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Scientific Supervisors
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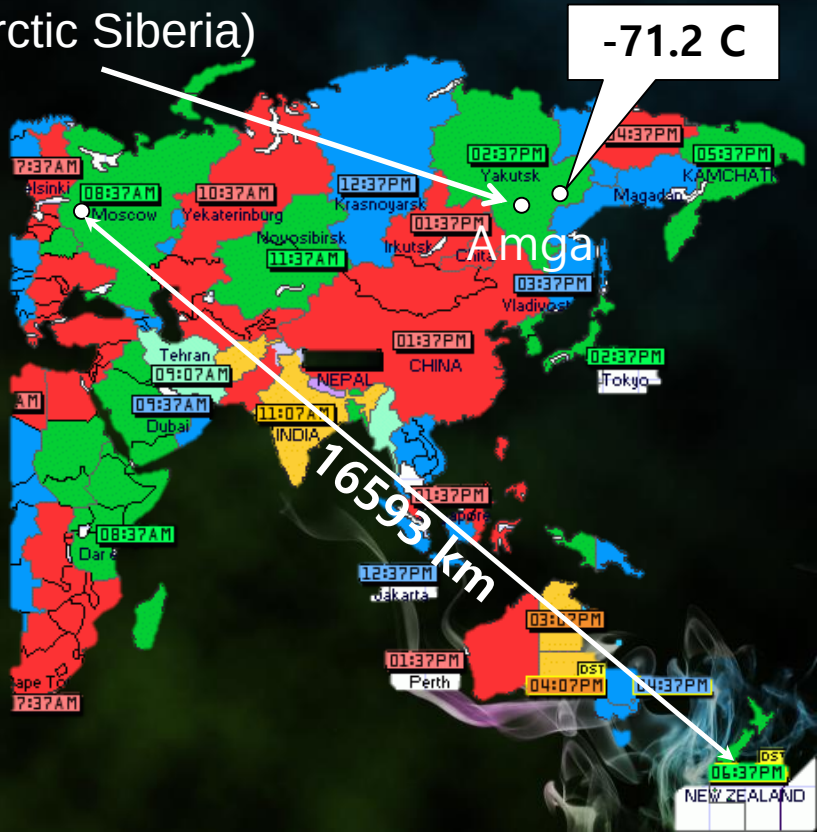
General Information

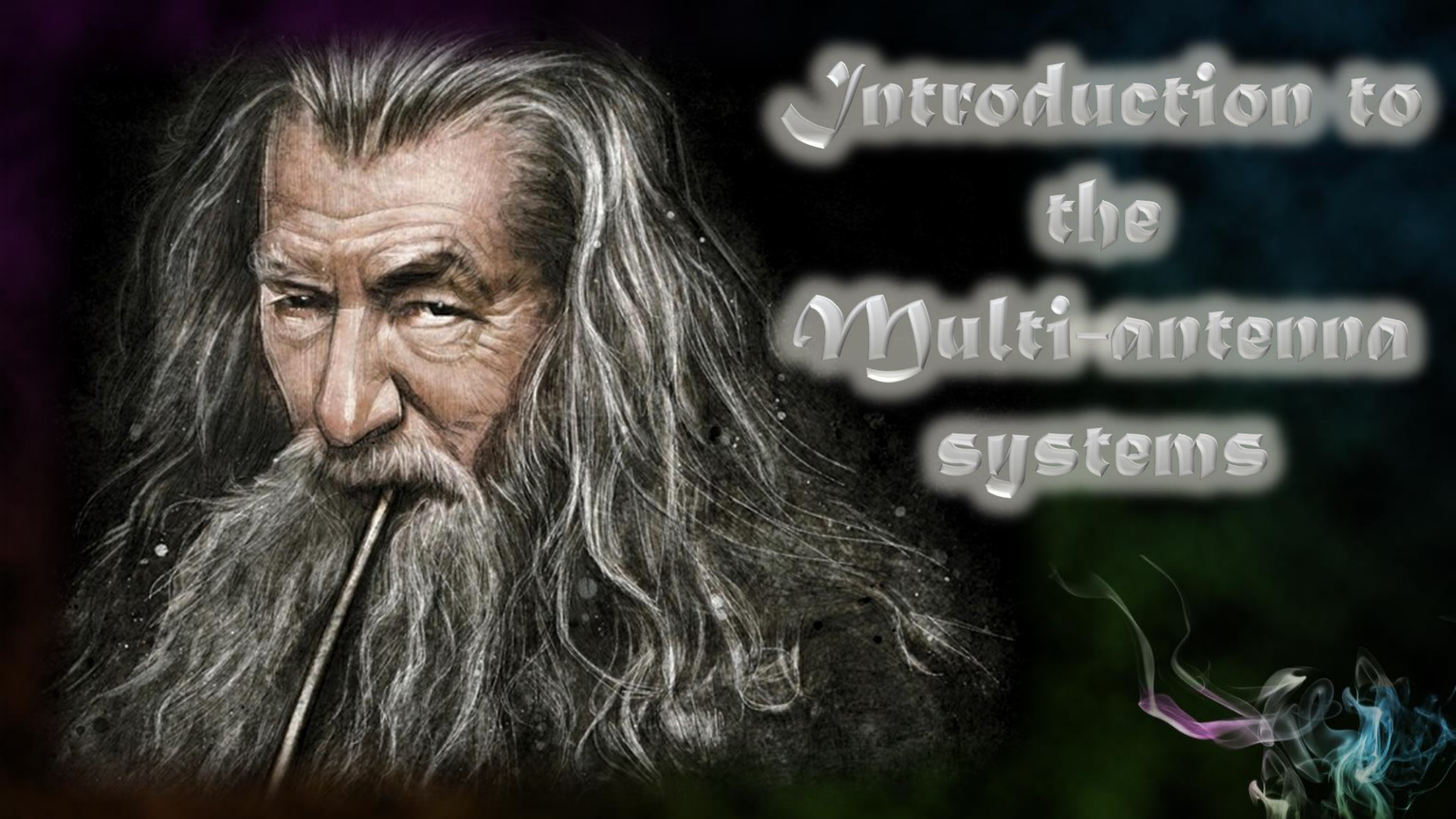
Place of birth
Yakutsk town, Sakha (Yakutia)

