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Development of Airborne Gamma-Ray Spectrometry Based on a CZT Detector

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Introduction

▶ Environmental radiation survey using diverse survey platforms

○ Comprehensive radiation survey in the environment by the accident phases

- Fundamental Information for the emergency preparedness
  - ✓ The variation of ambient dose rate at 1 m above the ground
  - ✓ Radioactivity in the ground and underwater due to **radioactive** deposits

○ Development of MARK (Monitoring of Ambient Radiation of KAERI) system

- **MARK-*Integrated*: *I***ntegrated survey system to maintain the data consistency
  - ✓ **MARK-*A* series: *A*irborne survey system using UAV** and MAV
  - ✓ MARK-*B* series: *B*ackpack survey system based on scintillation detector
  - ✓ MARK-*C* series: *C*arborne survey system based on large volume detector
  - ✓ MARK-*M* series: *M*ultipurpose system for environmental radiation survey
  - ✓ MARK-*K* series: *K*its for radiological protection at the emergency response
  - ✓ MARK-*T* series: *T*raining tool of radiation safety personnel
  - ✓ MARK-*U* series: *U*nderwater survey system using scintillation detector

○ MARK-*A1* for airborne survey in the high dose rate level

- Performance of developed MARK-A1 using a drone (Inspire 1)
  - ✓ **Field application to assess ambient dose rate due to natural radiations**
  - ✓ **Irradiation experiments using Cs-137 source: 0.001~20 mGy/h**

Materials and Methods

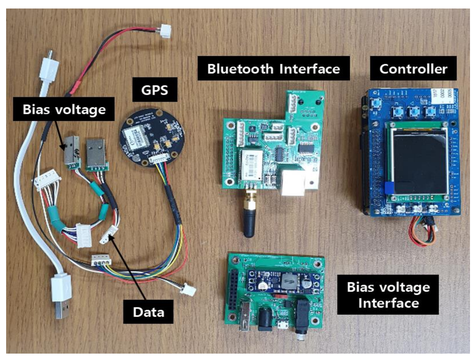
▶ Development of MARK-*A1* for airborne survey using a drone

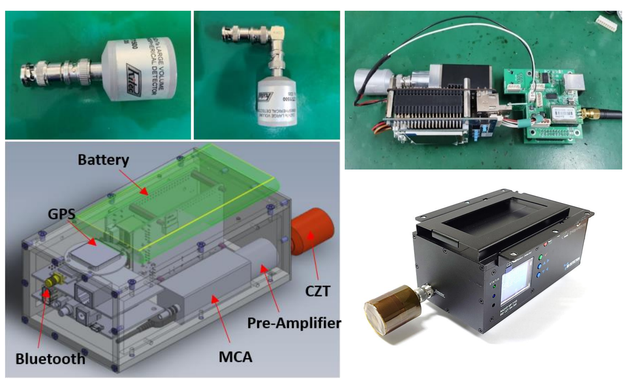
○ Development goals for application to areas with high dose rate level

- Total weight: 1 kg (Including detector system, battery, bracket for mounting a drone, GPS, and controller)
- Spectrometric determination: sufficient energy resolution to identify radionuclides of interest (^{131}I, ^{134}Cs, ^{137}Cs, and ^{60}Co)
- Capability to be continuously operated up to about 10 mGy/h (About 10^5 times to ambient dose rate level)

○ MARK-*A1* based on CZT detectors

- Two CZT(Cadmium Zinc Telluride) sensors (Ritec Inc.)
  - ✓ CZT500S (10x10x5 mm^3): BNC connector, +1400 V
    - Below 2.5% energy resolution (at 662 keV)
  - ✓ CZT1500 (15x15x7.5 mm^3): SHV connector, +2200 V
    - Below 3.5% energy resolution (at 662 keV)
- Signal processing unit (SI Detection Co. Ltd.)
  - ✓ SID CZT SM300
- HV circuit using an external battery pack
- GPS, Bluetooth interface, and controller with LCD display

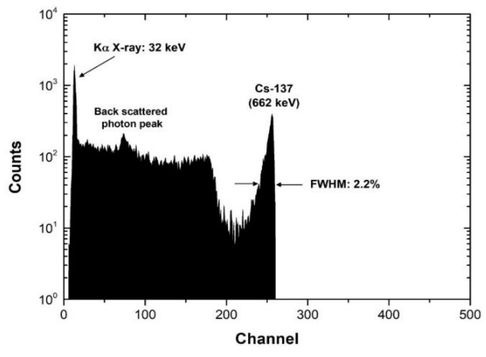


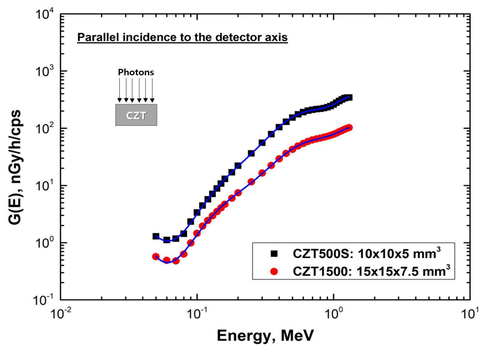


▶ System verification and simulation

○ Measurement of energy resolution using a point source (^{137}Cs)

