New Zealand After Nuclear War

THE BACKGROUND PAPERS

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BACKGROUND PAPER 5

EFFECTS OF ELECTROMAGNETIC PULSE ON POWER AND COMMUNICATIONS

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This is one of a set of background papers prepared, in consultation with the Nuclear Impacts Study Team, from material provided by a wide range of contributors for a study of the impacts on New Zealand of a major nuclear war. Along with other sources the papers comprised the basis of the book ***New Zealand After Nuclear War****, by Wren Green, Tony Cairns and Judith Wright, published by the New Zealand Planning Council, 1987. The assumptions that the study was based on are explained in Background Paper 1, note particularly the assumption that New Zealand is not a target, and the variable assumption involving an electromagnetic pulse (EMP - for an explanation, see Background Paper 5).*

INTRODUCTION

Nuclear explosions can generate very strong electromagnetic pulses (EMP), particularly from high altitude explosions. These effects can be very disabling and an EMP attack by one superpower on the other and its allies could be the precursor to a nuclear war.

One of the scenarios considered by the study group was that New Zealand suffered from the effects of an EMP attack on Australia coupled with isolation as a result of subsequent conflict. This paper attempts to look at the possible effects on New Zealand of that scenario. Much of the extrapolation of the known effects of EMP on a country's networks and infrastructure is the subject of much debate and research, and this paper works within the framework of that uncertainty and debate.

ELECTROMAGNETIC PULSE (EMP)

EMP is one of the lesser known effects of a nuclear explosion, unlike blast, thermal effects, and radiation which have been more widely publicised. In 1962 when atmospheric nuclear tests were banned, only two tests in the upper atmosphere had been carried out by the United States. During one of them, 300 streetlights went out and other damage occurred in Oahu, Hawai'i, 1300 km from the test site of the 1.4 Mt weapon which was exploded at an altitude of approximately 400 km. The existence of EMP had been recognised in earlier tests when instruments had failed or given strange results.

All nuclear explosions produce EMP, but with high altitude bursts the effect is most pronounced (strictly referred to as HEMP) mainly because it occurs over a very wide ground area but *without* the other nuclear effects.

The HEMP consists of a radiated pulse of electromagnetic energy from a source region below the explosion. The pulse is about 50 times faster than a lightning surge, with peak fields up to 50,000 volts/meter. It thus has a greater intensity and broader spectrum than most electromagnetic waves (Fig. 1*) which are discrete or only narrow-band. By comparison the urban background field is only 0.01-0.1 volts/meter, and that immediately adjacent to a radar station or microwave dish around 200 volts/meter. There is still debate about whether the 50,000 volts/meter is a maximum value independent of bomb size. Some French physicists believe this should be doubled.

The radiation consists of a plane wave (E/H = 377 ohms) with the E and H fields perpendicular to each other and to the direction of propagation. The maximum energy density is 0.6-0.9 J/sq.m. and 99.9% of the total energy lies below 100 MHz. Because of the short duration of the pulse, the instantaneous peak power is enormous - around 6 MW/sq.m. By comparison with a lightning pulse, which has little power level above 1 Mhz, the typical EMP spectrum extends one or two decades upward in frequency (Fig. 2). It is this portion of the signal which goes through ordinary protective devices, such as conventional surge diverters and spark gaps, since they react too slowly.

The method of generation of EMP is from the collision of gamma rays with air molecules in the rarefied upper atmosphere. Electrons knocked free are scattered forward, and interact with the earth's magnetic field resulting in an efficient conversion of the energy of the moving electrons into a radiated magnetic field. Depending on the height of burst, the gamma rays themselves can travel great distances before interacting with air molecules and thus the source region at a height of some 40 km can be thousands of kilometers in diameter and 20-40 km thick (Fig. 3).

The coverage or range of HEMP is determined by line-of-sight from this very large source region, and within the "illuminated" region the average field strength can still be half the peak value mentioned above. For example a nuclear blast 100km above Sydney would extend half way across the Tasman and a 400 km high blast would "illuminate" all of New Zealand and two-thirds of Australia (Fig. 4). Within the extent of the illuminated area, the field pattern is asymmetrical according to Hutton (also used in Bradley's paper) and shown in Fig. 5.

Direct EMP in space is also a major threat to satellites since it not only produces very high fields (about 1 million volts/meter and unattenuated by distance) but results in internally-generated EMP in equipment from the burst of gamma rays (known as system-generated EMP or SGEMP).

