HIGH IONIZING RADIATION FIELD REMOTE VISALIZATION DEVICE – SHIELDING REQUIREMENTS

Antonio P. Rodrigues Fernandez[1], Nelson M. Omi[2], Carlos Gaia da Silveira[2] Wilson A. Pajero Calvo[2]

[1]Serviço Nacional de Aprendizagem Industrial – SENAI /SP – Escola José Ephim Mindlin
Alameda Waghi Salles Nemer 124
06401-134 Barueri, SP
afernandez@sp.senai.br

[2]Instituto de Pesquisas Energéticas e Nucleares (IPEN/CTR/CNEN)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
nminoru@ipen.br, cgsilvei@ipen.br, wapcalvo@ipen.br

ABSTRACT

The high activity sources manipulation hot-cells use special and very thick leaded glass windows. This window provides a single sight of what is being manipulated inside the hot-cell. The use of surveillance cameras would replace the leaded glass window, provide other sights and show more details of the manipulated pieces, using the zoom capacity. Online distant manipulation may be implemented, too. The limitation is their low ionizing radiation resistance. This low resistance also limited the useful time of robots made to explore or even fix problematic nuclear reactor core, industrial gamma irradiators and high radioactive leaks. This work is a part of the development of a high gamma field remote visualization device using commercial surveillance cameras. These cameras are cheap enough to be discarded after the use for some hours of use in an emergency application, some days or some months in routine applications. A radiation shield can be used but it cannot block the camera sight which is the shield weakness. Estimates of the camera and its electronics resistance may be made knowing each component behavior. This knowledge is also used to determine the optical sensor type and the lens material, too. A better approach will be obtained with the commercial cameras working inside a high gamma field, like the one inside of the IPEN Multipurpose Irradiator. The goal of this work is to establish the radiation shielding needed to extend the camera's useful time to hours, days or months, depending on the application needs.

1. INTRODUCTION

This paper aims to present the results of one stage in the construction of the Remote System View Resistant to Ionizing Radiation that is being developed at the Center of Radiation Technology of the Institute of Energy Nuclear and Energy Research. This step was taken with the camera surveillance TOP CAM low cost brand, model TC 1868CDN with 1/3 Color sensor CCD 480 TVL, that was exposed to various dose rates in an panoramic source of cobalt-60, where the main objective the step in question was to determine whether such a camera has conditions to be used as part of marking the comparative efficiency of the reduction of dose rate on the camera equipment and commitment of capturing color and detail through the Remote System View resistant to ionizing radiation.

The main ionizing radiation present in glove boxes and exposure of radioactive materials are alpha, beta and gamma [2]. This radiation is the most degrading is the gamma [1].

On some occasions it is necessary to use surveillance cameras to aggregate closed circuit television (CCTV) systems allowing visual inspection of irradiation rooms or hot cells where high activity sources are manipulated or radiological accident sites.

The surveillance camera inside the irradiation rooms is useful to verify the Co^{60} source or products actual positions. For the hot cells, it is possible to increase the viewing angles (points) and can also eliminate the need for thick radiation shielding windows. And in radiological emergencies you can use a camera in remote controlled vehicles in high dose rates sites.

This work intended to verify the dose rate limit to get clear pictures, or a low level of electromagnetic noise (static) in a low cost CCTV device.

In low cost cameras which lacks resources such as optical zoom, high resolution, bit depth etc., it may not make sense to create a device to extend the its lifetime, but for cameras that can cost a few hundreds of dollars this perspective tends to change. For radiological emergencies where a high dose rate can compromise the image clarity, even when it is generated by a low-cost camera, to build a device to mitigate or even eliminate the electromagnetic noise produced by ionizing radiation sources in CCTV cameras begins to make sense.

To determine the effectiveness of the Remote System View Resistant to Ionizing Radiation it is necessary first to find out how the camera behaves in terms of generation of electromagnetic noise in the presence of some ionizing radiation levels. .

The index of loss quality of the digital image was created, to allow quantifying the influence of static for each color channel of the digital image.

