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Research Article

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Prove That the Half Retarded and Half Advanced Electromagnetic Theory is Equivalent to Maxwell's Classical Electromagnetic Theory

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Abstract

Dirac, Wheeler Feynman, and Cramer proposed the electromagnetic theory idea of current element generating half retarded wave and half advanced wave. The author further refined this idea. Proposed the laws of mutual energy flow and conservation of energy. And thus established a new set of electromagnetic theories. For calculating electromagnetic wave radiation of current elements, Maxwell's electromagnetic theory requires electromagnetic radiation to meet the boundary conditions of Sliver Müller. In the author's new theory, this boundary condition is replaced by the charge of the absorber covering the infinite sphere. The author assumes that these absorbers are sinks and will generate advanced waves. The radiation of the current element is a retarded wave. This retatarded wave and advanced wave form a mutual energy flow. The author believes that these mutual energy flows are photons. The sum of the energy of countless photons is the macroscopic electromagnetic radiation of the current element. This radiation should be consistent with the Poynting energy flow in classical electromagnetic theory. If the two are indeed consistent, it indicates that the two theories of electromagnetic radiation are equivalent. The author proves that the two theories are indeed equivalent. In this proof, the author also addresses an inherent loophole in Poynting's theorem. In addition, the author found that due to the introduction of sinks, both the field and potential must be compressed to the original %50. This corresponds precisely to the current generating either a %50 retarded wave or a %50 advanced wave. In this way, the author's electromagnetic theory can be seen as the lower level electromagnetic theory of Maxwell's electromagnetic theory. This macroscopic electromagnetic wave is composed of countless photons. Photons are mutual energy flows, which are composed of retarded waves emitted by the source and advanced waves emitted by the sink.

Keywords: Photons, Conservation of Energy, Poynting; Maxwell, Wheeler, Feynman; Dirac, Cramer, Electromagnetic Waves, Electromagnetic Field, Retarded Wave, Retarded Potential, Advanced Wave, Advanced Potential, Magnetic Field, Electric Field, Absorber, Source, Sink, Antenna, Dipose

I. Introduction

In 1938, Dirac proposed a scheme for electromagnetic radiation to solve the self source problem, which included half retarded wave and half advanced wave [1]. In 1945, Wheeler Feynman further developed this concept into the absorber theory [2,3]. Another starting point of absorber theory is the principle of action-at-a-distance[4-6]. In 1986, Cramer proposed a quantum mechanical transactional interpretation based on the absorber theory [7,8]. The transactional interpretation suggests that the source will emit a retarded wave, which is an offer wave. The sink will emit advanced waves, which are confirmation waves. On the connection between the source and sink, the retarded wave and the advanced wave are superimposed. Outside this connection, the retarded wave and advanced wave will cancel each other out. This creates a photon between the source and sink. In addition, Stephen's advanced wave theory also had a significant impact on the author [9].

On the other hand, Welch proposed its time-domain reciprocity theorem in 1960 [10]. This time-domain reciprocity theorem considers both retarded and advanced waves. The author proposed the mutual energy theorem in 1987 [11-13]. And propose the concept of the inner product of two electromagnetic fields. De Hoop proposed the reciprocity theorem for cross correlation in late 1987 [14]. Welch's timedomain reciprocity theorem and De Hoop's cross correlation reciprocity theorem can be transformed into mutual energy theorem through Fourier transform. Therefore,Welch's timedomain reciprocity theorem and De Hoop's cross correlation reciprocity theorem and mutual energy theorem can be regarded as one theorem. Everyone has different understandings of this theorem, and when we call it the reciprocity theorem, we position it as a mathematical formula. It's not a physical formula. When we call it the energy theorem, we naturally consider it a physical theorem, not just a mathematical theorem. Following the author's viewpoint, these three theorems can be collectively referred to as the mutual energy theorem.

In 2017, the author proposed the mutual energy flow theorem based on the absorber theory, quantum mechanics transactional interpretation, and the author's proposed mutual energy theorem. Mutual energy flow is the inner product of two electromagnetic fields proposed by the author in 1987 [11-13]. The author further believes that the mutual energy theorem is actually a law of conservation of energy. Combining the concept of mutual energy flow mentioned above, the mutual energy theorem becomes a localized law of energy conservation. The author found that the energy conservation law cannot be derived from Maxwell's equation, and it can only be derived one step back to obtain an energy theorem. This indicates that Maxwell's electromagnetic theory and this law of energy conservation are contradictory.

In order to solve this contradiction, the author has proposed various solutions, including the self energy collapse scheme and self energy flow are reactive-power scheme [15-27]. This constitutes a new electromagnetic theory.

The author's theory suggests that the source will generate retarded waves and the sink will generate advanced waves. The retarded wave and advanced wave form a mutual energy flow. The mutual energy flow is a photon. The common effect of countless mutual energy flows is macroscopic electromagnetic waves.

This article attempts to prove that although the electromagnetic theory proposed by the author differs greatly from Maxwell's electromagnetic theory, the electromagnetic radiations of the antenna in the far field obtained by both theoretical methods are almost the same. Therefore, the two theories are equivalent at the level of macroscopic electromagnetic waves.

The contribution of this article (1) provides the underlying reasons for the law of conservation of energy and the law of radiation does not overflow the universe. This reason is that there is no ether. Electromagnetic field theory should not rely on ether. The correct theory is the interaction and reaction between charges, i.e. the action at a distance. (2) A new boundary condition for solving electromagnetic field problems has been proposed, which states that the retarded and advanced waves of the electromagnetic field on the surface of the current cannot cancel each other, but should be enhanced by superposition. (3) Emphasize that electromagnetic field theory should be a retarded field rather than a retarded potential. (4) Due to the fact that not only the source of light generates energy flow, but also the sink generates energy flow, the energy flow will double. To solve this problem, there are two solutions. The first is to compress the amplitude of the retarded wave and the advanced wave by% 50. In this way, the current element generates either a half retarded wave or a half advanced wave. The second is to compress the mutual energy flow by% 50. (5) Macroscopic electromagnetic waves are composed of photons. Photons are composed of mutual energy flows. The mutual energy flow is composed of retarded waves and advanced waves. The mutual energy flow is generated at the source and annihilated at the sink. The retarded wave and advanced wave interfere with each other to form a photonic waveguide. Photon energy is transferred from the source to the sink through a photonic waveguide. Both retarded and advanced waves in photonic waveguides are quasi-plane waves.

