NURC
a NATO Research Centre
un Centre de Recherche de l'OTAN
PARTNERING FOR MARITIME INNOVATION

Reprint Series NURC-PR-2012-004

Target time smearing with short transmissions and multipath propagation

Chris H. Harrison

April 2012

Originally published in:

Journal of the Acoustical Society of America, Vol. 130, No. 3, September 2011, pp. 1282-1286.

About NURC

Our vision

- To conduct maritime research and develop products in support of NATO's maritime operational and transformational requirements.
- To be the first port of call for NATO's maritime research needs through our own expertise, particularly in the undersea domain, and that of our many partners in research and technology.

One of three research and technology organisations in NATO, NURC conducts maritime research in support of NATO's operational and transformation requirements. Reporting to the Supreme Allied Commander, Transformation and under the guidance of the NATO Conference of National Armaments Directors and the NATO Military Committee, our focus is on the undersea domain and on solutions to maritime security problems.

The Scientific Committee of National Representatives, membership of which is open to all NATO nations, provides scientific guidance to NURC and the Supreme Allied Commander Transformation.

NURC is funded through NATO common funds and respond explicitly to NATO's common requirements. Our plans and operations are extensively and regularly reviewed by outside bodies including peer review of the science and technology, independent national expert oversight, review of proposed deliverables by military user authorities, and independent business process certification.

NOTE: The NURC Reprint series reprints papers and articles published by NURC authors in the open literature as an effort to widely disseminate NURC products. Users are encouraged to cite the original article where possible.

Target time smearing with short transmissions and multipath propagation

Chris H. Harrison[a)]
NATO Undersea Research Centre, Viale San Bartolomeo 400, 19126 La Spezia, Italy

(Received 29 March 2011; revised 14 July 2011; accepted 15 July 2011)

In active sonar the target echo level is often estimated with a propagation model that adds all multipath arrivals. If the (post-correlator) transmitted pulse is short compared to the multipath time spread then there is effectively an extra loss (which may be substantial) since only a few of the paths contribute to the target echo at any one instant. This well known "time-smearing" loss is treated in a self-consistent manner with previous calculations of reverberation [Harrison, J. Acoust. Soc. Am. **114**, 2744–2756 (2003)] to estimate the target response and the signal-to-reverberation-ratio. Again isovelocity water, Lambert's law, and reflection loss proportional to angle are assumed. In this important short pulse regime the target response becomes independent of boundary reflection properties but proportional to transmitted pulse length. Thus the signal-to-reverberation-ratio becomes independent of pulse length. The effect on signal-to-ambient-noise is also investigated and the resulting formulas presented in a table.
[DOI: 10.1121/1.3623750]

PACS number(s): 43.30.Vh, 43.30.Cq [AIT] Pages: 1282–1286

I. INTRODUCTION

The target echo level in the active sonar equation is traditionally calculated as the source level plus target strength minus the two-way transmission loss (Urick, 1983, p. 23). Since the transmission loss typically includes all multipaths this implicitly assumes that the (correlation length of the) transmitted pulse is longer than the duration of the multipath returns. It is well known (Urick, 1983, p. 27 and 102) that for short pulses there is an additional "time smearing" or "stretching" loss because the multipaths do not all arrive at the same instant, making the target peak level weaker. In contrast neither the background ambient noise nor reverberation, coming from an extended area, are affected by this mechanism although they already depend on receiver bandwidth. Therefore, time smearing always affects signal excess if the pulse is short. Although the time smearing is clearly an environmental phenomenon it is often treated as a separate term in the sonar equation (Urick, 1983, pp. 27 and 102) that, by implication, can be calculated independently of the original transmission loss. This unsatisfactory procedure probably stems from the difficulty of extracting a pulse shape or pulse length from single-frequency propagation programs in the days when running repeat frequencies for Fourier analysis was prohibitive.