2. DESCRIPTION OF THE EXPERIMENT.

This work consists in to expose a simple surveillance camera, cheap and easy to find, a radioactive ^{60}Co source in the panoramic irradiator installed in the Radiation Technology Center, IPEN-CNEN/SP to check the intensity of electromagnetic noise produced in the camera surveillance.

Having an image as a parameter without noise denoted as standard and an image degraded by electromagnetic noise it is possible to obtain a digital image quality loss index under the effect of ionizing electromagnetic fields, where the higher the index value is greater degradation image.

The value of the digital image quality loss index is assigned as follows:

- the standard image and the image degraded by ionizing radiation are opened in an image editor application;
- the histogram of the red, green and blue channels, and the brightness (sum of RGB that generates gray), of each image was created;.
- the histograms for each color channel and the brightness of both images were compared by the method of difference between color channels, giving rise to a white area denotes the amount and intensity of the color difference for each depth value of each pixel channel color and brightness.

- calculating the total area, or the amount of pixels generated by the interpolation of difference, the value of the rate of the digital image quality loss is obtained.

The quality of digital image loss index is obtained by dividing the area of the difference (White area) by the total area of the histogram (white area over the black area), or by dividing the amount of white pixels present in the area of the difference by the total amount of pixels in the total area of the histogram.

To test for assessment of loss of digital image quality under the influence of ionizing electromagnetic fields used were the following items:

- Video surveillance TOP CAM brand, model TC 1868CDN with 1/3 color sensor CCD 480 TVL (sensor manufactured by SONY);

- Control software for viewing and recording images MultiViewer with the following settings: NTSC_M video standard with composite video;

- Physical interface with USB connection for converting analog signal into a digital model EasyCAP002 produced by EasyCAP to four video channels and a sound;

- Twenty-five meters of coaxial cable with five levels of armor and guide for camera power.

- Panoramic Cobalt Source of with 363.96 Ci activity on 11/07/2011.

The partial disassembly of the surveillance camera was made to verify the positioning of the CCD due to its sensibility to ionizing radiation. Its position was taken as reference distance from the cobalt source, whose main objective was to provide camera surveillance dose rates known.

The remote viewing was done outside the panoramic irradiator with a notebook as the image host and recorder.

At the beginning of the experiment, a 70% lead attenuator was used surrounding on the cobalt 60 source guide tube , in order to avoid accidental saturation of the CCD, since the effects of gamma radiation were unknown for the camera model. Typical failures of cameras with CCD image sensor happen after 100Gy total dose and a dose rate of 1kGy/h is usually the upper limit for a commercial CCD camera [3].

The source rise time was 23s, the descend time was 23s (46s in transit) and 6s in steady irradiation.

To compare the effect of electromagnetic noise on the image two of snapshots, one before the source exposition and another on the steady irradiation will be placed side by side

Knowing the dose rate for various points on the table overview of the source of exposure, according to the distance of these in relation to the longitudinal axis of the panoramic Co^{60} source, the surveillance camera was positioned.

The initial dose rate was 3.1Gy/h. As a result was obtained an image with few points of electromagnetic interference (static) - Figure 01 - top.

The highest dose rate by which the camera was exposed was 287.2Gy/h, creating a degraded image, as can be seen in figure 01 - bottom.