II. Maxwell's Electromagnetic Theory

1. Magnetic Quasistatic Maxwell Equation

The Maxwell equation, which does not include displacement current in Ampere's circuital law, is the Maxwell equation under magnetic quasi-static conditions,

$$\nabla \cdot \boldsymbol{D} = \frac{\rho}{\epsilon_0} \tag{1}$$

$$\nabla \cdot \boldsymbol{B} = 0 \tag{2}$$

$$\nabla \times \boldsymbol{E} = -\frac{\partial}{\partial t}\boldsymbol{B} \tag{3}$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J} \tag{4}$$

Where $\boldsymbol{D} = \epsilon_0 \boldsymbol{E}$, $\boldsymbol{B} = \mu_0 \boldsymbol{H}$. $\boldsymbol{J}, \rho$ is the current and the charge intensity. The solution obtained from this equation is for non retarded waves and non advanced electromagnetic fields,

$$\boldsymbol{E} = -\nabla\phi - \frac{\partial}{\partial t}\boldsymbol{A}, \quad \boldsymbol{B} = \nabla \times \boldsymbol{A} \tag{5}$$

$$\boldsymbol{A} = \frac{\mu_0}{4\pi}\int_V \frac{\boldsymbol{J}}{r} dV, \quad \phi = \frac{1}{4\pi\epsilon_0}\int_V \frac{\rho}{r} dV \tag{6}$$

2. Maxwell's Equation

If the Ampere's circuital law includes displacement current, for example,

$$\nabla \cdot \boldsymbol{d} = \frac{\rho}{\epsilon_0} \tag{7}$$

$$\nabla \cdot \boldsymbol{b} = 0 \tag{8}$$

$$\nabla \times \boldsymbol{e} = -\frac{\partial}{\partial t}\boldsymbol{b} \tag{9}$$

$$\nabla \times \boldsymbol{h} = \boldsymbol{J} + \frac{\partial}{\partial t}\boldsymbol{d} \tag{10}$$

The equation (7-10) constitutes the Maxwell equation. Note that we use capital letters for the electric and magnetic fields in the equations of magnetic quasi-static electric field and magnetic field. This is consistent with the symbols we usually use. But in Maxwell's equation, we use lowercase letters for electric and magnetic fields. This is to inform readers that there is a significant difference between the solution of Maxwell's equation being a delayed wave solution and a solution under quasi-static conditions. Distinguishing them is beneficial for distinguishing the two concepts. Therefore, there are,

$$\boldsymbol{e} = -\nabla\phi^{(r)} - \frac{\partial}{\partial t}\boldsymbol{A}^{(r)}, \quad \boldsymbol{h} = \frac{1}{\mu_0}\nabla \times \boldsymbol{A}^{(r)} \tag{11}$$

$$\boldsymbol{A}^{(r)} = \frac{\mu_0}{4\pi}\int_V \frac{[\boldsymbol{J}]}{r} dV, \quad \phi^{(r)} = \frac{1}{4\pi\epsilon_0}\int_V \frac{[\rho]}{r} dV \tag{12}$$

The square brackets indicate retardation, so there is,

$$[f] = f(t - r/c) \tag{13}$$

$r = |\boldsymbol{x} - \boldsymbol{x}'|$, c is the speed of light. x is the field point. x' is the source point.

3. Poynting's Theorem

Firstly, derive Poynting's theorem under magnetic quasistatic conditions,

$$\nabla \cdot \boldsymbol{E} \times \boldsymbol{H} = \nabla \times \boldsymbol{E} \cdot \boldsymbol{H} - \boldsymbol{E} \cdot \nabla \times \boldsymbol{H}$$
$$= (-\frac{\partial}{\partial t}\boldsymbol{B}) \cdot \boldsymbol{H} - \boldsymbol{E} \cdot (\boldsymbol{J}) \tag{14}$$

$$-\nabla \cdot \boldsymbol{E} \times \boldsymbol{H} = \boldsymbol{E} \cdot \boldsymbol{J} + \boldsymbol{H} \cdot \frac{\partial}{\partial t}\boldsymbol{B} \tag{15}$$

Or

$$-\oiint_\Gamma (\boldsymbol{E} \times \boldsymbol{H}) \cdot \hat{n} d\Gamma = \int_V (\boldsymbol{E} \cdot \boldsymbol{J} + \boldsymbol{H} \cdot \frac{\partial}{\partial t}\boldsymbol{B}) dV \tag{16}$$

Considering time integration,

$$\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{H} \cdot \frac{\partial}{\partial t}\boldsymbol{B}) dV = \int_{t=-\infty}^{\infty} dt \frac{\partial}{\partial t} U$$
$$= U(\infty) - U(-\infty) = 0 \tag{17}$$

$U(\infty)$ is the system energy at the end of the process. $U(-\infty)$ is the system energy at which the process has not started. These two energies are zero. Where U corresponds to,

$$U = \frac{1}{2}\int_V \boldsymbol{H} \cdot \boldsymbol{B} dV$$

Perform time integration on formula (16) to obtain

$$-\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{E} \times \boldsymbol{H}) \cdot \hat{n} d\Gamma = \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E} \cdot \boldsymbol{J}) dV \tag{19}$$

Compared with Poynting's theorem (16), this formula eliminates the energy term due to the addition of a time integral. The equation is equivalent to going through a relaxation process. This relaxation process makes (19) not as strict as formula (16). If the electromagnetic field satisfies the formula (16), it can definitely satisfy the formula (19). However, electromagnetic fields that satisfy the formula (19) may not necessarily satisfy the formula (16). So we say (19) is more relaxed than (16).

