Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [WNG Brain-Machine Interface based on Electrocorticography using high speed UWB wireless body area network]

Date Submitted: [18 July 2019]

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Email:[1; t.suzuki@nict.go.jp, 2;mhirata@ndr.med.osaka-u.ac.jp]

Re: []

Abstract: [A important use case of dependable body area network(WBAN) for implanted devices is introduced to perform reliable and massive data for ECoG-based Brain machine interface to require amendment for IEEE802.15.6 wireless medical body area network.]

Purpose: [information]

Brain-Machine Interface based on Electrocorticography using high speed UWB wireless body area network

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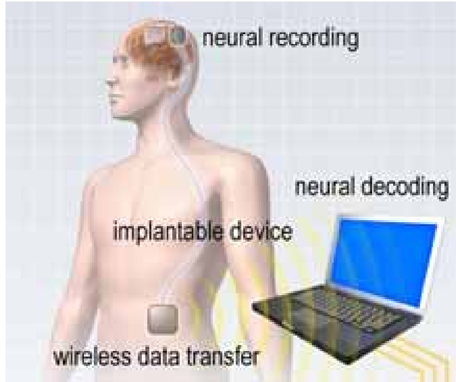
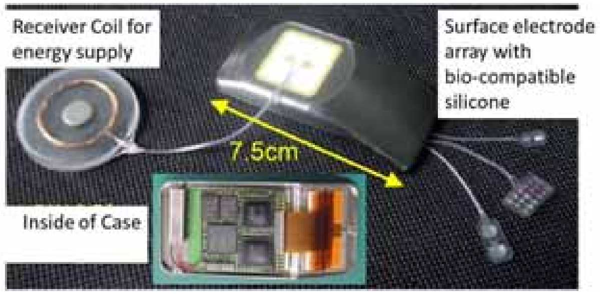
Outline



■ECoG-BMI system

■1st Genaration 128ch system: Clinical ECoG-BMI system

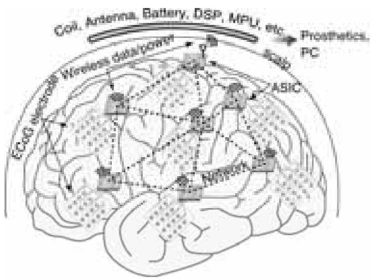
→ Clinical test in 2020



■2nd Generation 4096ch system

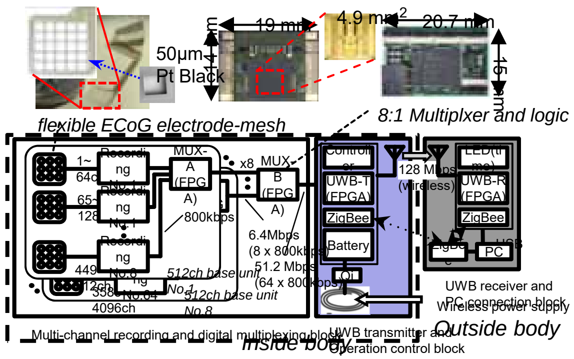
→ Next generation system

- Flexible electrode technology
- UWB wireless technology

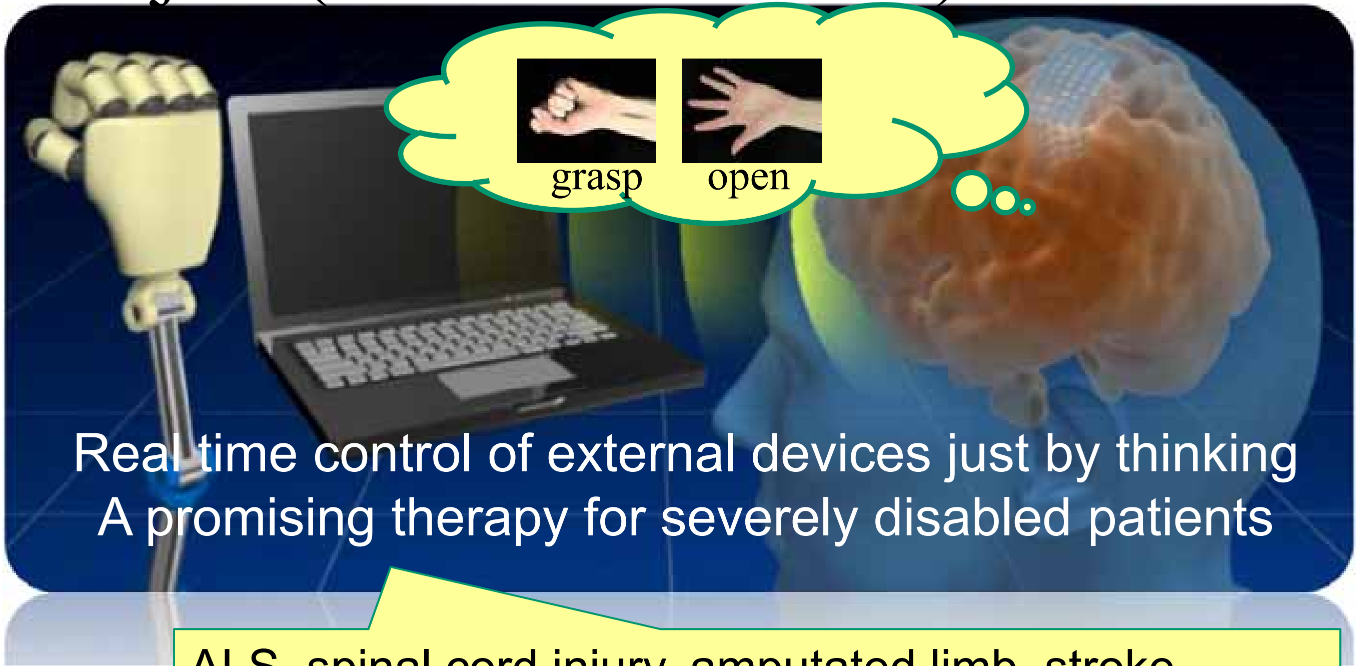


■BMI (system evaluation)

- Real-time decoding
- Robotic arm control and cortical adaptation

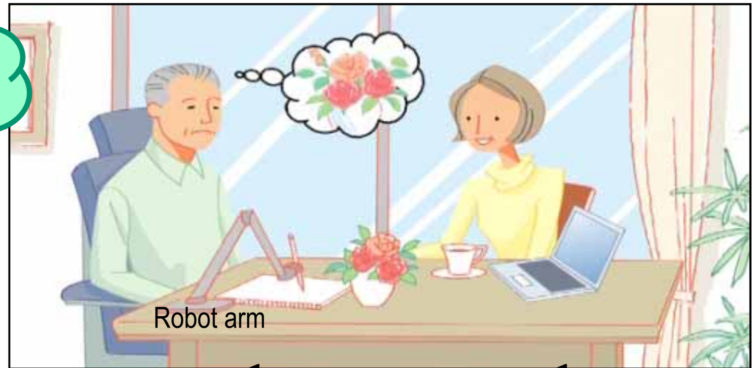


BMI Project (Osaka U & NICT)



ALS, spinal cord injury, amputated limb, stroke, ……..

