G3050

RadSearch: Radioactivity and Decommissioning Monitor

1. RadSearch overview

RadSearch is a gamma radiation detection device based on medium-resolution gamma ray spectroscopy (MRGS). It is a real time, self-contained, portable instrument that can be deployed by one person in less than 10 minutes. It is designed to find and quantify radioactivity and to determine surface dose rates on remote objects or surfaces. Results are displayed superimposed on a video image.

Gamma radiation is detected by a sensitive 1-inch by 1-inch Lanthanum Bromide (LaBr3) scintillation detector and photomultiplier. The detector assembly is located within a tungsten alloy shield, which attenuates radiation from all angles of incidence apart from the forwards direction. It has a user-selectable 4° or 18° aperture through which radiation is detected. The 4° aperture is achieved using a detachable collimating barrel made of stainless steel and tungsten.

A photograph of the RadSearch instrument unit is shown in Fig 1. A list of components and weights is shown in Table 1. In addition to the LaBr3 scintillation detector the detection head also contains a laser rangefinder and a colour CCD camera with zoom lens. These provide a colour video image of the area of plant or site under observation and the distance to the objects. The detector head is mounted on a motorised pan and tilt unit that can scan in 4π steradians (see Table 2). RadSearch is operated from a rugged remote laptop computer (which is designed for outdoor use) via a single cable that can be up to 80 metres long. This enables the instrument to be operated from a safe area minimising the operator dose uptake in accordance the ALARA principle. It can also be operated over a wireless link and powered from a 24 V battery.

RadSearch can scan the area to be monitored manually or it can be set to scan the area automatically. Indoors, it can automatically scan all surfaces of a room. During an automatic scan the system collects spectroscopic and video data from a raster of measurement points, essentially collecting data from equal angular intervals from the field of view (FOV) of the detector collimator. Typical scan increments are 3.4° or 4° with barrel collimator fitted, and 15° or 18° with the barrel collimator removed. The scan regime employed ensures uniform coverage of the area being scanned, in order to minimise the scan duration and to improve accuracy for any subsequent quantitative analysis.

Fig 1. RadSearch showing detector head, pan and tilt unit and tripod

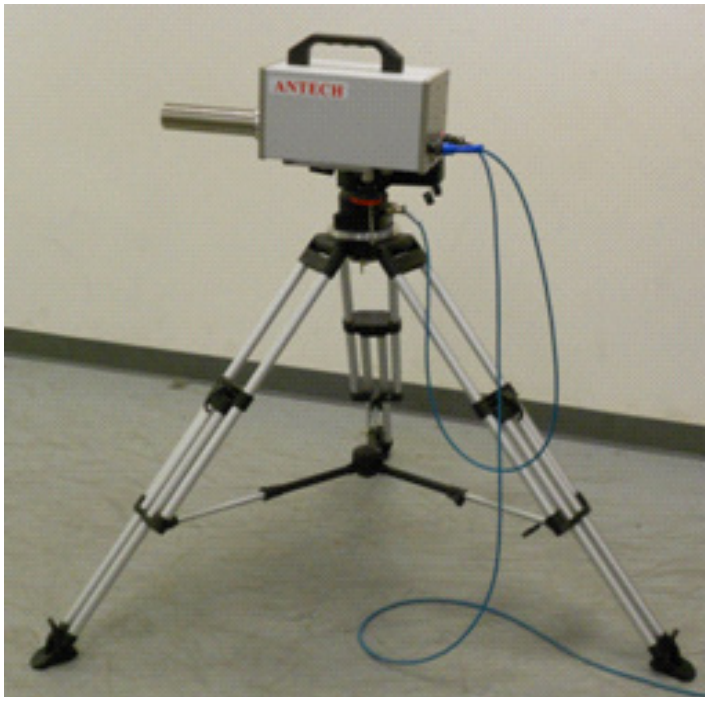


Table 1.

RadSearch Components	Weight
Detector head	20 kg
Detachable barrel collimator	4.1 kg
Pan-tilt mechanism	13 kg
Tripod	7 kg
Power supply unit (52 VDC)	1.4 kg
Rugged notebook computer	2.7 kg
100 m cable	3 kg
Local power and Ethernet connecting cables (4)	1 kg
Background plug	1 kg
Total weight	53.2 kg

Table 2.

