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Some Applications of Electromagnetic Theory

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Abstract

In this work we summarize the electromagnetic theory (E.M.T) and its applications precisely on receiving and transmitting antennas, electromagnetic resonance image (MRI) as well as microwaves oven.

Introduction

In physics, electromagnetic radiation (EM radiation or EMR) refers to the waves (or their quanta, photons) of the electromagnetic field, propagating (radiating) through space, carrying electromagnetic radiant energy[1]. It includes radio waves, microwaves, infrared, (visible) light, ultraviolet, X-rays, and gamma rays[2]. Classically, electromagnetic radiation consists of electromagnetic waves, which are synchronized oscillations of electric and magnetic fields that propagate at the speed of light, which, in a vacuum, is commonly denoted *c*. In homogeneous, isotropic media, the oscillations of the two fields are perpendicular to each other and perpendicular to the direction of energy and wave propagation, forming a transverse wave. The wave front of electromagnetic waves emitted from a point source (such as a light bulb) is a sphere. The position of an electromagnetic wave within the electromagnetic spectrum can be characterized by either its frequency of oscillation or its wavelength. Electromagnetic waves of different frequency are called by different names since they have different sources and effects on matter. In order of increasing frequency and decreasing wavelength these are: radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays[3]. Electromagnetic waves are emitted by electrically charged particles undergoing acceleration, and these waves can subsequently interact with other charged particles, exerting force on them[4,5]. EM waves carry energy, momentum and angular momentum away from their source particle and can impart those quantities to matter with which they interact. Electromagnetic radiation is associated with those EM waves that are free to propagate themselves ("radiate") without the continuing influence of the moving charges that produced them, because they have achieved sufficient distance from those charges. Thus, EMR is sometimes referred to as the far field. In this language, the near field refers to EM fields near the charges and current that directly produced them specifically, electromagnetic induction and electrostatic induction phenomena. In quantum mechanics, an alternate way of viewing EMR is that it consists of photons, uncharged elementary particles with zero rest mass which are the quanta of the electromagnetic force, responsible for all electromagnetic interactions[6]. Quantum electrodynamics is the theory of how EMR interacts with matter on an atomic level [7]. Quantum effects provide additional sources of EMR, such as the transition of electrons to lower energy levels in an atom and black-body radiation [8]. The energy of an individual photon is quantized and is greater for photons of higher frequency. This relationship is given by Planck's equation :

$E = h\nu$ (1)

Where *E* is the energy per photon, *ν* is the frequency of the photon, and *h* is Planck's constant. A single gamma ray photon, for example, might carry ~100,000 times the energy of a single photon of visible light. The effects of EMR upon chemical compounds and biological organisms depend both upon the radiation's power and its frequency. EMR of visible or lower frequencies (i.e., visible light, infrared, microwaves, and radio waves) is called non-ionizing radiation, because its photons do not individually have enough energy to ionize atoms or molecules or break chemical bonds. The effects of these radiations on chemical systems and living tissue are caused primarily by heating effects from the combined energy transfer of many photons. In contrast, high frequency ultraviolet, X-rays and gamma rays are called ionizing radiation, since individual photons of such high frequency have enough energy to ionize molecules or break chemical bonds. These radiations have the ability to cause chemical reactions and damage living cells beyond that resulting from simple heating, and can be a health hazard.

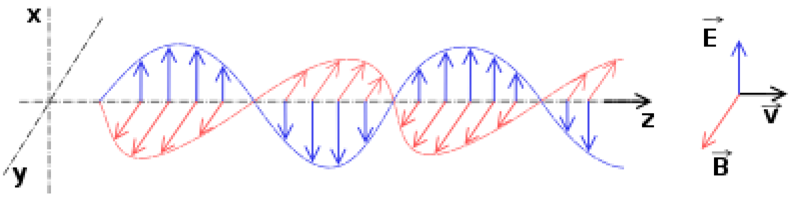

Fig. (1)A linearly polarized sinusoidal electromagnetic wave, propagating in the direction +z through a homogeneous, isotropic, dissipationless medium, such as vacuum. The electric field (blue arrows) oscillates in the ±x-direction, and the orthogonal magnetic field (red arrows) oscillates in phase with the electric field, but in the ±y-direction.

