E-ROD – A new metric to evaluate the relative detectability of two digital mammography systems

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Introduction

Relative Object Detectability (ROD) is a metric used to compare the detectors in two different radiology systems objectively and quantitatively. ROD is defined as the ratio of the product of the spatial frequency integral of the Fourier transform of the object function (OBJ) and the detective quantum efficiency (DQE) of one system to the product calculated for the system to which it is being compared.

Materials and Methods

In this work, ROD was modified to include scattering and focal spot blur as well as shape, dimensions and material of imaged object in order to assess the effective performance (E-ROD) of the whole imaging system. To do this DQE was replaced by effective Noise Equivalent Quanta (eNEQ) defined as:

$$eNEQ(u') = \frac{eMTF(u')^2(1-SF)^2}{eNNPS(u')}$$

where eMTF is a effective Modulation Transfer Function, SF is a scatter factor and eNNPS is a effective Normalized Noise Power Spectrum.

The new E-ROD parameter is therefore defined as:

$$E\text{-}ROD = \frac{d'^2_1}{d'^2_2} = \frac{\int_0^{u_{N1}}\int_0^{v_{N1}} |OBJ(u,v)|^2 \, eNEQ_1(u,v)\ dudv}{\int_0^{u_{N2}}\int_0^{v_{N2}} |OBJ(u,v)|^2 \, eNEQ_2(u,v)\ dudv}$$

where d' is the object detectability.

Object function is defined as Fourier transformation of the image of simulated element.

$$obj(x,y) = \left(1 - e^{-\mu t(x,y)}\right) \quad \Rightarrow \quad OBJ(u,v) = \iint obj(x,y)\, e^{-2\pi i(ux+vy)}\, dxdy$$

