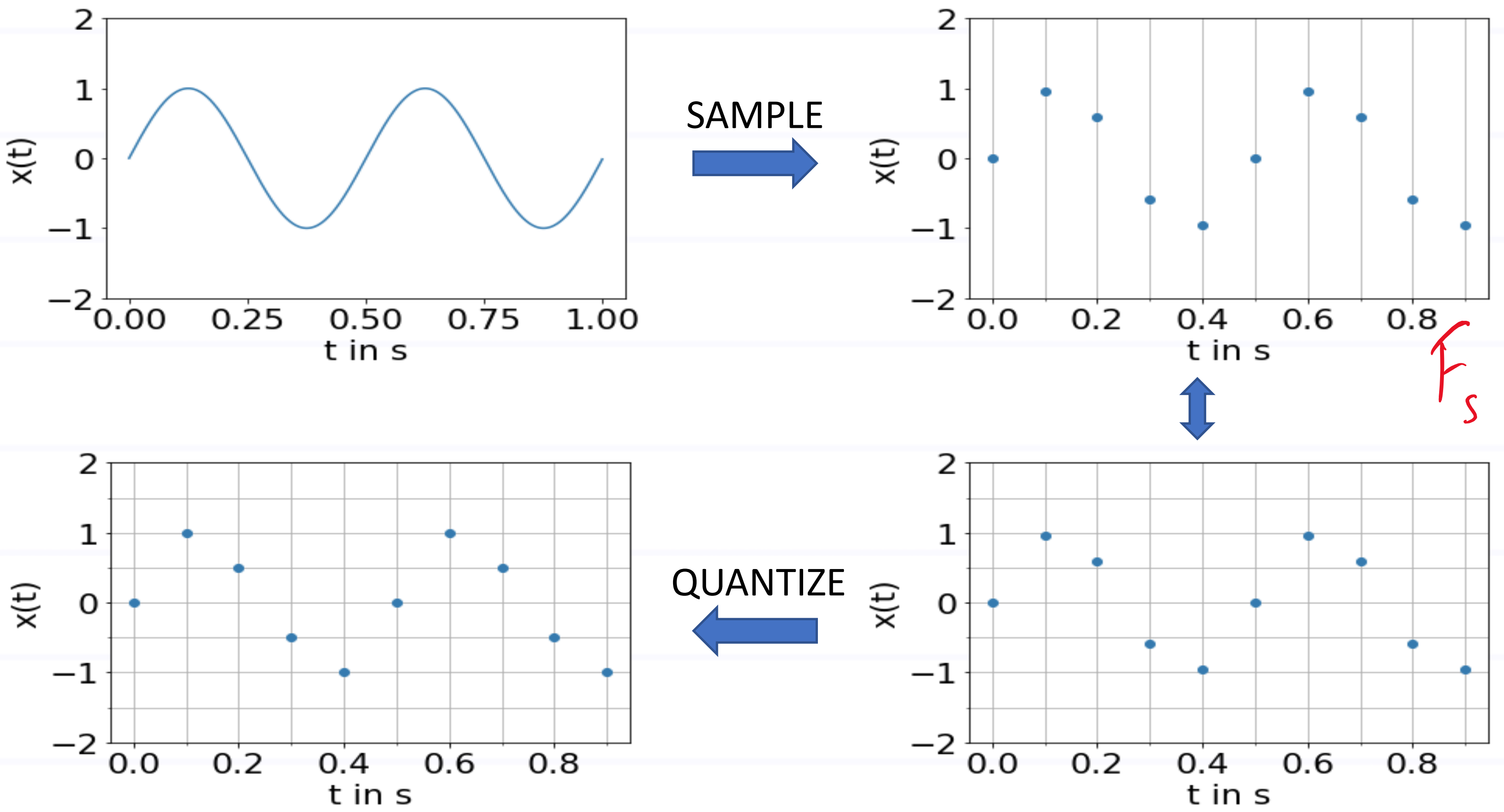
Digital Signal Processing-II

EE698V - Machine Learning for Signal Processing

Vipul Arora

Sampling and Quantization



3.142...