An earlier paper mainly on reverberation (Harrison, 2003) investigated the behavior of signal excess as a function of range and derived some relations between it and the environmental parameters such as water depth, reflection loss, and scattering strength by assuming isovelocity water, Lambert's law, and reflection loss proportional to angle. These relations were essentially for the long pulse case since no allowance for target time smearing was made. Below we derive modified relations for the short pulse isovelocity case which are entirely consistent with the propagation and dependent on the environment. Important differences are found from the point of view of defining procedures to maximize signal excess. Formulas for target response, signal-to-reverberation-ratio, and signal-to-noise-ratio with a short and long transmit pulse will be collected in Table I. These results could be extended to refracting cases by making use of the approach and pulse shapes in Harrison and Nielsen (2007). Although in the sonar equation logarithmic quantities may be more familiar, linear ones are used throughout this paper in an effort to preserve units.

This work was stimulated by open discussions at a recent workshop on sonar performance sponsored by the UK Institute of Acoustics (Strode, 2010).

II. DEPENDENCE OF TARGET ECHO STRENGTH ON PULSE LENGTH

To address this problem we need to know the shape of the two-way multipath spread. Smith (1971) and Harrison (2003) showed that for a point target, treating eigenrays as a continuum in angle, the one-way time spread could be derived directly from the angle spread of the multipaths, i.e., the integrand in the propagation angle integral. The two-way spread is then the convolution of the one-way pulse with itself. The final result is, of course, the convolution with the transmit pulse. If the transmission is very long then the latter convolution effectively integrates over the entire two-way impulse response. If the transmission is very short it essentially picks the value for each travel time and multiplies by the transmitted pulse duration. This was developed further for the short transmission case (actually an impulse) to include refraction (Harrison and Nielsen, 2007) and to consider the fine differences between reverberation as a function of time rather than range (Harrison and Ainslie, 2010). Also this one-way and two-way multipath pulse shape has been

TABLE I. Formulas for target response, signal-to-reverberation-ratio (SRR), and signal-to-noise-ratio (SNR) with a short and long transmit pulse. Terminology listed below.[a]

	Short pulse/S_T	Long pulse/S_T	Short/long pulse factor
Target response	$\frac{2\pi c t_p}{r^3 H^2}$	$\frac{2\pi}{\alpha r^3 H}[\mathrm{erf}(W)]^2$	$\frac{\alpha c t_p}{H[\mathrm{erf}(W)]^2}$
Target response (long range)	$\frac{2\pi c t_p}{r^3 H^2}$	$\frac{2\pi}{\alpha r^3 H}$	$\frac{\alpha c t_p}{H}$
Target response (short range)	$\frac{2\pi c t_p}{r^3 H^2}$	$\frac{4\theta_c^2}{r^2 H^2}$	$\frac{\pi c t_p}{2r\theta_c^2}$
SRR	$\frac{4\pi\alpha^2}{\mu\Phi H^2[1-\exp(-W^2)]^2}$	$\frac{4\pi\alpha[\mathrm{erf}(W)]^2}{\mu\Phi H c t_p[1-\exp(-W^2)]^2}$	$\frac{\alpha c t_p}{H[\mathrm{erf}(W)]^2}$
SRR (long range)	$\frac{4\pi\alpha^2}{\mu\Phi H^2}$	$\frac{4\pi\alpha}{\mu\Phi H c t_p}$	$\frac{\alpha c t_p}{H}$
SRR (short range)	$\frac{16\pi}{\mu\Phi r^2\theta_c^4}$	$\frac{32}{\mu\Phi c t_p r\theta_c^2}$	$\frac{\pi c t_p}{2r\theta_c^2}$
SNR	$\frac{2\pi\alpha c t_p^2}{A r^3 H^2}$	$\frac{2\pi t_p}{A r^3 H}[\mathrm{erf}(W)]^2$	$\frac{\alpha c t_p}{H[\mathrm{erf}(W)]^2}$
SNR (long range)	$\frac{2\pi\alpha c t_p^2}{A r^3 H^2}$	$\frac{2\pi t_p}{A r^3 H}$	$\frac{\alpha c t_p}{H}$
SNR (short range)	$\frac{2\pi\alpha c t_p^2}{A r^3 H^2}$	$\frac{4 t_p \alpha\theta_c^2}{A r^2 H^2}$	$\frac{\pi c t_p}{2r\theta_c^2}$

