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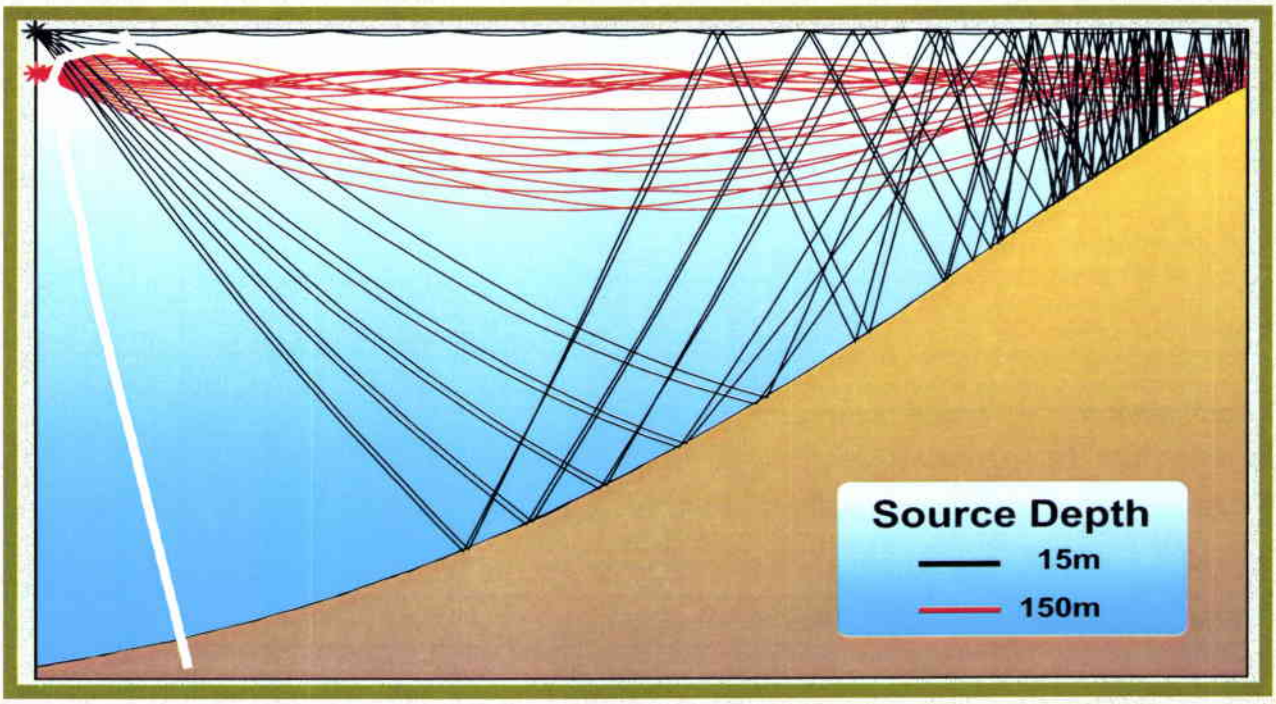
Performance assessment of the LYBIN - 2.0 propagation-loss model



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NORTH ATLANTIC TREATY ORGANIZATION ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD

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Jan L. Spoelstra
Director

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Performance assessment of the LYBIN-2.0 propagation-loss model

C.M. Ferla, C. Isoppo, G. Martinelli and F.B. Jensen

Executive Summary: The Allied Environmental Support System (AESS) is the standard sonar performance prediction system used by NATO Commands. The system includes environmental databases, acoustic models, system specific data, tactical decision aids, and various support facilities for data manipulation. The AESS is a powerful tool for optimizing the use of ships and sensors in complex tactical scenarios.

SACLANTCEN has previously done a performance assessment of six acoustic models (ASTRAL, MOCASSIN, PE, PROLOS, RAYMODE, SUPERSNAP) currently included in the AESS. To this end, a suitable set of test problems was defined covering typical operational scenarios in both deep and shallow water. AESS propagation-loss predictions were generated for each test scenario, for two sonar frequencies (500 and 3500 Hz) and for several source/receiver combinations. Reference solutions to all test problems were obtained with the GRAB range-dependent ray trace model, which, in turn, was thoroughly benchmarked against other models from the SACLANTCEN model library.

A new acoustic model LYBIN has been proposed for inclusion in the AESS model set. In order to determine this model's prediction accuracy and computational efficiency, SACLANTCEN was tasked to test LYBIN on exactly the same set of problems used earlier for the other AESS models. The general conclusion of this study, as reported here, is that the range-dependent ray-trace model LYBIN developed by the Norwegian Navy, is indeed a valid alternative to existing propagation models in the AESS. The LYBIN model has a prediction accuracy similar to the GRAB 'reference' model but is considerably faster.

In the current implementation of the LYBIN model, only bathymetry is allowed to change along a propagation track. For LYBIN to be of maximum utility to the AESS community, it is recommended that the model be extended to handle range dependence in all environmental input parameters.

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Performance assessment of the LYBIN-2.0 propagation-loss model

C.M. Ferla, C. Isoppo, G. Martinelli and
F.B. Jensen

Abstract: A new acoustic model LYBIN has been proposed for inclusion in the AESS model set. In order to determine this model's prediction accuracy and computational efficiency, SACLANTCEN was tasked to test LYBIN on exactly the same set of propagation problems used earlier for validating the current set of AESS models (ASTRAL, MOCASSIN, PE, PROLOS, RAYMODE, SUPERSNAP). The general conclusion of this test is that the range-dependent ray-trace model LYBIN, developed by the Norwegian Navy, is indeed a valid alternative to existing propagation models in the AESS. The LYBIN model has a prediction accuracy similar to the GRAB 'reference' model but is considerably faster.

Keywords: acoustic models ○ propagation loss ○ range dependence ○ sonar models

Contents

1 Introduction

The Allied Environmental Support System (AESS) [1] is the standard sonar performance prediction system used by NATO Commands. The system includes environmental databases, acoustic models, system specific data, tactical decision aids, and various support facilities for data manipulation. The AESS is a powerful tool for optimizing the use of ships and sensors in a complex tactical scenario.

SACLANTCEN has previously performed an assessment of the acoustic models included in the AESS v6.0, with the aim of providing guidelines for best model choice and identify shortfalls in current model implementations [2]. To this end, a suitable set of test problems was defined covering typical operational scenarios in both deep and shallow water. A full set of AESS propagation-loss predictions was then generated for each test scenario, for two sonar frequencies (500 and 3500 Hz) and for several source/receiver combinations. Reference solutions to all test problems were obtained with the GRAB range-dependent ray trace model, which, in turn, was thoroughly benchmarked against other models from the SACLANTCEN model library.

As a follow-up to the above study, SACLANTCEN was recently tasked to perform a similar assessment of a new propagation model LYBIN [3], developed by the Norwegian Navy, and proposed for inclusion in the standard AESS model set.

2
The LYBIN ray-trace model

LYBIN is a complete sonar performance prediction model developed over several years by the Norwegian Navy [3]. It is the acoustic transmission part that we are particularly concerned about here. That part is a range-dependent ray model, which, however, only allows for varying bathymetry along the propagation track. Hence, in the current implementation of LYBIN, ocean sound-speed structure and bottom-loss properties are assumed to be constant along each track. This is a limitation compared to the standard AESS set-up, and in order to perform a complete test of the LYBIN model, the original set of test problems had to be slightly modified to have constant bottom loss along each track.

The LYBIN model is clearly designed for speed and it provides acoustic field predictions at all frequencies in a matter of seconds on a standard PC. It is the accuracy of the field predictions that will be assessed here by comparing LYBIN transmission-loss curves with those generated by the GRAB and PAREQ reference models.

3
The GRAB and PAREQ reference models

A model validation and assessment study requires access to high-fidelity "reference" solutions to the full set of test problems. Considering that the current study covers a broad range of operational sonar scenarios from deep to shallow water, with range-varying bathymetry and sound-speed structure, and for frequencies between 500 Hz and 3.5 kHz, there is essentially only one type of model that can provide answers with an acceptable computational effort: a ray-based, range-dependent propagation model.

The Gaussian Ray Bundle (GRAB) model [4] developed recently for use by the US Navy was the choice for checking the original AESS predictions. GRAB was developed specifically for high-frequency applications in shallow water, but thorough testing showed excellent performance also at frequencies well below 500 Hz, and for deep-water applications in general. Two aspects of this model are unique: first, the use of Gaussian ray bundles, which causes a smoothing of the acoustic field and hence avoids the standard ray artifacts of infinite intensity near caustics; second, a careful treatment of ray reflections at boundaries using the concept of virtual rays. This is important for producing high-fidelity results in shallow water.

In the course of generating reference solutions with GRAB-3.99 for the entire set of test problems, we made several independent checks on the solution accuracy by comparing with other models from the SACLANTCEN model library [5, 6]. Some minor problems were detected with the two ray models for some of the test problems, and we therefore decided to include parabolic equation results from the PAREQ model as a true reference.

4

Test problem definition

Test scenarios for propagation model validation should encompass realistic operational conditions, i.e. consider both deep and shallow water scenarios, for both flat and sloping bottom conditions, and for a variety of different bottom-loss situations. Moreover, the test problems should cover a range of sonar frequencies and various sonar/target depths combinations.

As described in the AESS-6.0 model validation report [2], two tracks from the North Atlantic were selected, and database information (NSODB) available for bathymetry and bottom loss was used as input to the acoustic models. Both tracks have a length of 22 km.

There are two worldwide databases for bottom loss: BLUG (Bottom Loss UpGrade) and MGS (Marine Geophysical Survey). The two data sets are rather inconsistent with BLUG generally providing much lower bottom loss in a given area than MGS. Rather than going into the merits of one set of reflection loss curves versus the other, we provide transmission-loss results for both bottom types.

To investigate the most important propagation scenarios in shallow and deep water, each track was divided into three cases: (1) a flat bottom with a water depth corresponding to the deepest end of the track, (2) an upslope bottom with propagation from deep to shallow water, and (3) a downslope bottom with propagation from shallow to deep water. For simplicity a single sound-speed profile was used along each track as defined in [2].

