THE ROYAL NAVY'S APPROACH TO PERSONNEL RADHAZ

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ABSTRACT

With the probable introduction into service of new personnel non-ionising radiation (RADHAZ) levels, the potential exists for a conflict of interest between compliance with the new levels and the need to maintain ship operability. This article outlines the process the Royal Navy is pursuing in an attempt to embrace these changes whilst at the same time minimizing operational limitations. However, before any new guidance can be issued to the RN, it is essential that the magnitude of the ship radiation profile is known in order that the impacts of implementing the new levels are identified and where conflicts of interests exist, techniques/solutions are developed and implemented so that any constraints to the ship's operational performance/effectiveness are minimised.

Introduction

Under the auspices of the UK Health and Safety at Work Act the Ministry of Defence has a 'duty of care' to its employees and others to provide a 'a safe place of work', this includes all Royal Naval platforms both ashore and at sea. In support of the Act there is a need to provide personnel, protection from non-ionising radiation (RADHAZ) associated with electromagnetic fields.

Whilst RADHAZ guidelines for the RN have been in existence for many years, with the increase in knowledge as to the effects of non-ionising radiation coupled with tauter Health and Safety requirements, there is a need to reassess these RADHAZ guidelines. The new levels currently under consideration by the RN are those proposed in the UK's National Radiological Protection Board (NRPB):

Board statement on restrictions on human exposure to static and time varying electromagnetic field and radiation. Volume 4 No 5.

These guidelines set RADHAZ levels for the frequency range 0–300 GHz, in terms of: Field Strength (E&H fields), and Power Density. Although the guidelines cover the frequency spectrum 0–300GHz, from a practical/operational point of view, the main area of concern is that radiation associated with HF communication transmitters, as such this article will only concentrate on the Personnel RADHAZ associated with this portion of the spectrum.

In order to obtain an in-depth understanding of the HF RADHAZ characteristics of a platform, DGSS/SS625 is currently conducting a comprehensive ship survey programme which will address the effect of multiple transmissions and delineating of personnel safe boundaries on the upper deck of a ship. In support of this activity a transportable measuring system has been developed which is capable of assessing the worst-case HF fields and personnel hazards at all significant upper deck locations. The survey will not only highlight those areas in excess of the safety levels but also identify equipments located within the areas for which access/operation could be restricted. Following the survey, palliatives/procedures will need to be developed such that the operational capabilities of the ship can be maintained. These palliatives could well encompass such techniques as reduction in transmitted power and/or the application of non-conductive materials.

New non-ionising radiation levels

The new guidelines as defined by the NRPB are expressed in terms of Specific Absorption Rate (SAR). SAR is defined as the rate at which RF energy is imparted to an element of biological mass. It is convenient to use the concept of 'Standard Man' to aid discussion of the thermal aspects of RF radiation. The generally adopted standard man has a:

- Height of 1.75m (5′9″)
- Weight of 70kg (154lb)
- Surface area total of 1.85m^2 (20 sq. ft).

Average SAR in a body is the time rate of the total energy absorbed divided by the total mass of the body and is expressed in terms of watts per kilogram (W/Kg).

At very low frequencies (tens of kHz) energy absorption is relatively low. Absorption increases to a maximum at human resonance, which for adults starts at approximately 25MHz depending upon the height and whether the person is effectively earthy or not. Above resonance the absorption starts to decline.

The new NRPB guidelines set the whole body SAR level at 4 W/Kg divided by a factor of 10 to take account of additional thermal loading. Thus the general basis is 0.4W/Kg.

There is no direct means of determining SAR by practical measurements, thus the levels are expressed in terms of field strengths (Electric Field (E) and Magnetic Field (H)), wrist current and ankle current.