Living place
Amga village

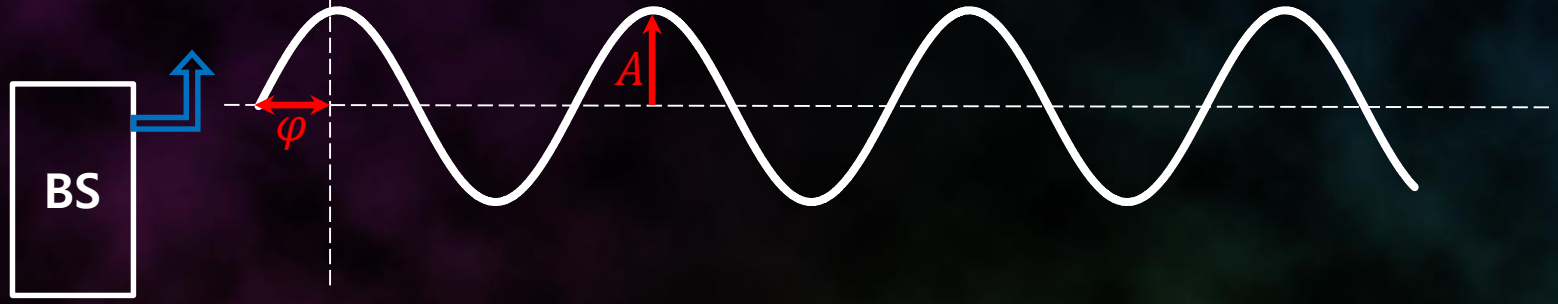


Leader or Team Member


Battle for the Path
Coping with MultiPath
propagation effects in
Wireless communication systems


