International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

A Novel Theory for Generation of Electromagnetic Waves

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Abstract: ***During the conclusion of 19th century, James Clerk Maxwell had already published his work 'A Dynamical Theory Of Electromagnetic Field'. In this he presented his famous four equations, along with other electromagnetic equations and derived the speed of electromagnetic waves, also claiming that light is an electromagnetic wave. After this, students of Hermann von Helmholtz - Max Planck and Heinrich Hertz also shifted their focus on electromagnetic waves. Hertz succeeded in proving the existence of Maxwell's theoretical electromagnetic waves and Planck started doing theoretical work on Hertz's electromagnetic waves. With the development of Planck's constant and Einstein's theory of relativity it became profound that light, which is type of electromagnetic wave, behaves both as a particle and as wave, thus the theory of wave-particle duality came into existence and is still being referred. The combined work of all the scientists named above stated the behavior, application and to some extent generation of electromagnetic waves. However, none of the scientists till date were able to successfully present a detailed theory with regards to generation of electromagnetic waves, as to which part of the charged particle or the electromagnetic field around it is responsible for the generation of electromagnetic waves. In this paper, an attempt is being made to fill the void stated above with an innovative theory for generation of electromagnetic waves.***

1. Introduction

James Clerk Maxwell was the first to put forward a complete electro-dynamic theory of Light, including mathematical for- mulations. Maxwell's passion for attaching a concrete physical meaning to all his mathematical expressions, led finally to his electromagnetic theory of light which was based on Faraday's work in the field of Electromagnetism [1]. It followed, of course, from Maxwell's conception that from any source of rapid and regular alternations of electric discharge equally frequent and regular alternations of electric state travel outward through the surrounding space with the velocity of light.

Heinrich Hertz, Maxwell's greatest adherent, experimentally proved the existence of electromagnetic waves predicted by Maxwell's equations of electromagnetism [2]. Hertz's work was followed by Max Planck's solution to the black-body radiation problem. His discovery of energy quanta opened the gates for Quantum Mechanics, but after proposing the energy quanta hypo thesis, neither Planck nor his contemporaries were aware about this revolutionary hypothesis, until in 1905, Albert Einstein showed that not only energy, but also light needs to be seen as quanta in radiation processes [3].

Einstein's hypothesis of light quanta (later named as photon) had to face opposition in the scientific community (in particular by Planck), as it was against the theory of the wave nature of light, which was being applied successfully until then. Einstein was inspired by Planck's successful representation of measured blackbody spectra. This hypothesis successfully explained the observed phenomenon of photoelectron emission. Now, however, more than another hundred years later, we still are experiencing conceptual conundrums in the field of electromagnetic waves. The theories that presently describe the generation of electromagnetic waves are given in the next section.

2. Current Theories for Generation of Electromagnetic Waves

If an electron is moving in a wire a current is said to flow in the wire in the direction opposite to that of the moving electron. A moving electron produces a magnetic field, but this magnetic field is constant because the electron's motion has a constant velocity. In order for an electron to radiate Electromagnetic (EM) Radiation, it needs to accelerate. Acceleration means its velocity needs to change, which can be achieved either by changing the electron's speed or its direction. Both types of change will produce an acceleration, and hence produce EM radiation. Following are methods of acceleration of charged particle by which an electromagnetic wave can be generated.

A. Different Methods of Acceleration

1) Acceleration by Spontaneous Emission:

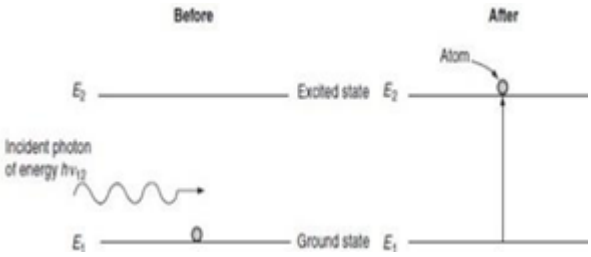

Figure 1: Acceleration by Spontaneous Emission

Acceleration by means of spontaneous emission occurs when an electron that is already present in an excited energy state spontaneously transitions to a lower energy state, emitting a photon. The energy of the photon is said to be equal to the energy difference between the two energy levels.

