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Wireless Biodevices and Systems

Off-body

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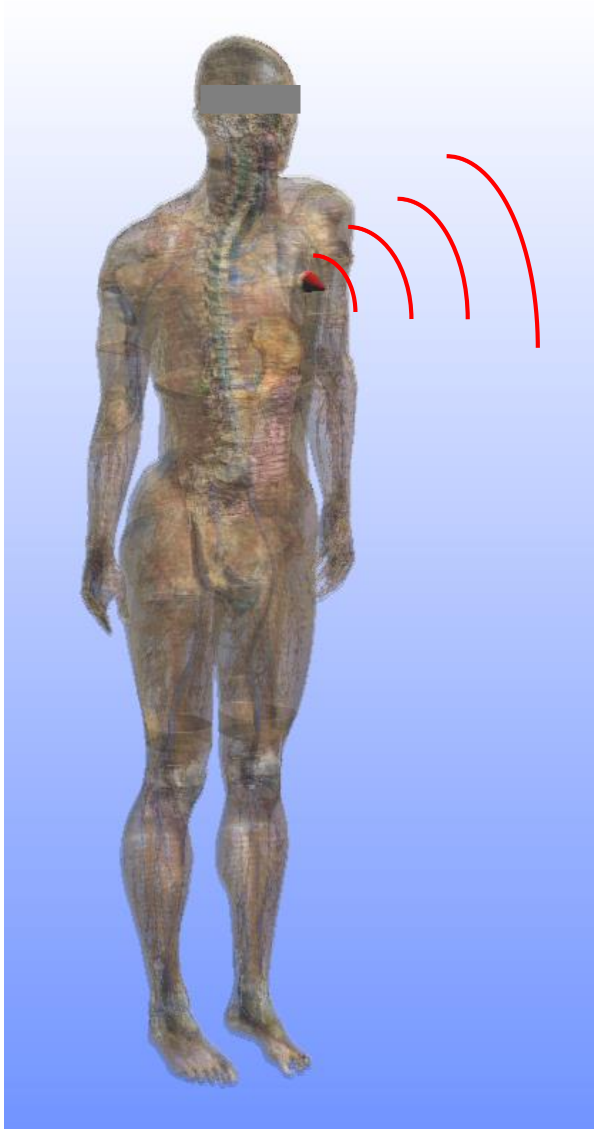
OUTLINE

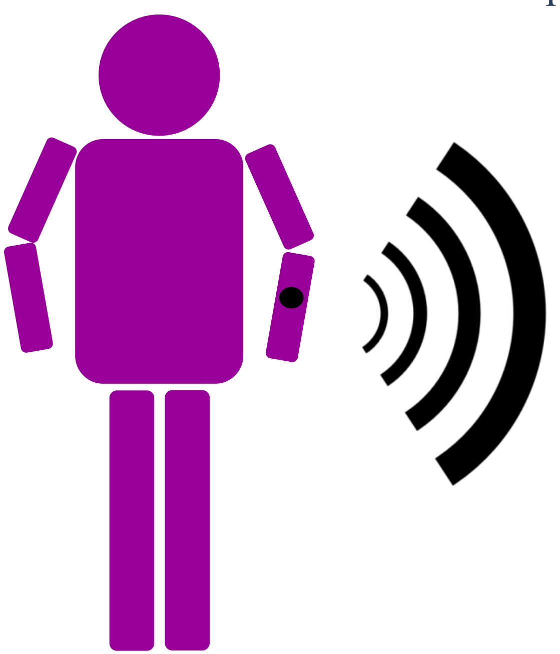
- Introduction
- Technologies
- Example: RFID
- Measurements
- Modelling



Introduction

Scenarios

Channel



Off-body

The channel is off of the body and in the surrounding space, only one antenna in the communications link is on the body. This is referred to as the off-body domain.

Introduction

Wireless radio connectivity is an obvious option for connecting body-worn devices. Same concepts than the ones for on-body devices apply.

