Weston α Description of Seafloor with Fast Fluid Layer over Basement Half-space

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Abstract - For sound incident at a seafloor at angles less than the critical angle, the Weston α parameter (Weston, D. E., J. Sound Vib. 18, 271-287, 1971) provides a good estimate of the slope of bottom loss in dB versus grazing angle for small angles. Formulae for the Weston α parameter, in terms of the seafloor geoacoustic properties, have been determined for uniform half-space seafloor types. This paper considers the Weston α parameter for a seafloor consisting of a uniform fast fluid layer over a uniform basement. In this initial segment of work, an analytic solution is obtained for a loss-less fluid layer over an elastic basement for which the shear speed is less than the seawater sound speed. Values of bottom loss obtained from this solution are compared with some existing computations available from the literature. The solution is sufficiently simple to permit hand calculations, plus it clarifies the dependence of bottom loss on the parameters of the layered seafloor, in particularly, the thickness of the fluid layer. Limitations to the solution are considered.

1 INTRODUCTION

The study of the reflection of plane wave acoustic signals from a layered seafloor is relatively mature. Material on this topic exists in the literature, for example, the work of Brekhovskikh and Godin (Brekhovskikh and Godin, 1998). Analytic solutions exist for the determination of the plane wave reflection coefficient $R(\beta)$ for numerous types of layered seafloors, and these provide a means of determining the reflection loss, or bottom loss, for reflection at all angles of incidence. For some applications, e.g. in relation to sound transmission in a shallow ocean, the nature of the bottom loss at small angles of incidence is particularly relevant as received signals may be dominated by arrivals at small angles. The Weston α parameter (Weston, 1971) has been shown to provide a good estimate of the slope of bottom loss in dB versus grazing angle for small angles for a wide range of uniform half-space seafloor types (Jones, 2023). It then enables a useful approximation to the function of bottom loss versus grazing angles for the span of angles relevant to some transmission situations. This paper shows the development of an analytic solution for the determination of the Weston α parameter for a layered seafloor. The initial solution developed is that of a seafloor with a fast loss-less fluid layer overlying an elastic basement. For this analysis, the geo-acoustic properties are considered uniform within each layer. The reflection from this seafloor is shown in Figure 1.

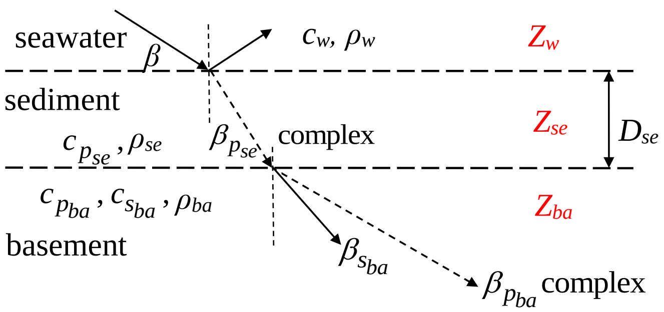

Figure 1 – Compressional wave incident at fluid seafloor layer over elastic half-space, when incident angle β is less than critical angles in sediment and in basement. Dashed lines represent complex angles.

Acoustics 2024 – Acoustics in the sun – Gold Coast Queensland

The layered seafloor of Figure 1 assumes that the compressional wave speeds of the basement, sediment layer and seawater have relativity $c_{p_{ba}} > c_{p_{se}} > c_w$. The incidence angle β at the seawater-sediment boundary is assumed less than the critical angle in the sediment layer, leading to the angles of compressional waves $\beta_{p_{se}}$ within the sediment, and $\beta_{p_{ba}}$ within the basement, being complex, as indicated in Figure 1. Within the sediment an evanescent wave propagates horizontally at a speed $c_w / \cos\beta$, less than $c_{p_{se}}$. The basement is assumed to be elastic, with basement shear speed $c_{s_{ba}} < c_w < c_{p_{se}}$, so that the angle of the basement shear wave $\beta_{s_{ba}}$ is real. The relevant critical angles are $\beta_{c_{se}} = \arccos\left(c_w / c_{p_{se}}\right)$ for a compressional wave in the sediment, and $\beta_{c_{ba}} = \arccos\left(c_w / c_{p_{ba}}\right)$ for a compressional wave in the basement.