Pan-Tilt Unit	Range
Pan angle range	± 180°
Tilt angle range	± 90°
Total range (steradians)	4 π

The location or coordinates of a measurement position may be captured at the start of a measurement sequence by recording the angles and distance to two prominent line-of-sight objects, which might be the corners of a room (if RadSearch is deployed indoors, for example). This may be done once the instrument is set into position for measurement. Once recorded, the video images, or Camera Fields of View (CFOV), and detector scans are associated in the measurement database with a specific measurement position. Note that the Detector FOV (which depends on which collimation - 4° or 18° has been selected) is less than the Camera FOV. At minimum zoom the Camera FOV is 51° in the horizontal direction and 30° in the vertical direction.

At each measurement point or scan angle (known as a Scan Element) the system stores the pan and tilt co-ordinates of the measurement, the range to the nearest line-of-sight object, a medium resolution gamma spectrum from the Detector FOV (DFOV) and the video images (full screen and zoomed to the Detector FOV) in compressed 'jpeg' format. Any gamma radiation found is overlaid using a colour scale onto the larger saved Camera FOV video image, the highest level in red and the lowest in blue. The top and bottom parameters of the dose rate scale are set automatically, based on the highest dose rate detected, to enable the required areas of radiation to be viewed. Using the camera zoom feature, a video image of the Detector FOV is also recorded for each scanned position, known as a Scan Element. An example of the type of overlay image produced is shown in Fig 2, which shows the distribution of radioactive contamination at a point on an external wall. The rectangular grid made up of Scan Elements constitutes the Scan Area.

