Miniature Electromagnetic Sensor Nodes for Wireless Surgical Navigation Systems

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IMPACT Lab
Integrated Microsystems Powered with Advanced Circuit Technology

KAIST

Outline

- **Introduction**
  - Surgical Navigation System
  - Previous Work
- **Design and Implementation**
  - EM Sensor Node System
  - Analog Signal Processing
  - Digital Signal Processing
  - Wireless Communication
- **Measurement Results**
  - Experimental Environment
  - Test Result
- **Conclusion**

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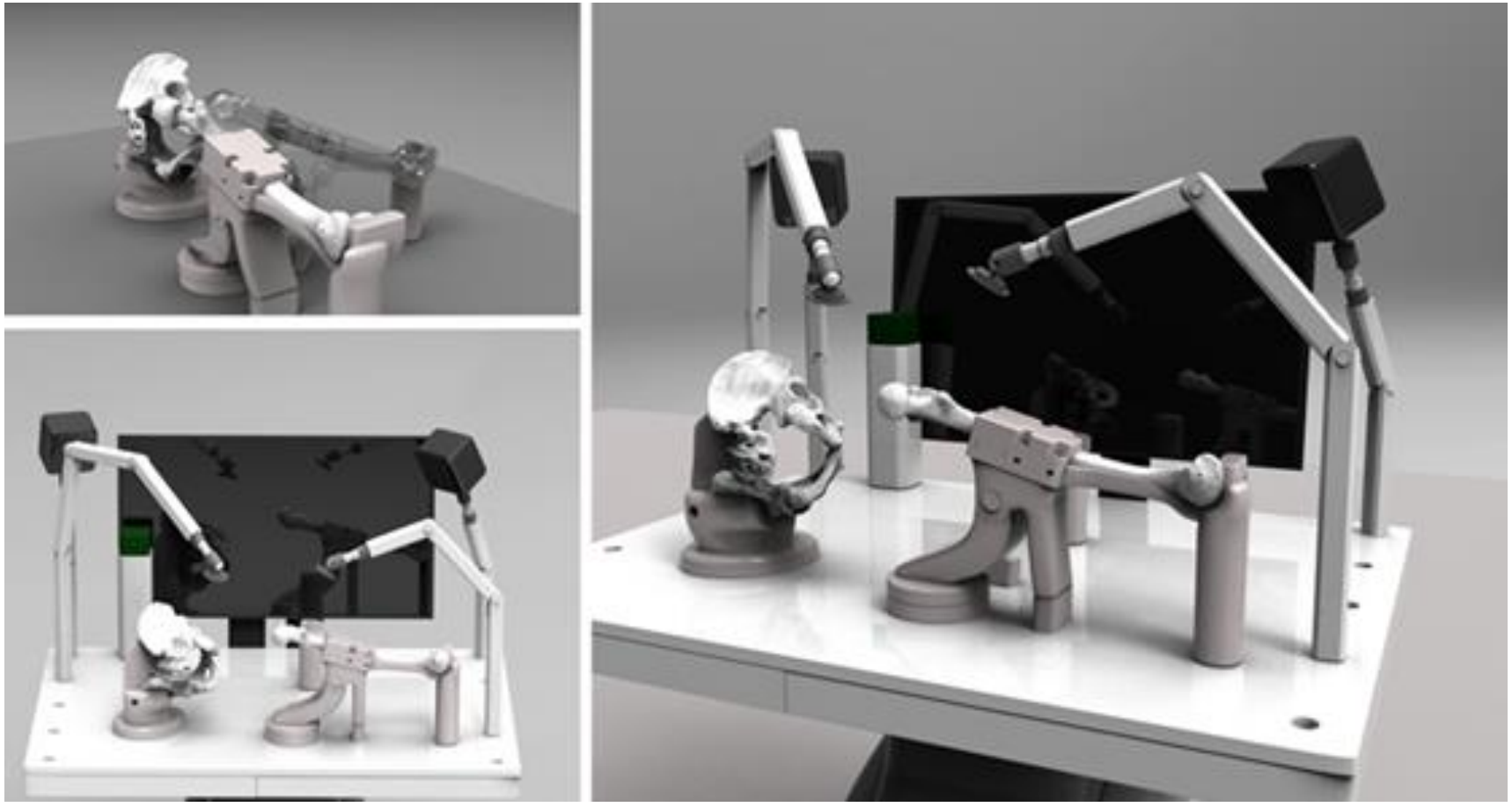
Surgical Navigation System



Previous Work

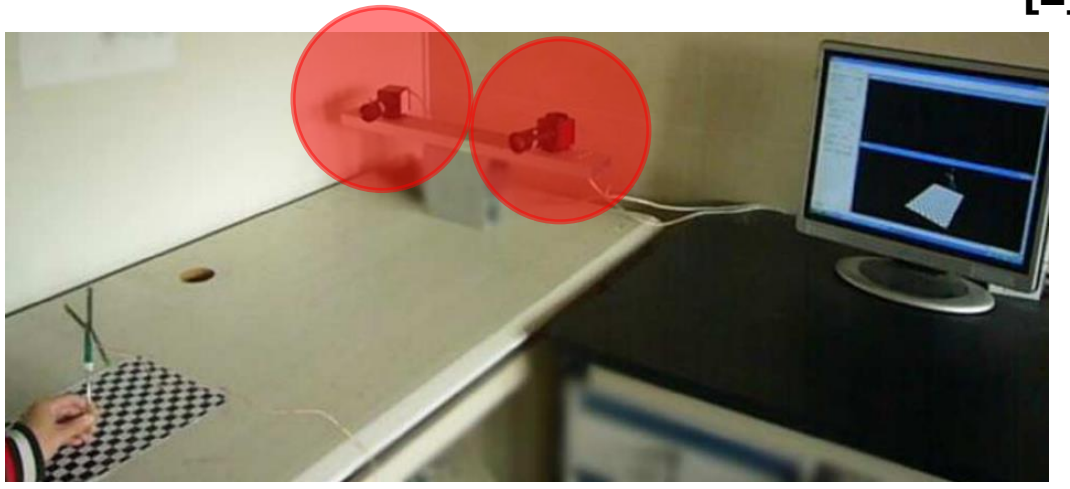
- **Infrared stereo camera tracking**

Previous Work

- **Infrared stereo camera tracking**

[1]

[2]

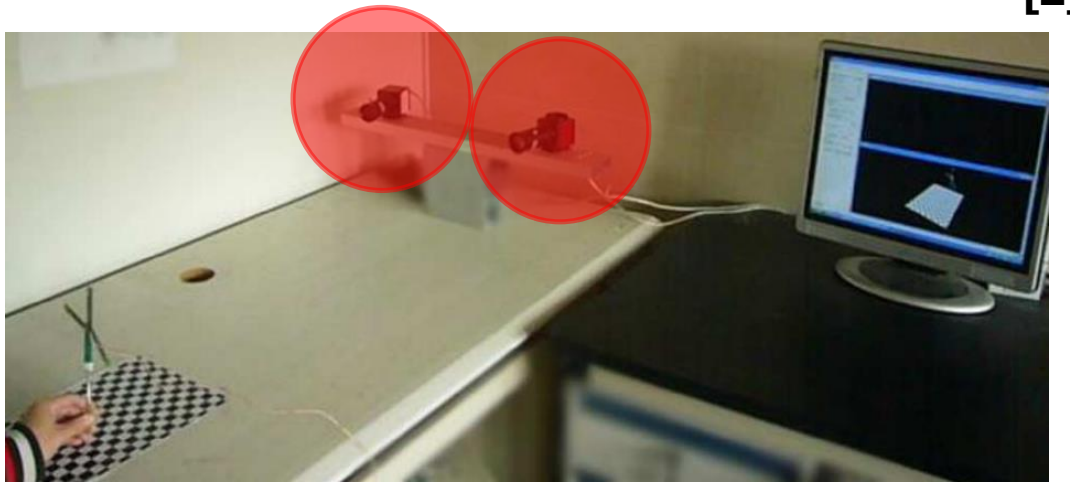


Previous Work

- **Infrared stereo camera tracking**
  - Pros
    - ➢ Used widely and proven effective

[1]

[2]

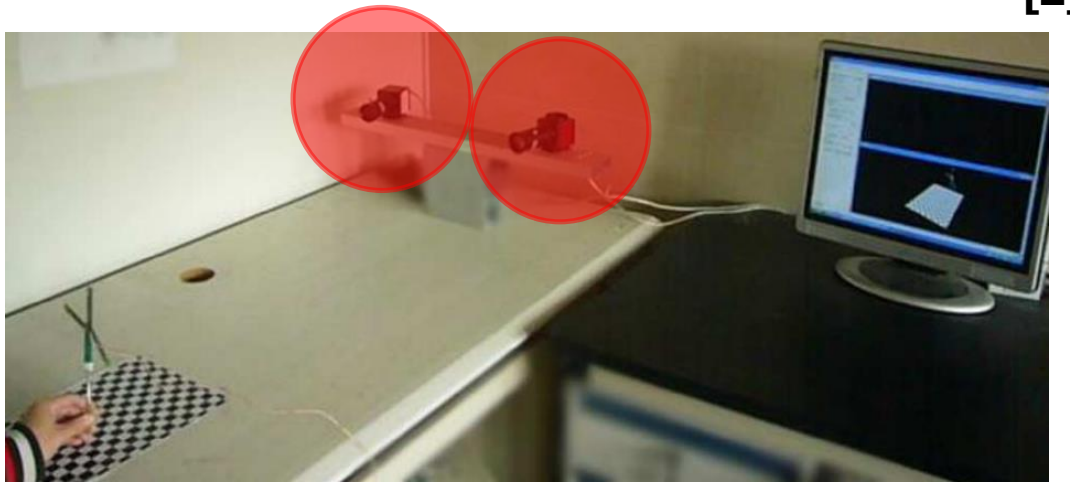


Previous Work

- **Infrared stereo camera tracking**
  - Pros
    - ➢ Used widely and proven effective
  - Cons
    - ➢ Need to secure the line of sight between the camera and markers
    - ➢ Bulky optical markers

[1]

[2]



Previous Work

- **Tracking system based on EM sensors**

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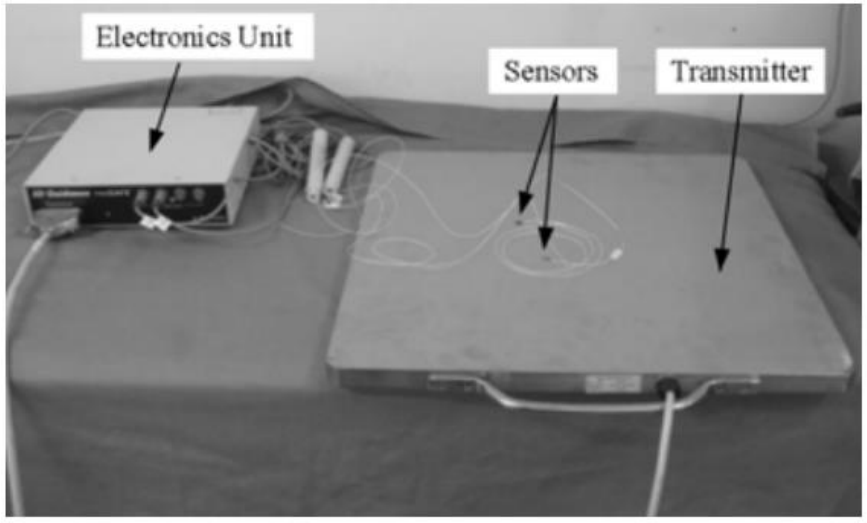
[3]



Previous Work

- **Tracking system based on EM sensors**
  - Pros
    - ➢ No need for line-of-sight

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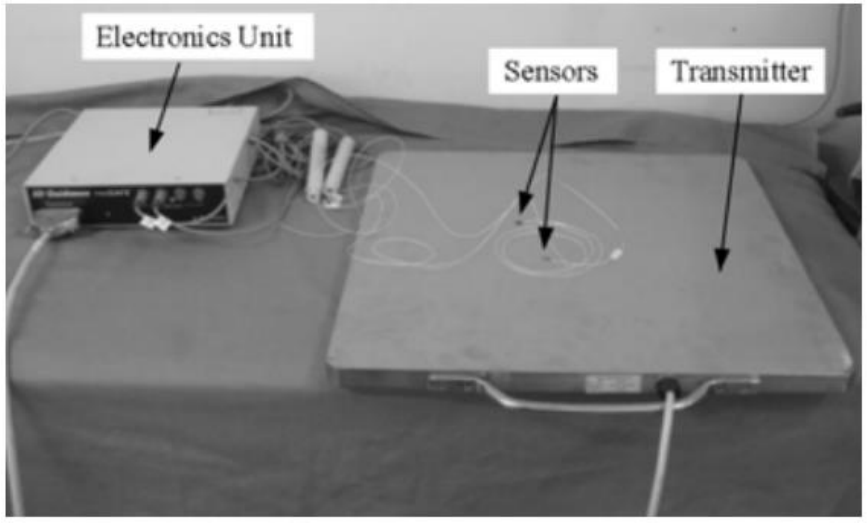
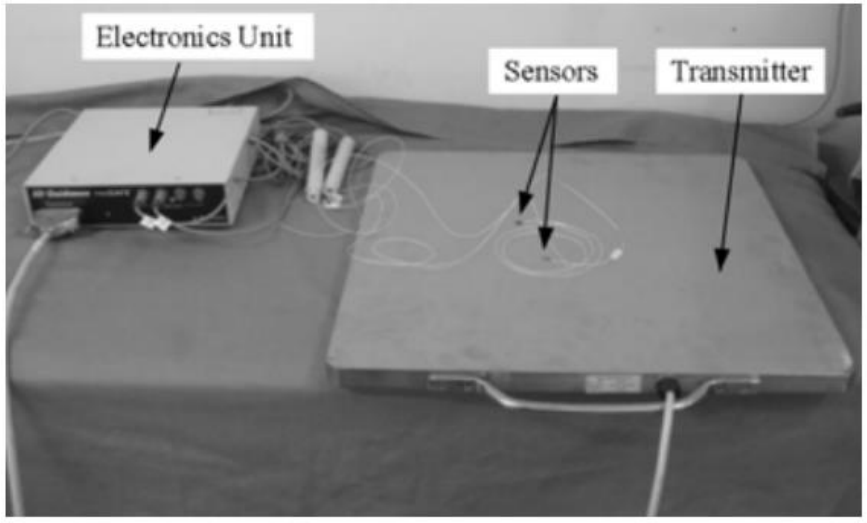


Previous Work

- **Tracking system based on EM sensors**
  - Pros
    - ➢ No need for line-of-sight
  - Cons
    - ➢ Inconvenience for surgeons, caused by wires in the wired system
    - ➢ Become more serious as the number of sensors increases

