Speck NET

Research Consortium in Speckled Computing

Channel Estimation for Specknet

Faisal Darbari
Supervised by
Prof R.W.Stewart, I.A.Glover
University of Strathclyde
Glasgow

The University of Edinburgh
University of Glasgow
Napier University Edinburgh
University of Strathclyde
University of St Andrews

Objective

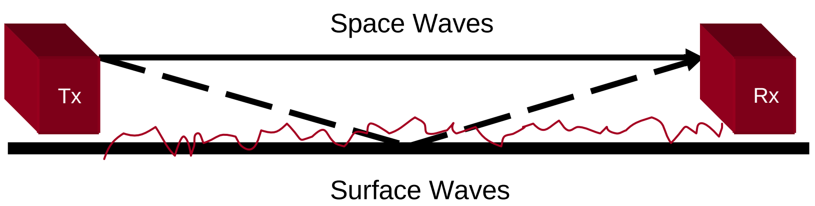
- **Wireless Channel Modeling:**
  - **Radio Propagation and Prediction for Speck Network**
  - **Estimating the Fading Model**
  - **Received Signal to Interference Ratio**
    - **Deployment Strategies**
    - **Antenna Characteristic**
    - **Media Access Methods (CSMA/CA)**
  - **Proposed Channel Model**
    - **Bit Error Rate**

Consideration for channel modelling

The presence of ground modifies the generation and propagation of radio waves so the received power is less than what would be expected

Electrical Properties (Ground):

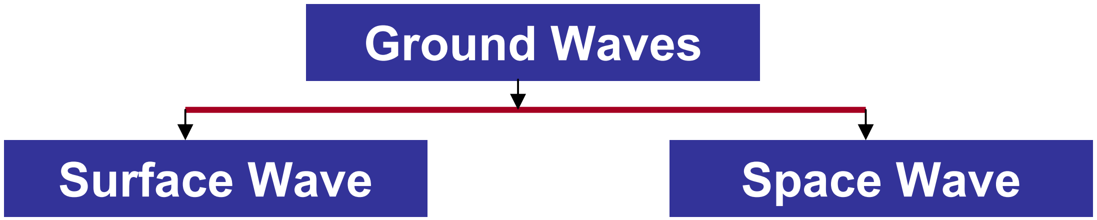
- Relative Permeability
- Dielectric Constant
- Conductivity



Equation for Wave Propagation:

$$E = 1 + Re^{jw} + (1-R)Ae^{jw}$$

(Direct Path) (Reflected Path) (Surface Waves)

