kVp measurements on mammography machines with the RaySafe X2 system

INTRODUCTION

This application note summarizes how to perform peak voltage (kVp) measurements on mammography machines with the RaySafe X2 system and covers:

- Design of the RaySafe X2 MAM sensor
- Settings for kVp measurements with the X2 MAM
- Sensor positioning
- kVp measurements above 40 kV
- kVp measurements on machines with tomosynthesis

Each chapter starts with the *What* and the *Why* of the subject, followed by a *How-To* section with measurement instructions.

RaySafe™

DESIGN OF THE RAYSAFE X2 MAM SENSOR

The RaySafe X2 MAM sensor (X2 MAM) is dedicated for quality assurance measurements on mammography machines. It measures dose, dose rate, time, half-value layer (HVL) and kVp, all in one exposure and non-invasively. All parameters but kVp are acquired without any settings.

The X2 MAM is designed to measure kVp on all mammography machines on the market, on at least one target/filter combination (beam quality) per machine model. Since the generator and the X-ray tube inside the mammography machine are the same, regardless of the filtration, it is usually enough to measure kVp on one beam quality per machine model.

Figure 1 shows the geometry of the X2 MAM with active sensor area, opening angles for kVp and dose measurements, and dose reference height.

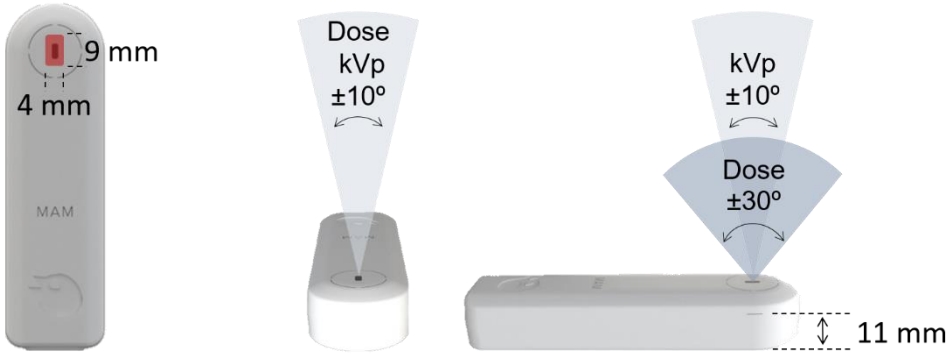

Figure 1: The X2 MAM has an active sensor area of 4 x 9 mm (marked in red) and an opening angle of 10° for kVp measurements. For dose measurements, the opening angle is 10° from the front and 30° from the side. The dose reference height is 11 mm.

SETTINGS FOR kVp MEASUREMENTS WITH THE X2 MAM

To measure kVp with the X2 MAM, you need to activate a setting in the X2 Base Unit, called ***kVp mode***. The kVp mode setting represents the beam quality of the machine and includes the set target/filter combination and the paddle configuration.

HOW TO SET kVp MODE

On the base unit display, swipe left from the home screen to find the Quick Settings for kVp mode, Figure 2. Select the beam quality (and paddle option) that matches your measurement conditions. You are now ready to measure kVp.

If your beam quality has a choice for ***paddle/no paddle***, the attenuation caused by a paddle in the beam affects the kVp measurement results and a selection is required to measure within the specified uncertainty for kVp. If your beam quality does **not** have a choice for *paddle/no paddle*, kVp measurements can be performed either with or without a paddle mounted, within the specified uncertainty for kVp. If you have the possibility, we recommend to measure without paddle.[1]

The setting ***Mo/Rh 2 mm Al*** means that a 2 mm aluminium filter needs to be placed on top of the sensor to measure kVp on Mo/Rh filtration. The filter and measurement instructions are included in the X2 MAM kit.

Note that the kVp mode setting refers to the X-ray tube inside the mammography machine. ***W/Rh Siemens*** is therefore the correct setting for the Fuji Amulet (F/S), the Philips Diagnost DR, and the Philips Diagnost (analogue version), since they all have Siemens P40 tubes.

