

# Ασύρματες Επικοινωνίες

Τμήμα Πληροφορικής και Τηλεπικοινωνιών

Πανεπιστημίου Πελοποννήσου

Αναπλ.Καθηγ. Γ. Αθανασιάδου

[gathanas@uop.gr](mailto:gathanas@uop.gr)

Εργαστήριο Ασυρμάτων και Κινητών Επικοινωνιών

[wmclab.uop.gr](http://wmclab.uop.gr)

**Ντετερμινιστικά Μοντέλα Διάδοσης  
Τεχνική Ανίχνευσης Ακτινών**

# Ντετερμινιστικές Τεχνικές

- Τα ντετερμινιστικά μοντέλα για την πρόβλεψη της απώλειας διαδρομής βασίζονται στη θεωρία της ηλεκτρομαγνητικής διάδοσης. Σε αντίθεση με τα εμπειρικά μοντέλα δεν χρησιμοποιούν εκτεταμένες μεθόδους μέτρησης αλλά βασίζονται στη λεπτομερή γνώση της μορφολογίας του περιβάλλοντος που οδηγεί στην ακριβή πρόγνωση της διάδοσης του σήματος.

# ΝΤΕΤΕΡΜΙΝΙΣΤΙΚΕΣ ΤΕΧΝΙΚΕΣ

## 1. Ray Tracing τεχνική

- Η τεχνική Ray Tracing βασίζεται στην γεωμετρική οπτική (Geometrical Optics). Η GO θεωρεί πώς η ενέργεια διαδίδεται σε πολύ μικρές δέσμες, τις λεγόμενες ακτίνες. Οι ακτίνες εκτοξεύονται από τον πομπό και στην συνέχεια αλληλεπιδρούν με το περιβάλλον μέσω της ανάκλασης, της διάθλασης και της σκέδασης.
- Η Uniform Theory of Diffraction (UTD) εισάγει την έννοια των περιθλούμενων ακτινών που σκοπός τους είναι η εισαγωγή ορθών διορθώσεων στις περιοχές ασυνέχειας.

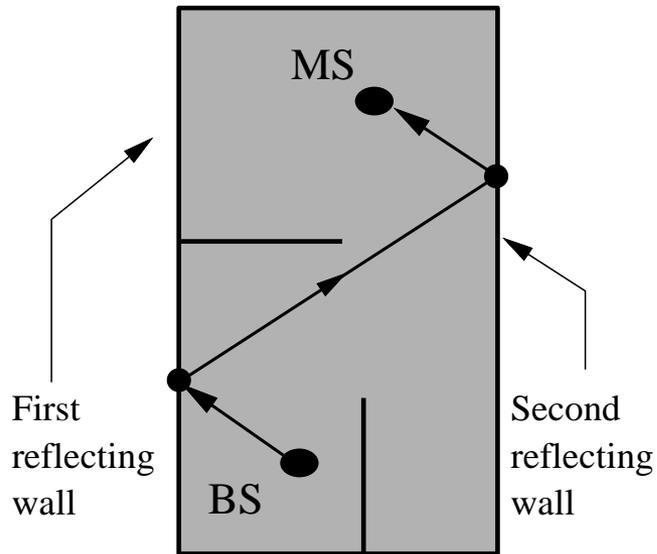
# ΝΤΕΤΕΡΜΙΝΙΣΤΙΚΕΣ Τεχνικές

## Image Method

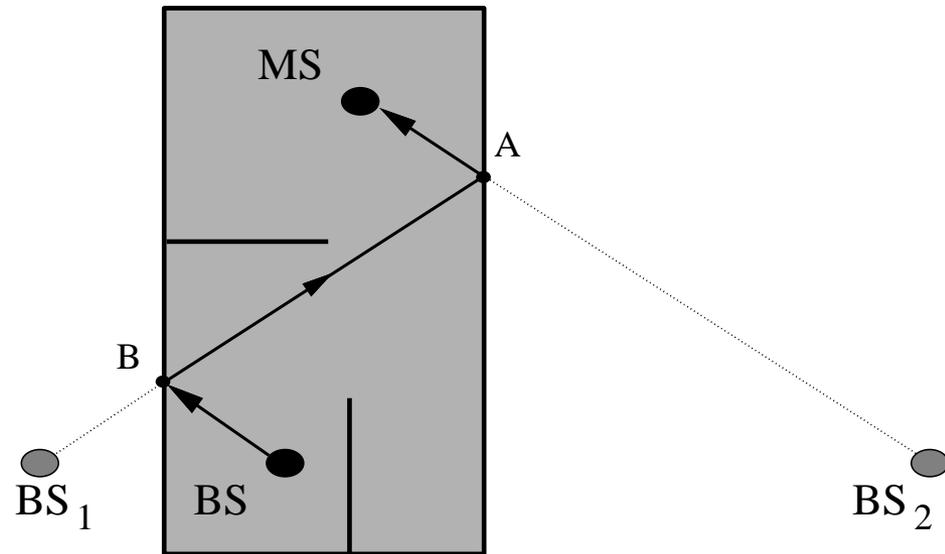
- Το Image Method δημιουργεί είδωλα (image) της πηγής σε σχέση με όλες τις επιφάνειες. Τα είδωλα αυτά εκτελούν καθήκοντα δευτερευόντων πηγών για τα διαδοχικά επίπεδα ανακλάσεων.
- Αν υπάρχουν  $N$  επίπεδα ανακλάσεων, θα υπάρχουν  $N$  είδωλα πηγής μιας ανάκλασης,  $N(N-1)$  είδωλα πηγών δύο ανακλάσεων,  $N(N-1)(N-1)$  είδωλα πηγών τριών ανακλάσεων κ.ο.κ.

# Image based Ray Tracing

A two reflection path

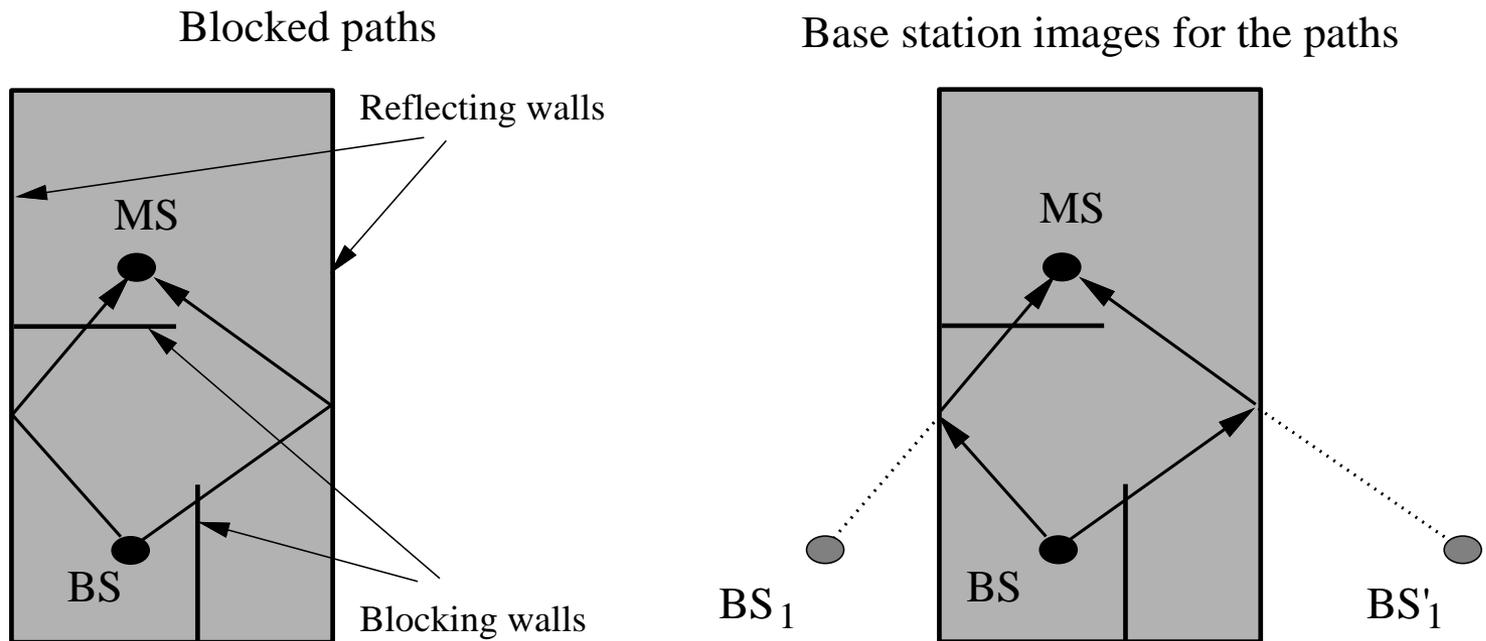


Base station images of the path



Representation of a reflection path by the ray tracing algorithm.

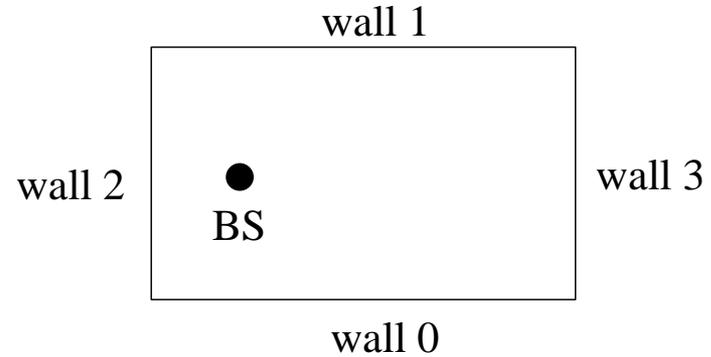
# Image based Ray Tracing



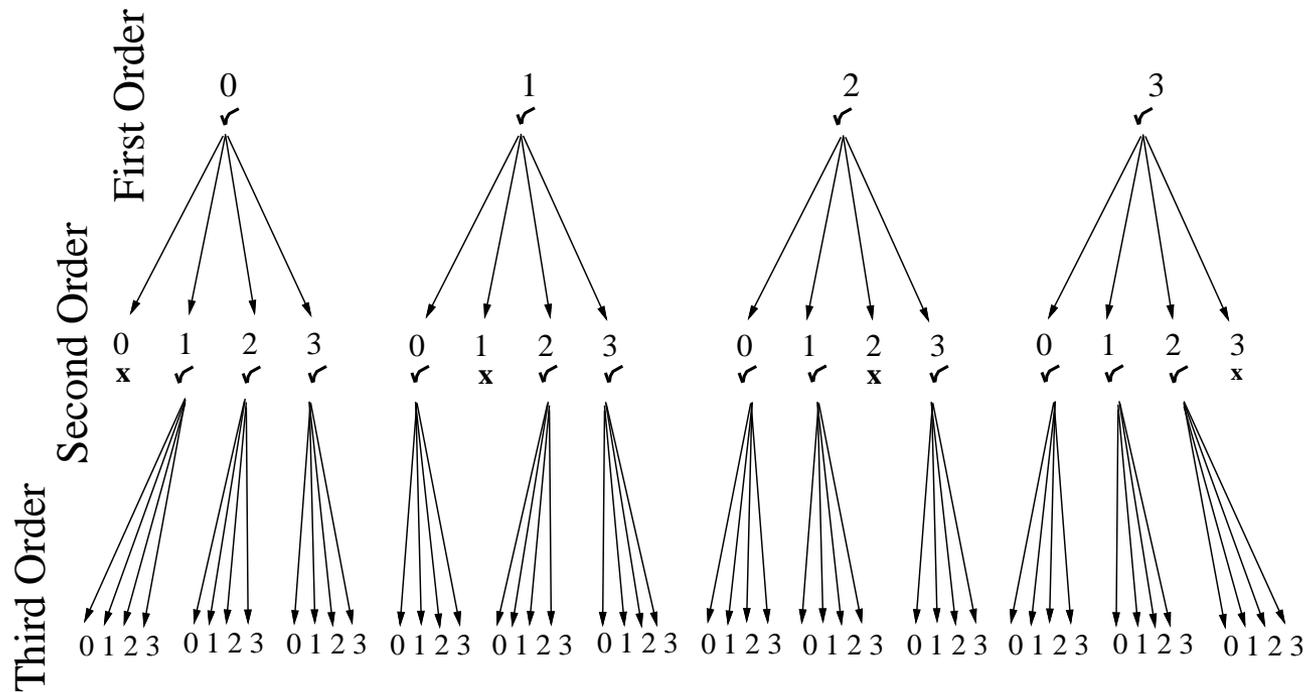
Representation of transmitted paths within the algorithm

# Image based RT - Image Tree

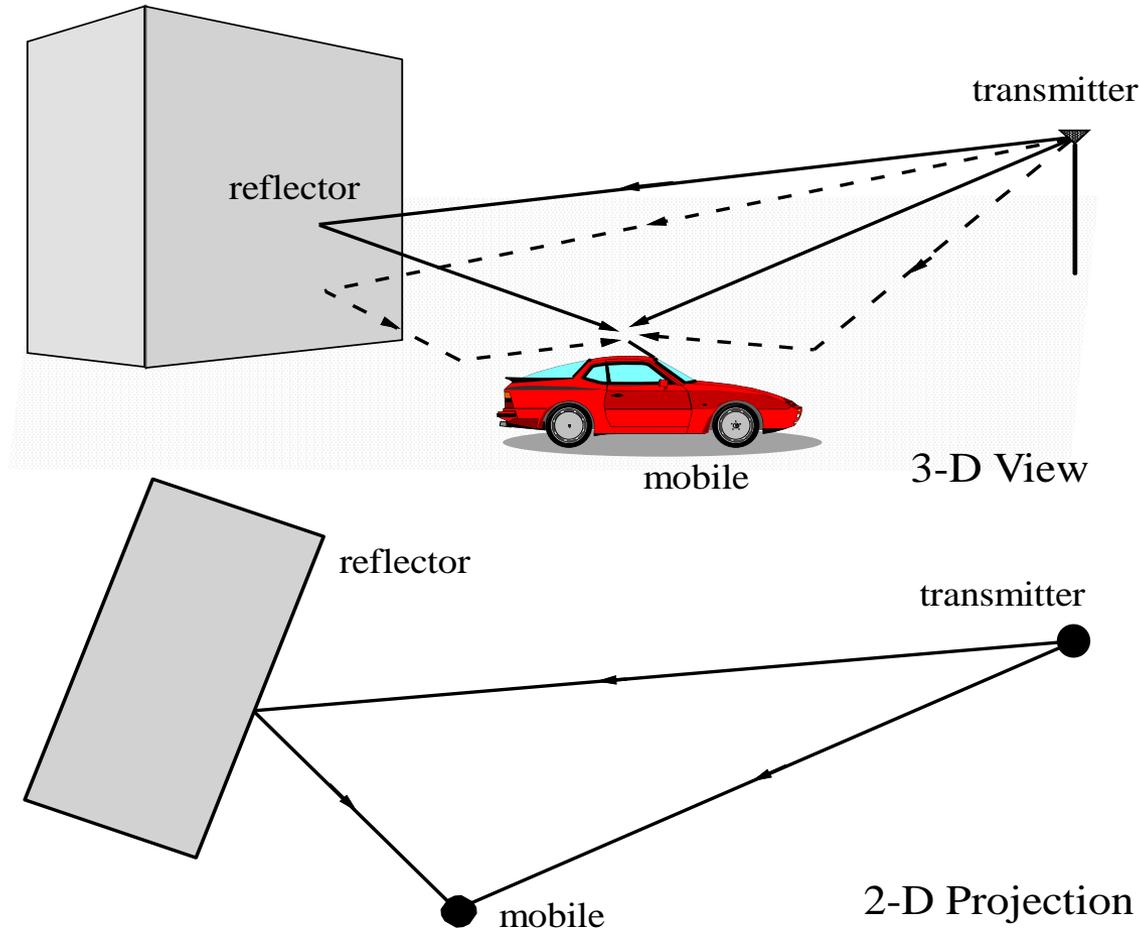
- ✓ Valid Image
- ✗ Not a Valid Image



## Permutations of Walls

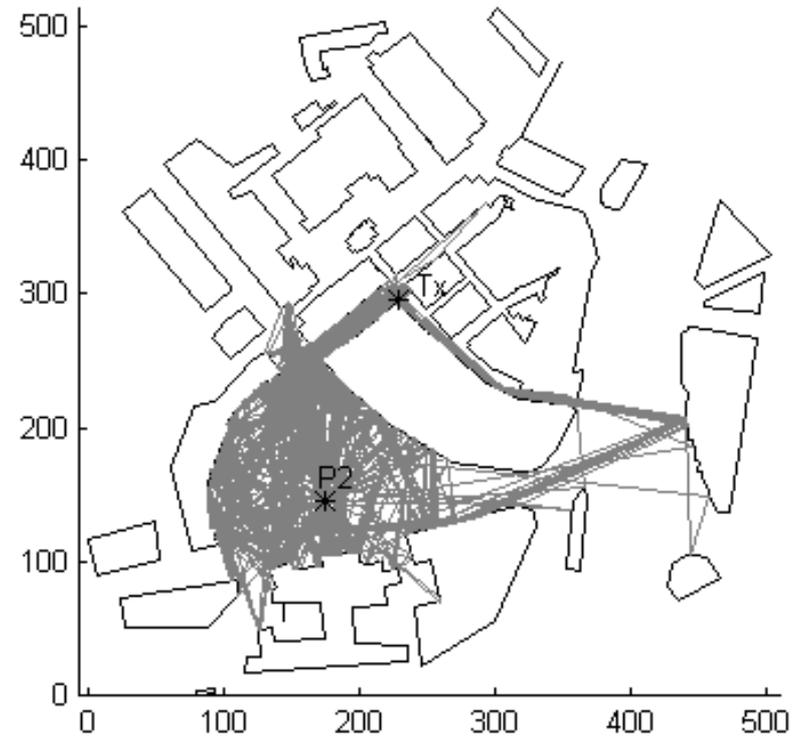
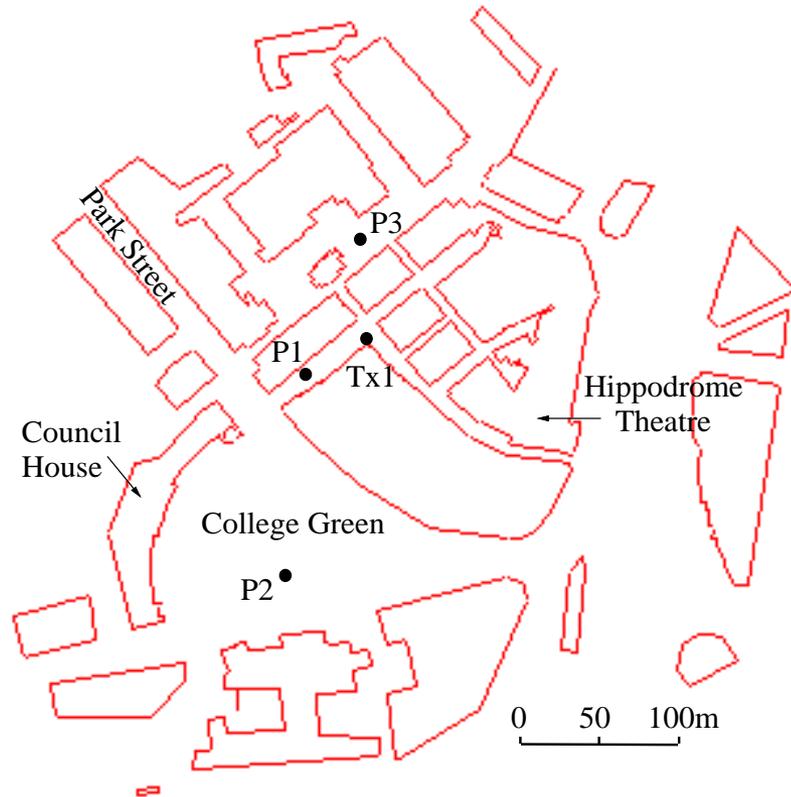


# Image based Ray Tracing



2Dimensional / 3Dimensional hybrid analysis

# Image based Ray Tracing



	Number of rays	Received power (dBm)	K-factor (dB)	RMS delay spread (nsec)
Point P1	4676	-32.96	-4.09	43.92
Point P2	2441	-69.36	-12.41	624.59
Point P3	301	-74.31	-6.27	295.66

# Ντετερμινιστικές Τεχνικές

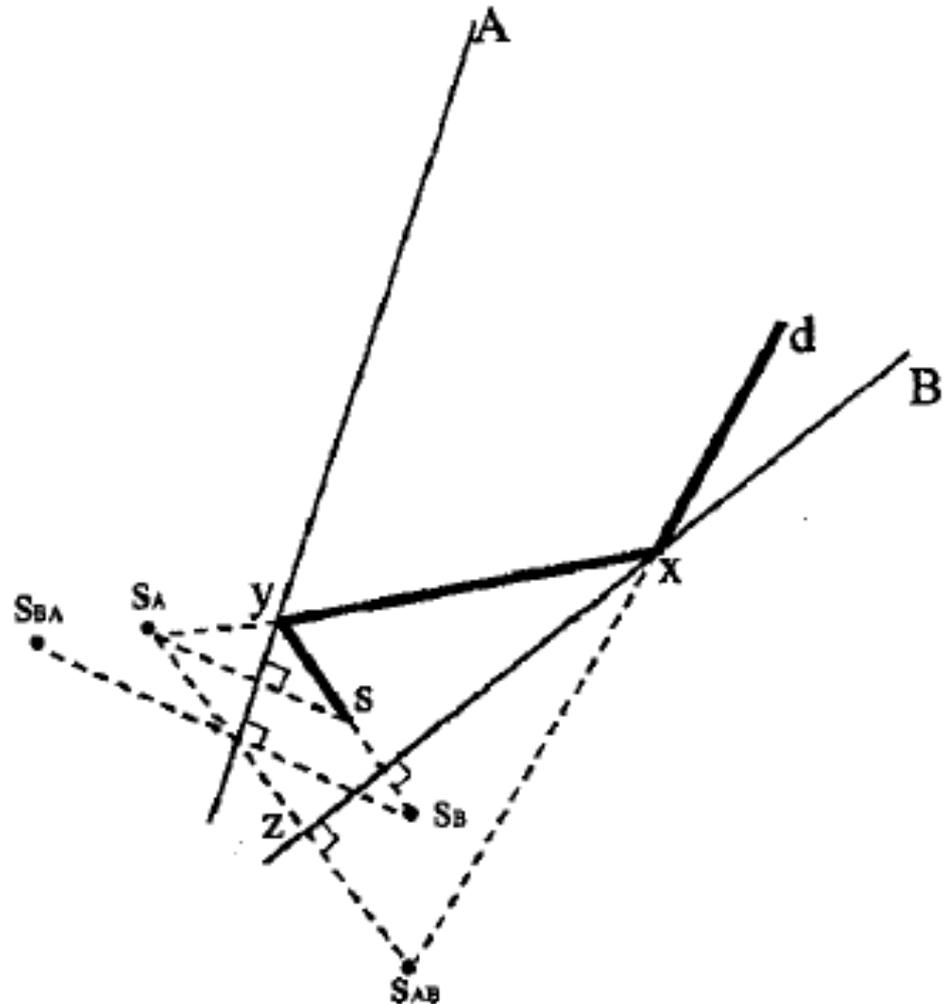
## Brute force ray tracing method – Ray Launching

- Αυτή η μέθοδος αποτελείται από ένα πλήθος από εκπεμπόμενες ακτίνες που μπορεί να φτάσουν στον παραλήπτη. Ο αριθμός των ακτινών που έχει υπολογιστεί και η απόσταση από τον πομπό στον παραλήπτη καθορίζει την διαθέσιμη ανάλυση χώρου και την ακρίβεια του μοντέλου.