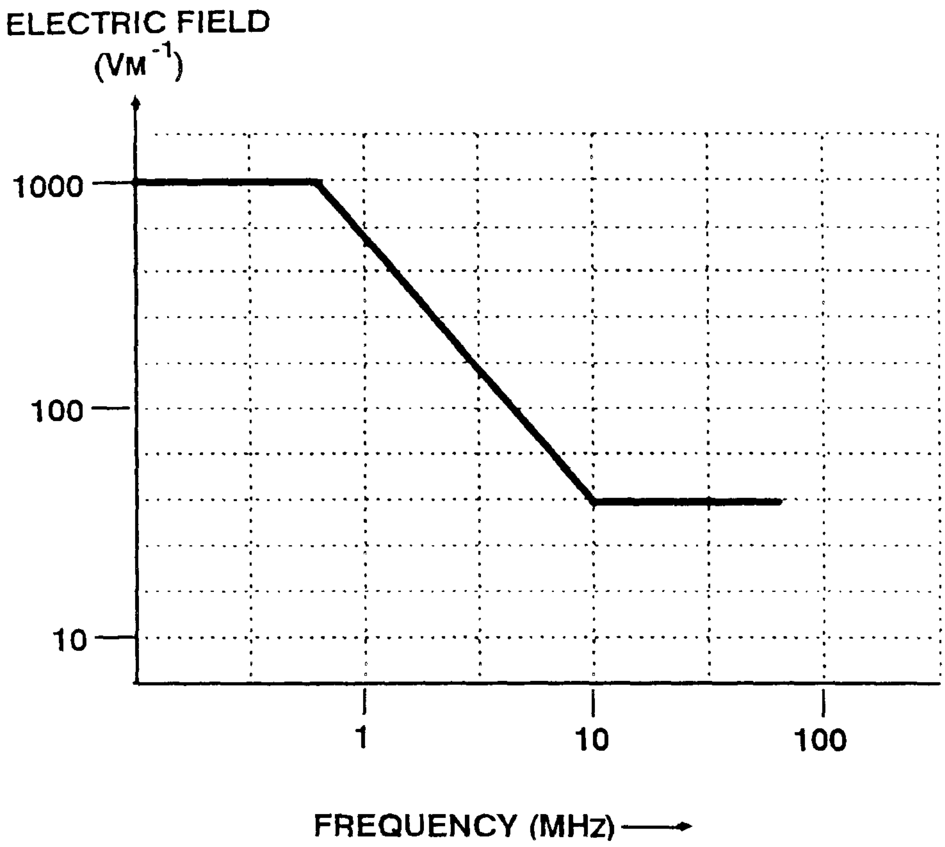

FIG. 1 — ELECTRIC FIELD

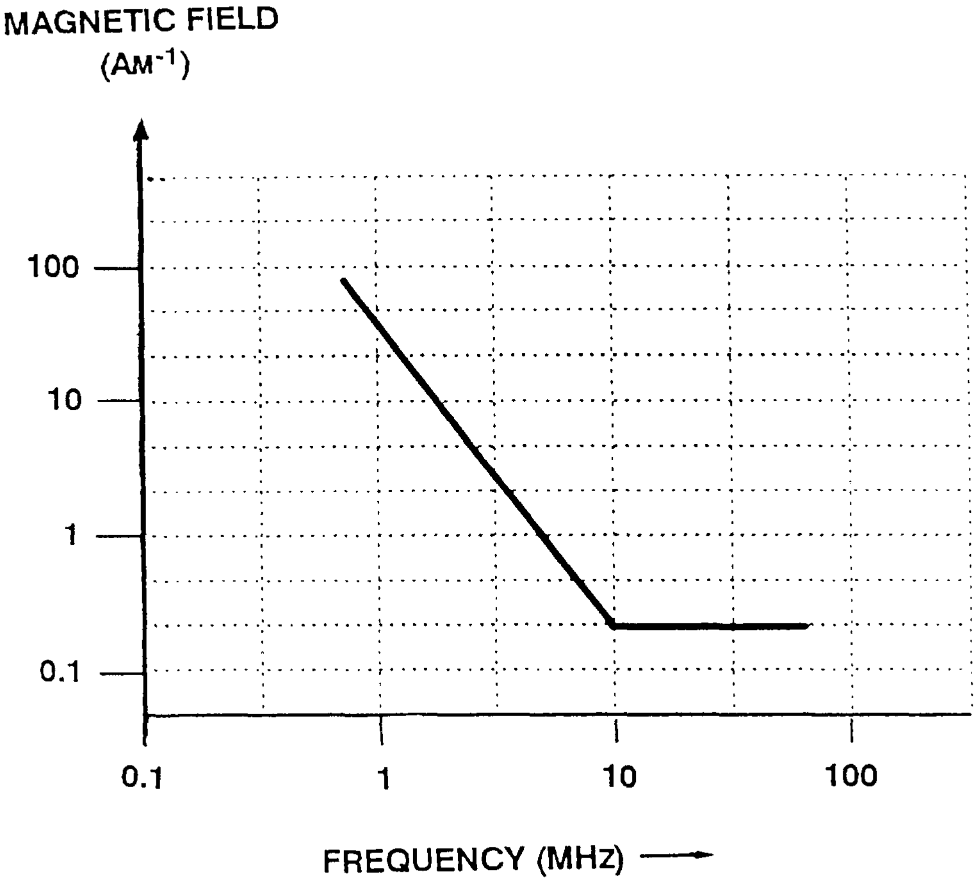

FIG. 2 — MAGNETIC FIELD

Investigation Levels

The E (FIG. 1) and H (FIG. 2) strengths are measured as investigation levels. This means that if these levels are exceeded, the limb currents will be measured in that area. However, if these investigation levels are not exceeded, the limb currents will not be measured in that area.

