Antennas and Radio Propagation for Ultra Wideband Body-Centric Networks

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Body-Centric Wireless Network

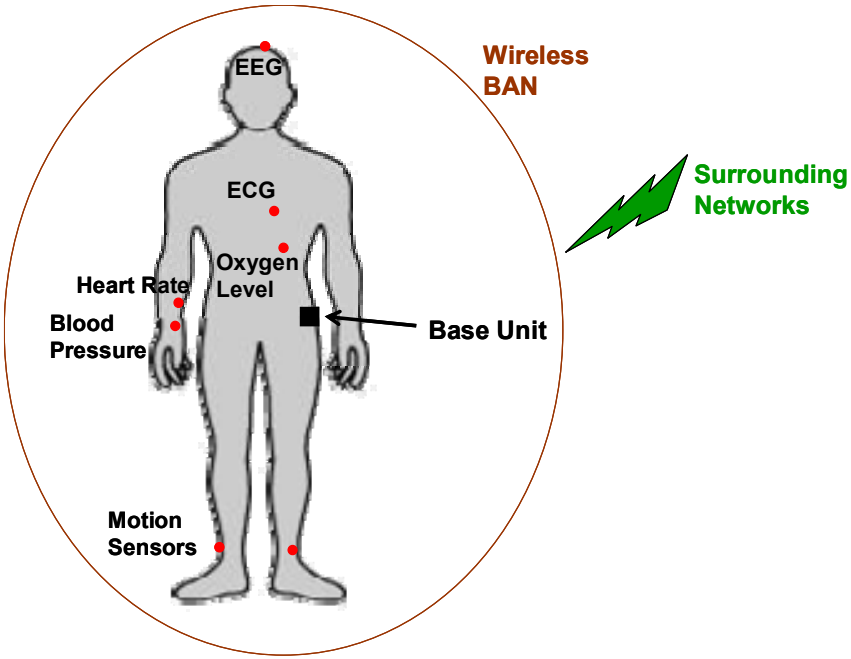
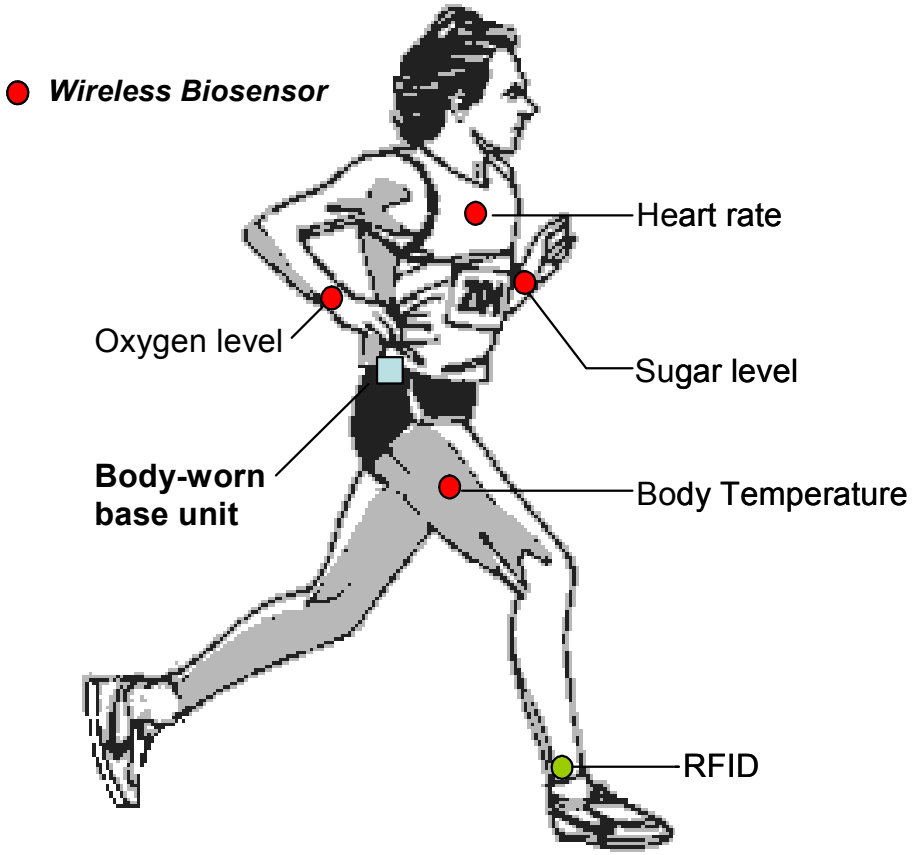