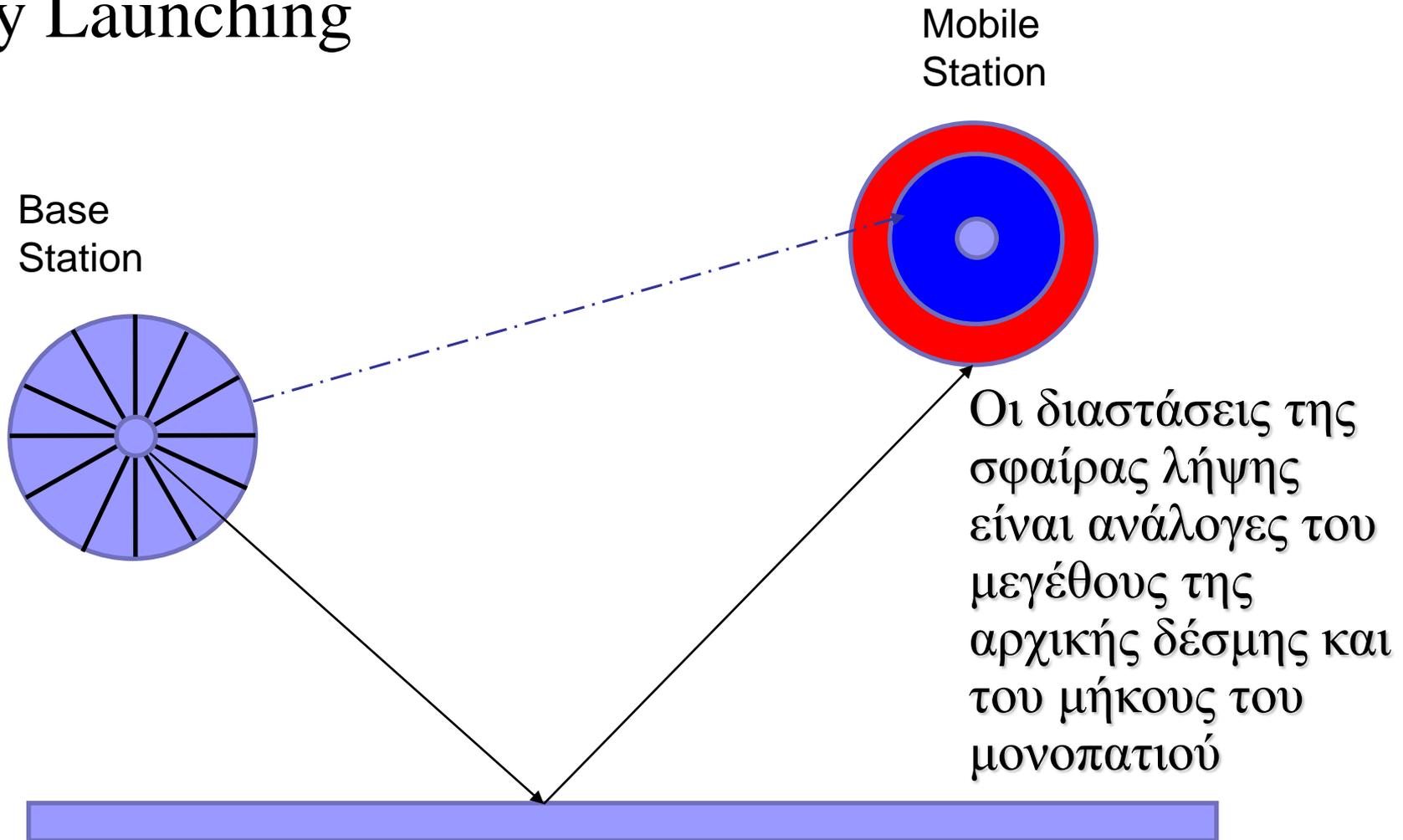
# ΝΤΕΤΕΡΜΙΝΙΣΤΙΚΕΣ Τεχνικές

## Ray Launching

Μια ακτίνα φεύγει προς κάθε κατεύθυνση. Αν η ακτίνα προσκρούσει σε ένα αντικείμενο τότε αναλύεται σε ανακλώμενη και διαθλώμενη. Αν προσκρούσει σε μια γωνία τότε προκύπτουν περιθλώμενες ακτίνες.



# Ray Launching



# An image based RT algorithm

- ✓ *Loading and processing the building, foliage and terrain databases*
- ✓ *Creating the AP image map*
- ✓ *For each CPE position all rays are traced in 3D*
- ✓ *Field calculations based on Geometrical Optics (GO) and Uniform Theory of Diffraction (UTD).*
- ✓ *Foliage attenuation is calculated as dB/m for the path length of each ray inside foliage.*
- ✓ *Channel characterization*



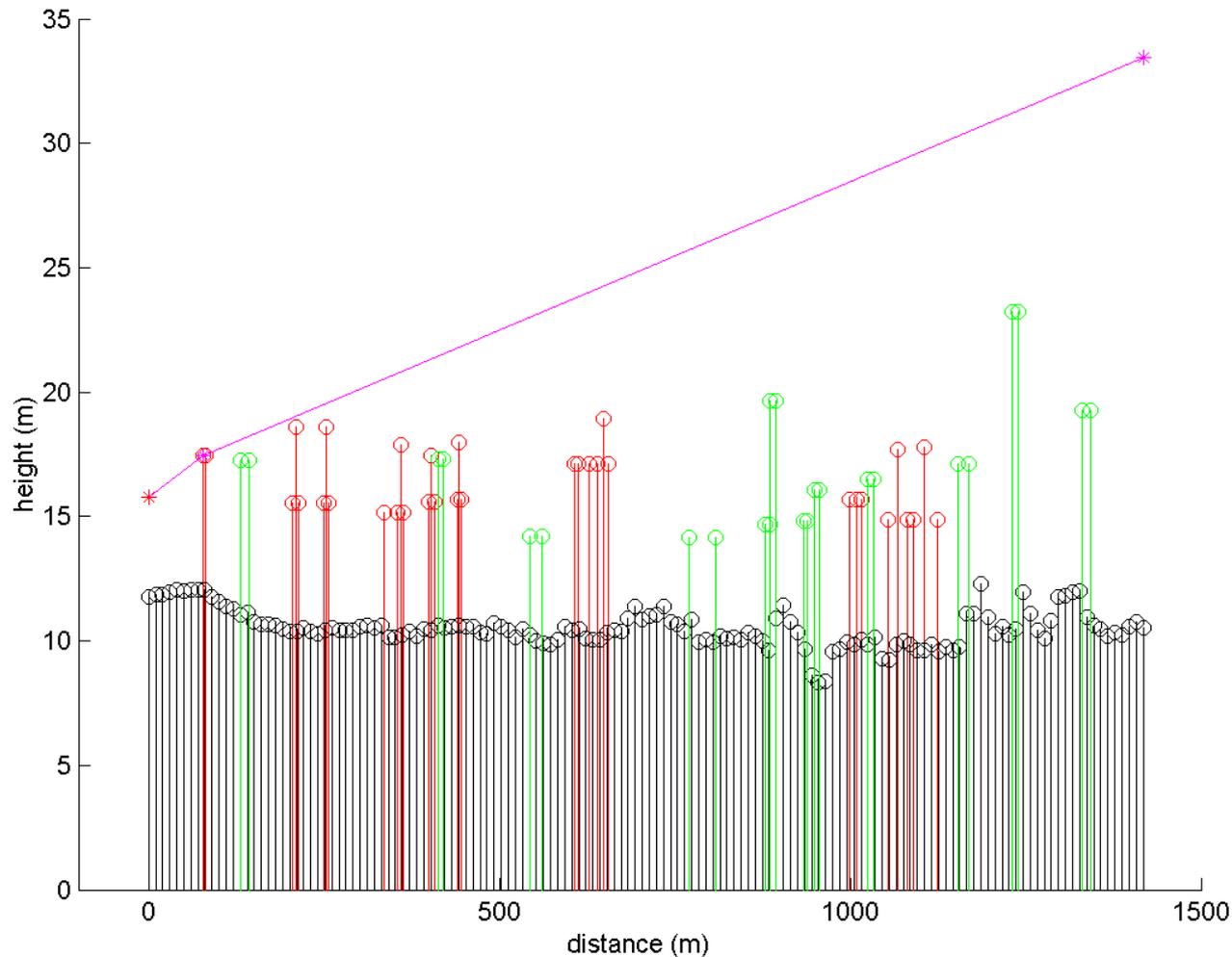
(1)

**Macrocellular (BFWA) scenario**

***central Cambridge***

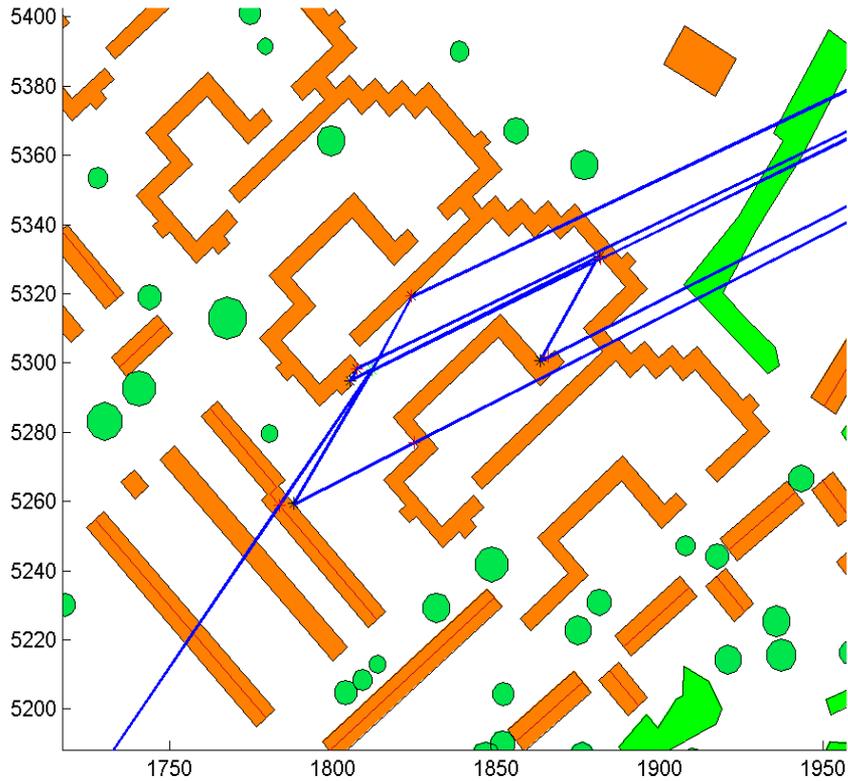


# Ray Tracing – Vertical Plane

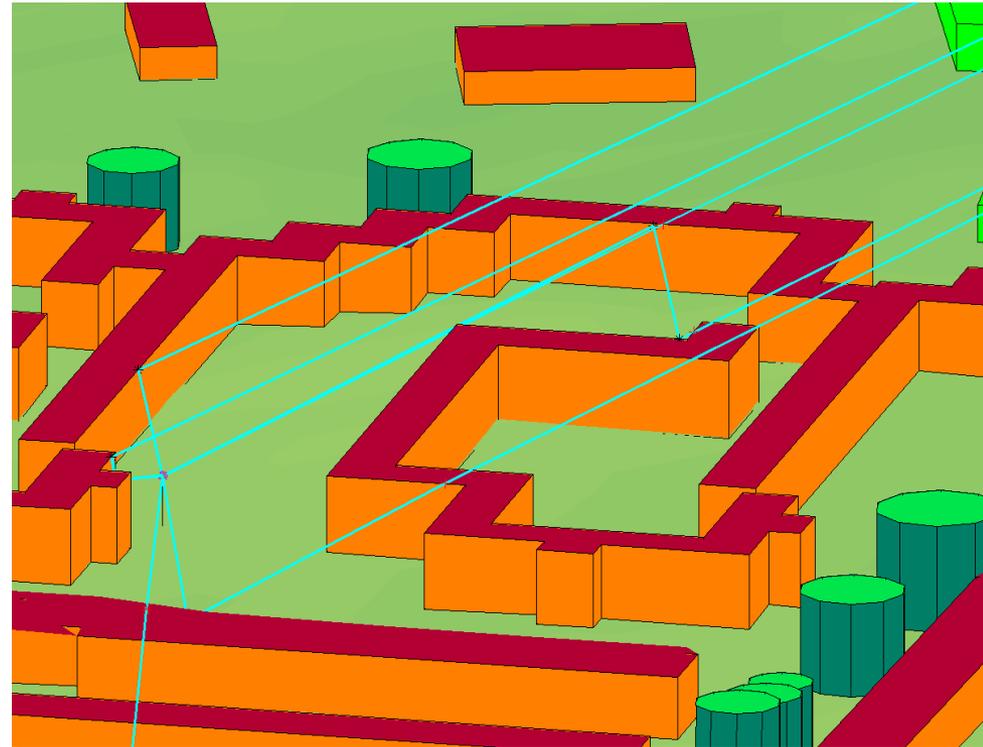


The building (red), vegetation (green) and terrain (black) points along the vertical cut between the two antennas.

