Dynamic Modelling of Atmospheric Microwave Transmission for Precipitation Quantification using Mie Scattering

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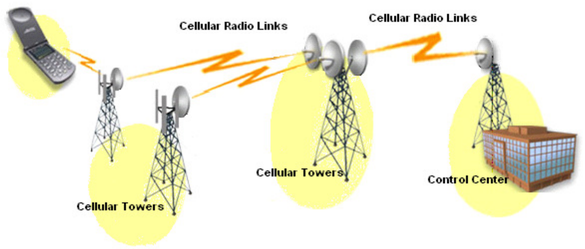
From Noise to Rain Field Characteristics

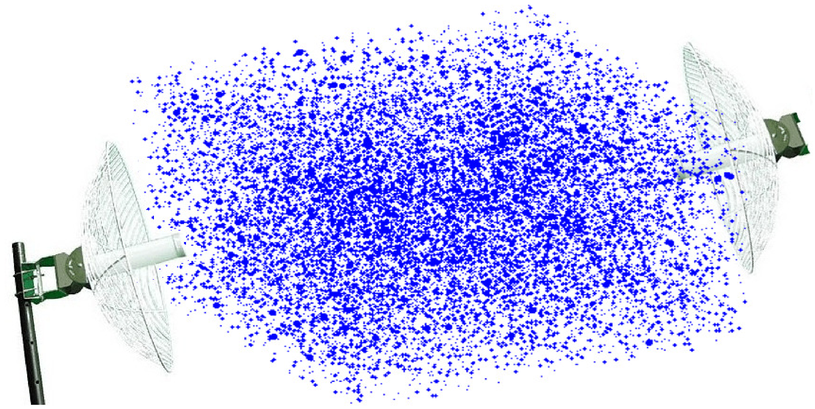


Precipitation measurement by point-to-point radio:
attenuation and *noise*

Development of a numerical model for both.

Virtual Rain

EM Field characteristics	frequency direction of propagation polarization path length plane or spherical wave
Rain characteristics	terminal velocity rain rate rain statistics
Drop dimension	max. drop radius
Simulation parameter	simulation volume simulation steps samptling rate



Scattering of Single Drop

➢ Solve Helmholtz equation

$$(\Delta + k^2)\Phi(\vec{r}) = 0$$

➢ preconditions:

➢ Assume spherical drops

➢ Drops size $\leq 5\,\text{mm}$:

22 GHz ($\lambda_0 = 15\,\text{mm}$) already beyond Rayleigh regime

$\Rightarrow$ Apply Mie theory

➢ Solution in spherical coordinates

$$\Phi = \begin{pmatrix} j_n(kr) \\ h_n^{(2)}(kr) \end{pmatrix} P_n^m(\cos\theta) \begin{pmatrix} \cos(m\varphi) \\ \sin(m\varphi) \end{pmatrix}$$

$\Rightarrow$ Scattering Matrix

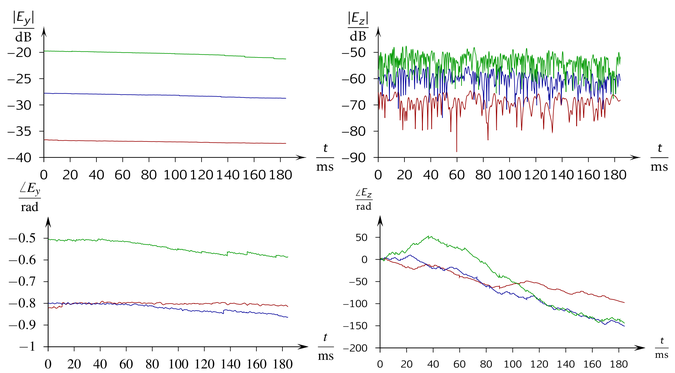
$$\begin{pmatrix} E_{s\theta} \\ E_{s\varphi} \end{pmatrix} = E_0 \frac{e^{-jkr}}{jkr} \begin{bmatrix} S_2 & 0 \\ 0 & S_1 \end{bmatrix} \begin{pmatrix} \cos\varphi \\ \sin\varphi \end{pmatrix}$$

$$S_1 = \sum_n \frac{2n+1}{n(n+1)} (a_n \pi_n + b_n \tau_n)$$

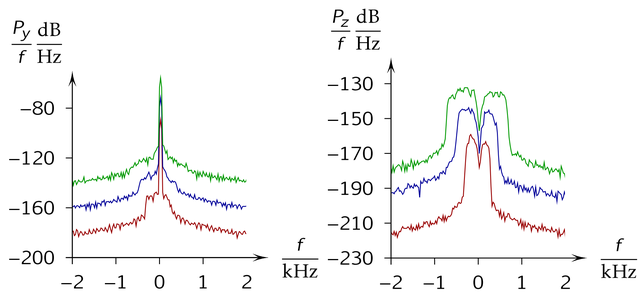
$$S_2 = \sum_n \frac{2n+1}{n(n+1)} (a_n \tau_n + b_n \pi_n)$$

Results

Time Domain Signals



Doppler Noise Spectrum and Cross Polarization



Simulation Parameter

Simulated rain rates:

- 0.2 mm/h
- 2.0 mm/h
- 20 mm/h

frequency	22 GHz
max. drop radius	5 mm
simulation steps	2300
sampling rate	12.5 kHz
terminal velocity	*Gunn-Kinzer*
rain statistics	*Marshall-Palmer*
rain drops total	~ 6 Million

Conclusion

➢ design of versatile software tool to model electromagnetic propagation through precipitation

➢ flexibility concerning

➢ rain statistics

➢ scattering model

➢ modelled volume

➢ obtain $\vec{E}$ field vector in time domain (Doppler noise)

➢ Post-processing results:

➢ Cross polarization from offside drops around -60 dB

➢ Doppler broadening increases with rain rate