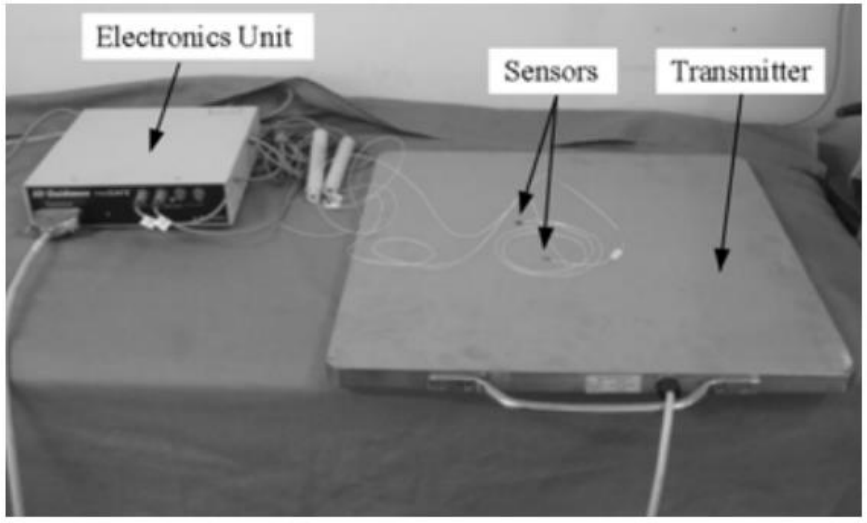
[3]



Previous Work

- **Tracking system based on EM sensors**
  - Pros
    - ➢ Not needed for line-of-sight
  - Cons
    - ➢ In wired system, Incurring inconvenience to surgeons by wires
    - ➢ As a large of sensor nodes are used, the problem is to be serious

[3]

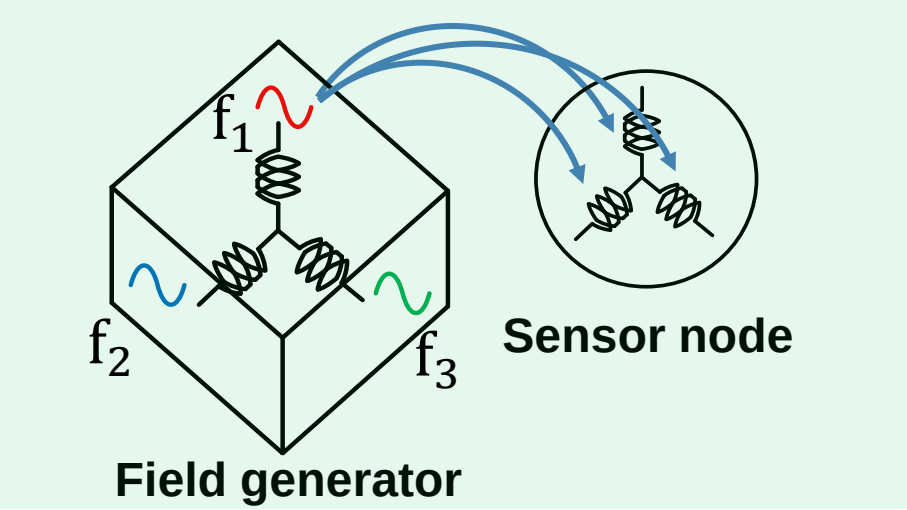


Sensor node is wireless and miniaturized !!

Previous Work

- **Tracking system based on EM sensors**

  - Structure
    - Field generator (3 coils)
    - Sensor node (3 coils)



  - Operation Principle
    - EM fields with different frequencies are generated by three coils in the field generator
    - The EM fields by the field generator
      → Electromotive forces induced to three coils in the sensor node
    - Different frequency components of the induced voltage signals
      → Position and orientation of the sensor node

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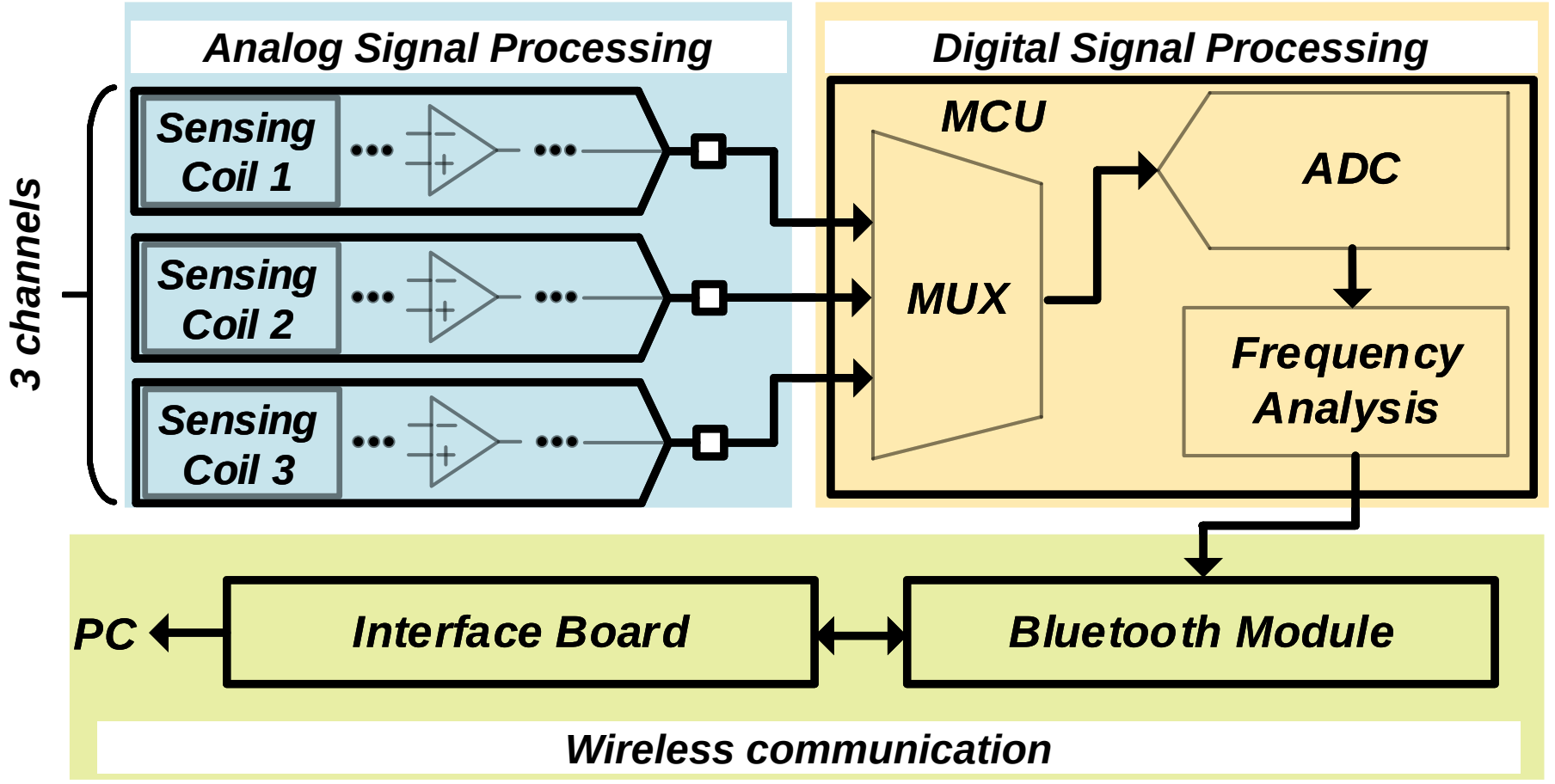
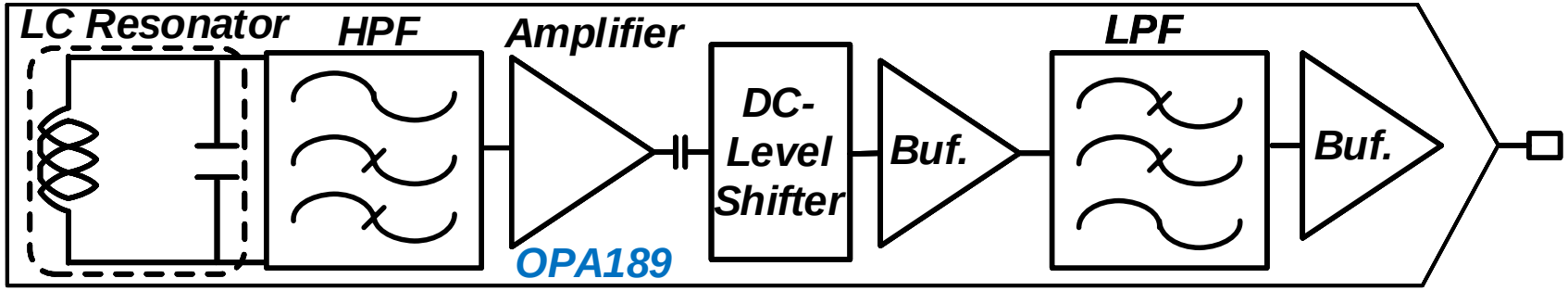
EM Sensor Node System



Analog Signal Processing



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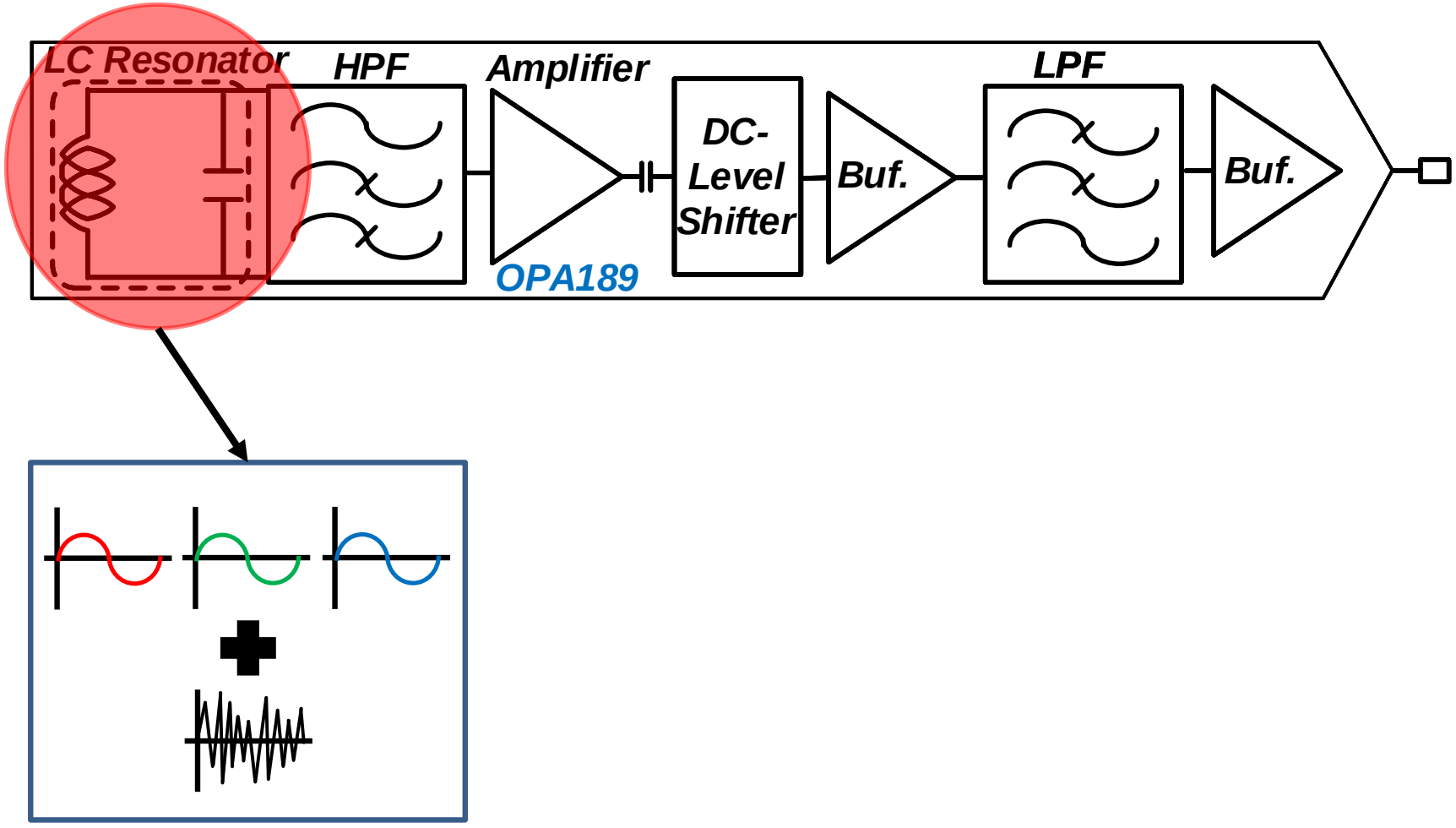

