Solutions to Quiz 3

Question 1

A communication system using OFDM will operate over a channel with a delay spread of 100 ns.

(a) For the OFDM signal bandwidth to be equal to the inverse of this delay spread, what is the minimum (complex) sampling rate that could be used?

(b) If the guard time is to be equal to ten times the delay spread, what is the duration of the cyclic extension in units of samples, assuming the sample rate above?

(c) If the OFDM symbol size is $N = 256$ samples, what is the subcarrier spacing?

Answer

(a) The inverse of the delay spread is $1/100{\times}10^{-9} = 10$ MHz. For complex sampling the minimum sampling rate to avoid aliasing is equal to the bandwidth so the minimum sampling rate would be 10 MHz.

(b) Ten times the delay spread is 10×100 ns $= 1\ \mu$s. For sample rate of 10 MHz the sample duration is $1/10{\times}10^6 = 100$ ns and the duration of the cyclic extension would be $1\ \mu\text{s}/100\ \text{ns} = 10$ samples.

(c) The subcarrier spacing is the sampling rate divided by the OFDM symbol size: $10{\times}10^6/N{=}256 \approx$ 39 kHz.

Question 2

A wireless system operating at 3 GHz uses 1 W transmit output power and an antenna with 15 dBi gain. The receiver is 8 km away and you can assume free-space loss. You can neglect feedline and other losses. The constant kT is -174 dBm/Hz, the noise figure is 2 dB, and the receiver bandwidth is 1.6 MHz (62 dB-Hz). The system requires an SNR of 25 dB to provide service.

Prepare a link budget for this system that takes into account the factors mentioned above. Include: (a) the computed path loss in dB, (b) received signal power in dBm, (c) received noise power in dBm, (d) received SNR in dB, and (e) the link margin in dB. Will this system provide service?

Answer

(a) the wavelength is $\lambda = 3{\times}10^8/3{\times}10^9 = 0.1$ m.

and the path gain is:

$$\left(\frac{\lambda}{4\pi d}\right)^2 = \left(\frac{0.1}{4\pi 8000}\right)^2 \approx 1 \times 10^{-12} = -120 \text{ dB}$$

(b) the received signal power is the transmitted signal power plus the antenna gain minus the path loss: 30 dBm + 15 − 120 = −75 dBm

(c) the receiver noise power is: $kTBF = -174 + 62 + 2 = -110$ dBm

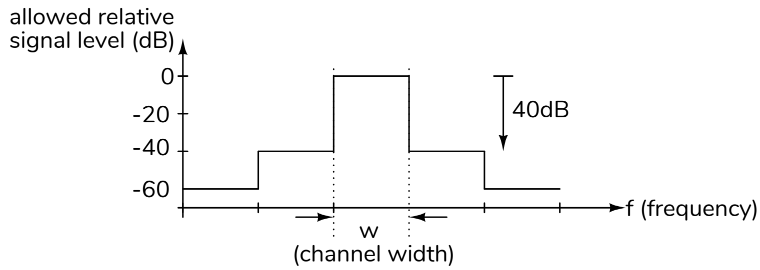
(d) the SNR is the ratio of signal to noise power: $-75 - (-110) = 35$ dB

(e) the link margin is the difference between the computed SNR and the required SNR: $35 - 25 = 10$ dB

(f) Yes, since the link margin is positive the system will provide service (to this user).

Question 3

The following "mask" shows the maximum allowed level of the in-channel and adjacent-channel signals transmitted by a device. The in-channel output power should be 20 dBm. What would be the minimum required OIP3 rating for the device's final RF amplifier?



Answer

The signals falling in the adjacent channel will be the third-order intermodulation products of signals within the in-channel frequency range.

The reduction in third-order products relative to the desired signal (40 dB in this case) is twice the reduction of the desired signal from the OIP3 point. So the required final amplifier OIP3 is $20 + 40/2 = 40$ dBm.

As a check, the desired signal is reduced by 20 dB from 40 dBm to 20 dBm while the third-order products are reduced by $3 \times 20 = 60$ dB from 40 dBm to -20 dBm resulting in the required difference of 40 dB (20 dBm $-$ (-20) dBm.