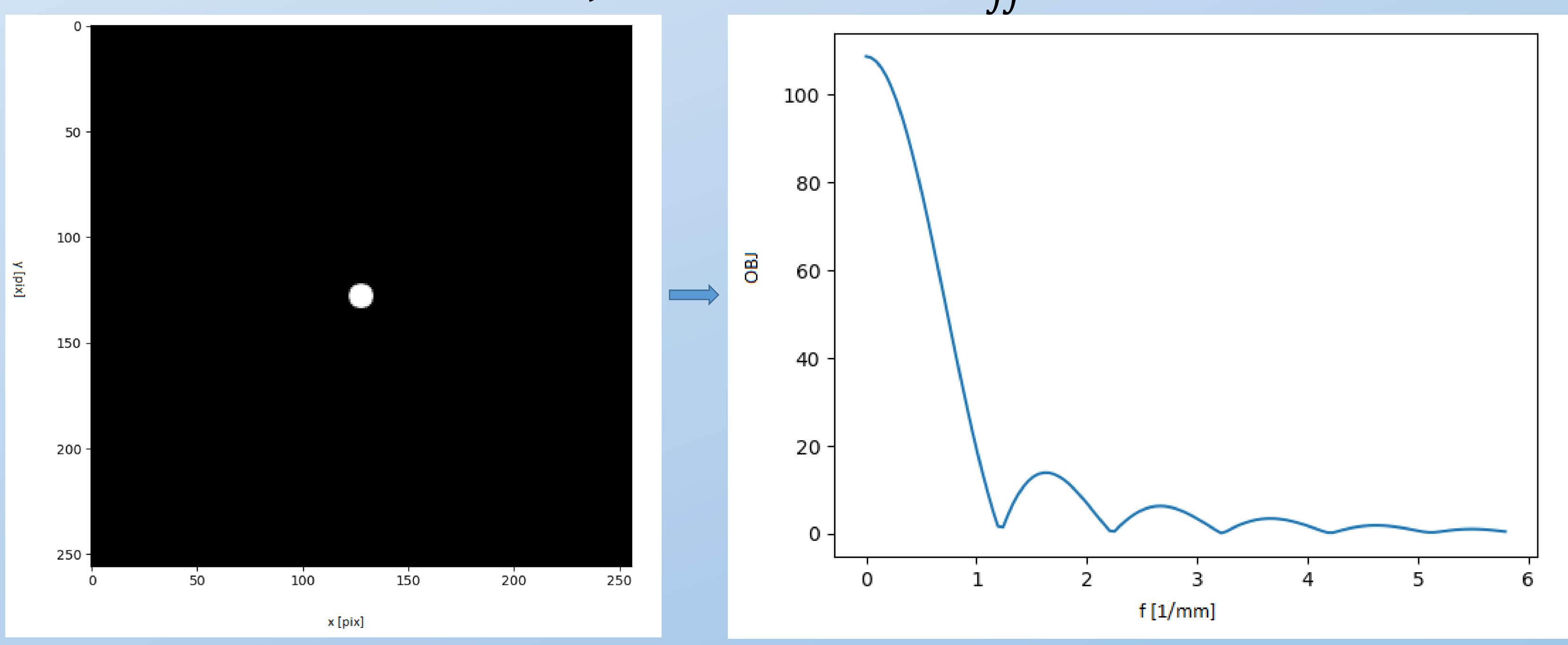

Fig. 1 Example of Fourier transformation of the image of simulated element

The digital mammography systems compared in this work were:

- two Siemens Mammomat Inspiration units with amorphous selenium detectors (pixel size 85 µm), W/Rh target/filter combination used clinically; and a
- GE Pristina Senographe unit with CsI scintillator detector (pixel size 100 µm), Mo/Mo and Rh/Ag target/filter combinations.

E-ROD was calculated for PMMA phantoms thicknesses of 20, 40, and 70 mm, with and without an anti-scatter grid, and using a selection of clinically relevant anode/filter combinations. Exposure parameters were automatically set by the AEC system. Simulated objects were gold discs of diameters and thicknesses consistent with elements in CDMAM 3.4 Phantom and high contrast spheres.

