Local Contrast-Enhanced Noise Suppression Method for Ultrasound Imaging

X. Li[1], J. Li[2], C. Guo[1], Z. Xu[1] and Z. Zheng[1]

1. Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, Guangdong, China
2. Shenzhen Middle School, Shenzhen, Guangdong, China
960457446@qq.com, lijiahuiszzx@163.com, {guochongchong, xuzhian, zhengzhu}@mindray.com

Ultrasound imaging has been widely used in medical diagnosis for its safety, non-invasive, real-time imaging and other advantages [1]. However, the influence of the resolution limit of the ultrasound image and the inherent side lobe artifact is difficult to obtain the diagnostic information of difficult cases through the B-mode image [2-3]. At present, methods to improve the image quality mainly include three aspects: transmission strategy, adaptive beamforming methods, and image post-processing.

Firstly, improved transmitting strategy, synthetic transmitting aperture (STA) can improve image focusing accuracy. Through sequential excitation of array elements, the multi-static echo data set is obtained, one low-resolution image is obtained for each transmitting, and finally the multi-frame image is combined to obtain high-resolution image, which can achieve bidirectional focusing of beam [4]. However, it is largely limited by a decrease in penetration and an increase in calculated consumption. Secondly, adaptive beamformer can dynamically calculates the array weight of each sampling time according to the echo data in real time, selects the direction and feature of the beam, and realizes spatial filtering [5]. It mainly includes minimum variance algorithm (MV) and coherence factor (CF) based method [6-7]. Adaptive calculation usually requires a certain number of samples to obtain reliable results. Moreover, it may involve operations such as inverse calculation and eigen decomposition of large matrices. Therefore, the complexity will be obviously increased [8]. Thirdly, image post-processing optimization, mainly for various image filters, such as non-local mean filter (NLM), etc. The performance of this type of filter often depends on the details of the matching search. The finer the matching search, the better the effect. However, the imaging efficiency also will be further limited [9-10].

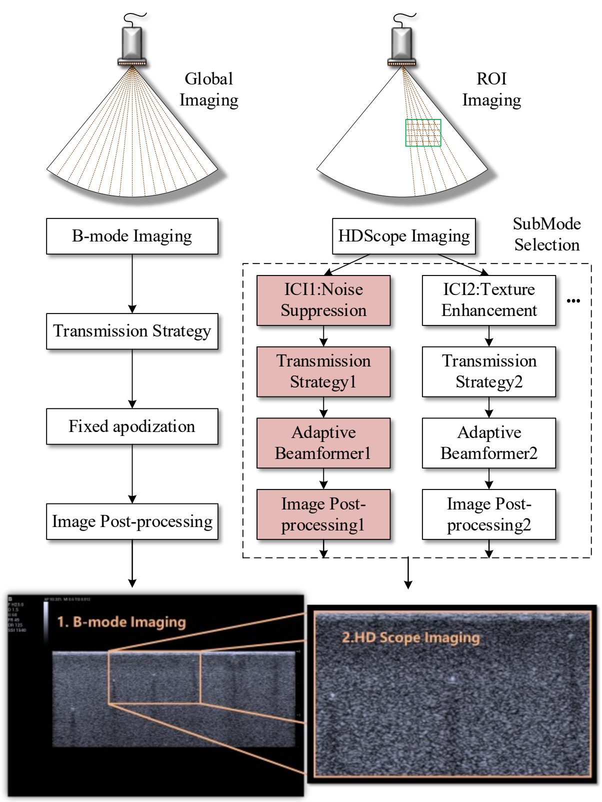


Figure 1. Principle diagram of HD Scope imaging mode

In general, most of the improved methods inevitably increase the resource consumption at the same time, and it is difficult to balance the image quality and imaging efficiency. The direct fusion of technologies still faces the risk of decreasing the real-time performance of ultrasonic equipment. Although the complexity optimization schemes for these technologies have been studied, they are focused on specific technology. The commercialization of adaptive beamformer still faces great challenges. Considering that the important information of lesion is usually located in the region of interest (ROI) in actual clinical diagnosis. If advanced transmitting strategy and adaptive algorithms are combined, and limited resources are concentrated on local image presentation, the image quality will be further improved.

