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Evaluation of COTS Rad Detection Apps

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Disclaimer

Mobile applications are currently under distribution to smart phones utilizing the built-in charge coupled-device (CCD) camera as a radiation detector. The CCD detector has a very low but measurable gamma interaction cross section so the mechanism is feasible, especially for higher dose rate environments. Given that in a large release of radioactive material these 'crowd sourced' measurements will be put forth for consideration, a testing and evaluation of the accuracy and uncertainty of the Apps is a critical endeavor. Not only is the accuracy of the reported measurement of concern to the immediate user's safety, a quantitative uncertainty is required for a government response such as the Federal Radiological Monitoring and Assessment Center (FRMAC) to accept the values for consideration in the determination of regions exceeding protective action guidelines. Already, prompted by the Fukushima nuclear material releases, several repositories of this crowd-sourced data have been created (http://japan.failedrobot.com, http://www.stubbytour.com/nuc/index_en.asp, and http://www.rdtn.org) although the question remains as to the reliability of measurements incorporated into these repositories. In cases of conflict between the real-time published crowd-sourced data and governmental protective actions prepared literature should be on-hand documenting why the difference, if any, exists.

Four applications for iOS devices were obtained along with hardware to benchmark their performance. Gamma/X-Ray Detector by Stephan Hotto, Geiger Camera by Senscare, and RadioactivityCounter App by Hotray LTD are all the applications available for distribution within the US that utilize the CCD camera sensor for detection of radiation levels. The CellRad app under development by Idaho National Laboratory for the Android platform was evaluated. In addition, iRad Geiger with the associated hardware accessory was also benchmarked. Radiation fields were generated in a Cs-137 JL Shepherd Model 89 shielded calibration range as seen in Figure 1. The accuracy of the exposure rate within the box calibrator is +/- 5% of the system settings and NIST traceable. This is the same calibration unit utilized for calibration of US DOE exposure rate meters. Measurements were performed from 0.2 to 40,000 mR/hr. Included in the following sections are discussions on each of the evaluated applications and their performance in reporting radiation field measurements. Unfortunately the applications do not provide a readily identifiable quality of the measurement in order to produce error bars or even out of range conditions. In general all the CCD based applications had issues detecting consistent measurements in radiation fields less than 5 mR/hr. This is most likely attributable to the electronic noise level on the CCD's becoming comparable to the signal level due to the ionizing radiation photons.

In order to collect the data the devices were connected to a computer running a development environment that could pull screen shots on demand of the device without interrupting the radiation exposure or exposing the radiation technologist to extra dose. Environmental conditions were monitored over the course of measurements and no significant change was observed. Devices tested were an Apple iPhone 4, iPhone 5 and iPod Touch (4'th Generation) and Samsung Galaxy S2, S3, and S4.

Figure 1: Shielded calibration range

GammaDetector

The Gamma/X-Ray Detector application developed by Stephan Hotto and available for free from the iTunes store utilizes the front facing camera of an iOS device. The camera aperture was covered with two layers of black electrical tape, as specified in the user's manual, in order to prevent visible light from reaching the CCD sensor. This application makes no attempt to present a calibrated measurement and simply reports the number of counts per minute it has detected. Although it does call out detection events where the photon deposits energy into multiple cells of the CCD, a characteristic of higher energy photons. One interesting feature of this application is it displays a real time display of the CCD's image readout. As seen in Figure 2, under a 2 R/hr radiation field, the human eye can observe the activated pixels. Figure 3 shows the reported values for the exposed radiation fields. Since the system makes no claim to calibration, linearity of the measurements is the primary performance aspect of concern. The purple line represents perfect linearity; the red and blue lines represent the tested devices. For the 2 mR/hr exposure on the red line the device reported zero as its measurement and not displayed on the log plot. For values exceeding 100 mR/hr the R^2 values of both devices exceed 0.999.


iPod
3:46 PM
Gamma / X-Ray Detector
EVT: 5
CNT: 562672
CPM: 108405
EPM: 136
PEM: 255
MCY: 37 Sec.
Sensor View
Clear
Threshold: 80
Time: CPM: EPM/PEM: EVT:
15:42:15 88860 136/255 +
15:43:15 107217 136/255 +
15:44:15 106159 135/255 +
15:45:15 107291 134/255 +
15:46:15 108405 136/255 +

