Electromagnetic Field Strength Measurements on Megapulse Units

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Summary: Electrotherapy equipment such as the Megapulse uses the application of short-duration pulses of electromagnetic energy for the treatment of damaged muscle and tissue. Operation of this type of equipment has been noticed to cause interference with nearby electrical and electronic systems, leading to concern among staff with regard to any possible corresponding health hazard. Details of the power outputs corresponding to different treatment settings are supplied by the manufacturers, but no information is provided about the distribution of that power around the Megapulse.

This report details an investigation made into the distribution of the electromagnetic field surrounding operating Megapulse units, and of the field strength levels in adjacent areas. The levels measured were, in general, low when compared with the appropriate guide lines. Safety guide lines in the UK are however, currently based solely on thermal considerations, while the Megapulse is claimed to be athermal in its effect.

Biography: Andrew McDowell began as a medical physicist in 1986 in the calibration and maintenance of radiotherapy equipment at Southend Hospital, before taking up his present post at Poole General Hospital. He is currently involved in the measurement of non-ionising radiation, and in the design of electronic aids for the disabled.

Michael Lunt started in medical physics in 1969 at St Bartholomew's Hospital, London, before moving to Rotherham District General Hospital. He took up his present position as head of the East Dorset Medical Physics Department in 1986. Specific interests are in ultrasound and in the theory of pulsed magnetic field therapy.

Introduction

THE Megapulse* is an example of electrotherapy equipment which produces electromagnetic radiation at the designated 'medical and scientific' frequency of 27.12 MHz. The electromagnetic output is delivered in short pulses which are adjustable in duration and repetition rate, enabling the operator to vary the mean (time-averaged) output power. A further control enables trains of these pulses to be delivered either continually, or for two-thirds of the time, or for one-third of the time. The corresponding mean power output for each of these settings is tabulated in the Megapulse *Operator's Handbook*, enabling the operator to select suitable treatment parameters for a desired output power. However, these figures refer only to the overall power emitted by the treatment applicator, and provide no information about the distribution of that power around the applicator.

This investigation seeks to measure the electromagetic fields emitted by the Megapulse treatment applicator, both to quantify the field strength levels, and to identify the distribution of the fields in the immediate vicinity of the unit and in the surrounding areas.

Electromagnetic Fields

Electromagnetic energy comprises two components: an electric field, and a magnetic field. The intensity of the electromagnetic field at a particular point is determined by the strength of each of these components, and by their relative phase (their synchronisation in time). In the locality of the treatment applicator, there is no fixed relationship between each of these components, so each must be measured separately. Electric fields are measured in units of volts per metre (V/m); magnetic fields are measured in units of amps per metre (A/m) or tesla (T). (In air, 1 A/m is approximately equal to 1.3 μT.) If the relative phase of these two components is known, the local power density may be derived, and expressed in units of watts per square metre (W/m²). The power density is the amount of power per unit area, and decreases with distance from the treatment applicator as the area over which the overall power is distributed increases.

Mean and Peak Power

The output from the Megapulse may be expressed in terms of either the peak power — the instantaneous power while the Megapulse is actually delivering a pulse — or the mean power, which is the average power over a period of time. The peak power is independent of treatment settings, whereas the mean value varies in accordance with the treatment parameters selected. The mean and peak power are related by the formulae below:

$$\text{mean power} = \text{peak power} \times \text{pps} \times \text{width} \times n$$

$$\text{peak power} = \frac{\text{mean power}}{\text{pps} \times \text{width} \times n}$$

where

pps = pulse per second

width = pulse width

n = ⅓ for '1 in 3', ⅔ for '2 in 3', 1 for 'norm'