979-8-3315-7370-6/25/$31.00 ©2025 IEEE IEEE SPMB 2025 December 6, 2025

Table 1. Parameters setting for experiments

Parameter name	Value
Sampling frequency	50 MHz
Center frequency	2.7 MHz
Probe type	Convex array
Imaging type	Harmonics imaging
Receiving aperture	192 elements

Inspired by this, in this paper, we propose to construct a set of independent signal processing links to optimize the imaging mode of local images, which is called HD Scope imaging mode. It can bring two benefits: Firstly, HD Scope can provide a real-time imaging solution for high complexity beamforming methods. Take phased array sector scanning as an example. If the scanning depth is denoted as R, the probe scanning area in B-mode can be denoted as $\theta\pi R^2/360$, and θ is the scanning angular range of the beam steering. Assume that the ROI region selected by HD Scope is a rectangular region with side length R/k, and the efficiency improvement E_k times is approximately as follows:

$$\mathrm{E}_k = (\frac{1}{k}R)^2 \Big/ (\frac{\theta}{360}\pi R^2) = \frac{360}{\theta k^2 \pi} \quad (1)$$

Because the processing process of ultrasound imaging can be seen as a combination of parallel computing in every pixel, and the number of pixels is proportional to the imaging area, therefore, in case of k=4, the resource consumption rate in HD Scope is only 7.96% in B-mode, it will be sufficient resources to implement more complex transmission strategy and adaptive beamformers.

Secondly, different technology combinations can be selected according to different scenes, so as to improve the local image quality. In HD Scope, several sub-modes of intelligent characteristic imaging (ICI) are designed according to different imaging scenarios by the adaptive beamforming methods. ICI1：Noise suppression: Applicable to liquid-containing structures such as fetal heart, ventricle, gastric bubble, ovarian cystic or cystic-solid lesions. ICI2：Texture Enhancement: Applicable to obtain gray scale differences in local tissues or lesions, such as fetal brain, lung, liver, and kidney. In this paper, we mainly quantified the effectiveness of ICI1 on noise suppression. The link differences between conventional B-mode and HD Scope mode are shown in Fig. 1.

In order to ensure the uniformity of data sources, this experiment uses Mindray Resona A20 ultrasound machine with AIT platform and SC7-1U convex array probe to collect the RF data, so as to ensure that the echo comes from the same frame. Test parameter as shown in Table 1.

The results of anechoic cysts tests are shown in Fig. 2, the conventional B-mode images are often accompanied by obvious side lobe artifacts, so the lateral boundary of cyst is fuzzy and the noise is obvious. The noise suppression function of HD Scope can eliminate side-lobe artifacts and greatly improve the image

