Real-time calibration of *in situ* measurements of target strength

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Abstract

The *in situ* measurement of target strength (*TS*) depends on exactly one fish being within the sampled volume. This is more likely to occur the nearer the transducer is to the fish targets. The detection rate can be improved by lowering the transducer on a cable from a stationary vessel, so decreasing the range to the observed fish. In this application a standard sphere is commonly suspended below the transducer to provide real-time calibration of the received signals. However, forward-scattering by the sphere distorts the transmitted pulse, and equally the returning fish echoes, causing a bias in the estimated *TS*. Further, in the case of a split-beam transducer, forward scattering of the fish echo by the sphere modifies the phase differences observed between the transducer segments. This changes the apparent distribution of targets, but not the estimated *TS*. The biases are not large, those considered being within ±0.9 dB, and they depend on the sonar frequency, the target range, and the direction. The theory of these effects is examined, and formulae are provided for correcting the observed fish echo to that which would be received in free-field conditions, i.e. with the sphere removed.

Forward-scatter distortions in real-time calibration

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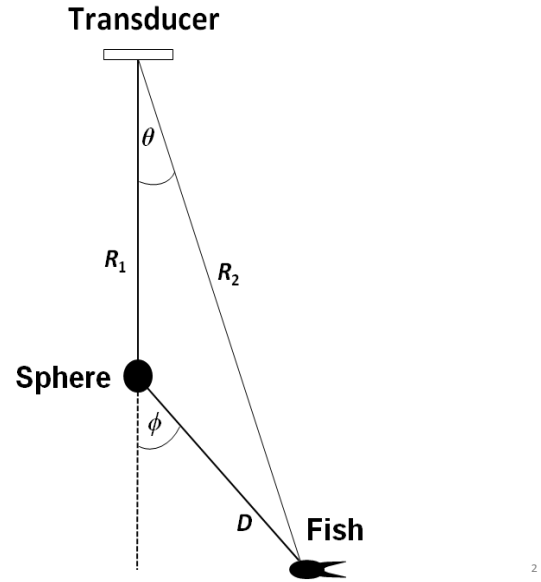

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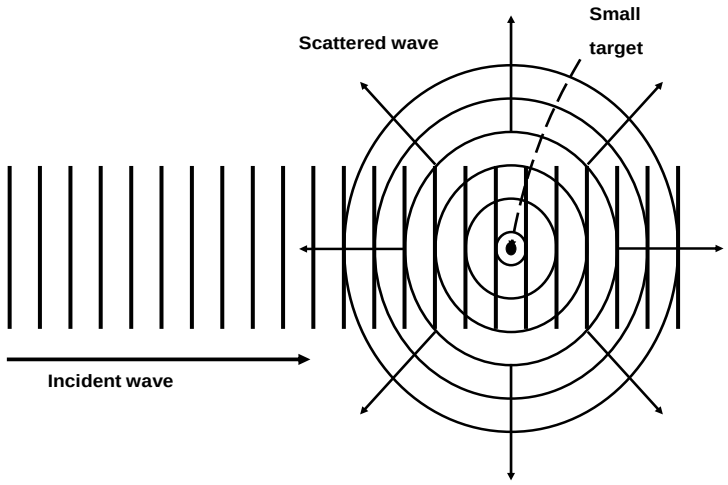

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Calculation of the forward-scatter distortion

$I/I_0 = \left| 1 + [\{a\, F(\phi)\, R_2\}/\{2DR_1\}] \exp[-i\,k\,(R_1 + D - R_2)] \right|^4$

where

I	= Received echo intensity with sphere present
I_0	= Received echo intensity with no sphere (free field)
a	= Sphere radius
$F(\phi)$	= Form function of the sphere
k	= Wavenumber ($2\pi / \lambda$)

This is a *continuous-wave* solution. For echoes with considerable overlap, it applies around the mid-point of the echo. More complicated at the start and end points.

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Here is a simpler formulation. Write:

$F(\phi)=\left|F(\phi)\right|\exp(i\beta)$

$h=\{a\left|F(\phi)\right|R_2\}/\{2DR_1\}$

$\gamma=\beta-k(R_1+D-R_2)$

Then the forward-scatter distortion is:

$I/I_0=[1+2h\cos\gamma+h^2]^2$

Thus I/I_0 is between $(1-h)^4$ and $(1+h)^4$

i.e. the distortion factor is greater or less than 1 depending on the geometry and phase shifts

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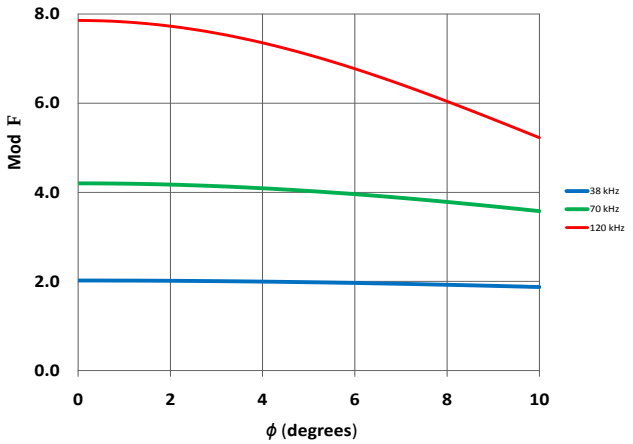

