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FLUX3D Simulations of CFAV QUEST

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Martec Technical Report Number: TR-07-36

Contract Number: W7707-06-3597

Contract Scientific Authority: Layton Gilroy, 902-426-3100 x365

Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2007-248
February 2008

Canada

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Author

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Approved by

Original signed by Layton Gilroy

Layton Gilroy

Scientific Authority

Approved for release by

Original signed by Jim L. Kennedy

Jim L Kennedy

DRP Chair

Disclaimer

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Abstract

As part of previous contracts, Martec Limited developed a static magnetic model of CFAV Quest for FLUX3D using an existing structural finite-element model of CFAV Quest. The model accounts for both the structural and some of the non-structural components of the ship. This report describes the work by Martec Limited for the current project in which previously developed models were used to further study the electromagnetic signature of CFAV Quest. A total of sixteen analyses were performed. Analyses included four ship headings (0° true, 90° true, 180° true and 270° true), two ship configurations (induced magnetization only, permanent magnetization only), and two aircraft altitudes (80 metres and 150 metres). The induced magnetic state of the ship was simulated by using values of zero for the permanent magnetic properties of the ship. In a similar manner, the permanent magnetic state of the ship was simulated by setting the permeability values for the ship to unity. These models were analyzed using FLUX3D and magnetic flux densities at the desired altitudes were recorded. Since the intent was to compare against field measurements, in the current study all components of the earth's magnetic field were considered.

Résumé

Dans le cadre de contrats précédents, Martec Limited a mis au point un modèle du champ magnétique statique du NAFC Quest pour le logiciel FLUX3D, en utilisant le modèle structural par éléments finis existant du NAFC Quest. Le modèle représente les composants structuraux et certains composants non structuraux du navire. Le présent rapport décrit les travaux réalisés par Martec Limited pour le projet en cours, et pour lequel les modèles élaborés précédemment ont été utilisés afin de pousser plus loin l'étude de la signature électromagnétique du NAFC Quest. En tout, seize analyses ont été réalisées. Les analyses couvraient quatre caps de navire (0° cap vrai, 90° cap vrai, 180° cap vrai et 270° cap vrai), deux configurations de navire (magnétisation induite seulement, magnétisation permanente seulement) et deux altitudes d'aéronef (80 et 150 mètres). L'état magnétique induit du navire a été simulé en attribuant une valeur nulle aux propriétés magnétiques permanentes du navire. De la même manière, nous avons simulé l'état magnétique permanent du navire, en donnant aux paramètres de perméabilité magnétique du navire la valeur de un. Nous avons analysé ces modèles à l'aide de FLUX3D, et nous avons enregistré les densités de flux magnétique aux altitudes voulues. Comme il s'agissait de comparer les données par rapport à des mesures en situation réelle, nous avons tenu compte, dans cette étude, de toutes les composantes du champ magnétique terrestre.

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Executive summary

Introduction

The electrostatic and magnetic fields produced during the operation of naval surface ships and submarines represents the non-acoustic signatures which pose a mine threat to surface ships and submarines. Minimizing all signatures, including underwater electrical potential and magnetic signatures, is the essence of stealth technology for naval platforms. Stealth provides delayed detection, identification and target acquisition by hostile forces, which enhances both the first strike capability and survivability. It therefore constitutes an important design consideration for naval platforms.

DRDC has focused its signature reduction investigations on the research vessel CFAV Quest. As part of previous contracts, Martec Limited developed a static magnetic model of CFAV Quest for FLUX3D using the structural finite-element model of CFAV Quest. The model accounts for both the structural and some of the non-structural components of the ship. This report describes the work by Martec Limited for the current project in which previously developed models were used to further study the electromagnetic signature of CFAV Quest.

Results

A total of sixteen analyses were performed. Analyses included four ship headings (0° true, 90° true, 180° true and 270° true), two ship configurations (induced magnetization only, permanent magnetization only), and two aircraft altitudes (80 metres and 150 metres). The four ship headings were simulated by rotating the vector that defined the earth's magnetic field about a vertical axis. Simulating the induced magnetic state of the ship was achieved by using values of zero for the permanent magnetic properties of the ship. In a similar manner, the permanent magnetic state of the ship was simulated by setting the permeability values for the ship to unity. These models were analyzed using FLUX3D and magnetic flux densities at the desired altitudes were recorded. Since the intent was to compare against field measurements, in the current study all components of the earth's magnetic field were considered (in a previous study only the vertical component was used).

Significance

This study will help improve the underwater magnetic modelling of CF vessels which will allow for reduced detection and improved vulnerability.

Wallace, J.C. 2007. FLUX3D Simulations of CFAV Quest. DRDC Atlantic CR 2007-248. Defence R&D Canada – Atlantic.

Sommaire

Introduction

Les champs électrostatiques et magnétiques produits pendant l'utilisation des navires de guerre et des sous marins constituent des signatures non acoustiques qui rendent ces bâtiments vulnérables aux mines. Pour les plates formes navales, tout effort visant à réduire toutes les signatures, y compris les signatures magnétiques et le potentiel électrique sous marins est au cœur de la technologie de la « furtivité », laquelle permet de retarder la détection, l'identification et l'acquisition de la cible par les forces hostiles, ce qui accroît la capacité de première frappe et la survivabilité. Elle constitue donc un élément important dans la conception des plates formes navales.

RDDC a concentré ses études sur les réductions de la signature du bâtiment de recherche NAFC Quest. Dans le cadre de contrats précédents, Martec Limited a mis au point un modèle du champ magnétique statique du NAFC Quest pour le logiciel FLUX3D, en utilisant le modèle structural par éléments finis existant du NAFC Quest. Le modèle représente les composants structuraux et certains composants non structuraux du navire. Le présent rapport décrit les travaux réalisés par Martec Limited pour le projet en cours, et pour lequel les modèles élaborés précédemment ont été utilisés afin de pousser plus loin l'étude de la signature électromagnétique du NAFC Quest.

Résultats

En tout, seize analyses ont été réalisées. Les analyses couvraient quatre caps de navire (0° cap vrai, 90° cap vrai, 180° cap vrai et 270° cap vrai), deux configurations de navire (magnétisation induite seulement, magnétisation permanente seulement) et deux altitudes d'aéronef (80 et 150 mètres). Les quatre caps ont été simulés par la rotation du vecteur qui définit le champ magnétique terrestre autour d'un axe vertical. L'état magnétique induit du navire a été simulé en attribuant une valeur nulle aux propriétés magnétiques permanentes du navire. De la même manière, pour simuler l'état magnétique permanent du navire, nous avons donné aux paramètres de perméabilité magnétique du navire la valeur de un. Nous avons analysé ces modèles à l'aide de FLUX3D, et nous avons enregistré les densités de flux magnétique aux altitudes voulues. Comme il s'agissait de comparer les données par rapport à des mesures en situation réelle, nous avons tenu compte, dans cette étude, de toutes les composantes du champ magnétique terrestre (dans une étude précédente, seule la composante verticale avait été utilisée).

Importance

Cette étude contribuera à améliorer la modélisation magnétique sous-marine des bâtiments des Forces canadiennes, afin de réduire leur détectabilité et leur vulnérabilité.

Wallace, J.C. 2007. FLUX3D Simulations of CFAV Quest (Simulation du NAFC Quest pour le logiciel FLUX3D). DRDC Atlantic CR 2007 248. Defence R&D Canada – Atlantic.

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Acknowledgements

The authors would like to thank Dr. Yueping Wang of DRDC Atlantic for his invaluable assistance and guidance throughout the course of this work.

In addition, we would like to thank Mr. Ken MacKay of Martec Limited for his assistance in conducting the analyses.

1. Introduction

The electrostatic and magnetic fields produced during the operation of naval surface ships and submarines represent the non-acoustic underwater signatures which are of concern in shallow water when faced with a mine threat. Minimizing all signatures, including underwater electrical potential and magnetic signatures, is the essence of stealth technology for naval platforms. Stealth provides delayed detection, identification and target acquisition by hostile forces, which enhances both the first strike capability and survivability. It therefore constitutes an important design consideration for naval platforms.

Recent investigations demonstrated the possibilities of the finite element method (FEM) to model the electromagnetic field of a steel-hulled vessel. Models were built using the FLUX3D package now licensed by DRDC Atlantic. The models are an important part of a larger effort to minimize a ship's electromagnetic (EM) signature and to optimize its degaussing systems. These investigations have demonstrated that the underwater electromagnetic signatures of steel-hulled vessels with active signature reduction measures can be modeled by this commercially-developed software package. The creation of accurate models is contingent on the use of accurate geometric descriptions, accurate material properties and sufficient model refinement.

One of the difficulties of the signature reduction program at DRDC has been the availability of experimental data to validate model predications and design theories. Early investigations focused on a steel-hulled naval vessel; however, the duties of these ships allow for very small windows-of-opportunity for conducting experimental trials and limit the ability to conduct the experiments in a controlled manner.

To overcome these difficulties DRDC has focused its signature reduction investigations on the research vessel CFAV Quest. As part of previous contracts, Martec Limited developed a static magnetic model of CFAV Quest for FLUX3D using the structural finite-element model of CFAV Quest. The model accounts for both the structural and some of the non-structural components of the ship. This report describes the work by Martec Limited for the current project in which previously developed models were used to further study the electromagnetic signature of CFAV Quest.

2. Model Generation

An existing FLUX3D model was used to compute a magnetic signature of the Quest at altitudes of 80 metres and 150 metres above sea level. This model had been developed for a previous study of Quest magnetic signatures (references [1-2]). It started as a structural model that was imported into FLUX3D. This model is shown in Figure 2.1. To this model, major non-structural steel components including engines, generators and propeller shafts were added. These are shown in Figure 2.2.

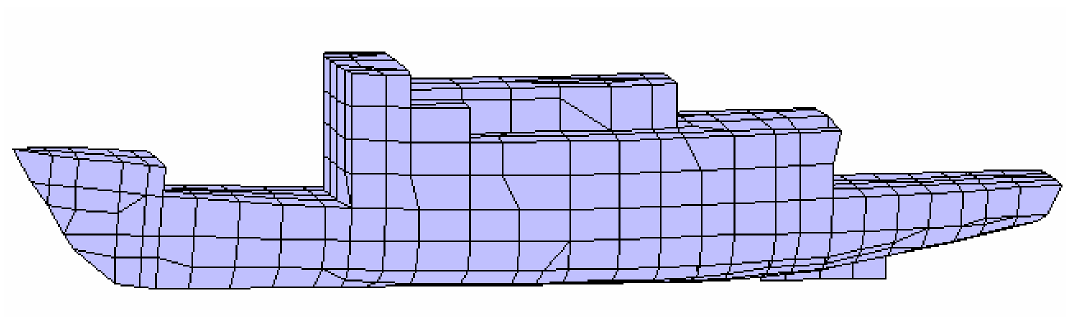

Figure 2.1 Structural finite element model

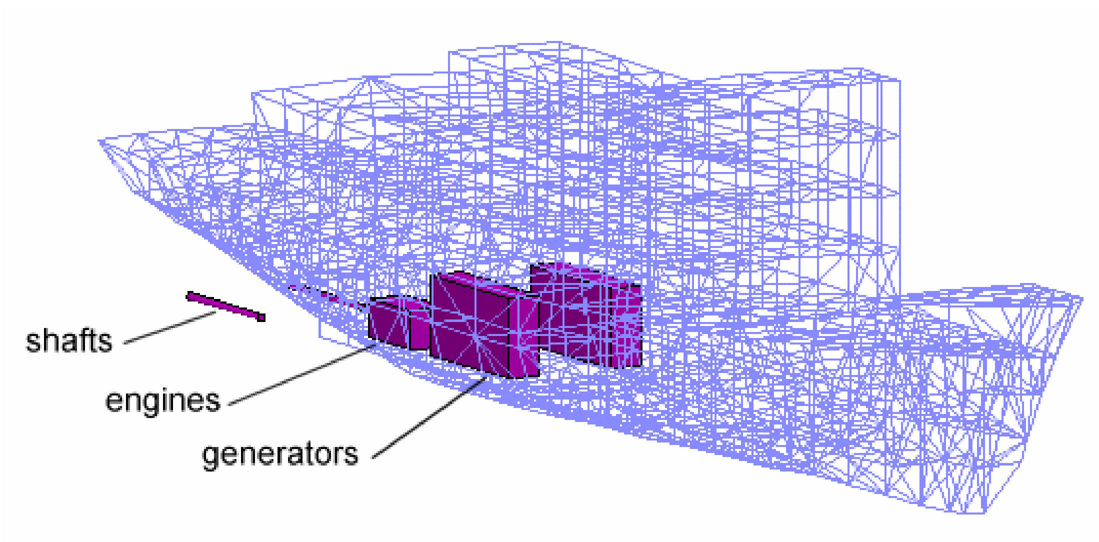

Figure 2.2 FLUX3D model with non-structural components

From previous studies of the magnetic fields surrounding ships, it was found that good results were obtained for:

1. Fine meshes (1 metre element size) used on the plane of interest,

2. Aligning the plane of interest with an inner face of the FLUX3D infinite box (which defines the limit of the finite element mesh),

3. A box thickness between inner and outer faces of 10 metres,

4. Having at least 2 second-order elements through the thickness of the infinite box, and

5. Using second-order elements throughout the model.

As there was no requirement to analyze the effect of degaussing coils, no coils were included in the model.

All ship geometry was assigned a mesh size of 1 metre. Second-order elements were used in all models. This resulted in a mesh for the ship that is shown in Figure 2.3.

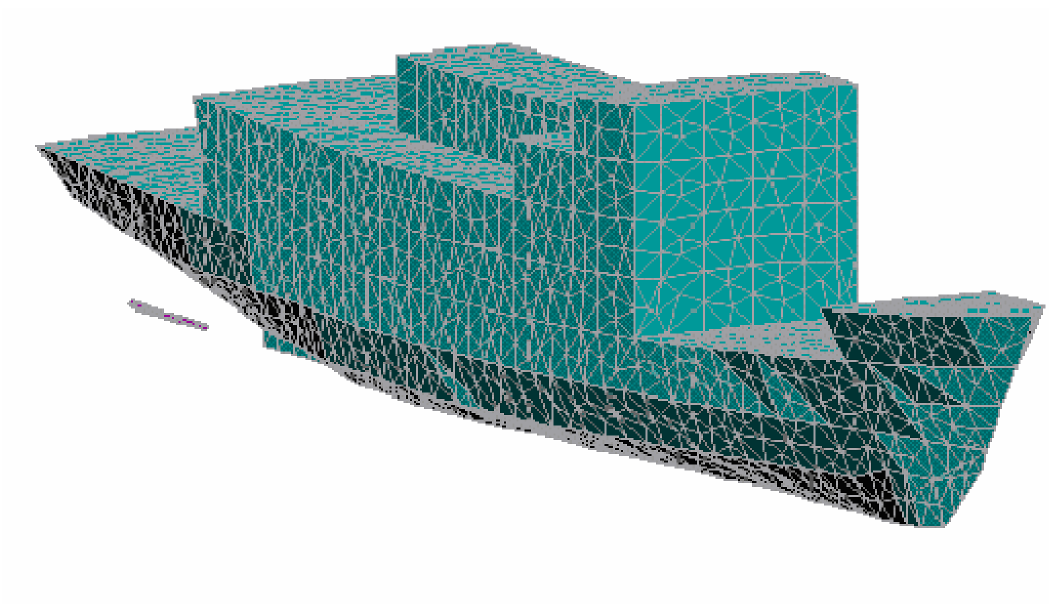

Figure 2.3 FLUX3D Meshed Ship

In the absence of specific information on the magnetic properties of the materials used in the ship, or in the percentage of ferromagnetic material within the non-structural components, or experimental measurements with which to calibrate material properties, all materials were assumed to have linear isotropic permeability with a relative permeability of 300. As the relative permeability is a ratio there are no units associated with it.

In order to account for any permanent magnetization that would have been introduced into the steel of the ship, a permanent vertical magnetization was added to the FLUX3D model. Following on the work of previous numerical studies of Quest, a value for the permanent magnetization that doubled the total signature at beam depth was used. This resulted in the use of an isotropic permeability of 300 used in combination with a Cartesian magnet material with a remnant magnetic flux density of –0.01502 Teslas along the vertical (Z) axis. . This represents the residual internal magnetic flux density left over when the external magnetic field has been removed.

Following recommended guidelines in the FLUX3D User's Guide [2], the FLUX3D scalar model was used for all magneto-static analyses. Also, the reduced scalar potential, with respect to H_j (MS3RED), formulation was used throughout as the following conditions applied:

- Sources consisted of a fixed field of constant value,
- Magnetic properties in the surrounding domain were linear isotropic, with permeability equal to that of a vacuum in the region of interest, and
- Ship materials were assumed to be either linear isotropic with a relative permeability of 300, or were treated as linear magnets with isotropic permeability (again with a permeability of 300).