2 GENERAL SOLUTION FOR REFLECTION AT LAYERED SEAFLOOR

For a seafloor consisting of a uniform fluid layer over a uniform elastic basement, the sound pressure reflection coefficient for an acoustic plane wave at frequency f at the seawater/seafloor interface is commonly expressed as

$$R(\beta, \phi_{se}) = \frac{R_{w/se}(\beta) + R_{se/ba}(\beta_{se})\exp(2i\phi_{se})}{1 + R_{w/se}(\beta) R_{se/ba}(\beta_{se})\exp(2i\phi_{se})}, \quad (1)$$

as shown by, e.g. Brekhovskikh and Godin (Brekhovskikh and Godin, 1998) in their equation (2.4.17). In Equation (1), $R_{w/se}(\beta)$ is the reflection coefficient at angle β at a boundary between seawater and a half-space of fluid layer material, $R_{se/ba}(\beta_{se})$ is the reflection coefficient at a fluid layer-basement boundary at angle $\beta_{p_{se}}$ (related to β by Snell's law), $\phi_{se} \equiv k_{se} D_{se} \sin\beta_{p_{se}}$ is the vertical phase delay for the compressional wave crossing the fluid layer and D_{se} is the thickness of layer, m. As is well-known, the reflection coefficients, in turn, may be expressed in terms of the impedances $Z_w = \frac{\rho_w c_w}{\sin\beta}$ kg m^{-2}s^{-1}, $Z_{se} = \frac{\rho_{se} c_{p_{se}}}{\sin\beta_{p_{se}}}$ kg m^{-2}s^{-1} and Z_{ba} of the seawater, layer and basement, respectively, as

$$R_{w/se}(\beta) = \frac{Z_{se} - Z_w}{Z_{se} + Z_w}, \quad (2)$$

$$\text{and } R_{se/ba}(\beta_{se}) = \frac{Z_{ba} - Z_{se}}{Z_{ba} + Z_{se}}. \quad (3)$$

so that, after some manipulation, Equation (1) may be written as

$$R(\beta, \phi_{se}) = \frac{Z_{se}(Z_{ba} - Z_w) - i\left(Z_{se}^2 - Z_w Z_{ba}\right)\tan\phi_{se}}{Z_{se}(Z_{ba} + Z_w) - i\left(Z_{se}^2 + Z_w Z_{ba}\right)\tan\phi_{se}} \quad (4)$$

which is the same as equation (1.70) of Jensen et al. (Jensen et al. 2011). The above equation is valid only for a fluid layer, however the basement may be fluid, elastic with shear speed $c_{s_{ba}} < c_w$, or elastic with $c_{s_{ba}} > c_w$.

Of course, similarly to Equations (2) and (3), the overall reflection coefficient $R(\beta,\phi_{se})$ of the composite layered seafloor in Equation (1) may be described using its overall normal acoustic impedance Z_{ov} kg/(m^{2}s), as

$$R(\beta,\phi_{se}) = \frac{Z_{\text{ov}} - Z_w}{Z_{\text{ov}} + Z_w}. \tag{5}$$

Equations (4) and (5) may now be used to obtain the following expression for Z_{ov}:

$$Z_{\text{ov}} = \frac{Z_{se}\left[Z_{ba} - iZ_{se}\tan\phi_{se}\right]}{Z_{se} - iZ_{ba}\tan\phi_{se}} \text{ kg m}^{-2}\text{s}^{-1} \tag{6}$$

which is the same as equation (2.4.7) of Brekhovskikh and Godin (Brekhovskikh and Godin, 1998).

