Advanced Signature Control Systems

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Abstract

Advanced signature control is the integrated management of electromagnetic countermeasures. This innovative approach to ship design and signature management ensures that the overall electromagnetic signature is fully optimized in whatever field of operation the vessel may be deployed. Benefits include increased stealth through improved signature control, mission oriented signature analysis, damage resilience, distributed weight, reduced cabling and improved installation flexibility.

A single intelligent signature control computer operating with complex control algorithms undertakes the overall management of the system with a common control ship-wide area network or dedicated bus connecting state of the art sensors and power controllers. By designing in compatibility with multi-influence range facilities, ranging data can be directly transmitted aboard and used for predictive and adaptive signature control. Thus an estimate of the vessel's current signature is always available from the ship's console. The intelligent control computer allows real time signature optimization compensating for vessel motion. Automatic adjustment of the degaussing coil settings occurs in the event of individual coil damage or failure. To aid in mission planning an onboard threat database enables the optimum degaussing strategy to be determined for the perceived threat.

1. Advanced Signature Control Systems

1.1 Signature Reduction Performance Measures

Due to the expanding range of mine types, it is becoming increasingly necessary to consider the relationship between mine threat and signature in some detail. In the case of magnetic signatures, it has previously been considered sufficient to minimize the peak in the vertical field at some reference depth for a particular vessel. The motive for this choice of signature optimization was partly the prevalence of certain well known mine types and partly the technological limitations of the degaussing industry at the time. Because of the technological developments in recent years, it has become practical to consider more sophisticated degaussing philosophies. Alongside this, the advances in technology have also enabled the development of more sophisticated mines and other threats. These two factors combined have led to an increasing demand for an approach to the optimization of vessel signatures which relates more directly to concepts such as ship safety and risk in an environment populated with a variety of threats.

A clear example of this is the magnetic mine that is sensitive to the gradient of the magnetic field instead of the more common peak total field value. The optimum degaussing strategy against such a mine would be different from the optimum strategy against a more conventional mine which used a peak total field fuse. Computer hardware is now available, which is more than capable of performing the necessary calculations to optimize a ship's signature against such a mine threat with very little associated cost. Enhanced on board degaussing current control equipment is also available to effect this optimization in near real time.

The gradient based mine algorithm is not the only innovation in mine technology. There are a wide variety of mine algorithms currently deployed, some of which are specifically designed to target individual vessel types as well as being sweep resistant. If information was available concerning the probabilities of the various mine types being encountered, then it may be beneficial to modify the degaussing coil currents on a mission to mission basis to provide maximum protection and minimum risk. The required information to do this is, however, not always available.

We propose here, an approach to degaussing which utilizes the advances in computer hardware and software and developments in coil control technology which have taken place since degaussing was more of a heuristic science.

Traditionally, a reduction of 10 to 1 would have been a realistic target for a conventional degaussing system. With these enhancements, we would expect to achieve a signature reduction of the order of 95%. This level of degaussing would have a significant operational impact for many vessels. As an example, for a typical vessel with an undegaussed signature of 3000 nT at 20 m, this could enable safe passage through a channel with a water depth of 50 m without the need for mine countermeasure vessel activity.

1.2 Optimum Signature

A study was conducted in 1993 by Thorn Automation (now part of Ultra Electronics) into signature optimization for ships. As part of this study, extensive vessel-mine encounters were simulated and an assessment made of the "best" overall signature metric in terms of safety. During this study, it became clear that the "best" signature was threat dependent. Although the study found an overall best strategy for signature reduction, this strategy did not necessarily give the best performance against *all* mine types. This suggests that the perceived current threat should be considered a factor in determining the type of signature to aim for. As an example, a particular threat may be associated with a specific depth and specific headings. In this case the signature should be optimized for that depth and not a standard reference depth. In addition, the relationship between heading and risk could result in a preferred choice of route in terms of stealth/safety. As a general point, the DG coil settings for an optimum near field signature is not always the same as the settings for an optimum far field signature.

1.3 World Wide Settings

Ultra Electronics have made extensive use of the International Geomagnetic Reference Field (IGRF) which calculates the magnetic field on the surface of the earth. This mathematical model takes latitude, longitude, date (and altitude) as input and calculates the magnetic field at that desired position and date. This in conjunction with heading and attitude information from the ship enables a prediction of the ambient field relative to the ship. The induced signature of the ship can then be calculated as it manoeuvres in a variety of locations.