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Properties of Electromagnetic Radiation

Electrodynamics is the physics of electromagnetic radiation, and electromagnetism is the physical phenomenon associated with the theory of electrodynamics. Electric and magnetic fields obey the properties of superposition. Thus, a field due to any particular particle or time-varying electric or magnetic field contributes to the fields present in the same space due to other causes. Further, as they are vector fields, all magnetic and electric field vectors add together according to vector addition [8]. For example, in optics two or more coherent light waves may interact and by constructive or destructive interference yield a resultant irradiance deviating from the sum of the component irradiances of the individual light waves. Since light is an oscillation it is not affected by traveling through static electric or magnetic fields in a linear medium such as a vacuum. However, in nonlinear media, such as some crystals, interactions can occur between light and static electric and magnetic fields — these interactions include the Faraday effect and the Kerr effect[9,10]. In refraction, a wave crossing from one medium to another of different density alters its speed and direction upon entering the new medium. The ratio of the refractive indices of the media determines the degree of refraction, and is summarized by Snell's law. Light of composite wavelengths (natural sunlight) disperses into a visible spectrum passing through a prism, because of the wavelength-dependent refractive index of the prism material (dispersion); that is, each component wave within the composite light is bent a different amount. EM radiation exhibits both wave properties and particle properties at the same time (see wave-particle duality). Both wave and particle characteristics have been confirmed in many experiments. Wave characteristics are more apparent when EM radiation is measured over relatively large timescales and over large distances while particle characteristics are more evident when measuring small timescales and distances. For example, when electromagnetic radiation is absorbed by matter, particle-like properties will be more obvious when the average number of photons in the cube of the relevant wavelength is much smaller than 1. It is not too difficult to experimentally observe non-uniform deposition of energy when light is absorbed; however this alone is not evidence of "particulate" behavior. Rather, it reflects the quantum nature of matter [11]. Demonstrating that the light itself is quantized, not merely its interaction with matter is a more subtle affair. Some experiments display both the wave and particle natures of electromagnetic waves, such as the self-interference of a single photon.[16] When a single photon is sent through an interferometer, it passes through both paths, interfering with it, as waves do, yet is detected by a photomultiplier or other sensitive detector only once. A quantum theory of the interaction between electromagnetic radiation and matter such as electrons is described by the theory of quantum electrodynamics. Electromagnetic waves can be polarized, reflected, refracted, diffracted or interfere with each other [12].

1. Antennas and Transmitters

Imagine holding out your hand and catching words, pictures, and information passing by. That's more or less what an antenna (sometimes called an aerial) does: it's the metal rod or dish that catches radio waves and turns them into electrical signals feeding into something like a radio or television or a telephone system. Antennas like this are sometimes called receivers. A transmitter is a different kind of antenna that does the opposite job to a receiver: it turns electrical signals into radio waves so they can travel sometimes thousands of kilometers around the Earth or even into space and back. Antennas and transmitters are the key to virtually all forms of modern telecommunication [13].

1.1 The Mechanism of the Antenna Work

First we must explain the basic mechanism of radiation and the fundamental types of antennas. Suppose you're the boss of a radio station and you want to transmit your programs to the wider world. How do you go about it? You use microphones to capture the sounds of people's voices and turn them into electrical energy. You take that electricity and, loosely speaking, make it flow along a tall metal antenna (boosting it in power many times so it will travel just as far as you need into the world). As the electrons (tiny particles inside atoms) in the electric current wiggle back and forth along the antenna, they create invisible electromagnetic radiation in the form of radio waves. These waves, partly electric and partly magnetic, travel out at the speed of light, taking your radio program with them. What happens when I turn on my radio in my home a few miles away? The radio waves you sent flow through the metal antenna and cause electrons to wiggle back and forth. That generates an electric current—a signal that the electronic components inside my radio turn back into sound I can hear [14].

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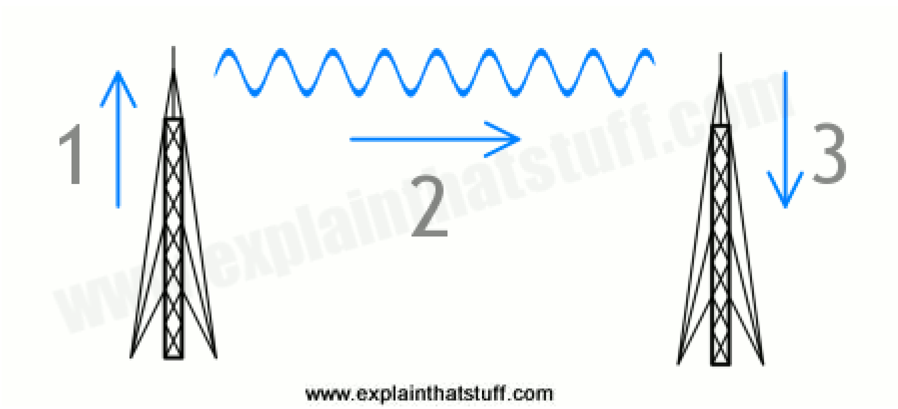

Fig. (2) Artwork: How a transmitter sends radio waves to a receiver. 1) Electricity flowing into the transmitter antenna makes electrons vibrate up and down it, producing radio waves. 2) The radio waves travel through the air at the speed of light. 3) When the waves arrive at the receiver antenna, they make electrons vibrate inside it. This produces an electric current that recreates the original signal.

