

COMPROMISING ELECTROMAGNETIC EMANATIONS OF WIRED AND WIRELESS KEYBOARDS

EPFL/LASEC/USENIX SECURITY'09

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**MODERN KEYBOARDS RADIATE
COMPROMISING ELECTROMAGNETIC
EMANATIONS**

**THESE EMISSIONS LED TO A FULL OR
A PARTIAL RECOVERY OF THE
KEYSTROKES AT A DISTANCE UP TO
20 METERS**

FULL SPECTRUM ACQUISITION METHOD

FOUR SOURCES OF INFORMATION LEAKAGE FROM KEYBOARDS

EXPLOITATION IN DIFFERENT SCENARIOS

WHY COMPUTER KEYBOARDS?



KEYBOARDS

MAIN INPUT DEVICE/PASSWORD

KEYBOARDS

SECURITY IS NOT A PRIORITY

KEYBOARDS

ALICE TYPES ON HER KEYBOARD...

KEYBOARDS

WHY ELECTROMAGNETIC EMANATIONS?

Bell 131-B2 Mar 1, 1944



- Bell 131-B2 mixing devices
- Encrypt teletypewriter communications with one time pad
- When a key is pressed, a peak appears
- Recover the plaintext at more than 25 meters away.



Project MOGUL was first conceived by Dr. Maurice Ewing of Columbia University and Woods Hole Oceanographic Institution, MA. Dr. Ewing had conducted considerable research for the Navy during World War II, studying, among other things, the "sound channel" in the ocean. He proved that explosions could be heard thousands of miles away with underwater microphones placed at a predetermined depth within the sound channel. He theorized that since sound waves generated by explosions could be carried by currents deep within the ocean, they might be similarly transmitted within a sound channel in the upper atmosphere. The military application of this theory was the long-range detection of sound waves generated by Soviet nuclear detonations or acoustical signatures of ballistic missiles traversed the upper

Japan Carries Out Terrible Bombings
Jan 1, 1962



Some strange antennas (Yagi) are discovered from one side of building (hospital) focused on a U.S. cryptocenter

Ignor White (Vietnam War)
Jan 1, 1968 - Feb 1, 1973



Operation Ignor White was a covert United States Air Force electronic warfare operation conducted from late January 1968 until February 1973, during the Vietnam War. The operation utilized electronic warfare, computers, and communications relay aircraft in an attempt to disrupt North Vietnamese intelligence collection. The system would then assist in the direction of strike aircraft to their targets. The objective of these attacks was the logical extension of the People's Army of Vietnam (PAVN) that was known as the Ho Chi Minh Trail line running from Laos to the North Vietnamese.



See World War II



See World War II



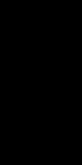
See World War II



See World War II



See World War II



See World War II

Markus Kuhn
Dec 1, 2003



Compromising Emanations:
Eavesdropping Risks of Computer
Displays.

Dmitri Asonov and Rakesh Agrawal
Jan 1, 2005



Keyboard Acoustic Emanations.

Davide Balzarotti, Marco Cova, and Giovanni Vigna
May 28, 2008



ClearShot: Eavesdropping on Keyboard
Input from Video.

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Information Theft by
Magnetic Radiation

2005

2010

2015

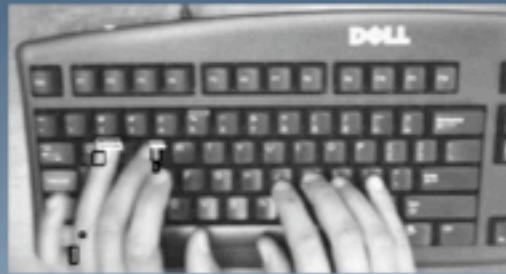
2020

Dmitri Asonov and Rakesh Agrawal
Jan 1, 2005



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2005

2010

2015

2020

ELECTROMAGNETIC COMPATIBILITY

CONDUCTIVE

RADIATIVE

ELECTROMAGNETIC COMPATIBILITY

CONDUCTIVE

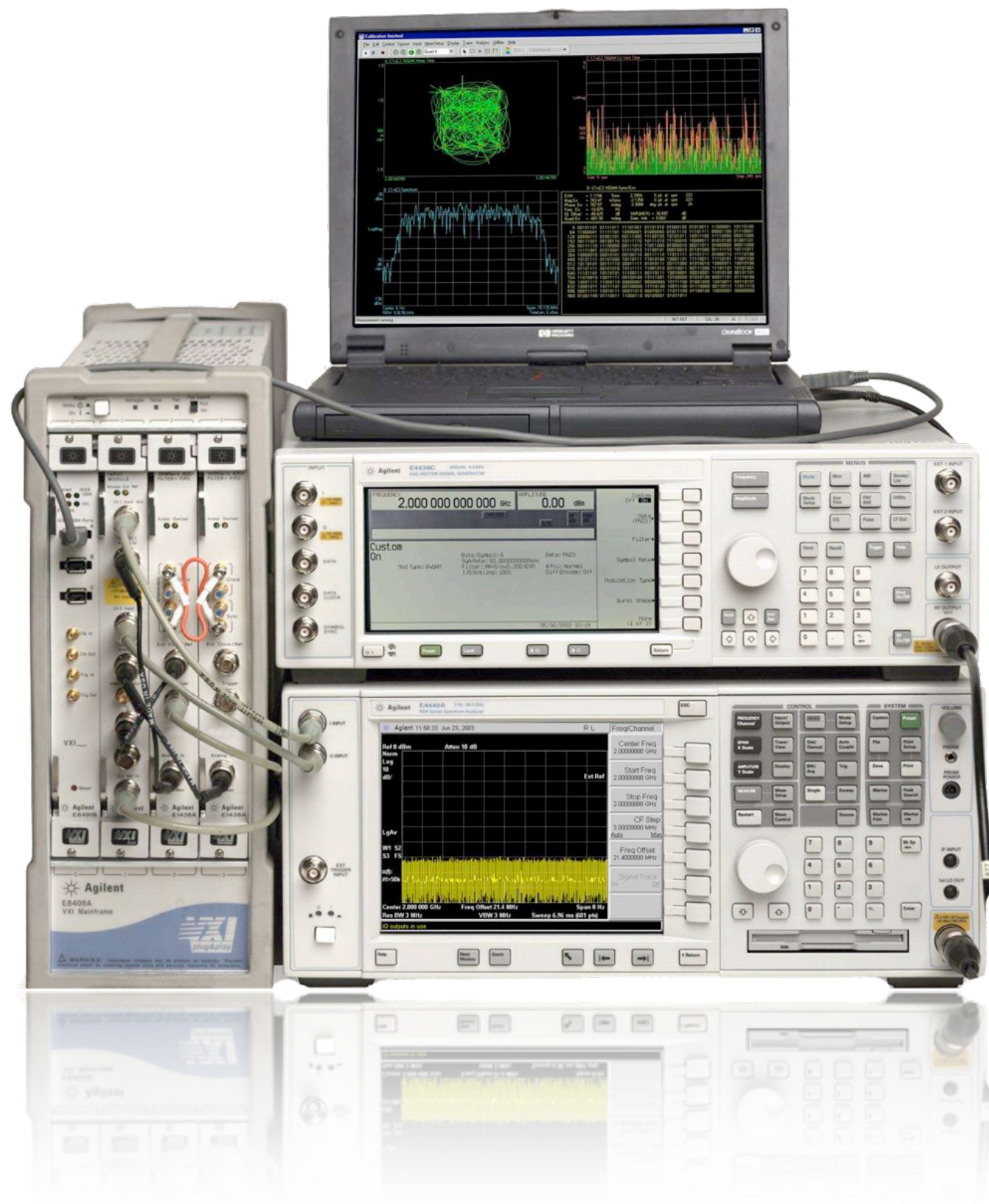
RADIATIVE

ATTACKER'S POINT OF VIEW

DIRECT EMANATIONS

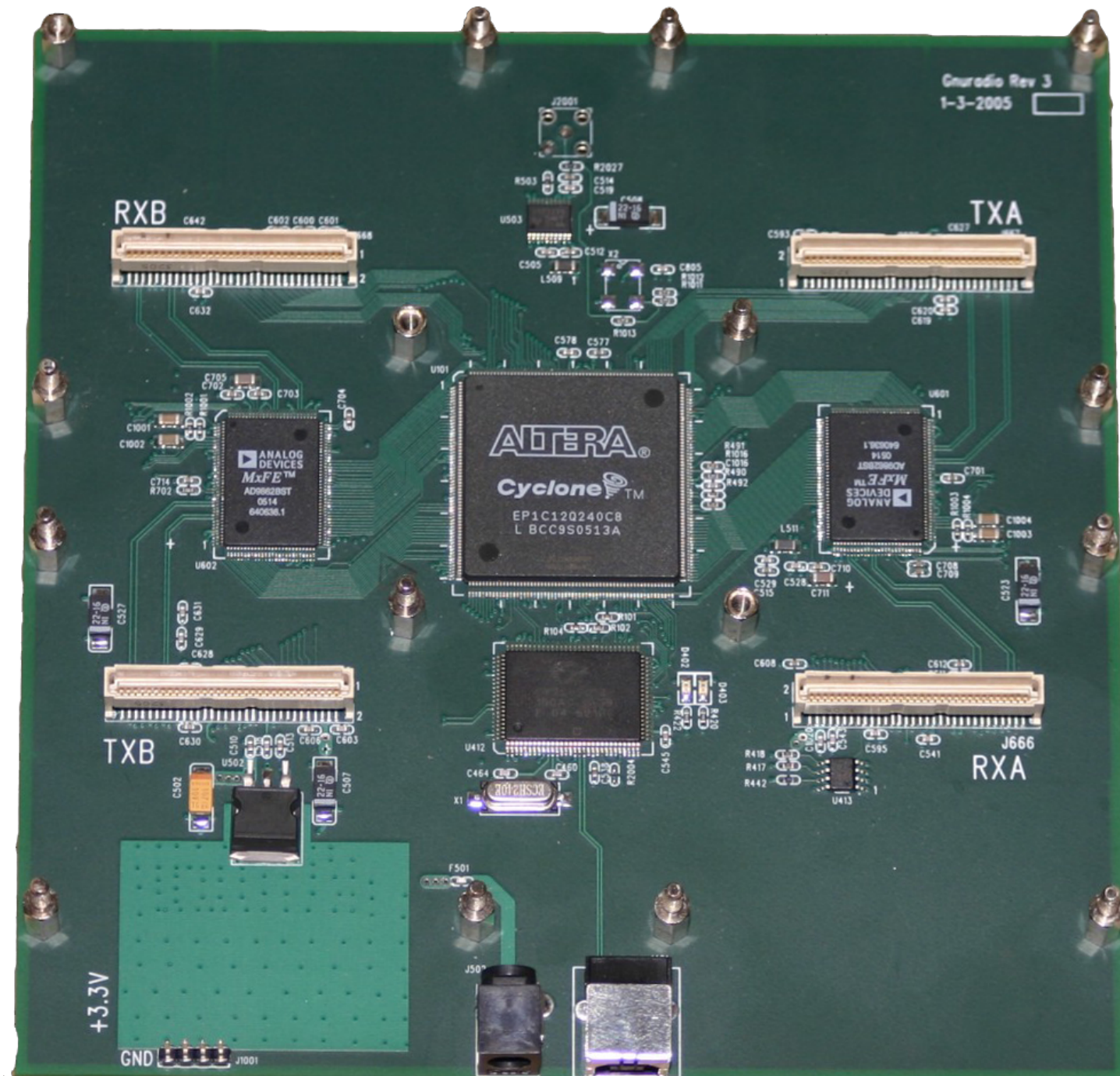
INDIRECT EMANATIONS

HOW TO DETECT COMPROMISING ELECTROMAGNETIC EMANATIONS?