1.4 Causal Component Modelling

Ultra Electronics have extensive experience in using state of the art finite element modelling techniques for determining the permanent magnetic field associated with both surface ships and submarines. This together with open range data allows the causal components of a ship's signature to be estimated. This in turn allows the calculation of the optimum degaussing currents for a particular scenario. As the vessel changes heading, pitches and rolls, the relationship between permanent and induced signatures can be estimated in real time and compensated for.

1.5 Mine Algorithm Development

The research department at Ultra Electronics have been involved for many years in the analysis and design of sea mine algorithms.

2. Advanced Degaussing Philosophy

Combining the above points, the advanced degaussing system envisaged for the next generation of degaussing systems would include the following:

A On board Longitudinal, Athwartships and Vertical degaussing coils designed for optimum performance with individual power supplies.

B On board computer with an extensive suite of prediction and analysis software. This would include the IGRF for ambient field prediction and interfaces with ship's systems to acquire attitude and heading information. All available range data and heading and attitude data would be integrated to form a best possible estimate of the "current" signature. This may involve the use of on board magnetometers to improve the accuracy of the signature estimate. In this way the signature can be optimized 'on the spot', including the compensation required for damaged or failed coils. For many years this has not been a practical proposition, but modern computer hardware and software is easily capable of handling the volume of data and processing speed which would be required.

C A database of mine algorithms and their characteristics. Also included would be the facility for profiling the intelligence information concerning the relative likelihoods of mine encounters of different types. The system would then provide options in terms of parameters which would control the degaussing strategy eg: minimize peak total field or mean gradient etc.

This database would be frequently updated as new mine types are discovered and new degaussing strategies are developed.

This database would also be updated with new information as and when it became available and transmitted directly to vessel.

D Analysis software which includes an assessment of risk or threat, given the magnetic characteristics of the vessel and the relationship between known threats and signatures. A possible implementation of this would be a new characterization of signatures in terms of their relationship with mine types.

3. Summary

It is essential that the relationship between perceived threat and degaussing requirements is correctly understood in terms of the optimization of signatures. This naturally leads one to investigate the relationship between various signature metrics and safety levels. For a degaussing system to be automatic, these relationships need to be quantified. The most natural way to quantify the relationship between mine and signature in terms of safety is to consider the mine as acting on the signature, producing a threat. Since signatures are mathematically well defined it would be straightforward to consider mines as mathematical operators acting on signatures. This is a common technique, especially if one imposes a restriction to linear operators. Then the whole theory of linear operators on vector spaces (spaces of signatures) becomes available. For actual mines, it may be necessary to include non-linear operators. Nevertheless, with the enormous computational capacity of even modest currently available computer systems, models of mines in terms of operators on signatures could be generated. These could then be used in a quantitative way to estimate the safety level for a particular vessel in a particular hostile environment, and adjust its degaussing coil currents to maximize

safety.

We believe that these enhancements to a conventional signature management regime are not prohibitively expensive and would radically improve the achievable level of safety for ships navigating in possibly hostile environments. The key benefits of such a system would be:

A Knowledge of one's own signature at all times.

B Ability to protect against specific threats.

C Easily modified as new threats are discovered.

There is no real obstacle today preventing the degaussing industry from facing the challenges of current mine technology. Installation of powerful inexpensive robust computer hardware and reliable software is becoming more common, as are more intelligent signature control algorithms customized for use in the degaussing world.

The introduction of the approach described above to signature management would, of course, require a cultural re-alignment within the degaussing industry. Ship's crew would bear more responsibility for the control of the ship's signature. They would have information on board, displayed on a console, giving the best current estimate of the signature together with an associated risk analysis based on the currently perceived threat. The ship's crew would therefore be in the best position to examine the ship's signature and carry out any required modifications to the DG coil current settings.

Similarly, the responsibility of DG range staff would change. The focus here would be on the integrity of the data which the DG range provides to vessels using the range. In particular, first of class coil effect signatures need to be measured accurately. However, since the range staff is unlikely to have access to a vessel's on board database, the onus would naturally be on the ship's crew to set the DG coils in accordance to their requirements.