Exploring the Potential of Residual Networks for Efficient Sub-Nyquist Spectrum Sensing

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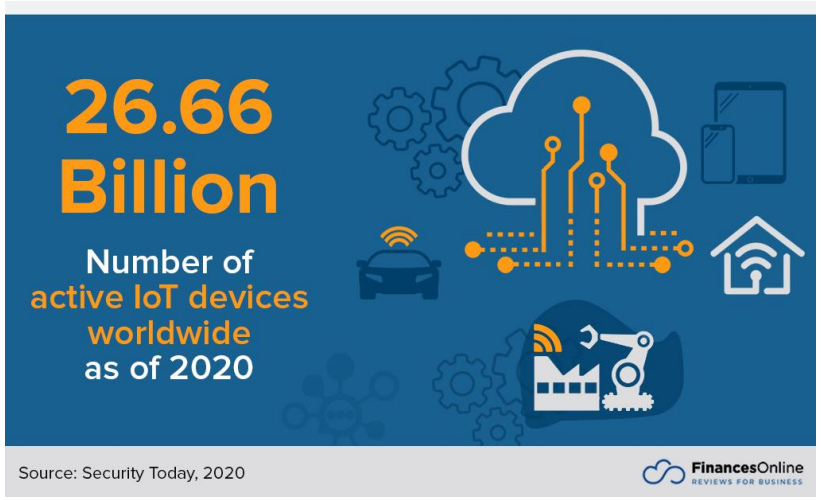
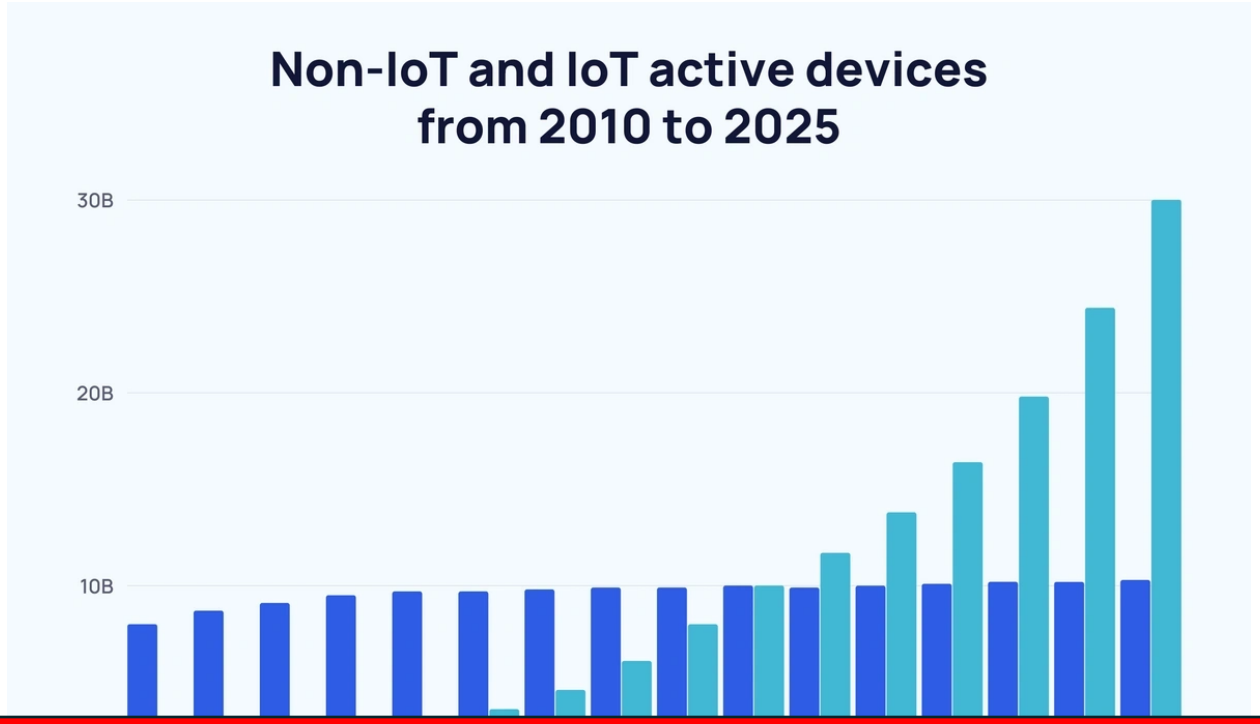
Research Motivation

Scarcity of Spectrum Resources

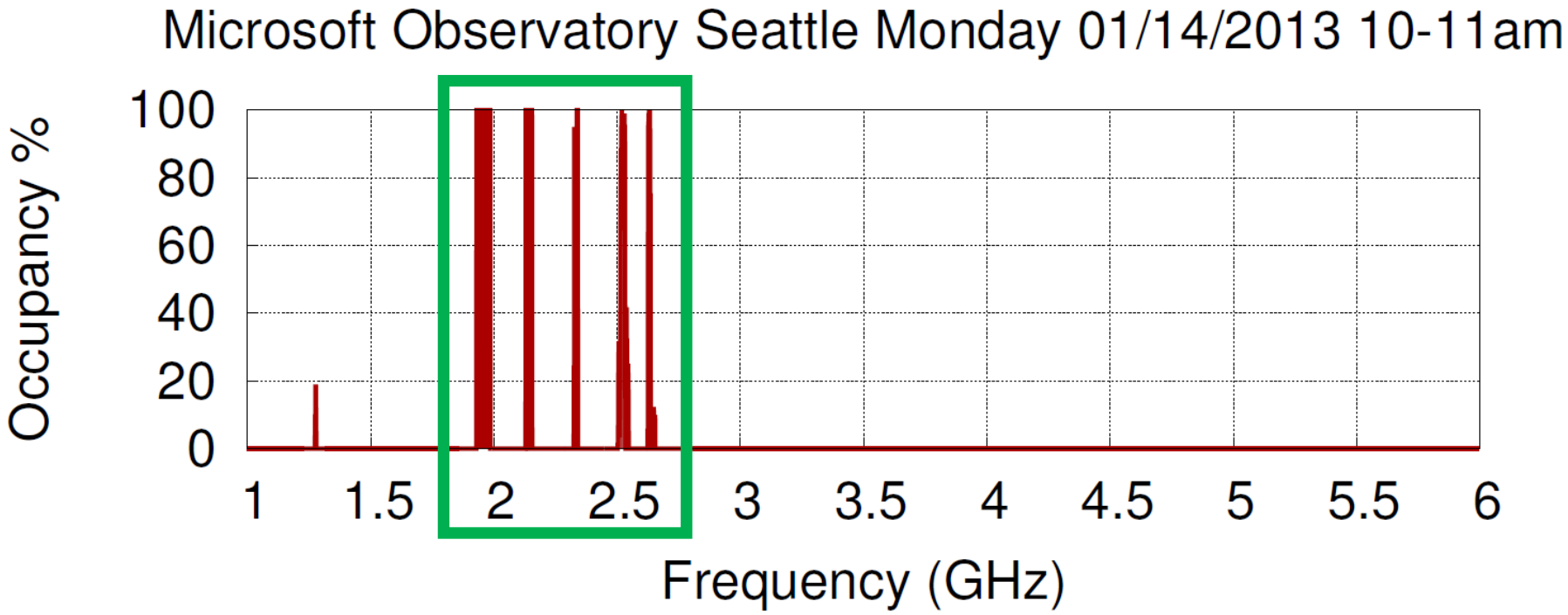




Increased number of active IoT devices
will require additional spectrum resources for communication