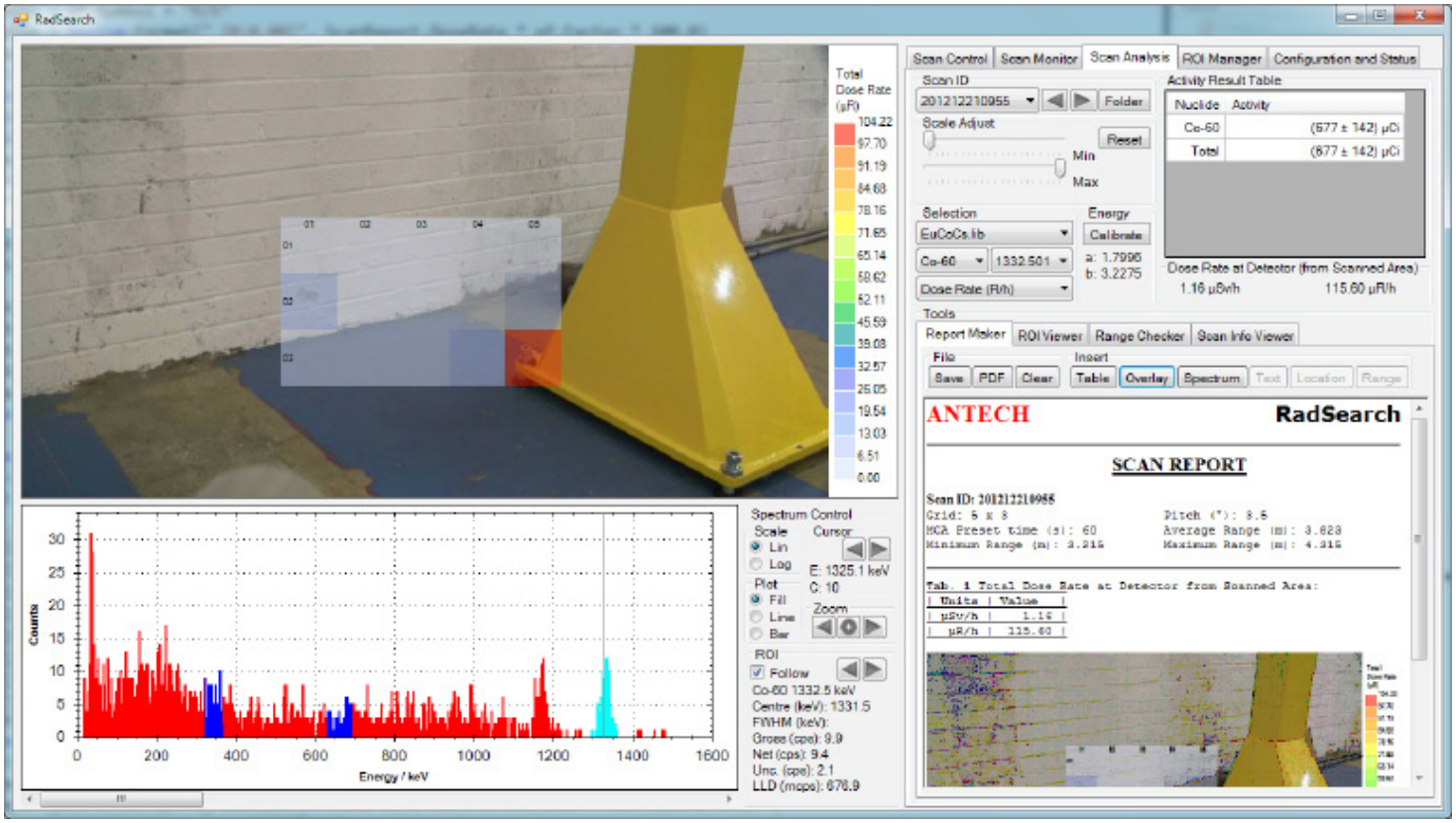
2. The RadSearch System

The ANTECH RadSearch radioactivity monitor remotely locates and characterises gamma ray emitting sources and gamma hotspots in a wide variety of environments including building surfaces, cells, glove-boxes, equipment and process vessels. It is a valuable inspection and measurement tool with applications in many disciplines, including decommissioning, waste stores, measurement of process activities, plant maintenance and radioactive clean-up.

The instrument maps and records the distribution and intensity of measured radiation using the factory calibrated LaBr3 scintillation detector, laser range finder and colour video camera built into the Detector head. Real–time colour video images from the camera FOV, which have the distribution of radioactivity superimposed as a coloured grid pattern of Scan Elements, can be viewed on the rugged notebook computer at a safe distance, thus minimising operator dose uptake.

The standard RadSearch configuration consists of the detector head, compact pan and tilt unit, collapsible and height

Fig 2. Results of a scan showing an overlay with the ROI set for Co-60. The video image shows the Scan Area made up of a 5 x 3 grid of Scan Elements. The report shows the Co-60 activity and the dose rate at the camera.



adjustable tripod, lightweight power supply unit and rugged notebook computer. The detector head and detachable pan and tilt unit can be deployed rapidly by a single user onto the lightweight tripod, which has a built-in levelling indicator. Alternatively RadSearch can be mounted on many other platforms including fixed or mobile stands, cranes, remotely operated vehicles (ROV's). It can be mounted directly to the building structure using integral quick release couplings and flanges. If mounted on an ROV, RadSearch can be powered from a 24-volt battery and communication can be by means of wireless Ethernet. Typically, the lightweight power supply unit and rugged notebook computer will be located in a safe area 40 or up to 80 metres away from the detector head. A view of all the components of RadSearch deployed indoors is shown in Fig 3.

Fig. 3 The RadSearch general arrangement, showing the complete unit deployed indoors.

3. RadSearch Detector Head

The detector head contains the following main items, which are described below. An assembly drawing of the detector head with covers removed can be seen in Fig 4.

