-BLAKE-

Introduction to communications systems

Example 1.1

Calculate the wavelength in free space corresponding to a frequency of:

(a) 1 MHz (AM radio broadcast band)
(b) 27 MHz (CB radio band)
(c) 4 GHz (used for satellite television)

Solution

C = $f\lambda$

$\lambda = \frac{c}{f}$

(a) $\lambda = \frac{300 \, X \, 10^6 \frac{m}{s}}{1 \, X \, 10^6 Hz}$

= 300m

(b) $\lambda = \frac{300 \, X \, 10^6 \frac{m}{s}}{27 \, X \, 10^6 Hz}$

= 11.1m

(c) $\lambda = \frac{300 \, X \, 10^6 \frac{m}{s}}{4 \, X \, 10^9 Hz}$

= 0.075m
= 7.5cm

Introduction to communications systems

Example1.4

A receiver has a noise power bandwidth of 10 kHz. A resistor that matches the receiver input impedance is connected across its antenna terminals. What is the noise power contributed by that resistor in the receiver bandwidth, if the resistor has temperature of 27 ^oC

Solution

$T(K) = T(^oC) + 273$

$= 27 + 273$

$= 300\ K$

$P_N = kTB$

$= (1.38 \times 10^{-23}\ J/K\ (300\ K)\ (10 \times 10^3\ Hz)$

$= 4.14 \times 10^{-17}\ W$

EXAMPLE 1.5

A 300Ω resistor is connected across the 300 Ω antenna input of a television receiver. The bandwidth of the receiver is 6 MHz, and the resistor is at room temperature (293 K or 20^{o}C or 68^{o}F). Find the noise power voltage applied to the receiver input.

Solution

$P_N = kTB$

$= (1.38 \times 10^{-23}\ J/K\ (300\ K)(293\ K)\ (6 \times 10^3\ Hz)$

$= 24.2 \times 10^{-15}\ W$

$= 24.2\ fW$

$V_N = \sqrt{4kTBR}$

$= \sqrt{4\ (1.38 \times 10^{-23}\ J/K)(293)(6 \times 10^6\ Hz)\ (300\ \Omega)}$

$= 5.4 \times 10^{-6}\ V$

$= 5.4 \mu V$

Introduction to communications systems

EXAPMLE 1.6

A diode noise generator is required to produce 10µV of noise in a receiver with an input impedance of 75 Ω, resistive, and a noise power bandwidth 0f 200 kHz. (These values are typical of FM broadcast receivers.) What must be current through the diode be?

Solution

$$I_N = \frac{V_N}{R}$$

$$= \frac{10\mu V}{75\ \Omega}$$

$$= 0.133\mu A$$

$$I_N = \sqrt{2qI_0B}$$

$$I^2_N = 2qI_0B$$

$$= \frac{I^2_N}{2qB}$$

$$= \frac{(0.133 \times 10^{-6}\ A)^2}{2(1.6 \times 10^{-19}\ C)(200 \times 10^3\ Hz)}$$

$$= 0.276\ A \text{ or } 276\ mA$$

EXAMPLE 1.8

A receiver produces a noise power of 200 mW with no signal. The output level increases to 5W when a signal is applied. Calculate (S + N)/N as a power ratio and in decibels.

Solution:

$$(S+N)/N = \frac{5\ W}{0.2\ W}$$

$$= 25$$

$$(S+N)/N\ (dB) = 10 \log 25$$

$$= 14dB$$

EXAMPLE 1.9

The signal power at the input to an amplifier is 100µW. at the output, the signal power is 1W and the noise power is 30mW. What is the amplifier noise figure, as a ratio?

Solution:

$$(S/N)_i = \frac{100\mu W}{1\mu W} = 100$$

$$NF\ (ratio) = \frac{100}{33.5} = 3$$

1µW

$$(S/N)_o = \frac{\quad}{0.03W} = 33.3$$

Introduction to communications systems

EXAMPLE 1.10

The signal at the input of an amplifier has an S/N of 42dB. If the amplifier has noise figure of 6dB, what is the S/N at the output (in decibel)?

Solution

$$NF\ (dB) = (S/N)_i(dB) - (S/N)_o(dB)$$

$$(S/N)_o(dB) = (S/N)_i(dB) - NF\ (dB)$$

$$= 42\ dB – 6\ dB$$

$$= 36dB$$

EXAMPLE 1.11

An amplifier has a noise figure of 2 dB. What is its equivalent noise temperature?

Solution

$$NF\ (dB) = 10 \log NF\ (ratio)$$

$$NF\ (ratio) = \text{antilog}\ \frac{NF(dB)}{10}$$

$$= \text{antilog}\ 0.2$$

$$= 1.585$$

$$Teq = 290\ (NF – 1)$$

$$= 290\ (1.585 – 1)$$

$$= 169.6\ K$$

Radio-Frequency Circuit

EXAMPLE 2.5

A varactor has a maximum capacitance of 80pF and is used in a tuned circuit with a 100 µH inductor.

(a) Find the resonant frequency with no tuning voltage applied
(b) Find the tuning necessary for the circuit to resonate at double the frequency found in part (a)

Solution

(a)

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{(100 \times 10^{-6})(80 \times 10^{-12})}}$$

$$= 1.78 \text{ MHz}$$

(b)

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$C = \frac{C_0}{\sqrt{1+2V}}$$

$$f_0 = \frac{1}{4\pi^2\sqrt{LC}}$$

$$\sqrt{1+2V} = \frac{C_0}{C}$$

$$f_0 = \frac{1}{4\pi^2 f_0^2 L}$$

$$1+2V = \left(\frac{C_0}{C}\right)^2$$

$$= \frac{1}{4\pi^2(2 \times 1..78 \times 10^6)^2 (100 \times 10^{-6})}$$

$$V = \frac{(C_{0/} C)^2 - 1}{2}$$

$= 20 \times 10^{-12}$ F

= 20pF

$= \dfrac{(80/20)^2 - 1}{2}$

= 7.5 V

Radio-Frequency Circuit

EXAMPLE 2.6

A portable radio transmitter has to operate at temperature form – 50°C to 350°C if its signal is derived from a crystal oscillator with a temperature coefficient of +1 ppm/degree C and it transmits at exactly 146 MHz at 20°C, find the transmitting frequency at the two extremes of the operating temperature range.

Solution

$f_T = f_0 + kf f_0 (T - T_0)$

f_{max} =146 MHz + (146 MHz)(1 X 10^{-6})(35 -20)

= 146.00219 MHz

f_{min} =146 MHz + (146 MHz)(1 X 10^{-6})(-5 -20)

= 145.99635 MHz

EXAMPLE 2.7

Sine – wave signals with frequencies of 10 MHz 11MHz are applied to square – law mixer. What frequencies appear at the output?

Solution

f_1 = 11MHz $\quad$ $2f_2$ = 22MHz $\quad$ $f_1 + f_2$ =21 MHz

f_2 = 11MHz $\quad$ $2f_2$ = 20MHz $\quad$ $f_1 - f_2$ = 1 MHz

EXAMPLE 2.8

A phase – locked loop has a VCO with a free – running frequency of 12 MHz. As the frequency of the reference input is gradually raised from zero, the loop locks at 10MHz and comes out of lock again at 16 MHz.

(a) Find the capture range and lock range

(b) Suppose that the experiment is repeated, but this time the reference input begins with a very high frequency and steadily moves downward. Predict the frequencies at which lock would be achieved and lost.

Solution

(a)

Capture range = 2(12 MHz – 10 MHz)
= 4 MHz

lock range = 2(16 MHz – 12 MHz)
= 8 MHz

(b)

12 MHz + 2 MHz =14 MHz
12 MHz – 4 MHz = 8 MHz

Radio-Frequency Circuit

EXAMPLE 2.9

Configure a simple PLL synthesizer using a 10 MHz crystal so that it will generate the AM broadcast frequencies from 540 to 1700 kHz.

Solution

$$Q = \frac{f_{OSC}}{f_{ref}}$$

$$= \frac{10 \text{ MHz}}{10 \text{ kHz}}$$

$$= 1000$$

$$f_0 = N f_{ref}$$

$$N = \frac{f_0}{f_{ref}}$$

$$N = \frac{540 \text{ kHz}}{10 \text{ kHz}}$$

$$= 54$$

1700 kHz

$$N = \frac{\quad}{10\ \text{kHz}}$$

$= 170$

Radio-Frequency Circuit

EXAMPLE 2.10

The synthesizer in Figure 2.40 has P = 10 and f_{ref} =10 kHz. Find the minimum frequency step size and compare it with that obtained using a fixed divided-by-10 prescaler.

Solution

Step size = $M f_{ref}$

= 10 X 10 kHz

= 10 kHz

$f_0 = (M+NP)\, f_{ref}$

= (M+NP)10 kHz

$f'_0 = (M+1+NP)\, f_{ref}$

= (M+1+NP)10 kHz

$f'_0 + f_0$ = (M+1+NP) 10 kHz – (M+NP)10kHz

= (M+1+NP – M - NP) 10 kHz

= 10kHz

EXAMPLE 2.11

A synthesizer of the type shown in figure 2.42 has f_{ref} =20 kHz and local oscillator operating at 10 Mhz. Find the frequency range of the output as the value of N ranges from 10 to 100. Also find the minimum amount by which the frequency can be varied.

Solution

$f_0 = N f_0 + f_{LO}$

f_0 = 10 X 20 kHz + 10 MHz

= 10.2 MHz

f_0 = 100 X 20 kHz + 10 MHz

= 12 MHz

$$\text{Step size} = \frac{12\text{ MHz} - 10.2\text{ MHz}}{100 - 10}$$

$$= \frac{1.8\text{ MHz}}{90} = 20\text{ kHz}$$

Amplitude Modulation

EXAMPLE 3.1

A carrier wave with an RMS voltage of 2V and a frequency of 1.5 MHz is modulated by a sine wave with a frequency of 500 Hz and amplitude of 1V RMS. Write the equation for the resulting signal.

Solution

$E_c = \sqrt{2}$ X 2V

= 2.83 V

$E_m = \sqrt{2}$ X 1V

= 1.41 V

$\omega_c = \sqrt{2}\pi$ X 1.5 X 10^6

= 9.42 X 10^6 rad/s

$\omega_m = \sqrt{2}\pi$ X 500

= 3.14 X 10^3 rad/s

$V(t) = (E_c + E_m \sin \omega_m t) \sin \omega_c t$

$= [2.83 + 1.41 \sin (3.14 \times 10^3 t)] \sin (9.42 \times 10^6 t) V$

EXAMPLE 3.2

Calculate m for the signal in Example 3.1, and write the equation for this signal in the form of Equation (3.5).

Solution

$$m = \frac{E_m}{E_c}$$

$$= \frac{1}{2}$$

$$= 0.5$$

$V(t) = E_c (1 + m \sin \omega_m t) \sin \omega_c t$

$= 2.83 [1 + 0.5 \sin (3.14 \times 10^3 t)] \sin (9.42 \times 10^6 t)$

Amplitude Modulation

EXAMPLE 3.3

Find the modulation index if a 10V carrier is amplitude modulated by three different frequencies with amplitudes of 1V, 2V, and 3V, respectively.

