Image Cover Sheet

CLASSIFICATION UNCLASSIFIED	**SYSTEM NUMBER** 498212

TITLE

COMPUTING SHIP RESOLUTION GAIN FOR HORIZONTAL TOWED ARRAYS

System Number:

Patron Number:

Requester:

Notes:

DSIS Use only:

Deliver to:

National Defence
Research and
Development Branch

Défense nationale
Bureau de recherche
et développement

TECHNICAL MEMORANDUM 96/211
March 1996

COMPUTING SHIP RESOLUTION GAIN FOR HORIZONTAL TOWED ARRAYS

David W. Craig

Defence
Research
Establishment
Atlantic

Centre de
Recherches pour la
Défense
Atlantique

Canada

DEFENCE RESEARCH ESTABLISHMENT ATLANTIC

9 GROVE STREET

P.O. BOX 1012
DARTMOUTH, N.S.
B2Y 3Z7

TELEPHONE
(902) 426-3100

CENTRE DE RECHERCHES POUR LA DÉFENSE ATLANTIQUE

9 GROVE STREET

C.P. BOX 1012
DARTMOUTH, N.É.
B2Y 3Z7

National Defence
Research and
Development Branch

Défense nationale
Bureau de recherche
et développement

COMPUTING SHIP RESOLUTION GAIN FOR HORIZONTAL TOWED ARRAYS

David W. Craig

March 1996

Approved by C.W. Bright
Deputy Director General

Distribution Approved by

C.W. Bright
Deputy Director General

TECHNICAL MEMORANDUM 96/211

Defence
Research
Establishment
Atlantic

Centre de
Recherches pour la
Défense
Atlantique

Canada

Abstract

Prediction of sonar performance is an essential step in the design and development of large sonar systems. The sonar equation[1,2] is most often used to predict detection performance, assuming constant mean values for signal and noise. Unfortunately, this analysis fails to account for changes in mean signal and noise conditions that may vary over hours, days or months. In the case of shipping noise and a horizontal towed array, the mean noise background may vary dramatically as ships move in and out of the main lobe of the beam pattern of a receiver. This report shows that computing probability density functions for actual receiver beam patterns, as well as imposing a constant ambient noise background over individual ship interferers, greatly alters Ship Resolution Gain (SRG) estimates. This is particularly true at low shipping densities, where the difference in SRG estimates may approach 30 dB. Lower SRG estimates are likely more representative of realistic ocean environments.

KEYWORDS: Sonar, Ship Resolution Gain, Towed Arrays

Résumé

La prédiction de performance d'un sonar s'avère une étape essentielle dans la conception et le développement de grands systèmes de sonar. L'équation de sonar[1,2] s'utilise le plus souvent pour prédire la performance de détection, des valeurs moyennes constantes pour le signal et le bruit étant présumées. Malheureusement, cette analyse ne rend pas compte des changements des conditions moyennes de signaux et de bruit qui peuvent varier à travers des heures, des jours ou des mois. Dans le cas du bruit de trafic maritime et d'un réseau remorqué horizontal, le bruit de fond moyen peut varier d'une manière frappante lorsque les bâtiments entrent et sortent du pétale principal du diagramme directionnel de rayonnement d'un récepteur. Ce rapport montre que la computation des fonctions de densité de probabilitè pour de véritables diagrammes directionnels de rayonnement des récepteurs, aussi bien que l'imposition d'un fond de bruit ambiant constant au-dessus des bâtiments individus perturbateurs, change grandement le calcul du SRG (Ship Resolution Gain), c-â-d. gain de résolution de bâtiments. Ceci s'applique particulièrement aux densités de trafic maritime basses où la différence des calculs du SRG peut s'approcher de 30 dB. Les calculs de SRG moins élevés sont probablement plus représentatifs des environnements de l'océan réels.

MOTS CLÉS: Sonar, Gain de Résolution de Bâtiments, Réseaux Remorqués

EXECUTIVE SUMMARY

COMPUTING SHIP RESOLUTION GAIN FOR HORIZONTAL TOWED ARRAYS

David W. Craig

Defence Research Establishment Atlantic
Esquimalt Defence Research Detachment

DREA Technical Memorandum 96/211

Background

Low frequency passive towed array sonars, such as CANTASS and SUBTASS, operate in the frequency band dominated by noise from surface ships. Determining the performance capabilities of these sensors for system design, deployment planning and operational use requires a description of the noise background. In the past, shipping noise has been assumed to be uniformly distributed in the horizontal plane. However, for arrays with sufficient bearing resolution to be able to isolate individual noise sources, this assumption is clearly invalid. In such cases, an array looking directly at one or more of the sources will see a high noise level, and hence will have poor detection performance in that direction. However, if the array 'looks between' the noise sources, a much lower noise level and correspondingly better detection performance will arise in those directions.

In order to provide a better model of the shipping noise background, and hence be able to model this performance variation, other investigators have proposed the use of an additional gain factor, called Ship Resolution Gain, to account for this ability to look at the holes in the noise background. Because of some simplifications, however, their model predicts that if there are no ships within a given array beam, the noise will be essentially non-existent, giving rise to extremely high gains. Array ambient noise measurements by the present author have shown that this is not the case in practice, hence a more realistic model of the noise is required. This is the subject of the current investigation.

Principal Results

This paper describes a new model for Ship Resolution Gain (SRG) which produces gain values that are consistent with the results of the experimental trials. Unlike the original SRG model, this new version includes a realistic implementation of the array beam patterns and a diffuse background noise which prevents the gains from

becoming inordinately large.

Significance of Results

By developing a more realistic model we are in a better position to make reliable predictions of array detection performance in noise dominated by ship traffic. This will be of use in designing and evaluating new array configurations, as a planning aid for exercises and deployments where towed arrays will be used, and as an operational tool for selecting optimal positioning and look directions while on patrol.

Future Work

This research activity has been closed as a result of the closure of the Defence Research Establishment Pacific. However, a number of enhancements are proposed which should be considered if the work be re-activated in the future. These include adding a detailed model of shipping lanes, adding discrete interference sources (e.g., oil tankers, drilling platforms, etc.) and allowing for an asymmetrical background noise. These modifications would increase the accuracy of the performance predictions for the relevant scenarios.

Introduction

Prediction of sonar performance is an essential step in the design and development of large sonar systems. The sonar equation[1,2] is most often used to predict detection performance, assuming constant mean values for signal and noise. Unfortunately, this analysis fails to account for changes in mean signal and noise conditions that may vary over hours, days or months. In the case of shipping noise and a horizontal towed array, the mean noise background may vary dramatically as ships move in and out of the main lobe of the beam pattern of the receiver. While the spatial shipping distribution may be considered fixed over the period of a few minutes of integration time, after a few hours or days the number and disposition of ships contributing to the acoustic field will change substantially. Typical performance assumptions for shipping noise assume that the noise background has constant mean power in azimuth. Large aperture towed array receivers are usually able to resolve individual ships within the noise field background as a result of narrow beamwidth, and detection performance can be greatly enhanced if the desired signal lies in an area of low noise between individual ship interferers. Conversely, detection performance can be much worse than average if the desired signal lies in an area of high shipping noise concentration.