Introduction to
the
Multi-antenna
systems

$$s(t) = A\,sin(\omega_0 t + \varphi)$$



$$s'(t) = s(t) + \xi(t)$$

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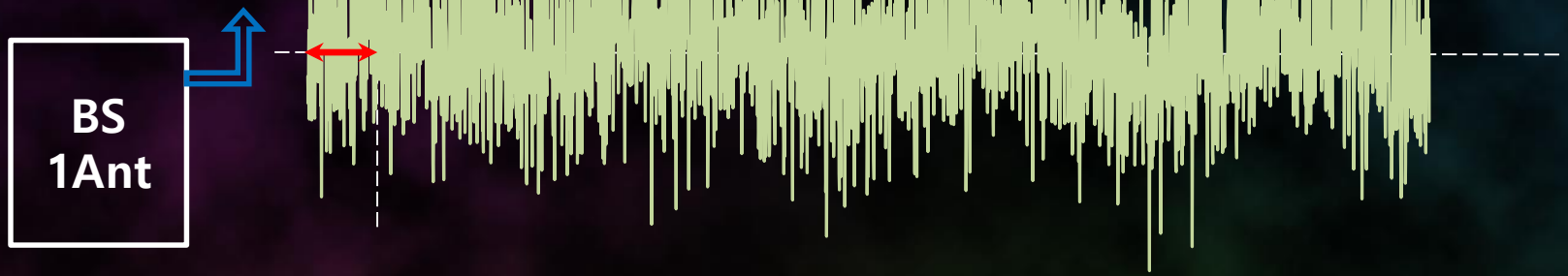
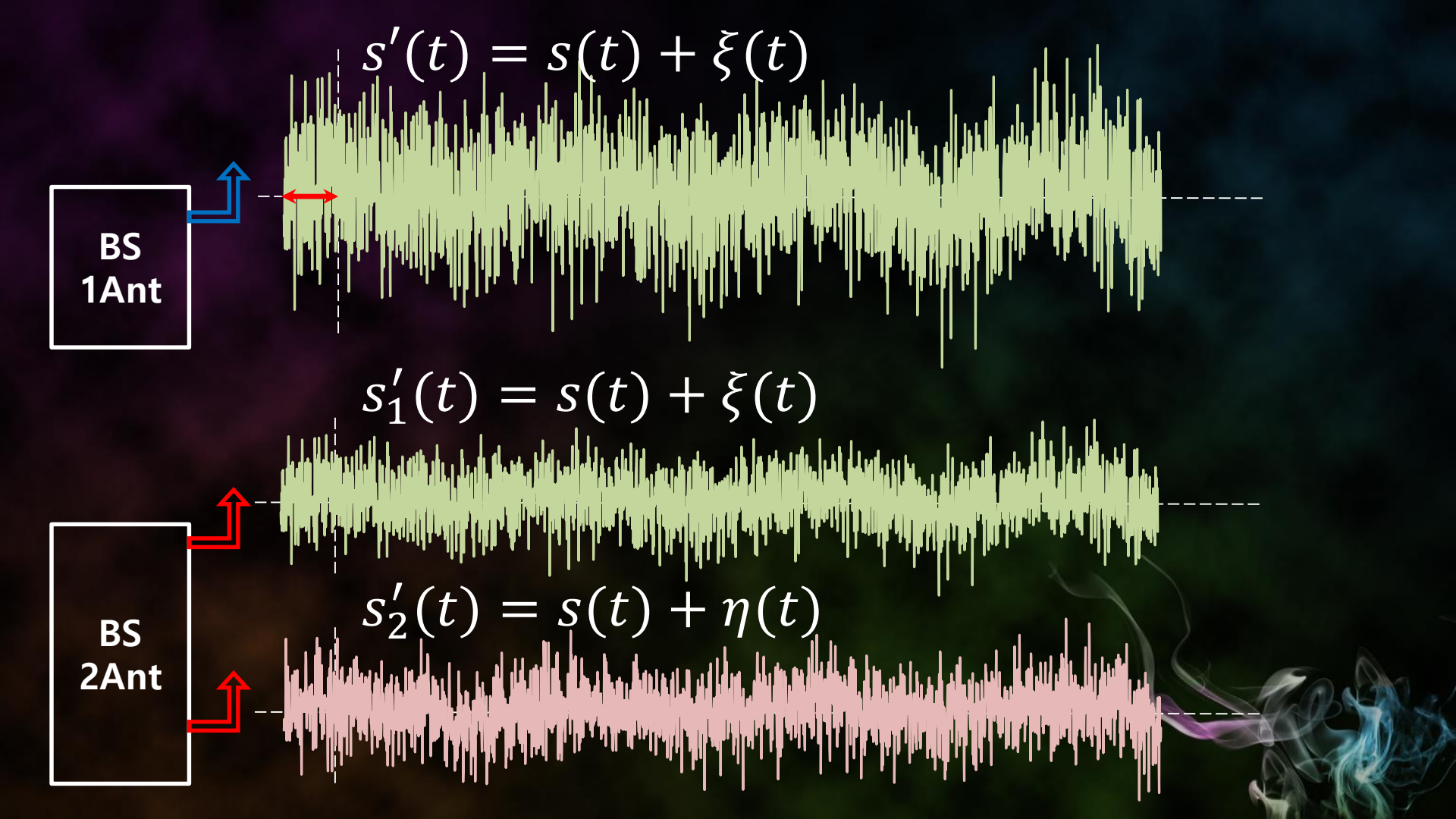
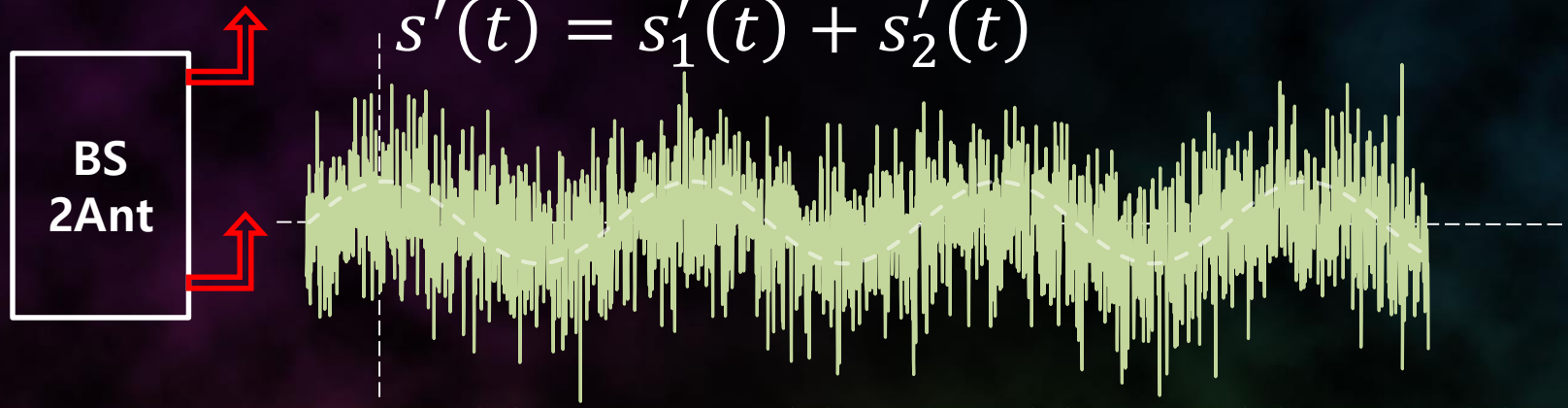
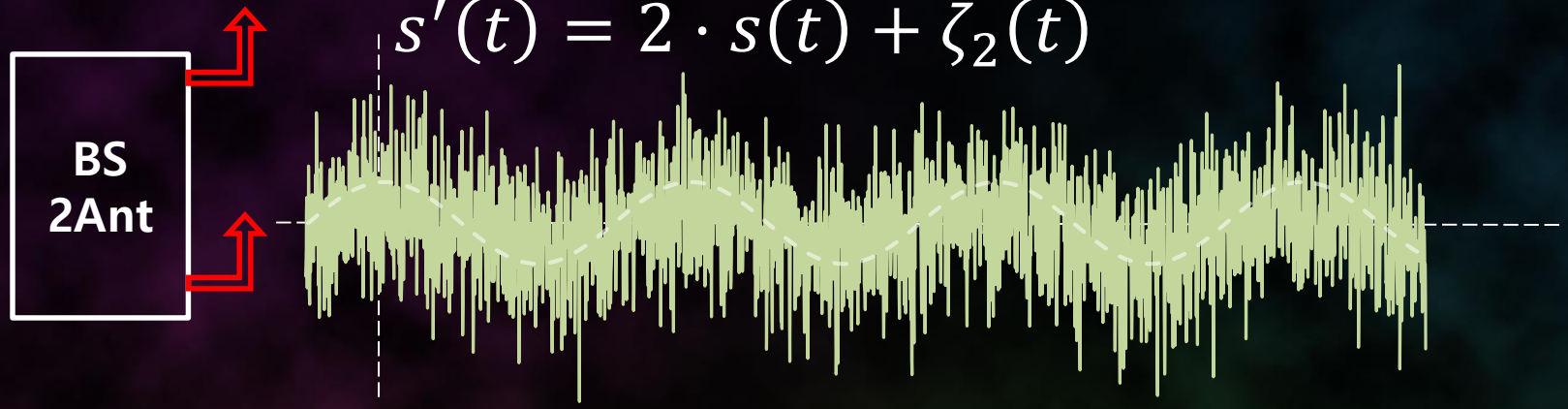
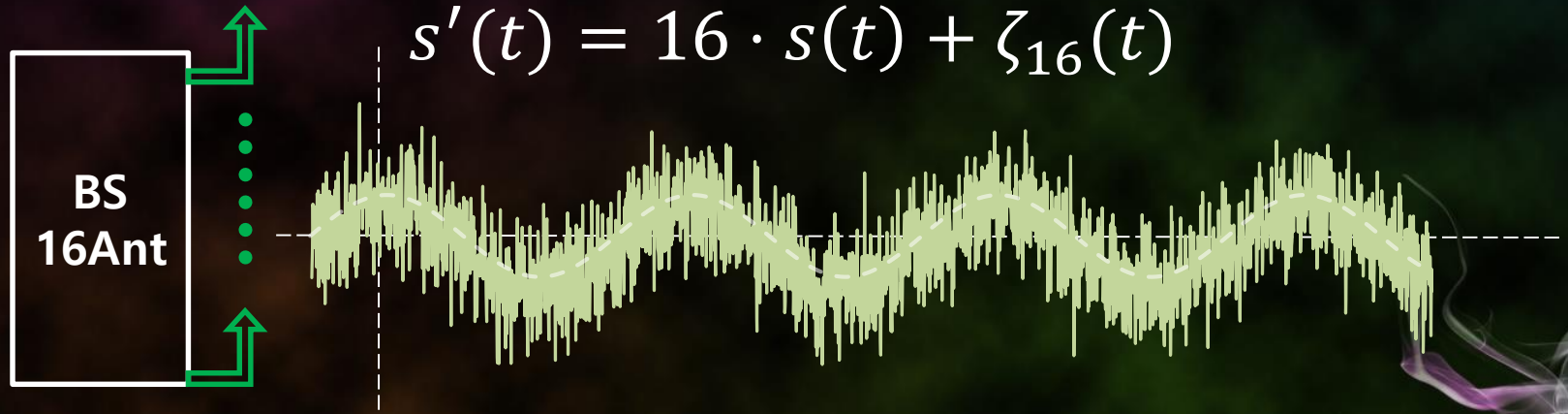