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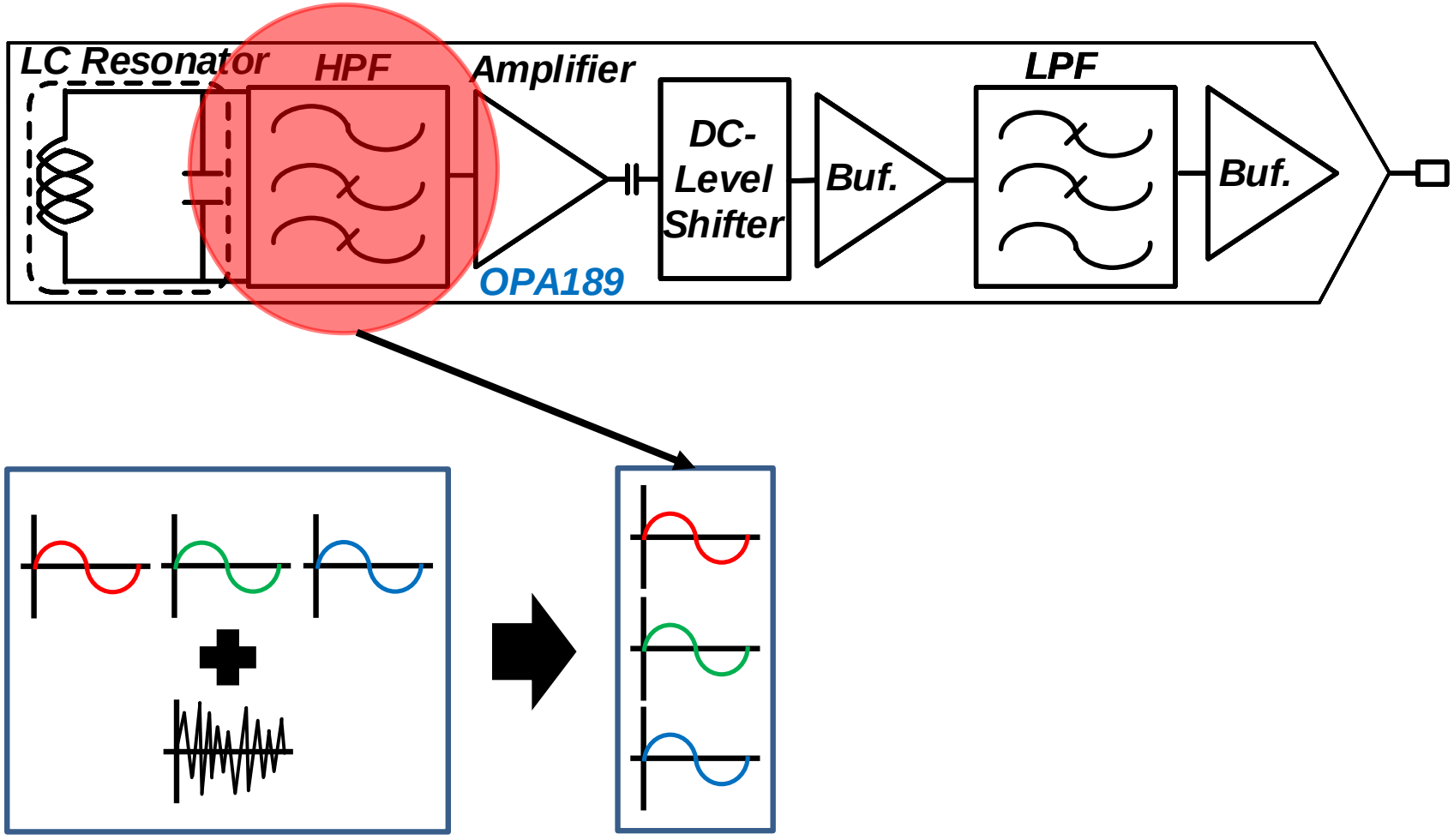

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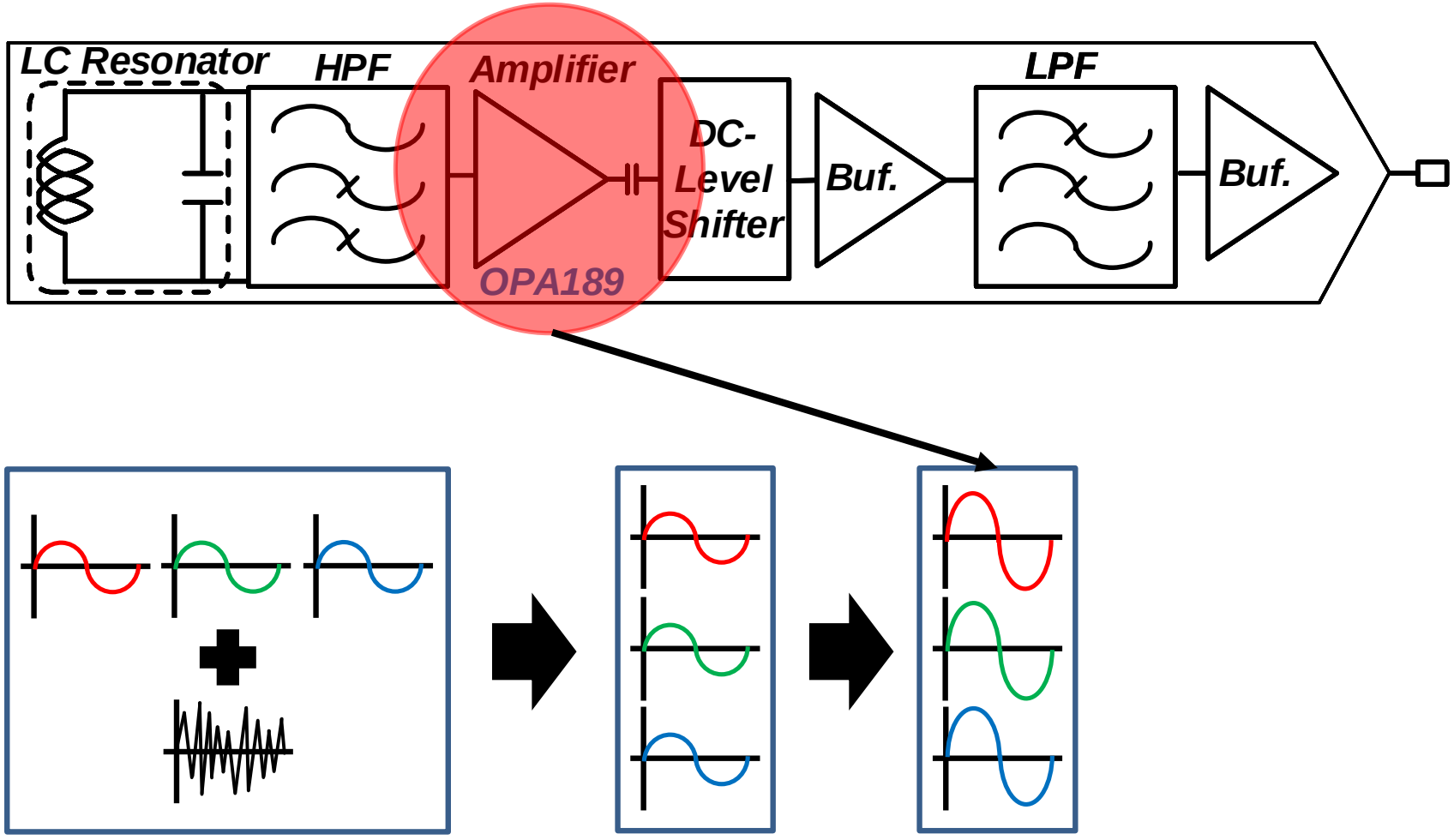

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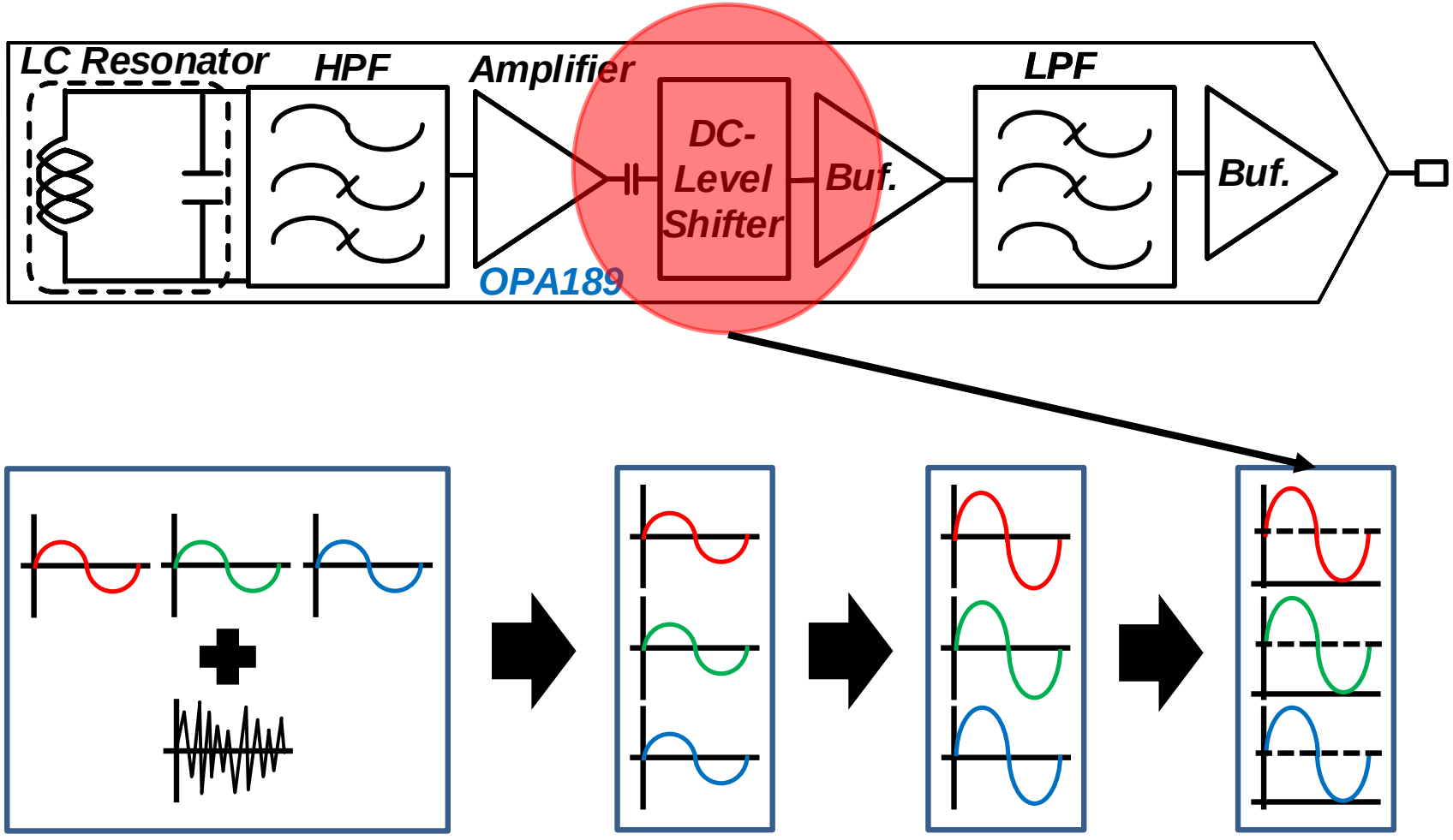

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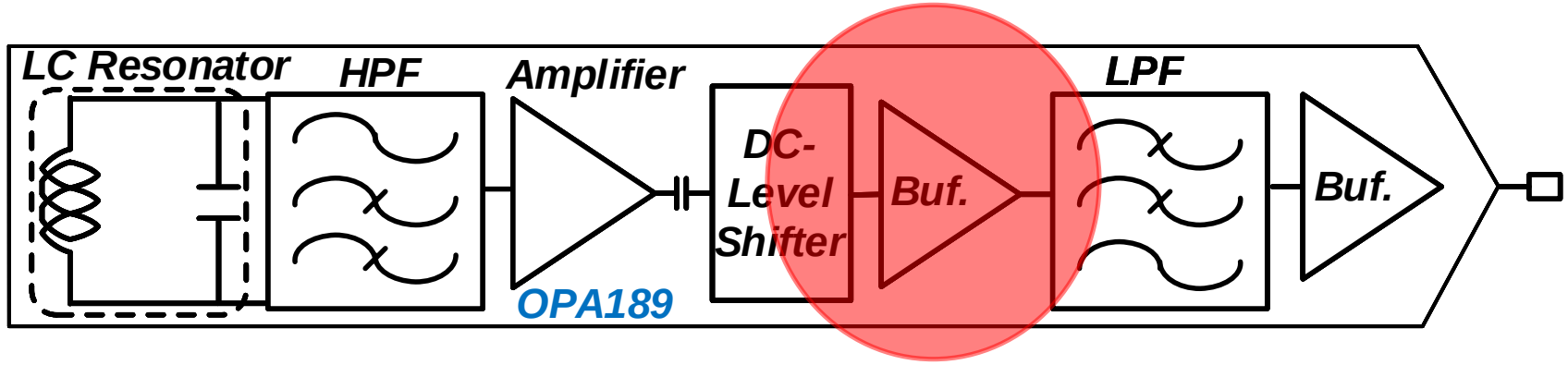

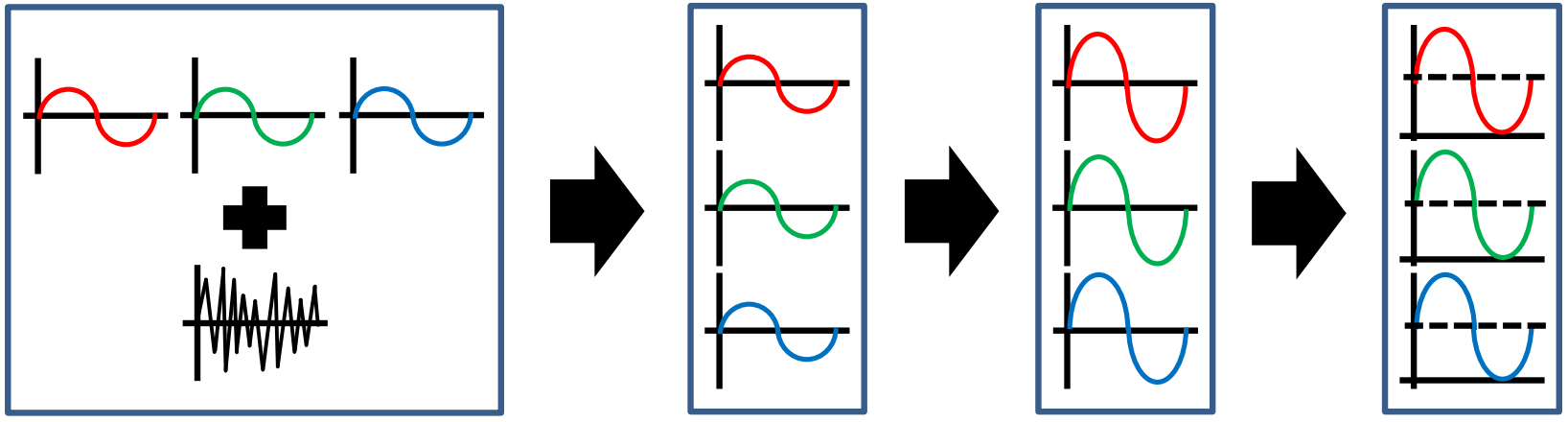

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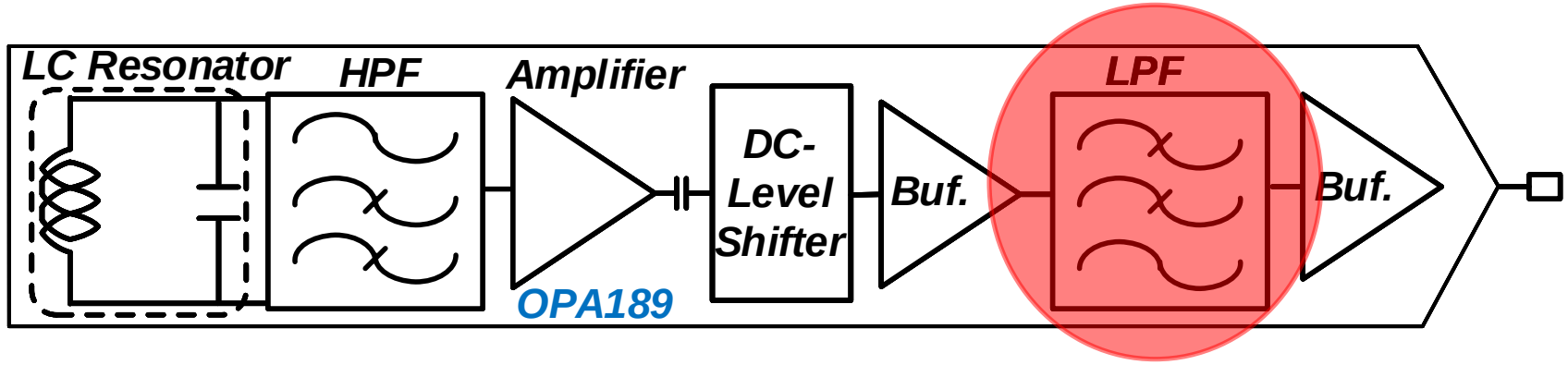