EFFECTS OF EMP

Any conducting object exposed to the fields of an EMP acts as a collector of electromagnetic energy and tends to raise its voltage with respect to earth, and absorb the energy from the pulse. The overvoltage can damage insulation, to the extent that if there is sufficient power available a damaging short circuit can occur. The energy absorption together with overvoltage can severely damage electronic components such as micro-chips (integrated circuits) or transistors, whose small size makes this even more acute by only allowing a low withstand for additional stresses.

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* Figures follow at the end of this paper.

However EMP does not directly affect people unless they are in contact with conducting material. Despite some dire predictions concerning possible shock or burns for people using electrical apparatus during an EMP effect, where a power system uses solid protective earthing as a prime safety measure as in New Zealand the risk is almost nil, particularly with modern equipment safety insulation standards. The only risk to people would be from casual contact with long metallic objects such as fences, pipelines or aerials.

Generally the larger the network or structure the greater is the amount of intercepted energy, and by this means the electricity grid which is a very large collector can focus large amounts of EMP energy on sensitive components. Electrical transmission systems may trip out, possibly with permanent damage to the insulation because of the peak voltages generated by HEMPs of up to 3 million volts. High peak currents of up to 10,000 amperes also occur but for very short duration and are thus less potentially damaging. Depending on the normal operating voltage, this can be up to two orders of magnitude more than the design limits of most electric power systems. It is as if the closest natural phenomenon to EMP, which is a lightning surge, were applied directly and simultaneously to many parts of the whole network.

Lower voltage overhead distribution systems, with shorter line lengths but lower basic and surge insulation levels, will be more at risk than transmission lines. Urban cable distribution networks should be adequately shielded.

Within milliseconds of an initial burst, the EMP-induced pulses in the power lines would be conducted to all connected apparatus: all computers, all plugged-in radios, TV sets and consumer appliances, all telephone networks, broadcasting systems, industrial control equipment. Simultaneously, all this electrical equipment would also be picking up the EMPs from direct radiation via antennas, aerials and internal wiring.

The relative vulnerability of electrical components to damage is shown in Fig. 6, ranging from power transformers which are relatively insensitive to damage to computer components such as integrated circuit chips which have extremely low thresholds of the order of 1/1000 to 1/1,000,000 the likely energy flux during an EMP.

Thus for electronic equipment, pulses reach it by direct diffusion of the field, or by conduction via mains. The equipment reacts either by treating the pulses as noise or error or by suffering permanent damage through destruction of sensitive components. Battery-powered home radios and TVs may escape since their antenna areas are small. Predicting how an entire system will react is difficult even though much is now known about individual components.

Whilst there is considerable theoretical knowledge about EMP, and limited practical testing of individual units for the degree of protection, there is still much debate and discussion concerning how extensive EMP damage would be to large networks and systems, and the equipment connected to them. The degree of uncertainty about any predictions must be emphasized.

CONSEQUENCES OF DISRUPTION

Nations potentially involved in a nuclear conflict

Communications are of major importance to the military, and in any civil defence planning. Vital military decisions may be impaired or unacceptably delayed. Public broadcasting and telephone systems may be out of action indefinitely. Electricity supply also is so essential that the removal of these facilities would do more than anything else to destroy the social organisation of a country.

The fact that HEMP damage had occurred would indicate to a country that there had been a nuclear attack. If the strategic nuclear potential of a country is vulnerable and unprotected, it could provoke the use of HEMP as a means to paralyse any retaliation, and deterrence as such becomes meaningless. The use of HEMP could escalate quickly into strategic nuclear war; or, even worse, a considerably degraded and interrupted strategic command and control system (C3) could lead to uncontrolled reactions escalating a so-called limited nuclear war into an all-out exchange.

At the moment it would be de-stabilising for the superpowers to ignore the threat of HEMP and not protect (or "harden") their nuclear arsenals and related C3 despite the cost. However any protection beyond the minimum required to achieve this would need to be carefully assessed as EMP protection can be very expensive.

Nations relatively uninvolved in a nuclear conflict

Uninvolved is meant to describe countries which are unlikely to be primary targets for nuclear weapons. Although New Zealand falls into this category, Australia and, to a much lesser extent, New Caledonia, may not. Likely targeting criteria are discussed in an unpublished paper by Bradley who believes that an EMP attack on the east coast of Australia is unlikely, the most economical targeting being a single warhead 300 km above a point 100 km south of the mid-point between North West Cape and Nurrungar, although he states that in Desmond Ball's opinion such a strike against Australia is unlikely. A scenario is postulated whereby US forces withdraw to Australian ports, provoking an EMP attack over either Sydney or the mid-Tasman Sea.