The implications of noise source resolution on detection performance of towed array receivers has been shown to be substantial. The term " Ship Resolution Gain " (SRG) was used[3] to describe the change in detection probability when mean signal and beam noise variations are taken into account. This gain was defined as the change in mean signal-to-noise ratio required to achieve the same detection probability in the presence of a constant noise background, and as such was a supplemental term to the sonar equation. The magnitude of the SRG term was estimated[3] to be over 30 dB for towed arrays with moderate to high directivity operating in low shipping densities. This estimate was based on a number of simplifying assumptions, including a constant-value sidelobe and mainlobe beam pattern for a Hann-shaded array, a zero noise floor between ship interferers and broadside-only beam steering. Subsequent work by Heitmeyer retained these simplifying assumptions but extended the results to include the effect of shipping noise anisotropy and sidelobe degradation[4] as well as the effect of range dependent transmission loss and different source level probabilities.[5]

As noted by Heitmeyer,[4] the magnitude of SRG estimates depends greatly upon the specific assumptions made about the noise field and the array receiver. The assumption of an approximate beam pattern with constant main and sidelobe levels coupled with a negligible noise floor between ship interferers[4,5] constrained the received beam noise levels to an artificially narrow range. While these assumptions were useful for obtaining analytic closed form solutions, numerical evaluation of probability density functions (pdf's) for specific array shadings and more general noise fields is required to more accurately model the range of received beam noise levels. This paper shows that computing pdf's for actual receiver beam patterns leads to a greater range of received beam noise values and consequently higher SRG values. Conversely, imposing a constant ambient noise background over individual ship interferers lowers the range of received beam noise and greatly lowers SRG estimates. Lower SRG estimates are in agreement with simulation results reported earlier[6] for realistic ocean environments and are likely more representative of achievable detection performance.

Beam Noise Models

The method for computing average detection probability is the sonar equation[1,2] which establishes the mean signal-to-noise ratio necessary to achieve a given level of performance. Signal excess (SE) is defined as the ratio of signal to noise needed to achieve a given probability of detection (P_d). The dependence of P_d on SE is described by a transition curve, $P_d(SE)$, computed for a given false alarm rate. This curve is based on short term fluctuation statistics that assume constant mean levels for both signal and noise. With a towed array receiver operating in a shipping noise environment, the mean noise level for each beam varies (on the order of hours to days) as a result of ships moving in and out of the main lobe, and through changes in the number of ships contributing to the sidelobe region. The fluctuations in dB for mean noise level relative to the ensemble long term average is represented by a pdf denoted $f_N(z)$. The long term transition curve $P_{dl}(SE)$, assuming a constant mean signal level and accounting for fluctuations in mean noise level, is given by[3]:

$$P_{dl}(SE) = \int_{-\infty}^{+\infty} P_d(z) f_N(SE - z) dz \tag{1}$$

In the short term, however, noise anisotropy can allow detections (in some directions) when the signal excess is significantly lower. SRG is simply the difference in signal-to-noise ratio necessary for the same probability of detection in the two cases. Defining $SE(P_d)$ as the signal excess required to attain a given P_d (the inverse of a transition curve), SRG is described as the difference of the two curves:

$$SRG(P_d) = SE_{dl}(P_d) - SE(P_d) \tag{2}$$

The computation of SRG may be simplified for the special case of $P_d = 0.5$ and a step function approximation for the fluctuation distribution function $F_N(z)$. For this special case, it may be shown by substitution in equation 1 that SRG is simply the negative of the dB value for normalized beam noise at the median of the fluctuation distribution function[3]:

$$SRG = -F_N^{-1}(0.5) \tag{3}$$

Typical beam noise fluctuation models assume that the shipping noise background consists of a random number of ships contributing to the acoustic field. The usual assumption is that the number of contributing ship interferers is governed by a Poisson density.[7,8,3] Time-independent beam noise models assume ergodicity and create density functions based on ensemble averages over all possible variations in number of ships, source level variations, transmission losses and ship locations. Such models are most appropriate for prediction of beam noise variation over the very long term, i.e., weeks or months. For prediction of shorter term variations in mean beam noise level, time-dependent statistics must be generated. This report will only be concerned with time-independent beam-noise models.

Evaluation of Beam Noise PDF's

The usual approach to computing time-independent beam shipping noise pdf's is to treat the total beam power as a finite sum of contributions from surface ships and include an additive, empirical omnidirectional noise term to represent wind noise and unresolved shipping.[7] The ocean area contributing to beam noise is assumed to be of finite extent and contains a random number of ships. The number of ships within this ocean area is normally assumed to be governed by a Poisson distribution.

Each ship noise contribution to the total beam noise power depends on the ship position relative to the receiver, the source level, the transmission loss from the ship to the receiver, and the receiver beam pattern. The narrowband source level for each ship is assumed to be a random variable with pdf $f_s(y)$ and characteristic function $\phi_s(\omega)$. The position $z(r,\theta)$ of each ship is assumed to be distributed randomly within a radius of contribution R_s around the array receiver with pdf $f_z(r,\theta)$. The transmission loss from source to receiver is assumed to have both a deterministic component T_D, dependent on ship position, and a stochastic component T_R, for a combined random transmission loss with pdf $f_T(y)$ and characteristic function $\phi_T(\omega)$. The receiver is assumed to be a horizontal towed array with receiver beam pattern $B(\theta)$, beampower pdf $f_B(y)$ and characteristic function $\phi_B(\omega)$. The assumption is made that shipping noise arrives in the horizontal plane and that beam reception is dependent only on arrival angle to the array. The narrowband noise contribution from each ship is $N(z)$ where the characteristic function $\phi_N(z)$ of the noise pdf $f_N(y)$ is expressed as:

$$\phi_N(\omega) = \phi_S(\omega)\phi_B(\omega)\phi_T(\omega) \tag{4}$$

At any time t there will be $M(t)$ ships in radius R of the ocean area, with the kth ship contributing N_k to the noise field. The cumulative noise summation N_T, including an azimuthally omnidirectional background N_0, is given by:

$$N_T = \sum_{k=1}^{M(t)} N_k + N_0 \tag{5}$$

Assuming that P_k represents the probability that k ships are present at any time t, the characteristic function for the cumulative noise pdf for long term noise statistics is given by:

$$\phi_{N_T}(\omega) = \sum_{k=1}^{\infty} \phi_N^k(\omega)\phi_{N_0}(\omega)P_k + \phi_{N_0}(\omega)P_0 \tag{6}$$

If the number of contributing ships is governed by a Poisson distribution, this summation may be expressed as:

$$\phi_{N_T}(\omega) = \phi_{N_0}(\omega)e^{(M\phi_N(\omega)-1)} \tag{7}$$

The expected value for the cumulative beam noise is computed from 7 as:

$$E[N_T] = E[N_0] + ME[N] \tag{8}$$

Numerical Computation of Beam Noise PDF's

Given the multi-valued functional relationship between the position variable and resultant transmission loss and beam value, it is difficult to compute analytic expressions for shipping noise pdf's. The method in[3,4] was used to avoid multi-valued functional relationships by approximating the deterministic component of transmission loss as a constant or linear loss and using a simple two-level beam pattern for the array receiver. While this approach permits analytic expression for cumulative noise characteristic functions, it is only a first-level approximation to the more complex functional relationships that exist.

