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Local Fading Characterization in Ground-Wave Propagation at MW Band

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1. Introduction

Digital Radio Services for MF band

- New digital radio services have been developed for MF band
  - HD-Radio (IBOC)
  - Digital radio Mondiale (DRM)

HD Radio
It's Time to Upgrade!

For AM,FM bands
USA

drm

Below 120 MHz
Open standard

- The coverage criteria when planning digital systems are more restrictive than in analogue services (95%, 99% locations)

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1. Introduction

International Telecommunication Union

- Question ITU-R 202-3/3
  "Methods for predicting propagation over the surface of the Earth"
  - To study the influence of building and man-made structures

- Question ITU-R 225-5/3
  "The prediction of propagation factors affecting systems at LF and MF including the use of digital modulation techniques"
  - "Are there significant variations in ground-wave field strength with location or with time?"

This study contributes with results for these questions

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2. Objectives

Main objective

Statistical analysis of the local fadings observed in ground wave propagation at MF band in rural and suburban environments

Partial objectives

- Identification of the causes of the local fadings
- Analysis of the local fadings at MF band
- Statistical characterization of the local variations (short-term):
  - Probability Distribution Functions (PDF)
  - Estimation of useful parameters for system planning

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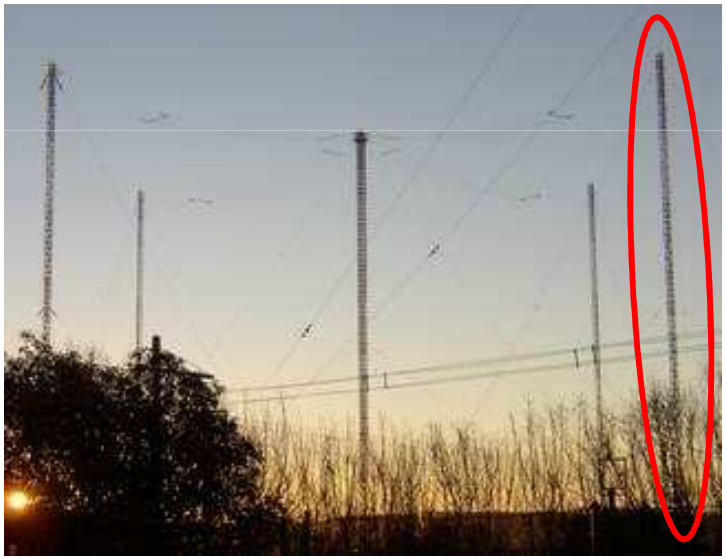
3. DRM Field Tests

Experimental network

- Location: Arganda (Madrid)
- Frequency 1359 kHz
- Nominal Bandwidth 9 kHz



- Modulator TELEFUNKEN DMOD2
- Amplifier TELEFUNKEN TRAM 10
- Output Power 4 kW EIRP
- Vertical monopole

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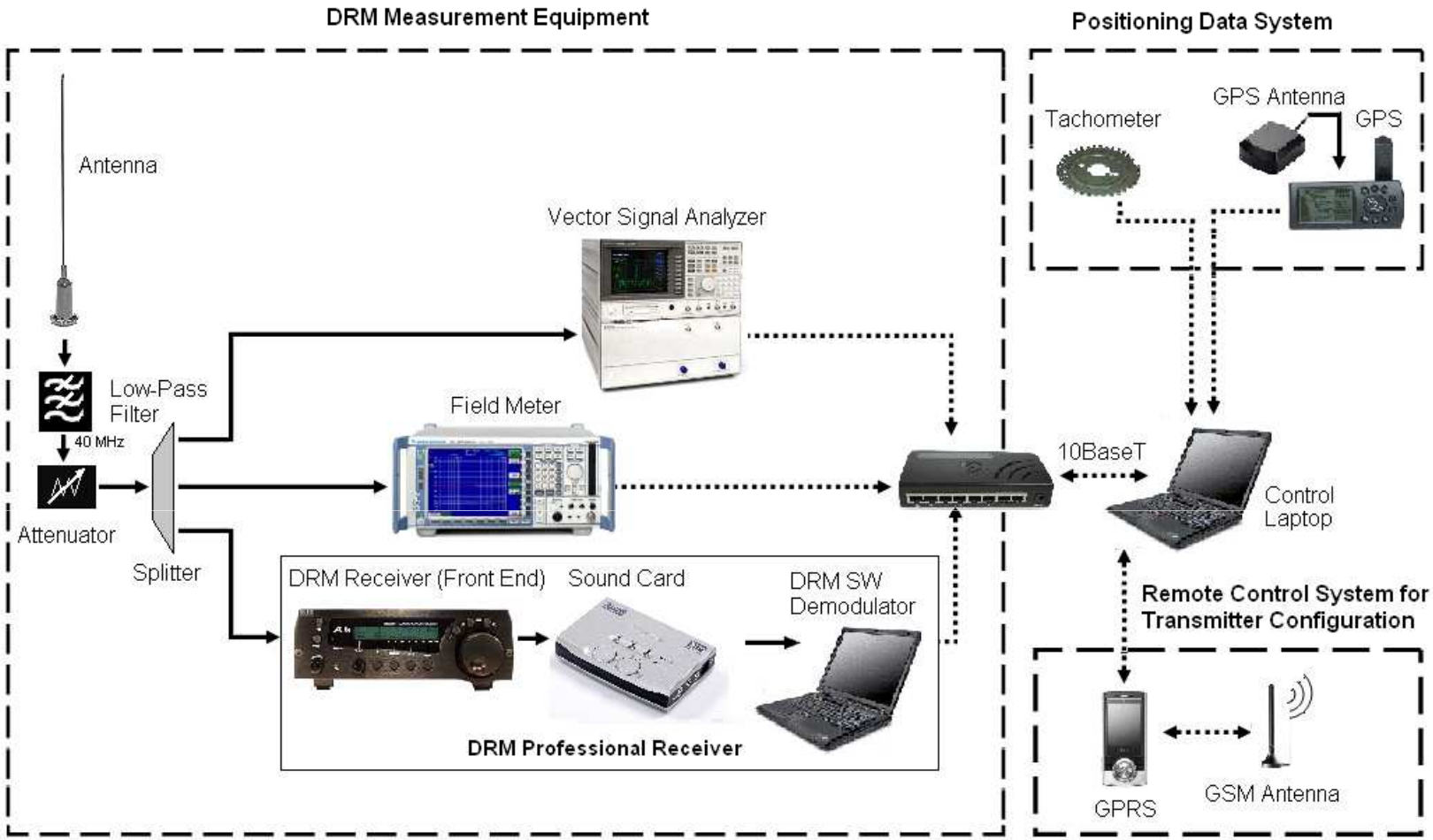
3. DRM Field Tests

