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Performance of a nuclide identification of HYPERGAM on the IAEA 2002 test spectra

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1. Introduction

An important part of the γ-ray spectrum analysis software is the ability to identify radionuclides on the spectrum, and to determine activity of each radionuclide. Rapid determination and a low number of missing & false hit are required to the γ-ray spectrum analysis software to be useful.

HyperGam has been developed to analyze an HPGe γ-ray spectrum by Applied Nuclear Physics Group in Seoul National University [1]. Through a series of subsequent studies [2,3], the on-line analysis as well as the off-line analysis was possible. In addition, the automatic algorithm of nuclide identification has been developed to identify the peaks on the spectrum considering with yield, efficiency, energy and peak area of the γ-ray line from radionuclide.

In this study, the performance of the nuclide identification of HyperGam is tested by using the IAEA 2002 set of test spectra and is compared to the well-known γ-ray spectrum analysis softwares.

2. IAEA 2002 test spectra

In 2002, the new set of test spectra for low-level γ-ray spectrometry was acquired with certified sources, and made available to the general public by the IAEA [4]. Two well-defined detection geometries were employed: a 500 ml Marinelli beaker on a 33% relative efficiency HPGe detector (SMALL detector); and a 100 ml pillbox on a 96% HPGe detector (BIG detector). Three kinds of spectra were acquired on each detector: Background spectra (BGSMALLPOINT, BGSMALLMARI and BGBIGPOINT), calibration spectra (MARICSMALL and PICBIG) and test spectra (MARITSMALL, PITBIG, MIX1EQ and MIX1NEQ).

The IAEA 2002 set of test spectra was used in an intercomparison of commercially available software packages, i.e. Anges 1.0, GammaVision 5.3, Gamma-W 1.68 for Windows, Genie2000 2.1, Hyperlab 2002.3.2.18, Interwinner 5.0 and UniSampo 1.97 [5]. The result of the intercomparison in reference [5] was used in this study to compare to the HyperGam.

3. Performance test

Performance of the nuclide identification by HyperGam has been tested by using the IAEA 2002 set of test spectra for low-level γ-ray spectrometry. Channel-energy calibration was performed and detection efficiency curves were obtained for the two counting geometries by using calibration spectra. The calibration data were used to obtain radionuclide activities for unknown samples.

Four test spectra were analyzed and candidate radionuclides were determined by using the nuclide identification function of HyperGam. If a radionuclide determined known to be detectably present in the sample was counted as ‘hits’. Similarly, any radionuclide known to be detectably present in the sample was not determined was counted as a ‘miss’, and any radionuclide determined but known not to be detectably present in the sample was counted as a ‘false hit’. For each ‘hit’ radionuclide, the ratio of reported to certified activity and its uncertainty were calculated as well as the reduced χ^2 value and two z-scores. The reduced χ^2 value and two z-scores are given by [5]:

$$\chi_r^2 = \frac{1}{N}\sum_{i=1}^{N} z_i^2 , \quad (1)$$

$$z_{rep} = \frac{A_{rep} - A_{cert}}{\sqrt{s_{rep}^2 + s_{cert}^2}} \quad (2)$$

and

$$z_{ref} = \frac{A_{rep} - A_{cert}}{s_{cert}} , \quad (3)$$

where A_{rep} and A_{cert} are the reported and certified activities, and s_{rep} and s_{cert} are the reported and certified one standard deviation(1σ) uncertainties, respectively. The z_{rep} could also be calculated for “false hits” by setting A_{cert} and s_{cert} to zero.

The ratios of analyzed and certified activities for the MARITSMALL and PITBIG spectra are shown in Table 1, along with their uncertainties. As can be seen in Table 1, HyperGam identified the five radionuclides present in the sample. However, the activities of Na-22 and Ba-133 were underestimated to the certified values. HyperGam didn’t support the coincidence summing correction, and therefore sum peaks such as the 1785 keV peak of Na-22 were not recognized in these test spectra.

Fig. 1 and 2 show the numbers of identified radionuclides, the misses and false hits as well as the associated χ^2_r values for the MIX1EQ spectrum. Fig. 1

Table 1. Ratio of analyzed and certified activities for the MARITSMALL and PITBIG spectra.