# Ray Tracing

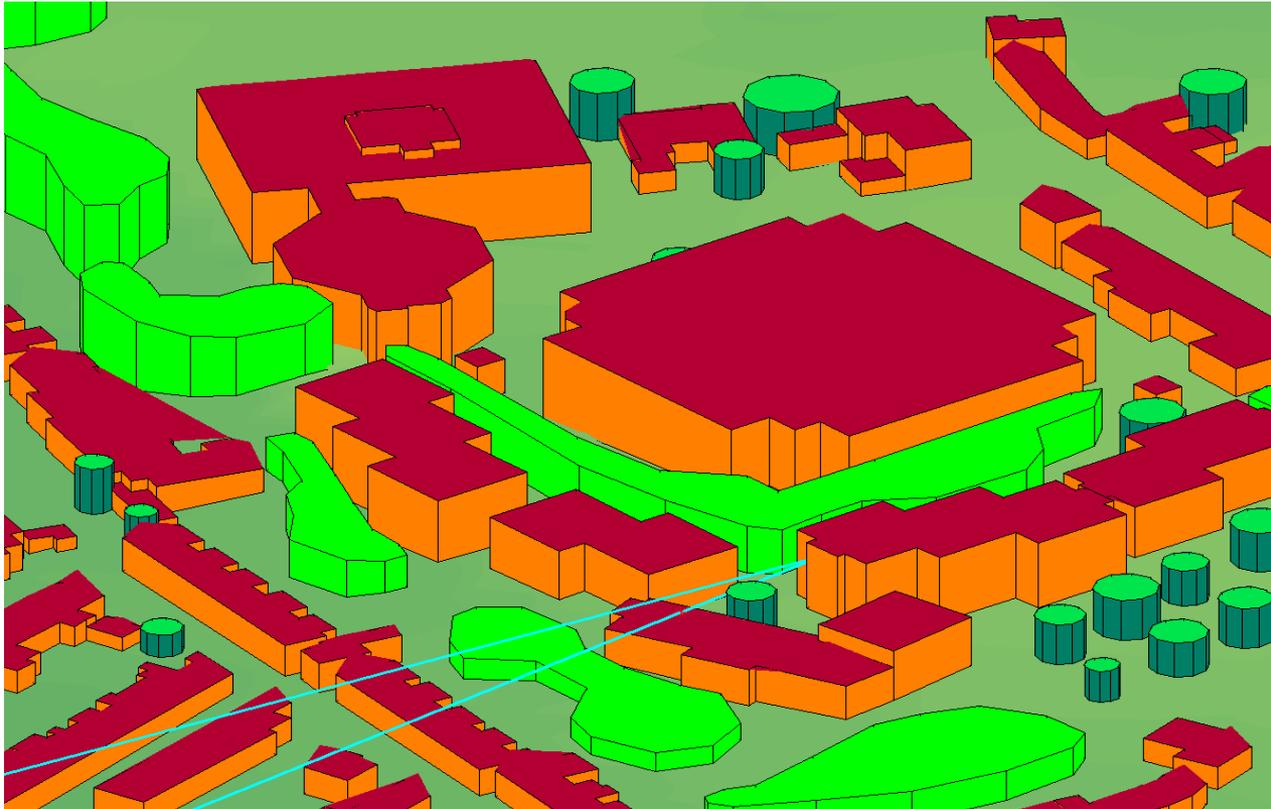


In 2 Dimensions



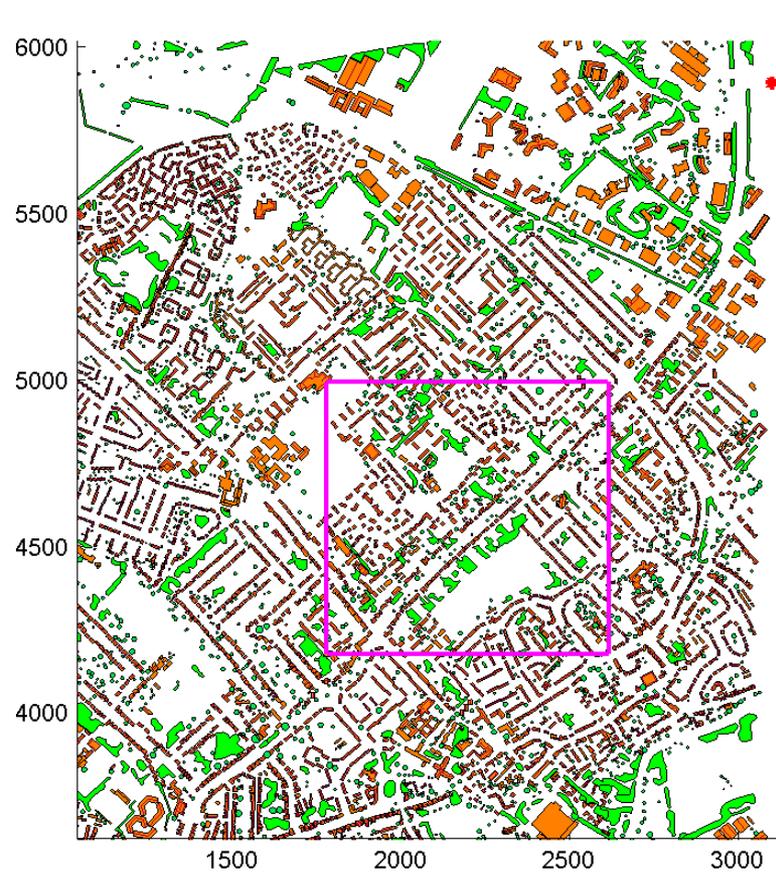
In 3 Dimensions

# Ray Tracing

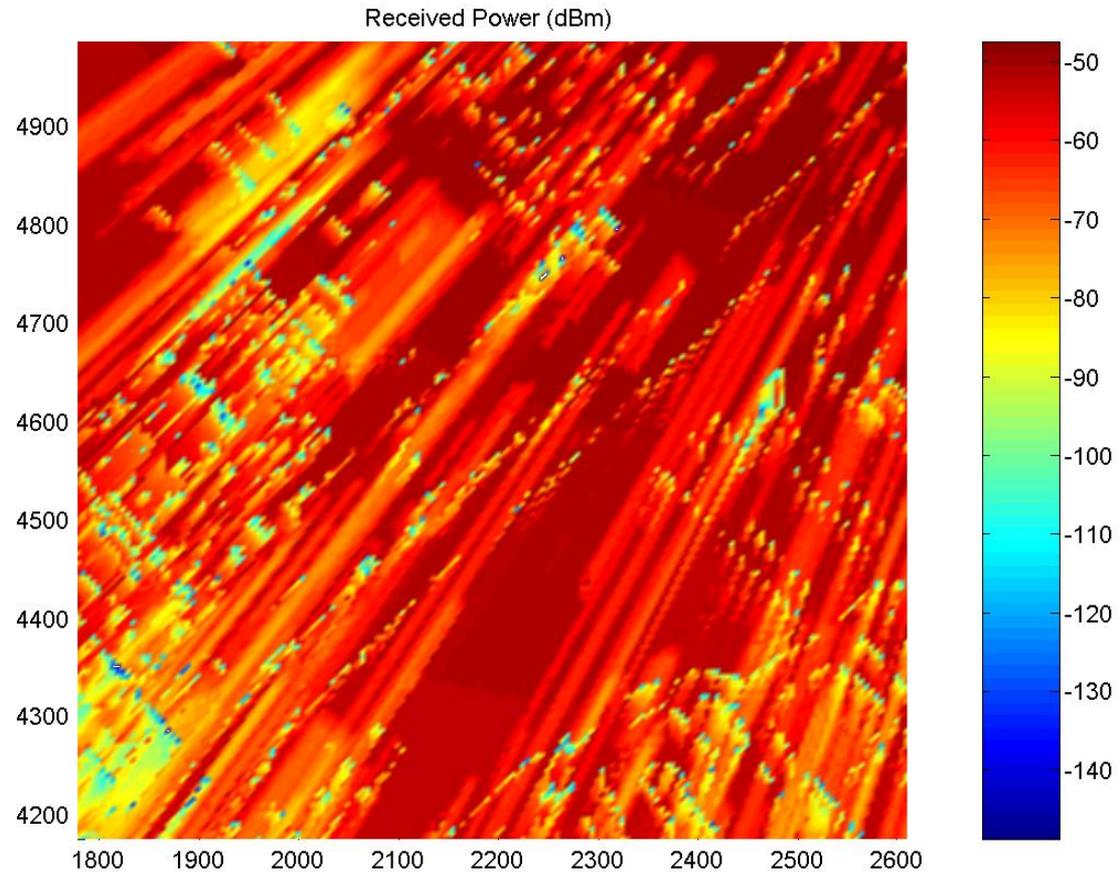


High and/or elevated buildings can cause reflections with long delays

# Ray Tracing Results



Area of Study

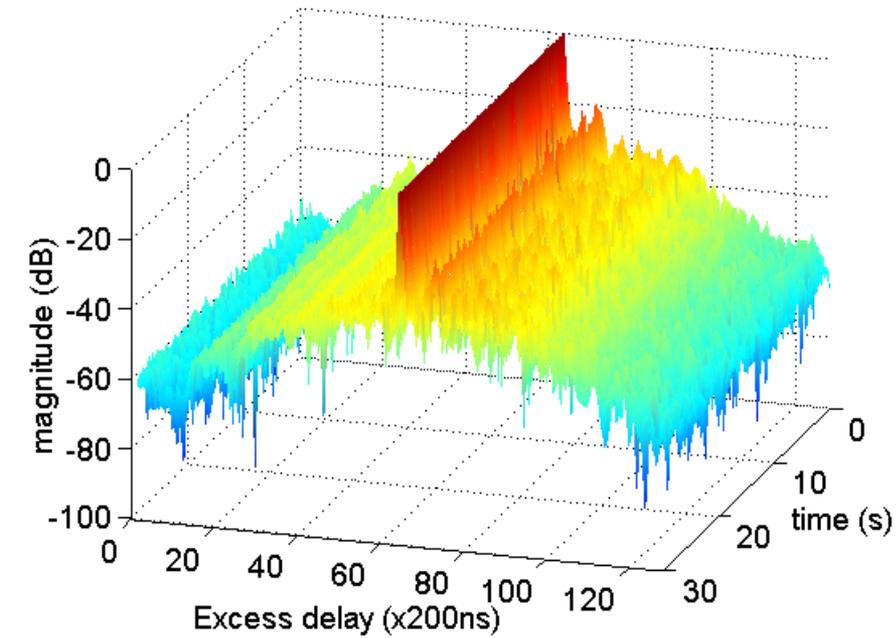


Received Power

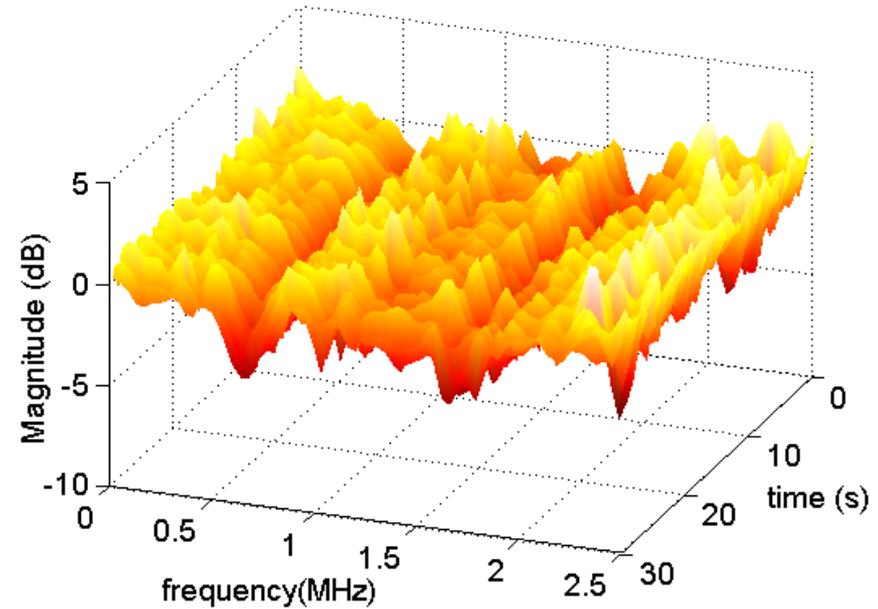
# Set-up of measurement campaign

- *Access Point position:* On top of tall buildings and hills
- *Access Point Antenna:* 4x1 patch antenna, 90° horizontal beamwidth
- *AP antenna directivity:* 16 dBi
- *CPE Antenna:* 3x3 patch antenna pointing towards the AP, 23° horizontal beamwidth
- *CPE antenna directivity:* 13 dBi
- *CPE antenna:* on a telescopic mast on top of a van
- *Polarisation:* RH Circular
- *Transmitted Power:* 29 dBm
- *Losses:* 3 dB
- *Frequency:* 3.5 GHz

# Field trial results

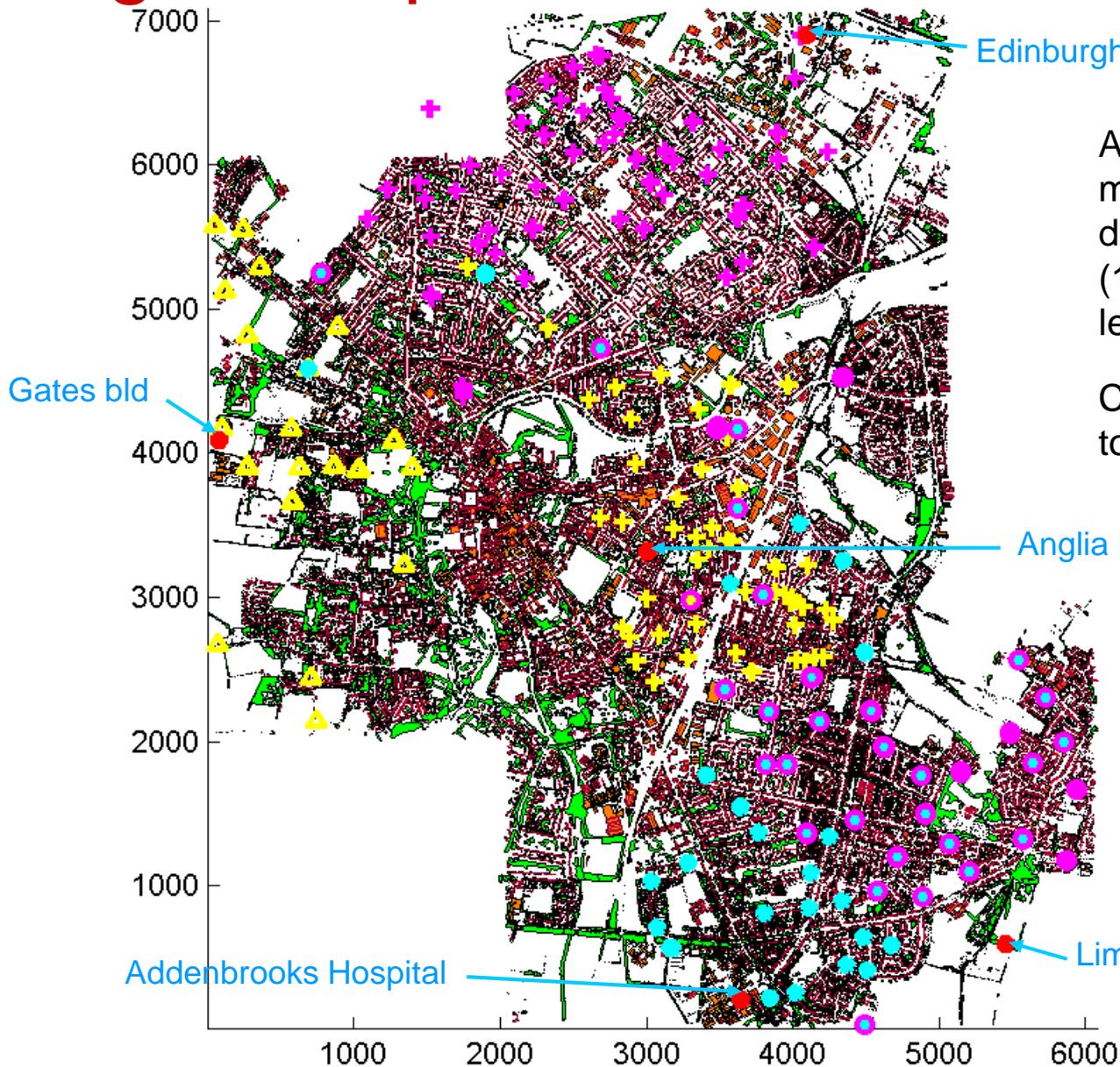


Sample excess delay profile



Sample frequency response

# Digital Map & Measurement Positions



Edinburgh House

At each CPE position, measurements were taken for different antenna heights (14m to 9m above ground level, with 1m step).

CPE antenna was pointing towards the AP antenna.

Anglia Polytechnic University

Total area = 31Km<sup>2</sup>

~180000 building vectors

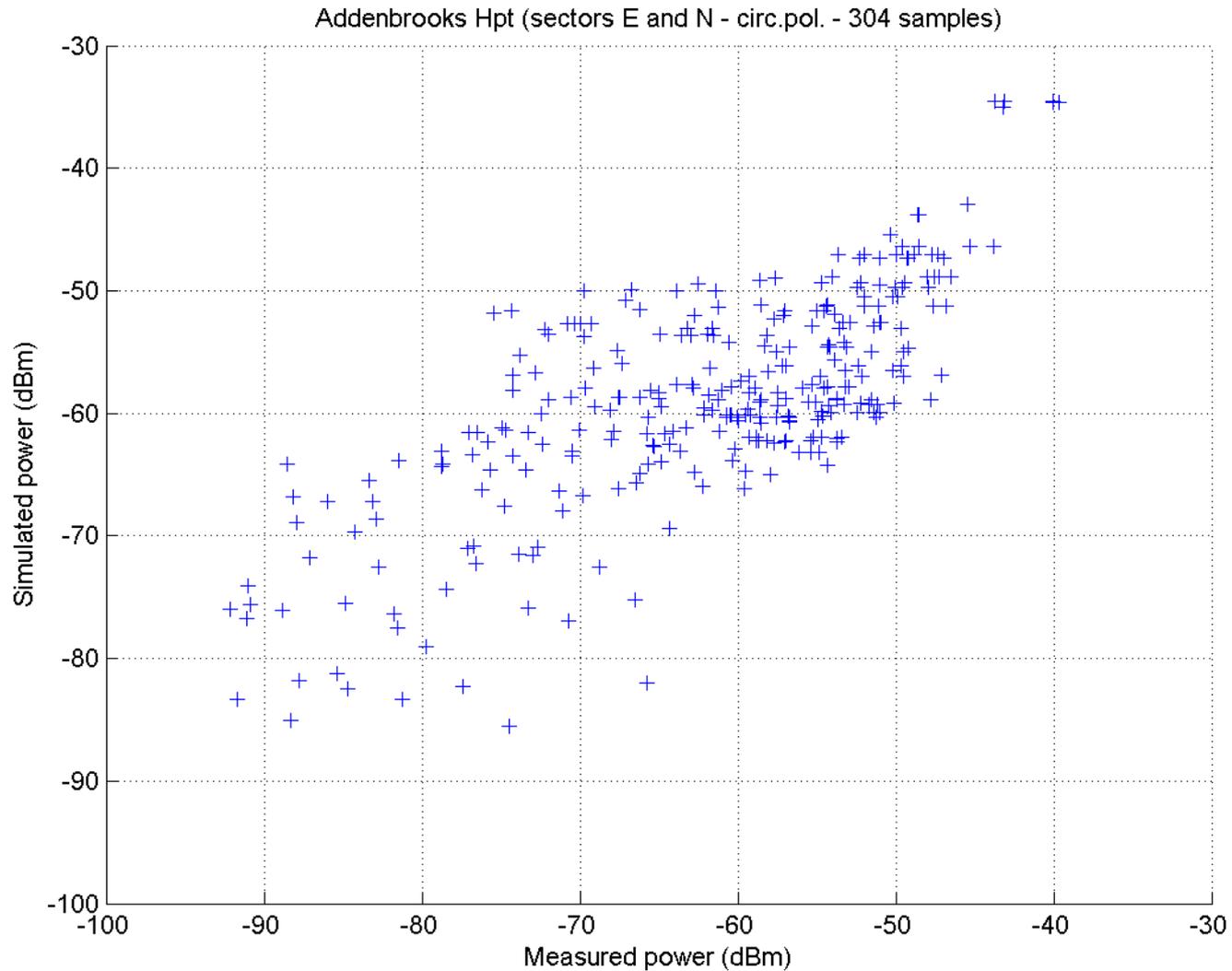
~160000 vegetation vectors

Lime Kiln Hill

Addenbrooks Hospital

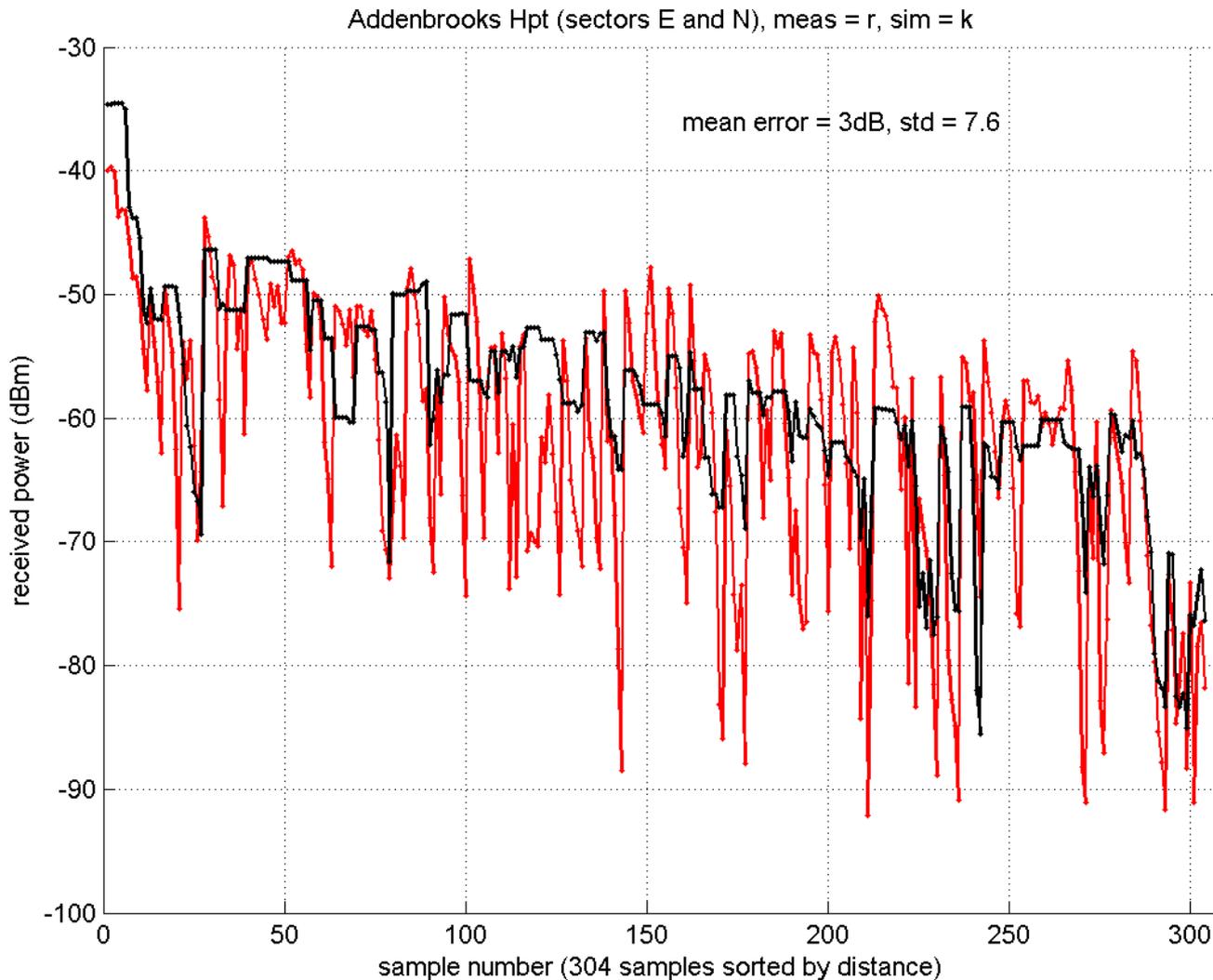
Gates bld

# Simulated vs measured results



Mean error = 3dB, std = 7.6dB

# Simulated vs measured results



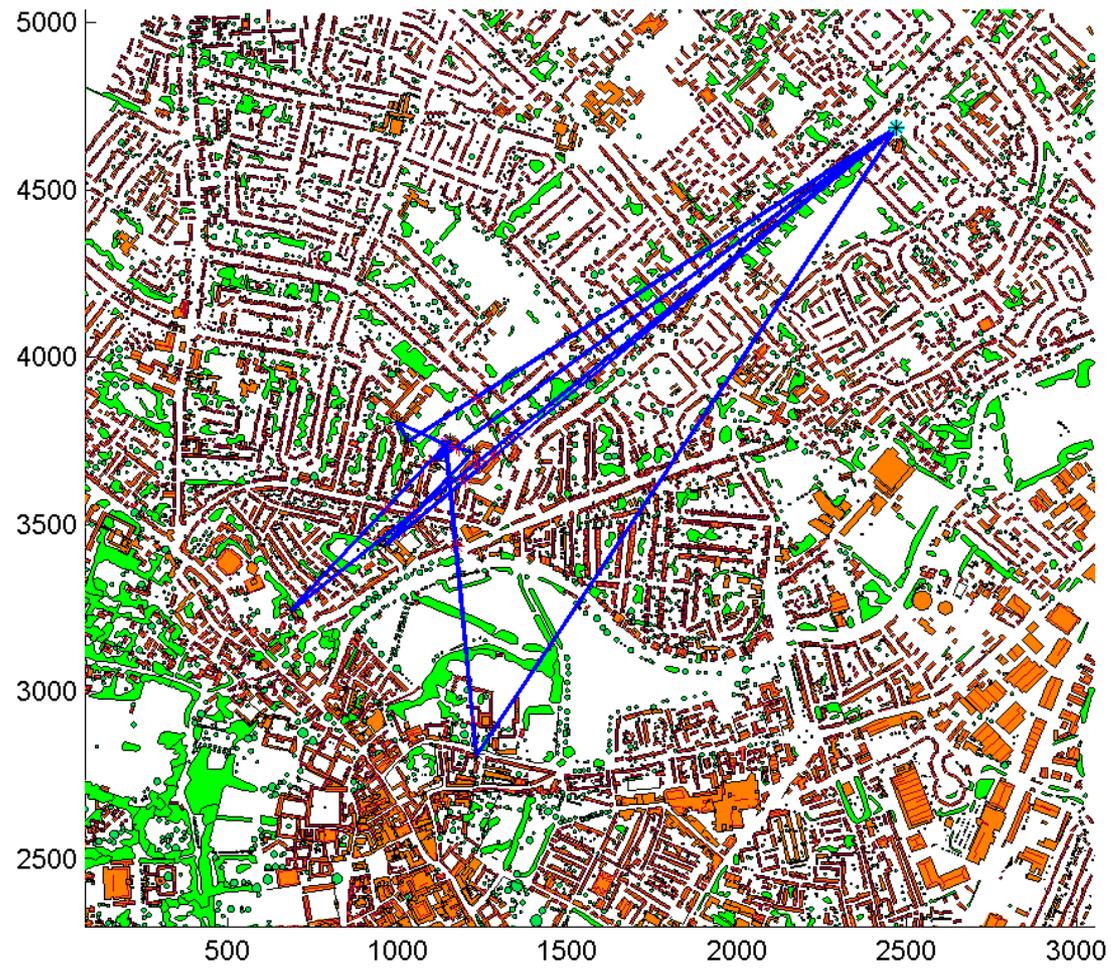
Measured results were averaged over time only.

