

A radiolucent and flexible high impedance coil array to increase the imaging performance of a 1.5T MR-linac



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Introduction

The MR-linac (Unity, Elekta AB, Stockholm, Sweden) is equipped with a diagnostic-grade 1.5T MRI scanner. However, the current clinical receive arrays are limiting, as they:

- only contain 4 channels each limiting parallel imaging (PI)
- are several centimeters away from the patient (low sensitivity)

Furthermore, traditional low impedance coils (LICs) are not ideal for use in an MR-linac array, as:

1. The capacitors for segmentation attenuate the photon beam and produce scatter. Therefore, they are not allowed in the irradiation window.
2. Dense arrays exhibit complex coupling between nearby elements.

Zhang et al. showed that high impedance coils (HICs) do not require capacitor segmentation and are well decoupled by design, making them especially suitable for use in an MR-linac.¹

Objective

Investigate the feasibility of a flexible array of high impedance coils to **increase the image quality and acquisition speed** of an MRI-linac treatment device **without affecting the delivered dose**.

Design and prototypes

Approach:

1. Design HIC array with radiation window (Figure 1A-B)
2. Create prototype for radiation experiments (Figure 1C)
3. Create a functional prototype for imaging (Figure 1D)

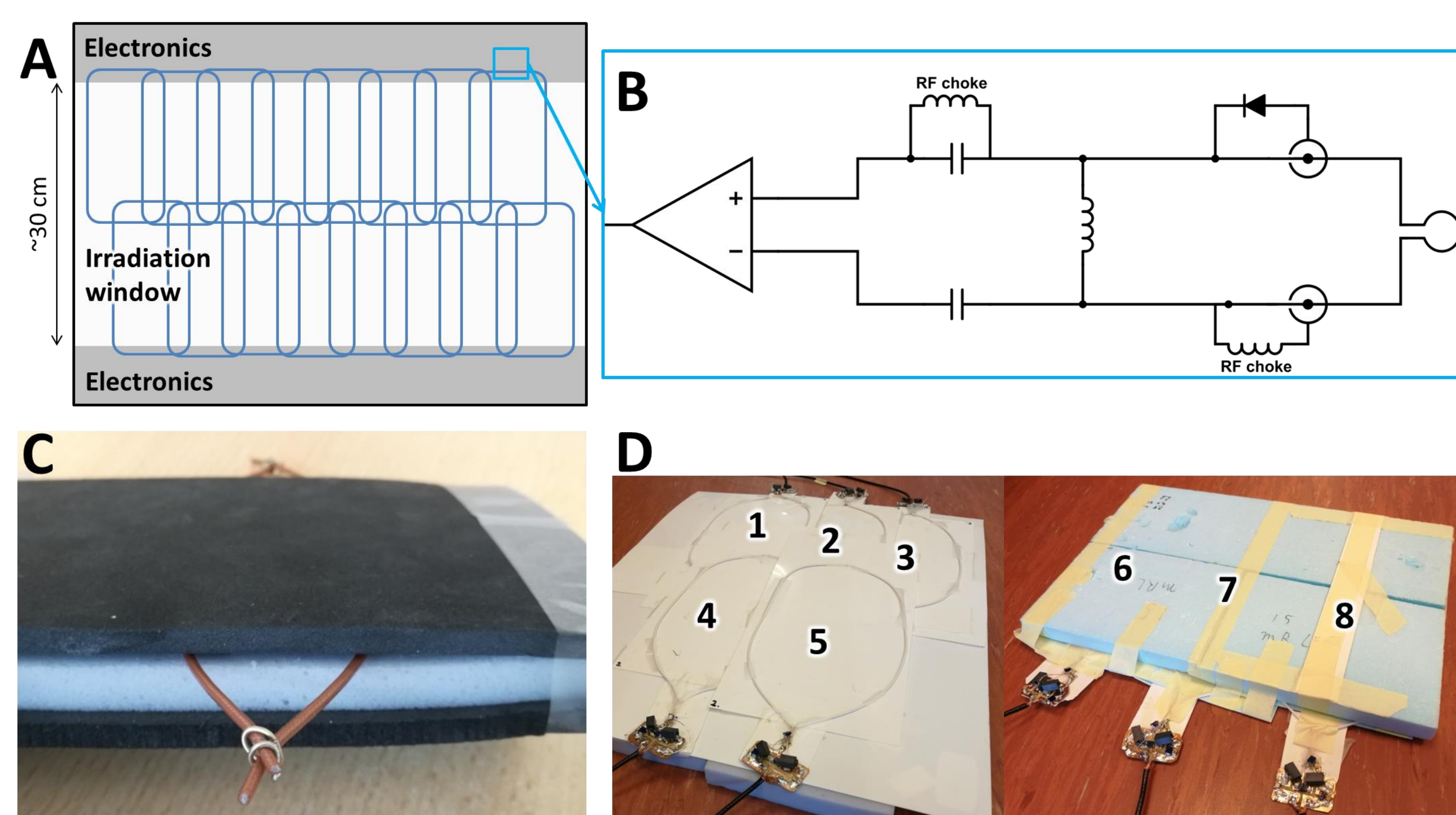


Figure 1. (a) Radiolucent array design. Loops made from AlphaWire 9432 are placed in two rows and their electronics are placed outside the irradiation window. (b) Detuning and matching circuitry. (c) Radiation prototype comprising four layers: 5 mm EVA-PE foam, loops, 10 mm Flamex foam, and 5 mm EVA-PE foam. (d) 8-channel imaging prototype.

Methods

Radiation: 5x5 cm² beams from 90° were delivered on an Elekta Synergy with and without the prototype. On an electronic portal imaging device (EPID), 50-frame signal averages (pixel size: 0.35x0.35 mm²) were acquired and normalized² and the attenuation was then calculated with:

$$A_{\text{prototype}} = \frac{S_{\text{prototype}} - S_{\text{open}}}{S_{\text{open}}}$$

Imaging: HIC prototypes and the current clinical array were placed on a phantom in a 1.5T Elekta Unity. A dynamic FFE scan (TE/TR = 4.0/30.0 ms, #dyn = 50) was acquired. SNR maps were calculated from both datasets.

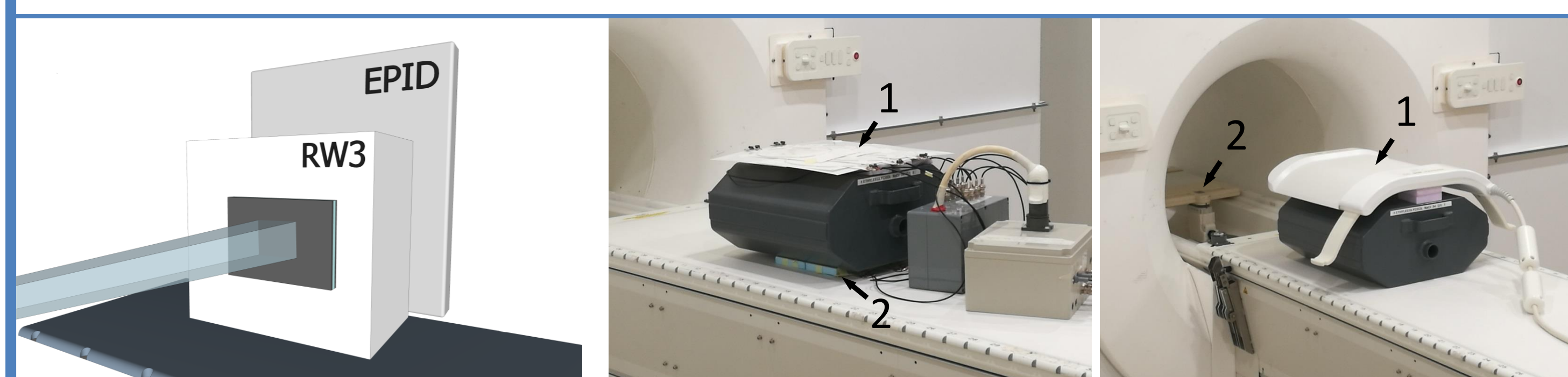


Figure 2. Experimental setups for radiation measurements (left) and imaging with the prototype (middle) and clinical arrays (right). Both anterior (1) and posterior (2) elements are used.

