Application Note:

Sidescan Sonar Beamwidth.

The Beamwidth of a sidescanning sonar is often defined or stated in terms of a beam angle. However the beam shape of a sidescanning sonar is not, a) a simple wedge or angular shape, and b) the energy points at which the beam angle is defined is not consistent across the industry.
This can lead to misunderstandings when interpreting a manufacturer's specifications.
This Application Note attempts to clarify some of the concepts and terms associated with the notion of beamwidth as it applies to high resolution sidescan sonars.

Nearfield and Farfield Regions

The spatial energy intensity distribution for a monochromatic (or narrow band) signal radiating from a simple linear array is sketched in simplified form below.

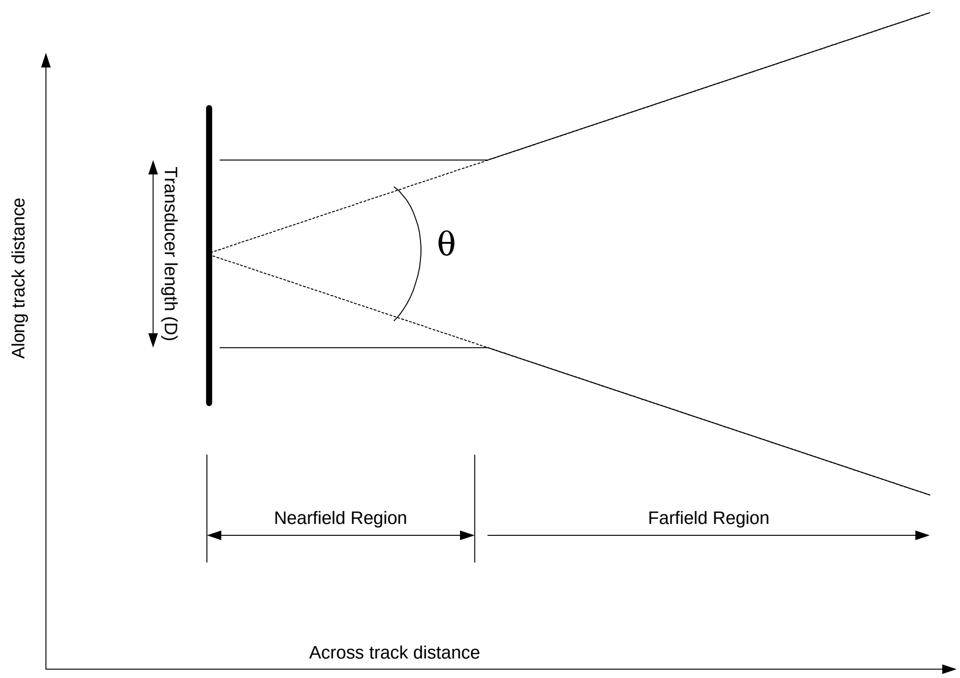

Figure 1

The Along track scale is exaggerated with respect to the across track scale for clarity.

In the Nearfield region, the energy is concentrated in an area of nearly constant along track length, and which is about a half of the physical aperture of the transmit/receive array. The extent of this region in the across track dimension is approximated by :

$$NR = D^2 / (4 \lambda) \qquad (1)$$

where D = the physical array length and λ is the wavelength of the signal.

Beyond this Nearfield region, the beam slowly starts to diverge and in the extreme, assumes a simple shape best defined by the Beam angle, θ. It is this final beam angle that is the much used definition or specification of a systems along track resolution, and is given by (approx) :

$$\theta \text{ (radians)} = \sin^{-1} (\lambda / D) \qquad (2)$$

for large D and small λ, in the same units.

This may also be approximated as :

$$\theta\text{(degrees)} = 3000 / (F(\text{khz}) . D(\text{inches})) \qquad (3)$$

where θ is now in degrees and F is in Khz and D in inches.

