Channel Models and Health

Anders J Johansson

Department of Electroscience
Lund University
Sweden

anders.j.johansson@es.lth.se

Outline

- **Magnet and Magnet Beyond**
- **Channel modeling for PAN/BAN**
- **Medical Implant Communications**
- **Health aspects of PAN/BAN/Implants**

MAGNET (BEYOND)

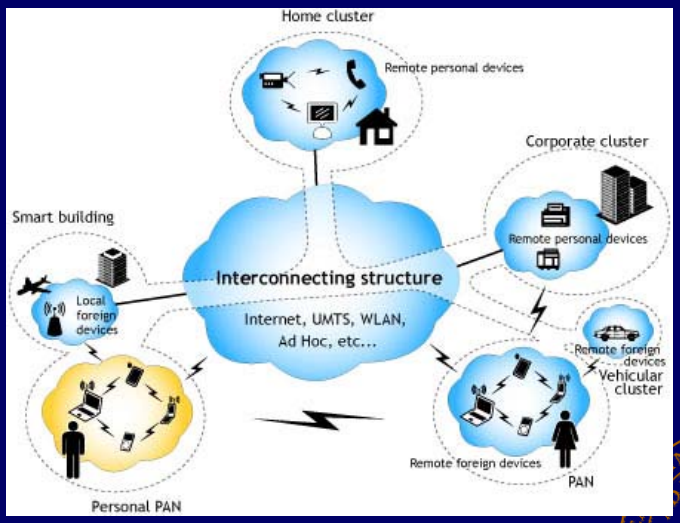
My Personal Area NETwork

- **MAGNET and MAGNET Beyond are integrated projects supported within the sixth framework program (FP6) of the EU Commission**
- ***"MAGNET Beyond is a worldwide R&D project within Mobile and Wireless Systems and Platforms Beyond 3G. MAGNET Beyond will introduce new technologies, systems, and applications that are at the same time user centric and secure."***
- **MAGNET focus on PAN and BAN**

Partners

- **30 Partners from 15 Countries**
  - **13 Universities**
  - **6 Research centers**
  - **11 Companies**
- **Coordinator: Ramjee Prasad**
  Aalborg University
- **http://www.ist-magnet.org/**
- **magnet@adm.aau.dk**

Magnet Vision



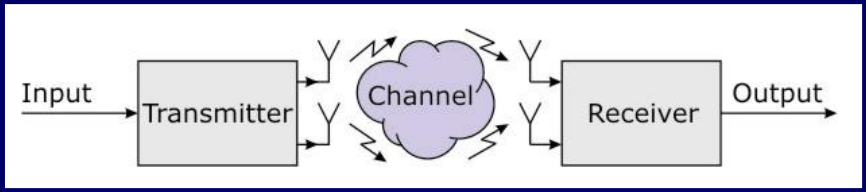
MAGNET devices

Two different air interfaces:

- **HDR – High Data Rate**
  - **5.2 GHz**
  - **40/20 MHz bandwidth**
  - **10-100 Mb/s**
- **LDR – Low Data Rate**
  - **4.0/4.5 GHz**
  - **1 GHz/ 500 MHz bandwidth**
  - **<100 kb/s**

Channel modeling

- Classically the channel is seen as being in between the transmitter and receiver antenna



- Three different types
  - Stored channel impulse responses
  - Deterministic channel models
  - Stochastic channel models

New models needed with new channel surroundings

Channel models for PAN and BAN

- Classic models not useful
  - Antenna part of channel
- Main differences from classical models
  - Short distances
  - Arbitrary orientation of antennas
  - User influence
- The user influence and “typical antenna device” are included in the model as a part of the channel

Directional Models

- Double Directional Delay Power Spectrum

$$DDDPS(\Omega,\Psi,\tau) = APS^{BaseStation}(\Omega)\,APS^{MobileStation}(\Psi)\,P_h(\tau)$$

APS: Angular Power Spectrum
Separates the channel from the delay of the channel.

- But direction of departure (DoD) and direction of arrival (DoA) are not possible to measure on a BAN due to size restrictions.

