STANAG No. 2345
(Edition 3)

NORTH ATLANTIC TREATY ORGANIZATION
(NATO)

NATO STANDARDIZATION AGENCY
(NSA)

STANDARDIZATION AGREEMENT
(STANAG)

SUBJECT: EVALUATION AND CONTROL OF PERSONNEL EXPOSURE TO RADIO FREQUENCY FIELDS - 3kHz to 300 GHz

Promulgated on 13 February 2003

Jan H ERIKSEN
Rear Admiral, NONA
Director, NSA

RECORD OF AMENDMENTS

No.	Reference/date of amendment	Date entered	Signature

EXPLANATORY NOTES

AGREEMENT

1. This NATO Standardization Agreement (STANAG) is promulgated by the Director NSA under the authority vested in him by the NATO Military Committee.

2. No departure may be made from the agreement without consultation with the tasking authority. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals and instructions implementing this STANAG will include a reference to the STANAG number for purposes of identification.

DEFINITIONS

4. Ratification is "In NATO Standardization, the fulfilment by which a member nation formally accepts, with or without reservation, the content of a Standardization Agreement" (AAP-6).

5. Implementation is "In NATO Standardization, the fulfilment by a member nation of its obligations as specified in a Standardization Agreement" (AAP-6).

6. Reservation is "In NATO Standardization, the stated qualification by a member nation that describes the part of a Standardization Agreement that it will not implement or will implement only with limitations" (AAP-6).

RATIFICATION, IMPLEMENTATION AND RESERVATIONS

7. The NSDD gives the details of ratification, implementation, reservations and comments on this agreement. If no details are shown it signifies that the nation has not yet notified the tasking authority of its intentions.

FEEDBACK

8. Any comments concerning this publication should be directed to NATO/NSA - Bvd Leopold III - 1110 Brussels - BE.

NATO STANDARDIZATION AGREEMENT (STANAG)

EVALUATION AND CONTROL OF PERSONNEL EXPOSURE TO RADIO FREQUENCY FIELDS - 3 kHz to 300 GHz

Annexes:
- A. Definitions
- B. Control Measures
- C. Permissible Exposure Levels (PEL)
- D. Hazard Evaluation
- E. Actions to be Taken in Case of Suspected or Actual Exposure Above PEL
- F. Warning Signs
- G. RFR Overexposure Medical Format Proforma
- H. References

Related Documents: See Annex H

AIM

1. The aim of this agreement is to protect personnel engaged in NATO operations from exposures to Radio Frequency (RF) fields, at levels that may be hazardous to health.

2. This agreement does not address effects such as electromagnetic interference (EMI) nor cover risks associated with electro-explosive devices. For the purpose of this agreement, the RF fields of interest range from 3 kHz to 300 GHz.

AGREEMENT

3. Participants agree to:

a. Use the definitions listed at Annex A.

b. Apply exposure limitations and protection principles as stated in Annex B and C, as minimum safety guidance, to prevent harmful effects to personnel exposed to electromagnetic (EM) fields.

c. Take into consideration the hazard evaluation stated in Annex D.

d. Follow procedures listed in Annex E in the case of alleged or actual overexposure to RF fields.

e. Use standard signs, such as national signs, or those specified in STANAG 1379, e.g. such as those shown in Annex F subject to operational requirements in 2a, 2b, and 2c (Annex B) to identify areas where RF field levels exceed, or may exceed, the Permissible Exposure Levels (PELs) defined in Table C-I.

BACKGROUND

4. Exposure to RF at sufficiently high intensity can lead to effects associated with tissue heating and can induce currents in the human body that can lead to shocks or burns. PELs, based on the results of animal studies and observations of people, have been developed to prevent such effects. Protection against harm is achieved by identifying areas/sources where potential exposures might exceed the PELs and applying the appropriate administrative or engineering controls described in Annexes B, D, and E.

5. The RF protection standards are primarily based on the specific absorption rate (SAR), expressed in W/kg. The standards take into consideration the frequency dependency of SAR, and give appropriate advice on the limitation of plane wave field intensity.

6. When personnel are exposed to RF, the two most significant effects are:

a. Thermal effects: The RF energy is directly absorbed in tissues of exposed personnel in the form of heat. In general, protection is achieved by restricting access to antennas, or by maintaining a minimum safe distance from such antennas.

b. Shock/burn effects: A shock or burn may be experienced by personnel when touching a conducting structure exposed to RF fields.

IMPLEMENTATION OF THE AGREEMENT

7. This STANAG is implemented when the necessary orders/instructions have been issued directing the national forces of alliance members to put the content of this agreement into effect.

DEFINITIONS

The following definitions are used for the purpose of this STANAG only.

1. Average Power Density. The power of RF field per unit cross sectional area normal to the direction of propagation expressed at a given point in watts per square meter (W/m^2) and averaged over a given period.

2. Averaging Time (Tavg). The time period over which exposure is averaged for determining compliance with a PEL value.

3. Contact Current. RF current flowing through an individual touching a conductive object. For compliance with standards, this is normally measured as the current through the hand or wrist of the individual grasping a conductive object.

4. Current Density. The ratio of the current flowing to the cross-sectional area perpendicular to the current flow (A/m^2).

5. Duty Factor. The ratio of pulse duration to the pulse period of a periodic pulse train. A duty factor of 1.0 corresponds to continuous-wave (CW) operation.

6. Electric Field. A fundamental component of electromagnetic (EM) waves, which exists when there is a voltage difference between two points in space.

7. Electric Field Strength (E). The magnitude of the electric field expressed in volts per meter (V/m).

8. Electromagnetic Interference (EMI). Any EM disturbance, whether intentional or not, which interrupts, obstructs, or otherwise degrades or limits the effective performance or safe operation of electronic, electrical equipment, or ordnance.

9. Exposure, Non-uniform. Non-uniform exposure results when the entire body is exposed either in the near field of an emitter or to a field with substantial standing waves produced by reradiating objects or reflective surfaces, both resulting in RF fields that may vary by a minor amount or substantially over the body.

