    STR     R5, [R1, #0x4]
    STR     R5, [R2, #0x4]
    STR     R5, [R3, #0x4]
    STR     R5, [R4, #0x4]
```

```
    STR     R5, [R1]
    STR     R5, [R2]
    STR     R5, [R3]
    STR     R5, [R4]
```

All Pins off

Funtenna In Practice (GPIO)

```
.equ all_p1mp, 0xffffffff
.equ gpio_bank_a_off_addr, 0xFD040020
.equ gpio_bank_b_off_addr, 0xF8040020
.equ gpio_bank_c_off_addr, 0xF8041020
.equ gpio_bank_d_off_addr, 0xF8042020
_loopy:
    LDR     R5, =all_p1mp
    LDR     R1, =gpio_bank_a_off_addr
    LDR     R2, =gpio_bank_b_off_addr
    LDR     R3, =gpio_bank_c_off_addr
    LDR     R4, =gpio_bank_d_off_addr
```

```
    STR     R5, [R1, #0x4]
    STR     R5, [R2, #0x4]
    STR     R5, [R3, #0x4]
    STR     R5, [R4, #0x4]
```

All Pins on

```
    STR     R5, [R1]
    STR     R5, [R2]
    STR     R5, [R3]
    STR     R5, [R4]
```

Funtenna In Practice (GPIO)

```
.equ all_p1mp, 0xffffffff
.equ gpio_bank_a_off_addr, 0xFD040020
.equ gpio_bank_b_off_addr, 0xF8040020
.equ gpio_bank_c_off_addr, 0xF8041020
.equ gpio_bank_d_off_addr, 0xF8042020
_loopy:
    LDR     R5, =all_p1mp
    LDR     R1, =gpio_bank_a_off_addr
    LDR     R2, =gpio_bank_b_off_addr
    LDR     R3, =gpio_bank_c_off_addr
    LDR     R4, =gpio_bank_d_off_addr
```

```
    STR     R5, [R1, #0x4]