Results

The results of the radiation and imaging experiments are shown in Figure 3 and 4, respectively.

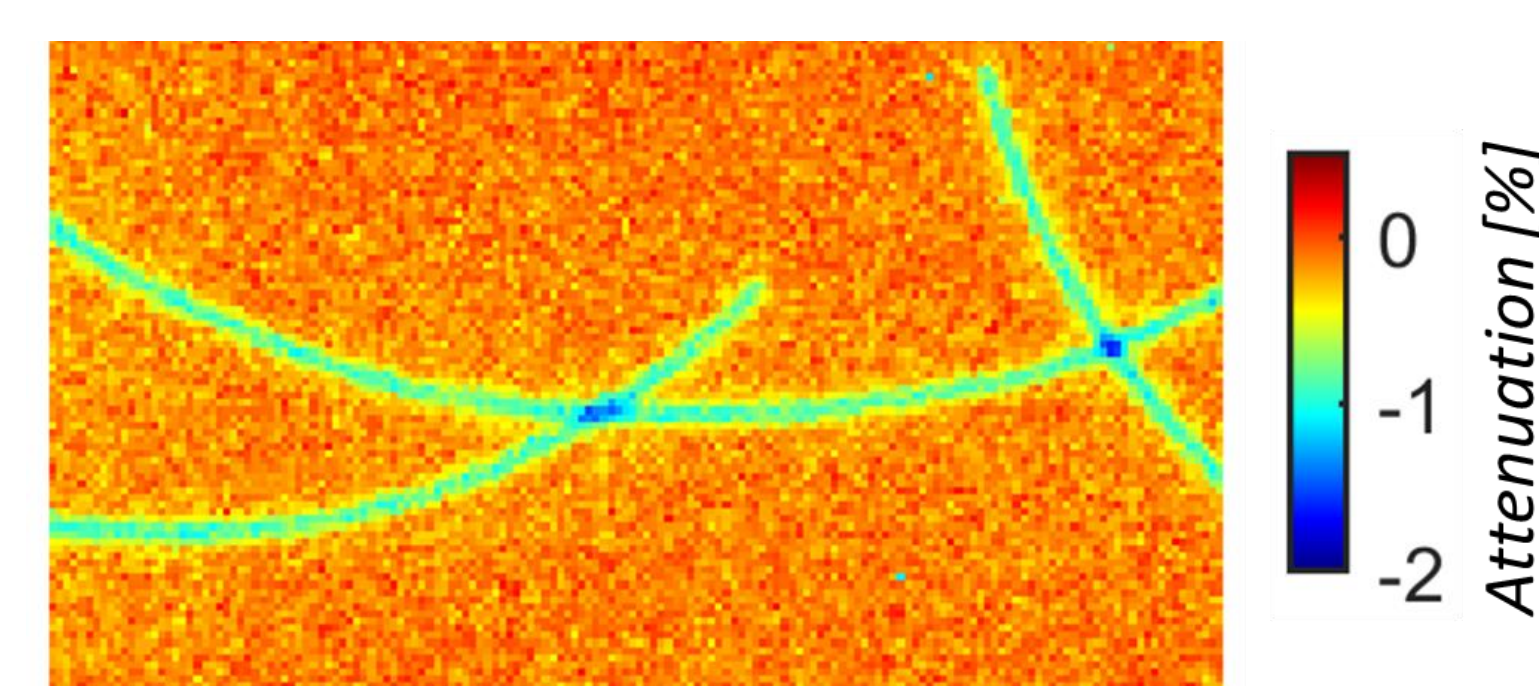


Figure 3. Attenuation map of the radiation prototype. The wire causes a decrease of around 0.83±0.12% for a single wire and around 1.5% for two overlapping wires. Anatomical motion and multi-beam treatments will limit the dosimetric impact to a clinically insignificant level.