As indicated, the model was limited to linear material behaviour. Any calculations of total magnetic field or magnetic flux density in regions of high permeability (i.e. inside the ship structure) would lack precision. Fortunately, all areas of interest were outside the ship in regions comparable to a vacuum.

As in phase 1, the magnetic field of the earth was specified using values obtained from the website of the "NOAA Satellite and Information Service" of the "National Geophysical Data Center" (www.ngdc.noaa.gov/weg/geomag/jsp/struts/calcPointIGRF). Using the location of Halifax Harbour, the earth's magnetic field, as used in these analyses, was calculated. Figure 2.4 shows the computed field.

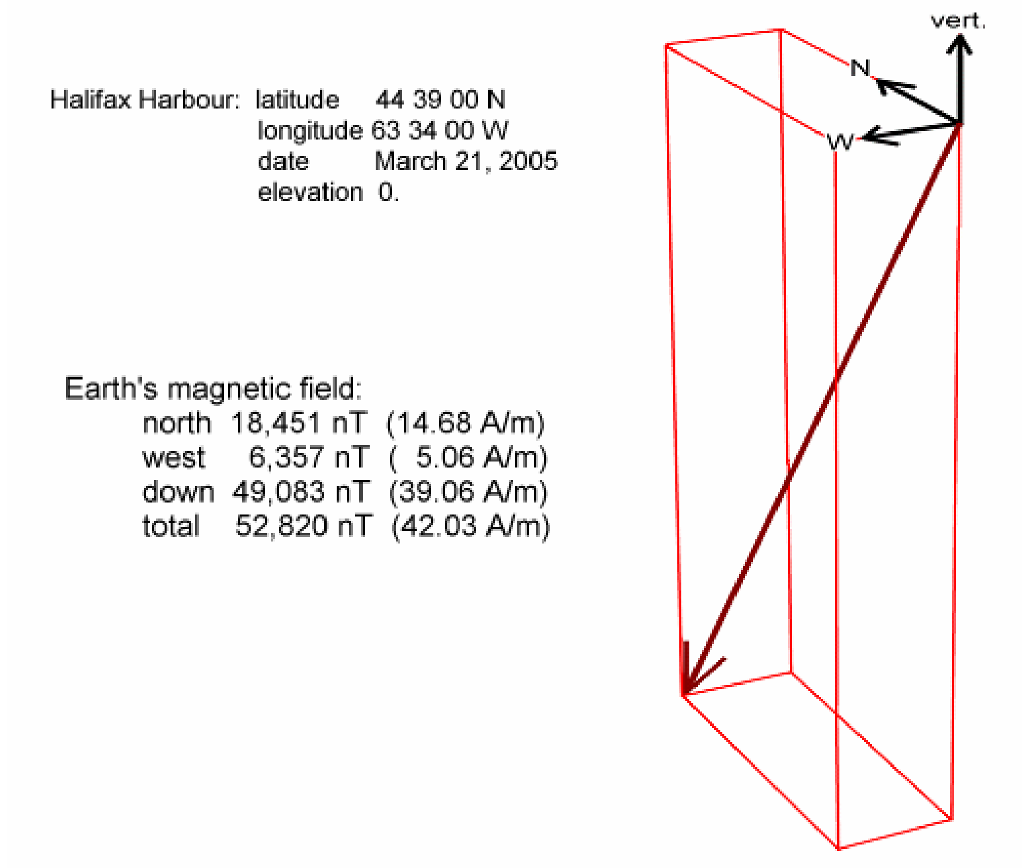

Figure 2.4 Earth Magnetic Field

In previous studies, one ship heading and ship magnetization state was considered. In this study, the surrounding meshed domain, as defined by the inner coordinates of the FLUX3D domain box, extended 381 metres fore and aft, 63.5 metres port and starboard and 80 metres above the waterline.

A second FLUX3D model was generated in order to compute the magnetic flux density at an altitude of 150 metres. This model was similar to the 80 metre model except that the domain extended to 90 metres port and starboard and 150 metres above the waterline.

3. Magnetic Signatures

A total of sixteen analyses were performed. Analyses included:

1. Four ship headings (0° true, 90° true, 180° true and 270° true),

2. Two ship configurations (induced magnetization only, permanent magnetization only), and

3. Two aircraft altitudes (80 metres and 150 metres)

Ship headings of 0º True, 90º True, 180º True, and 270º True were simulated by rotating the vector that defined the earth's magnetic field about a vertical axis. Simulating the induced magnetic state of the ship was achieved by using values of zero for the permanent magnetic properties of the ship. In a similar manner, the permanent magnetic state of the ship was simulated by setting the permeability values for the ship to unity.

These models were analyzed using FLUX3D. Magnetic flux densities for all sixteen combinations of heading, magnetic state and altitude were recorded.

In the previous study only the vertical component of the earth's magnetic field was used since the intent was to compare against field measurements, which were processed so as to eliminate the effects of the horizontal components of the earth's field. This was achieved by combining field measurements from two runs, which were in opposite directions. This procedure is based on the assumption that for the given material condition there is a linear relationship between the external field and the resulting signature.

All FLUX3D analyses were based on linear behaviour. In the current study all components of the earth's magnetic field were considered.

The following three figures (Figures 3.1 to 3.3) show the magnetic anomaly at an altitude of 80 metres for the case of induced magnetization and a ship heading of 0 degrees. Results are shown along three lines running north-south.

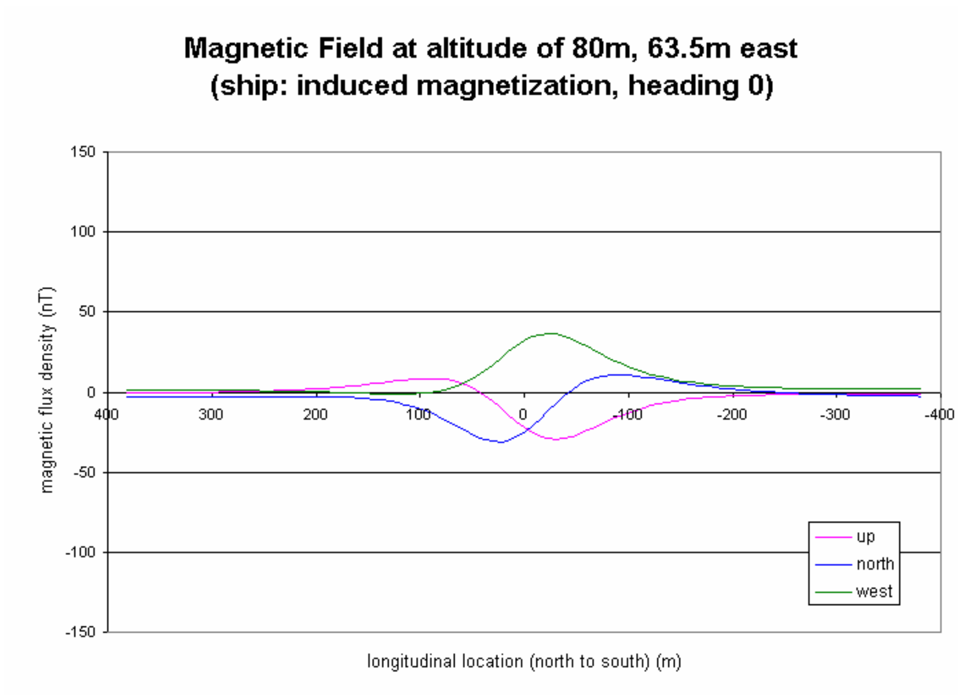

Figure 3.1 Magnetic flux density at 80 m along a line 63.5m east, (induced, 0º)

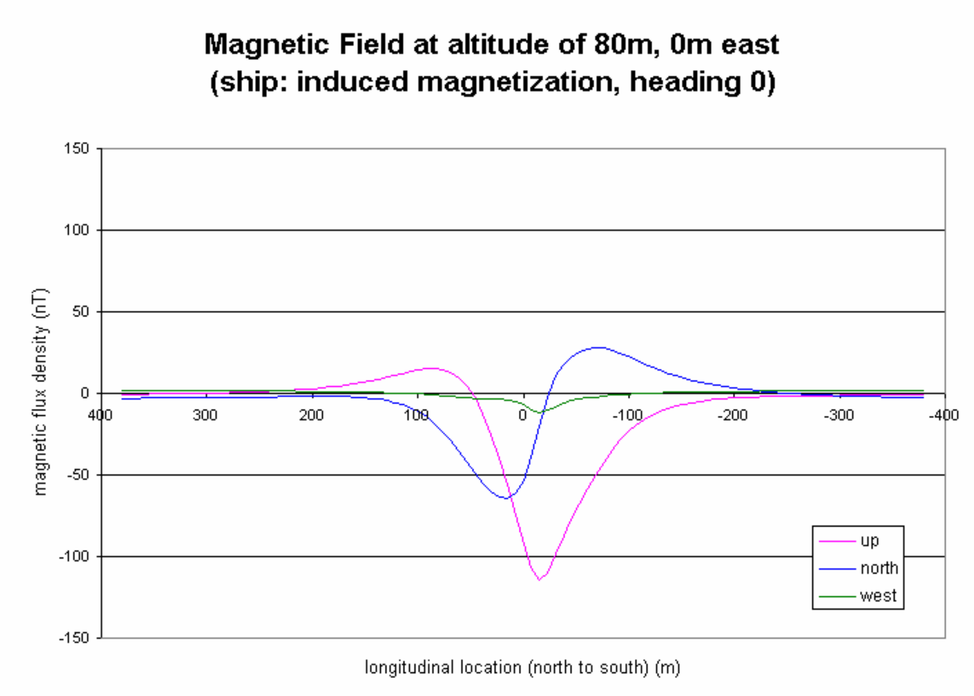

Figure 3.2 Magnetic flux density at 80 m along a line 0.0m east, (induced, 0°)

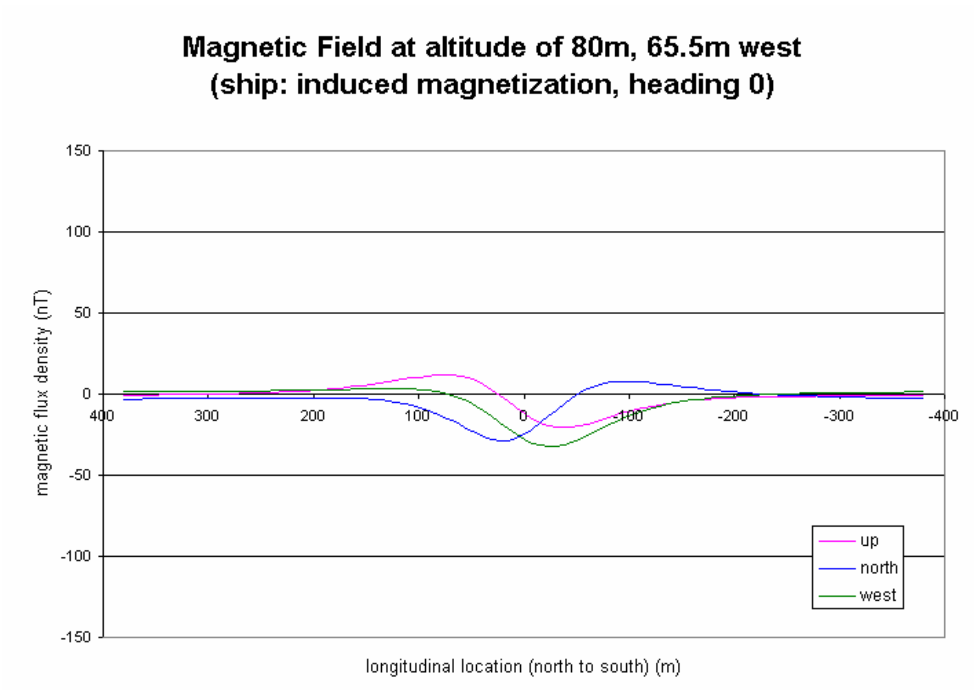

Figure 3.3 Magnetic flux density at 80 m along a line 63.5m west, (induced, 0°)

The following three figures (Figures 3.4 to 3.6) show the magnetic anomaly at an altitude of 80 metres for the case of induced magnetization and a ship heading of 90 degrees. Results are shown along three lines running north-south.

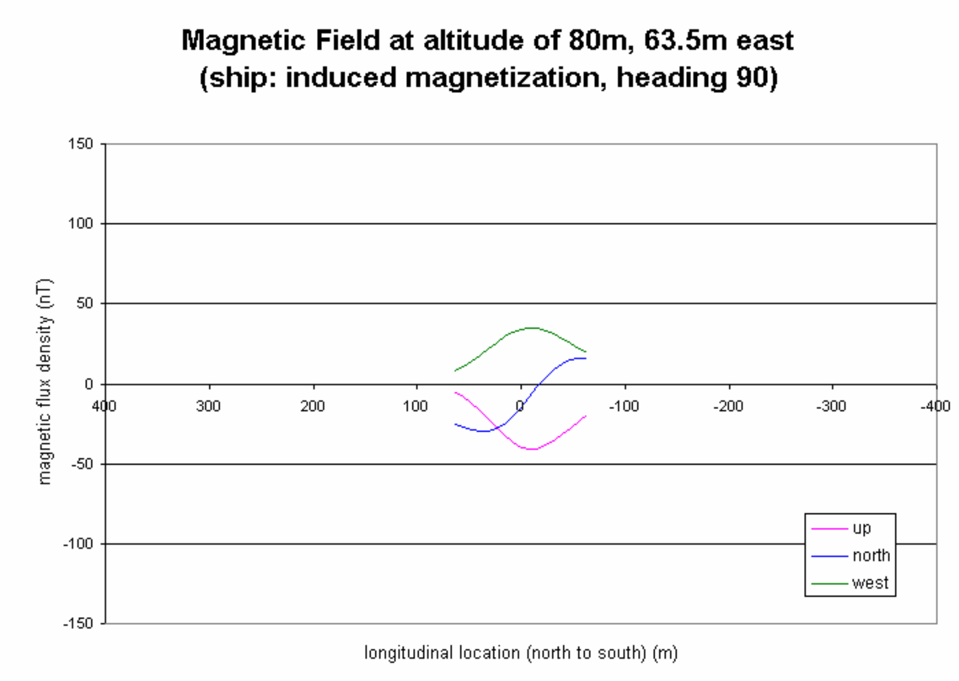

Figure 3.4 Magnetic flux density at 80 m along a line 63.5m east, (induced, 90º)

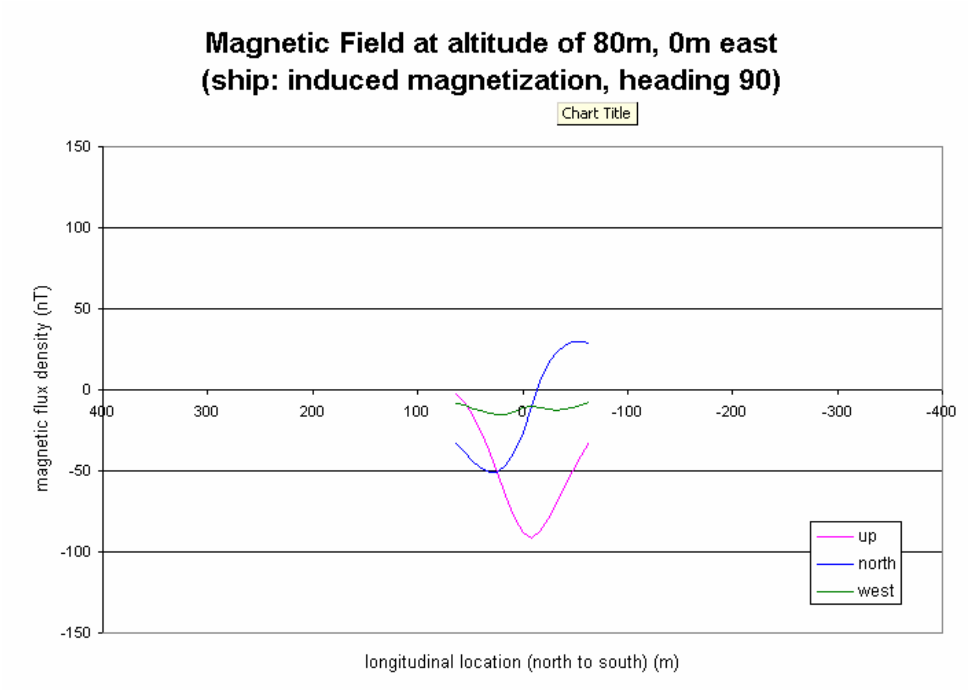

Figure 3.5 Magnetic flux density at 80 m along a line 0m east, (induced, 90°)

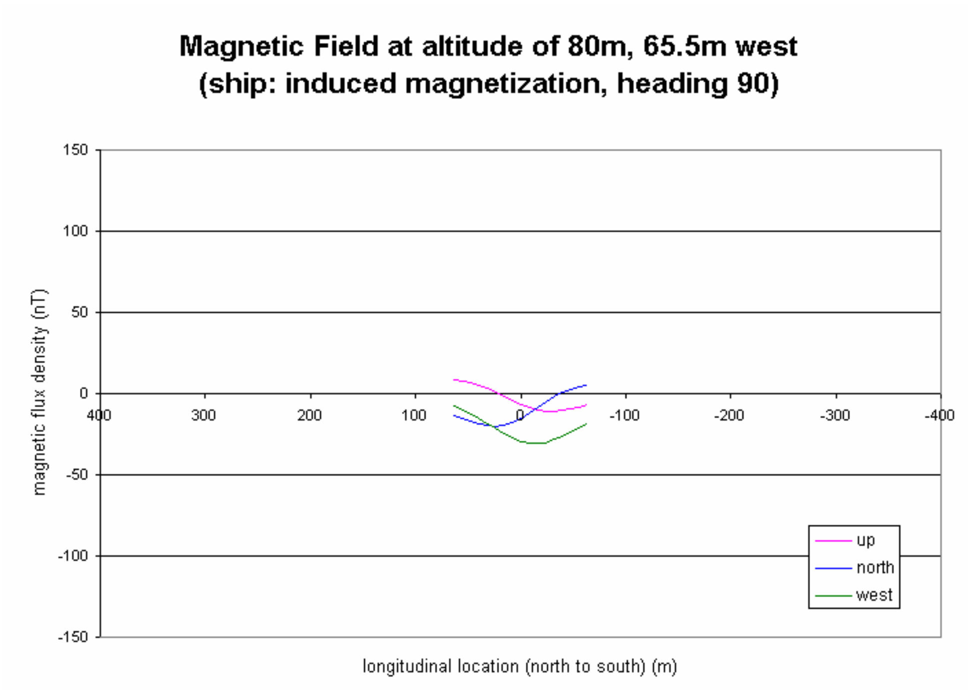

Figure 3.6 Magnetic flux density at 80 m along a line 63.5m west, (induced, 90°)

The following three figures (Figures 3.7 to 3.9) show the magnetic anomaly at an altitude of 80 metres for the case of induced magnetization and a ship heading of 180 degrees. Results are shown along three lines running north-south.