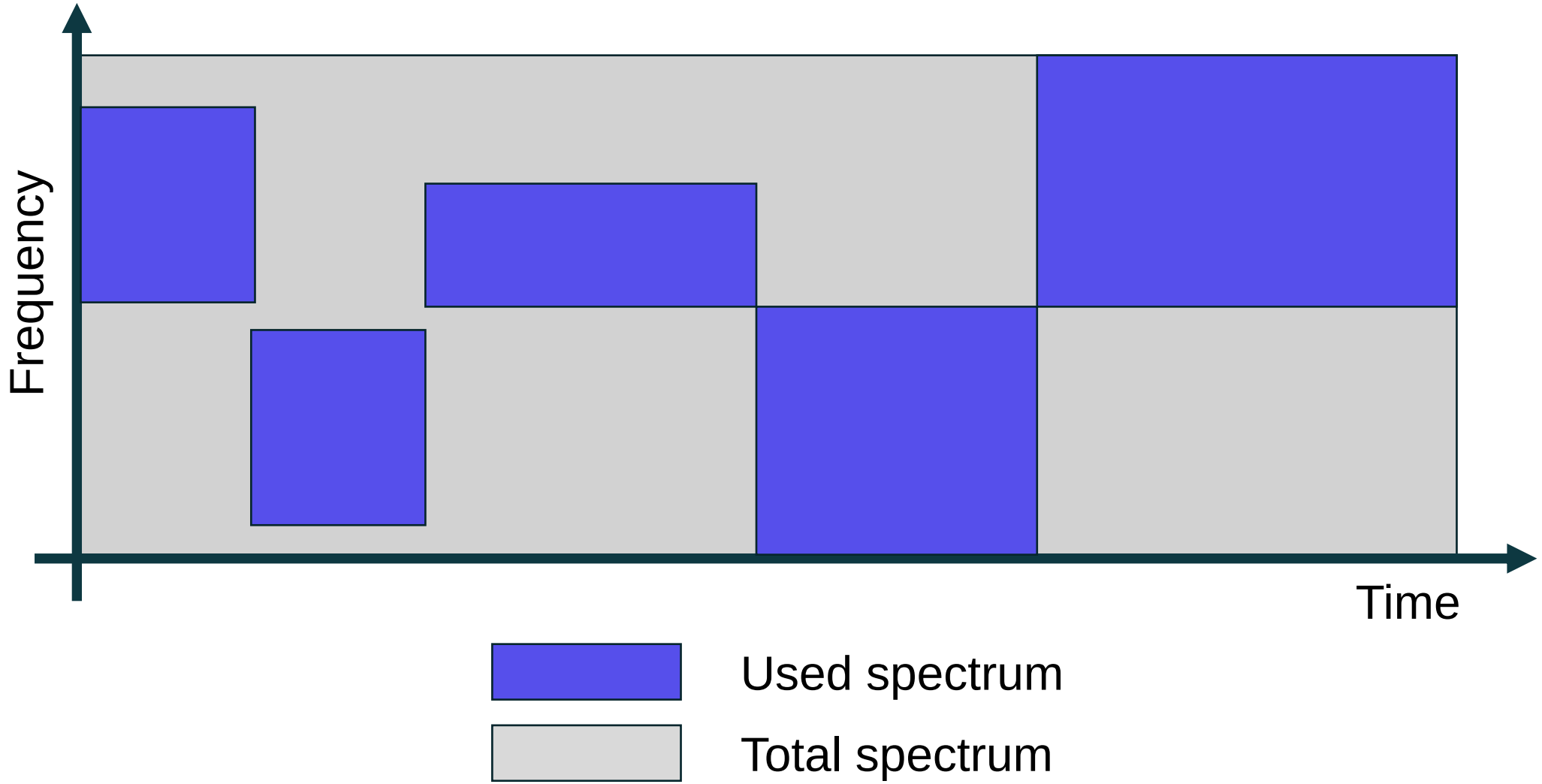
Source: https://explodingtopics.com/blog/iot-stats

Sparse Spectrum Utilization



Hassanieh, et al., 2011

Spectrum Holes



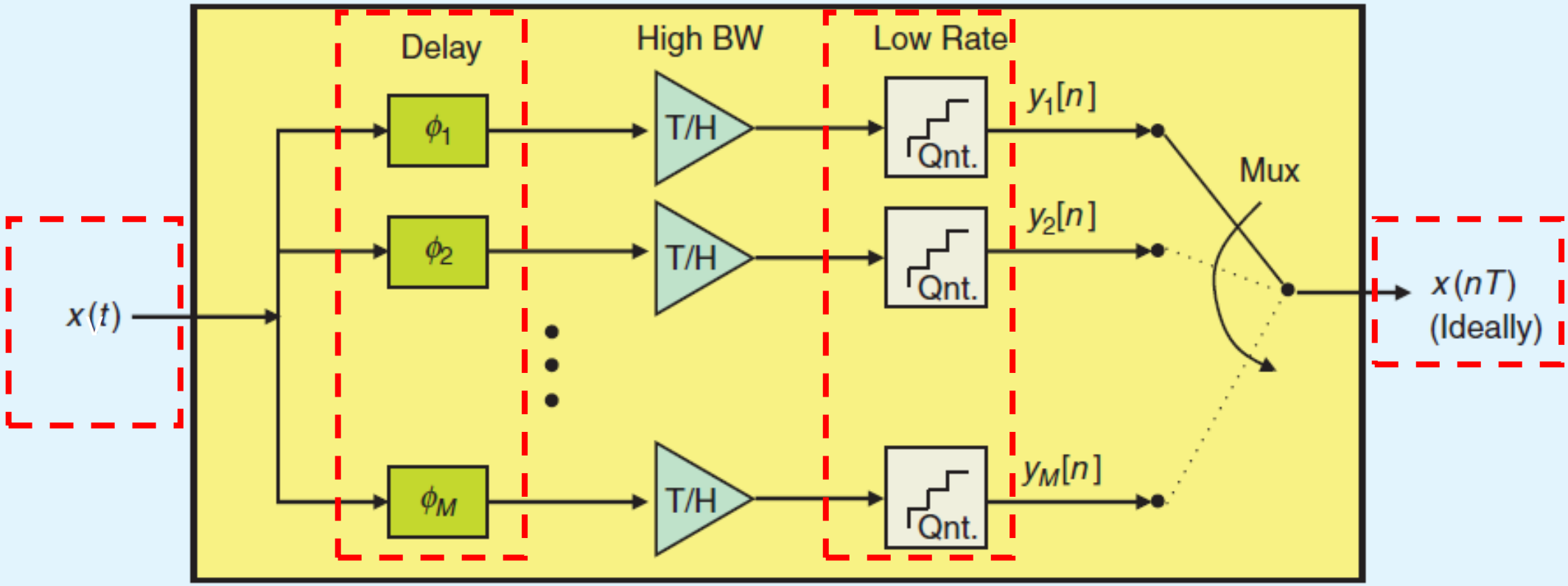
Maximizing Spectrum Utilization

Mobile devices need to detect spectrum hole before they can utilize it

High-Frequency Spectrum Detection

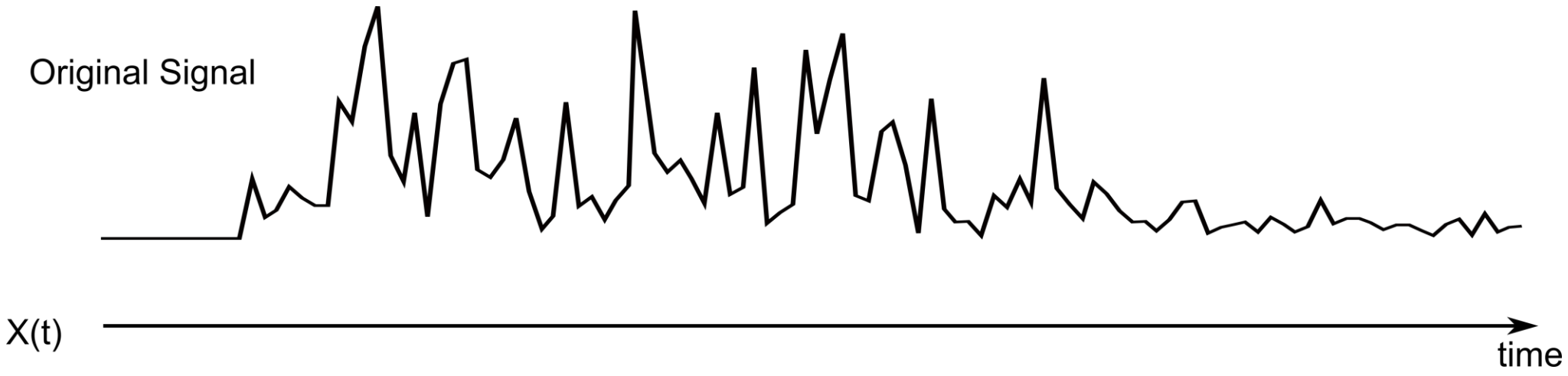
High-frequency detection requires a high-frequency ADCs, but they are costly and not available on IoT/mobile devices