[a]Terminology for Table I:
$W = W^2 \equiv \frac{\alpha r\theta_c^2}{2H} \equiv \frac{\alpha\tau_c}{t_H}$;
α = Reflection loss (RL_{dB}) linearity constant: $\alpha\theta = RL_{dB}/[10\log(e)]$; also power reflection coefficient = $\exp(-\alpha\theta)$;
θ_c = Critical angle;
H = Water depth;
$t_H = H/c$;
c = Sound speed in water;
r = Range to target and scattering area;
$\tau_c = r\theta_c^2/(2c)$;
t_p = (Post correlator) transmit pulse length (assumed short cf. multipath response);
μ = Lambert scattering constant;
Φ = Horizontal beamwidth of sonar;
A = An ambient noise constant dependent on wind speed and frequency.

used experimentally to determine bottom reflection properties (Prior and Harrison, 2004; Prior *et al.*, 2007).

A. Long pulse

In isovelocity water of depth H with a point target at range r, the multipath boundary losses form a Gaussian spread in angle θ as $\exp\{-\alpha\theta^2 r/(2H)\}$ up to a critical angle θ_c.

Here we assume reflection loss to be proportional to angle such that reflected power is $\exp(-\alpha\theta)$ up to the critical angle θ_c. This was shown [Harrison and Nielsen, 2007, Eqs. (8) and (9)] to be equivalent to a two-way pulse shape $P(T)$, a function of two-way travel time T, with a unit power source, defined as

$$P(T)dT = \frac{2\pi c}{r^3 H^2}\exp\{-\alpha T/t_H\}dT; \quad \text{for } 0 < T < \tau_c, \quad (1)$$

$$P(T)dT = \frac{4c}{r^3 H^2}\mathrm{asin}[(2\tau_c/T) - 1] \times \exp\{-\alpha T/t_H\}dT; \quad \text{for } \tau_c < T < 2\tau_c, \quad (2)$$

where c is sound speed, t_H is H/c, and τ_c is defined as $\tau_c = r\theta_c^2/(2c)$. The units of P are such that when integrated over time and multiplied by a target area the result is an intensity from a unit power source.

Thus the first half of this pulse is exactly exponential in time with a time constant of t_H/α. The second half beyond τ_c has a more rapid decay (see Fig. 2 of Harrison and Nielsen, 2007). The time integral of this complete two-way pulse is, by definition [see, e.g., Harrison and Ainslie, 2010, Eq. (6)], the same as the square of the propagation angle integral, and when multiplied by the target cross section S_T gives the received intensity for a unit power source, i.e., the target response for a long pulse I_T^L,

$$I_T^L = \int_0^\infty P dT \times S_T = \left(\frac{2}{rH}\int_0^{\theta_c}\exp\left\{-\frac{\alpha\theta^2 r}{2H}\right\}d\theta\right)^2 S_T = \frac{2\pi}{\alpha r^3 H}[erf(W)]^2 S_T, \quad (3)$$

where the shorthand

$$W^2 \equiv \frac{\alpha r\theta_c^2}{2H} \equiv \frac{\alpha\tau_c}{t_H} \quad (4)$$

has been introduced. Away from the leading edge and tail of a long transmit pulse the target echo level would stabilize at the value given by Eq. (3), and this corresponds to Eq. (24) of Harrison (2003). In terms of range dependence (or long term time dependence) the target response for a long pulse has two regimes determined by the erf function. Remembering that, for small X, $\mathrm{erf}(X) \approx 2X/\sqrt{\pi}$ and $\mathrm{erf}(\infty) = 1$, at short range

