Formatting (2A)

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This document was produced by using OpenOffice and Octave.

Formatting and Source Coding

Formatting

Make the source signal compatible with digital processing

Transmit Formatting

A transformation from source information to digital symbols

Source Coding

Formatting + Data Compression

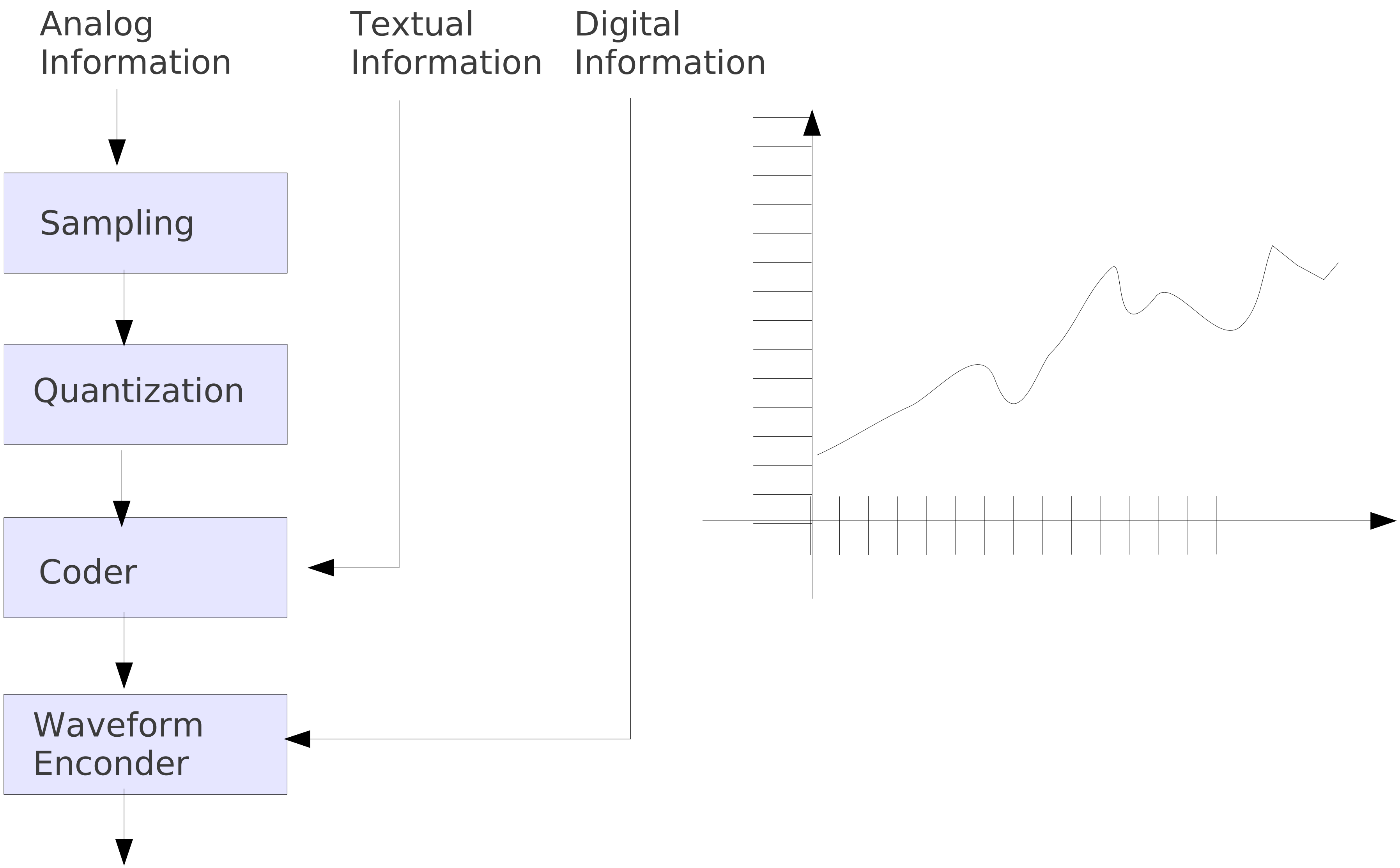
Baseband Signal

From DC up to some finite frequency (< a few MHz)
Transmitted over the cable
Not appropriate to transmit over long distance → Bandpass Mod

