ANNEX F

NON-IONISING EM EFFECTS ON HUMANS

EM FIELD FROM A PLASMA

1. The EM field from a radiating plasma is assumed to be present in three forms:

- The Radiation field which diminishes with range at $\frac{1}{R^2}$.
- Induction components which diminish at $\frac{1}{R^2}$.
- A Quasi-Static field which reduces at $\frac{1}{R^3}$.

2. **Near Fields** The induction and quasi-static fields are near field components, only of significance close to the source and thus of particular interest in the study of those UAPs which might be caused by plasmas or electrically charged bodies. Assuming that the dimension D (effective linear 'aperture') of the plasma is large compared with the wavelength (λ), then the near field is taken to extend to a distance $2D^2/\lambda$ from the source. The Radiation Field (far-field) is not of interest in this study. In the normal case of an EM source (for example, antenna emission) the radiation field beyond the near field stabilises with spatially uniform distributions of the E and H field components, which are at right angles to each other and transverse to the direction of propagation, they are in phase and have a constant amplitude relationship.

3. **UAP Near Fields** Assuming that EM radiation may be present in at least some of the UAP sources (e.g. ball lightning, bead lightning, 'earth lights' and other charged air-masses, it is possible to calculate, as shown at Table F-2, some expected near-field distances.

4. For effects on humans calculations are made to determine power flux-density (watts/m^2). In the near field this value is determined from the vector product of the E and H fields, making calculation more complex than the familiar terms ($S\text{-}PGi/4\pi R^2$) used, for example, for radar calculations. For the near-field there is an arbitrary phase and amplitude relationship between E and H which must be taken into account for every point in the near-field region if power flux-density values are required. To simplify calculations for the near-field a 'plane-wave equivalent' value is sometimes used. If the E field or H fields are known, power density is evaluated respectively from E^2/Z_o or H^2/Z_o. Z_o is the familiar characteristic wave impedance of free space 377Ω.

5. It is not clear whether single, multiple or broad-band radiation frequencies are emitted from the airborne sources of interest (UAPs). Unfortunately there are no electric or magnetic field strength measurements taken, the majority of UAP events only being present for a few seconds.

6. Standard radiation hazard calculations assume that at MF/HF the frequencies are below whole human body resonance frequencies and direct hazard effects can be high. Most of the work concerning radiation levels concentrates on the specific absorption rates (SAR) in biological tissues (for thermal reasons). The maximum amount the body absorbs depends on the rate between body length and the free-space wavelength of 0.4. For the human body a significant absorption maximum therefore occurs at ~80MHz (λ = 3.75m), varies with adults and children and is dependent on whether the subject is in contact with a conductive ground or in free space.

7. **Variation with RF** Below an RF of ~30kHz, thermal effects can be neglected in comparison to stimulation effects on nerve and tissue cells. In the RF range from ~100kHz to 1MHz the thermal and stimulation effects are of the same order. Figure F-1 shows the combined experimental results for RFs up to 100kHz. For the study of possible radiation

from UAPs the following zones on the shaded diagram are of interest. Lines A and B (Figure F-1(d) & (e) are the value of electric current densities occurring in tissue. The information at Figure F-1 is converted into incident E and H fields at Figures F-2 and F-3. Since, for this study it seems likely that UAP radiation affect the human temporal lobes, a sphere is used as the model at Figures F-3 and F-4, with the same current densities as at Figure F-1.

8. The source of these values[1] recognises that the maximum current densities may be in error by up to an order. Hence, they can only be used with caution. In general, from 3 to 300MHz power densities $<1 mW.cm^{-2}$ are considered 'weak' fields.

9. **Athermal Effects** Very little agreed scientific knowledge exists about athermal effects other than stimulating effects. Localised absorption is known to occur, for example at 3MHz around the ankles and head, indicating a higher likelihood of higher current distributions (see Figure F-1) in the body area where brain stimulation may be affected. This is not to imply that adverse effects are certain - because no biophysical action model exists to produce reliable information on which to base a firm hypothesis. It is not known whether UAP emissions produce mixed frequency effects.

10. **Modulations** Effects on humans are also concerned with any modulation which may be present and this clearly affects total received energy and may therefore affect human brains in different ways, depending on the coupling mechanism.

11. **Near-Field Coupling** Due to complicated near-field structures, with temporal phase differences between the E and H fields, a considerable variation can occur in polarisation. Very few investigations have been made to determine near-field coupling and absorption. Optimum coupling into a body can only take place when its orientation (polarization characteristic) is identical to the incident wave at that point. It is clear from this that it might be possible for a human to be close to a UAP radiation, in fact within its near-field with little effect, while a short distance away the coupling conditions may cause another human to receive stimulation resulting in quite different description of what is being seen. The generalised values deemed to be acceptable radiation hazard levels do not necessarily apply in the case of UAPs, where it is suggested that very low levels of radiation in the near-field (and possibly containing unknown modulations) may couple with the human brain. There is also some evidence that some humans are more susceptible than others to this phenomena. This may well account for the fact that often the same person repeatedly 'observes' UAP events while others do not.

