

Challenges for Low-Power Bio-Medical RFIC

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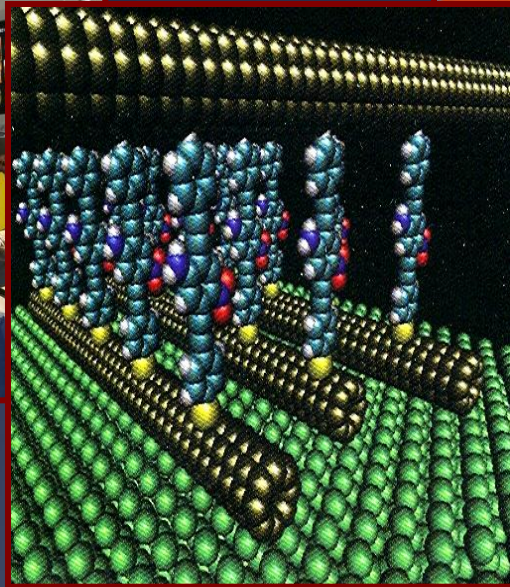
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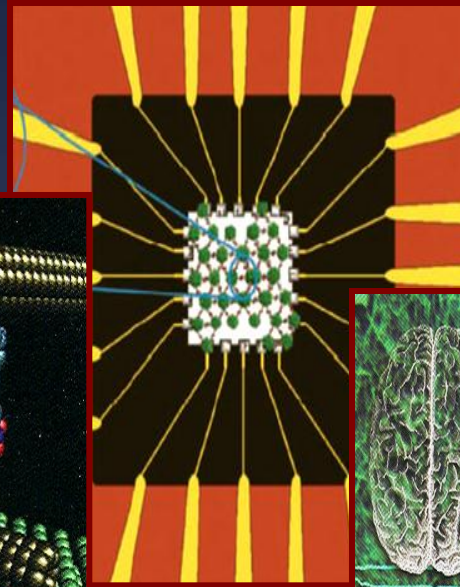
Science & Technology Convergence



