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CREaTION

Application of Software Defined Radios to eHealth

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COMPETE
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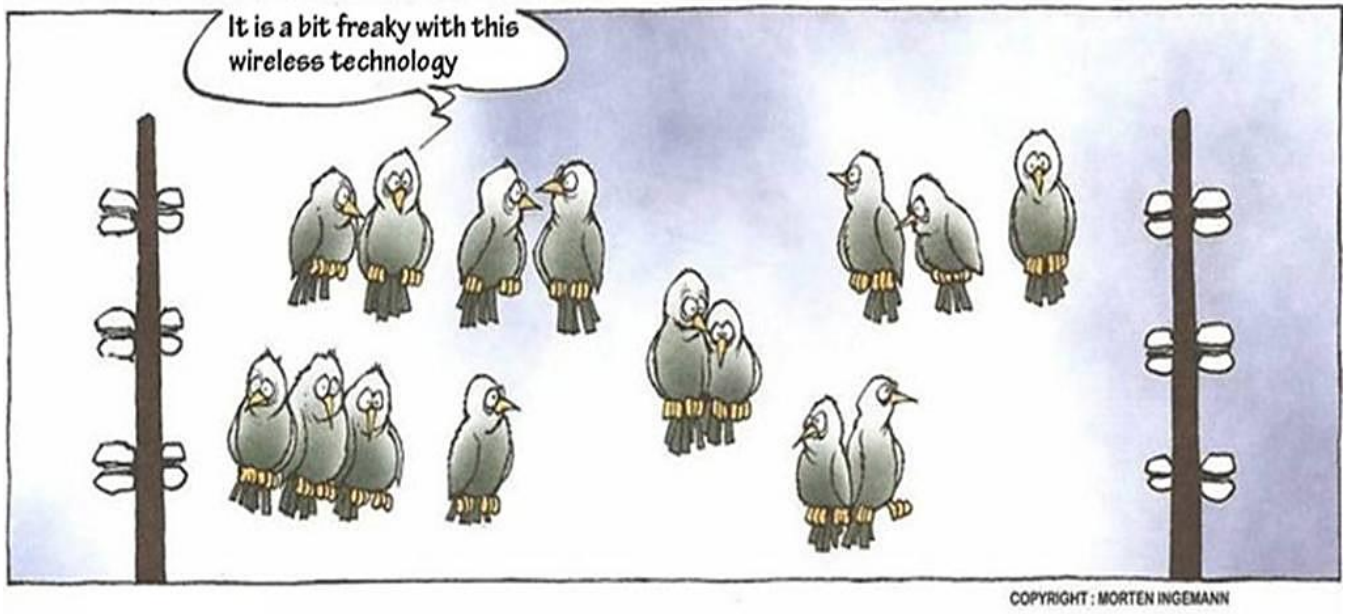
Motivation

Radio frequency technology as been strongly contributing to the improvement of different healthcare solutions resulting from novel ways of illness detection and treatment. Improved patient life quality is achieved and with this goal in mind, further development and investigation of RF health applications is encouraged.



Healthcare RF Application Main Areas

- Non-contact detection of vital signs (ex.: Heartbeat and Breath rate detection).
- Microwave Imaging (ex.: non invasive breast cancer detection).
- Medical Sensors (ex.: identification of cancer cells aggressiveness grade).
- Wireless for implants and body-centric communications (ex.: BANs).
- Medical treatments (ex.: Cancer Treatments).
- Cosmetic Surgery (ex.: skin treatment in dermatology and plastic surgery applications).
- Tightening Loose Joints (ex.: when applied to loose connective tissue surrounding joints, RF energy tightens the collagen and creates a tighter joint).
- Sleep Apnea (ex.: RF energy used to reduce the volume of the tongue)
- …

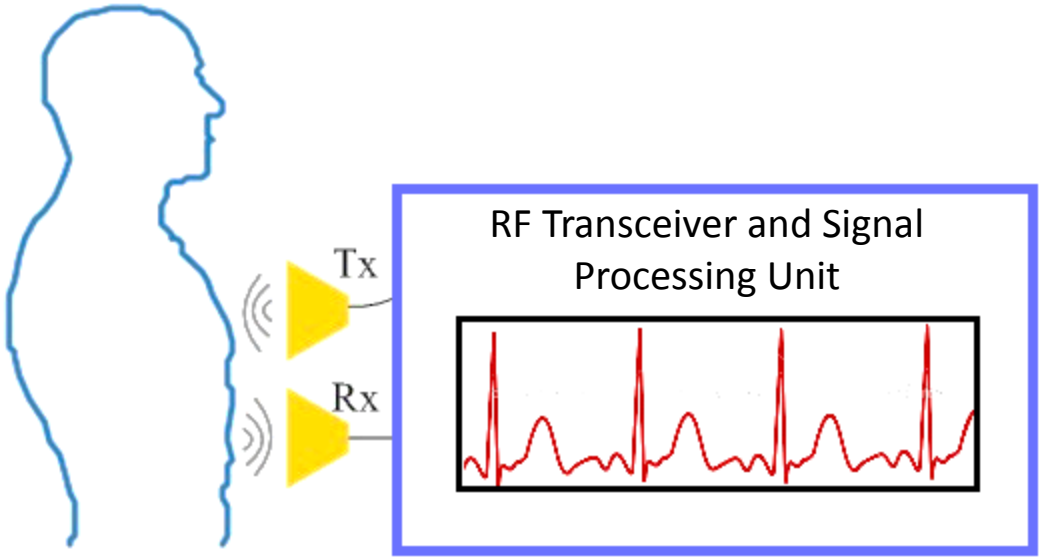
RF on Healthcare Applications

Contactless Heartbeat Rate Detection

- Doppler theory: A target with a periodic movement reflects the signal with its phase modulated by the time-varying position of the target.

