University of Anbar
College of Engineering
Department of Electrical Engineering

LECTURE NOTES IN:

Fundamentals of Digital Communications

for the classes: EE3329

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الثقافة هي ما يتبقى بعد ان تنسى كل ما تعلمته في المدرسة

"Education is what remains after one has forgotten what one has learned in school." Albert Einstein

REFERENCES

- *Introduction to Communication Systems*. Ferrel G. Stremler.
- Instructor's Lectures.

BIBLIOGRAPHY:

(1) *Modern Digital and Analog Communication Systems*. B. P. Lathi.

(2) *Communication Systems, an Introduction to Signals and Noise in Electrical Communications*. Bruce Carlson.

(3) *Communication Systems Engineering*. John G. Proakis and Masoud Salehi.

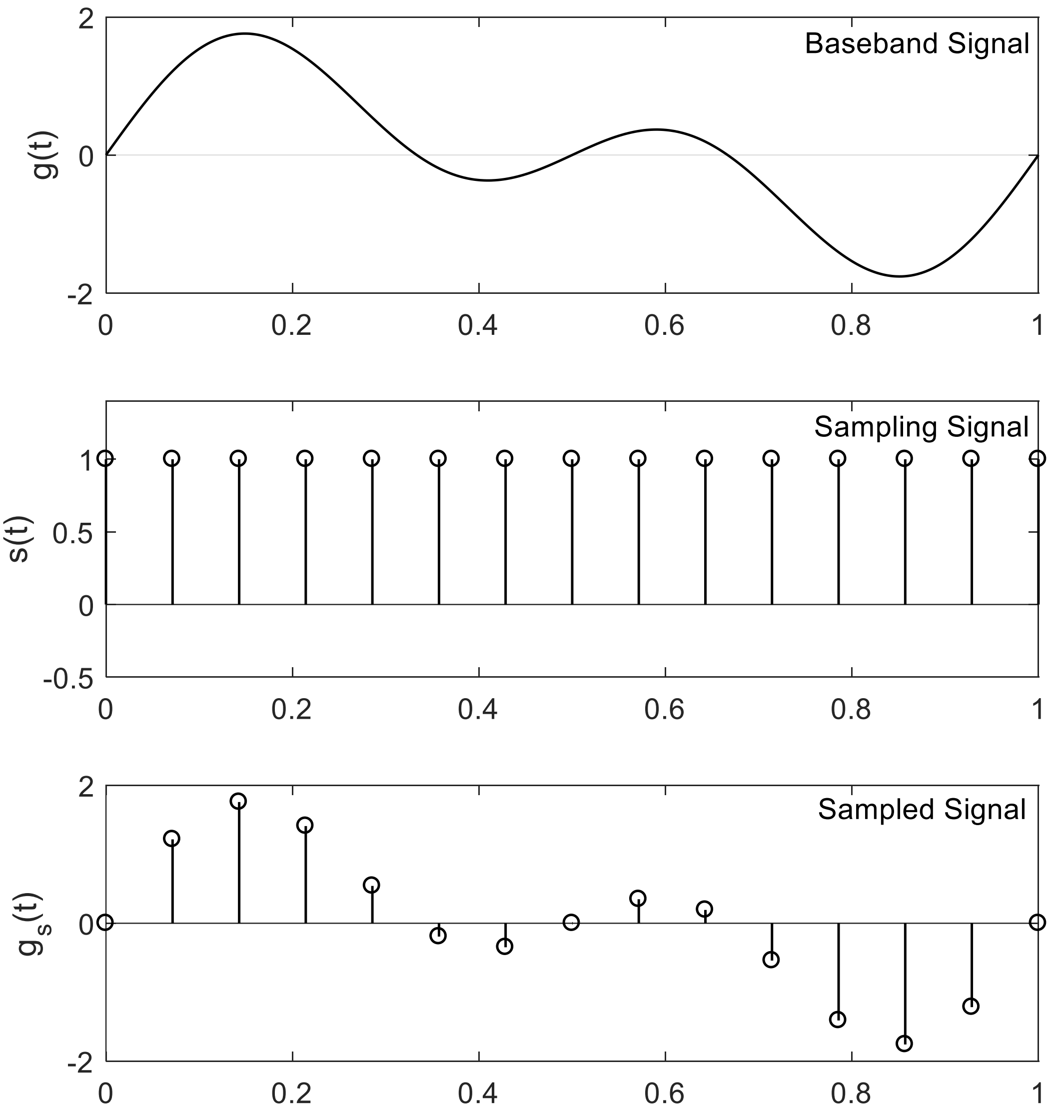
(4) *Digital and Analog Communication Systems*. Leon W. Couch.