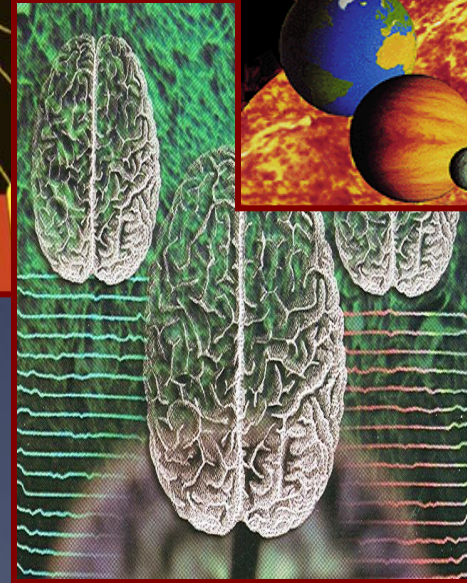
Biology
and
Medicine



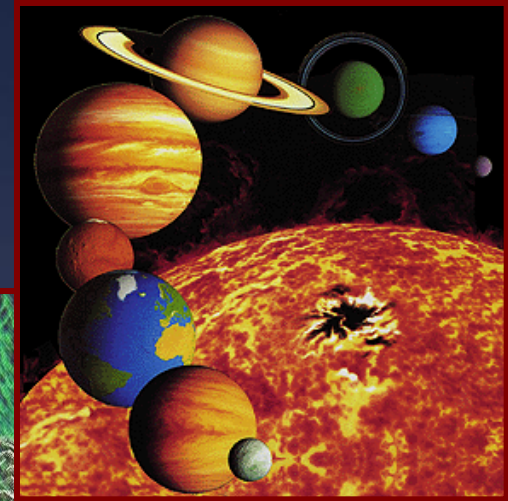
Nanotechnology



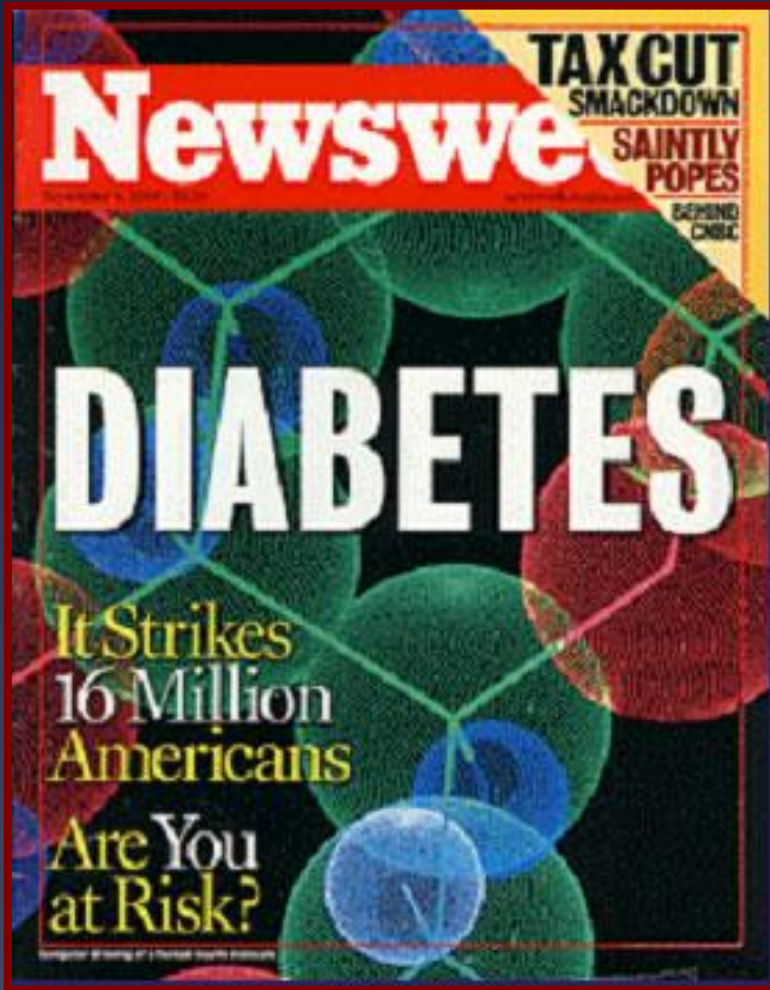
Electronics



Neurobiology
Chem, Phys, Geo,
Space

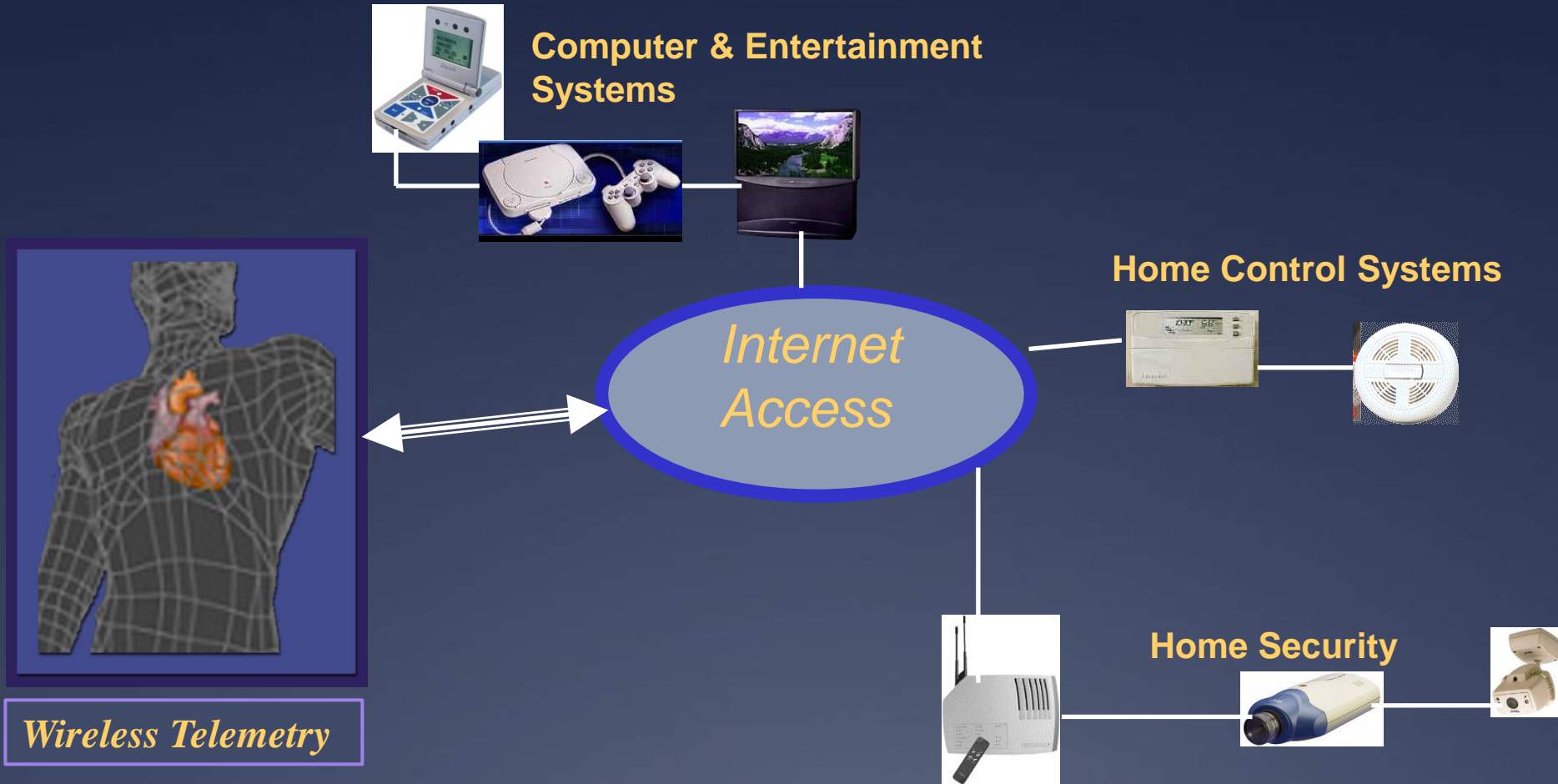


Bio-Telemetry

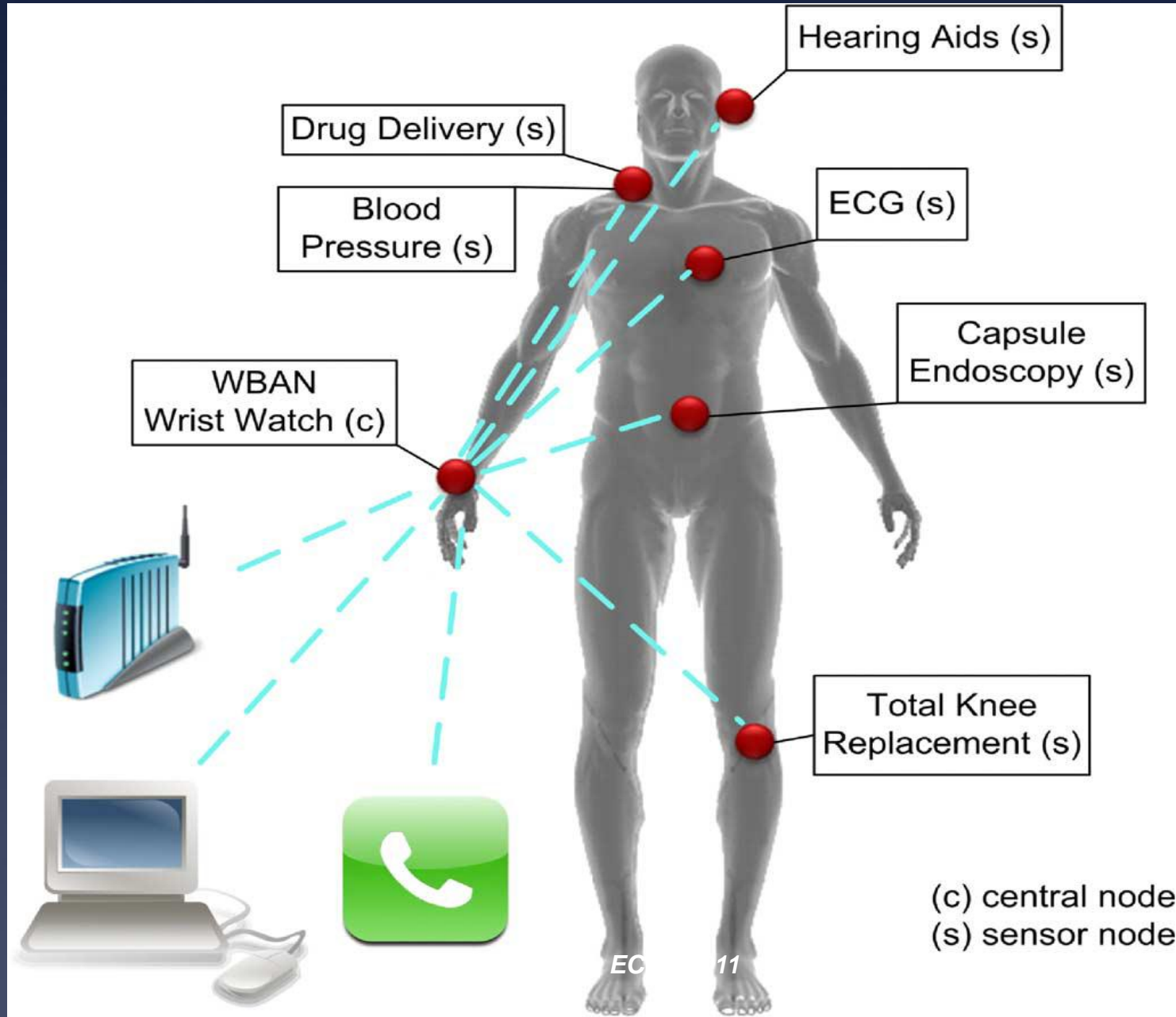


- * Wireless Telemetry
 - * Diabetes
 - * Blood Pressure
 - * Cholesterol
 - * DNA Meter
- * Location + Position + Orientation