$$I_T^L = \frac{4\theta_c^2}{r^2H^2} S_T, \tag{5}$$

and at long range

$$I_T^L = \frac{2\pi}{\alpha r^3 H} S_T. \tag{6}$$

B. Short pulse

With a short transmit pulse of length t_p, where either $t_p \ll \tau_c$ or $t_p \ll t_H/\alpha$ (or both), the time integral in Eq. (1) is truncated, and, to first order, the peak value becomes just the value of the integrand near the leading edge times t_p, i.e.,

$$\int_0^{t_p} P dT = \frac{2\pi c t_p}{r^3H^2}. \tag{7}$$

The ratio of the short pulse response to the long pulse response is then

$$f = \frac{\int_0^{t_p} P dT}{\int_0^{\infty} P dT} = \frac{\alpha c t_p}{H[\mathrm{erf}(W)]^2}. \tag{8}$$

For a short pulse this modifies the target response given in Harrison [2003, Eq. (24)] to

$$I_T^S = \frac{2\pi S_T}{\alpha r^3 H}[\mathrm{erf}(W)]^2 \times f = \frac{2\pi c t_p}{r^3H^2} S_T. \tag{9}$$

Now the target response depends on the transmitted pulse length, and surprisingly, it *does not depend on α, the bottom reflection loss gradient or critical angle*. This is because although the all-angle response is obviously weakened by high bottom losses, the multipath pulse is shortened by exactly the same factor and therefore less time-smeared. As a consequence the short pulse response's range dependence is always r^{-3}, the square of the mode-stripping value. This contrasts with the two range regimes of the long pulse in Eqs. (5) and (6).

The actual value of the ratio f can easily be evaluated using Eq. (8). For a half-space taking sound speeds in water and sediment as 1500 m/s and 1700 m/s, respectively, density ratio of 1.27, and volume absorption of 0.5 dB/wavelength we find reflection loss is proportional to angle with $\alpha = 0.348$/rad (Harrison, 2010). If we assume $H = 100$ m, $\mathrm{erf}(W) \sim 1$, with a frequency-modulated sweep from 500 Hz to 1 kHz, giving a band of 500 Hz or $t_p = 2$ ms, then $f = 0.01$, or –20 dB. Therefore, this is potentially a very important effect and can have serious consequences for detection range calculation. So it is important to calculate the factor consistently with transmission loss.

C. Order of magnitude confirmation

In retrospect the order of magnitude of the short pulse result can be confirmed through the angle integral of Eq. (3) instead of the time integral by noting that only those eigenrays that arrive within t_p of the first arrival can contribute. A (one-way) travel time difference of t_p allows an angle spread of

$$\theta_p = \sqrt{2ct_p/r}. \tag{10}$$

Substituting this as an approximation for the integral of Eq. (3), we obtain

$$I_T^S = \left(\frac{2}{rH}\right)^2 \times \frac{2ct_p}{r} S_T = \frac{8ct_p}{r^3H^2} S_T, \tag{11}$$

which is exactly the same behavior as in Eq. (9) although the numerical factor does not allow correctly for the two-way convolution in time.

III. SIGNAL EXCESS

Although the background reverberation and ambient noise do depend on receiver bandwidth (and therefore effective pulse length) and other environmental parameters they do not have any particular sensitivity to the changeover from long to short pulse. So, we can determine the signal excess for long and short pulses in terms of the (linear quantities) signal-to-reverberation-ratios R_L, R_S and signal-to-noise-ratios N_L, N_S. In addition the reverberation formula has interesting short range and long range approximations.