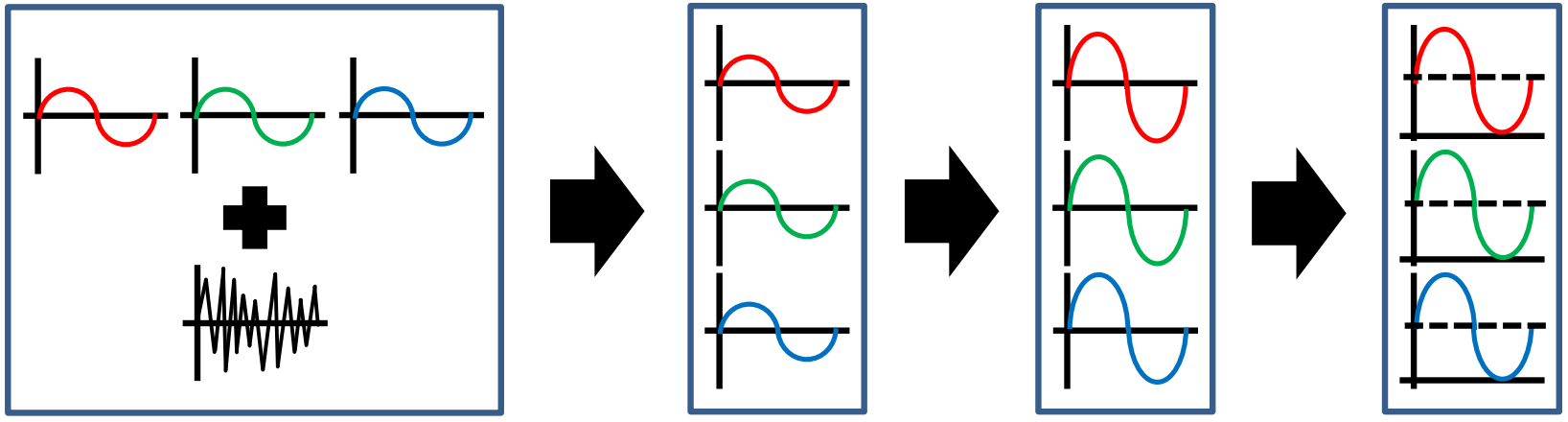

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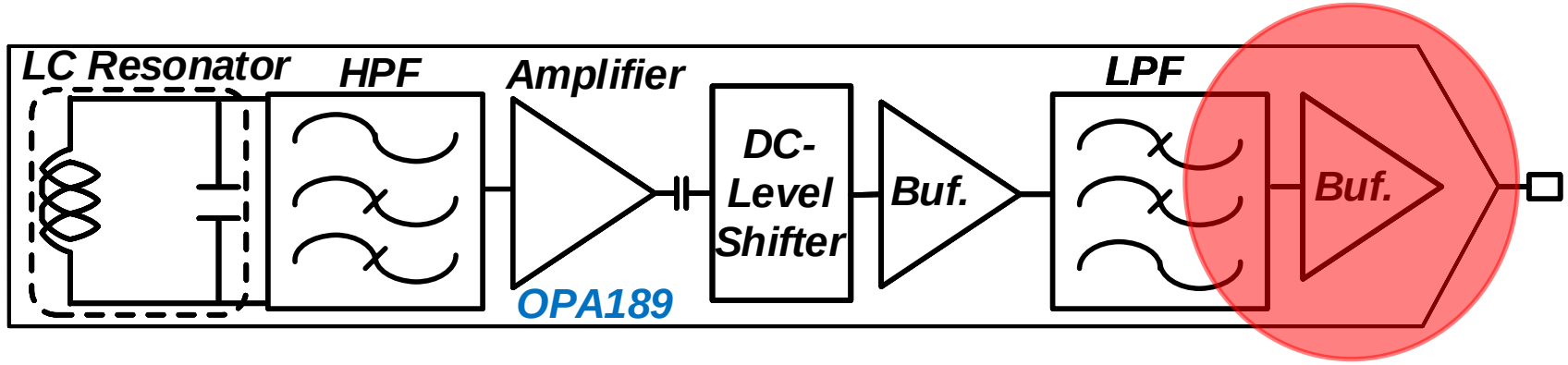
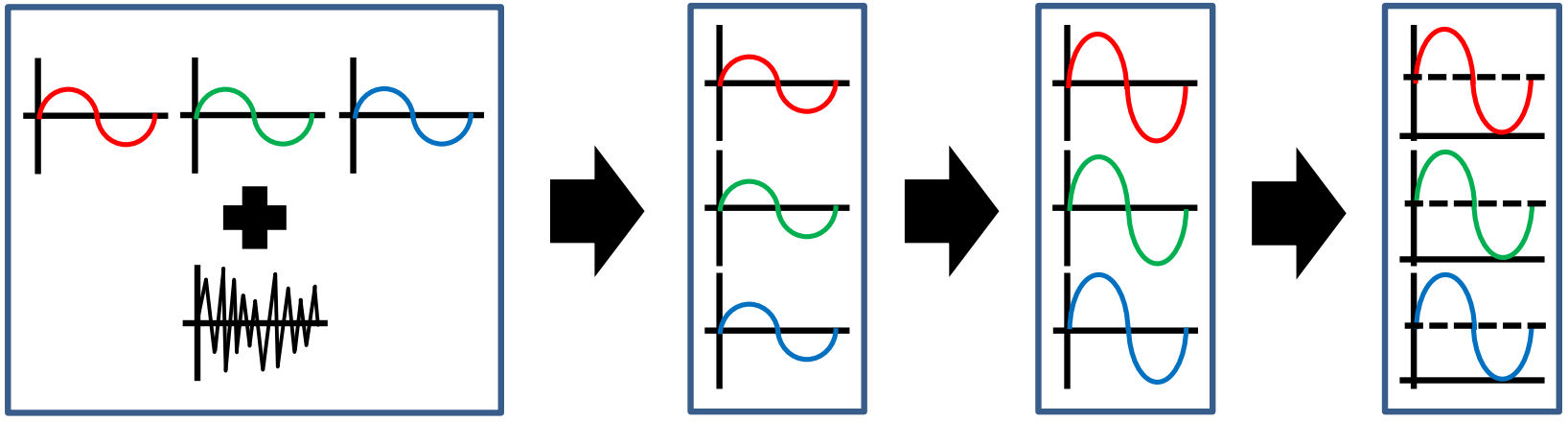
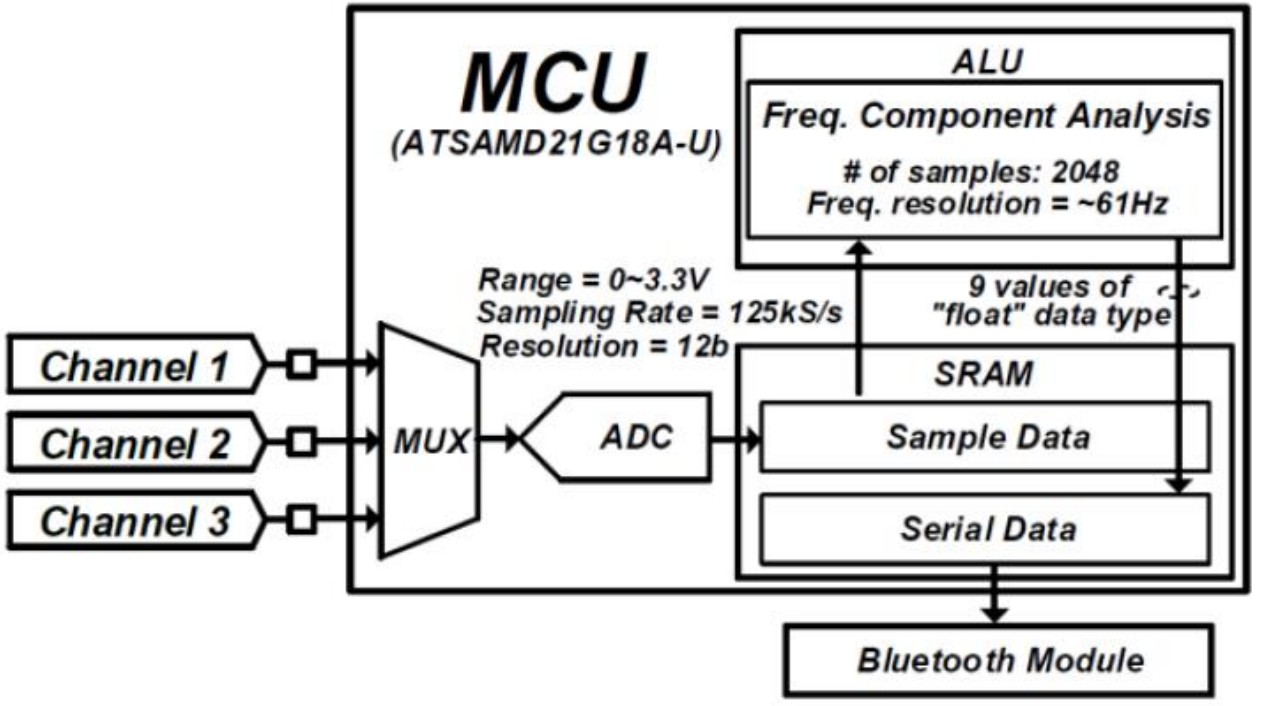




Digital Signal Processing



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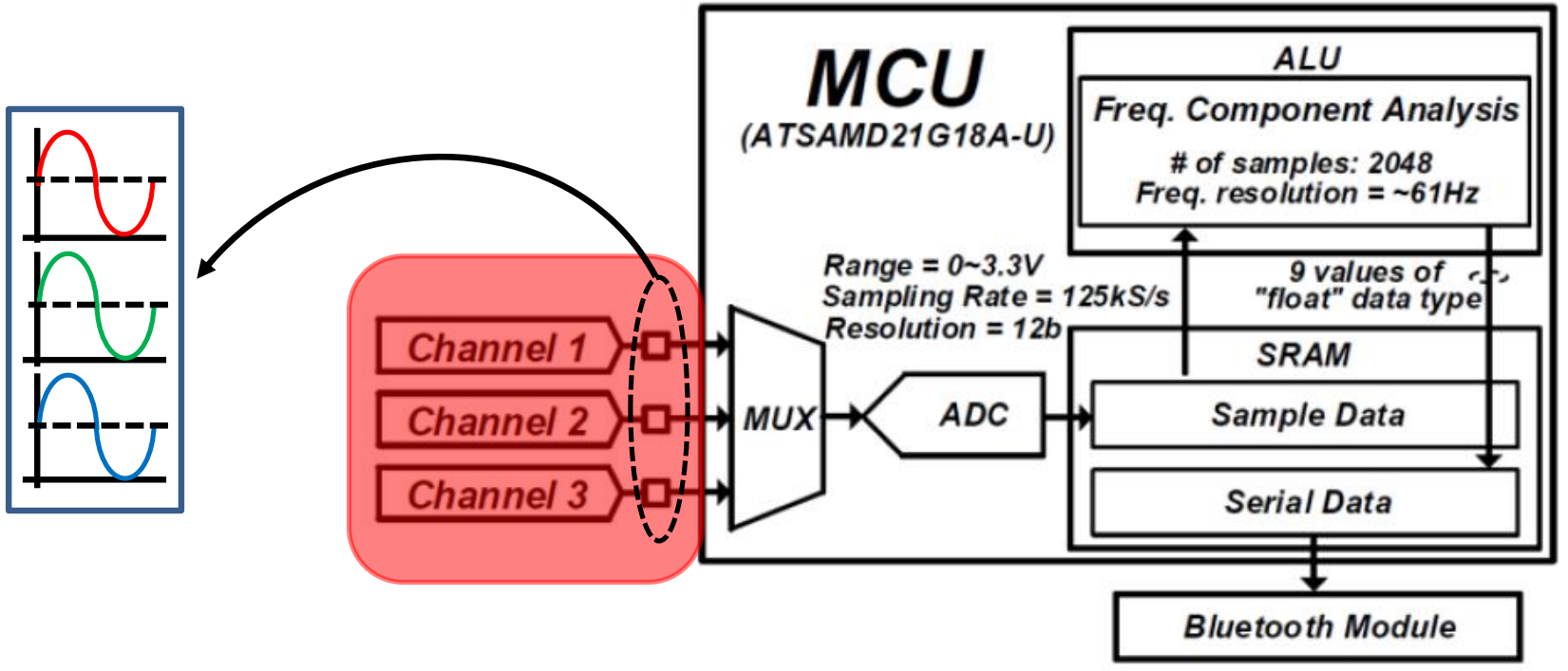