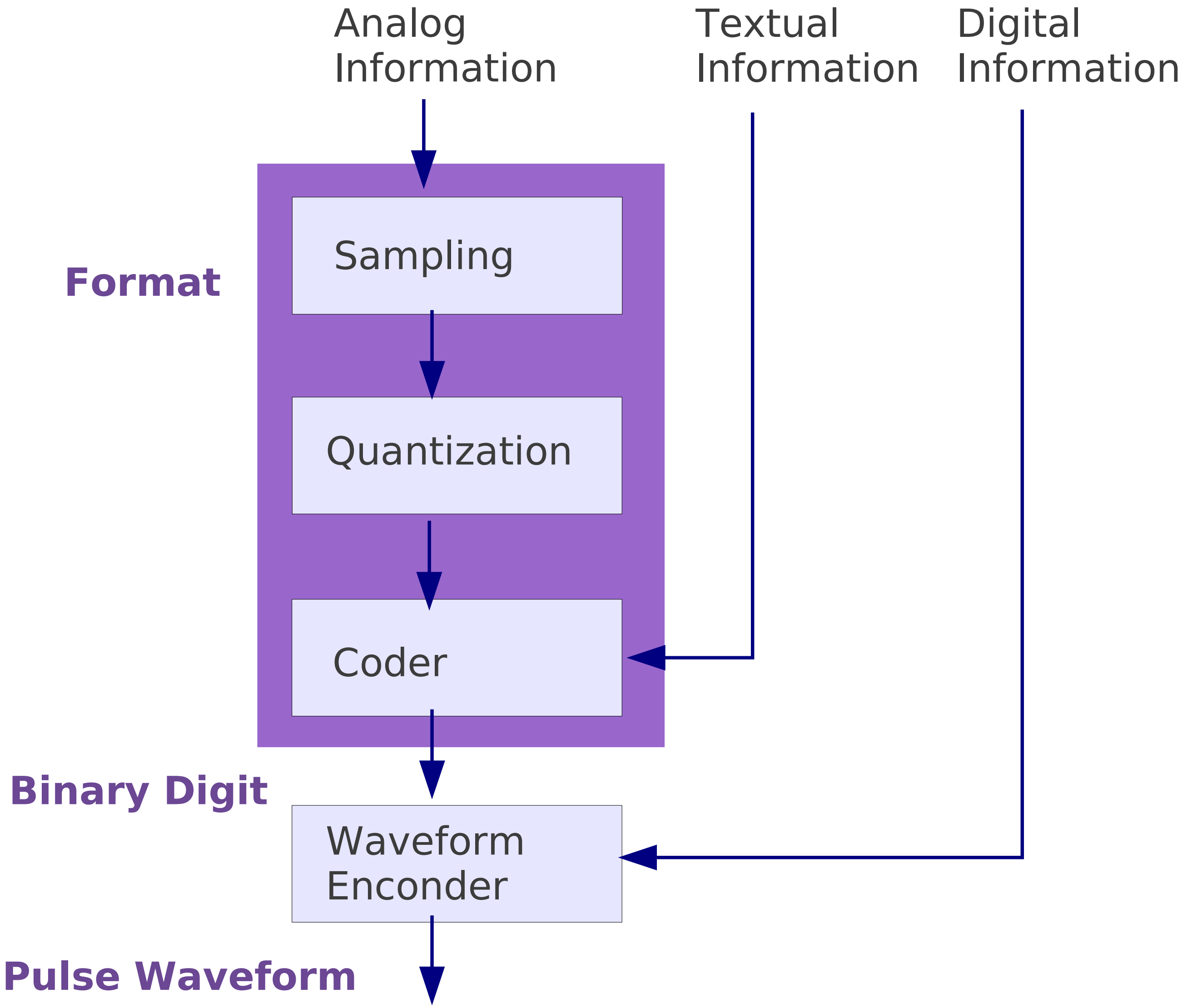
Pulse (Baseband) Modulation

Pulse waveforms are assigned that