    STR     R5, [R2, #0x4]
    STR     R5, [R3, #0x4]
    STR     R5, [R4, #0x4]
```

All Pins on

```
    STR     R5, [R1]
    STR     R5, [R2]
    STR     R5, [R3]
    STR     R5, [R4]
```

F = Approx 5mhz

Funtenna In Practice (GPIO)

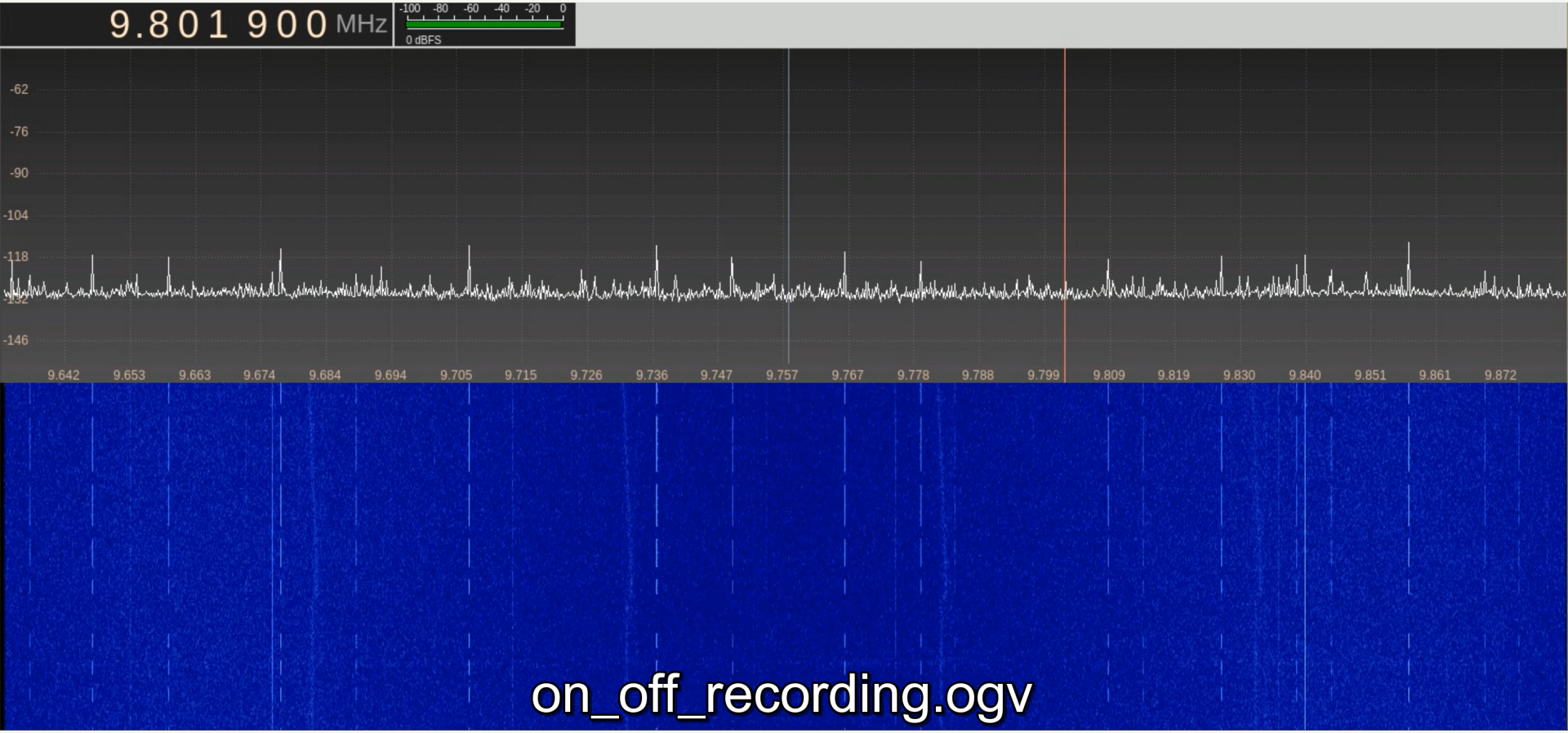
F = Approx 5mhz

And things get really interesting

Funtenna In Practice

Funtenna Demo 2: ALL GPIO Funtenna - On Off Keying

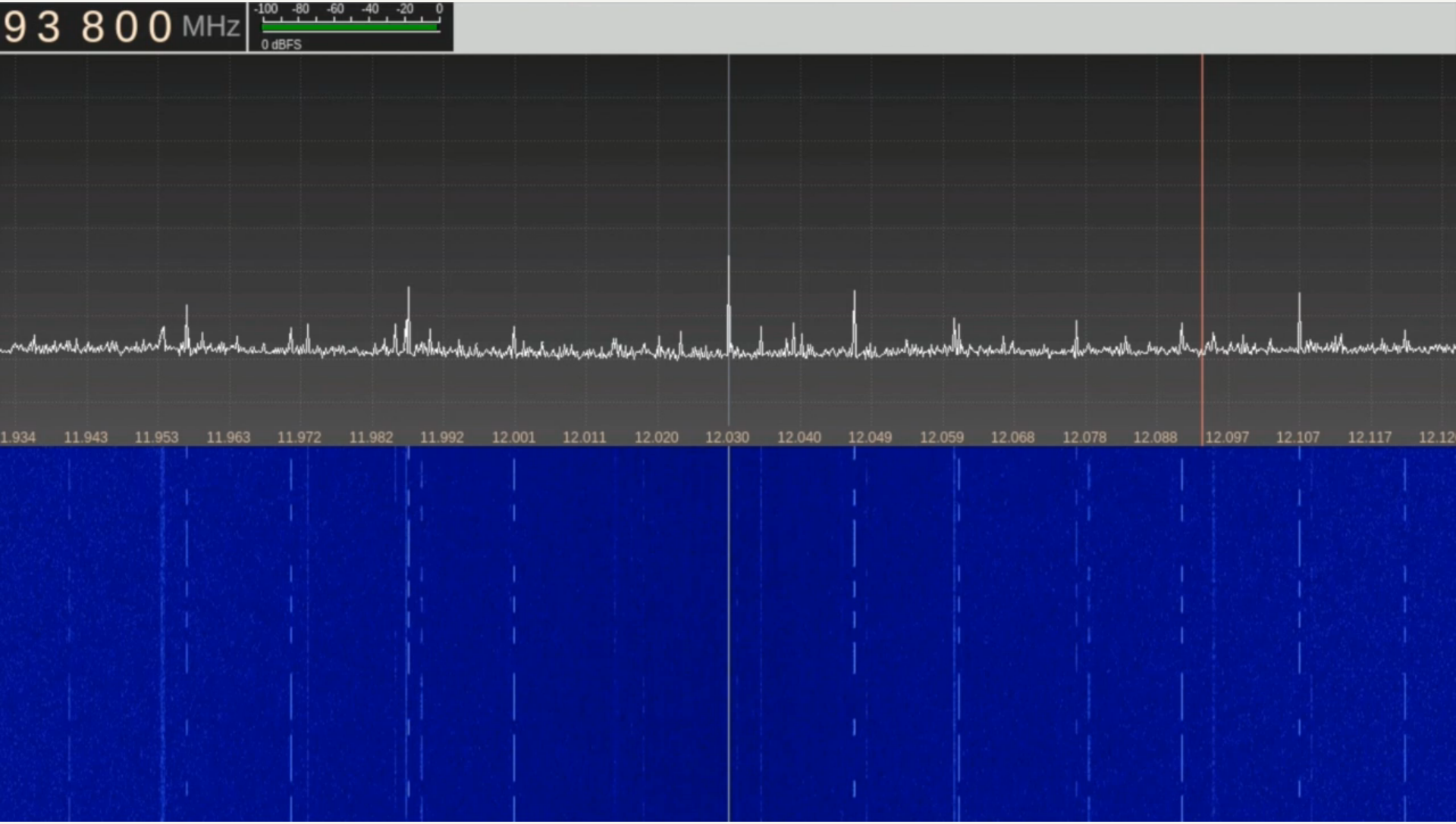
Funtenna Demo 2: ALL GPIO Funtenna - On Off Keying



Funtenna In Practice

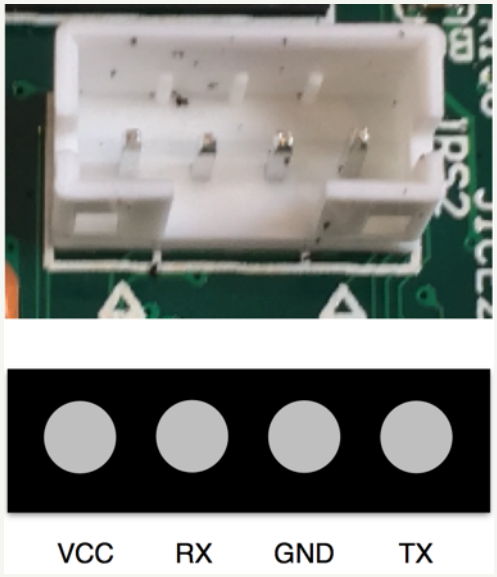
Funtenna Demo 2: ALL GPIO Funtenna - Freq Shift Keying (sort of)

