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FACULTEIT INGENIEURSWETENSCHAPPEN

Indoor off-body communication based on a textile multi-antenna system integrated in clothing for rescue workers

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PROETEX

Outline

- **Introduction**
  - *Advanced e-textiles for firefighters and civilian victims* (ProeTex) project
- **Textile multi-antenna system**
  - Circular-polarized textile antenna
    - **Design**
    - **Performance**
      - Return loss, Gain (anechoic chamber)
      - Off-body wireless link (antenna in suit of fully-equipped rescue worker)
  - Dual-polarized antenna textile antenna
    - **Design**
    - **Performance**
- **Conclusions**

Introduction: Proetex project

- **Firemen have excellent protective clothing**

Introduction: Proetex project

- **Yet, protection and safety can be improved**

Textiles + Electronics

=

Wearable Textile System

For

Sensing

Interconnecting

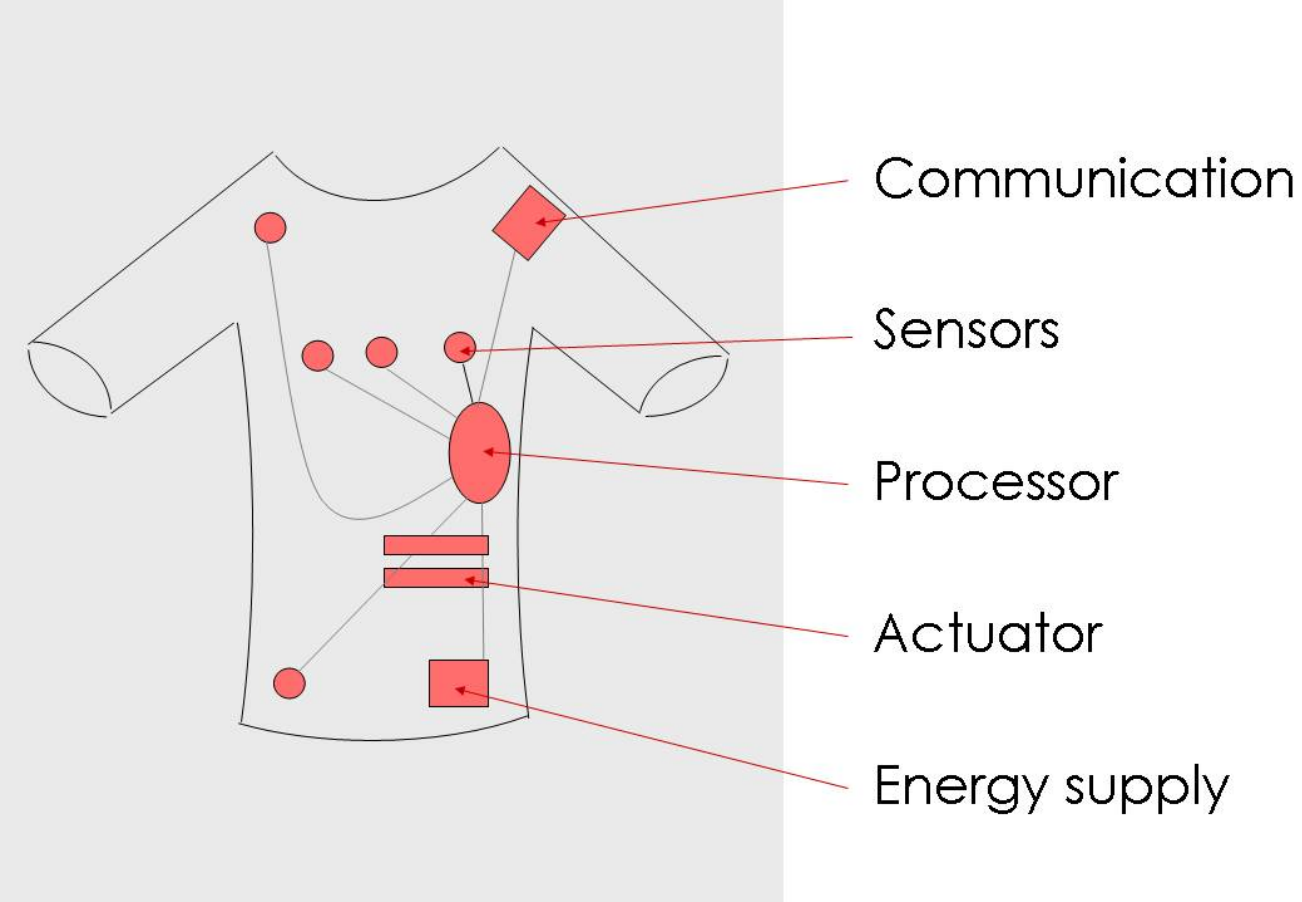
Communicating

Powering

Actuating

Introduction: Proetex project

- **Wearable textile system consists of**



Introduction: Proetex project

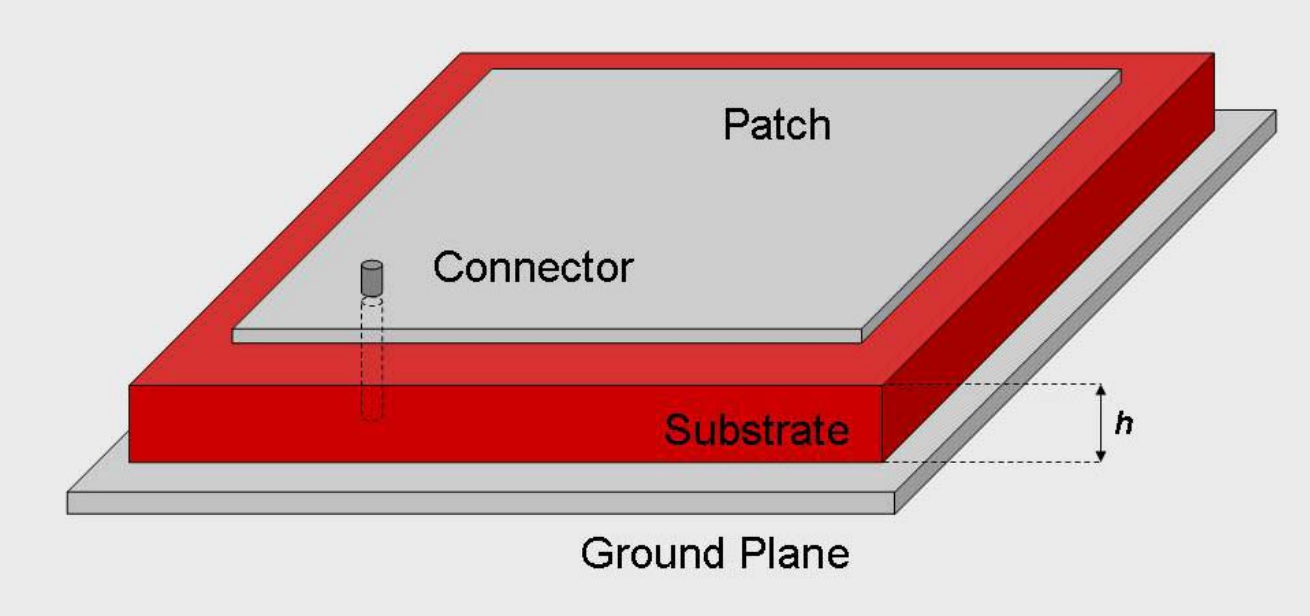
ProeTex wearable textile system

Introduction: Proetex project

- **First inner and outer garment prototypes**

Textile antenna: Design

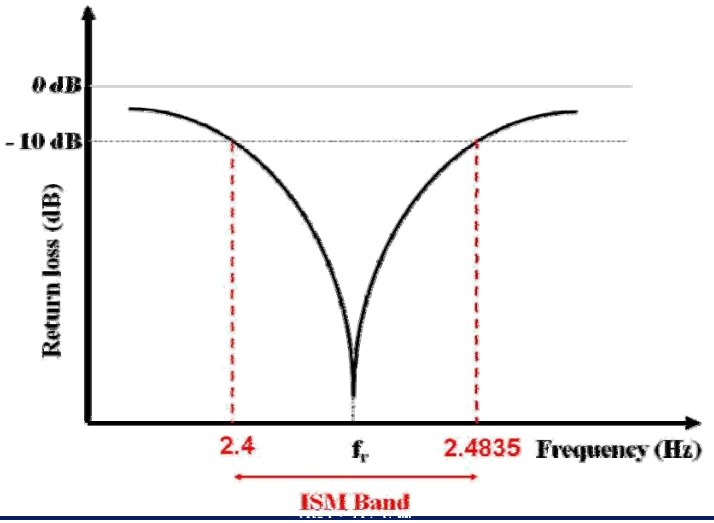
- **Microstrip patch antenna**
  - Low profile + easy to integrate



- **Textile materials:**
  - Breathable + comfortable to wear

Textile antenna: Design

- **Communication in 2.45GHz ISM band**
  - Use of existing protocols, e.g. WiFi
  - Use more transmit power during emergencies (>20dBm) to cover larger distances
- **Design criterion**
  - antenna operating in 2.4 – 2.4835 GHz range
  - -10dB return loss in entire ISM-band (90% power injected)



