Modeling of Air Attenuation Effects on Gamma Detection at Altitude

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Introduction

This paper focuses on modeling the detection capabilities of NaI sensor systems at high altitudes for ground sources. The modeling was done with the Monte Carlo N-Transport (MCNP) code developed at Los Alamos National Laboratory. The specific systems modeled were the fixed wing and helicopter aircraft sensor systems, assets of the U. S. Department of Energy’s National Nuclear Security Administration Nevada Operations Office (NNSA/NV) Aerial Measuring System (AMS).

In previous (2001) modeling\(^1\), Sodium Iodine (NaI) detector responses were simulated for both point and distributed surface sources as a function of gamma energy and altitude. For point sources, photo-peak efficiencies were calculated for a zero radial distance and an offset equal to the altitude. For distributed sources approximating an infinite plane, gross count efficiencies were calculated and normalized to a uniform surface deposition of 1 µCi/m\(^2\). To validate the calculations, benchmark measurements were made for simple source-detector configurations.

The 2002 continuation of the modeling presented here includes checking models against available data, and modifications to allow more effective and accurate directional biasing of
ground point and distributed sources. Fixed-wing data results will be shown for two point sources as a function of altitude.

**Summary of Previous Modeling**

Previous modeling for the fixed-wing B-200 and helicopter Bell 412 systems were presented in a 2001 paper and will only be summarized here. Both systems utilized NaI detectors, whose response was modeled with MCNP for both point and distributed ground sources for a range of energies and altitudes.

Point sources were modeled for the fixed-wing system at 0 degrees and +/- the altitude. The directional biasing method was tested with non-biased calculations at an altitude of 100 meters above ground level; photopeak results agreed within the statistical errors. Gross counts, however, were more sensitive to the degree of directional biasing.

The distributed sources were modeled after a uniform infinite plane surface distribution. In practice, a surface circular source of radius equal to the altitude was used for the fixed-wing due to very low statistics from inadequate biasing ability for the distributed source. For fixed-wing distributed sources, a simulated gamma spectrum was also used, while only a single source was modeled for the helicopter. Helicopter modeling included runs made at the lowest two altitudes for distributed sources with larger radii. Directional biasing was limited to biasing in the upper hemisphere for distributed sources.
Comparison to Data

Figs. 1 and 2 show a comparison of fixed-wing MCNP data to real data for an $^{192}$Ir source and Fig. 3 the comparison for the $^{60}$Co source. Gross count rate for the large NaI detector is shown for the Ir source, and count rates for the three detectors for the $^{60}$Co source. The $^{60}$Co data was taken with a relatively strong source and dead time/saturation effects were not calculated, therefore showing a lower data value at lower altitudes than MCNP predicts. A calculation for expected gross counts in the large detector at these altitudes agrees quite well with MCNP. The second set of $^{192}$Ir data was also for a strong source and the lower altitude data falls below MCNP due to saturation effects.

Effects of degrees of directional biasing are also apparent in the data comparisons. The first $^{192}$Ir data set, Fig. 1, shows a drop at higher altitudes, possibly due to the stronger degree of directional biasing. The second $^{192}$Ir data set, Fig. 2, uses very little directional biasing and shows a much closer comparison to data at high altitudes, although the statistics are worse.

![Figure 1](image-url)

**Fig. 1.** Fixed-Wing Large NaI Crystal - $^{192}$Ir Point Source - Directional Biasing
Fig. 2. Fixed-Wing - Large NaI Crystal Stronger $^{192}$Ir Source - Minimal Biasing

Fig 3. Fixed Wing Gross Count Rate - $^{60}$Co Point Source

**Grid Biasing**

With the modeling of the detector response to gamma radiation at high altitudes or large distances, directional biasing of the point or distributed source is necessary. One new approach to this modeling in 2002 was the attempt to develop a method for directional biasing of plane sources. Directional biasing of a point source is straightforward in MCNP, as the vector from
source point to detector is fixed. However, for a distributed plane source, MCNP starts source
particles randomly throughout the plane and defining a directional vector is more complicated.

The several options in MCNP to create lattice structures do not, in general, allow assigning
unique source attributes or coordinates to each grid. The biasing necessitated assigning a unique
vector direction to each grid and construction of a large number of grids. The final method,
although different than originally conceived, provided a grid structure, with source attributes for
each grid.

The changes to the model were the construction of the grid structure described above. The grid
cells were only 1 cm thick, filled with air, and positioned directly above the ground plane. The
cells were filled with air, and constricted the source particles in the X-Y directions, while a plane
through the center of the cells constrained them vertically. Particles were assigned a unique
vector to use for directional biasing based on the cell of origination; the vector was defined as the
line from the midpoint of the cell to the detector pod.

Figs. 4–7 show the geometries of the detector pods for the fixed-wing system model tested here;
Figs. 8–10 show the cell grid structure used on the ground plane. Due to inability to plot only
source cells (MCNP plots all cell geometries), the entire square grid is shown here. However,
cells were selected to simulate a circular plane source with the radius equal to altitude (1000
feet). The cut was made for cells whose midpoint radius from the grid center exceeded the
desired radius by more than the grid spacing.
Fig. 4. Fixed-wing NaI pod (blue) and HPGe pod (orange) - Vertical Cut

Fig. 5. Fixed-wing - Horizontal Cut
Fig. 6. Helicopter B200 Pod with 6 NaI detectors - Vertical Cut

Fig. 7. Helicopter Pod - Horizontal Cut
Fig. 8. Horizontal Cut of cell grid geometries

Fig. 9. Cell Grids - Vertical Cut  Cells above ground and void, below air
Conclusion

The MCNP modeling presented here extends the 2001 modeling of gamma detection through several mean free paths of air for the fixed-wing and helicopter Aerial Measuring Systems. The predicted results are being compared to newly available data on an ongoing process. Results already modeled for the fixed-wing systems appear to be consistent with the data. Helicopter data will also be compared with MCNP results as it becomes available. The gross count data is sensitive to the degree of directional biasing, and further investigation to develop the proper degree is warranted. Photopeak data comparisons to validate the 2001 MCNP photopeak predictions are also desirable.
Future work includes more extensive data testing of the models, as well as improvements incorporating wind speed, humidity, and air density changes. Also, the newly developed grid method for directional biasing of plane sources will be tested for calculational speed and accuracy, both dependent on the number of grids and biasing strength.

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