Measurement System



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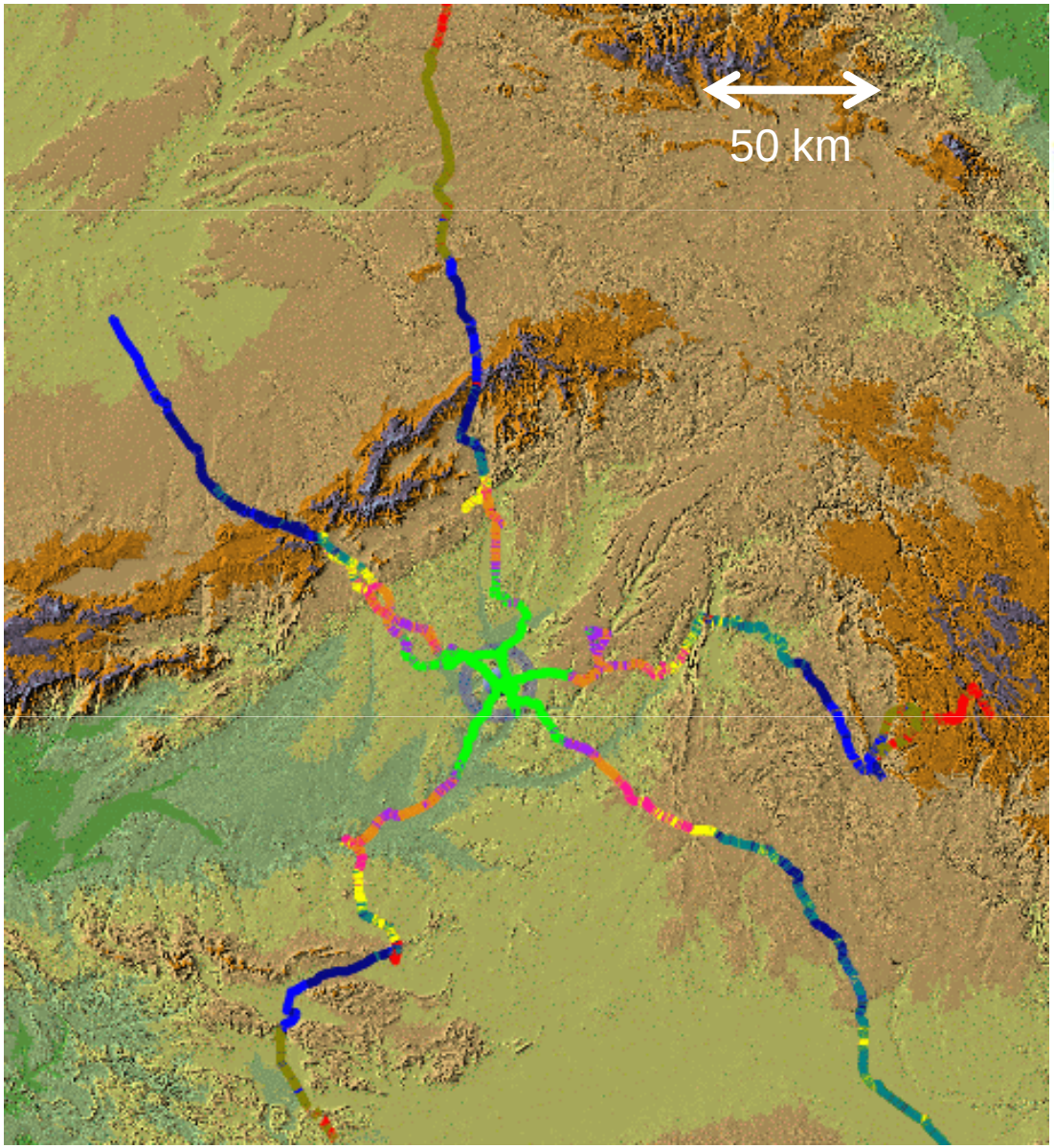
3. DRM Field Tests

Field trials

- 2200 km
  (> 1400 miles)
  in 5 radial journeys

Route selection:

- 168 routes for the analysis of local fadings
- 76 additional routes for obtaining the PDF in three reception environments



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4.1 Normalization of the signal

- The analysis of the local fadings requires the previous subtraction of the large scale variations of the field strength values
  - The large scale variations are formed by the consecutive local mean values along a route
  - The **(short-term**) normalized field strength values are obtained

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4.1 Normalization of the signal

- The analysis of the local fadings requires the previous subtraction of the large scale variations of the field strength values

- The Lee Method is the technique recommended by ITU-R for estimating the local mean values
  - In Rayleigh channel
  - Considering the Clarke's multipath model
  - At UHF band

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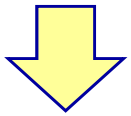
4.1 Normalization of the signal

- The analysis of the local fadings requires the previous subtraction of the large scale variations of the field strength values

- The Lee Method is the technique recommended by ITU-R for estimating the local mean values



- A generalized method has been developed by the authors for estimating the local mean values:
  - In any channel model
  - At any reception condition
  - At any frequency band
  - … and without a priori knowing the PDF of the signal

- This method has been applied to MF band, in order to obtain the normalized field-strength values

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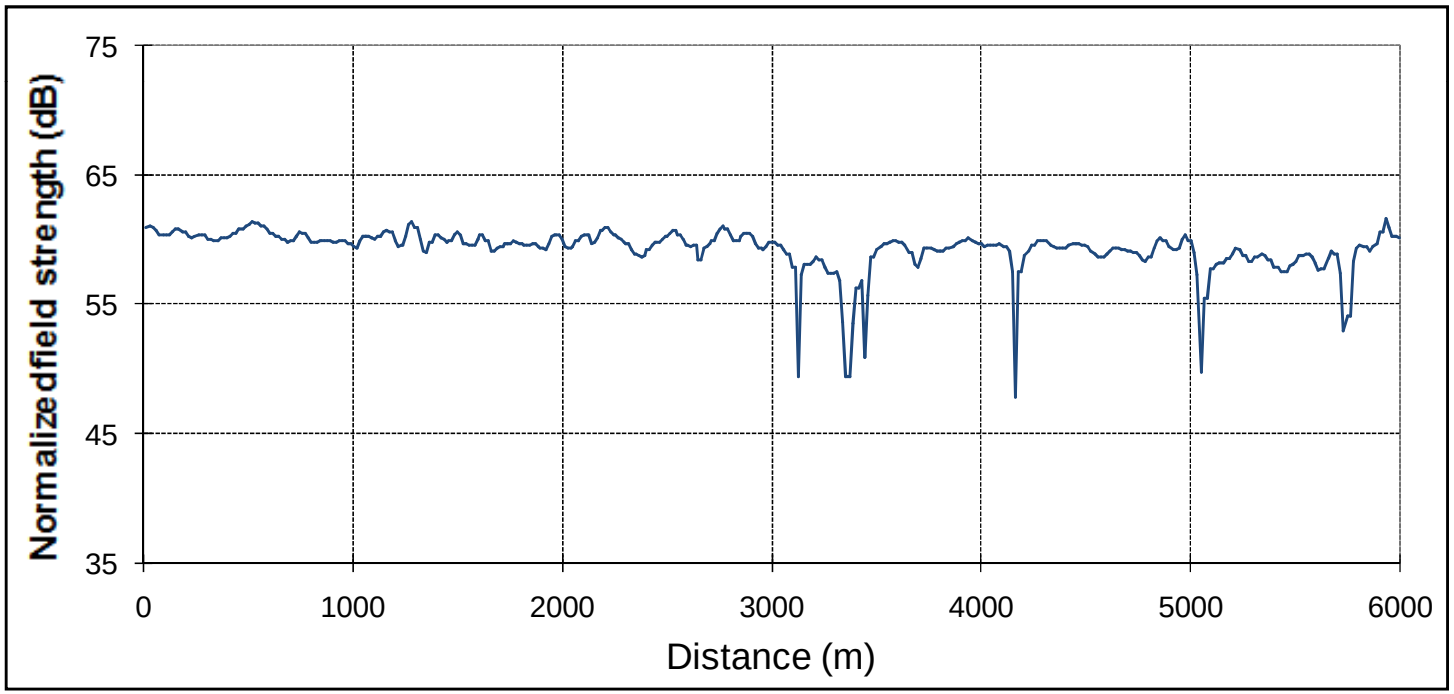
4.2 Analysis: Causes of the local fadings