As a result, uninvolved countries like New Zealand could still suffer damage to their electrical and electronic infrastructure as a result of HEMP. This could include the following items:

- The power system at all levels (Electricity Corporation of New Zealand and Power Boards), including generating stations, the Cook Strait d.c. link and operating cables. The transmission system, although subject to insulator flashover due to overvoltage, should not be permanently disabled.

- The telephone (and thus telex and data) network in its entirety (Telecom Corporation of New Zealand and internal systems), although some manually or mechanically switched portions may survive.

- Broadcasting systems, including microwave systems and satellite links, which would be vulnerable at their terminals. Base-mobile radio systems connected to power and antennae would be extremely vulnerable. Amateur radio systems would probably largely survive and could be used extensively during the post-EMP phase if properly co-ordinated.

- Transport and other infrastructural communication systems, including railways signalling and the rail electrification system, air traffic control, police and civil defence.
- Infrastructural items using electronic controls or data processing such as hospitals, the banking system, water supply, sewage pumping and treatment, and building services including lifts.
- Industrial production, particularly the process industries including major resources such as the oil and gas fields, the refinery, and the synthetic gasoline plant.

Damage includes both permanent damage (e.g. burned out or destroyed electronic components and insulators) and functional impairment in systems operating at the time of an EMP (e.g. digital processing systems such as "Databank").

Protection from EMP

Protection is to prevent the damaging (or upsetting) impulses from reaching sensitive components of the equipment or system. This is easy in principle but expensive and difficult to implement and even more difficult to maintain.

There are two basic methods of protection. The first is to provide a metallic shield which will not allow the electromagnetic fields to penetrate (Fig. 7), and to provide protective devices on all wires or pipes leading through the shield. A new technique can now create enhanced insulation within silicon chip wafers themselves and could be used in conjunction with other methods.

The second is to design and build the equipment ("tailor made") so that special parts can resist the EMP, or the effect is circumvented by turning the equipment off when EMP is sensed. Often the most cost-effective protection is a combination of all of these methods.

With exposed networks, such as the power grid, shielding is impractical. It would be possible to use high-speed gapless surge arrestors to divert transmission line overvoltages from terminal equipment, but at a considerable cost owing to the long useful life of units already installed.

Disconnecting the system once an EMP is detected is impractical for technical reasons. One US study looked at the time for system operators to isolate vulnerable equipment by remote and manual switching when a 45 minute warning of an impending attack was available and found it would be possible to protect about 50% of the US system. The figure in New Zealand is likely to be even higher but it all hinges on the likelihood of pre-knowledge of an EMP attack, and whether the population would tolerate the disruption caused by such preventive measures.

Verification of the effectiveness of protection requires testing which is also complex and costly. Otherwise, inspection and theoretical analysis must be relied upon, with their inherent uncertainty. The cost of EMP protection is high: as much as the original equipment cost for retrofitting, or 10-30% for new systems.

Obviously to protect an entire telephone network would be prohibitive.

Where the cost of preventive protection is prohibitive, a secondary strategy can be adopted of minimising the possibility of damage and subsequent repair. To do this can involve changing operational procedures, so that networks are not always fully utilised, critical spares are stockpiled to replace items which will inevitably be damaged, and complete units (e.g. radio transmitters) are kept in screened stores. The cost of even these measures can be considerable and the first requirement is to consider the priority of various types of infrastructure before recommending any stockpiling policy.

OPTIMAL COURSE FOR NEW ZEALAND

Some preliminary conclusions on the likely effects and the possibilities for recovery based on a nuclear explosion more than 400km above the east coast of Australia are discussed below. Whilst not based on a detailed or theoretical analysis, the conclusions have been modified wherever possible after discussion with knowledgeable staff in the areas concerned.

Power generation transmission and distribution

The power system, including generating stations, could probably be restored to some operational capacity within days (e.g. 20% of hydro generation within 10 days) based on existing spares. However, thermal power stations, if their control and instrumentation systems were extensively damaged, could take 1-2 years to restore to full operation and in the worst case may be unable to be repaired at all. This would cause severe power shortages to the North Island, particularly Auckland.

The transmission system would probably survive relatively undamaged. The Cook Strait d.c. link terminal equipment would probably be badly damaged and only repairable after long delays, although sufficient spares are available. The d.c. undersea cables could also be damaged, although the spare cable means that 50% capacity would be available using earth return.

Associated communications damage would probably mean that operation of the power system as a "fully connected national grid" would be out of the question for weeks or months, making an adequate and secure supply to large-load centres such as Auckland, Christchurch, and particularly Wellington, unlikely.

