Challenges for Low-Power Bio-Medical RFIC

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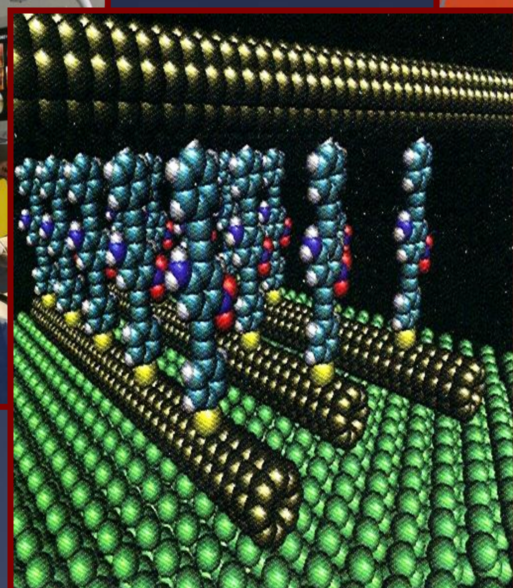
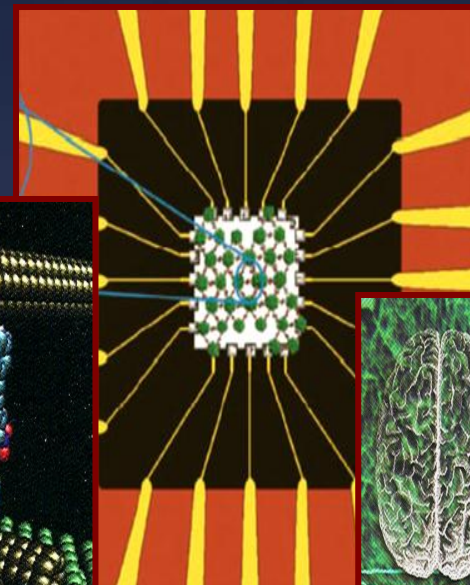
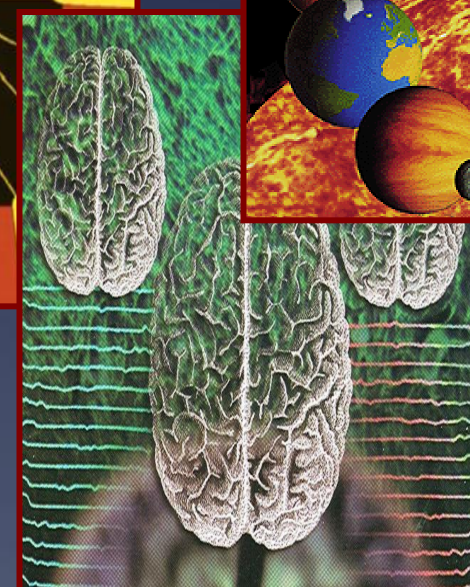
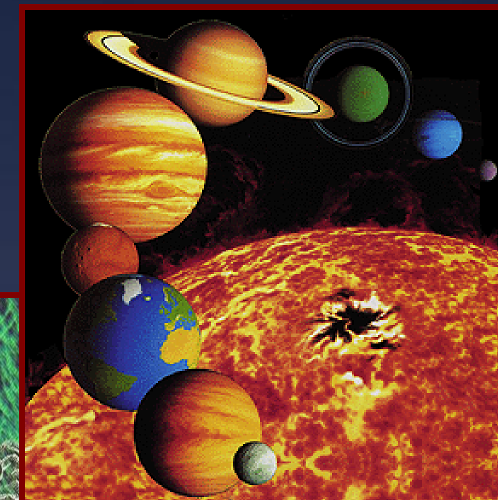
ECTC 2011

