

VARIATION OF THE PRACTICAL PEAK VOLTAGE WITH THE SAMPLE RATE FOR A MAMMOGRAPHY WAVEFORM GENERATOR

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ABSTRACT

The Practical Peak Voltage (PPV) was introduced by the IEC 61676 standard as an electrical parameter strongly related to the image contrast, which is determined from the X-ray tube voltage waveform. This quantity is used in diagnostic radiology reference systems quality control.

Measurements have been made using a mammography equipment model Senographe 700T, manufactured by GE (General Electric). This equipment works in the voltage range from 22 to 35 kV and the tube has a molybdenum anode. Its internal voltage divider was used to do the acquisition of the voltage data of the X-ray tube.

To acquire the waveforms of the equipment, it has been used an acquisition board model NI 5911 (National Instruments) and a LabVIEW routine that calculates all the voltage parameters associated with the X-ray tube. During the measurements, the sample rate was varied from 100 samples/s to 1 Msamples/s for a 24 kV voltage reference. Results showed a variation less than 0.05 kV for the PPV value. At the same time, it was evaluated the maximum value of the tube waveform (kV_p – maximum). The results have shown that the value of kV_p (maximum) varies up to 1 kV, for the higher sample rates, and have confirmed the low dependence of PPV with the sample rate of the tube waveform, in comparison with kV_p (maximum), in mammography range.

1. INTRODUCTION

The quality control in diagnostic radiology departments is a requirement of Health Brazilian Ministry rule 453[1] which indicates the basic protection laws to work with radiological equipments. For some tests of reproducibility and accuracy with X-ray systems is essential to use a non invasive meter to determine the peak voltage applied in the X-ray tube (kVp).

Voltage between electrodes of an X-ray tube increases the electrons kinetic energy and thus the maximum energy of photons emerging from the tube. In this way, voltage affects the patient dose as well as the quality of the provided images. There are many studies about the development of a trustworthy method to determine the voltage applied in the X-ray tube, however, there is not an agreement about which definition of kVp has to be used. According to Rannalo[2], the definitions of kVp can be: absolute peak voltage (kVp_{abs}), maximum cycle voltage (kV_{ciclo}), average voltage(kV_{ave}), average peak voltage (kVp_{ave}) and effective peak voltage (kVp_{eff}).

This fact motivated Kramer and others to introduce the quantity practical peak voltage (PPV) [3,4] that compares the air kerma contrast produced by a constant potential waveform and by an arbitrary waveform for a specific tube. Since the introduction of this quantity, many works have been presenting studies about the PPV and its application in radiological departments. The propose of this work is to study the variation of the PPV with the sample rate of the waveform voltage for a mammography waveform generator.

The IEC 61676 [4] presents a method to calculate this quantity from the waveform voltage, showd in the equation 1.

$$U = \frac{\sum_{i=1}^n p_i(U_i) \cdot U_i \cdot w(U_i)}{\sum_{i=1}^n p_i(U_i) \cdot w(U_i)} \quad (1)$$

Where U is the value of PPV, P(U_i) is the probability to occur a voltage value between [U_i - (ΔU/2), U_i + (ΔU/2)], w(U_i) is the weighting factor for each instantaneous value of voltage U_i. For the mammography range, the values of w(U_i) can be found by the equation 2:

$$w(U_i) = \exp(a.U_i^4 + b.U_i^3 + c.U_i^2 + d.U_i + e) \quad (2)$$

Where:

$$\begin{aligned} a &= -2.142352 \times 10^{-6} \\ b &= +2.566291 \times 10^{-4} \\ c &= -1.968138 \times 10^{-2} \\ d &= +8.506836 \times 10^{-1} \\ e &= -1.5143662 \times 10^1 \end{aligned}$$

2. MATERIALS AND METHOD

Measurements have been made using a X ray tube model GS 512-4 manufactured by GE (General Electric) with 49 kV of maximum value of voltage and a molibdenium anode. This tube is conectd in the mammography equipment model Senographe 700T, manufactured by GE, from the IEE-USP (Eletrotecnical and Energy Institute). The internal voltage divider was used to do the acquisition of the voltage data of the X-ray system. Figure 1 shows a photo of this equipment.

Senographe 700T, mammography equipment



Controler Senographe 700T



Figure 1: Mammography X-ray equipment model Senographe 700T (GE).

The calibration factor for this voltage divider was determined using a method described in [7] and it used a value of the bremsstrahlung spectrum to obtain the average peak voltage. The figure 2 show the calibration curve to determined the rasion between the voltage from the display of the equipment and the voltage from the spectrum bremsstrahlung.