- Acquisition of vital signals without the need for contact.

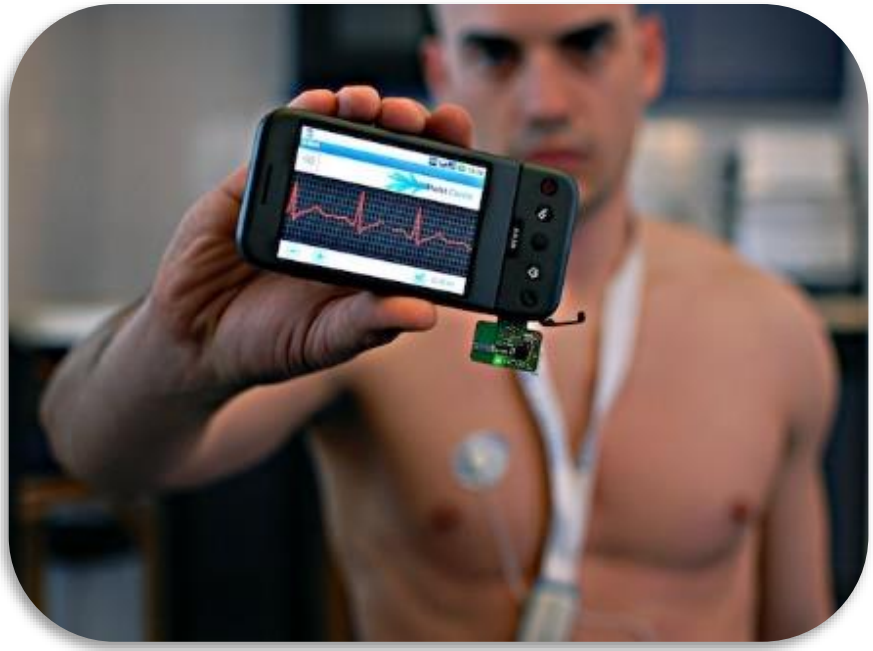
- Patients with particular conditions:
  - Burn victims;
  - Infants at risk of sudden infant syndrome;
  - …



RF on Healthcare Applications

Wireless Body-Area-Networks (BAN)

- Promotes comfort for patients with a worn or implanted BAN.
- Monitoring of specific signals can be done while patient lives his daily life.
- Enables self or on-line medical monitoring (if web-connected).
- Provides physical condition tracking for athletes.

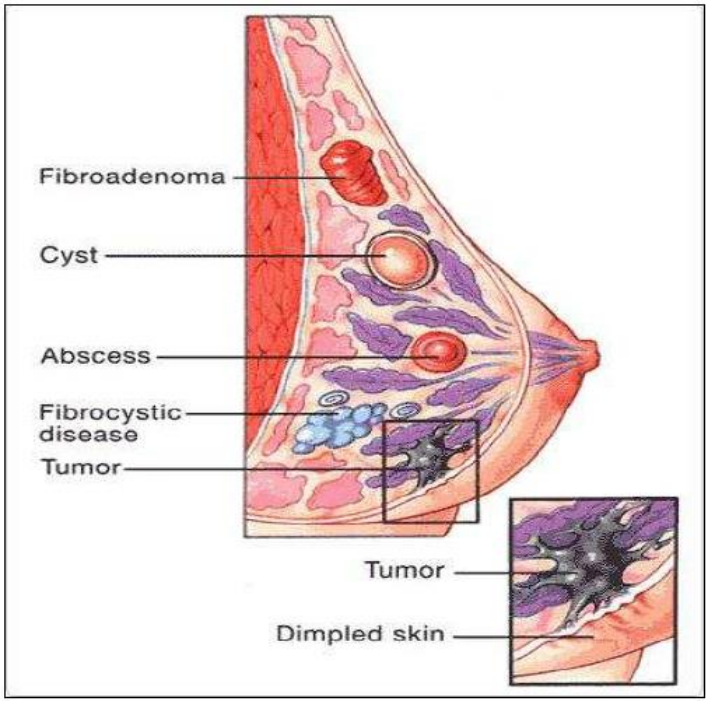


http://www.vivasemfio.com/blog/wireless-body-area-network/

RF on Healthcare Applications

Ultra-Wideband (UWB) radars for breast cancer detection

- Microwaves reflect differently for tumors and healthy tissues (order of magnitude >5).
- Detection is possible at early and more prom-to-curable stage.
- Patient-comfortable.
- Small cost.
- Prone to be used on community healthcare centers.
- High potential to replace X-Ray.