In the next section LYBIN transmission-loss (TL) predictions will be compared with the GRAB/PAREQ reference solutions (using either MGS or BLUG bottom loss curves) for frequencies of 500 Hz and 3.5 kHz and for several source/receiver combinations. PAREQ results are shown only for the MGS bottoms even though spot checks were done also with BLUG.

5
Test problem results

5.1 Track A: flat bottom

This is a simplified range-independent, deep-water scenario as illustrated in Fig. 1. The water depth is 2260 m; there is a single sound-speed profile for the entire track with a shallow surface duct of 50-m depth and a deeper sound channel centered at 165-m depth. The bottom loss is given by the BLUG and MGS curves used previously [2].

Two source depths are considered, 15 and 100 m, and the associated ray diagrams are shown in Fig. 1. Note that the shallow source transmits energy directly into the surface duct (black rays) and energy via bottom-interacting paths to receivers below the surface duct. Hence for receivers below 50 m, the TL prediction will be strongly dependent on the bottom-loss model used. For the deep source (red rays) there are waterborne ray arrivals at most receiver depths and TL predictions should therefore be less dependent on the choice of bottom-loss model.

The set of LYBIN predictions compared to the GRAB/PAREQ reference solutions is given in Figs. 2–5. Each plot is for a different frequency and a particular source/receiver depth combination. The legend on top of each figure groups the results according to the type of bottom-loss model used. For example, in Fig. 2 the two dashed curves are LYBIN and GRAB results using the BLUG tables (hard bottom). The three continuous-line curves are LYBIN, GRAB and PAREQ solutions using MGS tables (soft bottom), and we assume that the blue PAREQ result is the reference solution to this propagation problem. This has been explicitly verified by checking the PAREQ results against other high-fidelity model solutions based on normal-mode or wavenumber integration techniques.

A closer look at the results in Fig. 2 show a spread on TL predictions of 15–20 dB beyond a range of 5 km. There are two reasons for this: (1) the use of different bottom loss tables, and (2) model implementation errors. The effect of using different bottom-loss tables is already clear by comparing the two GRAB solutions, one using BLUG (dashed black line) and the other using MGS (continuous black line). The MGS bottom is much more lossy resulting in a TL that, beyond 3 km, is 5–10 dB higher than the prediction using the BLUG curve. Clearly, it would be important for the user to know which of the two bottom models is closest to reality for Track A.

The two dashed curves in Fig. 2 are in agreement to within 3 dB over the full propagation range indicating that LYBIN and GRAB give similar results for a hard BLUG bottom. On the other hand, there are considerable level differences for the softer MGS bottom, where the GRAB result is much closer to the PAREQ reference solution than the LYBIN result. This case with the source in the surface duct (15 m) and the receiver below the duct (200 m) is particularly difficult for ray models.

As is evident from the ray trace (black curves) in Fig. 1, the insonification at a receiver at 200 m is either due to energy leakage out of the surface duct or ray reflections off the bottom. In the case of a soft MGS bottom very little energy is reflected from the bottom, and hence the main contributor to insonification below the duct becomes energy leakage. This phenomenon is not included in classical ray theory, but can be corrected for via empirical formulas. In this case (Fig. 2) GRAB provides a quite accurate prediction compared to the PAREQ reference, whereas LYBIN predicts too high losses by nearly 15 dB beyond a range of 5 km. In general, ray predictions of duct leakage will be poor, particularly at lower frequencies.

Turning to the next example given in Fig. 3 for a deeper source at 100 m, we see a similar picture as before. The LYBIN and GRAB results are in quite good agreement for the hard BLUG bottom, but in poor agreement for the softer MGS bottom, particularly for ranges between 5 and 15 km. The GRAB result is again a little better than the LYBIN result, but both ray solutions are inaccurate in this range interval. The reason is the same as above, i.e. the receiver is in a shadow zone where energy leakage (or diffraction) is important.

We finally show two high-frequency results in Figs. 4 and 5. For the shallow source in Fig. 4 there is excellent agreement between LYBIN and GRAB results for the hard BLUG bottom. For the softer MGS bottom it is now LYBIN that performs best compared to the PAREQ reference solution. GRAB produces a sequence of convergence zones beyond 5 km, which should not be there. The reason for this artifact is not clear, and it was not present in version 2.0 of the GRAB model.

For the deeper source in Fig. 5 there is generally good agreement between LYBIN and GRAB for both bottom types. One peculiar difference is in predicting the presence of a caustic at either 12 km (GRAB) or 13.5 km (LYBIN). By comparing to the PAREQ reference solution it is clear that neither of the two ray solutions are accurate in this range interval.

Model performance summary: Track A – flat.

- LYBIN and GRAB results are in close agreement for the hard BLUG bottom.
- Both LYBIN and GRAB are inadequate for modeling transmission into shadow zones; GRAB is better than LYBIN at low frequencies, whereas LYBIN is better than GRAB at high frequencies.

5.2 Track A: upslope bottom

We now introduce a sloping bathymetry along Track A with propagation from deep to shallow water, see Fig. 6. There is still a single sound-speed profile along the entire track, and bottom losses are given by the BLUG and MGS curves used previously [2]. This range-dependent environment provides an added degree of complexity for validation of the LYBIN model.

Two source depths are considered, 15 and 150 m, and the associated ray diagrams are shown in Fig. 6. Note that the effect of the sloping bottom on long-range propagation is felt only for the shallow source and for receivers below the surface duct. By comparing Figs. 1 and 6 we see that the number of ray reflections off the sloping bottom increases towards the shallow end of the track, which, in turn, results in higher transmission losses.

The set of LYBIN model predictions compared to the GRAB/PAREQ reference solutions is given in Figs. 7–10. Only at the very end, beyond 20 km, is there an unexpected sharp roll-off of the LYBIN curve. That this is an artifact is evident in the soft-bottom MGS result, where GRAB and PAREQ are in fairly good agreement, whereas the LYBIN result is 10 dB too low and exhibits a sharp roll-off at around 16 km.

Turning to the next example in Fig. 8 for a source and receiver near the sound channel axis, we have good agreement between all models. Note that the acoustics here is particularly simple with sound being channeled to long ranges without boundary interaction, as illustrated by the ray diagram in Fig. 6.

We finally show two high-frequency results in Figs. 9 and 10. For the shallow source in Fig. 9 there is excellent agreement between LYBIN and GRAB results for the hard BLUG bottom, except near the end of the track. For the softer MGS bottom LYBIN performs best compared to the PAREQ reference solution, but there is again a sharp roll-off around 16 km. As for the flat-bottom case, GRAB produces a sequence of convergence zones beyond 5 km, which should not be there. For the simple channel propagation situation in Fig. 10, we have excellent performance by all models.

Model performance summary: Track A – upslope.

- LYBIN and GRAB results are in close agreement for the hard BLUG bottom.
- Both LYBIN and GRAB are inadequate for modeling transmission into shadow zones; GRAB is better than LYBIN at low frequencies, whereas LYBIN is better than GRAB at high frequencies.
- LYBIN exhibits some artifacts with a sharp drop-off in level when propagating from deep into very shallow water.

5.3 Track A: downslope bottom

For completeness we next consider the opposite propagation direction with transmission from shallow to deep water along Track A, see Fig. 11. This scenario is acoustically simpler than the upslope case because there is less bottom interaction.

The LYBIN predictions compared to the GRAB/PAREQ reference solutions are given in Figs. 12–15. For a 500-Hz source at 15 m and a receiver at 200 m (Fig. 12) the agreement between LYBIN and GRAB is fair for both bottom types. For the deeper source in Fig. 13 we have even better agreement except in the range 12–18 km for the MGS bottom, where both ray solutions are inaccurate due to the presence of a shadow zone.

The 3.5-kHz results are shown in Figs. 14 and 15. For the shallow source there is good agreement between LYBIN and GRAB results for the hard BLUG bottom. For the softer MGS bottom it is LYBIN that performs best compared to the PAREQ reference solution. GRAB produces a sequence of convergence zones beyond 5 km, which should not be there.

For the deeper source in Fig. 15 there is generally good agreement between LYBIN and GRAB for both bottom types. However, both ray models are seen to provide wrong answers between 12 and 18 km for the soft MGS bottom. This is again the effect of diffraction into the shadow zone handled incorrectly by ray-based models.

Model performance summary: Track A – downslope.

- LYBIN and GRAB results are in close agreement for the hard BLUG bottom.
- Both LYBIN and GRAB are inadequate for modeling transmission into shadow zones; GRAB is better than LYBIN at low frequencies, whereas LYBIN is better than GRAB at high frequencies.

5.4 Track B: flat bottom

This is a simplified constant-depth, shallow-water scenario as illustrated in Fig. 16. The water depth is 500 m; there is a single sound-speed profile for the entire track with a surface duct of 10-m depth and a weak sound channel centered at 80 m. The bottom loss is given by the BLUG and MGS curves used previously [2]. Note that this track originally straddled two MGS provinces, with low loss to the south (MGS 2) and much higher loss to the north (MGS 6). Here this track will be run with constant bottom properties (MGS 6) along the entire track. Therefore model results presented here will be different from the results in Ref.[2].

Two source depths are considered, 15 and 100 m, and the associated ray diagrams are shown in Fig. 16. Note that rays leaving the shallow source all interact with both surface and bottom, which will cause TL prediction to be strongly dependent on the bottom-loss model used (typical shallow-water scenario). For the deep source (red rays) there are waterborne ray arrivals, but only near the channel axis.

The LYBIN predictions compared to the GRAB/PAREQ reference solutions are given in Figs. 17–20. Each plot is for a different frequency and a particular source/receiver depth combination. The legend on top of each figure groups the results according to the type of bottom-loss model used. For example, in Fig. 17 the two dashed curves are LYBIN and GRAB results using the BLUG tables (hard bottom). The three continuous-line curves are LYBIN, GRAB and PAREQ solutions using MGS tables (soft bottom), and we assume that the blue PAREQ result is the reference solution to this propagation problem. This has been explicitly verified by checking the PAREQ results to other high-fidelity model solutions based on normal-mode or wavenumber integration techniques.