Transmitter and receiver antennas are often very similar in design. For example, if you're using something like a satellite phone that can send and receive a video-telephone call to any other place on Earth using space satellites, the signals you transmit and receive all pass through a single satellite dish—a special kind of antenna shaped like a bowl (and technically known as a parabolic reflector, because the dish curves in the shape of a graph called a parabola). Often, though, transmitters and receivers look very different. TV or radio broadcasting antennas are huge masts sometimes stretching hundreds of meters/feet into the air, because they have to send powerful signals over long distances. (One of the ones I tune into regularly, at Sutton Coldfield in England, has a mast 270.5 meters or 887ft high, which is something like 150 tall people standing on top of one another.) But you don't need anything that big on your TV or radio at home: a much smaller antenna will do the job fine. Waves don't always zap through the air from transmitter to receiver. Depending on what kinds (frequencies) of waves we want to send, how far we want to send them, and when we want to do it, there are actually *three* different ways in which the waves can travel [15]:

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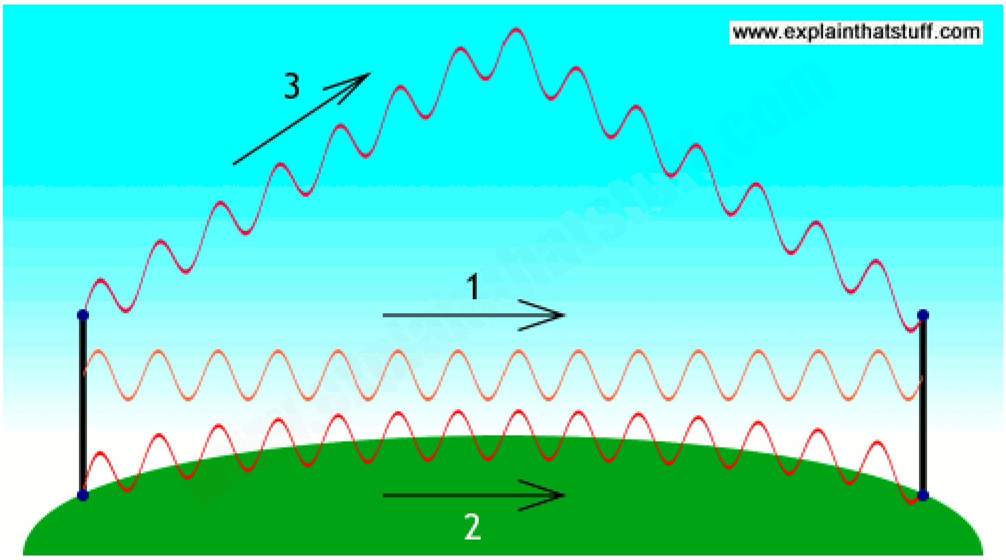

Fig. (3)Artwork: How a wave travels from a transmitter to a receiver: 1) By line of sight; 2) By ground wave; 3) Via the ionosphere.

1. As we've already seen, they can shoot by what's called "line of sight", in a straight line—just like a beam of light. In old-fashioned long-distance telephone networks, microwaves were used to carry calls this way between very high communications towers (fiber-optic cables have largely made this obsolete).
2. They can speed round the Earth's curvature in what's known as a ground wave. AM (medium-wave) radio tends to travel this way for short-to-moderate distances. This explains why we can hear radio signals beyond the horizon (when the transmitter and receiver are not within sight of each other).
3. They can shoot up to the sky, bounce off the ionosphere (an electrically charged part of Earth's upper atmosphere), and come back down to the ground again. This effect works best at night, which explains why distant (foreign) AM radio stations are much easier to pick up in the evenings. During the daytime, waves shooting off to the sky are absorbed by lower layers of the ionosphere. At night, that doesn't happen. Instead, higher layers of the ionosphere catch the radio waves and fling them back to Earth—giving us a very effective "sky mirror" that can help to carry radio waves over very long distances.