Power distribution systems would first be largely dependent on the Electricorp system being brought back into operation before being themselves operational. Secondly, although urban cable networks may survive, systems involving aerial lines which include both rural and suburban areas could be out of commission for some months because of a shortage of both materials and labour.

Transport

Some transport and other infrastructural communications systems, including railways signalling, air traffic control, police and civil defence, could be restored, and military equipment could be used to some extent for these purposes since all modern military communications equipment which may have even the remotest chance of being used on a nuclear battlefield is routinely protected against EMP.

Rail signalling and traffic control might not be badly damaged, especially where fibre optic cables have been used. The system could, however, revert to manual types of operation if necessary, with the only cost being a substantial loss of efficiency.

The rail electrification system would also probably be severely damaged owing to control failure and possibly insulator flashovers, but would be a low priority for repair if diesel locomotives and diesel fuel were available.

Telecommunications

The telephone network would be largely out of action, principally because of damage to exchange equipment. Currently, 25% of telephone exchanges are electronic and this will rapidly increase to 50% within a year or so and 100% by the mid-1990s. Similarly, long-distance communications, most of which use solid state repeaters, would probably be severely damaged.

Progressive restoration of local circuits and overseas cable circuits could be expected over succeeding days and months, based on existing priorities established through civil defence. The present spares ratio is approximately 5% and this would be insufficient to repair all the prospectively damaged equipment. A return to an electromechanical system as in the 1930-50 period would not be a short-term solution but, depending on the overseas situation, could be feasible for rebuilding purposes. The technical capacity for this, however, is rapidly being lost.

Microwave links and satellite earth stations, particularly with electronics exposed on the dishes, would be vulnerable unless they had been specifically hardened. Fibre optic cables would survive, but not necessarily the associated electronics.

Communications could be maintained by the Amateur Radio Emergency Corps, since it has been estimated that some 60-70% of the 6000 amateur operators would still have functioning equipment. Their usefulness has been recently demonstrated during the Edgecumbe earthquake and other civil defence emergencies.

Television and Radio Broadcasting

Local broadcasting systems could be repaired by utilising standby equipment in the case of low-power replacement units (e.g. FM stations). Major transmitters, television and networking would take considerably longer to re-establish in even rudimentary form.

The BCNZ consider the re-establishment of the four major AM broadcasting stations (1YA, 2YA, 3YA and 4YA) a top priority since these cover most of the population of New Zealand. These all have standby generation facilities. Secondly, they would maintain their microwave links presently used for TV but which could provide alternative voice and data circuits to NZPO circuits.

The re-establishment of FM radio and television services, including networking, would be unlikely "for some considerable time". Present holdings of spares would be sufficient for 2-5 years' operation at normal maintenance levels, but cannibalisation would have to be resorted to if major EMP damage was suffered.

Other infrastructure

Those infrastructural items using electronic controls or data processing such as hospitals, the banking system, water supply, sewage pumping and treatment, and building services, including lifts, would be out of action for various times.

Particularly important is the standby generation facilities for hospitals. Most hospitals, apart from those in major cities such as Wellington which generate a substantial part of their own power, would have extremely limited facilities since the standby generators are usually only sufficient for essential services and would not extend to catering and other large uses. Spares holdings for generators should be enhanced to ensure that damaged controls can be replaced if necessary, although adequate protection may already be provided for generators installed within reinforced concrete buildings.

Another important area is data processing and computers. The use of computers is now deeply embedded in New Zealand society. EMP would cause the loss of all computer networking capability, some loss of stored data not on optical disks and major equipment damage. This would be coupled with the problem of lack of electric power. Restoration of local computing on a limited basis could take 1-6 months and networking up to 3 years.

Industry

Industrial production in the absence of power would cease temporarily, with in some cases long and expensive shutdowns of 3-12 months. The immediate problems would be lack of fuel and energy but over the first 6-month period, with no industrial production, all stocks would become totally depleted.

The synthetic fuel plant at Motunui would suffer major repercussions from an unanticipated shutdown, and, depending on the world situation, might never run again. Similarly, steel, aluminium and refinery plants subject to unplanned shutdowns would take many months to resume even partial production, and might not in fact be economic or feasible to repair. The freezing industry would lose its storage facilities, with consequent waste and disposal problems.

The exact nature of the long-term consequences would depend on the situation in the outside world following an EMP attack. However in the immediate short term (0-6 months), it can be predicted that there would be severe disruption to our way of life. Systems when restored would function at reduced levels, and in general we would return to a way of life more akin to the 1950s.

