White Paper

Advanced Beamforming

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Introduction

Image quality is the single most important aspect of any ultrasound system. There are many factors that affect the quality of an ultrasound image, but it begins with the individual beams that are formed in the scanner. The ability of the system to properly focus the beams and reconstruct individual imaging lines from them has a significant impact on the quality of the final ultrasound image. Clarius addresses the trade-offs of traditional beamforming techniques through its own unique implementation, which enables acquisition of high-quality and high frame rate images on a portable ultrasound scanner.

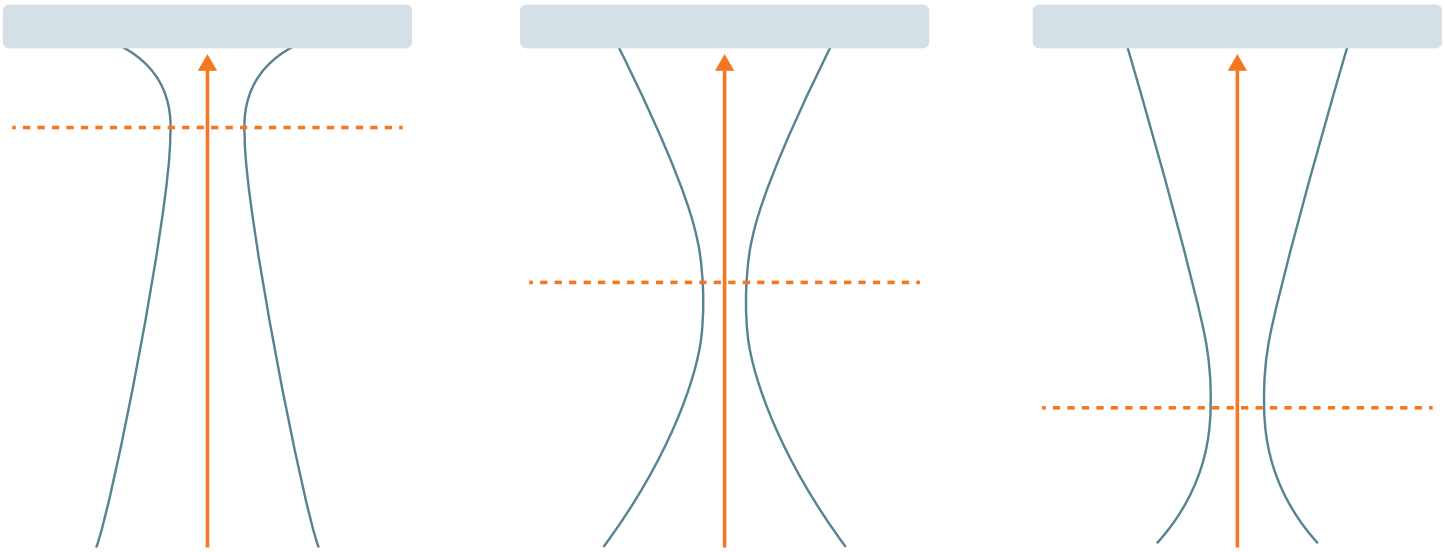
Beamforming Techniques

Fixed-focus Beamforming

In the past decades, ultrasound imaging has mainly used fixed-focus techniques to generate ultrasound images one line at a time. With these techniques, the user selects a focus point on the image, and the system creates an ultrasound image mainly focused around the designated area. The system repeats this process for each imaging line until the entire image is acquired (Fig 1).

Fixed-focus techniques are simple to implement and are offered on all traditional ultrasound scanners. With these techniques, the user is expected to manually adjust the focal point to get a better image. However, these methods have several limitations. When using single focusing techniques, the image quality is not uniform, as the resolution and contrast are always better in the area around the focus point, leaving the other areas unfocused. As a result, the user needs to continuously readjust the focus point to get a better image.

