Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	ELECTRONIC COMMUNICATION SYSTEMS
COURSE CODE	:	BEJ 30103
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **TWELVE (12)** PAGES

Q1 A Frequency Modulation (FM) transmitter consists of a collection of analog electronic devices that convert the original input signal into a radio signal suitable for transmission through the medium. Answer the following questions related to the FM transmitter.

(a) List **TWO (2)** types of FM Modulators.

(2 marks)

(b) Explain the process of Pre-emphasis and De-emphasis using a suitable diagram.

(6 marks)

(c) Given an FM wave as $v_{FM}(t) = 20sin(200\pi \times 10^6 t + 2cos8\pi \times 10^3 t)$. From the experimental works of the circuit, the output frequency proportionally increases with the increase of the input voltage, as tabulated in **Table Q1.1**.

(i) Determine the frequency deviation K_f.

(1 mark)

(ii) Formulate an expression of the information signal, $v_m(t)$.

(2 marks)

(iii) Sketch and label the amplitude spectrum of the FM signal.

(3 marks)

Table Q1.1 Voltage vs frequency of FM modulator

Voltage (V)	1.5	2.0	2.5	3.0	3.5
Frequency (kHz)	1.0	2.0	3.0	4.0	5.0

(d) **Figure Q1.1** shows the Narrowband FM Phase Modulator block diagram is combined with a bandpass filter and a multiplier. Given the carrier signal $v_c(t) = 20\cos(190\pi \times 10^5 t)$, the modulating signal $v_m(t) = 10\cos(20\pi \times 10^3 t)$ and frequency deviation sensitivity $K_f = {}^{0.7kHz}/_{V}$. Produce the FM signal equation at point "A".

(6 marks)

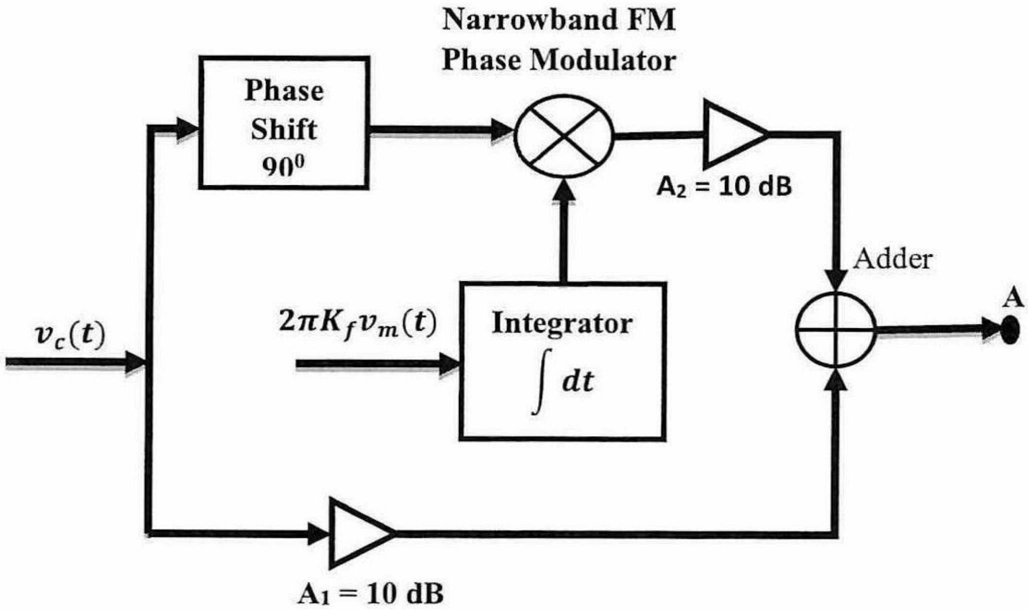

Figure Q1.1 Narrowband FM Modulator

Q2 A Frequency Modulation (FM) receiver receives the broadcasted radio signal from the medium and converts into original signal through several analog signal processing. Answer the following questions related to the FM receiver.