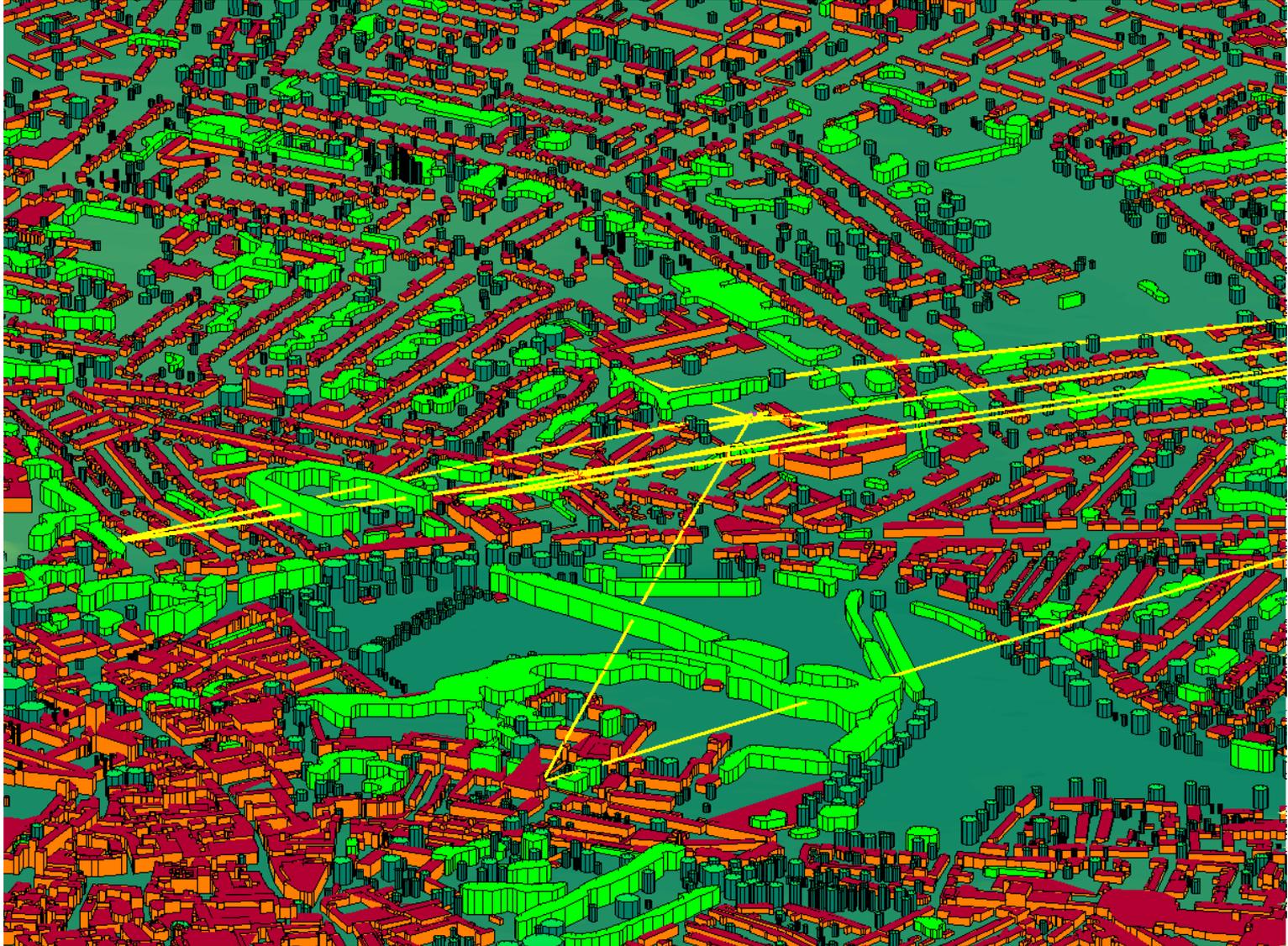
Simulated results were averaged over space (9 samples in a 6mx6m grid).

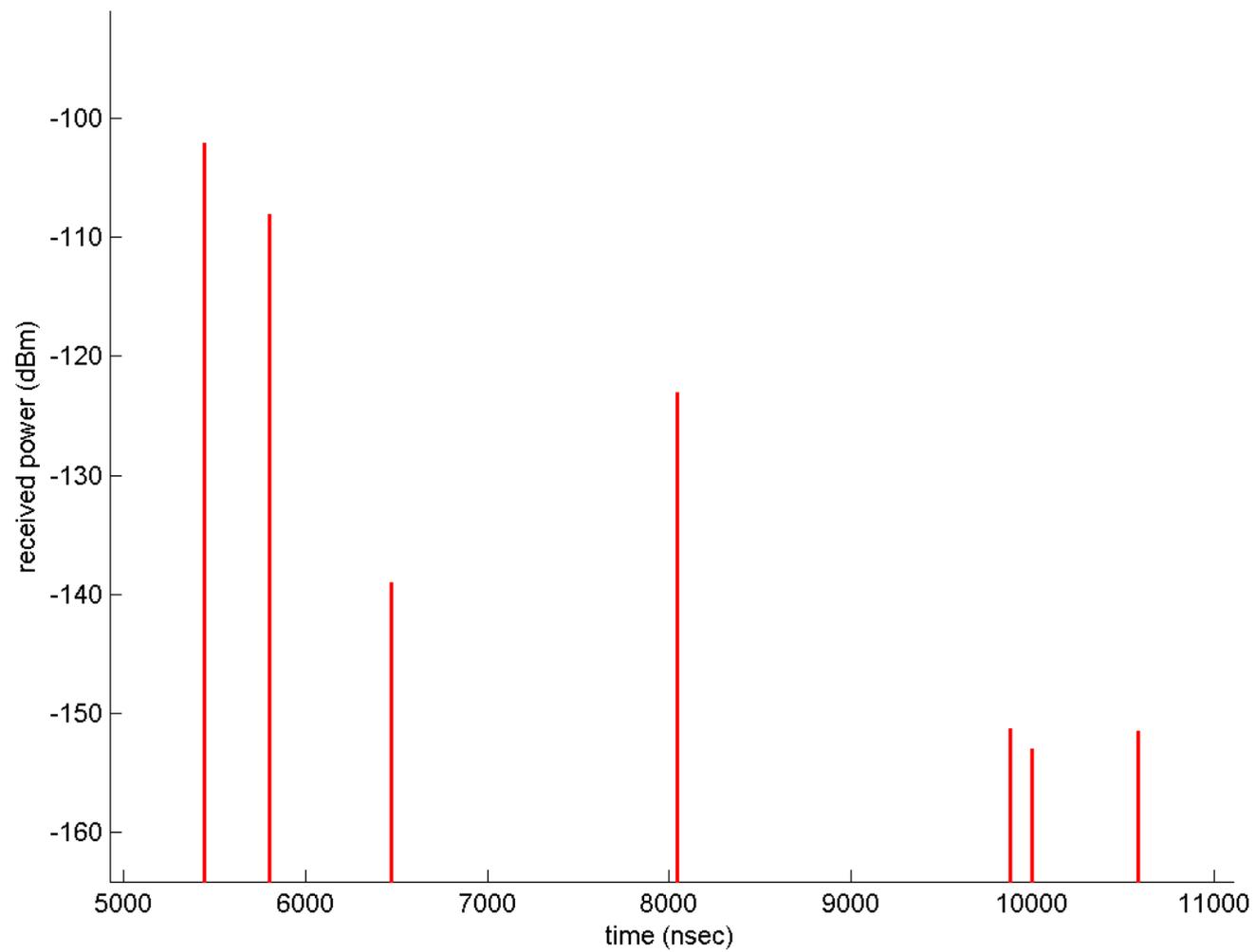
Foliage attenuation = 0.3dB/m

The ray tracing results for BFWA systems are mostly affected by the foliage attenuation parameters and the diffraction equations for grazing angles.