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

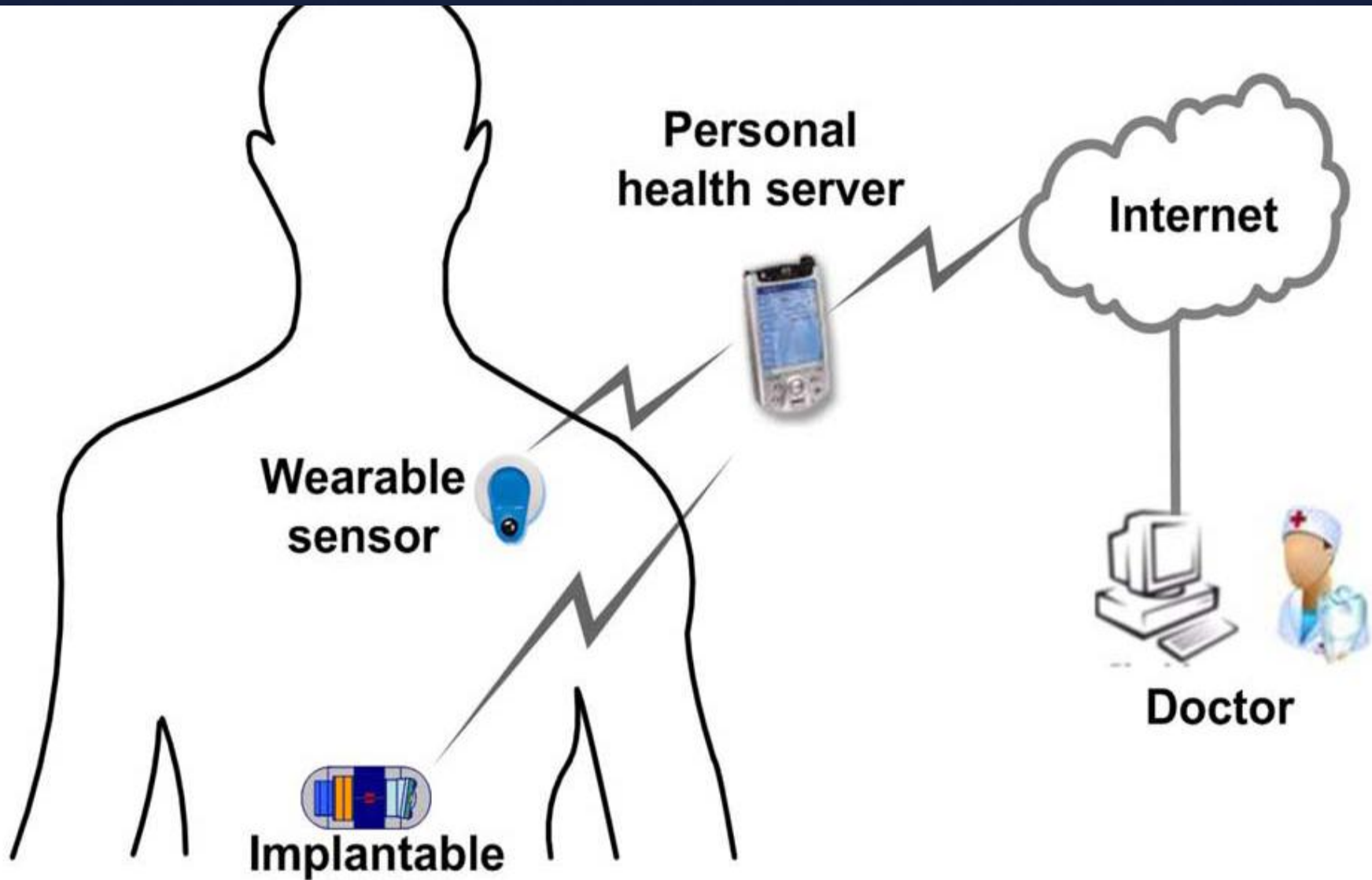
Implantable RF Transceiver

* 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 Environment

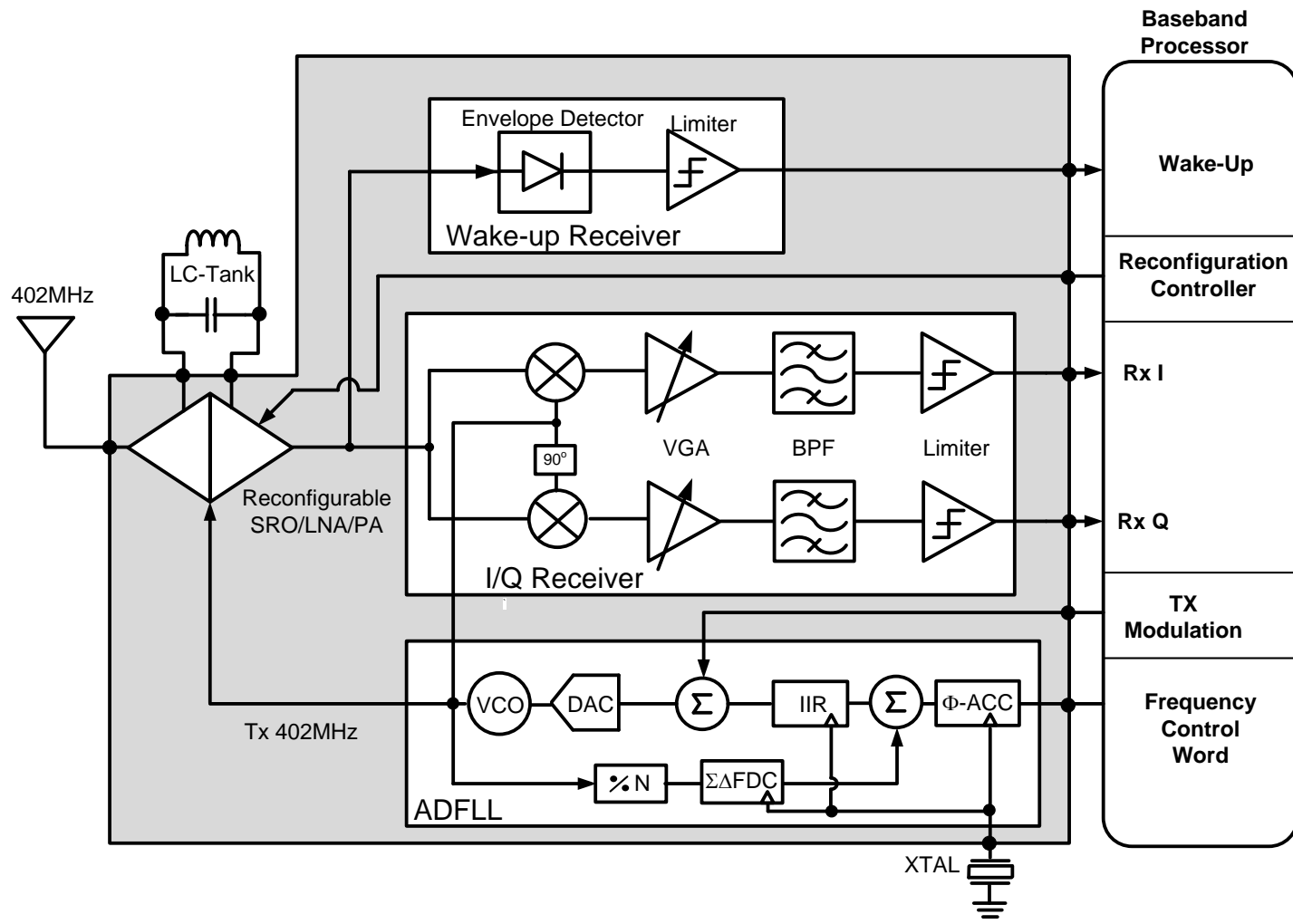


MICS Specifications [1]

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

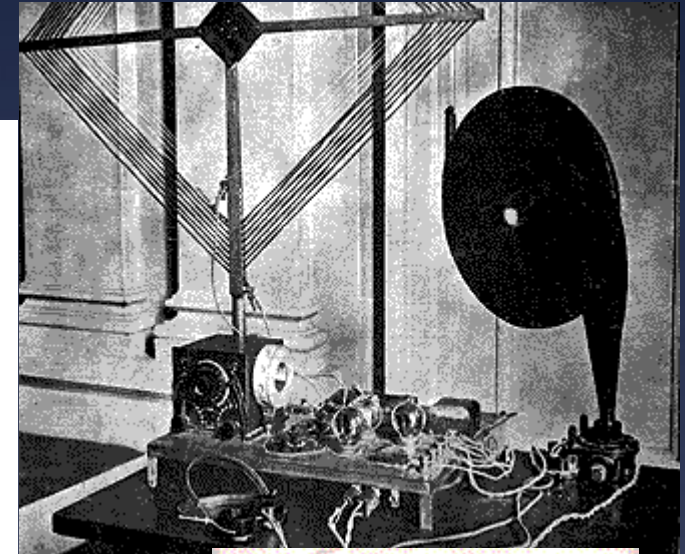
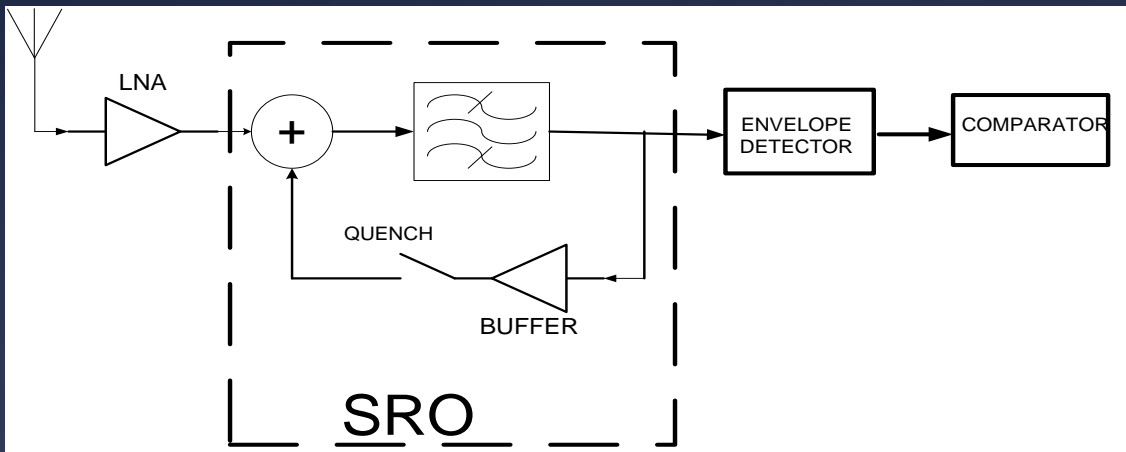
[1] MICS Band Plan, *FCC Rules and Regulations, Part 95*, Jan 2003.