Funtenna Demo 2: ALL GPIO Funtenna - Freq Shift Keying (sort of)



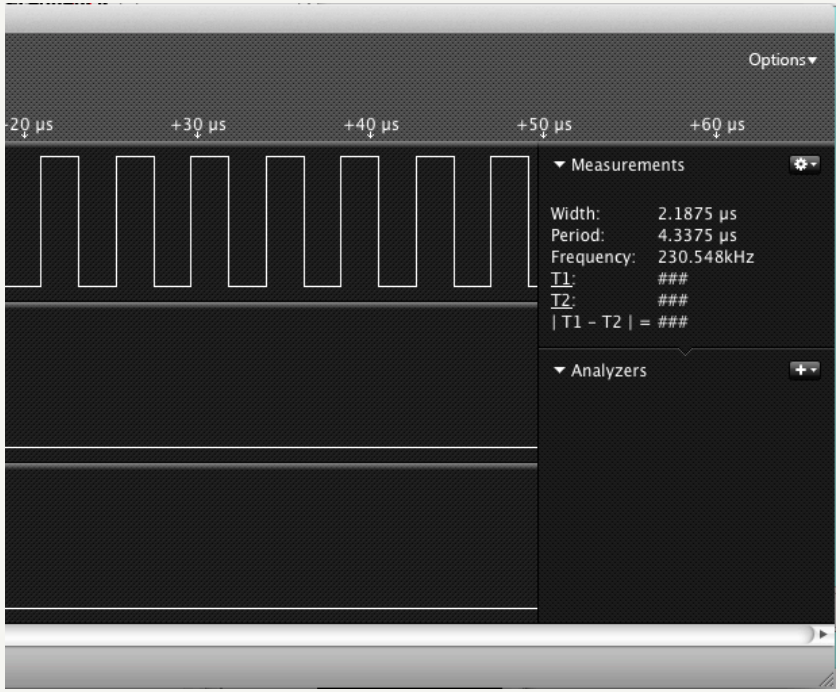
Funtenna In Practice

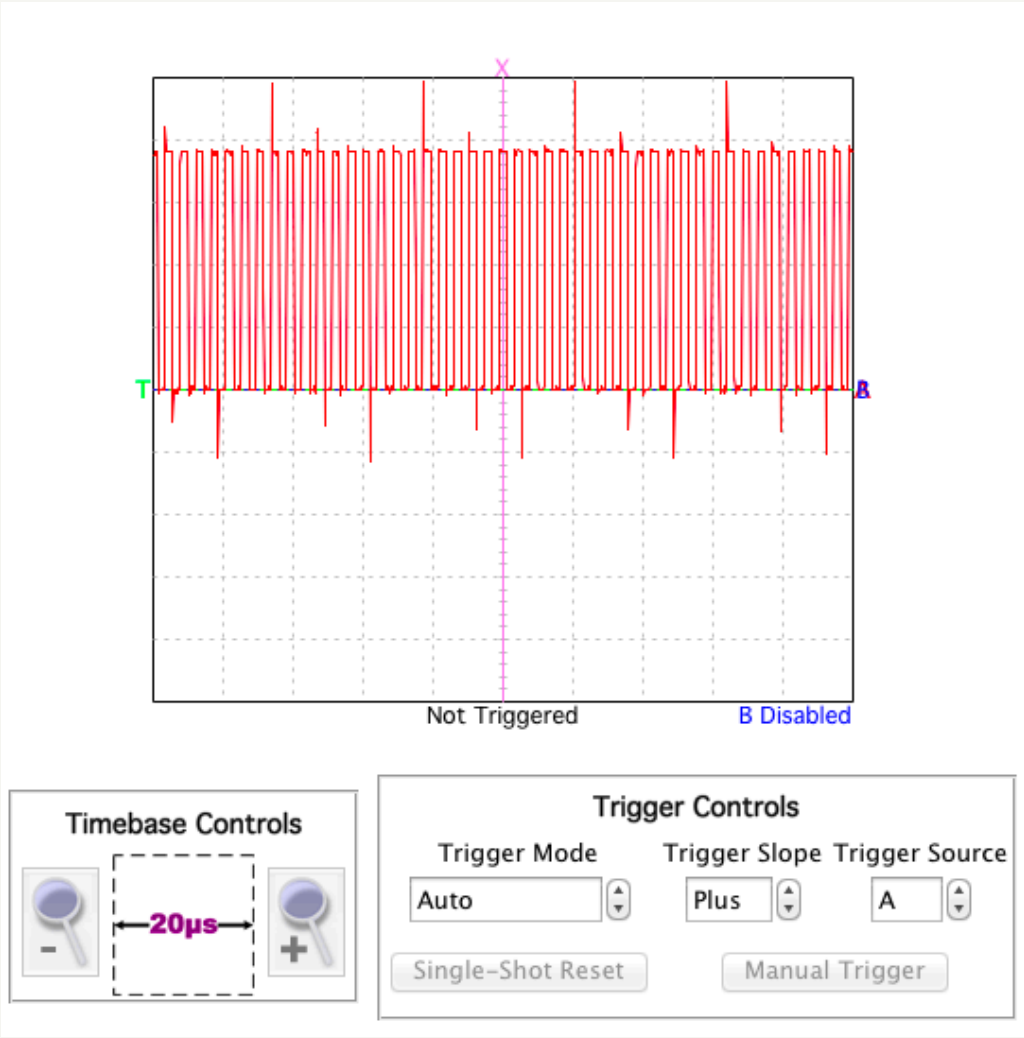
Pantum P2502W Wireless Monochrome Laser Printer



UART Funtenna

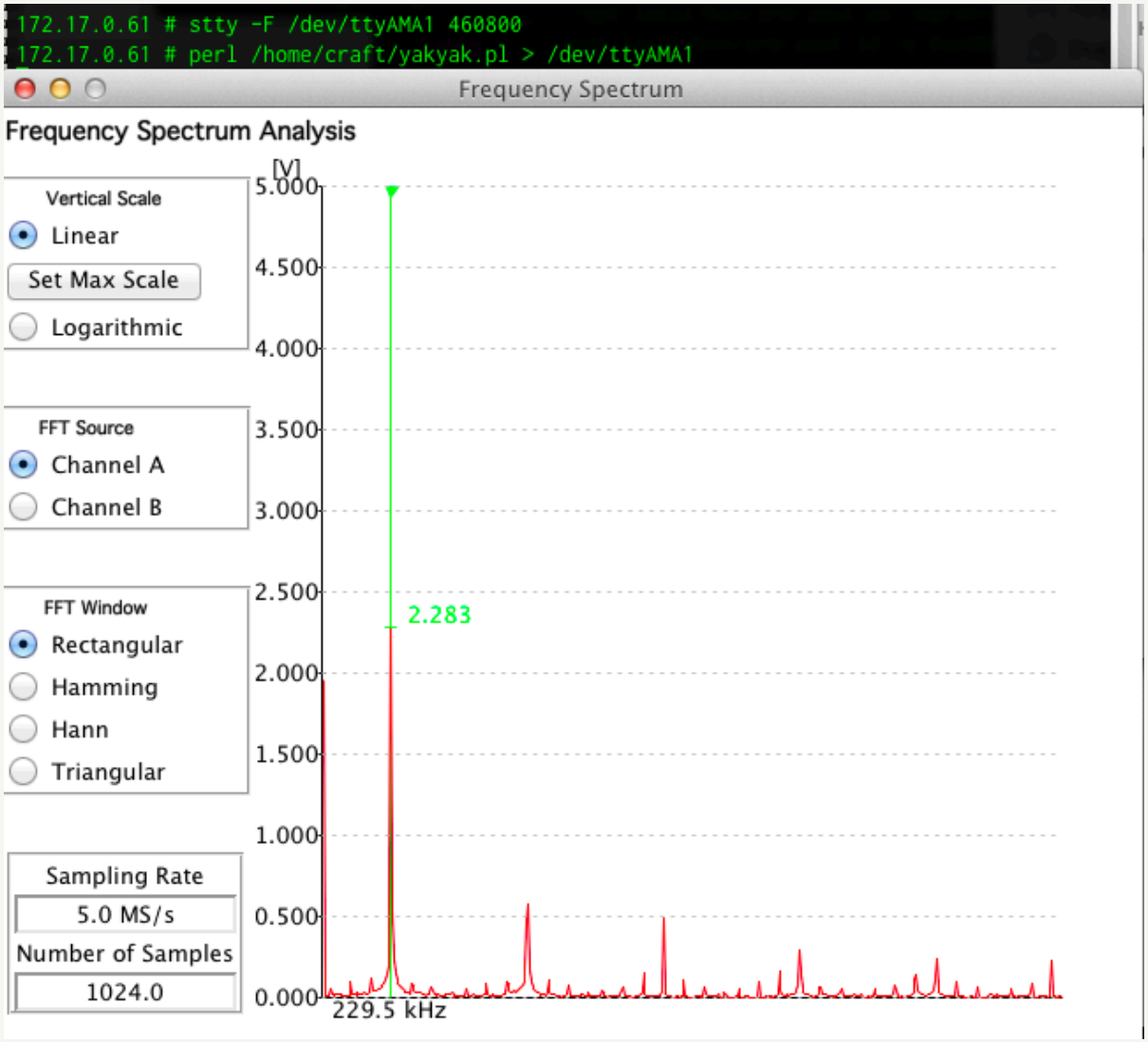
UART Funtenna 460800 baud



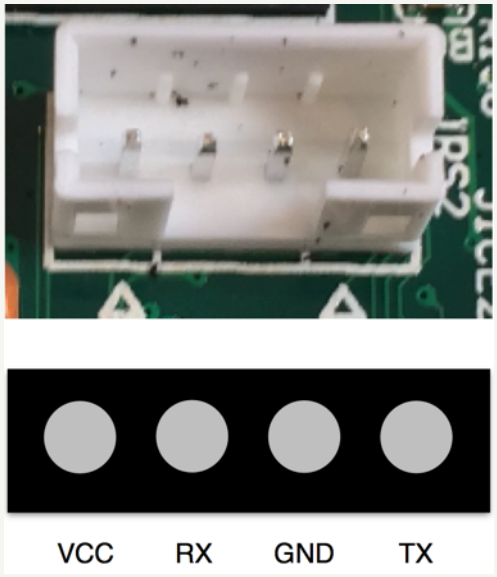


"UUUUUUUUUUUU"

UART Funtenna 460800 baud



Funtenna In Practice

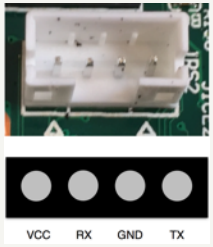


Let's be more sneaky…

Funtenna In Practice

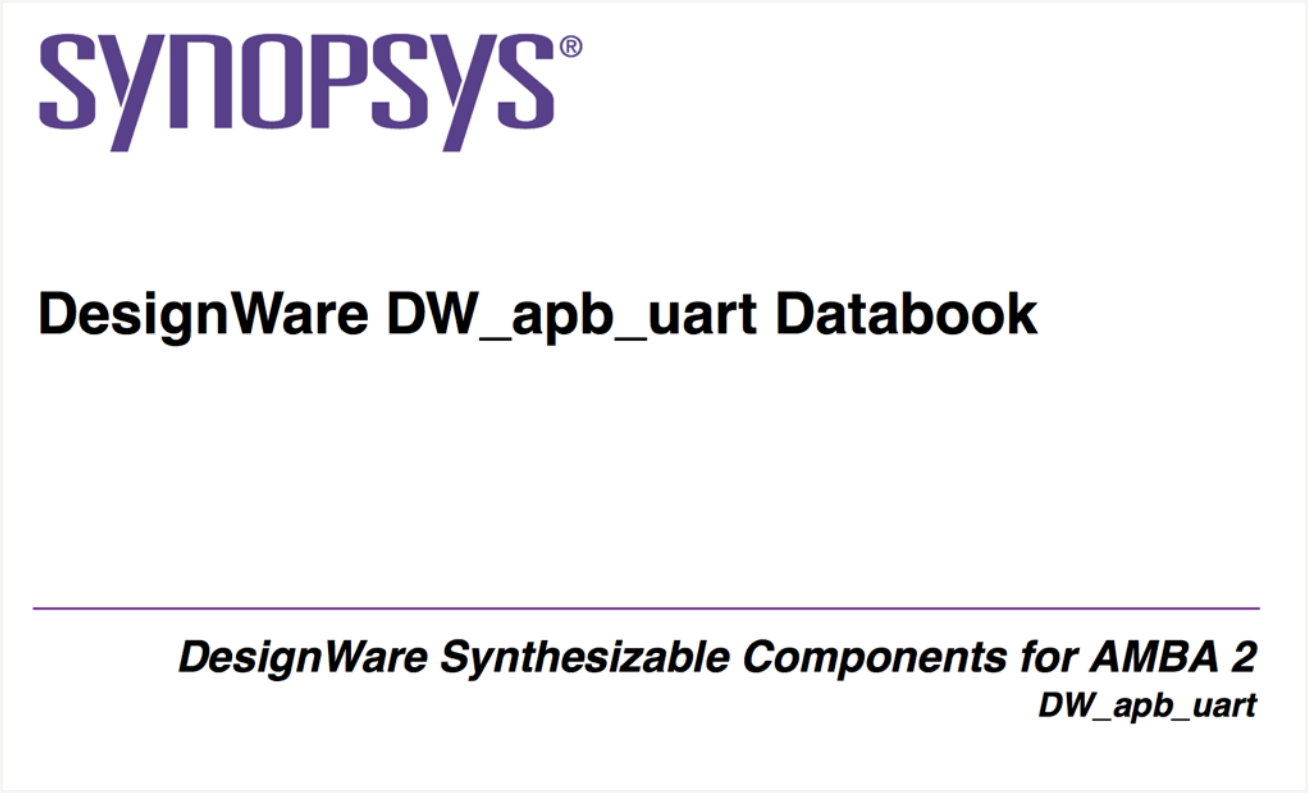
```
LDR             R3, =asc_1121944 ; "/home/lihaixiong/source/common/devices/"...