10. Exposure, Partial-Body. Partial-body exposure results when the body is subjected to a highly localized source, e.g., from an open waveguide or highly directional horn antenna, a radiating source with small dimension (relative to the human body), or inserting a part of the body into a confined field.

11. Far-Field Region (Fraunhofer Region). The region far enough from an antenna that the power per unit area decreases with the square of the range. In the far-field region, the field EM energy is predominantly plane-wave in character; i.e., the magnetic and electric field vectors are perpendicular to each other and the direction of the propagation.

12. Hertz (Hz). The unit for expressing frequency. One hertz equals one cycle per second. Common multiples are kilo-hertz (kHz; 1,000 Hz), mega-hertz (MHz; 1,000,000 Hz),and giga-hertz (GHz; 1,000,000,000 Hz).

13. Human Resonance Range. The frequency region where absorption of RF energy in the body is enhanced. For sizes ranging from a baby to an adult, peak absorption varies depending on the individual's size relative to the wavelength and orientation relative to the polarization of the wave. The PELs have been established to cover the range in human sizes, shapes, and positions.

14. Induced Current. RF current flowing in the body in a freestanding condition (no skin contact with metallic objects). For compliance with standards, this is normally measured as the current through the feet or ankles of the individual to ground.

15. Joule (J). A unit of work or energy. One joule is equivalent to one watt for one second. 1 J = 1 Ws

16. Magnetic Field. A fundamental component of EM waves produced by a moving electric charge.

17. Magnetic Field Strength (H). The strength of the magnetic field expressed in amps per meter (A/m).

18. Near-Field Region. A region generally in close proximity to an antenna or other radiating structure in which the electric and magnetic fields do not exhibit a plane-wave relationship, and the field strength does not decrease proportionally with the distance from the source but varies considerably from point to point. The near-field region is further subdivided into the reactive near field, which is closest to the radiating structure and contains most or nearly all of the stored energy, and the radiating near-field region where the radiating field predominates over the reactive field, but is not a plane wave and has complex field characteristics.

19. Overexposure. Any irradiation of personnel that exceeds the limits given in Annex C.

20. Permissible Exposure Level (PEL). Exposure level of RF fields, to which personnel can be exposed, with an acceptable safety factor, without health risk. The root-mean-square (rms) electric and magnetic field strengths, their squares, or the plane-wave-equivalent power densities associated with these fields and the induced and contact currents to which a person may be exposed without harmful effect. There are no expectations that any adverse health effects will occur with exposures that are within the PEL even for repeated or long-term exposures. The PELs limit the whole-body averaged SAR to 0.4 W/kg. This SAR is lower, by a factor of ten, than the threshold for the most sensitive, reproducible effect reported in laboratory animals. Exposures slightly in excess of the PELs are not necessarily harmful; however, such exposures are not desirable and should be prevented wherever possible.

21. Plane Wave. An EM wave characterized by mutually orthogonal electric and magnetic fields that are related by the impedance of free space (377 ohms). For plane waves, power density (*S*), the electric field strength (*E*) and magnetic field strength (*H*) exhibit the following relationship: $S = E^2/377 = 377\ H^2$, where *S* is in units of W/m^2, *E* is in V/m, and *H* is in A/m.

22. Plane-Wave-Equivalent Power Density. A commonly used term associated with any EM wave, equal in magnitude to the power density of a plane wave having the same electric (*E*) or magnetic (*H*) field strength.

23. Power Density (*S*). The EM power density of the radiating source in the far-field (plane wave power per unit area), is given in watts per square meter (W/m^2) or for convenience, in units such as milli-watts per square centimeter (mW/cm^2). The plane wave's power density (*S*), the electric field strength (*E*) and magnetic field strength (*H*) are related by the impedance of free space, i.e., 377 Ω.
In particular,

$$S = \frac{E^2}{377} = 377H^2$$

where *E* and *H* are expressed in units of V/m and A/m, respectively, and *S* in units of W/m2.

24. Pulse Repetition Frequency. In pulse-modulated RF systems using recurrent pulses, the number of pulses per unit of time (sec).

25. Pulse Repetition Period. In a pulse-modulated RF system using recurrent pulses, the reciprocal of pulse repetition frequency.

26. Pulsed RF Fields. RF electric and magnetic fields that are produced by amplitude modulating a continuous-wave carrier at a known pulse repetition frequency with a controlled duty factor.

27. Radio and Radar Radiation Hazard to Personnel (RADHAZ). (Also known as Hazards of Electromagnetic Radiation to Personnel, HERP). RF fields that exceed the PEL contained in this STANAG are to be considered a potential RF hazard. Because of the safety margin incorporated into the PEL, exposures in excess of the PEL are not necessarily harmful.

28. Radio Frequency (RF). The RF region of concern in STANAG 2345 is defined as that part of the EM spectrum extending from 3 kHz to 300 GHz.

29. Re-Radiated Field. RF fields resulting from currents induced in a secondary, predominantly conducting object, by EM waves incident on that object from one or more primary radiating structures or antennas. Re-radiated fields are sometimes called reflected or scattered fields. The scattering object is sometimes called a re-radiator, or a secondary or parasitic radiator.

30. RF "Hot Spot." A highly localized area of relatively intense RF fields that manifests itself in two principal ways:

a. Intense electric or magnetic fields immediately adjacent to conductive objects immersed in lower intensity ambient fields (often referred to as reradiation).

b. Localized areas, not necessarily close to conductive objects, in which there exists a concentration of radio frequency fields caused by reflections (non-uniform exposure) or a concentration of radio frequency field caused by a highly directional source (partial-body exposure). In both cases, the fields are characterized by very rapid changes in field strength with distance or location. This is not to be confused with an actual thermal hot spot in the body.