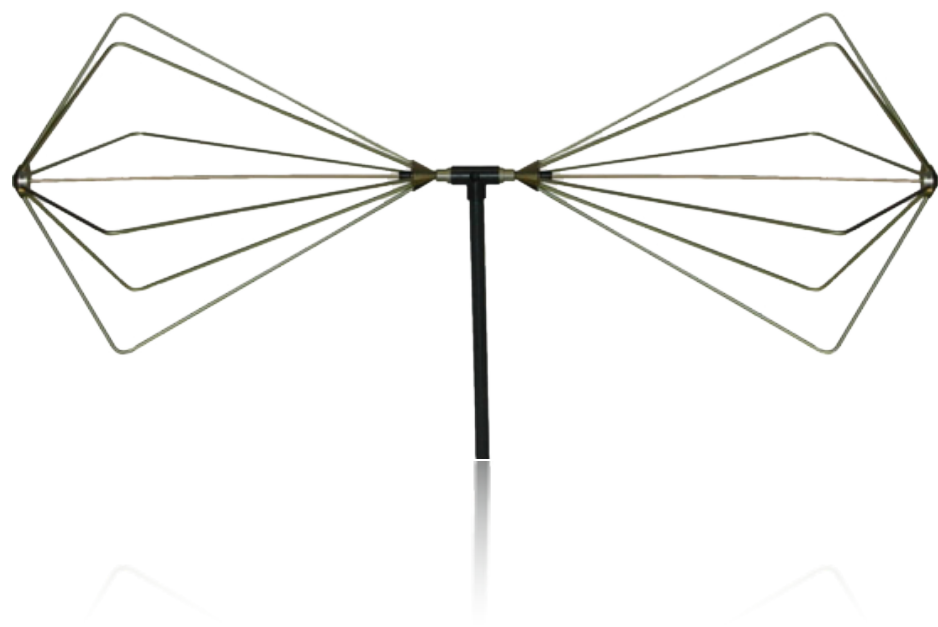


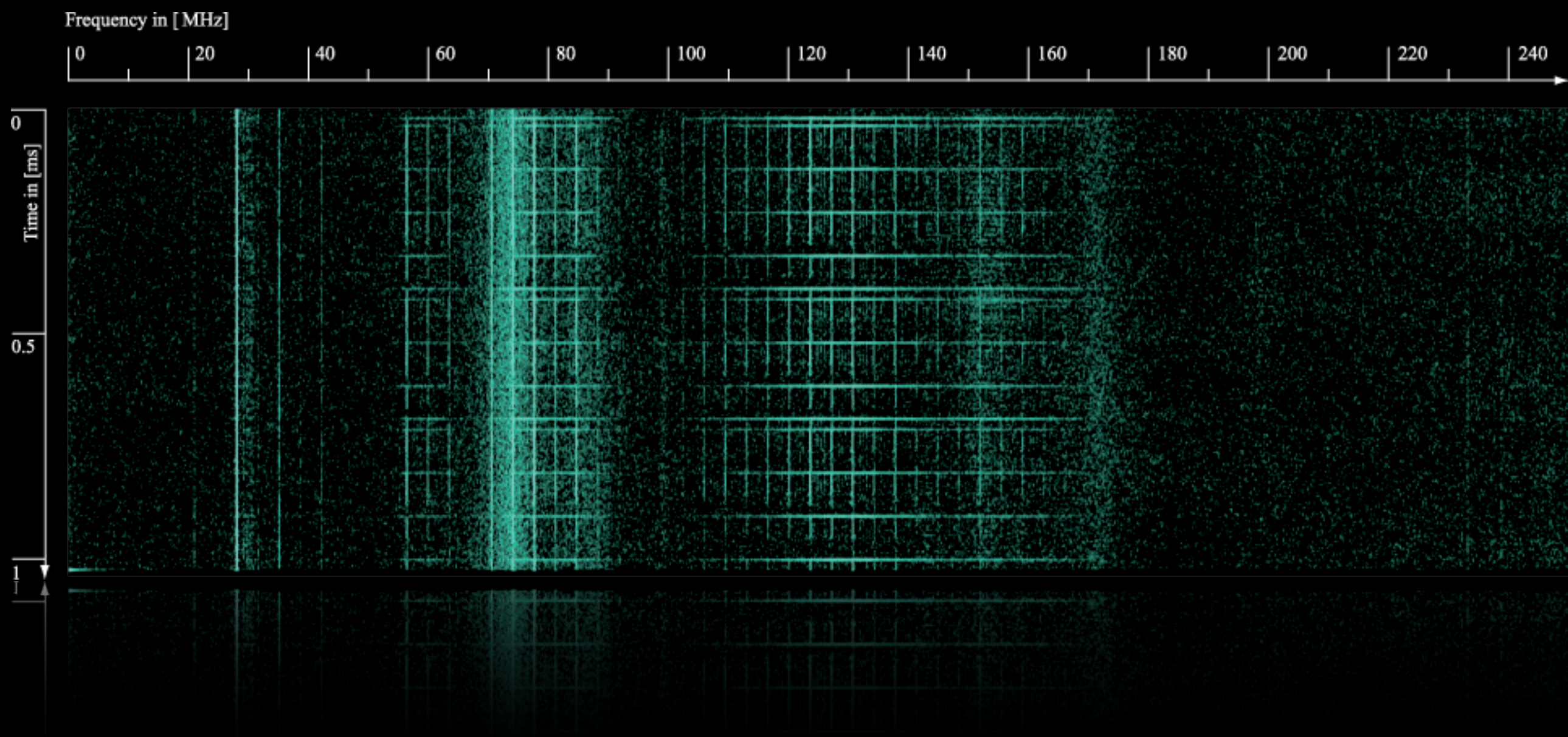




FULL SPECTRUM ACQUISITION METHOD

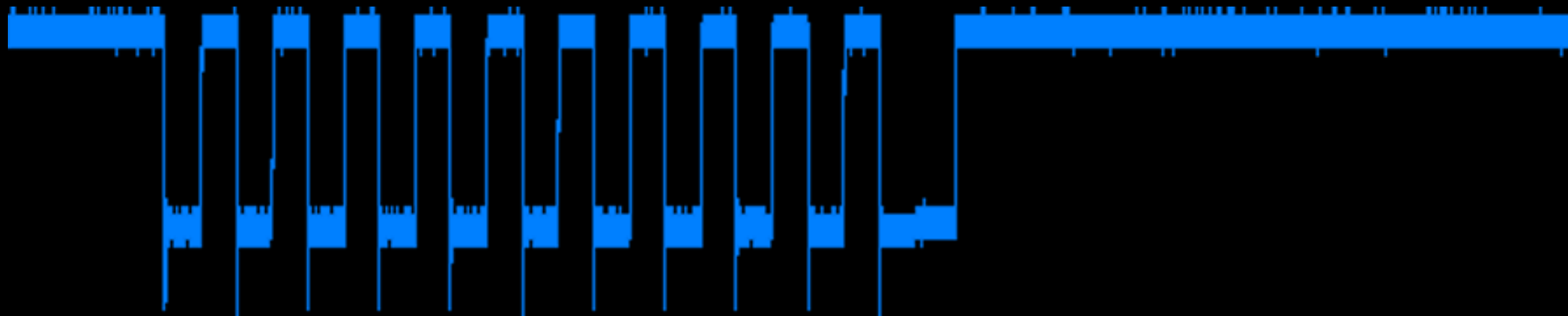




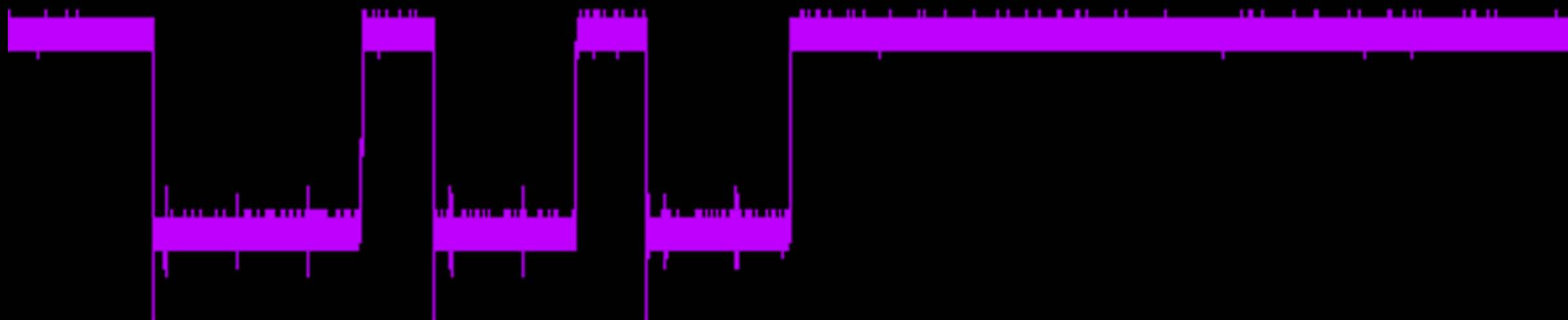


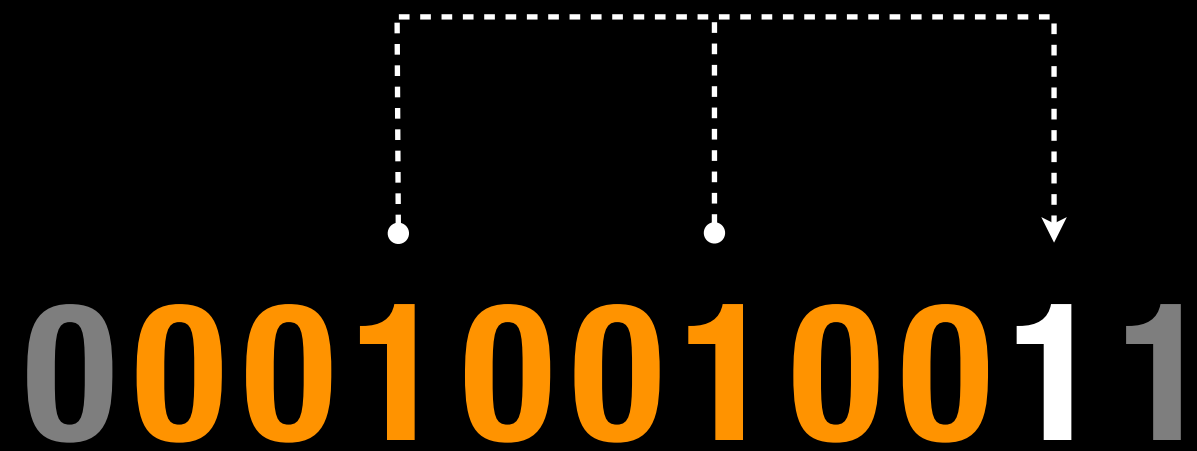
HOW TO DETECT COMPROMISING SIGNALS?

DIRECT EMANATIONS

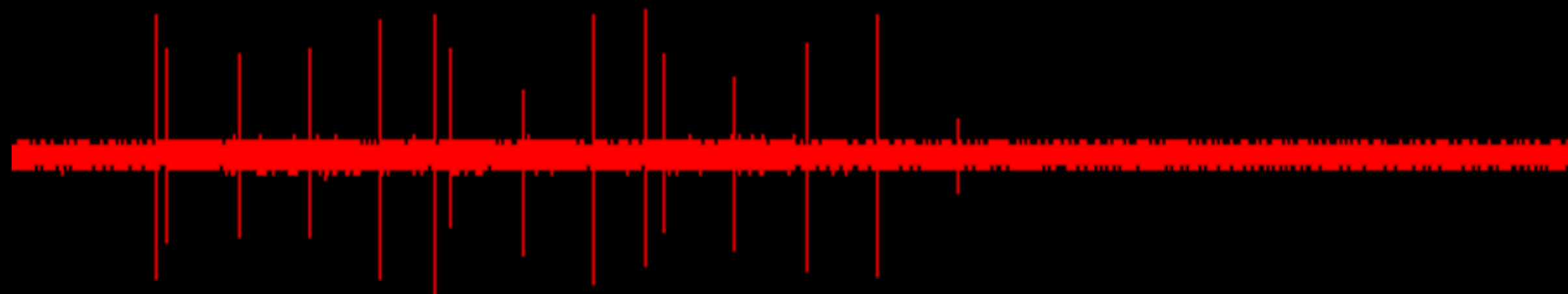
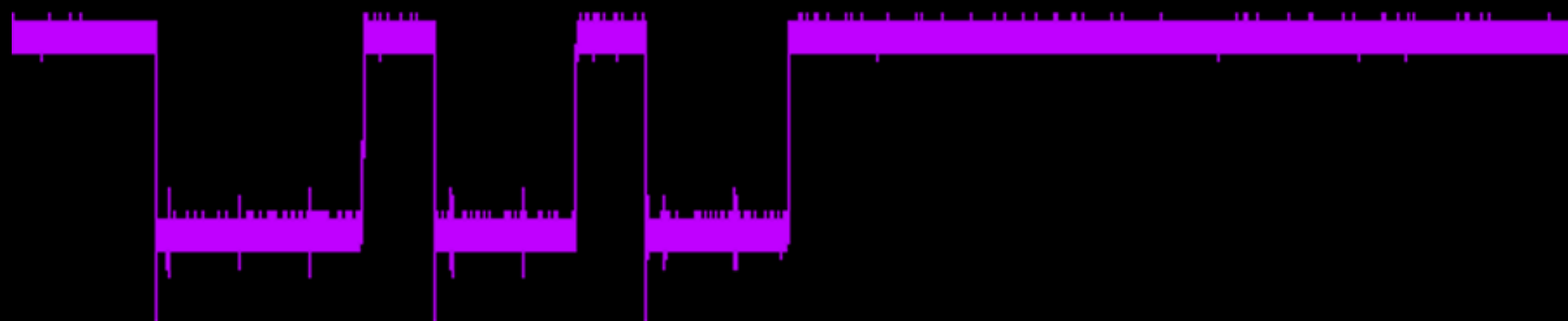
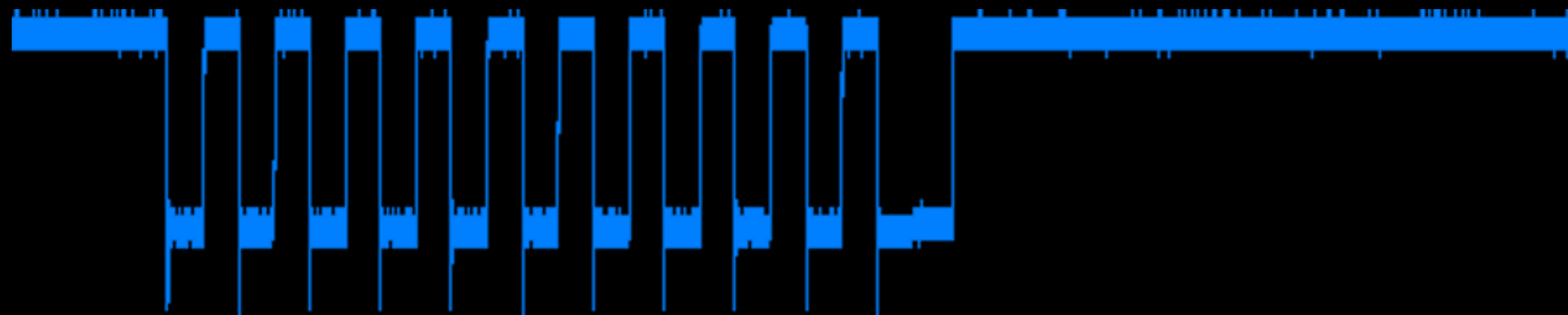