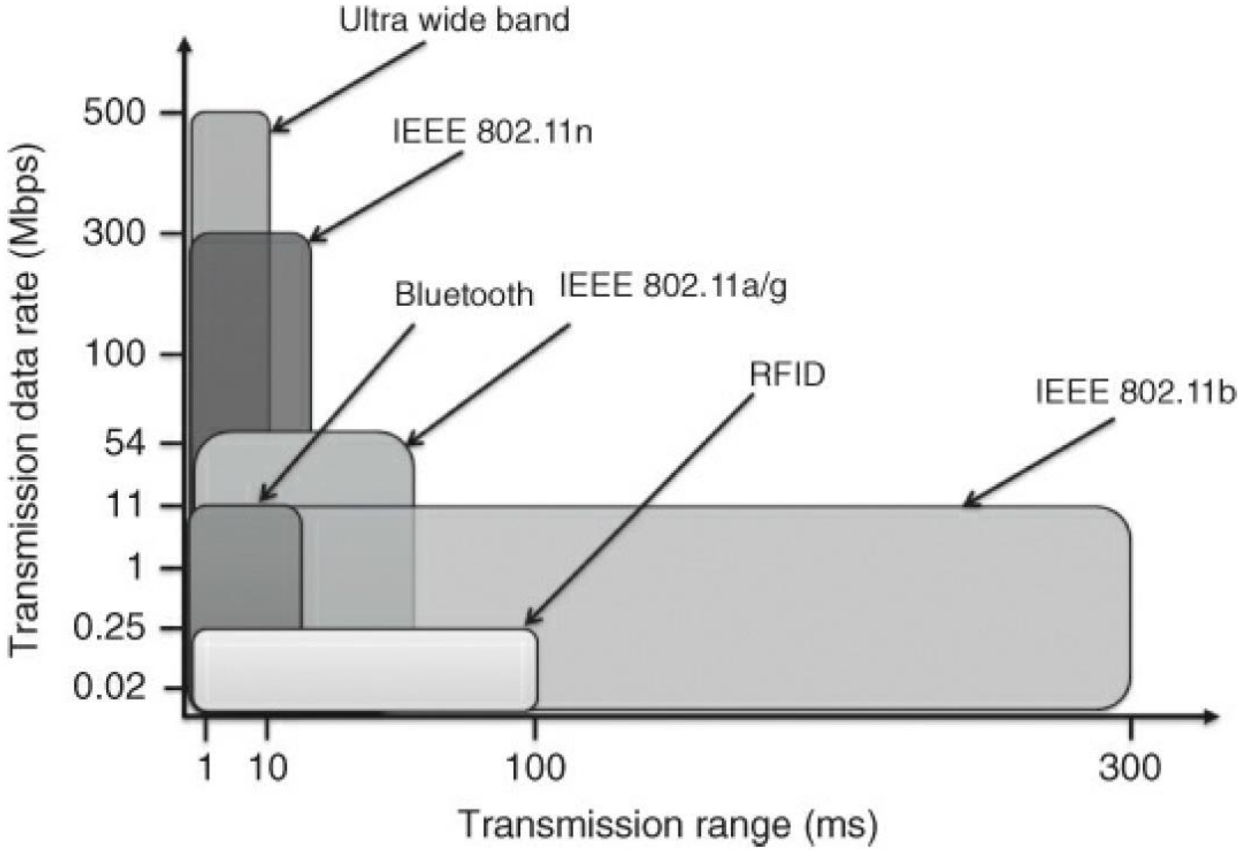
	Channel variations
Conventional communications	Interference between multiple rays scattered from the local environment: walls, buildings, furniture, etc.

+

	Channel variations
Off-body communications	Changes in the geometry of the body

Situation	Type of movement
Standing/sitting	Small
Normal activities	Significant
Playing sport	Extreme

Focusing on wireless technologies, the next figure presents the most prominent wireless technologies for medical applications depicting the order of magnitude of their transmission data rate versus their connectivity range.



Handbook of Biomedical Telemetry, K. Nikita

Technologies

In the communications field the terms LAN (Local Area Network) and WAN (Wide Area Network) are used to denote a network able to cover an area such as a house, a housing complex, a hospital, an institution, or a city.

The terms BAN (body area network) and PAN (personal area network) are used to denote a network of a smaller scale, analogous to humans, their dimensions, and their personal area, that is, a few meters or less.

The same network and the same technology could be characterized by different terms depending on its application and not its maximum coverage allowed by the technology, which may vary.

The term BAN usually refers to networks with limited coverage which cover only a person's body or refers to networks with applications having to do only with that specific person and not his or her surroundings.

The term PAN usually refers to wider networks, in contrast to a BAN, or applications which use it involve not only that specific person but also his or her surroundings, for example, other computers in proximity, environmental sensors, or devices of other individuals in proximity.

Technologies

No single technology is perfectly balanced to support all of the required characteristics.

Selecting the appropriate protocol depends heavily on the specific use case and the required trade-off between data rate, power consumption, range, and other factors, such as mobility, connectivity, stability, storage capabilities, routing protocols, data formats, and streaming data transfers.

Four primary parameters must guide the selection of the most appropriate wireless medical technology:

a. Range over which the device(s) needs to operate

b. Amount of data that needs to be transferred

c. Throughout speed needed to fulfill accurate estimations, the frequency of these transfers—how often data need to be sent

d. Power available—typically whether the devices are battery operated or main-supply powered

Technologies

Communication Types:

1) Narrowband communications represent current market trends in body-centric wireless communications. Narrowband is better suited to a greater number of healthcare applications due to its lower carrier frequencies that suffer less attenuation from the human body. Its smaller bandwidth (1 MHz or less) also means that multipath is unlikely to cause significant inter-symbol-interference. Such systems use a wide selection of frequency bands.

