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Attacking at non-harmonic frequencies in screaming-channel attacks

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Outline

Screaming channel attacks:

- Side-channel leakage transmited by a RF module

Limitation of this attack:

- Polluted harmonics

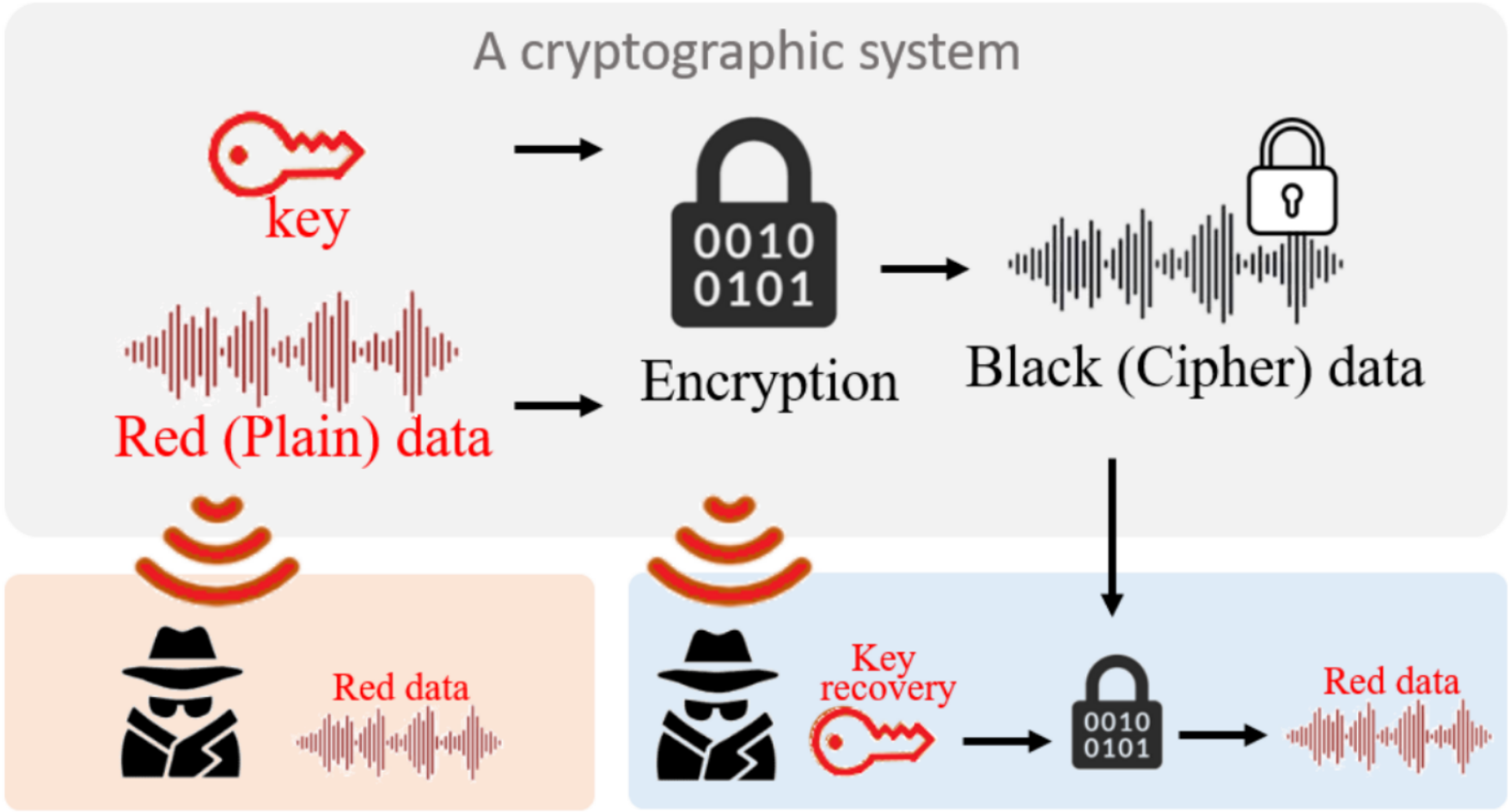
Proposed solution:

- Investigating the screaming-channel attack at other frequencies than the harmonics

Impact on the attack:

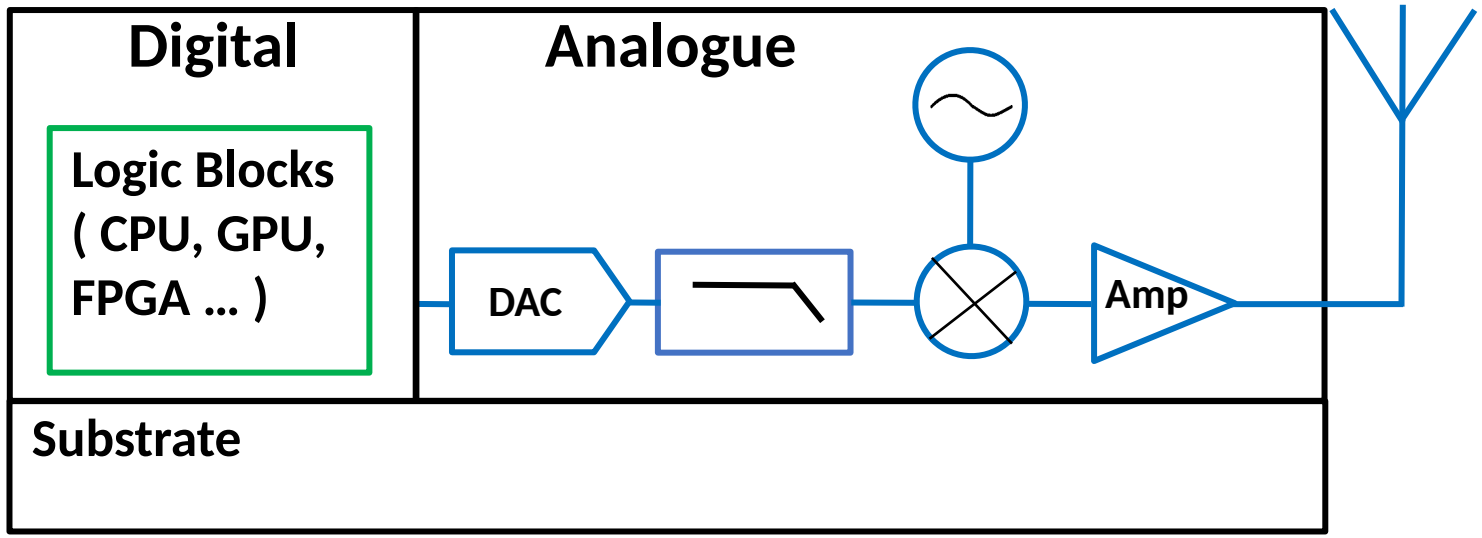
- Demonstrate that non-harmonics are good enough for attacks

Side-channel attacks



[1] J. Choi, H.-Y. Yang, and D.-H. Cho, “TEMPEST Comeback: A Realistic Audio Eavesdropping Threat on Mixed-signal SoCs,”, ACM SIGSAC, 2020.

Screaming channel attacks



[2] G. Camurati, S. Poeplau, M. Muench, T. Hayes, and A. Francillon, "Screaming Channels: When Electromagnetic Side Channels Meet Radio Transceivers," ACM SIGSAC, 2018

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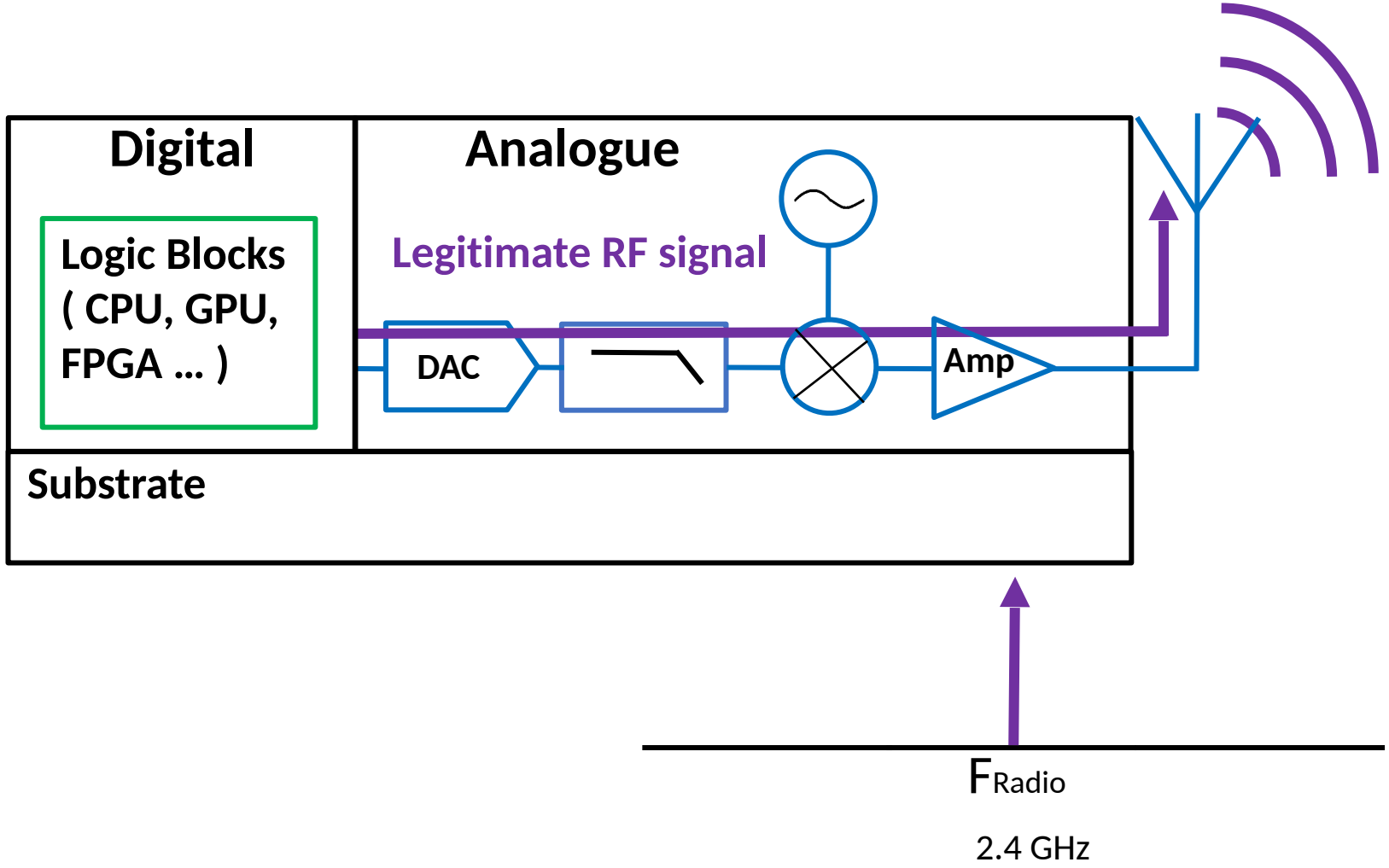

