MICROWAVE & RF RADIATION:

(RFR Information - Technology Newsletter, *Full Version*)

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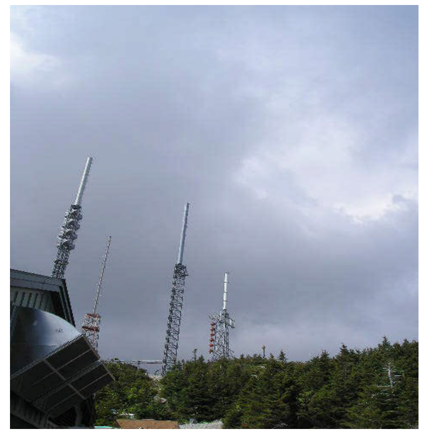

Questions:

-What is Microwave & Radiofrequency, (RF), Radiation?
-What are its Characteristics?
-Is Industrial Microwave Technology Effectively Applied Currently?

…Through the paragraphs that follow, the reader will emerge more familiarized with some of the fascinating elements of this otherwise mysterious phenomenon.

-Overview:

For very quick reference, the first section of this Newsletter is a brief, qualitative description of Radiofrequency Radiation, (RFR), as well as a "to-the-point" overview of its risks and effects, as understood currently. For interested readers, I've written a much more in-depth explanation of exactly what Electromagnetic Radiation is, and how the radio and microwaves interact with human tissue.

-Background:

Cell Phone Towers, Radio and TV Broadcast Transmitting Facilities, Blackberries, Microwave Ovens, Wireless Internet Connections and many, many other modern devices widely in use today **rely completely** on radio frequency, (RF), energy, or radiofrequency radiation, (RFR) in order for them to work at all. The ability of Radio Waves, (which includes microwaves), to travel through space and connect us directly to the world has become a nearly essential part of our lives. Microwave ovens are now commonplace in just about every corner of the developed world. But what is this mysterious form of energy that completely envelops our bodies…and our lives? Can we see it? What are its long term effects?

These and other questions are considered in the following paragraphs.

-Radiofrequency Radiation, (RFR):

Radiofrequency Radiation, (RFR), or simply radio waves occupy a small portion of what is known as the Electromagnetic, (EM) Spectrum. In addition to radio waves, the entire EM Spectrum includes light, X-rays, gamma rays and others. All Electromagnetic Waves are made up of, (as its name implies), interrelated oscillating Electric and Magnetic fields, traveling through space together at the speed of light. These two fields are oscillating or "vibrating" at various rates called frequencies. It's the frequency of oscillation of an EM wave that determines what type of Electromagnetic Radiation, (EMR) it is…radio, X-rays, gamma rays, etc. Almost all of the wireless devices we use today employ radio waves to transport data and other information. Information that we want to transmit from one place to another is first embedded into radio waves before they're sent on their way. (The process of embedding data onto the waves is called "modulation".) Radio waves are great because they travel extremely fast and will fly right through most walls, doors and buildings, and are used for just about everything from TV and radio broadcasting, wireless internet connections, cell phones, Blackberries, etc. But because they're so pervasive, that means that we're right in "the thick of it".

…So how does all this Radiofrequency Radiation affect us? Let's take a look:

-RFR Effects on Humans:

Biological effects can result from exposure to RFR. Some of these effects come from actual heating of the tissue by RFR, called thermal effects. It's been known for many years that exposure to very high levels of RFR can be harmful due to the ability of the energy to heat biological tissue very rapidly. The energy in the RFR is converted to heat energy directly within the volume of the tissue. The RFR penetrates the tissue and is then converted to heat inside instantaneously. This is the same principle by which microwave ovens operate. Tissue damage in humans could occur during exposure to high levels of RFR due to the body's inability to cope with or to dissipate the heat generated. Also, within the volume of a biological tissue mass, there could be small regions that would respond more to the heating capabilities of higher levels of RFR than others. (This is called “preferential volumetric heating”.) If this heat deposition occurs at zones within the tissue where the temperature is highly critical, such as in the testis or certain regions of the eye the possibility exists for damage to result.

At levels of RFR below which there is significant heating, the actual effects are ambiguous and unproven. Any of these effects, if present, are referred to as “non-thermal” effects. There is a small body of, (relatively un-substantiated), concern that some of these non-thermal effects could include damage to the structure of the DNA in cells, causing them to undergo transformations that could lead to diseases like cancer or other maladies.