2.1 Reflection at grazing incidence, slow shear speed in elastic basement

The layered seafloor type of most interest will have a fast sediment layer over a fast basement. That is, the compressional wave speeds will be of relativity $c_{p_{ba}} > c_{p_{se}} > c_w$. The relevant incidence angle β at the seawater-sediment boundary will be less than the critical angle in the sediment layer, and the angles $\beta_{p_{se}}$ within the sediment, and $\beta_{p_{ba}}$ within the basement, will be complex, as indicated by the dashed lines in Figure 1. For the present analysis, the basement will be assumed to be elastic, with basement shear speed $c_{s_{ba}} < c_w$, so angle $\beta_{s_{ba}}$ is real.

With grazing angle β less than the sediment's critical angle $\beta_{c_{se}}$, $\cos\beta > \cos\beta_{c_{se}}$, that is $\cos\beta > \left(c_w / c_{p_{se}}\right)$, so from Snell's Law, for which $\cos\beta_{p_{se}} = \left(c_{p_{se}} / c_w\right)\cos\beta$, $\cos\beta_{p_{se}} > 1$. In turn, from the trigonometric expression $\sin^2\beta_{p_{se}} = 1 - \cos^2\beta_{p_{se}}$, $\sin^2\beta_{p_{se}}$ is negative with $\sin^2\beta_{p_{se}} = -\left(\cos^2\beta_{p_{se}} - 1\right)$ and $\sin\beta_{p_{se}} = i\sqrt{\cos^2\beta_{p_{se}} - 1}$, hence the angle is complex. Using the above Snell's Law substitution then gives

$$\sin\beta_{p_{se}} = i\frac{c_{p_{se}}}{c_w}\sqrt{\sin^2\beta_{c_{se}} - \sin^2\beta}, \tag{7}$$

and so $Z_{se} = -i\dfrac{\rho_b c_{p_{se}}}{\left|\sin\beta_{p_{se}}\right|}$ kg m^{-2}s^{-1} and is purely imaginary (e.g. Brekhovskikh and Godin section 2.4.5 (Brekhovskikh and Godin, 1998)). For small β, Equation (7) approximates as $\sin\beta_{p_{se}} = i\dfrac{c_{p_{se}}}{c_w}\sin\beta_{c_{se}}$, so

$$Z_{se} \approx -i\frac{\rho_b c_w}{\sin\beta_{c_{se}}} \text{ kg m}^{-2}\text{s}^{-1}, \tag{8}$$

also, the vertical phase delay $\phi_{se} = i\left|\phi_{se}\right| = i\ k_{p_{se}} D\left|\sin\beta_{p_{se}}\right| \approx i\ k_{p_{se}} D\frac{c_{p_{se}}}{c_w}\sin\beta_{c_{se}}$. As $\cos\beta_{c_{se}} = c_w / c_{p_{se}}$,

$$\left|\phi_{se}\right| \approx D\ k_{p_{se}} \tan\beta_{c_{se}} \approx 2\pi D \tan\beta_{c_{se}} / \lambda_{p_{se}}. \tag{9}$$

Using the general substitution $i\tan\left(i\ x\right) = -\tanh x$ in Equation (4) and re-arranging, $R\left(\beta,\phi_{se}\right)$ may be written as

$$R\left(\beta,\phi_{se}\right) = \frac{Z_{se}\left(Z_{ba} + Z_{se}\tanh\left|\phi_{se}\right|\right) - Z_w\left(Z_{se} + Z_{ba}\tanh\left|\phi_{se}\right|\right)}{Z_{se}\left(Z_{ba} + Z_{se}\tanh\left|\phi_{se}\right|\right) + Z_w\left(Z_{se} + Z_{ba}\tanh\left|\phi_{se}\right|\right)}. \tag{10}$$