○ Calculation of dose conversion factor using MCNP code



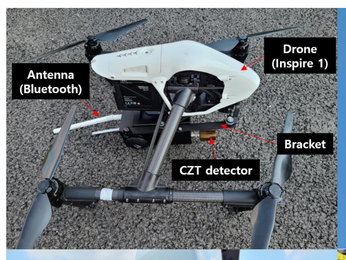


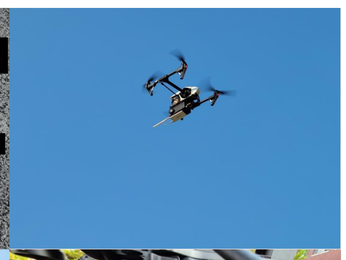
Results and Discussions

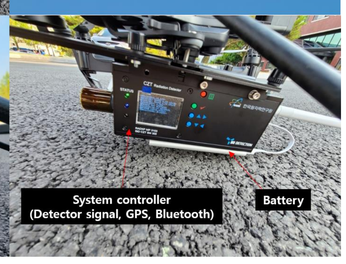
▶ Airborne gamma-ray spectrometry using a drone

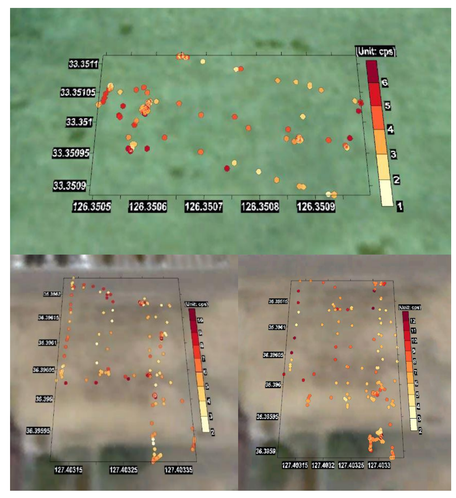
○ Estimation of ambient dose rate induced from only natural radionuclides

- Survey sites: Jeju Island (~30 nGy/h) and Daejeon (~80 nGy/h)
- Survey conditions: flight height of 10 m and 1~2 m/s of survey speed
- Measurement of energy spectrum from 50 ~ 1500 keV
  - ✓ Ambient dose rate: $\dot{X} = \int n(E)G(E)dE$
  - ✓ Total count rate in the energy spectrum
- Comparison of survey results with those of ground-based gamma-ray spectrometry using a tripod at the same survey site
  - ✓ **A good performance: below 20% difference between two methods**







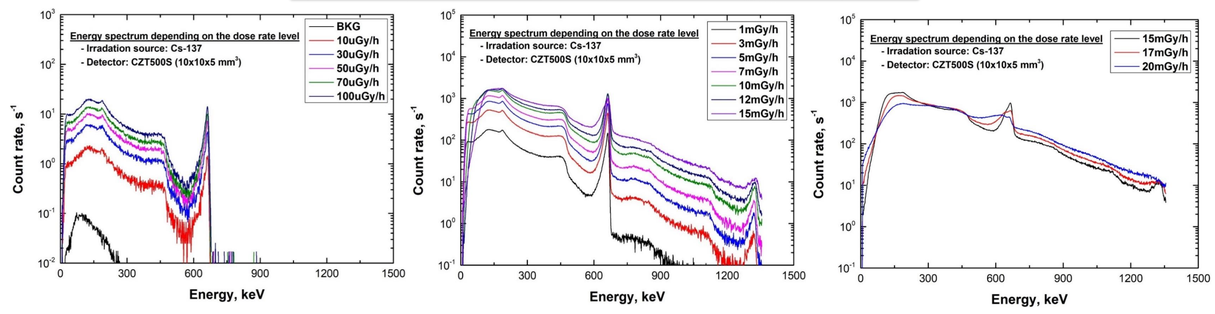


▶ Availability to the high dose rate level of MARK-*A1*

○ Irradiation experiments using ^{137}Cs source

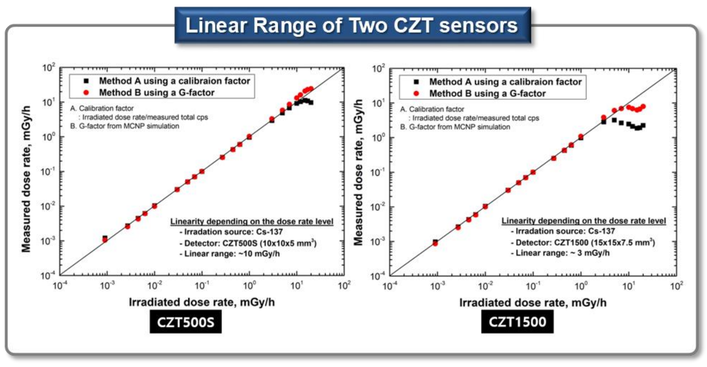
- MARK-*A1*: CZT500S and CZT1500
- Irradiated dose rate
  - ✓ Range: 0.001 ~ 20 mGy/h
  - ✓ 21 points of dose rates
  - ✓ Irradiation time: 2 min
- Energy spectra depending on irradiated dose
  - ✓ Spectrum analysis: total cps and peak cps, FWHM and FWTM

Example of CZT500S (BKG ~ 20 mGy/h)



- **Assessment of linearity of MARK-A1 depending on the dose rate level**
  - ✓ Calibration factor for total cps to evaluate the ambient dose rate
  - ✓ Verification and correction of a dose conversion factor, G(E)

Linear Range of Two CZT sensors



- **CZT500S: linearity up to 10 mGy/h, Stable energy resolution of ~2% (662 keV)**
- **CZT1500: linearity up to 3 mGy/h, Stable energy resolution of below 2% (662 keV)**

Conclusions

○ Development and performance of MARK-*A1* based on CZT detector

- **Light weight of about 1 kg to be mounted to a commercial drone**
- **Successful application of spectrometric determination of ambient dose rate**
- **Determination of linear range of MARK-*A1*: up to 10 mGy/h**