Attenuation measurement uncertainties caused by speckle statistics

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$$p_{bs}(r) = \frac{A}{r}\int e^{j2k_0\mathbf{n}\cdot\mathbf{r}'}\gamma(\mathbf{r}')dv' \qquad (1)$$

expression to evaluate the magnitude of backscattered pres-

where A is a complex factor dependent on frequency, medium density, and amplitude of the incident wave; v' represents the sample volume of integration; and $\mathbf{n}$ is a unit vector

we have

$$|p_{bs}(d)|_i = [A_0 e^{-2\alpha d}/(r_0+d)]\, p_{i,d}\ , \qquad (8)$$

noise-to-signal log expansion, enabling continued use of [illegible]

[illegible]

more, the last expression shows that the variability in backscattered pressure, originally proportional to the mean backscattered pressure, is transformed to a constant in the log variable domain. This concept is illustrated in Fig. 1(a) and [illegible]

[illegible]

The variance of a least-squares estimate for the slope b can now be written as[17,18]

$$\sigma_b^2 = \frac{\sigma_y^2}{[\Sigma_{j=1}^{M} (X_j - \overline{X})^2]}, \tag{21}$$

where there are M independent sample volume depths for which data are obtained. Assuming the sample volumes are [illegible]

which depends only on the number of sample depths and [illegible]

[illegible]

Combining Eqs. (22), (21), and (20) produces the desired result:

$$\sigma_\alpha = \frac{0.44}{[illegible]}. \tag{23}$$

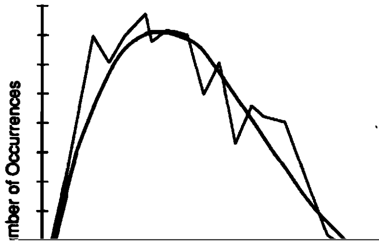
[illegible]

which shows that the expected variability or error in attenuation measurement is a constant which depends on the number and spacing of the sample volumes, not on the material backscatter coefficient (the mean value a of the Rayleigh statistics) or the magnitude of attenuation. Thus the fractional error in attenuation σ_α/α decreases with increasing frequency, as shown in Fig. 1(c).

When the value of attenuation is measured at F independen- [illegible] ful approximation we have from least-squares error analysis[17,18]

$$\sigma_{a'}^2 = \sigma_{y'}^2 \left\{ \frac{\Sigma \ln^2(f_i)}{F \Sigma [\ln(f_i) - \overline{\ln(f)}]^2} \right\}, \quad (32)$$

where the summation is over discrete frequencies $i = 1$ to F. Using the small error approximation of Eq. (18) to revert from the log-transformed variable a' to the parameter of



(a)

ULTRA-

Whereas projecting to 1 MHz to find α_0, using Eq. (33),

identical attenuation magnitudes near the mean frequency,
tend to cluster along a reciprocal or hyperbolic shaped

$$\Delta f \cong 1/\Delta t = C/2\Delta X. \quad (48)$$

the results of Eq. (52), yields:

$$\Delta X = L/M \quad \text{and} \quad \Delta f = B/F. \quad (49)$$

tors.

use use

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