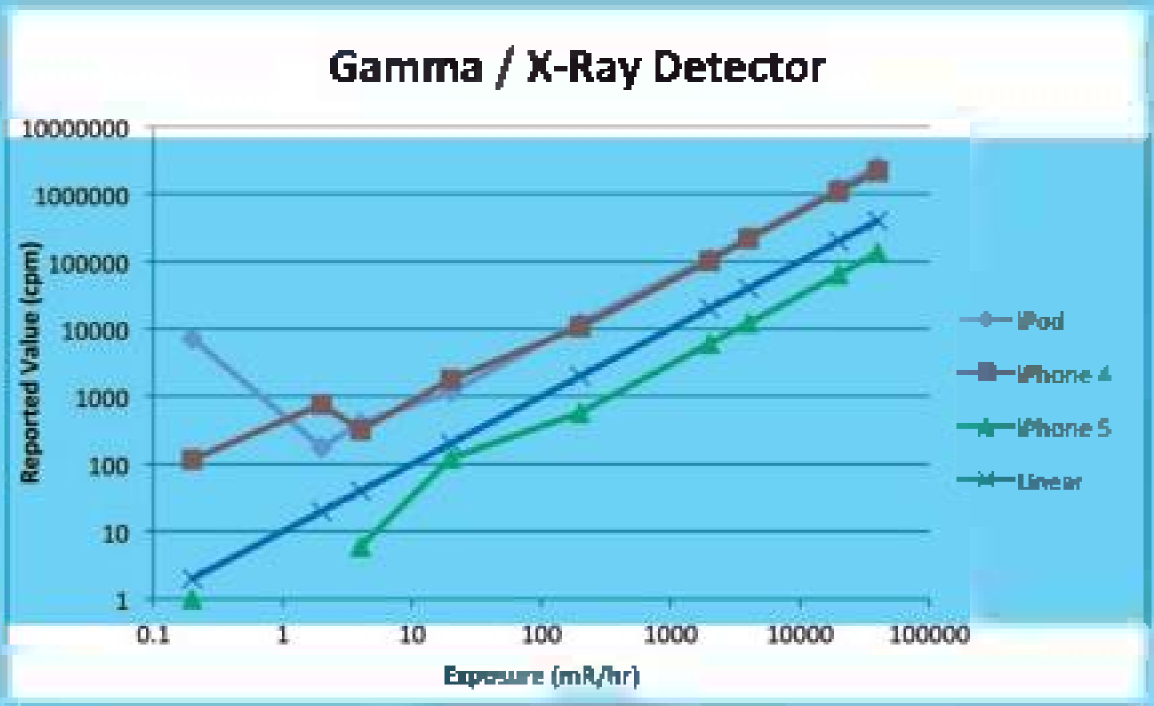

Gamma / X-Ray Detector
Reported Value (cpm)
10000000
1000000
100000
10000
1000
100
10
1
0.1
1
10
100
1000
10000
100000
Exposure (mR/hr)
iPod
iPhone 4
iPhone 5
Linear

Table 1: Gamma / X-Ray Detector Raw Measurements

Dose Rate (mR/hr)	iPod (cpm)	iPhone 4 (cpm)	iPhone 5 (cpm)
0.2	7189	116	1
2	175	765	0
4	400	317	6
20	1160	1801	121
200	12517	10611	575
2000	111151	101792	6067
4000	227968	215939	12319
20000	1217258	1108736	64331
40000	2598368	2140294	135152

Geiger Camera

The Geiger Camera application developed by Senscare and available for 99 cents from the iTunes store has the simplest user interface but the worst performance. At its best it underreports by nearly an order of magnitude. Also, once the device is exposed to fields above 200 mR/hr it appears to plateau in the reported measurement with no warning to the user that it has reached a plateau. In practice the application had significant measurement variability for the first several minutes in all radiation fields, therefore a 40-minute data collection time was utilized in order to give it time to stabilize. Figure 4 shows a screen shot of the application operating in a 4 R/hr (40 mSv/hr) field. Currently the application's reviews in the iTunes store are negative and the support/vendor web site is no longer reachable. In-application documentation is minimal and the vender was unresponsive to requests for more information.

Figure 4: Geiger Camera screen shot.

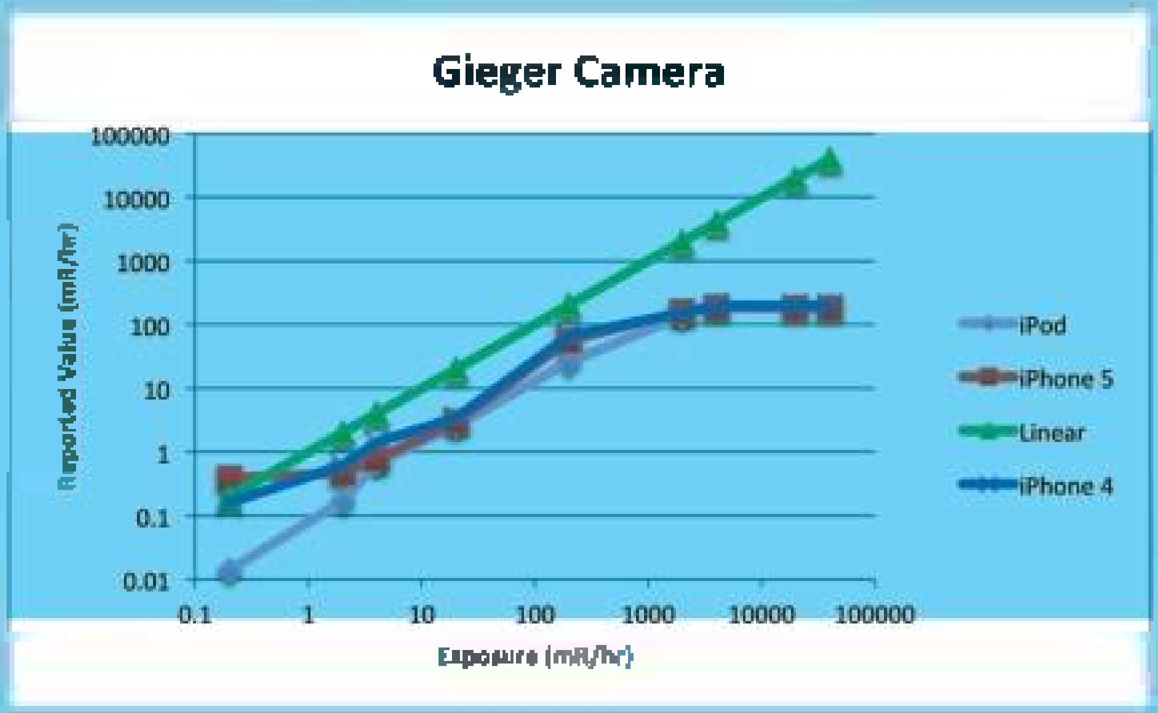


Table 2: Geiger Camera Raw Measurements

Dose (mR/hr)	iPod (mR/hr)	iPhone 5 (mR/hr)	iPhone 4 (mR/hr)
0	0.01	0.011	0.156
0.2	0.014	0.39	0.16
2	0.169	0.468	0.624
4	0.656	0.785	1.415
20	2.619	2.994	3.45
200	25.683	56.892	66.113
2000	137	159	152
4000	196	190	198
20000	188	184	199
40000	192	184	198

