

## Harmonic Spatial Control

### Overview

**Harmonic Spatial Control (HSC)** is an extension of tissue harmonic imaging (THI), conceived to provide a marked improvement in lateral resolution over conventional technology, while maintaining a high dynamic range throughout the depth-of-field. The hypothesis is that in deep abdominal studies, although the second harmonic signal may be insufficient for imaging, it is sufficient to efficiently control the lateral profile response of the primary signal. The goal of HSC processing is to obtain deep signals with almost twice the lateral resolution of the normal fundamental signal.

### Relevance

Clinically, HSC processing can be used to enhance biopsy procedures for most deep-lying organs, including the liver, pancreas, retroperitoneum, and aortic pelvic nodes. In the liver, for example, the maximum depth-of-field achievable with THI is about 10 cm; for deeper biopsies, the procedure is therefore usually conducted with a sector probe imaging in fundamental mode at 3.5 to 5.0 MHz. With HSC, the imaging frequency remains 3.5 to 5.0 MHz (i.e., maintaining the same axial resolution), but with a high frequency signal of 7.0 to 10 MHz controlling the beamwidth – essentially doubling the lateral resolution (making it almost equal to the axial resolution). This, together with the large dynamic range, will result in improved tissue definition.

HSC processing has several engineering advantages: (1) the full on-axis dynamic range, axial resolution, rms speckle level and penetration are controlled by the low frequency, low absorption transmission; and (2) the spatial properties off-axis are controlled only by the relative rate-of-change of the propagating amplitude or (phase) response between the low and high frequencies. The relative sensitivity of the high frequency threshold, as a function of off-axis arrival angle, can be controlled to any desired level of the high frequency profile function. HSC in effect produces a "cookie-cutter" beam, having steep mainlobe sides without sidelobes, providing full dynamic range on axis. The effective beamwidth will be much narrower than that of the high frequency control beam, considerably improving the contrast resolution. Moreover, spatial sidelobes, which introduce artifacts from strong echoes off-axis, may be markedly reduced with HSC processing. Although the THI signal suffers from greater attenuation losses (making it unsuitable for imaging at larger depths), only a small dynamic range is required for control (less than 6 dB).

### Technological Innovation

HSC uses the nonlinearities in a biological medium to control the spatial lateral resolution of the detected acoustic field. The need for a propagated control signal, rather than employing a synthetically-generated signal, is attributed to the anisotropic and inhomogeneous nature of real biological tissue. By using the medium-generated harmonic signal itself for spatial threshold control, the nonlinear properties of the intervening tissue are impressed on both the original transmission and its medium-generated harmonics.