Figure: Wireless BAN in Healthcare Applications

- Natural progression of Wireless PAN
- Communication between body mounted devices and with off-body units
- Should provide constant availability, re-configurability, unobtrusiveness and true extension of a human's mind
- Potential applications in healthcare and personal networks applications

Objectives and Applications



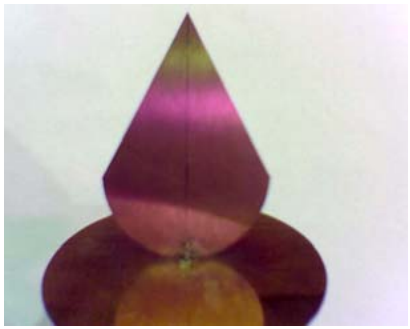
- On-body communication introduces dynamic and distinct propagation environment.
- The importance of antenna optimisation and effects on the communication channel due to close proximity to human body.
- The rapid changes in on-body channels geometry and surroundings raise difficulties in obtaining deterministic propagation models.

Why Ultra Wideband?

- UWB provides high capacity, multipath robustness, fine time resolution for accurate delay estimate, inexpensive systems and Multi-access.
- Approved by FCC and recently by Ofcom for consume electronics applications (3.1 - 10.6 GHz) with power spectral density emission limit set at -41.3 dBm/MHz.
- Ultra low-power, low/high data rate technology suitable for body area sensor technology.
- Dispersion of both antenna and human tissue electric properties across the band need to be considered.