Science & Technology Convergence









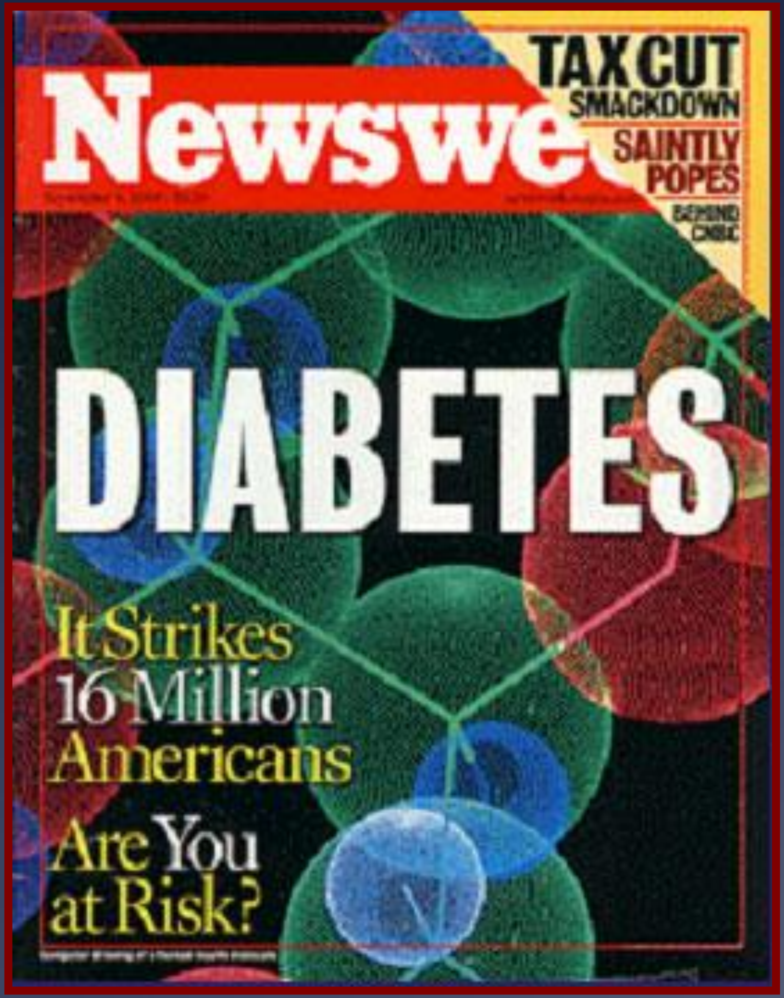
Biology and Medicine

Nanotechnology

Electronics

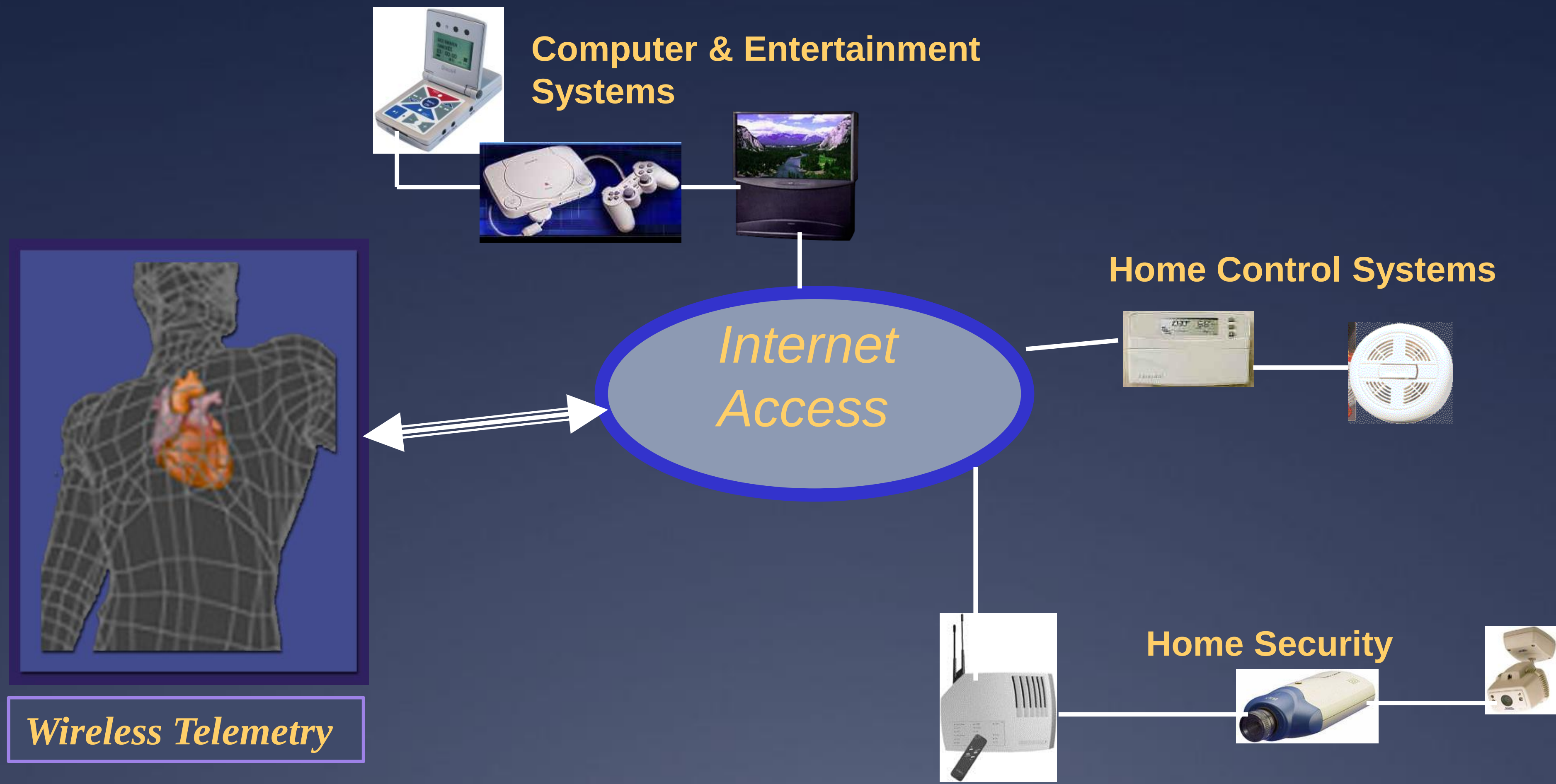
Neurobiology Chem, Phys, Geo, Space

Bio-Telemetry

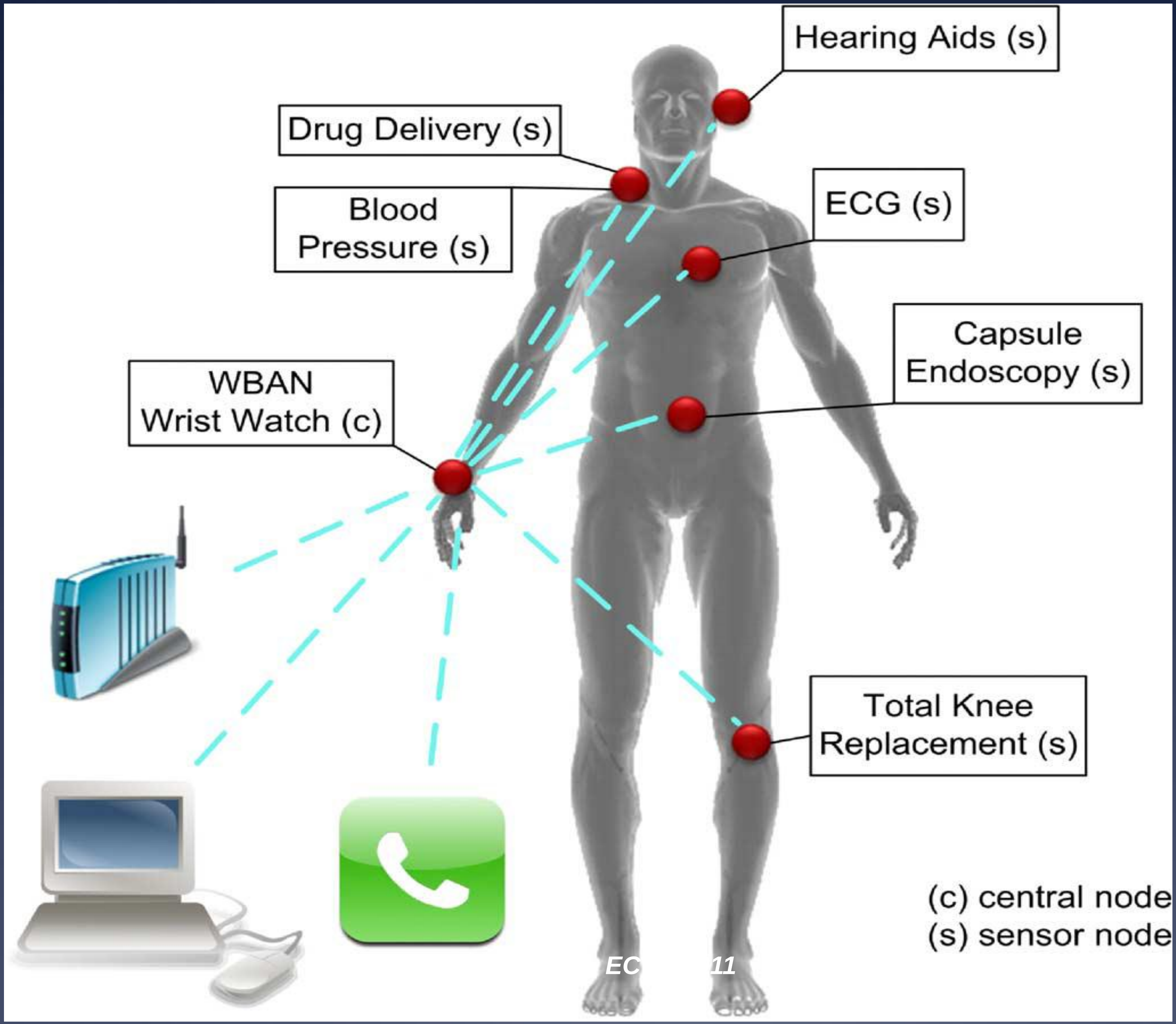


- Wireless Telemetry
  - Diabetes
  - Blood Pressure
  - Cholesterol
  - DNA Meter
- Location + Position + Orientation

Intelligent Wireless Systems



Typical Wireless Body Area Network



System Requirements

* Adaptive
* Low-Power / Self Powered
* Reconfigurable
* Miniature
* Harsh Environment

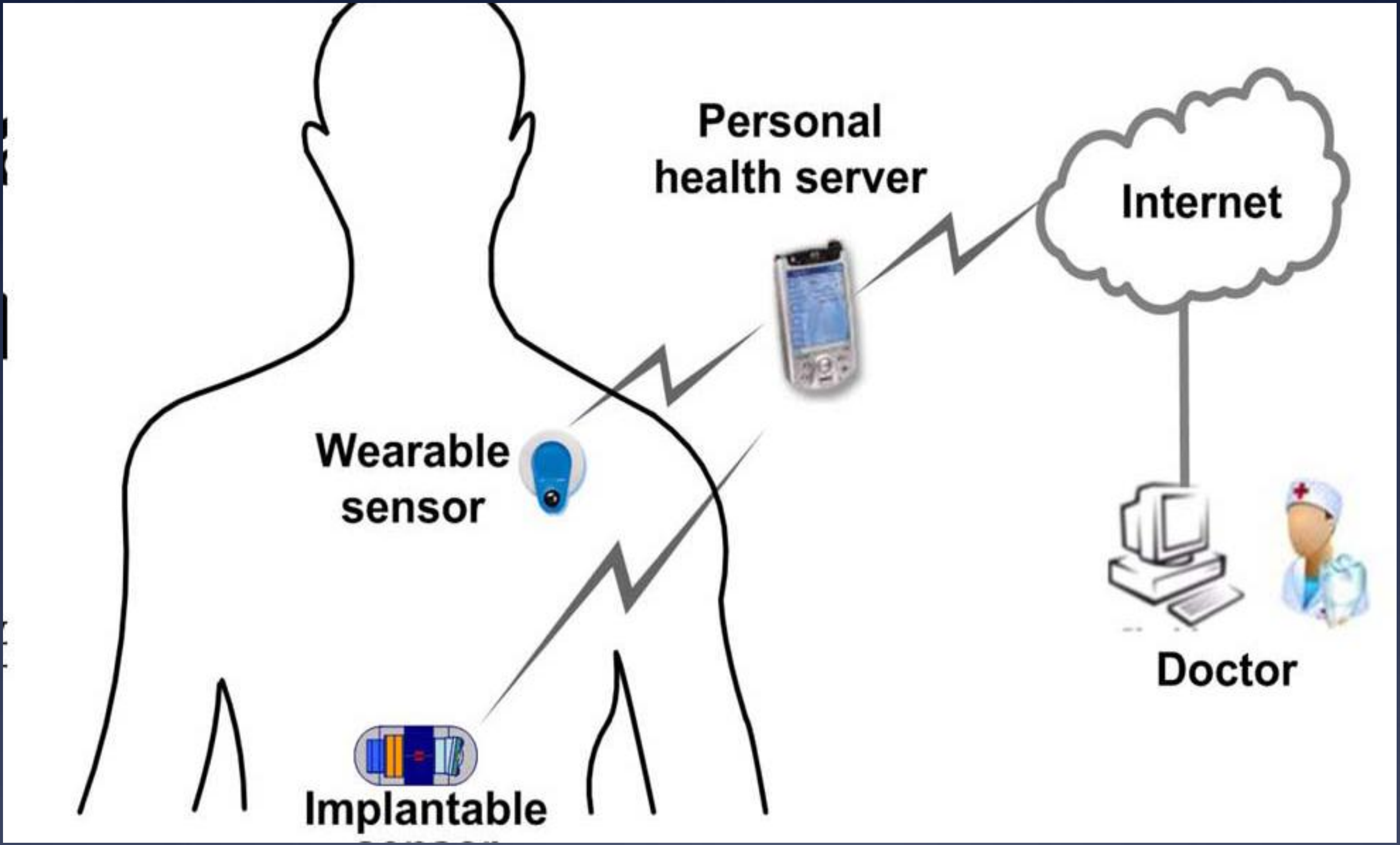
Challenges in:

* Medical Implanted Communication System (MICS)
* Implanted Sensor
* Adaptive SNR Digital Hearing Aid System

Implantable RF Transceiver

- Applications:
  - Treating Heart conditions (regulating heart rates via pacing and/or defibrillation)
  - Time Release Pain Control
  - Internal Imaging
  - Time Release Location Aware Drug Delivery

- System Constraints:
  - Power, Size, Complexity
  - System, Architecture
  - RF Circuit: Sensitivity, Selectivity, Linearity, Power
  - Packaging, Harsh Envirnment

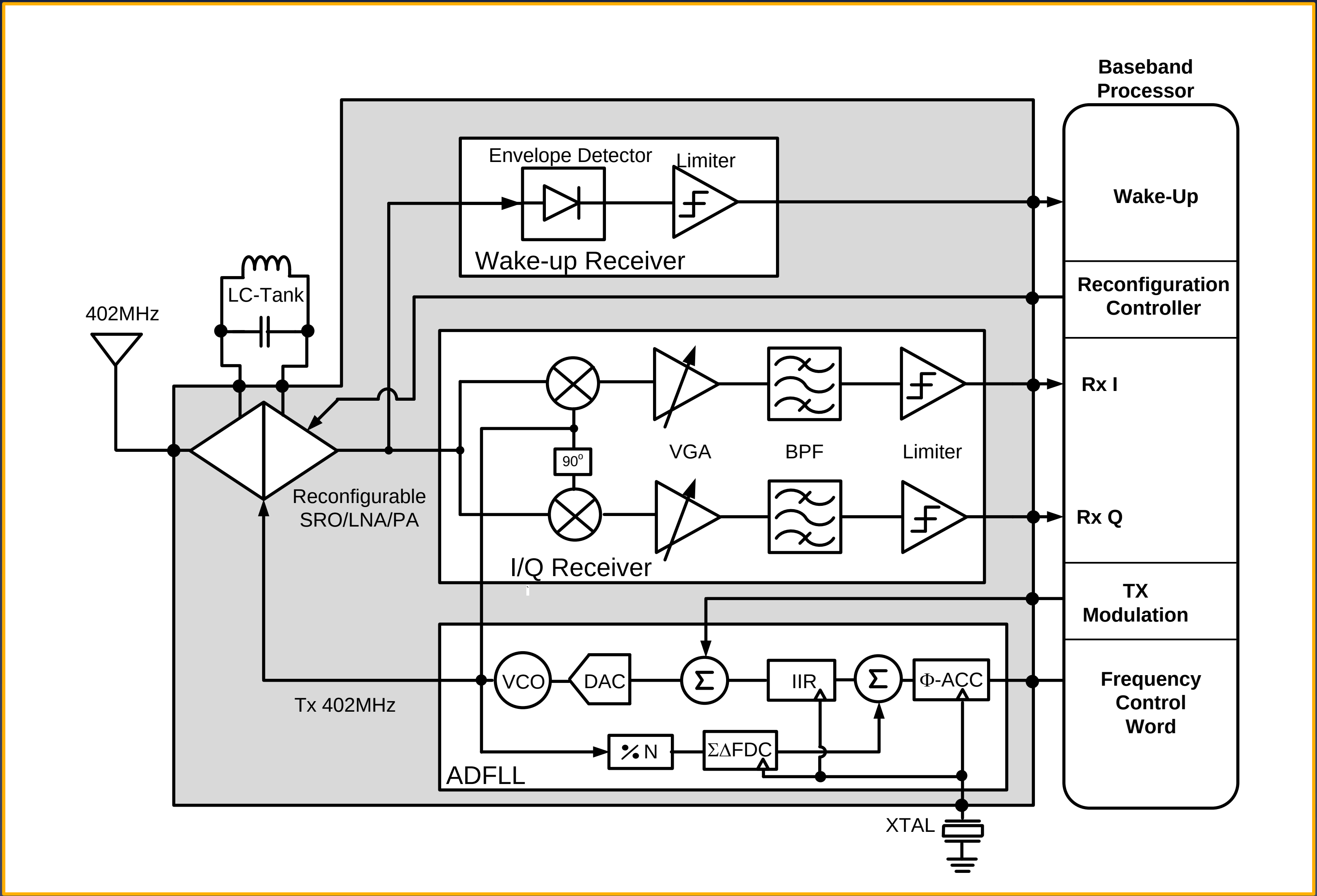

Personal
health server
Internet
Wearable
sensor
Doctor
Implantable

MICS Specifications [1]

* 402-405 MHz operating band
* 10 channels, 300 KHz each
* -16 dBm (25µW) maximum Tx Antenna power
* Data-rate, modulation schemes, and BER not specified
* Wakeup Rx: 98%, Rx (1%), Tx (1%)

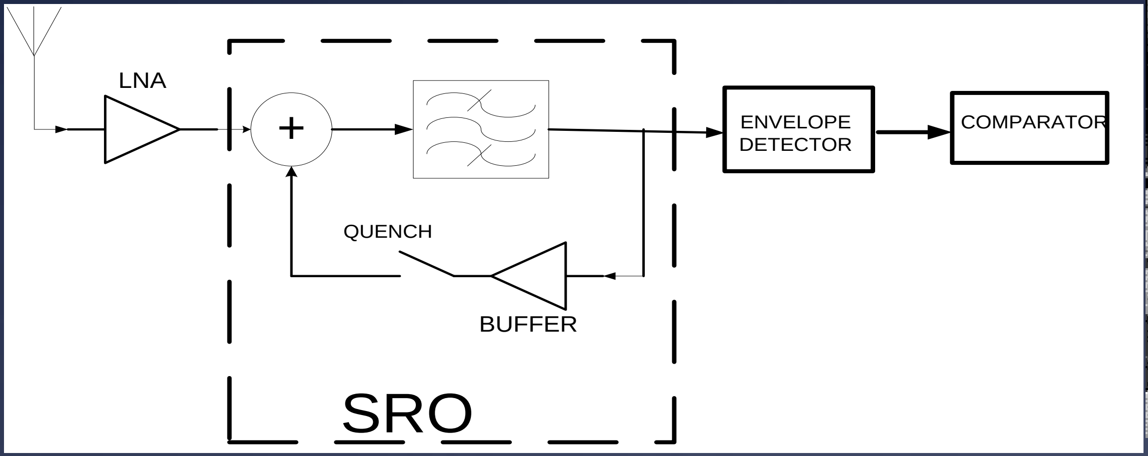
[1] MICS Band Plan, *FCC Rules and Regulations*, Part 95, Jan 2003.

