The Threat to Airborne Systems From High Power Microwave, Direct Energy Weapons

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Abstract

The Threat to Airborne Systems From High Power Microwave (HPM) Direct Energy Weapons.

Microwave weapons concepts originated early in WWII, when British radar engineers came up with the idea of a “super interferometer” which would produce microwaves capable of destroying enemy electronics.

Further high power microwave and pulse power generation research grew out of investigations of nuclear electromagnetic pulses (EMP’s) during the 1940’s through the 1960’s.

The years following WWII saw exponential growth in the use of electronic systems such as GPS, Phased Array Antennas, Infra Red Sensors etc. As the technology developed, equipment became more powerful, sophisticated and smaller.

It is clear therefore, that military systems have long exploited the electromagnetic frequency spectrum. The down side to this is that the modern battlefield and airspace has become a target rich environment with a greater dependence being placed on electronic sub-systems. It is these systems that are potential targets for direct energy weapons in the form of High Power Microwaves.

Today, HPM weapons for both defence and attack have been deployed and used successfully in a number of theatres of conflict.

This paper attempts to highlight the effect of these weapons on airborne equipment and sensor systems.

Introduction

Direct Energy Weapons (DEW) typically fall into one of three classes; lasers, radio frequency (RF) and energetic particle beams. In this paper we will discuss mainly the RF or High Power Microwave (HPM) and their affects on airborne systems.

Early affects of HPM were recorded during the testing of the Trinity event at what is now the White Sands Missile Range, NM. Apart from the obvious blast and thermal effects of the weapon, the most far reaching (with the exception of radioactive fallout) of the effects of the nuclear detonation was the electromagnetic pulse (EMP). Depending on the height and yield of the detonation, a continental sized area could be bathed in EMP. Due to the sensitivity of modern electronics the effect of the pulse would deny, disrupt, damage or destroy the components, sub-systems or render complete systems unusable by its effects.

A less well known effect of a high altitude burst was one of "pumping" of the Van Allen belts with a large number of electrons for periods of greater than a year. Any un-hardened satellites traversing these belts in low earth orbit would experience the demise of certain electronic sub systems in a matter of days or weeks.

It is not surprising therefore that various military establishments and countries are actively developing their own HPM technology and systems. In recent years, circa. 1980 to the present day HPM research has covered the frequencies $1x10^{6}$Hz to$1x10^{11}$Hz and above.

It should be noted that electronic countermeasures (ECM), while operating in a similar manner to HPM do not come under the umbrella of microwave weapons. ECM requires that the equipment being "jammed" is actually operating. Also the effect of the jammer is non permanent. The removal of the ECM source allows the targeted asset to operate as normal. There are also many methods to counter the ECM threat through Electronic Counter Counter Measures (ECCM).

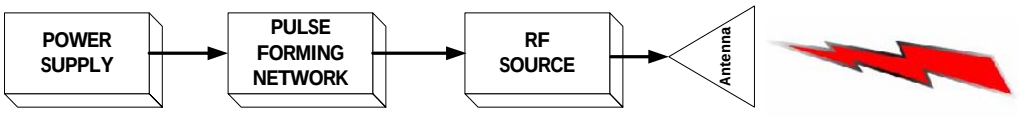
The HPM weapon by comparison does not require the targeted asset to be operating; no specific operating knowledge i.e. frequency of the asset is required and the HPM device will affect the asset even if it is not powered up.

W.L. Gore & Associates, the manufacturer of GORE-TEX® have been developing unique products and solutions to counter the threat posed by these devices. Systems have been developed to shield against the effects of HPM, reduce the radar cross signature of equipment and in some cases a combination of the two.

Finally, the challenge for the system platform designer is how to integrate all the platform sub-systems into a system that is hardened against the HPM threat.

High Power Microwave Technology

If the sole source of EMP energy were from nuclear detonation then there would be a number of other “issues” that would need to be addressed not just the effect on airborne systems. However, many components that make up a HPM device are available as commercial off the shelf parts and with minimal engineering knowledge can be assembled into an effective HPM generator.



The schematic above shows the main components that are required to assemble a rudimentary HPM source. When operated, the resulting power levels are in the region of 2.0 gigawatts. At this power level, permanent damage is observed to a GPS system, personal computer motherboard and various sensors during testing and at considerable range.

What is important when considering the HPM threat, is whether the HPM energy is in band, out of band or broad band.

In Band: Electromagnetic energy that operates in the same frequency band that the target sends, receives and processes. For example to disrupt a C band radar the RF/HPM source would be tuned between 5GHz to 6GHz.

Out of Band: Electromagnetic energy that operates outside the frequency band that the target sends, receives and processes. In this case the HPM threat may operate at a frequency a number of octaves higher or lower than the system being attacked.

Broadband: Electromagnetic energy that is transmitted over a number of frequencies utilising a very short pulse width. This method may be chosen if the target system is not known or a number of targets are being covered. By frequency “hopping” the probability of covering the resonant frequency of the target system is increased. The down side to this approach is the requirement for much higher power levels to achieve the required level of disruption or kill.

It may be desirable to have the HPM system operate in one or more of the aforementioned methods depending on the system being attacked or chosen attack method.

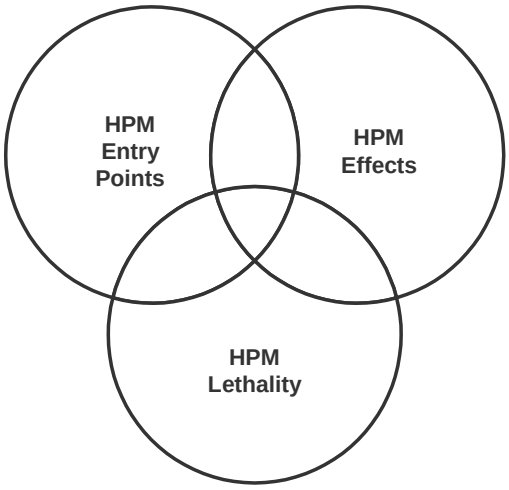
The current difficulty with HPM weapons is establishing the level of effect or probability of kill. The probability of kill is dependent on the platform being attacked, the range from the HPM source and a number of other factors. What is certain is that the continuing miniaturisation of electronic components makes them more susceptible to the HPM threat.