3.5 The Length of the Antenna

The simplest antenna is a single piece of metal wire attached to a radio. The first radio I ever built, when I was 11 or 12, was a crystal set with a long loop of copper wire acting as the antenna. I ran the antenna right the way around my bedroom ceiling, so it must have been about 20–30 meters (60–100 ft) long in all!Most modern transistor radios have at least two antennas. One of them is a long, shiny telescopic rod that pulls out from the case and swivels around for picking up FM (frequency modulation) signals. The other is an antenna inside the case, usually fixed to the main circuit board, and it picks up AM (amplitude modulation) signals. (If you're not sure about the difference between FM and AM, refer to our radio article.)Why do you need two antennas in a radio? The signals on these different wave bands are carried by radio waves of different frequency and wavelength. Typical AM radio signals have a frequency of 1000 kHz (kilohertz), while typical FM signals are about 100 MHz (megahertz)—so they vibrate about a hundred times faster. Since all radio waves travel at the same speed (the speed of light, which is 300,000 km/s or 186,000 miles per second), AM signals have wavelengths about a hundred times bigger than FM signals. You need two antennas because a single antenna can't pick up such a hugely different range of wavelengths. It's the wavelength (or frequency, if you prefer) of the radio waves you're trying to detect that determines the size and type of the antenna you need to use. Broadly speaking, the length of a simple (rod-type) antenna has to be about half the wavelength of the radio waves you're trying to receive (it's also possible to make antennas that are a quarter of the wavelength, compact miniaturized antennas that are about a tenth the wavelength, and membrane antennas that are even smaller, though we won't go into that here).The length of the antenna isn't the only thing that affects the wavelengths you're going to pick up; if it were, a radio with a fixed length of antenna would only ever be able to receive one station. The antenna feeds signals into a tuning circuit inside a radio receiver, which is designed to "latch onto" one particular frequency and ignore the rest. The very simplest receiver circuit (like the one you'll find in a crystal radio) is nothing more than a coil of wire, a diode, and a capacitor, and it feeds sounds into an earpiece. The circuit responds (technically, resonates, which means electrically oscillates) at the frequency you're tuned into and discards frequencies higher or lower than this. By adjusting the value of the capacitor, you change the resonant frequency—which tunes your radio to a different station. The antenna's job is to pick up enough energy from passing radio waves to make the circuit resonate at just the right frequency [16].

3.6 The Types of Antennas

The simplest radio antennas are just long straight rods. Many indoor TV antennas take the form of a dipole: a metal rod split into two pieces and folded horizontally so it looks a bit like a person standing straight up with their arms stretched out horizontally. More sophisticated outdoor TV antennas have a number of these dipoles arranged along a central supporting rod. Other designs include circular loops of wire and, of course, parabolic satellite dishes. Why so many different designs? Obviously, the waves arriving at an antenna from a transmitter are exactly the same, no matter what shape and size the antenna happens to be. A different pattern of dipoles will help to concentrate the signal so it's easier to detect. That effect can be increased even more by adding unconnected, "dummy" dipoles, known as directors and reflectors, which bounce more of the signal over to the actual, receiving dipoles. This is equivalent to boosting the signal—and being able to pick up a weaker signal than a simpler antenna [17].

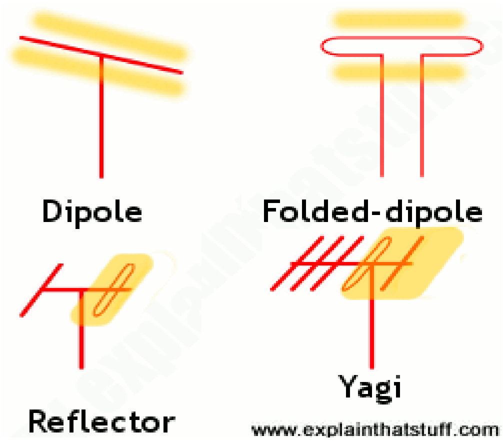

Fig.(4)Artwork: Four common types of antenna (red) and the places where they pick up best (orange): A basic dipole, a folded dipole, a dipole and reflector, and a Yagi. A basic or folded dipole antenna picks up equally well in front of or behind its poles, but poorly at each end. An antenna with a reflector picks up much better on one side than the other, because the reflecting element (the red, dipole-like bar on the left) bounces more signal over to the folded dipole on the right. The Yagi exaggerates this effect even more, picking up a very strong signal on one side and almost no signal anywhere else. It consists of multiple dipoles, reflectors, and directors.

3.7 Important Properties of Antennas

Three features of antennas are particularly important, namely their directionality, gain, and bandwidth [18].