Results

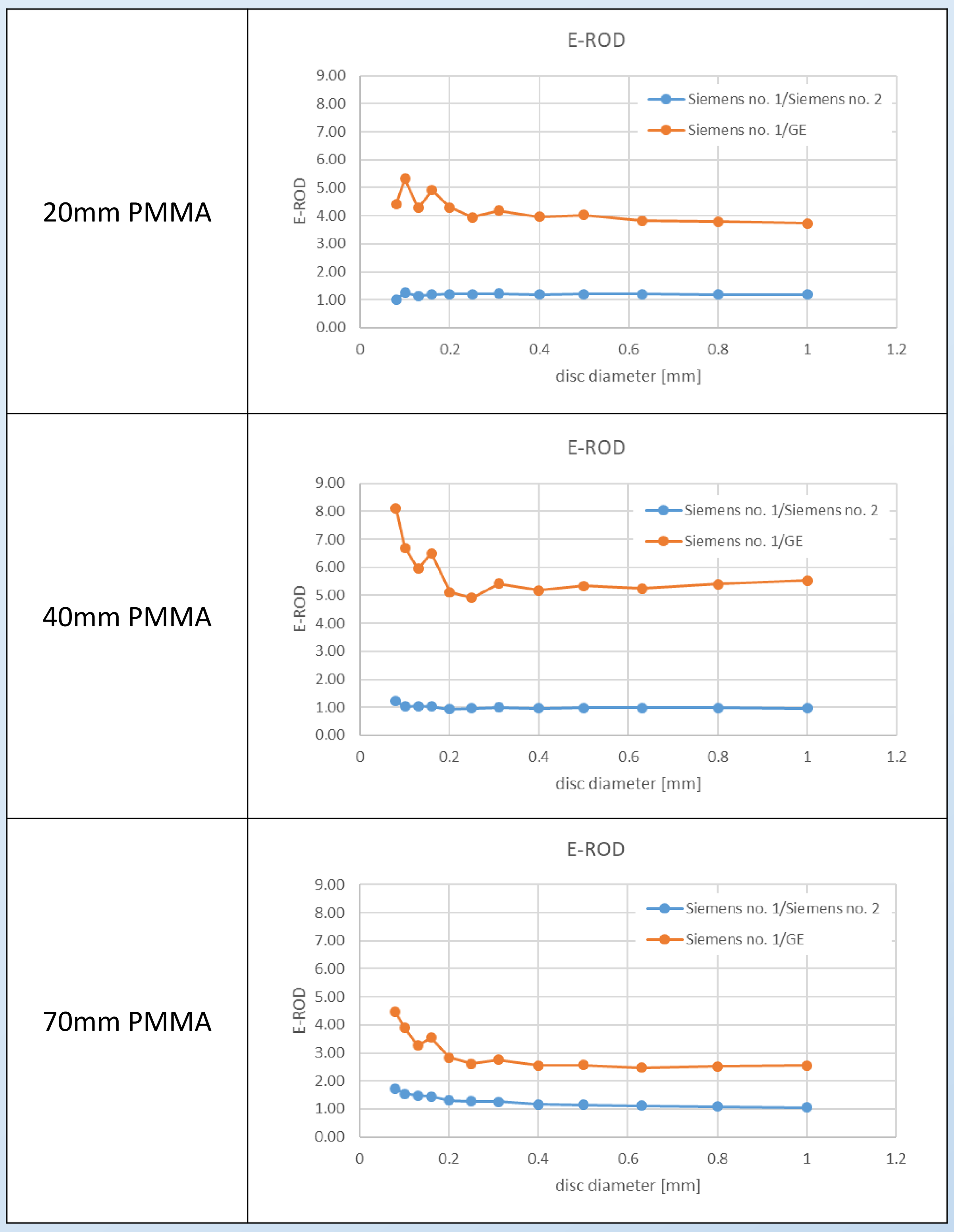

Fig. 2 Calculated E-ROD as a function of simulated discs diameter

PMMA phantom thickness [mm]	disc diameter [mm]	Predicted Human Gold Thickness [µm] Siemens no.1	GE
20	0.1	0.804	1.116
	0.2	0.253	0.330
	0.5	0.097	0.096
	1	0.053	0.047
40	0.1	0.841	1.124
	0.2	0.369	0.385
	0.5	0.103	0.124
	1	0.069	0.063
70	0.1	1.867	1.684
	0.2	0.505	0.519
	0.5	0.134	0.169
	1	0.085	0.084