31. Root-Mean-Square (rms)Value. The effective value, or the value associated with joule heating, of a periodic electromagnetic wave. The square root of the average of the squared value of the instantaneous magnitude of the electric or magnetic field taken over the complete cycle.

32. Safety Distance. The minimum distance at which the PEL for personnel is not exceeded.

33. Spatial Average. As applied to the measurement of electric or magnetic fields in the assessment of whole-body exposure the averaging of power density or the squared *E* or *H* values over the vertical cross-sectional area of the body. The spatial average is obtained by scanning (with a suitable measurement probe) a planar area equivalent to the area occupied by a standing adult human (projected area). In most instances, a simple vertical linear scan of the fields over a six foot height will be sufficient for determining compliance with the PELs.

34. Specific Absorption Rate (SAR). The time rate at which RF energy is imparted to an element of biological body mass. Average SAR in a body is the time rate of the total energy absorbed divided by the total mass of the body. SAR is expressed in units of watts per kilogram (W/kg). Specific absorption (SA) refers to the amount of energy absorbed over an exposure time period and is expressed in units of joules per kilogram (J/kg).

CONTROL MEASURES

1. IT IS NATO POLICY TO:

a. Identify and attenuate, or control by engineering design, protective equipment, administrative actions, or a combination thereof, potentially hazardous RF fields. That policy shall be emphasized during all phases of equipment design, acquisition, installation, operation, and maintenance.

b. As minimum safety guidance, limit RF field exposure of personnel to levels that do not exceed the PELs given in Annex C.

c. Use physical controls rather than administrative controls when possible. Physical controls include interlocks, fences, locks, etc. Administrative controls include signs, operational procedures, training, etc.

d. Define and control areas in which RF exposure of personnel could exceed the PEL, including simultaneous exposure from more than one RF emitter.

e. Ensure that personnel are aware of potential RF exposures in their workplaces and duty assignments, and the control measures imposed to limit their RF exposures.

f. Investigate, document, and prevent recurrence of RF overexposure incidents.

2. RF HAZARD WARNING SIGNS.

a. The RF hazard warning sign basic format such as that authorized in STANAG 1379, or those shown in Annex F, should be used. European community nations are required to use RF hazard warning signs conforming to a format specified in Directive 92/58/EEC which conforms to ISO 3864:1984, one possible example of which is shown at Annex F Figure F-1. The United States uses the format shown at Annex F Figure F-2. Canada uses the formats shown at Annex F Figure F-3. Other nations agree to adopt one of these formats. Variations to include subdued signs for camouflage or tactical reasons, or to provide improved visibility under certain lighting conditions, are authorized, provided the general shape and layout of the sign remains the same.

b. RF hazard warning signs are required at all access points to areas in which levels exceed the PELs listed in Table C-I, Section A. Instructional or warning statements should be inserted on the signs. Examples of such statements are shown in Annex F. Safety and occupational health professionals may waive the requirement for signs when necessary in response to considerations of military operations, provided that personnel are informed of possible hazards by other means.

c. In areas where access to levels greater than 10 times the PELs listed in Table C-I, Section A may exist, warning signs alone do not provide adequate protection. Other warning devices, such as flashing lights, audible signals or other means such as barriers, interlocks, and sector blanking for radars should be considered.

3. PROTECTIVE CLOTHING.

a. LIMITATIONS ON USE. Until sufficient data are obtained to develop standardized safety procedures, RF protective clothing is not recommended for routine use as a means of protecting personnel. It is, however, permitted for limited use when adequate safety procedures are enforced. The clothes are only considered effective and safe when they have been tested in operational conditions.

b. REQUIREMENTS AND SPECIFICATIONS. To provide full-body protection, components of the RF Protective gear must include a full integrated hood, overshoes, socks, and gloves. Omission of parts of the protective suit must only be permitted with data demonstrating compliance with STANAG limits for both SAR and Partial Body exposures. The clothing should have minimal restriction of movement and vision. The material should be able to withstand treatment comparable to standard-issue work-clothes. The material must be demonstrated to have Breakdown Threshold well in excess of the RF-induced heating experienced during the intended use. Limitations on the use of the clothing must be specified, such as in terms of maximum field strength for a given range of frequencies. Concomitant heating due to environmental factors and user heat production due to exercise and metabolic processes will add to thermal burden and must be monitored. Surface Temperature Stability data must ensure that the fabric dissipates RF-induced heating sufficiently so that its surface temperature does not become excessive to the wearer within the field intensities of intended use. Since the protective capability will vary significantly with certain RF field characteristics, particularly frequency, the actual reduction in SAR must be determined to be adequate to achieve compliance with this STANAG.

c. CARE OF PROTECTIVE CLOTHING. The user must be instructed on care and use of the protective clothing. The protective suits are subject to loss of protective efficacy (i.e. attenuative characteristics are diminished) depending on the aging of the material used and the number of times they are cleaned. The clothing should be inspected with each use and routinely tested.

d. CONTACT CURRENT PROTECTIVE CLOTHING. Protective clothing such as electrically insulated gloves and shoes for protection against RF shock and burn or for insulation from the ground plane, is authorized where necessary for compliance with the current limits of Table C-I, Section B.

4. RF SAFETY TRAINING. Personnel who work directly with equipment that emits RF fields in excess of the PELs in Table C-I, or whose work environment contains

equipment that emits levels in excess of the PELs in Table C-1 should receive safety training. Training should include: awareness of the potential hazards of RF, established procedures to control RF exposures, restricted areas, and the responsibility of personnel to limit their exposures. Training should be conducted before assignment to such work areas. Refresher training should be given and may be incorporated into other periodic safety training programs.

5. OPERATIONAL SYSTEMS. Technical orders, handbooks, manuals, and other publications concerned with siting, operation, and maintenance of RF emitters and equipment should include RF safety and occupational health requirements and procedures for responding to over-exposures and accidents (see Annex E).