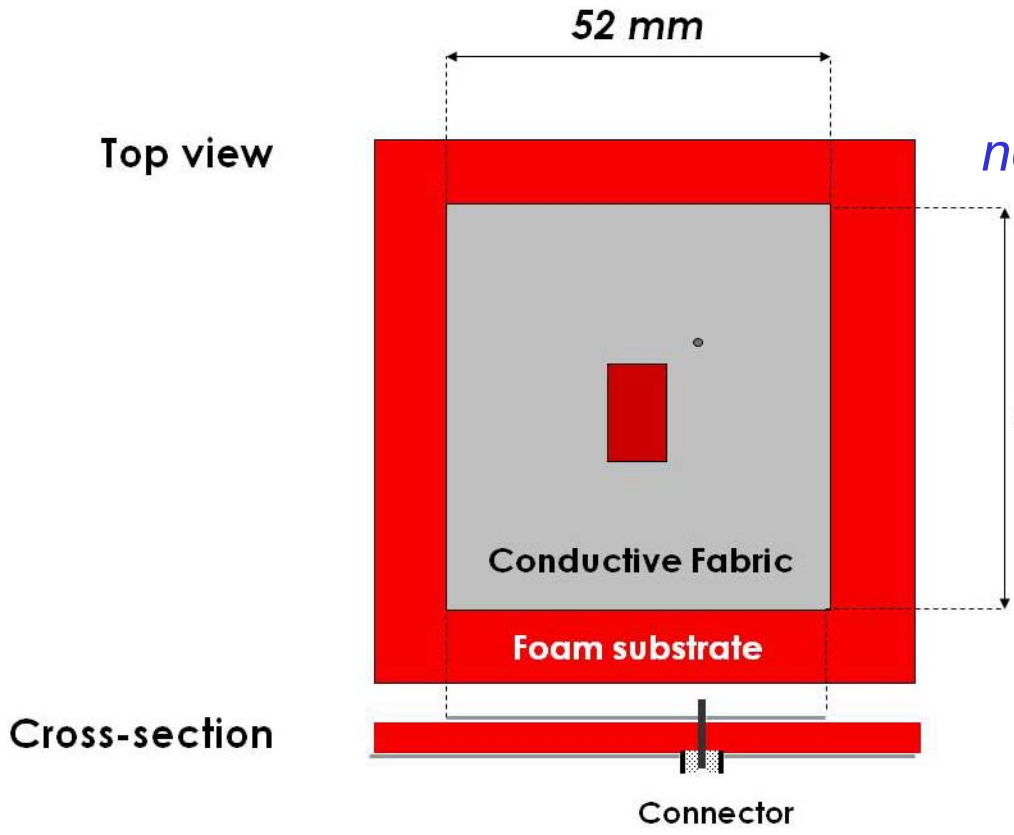
Textile antenna: Design

- **Antenna substrate: protective foam**
  - Commonly used in fire-fighter garments
    - **flexible, shock-absorbing, fire-retarding, moisture repellent**
  - Thickness: 5.5mm
    - **uniform thickness, even after compression**
    - **large bandwidth**
  - moisture regain (MR) of 0.84%

$$moisture\ \ regain = \frac{conditioned\ weight - dry\ weight}{dry\ weight} 100\%$$

    - **stable antenna characteristics**

- **Antenna topology: rectangular ring**

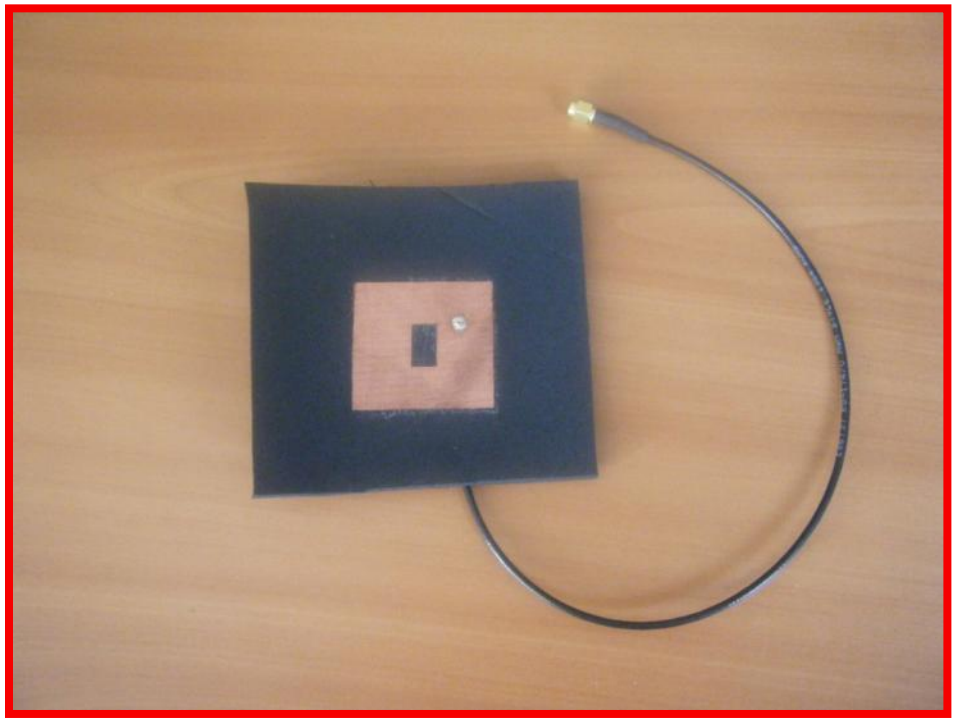


Exciting
two orthogonal modes
provides
nearly-circular polarization

+

large bandwidth

Textile antenna prototype



The antenna patch,
radiating away from the person

A flexible cable,
to connect to the electronic box

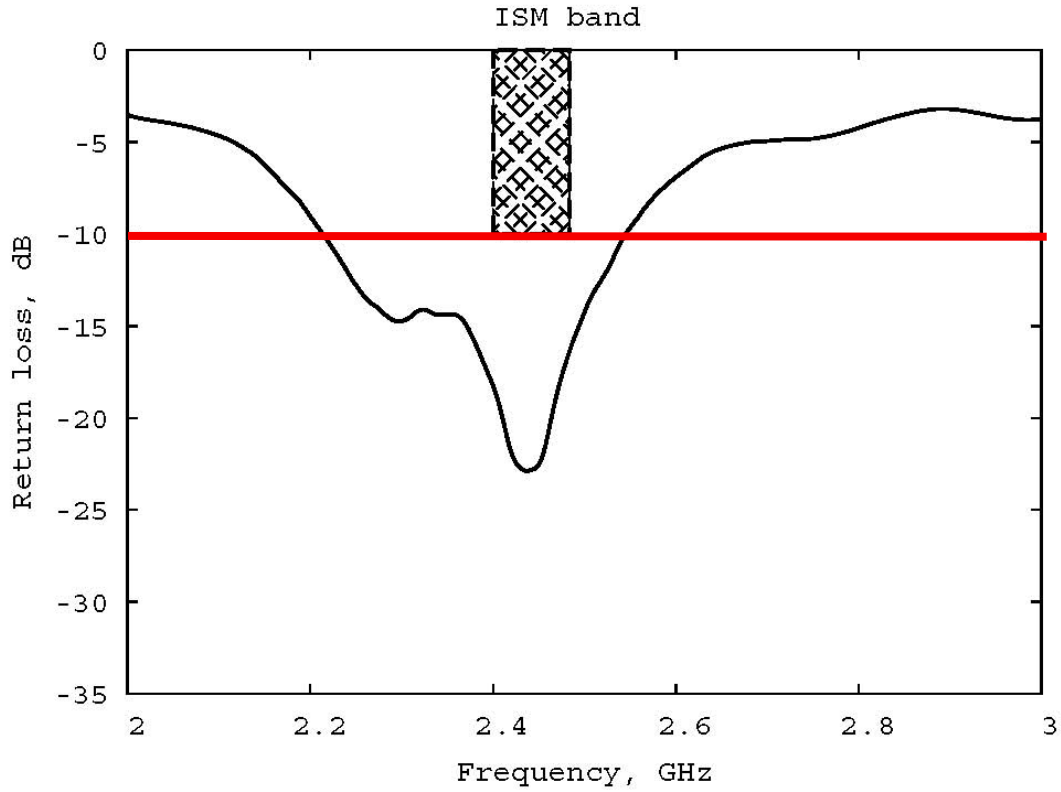
The ground plane,
improving radiation away from the person and shielding the body from radiation

Textile antenna performance

- Reflection measurements
  - check impedance bandwidth
- Moisture influence
  - evaluate effect relative humidity in jacket
- Transmission measurements
  - anechoic chamber:
    - **antenna gain**
    - **antenna efficiency**
- **Real-life scenario – antenna in fireman suit**
  - indoor environment:
    - **Signal-to-Noise Ratio**
    - **Bit-Error-Rate**