represent formatted symbols

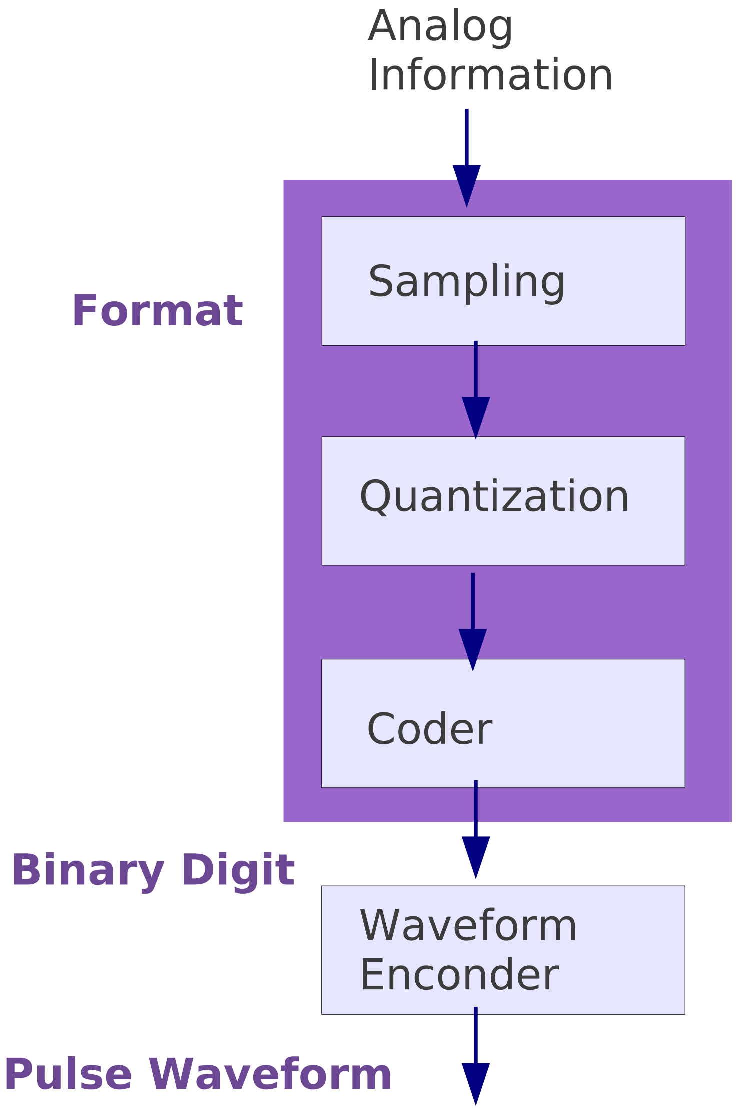
Energy and Power Spectral Densities (2)