In order to evaluate multi-valued functions for transmission loss and beam patterns, a numerical approach must be taken in regard to evaluation of beam noise pdf's. The pdf $f_X(x)$ may be approximated by a histogram $p_x(n)$ as:

$$p_X(n) = f_X(n\Delta x)\Delta x \tag{9}$$

Assuming that $Y = g(X)$ represents the functional relationship and $X = h(Y)$ is the (possibly) multivalued inverse function of degree n, the histogram $p_Y(m)$ for the inverse function $h(Y)$ is given by:

$$p_Y(m) = \sum_{k=1}^{n(m)} p_X(k) \tag{10}$$

Characteristic functions are approximated numerically using an inverse discrete Fourier transform of the sampled values of the pdf as:

$$\phi(k\Delta\omega) = \Delta x \; IFFT(f_X(n\Delta x)) \tag{11}$$

As part of the computation of beam noise pdf's, it is frequently necessary to compute the pdf in both the linear and logarithmic domain. Using sampled values of the pdf, the transformation from the linear to log domain is given by:

$$f_Y(n\Delta y) = \frac{1}{\Delta y} f_X(10^{\frac{n\Delta y}{10}})(10^{(n\Delta x + \frac{\Delta x}{2})/10} - 10^{(n\Delta x - \frac{\Delta x}{2})/10}) \tag{12}$$

Similarly, the transformation from the logarithmic to linear domain is given as:

$$f_Y(n\Delta y) = \frac{1}{\Delta y} f_X(10log(n\Delta y))(10log(n\Delta x + \frac{n\Delta x}{2}) - 10log(n\Delta x - \frac{n\Delta x}{2})) \tag{13}$$

Numerical Example for SRG

To illustrate the effect of noise field and array receiver assumptions, SRG will be evaluated numerically for specific examples of array shadings and noise backgrounds. A 32-element array is assumed to be towed in an ocean area with a number of ships contributing to the background noise field. For the purposes of this example, a radius of contribution $R = 500$ kilometres will be assumed. The number of ships contributing to the noise field is assumed to be distributed uniformly throughout the area, with the total number in the region governed by a Poisson distribution. Transmission loss (TL) in this area consists of a deterministic loss portion determined by range, shown in Figure 1 and a stochastic portion consisting of random fluctuations in range. The stochastic portion is assumed be governed by an exponential distribution function with unity mean, to facilitate comparison to previous SRG estimates.[4,5]

The receiver hydrophone array elements are assumed to be weighted according to either Uniform, Kaiser-Bessel, Hanning or Taylor weights. Figure 2 shows the beam pattern produced for Hanning weights when the beam steering angle is broadside to the array. The approximation to this beam pattern, also shown in the Figure, is based on equivalent matching power ratio for the mainlobe-to-sidelobe area as well as equivalent integral power in the linear domain. This approximate pattern was used in previous studies[3] to avoid computation of the beam power pdf, but as illustrated in Figure 2, this equivalent pattern has much higher sidelobe levels and a narrower mainlobe than the true beam pattern.

To facilitate comparison with results presented earlier,[3] SRG values computed for the various hydrophone weightings will first be shown for the case of stochastic TL fluctuations only, and with no omnidirectional noise background. Figure 3 shows the Ship Resolution Gain (SRG) computed for the approximate beam pattern for each of the four hydrophone weightings. The approximate sidelobe and mainlobe values are shown in Table I. As can be seen in Figure 3, hydrophone weighting for the approximate beam pattern makes little difference to the overall SRG. At higher ship densities, larger values of SRG result from smaller beamwidths, with Uniform weighting having the largest value. Figure 4 shows the same computation for actual, rather than approximate, beam patterns. The use of actual beam patterns, with much lower sidelobe levels, results generally in increased SRG values for shipping densities up to 20 ships in the region. The most marked difference is exhibited by Hanning weighting for low shipping densities, where the much lower sidelobe levels of the true beam pattern result in very high SRG values. For shipping densities up to 10 ships in the region, this difference is in excess of 30 dB over the approximate pattern.

Clearly, the high SRG values in Figures 4 and 5 are not realistic and are reflective of the assumption of the absence of any noise background other than discrete ship interferers. As the mean number of discrete interferers decreases, or directivity increases, the likelihood of encountering near-zero beam noise increases and high gain values result. Figure 5 imposes a constant noise background equal to the average source level of discrete ship interferers. The effect of an omnidirectional background is to reduce the overall values of SRG in proportion to the background level, and causes the gain to decrease to zero with the mean number of discrete interferers: in the limit of no discrete interferers, the noise background approaches a constant value, where, by definition, there is no SRG. The maximum level of SRG attained depends on the ratio between the constant omnidirectional noise and the average level of discrete interferers. The SRG will decrease in proportion to the magnitude of background omnidirectional noise.

Explicit numerical evaluation of the beam noise pdf also permits comparison of SRG as a function of beam steering angle. Figure 6 shows the increase in SRG as the beam steering angle approaches broadside. The dependence of SRG on beam angle is inversely proportional to beamwidth and is similar to the functional relationship for array gain.

The dependence of SRG on directivity index is shown in Figure 7. As directivity increases, beamwidth decreases and SRG levels rise due to the increased likelihood of low noise levels. In general, lower sidelobe levels contribute to the highest SRG values for Hanning weights and the lowest values for Uniform weights.

The effect of deterministic TL fluctuations is shown in Figure 8, for the case of uniformly distributed shipping in the radius of contribution. The net effect of including deterministic fluctuations caused by random ship interferer positions is to increase SRG by approximately 3 dB over the range of shipping densities. This gain supplement is dependent on the ship position pdf and would likely decrease if ship positions were to be constrained to regions such as shipping lanes.

Summary

This report has described a numerical approach to computing Ship Resolution Gain (SRG) which accounts for the effect of array weighting, deterministic transmission loss (TL) and omnidirectional background noise superimposed on discrete ship interferers. Previous work in computing SRG assumed an approximate two-level beampattern, constant or linear deterministic TL and zero omnidirectional background noise. Computation of the beam noise pdf's for four array weighting (Hanning, Uniform, Taylor and Kaiser-Bessel) showed that the use of actual, rather than approximate beam patterns significantly alters previously reported SRG predictions.

Comparison of computed SRG levels differ by up to 30 dB for low shipping densities. Lower sidelobes in actual beam patterns result in elevated SRG levels due to the probability of low beam noise levels. Specific computations for a 32-element array showed that Hanning weights resulted in the highest SRG among the weighting schemes examined.

The assumption that the noise field consists entirely of discrete interferers, with no omnidirectional noise floor due to wind or unresolved noise sources, leads to unrealistically high SRG values. This is particularly true for arrays with high directivity index, or low shipping densities where individual interferers are resolved. As in the previous case, the highest gain values were exhibited by the array weighting with the lowest sidelobe levels. When a constant omnidirectional background noise level was added to the noise field of discrete interferers, overall SRG decreased substantially and, in fact, decreased to zero as discrete interferers were eliminated from the noise field. Comparative SRG values for the various array weightings were dependent on omnidirectional background level, beamwidth and sidelobe structure, the effects of which were not clearly predictable without numerical evaluation.

Two other examples were presented to show the effect of numerical computation of beam pdf's. SRG was shown to be maximized with beam steering angle at broadside and decreased as beamwidth increased toward the front and rear of the array. Lastly, inclusion of deterministic transmission loss fluctuations was shown to increase SRG by approximately 3 dB over stochastic fluctuations alone.

