Department of Electrical Engineering, IIT Madras

EE5141 : Wireless and Cellular Communications (Jan.-Apr., 2022)

Tutorial Questions

Note: Questions marked with "*" are the harder ones; "**" are beyond what was discussed in class; there are purely optional questions.

1. Pilot Design and Overheads: Consider a 20 MHz OFDM system with FFT size of N=1024. Assuming that the sub-carriers are indexed from 512 to -511, the guard sub-carriers are indexed by (512 to 472) and -472 to -511). The sampling rate is taken to be f_s =20 MHz. Answer now the following:

(a) What is the sub-carrier band-width Δf_{sub} in KHz? Take 20MHz to be 20.48MHz for convenience!

$\Delta f_{sub} = 20.48/1024 = 20\,kHz$;

(b) If the Cyclic Prefix (CP) length N_{cp} is $\frac{1}{4}^{th}$ of the useful symbol duration, what is the duration (in μsec) of the full OFDM symbol? $T_u = \frac{1}{\Delta f_{sub}} = \frac{1}{20kHz} = 50\mu sec$; $T_{cp} = \frac{50}{4} = 12.5\mu$; $\therefore T_{OFDM} = T_u + T_{cp} = 62.5\mu$;

(c) If QPSK modulation is employed on all the useful subcarriers, what is the "gross" spectral efficiency of this OFDM system (in bits/sec/ Hz)? $\left((471 \times 2 \times 2\ bits/symbol) / 62.5\mu\right) / 20.48MHz$

$\rightarrow 1.472\ bits/s/Hz$

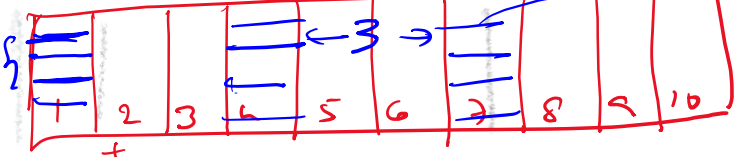
(d) This system is deployed to cover a circular area of 3 km radius, where the delay spread is 4 μsec or less. Also, the maximum Doppler frequency is expected to be 400Hz. Generally, it is advisable to have at least 1 or 2 pilot subcarriers (preferably 2 pilots) within a "Coherence band" , and pilots in time as often as every 10% of the " Coherence time" (which is approximately 36^0 phase change). Given this, how will you distribute pilot subcarriers in a 2-D manner (i.e., over frequency and time)? Explain with a figure.

4 μsec ⇒ Coh. band ≈ 1/4μ ≈ 250 kHz ⇒ 12 subs

400 Hz ⇒ 1 cycle every 2.5 msec ⇒ every 30 symbols ✓ coh. time

10% of coh. time ⇒ every 3 symbols

(or 6 subs / 12 subs) f_s



pilot subs

20 MHz

(e)* If 2ppm clocks are used on both the T_X and R_X nodes, how often should the preamble symbol be repeated in time so that between preambles, there is no more than half-a-sample of slip? (Hint: First find the slip-rate in number of sample slips per second.)

slip rate = (2+2) = 4 ppm × f_s ← 20.48 MHz → taking 20 MHz ≈ 80 slips per sec

⇒ 1 slip every 1/80 = 0.0122 sec = 12.2 msec

⇒ preamble every 12.2 m/62.5μ ≈ 195 symbols (blocks)

(f) Putting (d) and (e) together, make a neat sketch of the OFDM blocks, say drawn over two preamble intervals. The preamble can be assumed to also mark the beginning of a new frame. What is the frame rate in frames/sec?

(g) What is the "nett" spectral efficiency, after accounting for preamble and pilots?

multiply $1.472 \times \left(\frac{194}{195}\right)\left(\frac{942\times3 - 942/12}{942\times3}\right)$ → why?

why? →

(h) Now, the cell –radius is increased so that the maximum delay spread can at most equal the CP length defined in part (b). Recalculate your answer to part (d), and hence, redo your answer to part (g).

Do this!