Corresponding to Maxwell's equation, there is also a relaxed Poynting's theorem,

$$-\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{e} \times \boldsymbol{h}) \cdot \hat{n} d\Gamma = \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e} \cdot \boldsymbol{J}) dV \tag{20}$$

III. Mutual Energy Flow

1. Superposition Principle

Consider having N current elements in region V J_i, $i = 1$ N, the corresponding electromagnetic field is $[E_i, H_i]^T$. T is matrix transpose. The principle of superposition in this way,

$$\boldsymbol{J} = \sum_{i=1}^{N} \boldsymbol{J}_i, \quad \boldsymbol{E} = \sum_{i=1}^{N} \boldsymbol{E}_i, \quad \boldsymbol{H} = \sum_{i=1}^{N} \boldsymbol{H}_i \tag{21}$$

established. Substituting the above superposition principle into the relaxed Poynting's theorem (19) yields,

$$-\sum_{i=1}^{N}\sum_{j=1}^{N} \int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_j) \cdot \hat{n} d\Gamma$$
$$= \sum_{i=1}^{N}\sum_{j=1}^{N} \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i \cdot \boldsymbol{J}_j) dV \tag{22}$$

This Poynting's theorem formula can be broken down into two formulas,

$$-\sum_{i=1}^{N}\sum_{j=1, j\neq i}^{N} \int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_j) \cdot \hat{n} d\Gamma$$
$$= \sum_{i=1}^{N}\sum_{j=1}^{N} \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i \cdot \boldsymbol{J}_j) dV \tag{23}$$

$$-\sum_{i=1}^{N} \int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_i) \cdot \hat{n} d\Gamma$$
$$= \sum_{i=1}^{N} \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i \cdot \boldsymbol{J}_i) dV \tag{24}$$

(23) are all mutual energy terms, and (24) are all self energy terms.

2. Energy Conservation Law Under Magnetic Quasi-Static Conditions

Under quasi-static magnetic conditions, both electric and magnetic fields decay with distance to the second power,

$$\boldsymbol{E}_i \sim \frac{1}{r^2}, \boldsymbol{H}_i \sim \frac{1}{r^2}$$

"$\sim$" means proportional. Assuming the radius of sphere Γ is R. We have,

$$\lim_{R\to\infty} \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_i) \cdot \hat{n} d\Gamma \sim \lim_{R\to\infty} \frac{1}{R^2}\frac{1}{R^2} R^2 = 0 \tag{25}$$

$$\lim_{R\to\infty} \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_j) \cdot \hat{n} d\Gamma \sim \lim_{R\to\infty} \frac{1}{R^2}\frac{1}{R^2} R^2 = 0 \tag{26}$$

in addition

$$\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i \cdot \boldsymbol{J}_i) dV \Longleftrightarrow \Re \int_V (\boldsymbol{E}_i \cdot \boldsymbol{J}_i^*) dV \tag{27}$$

is the Fourier transform. "$*$" is a complex conjugate. The symbol "$\Re$" is the real part.

$$\int_V (\boldsymbol{E} \cdot \boldsymbol{J}^*) dV \to \int_C \boldsymbol{E} \cdot d\boldsymbol{l} I^* = \mathcal{E} I^* \tag{28}$$

We know

$$\mathcal{E} \triangleq \int_C \boldsymbol{E} \cdot d\boldsymbol{l} = -\frac{\partial}{\partial t}(MI) = -j\omega MI \tag{29}$$

The symbol $\triangleq$, defines what it means. So there is,

$$\mathcal{E}I^* = -j\omega MII^* \tag{30}$$

$$\Re\int_V (\boldsymbol{E}\cdot\boldsymbol{J}^*)dV = \Re(\mathcal{E}I^*) = 0 \tag{31}$$

Add back the subscript *i* to obtain,

$$\Re\int_V (\boldsymbol{E}_i\cdot\boldsymbol{J}_i^*)dV = 0 \tag{32}$$

Returning to the time domain to obtain,

$$\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i\cdot\boldsymbol{J}_i)dV = 0 \tag{33}$$

Substitute the formulas (33,25,26) into (23,24), and we obtain the law of conservation of energy,

$$\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i\cdot\boldsymbol{J}_j)dV = 0 \tag{34}$$

3. Failure of Energy Conservation Law Under Maxwell's Equation Conditions

Under the conditions of Maxwell's equation, Poynting's theorem (20) can be obtained, which is exactly the same as the magnetic quasi-static equation,

$$-\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{e}\times\boldsymbol{h})\cdot\hat{n}d\Gamma = \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}\cdot\boldsymbol{J})dV \tag{35}$$

Considering the principle of superposition, it is also obtained that,

$$\begin{aligned}&-\sum_{i=1}^{N}\sum_{j=1}^{N}\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{e}_i\times\boldsymbol{h}_j)\cdot\hat{n}d\Gamma\\ &=\sum_{i=1}^{N}\sum_{j=1}^{N}\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_i\cdot\boldsymbol{J}_j)dV\end{aligned} \tag{36}$$

Split the above equation into two formulas,

$$\begin{aligned}&-\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{e}_i\times\boldsymbol{h}_j)\cdot\hat{n}d\Gamma\\ &=\sum_{i=1}^{N}\sum_{j=1}^{N}\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_i\cdot\boldsymbol{J}_j)dV\end{aligned} \tag{37}$$

$$-\sum_{i=1}^{N}\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{e}_i\times\boldsymbol{h}_i)\cdot\hat{n}d\Gamma = \sum_{i=1}^{N}\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_i\cdot\boldsymbol{J}_i)dV \tag{38}$$

We split the formula (36) into two formulas just for convenience. In fact, the sum of the two equations is still (36). If we can prove that each of the following items is zero.

$$\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{e}_i\times\boldsymbol{h}_j)\cdot\hat{n}d\Gamma = 0 \tag{39}$$

$$\sum_{i=1}^{N}\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{e}_i\times\boldsymbol{h}_i)\cdot\hat{n}d\Gamma = 0 \tag{40}$$

$$\sum_{i=1}^{N}\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_i\cdot\boldsymbol{J}_i)dV = 0 \tag{41}$$