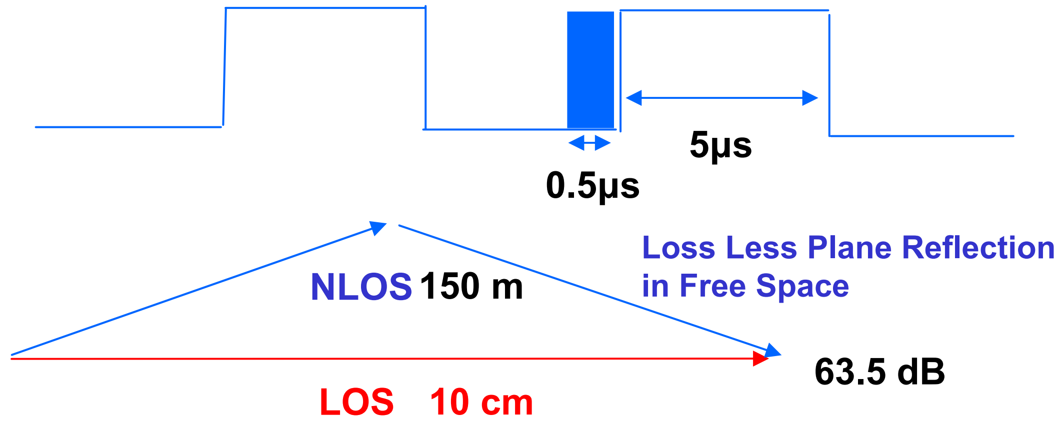


Sequence of Presentation

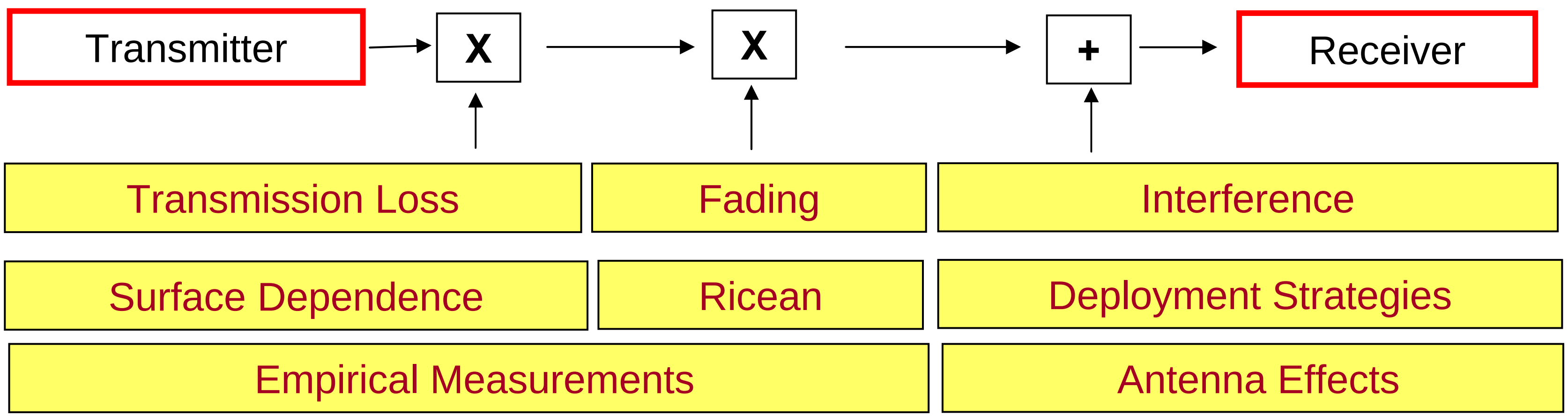
- Proposed Channel Model
- Empirical Measurements
  - Path Loss Measurement
    - Relative to distance and height of transmitting and receiving antennas
  - Fading Model
- Effect of (CSMA) Inhibition Distance on Received Signal to Interference Ratio
- Conclusion and Future Consideration

Channel Modelling

Broadband channel model requires only if channel delay spread is significant fraction of symbol duration.

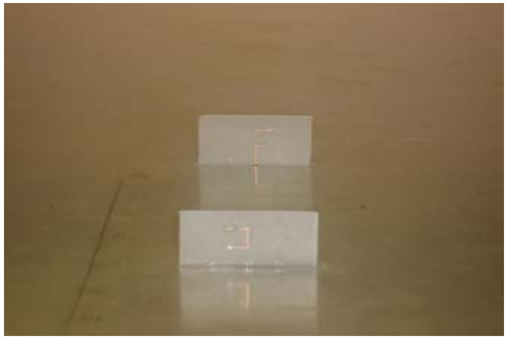


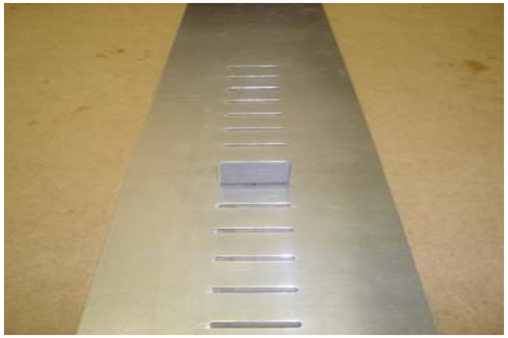
Narrowband channel subject to flat fading

