Human++

Wireless body-area networks (WBAN) for health monitoring applications

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SEEDS FOR TOMORROW'S WORLD

IMEC History

1984

Established by state government of Flanders in Belgium

Non-profit organization

Initial investment: 62M€

Initial Staff: ~70

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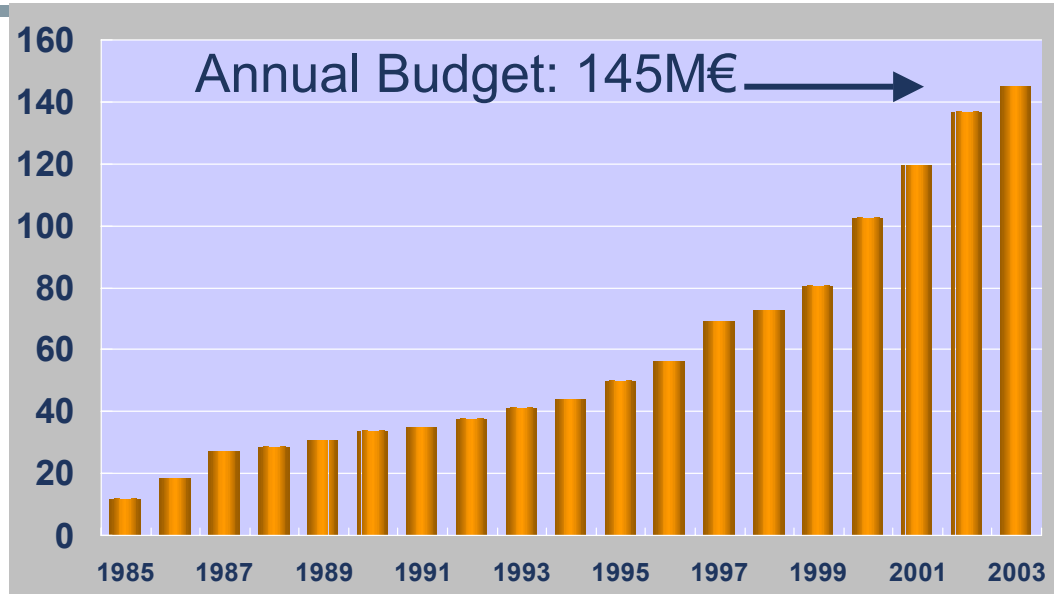
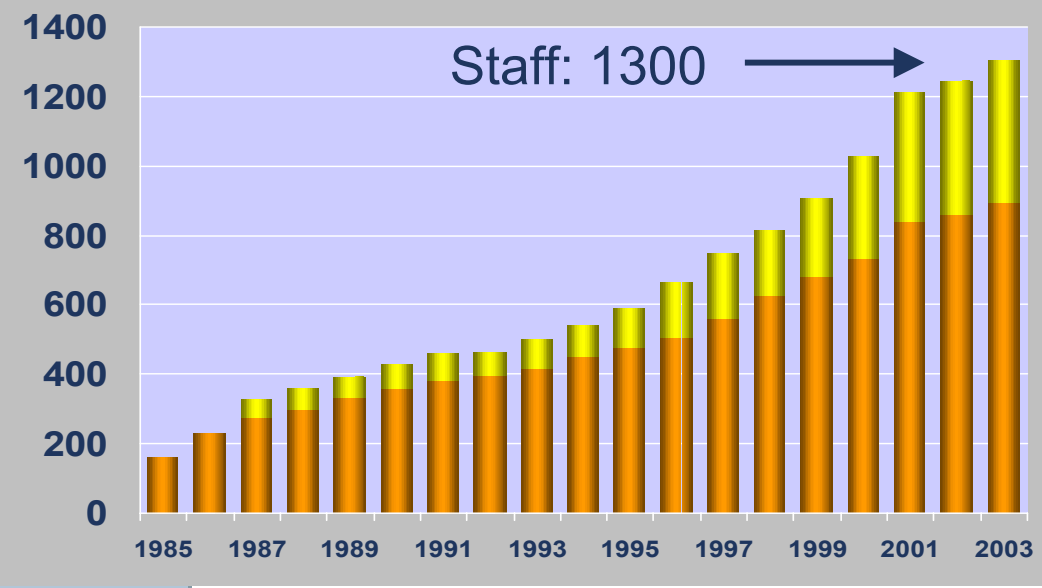




2003

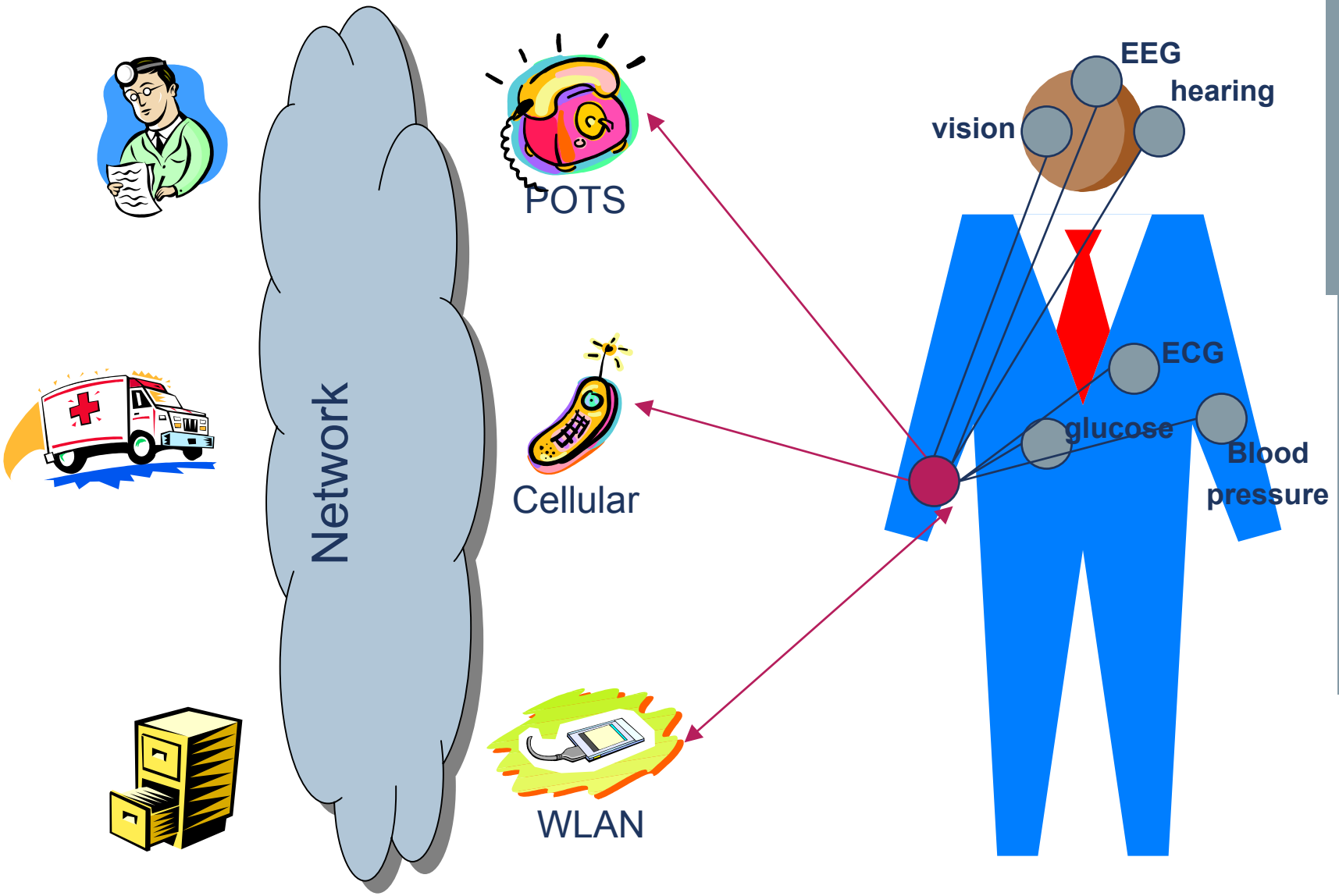
Largest independent R&D center in this field in Europe