As shown in Fig (a), suppose an electron is initially present in an excited state. If we wait sufficiently long, the electron makes transition voluntarily on its own, without any need of external medium's influence, and emits a photon of energy $h\nu_{12}$ (= E_2 - E_1) [4]. This is called spontaneous emission.

Different electrons of the medium emit photons at different times and in different directions. Hence, there is no phase relationship among the emitted photons, so they are incoherent.

2) Acceleration by Stimulated Emission

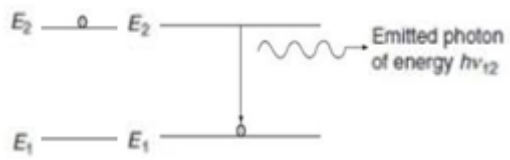

Figure 2: Acceleration by Stimulated Emission

Acceleration by stimulated emission was pointed out by Einstein in his fundamental paper on radiation theory published in 1917, within the framework of the old quantum theory, wherein the emission is described in terms of photons that are the quanta of the EM field. As shown in Fig. (b), a photon having energy hv_{12} (= E_2- E_1) impinges (or passes in the vicinity) on an atom present in the excited state and the atom is stimulated to make transition to the ground state and gives off a photon of energy hv_{12} [5]. The emitted photon is in phase with the incident photon. The two photons travel in the same direction and they possess same energy and frequency. They are coherent. This type of emission is known as stimulated emission.

3) Acceleration by Electric Field:
A charged particle placed in electric field experiences force, known as the Lorentz force. Lorentz force is the combined force on a charged particle due to both electric and magnetic fields, which are often considered together for practical applications. The electric field exerts a force that accelerates the charged particle. Electric force is along electric field and is capable to bring about change in both direction and magnitude depending upon the initial direction of velocity of the charged particle with respect to electric field. If velocity and electric vectors are at an angle then the particle follows a parabolic path. The electric field has a direction, positive to negative. This is the direction that the electric field will cause a positive charge to accelerate and negative charge to decelerate, and vice-a-versa when electric field direction is changed. During all the above mentioned conditions, the charged particle is either accelerated or decelerated, due to which there is production of electromagnetic waves. We should understand that elementary charged particles have mass of the order of 10^{-28} kg or less. Therefore, even small electric or magnetic force is capable to generate very high acceleration of the order of 10^{12} m/s^2 or more.

4) Acceleration by Magnetic Field
There is a distinction for magnetic field as acceleration due to magnetic field relates only to the change of direction of motion. Magnetic force applied by the magnetic field is always normal to the velocity of the particle and therefore the particle tends to move about a circular trajectory. No work is done, therefore particle's kinetic energy remains constant, and also there is no associated change in speed of charged particle. This is typical uniform circular motion. The force exerted on charged particle by magnetic field is also given by Lorentz Force Equation.

In all the above methods of charged particle acceleration for production of electromagnetic wave, it is mentioned how the electromagnetic wave is generated. However, which part of the charged particle is the electromagnetic wave is not described. Therefore, in the next section we are presenting a novel theory to fill-in the void present in our current understanding of electromagnetic wave generation.

3. Novel Theory for Generation of Electromagnetic Wave

The interpretation of field phenomena presents its own particular difficulties. The processes in space which are responsible for these phenomena are not directly observable. We can only infer these processes from observed effects. An attempt is being made for the same by trying to present a novel theory of electromagnetic wave generation.

The electron has three inherent properties, its electric charge, its intrinsic spin and its magnetic dipole moment [6]. All three are constant quantities. As electron has magnetic dipole moment, it can be considered as small bar magnet.

We know that, a bar magnet or permanent magnet has magnetic lines of force associated with it. These lines of force are present in the magnetic field, which is in turn present due to the dipole arrangement of the electrons in the permanent magnet. The lines of force are generally defined as an imaginary line which represents the strength and direction of a magnetic field at any point. As the lines of force and the magnetic field are present due electrons, the field around a permanent magnet is, in true sense, an electromagnetic field. Therefore, the lines of force are nothing but travel paths for the photons that are travelling at the speed of light, and photons are the carriers of electromagnetic force and thus the electromagnetic field [7] [8].