*Electro-Medical Supplies, Greenham

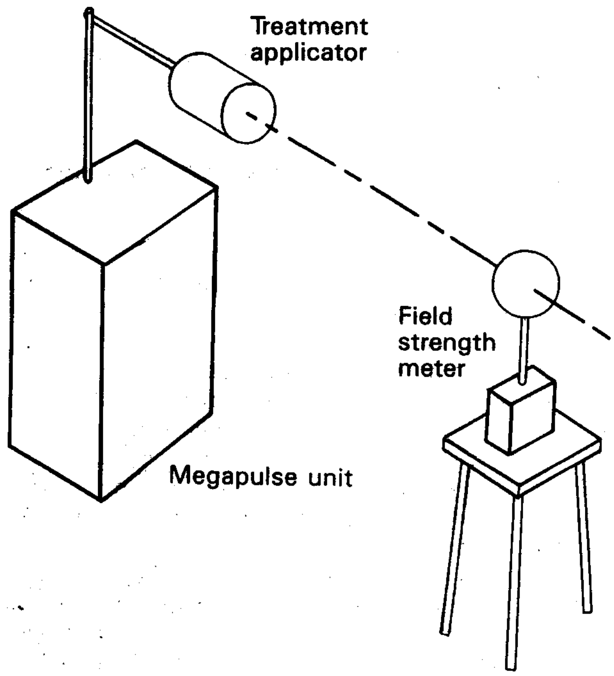


Fig 1: Equipment set-up

Similarly, electric and magnetic field strengths may also be expressed in terms of mean or peak values. Mean electric and magnetic field strengths are normally quoted as root-mean-square (rms) values, such that

$$\text{mean (rms) field strength} = \text{peak field strength} \times \sqrt{\text{pps} \times \text{width}} \times n$$

$$\text{peak field strength} = \frac{\text{mean (rms) field strength}}{\sqrt{\text{pps} \times \text{width} \times n}}$$

Method of Measurement

The field strength measurements were made using an Aeritalia TE307 electromagnetic field meter* in free space as shown in figure 1. The area around the Megapulse was cleared of all equipment except that needed to measure the field. While this may not truly reflect clinical circumstances, it does enable characteristics pertaining to the Megapulse itself to be established. Effects of equipment and personnel on the field then can be investigated separately.

The Megapulse units investigated in this study were of two types; an older model (37), having a peak power output of 310 W and a newer model (37A), with a peak power output of 125 W. The newer models have an increased pulses-per-second range to compensate for the lower peak power (100-800 pps as opposed to 25-400 pps, each with a maximum pulse width of 400 μs), so that both types can deliver approximately the same mean power when set to maximum output.

*Electro-metrics Ltd, Shefford, Bedfordshire

In this study, the Megapulse units were operated on their maximum settings, so as to provide 'worst case' results. The resulting mean power measurements quoted here can be considered to be comparable, though not identical, for both types.

The power and field strength levels expected at other treatment settings may be derived from the results given by using the formulae below:

$$P_{exp} = P_{mea} \times \frac{pps}{pps_{max}} \times \frac{width}{400} \times n$$

$$fs_{exp} = fs_{meas} \times \sqrt{\frac{pps}{pps_{max}} \times \frac{width}{400} \times n}$$

P_{exp} = expected power
P_{meas} = measured power
fs_{exp} = expected field strength
fs_{meas} = measured field strength
pps = pulses per second
pps_{max} = 400 for model 37 units
= 800 for model 37A units

width = pulse width (μs)

Safety Guide Lines

The biological effects of electromagnetic radiation encompass a wide range of reported phenomena (NCRP, 1986; Saunders *et al*, 1991), covering both thermal and athermal effects. While thermal effects are well documented, athermal effects are still little understood, with considerable inter-study variability precluding a quantitative evaluation of their significance. The International Radiation Protection Association has therefore issued guide lines regarding electromagnetic radiation based on thermal effects (IRPA/INIRC, 1988), and these have been adopted by the National Radiological Protection Board (NRPB, 1989) for implementation in the UK. Those guide lines which are relevant to the use of equipment such as the Megapulse are summarised below.

It should be noted that these guide lines do not apply to considerations of patient dosage, but are applicable only to occupational exposure levels.