(a) List **TWO (2)** types of FM Demodulator.

(2 marks)

(b) Describe the operation states in a Phase Locked Loop (PLL) using a suitable diagram.

(6 marks)

(c) An FM signal, $v_{FM}(t) = 50cos((200\pi \times 10^6 t) + 2sin(30\pi \times 10^3 t))$, is passed through a frequency up-conversion stage in the receiver. Determine the $f_{c(out)}$, $\Delta f_{(out)}$, and $\beta_{f(out)}$ parameters at the following scenarios.

(i) The output of a balanced modulator connected to a bandpass filter (BPF) tuned to the sum frequency and an oscillator with a frequency of 150 MHz.

(3 marks)

(ii) The output of frequency multiplier with a multiplication factor of 10.

(3 marks)

(d) **Figure Q2.1** shows a Superheterodyne FM receiver. The 1^{st} local oscillator has a frequency of 108.3 MHz and the 2^{nd} local oscillator has a frequency of 11.155 MHz. All the Bandpass Filters only select the lower sideband frequency from the input. If the receiver is tuned to the "Hot FM" radio channel at a frequency of 97.6 MHz, determine the frequencies at the output of 1^{st} Mixer and 2^{nd} Mixer, the first intermediate frequency (1^{st} IF), and the second intermediate frequency (2^{nd} IF) parameters.

(6 marks)

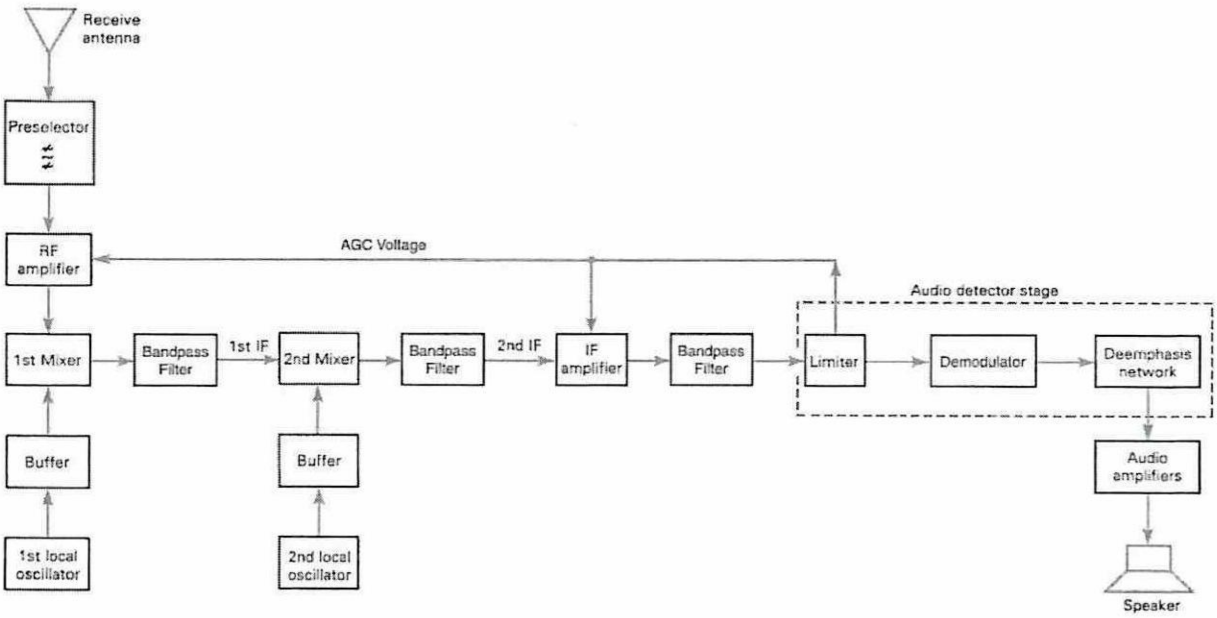

Figure Q2.1 Superheterodyne FM receiver

Q3 Digital communication is a process of exchanging information, data, or messages between individuals or devices using digital signals or data encoding.