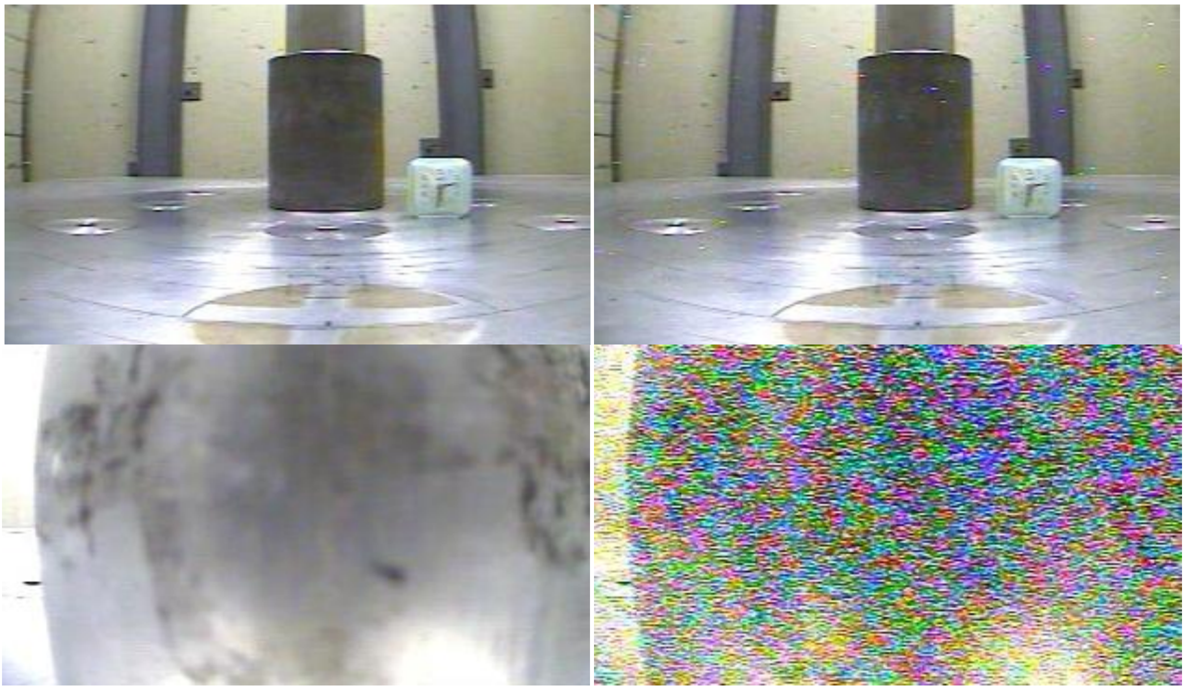

Figure 01 - Comparative imaging with and without electromagnetic noise generated under the influence of a dose rate of 3.1 Gy/h (top) and 287.2Gy/h (bottom).

Then each color channel of each image was generated, compared and then calculated the area of the total color difference for each color channel and the brightness of each image, with and without static.

Figure 02 shows the histograms for each color channel over the channel luminosity of each of the images of the Figure 01 - top.