The results for a 500-Hz source at 15 m and a receiver at 100 m (Fig. 17) show good agreement between LYBIN and GRAB for both bottom types. The slight range shift in the location of the convergence zones is a feature apparent only at low frequencies, and it is not clear which model is most accurate. Comparing LYBIN and GRAB results to the PAREQ reference solution for the MGS bottom shows that both ray solutions are heavily smoothed as a result of using random phase addition for transmission loss calculations. The PAREQ result being fully coherent show more detailed multipath interference.

Turning to the example for the deep source in Fig. 18, we see that LYBIN and GRAB results are in excellent agreement. For this source/receiver combination sound is traveling in the channel without bottom interaction, and hence results for the two bottom types are almost identical. Again, the fully coherent PAREQ result shows more interference structure.

We finally show some 3.5-kHz results in Figs. 19 and 20. Here there is excellent agreement between all model predictions for both bottom types.

Model performance summary: Track B – flat.

- LYBIN and GRAB results are in close agreement for both bottom types.
- The ray models are in closer agreement with the reference wave solution at high frequencies (3.5 kHz) than at low frequencies (500 Hz).

5.5 *Track B: upslope bottom*

The correct bathymetry along Track B is introduced next with propagation from deep to shallow water, see Fig. 21. There is still a single sound-speed profile along the entire track, and bottom losses are given by the BLUG and MGS curves used previously [2].

This range-dependent environment provides an added degree of complexity for validation of the LYBIN model.

Two source depths are considered, 15 and 100 m, and the associated ray diagrams are shown in Fig. 21. Note that the effect of the sloping bathymetry on long-range propagation is an increased number of ray reflections off the bottom toward the shallow end of the track. This, in turn, results in higher transmission losses compared to the flat-bottom scenario studied previously.

The LYBIN predictions compared to the GRAB/PAREQ reference solutions are given in Figs. 22–25. The results for a 500-Hz source at 15 m and a receiver at 100 m (Fig. 22) show excellent agreement between LYBIN and GRAB for both bottom types. Note that even extremely lossy shallow-water propagation conditions are handled consistently in the two ray models. However, comparing LYBIN and GRAB results to the PAREQ reference solution for the MGS bottom indicates that the smoothed ray solutions are a little off the correct answer for this frequency. At 3.5 kHz LYBIN and GRAB performs much better compared to the PAREQ reference, see Fig. 24.

Turning to the example for the deeper source in Fig. 23, we see that LYBIN and GRAB results are in excellent agreement for the hard BLUG bottom. For the softer MGS bottom GRAB performs better than LYBIN.

We finally show some 3.5-kHz results in Figs. 24 and 25. Here there is excellent agreement between all model predictions for both bottom types.

Model performance summary: Track B – upslope.

- LYBIN and GRAB results are in close agreement for both bottom types.
- The ray models are in closer agreement with the reference wave solution at high frequencies (3.5 kHz) than at low frequencies (500 Hz).

5.6 *Track B: downslope bottom*

For completeness we also consider the opposite propagation direction with transmission from shallow to deeper water along Track B, see Fig. 26. This scenario is acoustically simpler than the upslope case because there is less bottom interaction.

The LYBIN predictions compared to the GRAB/PAREQ reference solutions are given in Figs. 27–30. For a source at 15 m and a receiver at 150 m (Fig. 27) there is good agreement between LYBIN and GRAB for both bottom types. However, comparing to the PAREQ reference solution for the MGS bottom indicates that the smoothed ray solutions are a little off the correct answer.

Turning to the example for the deeper source in Fig. 28, we see that LYBIN predicts too high losses at long ranges. This is particularly evident for the MGS bottom where the LYBIN result drops below 120 dB at a range of 10 km. Here the GRAB answer is in much better agreement with the PAREQ reference solution.

The model predictions for a frequency of 3.5-kHz are given in Figs. 29 and 30. Here there is generally good agreement between the LYBIN and GRAB results, but the two ray solutions are not in close agreement with the PAREQ reference for the soft MGS bottom.

Model performance summary: Track B – downslope.

- For a 500-Hz source at 100 m depth LYBIN predicts too high losses compared to GRAB and PAREQ.
- At 3.5 kHz LYBIN and GRAB results are in close agreement for both bottom types.

6
Conclusions and recommendations

The general conclusion of this test is that the range-dependent ray-trace model LYBIN, developed by the Norwegian Navy, is indeed a valid alternative to existing propagation models in the AESS. The LYBIN model has a prediction accuracy similar to the GRAB 'reference' model but is considerably faster.

In the current implementation of the 'range-dependent' LYBIN model, only bathymetry is allowed to change along a propagation track. Hence, sea-surface conditions, ocean sound-speed structure, and bottom-loss properties are assumed to be constant along each track. This is a limitation compared to the standard AESS set-up, where all environmental parameters retrieved from the NATO Standard Oceanographic Data Base (NSODB) may vary along the propagation track. Consequently, for LYBIN to be of maximum utility to the AESS community, it is recommended that the model be extended to handle range dependence in all environmental input parameters.

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Figures

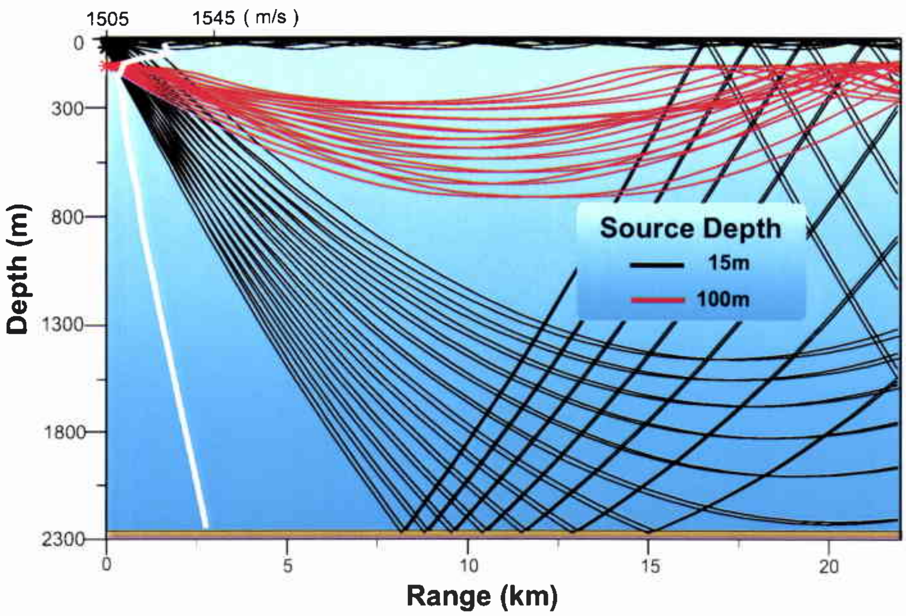

Figure 1 *Track A – flat: Ray diagrams for two different source depths.*

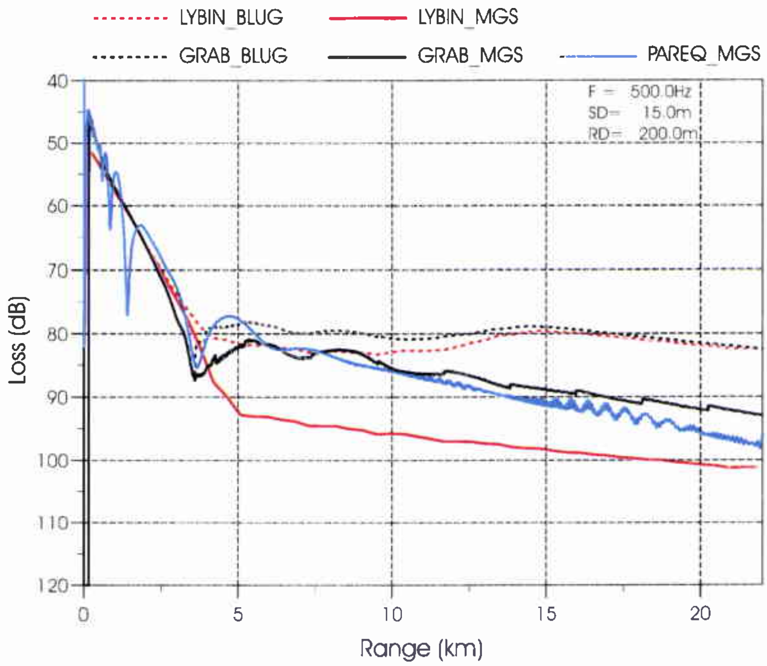

Figure 2 *Track A – flat: Model predictions at 500 Hz for source at 15 m and receiver at 200 m.*

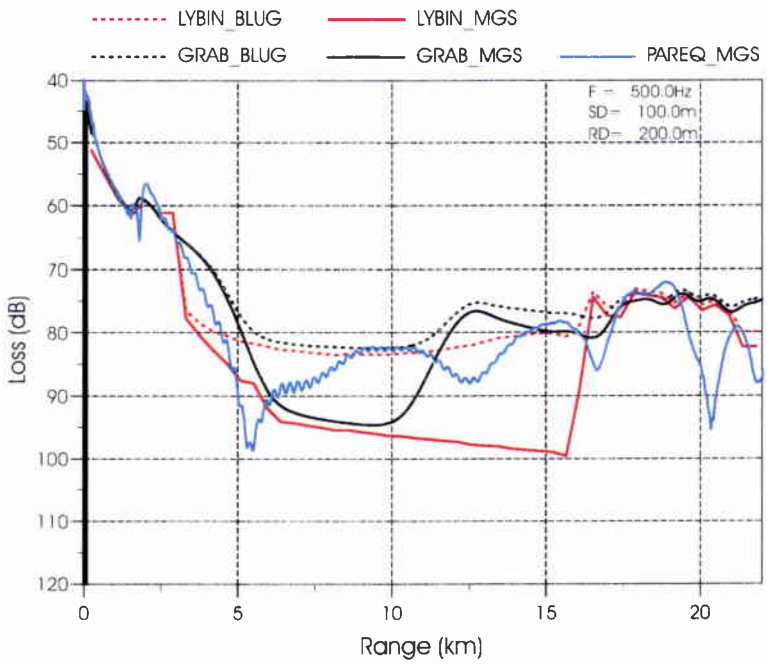

Figure 3 *Track A – flat: Model predictions at 500 Hz for source at 100 m and receiver at 200 m.*