Solution

$M_1 = \frac{1}{10} = 0.1$ $M_2 = \frac{2}{10} = 0.2$ $M_2 = \frac{3}{10} = 0.3$

$M_1 = \sqrt{m_1^2 + m_2^2 + m_3^2}$

$= \sqrt{0.1^2 + 0.2^2 + 0.3^2}$

$= 0.374$

EXAMPLE 3.6

CB radio channels are 10kHz apart. What is the maximum modulation frequency that can be used if a signal is to remain entirely within its assigned channel?

Solution

$$B = 2F_m$$

Or

$$F_m = \frac{B}{2}$$

$$= \frac{10 \text{ kHz}}{2}$$

$$= 5 \text{ kHz}$$

Amplitude Modulation

EXAMPLE 3.7

An AM broadcast transmitter has a carrier power output of 50kW. What total power would be produced with 80% modulation?

Solution

$$P_t = P_c\left(1 + \frac{m^2}{2}\right)$$

$$= (50\text{kW})\left(1 + \frac{0.8^2}{2}\right)$$

$$= 66\text{kW}$$

EXAMPLE 3.10

An transmitter generates an LSB signal with a carrier frequency of 8 MHz. What frequency will appear at the output with a two tone modulating signal with frequencies of 2 kHz and 3.5 kHz?

Solution

8 MHz – 2 KHz = 7.998 MHz

And

8 MHz – 3.5 kHz = 7.9965 MHz

Angle Modulation

EXAMPLE 4.1

An FM modulator has k_f = 30 kHz/V and operates at a carrier frequency of 175 MHz. Find the output frequency for an instantaneous value of the modulating signal equal to:

(a) 150 mV (b) -2V

Solution

(a) $f_{sig} = (175 \times 10^6 \text{ Hz}) + (30 \times 10^3 \text{ Hz/V})(150 \times 10^{-3} \text{ V})$

$= 175.0045 \times 10^6 \text{ Hz}$

$= 175.0045 \text{ MHZ}$

(b) $f_{sig} = (175 \times 10^6 \text{ Hz}) + (30 \times 10^3 \text{ Hz/V})(-2\text{V})$

$= (175 \times 10^6 \text{ Hz}) - (30 \times 10^3 \text{ Hz/V})(2\text{V})$

$= 174.94 \times 10^6 \text{ Hz}$

$= 174.94 \text{ MHZ}$

EXAMPLE 4.2

The same Fm modulator as in the previous example is modulated by a 3V sine wave.Calculate the deviation.

Solution

$E_m = 3\sqrt{2}V$

$= 4.24\ V$

$\delta = k_f E_m$

$= 30\ kHz/V \times 4.24\ V$

$= 127.2\ kHz$

Angle Modulation

EXAMPLE 4.3

An FM broadcast transmitter operates at its maximum deviation of 75kHz. Find the modulation index for sinusoidal modulating signal with a frequency of:

(a) 15 kHz (b) 50 kHz

Solution

(a)

$$m_f = \frac{\delta}{f_m}$$

$$= \frac{75\ kHz}{15\ kHz}$$

$= 5.00$

(b)

$$m_f = \frac{\delta}{f_m}$$

$$= \frac{75 \text{ X } 10^3 \text{ kHz}}{50 \text{ kHz}}$$

$$= 1500$$

Angle Modulation

EXAMPLE 4.4

A phase modulator has k_p = 2 rad/V. what RMS voltage of a sine wave would cause a peak phase deviation of 60^o?

Solution

$$360^o = 2\pi \text{ rad}$$

$$60^o = \frac{2\pi \text{ rad X } 60}{360^o}$$

$$= \frac{\pi}{3} \text{ rad}$$

$$k_p = \frac{\varphi}{\ell_m}$$

$$\ell_m = \frac{\varphi}{k_p}$$

$$= \frac{(\pi/3)\ \text{rad}}{2\ \text{rad/V}}$$

$$= \frac{\pi}{6}\ \text{V}$$

$$= 0.524\ \text{V}$$

$$V_{RMS} = \frac{V_{peak}}{\sqrt{2}\text{V}}$$

$$= \frac{0.524}{\sqrt{2}\text{V}}$$

$$= 0.37\ \text{V}$$

Angle Modulation

EXAMPLE 4.5

An FM communication transmitter has maximum frequency deviation of 5 kHz and range of modulating frequencies from 300 Hz to 3 kHz. What is the maximum phase shift that it produces?

Solution

$$m_f = \frac{\delta}{f_m}$$

$$\varphi = m_f$$

$$= \frac{\delta}{f_m}$$

$$= \frac{5000}{300}$$

$= 16.7$ rad

EXAMPLE 4.6

A phase modulator has a sensitivity of $k_p = 3$ rad / V. How much frequency deviation does it produce with a sine – wave input of 2V peak at frequency of 1kHz?

Solution

$$\varphi = k_p E_m \sin \omega_m t$$

$$m_p = \varphi_{max}$$
$$= k_p E_m$$
$$= 3 \text{ rad/V} \times 2\text{V}$$
$$= 6 \text{ rad}$$

$$m_f = \frac{\delta}{f_m}$$

$$\delta = m_f f_m$$
$$= 6 \times 1 \text{ kHz}$$
$$= 6 \text{ kHz}$$

Angle Modulation

EXAMPLE 4.9

An FM signal has frequency deviation of 5 kHz and a modulating frequency of 1 kHz. The signal – to – noise ratio at the input to the receiver detector is 20dB. Calculate the approximate signal – to noise ratio at the detector output.

Solution

$$E_S/E_N = \log^{-1} \frac{(S/N)(dB)}{20}$$

$$= \log^{-1} \frac{20}{20}$$

$$= 10$$

$$E_N/E_s = 1/10$$
$$= 0.1$$

$$\varphi \approx E_N/E_s$$
$$= 0.1 \text{ rad}$$

$$m_{fN} = 0.1$$

$\delta_N = m_f f_m$
$= 0.1 \times 1$ kHz
$= 100$ Hz

$(E_S/E_N)_0 = \delta_s/\delta_N$
$= 5$ kHz / 100 Hz
$= 50$

$(S/N)_0$ (dB) = 20 log 50
= 34dB

Transmitters

EXAMPLE 5.1

A crystal oscillator is accurate within 0.0005%. How far off frequency could its output be at 27 MHz?

Solution

$$27 \times 106 \text{ Hz} \times \frac{0.0005}{100} = 135 \text{ Hz}$$

EXAMPLE 5.2

A transmitter has a carrier power of 10 W at an efficiency of 70 %. How much power must be supplied by the modulating amplifier for 100 % modulation?

Solution

$$\eta = \frac{P_0}{P_s}$$

$$P_s = \frac{P_0}{\quad}$$

$$\eta$$

$$= \frac{10}{0.7}$$

$$= 14.3 \text{ W}$$

$$Pa = 0.5\, P_s$$
$$= 7.14 \text{ W}$$

Transmitters

EXAMPLE 5.3

A transmitter operates from 12 V supply, with a collector current of 2A. The modulation transformer has a turns ratio of 4 : 1. What is the load impedance seen by audio amplifier?

Solution

$$Za = \frac{Vcc}{I_c}$$

$$= \frac{12 \text{ V}}{2 \text{ A}}$$

$$= 6\ \Omega$$

$$Z_p = Za\left(\frac{N_1}{N_2}\right)^2$$

$$= (6\ \Omega)(4^2)$$

$$= 96\ \Omega$$

EXAMPLE 5.4

A collector-modulated Class C amplifier has a carrier output power P_c of 100 W and an efficiency of 70%. Calculate the supply power and the transistor power dissipation with 100% modulation

Solution

$$P_O = 1.5\ P_c$$
$$= 1.5 \times 100\ W$$
$$= 150\ W$$

$$P_s = \frac{P_O}{\eta}$$

$$= \frac{150\ W}{0.7}$$

$$= 214\ W$$

$$P_D = P_S - P_O$$
$$= 214\ W - 150\ W$$
$$= 64\ W$$

EXAMPLE 5.5

An AM transmitter is required to produce 10 W of carrier power when operating from a 15 V supply. What is the required load impedance as seen from the collector?

Solution

$$R_L = \frac{V^2cc}{2P_c}$$

$$= \frac{15^2}{2 \times 10}$$

$$= 11.25\ \Omega$$

EXAMPLE 5.21

A PLL FM generator has the block diagram shown in Figure 5.25, with f_{ref} = 100kHz, N= 200, and k_f = 50 kHz/V.

(a) Calculate the carrier frequency of the output signal
(b) What RMS modulating voltage will be required for a deviation of 10 kHz at the carrier frequency?

(a) $f_c = Nf_{ref}$ V_p

$= 200 \times 100$ kHz

$= 20$ MHz

(b) $k_f = \frac{\delta}{V_p}$

$V_p = \frac{\Delta}{k_f}$

$= \frac{10 \text{ kHz}}{50 \text{ kHz/V}}$

$= 0.2$ V

$V_{RMS} = \frac{}{\sqrt{2}}$

$= \frac{0.2 \text{ V}}{\sqrt{2}}$

$= 0.141$ V

$= 141$ mV

Receivers

EXAMPLE 6.1

A tuned circuit tunes the AM radio broadcast band (from 540 to 1700 kHz). If its bandwidth is 10 kHz at 540 kHz, what is it at 1700 kHz?

Solution

$B = 10 \text{ kHz} \times \sqrt{\frac{1700}{540}}$

$= 17.7$ kHz

EXAMPLE 6.4

A receiver has a sensitivity of 0.5 µV and a blocking dynamic range of 70 dB. What is the strongest signal that can be present along with a 0.5 µV signal without blocking taking place?

Solution

$\frac{P_1}{P_2}(\text{dB}) = 20 \log \frac{V_1}{V_2}$

$\frac{P_1}{}(\text{dB}) = 70$

P_2

$$\frac{V_1}{V_2} = \text{antilog}\ \frac{P_1/P_2\ (\text{dB})}{20}$$

$$V_1 = V_2\ \text{antilog}\ \frac{P1/P2\ (\text{dB})}{20}$$

$$= (0.5\ \mu V)\ \text{antilog}\ \frac{70}{20}$$

$$= 1581\ \mu V$$

$$= 1.58\ mV$$

Receiver

EXAMPLE 6.5

The receiver in figure 6.5 is tuned to a station at 590 kHz.

(a) Find the image frequency

(b) Calculate the image rejection in decibels, assuming that the input filter consists of one tuned circuit with a Q of 40.