BL              sub_49F668
MOV             R3, R0
MOV             R2, R3
LDR             R3, =dword_EC6
STR             R2, [R3]
```

```
asc_1121944     DCB "/home/lihaixiong/source/common/dev"
                DCB "ices/uart/dwapb/src/dw_apb_uart.c",0
```



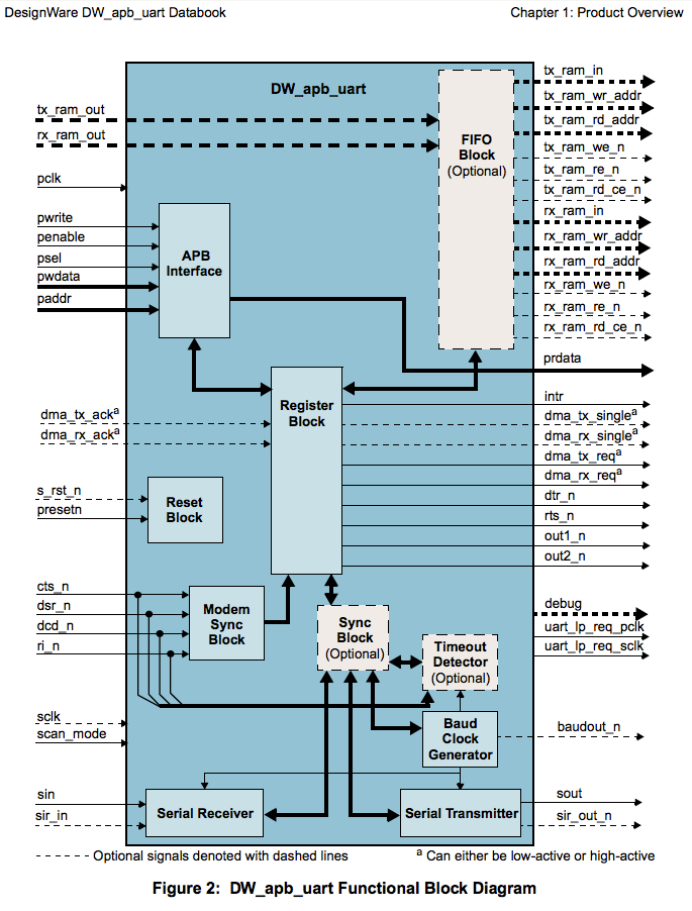
dw_apb_uart.c

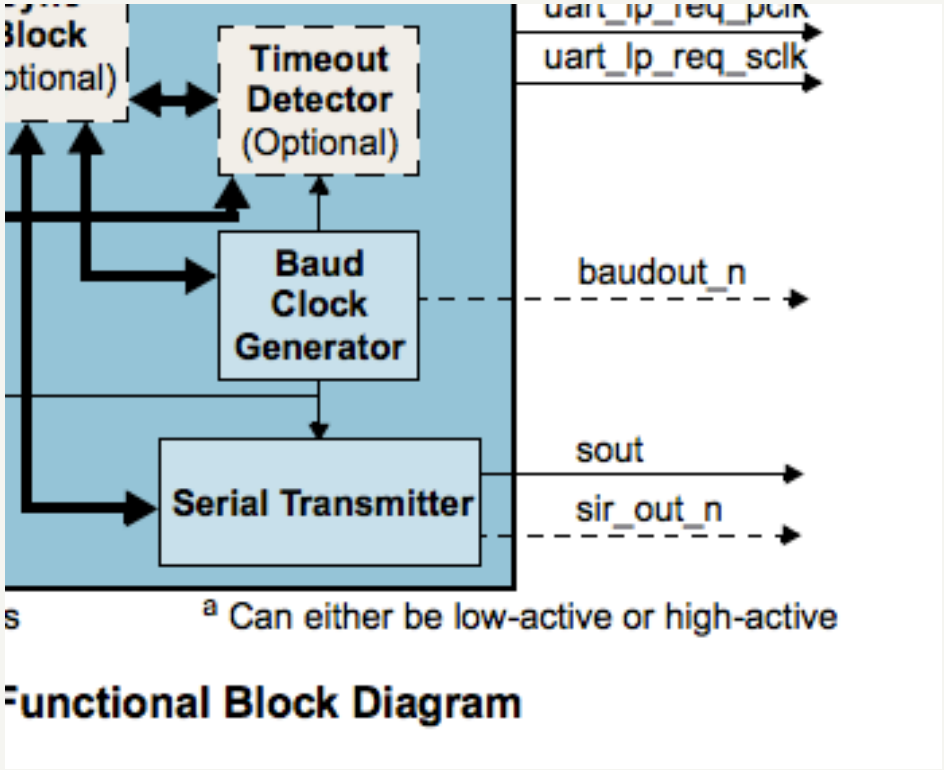
Funtenna In Practice



dw_apb_uart.c

Funtenna In Practice



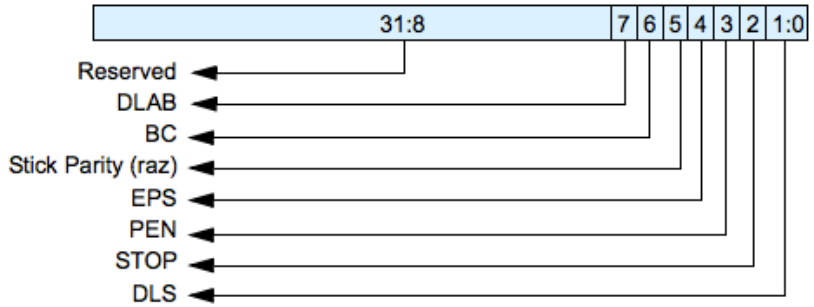


FLIP sout pin

Step 1: UART Break-Ctrl Bit -> 1

LCR

- **Name:** Line Control Register
- **Size:** 32 bits
- **Address Offset:** 0x0C
- **Read/write access:** read/write



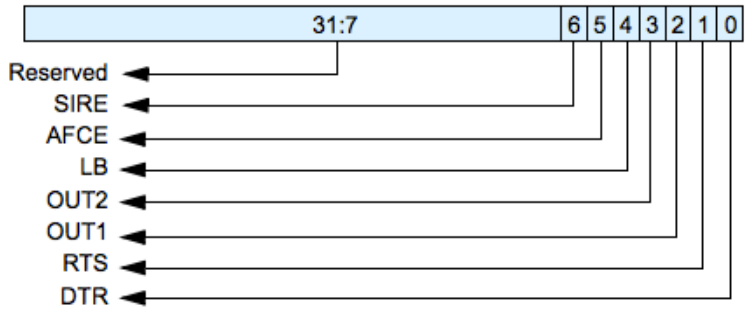
6	Break (or BC)	R/W	Break Control Bit.This is used to cause a break condition to be transmitted to the receiving device. If set to one the serial output is forced to the spacing (logic 0) state. When not in Loopback Mode, as determined by MCR[4], the sout line is forced low until the Break bit is cleared. If SIR_MODE == Enabled and active (MCR[6] set to one) the sir_out_n line is continuously pulsed. When in Loopback Mode, the break condition is internally looped back to the receiver and the sir_out_n line is forced low. **Reset Value:** 0x0

FLIP sout pin

Step 2: UART Loopback bit -> 1

MCR

- **Name:** Modem Control Register
- **Size:** 32 bits
- **Address Offset:** 0x10
- **Read/write access:** read/write



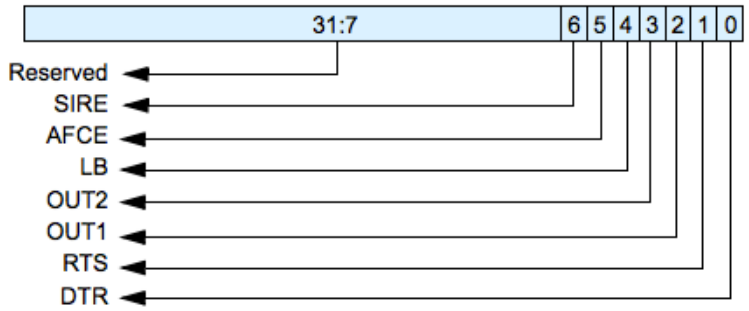