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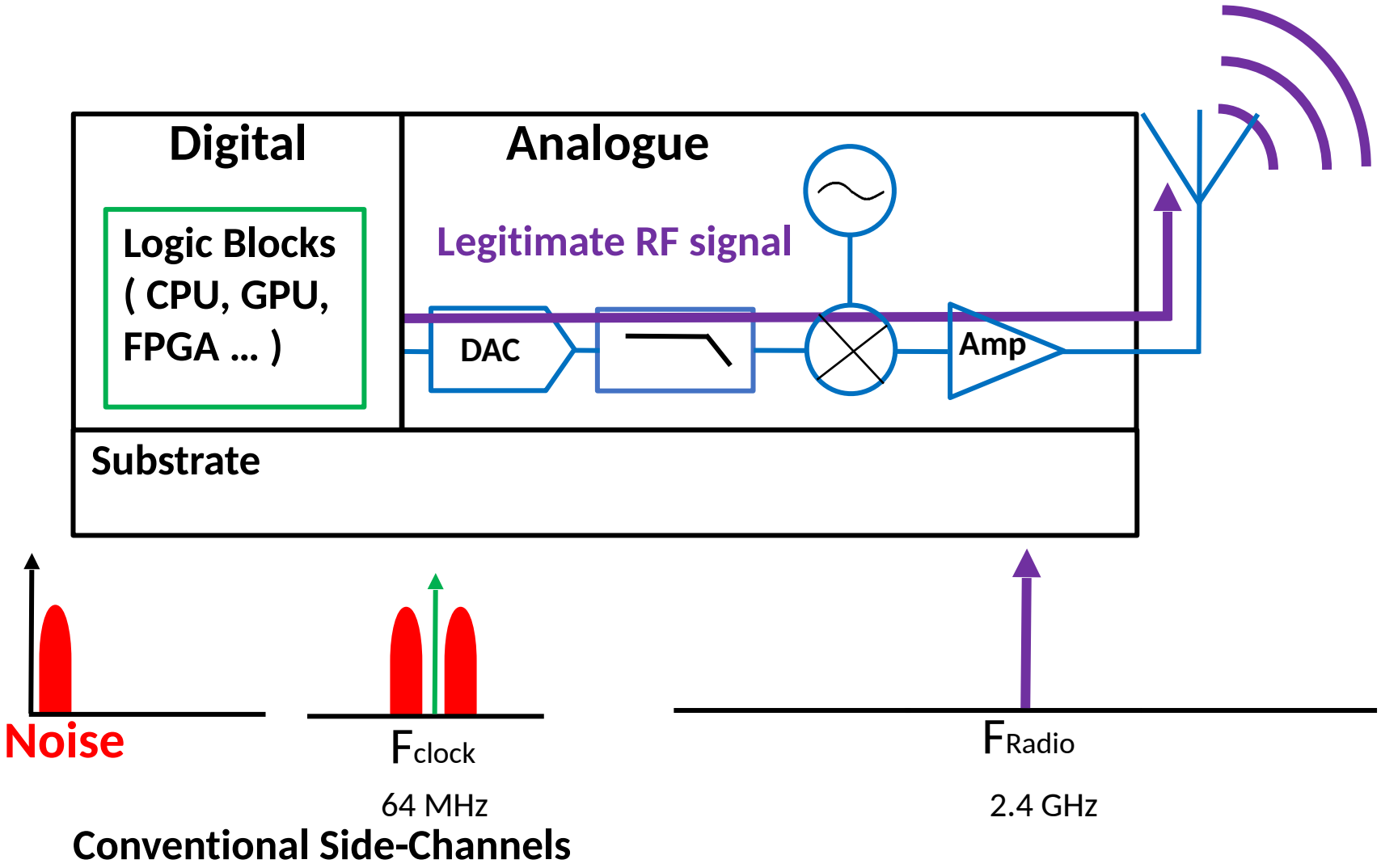

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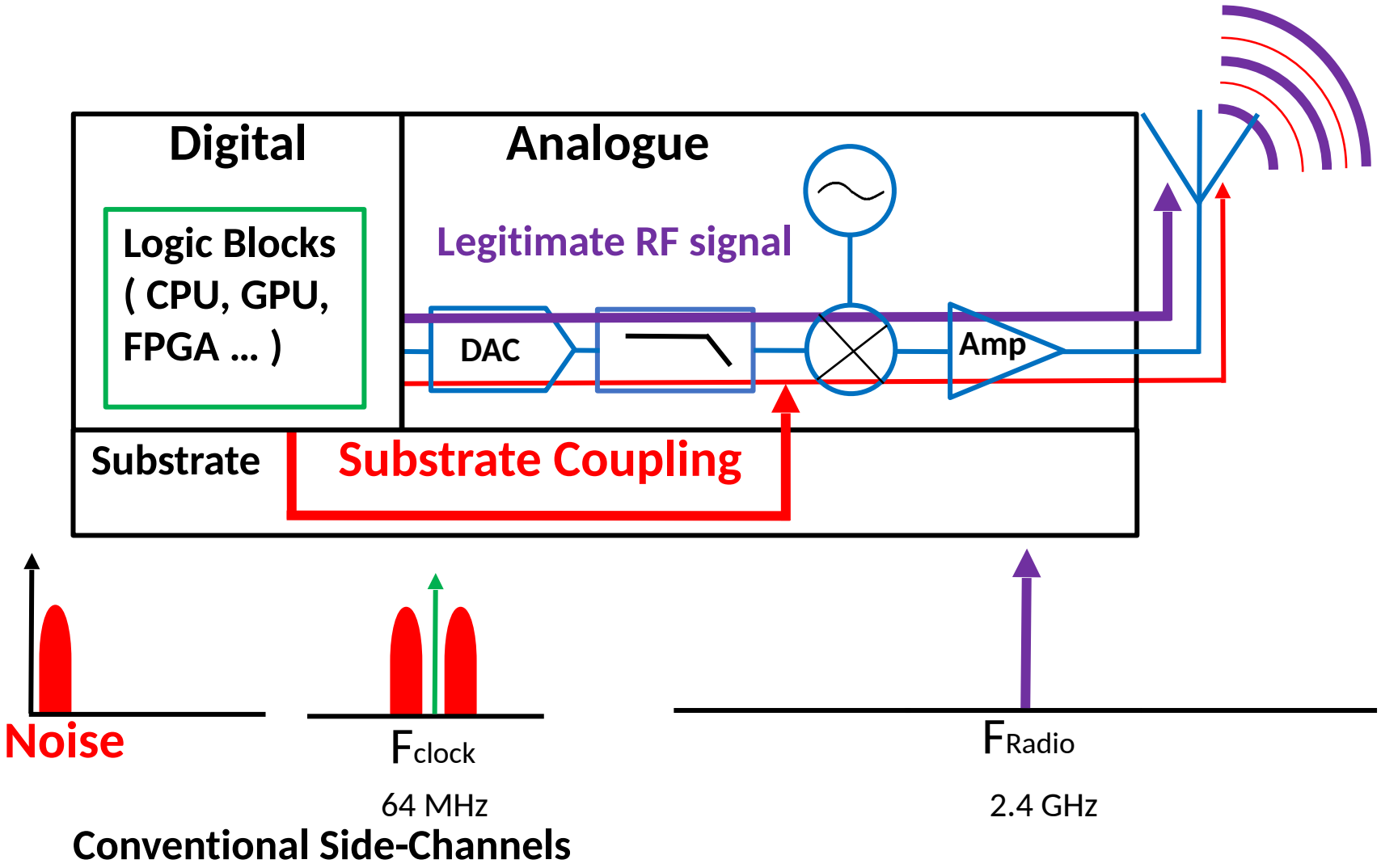

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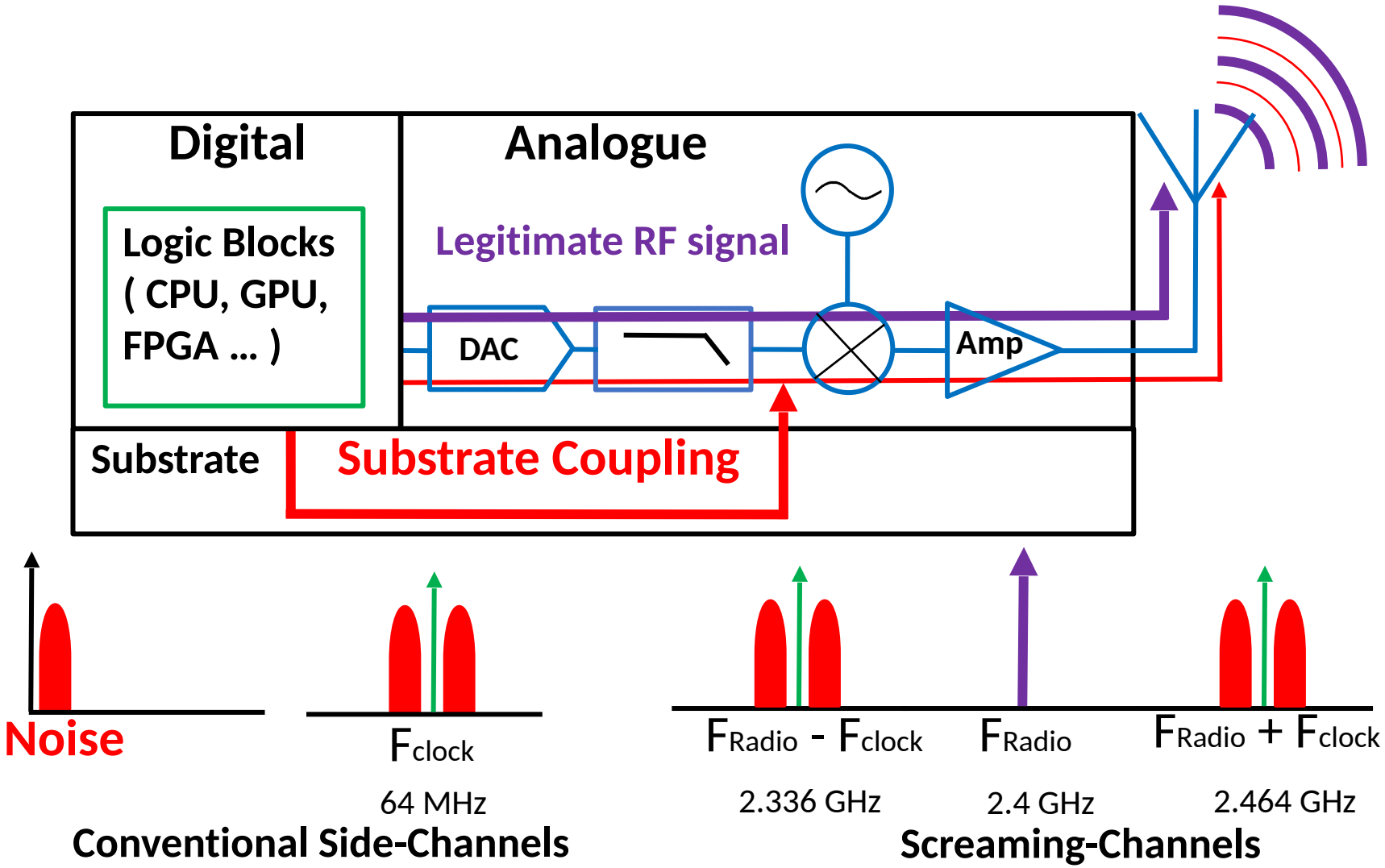