A. Signal-to-reverberation-ratio

The reverberation, assuming a small angle Lambert's law such that scattering strength can be written as $S = \mu \times \theta_{\mathrm{in}} \times \theta_{\mathrm{out}}$ [Harrison, 2003, Eq. (28)], remains as

$$I_R = \frac{\mu\Phi c t_p/2}{\alpha^2 r^3}\left[1 - \exp(-W^2)\right]^2 \tag{12}$$

with continuing proportionality to t_p, and Φ is the receiver's horizontal beamwidth. Consequently the short pulse signal-to-reverberation-ratio R_S can be derived from the long pulse ratio R_L (see Table III of Harrison, 2003) by using the ratio f from Eq. (8) as follows

$$\begin{aligned} R_S &= R_L \times f \\ &= \frac{4\pi\alpha[\mathrm{erf}(W)]^2 S_T}{\mu\Phi H c t_p[1 - \exp(-W^2)]^2} \times \frac{\alpha c t_p}{H[\mathrm{erf}(W)]^2} \\ &= \frac{4\pi\alpha^2}{\mu\Phi H^2[1 - \exp(-W^2)]^2} S_T. \end{aligned} \tag{13}$$

Because the target echo and reverberation are now both proportional to transmitted pulse length the R_S becomes independent of it. At long range this reduces to the range-independent value

$$R_S = \frac{4\pi\alpha^2}{\mu\Phi H^2} S_T. \tag{14}$$

Notice that R_L is proportional to α so, paradoxically, high bottom loss leads to high signal-to-reverberation-ratio as already noted by Harrison (2003). Now R_S, being proportional to α^2, behaves even more non-intuitively. It also increases strongly as water depth decreases.

At short range R_S reduces to

$$R_S = \frac{4\pi}{\mu\Phi c^2\tau_c^2} S_T = \frac{16\pi}{\mu\Phi r^2\theta_c^4} S_T, \tag{15}$$

and R_S depends on range r and strongly on critical angle θ_c but not on reflection loss slope α.

B. Signal-to-noise-ratio

Ambient noise has many well known components. Here we are interested only in the dependence of the signal-to-noise-ratio on environmental and signal processing variables relevant to the pulse length discussion. Wind and wave noise can be thought of as a source of power per unit sea surface area and per unit bandwidth. Assuming the receiver band matches the transmitted pulse (correlation length) this power is proportional to $1/t_p$. The conversion from this power per unit area at the sea surface to intensity at the receiver via multipaths was shown in Harrison (1996) [Eqs. (9), (11), and (15)–(18)] to be a dimensionless geometric factor times $1/\alpha$. Thus, crudely, wind noise intensity per unit band can be represented as

$$I_N = \frac{A}{\alpha t_p}, \tag{16}$$

where A is a constant depending on wind speed and frequency. Equations (13) and (14) for reverberation shows that high bottom loss (α) leads to high signal-to-reverberation-ratio. Similarly high boundary loss leads to a quiet environment, or alternatively loss-free propagation leads to a noisy environment.

Combining this with the target response we have a signal-to-noise-ratio for a long pulse N_L of

$$N_L = \frac{2\pi t_p}{Ar^3 H}[\mathrm{erf}(W)]^2 S_T, \tag{17}$$

which reduces at long range to

$$N_L = \frac{2\pi t_p}{Ar^3 H} S_T \tag{18}$$

and at short range to

$$N_L = \frac{4 t_p \alpha \theta_c^2}{Ar^2 H^2} S_T. \tag{19}$$

The signal-to-noise-ratio for a short pulse and any range is

$$N_S = \frac{2\pi\alpha c t_p^2}{Ar^3 H^2} S_T. \tag{20}$$

IV. VALIDITY OF THESE FORMULAS

Although a continuum of eigenrays has been assumed, in principle a broad band sonar could be sensitive to individual eigenray arrival impulses. In isovelocity water the separation of the impulses gradually increases after the first return. With a narrower band these arrivals form groups of modal arrivals, but the separation of the arrivals still increases after the first return. In the context of this paper a "short" transmitted pulse means shorter than the multipath pulse envelope but longer than the separation of the individual eigenrays. This regime must always exist at some reasonably long range because the decay time of the multipath pulse envelope [i.e., $\tau_e \equiv H/(c\alpha)$] is *independent of range* (Harrison, 2003, p. 2753; Harrison and Nielsen, 2007, p. 1364) whereas the eigenray time separation decreases with range. The eigenray time separation $\delta\tau$ can be estimated by converting their angular separation ($\delta\theta = 2H/r$) to a time by differentiating the relation between time and angle, $c\tau = r\theta^2/2$ to obtain