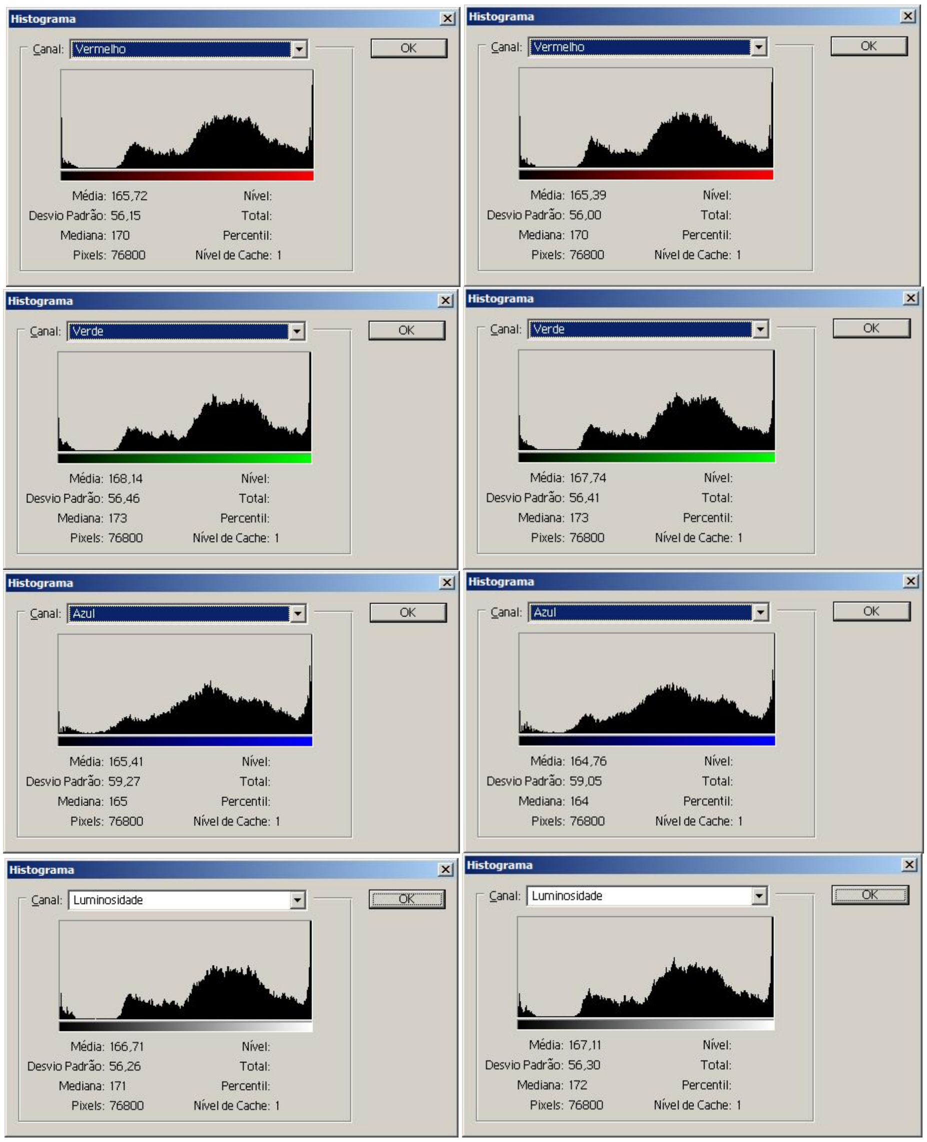

Figure 02 - Comparison between the histograms for each color channel of each of the images (with and without electromagnetic noise generated by a dose rate of 3.1Gy/h).

To determinate the degradation of the digital image obtained on the influence of ionizing radiation the method of the difference between the color channels was used first. In this method the color channels of the standard image and the image degraded by ionizing electromagnetic radiation (which produces noise, also known as static) are compared by intersection, appearing a white area between them, which represents the color difference for each channel and luminosity.

Figure 03 shows the histograms obtained by the method of the difference between color channels was used to compare with the standard image generated by static image with a dose rate of 3.1Gy/h.