8

3.1

$F_s = 10/s$

$F = 2$ cps

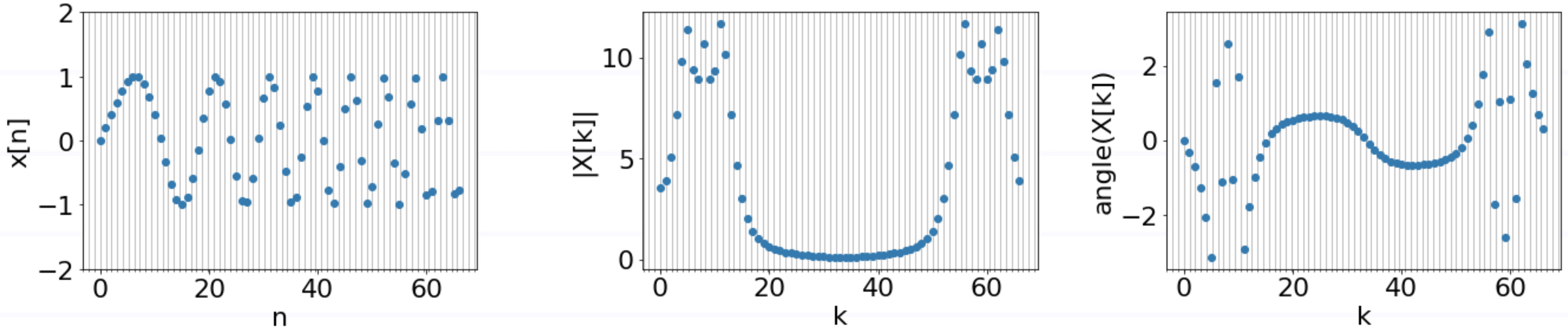
$F = 2c/s$

Sampling

- Sampling rate, $F_s = 1/T_s$
- How small a sampling rate can we choose?
  - We need at least 2 samples in a cycle to represent a frequency
  - Nyquist rate = $2*F_0$
- What is the highest frequency we can represent, given F_s?
  - $F_{max} = F_s/2$