CONCLUSIONS AND RECOMMENDATIONS

There are likely to be severe disruptions to our way of life if a nuclear conflict occured, even if New Zealand was not a primary target. An EMP from a high-altitude explosion over Australia or the Tasman Sea would affect our infrastructure in such a way as to take at the least some days to restore minimal services and months or years to restore completely, depending on our spares stocks and the continued availability of future spares.

If a nuclear winter phenomenon occured simultaneously, the possibility is that there would be a significant number of casualties as a result of the lack of services, shortage of power and perishable food.

The only solution, apart from the obvious and most important one of aiding and initiating efforts to prevent nuclear war occurring, appears to be to decide on a system of priorities for different classes of infrastructure items. It would then be possible to recommend the establishment of policies for judicious spares holdings based on cost-benefit approach. These spares would be a part of the normal maintenance inventory, but would in many cases be merely an enhancement, after audit of normal spares holdings. They would need to be kept in secure and EMP-proof storage. Organisations most at risk would be those which rely on spares being supplied from manufacturers or agents.

There is obviously a limit to the amount of resources that can be allocated to the relatively remote possibility of such an event occurring. However, as with all risk analysis, the consequences of such an event, however unlikely, need to be balanced against the costs.

Most of our infrastructure (such as the BCNZ system) is acknowledged as having been designed without regard to EMP, and, at the very least, requires a cursory examination by staff of likely vulnerabilities. This information can then be applied to a spares and maintenance audit. This process has to some extent already been initiated by this New Zealand impacts study, which ideally should provide some directions for future research and effort.

SELECTED REFERENCES & FURTHER READING

(Note: only reasonably readily obtainable material has been included)

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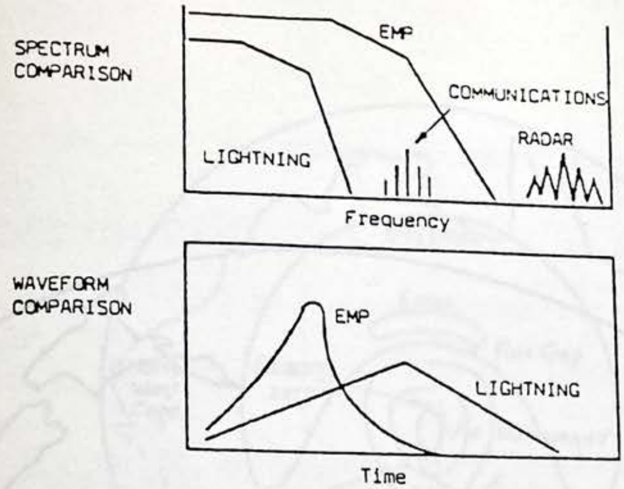

Fig. 1: EMP Characteristics compared with other radiation
(From Lippert: "The Hidden Destroyer")

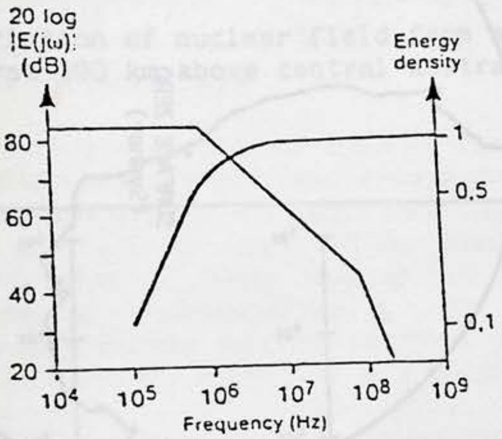

Fig 2: Spectrum of the electrical field and corresponding normalised energy density of HEMP showing high power at high frequencies. (From Wik: "Hardening of Telecommunication Networks Against EMP")

