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Local Fading Characterization in Ground-Wave Propagation at MW Band

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INDEX

1. Introduction
2. Objectives of the study
3. DRM field trials
4. Local fading characterization
5. Conclusions

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)

1. Introduction

International Telecommunication Union

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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INDEX

1. Introduction

2. Objectives of the study

3. DRM field trials

4. Local fading characterization

5. Conclusions

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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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INDEX

1. Introduction
2. Objectives of the study
3. DRM field trials
4. Local fading characterization
5. Conclusions

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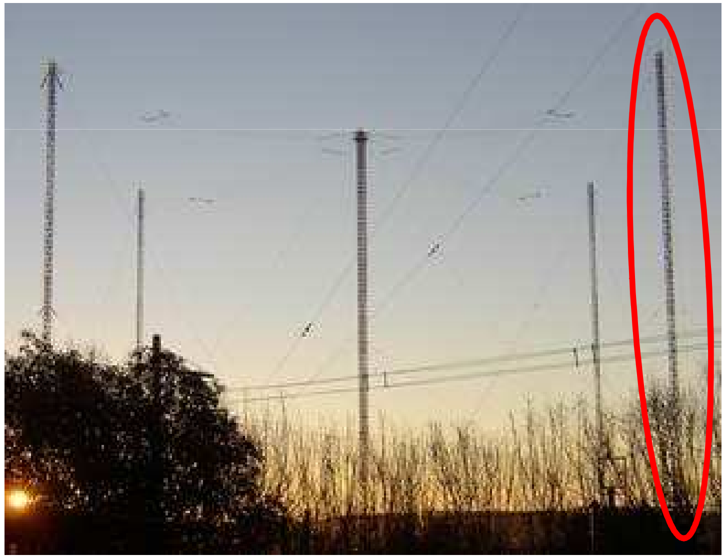
3. DRM Field Tests

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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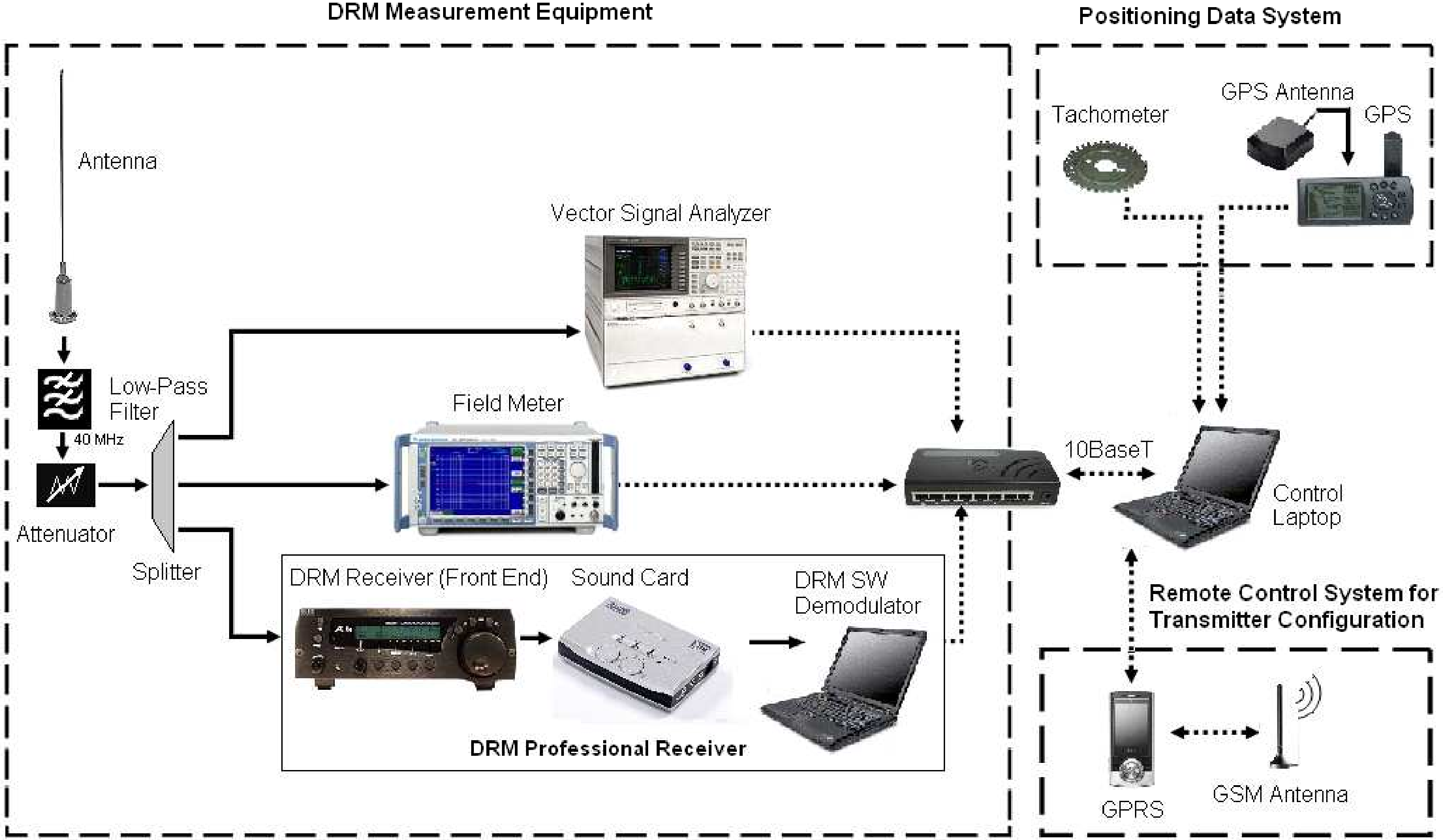
3. DRM Field Tests