Body-Worn Antennas

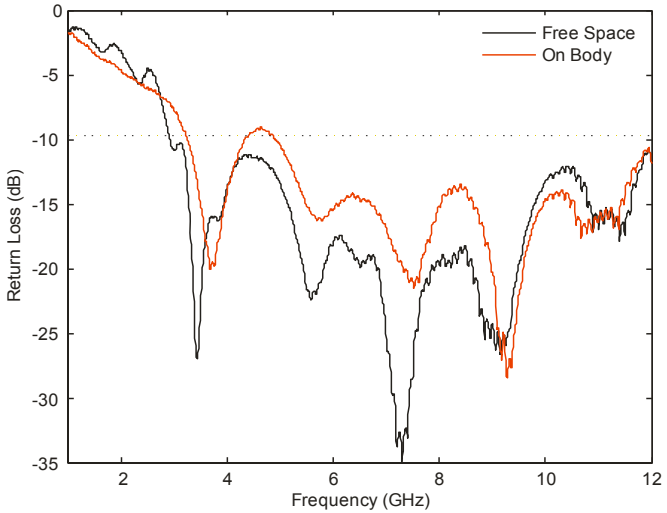
Vertical Inverted Cone Antenna



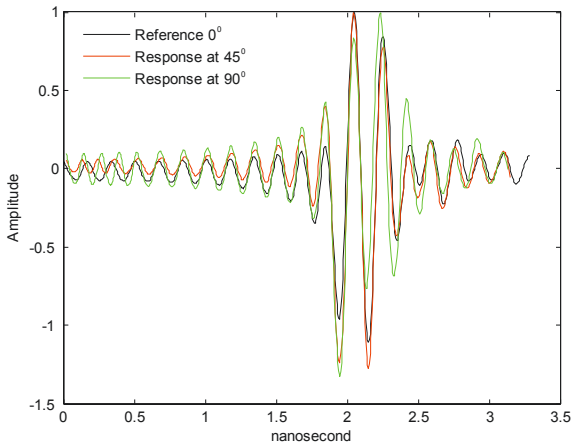
CPW-fed antenna Compact slot antenna

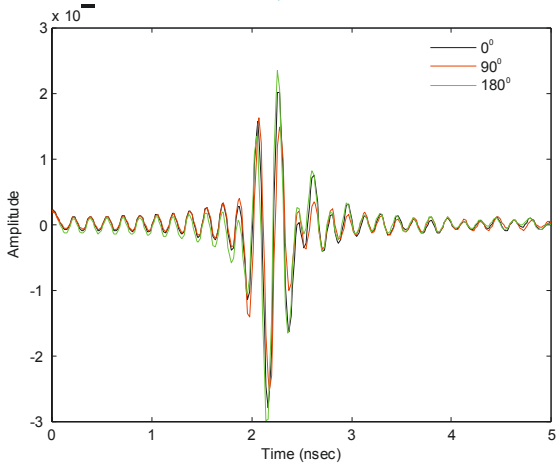
- Compact size with extra care taking in preserving good performance.
- Low-cost, easily integrated with front-end components and transceivers
- Excellent frequency and time domain (Necessary in UWB) characteristics when placed on human body and in various environments.
- Transmitted and received pulses at different radiation angles with similar data rate and efficiency

Antenna Performance



- **Excellent impedance matching off and on the body**
- **Angular dependency of radiated pulses described applying the Fidelity factor**
  - **Span: 89% - 96%**





On-Body Radio Channel Characterisation

HP8720ES Vector Network Analyser used for on-body frequency domain measurement

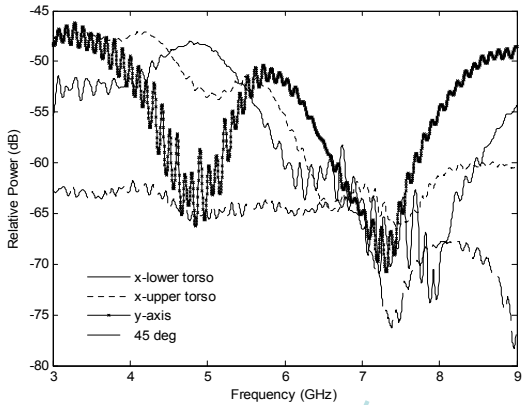
Hollow physical phantom in the Antenna Measurement Laboratory, Queen Mary, University of London, used for measurement protocol settings

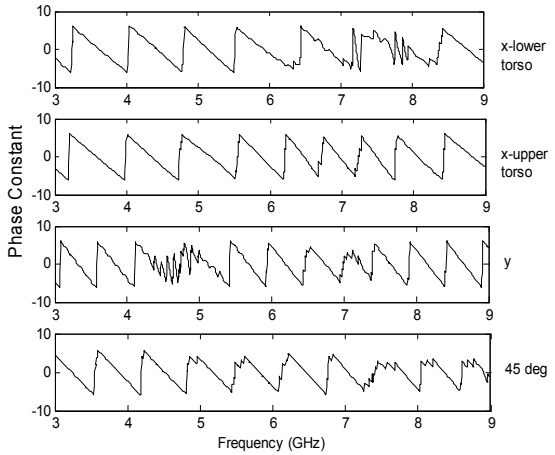
Microstrip patch antennas placed on the left waist (Tx) and right side of the chest (Rx) for 2.4 GHz on-body propagation measurement in the chamber

CPW-fed UWB antennas placed on the left waist and right side of the chest for frequency domain ultra wideband on-body channel measurement

- Experimental investigations of on-body propagation channels applying different antenna types.
- Statistical and deterministic modelling of radio channels in various environments.
- Different scenarios are explored extensively for body-centric networks in both spectral and transient domains.