Farfield Beam Shape

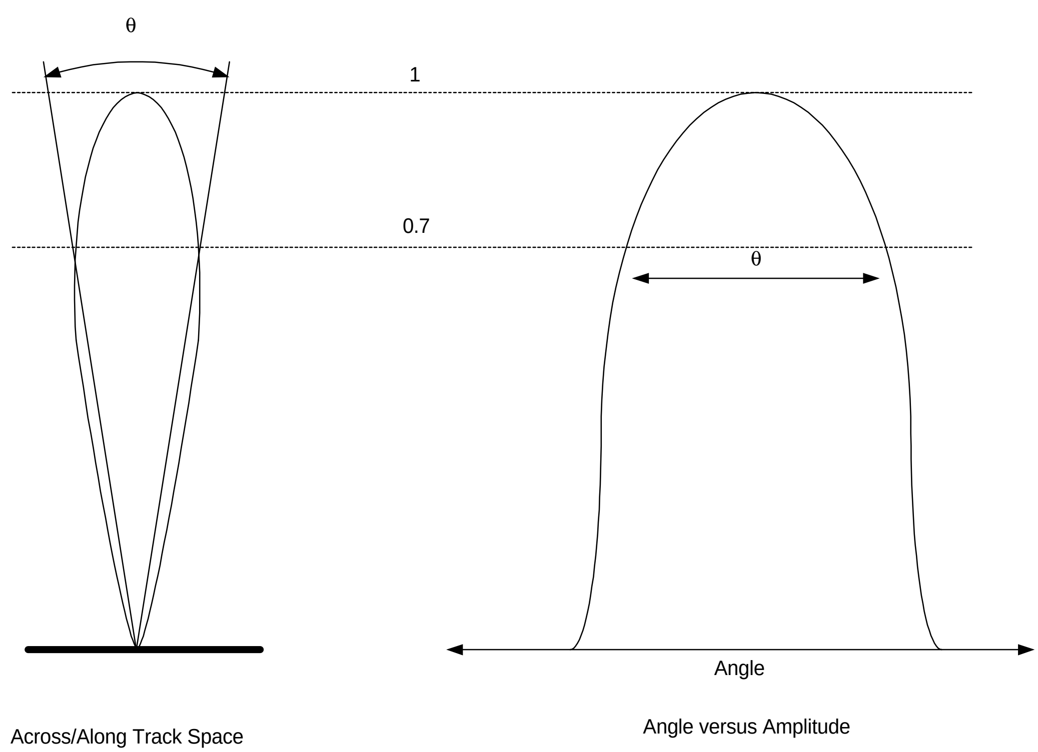

Figure 2

The farfield beam shape is approximately as shown above (sidelobes not shown). This shows the intensity of the radiated energy as a function of angle off the main lobe of the transducer. The conventional definition of the beam angle for these shapes is the point where the intensity has reached 70% of its peak value, or the –3dB points in decibels.

This is called the one-way beamwidth.

The final beamwidth of a sidescan sonar is smaller than this, due to the 2 way beam shaping that occurs during the transmit and receive processing of the array. The net result is that the composite or 2 –way beamwidth is the mathematical squaring of the one way beam shape.

This reduces the 2-way beam width to be about 0.72 times the one way beamwidth.

$$\theta_{(2\text{-way})} = \theta_{(1\text{-way})} \times 0.72 \qquad (4)$$

When comparing specifications between systems it is important to ensure that like is being compared to like in this respect. There is no accepted industry standard for stating beamwidths as 1 or 2-way, and some specifications even use different energy levels to achieve smaller angular numbers.

Sidelobes

A particularly undesirable aspect of the beam shape produced by simple linear arrays, are the sidelobes they produce.

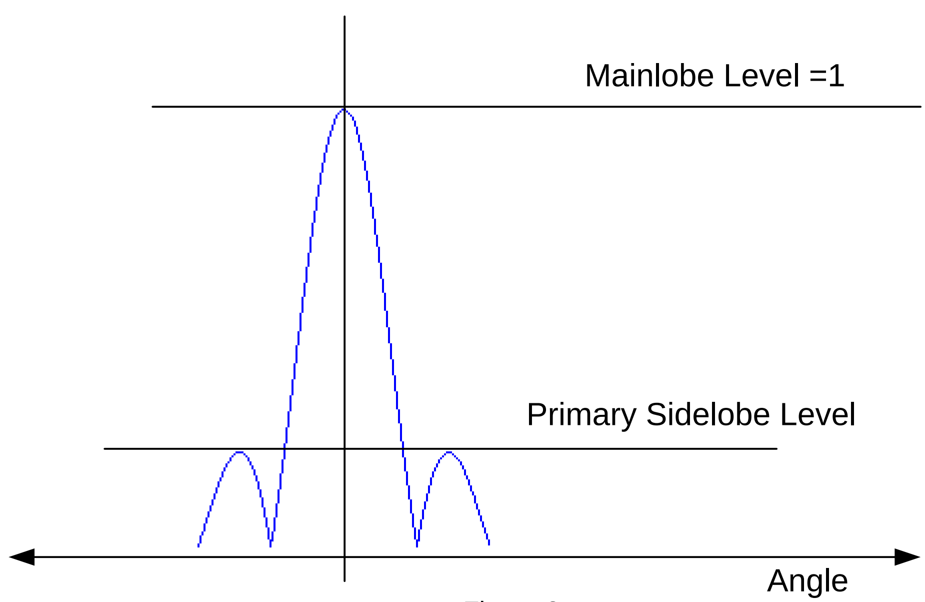

Figure 3

The sidelobes of the beam extend beyond the primary lobe shown above, and generally decrease with increasing angle. The main sidelobes (as shown) are the strongest and can contribute to unwanted ghosting and artifacts in the sidescan image.