In all of these cases, it is important to understand RFR and its effects, in order to establish reasonable parameters and limits on its exposure, and very importantly, to design equipment that will reduce and limit the amount of RFR exposure that the public is subjected to, while at the same time, enabling all of us to enjoy all of the tremendous benefits from the many wonderful devices we use.

-Cell Phones:

As a practicing Electromagnetics Engineering Physicist, cell phones are the most commonly expressed source for concern from clients. The accepted quantification of RFR from cell phones is the Specific Absorption Rate, (or SAR). The quantity is specified in units of watts per kilogram, (W/kg), or miliwatts per gram, (mW/g). For cell phones, this corresponds to the relative amount of RF energy that is absorbed in the head of a person using a cell phone. Currently, the SAR limit established by the Federal Communications Commission, (FCC), is a maximum of 1.6 watts of RFR power per kilogram. There are many factors that affect a particular cell phone’s SAR. The power of the phone’s transmitter is one determining component, as well as the phone’s internal antenna design and its specific design and implementation. Cell phone manufacturers publish the SAR of the various phone models they offer. Most of this information is included with the package that comes with the phone, and/or is available via inquiry from the manufacturer or on-line.

-How RFR is Generally Measured and Quantified:

Since an Electromagnetic Wave has both an electric and a magnetic field component, it is often convenient to express the intensity of the RFR environment at a given location in terms of units that are specific to each field component. For the electric “field strength”, the units are expressed in “volts per meter”, (V/m), and for the magnetic “field strength”, the units are expressed in “amperes per meter”, (A/m). A commonly-used unit for characterizing the total RFR electromagnetic field is called “power density”, or RFR power per unit area. Commonly-used units are expressed as watts per meter squared, (W/m^2), or miliwatts per centimeter squared, (mW/cm^2). Power density is most appropriately used in situations involving cell towers or large broadcast transmitting facilities where the people exposed are much farther away from the transmitting source, (called the “far field”), than is the case with cell phones.

In terms of power density, maximum exposure limits to the general public depend on several factors, including the frequency. For example, the maximum power density allowed for the general public at a frequency of 146 MHz is 0.2 mW/cm^2.

In addition to absolute power density levels, **exposure time** is also a very important parameter.

FOR THE EVEN MORE CURIOUS READER…A DEEPER DISCUSSION OF THE PHENOMENON OF ELECTROMAGNETIC RADIATION FOLLOWS:

-Radiofrequency Radiation…A Closer Look:

Radiofrequency Radiation is actually a sub-set of the overall Electromagnetic Radiation, (EMR), Spectrum. The entire EMR Spectrum includes not only the radiofrequency portion, (addressed in this Newsletter), but also encompasses light, x-rays and gamma rays, to mention a few. The fundamental difference between these types of EMR is the ***frequency range*** that characterizes each sub-set within the Spectrum.

-Frequency:

In order to understand the concept of the frequency associated with Electromagnetic Radiation, it's very useful at first to briefly discuss the two individual fields of force that comprise EMR. Electromagnetic Radiation, as its name implies, consists of **Electric** and **Magnetic** fields. All of us are at least, somewhat familiar with both of these. An Electric Field is produced, and its effects are what we experience, when a balloon is rubbed on a woolen sweater and afterwards, attracts strands of hair or pieces of paper to it. Another manifestation of the Electric Field is that it will cause the balloon to "stick" to a wall. The Electric Field around the balloon generates a force that attracts the hair strands or pieces of paper to it, or holds the balloon to the wall. A Magnetic Field is produced by magnetic materials in a magnet, or by an electric current passing through a conductor. A Magnetic Field's effects are observed when a magnet, or a wire connected to a battery, (so that the wire is carrying an electric current), is brought near a compass needle and the needle moves in response.

Electric and Magnetic Fields can be very strong or very weak. The strength of the field is referred to as its magnitude. Also, each field points in a unique direction. Since they have **both** a magnitude, (strength), and point in a certain direction, they're characterized as **vector** force fields. By convention, in the case of the Electric Field, its vector always points away from a positive charge and/or toward a negative charge. Similarly, by convention, a Magnetic Field vector points away from the "north" magnetic pole and toward the "south" magnetic pole. In both of these are examples, the fields are stationary, i.e., they're not changing with time. Therefore, they're often referred to as "static" or stationary fields.

