ITS323 – Data Transmission Notes

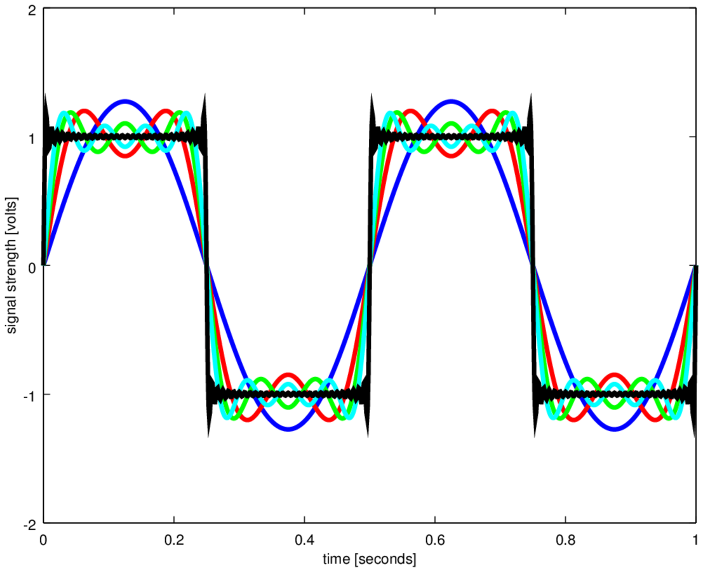


Figure 1: Time domain plot of multiple signals; Lecture 06

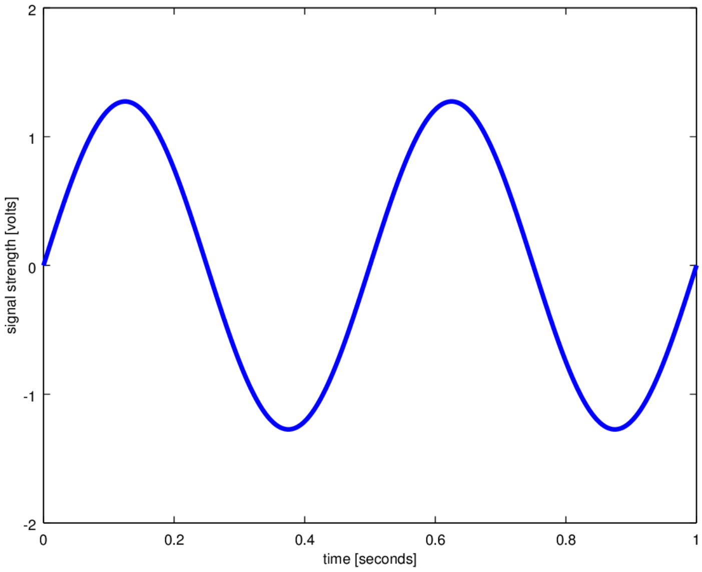


Figure 2: Time domain plot of signal s1; Lecture 06

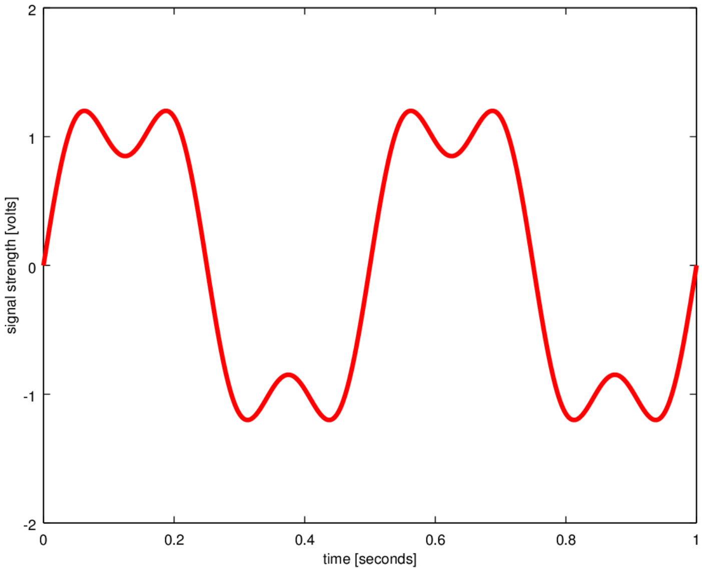
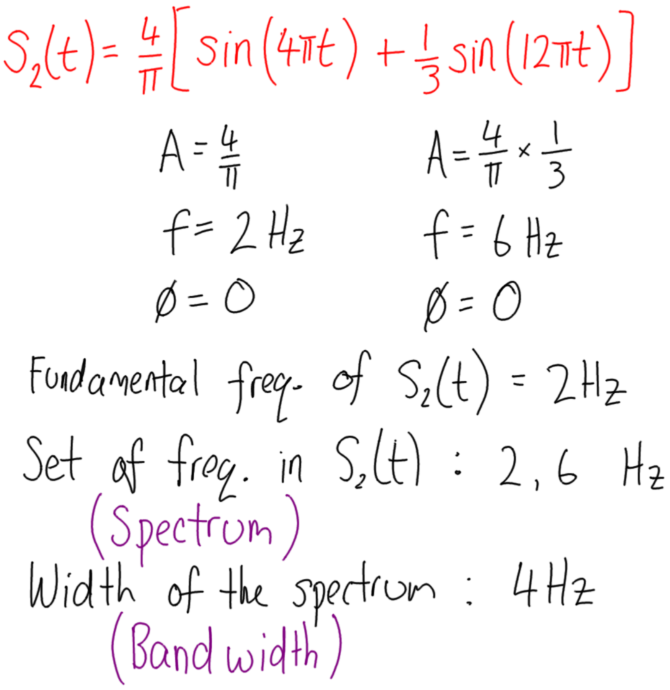