The High Power Microwave Attack

HPM weapons are significantly different in their effect when compared to conventional kinetic energy weapons. A HPM kill may not result in the destruction of the platform being attacked. For example a HPM kill of a fighter aircraft's altimeter can result in the IBIT (internal self test) not functioning correctly and reporting a radar/altimeter failure. In this case the aircraft would be grounded for the duration of the failure investigation and repair.

There are three main areas that must be considered when assessing the threat from HPM attack

HPM Entry Points



There are a number of ways through which HPM energy can gain access to a system. The easiest and most direct is through the **"front door"**. By this we mean any opening in the system that is designed to allow the transmission or reception of energy. For example ground mapping & terrain following radar, IFF, FLIR, GPS antennae.

The other method of HPM entry is via the **"back door"**. In this situation the HPM energy would travel along the skin of the airframe as a surface wave until it meets a seam or other opening. When the current crosses a seam in the barrier (airframe maintenance cover etc.) a voltage is created across the seam, where the value of the voltage is equal to the current times the impedance of the seam. The seam then becomes a radiating antenna where the impedance and pattern is similar to that of a slot antenna.

HPM Effects

HPM energy can couple with platform sub-systems and system components and in most cases visible damage cannot be seen. The coupling of the HPM energy can mean that a number of components can be affected as the energy affects systems from the inside out. Testing carried out on a GPS system after exposure to HPM energy reported that the GPS antenna was functioning correctly however no signal was being received. The GPS self test reported that the antenna was operating correctly. Upon further investigation it was discovered that bandpasses were functioning correctly and all resistors and capacitors were working properly; however, amplifiers had been destroyed. This was the result of an HPM attack with anexternal field strength of 1kV/m.

HPM Lethality

Modern electronic systems, in particular integrated circuits, are highly susceptible to damage from HPM weapons. The 4D's describe the levels of lethality:

1. *Deny*, this involves electronic upset or jamming. This might cause malfunctions within relay and processing circuits.
2. *Degrade*, this involves locking up a system or limiting its capabilities enough to require the system to be re-booted. It may require the system to be turned off and on which may be a lengthy process relative to the function of the system being re-set .
3. *Damage*, this can be a permanent effect that "latch up" a system. Permanent damage to components can mean weeks of diagnostics and repairs. Due to the entry method of HPM weapons it is likely that a number of components will be affected.
4. *Destroy,* this is the ultimate HPM kill, requiring complete replacement of the sub-system and long term grounding of aircraft.

HPM Weapon Deployment

The HPM energy will travel at close to the speed of light from its source and unlike other forms of weaponry is not affected by weather. Further the range of the weapon is only limited by the available power.

It is possible to build an effective close quarter's HPM device that will fit within a hand held briefcase. Placing this device close sensitive equipment can result in the effects described previously highlighted.

Scaling this up to the cargo space of a small van or larger truck would realise a very high power weapon. If this device were to be located near an airfield or other target rich area, one can appreciate the damage and cost associated with such an attack.

Of course a HPM attack is not only restricted to surface to surface. It has been reported that during operations in the Balkans, Afghanistan and most recently Operation Iraqi Freedom/TELIC, HPM devices were deployed. It is suggested that these devices in the form of air detonated precision guided munitions were used to deliver high power microwaves with field strengths of many thousands of volts over an area of approximately half a kilometre in diameter. The nett effect of this was disruption to military command and control systems and also civilian television and radio.

A measure of the interest in HPM technology can be gained from the number of countries including UK, USA, Russia, Sweden, Germany and France that are actively involved in HPM research.

HPM Countermeasures

All systems that use electronic components are targets for HPM weapons. As such these systems and weapons platforms must be protected through shielding and hardening. Most sub-systems take into consideration the effects of electromagnetic interference at the design stage. However, standard EMI tests can not replace dedicated HPM tests. The difficulty arises when one considers that most defence agencies are reluctant to release a complete high value airframe for HPM testing.

At the time of writing the only complete airframe that has been subjected to HPM testing is the F-16 and its associated LANTIRN navigation and targeting pod.

A further impediment to testing HPM is the relative lack of test facilities. Most knowledge and test tools have been developed based on conventional kinetic energy weapons and through trial and error. These test methods do not reflect the effects of HPM. The issue is further compounded when testing moves from the relative safety of the laboratory to in-flight testing. Here consideration must be given to the effect of the HPM energy encroaching upon the outside community. This can happen through direct contact with the HPM energy or through tropospheric ducting of the RF energy in areas remote from the actual test.

Conclusions

High power microwaves travel at the speed of light, are not affected by weather, require only course pointing and can render targeted electronics useless in a fraction of a second. Effects on the electronics range from disruption to destruction depending on the susceptibility of the targeted system to the effects of HPM and its delivery system parameters.

Currently there are very few complete airborne systems that have been tested for the effects of HPM weapons. The ease of detection of an attack can take a considerable amount of time and resource to locate and rectify, during which the system will be out of commission.

Since the end of the second world war military technology has progressed at an extremely rapid rate. The development and deployment of direct energy weapons in the form of high power microwave devices are an area that the system designer should consider as an active threat. It is also an area that should be considered at the earliest stages of the design process for new systems and during the upgrade of existing platforms.