2) Ultra-wideband (UWB) communications is one of the key emerging technologies targeted particularly for short-range and low-power communication systems. One particularly suitable application of UWB in BAN is in consumer electronics as UWB offers higher throughput due to its larger bandwidth; each UWB channel has a bandwidth of 499 MHz.

Technologies

Table 1.1 A Summary of Available Technologies in Body-Centric Wireless Communications

Standard	*Frequencies (MHz)*	*Data Rate*	*Max. Power*	*Range (m)*	*Chapter Number*
UHF/VHF	~10	Very low	Very low	<= 0.5	4
Medical Implant Communications Service (MICS)	402-405	Low	Low	<= 2	8, 9
Wireless Medical Telemetry Services (WMTS)	420–429 440–449 (Japan) 608–614 1395–1400 1427–1429.5 (USA)	Low	Low	~10	8, 9
BodyLAN	900	32 kb/s	0 dBm	2–10	8
Bluetooth	2400–2480	1 Mb/s	0 dBm	0.1–10	3, 7, 8
ZigBee	2400 915 868	250 kb/s 40 kb/s 20 kb/s	Low	1–100	3
WLAN	2400, 5200	10-50 Mb/s	0 dBm	30–50	8
UWB	3100–10,600	1 Gb/s	–41 dBm/MHz	10	5

Antennas and Propagation for Body-centric Wireless Communications. P.S. Hall and Y. Hao.

Technologies

Standard	Bluetooth	UWB	Zigbee	Wi-Fi
IEEE spec..	802.15.1	802.15.3a	802.15.4	802.11a/b/g
Frequency band	2.4GHz	3.1-10.6 GHz	868/915 MHz; 2.4 GHz	2.4 GHz; 5 GHz
Max signal rate	1 Mb/s	110Mb/s	250kb/s	54Mb/s
Nominal range	10 m	10 m	10-100 m	100 m
Nominal TX power	0 - 10 dBm	-41.3 dBm/MHz	(-25) - 0 dBm	15 - 20 dBm
Number of RF channels	79	(1-15)	1/10;16	14(2.4GHz)
Channel bandwidth	1MHZ	500MHz-7.5GHz	0.3/0.6 MHz; 2 MHz	22MHz
Modulation type	GFSK	BPSK, QPSK	BPSK (+ ASK), O-QPSK	BPSK, QPSK COFDM, CCK, M-QAM
Spreading	FHSS	DS-UWB, MB-OFDM	DSSS	DSSS, CCK, OFDM
Coexistence mechanism	Adaptive freq. hopping	Adaptive freq. hopping	Dynamic freq. selection	Dynamic freq. selection transmit power control (802.11h)
Basic cell	Piconet	Piconet	Star	BSS
Extension of the basic cell	Scatternet	Peer-peer	Cluster tree-mesh	ESS
Max number of cell nodes	8	8	> 65000	2007
Data protection	16-bit CRC	32-bit CRC	16-bit CRC	32-bit CRC

A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi. Karunakar Pothuganti and Anusha Chitneni, Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 4, Number 6 (2014), pp. 655-662

RFID

- Introduction
- RFID parts
- RFID types
- RFID frequency bands
- RFID operation

ID

Identification

Personal

Smart card

7890193241009932430376

Bar code

RFID?

Bar code

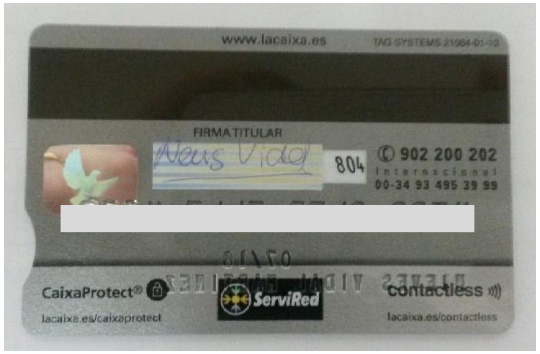
Optical representation of data.
Uses a sequence of predetermined pattern.
Upon reading the barcode, the sequence can be interpreted numerically.

7890193241009932430376

1-D or linear barcodes use bars and gaps to represent data.

2-D barcodes use geometrical patterns (dots, squares).

Magnetic Stripe Card (magstripe)



Stores data by altering magnetism of the iron-based magnetic particles on a plastic-like film band.

Its operation requires physical contact.

Usually they content 3 tracks.
Data: personal information, identification number, expiration date, etc.

Smart Card

It is defined as an electronic data storage system.
It embeds an integrated circuit.
It has the capability of processing data.