6. SPECIAL CONSIDERATIONS FOR INDUCED AND CONTACT CURRENT.

a. While Section A of Table C-I specifies maximum time-averaged exposure field strengths, it is recommended that in those cases where RF shock and burn hazards might exist, action be taken to prevent occurrence, either by reducing the induced currents or by restricting area access.

b. Mitigative measures can be taken to reduce the probability of hazardous conditions from induced and contact currents. Such measures may include: protective gloves, awareness programs so that individuals are alerted to the possible presence of induced currents between the human body and conductive objects, and work practices which lessen the probability of receiving unexpected shocks or burns.

PERMISSIBLE EXPOSURE LEVELS

1. PELs

The basic dosimetric limit for RF exposure in the frequency range of 100 kHz to 6 GHz is a whole-body SAR of 0.4 watts per kilogram (W/kg). That level incorporates a safety factor of 10 on the SAR of 4.0 W/kg, which has been assumed to be a threshold for potentially deleterious biological effects in people. Below 100 kHz, internal current density resulting in electro-stimulation of biological tissue is the basic dosimetric parameter. Above 6 GHz, the exposures are quasi-optical and power density is the exposure parameter used. PELs are given in terms of measurable field components as a convenient correlation to the SAR.

a. The PELs, listed in Table C-I, Section A, refer to time-averaged exposure values obtained by spatial averaging of S or the mean squared *E* and *H* values over an area equivalent to the vertical cross-section of the human body (projected area). In non-uniform fields, spatial peak values could exceed the PELs even though the spatially averaged value does not exceed the PELs. Spatial peak values are limited by the non-uniform exposure PELs given in Section C of Table C-I.

b. All exposures should be limited to a maximum peak, in terms of *E*-field, of 200 kV/m in a single pulse.

c. For exposures at frequencies less than 300 MHz, the applicable PELs shown in Table C-I are given in terms of rms *E* or *H* values. Although not technically correct, for convenience, under near-field conditions, PELs also may be expressed in terms of plane-wave equivalent values as shown by the power density (S) values in parentheses for the *E* and *H* fields, respectively, at frequencies less than 300 MHz. The PELs are also shown graphically in Figure C-1.

d. The PELs in Section A of Table C-I refer to values averaged over any 6-minute period for frequencies less than 15 GHz, and over shorter periods for higher frequencies (e.g. 10 seconds at 300 GHz).

e. For exposure durations less than the averaging period, the maximum permissible exposure level, PEL′, in any time interval equal to the averaging period is, $PEL' = PEL\,[T_{avg}/T_{exp}]$, where T_{exp} is the exposure duration in that interval expressed in the same time units as T_{avg}. The PEL is S, E^2, or H^2 for this equation.

f. Measurements to determine compliance with the PELs of this STANAG shall be made (with appropriate instruments) at distances no closer than 0.05 m from any generating device and its associated attachments, Measurements shall be made no closer than 0.20 m from re-radiating

(passive or scattering) objects. If determination of compliance with the PELs of this STANAG requires measurements to be made at distance of 0.05 m from any generating device and its associated attachments, both *E*- and *H*-field measurements may be necessary. If suitable instrumentation for such objects is not available, compliance with the exclusion conditions of paragraph 2 of Annex C is necessary. If measurements (with appropriate instruments) at distances of 0.05 m from any generating device and its associated attachments are in compliance with the PEL, then the PEL may be exceeded at distances closer than 0.05 m from the radiating source.
Note: The 0.20 m measurement distance is allowed for reradiating objects or scatterers where little energy absorption is involved.

g. In applying the PELs listed in Table C-I for different situations, such as characterizations of EM fields, determination of the safe distance from a source or assessment of personnel exposures, different measurement considerations may be applied as follows:

(1) <u>RF Field Characterization.</u> For reactive near-field conditions, generally both the *E* and *H* fields should be determined for frequencies less than 300 MHz. For frequencies equal to or less than 30 MHz, assessments can only be accomplished by measurement of both field components. The need to measure both *E* and *H* fields below 300 MHz derives from a consideration of the spatial variation in *E* and *H* field strengths in the reactive near field of an antenna. Field measurements may be made from two perspectives: the PEL boundary locations are established by determining the farthest distance from the radiating source that a PEL value can be exceeded using appropriate measurement techniques, or the actual workplace exposures are determined.

(2) <u>Assessment of Personnel Exposure.</u> To determine whether a person has received exposure in excess of the PEL, exposure averaging times and whole-body spatial averaging should be considered. Also, in some cases, (e.g., at frequencies near body resonance) the vertical *E* field component rather than the total *E* field is appropriate to determine whether an individual received an over exposure in terms of whole-body-averaged SARs. For low-power devices, such as hand-held, mobile, and marine transmitters, the low-power exemption criteria of paragraph 2.d, can be used in assessing exposure conditions. Even though these low-power devices may have localized fields that exceed the PEL field values, the whole-body or spatial peak SARs will not be exceeded.

h. For mixed or broadband fields at several frequencies for which there are different values of the PEL, the fraction of the PEL in terms of E^2, H^2, or *S* incurred within each frequency interval should be determined and the sum of all such fractions should not exed unity.

2. <u>EXCLUSIONS</u>. The PEL values may be relaxed as follows:

a. SAR EXCLUSION RULE. The PELs in Section A of Table C-I may be relaxed by reference to SAR limits through calculations or measurements, as follows:

At frequencies between 100 kHz and 6 GHz, the PEL may be exceeded if the exposure conditions can be shown by appropriate techniques to produce SARs below 0.4 W/kg as averaged over the whole body, and spatial peak SAR values not exceeding 8 W/kg as averaged over any one gram of tissue, except for the hands, wrists, feet, and ankles where the spatial peak SAR should not exceed 20 W/kg as averaged over any 10 grams of tissue, and the induced body currents conform with the values in Section B of Table C-I.

