Analysis of Lanthanum Bromide Spectra for Identification of Depleted Uranium

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INTRODUCTION

Photon detectors may be designed to have favorable efficiency, or excellent resolution, or short resolving time. The sodium iodide detector is relatively efficient; however, better resolution and resolving time can be found in other designs. One that is better in all three categories is the lanthanum bromide ($LaBr_3(Ce)$) detector. An assessment of the effectiveness of the lanthanum bromide detector for field survey use to detect depleted uranium (DU) is necessary. A transform method is investigated for interpretation of data from this design.

DESCRIPTION OF THE WORK

A transform technique originally developed for analyzing sodium iodide (NaI) spectra has been tested for application to $LaBr_3(Ce)$ acquisitions. The number of counts C(E) in a channel at approximate energy E may be considered to consist of three components:

1. U(E), representing unscattered photons,
2. S(E), representing contributions from scattered photons,
3. N(E), attributable to other factors.

Thus,

$$C(E) = U(E) + S(E) + N(E). \qquad (1)$$

A file of comparison spectra was created using surveys from known geometry and source information. Transforms of individual "field" or "test" spectra were compared with those from a set of reference spectra. A Comparison Measure was calculated by

1. computing the modulus of each transform,
2. calculating the difference of the moduli of the transform of the field spectrum and each of the comparison spectra,
3. determining the Comparison Measure by summing the absolute values of the differences at each value of the transform parameter, and
4. sorting the Comparison Measures for each reference spectrum in ascending order, retaining associated identification data.

The Comparison Measures having the least value indicate the closest agreement between the transforms.

Special Properties of the $LaBr_3(Ce)$ Detector

The lanthanum bromide detector is superior to the sodium iodide (NaI) detector in important respects, but contains a long-lived isotope ^{138}La which emits β-particles and photons. The photon energies are 788.7 keV and 1435.8 keV. The latter, when summed with the accompanying 32-keV X-ray, is virtually the same as the 1460.8 keV γ ray from the naturally-occurring radionuclide ^{40}K. Further, photons are generated in the bremsstrahlung process accompanying the energy loss of the 255.3-keV β-particle emitted in 33.6 % of the ^{138}La disintegrations (1,2). Contributions to the photon spectrum from decay of the ^{138}La nuclide are summarized in Table I.

Table I. ^{138}La Decay Characteristics	
Disintegration	Photon Energy (keV)
β decay	788.7 + bremsstrahlung, 0 to 255
Electron capture	1435.8

While the Comparison Method may be applied to both $LaBr_3$ and NaI detector, ^{138}La decay provides a systematic component which would render N(E) for the $LaBr_3$ crystal as a sum of the extraneous term $N_1(E)$ and a stochastic term $N_2(E)$. Fig. 1 is spectrum for the lanthanum bromide detector which reflects contributions from the ^{138}La decay and natural background. The photopeak at 1.46 MeV is almost entirely due to internally-generated photons.

A spectrum having low contributions from external sources will be dominated by the internal radionuclide decay component $N_1(E)$. Applying a transform operator $\mathcal{T}$ to C,

$$\mathcal{T}(C) = \mathcal{T}(U) + \mathcal{T}(S) + \mathcal{T}(N_1) + \mathcal{T}(N_2) \qquad (2)$$

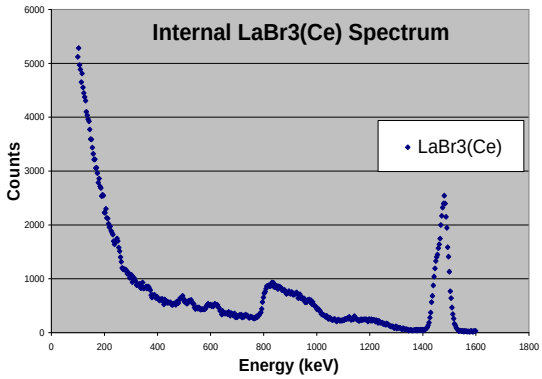

Fig. 1. Spectrum from ^{138}La.