12. **Radiation Pattern** Although it may be assumed that the (idealised) shape of the radiating UAP is spherical and that its radiation pattern is uniformly omni-directional, in practice this may not be the case. Frequent reports suggest that the (assumed plasmas) take up a variety of shapes and have 'hot spots' which are visible. Conventional logic is that the inhomogeneity and shape variation will lead to a non-uniform radiation distribution. Hence, there may well be 'hot spots' of radiation emanating along some axes - which the close observer may or may not be exposed to. Further, the objects of interest are often observed/approached by witnesses travelling in cars which will provide some screening. On other occasions the screening is supplied because witnesses are in aircraft. Finally, there are cases where people have left their cars and suffered both immediate and after-effects.

[1] "RF Hazards Exposure Limits". European Union Geneva 1995 Tech. 3278-E

POTENTIAL MENTAL EFFECTS ON HUMANS

13. Neurological, rather than biological effects may be the clue to some human behaviour after exposure in the near field of UAP radiation. Particularly sensitive are the temporal lobe areas of the brain. Unlike other parts of the brain, the temporal cortex can be rendered el ectrically unstable. The connection between RF fields and brain activity was confirmed by the 1980s. In the last 20 years much of the work has been concerned, on the one hand with protection of humans against RF hazards and secondly to understand the viability of microwave weapons. The amount of scientific papers on human interaction with RF fields in prodigious - 4500 papers alone between 1978 and 1984! The linking of brain activity to UAP events, where the witness is presumably within the near field influences, is currently only partially understood, since assumptions must be made (in the absence of real values) as to the type of fields being encountered. Within the UKADR these close encounters occur only a very few times each year. The well-reported Rendlesham Forest/Bentwaters event is an example where it might be postulated that several observers were probably exposed to UAP radiation for longer than normal UAP sighting periods There may be other cases which remain unreported. It is clear that the recipients of these effects are not aware that their behaviour/perception of what they are observing is being modified. The E field strengths which are known to affect the brain are of the order 50 multivolts per centimetre at between 1 and 100MHz and experiments have shown that effects can be produced at levels of 10^{-7} to 10^{-8} volts per centimetre.

14. An important fact is that the reported effect of (presumed) UAP radiation on humans is that it is quick-acting and remembered - although, curiously, following the event there is little or no recall of events as a continuum. In short, the witness often reports an apparent 'gaps' or 'lost time' - often not accounting for up to several hours. It is described as though the exposure causes a temporary memory erasure. Experiments (on animals) have shown that low ($3mW.cm^{-1}$ at 450MHz) exposures affect brain calcium ions and that these are known to play an important role in the transmission of nerve impulses. Various modulations (e.g. 5Hz, 16Hz) were imposed on the radiation. However, whereas earlier experiments went on for tens of minutes - or even for hours: as such they were not (and not intended to be) representative of the very short UAP exposure times of a few seconds In 1981 it was discovered that E fields (at ELF) of 10-50 or $V.cm^{-2}$ at a modulation of 5Hz for only 5 to 10 seconds could increase the excitability of nerves for hours.

15. It is concluded therefore that if some UAPs, as is believed and correlated by actual reports (collateral effects on, for example, car electrical equipment) produce EM radiation then there is a high probability that they can affect the human brain.

16. It would seem that this effect can occur when close to a UAP, either outdoors or indoors. This causes the brain to interact in an unusual way with the imagination 'library', causing reports of visual activity which are not in fact a true representation of the facts. It is of particular :interest that a perusal of a limited number of old UAP reports (pre- 20th century), while often similar or even identical to madern reports, does not produce evidence of 'space-craft' aliens (grey or green), 'portholes' or 'searchlight' beams!

APPLICABILITY TO UAP EVENTS

17. As there are few, if any, measurements of UAP radiation anywhere in the world, one option is to eliminate those RFs, modulations and radiation values which are known **not** to affect the human brain. For example, research has been done in this area in programmes which try to identify human susceptibility to mobile phones. In particular, operating at 160, 350 and 915MHz; and the new RF for mobiles at 1700MHz. Of course any pursuit of this process of identification or elimination is pointless if it turns out that UAP radiation is

other than EM radiation as we currently understand it.

18. For experimental purposes RF energy has been launched using resonant dipole antennas in both E and H orientation[2]. The amount absorbed was greatest at lower RFs (longer wavelengths) and at E field polarisation. However, it is recognised [for the UAP Study of Effects] that it may not be the **amount** of energy absorbed which causes unexpected brain responses to close encounters with a UAP, but possibly some sort of modulations at much lower energy levels.