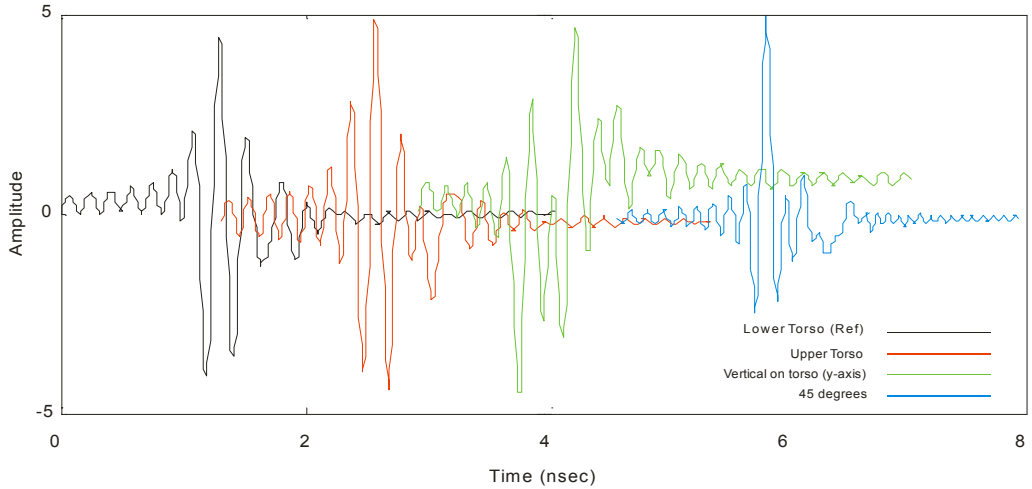
Spectral and Transient Analysis





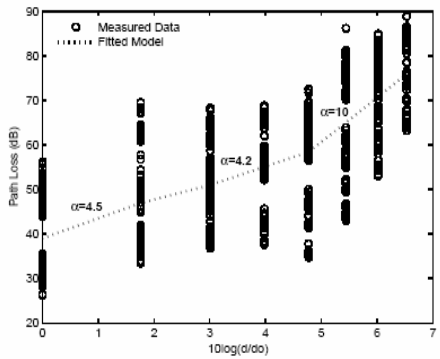
Inverse FFT

Fidelity factors of 80.1%, 37.15% and 77.06% for various on-body locations with reference pulse (lower torsoe, side-by-side on the body).



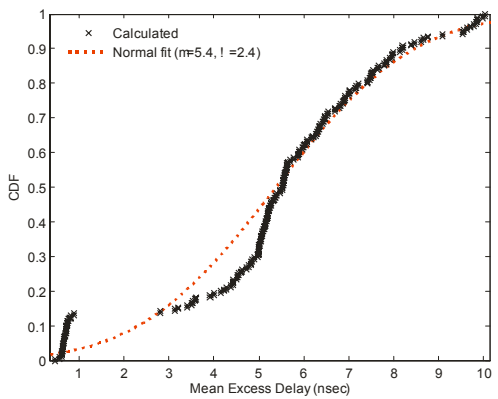
Statistical Analysis

Path Loss



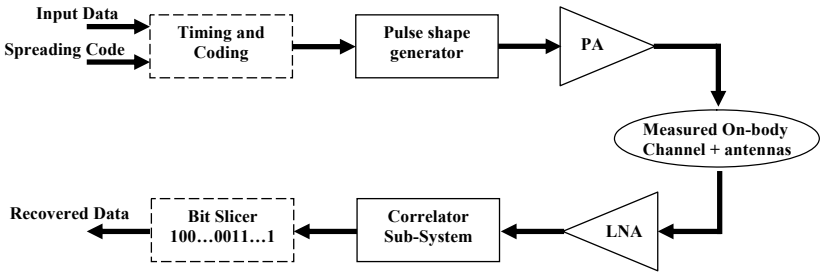
$$PL_{dB}(d) = \begin{cases} PL_{dB}(d_0) + (4.5) \cdot 10log\left(\frac{d}{d_0}\right) & for 10cm \le d < 20cm \\ PL_{dB}(d_{bp1}) + (4.2) \cdot 10log\left(\frac{d}{d_{bp1}}\right) & for 20cm \le d < 35cm \\ PL_{dB}(d_{bp2}) + (10) \cdot 10log\left(\frac{d}{d_{bp2}}\right) & for 35cm \le d < 50cm \end{cases}$$