Solution

(a) $F_{image} = f_{sig} + 2f_{IF}$

$= 590\ kHz + 2(455\ kHz)$

$= 1500\ kHz$

(b)

$$X = \frac{f_{image}}{f_{sig}} - \frac{f_{sig}}{f_{image}}$$

$$= \frac{1500\ kHz}{590\ kHz} - \frac{590\ kHz}{1500\ kHz}$$

$$= 2.149$$

A_{sig}

$$\frac{}{A_{image}} = \sqrt{1 + Q^2 X^2}$$

$$= \sqrt{1 + 40^2 X 2.149^2}$$

$= 85.97$

IR (dB) $= 20 \log 85.97$

$= 38.7$ dB

Receiver

EXAMPLE 6.7

An FM detector produces a peak – to – peak output voltage of 1.2 V from an fm signal that is modulated to 10 kHz deviation by sine wave. What is the detector sensitivity?

Solution

$$V_0 \text{ peak} = \frac{V_0 \text{ peak – to – peak}}{2}$$

$$= \frac{1.2 \text{ V}}{2}$$

$= 0.6$ V

$$k_d = \frac{0.6 \text{ V}}{10 \text{ kHz}}$$

$= 60$ µV/Hz

EXAMPLE 6.8

A PLL FM detector uses a VCO with kf= 100 kHz/V. If it receives an FM signal with a deviation of 75 kHz and sine – wave modulation, what is the RMS output voltage from the detector?

Solution

$$V_o \text{ peak} = \frac{\delta}{k_f}$$

$$= \frac{75 \text{ kHz}}{100 \text{ kHz/V}}$$

$$= 0.75 \text{ V}$$

$$V_o \text{ RMS} = \frac{V_o \text{ peak}}{\sqrt{2}}$$

$$= \frac{0.75 \text{ V}}{\sqrt{2}} = 0.53 \text{ V}$$

Receiver

EXAMPLE 6.9

An IF transformer operates at 455 kHz. The primary circuit has a Q of 40 and the secondary has a Q of 30. Find

(a) The critical coupling
(b) The optimum coupling factor
(c) The bandwidth using the optimum coupling factor

Solution

(a)
$$k_c = \frac{1}{\sqrt{Q_p Q_s}}$$

$$= \frac{1}{\sqrt{40 \times 30}}$$

$$= 0.0289$$

(b) $k_{opt} = 1.5\ k_c$

$= 1.5 \times 0.0289$

$= 0.0433$

(c) $B = kf_0$

$= 0.0433 \times 455$ kHz

$= 19.7$ kHz

Receiver

EXAMPLE 6.11

An S-meter of the type described above reads S-6. Calculate the signal strength at the receiver input.

Solution

$$dB = 20 \log \frac{V1}{V2}$$

$V1 = 50\ \mu V$

$$\frac{V1}{V2} = \text{antilog} \frac{dB}{20}$$

$$V2 = \frac{V1}{\text{Antilog } (dB/20)}$$

$$= \frac{50\ \mu}{\text{Antilog } (18/20)}$$

$= 6.29\ \mu V$

Digital Communications

Example 7.1

A telephone line has a bandwidth of 3.2 kHz and a signal – to – noise ratio of 35 dB. A signal is transmitted down this line using a four – level code. What is the maximum theoretical date rate?

Solution

$C = 2B \log_2 M$

$= 2\ (3.2 \times 10^3) \times \log_2 4$

$= 12.8 \times 10^3$ b/s

$= 12.8$ kb/s

S/N = antilog10 (35/10)

= 3162

$C = B\ og_2\ (1 + S/N)$

$= (3.2 \times 10^3) \log_2 (1 + 3162)$

= 37.2 kb/s

EXAMPLE 7.2

An attempt is made to transmit a baseband frequency of 30 kHz using a digital audio system with a sampling rate of 44.1 kHz. What audible frequency would result?

Solution

$$fa = fs - fm$$
$$= 44.1 \text{ kHz} - 30 \text{ kHz}$$
$$= 14.1 \text{ kHz}$$

EXAMPLE 7.3

Calculate the number of levels if the number of bits per sample is?

(a) 8 (as in telephony)
(b) 16 (as in compact disc audio systems)

Solution

(a) $N = 2^m$
$= 2^8$
$= 256$

(b) $N = 2^m$
$= 2^{16}$
$= 65{,}536$

Digital Communications

EXAMPLE 7.4

Find the maximum dynamic range for a linear PCM system using 16 – bit quantizing.

Solution

$$DR = 1.76 + 6.02m \text{ dB}$$
$$= 1.76 + 6.02 \times 16$$
$$= 98.08 \text{ dB}$$

EXAMPLE 7.5

Calculate the minimum data rate needed to transmit audio with sampling rate of 40 kHz and 14 bits per sample

Solution

$$D = f_s m$$
$$= 40 \times 10^3 \times 14$$
$$= 560 \times 10^3 \text{ b/s}$$
$$= 560 \text{ kb/s}$$

EXAMPLE 7.6

A signal at the input to a mu – law compressor is positive, with its voltage one – half the maximum value. What proportion of the maximum output voltage is produced?

Solution

$$v_0 = \frac{V_0 \ln(1 + \mu v_i/V_i)}{\ln(1 + \mu)}$$

$$= \frac{V_0 \ln(1+255X0.5)}{\ln(1 + 255)}$$

$$= 0.876\ V_0$$

The Telephone System

EXAMPLE 8.1

A local loop has a resistance of 1 kΩ, and the telephone connected to it has an off – hook resistance of 200 Ω. Calculate the loop current and the voltage across the telephone when the phone is:

(a) On hook
(b) Off hook

Solution

RT = 1000 Ω + 200 Ω = 1200 Ω

I = 48 V/ 1200 Ω = 40 mA

V = IR = 40 mA X 200 Ω = 8 V

EXAMPLE 8.3

A telephone signal takes 2 ms to reach its destination. Calculate the via net loss required for an acceptable amount of echo

Solution

$$VNL = 0.2t + 0.4 \text{ dB}$$
$$= 0.2 \times 2 + 0.4 \text{ dB}$$
$$= 0.8 \text{ dB}$$

EXAMPLE 8.5

Find the (suppressed) carrier frequency for channel 5 of a group.

Solution

$$F_c = 64 \text{ kHz} + 4 (12 - 5) \text{ kHz} = 92 \text{ kHz}$$

EXAMPLE 8.6

A 2kHz tone is present on channel 5 group 3 of a supergroup. At what frequency does the tone appear in the supergroup output?

Solution

$$F_g = 92 \text{ kHz} - 2 \text{ kHz} = 90 \text{ kHz}$$

$$F_{sg} = 516 \text{ kHz} - 90 \text{ kHz} = 426 \text{ kHz}$$

Data Transmission

EXAMPLE 9.2

Calculate the maximum efficiency of an asynchronous communication system using ASCII with seven data bits, one start bit, one stop bit, and one parity bit.

Solution

$$\eta = N_D / N_T$$
$$= 7 / 10$$
$$= 0.7 \text{ or } 70 \%$$

EXAMPLE 9.4

Generate the vertical and longitudinal redundancy checks, using odd parity, for the block

STX L R C ETB

Solution

Bits		STX	L	R	C	ETB
(MSB)	7	0	1	1	1	0
	6	0	0	0	0	0
	5	0	0	0	0	1

4	0	1	0	0	0
3	0	1	0	0	1
2	1	0	1	1	1
1	0	0	0	1	1

Bit	STX	L	R	C	ETB
7	0	1	1	1	0
6	0	0	0	0	0
5	0	0	1	0	1
4	0	1	0	0	0
3	0	1	0	1	1
2	1	0	1	1	1
1	0	0	0	1	1
VRC	0	0	0	0	1

Bit	STX	L	R	C	ETB	LRC
7	0	1	1	1	0	0
6	0	0	0	0	0	1
5	0	0	1	0	1	1
4	0	1	0	0	0	0
3	0	1	0	0	1	1
2	1	0	1	1	1	1
1	0	0	0	1	1	1
VRC	0	0	0	0	1	0

Data Transmission

EXAMPLE 9.5

The following block contains exactly one error. Find the error and decode the block. Odd parity is used.

0	1	1	1	1	0	1
0	0	1	1	1	0	0
0	0	0	0	0	1	1
0	0	0	0	0	0	1
0	0	0	1	1	1	0
1	1	0	0	0	1	0
0	0	1	1	0	1	0
0	1	0	0	0	1	1

Solution

0	1	1	1	1	0	1
0	0	1	1	1	0	0
0	0	0	0	0	1	1 – Error in this row
0	0	0	0	0	0	1
0	0	0	1	1	1	0

1	1	0	0	0	1	0
0	0	1	1	0	1	0
0	1	0	0	0	1	1
		|				

Error in
this column

0	1	1	1	1	0	1
0	0	1	1	1	0	0
0	0	0	1	0	1	1
0	0	0	0	0	0	1
0	0	0	1	1	1	0
1	1	0	0	0	1	0
0	0	1	1	0	1	0
0	1	0	0	0	1	1

0	1	1	1	1	0
0	0	1	1	1	0
0	0	0	1	0	1
0	0	0	0	0	0
0	0	0	1	1	1
1	1	0	0	0	1
0	0	1	1	0	1
S	B	a	u	d	E
T					T
X					B

Data Transmission

EXAMPLE 9.6

How many hamming bits are required for a block length of 21 message bits

Solution

$2^n \geq m + n + 1$

$2^5 \geq 21 + 5 + 1$

$32 \geq 27$

$2^n \geq m + n + 1$

$24 \geq 21 + 4 + 1$

$16 \geq 26$

Digital Modulation and Modern

EXAMPLE 12.1

A radio channel has a bandwidth of 10 kHz and a single – to – noise ratio of 15dB. What is the maximum data rate that can be transmitted?

(a) Using any system?
(b) Using a code with four possible state?

Solution

(a)

$$\frac{S}{N} = \log^{-1}\left(\frac{15}{10}\right)$$

$C = B \log_2 (1 + S/N)$
$= 10 \times 10^3 \log_2 (1+31.6)$
$= 10 \times 10^3 \times 5.03$
$= 50.3$ kb/s

$C = 2B \log_2 M$
$= 2 \times 10 \times 10^3 \times 2$
$= 40$ kb/s

Digital Modulation and Modern

EXAMPLE 12.2

A modulator transmits symbols, each of which has sixty – four different possible states, 10,000 times per second. Calculate the baud rate bit rate

Solution

$C = S\log_2 M$
$= 10 \times 10^3 \times \log_2 64$
$= 60$ kb/s

EXAMPLE 12.3

The GSM cellular radio system uses GMSK in a 200 – kHz channel, with a channel data rate of 270.833 kb/s Calculate:

(a) The frequency shift between mark and space
(b) The transmitted frequencies if the carrier (center) frequency is exactly 880 MHz

Solution

(a)

$f_m - f_s = 0.5f_b = 0.5 \times 270.833$ kHz $= 135.4165$ kHz

(b)

f_{max} = f_c + $0.25f_b$ = 880 MHz - 0.25 X 270.833 kHz = 880.0677 kHz

f_{max} = f_c - $0.25f_b$ = 880 MHz - 0.25 X 270.833 kHz = 879.9329 kHz

EXAMPLE 12.6

A typical dial – up telephone connection has a bandwidth of 3 kHz and a signal – to – noise ratio of 30 dB. Calculate the Shannon limit.