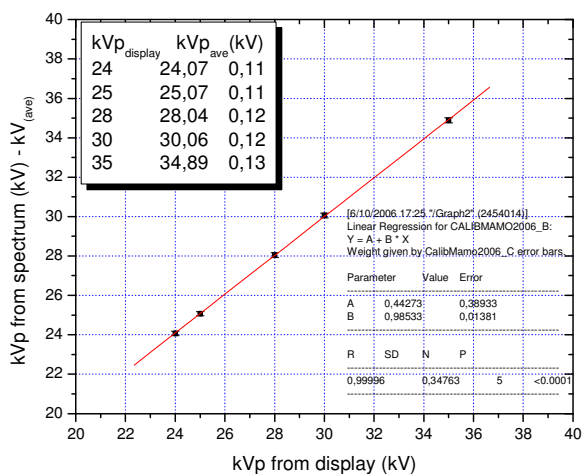


Figure 2: Calibration curve for the mammograph equipment

To acquire the waveforms of the equipment, a conductor cable was connected to an attenuated output of the generator. It was also used an acquisition board model NI 5911 (National Instruments) and a LabVIEW computational routine that calculates all of the voltage parameters associated with the X-ray tube such as kVp_{abs} , kVp_{ave} and PPV. Figure 3 have shown the front panel of the LabVIEW routine.

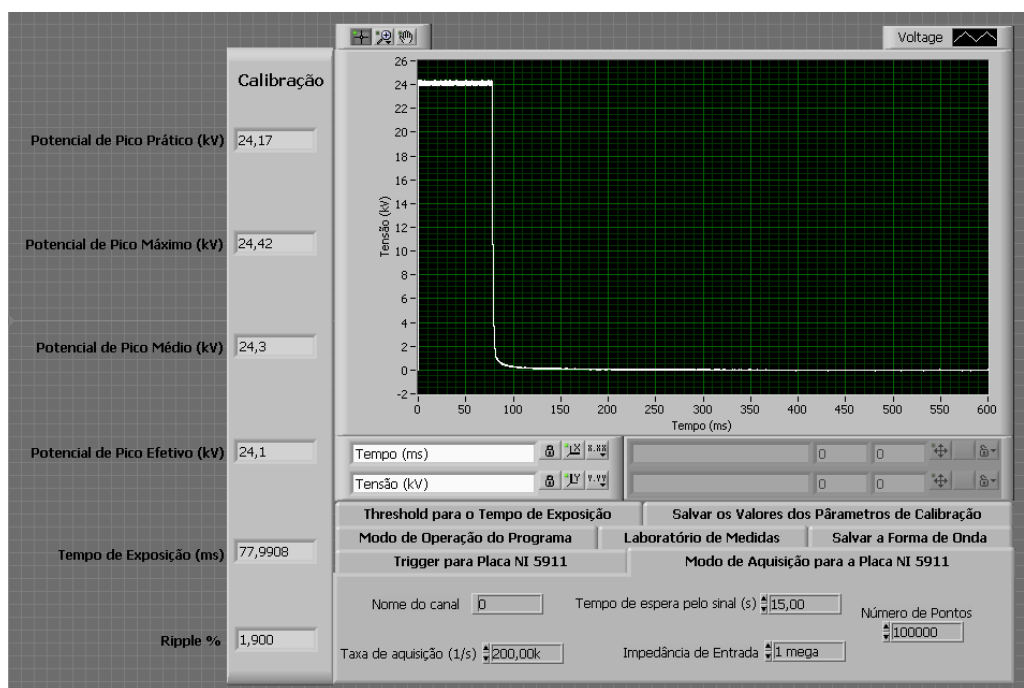


Figure 3: LabVIEW routine to calculate radiological parameters associated with X ray Tube.

During the measurements, the sample rate was varied between 100 samples/s to 1 Msamples/s for 24 kV voltage waveform as references in order to obtain a statistic variation of the measurements, it was used the same configuration tree times. The uncertainties were calculated from the standard deviation of the average of 3 measurements and, the type B uncertainties were calculated according to the Guide to the Expression of Uncertainty in Measurement [6].

3. RESULTS

Table 1 shows the average value of PPV, for three measurements, and $kV_{p_{max}}$ (maximum value for voltage X-ray tube waveform) for sample rates from 1,000,000 samples/s to 100 samples/s.

Table 1: Results obtained for the PPV and kV_p maximum in different sample rates.

Sample Rate (samples/s)	kV_p -maximum (kV)	PPV (kV)	$\Delta_{PPV-kV_{max}}$ (kV)
1000000	24.37±0.45	24.16±0.44	0.21
500000	24.37±0.45	24.16±0.44	0.21
250000	24.38±0.44	24.16±0.44	0.22
100000	24.26±0.45	24.16±0.44	0.10
50000	24.23±0.45	24.16±0.44	0.07
25000	24.22±0.44	24.16±0.44	0.06
10000	24.23±0.44	24.16±0.44	0.07
1000	24.23±0.44	24.15±0.44	0.08
100	24.21±0.44	24.15±0.44	0.06

4. CONCLUSIONS

It's possible to see that the difference between the PPV and the $kV_{p_{max}}$ increases when the sample rate also increases. This occurs because the sample rate is directly related with the time resolution; therefore, it's possible to have specific frequency components that are absent for the lower sample rates.

Results showed a variation less than 0.02 kV for the PPV value and, for the $kV_{p_{max}}$, a variation of less than 0.2kV. PPV are nearly insensitive to the acquisition sample rate in this case. Considering these measurements, it is possible to calculate the PPV for clinical common mammography range with a sample rate less than 1 ksamples/s.

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