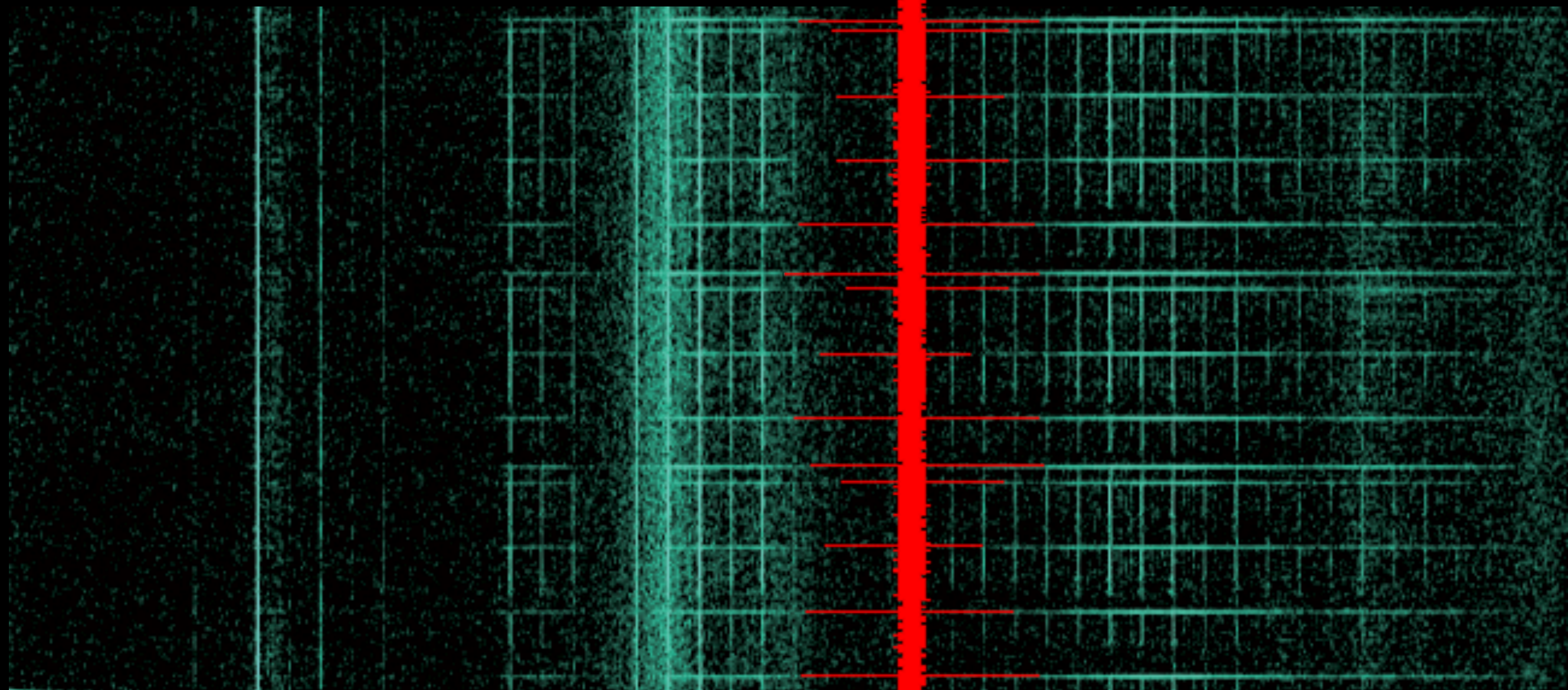
00010010011

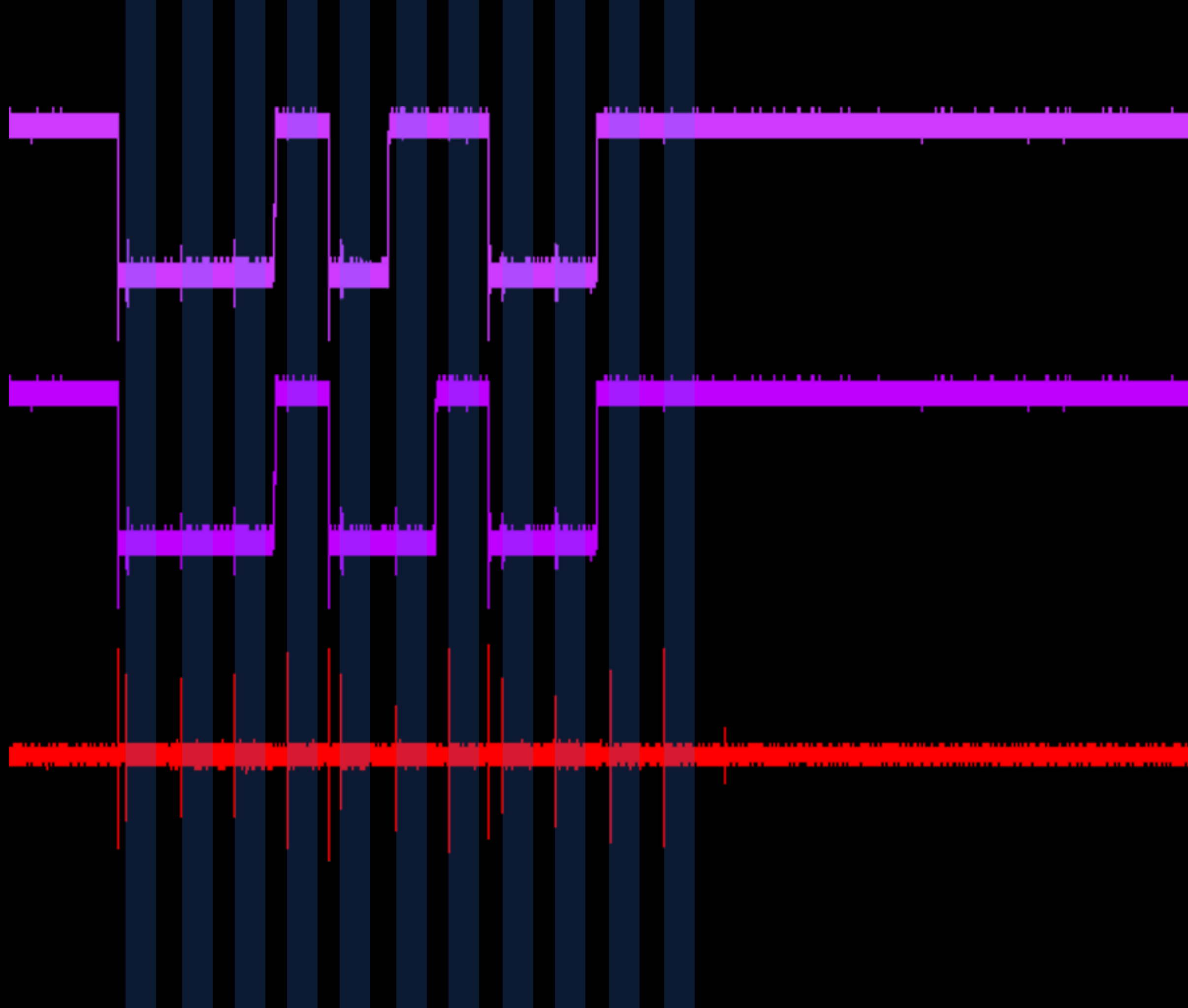




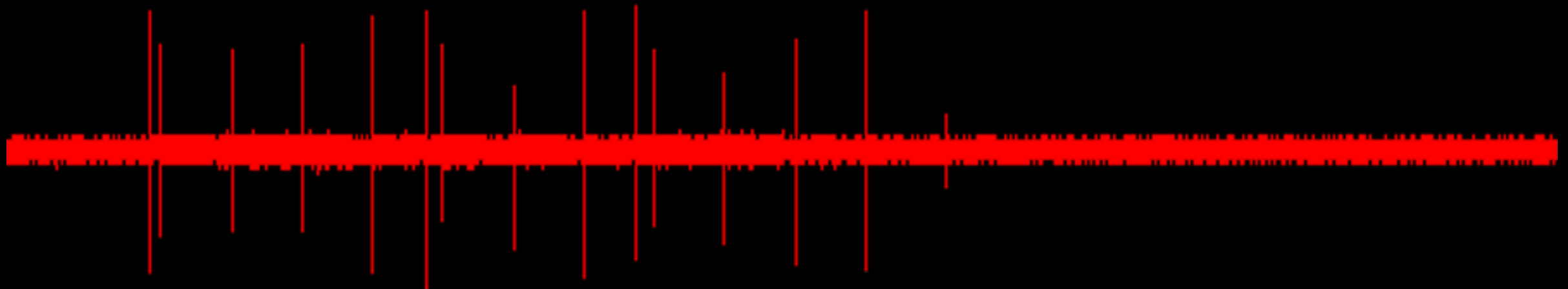
00100100 = 0x24 = E







21112112111 = 3,6,E,G



2111111111 <non-US-1>
2111111121 <Release key>
2111111211 F11 KP KP0 SL
2111112111 8 u
2111121111 2 a
2111121211 Caps Lock
2111211111 F4 '
2111211211 - ; KP7
2111212111 5 t
2111211111 F12 F2 F3
2111211121 Alt+SysRq
2111211121 9 Bksp Esc KP6 NL o
2111211211 3 6 e g
2111212111 1 CTRL L
2111212121 [
2112111111 F5 F7
2112111121 KP- KP2 KP3 KP5 i k
2112111211 b d h j m x

2112112111 SHIFT L s y
2112112121 ' ENTER]
2112121111 F6 F8
2112121121 / KP4 I
2112121211 f v
2121111111 F9
2121111121 , KP+ KP. KP9
2121111211 7 c n
2121112111 Alt L w
2121112121 SHIFT R \
2121121111 F10 Tab
2121121121 . KP1 p
2121121211 Space r
2121211111 F1
2121211121 0 KP8
2121211211 4 y
2121212111 q
2121212121 =