(a) List **TWO (2)** advantages of digital communication.

(2 marks)

(b) **Figure Q3.1** shows a signal being sampled at Ts = 0.5ms and then each sample is quantized using 3 binary bits to generate pulse code modulation (PCM) encoded sequences.

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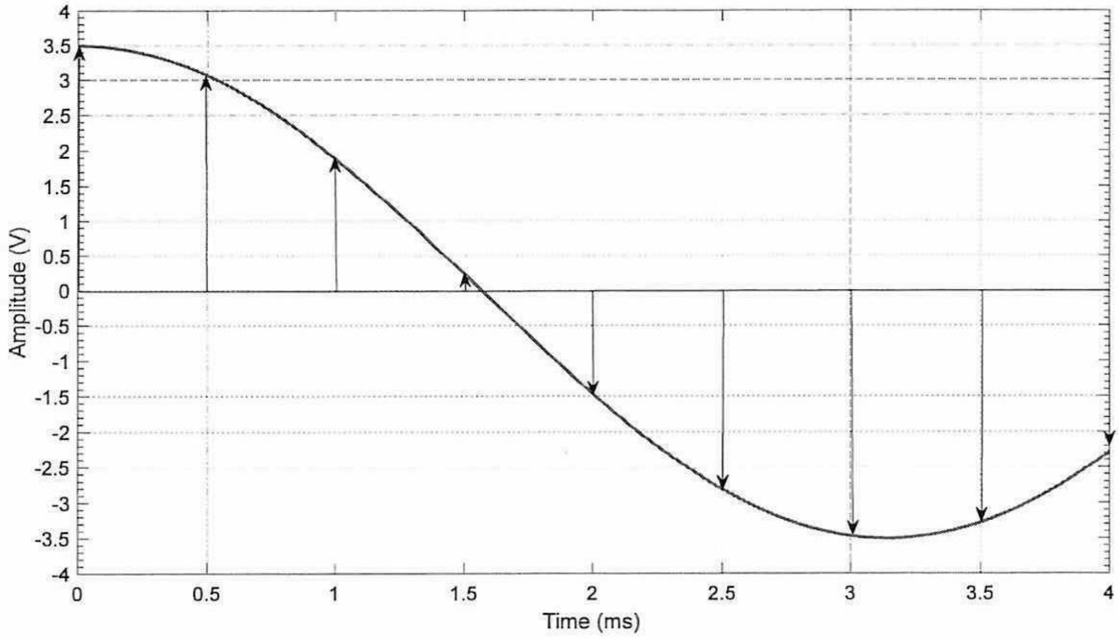

Figure Q3.1

(i) Determine the number of discrete levels that are represented.

(1 mark)

(ii) Determine the dynamic range of the quantized signal.

(1 mark)

(iii) Determine the resolution.

(1 mark)

(iv) Determine the bit rate produced by the PCM codes

(3 marks)

(v) Analyse and discover the PCM encoded signal sampled from 1 ms to 2.5 ms.

(6 marks)

(c) Explain the Frequency Shift Keying (FSK) modulation technique with the aid of suitable diagrams.

(6 marks)

Q4 A transmission line is a conductor that carries electrical signals from one point to another. It is responsible for transmitting the electromagnetic signal generated by a transmitter to the antenna.

(a) List **TWO (2)** possible modes of transverse waves.

(2 marks)

(b) Sketch the transmission line equivalent circuit with proper labelling.

(3 marks)

(c) Explain why isotropic antenna is used as a reference antenna.

(3 marks)

(d) A 85-Ω polyethylene-filled RG-58/U cable has an inner conductor diameter of 0.812 mm. Determine the outer conductor radius. Note: The relative permittivity of polyethylene is 2.50.