Annual Budget: >145M€ (includes 34 M€ yearly grant from government)

Staff: >1300 (>100 PhD, >300 Residents)

Collaboration with >500 partners

Human++: WBANs for health monitoring applications



Entertainment, fitness, comfort systems

Measures

- Accelerometer
- Heat flux
- Galvanic skin response
- Skin temperature
- Near body Ambient temperature
- Event timestamp
- Oxygen consumption

Applications

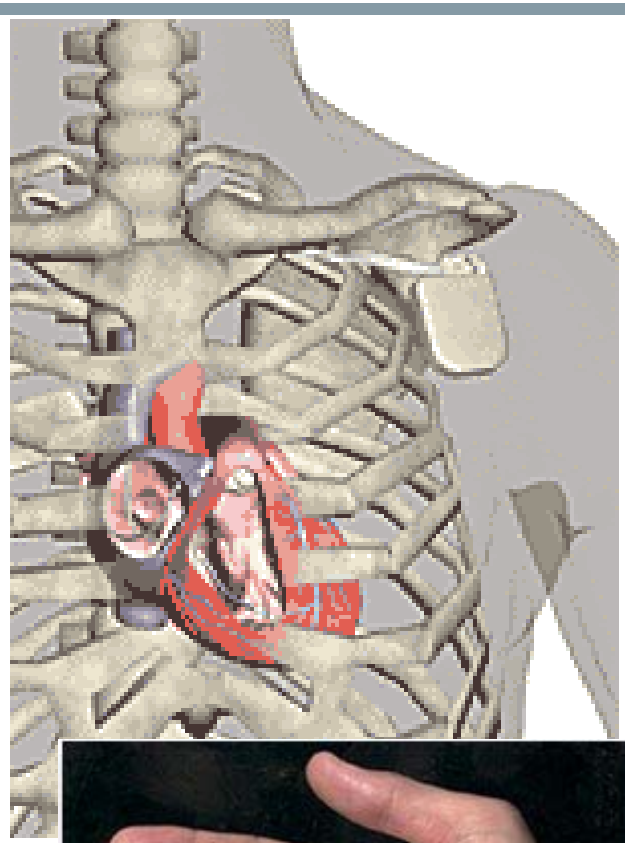
- biometrics
- fatigue,
- sleep,
- Comfort
- Speed
- Distance
- metabolism