4	LoopBack (or LB)	R/W	LoopBack Bit. This is used to put the UART into a diagnostic mode for test purposes. If operating in UART mode (SIR_MODE != Enabled or not active, MCR[6] set to zero), data on the sout line is held high, while serial data output is looped back to the sin line, internally. In this mode all the interrupts are fully functional. Also, in loopback mode, the modem control inputs (dsr_n, cts_n, ri_n, dcd_n) are disconnected and the modem control outputs (dtr_n, rts_n, out1_n, out2_n) are looped back to the inputs, internally. If operating in infrared mode (SIR_MODE == Enabled AND active, MCR[6] set to one), data on the sir_out_n line is held low, while serial data output is inverted and looped back to the sir_in line. **Reset Value:** 0x0

FLIP sout pin

Step 3: UART Loopback bit -> 0

MCR

- **Name:** Modem Control Register
- **Size:** 32 bits
- **Address Offset:** 0x10
- **Read/write access:** read/write



4	LoopBack (or LB)	R/W	LoopBack Bit. This is used to put the UART into a diagnostic mode for test purposes. If operating in UART mode (SIR_MODE != Enabled or not active, MCR[6] set to zero), data on the sout line is held high, while serial data output is looped back to the sin line, internally. In this mode all the interrupts are fully functional. Also, in loopback mode, the modem control inputs (dsr_n, cts_n, ri_n, dcd_n) are disconnected and the modem control outputs (dtr_n, rts_n, out1_n, out2_n) are looped back to the inputs, internally. If operating in infrared mode (SIR_MODE == Enabled AND active, MCR[6] set to one), data on the sir_out_n line is held low, while serial data output is inverted and looped back to the sir_in line. **Reset Value:** 0x0

FLIP sout pin

