The Electromagnetic Cause of Shell Shock

Frank H. Makinson *IEEE Member*

Abstract—The pathology of shell shock, contemporaneously grouped with post-traumatic stress disorder, has been identified by researchers. The brain injury occurs primarily in the frontal lobes and has a "distinctive honeycomb pattern of broken and swollen nerve fibers." The characteristics of the head protection used by soldiers can explain why the particular shell shock brain injury has an inordinate prevalence today, but without the massive artillery barrages. Every munitions explosion emits a broadband pulse of electromagnetic energy. The basis of the mechanism that produces the broadband EMP is introduced. Kevlar helmets provide no protection from an electromagnetic pulse.

Introduction

"The mystery of shellshock solved: Scientists identify the unique brain injury caused by war."[1] The description of the brain injury in the article is provided in one paragraph, "*Described as a 'distinctive honeycomb pattern of broken and swollen nerve fibres', the injuries were not the same as those found in car crash and drug overdose victims, or sufferers of punch-drunk syndrome, which is caused by repeated blows to the head.*" Another article stated, "*Scientists have discovered what a traumatic brain injury, or TBI, suffered by a quarter-million combat veterans of Iraq and Afghanistan looks like, and it's unlike anything they've seen before: a honeycomb pattern of broken connections, primarily in the frontal lobes, our emotional control center and the seat of our personality.*"[2]

Both articles were summarizing a Jan. 2015 news release from John Hopkins School of Medicine (JHM).[3] That news releases are a summarization of an article published in Acta Neuropathologica Communications in Nov. 2014.[4] The introduction of the article stated, "*Blast injury to brain, a hundred-year old problem with poorly characterized neuropathology, has resurfaced as health concern in recent deployments in Iraq and Afghanistan.*" The researchers identified the pathological characteristics of the brain damage, but did not speculate on the specific mechanism that caused the unique damage.

In World War I (WWI), the massive artillery barrages exposed soldiers to nearby munitions explosions and many of those that survived the blast damage, with no obvious cranial injuries, displayed erratic emotional behavior. The term *shell shock* was coined to describe the outward characteristics. The term *shell shock* was not used in World War II (WWII) and the Korean War; the terminology was changed to *combat* or *battle fatigue*. Vietnam veterans, and those thereafter, exhibiting the same behavior as those suffering from *shell shock* were classified as having *post-traumatic stress disorder* (PTSD). The *thousand yard stare*, one outward symptom of shell shock, was evident during WWII.[5]

The first report using the term *shell shock* was in 1916. The term *faradisation* was coined during WWI as a treatment for shell shock.[6] *Faradisation* was used to successfully treat some *shell shock* victims that had erratic physical gaits and other erratic motions that were referred to as *tics*. The term *shell shock* was banned in the UK after WWI. A good summary of the history of *shell shock*, and why the term was banned, is provided in the article titled, "Traumatic Brain Injury, Shell Shock, and Posttraumatic Stress Disorder in the Military-Past, Present and Future."[7]

Cranial Protection

When warfare began to be fought with bullets, the metal head and body protection used for protection from swords, lances, arrows and other weapons was deemed an impediment, as it didn't stop bullets. In WW1, the use of artillery produced an inordinate amount of head injuries from shrapnel. The French developed the M15 Adrian helmet in 1915, the British developed the Brodie helmet and the similar design M-1917 was issued to U.S. Troops. These helmets covered the top cranial area and the flared rim did not extend below the top of the ear lobe and much of the forehead was exposed. The Germans developed and issued the Stahlhelm in 1916 for the same reason, an inordinate number of head injuries. Each of the helmets differed in their steel composition, some being more penetration resistant. The steel U.S. M1 helmet was adopted in 1941, and it covered a larger percentage of the cranial area in the front, and the sides extended downward about halfway over the ear. The non-steel Kevlar helmet was adopted by the U.S. in the mid-1980s. The Kevlar has superior ballistic performance over steel and its size protects a greater percentage of the cranial area.

A high intensity broadband EMP will not readily penetrate steel, but the Kevlar helmet will provide essentially no protection from an EMP that has wavelengths that can cause serious internal tissue damage.

Electromagnetic Radiation From Chemical Explosions

"*The emission of electromagnetic radiation from a chemical explosion is well established.*"[8] That quote is from a LANL report, but many may conclude that the bright flash and heat felt are the extent of the EM radiation. The range of frequencies being produced by an explosion are very broad. The LANL report summarized reports from 1954 to 1993 and the summary of the **spectrum** section stated, "Quoted frequency ranges vary from 1 Hz to an excess of 100 MHz. Possibly the spectrum shifts to lower frequencies with increasing mass. Theoretically, the spectrum should broaden to higher frequencies as the detonation time is shortened."