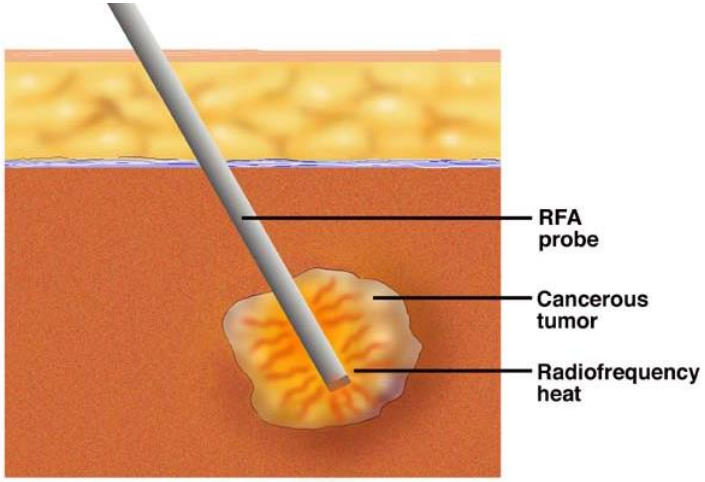


http://www.medindia.net/patients/patientinfo/breast-cancer-anatomy.htm

RF on Healthcare Applications

Radio Frequency Ablation for Cancer Treatment

- Radio Frequency Ablation (RFA) treatment has proven to be the most effective and safest approach to destroying inoperable early-stage cancer.
- Samsung Medical Center significant success rates with RFA treatments across 3600 cases of liver cancer patients for the ten years from 1999 to 2009:
  - 570 early-stage cancer patients were screened;
  - survival rate for one, three and five years is 95%, 70% and 58% respectively.

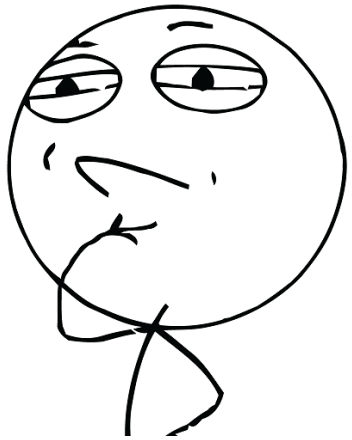


http://www.sirweb.org/patients/bone-cancer/

RF on Healthcare Applications

Indeed there are very important Healthcare areas to which Radio Frequency solutions can (and already are) provide a major contribution, resulting on better life quality for most patients.

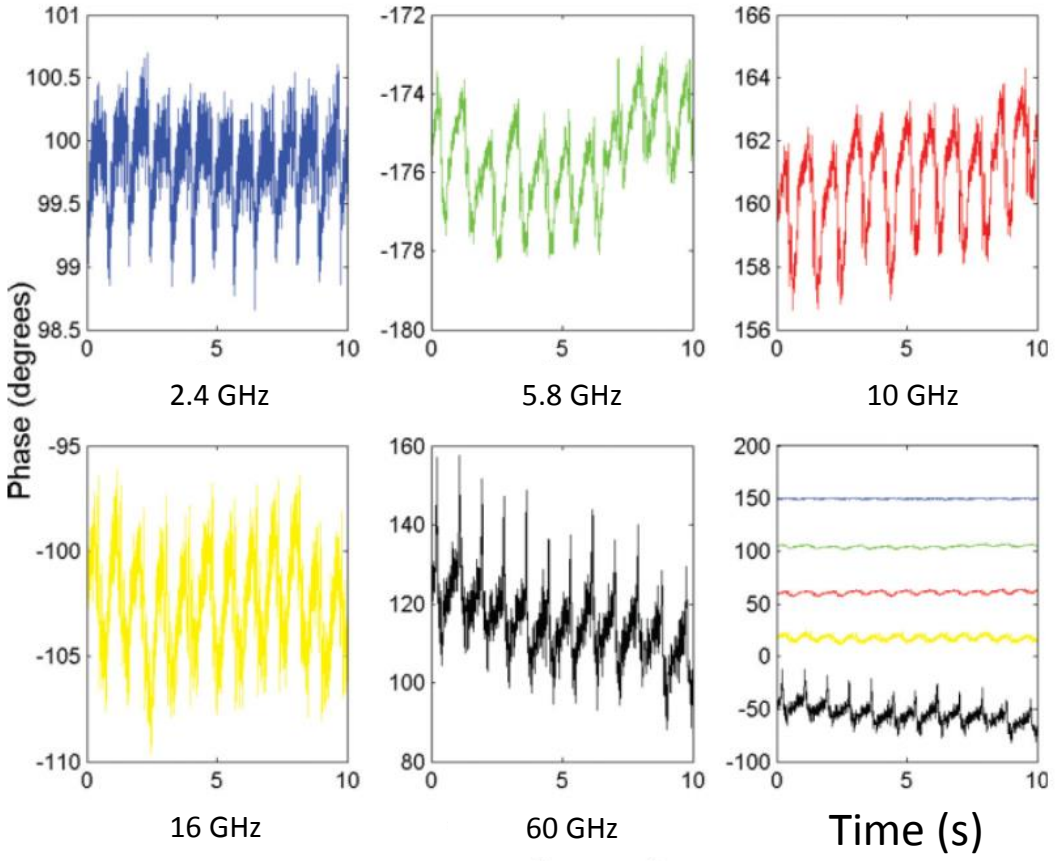
So what is the technical challenge??!



Technical Requirements

Contactless Heartbeat Rate Detection

- Operating frequencies range from 2.4 to 60 GHz.
- Output power levels from -27 dBm to -2dBm.