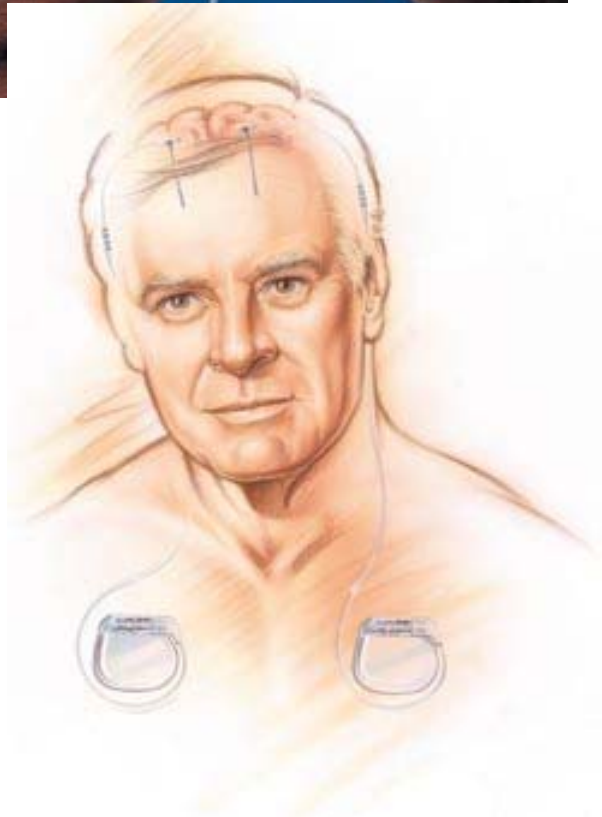
Bodymedia

Dynastream/Nike

HealtheTech

Medtronic pacemakers for heart and brain

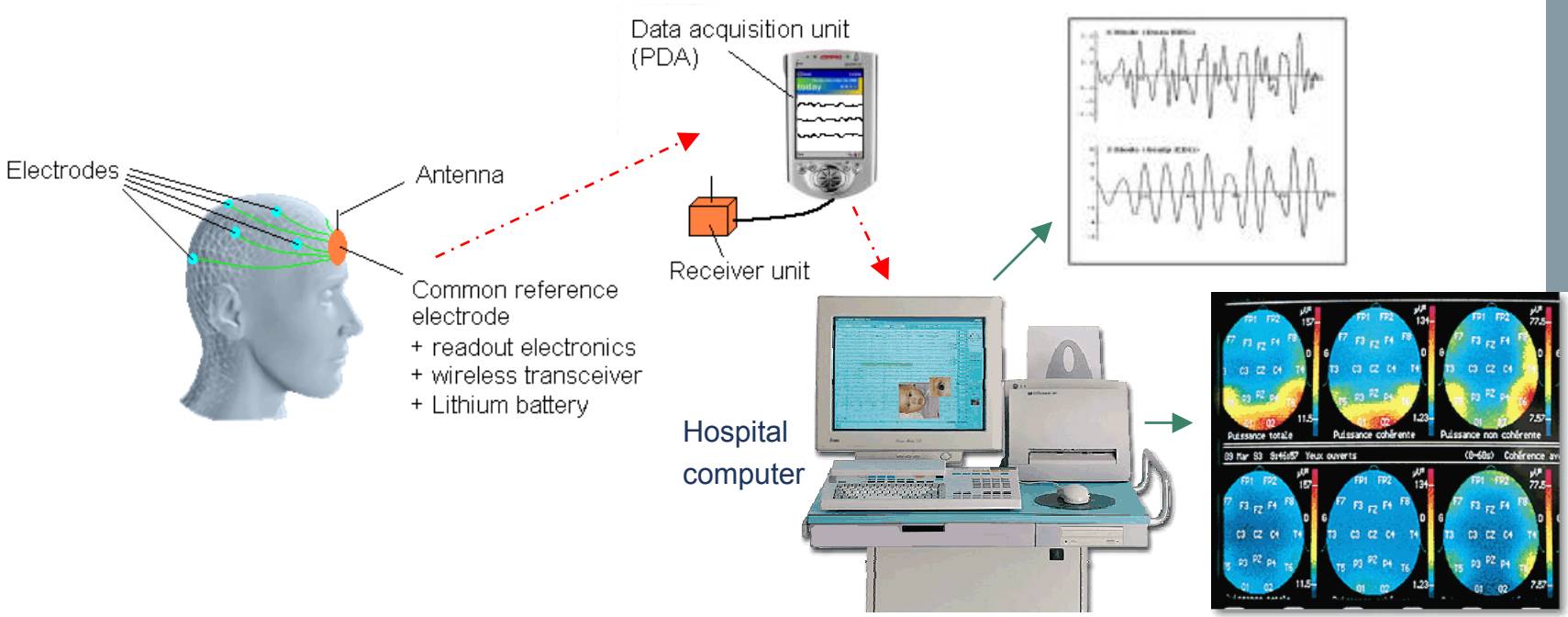




Given Imaging camera pill

- Capsule details
  - 11x26mm
  - 4g
  - 2fps
  - 57000 images total
- Wireless connection
- Data storage in worn 9GB hard drive
- Visualization of small intestine
- Can go where no endoscope has gone before

Human++ technology driver: epilepsy monitoring and suppression system

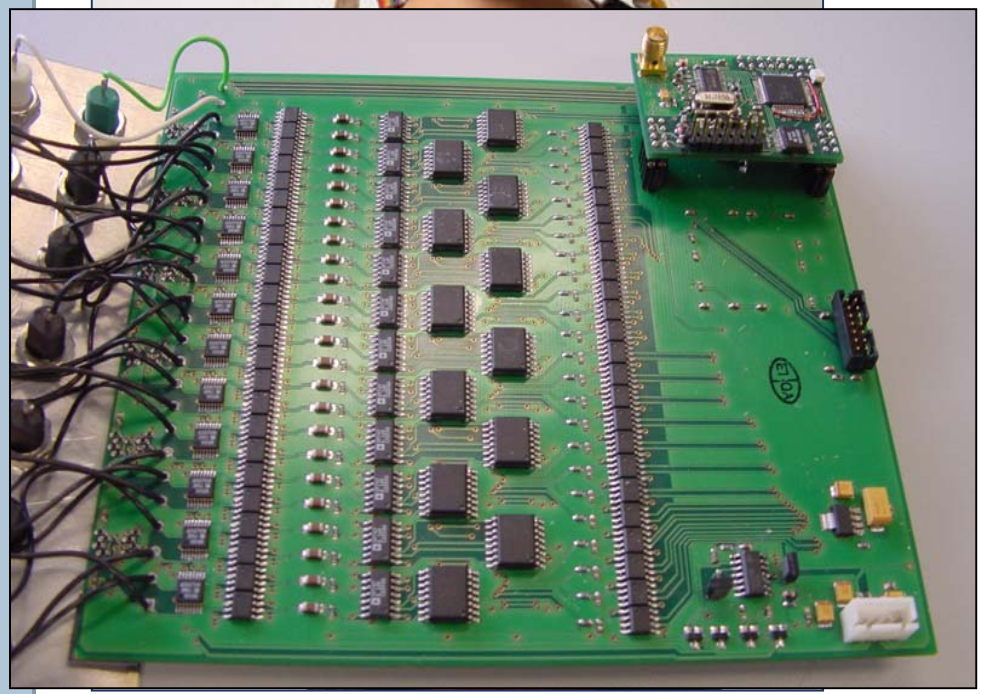


Improving mobility of patient

Detection of upcoming seizures

Suppression of upcoming seizures

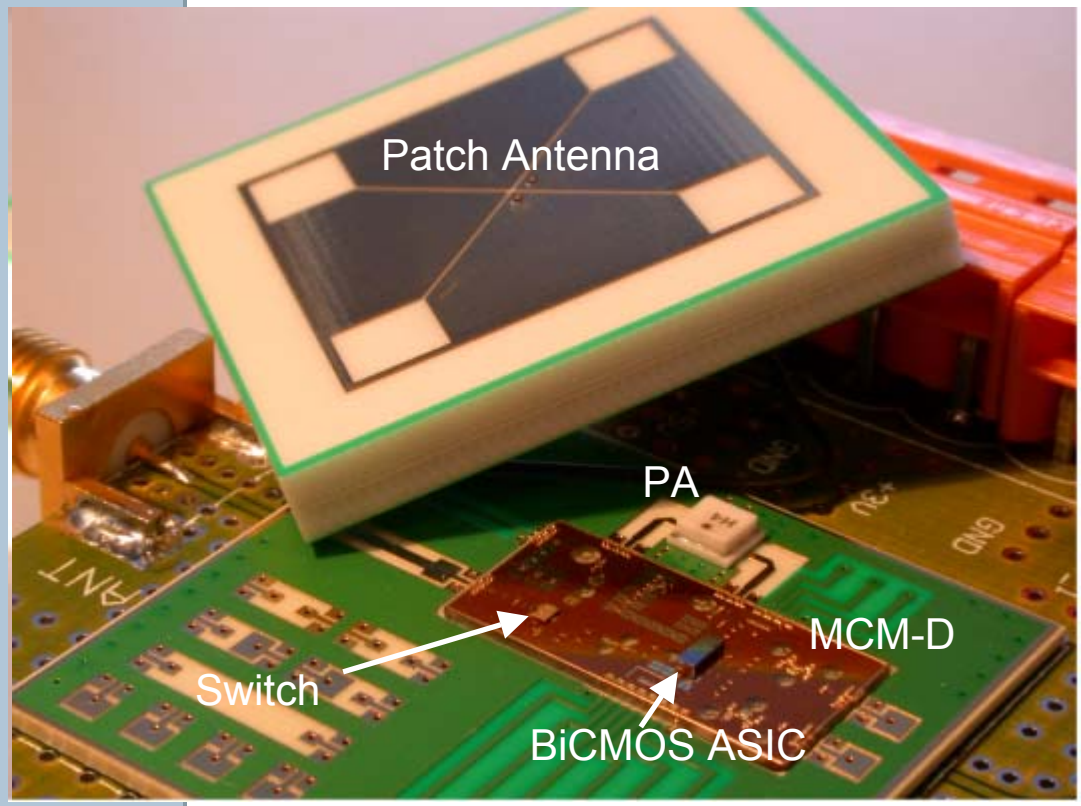
Ambulatory EEG system using COTS components