High-Frequency Spectrum Sensing on Mobile Devices

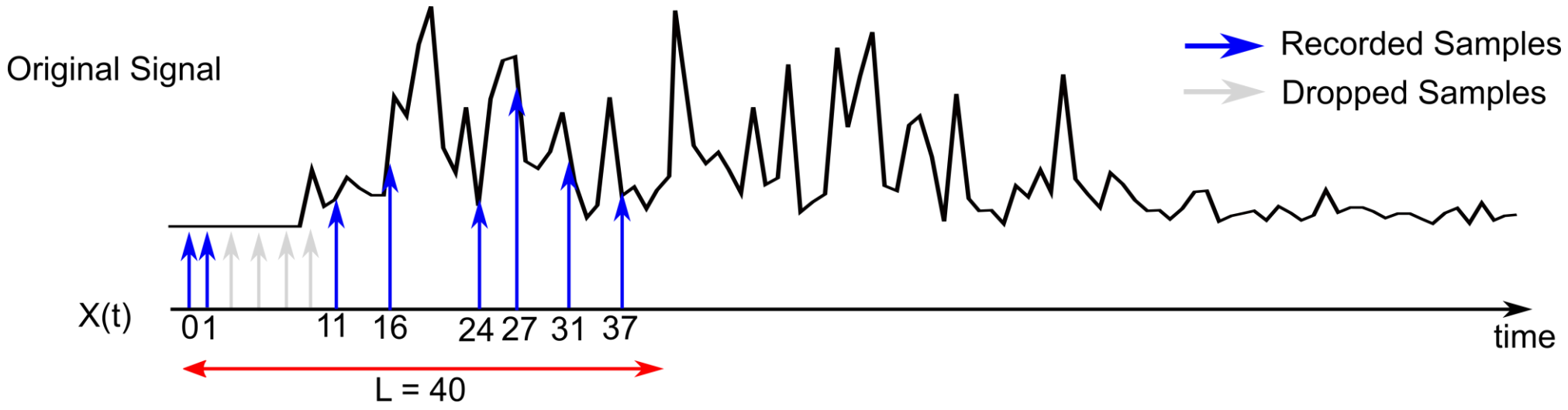


Mishali, et al., 2011

Multicoset Sampling Principle



Multicoset Sampling Principle



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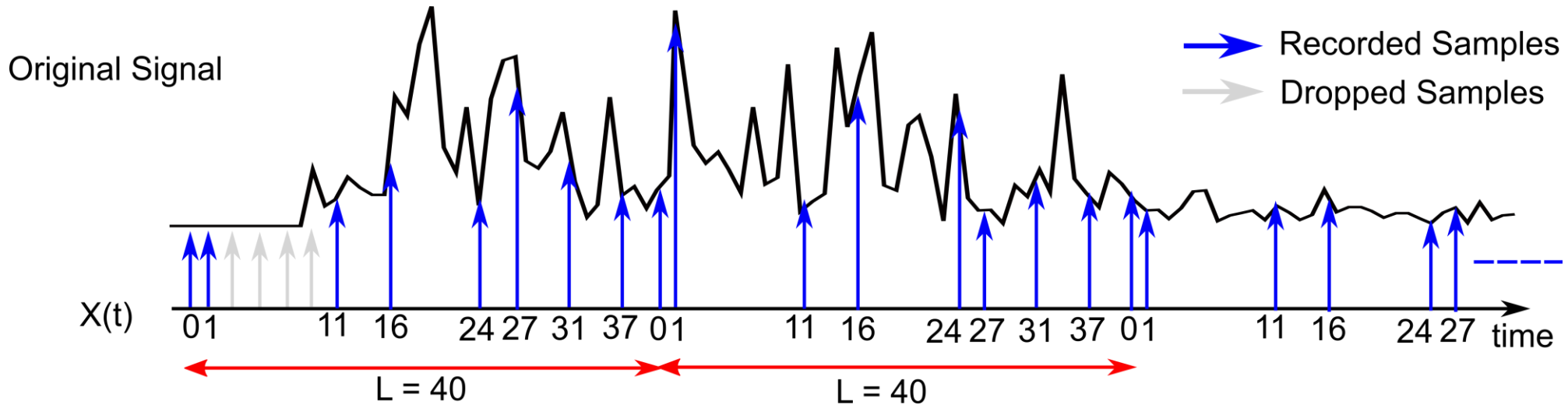