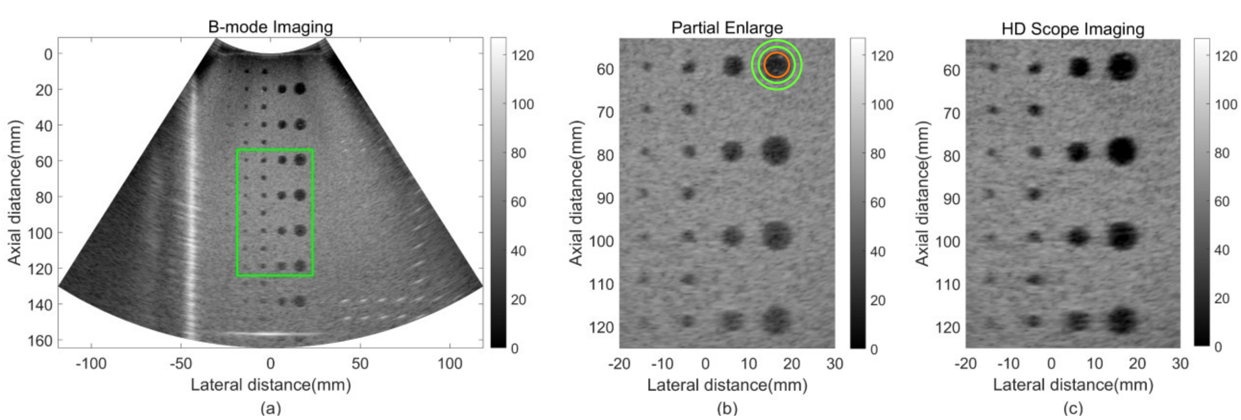


Figure 2. Comparison of B-mode partial enlarge and HD Scope imaging

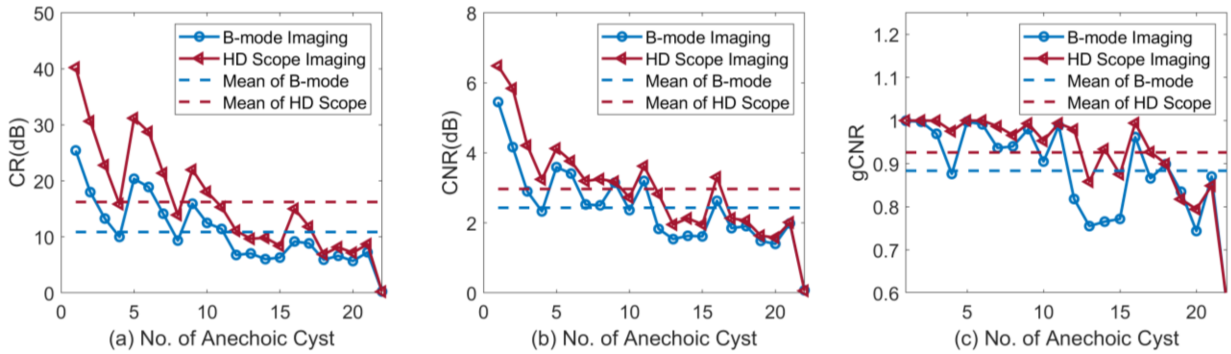
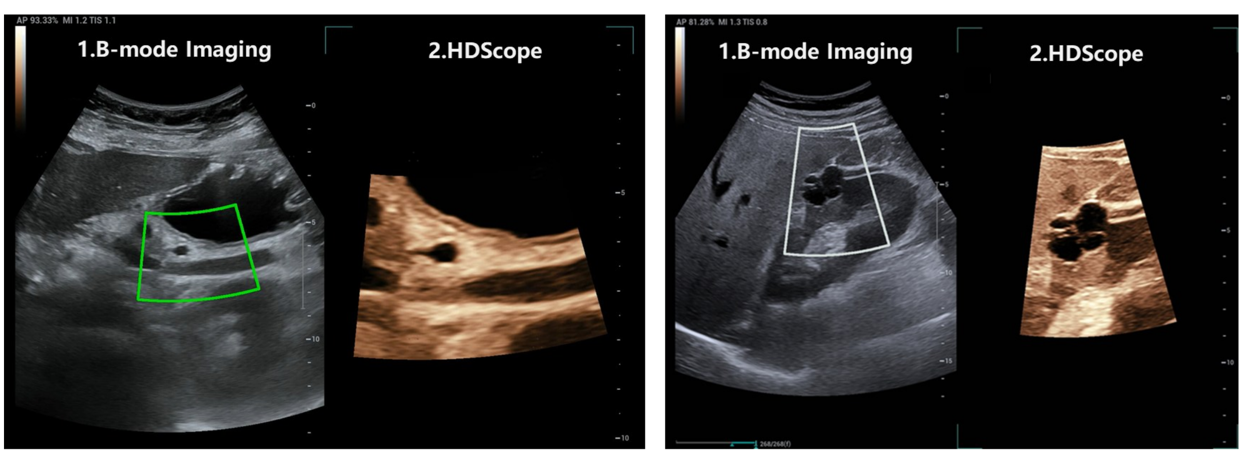


Figure 3. Contrast indexes comparison between B-mode imaging and HD Scope imaging

contrast, providing a clear cyst profile. In addition, we labeled the 22 anechoic cysts in the local image as 1~22 from top to bottom and from right to left. Meanwhile, we plotted the CR, CNR, and gCNR indexes measured from each anechoic cysts as curves, as shown in Fig. 3. As can be seen in Fig. 3(a), the mean CR, CNR, gCNR improvement of HD Scope imaging is about 49.28%, 21.76% and 4.81% than those of B-mode imaging. This also means that the independent links of HD Scope can fully utilize the hardware resources, thereby obvious improving the contrast performance of local images.