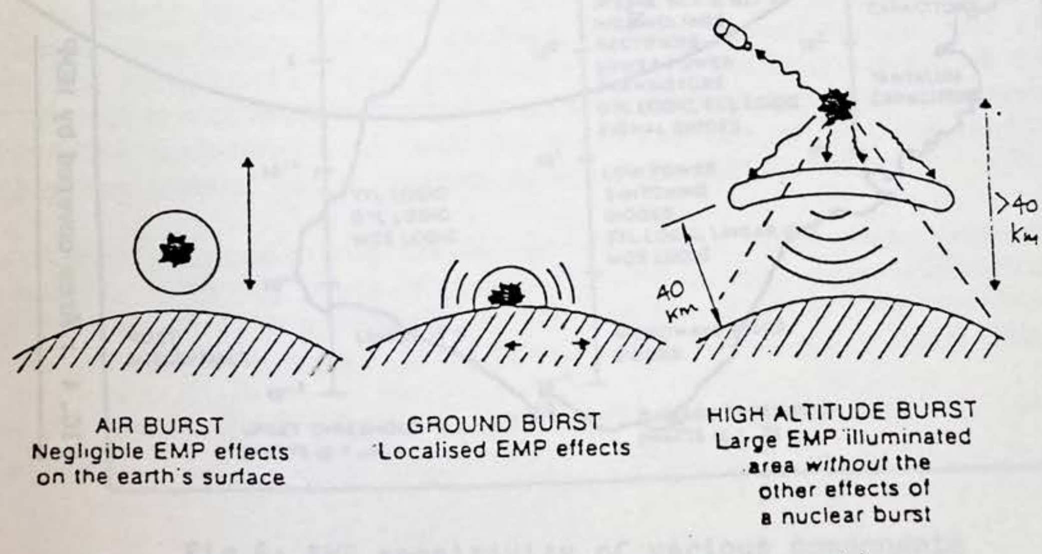

Fig 3: EMP related to height of burst (From Lippert)