We have proven the law of conservation of energy,

$$\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_i\cdot\boldsymbol{J}_j)dV = 0 \tag{42}$$

However, from classical electromagnetic theory, we know that the Poynting energy flow of the far-field radiation of the antenna is not zero, that is,

$$\oiint_\Gamma (\boldsymbol{e}_i\times\boldsymbol{h}_i)\cdot\hat{n}d\Gamma \neq 0 \tag{43}$$

From this we cannot obtain (40), and further we cannot prove the law of conservation of energy (42). But we can still take a step back and prove that (42) is an energy theorem. Subtract (38) from (36) to obtain (37). Because (36) and (38) are both some form of Poynting's theorem. Both are energy theorems, so (37) is also an energy theorem. Considering that we can prove (39), by substituting (39) into (37) we obtain (42). So (42) is the energy theorem. The author referred to it as the mutual energy theorem in 1987 [9, 29, 30].

Below we prove (39). This is because if $[e_i, h_i]^T$, $[e_j, h_j]^T$ one is the retarded wave and the other is the advanced wave. Here, T is the matrix transposition, where one reaches the surface Γ at a certain time in the past and the other reaches the surface Γ at a certain time in the future. Therefore, they do not reach the surface Γ at the same time. So they always have a zero on the surface Γ . Therefore, the left side of equation (39) is zero. Proof completed.

4. Mutual Energy Theorem

Therefore, although we cannot prove from the Maxwell equation that (42) is a law of conservation of energy, we can still take a step back and prove that it is an energy theorem. If $N = 2$, (42) is transformed into,

$$-\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_2 \cdot \boldsymbol{J}_1) dV = \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_1 \cdot \boldsymbol{J}_2) dV \tag{44}$$

The above equation is the time-domain reciprocity theorem proposed byWelch in 1960 [28]. If transformed to the Fourier frequency domain we obtain,

$$-\int_V (\boldsymbol{e}_2^* \cdot \boldsymbol{J}_1) dV = \int_V (\boldsymbol{e}_1 \cdot \boldsymbol{J}_2^*) dV \tag{45}$$

The above equation is the mutual energy theorem proposed by the author in 1987 [11-13]. (45, 44, 42) is the energy theorem under Maxwell's equation, and is the law of conservation of energy under the magnetic quasi-static condition.

It is worth mentioning that the formula (34, 42) holds if the surface Γ surrounds all current elements, and we take the surface Γ as an infinite sphere for this purpose. If there are some sources $\boldsymbol{J}_i$ does not within the surface Γ. The formula (34,42) generally does not hold. But the formula (23,37) is still the energy theorem. It can be seen as a generalized theorem of mutual energy. Formula (23) is the law of conservation of energy under magnetic quasi-static conditions, which is even stronger.

It is worth mentioning that the formula (45) has been discovered multiple times in history, including Rumsey's new reciprocity theorem in 1963] and Petrusenko's missing reciprocity theorem in 2009 [28,29]. Everyone positions the formula (45) as the reciprocity theorem. The reciprocity theorem is a mathematical theorem. Only the author believes that this theorem is the energy theorem. In 2015, the author restudied this formula and discovered this issue. The author first asks himself whether this theorem is the energy theorem or the reciprocity theorem? If we prove this theorem from Maxwell's equation, we cannot guarantee that it is an energy theorem. It is important to prove this theorem from Poynting's theorem, as it is accepted that Poynting's theorem is an energy theorem. Therefore, the sub-theorems of Poynting's theorem can be regarded as energy theorems. The proof of the formula (42) in this chapter is based on Poynting's theorem. Therefore (42) is indeed the energy theorem.

But why do we say that under the conditions of Maxwell's equation, the formula (42) is not a law of conservation of energy? The law of conservation of energy includes the amount of energy used. Under the conditions of Maxwell's equation, the formula (43) holds, indicating that the left side of the formula (42) does not include all energy, and energy is leaked out through the formula (43). So the formula (42) is not the law of conservation of energy.

It is worth mentioning that the formula (42) is actually the law of energy conservation. The inability to prove this energy law from Maxwell's equation is a loophole in Maxwell's electromagnetic theory! Essentially, Maxwell's electromagnetic theory is an ether theory. After the negation of the ether, everyone no longer mentions it. However, the ether reappeared as a field. We now say that Maxwell's electromagnetic theory is a theory of fields. The source or current element first transfers the energy of electromagnetic waves to the ether or so-called "field", and then the field transfers the energy to the sink or other current element. If the energy in the ether or field does not later encounter other sinks or current elements, this energy will continue to be transmitted in the ether or field. This leads to the formula (43). This is just like the energy of sound waves can be transmitted to infinity in the air medium.

However, the working principle of electromagnetic phenomena may not comply with the theory of ether or field! Electromagnetic phenomena may be the interaction between charge or current elements. The disturbance of current element $\boldsymbol{J}_A$ is directly applied to another current element $\boldsymbol{J}_B$. There is no need for ether or field as the medium. If so, the action can only occur between two charges. If we take N very large and include the current elements of the entire universe, the formula (42) includes all the energy. So the formula (42) must be the law of conservation of energy. In history, Maxwell Faraday supported the theory of the ether. But many of Maxwell's contemporaries supported the theory of action-at-a-distance. This includes Ampere, Weber, Neumnan, Kirchhoff, Lorenz, and others. Wheeler Feynman's absorber theory is also a theory of action-at-a-distance. Everyone is constantly arguing about this issue. Actually, no formula has been found as a touchstone for these two theories. In fact, in the author's opinion, the formula (42) is the touchstone. If this formula is the law of conservation of energy, the theory of action-at-a-distance holds, otherwise the theory of ether or field holds.