2.6 GHz antennas

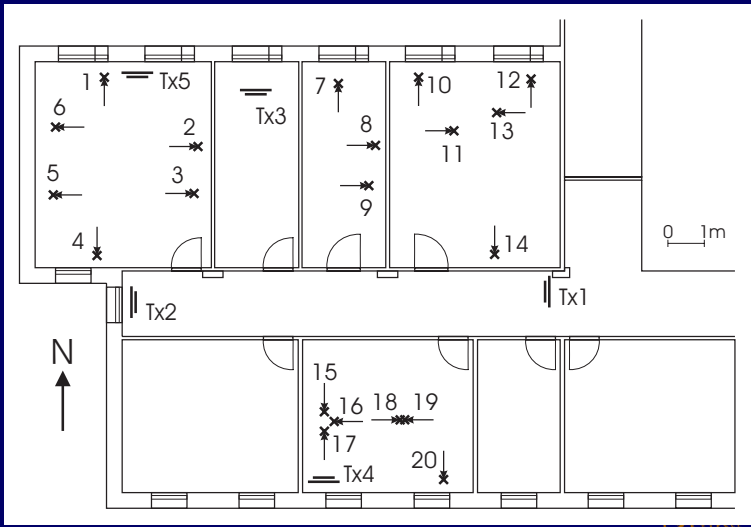
2 port
hand held

4 port
hand held

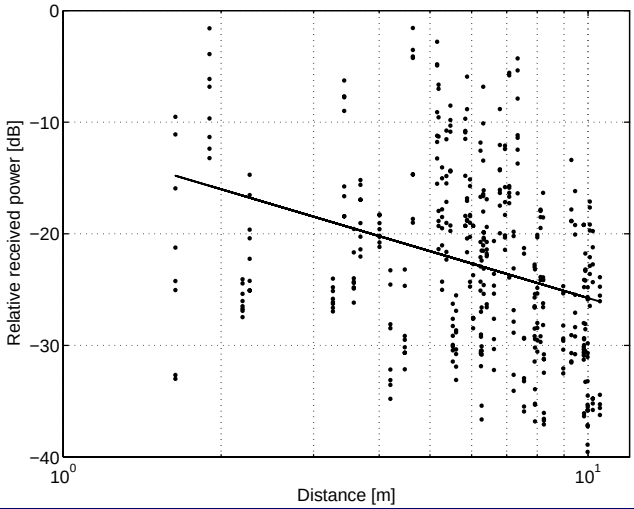
PC

fixed
device

Measurements performed at typical work positions



Shadowing is more important than distance for the path loss



Fixed device – PC
NLOS
co-polarized

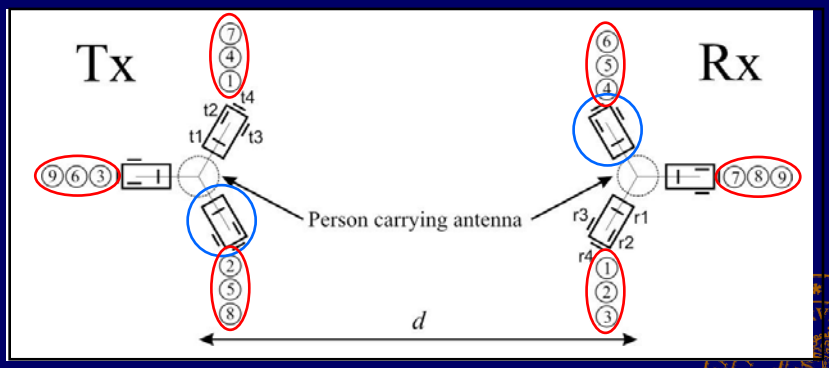
5.2 GHz antennas

Handheld

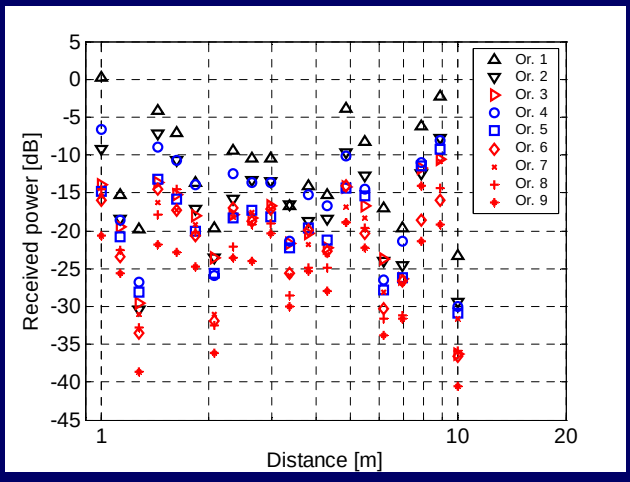
Body-worn

Measurement positions Handheld –to-Handheld

- Several rotations of (person carrying) Tx and Rx ⇒ body shadowing
- Antenna elements have different directions



Handheld to handheld, LOS, 5.2 GHz

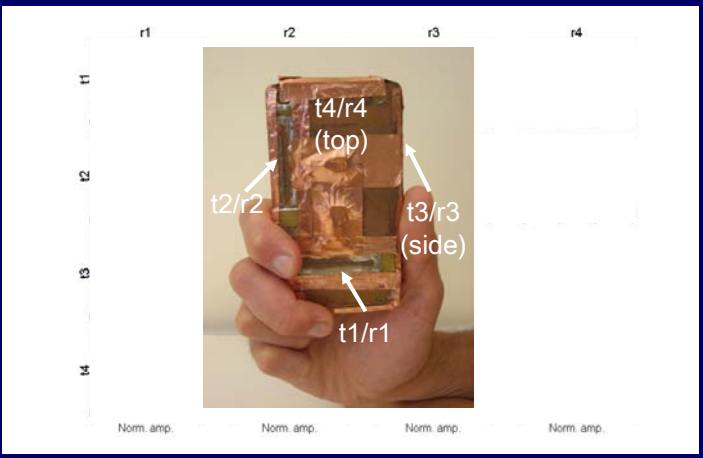


- Power varies up to 20 dB depending on orientation
- Shadowing is more important than distance for the pathloss