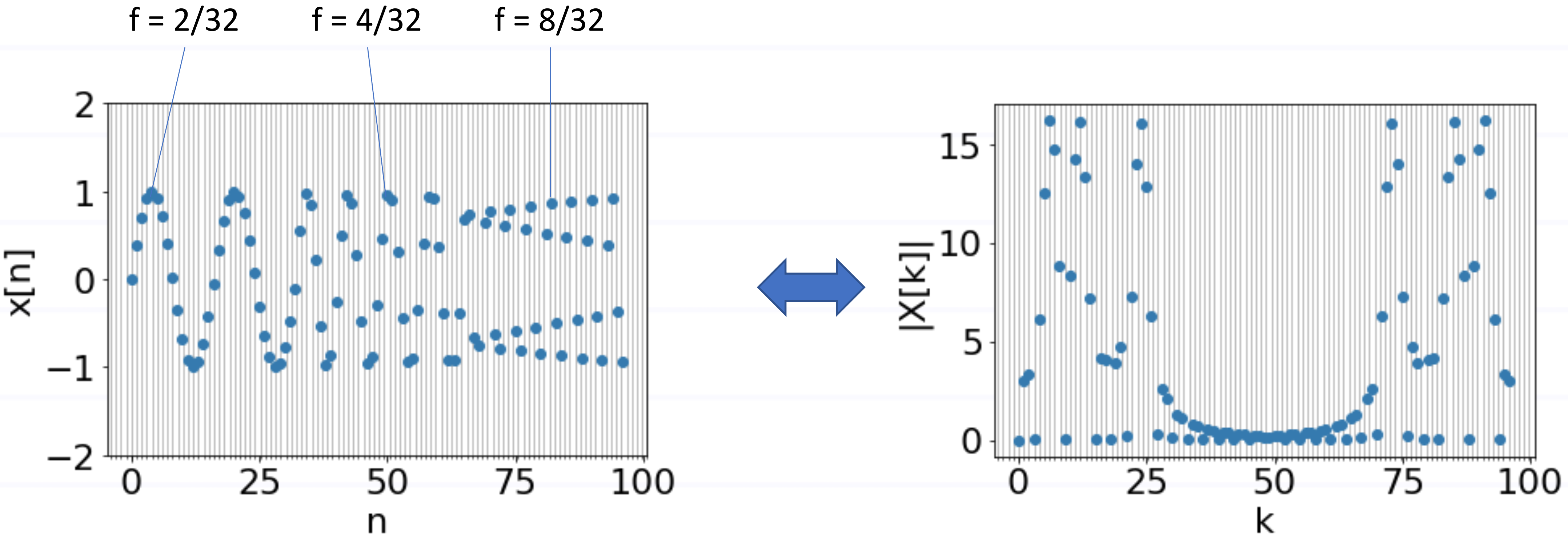
Discrete Fourier Transform

- This representation is valid is the signal is stationary, i.e., its characteristics do not change with time
- How about a non-stationary signal? a mess?



x[n] = sin(2π * f * n); where, f varies from 2/32 to 8/32 linearly with n

Discrete Fourier Transform



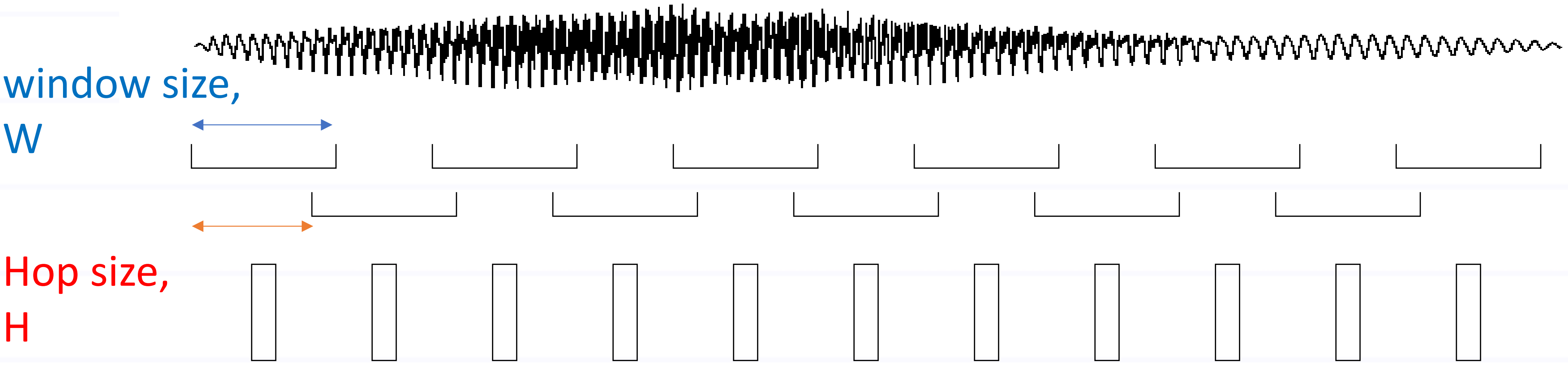
x[n] = sin(2π * f * n)