Measurement System



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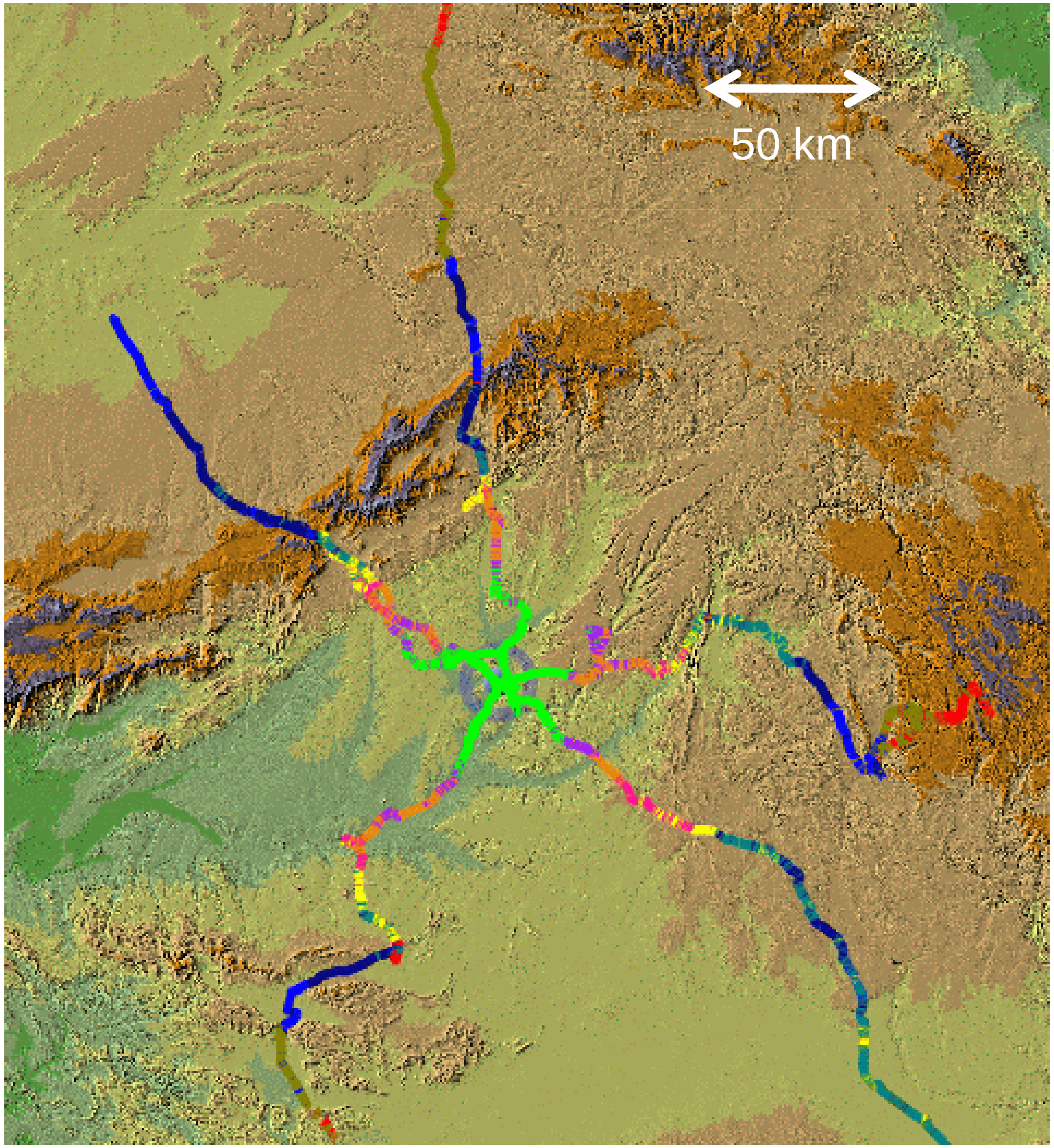
3. DRM Field Tests

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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INDEX

1. Introduction

2. Objectives of the study

3. DRM field trials

4. Local fading characterization

    4.1 Normalization of the signal

    4.2 Identification of the causes of the local fadings

    4.3 Analysis of local fadings

    4.4 Characterization of the short-term

5. Conclusions

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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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INDEX

1. Introduction

2. Objectives of the study

3. DRM field trials

4. Local fading characterization

   4.1 Normalization of the signal

   4.2 Identification of the causes of the local fadings

   4.3 Analysis of local fadings

   4.4 Characterization of the short-term

5. Conclusions

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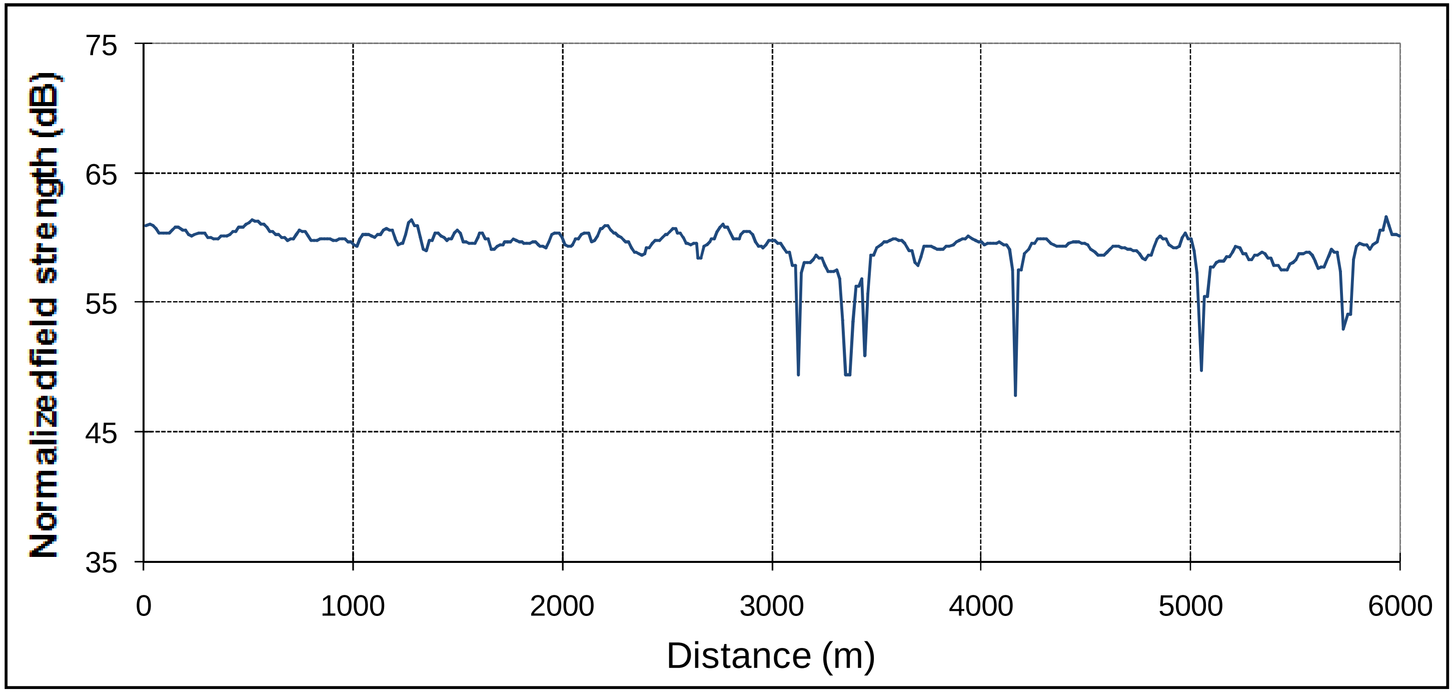
4.2 Analysis: Causes of the local fadings