Tab. 1 Results from CDMAM Phantom for Siemens no.1 and GE mammograph

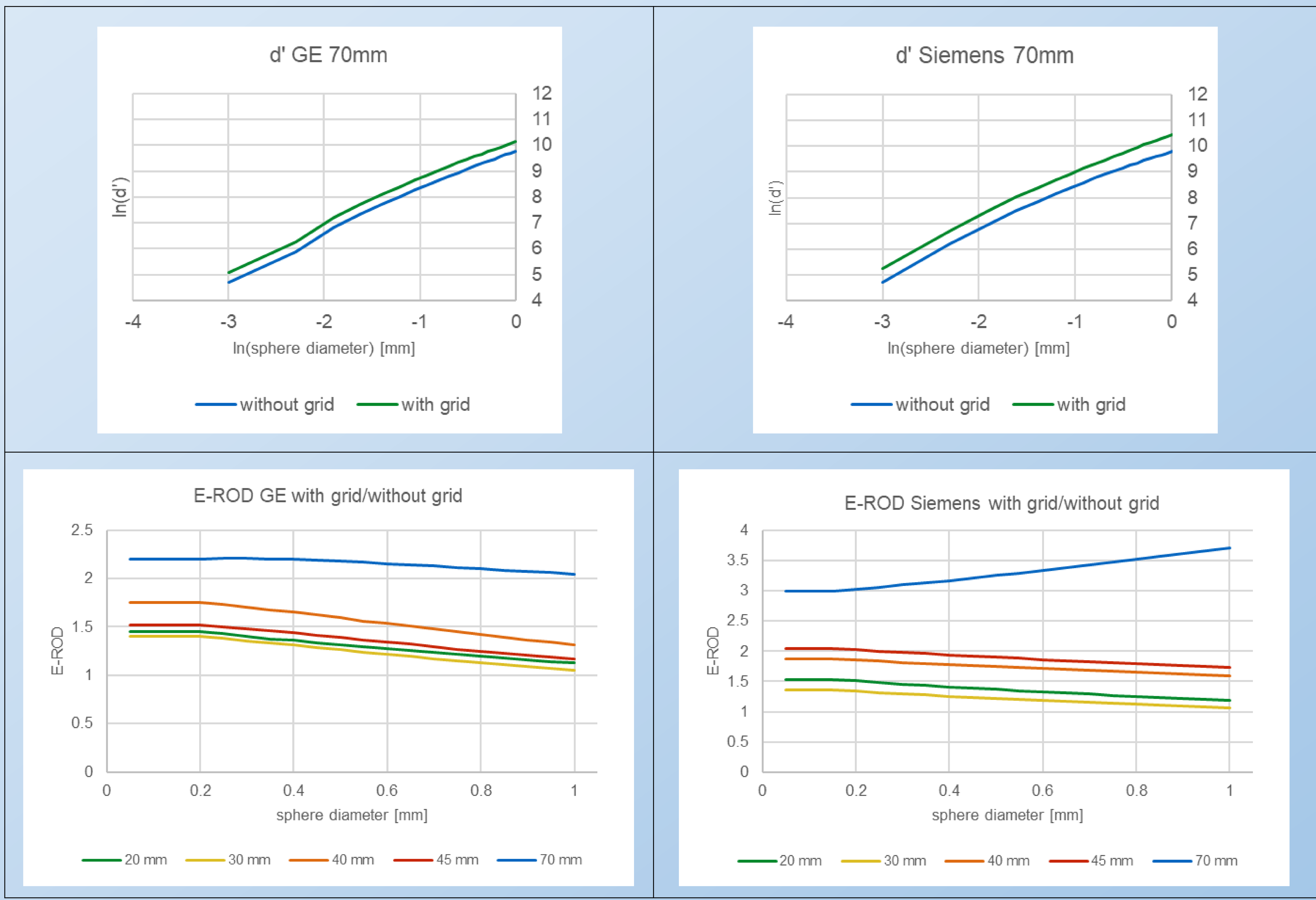

Fig. 3 Calculated d' and E-ROD as a function of diameter of simulated spheres

Effective Relative Object Detectability (E-ROD) is a new metric that allows quantitative analysis of the relative performance of two imaging systems, or a single system working under different conditions, with or without an anti-scatter grid. We have performed image measurements for two Siemens Mammomat Inspiration units and a GE Pristina Senographe (Fig.2) and for each system working with or without grid (Fig.3).

We have shown that E-ROD for Siemens units for 20 and 40 mm phantoms is equal to 1 for all disc diameters. This dependency is also achieved with a 70 mm phantom, but with small differences for discs with diameters less than 0.2 mm (Fig.2).

When we compared the Siemens and GE systems, we observed similar behavior of E-ROD curves. The main differences were observed for discs diameter below 0.3 mm. E-ROD values decreased with increasing diameter of the discs: from 5 to 4, 8 to 5 and 4.5 to 2.8 at 20, 40 and 70mm phantoms respectively.

The characteristics of E-ROD curves are consistent with most of the Predicted Human Gold Thicknesses received with a CDMAM 3.4 Phantom at the same disc diameters (Tab.1).

We also demonstrated that E-ROD for these mammography units is higher when the anti-scatter grid is turn on (Fig.3).

Summary

E-ROD permits comparison of mammography systems that differ in terms of used detectors, focal spot dimensions, exposure conditions and characteristic of imaging object. The method has limitations, but obtained results may be useful in choosing the optimal mammography system to attain maximum imaging quality in specific clinical conditions.