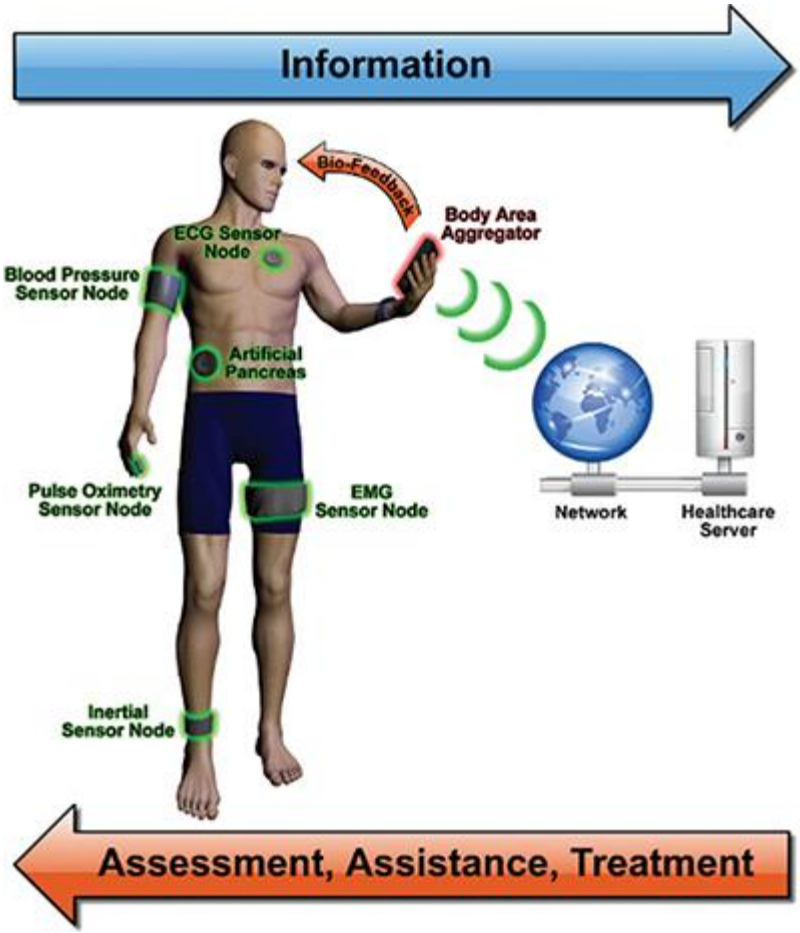


Dany Obeid, Sawsan Sadek, Gheorghe Zaharia and Ghais El Zein, "Multitunable Microwave System For Touchless Heartbeat Detection and Heart Rate Variability Extraction", Microwave and Optical Technology Letters, Vol. 52, No.1

Technical Requirements

Wireless Body-Area-Networks (WBANs)

- Standards for WBAN span from 2.36 to 2.4 GHz.
- Link quality changes with patient movement, pushing fixed power solutions to have:
  - Higher losses (when link quality is bad);
  - Energy wastes (when link quality is good).
- Adaptive power systems enable energy savings from 9 to 25%.
- RF Transceiver solutions are performing:
  - Receiver sensibility of -104 dBm with 4.8 mW consumption;
  - +3/+5 dBm output power, consuming 12.3 mW.

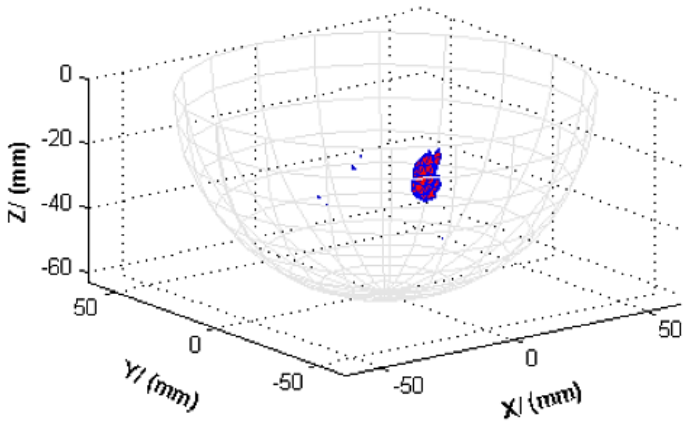


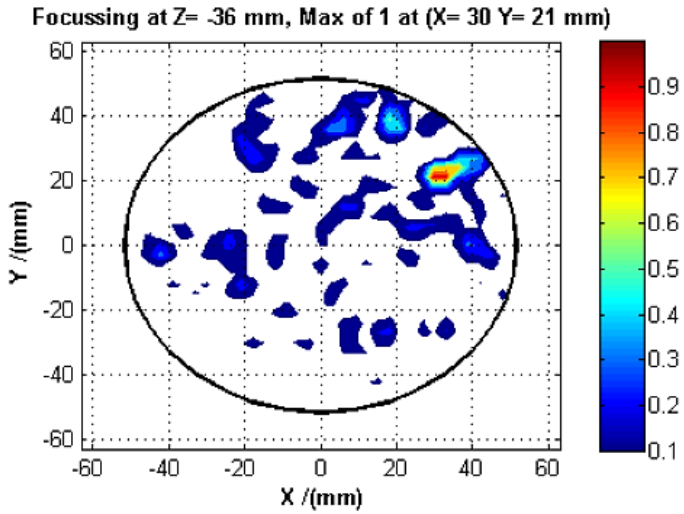
http://wirelesshealth.virginia.edu/

Technical Requirements

Ultra-Wideband (UWB) radars for breast cancer detection

- Proven prototypes working at 2.75 GHz.
- For imagery purposes, multiple Tx and Rx are commonly used.
- MIMO and SAR combined solutions provide a good trade-off between measurement speed and image quality.
- Output Impedance Adaptation to each patient is crucial.



