Electromagnetic Waves, Light and Information

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ABSTRACT

In this paper electromagnetic waves and visible light were examined. Information and communication technology were studied. Electromagnetic radiation, quantum energy, photon and electromagnetic waves were considered. The methodology of macroscopic and microscopic approach were used. Discrete energy quantity, photon, and information were employed. In this paper the light spread law was derived, first time in literature. The sun light changeable velocity was defined. Also, equation for information transfer functionalities were developed. These results can be applied in communication.

Keywords: Electromagnetic waves, light spread, information, length, frequency.

INTRODUCTION

The electromagnetic (EM) spectrum is the range of all types of EM radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station.

For now, there was not equation for visible light spread around. Light velocity was considered as constant [1]-[4].

In physics, *electromagnetic radiation* (*EM radiation* or EMR) refers to the waves (or their quanta, photons) of the electromagnetic field, propagating (radiating) are two types of electromagnetic radiation [5]-[8].

Electromagnetic radiation refers to the waves of the electromagnetic field, propagating through space, carrying electromagnetic radiant energy. It includes radio waves, microwaves, infrared, light, ultraviolet, X-rays, and gamma rays [9]-[11].

6G-sixth-generation wireless is the successor to 5G cellular technology. 6G networks will be able to use higher frequencies than 5G networks and provide substantially higher capacity and much lower latency. One of the goals of the 6G internet will be to support one micro-second latency communications, representing 1,000 times faster or 1/1000th the latency than one millisecond throughput [4]-[6].

The 6G technology market is expected to facilitate large improvements in the areas of imaging, presence technology and location awareness. Working in conjunction with artificial intelligence, the computational infrastructure of 6G will be able to autonomously determine the best location for computing to occur; this includes decisions about data storage, processing and sharing.

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5G is the 5th generation mobile network. It is a new global wireless standard after 1G, 2G, 3G, and 4G networks. 5G enables a new kind of network that is designed to connect virtually everyone and everything together including machines, objects, and devices.Some 5G pundits contend that the new network generates radiofrequency radiation that can damage DNA and lead to cancer; cause oxidative damage that can cause premature aging; disrupt cell metabolism; and potentially lead to other diseases through the generation of stress proteins.

At low frequencies, external electric and magnetic fields induce small circulating currents within the body. The main effect of radiofrequency electromagnetic fields is heating of body tissues. There is no doubt that short-term exposure to very high levels of electromagnetic fields can be harmful to health [13]-[15].

To protect against 6G and 5G and other electromagnetic fields in your home, the electromagnetic field home adaptor is recommended. The home adaptor will correct the 6G or 5G or 4G signal going to devices like a tablet in our home. It will not fully protect against fields originating out of your home (such as the neighboring routers and cell towers.

Some studies have found a link between electromagnetic field exposure and a higher risk of childhood leukemia, but other studies have not. Other studies have not found proof that electromagnetic field exposure causes other childhood cancers. Studies in adults did not prove that electromagnetic field exposure causes cancer.

In this work electromagnetic waves, light spread and information was examined. Equations for the light spread were derived as the first appearing in literature. Equation for information transfer was derived.

ELECTROMAGNETIC WAVES

Electromagnetic waves can be imagined as a self propagation transverse oscillating wave of electric and magnetic fields. This 3D animation shows a plane linearly polarized wave propagating from left to right. The electric and magnetic fields in such a wave are in-phase with each other reaching minima and maxima together.

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. 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.

The electromagnetic fields of light are 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 Kerr effect.

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. 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. 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 so 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. Demonstrating that the light itself is quantized, not merely its interaction with matter, is a more subtle affair.

Some experiment display both the wave and particle natures of electromagnetic waves, such as the self-interference of a single photon. When a single photon is sent through an interferometer, it passes through both paths, interfering with itself, as waves do, yet is detected by a photo multiplier or other sensitive detector only once.

Representing of the electric vector of wave of circularly polarized electromagnetic radiation. In homogeneous, isotropic media, electromagnetic radiation is a transverse wave meaning that its oscillations are perpendicular to the direction of energy transfer and travel.

The electric and magnetic parts of the field in an electromagnetic wave stand in a fixed ratio of strengths to satisfy the two that specify how one is produced from the other. In dissipation-less (lossless) media, these electric and magnetic fields are also in phase, with both reaching maxima and minima at the same points in space. A common misconception is that the electric and magnetic fields in electromagnetic radiation are out of phase because a change in one produces the other, and this would produce a phase difference between them as sinusoidal functions (as indeed happens in electromagnetic induction, and in the near-field close to antennas). However, in the far-field EM radiation which is described by the two source-free Maxwell curl operator equations, a more correct description is that a time-change in one type of field is proportional to a space-change in the other. These derivatives require that the electric and magnetic fields in EMR are in-phase. An important aspect of light's nature is its frequency. The frequency of a wave is its rate of oscillation and is measured in hertz, the SI unit of frequency, where one hertz is equal to one oscillation per second. Light usually has multiple frequencies that sum to form the resultant wave. Different frequencies undergo different angles of refraction, a phenomenon known as dispersion.