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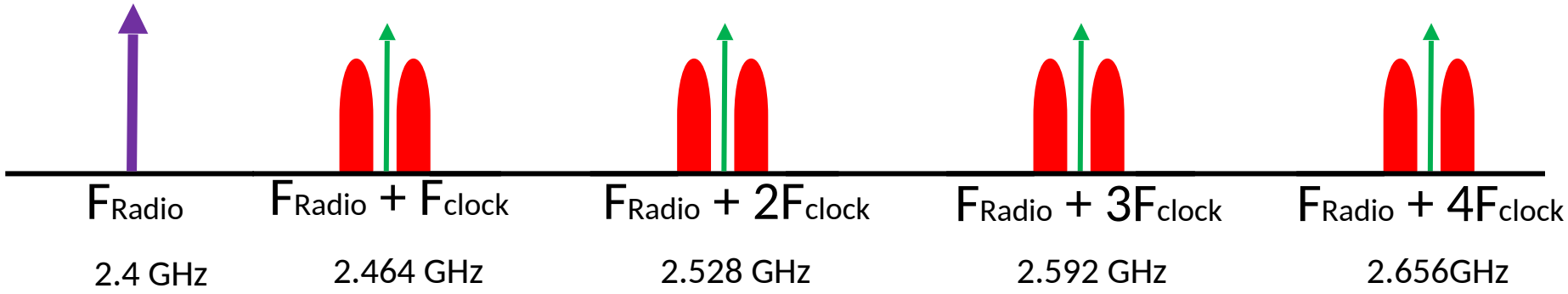
Frequency diversity

Previous works:



- The leakage is present at each harmonic of the digital clock frequency

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[3] R.Wang, H.Wang, E.Dubrova, "Far field em side-channel attack on aes using deep learning," ACM, 2020

Frequency diversity

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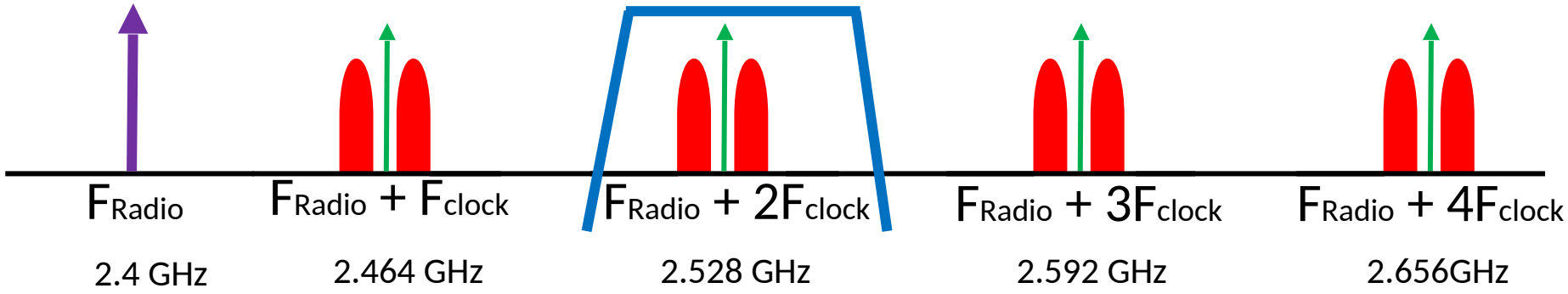


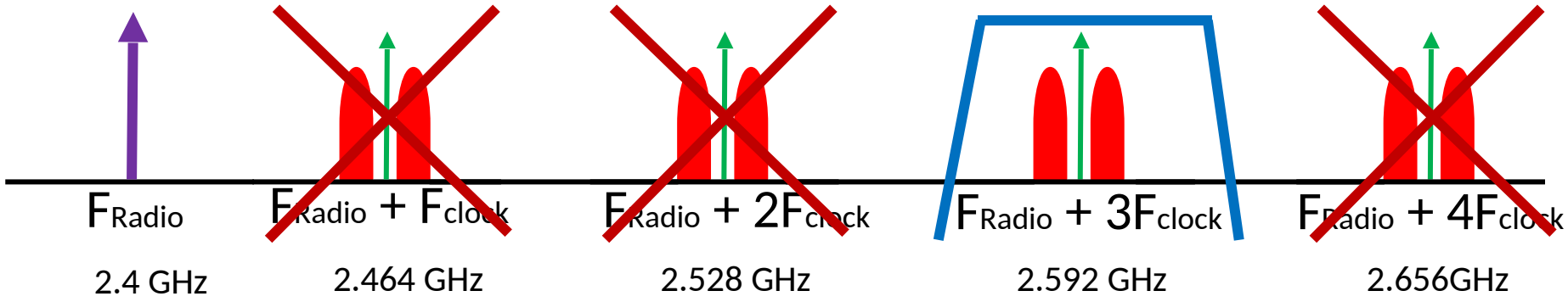
- The leakage is present at each harmonic of the digital clock frequency
- Previous works on screaming channel used only the second at 2,528 GHz

[2] G. Camurati, S. Poeplau, M. Muench, T. Hayes, and A. Francillon, "Screaming Channels: When Electromagnetic Side Channels Meet Radio Transceivers," ACM SIGSAC, 2018

[3] R.Wang, H.Wang, E.Dubrova, "Far field em side-channel attack on aes using deep learning," ACM, 2020

Frequency diversity

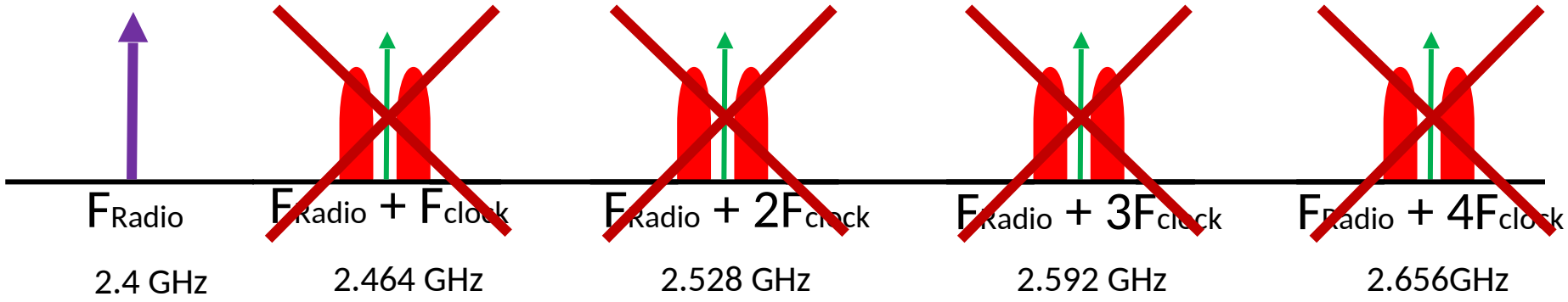
In our environment:



- Only one harmonic is both unpolluted and sufficiently strong to mount a successful attack

Frequency diversity

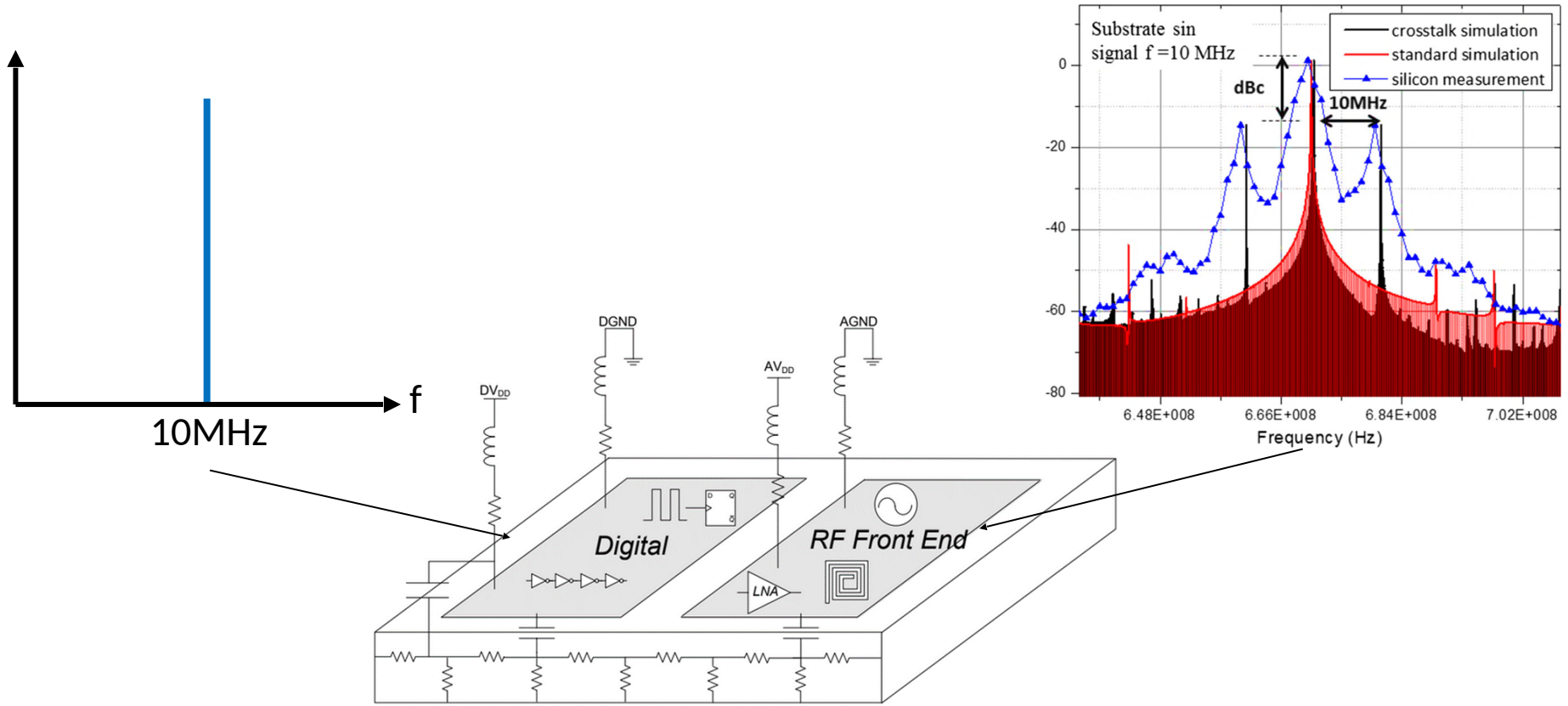
Questions:



- What happen if all harmonics are polluted?
- Can we use other frequencies?