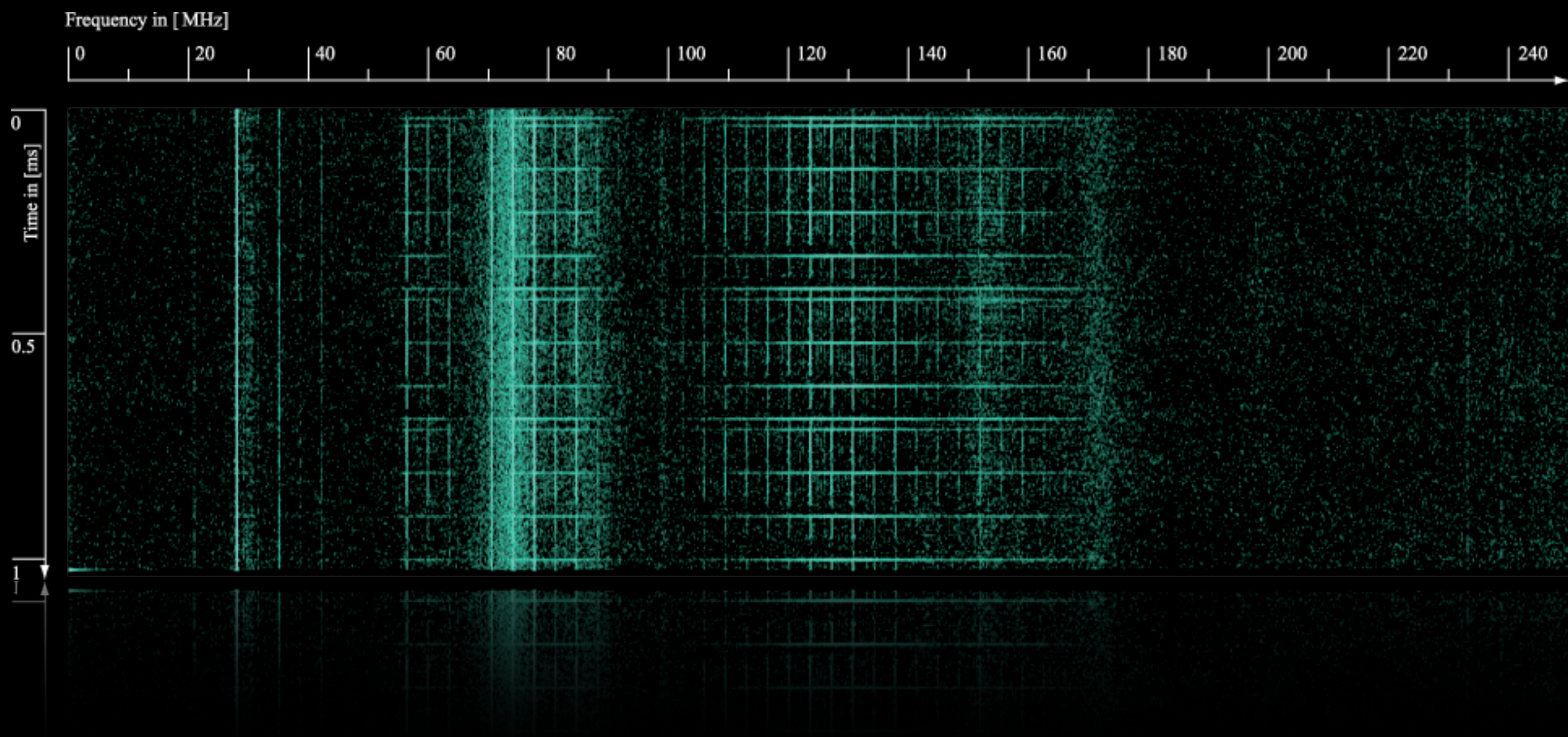
FALLING EDGE TRANSITION

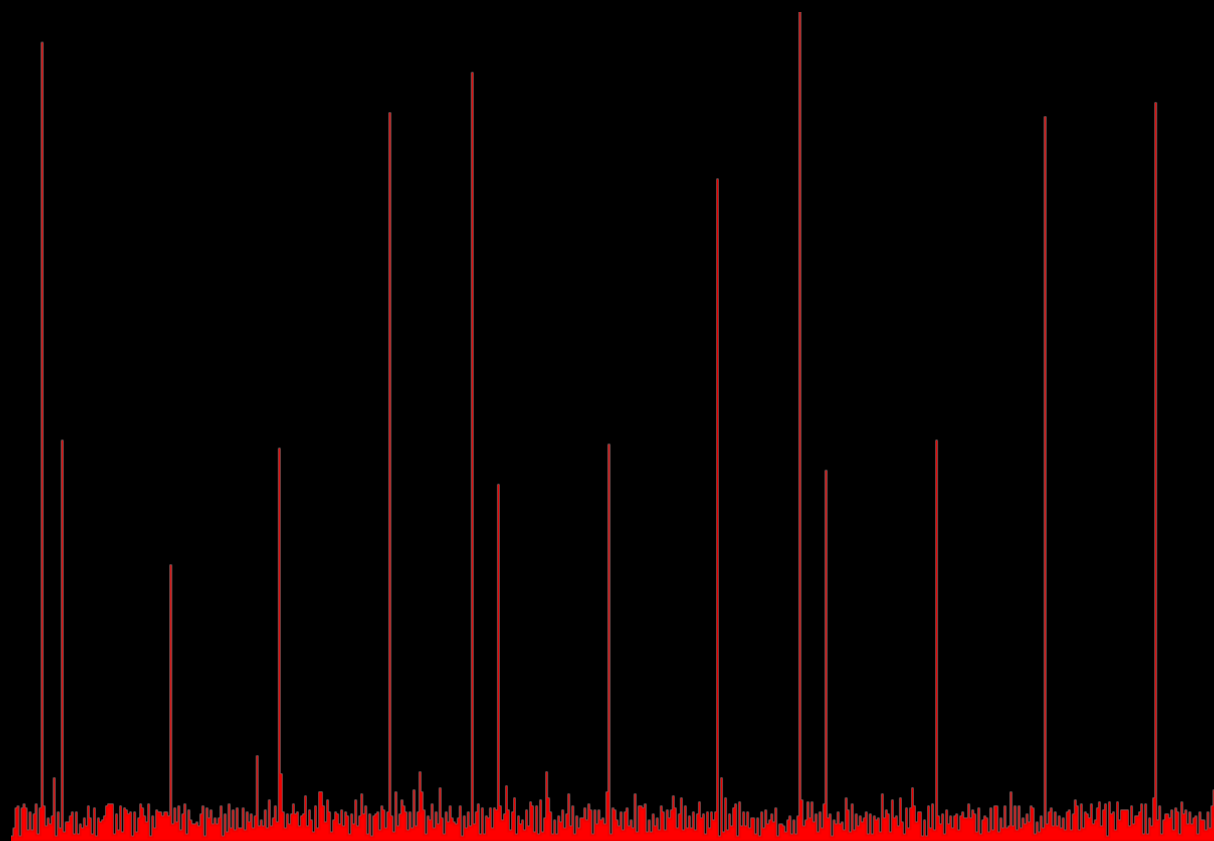
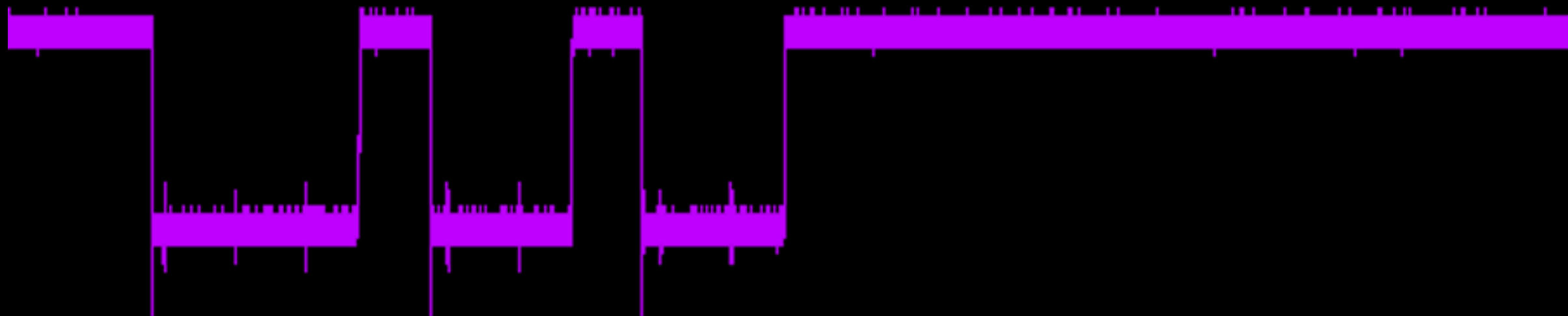
TECHNIQUE