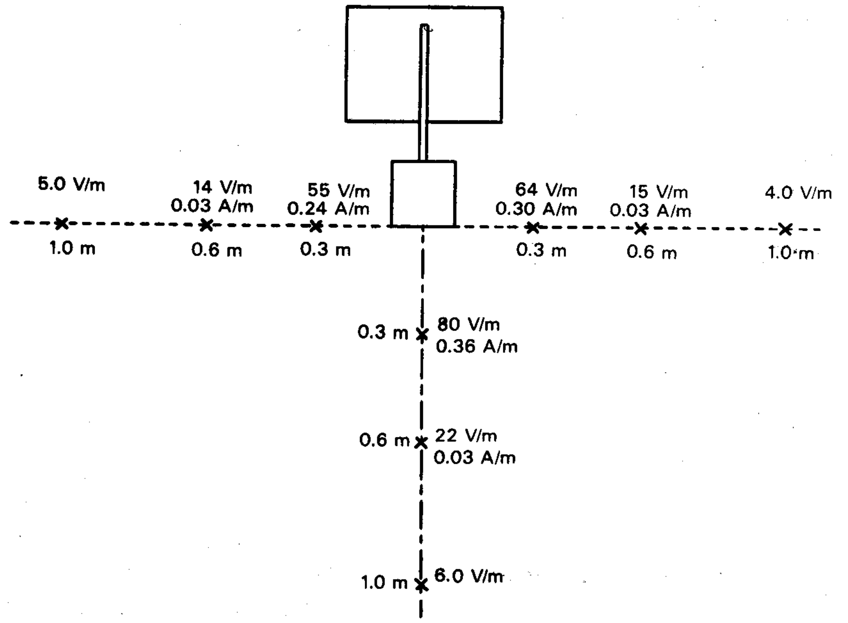
- The average energy absorption rate in the body over any six-minute period should not exceed 0.4 W/kg for workers.
- The maximum energy absorption rate for workers in any 0.1 kg of tissue in the hands, wrists, feet and ankles should not exceed 20 W/kg, or 10 W/kg in any other tissues.
- 1. Maximum mean electric field strength should not exceed 61 V/m.

  2. Maximum mean magnetic field strength should not exceed 0.16 A/m.

  3. Maximum mean power density should not exceed 10 W/m^2.
- Peak field strengths should be no greater than 32 times the limits for mean field strengths; peak power density should be no greater than 1,000 times the limit for mean power density.

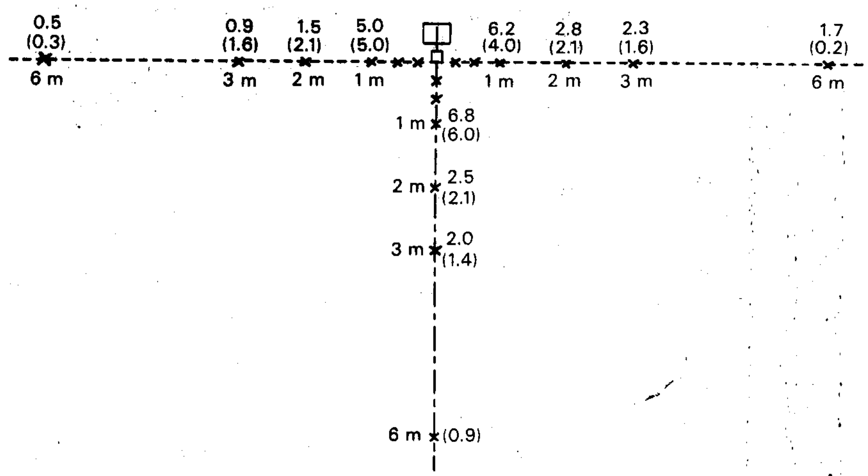
Field Distribution

Measurements were made of the electric and magnetic field strengths within the horizontal plane of the treatment applicator of an older-type unit operating at maximum output (400 pps, 400 μs, 'norm'), at distances of 0.3 m, 0.6 m and 1.0 m. Electric fields were also measured using at distances of 1 metre, 2 m, 3 m and 6 m using an older-type and a newer-type unit (both operating at maximum output:



Graph 1: Electric and magnetic field strengths

Measurements show mean (rms) field strength using older-type Megapulse unit operating at maximum output (400 pps, 400 μs, 'norm')



Graph 2: Electric field strength levels

Unenclosed figures represent measurements made on newer-type Megapulse unit. Figures in parentheses represent measurements made on older-type Megapulse unit. All measurements are in V/m

400/800 pps, 400 μs, 'norm'). The resulting measurements are shown on graphs 1 and 2.