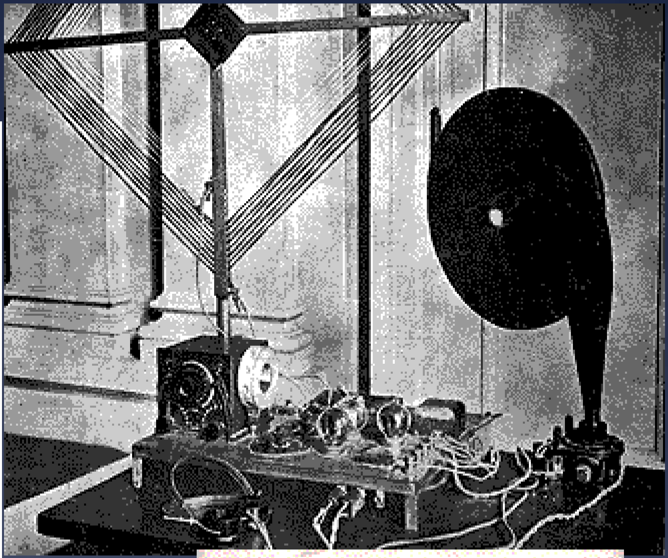
Transceiver Architecture



Wakeup Receiver (WRX)

Super-Regenerative Receiver architecture [2]

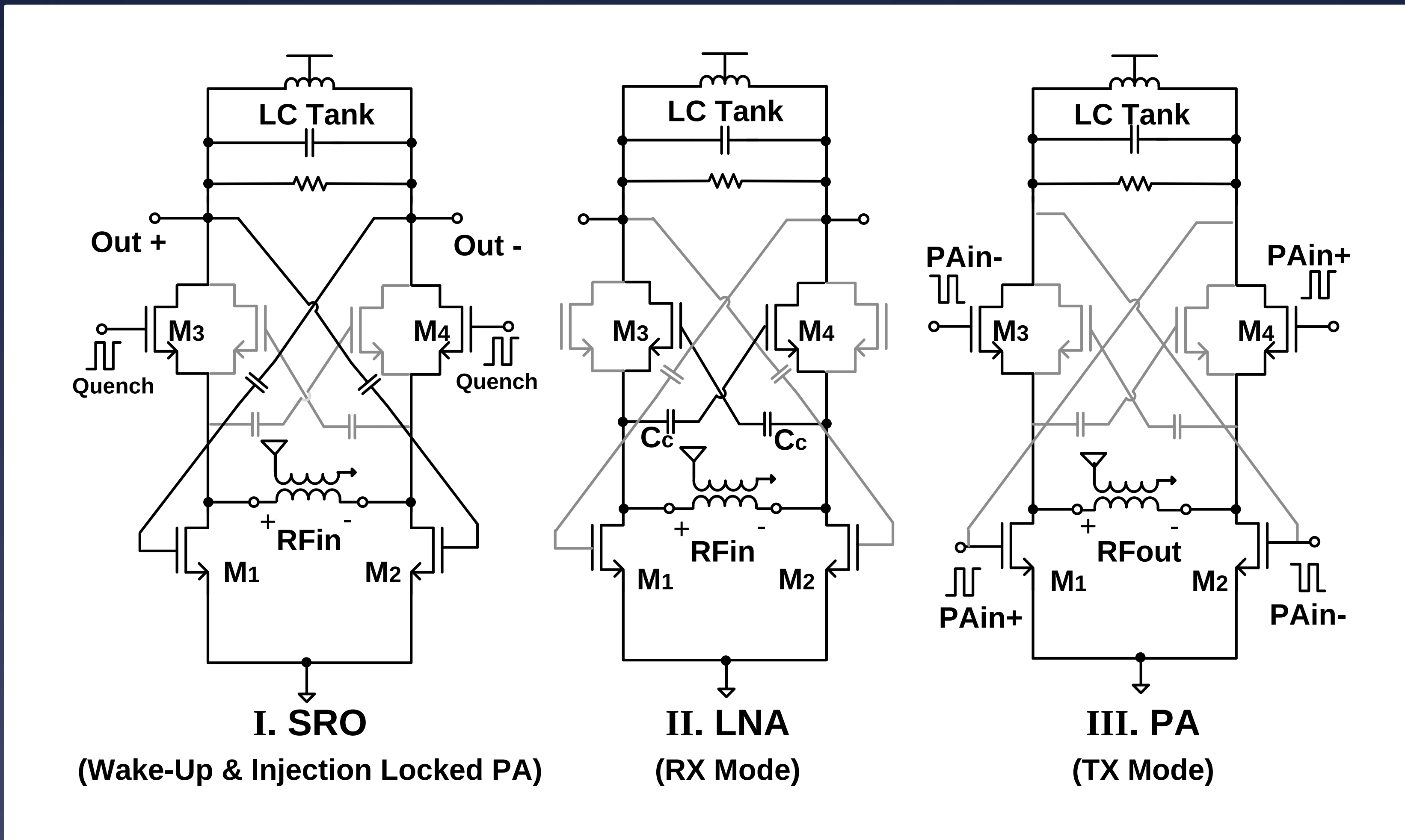




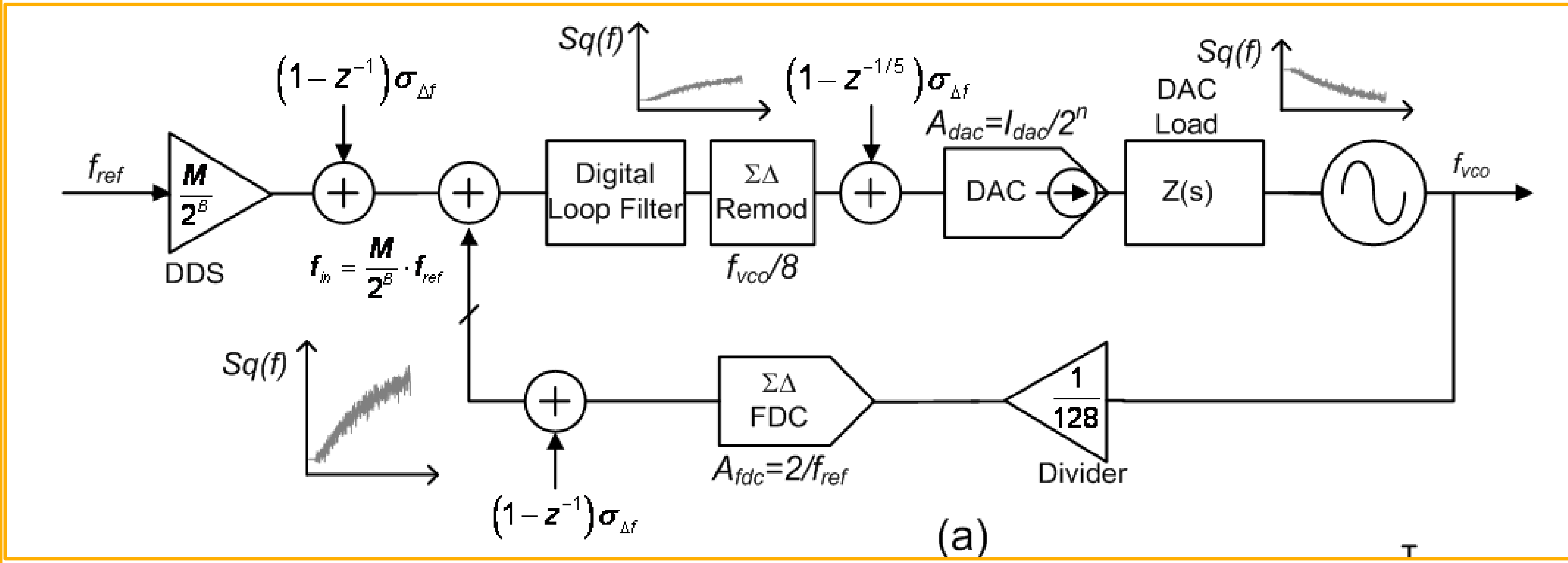
The inventor of FM radio, Edwin Armstrong, invented and patented the regenerative circuit while he was a junior in college, in 1914. He patented the super-regenerative circuit in 1922, and the superheterodyne receiver in 1918.