The Journal of Radioelectronics (JRE) is a Russian Academy of Sciences report. A JRE report summarized research on the EM emissions from explosives, 1940 up to 1999.[9] The JRE report did not summarize the spectrum identified, but the measured frequencies noted in the report ranged from 14 MHz up to 100 GHz. The reported frequencies became higher and higher as measurement equipment became available that could detect these frequencies. The JRE report was focused on microwave frequencies and referred to a specific reference for lower frequencies. In regards to the microwave radiation, the JRE report provided this statement, "*The intensity of this radiation much surpasses intensity of thermal radiation.*" The report also stated, "*The larger the explosion the higher EMP intensity.*" High intensity microwave frequencies can cause tissue damage.

The LANL and JRE reports were not considering human exposure, thus they did not consider the attenuation and frequency lowering effect when an EM wave passes through a material that has an index of refraction greater than one. The human skull and body tissue will have an index of refraction greater than one.

The scaling for the damaged areas in the brain shown in ref. (4) provides sizes from 100 to 10 μm, which would correspond to wavelengths of frequencies from 3,000 GHz to 30,000 GHz. The infrared spectrum extends from 300 GHz to 430 THz. The frequencies in the EMP being produced by a chemical explosion have a range of wavelengths that will allow efficient EM energy transfer to many conducting structures in the human body.

"*In the brief instant of a high-explosive detonation, some remarkable events take place: the shock wave produces pressure up to 500,000 times that of Earth's atmosphere, the detonation wave travels as fast as 10 kilometers per second, temperatures can soar to 5,500 kelvins, and power approaches 20 billion watts per square centimeter.*"[10] That statement is from a 1999 Lawrence Livermore National Laboratories (LLNL) internet page. Because there is so much power produced, it is important that the EM intensities are quantified in the various EM spectrum ranges for different types of explosives, including the Improvised Explosive Device (IED).

Available literature does not identify the mechanism that produces the broadband EM pulse, but the basis of the process is readily identified by how EM waves interact in a plasma, a nonlinear medium.

Synergistic Heterodyne Process

Everything that is taught about the heterodyne process is where two colinear EM waves with the same polarity and different frequencies interact within a plasma of electrons. The mathematics are simple for colinear waves. When the two interacting EM waves are not colinear, which can be combinations of different polarities and angles of incidence, the heterodyne products will have more complex characteristics. As the angle of incidence increases the resulting heterodyne products will become segments of the two original signals with a pulse repetition rate based upon the original mixing signals frequencies.

An EM wave consists of two interrelated components, an electric field and a magnetic field. The plasma of an explosion consists of electrons and ions. Electrons have an electric field with a negative charge and have a magnetic moment. Ions can have a positive or negative charge and have a magnetic moment. The available literature does not explain how EM waves interact with the electric and magnetic fields of electrons and ions in a plasma to produce heterodyne products.

The rapidly expanding gas plume of a chemical explosion, a plasma, has an abundance of electrons and ions in motion. The rapid acceleration and deceleration of electrons and ions produce EM waves that propagate in all directions. The propagating waves within the plasma will interact synergistically to produce more and more *heterodynes*. This three dimensional interaction will produce a broadband spectrum of discernible EM emissions accompanied by what appears as noise, the finely chopped up segments. With 20 billion watts of power being distributed by large chemical explosions, some of this power will be in EM spectrum segments that can induce heating in conductive cellular structures in a millisecond time frame.

Electromagnetic Spectrum and Human Exposure

We are constantly exposed to a broad spectrum of EM radiation from planetary, solar system, galactic and cosmic sources. The EM spectrum covers frequencies from very low to very high frequencies that extend well above the optical spectral range. With the advent of man-made EM sources, we are now exposed to many local EM sources and the effects these have on the human body are not fully understood.[11]

Our human sensory systems can directly detect the presence of EM radiation in the optical range and the invisible infrared and ultraviolet frequencies when they produce secondary effects, which are surface heating and sunburn. The effects of long term cranial exposure to various levels of EM emissions are being studied, but none of the studies involve very high magnitude EM sources, as it is already known these can cause severe internal cellular damage by heating.

When an EM wave has a wavelength that is matched to the size of a conducting structure, the energy of the wave can be efficiently transferred. Just a close match between the wavelength and the conducting structure size can transfer some power. A human body contains many different sizes of conducting structures.