We further tested the performance of HD Scope in clinical diagnosis. As shown in Fig.4, in pancreatic imaging, the focal lesion on the global imaging is difficult to judge solid or cystic, with the noise suppression of HD Scope, it is clearly shown cystic lesion and communicated with the pancreatic duct. In another case, in kidney imaging, the complex cyst is seen but lack of details on global imaging, however, the noise suppression of HD Scope can effectively suppress artifacts and clutters, brings out the clear image within the cyst, several thin and smooth septa without nodule protrusion, then the BOSNIAK classification is given 2F, and only regular follow-up is required. In terms of real-time imaging, the SC7-1U convex array probe can reach more than 24fps in the default mode with 160mm detection depth. When k=3.4, the noise suppression of HD scope and B-image can stably reach more than 16fps at the same time.

In this paper, the HD Scope method with local characteristics enhancement is proposed. Since limited hardware resources are concentrated on the local image, it can provide real-time imaging solutions for high complexity adaptive beamformers and other processing technologies, and use different combinations of technologies for different scenes, so as to improve the local image quality. The phantom test results show



(a) Pancreas Imaging (b) Kidney Imaging

Figure 4. Comparison of HD Scope imaging and B-mode imaging in pancreas and kidney diseases

that the noise suppression of HD Scope can significantly improve the local contrast of ultrasound image, and obtain clearer image in the imaging of pancreas and kidney, which is helpful for the classification and diagnosis of lesions.

REFERENCES

[1] T. L. Szabo, "Diagnostic ultrasound imaging: inside out. Amsterdam," *The Netherlands: Elsevier*, 2014.

[2] V. Ganesan, S. De, D. Greene, F. C. M. Torricelli, and M. Monga, "Accuracy of ultrasonography for renal stone detection and size determination: Is it good enough for management decisions?" *BJU International*, vol. 119, no. 3, pp. 464–469, Mar. 2017.

[3] D. Hyun, G. B. Kim, N. Bottenus and J. J. Dahl, "Ultrasound lesion detectability as a distance between probability measures," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 69, no. 2, pp. 732-743, 2022.

[4] S. Kang, J. Lee, J. H. Chang, "Effectiveness of synthetic aperture focusing and coherence factor weighting for intravascular ultrasound imaging," *Ultrasonics*, vol. 113,106364, 2021.

[5] J.-F. Synnevag, A. Susteng, and S. Holm, "Adaptive beamforming applied to medical ultrasound imaging," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 54, no. 8, pp. 1606–1613, 2007.

[6] Q. W. Li, P. Wang, X. T. Li, J. H. Chen, Y. Shen, "Dual criteria projection frequency domain minimum variance beamformer based on sub-band sparsity for ultrasound imaging," *Biomedical Signal Processing and Control*, vol. 96, Part A, 106639, 2024.

[7] X. W. Zhang, Q. Wang, "Improving lateral resolution and contrast by combining coherent plane-wave compounding with adaptive weighting for medical ultrasound imaging," *Ultrasonics*, vol. 132, 106972, 2023.

[8] A. M. Deylami, B. M. Asl, "Low complex subspace minimum variance beamformer for medical ultrasound imaging," *Ultrasonics*, vol. 66, pp. 43-53, 2016.

[9] P. Coupe, P. Hellier, C. Kervrann, C. Barillot, "Nonlocal means-based speckle filtering for ultrasound images," *IEEE Transactions on Image Processing*, vol. 18, pp. 2221-2229, 2009.

[10] A. Perperidis, "Postprocessing approaches for the improvement of cardiac ultrasound B-mode images: A Review," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 63, pp. 470-484, 2016.

Local Contrast-Enhanced Noise Suppression Method for Ultrasound Imaging

Xitao Li, Jiahui Li, Chongchong Guo, Zhian Xu, and Zhu Zheng

1 Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, Guangdong, China

2 Shenzhen Middle School, Shenzhen, Guangdong, China

Abstract

- Transmission strategy, adaptive beamforming methods, and image post-processing links optimization have been shown to effectively improve the resolution and contrast of ultrasound imaging.
- However, these methods also lead to the increase of imaging complexity, and the direct integration of technologies may result in real-time imaging no longer meeting the requirements. Therefore, balancing real-time performance and image quality is currently one of the main challenges in ultrasound imaging.
- In this paper, we propose a HD Scope method to solve this problem. In HD Scope, a set of independent signal processing links is used to optimize the effect of local image. Different from simple enlargement processing, HD Scope can use specific adaptive beamformer for different scenes to achieve optimal results in a certain aspect.
- The phantom and in vivo experiments were used to inspect the performance of HD Scope, which indicate that the proposed HD Scope significantly enhances the contrast, and improves CR and CNR by an average of 49.28% and 21.76%, respectively. Finally, the diagnostic results for pancreatic and renal lesions further demonstrate the effectiveness of the localized optimal link in HD Scope.