Spectrum \ Nuclides		Na-22	Cr-51	Co-60	Ba-133	Eu-152
MARITSMALL	Ratio	0.90	1.01	0.97	0.97	1.02
	Error	0.02	0.04	0.02	0.05	0.02
PITBIG	Ratio	0.79	0.90	0.93	0.84	0.93
	Error	0.01	0.02	0.02	0.01	0.02

indicated that HyperGam performed best with respect to the number of hits (15 of 22 unknown radionuclides in the sample). However it mistook one γ-line (340.98 keV) of Ac-228 for γ-line (340.6 keV) of Cs-136 that was not present in the sample. The result in Fig. 2 shows that the best activities are reported by Anges, but it failed to report 14 radionuclides. And HyperGam reported second smallest value of reduced χ^2 (reference).

4. Conclusion

The nuclide identification function of HyperGam has been tested by using the IAEA 2002 test spectra. From the results of the test, HyperGam performed outstanding ability to identify unknown radionuclides and to determine activity of the radionuclides compared to other softwares. Meanwhile, a mismatch in activity determination and a number of misses/false hits which were revealed from the tests remain issues. Future work shall focus on modification of library and incorporating correction routines such as the sample self-attenuation and coincidence summing to enhance reliability and accuracy of the nuclide identification of HyperGam.

ACKNOWLEDGEMENTS

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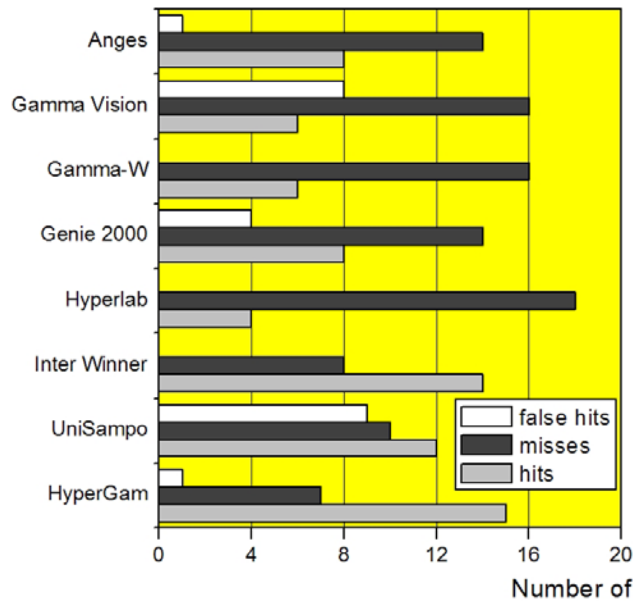

Fig. 1. Number of identified radionuclides, misses and false hits in the MIX1EQ spectrum.

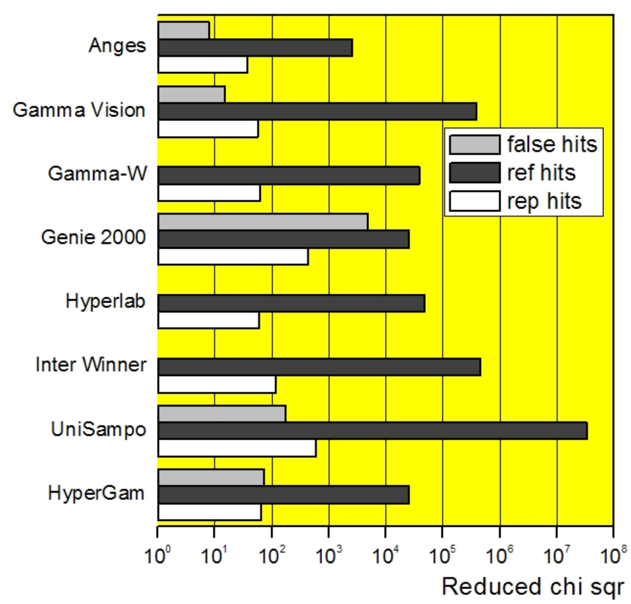

Fig. 2. Reduced χ^2 value based on reported uncertainties ("false hits" and "rep hits") and on certified uncertainties ("ref hits") for the MIX1EQ spectrum.