Small-Scale Amplitude Statistics

Rows – Tx elements

Columns – Rx elements



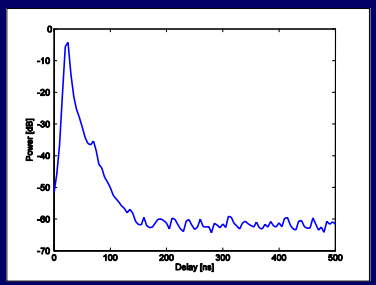
- **Some Tx-Rx combinations exhibit Rayleigh statistics**
- **Some Tx-Rx combinations exhibit Rice statistics**
- **Some Tx-Rx combinations exhibit ”other” statistics**
- Measurement is ”LOS”!

Magnet 2.6/5.2 GHz channel model

- **Tapped delay line model**
  - **Power delay profile**
    Classical one cluster exponential decay

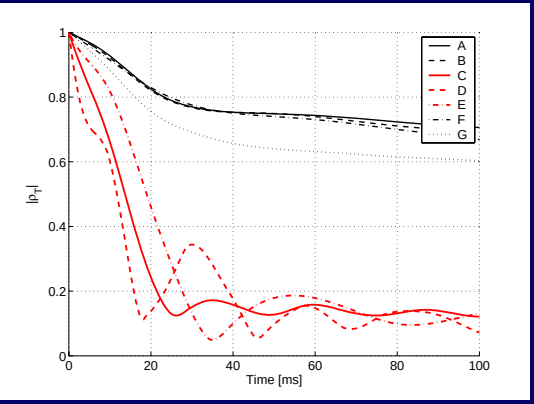
$$P(\tau) = |\beta|^2 e^{-\tau/t}$$

  - **Impulse response**
    Rather fast decay gives large coherence bandwidth



Antenna Correlation

- Correlation between antenna elements is generally low
- Time correlation varies between scenarios:



A, B: Stationary terminals, stationary environment

C,D,E: Moving terminals

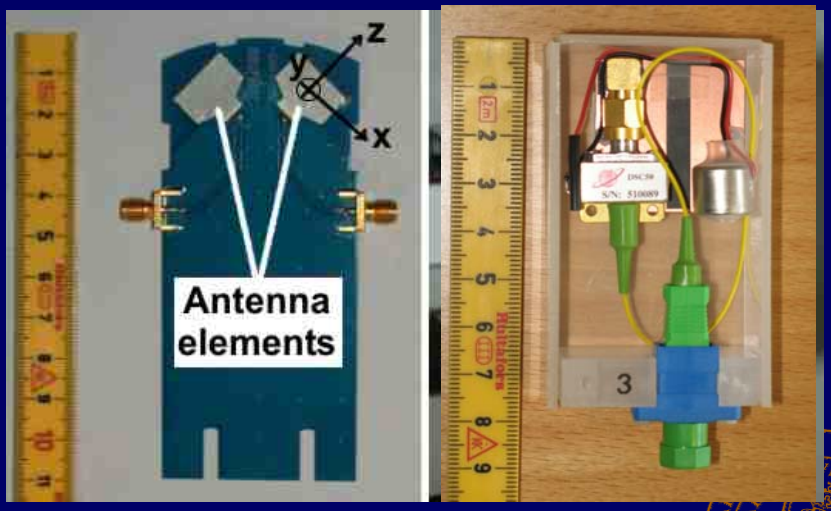
F,G: Moving environment (people walking)

MIMO model

- Uses the full correlation matrix
  - Suitable for small number of TX and RX antennas
- Generalize to Weichselberger model for larger number of antennas.

$$H_{model} = U_A \left(\tilde{\Omega} \odot G \right) U_B^T$$

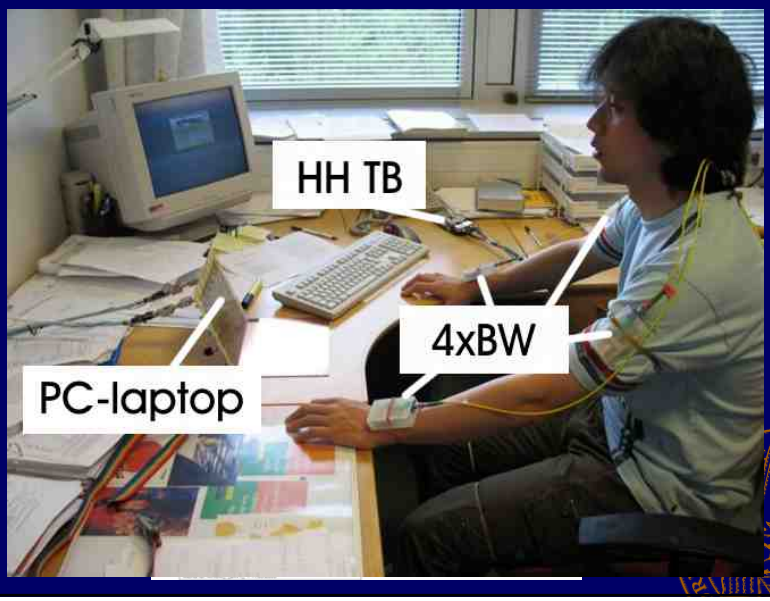
UWB Body Area Network



Sky-cross antenna

Directional slot antenna

BAN measurements



UWB BAN vs Free-space

- Low wideband power fluctuations
- Difference between walking and seated users in dual exponential decay characteristics
- Cluster and ray arrival rates the same as in free-space, but higher attenuation.
- User proximity and dynamics gives a higher fading of the signal clusters and received wide-band power.

Magnet UWB channel model

- Magnet uses a modified Saleh-Valenzuela model for the UWB SISO channel.
- Based on IEEE 802.15.3a and IEEE 802.15.4a
  - Modified to account for hand-held user-proximity effects.
- 5 different models proposed: 3 for walking users, 2 for seated users.
  - 3 of these "pure BAN": 2 walking, 1 seated

Parameters:

- RMS delay spread
- Cluster arrival rate
- Ray arrival rate within cluster
- Cluster peak power decay factor
- Signal power decay factor within cluster
- Signal power decay factor within tail cluster
- *Weibull ray power distribution over the average decay within cluster.*
- Log-normal cluster fading
- Log-normal shadowing

Medical Systems

- Communication with transceivers inside the body, and not only on top of the surface of it.