Radioactivity Counter

The Radioactivity Counter application developed by Hotray LTD is available for $4.99 from the iTunes store. Of all the applications tested this one had the most comprehensive and complex user interface. It allows the user to select which camera is utilized and there is also the capability to enter your own calibration factor for conversion from counts to exposure / dose rate measurments. In addition it has a builtin routine for setting the CCD noise threshold based on a short background measurement in order to maximize its operational range. Figure 6 shows the standard operating interface. The average value of the measurement period is prominentaly displayed along with a history of the current dose rates for every preceeding minute. As seen in Figure 7 the application normalizes counts between different devices and is highly linear and accurate over the widest range of all tested applications with an R^2 exceeding 0.99 from 2 mR/hr to 40 R/hr. A significant drawback for this software is the difficulty in operation. It required a significant amount of trial and error from the PI and the radaition technicions in order to obtain useful measurements which does not lend itself for use by the novice user.

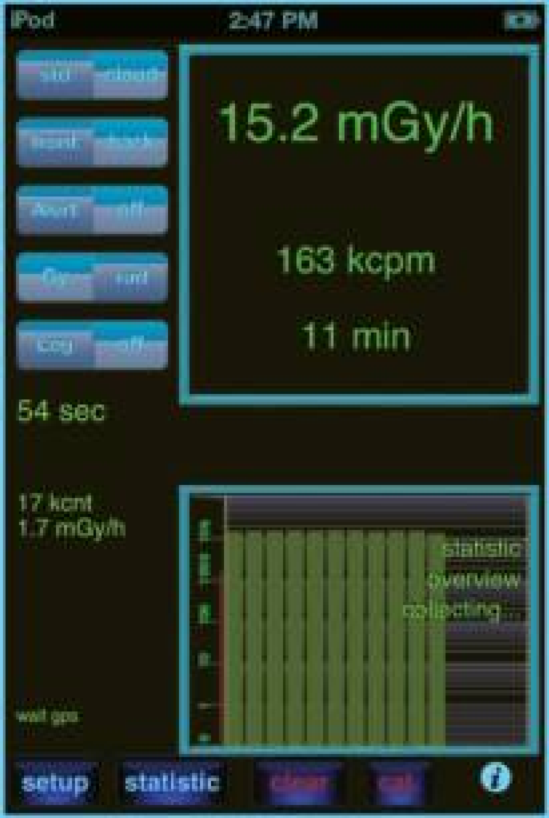


Figure 6: Radioactivity Counter

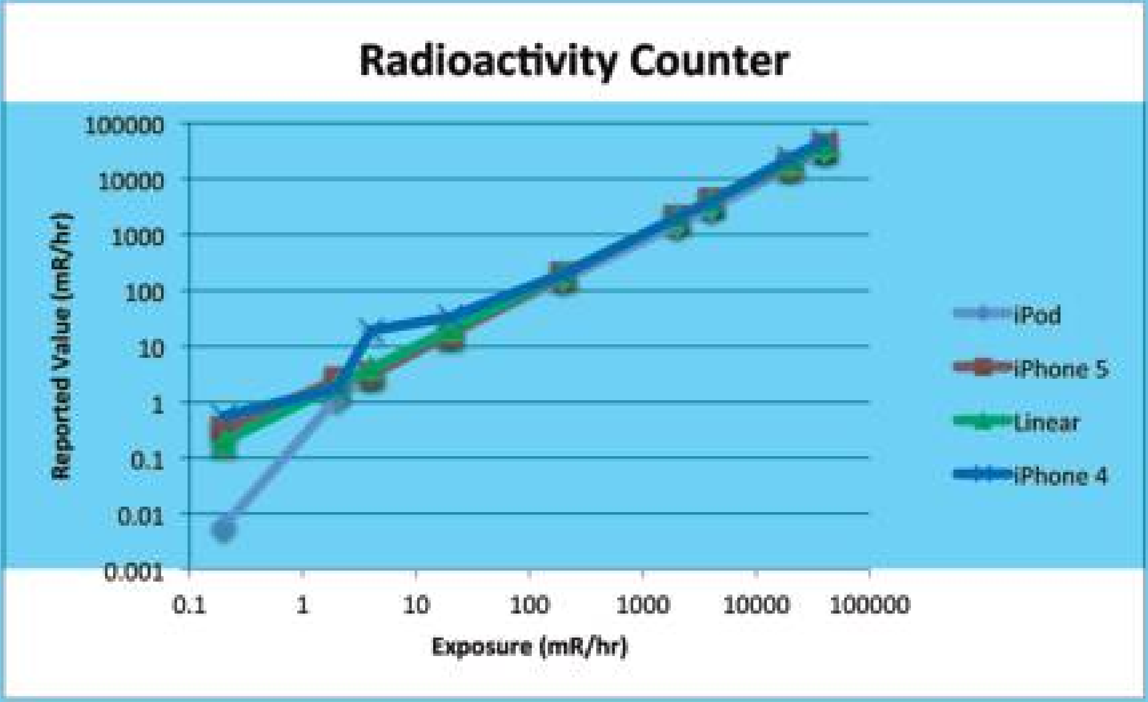


Table 3: Radioactivity Counter Raw Measurements

Dose Rate (mR/hr)	iPod (mR/hr)	iPhone 4 (mR/hr)	iPhone 5 (mR/hr)
0.2	0.006	0.5628	0.331
2	1.2	1.8	2.54
4	2.98	19.2	3.16
20	17.18	33.9	16.55
200	160	196.7	190
2000	1520	2000	2010
4000	3010	4000	4120
20000	16280	23200	17770
40000	31840	47600	38470