A Quasi-stationary Signal

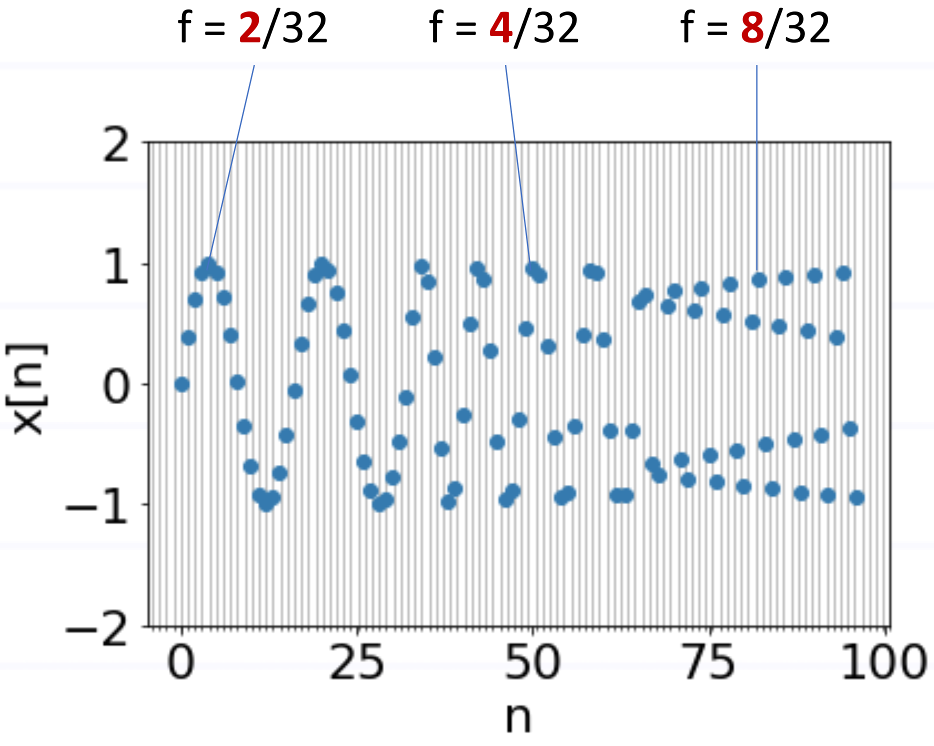
almost stationary in small intervals

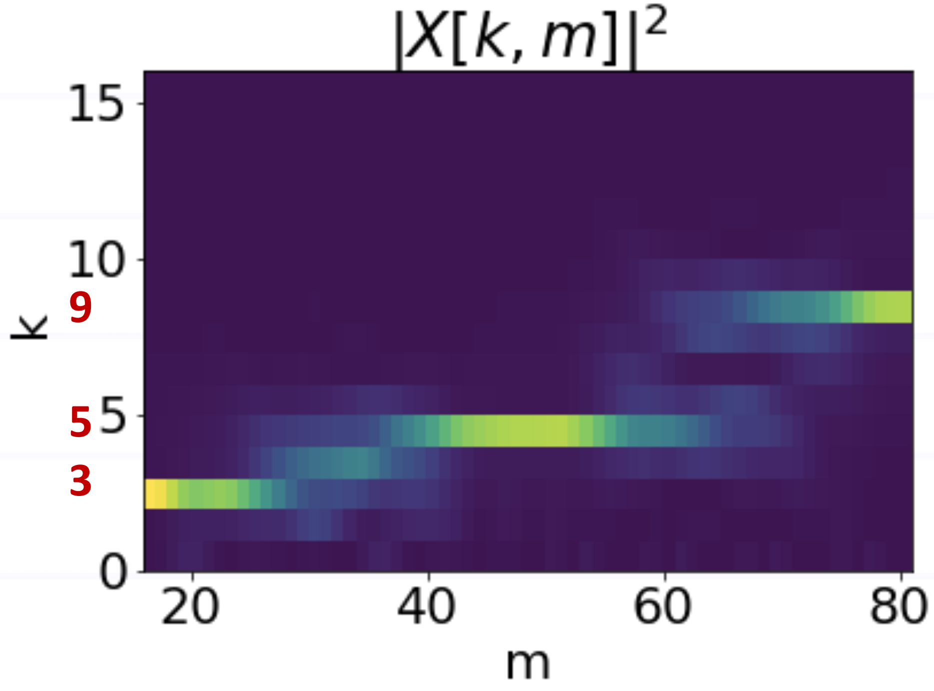
Short-time Fourier Transform (STFT)

- Intuitively,



Short-time Fourier Transform (STFT)





x[n] = sin(2π * f * n)