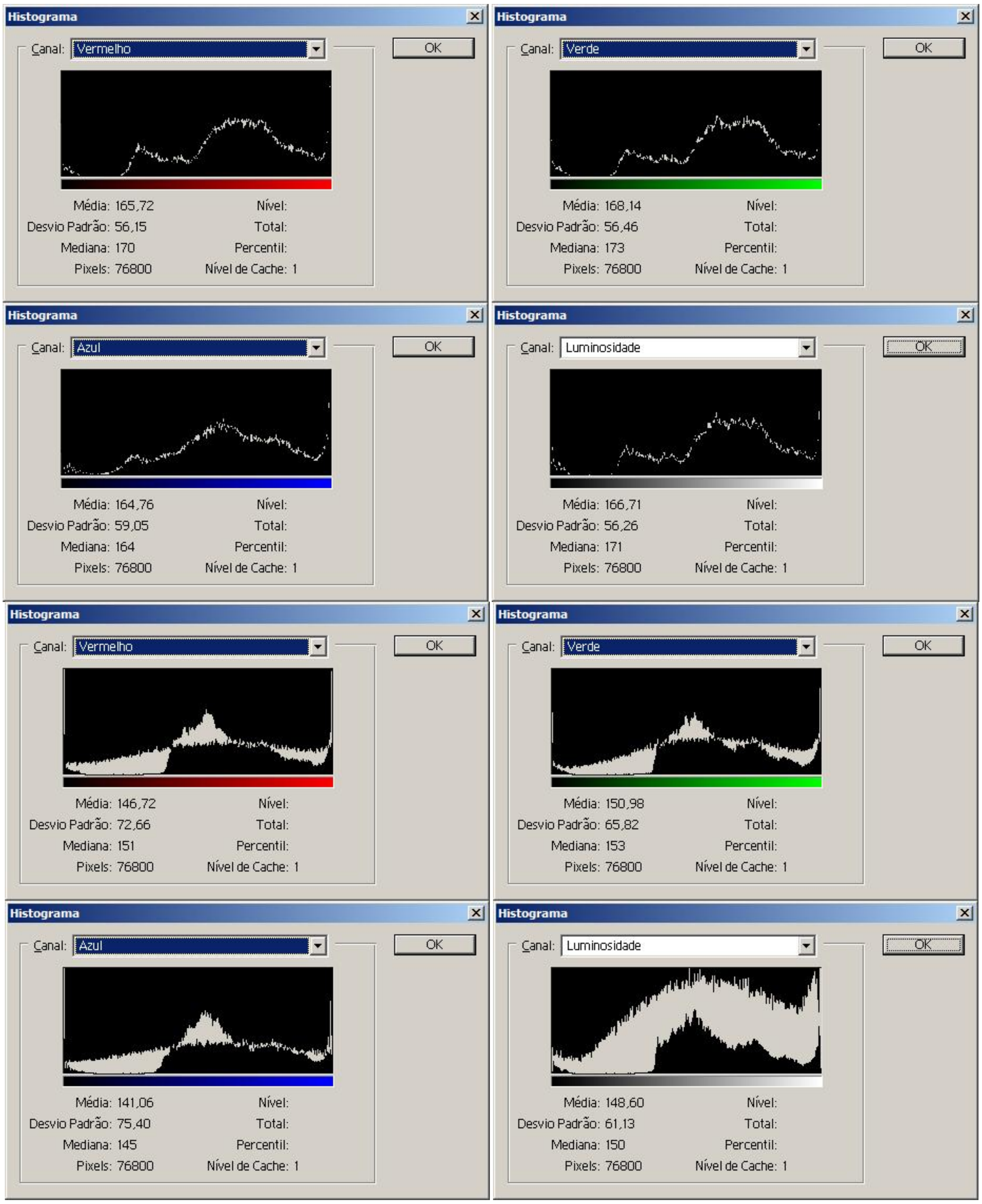

Figure 03 - Histograms obtained by the method of difference between color channels generated from the intersection of the color channels of digital imaging with and without electromagnetic noise generated by a dose rate of 3.1Gy/h (four images in top) and 287.2Gy/h (four images in bottom).

Then we calculated the value of the white area (sum of all pixels white histogram) and that area was divided by the total area of the histogram graph, obtaining then the digital image quality loss index, where an index zero means that there was no degradation of the digital image and the index equal to one have been a total degradation of the digital image due to static.

This method eliminates the subjectivity in judging the digital images quality that are degraded by ionizing electromagnetic fields.

The surveillance camera was exposed to various dose rates, and for each one of them were done filming. These shots were taken snapshots that were in turn used to generate histograms of the color channels and through the difference between color channels method. The calculated quality loss rates are shown in Table 01.

Table 1: **Index of quality loss obtained by the method of difference between color channels**

Dose rate	Channel Red	Green Channel	Blue Channel	Luminosity.
3.1	0.017	0.017	0.018	0.014
4.3	0.022	0.018	0.021	0.017
6.2	0.025	0.021	0.027	0.022
10.2	0.026	0.023	0.028	0.022
17.7	0.043	0.036	0.058	0.036
44.3	0.089	0.097	0.080	0.085
59.0*	0.051	0.044	0.055	0.045
147.6	0.093	0.095	0.125	0.232
287.2	0.116	0.100	0.104	0.441

When you want to check the effects of static images obtained from multi-colored targets need to be aware that the static is a cluster of tiny colored dots that may lead to confusion in determining the index of loss of quality if used the method of difference between channels, as shown below.

Figure 04 shows the left side a multicolored pattern used to check, in addition to digital image quality, the effects of static. On the right side was placed a standard created by a static image editing program bitmaps.