Transceiver Architecture

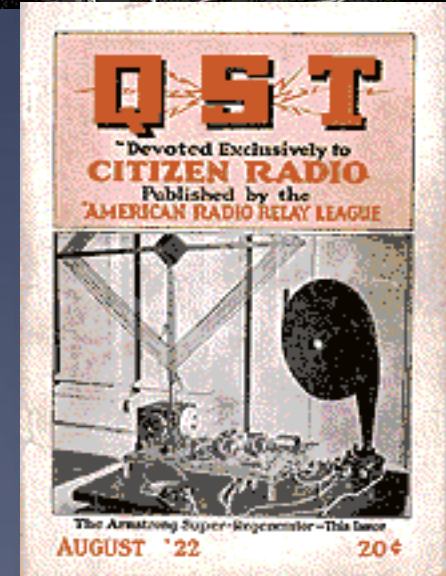


Wakeup Receiver (WRX)

Super-Regenerative Receiver architecture [2]

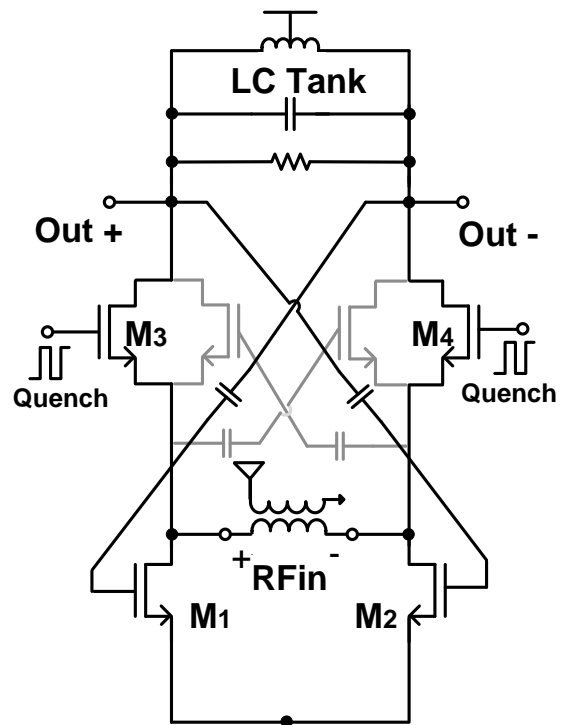


The inventor of FM radio, Edwin Armstrong, invented and patented the regenerative circuit while he was a junior in college, in 1914. He patented the super-regenerative circuit in 1922, and the superheterodyne receiver in 1918.



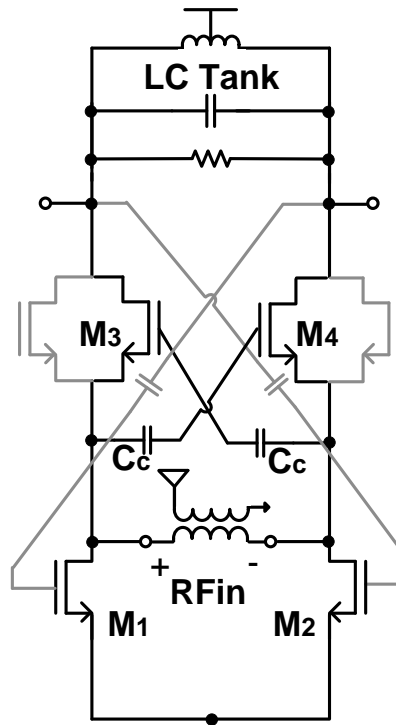
[2] J. R. Whitehead, Super-Regenerative Receivers, ECTC 2011
Cambridge, U.K. ; Cambridge Univ. Press, 1950

Reconfigurable Front-End



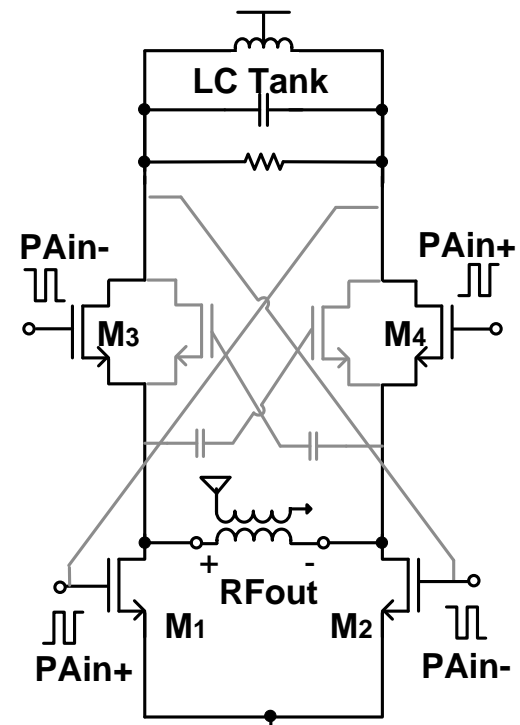
I. SRO

(Wake-Up & Injection Locked PA)



II. LNA

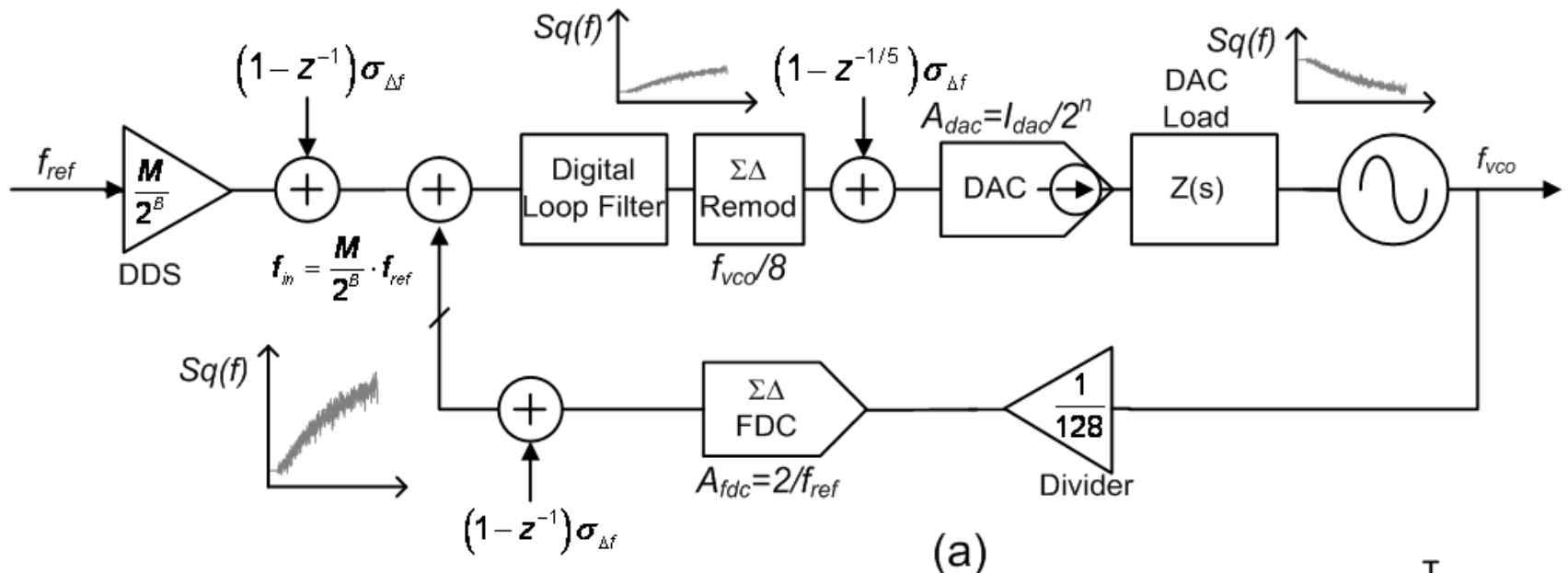
(RX Mode)



III. PA

(TX Mode)

