Electric and magnetic signatures: ship design and signature management

S.J.Davidson, C.P.Ganderton, P.G.Rawlins and S.M.Watson
Ultra Electronics PMES Signature Management, Armitage Road, Rugeley, Staffs, WS15 1DR, United Kingdom
Tel: +44 (0)1889 503437, Fax: +44 (0)1889 572929
Email:Samantha.davidson@ultra-pmes.com, Web site: www.ultra-pmes.com

Abstract

This paper will examine the electromagnetic signature management of vessels from initial concept through to vessel ranging. The complete process from the preliminary design stage to vessel signature acceptance will be discussed with particular reference to design tools and range configuration. We will describe the model of **'complete signature responsibility'** in which the customer will specify only the target signature/s to be achieved by the signature management contractor for the proposed vessel. We have previously presented work on the multi-influence measurement ranges and in this paper will look at single sensor applications and single influence (electric or magnetic) measurement arrays. This paper will be illustrated with both real and simulated vessels and signatures.

Introduction

Electromagnetic signature management process for a vessel ideally begins at the concept stage; one example is looking at the signature effect of the types of drives used. The complete signature design process will be discussed with particular reference to tools used from the preliminary design stage to vessel signature acceptance. The electromagnetic design team may be involved throughout the development of the vessel design looking at the effect on the signature of changes proposed by the Naval Architect.

This paper will examine the electromagnetic signature management of vessels from initial concept through to vessel ranging. The complete process from the preliminary design stage to vessel signature acceptance will be discussed with particular reference to design tools and range configuration. We suume the model of 'complete signature responsibility' in which the customer will specify only the target signature/s to be achieved by the signature management contractor for the proposed vessel.

We have previously presented work on the multi-influence measurement ranges and in this paper will look at single/multi-sensor applications and single/multi-influence sensor arrays with respect to determining the ideal measurement or signature calibration solution [1]-[6].

As an example of the design process we consider here the optimization of the static magnetic vessel signature.

Design and Evaluation of Degaussing Coil Systems

Steel or iron generates its own magnetic field. This is the phenomenon known as ferromagnetism. Some other metals generate magnetic fields, but the ferromagnetic

effect of iron and steel dominates naval design process. There is a significant magnetic field present everywhere on the globe causing every vessel to generate a measurable magnetic field. This field is dependant on the quantity of the ferromagnetic material in the vessel's construction, the geometry of the vessel and the local magnetic field (and the vessel's orientation relative to it).

The generated field, also known as the magnetic anomaly or magnetic signature, can be used to detect that vessel e.g. by a mine fuse or aircraft.

To prevent detection the magnetic signature should be reduced below a suitable threshold, known as the target signature. Two methods are available: degaussing and deperming. Naval vessels can have their signature reduced by either or a combination of both methods.

Degaussing

Degaussing is the name given to the process of counteracting a vessel's magnetic field by using electromagnetic coils (DG coils) to generate a field equal but opposite to the natural magnetic signature. The coils are always on, with the current varying to compensate for changes in the ambient magnetic field experienced by the vessel.

The process is not perfect, there will always be a residual signature. The effectiveness of the DG coils are limited by weight, cost and power constraints. Balancing the performance of the DG system with the constraints requires significant expertise.

Magnetic Modelling

The physical laws of magnetics are well known and it is possible to predict the magnetization of simple shapes under an external field. However vessels are very complicated shapes and it is not possible to predict the magnetization directly.

One approach is to represent complicated shapes as lots of simpler shapes and solve for each simple shape individually. In magnetics each simple shape cannot be considered in isolation, but is influenced by the field produced by all nearby shapes. To obtain a solution requires many calculations. Fortunately the increase in computing power in recent decades has made numerical modelling of things as complex as a vessel a viable proposition.

At Ultra Electronics PMES the preferred method of magnetic modelling is using Finite Element Analysis (FEA). In using FEA the problem domain is split into a number of smaller sub-domains. We then apply trials functions (shape functions) over each domain individually and constrain the problem over the whole domain. This is the Finite Element method. We use a commercial magnetic finite element package, supplemented by our own FEMAP package. FEMAP (*Finite Element Magnetic Analysis Package)* is Ultra Electronics PMES's proprietary software package for the development of degaussing coil systems.

Finite Element Analysis

Any finite element signature analysis package requires the following functions to enable the magnetic signatures to be minimised.