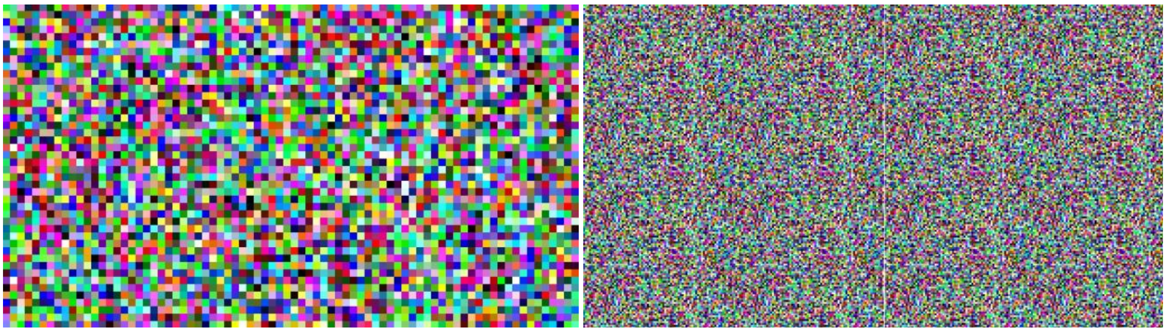

Figure 04 - Comparison between color target and static.

Despite the image on the left side is a colorful pattern and the image of the right just be static, to the method to the difference between color channels the index of loss of quality finished directing the unwary to the conclusion that images are equal, because the principle would be considered static an almost perfect digital replica of the target image color. The figure 05 shows the histograms for each color channel obtained by the method of the difference between the color channels.

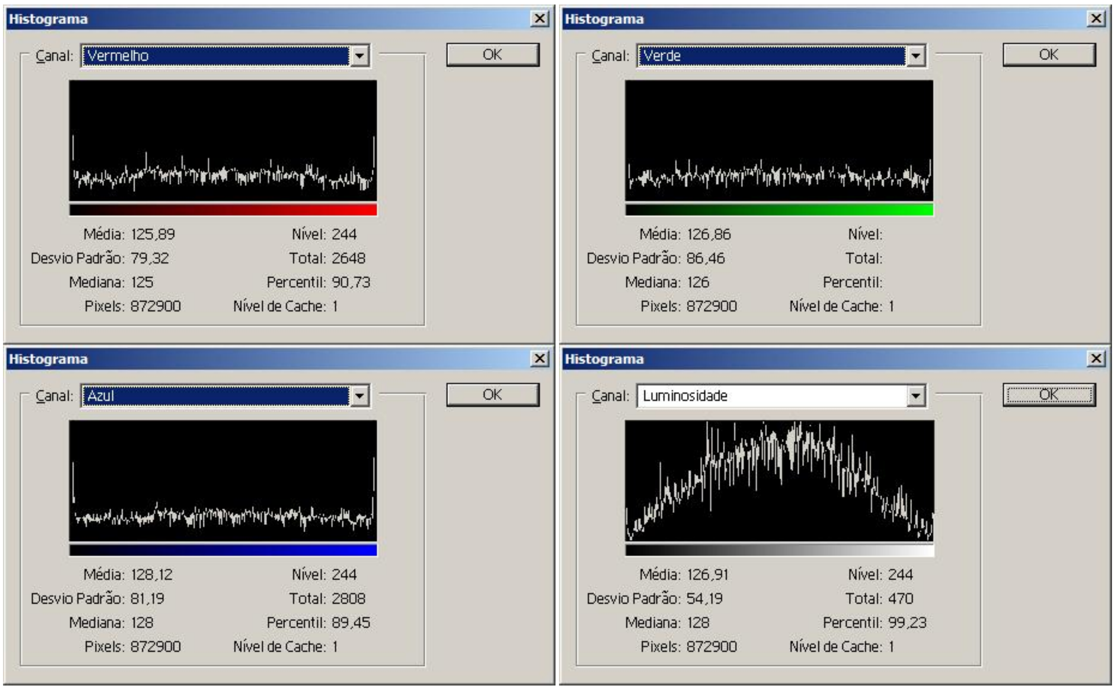

Figure 05 - Histograms of the difference between the color channels of the color target and static.

The index of loss of digital image quality for the example in question was 0.045 for the red channel, 0.044 for the green channel, the 0.043 for the blue channel and 0.106 for luminosity. So one criterion only numerical method using the difference between the color channels would lead to a failed trial of digital image quality, because it would be considered a static image too close in color to the target color, which does not really is.