Figure 3: Time domain plot of signal s2; Lecture 06



$S_2(t) = \frac{4}{\pi}\left[\sin(4\pi t) + \frac{1}{3}\sin(12\pi t)\right]$

$A = \frac{4}{\pi}$ $A = \frac{4}{\pi} \times \frac{1}{3}$

$f = 2$ Hz $f = 6$ Hz

$\phi = 0$ $\phi = 0$

Fundamental freq. of $S_2(t)$ = 2 Hz

Set of freq. in $S_2(t)$: 2, 6 Hz
(Spectrum)

Width of the spectrum : 4 Hz
(Bandwidth)

Figure 4: Signal equation and characteristics of signal s2; Lecture 06

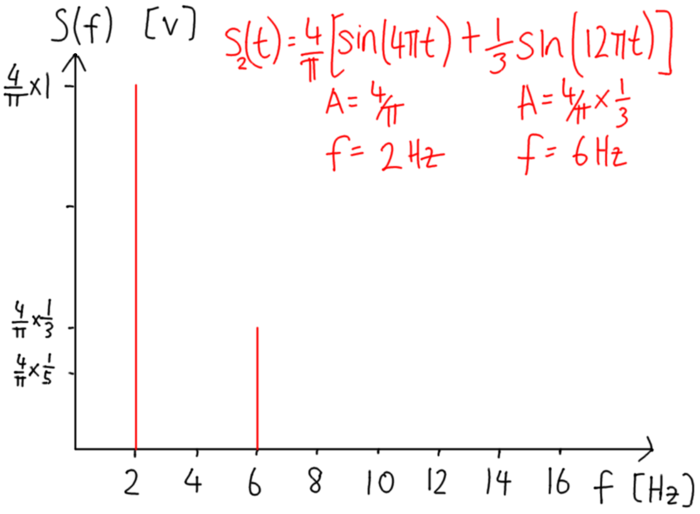


Figure 5: Frequency domain plot of signal s2; Lecture 07

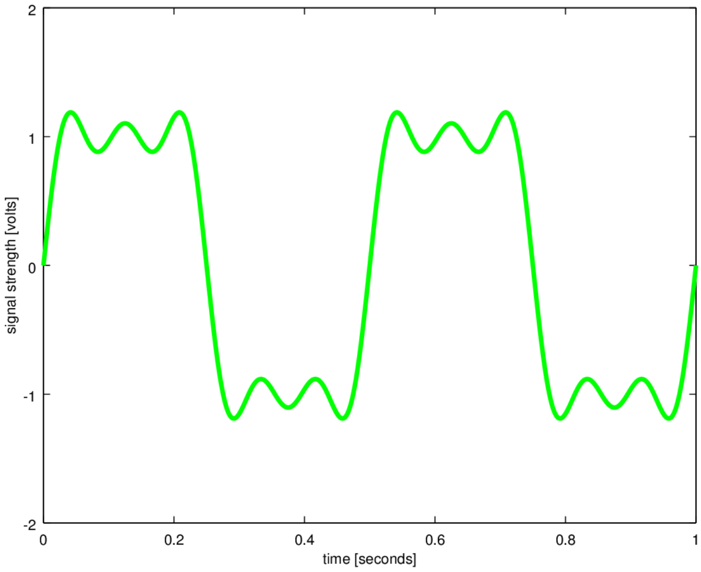


Figure 6: Time domain plot of signal s3; Lecture 06

$$S_3(t) = \frac{4}{\pi}\left[\sin(4\pi t) + \frac{1}{3}\sin(12\pi t) + \frac{1}{5}\sin(20\pi t)\right]$$