b. PARTIAL-BODY AND NON-UNIFORM EXPOSURE. In the case of partial-body exposure from highly directional or localized sources or from nonuniform exposure over an area equivalent to the body, relaxation of the PELs in Section A of Table C-I is allowed for exposures limited to portions of the body. In the frequency range of 0.1 to 300 MHz, the relaxation of the *E* and *H* PEL shown in Section C of Table C-I allows the spatially averaged square of the *E* and *H* fields to be as high as 20 times the whole body PEL. The relaxation of the power density and mean squared field strength limits shown in Section C of Table C-I is allowed for non-uniform exposure of all parts of the body. The relaxation of the power density and mean squared field strength limits shown in Section C of Table C-I is allowed for partial-body exposure of all parts of the body except the eyes and the testes. At frequencies above 6 GHz, where body absorption is quasi-optical and body resonance considerations do not apply, the SAR exclusion rule is not applicable. The PELs may be relaxed using the 6 minute time-averaged limits for partial body/nonuniform exposures given in Section C, Table C-I.

c. PEAK RMS CURRENT DENSITY. At frequencies between 3 kHz and 100 kHz, the SAR exclusion rule does not apply. The PEL can be exceeded, if it can be shown that the peak rms current density as averaged over any 0.0001 m^2 area of tissue and over 1 second does not exceed 0.35f A/m^2, where f is expressed in kHz.

d. LOW-POWER DEVICE EXEMPTION. Measured values of RF field intensities close to radiating antennas of low power devices may exceed the PEL values listed in Section A of Table C-I, even though RF exposure to the body from using the device will not actually exceed the SAR criteria. At frequencies between 100 kHz and 1.5 GHz, the PELs given in Table C-I, may be exceeded under the following conditions:

(1) At frequencies between 100 kHz and 450 MHz, if the radiated power into free space in the absence of any nearby objects, is 7 watts, or less.

(2) At frequencies between 450 and 1500 MHz, if the radiated power is 7x450/f watts, or less, where f is expressed in MHz.

This exclusion does not apply to devices with the radiating structure maintained within

2.5 cm of the body.

3. INDUCED AND CONTACT CURRENT LIMITS

a. Guidance is provided for limiting the RF induced currents in the human body for free-standing conditions (no skin contact with conducting objects), and under conditions of grasping contact with conducting objects to limit the maximum RF current through the human body. For frequencies of 3 kHz to 100 kHz, both induced currents and contact currents are averaged over any 1 second. For frequencies of > 100 kHz to 100MHz, induced currents and contact currents are averaged over any six minute period, subject to a ceiling limit of 500 mA using the square of the induced currents calculated as follows: (I^2 max = I^2ave (T_{ave}/T_{max}). Induced current measurements are not necessary at frequencies over 100 MHz.

b. Adherence to the induced body current limits (section B of Table C-I) will prevent localized SAR in the ankles or wrists from exceeding 20 W/kg (see 2.a). In general, between 3 kHz and 100 kHz, the perception threshold is related to a tingling or prickling sensation, while between 100 kHz and 100 MHz, the perception threshold is related to a sensation of heat or warmth. Under some conditions, touching conductive objects that are in the vicinity of a radiating RF antenna could result in a flow of RF current of sufficient magnitude to be painful or to produce a burn at the point of contact.

c. Evaluation of induced RF currents will generally require a measurement to determine the RF current flowing to ground through the feet of the individual, or the RF current flowing through the hand in contact with a conductive surface. To avoid the possibility of further overexposure it is recommended that currents be measured by instruments that simulate the electrical characteristics of the human body. Induced current measurements are not required if the spatially-averaged electric field strength does not exceed the PEL at frequencies of 0.45 MHz or less and does not exceed the limits shown in Figure C-2 at frequencies greater than 0.45 MHz.

d. Under various exposure conditions, application of the field strength limits in Table C-I, Section A in conjunction with the induced current limits in Table C-I, Section B may not be consistent or amenable to analysis. Many variables, such as near-field exposure conditions, physical contact with or close proximity to nearby conductive surfaces, RF absorption enhancement under resonance frequency conditions, and inherent differences in human body sizes, will affect the measured induced currents.

4. NON-UNIFORM PARTIAL-BODY EXPOSURE LIMITS.

a. Implicit in the PEL definition of a whole-body averaged SAR of 0.4 W/kg, is the assumption that spatial peak SARs in a biological body are acceptable at 10 to 20 times higher than the whole-body averaged values. The values provided in Section C of Table C-I allow for equating substantially non-uniform field exposure or partial-body exposure to an equivalent uniform field exposure.

b. For exposure of parts of the body, the spatially averaged PELs given in Section A of Table C-I may be relaxed provided:

(1) The peak value of the mean squared field strength does not exceed 20 times the square of the allowed spatially averaged values at frequencies below 300 MHz, or

(2) The equivalent S levels do not exceed the levels shown in Section C of Table C-I as averaged over the T_{avg} periods given for frequencies above 300 MHz.

c. The non-uniform exposure relaxation rules (Table C-I, Section C) apply to all parts of the body for non-uniform exposures; the non-uniform exposure rules do not apply to the eyes for partial-body exposure, but the SAR exclusion rules (2.a), can still be used to show conformance to the PEL, despite localized S values above the specified whole-body average. In such cases, exposures to the eyes are limited by the basic exposure criteria of a whole-body averaged SAR of 0.4 W/kg, and spatial peak SARs of 8 W/kg as averaged over any one gram of tissue.