All Digital PLL



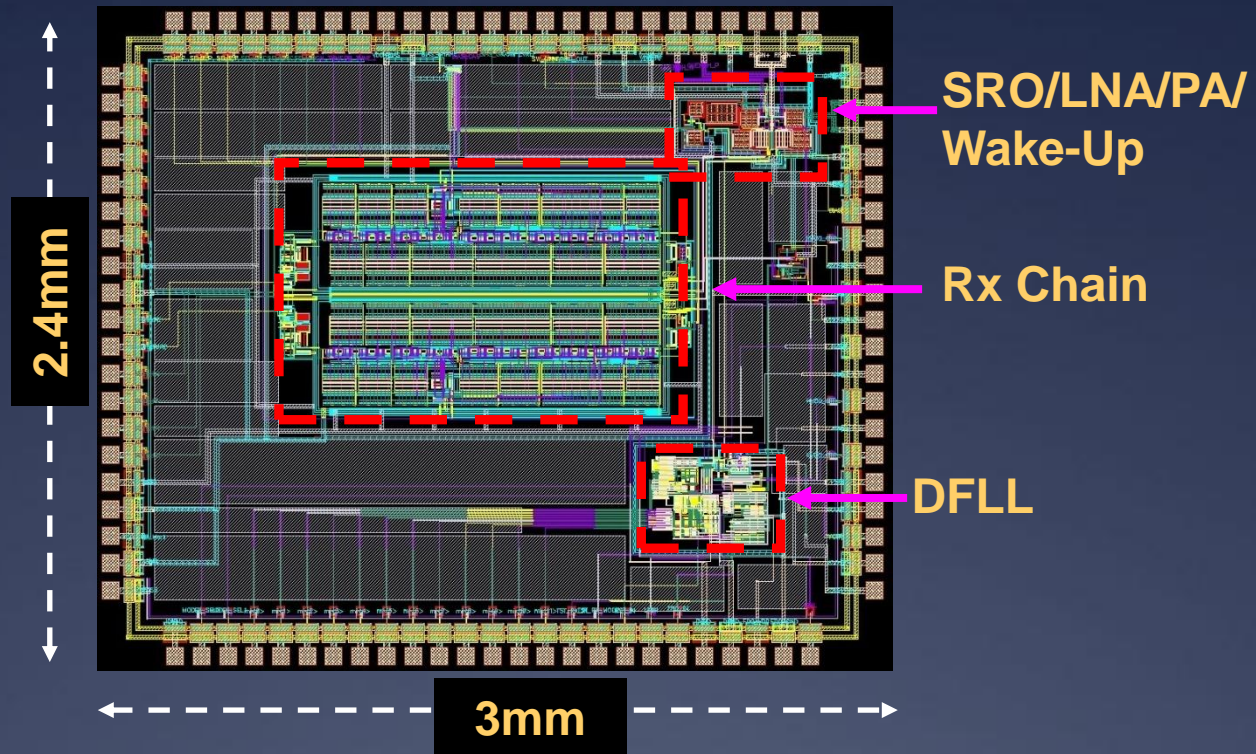
Non-coherent FSK

Shorter Lock time

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

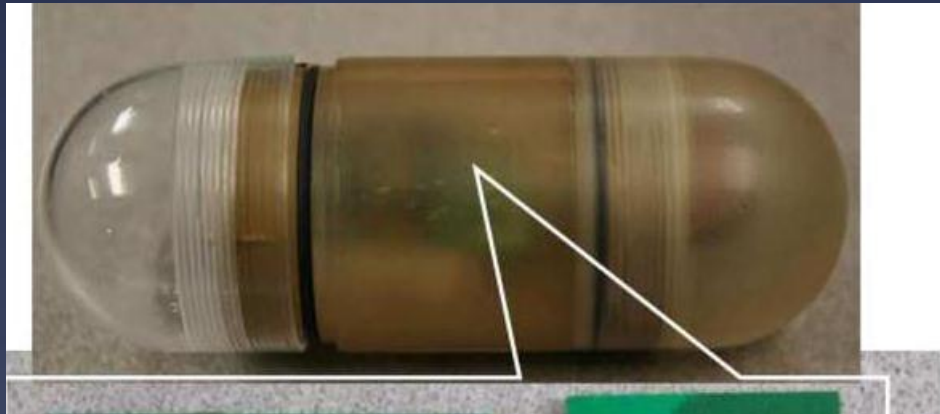
IC Floor Plan

0.18 micron CMOS



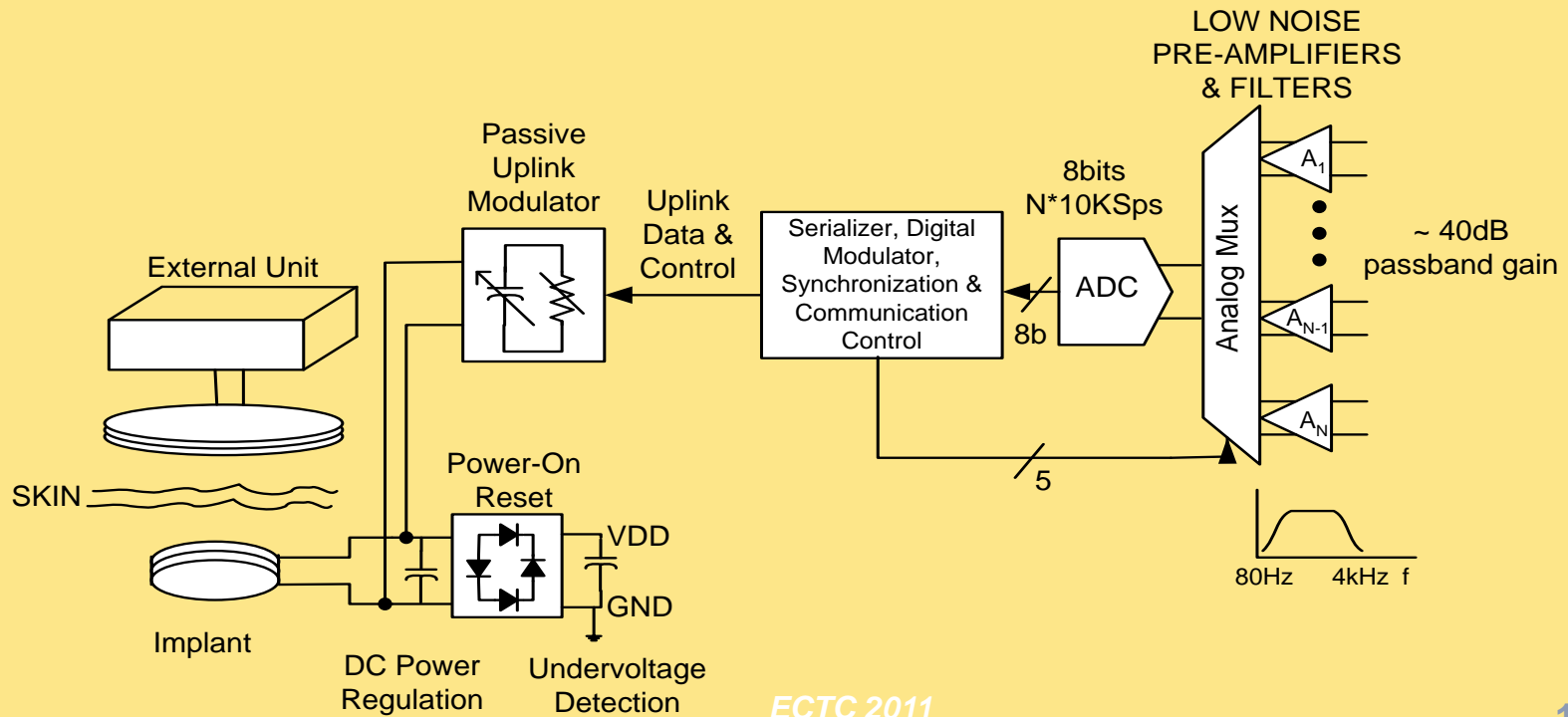
Wireless Capsule

Typical Capsule with Imaging Capability*

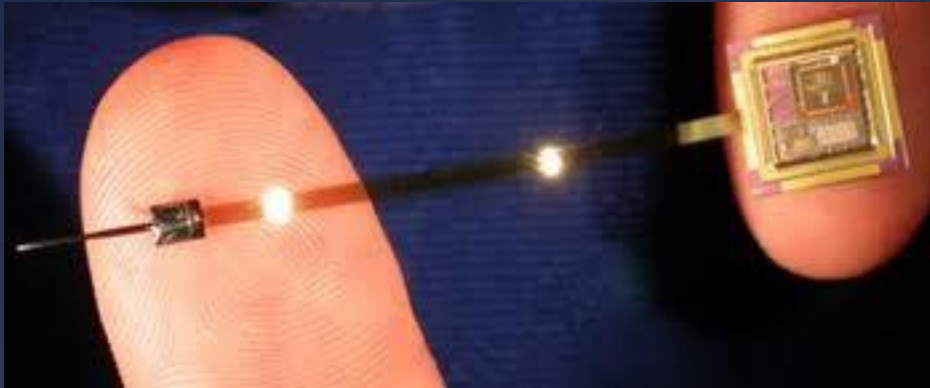


* Low-Power Ultrawideband Wireless Telemetry
Transceiver for Medical Sensor Applications
Yuan Gao*, *Member, IEEE*, Yuanjin Zheng, *Member, IEEE*, Shengxi Diao,
Wei-Da Toh, Chyuen-Wei Ang,
Minkyu Je, *Member, IEEE*, and Chun-Huat Heng, *Member, IEEE*

