Frequency Spectrum Notes

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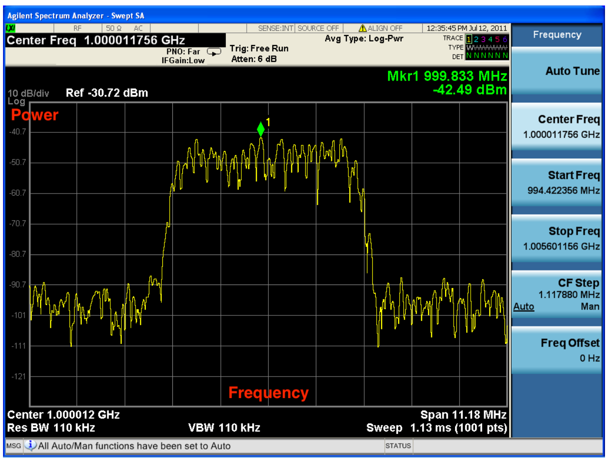
1 Spectrum Analyzer

Observe magnitude of a signal with respect to frequency.

- X-axis: frequency
- Y-axis: amplitude

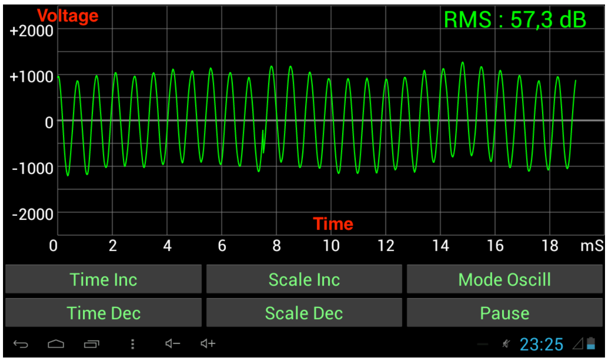


Sources:

- https://en.wikipedia.org/wiki/Spectrum_analyzer

2 Oscilloscope

Observe change of a signal with respect to time



- X-axis: time
- Y-axis: voltage

Sources:

- https://en.wikipedia.org/wiki/Oscilloscope

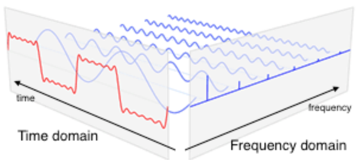
3 Frequency Domain vs. Time Domain

Frequency domain:

- X-axis frequency
- Y-axis magnitude of signal at this frequency

Time domain:

- X-axis time
- Y-axis magnitude of signal at this time



Sources:

- https://en.wikipedia.org/wiki/Frequency_domain

4 Time Series

Sequence of data points.

- X-axis: time
- Y-axis: measured values

5 Spectral Analysis

Describe time series by comparing them to sines an cosines.

Given a time series, figure out how to construct it using sines and cosines (*Fourier representation* for a time series).

Sources:

- https://faculty.washington.edu/dbp/PDFFILES/GHS-AP-Stat-talk.pdf

5.1 Fourier Analysis

study of the way general functions may be represented or approximated by sums of simpler trigonometric functions

The decomposition process itself is called a Fourier transformation. Output of transformation is called Fourier transform

Sources:

- https://en.wikipedia.org/wiki/Fourier_analysis

5.2 Discrete Fourier Transform (DFT)/Fast Fourier Transform (FFT)

Convert time series into combination of sine waves, ordered by their frequencies

5.3 Spectral Power Density (PSD)

6 Channel Coherence Time

Time during which the attenuation and interference of a channel is considered as constant.

The channel coherence time T_c is inversely related to D_s, the Doppler spread: $T_c \approx \frac{1}{D_s}$

Sources:

- https://en.wikipedia.org/wiki/Coherence_time_(communications_systems)
- https://en.wikipedia.org/wiki/Fading#Slow_versus_fast_fading

7 Doppler Spread

In a multipath scenario, different paths of the same signal may have different Doppler shifts (change in frequency due to velocity of transmitter of receiver). The range of these Doppler shifts is the Doppler spread.

Doppler spread negatively affects channel coherence time.

- https://en.wikipedia.org/wiki/Fading#Slow_versus_fast_fading

8 Fading

Variation of attenuation of a signal.

May vary with:

- Time
- Position

- Frequency

May be induced by:

- Multipath propagation
- Shadowing

Can be combated by diversity (multiple antennas at receiver and/or transmitter).

Sources:

- https://en.wikipedia.org/wiki/Fading

8.1 Multipath-Induced Fading vs. Shadow Fading

Multipath-induced fading: receiver sees superposition of copies of the transmitted signal. Each copy experiences a different attenuation, delay, and phase shift. This can result in either constructive or destructive interference, and amplification or attenuation of the signal.

Shadow fading:

8.2 Slow Fading vs. Fast Fading

Slow fading: large coherence time with respect to delay requirements of application. Attenuation and interference can be regarded as static over the period of use (e.g. data session, call).

Fast fading: small coherence time of channel with respect to delay requirements of application. Attenuation and interference vary over period of use (e.g. data session, call).

8.3 Frequency-Selective Fading

Different frequency components of a signal experience different attenuation and interference.

Equivalent to time dispersion (signal energy associated with each symbol is spread out in time).

In OFDM frequency-selective fading is mitigated because bandwidth is divided into narrow subcarriers that are smaller than the frequency-selective fading granularity.

Sources:

- https://en.wikipedia.org/wiki/Fading#Selective_fading

9 Noise

9.1 Thermal Noise (JohnsonNyquist Noise)

Noise that is intrinsic to the conductor even without any applied voltage. Generated by the thermal agitation of the charge carriers (usually the electrons) inside the conductor.

The power of thermal noise depends on the temperature of the carrier: the higher the temperature, the higher the power.

Thermal noise is approximately "white" (see Section 9.2).

Sources:

- https://en.wikipedia.org/wiki/Johnson%E2%80%93Nyquist_noise
- http://www.physics.utoronto.ca/~phy225h/experiments/thermal-noise/Thermal-Noise.pdf

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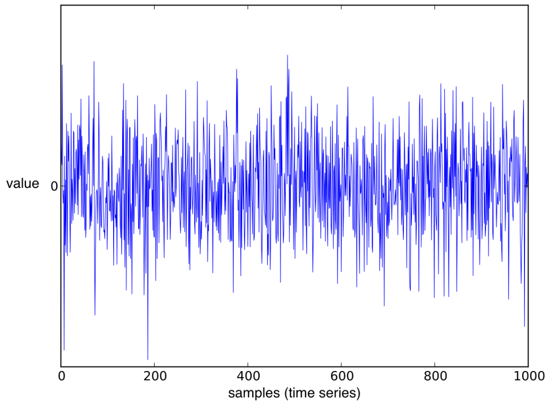

Figure 1: Gaussian white noise signal (time series).

9.2 White Noise

Random signal with a constant power spectral density.

Sources:

- https://en.wikipedia.org/wiki/White_noise

9.3 Additive White Gaussian Noise (AWGN)

White noise with each sample (time series point) having a normal distribution with zero mean.

- **Additive** because it is added to any noise that might be intrinsic to the information system
- **White** because it has uniform power across the frequency band for the information system
- **Gaussian** because each sample has a normal distribution with zero mean

Sources:

- https://en.wikipedia.org/wiki/Additive_white_Gaussian_noise