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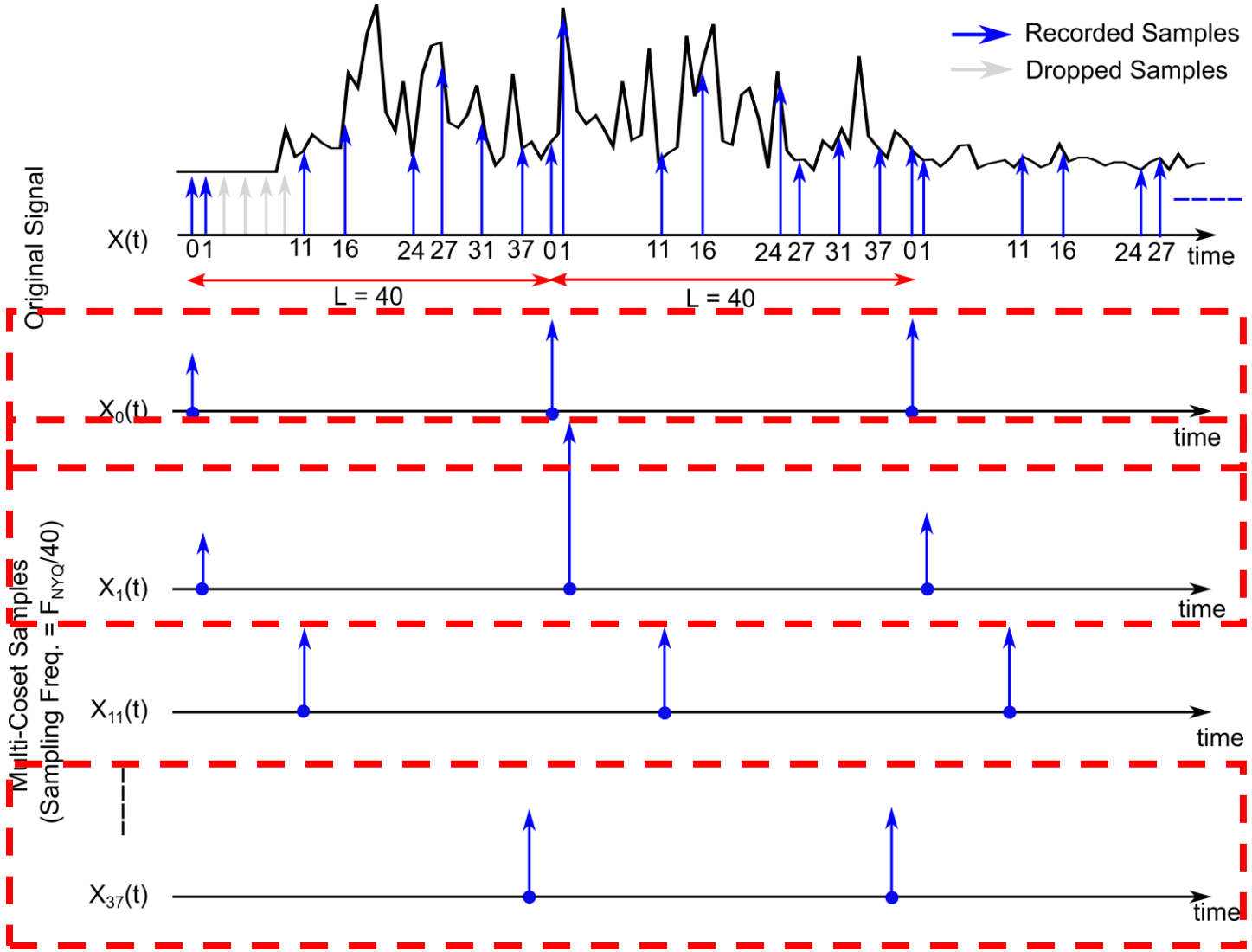
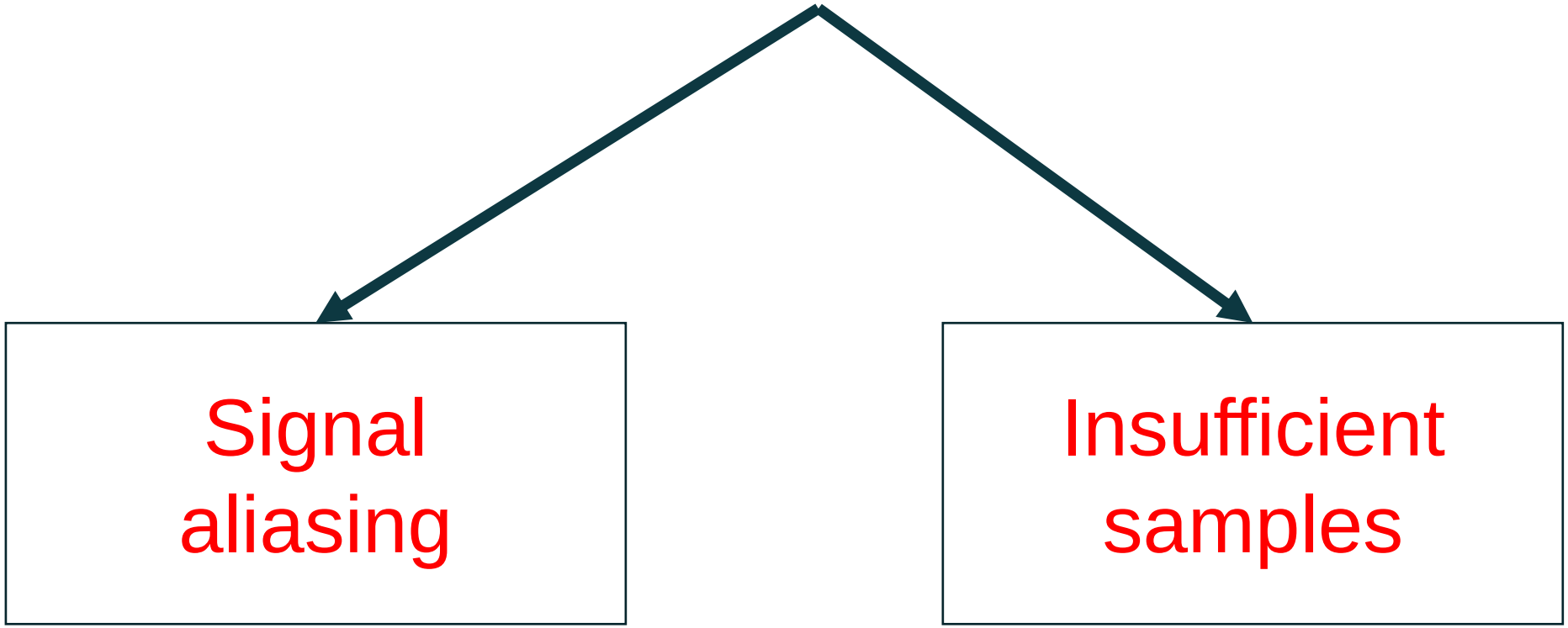


Challenges in Signal Reconstruction

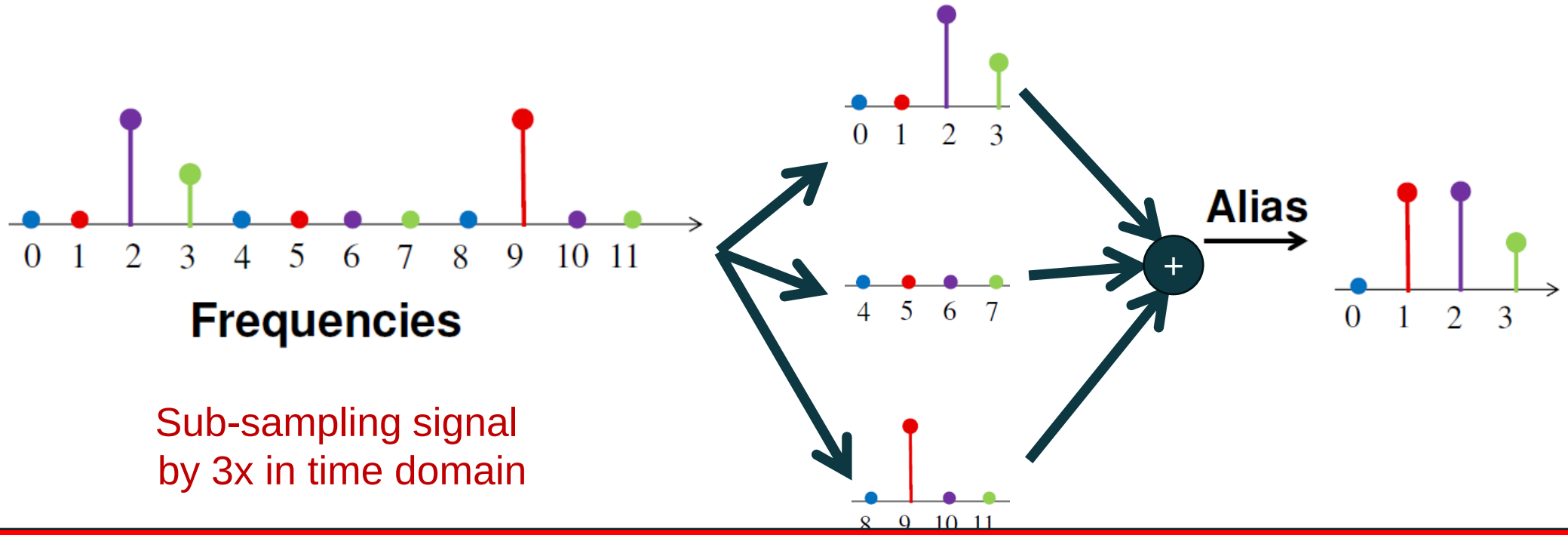


Signal Aliasing

Even though the helicopter is taking off,
the blades do not seem to be moving at all