communication



robot control

Recording methods for clinical BMI

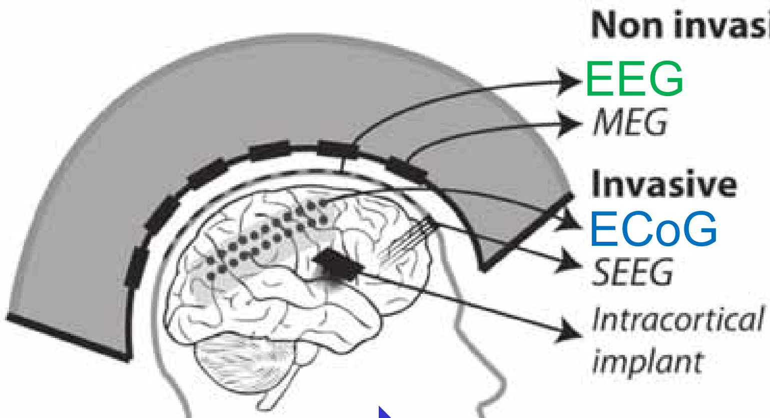
ECoG：Electrocorticogram

Good balance (Information rate, invasiveness, long-term stability)

①fMRI, MEG

◎No invasive
◎Info: high
✕Huge system

② EEG



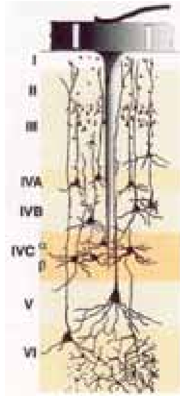
◎No invasive
△Info : low
(On/Off (1bit) selection slowly)
〇Long-term

x10 info

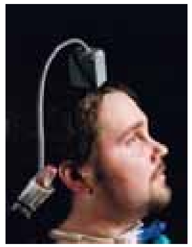
③ECoG

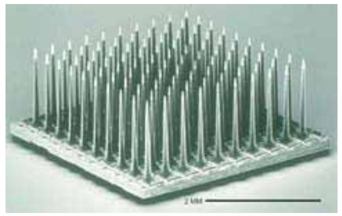
△Low invasive
〇Info: middle
(Robotic hand control in RT)
〇Long-term

④Spike or LFP



✕High Invasive
◎Info:high
✕Short-term

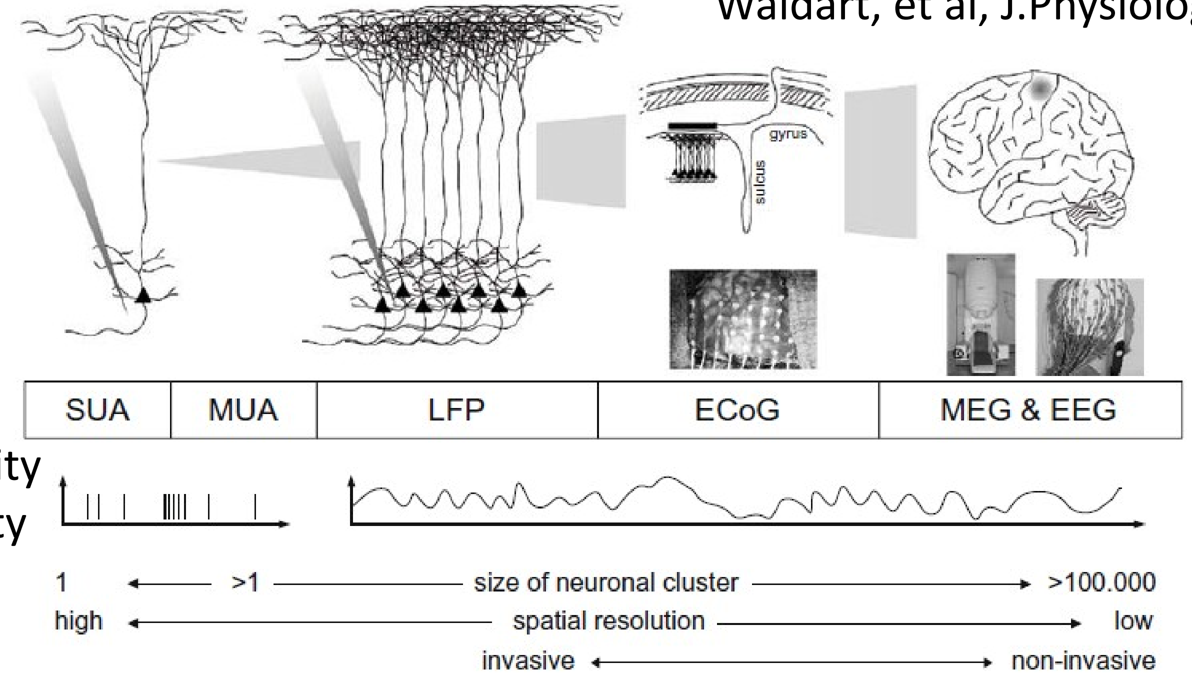


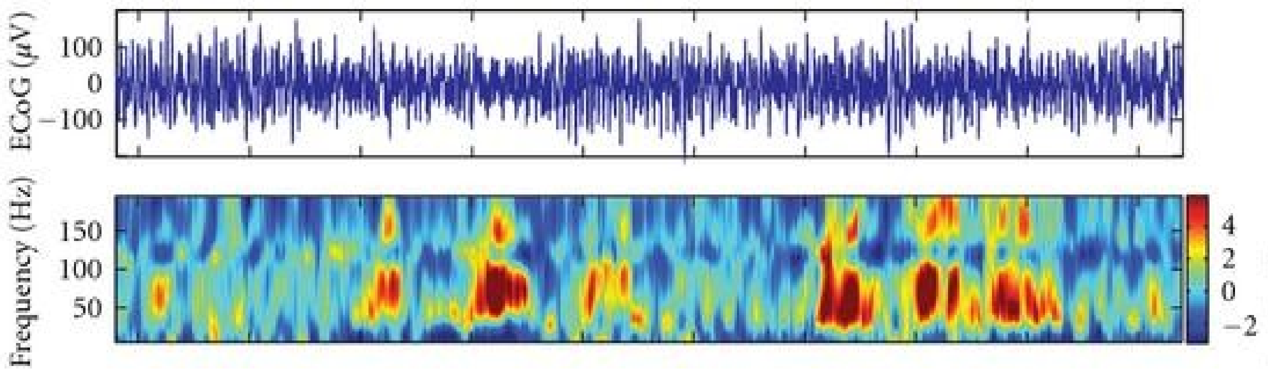


ECoG signal

Waldart, et al, J.Physiology, 2009

SUA: Single Unit Activity
MUA: Multi Unit Activity

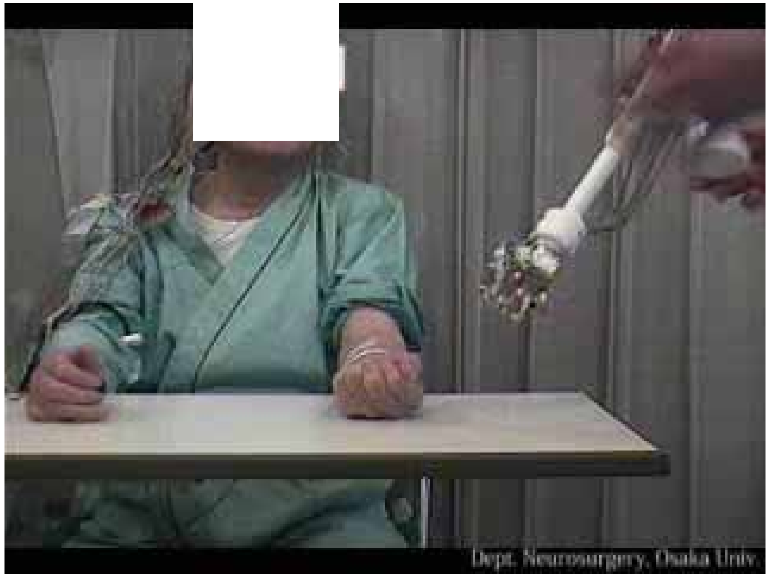




ECoG(50〜180Hz)
sync with motion
= informative

Clinical Research (using wired ECoG-BMI system)

(by Osaka Univ.)