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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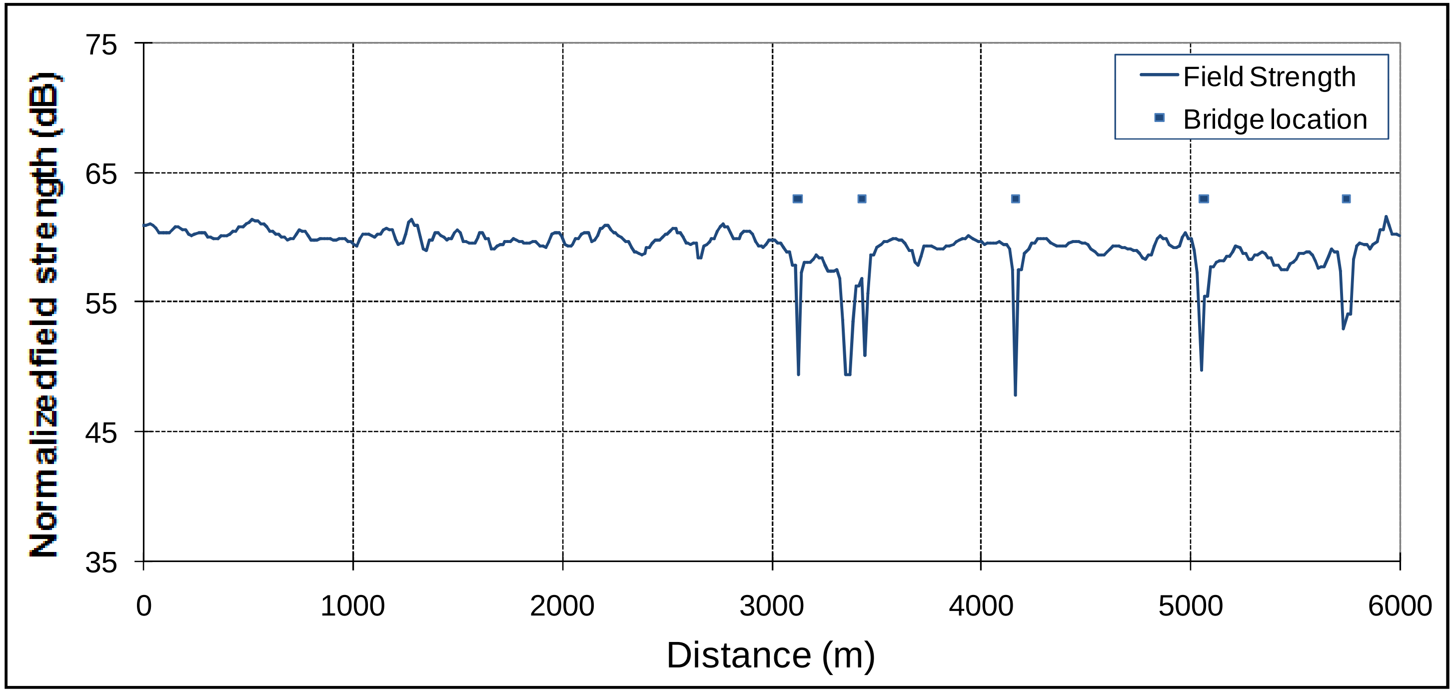
4.2 Analysis: Causes of the local fadings

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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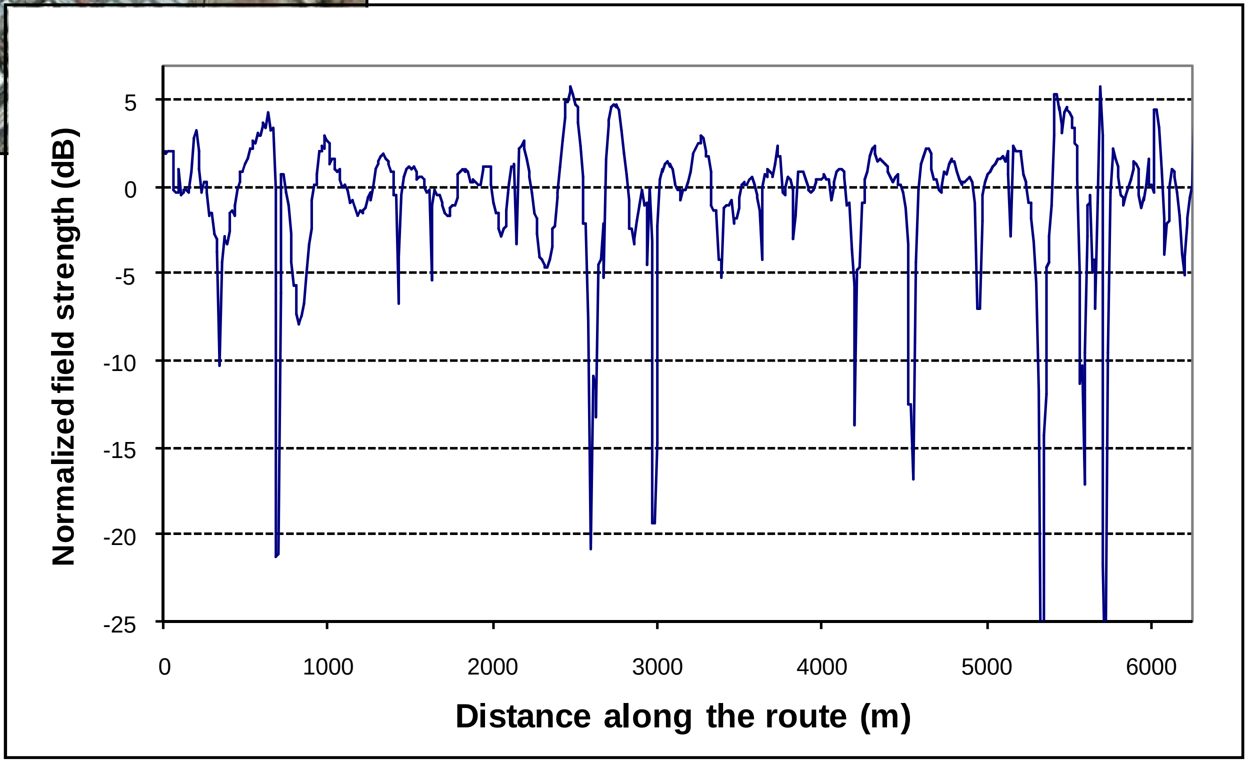
4.2 Analysis: Causes of the local fadings