$s'(t) = s(t) + \xi(t)$
BS
1Ant
$s_1'(t) = s(t) + \xi(t)$
$s_2'(t) = s(t) + \eta(t)$
BS
2Ant


BS
2Ant
$s'(t) = s'_1(t) + s'_2(t)$
$s'(t) = 2 \cdot s(t) + \zeta_2(t),\ \zeta_2(t) = \eta(t) + \xi(t)$


$s'(t) = 2 \cdot s(t) + \zeta_2(t)$
BS
2Ant


$s'(t) = 16 \cdot s(t) + \zeta_{16}(t)$
BS
16Ant

$$s_1'(t) = s(t) + \sigma\xi(t), \qquad \xi(t) \sim N(0,1)$$

$$s_2'(t) = s(t) + \sigma\eta(t), \qquad \eta(t) \sim N(0,1)$$

$$E[\xi(t)] = 0, \qquad E[\xi^2(t)] = 1 \qquad E[\eta(t)] = 0, \qquad E[\eta^2(t)] = 1$$

$$E[\xi(t)\eta(t)] = 0$$

$$s'(t) = s_1'(t) + s_2'(t) = 2s(t) + \sigma_{new}\zeta(t), \qquad \zeta(t) \sim N(0,1)$$

$$E[\sigma(\xi + \eta)] = \sigma E[\xi] + \sigma E[\eta] = 0$$

$$E[\sigma^2(\xi + \eta)^2] = \sigma^2 E[\xi^2 + 2\xi\eta + \eta^2] = \sigma^2\big(E[\xi^2] + E[\eta^2] + 2E[\xi\eta]\big) = 2\sigma^2$$

$$\| \qquad \| \qquad \|$$

$$1 \qquad 1 \qquad 0$$

$$s'(t) = 2s(t) + \sqrt{2}\,\sigma\,\zeta(t)$$

$$s''(t) = s(t) + \frac{\sigma}{\sqrt{2}}\,\zeta(t)$$

$$\sigma_{new} = \sqrt{2}\,\sigma$$

$$s_1'(t) = s(t) + \sigma\xi(t), \qquad \xi(t) \sim N(0,1)$$

$$s_2'(t) = s(t) + \sigma\eta(t), \qquad \eta(t) \sim N(0,1)$$

$$E[\xi(t)] = 0, \qquad E[\xi^2(t)] = 1 \qquad E[\eta(t)] = 0, \qquad E[\eta^2(t)] = 1$$

$$E[\xi(t)\eta(t)] = 0$$

$$s'(t) = s_1'(t) + s_2'(t) = 2s(t) + \sigma_{new}\zeta(t), \qquad \zeta(t) \sim N(0,1)$$

$$E[\sigma(\xi + \eta)] = \sigma E[\xi] + \sigma E[\eta] = 0$$

$$E[\sigma^2(\xi + \eta)^2] = \sigma^2 E[\xi^2 + 2\xi\eta + \eta^2] = \sigma^2\big(E[\xi^2] + E[\eta^2] + 2E[\xi\eta]\big) = 2\sigma^2$$

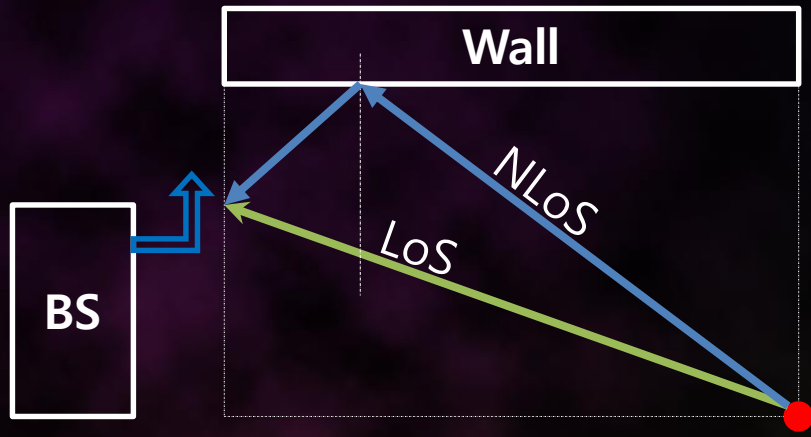
$$s'(t) = 2s(t) + \sqrt{2}\,\sigma\,\zeta(t)$$

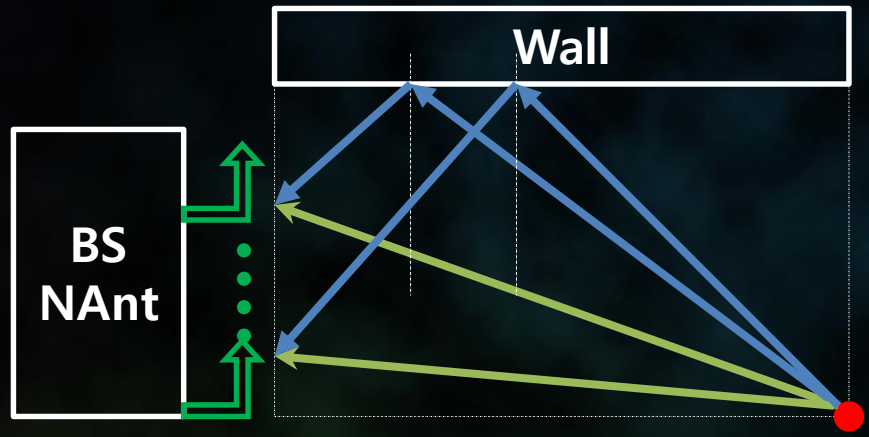
$$s''(t) = s(t) + \frac{\sigma}{\sqrt{2}}\,\zeta(t)$$