This report has briefly considered the numeric evaluation of SRG, with the intent of providing more realistic supplemental gain values for inclusion in system performance predictions. While general results indicate lower SRG values should be used than previously reported,[3,4] specific SRG computation needs to be done for each case of shipping density, array weighting, directivity index, beam angle and background omnidirectional noise level. Future work in SRG computation could investigate the effects of shipping lanes, discrete interferers and asymmetrical background noise to increase the generality of the predictions.

TABLE I. Beamwidth and sidelobe levels for approximate beam patterns.

Weighting	Beamwidth (Degrees)	Sidelobe Level (dB)
Hanning	5.55	-22.0
Kaiser-Bessel	4.57	-22.9
Taylor	4.16	-23.2
Uniform	3.62	-23.3

REFERENCES

[1] R. J. Urick, *Principles of Underwater Sound.* McGraw-Hill Book Company, Third Edition, 1973.

[2] W. S. Burdic, *Underwater Acoustic System Analysis.* Prentice-Hall, Inc., Second Edition, 1991.

[3] R. Heitmeyer, L. Davis, and N. Yen, "Implications of noise source resolution on detection performance for horizontal directional systems operating in ship-induced noise fields," Tech. Rep. NRL Report 8863, Naval Research Laboratory, February 1985.

[4] R. Heitmeyer, "Properties of beam-noise fluctuations for horizontal arrays in ship induced noise fields," Technical Report SR-116, SACLANTCEN ASW Research Centre, April 1988. [AD A 197 248].

[5] R. Heitmeyer, "A model for beam noise fluctuations for a horizontal array operating in a ship induced noise field," Technical Report SR-152, SACLANTCEN Undersea Research Centre, April 1989.

[6] D. Craig and L. Tan, "Beam noise and array gain models for computing ship resolution gain," *J. Acoust. Soc. Am.*, vol. 92, p. 2305, October 1992.

[7] Science Applications, Inc., McLean, VA, *Reviews of Models of Beam Noise Statistics*, November 1977. [AD A 055 728].

[8] M. Moll, R. Zeskind, and W. Scott, "An algorithm for beam-noise prediction," Tech. Rep. BBN 3653, Bolt, Berenek and Newman, Inc, Arlington, VA, 1979. [AD A 076 615].

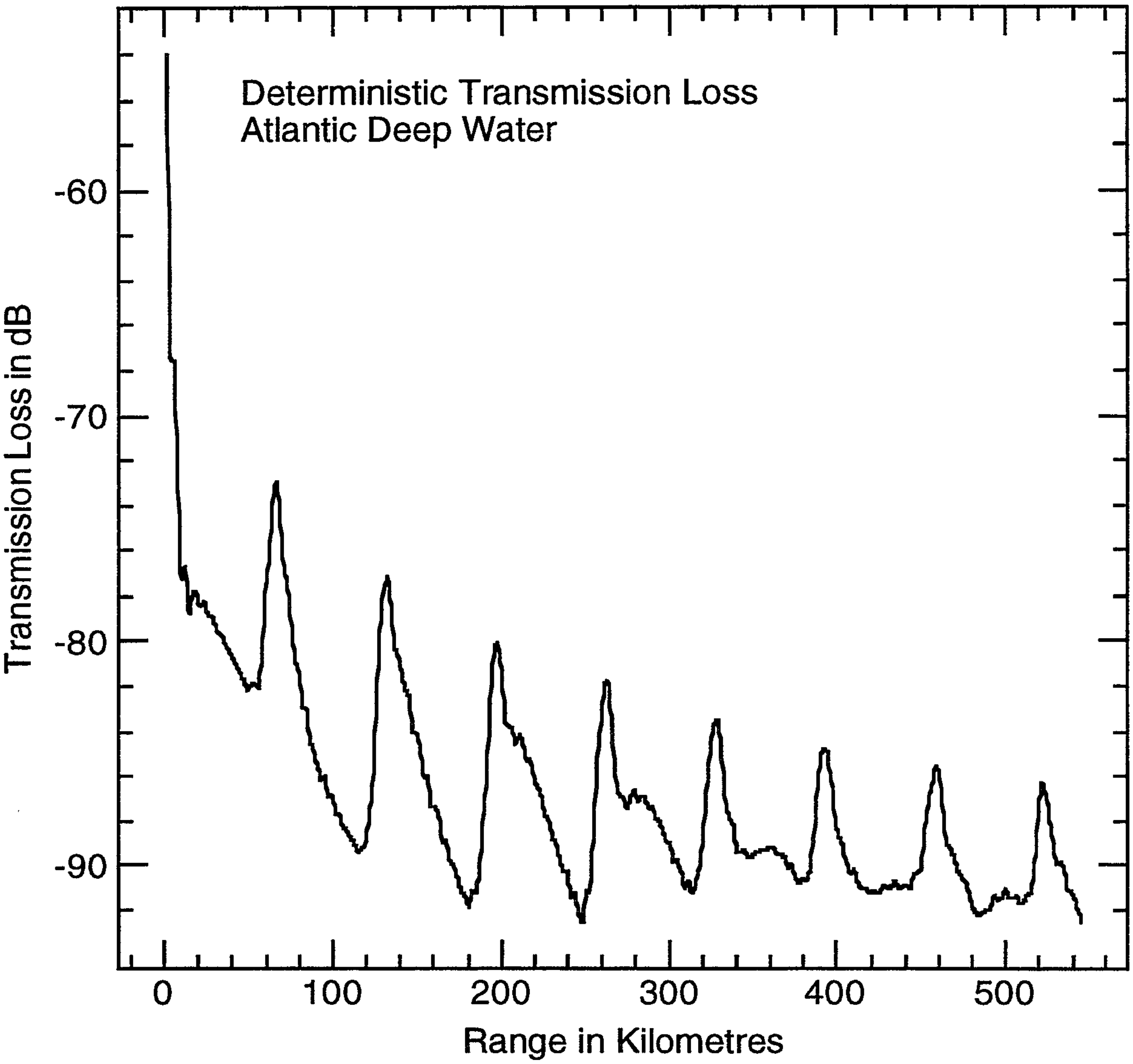

FIG. 1. Example deterministic transmission Loss for the Atlantic deep water region, showing typical convergence zone behavior.