$A_1 = \frac{4}{\pi}$ $A_2 = \frac{4}{\pi} \times \frac{1}{3}$ $A_3 = \frac{4}{\pi} \times \frac{1}{5}$

$f_1 = 2\text{ Hz}$ $f_2 = 6\text{ Hz}$ $f_3 = 10\text{ Hz}$

Fundamental freq.: 2 Hz

Spectrum: 2, 6, 10 Hz

Bandwidth: 8 Hz

Figure 7: Signal equation and characteristics of signal s3; Lecture 06

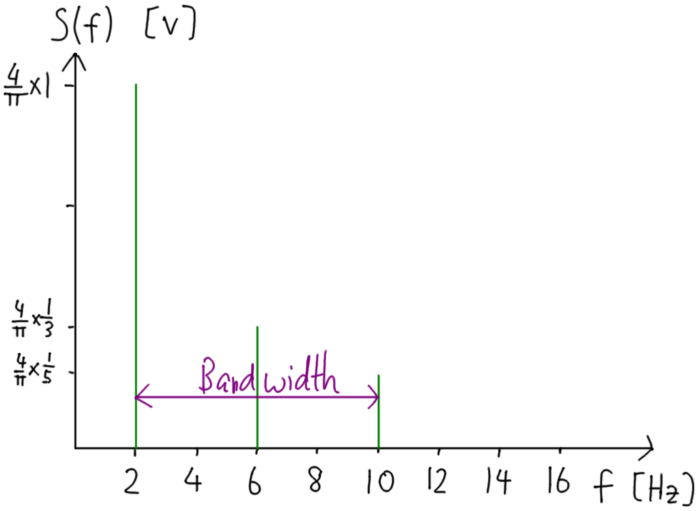


Figure 8: Frequency domain plot of signal s3; Lecture 07

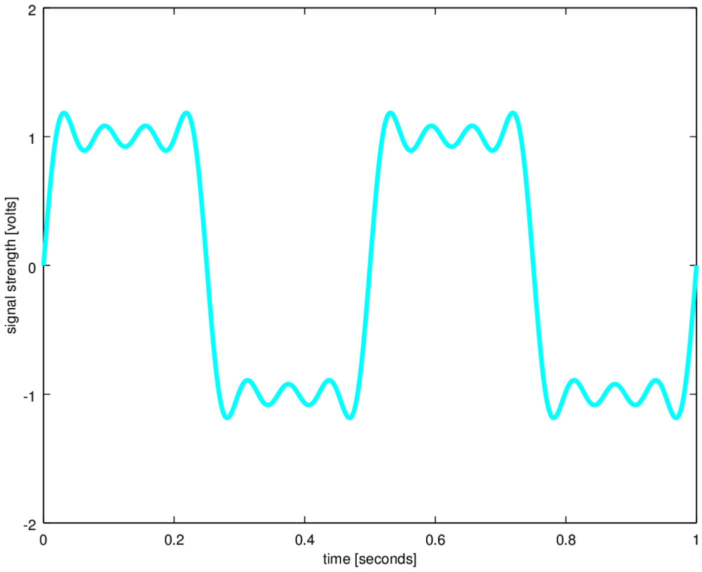