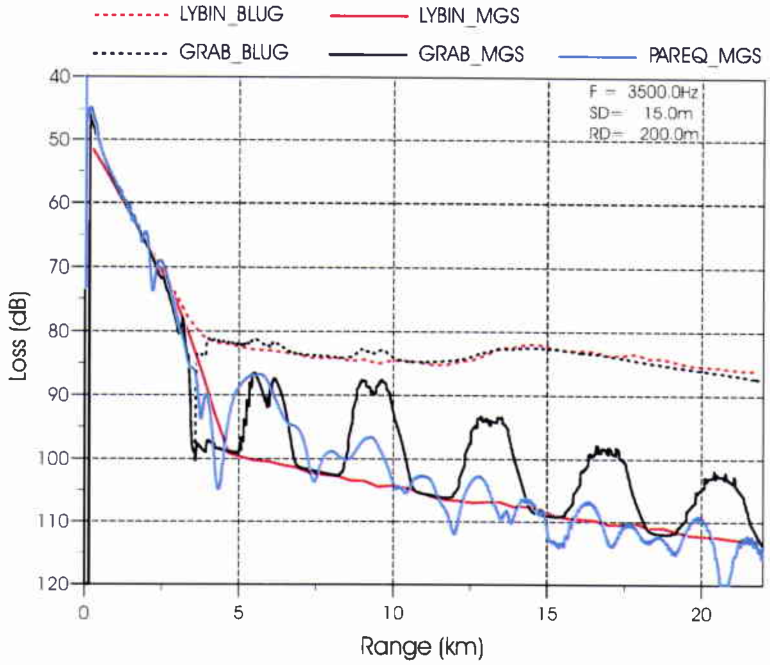

Figure 4 *Track A – flat: Model predictions at 3500 Hz for source at 15 m and receiver at 200 m.*

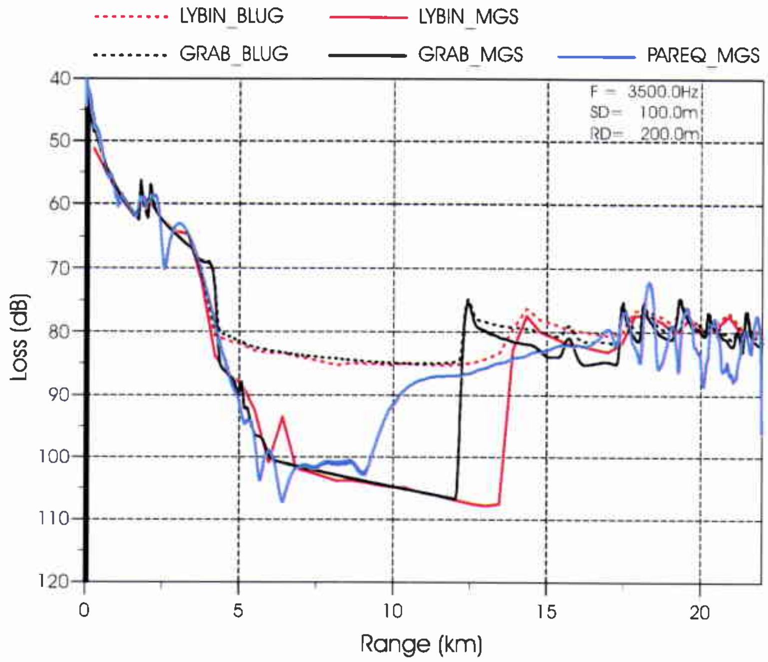

Figure 5 *Track A – flat: Model predictions at 3500 Hz for source at 100 m and receiver at 200 m.*

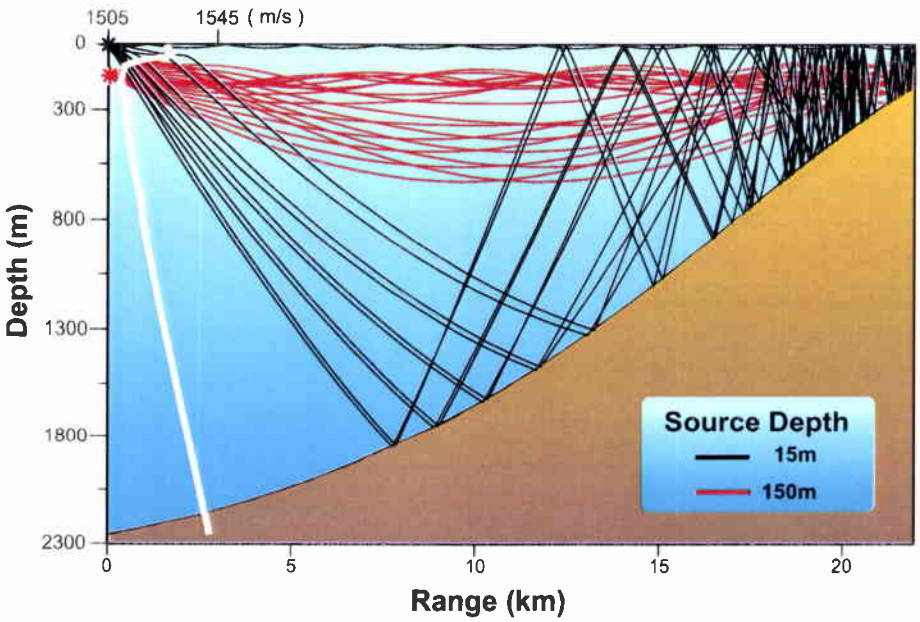

Figure 6 *Track A – upslope: Ray diagrams for two different source depths.*

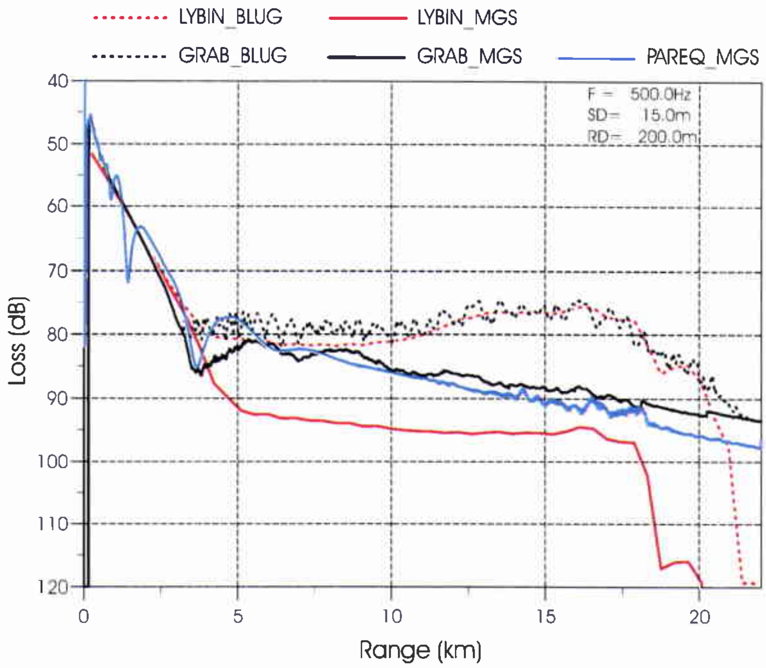

Figure 7 *Track A – upslope: Model predictions at 500 Hz for source at 15 m and receiver at 200 m.*

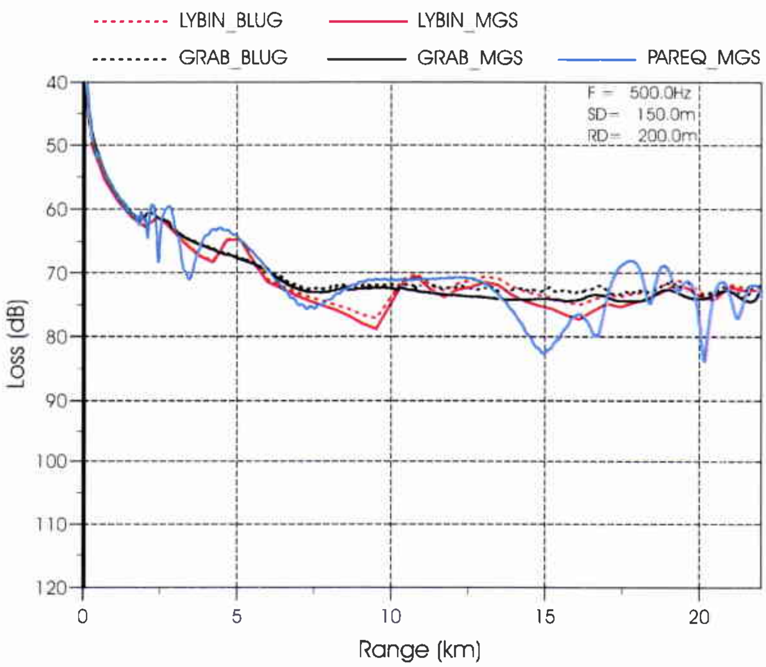

Figure 8 *Track A – upslope: Model predictions at 500 Hz for source at 150 m and receiver at 200 m.*