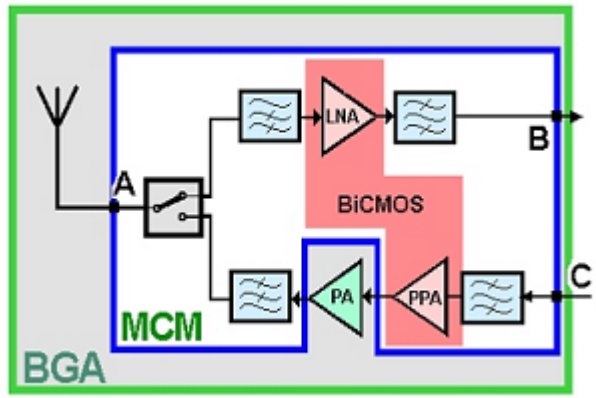


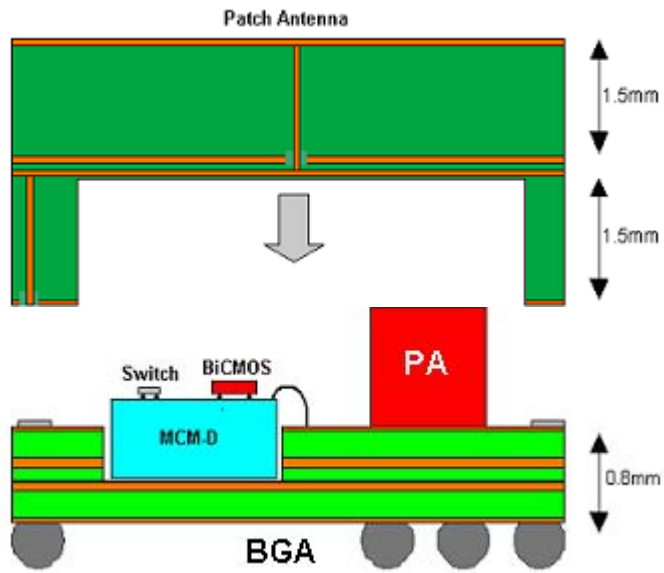
24 channels @ 256 samples/s
Resolution: 12 bit / sample
Raw data rate: 76kbit/s
FSK modulation @ 868MHz
Output power: -10dBm
FEC: reed solomon

Power consumption:
Wireless: 30 mW (390 nJ/bit)
Processing: 14 mW
Sensor interfaces: 101 mW
Total: 145mW
Operational lifetime: 3 days on 4AA batteries

IMEC has shown a single package radio with no external RF whatsoever





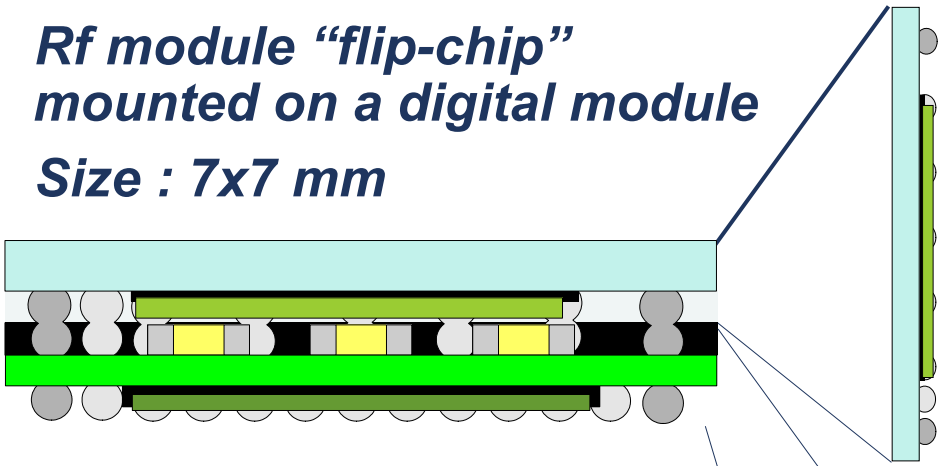


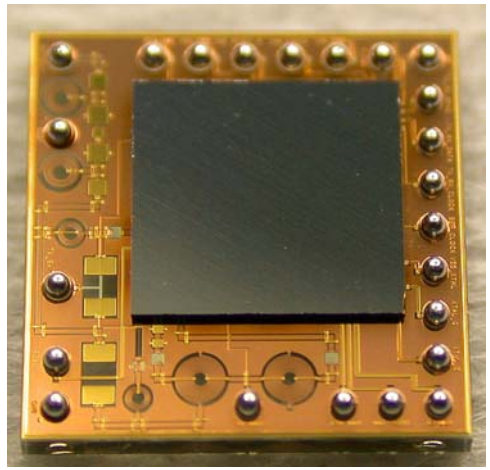
BiCMOS RF ASIC
and GaAs switch flip-chip
mounted on glass substrate
with high quality integrated
thin film passives

3D fully integrated radio

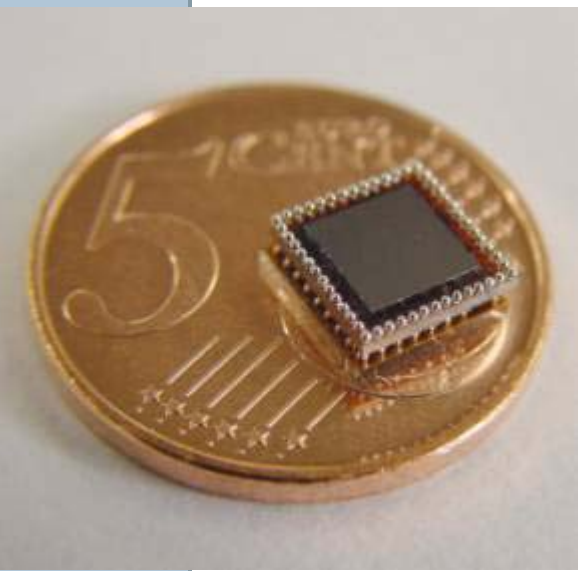
Rf module "flip-chip" mounted on a digital module