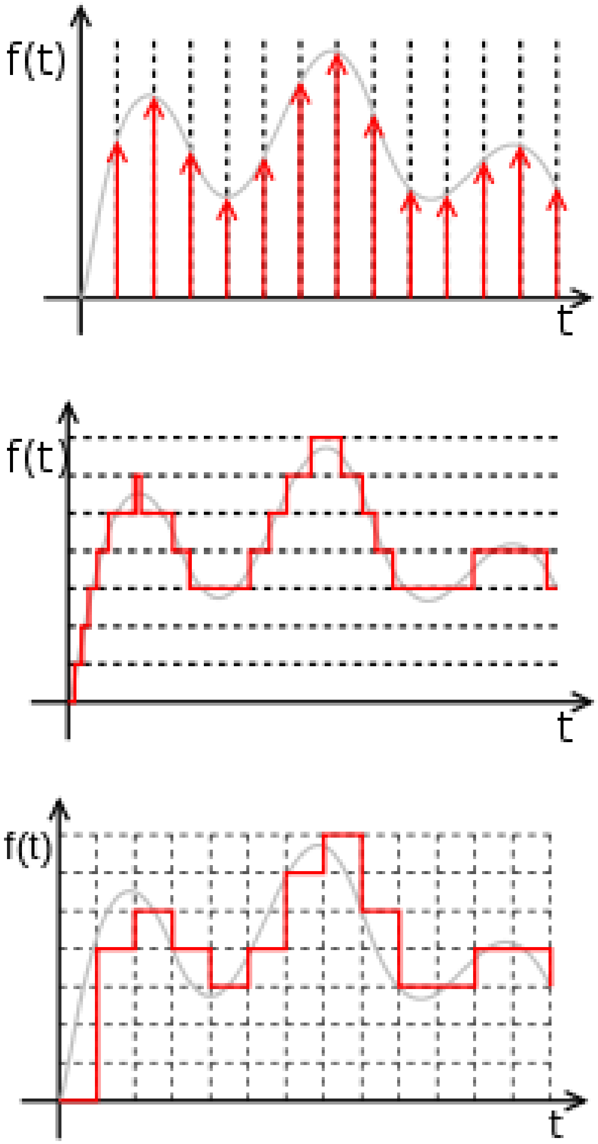


Baseband Signal

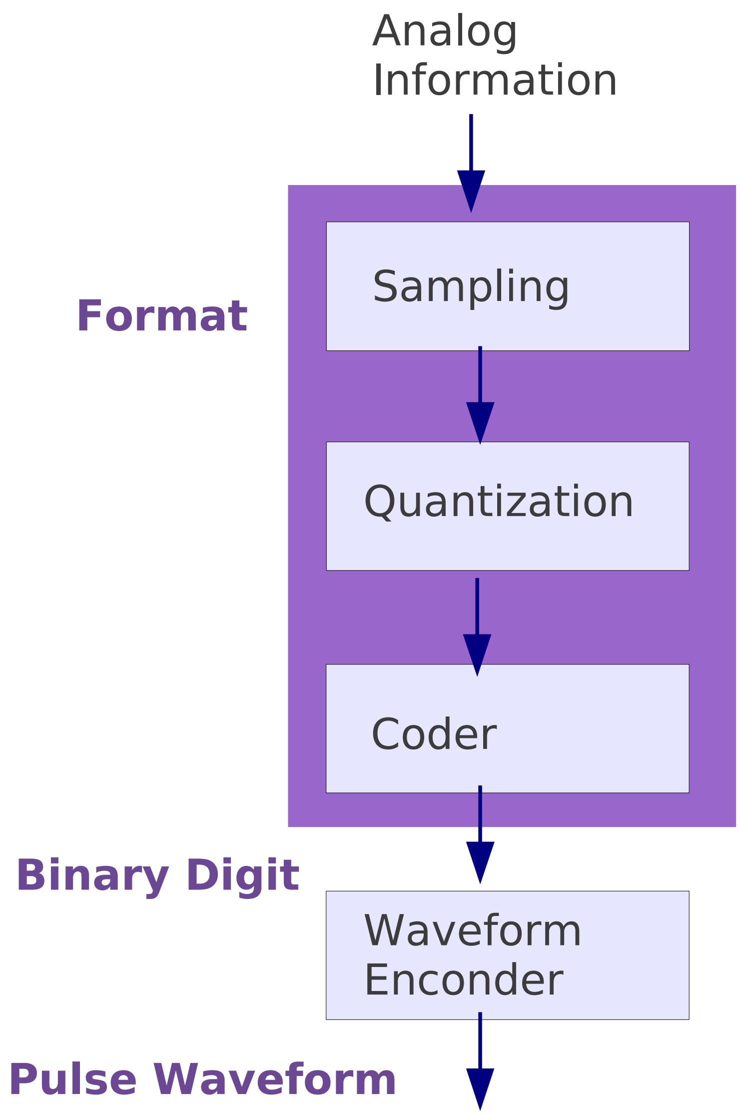


Sampling and Quantization

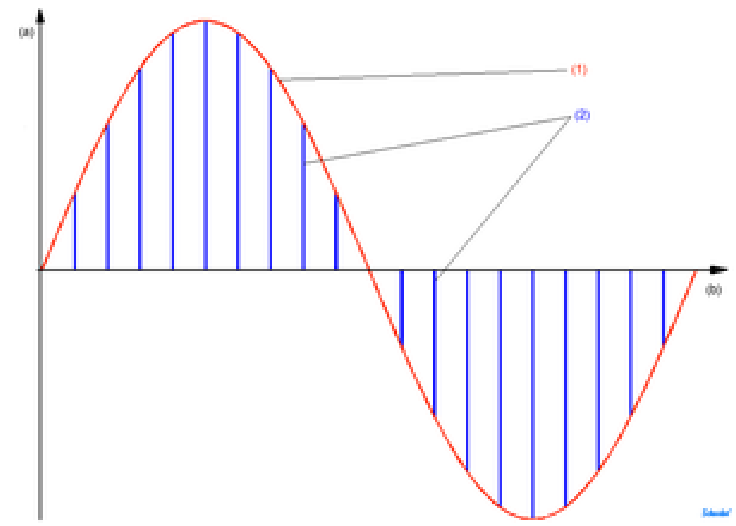


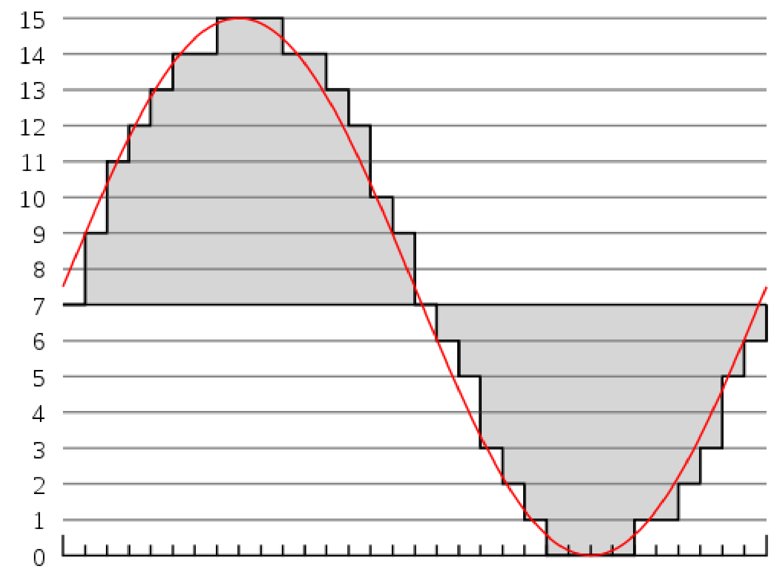


PAM and PCM



Analog Information
Format
Sampling
Quantization
Coder
Binary Digit
Waveform Enconder
Pulse Waveform





15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0

8-ary Symbol

T		H		I		N		K		**Message**
001010		000100		100100		011100		110100		**6-bit ASCII**
001	010	000	100	100	100	011	100	110	100	
1	2	0	4	4	4	3	4	6	4	8-ary digits `(symbols)
$s_1(t)$	$s_2(t)$	$s_0(t)$	$s_4(t)$	$s_4(t)$	$s_4(t)$	$s_3(t)$	$s_4(t)$	$s_6(t)$	$s_4(t)$	8-ary waveform

Binary Symbol

T	H	I	N	K	**Message**
001010	000100	100100	011100	110100	**6-bit ASCII**

0 0 1 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 0 1 1 1 0 0 1 1 0 1 0 0

0 0 1 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 0 1 1 1 0 0 1 1`

binary digits
(symbols)