Funtenna In Practice (UART)

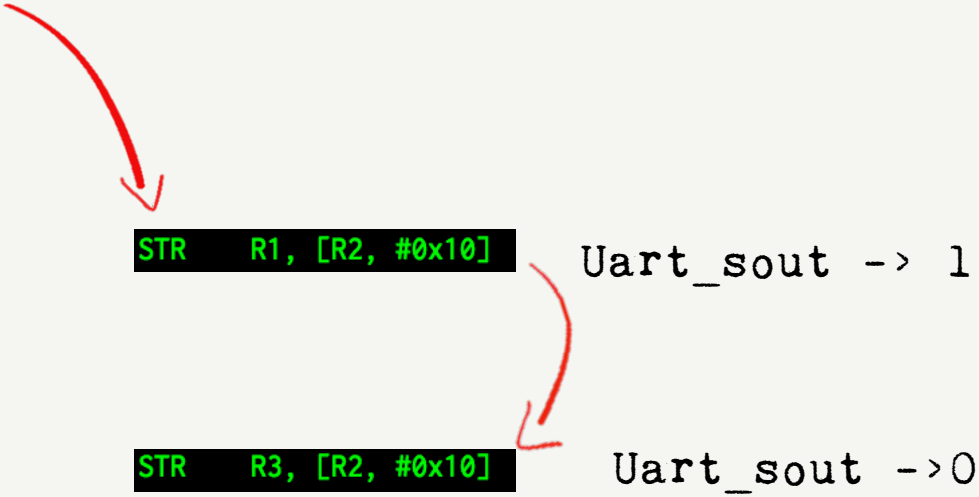
```
.equ uart_conf_reg, 0xFD060000
    @ set BREAK bit to force SOUT to low
    MOV     R1, #0x43
    LDR     R2, =uart_conf_reg
    STR     R1, [R2, #0xc]
    MOV     R1, #0x23
    MOV     R3, #0x33
```

```
STR     R1, [R2, #0x10]
```

Uart_sout -> 1

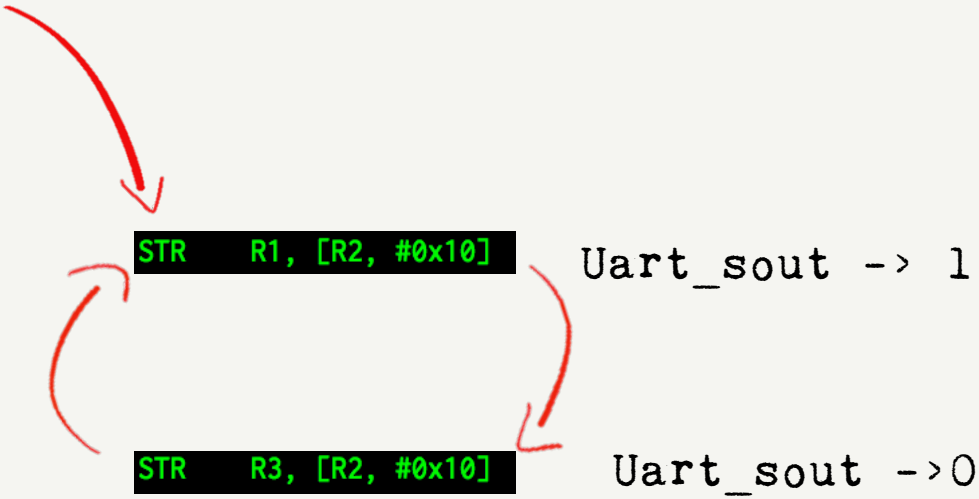
Funtenna In Practice (UART)

```
.equ uart_conf_reg, 0xFD060000
    @ set BREAK bit to force SOUT to low
    MOV     R1, #0x43
    LDR     R2, =uart_conf_reg
    STR     R1, [R2, #0xc]
    MOV     R1, #0x23
    MOV     R3, #0x33
```



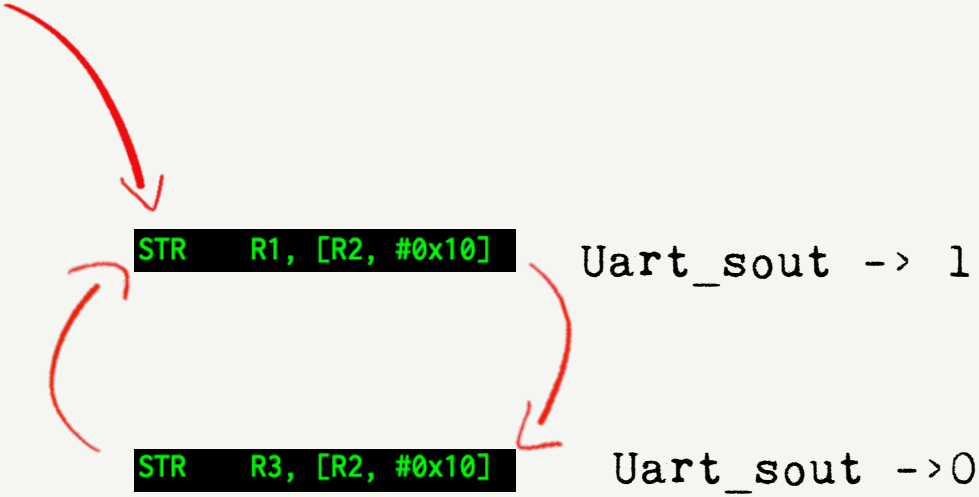
Funtenna In Practice (UART)

```
.equ uart_conf_reg, 0xFD060000
    @ set BREAK bit to force SOUT to low
    MOV     R1, #0x43
    LDR     R2, =uart_conf_reg
    STR     R1, [R2, #0xc]
    MOV     R1, #0x23
    MOV     R3, #0x33
```



Funtenna In Practice (UART)

```
.equ uart_conf_reg, 0xFD060000
   @ set BREAK bit to force SOUT to low
   MOV     R1, #0x43
   LDR     R2, =uart_conf_reg
   STR     R1, [R2, #0xc]
   MOV     R1, #0x23
   MOV     R3, #0x33
```



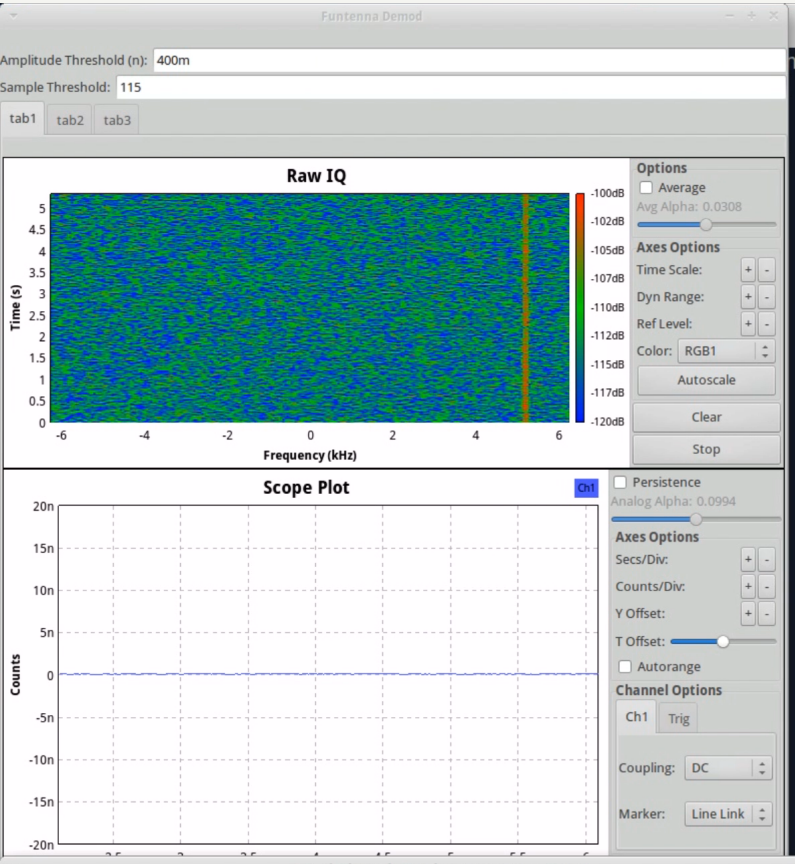
F = Approx 500khz

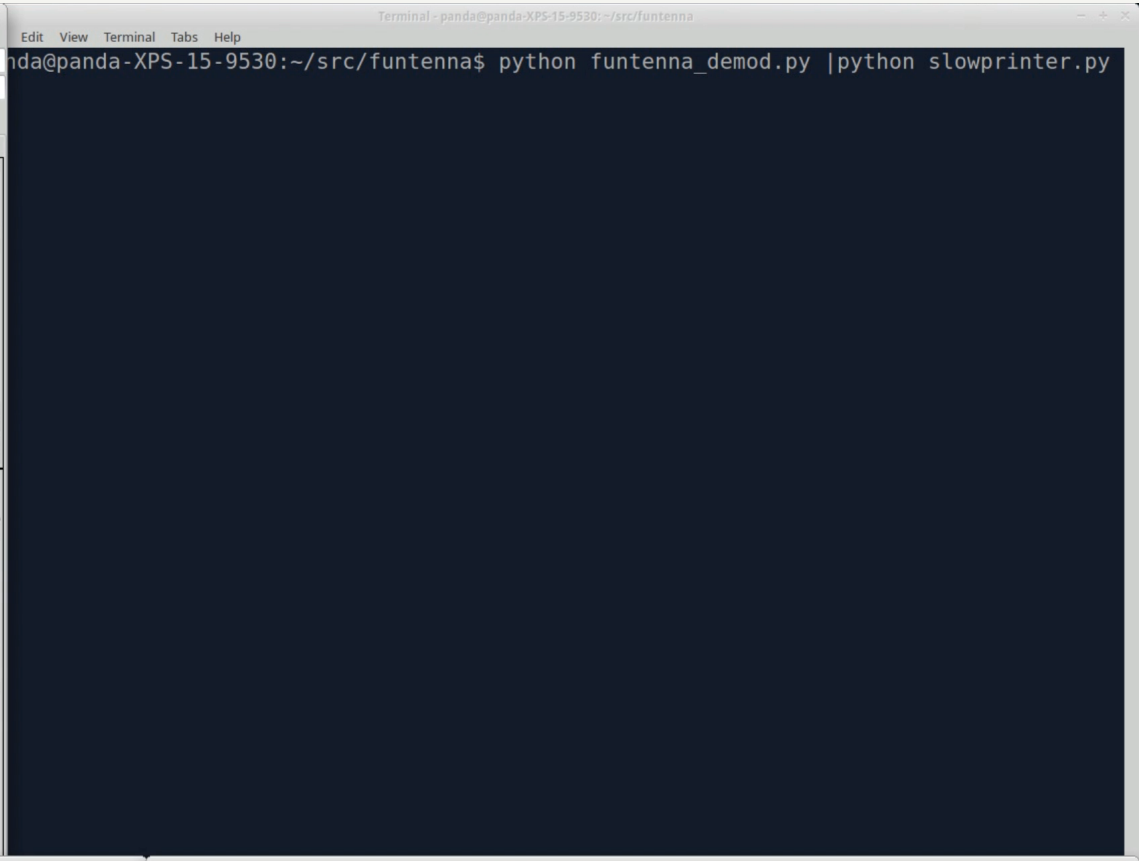
Funtenna In Practice

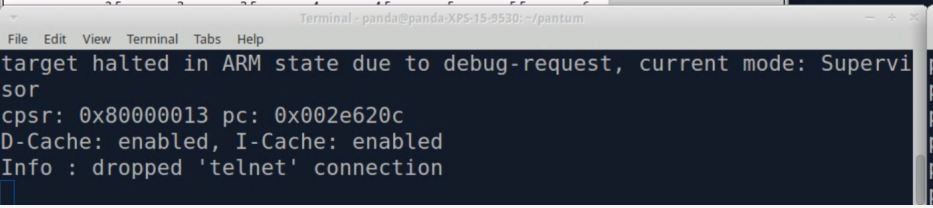
Funtenna Demo 2: UART, On Off Keying

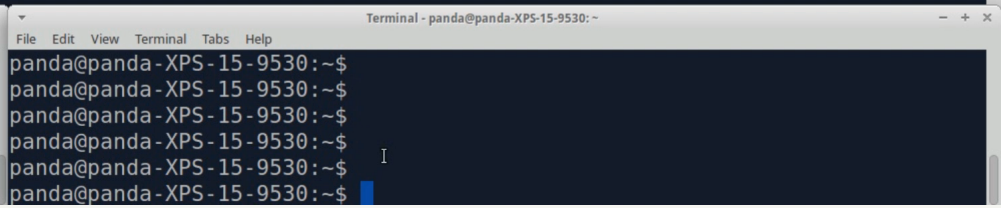
UART Pin, 10 feet of console cable

Funtenna Demo 2: UART FUNTENNA DEMOD









Take Away

- Funtenna works
- Network IDS is no substitute for host-based defense
- Host-based embedded defense important!

Big Thanks!

Chris Evans

Big Thanks!