Source: Pinterest

Signal Aliasing

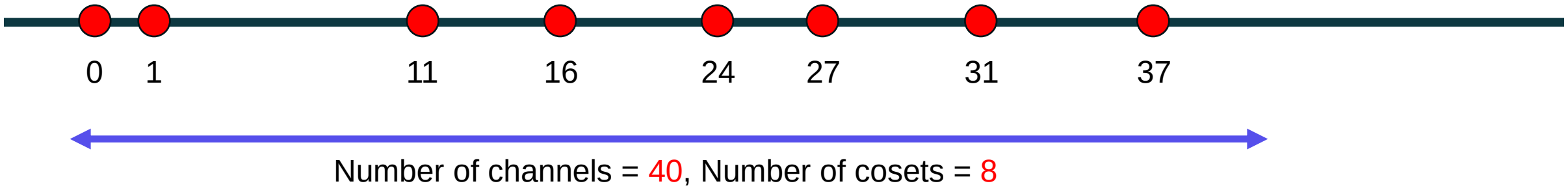


Sub-sampling signal
by 3x in time domain

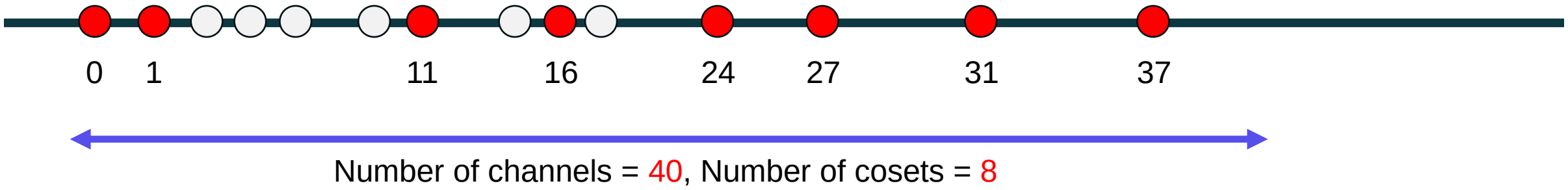
Aliasing occurs because high-frequency components overlap with low-frequency components due to low-frequency sampler

Hassanieh, et al., 2011

Insufficient Samples

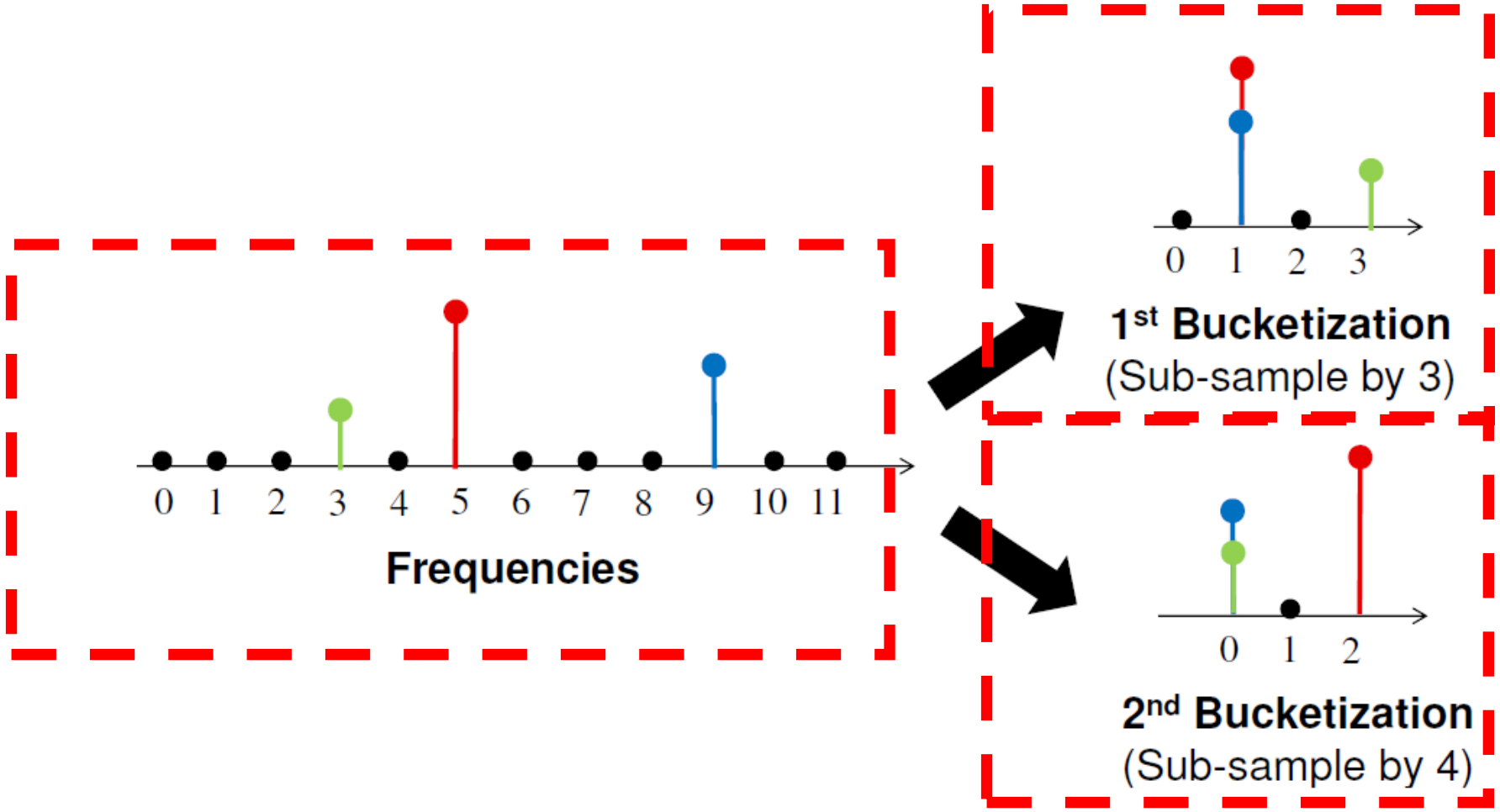


Insufficient Samples



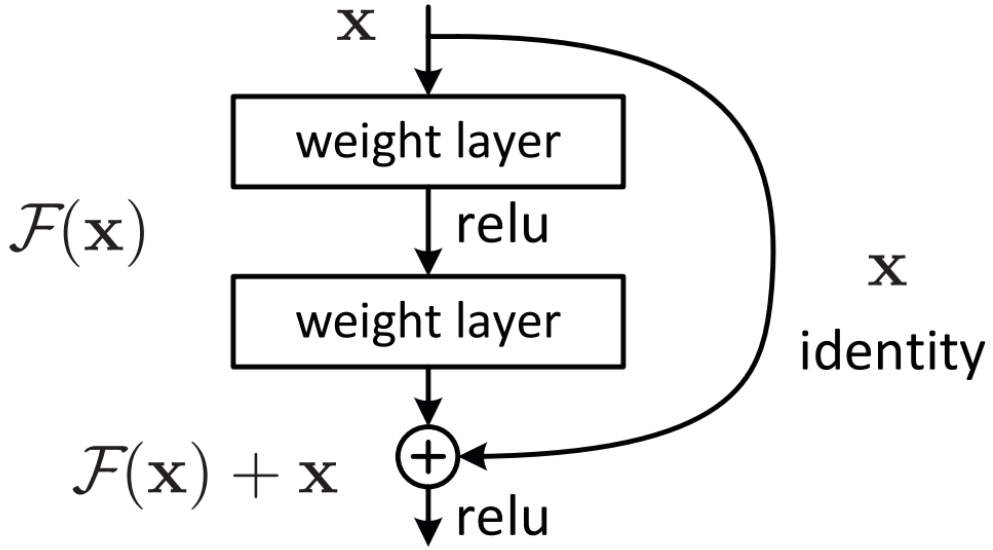
Most of the samples are not recorded during sampling, which need to be recovered for signal reconstruction

