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Universal Law of Gravitation Compares with Electromagnetic Waves Propagation

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Abstract: *Sir Isaac Newton invented law of gravitation to ensure very theme the force of attraction between the particles and the reason of falling particles downwards. Later on same type of equation is developed by Coulomb for finding the force between electrically charged particles or magnetic poles. Simply this formula originated by Newton for calculating force of attraction or gravitation is called inverse-square law in which the force is inversely proportional to the square of the distance between the particles. This becomes universal law. Newton's law of gravitation deals with the potential and kinetic energy possessed by a particle due to gravity, considering mechanical forces. Electromagnetic waves in the electromagnetic spectrum consist of electric and magnetic energy which are significantly used in different fields such as communication, navigation, medical etc. Electromagnetic waves carry energy through air or space and ultimately supply this energy to an antenna. In this paper, working of electromagnetic waves is clearly studied and developed Friis free space equation. It is explained how electromagnetic energy creates voltage at the terminals of an antenna by spin alignment in the outermost shell unpaired electrons of the atoms in the antenna material. Finally it is proved that the equation for electrical power received by an antenna from electromagnetic waves energy resembles with the equation of law of universal gravitation. At last earth's magnetism is enlightened in a new way.*

Keywords: *Acceleration due to gravity, Coulomb's law, Earth's magnetism, Electromagnetic waves, Law of universal gravitation, Planck's equation, Received electrical power in an antenna, Theory of general relativity.*

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I. Newton's Law of Universal Gravitation

Universal law of gravitation states that every particle in the universe attracts every other particle with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers [1]-[2]. Sir Isaac Newton published this law in Philosophiae Naturalis Principia Mathematica on 5th July, 1687. Modern law of gravitation pronounces that every point mass attracts every other point mass by a force acting along the line intersecting the two points. The force is proportional to the product of the two masses, and inversely proportional to the square of the distance between them.

Thus the force of attraction (F) between two masses m_1 and m_2 separated by a distance of s is given by,

$F \propto \frac{m_1 \times m_2}{s^2}$ ....(1)

[$\propto$ indicates proportional to or varies as]

or, $F = G\frac{m_1 \times m_2}{s^2}$ ....(2)

G is called Constant of Gravitation.

If $m_1 = m_2 = 1$ gm, $s = 1$ cm, $G = 6.6576 \times 10^{-8}$ dyne.

If $m_1 = m_2 = 1$ kg, $s = 1$ meter, $G = 6.673 \times 10^{-11}$ newton meter^2/kg^2.

When one particle (m_1) is earth, i.e., $m_1 = M$ = mass of earth, then the center of the other particle having mass m is lying at a distance s from the center of earth, experience a force of gravitation, $F = G\frac{M \times m}{s^2}$

If this mass (m) falls with an acceleration (g) due to gravity, $F = mg$

Weight of the particle or body is mg and the potential energy is acquired by a body due to its position.

Thus the potential energy possessed by the particle at a height h from the surface of earth is E_{PE}, $E_{PE} = mgh$.

So, $mg = G\frac{M \times m}{s^2}$

or, $g = \frac{GM}{s^2}$

or, $g \propto \frac{1}{s^2}$ ....(3)

$g = 981$ cm/sec^2 = 32 ft/sec^2.

If v be the velocity of the particle having mass m falling at any moment downwards due to gravity, the kinetic energy acquired by the particle at that moment is E_{KE}, $E_{KE} = \frac{1}{2}\, mv^2$.

Therefore, acceleration due to gravity (g) is less at hill and below earth (mines) than that of the surface of earth, more at the poles than that of the equator, and $g = 0$ at the center of earth. This equation identifies the potential energy and kinetic energy possessed by a falling particle at any time due to gravity.

Thus earth gravitation (gravity) causes bodies to fall to earth with a uniform acceleration, but the magnitude of the acceleration due to gravity varies with geographical location and altitude.

Newton's law of gravitation is similar to Coulomb's law of electrical and magnetic forces invented by scientist Charles de Coulomb, which are used to calculate the magnitude of the electrical force between electrically charged particles or the magnetic force between two magnet poles. All satisfies the inverse-square law, where the force is inversely proportional to the square of the distance between the bodies or particles.

Since Newton's law of gravitation has been superseded by Albert Einstein in his theory of general relativity, but it continues to be used as an excellent approximation of the effects of gravity in most applications. Relativity is required only when there is a need for extreme accuracy, or when dealing with strong gravitational fields, such as those found near extremely massive and dense objects or at very close distances to star or planet.

II. Electromagnetic Waves Generation and Its Characteristics

When an electron beam is subjected to pass through an accelerating voltage V, the Kinetic Energy of electrons (called photons) be, KE = $eV = \frac{1}{2} m_0 v^2$ ....(4)

where e = electron charge = 1.6021×10^{-19} C,

V = accelerating voltage, m_0 = electron rest mass = 9.1085×10^{-31} kg,

v = velocity of electrons or photons.