For a simple linear array, with uniform amplitude shading , these primary sidelobes are –13dB below the main lobe. For the 2-way consideration of transmit and receive this is reduced to a –26dB effect, or about 5% of the main lobe.

It is possible through careful design of the sidescan array to reduce these sidelobe levels. Typical levels for a well designed array without an unwarranted increase in cost and complexity, is about -18db one way or -36dB 2 way for a level of about 1.5% of the main lobe.

An unfortunate and *unavoidable* consequence of sidelobe reduction is an attendant increase in the main lobe width.

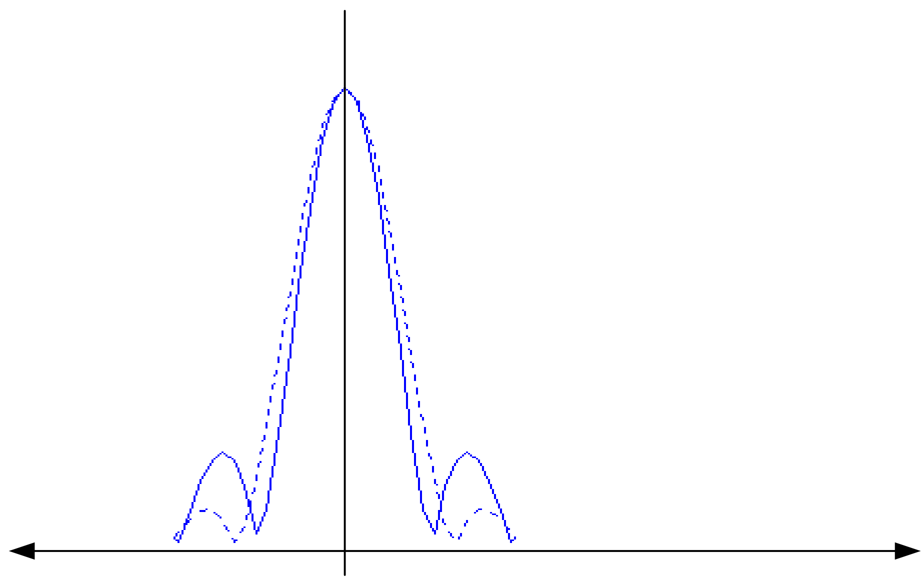

Figure 4

This effect is shown above, where the sidelobe level (as shown by the dotted shape) has been reduced at the expense of a slightly wider main lobe. Typical values for main lobe widening for a –36dB sidelobe level is +15%, or a factor of 1.15. The sidescan image is much improved due to these smaller sidelobes even with this slight broadening of the main lobe.

It is important to note almost EVERY practical array will produce some level of these undesirable lobes.

<u>Practical beamwidths and resolution</u>

An example may best illustrate and reinforce these concepts.

Consider an array with the following specifications:

Length (D)	20" (50.8cm)
Frequency (F)	410kHz.
Weighting	-18dB sidelobe suppression

The one-way Beamwidth in degrees is from equation (2), approximately:

$\theta = 3000 / (20 * 410) = 0.36$ degrees

Using Equation 4 , we can estimate the 2 way beamwidth to be

$0.36 * 0.72 = 0.26$ degrees.

With sidelobe suppression about –18dB one way, we allow for main lobe expansion by a factor of 1.15 :

BW_2_Way = 0.26 * 1.15 = 0.3 degrees

The Nearfield/farfield region transition can be estimated from (1), and C = speed of sound:

NR $= D^2 / (4\ C/F)$ where $\lambda = F/C$ has been used

$= (20/39)^2 / (4 * 1500/410000)$ [1m = 39" approx]

= 18m

The actual beam shape for this array is shown below.