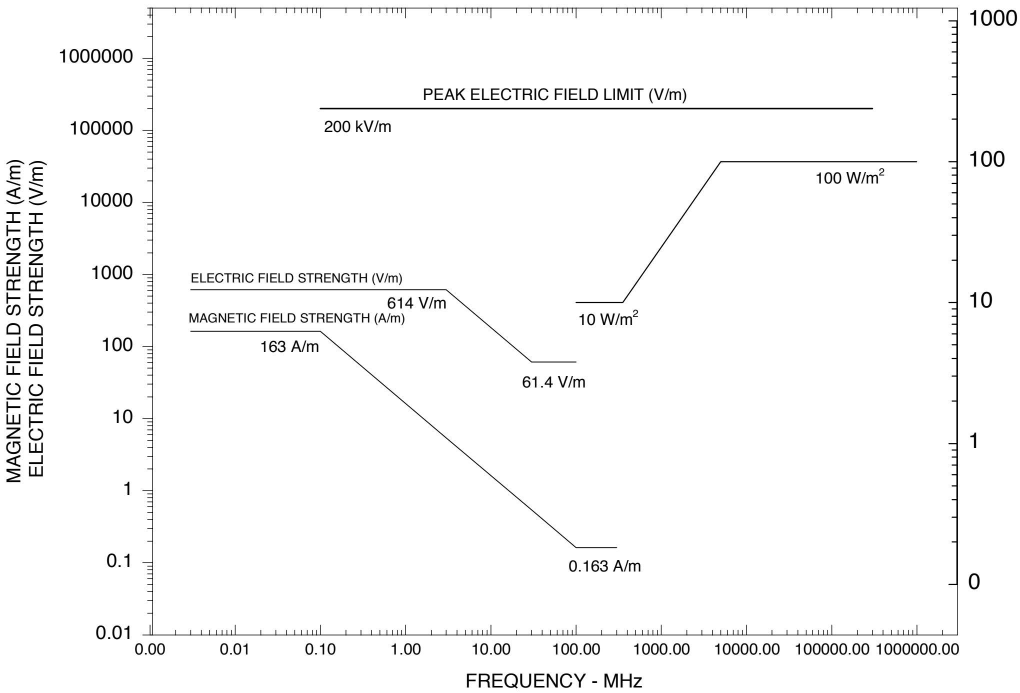


Figure C-1: Permissible exposure limits.

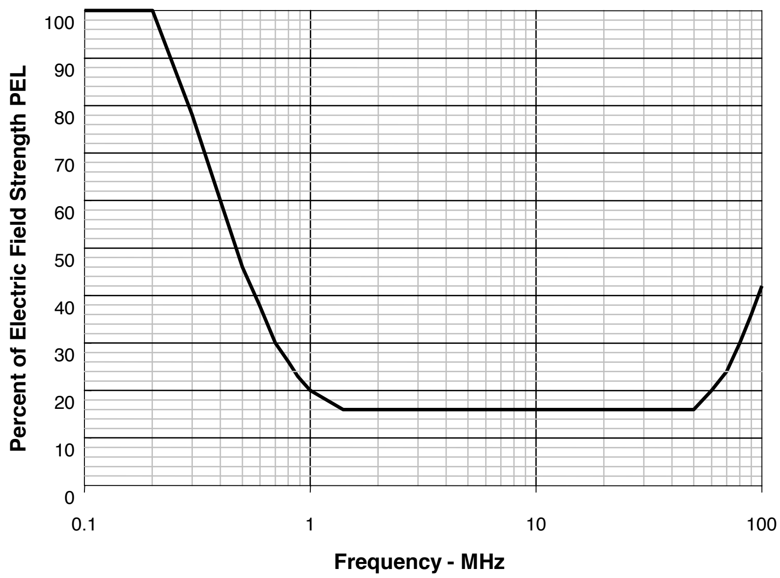


Figure C-2: Percent of Electric Field strength PELs current measurements below which current measurements are *not* required

TABLE C-I. PERMISSIBLE EXPOSURE LEVELS

A. RF FIELDS

Frequency Range (*) (MHz)	Electric Field (E) (V/m)	Magnetic Field (H) (A/m)	Power Density (S)† E field, H field (W/m^2)	Averaging Time (T_{avg} in min.) (E, H, S)
0.003 - 0.1	614	163	(10^3, 10^7)**	6
0.1 - 3.0	614	16.3/f	(10^3, $10^5/f^2$**	6
3 - 30	1842/f	16.3/f	($9000/f^2$, $10^5/f^2$)**	6
30 - 100	61.4	16.3/f	(10, $10^5/f^2$)**	6
100 - 300	61.4	0.163	10**	6
300 - 3000			f/30	6
3000 - 15000			100	6
15000 - 300000			100	$616000/f^{1.2}$

B. RF INDUCED AND CONTACT CURRENT RESTRICTIONS

Frequency Range (f) (MHz)	Maximum Current Through Both Feet (mA)	Maximum Current Through Each Foot (mA)	Contact Current (mA)	Averaging Time
0.003 - 0.1	2000f	1000f	1000f	1 sec
0.1 - 100	200	100	100	6 min ***

C. PARTIAL-BODY EXPOSURES

Frequency Range (f) (MHz)	Maximum Value of Spatially Averaged Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (W/m^2)	Averaging Time (T_{avg} in min.) (E, H, S)
0.1 - 300	$< 20[\overline{E}]^2$ or $20[\overline{H}]^2$		
300 - 6000		< 200	6
6000 – 15000		$< 200(f/6000)^{0.25}$	6
15000 - 96000		$< 200(f/6000)^{0.25}$	$616000/f^{1.2}$
96000 - 300000		400	$616000/f^{1.2}$

* Expressed in MHz throughout Table C.
† S denotes plane-wave equivalent power density
** These plane-wave equivalent power density values, although not appropriate for near-field conditions, for <300 MHz, are commonly used as a convenient comparison with PELs at higher frequencies and are displayed on some instruments in use.
*** Subject to 500 mA ceiling

HAZARD EVALUATION

1. GENERAL.

The hazard evaluation process involves the recognition and evaluation of the risk to human health. This starts with identifying RF emitters. The applicable PEL for the system is determined and then the system is assessed to see where personnel might be exposed to levels in excess of those PELs. Following this hazard evaluation, suitable control measures as described in Annex B should be implemented.