Android Developmental Application

An application currently under development at a National Laboratory was designed for the Android platform. It is not publically available at this time. The application actually consists of two applications, the first of which periodically obtains a photograph and a second that provides the user interface. Hopefully the two could be combined into one application for ultimate distribution to end users in order to avoid confusion. The application screen is show in Figure 8 consists of a large gauge indicative of the radiation exposure rate and a number below it. The On/Off button in the upper left has the same issue as the Radioactivity Counter app in that you press Off to start the measurement and you press On to stop the measurement. Unfortunately the authors only claim correct calibration for the Nexus S, Nexus 4, and Galaxy Nexus brands. In our testing we only had access to Samsung Galaxy S4, Galaxy S3, and Galaxy S2. While running the same Android OS version, the multi-vendor hardware fragmentation issue presented significant differences that caused compatibility issues. The Galaxy S2 was unable to run the app for more than 30 seconds before the secondary app would fail. The S3 and S4 could run the app longer between crashes but still suffer periodic freezes, keep in mind though that the suite is still in development and contains a significant amount of debugging code.

Unfortunately, as seen in Figure 9, at the time of evaluation it is still an application in the developmental process and a valid response could not obtained. Presumably this is due to minute differences between the Android OS between the two manufacturers.

Figure 8: Android application interface

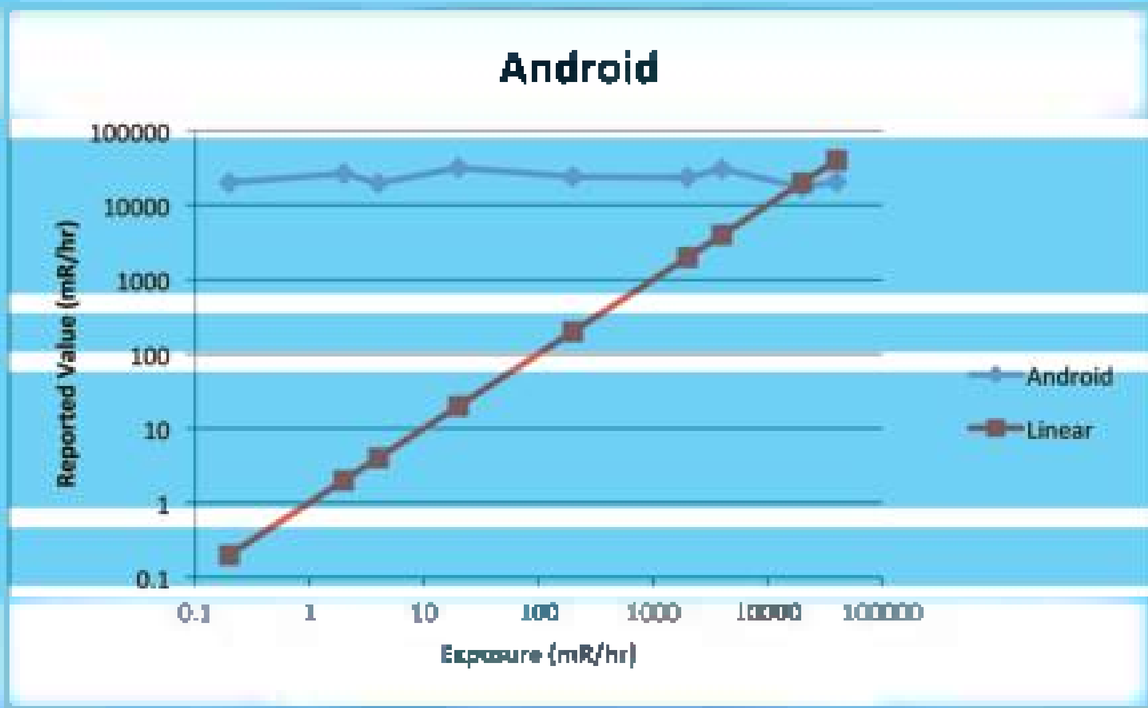


Figure 9. Android developmental application performance plot

Table 4. Android developmental application raw measurements

Dose Rate (mr/hr)	Android (mR/hr)
0.2	20177
2	26411
4	19800
20	31507
200	24167
2000	23333
4000	30389
20000	17300
40000	20330

iRad Geiger

The iRad Geiger application developed by Creative Electron utilizes an external accessory shown in Figure 10 that attaches to the headphone/microphone jack. It is essentially a Geiger-Mueller tube powered by an audio signal produced by the host device and delivering a detection signal into the microphone input. The application makes no use of the built-in CCD sensors and is available freely from the iTunes store. But the accessory costs $200 and is required in order to use the application. We tested the device over the entire range but the device is only rated for use from 0.014 to 100 mR/hr although it appeared to plateau at less than 10 mR/hr as seen in Figure 12. Other GM tubes with the same interface are available for purchase from the vendor for additional ranges of radiation fields.

An additional feature of this application is a built-in crowd source server application utilizing Pachube to upload the measurements along with the location obtained from the host device's internal GPS to crowd sourcing web sites automatically or e-mail the same data to any address.

