

How can I calculate the size and shape of the focal zone?

The ultrasound pressure field produced by a piezoelectric focused element is typically of ellipsoid shape with varying axis relations depending on transducer geometry, energy settings and characteristics of the medium in which it propagates.

In cases, where the radiation element is similar to the element shown in Fig 1, it can be modelled numerically quite accurately, where e.g. the -6 dB boundaries of pressure distribution can be calculated in the XYZ space surrounding the focal zone.

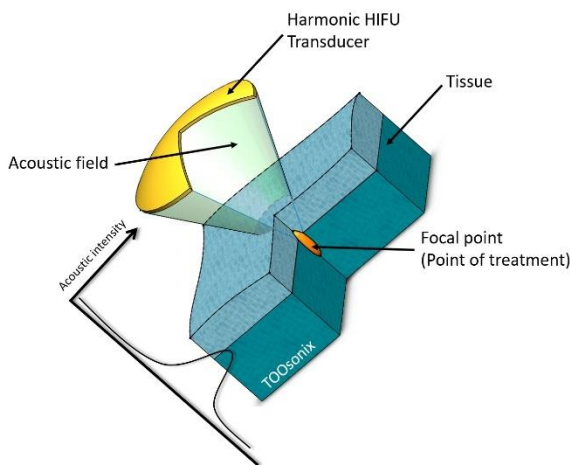


Fig. 1. Ellipsoidal focal zone e.g. defined by a -6 dB pressure zone around the geometrical focal point of the spherically focused piezoelectric element.

From the model, one can derive from that the maximum diameter of the ellipsoid, FD , in the plane perpendicular to the focal axis (i.e. the diameter of the ellipsoid) can be approximated by:

$$FD(6dB) \approx 1.44 \left(\frac{R_0}{2a} \right) \lambda = 1.44FN\lambda$$

where a is the aperture of the spherically focused transducer of radius of curvature R_0 and λ is the wavelength of the soundwave emitted from the focused element of F-number FN .

Similarly, the maximum length of the ellipsoid, or depth of focus, DoF , of a piezoelectric spherically focused element (i.e. the length of the ellipsoid) can be approximated by the following formula:

$$DoF(6dB) \approx 9.68 \left(\frac{R_0}{2a} \right)^2 \lambda = 9.68(FN)^2 \lambda$$

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Frequently Asked Questions

With this model, several key conclusions can be drawn, which are very useful when designing optimal transducers for certain HIFU treatments. The most profound conclusion for TOOsonix, as a producer of systems for accurate treatment of small features, is that the operating frequency need to be high in order to limit the size of the focal zone.

This conclusion can be quantified in the following two calculated examples.

Example 1

A piezoelectric spherically focused element made from a hard PZT material (e.g. Navy type I) is operated in water (c - comparable to speed of sound in tissue) under the following conditions:

Parameter	Symbol	Value	Unit
Sound velocity in water	c	1480	m/s
Frequency	f	5	MHz
Element diameter	D	20	mm
Element Focal radius	R ₀	15	mm

One can calculate that the wavelength of acoustic wave in tissue (similar to water) would be 296 μm . This will result in a 6 dB focal zone, characterized by focal diameter of 320 μm with a depth of focus of 1612 μm .

Example 2

A piezoelectric spherically focused element made from a hard PZT material (e.g. Navy type I) is operated in water (c - comparable to speed of sound in tissue) under the same conditions as in Example 1, at a frequency of 20 MHz:

Parameter	Symbol	Value	Unit
Sound velocity in water	c	1480	m/s
Frequency	f	20.00	MHz
Element diameter	D	20	mm
Element Focal radius	R ₀	15	mm

At this frequency one can calculate the wavelength of an acoustic wave in tissue (similar to water) would be 74 μm . This smaller wavelength, compared with that generated by a 5 MHz element, will result in a smaller 6 dB focal zone characterized by focal diameter of 80 μm and a depth of focus of 403 μm .