Types:

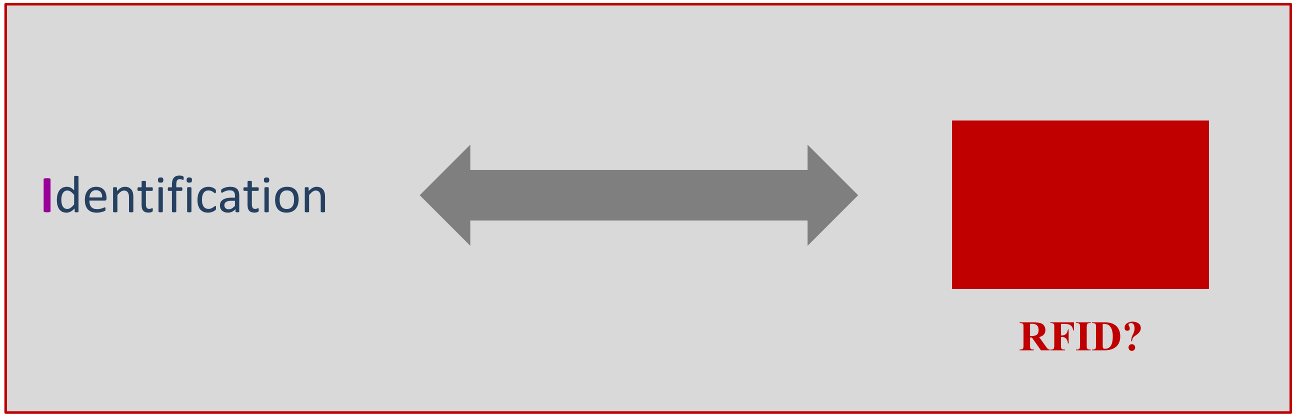
Contact

It is battery-less.
It is powered by the reader, which needs mechanic contact.
Widely used though mobile phone usage.

Contactless

The chip communicates with the reader using a built inductor.

RFID



http://youtu.be/gEQJxNDSKAE

Applications:
Security
Control and tracking
Stock management
…
http://www.rfidjournal.com/articles/view?4560/

http://www.simonsothcott.com/2011/11/what-is-rfid-10-examples-of-rfid.html

RFID

RFID

Radio **F**requency **I**dentification

Technology based on the wireless use of radio-frequency electromagnetic fields to transfer data.

Wireless transfer of information through radio waves

The purpose is automatically identify objects, animals and persons.

It is composed of a tag attached to objects and a reader system.

The tags contain electronically stored information.

Origin: World War II to identify aircrafts

RFID

RFID

The tag does not necessarily need to be within line of sight of the reader and may be embedded in the tracked object.

Uses wireless

Penetrates non-conductive obstacles

Conductive objects?

Mobile

Simultaneously reads different tags

Reusable

Rewritable

RFID in health care?

http://youtu.be/RzHlJeP0z1Q

RFID

Identification + Additional functionalities

RFID-Enabled sensors

Integration of sensors

Simple sensors

1 bit
Examples: cold chain,
bumps during transportation, opened packaging

Complex sensors

RFID

RFID parts

Reader

Reading Unit

Transponder/Tag

Trend: cheaper tags/increased complexity of the readers

TAG

What is it consist of?

Chip: stores information.
Reader hits the tag with Radio waves and activates the chip.
The chip sends its information back to the reader.

Antenna: the most important part, nothing works without the antenna.
Determines How far away can we send the data and depending on the frequency operating band
the amount of information. Different kind of antennas.

Encapsulation (various types): plastic, film, paper
They can be placed on products like clothes.

READER

What is the reader?/How tags are read?

It's a communication system consisting of:

1) Antenna adapted to the frequency of operation

2) Front-End transceiver (transmitter/receiver): RF analog signal processing amplification, filtering, etc.

3) Back-End: analog to digital conversion and digital signal processing

4) Computer: information processing and storage. The software (Middelaware) tells the reader to go out and look for the tag, or point information on database, etc.

Readers can be fixed, portable and programmable.

RFID

Types of RFIDs ⟷ **Types of tags**

Passive

- The tags don't require batteries.
- The tags have an indefinite operational life.
- The tags are smaller. They can fit into a practical adhesive label.

Active

- The tags require a power source.
- The tags have a limited lifetime (number of read operations the device must undergo).