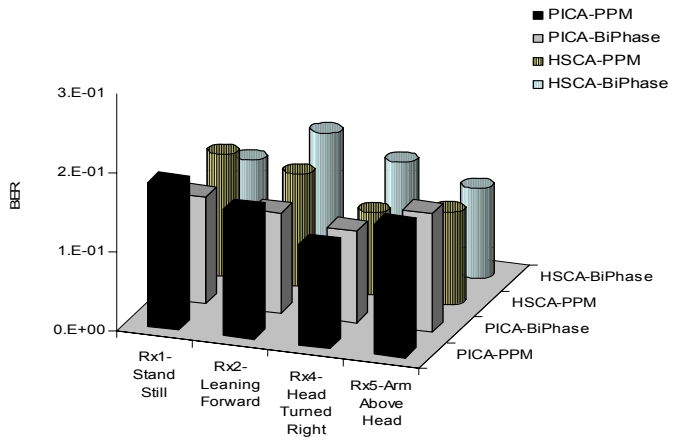
Mean Excess Delay



- Deriving large and small-scale radio channel models applying empirical data.
- Path loss for on-body channels can be represented using multi-slope models.
- Channel parameters such as shadowing factor, mean excess delay and RMS delay spread are extracted from measured data.

System-Level Modelling of Potential BCWN Radio Systems



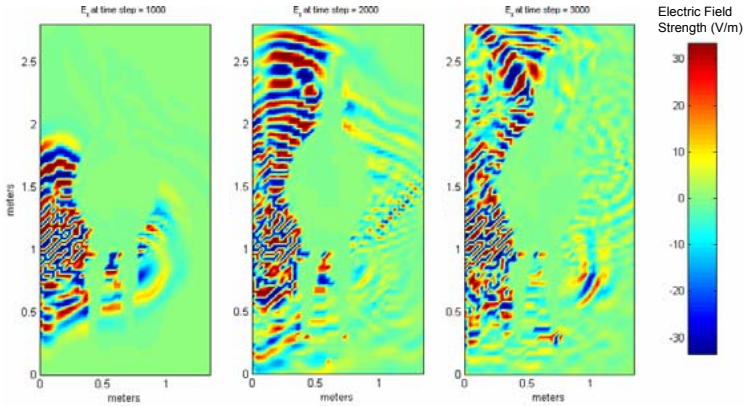


- Different modulation techniques including PPM, Bi-Phase and OFDM.
- Rake receivers applied to collect energy in multipath components direction in order to determine BER performance for body-centric networks.

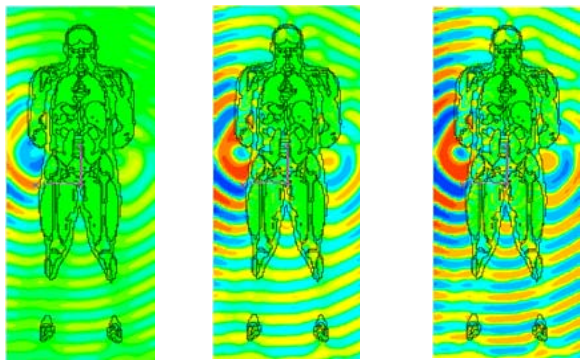
Summary

- On-body UWB radio channel characterisation in spectral and transient domains.
- Highlighting the effect of the human tissue electrical properties on antenna performance.
- Statistical models of on-body communication channels for different antennas and body postures, including large-scale and small-scale variations.
- System-level modelling of low-power radio systems applying different modulation techniques, data rates and derived on-body channel parameters.

Numerical Modelling of On-Body Communication Channels



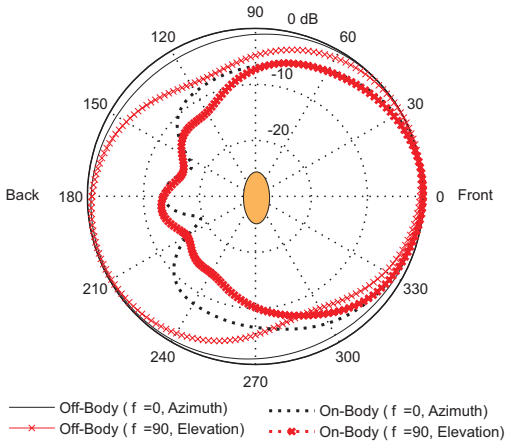
(a)



(b)