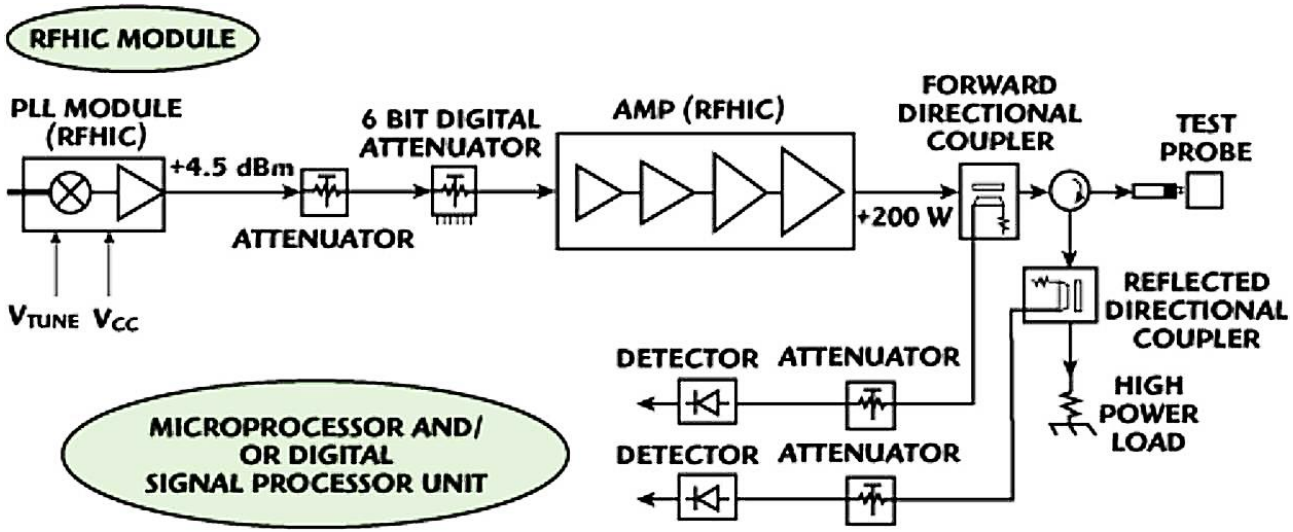


M. Klemm, I. J. Craddock, J. A. Leendertz, A. Preece D. R. Gibbins, M. Shere and R. Benjamin, "Clinical Trials of a UWB Imaging Radar for Breast Cancer", University of Bristol

Technical Requirements

Radio Frequency Ablation for Cancer Treatment

- RFHIC RF solutions for Tumor ablation:
  - 2.3 to 2.5 GHz;
  - output power of 100 W;
  - four stage amplifier design delivering 31 dB of gain;
  - 55% efficiency in class A/B and 90% in class E;
- During hyperthermia, cancer cells may change their RF permeability by more than two orders of magnitude.



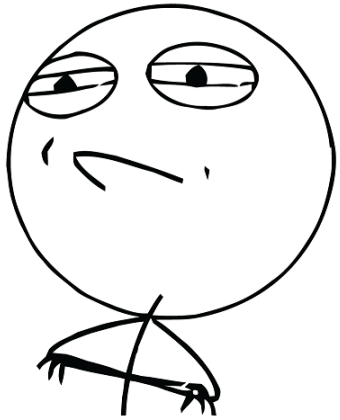
http://www.rfhic.com/eng/index.php

Challenge

Develop an as-adaptive-as-possible RF transceiver capable of being used on different applications without compromising functionality.

Some of the main characteristics to address are:

- ❑ Adjustable output power;
- ❑ Energy efficient power stage;
- ❑ Adjustable working frequency;
- ❑ Impedance adaptation;
- ❑ Antenna geometry;



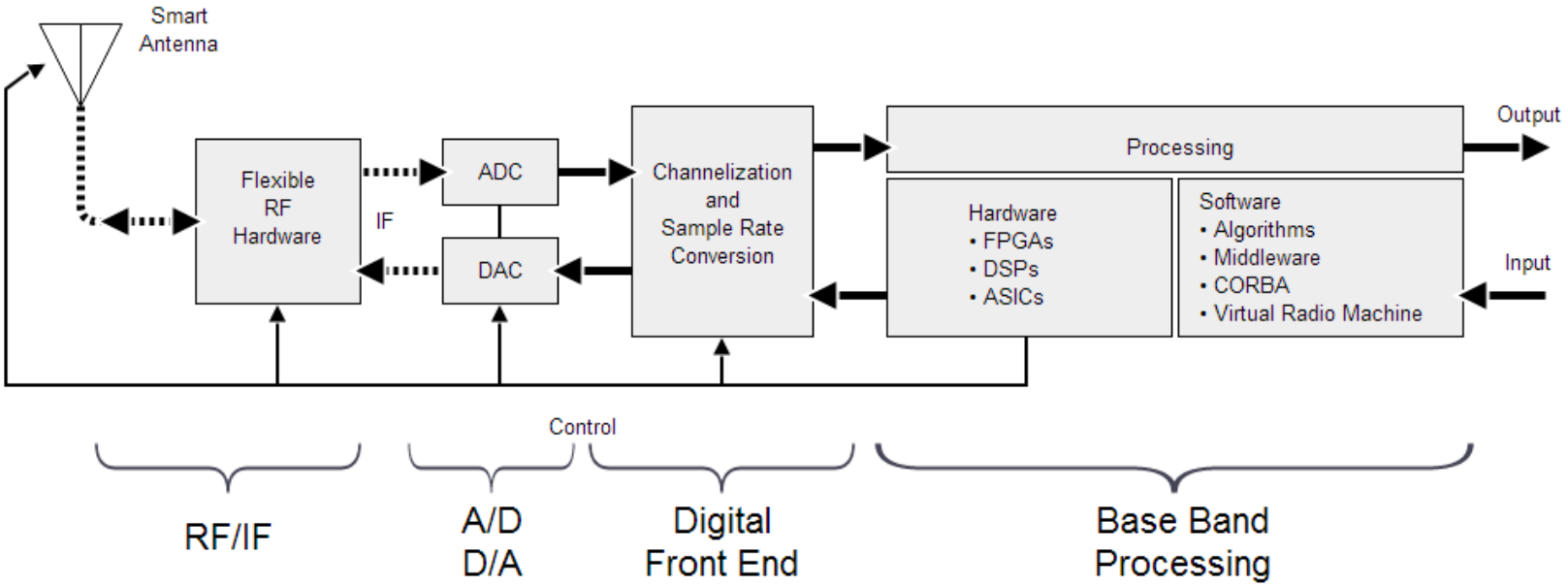
Software Defined Radio?