Fig. 1
Fixed-focus beamforming



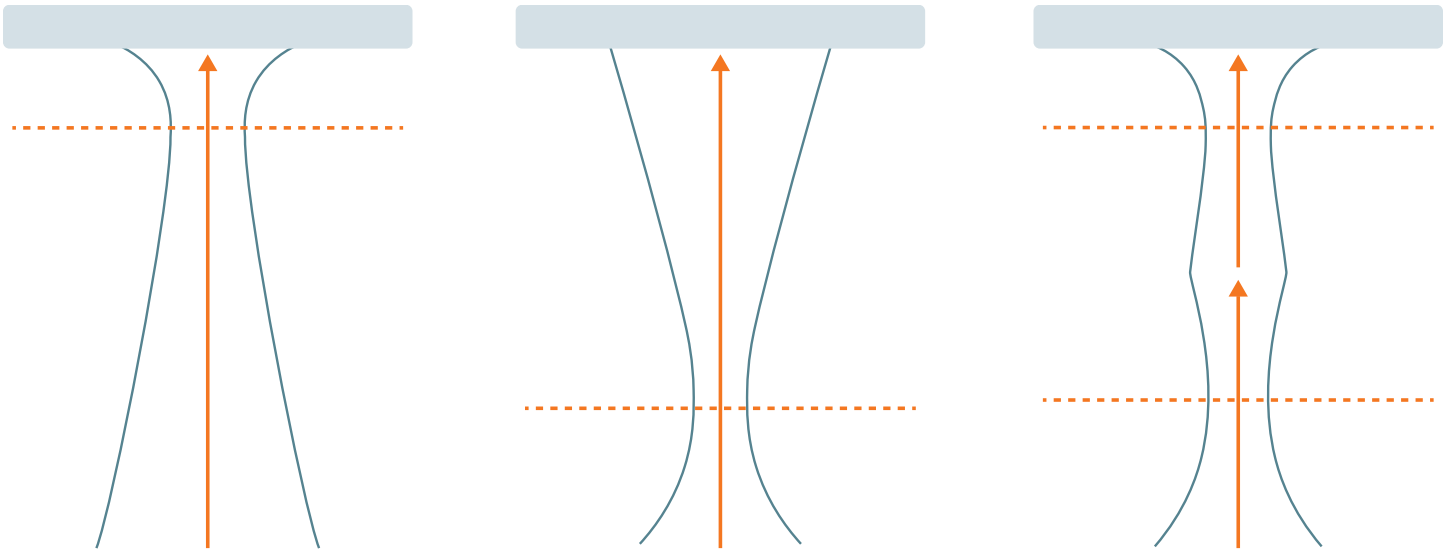
Multiple-focus Beamforming

Using multiple-focus beamforming can alleviate the problems associated with fixed-focus beamforming. With multiple-focus techniques, instead of having a single focus point for each imaging line, multiple beams are acquired with slightly different focus points, resulting in separate imaging lines. The lines are then stitched together to create a single ultrasound line (Fig. 2).

Multiple-focus beamforming generates better images than fixed-focus beamforming, as it allows the ultrasound image to be focused on multiple points. However, there are still several limitations with multi-focus beamforming:

- The image quality is not uniform, as images generally look better around the focus points and unfocused farther away from them,
- The stitching process that generates a single imaging line from multiple beams can introduce artefacts in the final ultrasound image,
- The user needs to readjust both the focus points and the spacing between focus points to get an optimally focused image,
- The frame rate decreases because multiple beams are required to generate each line.