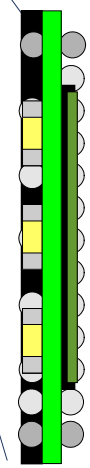
Size : 7x7 mm

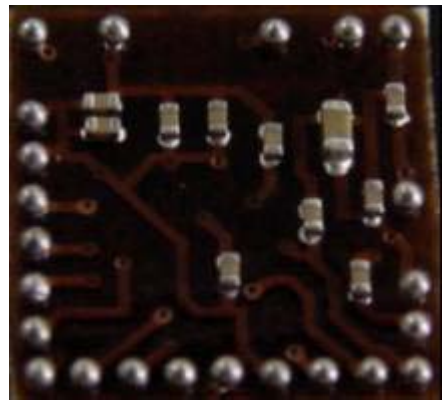




Rf chip "flip-chip" mounted on rf-integrated passives substrate

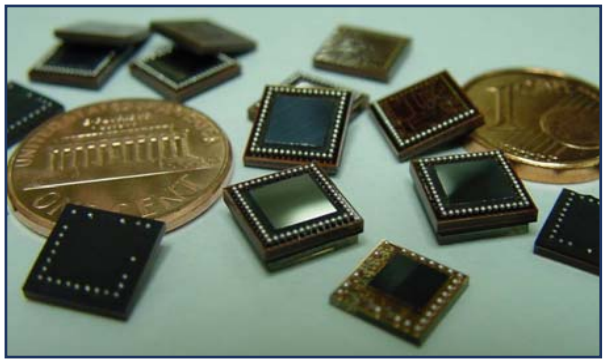


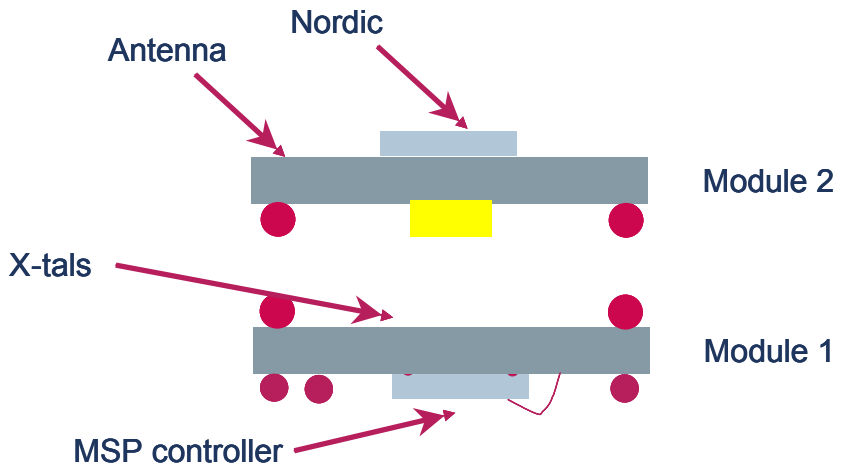




High density laminate with SMD passives on top side and Digital Base band chip on Bottom side

3D stack development for wireless sensor node is in a final stage





Full low power wireless/computing unit on BGA

14x14 mm <=> 60% antenna efficiency

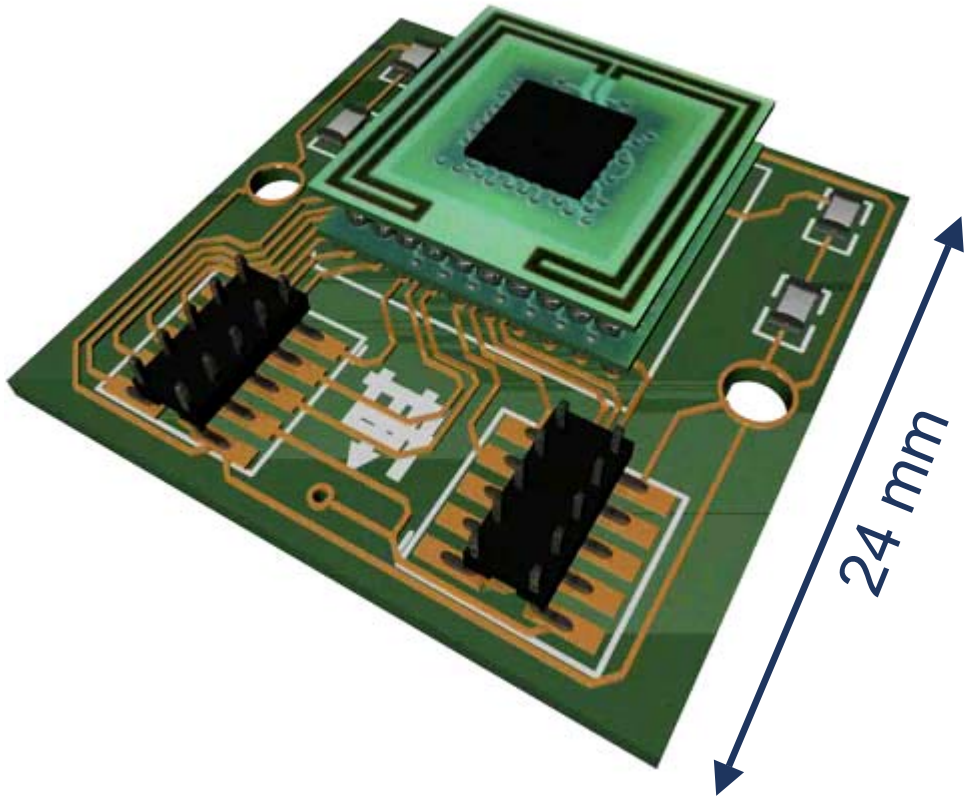
Uses IMEC`s 3D stack technology

Based on Nordic nRF2401 (18nJ/bit) and TI MSP430 (200μW/MIP)

First output: April 2004

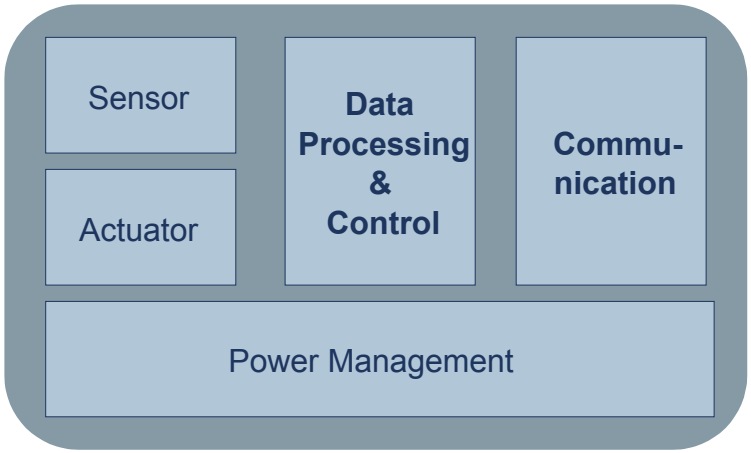
Next month a first demonstrator will be available