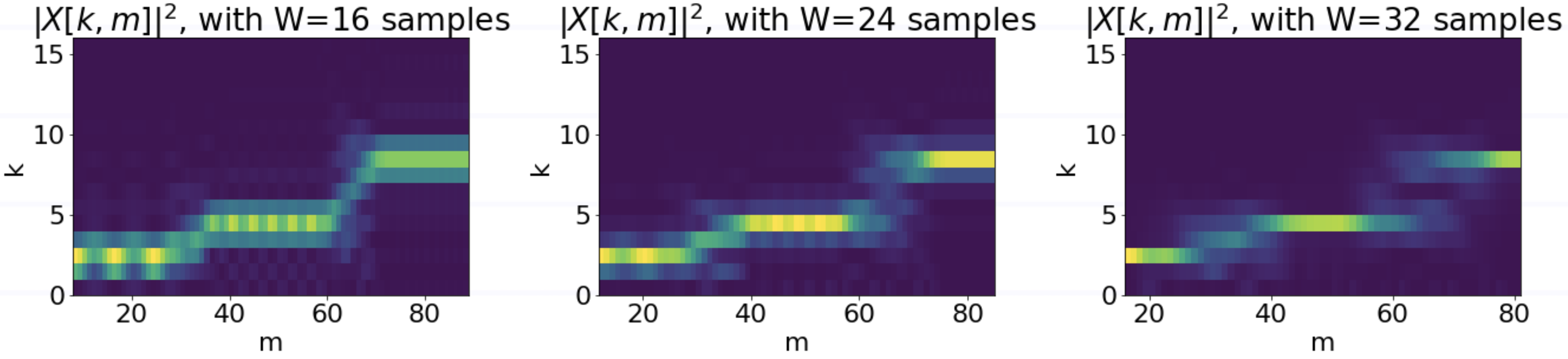
A Quasi-stationary Signal

W = 32
H = 1

STFT preserves the signal characteristics, both in time and frequency

Short-time Fourier Transform (STFT)

- The effect of changing window size, W

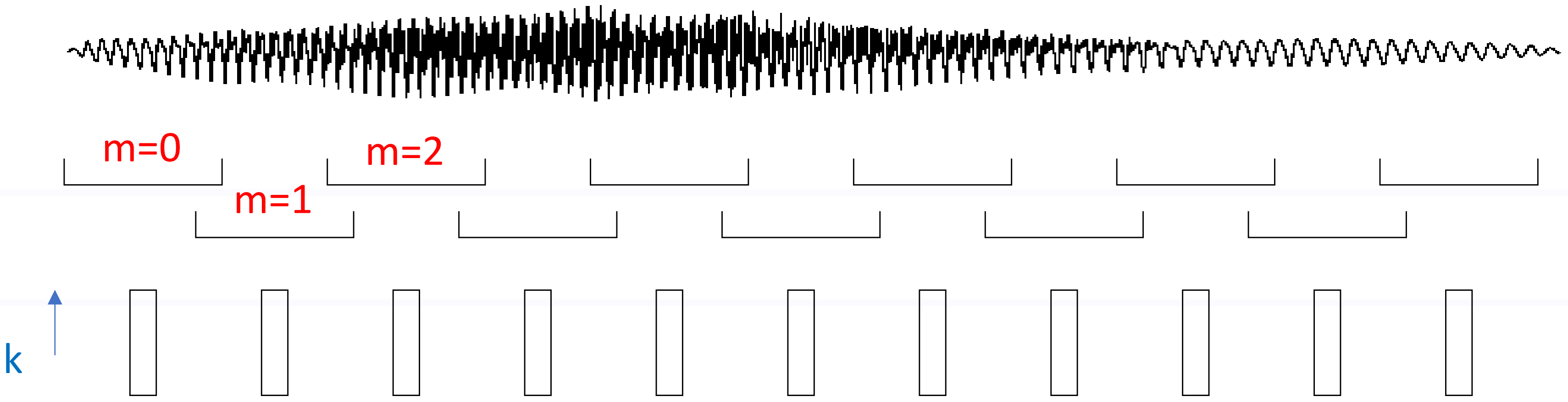


- Notice the trade off between **time** resolution vs **frequency** resolution
- Heisenberg uncertainty principal