19. A wealth of other international experimental measurements (in 18,000 research papers) have been taken using devices which radiate at most RFs, including ELF (e.g. 50Hz). Much of this work is based upon the necessity to understand hazards from, mobiles, AC mains and equipment such as VDUs broadcast stations, etc. It is of interest, in the UAP context, that maximum absorption (and logically the maximum effect is in the human head irrespective of wavelength. See Figure F-1. This also appears to be the case irrespective of human orientation (i.e. facing or side-on to the source). Near-field exposure deposits a far greater rate of absorption in the head than when in the far-field. It is also clear that time-varying electric fields, acting on nerve axons, can given rise to sensory stimulation. Further, the effect will not be the same on every person. Unfortunately, the stress on experimental measurements has always been human (or animal) biological changes, rather than possible neurological effects. It is of interest that at some RFs (e.g. at 900 and 1700MHz) some field focusing occurs in the head and it must be considered that while this may occur at other RFs; it may be some focusing effects or even the occurrence of several interacting frequencies from a UAP which cause the reported effects.

[2] "RF Energy, Deposition in a Heterogeneous Model of Man: Near Field Exposures M.A. Stuchey et al. IEEE Trans. Biomed. Eng. Dec 1987

SUMMARY

20 Because few persons are exposed to the postulated UAP radiation, the following points are pertinent:

- There is no history of after-effects of "UAP exposure" reported beyond "feeling unwell for a few hours".
- Unlike other EM radiation sources no cumulative effects are reported or studied.
- It is not certain that the radiation/fields are conventional and electromagnetic in nature.
- No other known (even repeated) exposures to EM radiation (with conventional modulations) causes the "loss of time" syndrome reported by many (close encounter) witnesses world-wide.

		Microwave	Microwave Threshold ($mW.cm^{-2}$)	Radio Frequency (MHz)	PRF (Hz)	Pulse Duration (μsec)
Heard as:	Shockwaves	YES	?	>60,000	?	?
	Low Pitch	YES	12	200-3000	50-100	1-100
	High Pitch	YES	~2000	Any	Any	Any
Smell		YES	?	Any	[3]	Any
Taste[4]		YES	<13.1	Any	<1000	Any
Felt as:	Heat[5]	YES	~8.4	30,000	Any	Any
	Shock[2]	YES	?	Any	Any	Any
	Burns	YES	?	30,000	Any	Any
	Internal Burns	YES	?	<3,000	Any	Any
	Paralysis	YES	?	~3,000[11]	>500	Any

Table F-1 HUMAN EFFECTS THRESHOLD (U)

Notes

[1] Reportedly enhanced if >500Hz

[2] Electrical shock

[3] Reportedly enhances smell

[4] >100μ Amp

[5] Added to those microwave heating effects can be the effects of IR

Object (UAP)[1] Diameter (m)	λ(m){f(MHz)}[2]				
	100{3}	10{30}	1{300}	0.10{3.000}	0.01{30,000}
0.5	0.005	0.05	0.5	5.0	5.0
1.0	0.020	0.20	2.0	20	200
1.5	0.045	0.45	4.5	45	450
3.0	0.180	1.80	18.0	180	1800
10.0	2.000	20.0	200	2000	20.000
20.0	8.000	80.0	800	8000	80.000

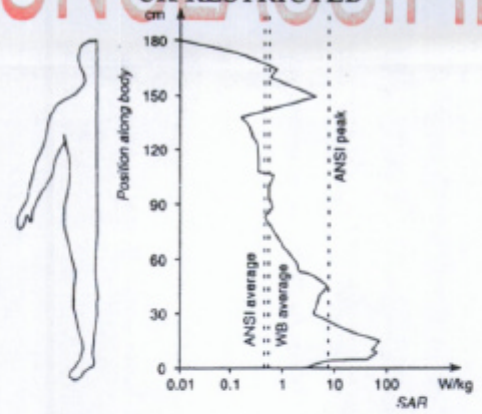
TABLE F-2: NEAR FIELD DISTANCES[3] (m)

Notes: [1] Assumes that UAP is a radiation plasma or charged mass source with effective aperture shown. The recorded appearance of plasma balls exceptionally reaches the largest value shown. However, this should not be confused with the large triangles, rectangles and other large shapes reported. These possibly have radiating peaks (e.g. at the 'corners' but, as they do not appear to be (visually) homogeneous seem unlikely to represent a total radiation aperture.

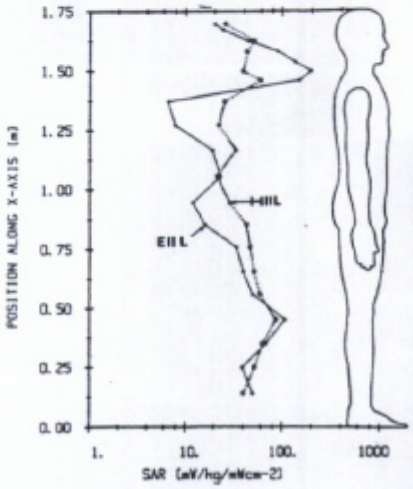
[2] It is not known whether UAPs radiate narrow or wide-band RFs.