RFID

RFID frequency bands

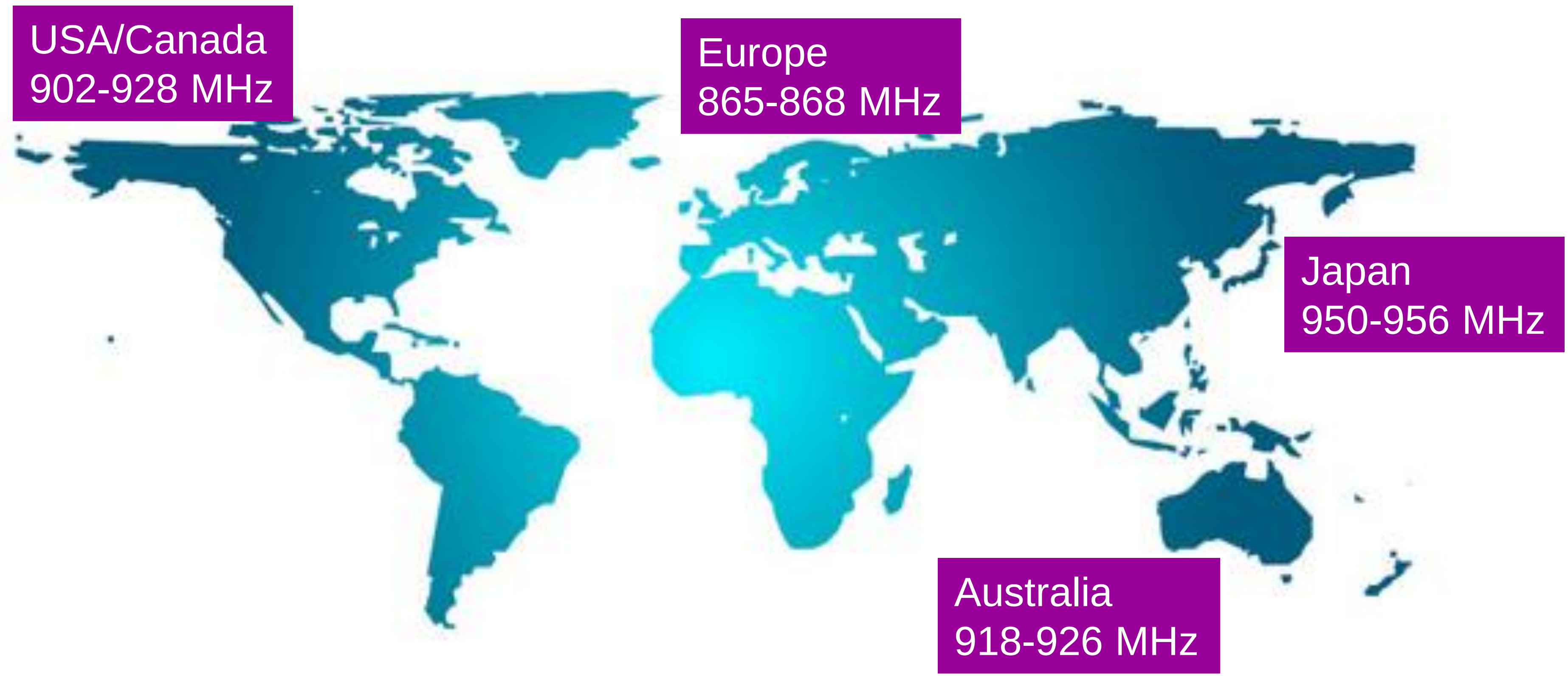
Bands

- LF – Low Frequency
- HF - High Frequency
- VHF – Very High Frequency
- UHF – Ultra High Frequency
- Microwave

Depending on the band

Capabilities

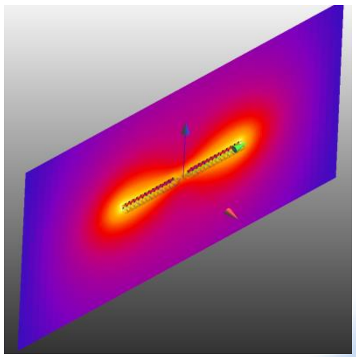
Band	RFID Frequency	ISO
LF	125 KHz and 134 KHz	1800-2
HF	13.56 MHz	1800-3
UHF	433 MHz	1800-7
	840 - 960 MHz	1800-6
Microwave	2.45 GHz	1800-4



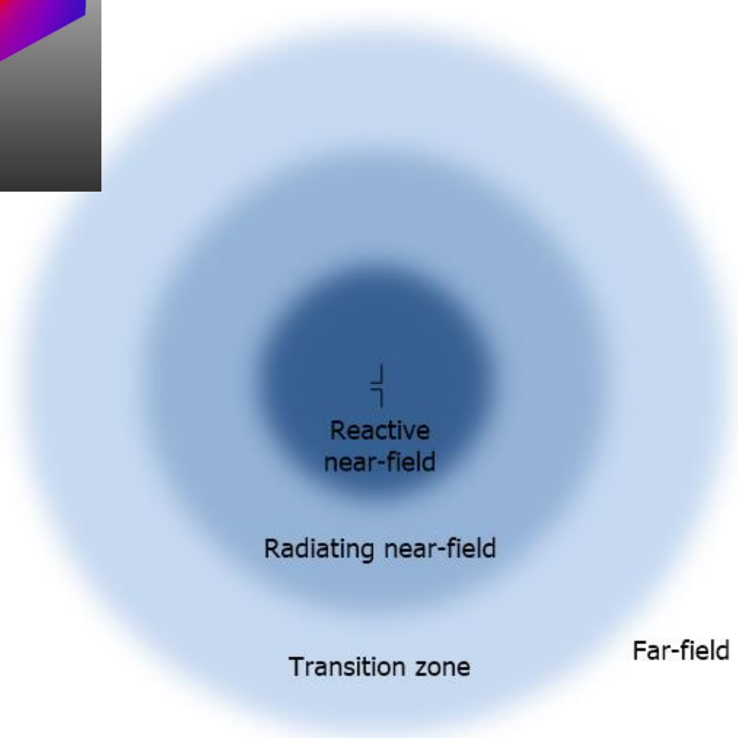
Band	RFID Frequency	ISO
UHF	840 - 960 MHz	1800-6

RFID operation

Two different RFID design approaches exist for transferring power from the reader to the tag: magnetic induction and electromagnetic wave capture.