Solution

$$S/N = \text{antilog}\ (30/10) = 1000$$

$$\begin{aligned} C &= B \log_2 (1 + S/N) \\ &= 3 \times 10^3 \times \log_2 1001 \\ &= 29.9 \text{ kb/s} \end{aligned}$$

Multiplexing and Multiple – Access Techniques

Example 13.1

How many of each of the following signals would fit into a 1 MHz spectrum allocation?

(a) Voice, with a maximum frequency of 4kHz, modulated using SSBSC AM.
(b) The same voice signal using DSB full – carrier AM.
(c) High – fidelity music with a maximum baseband frequency of 15 kHz, using wideband FM with a maximum deviation of 75 kHz.
(d) A bit stream at 56 kb/s, using QPSK modulation and assuming a noise – less channel.

Solution

(a)
$$N = \frac{1\text{MHz}}{4 \text{ kHz}} = 250$$

(b)
$$N = \frac{1\text{MHz}}{8 \text{ kHz}} = 125$$

(c) $B = 2 (\delta_{max} + f_{mmax}$ = 2(75 kHz + 15 kHz) = 180 kHz

$$N = \frac{1\text{ MHz}}{180\text{ kHz}} \quad 5$$

(d) $C = 2B \log_2 M$

$$B = \frac{C}{2 \log_2 M}$$

$$= \frac{56\text{ kHz}}{2 \log_2 4}$$

$$= 14\text{ kHz}$$

$$N = \frac{1\text{ MHz}}{14\text{ kHz}} = 71$$

Multiplexing and Multiple – Access Techniques

Example 13.2

A voice transmission occupies a channel 30 kHz wide. Suppose a spread – spectrum system is used to increase its bandwidth to 10 MHz. If the signal has a total signal power of – 110 dBm at the receiver input and the system noise temperature referred to the same point is 300 K, calculate the signal – to – noise ratio for both systems.

Solution

$P_N(30\text{ kHz}) = 1.38 \times 10^{-23}$ J/K X 300 K X 30 X 103 Hz

$= 124 \times 10^{-18}$ W

= -129 dBm

S/N = -110 dBm – (- 129 dBm) = 19 dB

S/N = - 110 dBm – (- 104 dBm) = - 6 dB

EXAMPLE 13.3

A Frequency – hopping spread – spectrum system hops to each of 100 frequencies every 10 seconds. How long does it spend on each frequency?

Solution

t = 10 seconds / 100 hops
= 0.1 second per hop

EXAMPLE 13.4

A digital communication scheme uses DQPSK to transmit a compressed PCM audio signal which has a bit rate of 16 kb/s. the chipping rate is 10 to 1. Calculate the number of signal changes (symbols) which must be transmitted each second.

Solution

160 / 2 = 80 kilobaud

Multiplexing and Multiple – Access Techniques

Example 13.5

A signal would have a bandwidth of 200 kHz and a signal – to – noise ratio of 20 dB if transmitted without spreading. It is spread using a chipping rate of 50:1. Calculate its bandwidth and a signal – to – noise ratio after spreading.

Solution

$$G_P = \frac{B_{RF}}{B_{BB}}$$

BRF = GPBBB
= 50 X 200 kHz
= 10 MHz

G_P(dB)= 10 log G_P
= 10 log 50
= 17 dB

$$G_P\ (dB) = (S/N)_i(dB) - (S/N)_o\ (dB)$$

$$(S/N)_o(dB) = (S/N)_i(dB) - G_p\ (dB)$$

$$= 20\ dB - 17\ dB$$

$$= 3\ dB$$

Transmission Lines

EXAMPLE 14.1

A coaxial cable has capacitance of 90 pF/m and a characteristics impedance of 50 Ω. Find the inductance of 1m length.

Solution

$$Z_0 = \sqrt{\frac{L}{C}}$$

$$Z_0^2 = \frac{L}{C}$$

$$L = Z_0^2 C$$

$$= 50^2 \times 90 \times 10^{-12}\ H/m$$

$$= 225\ nH/m$$

EXAMPLE 14.2

Find the characteristic impedance of each of the following lines:

(a) An open – wire line with conductors 3 mm in diameter separated by 10 mm
(b) A coaxial cable using a solid polyethylene dielectric having ϵ_r = 2.3, with a inner conductor 2 mm in diameter and an outer conductor 8 mm in inside diameter

Solution

(a) $Z0 \approx 276 \log D / r$

$= 276 \log 10 \text{ mm} / 1.5 \text{ mm}$

$= 227\ \Omega$

(b)

$$Z0 = \frac{138}{\sqrt{\epsilon_r}} \log \frac{D}{d}$$

$$= \frac{138}{\sqrt{2.3}} \log \frac{8}{2}$$

$= 54.8\ \Omega$

Transmission Lines

EXAMPLE 14.3

Find the velocity factor and propagation velocity for a cable with a Teflon dielectric (ϵ_r = 2.1).

Solution

$$V_f = \frac{1}{\sqrt{\epsilon_r}}$$

$$= \frac{1}{\sqrt{2.1}}$$

$= 0.69$

$$V_f = \frac{V_p}{c}$$

$V_p = V_f\, c$

$= 0.69 \times 300 \times 10^6$ m/s

EXAMPLE 14.5

What length of standard RG – 8/U coaxial cable would be required to obtain a 45 phase shift at 200 MHz?

Solution

$v_p = v_f c$

$= 0.66 \times 300 \times 10^6$ m/s

$= 198 \times 10^6$ m/s

$v_p = f\lambda$

$$\lambda = \frac{v_p}{f}$$

$$= \frac{198 \times 10^6 \text{ m/s}}{200 \times 10^6 \text{ Hz}}$$

$= 0.99$ m

$L = 0.99 \text{ m} \times 45^o / 360^o$

$= 0.124$ m

Transmission Lines

EXAMPLE 14.3

A 50 Ω line is terminated in a 25Ω resistance. Find the SWR.

Solution

$$SWR = \frac{Z_0}{Z_L}$$

$$= \frac{50}{25}$$

$= 2$

EXAMPLE 14.7

A generator sends 50mW down a 50Ω line. The generator is matched to the line, but the load in not. If the coefficient of reflection is 0.5, how much power is reflected and how is dissipated in the load?

Solution

$P_r = T^2 P_i$

$= 0.5^2 \times 50$ mW

$= 12.5$ mW

$P_L = P_i - P_r$

$= 50$ mW – 12.5 mW

$= 37.5$ mW

$P_L = P_i\,(1 - T^2)$

$= 50$ mW X $(1 - 0.5^2)$

$= 37.5$ mW

EXAMPLE 14.8

A transmitter supplies 50 W to a load through a line with an SWR of 2:1. Find the power absorbed by the load.

Solution

$$P_L = \frac{4SWR}{(1 + SWR)^2} P_i$$

$$= \frac{4 \times 2}{(1 + 2)^2} \times 50 \text{ W}$$

$$= 44.4 \text{ W}$$

Transmission Lines

EXAMPLE 14.9

Calculate the impedance looking into a 50 Ω line 1m long, terminated in load impedance of 100 Ω, if the line has a velocity factor of 0.8 and operates at a frequency of 30 MHz

Solution

$$\lambda = \frac{V}{f}$$

$$= \frac{v_f c}{f}$$

$$= \frac{0.8 \times 300 \times 10^6 \text{ m/s}}{30 \times 10^6 \text{ Hz}}$$

$$= 8 \text{ m}$$

1m

$$\theta = \frac{}{8\text{ m}} \times 360^\circ$$

$$= 45^\circ$$

$$Z = Z_0 \frac{Z_L + jZ_0 \tan\theta}{Z_0 + jZ_L \tan\theta}$$

$$= 50\ \Omega \frac{100\ \Omega + j(50\ \Omega) \tan 45^\circ}{50\ \Omega + j(100\ \Omega) \tan 45^\circ}$$

$$= 50\ \Omega \frac{100\ \Omega + j(50\ \Omega)}{50\ \Omega + j(100\ \Omega)}$$

$$= \frac{100\ \Omega + j(50\ \Omega)}{1 + j2}$$

$$= \frac{[100\ \Omega] + j(50\ \Omega)](1 - j2)}{(1 + j2)(1 - j2)}$$

$$= \frac{100\ \Omega + j(50\ \Omega) - j(200\ \Omega) + 100\ \Omega}{1 + 4}$$

$$= \frac{200\ \Omega - j(150\ \Omega)}{5}$$

$$= 40\ \Omega - j(30\ \Omega)$$

EXAMPLE 14.10

A series tuned circuit operating at a frequency of 1 GHz is to be constructed from a shorted section of air – dielectric coaxial cable. What length should be used?

Solution

$$v_p = v_f c$$

$$= 0.95 \times 300 \times 10^6 \text{ m/s}$$

$$= 285 \times 10^6 \text{ m/s}$$

$$v_p = f\lambda$$

v_p

$$f\lambda = \frac{}{f}$$

$$= \frac{285 \times 10^6 \text{ m/s}}{1000 \times 10^6 \text{ Hz}}$$

$$= 0.285 \text{ m}$$

$$L = \frac{\lambda}{2}$$

$$= \frac{0.285 \text{ m}}{2}$$

$$= 0.143 \text{ m}$$

Transmission Lines

EXAMPLE 14.11

A transmitter is required to deliver 100W to an antenna through 45 m coaxial cable with a loss of 4 dB/100 m. What must be the output power of the transmitter, assuming the line is matched?

Solution

$$\text{loss (dB)} = 45 \text{ m} \times \frac{4\text{dB}}{100 \text{ m}}$$

$$= 1.8 \text{ dB}$$

$$\frac{P_{in}}{P_{out}} = \text{antilog} \frac{1.8}{10}$$

$$= 1.51$$

$$P_{in} = 1.51 \times 100 \text{ W}$$

$$= 151 \text{ W}$$

EXAMPLE 14.12

Normalize and plot impedance of 100 + j25Ω on 50-Ω line.

Solution

$$z = \frac{Z}{Z_0}$$

$$= \frac{100 + j25\ \Omega}{25\ \Omega}$$

$$= 2 + j0.5$$

EXAMPLE 14.18

A TDR display shows a discontinuity 1.4 μs from the start. If the line has a velocity factor of 0.8, how far is the fault from the reflectometer?

Solution

$$d = \frac{v_p t}{2} = \frac{0.8(300 \text{ X } 106 \text{ m/s})(1.4 \text{ X } 10\text{-}6 \text{ s})}{2}$$

$$= \frac{v_f ct}{2} = 168 \text{ m}$$

Transmission Lines

EXAMPLE 14.19

Two adjacent minima on a slotted line are 23 cm apart. Find the wavelength and the frequency, assuming a velocity factor.

Solution

$$\lambda = 2 \text{ X } 23 \text{ cm}$$

$$= 46 \text{ cm}$$

$$vp = f\lambda$$

$$f = \frac{vp}{\lambda}$$

$$= \frac{vfc}{\lambda}$$

$0.95 \text{ X } 300 \text{ X } 10^6$ m/s

$$= \frac{}{0.46\ m}$$

$= 620 \times 10^6$ Hz

= 620 MHz

EXAMPLE 14.20

The forward power in a transmission line is 150W, and the reverse power is 20W. Calculate the SWR on the line.