Part 1 SAMPLING & PULSE MODULATION

1.1 INTRODUCTION

Experimental data and mathematical functions are frequently displayed as continuous curves, even though a finite number of discrete points were used to construct the graph. If these points or samples have sufficiently close spacing, we obtain a smooth curve drawn through them. Therefore, it can be said that: a continuous curve is adequately described by its sample points alone.

Sampling, therefore, makes it is possible to transmit messages in the form of pulse modulation rather than as continuous signals. Usually, the pulses are quite short compared to the time between them.



Pulse modulation offers two main advantages over continuous wave modulation:

(1) The transmitted power can be concentrated into short bursts instead of being generated continuously.

(2) The time interval between pulses can be filled with sample values from other signals. (TDM).

However, the main disadvantage is the requirement for large transmission bandwidth compared to the original message bandwidth.

1.2 SAMPLING THEOREM

1.2.1 Ideal Sampling

Ideal sampling♣ is done by multiplying the baseband signal $g(t)$ by the impulse signal $s(t)$.

$$g_s(t) = g(t) \cdot s(t)$$

$$s(t) = \sum_{k=-\infty}^{\infty} \delta(t - kT_s)$$

The Fourier transform of $s(t)$ is:

$$S(f) = \frac{1}{T_s} \sum_{k=-\infty}^{\infty} \delta(f - kf_s) \quad \text{where } f_s = \frac{1}{T_s}$$

Let's now evaluate $G_s(f)$, the Fourier transform of the output signal $g_s(t)$. So

$$G_s(f) = \mathcal{F}\{g_s(t)\} = \mathcal{F}\{g(t) \cdot s(t)\}$$

Multiplication in the time domain is convolution in the frequency domain:

$$G_s(f) = G(f) \star S(f) = G(f) \star \frac{1}{T_s} \sum_{k=-\infty}^{\infty} \delta(f - kf_s)$$

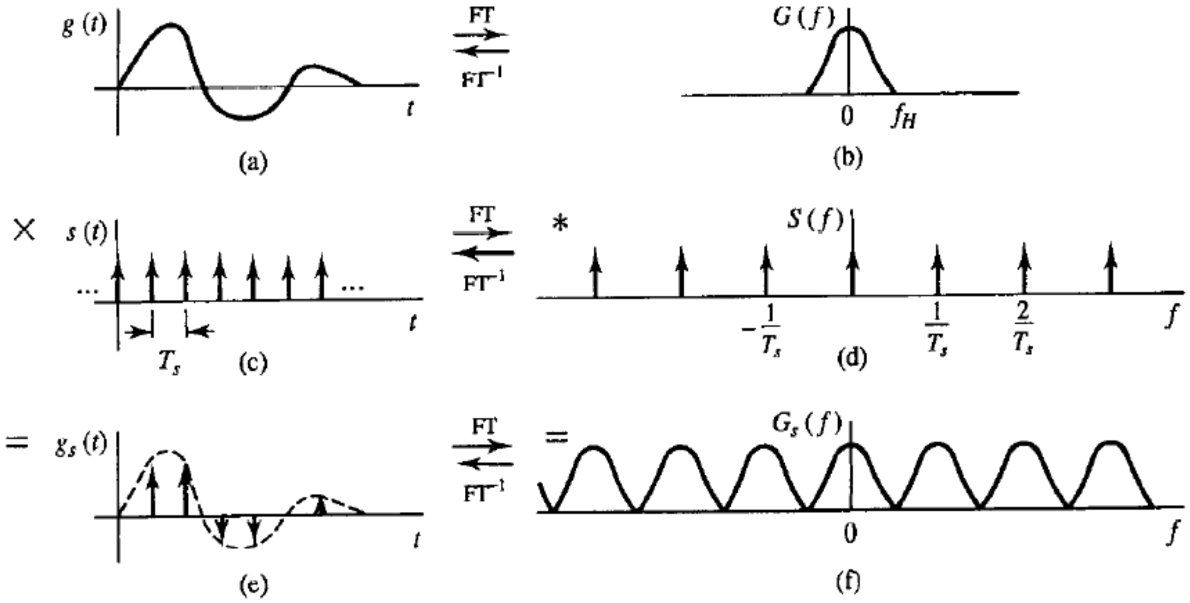
Where $\star$ denotes convolution. Next, we apply simple properties of convolution to move $G(f)$ inside the sum; that is, $G_s(f)$ becomes:

$$G_s(f) = \frac{1}{T_s} \sum_{k=-\infty}^{\infty} G(f) \star \delta(f - kf_s)$$

♣ It is impossible to physically carry out ideal sampling, but it is used to understand the sampling theorem.