A monochromatic waves (a wave of a single frequency) consists of successive troughs and crests, and the distance between two adjacent crests or troughs is called the wavelength. Waves of the electromagnetic spectrum vary in size, from very long radio waves longer than a continent to very short gamma rays smaller than atom nuclei. Frequency is inversely proportional to wavelength, according to the equation:

$$v = f\lambda \qquad (1)$$

where v is the speed of the wave, f is the frequency and λ is the wavelength. As waves cross boundaries between different media, their speeds change but their frequencies remain constant. Electromagnetic waves in free space must be solutions of Maxwell's electromagnetic wave equation. Two main classes of solutions are known, namely plane waves and spherical waves. The plane waves may be viewed as the limiting case of spherical waves at a very large (ideally infinite) distance from the source. Both types of waves can have a waveform which is an arbitrary time function (so long as it is sufficiently differentiable to conform to the wave equation). As with any time function, this can be decomposed by means of Fourier analysis into its frequency spectrum, or individual sinusoidal components, each of which contains a single frequency, amplitude and phase. Such a component wave is said to be monochromatic. A monochromatic electromagnetic wave can be characterized by its frequency or wavelength, its peak amplitude, its phase relative to some reference phase, its direction of propagation, and its polarization.

Interference is the superposition of two or more waves resulting in a new wave pattern. If the fields have components in the same direction, they constructively interfere, while opposite directions cause destructive interference. An example of interference caused by EMR is electromagnetic interference (EMI) or as it is more commonly known as, radio-frequency interference (RFI). Additionally, multiple polarization signals can be combined (i.e. interfered) to form new states of polarization, which is known as parallel polarization state generation.

ELECTROMAGNETIC RADIANT ENERGY

In physics, electromagnetic radiation (EMR) consists of waves of the electromagnetic (EM) field, which propagate through space and carry electromagnetic radiant energy. It includes radio waves, microwaves, infrared, (visible) light, ultraviolet, X-rays, and gamma rays. All of these waves form part of the electromagnetic spectrum.

Classically, electromagnetic radiation consists of electromagnetic waves, which are synchronized oscillations of electric and magnetic fields. Electromagnetic radiation or electromagnetic waves are created due to periodic change of electric or magnetic field. Depending on how this periodic change occurs and the power generated, different wavelengths of electromagnetic spectrum are produced. In a vacuum, electromagnetic waves travel at the speed of light, 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 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.

Electromagnetic waves are emitted by electrically charged particles undergoing acceleration, and these waves can subsequently interact with other charged particles, exerting force on them. 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 alternative way of viewing EMR is that it consists of photons, uncharged elementary particles with zero rest mass which are the quanta of the electromagnetic field, responsible for all electromagnetic interactions. Quantum electrodynamics is the theory of how EMR interacts with matter on an atomic level. Quantum effects provide additional sources of EMR, such as the transition of electrons to lower energy levels in an atom and black-body radiation. The energy of an individual photon is quantized and is greater for photons of higher frequency. This relationship is given by Planck’s equation

$$\varepsilon = hf \qquad (2)$$

where ε is the energy per photon, f 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 [5]. 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. Electromagnetic energy travels in waves and spans a broad spectrum from very long radio waves to very short gamma rays. The human eye can only detect only a small portion of this spectrum called visible light. A radio detects a different portion of the spectrum, and an X-ray machine uses yet another portion.

MOBILE EDGE NETWORKS

6G is expected to support 1 terabyte per second (Tbps) speeds. This level of capacity and latency will be unprecedented and will extend the performance of 5G applications along with expanding the scope of capabilities in support of increasingly new and innovative applications across the realms of wireless cognition, sensing and imaging. 6G's higher frequencies will enable much faster sampling rates in addition to providing significantly better throughput. The combination of sub-mmWave (e.g. wavelengths smaller than one millimeter) and the use of frequency selectivity to determine relative electromagnetic absorption rates is expected to lead to potentially significant advances in wireless sensing solutions.

Additionally, whereas the addition of mobile edge computing –MEC is a point of consideration as an addition to 5G networks, MEC will be built into all 6G networks. Edge and core computing will become much more seamlessly integrated as part of a combined communications/computation infrastructure framework by the time 6G networks are deployed. This will provide many potential advantages as 6G technology becomes operational, including improved access to artificial intelligence -AI capabilities.