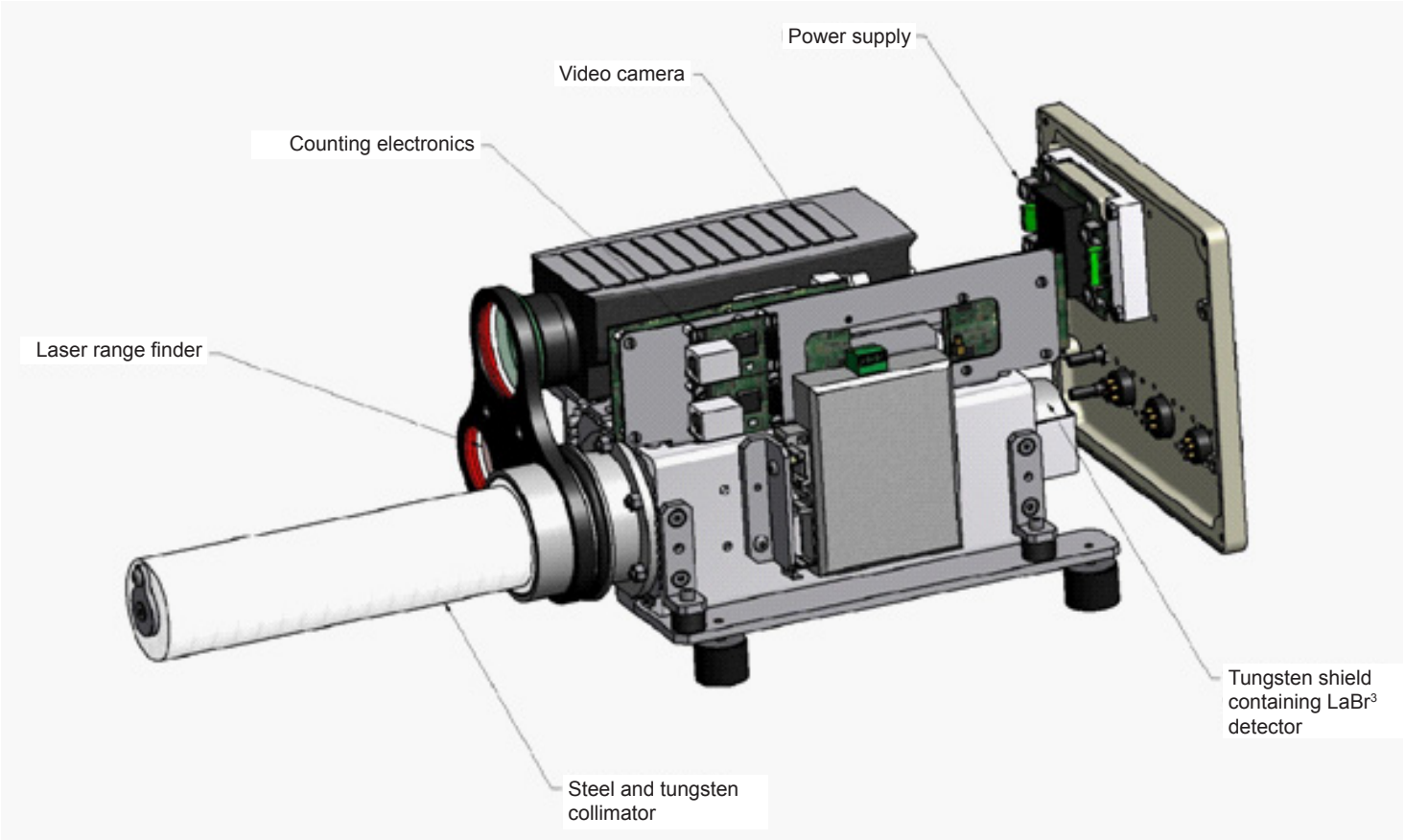
3.1 Detector

The gamma detector is a 1-inch by 1-inch Lanthanum Bromide (LaBr3) scintillation detector and photomultiplier, located within a tungsten shield and collimator. The detector will measure radiation within the range from 30keV to 2000keV.

3.2 Tungsten shielding

A tungsten shield and collimator for the detector provides a field of view (FOV) of 18°. A collimator barrel is provided as standard and is used to reduce the FOV to 4°. This collimator arrangement minimises the effects of any background radiation and ensures that the radiation detection system is completely directional. RadSearch is normally operated using the 4° FOV collimator (barrel attached).

Fig. 4 The detector head



3.3 Colour camera and zoom lens

The camera has a HD colour 1/3" Progressive Scan CMOS image sensor (2 Megapixel, 1920 x 1080 resolution). The minimum illumination is 2 Lux for colour and 0.2 Lux for B/W. It is equipped with a lens with motorised 10x optical zoom, autofocus and auto-iris (F 5.1 - 51 mm, F1.8 - 2.1).

3.4 Laser range finder

The range finder comprises a red laser diode (with a visible 'spot') and has a measurement range of 0.05 m - 65 m on natural surfaces and 0.05 m - 150 m on an orange (reflective) target plate. The typical accuracy is +/- 3 mm.

3.5 Multichannel Analyser (MCA)

The Multichannel Analyser is a full function MCA designed specifically for collecting data arising from MRGS detectors, with 8,192 channels. For spectral analysis and data storage, data is transferred by Ethernet from the MCA to the rugged notebook computer.

4. The Pan & Tilt Unit

The detector head is mounted onto a pan and tilt unit by a quick release fitting to aid rapid assembly and disassembly. The unit is connected to the detector head by a single cable carrying both power and signal. The pan and tilt unit is motorised and can scan in 4π steradians (see Table 2).

The pan and tilt unit allows the detector head to pan (rotate about a vertical axis - ± 180°) and tilt (rotate about a horizontal axis - ± 90°). The pan and tilt unit is attached to the tripod (or other platform) and the detector head by means of quick release couplings.

5. Tripod

The tripod is collapsible for transport and the height at which the pan and tilt unit and the detector head are mounted is adjustable. The quick release mounting mechanism to which the pan and tilt unit is fixed contains an X and Y spirit level indicator so that the unit can be set in a level position before the pan and tilt unit and subsequently the detector head are mounted. This feature is especially useful if the unit is positioned on rough ground and it reduces the set-up time when the unit is repositioned.