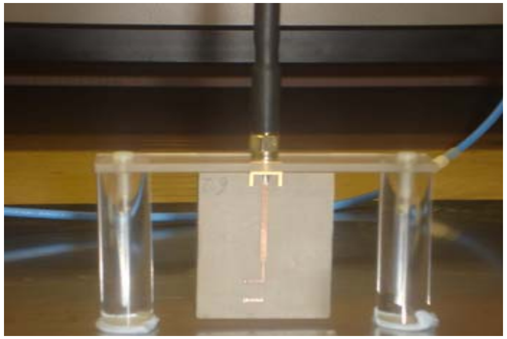


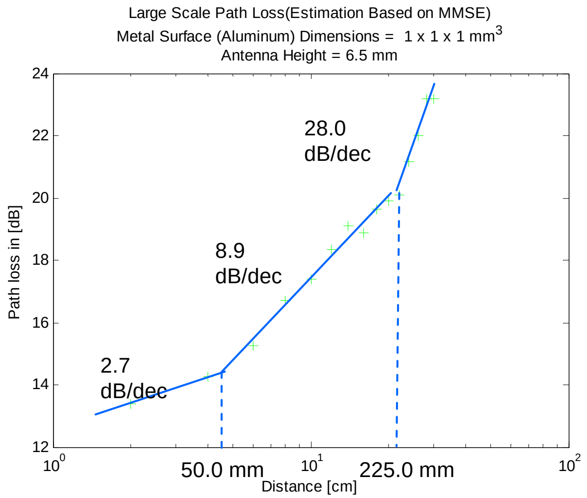
Channel Modelling (Transmission Loss (measurements)

Measurements with varying antenna heights, separation distance, ground surfaces





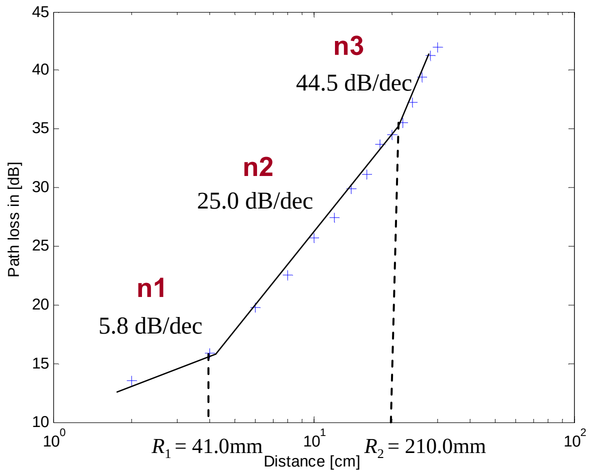




$$L(\mathrm{dB}) = \begin{cases} K + 10 n_1 \log_{10}\left(\dfrac{R}{R_1}\right), & \text{for} \quad R \le R_1 \\ K + 10 n_2 \log_{10}\left(\dfrac{R}{R_1}\right), & \text{for} \quad R_1 \le R \le R_2 \\ K + 10 n_2 \log_{10}\left(\dfrac{R_2}{R_1}\right) + 10 n_3 \log_{10}\left(\dfrac{R}{R_2}\right), & \text{for} \quad R \ge R_2 \end{cases}$$

Observations

1. Generally low values of *n*1 are thought to be due to non-radiating near-field coupling between Tx and Rx antennas.
2. The values of *n*3 are generally close to 4.0 as expected for far-field ranges greater than the farthest point of constructive interference over a plane reflective surface