Figure 10 The iRad GM Tube

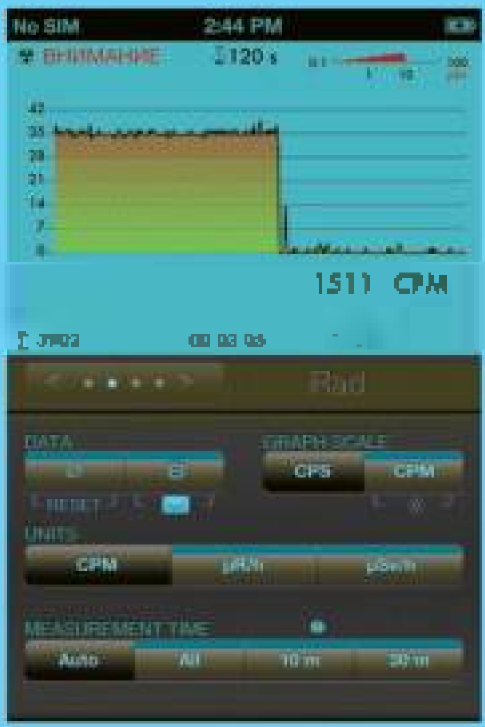
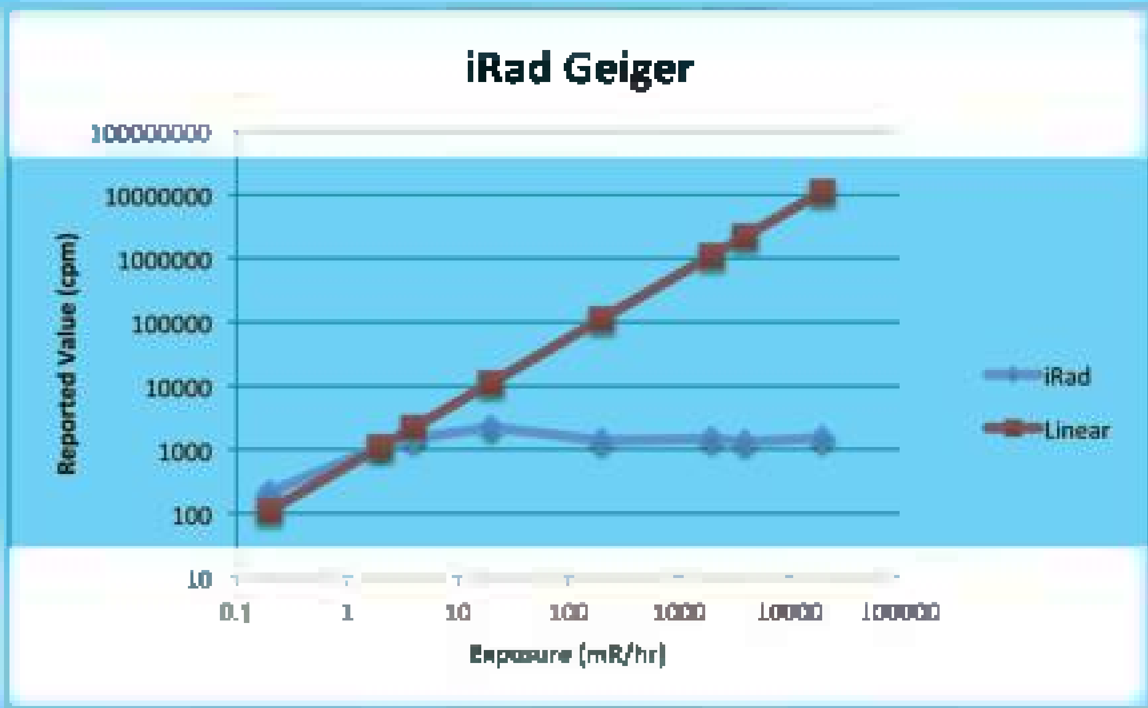


Figure 11 iRad Geiger user screen



Dose Rate (mR/hr)	Measurement (cpm)
0.2	216
2	1120
4	1473
20	2249
200	1386
2000	1501
4000	1316
20000	1509

Conclusions

The basic mechanism of detecting radiation is well demonstrated as feasible but there are significant concerns in the trustworthiness of reported values. Of primary concern is how two of the applications reach a plateau in the reported measurement but do not indicate to the user that the value could exceed. Although the plateaus are relatively high and a user should evacuate at even those levels, stay times calculated using those numbers could be significantly affected.

Possible future work would consist of collecting data across a wider hardware field including additional Android devices and investigating the effect of ionizing radiation on memory cell bit flips during their refresh cycle.

For an end user some key points to keep in mind when considering the use of such an application include:

- Measurement units
    - Are measurements reported in counts per minute or exposure rate?
- Performance of the application at low doses
    - Is zero reported? A value less than a minimum value, or is there a default minimum value displayed?
- Performance of the application at high doses
    - Do measurements plateau; is there a warning when operational limits are exceeded?
- Required count times
    - Are measurements instantaneous or is their a required count time

