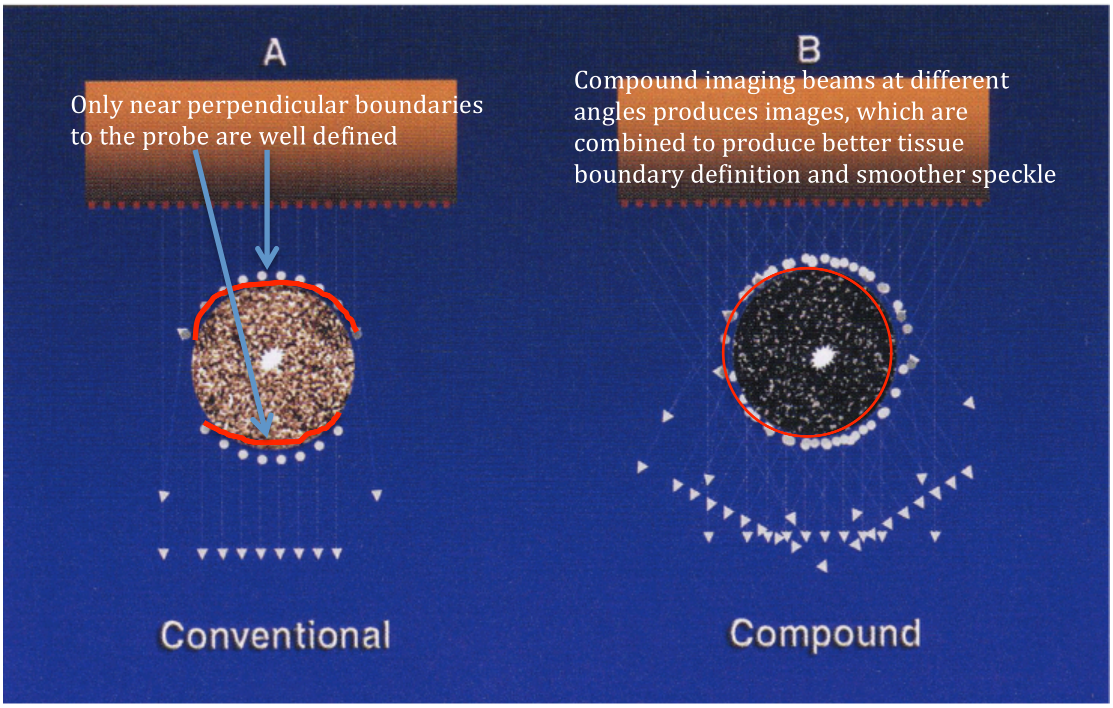
COMPOUND IMAGING AND HARMONICS

COMPOUND IMAGING

This is a method that helps to delineate tissue boundaries and structures more clearly, as well as provide a smoother speckle pattern echo texture.

- In standard imaging echoes from a tissue boundary will only be received if the incident beam is near perpendicular to the interface. If not that beam will be reflected out of the transducer receive aperture. The result is incomplete tissue boundary imaging.



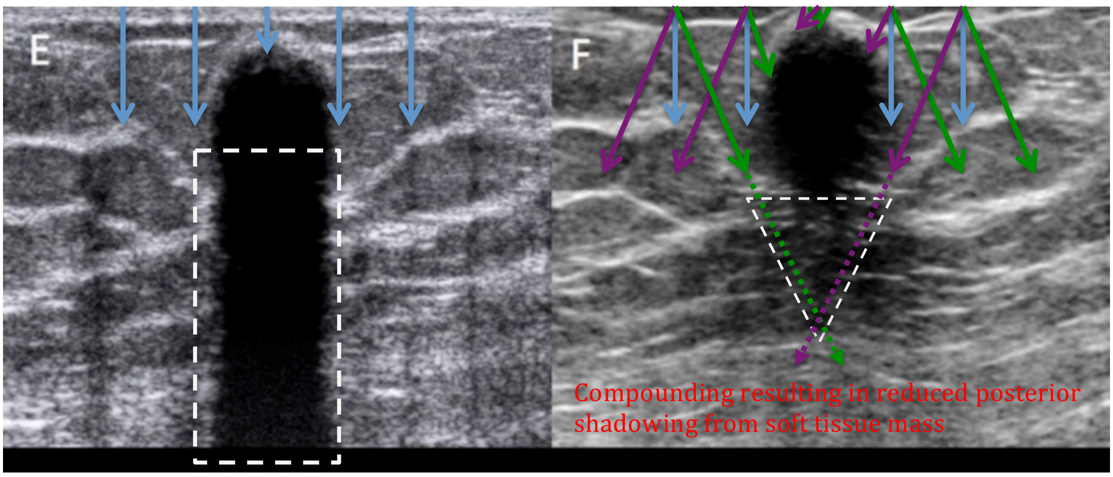
Source: Smith et al. - Journal of Diagnostic Medical Sonography 2008 (Modified)