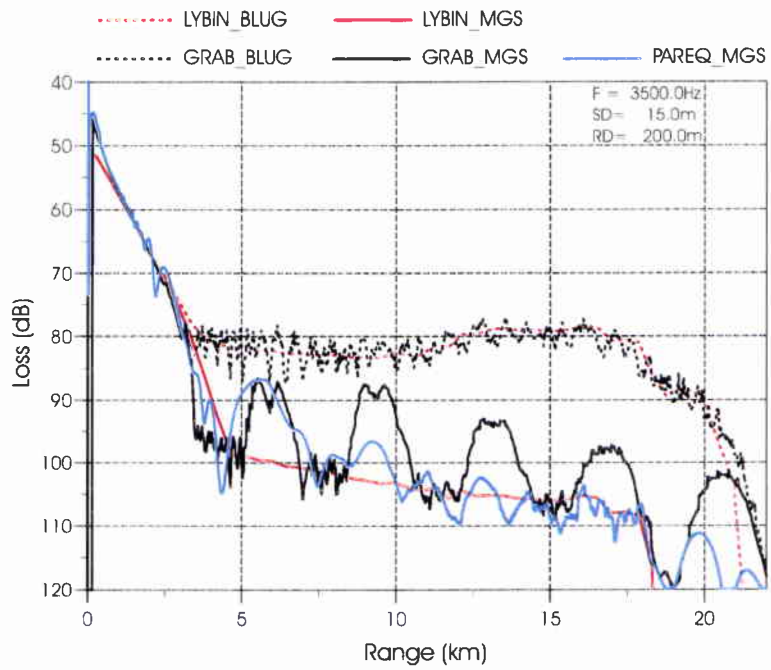

Figure 9 *Track A – upslope: Model predictions at 3500 Hz for source at 15 m and receiver at 200 m.*

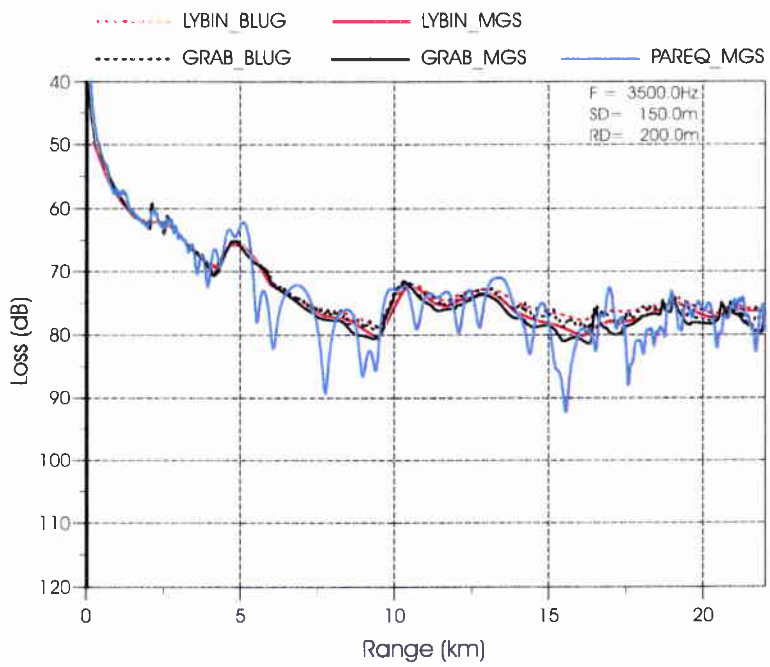

Figure 10 *Track A – upslope: Model predictions at 3500 Hz for source at 150 m and receiver at 200 m.*

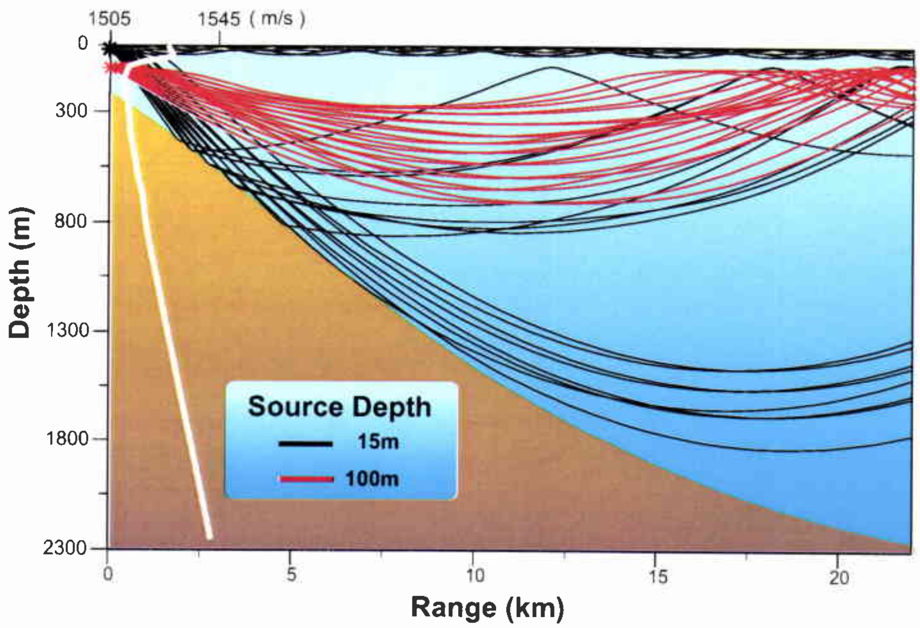

Figure 11 *Track A – downslope: Ray diagrams for two different source depths.*

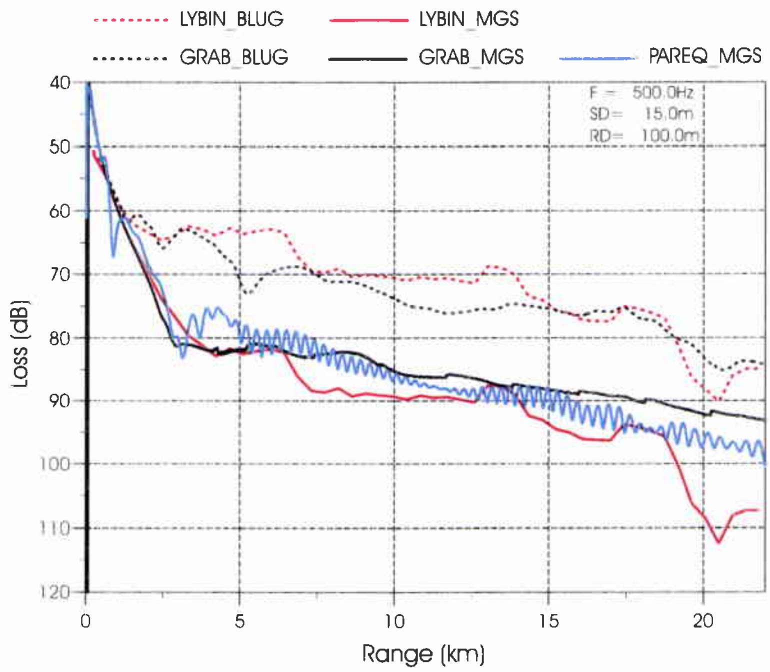

Figure 12 *Track A – downslope: Model predictions at 500 Hz for source at 15 m and receiver at 100 m.*

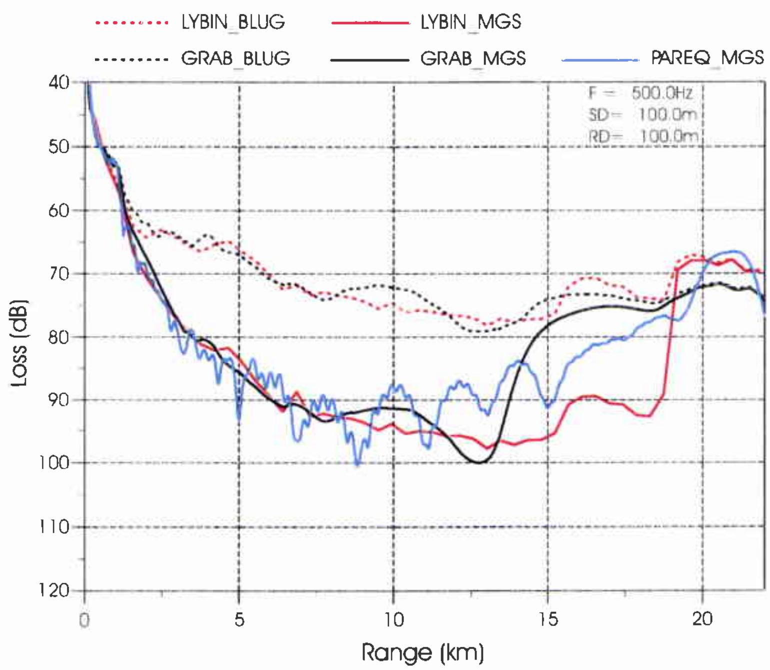

Figure 13 *Track A – downslope: Model predictions at 500 Hz for source at 100 m and receiver at 100 m.*

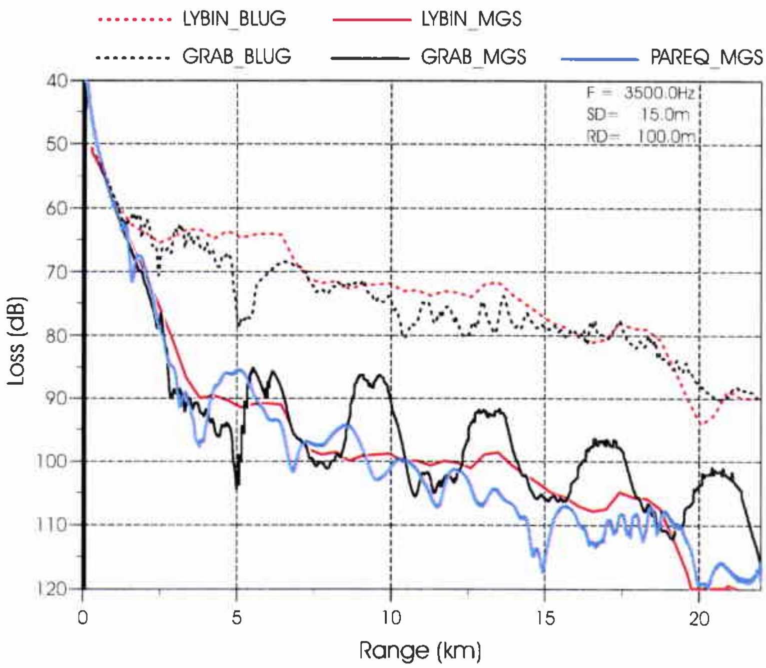

Figure 14 *Track A – downslope: Model predictions at 3500 Hz for source at 15 m and receiver at 100 m.*