(3 marks)

(e) Analyse the reflection coefficient of a 50-Ω transmission line when the line is terminated:

(i) in open circuit

(ii) with a load of 50 Ω

(iii) with a load of 75 Ω

(6 marks)

(f) A field strength of 30 mV/m is measured from an unknown antenna with a gain of 2 dB. Calculate the field strength if an isotropic antenna is used at the same location.

(3 marks)

Q5 Antennas are essential components in the process of wave propagation where they enable the efficient conversion of electrical signals into electromagnetic waves for transmission and the reception of incoming waves, forming a crucial link in wireless communication systems.

(a) List **TWO (2)** types of antennas.

(2 marks)

(b) With the help of suitable diagrams, differentiate between reflection and refraction in regard to radiowave propagation.

(6 marks)

(c) A transmit antenna has a power gain of 10 dB and an input power of 40 dBm.

(i) Calculate the EIRP (in dBm) of the antenna.

(ii) Compare the power density at 10 km from this transmit antenna with an isotopic antenna with the same input power.

(6 marks)

(d) A microwave link is to be set up between two cities which are 50 km away from each other. The link will be operating at 2 GHz and is using parabolic antenna at both the transmitter and the receiver. The actual area of the antennas is 1 m^2 and the antennas are rated at 90% efficiency. The transmit power is 20 W. Analyse the feasibility of the link based on its free space loss (in dB) and the power at the receiver (in dBW). Assume there are no other losses, and the antennas are reciprocal.

(6 marks)

- END OF QUESTIONS -

APPENDIX A

Complimentary Error Function Table

$$\mathrm{erfc}(x) = 1 - \frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}\,dt$$

	Hundredths digit of x									
x	0	1	2	3	4	5	6	7	8	9
0.0	1.00000	0.98872	0.97744	0.96616	0.95489	0.94363	0.93238	0.92114	0.90992	0.89872
0.1	0.88754	0.87638	0.86524	0.85413	0.84305	0.83200	0.82099	0.81001	0.79906	0.78816
0.2	0.77730	0.76648	0.75570	0.74498	0.73430	0.72367	0.71310	0.70258	0.69212	0.68172
0.3	0.67137	0.66109	0.65087	0.64072	0.63064	0.62062	0.61067	0.60079	0.59099	0.58126
0.4	0.57161	0.56203	0.55253	0.54311	0.53377	0.52452	0.51534	0.50625	0.49725	0.48833
0.5	0.47950	0.47076	0.46210	0.45354	0.44506	0.43668	0.42838	0.42018	0.41208	0.40406
0.6	0.39614	0.38832	0.38059	0.37295	0.36541	0.35797	0.35062	0.34337	0.33622	0.32916
0.7	0.32220	0.31533	0.30857	0.30190	0.29532	0.28884	0.28246	0.27618	0.26999	0.26390
0.8	0.25790	0.25200	0.24619	0.24048	0.23486	0.22933	0.22390	0.21856	0.21331	0.20816
0.9	0.20309	0.19812	0.19323	0.18844	0.18373	0.17911	0.17458	0.17013	0.16577	0.16149
1.0	0.15730	0.15319	0.14916	0.14522	0.14135	0.13756	0.13386	0.13023	0.12667	0.12320
1.1	0.11979	0.11647	0.11321	0.11003	0.10692	0.10388	0.10090	0.09800	0.09516	0.09239
1.2	0.08969	0.08704	0.08447	0.08195	0.07949	0.07710	0.07476	0.07249	0.07027	0.06810
1.3	0.06599	0.06394	0.06193	0.05998	0.05809	0.05624	0.05444	0.05269	0.05098	0.04933
1.4	0.04771	0.04615	0.04462	0.04314	0.04170	0.04030	0.03895	0.03763	0.03635	0.03510
1.5	0.03389	0.03272	0.03159	0.03048	0.02941	0.02838	0.02737	0.02640	0.02545	0.02454
1.6	0.02365	0.02279	0.02196	0.02116	0.02038	0.01962	0.01890	0.01819	0.01751	0.01685
1.7	0.01621	0.01559	0.01500	0.01442	0.01387	0.01333	0.01281	0.01231	0.01183	0.01136
1.8	0.01091	0.01048	0.01006	0.00965	0.00926	0.00889	0.00853	0.00818	0.00784	0.00752
1.9	0.00721	0.00691	0.00662	0.00634	0.00608	0.00582	0.00557	0.00534	0.00511	0.00489
2.0	0.00468	0.00448	0.00428	0.00409	0.00391	0.00374	0.00358	0.00342	0.00327	0.00312
2.1	0.00298	0.00285	0.00272	0.00259	0.00247	0.00236	0.00225	0.00215	0.00205	0.00195
2.2	0.00186	0.00178	0.00169	0.00161	0.00154	0.00146	0.00139	0.00133	0.00126	0.00120
2.3	0.00114	0.00109	0.00103	0.00098	0.00094	0.00089	0.00085	0.00080	0.00076	0.00072
2.4	0.00069	0.00065	0.00062	0.00059	0.00056	0.00053	0.00050	0.00048	0.00045	0.00043
2.5	0.00041	0.00039	0.00037	0.00035	0.00033	0.00031	0.00029	0.00028	0.00026	0.00025
2.6	0.00024	0.00022	0.00021	0.00020	0.00019	0.00018	0.00017	0.00016	0.00015	0.00014
2.7	0.00013	0.00013	0.00012	0.00011	0.00011	0.00010	0.00009	0.00009	0.00008	0.00008
2.8	0.00008	0.00007	0.00007	0.00006	0.00006	0.00006	0.00005	0.00005	0.00005	0.00004
2.9	0.00004	0.00004	0.00004	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00002
3.0	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00001	0.00001	0.00001
3.1	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
3.2	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