Figure 9: Time domain plot of signal s4; Lecture 06

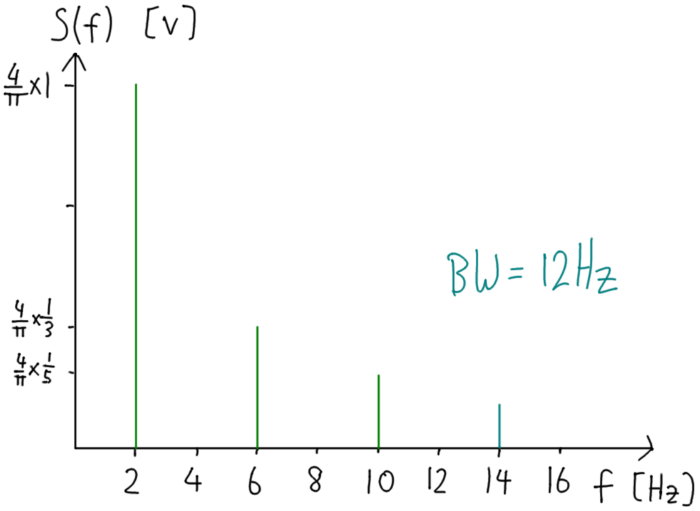


Figure 10: Frequency domain plot of signal s4; Lecture 07

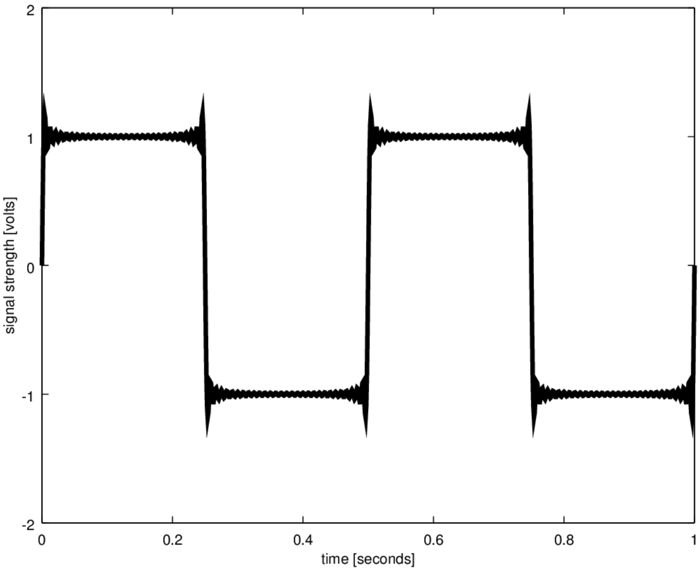


Figure 11: Time domain plot of signal s with 27 components; Lecture 06

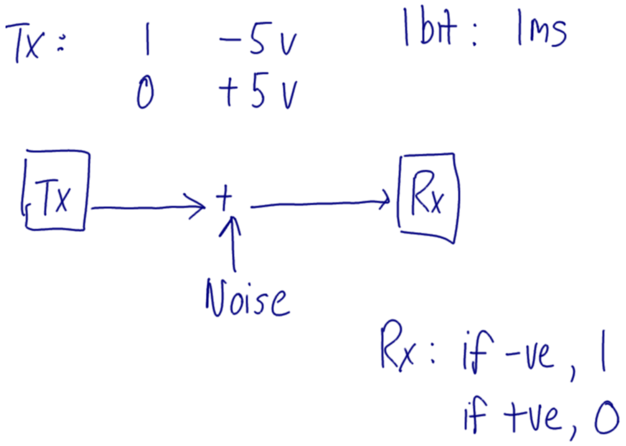


Figure 12: Transmission scheme for noise example; Lecture 08

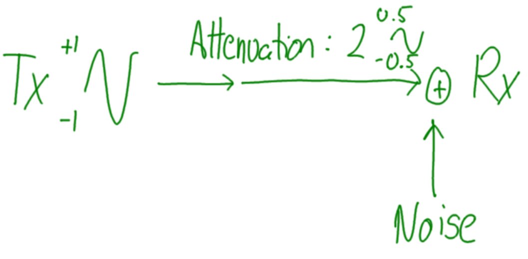
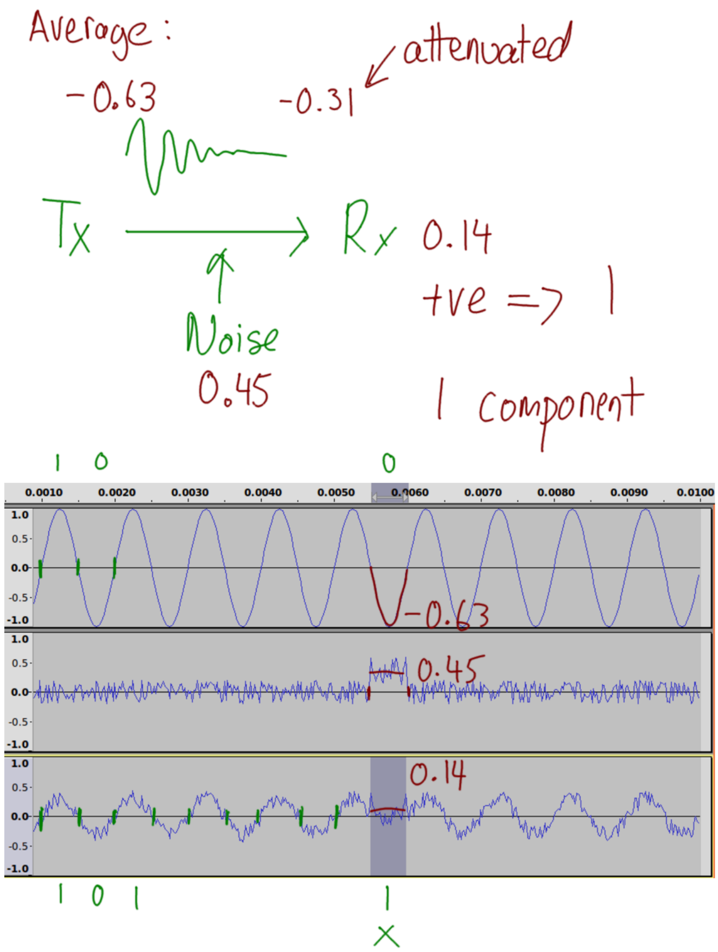