6. Operator's Rugged Notebook Computer & Power Supply Unit

Normally the lightweight power supply unit and the rugged notebook computer are positioned at a distance from the detector head, pan and tilt unit and tripod, in keeping with the ALARA principle. Cables of 5 and 40 meters are supplied as standard to connect the lightweight power supply unit and the rugged notebook computer to the RadSearch detector head. A cable of 80 meters length is also available. The cable supplies power at 50 volts DC and Ethernet to the detector head. The rugged notebook computer is connected to the lightweight power supply unit by a 3 meter Ethernet cable. Both the lightweight power supply unit and the rugged notebook computer operate on either 110 or 230 volts AC.

The rugged notebook computer (which is supplied as standard) is built into a rugged and protected case. It is fitted with a solid-state disk, a screen designed to be visible in sunlight and it has extended battery life. It is supplied with Microsoft Windows 7™ and comes loaded with all necessary RadSearch operating software.

During a measurement or scan, the measured radiological gamma ray spectral data, video images and range information are relayed to the rugged notebook computer where the data are saved in a unique file on the system solid state hard drive. As indicated earlier, the rugged notebook computer can be located up to 80 metres from the detector head. The data acquisition and data analysis software is installed and run independently on the rugged notebook computer and on-screen information is presented using Microsoft Windows 7™ compatible software.

7. Data Acquisition & Analysis Software

The Data Acquisition and Analysis Software is used to configure the measurement parameters and to collect and store the data from the detector head and analyse the data once it has been obtained. User configurable parameters include things such as the orientation of the detector head, the detector collimation and the choice of radionuclides to be identified. The data acquisition screen is shown in Fig. 5 (see below). Note that the collimation is changed manually by unscrewing and removing the collimator barrel.

Regions of Interest (ROI's) are regions of the energy spectrum used to identify and quantify specific radionuclides. The ROI's for a number of radionuclides of interest are incorporated automatically in the data acquisition and analysis software. Some of these radionuclides of interest are listed in Table 3. Additional radionuclides and their ROI's can be added by the user, if required. The results of a scan are shown on the Scan Analysis screen (displayed in Figure 2).

At any time during manual scanning, the user can view a display of the current video image (Camera FOV) with an on-screen Detector FOV circle and the acquired spectrum from the currently viewed Scan Element. All status, geometric and radiometric data is permanently displayed. Measurement data and its associated system parameters are recorded in a database on the rugged notebook computer.

An automatic scan is set up by positioning the camera field of view with the cursor at the centre of the object or

feature. The size of the Scan Grid and the Scan Pitch are then selected. The Scan Area is shown on the screen as a rectangular box.

Upon entering the time allowed for acquisition of data at each measurement position, an estimate for the duration of the scan is displayed. If it is accepted, the entire scan is performed automatically. During the scan the count rate(s), angles and distance, acquired spectra, calculated dose-rate and video frame for each Scan Element (detector FOVs) are recorded to a measurement data file.

During the process of manual operation the camera field of view (Camera FOV) can be adjusted by changing either the camera lens zoom or by adjusting the angular settings of the pan and tilt unit. The Camera FOV also displays the collimated Detector FOV as a circle overlay on the video image. This is how the Detector FOV can be set by the operator in order to look at a specific object or position during manual operation. Using either the mouse, the computer keys or a USB Joystick plugged into the notebook computer the operator can manually scan an object or area and monitor the dose-rate and the spectrum display arising from objects in the Detector FOV.

Previously recorded scans are stored in the measurement database with their associated Camera FOV and they can be reviewed at a later date, as required by the user. Such previous measurement data retrieved from the database is presented to the user in the form of a Camera FOV video image, which shows a colour graphic overlay image of each Scan Element (see Fig. 2). The user can choose to display data from any one of the ROI's associated with a specific radionuclide, as pre-configured in the database.