It can be seen that the free-field output from the treatment applicator is to a large extent omni-directional; there is very little difference between the field radiated forwards from the applicator and to the sides. This situation does not necessarily apply under clinical conditions however; where the applicator is in close proximity to a patient, one might reasonably expect the main transfer of energy to be to the patient. It can be seen that under free-field conditions, the occupational exposure limits of 61 V/m and 0.16 A/m, for the electric and magnetic field strength levels respectively, fall within a radius of approximately 0.5 m of the treatment applicator. At lower power settings, the boundaries of these field strength limits become correspondingly closer to the applicator. Apart from the possible momentary positioning of the treatment applicator while the unit is operating, it is therefore highly unlikely that the occupational exposure field strength limits will ever be exceeded. These results are in agreement with the findings of previous studies (Martin *et al*, 1990, 1991).

The electric field strength measurements made at distances of 1 m, 2 m, 3 m and 6 m from the applicator provide a good indication of typical field strengths outside the immediate vicinity of the unit. Graph 2 shows how the electric field strength decreases with distance, down to levels of the order of 1 V/m at distances of 6 m or so. At these distances, the field strength level is determined less by the distance away from the treatment applicator, than by other factors such as the distribution of metallic objects in the room — the presence of radiators, beds, and overhead storage racks for example, and reflection of the electromagnetic radiation from walls and other surfaces. It should be noted that despite the difference between the models of Megapulse unit measured in each of these surveys, their output characteristics are roughly the same, and fall off with distance in a similar pattern. This is perhaps surprising, since the manufacturers of the Megapulse state that the applicator of the newer-type (model 37A) Megapulse is screened so as to prevent electric fields from emanating in directions other than the direction of the treatment beam, whereas the applicator of the older-type (model 37) Megapulse is unscreened.

Departmental Survey

Because of the widespread occurrence of various interference effects while Megapulse units were in operation, measurements were made to determine the electric field strength levels in rooms surrounding the Megapulse treatment area in a typical physiotherapy department. The

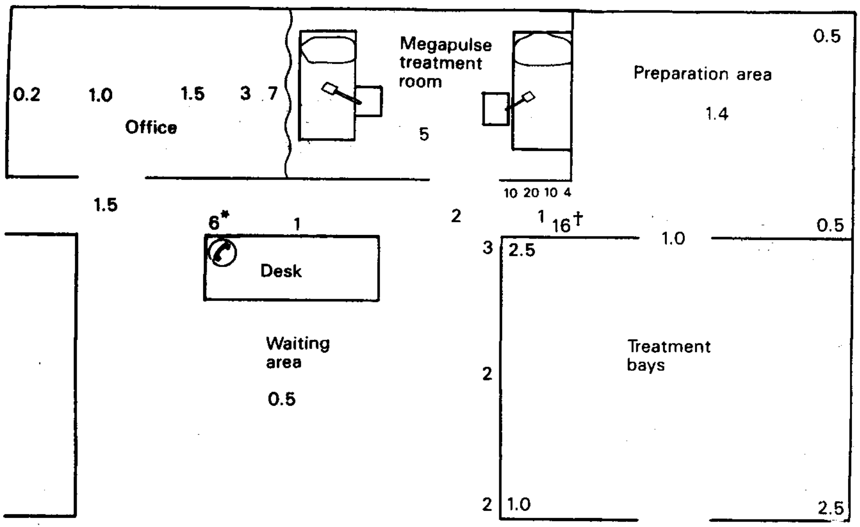


Fig 2: Electric field levels in a typical physiotherapy department

*reading taken at telephone
†reading taken at telephone point (low with phone removed)
All measurements in V/m