Leakage at non-harmonics frequencies

Substrate spreading a harmonic over a large band of frequencies:

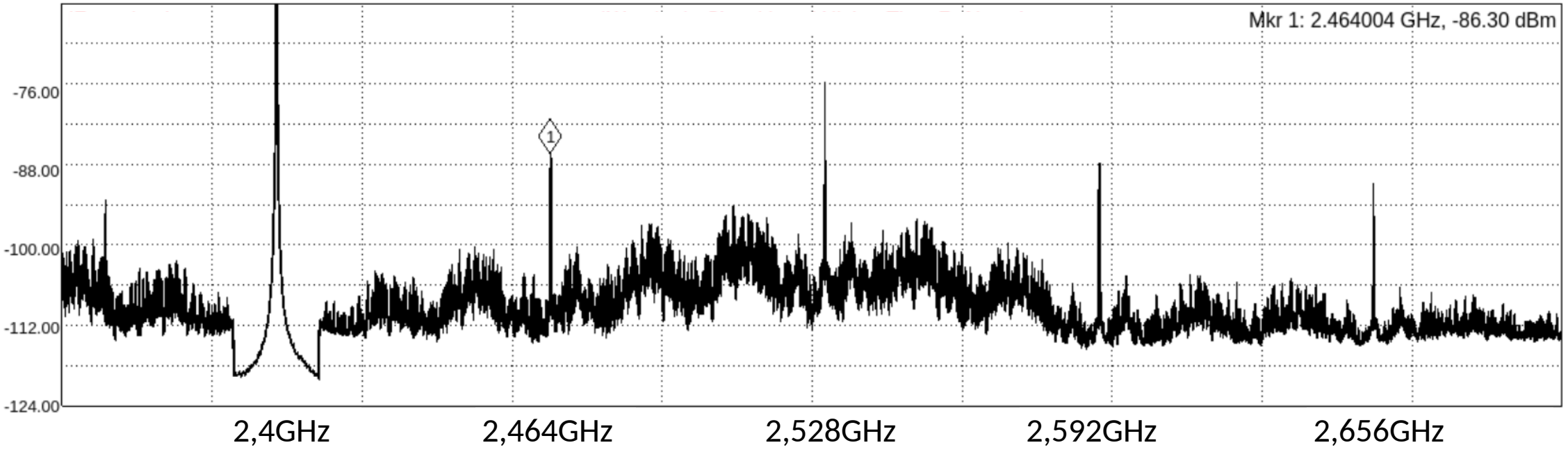


[4] T.Noulis, and P.Baumgartner, "CMOS substrate coupling modeling and analysis flow for submicron SoC design". Analog Integrated Circuits and Signal Processing, 2017

Leakage at non-harmonics frequencies

Radio spectrum at the output of the victim device

- Energy is also present between the harmonics

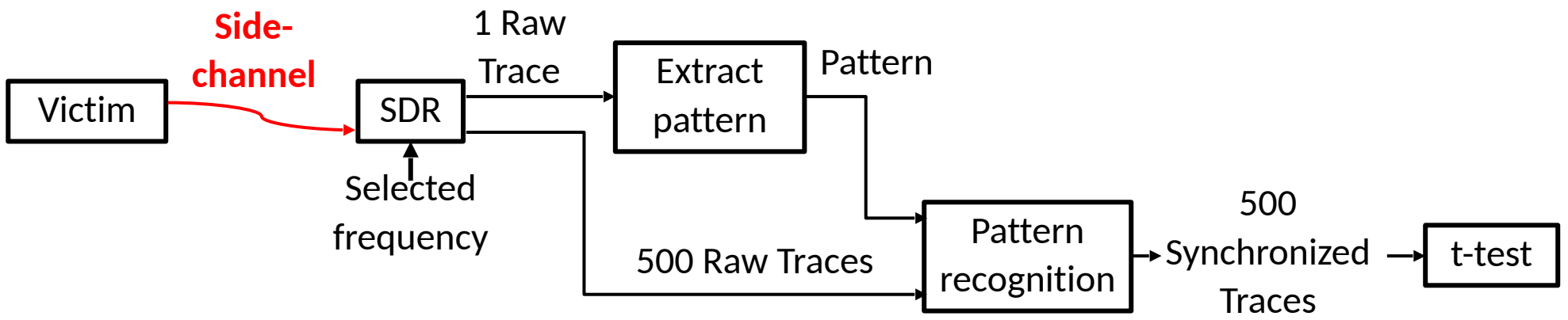


Leakage at non-harmonics frequencies

Questions:

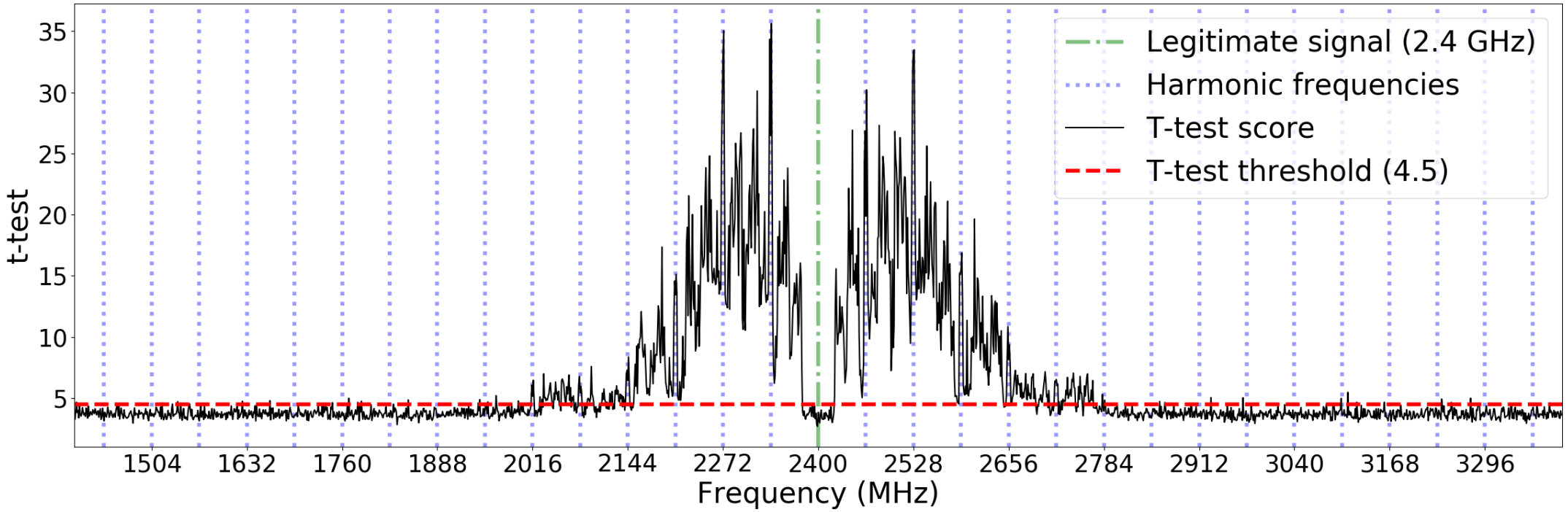
- Is the leakage also present at non-harmonic frequencies?
  - Perform a t-test at multiple frequencies over the spectrum.
- In case it is, is the attack more difficult there than at the harmonics?
  - Perform a template attack at frequencies where leakage is detected.

T-test



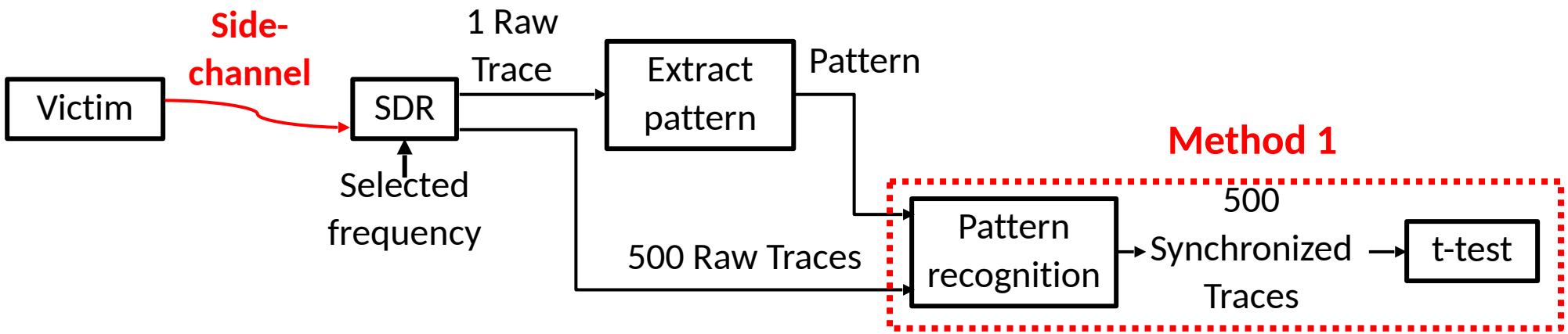
- Range of frequency: from 1,4GHz – 3,4GHz (1MHz resolution)
- Fixed vs fixed t-test, 500 traces per frequency:
  - 250 Plaintexts full of 0s, 250 Plaintexts full of 1s.
- The key is full of 0s