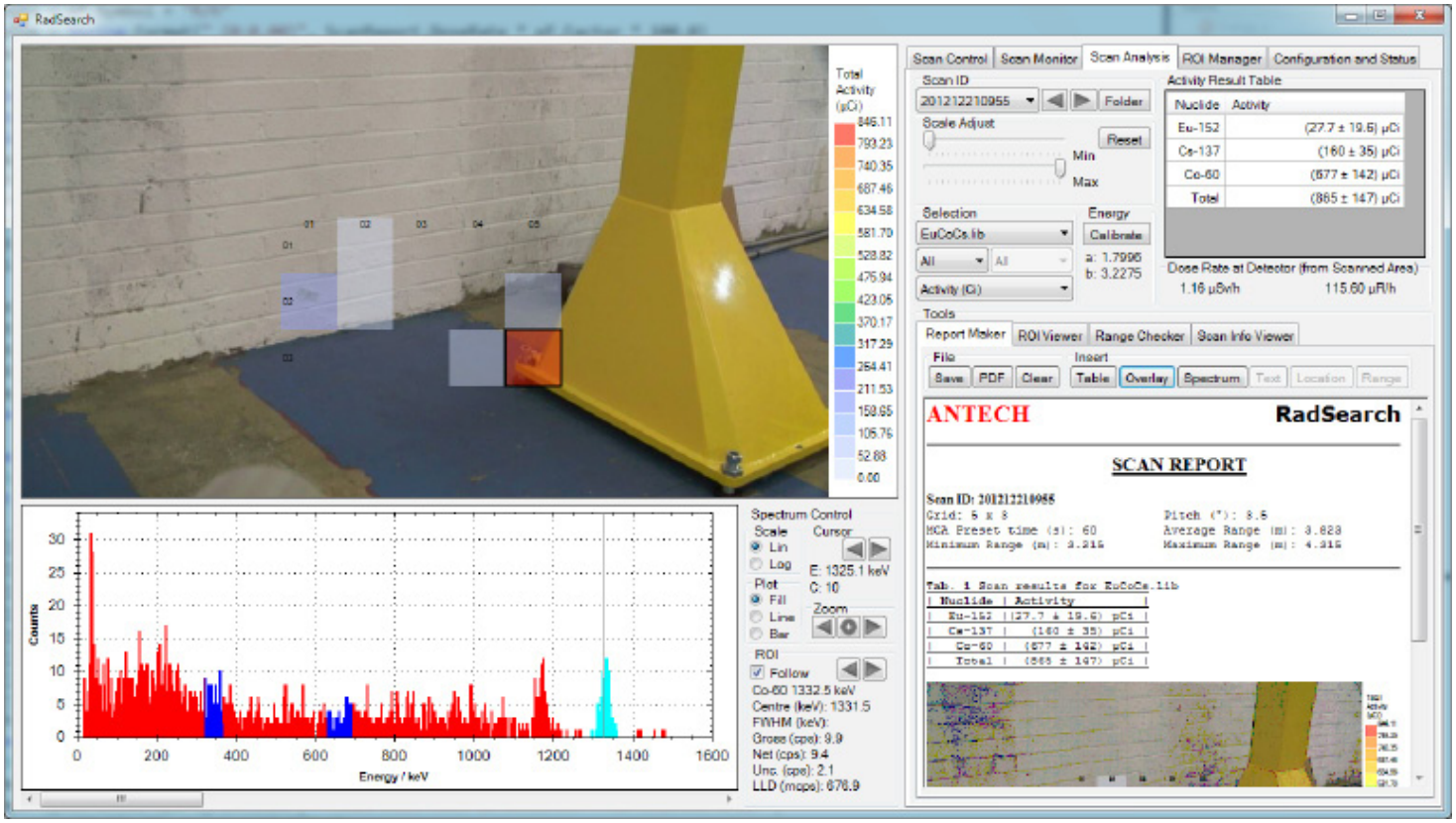
A threshold for a selected ROI can be adjusted using the 'Scale Adjust' function and the system will display the Scan Elements at which the count rate in the ROI exceeds the threshold. As indicated earlier, the user has the facility to create new ROI's and post process the acquired data to form new ROI count rates. These may be used to search for previously unidentified hot spots.

RadSearch displays the count rate(s) (corrected for dead-time) at the detector from objects within the Detector FOV from selected ROI's as configured in the Data Acquisition and Analysis Software. A user can opt to correct the count rate to what it would be if the object were at a range specified by the user.

8. System Interconnections

The system is quickly and easily assembled using quick release mechanical and multi-way electrical connectors. The pan and tilt unit is connected to the tripod by a single quick release mechanical screw connector. The detector head is similarly connected to the pan and tilt unit by a single quick

Fig. 5. Scan Analysis screen showing the activities for three radionuclides and the dose rate at the RadSearch detector head. In Scan Analysis the user can generate reports using the Report Maker and insert table, overlay or spectrum commands. The report can be saved as a PDF.



release mechanical screw connector. The detector head is placed on the pan and tilt mounting position and slid forward until it locates in position. The screw mechanism is then secured. The detector head is electrically connected to the pan and tilt unit by a single cable with multi-way electrical connectors, which transmit both power and control signals.

The pan and tilt unit and detector head assembly is electrically connected to the lightweight power supply unit via a single cable, (typically 6, 40 or 80 metres in length), which transmit both power and control signals. A short Ethernet cable connects the lightweight power supply unit to the operator's rugged notebook computer. These units are located close together. The tripod, pan and tilt unit and detector head can be assembled by a single person in less than ten minutes, therefore minimising the amount of time that personnel are required to spend in the hot area.