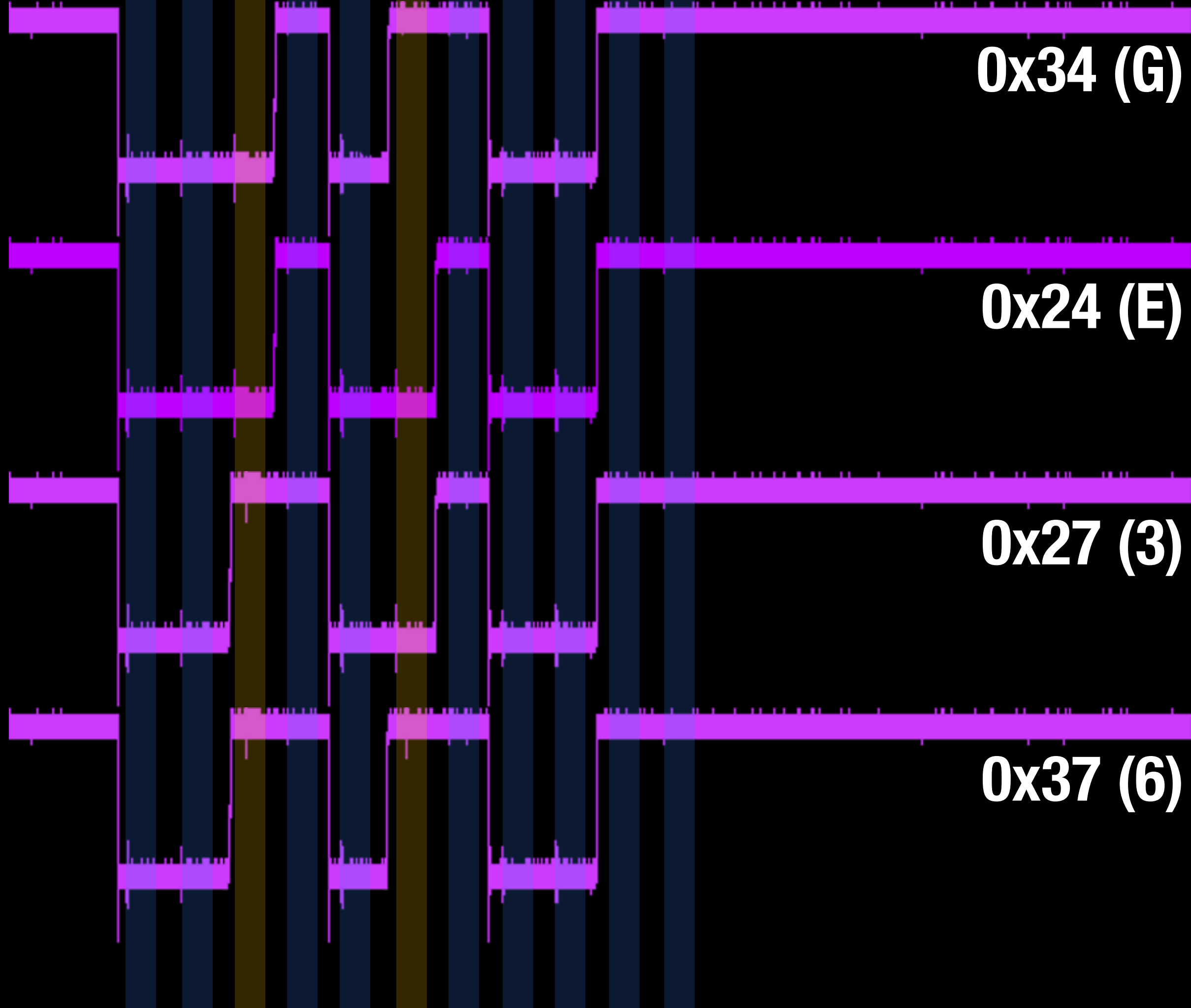
1. PEAK DETECTION

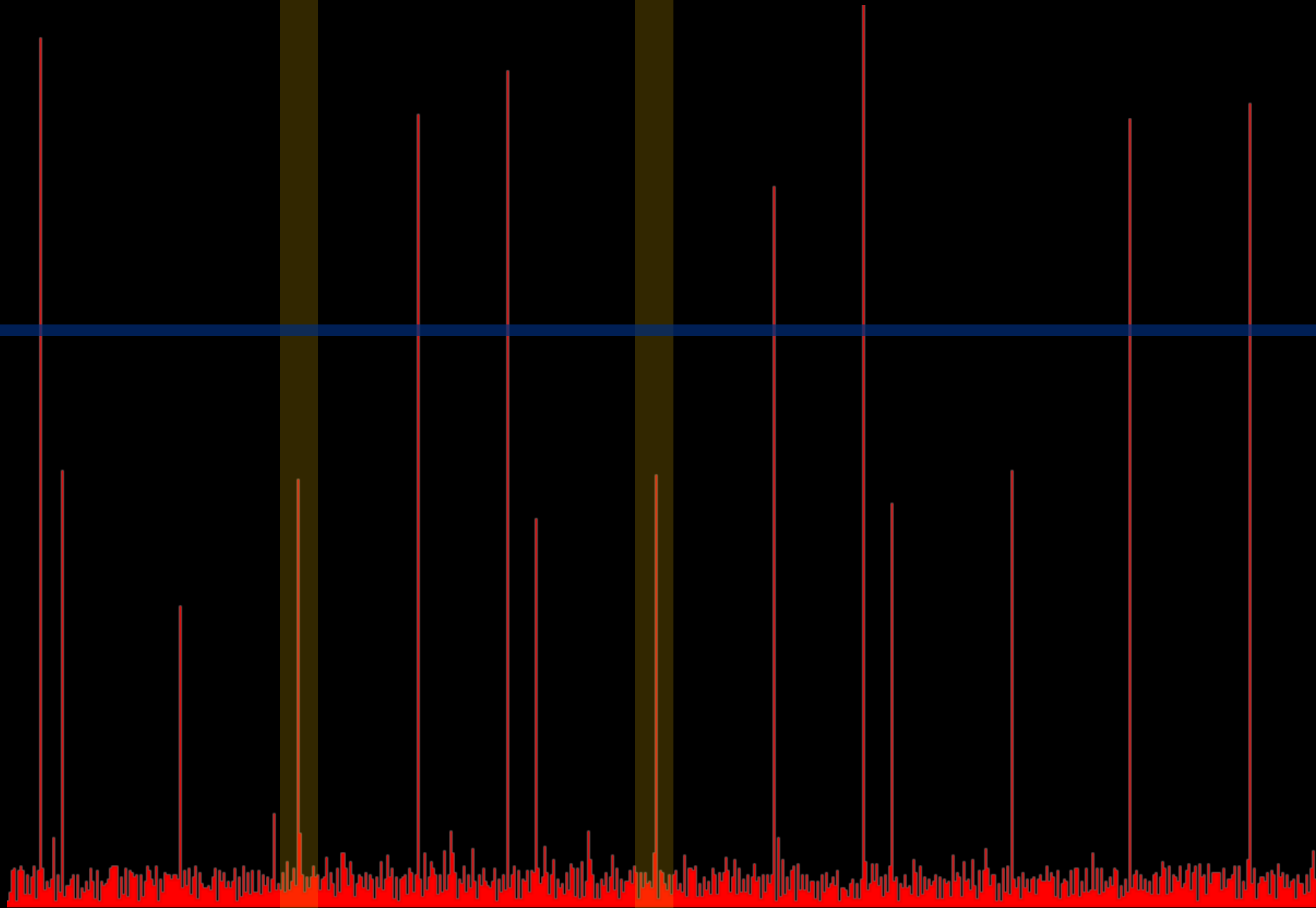
2. TRACE COMPARISON

HOW TO **AVOID THESE COLLISIONS?**









GENERALIZED TRANSITION TECHNIQUE

1. PEAK DETECTION

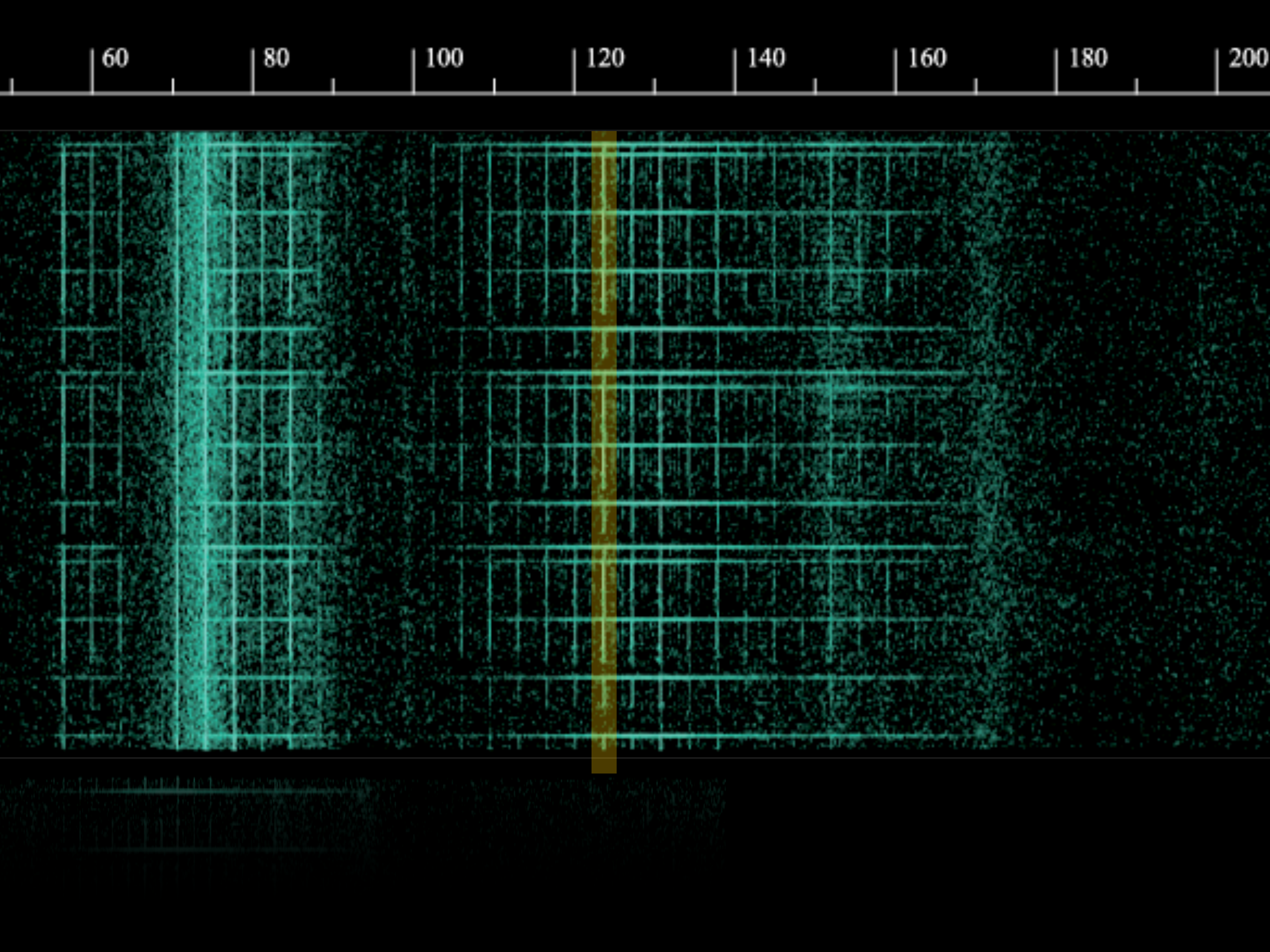
2. TRACE SUBSET (E,G,3,6)

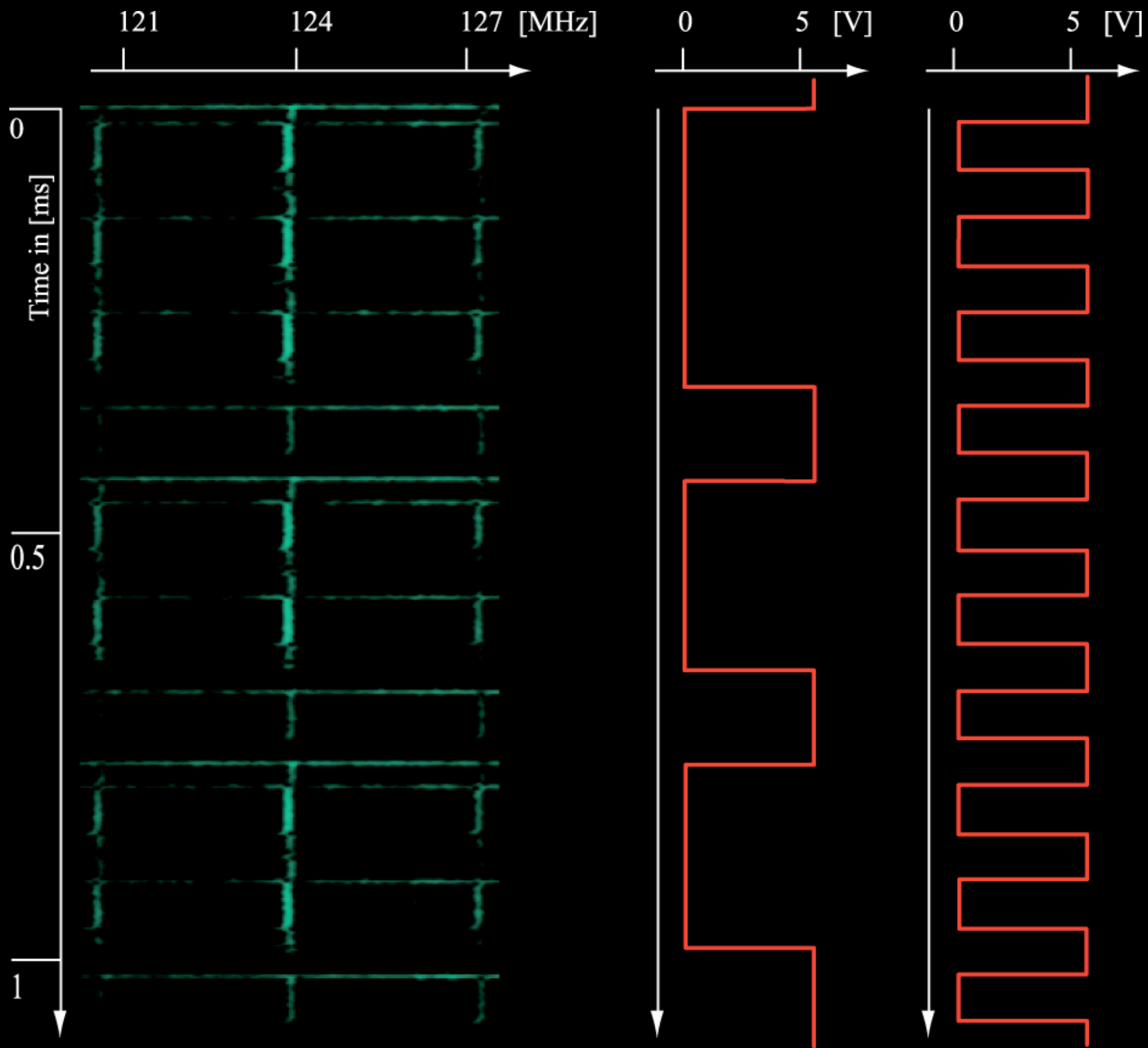
3. COMPUTE THRESHOLD

4. MEASURE CRITICAL BITS

HOW TO DETECT COMPROMISING SIGNALS?