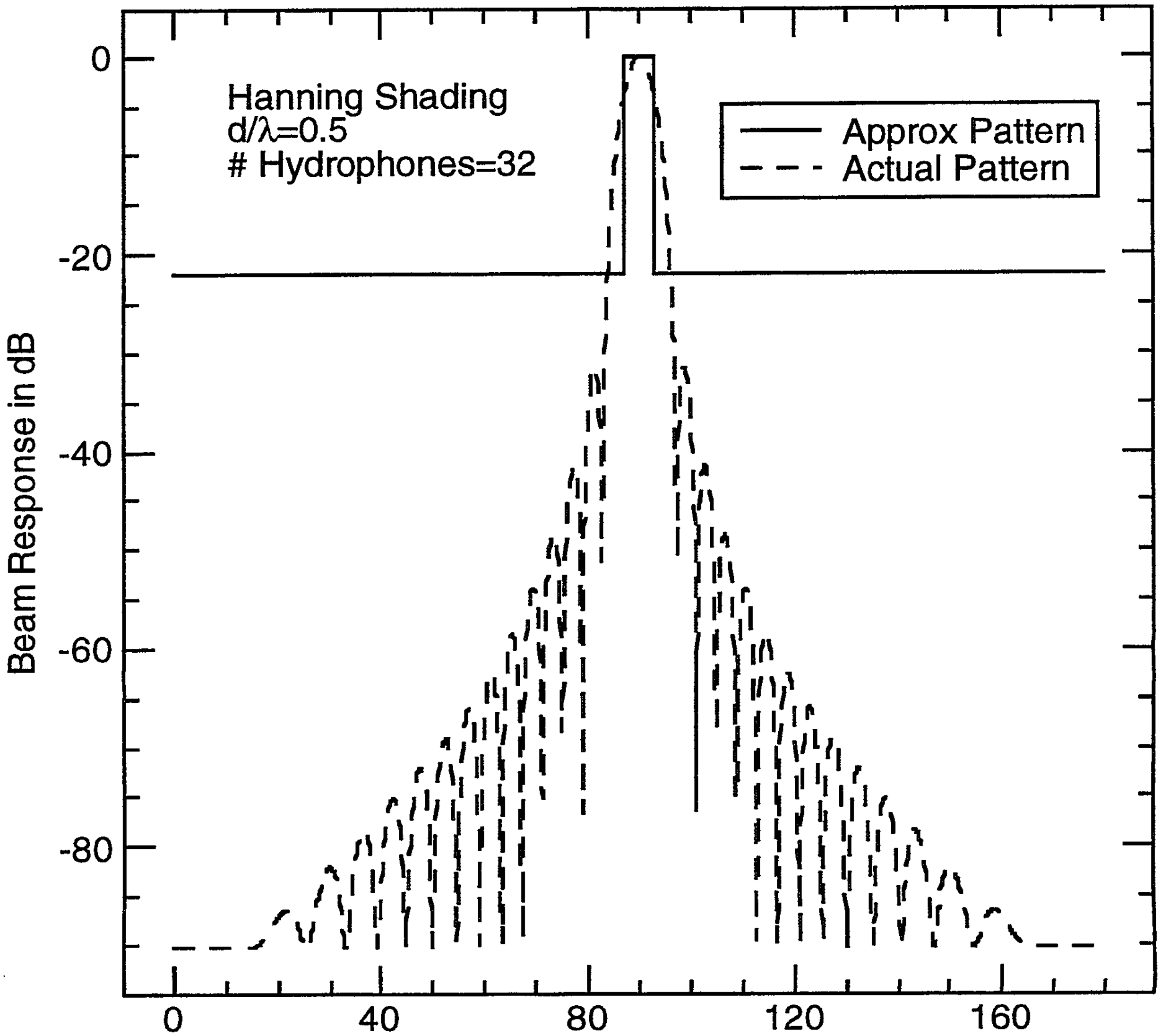

FIG. 2. Actual and approximate beam patterns for Hanning Weighting.

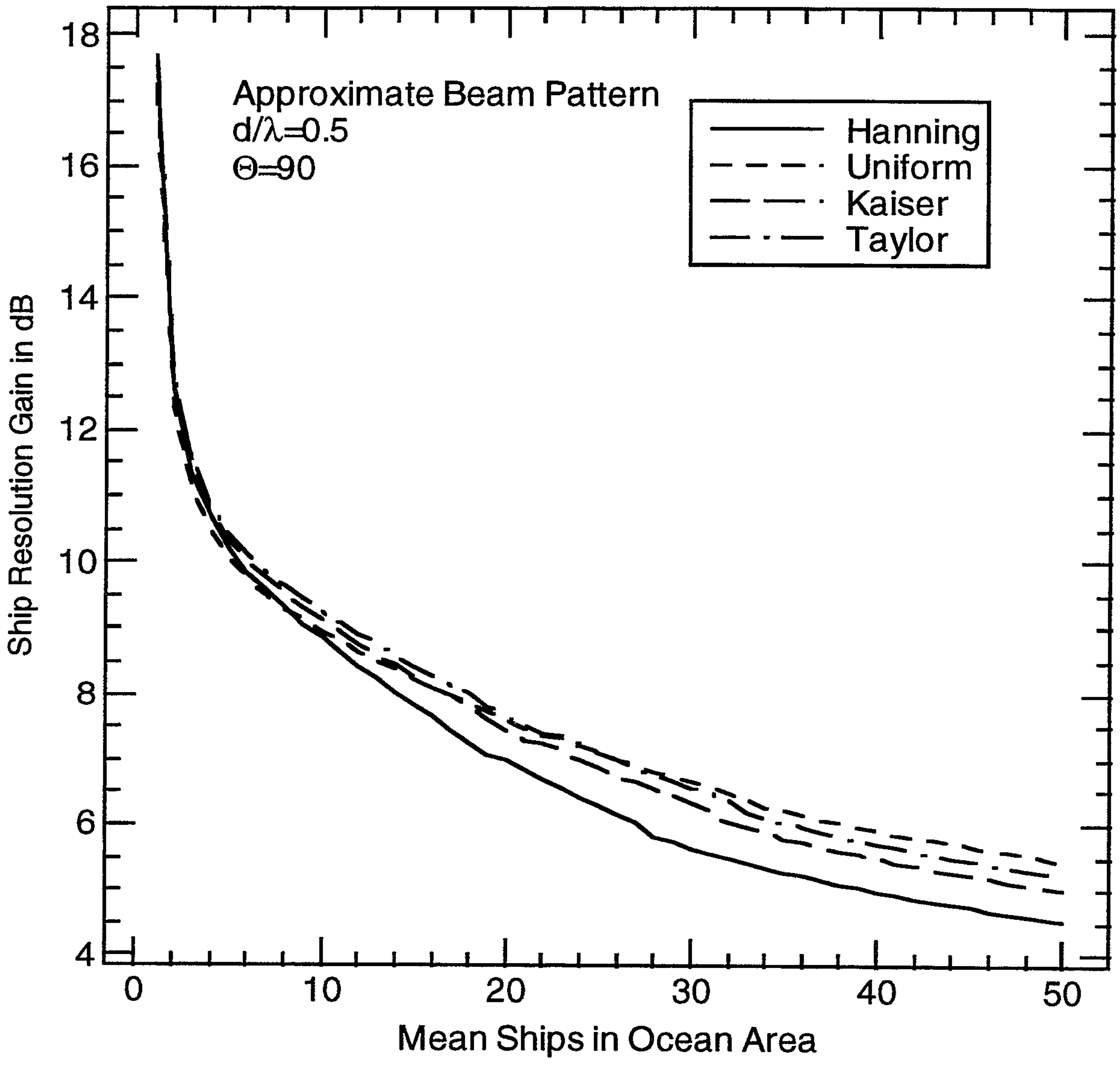

FIG. 3. Ship Resolution Gain for the approximate beam patterns, assuming discrete ship interferers with no background noise and exponential transmission loss fluctuations.