Grasp

(Yanagisawa, Ann Neurol)

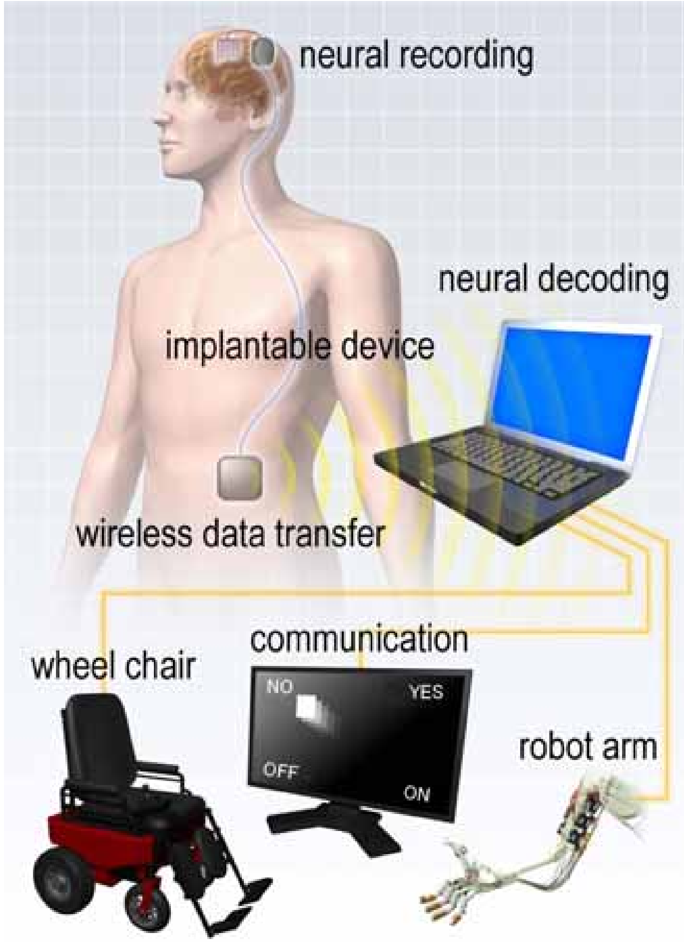
ALS patient (1st Clinical Research)

(NHK news)

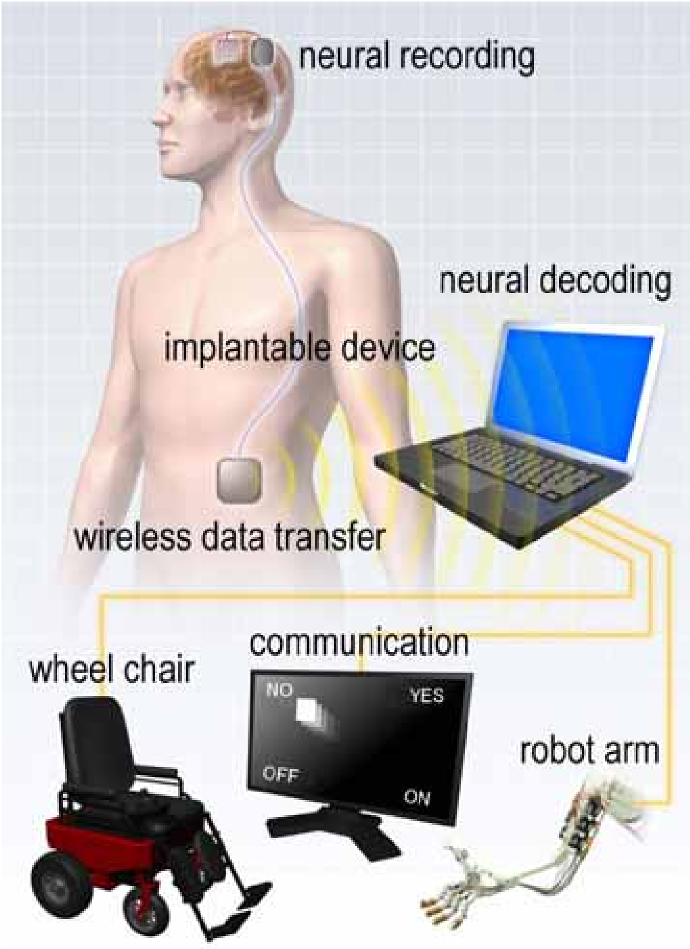
Implantable system is necessary for daily life support by BMI system ⇒ "Wireless" is the key

1st generation ECoG BMIsystem

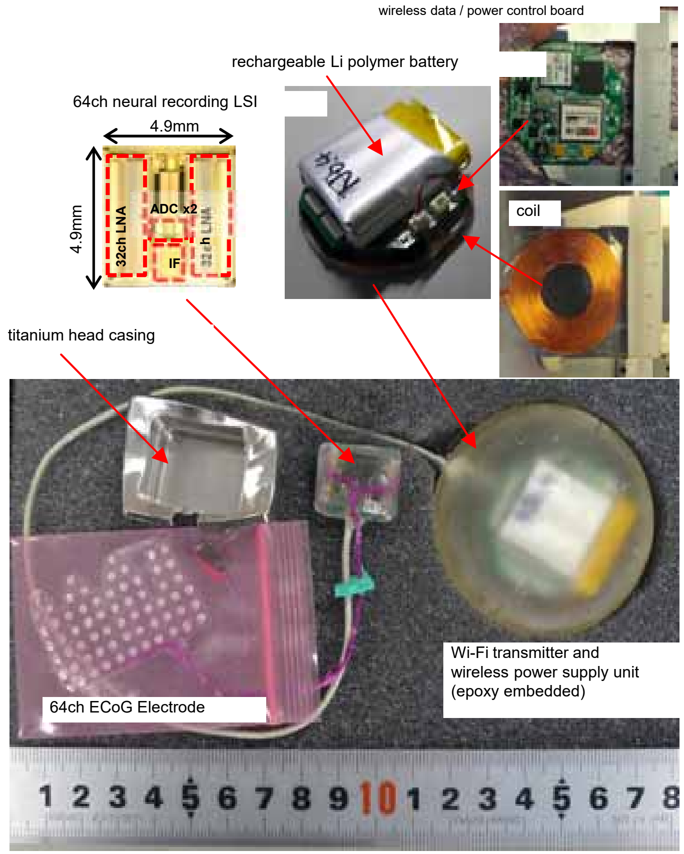
- 128ch (# of electrodes)
- ISM band (2.4GHz)
- Clinical test in 2020
- Communication device for ALS
- Robot arm control for Paralysis



A fully implantable wireless BMI system



Pre-clinical test in 2017-
⇒ Clinical test in 2020



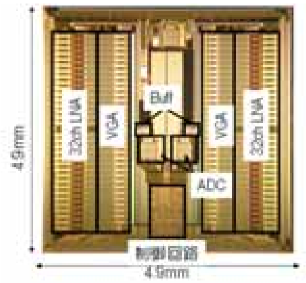
Prototype 64/128ch system
six months in a monkey (2013)

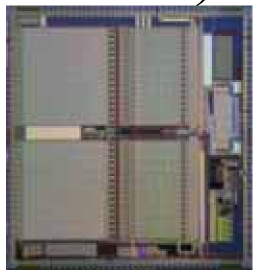
1st Generation 128ch system (Improvement for clinical use)

■Abdomen unit

→ Integrated into head unit

Smaller system can decrease various risks.