Implantable Wireless Neural-Sensor and Control



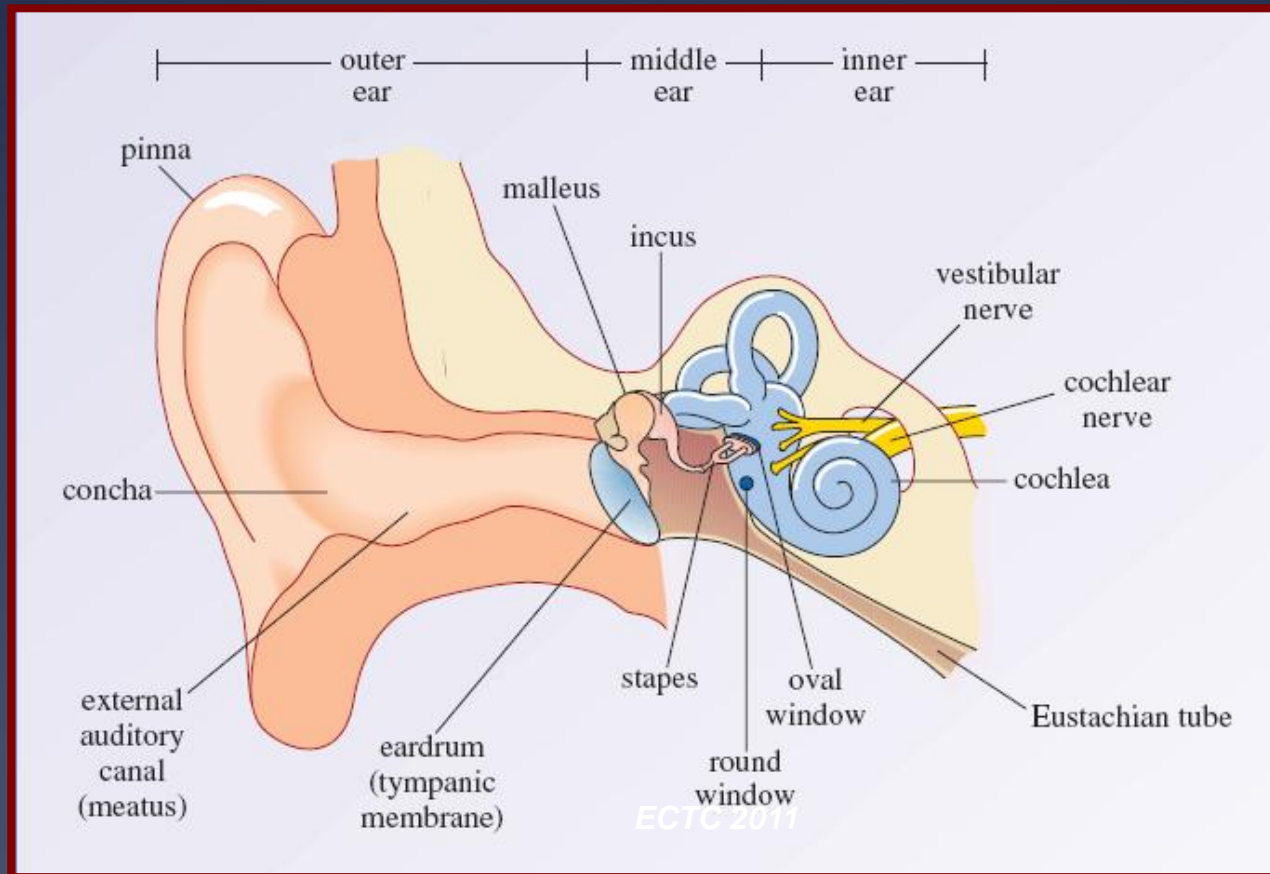
Cochlear Implant Used as Sensor



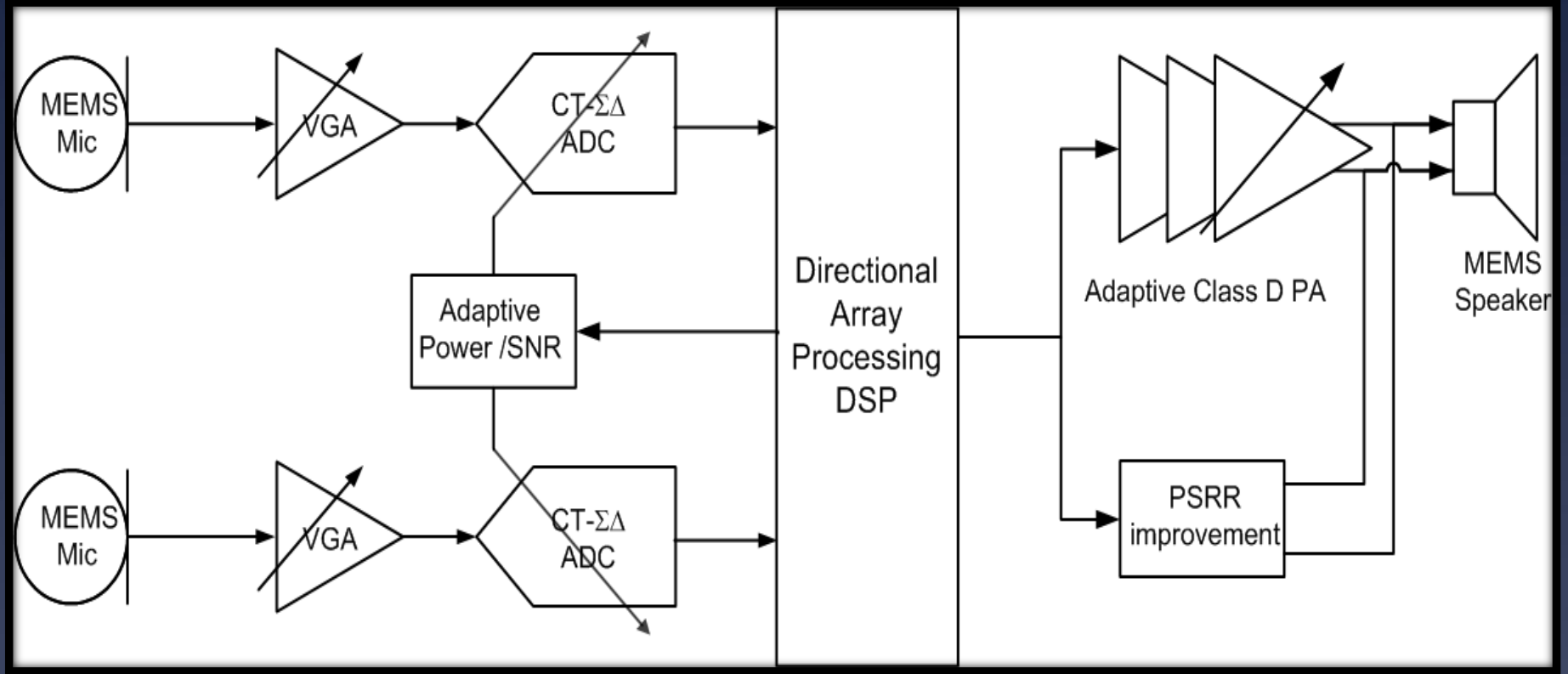
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Integrated Hearing Aid