It is now easy to see, that for layer thickness $D \to 0$, $\left|\phi_{se}\right| \to 0$ and $\tanh\left|\phi_{se}\right| \to 0$, and $R\left(\beta,\phi_{se}\right)$ from Equation (10) approaches that in Equation (3), implying that the reflection resembles that from a half-space of basement material. Conversely, as layer thickness becomes infinite, $\left|\phi_{se}\right| \to \infty$ and $\tanh\left|\phi_{se}\right| \to 1$, and $R\left(\beta,\phi_{se}\right)$ from Equation (10) approaches that in Equation (2), and the reflection resembles that from a half-space of sediment.

Making the substitution $i\tan\left(i\left|\phi_{se}\right|\right) = -\tanh\left|\phi_{se}\right|$ in Equation (6), the overall input impedance of the combined layer and half-space may be written as

$$Z_{\text{ov}} = \frac{Z_{se}\left[Z_{ba} + Z_{se}\tanh\left|\phi_{se}\right|\right]}{Z_{se} + Z_{ba}\tanh\left|\phi_{se}\right|}\ \text{kg m}^{-2}\text{s}^{-1}. \tag{11}$$

It is now easy to see that, as $\left|\phi_{se}\right|$ transitions from 0 to infinity, Z_{ov} moves from equalling the basement impedance Z_{ba} to approaching the sediment impedance Z_{se}. As with Equation (10), this analysis requires the sediment layer to have zero shear speed, however, it need not be loss-less and may have absorption. There is no restriction on the basement, apart from it being a uniform half-space. From, e.g. Brekhovskikh and Godin equation (4.2.33), the impedance Z_{ba} of the basement may be written as

$$Z_{ba} = Z_{p_{ba}}\cos^2 2\beta_{s_{ba}} + Z_{s_{ba}}\sin^2 2\beta_{s_{ba}}\ \text{kg m}^{-2}\text{s}^{-1}. \tag{12}$$

Assuming now $c_{s_{ba}} < c_w$, the shear wave angle $\beta_{s_{ba}}$ is real and the impedance for the shear wave $Z_{s_{ba}} = \frac{\rho_{ba} c_{s_{ba}}}{\sin\beta_{s_{ba}}}\ \text{kg m}^{-2}\text{s}^{-1}$. From Snell's Law, $\cos\beta_{s_{ba}} = c_{s_{ba}}\cos\beta / c_w$, hence $\sin\beta_{s_{ba}} = \sqrt{1 - \left(c_{s_{ba}}\cos\beta / c_w\right)^2}$.

Also, writing $\sin^2\left(2\beta_{s_{ba}}\right)$ as $4\sin^2\beta_{s_{ba}}\left(1 - \sin^2\beta_{s_{ba}}\right)$, for small angles β it follows that

$$Z_{s_{ba}}\sin^2 2\beta_{s_{ba}} \approx 4\rho_{ba} c_{s_{ba}}\left(\frac{c_{s_{ba}}}{c_w}\right)\sqrt{1 - \left(\frac{c_{s_{ba}}}{c_w}\right)^2}\ \text{kg m}^{-2}\text{s}^{-1}. \tag{13}$$

Also assuming $c_{p_{ba}} > c_w$, the angle $\beta_{p_{ba}}$ of the basement compressional wave is complex, as for the compressional wave in the sediment. Drawing on the result in Equation (7), for small angles β the impedance of the basement compressional wave $Z_{p_{ba}} \approx -i\dfrac{\rho_{ba}c_w}{\sin\beta_{c_{ba}}}$ $\mathrm{kg\,m^{-2}s^{-1}}$ and is wholly imaginary. Next, replacing $\cos^2\left(2\beta_{s_{ba}}\right)$ as $\left(1-2\sin^2\beta_{s_{ba}}\right)^2$, which for small angles may be written as $\left[2\left(c_{s_{ba}}/c_w\right)^2-1\right]^2$, gives

$$Z_{p_{ba}}\cos^2 2\beta_{s_{ba}} \approx -i\frac{\rho_{ba}c_w}{\sin\beta_{c_{ba}}}\left[2\left(\frac{c_{s_{ba}}}{c_w}\right)^2-1\right]^2 \mathrm{kg\,m^{-2}s^{-1}}. \quad (14)$$