Example 1: Rural environment



- Similar reception environment along the route: rural and open area
- An increase of the variability of the field strength is noticeable in the second part of the route

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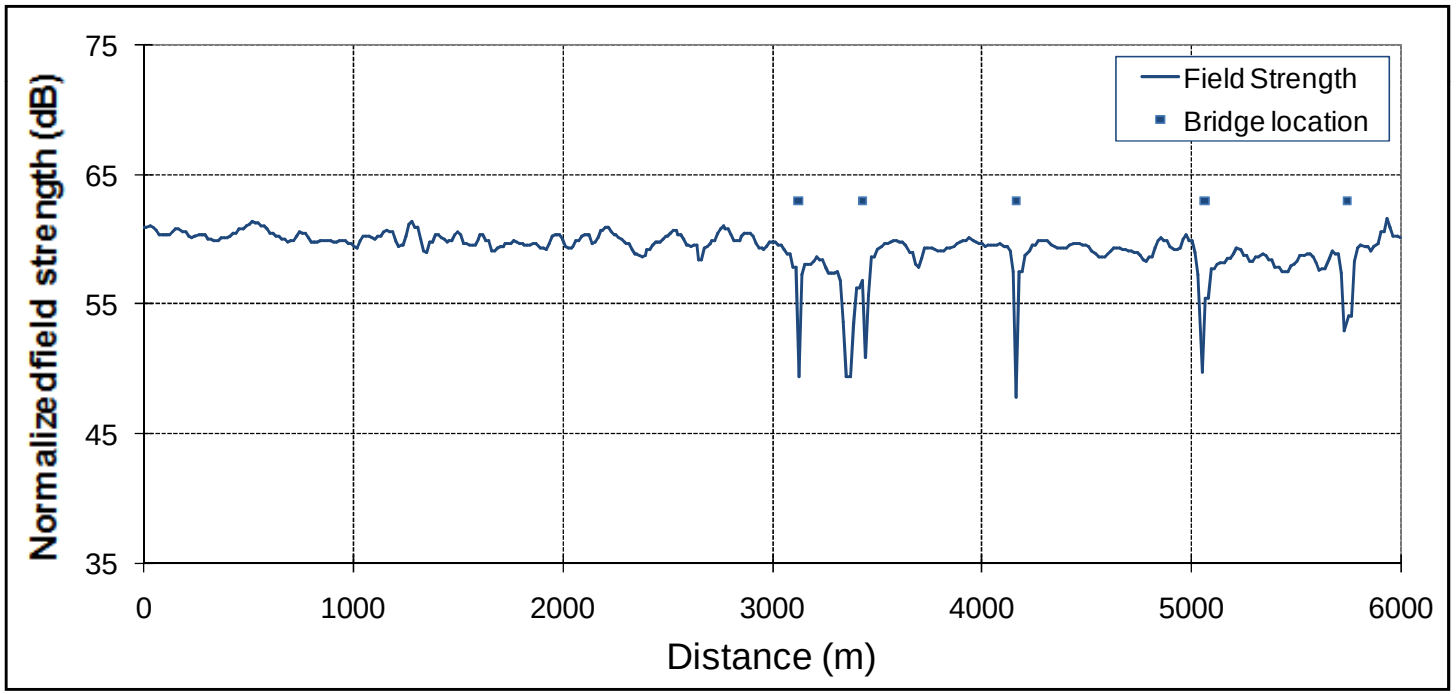
4.2 Analysis: Causes of the local fadings

Example 1: Rural environment



- Great structures (bridges) can change significantly the signal variability

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4.2 Analysis: Causes of the local fadings

Example 2: Relief road of a big city, suburban environment

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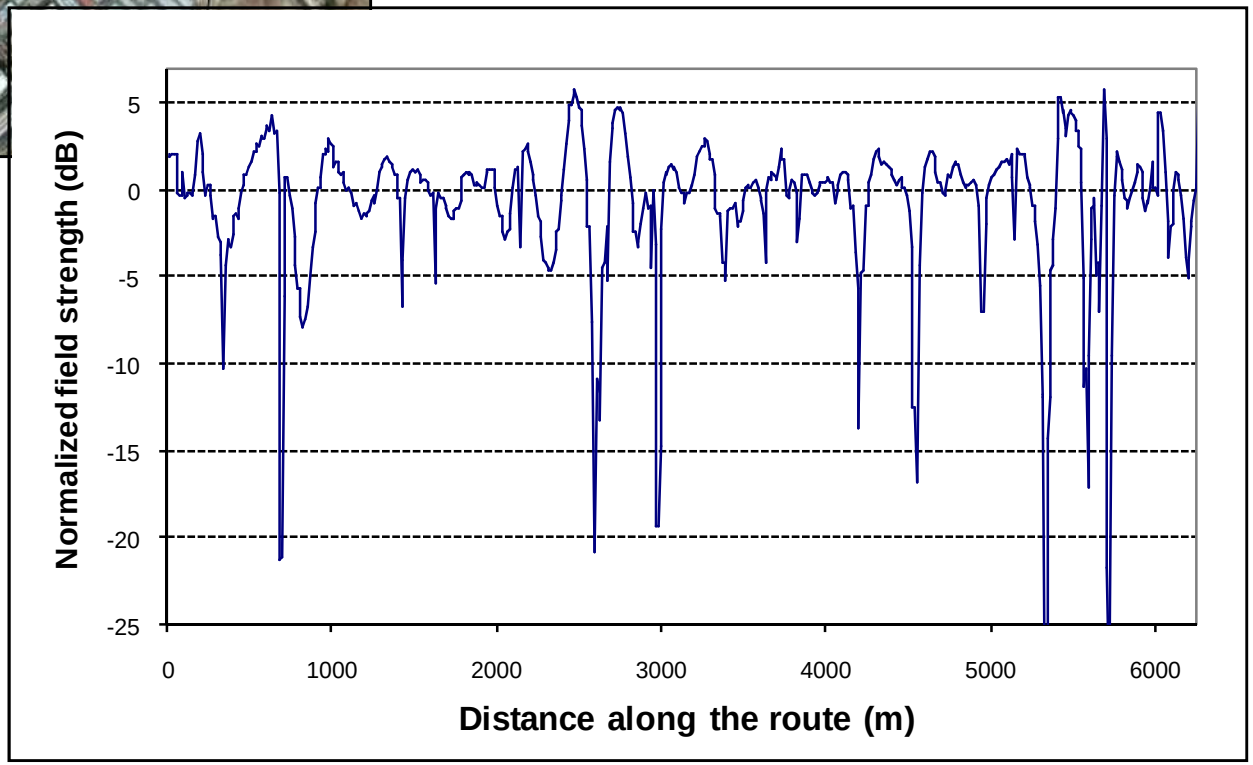
Example 2: Relief road of a big city, suburban environment



