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Radiotherapy equipment – Coordinates, movements and scales

Appareils utilisés en radiothérapie – Coordonnées, mouvements et échelles

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CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
INTRODUCTION (to amendment 2)	9
1 Scope and object.....	10
2 Coordinate systems.....	10
2.1 General rules	10
2.2 Fixed reference system ("f") (figure 1a)	12
2.3 GANTRY coordinate system ("g") (figure 4)	12
2.4 BEAM LIMITING DEVICE or DELINEATOR coordinate system ("b") (figure 5)	12
2.5 WEDGE FILTER coordinate system ("w") (figure 7)	13
2.6 X-RAY IMAGE RECEPTOR coordinate system ("r") (figures 6 and 8)	13
2.7 PATIENT SUPPORT coordinate system ("s") (figure 9)	14
2.8 Table top eccentric rotation coordinate system ("e") (figures 10 and 11).....	14
2.9 Table top coordinate system ("t") (Figures 10, 11, 18 and 19).....	15
2.10 PATIENT coordinate system ("p") (Figures 17a and 17b).....	16
3 Identification of scales and digital DISPLAYS	16
4 Designation of EQUIPMENT movements	17
5 EQUIPMENT zero positions	18
6 List of scales, graduations, directions and DISPLAYS.....	18
6.1 Rotation of the GANTRY (figures 14a and 14b).....	18
6.2 Rotation of the BEAM LIMITING DEVICE or DELINEATOR (figures 15a and 15b)	18
6.3 Rotation of the WEDGE FILTER (figures 7 and 14a).....	19
6.4 Radiation field or delineated radiation field.....	19
6.5 Patient support isocentric rotation.....	21
6.6 Table top eccentric rotation	21
6.7 Table top linear and angular movements	22
6.8 X-ray image receptor movements	22
6.9 Other scales.....	23
Annex A (informative) Examples of coordinate transformations between individual coordinate systems.....	59
Annex B (informative) Bibliography	66
Annex C (informative) Rationale for changes in IEC scales.....	67
Annex D (informative) Summary of additions and changes to scale statements in IEC 60601-2-1, IEC 60601-2-11, IEC 60976 and IEC 60977	70
Annex E (informative) Terminology	71
Annex F (informative) Coordinate transformations between IEC and DICOM PATIENT coordinates.....	72