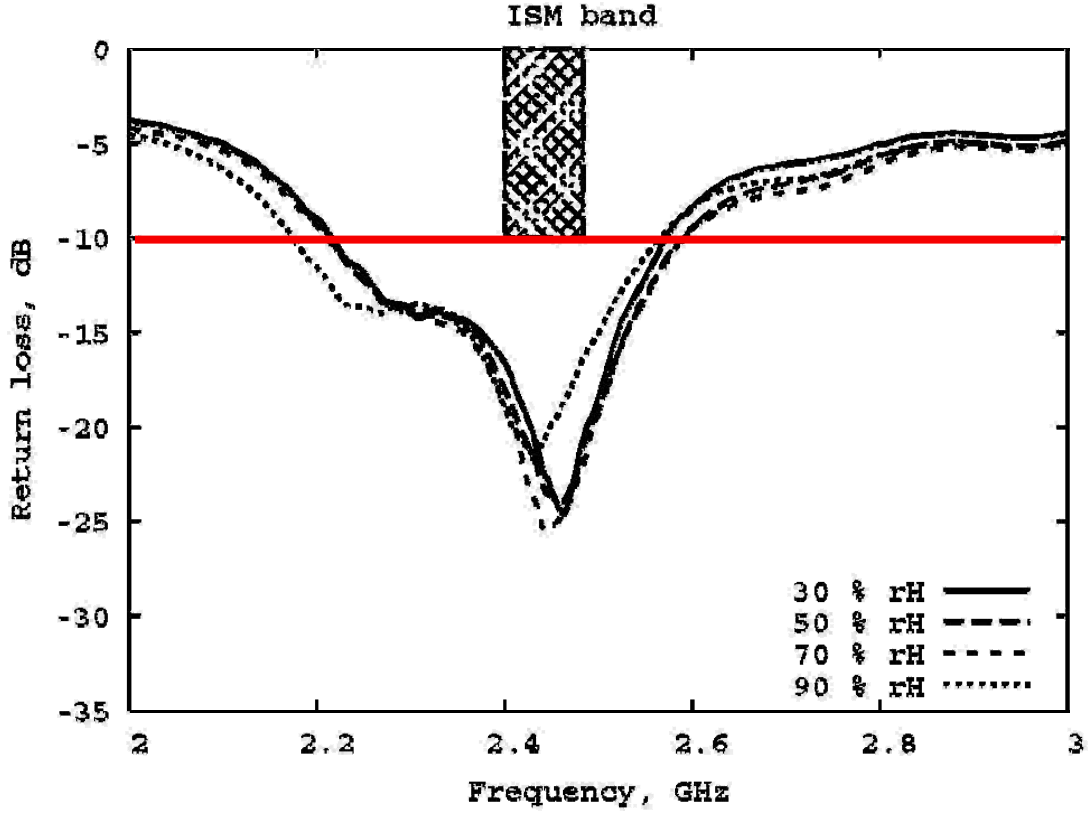
Textile antenna performance

- Reflection measurements
  - Impedance bandwidth: ISM band covered



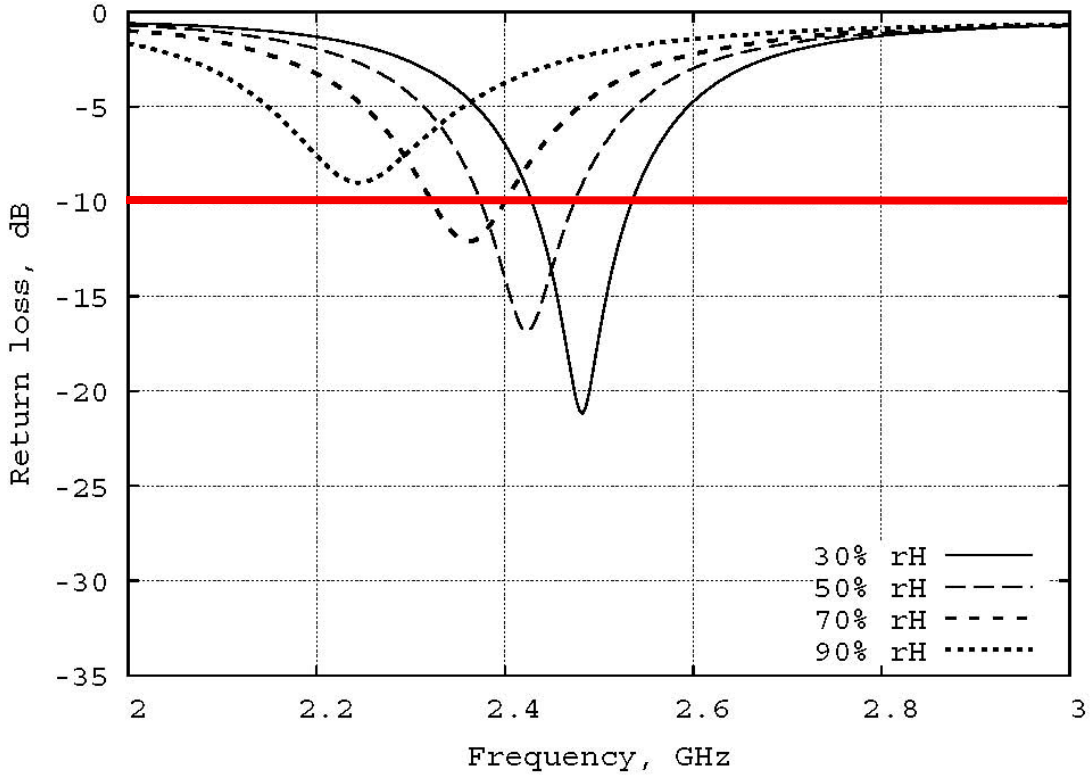
Textile antenna performance

- Effect of humidity
  - Changing humidity alters reflection characteristic only slightly (Foam MR = 0,84%)



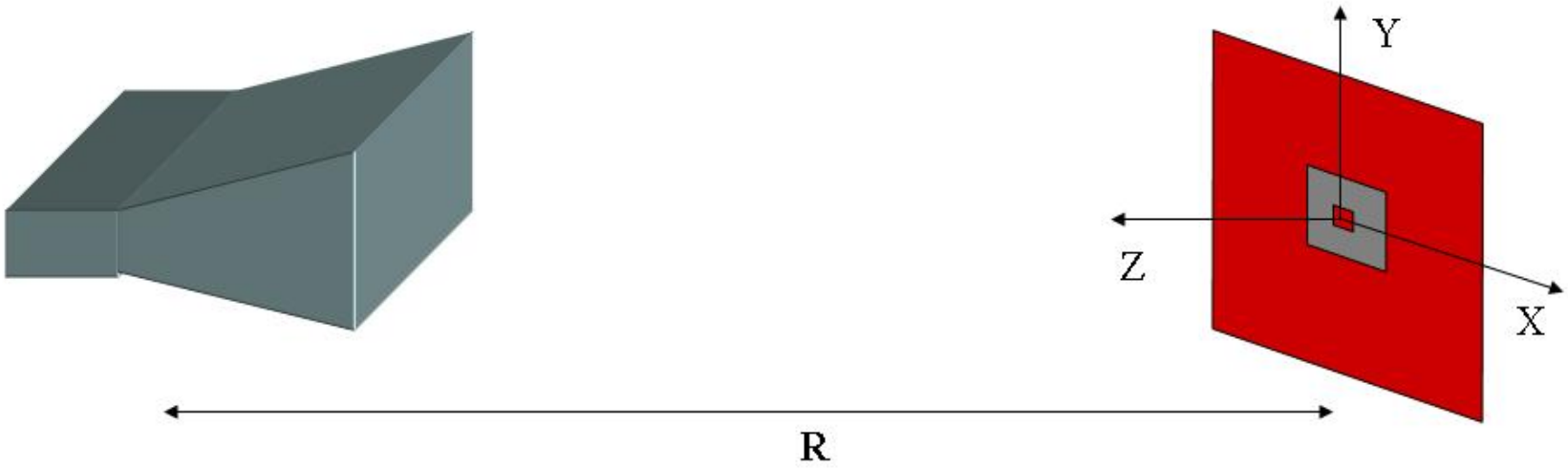
Textile antenna performance

- Effect of humidity
  - For comparison:
    cotton as substrate material (MR = 7.33%)



