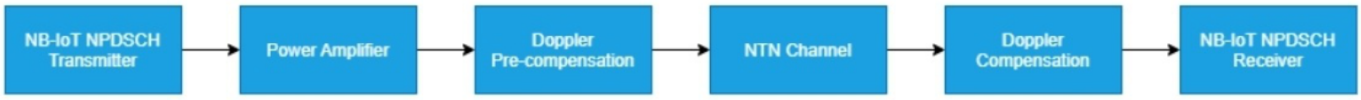
The figure shows the implemented processing chain. For clarity, the figure does not show the NRS and synchronization signals.



channel Model

- free-space path loss (without antenna gain)
  FSPL = 10 × log[(4pi × d × f × 1/c)^2]
  = 20 × log(4pi × d × 1/ lambda)
  Speed of propogation divided by signal frequency
  (lambda = c / f)

$$PL_{FS} = 32.45 + 20\log_{10} f_c + 20\log_{10} d$$

$$d = \sqrt{R_E^2 \sin\alpha^2 + h_0^2 + 2h_0 R_E} - R_E \sin\alpha$$

- Doppler shift model
  (Doppler pre-compensation => method statement)
  - Input : frequency (residential, edge), receiver speed, alpha
  - Output : doppler shift
- 3GPP TR 38.811 (R15)
  - New Radio (NR) to support NTN
- 3GPP TR 38.901 (R16)
  - Channel model for frequencies from 0.5 to 100GHz
- Fading channel model
  - 3GPP TDL-A~C : defined for non line-of-sight
    - TDL-D (Tapped delay line):
      - outdoor environment with line-of-sight
      - first tap : Ricean fading distribution

        - Fading distribution : Rayleigh fading
        - Use correlation matrix
    - 模擬多徑效應，若不需MIMO系統則可以採用
- AWGN : Add Gaussian noise to signal
    - Ka頻段上的低軌衛星多徑效應

Parameters(Uplink & downlink)

- UE(terminal parameter):
    - 學姐的論文參數?
    - 3GPP: LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment radio transmission and reception (Rel 14)
- Link-budget :
    - 3GPP: Discussion on link budget for NTN, . TSG RAN WG1 Meeting R1-1903998

Uplink

- Orbit Propogator : sgp4
- modulation format : SC-FDMA
- modulation order : QPSK
- carrier frequency parameter : 2000 MHz (2GHz)
- frequency offset : fd = fc × VD / c

  fc = carrier frequency

  VD = relative speed between satellite & user
    - 地球同步衛星：0
    - 太陽同步衛星：考慮相對速度

  c = speed of light

  antenna type (Satellite & GS)
    - ground stations :
        - phased array antenna(custom-48 beam for

Iridium)

- UE :
  - (1,1,2) with omnidirectional antenna element (全向天線)
- Satellite :
  - phased array antenna(custom-48 beam)
  - omnidirectional antenna(有論文支援參數)

Method statement

- Doppler pre-compensation
  (1) Frequency offset
  (2) phase, fast Fourier transform (FFT) size
  (3) Channel estimation : DMRS (number of symbols)

Compared with

- BS使用其他種類天線
- 不同高度的低軌衛星
- 不同家低軌衛星供應商（starlink數量最多，覆蓋面積...）
- 不同軌道傳播器（two_kepler, sgp4, sdp4）
- Beam diameter
  - 波束大小影響覆蓋範圍
  - 基地台部署數量
  - 論文實驗方法：縮小波束覆蓋範圍
- throughput
- resource utilization
- energy save
- subframe 消耗個數

Uplink Simulation Result

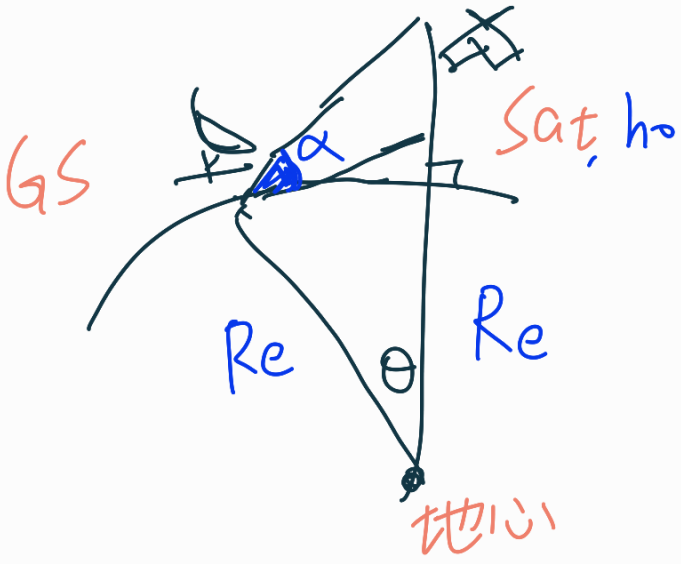
- Block error rate (BLER) & SNR
  SNRmin=(Eb/No)dB + 10log (Rb/B)dB