Fig. 2
Multiple-focus beamforming

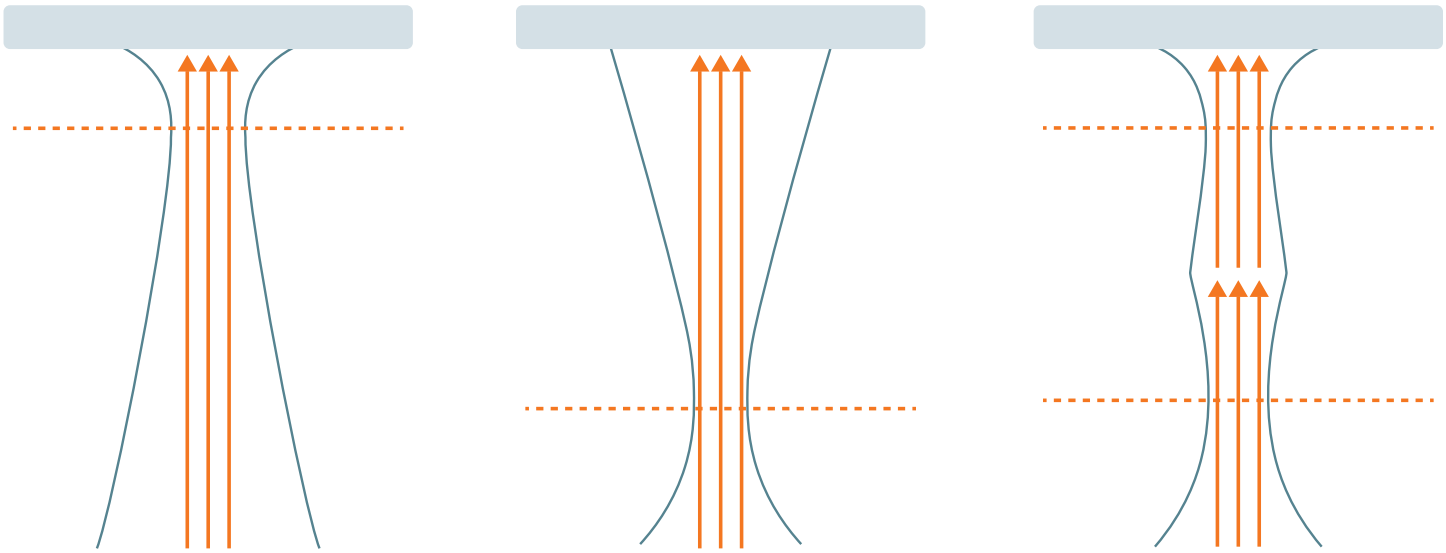


Multi-line Beamforming

Multi-line beamforming addresses the issue of decreased frame rate. It can generate up to 16 imaging lines from a single beam by processing the received data in parallel. Multi-line beamforming can help with the data acquisition rate and can be used with both fixed- and multiple-focus beamforming (Fig. 3). However, it still has its limitations:

- Imaging lines are not uniform and have similar limitations to fixed-focus and multi-focus beamforming.
- Multiple parallel calculations are required to resolve image lines in real-time, which are placed close together and are generated from the same beam. As a result, high-precision beamformers are required for multi-line beamforming.
- Increasing the number of parallel beamformers increases the complexity of the design of the ultrasound system. As a result, multi-line beamforming is mainly available on larger and more advanced ultrasound systems.