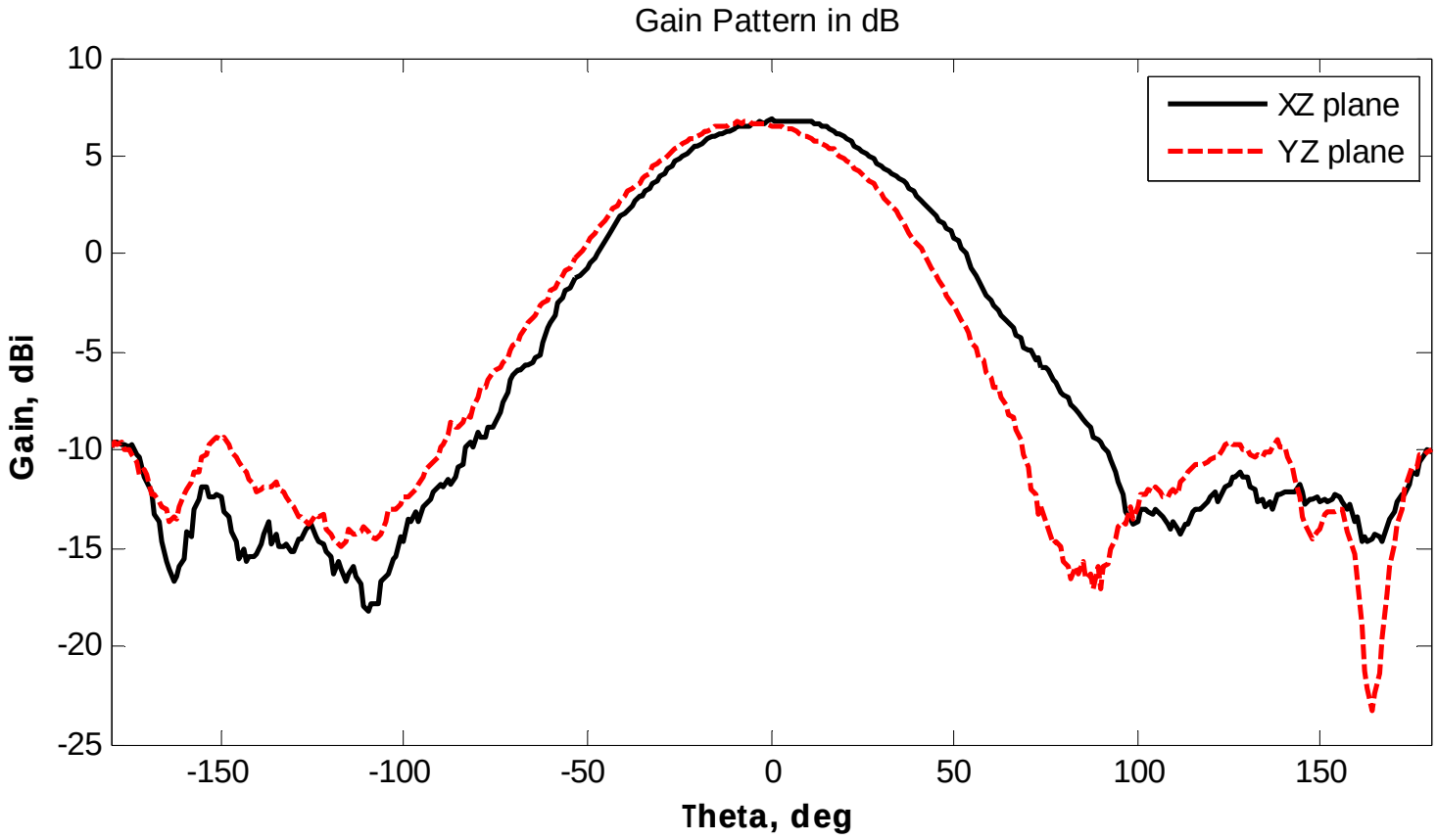
Textile antenna performance

- Transmission measurements
  - **anechoic chamber**



Textile antenna performance

- Transmission measurements
  - **Antenna gain of 6.7 dBi along broadside**

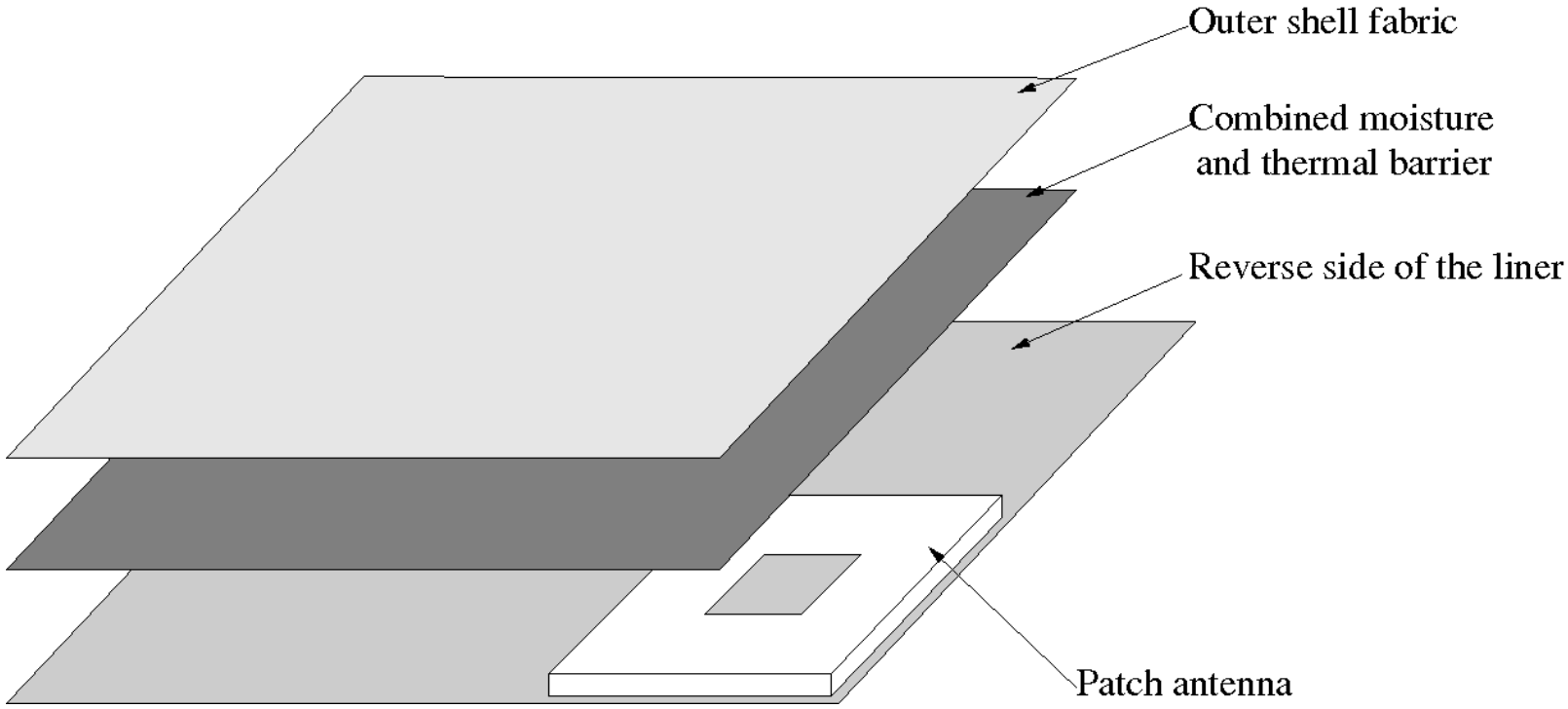


Textile antenna performance

- Real-life scenario
  - **two antennas integrated into fire fighter jacket**

Textile antenna performance

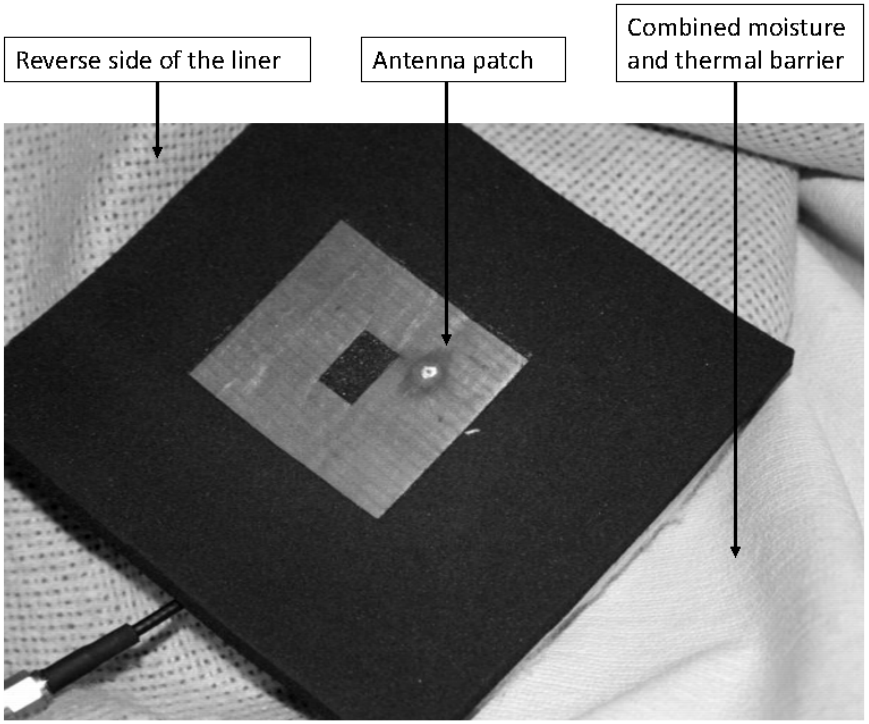
- Real-life scenario
  - **Antenna location: under 2 outermost layers**



Antenna protected against heat and moisture

Textile antenna performance

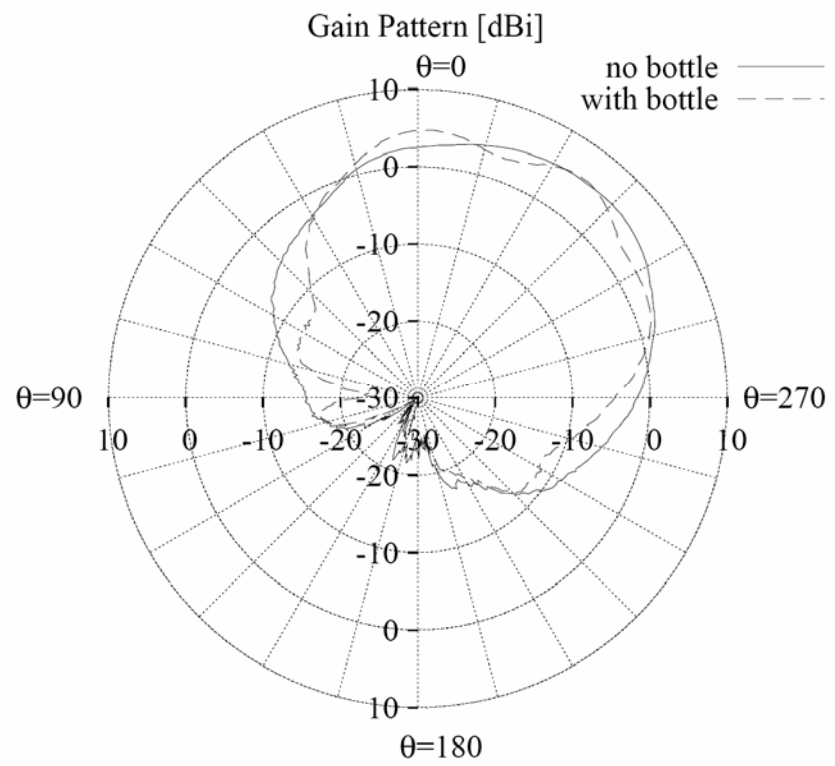
- Real-life scenario
  - **Textile antenna inside the jacket**



Antenna protected against heat and moisture

Textile antenna performance

- Radiation pattern: Effect of the air bottle
  - **Textile antenna inside the jacket (front side)**