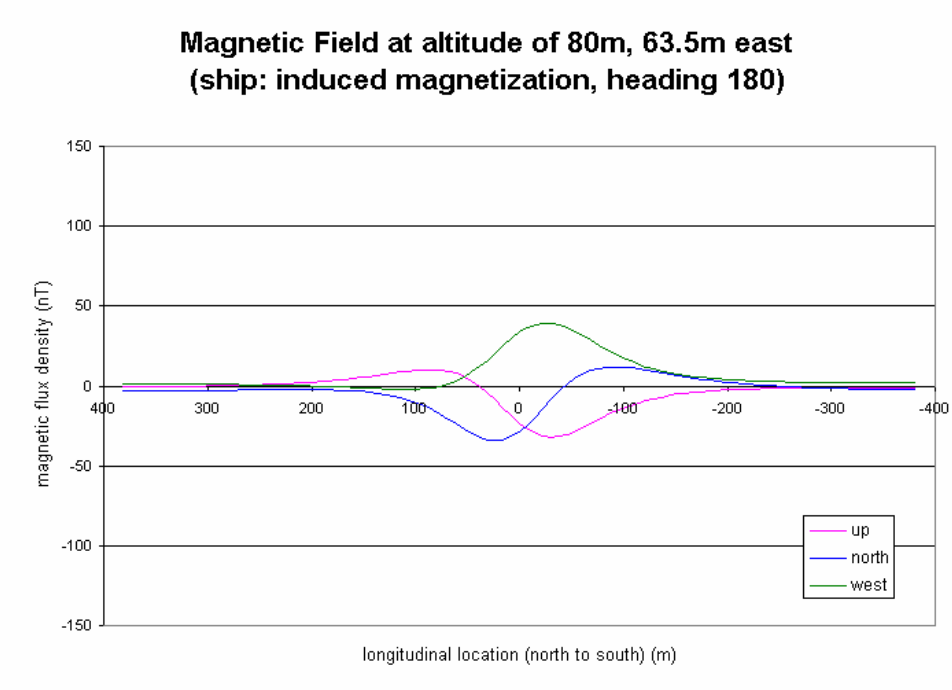

Figure 3.7 Magnetic flux density at 80 m along a line 63.5m east, (induced, 180º)

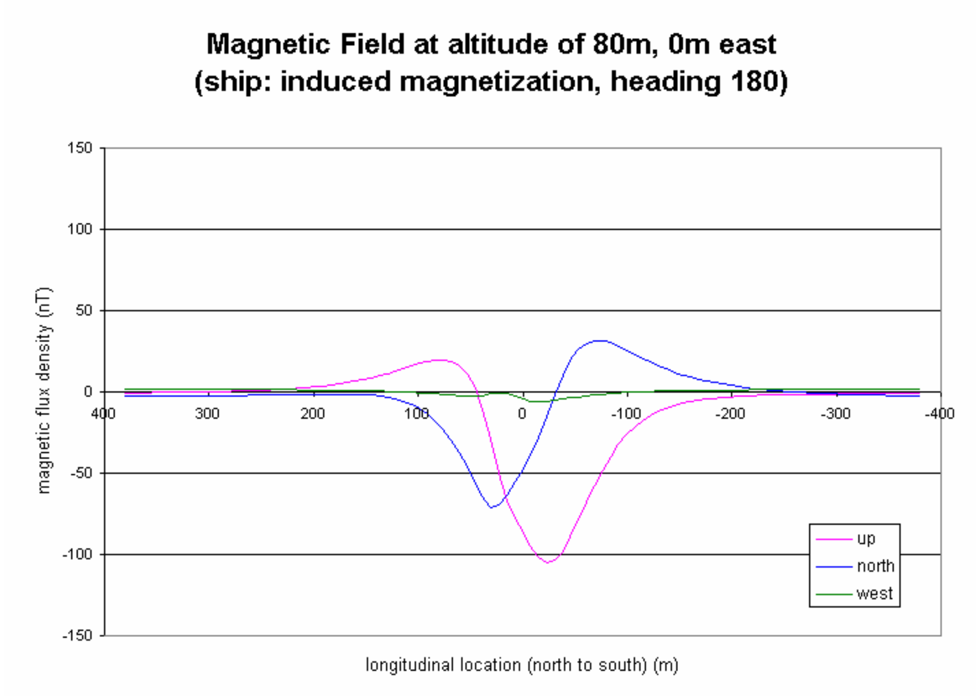

Figure 3.8 Magnetic flux density at 80 m along a line 0m east, (induced, 180°)

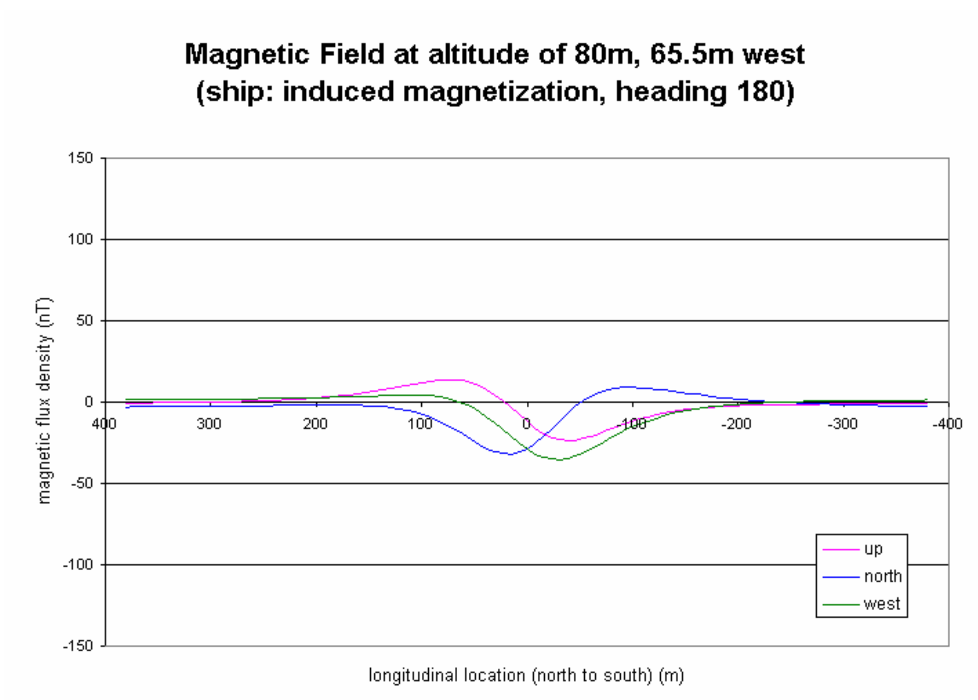

Figure 3.9 Magnetic flux density at 80 m along a line 63.5m west, (induced, 180°)

The following three figures (Figures 3.10 to 3.12) show the magnetic anomaly at an altitude of 80 metres for the case of induced magnetization and a ship heading of 270 degrees. Results are shown along three lines running north-south.

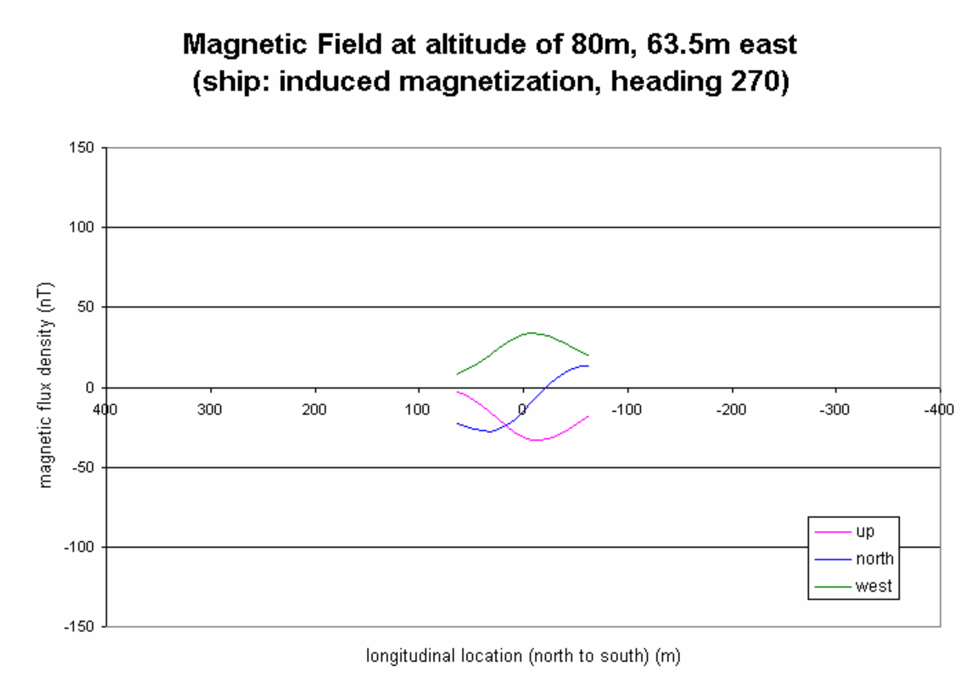

Figure 3.10 Magnetic flux density at 80 m along a line 63.5m east, (induced, 270º)

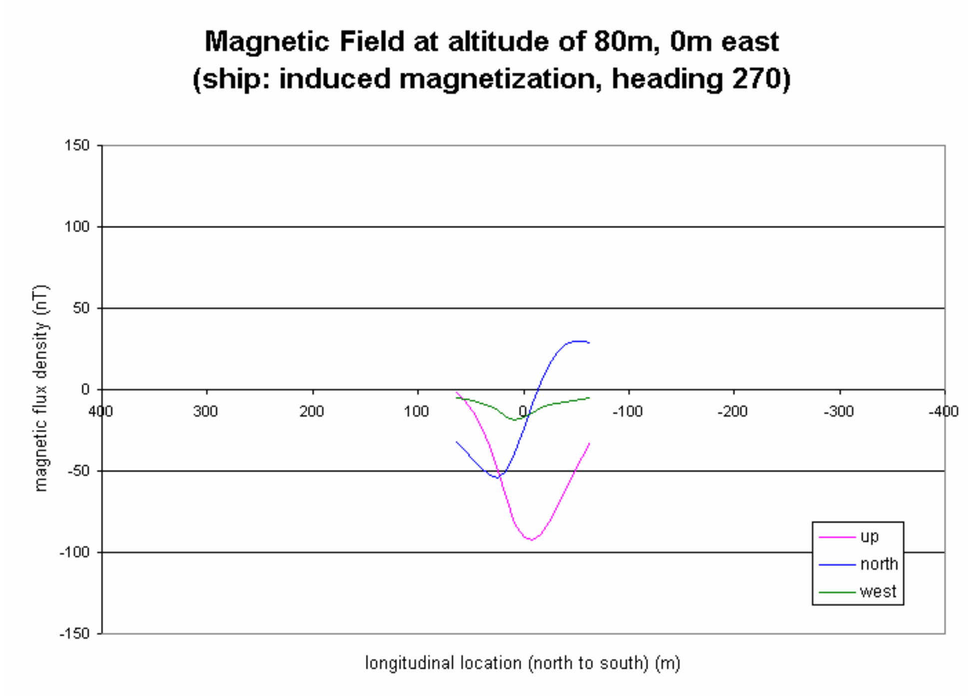

Figure 3.11 Magnetic flux density at 80 m along a line 0m east, (induced, 270°)

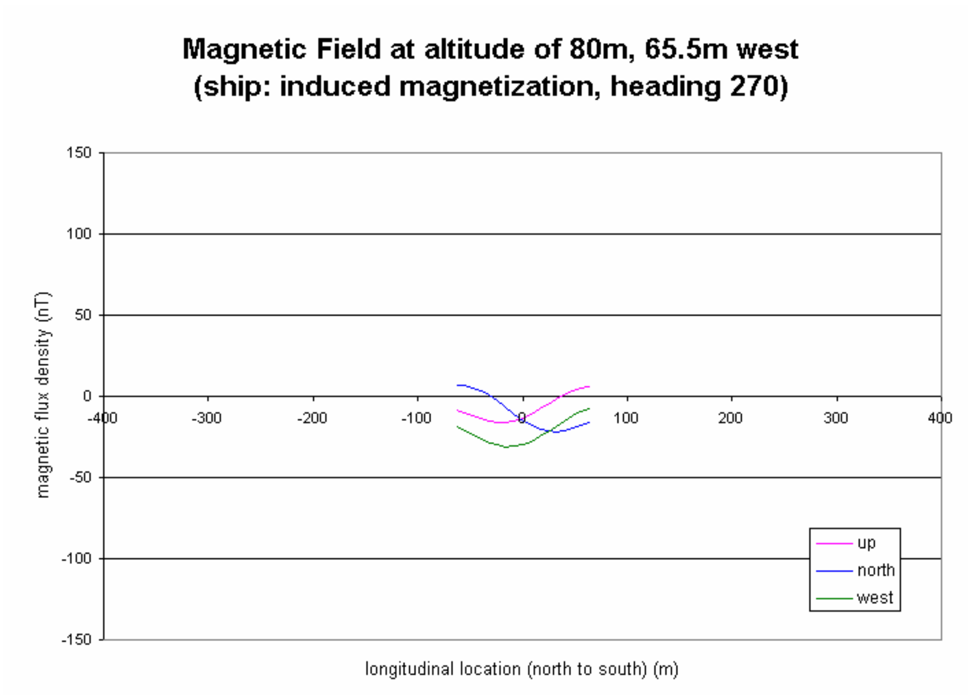

Figure 3.12 Magnetic flux density at 80 m along a line 63.5m west, (induced, 270°)

The following three figures (Figures 3.13 to 3.15) show the magnetic anomaly at an altitude of 80 metres for the case of permanent magnetization and a ship heading of 0 degrees. Results are shown along three lines running north-south.