In case of electromagnetic waves, v = speed of light (c) = 2.9979×10^8 meter/sec or 1,86,000 mile/sec.

Therefore, Kinetic Energy of electromagnetic waves, KE = $\frac{1}{2} m_0 c^2$

When a current flows through a conductor, a magnetic field exits perpendicular to the flow of current. Thus a changing magnetic field will induce a changing electric field and vice versa. When an electron beam is subjected to accelerate or oscillate under electric and magnetic fields acting perpendicularly, electromagnetic waves (formed by photons) are generated and propagate through air, space, solid materials etc. with the speed of light at right angles to the electric and magnetic fields, i.e., forming a transverse wave [3]-[9]. Scientist Max Planck describes that electromagnetic waves are consisting of chunks of photons known as quanta, and energy of electromagnetic waves (E) or photons is expressed as Planck-Einstein relation, popularly known Planck's Equation, $E = hf$ ....(5)

where h is Planck's constant, $h = 6.626 \times 10^{-34}$ Joule-seconds, and f represents the frequency of electromagnetic waves (signal) in Hz, E is in joules. Scientist Louis de Broglie expressed in 1924 that electrons or photons exhibit wave-particle duality which is strongly supported by famous scientist Albert Einstein. An electromagnetic wave within the electromagnetic spectrum can be characterized by either its frequency of oscillations (f) or its wavelength (λ), and the range is mentioned below.

f = 3 Hz ~ 10^{24} Hz, $\lambda = 10^8$ m ~ 10^{-16} m, $E = hf$ = 12.4 feV ~ 124 keV.

Thus electromagnetic (EM) waves include radio waves, microwaves, infrared, visible light, ultraviolet rays, X-rays and gamma rays as increasing frequency order. Microwaves frequencies and wavelengths are lying between 300 MHz (1m) ~ 300 GHz (1 mm), extended up to 600 GHz (0.5 mm). Electromagnetic waves carry energy, momentum and angular momentum away from their source particle and can impart those quantities to matter which they interact [3]-[9].

III. Electromagnetic Waves Transfer Energy To Antenna

An antenna is a device through which electromagnetic energy having certain frequency is coupled from the transmitter to the outside-world (air), also, to the receiver from the outside-world (air). Thus the antenna is capable of converting high frequency currents into electromagnetic waves and vice versa.

These electromagnetic (EM) waves (generally radio waves and microwaves) are impinged and reflected by the receiver antenna. These high energy photons with the speed of light as EM waves make spin alignment clockwise (as shown in Fig. 1) or anticlockwise (as shown in Fig. 2) to the outermost shell unpaired electrons of the atoms in the antenna material like modern scientific theory of magnetism. These clockwise or anticlockwise unfilled electrons spin develop a voltage at the terminals of the antenna rods [3]-[9].

If the antenna material is manufactured by iron, then the interaction of high energy photons (electromagnetic waves) on the iron atoms are explained below.

The electronic configuration of iron, Fe^{26} = [Ar] $3d^6 4s^2$. Electronic structure of Argon is $Ar^{18} = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. It is proved that the electrons in outer orbits of an atom having parallel unpaired spin repel each other, and exhibit magnetic and electric property. In iron, outermost d shell unfilled four electrons spin are arranged following two ways:

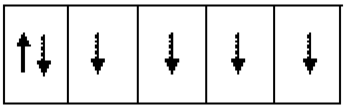

Figure 1. Iron unfilled electrons spin d sub-shell- clockwise.

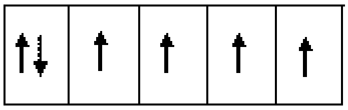

Figure 2. Iron unfilled electrons spin d sub-shell- anticlockwise.

Due to this effect, voltage in microvolt (μV) range is developed in the antenna terminals with an alternate polarity (ac nature) for each half wavelength of the EM waves (radio waves or microwaves). The amplitude of voltage induced in the antenna terminals directly proportional to the energy of EM waves, i.e., the frequency of EM waves (signal). The high energetic photons of the electromagnetic waves are repelled or reflected by the outermost shell electrons of the atoms resting in the antenna material. If the reflection coefficient (ρ) of the antenna material is one, i.e., ρ = 1, the EM waves are totally reflected; otherwise some portion of the EM waves will be absorbed in the antenna material. Thus reflection coefficient describes how much of an electromagnetic waves are reflected by an impedance discontinuity in the transmission medium. It is measured to the ratio of the amplitude of the reflected EM waves to the incident EM waves.