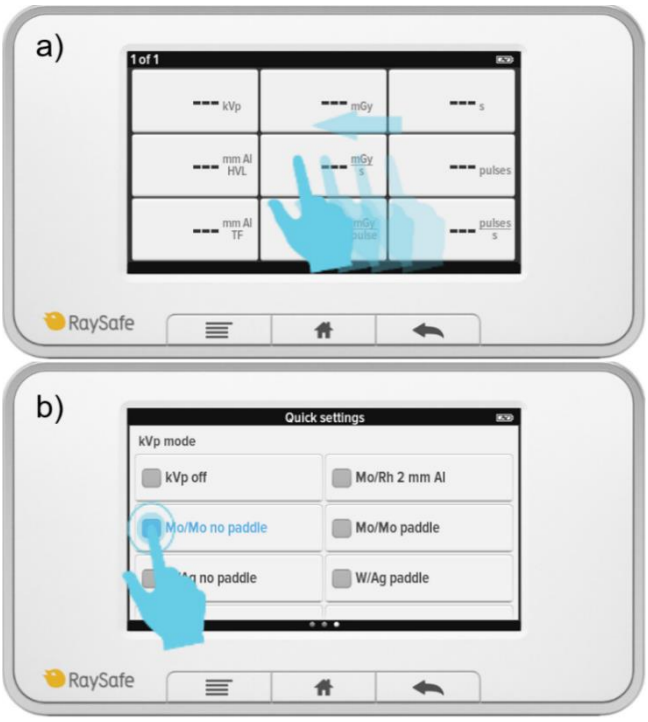

Figure 2: How to find the Quick settings for kVp mode. **a)** Swipe left from the home screen. **b)** Select beam quality and paddle option.

[1] See specifications in the X2 Base Unit for kVp measurements with the X2 MAM.

SENSOR POSITIONING

How to position a sensor for QA measurements on a mammography machine is determined by local regulations or by the manufacturer. While the regulations normally refer to the sensor position for *dose* measurements, the same placement is suitable for kVp measurements since the X2 sensors measure all parameters in one exposure.

HOW TO POSITION THE X2 MAM

Position the X2 MAM in the middle of the X-ray field, with the sensor area at the required distance from the chest wall side and height from the examination table, Figure 3a. Common recommended sensor positions in mammography are at **4 or 6 cm from the chest wall side**, at a height of 0–4.5 cm from the examination table. Note that the measures refer to the position of the active sensor area and the dose reference height of the sensor, Figure 1.

The X2 MAM can be rotated in the plane, as long as the active sensor area faces the X-ray source and is at the correct distance from the chest wall side (Figure 3b).

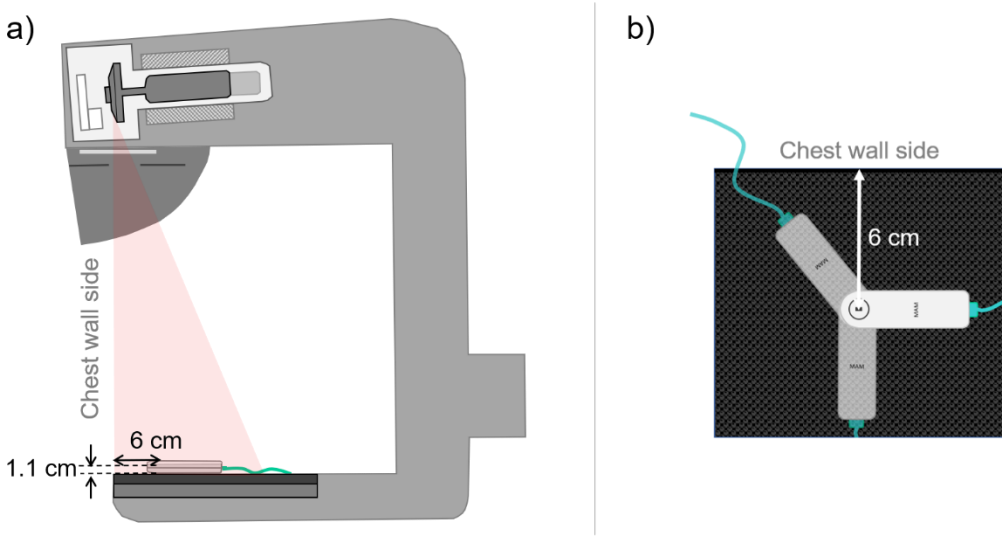

Figure 3: Examples of how to position the X2 MAM. **a)** The active sensor area of the X2 MAM is positioned in the middle of the X-ray field, at 6 cm from the chest wall side and 1.1 cm above the examination table. **b)** Top view of the examination table with different examples of how to place the active sensor area at 6 cm from the chest wall side.

kVp MEASUREMENTS ABOVE 40 kV

While most mammography machines operate below 40 kV, higher X-ray tube voltages are used in certain cases:

- Machines that utilize different types of filtration of the X-ray beam in the same examination to create overlay images. Common materials to achieve high filtration are titanium (Ti) and copper (Cu), used at tube voltages of 40–49 kV.
- Machines that use up to 49 kV in service mode.
- Machines that operate above 40 kV in tomosynthesis mode (see *Tomosynthesis Machines* for details).

The X2 MAM sensor measures kVp on set X-ray tube voltages of up to 40 kV. If you need to measure kVp on tube voltages above 40 kV, use the X2 R/F sensor:

HOW TO MEASURE PEAK TUBE VOLTAGE ABOVE 40 kV

Use the **X2 R/F sensor** for kVp measurements above 40 kV. No kVp mode settings are needed with the X2 R/F sensor. The X2 MAM and the X2 R/F have the same sensor area, dose reference height and opening angles for kVp (Figure 1) and are positioned in the same way at measurements (Figure 3).

