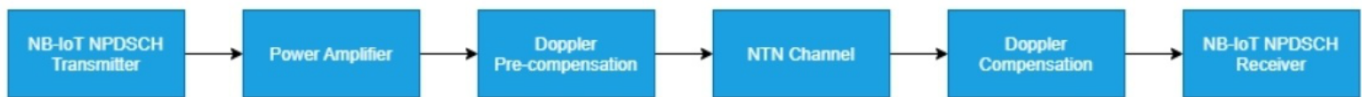


The figure shows the implemented processing chain. For clarity, the figure does not show the NRS and synchronization signals.



channel Model

- free-space path loss (without antenna gain)

$$FSPL = 10 \times \log[(4\pi \times d \times f \times 1/c)^2]$$

$$= 20 \times \log(4\pi \times d \times 1/\lambda)$$

Speed of propagation divided by signal frequency

$$(\lambda = c / f)$$

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

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

- 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 : $f_d = f_c \times v_D / c$

f_c = carrier frequency

v_D = 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)

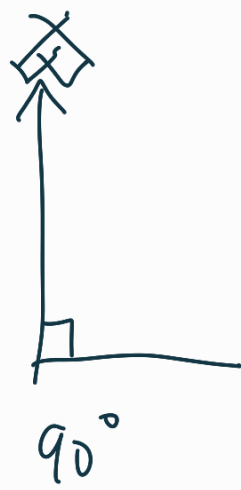
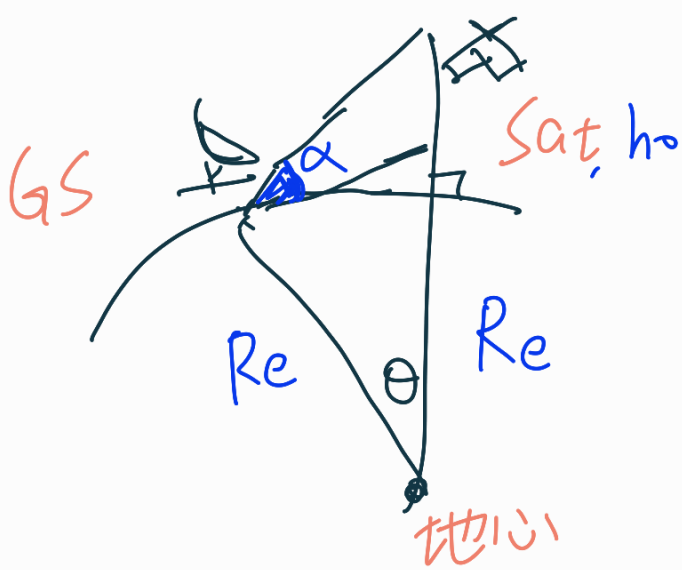
- Satellite :
 - phased array antenna(custom-48 beam)
 - omnidirectional antenna(有論文支援參數)

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

Uplink Simulation Result

- Block error rate (BLER) & SNR
$$\text{SNR}_{\min} = (\text{Eb}/\text{No})_{\text{dB}} + 10 \log (\text{Rb}/\text{B})_{\text{dB}}$$
$$\text{Rb} = \text{bit rate per second (bit/s or bps)}$$
$$\text{B} = \text{bandwidth (Hz)}$$
- 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



\Rightarrow



\Rightarrow



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

余弦

$$d^2 = Re^2 + (Re + h_0)^2 - 2 \times Re \times (Re + h_0)$$

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

\parallel

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

γ – Central Angle

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

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

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