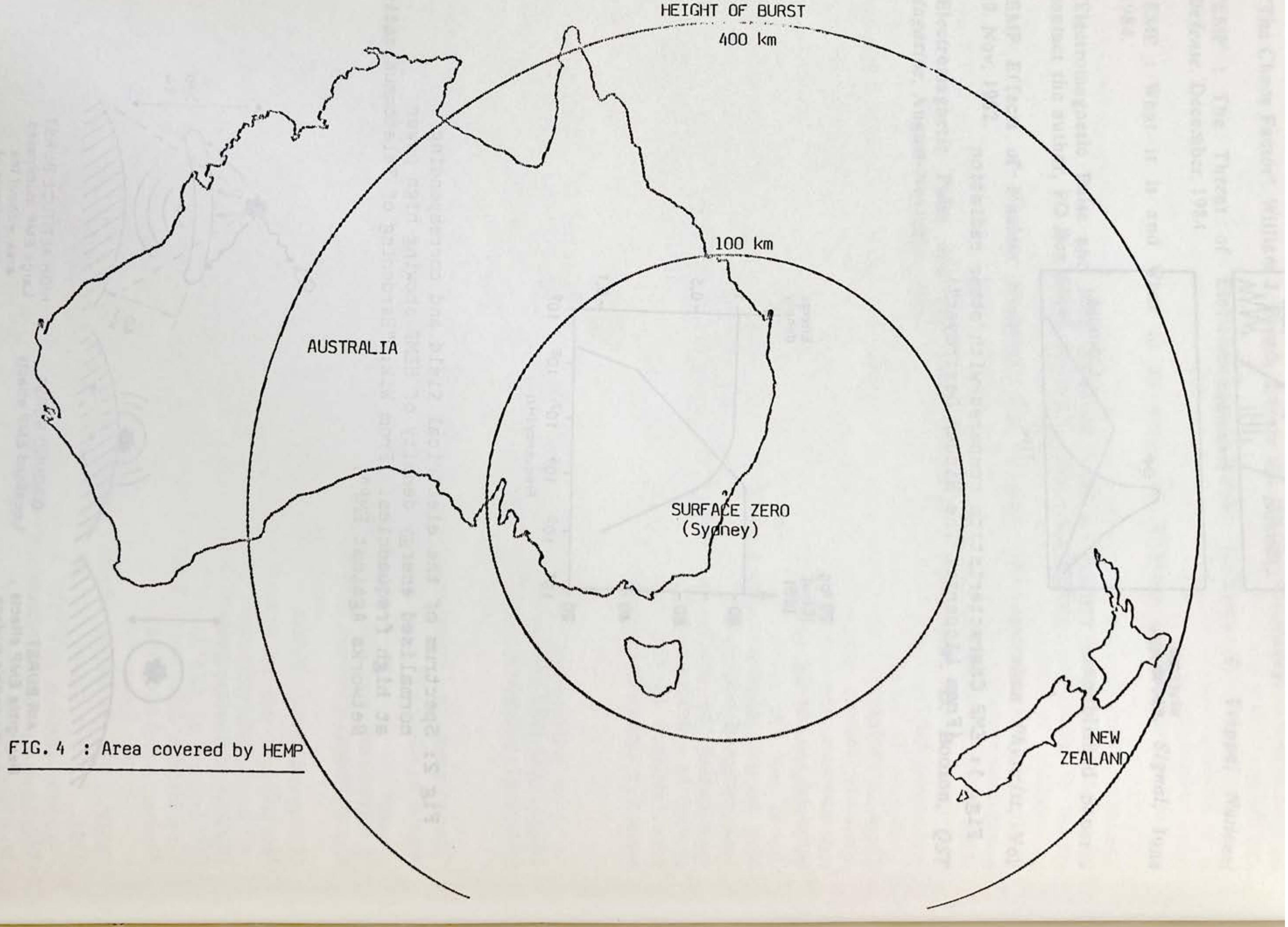

FIG. 4 : Area covered by HEMP

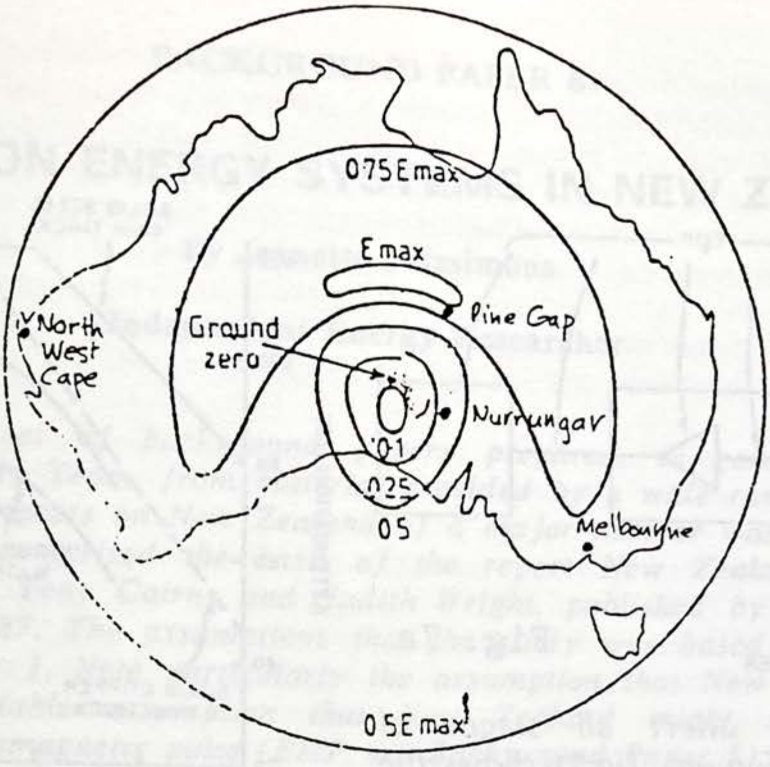

Fig 5: Variation of nuclear field from a nuclear burst 300 km above central Australia (From Hutton/Bradley)