- In compound imaging the beam is directed at different directions, with images formed in rapid succession are combined to produce a compound image (image averaging):

- Better tissue boundary definition especially of curved tissue boundaries
- Smoothed speckle and better contrast resolution
- Reduction in some image artifacts (Shadowing, edge artifact, acoustic enhancement, reverberations)
- Reduction in beamwidth and sidelobe artifact

COMPOUND ARTIFACT REDUCTION

As the true image remains in the same location despite beam angle, compounding will reinforce this image. However, as artifacts will be at different locations that are relative to the beam angle, combining of the images will result in some mitigation of the relevant artifact.



Source: Carpentier et al. – Journal of Ultrasound Medicine 2017 (Modified)

- Some artifacts help with diagnostic imaging so compound imaging may not be helpful in these scenarios, for example:

- Defining gallstone posterior acoustic shadowing
- Posterior acoustic enhancement of a fluid containing cyst

COMPOUND IMAGING AND TEMPORAL RESOLUTION

As compound imaging requires the combination of a number of images produced at different angles, the frame rate (FR) will be reduced.

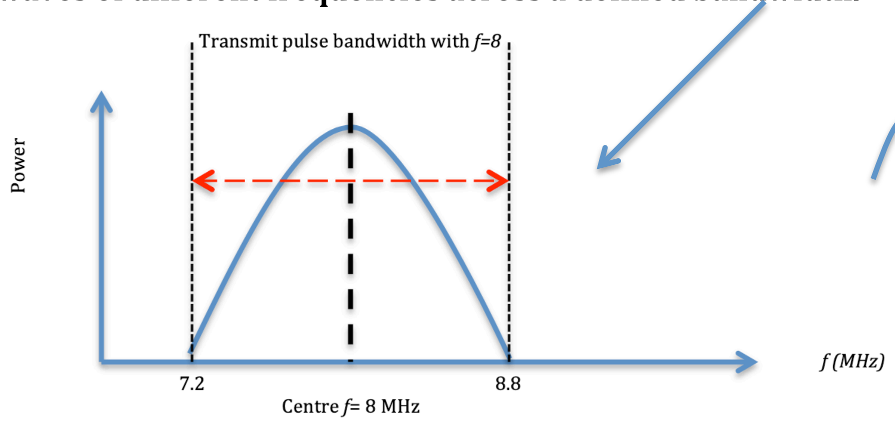
- **FR is inversely proportional to the number of lines of sight and number of transmit pulses required per line of sight**

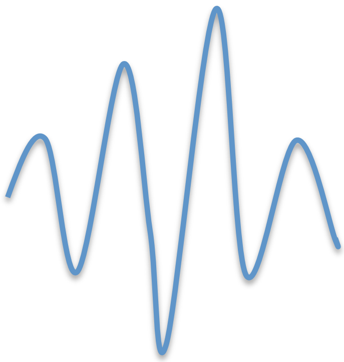
- The use of multiple simultaneous beam-forming technology can help reduce the negative impact on temporal resolution

- **FR is directly proportional to the number of simultaneous beams formed**

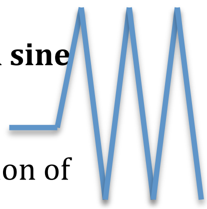
HARMONIC IMAGING

Any sinusoidal transmit pulse is made up of an infinite number of sine waves of different frequencies across a defined bandwidth.





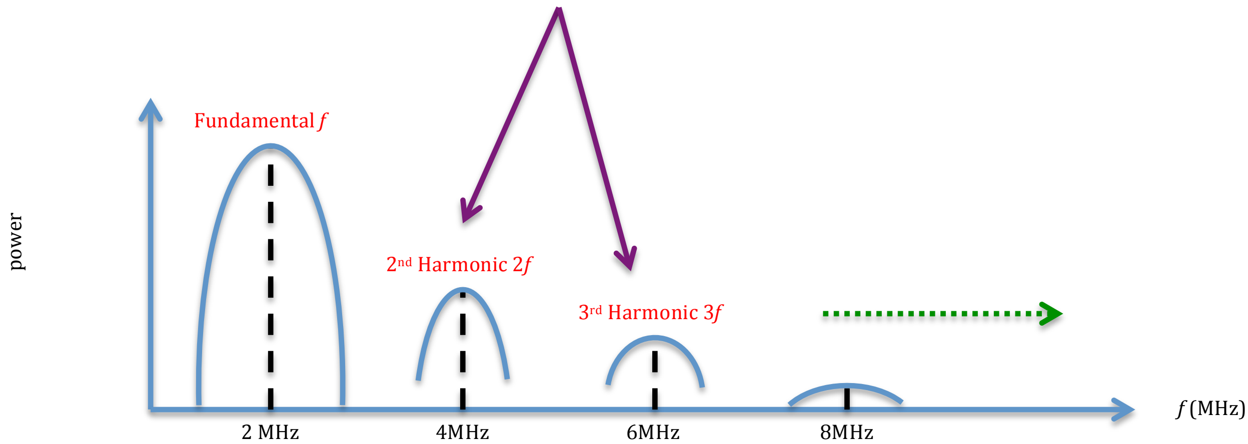
A distorted non-sinusoidal wave is made up of a sum of a fundamental sine wave (f) and a series of harmonic waves (2f, 3f, 4f……..)