[2] J. R. Whitehead, Super-Regenerative Receivers. Cambridge, U.K. ; Cambridge Univ. Press, 1950

Reconfigurable Front-End



All Digital PLL

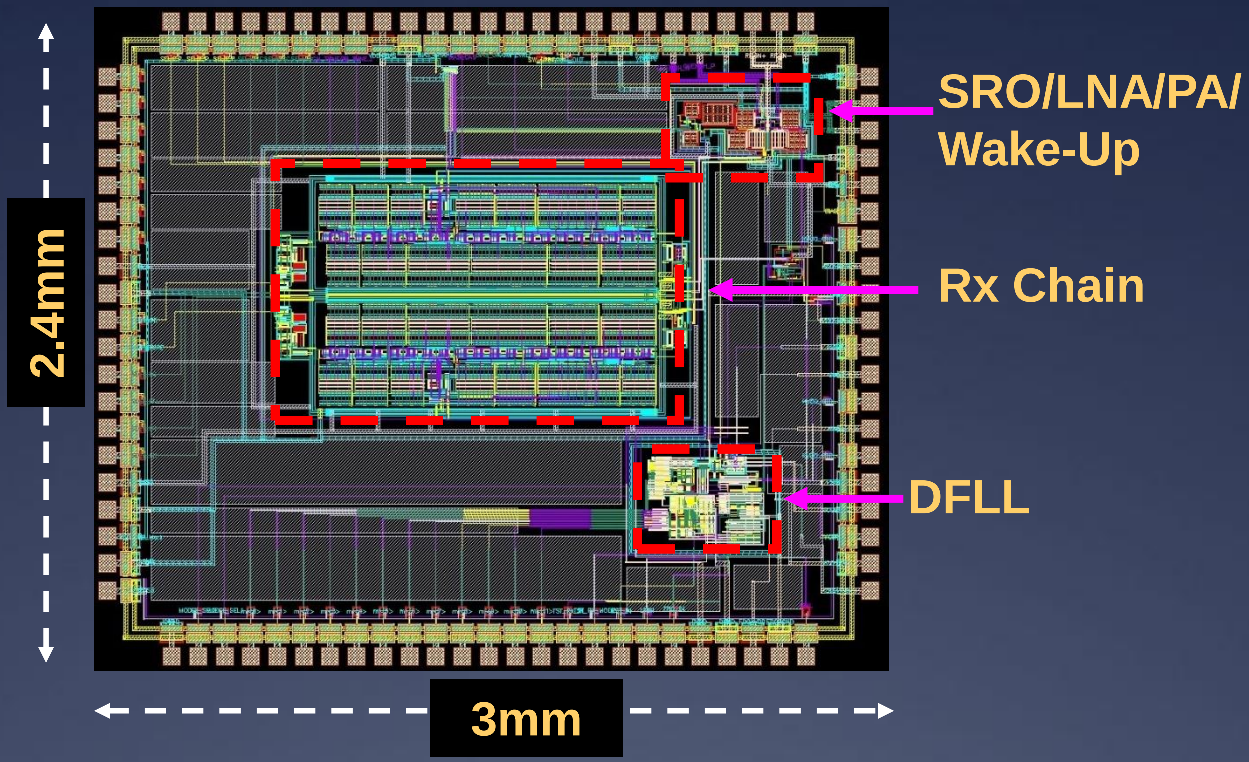


Non-coherent FSK

Shorter Lock time

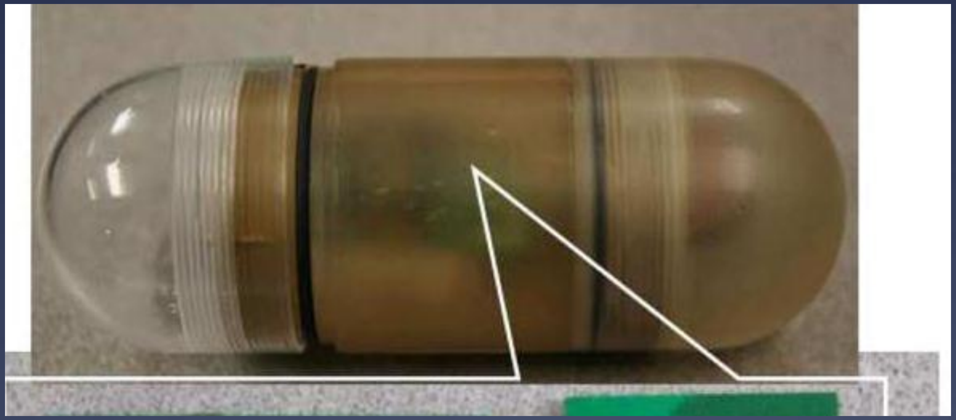
All Digital Implementation
- DDS (Direct Digital Synthesis)
  - Frequency discriminator.
  - Frequency-to-voltage
  - Frequency-to-digital

IC Floor Plan
0.18 micron CMOS



Wireless Capsule

Typical Capsule with Imaging Capability*



* Low-Power Ultrawideband Wireless Telemetry Transceiver for Medical Sensor Applications
Yuan Gao*, *Member, IEEE*, Yuanjin Zheng, *Member, IEEE*, Shengxi Diao, Wei-Da Toh, Chyuen-Wei Ang,
Minkyu Je, *Member, IEEE*, and Chun-Huat Heng, *Member, IEEE*

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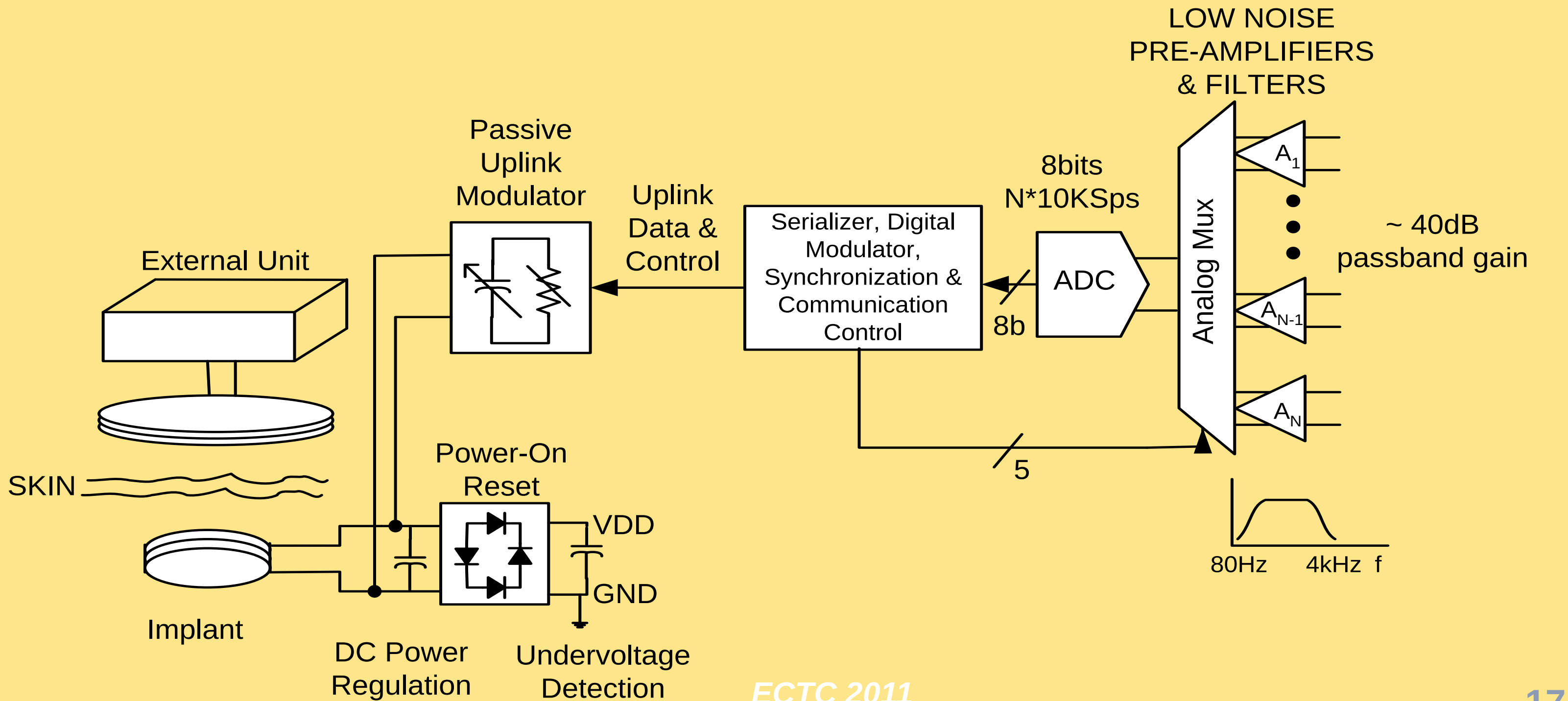
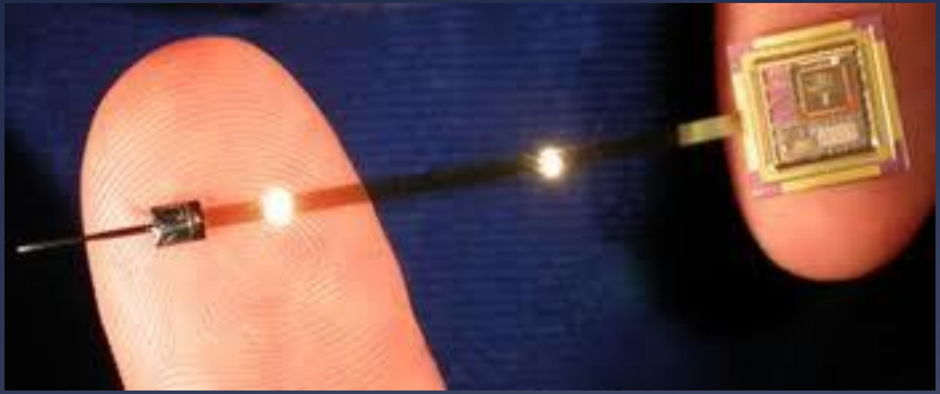
Implantable Wireless Neural-Sensor and Control