Figure 1a – Coordinate systems (see 2.1.2) with all angular positions set to zero	25
Figure 1b – Translation of origin I_d along X_m , Y_m , Z_m and rotation around axis Z_d parallel to Z (see 2.1.4).....	26
Figure 1c – Translation of origin I_d along X_m , Y_m , Z_m and rotation around axis Y_d parallel to Y_m (see 2.1.4).....	26
Figure 2 – X Y Z right-hand coordinate mother system (isometric drawing) showing ψ , ϕ , θ directions of positive rotation for daughter system (see 2.2).....	27
Figure 3 – Hierarchical structure among coordinate systems (see 2.1.3 and 2.1.5)	28
Figure 4 – Rotation ($\phi_g = 15^\circ$) of GANTRY coordinate system X_g , Y_g , Z_g in fixed coordinate system X_f , Y_f , Z_f (see 2.3)	29
Figure 5 – Rotation ($\theta_b = 15^\circ$) of BEAM LIMITING DEVICE or DELINEATOR coordinate system X_b , Y_b , Z_b in GANTRY coordinate system X_g , Y_g , Z_g , and resultant rotation of RADIATION FIELD or DELINEATED RADIATION FIELD of dimensions F_X and F_Y (see 2.4).....	30
Figure 6 – Displacement of image intensifier type X-RAY IMAGE RECEPTOR coordinate system origin, I_r , in GANTRY coordinate system, by $R_x = -8$, $R_y = +10$, $R_z = -40$ (see 2.6).....	31
Figure 7 – Rotation ($\theta_w = 270^\circ$) and translation of WEDGE FILTER coordinate system X_w , Y_w , Z_w in BEAM LIMITING DEVICE coordinate system X_b , Y_b , Z_b , the BEAM LIMITING DEVICE coordinate system having a rotation $\theta_b = 345^\circ$ (see 2.5).....	32
Figure 8 – Rotation ($\theta_r = 90^\circ$) and displacement of RADIOGRAPHIC CASSETTE type X-RAY IMAGE RECEPTOR coordinate system X_r , Y_r , Z_r in GANTRY coordinate system X_g , Y_g , Z_g (see 2.6).....	33
Figure 9 – Rotation ($\theta_s = 345^\circ$) of PATIENT SUPPORT coordinate system X_s , Y_s , Z_s in fixed coordinate system X_f , Y_f , Z_f (see 2.7).....	34
Figure 10 – Table top eccentric coordinate system rotation θ_e in PATIENT SUPPORT coordinate system which has been rotated by θ_s in the fixed coordinate system with $\theta_e = 360^\circ - \theta_s$ (see 2.8 and 2.9).....	35
Figure 11a – Table top displaced below ISOCENTRE by $T_z = -20$ cm (see 2.8 and 2.9).....	36
Figure 11b – Table top coordinate system displacement $T_x = +5$, $T_y = L_e + 10$ in PATIENT SUPPORT coordinate system X_s , Y_s , Z_s rotation ($\theta_s = 330^\circ$) in fixed coordinate system X_f , Y_f , Z_f (see 2.8 and 2.9).....	36
Figure 11c – Table top coordinate system rotation ($\theta_e = 30^\circ$) about table top eccentric system. PATIENT SUPPORT rotation ($\theta_s = 330^\circ$) in fixed coordinate system $T_x = 0$, $T_y = L_e$ (see 2.8 and 2.9).....	36
Figure 12a – Example of BEAM LIMITING DEVICE scale, pointer on mother system (GANTRY), scale on daughter system (BEAM LIMITING DEVICE), viewed from ISOCENTRE (see 2.1.6.2 and clause 3)	37
Figure 12b – Example of BEAM LIMITING DEVICE scale, pointer on daughter system (BEAM LIMITING DEVICE), scale on mother system (GANTRY), viewed from ISOCENTRE (see 2.1.6.2 and clause 3)	38
Figure 12c – Examples of scales (see clause 3).....	39
Figure 13a – Rotary GANTRY (adapted from IEC 60601-2-1) with identification of axes 1 to 8, directions 9 to 13, and dimensions 14 and 15 (see clause 4)	40
Figure 13b – ISOCENTRIC RADIOTHERAPY SIMULATOR or TELERADIOTHERAPY EQUIPMENT, with identification of axes 1; 4 to 6; 19, of directions 9 to 12; 16 to 18 and of dimensions 14; 15 (see clause 4).....	41
Figure 13c – View from radiation source of teleradiotherapy radiation field or radiotherapy simulator delineated radiation field (see clause 4).....	42
Figure 14a – Example of ISOCENTRIC TELERADIOTHERAPY EQUIPMENT (see 6.1 and 6.3).....	43
Figure 14b – Example of ISOCENTRIC RADIOTHERAPY SIMULATOR equipment (see 6.1).....	44