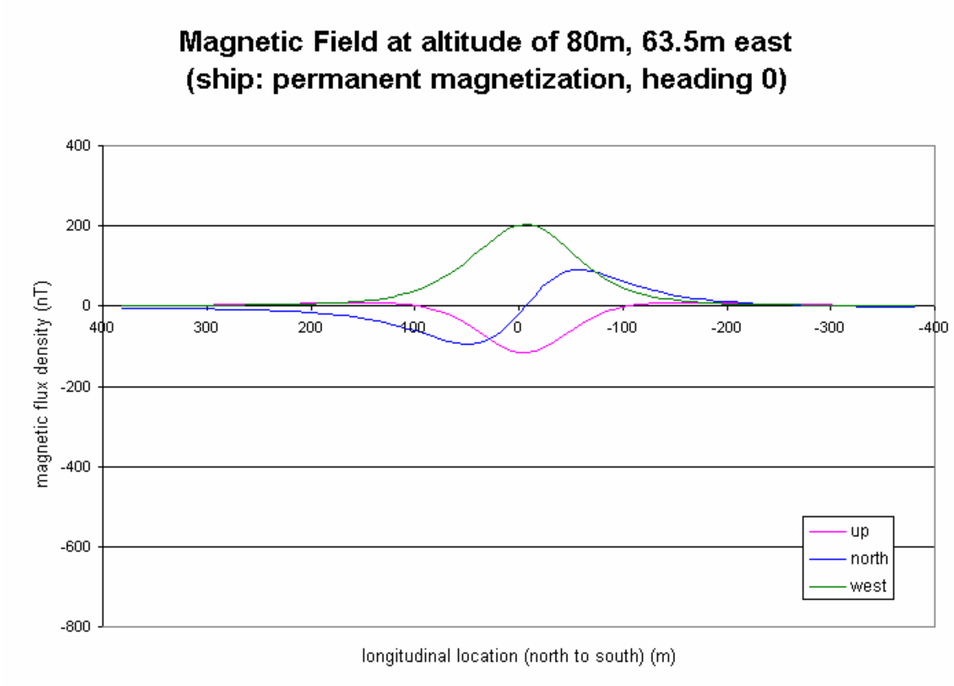

Figure 3.13 Magnetic flux density at 80 m along a line 63.5m east, (permanent, 0º)

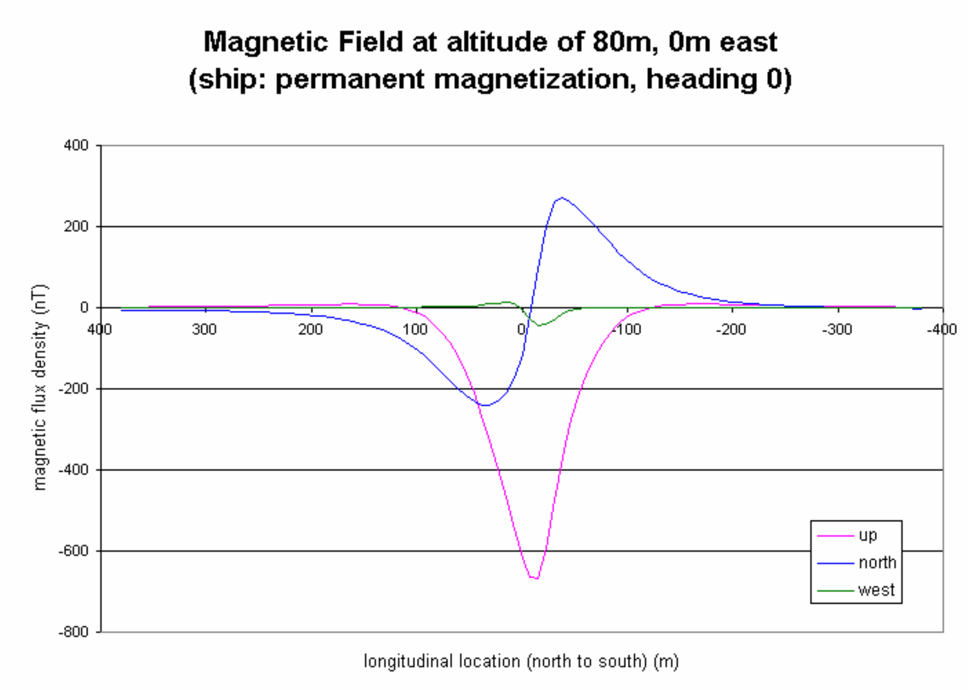

Figure 3.14 Magnetic flux density at 80 m along a line 0.0m east, (permanent, 0°)

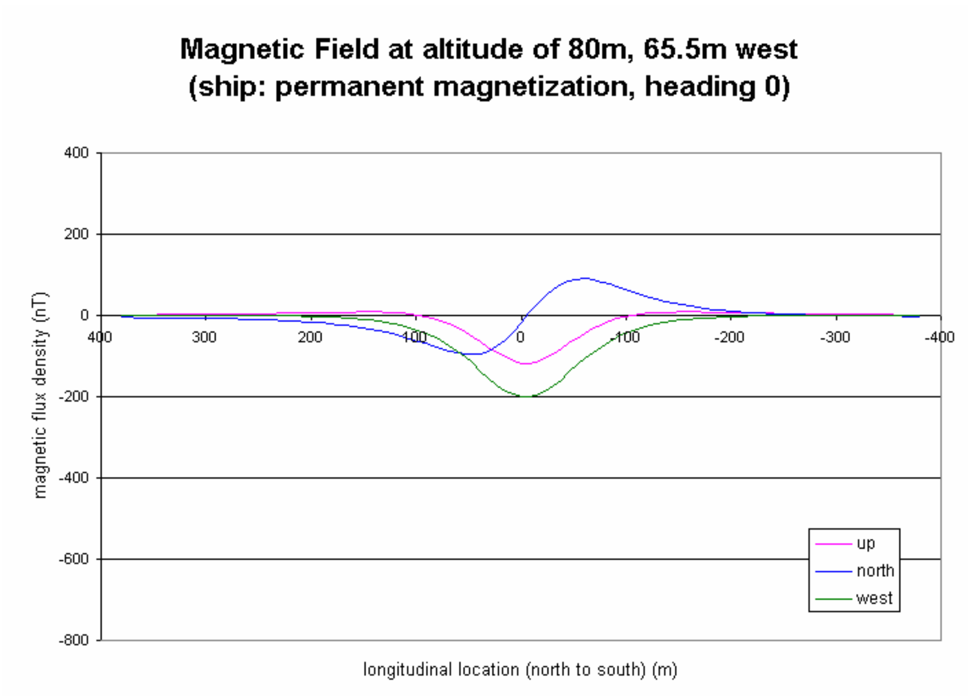

Figure 3.15 Magnetic flux density at 80 m along a line 63.5m west, (permanent, 0°)

The following three figures (Figures 3.16 to 3.18) show the magnetic anomaly at an altitude of 80 metres for the case of permanent magnetization and a ship heading of 90 degrees. Results are shown along three lines running north-south.

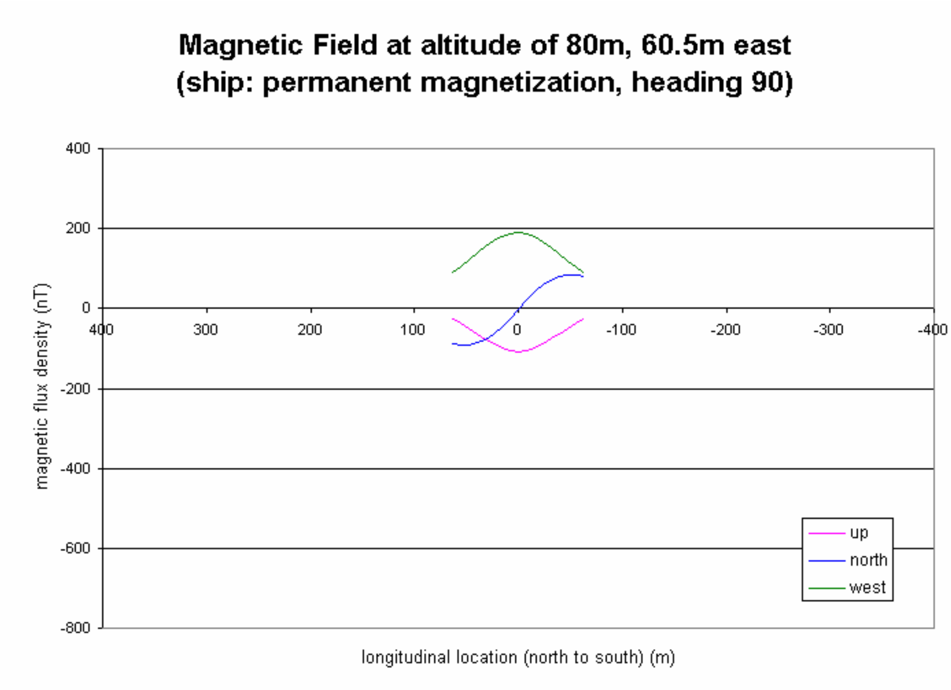

Figure 3.16 Magnetic flux density at 80 m along a line 63.5m east, (permanent, 90º)

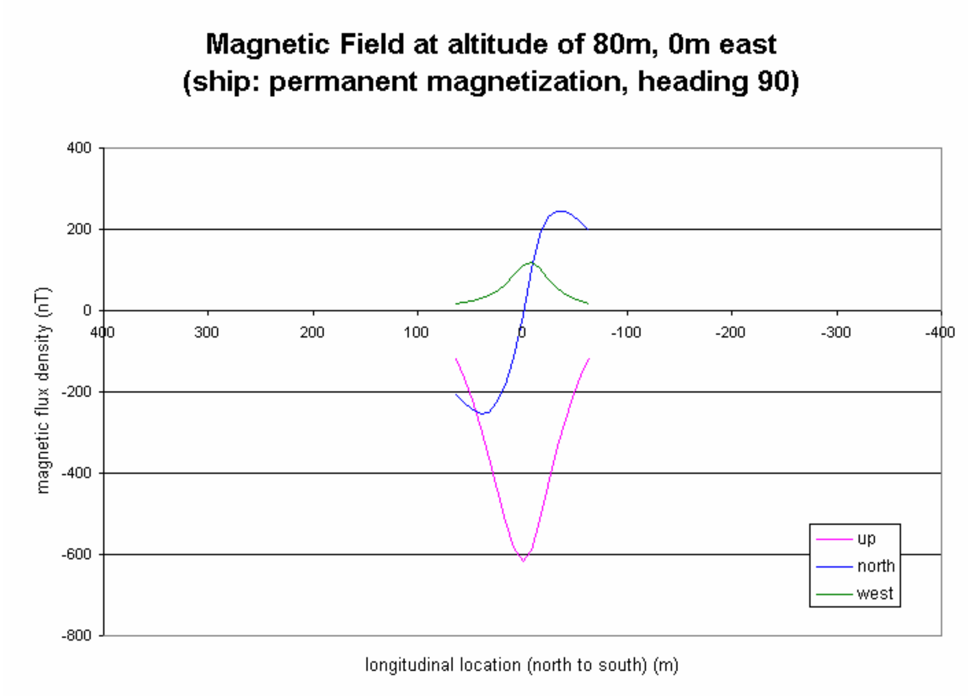

Figure 3.17 Magnetic flux density at 80 m along a line 0m east, (permanent, 90^o)

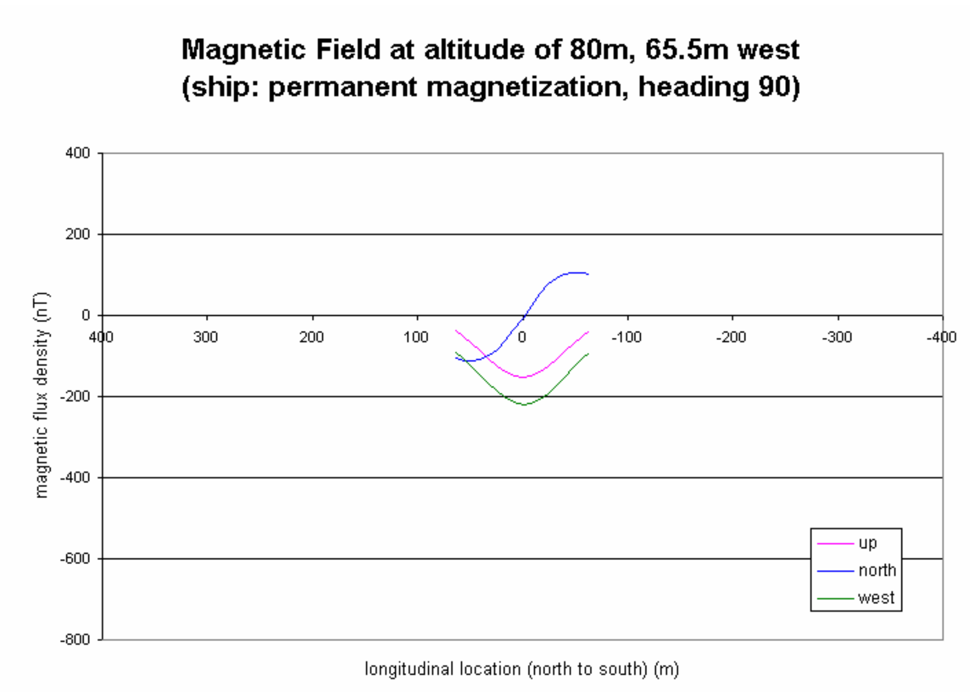

Figure 3.18 Magnetic flux density at 80 m along a line 63.5m west, (permanent, 90^o)

The following three figures (Figures 3.19 to 3.21) show the magnetic anomaly at an altitude of 80 metres for the case of permanent magnetization and a ship heading of 180 degrees. Results are shown along three lines running north-south.

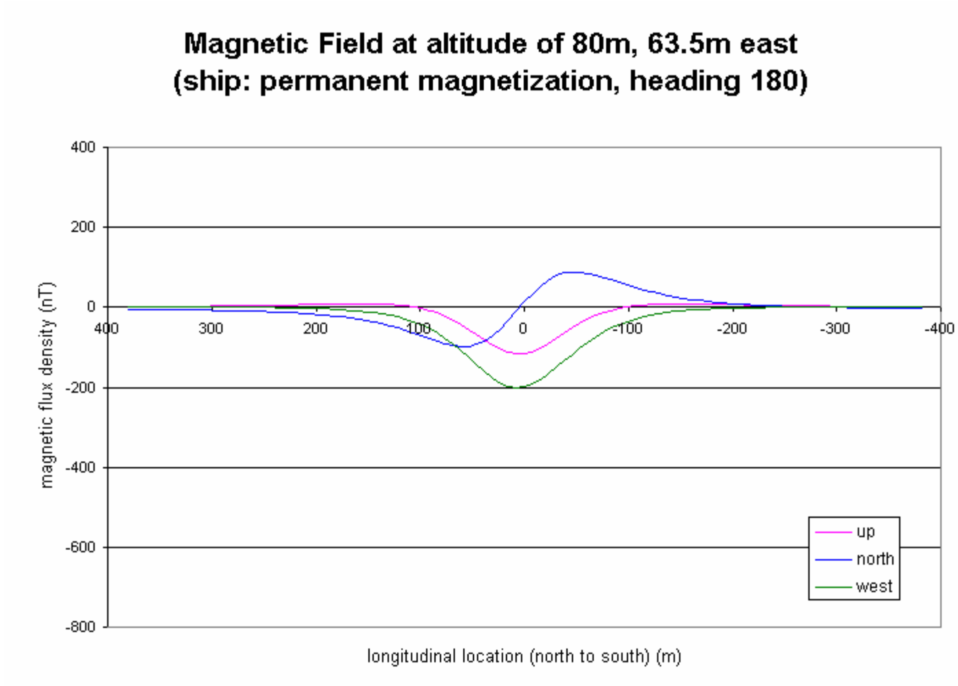

Figure 3.19 Magnetic flux density at 80 m along a line 63.5m east, (permanent, 180°)

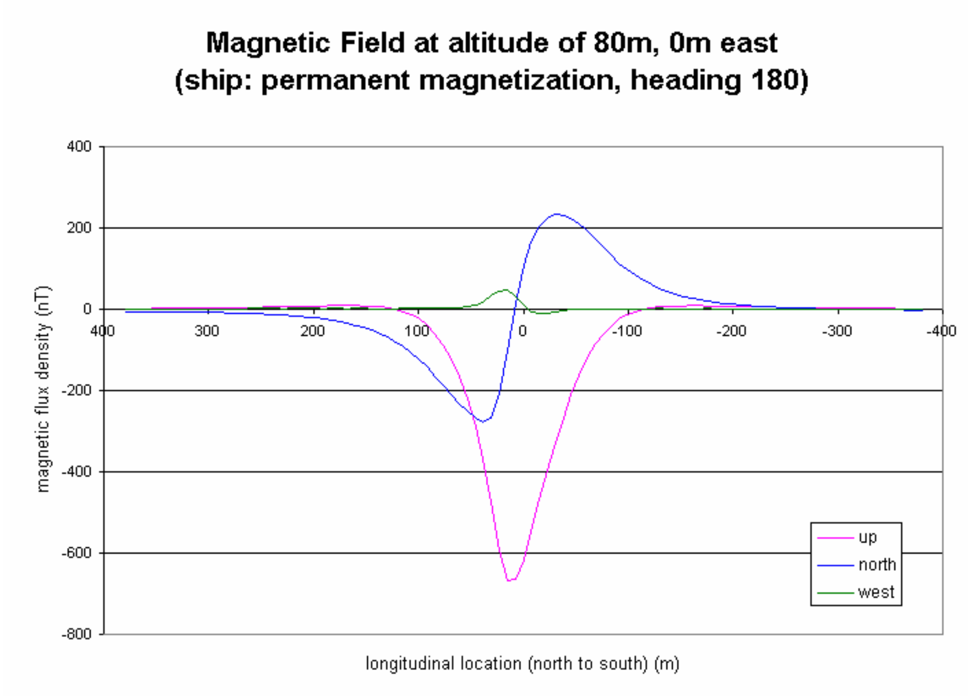

Figure 3.20 Magnetic flux density at 80 m along a line 0m east, (permanent, 180º)