Figure 13: Attenuation and Noise; Lecture 09



Average:

-0.63 -0.31 ↙ attenuated

Tx → Rx 0.14

+ve => 1

Noise 0.45

1 component

Figure 14: Sine Wave and Noise; Lecture 09

Tx : -1
Attenuated : -0.5
Noise : 0.45
Rx : - 0.05 -ve => 0

∞ components

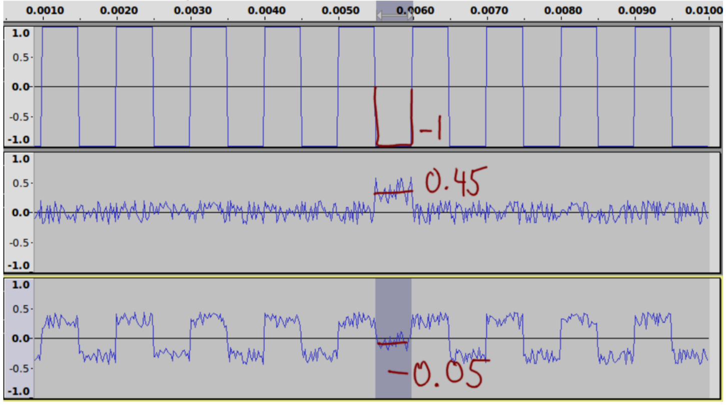
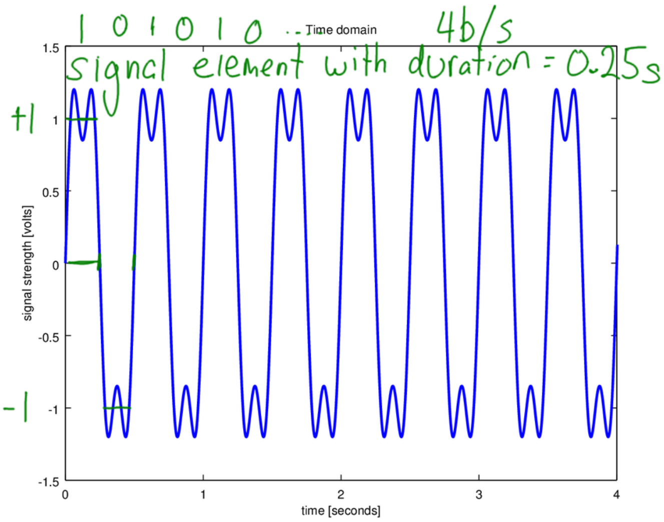


Figure 15: Square Wave and Noise; Lecture 09



signal element with duration = 0.25s

Figure 16: Signal with 2 Levels (1); Lecture 09

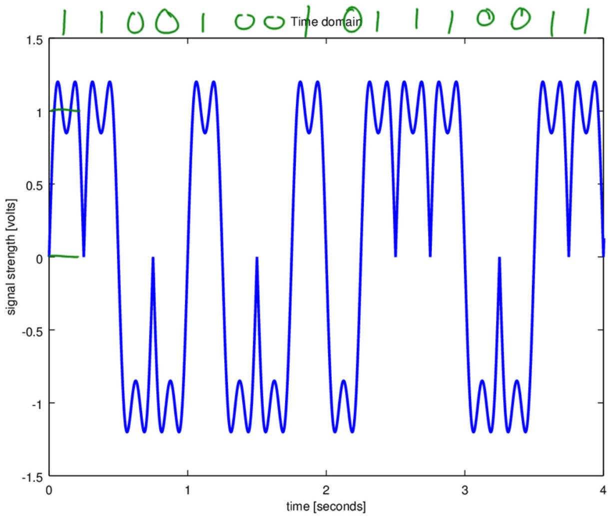
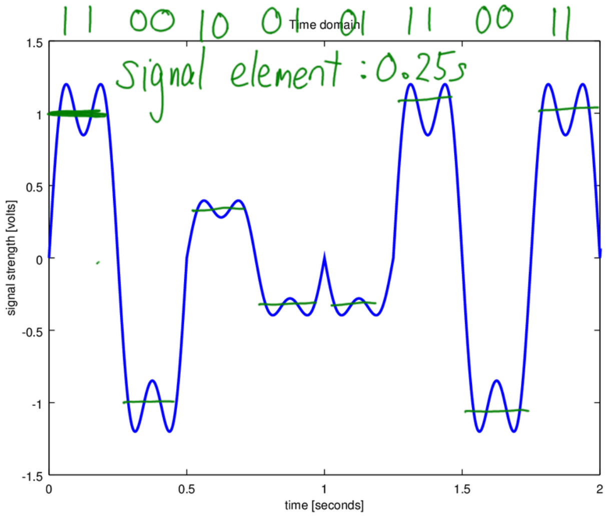