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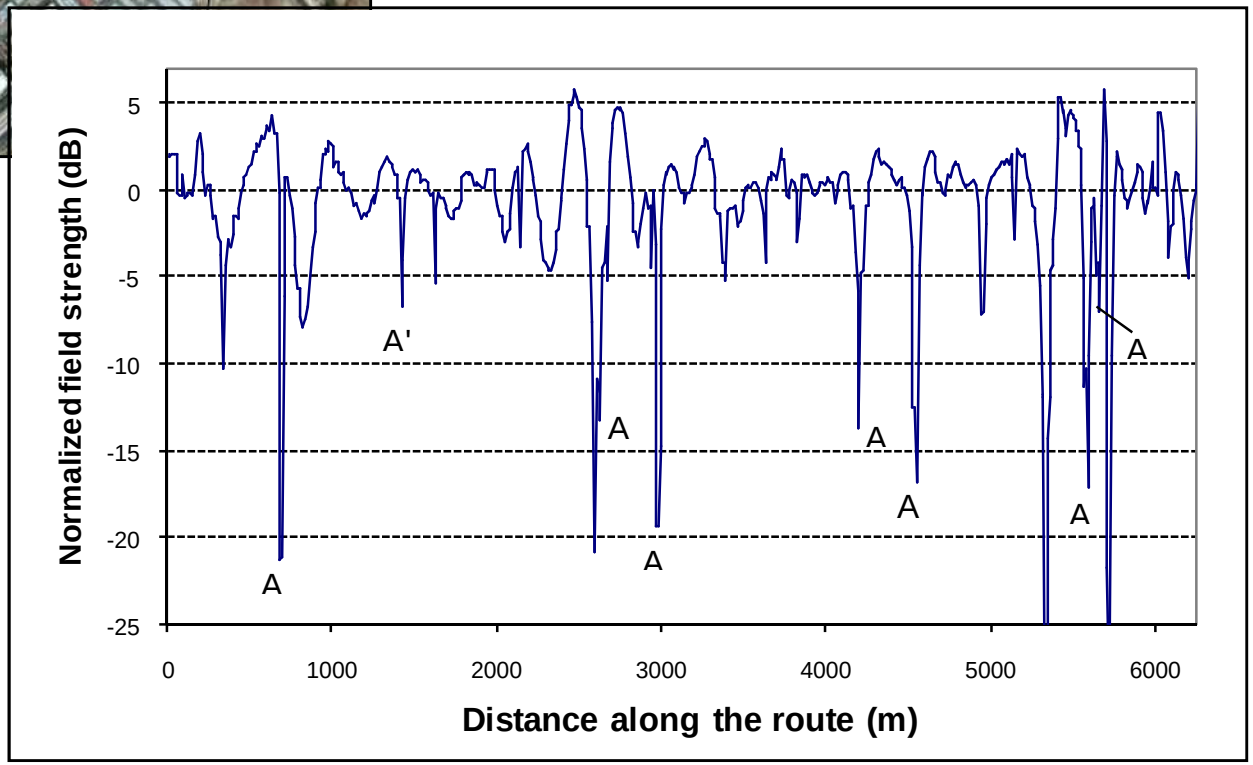
4.2 Analysis: Causes of the local fadings

Example 2: Relief road of a big city, suburban environment



A- Bridges and pedestrian overpasses

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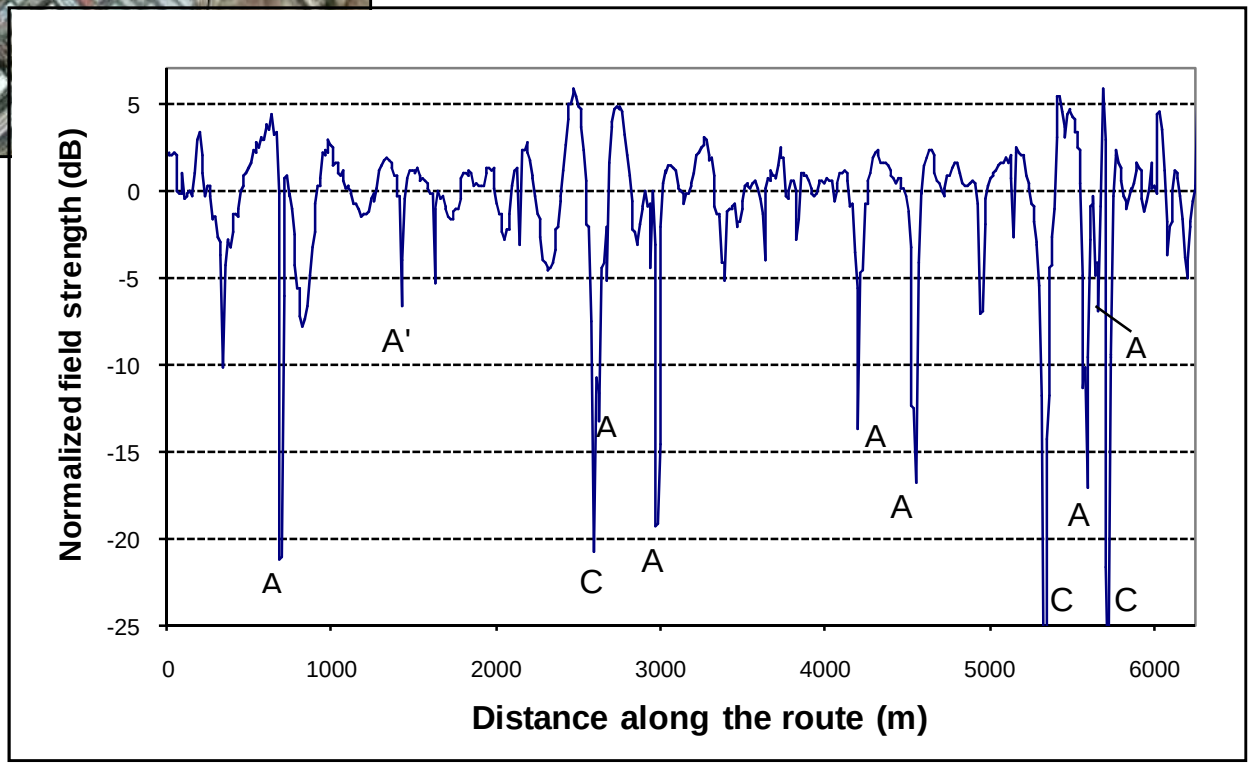
4.2 Analysis: Causes of the local fadings