9. Anti-contamination PVC Hood

A disposable, PVC hood is being designed and can be supplied for use when RadSearch is to be deployed in contaminated environments. This hood completely covers the detector head and tripod and has a clear front window where the video camera and laser range finder are located on the front face of the detector head. Its purpose is to prevent the instrument from becoming contaminated.

10. RadSearch Operation and Scanning

Once the RadSearch is deployed and made operational, the operator, as part of the setup procedure, will be invited or required to input certain parameters such as the location or coordinates of a measurement position, the measurement time at each data collection point and other data. The operator can scan an area manually or set up either an automatic scan within the Camera FOV, a Camera FOV Scan, or an automatic scan which has an angular extent greater than the angular extent of the Camera FOV. The latter type of automatic scan could, for example, be a scan of the entire internal surfaces of a room. It would have associated with it several Camera FOVs. RadSearch has the capability to scan large areas without the need to be re-deployed.

Scanning is performed in a raster format. For each measured point of the raster (Detector FOV or fractional Detector FOV) the video frame image, measured radiometric data, range and pan and tilt angular data are all saved to the data base for the specific measurement on the rugged notebook computer solid state hard drive.

10.1 Performing a manual scan:

The operator can manually scan an area of interest using the mouse, the keyboard keys or a USB joystick. A manual scan is sometimes useful to locate a particular area of interest within a larger area, after which a smaller automatic scan can be performed to obtain and record the detail from the area of interest. For example, a large wall 4 metres x 3 metres may only have two hotspots both contained within an area of one square metre. A quick manual scan over the whole wall area will identify the hotspots. The operator could then perform a detailed automatic scan on this smaller portion of the wall area only, thus saving considerable scanning time.

10.2 Performing an automatic scan:

The automatic scan is generally used when scanning a large area. An automatic scan is easy to set up; typically the operator is required to drive the detector head to the centre of the area to be scanned. The operator can then use the mouse or key strokes to set the grid pattern of Scan Elements defining the Scan Area. Other parameters, such as the measurement time for each Scan Element (Detector FOV), can also be entered during the setup. Once the setup is complete the operator initiates the scan and the instrument will automatically commence the scan from the top left corner. The automatic scan of a large area can take many hours to complete and a considerable advantage of the automatic scan is that once the scan has commenced the operator can leave the instrument to complete the scan unattended. A scan could be set to run overnight, for instance, and be completed by the beginning of the next working day.

10.3 Performing a Camera FOV Scan:

A Camera FOV Scan only scans the area within the field of view of the Camera (Camera FOV). If the operator has located a hotspot within the Camera FOV and wishes to scan only the immediate area around this hotspot he can use the Camera FOV scan to do this. The actual area of the scan can be enlarged or decreased using the zoom lens facility; zooming in will decrease the size of the camera's FOV and, therefore, the area to be scanned.

10.4 A further advantage of scanning:

A further significant advantage of the RadSearch integral scanning capability is the possibility of scanning large areas from a short distance (down to 1 metre from the target area). This is particularly useful when the target area contains hotspots or areas of contamination with low activity. The RadSearch tungsten shielding is also a considerable advantage in these low level situations, especially where there is a significant background activity or out of view sources are present.

RadSearch is supplied as standard with a tungsten collimator barrel plug, which closes the collimator aperture and completely shields the LaBr3 scintillation detector. Using the shield plug one can assess the background arising from all angles and directions (4π steradians) and make an accurate background correction. RadSearch is much more versatile than far field gamma ray measuring instruments with a fixed and generally large field of view. With the barrel collimator removed and a resulting 18° aperture FOV, RadSearch can be used for far field assay measurement applications.

11. Regions of Interest (ROIs)

RadSearch provides a number of predefined ROI's for radionuclides of interest and one for the whole spectrum. These spectrum ranges are known as 'Regions Of Interest' (or ROI's) and the analysis software will use this data to display overlays for the isotope(s) within the selected ROI only.

ANTECH has included a number of ROI's on the RadSearch system prior to shipment for radionuclides of interest. These include a suitable ROI covering the photopeak region for Am-241 (centred on 60 keV), Cs-137 (centred on 662 keV), Co-60 (covering the 1173 keV and 1332 keV photopeaks), (see Table 3). An operator can create additional ROI's, modify existing ROI's and delete existing ROI's.