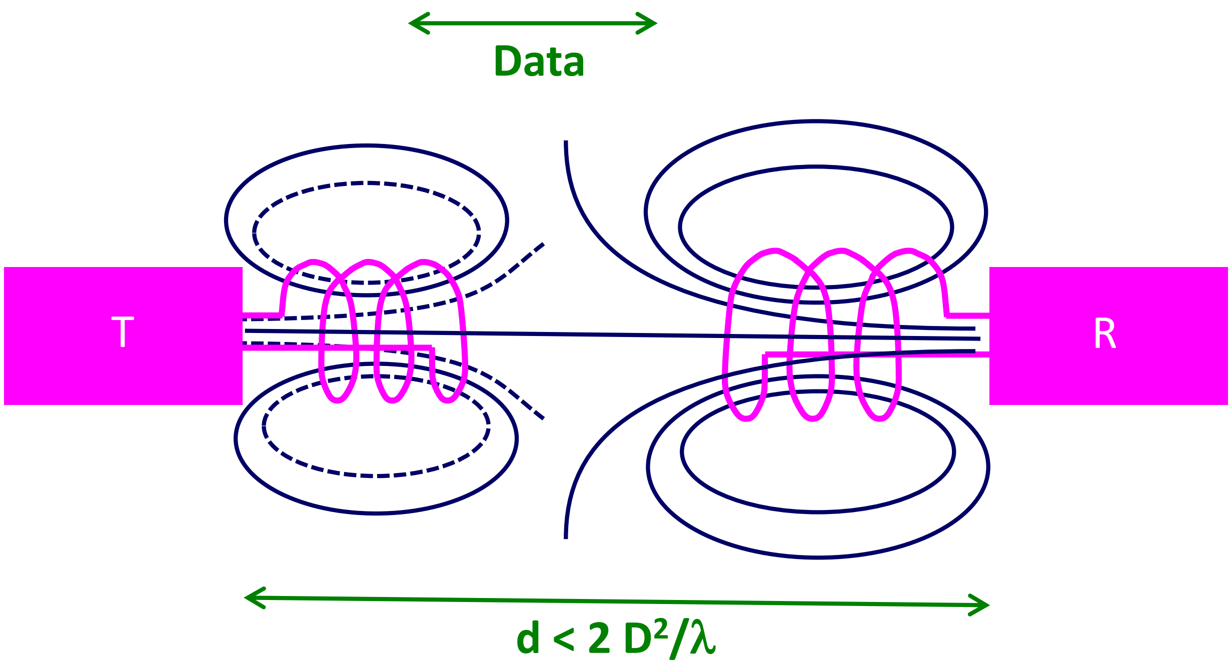


NEAR-FIELD **FAR-FIELD**



The boundary between the near-field and the far-field regions in electrically small antennas ranges from 1 to 2 times the wavelength, and the reactive near-field zone finishes at a distance of $\lambda/2\pi$.