[3] The standard near-field criteria is used ($2D^2/\lambda$).

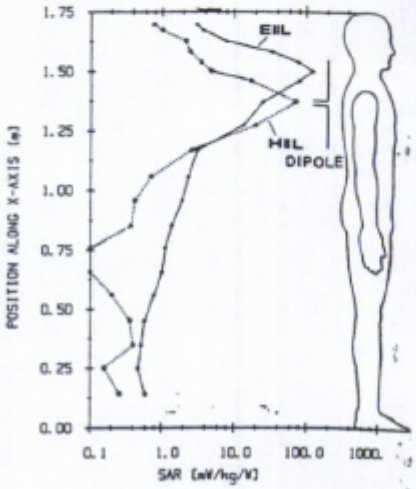
(a)



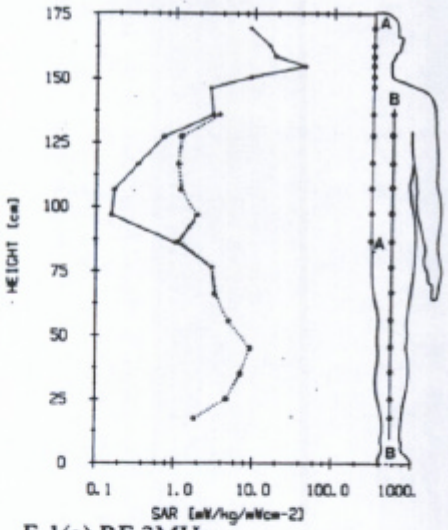
(b)



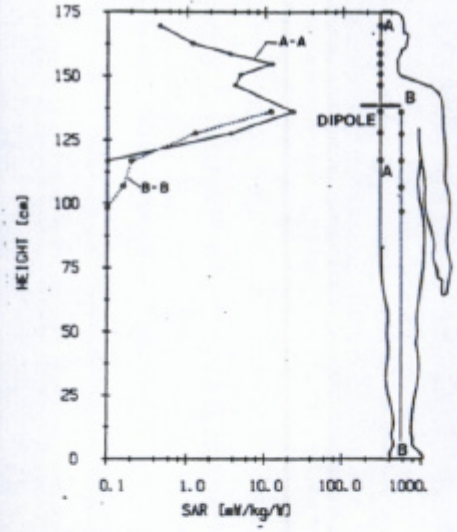
(c)



(d)