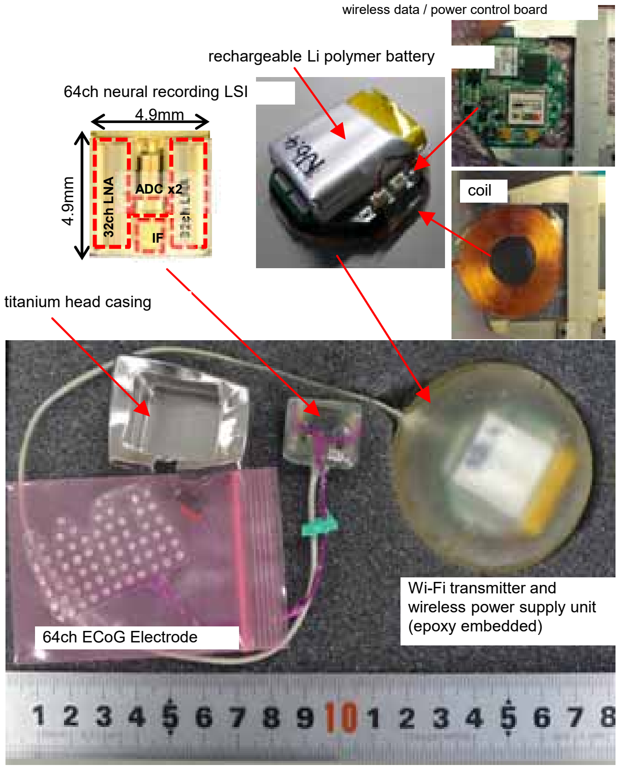




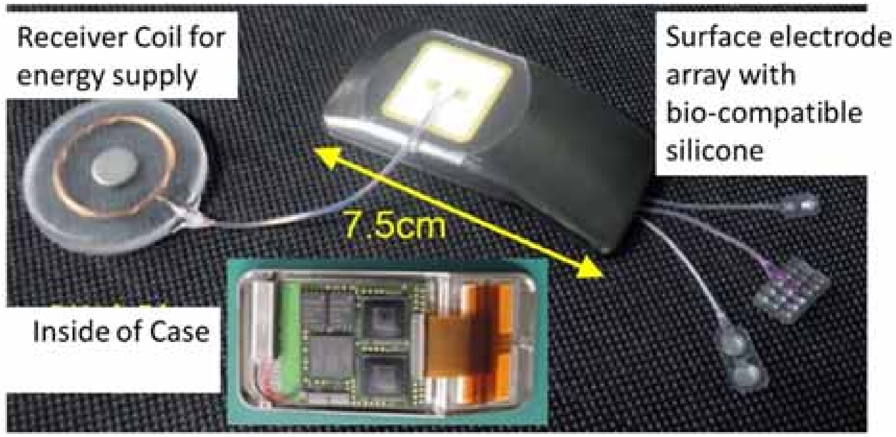
TSMC CMOS 0.25µm (7.1mm×7.3mm)

- LSI improvement

→ Lower noise, safety, etc.

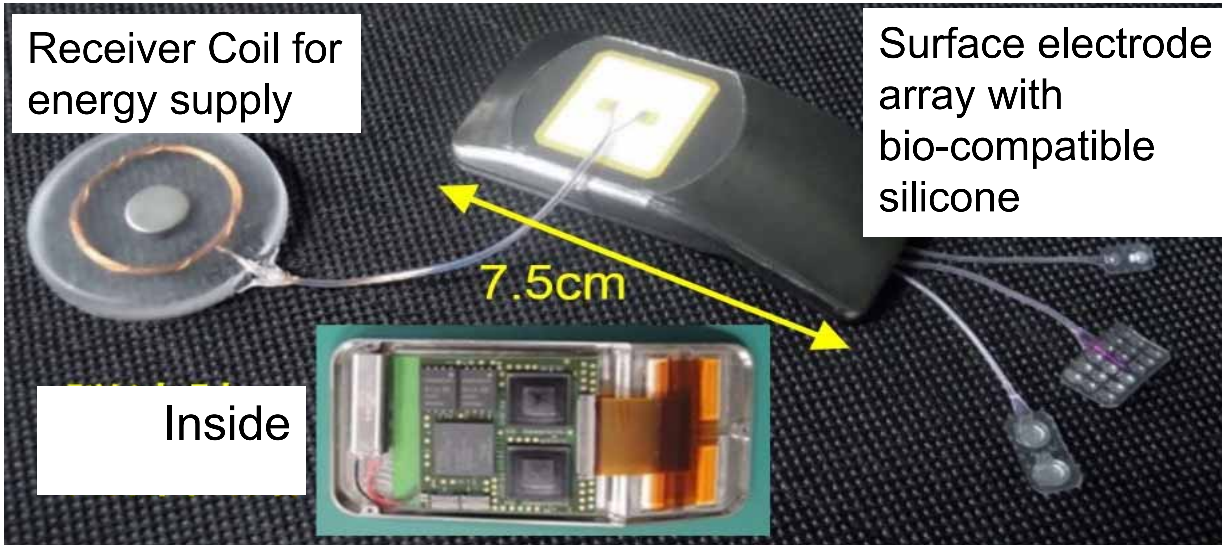


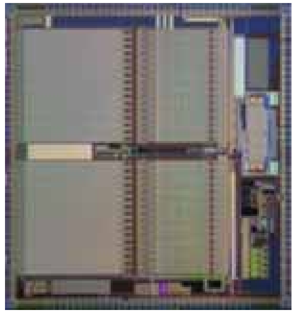
Prototype 64/128ch system six months in a monkey (2013)



Current version:
Casing, non-touch energy supply

1st Generation 128ch system (Improvement for clinical use)

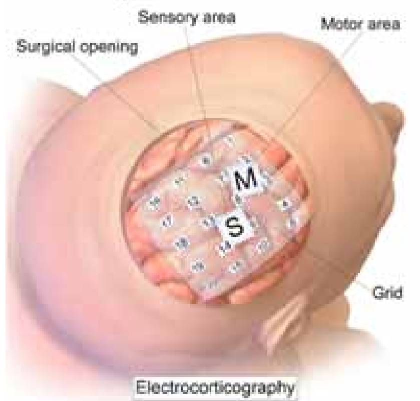


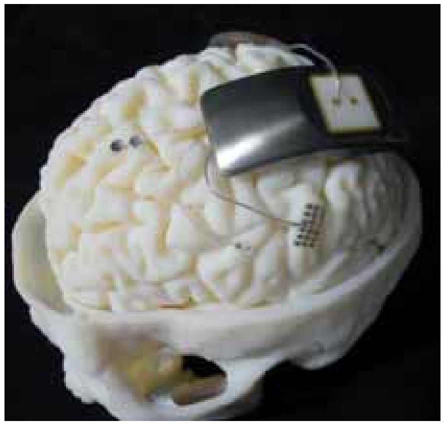


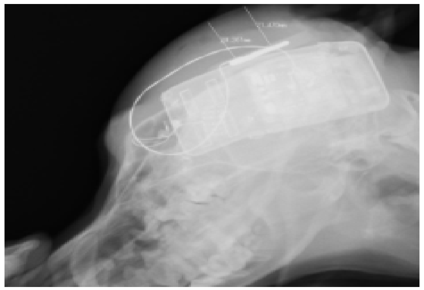
TSMC CMOS 0.25μm (7.1mm✕7.3mm)
- -32ch x 4chips
- -Noise (input) 3μVpp
- -Capable of High-γ band recording