INDIRECT EMANATIONS



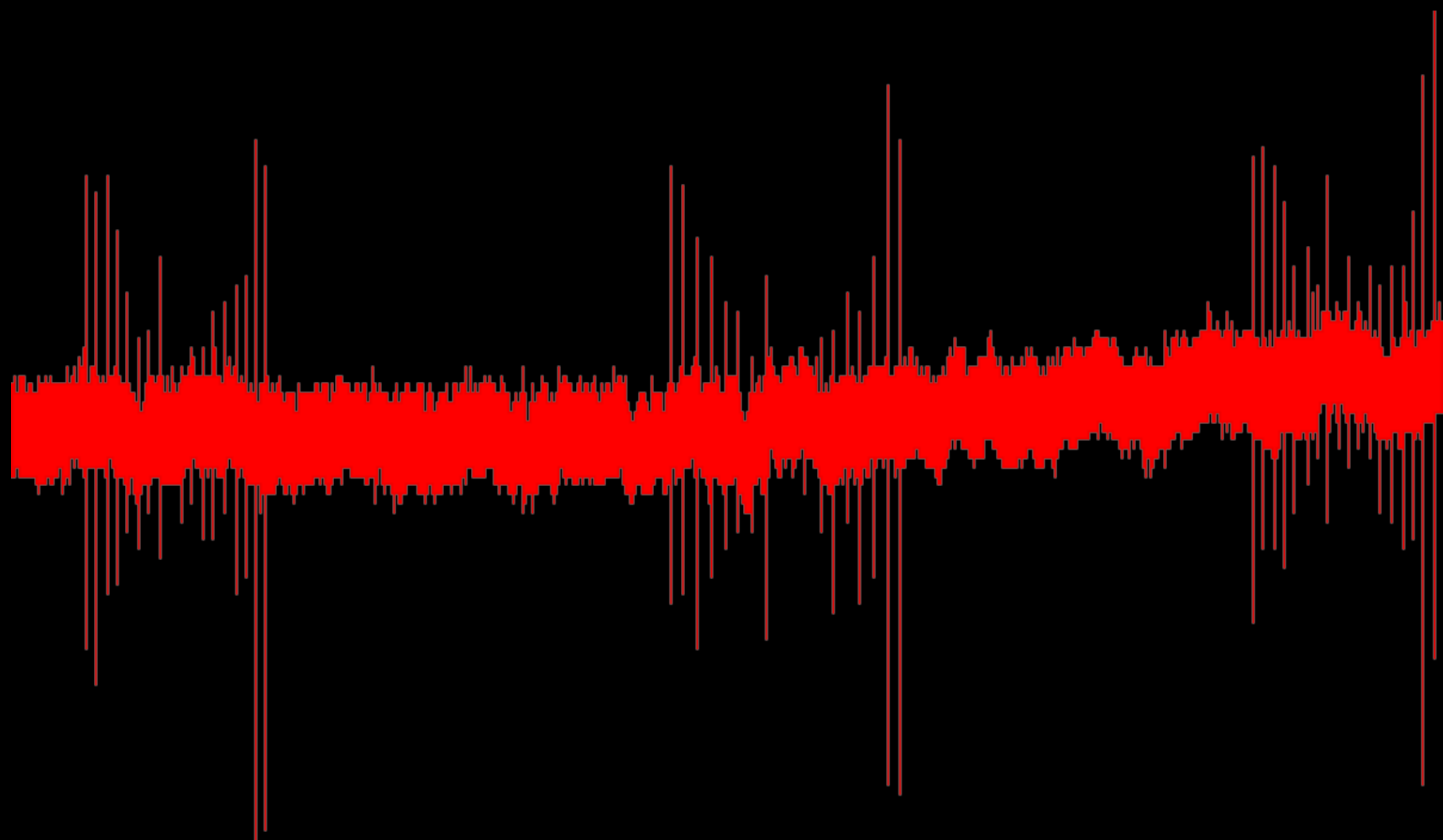


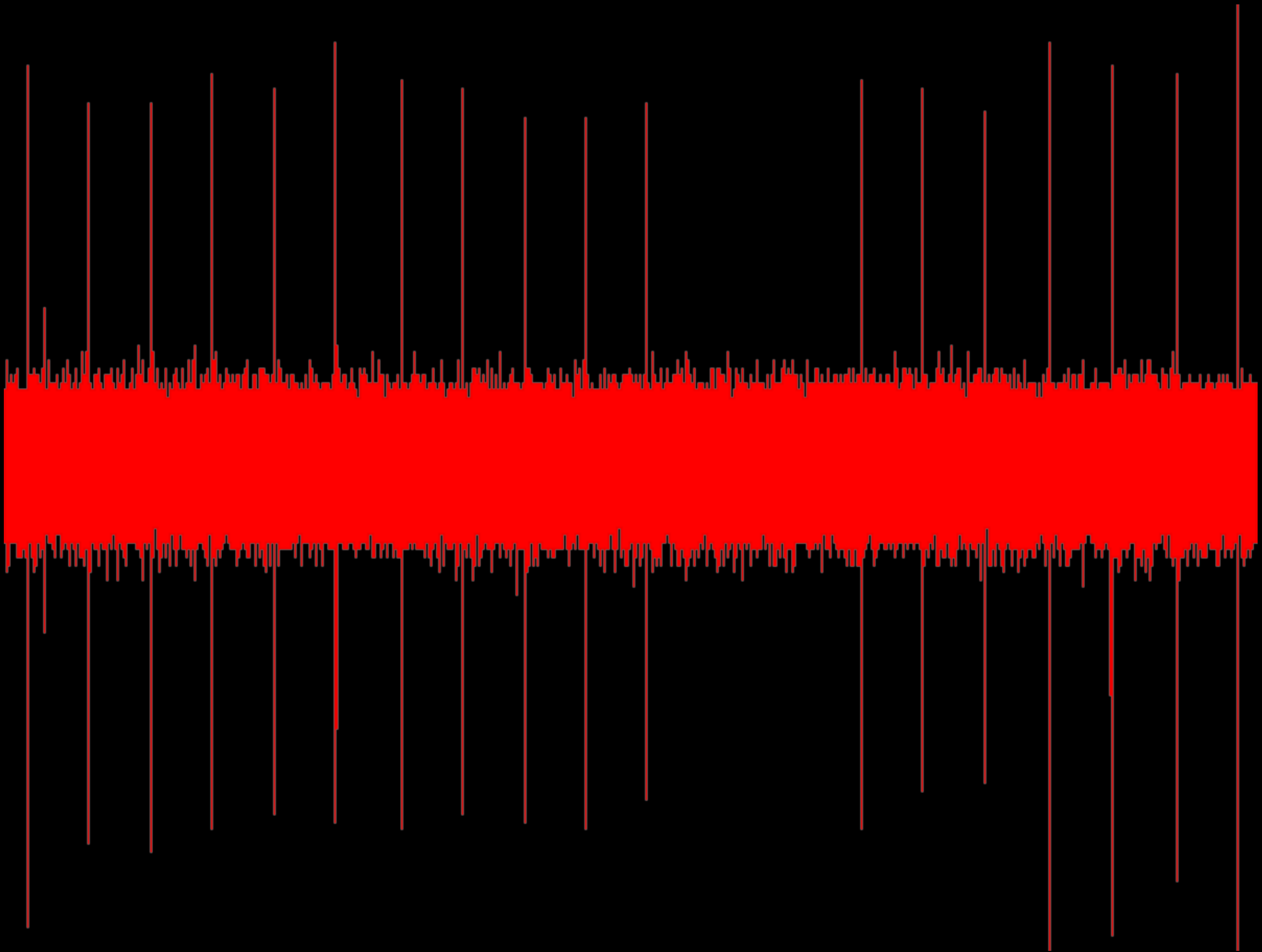
MODULATION **TECHNIQUE**

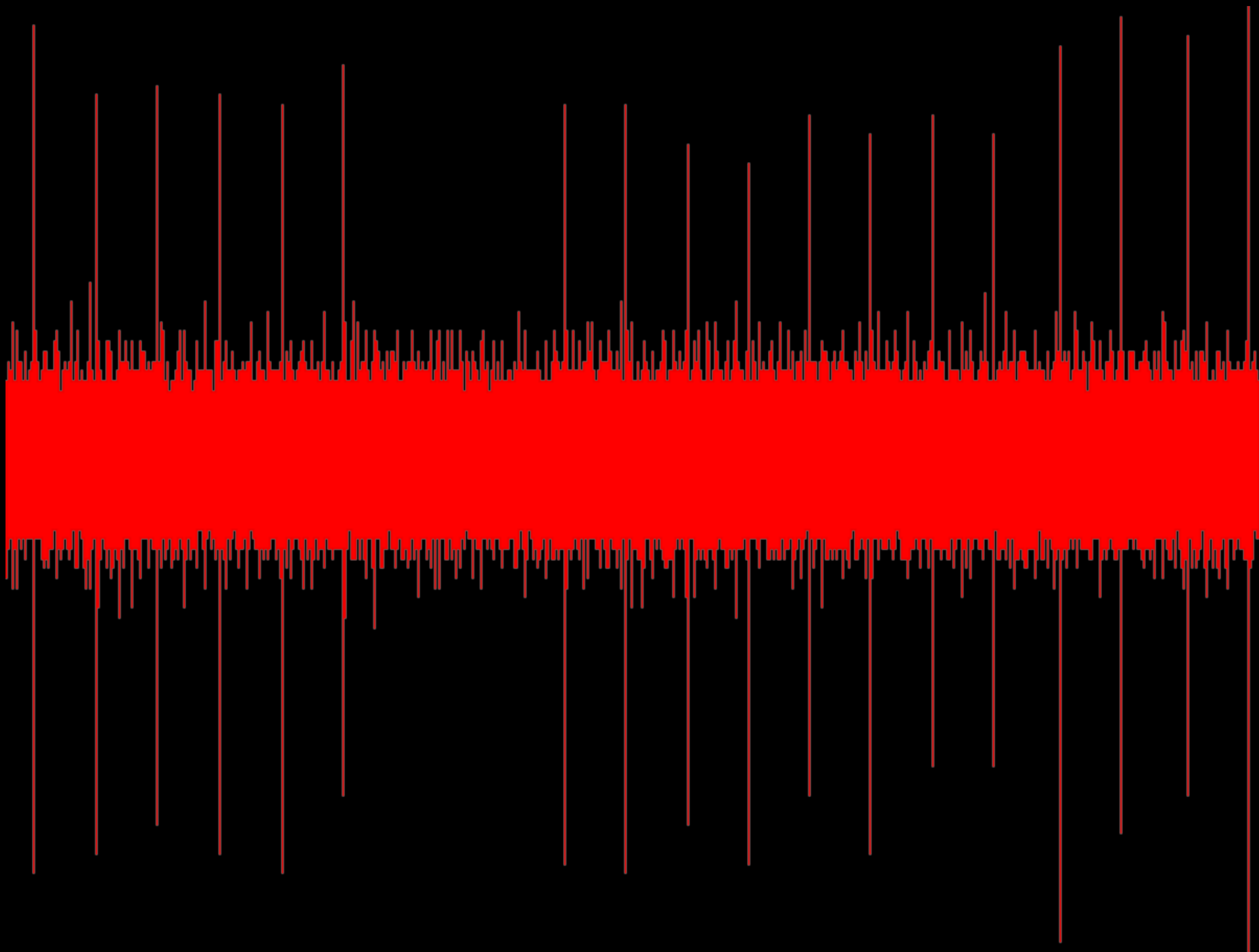
1. DETECT CARRIER(S)

2. DEMODULATION (AM & FM)

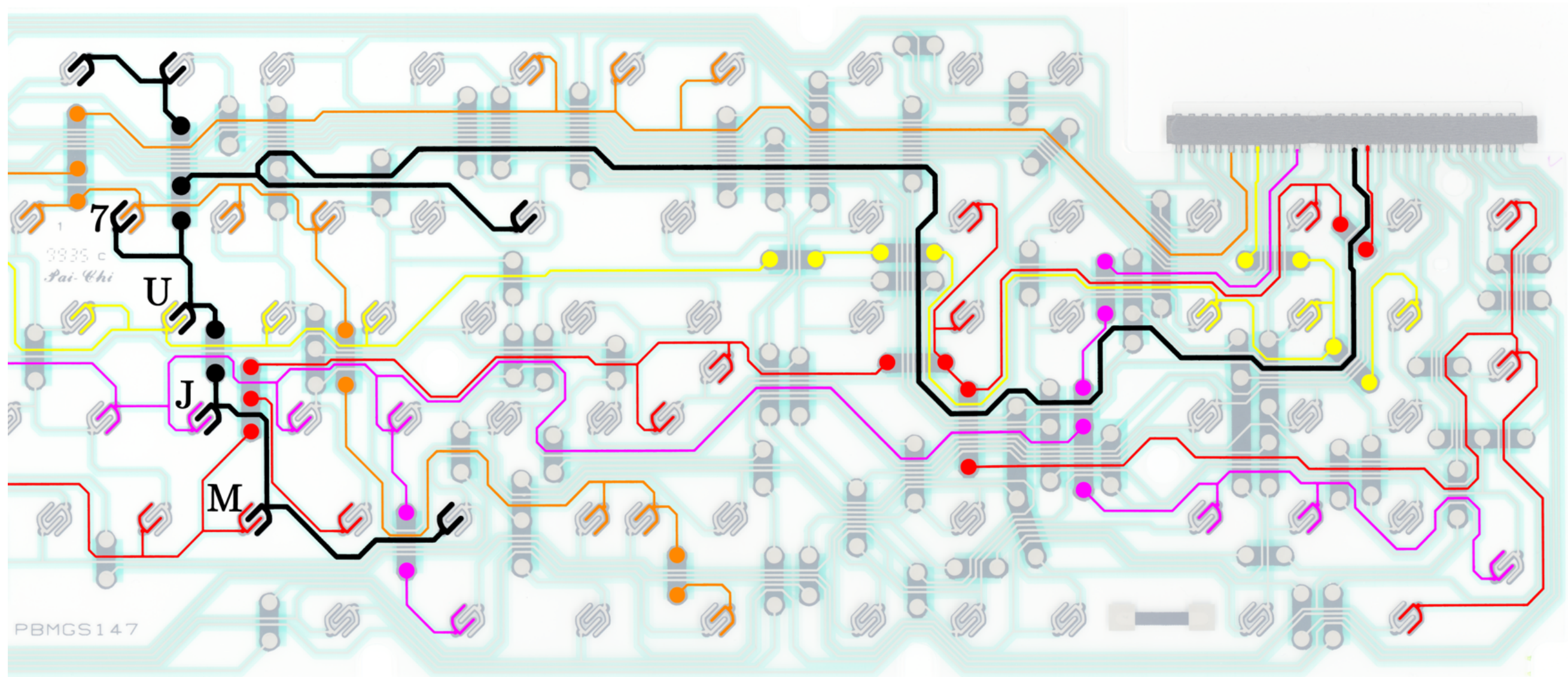
WHAT ABOUT **USB AND **WIRELESS**
KEYBOARDS?**

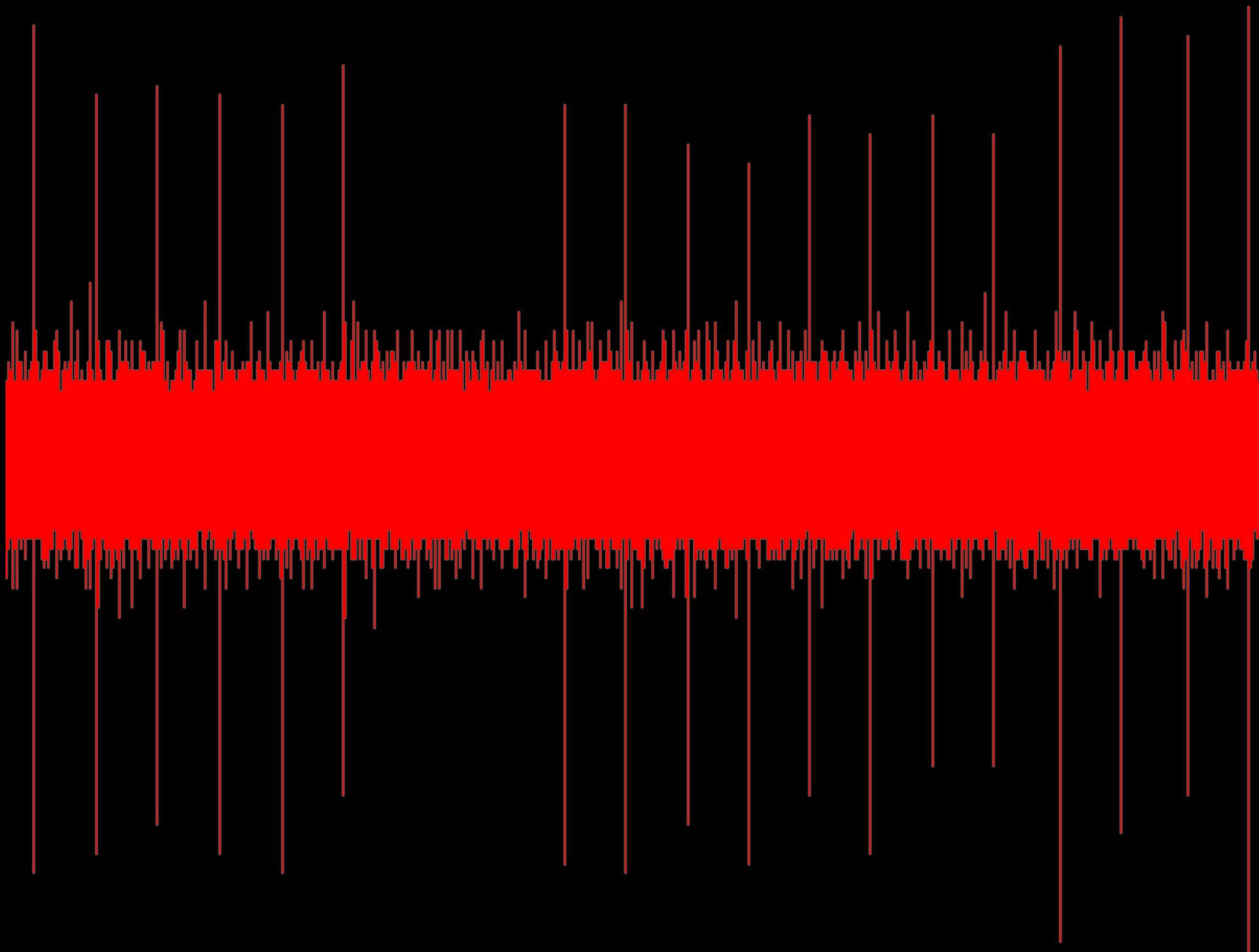






7	6, 7, H, J, M, N, U, Y
8	4, 5, B, F, G, R, T, V
9	BACKSPACE, ENTER
10	9, L, O
11	O, P
12	3, 8, C, D, E, I, K
13	1, 2, S, W, X, Z
14	SPACE, A, Q





MATRIX SCAN **TECHNIQUE**

1. PEAK DETECTION

2. TRACE COMPARISON

presence of the signal is clear. On the right, the screen content was low-pass filtered as in Fig. 7 and the received Tempest signal has vanished except for the horizontal sync pulses.

to its periodic nature, a video signal can easily be separated from other signals and from noise by periodic averaging.