When it is found that the method of the difference between color channels leads to a gross error of judging the quality of the digital image generated under the influence of ionizing radiation, another method called the method of difference between layers was used. In this method the standard image and the image degraded by the ionizing electromagnetic radiation are applied to a system of software layers in a bitmap image editing (Photoshop or Photo-Paint program, for example). Then the two images are merged into a different method known as layering. As a result of any color difference between images that are in adjacent layers appear as colored dots (pixels) of the negative of the total difference between the colors and the colors remain the same between the images in lighting conditions are zero, and identical pixels between adjacent layers are black, while the pixels that have complementary colors are white. Thus the histogram of brightness to this method is very important because a large area under the curve represents the same big difference between the images being compared.

Figure 06 shows the histograms of the color difference for each channel of the target image color and the static obtained by the method of the difference between layers, where it is factually possible to verify that there is a significant difference between the two images.

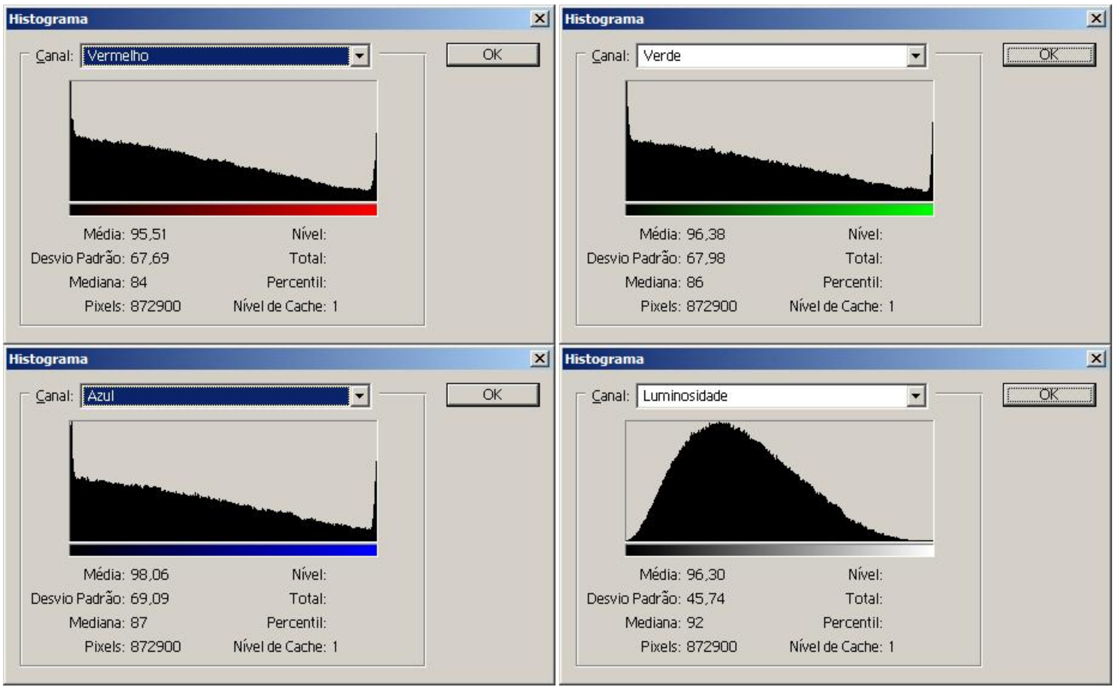

Figure 06 - Histograms of the color channels obtained by the method of difference layers for the target image color (default) and the static image.

In the method of the difference between layers the values of the index of loss of digital image quality are obtained in the same way as for the method of the difference between the color channels.

For example in question the values of the index of loss of quality were 0.328 for the red channel, 0.317 for the green channel, 0.337 to the channel of blue and 0.457 for the luminosity, and are larger than those obtained by the method of difference between the color channels.

The method of the difference between layers was used to obtain the index of loss of quality of digital images generated by the surveillance camera for the different dose rates as shown in table 02.