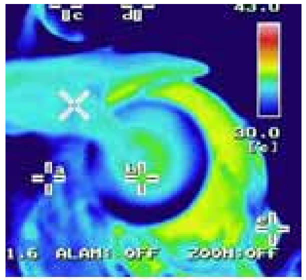
Wireless transmitter (2.4 GHz ISM Band) ～ 1.9Mbps

- GLP test (bio-compatiblilty)
- Implant test (animal)









2nd generation ECoG BMIsystem

- 4096ch〜 (# of electrodes)
- UWB band (7.9GHz)
- Clinical test in 2030?
- Robot arm control
  for Paralysis
  with individual finger control

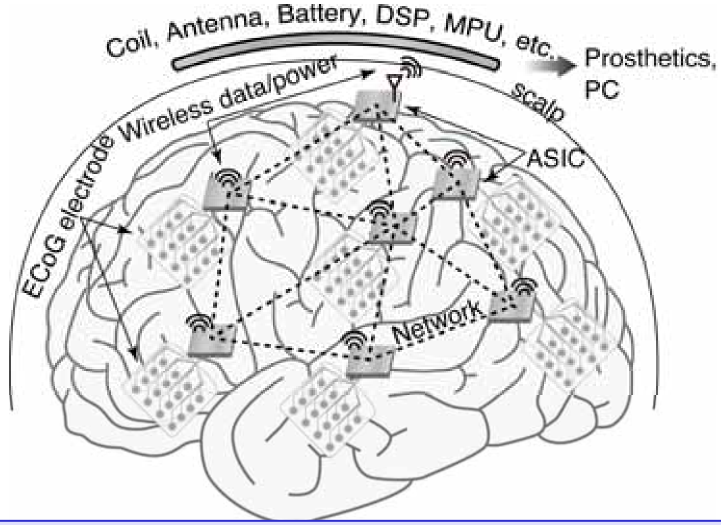
Next generation multi-channel BMI system more than 4,000 channels

For more accurate estimation of movement intentions

- a large number of recording channels
- recording at several regions simultaneously

Our target

implantable, distributed, and wireless



Issue of multi-channel system: volume of data

ex. ECoG, 1kS/s, 12bit-ADC

⇒ ~1Mbps@100ch, **~100Mbps@10,000ch**

Improvement for next generation (128ch-> 4096ch)

Issues to be solved

(1): High density electrode array

Silicone + Pt array

→ Parylene-C + Pt (or Au)

(2): LSI (amplifier + ADC)

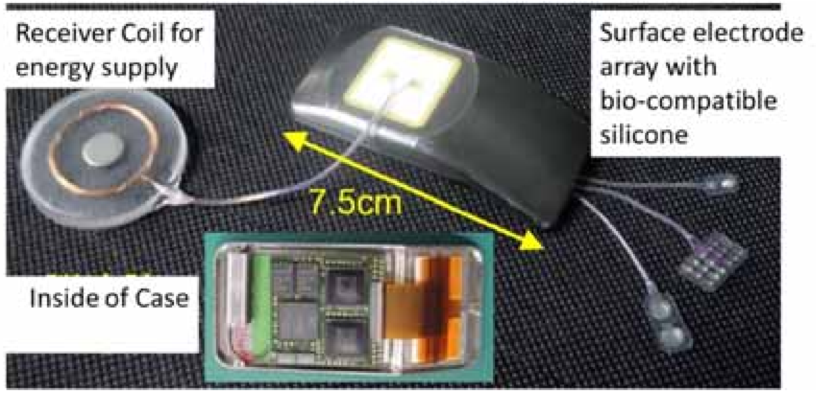
32ch x 4 chips

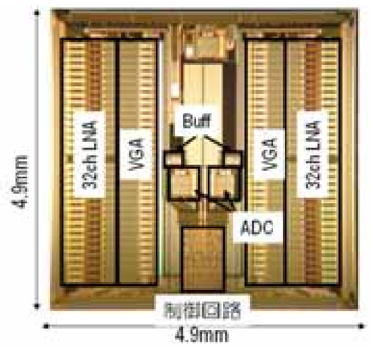
→ 64ch x 64chips

(3): Wireless transmitting

ISM (1.9Mbps)

→ UWB(128Mbps)

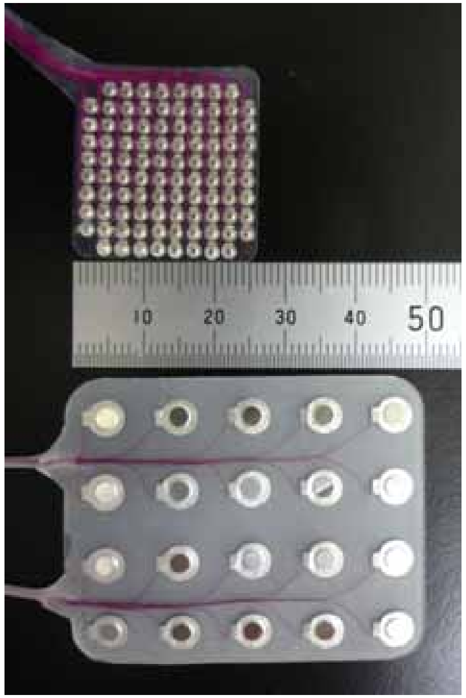




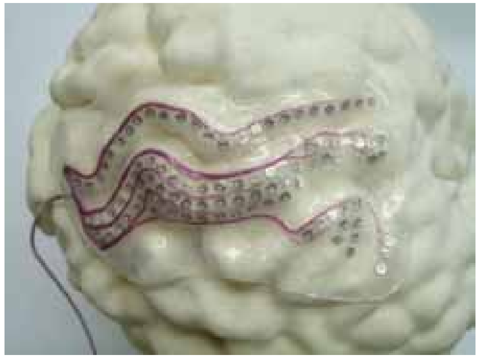
2nd Generation (4096ch ECoG-BMI system)

Flexible electrode technology

Electrode Array (Safety, High density, Stability)

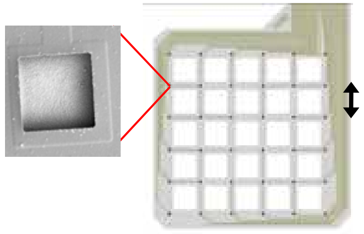


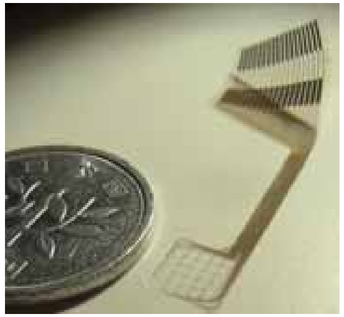
Up: High Density
(IED: 2.5mm)
Down:Clinical