Transforms of both test and library spectra in a desired region of analysis are normalized before the differencing procedure is performed. For a single test spectrum, a comparison procedure for the chosen energy region, say 700 keV to 1200 keV, will show the degree of correlation with each spectrum in the reference library. Evaluation of transform results is based upon gross count data. Interpretation of a gamma-ray spectrum to determine the probability of a DU source is enhanced by having a method that is sensitive to its shape. Further, the internal ^{138}La gamma rays provide a source that may be used at any time for energy calibration.

The transform computation employed in this evaluation was *fft,* the Fast Fourier Transform module in MATLAB® (3).

RESULTS

48 gamma-ray spectra have been acquired for inclusion in a Comparison Library. Many test spectra have been taken in field surveys. One of these has been selected for exhibiting the effectiveness of the method applied to the lanthanum bromide detector. A parametric method based upon attenuating distance is employed. For each spectrum in the Comparison Library, the attenuating distance between a single discrete source and the detector is known. A test spectrum that compares well with one or more library spectra is presumed to have resulted from

1. the same source and
2. a similar thickness of attenuating medium between source and detector.

Computations resulting in a predicted attenuating distance should be a useful indicator of the location of depleted uranium. Tables II and III provide examples of information for such a decision. The smallest Comparison Measures are associated with certain library files. Their attenuating distances are listed. The largest Comparison Measures suggest a lack of comparison resulting from different attenuating distances or different sources. When spectrum identification data are ordered according to Comparison Measure, the procedure provides additional data for an inference of source depth. The four best and the four poorest comparisons are provided in the tables.

Table II. Comparison Method Results for Test File Name 8_3.4.

Energy Range: 700 keV-1200 keV

Comparison Measure	Comparison File Identifier [depth, offset, acquisition time]	Attenuating Distance (cm)
0.129	20_30.48_600	26.4
0.133	30_0_600	30
0.143	25_30.48_600	31.4
0.168	25_0_600	25
.	.	.
.	.	.
1.465	0_30.48_10	0
1.500	5_0_600	5
1.599	0_0_10	0
1.633	0_0_600	0

Table III. Comparison Method Results for Test File Name 8_3.4.

Energy Range 900 keV-1100 keV

Comparison Measure	Comparison File Identifier [depth, offset, acquisition time]	Attenuating Distance (cm)
0.170	25_0_600	25
0.170	15_30.48_600	21.3
0.170	20_30.48_600	26.4
0.175	30_30.48_600	36.2
.	.	.
.	.	.
1.126	5_0_10	5
1.127	5_0_600	5
1.178	0_0_10	0
1.212	0_0_600	0

The Test Spectrum was generated by a 60-second live time count from a source buried 8 cm deep. The detector was offset from the source a lateral distance of 91.44 cm. For a detector positioned 6 inches above the soil surface, the attenuating distance was 32.5 cm. Nine other test spectra were examined, with similarly encouraging results.

CONCLUSIONS

An integral transform is a mapping from one space into another. The primary variable is photon energy. The transform variable will have units of reciprocal energy. While no physical meaning can be ascribed to the transform variable, the Comparison Method appears to be useful in source identification. Using an analogy from electrical engineering, a transform containing significant "higher frequency" terms would indicate a gamma-ray spectrum having non-monotonic variations over the region of analysis. Such variations might be attributable, for example, to photopeaks from unscattered photons. On the other hand, if some portion of a gamma-ray spectrum arose from scattered photons originating from a single disintegration energy, the gamma-ray spectrum would be monotonic and therefore its transform would be dominated by the "low frequency" components.

For the $LaBr_3$(Ce) detector, numerical results show that values of the Comparison Measure around 0.2 imply good comparison between two spectra, while values greater than unity will result when two spectra differ significantly. For any energy region, a test spectrum may be compared with all spectra in a reference library. Where there is additional knowledge, such as is the case for depleted uranium search, the definition of such regions are easily accomplished.

Application of an integral transform to spectra obtained "in the field" provides information not obtainable from the gross spectrum by itself. Any number of regions for analysis may be defined for application of the transform. A metric for comparison of transforms has been defined. Testing of the method for spectra acquired with a $LaBr_3$(Ce) detector has established its usefulness in the presence of internally-generated photons.

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ACKNOWLEDGEMENTS

This investigation was sponsored by the US Army under the following contracts:

DOD/USAERDC Contract No. W912HZ-09-2-0029

The Consortium for Energy, Environment and Demilitarization (CEED) Contract No. N10OT0005 (Project Award 0002)