According to IEEE P1900.1 group, the definition is:

"Radio in which some or all physical layer functions are software defined."

Software Defined Radio (SDR) is a promising solution that places the software closer to the antenna and thus provides some important characteristics like:

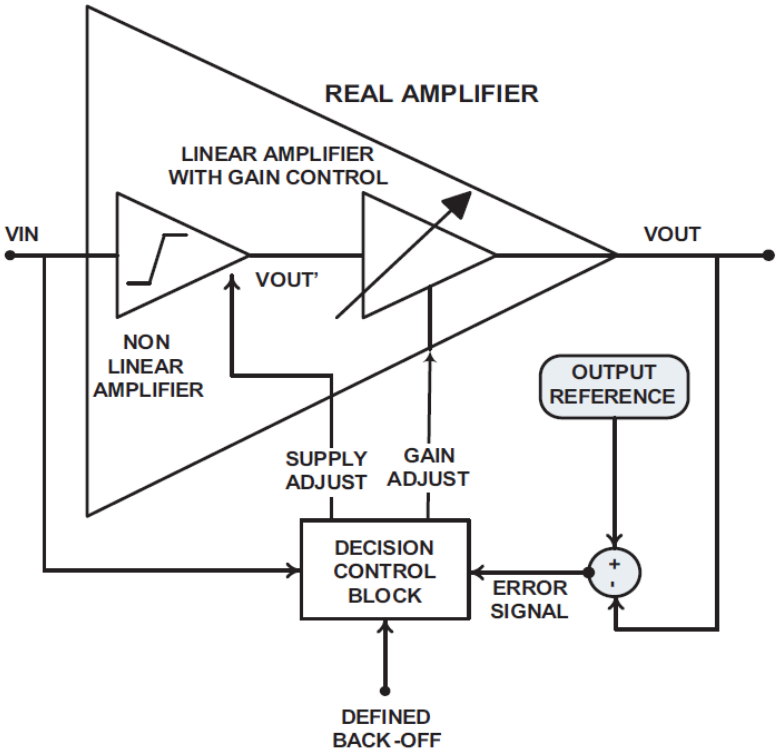
- ❑ Design Flexibility;
- ❑ Upgrade without the need of changing parts;
- ❑ Smaller costs when compared to "less-digital" solutions;
- ❑ …



http://en.wikipedia.org/wiki/File:SDR_et_WF.svg

Adaptive RF Power Amplifier Scheme

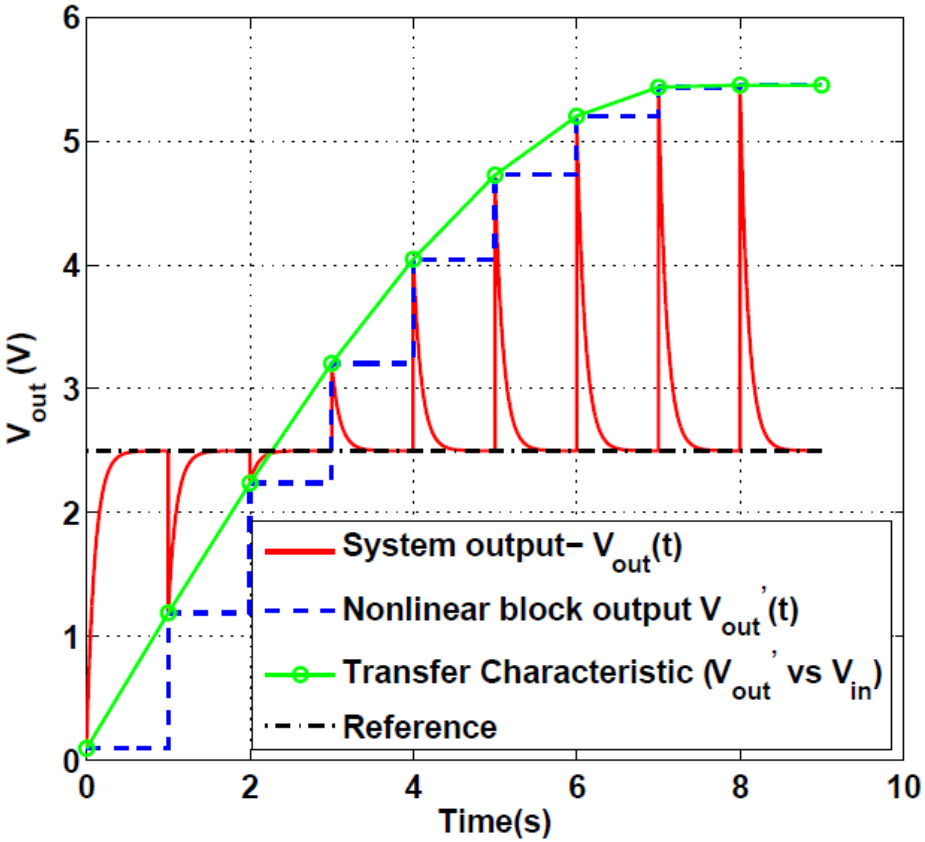
To compensate for variations of a PA functional characteristics due to components drift with time, temperature and voltage variations, load channel changes, and component tolerances.