Table 3. Radionuclides with Pre-selected ROIs in the Gamma-ray Energy Spectrum

Radionuclide	Gamma-ray Energy (keV)
K-40	1460
Co-60	1332
I-131	364
Ba-133	356
Cs-134	796
Cs-137	662
U-235	186
Am-241	60
Pu-239	414

After an automatic scan has been completed, the data from each ROI can be displayed in turn (but not at the same time) by selecting the appropriate ROI for a given radionuclide such as Cs-137 on the screen. The measured count rate activity or dose rate from an ROI is superimposed onto each Scan Element of video captured during the automatic scan. It is easy to search all Scan Elements on the grid superimposed on the video for gamma hotspots and to move between displaying the different ROI's. A single scan collects data from each of the selected ROI's so there is no need to perform a separate scan for each of the ROI's.

The operator can retrospectively change any or all of the ROI's and view the same scene as if it had been scanned with different ROI's. No additional scanning is required. This powerful feature is possible because the entire spectrum for each Scan Element is recorded to the rugged notebook computer. This feature is beneficial if the operator feels that an incorrect ROI was used during the collection of the original data in an automatic scan, or if new information suggests that it would be worthwhile viewing the same scene with a different ROI or ROI's.

12. The Results

An example of a results screen can be viewed in Fig. 2. In this case the Camera FOV has a colour graphical overlay representing the radiological data recorded for the measurement scan. Note that selected measurement point is highlighted and the data relevant to that point is displayed on the screen. An automatically adjusted count rate, activity or dose-rate scale is displayed next to the image. The results screen also displays the activity of the complete Scan Area based on a factory calibration of the shielded detector.

In terms of sensitivity the detection level for the detector is less than 1 µCi for a point source of Cs-137 at 1 metre from the collimated detector (collimator barrel fitted) with a measurement time of 100 seconds. This results in a measured dose-rate of 0.0028 µSv/h. A 10 µCi Cs-137 point source at 1 metre measured for 100 seconds results in a dose-rate of 0.028 µSv/h, and RadSearch can measure this source with a precision of about 20% (1 sigma). Based on this measurement, Table 4 lists the Cs-137 point source activity that can be measured by RadSearch in 100 seconds with a measurement precision of 20% (1 sigma) for various distances between the RadSearch Detector Head and the point source.

Table 4. RadSearch Measurement Sensitivity for Cs-137 Point Sources for a measurement precision of 20% (1 sigma) with a 100 second measurement time

Distance (metre)	1	2	5	10	15	20
Activity of Cs-137 (µ Ci)	10	40	254	1035	2375	4306

13. Specification

Item		Unit	
1	Detector head	Size (L x W x H)	36.5 cm x 20.5 cm x 17.5 cm
		Mass	20 kg (24 kg with barrel fitted)
		Orientation	Not restricted
1.1	Detector	Detector type	$LaBr_3$ 1 in. x 1 in. with photomultiplier
		Energy range	~ 30 keV to 1,500 keV
		Operating range	< 1 µCi to 0.5 Ci for Cs-137 in field of view at 1 metre
		Dose rate range	0 – 500 mGy / h for Cs-137 (high end with plug to reduce detector field of view)
1.2	Video camera	Specification / Type	HD Colour 1/3” progressive scan CMOS, 2 Lux, 10x optical zoom lens, autofocus and auto-iris
		Maximum Field of View (FOV)	51˚ horizontal, 30˚ vertical
1.3	Laser range finder	Colour	Red laser diode with visible spot
		Laser class	IEC 825-1:1993, Class 2
		Range (natural surfaces)	0.05 m to 65 m, ± 3 mm
1.4	Detachable barrel collimator	Size (L x Diameter)	26 cm x 5.5 cm
		Mass	4.1 kg
		Detector FOV (with barrel collimator)	4˚
		Detector FOV (without barrel collimator fitted)	18˚
2	Pan and tilt unit	Mass	13 kg
		Envelope (H x W x D)	35 cm x 22 cm x 35 cm
		Scanning angles	± 180˚ pan; ± 90˚ tilt (4π steradians)
3	Tripod	Mass	7 kg
		Size envelope when collapsed (L x Diameter)	83 cm x 20 cm
4	Interconnecting cable	Voltage	50 V DC
		Signal	Ethernet
		Length	Up to 80 m
		Mass	3 kg
5	Power supply unit	Mass	1.4 kg
		Size (L x W x H)	26 cm x 18.5 cm x 6 cm
		Input	110 or 230 V AC, 50/60 Hz (wide ranging)
		Output	50 V DC
		Power connector	IEC
6	Rugged notebook computer	Mass	2.7 kg
		Size (W x D x H)	352 mm x 256 mm x 41 mm
		Operating system	Windows 7
		Data storage media	Intel 80 GB solid state drive
		Battery life	Extended (9 cells)
		Screen	Anti-reflective LCD screen (outdoor use), 14 in display
		Processor	Intel Dual Core 2.3 GHz