$\boxed{5.16}$ When $\sigma / T_s \leq 0.1$, no equalizer is required.

For USDC using $\frac{\pi}{4}$ DQPSK modulation.

Symbol period $T_s = \frac{2}{\text{RF Data Rate}} = \frac{2}{48.6 \times 10^3} \doteq 41.2\ (\mu s)$

$\Rightarrow \sigma_{max} = 0.1\, T_s = 0.1 \times 41.2 = \underline{\underline{4.12\ (\mu s)}}$

For GSM using 0.3 GMSK modulation,

$T_s = \frac{1}{0.3 \times \text{RF Data Rate}} = \frac{1}{0.3 \times 270.833 \times 10^3} \doteq 12.3\ (\mu s)$

$\Rightarrow \sigma_{max} = 0.1\, T_s = 0.1 \times 12.3 = \underline{\underline{1.23\ (\mu s)}}$

For DECT using 0.3 GMSK modulation,

$T_s = \frac{1}{0.3 \times \text{RF Data Rate}} = \frac{1}{0.3 \times 1152 \times 10^3} \doteq 2.89\ (\mu s)$

$\Rightarrow \sigma_{max} = 0.1\, T_s = 0.1 \times 2.89 = \underline{\underline{0.289\ (\mu s)}}$

5.28 (a) mean excess delay $\bar{\tau} = \frac{1\times 0 + 0.1\times 1 + 1\times 2}{1+0.1+1} = 1\ (\mu s)$

$$\overline{\tau^2} = \frac{1\times 0 + 0.1\times 1 + 1\times 2^2}{1+0.1+1} \doteq 1.95\ (\mu s^2)$$

rms delay spread $\sigma_\tau = \sqrt{1.95 - 1^2} \doteq \underline{\underline{0.976\ (\mu s)}}$

(b) maximum excess delay (20 dB) = $\underline{\underline{2\ \mu s}}$

(c) $T_{min} = 10\,\sigma_\tau = 10\times 0.976 = 9.76\ (\mu s)$

$\Rightarrow$ maximum RF symbol Rate $= \frac{1}{T_{min}} = \frac{1}{9.76\times 10^{-6}} \doteq \underline{\underline{102\ \text{Kbp}}}$

(d) Let $f_c = 900\ MHz \Rightarrow \lambda = \frac{c}{f_c} \doteq 0.33\ (m)$

$$V = \frac{30\times 10^3 m}{3600 S} \doteq 8.33\ (m/s)$$

$$\Rightarrow f_m = \frac{V}{\lambda} = \frac{8.33}{0.33} = 25\ (HZ)$$

$$\Rightarrow \text{Coherence time } T_c = \frac{0.423}{f_m} = \frac{0.423}{25} \doteq \underline{\underline{0.017\ (S)}}$$

5.29 (a) $\lambda = \frac{c}{f_c} = \frac{3\times 10^8 m/s}{6\times 10^9 Hz} = 0.05\ (m)$

$$V = \frac{80\times 10^3 m}{3600 S} \doteq 22.22\ (m/s)$$

$$\Rightarrow f_m = \frac{V}{\lambda} = \frac{22.22}{0.05} \doteq 444.4\ (HZ)$$

For $\rho = 1$, $N_R = \sqrt{2\pi}\cdot f_m \cdot \rho\, e^{-\rho^2} = \sqrt{2\pi}\times 444.4\times 1\times e^{-1}$

$\doteq 409.7$ (crossings/sec)

$\Rightarrow$ Number of positive-going zero crossings about the rms value that occur over a 5 second interval

$= N_R\cdot t = 409.7\times 5 \doteq \underline{\underline{2048.}}$

5.29 Cont'd

(b) $\bar{\tau} = \frac{e^{\rho^2}-1}{\rho \cdot f_m \sqrt{2\pi}} = \frac{e^1 - 1}{1 \times 444.4 \times \sqrt{2\pi}} \doteq 1.54 \times 10^{-3} (s) = 1.54 (ms)$

(c) For $\rho = -20dB = 0.1$, we have

$$\bar{\tau} = \frac{e^{\rho^2}-1}{\rho \cdot f_m \cdot \sqrt{2\pi}} \doteq \frac{e^{0.01}-1}{0.1 \times 444.4 \times \sqrt{2\pi}} \doteq 9.02 \times 10^{-5} (s) = \underline{\underline{90.2 (\mu s)}}$$

$\boxed{5.30}$

$$\text{Fast Fading} \;:\; f_M \gg \frac{1}{T_s}$$
$$\text{Slow Fading} \;:\; f_M \ll \frac{1}{T_s}$$

$$\text{Flat Fading} \;:\; T_s \gg$$
$$\text{Freq. Selective Fading} \;:\; T_s \ll$$

(a)

$$f_m \text{ Doppler} \approx 200 \text{ Hz (highway speed)}$$

$$\sigma_\tau(\text{urban}) \approx 2\mu s \quad \text{(typical)}$$

Given

$$1/T_s = 500 \text{ kbps} \Rightarrow T_s \approx 2\mu s.$$

$$\text{Slow fading} \;:\; \text{since } f_M \ll \frac{1}{T_s}$$
$$\text{Freq. Selective Fading} \;:\; \text{since } T_s < \sigma_\tau$$

(b)

$$\text{Flat Fading} \;:\; \text{since } T_s \gg \sigma_\tau$$
$$\text{Slow Fading} \;:\; \text{since } f_M \ll \frac{1}{T_s}$$

(b)

$$\text{Fast Fading} \;:\; \text{since } f_M \gg \frac{1}{T_s}$$
$$\text{Flat Fading} \;:\; \text{since } T_s \gg \sigma_\tau$$