We have identified two more potential sources of periodic signals in every PC, both of which can be fixed at low cost by software or at worst firmware changes [28]. Keyboard controllers execute an endless key-matrix scan loop, with the sequence of instructions executed depending on the currently pressed key.

A short random wait routine inside this loop and a random scan order can prevent an eavesdropper doing periodic averaging. Secondly, many disk drives read the last accessed track continuously until another access is made. As an attacker might try to reconstruct this track by periodic averaging, we suggest that after accessing sensitive data, the disk head should be moved to a track with unclassified data unless further read requests are in the queue.

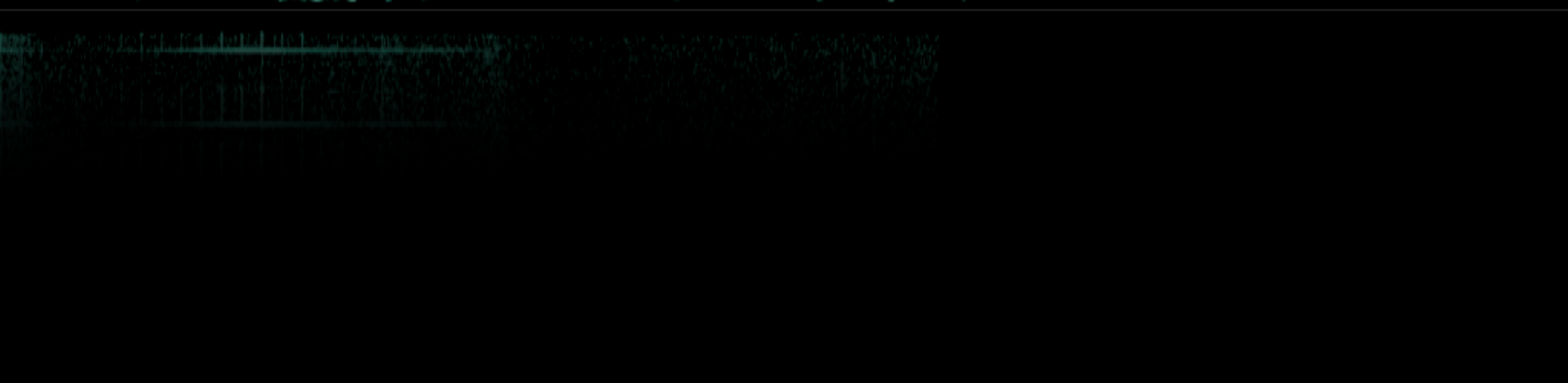
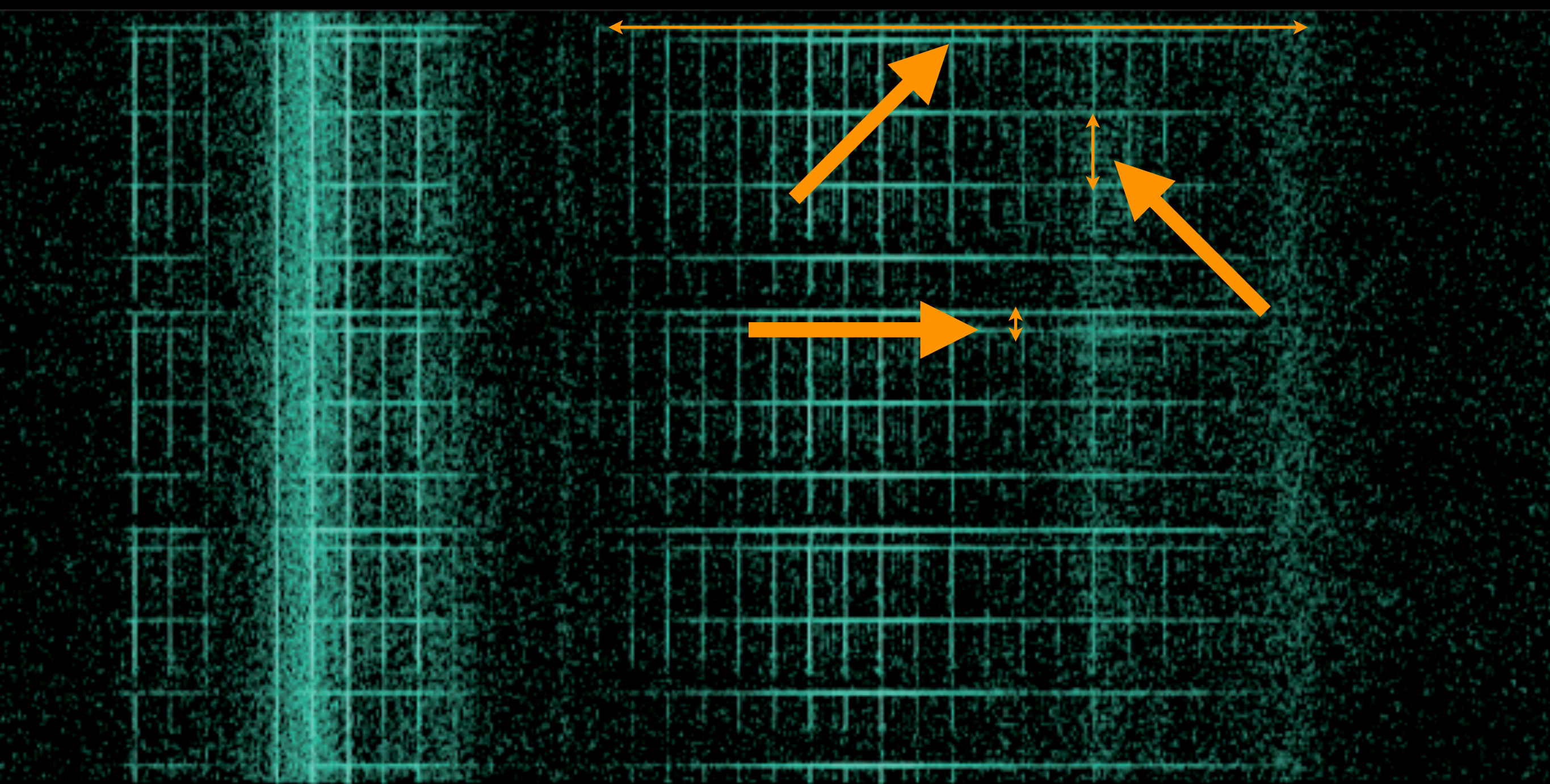
DRAM refresh is another periodic process in every computer that deserves consideration. The emanations from most other sources, such as the CPU and peripheral devices, are usually constant. An eavesdropper could use a lock-in amplifier to have to install software that drives them periodically, or at least have obtained knowledge of the system configuration and the executed software.

We are convinced that our Soft Tempest techniques, and in particular Tempest fonts, can provide a significant increase in emanation security at a very low cost. There are many applications where they may be enough; in medium sensitivity applications, many governments use a zone model in which computers with confidential data are not shielded but located in rooms far away from accessible areas. Here, the 10–20 dB of protection that a Tempest font affords

MARKUS KUHN & ROSS ANDERSON
1998



MULTIPLE KEYBOARDS

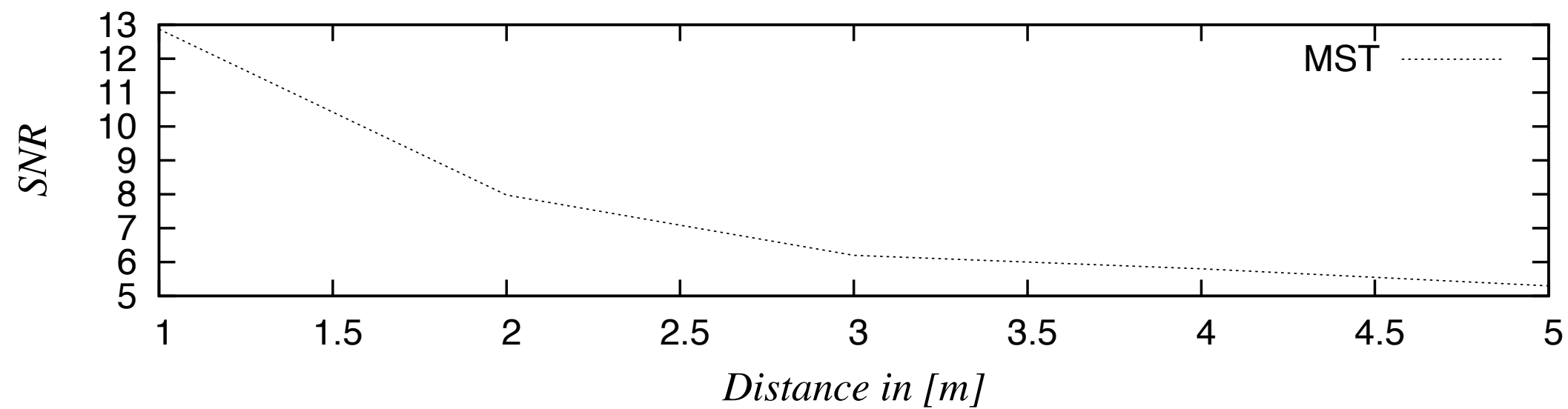
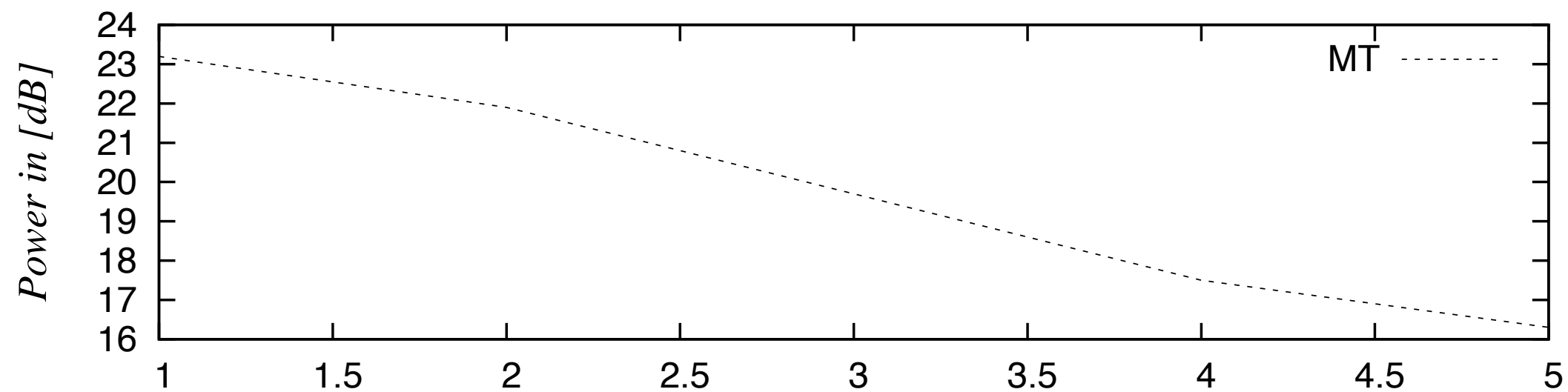
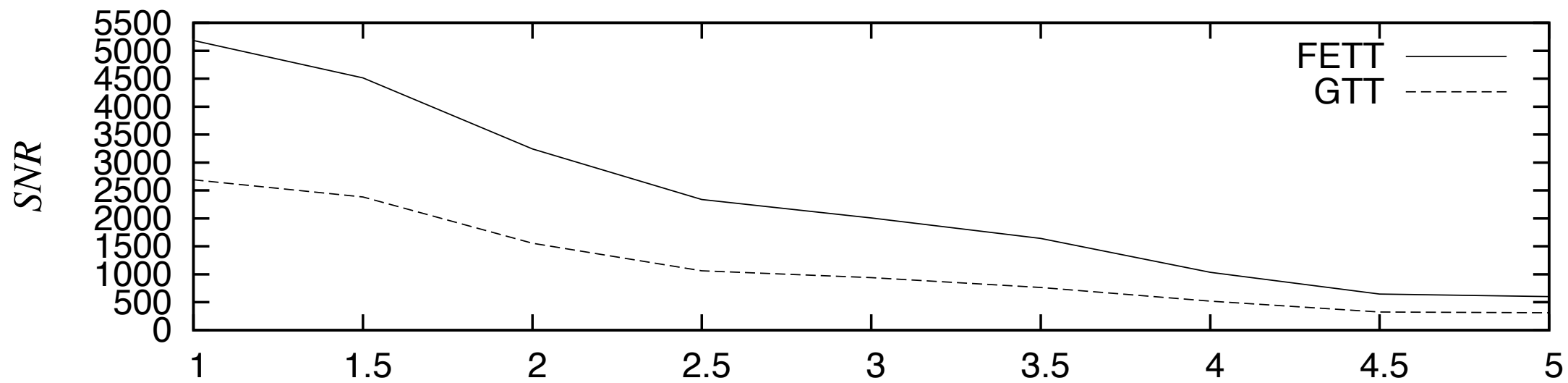