6G is expected to launch commercially in 2030. 6G is being developed in response to the increasingly distributed radio access network – RAN and the desire to take advantage of the terahertz – THz spectrum to increase capacity and lower latency. While some early discussions have taken place to define 6G, research and development – R&D activities will start in earnest in 2020. Many of the problems associated with deploying millimeter wave radio for 5G new radio are expected to be solved in time for network designers to address the challenges of 6G. It's expected that 6G wireless sensing solutions will selectively use different frequencies to measure absorption and adjust frequencies accordingly. This is possible because atoms and molecules emit and absorb electromagnetic radiation at characteristic frequencies and the emission and absorption frequencies are the same for any given substance.

QUANTUM ENERGY

The discovery that particles are discrete packets of energy with wave-like properties led to the branch of physics dealing with atomic and subatomic systems which is today called quantum mechanics. In physics, a quantum is the minimum amount of any physical entity (physical property) involved in an interaction. The fundamental notion that a physical property can be "quantized" is referred to as "the hypothesis of quantization". This means that the magnitude of the physical property can take on only discrete values consisting of integer multiples of one quantum. For example, a photon is a single quantum of light or of any other form of electromagnetic radiation. Similarly, the energy of an electron bound within an atom is quantized and can exist only in certain discrete values. Indeed, atoms and matter in general are stable because electrons can exist only at discrete energy levels within an atom. Quantization is one of the foundations of the much broader physics of quantum mechanics. Quantization of energy and its influence on

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how energy and matter interact (quantum electrodynamics) is part of the fundamental framework for understanding and describing nature.

Basic problem in classic physics and chemistry was consideration that emission, transfer and absorption electromagnetic waves (radiation) performed continues.

Quant mechanical moving of electrons in atoms make magnetic field permanent feromagnets. Electrical particles with spin also have magnetic moment. Some electrical neutral particles, for example neutron, which have spin, also have magnetic moment because of distribution electricity in their inner structure. Particles without spin never have magnetic moment.

The magnetic field of permanent magnets can be quite complicated, especially near the magnet. The magnetic field of a small straight magnet is proportional to the magnet's strength (called its magnetic dipole moment). The equations are non-trivial and also depend on the distance from the magnet and the orientation of the magnet. For simple magnets, points in the direction of a line drawn from the south to the north pole of the magnet. Flipping a bar magnet is equivalent to rotating its *m* by 180 degrees.

The magnetic field of larger magnets can be obtained by modelling them as a collection of a large number of small magnets called dipoles each having their own m. The magnetic field produced by the net magnetic field of identical (to a multiplicative constant) so that in many cases the distinction can be ignored. This is particularly true for magnetic fields, such as those due to electric currents, that are not generated by magnetic materials.

Equation of electron, quant moving in magnetic field:

$$m\frac{dv}{dt} = m(g + v_r), \qquad (3)$$

$$F_M = m\frac{dv}{dt} - m(g + v_r). \qquad (4)$$

where *v* electrons speed moving, *m* electron's mass, g gravity acceleration, v_r friction acceleration, *t* time and F_M magnetic force. In this way is defined magnetic force and magnetic moment. By equation (4) can control and seek out conditions for wished force of electromagnetic field. If more electromagnetic field fixed in set then is obtained resulted magnetic force as shown in the following equation:

$$m\frac{dv}{dt} = m(g + v_r), \qquad (5)$$

Magnetic force is expressed in SI system.

In classical physics and chemistry is opinion that electromagnetic waves emission, transfer and absorption are performed continuous. Max Planck introduce assumption that electromagnetic radiation emitted in discrete energy quantity called energy quant. It means energy emitted discontinuously, with break, in energy package. Energy of one quant proportional is frequency radiation $\boldsymbol{f}$.

$\varepsilon = hf = h\frac{c}{\lambda}$, (6) where h = $6.62 \quad 10^{-34} Js$universal Planck's constant, a c light velocity, f frequency and λ wave length of electromagnetic waves which emitted.

The photon energy formula is used to compute radiant energy in joules based on Planck's constant and a frequency of radiation in hertz.

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Einstein is proved Planck's hypothesis on quant applying to describing photo effect. Einstein extended Planck's hypothesis that energy electromagnetic radiation transferring in quant to some obstacle which it absorbed. Instead Planck's name quant (small pieces) Einstein suggested name photon (light pieces). Idea about photons (quant) means the following: electromagnetic waves energy have discontinuous structure. These small energy pieces are rely photons (quant). Planck's formula for energy one photon shows that different electromagnetic waves have photons non-equal energy. Since photon's energy in opposition proportion with radiation waves length then minimal energy of photons have electromagnetic waves with maximum waves length, and such as radio waves, until maximum photons energy have path of specter which have minimal waves lengths and those are cosmic waves [16]-[17].