$$s_{16}'(t) = 16s(t) + \sqrt{16}\,\sigma\,\zeta(t)$$

$$s_{16}''(t) = s(t) + \frac{\sigma}{4}\,\zeta(t)$$


MultiPath
Propagation Effects

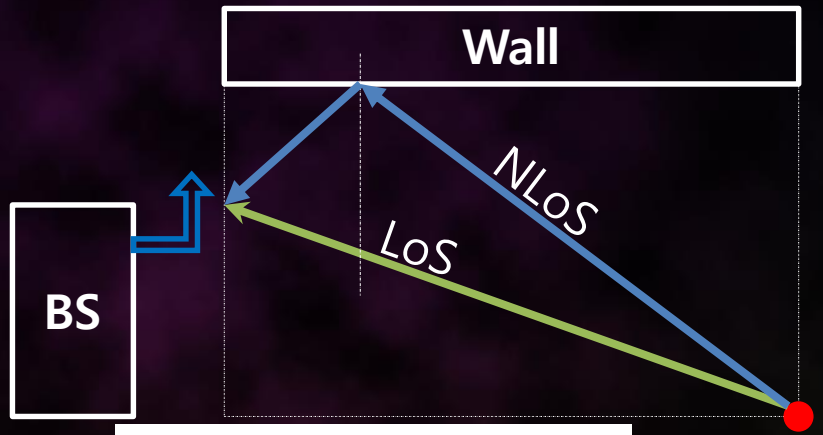




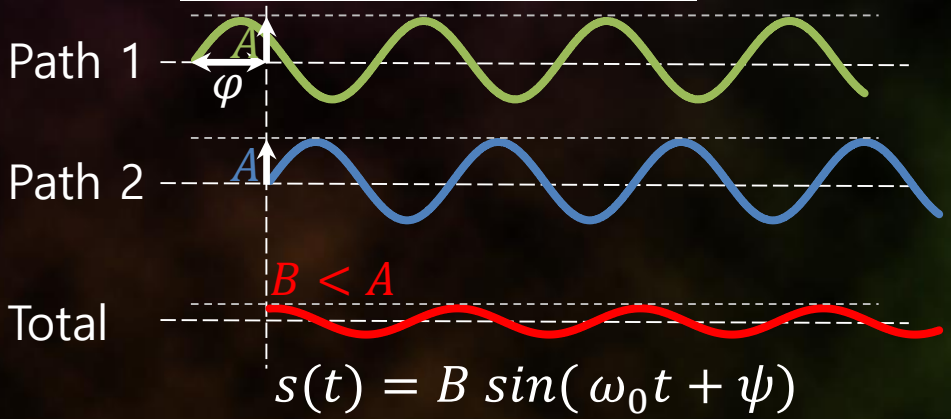
D_{NLoS} - the length of the NLoS path

D_{LoS} -the length of the LoS path

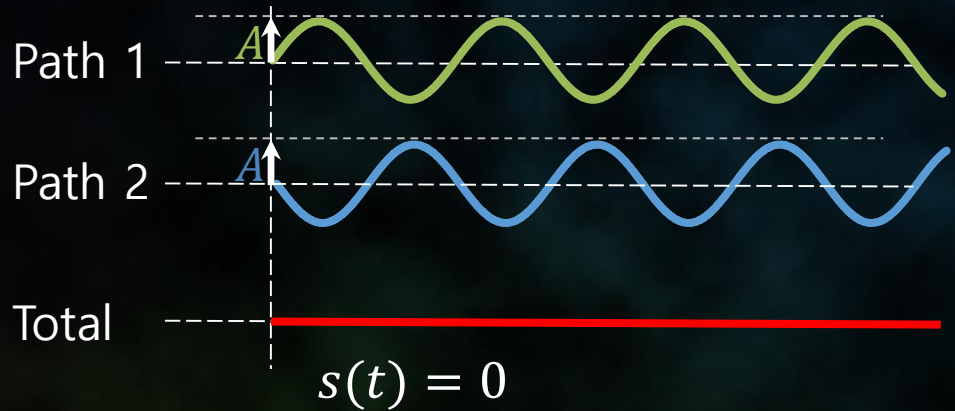
$$t_{delay} = \frac{D_{NLoS} - D_{LoS}}{c}$$



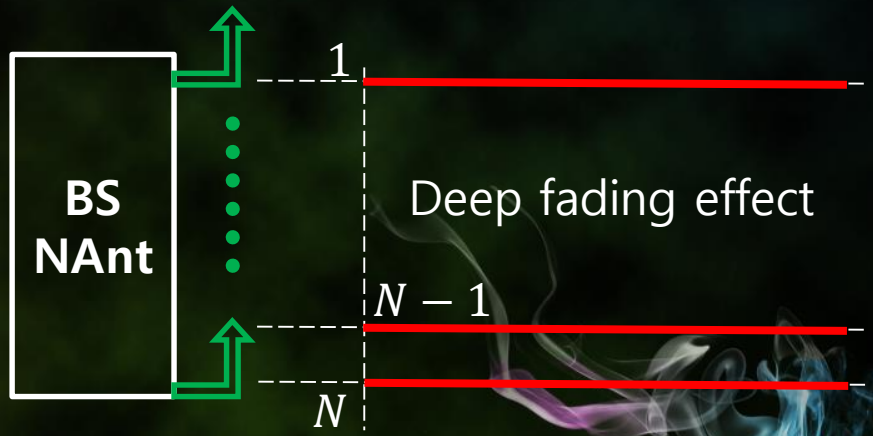
$$\varphi = \omega_0 \cdot \frac{D_{NLoS} - D_{LoS}}{c}$$