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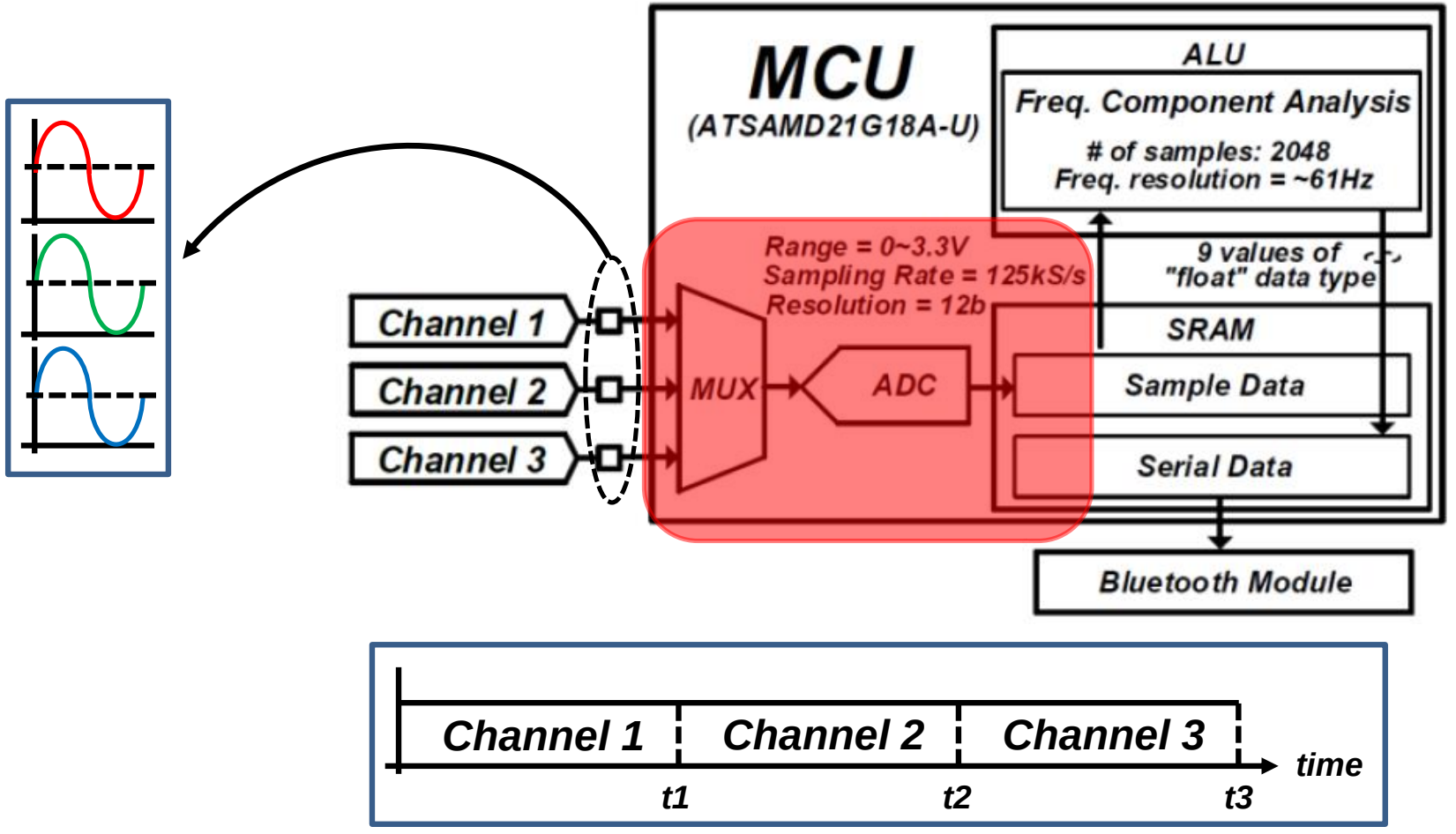

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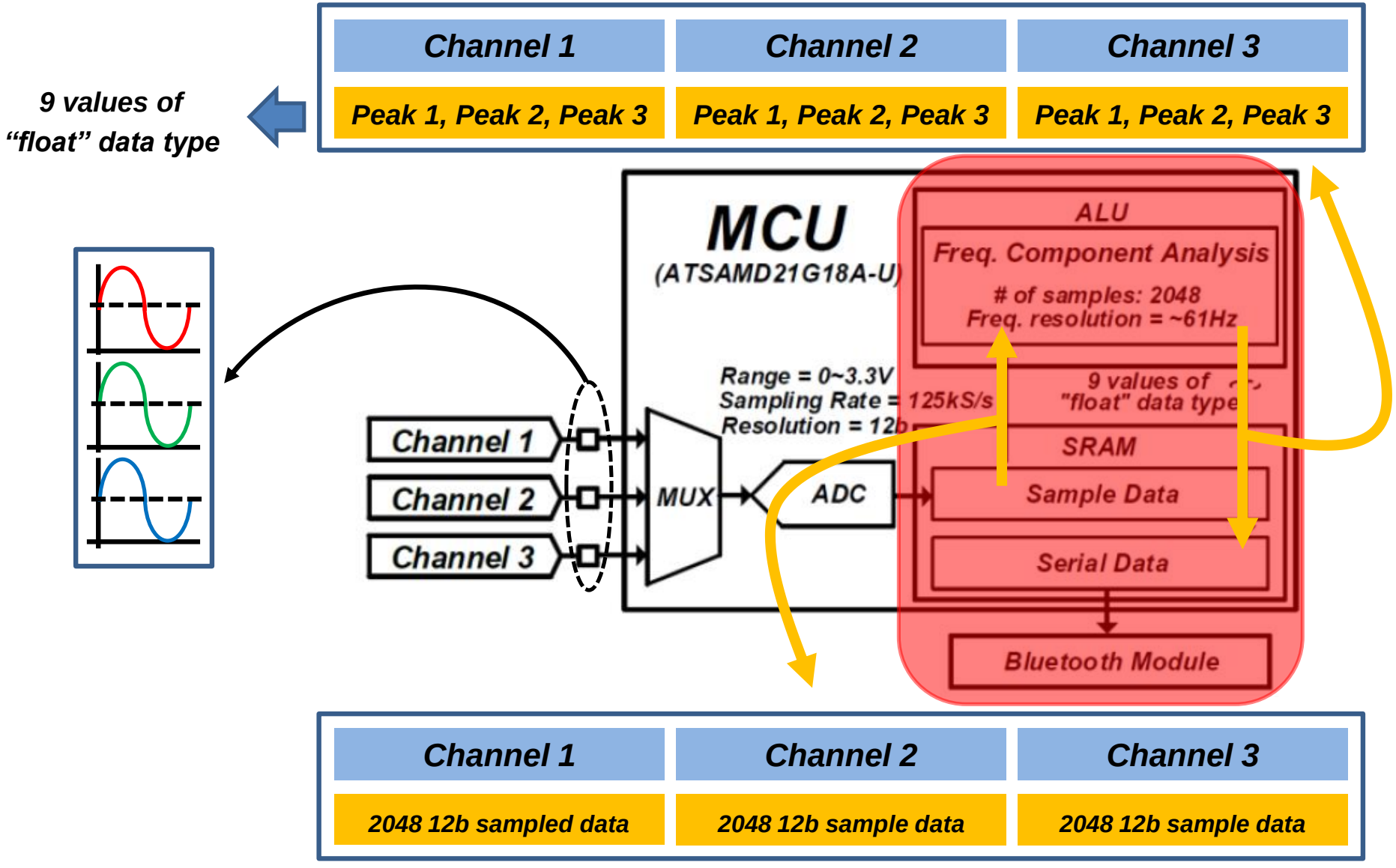
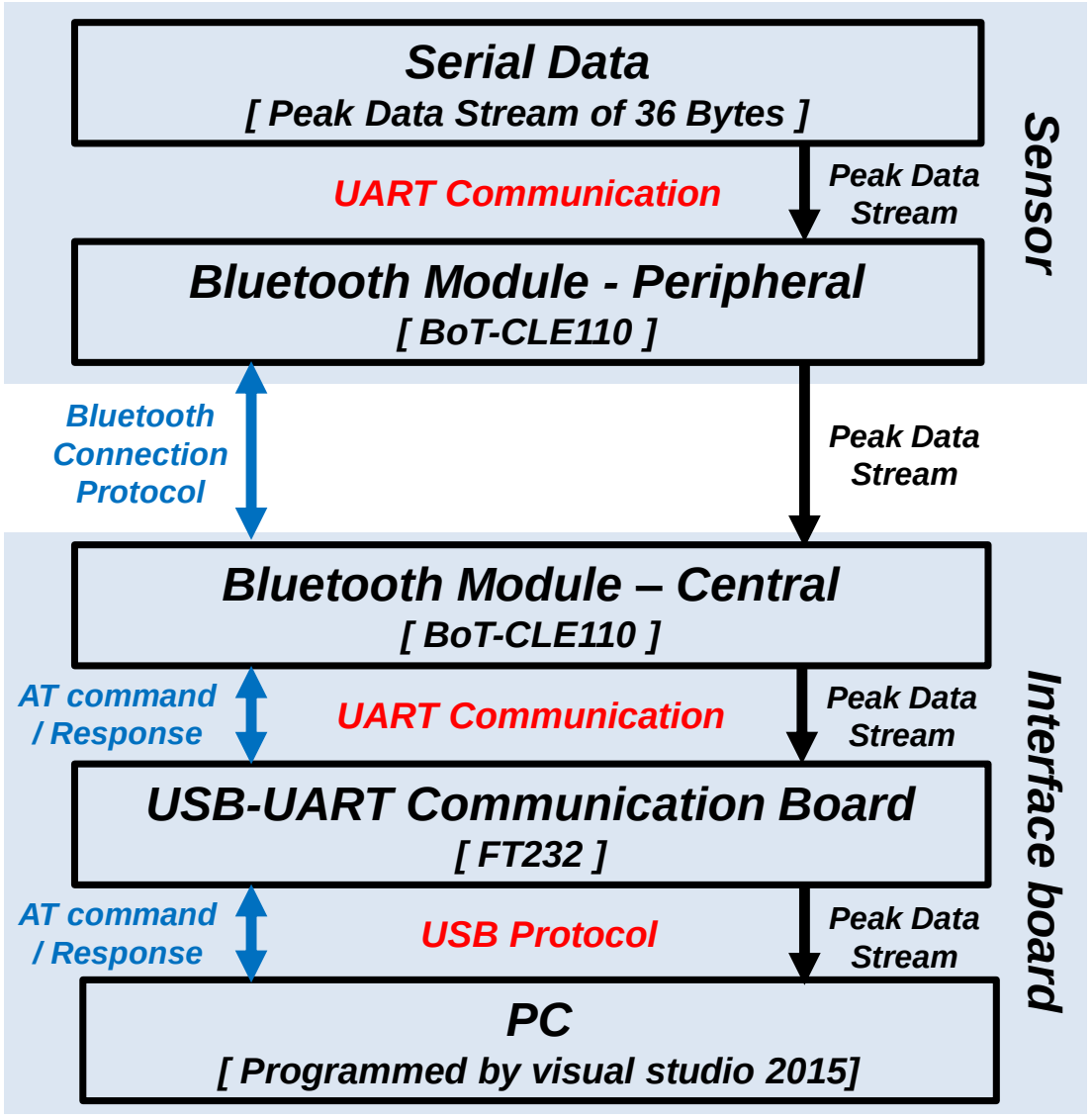


Wireless Communication



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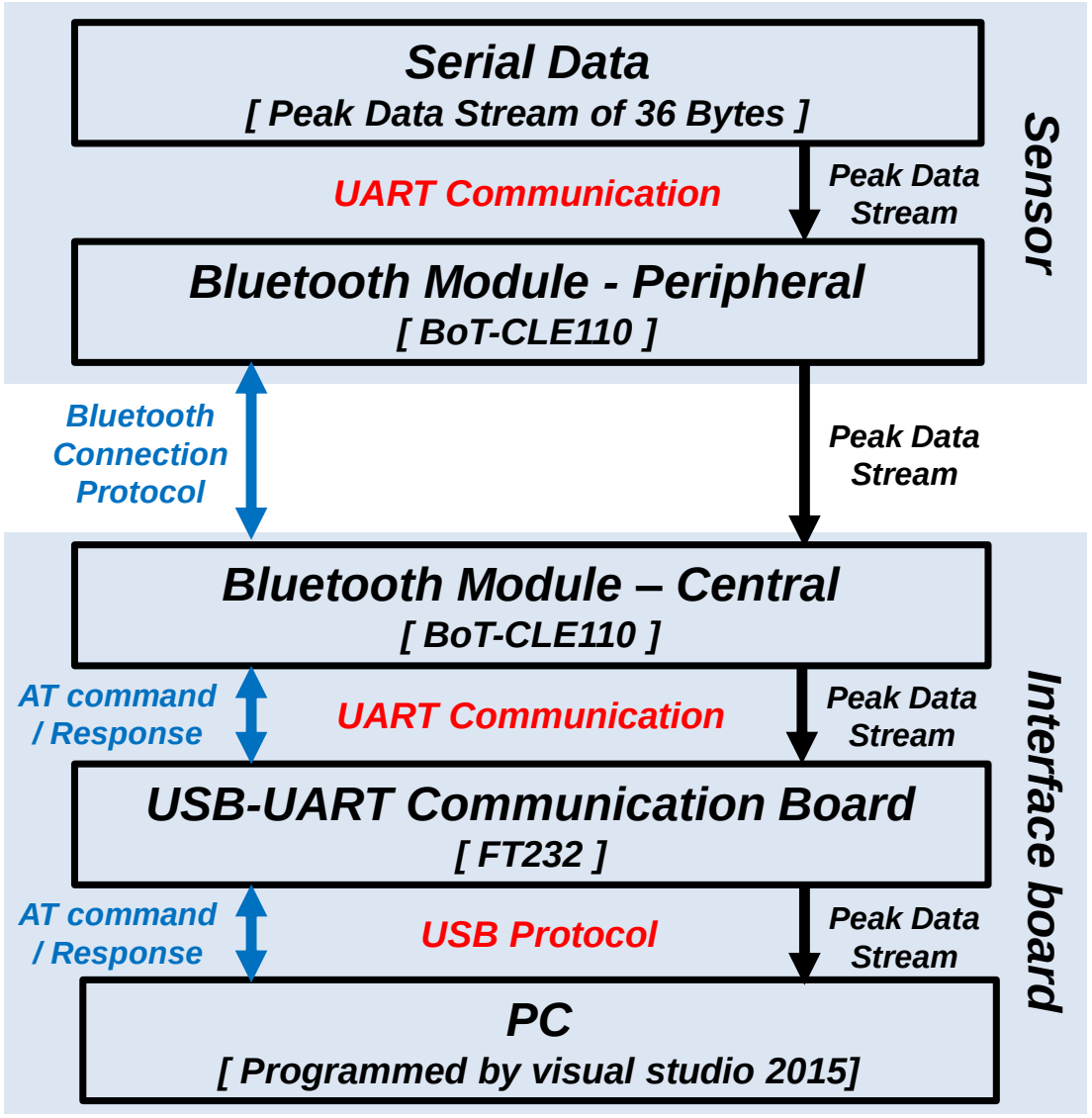