If electromagnetic waves emitted in the form of quant, with that energy each quant $\varepsilon = hf$, than all emitted energy:

$$E = nhf, \qquad (7)$$

where n = 1,2,3,4…..

According this equation (7) follows that:

- The smallest energy which can emitted equal energy one quant (energy can not be less from this energy but can not be emitted).

- All amount emitted energy must be equal integer product of energy of one quant.

Equation (7) can be write in the following form:

$$\text{If}, \omega = 2\pi f \ , f = \frac{\omega}{2\pi}, \qquad (8)$$

$$h^* = 1.05 \quad 10^{-34} Js.$$

Electromagnetic waves emitted in the form of quant, with total emitted energy $E = nhf$ to the final product. When these quant energies are high density then becomes matter. Thus substance in the high density energy.

Light spread from the sun to the Earth

Sunlight is electromagnetic waves. Light spread and their quant, photon can be described as the following

$$\frac{\partial\rho}{\partial t} + c_x\frac{\partial\rho}{\partial x} + c_y\frac{\partial\rho}{\partial y} + c_z\frac{\partial\rho}{\partial z} + \sum_{i=1}^{n} \frac{\partial(c_i\rho)}{\partial\xi_i} - D_f\left(\frac{\partial^2\rho}{\partial x^2} + \frac{\partial^2\rho}{\partial y^2} + \frac{\partial^2\rho}{\partial z^2}\right) - \rho g + (R_i) = 0 \qquad (9)$$

where ρ quant density probability, c sunlight velocity, D_f diffusion coefficient, g gravity acceleration, R_i reactions on the Sun, x,y and z space coordinate, ξ attribute of interest, and t is time.

$$\rho c_p(\frac{\partial T}{\partial t} + c_x \frac{\partial T}{\partial x} + c_y \frac{\partial T}{\partial y} + c_z \frac{\partial T}{\partial z} + \sum_{i=1}^{n} \frac{\partial (c_i T)}{\partial \xi_i}) - \lambda_c(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}) + S_R = 0 \qquad (10)$$

where T temperature probability, c sunlight velocity, λ_c conductivity coefficient, S_R heat generation,x,y and z space coordinate, ξ attribute of interest, and t is time.

The equations (9) and (10) the first time derived in this paper.

PHOTON AND INFORMATION

The photon energy term shows potential according to following equation:

$$\Delta p \Delta q = \varepsilon \Delta t \qquad (11)$$

where P probability of position, q is time's probability, ε is quant energy and t is time. This formula includes no determine principle. Vibration change can be defined as:

$$\Delta f = \frac{\varepsilon}{h} \qquad (12)$$

where f frequency.

Like other waves, electromagnetic waves have properties of speed, wavelength, and frequency [17]-[18]-[20].

Information can defined as photon, nanophoton [21]:

Information quantum $I_v = -\sum_i p_i \, log_2 \, p_i$ (11)

Interaction light photons defines the new information value. The new information value can be expressed as:

$$I_v = -\sum_{i=1}^{n} p_i \,(output/input)\, log_2 \, p_i \,(output/input) \qquad (12)$$

where P_i probability.

Information transfer is very important in communication.

CONCLUSION

In this paper light spread and information functionalities were derived. Properties of the electromagnetic waves were examined. Electromagnetic radiant energy and quantum energy were discussed. Expression for magnetic force was derived. Quantum electrodynamics of energy and its influence on how energy and

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matter interact is part of the fundamental framework for understanding nature.

The light spread and changeable light velocity were examined. The equations for light spread were derived.

The photon energy term and information were examined.

The obtained results in this paper show applicability to electromagnetic nature to light and information.

Notation

c- light velocity, m/s

f- frequency, s^{-1}

g -gravity acceleration, m/s^2

F_M– magnetic force, *N*

$h = 6.62 \quad 10^{-34} Js$ -universal Plank's constant

I_v– information value, *Byte*

M – electron mass

P– probability of position

P_i – probability of event

q – probability of time

t– time, s

v- velocity moving, m/s

v_r– friction velocity, m/s

*Greek symbol*s

ε -quant energy, J

λ wave length, m

λ_c– conductivity coefficient, J/mKs

Abbreviation

EM-electromagnetic

EMR- electromagnetic radiation

MEC-mobile edge computing

RAN- radio access network

EMI-electromagnetic interference

RFI-radio frequency interference

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