- Non-linearity characterization;
- Automatic gain control (AGC);
- Non-linearity correction.

Pedro Mota thesis, "In-Circuit Test and Linearization of RF Power Amplifiers", January 2012

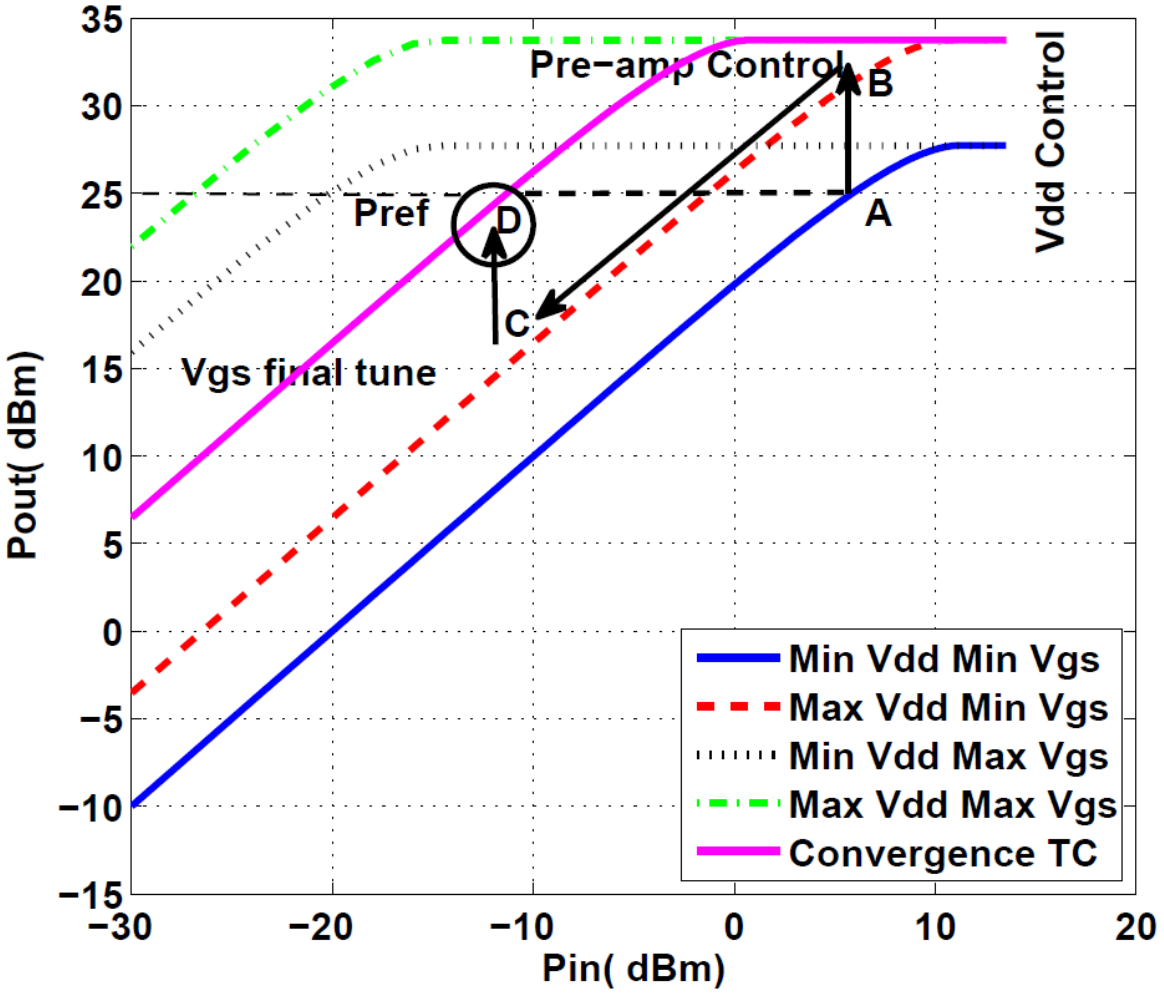
Behavioural Simulation of the AGC mode



Pedro Mota thesis, "In-Circuit Test and Linearization of RF Power Amplifiers", January 2012

Settling time depends on the difference between the non-linear amplifier output and the chosen reference, as well as on the time constant of the controller.