Basic Restrictions

The concept of limb current as a safety limit is relatively new and as such been agreed, with the NRPB, to set an interim level of 100mA over the HF band for both the ankle and the wrist. This interim level will be used until a more representative level has been determined.

Wrist current

This is a measure of the RF induced currents in a limb in firm contact with a metal structure. This will act as a conductor sufficiently to cause a build up of body heat. An induced wrist current 100mA is equivalent to the localized SAR induced into a single limb of the level 20W/Kg.

Ankle current

This is a measure of the RF induced currents flowing through the ankle of a human body in free-standing conditions (i.e. no contact with any metallic objects apart from the feet). An induced ankle current of 100mA is equivalent to the whole body averaged SAR of 0.4W/Kg.

Shock/burn hazards

Contact with passive objects in RF fields may result in currents flowing through that part of the body, usually the hands, possibly causing RF burns.

These effects can result from contact with almost any conductive object such as ladders and other metallic structures.

Burns may result when the current density ($mAcm^{-2}$) is excessive due to the contact area being relatively small. The probability of a RF burn is reduced with the greater area of the full hand grasp (this then becomes a limb current hazard). These burns in turn may cause startle responses which are an extremely dangerous indirect effect of electro-magnetic fields. Quite small burns incurred by personnel working aloft can cause an involuntary movement (startle response) and could lead to a fall.

Ship RADHAZ profile survey

In order to determine the RADHAZ profile of a ship, it is necessary to conduct a measurement survey of the ship's non-ionising radiation levels when transmitting on its HF communication systems. Because of the Health and Safety implications it is essential to determine the levels at the worst case scenario i.e. maximum power, worst frequency, multiple antennae.

The first phase of the RADHAZ survey involves identifying the areas of the upper deck in which potential RF hazards may exist. These areas are determined after reference to the ships antenna rig drawings, the RF characteristics of each emitter, personal observations on board and consultation with the ships staff. Areas of potential hazard are defined as those to which ships staff have access, and which, at the same time may be irradiated with levels of RF equal to, or in excess of the proposed reference levels, by operation of one or more of the ships emitters.

Until recently the method of carrying out RADHAZ surveys of ships involved the use of hand held field probes and personnel hazard monitors. The ship's transmitters were operated at ten discrete frequencies between 1.5 and 30Mhz, and measurements were made at a number of locations on the ship for each frequency in turn. After the results had been computer processed, the worst case combination of emissions from the various ship transmitters is reproduced at each location, and the safe boundaries for personnel hazards are established according to the NRPB recommendations.

Measuring instrumentation

Despite progressive development of the various probes to improve their accuracy, speed of measurement and ease of use, it is recognized that the previous surveys were far from comprehensive. Investigatory trials, using small increments in frequency, revealed very rapid variations in the measured parameters due to sharp resonance's in ship superstructure and fittings. Several hundred frequency steps would be required to trace the resonant effects. The time allotted to the trials prohibits a more detailed search using the existing method. Even if rapid switching of the ship transmitter frequency was possible, manual recording of the results would be out of the question.

Measurements of the E and H fields were previously made using vertically polarised single axis probes. The field in the vicinity of HF whips is very complex, comprising both vertical and radial components. To meet the requirements of NRPB limits of exposure it is necessary to measure the complete field, for which true 3-axis probes are necessary. To overcome these difficulties there was clearly a need to develop an automatic field sweeping, measurement, recording and processing system.

In an attempt to provide a more comprehensive RADHAZ footprint, a new autonomous instrumentation package, known as Low Level Sweep (LLS) (FIG. 3), was developed. This equipment sweeps the band at much reduced power levels, using its own transmitter interfaced to the ships antennas, thereby allowing a maximum of 600 frequencies per sweep to be evaluated.