Directionality

Dipoles are very directional: they pick up incoming radio waves traveling at right angles to them. That's why a TV antenna has to be properly mounted on your home and facing the correct way, if you're going to get a clear picture. The telescopic antenna on an FM radio is less obviously directional, especially if the signal is strong: if you have it pointed straight upward, it will capture good signals from virtually any direction. The ferrite AM antenna inside a radio is much more directional. Listening to AM, you'll find you need to swivel your radio around until it picks up a really strong signal. (Once you've found the best signal, try turning your radio through exactly 90 degrees and notice how the signal often falls off almost to nothing.)Although highly directional antennas may seem like a pain, when they're properly aligned, they help to reduce interference from unwanted stations or signals close to the one you're trying to detect. But directionality isn't always a good thing. Think about your cell phone. You want it to be able to receive calls wherever it is in relation to the nearest phone mast, or pick up messages whichever way it happens to be pointing when it's lying in your bag, so a highly directional antenna isn't much good. Similarly for a GPS receiver that tells you where you are using signals from multiple space satellites. Since the signals come from different satellites, in different places in the sky, it follows that they come from different directions, so, again, a highly directional antenna wouldn't be that helpful.

Gain

The gain of an antenna is a very technical measurement but, broadly speaking, boils down to the amount by which it boosts the signal. TVs will often pick up a poor, ghostly signal even without an antenna plugged in. That's because the metal case and other components act as a basic antenna, not focused in any particular direction, and pick up some kind of signal by default. Add a proper directional antenna and you'll *gain* a much better signal. Gain is measured in decibels (dB), and (as a broad rule of thumb) the bigger the gain the better your reception. In the case of TVs, you get much more gain from a complex outdoor antenna (one with, say, 10–12 dipoles in a parallel "array") than from a simple dipole. All outdoor antennas work better than indoor ones, and window and set-mounted antennas have higher gain and work better than built-in ones.

Bandwidth

An antenna's **bandwidth** is the range of frequencies (or wavelengths, if you prefer) over which it works effectively. The broader the bandwidth, the greater the range of different radio waves you can pick up. That's helpful for something like television, where you might need to pick up many different channels, but much less useful for telephone, cell phone, or satellite communications where all you're interested in is a very specific radio wave transmission on a fairly narrow frequency band.

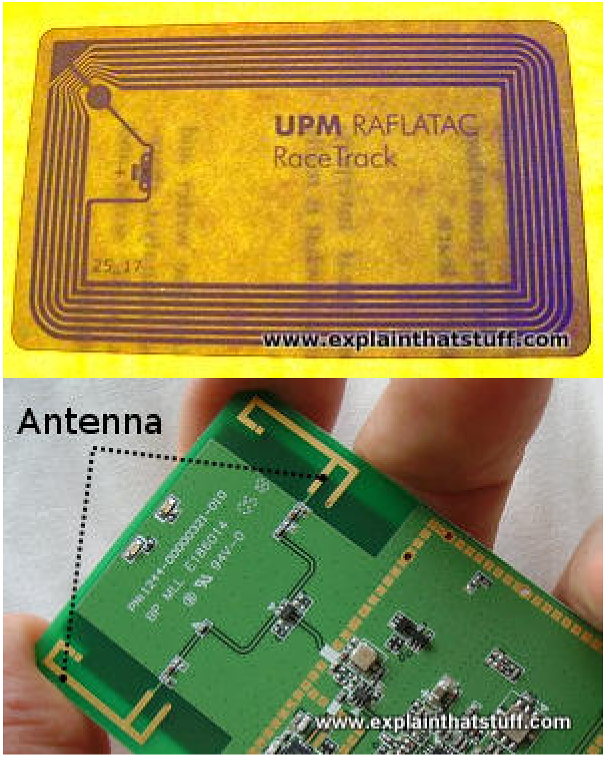

Fig. (5): More antennas: 1) The antenna that powers an RFID tag **stuck inside a library book. The circuit inside it has no power source: it gets all its energy from the incoming radio waves. 2) The dipole antenna inside a PCMCIA** wireless **Internet Wi-Fi card. This one works with 2.4GHz radio waves of wavelength 12.5cm, which is why it only needs to be about 6cm long or so.**

2. Magnetic Resonance Image (MRI)

The beginnings of MRI go back more than 25 years. This imaging technique is based on the fact that body tissues act differently in strong magnetic fields, because the water content of the individual tissues varies. The hydrogen nuclei within the water molecules align themselves in a specific direction in strong magnetic fields. When radio wave pulses of an appropriate frequency are directed perpendicular to the magnetic field at a tissue, the nuclei are deflected from their normal alignment. When the radio waves are switched off, the nuclei return to their original orientation and emit weak electromagnetic waves during this short "relaxation time". These electromagnetic waves are acquired as signals, which are used by a computer to generate high-contrast images of the tissue. Stronger magnetic fields enable stronger signals to be received, resulting in clearer images and/or shorter total examination times [19].