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



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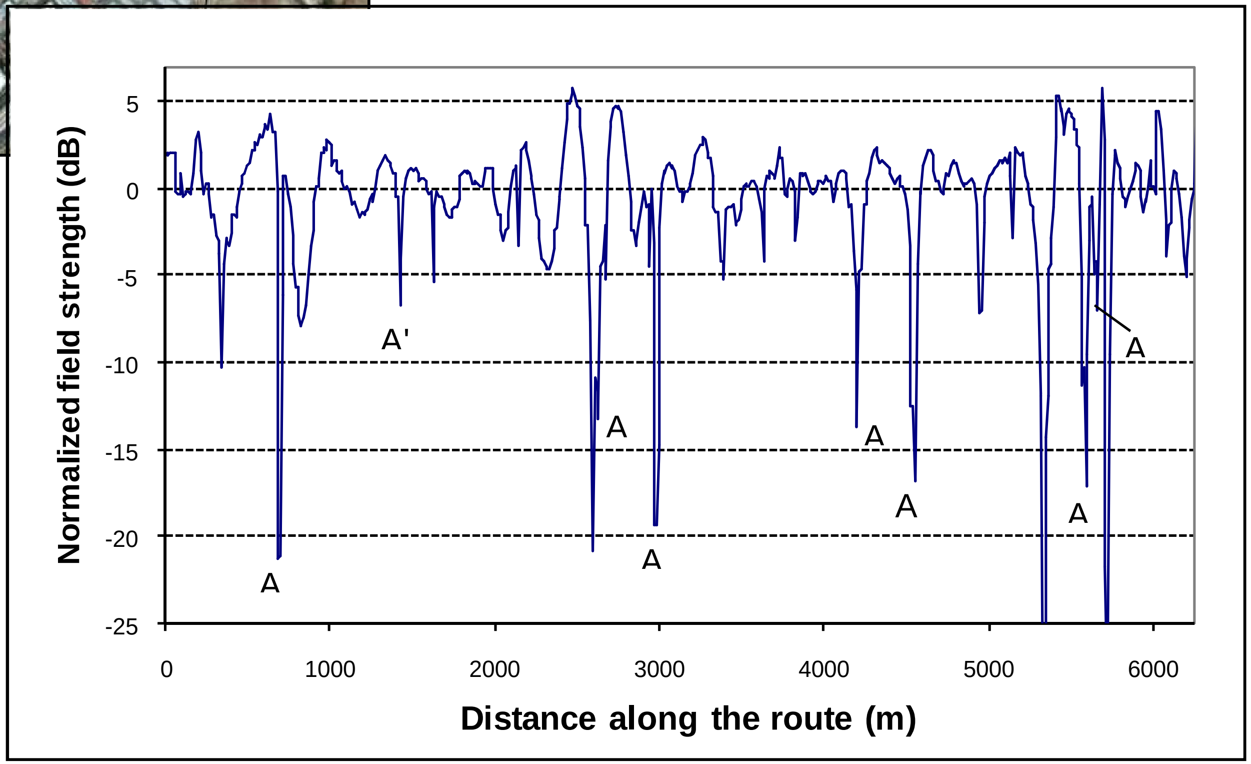
4.2 Analysis: Causes of the local fadings

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



A- Bridges and pedestrian overpasses

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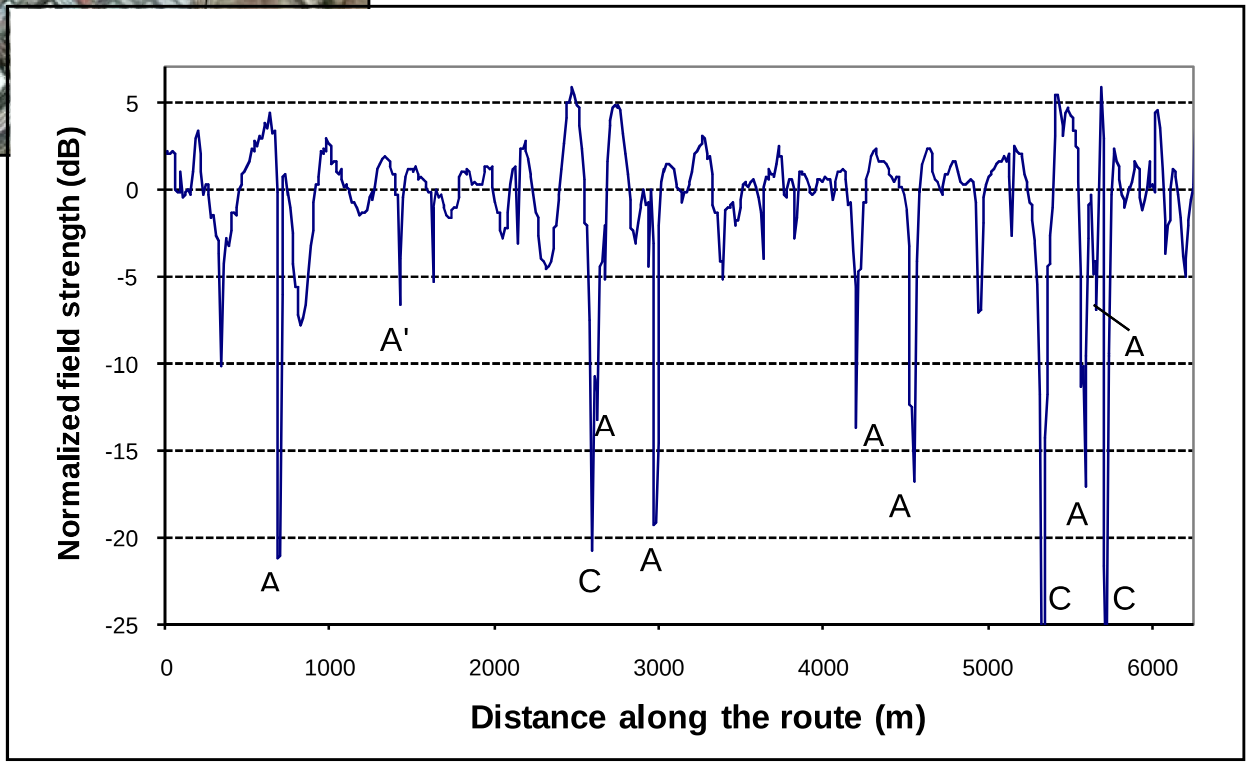
4.2 Analysis: Causes of the local fadings