3D-shape
Individutl MRI Data
1st Generation

3D-double surface
for intra-sulcus





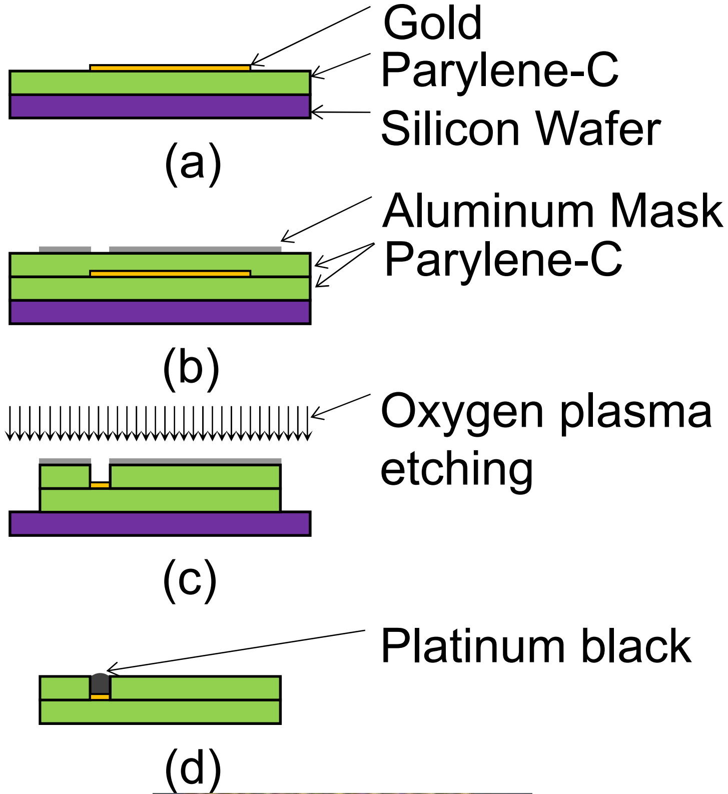
Flexible electrode array

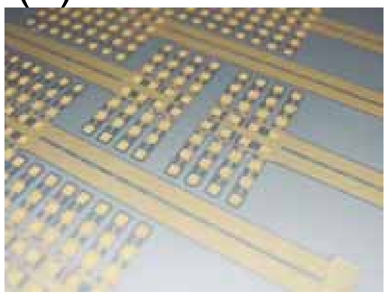
- Parylene-C、 High Density: IED 50μm
- Relationship between intracortical and ECOG signal

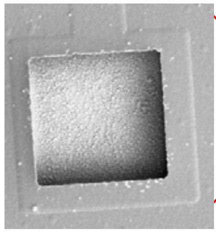
2nd Generation

(Hirata M, IEICE Trans Commun, 2011)

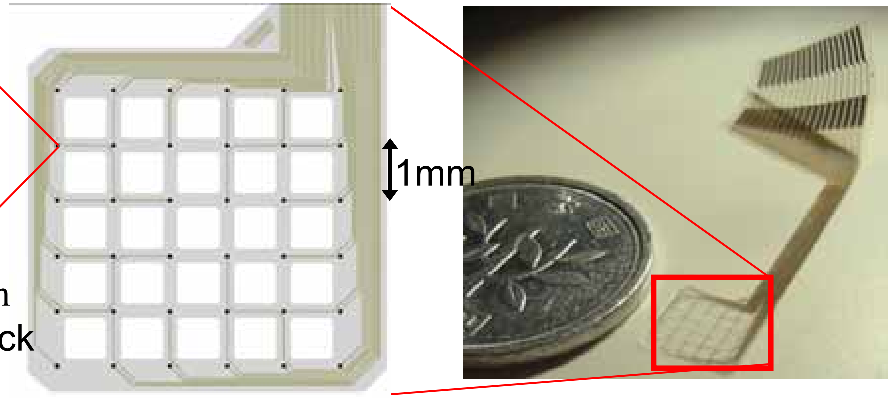
Flexible Electrode array for ECoG



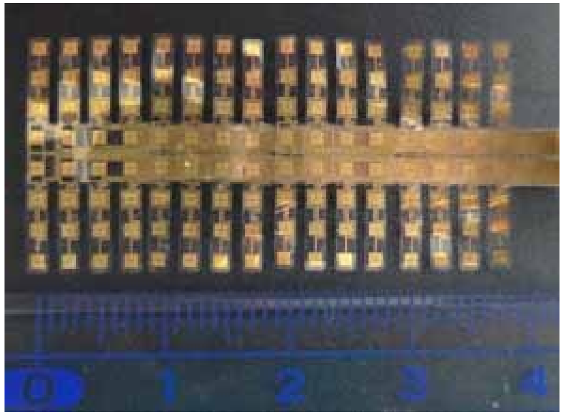


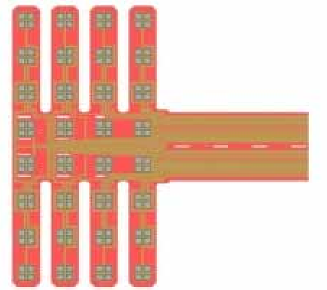


- 50μm x 50μm
- Platinum black



Toda, Neuroimage(2011)





Monkey128ch
- \> 2.5 years
- into sulcus

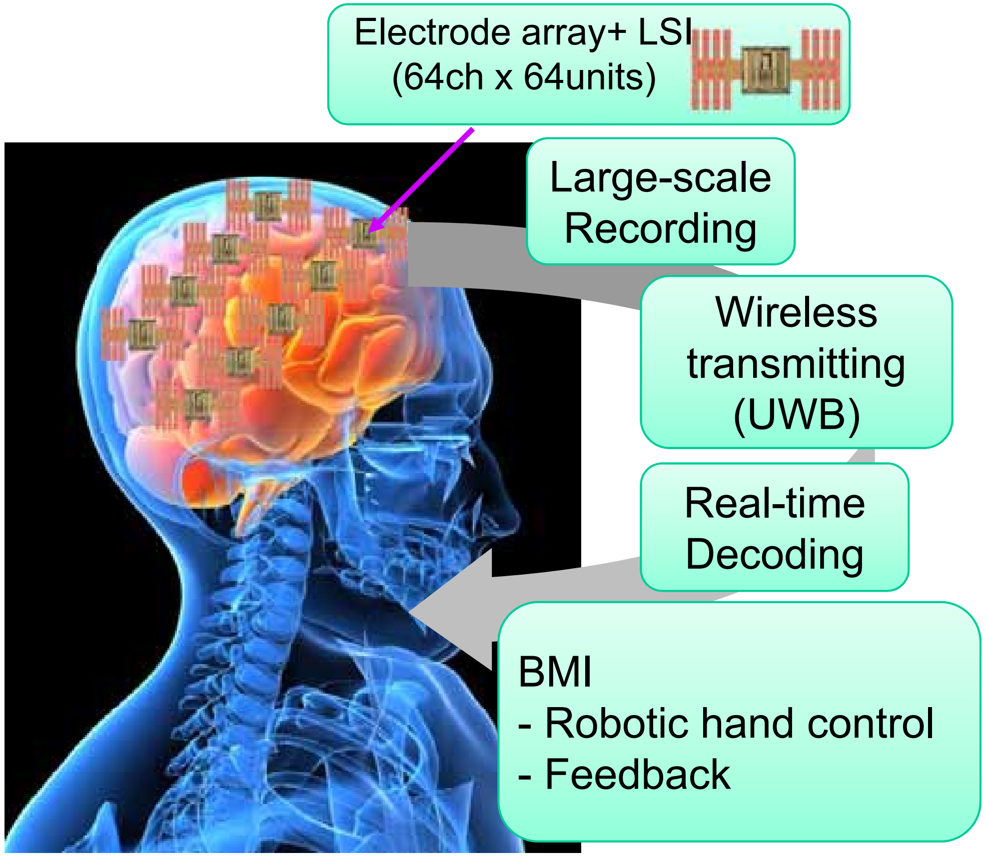
(Hasegawa Lab, Niigata Univ.)