$$\delta\tau = r\theta\, \delta\theta/c = 2H\sqrt{\frac{2\tau}{cr}}, \tag{21}$$

where τ is time after the first arrival. However the decay of the envelope means that eigenray amplitudes are negligible after $\tau \sim t_e$, so effectively $\delta\tau$ is limited to

$$\delta\tau = \frac{2H}{c}\sqrt{\frac{2H}{r\alpha}} = t_e\sqrt{\frac{2H\alpha}{r}}. \tag{22}$$

Clearly the condition

$$t_e > t_p > 2H\sqrt{\frac{2\tau}{cr}} > t_e\sqrt{\frac{2\alpha H}{r}} \tag{23}$$

can always be met, confirming that the regime exists. Actually there are typically four eigenrays in the assumed angle range $\delta\theta$, so the time separations are smaller still, making this criterion, if anything, over-stringent. In addition there are a number of other physical mechanisms that tend to blur out the individual eigenray arrivals. They could, for instance, be blurred by

(1) the finite dimensions of the target;
(2) convolution of the outward and return paths; and
(3) differences between the outward and return paths, for instance in bistatic operation.

From the point of view of straightforward frequency-domain propagation modeling the "short range" solution here has the same limitations as the discrete normal mode solution at short range, namely, imposition of a critical angle makes it miss out the steep angle lossy returns for the target and also the fathometer returns that are often considered part of reverberation.

The essence of mode-stripping is that the vertical Gaussian beam caused jointly by reflection loss and cycle distance behavior [see, for instance, Eq. (3)] narrows as range increases. Finally, at very long range the Gaussian becomes so narrow that its width is comparable with the angular separation of the equivalent modes (Weston, 1971). Formulas for this very long range, long transmission case were given by Harrison (2003) and are still valid. For the short pulse case the erf functions in Eqs. (3), (8), and (9) will be modified by the discretization. However, they still cancel out leaving the result, Eq. (9), unchanged in this case.

V. CONCLUSIONS

Nowadays there are many numerical models of targets, propagation, reverberation, and ambient noise, and these may form part of performance models, tactical decision aids or operational research models. The point of the search for formulas in this paper is not to replace these numerical models but instead to help understand the mechanisms and perhaps decide on active sonar strategy—in short to provide some insight.

The real surprise is the short pulse target response [Eq. (9)] which depends on the transmit pulse length in the same way as reverberation, but *does not depend on* α*, the bottom reflection loss gradient or critical angle*. Consequently the signal-to-reverberation-ratio does not depend on transmit pulse length but does depend strongly on bottom loss through α [Eq. (13)]. This reduces further to Eqs. (14) and (15) at long and short ranges. Equivalent formulas exist already for a long transmit pulse, and all are shown in Table I. All calculations assume isovelocity water, reflection loss proportional to angle, and Lambert's law.

On the assumption that ambient noise from sea surface sources suffers equivalent multipath boundary losses and that the receiver's band is inversely proportional to the transmit pulse length it is possible to calculate a compatible signal-to-noise-ratio for the short and long pulse, and these results are included in Table I.

An estimate of the magnitude of the effect of ignoring time smearing, without choosing extreme cases (see Sec. II B), showed that the target echo, and therefore signal excess, could be overestimated by as much as 20 dB. So it is potentially extremely important.