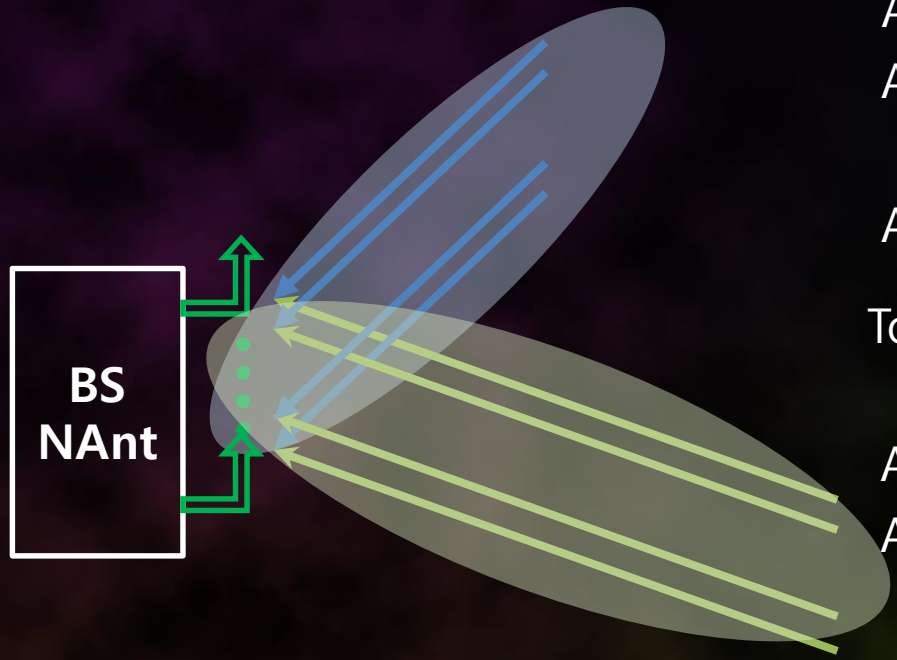


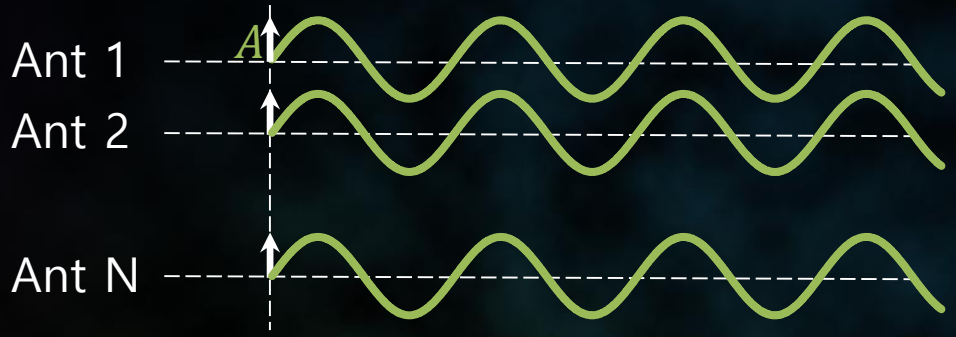
$$s(t) = B\ sin(\omega_0 t + \psi)$$



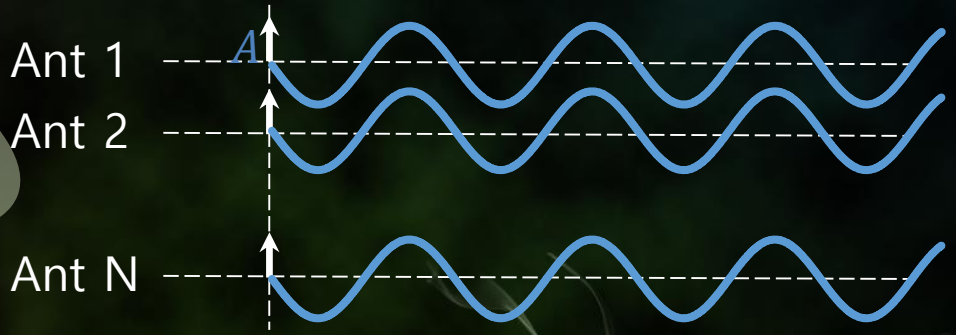
$$s(t) = 0$$







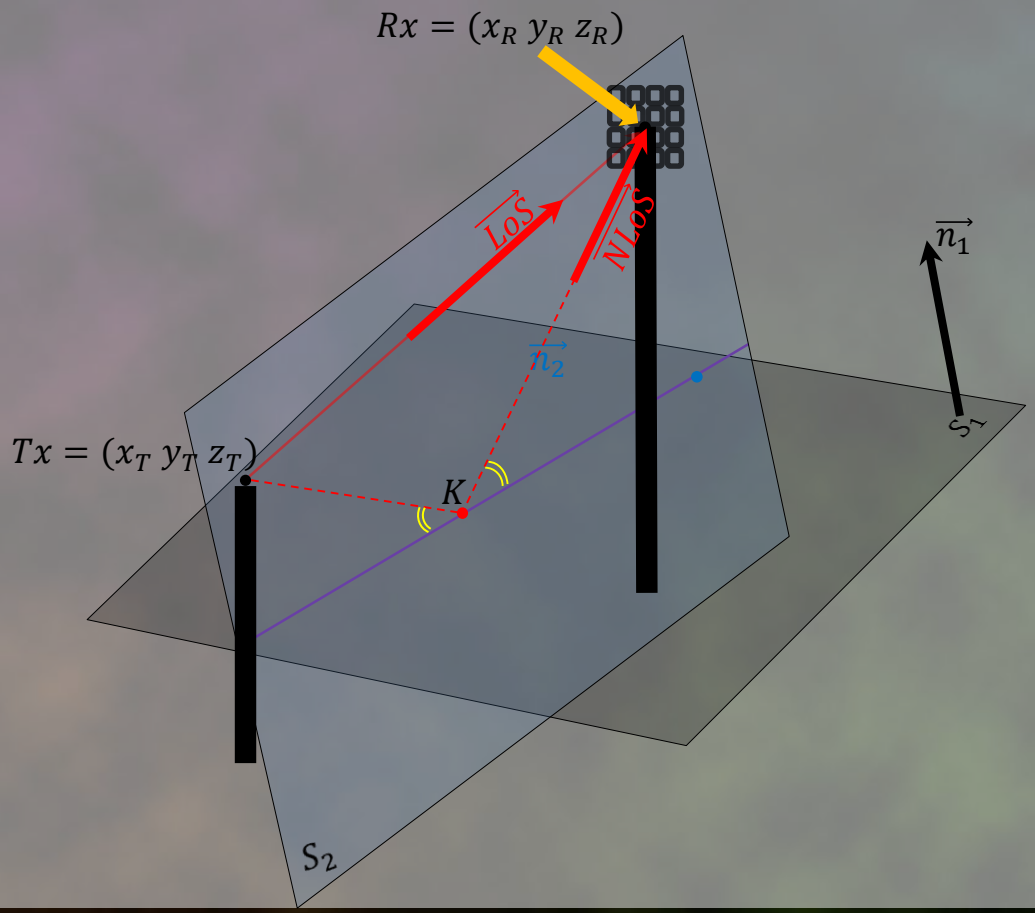
Total Path 1 $s_{P1}(t) = N \cdot s(t)$



Total Path 2 $s_{P2}(t) = N \cdot s(t)$

Battle for the Path


Battle for the Path
Simulation
Environment and
Results


$Rx = (x_R\ y_R\ z_R)$
$\overrightarrow{LoS}$
$\overrightarrow{NLoS}$
$\overrightarrow{n_1}$
$\overrightarrow{n_2}$
$Tx = (x_T\ y_T\ z_T)$
K
S_1
S_2