Figure 15a – Rotated ($\theta_b = 30^\circ$) symmetrical rectangular RADIATION FIELD (FX \times FY) at NORMAL TREATMENT DISTANCE, viewed from ISOCENTRE looking toward RADIATION SOURCE (see 6.2)	45
Figure 15b – Same rotated ($\theta_b = 30^\circ$) symmetrical rectangular RADIATION FIELD (FX \times FY) at NORMAL TREATMENT DISTANCE, viewed from RADIATION SOURCE (see 6.2)	45
Figure 16a – Rectangular and symmetrical RADIATION FIELD or DELINEATED RADIATION FIELD, viewed from RADIATION SOURCE (see 6.4).....	46
Figure 16b – Rectangular and asymmetrical in Yb RADIATION FIELD or DELINEATED RADIATION FIELD, viewed from RADIATION SOURCE (see 6.4).....	47
Figure 16c – Rectangular and asymmetrical in Xb RADIATION FIELD or DELINEATED RADIATION FIELD, viewed from RADIATION SOURCE (see 6.4).....	48
Figure 16d – Rectangular and asymmetrical in Xb and Yb RADIATION FIELD or DELINEATED RADIATION FIELD, viewed from RADIATION SOURCE (see 6.4).....	49
Figure 16e – Rectangular and symmetrical RADIATION FIELD, rotated by $\theta_b = 30^\circ$, viewed from RADIATION SOURCE (see 6.4).....	50
Figure 16f – Rectangular and asymmetrical in Yb RADIATION FIELD, rotated by $\theta_b = 30^\circ$, viewed from RADIATION SOURCE (see 6.4).....	51
Figure 16g – Rectangular and asymmetrical in Xb RADIATION FIELD, rotated by $\theta_b = 30^\circ$, viewed from RADIATION SOURCE (see 6.4).....	52
Figure 16h – Rectangular and asymmetrical in Xb and Yb RADIATION FIELD, rotated by $\theta_b = 30^\circ$, viewed from RADIATION SOURCE (see 6.4).....	53
Figure 16i – Irregular multi-element (multileaf) contiguous RADIATION FIELD, viewed from RADIATION SOURCE, with element motion in Xb direction (see 6.4)	54
Figure 16j – Irregular multi-element (multileaf) two-part RADIATION FIELD, viewed from RADIATION SOURCE, with element motion in Xb direction (see 6.4)	55
Figure 16k – Irregular multi-element (multileaf) contiguous RADIATION FIELD, viewed from RADIATION SOURCE, with element motion in Yb direction (see 6.4)	56
Figure 17a – PATIENT coordinate system (PATIENT is supine).....	57
Figure 17b – Rotation of PATIENT coordinate system	57
Figure 18 – Table top pitch rotation of table top coordinate system X _t , Y _t , Z _t (see 6.7.4).....	58
Figure 19 – Table top roll rotation of table top coordinate system X _t , Y _t , Z _t (see 6.7.5).....	58
Figure F.1 – Coordinate transformations between IEC and DICOM PATIENT coordinates	73
Table 1 – EQUIPMENT movements and designations	17
Table 2 – Individual coordinate systems.....	24
Table A.1 – Rotation matrices.....	59

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**RADIOTHERAPY EQUIPMENT –
COORDINATES, MOVEMENTS AND SCALES**

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International Standard IEC 61217 has been prepared by sub-committee 62C: Equipment for radiotherapy, nuclear medicine and radiation dosimetry, of IEC technical committee 62: Electrical equipment in medical practice.

This consolidated version of IEC 61217 consists of the first edition (1996) [documents 62C/143/FDIS and 62C/165/RVD], its amendment 1 (2000) [documents 62C/279/FDIS and 62C/287/RVD] and its amendment 2 (2007) [documents 62C/418/CDV and 62C/428/RVC].

The technical content is therefore identical to the base edition and its amendments and has been prepared for user convenience.

It bears the edition number 1.2.

A vertical line in the margin shows where the base publication has been modified by amendments 1 and 2.

Annexes A, B, C, D, E and F are for information only.

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INTRODUCTION

RADIOTHERAPY is performed in medical centres where a variety of EQUIPMENT from different MANUFACTURERS is usually concentrated in the RADIOTHERAPY department. In order to plan and simulate the treatment, set up the PATIENT and direct the RADIATION BEAM, such EQUIPMENT can be put in different angular and linear positions and, in the case of MOVING BEAM RADIOTHERAPY, can be rotated and translated during the IRRADIATION of the PATIENT. It is essential that the position of the PATIENT, and the dimensions, directions, and qualities of the RADIATION BEAM prescribed in the treatment plan, be set up or varied by programmes on the RADIOTHERAPY EQUIPMENT with accuracy and without misunderstanding. Standard identification and scaling of coordinates is required for EQUIPMENT used in RADIOTHERAPY, including RADIOTHERAPY SIMULATORS, because differences in the marking and scaling of similar movements on the various types of EQUIPMENT used in the same department may increase the probability of error. In addition, data from EQUIPMENT used to evaluate the tumour region, such as ultrasound, X-ray, CT and MRI should be presented to the treatment planning system in a form which is consistent with the RADIOTHERAPY coordinate system. Coordinate systems for individual geometrical parameters are required in order to facilitate the mathematical transformation of points and vectors from one coordinate system to another.