Figure 17: Signal with 2 Levels (2); Lecture 09

00 : −1
01 : − 0.33
10 : +0.33
11 : +1


11 00 10 01 01 11 00 11

Signal element : 0.25s

Figure 18: Signal with 4 Levels (1); Lecture 09

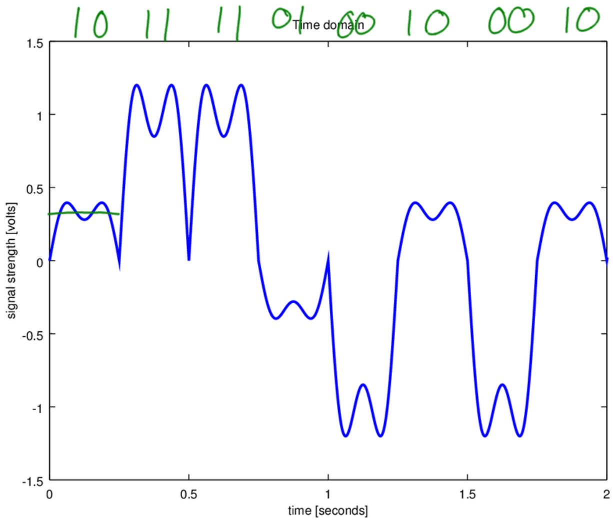
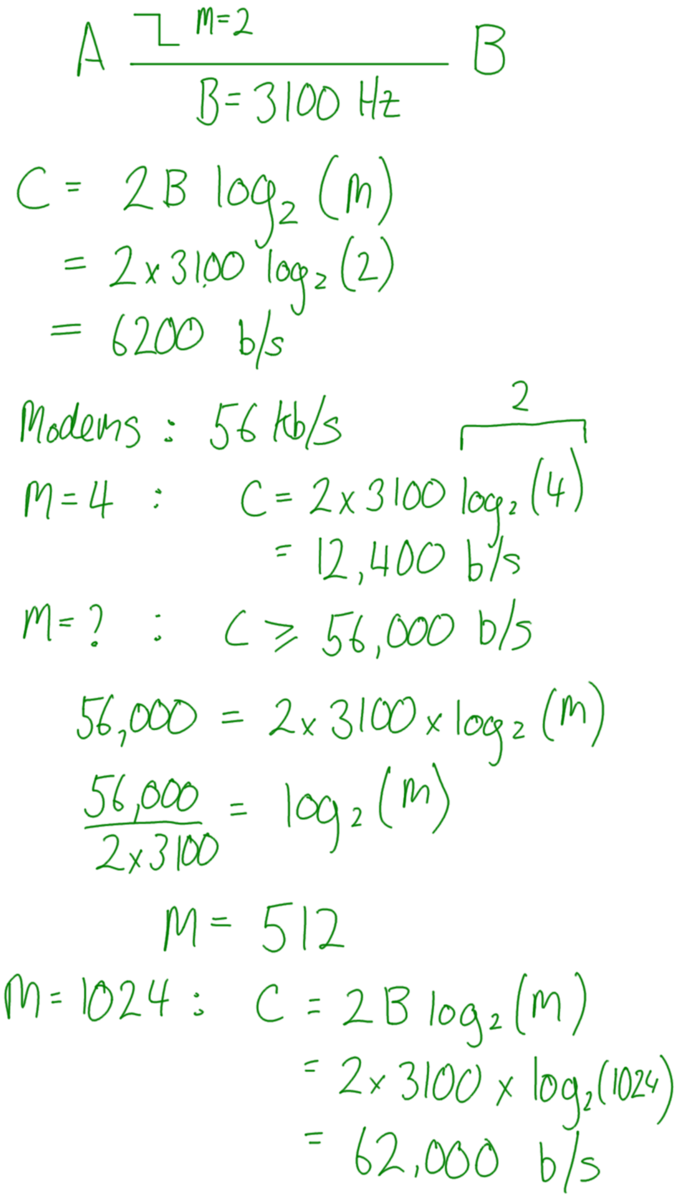