Coordinates of Transmitter – Tx, Receiver – Rx and the plane S_1 are given information

Line of Sight $\overrightarrow{LoS} = \dfrac{Rx - Tx}{\|Rx - Tx\|}$

$\overrightarrow{n_2} = \dfrac{[\overrightarrow{LoS}, \overrightarrow{n_1}]}{\|[\overrightarrow{LoS}, \overrightarrow{n_1}]\|}$,

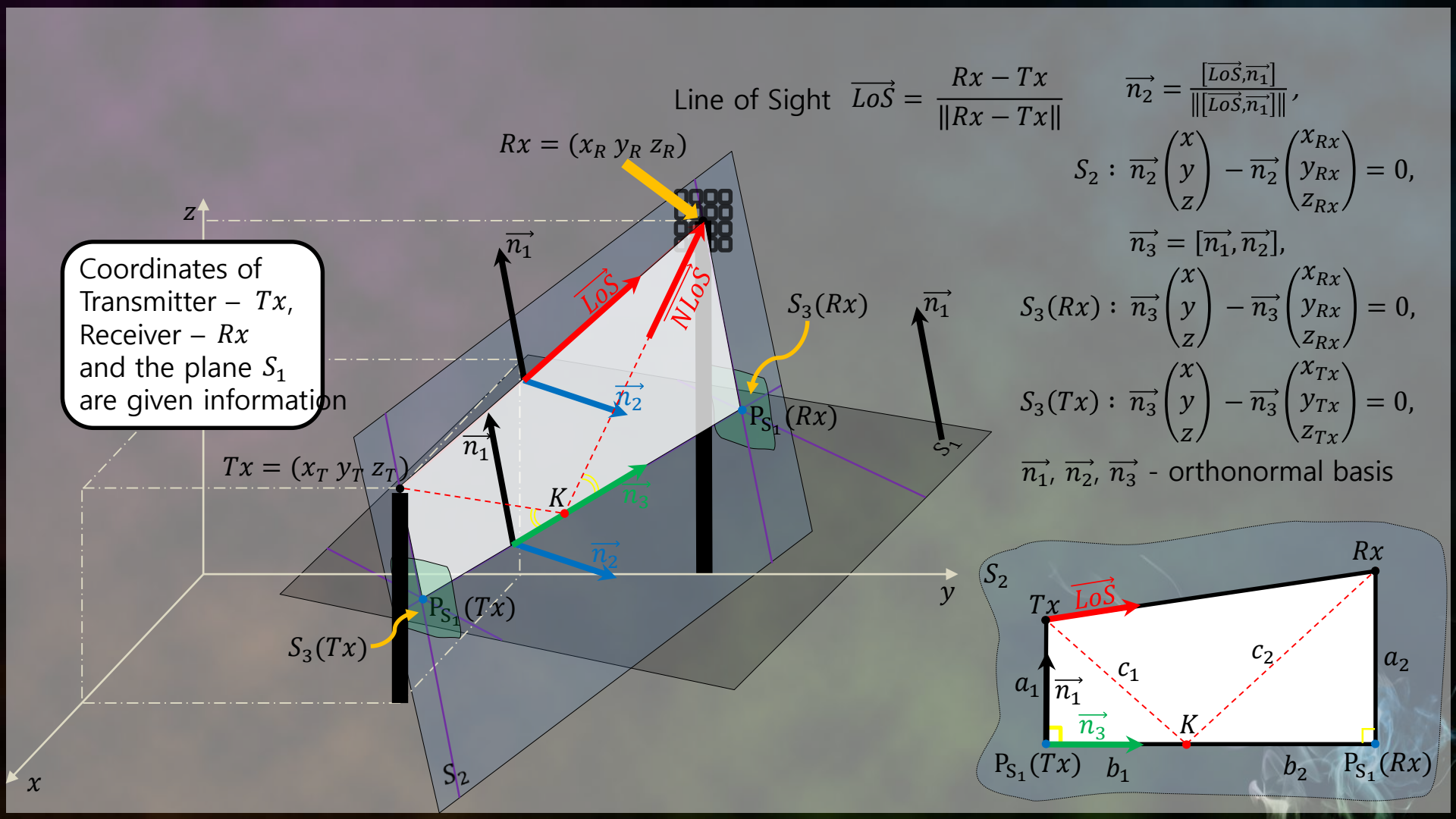
$S_2 : \overrightarrow{n_2}\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \overrightarrow{n_2}\begin{pmatrix} x_{Rx} \\ y_{Rx} \\ z_{Rx} \end{pmatrix} = 0,$