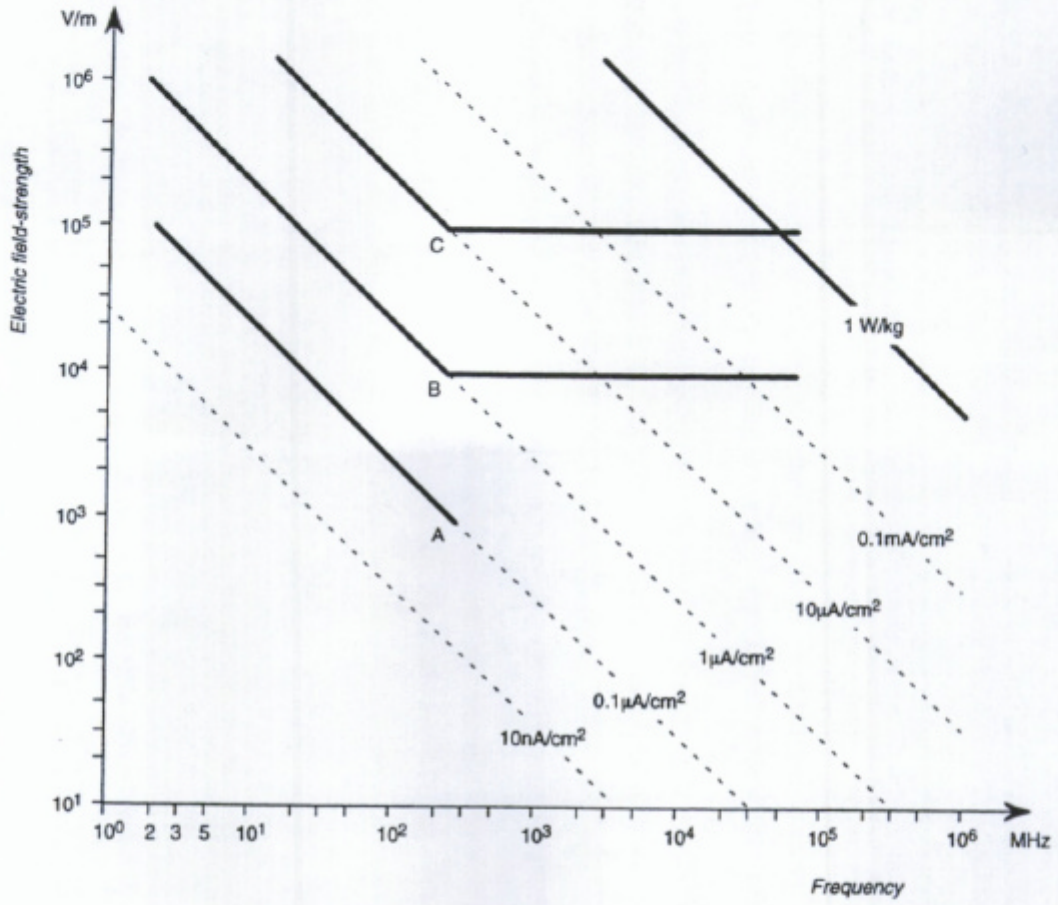


(e)



Notes F-1(a) RF 3MHz
Figure F-1(b) RF 350MHz Far Field (1mW.cm^2)
Figure F-1(c) RF 350MHz Near Field for same far field
Figure F-1(d) RF 915MHz Far Field
Figure F-1(e) RF915MHz Near Field

FIGURE F-1: DISTRIBUTION OF ABSORBED RADIATION



Notes:

1. The longitudinal axis of the man is parallel to the orientation of the field.
2. Numerical RMS values apply to the undisturbed field.
3. In other parts of the body (e.g. wrists or ankles), depending on the exposure conditions, current-density values up to tenfold greater are possible.
4. For curves A, B and C, see the notes given in Figure F-3.

FIGURE F-2: ELECTRIC FIELD-STRENGTHS WHICH INDUCE APPROXIMATELY THE INDICATED CURRENT DENSITIES IN THE HEAD AND IN THE CARDIAC REGION OF A MAN

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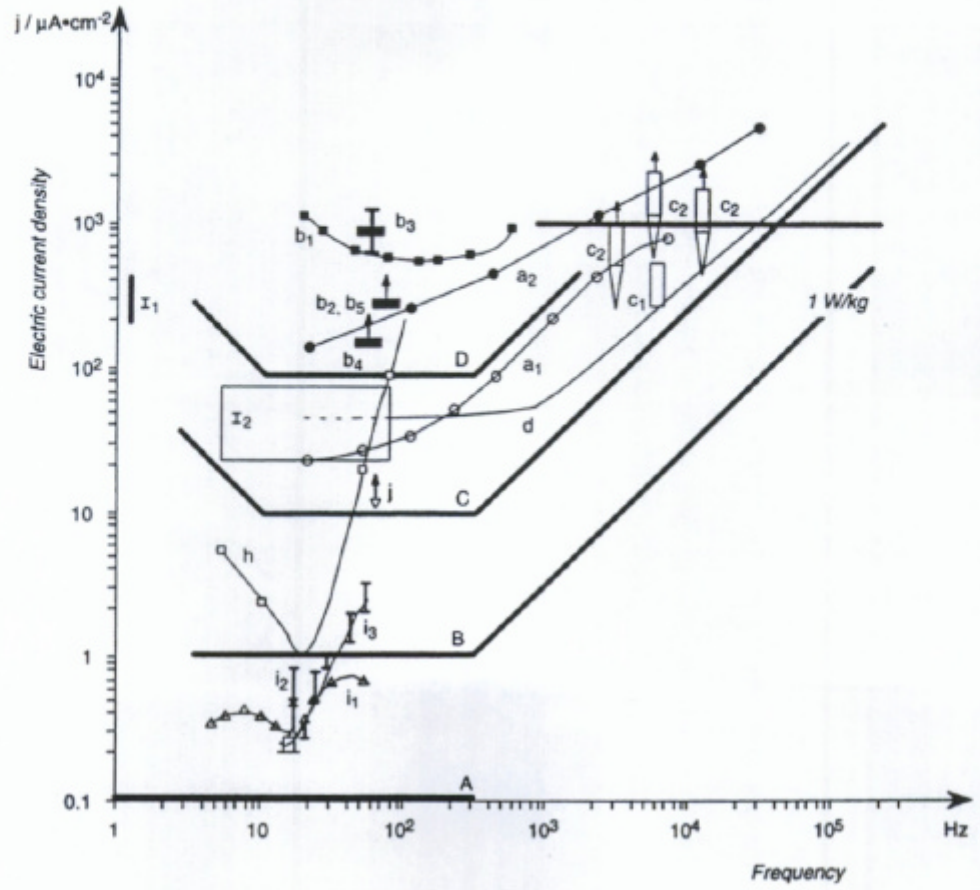