2.1 MRI Principle

Routine MRI is based on the magnetic characteristics of the 1H hydrogen atom. The patient is placed in a strong magnetic field (e.g., 1 Tesla = 10,000 Gauss) that is externally shielded. “To compare: the Earth’s magnetic field is 0.3 to 0.7 Gauss, a magnet on the refrigerator door has strength of approx. 100 Gauss or 0.01 Tesla”. High-frequency energy in the form of radio waves is applied to the patient. This energy is then emitted by the body in specific forms and at certain intervals. An antenna (coil) receives this energy, called the MR signal. For localization of these MR signals low frequency magnetic pulses are applied to the patient by the gradient system. Using a mathematical transformation, the MR signals are converted into grey scale images. A patient study may take up typically 30 minutes per examination [20].

2.2 The Mechanism of MRI

MRI has moved to the forefront of medical imaging in recent years covering almost all areas ranging from neurological imaging, musculoskeletal imaging to cardio vascular and interventional. Complex, novel techniques like diffusion and perfusion imaging, functional imaging have even affected the approach to certain diseases and patients. The advances in hardware have had an impact in the still growing and maturing applications like parallel imaging techniques. These new advances might start a revolution in patient management and the role of MR in diagnosis of diseases. These statements only prove true if the application and further technological development of MR systems are not constricted by strict occupational exposure limits applicable to the medical personnel working at the MR system. The clinical benefit of MR scanners for the patient can best be illustrated by reference to the enormous amount of literature on MR in the medical and scientific international journals). The number of MR units installed worldwide is estimated to be > 20.000 and since the introduction in 1983 more than 200.000.000 patients have been examined in thes canners. Up till now no adverse effects from the exposure of these patients nor from the exposure of the workers to the electromagnetic field created by MR systems is known. The exposure of patients is not addressed in the European Directive proposal and therefore only mentioned in this memo for illustration. Actual limits for the parameters for patient scanning are given in the IEC 60601-2-33 particular standard for the safety of MR scanners. For information, the static magnetic field ceiling value is 4 T for patients for whole body scanning, a number which is based on the clinical experience with 4 T MR scanners at a limited number of hospital sites since 1987.At present the exposure to the static magnetic field of system engineers in them an factoring area and service engineers in the hospital environment is minimized by introducing specific tools. For all normal engineering activities these tools can be applied. For abnormal situation, whereby troubleshooting is required, it may however be unavoidable that these engineers are exposed to higher values (then proposed in the draft directive).The exposure time to the static magnetic field of the operators in the hospital is typically a few minutes per patient. In the worst case they are exposed to the maximum static magnetic field of the magnet, because they must position the patient on the patient support and therefore approach the magnet at a position where the static magnetic field is as high as the main magnetic field of the system. The operators in the hospital are typically not exposed to gradient- and RF-fields, because during the scanning of the patient, the operator is relative far away from the patient (at the operator's console of the scanner).

The exposure of the medical staff during interventional MR however is much higher than the proposed limits in the draft directive. For both, the open MR systems and the cylindrical MR systems, the medical doctor can be present near the scanner during a longer time (up to one hour or even more) and is present in or close to the maximum static magnetic field with his hands and partially with his body. Since he is present near the patient during scanning, he is also exposed by gradient- and RF-fields. At parts of the body (extremities, head) they can reach values which can be maximally equal to those applied to the patient. In view of the practical experience up to now, the large installed base for MR scanners at present, the importance of the diagnostic capabilities of these MR scanners for the health care and the weak scientific base for the proposed limiting values, it seems unrealistic and not in the interest of the patients to impose the requirements in the draft directive to medical equipment and MR scanners in particular. There are already several national and international guidelines, recommendations and standards in place addressing the safety of medical personnel in the MR environment (for example: the recommendation of the “Strahlenschutzkommission” in Germany, the White Paper on MR safety of the American College of Radiology or the IEC60601-2-33 particular standard for the safety of MR scanners). These papers also require permanent training of the personnel, special procedures to be defined and followed or the generation of emergency plans. That means, they are much more specific in addressing the potential hazards in the particular MR vicinity [21].

3. The Discovery of Microwaves

In 1945, the specific heating effect of a high-power microwave beam was accidentally discovered by Percy Spencer, an American self-taught engineer from Howland, Maine. Employed by Raytheon at the time, he noticed that microwaves from an active radar set he was working on started to melt a chocolate bar he had in his pocket. The first food deliberately cooked with Spencer's microwave was popcorn, and the second was an egg, which exploded in the face of one of the experimenters [22]. To verify his finding, Spencer created a high density electromagnetic field by feeding microwave power from a magnetron into a metal box from which it had no way to escape. When food was placed in the box with the microwave energy, the temperature of the food rose rapidly. On 8 October 1945, Raytheon filed a United States patent application for Spencer's microwave cooking process, and an oven that heated food using microwave energy from a magnetron was soon placed in a Boston restaurant for testing [23].