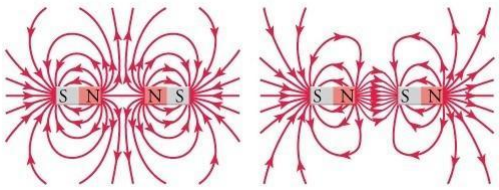

Figure 3: Interaction of magnetic lines of force

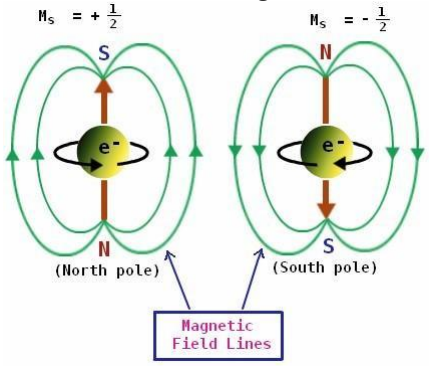

Figure 4: Lines of force due to electron's dipole moment

Fig 3 shows the permanent magnet and their associated lines of force, along with the interaction of lines of force of two permanent magnets. Considering electron as a small bar magnet Fig 4 shows the lines of force associated with it.

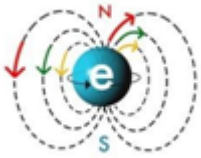

Figure 5: Electron moving at uniform velocity

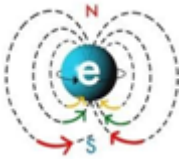

Figure 6: Electron after being accelerated by external field

Now imagine that the photons are continuously travelling along the lines of force, at the speed of light 'c', through the electron going outside from North Pole and received by the South Pole Fig [5]. Consider a case where an electron in moving with a uniform velocity, and suddenly it is accelerated by some external field, due to this sudden acceleration the photon that has already left the North Pole is not received by the South Pole Fig[6] and thus travels into the surrounding at the same speed i.e. the speed of light. This is our novel idea for generation of a photon or electromagnetic wave. Once this photon is emitted outside by electron, a new photon is originated from the electron which takes the path of the earlier photon. The various lines of force represent the energies of photons, the closer is the photon to the center of the charged particle it has higher frequency and possesses more energy, and the farther it is from the center of the charged particle it has lower frequency and less energy is possessed by it. Therefore the acceleration required for obtaining a higher energy wave nearer to the center will be more i.e. higher acceleration will be required to obtain a x-ray or gamma ray as compared to the acceleration required for obtaining radio or micro wave.

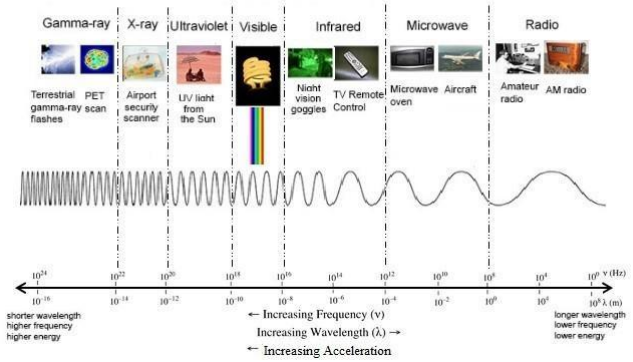

Figure 7: Electromagnetic Waves Spectrum

The absorption of electromagnetic wave according to this theory is similar to that of Compton Effect. In this an incident photon occupies the travel path of one of the photon, and as a result of this the photon in this path is emitted by the electron after some delay [9].

4. Conclusion

The novel theory presented in this paper innovatively states which part of the electromagnetic field, around a charged particle, is the electromagnetic wave. It is also able to present explanations about generation of different types of electromagnetic waves, their frequency, wavelength, and energy. Therefore, we conclude that this novel theory gives an exact description of the process of electromagnetic wave generation.

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