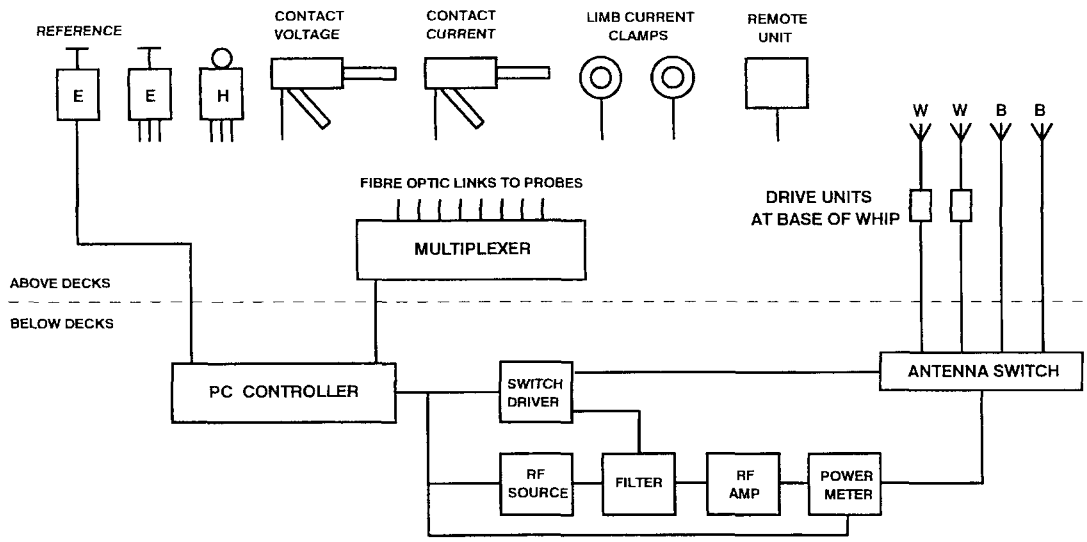

FIG. 3 — LOW LEVEL SWEEP

The system produces a computer-controlled step-swept RF field over the frequency range 1.5MHz to 30MHz, using the ship's antennas (whip and broadband). Prior to the LLS, the antenna radiation characteristics were measured and recorded using the ship's transmitter. The in-line power meter is used to confirm the ship's transmitter power.

The reference probe reading at a number of frequencies is used to compute the relationship between true transmitted power and field intensity at some convenient arbitrary point. During the subsequent LLS, the same antenna at the same point will register the swept field, its readings being interpolated as necessary.

Once the reference antenna has been calibrated, all subsequent measurements can be normalized automatically to the maximum field, allowing for variation of power level, NRPB reference levels and antenna SWR.

The frequency sweep comprises 600 steps between 1.5–30mhz. At each location, seven sweeps are required to make sequential measurements of the spatial 3-axis E and H-field, contact current and voltage, ankle and wrist currents. The reference probe is monitored continuously.

The limb current probe monitors the current flowing through an operators limb, be it ankle or wrist, using a proprietary current clamp. This is clamped around the operators limb and is held in place with straps and suitable foam padding.

The contact current and voltage probes measures the relevant levels presented to the associated limbs. A metal spike on the probe tip makes electrical contact with the structure, the return being made through the operator.

Data from all of the probes is read, normalized, displayed on-screen and recorded. This process is repeated at each location for up to four separate antennas. From the recorded data, the worst frequencies (allowing for normalization to maximum power) for each measured effect due to each antenna is computed. Where the resultant combined field could exceed the acceptable limit (based on NRPB recommendations), the worst case combination of frequency and antenna is reproduced and the safe boundary in that location may be traced. The remote monitor will provide the operator with a visual indication of his progress.

Ship survey results

Those areas of the ships upperdeck found to be in-excess of the new levels are plotted on a ships drawing to provide not only a visual indication of the extent of the problem but also identify those areas where control mechanisms may need to be invoked such as out of bounds or restricted access. (FIG. 4) is a typical plot showing those areas in excess.