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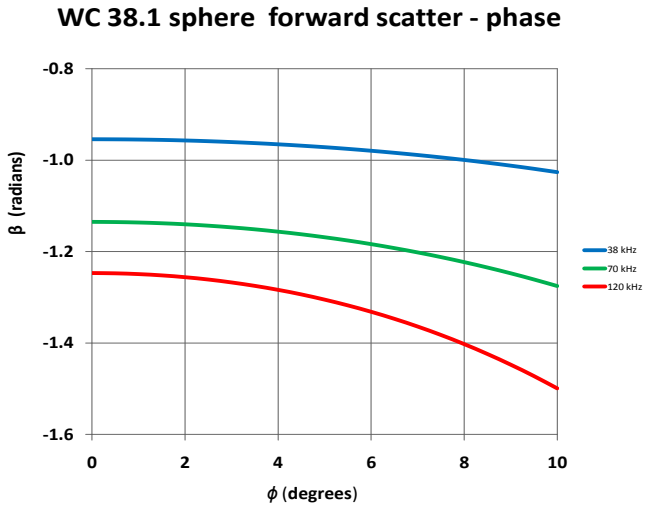

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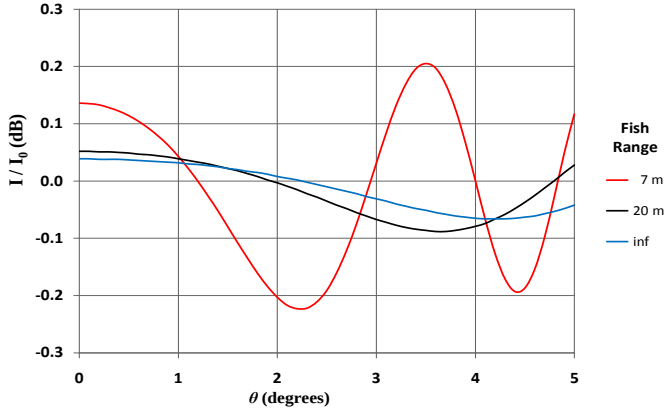

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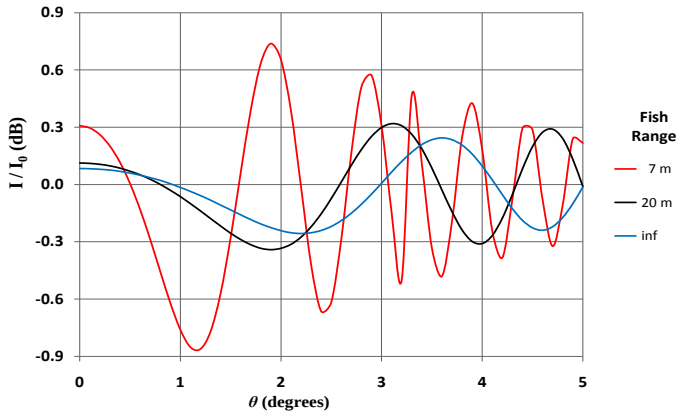
Split-beam TS adjustment for forward-scatter effect
WC 38.1 sphere at 5m range, 120 kHz



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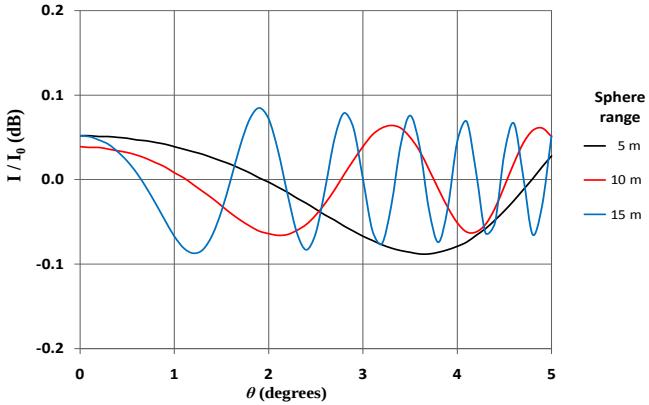
Split-beam TS adjustment for forward-scatter effect
WC 38.1 sphere, fish at 20 m range, 38 kHz



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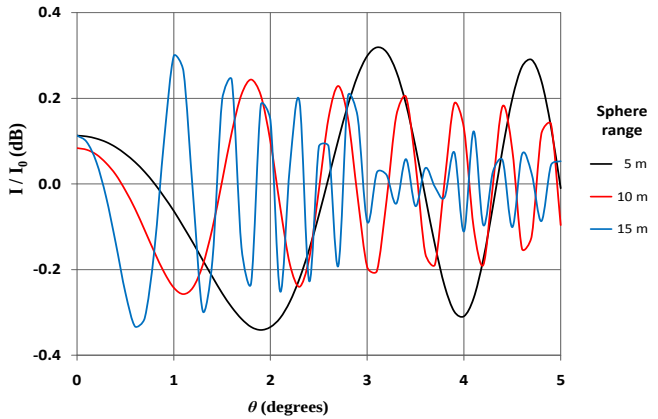
Split-beam TS adjustment for forward-scatter effect
WC 38.1 sphere, fish at 20 m range, 120 kHz



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Conclusions

1. The forward-scatter effect is small (< 1 dB) in current applications
2. Effect on mean TS over many targets is negligible
3. Main effect is increased variance of TS distribution (up to 1 dB)
4. The forward-scatter effect increases with frequency
5. Good scientific practice indicates this should be checked
6. Future work – problem of two fish detected in same ping

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