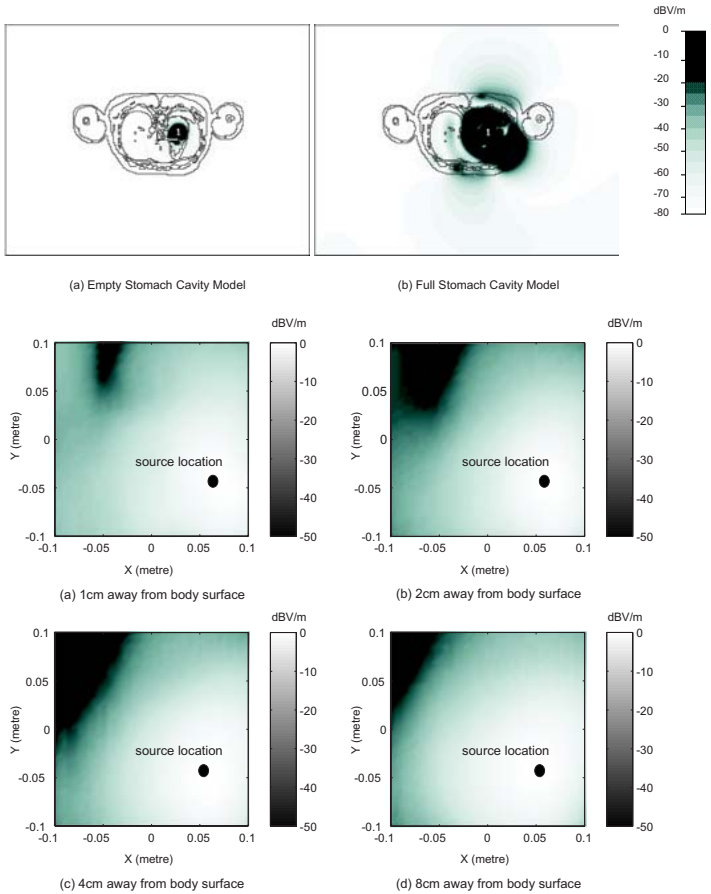
- Advanced numerical techniques (Conformal FDTD) applied to model body curvature and overcome inherited problems in conventional methods.
- In-house modelling results are compared to commercial simulations and measurements with good agreement.

Compact Medical Sensors



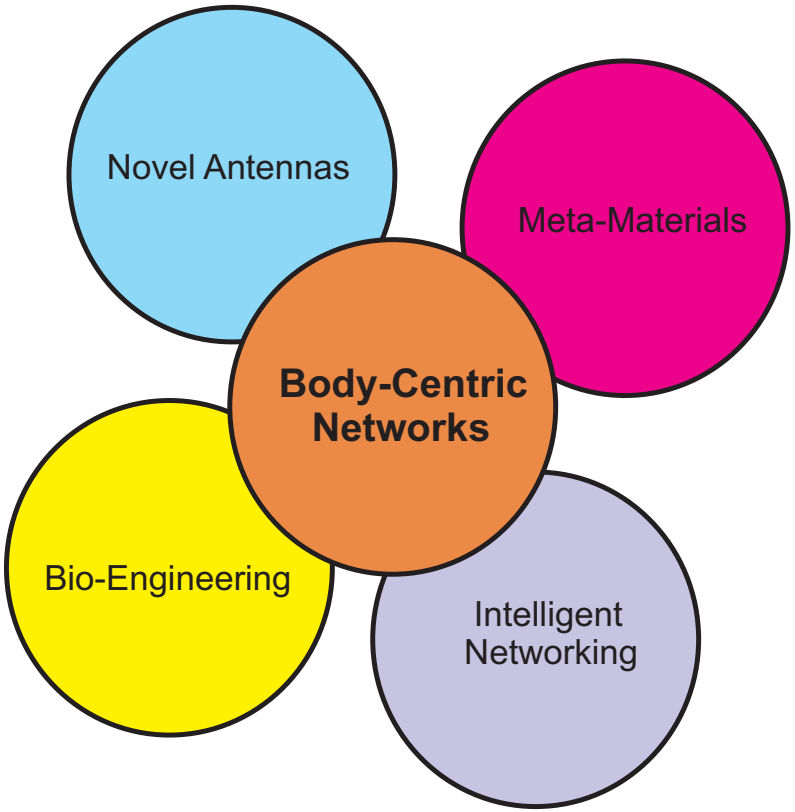
- Improvements in antenna performance to allow maximum achievable range for tele-care applications.
- Applying both theoretical and experimental skills to solve the given problem for industrial partner..