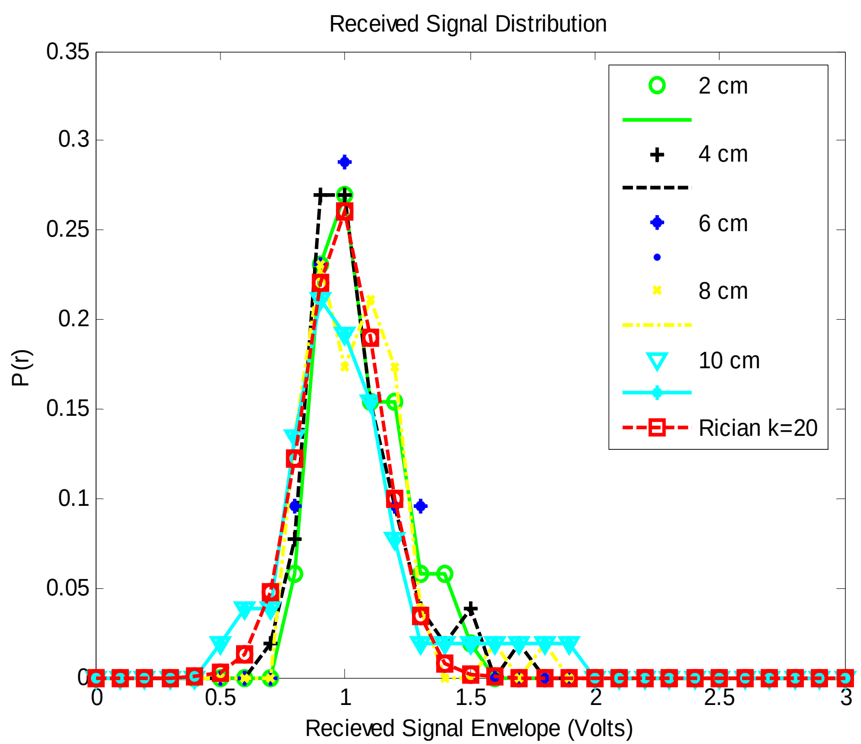


3. Near-field coupling between antenna and surface launches a surface wave which dominates in the intermediate region (between R1 and R2)
4. A decreasing value of n2 with increasing antenna height above the surface is also consistent with a surface wave interpretation; a decrease in coupling resulting in a decrease in the relative strength of the surface wave.

Since wireless nodes will be communicating close to the ground plane it will result in three independent mode of operations, that could result in higher value of path loss index due to I^2 R losses.

Channel Modelling (Fading Model)

- An empirical fading model has been derived by making many independent measurements for each transmitter-receiver path length
- The test-bench was displaced by at least one wavelength between measurements.



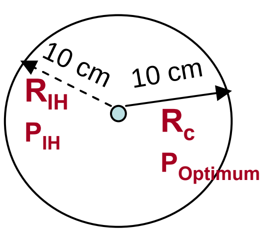
Channel Modelling (Interference)

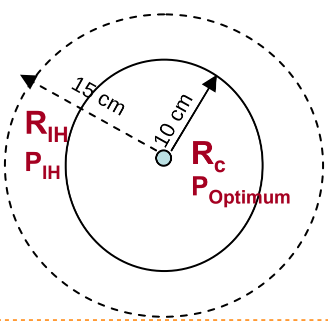
- Asynchronous sensor networks use (CSMA/CA) as the MAC protocol
  - Inhibition distance
  - Antenna characteristic (including polarization)
  - Node deployment strategies
- CSMA/CA based networks could be defined by two radiuses
  - Communication radius (Rc) is the max range between the communicating Nodes in the absence of interference or minimum/optimum power ($P_{optimum}$) required to drive the receiver
  - Inhibition radius (R_{IH}, which is called Inhibition distance) is defined as the range within which a node is inhibited by a transmitting node or minimum power required for an inhibition threshold (P_{IH})