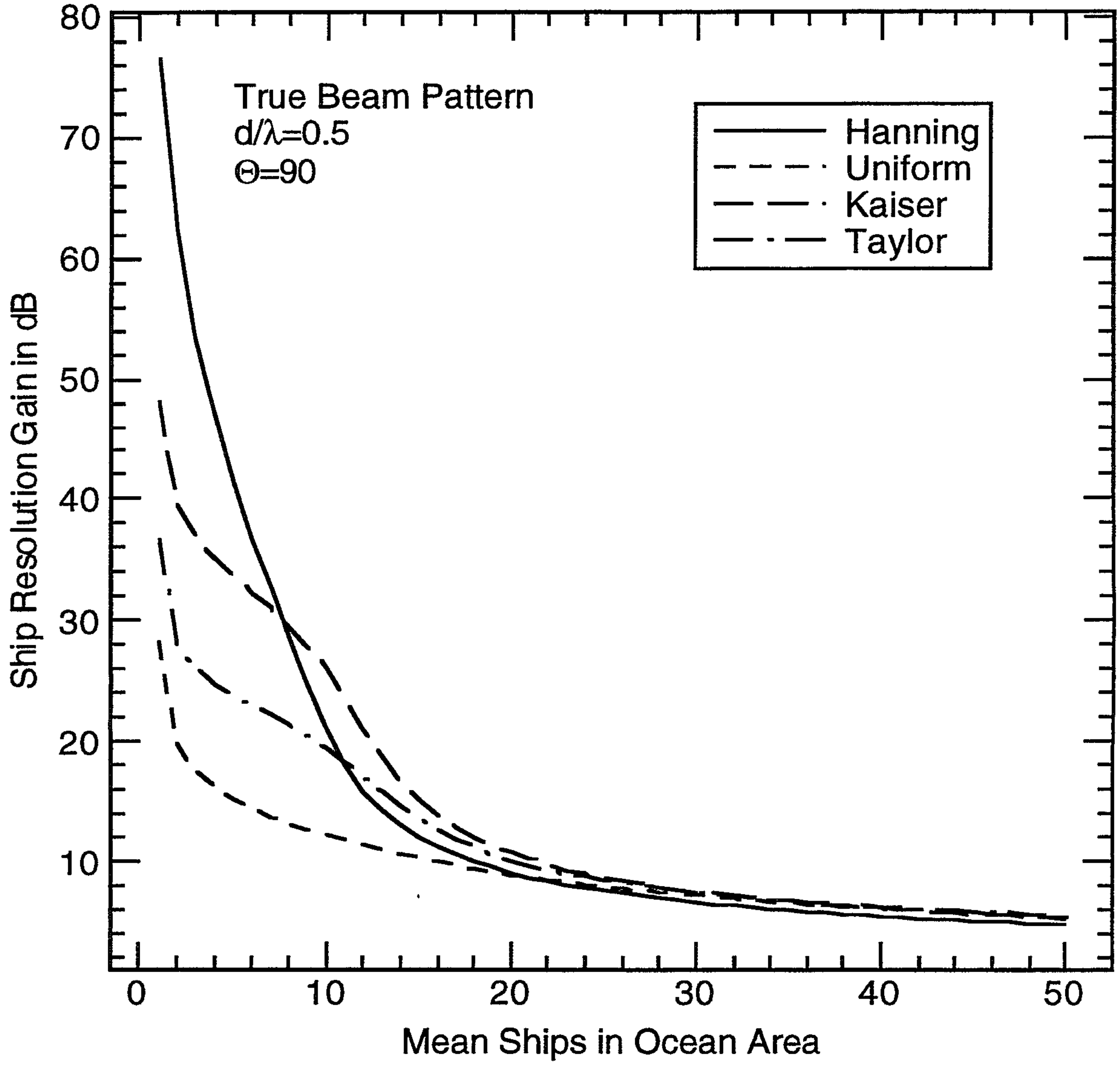

FIG. 4. Ship Resolution Gain for Hanning, Uniform, Kaiser-Bessel and Taylor weighting and a broadside beam steering angle.

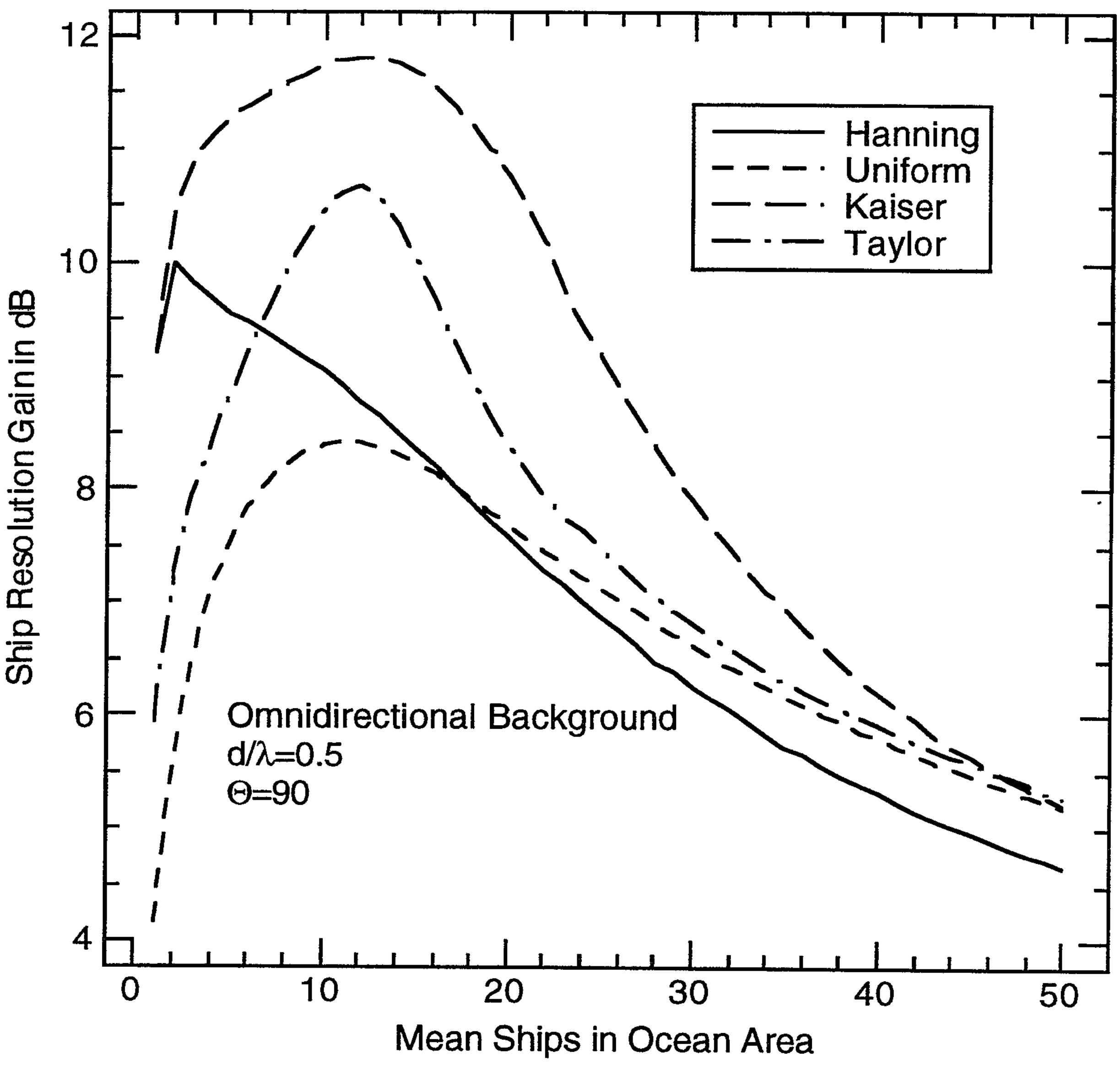

FIG. 5. Ship Resolution Gain for the actual beam patterns, assuming discrete ship interferers with constant background noise of the same source level as a single ship and exponentially-distributed transmission loss fluctuations.