The basement impedance is given by the sum of the components in Equations (13) and (14). If absorption of compressional and shear waves within the basement is ignored, these equations represent the real and imaginary parts of the impedance Z_{ba}.

3 WESTON α PARAMETER REVISITED

It may be shown that the normal acoustic impedance of a seafloor is relatively constant for a span of grazing angles commencing at $\beta = 0$. This may be seen for the basement half-space by obtaining Z_{ba} from Equation (12) using Equations (13) and (14). The sub-components in Equations (13) and (14) were already approximated for small β, but it is clear that the impedance of the basement is relatively constant, so long as $\cos\beta \approx 1$ and $\sqrt{\sin^2\beta_{c_{ba}} - \sin^2\beta} \approx \sin\beta_{c_{ba}}$. Weston (Weston, 1971) showed that the combination of relative constancy of seafloor impedance and inverse linear impedance of seawater, as $Z_w = \rho_w c_w / \sin\beta \ \mathrm{kg\,m^{-2}s^{-1}}$, gives an interesting result. From Equation (5), it follows that

$$R\left(\beta,\phi_{se}\right) = \frac{Z_{\mathrm{ov}}\sin\beta - \rho_w c_w}{Z_{\mathrm{ov}}\sin\beta + \rho_w c_w} \quad (15)$$

so that, for small angles β, $R\left(\beta\right) \approx -1 + 2Z_{\mathrm{ov}}\beta/\left(\rho_w c_w\right)$ which leads to $\left|R\left(\beta\right)\right| \approx 1 - 2X_{\mathrm{ov}}\beta/\rho_w c_w$, and then to

$$\text{Bottom Loss BL} = -20\log\left|R\left(\beta\right)\right| \approx 40X_{\mathrm{ov}}\beta/\left[\ln\left(10\right)\rho_w c_w\right] \ \mathrm{dB}, \text{ and} \quad (16)$$

$$F = \mathrm{BL}/\beta \approx 40X_{\mathrm{ov}}/\left[\ln\left(10\right)\rho_w c_w\right] \ \mathrm{dB/radian}. \quad (17)$$

where Equation (16) is equivalent to Weston's equation (16), and F dB/radian is the same as Weston's "α". In this paper, F dB/radian is also termed the "bottom loss parameter".

3.1 Weston α parameter for seafloor with loss-less layer

In general, in Equation (11) the substitutions $Z_{se} = X_{se} + iY_{se}$ $\mathrm{kg\,m^{-2}s^{-1}}$ and $Z_{ba} = X_{ba} + iY_{ba}$ $\mathrm{kg\,m^{-2}s^{-1}}$ apply, where the impedances are considered as having both real and imaginary components. If the sediment layer is assumed to be a loss-less fluid, $Z_{se} = iY_{se}$ as the real component is zero. Equation (11) may then be written as

$$Z_{\text{ov}} = \frac{iY_{se}\left[X_{ba} + iY_{ba} + iY_{se}\tanh|\phi_{se}|\right]}{iY_{se} + \left(X_{ba} + iY_{ba}\right)\tanh|\phi_{se}|}\ \text{kg m}^{-2}\text{s}^{-1}. \quad (18)$$

After manipulation of this expression, the real part of Z_{ov} kg m^{-2}s^{-1} may be written as

$$X_{\text{ov}} = \frac{X_{ba}Y_{se}^{2}\left[1-\tanh^{2}|\phi_{se}|\right]}{\left(X_{ba}\tanh|\phi_{se}|\right)^{2} + \left(Y_{se} + Y_{ba}\tanh|\phi_{se}|\right)^{2}}\ \text{kg m}^{-2}\text{s}^{-1} \quad (19)$$