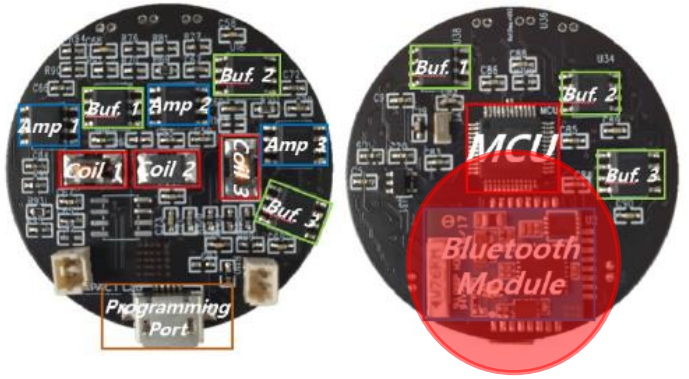

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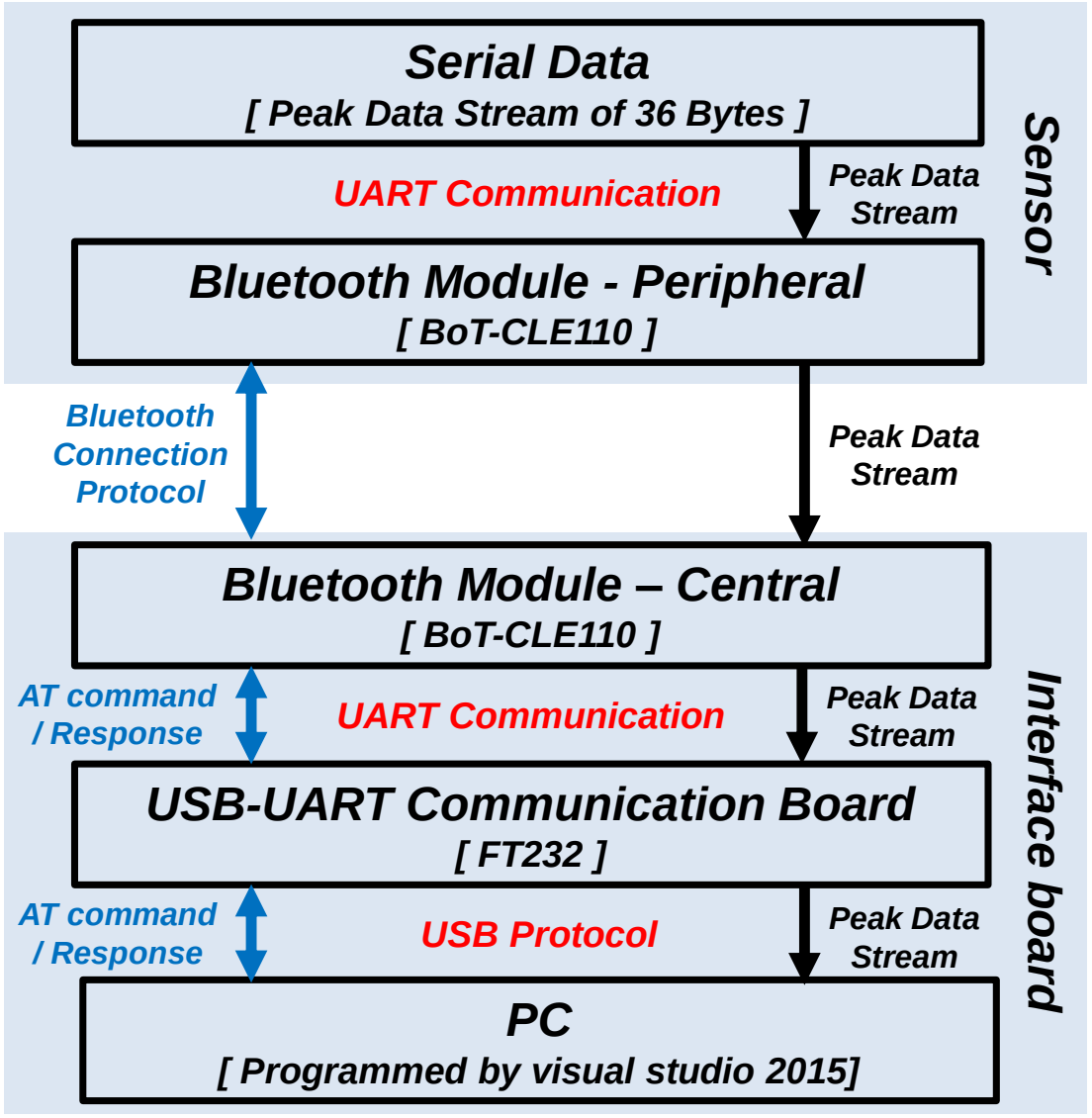

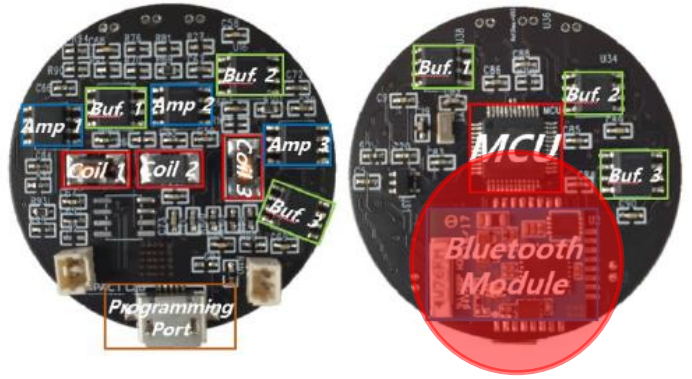

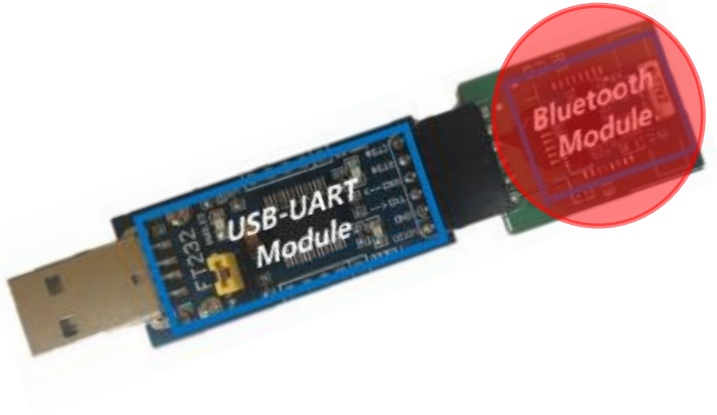

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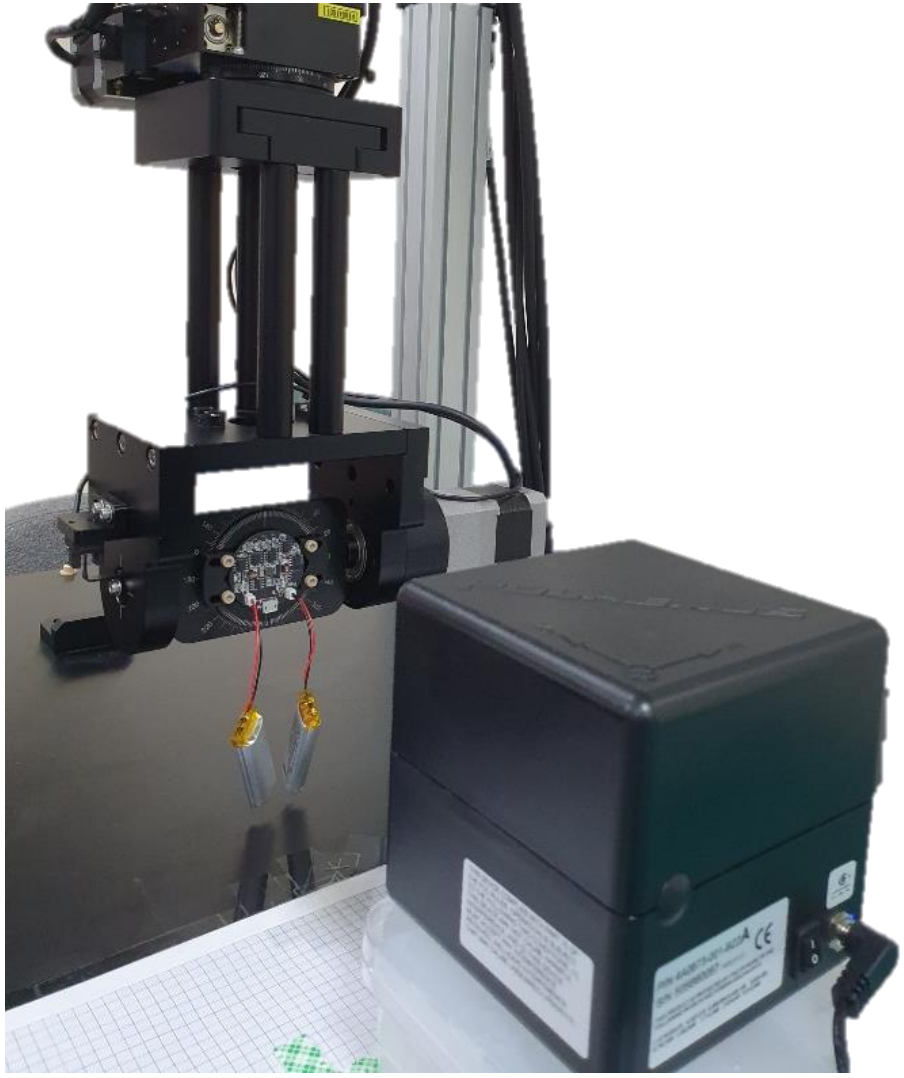
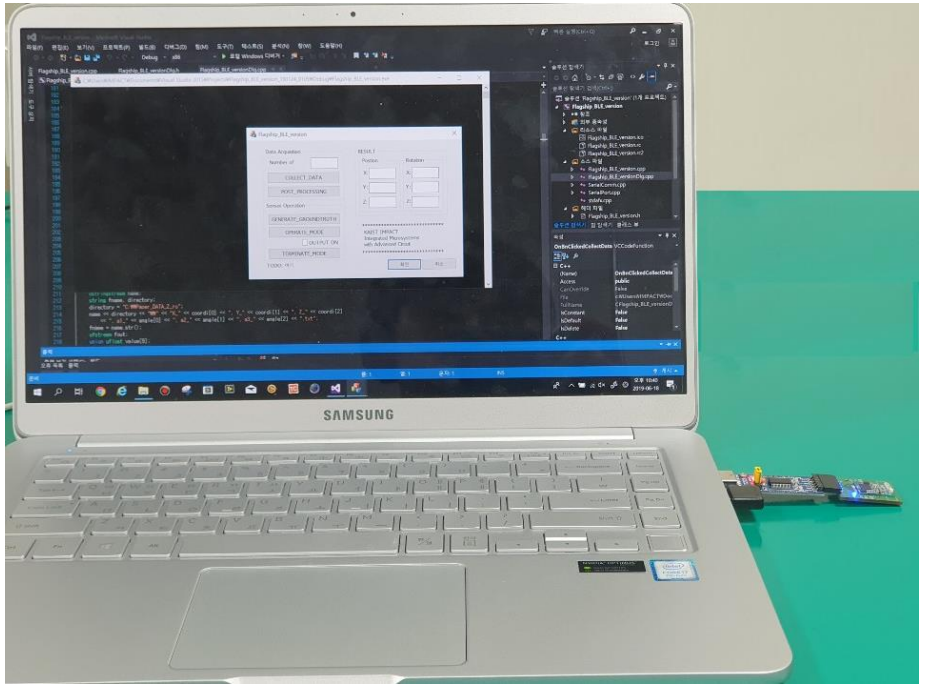
Experimental Environment





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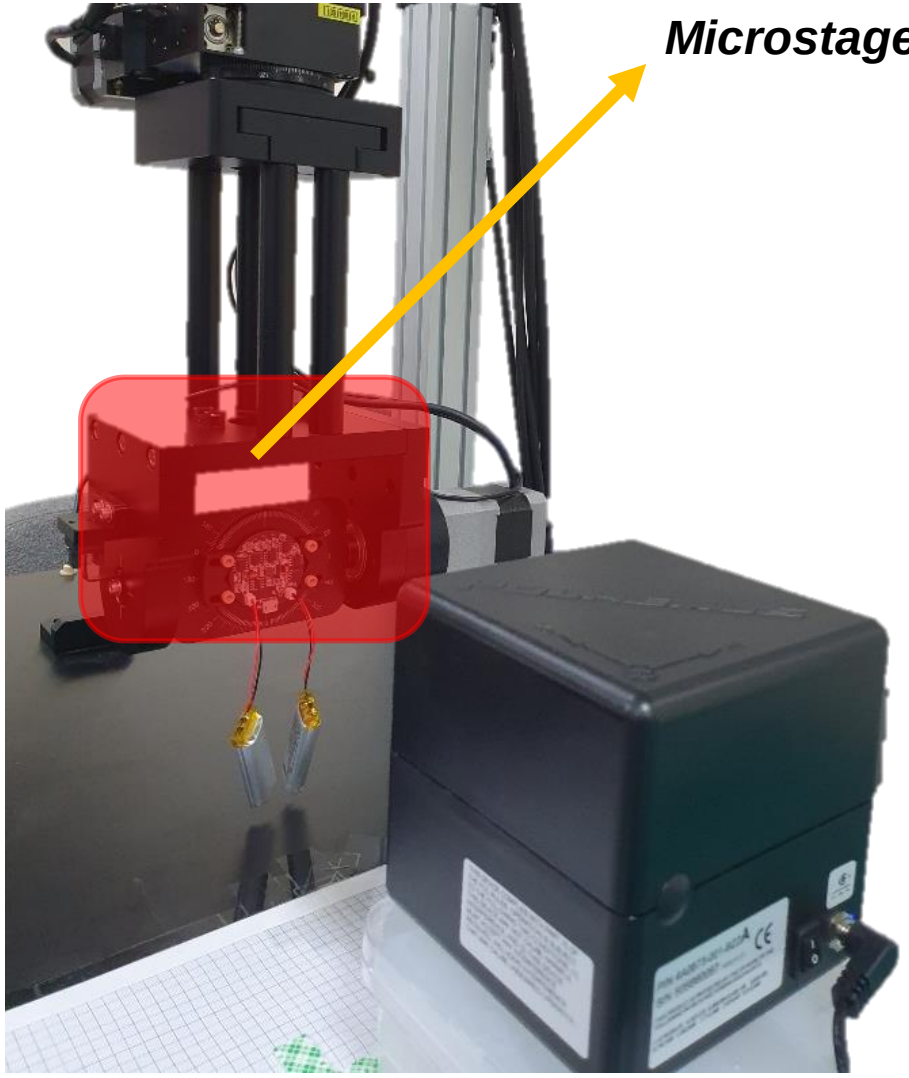