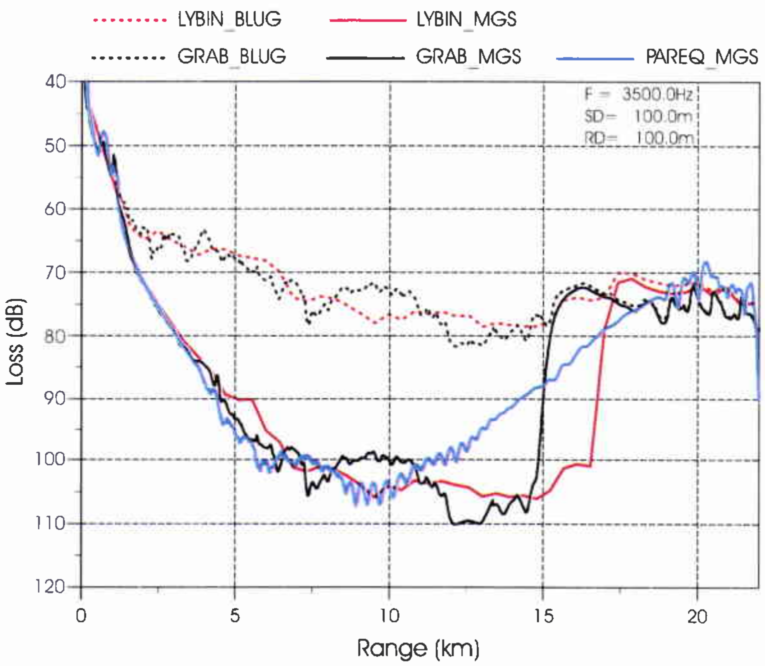

Figure 15 *Track A – downslope: Model predictions at 3500 Hz for source at 100 m and receiver at 100 m.*

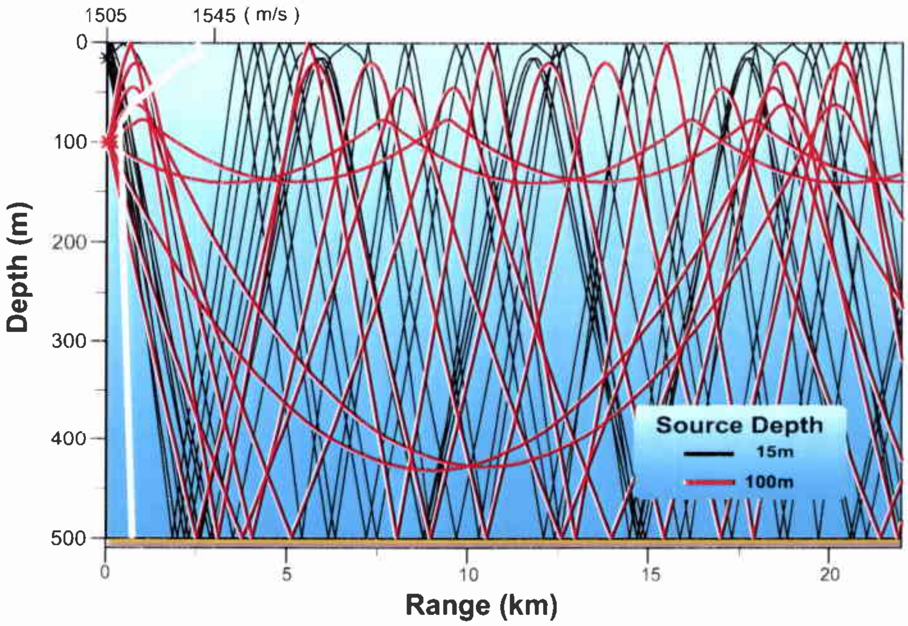

Figure 16 *Track B – flat: Ray diagrams for two different source depths.*

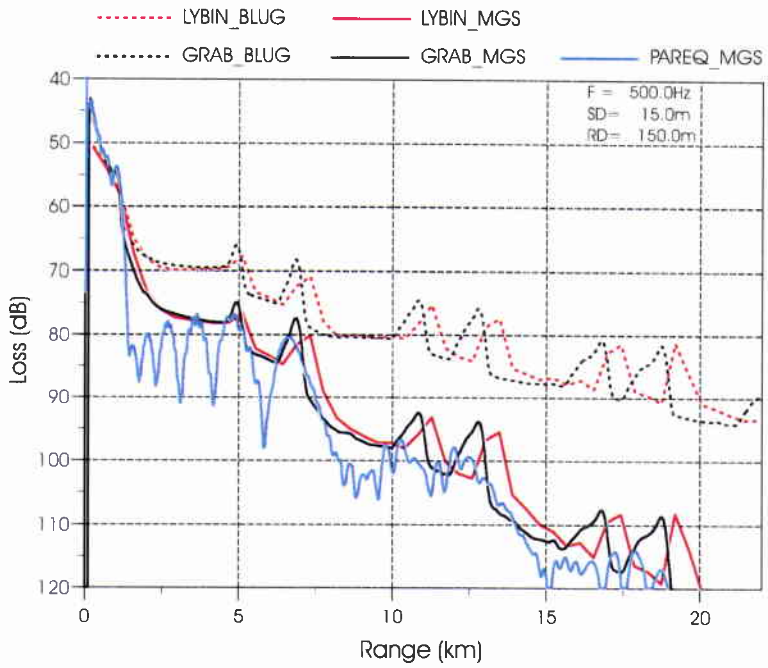

Figure 17 *Track B – flat: Model predictions at 500 Hz for source at 15 m and receiver at 150 m.*

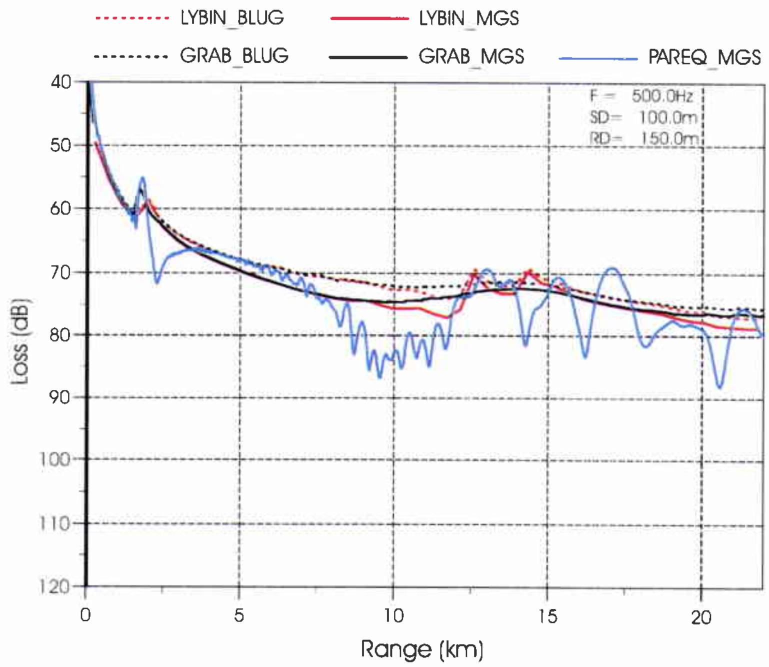

Figure 18 *Track B – flat: Model predictions at 500 Hz for source at 100 m and receiver at 150 m.*

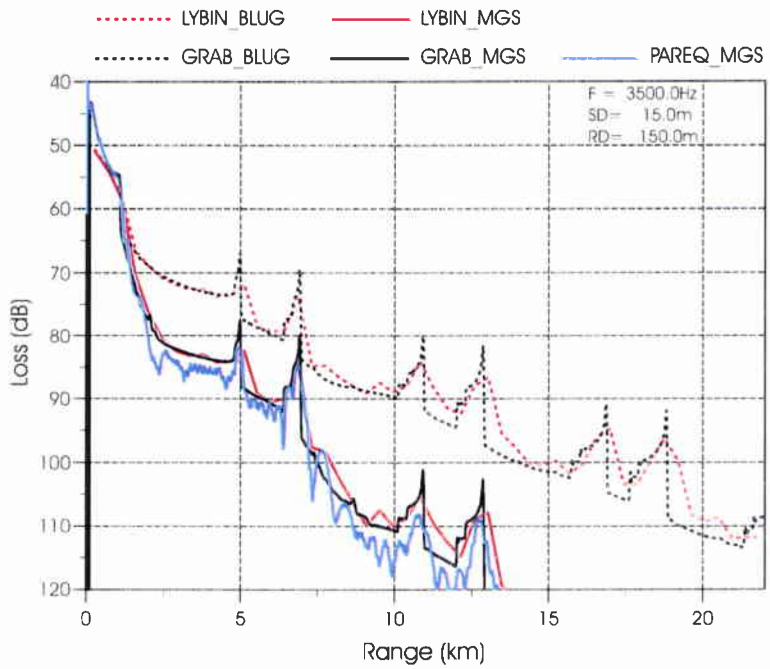

Figure 19 *Track B – flat: Model predictions at 3500 Hz for source at 15 m and receiver at 150 m.*