Now, in general, Equation (16) may be used for small angles of incidence to obtain bottom loss (BL), giving

$$\text{BL} \approx \frac{40X_{ba}Y_{se}^{2}\beta\left[1-\tanh^{2}|\phi_{se}|\right]}{\ln(10)\rho_{w}c_{w}\left[\left(X_{ba}\tanh|\phi_{se}|\right)^{2} + \left(Y_{se} + Y_{ba}\tanh|\phi_{se}|\right)^{2}\right]}\ \text{dB}. \quad (20)$$

The bottom loss parameter, being the Weston α parameter, is given by the above value of BL divided by angle β, and applies for β small. For $|\phi_{se}| < 0.2$ approximately, terms in $\tanh^{2}|\phi_{se}|$ may be eliminated, giving

$$\text{BL} \approx \frac{40X_{ba}\beta\left[1-2\,|\phi_{se}|Y_{ba}/Y_{se}\right]}{\ln(10)\rho_{w}c_{w}}\text{dB}. \quad (21)$$

Clearly, for $|\phi_{se}| = 0$ the BL is that for a half-space of basement material, but as $|\phi_{se}|$ increases from zero, the BL will reduce linearly with $|\phi_{se}|$, so long as $|\phi_{se}|$ is small.

4 REFLECTION AT LAYERED SEAFLOOR

Calculations existing in the literature which may be compared against Equation (20) include those of by Li et al. (Li et al., 2009). Figure 1 of Li et al., shows the amplitude of the sound pressure reflection coefficient $|R(\beta,f)|$ as a function of grazing angle β for a seafloor consisting of a uniform fluid of zero shear speed (sand) over a uniform elastic basement (calcarenite) for which the shear speed is less than the water sound speed. The relevant parameters of the seawater and seafloor are shown in Table 1.

Table 1 - Geoacoustic Properties: Layered Fluid Seafloor, Table 1 of Li et al. (Li et al., 2009)

Layer	Density (kg/m^3)	comp. speed (m/s)	shear speed (m/s)	comp. attn. α_p (dB/λ)	shear attn. α_p (dB/λ)
seawater	1024	1523	-	0.0	-
sand	1800	1700	0.0	0.8	0.0
calcarenite	2400	2800	1400	0.1	0.2

From the expressions given earlier in this paper, the values of the real and imaginary parts of the impedances Z_{se} kg m^{-2}s^{-1} and Z_{ba} kg m^{-2}s^{-1} may be determined for the parameters in Table 1. These impedances as determined are, of course, relevant for incident angle $\beta \to 0^{+}$ and are constant with acoustic frequency. Non-dimensionalised by the value of $\rho_w c_w$ from Table 1, for numeric convenience, these impedances are as follows: $Y_{se}/(\rho_w c_w) = -3.9562$, $X_{ba}/(\rho_w c_w) = 2.867$, $Y_{ba}/(\rho_w c_w) = -1.3298$. In using these non-dimensionalised values in Equations (20) and (21) to derive BL, $\rho_w c_w$ must be deleted from the denominator in each.

BL may now be determined from Equations (20) and (21) for the various values of $|\phi_{se}| \approx 2\pi D \tan\beta_{c_{se}} / \lambda_{p_{se}}$. For the thicknesses of sand layer appropriate to figure 1 of Li et al. (Li et al., 2009), these values are $|\phi_{se}| = 0.0$ for $D/\lambda_{p_{se}} = 0.0$, $|\phi_{se}| = 0.3116$ for $D/\lambda_{p_{se}} = 0.1$, $|\phi_{se}| = 0.6233$ for $D/\lambda_{p_{se}} = 0.2$, $|\phi_{se}| = 1.5581$ for $D/\lambda_{p_{se}} = 0.5$, $|\phi_{se}| \to \infty$ for $D/\lambda_{p_{se}} \to \infty$. Values of bottom loss parameter F dB/radian so obtained are shown in Table 2. Corresponding values were determined from figure 1 of Li et al. (Li et al., 2009), making use of the expected near-linear variation $|R(\beta)| \approx 1 - 2X_{\mathrm{ov}}\beta / \rho_w c_w$ for very small values of β.