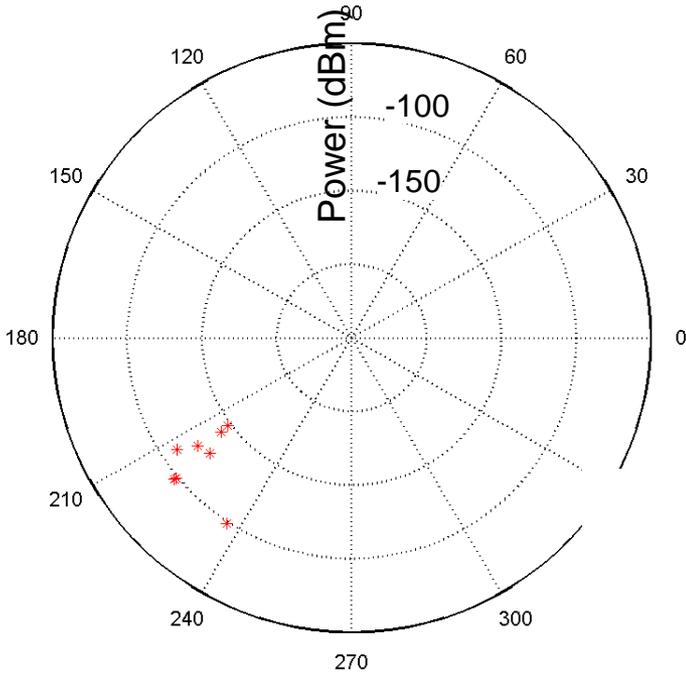
Mean error = 3dB, std = 7.6dB



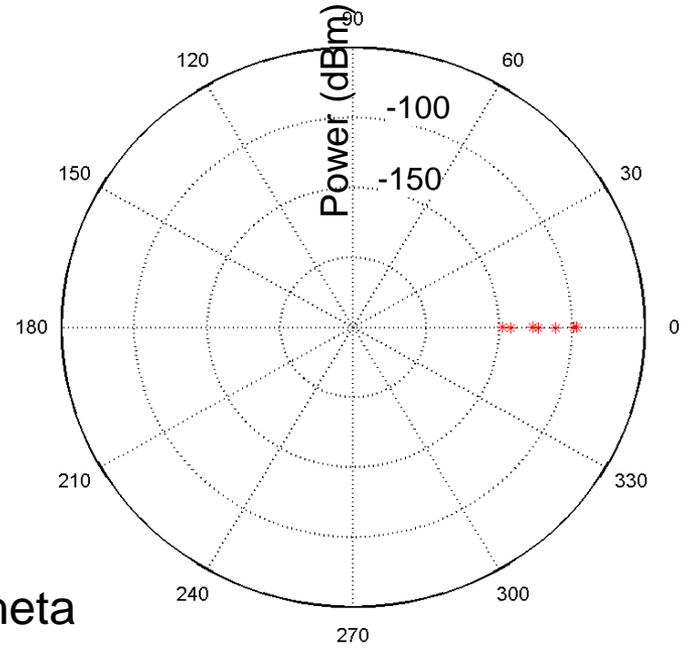


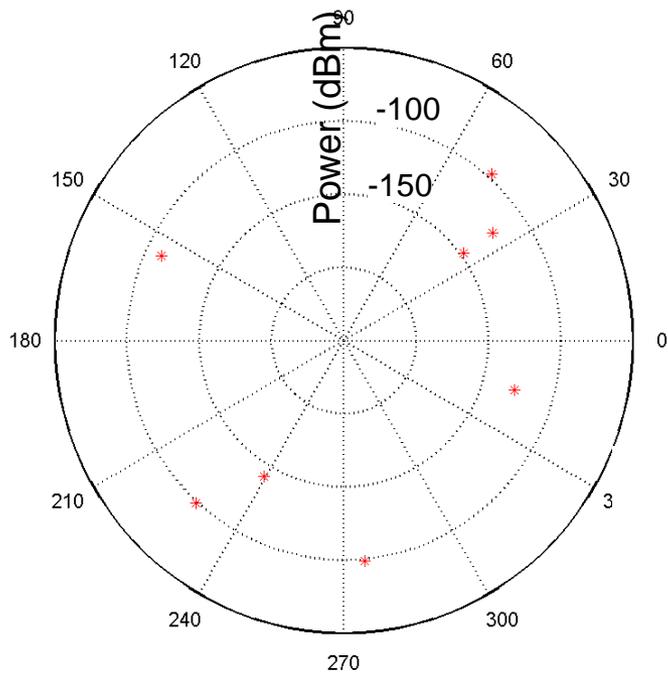


bsphi

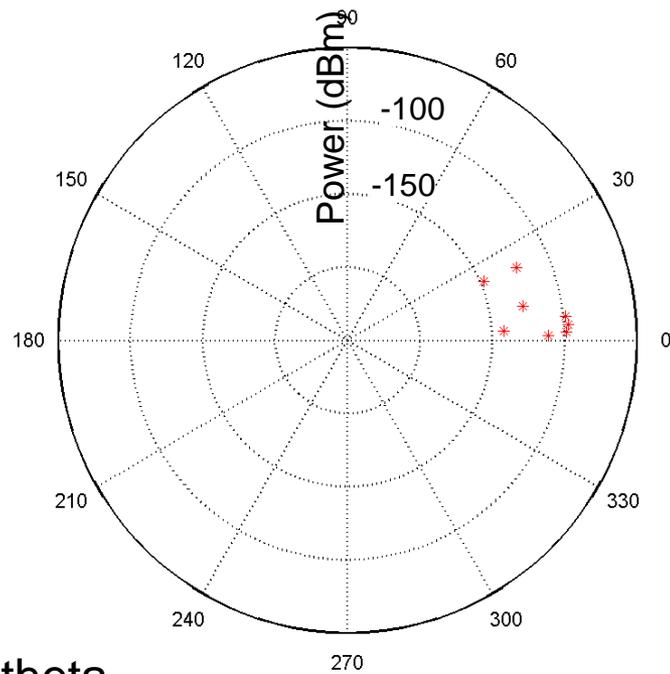


bstheta





msphi

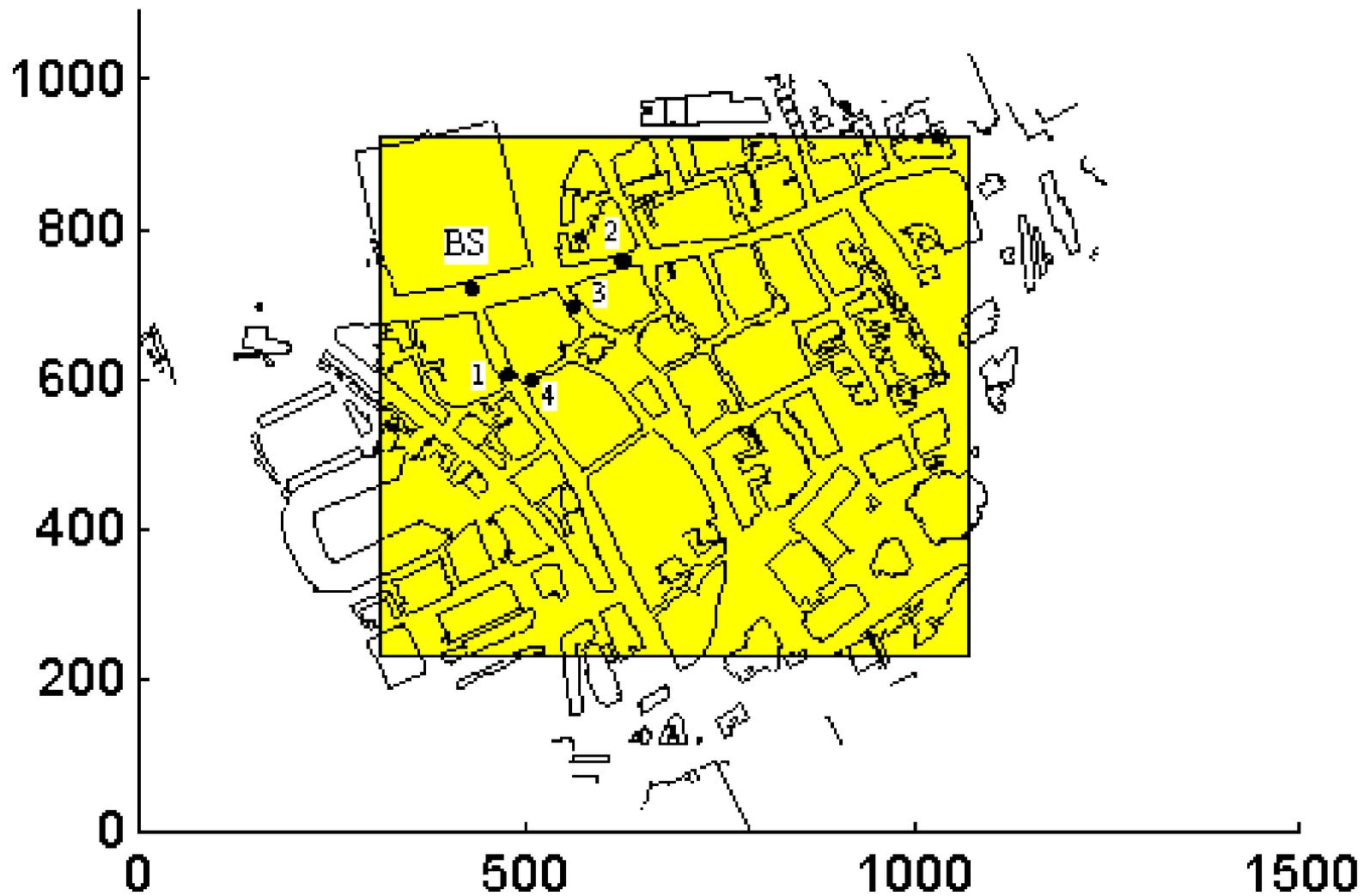


mstheta

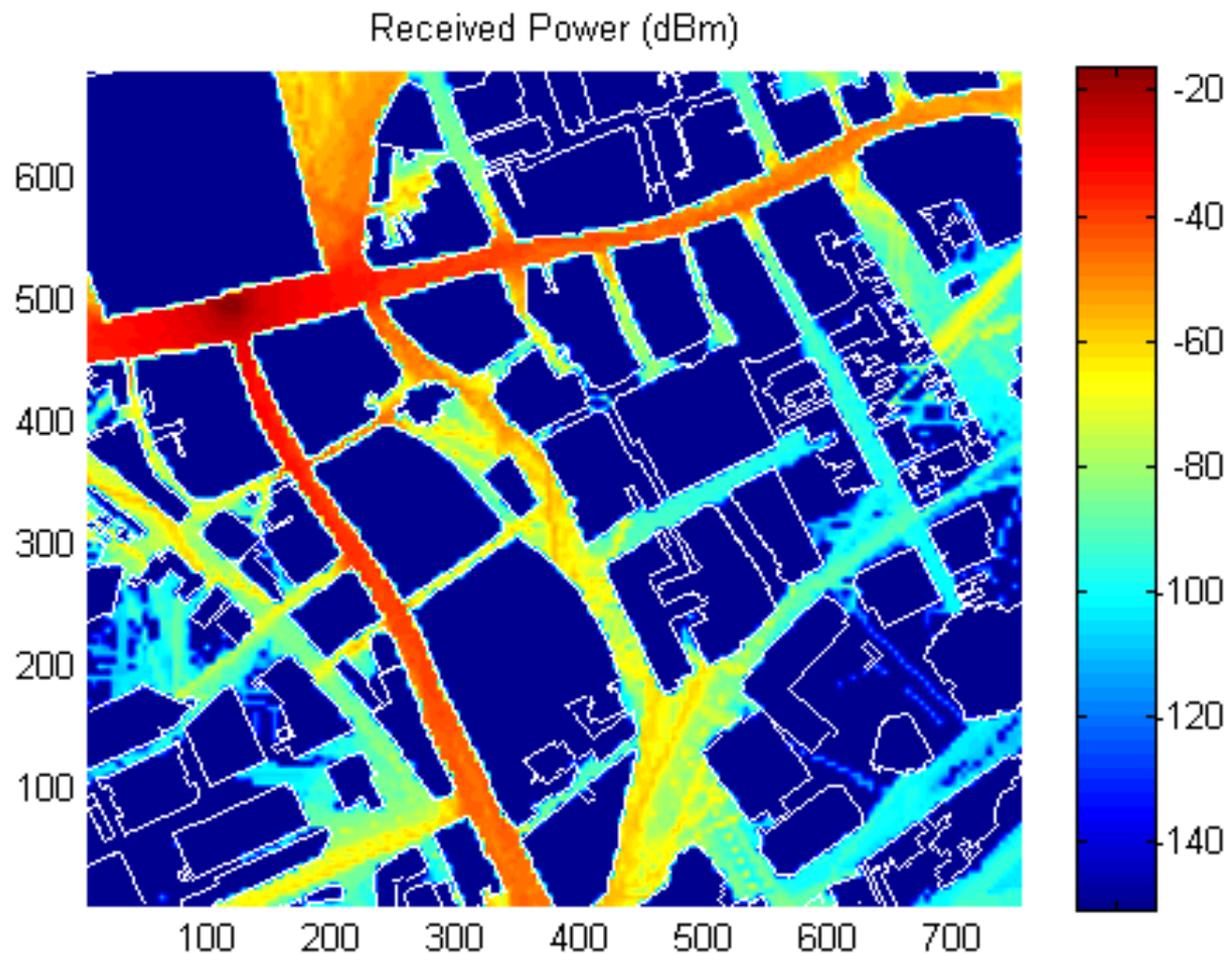


**(2)**

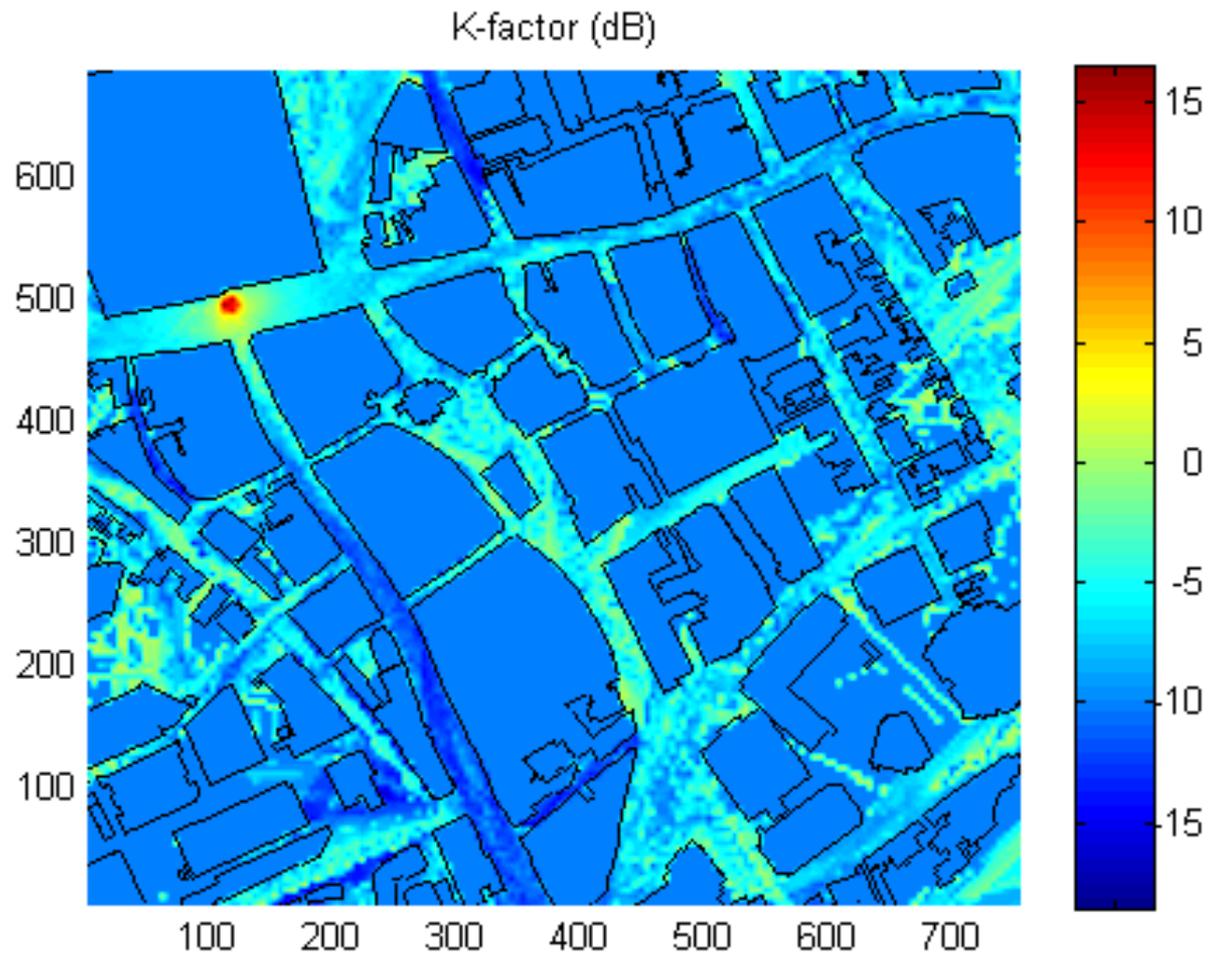
**Microcellular environment**



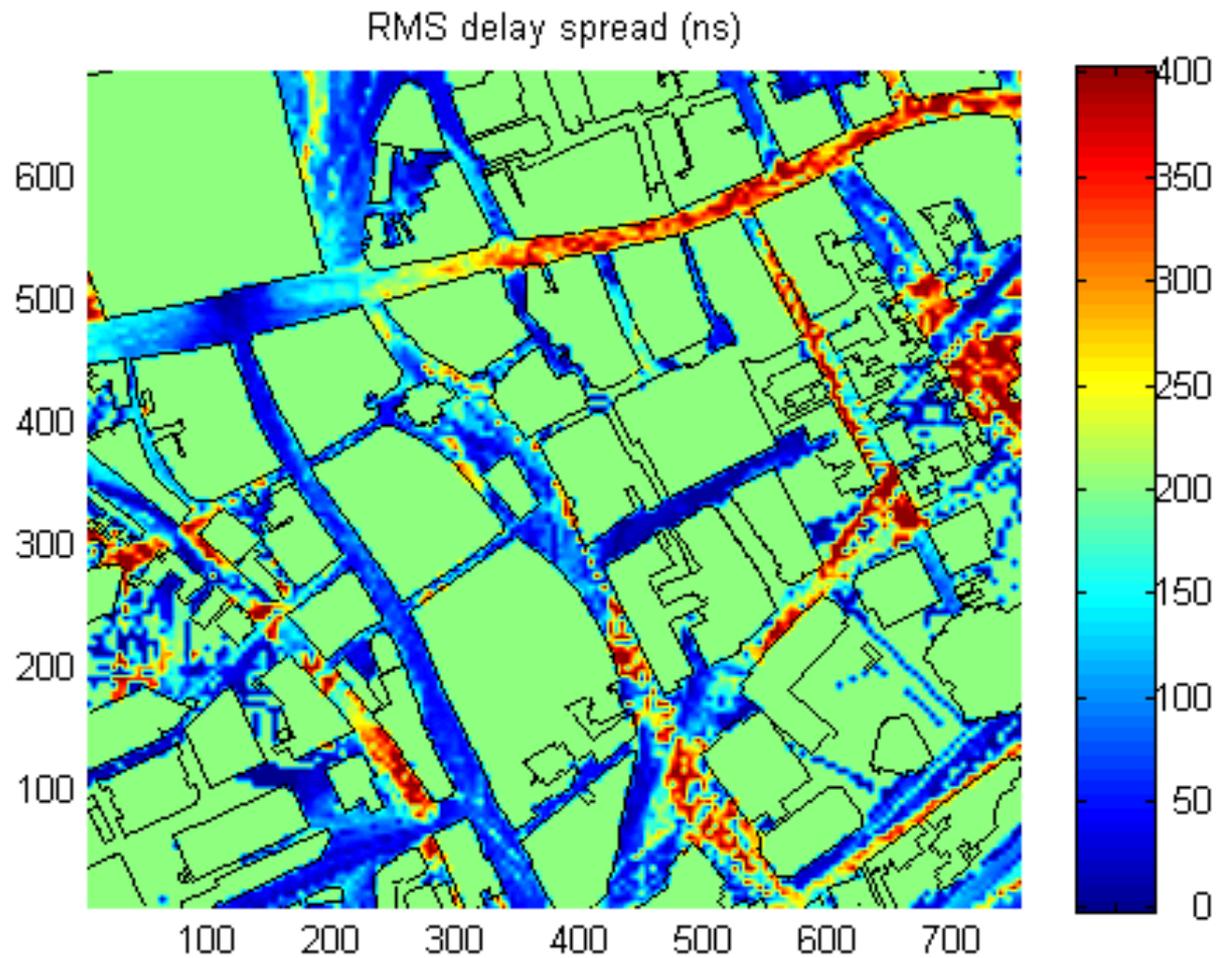
## Power predictions throughout the studied area



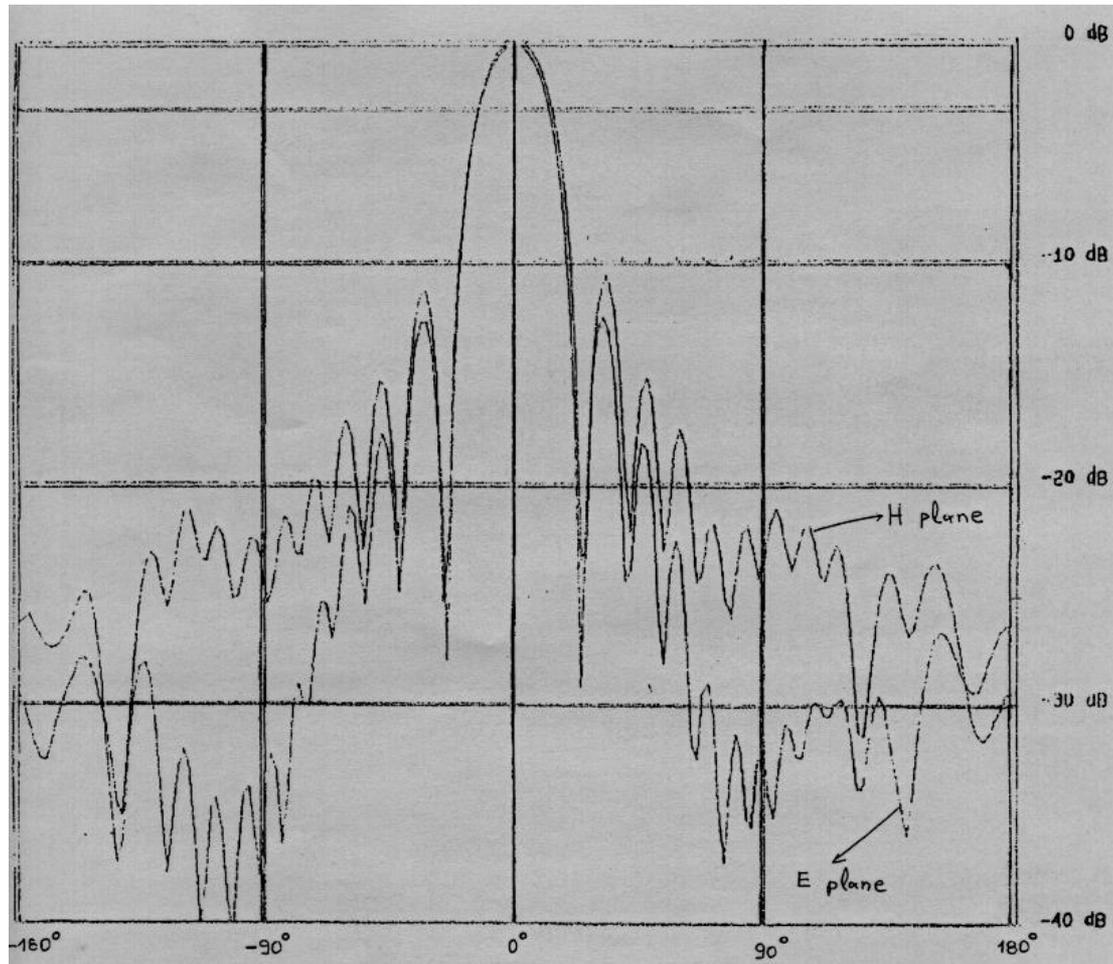
## k-factor predictions throughout the studied area



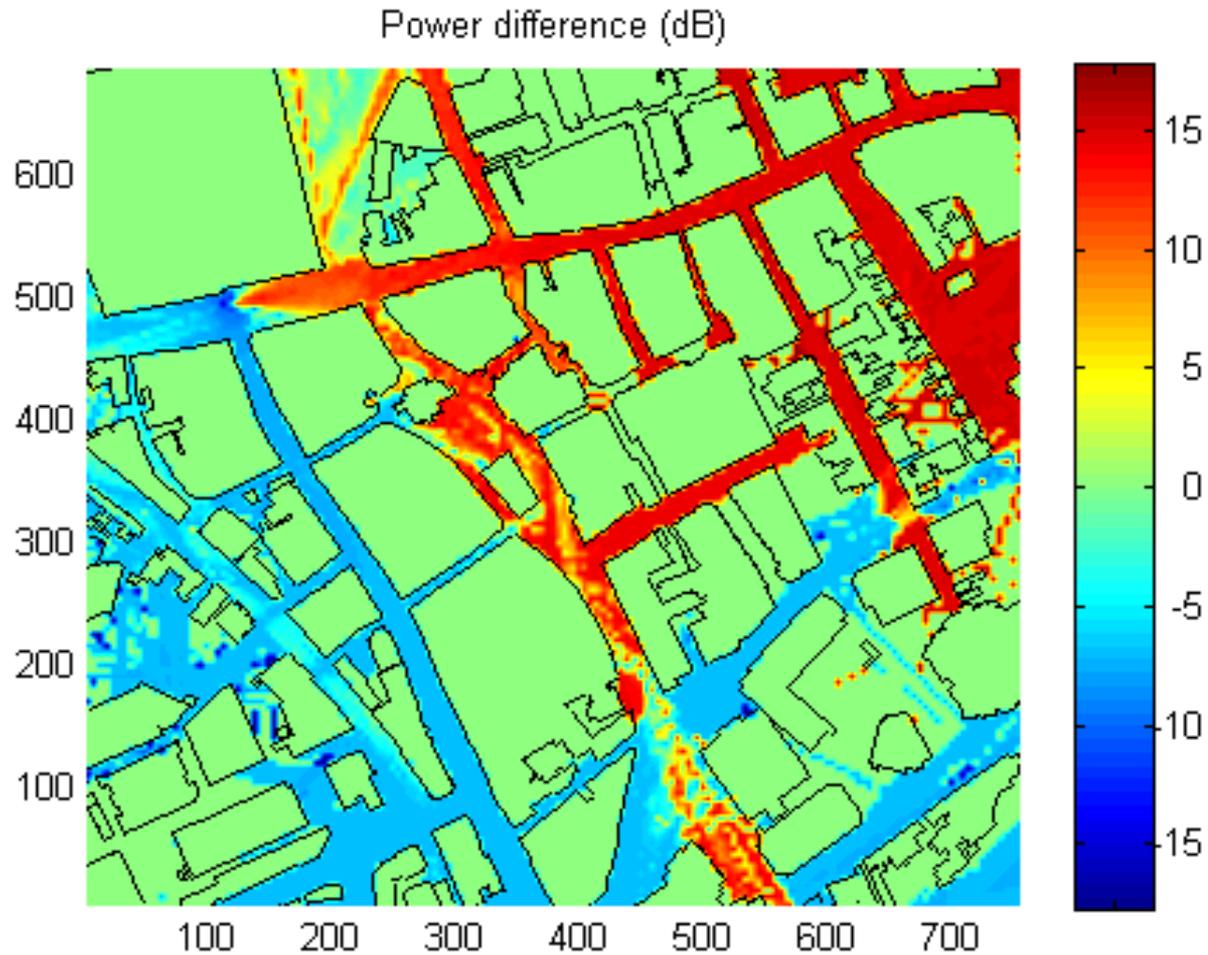
## RMS delay spread predictions throughout the studied area



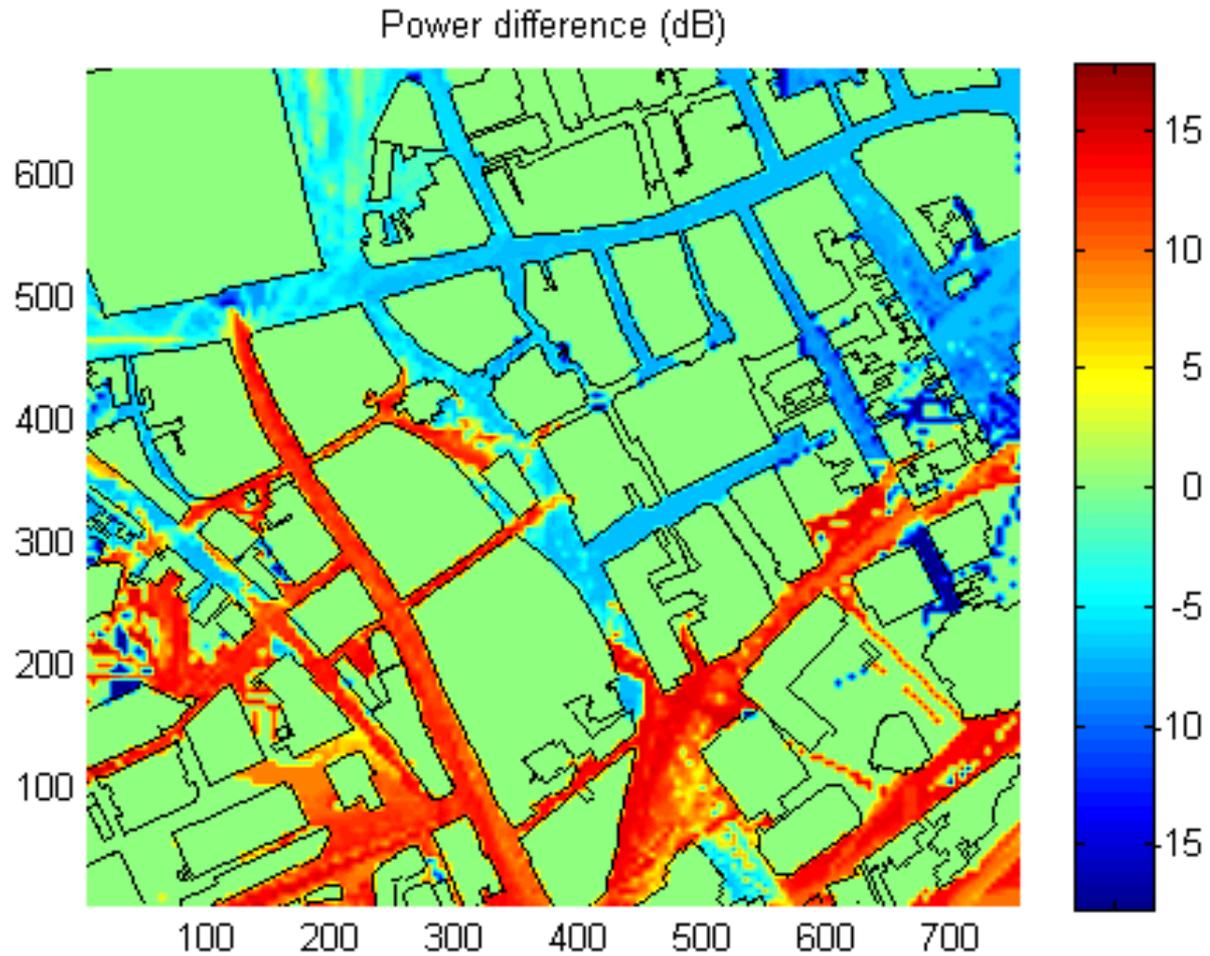
# Radiation pattern of the directional antenna