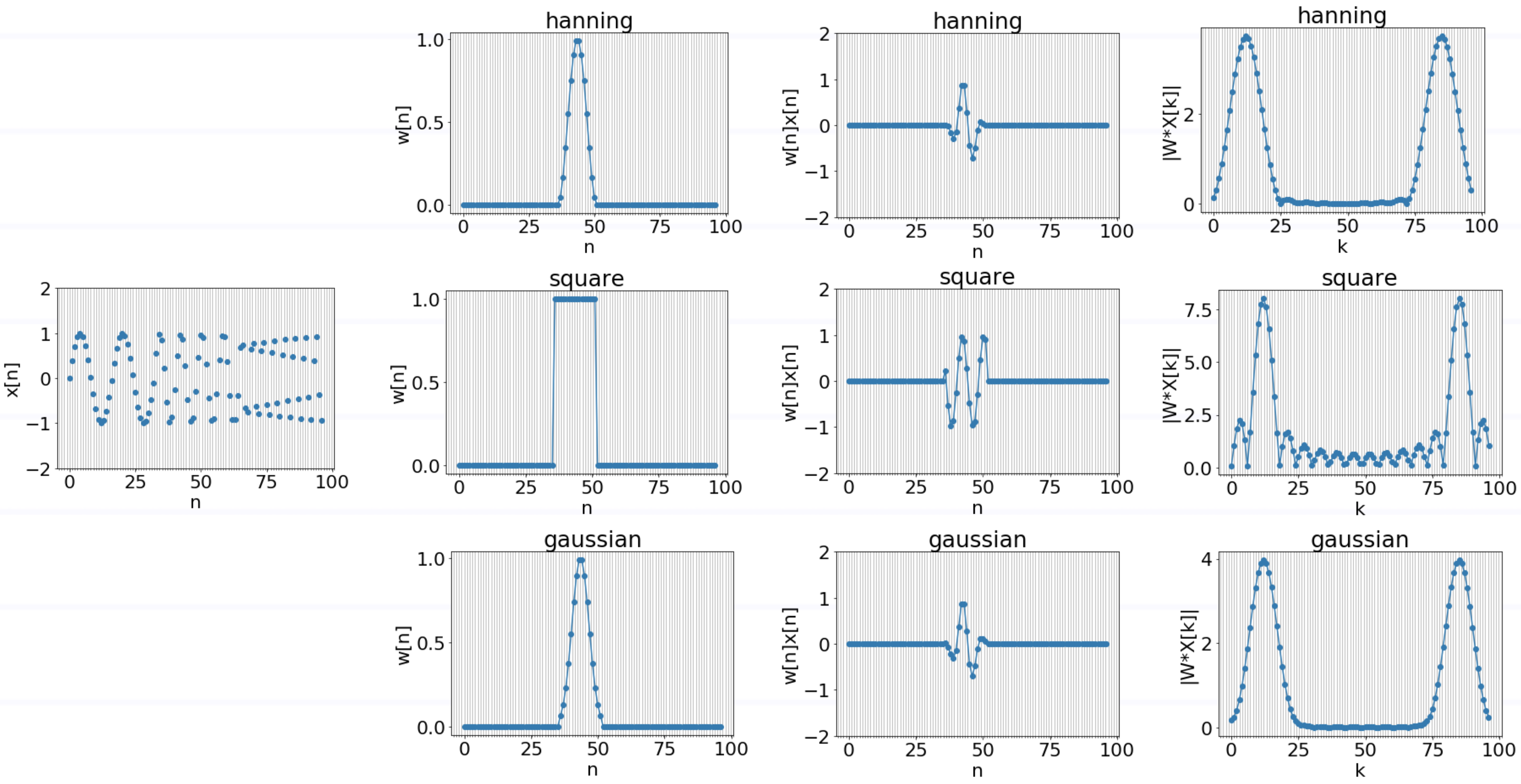
Short-time Fourier Transform (STFT)

- Mathematically,

$$X[k,m] = \sum_{n=0}^{N-1} x[n]w[n-mH]e^{-j\frac{2\pi}{N}kn}; \quad k = 0, 1, \ldots, N-1$$