A goal of this standard is to avoid ambiguity, confusion, and errors which could be caused when using different types of EQUIPMENT. Hence, its scope applies to all types of TELERADIOTHERAPY EQUIPMENT, RADIOTHERAPY SIMULATORS, information from diagnostic EQUIPMENT when used for RADIOTHERAPY, recording and verification EQUIPMENT, and to data input for the treatment planning process.

Movement nomenclature is to be classified as defined terms according to IEC 60788 and appendix AA of IEC 60601-2-1 and IEC 60601-2-29 (see annex E).

This standard is issued as a publication separate from the 601 series of safety standards. It is not a safety code and does not contain performance requirements. Thus, the present requirements will not appear in future editions of the IEC 60601-2 series, which deals exclusively with safety requirements.

IEC 60601-2-1, IEC 60601-2-11, IEC 60601-2-29, IEC 60976, IEC 60977, IEC 61168 and IEC 61170 include EQUIPMENT movements and scale conventions. A number of changes and additions have been made in this standard. These are summarized in annex D.

A major value of a standard coordinate system is its contribution to safety in RADIOTHERAPY treatment planning. The scales that are demonstrated in this standard are consistent with the coordinate systems described herein. USERS may use other scale conventions. It is anticipated that MANUFACTURERS will normally employ the scale conventions of this standard for new EQUIPMENT.

If MANUFACTURERS provide other optional scale conventions when requested by USERS, such as to match existing EQUIPMENT in a USER's facility or to comply with local convention or regulations, such EQUIPMENT cannot be said to comply with this standard.

It is also anticipated that MANUFACTURERS may provide, as options, scales to convert a USER'S existing EQUIPMENT to the scale conventions of this standard.

This standard does not address non-ISOCENTRIC EQUIPMENT and pitch or roll movements of the RADIATION HEAD, due to limited clinical use.

It is anticipated that future amendments may address the following:

- PATIENT coordinate system;
- Three-dimensional RADIOTHERAPY SIMULATORS;
- CT type RADIOTHERAPY SIMULATORS;
- non-ISOCENTRIC EQUIPMENT.

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INTRODUCTION (to amendment 2)

This Amendment 2 extends the rotation of the patient support devices around the Z-axis in the IEC fixed coordinate system to two additional rotations – rolling around the patient's longitudinal axis and pitching around the patient's transversal axis.

The use of the two new additional degrees of freedom (pitch and roll) generalizes the coordinate systems to include systematically 3 rotations and 3 translations, therefore supporting 6 degrees of freedom in a systematic way. Modern patient support devices with 6 degrees of freedom can use a combined translation and rotation to get the same result as the eccentric table top rotation. When changing table position data using the new IEC systems, the definition of isocentric rotations is sufficient to transfer all treatment-related information. The eccentric table top coordinate system is however maintained for backward compatibility.

NOTE It is quite common in proton therapy to use a treatment chair, where the patient can be rotated and tilted, while the beam line has a fixed direction.

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RADIOTHERAPY EQUIPMENT – COORDINATES, MOVEMENTS AND SCALES

1 Scope and object

This International Standard applies to equipment and data related to the process of tele-radiotherapy, including patient image data used in relation with radiotherapy treatment planning systems, radiotherapy simulators, isocentric gamma beam therapy equipment, isocentric medical electron accelerators, and non-isocentric equipment when relevant.

The object of this standard is to define a consistent set of coordinate systems for use throughout the process of teleradiotherapy, to define the marking of scales (where provided), to define the movements of equipment used in this process, and to facilitate computer control when used.