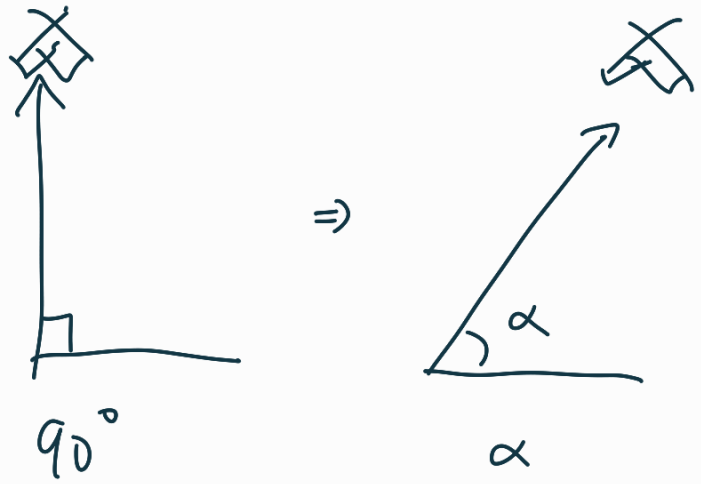
Rb=bit rate per second (bit/s or bps)

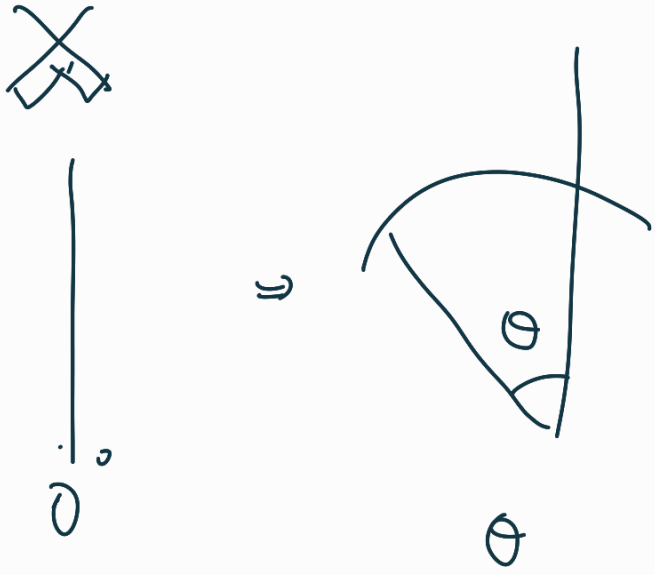
B = bandwidth (Hz)

- Throughput (Kbps) & SNR & Number of BS
- 如果發射衛星數量夠多，則覆蓋範圍大
  - 定點式（地球同步衛星）：
  - 2024/2 starlink has 5438 satellites
- 如果發射衛星數量不足，移動速度加快
  - 移動式（太陽同步衛星）：
  - Eutelsat-Oneweb：600 satellites
- 轉傳演算法策略
  - 近點（給衛星傳）
  - 遠點（先由地面基地台轉送）

3/19 meeting 補







$$\theta = \alpha - 90^\circ$$

餘弦

$$d^2 = Re^2 + (Re+h_0)^2 - 2 \times Re \times (Re+h_0) \times \cos(\alpha - 90^\circ)$$

$$\| $$

$$\cos(90^\circ - \alpha)$$

γ – Central Angle

- γ is defined so that, it is non-negative and by the law of cosines.
- $\cos(\gamma) = \cos(\boldsymbol{L_e})\cos(\boldsymbol{L_s})\cos(\boldsymbol{l_s} - \boldsymbol{l_e}) + \sin(\boldsymbol{L_e})\sin(\boldsymbol{L_s})$

The magnitude of the vectors joining the center of the Earth, the satellite and the Earth station are related by the law of cosine

- $d = r_s \left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma)\right]^{1/2}$ --(1)
- It is the communications path length, d along which path losses will be calculated.