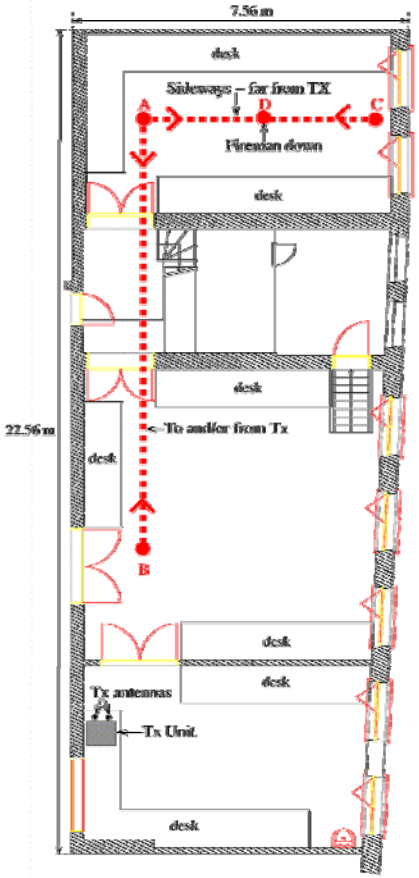


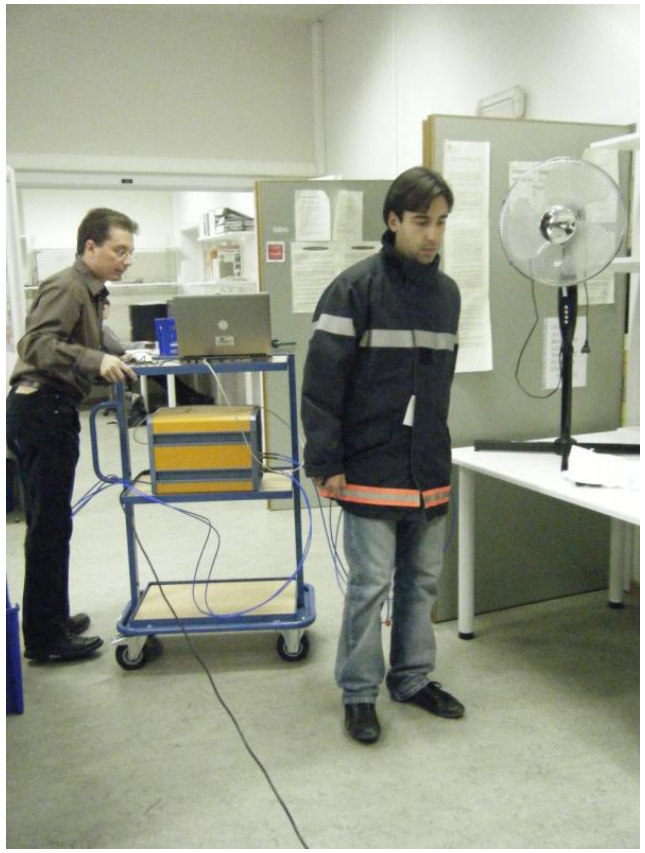
Integration in jacket and presence air bottle do not substantially reduce antenna gain

Direction of maximum gain tilted to 40°

Textile antenna performance

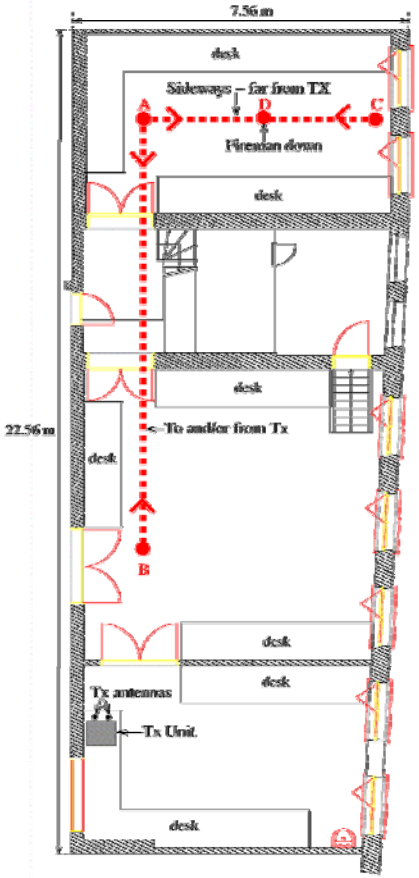
- Real-life scenario
  - **Equipped fire fighter in indoor environment**





Textile antenna performance

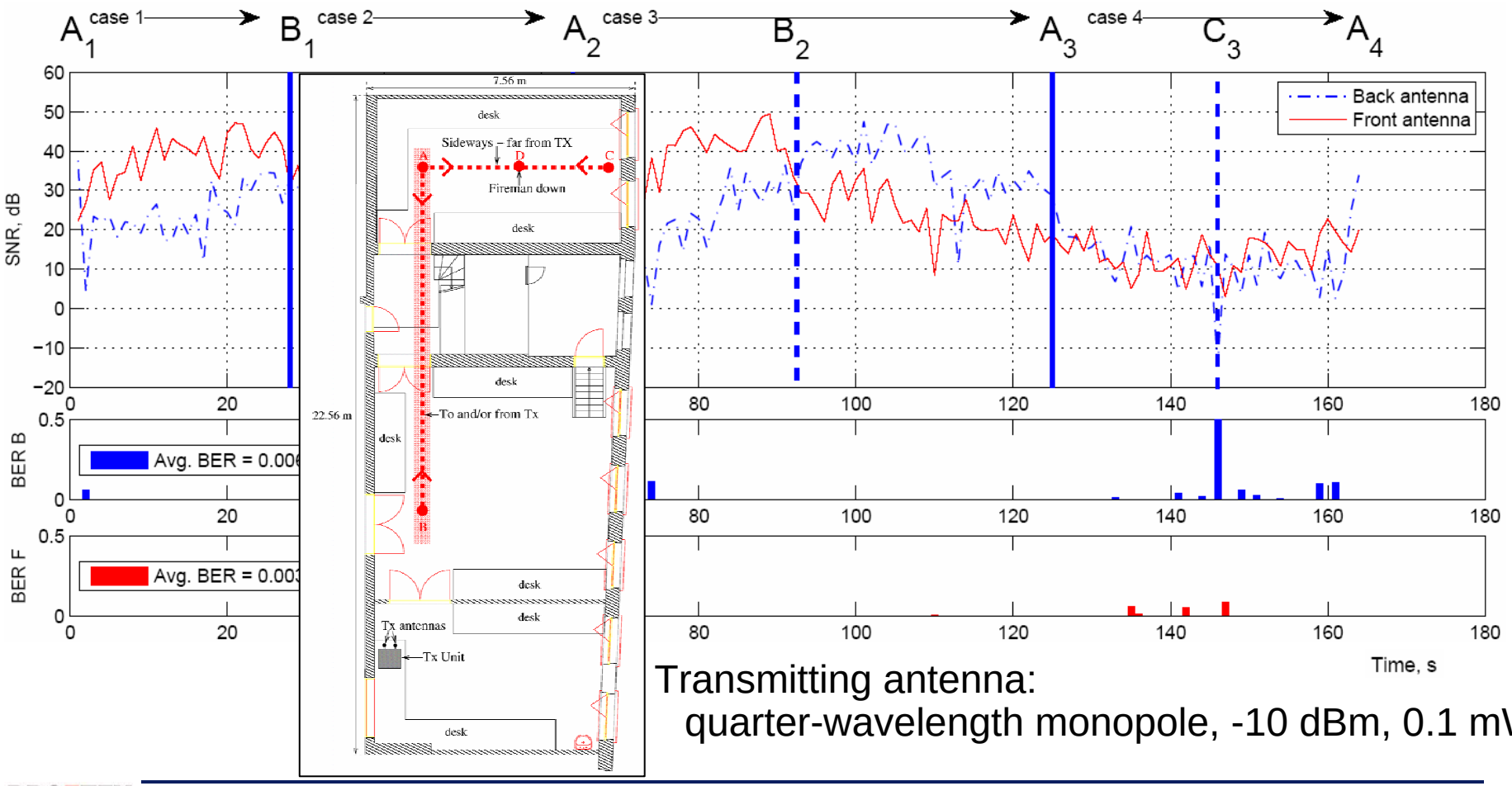
- Real-life scenario
  - **Wireless link: shadowing and fading**



1. fading: multipath radio propagation
2. shadowing by body: hemispherical coverage by *single* on-body antenna
3. *two* textile patch antennas, in front and back: full coverage improves communication reliability

Textile antenna performance

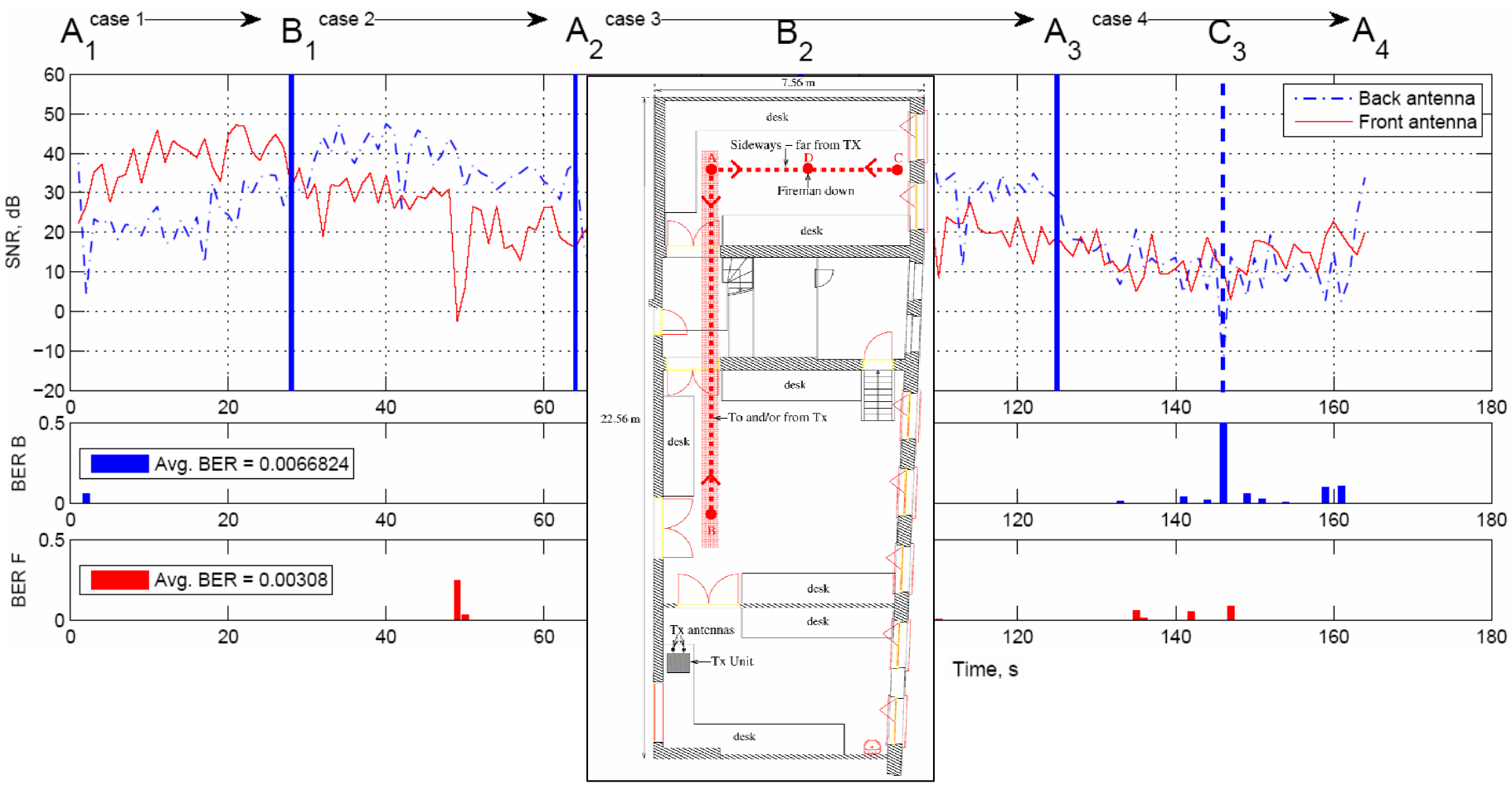
- Real-life scenario: measured SNR and BER