Example 2: Relief road of a big city, suburban environment



A- Bridges and pedestrian overpasses

C- Bridges (railway)

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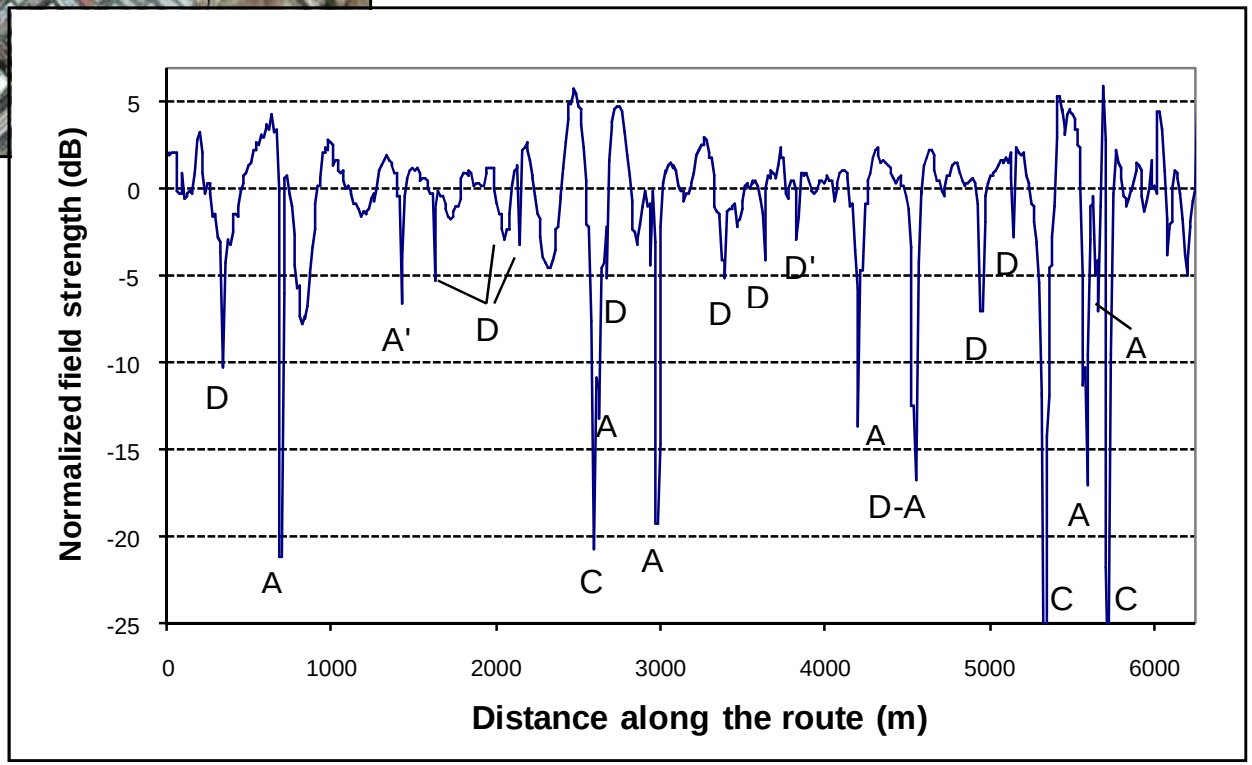
4.2 Analysis: Causes of the local fadings

Example 2: Relief road of a big city, suburban environment



A- Bridges and pedestrian overpasses

C- Bridges (railway)

D- Information panels over the road

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4.2 Analysis: Causes of the local fadings

- There is a complete correlation between the relevant fadings of the received signal and the presence of great man-made structures in the vecinity of the receiver location

- The compilation of a significant number of items will allow the statistical characterization of the influence of these great man-made structures on the field strength level

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4.3 Fading characterization

Elements included in the analysis:

- Bridges and pedestrian overpasses
- Bridges (railway)
- Information panels over the road
- Power lines

Parameters of the DRM signal:

- Field strength (RF)
- MER (IQ)
- AudioQ (Service data)

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4.3 Fading characterization

Methodology:

- Selection of elements located in rural areas (to avoid additional influences)
- The variation of the field strength level is analyzed in every single structure
- Relations between the characteristics of the structures and the field strength fadings are obtained

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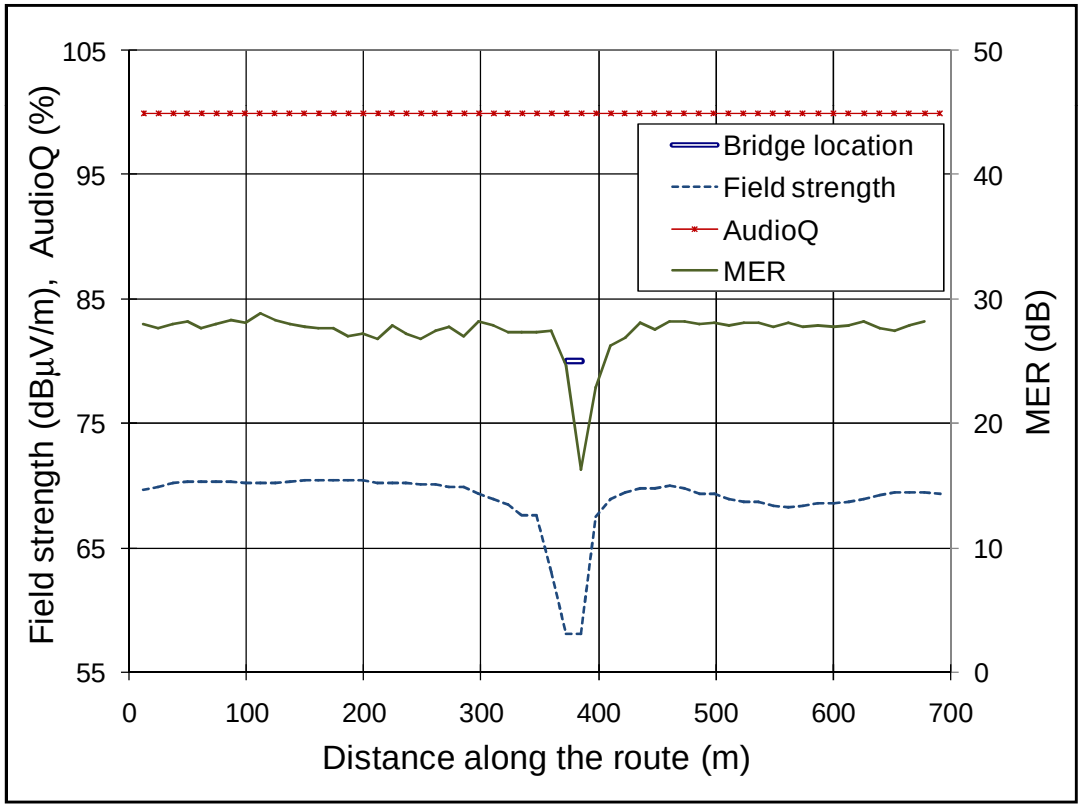
4.3 Fading characterization