Introduction

- Ultrasound imaging has been widely used in medical diagnosis for its safety, non-invasive, real-time imaging and other advantages. Resolution and contrast are the main improvement directions of ultrasound imaging.
- At present, methods to improve the image quality include three aspects: Firstly, improved transmitting strategy, in which the scheme with the best image effect is the scheme of synthetic transmitting aperture.
- In General, most of the improved methods inevitably increase the resource consumption at the same time, and it is difficult to balance the image quality and imaging efficiency. The direct fusion of technologies still faces the risk of decreasing the real-time performance of ultrasound.
- Considering that the important information of lesion is usually located in the region of interest in actual clinical diagnosis. If advanced transmitting strategy and adaptive algorithm are combined and limited resources are concentrated on local image presentation, the image quality will be further improved.
- Inspired by this, in this paper, we proposes to construct a set of independent signal processing links in the detection of local images to optimize the imaging mode of local images, which is called HD Scope imaging mode.

Method

- In HD Scope imaging, the transmitting strategy, beamformer and image post-processing methods are designed separately from B-mode imaging to achieve optimal local performance in different scenes, so as to obtain clearer local images and more gray diagnostic information compared with the conventional B-mode images.

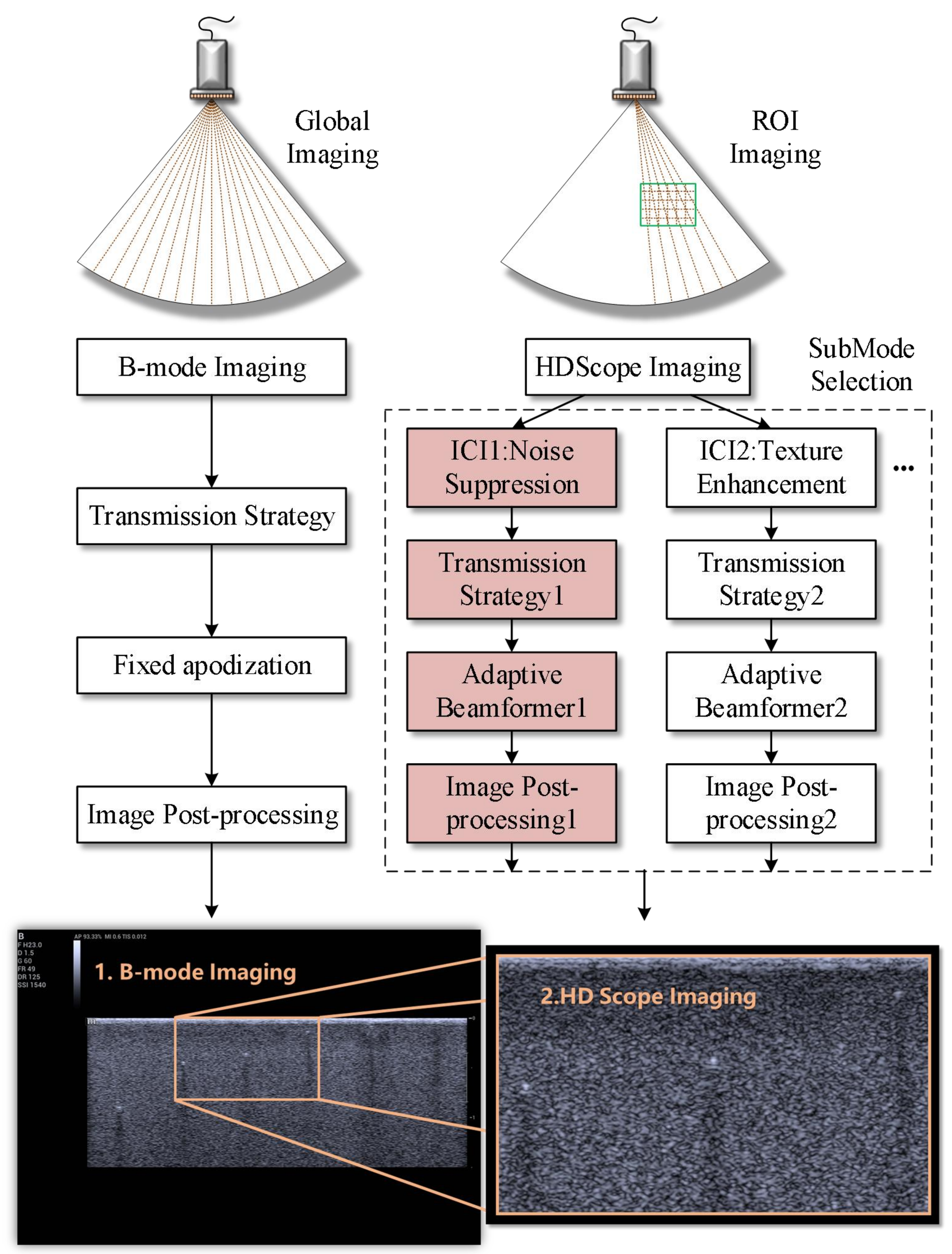


Figure1. Principle diagram of HD Scope Imaging Mode

- Take phased array sector scanning as an example. If the scanning depth is denoted as R, the probe scanning area in B-mode imaging mode can be denoted as $\theta\pi R^2/360$. The ROI region selected by recording HD Scope is the rectangular scanning region with side length , and the efficiency improvement times is approximately as follows:

$$E_k = (\frac{1}{k}R)^2 \Big/ (\frac{\theta}{360}\pi R^2) = \frac{360}{\theta k^2 \pi}$$

- As shown in Fig.1, the value of HD Scope imaging is to design the local optimal link according to the complex and variable ultrasound clinical scenarios to obtain the local optimal effect. The design of the sub-mode: noise suppression, texture-enhancement, etc.
- In this paper, we mainly quantified the effectiveness of noise suppression:
- Applicable to liquid-containing structures such as fetal heart, ventricle, gastric bubble, ovarian cystic or cystic-solid lesions;

Result

- In order to ensure the uniformity of data sources, this experiment uses Mindray Resona A20 ultrasound machine with AIT platform and SC7-1U convex array probe to collect the RF data, and uses offline datasets to process and analysis, so as to ensure that the echo comes from the same frame.
- As shown in Fig. 2, the conventional B-mode images are often accompanied by obvious side lobe artifacts, so the lateral boundary of cyst is fuzzy and the noise is obvious. Noise suppression function of HD Scope can eliminate side-lobe artifacts and greatly improve the image contrast, providing a clear cyst profile.