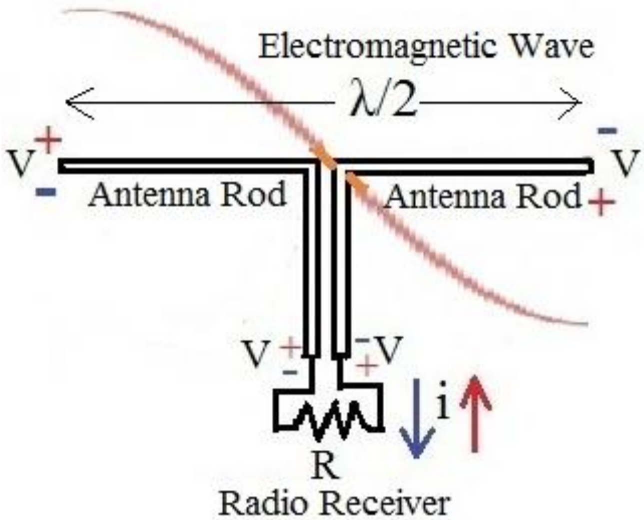

Figure 3. Half wave dipole antenna.

Half wave dipole antenna receives electromagnetic waves (radio waves or microwaves) with high energy as shown in Fig. 3. The antenna consists of two metal rods connected to a receiver R. The electric field or energy (E) of the incoming EM waves makes alignment the outermost shell electrons of the atoms in the antenna rods clockwise in positive half wave length and anticlockwise in the negative half wavelength, as a result alternately positive (+) and negative (−) voltages develop in the antenna rods. Since the terminals of the antenna are connected to the receiver R, current i flows through the receiver, but changes its direction after every half wave length of the EM waves. Thus the oscillating field induces standing waves of voltage (V) and current (i) in the antenna rods. Hence we compute the power received or induced in the antenna by the incoming electromagnetic waves energy or power. Antenna factor is calculated by the equation,

Antenna Factor = $\frac{E}{V}$ 1/meter ....(6)

Where E = Electric field strength in V/m or μV/m.

V = Voltage developed in the antenna in V or μV.

Voltage developed in the antenna in few microvolts (μV), depends on field strength or frequency of the electromagnetic waves (signal), the antenna impedance or gain and the resonance of the antenna at the frequency of the EM waves (signal).

In case of dipole antenna, the length of the antenna is taken half of the wavelength of the EM waves (radio waves or microwaves) to have the maximum power, because at the end of each half wavelength of the

EM waves, voltage polarity at the terminals of the dipole is changed like ac voltage. If the length of the dipole antenna is taken less than that of the half wavelength of the EM waves, some parts of the EM waves do not fall in the antenna material, as a result some energy of the EM waves are wasted. The radiation pattern of the half wave dipole is maximum perpendicular to the conductor, falling to zero in the axial direction, thus implementing an omnidirectional antenna if installed vertically or weakly directional antenna if horizontal.

IV. Received Electromagnetic Energy in an Antenna

There are two types of antennas [4]-[9].

(i) Omnidirectional or Isotropic antenna: In this antenna, EM waves (radio waves or microwaves) having certain frequency energy signals are transmitted in all directions, e.g., Dipole antenna, Horizontal loop antenna, Whip antenna, Discone antenna.

(ii) Directional or Non-isotropic antenna or Panel antenna: These antennas are used to concentrate the signal both vertically and in a specific horizontal sector and they have a high gain, e.g., Yagi antenna, Parabolic reflector or Dish antenna, Patch array antenna, MIMO (Multiple Input Multiple Output) antenna, Magnetic polarization antenna and Phased array antenna.

Calculation of Electrical Power Received in an Antenna from Electromagnetic Waves Energy:

(a) Isotropic Antenna: An isotropic antenna (radiator) radiates energy (electromagnetic waves) equally in all directions, i.e., an ideal antenna, but practically isotropic antenna cannot be physically manufactured. If P_t (in watts) be the average power radiated equally in all direction (isotropically) at the transmitting antenna, the EM waves (radio waves or microwaves) will spread out spherically as it travels away from the source. So, at a distance d (in meters) from the isotropic transmitter, the power at a distance d is P_d (in watts/m^2), which is the power per unit area of the EM waves front,

$$P_d = \frac{P_t}{4\pi d^2} \qquad \text{..............................(7)}$$

[Since $4\pi d^2$ is the surface area of the sphere of radius d centred on the source.]

Thus the power density varies inversely as the square of the distance from a point source, and it is familiar to the inverse-square law that governs the propagation of electromagnetic waves in free space.