## Power difference between an omni-directional and a directional antenna at the base station (1)



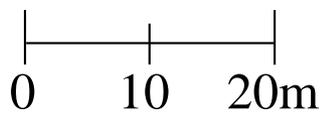
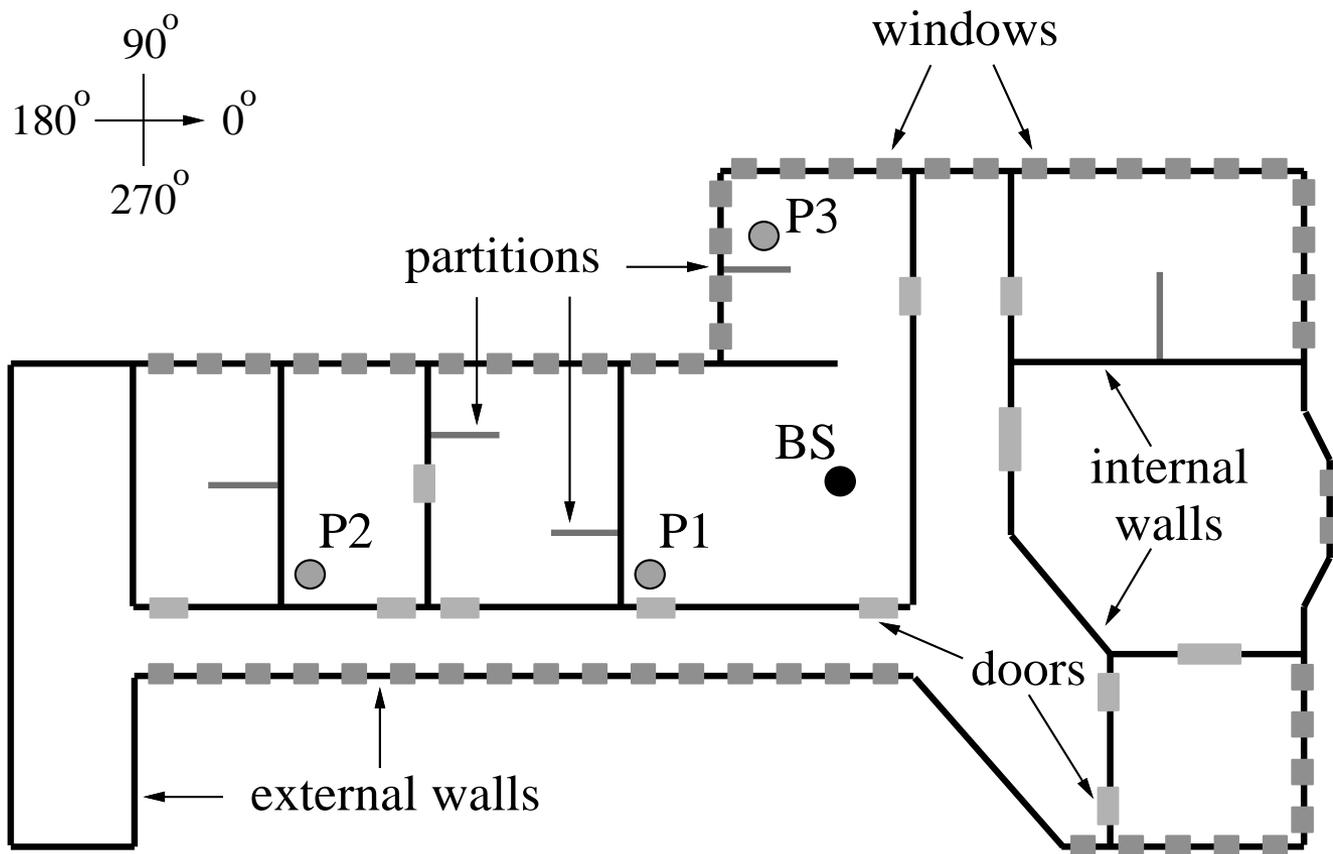
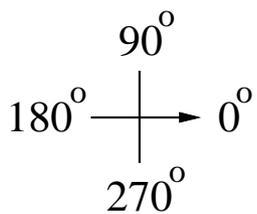
## Power difference between an omni-directional and a directional antenna at the base station (2)



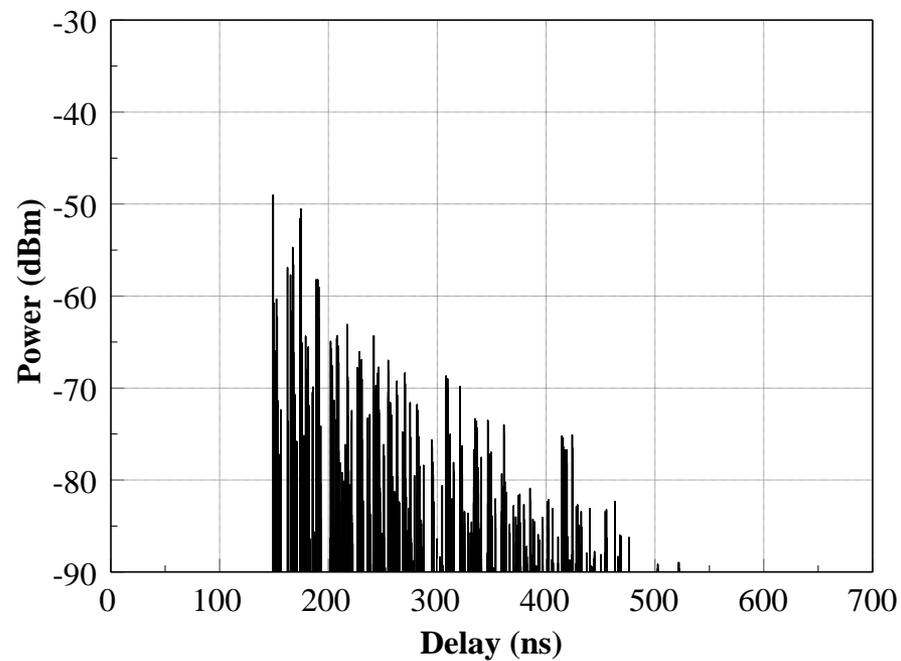
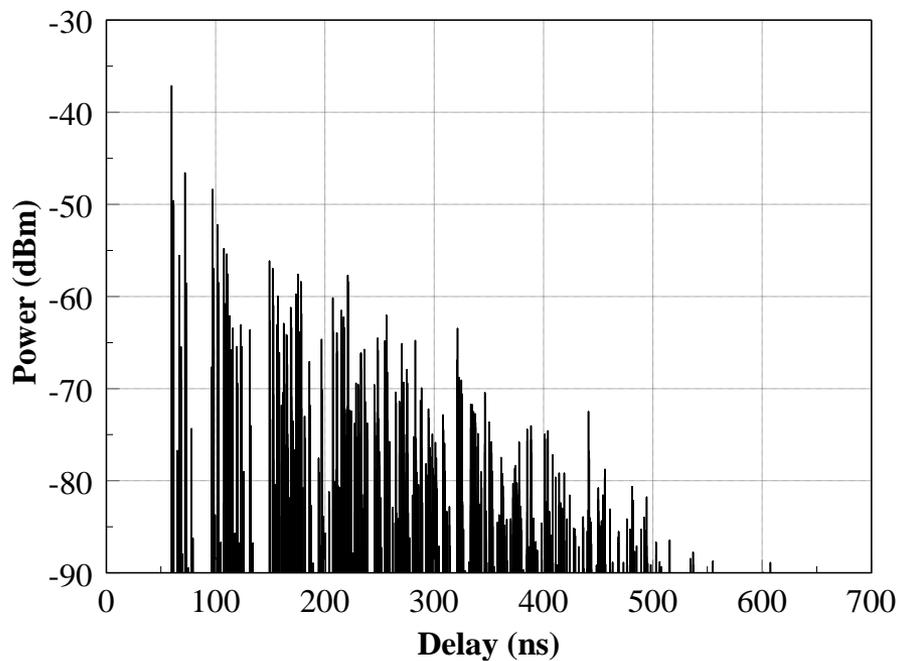


**(3)**

**Indoor environment**

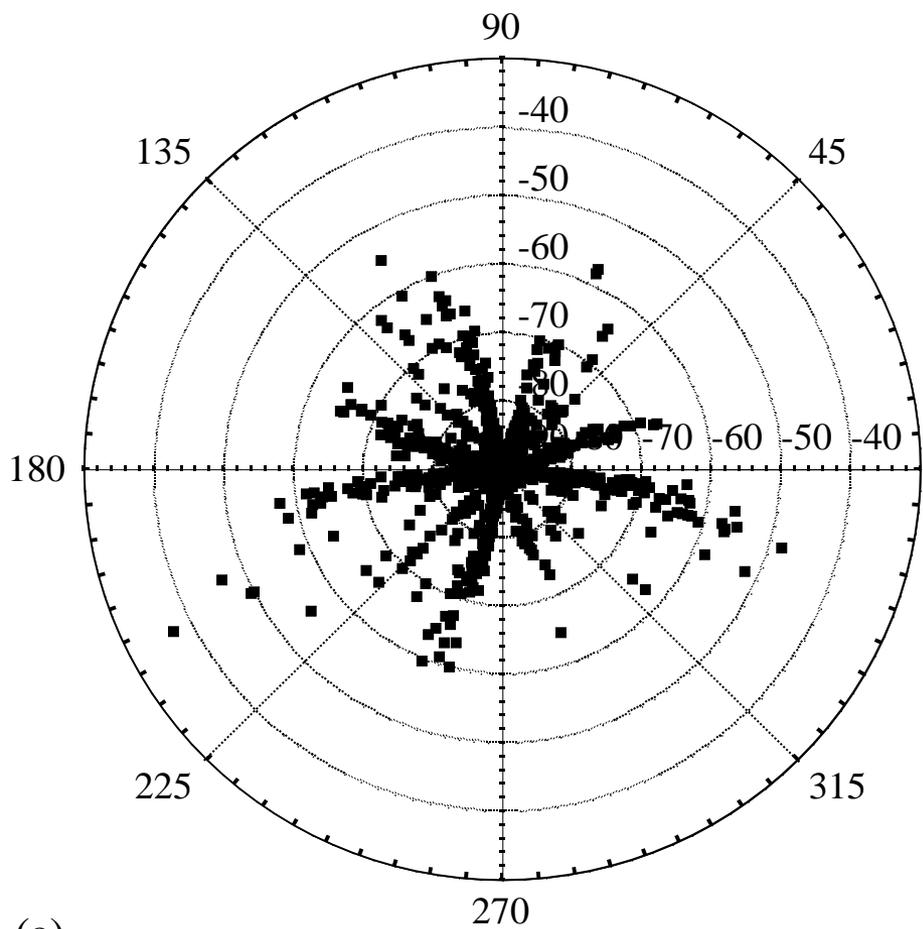


## Impulse response at points P1 and P2

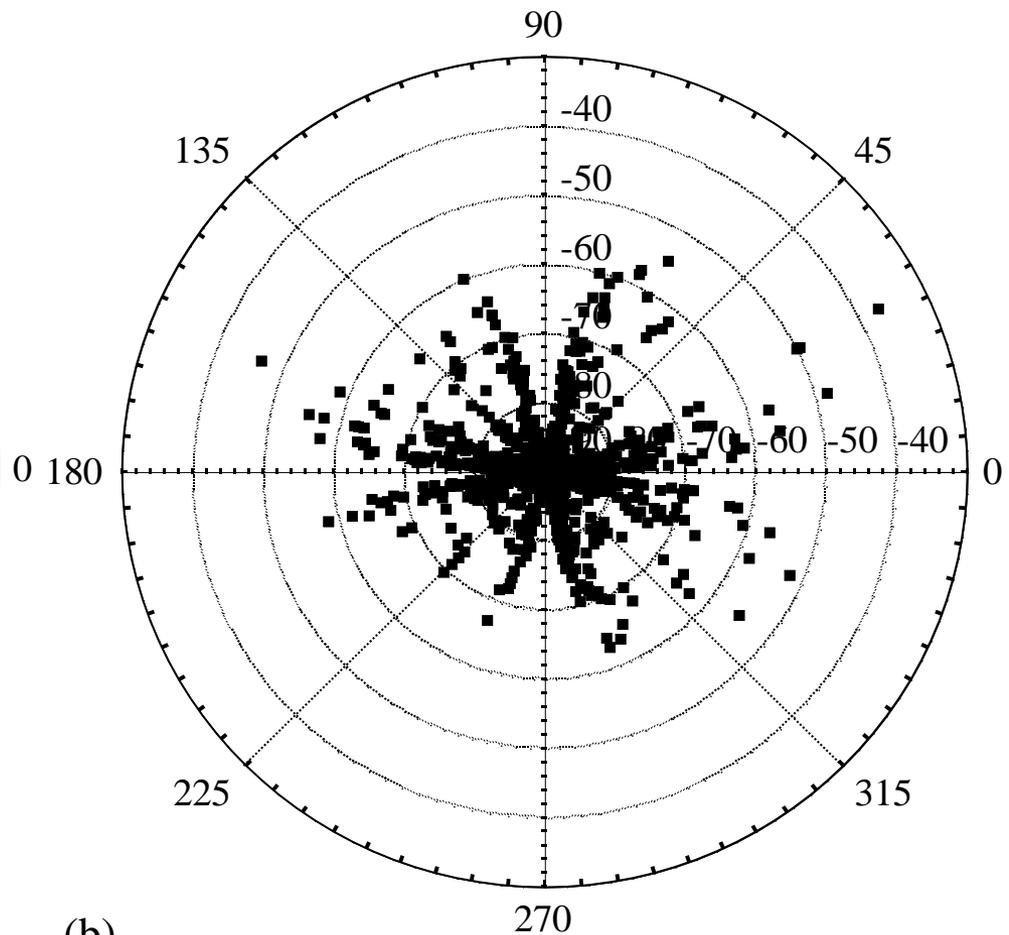


	Number of rays	Received power (dBm)	K-factor (dB)	RMS delay spread (ns)
Point P1	2586	-35.13	1.75	41.97
Point P2	1828	-42.19	-6.00	38.89
Point P3	2174	-36.30	-3.07	34.28

# Angles of arrival at the base station (a) and the mobile (b) at LOS point P1

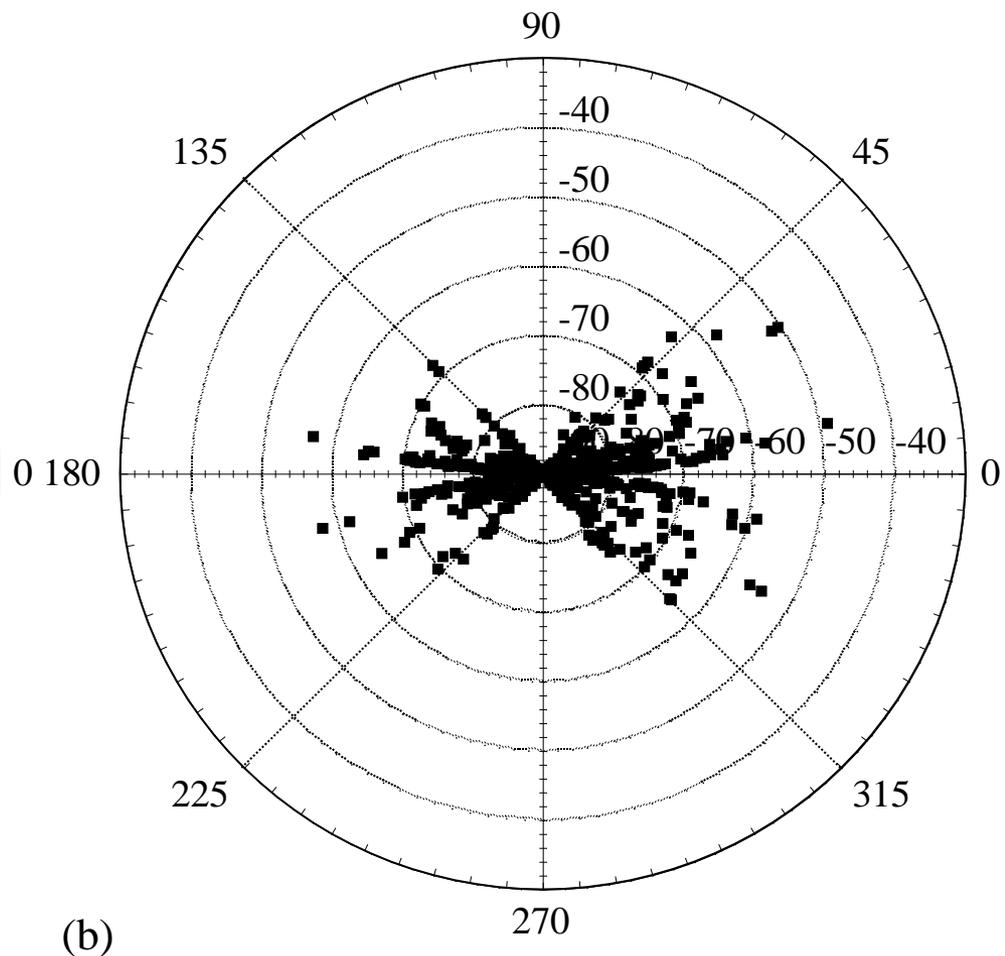
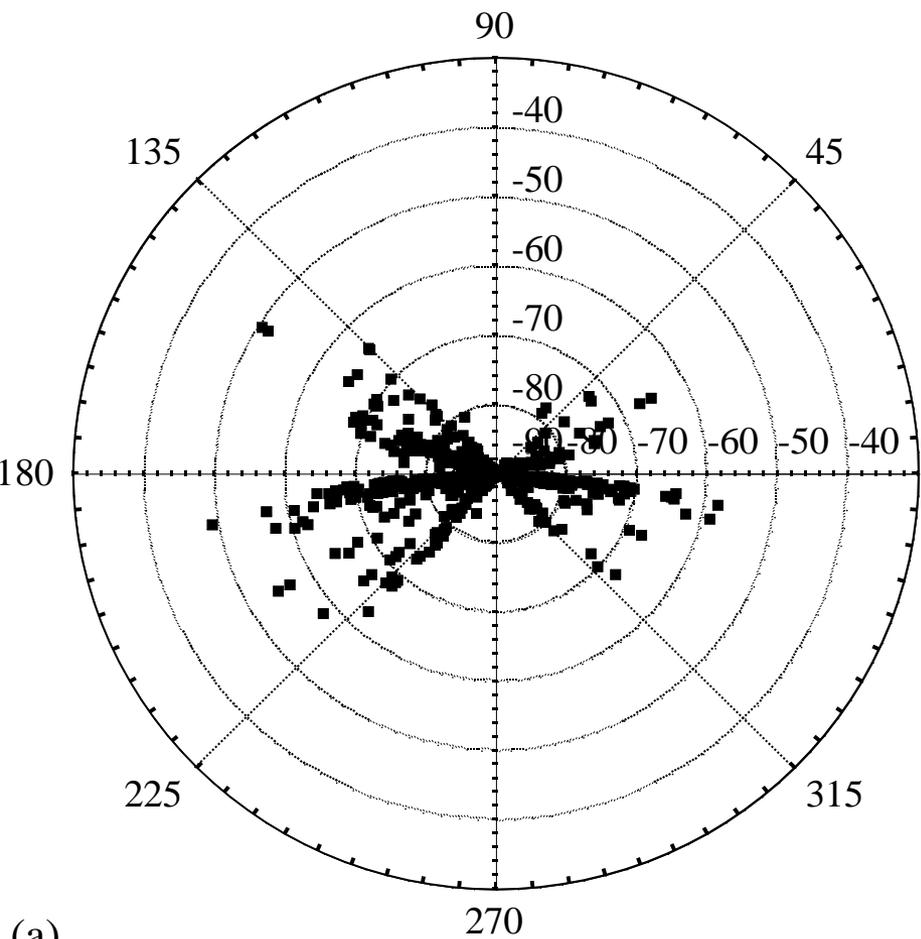


(a)