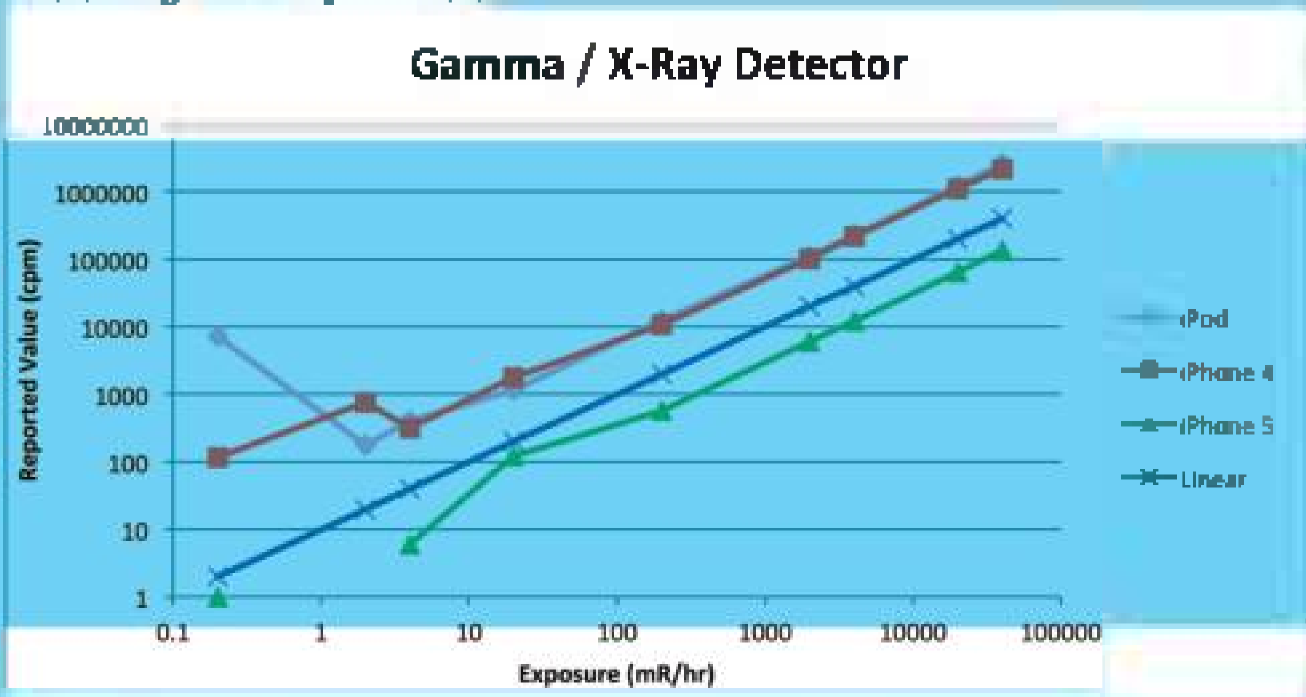
In general the currently deployed CCD based programs have in common a lack of sensitivity in the uR/hr region making the measurements highly dependent on the exposure time, CCD electronics noise and greater sensitivity to light leaks. Therefore measurements below 1 mR/hr should be considered highly suspect and ideally an application developer would provide feedback indicating this fact. What follows are some short appendices for each application describing recommendations on how to handle data received from those applications and to help inform the public if required.

Application: Gamma/X-Ray Detector v1.1
Vendor: Stephan Hotto
Measurement Type: CPM
Valid Range: 10 mR/hr – 40 R/hr

Pro: Freely available. Linear results over a wide range of measurements

Con: Measurements are host device specific. No user settable calibration factor. Does not provide a dose rate nor exposure rate measurement

Notes: Measurement values should only be compared between those from the same device. Application may function at higher levels beyond 40 R/hr.



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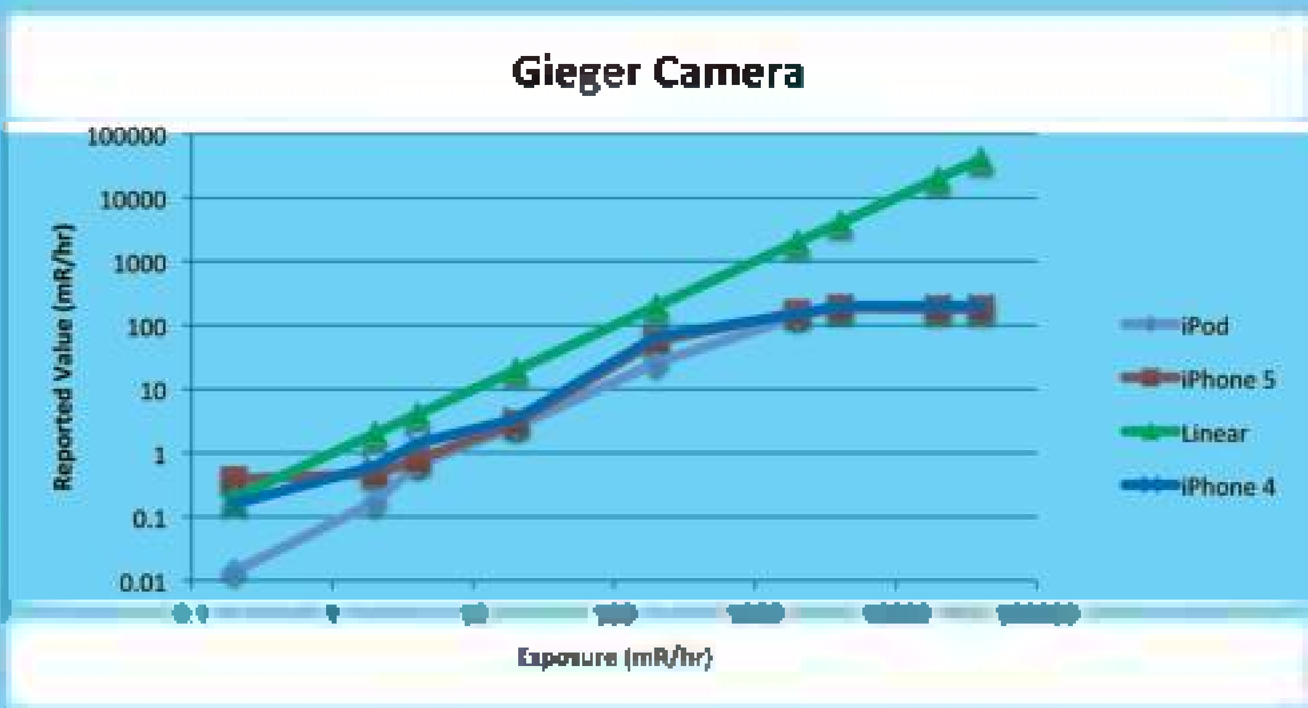
20000	1217258	1108736	64331
40000	2598368	2140294	135152

Application: Geiger Camera v1.0
Vendor: Senscare
Measurement Type: uSv/hr
Valid Range: none

Pro: Low cost ($0.99). Simple interface.