Case I

Inhibition Distance = 10 cm

$P_{IH} = P_{Optimum}$





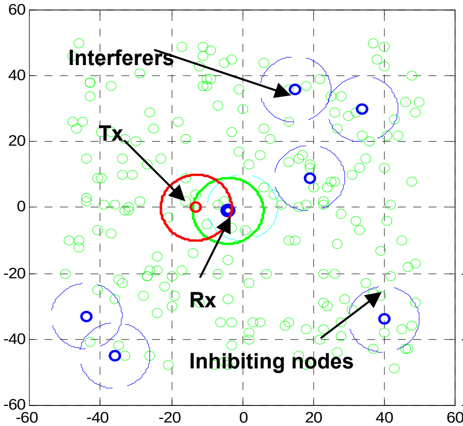
Case II

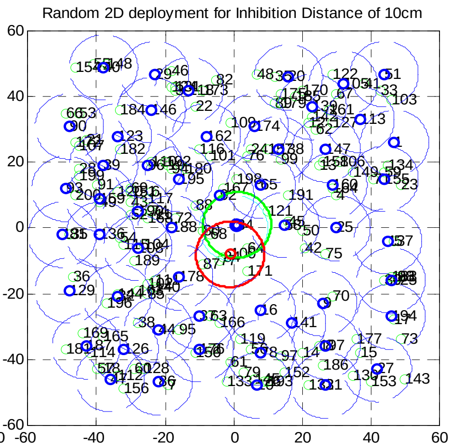
Inhibition Distance = 15 cm

$P_{IH} = 2.6\ P_{Optimum}$

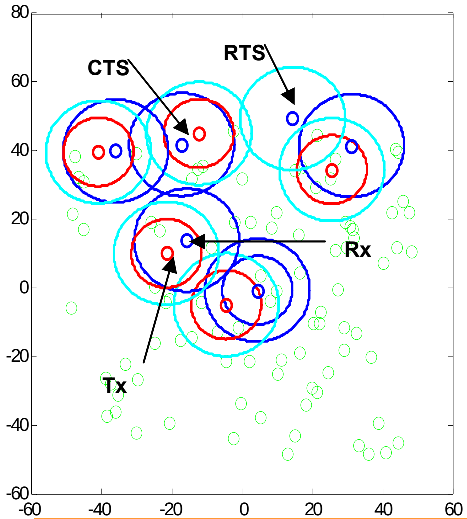
Channel Modelling (Interference)

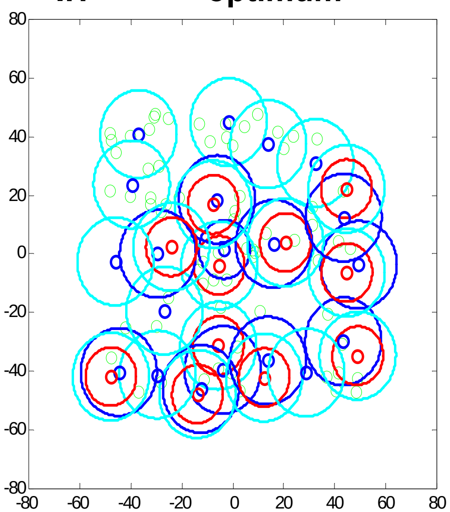
Case 1: $R_{IH} = R_c$ $(P_{IH} = P_{optimum})$





Case 2: $R_{IH} = X.R_c$ $(P_{IH} = X\, P_{optimum})$

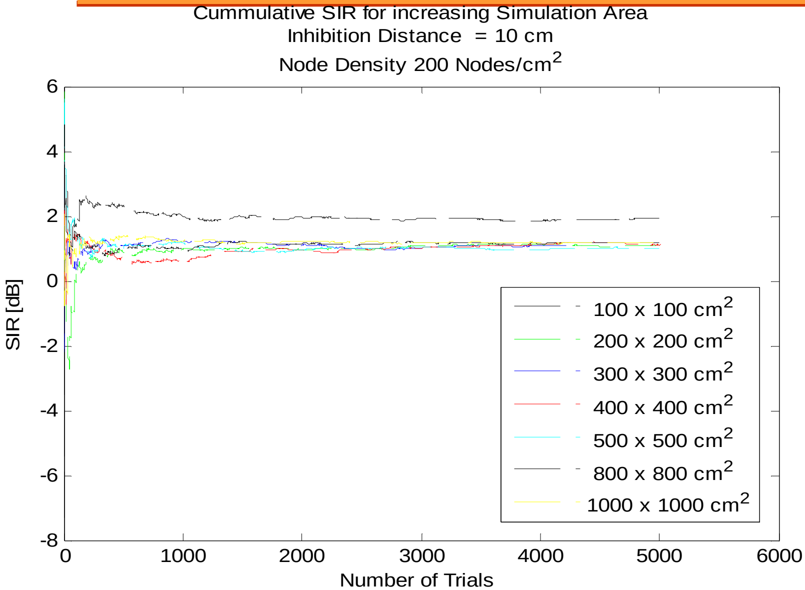




Inhibition distance (R_{IH}) [cm]	10, 15, 20, 25, 30, 35, 40
Simulation space	200 cm x 200 cm
Mean speck density [/m^2]	200
Deployment	2-D, Poisson distributed
MAC protocol	CSMA/CA
Antenna	Dipole
Polarization	Vertical
Path loss model	Measurement