For kVp measurements above 40 kV on **W/Al** filtration, place a 2 mm aluminium filter on top of the X2 R/F sensor.

kVp MEASUREMENTS ON MACHINES WITH TOMOSYNTHESIS

While we recommend measuring kVp in 2D mode, measurements of kVp in tomosynthesis mode are possible with the X2 system:

In tomosynthesis, the X-ray tube moves during the examination to make multiple exposures, Figure 4a. Since the angle of incidence to the examination table is different for each projection, the opening angle of the X2 sensor needs to be considered, see instructions below.

At QA measurements, you may encounter machines that are not correctly adjusted, where the dose rate value of the tomosynthesis pulses varies with time and affects the measured kVp value, Figure 4b. To check the adjustment, view the dose rate waveform in the X2 Base Unit and zoom in on the peaks. The dose rate waveform should have a horizontal plateau, Figure 4c.

If the pulses in tomosynthesis mode are too short to have a horizontal plateau, we recommend measuring kVp in 2D mode.

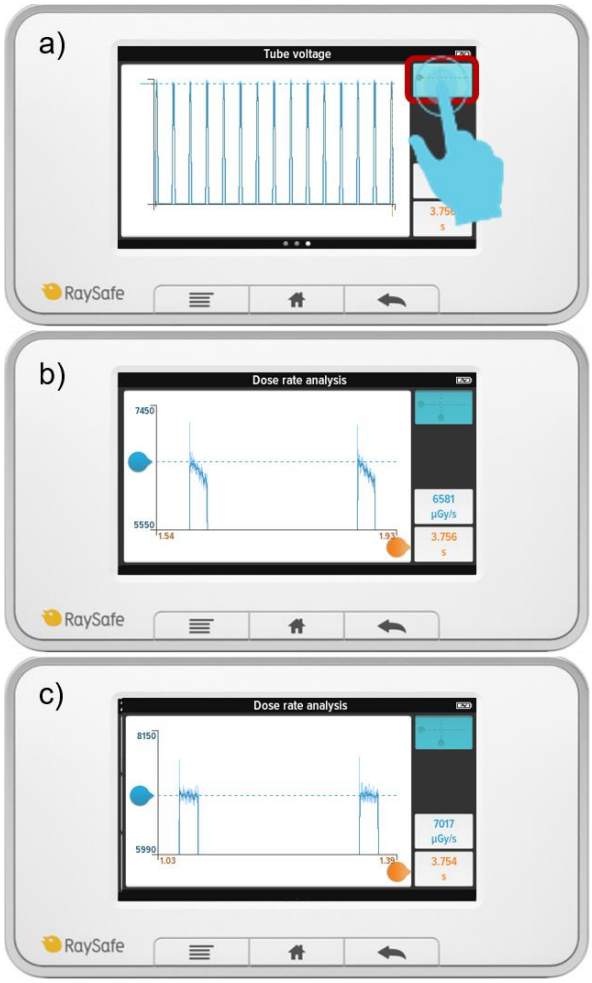

Figure 4: Examples of dose rate pulses in tomosynthesis mode, viewed in the X2 Base Unit. **a)** Overview of 15 tomosynthesis pulses. Press the blue box with cursors (marked in red) to enable zooming in the graph (pinch to zoom). **b)** Example of dose rate pulses with clear slopes. The machine needs to be adjusted prior to kVp measurements. **c)** Example of dose rate pulses with horizontal plateaus. The machine is correctly adjusted and kVp can be measured correctly.

HOW TO MEASURE kVp ON TOMOSYNTHESIS MACHINES

To measure kVp on tomosynthesis machines, **park the X-ray tube** at a zero-degree angle to the examination table, Figure 5. Measure as usual (see *Settings for kVp Measurements* and *Sensor Positioning*). If the angle of the tomosynthesis movement is smaller than the opening angle of the sensor (±10°), there is no need to park the tube.

kVp measurements **above 40 kV** require an X2 R/F sensor.

kVp measurements on **W/Al filtration above 40 kV** require an additional 2 mm aluminium filter on top of the X2 R/F sensor.

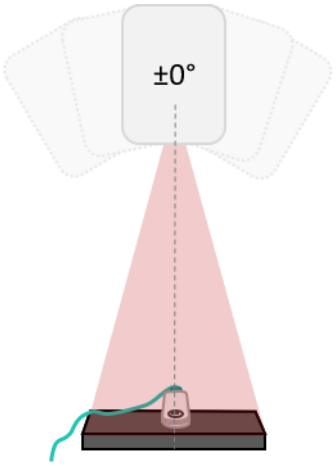

Figure 5: Measure kVp on tomosynthesis machines with the tube parked at a zero-degree angle to the examination table.

ADDITIONAL INFORMATION

For specifications, general information and instructions for measurements with the X2 MAM sensor, see the X2 MAM help in your X2 Base Unit.

For a summary of what parameters the different RaySafe sensors measure on common mammography machines, see the Mammography coverage table.

CONTACT

Please visit www.raysafe.com for more information.