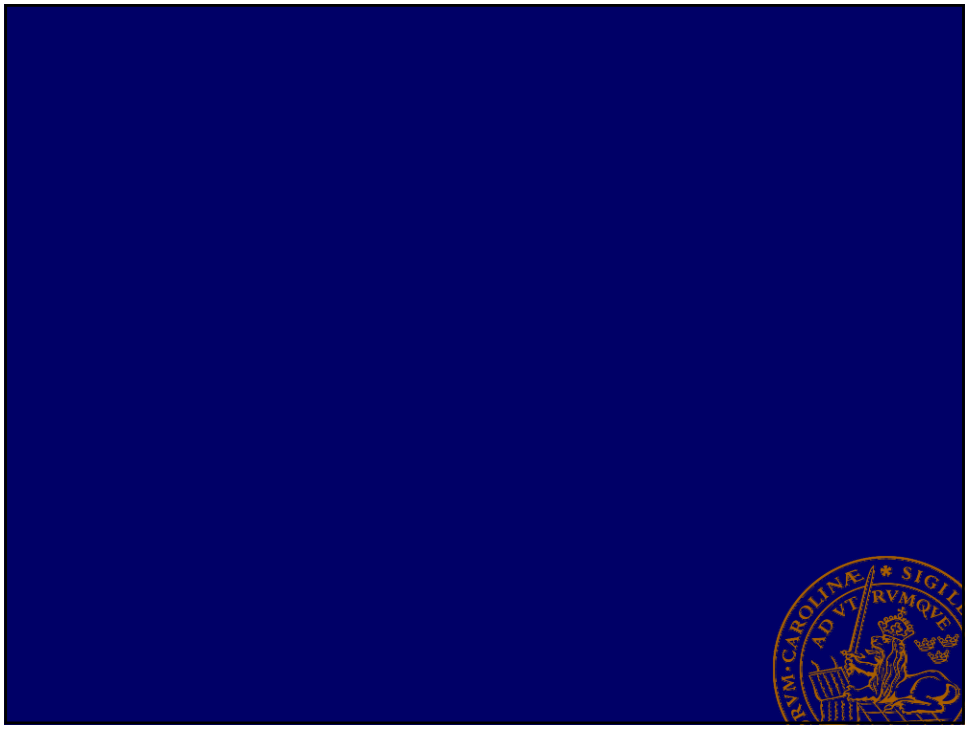
MICS

- **M**edical **I**mplant **C**ommunication **S**ystem

  Frequency allocation for communication with medical implants.
  - Frequency band: 402 - 405 MHz
  - Max EIRP 26uW = -16 dBm
  - BW < 200 kHz

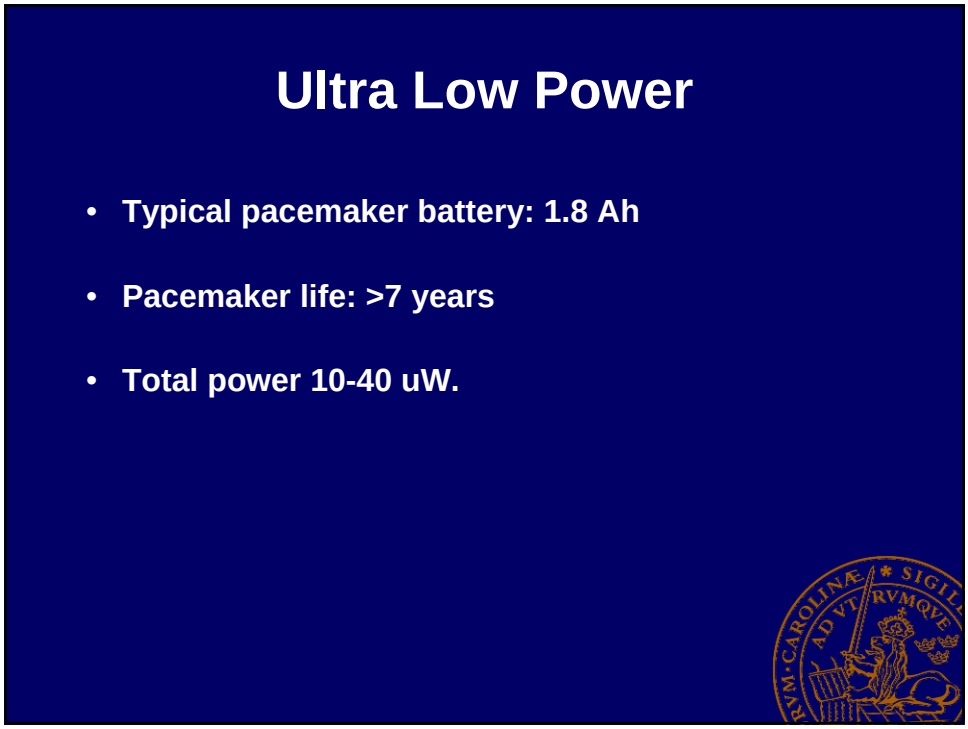
- Frequency band shared with the weather balloon service