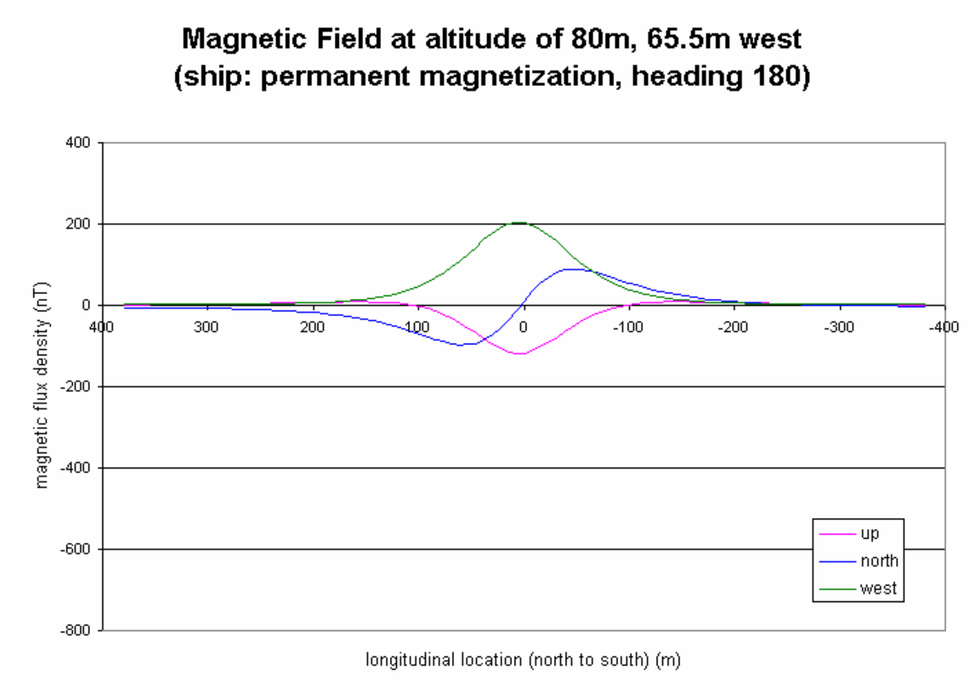

Figure 3.21 Magnetic flux density at 80 m along a line 63.5m west, (permanent, 180º)

The following three figures (Figures 3.22 to 3.24) show the magnetic anomaly at an altitude of 80 metres for the case of permanent magnetization and a ship heading of 270 degrees. Results are shown along three lines running north-south.

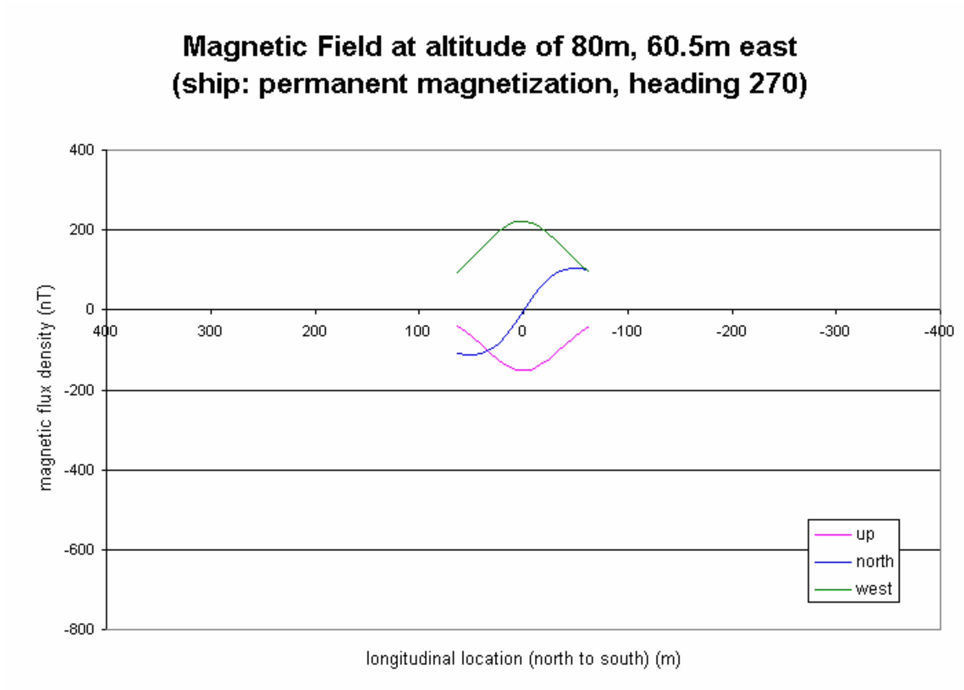

Figure 3.22 Magnetic flux density at 80 m along a line 63.5m east, (permanent, 270º)

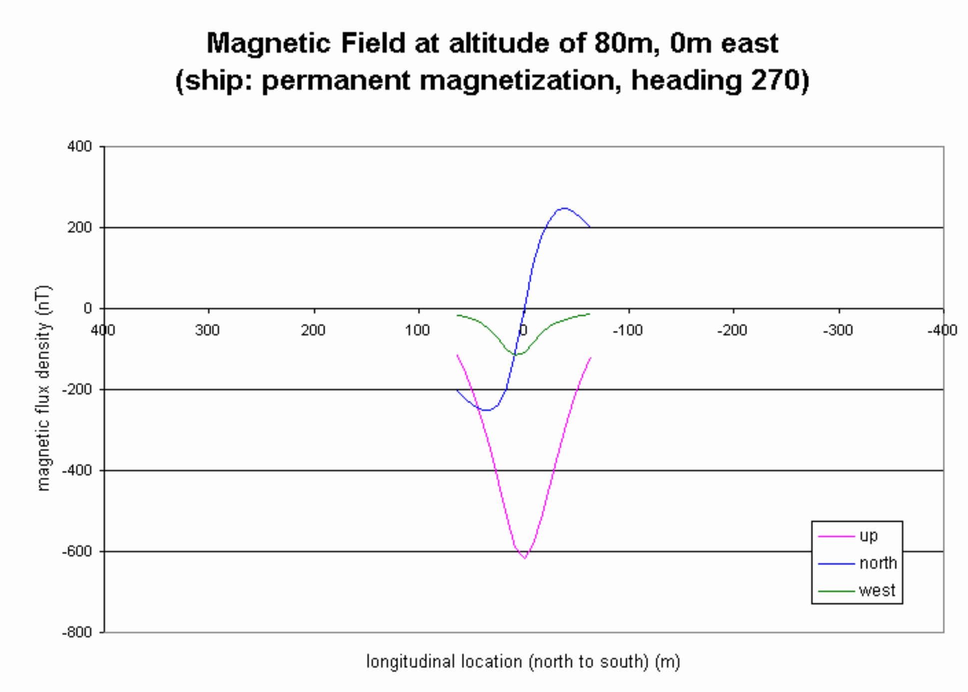

Figure 3.23 Magnetic flux density at 80 m along a line 0m east, (permanent, 270°)

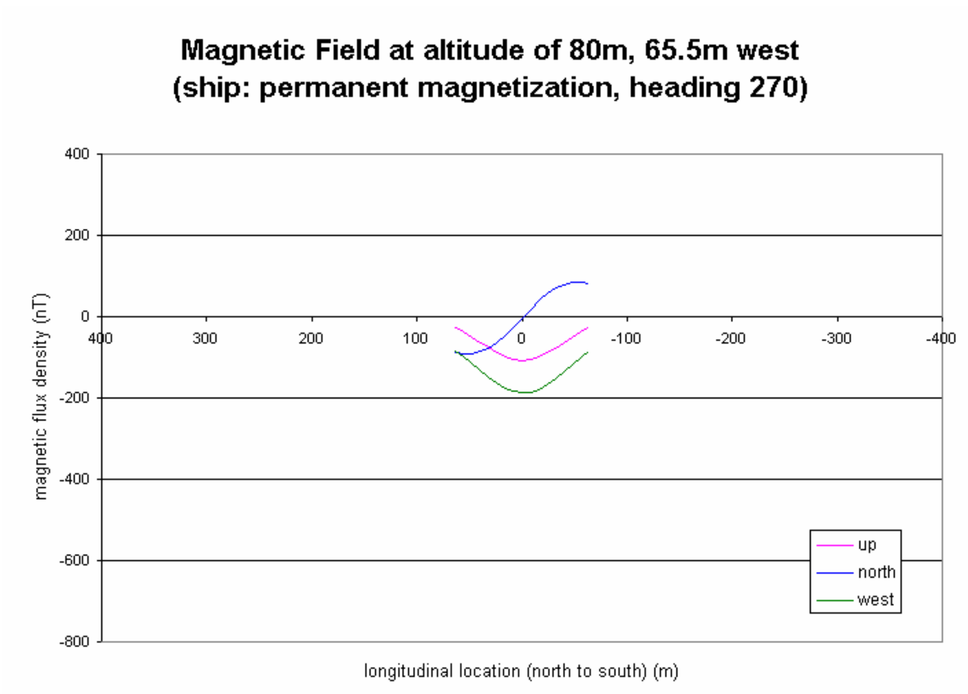

Figure 3.24 Magnetic flux density at 80 m along a line 63.5m west, (permanent, 270º)

The following three figures (Figures 3.25 to 3.27) show the magnetic anomaly at an altitude of 150 metres for the case of induced magnetization and a ship heading of 0 degrees. Results are shown along three lines running north-south.

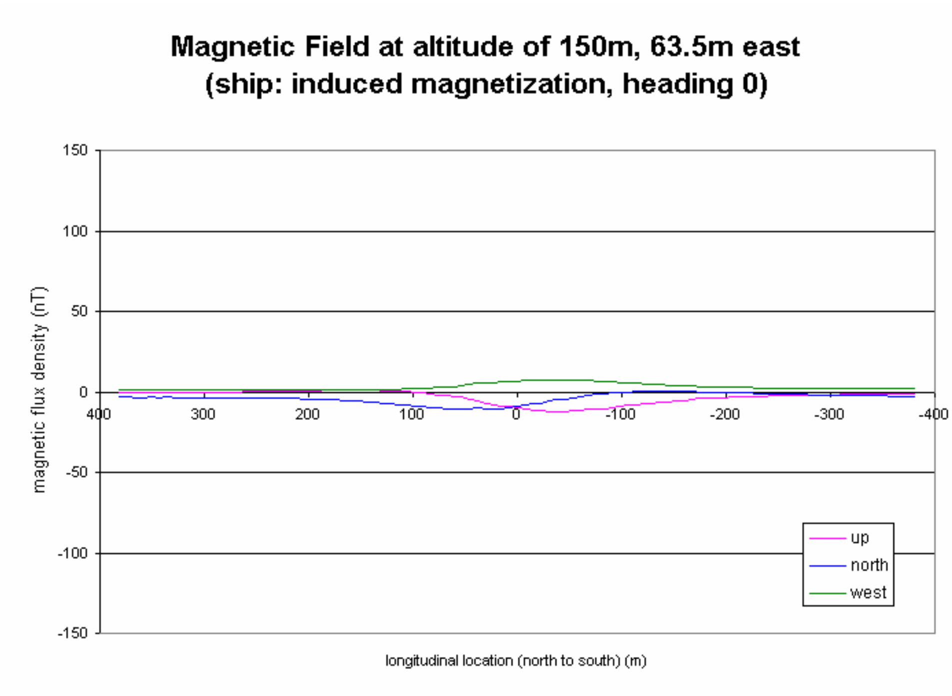

Figure 3.25 Magnetic flux density at 150 m along a line 63.5m east, (induced, 0°)

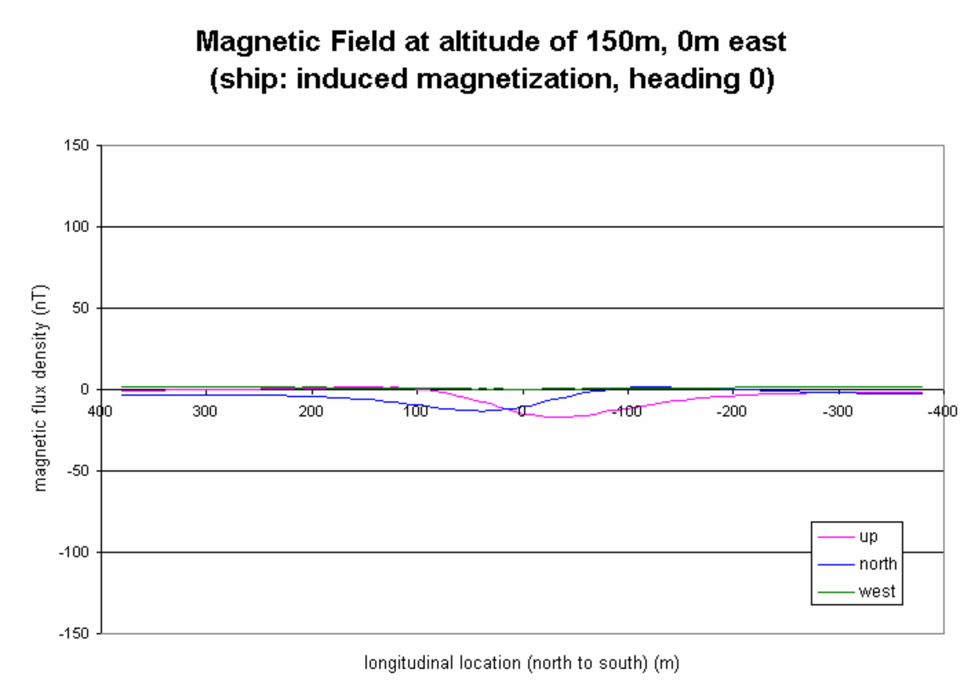

Figure 3.26 Magnetic flux density at 150 m along a line 0.0m east, (induced, 0°)

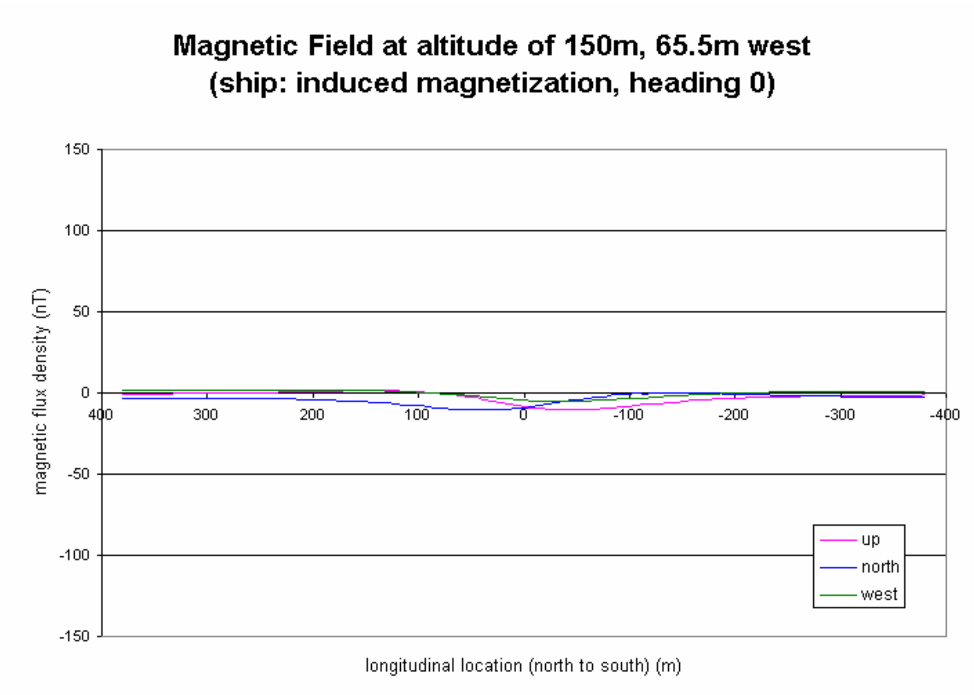

Figure 3.27 Magnetic flux density at 150 m along a line 63.5m west, (induced, 0°)

The following three figures (Figures 3.28 to 3.30) show the magnetic anomaly at an altitude of 150 metres for the case of induced magnetization and a ship heading of 90 degrees. Results are shown along three lines running north-south.