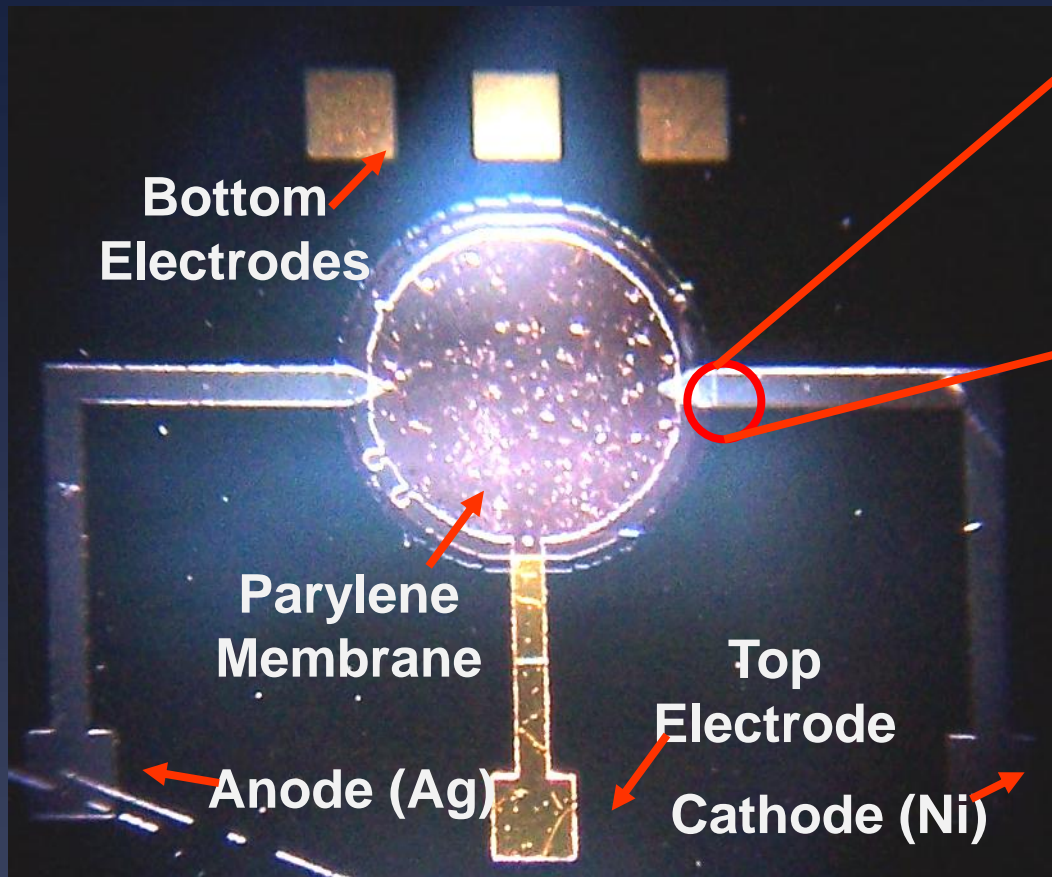
- * MicroPhone Array
 - * MEMS Based
- * Adaptive CT $\Sigma\Delta$ Modulator



Adaptive-Microphone Array DHA



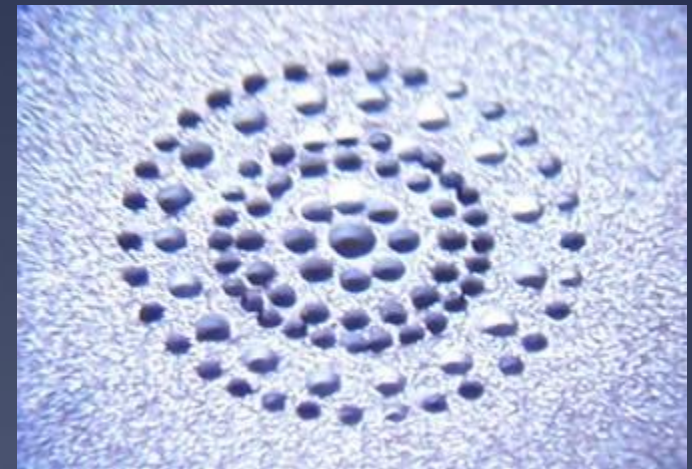
Matched MEMS Microphones for Ultra-small Hearing Aids



(a)



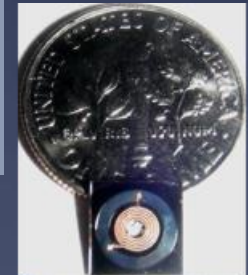
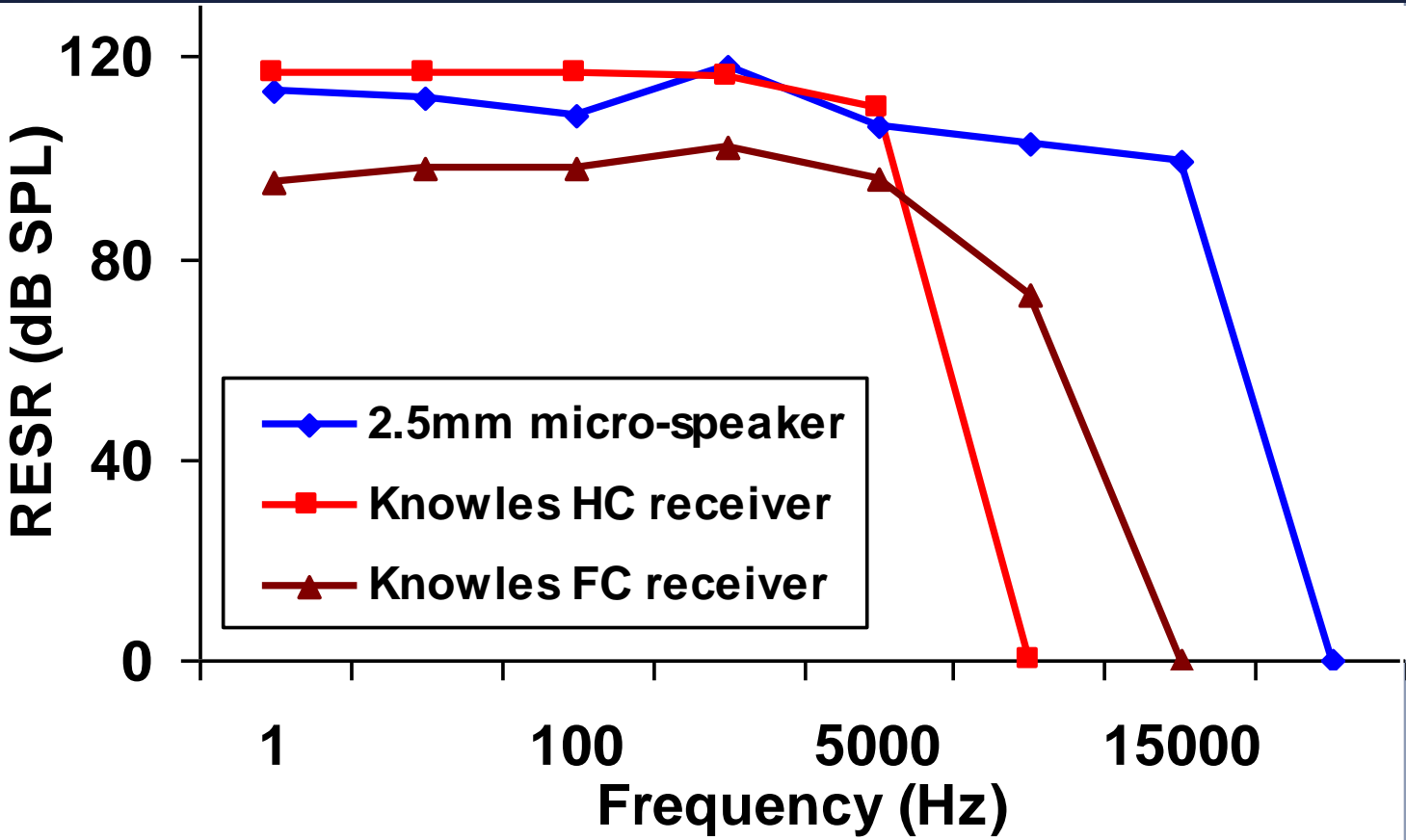
Ag Nano-electrodeposit
(b)



(c)

