5. (a) Given the signal $x_c(t)=10\cos(2\pi 10^8 t+200\cos 2\pi 10^3 t)$, what is its bandwidth in [Hz]?

(b) What is the instantaneous frequency [Hz] of the signal $x_b(t)=10\cos(20\pi t+\pi t^2)$ at the time instance t = 0?

(c) What is its rate of frequency change [Hz] per second?

Collection of Formulas

$$C = W_C \cdot \log_2(1+SNR)\ ,\ \begin{cases} r_{\max} = 2B_T = r_b/n = r_b/\log_2(L) \\ \Rightarrow r_b = 2B_T\log_2(L), L = 2^n \end{cases},\ r = n\cdot f_S$$

$$C = W_C \cdot \log_2(1+SNR)$$

$$P_{dB} = 10\log(P_1/P_2), P_{dB} = 20\log(V_1/V_2), P_{dBm} = 10\log(P_1/1mW),\ \frac{V_g}{V_i} = \frac{Z_g+Z_L}{Z_i}$$

$$\begin{cases} \text{y(t)=Kx(t - t}_d) \\ \Rightarrow \text{Y(f)=F [y(t)]=}\underbrace{\text{Kexp(-j}\omega\text{t}_d)}_{H(f)}X(f) \\ G_y(f) = |H(f)|^2 G_x(f)\ \text{(= output PDF)} \end{cases},\ \begin{cases} l = d_{\min}-1, t = \lfloor l/2 \rfloor, R_C = k/n \le 1 \\ d_{\min}\big|_{\max} = n-k+1\ \text{(repetition codes)} \end{cases}$$

$$\begin{cases} N_R = \int_{-\infty}^{\infty}(\eta/2)|H_R(f)|^2 df \\ \quad = \int_{B_T}(\eta/2)df + \int_{B_T}(\eta/2)df = \eta B_T \end{cases}\quad \begin{cases} P(n,k) = \binom{n}{k}\alpha^k(1-\alpha)^{n-k} \\ \binom{n}{k} = \frac{n!}{k!(n-k)!} \end{cases}$$

$$c_n = \frac{1}{T}\int_T x(t)\exp(-j2\pi f_0 tn)dt$$

$$\begin{cases} B_T = 2|D-1|W, 1 >> D >> 1 \\ \beta = A_m f_\Delta / f_m\big|_{A_m=1, f_m=W} = f_\Delta/W \equiv D \\ B_{T,DSB} = 2W, B_{T,SSB} = W \end{cases}\quad \begin{cases} f(x) = a_0/2 + \sum_{n=1}^{\infty} a_n\cos(nx) + \sum_{n=1}^{\infty} b_n\sin(nx) \\ a_0 = \pi^{-1}\int_{-\pi}^{\pi} f(x)dx, a_n = \pi^{-1}\int_{-\pi}^{\pi} f(x)\cos(nx)dx \\ b_n = \pi^{-1}\int_{-\pi}^{\pi} f(x)\sin(nx)dx \end{cases}$$

$$\begin{cases} x_C(t) = A_c\cos(\omega_c t + \phi(t)) \\ \phi_{PM}(t) = \phi_\Delta x(t) \\ \phi_{FM}(t) = 2\pi f_\Delta \int_{t_0}^{t} x(\lambda)d\lambda, t \ge t_0 \end{cases}\quad \phi(t) = \begin{cases} \underbrace{\phi_\Delta A_m}_{\beta}\sin(\omega_m t), \text{PM} \\ \underbrace{(A_m f_\Delta / f_m)}_{\beta}\sin(\omega_m t), \text{FM} \end{cases}\quad \begin{cases} \gamma = S_R/(\eta W) \\ S_R/N_R = \gamma W/B_T \\ \gamma_b = E_b/N_0 \end{cases}$$

$$y(t) = \begin{cases} v_i(t) & \text{Synchronous detector} \\ A_v(t) - \overline{A_v} & \text{Envelope detector} \\ \phi_v(t) & \text{Phase detector} \\ d\phi_v(t)/dt & \text{Frequency detector} \end{cases},\quad \begin{cases} x_{AM}(t) = A_C[1+\mu x_m(t)]\cos(\omega_c t) \\ x_{DSB}(t) = x_m(t)\cos(\omega_c t) \end{cases}$$