T-test



- Fixed vs fixed t-test
- 500 traces per frequency
- 27 hours of computation

Pattern detection



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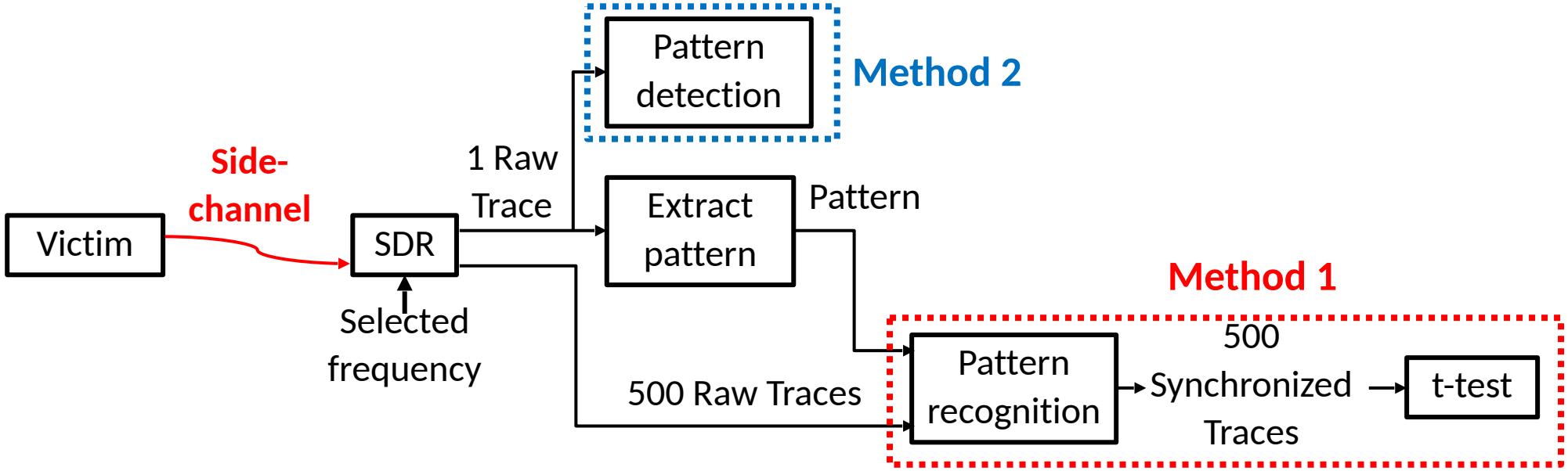

Pattern detection

Based on the concept of Virtual Trigger[3]:

- A series of Cryptographic Process (CP) is executed recursively without interruptions

[5] J.Guillaume, M.Pelcat, A.Nafkha, R.Salvador, "Virtual Triggering: a Technique to Segment Cryptographic Processes in Side-Channel Traces," SIPS, 2022.

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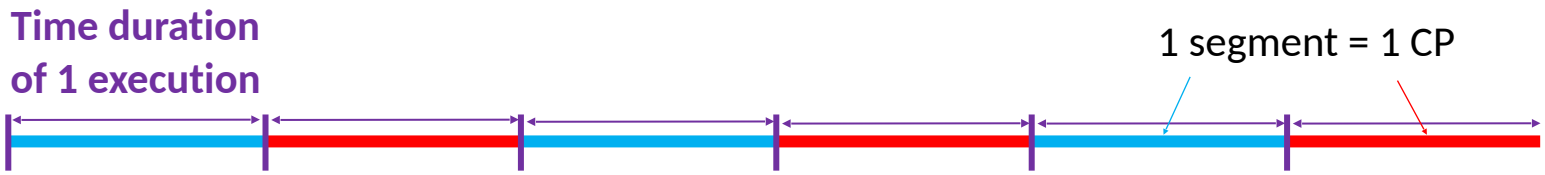
- By knowing precisely enough the CP execution time: possibility to create a Virtual Trigger (VT) that points to a common instant in each CP



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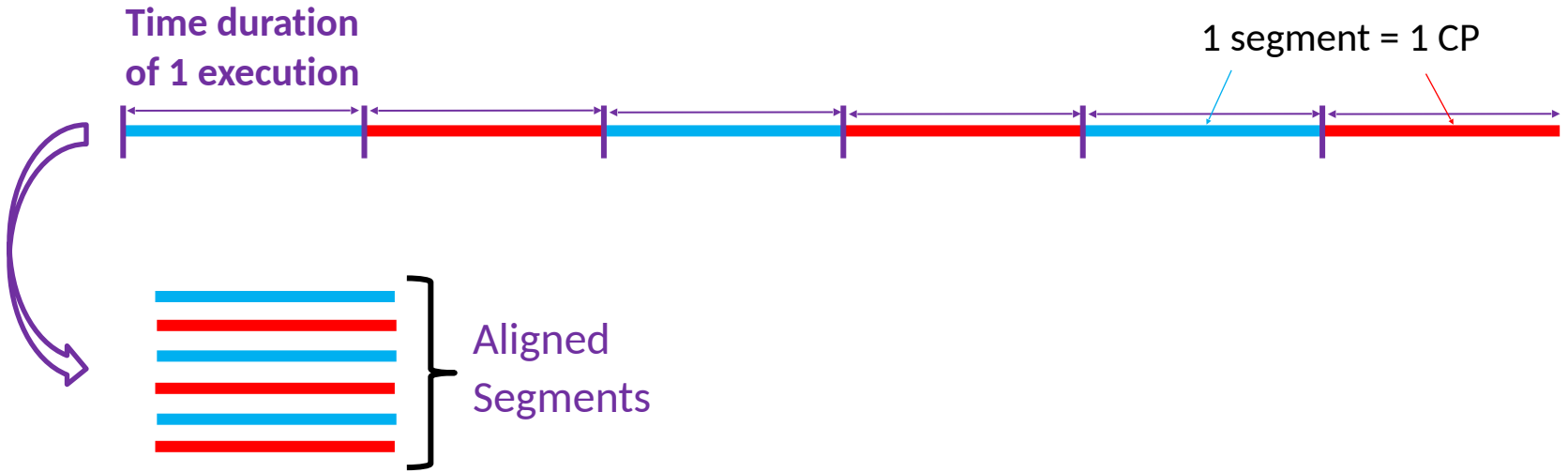

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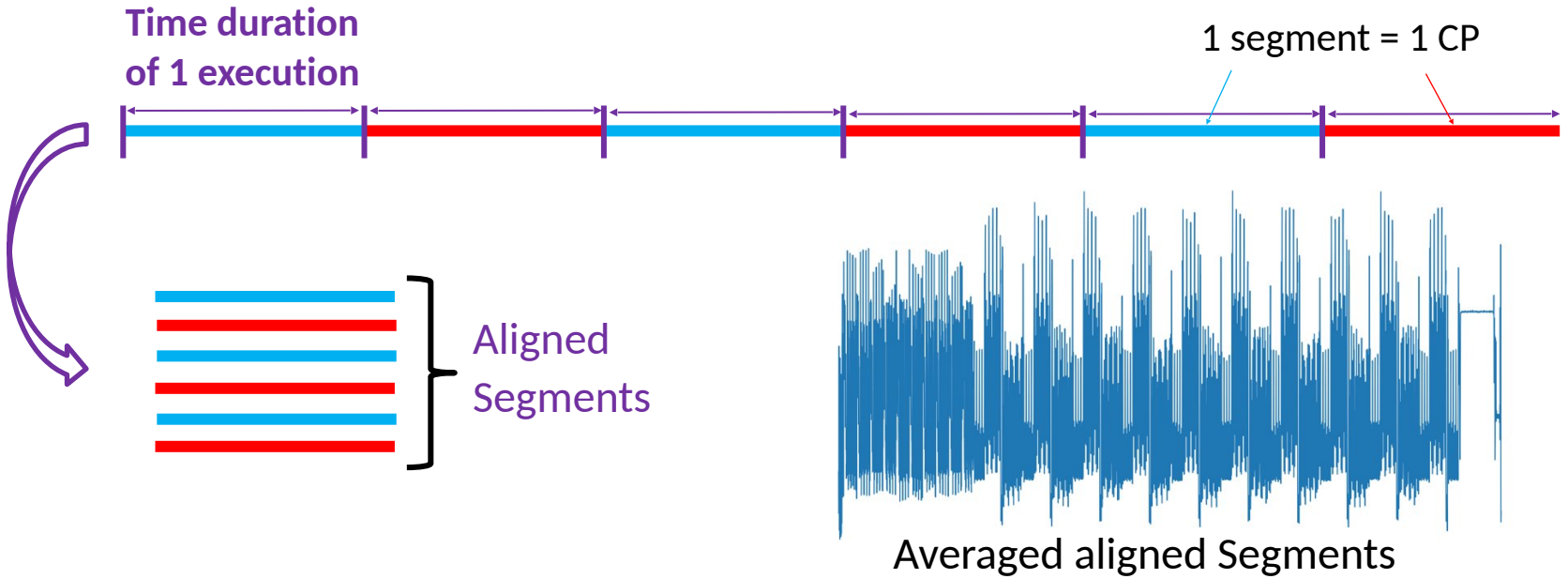

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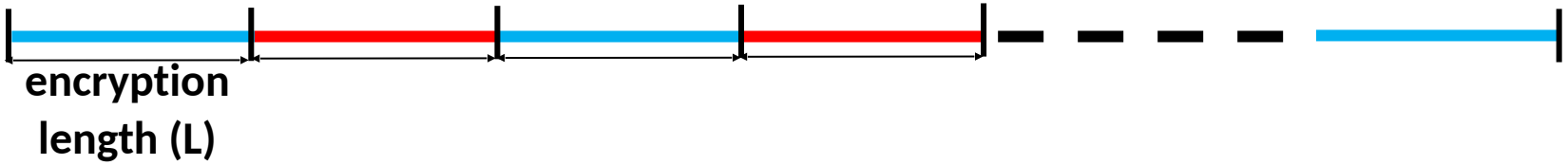
Pattern detection

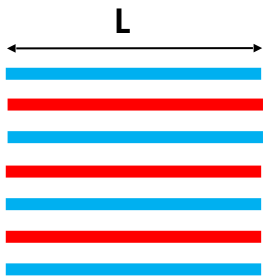
Initial trace



Pattern detection

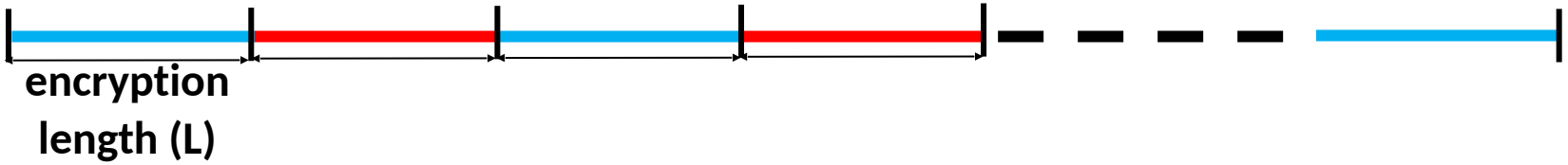
Initial trace

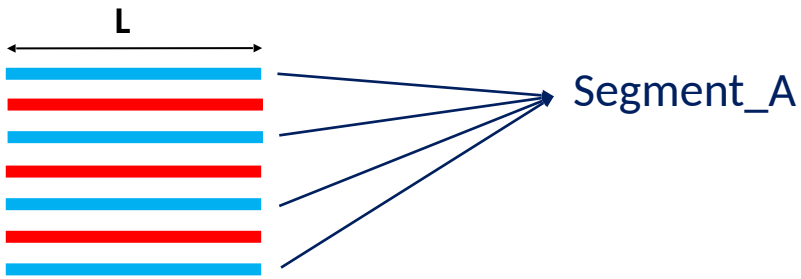
encryption length (L)



