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Evaluating the effect of antenna tilt and rotation on antenna performance in an indoor environment

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Aim of study

Undertake an initial evaluation of the performance of antenna elements suitable for a mobile handset for operation at 5.2GHz

- See how performance varies with tilt and rotation of antennas
- Require suitable measured angle of arrival (AoA) data
- Need to benchmark performance

Plan of action

Antenna elements: 3 element types (Cavity-backed Slot, Printed Inverted-F and Dielectric Resonator) at two positions on a small mobile terminal

Propagation data: Combine the measured full (3D) far-field radiation patterns of each antenna with measured AoA data for a laboratory/office space

Terminal orientation: Tilted and rotated in order to determine the variation in performance that is obtained for the 3 transmitter locations

Benchmarking: Results are presented as cumulative distribution functions of directivity relative to a benchmark Hertzian dipole for operation at 5.2GHz

Antenna orientation

Antenna tilted in
y-z plane:
Range 5° to 45°

Antenna tilted
in x-z plane:
Range 0° to 60°

Two antenna mounting positions on terminal:
11cm high, 6cm wide, 1.4cm thick

🔥 The bigger picture

For full antenna evaluation need to take into account all of this

🔥 Transmitter positions

Measurements performed at 10 transmitter locations in Laboratory

- Consider 3 of the transmitter positions here
- Single floor level

Laboratory environment

Corner of laboratory

Suspended ceiling

Anechoic chamber →

Floor (metal plates)

Open plan environment:

- Floor area about 18m by 20m
- Ceiling height >3.2m
- High and low level benching

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Scanning antenna

Antenna used to scan full Azimuth & Elevation for both V & H-polarisations

Flann dual-polarised horn antenna

- Directivity of 14.5dBi at 5.2GHz
- 30° & 33° HPBW in principal planes

Measured far-field
radiation patterns
(vertical feed)

🔥 Transmitter in kitchen

Signal intensity as projected onto wall area

Measured data from scanning antenna

Azimuth

Elevation

Signal AoAs

Process raw data
to determine AoA
components
(Tx in Kitchen)

Process is being refined to improve the AoA determination

Corner of laboratory

Azimuth

Elevation

Corner of room resembles
a corner reflector antenna

Main ray paths

The main ray clusters are shown for each of the 3 locations

- azimuth perspective

Colour indicates Tx position:

- Solid lines show highest levels
- Dotted lines indicate the extent of high level signals

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Summary of signal strengths

Corner of Lab (LoS)

Kitchen

Chamber

Full azimuth & elevation perspective

- Relative power levels, Tx (V) – Rx (V)
- Blue indicates signal levels of 10dB below peak levels
- Tx (V) - Rx (H) levels are 8.3dB lower for LoS and 3.5dB for Chamber

Measurement repeatability

Kitchen
(raw data)

Difference
(data normalised to maximum)

Along corridor

Peak value for
difference pattern
is 7dB lower than
raw data

Entrance to kitchen

🔥 Antenna orientation - reminder

Antenna tilted in
y-z plane:
Range 5° to 45°

Antenna tilted
in x-z plane:
Range 0° to 60°

Antenna rotated
in x-y plane:
Range 0° to 360°

Apply equal probability for all configurations

Example of antenna tilt

🔥 Cavity-backed slot antenna

Vertical component

Horizontal component

Measured far-field radiation patterns for Element 3 (side)

A. Pal, C. Williams, G. Hilton, and M. Beach, "Evaluation of Diversity Antenna Designs Using Ray Tracing, Measured Radiation Patterns, and MIMO Channel Measurements", *EURASIP Journal on Wireless Communications and Networking*, Article ID 58769, 2007.

DRAs & IFAs

Patterns for one of each type of element

Dielectric resonator

Vertical components Horizontal components

Inverted F

York University and Antenova designs

Directivity levels

Slot		DRA		IFA		Ideal dipoles	
Top	Side	Top	Side	Top	Side	Jz	Jy
6.8	6.5	7.8	7.2	8.8	5.9	1.8	1.8

Maximum Directivity levels for the elements in dBi

All practical elements on terminal have a
Directivity between 5.9 and 8.8dBi

IFA has variation of about 3dB with same
element though different position on terminal

Statistical analysis

Cumulative Distribution showing outcome of antenna tilts in two planes with full 360° rotation

Antenna field levels

AoA field levels

No. of paths

$$D_{r(norm)} = 10 \log \left| \frac{\sum_{n=1}^N g_n C_n \Gamma_n}{\sum_{n=1}^N d_n C_n \Gamma_n} \right|^2$$

Polarisation misalignment

Normalisation:
Jz source, no tilt

Solid line – top antenna
Dashed line – side antenna

$$|g_n|^2 = D(\theta_n, \phi_n)$$

Top Antenna – 'horizontal' mounting
Side Antenna – 'vertical' mounting

Vertical and horizontal orientations for all types of element

Summary of results

Corner of Lab.

Kitchen

Chamber

How to analyse overall performance?

- Plots mainly to right – better overall performance
- Levels below a given threshold, say -5dBi ('outage')

Azimuth rotation tends to favour the more omni-directional elements
Vertical Tx favours antennas with more dominant vertical component

Conclusions

AoA data for a number of transmitter locations within an indoor environment are considered, and these show that with no direct (visible) LoS, the signals reaching the receiver tend to be dominated firstly by the diffracted paths and then any reflected paths - these tend to be clustered

For the environment considered, it is a predominantly 'static' environment and hence magnitudes & phases of received signals are similar with repeat measurements

Variations in element patterns result in directivities ranging from 5.9 to 8.8dBi, though this does not help to identify which element will perform best under the test conditions considered here.

Variations in signal strength of greater than 30dB (with respect to the benchmark dipole) were observed due to polarisation misalignment and pattern directivity.

🔥 Where to next?

- Programme of measurements for home & office environments
- Use of access point antennas in addition to monopole Tx
- Use of horizontal and vertical polarisations for Tx

Evaluating system performance on different floors in a terrace house

Any Questions?

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