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



A- Bridges and pedestrian overpasses

C- Bridges (railway)

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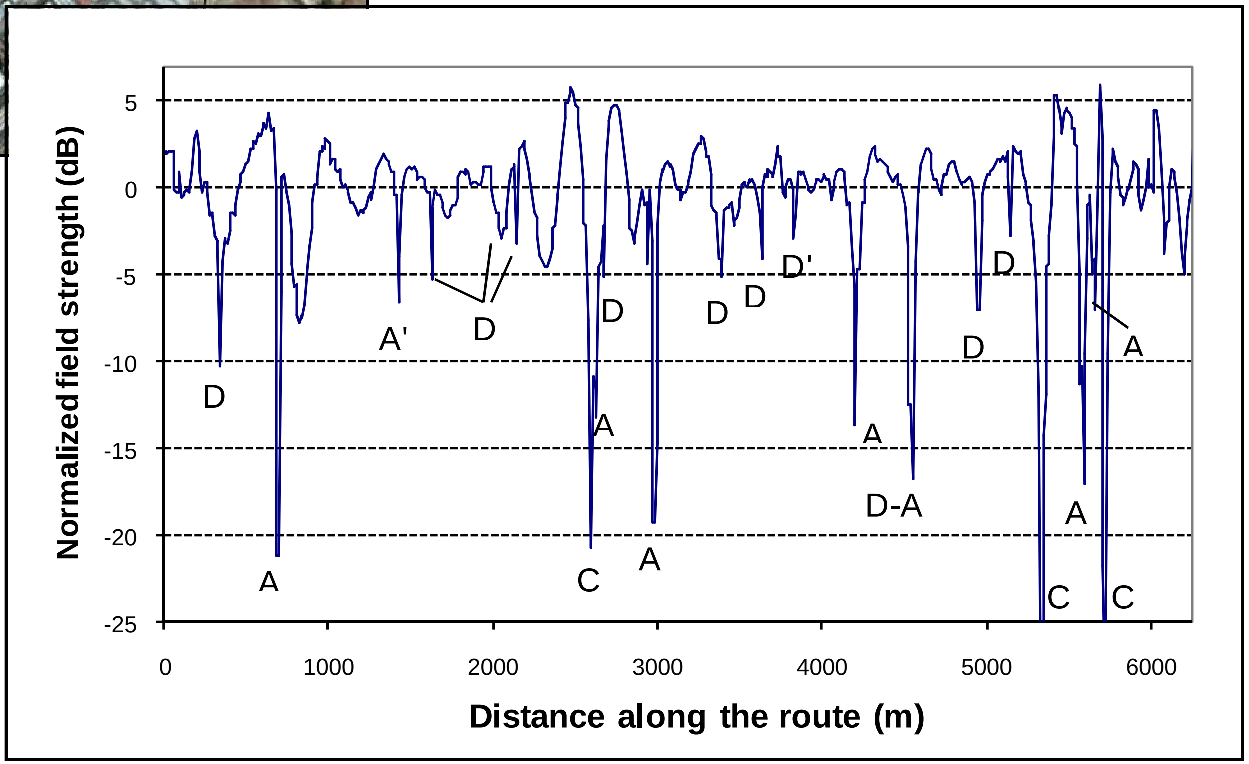
4.2 Analysis: Causes of the local fadings

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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INDEX