Solution

$$\sqrt{\frac{Pr}{Pi}} = \sqrt{\frac{20W}{150W}}$$

$= 0.365$

$$SWR = \frac{1 + 0.365}{1 - 0.365}$$

$= 2.15$

Radio – Wave Propagation

EXAMPLE 15.1

Find the characteristic impedance of polyethylene, which has a dielectric constant of 2.3

Solution

$$L = \frac{377}{\sqrt{\epsilon_r}}$$

$$= \frac{377}{\sqrt{2.3}}$$

$= 249\ \Omega$

EXAMPLE 15.2

The dielectric strength of air is about 3MV/m. Arcing is likely to take place at field strengths greater than that. What is the maximum power density of an electromagnetic wave in air?

Solution

$$P_D = \frac{E}{L}$$

$$= \frac{(3 \times 10^6)^2}{377}$$

$= 23.9\ GW/m^2$

EXAMPLE 15.3

A power of 100 W is supplied to an isotropic radiator. What is the power density at a point 10km away?

Solution

$$P_D = \frac{P_t}{4\pi r^2}$$

$$= \frac{100\ W}{4\pi\ (10 \times 10^3\ m)^2}$$

$= 79.6\ nW/m^2$

Radio – Wave Propagation

EXAMPLE 15.4

Find the electric field strength for the signal in the previous example

Solution

$$E = \frac{\sqrt{30Pt}}{r}$$

$$= \frac{\sqrt{30 \times 100}}{10 \times 10^3}$$

$= 5.48\ mV/m$

EXAMPLE 15.5

A transmitter has a power output of 150 W at a carrier frequency of 325 MHz. it is connected to an antenna with a gain of 12 dBi. The receiving is 10 km away and has a gain of 5 dBi. Calculate the power delivered to the receiver, assuming free – space propagation. Assume also that there are no losses or mismatches in the system.

Solution

$$L_{fs} = 32.44 + [20 \log d\ (km)] + [20 \log f\ (MHz)] - [G_T (dBi)] - [G_R (dBi)]$$
$$= 32.44 + 20\log 10 + 20\log 325 - 12 - 5$$
$$= 85.7\ dB$$

$$10 \log \frac{P_T}{P_R} = 85.7$$

$$\log \frac{P_T}{P_R} = \frac{85.7}{10}$$

$$\frac{P_T}{P_R} = \text{antilog} \frac{85.7}{10}$$

$$P_R = \frac{P_T}{\text{antilog}(85.7/ 10)}$$

$$= \frac{150\ W}{372 \times 10^6} = 404 \times 10^{-9}\ W \text{ or } 404\ nW$$

Radio – Wave Propagation

EXAMPLE 15.8

The critical frequency at a particular time is 11.6 MHz. What is the MUF for transmitting station if the required angle of incidence for propagation to a destination is 70^0?

Solution

$$f_m = \frac{f_c}{\cos \theta_1}$$

$$= \frac{11.6}{\text{Cos } 70^0}$$

$$= 33.9\ MHz$$

EXAMPLE 15.9

A taxi company uses a central dispatcher, with an antenna at the top of a 15m tower, to communicate with taxicabs. The taxi antennas are on the roofs of the cars, approximately 1.5 m above the ground. Calculate the maximum communication distance:

(a) Between the dispatcher and a taxi
(b) Between two taxis

Solution

(a) $d = \sqrt{17h_T} + \sqrt{17h_R}$

$= \sqrt{17 \times 15} + \sqrt{17 \times 1.5}$

$= 21.0$ km

(b) $d = \sqrt{17h_T} + \sqrt{17h_R}$

$= \sqrt{17 \times 1.5} + \sqrt{17 \times 1.5}$

$= 10.1$ km

Radio – Wave Propagation

EXAMPLE 15.10

Find the propagation loss for a signal at 800 MHz, with a transmitting antenna height of 30m, over a distance of 10 km, using:

(a) The free – space model (Equation 15.32)
(b) The mobile – propagation model (Equation 15.33)

Solution

(a) $L_{FS} = 32.44 + 20 \log d + 20 \log f$

$= 32.44 + 20 \log 10 + 20 \log 800$

$= 110.5$ dB

(b) $L_p = 68.75 + 26.16 \log f - 13.82 \log h + (44.9 - 6.55 \log h) \log d$

$= 68.75 + 26.16 \log 800 - 13.82\ 30 + (44.9 - 6.55 \log 30) \log 10$

$= 159.5$ dB

EXAMPLE 15.11

An automobile travels at 60 km/hr. Find the time between fades if the car uses:

(a) A cell phone at 800 MHz
(b) A PCS phone at 1900 MHz

Solution

$$\frac{60\ km}{hr} = \frac{60 \times 10^3\ km}{3.6 \times 10^3\ s}$$

$$= 16.7\ m/s$$

(a)

$$T = \frac{C}{2fv}$$

$$= \frac{300 \times 10^6}{2 \times 800 \times 10^6 \times 16.7}$$

$$= 11.2\ ms$$

(b)

$$T = \frac{C}{2fv}$$

$$= \frac{300 \times 10^6}{2 \times 1900 \times 10^6 \times 16.7}$$

$$= 4.7\ ms$$

Radio – Wave Propagation

EXAMPLE 15.12

A metropolitan area of 1000 square km is to be covered by cells with a radius of 2 km. how many cell sites would be required, assuming hexagonal cells?

Solution

$$N = \frac{A}{3.464r^2}$$

$$N = \frac{1000}{3.464 \times 2^2}$$

$$= 73$$

Antennas

EXAMPLE 16 .1

Calculate the length of a half – wave dipole for an operating frequency of 20 MHz.

Solution

$$L = \frac{142.5}{f}$$

$$= \frac{142.5}{20}$$

$$= 7.13 \text{ m}$$

EXAMPLE 16.2

A dipole antenna has a radiation resistance of 67Ω and a loss resistance of 5 Ω, measured at the feedpoint. Calculate the efficiency.

Solution

$$\eta = \frac{R_r}{R_T}$$

$$= \frac{67}{67 + 5}$$

$$= 0.93 \text{ or } 93 \%$$

Antennas

EXAMPLE 16 .3

Two antennas have gains of 5.3 dBi and 4.5 dBd, respectively, Which has greater gain?

Solution

$$G = 4.5 \text{ dBd}$$

$$= 4.5 + 2.14 \text{ dBi}$$

$$= 6.64 \text{ dBi}$$

EXAMPLE 16.4

A dipole antenna has an efficiency of 85%. Calculate its gain in decibels.

Solution

$$D = \log^{-1} \frac{2.14}{10}$$

$$= 1.638$$

$$G = D\eta$$

$$= 1.638 \text{ X } 0.85$$

$= 1.39$

$G(dBi) = 10 \log 1.39$
$= 1.43$ dBi

EXAMPLE 16.6

The ERP of a transmitting station is specified as 17 W in a given direction. Express this as an EIRP in dBm so that it can be used with the path loss equations in Chapter 15.

Solution

$$ERP\ (dBm) = 10 \log \frac{ERP}{1mW}$$

$$= 10 \log (17 \times 10^3)$$

$$= 42.3 \text{ dBm}$$

$$EIRP(dBm) = ERP(dBm) + 2.14 \text{ dB}$$

$$= 42.3 + 2.14$$

$$= 44.44 \text{ dBm}$$

Antennas

EXAMPLE 16 .7

A helical antenna with eight turns is to be constructed for frequency of 1.2 GHz

(a) Calculate the optimum diameter and spacing for the antenna and find the total length of the antenna
(b) Calculate the antenna gain in dBi
(c) Calculate the bandwidth.

Solution

(a)

$$\lambda = \frac{c}{f}$$

$$= \frac{300 \times 10^6}{1200 \times 10^6}$$

$$= 0.25 \text{ m}$$

$$D = \frac{\lambda}{\pi}$$

$$= \frac{0.25}{\pi}$$

= 0.08 m

= 80 m

$$S = \frac{\lambda}{4}$$

$$= \frac{0.25}{4}$$

= .0625 m

= 62.5 m

L = NS

= 8 X 62.5 mm

= 500 mm

Antennas

EXAMPLE 16 .7

(b)

$$G = \frac{15NS(\pi D)^2}{\lambda}$$

$$= \frac{15 \times 8 \times 0.0625 (\pi \times 0.08)^2}{0.25^3}$$

= 30.3

= 14.8 dBi

(c)

$$\theta = \frac{52\lambda}{} \sqrt{\frac{\lambda}{}}$$

πD NS

$$= \frac{52 \times 0.25}{\pi \times 0.08} \sqrt{\frac{0.25}{8 \times 0.0625}}$$

$= 36.6^{o}$

Antennas

EXAMPLE 16 .8

Design a log – periodic antenna to cover the frequency range from 100 to 300 MHz. Use $\tau = 0.7$ and $\alpha = 30^{o}$

Solution

$$L = \frac{142.5}{f}$$

$$L = \frac{142.5}{90}$$

$= 1.58$ m

$$L = \frac{142.5}{320}$$

$= 0.445$ m

$$L_2 = \frac{L_1}{\tau}$$

$$= \frac{0.445}{0.7}$$

$= 0.636$ m

$$L_3 = \frac{L_2}{\tau}$$

$$= \frac{0.636}{}$$

L_1 α

$$\frac{}{2D_1} = \tan\frac{}{2}$$

0.7

= 0.909 m

$$D_1 = \frac{L_1}{2 \tan \frac{\alpha}{2}}$$

$$= \frac{0.445}{2 \tan 15^{o}}$$

= 0.830 m

Microwave Devices

EXAMPLE 17 .1

Find the cutoff frequency for the TE10 mode in an air – dielectric waveguide with an inside cross section of 2cm by 4cm. Over what frequency range is the dominant mode the only one that will propagate?

Solution

$$f = \frac{c}{2a}$$

$$= \frac{300 \times 10^{6}\ m/s}{2 \times 4\ 10^{-2}\ m}$$

$= 3.75 \times 10^{9}$ Hz

= 3.75 GHz

EXAMPLE 17.2

Find the group velocity for the waveguide in Example 17.1 at a frequency of 5 GHz.

Solution

$$v_g = c\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$$

$$= (300 \times 10^6 \text{ m/s})\sqrt{1 - \left(\frac{3.75}{5}\right)^2}$$

$$= 198 \times 10^6 \text{ m/s}$$

Microwave Devices

EXAMPLE 17 .3

A waveguide has a cutoff frequency for the dominant mode of 10GHz. Two signals with frequencies of 12 and 17 GHz propagate down a 50 m length of the guide. Calculate the group velocity for each and the difference in arrival time for two.