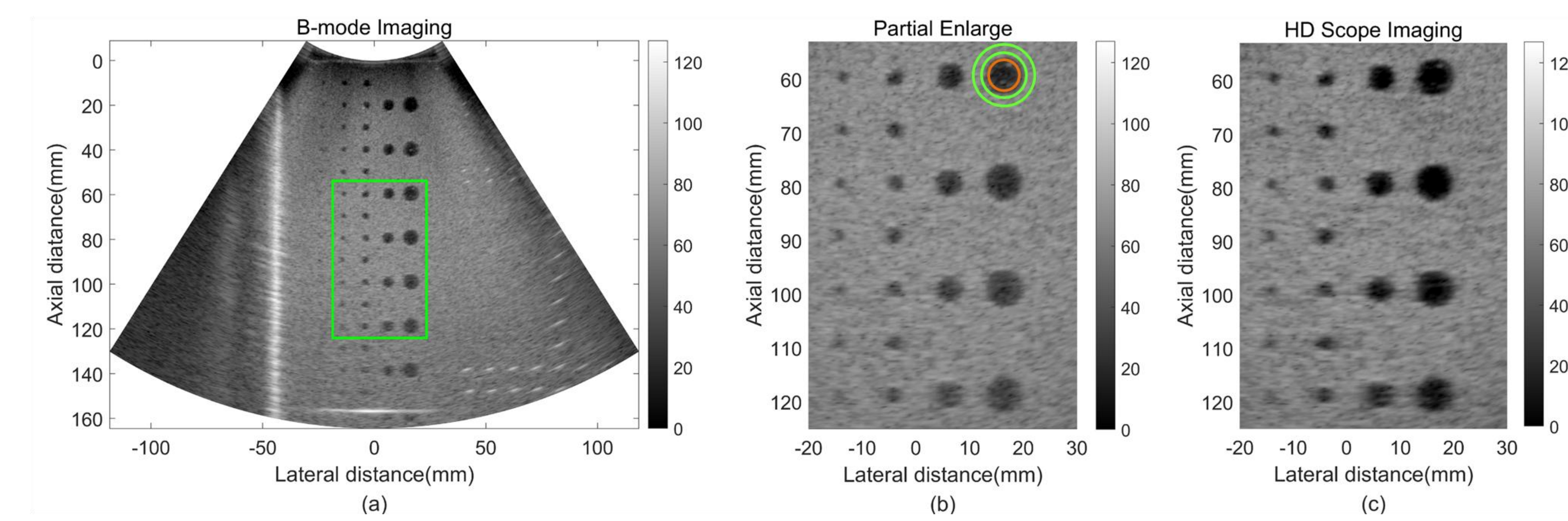


Figure2. Comparison of B-mode partial enlarge and HD Scope imaging

- In order to further compare the contrast performance between traditional B-mode imaging and HD Scope imaging. We labeled the 22 anechoic cysts in the local image as 1-22 from top to bottom and from right to left. Meanwhile, we plotted the CR, CNR, and gCNR indexes measured from each anechoic cysts as curves, as shown in Fig. 3. As can be seen in Fig. 3(a), the CR of HD Scope imaging are higher than that of B-mode imaging in all anechoic cysts. The mean CR improvement of HD Scope imaging is about 49.28% than B-mode imaging. In addition, the mean CNR improvement of HD Scope imaging is about 21.76% than B-mode imaging. Finally, it can be noted that HD Scope has higher CNR and gCNR compared to B-mode imaging in almost all cyst detections. This also means that the independent links of HD Scope can fully utilize the hardware resources, thereby obvious improving the contrast performance of local images.