Wireless Telemetry from Implants



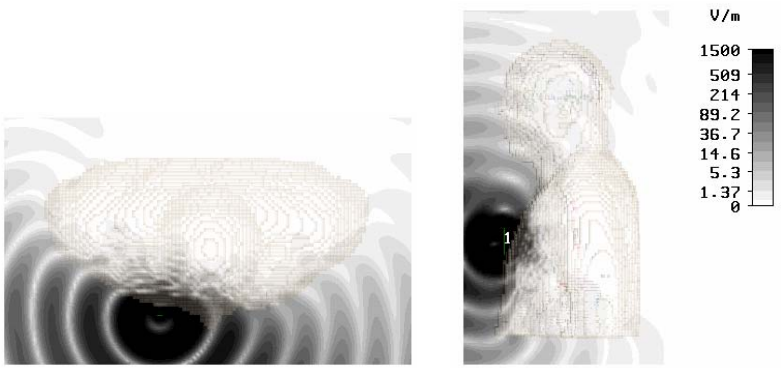
- Radio wave propagation form ingested sources to be applied mainly in wireless endoscopy applications.
- Work can be extended to provide a comprehensive body-centric healthcare networks.

Potential Research Activities



- Applying new techniques and acquired skills.
- Broaden application areas.
- Interdisciplinary research is a necessity.

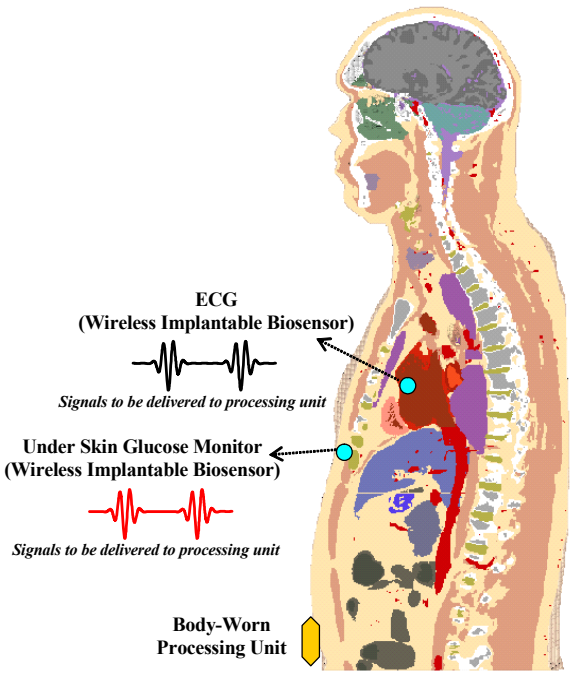
Novel Antennas for BCWN



(a) Top view (b) Side view

- Antennas that launch surface guided waves for on-body communications.
- Immunity from detuning and pattern deformation due to the body presence.
- High efficiency and constant performance regardless of environment and placement.

Bio-Sensors for Performance Monitoring



- Integration of current and potential bio-sensors with wireless technologies.
- Constant monitoring of patient's health in medical care applications and athlete's performance enhancement.
- Very compact sensors and ultra-low power consumptions.

Networking Issues of Body-Centric Networks

- Ad-Hoc Wireless Networks
  - Hierarchical use of scattered nodes on the body could prove to be more efficient specifically for in to on-body communications.
  - Better use of available resources.
- Intelligent Networks
  - Combined with radio systems to overcome link loss, performance degradation.
  - Minimise load off radio front-end systems.

Final Remarks

- Increasing interests in user-centric approaches to wireless personal communications is the main drive for continuous and active research in body-centric networks.
- In addition to academic interests, industrial applications and potential commercialisation will always provide the platform for further collaborations specially interdisciplinary research.

Thanks for your attention