The author supports the theory of action-at-a-distance. Therefore, we agree that the formula (42) is the law of conservation of energy. That is to say, the author believes that Maxwell's electromagnetic theory has loopholes. (42) is the law of energy conservation, which also gives the radiation electromagnetic field theory containing electromagnetic waves and the magnetic quasi-static electromagnetic field theory the same form of energy conservation law, see formula (34).

5. The Law (Theorem) of the Mutual Energy Flow

We can prove the following law of mutual energy flow using the formula (23) [10],

$$-\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_2 \cdot \boldsymbol{J}_1) dV = (\xi_1, \xi_2)$$

$$= \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2) dV \tag{46}$$

$$(\xi_1, \xi_2) \triangleq \int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n} d\Gamma \tag{47}$$

"$\triangleq$" means by definition. $\oiint_\Gamma (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n} d\Gamma$ is the mutual energy flow. (ξ_1, ξ_2) is the energy flowing through the surface Γ. Γ is any closed surfaces that can separate the current $\boldsymbol{J}_1$ and $\boldsymbol{J}_2$.(46) is the law of energy conservation under magnetic quasi-static conditions. Under Maxwell's equation, we can also obtain the energy theorem,

$$-\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_2 \cdot \boldsymbol{J}_1) dV$$

$$= (\xi_1, \xi_2) = \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{e}_1 \cdot \boldsymbol{J}_2) dV \quad (48)$$

$$(\xi_1, \xi_2) \triangleq \int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{e}_1 \times \boldsymbol{h}_2 + \boldsymbol{e}_2 \times \boldsymbol{h}_1) \cdot \hat{n} d\Gamma \quad (49)$$

The above two equations are the energy theorem under the condition of Maxwell's equation. The author believes that The above two equations should be the law of conservation of energy. The author will make appropriate revisions to Maxwell's electromagnetic theory below. After revisions, the above two equations become the law of conservation of energy.

IV. Author's Electromagnetic Theory

1. Maxwell's Equation

In the author's electromagnetic theory, the Maxwell equation is an auxiliary equation. In the author's electromagnetic theory, Maxwell's equation is not considered an axiom. Wheeler and Feynman expressed doubts about the Maxwell equation in the absorber theory [1, 2]. They said that the electromagnetic field in Maxwell's equation is only a record of the action-at-a-distance theory, and does not have its own degrees of freedom. Although they suspected that there was something wrong with the Maxwell equation, they did not find a way to correct it. The author abandons the Maxwell equation here, but retains some theorems derived from the Maxwell equation, mainly those related to Poynting's theorem. In addition, add some electromagnetic laws that the author believes should be in place.

2. Action-at-a-Distance Theory and the Law of Energy Conservation

In the author's electromagnetic theory, electric and magnetic fields use capital letters. This is because the author believes that this theory is closer to the magnetic quasi-static theory. Our magnetic quasi-static theory here is written in capital letters. The author's theory is the theory of action-at-a-distance theory. This theory is not an ether theory. This theory suggests that there is only an interaction between charges (currents). Electric current cannot transmit energy to the ether. Alternatively, current can transmit energy to the ether, but the ether must ultimately return the energy to the current. Therefore (42) is the law of conservation of energy, that is,

$$\sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i \cdot \boldsymbol{J}_j) dV = 0 \quad (50)$$

This law of conservation of energy is not only valid for magnetic quasi-static conditions, but the author believes that it also holds when considering radiated electromagnetic waves. This is because if the system has N current elements, energy can only propagate between these N current elements. If the the energy of $\boldsymbol{J}_i$ increases, there will definitely be another current element $\boldsymbol{J}_j$ lost the energy. It is not allowed to hand over energy to the ether or field, and let the ether or field transfer energy again. Or to put it further, if a certain current transfers energy to the ether, ultimately these energies must be returned to their original owners.

3. Any Current Generates Half Retarded and Half Advanced Waves

The author originally considered that the current element of the emitter generates a retarded wave, while the current element of the sink generates a advanced wave. But current elements are either sources or sinks, it is difficult to distinguish when they should be sources and when it should be sinks. Therefore, the best solution is for the current element, whether it is a source or a sink, to simultaneously generate half the retarded wave and half the advanced wave. This is mathematically consistent. Dirac, Wheeler Feynman, Cramer's theory are all like this [1-3, 7,8].

4. The Law of Radiation does not Overflow the Universe

Considering that nothing can escape beyond the universe, therefore electromagnetic fields cannot overflow the universe.

Therefore, there should be,

$$\int_{t=-\infty}^{\infty} \oiint_\Gamma (\boldsymbol{E} \times \boldsymbol{H}) \cdot \hat{n} d\Gamma = 0 \quad (51)$$

This formula indicates that electromagnetic waves cannot overflow the universe. Where Γ is a sphere with an infinite radius. The integral of the Poynting vector $S = \boldsymbol{E} \times \boldsymbol{H}$ on this sphere must be zero. This axiom contradicts classical electromagnetic theory. The integral of the Poynting theorem in classical electromagnetic theory is generally not zero. This precisely indicates that the author's electromagnetic theory is different from Maxwell's electromagnetic theory. Consider the principle of superposition (21), there is,

$$\sum_{i=1}^{N} \sum_{j=1}^{N} \int_{t=-\infty}^{\infty} \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_j) \cdot \hat{n} d\Gamma = 0 \quad (52)$$

Or split the above equation into two formulas,

$$\sum_{i=1}^{N} \int_{t=-\infty}^{\infty} \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_i) \cdot \hat{n} d\Gamma = 0 \quad (53)$$

$$\sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \int_{t=-\infty}^{\infty} \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_j) \cdot \hat{n} d\Gamma = 0 \quad (54)$$

(53) indicates that the self energy flow is not overflow the universe, and (54) indicates that the mutual energy flow is not overflow the universe. In the Fourier frequency domain, the above two equations can be rewritten as,

$$\Re \sum_{i=1}^{N} \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_i^*) \cdot \hat{n} d\Gamma = 0 \quad (55)$$

$$\Re \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \oiint_\Gamma (\boldsymbol{E}_i \times \boldsymbol{H}_j^*) \cdot \hat{n} d\Gamma = 0 \quad (56)$$