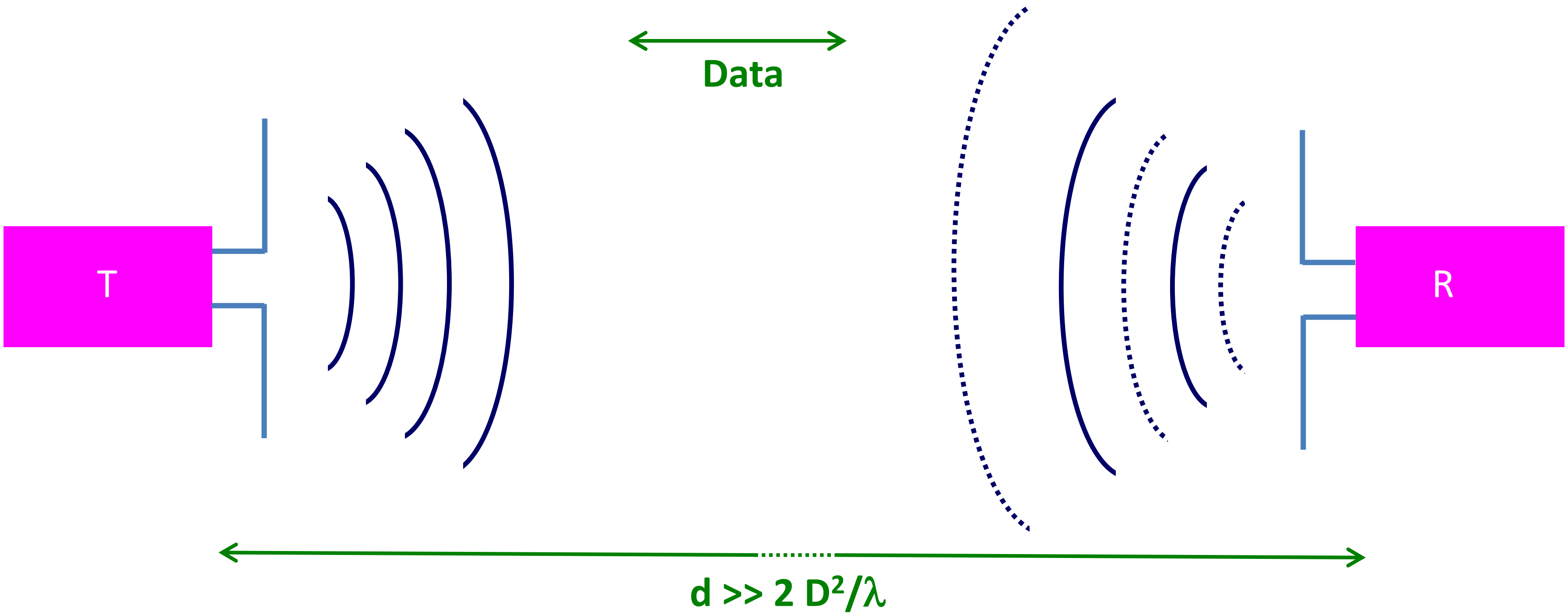
NEAR-FIELD



Uses magnetic coupling
Very short rang of distances, typically few tens of cm
Low bit rates
Easy to implement

RFID

FAR-FIELD



Uses RF coupling
Medium range of distances, typically up to tens of m
More complex implementation, mainly due to the antenna (design, environment, matching, etc.)

Passive RFID

Passive

They are the most commonly used.

A passive tag consists of three parts: an antenna, a chip attached to the antenna, and some form of encapsulation.

The tag reader is responsible for powering and communicating with a tag.

The tag antenna captures energy and biases the chip.
When activated the chip generates the information string wihich is transmitted back to the reader by the antenna.

The encapsulation maintains the tag's integrity and protects the antenna and chip from environmental conditions.

RFID

Active RFID

Active

An active tag consists of four parts: an antenna, a chip attached to the antenna, a battery or energy storage device, and some form of encapsulation.

The tag is itself responsible for powering and communicating with the reader.

The tag antenna captures energy from the incoming signal and awakes the chip. When awaked the chip generates the information string which is transmitted back to the reader by the antenna.

The encapsulation maintains the tag's integrity and protects the antenna and chip from environmental conditions.