Influence of a bridge (road):



- Local field strength fading of significant level
- MER decreasing (same level as field strength)
- Audio quality remains OK in most of the cases (AudioQ=100%)

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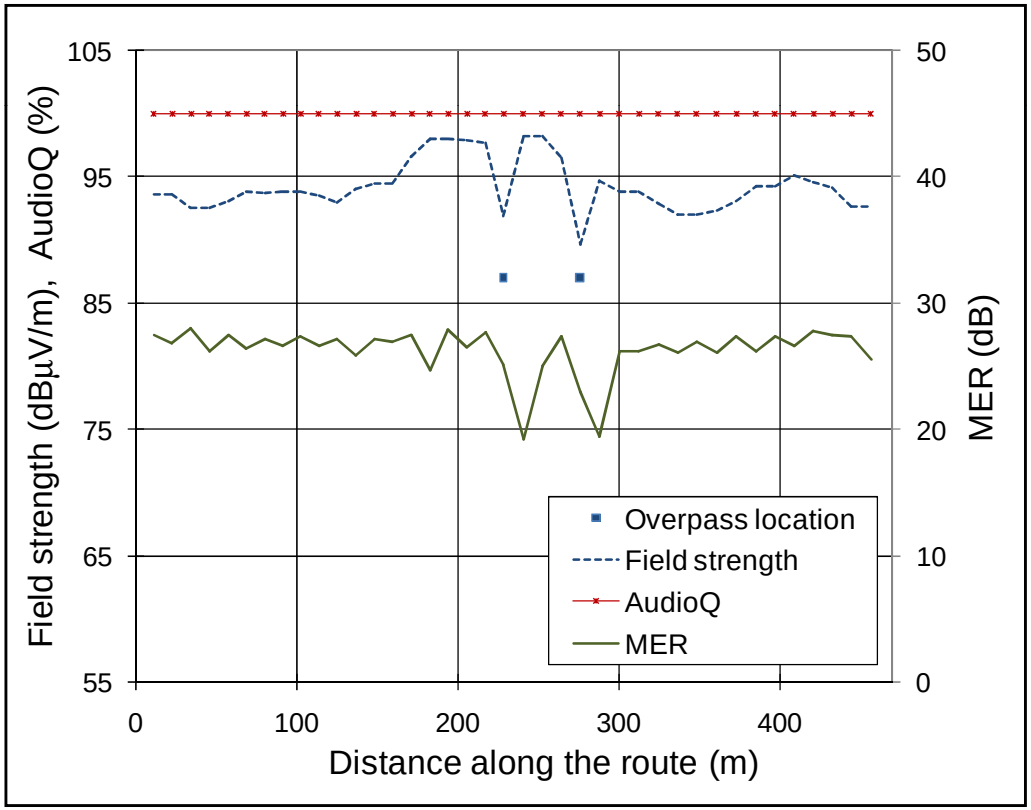
4.3 Fading characterization

Influence of a pedestrian overpass:



- Local field strength fading of lower level
- MER decreasing (same level as field strength)
- Audio quality remains OK in all the cases (AudioQ=100%)

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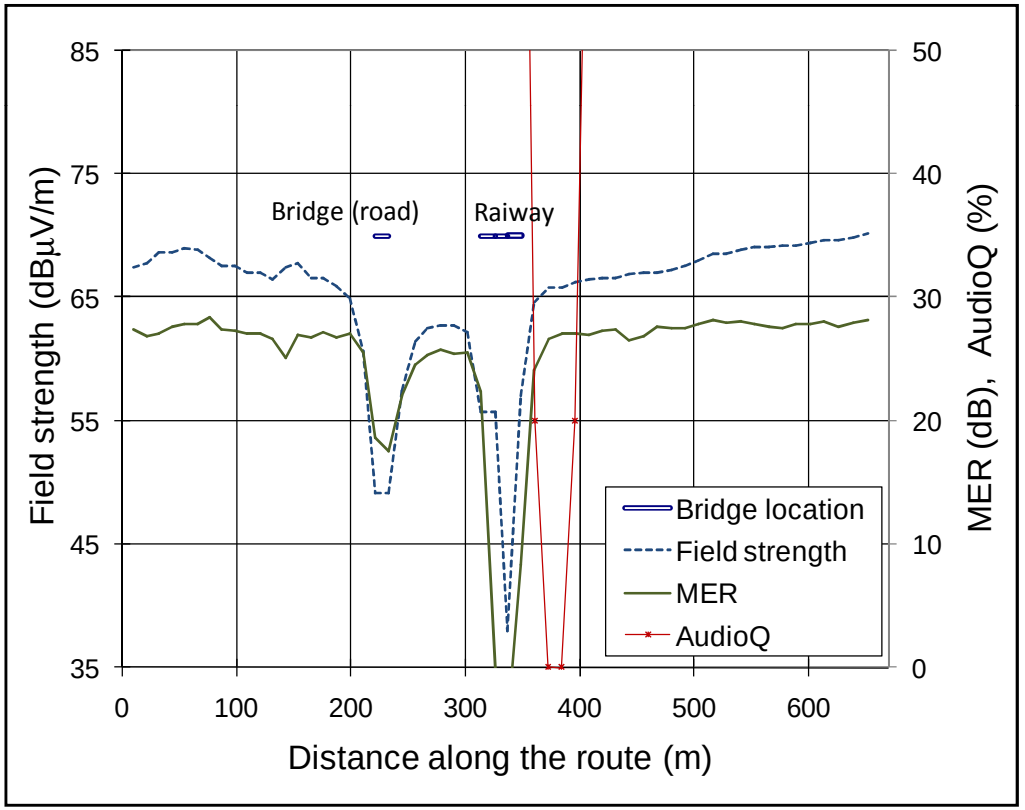
4.3 Fading characterization

Influence of a bridge (railway):



- Local field strength fading is significantly higher
- MER decreasing is higher too
- Audio quality falls bellow 100% in many cases