3.1 The Mechanism of The work of Microwaves

A microwave oven heats food by passing microwave radiation through it. Microwaves are a form of non-ionizing electromagnetic radiation with a frequency higher than ordinary radio waves but lower than infrared light. Microwave ovens use frequencies in one of the ISM (industrial, scientific, medical) bands, which are reserved for this use, so they do not interfere with other vital radio services. Consumer ovens usually use 2.45 gigahertz (GHz)— It is a wavelength of 12.2 centimeters (4.80 in)— while large industrial/commercial ovens often use 915 megahertz (MHz)—32.8 centimeters (12.9 in)[108]. Water, fat, and other substances in the food absorb energy from the microwaves in a process called dielectric heating. Many molecules (such as those of water) are electric dipoles, meaning that they have a partial positive charge at one end and a partial negative charge at the other, and therefore rotate as they try to align themselves with the alternating electric field of the microwaves. Rotating molecules hit other molecules and put them into motion, thus dispersing energy. This energy, dispersed as molecular rotations, vibrations and/or translations in solids and liquids raises the temperature of the food, in a process similar to heat transfer by contact with a hotter body it is a common misconception that microwave ovens heat food by operating at a special resonance of water molecules in the food. As noted microwave ovens can operate at many frequencies. Microwave heating is more efficient on liquid water than on frozen water, where the movement of molecules is more restricted. Dielectric heating of liquid water is also temperature-dependent: At 0 °C, dielectric loss is greatest at a field frequency of about 10 GHz, and for higher water temperatures at higher field frequencies. Compared to liquid water, microwave heating is less efficient on fats and sugars (which have a smaller molecular dipole moment). Sugars and triglycerides (fats and oils) absorb microwaves due to the dipole moments of their hydroxyl groups or ester groups. However, due to the lower specific heat capacity of fats and oils and their higher vaporization temperature, they often attain much higher temperatures inside microwave ovens. This can induce temperatures in oil or very fatty foods like bacon far above the boiling point of water, and high enough to induce some browning reactions, much in the manner of conventional broiling (UK: grilling), braising, or deep fat frying. Foods high in water content and with little oil rarely exceed the boiling temperature of water. Microwave heating can cause localized thermal runaways in some materials with low thermal conductivity which also have dielectric constants that increase with temperature. An example is glass, which can exhibit thermal runaway in a microwave to the point of melting if preheated. Additionally, microwaves can melt certain types of rocks, producing small quantities of molten rock. Some ceramics can also be melted, and may even become clear upon cooling. Thermal runaway is more typical of electrically conductive liquids such as salty water.

Another misconception is that microwave ovens cook food "from the inside out", meaning from the center of the entire mass of food outwards. This idea arises from heating behavior seen if an absorbent layer of water lies beneath a less absorbent drier layer at the surface of a food; in this case, the deposition of heat energy inside a food can exceed that on its surface. This can also occur if the inner layer has a lower heat capacity than the outer layer causing it to reach a higher temperature, or even if the inner layer is more thermally conductive than the outer layer making it feel hotter despite having a lower temperature. In most cases, however, with uniformly structured or reasonably homogenous food item, microwaves are absorbed in the outer layers of the item at a similar level to that of the inner layers. Depending on water content, the depth of initial heat deposition may be several centimeters or more with microwave ovens, in contrast to broiling/grilling (infrared) or convection heating—methods which deposit heat thinly at the food surface. Penetration depth of microwaves is dependent on food composition and the frequency, with lower microwave frequencies (longer wavelengths) penetrating further [24].

3.2 The Components of the Microwaves Oven

A microwave oven consists of:

- a high-voltage power source, commonly a simple transformer or an electronic power converter, which passes energy to the magnetron
- a high-voltage capacitor connected to the magnetron, transformer and via a diode to the chassis
- a cavity magnetron, which converts high-voltage electric energy to microwave radiation
- a magnetron control circuit (usually with a microcontroller)
- a short waveguide (to couple microwave power from the magnetron into the cooking chamber)
- a metal cooking chamber