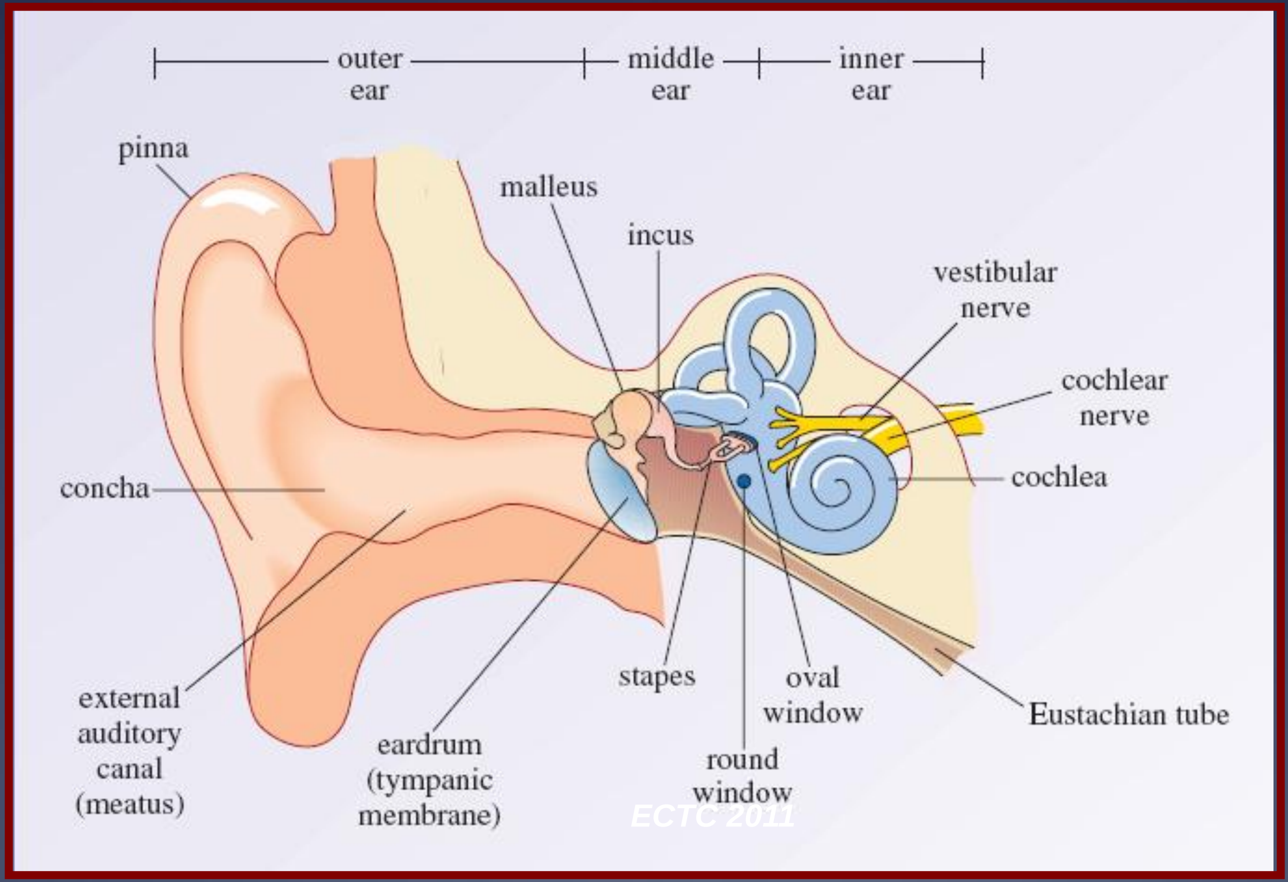


Cochlear Implant Used as Sensor

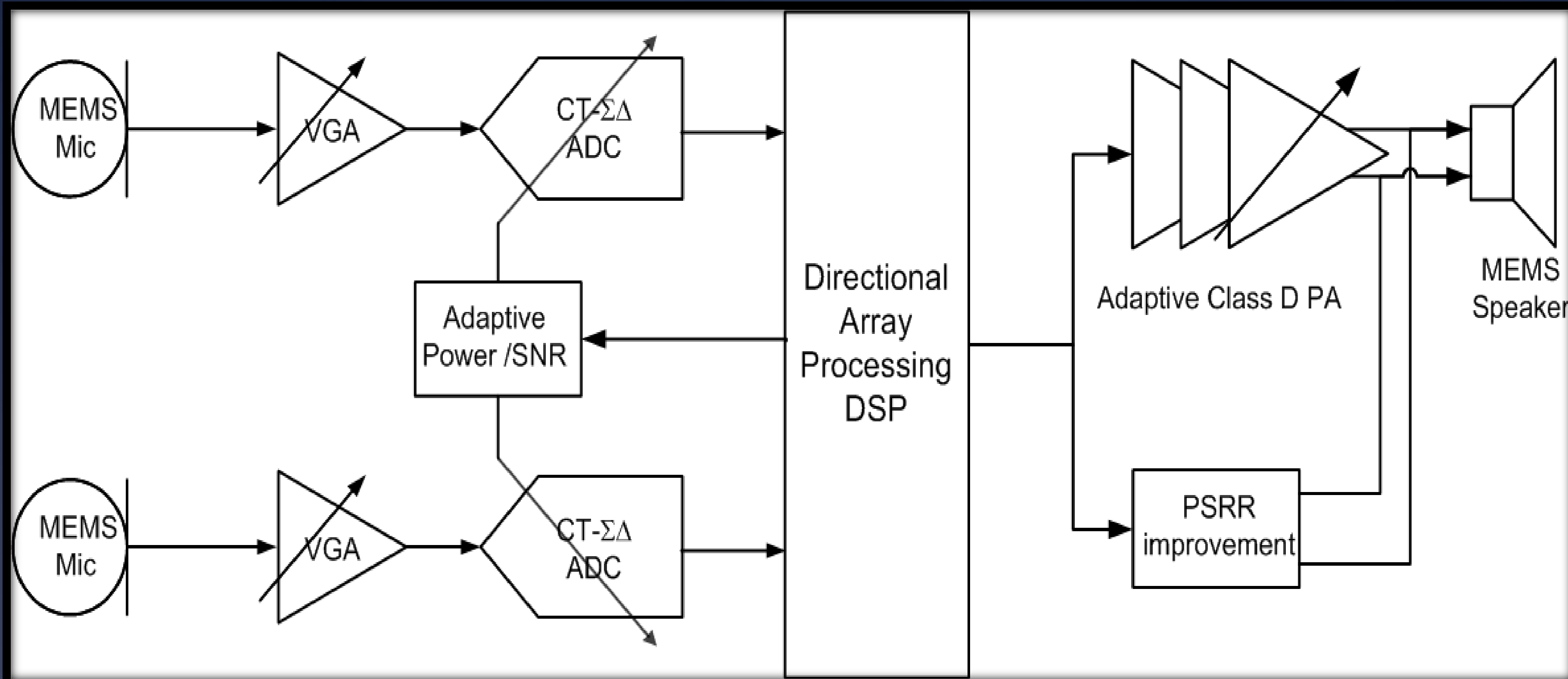


Integrated Hearing Aid

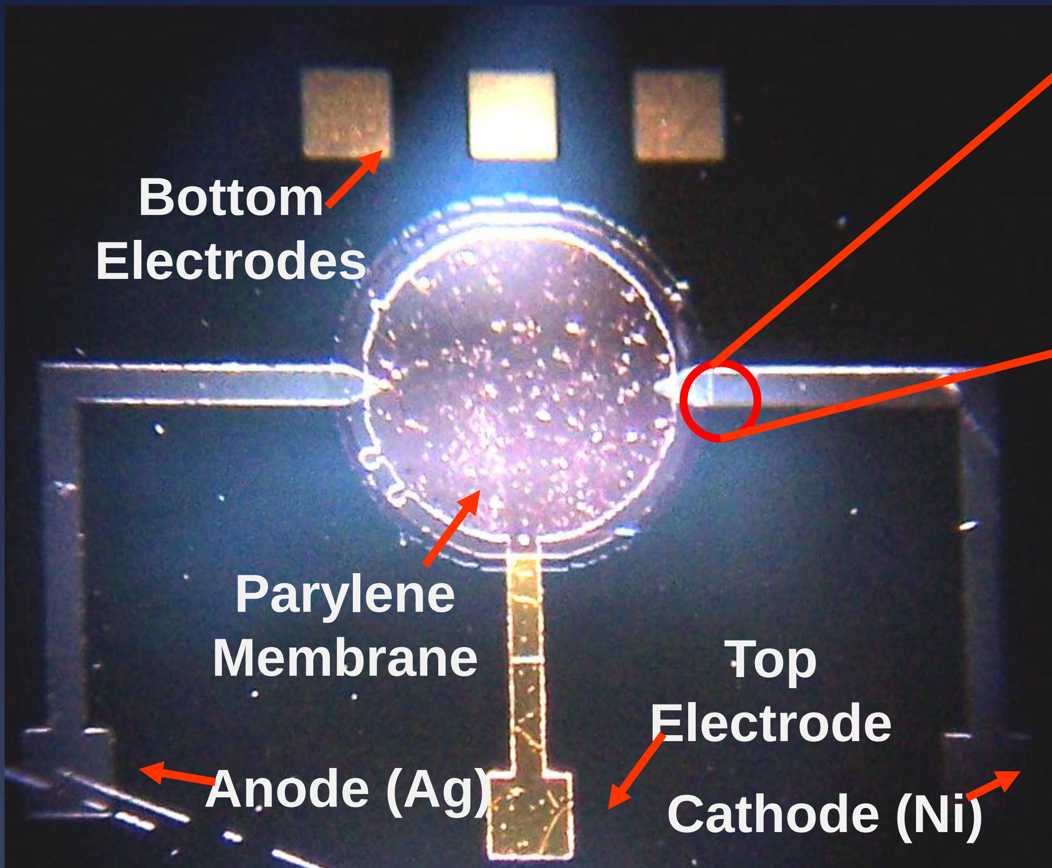
- MicroPhone Array
  - MEMS Based
- Adaptive CT ΣΔ Modulator



Adaptive-Microphone Array DHA

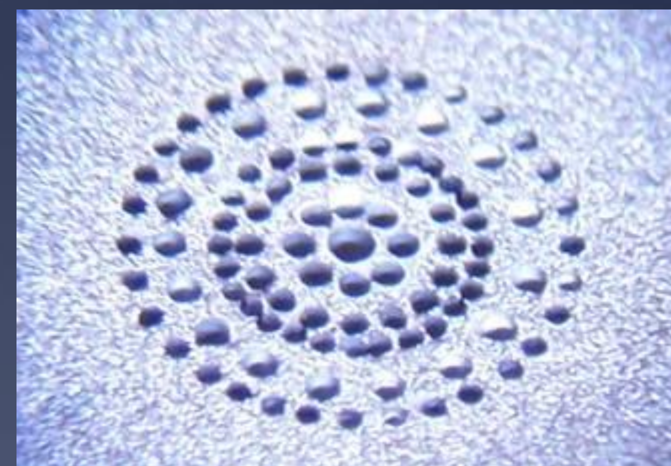


Matched MEMS Microphones for Ultra-small Hearing Aids



(a)

