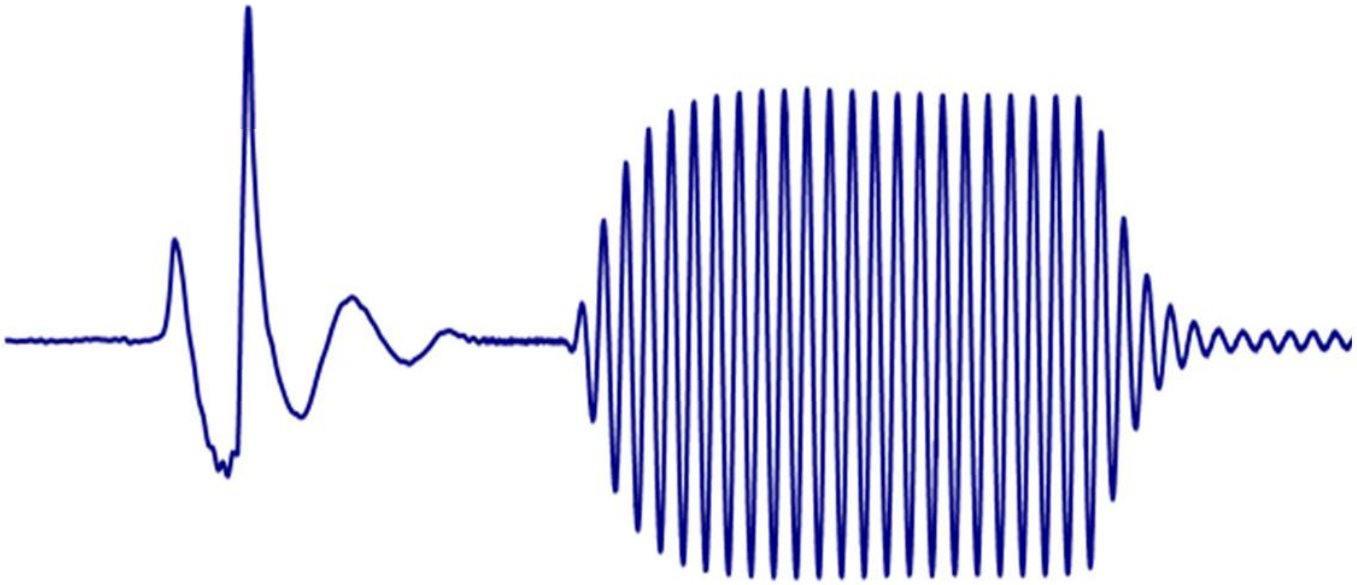
PRECISION ACOUSTICS

Simple guidelines on conducting ultrasonic intensity measurements



APPARATUS

What you will need:

- A suitable hydrophone (such as a Precision Acoustic Needle hydrophone)
- A recent, current calibration certificate for this hydrophone, issued preferably by one of the national standards laboratories (e.g. NPL (London) or PTB (Braunschweig))
- A source of ultrasound - Normally the transducer that you wish to test.
- A water tank filled with de-ionised, degassed water (a guidance document suggesting methods of achieving this, and lists of suppliers can be purchased from Precision Acoustics Consultancy Services, if required).
- A good quality oscilloscope (preferably a Digital Storage Oscilloscope – DSO)

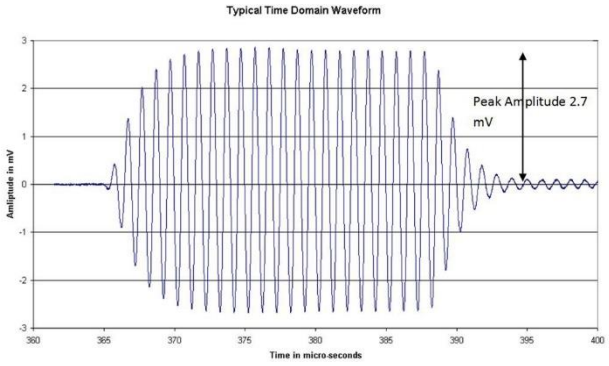
SIGNAL CONSIDERATIONS

It is assumed that you have set up the hydrophone as recommended in the instruction leaflet, and that both the transducer and hydrophone are correctly aligned in the water tank, with the output of the hydrophone being displayed the screen of the oscilloscope. A typical time domain waveform is shown in Figure 1.