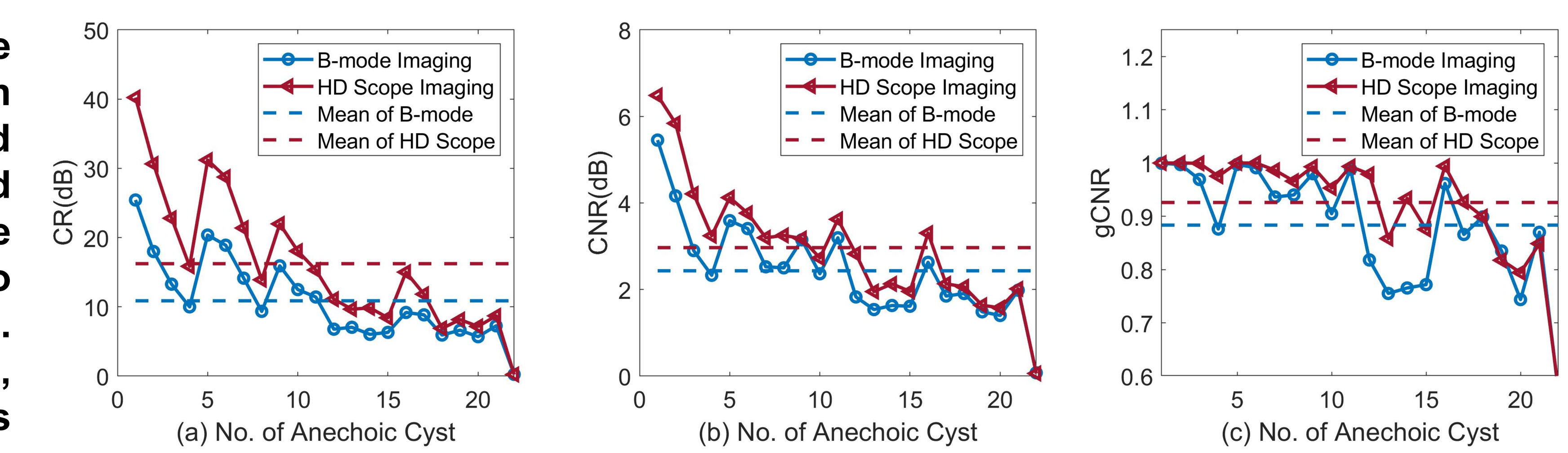
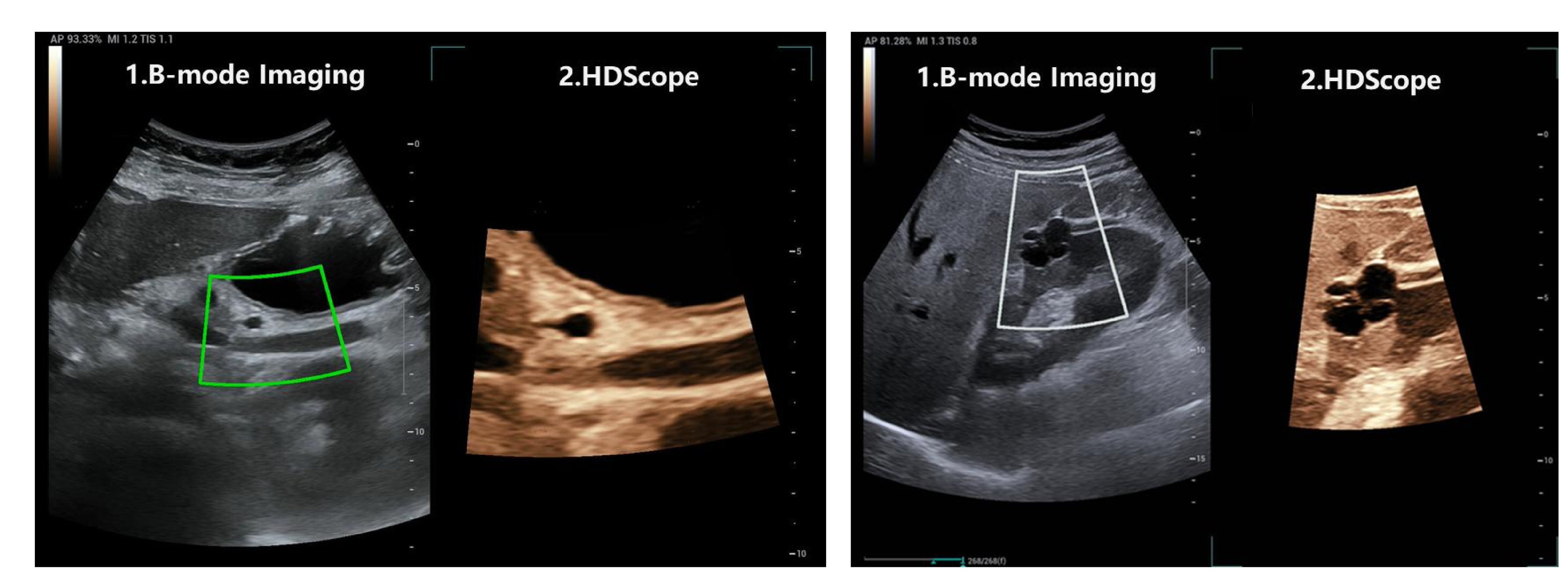


Figure3. Contrast indexes comparison between B-mode imaging and HD Scope imaging

- As shown in Fig.4, in pancreatic imaging, the focal lesion on the global imaging is difficult to judge solid or cystic, with the noise suppression of HD Scope, it is clearly shown cystic lesion and communicated with the pancreatic duct. It makes diagnosis more confident. In another case, in kidney imaging, the complex cyst is seen but lack of details on global imaging, however, the noise suppression of HD Scope can effectively suppress artifacts and clutters, brings out the clear image within the cyst, several thin and smooth septa without nodule protrusion, then the BOSNIAK classification is given 2F, and only regular follow-up is required.



(a) Pancreas Imaging (b) Kidney Imaging

Figure4. Comparison of HD Scope imaging and B-mode imaging in pancreas and kidney diseases

Summary

- In this paper, the HD Scope method with local characteristics enhancement is proposed. Since limited hardware resources are concentrated on the local image, the optimal single index can be achieved by independent signal processing links.
- The phantom test results show that the noise suppression of HD Scope can significantly improve the local contrast of ultrasound image.
- In the imaging of pancreas and kidney, the noise suppression of HD Scope can obtain clearer image, which is helpful for the classification and diagnosis of lesions.