(b) Non-Isotropic Antenna: A non-isotropic antenna has not the unit gain in the transmit and receive mode. A non-isotropic transmit antenna will have a gain of G_t and its effective isotropic radiated power (EIRP) indicates the maximum radiated power is available in the direction of maximum antenna gain, EIRP = $P_t \times G_t$ (in watts), where P_t (in watts) is the power radiated at the transmitting antenna in the direction of gain G_t. In practice, effective radiated power (ERP) is used instead of EIRP to denote maximum radiated power. For dipole (having length half wave length of the EM waves) antenna has a gain of 1.64, ERP is 2.15 dB smaller than the EIRP for the same transmission system. Thus for a non-isotropic transmitter, the power at a distance d is P_d,

$$P_d = \frac{P_t\, G_t}{4\pi d^2} \qquad \text{.......................(8)}$$

If the power received by a non-isotropic antenna placed in these EM waves field is $P_r(d)$ [in watts], i.e., power delivered by the receiving antenna to the receiver,

$$P_r(d) = P_d \times A_e \times G_r \qquad \text{.....................(9)}$$

where G_r is the received antenna gain, A_e is known as the effective aperture of the receiving antenna. It is the equivalent to power absorbing area of the isotropic antenna which is related to the physical size of the antenna. Effective aperture of an isotropic antenna is,

$$A_e = \frac{\lambda^2}{4\pi} \qquad \text{.........................(10)}$$

where λ is the wavelength of the EM waves (signal) and it is related to the EM waves frequency f or ω_c,

$\lambda = \frac{c}{f} = \frac{2\pi c}{\omega_c}$, where f is the frequency in hertz, ω_c is the frequency in radians per sec,

c is the velocity of light, $c = 2.9979 \times 10^8$ meter/sec. From equations (8), (9) and (10), we have,

$$P_r(d) = \frac{P_d\, G_r\, \lambda^2}{4\pi} = \frac{P_t\, G_t\, G_r\, \lambda^2}{(4\pi)^2 d^2}$$

If L is the system loss factor which is not related to EM waves propagation, and $L \geq 1$,

then, $$P_r(d) = \frac{P_t\, G_t\, G_r\, \lambda^2}{(4\pi)^2 d^2 L} \qquad \text{..........................(11)}$$

The above equation was invented by radio engineer of Bell Laboratories, Harald Trap Friis in 1946. The equation is called the *Friis free space equation*, i.e., the free space power (where unobstructed line-of-sight path available) received by a receiver antenna which is separated from a transmitter antenna by a distance d.

The miscellaneous losses or system losses L ($L \geq 1$) are usually due to transmission line attenuation, filter losses and antenna losses in the communication system. When L = 1, then no losses occur in the system hardware. The Friis free space equation shows that received power [P_r (d)] falls off as the square of the transmitter-receiver separation distance [d], hence it identifies the inverse-square law.

For simplicity, we can consider, $G_t = G_r = L = 1$, then equation (11) turns to,

$P_r(d) = \frac{P_t \lambda^2}{(4\pi)^2 d^2} = \frac{1}{(4\pi)^2} \frac{P_t \lambda^2}{d^2}$

So, $P_r(d) \propto \frac{P_t \lambda^2}{d^2}$ ....(12)

V. Similarities between Universal Law of Gravitation and Electromagnetic Waves Energy Propagation

The above equation (12) for received electromagnetic energy by an antenna at a distance d from the transmitter antenna resembles with law of universal gravitation equation (1), here P_t is the power transmitted by the electromagnetic waves (generally radio waves or microwaves) at the transmitter antenna, (similar to the mass of one particle), λ is the wavelength of electromagnetic waves which ultimately specifies the length of the antenna, and λ^2 indicates the area or aperture of the receiver antenna, i.e., total atoms lying in the antenna material on which the electromagnetic waves interacting (similar to the mass of another particle), and both the equations obey the inverse-square law [1]-[9]. In case of Newton's law of universal gravitation, the force of attraction between two particles or falling of a particle towards earth due to gravity, i.e., mechanical force to a particular direction evolves, whereas electrical and magnetic energy carrying by electromagnetic waves thrust the outermost shell unpaired electrons of the atoms in the antenna material for setting clockwise or anticlockwise to develop electrical energy (voltage) at antenna terminals. In this world all kinds of materials such as building, structure, land, water, earth, living and non-living animals including human beings act as antenna to electromagnetic waves.

VI. Cause of Earth's Magnetism

The present belief of existing molten or solid iron and magnetic materials below the surface of earth causing earth magnetism is not correct. It can be concluded from above discussion that earth's magnetism is existing due to continuous bombardment of cosmic rays, ultraviolet rays and electromagnetic waves on the earth surface, as a result the outermost shell unpaired electrons of the atoms in earth materials spin clockwise and anticlockwise, finally it builds up north and south magnetic poles inclined at the earth north and south poles respectively. Although earth's magnetic field above the ionosphere deflects the solar wind composed of cosmic rays, high energy charged particles, ultraviolet rays etc., but formation of earth's magnet is caused due to those rays only.

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