2nd Generation (4096ch ECoG-BMI system)

Wireless technology

⇒UWB(Ultra-Wide Band)

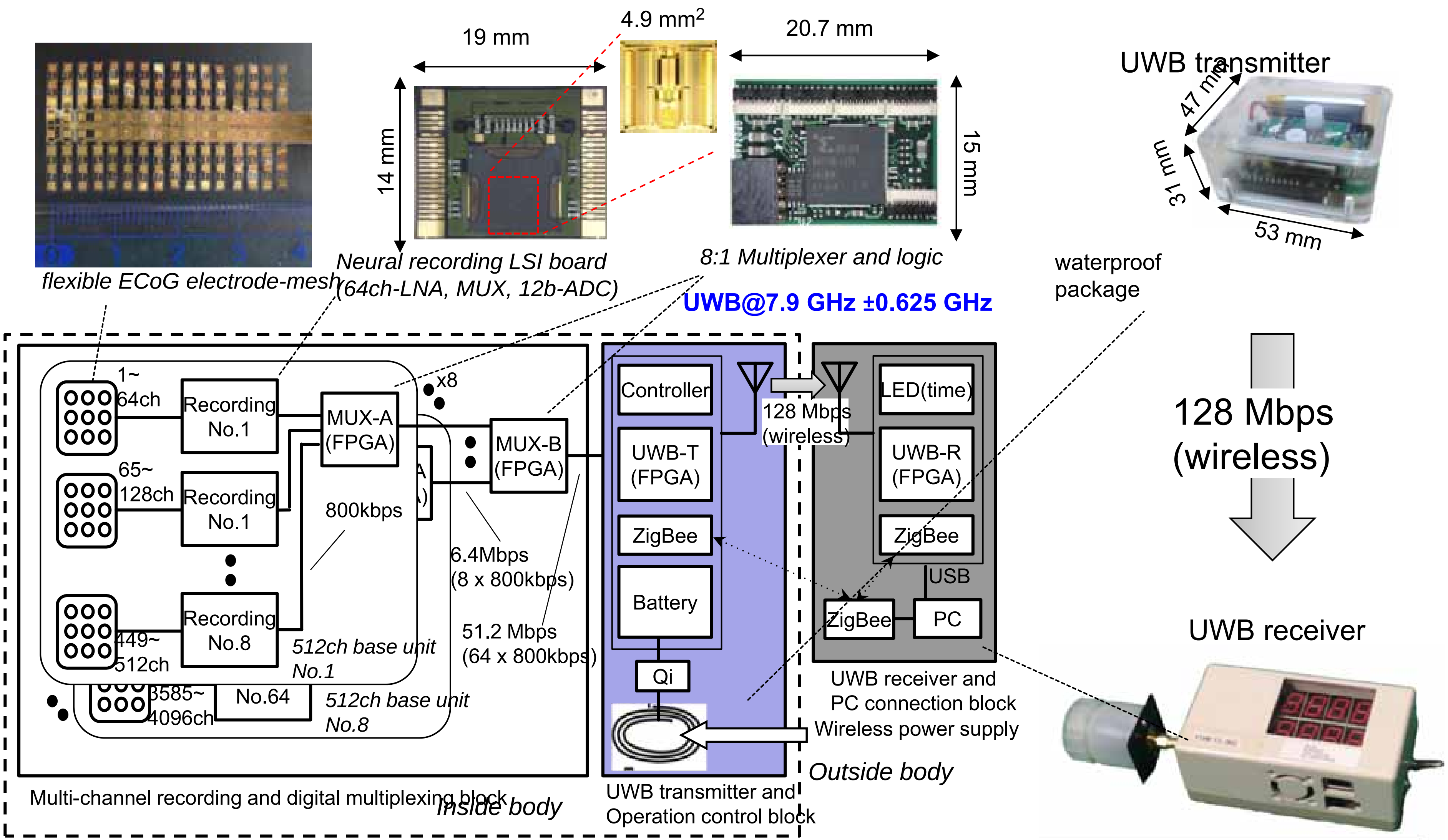
Super multi-channel system using UWB(4096ch～)



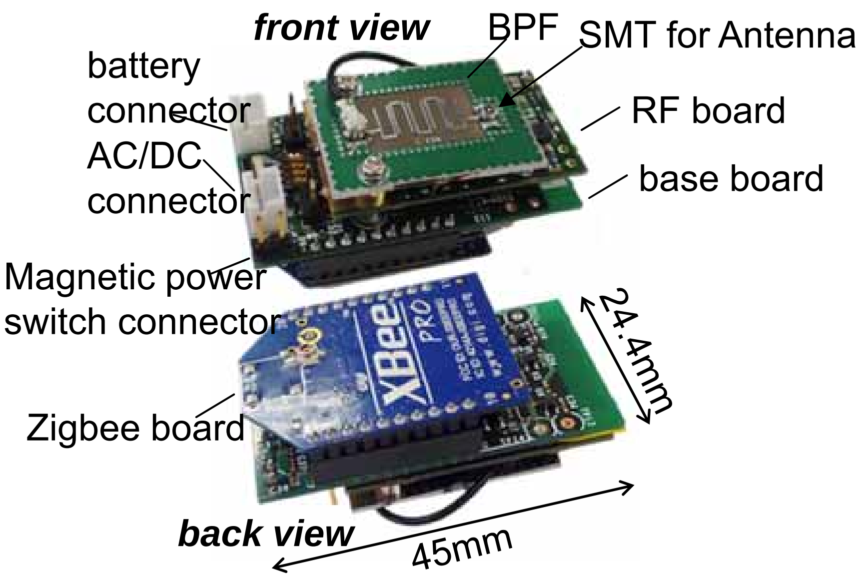
1st Generation (128ch)
-ISM band (2.4GHz) [1.9Mbps]
12bit x 1kHz x 128ch
= 1.5 Mbps

2nd Generation (>4000ch)
12bit x 1kHz x 4096ch
= 49Mbps → UWB
(Ultra Wide Band)
+ Distributed system