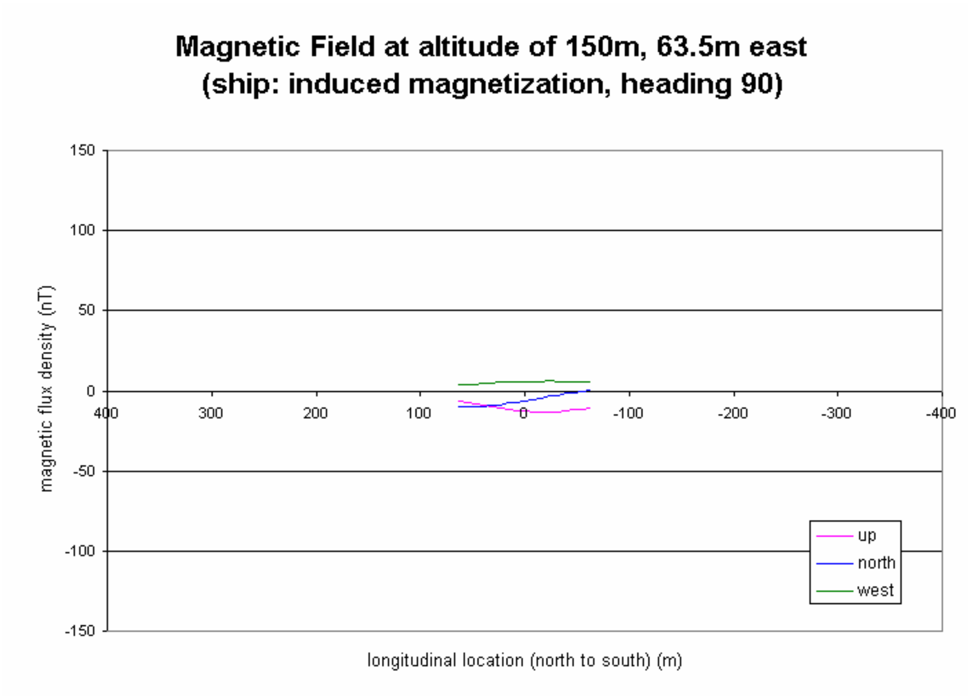

Figure 3.28 Magnetic flux density at 150 m along a line 63.5m east, (induced, 90°)

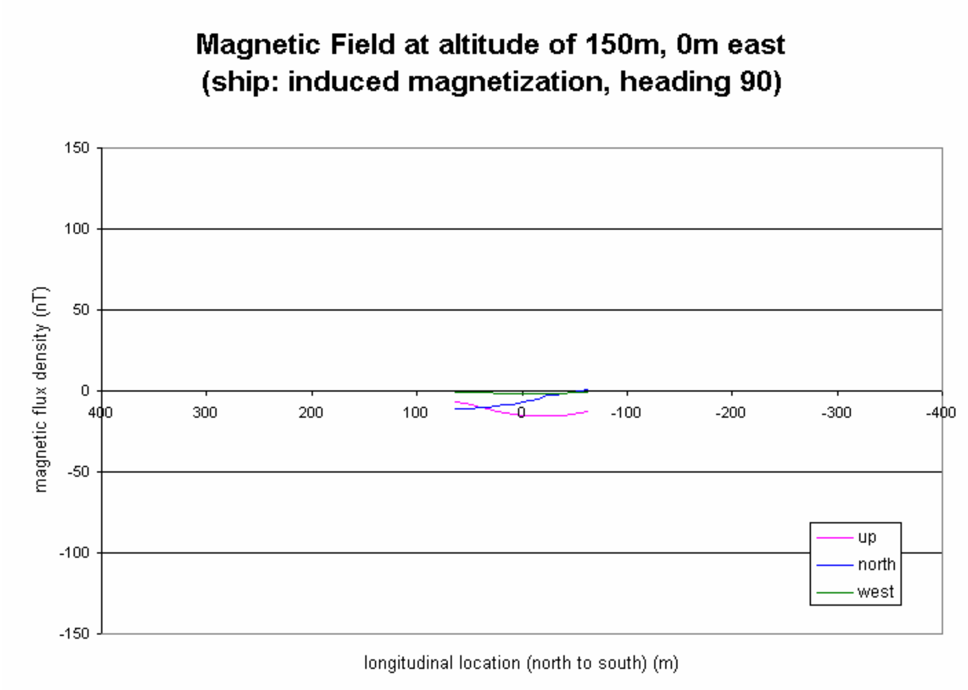

Figure 3.29 Magnetic flux density at 150 m along a line 0m east, (induced, 90^o)

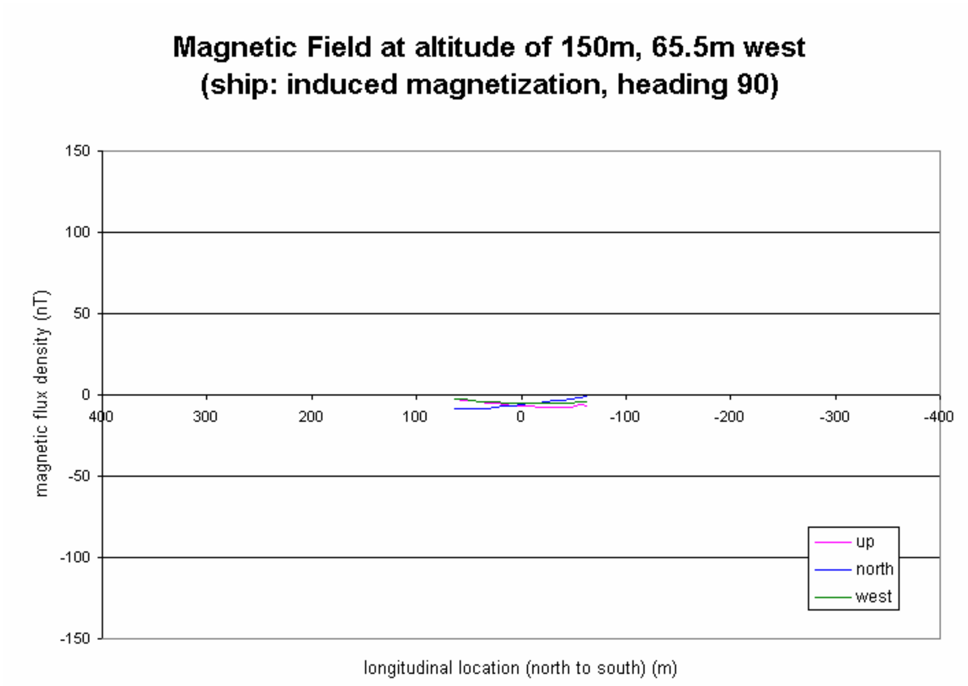

Figure 3.30 Magnetic flux density at 150 m along a line 63.5m west, (induced, 90^o)

The following three figures (Figures 3.31 to 3.33) show the magnetic anomaly at an altitude of 150 metres for the case of induced magnetization and a ship heading of 180 degrees. Results are shown along three lines running north-south.

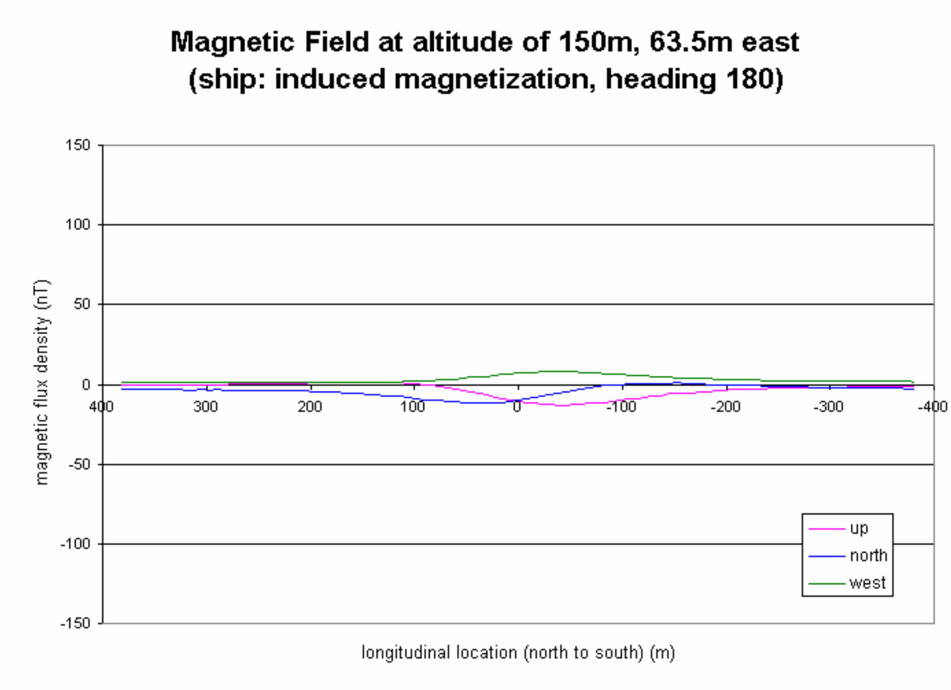

Figure 3.31 Magnetic flux density at 150 m along a line 63.5m east, (induced, 180°)

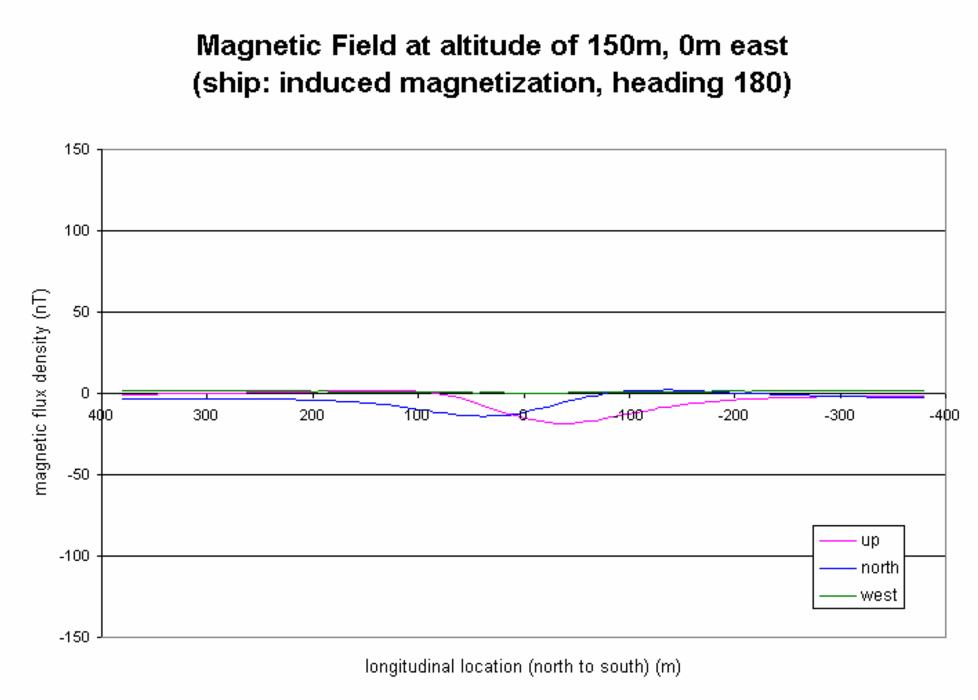

Figure 3.32 Magnetic flux density at 150 m along a line 0m east, (induced, 180°)

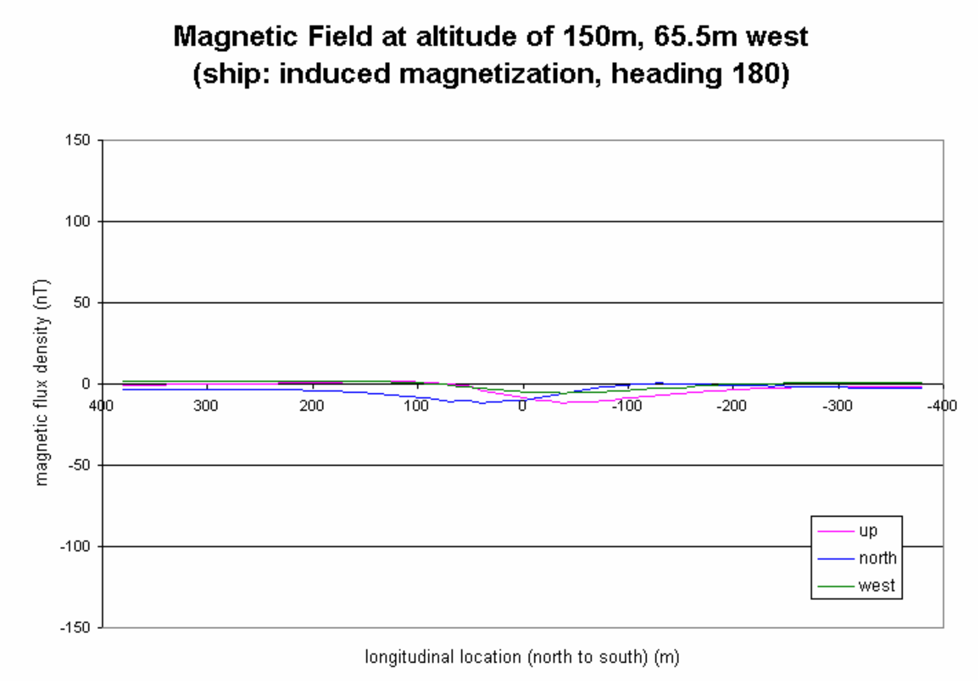

Figure 3.33 Magnetic flux density at 150 m along a line 63.5m west, (induced, 180°)

The following three figures (Figures 3.34 to 3.36) show the magnetic anomaly at an altitude of 150 metres for the case of induced magnetization and a ship heading of 270 degrees. Results are shown along three lines running north-south.

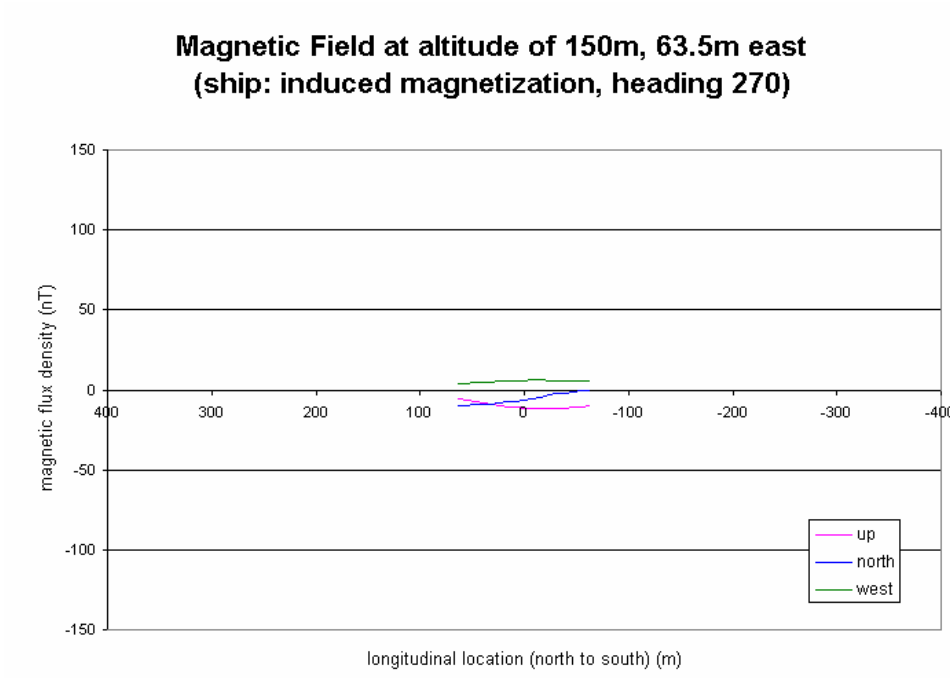

Figure 3.34 Magnetic flux density at 150 m along a line 63.5m east, (induced, 270°)