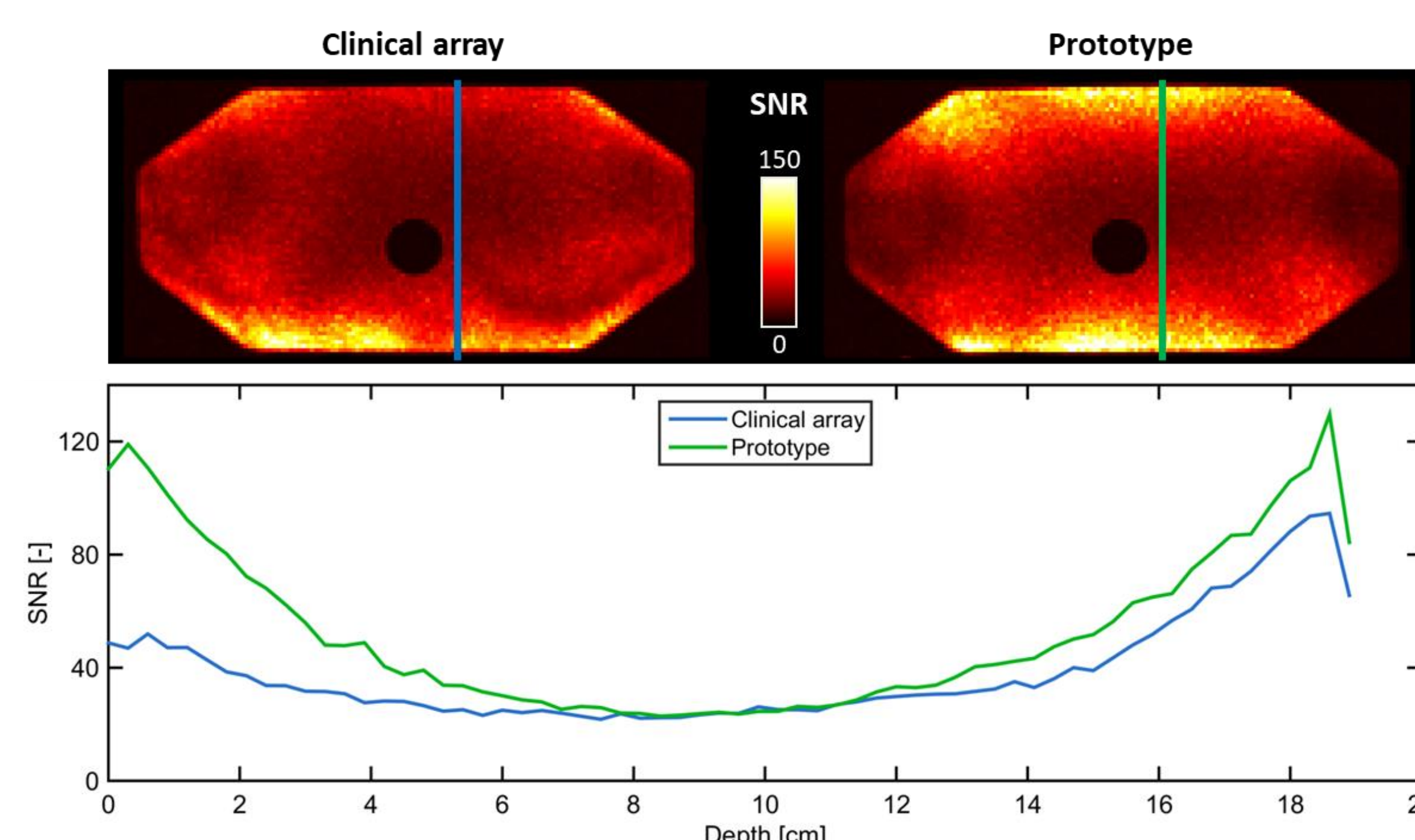


Figure 4. Profiles of the SNR over the depth of the phantom. The overlapped array clearly outperforms the current clinical array.

Discussion and conclusion

- No significant dose changes are found due to our on-body prototype.
- The prototype shows better SNR performance than the current clinical array.
- **The increased channel count of our prototype can strongly improve the imaging performance of the MR-linac for high spatiotemporal monitoring of the 3D anatomy during treatments, while the array does not interfere with the dose delivery.**