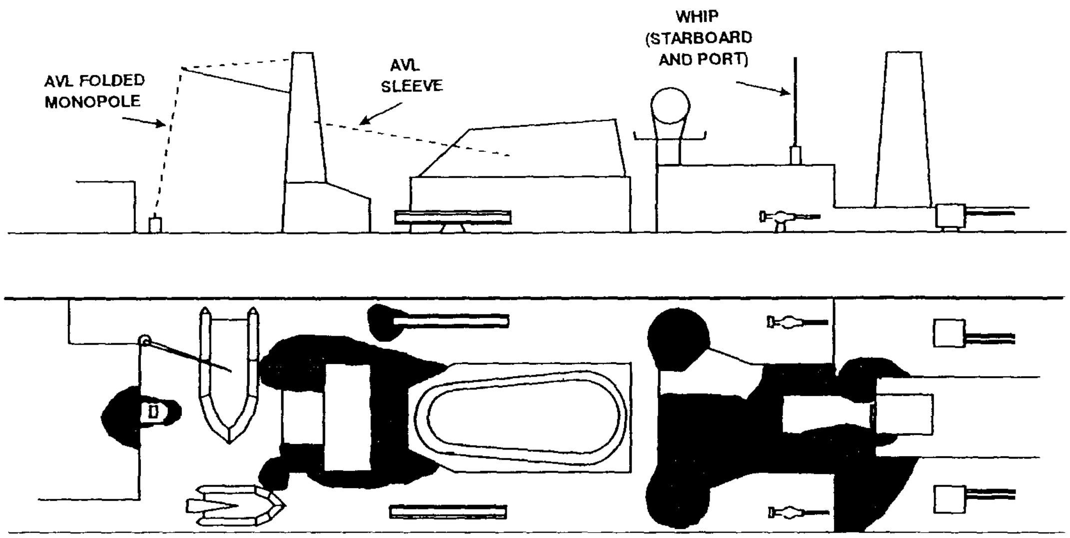

FIG. 4 — PLOT OF AREAS IN EXCESS OF ANKLE CURRENT LEVEL

Implementation of new levels

As identified in FIG. 4, under certain conditions, large portions of the upper deck are likely to be in-excess of the new levels. However rather than just embrace these levels and accept the limitations they impose, a programme of work has been set in place to identify a set of palliatives that when invoked would allow the ship to comply with the new levels whilst maintaining operational capability. Such palliatives could include, reduction/control of maximum transmission power, re-siting of transmission antennas, replacement of re-radiating elements with non-conducting materials, sponsor research into a greater understanding of the biological effects of non-ionising radiation.

With regard to a more in-depth understanding of the biological effects of non-ionising radiation on the human body, the NRPB were tasked to calculate the SAR in an anatomically realistic model of the human body for irradiation conditions typical of HF antennas on board a ship from 1.5 to 30MHz.

This study performed calculations of the localized SAR in the ankle as a function of frequency from 1 to 30MHz for a unit injected current; and whole body averaged SAR values for plane wave irradiation, for irradiation from a monopole on an infinite ground plane, and for various positions and irradiation conditions from a NEC model of a typical shipboard environment.

The rationale of the study was to use the ankle current as an indicator of the whole body averaged SAR and the localized SAR in the leg. Table 1 represents an envelope of maximum ankle currents induced in the leg which equate to either 0.4W/Kg whole body SAR or 20 W/kg averaged over 100g in the leg.

TABLE 1—*Level of ankle current against frequency for a SAR of 0.4W/Kg*

Frequency (MHz)	Ankle Current (mA)
1	157
2	167
5	180
10	185
15	197
20	200
25	203
30	184

These ankle current levels are a more accurate representation of whole body SAR than those presently used (100mA) and therefore if implemented will allow the Royal Navy greater operational flexibility and considerably more unrestricted deck space.

Most ship borne HF transmitters are capable of transmitting at power levels up to 1KW, however RN policy states:

> 'Normally only the power sufficient to maintain satisfactory communications is to be used. Maximum power limitations have been laid down in some cases, particularly at HF, to avoid causing interference to others'.

However evidence would suggest that policy is always adhered to.

High Frequency communications requires only a few tens of watts to be transmitted across the world, therefore, the power transmitted by the high power amplifier could be locked at a lower power so reducing the hazards in the vicinity of the antenna. If for some reason a higher power was required, the hazard areas could be placed out of bounds whilst the high level transmission is in progress.

In an attempt to reduce the RF burn and wrist current hazards associated with re-radiators such as guard-rails, stanchions, ladders, boat downhauls and other metallic structures. A trial was conducted onboard HMS *Coventry* in December 1996 to assess the likely reduction in RADHAZ levels obtained with the installation of GRP stanchions and parafil guard-rails. The trial showed that practically all wrist current and shock/burn hazards on the stanchions and guard-rails themselves were eliminated.

Conclusions

The aim of this article has been to draw attention to the potential operational restrictions which may be encountered if new guidelines on RADHAZ have to be implemented. Whilst the paper has attempted to highlight the concerns associated with the implementation of new RADHAZ guidelines, it is not yet possible to give an in-depth analysis of RADHAZ within the Royal Navy.

As information from the comprehensive platform survey and the NRPB research becomes available, a more in-depth understanding of the magnitude of the problem will emerge. This greater understanding coupled with possible new legislation may dictate the need to reassess the RADHAZ regime in order that full compliance with the requirements can be achieved.