- Primarily used for communication with heart pacemakers



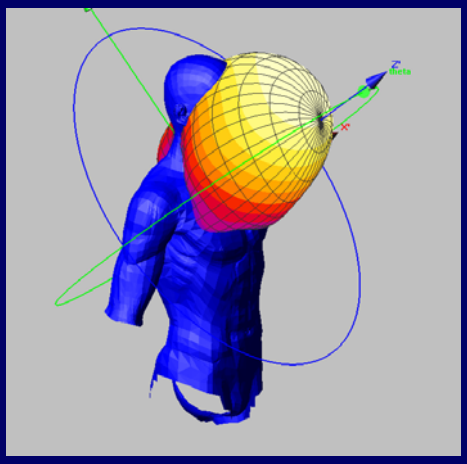
Ultra Low Power

- Typical pacemaker battery: 1.8 Ah
- Pacemaker life: >7 years
- Total power 10-40 uW.



Implant antenna

- **The human body with the implant will act as a dielectric antenna fed by the implant.**



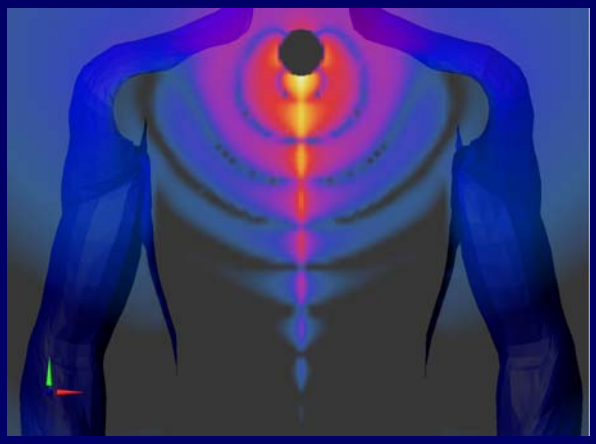
Pattern will change with:

•Body shape and size (male, female, young, old, skinny, heavy, etc.)