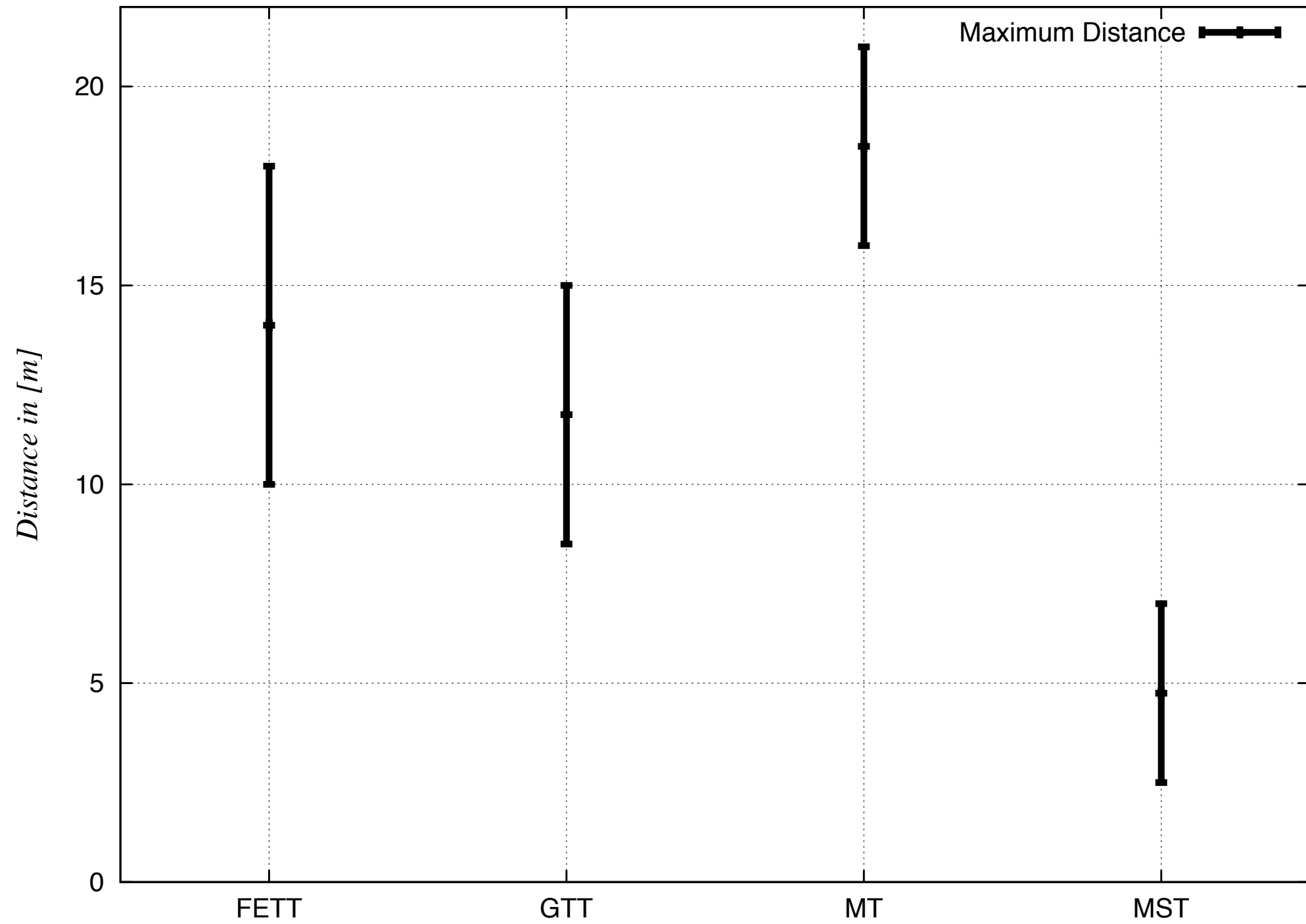
THEORY VS. PRACTICE

RECOVER 95% OF 500+ KEYSTROKES

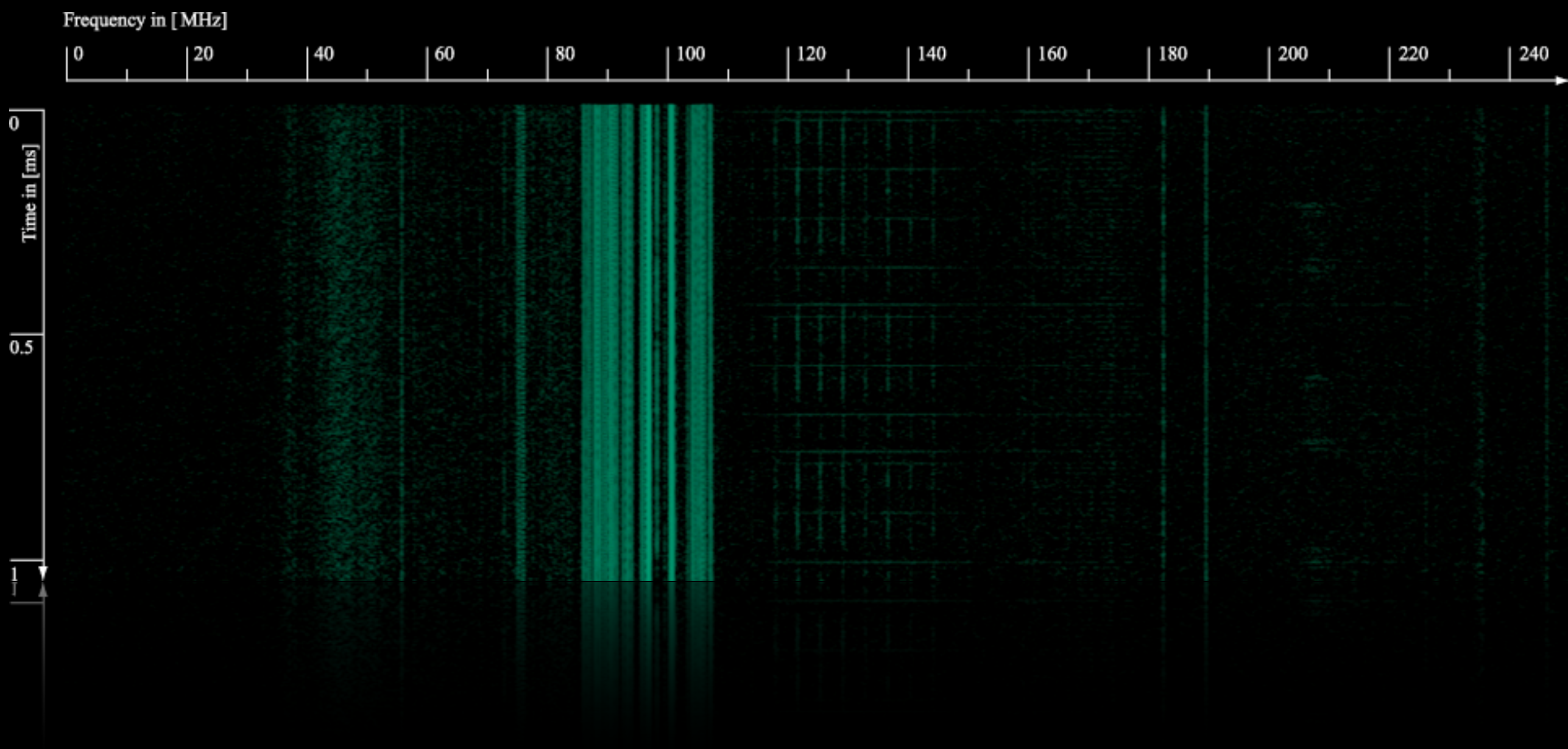
SETUP1: A SEMI ANECHOIC CHAMBER

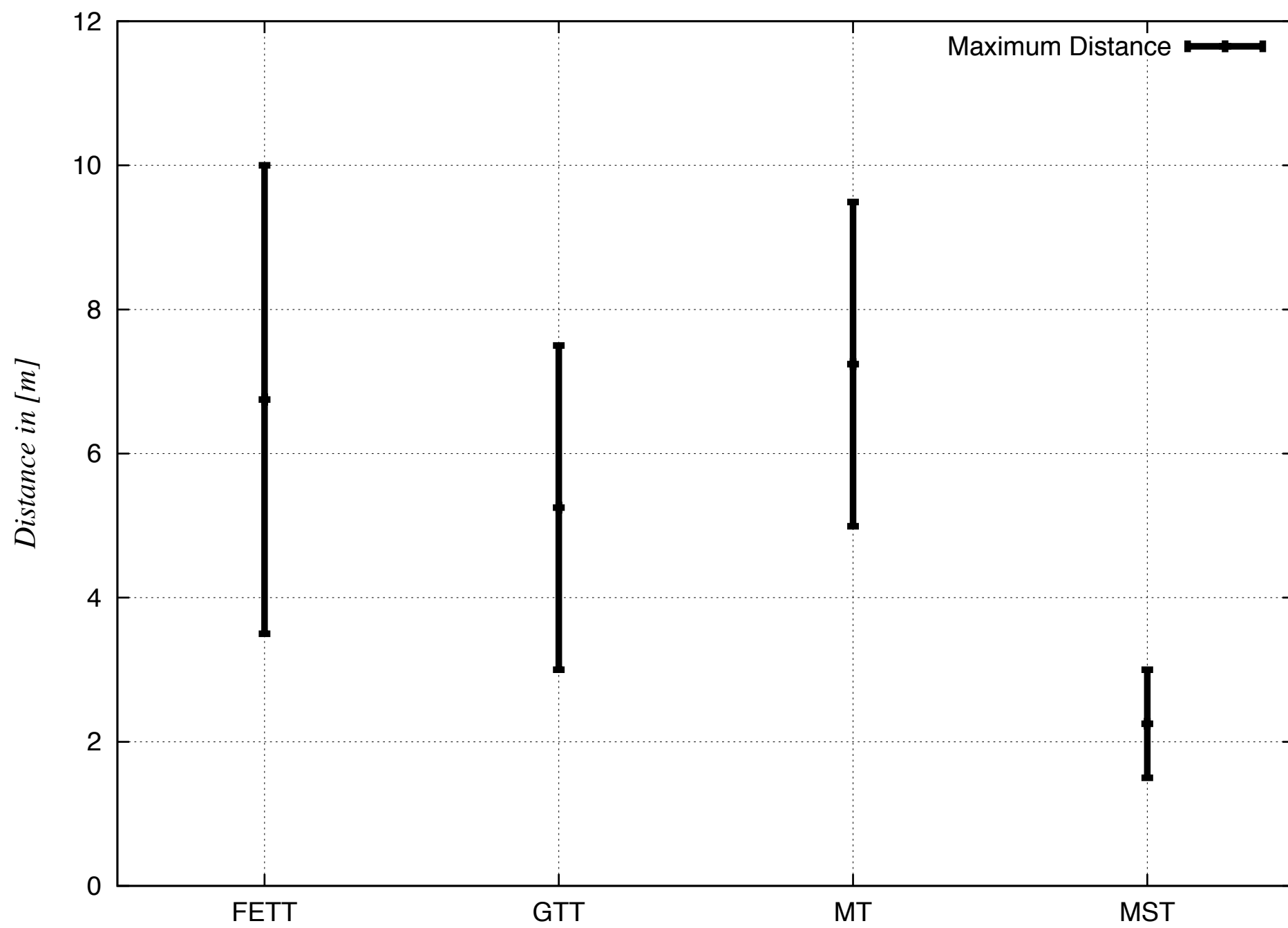






SETUP2: THE OFFICE





SETUP3: THE OFFICE WITH WALL

VIDEO



SETUP4: A FLAT

**ALL THE ATTACKS WORKS WITH THE
KEYBOARD AT THE 5th FLOOR AND
THE ANTENNA IN THE BASEMENT, 20
METERS AWAY!**

**SHARED GROUND OF THE BUILDING
ACT AS ANTENNA!**

**CONDUCTIVE AND RADIATIVE
COUPLING**

**DISTANCE BETWEEN THE KEYBOARD
AND THE SHARED GROUND**

+

**DISTANCE BETWEEN THE SHARED
GROUND AND THE ANTENNA**

WATER PIPE OF THE BUILDING CAN
BE USED AS WELL:

**BETTER SIGNAL-TO-NOISE RATIO
SINCE LESS ELECTRIC POLLUTION**

THANKS TO

ERIC AUGÉ

LUCAS BALLARD

DAVID JILLI

MARKUS KUHN

ERIC OLSON

FARHAD RACHIDI

PIERRE ZWEIACKER