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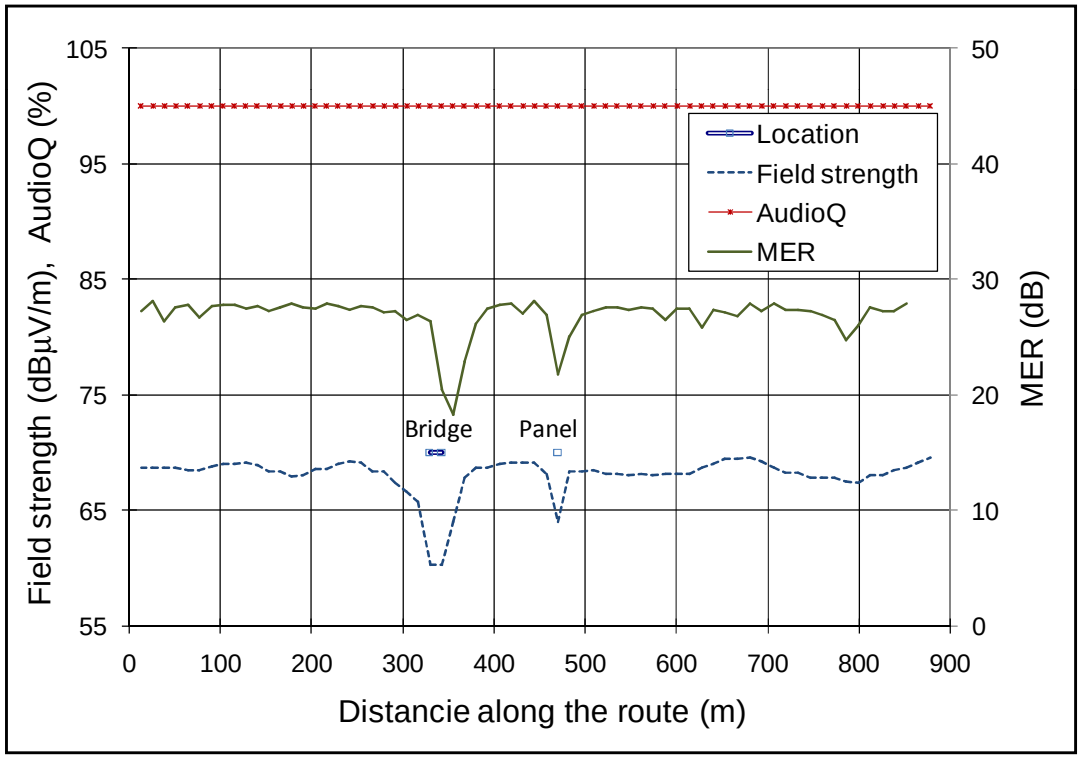
4.3 Fading characterization

Influence of an information panel (supports in both verges):



- Local field strength fading is lower than the previous cases
- MER decreasing is proportional
- Audio quality remains OK in all the cases (AudioQ=100%)

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4.3 Fading characterization

Results

Structure	Width (m)	Fade depth (dB)	Fade length (m)
Highway or road overpass	*18 - 24*	23.1	51.5
	14 - 16	12.6	
	10 - 12	9.8	41.0
	6 - 9	8.3	30.5
	All	9.1	20 m - 40 m longer than the bridge width
Pedestrian overpass	*2 - 3*	6.5	17.5

- There is a clear correspondence between the width of the bridge and both the fade depth and fade length
- Bridges (railway): fade depths between 22 dB and 37 dB

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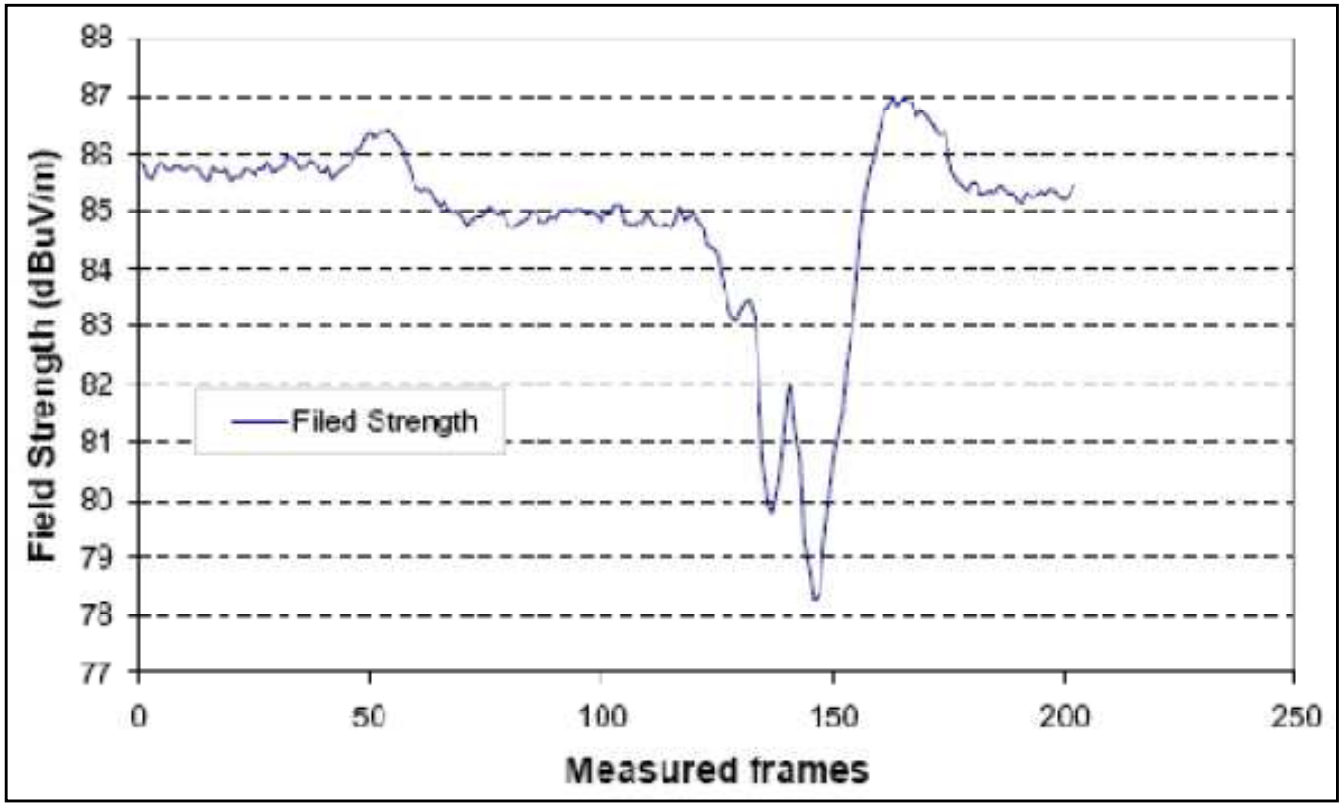
4.3 Fading characterization

