Maximum likelihood spectral reconstruction for real-time gamma-ray spectroscopy

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Among the plethora of analysis strategies in gamma-ray spectroscopy, full spectrum analysis is the only attempt to fully exploit all the information available. However, in environmental radioactivity, the analysis often relies on the least squares fitting of fundamental spectra. Least-squares minimization involves the hypothesis that the fluctuation of the number of counts per channel is Gaussian, which is not true for short-duration spectra, or for channels with low counts (often those of high energies). As a result, long integration times are required, and some energy bands may need to be excluded from the analysis.

In a recent article we showed how we can acquire highly specific fundamental spectra from remote stations, without need of Monte-Carlo, by unfolding the contributions from ^{214}Bi+^{214}Pb, ^{212}Pb, ^{208}Tl and a constant background. Here, we show that a fully Poissonian treatment combining these spectral components is possible, resulting in maximum-likelihood reconstruction of spectra recorded by remote stations in just 10 minutes. This allows us to routinely check for benchmark isotopes like ^{131}I, ^{137}Cs and ^{60}Co; Moreover, we can search for ^{234}Th, whose photo-peaks at 63 and 92 keV are very hard to evaluate using other methods. Last but not least, we are capable of performing a blind search, where the significance of unexpected photo-peaks is evaluated.

Our method enables us to perform a highly sensitive, real-time analysis of the data from the Radiological Surveillance Network of Catalonia. 10-minute measurements achieve a minimum detectable activity concentration of 3.5/3.5/2.0 Bq/m³ for ^{131}I/^{137}Cs/^{60}Co using a 2"x2" $LaBr_3$(Ce) detector; and 73 Bq/m³ for ^{234}Th using a 2"x2" SrI_2(Eu) detector. We also show an application to extremely short-duration spectra of 30 seconds recorded by a mobile unit. Finally, we discuss the implementation for unattended operation of networks, and we provide an outlook towards the use in detectors with particulate filter and water detectors.