Transmitting antenna:
quarter-wavelength monopole, -10 dBm, 0.1 mW

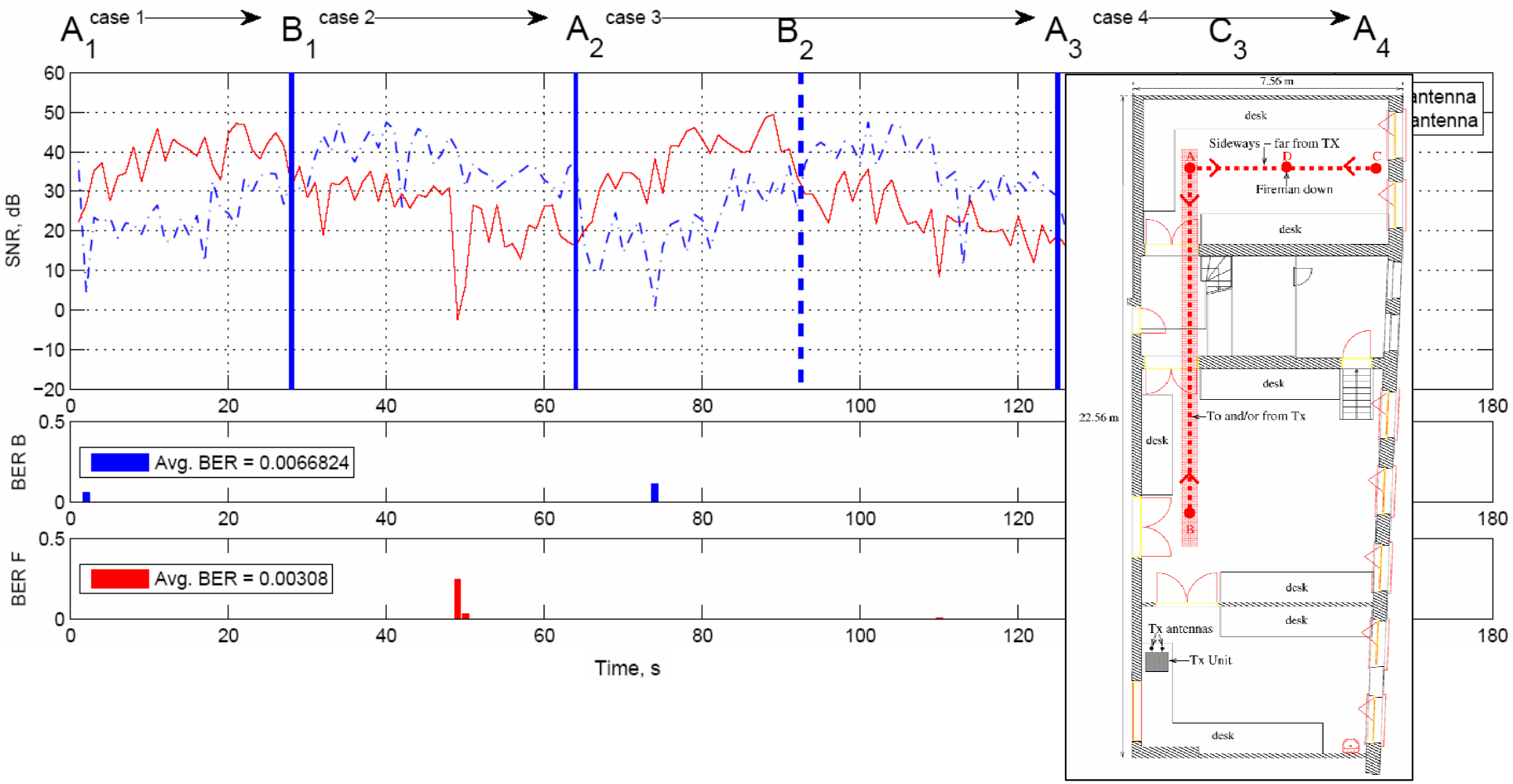
Textile antenna performance

- Real-life scenario: measured SNR and BER



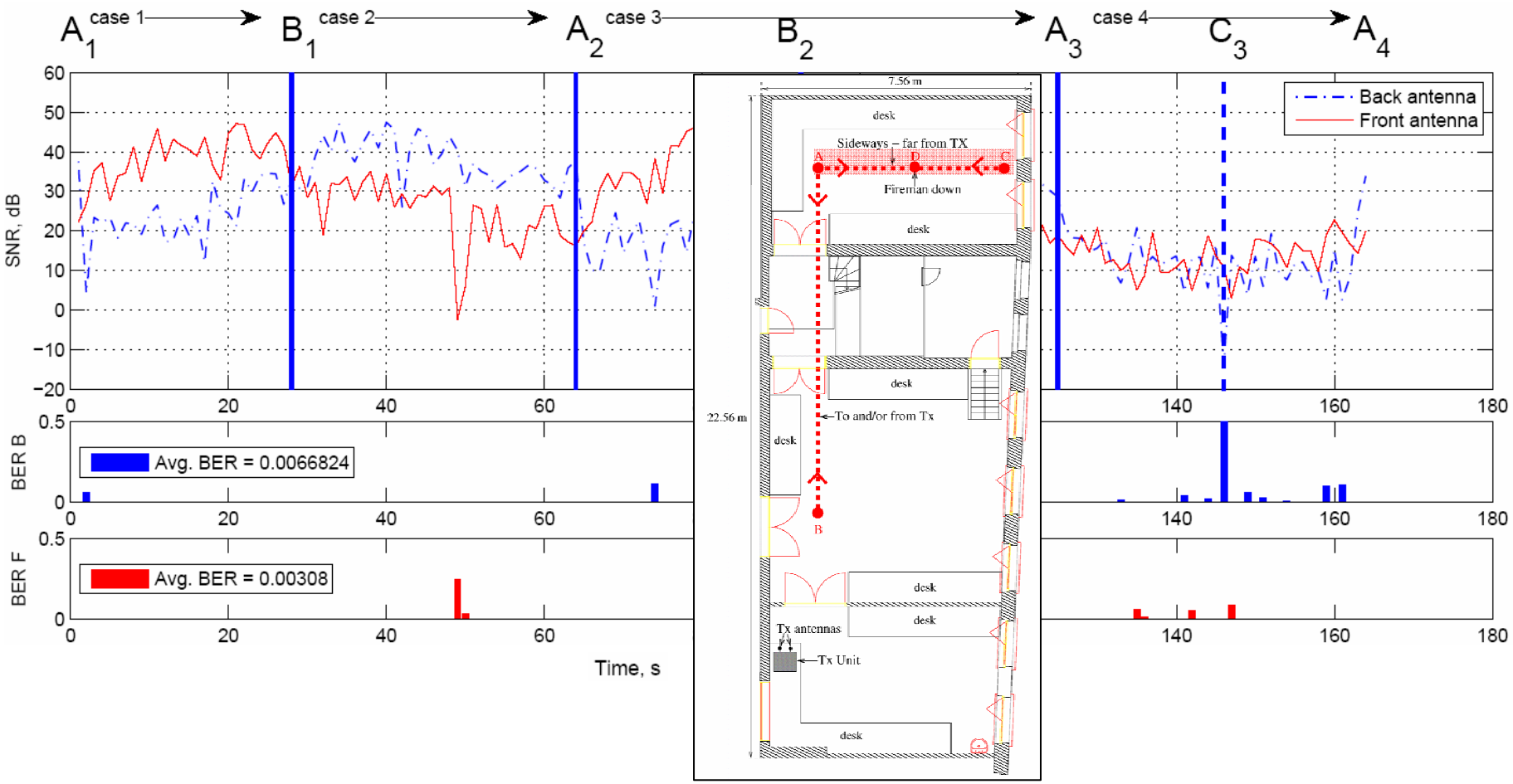
Textile antenna performance

- Real-life scenario: measured SNR and BER



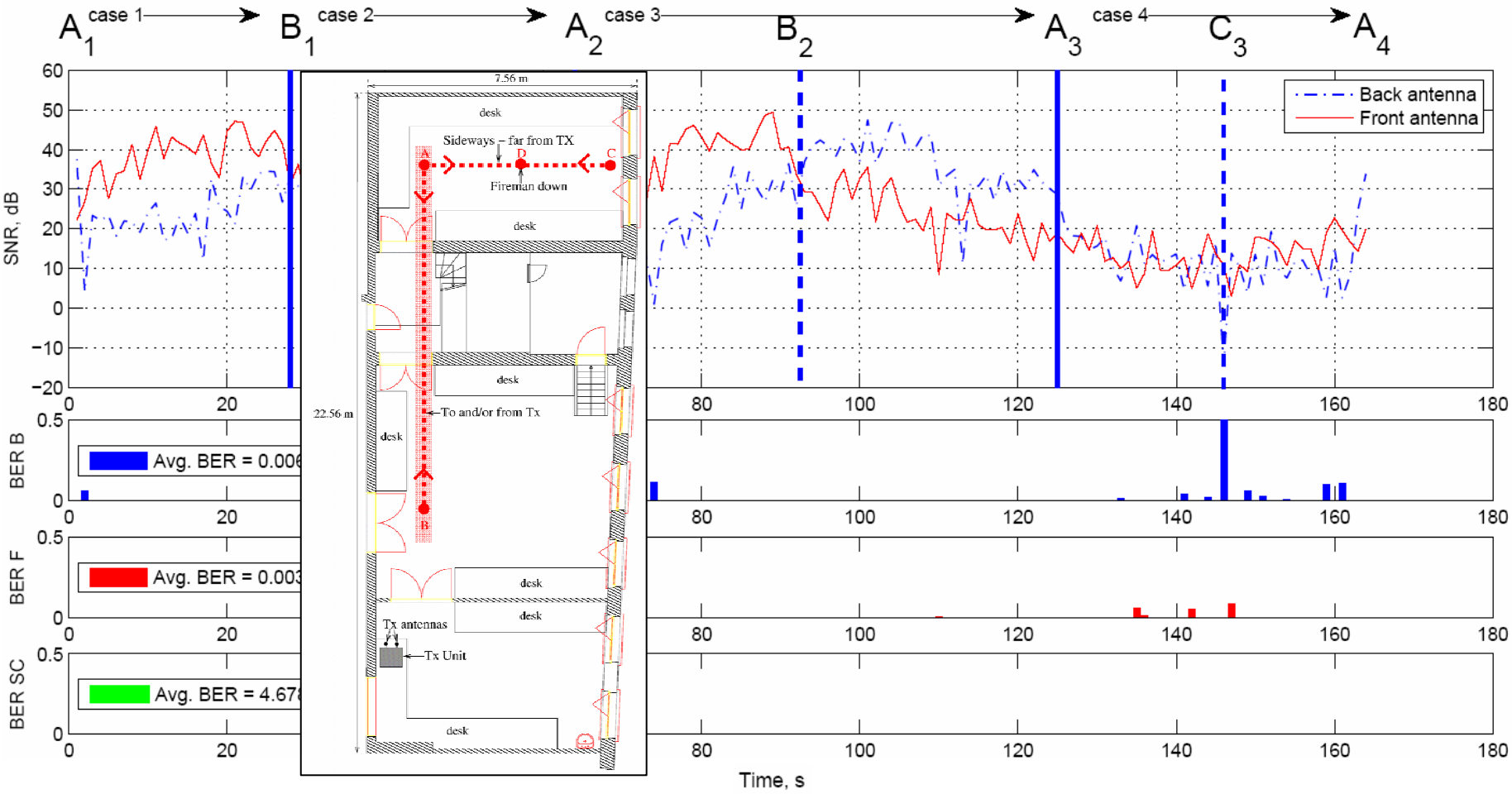