- The nature of tissues differing propagation speeds results in distortion of the transmitted pulse (fundamental sine wave) into saw toothed triangular waves resulting in production of harmonic frequencies. The distortion of the fundamental wave is dependent on the amplitude of the transmitted wave and also the distance travelled in the tissue.

- The result is that some of the echoes are no longer purely sinusoidal but distorted with some of the energy returning to the transducer being at harmonic frequencies.

- **For a transmit pulse the harmonic generated is an entire spectrum produced at the harmonic intervals**



➢ Echoes that are distorted returning to the transducer will have a significant component of energy returning at the 2nd harmonic *f.*

TISSUE HARMONIC IMAGING (THI)

As a transmit pulse travels through tissue it results in areas of increased and decreased tissue pressure. Increased tissue pressure causes tissue stiffness and relative increased tissue propagation speed, and conversely low pressure results in tissue elasticity and lower propagation speed.

- Distortion of the wave increase over depth and time

- The tissue pressure effects are maximal along the main beam and focal zone of the ultrasound where intensity is the highest, and therefore distortion of the transmitted pulses are also most prominent in this zone

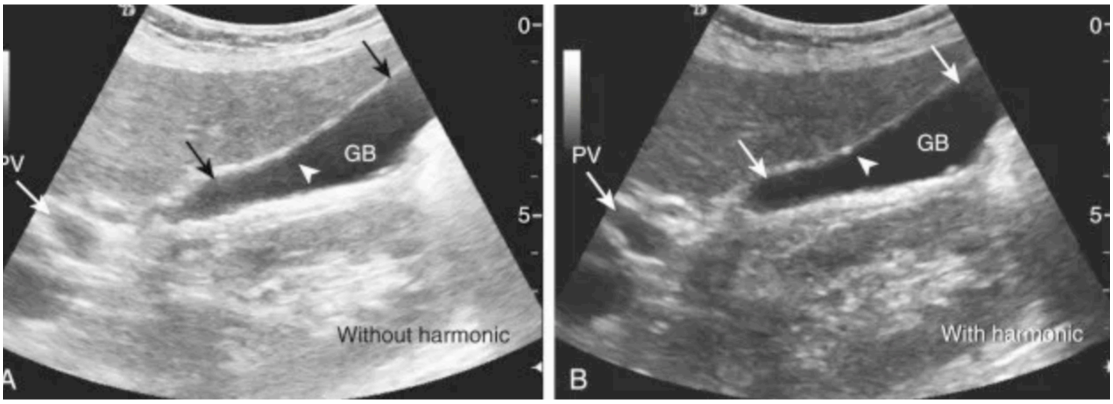
- As a result harmonics will be mainly generated from echoes within the central axis of the beam (i.e. not in the peripheries or sidelobes)

- THI uses the 2nd Harmonic to make an image and ignores the fundamental frequency. (Other harmonic frequencies are of too lower power to be useful)

The main benefit of THI is that the harmonics used to create the image arise only from the central beam axis (high intensity zone), which is the area of interest in our imaging.:

- Artifacts produced from lower intensity zones that produce sidelobes, slice thickness and beamwidth artifacts will be reduced

- Harmonics are not significantly produced in superficial structures; so echoes from here will be weak resulting in reduced distortion of the image from the effects of reverberation from superficial reflectors.



Source: Radiology Key

Disadvantages of THI are related to a reduced depth of penetration as the 2nd Harmonic is at a higher frequency compared to the fundamental beam.

Also THI can reduce FR and temporal resolution due to the increased number of transmit pulses required per image .

<u>REFERENCES</u>

The Physics and technology of Diagnostic Ultrasound: A Practitioner's Guide. By Dr Robert Gill.

Artifacts in Diagnostic Medical Ultrasound: Volume 1 Grayscale Artifacts. By Martin Necas

Back to Basics Ultrasound. Royal Brompton and Harefield Hospital. By Dr Josefa Paredes.

Basic Physical Principles of Ultrasound. AIU

Sonoguide Ultrasound Physics. ACEP