•Body posture, limb position

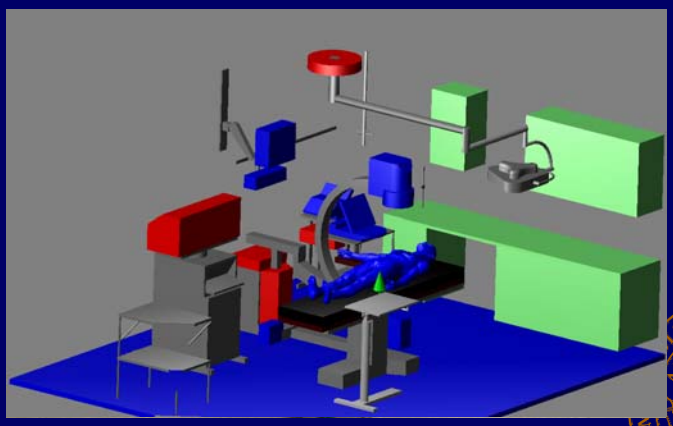
MICS channel

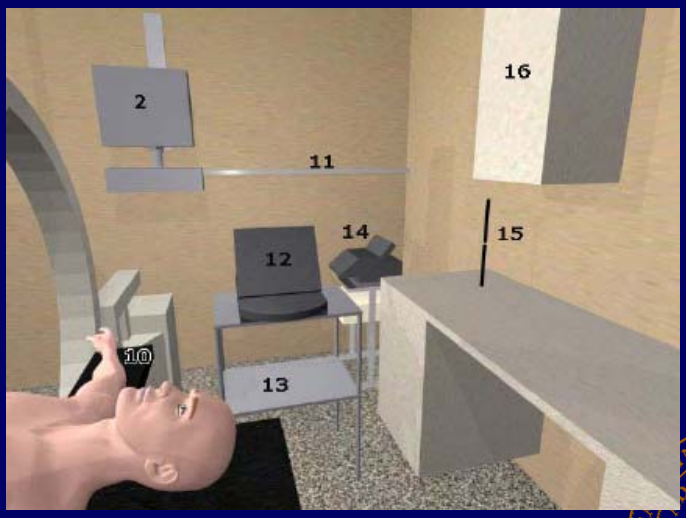
- **Body propagation**
  - **Wavelength reduction inside the body**



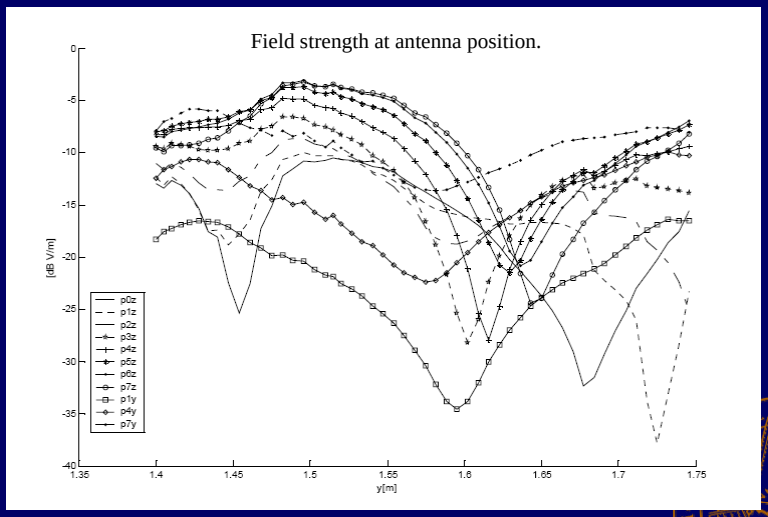
MICS channel

- **Near-field channel**
  - **All communication at a distance of a few wavelengths between base-station and human body.**





Path loss dependent on implant position



Health aspects

ICNIRP

- International Commission on Non-Ionizing Radiation Protection
- 1 Hz to 10 MHz: Basic restrictions are provided on current density to prevent effects on nervous system functions.
- 100 kHz to 10 GHz: Basic restrictions on SAR are provided to prevent whole-body heat stress and excessive localized tissue heating.
- 10 GHz to 300 GHz: Basic restrictions are provided on power density to prevent excessive heating in tissue at or near the body surface.

Measures of exposure

- Measures are of rms values
- Far/Near-field
  - SAR (W/kg) =(J/kg/s)
    - Specific Absorption Rate
- Far-field also uses derived values:
  - Power flow (W/m^2)
  - Field strength (V/m)
- Accumulated doses are not used!

10 MHz to 10 GHz

- Whole-body SAR in plane-field conditions
  - People in the far-field
- Local SAR in near-field conditions
  - People handling the transmitters
  - People with implanted transmitters
- Limit set to guard against heating. Temperature increase is to be kept below 1^{o}C.
- Limit is set according to an averaging over 6 minutes, after which temperature equilibrium is reached.

Health aspects

- Main hazard of RF: Absorption of energy leads to heating
  - Microwave ovens work on this principle
- Other effects: High field strengths interact with the nervous system
  - Sensations in the skin
  - High Power pulsed microwaves are “audible”
- Possible long-term effects?
  - None established this far according to experts.
  - Continuous monitoring of the research is necessary.

