**Frequency ranges normally valid**

* A spectrum analyzer's frequency range varies from approximately 3 Hz to 50 GHz.

<https://www.keysight.com/used/us/en/knowledge/guides/spectrum-analyzer-buying-guide#:~:text=For%20example%2C%20some%20spectrum%20analyzers,frequencies%20you%20need%20to%20measure>.

**Methods used in analyse the spectrum of the signal**

**Fourier Transform (FT)**

|  |  |
| --- | --- |
| **Advantages** | Provides exact frequency representation  Suitable for stationary signals |
| **Disadvantages** | Not effective for non-stationary signals  Cannot provide time information |
| **Applications** | Analyzing signals that are constant over time |

**Fast Fourier Transform (FFT)**

|  |  |
| --- | --- |
| **Advantages** | Efficient and fast computation  Widely used |
| **Disadvantages** | Shares limitations with FT  Lack of time resolution for non-stationary signals |
| **Applications** | Real-time signal processing  Audio and image processing |

**Short-Time Fourier Transform (STFT)**

|  |  |
| --- | --- |
| **Advantages** | Provides time-frequency representation  Useful for non-stationary signals |
| **Disadvantages** | Fixed window size limits resolution trade-off between time and frequency |
| **Applications** | Speech analysis, Time-varying signal analysis |

**Wavelet Transform**

|  |  |
| --- | --- |
| **Advantages** | Multi-resolution analysis  Suitable for both stationary and non-stationary signals |
| **Disadvantages** | More complex to implement and understand |
| **Applications** | Image compression  Biomedical signal processing |

**Hilbert-Huang Transform (HHT)**

|  |  |
| --- | --- |
| **Advantages** | Adaptive and data-driven  Effective for non-linear and non-stationary signals |
| **Disadvantages** | Computationally intensive  Relatively new and less standardized |
| **Applications** | Geophysical data analysis  Biomedical signal analysis |

**Periodogram**

|  |  |
| --- | --- |
| **Advantages** | Simple to implement  Provides a straightforward estimate of the power spectral density |
| **Disadvantages** | High variance of the spectral estimate  Limited frequency resolution for short data segments |
| **Applications** | Preliminary spectral analysis  Power spectral density estimation |

**Welch’s Method**

|  |  |
| --- | --- |
| **Advantages** | Reduces variance of the spectral estimate  Averaging improves frequency resolution |
| **Disadvantages** | Slightly more complex than a basic periodogram  Smoothing can reduce peak sharpness |
| **Applications** | Power spectral density estimation in noisy environments |

**Autoregressive (AR) Methods**

|  |  |
| --- | --- |
| **Advantages** | High-resolution spectral estimates  Suitable for short data records |
| **Disadvantages** | Model order selection can be challenging  Computational complexity increases with model order |
| **Applications** | Speech and audio signal analysis |

Real time signal analyzation and time varying signal analysis need here, so we have to pick , **Fast Fourier Transform (FFT) , Short-Time Fourier Transform (STFT), Wavelet Transform, Hilbert-Huang Transform (HHT), Periodogram, Welch’s Method.**

Fast Fourier Transform (FFT)

* FFT is computationally efficient, making it suitable for real-time analysis.
* It quickly transforms time-domain signals into frequency-domain representation.
* FFT algorithms are widely available and easy to implement.
* Provides high frequency resolution, especially for long signals.

Why Eliminating Other Methods ?

**Short-Time Fourier Transform (STFT)**

* A smaller window provides better time resolution but poorer frequency resolution, and vice versa.
* Requires multiple FFTs to be computed over different segments, increasing computational load.

**Wavelet Transform**

* Wavelet Transform is more complex to implement and requires more computational resources than FFT.
* While it provides good time and frequency localization, the choice of wavelet function can be non-trivial and may need to be tailored to specific types of signals.
* Increased computational overhead compared to FFT, making it less suitable for real-time applications.
* MATLAB or Python, wavelet libraries provide functions for different wavelets, but understanding and choosing the right parameters require in-depth knowledge.

**Hilbert-Huang Transform (HHT)**

* Computational Intensity, challenging.
* HHT is relatively new and less standardized, leading to potential issues with consistency and reproducibility.
* Requires decomposition of the signal into intrinsic mode functions (IMFs), which is complex and time-consuming.

**Periodogram**

* The periodogram has a high variance, which can lead to less accurate spectral estimates.
* Limited frequency resolution for short data segments compared to FFT.
* Less efficient compared to FFT for real-time analysis due to the direct computation of the power spectral density.

**Welch’s Method**

* Welch’s method involves averaging modified periodograms, which can reduce sharpness and detail in the spectrum.
* More computationally intensive than FFT due to overlapping and windowing of segments.
* The need to segment and window the signal adds latency, which is not ideal for real-time applications.