Fig. 3
Multi-line beamforming

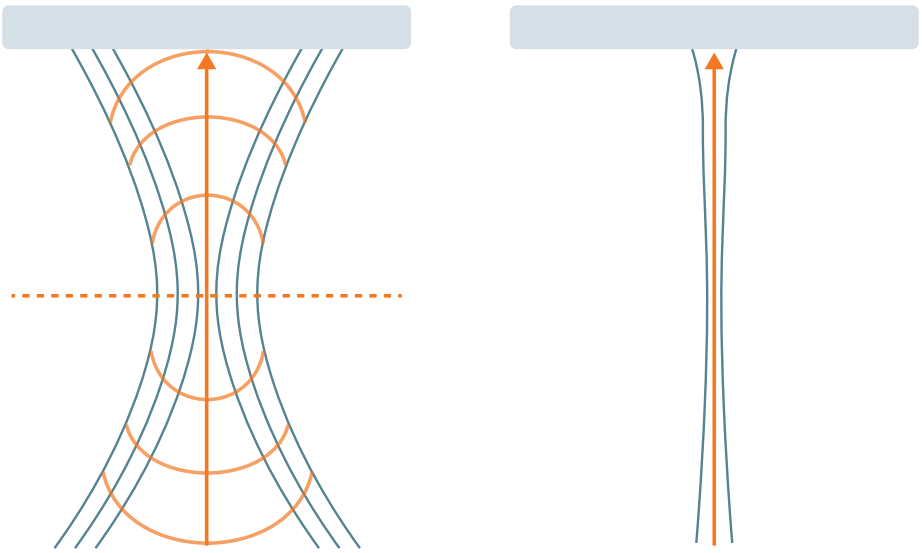


Synthetic-focus Beamforming

Very recent advances in ultrasound technology have enabled synthetic-focus beamforming to address the problems associated with fixed and multi-focus beamforming. Unlike those techniques, where each imaging pixel is reconstructed from one individual beam, synthetic focusing uses data from several beams across the imaging plane to reconstruct each imaging line. This is done by computing and correcting for the time of flight from each beam to each imaging pixel. This way, each pixel on the final images is reconstructed using data from multiple sources, which are added to generate the final pixel value. The resulting image is synthetically focused everywhere (Fig 4).

Synthetic-focus beamforming eliminates the need for the user to adjust the focus points. While effective, full synthetic-focus beamforming is computationally intensive and requires a lot of hardware resources and parallel processing. As a result, it has become available only on large and high-end ultrasound systems that offer a significant amount of processing power, including multiple CPUs, GPUs, and DSPs. Other systems either do not implement full synthetic-focus beamforming or limit its performance by making several assumptions or simplifying its computation, resulting in lower-quality images.

Fig. 4
Synthetic-focus beamforming



Clarius Beamforming

Over the past few years, there has been significant interest in miniaturizing ultrasound technology and making it more portable to expand its applications. Since then, several portable scanners have been introduced in the market. Unfortunately, most these scanners had to sacrifice image quality to achieve portability.

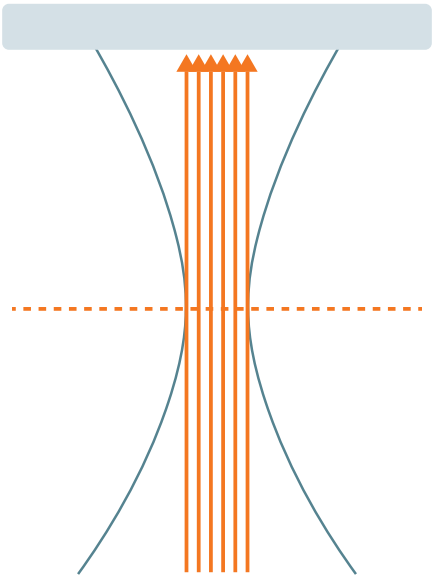
One of the main goals at Clarius has always been to offer premium image quality on a portable ultrasound scanner that is easy-to-use. Clarius addresses these design challenges of putting advanced and massively parallel processing on a very small device through several innovative ways with are described below.

Power Efficient and Electronics Efficient Multi-line Beamforming

As mentioned earlier, multi-line fine delay beamforming is demanding in both resources and power and is typically not available on portable ultrasound scanners as it. Most portable scanners use conventional fixed or multi-focus beamforming instead, which sacrifices image quality, increases operator dependence, and decreases frame rates.

Clarius scanners use micron-level calculators for calculating the time of flight and weight coefficients. By sharing data among multiple beamformers, Clarius scanners allow for accurate multi-line focusing that can be scaled from 4 to 16 lines in parallel, all while consuming a much smaller amount of power. This level of parallel processing is normally offered only large and high-end scanners that are not limited by power or hardware resources. Multi-line beamforming on a Clarius scanner allows for high frame rate image acquisition not typically available on a portable scanner.