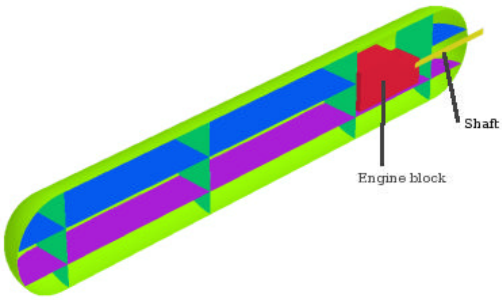
- Quick definition of degaussing coils
- Evaluation of proposed DG coil designs and power supply function
- Worldwide signature minimization using predicted coil currents

It is essential that these processes are undertaken in order to achieve a cost effective degaussing solution for the customer. This is of further importance when taking complete signature responsibility for a vessel because the supplier must guarantee that the vessel will meet its signature target when ranged.

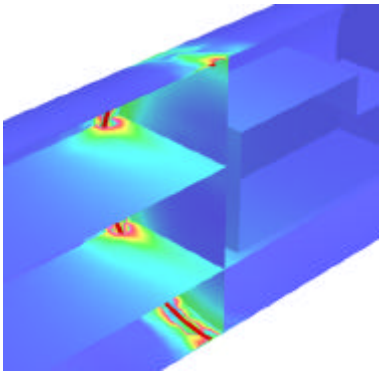
Degaussing System Design Example

The simplest models can be analysed very quickly and are suitable for rapid evaluation of potential designs at the concept stage. More detail is used for design optimisation and in particular with regard to more stealthy target signature levels.

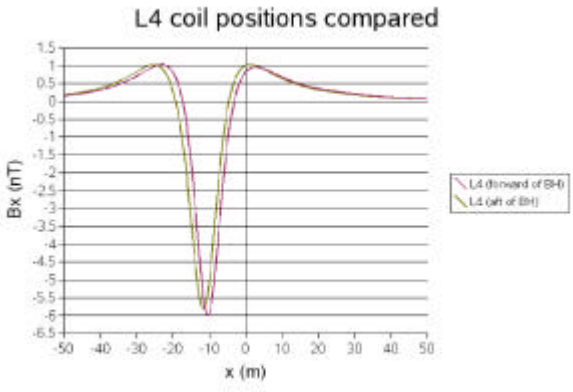
Presented here is a sample design exercise for a generic diesel-electric submarine. The submarine is 48m long and has a diameter of 8m. It has two decks and a number of transverse bulkheads.



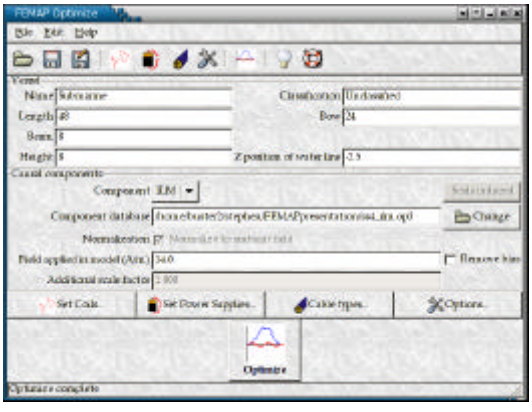
Adding model features (simplified model)



Local magnetic effects of a DG coil



Effects of coil location on its signature



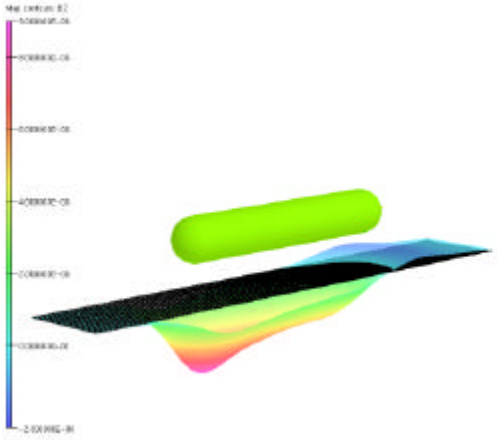
Optimising signature components (FEMAP)

FEMAP is able to handle the common cases of independent or series controlled coils. For a series set of DG coils, the coils are controlled by a single power supply providing a common current to each coil. Therefore adjusting the number of active turns is the only method to optimally reduce the vessel's signature. Various constraints can be used when designing a degaussing system to ensure that the most stealthy signature is achieved with respect to system cost budget or weight for example.

