Lab 05

Study the effects of transmission impairments on a digital signal

OBJECTIVES OF THE LAB

In this lab, we will cover the following topics:

- How to generate a simple digital signal in matlab?
- Effect of thermal noise on the signal generated
- Effect of delay distortion on a digital signal
- Effect of attenuation on a digital

3.1 DIGITAL SIGNAL GENERATION

A digital signal is one in which the signal intensity maintains a constant level for some period of time and then changes to another constant level. However, with all its sudden changes, digital signal is a composite signal having infinite number of frequencies.

Digital signal can be both periodic and aperiodic. Periodic digital signal can be generated using Fourier Synthesis of Square Wave, while aperiodic digital signal can be represented through Fourier Transform.

3.1.1 Synthesis of Square Wave

The Square Wave for one cycle can be represented mathematically as:

$$x(t) = \begin{cases} 1 & , 0 \le t < \frac{T}{2} \\ -1 & , \frac{T}{2} \le t < T \end{cases}$$

The Complex Amplitude is given by:

$$x(t) = \begin{cases} \frac{4}{j\pi k} & , k : odd \\ 0 & , k : even \end{cases}$$

For a fundamental frequency of f=1/T=10Hz, only the odd frequencies harmonics i.e. ±10, ±30, ±50 Hz etc. make up the spectrum.

--TASK 01---

Using Matlab built-in function ''square'', generate a square wave of 20 Hz. For details about mentioned function, type: help square in matlab command window.

3.2 TRANSMISSION IMPAIRMENTS

When a signal is transmitted through a transmission medium, various impairments can corrupt or distort the received signal. These impairments include thermal noise, attenuation, delay distortion, intermodulation noise, impulse noise, etc.

3.2.1 Effect of Thermal or White Gaussian Noise on a signal

Thermal noise is due to thermal agitation of electrons. It is present in all electronic devices and transmission media. It is uniformly distributed across the bandwidth used in communication system and hence is often referred as white noise. It cannot be eliminated completely, thus places an upper bound on communications system performance.

To generate white noise in matlab, following commands are used:

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wgn(m, n, p)	Generates an m-by-n matrix of white noise with output power 'p' specified in dBW by default
wgn(m, n, p, output type)	Same as above except output type specifies whether the noise is 'real' or 'complex'
wgn(m, n, p, imp, output type)	Same as above but now power is generated across the load whose impedance is expressed in ohms
awgn(x, SNR)	Adds white noise in a vector x; where SNR is signal-to-noise ratio per sample in dB
awgn(x, SNR, 'measured')	Same as above except that awgn measures the power of x before adding noise

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EXAMPLE – GENERATING REAL WHITE NOISE

To generate a row vector of length 100 containing real white Gaussian noise of power 0 dBW, following command is used:

```
>> y1 = wgn(1, 100, 0);
```

EXAMPLE – GENERATING COMPLEX WHITE NOISE

To generate a row vector of length 100 containing complex white Gaussian noise, where each component has a noise power of 0 dBW, type in matlab following command

```
>> y2 = wgn(1, 100, 0, 'complex');
```