results of this survey are shown on figure 2, and illustrate many of the points mentioned above. In general, it was observed that the background levels drop substantially outside the immediate treatment area; apart from localised 'hot-spots', the field strength decreased by a factor of approximately 5 when separated from the immediate treatment area by an interior wall. Far less attenuation of the field strength was found to be provided by a room-divider; nevertheless, field strengths at distances of 1 m or so from the treatment applicator were still well below the maximum recommended levels. A great deal of pick-up was found to be present between the electromagnetic fields and any telephone lines in and near the treatment area, resulting in substantial audio-frequency interference in the telephone system, and relatively high field strength levels — of the order of 10 V/m — emanating from telephones and their jack points. These levels were found to be extremely localised, however, the surrounding fields being of much less strength, typically of the order of 1 V/m. There was also coupling between water piping and the fields in the treatment room, resulting in relatively high field strength levels being present at radiators in the various rooms, again of the order of 10 V/m. These raised levels were also extremely localised, and not representative of the levels throughout the rest of the room.

Field Strength Levels in a Maternity Environment

In a maternity ward the Megapulse unit is likely to be operated in close proximity to metal-framed beds and cots. This relatively high prevalence of metal structures has led to concern regarding possible field concentrations, in particular relating to the likelihood of babies in nearby cots being exposed to undesirably high field strength levels. In a multi-bed ante-natal ward for example, it is possible for the situation to arise where a Megapulse unit being used to treat one patient is placed immediately adjacent to a neonate in a cot in the next bay, as shown in figure 3.

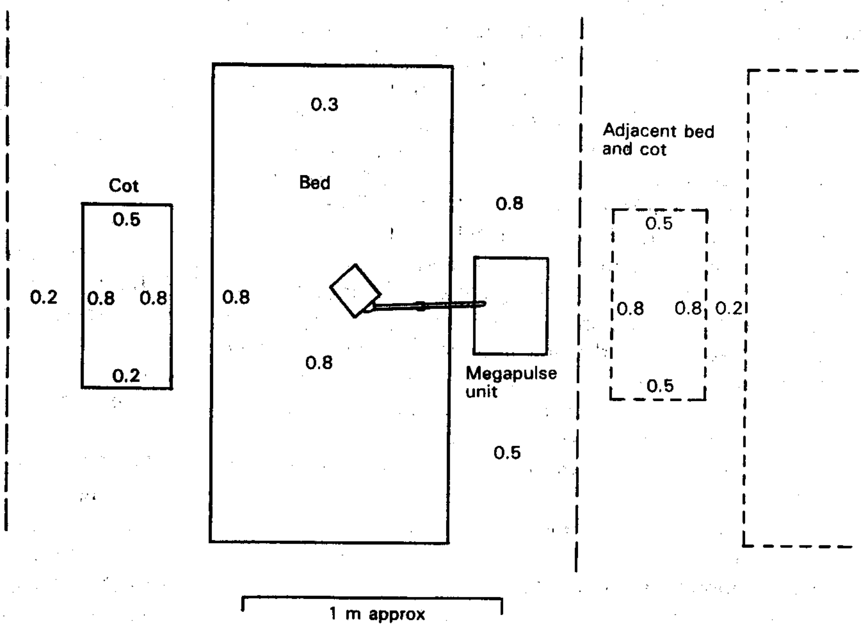
Typical settings used for obstetric treatment regimes are relatively low, normally ranging from 20 μs at 100 pps to 65 μs at 200 pps, using the '1 in 3' setting (Bewley, 1986; Grant *et al*, 1989). Measurements were made at the maxima of these settings, ie 200 pps, 65 μs, '1 in 3', equating to 3% of maximum power (or 16.5% of maximum field strength) for the older types of Megapulse unit (model 37), or 1.4% (12%) for the newer-type (model 37A) units.

It can be seen from figure 3 that the typical mean field strength levels associated with such treatment regimes are very low, and are always well below the safety guide line level of 61 V/m. The field distribution is distorted significantly by the prevalence of metal structures, resulting in the electric field being 'stretched' to the edges of a metal-framed bed

Fig 3: Field strength levels in a typical maternity treatment set-up

All measurements in V/m

Measurements made at ⅓ setting, 200 pps, 65 μs (312.5 W units)



for example. This situation is of advantage however: the resulting field strength levels found within the metal-framed enclosure of a cot are much lower than the surrounding levels, due to the screening effect of the metal frame.