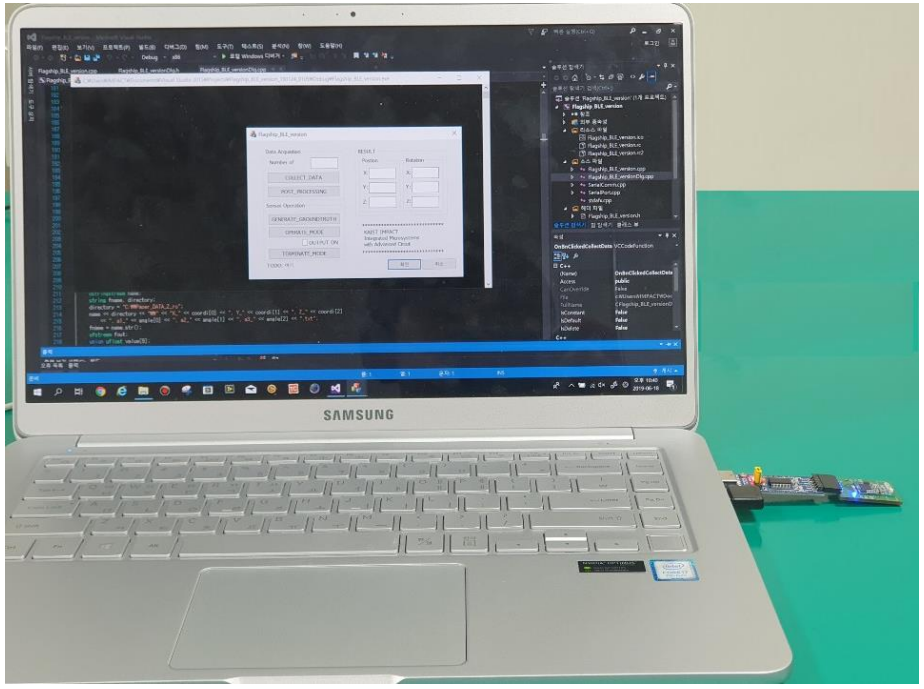

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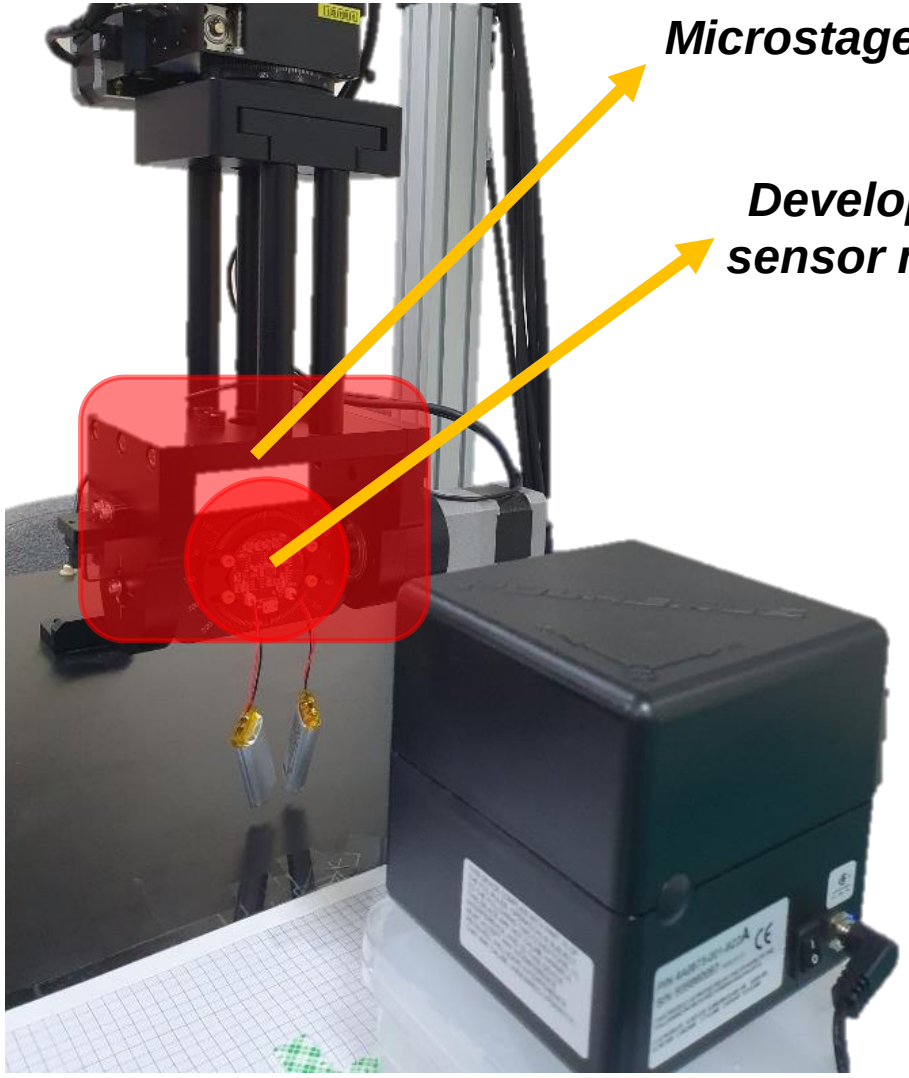

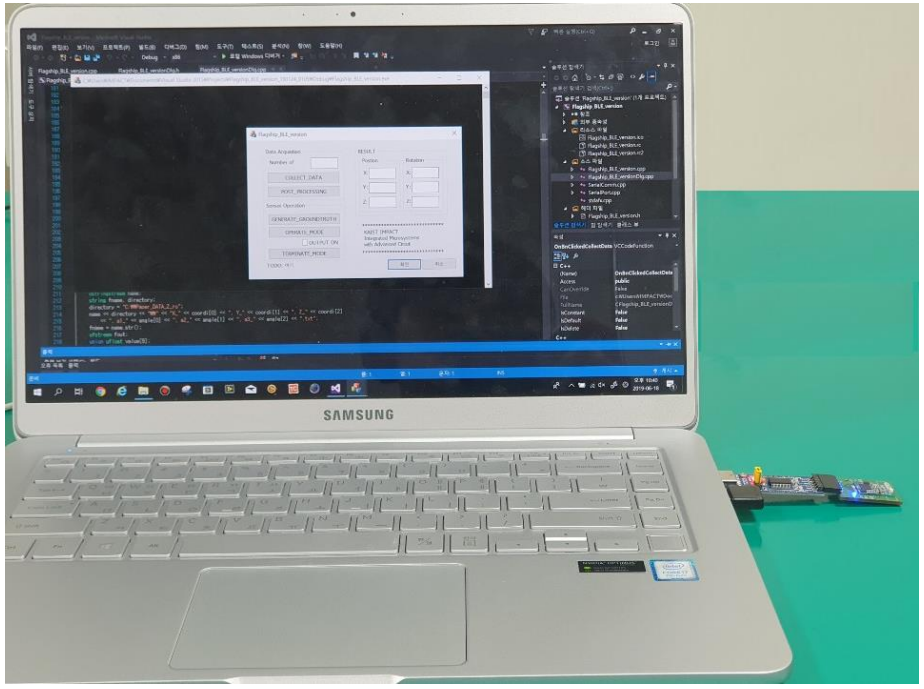

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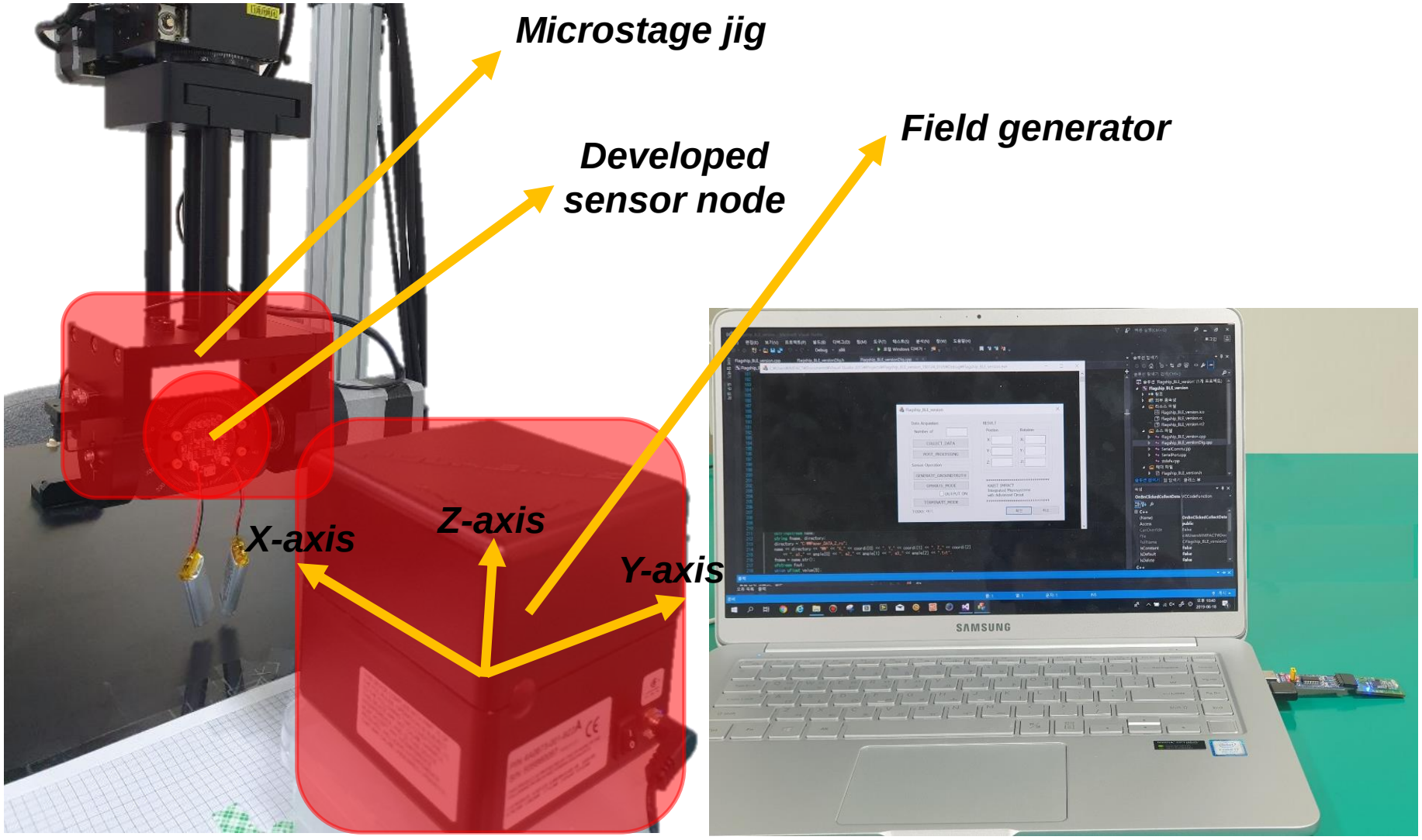

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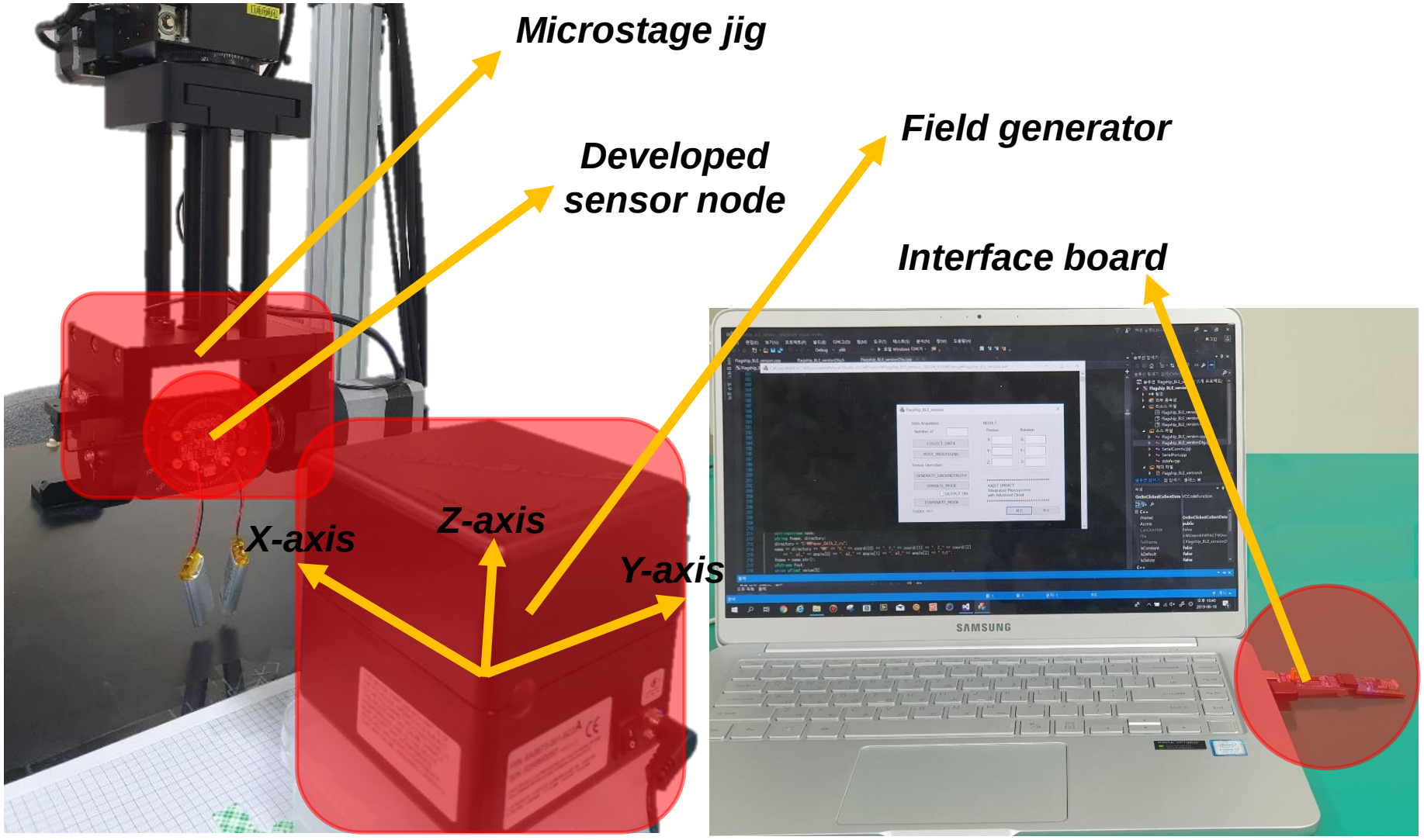
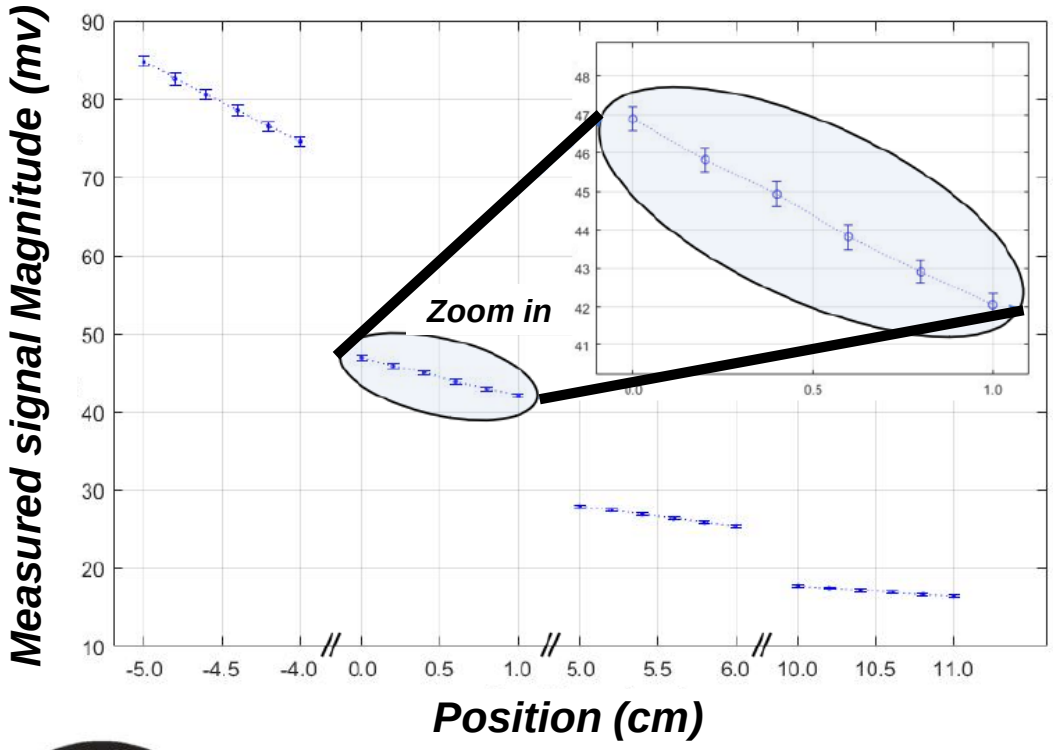
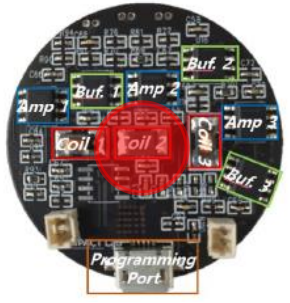