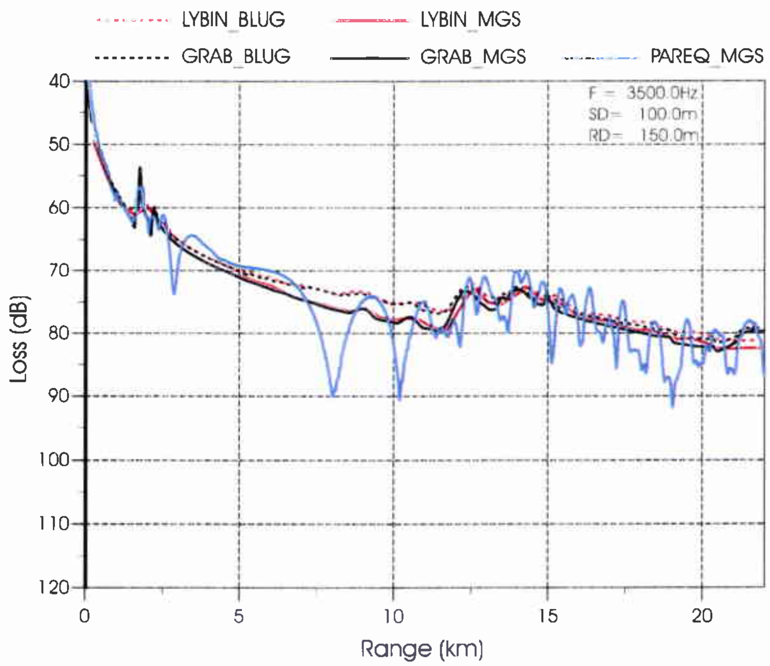

Figure 20 *Track B – flat: Model predictions at 3500 Hz for source at 100 m and receiver at 150 m.*

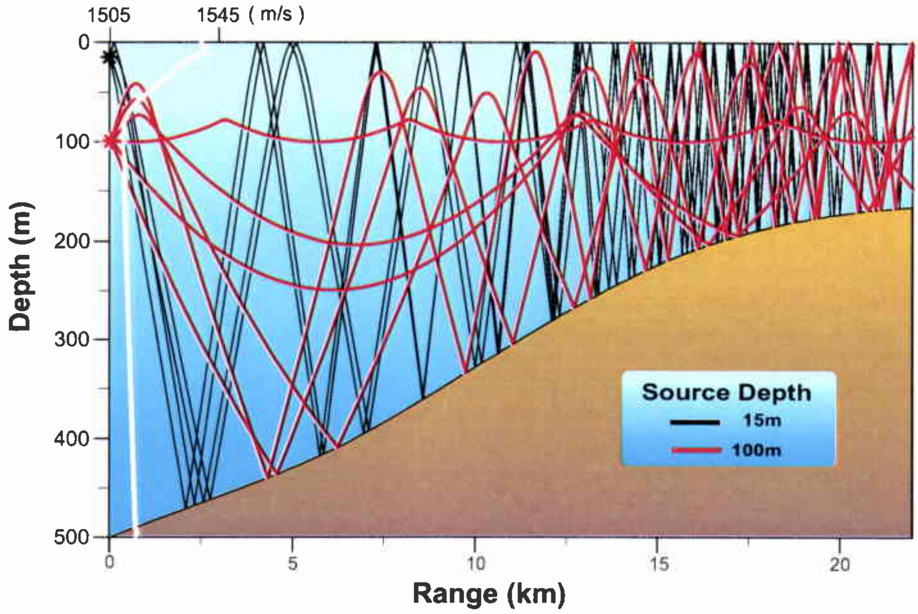

Figure 21 *Track B – upslope: Ray diagrams for two different source depths.*

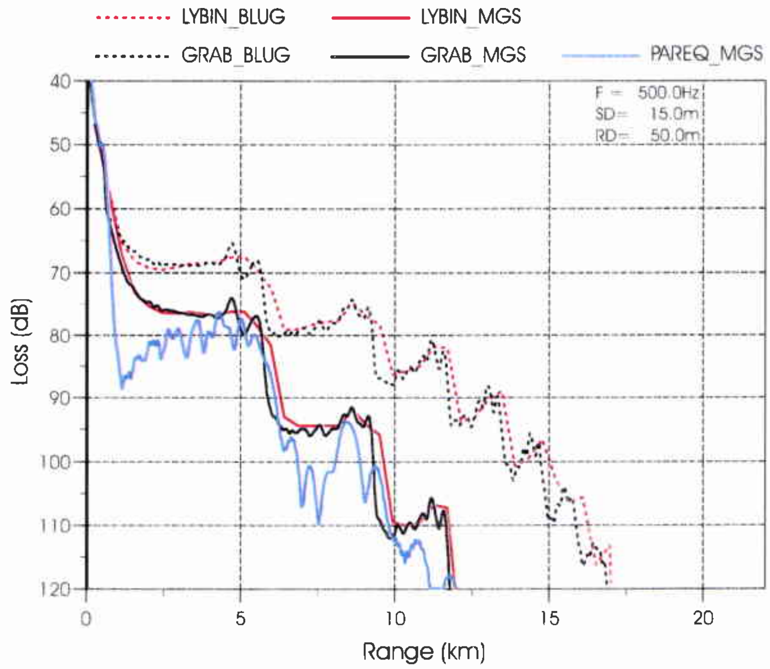

Figure 22 *Track B – upslope: Model predictions at 500 Hz for source at 15 m and receiver at 50 m.*

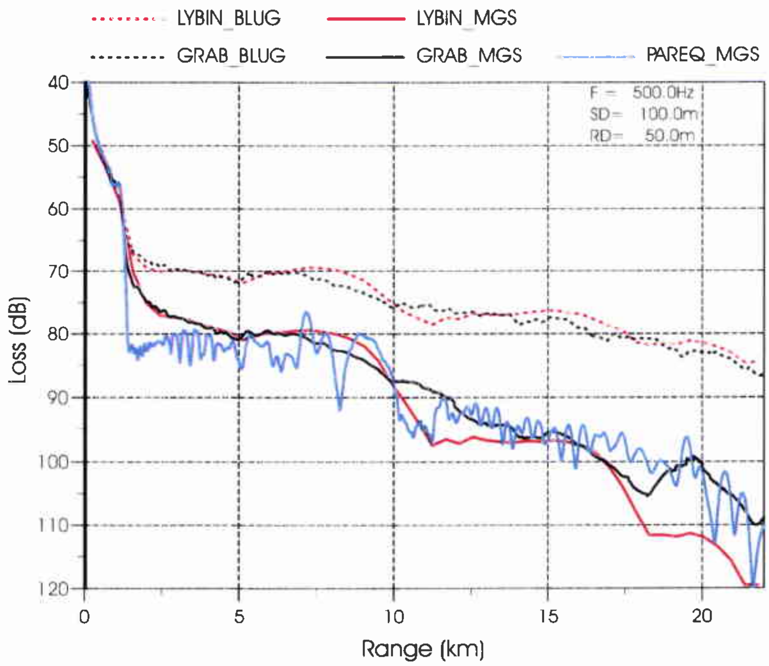

Figure 23 *Track B – upslope: Model predictions at 500 Hz for source at 100 m and receiver at 50 m.*

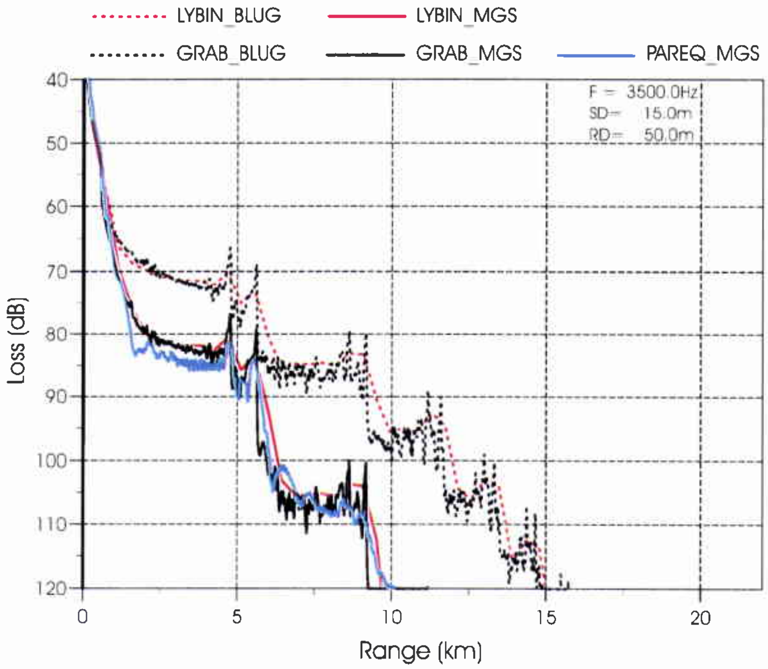

Figure 24 *Track B – upslope: Model predictions at 3500 Hz for source at 15 m and receiver at 50 m.*

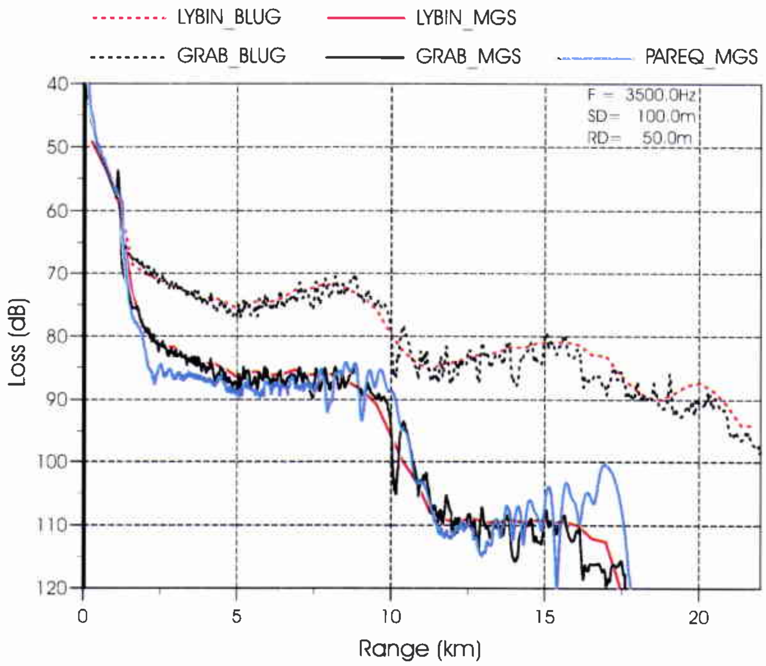

Figure 25 *Track B – upslope: Model predictions at 3500 Hz for source at 100 m and receiver at 50 m.*