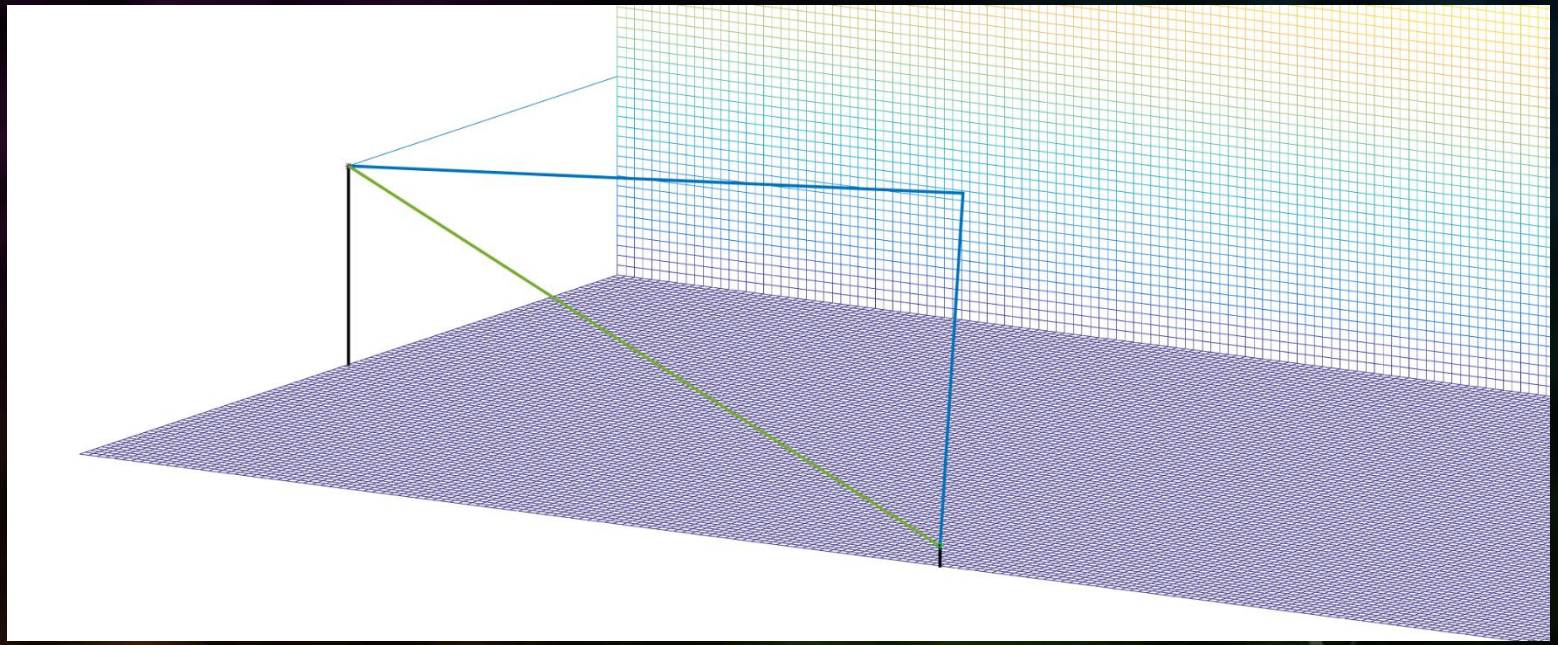
$\overrightarrow{n_3} = [\overrightarrow{n_1}, \overrightarrow{n_2}],$

$S_3(Rx) : \overrightarrow{n_3}\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \overrightarrow{n_3}\begin{pmatrix} x_{Rx} \\ y_{Rx} \\ z_{Rx} \end{pmatrix} = 0,$

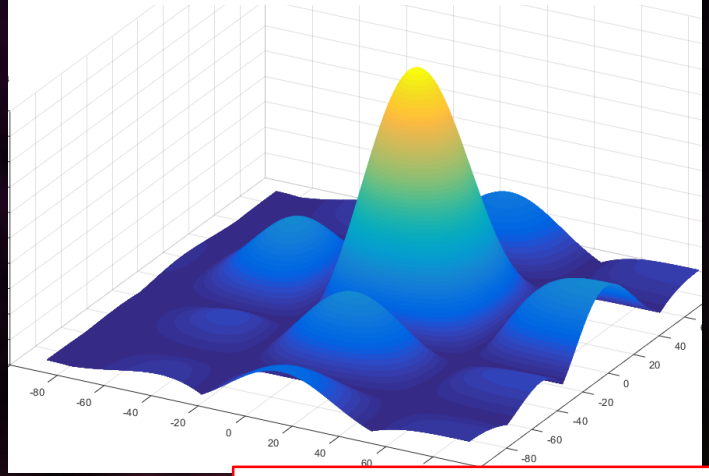
$S_3(Tx) : \overrightarrow{n_3}\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \overrightarrow{n_3}\begin{pmatrix} x_{Tx} \\ y_{Tx} \\ z_{Tx} \end{pmatrix} = 0,$

$\overrightarrow{n_1}, \overrightarrow{n_2}, \overrightarrow{n_3}$ - orthonormal basis

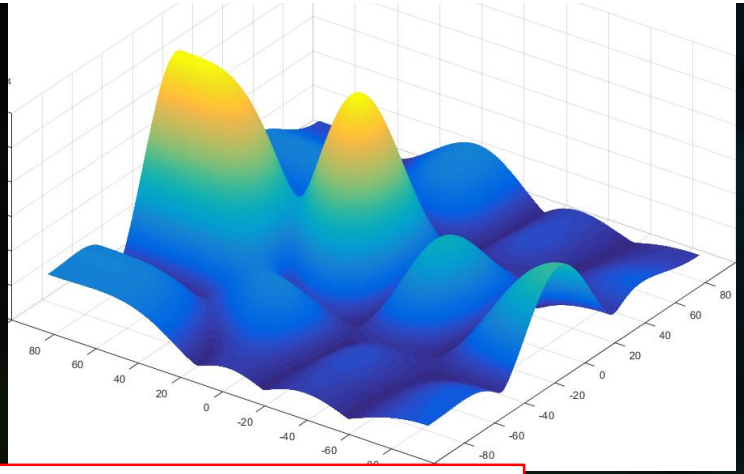




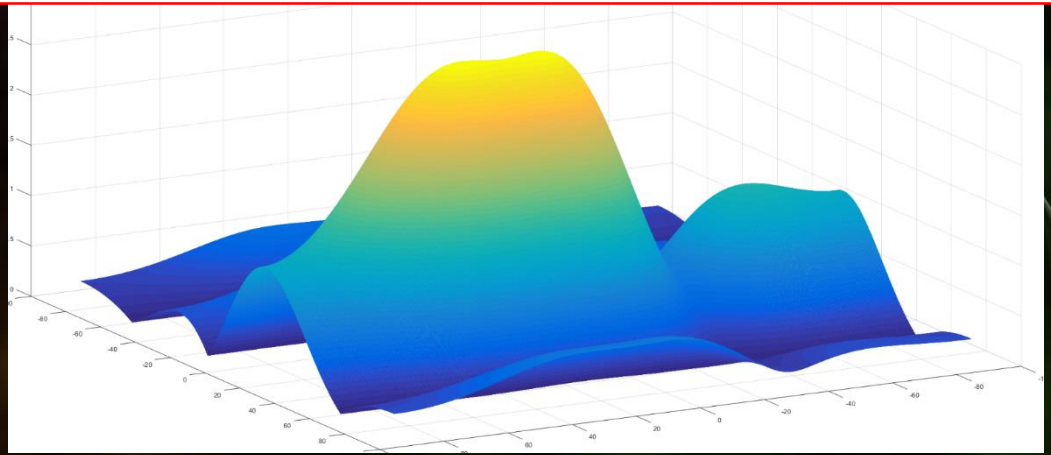
One direction can be easily localized



Two directions can be easily localized if there enough far



Two directions can be hardly localized if they are close to each other




Battle for the Path
is continuing !
Thank You!