Key:

a_1, a_2	Stimulation of sensory receptors immediately underneath surface electrodes (Geddes et al., 1969).
$b_1 - b_5$	Ventricular fibrillation thresholds for stimulation times of 1 sec or longer (b_1: Imich et al., 1974; b_2: Roy et al., 1976; b_3: Jacobsen et al., 1974; b_4: Osypka, 1963; b_5: Watson et al., 1973).
D	"Envelope" threshold curve for extrasystole elicitation and ventricullar fibrillation; stimulation, 1 sec or longer (injury threshold).
c_1, c_2	Extra-cellular stimulation thresholds of single cells (c_1: Roberts and Smith, 1973; c_2: Ranck, 1975).
d	Frequency dependence of stimulation thresholds for nerve/muscle systems (modified from Schaefer, 1940). This curve may be used as a lower "envelope" curve for excitation thresholds for single unidirectional pulses or pulse sequences.
I_1	Threshold for modulation among different neurons (Chan and Nicholson, 1986).
I_2	Modulation of neuronal excitability in rat hippocampal slices (Bawin et al., 1984).
C	"Envelope" threshold value curve for stimulating effects (possibly hazardous).
h, i, j, B	Calculated current densities for the threshold values of electrophosphenes (h: Adrian, 1977) magnetophosphenes (calculated current densities; i_1: Silny, 1981; i_2 and i_3: Bernhardt, 1985) and variations of optically-generated reaction potentials (j: Silny, 1981). B shows the range over which biological effects are expected and observed.
A	Average value of naturally-flowing current density in the body tissue; the values of the current densities due to the electrical events in the brain or in the heart are usually much larger at a microscopic level. Below this current density, absence of detectable effects is assumed.
1 W/kg	The current density range above which additional thermal effects have to be considered.

FIGURE F-3: THRESHOLD VALUES OF ELECTRIC CURRENT DENSITY FOR DIFFERENT BIOLOGICAL EFFECTS

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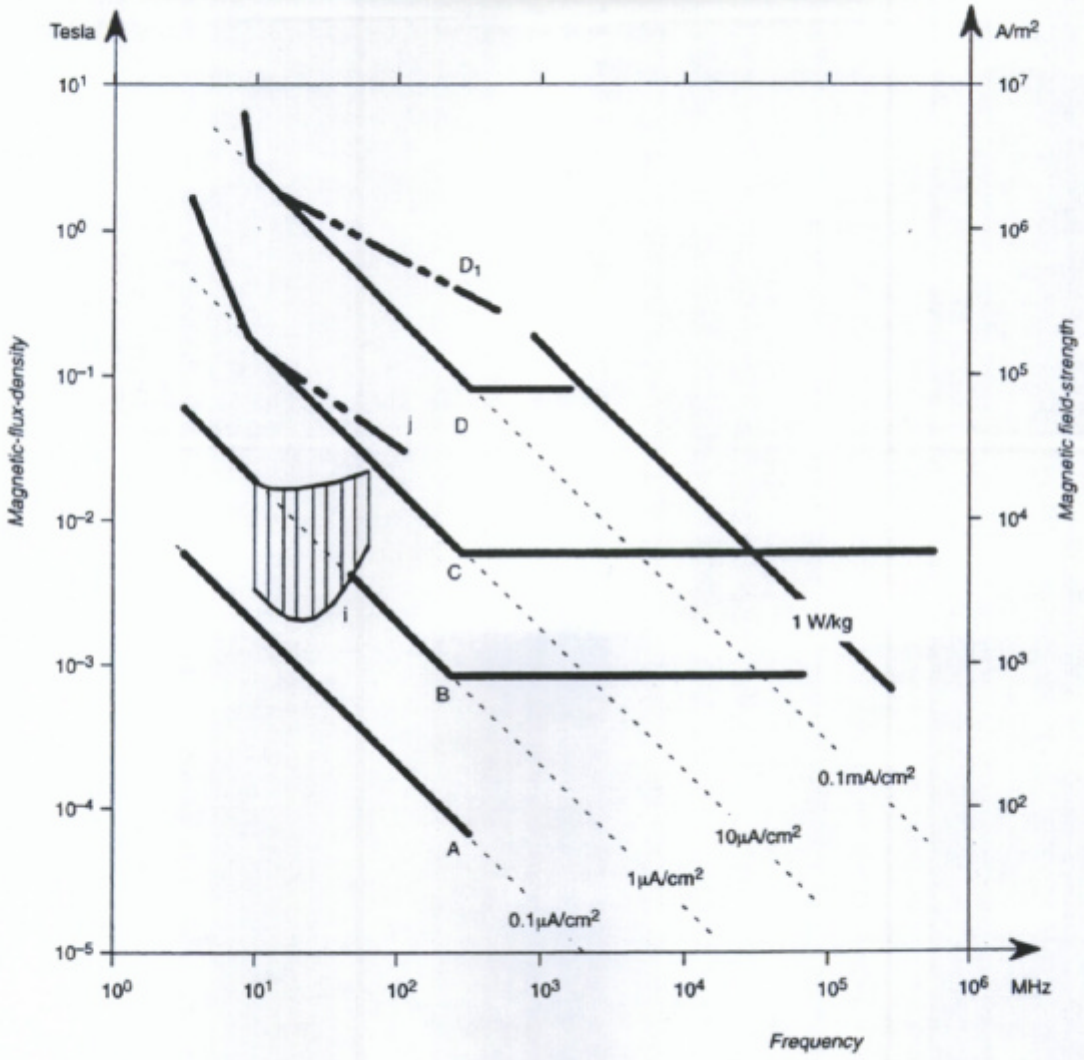

Key: i Threshold values for magnetophosphenes; the upper curve corresponds to magnetic fields where phosphenes were observed as patterns.

j Changes in visually-produced potentials (from Silney, 1981).