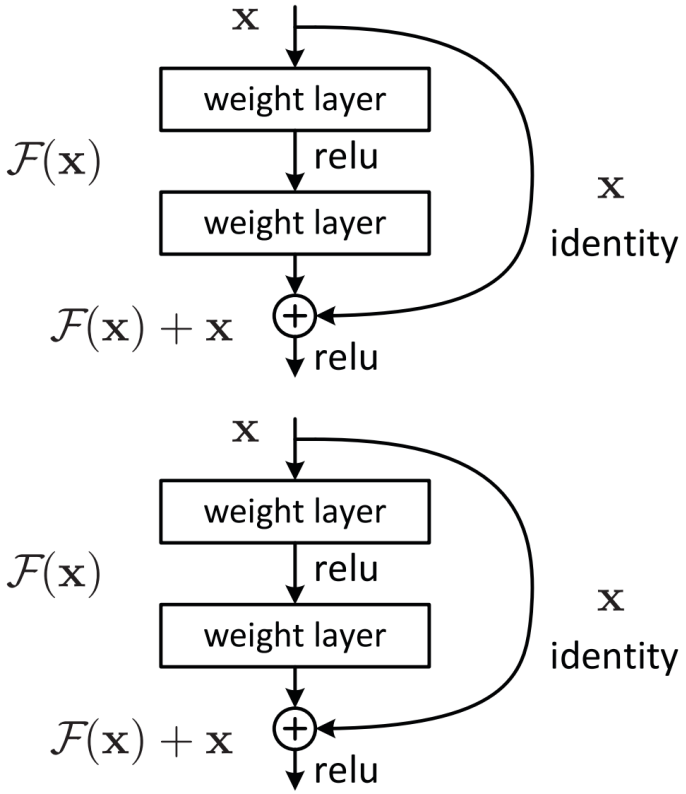
Anti-Aliasing With Downsampling



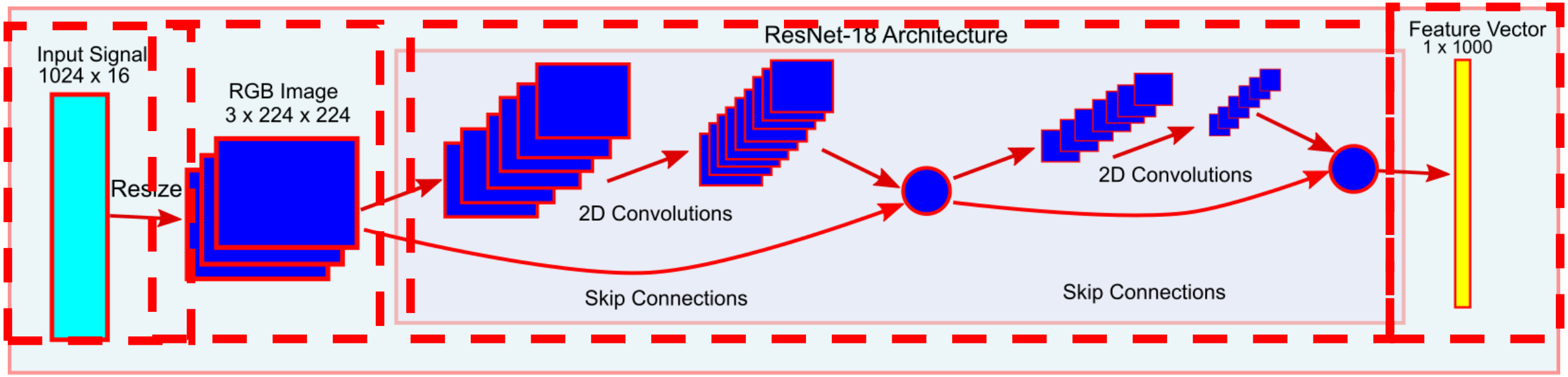
Hassanieh, et al., 2011

Residual Networks: Unit Block

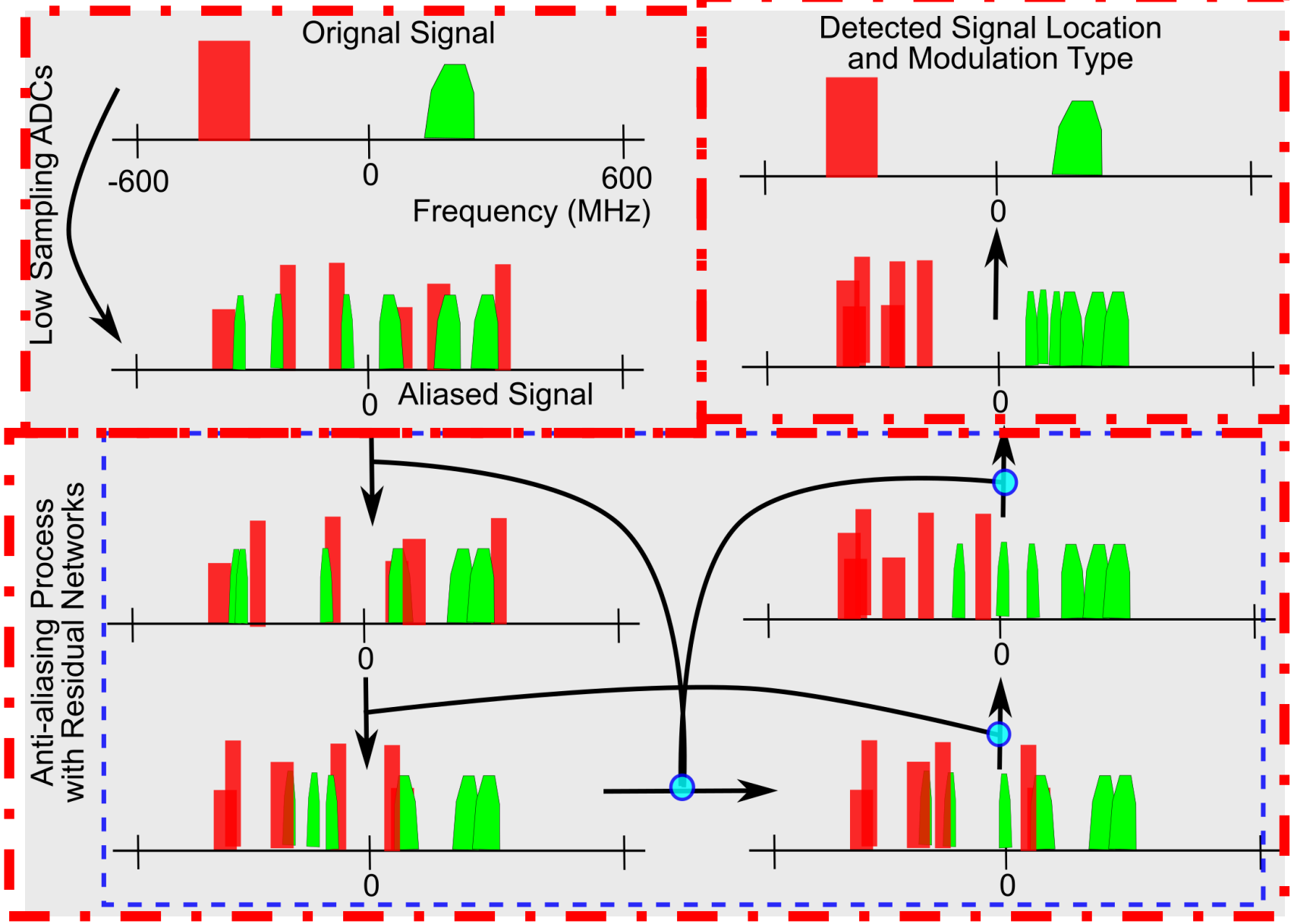




Residual Networks for Signal Recovery



How Residual Network Works?