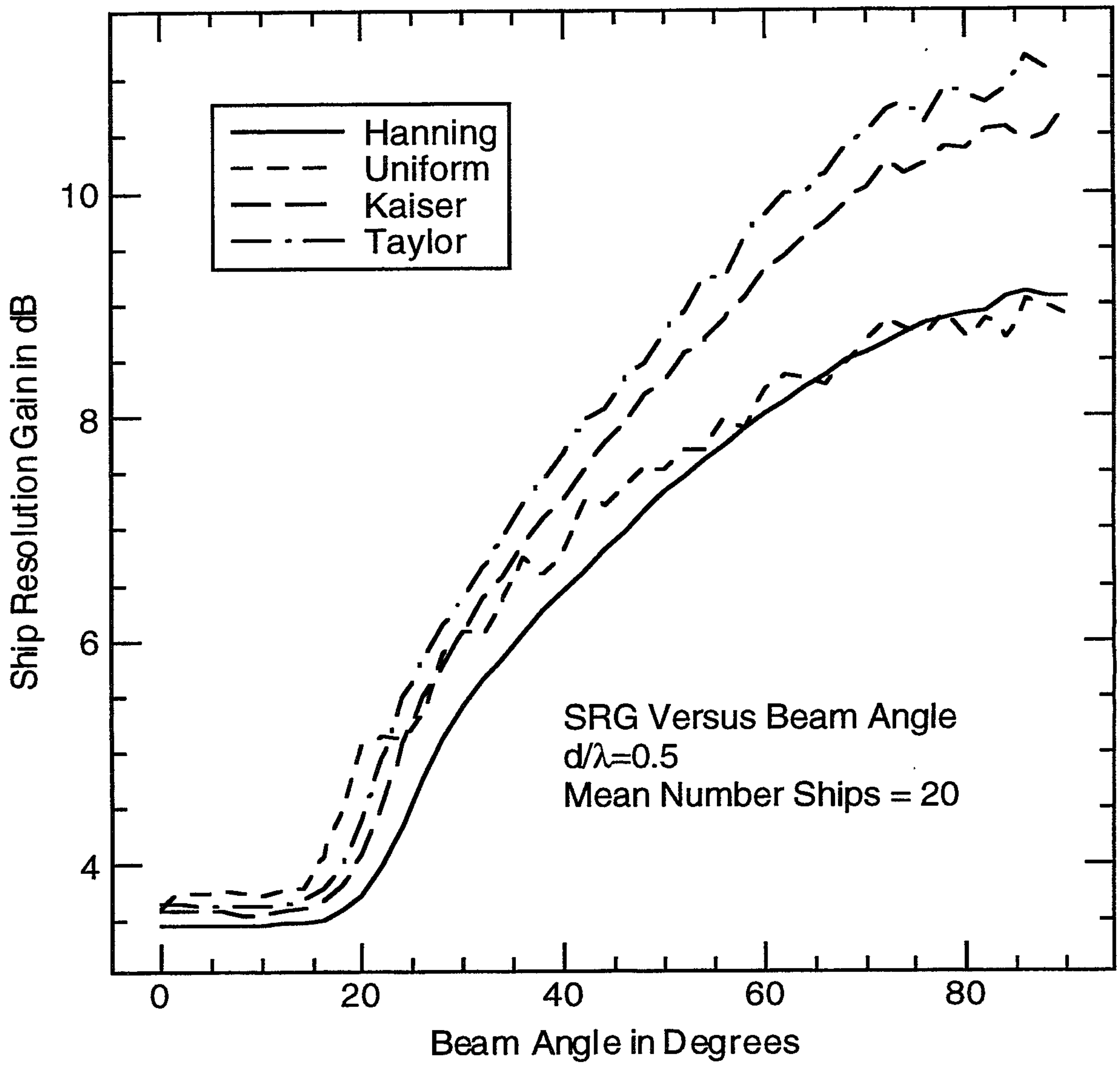

FIG. 6. Ship Resolution Gain as a function of beam steering angle.

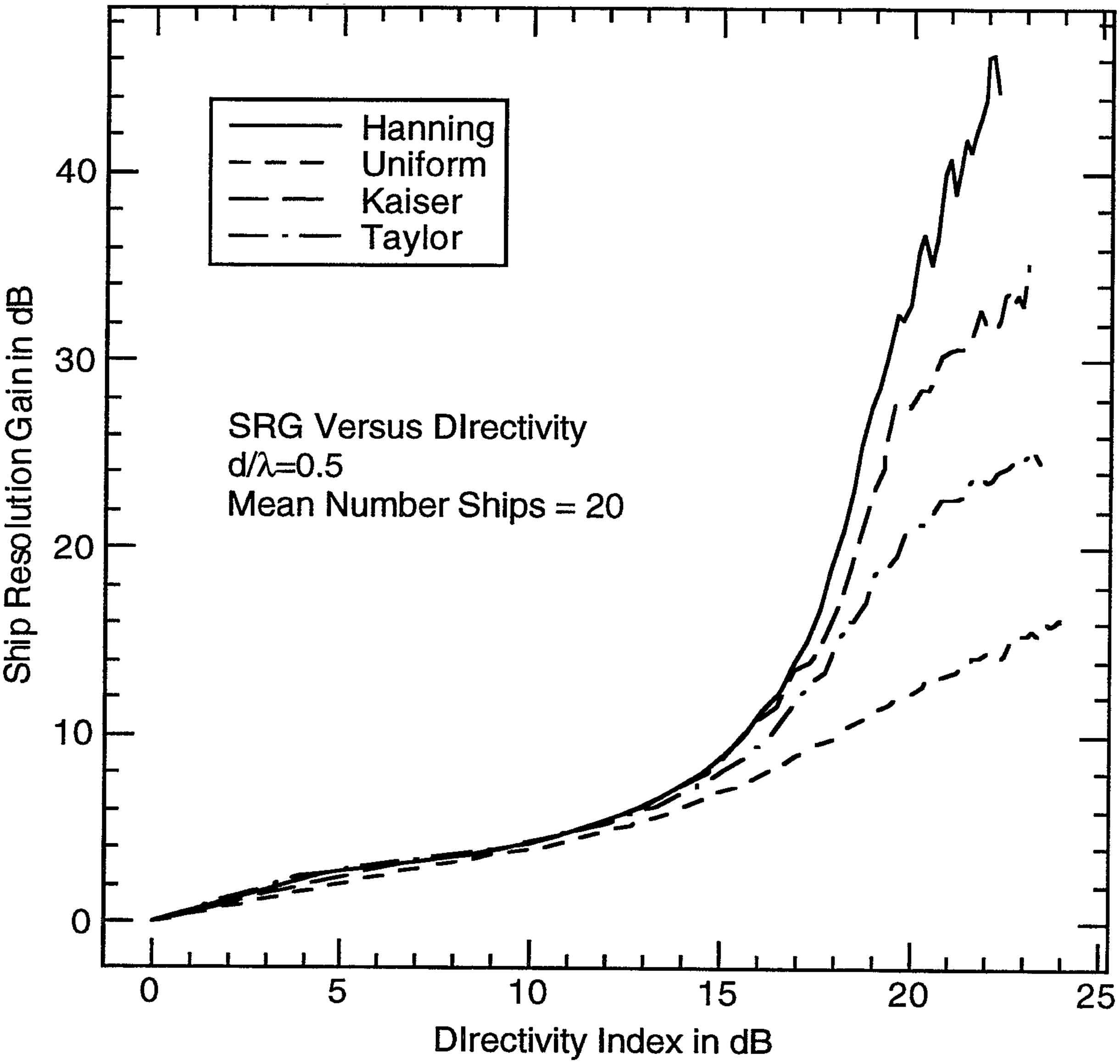

FIG. 7. Ship Resolution Gain as a function of directivity index for a noise field with a mean of 20 discrete interferers, no background noise and exponentially-distributed transmission loss fluctuations.