D_1 Experimental values for cardiac stimulations, calculated for humans from experiments conducted on animals (from Silney, 1986).

For curves A, B, C and D, see the notes given in *Fig. 16*.

Notes: 1. The magnetic field is varying sinusoidally.

2. Due to larger conductivities and current loops at a local level, induced body-current densities may exist at levels which are higher by one order of magnitude than those indicated.

FIGURE F-4: MAGNETIC FLUX DENSITIES WHICH INDUCE APPROXIMATELY THE INDICATED CURRENT DENSITIES IN THE BRAIN AND THE HEART OF A MAN

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WORKING PAPER NO. 2

BALL AND BEAD LIGHTNING

February 1, 2000

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THE CHARACTERISTICS OF BALL AND BEAD LIGHTNING

INTRODUCTION

1. A review of the nature of Ball and Bead Lightning has been made, because of the possibility of this being reported:

- As a visual unexplained UAP sighting - since this phenomena can exist up to two hours after a storm and the luminous globe can be retained on the human eye (as an after image on the retina) and reported as an object.

- As a potential UAP phenomena which can occur in all weather situations - even in a clear sky.

- The sounds and colours which can be produced by ball lightning are frequently similar to those which appear on UK UAP reports.

Lightning, as a topic, has only been seriously (scientifically) investigated for the last 200-300 years. Reports go back to at least 'Globes Igneous', (St. Gregory of Tours 6th Century AD), Aristotle 4th Century BC and others in the First Century BC. On occasions the Ball variety of lightning is known as a 'solid' or simply 'fireball'. The phenomenon of Ball Lightning is assessed to involve the disciplines of chemistry, meteorology, physics, electrostatics and electromagnetics. Chemical, optical and various electrical models and explanations have been proposed. These are only investigated here to a depth to show the consistency of characteristics as an aid to the identification of many UAP events as ball lightning or its similar relation phenomenon 'Earth Lights'. Of the numerous explanations there is generally at least one important aspect that is not totally fulfilled and a variety of theories are put forward to explain the missing link. Either lifetime (duration) is explained and stability not, or for example, colour does not match expected temperatures. For other theories, for example the vortex explanation, does not explain electrical properties. Apart from Ball Lightning and Earth Lights, many such occurrences are known simply as 'atmospheric spherical formations'. While the probability of the occurrence of ball lightning somewhere on earth has been calculated as between 10^{-9} and 10^{-8} per square kilometre per minute (equating to about 100 to 1000 balls world-wide per hour); it can only be seen at close range and many events must be unrecorded. Some, of course, are black, others translucent, both have weak thermal radiation. Reportedly bright spots or 'beams of light' are likely to occur when the phenomenon approaches a conducting object. [Comment: This is important in the context of reports, often by car owners who report supposed 'extra terrestrial' objects with illuminated 'portholes']. The 'beams' often converge unlike, for example, searchlights and this appears to be due to lens effects caused by the high electric field intensity of the surface, or 'shell' of the ball (or other shape seen)

2. **Ball Lightning** A study of Ball Lightning can be classified under the following headings:

- Conditions and locations for occurrence.
- Shapes, sizes and structures
- Motion (Velocity and Trajectory)
- Sounds
- Duration
- Radiation (Heat and Light)

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- Effect on Humans
- Effect on the Environment
- Effect on Equipment
- Odours
- Electrical/Chemical theory

Ball Lightning decays in a variety of ways - see Sounds/Colours, below.