2. MEASUREMENT AND EVALUATION OF RF FIELDS.

Trained personnel should use measurement procedures and techniques such as those recommended in IEEE C95.3-1991, as basic guidance. This requirement does not preclude using other RF measuring and evaluation methodologies.

a. Records of surveys, reports, calculations, and control measures imposed should be maintained for each fielded RF emitter which is capable of exceeding the PELs in Table C-I.

b. Where multiple RF emitters may be collocated in fixed arrangements, such as aboard ships or at communication sites, RF field evaluation data should include a determination of the weighted contribution from emitters expected to be simultaneously operated to ensure that personnel are not exposed to RF levels above the applicable PEL. To comply with the PEL, the fraction of the PEL in terms of *E*2, H2 (or power density) incurred within each frequency interval should be determined and the sum of all the fractions should not exceed unity.

Probes containing dipole-diode elements separately or in conjunction with thermocouple elements have been designed to provide a readout in "% of the Standard." The proves are tailored to the specific PEL or Maximum Exposure Permitted (MEP) specified in the IEEE Std C95.1-1999.

ACTIONS TO BE TAKEN

IN CASE OF

A SUSPECTED OR ACTUAL EXPOSURE ABOVE PEL

1. All national forces of NATO members shall investigate and document all incidents involving exposures that may exceed the PELs described herein.

2. Because of the safety margin incorporated into the PEL, exposures in excess of the PEL are not necessarily harmful. As a minimum measure, the following actions for personnel exposures occurring at, or above, five times the PELs in terms of the spatial and time averaged power density, in Table C-I, will be taken:

a. RF field measurements for documentation of the RF exposure that may have been received.

b. Review of the circumstances and counseling by a Medical Officer, with notation in the medical record which is to include the decision whether ophthalmologic referral is recommended.

c. Documentation should provide a complete description of the circumstances surrounding the exposure incident, equipment operating parameters at the time of the incident, statements from personnel involved in that incident, and recommendations to prevent similar occurrences. A RFR Overexposure Medical Format Proforma may be used to document physical considerations and circumstances (Annex G).

d. The national forces of alliance members should maintain a repository file for all investigations of exposure incidents in which personnel were exposed to RF levels in excess of five times the Table C-I adjusted PELs in terms of spatial and time averaged power density.

3. SIGNS AND SYMPTOMS OF RFR OVEREXPOSURE

a. The vast majority of RFR overexposures result in no symptoms at all. Because of the large safety margin in existing standards, most people suffer no harm and are not even aware that they were overexposed. Upon learning that they had been exposed, some people develop acute anxiety reactions, and require reassurance if appropriate.

b. The most common non-psychological symptom of overexposure is an internal warm sensation, located in the region of the body exposed to the RFR beam. The warm sensation turns into pain if the exposure is great enough and the person remains in the beam. Most often, personnel, upon feeling warmth, will move away from the beam and thereby limit the exposure. Because metals are highly conductive and tend to concentrate electromagnetic fields, additional heating occurs in the local vicinity of metallic objects, such as jewelry or metallic implants. Therefore, localized hot sensations and burns are possible even with whole-body exposures. For example, a hot sensation at the site of a metallic watchband (at the time of the overexposure) might be the only complaint from a person who had been overexposed.

c. The medical consequences of thermal injury depend on what tissues are involved, how well they are perfused, and whether or not they can regenerate. Especially vulnerable to overexposures are the nervous system and the lens of the eye, neither of which regenerate. Heating of the testes can cause a temporary spermatopenia. Many of the acute symptoms, such as nausea, vomiting, headaches, loss of equilibrium, malaise, and fatigue are related to heating of the central nervous system. Some of the latter symptoms may be the result of anxiety rather than the consequence of overheating.

d. Long term effects can occur with high exposures. In addition to psychological problems, some of the acute symptoms can persist long after the overexposure. Also, organ damage may not be detectable until some time after an overexposure. For example, cataract formation, dryness in the mouth, and palpitations may not occur immediately following an overexposure. If an individual received an overexposure to his head, it is also possible for signs and symptoms similar to that of a post-concussion syndrome to develop.

e. Except for the localized burns when present, there is very little objective medical evidence to substantiate damage from a possible overexposure. Most of the symptoms are non-specific, and it may be impossible to determine if they are in fact due to the overexposure.

4. ROLE OF THE PHYSICIAN

a. A person brought to a physician because of a suspected RFR overexposure is invariably frightened and agitated. Reassurance to the patient will be helped by knowledge of the amount of overexposure. The determination of whether or not an overexposure had occurred requires careful analysis by experts trained in RFR measurements and dosimetry. Many times there is actually no overexposure at all. If no overexposure has occurred, it is only necessary to treat the patient for the anxiety reaction.

b. If an overexposure has occurred, an appropriate history and physical examination should be obtained. The patient should be questioned about what was felt during the overexposure. Did the patient experience a warm sensation in the region of his body exposed to the RFR beam? If this is not the case, the likelihood of an adverse effect is very much lower, unless the individual has a neural deficit in the region exposed. The symptoms occurring before and after the overexposure, in addition to those occurring during the overexposure should be recorded.

c. The physical examination should include an ophthalmologic exam, especially for lenticular opacities. If there is any evidence of possible damage, the patient should be referred to an ophthalmologist. The skin should be examined for areas of erythema and for surface burns in the vicinity of metallic objects. A neurologic exam should be performed to ascertain any paresthesias or paralysis.

d. Laboratory tests should be performed in accordance with the likelihood and the severity of the overexposure. If there are any cardiac symptoms present, an ECG should be performed. If there is suspicion that internal organ damage has occurred, appropriate serum enzyme levels determined and urine analyses should be conducted. If there are significant neurologic symptoms, it may be helpful to obtain an EEG and/or a MRI examination.

e. Treatment of conditions arising from RFR overexposure should follow the same care and attention given to symptoms of any other suspected injury.