So how does all of this explain what electromagnetic radiation is? …THAT is where this entire discussion becomes very interesting!

The above discussions were of static or stationary electric and magnetic fields. Stationary fields are not electromagnetic radiation at all. BUT let's now consider what happens when we begin to move or change these fields with time. Let's take a look at a common bar magnet, like the ones used in science class in school. The magnet has a "north" and a "south" magnetic pole, usually marked "N" and "S" on each end. (Because there are two poles, north and south, it's an example of what's known in physics as a magnetic **dipole**…two poles.) Now let's imagine that we mount that magnet to an electric drill, motor shaft or something that will spin the bar magnet from its center, like an airplane propeller, and spins it at, say, 3,600 revolutions per minute, (RPM). When the magnet is spinning in the drill, it should be fairly easy to visualize that the magnetic field around it will be spinning too. Each full revolution will constitute one complete "cycle", or revolution. If we check out the **Magnetic Field** at a fixed reference point in the space near the spinning magnet, it will be moving too, following the magnet's rotation. This is an example of an alternating magnetic field. The field will alternate or rotate through one full cycle following the magnet, 3,600 times per minute. Since frequency is measured in cycles per second, and there are 60 seconds in a minute, the Magnetic Field at that fixed reference point in space rotates through one complete cycle, (3,600 divided by 60), or 60 times each second.

NOW comes the leap from the spinning magnet and its corresponding oscillating Magnetic Field to Electromagnetic Radiation! The laws of physics tell us that this **time-varying** magnetic field, (from the spinning bar magnet), will CAUSE a time-varying **ELECTRIC FIELD,** whose magnitude and direction oscillate as well, linked to the time-varying Magnetic Field causing it! (Please bear in mind that this only happens in response to a magnetic field that is **changing in time**…static magnetic fields do not give rise to static electric fields.) FINALLY…the laws of physics tell us another thing…they tell us that when an ELECTRIC FIELD is changing in time…IT will then give rise to a time-varying MAGNETIC FIELD again, following the time-changes of the causal, time-varying Electric Field. The time-varying Magnetic Field initially from the spinning magnet gives rise to a time-varying Electric Field which in tern causes yet another time-varying Magnetic Field and so fourth. These two interrelated time-varying Electric and Magnetic fields move off together, away from the rotating bar magnet through space at the speed of light. This resulting system of fields moving through space is called an ELECTRO-MAGNETIC FIELD and is RADIATING away from the source…in this example, the spinning magnet. We have Electromagnetic Radiation!

Note: For the science-minded readers of this Newsletter, the mathematical or quantitative characterization of this interrelationship between the time-varying electric and magnetic fields in electromagnetic radiation is governed by a set of physical laws described by mathematical equations, collectively known as Maxwell's Equations, named for James Clerk Maxwell, a Scottish theoretical physicist who lived in the mid 1800's and who elegantly described these phenomena.

In this example, the two fields alternate back and fourth, making one complete cycle 60 times each second. Therefore, this electromagnetic field has a frequency of 60 cycles per second…or 60 Hertz.

-Radio Waves and Microwaves…

In the example above, an easy-to-visualize scenario of a rotating bar magnet was used in order to develop the concept and to describe electromagnetic radiation. The physically-spinning bar magnet in this example was used to develop electromagnetic radiation whose fields alternated at only 60 Hertz. Radio waves characterize electromagnetic radiation where the fields oscillate at frequencies that are much, much higher. Instead of oscillating at 60 Hertz, in order for electromagnetic radiation to be characterized as radio waves, their fields must oscillate at up to SEVERAL HUNDRED BILLION Hertz! Obviously, a source for electromagnetic radiation at these frequencies cannot possibly consist of anything "spinning" at that rate. Instead of a spinning bar magnet, in order to produce EMR in devices that use it like cell phones, electrons are made to move back and fourth inside of these devices at radio and microwave frequencies, (several billion hertz). Since moving electrons constitute electric currents, and an electric current causes a magnetic field, (as with the wire-and-battery and compass needle example), these rapidly-oscillating electrons will generate likewise, rapidly-oscillating magnetic fields in response. That gives rise to electromagnetic radiation at radio and microwave frequencies, used in all of our modern electronic devices.

If you're interested in learning more, please feel free to call or e-mail for a no-cost initial consultation.

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