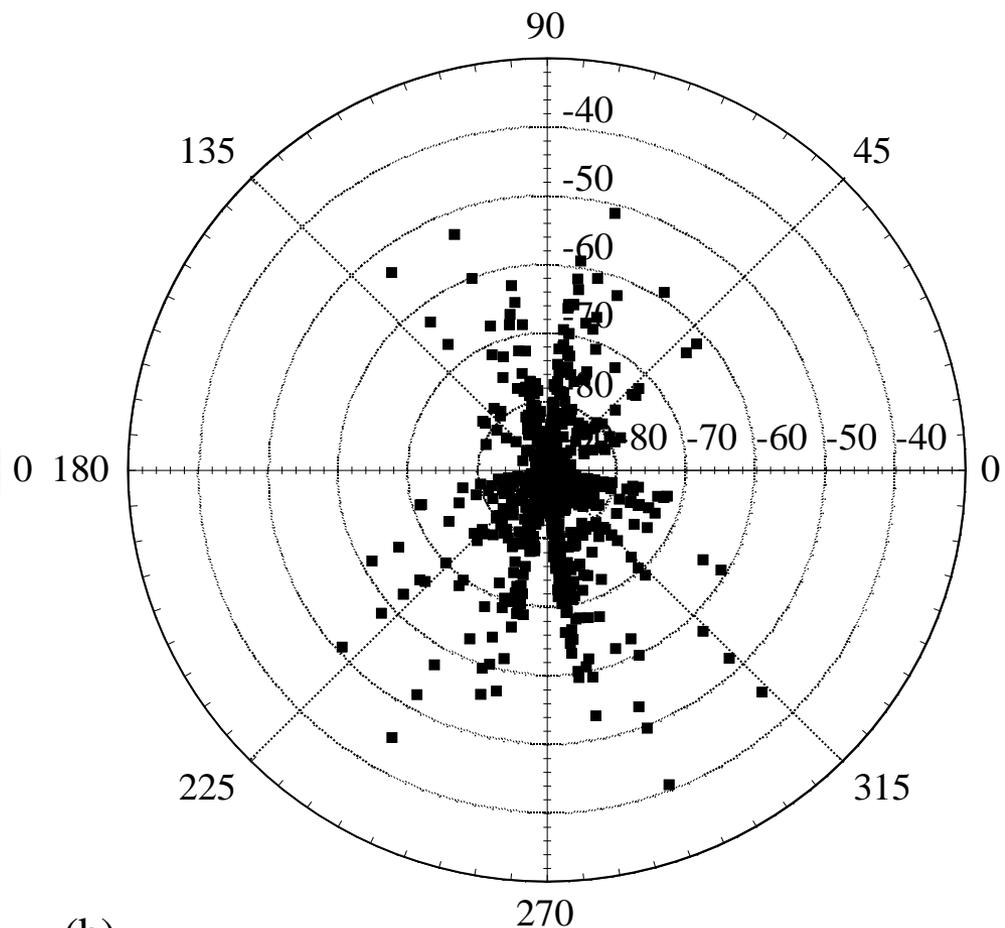
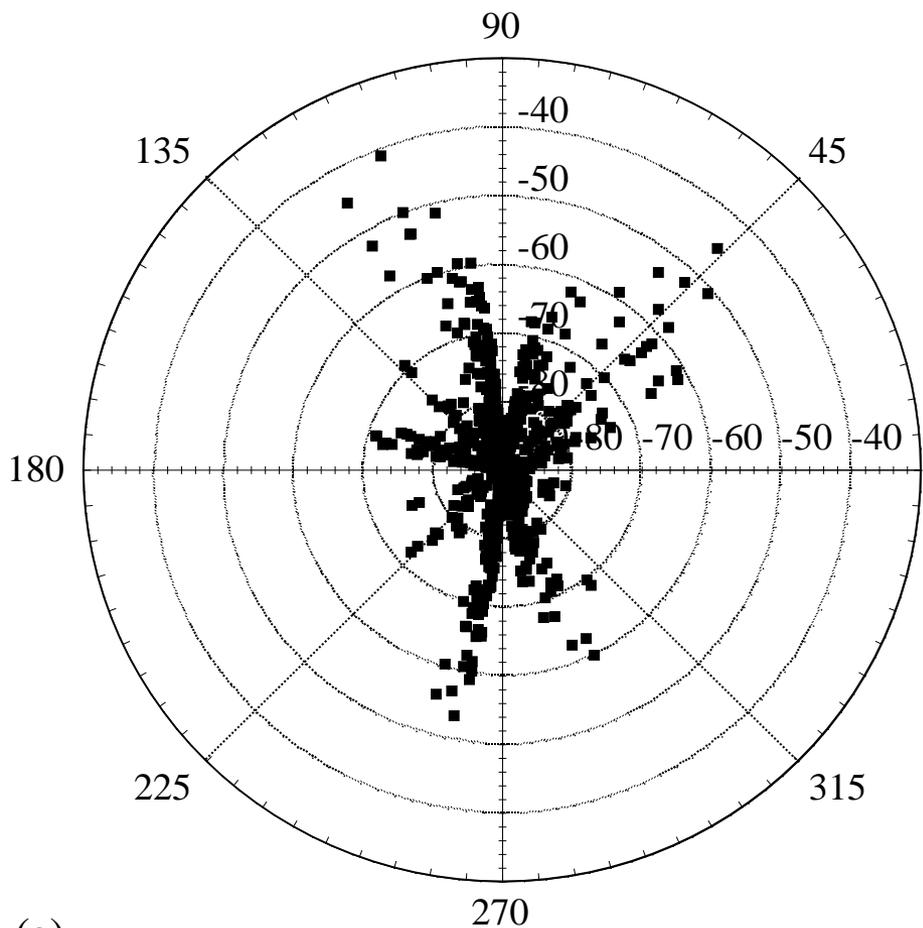


(b)

# Angles of arrival at the base station (a) and the mobile (b) at NLOS point P2



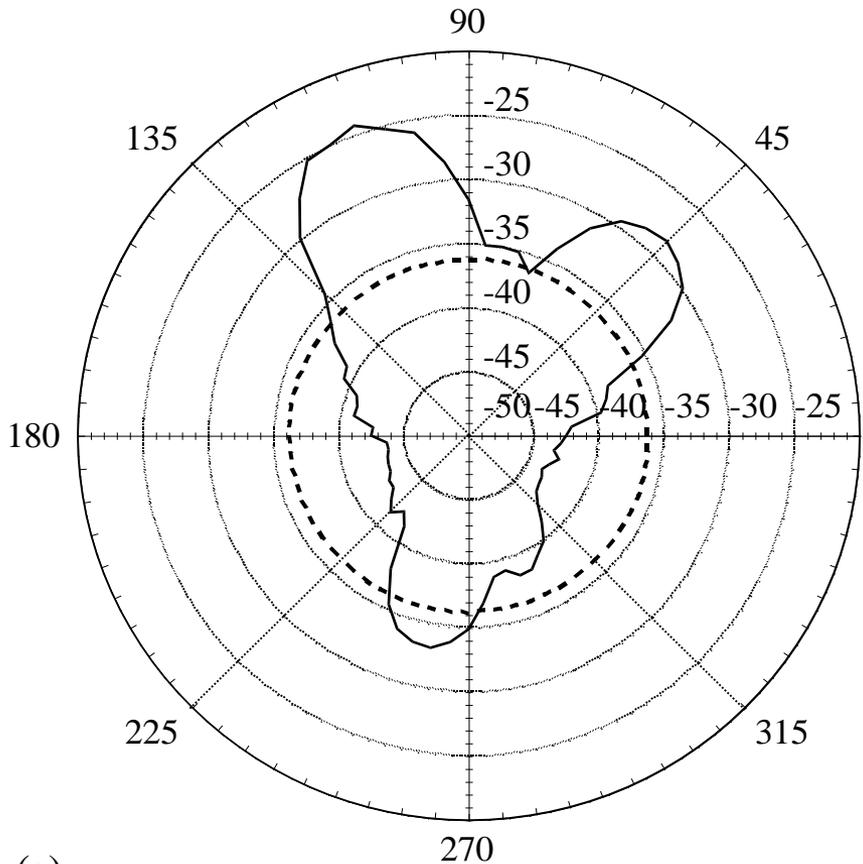
# Angles of arrival at the base station (a) and the mobile (b) at NLOS point P3



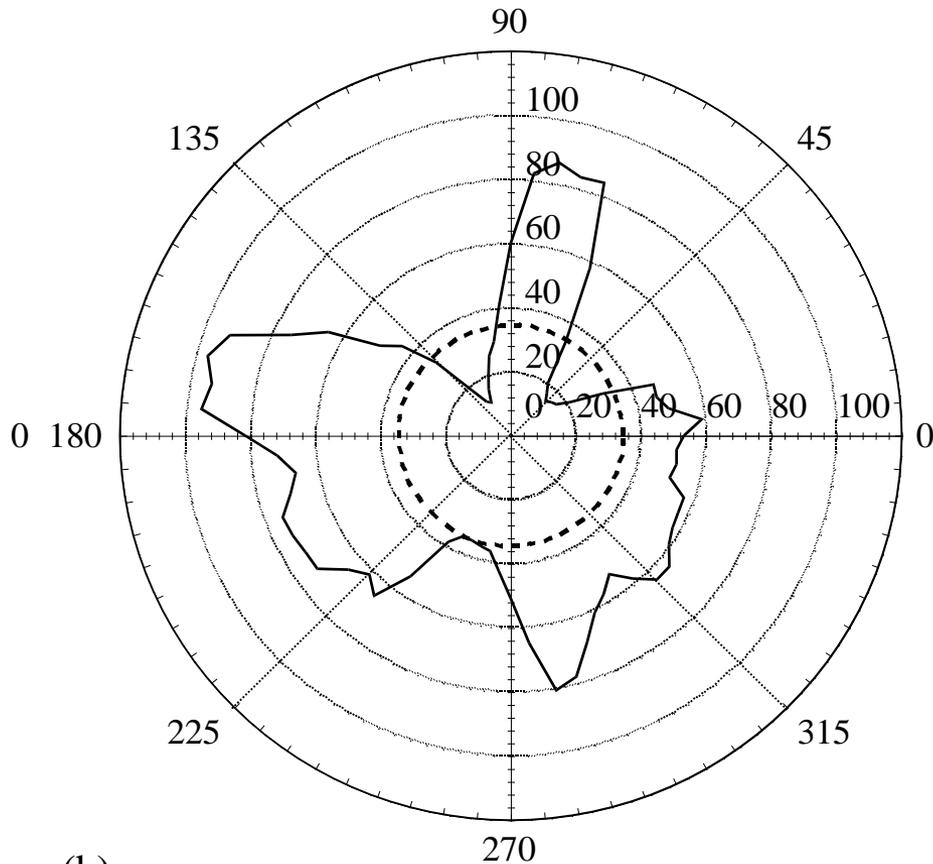
(a)

(b)

**Power (a) and RMS delay spread (b) as a function of the pointing angle of the directional antenna at the base station, when the mobile is at NLOS point P3**

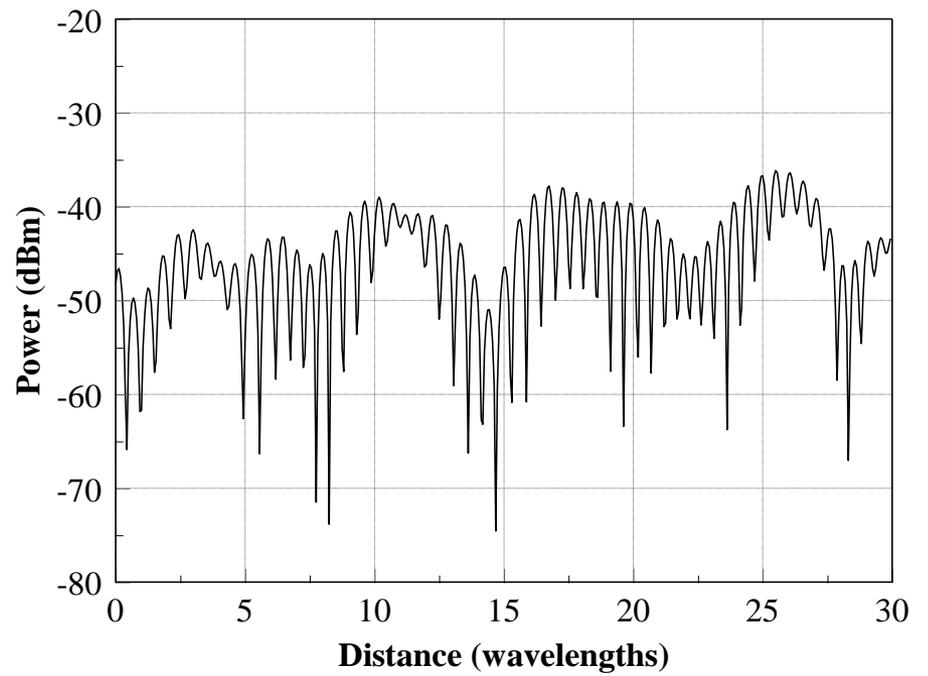
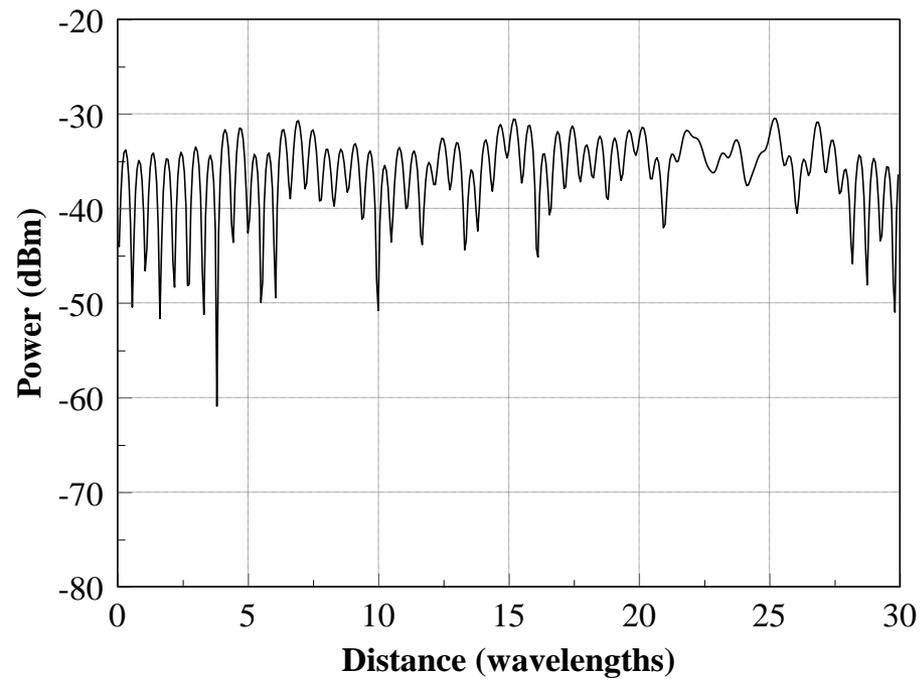


(a)



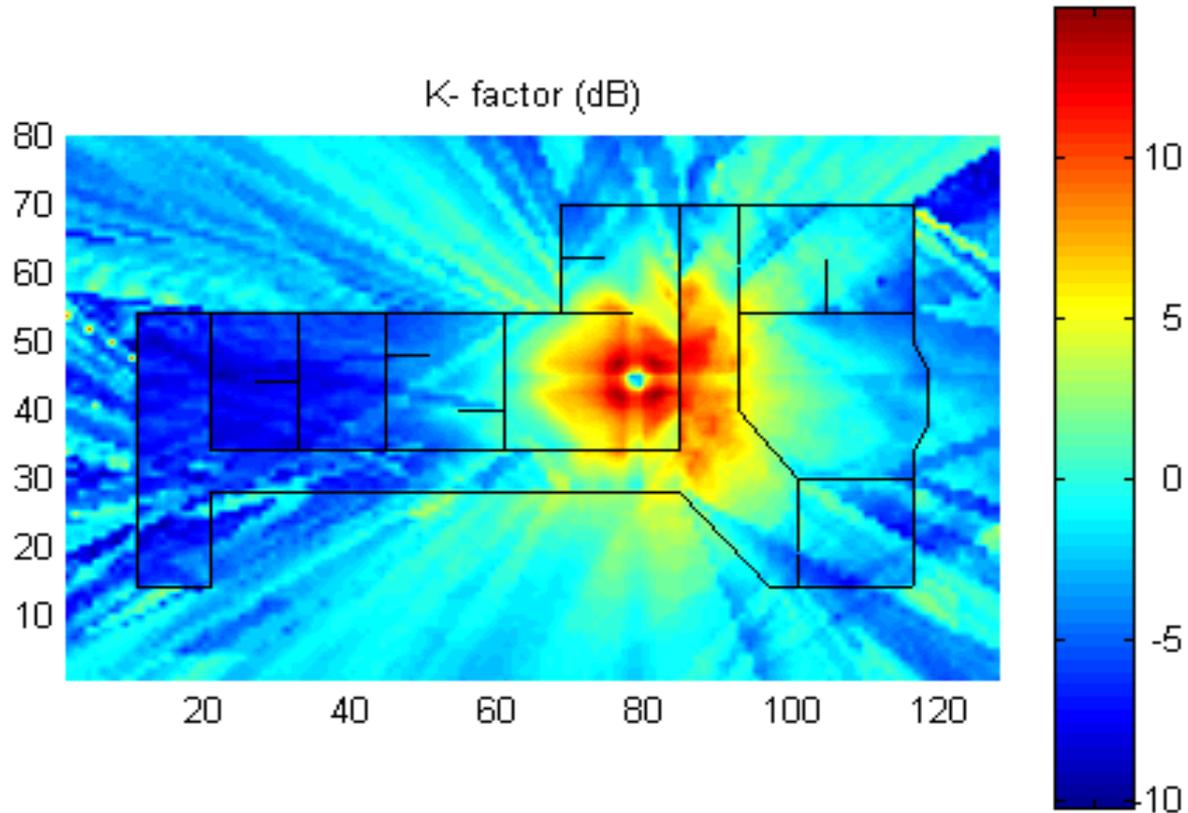
(b)

## Power envelope at point P1 and P2

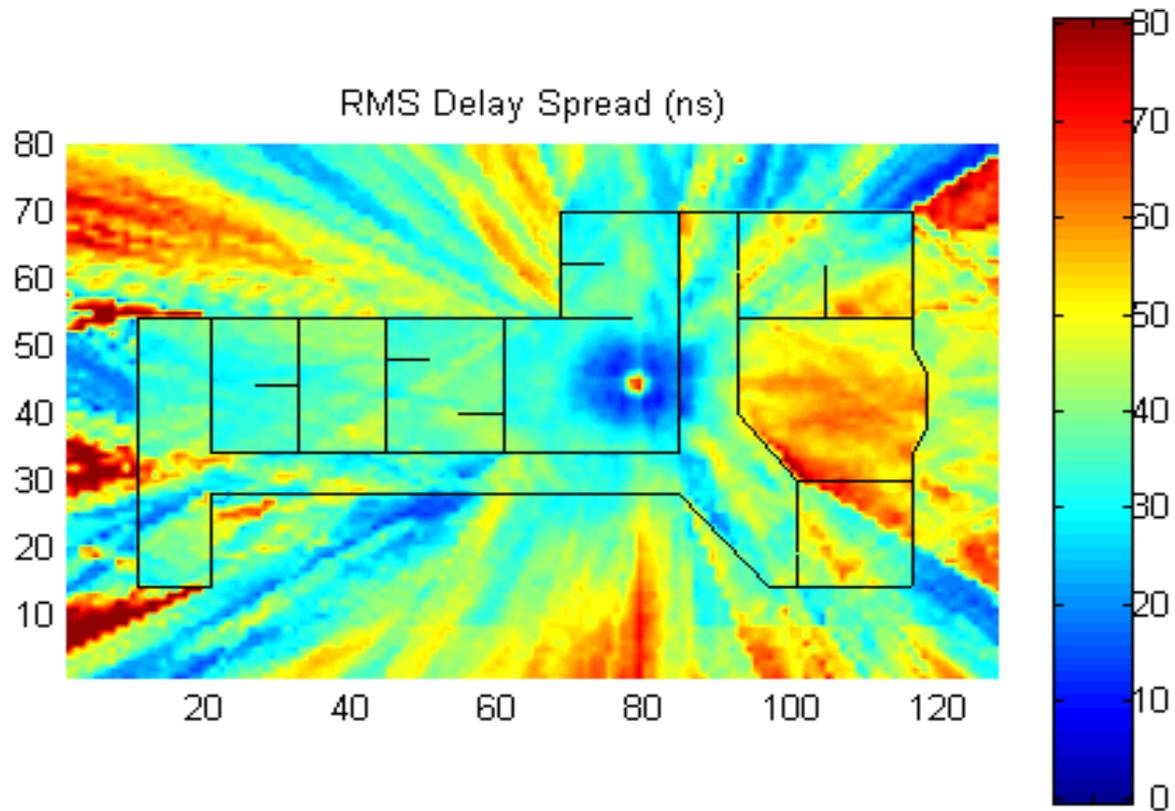




# K-factor predictions throughout the studied area



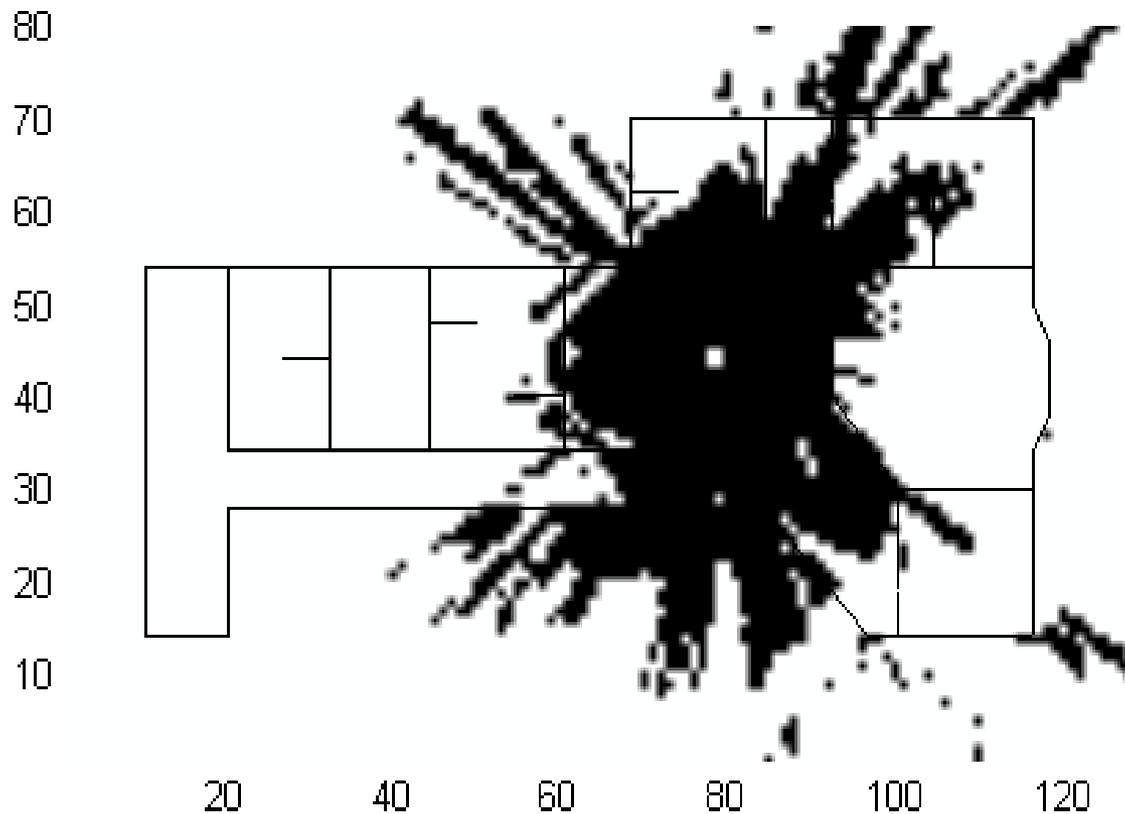
## RMS delay spread predictions throughout the studied area