Textile antenna performance

- Real-life scenario: measured SNR and BER



Textile antenna performance

- Mitigating fading by Selection Combining



Textile antenna performance

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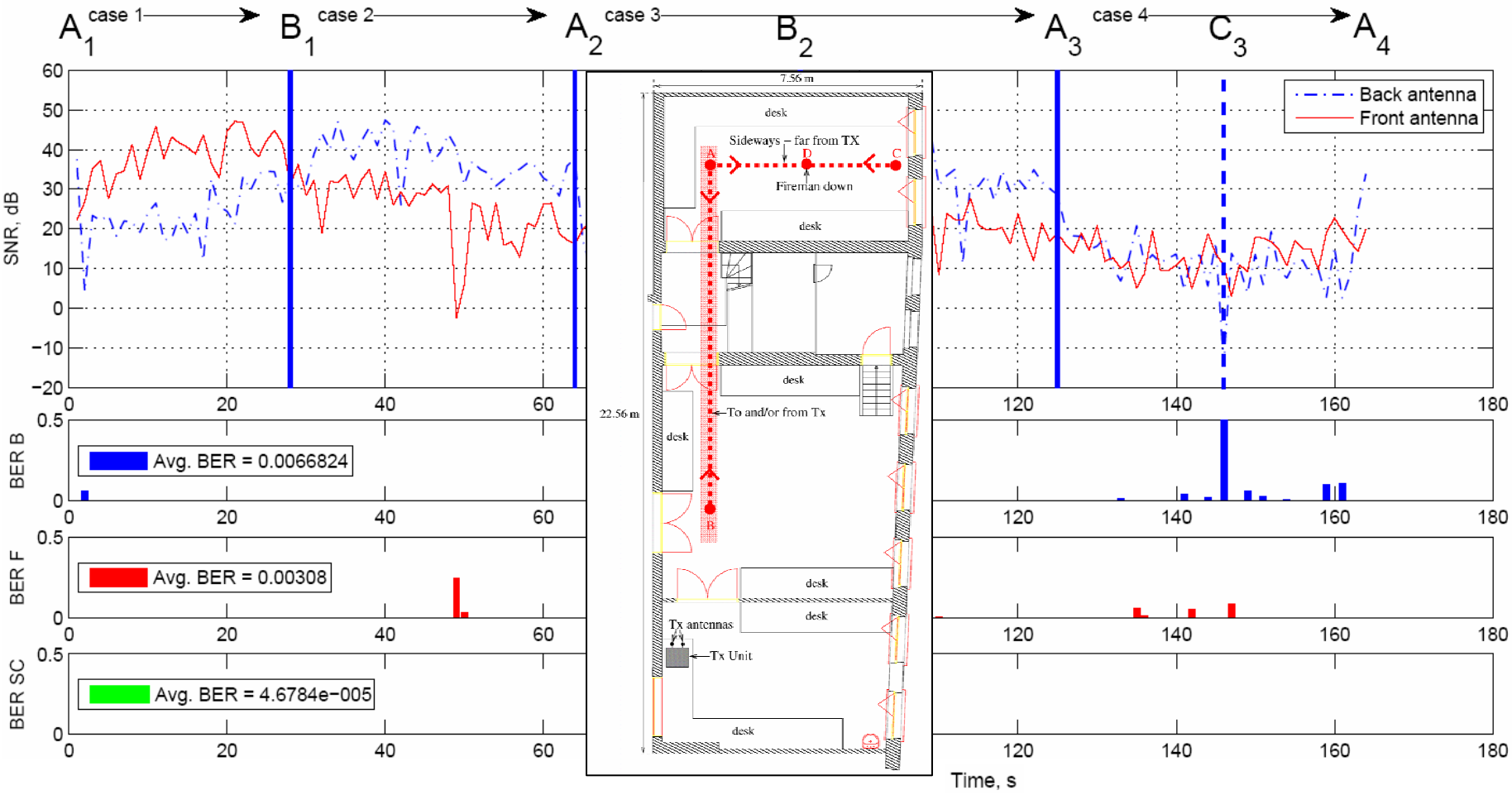
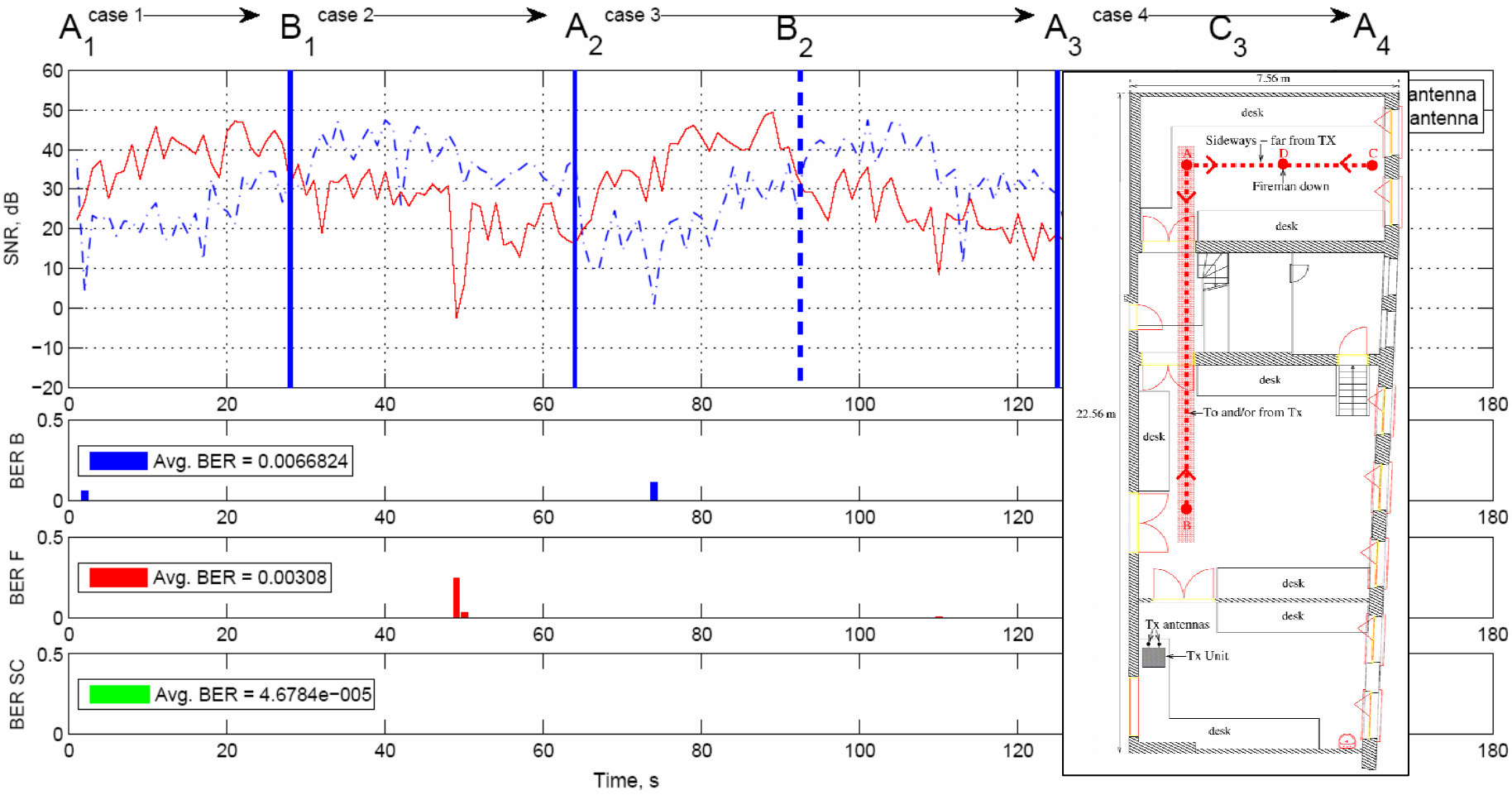