Nevertheless, it should be remembered that the *peak* field strengths are independent of treatment settings, and are consequently of the same level as would be found if the Megapulse was operated on full power.

Discussion

As a general observation, it should first be noted that the results obtained strictly only apply when the Megapulse is set up exactly in the manner in which it was when the measurements were made; the presence of people near the treatment applicator can distort the fields considerably, as can equipment such as metal tables and chairs. The readings obtained give a good indication of the strength of the fields generated by the Megapulse units; they should not, however, be treated as precise values which can be applied under every circumstance.

Within the immediate vicinity of the treatment applicator, it has been shown that it is possible for field strength limits and energy absorption rate limits to be exceeded. In the area immediately behind the treatment applicator, the field levels are somewhat undefined, since they are distorted by the metal applicator supports. Even in worst-case conditions however, ie with the Megapulse operating at full power, the field strength limits can be considered to be contained within a radius of 0.5 m from the treatment applicator. It is perhaps unsurprising that most parameters measured are well below recommended safety limits, since these are based on thermal effects; while athermal effects remain as little-understood phenomena, thermal considerations are the extent to which electromagnetic safety limits can be prescribed.

The presence of a patient or operator in the vicinity of the treatment applicator introduces a significant local distortion of the fields. Measurements have been made of the local field distributions using saline-filled phantoms to simulate typical treatment conditions (Martin *et al*, 1990, 1991); however, because of the difficulty in simulating treatment conditions which may be considered to be representative, the fields were measured in an unperturbed state in this study.

It is clear that the output power from the applicator falls off very rapidly with distance: interference with electrical equipment such as telephones does not necessarily reflect a high field strength level in the place where the interference is observed, but is more an indication of pick-up in the wiring where it runs near the Megapulse equipment itself. Although this pick-up is strong enough to cause excessive audio interference in telephone systems, none of the field strength levels measured were considered high enough to cause damage to electrical and electronic equipment. The possibility of malfunction or spurious operation cannot however be ruled out; even in areas of low field strength, a mains lead can act as an effective aerial, and pick up a substantial amount of interference. While the output from the Megapulse unit is electromagnetic, and consequently produces interference to which electrical and electronic equipment is highly susceptible, it should be noted that a seemingly substantial effect on electrical apparatus, such as loud noises present on telephone systems, does not necessarily indicate a correspondingly substantial effect on the human body.

All these measurements have been made in terms of the mean field strength and power density levels; these mean values vary depending on the particular machine settings. To obtain 'worst-case' results, all measurements — excepting those in the maternity environment — have been made with the Megapulse units operating at their maximum output settings. In clinical practice the units are usually used on lower output settings, and the mean fields and power density levels will be lower than those reported in this study. However, the *peak* output power for a given unit is independent of the output settings, differing only between the older and newer models of Megapulse. It is interesting to note that the manufacturers of the Megapulse, Electro-Medical Supplies, themselves state that 'it is the peak power of the pulsed output which produces the effective treatment'. If this is truly the case, one might reasonably expect significantly different results from patients treated on the older Megapulse units — having a peak power output of 310 W — to those treated on the new units, which have a peak power of 125 W.

Studies comparing the Megapulse with other models of pulsed therapy equipment (DHSS, 1987; Martin *et al*, 1990, 1991) have shown the output power from the Megapulse to be relatively low. While the figures reported in this study cannot therefore be directly applied to other models of equipment, it is reasonable to assume that the qualitatative effects described here will apply similarly to other models of pulsed electrotherapy equipment.

Conclusion

These measurements have shown that the NRPB safety guide lines are exceeded only at distances less than 50 cm from the treatment applicator, even when the equipment is operated at maximum output. Consequently, there appears to be no hazard to staff using the equipment in the normal way, nor to staff in adjacent rooms.

Interference in sensitive electronic equipment can be a problem when using the Megapulse, but levels are such that this will not cause permanent damage to the equipment, provided it is kept at a reasonable distance from the Megapulse.

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