1)

Subcarrier spacing = 30 kHz

subcarriers = 240

1 cp ⇒ $\frac{1}{4} \cdot T_{sym.u}$

2 cp ⇒ $\frac{1}{16} T_{sym.u}$

$T_s = T_{su} + T_{cp}$

- $T_{su} = \frac{1}{30} \times 10^{-3} s = 33 ms$
- for 1 cp case.

$T_s = T_{su} + \frac{1}{4} T_{su} = 33 + \frac{1}{4} 33$

$= 41.25 ms$

for 2 cp case

$T_s = T_{su} + \frac{1}{16} T_{su} = 33 + \frac{1}{16} 33$

$= 35.06 ms$

- $BW = N \times \Delta f$

$= 240 \times 30 \times 10^3 = 7.2 MHz$

$R = \frac{M \times \Delta f}{N} \times N = 4 \times 30 \times 240$

$= 27.2 Mbps$

- Guard BW = 10 - 7.2
  = 2.8 MHz
- Spectrum Eff = $\frac{23.2 \text{ Mbits/s}}{10 \text{ MHz}}$ = 2.36 bps/Hz
- Smallest FFT is = $\frac{10 \text{ MHz}}{30 \text{ kHz}}$ = $\frac{10 \times 10^6}{3 \times 10^4}$
  = 333.3 subcarrier spa
- 5
  ∴ 512 is the smallest possible FFT
- Sampling rate = $512 \times 30 \times 10^3$ = 15.36 MHz.
- for CP1
  $E(Tx)$ overhead = $10 \log\left(\frac{T_S}{T_{sym}}\right)$
  = $10 \log\left(\frac{41.25}{33}\right)$ = 0.96 dB

for CP2
$E(Tx)$ overhead = $10 \log\left(\frac{35.06}{33}\right)$ = 0.26 dB

) $T_{sym} = \frac{1}{\Delta f}$

$T_{sym} + T_{cp} = T_S = \frac{1}{\Delta f} + T_{cp}$

$T_S = D + T_{cp} + 1$

$T_{cp} = (T_S - 1)\frac{1}{\Delta f}$

T_S = Overall symbol period
Δf = Subcarrier spacing
T_{cp} = CP length

Transmitted energy overhead $= 10 \log\left(\frac{T_s}{T_{sym}}\right)$

$$= 10 \log\left(\frac{\Delta f T_{cp} + 1}{T_{sym}}\right)$$

$$= 10 \log\left(\frac{\Delta f T_{cp}}{T_{sym}} + \frac{1}{T_{sym}}\right)$$

$$= 10 \log\left[(T_{cp}\Delta f + 1)\Delta f\right]$$

$$10 \log\left[(T_{cp}\Delta f + 1)\Delta f\right] \leq 0.5$$

$$\log\left[(T_{cp}\Delta f + 1)\Delta f\right] \leq 0.05$$

$$T_{cp}\Delta f^2 + \Delta f \leq 10^{0.05} = 1.122$$

$$T_{cp}\Delta f + 1 \leq 1.122$$

$$T_{cp}\Delta f \leq 0.122$$

$$\Delta f \leq \frac{0.122}{T_{cp}}$$

let's assume $T_{cp} = 6\,\mu s$

$$\Delta f = \frac{0.122}{6 \times 10^{-6}}$$

$$\Delta f = 20\,kHz$$ //