1. Introduction

2. Objectives of the study

3. DRM field trials

4. Local fading characterization

   4.1 Normalization of the signal

   4.2 Identification of the causes of the local fadings

   4.3 Analysis of local fadings

   4.4 Characterization of the short-term

5. Conclusions

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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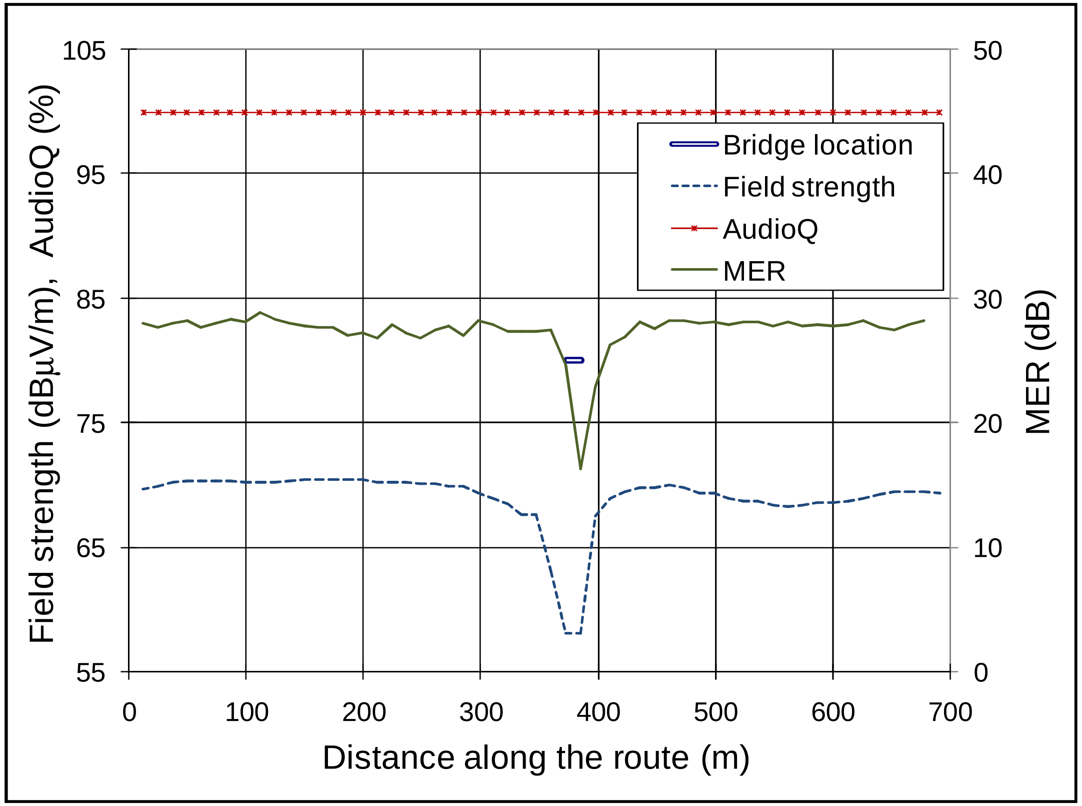
4.3 Fading characterization

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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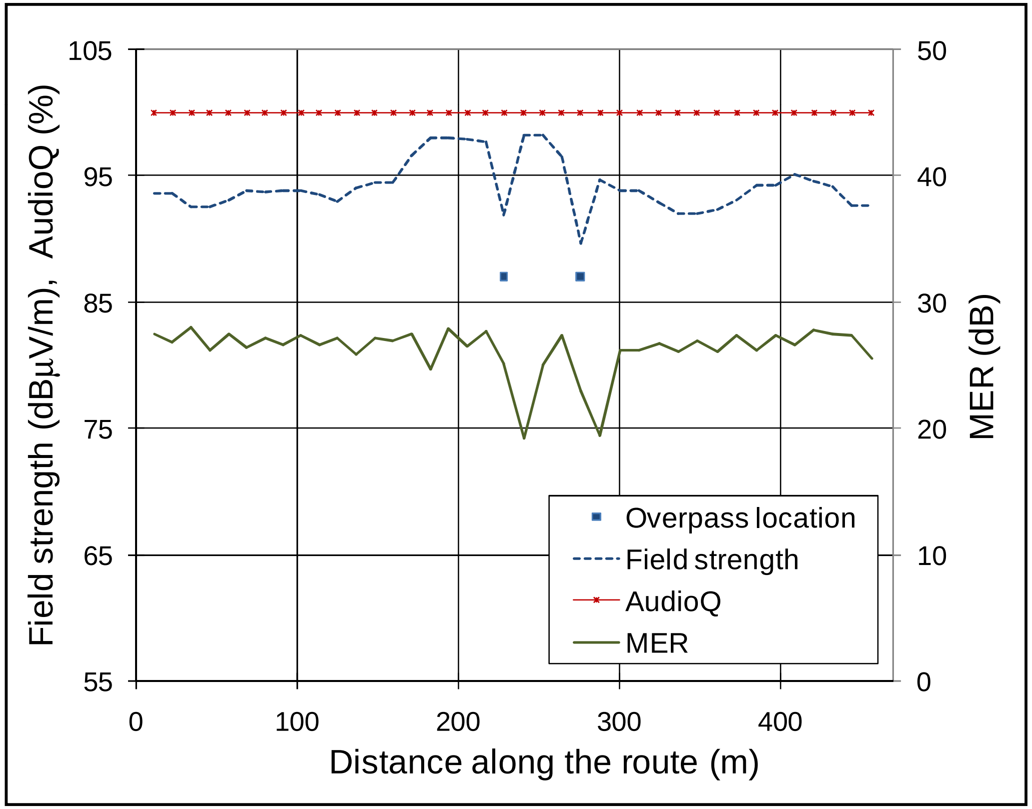
4.3 Fading characterization

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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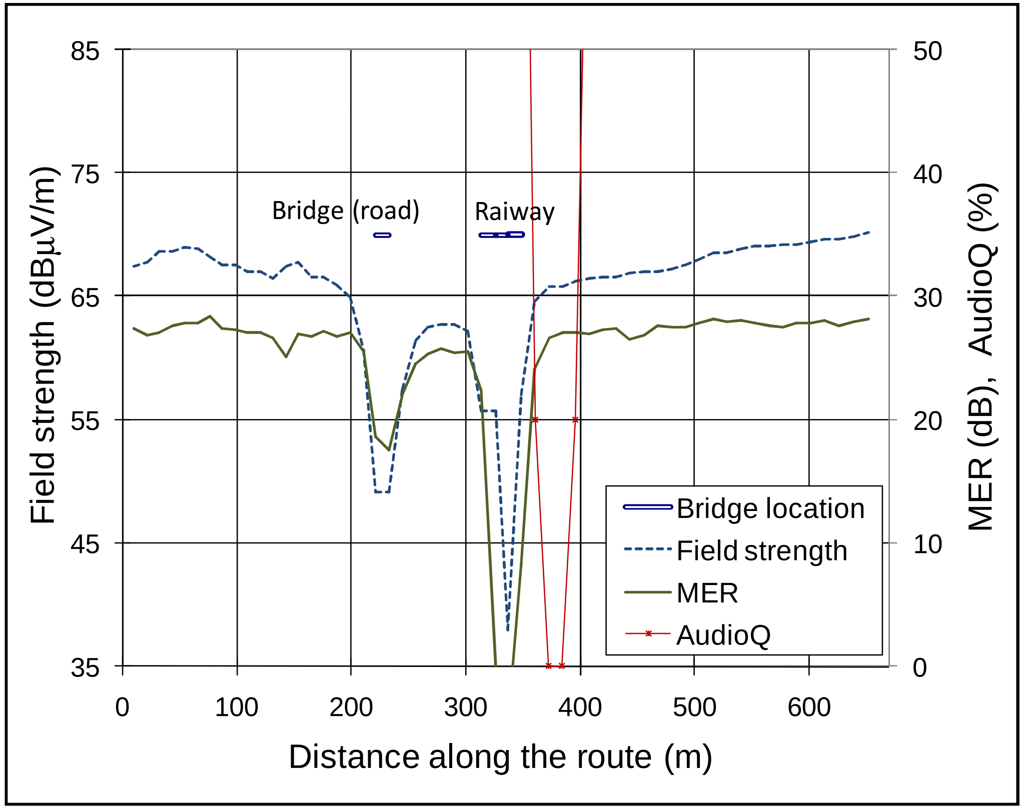
4.3 Fading characterization