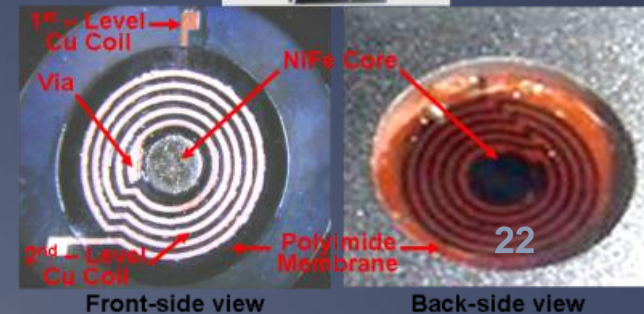
A fabricated capacitive microphone covered by Ge-Se solid electrolyte on suspended parylene membrane. (a) Top view, (b) Ag nano-dendrite from Ni tip, (c) backside view of the microphone

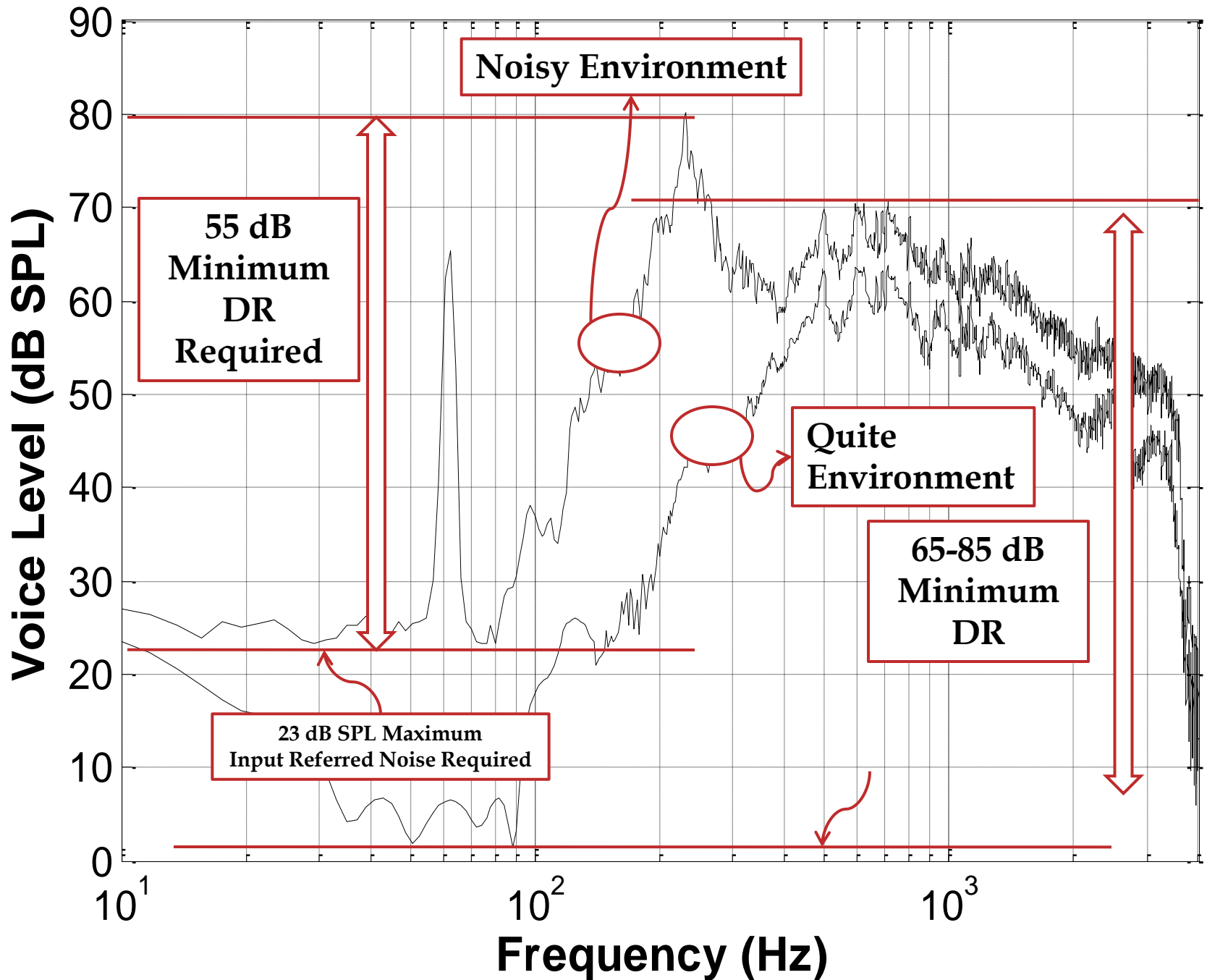
Micro-speaker



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

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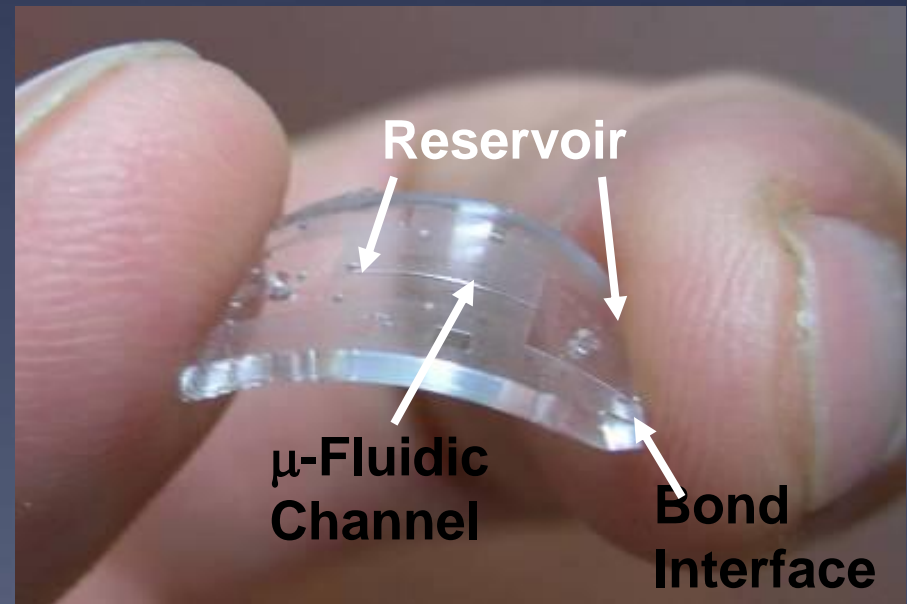


Power Scaling

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

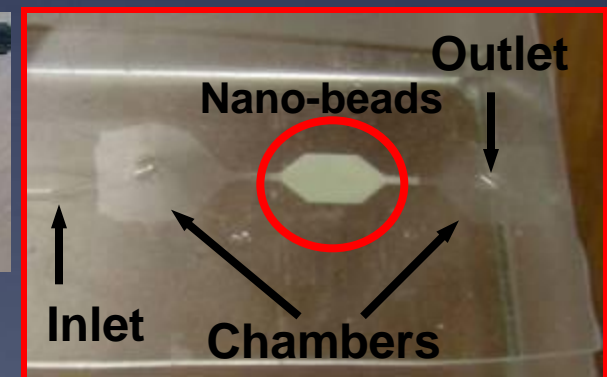
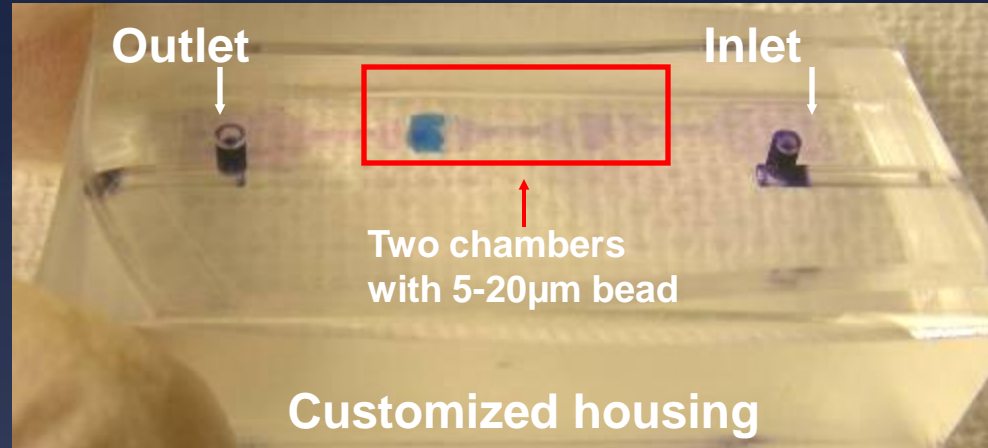
All Flexible Microfluidics

- * 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