Test Results





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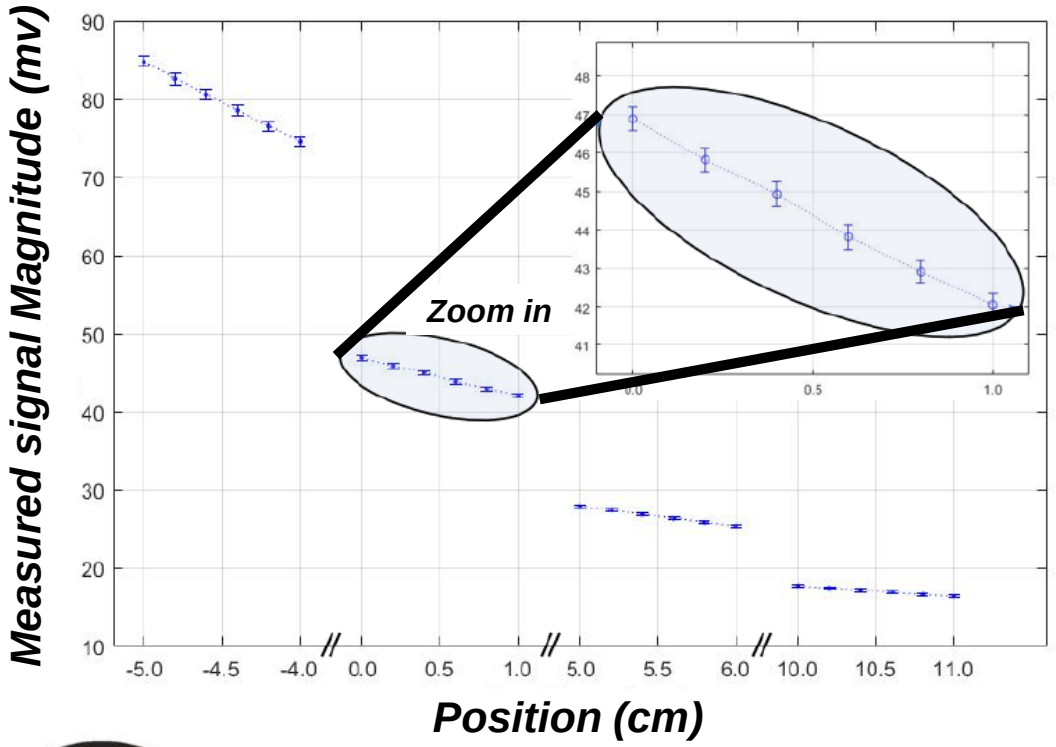
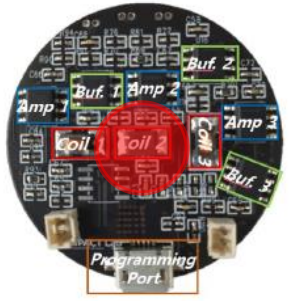
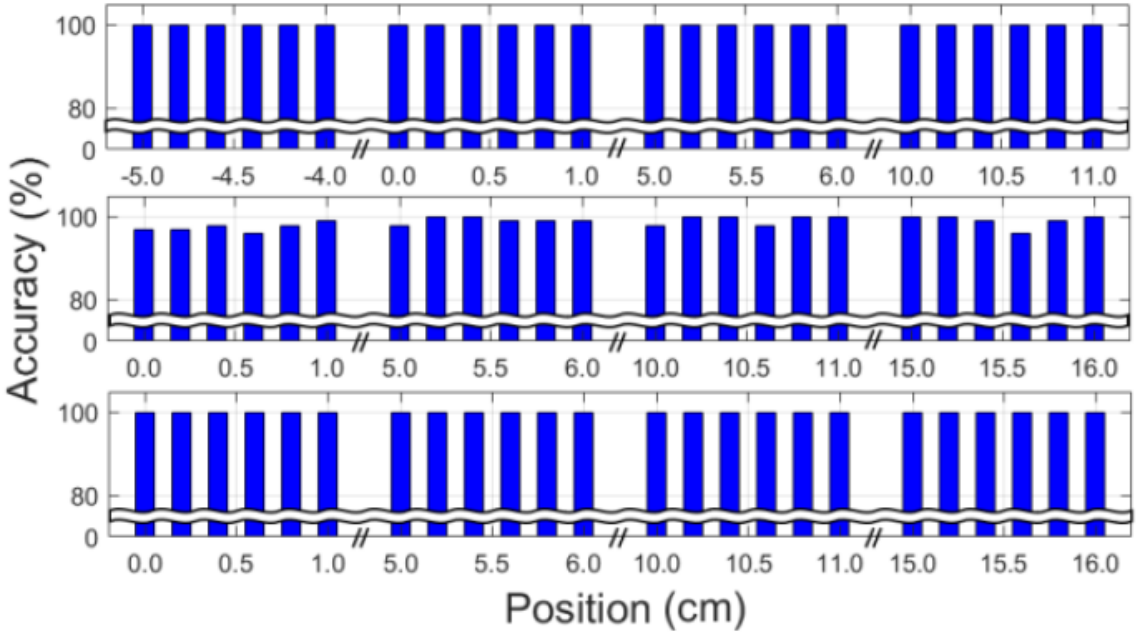


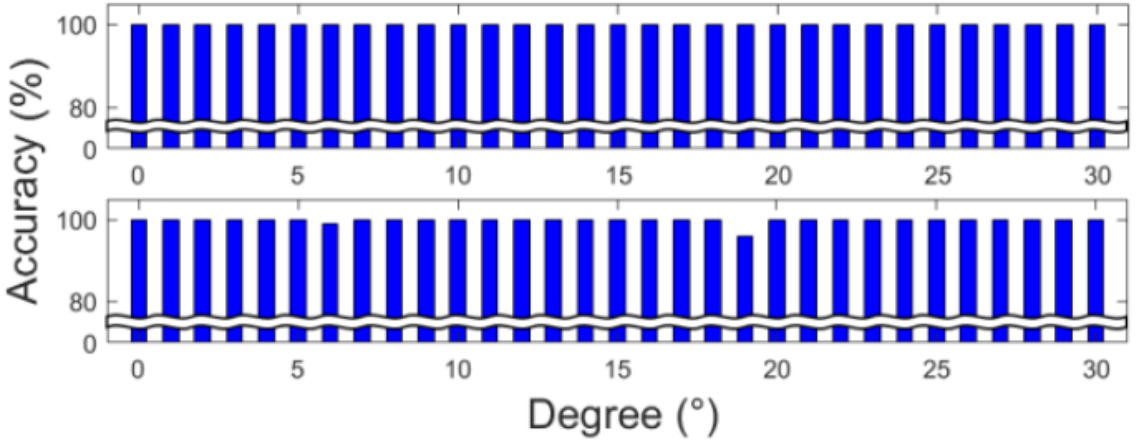


Experiment	Coil	Standard Deviation (σ, N^a = 200) (mV)		
		Frequency 1 17.281kHz	*Frequency 2 18.481kHz*	*Frequency 3 19.682kHz*
Position (x-axis)	1	0.1777	0.3143	0.3605
	2	0.3271	0.2934	0.2375
	3	0.1996	0.3830	0.2021
Position (y-axis)	1	0.1691	0.2983	0.3160
	2	0.3192	0.3806	0.2563
	3	0.1937	0.3098	0.1748
Position (z-axis)	1	0.2390	0.2175	0.3026
	2	0.2614	0.3189	0.2489
	3	0.1957	0.3720	0.1964
Orientation (yaw)	1	0.2491	0.2008	0.3568
	2	0.2604	0.3480	0.2717
	3	0.2133	0.4113	0.1912
Orientation (pitch)	1	0.1874	0.3508	0.3785
	2	0.3077	0.3874	0.2391
	3	0.2242	0.3888	0.2138

[a] The number of samples (N)

Test Results





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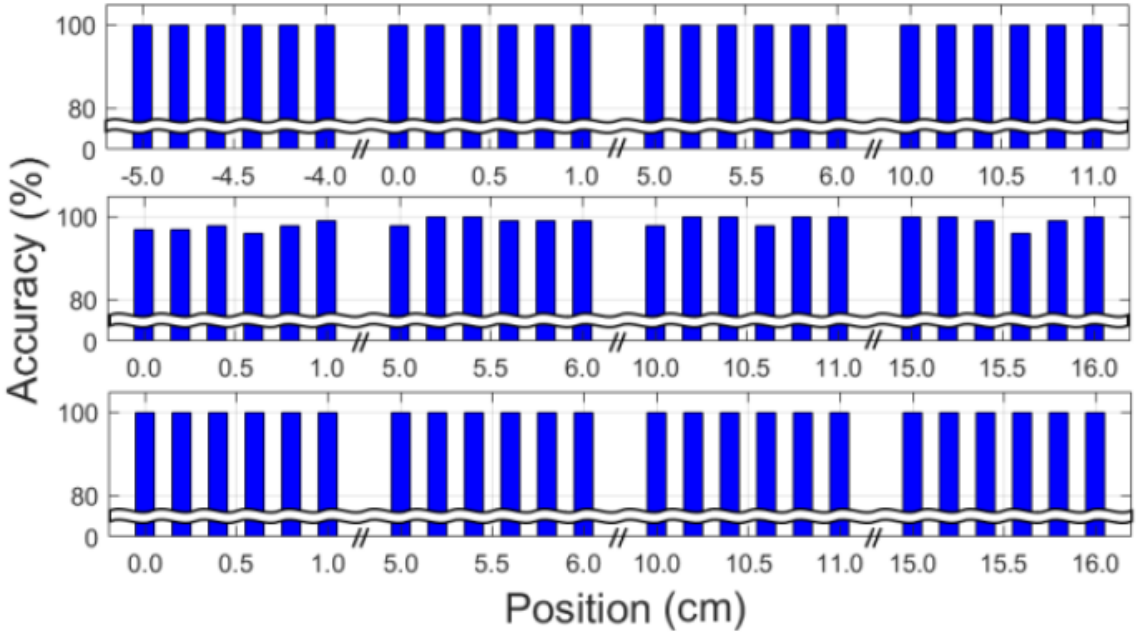
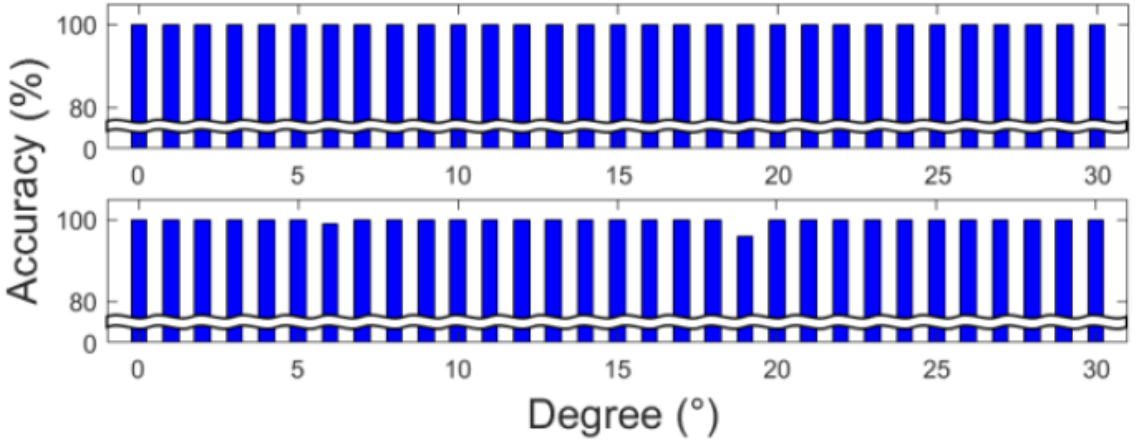


The accuracy is 100%, 98.75%, 100% according to the movement of each of the x-, y-, z-axes



The accuracy is 99.58%, 99.92% according to the rotation around yaw and pitch

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  - Miniaturized
    - Volume: 8.84 cm^3(Diameter: 3.80cm, Height: 0.78cm)

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  - Miniaturized
    - Volume: 8.84 cm^3(Diameter: 3.80cm, Height: 0.78cm)
  - Using wireless communication

Conclusion

- **Developed EM sensor node**
  - Miniaturized
    - Volume: 8.84 cm^3(Diameter: 3.80cm, Height: 0.78cm)
  - Using wireless communication
  - High accuracy
    - 99.58% for position sensing
    - 99.92% for orientation sensing

Conclusion

- **Developed EM sensor node**
  - Miniaturized
    - Volume: 8.84 cm^3(Diameter: 3.80cm, Height: 0.78cm)
  - Using wireless communication
  - High accuracy
    - 99.58% for position sensing
    - 99.92% for orientation sensing

Miniature EM sensor node providing high-accuracy sensing performances and wireless communication capability

References

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Thank you