Summary of Datasets

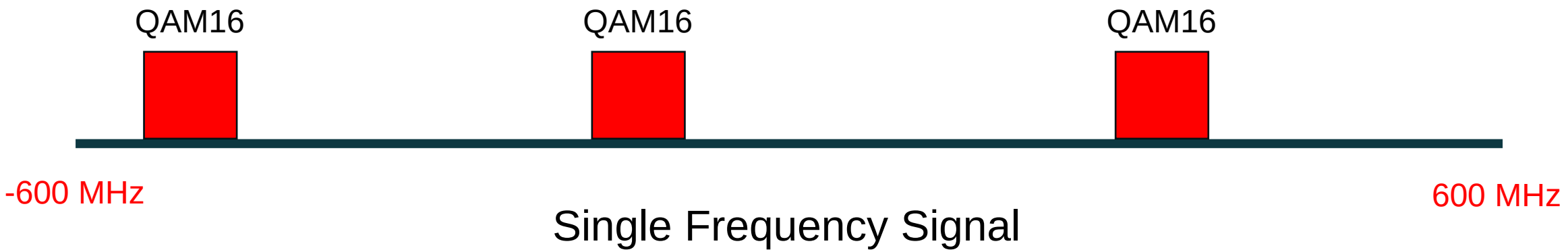
- Modulation detection is part of the signal detection and recovery
- Using aliased samples to detect the modulation of the signal
- Source of dataset: http://www.gbsense.net/challenge/

Single Frequency: Signal with several MHz bandwidth with the unknown center frequency between [-600, 600] MHz

Double Frequency: Two signals with several MHz bandwidths with the center frequency between [-600, 600] MHz, 24 sub-bands

Modulation Types

Possible Modulation Types: APSK16, APSK32, APSK64, ASK8, BPSK, OQPSK, PSK16, PSK8, QAM128, QAM16, QAM256, QAM64, QPSK (Total: 13)



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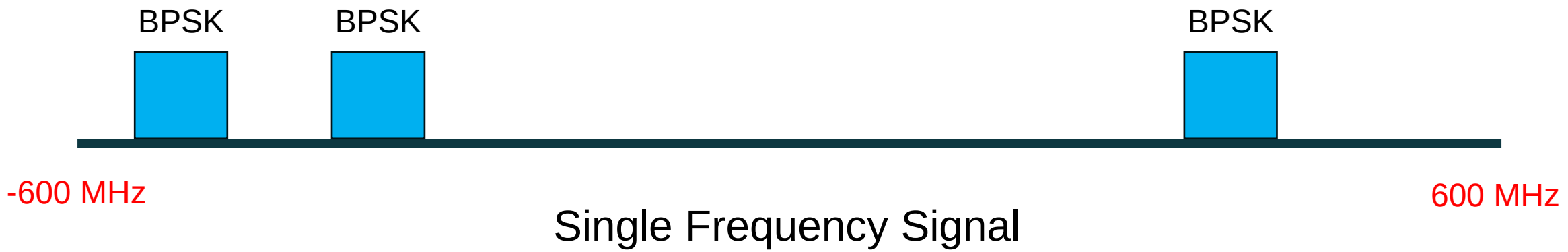

Single Frequency Signal

Modulation Types

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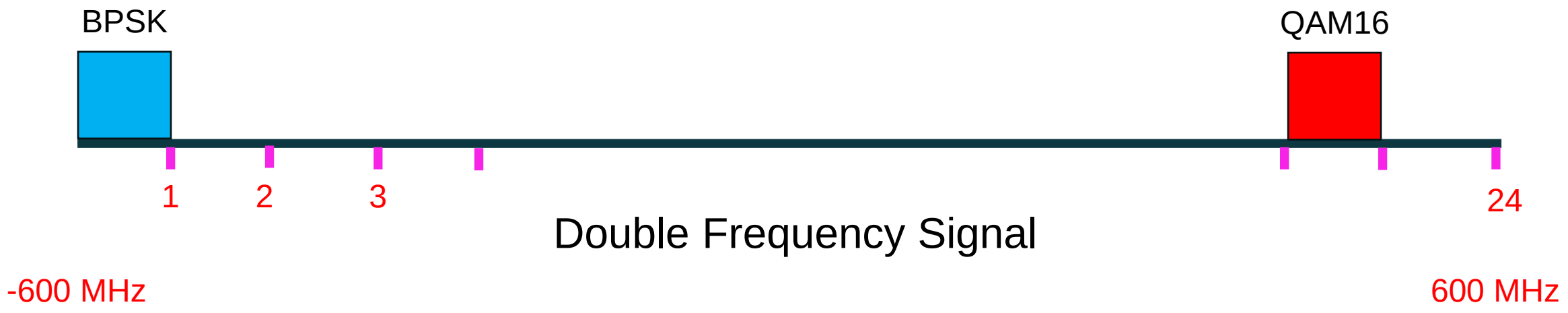

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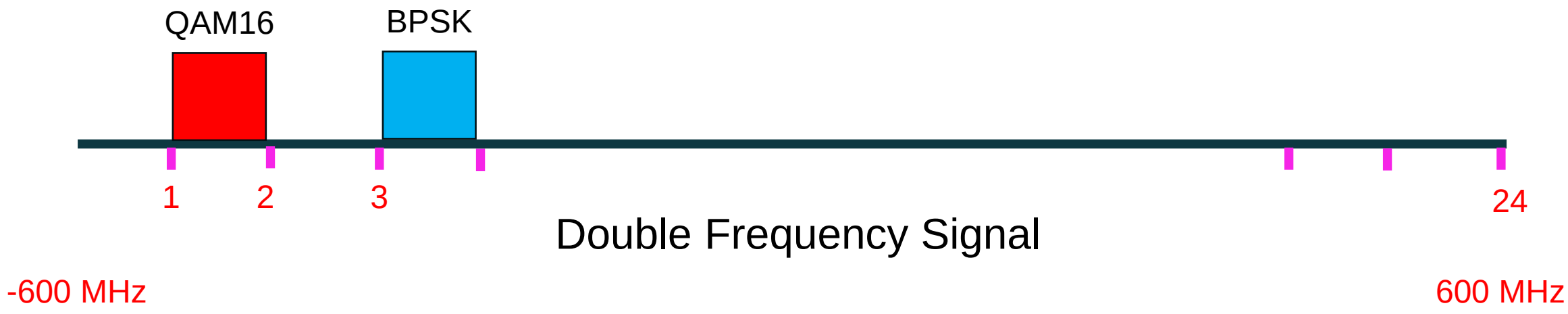
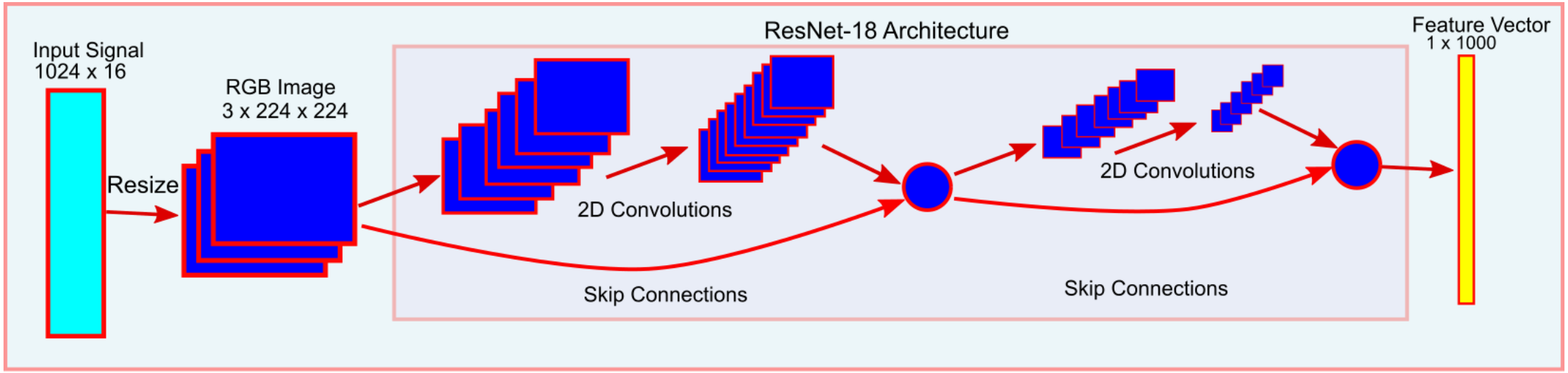
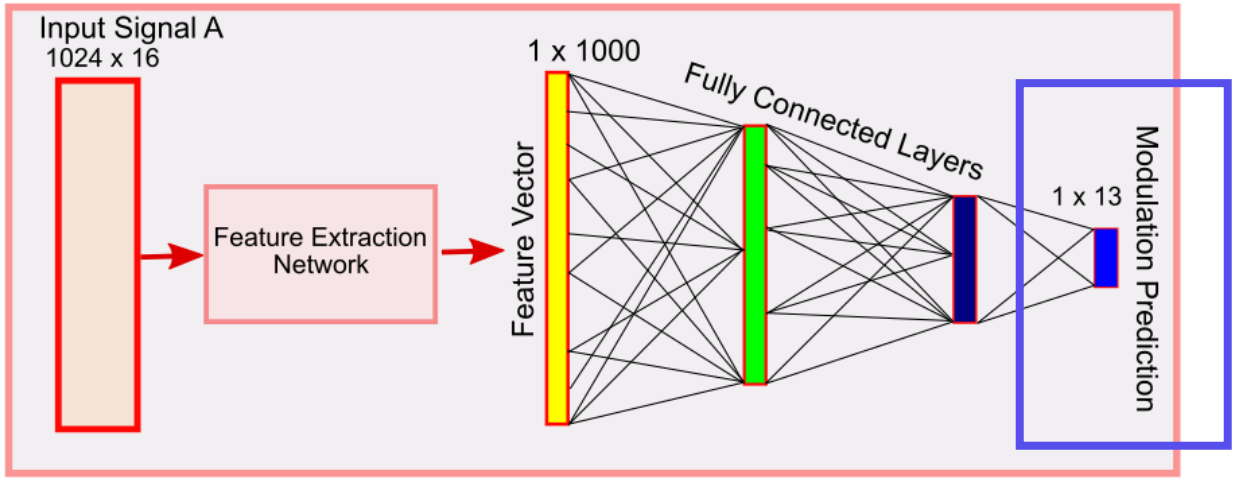