Solution

$$v_g = c\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$$

$$= (300 \times 10^6 \text{ m/s})\sqrt{1 - \left(\frac{10}{12}\right)^2}$$

$$= 165.8 \times 10^6 \text{ m/s}$$

$$t_1 = \frac{50 \text{ m}}{165.8 \times 10^6 \text{ m/s}} = 301.6 \text{ ns}$$

50 m

$$t_2 = \frac{}{242.6 \times 10^6 \text{ m/s}} = 206.1 \text{ ns}$$

$$t_1 - t_2 = 301.6 \text{ ns} - 206.1 \text{ ns} = 95.5 \text{ ns}$$

EXAMPLE 17.4

Find the phase velocity for the waveguide used in Example 17.1 and 17.2, at a frequency of 5 GHz.

Solution

$$v_p = \frac{c}{\sqrt{1 - \left(\frac{fc}{f}\right)^2}}$$

$$v_p = \frac{300 \times 10^6 \text{ m/s}}{\sqrt{1 - \left(\frac{3.75}{5}\right)^2}}$$

$$= 4.54 \times 10^8 \text{ m/s}$$

Microwave Devices

EXAMPLE 17.5

Find the characteristic impedance of the waveguide used in the previous examples, at a frequency of 5 GHz.

Solution

$$Z_0 = \frac{377}{\sqrt{1 - \left(\frac{fc}{f}\right)^2}} \Omega$$

$$= \frac{377}{\sqrt{1 - \left(\frac{3.75}{5}\right)^2}} \Omega$$

$$= 570 \Omega$$

EXAMPLE 17.6

Find the guide wavelength for the waveguide used in the previous examples.

Solution

$$\lambda_g = \frac{v_p}{f}$$

$$= \frac{454 \text{ X } 106 \text{ m/s}}{5 \text{ X } 106 \text{ Hz}}$$

= 0.0908 m

= 9.08 cm

Microwave Devices

EXAMPLE 17.7

A signal with a level of 20 dBm enters the main waveguide of a directional coupler in the direction of the arrow. The coupler has an insertion loss of 1dB, coupling of 20 dB, and directivity of 40 dB. Find the strength of the signal emerging from each guide. Also, find the strength of the signal that would emerge from the secondary guide if the signal in the main guide were propagating in the other direction.

Solution

20 dBm – 1dB = 19 dBm

20 dBm – 20dB = 0 dBm

0 dBm – 40 dB = -40 dBm

EXAMPLE 17.8

A Gunn device has a thickness of 7 µm. At what frequency will it oscillate in the transit – time mode?

Solution

d

$$t = \frac{}{v}$$

$$= \frac{7 \times 10^{-6}\ m}{1 \times 10^{5}\ m/s}$$

$$= 7 \times 10^{-11}\ s$$

$$f = \frac{1}{T}$$

$$= \frac{1}{7 \times 10^{-11}\ s}$$

$$= 14.3 \times 109\ Hz$$

$$= 14.3\ GHz$$

Microwave Devices

EXAMPLE 17.9

A pulsed magnetron operates with an average power of 1.2kW and a peak power of 18.5 kW. One pulse is generated every 10 ms. Find the duty cycle and the length of a pulse.

Solution

$$P_{avg} = P_P D$$

$$D = \frac{P_{avg}}{P_P}$$

$$= \frac{1.2}{18.5}$$

$$= 0.065 \text{ or } 6.5\%$$

$$D = \frac{T_{on}}{T_T}$$

$T_{on} = D\ T_T$

$= 0.065 \times 10$ ms

$= 0.65$ ms

EXAMPLE 17.10

A pyramidal horn has an aperture (opening) of 58 mm in the E plane and 78 mm in the H plane. It operates at 10 GHz. Calculate:

(a) Its gain in dBi
(b) The beamwidth in the H plane
(c) The beamwidth in the E plane

Solution

(a)

$$\lambda = \frac{c}{f}$$

$$= \frac{300 \times 10^6}{10 \times 10^6}$$

$= 0.03$ m

Microwave Devices

EXAMPLE 17.10

$$G = \frac{7.5\ d_E d_H}{\lambda^2}$$

$$= \frac{300 \times 10^6}{10 \times 10^6}$$

$= 0.03$ m

(b)

$$\theta_H = \frac{70\ \lambda}{d_H}$$

$$= \frac{70 \times 0.03}{0.078}$$

$$= 26.9^0$$

(c)

$$\theta_E = \frac{56\ \lambda}{d_H}$$

$$= \frac{56 \text{ X } 0.03}{0.058}$$

$$= 29\ ^0$$

Microwave Devices

EXAMPLE 17.11

Calculate the approximate dimension for a square patch antenna for a frequency of 2 GHz, on a substrate with a relative permittivity of 2

Solution

$$v_p = \frac{c}{f\sqrt{\epsilon_r}}$$

$$v_p = \frac{300 \text{ X } 10^6}{2 \text{ X } 10^9 \sqrt{2}}$$

$$= 0.106 \text{ m}$$

EXAMPLE 17.12

A radar transmitter as a power of 10kW and operates at a frequency of 9.5 GHz. Its signal reflects from a target 15 km away with a radar cross section of 10.2 m2. The gain of the antenna is 20 dBi. Calculate the received signal power.

Solution

$$\lambda = \frac{c}{f}$$

$$v_p = \frac{300 \text{ X } 10^6}{9.5 \text{ X } 10^6}$$

$= 0.0316$ m

$$G = \text{antilog} \frac{dB}{10}$$

$$= \text{antilog} \frac{20}{10}$$

$= 100$

$$P_R = \frac{\lambda^2 P_T G^2 \sigma}{(4\pi)^3 r^4}$$

$$= \frac{0.0316^2 (10 \text{ X } 10^2)(100^2)(10.2)}{(4\pi)^3 (15 \text{ X } 10^3)^4}$$

$= 10.1 \text{ X } 10^{-15}$ W

$= 10.1$ fW

Microwave Devices

EXAMPLE 17.13

A pulse sent to target returns after 15 µs. How far away is the target?

Solution

$$R = \frac{ct}{2}$$

$$= \frac{(300 \text{ X } 10^6)(15 \text{ X } 10^{-6})}{2}$$

$= 2250$ m

$= 2.25$ km

EXAMPLE 17.14

A pulse radar emits pulses with a duration of 1µs and a repetition rate of 1 kHz. Find the maximum and minimum range for this radar.

Solution

$$R_{max} = \frac{c}{2f}$$

$$= \frac{300 \times 10^6}{2 \times 1000}$$

$= 150 \times 10^3$ m

= 150 km

$$R_{max} = \frac{cT_P}{2}$$

$$= \frac{(300 \times 10^6)(1 \times 10^{-6})}{2}$$

= 150 m

EXAMPLE 17.15

Find the Doppler shift caused by a vehicle moving toward a radar at 60 mph, if the radar operates at 10 GHz.

Solution

60 mph = 60 X 1.6 km/h

= 96 km/h

$$96 \text{ km/h} = \frac{96 \times 1000}{3600} \text{ m/s}$$

= 26.7 m/s

$$f_D = \frac{2v_r f_i}{c} \text{ m/s}$$

$$= \frac{2(26.7)(10 \times 10^9)}{300 \times 10^6}$$

= 1.778 kHz

Terrestrial Microwave Communication Systems

EXAMPLE 18.1

Suppose that the transmitter and receiver towers have equal height. How high would they have to be to communicate over a distance of 40 km?

Solution

$$d = \sqrt{17 h_T} + \sqrt{17 h_R}$$

$$d = 2\sqrt{17 h_T}$$

$$h = \frac{d^2}{68}$$

$$= \frac{40^2}{68}$$

$$= 23.5 \text{ m}$$

EXAMPLE 18.2

A line – of – sight radio link operating at a frequency of 6 GHz has a separation of 40 km between antennas. An obstacle in the path is located 10km from the transmitting antenna. By how much must be beam clear the obstacle?

Solution

$$R = 10.4 \sqrt{\frac{d_1 d_2}{f\,(d_1 + d_2)}}$$

$$R = 10.4 \sqrt{\frac{10 \times 30}{6\,(10 + 30)}}$$

$$= 11.6 \text{ m}$$

Terrestrial Microwave Communication Systems

EXAMPLE 18.3

A Transmitter and a receiver operating at 6 GHz are separated by 40 km. How much power (in dBm) is delivered to the receiver if the transmitter has an output power of 2W, the transmitting antenna has a gain of 20 dBi, and the receiving antenna has a gain of 25 dBi?

Solution

$$\frac{P_R}{P_T}(\text{dB}) = G_T(\text{dBi}) + G_R(\text{dBi}) - (32.44 + 20 \log d + 20 \log f)$$

$$= 20 + 25 - (32.44 + 20 \log 40 + 20 \log 6000)$$

$$= -95 \text{ dB}$$

$$P_T\,(\text{dBm}) = 10 \log \frac{2\text{W}}{1\text{mW}} = 33 \text{ dBm}$$

$$P_R\,(\text{dBm}) = 33 \text{ dBm} - 95 \text{ dB} = -62 \text{ dBm}$$

EXAMPLE 18.4

In a microwave system, the antenna sees a sky temperature of 120 K, and the antenna feedline has a loss of 2dB. Calculate the noise temperature of the antenna/feedline system, referenced to the receiver input.

Solution

$L = \text{antilog}\ (2/10) = 1.58$

$$T_a = \frac{(L - 1)\ 290 + T_{sky}}{L}$$

$$= \frac{(1.58 - 1)\ 290 + 120}{1.58}$$

$= 182\ K$

EXAMPLE 18.5

A receiver has a noise figure of 2dB. Calculate its equivalent noise temperatue.

Solution

$NF = \text{antilog}\ (2/10) = 1.58$

$T_{eq} = 290\ (NF - 1)$

$= 290\ (1.58 - 1)$

$= 168\ K$

Terrestrial Microwave Communication Systems

EXAMPLE 18.6

The antenna and feedline combination from example 18.4 is used with the receiver from example 18.5. Calculate the thermal noise power in dBm, referred to the receiver input, if the receiver has a bandwidth of 20 MHz.

Solution

$T_N(\text{system}) = Ta + Teq$

$= 182\ K + 168\ K$

$= 350\ K$

$P_N = kTB$

$= 1.38 \times 10^{-23}\ J/K \times 350\ K \times 20\ MHz$

$= 96.6\ fW$

$P_N(dBm) = 10 \log\ (96.6\ fW/1\ mW)$

$= -100\ dBm$

EXAMPLE 18.7

Calculate the carrier – to – noise ratio, for the signal in Example 18.3, received by the installation in Example 18.6

Solution

P_R = - 62 dBm

P_N = -100 dBm

C/N= -62 – (- 100) = 38 dB

EXAMPLE 18.8

The system in Example 18.7 operates at a bit of 40 Mb/s. Calculate the energy per bit to noise density ratio, in decibels.

Solution

P_R = antilog (-62/10) mW
= 631 pW

N_0 = kT
= 1.38 X 10^{-23} X 350
= 4.83 X 10^{-21} W/Hz

$$E_b = \frac{PR}{fb}$$

$$= \frac{631\ pW}{40\ Mb/s}$$

= 15.8 X 10^{-18} J

$$\frac{E_b}{N_0} = 10 \log \frac{15.8 \times 10^{-18}}{4.83 \times 10^{-21}} = 35.1\ dB$$

Terrestrial Microwave Communication Systems

EXAMPLE 18.9

In the receiver in Figure 18.7(b), the received carrier frequency is 6870 MHz and the IF is 70 MHz. Calculate the local oscillator frequency if the receiver uses low – side injection.