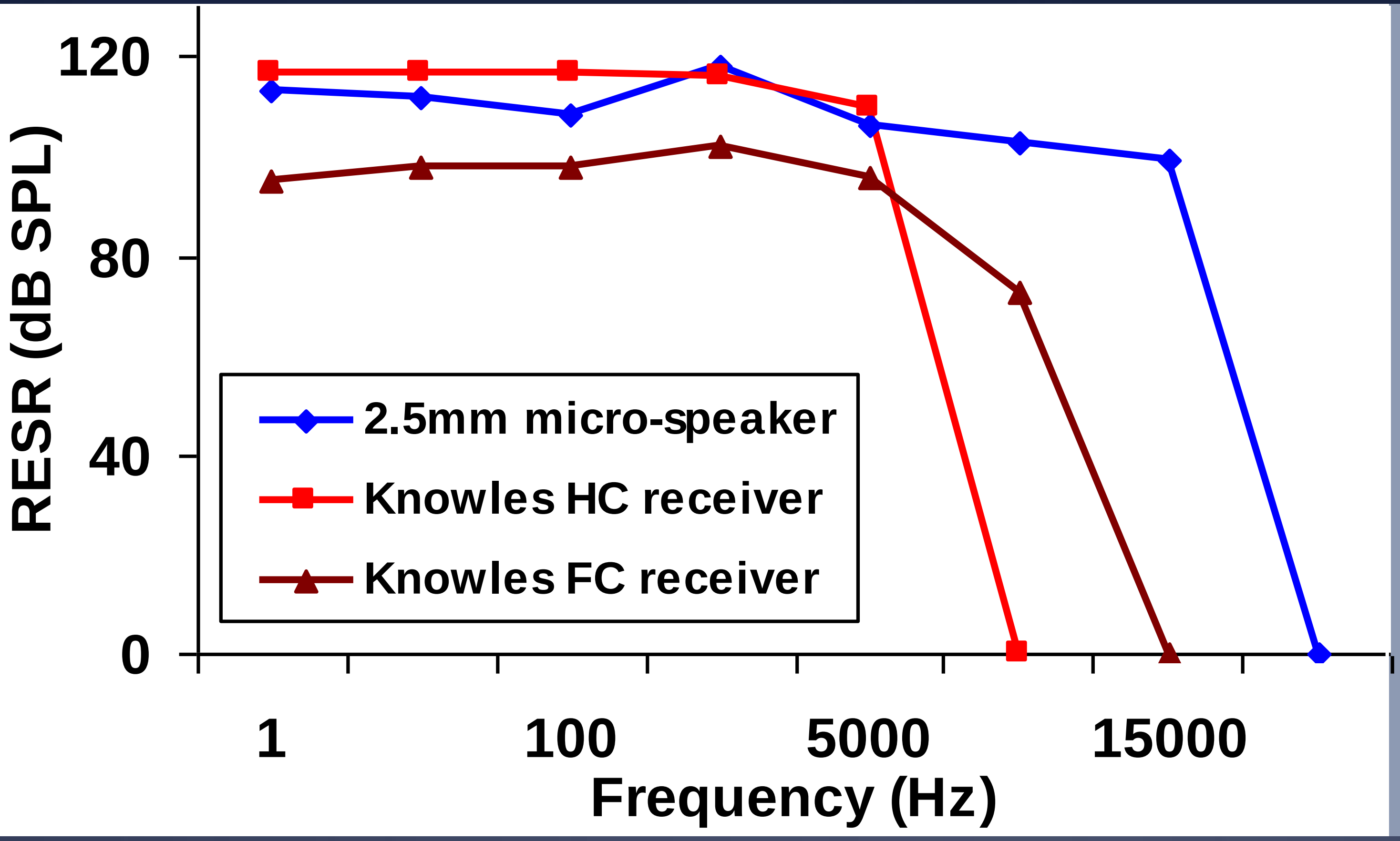
(b)



(c)

A fabricated capacitive microphone covered by Ge-Se solid electrolyte on suspended parylene membrane. (a) Top view, (b) Ag nano-dendrite from Ni tip, (c) backside view of the microphone

Micro-speaker



Comparable Performance with Significant Reduced Power Consumption
→ Prolong Battery Life of Hearing Aids
(The most demanded feature)