2 Coordinate systems

An individual coordinate system is assigned to each major part of the EQUIPMENT which can potentially be moved in relation to another part, as illustrated in figure 1a and summarized in table 1. Furthermore a fixed reference system is defined. Each major part (e.g. GANTRY, RADIATION HEAD) is always stationary with respect to its own coordinate system.

Perspective views of an ISOCENTRIC MEDICAL ELECTRON ACCELERATOR and a RADIOTHERAPY SIMULATOR are shown in figures 1a, 14a and 14b. Isometric projection drawings of coordinate systems are shown in several figures. In the figures, an elliptic (isometric projection) arrow around an axis of a coordinate system always shows clockwise rotation of that coordinate system about that axis when viewed from its origin and in the positive direction.

NOTE In the following description of individual coordinate systems, counter-clockwise (ccw) rotations are sometimes described in which the axis of rotation is not viewed from the origin of the individual coordinate system.

The definitions of coordinate systems, as stated in the following subclauses, allow mathematical transformations (rotation and/or translation) for the transfer of a point or vector coordinates in one system to any other coordinate system. See annex A for examples of coordinate transformations.

2.1 General rules

2.1.1 All coordinate systems are Cartesian right-handed. The positive parameter directions of linear and angular movements between systems are identified in figure 2. With all coordinate system angles set to zero, all coordinate system Z axes are vertically upward.

2.1.2 Coordinate axes are identified by a capital letter followed by a lower-case letter, representing coordinate system identification.

2.1.3 Coordinate systems have a hierarchical structure (mother-daughter relation) in the sense that each system is derived from another system. The common mother system is the fixed reference system. Figure 3 and table 2 show the hierarchical structure which is divided into two sub-hierarchical structures, one in relation to the GANTRY, the second in relation to the PATIENT SUPPORT.

2.1.4 The position and orientation of each daughter coordinate system (d) is derived from its mother coordinate system (m) by translation of its origin I_d along one, two or three axes of its mother system and then by rotation of the daughter system about one of the daughter translated system axes.

NOTE The mechanical motions of parts of the EQUIPMENT may follow a different sequence, as long as the EQUIPMENT ends up in the same position and orientation as it would have done if the indicated sequence had been followed.

Figures 1b and 1c show examples of translation of the daughter system origin I_d along the mother system coordinate axes X_m , Y_m , Z_m .

Figure 1b shows translation of origin I_d along X_m , Y_m , Z_m and rotation about axis Z_d which is parallel to Z_m .

Figure 1c shows translation of origin I_d along X_m , Y_m , Z_m and rotation about axis Y_d which is parallel to Y_m .

Example: The BEAM LIMITING DEVICE coordinate system is derived from the GANTRY system and the latter from the fixed system. Thus, a rotation of the GANTRY system causes an analogous rotation of the coordinate axes of the BEAM LIMITING DEVICE coordinate system in the fixed system and the origin of the BEAM LIMITING DEVICE system (position of the RADIATION SOURCE) is displaced in the fixed system (in space).

2.1.5 A point defined in one system can be defined in the coordinates of the next higher system (its mother) or the next lower system (its daughter) by applying a coordinate transformation, see figure 3 and annex A. Thus, it is possible to calculate, for a point defined in the BEAM LIMITING DEVICE system, its coordinates in the table top system by application of successive coordinate transformations (rotations and translations of the origin, as defined in 2.1.4), going first from the BEAM LIMITING DEVICE system upwards to the fixed system (i.e. BEAM LIMITING DEVICE system to GANTRY system to fixed system) and from this downwards to the table top system (i.e. fixed system to PATIENT SUPPORT system to table top eccentric rotation system, if available, to table top system). Such a coordinate transformation may considerably facilitate the solution of complex geometrical problems encountered in treatment planning, as well as minimize errors in the positioning of EQUIPMENT.

2.1.6 Notations

2.1.6.1 Capital letters are used for coordinate axis identification and lower-case letters are used for coordinate system identification.