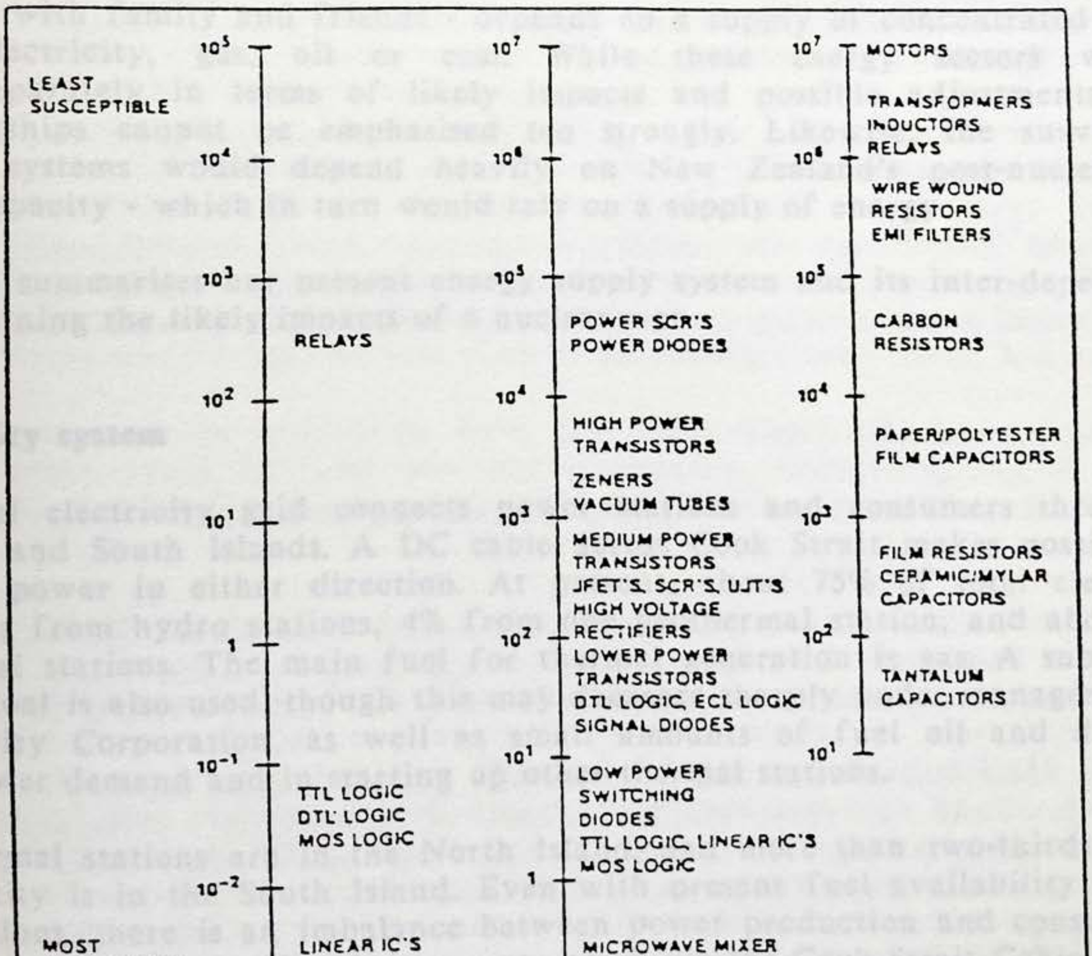

Fig 6: EMP sensitivity of various components

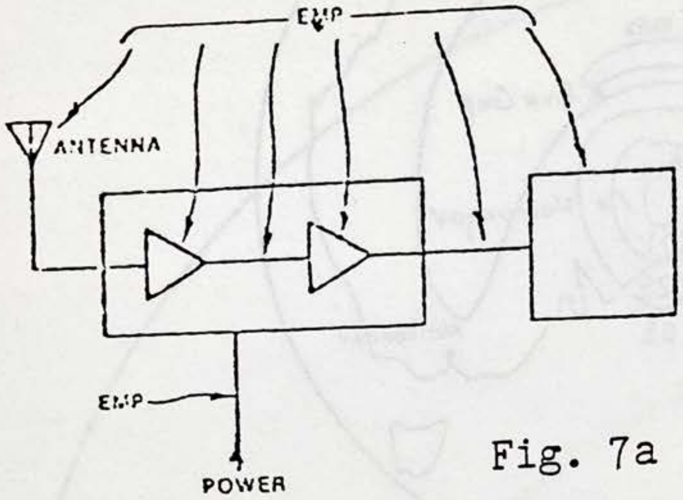

Fig. 7a

Pulses would affect all stages of electronic equipment. Fig 7b shows the effectiveness of various shielding materials.

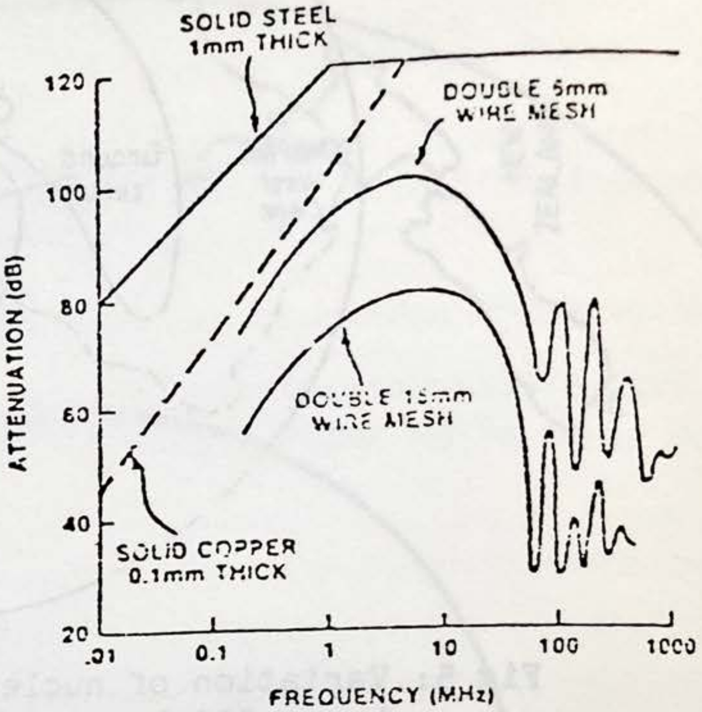

Fig.7b