APPENDIX B

Bessel Function Table

Modulation index	Carrier J_0	Sidebands									
		J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}
0.0	1.00	—	—	—	—	—	—	—	—	—	—
0.25	0.98	0.12	—	—	—	—	—	—	—	—	—
0.5	0.94	0.24	0.03	—	—	—	—	—	—	—	—
1.0	0.77	0.44	0.11	0.02	—	—	—	—	—	—	—
1.5	0.51	0.56	0.23	0.06	0.01	—	—	—	—	—	—
2.0	0.22	0.58	0.35	0.13	0.03	—	—	—	—	—	—
2.5	−0.05	0.50	0.45	0.22	0.07	0.02	—	—	—	—	—
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01	—	—	—	—
4.0	−0.40	−0.07	0.36	0.43	0.28	0.13	0.05	0.02	—	—	—
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.06	0.02	—	—
6.0	0.15	−0.28	−0.24	0.11	0.36	0.36	0.25	0.13	0.06	0.02	—
7.0	0.30	0.00	−0.30	−0.17	0.16	0.35	0.34	0.23	0.13	0.06	0.02
8.0	0.17	0.23	−0.11	−0.29	0.10	0.19	0.34	0.32	0.22	0.13	0.06

APPENDIX C

Miscellaneous Equations (1)

Trigonometry Identity	
$sin(A + B) = sinAcosB + cosAsinB$	$sin(A - B) = sinAcosB - cosAsinB$
$cos(A + B) = cosAcosB - sinAsinB$	$cos(A - B) = cosAcosB + sinAsinB$
$sin(2A) = 2\ sinAcosA$	$cos(2A) = cos^2A - sin^2A$
$cos^2A=(1/2)[1+cos2A]$	$sin^2A=(1/2)[1-cos2A]$
$SinAsinB=(1/2)[cos(A-B)-cos(A+B)]$	$cosAcosB=(1/2)[cos(A-B)+cos(A+B)]$

