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# Real-time ultrasonic imaging with a nonlinear beamformer based on p-th root compression

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## ABSTRACT

Ultrasonic imaging is widely used in several domains such as medical imaging, nondestructive evaluation (NDE) or underwater acoustics, because of its low cost and non-invasive property. Delay and sum (DAS) as a software processing is a standard beamforming process for fast plane wave imaging (PWI). However, the latter suffers from a lack of resolution and contrast compared to conventional hardware focused imaging. Improving resolution and contrast while maintaining a high-speed imaging is therefore a challenge. The use of a nonlinear beamformer based on p-th root (pDAS) has been introduced for medical imaging to increase image quality of PWI. The principle is first to apply the p-th root to raw radiofrequency data and then to take the p-th power after the summation. In this paper, we propose to implement this beamformer for real-time applications in medical imaging and NDE. To do so, this beamformer has been efficiently programmed on graphics processing units (GPU). This process can be applied to any standard acquisition schemes such as PWI, synthetic aperture focusing technique (SAFT) and total focusing method (TFM). Both in medical and NDE experimental applications, within a PWI framework, we obtain an improvement in terms of resolution and contrast while keeping a similar frame rate compared to DAS. For instance, on an experimental medical phantom, for  $p=2$ , the contrast ratio is improved by about a factor two. On an NDE test block containing side drilled holes, for  $p=2$ , the lateral resolution is improved between 20% and 50%. We also present the effect of changing the coefficient  $p$ . Increasing  $p$  expands the dynamic of the images, improving again contrast and resolution.

## 1. CONTRAST FROM AN ANECHOIC REFLECTOR

Figure 1 presents contrast ratio (CR) results from a medical imaging application. It is based on PWI of an anechoic reflector from a phantom (CIRS-040GSE). The CR increases as a function of coefficient  $p$ .

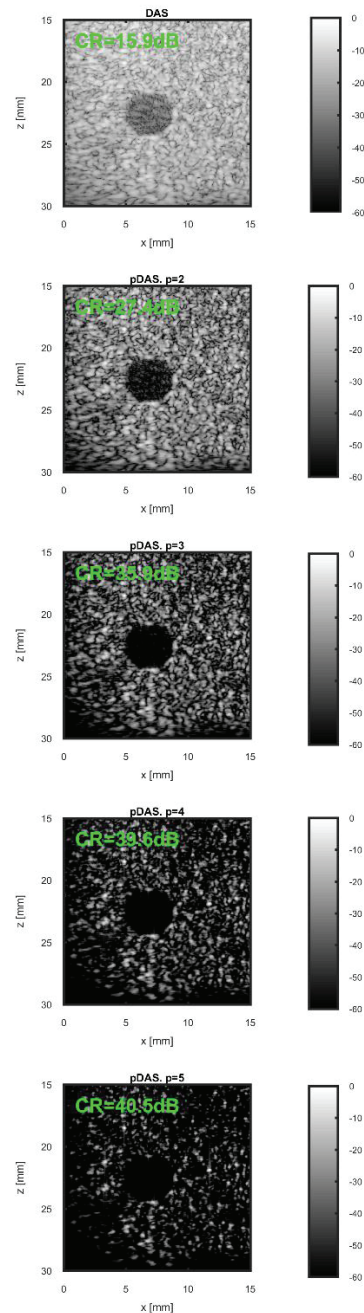
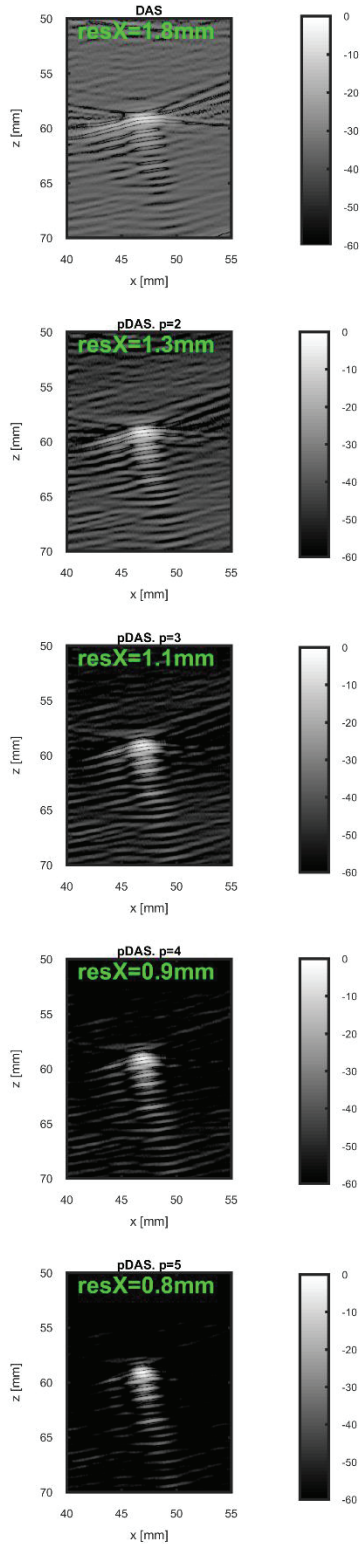


Figure 1. Contrast values from an anechoic reflector for several  $p$  values.

## 2. RESOLUTION FROM A HOLE IN ALUMINUM

This NDT example is from the inspection of an aluminum sample containing 1mm side drilled hole. The beamformed images and the corresponding lateral resolutions are plotted in **Figure 2**. The lateral resolution is decreasing as  $p$  increases.



**Figure 2.** Resolution values from a side drilled hole in aluminum for several  $p$  values.

## 3. CONCLUSION

The pDAS beamformer has been implemented for GPU computing allowing real time imaging for medical and NDT applications. The two previous examples show improvement in terms of contrast and resolution.

## 4. REFERENCES

- [1] M. Polichetti, F. Varray, J.-C. Béra, C. Cachard, B. Nicolas: “A nonlinear beamformer based on  $p$ -th root compression – Application to plane wave ultrasound imaging,” *Applied science*, Vol 8, 599, 2018.