Precision Acoustics Ltd Hampton Farm Business Park, Higher Bockhampton, Dorchester, Dorset DT2 8QH, UK

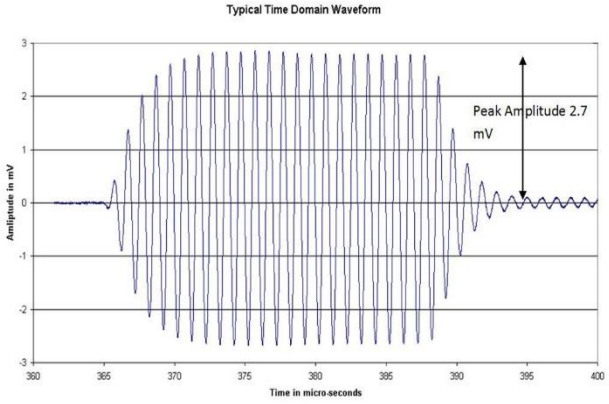
t. +44 (0) 1305 264669 **e.** office@acoustics.co.uk **w.** acoustics.co.uk

Figure 1.



The time domain waveform as shown in Figure 1 is a toneburst of centre frequency 1 MHz. It is important to consider the contribution that all frequency components within your measured waveform have upon the final signal. In the case of the waveform in Figure 1, the frequency spectrum is shown below in Figure 2. If the DSO that you are using is capable of recording frequency spectra then this saves some time. However, if you are only able to record a time domain waveform, then some form of Signal Processing software will have to be used to obtain the spectral amplitudes.

Figure 2.



Clearly in this case the frequency spectrum is dominated by the 1MHz component, but the 2MHz component is still clearly visible. As a first approximation, for this waveform, we could neglect the contribution from components other than 1 MHz. This would serve to simplify our calculations, at the expense of a little accuracy.

However, if the nature of the time domain signal were that of a short pulse, then the frequency spectrum would contain many different frequency components. To neglect the contribution from frequency components other than the main one would be serious mistake and would lead to major errors.

Which parameters do I need?

There is a wide range of intensity parameters that are used to characterise ultrasonic fields. Which parameters you require are entirely dependent upon which regulatory structure that you are working to. By way of an example and IEC61157 type characterisation requires an assessment of Peak Negative Acoustic pressure, Spatial Peak Temporal Average Intensity, Maximum Temporal Average Power, distance to position of Maximum Pulse Pressure Squared Integral etc. A second example is that submissions for FDA 510(k) Track 3 Approval require all parameters to be de- rated at 0.3 dB / MHz. You should consult the documentation relevant to you specific needs to advise you on which parameters should be assessed and the methods by which they should be calculated.

Example calculations

For the purposes of this document, we shall be considering the calculation of temporal peak acoustic intensity.

We will assume that our calibration certificate provides us with the following data:

Frequency MHz	Sensitivity mV/MPa
1	100
2	88
3	92
…	…
etc	…

Our first task is to convert the raw voltage output of the hydrophone into a pressure value using the expression $p = \frac{V}{M(f)}$ where p is the acoustic pressure, V is the measured voltage, and M(f) is the sensitivity of the hydrophone as a function of frequency.

Frequency MHz	Measured Voltage (mV)	Sensitivity mV/MPa	Acoustic Pressure (kPa)
1	2.7	100	27
2	0.14	88	1.6

The expression for instantaneous acoustic intensity, I, provided by IEC 62127-1 is $I = \frac{p^2}{\rho c}$ where ρ is the density of the propagating medium, and c is the velocity of sound in the propagating medium. For water at room temperature, we can assume that ρ has a value of 1000 kg/m3 and that c has a value of 1480 m/s. It should be noted that the expression for intensity as provided above and in IEC 62127-1 assumes that measurements have been made in the far field of transducer. Thus, our acoustic pressure values now become acoustic intensity values.

Frequency MHz	Acoustic Pressure (kPa)	Acoustic Intensity (mW/cm²)
1	27	49.3
2	1.6	0.17

Thus, the peak instantaneous acoustic intensity for this waveform is 49.3 + 0.17 = 49.47 mW/cm2.

This type of procedure needs to be completed for each frequency component of significance within the frequency spectrum.

Once you have obtained all of the intensity parameters that you require, it is then possible to calculate the power generated within the ultrasonic field, provided that you have been able to determine the beam area. Determination of the beam area can be conducted by scanning a hydrophone through the ultrasonic field and determining the limits (typically – 6dB but once again, this depends upon which regulatory structure you are governed by) of the field.

By way of an example, the Maximum temporal average power can be calculated from the Spatial Peak Temporal Average Intensity (ISPTA) as follows

$$Max\ temporal\ average\ power = \left(\sum_{Beam\ Area} I_{SPTA} \right) . Beam\ Area$$

Useful reference

IEC62127-1 Ultrasonics – Hydrophones – Part 1: Measurement and characterisation of medical ultrasonic fields up to 40 MHz., Publ: IEC, Switzerland

IEC61157 Requirements for the Declaration of the acoustic output of medical diagnostic ultrasonic equipment., Publ: IEC, Switzerland

Information for manufacturers seeking marketing clearance of diagnostic ultrasound systems and transducers. Publ: FDA, USA