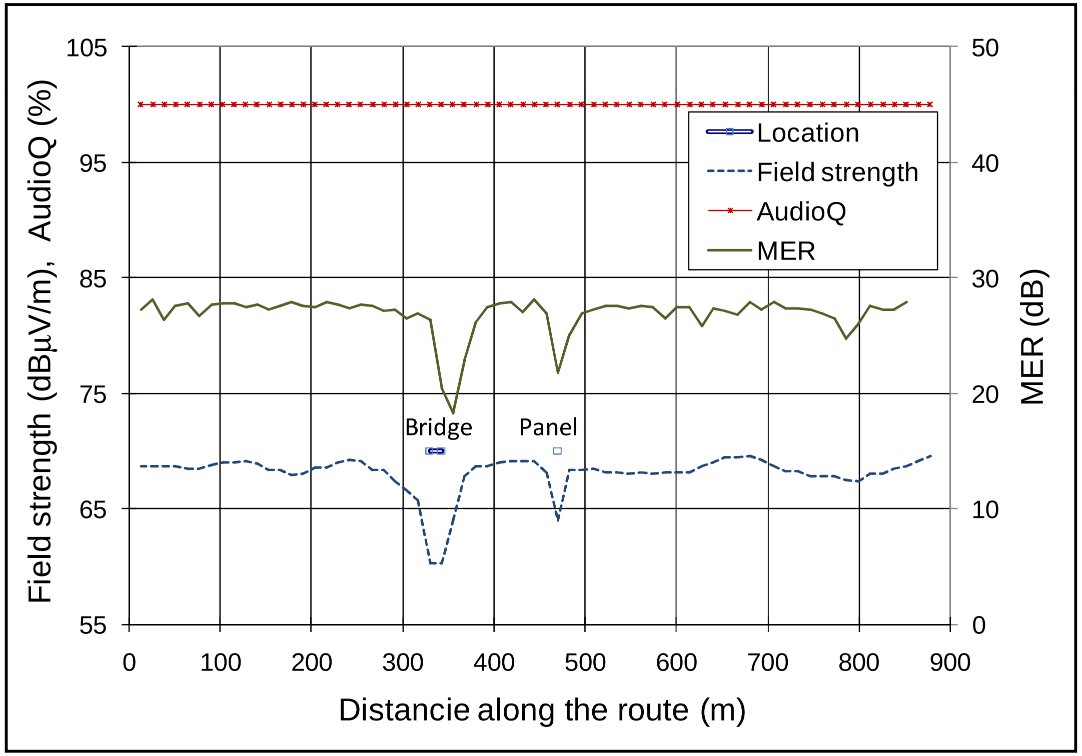
Influence of a bridge (railway):



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

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%)

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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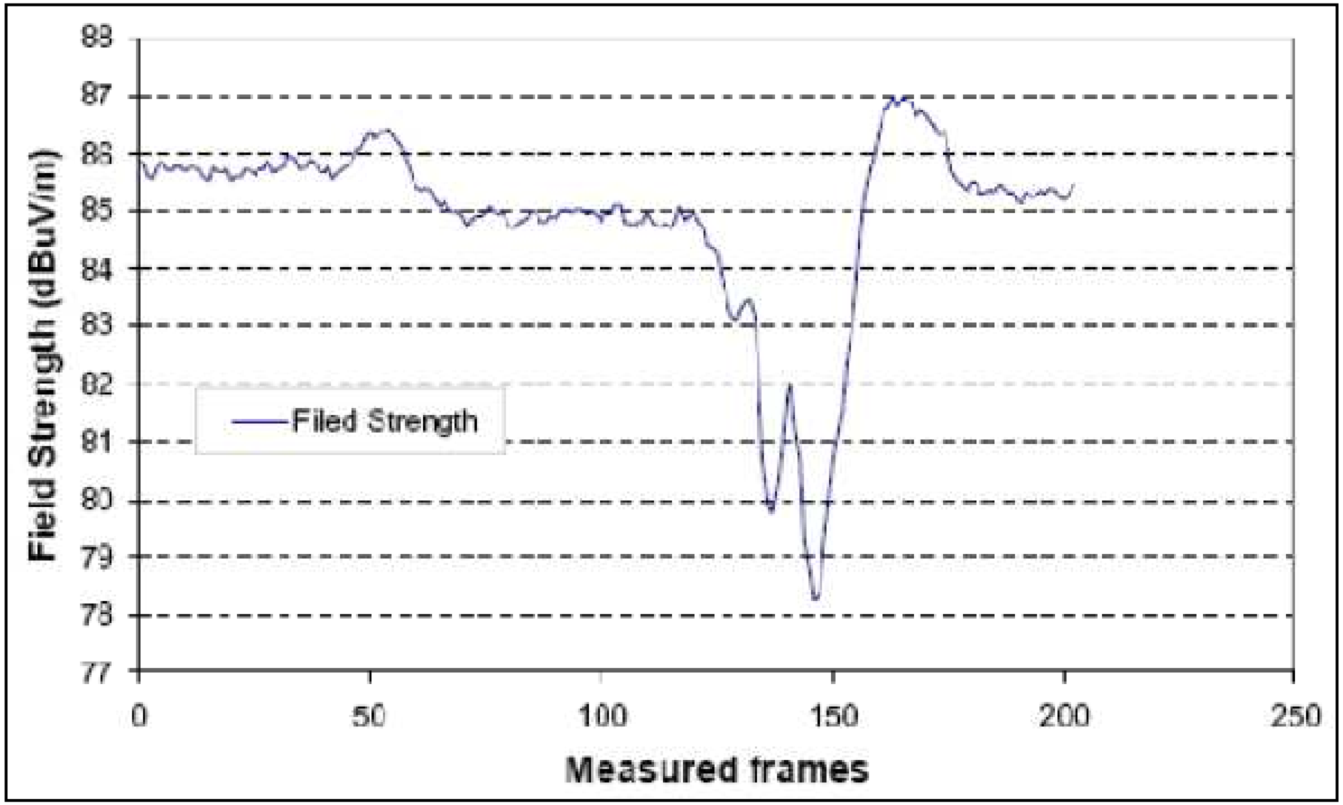
4.3 Fading characterization