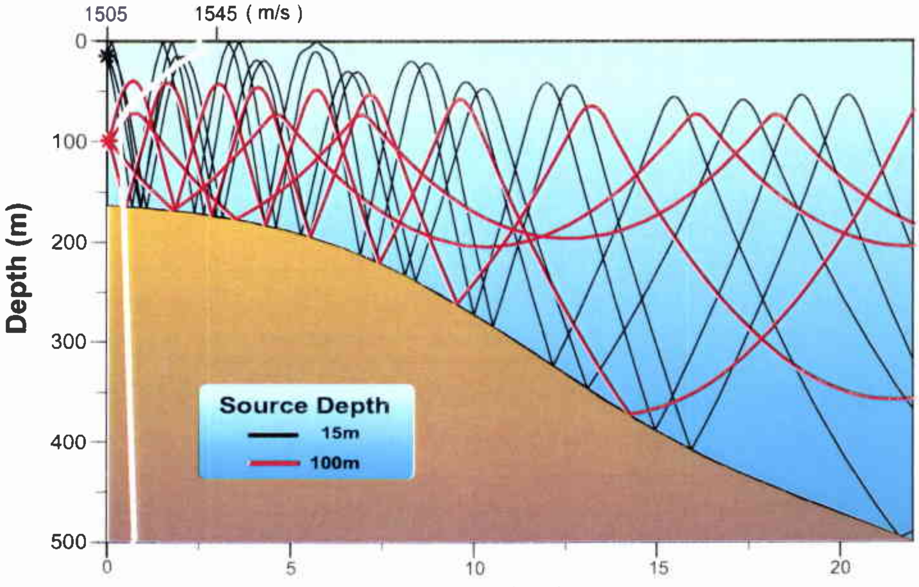

Figure 26 *Track B – downslope: Ray diagrams for two different source depths.*

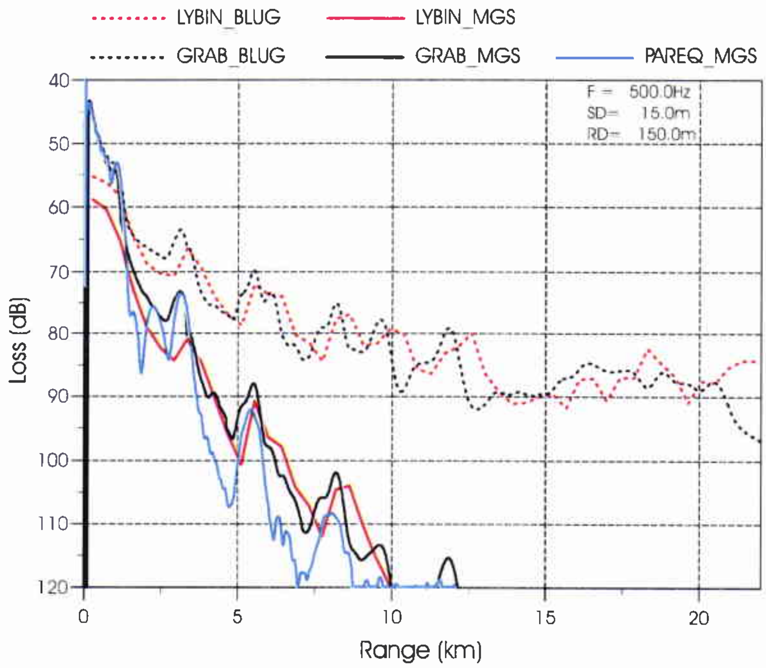

Figure 27 *Track B – downslope: Model predictions at 500 Hz for source at 15 m and receiver at 150 m.*

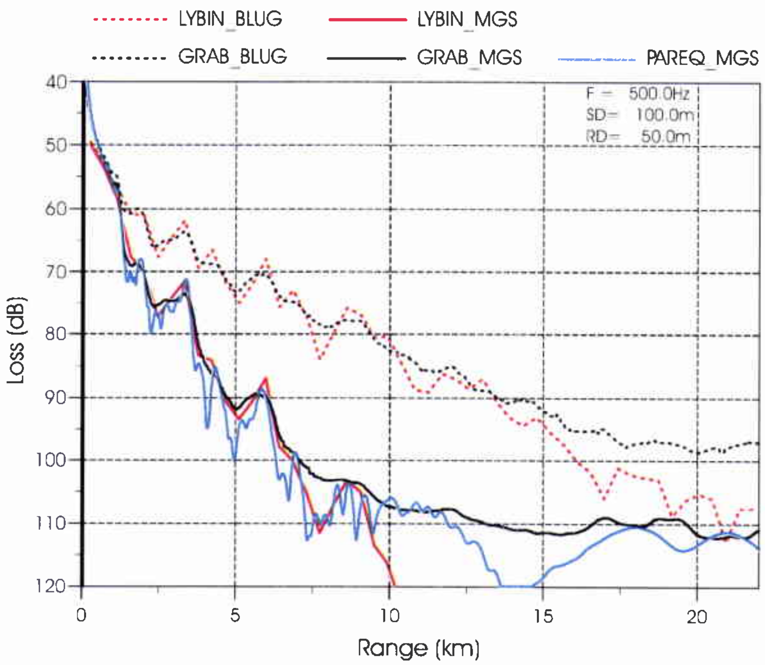

Figure 28 *Track B – downslope: Model predictions at 500 Hz for source at 100 m and receiver at 50 m.*

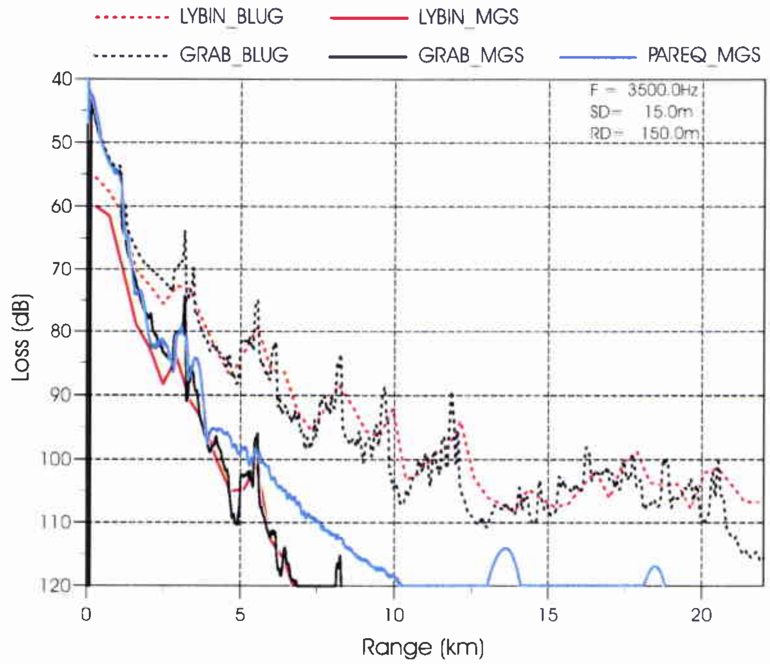

Figure 29 *Track B – downslope: Model predictions at 3500 Hz for source at 15 m and receiver at 150 m.*

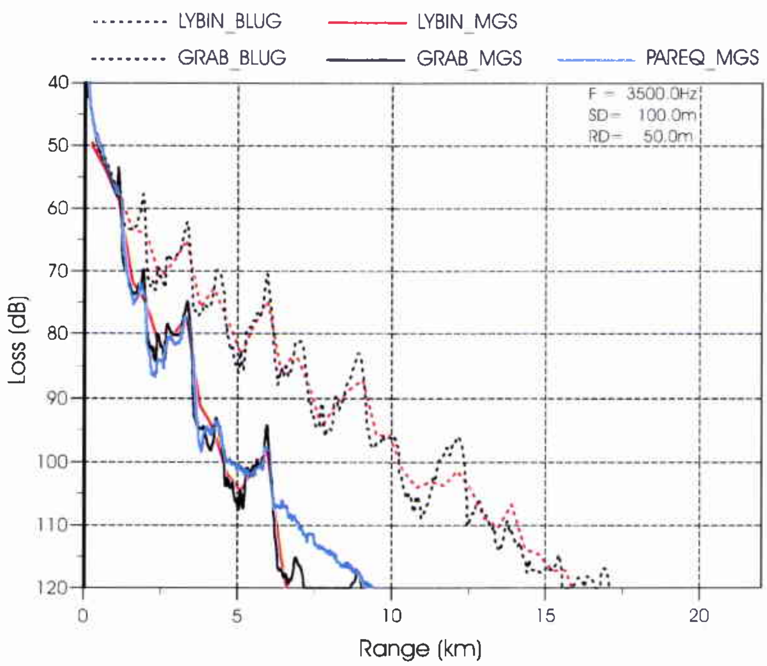

Figure 30 *Track B – downslope: Model predictions at 3500 Hz for source at 100 m and receiver at 50 m.*

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Title

Performance assessment of the LYBIN-2.0 propagation-loss model

Abstract

A new acoustic model LYBIN has been proposed for inclusion in the AESS model set. In order to determine this model's prediction accuracy and computational efficiency, SACLANTCEN was tasked to test LYBIN on exactly the same set of propagation problems used earlier for validating the current set of AESS models (ASTRAL, MOCASSIN, PE, PROLOS, RAYMODE, SUPERSNAP). The general conclusion of this test is that the range-dependent ray-trace model LYBIN, developed by the Norwegian Navy, is indeed a valid alternative to existing propagation models in the AESS. The LYBIN model has a prediction accuracy similar to the GRAB 'reference' model but is considerably faster.

Keywords

acoustic models – propagation loss – range dependence – sonar models

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