Example: Y_g means y axis of the GANTRY system.

2.1.6.2 The rotation of one coordinate system with respect to its mother system about one particular axis of its own system is designated by the rotation angle which identifies the axis about which it rotates (ψ about X, ϕ about Y, and θ about Z), and by a lower-case letter identifying the system involved.

Example: $\theta_b = 30^\circ$ means rotation of the "b" system with respect to the "g" system by an angle of 30° (clockwise as viewed from ISOCENTRE) around axis Z_b of the "b" system (see figures 12a, 12b and also figure 5, where $\theta_b = 15^\circ$).

2.1.6.3 The linear position of the origin of a coordinate system within its mother system is designated by capital letters identifying the daughter coordinate system and by the designation of the coordinate axis of the mother system along which it is translated.

Example: $R_y =$ (numerical value) means position of the origin of the X-RAY IMAGE RECEPTOR coordinate system along coordinate axis Y_g (of its mother system).

2.1.6.4 For a movable component part which does not have its own coordinate system, its position within the system in which it moves is designated by a capital letter identifying the device in movement and a lower-case letter identifying the coordinate axis of the coordinate system along which it moves.

Example: X1 [Xb] = (numerical value) means position of RADIATION FIELD OR DELINEATED RADIATION FIELD edge X1 along axis Xb of the BEAM LIMITING DEVICE system.

NOTE When a component part position can be displaced along only one coordinate axis, then the designation of this coordinate axis can be omitted. Thus, for the above example, X1 = (numerical value) is sufficient.

2.1.6.5 The position of a point within a coordinate system is given by the numerical values of its coordinates in that system.

Example: Coordinate values of a point in the X-RAY IMAGE RECEPTOR system

xr = +20 cm
yr = -10 cm
zr = 0 cm

2.1.7 For rotational transformations involving more than one rotation the sequence of the rotations must be kept consistent. If the rotational sequence varies, the resulting transformation matrix and the orientation of the axis will be different.

The sequence in which the rotations shall be applied is the sequence in which these rotations are described in Clause 2 of this standard.

NOTE $M_{ab}^{-1} = M_{ba}$ (see Clause A.1).

2.2 Fixed reference system ("f") (figure 1a)

The fixed coordinate system "f" is stationary in space. It is defined by a horizontal coordinate axis Yf directed from the ISOCENTRE toward the GANTRY, by a coordinate axis Zf directed vertically upward and by a coordinate axis Xf, normal to Yf and Zf and directed to the viewer's right when facing the GANTRY. For ISOCENTRIC EQUIPMENT the origin If is the ISOCENTRE Io and, therefore, Yf is the rotation axis of the GANTRY.

2.3 GANTRY coordinate system ("g") (figure 4)

The "g" coordinate system is stationary with respect to the GANTRY and its mother system is the "f" system. Its origin Ig is the ISOCENTRE. Its coordinate axis Zg passes through and is directed towards the RADIATION SOURCE. Coordinate axes Yg and Yf coincide.

The "g" system is in the zero angular position when it coincides with the "f" system.

The rotation of the "g" system is defined by the rotation of coordinate axes Xg, Zg by an angle ϕ_g about axis Yg (therefore about Yf of the "f" system).

An increase in the value of ϕ_g corresponds to a clockwise rotation of the GANTRY as viewed along the horizontal axis Yf from the ISOCENTRE towards the GANTRY.

2.4 BEAM LIMITING DEVICE or DELINEATOR coordinate system ("b") (figure 5)

The "b" coordinate system is stationary with respect to the BEAM LIMITING DEVICE or DELINEATOR system and its mother system is the "g" system. Its origin Ib is the RADIATION SOURCE. Its coordinate axis Zb coincides with and points in the same direction as axis Zg. The coordinate axes Xb and Yb are perpendicular to the corresponding edges X1, X2, Y1 and Y2 of the RADIATION FIELD OR DELINEATED RADIATION FIELD (see 6.4).