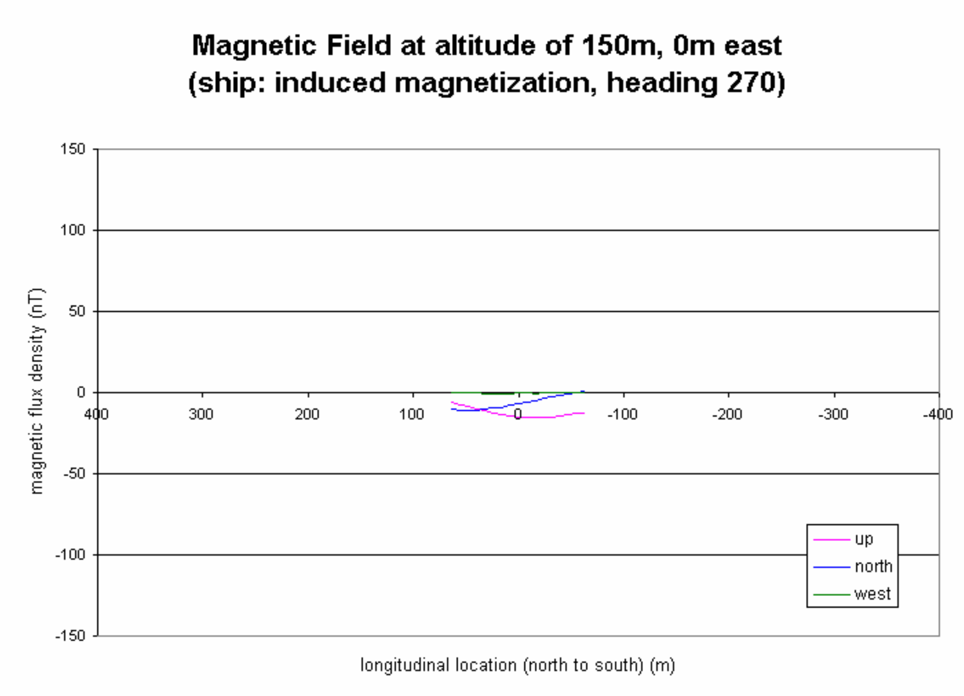

Figure 3.35 Magnetic flux density at 150 m along a line 0m east, (induced, 270°)

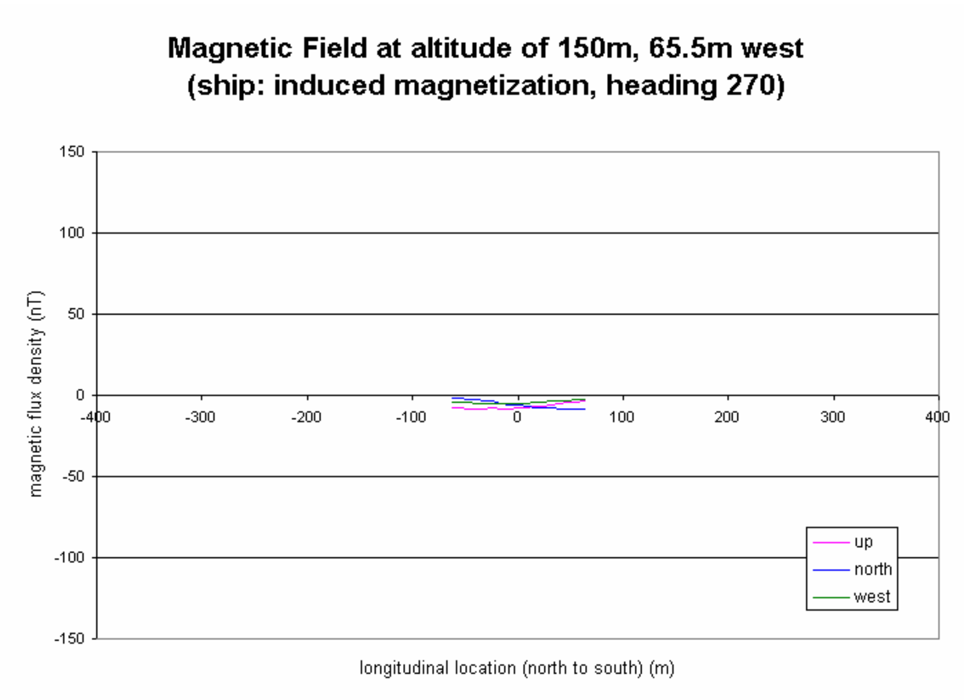

Figure 3.36 Magnetic flux density at 150 m along a line 63.5m west, (induced, 270°)

The following three figures (Figures 3.37 to 3.39) show the magnetic anomaly at an altitude of 150 metres for the case of permanent magnetization and a ship heading of 0 degrees. Results are shown along three lines running north-south.

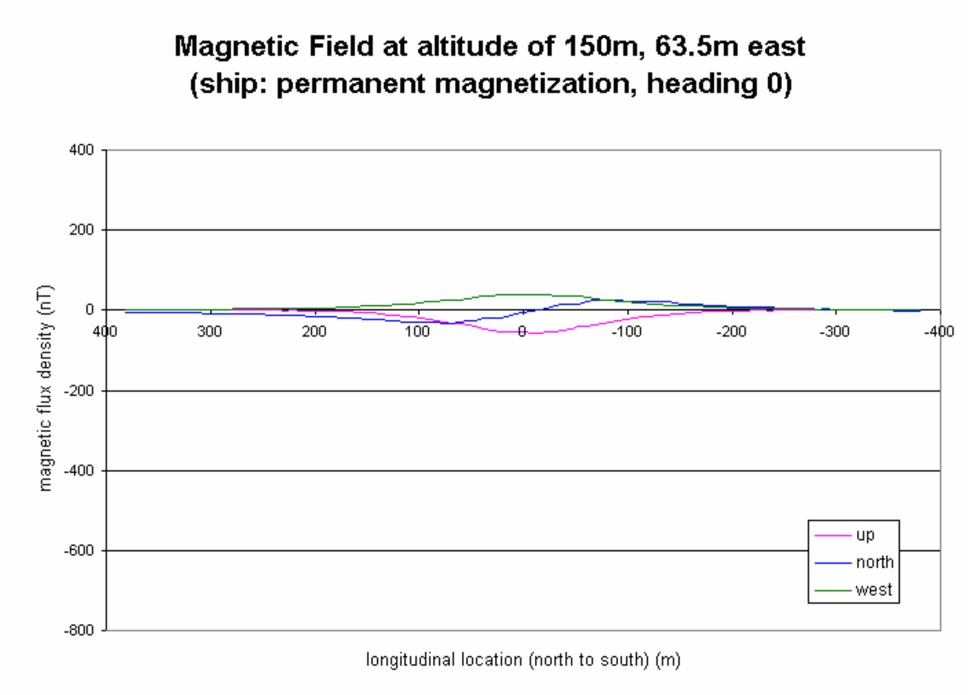

Figure 3.37 Magnetic flux density at 150 m along a line 63.5m east, (permanent, 0º)

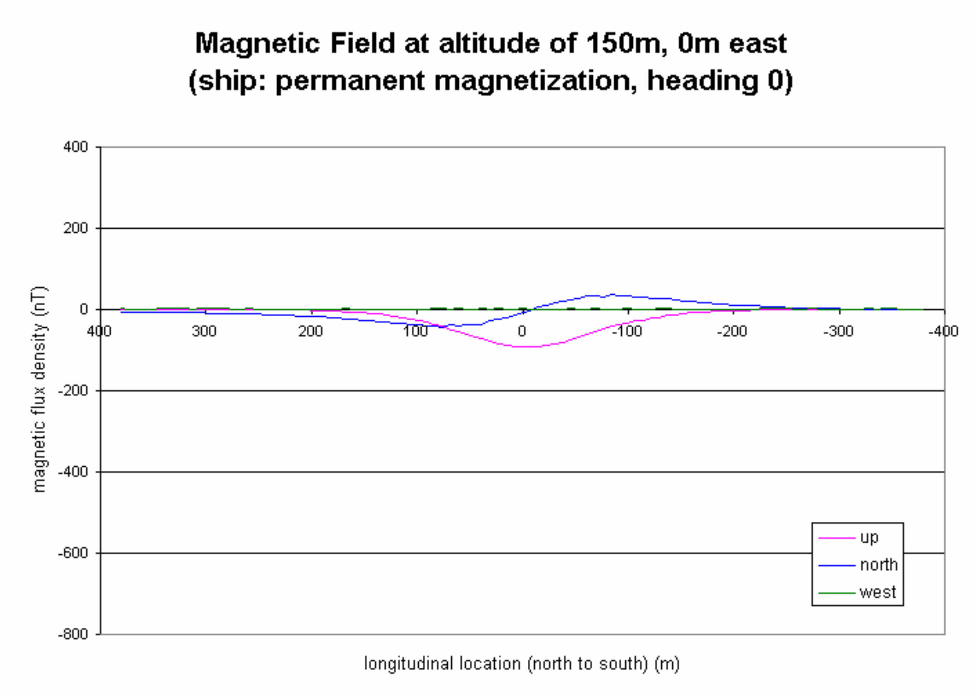

Figure 3.38 Magnetic flux density at 150 m along a line 0.0m east, (permanent, 0º)

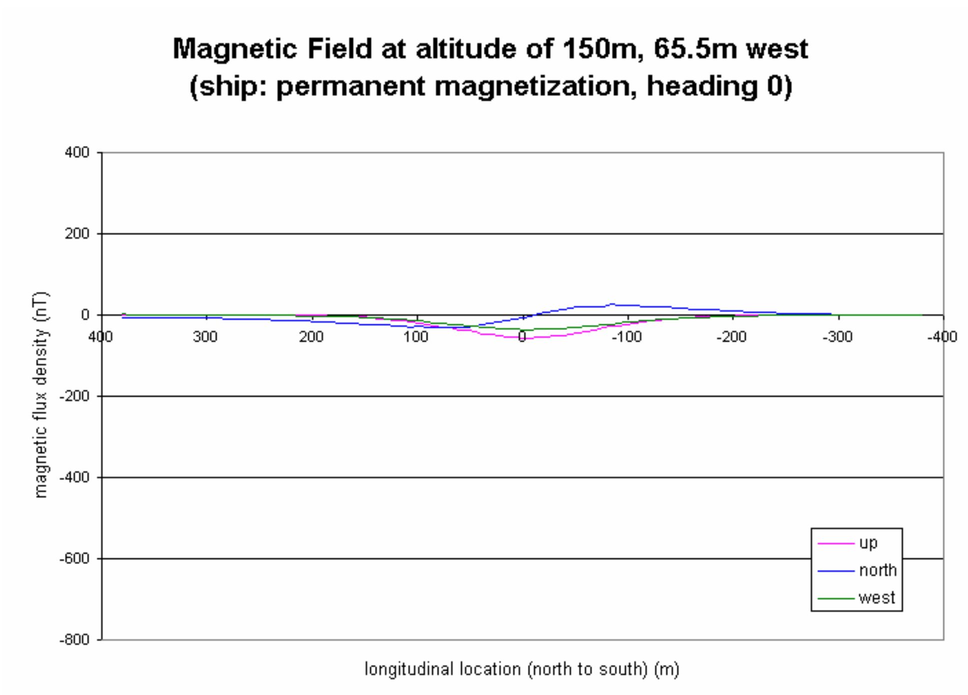

Figure 3.39 Magnetic flux density at 150 m along a line 63.5m west, (permanent, 0º)

The following three figures (Figures 3.40 to 3.42) show the magnetic anomaly at an altitude of 150 metres for the case of permanent magnetization and a ship heading of 90 degrees. Results are shown along three lines running north-south.

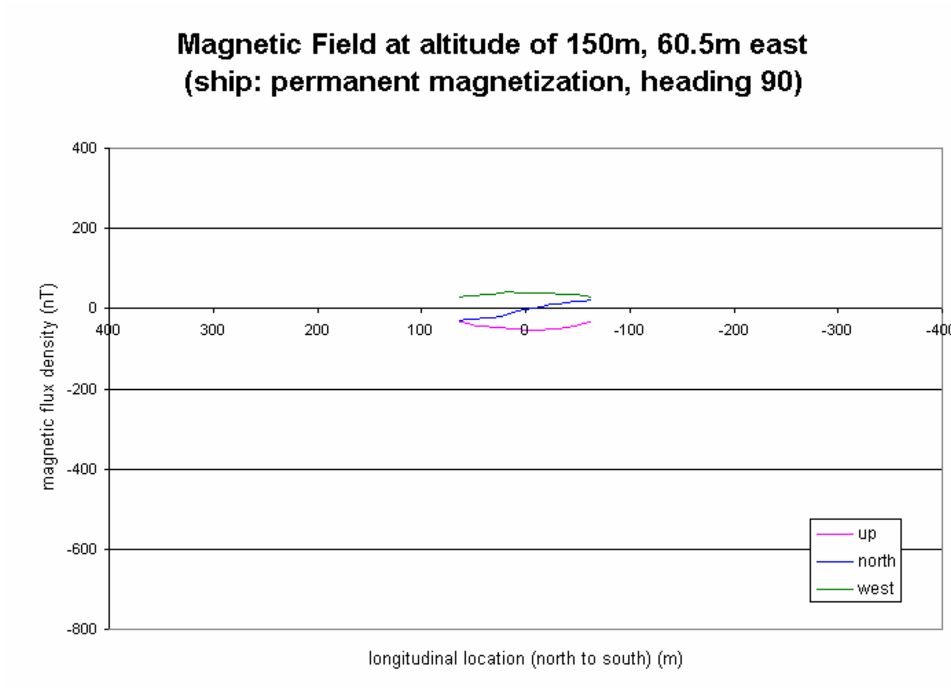

Figure 3.40 Magnetic flux density at 150 m along a line 63.5m east, (permanent, 90º)

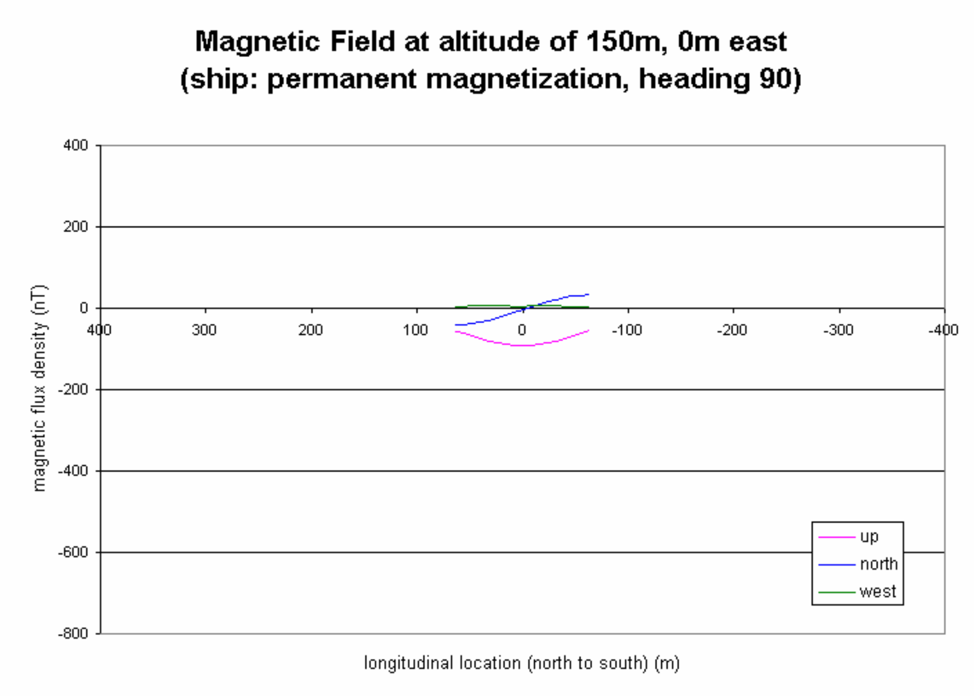

Figure 3.41 Magnetic flux density at 150 m along a line 0m east, (permanent, 90º)

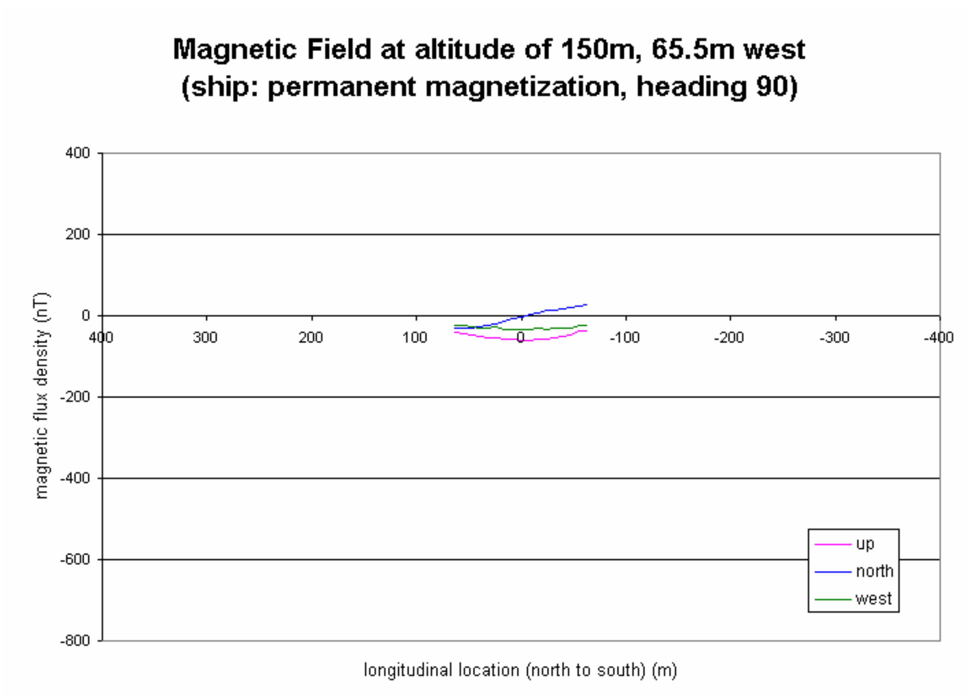

Figure 3.42 Magnetic flux density at 150 m along a line 63.5m west, (permanent, 90º)

The following three figures (Figures 3.43 to 3.45) show the magnetic anomaly at an altitude of 150 metres for the case of permanent magnetization and a ship heading of 180 degrees. Results are shown along three lines running north-south.