$s_0(t)$ $s_0(t)$ $s_1(t)$ $s_0(t)$ $s_1(t)$ $s_0(t)$ $s_0(t)$ $s_0(t)$ $s_0(t)$ $s_1(t)$ $s_0(t)$ $s_0(t)$

binary waveform

Impulse Sampling

Impulse train

$$x_\delta(t) = \sum_{n=-\infty}^{+\infty} \delta(t - nT_s) \quad \Longleftrightarrow \quad X_\delta(f) = \frac{1}{T_s}\sum_{n=-\infty}^{+\infty} \delta(f - nf_s)$$

Shifting property

$$x(t)\delta(t-t_0) = x(t_0)\delta(t-t_0)$$

$$x_s(t) = x(t)x_\delta(t) \quad \Longleftrightarrow \quad X_s(f) = X(f) * X_\delta(f)$$

$$= \sum_{n=-\infty}^{+\infty} x(t)\delta(t - nT_s) \qquad = X(f) * \left[\frac{1}{T_s}\sum_{n=-\infty}^{+\infty} \delta(f-nf_s)\right]$$

$$= \sum_{n=-\infty}^{+\infty} x(nT_s)\delta(t - nT_s) \qquad = \frac{1}{T_s}\sum_{n=-\infty}^{+\infty} X(f-nf_s)$$

Natural Sampling

Pulse train

$$x_p(t) = \sum_{n=-\infty}^{+\infty} c_n e^{j2\pi n f_s t} \quad \Longleftrightarrow \quad c_n = \frac{1}{T_s} sinc(\frac{nT}{T_s})$$

$$x_s(t) = x(t) x_p(t) \quad \Longleftrightarrow \quad X_s(f) = X(f) * X_p(f)$$

$$= x(t) \sum_{n=-\infty}^{+\infty} c_n e^{j2\pi f_s t}$$

$$= \sum_{n=-\infty}^{+\infty} c_n \left[x(t) e^{j2\pi f_s t} \right] \quad \Longleftrightarrow \quad = \sum_{n=-\infty}^{+\infty} c_n X(f - n f_s)$$

Sample and Hold

Sampled Pulse train

$$x_p(t) = \sum_{n=-\infty}^{+\infty} c_n e^{j2\pi n f_s t} \quad \Longleftrightarrow \quad c_n = \frac{1}{T_s} sinc(\frac{nT}{T_s})$$

$$x_s(t) = p(t) * [x(t) x_\delta(t)] \quad \Longleftrightarrow \quad X_s(f) = X(f) * X_p(f)$$

$$= p(t) * \left[x(t) \sum_{n=-\infty}^{+\infty} \delta(t - nT_s)\right] \quad \Longleftrightarrow \quad = P(f)\left[X(f) * \left[\frac{1}{T_s}\sum_{n=-\infty}^{+\infty} \delta(f - nf_s)\right]\right]$$

$$= P(f)\left[\frac{1}{T_s}\sum_{n=-\infty}^{+\infty} X(f - nf_s)\right]$$

Sampling Theorem

Uniform Sampling Theorem

A bandlimited signal having no spectral components above $\mathbf{f_m}$ Hz
can be determined uniquely
by values sampled at *uniform intervals* of $\mathbf{T_s}$ seconds

$$T_s \le \frac{1}{2 f_m} \qquad f_s = \frac{1}{T_s} \qquad f_s \ge 2 f_m$$

Upper limit of $\boldsymbol{T_s}$

Lower limit of $\boldsymbol{f_s}$

Nyquist Criterion

Nyquist Rate $f_s = 2 f_m$

Autocorrelation of Energy and Power Signals

Ensemble Average

WSS (Wide Sense Stationary)

Autocorrelation of Random and Power Signals

Time Averaging and Ergodicity

Autocorrelation of Random and Power Signals

Time Averaging and Ergodicity

References

[1] http://en.wikipedia.org/
[2] http://planetmath.org/
[3] M.L. Boas, “Mathematical Methods in the Physical Sciences”