The mathematical approach used in this paper results from dropping all acoustic phases and oscillations other than coarse spatial variations of the envelope. However it is not particularly a flux, mode, or eigenray approach since the same formulation can be derived from all three by assuming either a continuum of modes or a continuum of eigenrays (see Appendix B of Harrison and Ainslie, 2010). In that respect the formulation is very robust; it will break down, however, if there is either a small number of eigenrays, or a small number of modes, or if there is significant convergence or focusing.

ACKNOWLEDGMENTS

The author thanks Kevin LePage and Mike Ainslie for stimulating discussions during the Cambridge IOA sonar performance workshop.

Harrison, C. H. (**1996**). "Formulas for ambient noise level and coherence," J. Acoust. Soc. Am. **99**, 2055–2066.

Harrison, C. H. (**2003**). "Closed-form solutions for reverberation and signal-excess with mode-stripping and Lambert's law," J. Acoust. Soc. Am. **114**, 2744–2756.

Harrison, C. H. (**2010**). "An approximate form of the Rayleigh reflection loss and its phase: Application to reverberation calculation," J. Acoust. Soc. Am. **128**, 50–57.

Harrison, C. H., and Ainslie, M. A. (**2010**). "Fixed time versus fixed range reverberation calculation: analytical solution," J. Acoust. Soc. Am. **128**, 28–38.

Harrison, C. H., and Nielsen, P. L. (**2007**). "Multipath pulse shapes in shallow water: Theory and Simulation," J. Acoust. Soc. Am. **121**, 1362–1373.

Prior, M., and Harrison, C. H. (**2004**). "Estimation of seabed reflection properties from direct blast pulse shape," J. Acoust. Soc. Am. **116**, 1341–1344.

Prior, M. K., Harrison, C. H., and Nielsen, P. L. (**2007**). "Geoacoustic inversion using multipath pulse shape," J. Acoust. Soc. Am. **122**, 3268–3279.

Smith, P. J. (**1971**). "The averaged impulse response of a shallow-water channel," J. Acoust. Soc. Am. **50**, 332–336.

Strode, C. (**2010**). "From signal excess to track classification using the Multi Static Tactical Planning Aid (MSTPA)," in *David Weston Sonar Performance Assessment Symposium*, edited by M.A. Ainslie, Clare College, Cambridge, 7–9 April 2010, Proc. Institute of Acoustics, Vol. 32, Pt. 2, pp. 10–12.

Urick, R. J. (**1983**). *Principles of Underwater Sound*, 3rd ed. (Peninsula Publishing, Los Altos, CA), pp. 23, 27, 102.

Weston, D. E. (**1971**). "Intensity-range relations in oceanographic acoustics," J. Sound Vib. **18**, 271–287.

Document Data Sheet

Security Classification		*Project No.*
Document Serial No. NURC-PR-2012-004	*Date of Issue* April 2012	*Total Pages* 5 pp.

Author(s)

Harrison, C.H.

Title

Target time smearing with short transmissions and multipath propagation

Abstract

In active sonar the target echo level is often estimated with a propagation model that adds all multipath arrivals. If the (post-correlator) transmitted pulse is short compared to the multipath time spread then there is effectively an extra loss (which may be substantial) since only a few of the paths contribute to the target echo at any one instant. This well known "time-smearing" loss is treated in a self-consistent manner with previous calculations of reverberation [Harrison, J. Acoust. Soc. Am. 114, 2744–2756 (2003)] to estimate the target response and the signal-to-reverberation ratio. Again isovelocity water, Lambert's law, and reflection loss proportional to angle are assumed. In this important short pulse regime the target response becomes independent of boundary reflection properties but proportional to transmitted pulse length. Thus the signal-to-reverberation-ratio becomes independent of pulse length. The effect on signal-to-ambient-noise is also investigated and the resulting formulas presented in a table.

Keywords

Issuing Organization

NURC
Viale San Bartolomeo 400, 19126 La Spezia, Italy

[From N. America:
NURC
(New York) APO AE 09613-5000]

Tel: +39 0187 527 361
Fax:+39 0187 527 700

E-mail: library@nurc.nato.int