NATO UNCLASSIFIED

ANNEX F TO
STANAG 2345
(Edition 2)

Figure F - 1

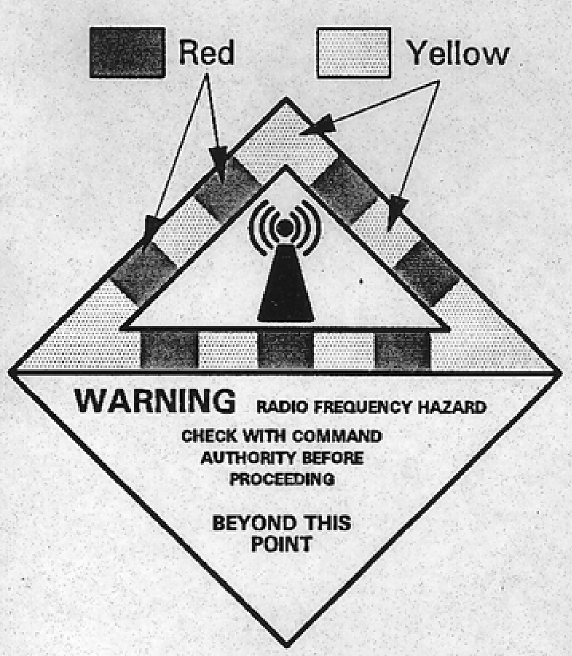


Figure F - 2

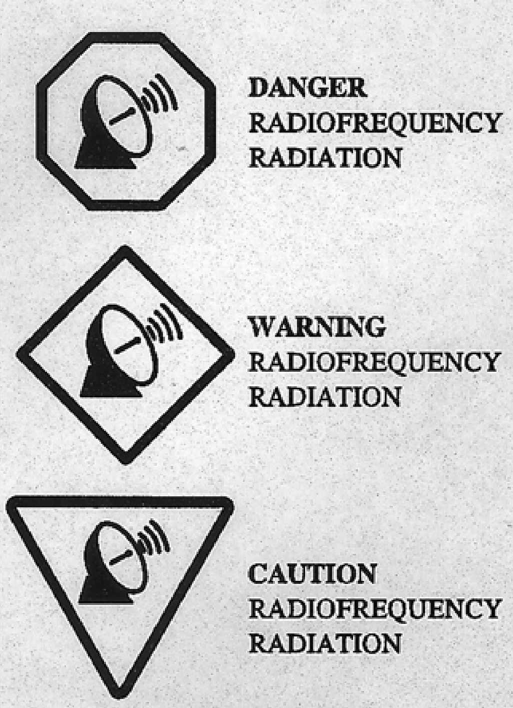


Figure F - 3

F-1

RFR OVEREXPOSURE PHYSICAL FORMAT						
Name **Date of birth** Address of reporting office:				Item/RPT N).		
Address of reporting office :			Date/ Ref. N°. of incident :			
Type of vessel / establishment :						
Location	shore based	harbor facility	vessel at harbor	vessel at sea	other (specify)	
Individual (s) concerned :						
Equipment concerned / involved in incident :						
Description of incident, including Likely cause :						
Is the cause Confirmed?		Severity of incident	A Critical	B Major	C Minor	
Transmission frequency/band				Transmitter power		
Tx mode (CW, long/short pulse)						
Antenna type & mode						
Spatial relationship of victim person or equipment to antenna : (Consider partial body exposure)						
Length of time at this position :						
Medical actions taken :						
Actions taken to prevent repetition of incident :						
Comments :						

Figure G.1

RFR OVEREXPOSURE MEDICAL FORMAT

General feelings: warmth/burn: weakness: spark discharge/shock: headache:

fasciculations/tremor: mechanic wounds: others:

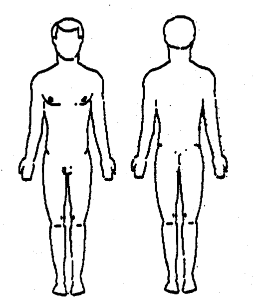
loss of balance: record of whole body temperature:

Sensorial signs: Visual: **Psychological symptoms**:

Auditory:

Date of apparition and development of symptoms:

Areas exposed:

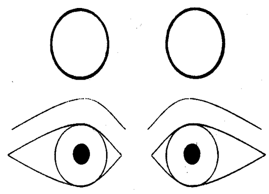


Physical examination*:*

blood pressure: cardiac frequency: cardiac rhythm:

neurologic examination:

dermatologic (burn, erythema, others:



Lenses

Right Left

Ophthalmologic examination

- conjunctivas/corneas lesions/burn :

- visual acuity without correction: Right /10 Left /10
- visual acuity with correction: Right /10 Left /10
- visual acuity before present overexposure
- lenses and retina (fundi after dilatation):

Urine analysis

Blood count (WBC, Hb) at day 0 and day+8:

D0 *D8*

In the case of specific signs

Electro Encephalographic recording:

Electrocardiographic recording:

Figure G.2

REFERENCES

STANAG 1307 RAD - MAXIMUM NATO NAVAL OPERATIONAL ELECTROMAGNETIC ENVIRONMENT PRODUCED BY RADIO AND RADAR

STANAG 1379 RAD - NATO RADHAZ WARNING SIGN

AECP-2 - NATO NAVAL RADIO AND RADAR RADIATION HAZARDS MANUAL

AAP-6 - NATO GLOSSARY OF TERMS AND DEFINITIONS

- Documents of National Radiological Protection Board (NRPB) Vol.4,No.5, 1993

- Institute of Electrical and Electronics Engineers (IEEE)Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz IEEE C95.1-1999 Edition (Incorporating IEEE td C95.1-1991 and IEEE Std C95.1 1a-1998).

- Institute of Electrical and Electronics Engineers (IEEE)Standard Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave IEEE C95.3-1991 as recognized by American National Standards Institute (ANSI).

- COUNCIL DIRECTIVE 92/58/EEC provision of safety and/or health signs at work.

- ISO 3864: 1984 International Standard Safety colours and safety signs.

- CA Safety Code 6 79-EHD-30 Limits of Exposure to Radiofrequency Fields at Frequencies from 10 kHz - 300 GHz.