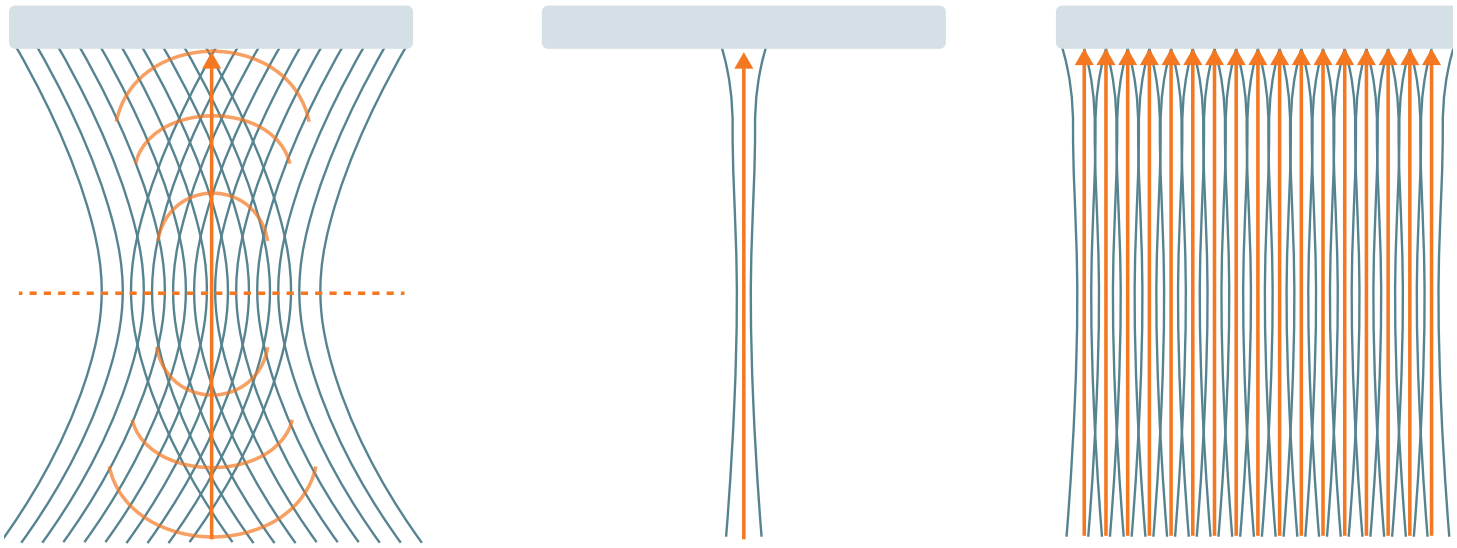
Fig. 5
Power efficient and electronics efficient multi-line beamforming



Multi-stage Synthetic Beamforming

In addition to multi-line beamforming which provides more data at high frame rates, Clarius' reprogrammable architecture also allows for caching previous data for further processing. A Clarius scanner first caches multiple beamformed data (4 to 16 lines), acquired from each individual beam, into its memory. It then uses data from several adjacent beams (up to 64) to perform synthetic-focus beamforming using parallel re-focusing technology. By using a massive amount of beam data, the Clarius scanner allows for full synthetic-focus beamforming. The resulting beamformed image then goes through few more processing blocks before it is sent wirelessly to a mobile device for display.

Fig. 6
Multi-stage synthetic beamforming



Results

The combination of multi-line beamforming and synthetic-focus beamforming allows Clarius scanners to generate premium image quality at a high frame rate. This is the first time that these technologies have been implemented on portable scanner. The resulting image is uniformly focused from top to bottom and does not require the user to adjust any focusing parameters, and as a result, the scanners provide high-quality image as well as a simplified workflow.