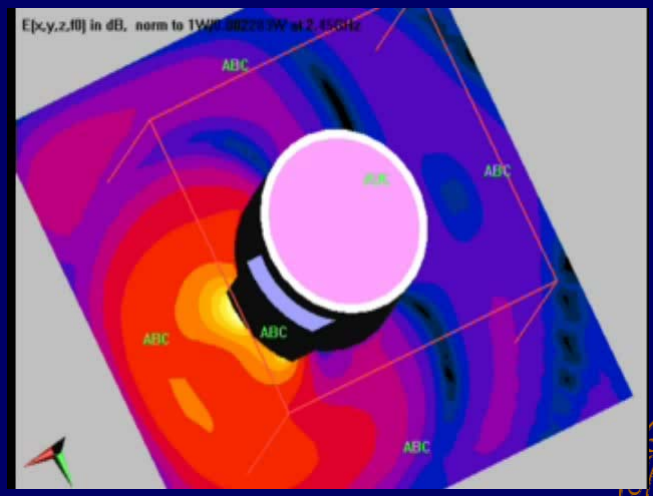
Local SAR

- Measured in the near-field
- Cubic volume is moved around and position with the maximum absorption is registered.
  - Done either by simulation or measurements in a liquid filled phantom, usually a head.

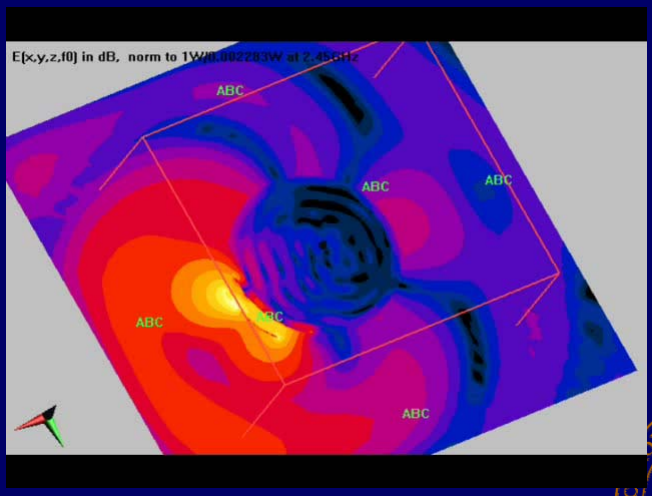
SAR Limits

- Limits for local exposure (Head)
- EU: 2 W/kg in 10 gram
  - TX power < 20 mW can not exceed the limit
- US: 1.6 W/kg in 1 gram
  - TX power < 1.6 mW can not exceed the limit

Electric field from soft patch antenna on arm

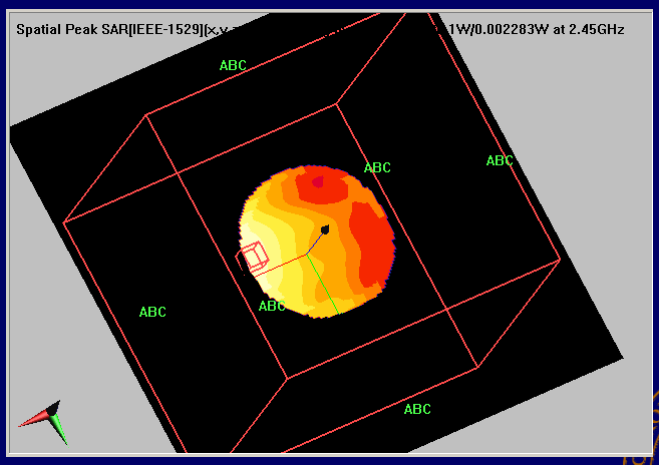


Electric field from soft patch antenna on arm



SAR distribution

- Cube represents maximum 1g volume.



BAN concerns

- Body-mounted devices have their antennas very close to the wearers body
- Implant devices will have their antenna in direct contact with the wearer

BAN Consequences

- Keep transmit powers down
  - Maximize battery life
  - Minimize SAR
- Minimize Body loss by shaping near-field
  - Maximize useful communication power
  - Maximize battery life
  - Optimize communication link
  - Minimize SAR

End

Thank You for Your Attention!

Contact: anders.j.johansson@es.lth.se