Constants		
$c = 3x10^8\ m/s$	$k = 1.38 \times 10^{-23}\ J/K$	$T= \theta^0 + 273\ K$

Gain, Attenuation, SNR and Noise Parameters	
$A_v = \frac{V_o}{V_i}$	$A_p = \frac{P_o}{P_i}$
$A_T = A_1 \times A_2 \times A_3 \times \cdots \times A_n$	$\lambda = \frac{c}{f}$
$T = \frac{1}{f}$	$P(dBm) = 10\log\left(\frac{P}{1\times10^{-3}}\right)$
$SNR(dB) = 10\log\left(\frac{P_1}{P_2}\right)$	$SNR(dB) = 20\log\left(\frac{V_1}{V_2}\right)$
$F_T = F_1 + \frac{F_2 - 1}{A_1} + \frac{F_3 - 1}{A_1A_2} + \cdots + \frac{F_n - 1}{A_1A_2\cdots A_{n-1}}$	$T_e = T(F-1)$
$A = \frac{R_2}{R_1 + R_2}$	$P_N=kTB$ $V_N = \sqrt{4RkTB}$
$\frac{S_{out}}{N_{out}} = \frac{A_pS_i}{A_pN_i + N_d}$	$F = \frac{SNR_{in}}{SNR_{out}}$

Amplitude Modulation Equations	
$v_m(t) = V_m \sin 2\pi f_m t$ $v_c(t) = V_c \sin 2\pi f_c t$	$V_c = \frac{V_{max} + V_{min}}{2}$
$V_m = \frac{V_{max} - V_{min}}{2}$	$m = \frac{V_m}{V_c}$
$V_{AM}(t) = V_c \sin 2\pi f_c t + \frac{V_m}{2}\cos 2\pi(f_c - f_m)t - \frac{V_m}{2}\cos 2\pi(f_c + f_m)t$	
$P_c = \frac{V_c^2}{2R}$	$P_T = P_c\left(1 + \frac{m^2}{2}\right)$
$P_{USB} = P_{LSB} = \frac{V_m^2}{8R}$	$I_T = I_c\sqrt{\left(1 + \frac{m^2}{2}\right)}$

APPENDIX D

Miscellaneous Equations (2)

Amplitude Modulation Equations	
$SF = \frac{BW_{(-60dB)}}{BW_{(-3dB)}}$	$Q = \frac{f_r}{BW}$
$BI = \frac{B_{RF}}{B_{IF}}$	$Q = \frac{X_L}{R}$
$f_{LO} = f_{RF} \pm f_{IF}$	$f_{image} = f_{LO} + f_{IF}$
$\alpha = \sqrt{1 + Q^2\rho^2}$ $IFRR(dB) = 20 \log \alpha$	$\rho = \frac{f_{image}}{f_{RF}} - \frac{f_{RF}}{f_{image}}$
Angle Modulation Equations	
$v(t) = V_c \sin(2\pi f_c t + \theta(t))$	$\theta(t) = k_p v_m(t)$ rad
$\theta'(t) = k_f v_m(t)$ rad/s	$\theta(t) = \int \theta'(t) dt$
$v_{PM}(t) = V_c \sin[\omega_c t + \theta(t)]$	$v_{FM}(t) = V_c \sin[\omega_c t + \int \theta'(t) dt]$
$\beta_p = k_p V_m$ rad	$\beta_f = \frac{k_f V_m}{\omega_m}$ or $\frac{k_f V_m}{f_m}$
$\Delta f_c = k_f V_m$ Hz	$\Delta\theta = k_p V_m$ rad
$\%\text{ modulation} = \frac{\Delta f_{actual}}{\Delta f_{max}} \times 100\%$	$BW_{Bessel} = 2\ (n \times f_m)$ Hz
$BW_{Carson} = 2\ (\Delta f + f_m)$ Hz	$DR = \frac{\Delta f_{max}}{f_{m(max)}}$
$P_t = P_0 + 2(P_1 + P_2 + P_3 + \ldots\ldots + P_n)$ W	$P_n = \frac{(J_n \times V_c)^2}{2R}$ W
$\Delta\theta_{peak} = \frac{V_n}{V_c}$ rad	$\Delta f_{peak} = \frac{V_n}{V_c} f_n$ Hz
Digital Modulation Equations	
$Q_e = \lvert Sampled\ value - Quantized\ value \rvert$ $SQR = \frac{V}{Q_n}$ $DR = \frac{V_{max}}{V_{min}} = \frac{V_{max}}{Resolution}$ $DR = 2^n - 1$	$y = y_{max} \frac{\ln[1 + \mu(\frac{\lvert x \rvert}{x_{max}})]}{\ln(1 + \mu)} \operatorname{sgn} x$ $\operatorname{sgn} x = \begin{cases} +1 & x \geq 0 \\ -1 & x < 0 \end{cases}$