'*' is a complex conjugate. The above equation (56) is further rewritten as,

$$\Re\sum_{i=1}^{N}\sum_{j=1,j<i}\oiint_{\Gamma}(\boldsymbol{E}_i^*\times\boldsymbol{H}_j+\boldsymbol{E}_i\times\boldsymbol{H}_j^*)\cdot\hat{n}d\Gamma=0 \quad (57)$$

The sum sign above can be discarded,

$$\Re\oiint_{\Gamma}(\boldsymbol{E}_i\times\boldsymbol{H}_i^*)\cdot\hat{n}d\Gamma=0 \quad (58)$$

$$\Re\oiint_{\Gamma}(\boldsymbol{E}_i^*\times\boldsymbol{H}_j+\boldsymbol{E}_i\times\boldsymbol{H}_j^*)\cdot\hat{n}d\Gamma=0 \quad (59)$$

The above two equations indicate that neither self energy flow nor mutual energy flow can overflow the universe. (58) it indicates that the electric field must maintain a 90 degree phase difference from the magnetic field. So,

$$\Re\boldsymbol{E}_i\times\boldsymbol{H}_i^*=0 \quad (60)$$

Therefore, there is (58). The above formula requires electric and magnetic fields $\boldsymbol{E}_i$, $\boldsymbol{H}_i$ is a reactive power wave. The average value of energy transmitted forward by this reactive wave is zero.

5. Relaxed Poynting's Theorem Still Holds

Although the author no longer acknowledges the Maxwell equation, he believes that the relaxed Poynting theorem still holds, that is,

$$-\int_{t=-\infty}^{\infty}dt\oiint_{\Gamma}(\boldsymbol{E}\times\boldsymbol{H})\cdot\hat{n}d\Gamma=\int_{t=-\infty}^{\infty}dt\int_{V}(\boldsymbol{E}\cdot\boldsymbol{J})dV \quad (61)$$

The above equation is a time integral of Poynting's theorem. This time integral has a relaxing effect on Poynting's theorem. This relaxation process eliminates the need for the above equation to satisfy the Maxwell equation. Considering the superposition principle (21) or (61),

$$-\sum_{i=1}^{N}\sum_{j=1}^{N}\int_{t=-\infty}^{\infty}dt\oiint_{\Gamma}(\boldsymbol{E}_i\times\boldsymbol{H}_j)\cdot\hat{n}d\Gamma$$
$$=\sum_{i=1}^{N}\sum_{j=1}^{N}\int_{t=-\infty}^{\infty}dt\int_{V}(\boldsymbol{E}_i\cdot\boldsymbol{J}_j)dV \quad (62)$$

The above equation can be broken down into two formulas,

$$-\sum_{i=1}^{N}\int_{t=-\infty}^{\infty}dt\oiint_{\Gamma}(\boldsymbol{E}_i\times\boldsymbol{H}_i)\cdot\hat{n}d\Gamma=\sum_{i=1}^{N}\int_{t=-\infty}^{\infty}dt\int_{V}(\boldsymbol{E}_i\cdot\boldsymbol{J}_i)dV \quad (63)$$

$$-\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}\int_{t=-\infty}^{\infty}dt\oiint_{\Gamma}(\boldsymbol{E}_i\times\boldsymbol{H}_j)\cdot\hat{n}d\Gamma$$
$$=\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}\int_{t=-\infty}^{\infty}dt\int_{V}(\boldsymbol{E}_i\cdot\boldsymbol{J}_j)dV \quad (64)$$

Considering the cosmic law of radiation non overflow (53), the left side of (63) is zero, while the right side is zero. That is, both sides of (63) are zero. Considering (54), we obtain

$$\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}\int_{t=-\infty}^{\infty}dt\int_{V}(\boldsymbol{E}_i\cdot\boldsymbol{J}_j)dV=0 \quad (65)$$

In this way, we obtain the law of conservation of energy. The law of conservation of energy is still valid in the author's theory of electromagnetic radiation and electromagnetic fields. Note that in the author's theory, the law of conservation of energy (65) and the law of the radiation does not overflow the universe are not independent, and both are sufficient and necessary conditions for each other. One of the two laws is sufficient, and the other can be seen as derivable theorem. In addition, the relaxed Poynting's law (61) already includes useful information from the Maxwell equation.

6. Law of the Mutual Energy Flow

We can obtain the energy flow law from (64),

$$-\int_{t=-\infty}^{\infty}dt\int_{V}(\boldsymbol{E}_2\cdot\boldsymbol{J}_1)dV=(\xi_1,\xi_2)=\int_{t=-\infty}^{\infty}dt\int_{V}(\boldsymbol{E}_1\cdot\boldsymbol{J}_2)dV \quad (66)$$

$$(\xi_1,\xi_2)\triangleq\int_{t=-\infty}^{\infty}dt\oiint_{\Gamma}(\boldsymbol{E}_1\times\boldsymbol{H}_2+\boldsymbol{E}_2\times\boldsymbol{H}_1)\cdot\hat{n}d\Gamma \quad (67)$$

Note that in the author's theory, it is stated that not only under magnetic quasi-static conditions, but also in the presence of electromagnetic wave radiation, the above two equations hold as the law of energy conservation. This is different from under the conditions of Maxwell's equation. Under the conditions of Maxwell's equation, the above two equations can only serve as energy theorems and cannot be established as laws of conservation of energy. In outher's theory, the above two equations are not only laws of energy conservation, but also localized laws of energy conservation. Localization here refers to the energy being transmitted through the energy flow $\oiint_{\Gamma}(\boldsymbol{E}_1\times\boldsymbol{H}_2+\boldsymbol{E}_2\times\boldsymbol{H}_1)\cdot\hat{n}d\Gamma$. The author will no longer prove the law of mutual energy flow here. This proof can be referred to [30].