Pattern detection

Initial trace





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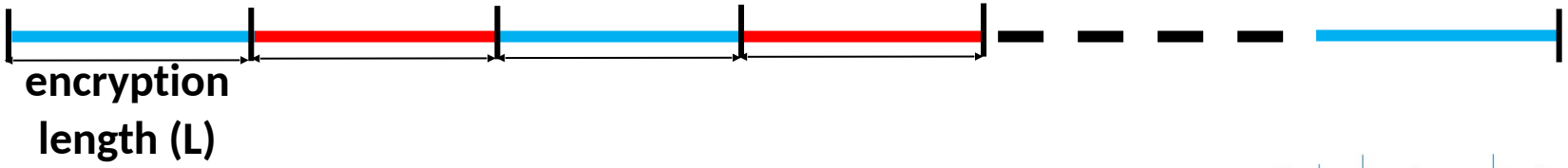

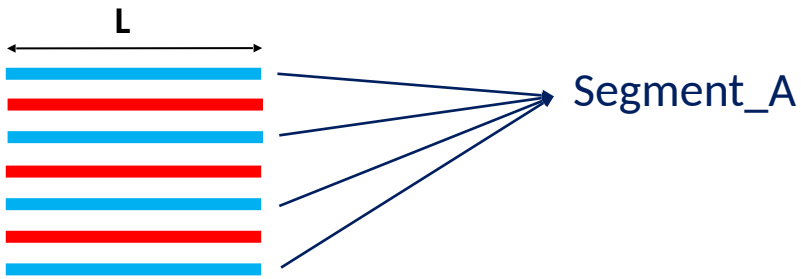

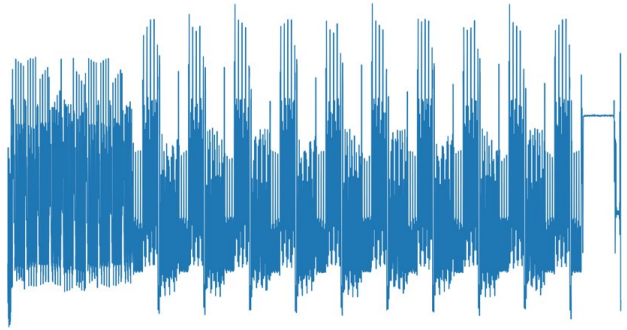

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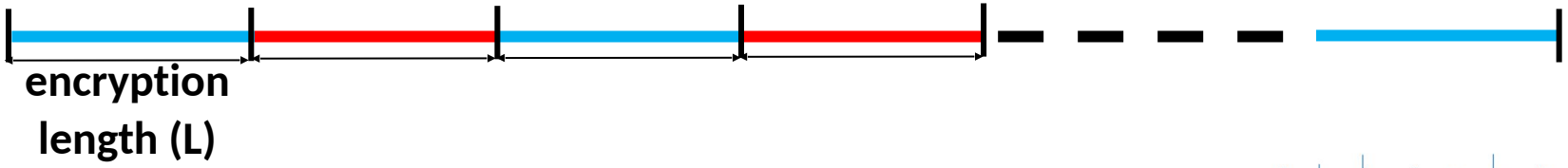

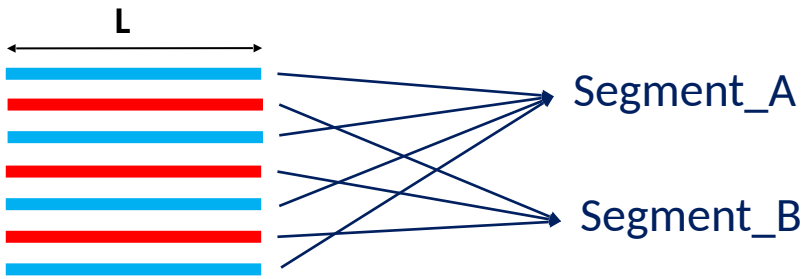

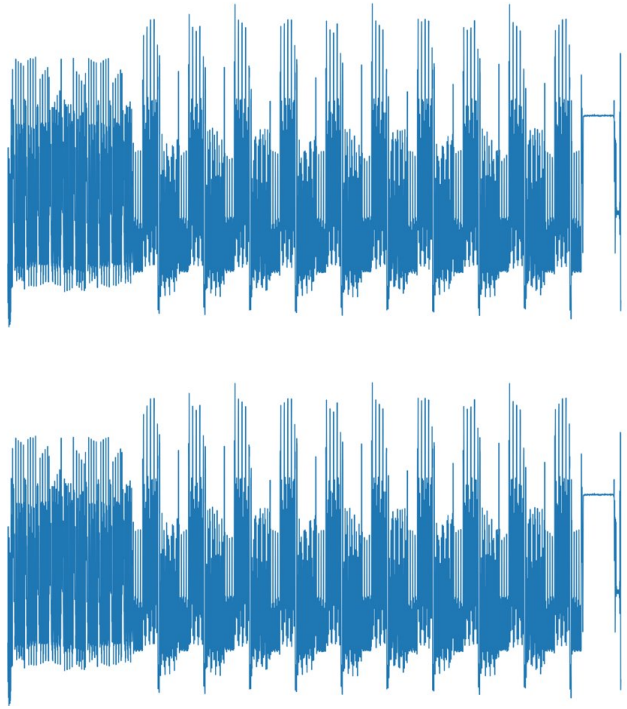

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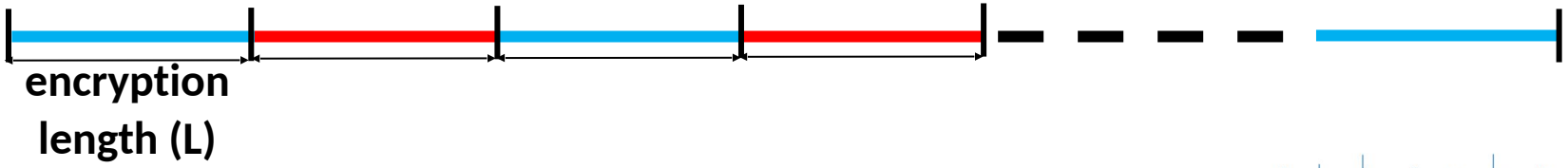

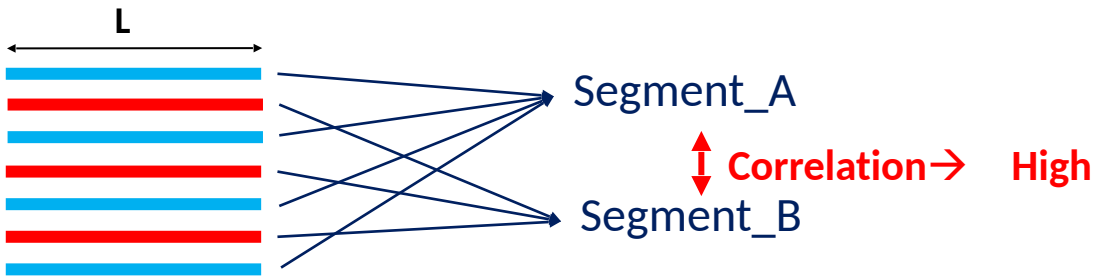

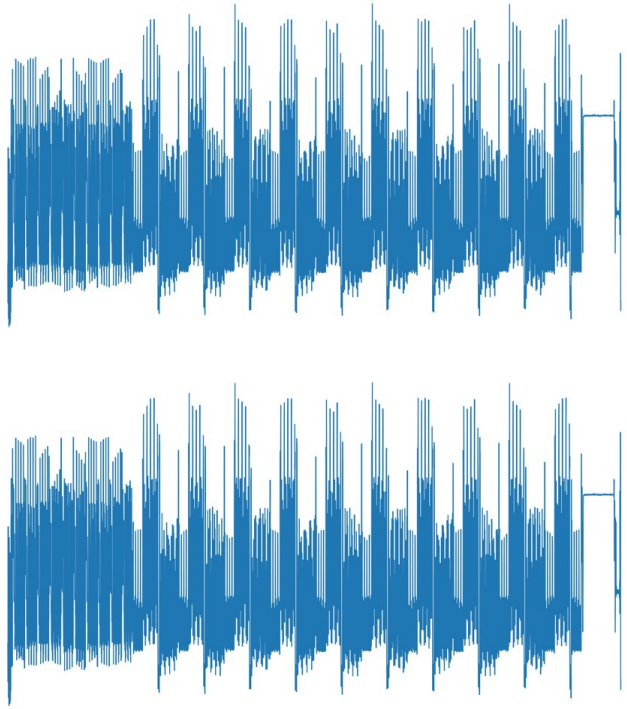

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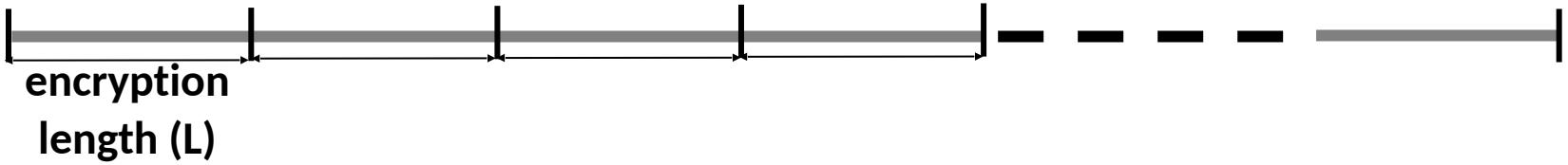