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APPENDIX E

Miscellaneous Equations (3)

Digital Modulation Equations	
$y = \begin{cases} y_{\max}\dfrac{A(\frac{\lvert x\rvert}{x_{\max}})}{1+\ln A}\operatorname{sgn} x & 0<\dfrac{\lvert x\rvert}{x_{mac}}\le\dfrac{1}{A} \\ y_{\max}\dfrac{1+\ln[A(\frac{\lvert x\rvert}{x_{\max}})]}{1+\ln A}\operatorname{sgn} x & \dfrac{1}{A}<\dfrac{\lvert x\rvert}{x_{\max}}<1 \end{cases}$	$\text{Coding efficiency} = \dfrac{\text{minimum number of bits}}{\text{actual number of bits}}\times 100\%$
$E_b = P_R T_b$	$N_o = kT_N$
$C = 2BW\log_2 M$	$BW = (\dfrac{B}{\log_2 M})$
$Baud = \dfrac{C}{k}$	$erfc(z) = 1 - erf(z)$
$P_{be} = \dfrac{1}{2}erfc\sqrt{\dfrac{E_b}{2N_o}}$	$P_{be} = \dfrac{1}{2}e^{\frac{-E_b}{2N_o}}$
$BR = SR \times n$	$BW_{min} \le \dfrac{1}{2}BR$ $BW_{pcm} = BR$
Transmission Line, Antenna & Propagation Equations	
$P_R = \left(\dfrac{P_T G_T G_R}{\left(\frac{4\pi d}{\lambda}\right)^2}\right)\times\dfrac{1}{L_t L_r}\quad \text{W}$	$P_d = E \times H = \dfrac{E^2}{120\pi} = \dfrac{P_{in}G_P}{4\pi d^2} = \dfrac{EIRP}{4\pi d^2}\quad \dfrac{\text{W}}{\text{m}^2}$
$E = \dfrac{\sqrt{30PG}}{d}\quad \dfrac{\text{V}}{\text{m}}$	$G_R = \dfrac{4\pi A_e}{\lambda^2}$
$\Gamma = \dfrac{VSWR-1}{VSWR+1} = \dfrac{Z_L - Z_0}{Z_L + Z_0}$	$Z_{0(lossless)} = \sqrt{\dfrac{L'}{C'}}\quad \Omega$
$Z_{0(coax)} = \dfrac{138}{\sqrt{\varepsilon_r}}\log_{10}\left(\dfrac{D}{d}\right)\quad \Omega$	$Z_{0(two-wire)} = 276\log_{10}\left(\dfrac{D}{r}\right)\quad \Omega$
$Z_{in} = Z_0\dfrac{Z_L + jZ_0\tan\beta l}{Z_0 + jZ_L\tan\beta l}\quad \Omega$	$\gamma = \alpha + j\beta$ $= \sqrt{(R' + j\omega L')(G' + j\omega C')}\quad \dfrac{\text{Np}}{\text{m}}\text{ or }\dfrac{\text{rad}}{\text{m}}$