7. Retarded Field Instead of Retarded Potential

As we mentioned earlier, electromagnetic fields should satisfy the requirement that radiation does not overflow into the universe, which requires the formulas (52,58,60) to be satisfied. The simplest way to satisfy these formulas is to always keep the phase of the electric and magnetic fields consistent. We know that under quasi-static magnetic conditions, the electric and magnetic fields maintain a phase difference of approximately 90 degrees. If the phase difference between the electric and magnetic fields remains the same after this, the formula (60) can be satisfied.

Maxwell's electromagnetic field theory is the theory of retarded potential. The theory of retarded potential is,

$$\boldsymbol{A} \sim \int \frac{[\boldsymbol{J}]}{r} dV, \quad \phi \sim \int \frac{[\rho]}{r} dV \tag{68}$$

where in,

$$[q] = q(t - r/c) \tag{69}$$

q is an arbitrary function. We use lowercase letters to representthe electric and magnetic fields obtained from Maxwell's equations,

$$\boldsymbol{e} = -\frac{\partial}{\partial t}\boldsymbol{A} - \nabla\phi, \quad \boldsymbol{h} = \nabla \times \boldsymbol{A} \tag{70}$$

In the author's theory, the electric and magnetic fields are derived based on the theory of retarded fields, so there is,

$$\boldsymbol{E} \sim \int [\boldsymbol{J}] f(r) dV \tag{71}$$

$$\boldsymbol{H} \sim \int [\boldsymbol{J}] g(r) dV \tag{72}$$

f(r); g(r) are undetermined functions of a complex number.

8. Law of Non Cancellation of Retarded and Advanced Waves Emitted by Current

In the author's theory, any current element emits both retarded and advanced waves simultaneously. Therefore, we must ensure that the retarded wave and advanced wave cannot cancel each other near the current. And it should be superimposed on each other. This requirement cannot be met by Maxwell's electromagnetic theory. Assuming a current element $\boldsymbol{J}$, according to Maxwell's electromagnetic theory,

$$\boldsymbol{A}^{(r)} \sim \int_V \frac{\boldsymbol{J}}{r} \exp(-jkr) dV \tag{73}$$

The superscript "(r)" means retarded,

$$\boldsymbol{e}^{(r)}(r=0) = -j\omega \boldsymbol{A}^{(r)} \sim -j \int_V \frac{\boldsymbol{J}}{r} \exp(-jkr) dV$$

$$\sim -j \int_V \frac{\boldsymbol{J}}{r} dV \sim -j\boldsymbol{J} \tag{74}$$

$$\boldsymbol{h}^{(r)} \sim \nabla \times \boldsymbol{A}^{(r)} \sim \nabla \times \int_V \frac{\boldsymbol{J}}{r} \exp(-jkr) dV$$

$$\sim \int_V \nabla(\frac{1}{r}\exp(-jkr)) \times \boldsymbol{J} dV$$

$$\sim \int_V (-\frac{\boldsymbol{r}}{r^3} + \frac{-jk\hat{r}}{r}) \exp(-jkr) \times \boldsymbol{J} dV$$

$$\sim \int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + \frac{jk\hat{r}}{r}) \exp(-jkr) dV \tag{75}$$

The superscript "*a*" means leading wave,

$$\boldsymbol{A}^{(a)} \sim \int_V \frac{\boldsymbol{J}}{r} \exp(-jkr) dV \tag{76}$$

According to Maxwell's electromagnetic theory, the electric field of retarded and advanced waves on the surface of the current is,

$$\boldsymbol{e}^{(r)}(r=0) \sim -j\boldsymbol{J} \tag{77}$$

$$\boldsymbol{e}^{(a)}(r=0) \sim -j\boldsymbol{J} \tag{78}$$

the magnetic field,

$$\boldsymbol{h}^{(a)} \sim \nabla \times \boldsymbol{A}^{(a)} \sim \nabla \times \int_V \frac{\boldsymbol{J}}{r} \exp(+jkr) dV$$

$$\sim \int_V \nabla(\frac{1}{r}\exp(+jkr)) \times \boldsymbol{J} dV$$

$$\sim \int_V (-\frac{\boldsymbol{r}}{r^3} + \frac{+jk\hat{r}}{r}) \exp(+jkr) \times \boldsymbol{J} dV$$

$$\sim \int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} - \frac{jk\hat{r}}{r}) \exp(+jkr) dV \tag{79}$$

According to Marx's electromagnetic theory, the magnetic field on the surface of a current is,

$$\boldsymbol{h}^{(r)}(r=0) \sim \int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + \frac{jk\hat{r}}{r}) dV \tag{80}$$

$$\boldsymbol{h}^{(a)}(r=0) \sim \int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} - \frac{jk\hat{r}}{r}) dV \tag{81}$$

We see that according to Maxwell's electromagnetic theory, the retarded and advanced waves of the electric field are in phase at $r = 0$ and therefore are superimposed and strengthened (77, 78). However, there is one term in the magnetic field of the retarded wave and advanced wave formulas (80, 81) that is additive and canceling. If we want the retarded wave and the advanced wave to avoid superposition and cancellation near the current, we must make corrections to the far field of the magnetic field. For retarded waves, the correction factor is (- *j*). The correction factor for advanced waves is (*j*). After correction, the author's electromagnetic theory was obtained,

$$\boldsymbol{E}^{(r)} = \boldsymbol{e}^{(r)} = -j\omega \boldsymbol{A}^{(r)} \sim -j\omega \int_V \frac{\boldsymbol{J}}{r} \exp(-jkr) dV \tag{82}$$

$$\boldsymbol{E}^{(a)} = \boldsymbol{e}^{(a)} = -j\omega \boldsymbol{A}^{(a)} \sim -j\omega \int_V \frac{\boldsymbol{J}}{r} \exp(+jkr) dV \tag{83}$$

$$\boldsymbol{H}^{(r)} \sim \int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + (-j)\frac{jk\hat{r}}{r}) \exp(-jkr) dV \tag{84}$$

$$\boldsymbol{H}^{(a)} \sim \int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + (j)\frac{jk\hat{r}}{r}) \exp(+jkr) dV \tag{85}$$

Or,

$$\boldsymbol{H}^{(r)} \sim \int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + \frac{k\hat{r}}{r}) \exp(-jkr) dV \qquad (86)$$

$$\boldsymbol{H}^{(a)} \sim \int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + \frac{k\hat{r}}{r}) \exp(+jkr) dV \qquad (87)$$

From (82,83), it can be seen that the electric field is still superimposed and enhanced at (r = 0). The magnetic field (86, 87) is also superimposed and enhanced at (r = 0). Therefore, the author's correction is also reasonable.