10 11 11 01 00 10 00 10

Figure 19: Signal with 4 Levels (2); Lecture 09



$$C = 2B\log_2(M)$$
$$= 2\times 3100\log_2(2)$$
$$= 6200 \text{ b/s}$$

Modems : 56 kb/s

$M=4$: $C = 2\times 3100\,\overbrace{\log_2(4)}^{2}$

$= 12{,}400$ b/s

$M=?$: $C \geq 56{,}000$ b/s

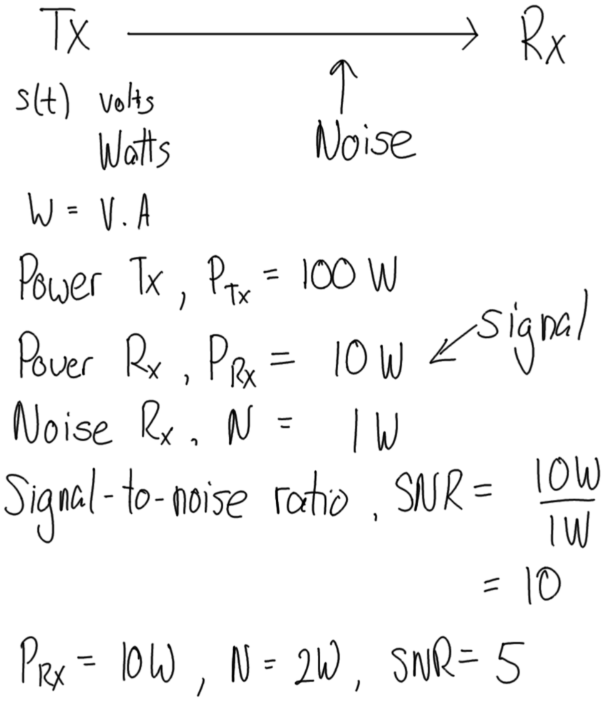
$$56{,}000 = 2\times 3100\times\log_2(M)$$
$$\frac{56{,}000}{2\times 3100} = \log_2(M)$$
$$M = 512$$

$M=1024$: $C = 2B\log_2(M)$

$= 2\times 3100\times\log_2(1024)$

$= 62{,}000$ b/s

Figure 20: Nyquist Capacity Example; Lecture 09



$W = V.A$

Power Tx, $P_{Tx} = 100\,W$

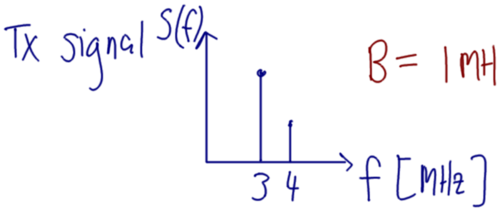
Power Rx, $P_{Rx} = 10\,W$ ← signal

Noise Rx, $N = 1\,W$

Signal-to-noise ratio, $SNR = \frac{10W}{1W} = 10$

$P_{Rx} = 10W$, $N = 2W$, $SNR = 5$

Figure 21: Signal to noise ratio; Lecture 10



B = 1 MHz

Measured SNR = 251

What is max. data rate?

$$
\begin{aligned}
C &= B \log_2(1+SNR) \\
&= 1 \times 10^6 \times \log_2(1+251) \\
&\approx 8 \times 10^6 \text{ b/s} \\
&= 8 \text{ Mb/s}
\end{aligned}
$$

How many levels needed?

$$
\begin{aligned}
C &= 2B \log_2(M) \\
8 \times 10^6 &= 2 \times 1 \times 10^6 \times \log_2(M) \\
\log_2(M) &= 4 \\
M &= 16
\end{aligned}
$$

Figure 22: Shannon and Nyquist Capacity Examples; Lecture 10

$$\text{SNR} = \frac{\text{signal power received}}{\text{noise power received}}$$

$$\text{SNR} = 251$$

$$\text{dB} = 10\log_{10}\left(\frac{P_1}{P_2}\right)$$

$$\underset{S}{P_1} = 251 \text{ mW}, \quad \underset{N}{P_2} = 1 \text{ mW}, \quad \text{SNR} = 251$$

$$10\log_{10}\left(\frac{P_1}{P_2}\right) = 10\log_{10}(251)$$
$$= 24 \text{ dB}$$

$$\text{SNR}: 251 = 24\text{dB}$$

$$S = 1004\text{W}, \quad N = 4\text{W}$$

$$\text{SNR} = \frac{1004\text{W}}{4\text{W}} = 251 = 24\text{dB}$$

Figure 23: SNR in dB; Lecture 10

Ratio 1 : 0 dB
10 : 10 dB
100 : 20 dB
1000 : 30 dB
2 : 3 dB
4 : 6 dB
8 : 9 dB
2x2x2 : 3dB + 3dB + 3dB