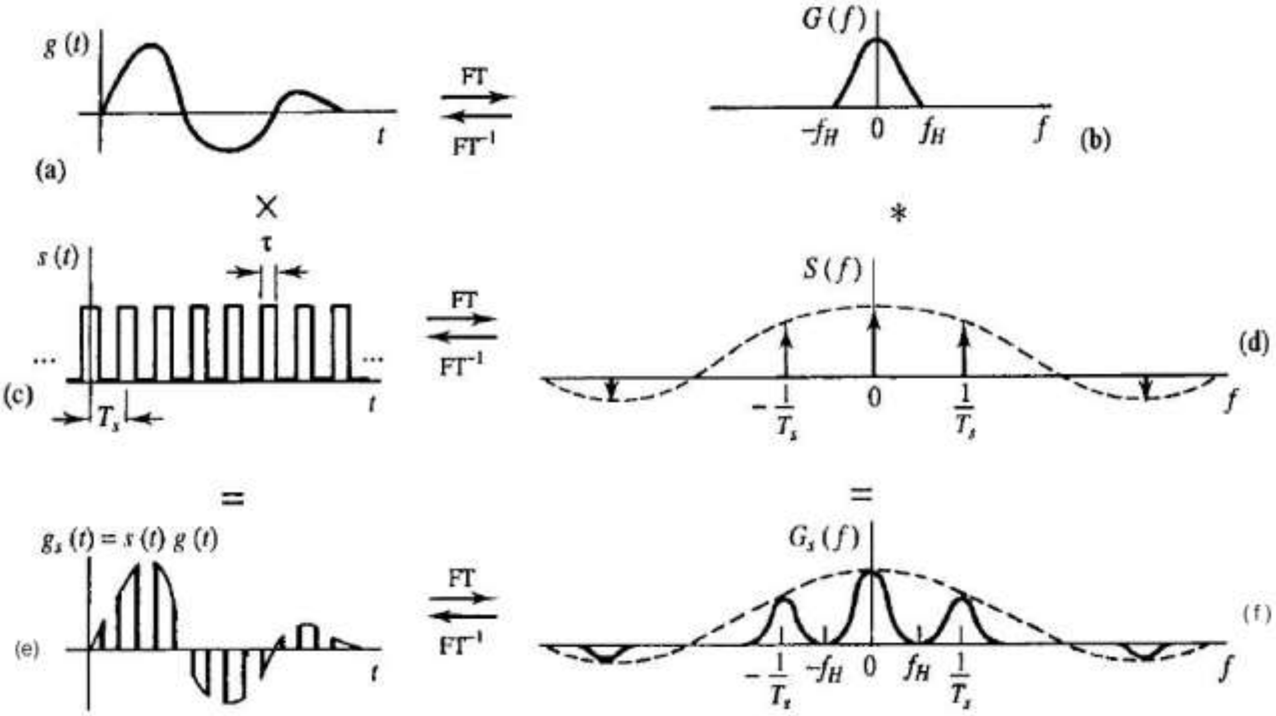
by applying the shifting property of the delta function:

$$G_s(f) = \frac{1}{T_s}\sum_{k=-\infty}^{\infty} G(f - kf_s) = \frac{1}{T_s}\begin{Bmatrix} G(f) + G(f + f_s) + G(f + 2f_s) + G(f + 3f_s) + \cdots \\ +G(f - f_s) + G(f - 2f_s) + G(f - 3f_s) + \cdots \end{Bmatrix}$$



1.2.2 Natural Sampling

The practical method of sampling is a naturally sampled signal which is produced by multiplying the baseband information signal $g(t)$ by the periodic pulse train $s(t)$.



Here, we also have: $G_s(f) = \mathcal{F}\{g_s(t)\} = \mathcal{F}\{g(t) \cdot s(t)\}$

And because $s(t)$ is a periodic signal:

$$s(t) = \sum_{k=-\infty}^{\infty} C_k e^{j2\pi k f_s t}$$

Where C_k is the Fourier series coefficient: $C_k = \frac{1}{T_s} \operatorname{sinc}\left(\frac{nT}{T_s}\right)$. So:

$$G_s(f) = \mathcal{F}\left\{g(t) \sum_{k=-\infty}^{\infty} C_k e^{j2\pi k f_s t}\right\} \equiv \sum_{k=-\infty}^{\infty} C_k \mathcal{F}\{g(t) e^{j2\pi k f_s t}\}$$

$$\Rightarrow G_s(f) = \sum_{k=-\infty}^{\infty} C_k G(f - k f_s)$$

This means: $G_s(f)$ consists of many copies of $G(f)$ added together, where the k^{th} copy is shifted by $k f_s$ and multiplied by C_k.