Joseph Pantoga

Big Thanks!

Kang-Wei Chang

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Backup slides

Funtenna In Practice (GPIO)

Which pin to flip? Every pin, at the same time!

Memory Mapped Registers

0x1600D58 <- Contains GPIO Bank & Register List

GPIO bank A - 0x1600DA8 MEMREG 0xFD040000
GPIO bank B - 0x16011B8 MEMREG 0xF8040000
GPIO bank C - 0x16015C8 MEMREG 0xF8041000
GPIO bank D - 0x16019D8 MEMREG 0xF8042000

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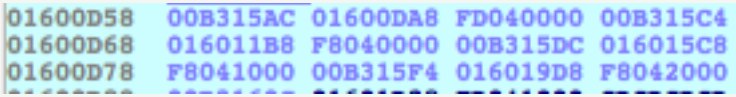

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```
01600D58  00B315AC 01600DA8 FD040000 00B315C4
01600D68  016011B8 F8040000 00B315DC 016015C8
01600D78  F8041000 00B315F4 016019D8 F8042000
```

```
01600DA8  4750494F 01600D58 CDCDCD00 FD040080  OIPGX.`
01600DB8  CDCDCD00 00000000 00000000 CDCDCDCD  ........
01600DC8  4750494F 01600D58 CDCDCD00 FD040084  OIPGX.`
01600DD8  CDCDCD00 00000001 00000000 CDCDCDCD  ........
01600DE8  4750494F 01600D58 CDCDCD00 FD040088  OIPGX.`
01600DF8  CDCDCD00 00000002 00000000 CDCDCDCD  ........
01600E08  4750494F 01600D58 CDCDCD01 FD04008C  OIPGX.`
01600E18  CDCDCD00 00000003 00000000 CDCDCDCD  ........
01600E28  4750494F 01600D58 CDCDCD01 FD040090  OIPGX.`
01600E38  CDCDCD00 00000004 00000000 CDCDCDCD  ........
01600E48  4750494F 01600D58 CDCDCD00 FD040094  OIPGX.`
01600E58  CDCDCD00 00000005 00000000 CDCDCDCD  ........
01600E68  4750494F 01600D58 CDCDCD01 FD040098  OIPGX.`
01600E78  CDCDCD00 00000006 00000001 00000000  ........
01600E88  4750494F 01600D58 CDCDCD00 FD04009C  OIPGX.`
```

GPIO Bank A