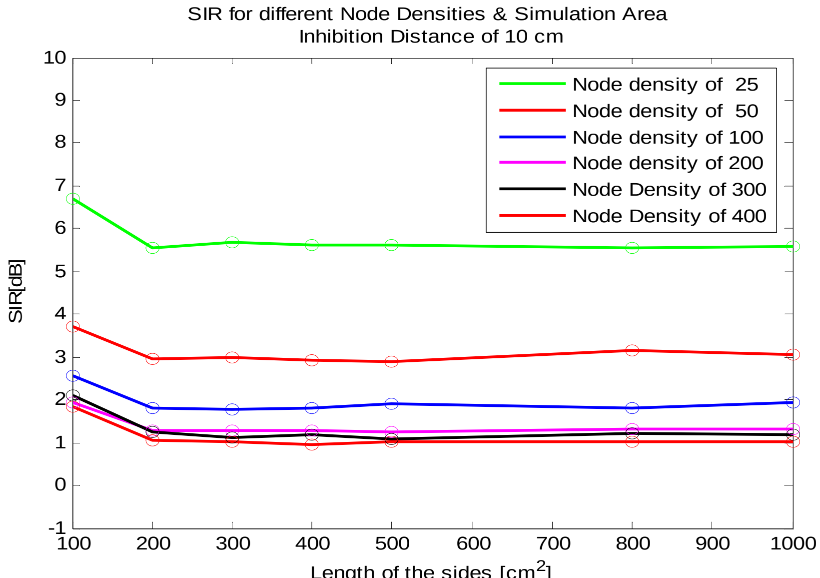
$$I = \sum_{k=1}^{N} G_T I_k \quad \longrightarrow \quad SIR = \frac{P_T - L}{I}$$

Density Dimensioning



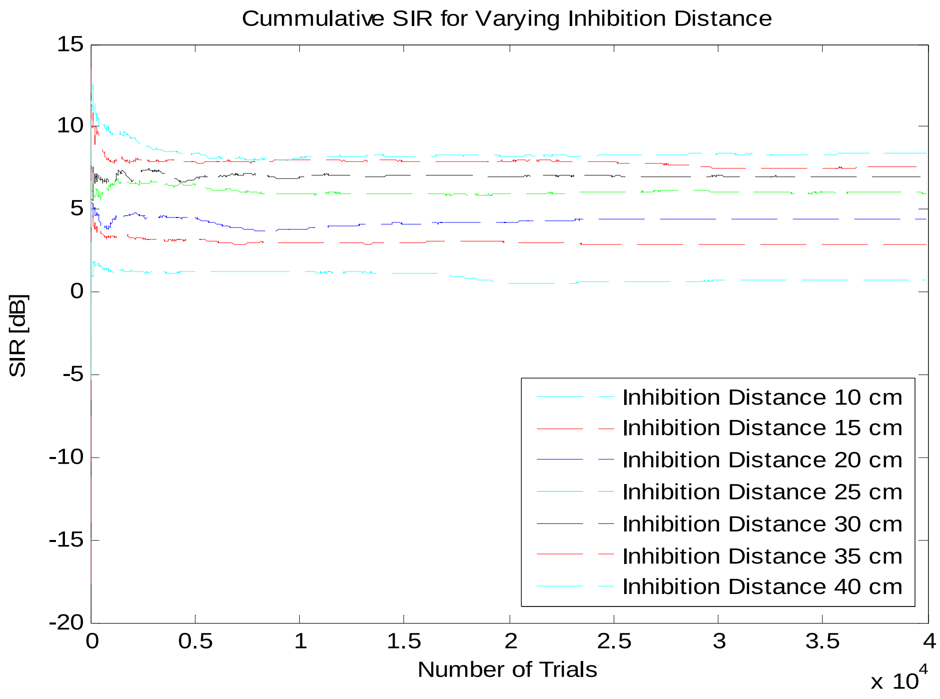
Simulation area [cm^2]	SIR [dB]	SIR increment [dB[
100 × 100	1.94	A
200 × 200	1.10	-0.84
300 × 300	1.09	-0.01
400 × 400	1.11	+0.02
500 × 500	1.13	-0.02
800 × 800	1.15	-0.02
1000 × 1000	1.14	+0.01

The table, together with Figure, suggests that a space of 200cm × 200cm gives a result close to (i.e. within the statistical noise of) that for and infinite plane



A constant inhibition distance excludes an increasing proportion of specks as their density increases. Beyond a speck density of 200 /m^2 there is only a small (0.12 dB) decrease in SNR as the SIR converges to that for an infinite speck density.

