EE698H: 4G/5G Wireless Standards Design **EE Dept. IITK**

Tutorial-2

5G-NR RF *June 2023*

1. The BS transmitter and UE receiver in a 5G NR system employ clock oscillators with a frequency of 1 MHz and tolerance of ±10 ppm (parts per million). These oscillators are employed to synthesize the carrier frequency of 5 GHz in the BS and UE. What will be worst-case frequency offset experienced by the UE receiver?

   [*Information about ppm*: For 1 MHz oscillator, with a tolerance of ±10 ppm, the transmitter and receiver clocks, in the worst case, will operate at 1 MHz +10 Hz and 1 MHz -10 Hz respectively, leading to an offset of 20 Hz. Also the offset scales with frequency]

2. We assume a 5G NR OFDM system with a subcarrier spacing of 30 kHz. For the frequency offset calculated above, a part of the offset has to be necessarily estimated and compensated in the time domain before taking the FFT at the receiver. This offset is called fractional frequency offset. The remaining frequency, called integer frequency offset, is estimated in frequency.

   - Why do you think the fractional frequency offset be calculated in the time domain, and calculate its value for the system considered herein.
   - Why should integer frequency offset be calculated in the frequency domain, and calculate its value for the system considered herein.

3. For the received signal RF signal $r(t) = s^o(t)+n_w(t) = \sqrt{2}I(t)\cos(\omega_0 t)-\sqrt{2}Q(t)\sin(\omega_0 t)+n(t)$ when demodulated using a carrier signal $\sqrt{2}\cos(\omega_0 t-\theta)$ and low pass filtering, results into equivalent baseband signal $\tilde{r}(t) = s(t)e^{j\theta} + \tilde{n}(t)$.