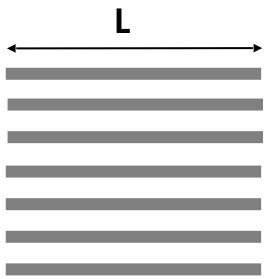

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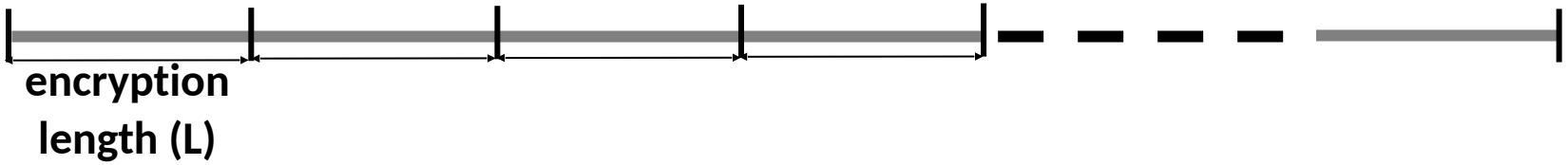

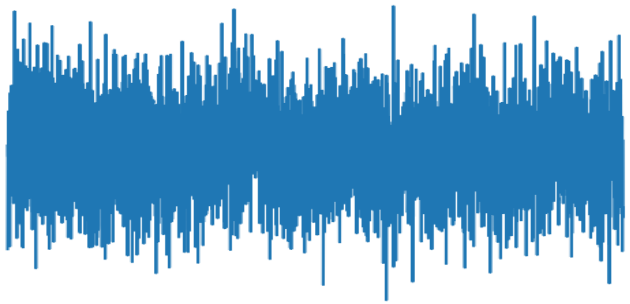

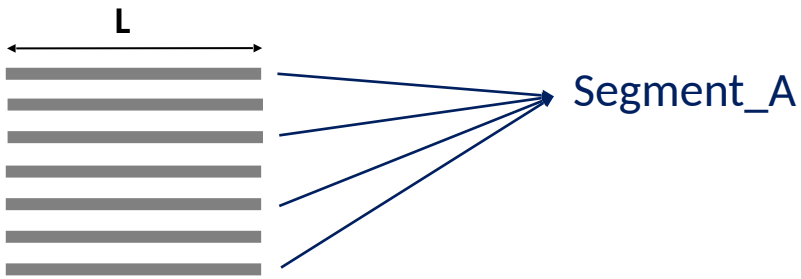

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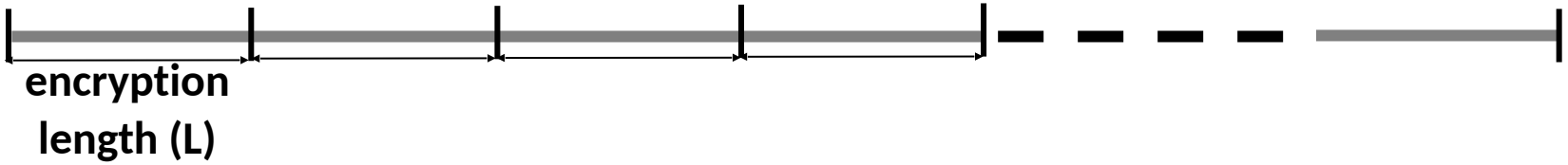
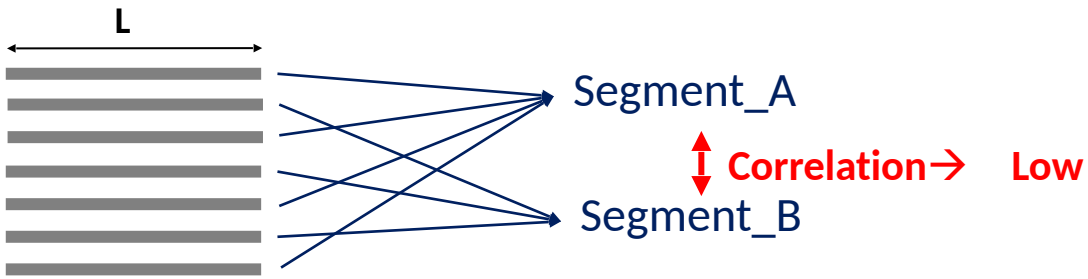
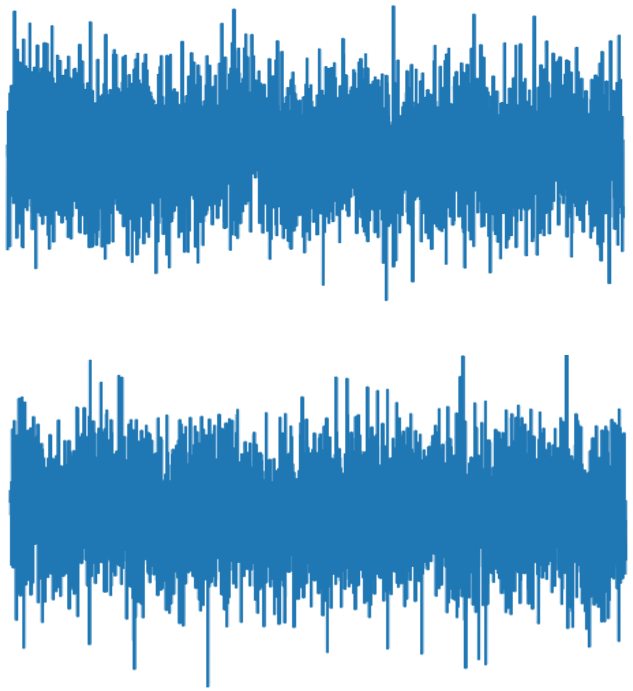
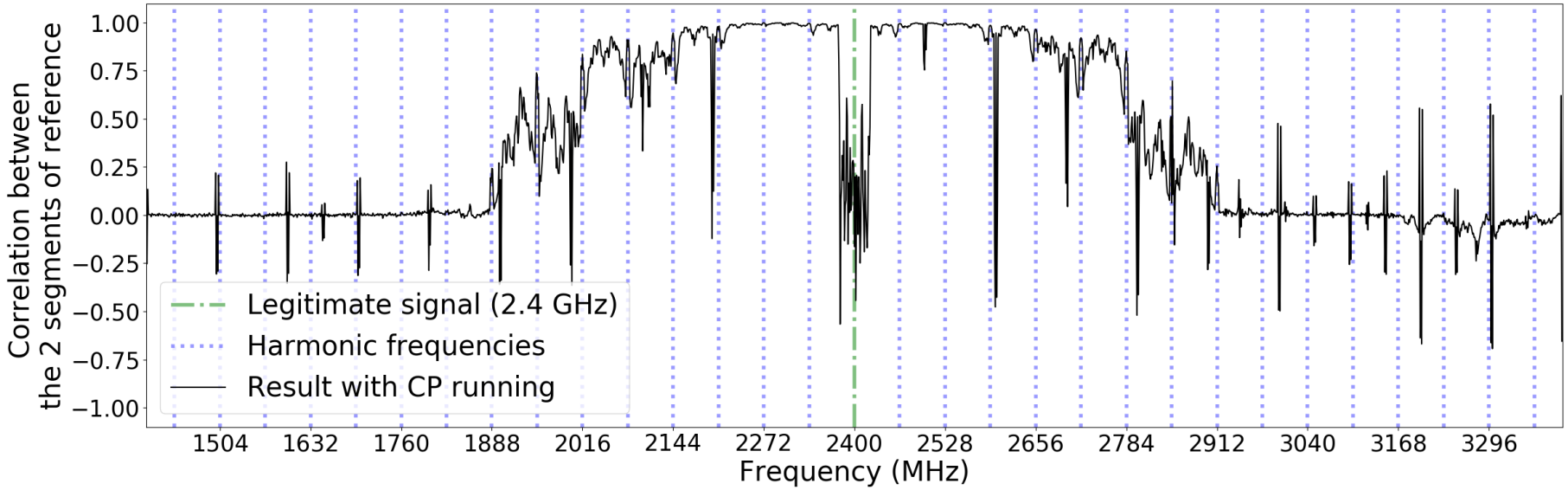






Pattern detection

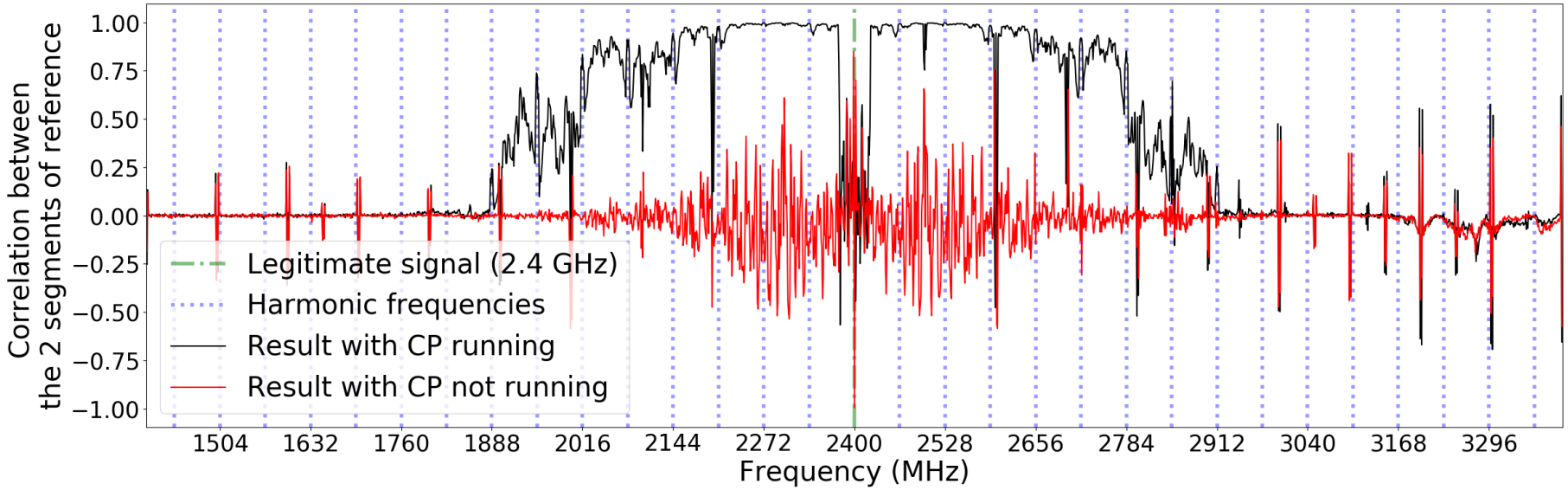
With running encryptions:



- 52 minutes of computation

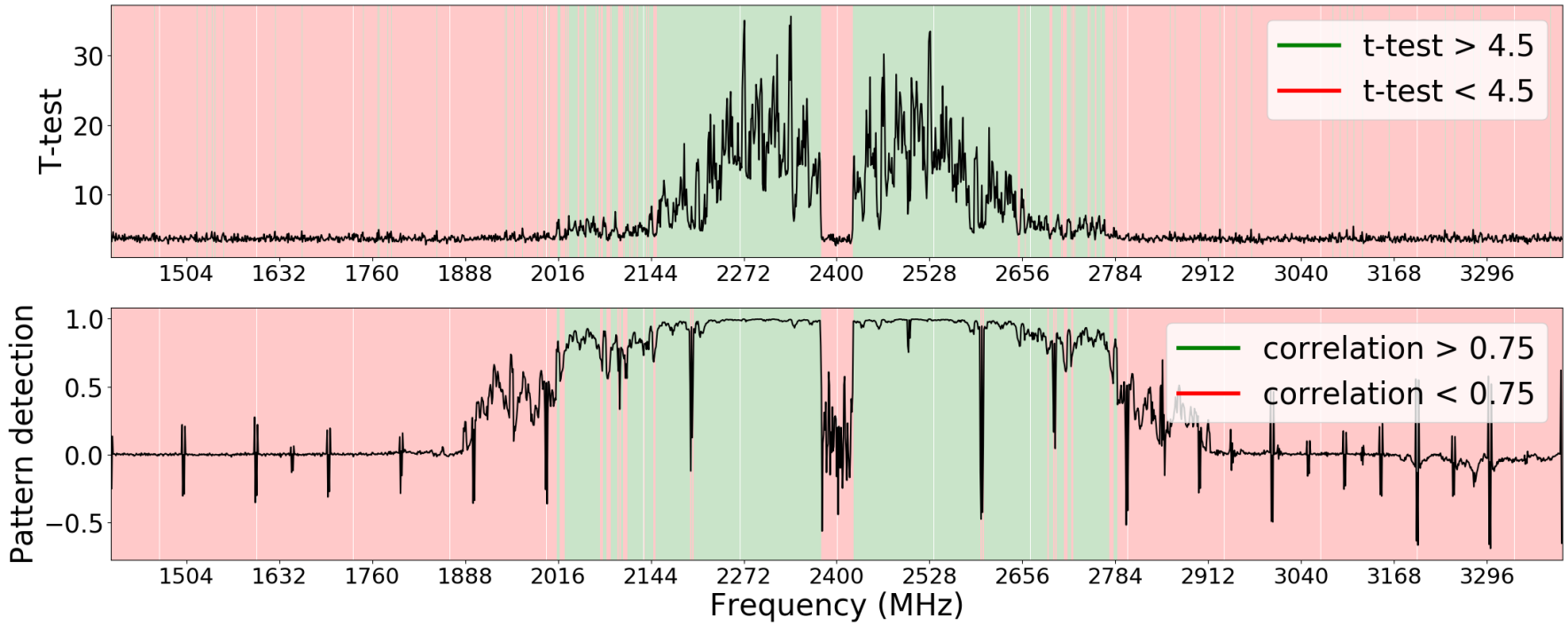
Pattern detection

Without running encryptions:



- 52 minutes of computation

Comparison of the 2 methods



- T-test: 27 hours of computation
- Pattern detection: 52 minutes

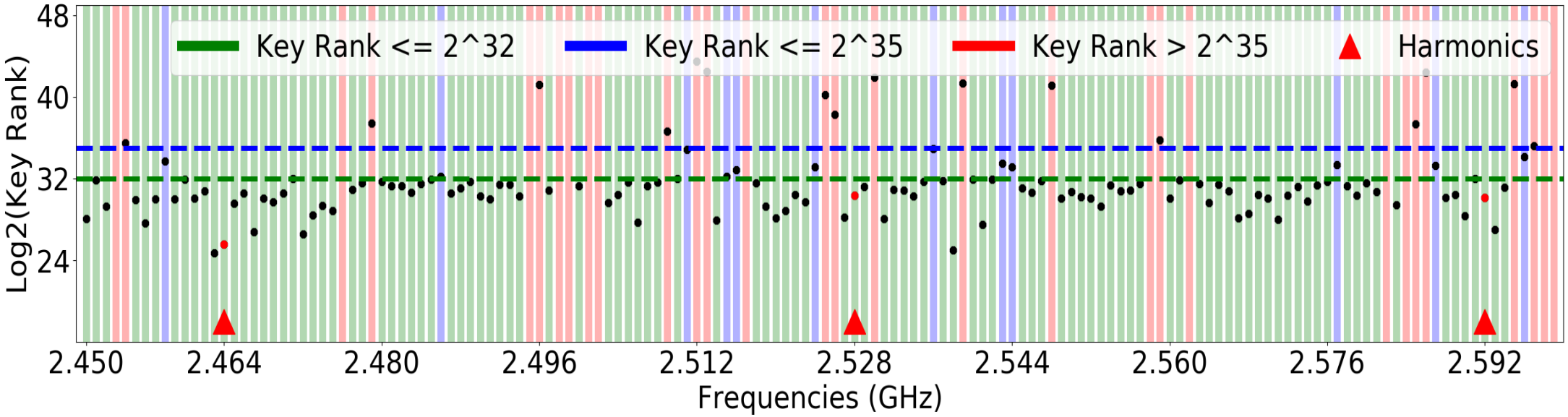
Attack at non-harmonic frequencies

- Evaluate attack potential: Attack in idealistic conditions
  - Attack by cable
  - Template attack with a big number of traces

- Increase the difficulty to get the attack more realistic
  - Add distance
  - Reduce the number of traces

Attack at non-harmonic frequencies

By cable:

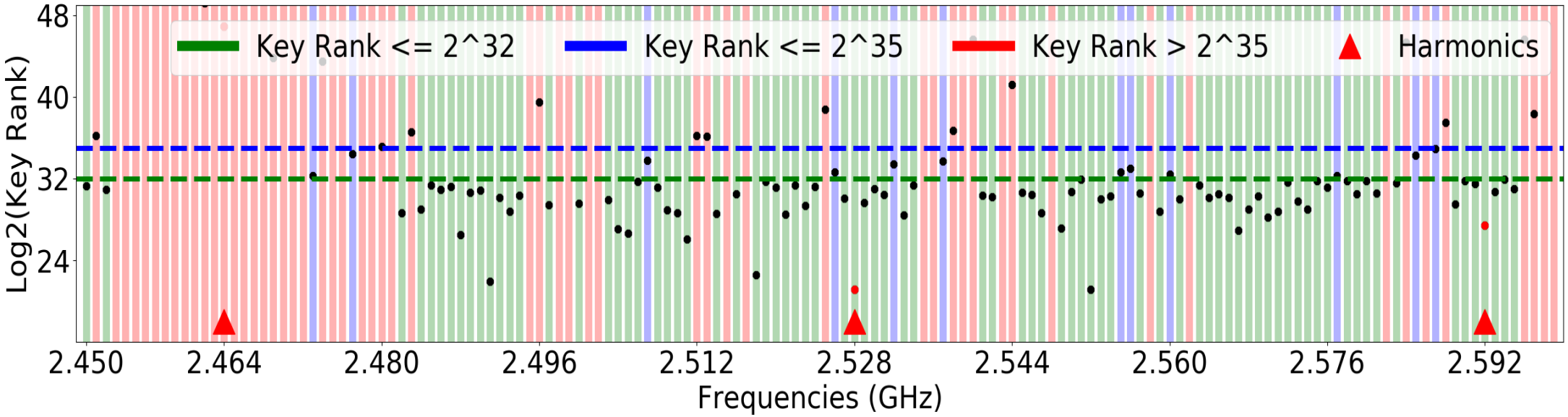


- Profiling phase: 15k Traces
- Attacking phase: 15k Traces

Key Rank	Time order
2^32	5min
2^35	1hour
2^39	1day
2^41	1week

Attack at non-harmonic frequencies

At 2 meters:



- Profiling phase: 15k Traces
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→ Loss of the first harmonic

Key Rank	Time order
2^32	5min
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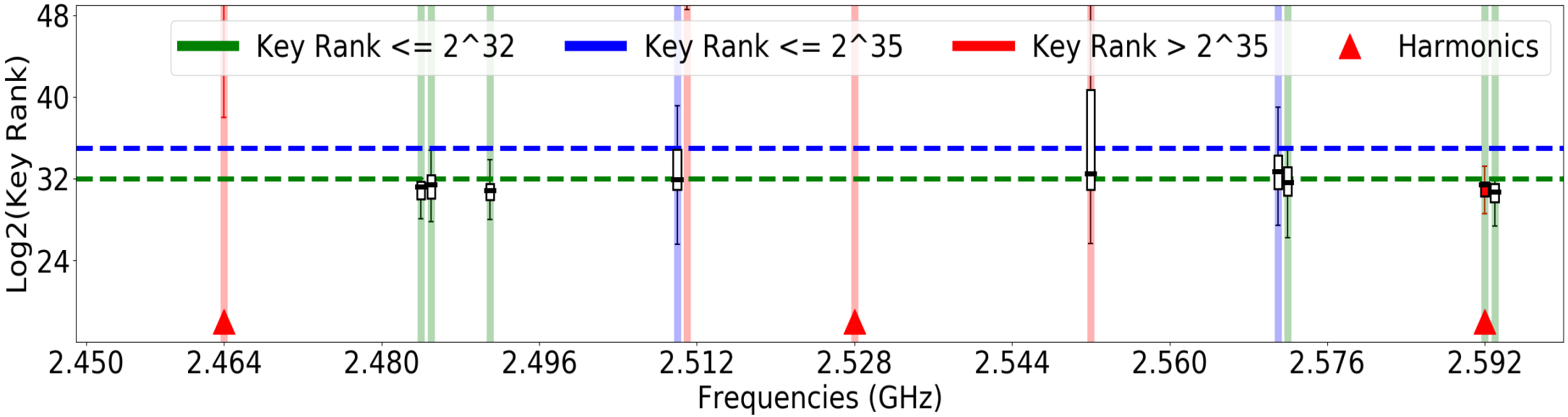
Attack at non-harmonic frequencies

At 7 meters, 50 attacks per frequency:



- Profiling phase: 15k Traces
- Attacking phase: 750 Traces

→ Loss of the 2 first harmonics

Key Rank	Time order
2^32	5min
2^35	1hour
2^39	1day
2^41	1week

Conclusion

- Demonstrated **the presence of leakage over the spectrum**:
  - By using t-test, a method frequently used by the community.
- Proposed **pattern detection, a second method that optimizes the time duration**.
- In the context of this work, the attack can be **as effective at non-harmonics as at harmonics**.
- This work cannot demonstrate that leakage will always be exploitable at non-harmonics on any devices, but **non-harmonics cannot be ignored**.

Future works

Evaluate the impact of frequency diversity:

Evaluate the **Key rank reduction** between the best frequency and the most efficient combination for different configurations:

- Distance: 5 / 10 / 15 meters and maybe further
- Number of traces used
- Environment: noise less / noisy

In which conditions is frequency diversity is interesting to apply?

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Thank you !
Do you have any questions ?

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