Temperature sensing: autonomy 1 year (1 sample/sec)



3D impression

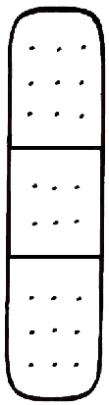
Human++ technical goals



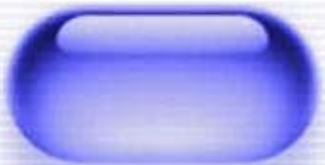
Operational life time: 1 week (band aid) to 10 years (implant)

Total average power consumption < 100μW

- **Communication < 50μW**
- **Computation < 40μW**
- **Sensor < 10μW**



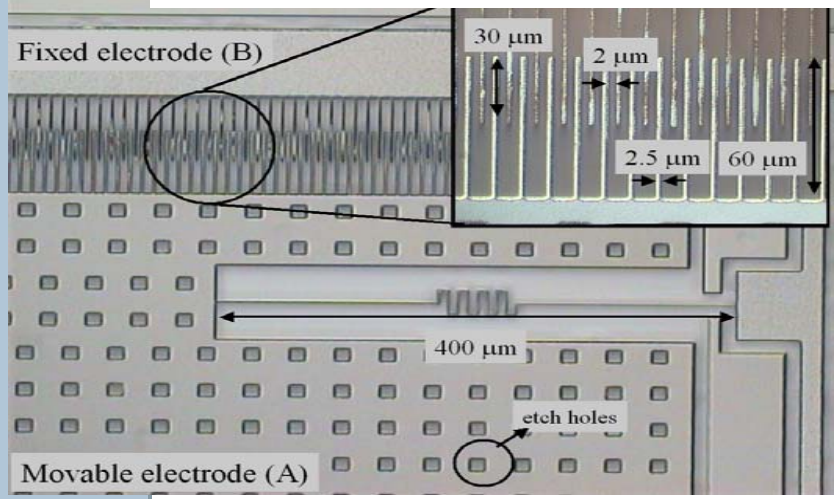
Thin, flexible
Stick to skin
Integrate in clothing
Solar cell,
Thermo-Electric convers
2D integration
5cm²

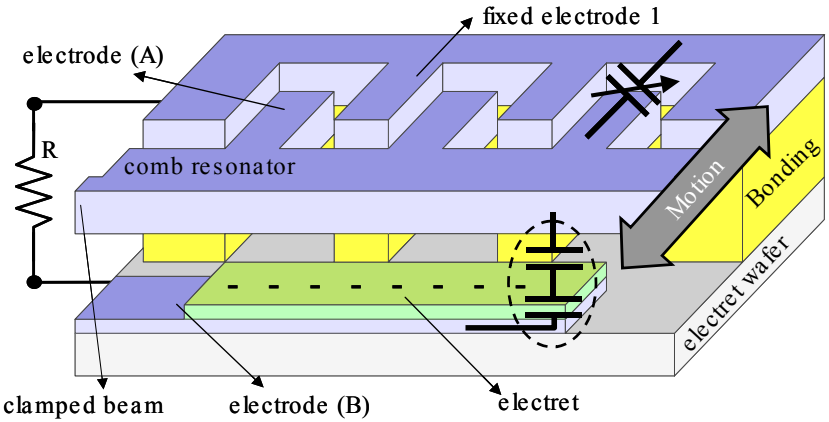


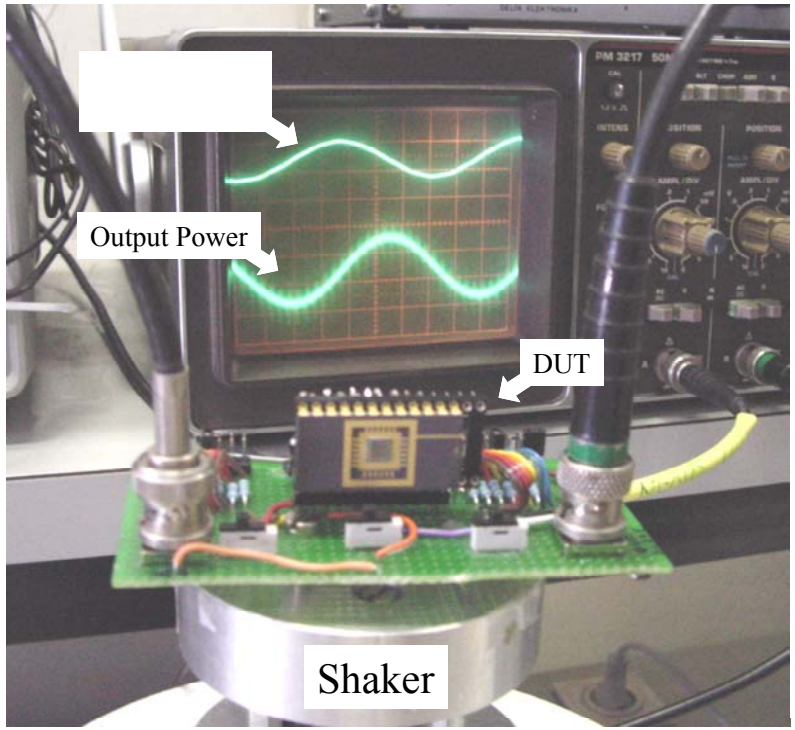
Thick, hard
Swallow
Implant
Mechanical energy
3D integration
1cm³

One early techno demonstration: MicroPower Generation

10 μW/cm² when extrapolated to practical size and normal operating conditions





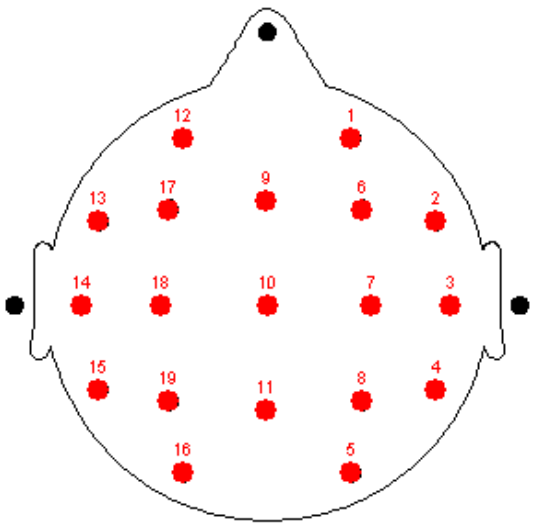


Simple epilepsy detection algorithm requires 22 MOPS

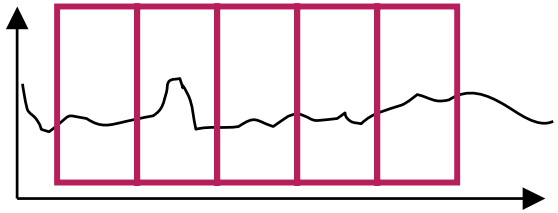
International 10-20 measurement setup:

- 19 data channels (+1 reference and 1 ground)
- 256 Hz sample rate
- 12 bit dynamic range

raw datarate: 58 kbit/s



Example: Simple Similarity Index algorithm can predict Epilepsy



- 22 ALU-MOPS @ 16 bit wordlength
- straightforward implementation leads to 4.4 mW on TI C54x low power DSP
- resulting wireless datarate: ~ 300bits/s

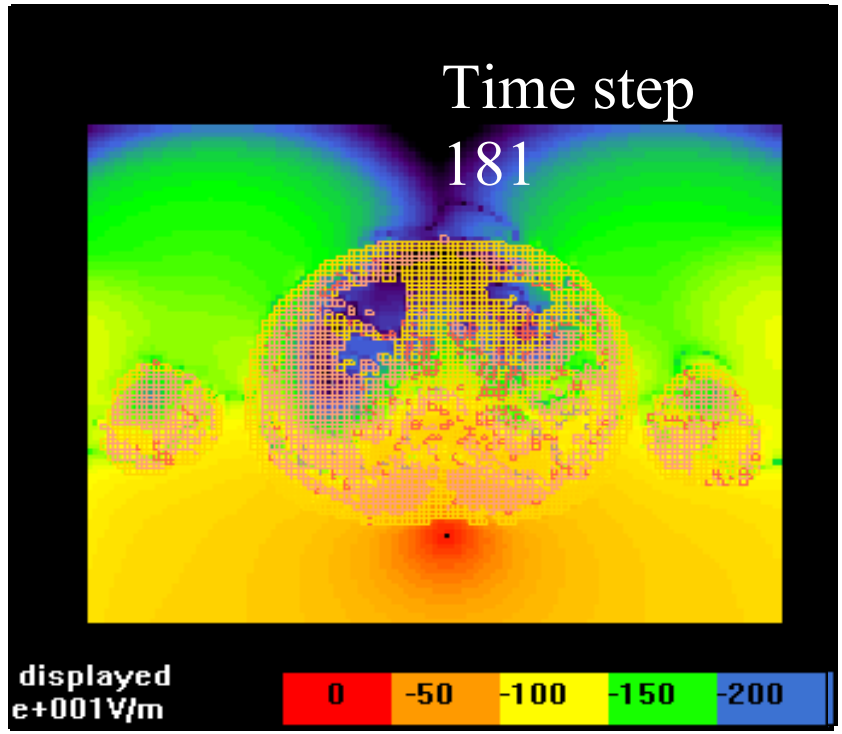
(Much) More complex algorithms (factor of at least 10) needed for epilepsy prediction !

Propagation around the body through creeping waves

EM waves propagate around the body via two paths:

- Penetration (dielectric losses, tissues interfaces losses)
- Creeping waves (diffraction mechanism)

REMCOM XFDTD software together with a complete body model:

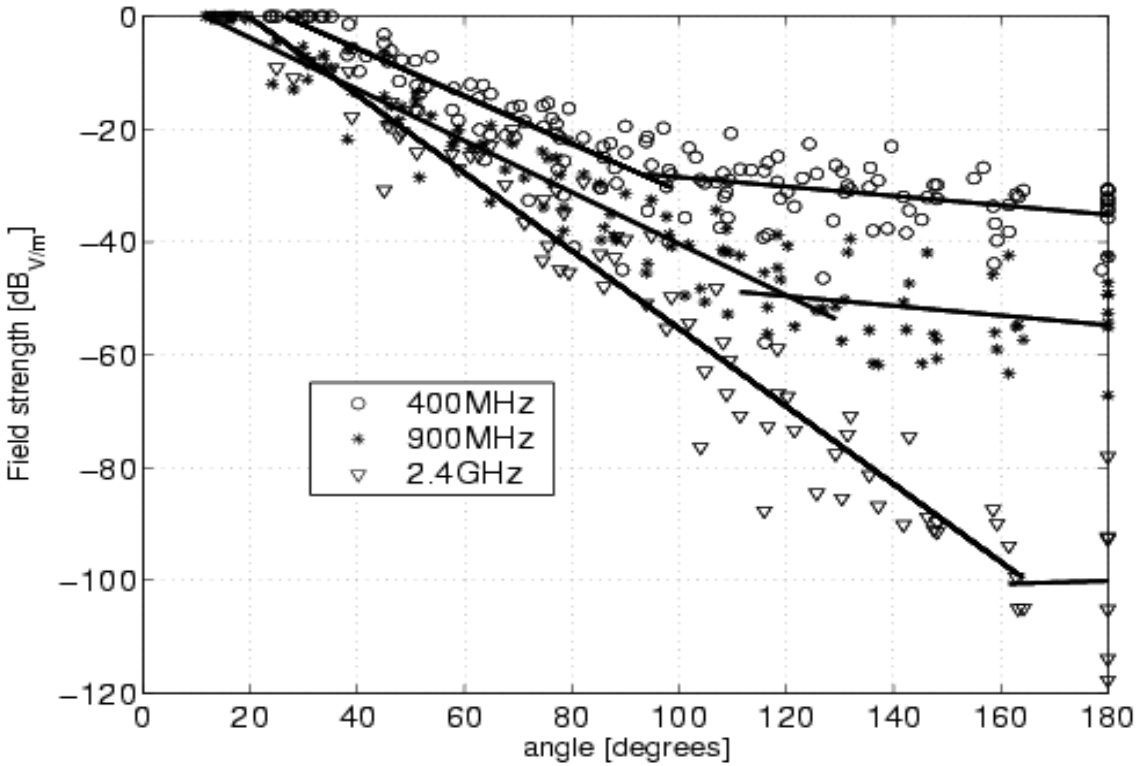


IMEC contribution to 802.15.4a standardization

(Channel modeling subgroup)

