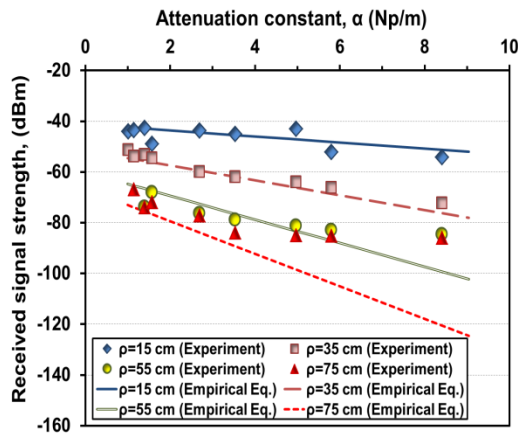


Signal Propagation Model



S. Yoon, L. Cheng, E. Ghazanfari, S. Pamukcu, and M. T. Suleiman, A radio propagation model for wireless underground sensor networks, in *Proc. of IEEE Globecom*, Houston, TX, Dec. 2011.



$$P_r/P_t = K \frac{e^{-2\alpha\rho}}{\rho^2}$$

$$\alpha = \omega \sqrt{\frac{\mu\epsilon}{2} \left[\sqrt{1 + \left(\frac{\sigma}{\omega\epsilon}\right)^2} - 1 \right]}$$

$$K = \frac{A_{eff}}{2|\eta|} \cos \theta_n \left[\frac{I d s \mu \omega}{4\pi} \right]^2$$

θ (phase angle of Intrin. Imped. η)	$\eta = \eta e^{i\theta}$
σ (electrical conductivity, mS/m)	24 - 123
ϵ (relative permittivity)	15 - 30
μ (magnetic permeability, H/m)	$\mu = 4\pi \times 10^{-7}$
c (light speed, m/sec)	$c = 3 \times 10^8$
f (frequency, Hz)	$f = 2.4 \times 10^9$
ω (angular frequency, radians/s)	$\omega = 2\pi \times f$ ($= 1.5 \times 10^{10}$)
λ (wave length, m)	$\lambda = c/f$
d_s (whip antenna length, m)	$d_s = \lambda/4$
A_{eff} (effective antenna area, m ²)	$A_{eff} = 1.64 \times \lambda^2 / (4 \times \pi)$
I (current, A)	$I = 10^{-3}$ Watt / 3 Volt

Experiments

S. Yoon, E. Ghazanfari, L. Cheng, S. Pamukcu, M. T. Suleiman, Subsurface event detection and classification using wireless signal networks, *Sensors*, Vol. 12, No. 11, 2012.