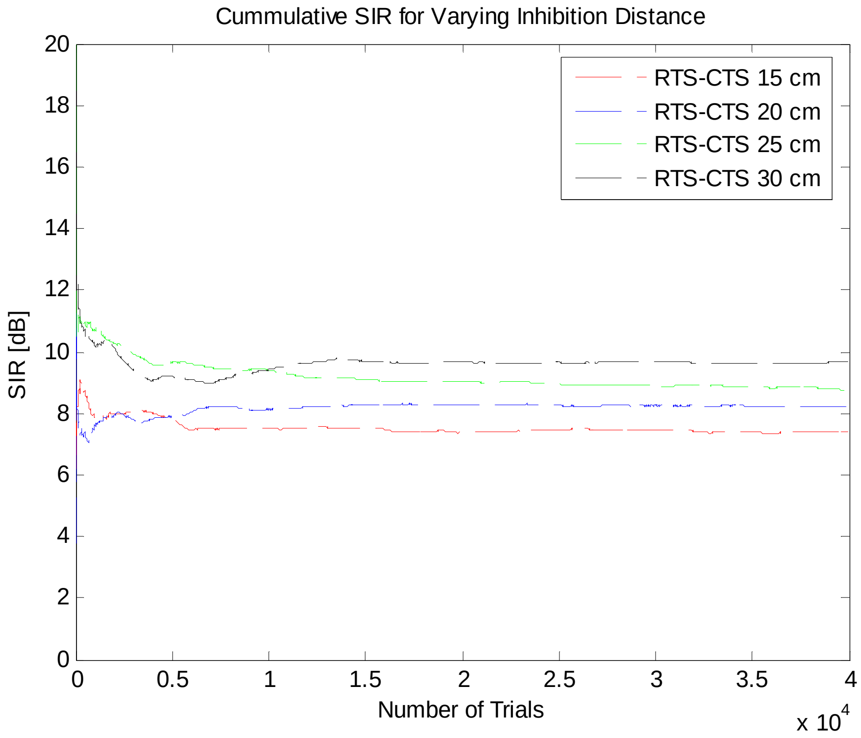
Results (case # I)



Inhibition Distance R_s[cm]	SIR [dB]	Improvement in SIR with respect to the inhibition distance (R_{IH}= R_s). [dB]
10	1.00	NA
15	2.90	1.9
20	4.50	1.6
25	5.90	1.4
30	7.0	1.1
35	7.7	0.7
40	8.3	0.6

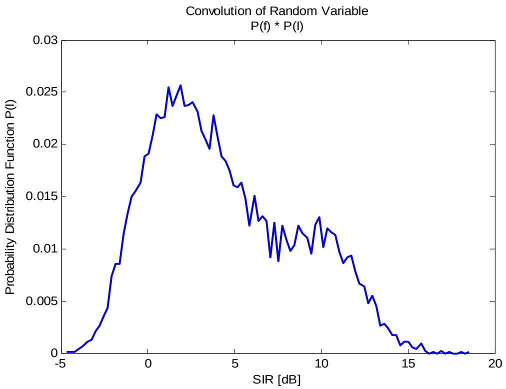
SIR improvement is significant for inhibition distance changes from 10 cm to 15 cm, and from 15 cm to 20 cm. Further increases in inhibition distance result in diminishing SIR returns

Results (case # II)