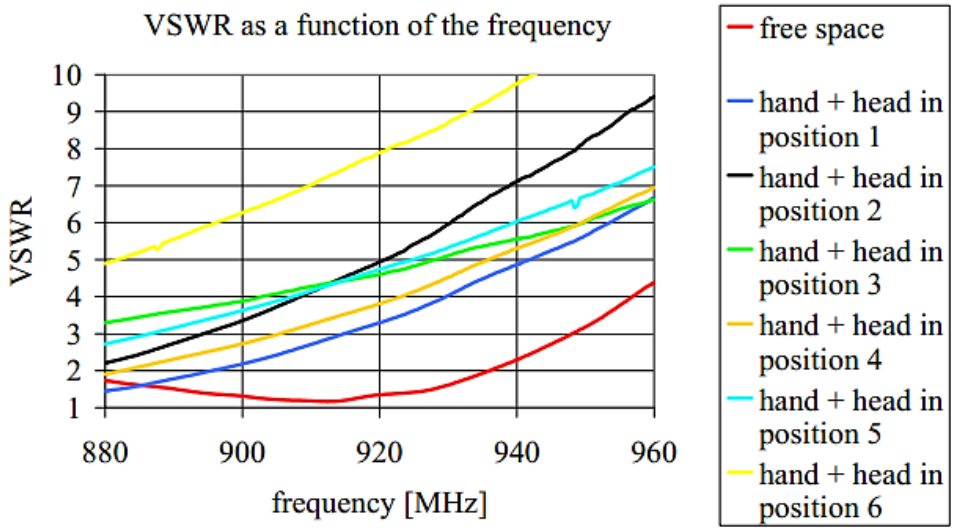
Non-Linearity Correction Process



Pedro Mota thesis, “In-Circuit Test and Linearization of RF Power Amplifiers”, January 2012

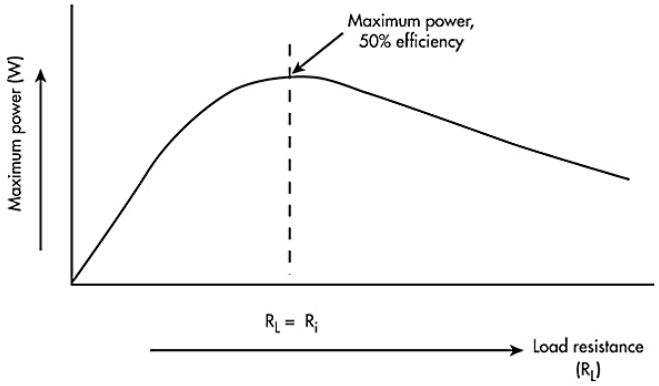
Antenna's Impedance

- Strongly influences PA functioning and therefore power efficiency.
- Human body tissues are seen by the antenna as different environments with different permeabilities.
- Impedance variation is mainly due to the complex part.
- In some situations a VSWR of 2:1 halves power efficiency.
- A really challenging goal is to maintain optimum operation of the transmitter with such range of impedance.

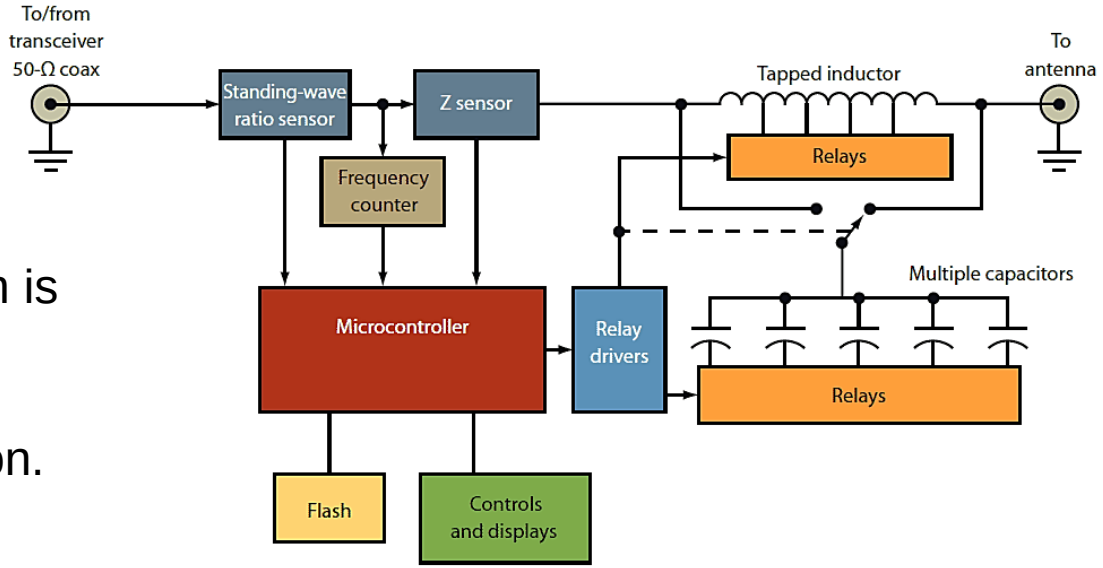


Ettore Lorenzo Firrao, Anne Johan Annema, Bram Nauta, "Antenna Behaviour in the Presence of Human Body", University of Twente, MESA+ Research Group

Impedance Matching



- For power transfer improvement, impedance matching between load and the RF amplifier is crucial!
- Load impedance varies with the environment on which the antenna is placed.



- Automatic adaptation is a “must have”.
- True power based impedance adaptation.

http://electronicdesign.com/communications/back-basics-impedance-matching-part-2#5

Aimed Solution

- For maximum flexibility, it is crucial to push the digital part of the system as close as possible to the antenna.
- Due to the unlikelihood of having a single antenna geometry capable of fitting the demands of different applications, it is acceptable to have this as the only replaceable part of the system, when needed.
- Apart from the antenna, it is expected that the analogue blocks will consist on the transmitting power amplifier and the conditioning schemes for the received signals.

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