The present U.S. concern about cell phones involve two frequency, 850 MHz and 1900 MHz. Cell phones produce a very lower power level, but it is the close proximity of the EM radiation to body tissue that creates concern. Most artificially produced EM radiation decays with distance by $1/r^2$, but EM waves in the *near field* come into play when within two wavelengths of an EM source. *Near field* issues can involve EM field components that do not decay with distance by $1/r^2$. With cell phones, users not using the speakerphone or headphone feature will always be in the *near field*. The low power levels of cell phones can damage mammalian brain tissue.[12] Those familiar with the damage shown in ref. (12) can determine whether it is similar to the *honeycomb* damage shown in ref. (4).

The acronym EMF, seen in some reports, refers to *electric and magnetic fields*, and is used in the guidelines that limit human exposure to these fields; the *specific absorption rate* (SAR) regulations.[13] The SAR regulations are focused on limiting EM power levels to avoid *tissue heating*. The SAR regulations are assuming the EM fields are decaying by $1/r^2$. EM energy can come in non-ionizing and ionizing form. The ionizing form is that produced from sources that produce extremely high frequency EM radiation, such as gamma and x rays. If the magnitude of EM radiation is high enough, even though it is does not have the high frequency of an ionizing emission, it can produce major damage to conducting body structures. Microwave ovens use a frequency of 2450 MHz or 2.450 GHz. That frequency causes a resonance in the water molecule to produce heating.

The JRE report noted frequencies that would cover the 2.450 GHz frequency. A question that can be asked is, "What EM intensity would be required to raise the temperature of the fluids in the brain axonal structures to a level that would produce the damage shown in the ref (4) report?" Water can be heated at the 2.450 GHz frequency, but a conducting structure in the brain that matches a particular EM wavelength could absorb power very efficiently and cause heating at lower power levels.

The JRE report emphasized the electron contribution to producing EM waves at microwave frequencies. "At higher frequencies the microwave radiation itself was found out, when the field decreases in inverse proportion to distance ($\sim R^{-1}$)." This is significant, as it states the EM radiation does not have spherical decay, $1/r^2$, which is what would occur if the EM radiation polarization was transverse to the axis of propagation. The SAR regulations are based upon exposures to EM radiation that decays with distance by $1/r^2$ rather than $1/r$. Ions and electrons are major products of the explosion. Nothing was mentioned in the LANL, JRE or LLNL reports on ion contribution to the EMP.

It cannot be excluded that nerve cell structures in other parts of the body are being damaged by an EMP where current non-invasive medical technology can not find any direct physical trauma evidence. This could be related to OEF/OIF veterans' experiences with chronic pain.[14] The erratic physical motions of WWI shell shock victims suggests other nerve structures in the human body were damaged.[15] Examples of patients receiving *faradisation* are contained in ref. (15).

Soldiers that are *breachers* and law enforcement SWAT teams that use *flash-bang* devices are exposed to repeated exposure to low-level blasts (LLB).[16] There are on-going studies of the cognitive functions of individuals involved as breachers.[17] Cognitive impairments have been identified in a New Zealand study of breachers.[18] The action being taken to mitigate the effects of LLB are focused on reducing exposure to the concussion effect of an explosion. Getting further away from the LLB will reduce the concussion and EMP exposure, but that lengthens the time to take advantage of the purpose of the LLB. The EM spectral characteristics of various LLB devices are not known.

Summary

There is physical evidence that low power level EM waves can produce damage in a mammalian brain. From an electrical engineers perspective, the type of damage observed in the JHM study suggests that human brains are being damaged by a very high frequency component of the EMP produced by a chemical explosion. The distance between the peaks of the wave should match the spread of the honeycomb pattern.

A chemical explosion produces an EMP with frequencies that range from 1 Hz to the optical frequencies. With a quarter million TBI victims, and counting, it is imperative that the EM signatures and spectral intensities of the EMP produced by various munitions explosions be fully identified, regardless of the technical difficulty. This should include gamma and x-ray detectors. This information will identify the needed EMP protection

Military ballistic protection head gear should provide protection from the EMP produced by nearby munition explosions. Breachers and SWAT team members should have breacher shields and head protection that protect them from the EMP of their low level explosives.

It is apparent that nerve structures in other parts of the human brain and body are being damaged by the EMP produced by a chemical explosion.

The term h*eterodyne* was not seen in any of the reports referenced or reviewed concerning the Em emissions created by chemical explosions. The three dimensional interaction of EM waves in a plasma are synergistically producing heterodyne products.