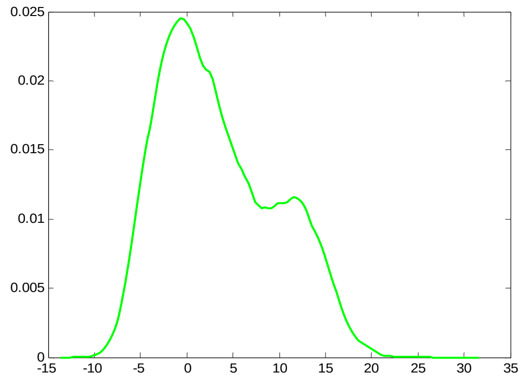


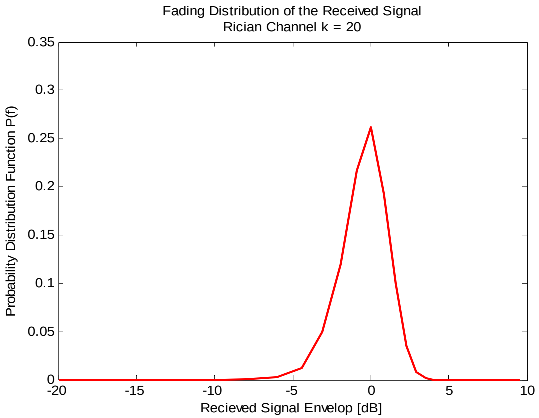
Inhibition Distance R_{Ih} [cm]	SIR [dB]	Improvement in SIR with respect to the inhibition distance [dB]
10	1.00	NA ($P_{Ih} = P_{Optimum}$)
15	7.40	6.40 ($P_{Ih} = 2.60 P_{Optimum}$)
20	8.25	0.85 ($P_{Ih} = 5.27 P_{Optimum}$)
25	8.70	0.45 ($P_{Ih} = 9.06 P_{Optimum}$)
30	9.10	0.40 ($P_{Ih} = 14.0 P_{Optimum}$)

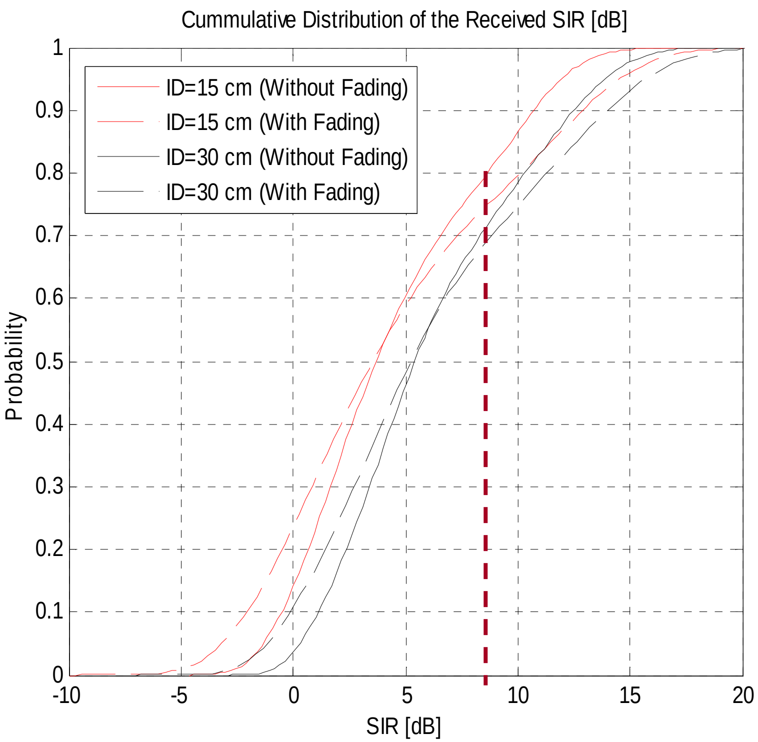
Incorporating Fading in Channel Model



Convolution







80% of time SIR is better than 8 dBs

Improvement in BER (OOK Modulation)

Link Budget Calculation (OOK Modulation)

	Case I	Case II
Communication Range (R_c)	10	10
Inhibition Distance [cm]	10	15
SIR [dB]	1	7.40
Energy [mW]	9.9	xxx
BER	0.30	0.01

Energy Consumption

$E_{SpeckMACD-I} = E_{SpeckMACD-TX-RX}$ Case I

$E_{SpeckMACD-II} = E_{SpeckMACD-RTS} + E_{SpeckMACD-CTS} + E_{SpeckMACD-TX-RX}$ Case II

Conclusion and Future Work

- The study links node density, deployment and CSMA inhibition distance to (worst case) expected SIR
- Sensor nodes in future will be small and will be deployed close to ground surface may result in ‘Surface waves’ that could result in higher value of path loss
- An appropriate selection of inhibition distance (i.e. R_{IH}) results in improved SIR
- Effect of antenna polarization on received signal to interference ration.
- Dependence of ‘Surface wave’ on antenna polarization

Inhibition Radius [cm]	Power [W]
15	$P_{Ih} = 2.6P_{Optimum}$
20	$P_{Ih} = 5.2P_{Optimum}$
25	$P_{Ih} = 9.0P_{Optimum}$
30	$P_{Ih} = 14P_{Optimum}$