Solution

F_{LO} = 6870 MHz – 70 MHz = 6800 MHz

EXAMPLE 18.10

A microwave repeater has the block diagram shown in Figure 18.9(a). The received signal has a carrier frequency of 6870 MHz, and the transmitted signal is to have a carrier frequency of 6710 MHz. the IF is 70 MHz. What should be the frequencies of the local oscillator and the shift oscillator? To what frequency should the output of mixer #3 be tuned? Verify these results by following the signal through the repeater.

Solution

F_{so} = 6870 MHz – 6710 MHz = 160 MHz

F_{LO} = F_o – 70 MHz
= 6710 MHz – 70 MHz

$= 6640\ MHz$

6640 MHz + 160 MHz = 6800 MHz

6870 MHz – 6800 MHz = 70 MHz

$f_o = 70\ MHz + 6640\ MHz = 6710\ MHz$

Television

Example 19.1

A video signal has 50% of the maximum luminance level. Find its level in IRE units.

Solution

$IRE = 7.5 + 0.5 \times 92.5$

$= 53.75$ IRE units

EXAMPLE 19.2

Calculate the total percentage of the signal time that is occupied by:

(a) Horizontal blanking
(b) Vertical blanking
(c) Active video

Solution

(a)

$$\text{horizontal blanking (\%)} = \frac{10}{63.5} \times 100$$

= 15.7 %

(b)

$$\text{vertical blanking (\%)} = \frac{42}{252} \times 100$$

= 8.0 %

(c)

active video (%) = (100 – 15.7) X 0.92

= 77.6 %

EXAMPLE 19.3

A typical low – cost monochrome receiver has a video bandwidth of 3 MHz. What is horizontal resolution in line?

Solution

LH = B (MHz) X 80

= 3 X 40

= 240 lines

Television

Example 19.4

An RGB video signal has normalized values of R = 0.2, G = 0.4, B =0.8. Find the values of Y, I, and Q

Solution

Y = 0.30R + 0.59G + 0.11B

= (0.30 X 0.2) + (0.59 X 0.4) + (0.11 X 0.8)

= 0.384

I = 0.60R – 0.28G – 0.32B

= (0.62 X 0.2) – (0.28 X 0.4) – (0.32 X 0.8)

= - 0.248

Q = 0.21R – 0.52G + 0.31B

= (0.21 X 0.2) – (0.52 X 0.4) + (0.31 X 0.8)

= 0.082

EXAMPLE 19.5

What proportion of the maximum transmitter power is used to transmit a black setup level?

Solution

P (black setup) = 0.675^2

$= 0.456$ or 45.6%

EXAMPLE 19.6

Suppose a television receiver tuned to channel 6 radiates a local oscillator signal into the cable. What channel will be interfered with?

Solution

$f_{LO} = 83.25 + 45.75$

$= 129$ MHz

EXAMPLE 19.7

Consider a digital video signal that has a resolution of 640 by 480 pixels, with a 30 Hz frame rate and progressive scan. The luminance is sampled using 8 bits per sample. The two chroma channels also use 8 bits per sample, but the color resolution in one – fourth that used for luminance. Find the approximate bit rate for this signal, neglecting synchronization, error correction and compression.

Solution

$N_{PL} = N_V N_H$

$= 480 \text{ X } 640 = 307.2 \text{ X } 10^3$ pixels

$N_{PT} = 1.5\ N_{PL} = 460.8 \text{ X } 10^3$ pixels

$f_b = NPTmR_f$

$= 460.8 \text{ X } 10^3 \text{ X } 8 \text{ X } 30$

$= 110.6$ Mb/s

Satellite Communication

EXAMPLE 20.1

Find the velocity and the orbital period of a satellite in a circular orbit

(a) 500 km above the earth's surface

(b) 36,000 km above the earth's surface (approximately the height of geosynchronous satellite)

Solution

(a)

$$v = \sqrt{\frac{4 \text{ X } 10^{11}}{(d + 6400)}}$$

$$= \sqrt{\frac{4 \text{ X } 10^{11}}{(500 + 6400)}}$$

$= 7.6$ km/s

$r = 6400 \text{ km} + 500 \text{ km} = 6900 \text{ km}$

$$C = 2\pi r$$
$$= 2\pi \times 6900 \text{ km}$$
$$= 43.4 \text{ Mm}$$

$$T = \frac{C}{V}$$

$$= \frac{43.4 \times 10^6 \text{ m}}{7.6 \times 10^3 \text{ m/s}}$$

$$= 5.71 \times 10^3 \text{ s}$$
$$= 1.6 \text{ hours}$$

Satellite Communication

EXAMPLE 20.1

Solution

(b)

$$v = \sqrt{\frac{4 \times 10^{11}}{(d + 6400)}}$$

$$= \sqrt{\frac{4 \times 10^{11}}{(36{,}000 + 6400)}}$$

$$= 3.07 \text{ km/s}$$

$$r = 6400 \text{ km} + 36{,}000 \text{ km} = 42.4 \text{ Mm}$$

$$C = 2\pi r$$
$$= 2\pi \times 42.4 \text{ km}$$

$= 266.4 \text{ Mm}$

$$T = \frac{C}{V}$$

$$= \frac{266.4 \times 10^6 \text{ m}}{3.07 \times 10^3 \text{ m/s}}$$

$= 86.8 \times 10^3 \text{ s}$

$= 24 \text{ hours}$

Satellite Communication

EXAMPLE 20.2

Calculate the angle of declination for an antenna using a polar mount at a latitude of 45°.

Solution

$$\theta = \arctan \left(\frac{6400 \sin 45^\circ}{36 \times 10^3 + 6400 (1 - 45^\circ)} \right)$$

$= 6.81^\circ$

EXAMPLE 20.3

Calculate the length of the path to geostationary satellite from an earth station where the angle of elevation is 30°.

Solution

$$d = \sqrt{(r + h)^2 - (r\cos\theta)^2} - r \sin\theta$$

$$d = \sqrt{(6400 + 36 \times 10^3)^2} - (6400 \cos 30^o)^2 - 6400 \sin 30^o$$
$$= 39 \times 10^3 \text{ km}$$

EXAMPLE 20.4

A satellite transmitter operates at 4 GHz with a transmitter power of 7 W and an antenna gain of 40dBi. The receiver has an antenna gain of 30dBi, and the path length is 40,000 km. Calculate the signal strength at the receiver.

Solution

$$\frac{P_R}{P_T} \text{(dB)} = G_T \text{(dBi)} + G_R \text{(dBi)} - (32.44 + 20 \log d + 20 \log f)$$
$$= 40 + 30 - (32.44 + 20 \log (40 + 103) + 20 \log 4000)$$
$$= -\ 126.5 \text{ dB}$$

$$P_T\text{(dBm)} = 10 \log \frac{7 \text{ W}}{1 \text{ mW}} = -\ 88 \text{ dBm}$$

$$P_R\text{(dBm)} = 38.5 \text{ dBm} - 126.5 \text{ dB} = -88 \text{ dBm}$$

Satellite Communication

EXAMPLE 20.5

A receiving antenna with a gain of 40 dBi looks at a sky with a noise temperature of 15 K. The loss between the antenna and the LNA input, due to the feedhorn, is 0.4 dB, and the LNA has a noise temperature of 40 K. Calculate G/T.

Solution

$$G = 40 \text{ dBi} - 0.4 \text{ dB}$$
$$= 39.6 \text{ dBi}$$

$$L = \text{antilog } (0.4/10) = 1.096$$

$$Ta = \frac{(L - 1)\, 290 + T_{sky}}{L}$$

$$Ta = \frac{(1.096 - 1)\, 290 + 15}{1.096}$$
$$= 39 \text{ K}$$

$$G/T\ (dB) = G_R\ (dBi) - 10 \log (T_a + T_{eq})$$
$$= 39.6 - 10 \log (39 + 40)$$
$$= 20.6\ dB$$

EXAMPLE 20.6

A receiver has noise figure 1.5 dB. Find its equivalent noise temperature

Solution

$$NF = \text{antilog}\ (1.5/10)$$
$$= 1.41$$

$$Teq = 290\ (NF - 1)$$
$$= 290\ (1.41 - 1)$$
$$= 119\ K$$

Satellite Communication

EXAMPLE 20.7

The receiving installation whose G/T was found in Example 20.5 is used as a ground terminal to receive a signal from a satellite at a distance of 38,000 km. The satellite has a transmitter power of 50 watts and antenna gain of 30 dBi. Assume losses between the satellite transmitter and its antenna negligible. The frequency is 12 GHz. Calculate the carrier – to – noise ratio at the receiver, for a bandwidth of 1 MHz.

Solution

$$PT\ (dBW) = 10 \log 50 = 17\ dBW$$

$$EIRP\ (dBW) = 17\ dBW + 30\ dBi = 47\ dBw$$

$$FSL\ (dB) = 32.44 + 20 \log d + 20 \log f$$
$$= 32.44 + 20 \log 38{,}000 + 20 \log 12{,}000$$
$$= 205.6\ dB$$
$$C/N(dB) = EIRP(dBW) - FSL(dB) - L_{misc} + G/T - K(dBW) - 10 \log B$$
$$= 47\ dBW - 205.6\ dB + 20.6\ dB + 228.6\ dBW - 10 \log (1 \times 10^6)$$
$$= 30.6\ dB$$

EXAMPLE 20.9

A typical TVRO installation for use with C – band satellites (downlink at approximately 4 GHz) has a has a diameter of about 3 cm and an efficiency of about 55%. Calculate its gain and beamwidth.

Solution

$$\lambda = \frac{c}{f}$$

$$= \frac{300 \times 10^6 \text{ m/s}}{4 \times 10^9 \text{ HZ}}$$

$$= 7.5 \text{ cm}$$

$$\lambda = \frac{0.55\, \pi^2 \times 3^2}{0.075^2}$$

$$= 8.69 \times 10^3$$

$$= 39 \text{ dB}$$

$$\theta = \frac{70\lambda}{D}$$

$$= \frac{70 \times 0.075}{3}$$

$$= 1.75^0$$

Satellite Communication

EXAMPLE 21.1

A Vehicle travels through a cellular system at 100 kilometer per hour. Approximately how often will handoffs occur if the cell radius is:

(a) 10 km
(b) 500 m

Solution

$$v = \frac{100 \text{ km/hr} \times 1000 \text{ m/km}}{3600 \text{ s/hr}}$$

$$= 27.8 \text{ m/s}$$

$$t = \frac{d}{v}$$

$$= \frac{1 \times 10^3 \text{ m}}{}$$

$$\frac{}{27.8\ m/s}$$
$$= 36\ s$$

EXAMPLE 21.2

A cellular telephone system uses a 12 – cell repeating pattern. There are 120 cells in the system and 20,000 subscribers. Each subscriber uses the phone average 30 minutes per day, but on average 10 of those minutes are used during the peak hour.