Con: Vendor website unavailable. Application has never been updated. Long measurement times are required in order to get a stable measurement. Reported value plateaus just under 200 mR/hr without any warning to the user. No user settable calibration factor.

Notes: People reporting values at this level should be warned their exposure level could be significantly higher



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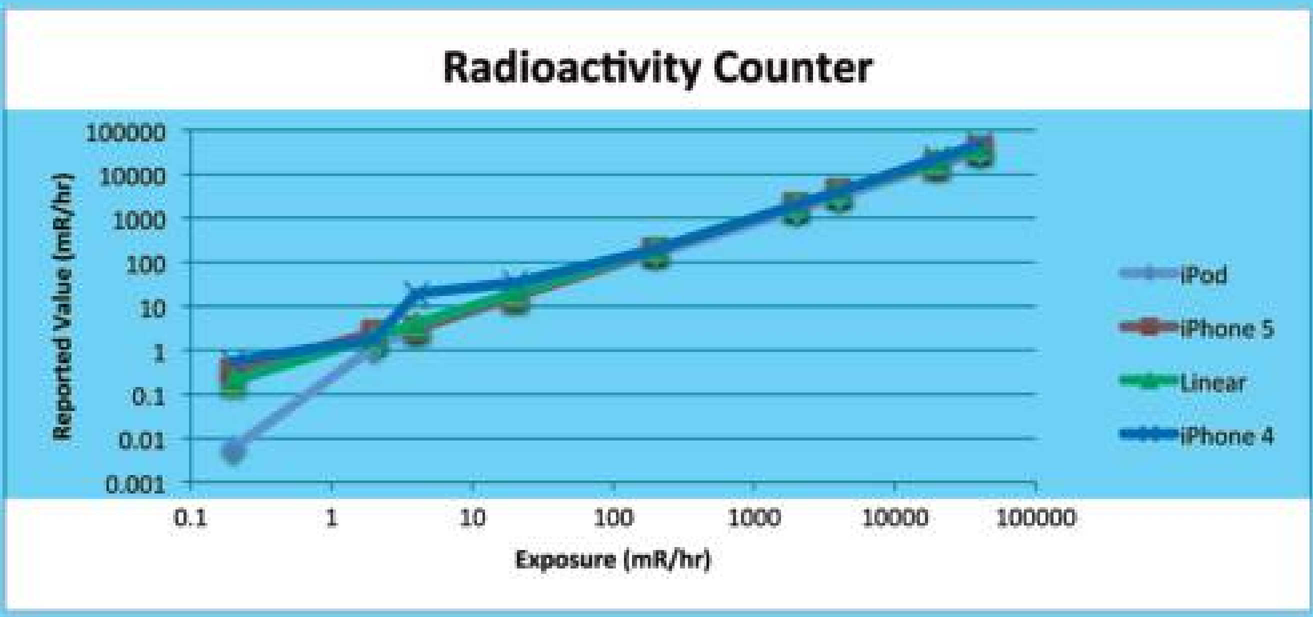
200	25.683	56.892	66.113
2000	137	159	152
4000	196	190	198
20000	188	184	199
40000	192	184	198

Application: RadioactivityCounter v1.1
Vendor: Hotray LTD
Measurement Type: Gy/h, rad/h
Valid Range: 2 mR/h – 40 R/h

Pro: The application normalizes data between hardware models. Values reported are highly linear. User can specify a manual calibration factor. Devices that pre-date the application's version have realistic default calibrations.

Con: High cost for a smart phone application ($4.99). Application updates required to incorporate normalization factors for new hardware. Complex user interface.

Notes. Lower range requires a successful calibration of the CCD in a background level radiation field to determine the level of electrical system noise, could be problematic if the application is first utilized after an environmental release. Most accurate results of all applications tested with the default settings.



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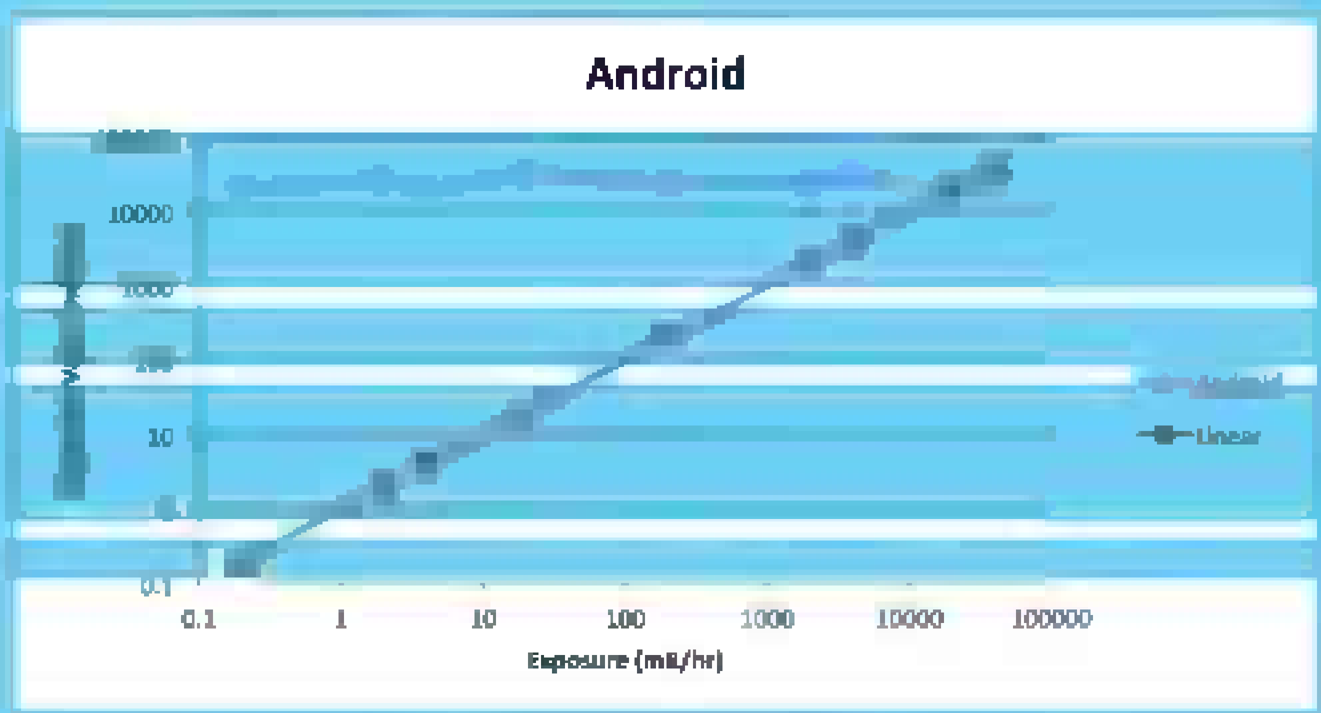
200	160	196.7	190
2000	1520	2000	2010
4000	3010	4000	4120
20000	16280	23200	17770
40000	31840	47600	38470