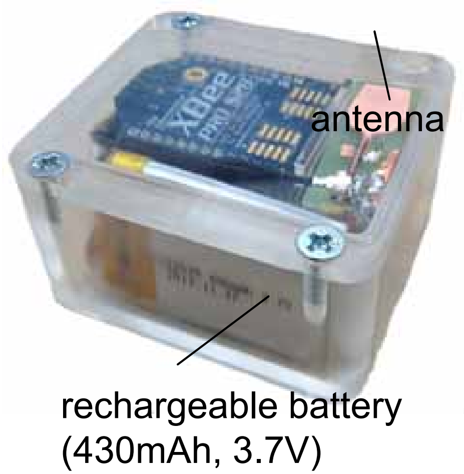
UWB system (4096ch) -Prototype-

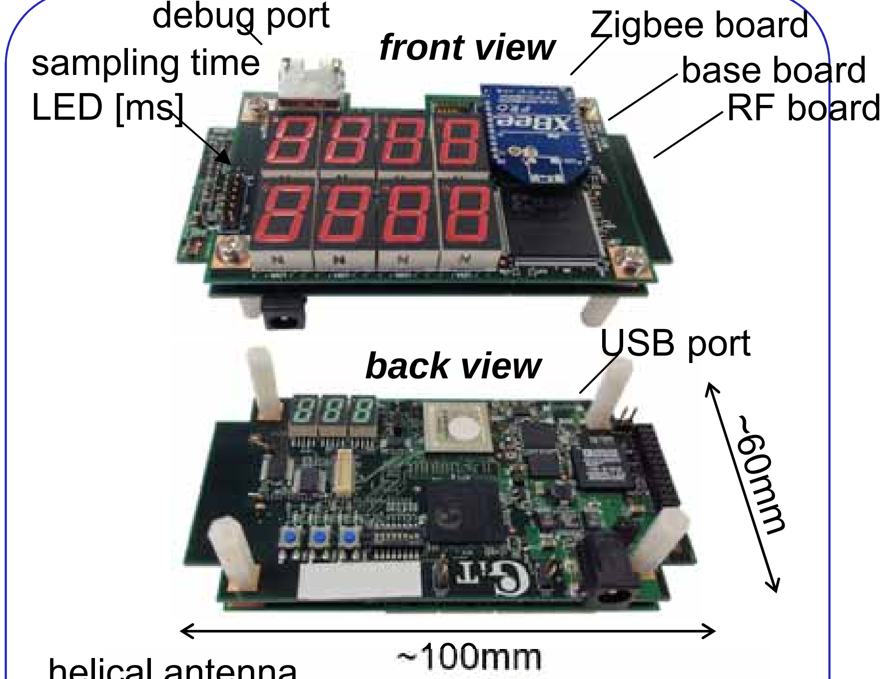


UWB transmitter and receiver



Including UWB transmitter, BPF, antenna, Zigbee, Li-ion polymer battery





-Including UWB receiver, antenna, Zigbee unit

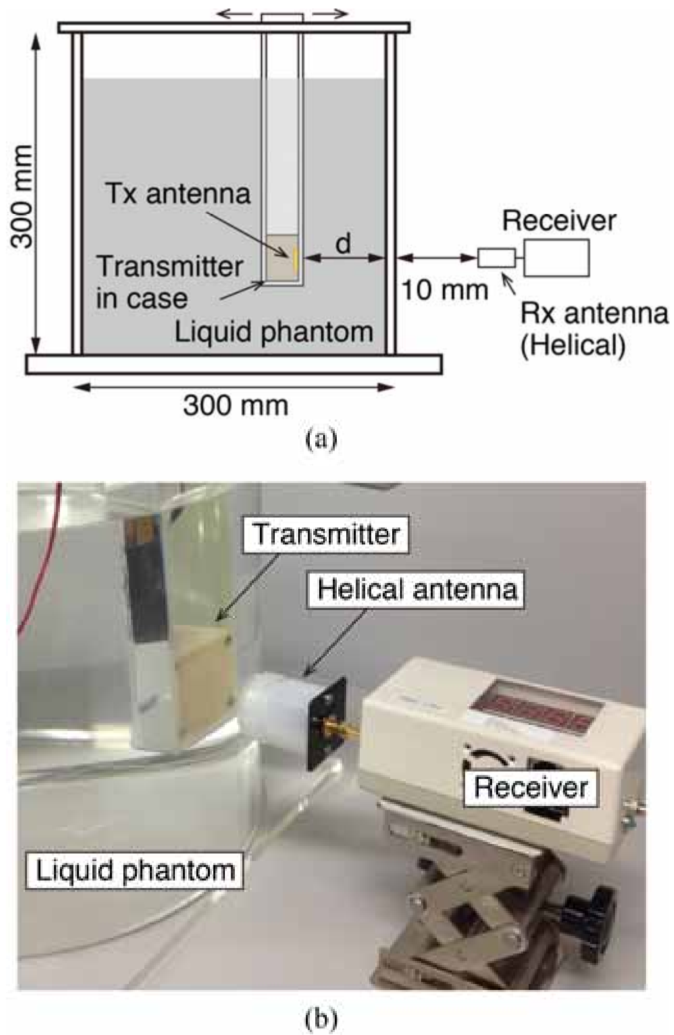
-Connected to PC by USB2.0

-Real-time Graphical view

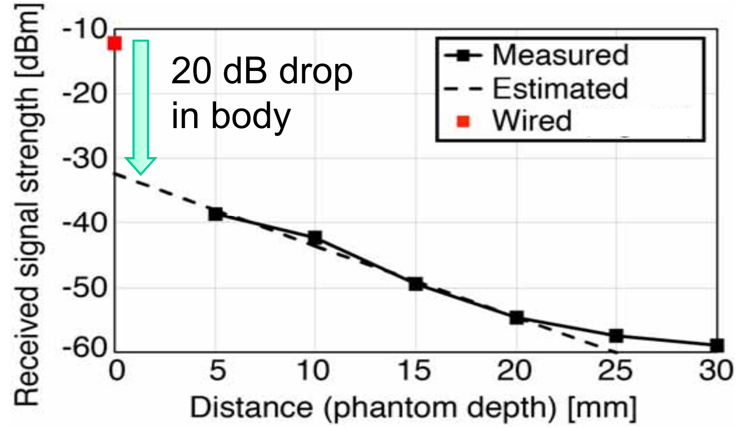
UWB system (Specification)

Number of channels	64~4096	ch	
Supply voltage	3.3	V	
Total power of implant devices	2.03	W	@4096ch (version 2014)
UWB bandwidth	7.275~8.525	GHz	for internationally usage
UWB data rate	128	Mbps	
MUX-A and MUX-B (common hardware)			
Xilinx Spartan6 XC6SLX16, FPC connector (11pin)			
UWB transmitter (water proof casing)			
RF, BPF and ZigBee board			
LVDS receiver (51.2Mbps), Magnetic Power SW (20mm range) and rechargeable Li polymer battery (400mAh)			
UWB receiver			
RF board, base board (Xilinx vertex4, USB2.0) and Zigbee board			
PC			
Core i7 3820 Win7 (USB2.0, GUI application)			

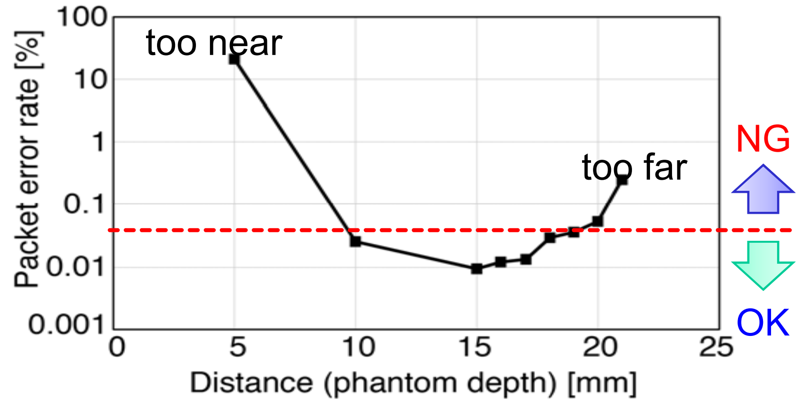
Evaluation of UWB in human equivalent liquid phantom



(a) Diagram and (b) photograph of the measurement setup.



Measured characteristics of received signal strength.



Packet error rate with respect to the phantom depth.

128 Mbps UWB wireless communication is available below 20 mm between inside to outside body.

Summary

Our collaborative project 1st and 2nd generation of ECoG BMI are introduced.

Medical applications will need
high speed (100Mbps〜) and secure
wireless communication.

Thank you for your attention