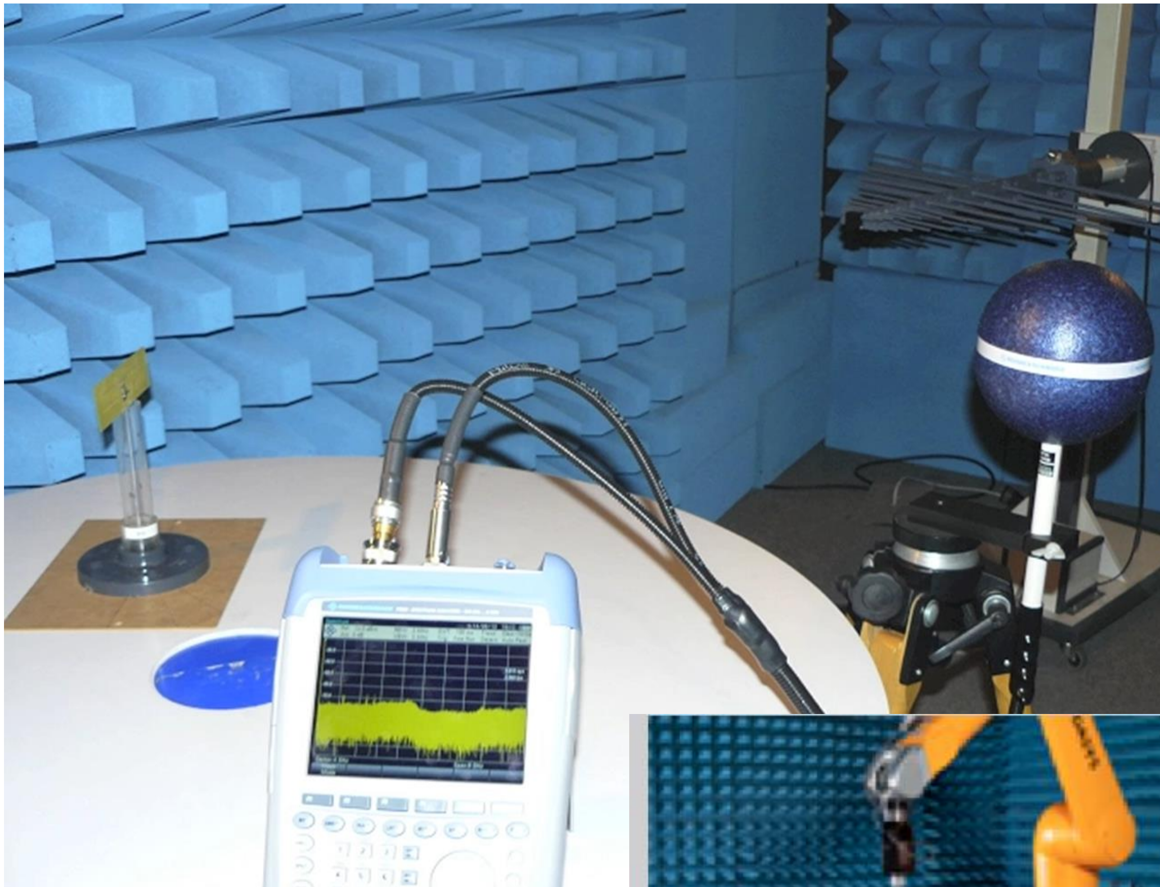
RFID

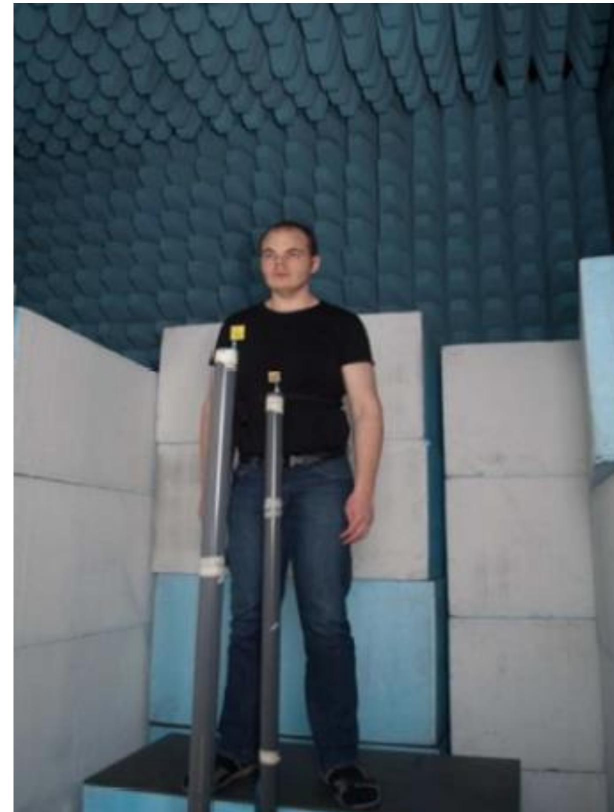
Tags

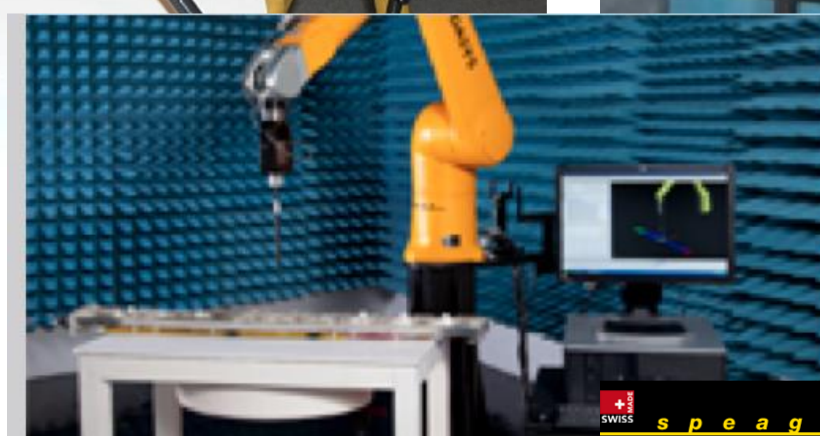
Passive	Active
Transmit a weaker signal	Transmit a stronger signal
Smaller read ranges (from cm to few m)	Longer read ranges (up to 100 m)
Operate until damage	Operate as a function of battery
Smaller size	Larger size
Operating frequencies: all	Operating frequencies: UHF, Microwave
Very cheap (cents/tag depending on quantity)	More expensve (few dolars/tag)

Measurements

SAR + Communication link







Channel Modeling for UWB WBAN On-Off Body Communication Link M. Särestöniemi, T. Tuovinen, M. Hämäläinen, K. Y. Yazdandoost, J. Iinatti. Centre for Wireless Communications, University of Oulu.

Modelling