Table 2 - Bottom Loss Parameter F dB/radian from Figure 1 of Li et al. (Li et al., 2009) vs Equations (20), (21).

Layer Thickness D/λ_{pse}	From Fig. 1 of Li et al.	From Equation (20)	From Equation (21)
0	48.5 dB/radian	49.8 dB/radian	49.8 dB/radian
0.1	34.6 dB/radian	35.9 dB/radian	39.4 dB/radian
0.2	21.3 dB/radian	22.0 dB/radian	28.9 dB/radian
0.5	7.0 dB/radian	3.77 dB/radian	-
∞	3.9 dB/radian	0.0 dB/radian	-

For layer thicknesses of zero, 0.1 and 0.2 wavelengths, results from Equation (20) are close to those from figure 1 from Li et al. and appear to confirm the present analysis. The values of $|\phi_{se}| = 0.3116$ for $D/\lambda_{p_{se}} = 0.1$ and $|\phi_{se}| = 0.6233$ for $D/\lambda_{p_{se}} = 0.2$ are larger than expected for validity of Equation (21), hence its poorer results.

For layer thicknesses of 0.5 wavelength and infinity, the values from Equation (20) are smaller compared with those inferred from figure 1 of Li et al. However, from data in Table 1, the sediment layer of Li et al. (Li et al., 2009) is not loss-less, with a compressional attenuation $\alpha_{p_{se}} = 0.8$ dB/λ. From, for example, the first term of equation 1.8a of Chapman (Chapman, 2001), a non-zero value of the real part of impedance X_{se} will result, with $X_{se} \approx \dfrac{\rho_{se} c_w \alpha_{p_{se}} \cos^2\beta_{c_{se}}}{40\pi \log(e) \sin^3\beta_{c_{se}}}$ kg m^{-2}s^{-1}. For an infinitely thick sediment layer, the expected BL due to the attenuation of compressional waves in this layer is then $\mathrm{BL}\big|_{|\phi_{se}|\to\infty} \approx \dfrac{40 X_{se}\beta}{\ln(10)\rho_w c_w} \approx 4.10$ dB. This gives $F \approx 4.10$ dB/radian which is very close to the value of 3.9 dB/radian obtained from figure 1 of Li et al. It is then reasonable to presume that values obtained from Equation (20) are less than those obtained from figure 1 of Li et al. due to the neglection of absorption within the sediment layer in the analysis. It is also reasonable to presume that for the small values of layer thickness, the result is dominated by the loss due to transmission of shear waves into the basement.

5 CONCLUSIONS

An analysis has been developed for the determination of the Weston α parameter for a seafloor consisting of a loss-less fast fluid sediment layer over an elastic basement for which shear speed is less than the seawater sound speed, but compressional speed is faster. This analysis is based on consideration of impedance for each of the seawater, fluid layer and basement half-space. Comparisons with values derived from conventionally calculated published material have been made for a seafloor consisting of a fast, absorbing fluid sediment layer over a basement for which shear speed is considerable, but less than the seawater sound speed. Calculations for the layer having thickness up to 0.2 wavelengths indicate that the derived analysis produces very similar values for the Weston α parameter as obtained from the published conventional calculations. However, when the layer thickness increases to a half-wavelength and greater, the present analysis produces smaller values for the Weston α parameter than the published reference. It is believed that this occurs due to the neglection of absorption in the fluid layer with the present analysis.

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