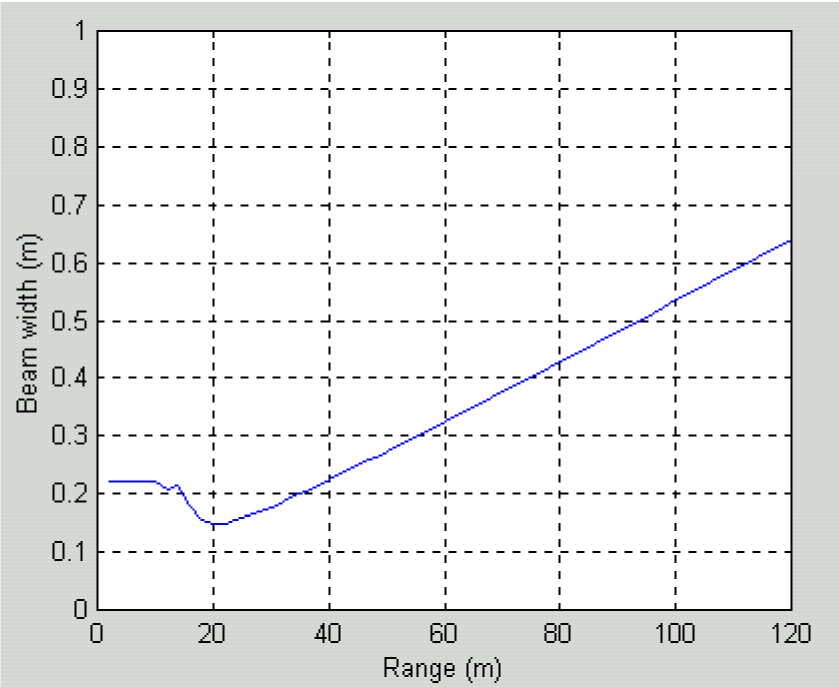

Figure 5

Note: The beam shape inside the Nearfield region is complex and exhibits many ripples and is not smooth and well defined as shown in Figure 3. However the concept of a definite beam capable of properly resolving targets is still valid.

The beamwidth is seen to actually reduce slightly in the Nearfield/farfield transition region (18m for this array) before starting to diverge beyond 20m.

The final beamwidth is given by the far range width divided by the range: 0.64/120 in radians or :

0.64 / 120 * (180/pi) = 0.31 degrees.

This is in good agreement with the calculation above after allowing for the beam widening due to the sidelobe suppression applied.

It is instructive to compare this beam pattern with one produced by a smaller array, that will have a wider beam angle.

The Figure 6 shows the beam shape produced by a 15" long array at the same frequency, 410Khz.

---- (dashed) = Beam patterns from a 15" long array with shading at 410Khz.
___ (solid) = Beam patterns from a 20" long array with shading at 410Khz.

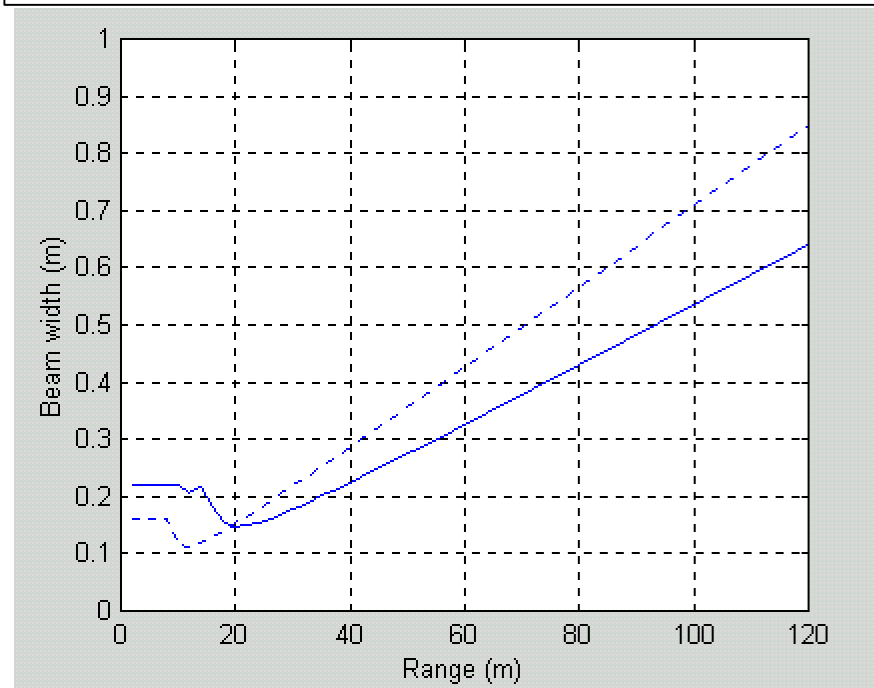

Figure 6

The final beam angle for this 15" array is 0.41 degrees.

Compare this to our approximate calculations (allowing for 2-way, and sidelobe suppression):

BW = 3000/(15*410) * 0.72 * 1.15 = 0.40 degrees . This in good agreement.

The important thing to note is that the initial resolution of this smaller array, with the larger beam angle, is actually BETTER than that of the narrower beam angle array, for ranges inside the nearfield region.

However outside of this region, the superior beamwidth of the longer array will yield better image resolution.

This can be an important consideration when comparing images from different sonars.

Conclusion

Manufacturers' statements of beamwidth for the equipment can be confusing and sometimes misleading.

Beamwidths may be calculated or measured using differing criteria such as –3dB or -6dB levels, and may be stated using 1 or 2 –way responses, making multiple equipment comparisons difficult.

If in doubt ask for the true frequency and array length, and do your own estimates of beamwidth.