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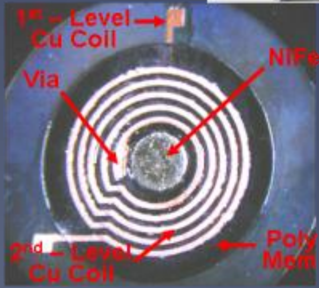
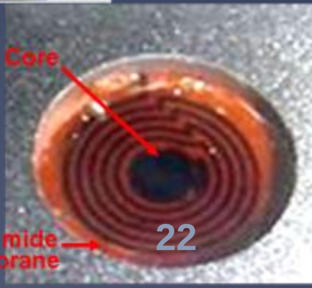
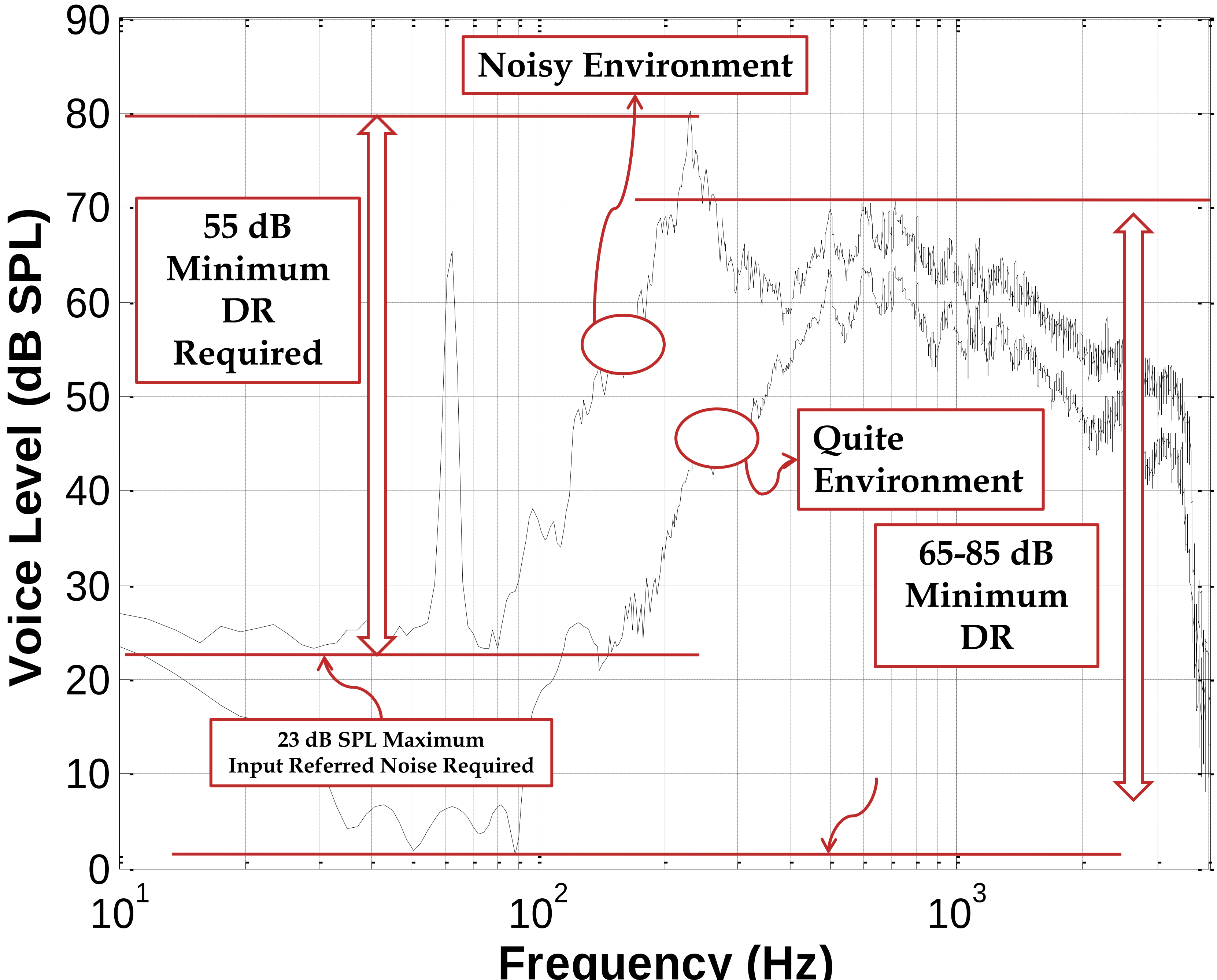


Front-side view



Back-side view


Noisy Environment
55 dB Minimum DR Required
Quite Environment
65-85 dB Minimum DR
23 dB SPL Maximum Input Referred Noise Required
Voice Level (dB SPL)
Frequency (Hz)
90
80
70
60
50
40
30
20
10
0
10^1
10^2
10^3

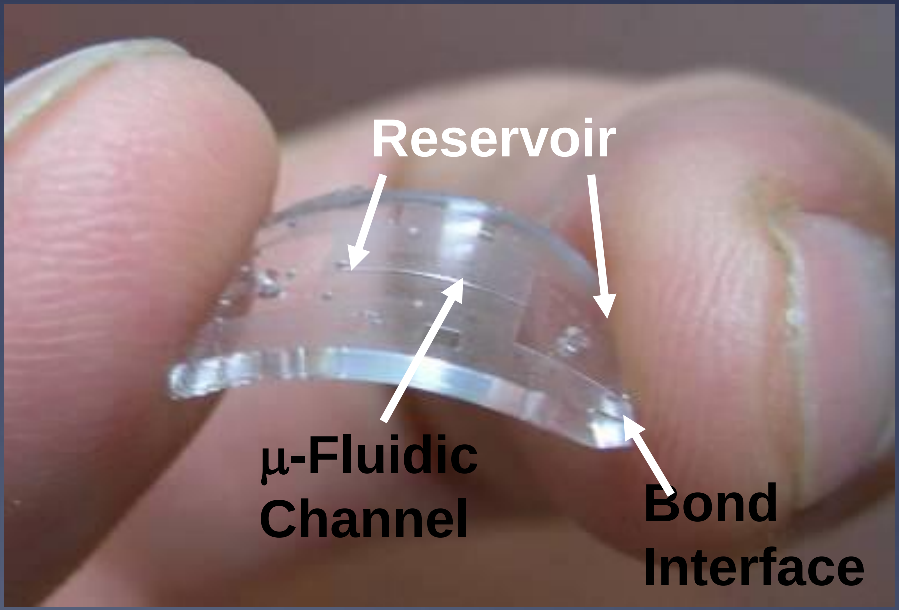
Power Scaling

Power (uW)	SNR (dB)
106	87
72	85
55	82
47	75

All Flexible Microfluidics

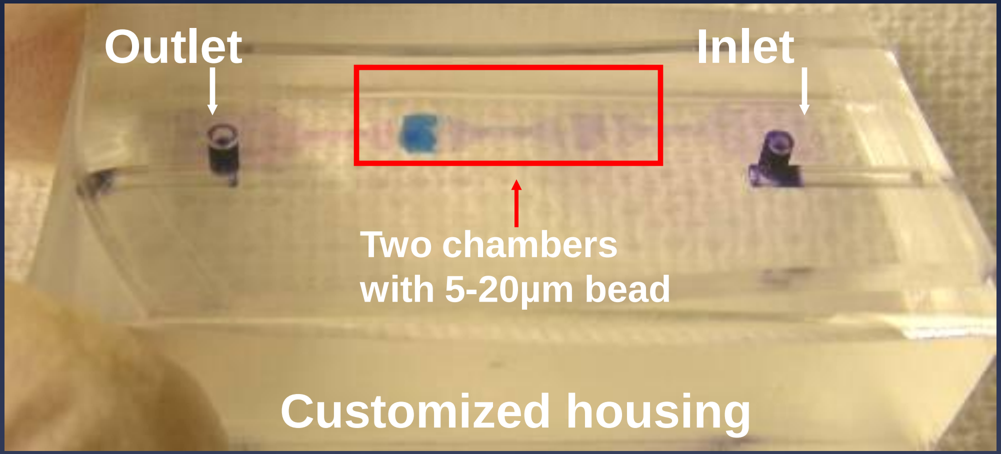
- Existing medical implants are structurally rigid
  - Damage surrounding tissues or muscles

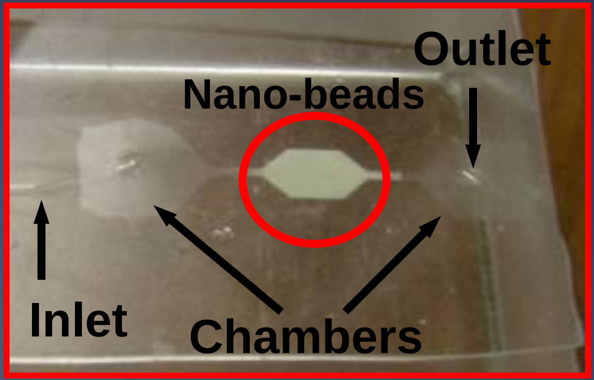
- All flexible micro-fluidics for implantable modules
  - Reservoirs, Channels, Valves, Pumps in a flexible enclosure
  - Low-power osmotic pumps



Prototype of all flexible microfluidics

Fabricated Proto-type Separation





A factor of ~ 20,000 size reduction

Thank You