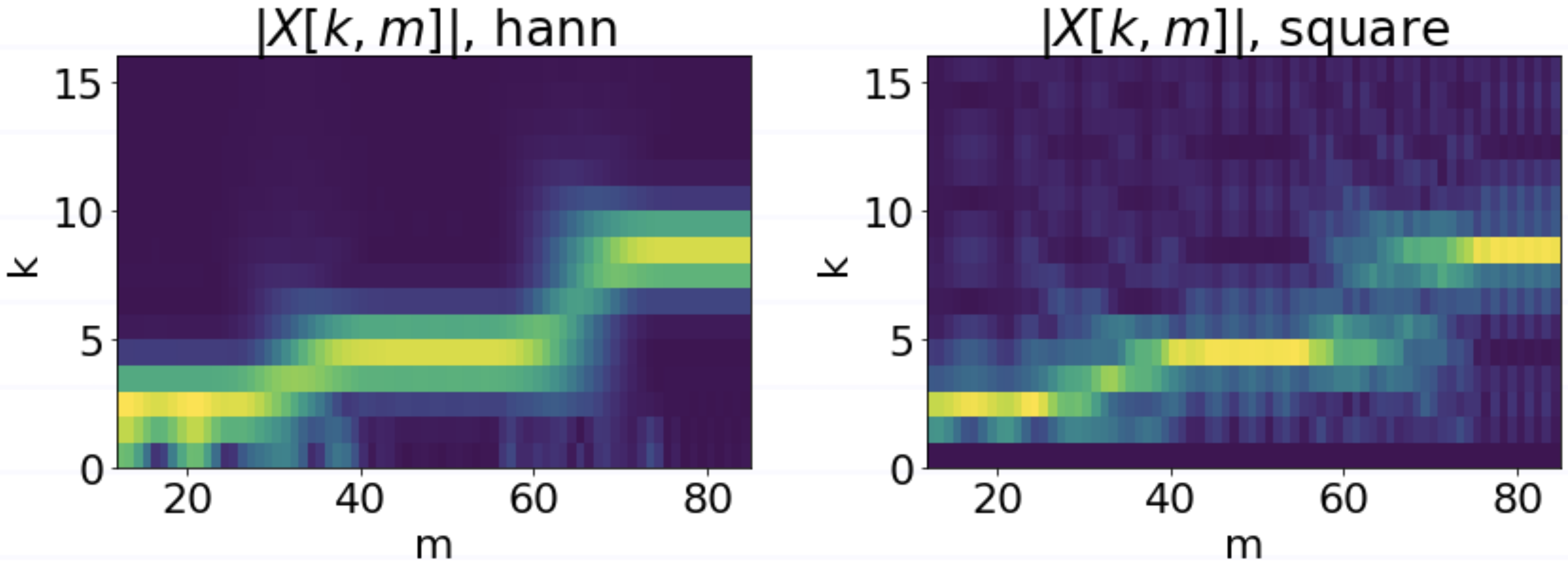


Window



Sharp discontinuities in signal cause more side lobes in |X[k]|

Spectrogram with windowing



Fast Fourier Transform

- FFT, $O(N\log N)$, is a faster implementation of DFT, $O(N^2)$
- Using FFTs in your computations results in computational gains

Topics studied

- Short-time Fourier Transform: signals changing over time

References

- https://www.tutorialspoint.com/digital_signal_processing/index.htm
- Quatieri, T. F. (2006). *Discrete-time speech signal processing: principles and practice*. Pearson Education India (Chapter 2)
- Oppenheim, A.V., Willsky, A.S., & Nawab, H.S. (1996). Signals and systems. *Pearson press, USA*.

Programming

- Programming languages
  - Python (mostly)
  - Bash scripts
- Python Jupyter, either of these:
  - Install on your machine
    - anaconda, jupyter, …
  - Microsoft Azure Notebooks - https://notebooks.azure.com/
  - Google Colab - https://colab.research.google.com/

Python Tutorials

- Python Basics 1
  - https://www.youtube.com/watch?v=qZ_RJSJk534
- Python Basics 2
  - https://www.youtube.com/watch?v=KZO9W3MPf68
- Python Basics 3
  - https://www.youtube.com/watch?v=kxQ-HOENUIQ