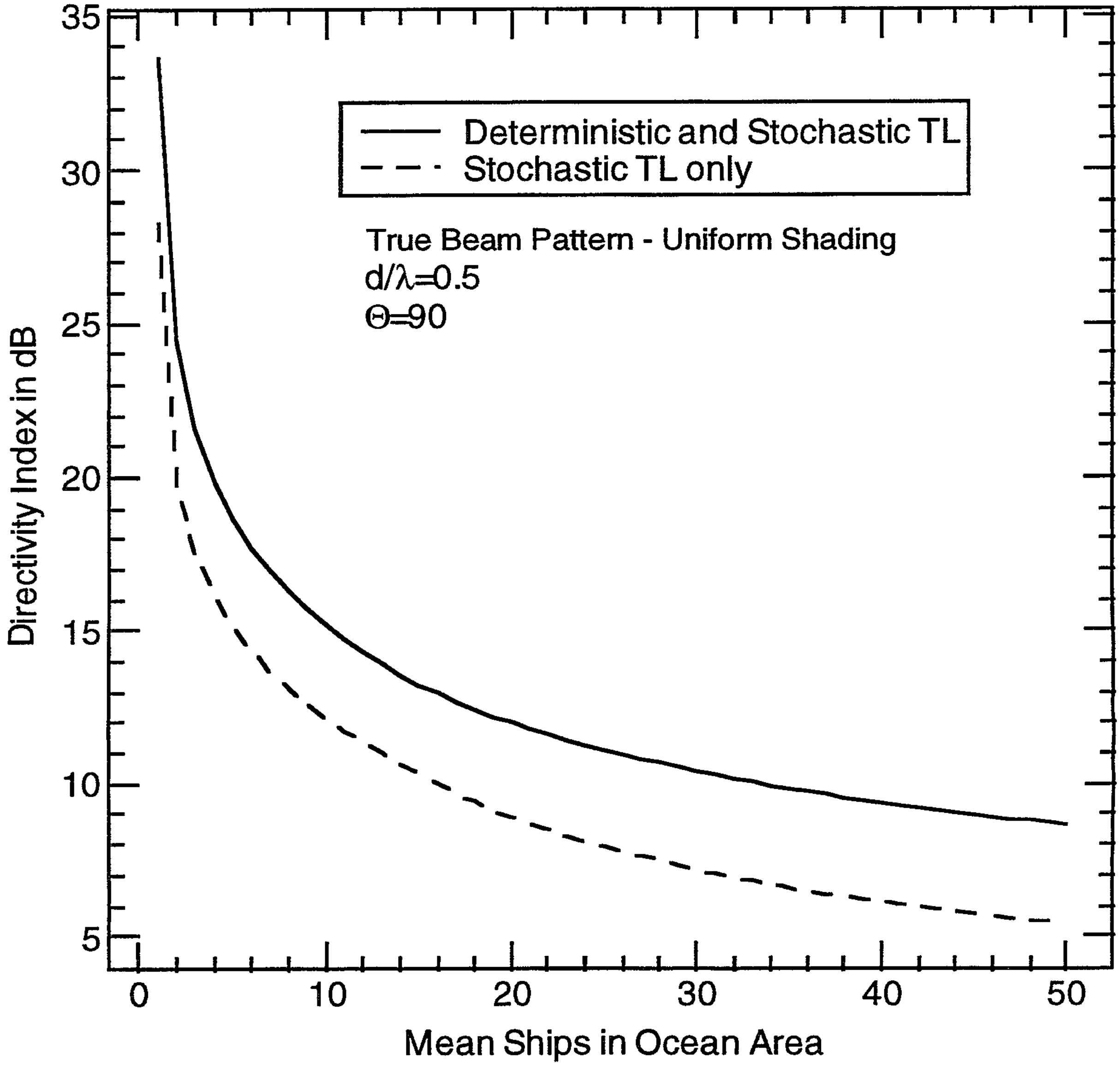

FIG. 8. Comparison of Ship Resolution Gain for stochastic TL and stochastic plus deterministic TL fluctuations.

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)

DREA/Esquimalt Defence Research Detachment
Forces Mail Office, Victoria, B.C., V0S 1B0

2. SECURITY CLASSIFICATION (Overall security of the document including special warning terms if applicable.)

UNCLASSIFIED

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

Computing Ship Resolution Gain for Horizontal Towed Arrays

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

CRAIG, David W.

5. DATE OF PUBLICATION (Month and year of publication of document.)

February 1996

6a. NO. OF PAGES (Total containing information. Include Annexes, Appendices, etc.)

22

6b. NO. OF REFS. (Total cited in document.)

8

6. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Memorandum

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the reseach and development. include the address.)

DREA/Esquimalt Defence Research Detachment
Forces Mail Office, Victoria, B.C., V0S 1B0

9a. PROJECT OR GRANT NUMBER (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)

Thrust 5.a

9b. CONTRACT NUMBER (If appropriate, the applicable number under which the document was written.)

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number mrst be unique to this document.)

DREA Technical Memorandum 96/211

10b. OTHER DOCUMENT NUMBERS (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification)

☒ Unlimited distribution
☐ Distribution limited to defence departments and defence contractors; further distribution only as approved
☐ Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
☐ Distribution limited to government departments and agencies; futher distribution only as approved
☐ Distribution limited to defence departments; further distribution only as approved
☐ Other (please specify):

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic annoucement of this document. This will normally correspond to the Document Availability (11). However, where futher distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

Prediction of sonar performance is an essential step in the design and development of large sonar systems. The sonar equation is most often used to predict detection performance, assuming constant mean values for signal and noise. Unfortunately, this analysis fails to account for changes in mean signal and noise conditions that may vary over hours, days, or months. In the case of shipping noise and a horizontal towed array, the mean noise background may vary dramatically as ships move in and out of the main lobe of the beam pattern of a receiver. This report shows that computing probability density functions for actual receiver beam patterns, as well as imposing a constant ambient noise background over individual ship interferers, greatly alters Ship Resolution Gain (SRG) estimates. This is particularly true at low shipping densities, where the difference in SRG estimates may approach 30 dB. Lower SRG estimates are likely more representative of realistic ocean environments.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title).

Sonar
Ship Resolution Gain
Towed Arrays

DREA

CRDA

498212