Our Approach for Single Frequency Signal

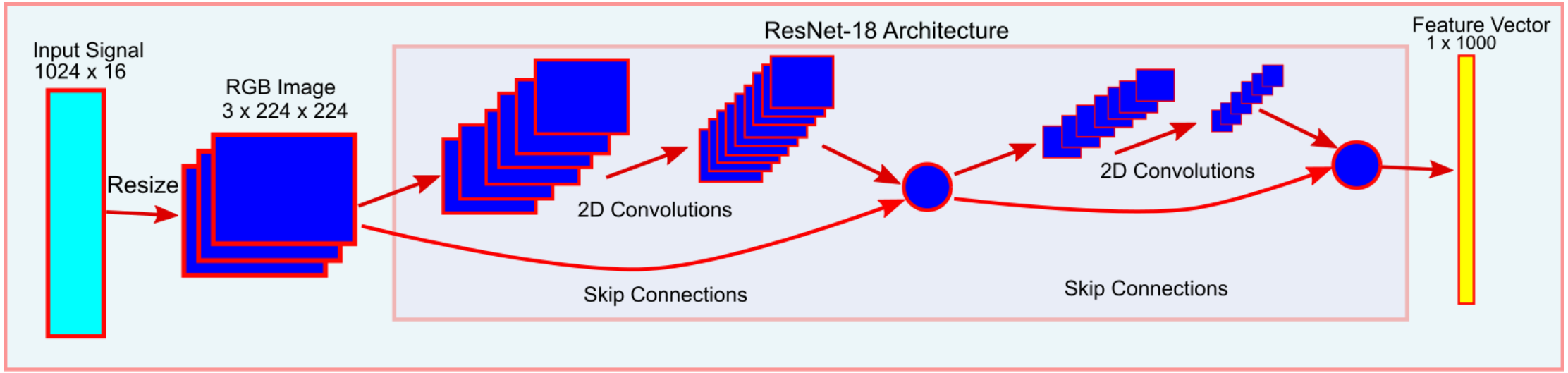


Feature Extraction Network



Modulation Prediction for Single Frequency

Our Approach for Double Frequency Signal



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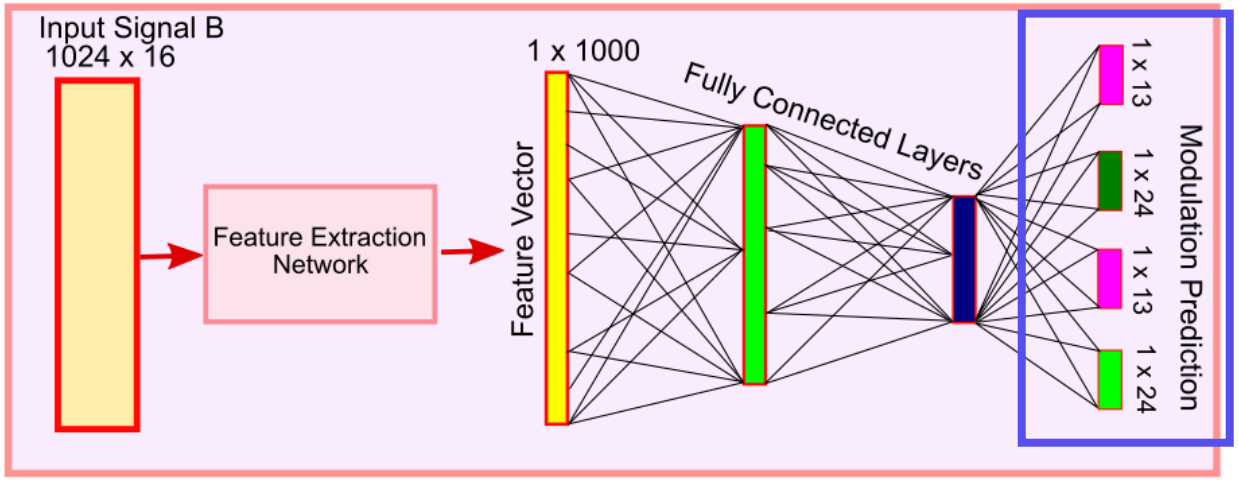


Modulation Prediction for Two Frequencies

Network Implementation

Platforms

Model size

~ 48 MB

Performance Evaluation

Single Frequency

- Number of train samples: 124K
- Number of test samples: 31K
- Accuracy of modulation type: 95%

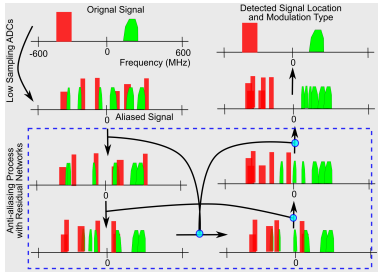
Double Frequency

- Number of train samples: 102K
- Number of test samples: 10K
- Accuracy of position of the signals: 99%
- Accuracy of modulation type: 41%

Conclusion

- Our system uses **residual networks** to overcome **aliasing and insufficient samples** for modulation detection
- **Residual networks** detect **modulation type** accurately for **single and double frequency signals** for signal recovery

Thank you!



Check out our group website for more details

Contact:
hregmi@email.sc.edu

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