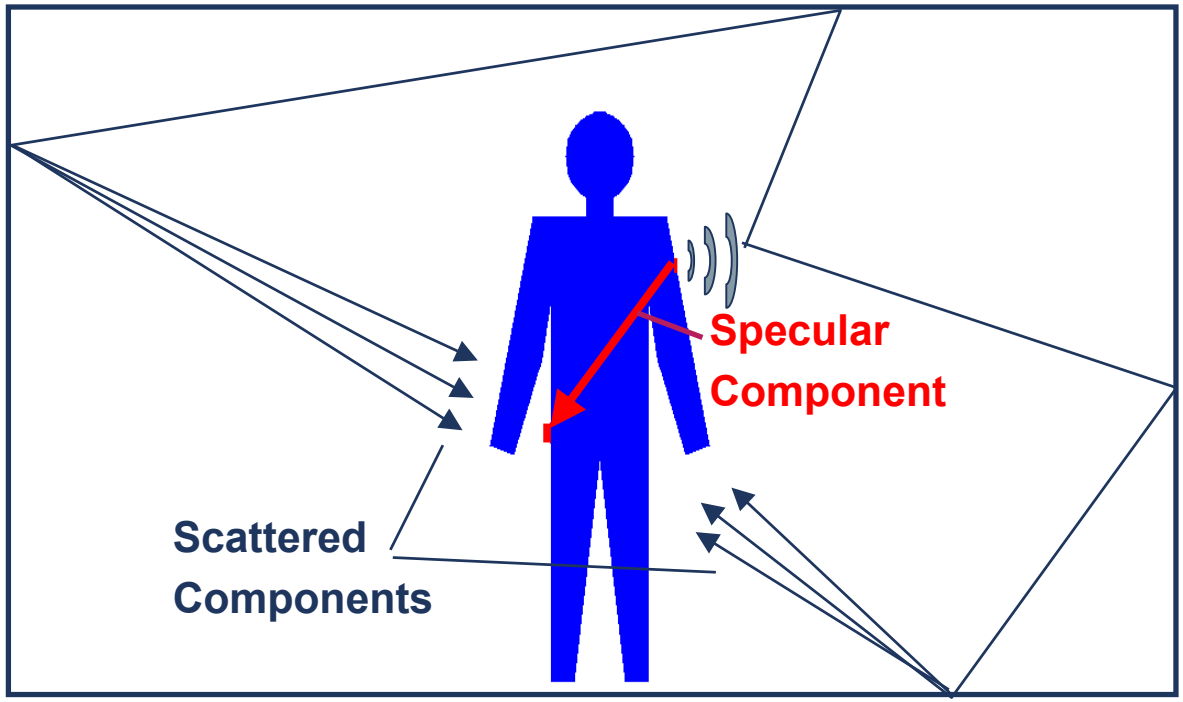
1 time step = 10ps

We determined the path loss near the human body by simulation.



Exponential decay with angle difference
Height difference less important
Path loss is higher for higher frequencies
Variance is larger in the interference region

We propose a Rician Model to simulate nearby walls and obstacles

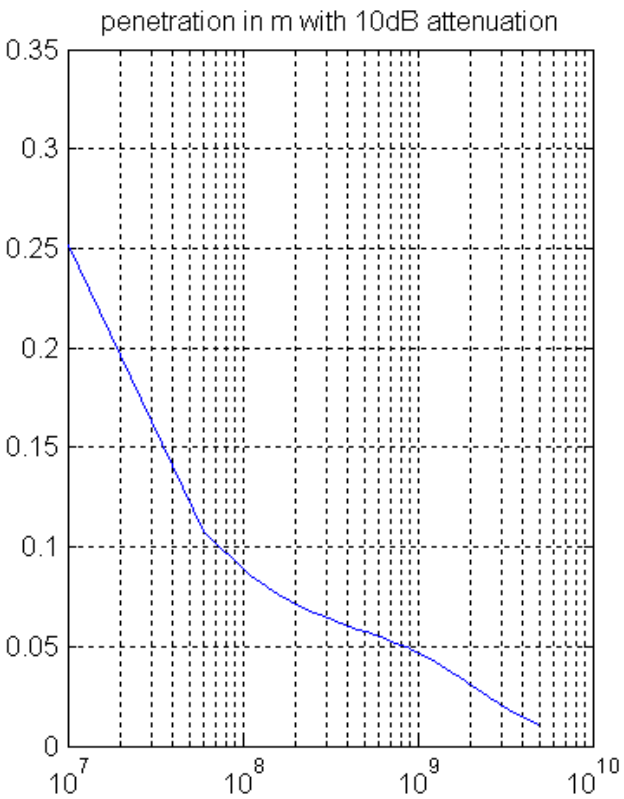


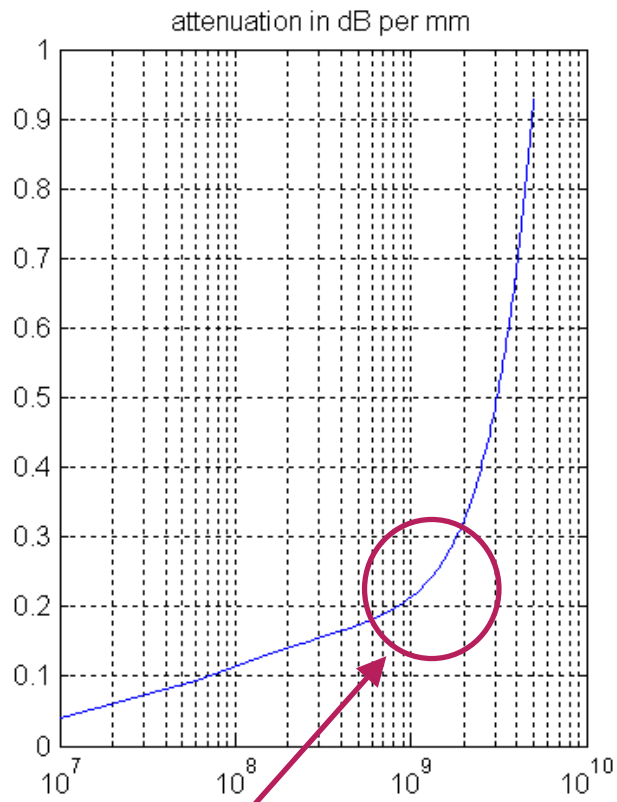
Based on Rician “line of sight” channel model.

The variance and attenuation of creeping wave << reflected paths.

Ratio of Specular (Line of sight) power and Scattered (reflected power) must be estimated.

Stay below 1 GHz for communication with implanted devices





Strong attenuation above 1GHz!

Wanted: ultra-low-power solutions!

- reduce wireless data rate by ultra-low-power local processing in sensor node
- operate radio at relatively high data rate in burst mode with very low duty cycle:
  - Minimize start-up times
  - Minimize standby power consumption (e.g. leakage!)
- optimal air interface for communication around human body (a good channel model is a must):
  - RF communication (narrowband, spread-spectrum, UWB)
  - Inductive coupling (“near-field communication”, RF-ID tags)
  - Capacitive coupling
- exploit asymmetry in communication link to reduce power consumption in sensor node
- ultra-low-power implementation (architecture + circuit design)

SEEDS FOR TOMORROW'S WORLD

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