- a turntable or metal wave guide stirring fan.
- a control panel

In most ovens, the magnetron is driven by a linear transformer which can only feasibly be switched completely on or off. (One variant of the GE Space maker had two taps on the transformer primary, for high and low power modes.) Usually choice of power level doesn't affect intensity of the microwave radiation; instead, the magnetron is cycled on and off every few seconds, thus altering the large scale duty cycle. Newer models use *inverter* power supplies that use pulse-width modulation to provide effectively continuous heating at reduced power settings, so that foods are heated more evenly at a given power level and can be heated more quickly without being damaged by uneven heating[25]. The microwave frequencies used in microwave ovens are chosen based on regulatory and cost constraints. The first is that they should be in one of the industrial, scientific, and medical (ISM) frequency bands set aside for unlicensed purposes. For household purposes, 2.45 GHz has the advantage over 915 MHz in that 915 MHz is only an ISM band in the ITU Region 2 while 2.45 GHz is available worldwide. Three additional ISM bands exist in the microwave frequencies, but are not used for microwave cooking. Two of them are centered on 5.8 GHz and 24.125 GHz, but are not used for microwave cooking because of the very high cost of power generation at these frequencies. The third, centered on 433.92 MHz, is a narrow band that would require expensive equipment to generate sufficient power without creating interference outside the band, and is only available in some countries. The cooking chamber is similar to a Faraday cage to prevent the waves from coming out of the oven. Even though there is no continuous metal-to-metal contact around the rim of the door, choke connections on the door edges act like metal-to-metal contact, at the frequency of the microwaves, to prevent leakage. The oven door usually has a window for easy viewing, with a layer of conductive mesh some distance from the outer panel to maintain the shielding. Because the size of the perforations in the mesh is much less than the microwaves' wavelength (12.2 cm for the usual 2.45 GHz), microwave radiation cannot pass through the door, while visible light (with its much shorter wavelength) can [26].

Conclusion

Electromagnetic radiation is a flood of energy through space nearly the speed of light these waves are important in the live. it appear in many forms. All living organisms on Earth depend on electromagnetic radiation from the sun. There are many types of electromagnetic such as; x-ray, visible, radio waves. Electromagnetic spectrum used to extend frequencies from the very lowest frequencies to the highest possible frequencies. These waves includes in the life such as; radar, cooking, etc…

Advantages

One advantage to using an electromagnetic energy source is that, depending upon the electromechanical device used, you don't need an external electrical source to generate electrical power. One example of this is an alternating-current (AC) generator. When rotational mechanical energy turns a coil inside of the generator, it exposes that coil to changes in magnetic field. Those changes induce the production of alternating current voltage – voltage where the current changes directions with a certain frequency – between the two output ends of the coil. Since no other energy is required other than the mechanical motion of the rotating coil, this type of device can be advantageous in situations where there is a ready source of mechanical energy, such as a steam or gas turbine, or a diesel or gasoline engine. Another advantage of using an electromagnetic energy source is that you can generate either AC or direct-current (DC) electrical power. As noted before, an AC generator uses changing magnetic fields to create AC electrical power. A DC generator operates in a similar fashion; however, it requires a few extra pieces to convert AC electrical power to DC. Many DC motors and generators use a device called a commutator to convert the alternating current that comes out of the power generator into current that flows in only one direction, or direct current. As with an AC generator, many types of DC generators only require a reliable source of mechanical energy to generate electricity.

Disadvantages

Electromagnetic power sources may not be as useful, or can perhaps be dangerous to use, under certain circumstances. For instance, if you need to have a power source that must have a regulated current output, both AC and DC power generators would need to be run at a non-varying speed. Further, while a DC power generator produces electrical current that flows in one direction, the electrical current is irregular. To regulate the current produced by a DC generator, you would need additional electrical equipment, such as a battery, a capacitor and an inductor, as well as electronic components called diodes to ensure that the current stays within a regulated range. Since generators use electromagnetic fields to produce electricity, these fields can be dangerous to some people who use sensitive medical equipment, such as pacemakers. These same electromagnetic fields can also interfere with other electrical and electronic devices, such as cell phones and computers. The electrical energy generation process also produces heat; therefore, it would be best not to use a generator around items or in environments where there is flammable or combustible material.

Electromagnetic theory applications can be useful as follow:

***Cooking**
microwave radiation is absorbed by water molecules which heats up and cooks the food whilst killing bacteria.
***Communication**
Microwave radiation can also be used to transmit signals.
Some microwave radiation wavelengths can transmit signals out of earths orbit and into space and are used to communicate with satellites.
***X - Rays**
- Medical X-Rays: Allow doctors to observe the bones structure of patients without actually performing invasive surgeries.
***Security:**
Allows airport security to observe the internal contents of objects and luggage using airport scanners.
***Gamma Rays**
Gamma rays have a very high frequency and cannot be heard or felt however it can be used to sterilize surgical instruments, food and can also be used to kill cancer cells, however in larger amounts it can also create cancer.
***Ultraviolet Radiation**
Found naturally in sunlight and cannot be seen or felt.
Skin turns darker to so that UV Radiation does not reach the deep skin cells.
Sun Beds.
Security Pens.
Fluorescent Lights.
Infrared Radiation.
***Burglar Alarms**
It can also be used to transfer information from place to place
Microwave radiation.
***Radio waves**
Radio programs.
Television uses higher frequency waves than radio program.

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