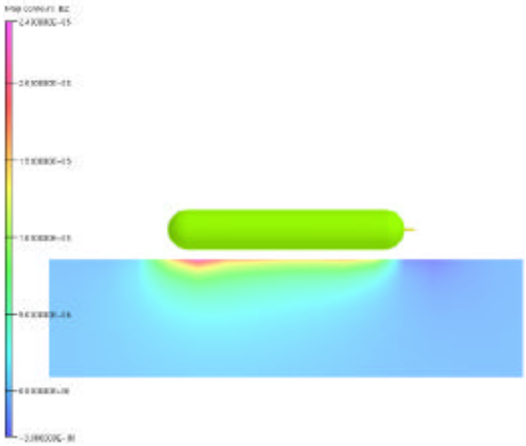
FEMAP generates the induced magnetisation hull models and the coil definitions and then generates:

- the DG off signatures,
- the individual coil signatures,
- the optimum coil settings, and
- the predicted DG on signatures and performance

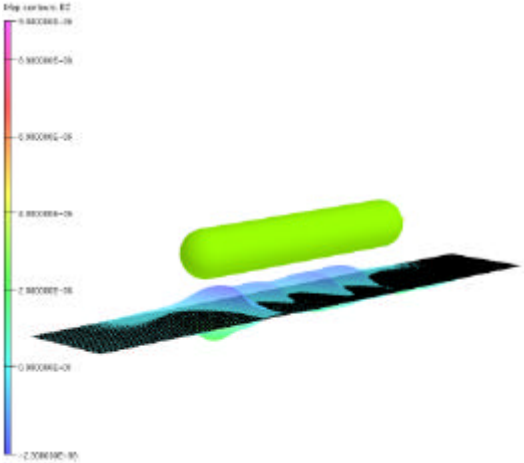
The signatures are then evaluated against customer specified targets worldwide or the areas of interest.



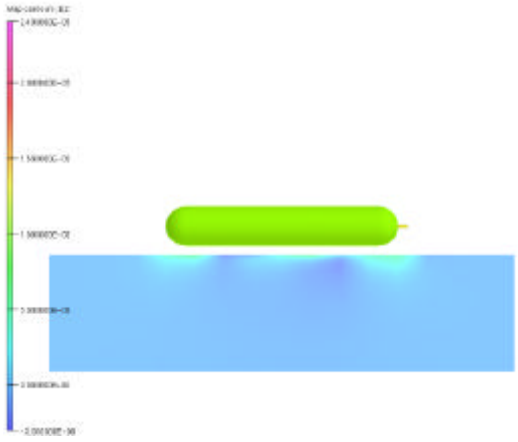
DG off vessel signature (isometric)



DG off vessel signature (contour)



DG on vessel signature (isometric)



DG on vessel signature (contour)

The results can then be exported in a variety of formats: textual summary, predicted signatures, spreadsheet output, import file for range software, XML file etc.

Complete Signature Responsibility

In order to undertake complete signature responsibility a skilled electromagnetic design team should be involved throughout the development of the vessel design. Initially the team will look at the signature from initial concept based on their experience of modeling vessel signatures. As the design process develops the team can evaluate the signature based on actual ship designs and advise on the effect on signature of changes proposed by the Naval Architect. In the final stage the team can advise the Navy on the setting of the coils using their experience gained through the design process. For a vessel for which complete signature responsibility has been undertaken the electromagnetic signature team will normally assist at the final acceptance of the vessel's signature on a measurement range.

Conclusion

In summary, the electromagnetic signature management process ideally begins at the concept stage and progresses through to vessel signature acceptance. Here we have shown a brief indication of the design work that is undertaken when optimizing a degaussing system. Such a detailed design process is necessary for all electromagnetic signatures in order to undertake 'complete signature responsibility' for a vessel's signature The complete signature design process for all electromagnetic influences [4]-[6] will be discussed in the full presentation.

References

[1] 'Transmag – a transportable degaussing range', S.J.Davidson, T.D.Cassell, G.J.Webb and A.M.Cross, pages 183-187, Conference Proceedings UDT 1994, Wembley Conference Centre, London, UK, 1994.
[2] 'Enhancement of magnetic range performance by compensation of the corrosion related magnetic field', G.J.Webb, S.J.Davidson and M.A.Houghton, Conference Proceedings UDT 1997, pages 443-446, Hamburg Congress Centre, Germany, 1997.
[3] 'Multi-influence electromagnetic and acoustic ranging', G.J.Webb, S.S.Tut, S.J.Davidson and A.J.Wilkinson, pages 11-14, Conference Proceedings UDT Pacific 98, Sydney Convention Centre, Australia, 1998.
[4] 'Aspects Of Corrosion Related Magnetic (CRM) Signature Management', P.G. Rawlins, S.J. Davidson and P.B. Wilkinson, 237-240, Conference Proceedings UDT 1998, Wembley Conference Centre, London, UK, 1994.
[5] 'Modelling Of AC Vessel Signatures Using Time Dependent Dipoles', P.G.Rawlins and S.J.Davidson, Marelec 99, Brest, France, 1999
[6] 'A Multi-influence Range with Electromagnetic Modelling', S.J.Davidson and P.G.Rawlins, Marelec 2006, Amsterdam, Netherlands, 2006

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