Application: Android Developmental
Vendor: National Laboratory
Measurement Type: mrem/h
Valid Range: none on Samsung Galaxy

Pro: The application runs on Android OS potentially available for a larger range of models

Con: Currently non-functional on the evaluated Samsung Galaxy model line.

Notes: The user interface GUI elements do not always line up with corresponding elements in the interface. The degree of misalignment seems to be a function of screen size.



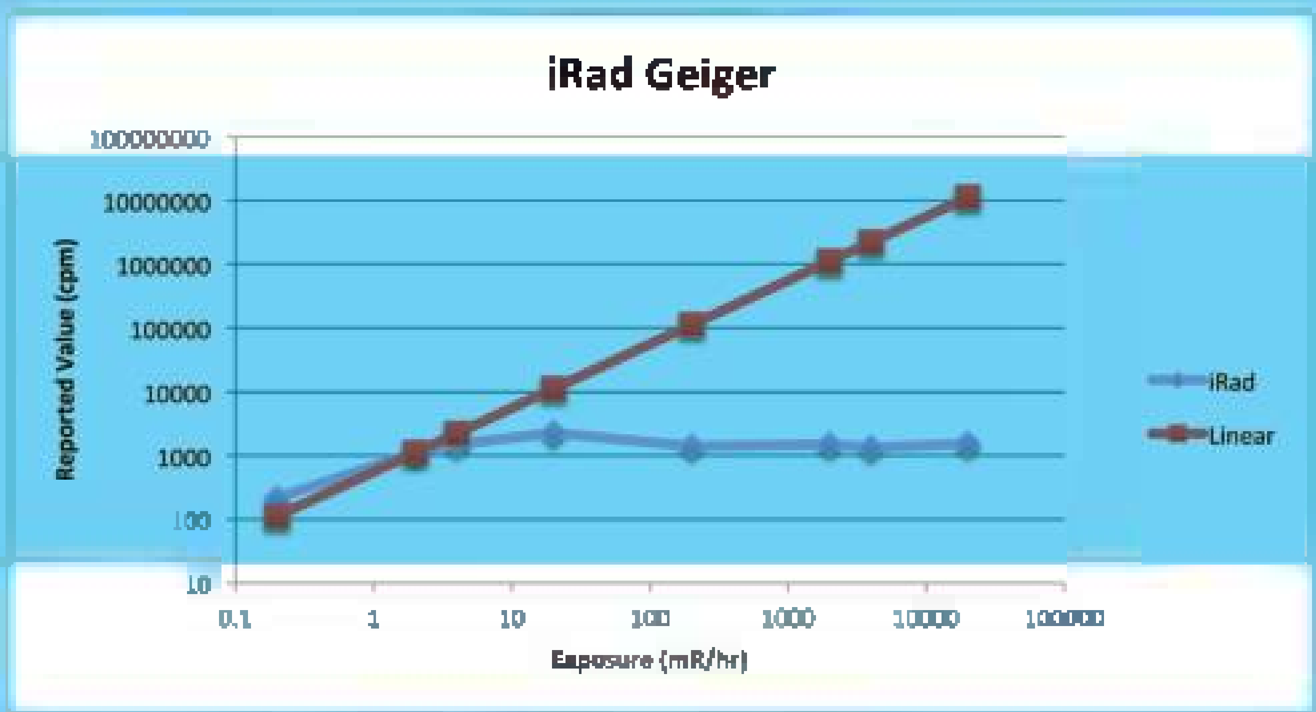
Dose Rate (mr/hr)	Android (mR/hr)
0.2	20177
2	26411
4	19800
20	31507
200	24167
2000	23333
4000	30389
20000	17300
40000	20330

Application: iRad Geiger v2.2
Vendor: Creative Electron
Measurement Type: CPM, uR/h, uSv/h
Valid Range: varies

Pro: Freely available application. Essentially an off-the-shelf energy compensated Geiger-Müller tube.

Con: Non-functional without costly accessory ($199). Does not warn the user when the dose rate exceeds the operating specs of the attached Geiger-Müller tube.

Notes: Tested with SBM20 GM tube with a published working range of 0.014 – 100 mR/h.



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