The basic method of producing a man-made propagating EM wave has an unanswered question, "Does the magnetic moment of electrons and ions influence the polarity of propagating EM waves?"

References

[1]www.independent.co.uk/news/the-mystery-of-shellshock-solved-scientists-identify-the-unique-brain-injurycaused-by-war-9981443.htm
[2] Amy Ellis Nutt, "Wounds of war that never heal", Washington Post, Health and Science, Jan 19, 2015 Available: http://www.washingtonpost.com/national/health-science/wounds-of-war-that-never-heal/2015/01/16/a1fbeb84-9cd3-11e4-bcfb-059ec7a93ddc_story.html
[3] Johns Hopkins Medicine "Combat Veterans' Brains Reveal Hidden Damage from IED Blasts" Jan 14, 2015 Available: http://www.hopkinsmedicine.org/news/media/releases/combat_veterans_brains_reveal_hidden_damage_from_ied_blasts
[4] Koliatsos, V., et.al. "The problem of axonal injury in the brains of veterans with histories of blast exposure" Acta Neuropathologica Communications 2014, 2:153 (25 November 2014) http://www.actaneurocomms.org/content/pdf/s40478-014-0153-3.pdf and http://www.actaneurocomms.org/content/epub/s40478-014-0153-3.epub
[5] Tom Lea "Thousand Yard Stare" https://www.nps.gov/pwro/piso/peleliu/lea2.htm
[6] Faradization "Medical Dictionary, © 2009 Farlex and Partners" http://medical-dictionary.thefreedictionary.com/faradization
[7] Shively, S..; Perl, D., "Traumatic Brain Injury, Shell Shock, and Posttraumatic Stress Disorder in the Military—Past, Present, and Future" Journal of Head Trauma Rehabilitation. 27(3):234-239, May/June 2012. http://journals.lww.com/headtraumarehab/Fulltext/2012/05000/Traumatic_Brain_Injury,_Shell_Shock,_and.10.aspx PDF and EPUB versions are available free from the URL cited.
[8] Kelly, B. "EMP From Chemical Explosions" Los Alamos National Laboratory, Group P-14, March 1993 http://library.lanl.gov/cgi-bin/getfile?00205425.pdf
[9] Cherepenin, V.A., Shumilin, V.P., "Mechanism of Wideband Microwave Radiation at Explosion of

Condensed High Explosives" Journal of Radioelectronics N 1, 1998 http://jre.cplire.ru/koi/dec98/3/text.html
[10] Lawrence Livermore National Laboratory "High-Explosives Detonation Research" https://str.llnl.gov/str/Simpson99.html
[11] Nittby, H., et.al.,"Radiofrequency and Extremely Low-Frequency Electromagnetic Field Effects on the Blood-Brain Barrier" Electromagnetic Biology and Medicine, 2008, 27:2, 103 — 126 DOI:10.1080/15368370802061995 http://weepinitiative.org/LINKEDDOCS/health/nittby.PDF
[12] Nittby, H. et.al., "Increased blood–brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone", Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.001 http://www.pathophysiologyjournal.com/article/S0928-4680%2809%2900013-3/pdf
[13] FCC, "Radio Frequency Safety" http://www.fcc.gov/encyclopedia/radio-frequency-safety
[14] Matthias, M.S., et.al., "A qualitative Study of Chronic Pain in Operation Enduring Freedom/Operation Iraqi Freedom Veterans: 'A Burden on my Soul'", Military Medicine, 179,1:26, 2014 http://publications.amsus.org/doi/pdf/10.7205/MILMED-D-13-00196
[15] Dr. Alan Brown "Shell Shock in WWI" https://www.youtube.com/watch?v=faM42KMeB5Q
[16] Baker, A. ,et.al., "Controlled blast exposure during forced explosive entry training and mild traumatic brain injury", J Trauma. 2011 Nov;71(5 Suppl 1):S472-7. doi: 10.1097/TA.0b013e318232e7da. Abstract: http://www.ncbi.nlm.nih.gov/pubmed/22072006
[17] U.S. Army "Low-level blasts possible TBI Link" Feb. 12, 2015 http://www.army.mil/article/142760/Low_level_blasts_possible_TBI_link/
[18] Tate CM1, et.al., "Serum brain biomarker level, neurocognitive performance, and self-reported symptom changes in soldiers repeatedly exposed to low-level blast: a breacher pilot study." J Neurotrauma. 2013 Oct 1;30(19):1620-30. doi: 10.1089/neu.2012.2683. Epub 2013 Aug 29. Abstract: http://www.ncbi.nlm.nih.gov/pubmed/23687938