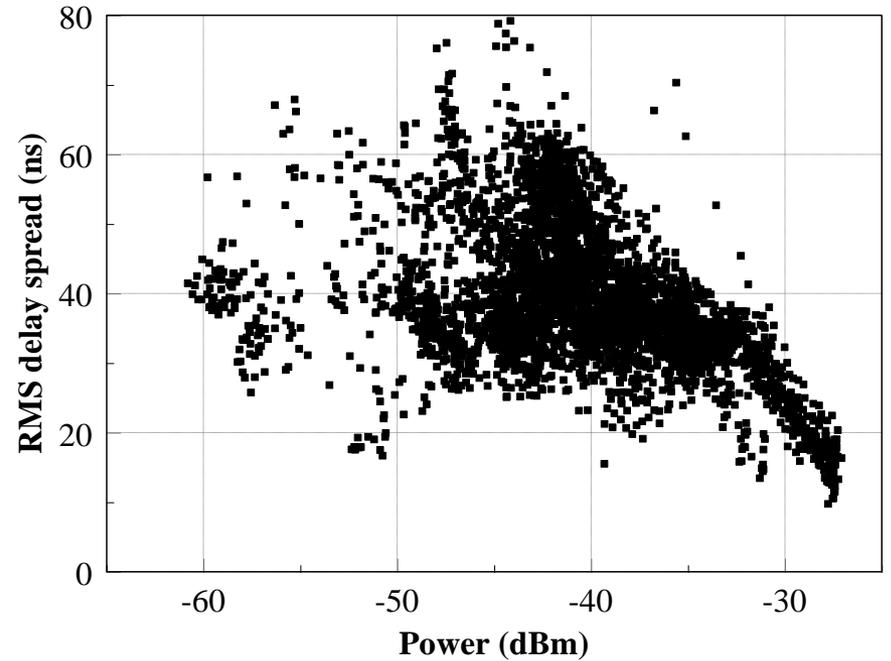
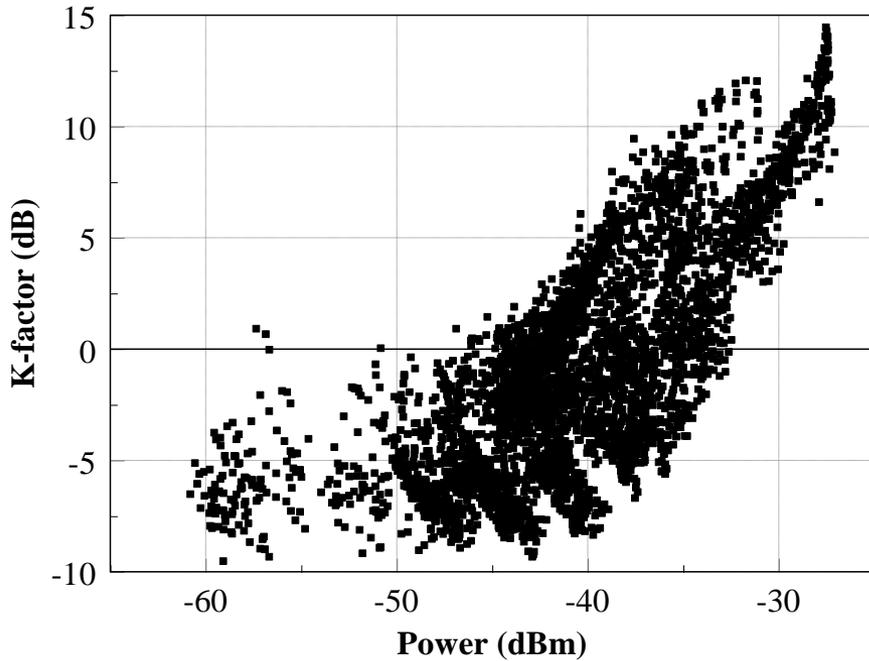
## Example of spatial outage for a system working at 5.2GHz

*Outage criteria for the analysis:*

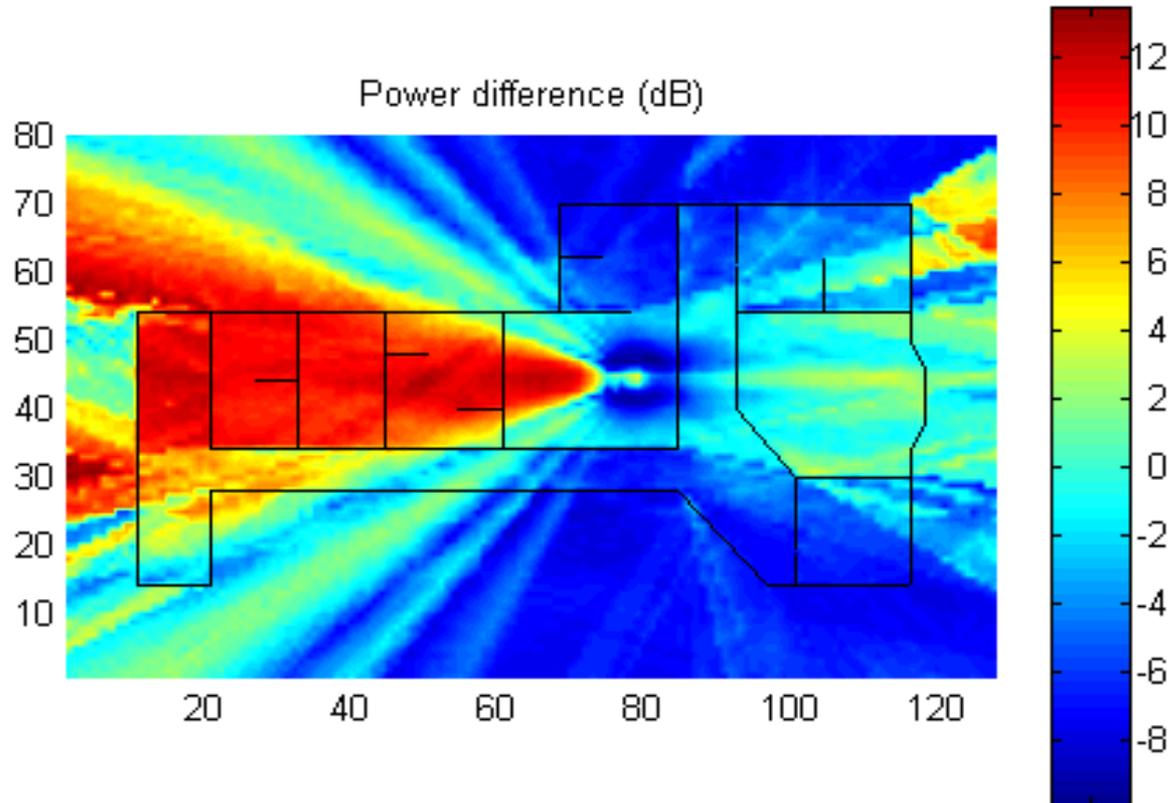
Received power	$> -50\text{dBm}$
RMS delay spread	$< 50\text{nsec}$
K-factor	$> 0\text{dB}$



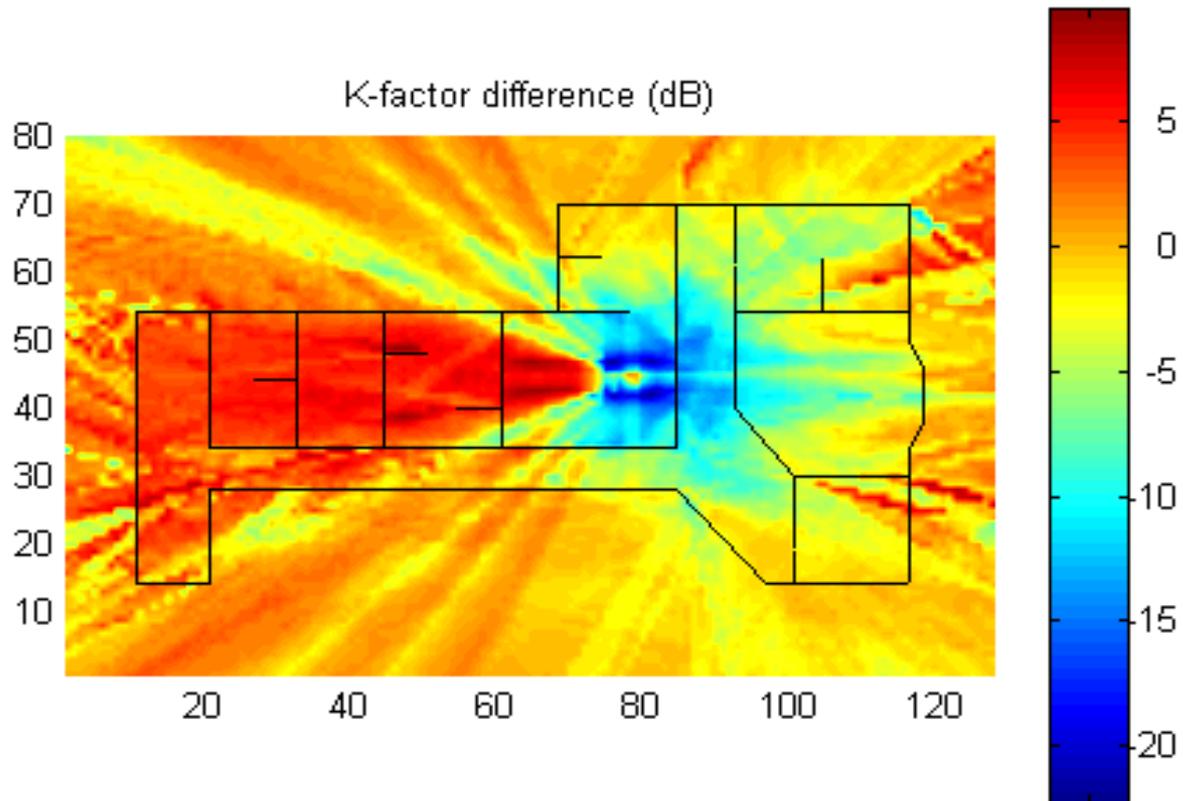
## k-factor and RMS delay spread versus power for the mobile positions inside the building



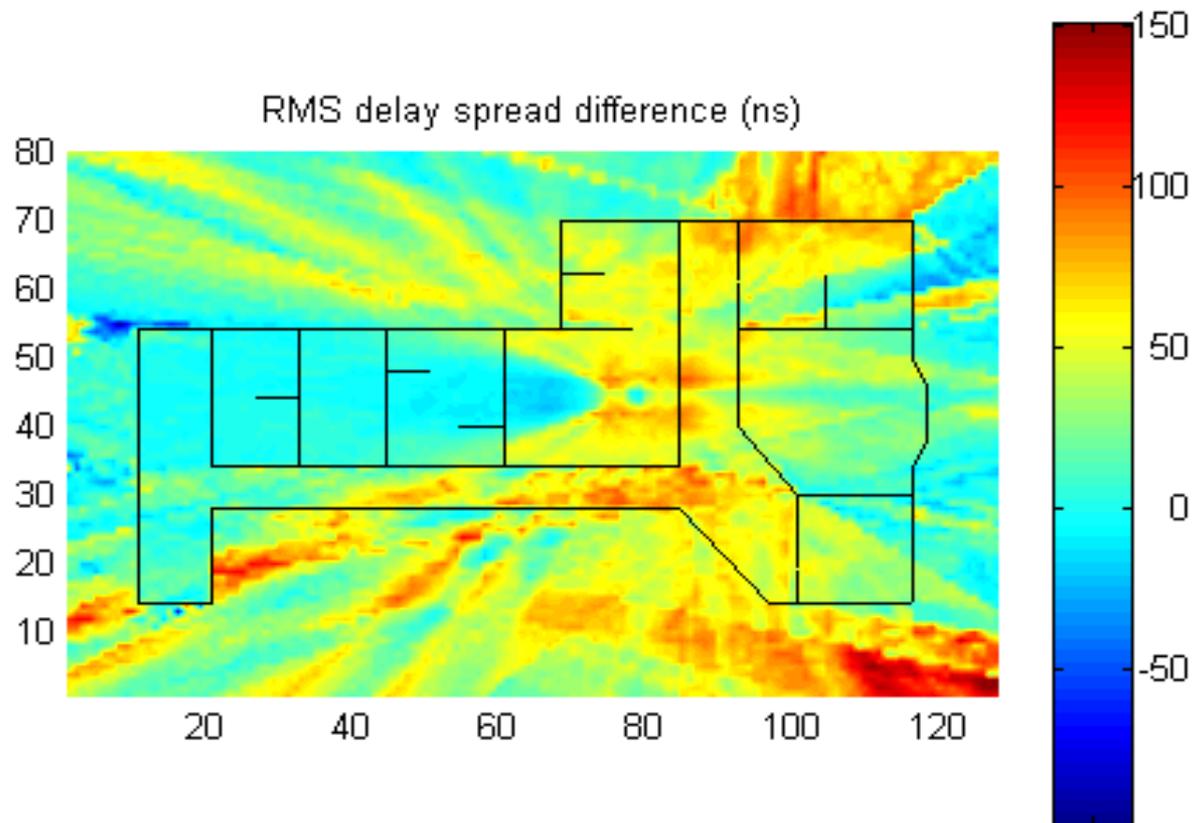
# Difference between the predictions for a directional antenna and a vertical dipole at the base station



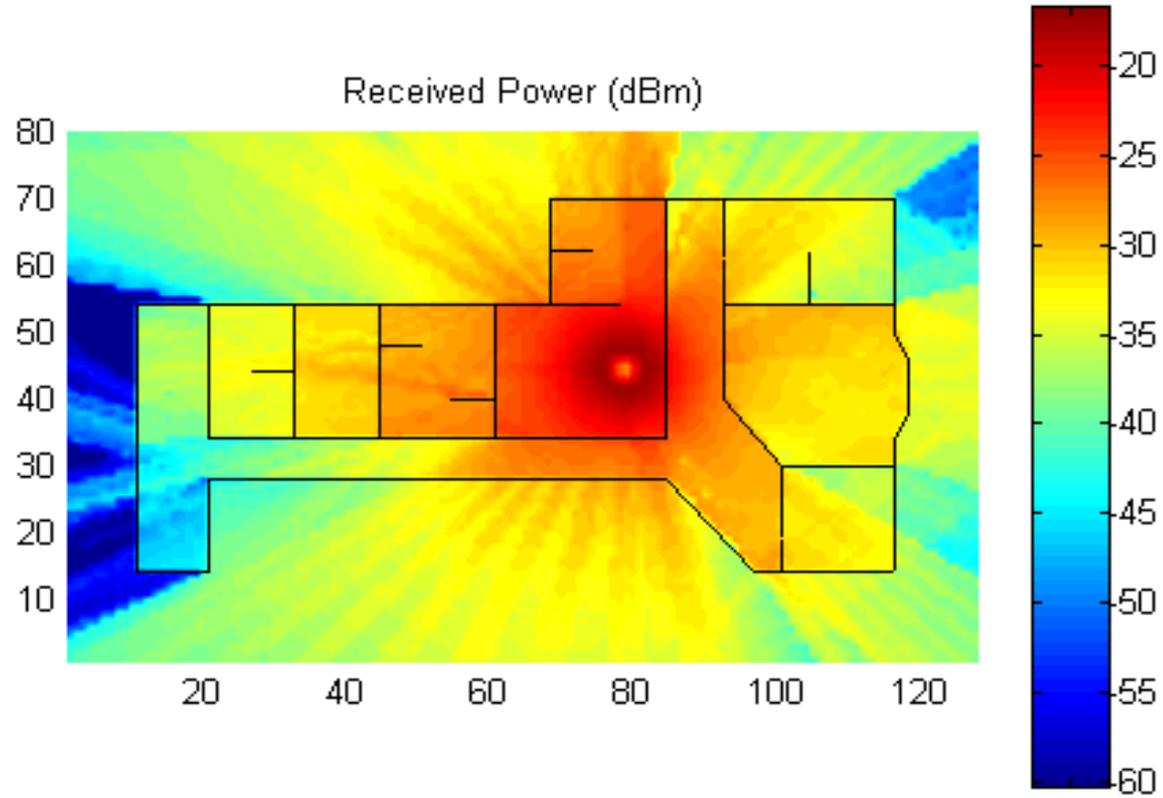
# Difference between the predictions for a directional antenna and a vertical dipole at the base station



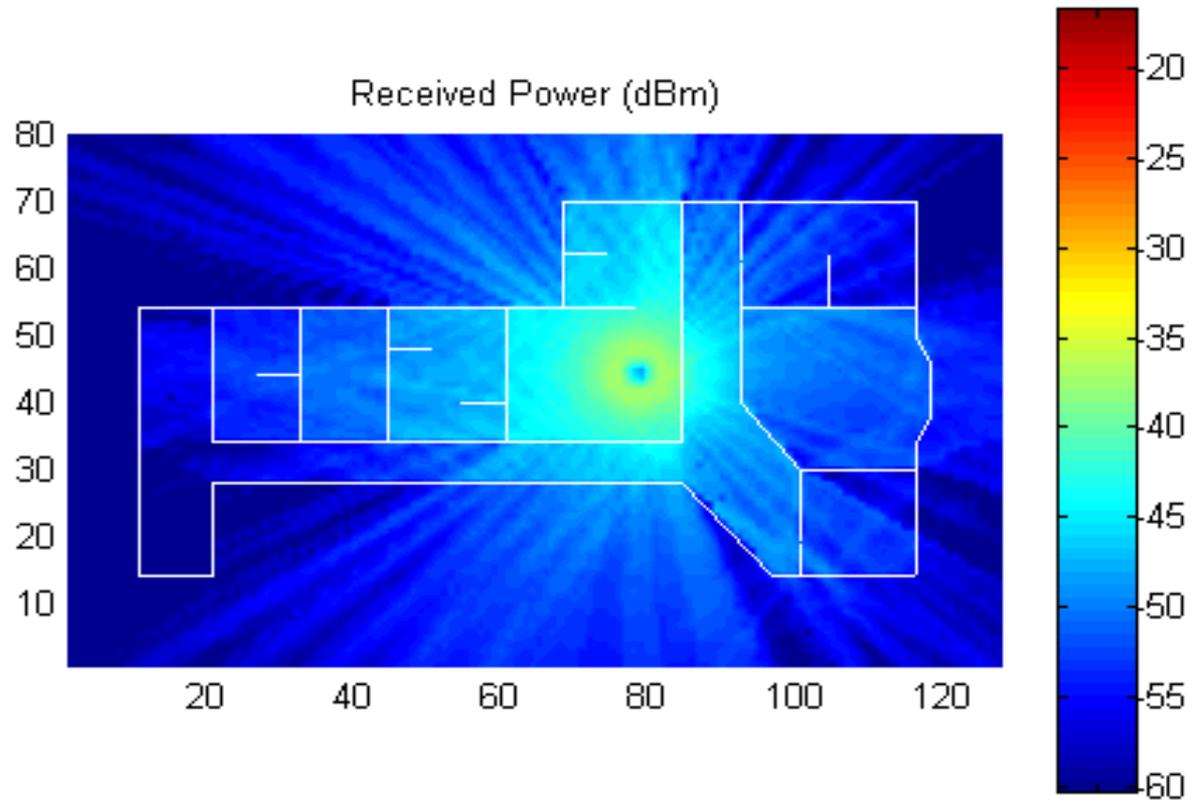
# Difference between the predictions for a directional antenna and a vertical dipole at the base station

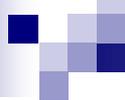


## Received power at 1.8GHz



## Received power at 17GHz





# Ντετερμινιστικές Τεχνικές

**2.FDTD MODELS (FINITE DIFFERENCE TIME DOMAIN)**

**3.MOMENT METHOD MODELS**

**4.ARTIFICIAL NEURAL NETWORK MODELS**

**5.VECTOR PARABOLIC-EQUATION MODEL**

**6.WAVEGUIDE MODEL**

# ΣΥΝΟΨΗ ΜΟΝΤΕΛΩΝ ΓΙΑ PATH LOSS

Model Name	Suitable Environment	Complexity	Experimental Data	Details of Environment	Accuracy	Time	Other
Okumura Model	Macrocell	Simple	Based on experiments	No	Good	Little	Graphical path-loss data
Hata Model	Macrocell (early cellular)	Simple	No	No	Good	Little	
COST-231	Microcell (outdoor)	Simple	No	No	Good	Little	
Dual-Slope	Microcell and picocell (LOS region)	Simple	No	No	Good	Little	
Ray-Tracing	Outdoor and indoor	Complex	No	Yes	Very Good	Very Much	
FDTD	Indoor (small)	Complex	No	Every detail	Best	Very Much	Often combined with ray tracing
MoM	Indoor (small)	Complex	No	Every detail	Best	Very Much	
ANN	Outdoor and indoor	Complex	Yes	Detail	Very Good	Little	Takes time to learn from experimental data