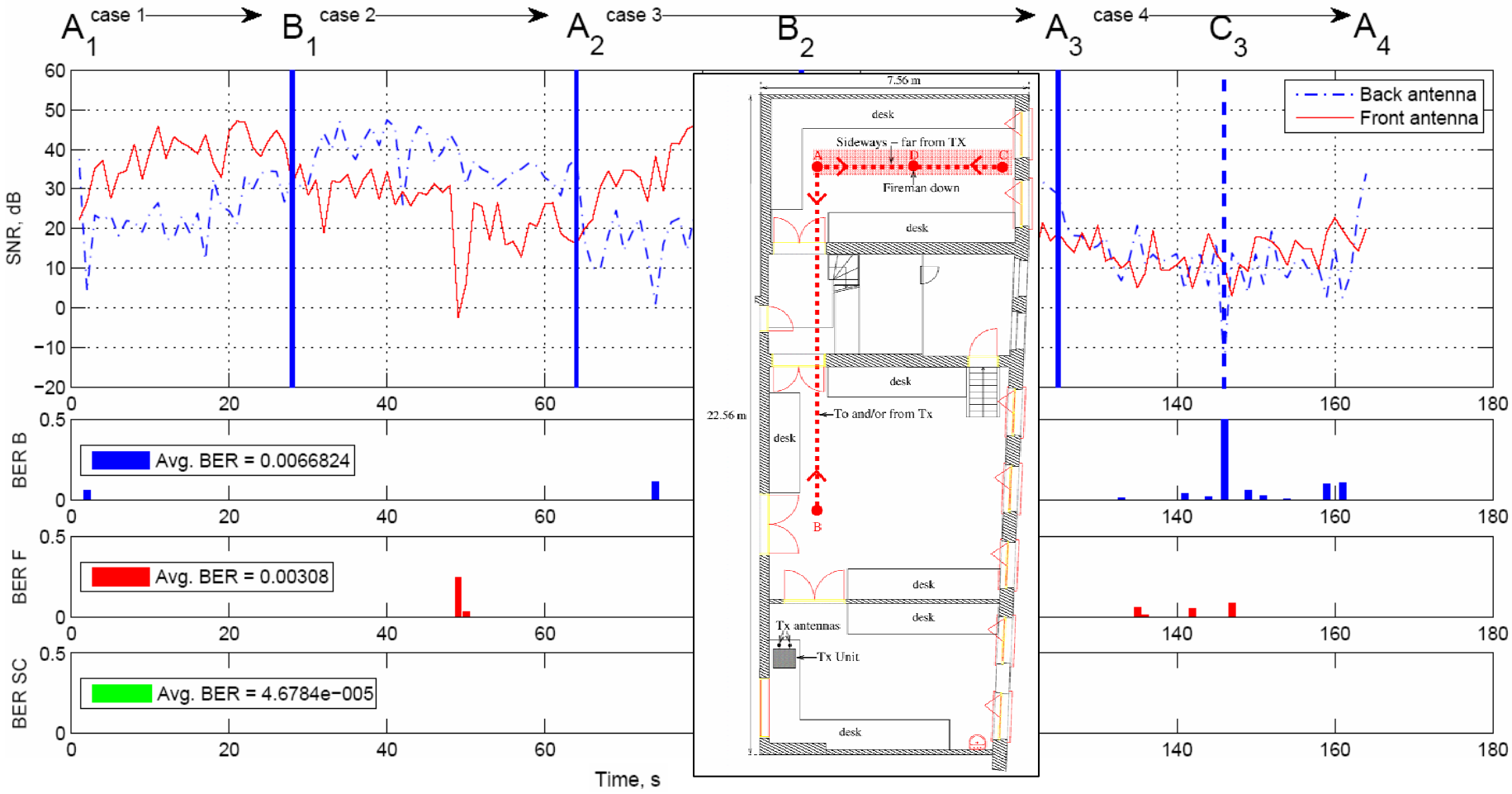
Textile antenna performance

- Mitigating fading by Selection Combining



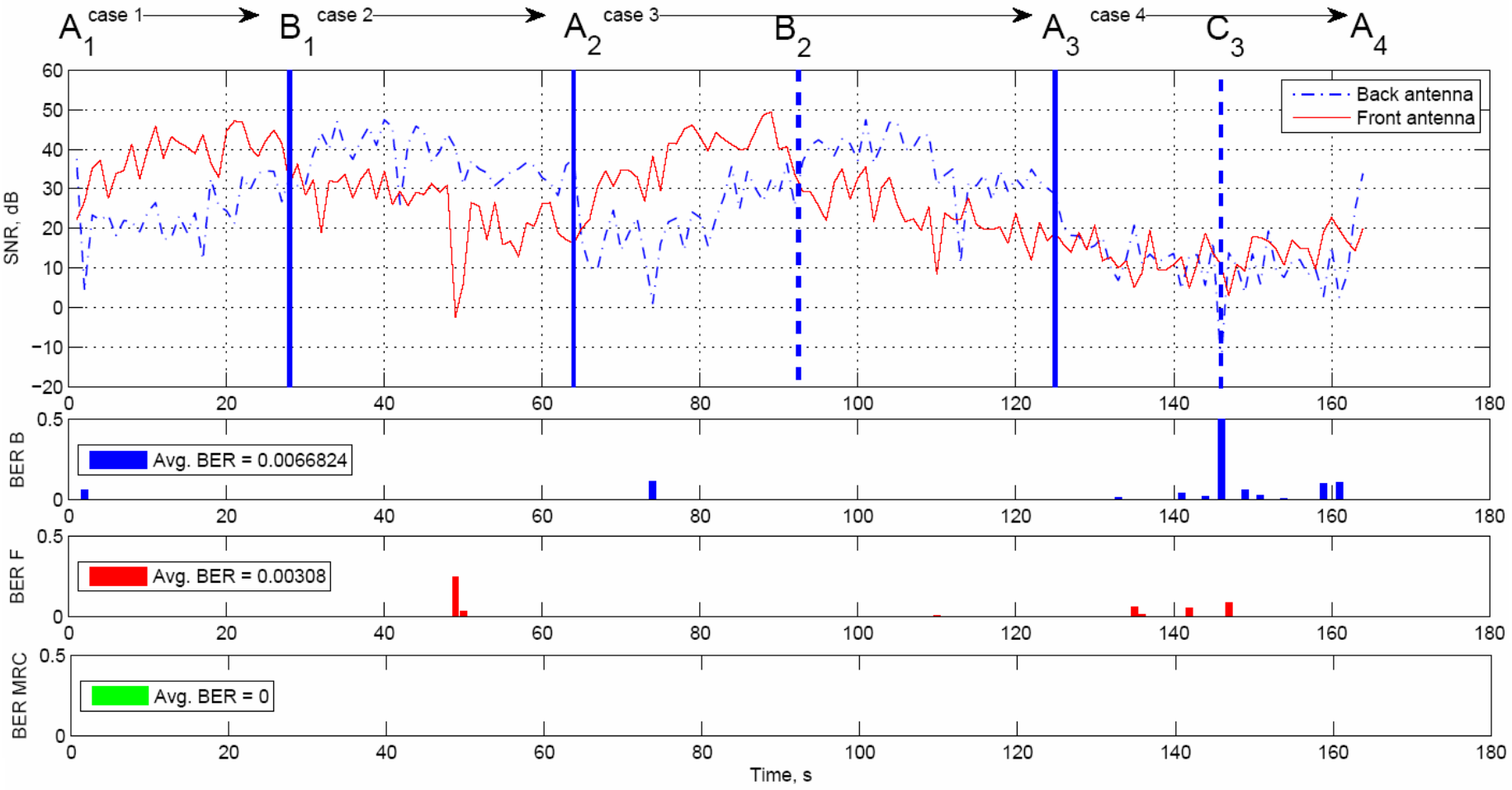
Textile antenna performance

- Mitigating fading by Selection Combining



Textile antenna performance

- Mitigating fading by Maximum-Ratio Combining



Textile antenna performance

- Fireman-down scenario

horizontal polarization required at transmitter

Textile antenna performance

- Real-life scenario : conclusions
  - **Dual textile-antenna system**
    - Reliable communication by
      1. **no shadowing by body by placing one antenna at the front and one at the back**
      2. **limited effect of movement and equipment on antenna performance by choosing suitable locations and by careful textile antenna design**
      3. **mitigating fading by exploiting second-order receiver diversity on body**
      4. **careful choice of antenna polarizations**
         a) **circular polarization for on-body antennas avoids need for alignment**
         b) **horizontal polarization at transmitter detects fireman down**

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  - DIGCOM Group (prof. M. Moeneclaey), **Department of Telecommunications and Information Processing**, UGent
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SIXTH FRAMEWORK PROGRAMME

Information Society Technologies

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Abstract
The paper presents a collection of slides that deals with indoor off-body communication based on a textile multi-antenna system integrated in clothing for rescue workers. It discusses the design and performance of circular-polarized and dual-polarized textile antennas.