(a) The average and peak traffic in erlangs for the whole system
(b) The average and peak traffic in erlangs for one cell, assuming callers are evenly distributed over the system
(c) The approximate average call – blocking probability
(d) The approximate call – blocking probability during the peak hour.

Solution

(a)

$$T = 20{,}000 \times \frac{0.5}{24}$$
$$= 416\ E$$

$$t = \frac{416}{120}$$
$$= 3.47\ E$$

$$T = 20{,}000 \times \frac{10}{60}$$
$$= 3333\ E$$

$$t = \frac{3333}{120}$$
$$= 27.8\ E$$

Satellite Communication

EXAMPLE 21.3

Calculate the maximum distance between base and mobile that can be accommodated with a guard time of 123µs.

Solution

$$d = ct$$
$$= 300 \times 10^{6}\ m/s \times 123 \times 10^{-6}\ s$$
$$= 36.9\ km$$

Personal Communication Systems

EXAMPLE 22.1

A CDMA mobile measures the signal strength from the base as -100 dBm. What should the mobile transmitter power be set to as a first approximation?

Solution

$$P_T = -76\ dB - PR$$

= -76 dB – (-100 dBm)
= 24 dBm
= 250 mW

Paging and Wireless Data Networking

EXAMPLE 23.1

Suppose the POCSAG system is used with simple tone pagers, which require only an address field. If all the frames are used for address, how many pages could be transmitted by this system in 1 minute if it operates at the slowest POCSAG rate of 512b/s? Assume that only one preamble is needed.

Solution

Total number of usable bits/minute = 512 X 60 – 576 = 30, 144 bits

$$\text{batches /min} = \frac{\text{bits/min}}{\text{bits/batch}}$$

$$= \frac{30,144}{544}$$

= 55,412 batches/min

Address/min = batches/min X address/batch
= 55.412 X 16
= 886

Paging and Wireless Data Networking

EXAMPLE 23.2

Calculate the efficiency, in terms of bits per second per hertz of RF bandwidth, for the FLEX system at its maximum data rate.

Solution

$$\frac{6400 \text{ b/s}}{25 \text{ kHz}} = 0.256 \text{ b/sHz}$$

EXAMPLE 23.3

Calculate the maximum and minimum hopping rate for the Bluetooth system.

Solution

$$f_h\,(\max) = \frac{1}{625\ \mu s}$$

$$= 1600\ Hz$$

$$f_h\,(\min) = \frac{1}{5 \times 625\ \mu s}$$

$$= 320\ Hz$$

Fiber Optics

EXAMPLE 24.1

A fiber has an index of refraction of 1.6 for the core and 1.4 for the cladding. Calculate:

(a) The critical angle

(b) θ_2 for $\theta_1 = 30^o$

(c) θ_2 for $\theta_1 = 70^o$

Solution

(a)

$$\theta_c = \arcsin \frac{n_2}{n_1}$$

$$= \arcsin \frac{1.4}{1.6}$$

$$= 61^o$$

(b)

$$\sin\ \theta_2 = \frac{n_1}{n_2} \sin\ \theta_1$$

$$= \frac{1.6}{1.4 \sin 30^o}$$

$= 0.571$

$\theta_2 = \arcsin 0.571$

$= 34.8^o$

EXAMPLE 24.2

Calculate the numerical aperture and the maximum angle of acceptance for the fiber described in Example 24.1

Solution

$$N.A. = \sqrt{n_1^2 - n_2^2}$$

$$= \sqrt{1.6^2 - 1.4^2}$$

$= 0.775$

$\arcsin 0.775 = 50.8^o$

Fiber Optics

EXAMPLE 24.3

A single – mode fiber has a numerical aperture of 0.15. What is the maximum core diameter it could have for use with infrared light with a wavelength of 820 nm?

Solution

$$r_{max} = \frac{0.383\lambda}{N.A.}$$

$$r_{max} = \frac{0.383 \times 820 \times 10^{-9} \text{ m}}{0.15}$$

$= 2.1 \times 10^{-6}$ m

$= 2.1$ µm

EXAMPLE 24.4

An optical fiber has a bandwidth – distance product of 500 MHz –km. if a bandwidth of 85 MHz is required for a particular mode of transmission, what is the maximum distance that can be used between repeaters?

Solution

Bandwidth X distance = 500 MHz – km

$$\text{distance} = \frac{500 \text{ MHz – km}}{\text{bandwidth}}$$

$$= \frac{500 \text{ MHz – km}}{85 \text{ MHz}}$$

= 5.88 km

Fiber Optics

EXAMPLE 24.5

The fiber whose dispersion equation is given in Equation (24.11) has zero dispersion at a wavelength of 1310 nm and has a zero – dispersion slope of 0.05 ps/(nm^2 . km). Calculate the total dispersion of 50 km of this fiber when it is used with source having a line width of 2 nm at a wavelength of 1550 nm.

Solution

$$D_c(\lambda) = \frac{S_0}{4}\left(\lambda - \frac{\lambda_0^4}{\lambda^3}\right) \text{ ps/km (nm . km)}$$

$$D_c(\lambda) = \frac{0.05}{4}\left(1550 - \frac{1310^4}{1550^3}\right)$$

= 9.49 ps/km (nm . km)

D = $D_c\Delta\lambda$

= 9.49 ps/(nm . km) X 2 nm

$= 18.98$ ps/km

$\Delta t = Dt$

$= 18.98$ ps/km

$= 949$ ps

EXAMPLE 24.6

Find the bandwidth and bandwidth – distance product for the fiber in Example 24.5

Solution

$$B = \frac{1}{2\Delta t}$$

$$B = \frac{1}{2 \times 949 \text{ ps}}$$

$= 526.8$ MHz

526.8 MHz X 50 km = 26.3 GHz – km

EXAMPLE 24.7

An optical has one input (port 1) and two outputs (port 2 and 3). Its specification are given below. Even though negative signs are not used for the coupling specifications, they are implied. Since this is a passive coupler, the output power must always be less than the input power.

Input port	Output port	Coupling dB
1	2	3
1	3	6
2	1	40
2	3	40
3	1	40
3	2	40

Find :

(a) The percentage of the input power that emerges from each of ports 2 and 3 when the input is at port 1
(b) The directivity
(c) The excess loss in decibels

Solution

(a) $\frac{P_2}{P_{in}} = \log^{-1}\left(\frac{-3}{10}\right) = .501 = 50\%$

$\frac{P_3}{P_{in}} = \log^{-1}\left(\frac{-6}{10}\right) = .251 = 25.1\%$

Fiber Optics

EXAMPLE 24.8

Find the energy, in electron – volts, in one photon at a wavelength of 1µm.

Solution

$$f = \frac{C}{\lambda}$$

$$f = \frac{3 X 10^{8} m/s}{1 X 10^{-6} m}$$

$$= 3 X 10^{14} Hz$$

$$E = hf$$

$$= (6.26 X 10^{34})(3 X 10^{14})$$

$$= 1.99 X 10^{-19} J$$

$1\ eV = 1.6 \times 10^{-19}\ J$

$$1J = \frac{1}{1.6 \times 10^{-19}}\ eV$$

$= 6.25 \times 10^{18}\ eV$

$E = (1.99 \times 10^{-19})(6.25 \times 10^{18})$

$= 1.24\ eV$

EXAMPLE 24.9

A typical photodiode of the type shown in Figure 24.25 has an input optical power of 500 nW. Calculate the diode current.

Solution

1 = 500 nW X 0.33 A/W

= 150 nA

Fiber – Optic System

EXAMPLE 25.1

A fiber – optic link extends for 40 km. The laser – diode emitter has an output power of 1.5 mW, and the receiver requires a signal strength of -25 dBm for satisfactory signal – to – noise ratio. The fiber is available in length of 2.5 km and can be spliced with a loss of 0.25 dB per splice. The fiber has a loss of 0.3 dB/km. The total of all the connector losses at the two ends is 4dB. Calculate the available system margin.

Solution

$P_{in}(dBm) = 10 \log P_{in}(mW)$

$= 10 \log 1.5$

$= 1.76\ dBm$

span length/ fiber length = 40 km / 2.5 km

= 16

Connector losses	4	dB
Fiber loss : 40 km X 0.3 dB/km	12	dB
Splice loss : 15 splice X 0.25 dB/splice	3.75	dB

Total 19.75 dB

P_{out} = 1.76 dBm – 19.75 dB
= -17.99 dBm

System margin = - 17.99 dBm – (-25 dBm)
= 7.01 dB

EXAMPLE 25.2

A 45 km length of fiber must not lengthen pulses by more than 100 ns. Find the maximum permissible value for the pulse – spreading constant.

Solution

$$D = \frac{\Delta t}{L}$$

$$D = \frac{100 \text{ ns}}{45 \text{ km}}$$

$$= 2.22 \text{ ns/km}$$

Fiber – Optic System

EXAMPLE 25.3

Calculate the maximum data rate for the 45 km fiber system in the previous example when it is used with a transmitter having a rise time of 50 ns and a receiver having a rise time of 75 ns, if the code is

(a) NRZ
(b) RZ

Solution

$$T_{RT} = \sqrt{T_{Rtx}^2 + T_{Rrx}^2 + T_{Rf}^2}$$

$$= \sqrt{50^2 + 75^2 + 100^2}$$

$$= 135 \text{ ns}$$

(a)

$$f_b = \frac{1}{T_{RT}}$$

$$= \frac{1}{}$$

$$= \frac{1}{135 \text{ ns}}$$

$$= 7.4 \text{ MHz}$$

(b)

$$f_b = \frac{1}{2T_{RT}}$$

$$= \frac{1}{2 \times 135 \text{ ns}}$$

$$= 3.7 \text{ MHz}$$

EXAMPLE 25.4

A Fiber is rated as having a bandwidth – distance product of 500 MHz – km. Find its dispersion in ns/km, and find the rise time of pulse in 5km length of this cable.

Solution

$$Bl = \frac{500}{D}$$

$$D = \frac{500}{Bl} = \frac{500}{500} = 1 \text{ ns/km}$$

Fiber – Optic System

EXAMPLE 25.5

A fiber – optic system uses a detector with a rise time of 3ns and a source with a rise time of 2ns. If RZ code is used with a data rate of 100Mb/s over a distance of 25 km, calculate the maximum acceptable dispersion for the fiber and the equivalent bandwidth – distance product.

Solution

$$f_b = \frac{1}{2T_{RT}}$$

$$f_b = \frac{1}{2T_{fb}}$$

$$= \frac{1}{2 \times 100 \times 10^6 \text{ b/s}}$$

$$= 5 \text{ ns}$$

$$D = \frac{3.46 \text{ ns}}{25 \text{ km}} = 0.1386 \text{ ns/km}$$

$$Bl = \frac{500}{0.1386} = 3608 \text{ MHz} - \text{km} = 3.61 \text{ GHz -km}$$