---TASK 02--

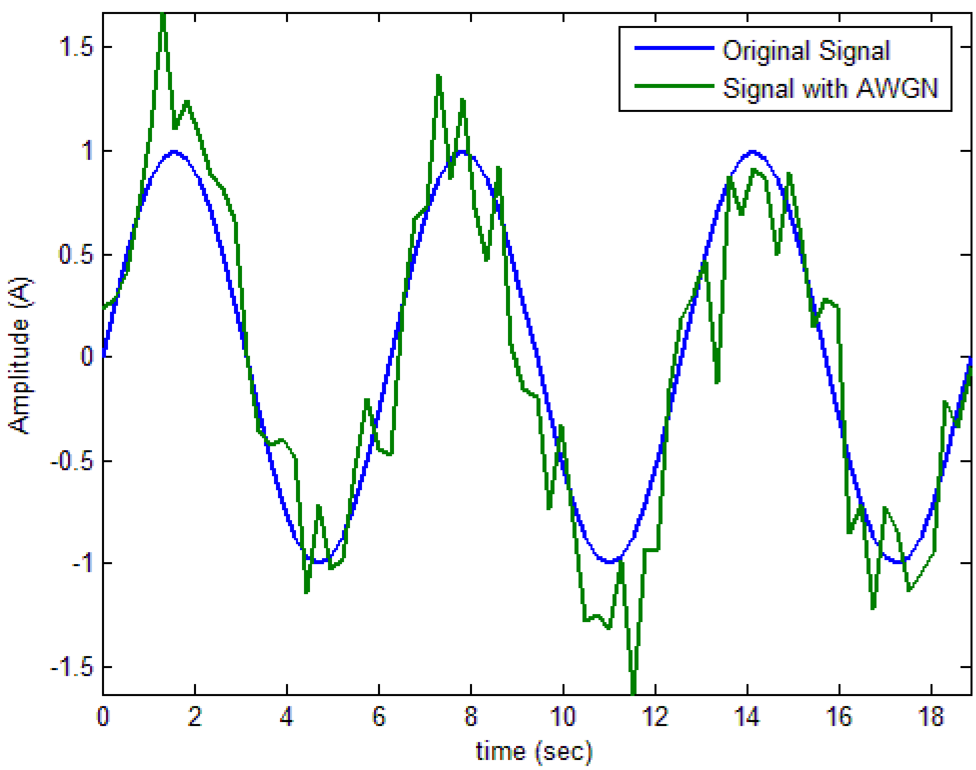
Generate a column vector of length 512 containing real noise of power 3 dBW across a 50 ohm load.

Example – Add White Noise in a Sinusoidal Signal

Following piece of code adds white Gaussian noise to a sinusoid of 3 Hz such that each sample has SNR of 10 db. It then plots the original and noisy signals.

```
clc
clear all

t = 0:pi/12:6*pi;
x = sin(t);                         % create sinusoidal signal
y = awgn(x, 10);                    % add white Gaussian noise
plot(t, x, t, y, 'lineWidth', 2);   % plot both signals
xlabel('time (sec)');
ylabel('Amplitude (A) ');
legend('Original Signal ', 'Signal with AWGN ');
axis tight;
```



---**TASK 03**---

Add measured white noise of 15 db to square wave generated in task 01. Plot the original and noisy signals on the same graph. Comment on the result.

3.2.2 Effect of Delay Distortion on a signal

Delay distortion occurs because propagation velocity of a signal varies with frequency. Considering a bandlimited signal, velocity is highest near the center frequency and falls off toward the two edges of the band. As a result, various frequency components of a signal arrive at the receiver at different time, resulting in phase shifts between the different frequencies.

This effect is referred to as delay distortion because the received signal is distorted due to varying delays experienced at its component frequencies.

3.2.3 Effect of Attenuation on a signal

Signal strength falls off with the distance it travels on any transmission medium. This property is generally termed as attenuation. For guided media, it is exponential and expressed in units of decibels/distance. Mathematically, decibel is a measure of the ratio between two signal levels.

Attenuation i.e. power loss can be calculated as

$$L_{dB} = -10 \log_{10}\left(\frac{P_{out}}{P_{in}}\right) = 10 \log_{10}\left(\frac{P_{in}}{P_{out}}\right)$$

Example – Measuring Amount of Attenuation in a Sinusoidal Signal

Suppose a sinusoid travels through a transmission medium and its power is reduced to one-half. This means that $P_{out} = ½ P_{in}$. Following matlab code determines the attenuation or power loss encountered by the transmitted signal:

```
clc
clear all

t = 0:pi/12:6*pi;
x_t = sin(t);                  % create sinusoidal signal for transmission
Ex_t = sum(x_t .* conj(x_t));  % measure transmitted signal energy
P_in = Ex_t/length(t);         % measure transmitted signal power
```

```
x_r = 0.5*sin(t);               % reduce sinusoid strength to ½
Ex_r = sum(x_r .* conj(x_r));   % measure received signal energy
P_out = Ex_r/length(t);         % measure received signal power

L = -10*log10(P_out/P_in)       % calculate attenuation or power loss
```

SAMPLE RUN

```
L = 6.0206
```

---TASK 04---

Write matlab code that calculates amount of attenuation if signal power (of sinusoid created in above example) is reduced to 1/3 of original signal's power.