Table 2: Index of quality loss obtained by the method of the difference between layers

Dose rate	Channel Red	Green Channel	Blue Channel	Luminosity.
3.1	0.048	0.044	0.069	0.042
4.3	0.059	0.051	0.078	0.050
6.2	0.062	0.056	0.080	0.056
10.2	0.064	0.057	0.084	0.053
17.7	0.076	0.069	0.106	0.072
44.3	0.142	0.140	0.169	0.137
59.0*	0.124	0.113	0.155	0.118
147.6	0.173	0.157	0.201	0.168
287.2	0.200	0.193	0.238	0.254

3. RESULTS AND DISCUSSION

For the dose rate of 59.0Gy/h (tables 1 and 2) the rates of quality loss are smaller than for the dose rate of 44.3Gy/h. This was due to the characteristics of brightness, hue and saturation of the target. For a future test will be set such features of the target for the evaluation of the results of ionizing electromagnetic radiation on the camera captures is more consistent.

As seen in line with dose rate of 287.2Gy/h of the table 01 the value of index quality loss did not exceed the higher value of 0.441. One would expect that for such a static index value of quality loss was very close to one (upper limit). The index value of quality loss will hardly 0.500 due to the characteristics of the target (inside the panoramic camera), because it is predominantly gray (intensity of pixel depth mean), and has high brightness, which turns out to mask the static.

We analyzed two methods to determine the digital images quality loss index obtained under the effect of ionizing electromagnetic fields, one called interpolation of difference between channels and another called difference between layers. It was noted that the interpolation method of difference between channels had to be inefficient, since they may have generate low rates of loss of quality for intensive static, especially when the target (captured image) is colored.

It is necessary that the value of brightness, saturation and hue of the target (filmed image) is kept constant at every change of dose rate of the source; otherwise the results may be distorted.

For the method of obtaining the index of lost quality of digital images by the method of difference between channels is absolutely necessary that the target has a black area in order that this method is effective.

Using the index of loss of quality digital images you can create a quantitative criterion in the choice of digital camera equipment to be used in environments where there is presence of ionizing radiation. For this simply use a reference image to be captured by equipment for various dose rates and thus to compare the rate of loss of quality for each color channel, choosing, in terms of image quality, the equipment that generate images with the lowest rate of loss of quality.

It was found that the changes in the chromatic and details of the target (image shot) did not establish a direct relationship between dose rate, noise generation and degradation of the captured image. For the next stages of construction and evaluation of the Remote System View Ionizing Radiation Resistant be used to target fixed (unchanging image) to give a better correlation between dose rate, noise and degradation of the filmed image.

CONCLUSIONS

The surveillance camera TOP CAM model TC 1868CDN can be used in subsequent stages of construction of the Remote System View Resistant to Ionizing Radiation, with the testing environment of the panoramic ^{60}Co irradiator installed in the CTR, IPEN. With a dose rate of 17.7Gy/h the camera showed a minimal amount of static generated by ionizing electromagnetic radiation, according to numerically represented by the index of loss of quality achieved by the method of the difference between layers.

Quantitative methods can be applied to assess the quality of the digital image generated in the electromagnetic field radiation. As evidence of it has been stated the digital images quality loss rate generated in the presence of ionizing electromagnetic fields that allows analyzing by numbers until the dose rate limit of the surveillance camera can be used without compromising the level of detail and color image.

REFERENCES

1. HOUSSAYE, LAURENT.P. Robotics and radiation hardening in the nuclear industry. 2000. Thesis (master's degree) - University of Florida, Florida, United States of America, 210 p.
2. TAUHATA, L. OLIVEIRA RAMOS, M, M. Quantities and units for ionizing radiation (recommendations and definitions). National Metrology Laboratory of Ionizing Radiation, Institute of Radioprotection and Dosimetry, National Nuclear Energy Commission, Ministry of Science and Technology. Rio de Janeiro, RJ. 2002. 27 p.
3. AVRAM, A. Study of a teleoperated robotic system for inspection of nuclear facilities. 2008. Thesis (master's degree) - Federal University of Rio de Janeiro / COPPE, Rio de Janeiro, RJ. 133 p.