Power lines

- There is no homogeneous behaviour in the signal variation



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4.3 Fading characterization

Power lines

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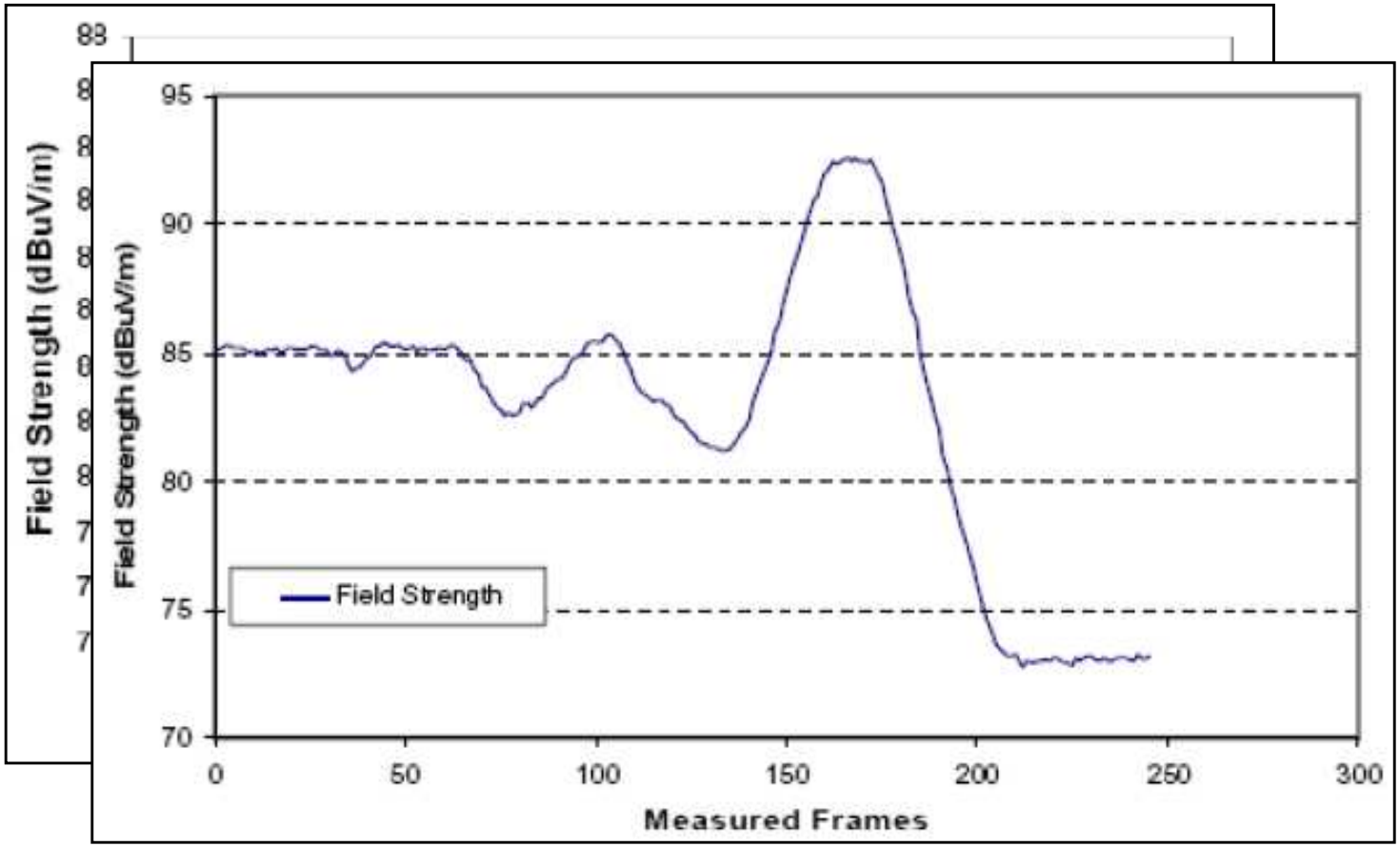

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4.3 Fading characterization

Power lines

- The power lines generate high level noise at MF band ⇒ S/N decreases
- The wires obstruct the propagation of the signal ⇒ Field strength fadings

- There are many cases where fading depth is similar to the generated by small bridges:
  - Field strength fade depth (median): 8.5 dB
  - Field strength fade length (median): 40 m (120 ft)

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4.4 Characterization of the short-term

Aim of the statistical characterization

- The local variability can be modelled by a PDF, which allows the use of a theoretical functions in coverage planning:
  - Detailed knowledge of location variability
  - Estimation of additional signal level necessary for covering a specific percentage of locations

Methodology

- Statistical inference techniques (chi-2, MLE), to obtain the PDF that best fits field data

- Moreover, empirical estimation of the sample variability: standard deviation of normalized values, fade depth

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4.4 Characterization of the short-term

Reception environments

- “Generic” rural (out of the cities)

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4.4 Characterization of the short-term

Reception environments

- "Generic" rural (out of the cities)
  - Open rural

4.4 Characterization of the short-term

Reception environments

- "Generic" rural (out of the cities)
  - Open rural
  - Rural with large structures or buildings

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4.4 Characterization of the short-term

Reception environments

- "Generic" rural (out of the cities)
  - Open rural
  - Rural with large structures or buildings
  - Suburban:
    industrial estates, relief roads

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4.4 Characterization of the short-term

Results

	Open Rural	*Rural (man-made structures)*	*Suburban*
σ of normalized field strength values	0.8 dB	1.7 dB	2.3 dB
Fade depth *50% ~ 90%* *50% ~ 95%* *50% ~ 99%*	 1.0 dB 1.3 dB 2.4 dB	 1.3 dB 2.5 dB 6.5 dB	 2.8 dB 4.1 dB 8.0 dB
Best PDF	Gaussian (σ = 0.78 dB)	Weibull (b = 0.95; α = 9.18)	Weibull (b = 0.92; α =5.38) Gaussian (σ = 2 dB)

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5. Conclusions (1)

- Significant field strength fadings are due mainly to the presence of great structures in the nearness of the receiver location
- Some of the most representative structures have been identified and selected
- Relations between the signal variations and the most influent characteristics of the structures have been found

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5. Conclusions (2)

- Bridges (road) cause significant field strength fadings:
  - Fade depth between 6 dB and 28 dB
  - Fade length (at - 3dB) between 24 m and 66 m (72 to 200 ft)
  - Both values depend, mostly on the width of the bridge, and on the orientation respect to the propagation direction
- Bridges (railway) cause field strength fadings noticeable higher (22 to 37 dB)
- Overpasses and information panels causes lower fadings
  - Fade depth between 4 dB and 9 dB
  - Fade length (- 3dB) between 10 m and 30 m

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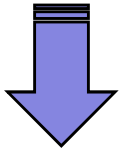
5. Conclusions (3)

- The influence of the power lines is the combination of:
  - A lower S/N due to the high level noise generated by the power lines
  - A field strength fading due to the obstruction of the signal reception



  - There is no homogeneous behavior in the signal variation
  - There are some cases where fading depth is similar to the generated by small bridges

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5. Conclusions (4)

- Characterization of the short-term (normalized field strength)

	Open Rural	***Rural (man-made structures)***	***Suburban***
σ of normalized field strength values	0.8 dB	1.7 dB	2.3 dB
Fade depth *50% ~ 90%* *50% ~ 95%* *50% ~ 99%*	 1.0 dB 1.3 dB 2.4 dB	 1.3 dB 2.5 dB 6.5 dB	 2.8 dB 4.1 dB 8.0 dB
Best PDF	Gaussian (σ = 0.78 dB)	Weibull (b = 0.95; α = 9.18)	Weibull (b = 0.92; α =5.38) Gaussian (σ = 2 dB)

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