

# Turbidity in Future High Frequency Sonar Performance Models

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**Abstract:** Current sonar performance prediction models are incapable of accurately predicting the performance of high frequency sonars in highly variable turbid coastal waters. There is therefore a requirement for improved models incorporating the additional effects in such environments. In this paper it is demonstrated how the additional attenuation due to suspended mineral particles may be included in a simple sonar model. Results presented show that the effect of suspended particles can significantly influence the detection range of a high frequency sonar.

## INTRODUCTION

Current interest in sonar performance modelling is focused on high frequency sonars operating at frequencies of the order of tens to hundreds of kHz over ranges of the order of hundreds of metres in shallow coastal environments characterized by relatively high concentrations of suspended particulate matter. Existing high frequency models are incapable of predicting with any accuracy the temporal and spatial variability in sonar performance observed in such environments. The effects of suspended particles on the high frequency acoustic attenuation coefficient in turbid seawater may partially account for the observed variability and these phenomena should therefore be incorporated into future high frequency sonar performance models.

## THEORY

Solid particles suspended in seawater can lead to increased sound attenuation through the processes of scattering and viscous absorption. The acoustic attenuation coefficient in seawater containing suspended particles may therefore be written

$$\alpha = \alpha_w + \alpha_v + \alpha_s \quad (1)$$

where the subscripts  $w$ ,  $v$ , and  $s$  refer to the clear seawater, viscous absorption and scattering contributions to the total attenuation respectively. Several empirical expressions exist in the literature for calculating the absorption coefficient in clear seawater (e.g. (1)) and these expressions are used in existing propagation models. To include the effects of suspended particles the other two terms of Eq. (1) are added to this clear water attenuation. Suitable expressions for these terms were discussed in Ref. (2). Many workers have validated the expressions for the scattering coefficient experimentally, and the viscous absorption coefficient has been verified experimentally over the parameter range of interest as part of the present study (3).

The effect of temperature, pressure and salinity on the attenuation in seawater containing suspended solid particles has been investigated (4) and temperature in particular has been shown to be important. Salinity was found to be less significant and the effect of pressure was found to be negligible for shallow water applications.

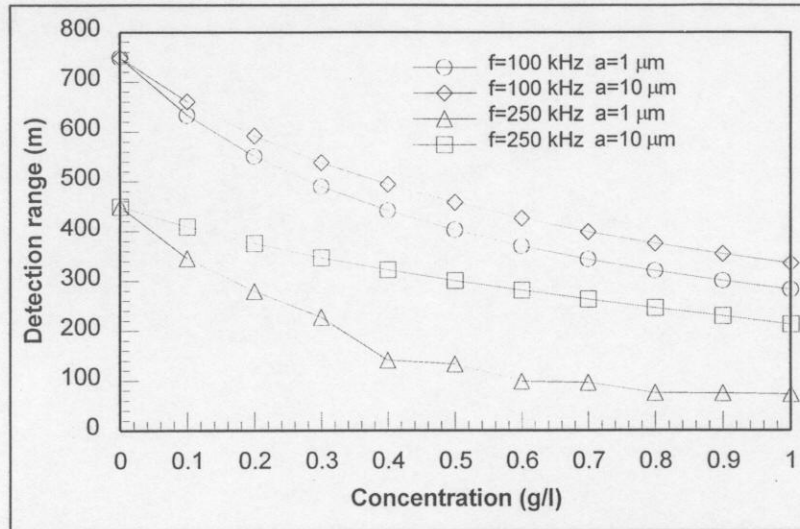
To demonstrate the effect of suspended particles on sonar performance an attenuation coefficient of the form given in Eq. (1) has been incorporated in a simple sonar performance calculation, described in Ref. (5). The additional attenuation contributions may similarly be included in more sophisticated propagation models.

## RESULTS

Figure 1 shows the results of an example calculation of detection range in a typical high frequency, shallow water sonar scenario, as a function of suspended particle concentration for two different frequencies and two different particle radii. In this example the calculations have been performed assuming that all the particles in suspension are

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of uniform size, although it is a simple matter to include the effects of a distribution of particle size by integrating calculations over the particle size distribution. It is clear in each of the cases shown in this figure that the presence of suspended particles significantly reduces the detection range of the sonar.



**FIGURE 1.** Detection range in a typical high frequency, shallow water sonar scenario, as a function of suspended particle concentration for 2 frequencies and 2 particle radii

It is also clear from the figure that particle size has a significant effect on the magnitude of the additional attenuation. This is as expected since viscous absorption is an inertial phase-lag effect. It will therefore be necessary to have both suspended particle concentration and particle size data in order to carry out predictions of sonar performance operationally. Methods of obtaining these data are the subject of current research.

### CONCLUSIONS

Results presented in this paper demonstrate that suspended particulate matter can have a significant impact on the detection range of a high frequency sonar operating in a turbid coastal environment and may therefore partially account for the observed variability in sonar performance in these environments. Consequently, the effects of suspended particles should be included in future high frequency sonar performance models. This may be achieved using the methods discussed in this paper.

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