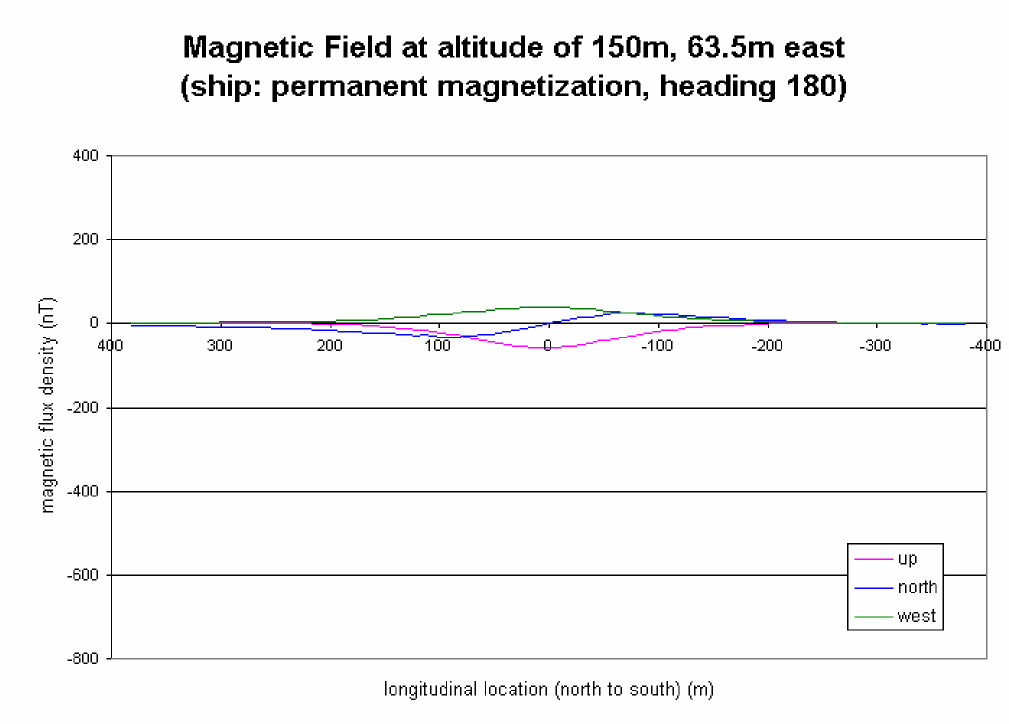

Figure 3.43 Magnetic flux density at 150 m along a line 63.5m east, (permanent, 180º)

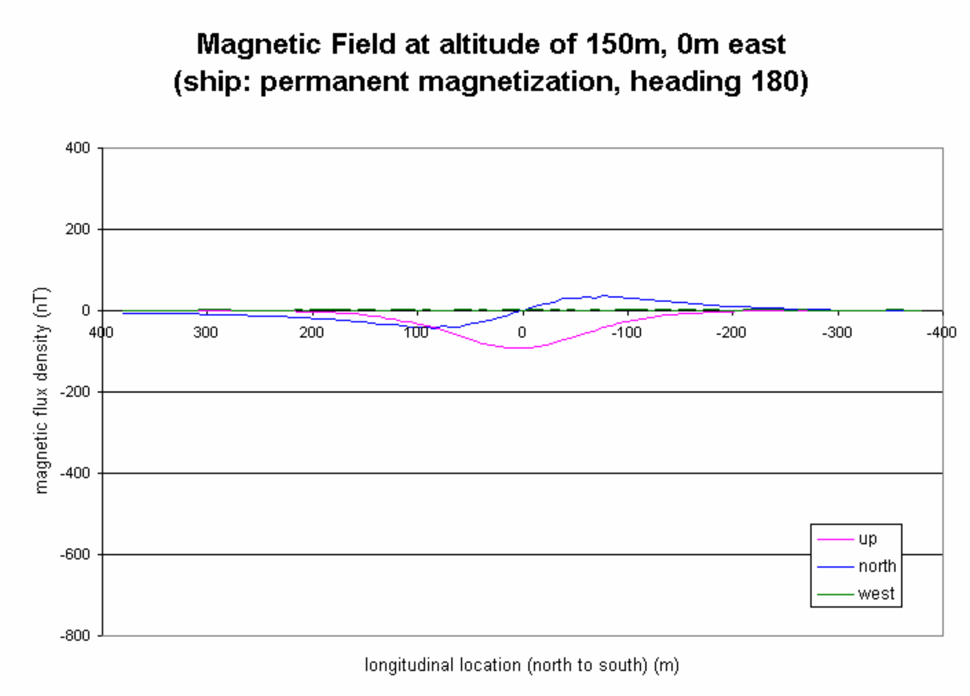

Figure 3.44 Magnetic flux density at 150 m along a line 0m east, (permanent, 180°)

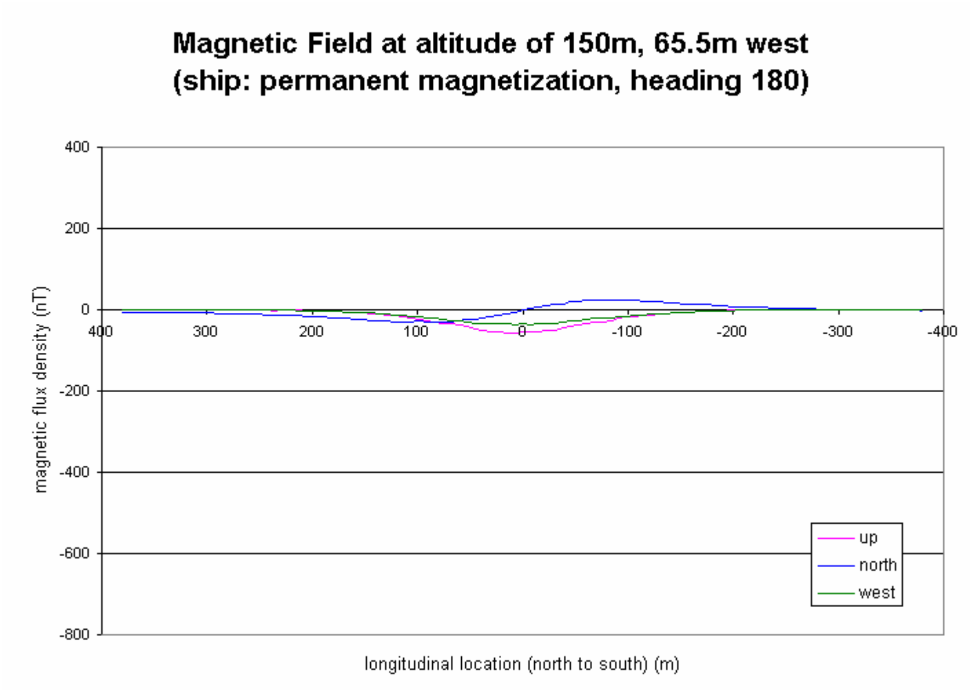

Figure 3.45 Magnetic flux density at 150 m along a line 63.5m west, (permanent, 180°)

The following three figures (Figures 3.46 to 3.48) show the magnetic anomaly at an altitude of 150 metres for the case of permanent magnetization and a ship heading of 270 degrees. Results are shown along three lines running north-south.

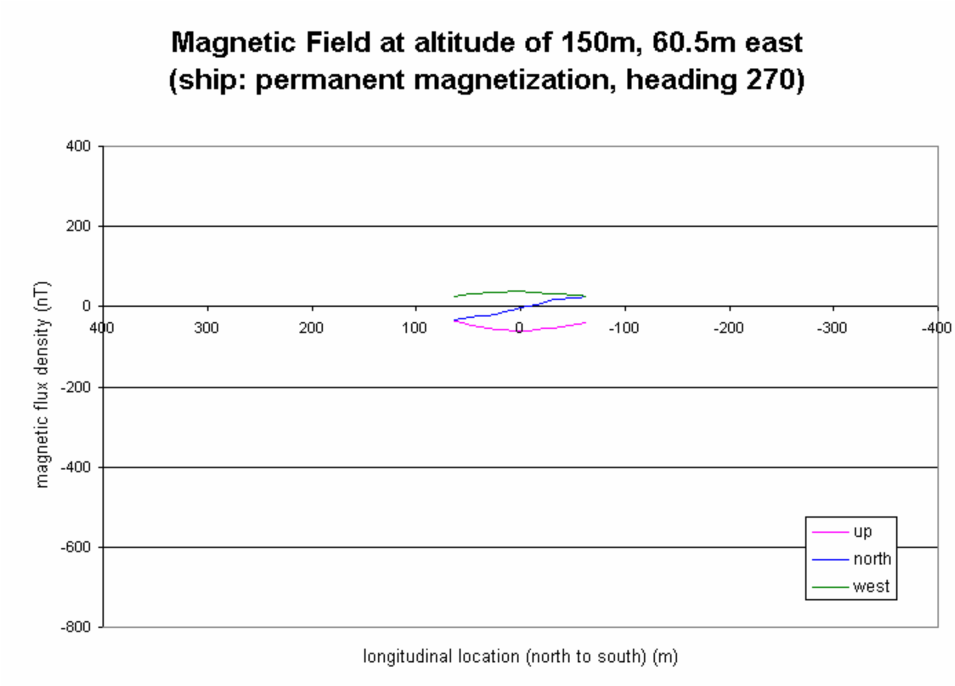

Figure 3.46 Magnetic flux density at 150 m along a line 63.5m east, (permanent, 270°)

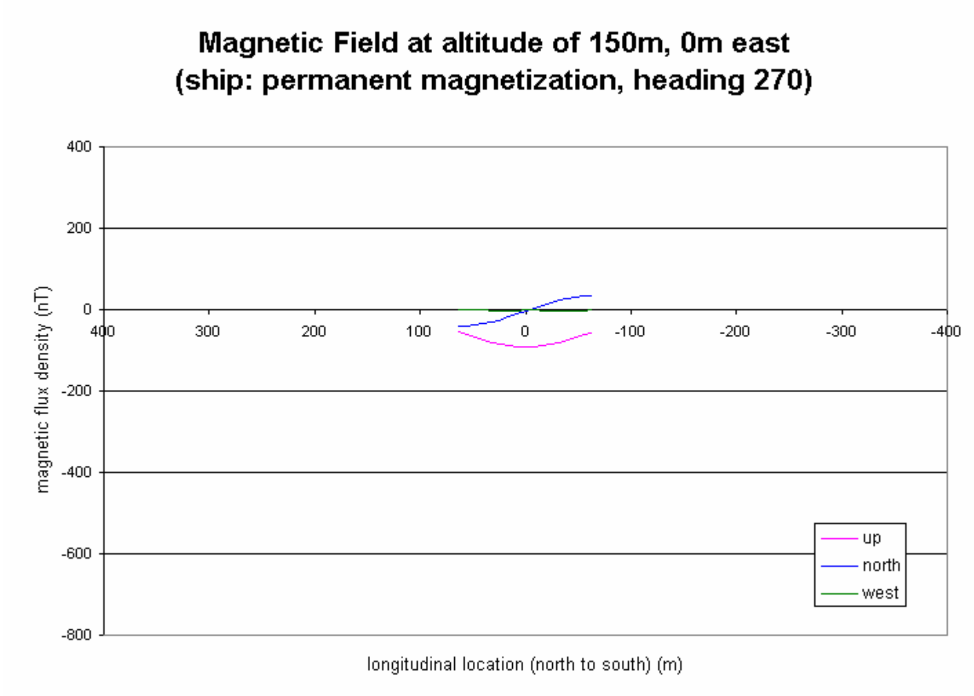

Figure 3.47 Magnetic flux density at 150 m along a line 0m east, (permanent, 270°)

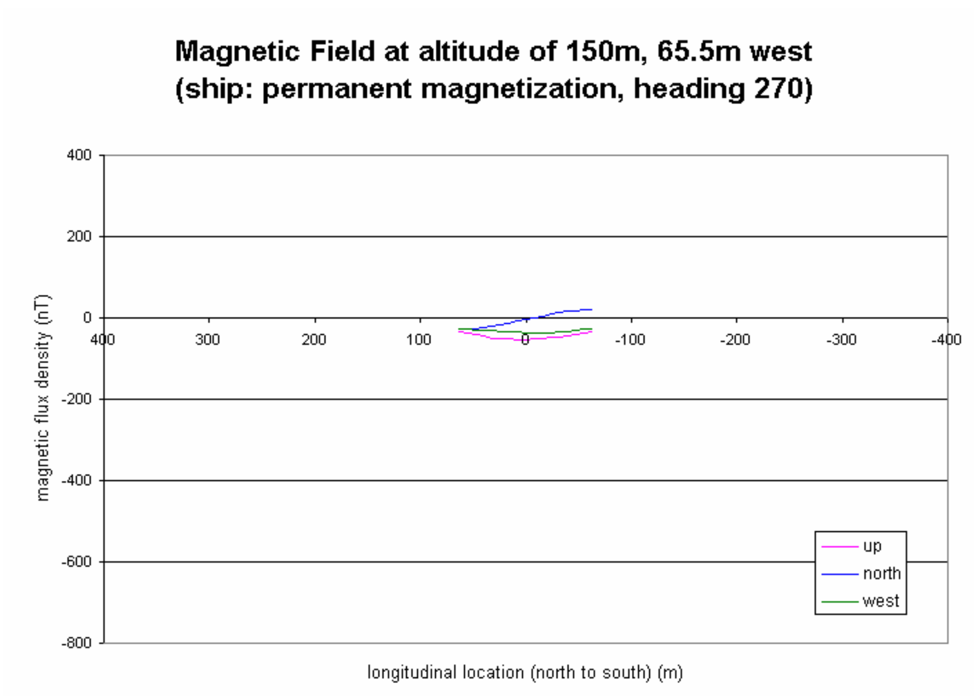

Figure 3.48 Magnetic flux density at 150 m along a line 63.5m west, (permanent, 270°)

4. Summary and Conclusions

As part of previous contracts, Martec Limited developed a static magnetic model of CFAV Quest for FLUX3D using the existing structural finite-element model. The model accounts for both the structural and some of the non-structural components of the ship. This report describes the work by Martec for the current project in which these previously developed models were used to further study of the electromagnetic signature of CFAV Quest.

Ship headings of 0º True, 90º True, 180º True, and 270º True were simulated. For each of these ship orientations, the magnetic field produced by the induced magnetic state of the ship and the permanent magnetic properties of the ship was computed. Magnetic field values at altitudes 80m and 150m above the water surface were computed.

Results from these sixteen different configurations have been tabulated. It is important that when comparing these results against field measurements it be remembered that the material properties used in the numerical simulations were not the result of calibration with physical measurements but were chosen based on a requirement that the permanent magnetization be sufficient to double the magnetic field anomaly strength at beam depth. More accurate results would require the use of material properties that are based on field measurements.

5. References

1. Wallace, J., K. MacKay. 2006. "Electromagnetic Modelling of Canadian Forces Auxiliary Vessel (CFAV) Quest: Phase II Report". Martec Technical Report TR-06-09, Martec Limited, Halifax, Nova Scotia

2. Wallace, J., K. MacKay. 2005. "Electromagnetic Modelling of Canadian Forces Auxiliary Vessel (CFAV) Quest: Phase I Report". Martec Technical Report TR-05-26, Martec Limited, Halifax, Nova Scotia.

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As part of previous contracts, Martec Limited developed a static magnetic model of CFAV Quest for FLUX3D using an existing structural finite-element model of CFAV Quest. The model accounts for both the structural and some of the non-structural components of the ship. This report describes the work by Martec Limited for the current project in which previously developed models were used to further study the electromagnetic signature of CFAV Quest. A total of sixteen analyses were performed. Analyses included four ship headings (0° true, 90° true, 180° true and 270° true), two ship configurations (induced magnetization only, permanent magnetization only), and two aircraft altitudes (80 metres and 150 metres). The induced magnetic state of the ship was simulated by using values of zero for the permanent magnetic properties of the ship. In a similar manner, the permanent magnetic state of the ship was simulated by setting the permeability values for the ship to unity. These models were analyzed using FLUX3D and magnetic flux densities at the desired altitudes were recorded. Since the intent was to compare against field measurements, in the current study all components of the earth's magnetic field were considered.

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