3. Ball Lightning is believed to be formed from an 'ordinary' flash of lightning - for which the familiar 'electrical' storms are a generator. However, it can also occur without the presence of a storm or of visible/conventional lightning. Apart from these conditions, once present, the 'balls' or 'beads' can last for a few seconds up to minutes. Ball lightning can enter rooms (usually through apertures (e.g. chimneys, doors, windows) and can either leave by the same method or dissipate within the enclosed space. Instances have been reported where ball lightning has entered aircraft (BOAC 1938 and TWA 1948 Easter Airlines 1963, USAF KC-97 in 1960 and in Russia). In Europe 65% of all reports identified as ball lightning occur in the summer months. 95% are reported in the hours 1300-2359 hours and mostly clustered in the period 1600-2000 hours . It has even been seen in snow. Frequently the effect has been reported in the vicinity of marshes, volcanoes (lee-side) and during earthquakes. The balls/globes appear in rain, in clear skies, in still conditions or wind, move against the wind, can be vortex associated, in snow, near the ground and at altitude. Undoubtedly the largest occurrence is during storms/cyclonic conditions. Conditions for ball lightning formation appear to be:

- Charge particle connected
- Frictional action of dust (hence Volcanic links)
- Dependent on the presence of very high electrical charges and fields
- Possibly dependent on the formation of natural EM radiation
- Emitted from a 'bend' in conventional lightning
- Drop from clouds (initially)

On occasions ball lightning has no apparent connection with a storm. It can also leave a meteor-like trail.

4. **Bead Lightning** Bead lightning (5-15%) is much less prevalent than ball lightning (85-95%) and is the residue of cloud-to-cloud or cloud to surface lightning strokes where a row of balls are seen separated by darker regions in a string-like form. Bead lightning is generally observed at a distance, in contrast to ball lightning which is observed nearby. As for ball lightning, the incidence of the occurrence of bead lightning is quite low. One survey found only 1600 reports between 1850 and 1978! Bead lightning is also sometimes called 'pearl' lightning. Some 'strings' have been reported as quasi-sinusoidal in form, while elongation of the beads (or balls) suggests sausage or cigar-shapes [often a feature of UAP reports].

5. Most reports of ball and bead lightning occur at low altitude - most probably because that is the location of most observers; hence this limitation may not be true in practice (see para. 22 below). Insufficient evidence exists to be certain of all the conditions for ball and bead lightning formation. No single theory appears to satisfy all the criteria. The ball is sometimes seen with a halo.

6. Ball lightning is sometimes mistakenly reported as St. Elmo's fire.

SHAPES, SIZES AND STRUCTURES

7. On some occasions bead lightning, often described as a 'string of sausages' (i.e. elongated beads), converts or 'breaks off' into a single glowing ball as the pinching effect which separates the components disappears, leaving a single glowing ball (or balls). Shapes are invariably described as globes. Sometimes flames seem to be revolving inside the globe. On rare occasions, two balls have been reported linked together (a metre or two apart), while on others oval, or pear-shaped forms are reported. On even rarer occasions 'torus' and

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'rod-shaped' systems have been seen, and also 'hollow' spheres.

8. Ball dimension reported vary from a few centimetres to 12-15m in diameter. Some examples had ball diameters of 22cm (inside eastern Airlines Aircraft, 30cm, 50cm, 60cm, 8.5m, 12.8m, and a 38cm (rod). A summary of the scientific factors which control plasma sizing is at paragraph 30, below. Optical illusion effects can clearly change the perception of size. It is important to note that an increase of light intensity can be perceived as an increase/change in size or shape. The balls are sometimes hazy in outline and may not be truly spherical (when not one of the other shapes).

9. Within the bounds of the shapes, described above, there appear to be three structural types:

(a) Balls with a solid appearance with a dull or reflecting surface, or with a solid core in a translucent envelope (often 30-50cm in diameter).

(b) A rotating structure.

(c) A burning appearance (often <40cm diameter).

Reports suggest that single balls can break up into smaller ones (or disperse - see para. 12 below).

MOTION

10. The motion attributes reported are, firstly direction/profile, where the phenomena is reported as moving in one or more of the following directions or types of movement:

- Cloud-to-cloud
- Earth-to-cloud
- Cloud-to-earth
- In a horizontal path (55% of occasions and usually of the 'burning' type)
- Climbing and bouncing/rebounding
- Changing course
- Movement opposite to wind direction
- Very rapidly point to point (jumping or darting)
- Attracted to enclosures (e.g. indoors/in vehicles/aircraft)
- Rolling (on earth's surface, wet or dry)
- Emerge from Lake
- Turning sharply/abruptly
- Executing parabolic curves
- Spinning or spiralling
- Floating
- Motionless/hovering
- Diving (at high speed)
- Apparently moving at windspeed
- Jumping (to a few metres in height)
- Darting to a conductor (especially water, fences etc.)
- Attaching (to an object) or 'pushing' at an object
- Detracting (and floating away from an object)
- In complex trajectory (20% of reports)
- Vortex-associated
- Float ('squeeze') through a small hole and then expand to a large ball-shape.

11. **Velocity** Secondly the ball lightning often has velocity in one or more of the following categories.

- Often low velocity (including zero)
- Estimated 100-1200ms^{-1}.

Frequently the speed is reported (when near the ground) as that of a man walking or running. The spiral or rotational form, which is often vortex-associated, appears to take the form of a hydrodynamic or plasma vortex.

SOUNDS

12. Many sightings have been made when the ball makes no sound, while others have:

- Hissed (hence confusion with St. Elmo's fire)

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