Figure 24: Example Ratios and dB; Lecture 10

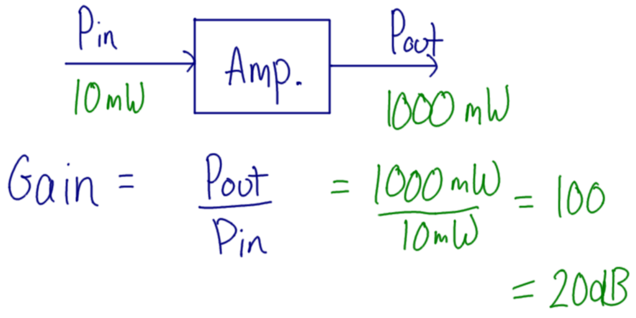


Figure 25: Amplifier Gain; Lecture 10

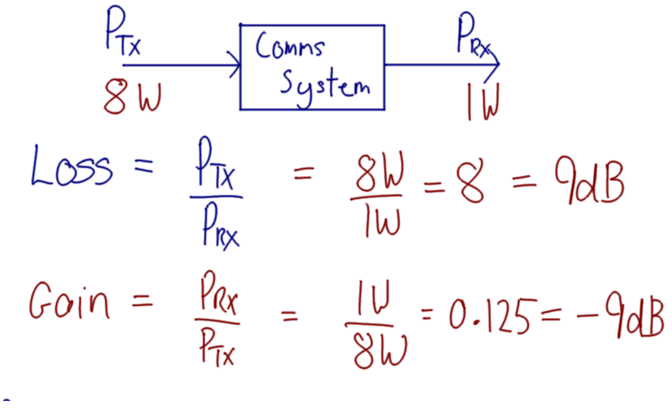


Figure 26: Communications System Loss; Lecture 10

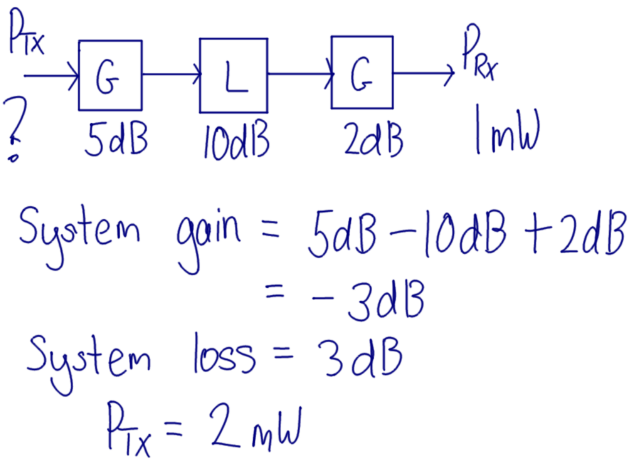


Figure 27: System Gain; Lecture 10

Rx power, $P_{rx} = 1\text{mW} = -30\text{dBW}$

$$10\log_{10}\left(\frac{P_1}{P_2}\right)$$

Reference point, $P_2 = 1\text{W}$

$$10\log_{10}\left(\frac{1\text{mW}}{1\text{W}}\right)$$

$$= 10\log_{10}(0.001)$$

$$= -30\text{ dBW}$$

$P_{tx} = 20\text{mW} = -17 \ \text{dB}\underline{\text{W}} = 13\text{dBm}\underline{\text{W}}$

$$10\log_{10}\left(\frac{20\text{mW}}{1\text{W}}\right) = 10\log_{10}(0.02)$$

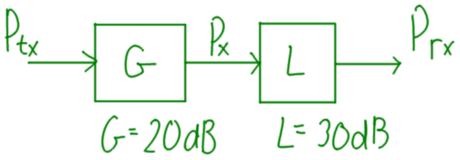
$$= -17\text{dBW}$$

$$10\log_{10}\left(\frac{20\text{mW}}{1\text{mW}}\right) = 10\log_{10}(20)$$

$$= 13\text{dBm}$$

Figure 28: dBW and dBm; Lecture 10

$P_{tx} = 13\text{dBm}$



$P_{tx} = 13\text{dBm} = 20\text{mW}$

$20\text{dB} = 100$

$P_x = 20\text{mW} \times 100 = 2000\text{mW}$

$30\text{dB} = 1000$

$P_{rx} = 2000\text{mW} \div 1000 = 2\text{mW}$

$P_{rx} = 13\text{dBm} + 20\text{dB} - 30\text{dB}$

$= 3\text{dBm}$

Figure 29: System Gain in dB; Lecture 10