Power lines

- There is no homogeneous behaviour in the signal variation



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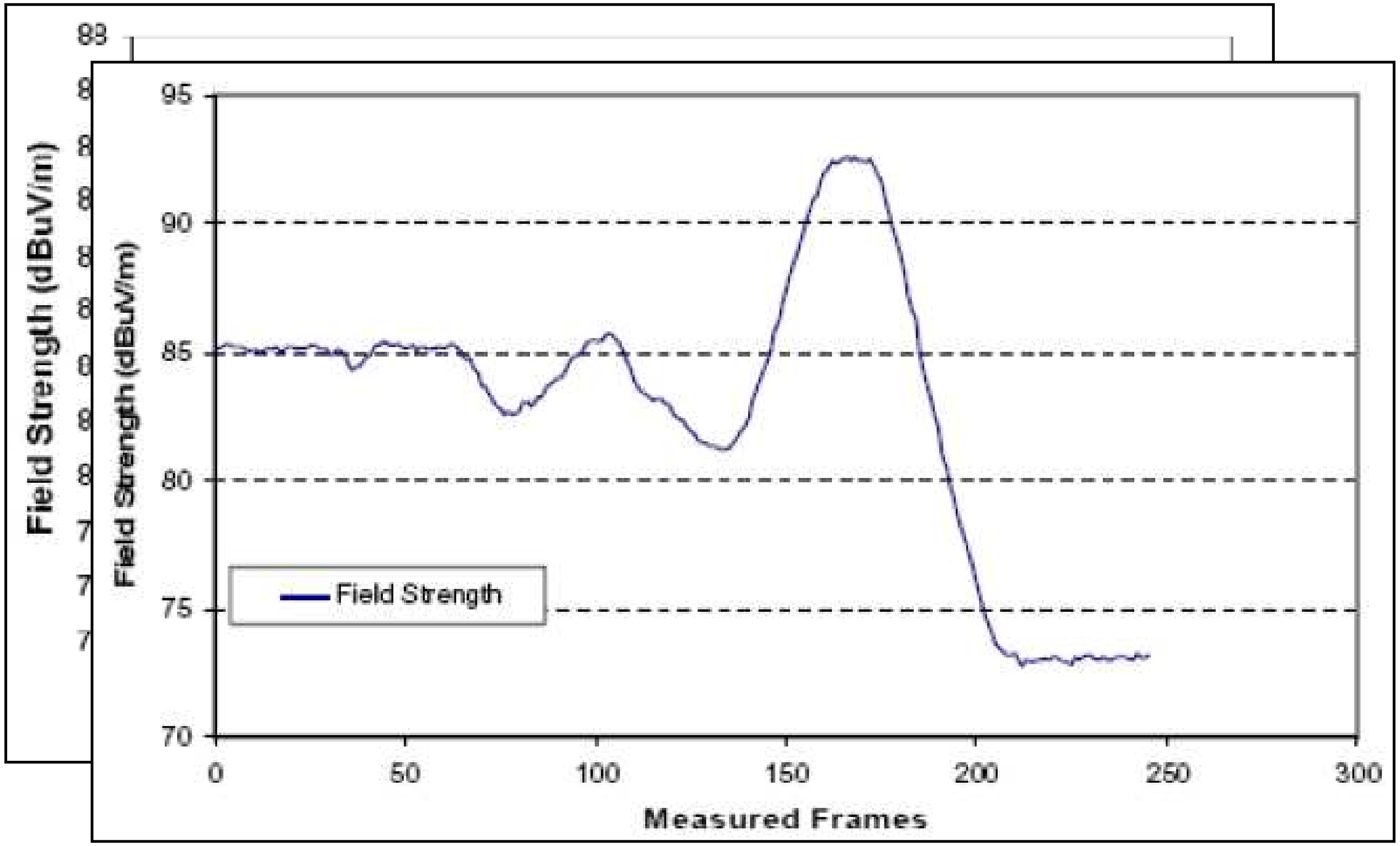
4.3 Fading characterization

Power lines

- There is no homogeneous behaviour in the signal variation



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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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INDEX

1. Introduction

2. Objectives of the study

3. DRM field trials

4. Local fading characterization

   4.1 Normalization of the signal

   4.2 Identification of the causes of the local fadings

   4.3 Analysis of local fadings

   4.4 Characterization of the short-term

5. Conclusions

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

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4.4 Characterization of the short-term

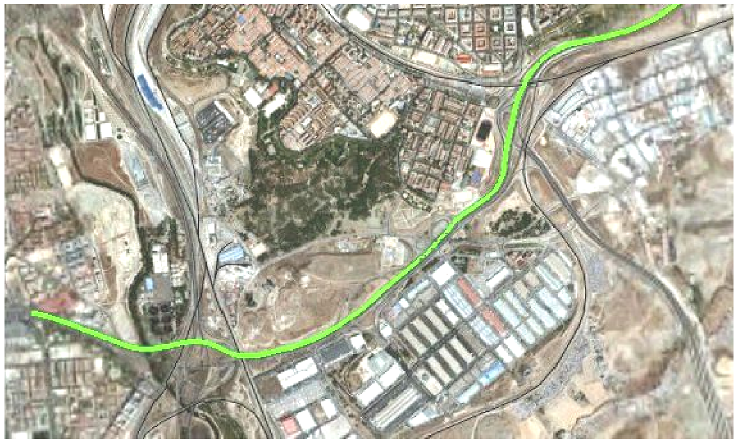
Reception environments

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

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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INDEX

1. Introduction
2. Objectives of the study
3. DRM field trials
4. Local fading characterization
5. Conclusions

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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

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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