9. A Example

Consider that *f* and g are two undetermined functions. The author's newly defined electric and magnetic fields are in uppercase letters. Because if that's the case, in the frequency domain, there is,

$$\boldsymbol{J} = \boldsymbol{J}_0 \exp(j\omega t) \qquad (88)$$

$$[\boldsymbol{J}] = \boldsymbol{J}(t - r/c) = \boldsymbol{J}_0 \exp(j\omega(t - r/c)) = \boldsymbol{J}_0 \exp(j\omega t - j\omega r/c))$$

$$= \boldsymbol{J}_0 \exp(j\omega t) \exp(-j\omega r/c) = \boldsymbol{J} \exp(-jkr) \qquad (89)$$

Among them,

$$k = \frac{\omega}{c} \qquad (90)$$

$$\boldsymbol{E} \sim \int_V \boldsymbol{J} \exp(-jkr) f(r) dV \qquad (91)$$

$$\boldsymbol{H} \sim \int_V \boldsymbol{J} \exp(-jkr) g(r) dV \qquad (92)$$

At least when V is relatively small,

$$\boldsymbol{E} \sim \boldsymbol{J} \exp(-jkr) f(r) \qquad (93)$$

$$\boldsymbol{H} \sim \boldsymbol{J} \exp(-jkr) g(r) \qquad (94)$$

The phases of the electric and magnetic fields remain constant, so if $r = 0$

$$\boldsymbol{E}(r=0) \times \boldsymbol{H}(r=0) \sim j \qquad (95)$$

It can still be maintained,

$$\boldsymbol{E}(r) \times \boldsymbol{H}^*(r) \sim \boldsymbol{J} \exp(-jkr) f(r) \times (\boldsymbol{J} \exp(-jkr) g(r))^*$$

$$= \boldsymbol{J} f(r) \times (\boldsymbol{J} g(r))^* = \boldsymbol{E}(r=0) \times \boldsymbol{H}(r=0)$$

$$\sim j \qquad (96)$$

Hence,

$$\Re(\boldsymbol{E}(r) \times \boldsymbol{H}^*(r)) = 0 \qquad (97)$$

Considering the vector potential,

$$\boldsymbol{A} \sim \int \frac{\boldsymbol{J}}{r} \exp(-jkr) dV \qquad (98)$$

The magnetic field calculated according to Maxwell's electromagnetic theory,

$$\boldsymbol{h} = \nabla \times \boldsymbol{A} = \int \nabla(\frac{1}{r} \exp(-jkr)) \times \boldsymbol{J} dV$$

$$= \int (-\frac{\boldsymbol{r}}{r^3} + \frac{-jk\hat{r}}{r}) \exp(-jkr) \times \boldsymbol{J} dV$$

$$= \int \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + \frac{jk\hat{r}}{r}) \exp(-jkr) dV \qquad (99)$$

We can adjust the phase of the far-field part to be the same as that of the near-field part by adding a phase (- j) to the far-field part in the above equation. Use the subscript n to represent the near field, and the subscript f to represent the far field,

$$\boldsymbol{H} = \boldsymbol{h}_n + (-j)\boldsymbol{h}_f$$

$$= \frac{\mu_0}{4\pi} \int \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + (-j)\frac{jk\hat{r}}{r}) \exp(-jkr) dV$$

$$= \frac{\mu_0}{4\pi} \int \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + \frac{k\hat{r}}{r}) \exp(-jkr) dV \qquad (100)$$

For induced electric fields,

$$\boldsymbol{e}_i = -j\omega \boldsymbol{A} = -j\omega \frac{\mu_0}{4\pi} \int \frac{\boldsymbol{J}}{r} \exp(-jkr) dV \qquad (101)$$

There is no need to make any adjustments to this section.

$$\boldsymbol{E}_i = -j\omega \frac{\mu_0}{4\pi} \int \frac{\boldsymbol{J}}{r} \exp(-jkr) dV \qquad (102)$$

Consider,

$$\phi \sim \int \frac{\rho}{r} \exp(-jkr) dV \qquad (103)$$

Calculate the electrostatic field according to Maxwell's electromagnetic theory,

$$\boldsymbol{e}_s = -\nabla\phi \sim -\int \rho \nabla(\frac{1}{r} \exp(-jkr)) dV$$

$$= -\int \rho(-\frac{\boldsymbol{r}}{r^3} + \frac{-jk\hat{r}}{r}) \exp(-jkr)) dV$$

$$= \int \rho(\frac{\boldsymbol{r}}{r^3} + \frac{jk\hat{r}}{r}) \exp(-jkr)) dV \qquad (104)$$

For $\boldsymbol{E}_s$ It may also need to be corrected. However, the current situation encountered by the author is plane wave electromagnetic radiation. In plane waves, due to symmetry, the electric field is only determined by the vector potential. Therefore, we will not discuss the correction of $\boldsymbol{E}_s$ for the time being. In this example, we see that the far field of the magnetic field calculated according to Maxwell's equation needs to be corrected. Use $(-j)$ to correct the far field of the retarded magnetic field. Use (j) to correct the far-field of the magnetic field of the advanced wave.

V. Phonton

The author believes that there are two types of current elements, one is the source and the other is the sink. The radiation source includes: 1) transmitting antenna, 2) primary coil of transformer, and 3) emiter charge. The sink includes 1) the receiving antenna, 2) the secondary coil of the transformer, and 3) the absorber charge. But in fact, the current element always radiates both retarded and advanced waves simultaneously. However, due to the fact that electromagnetic waves

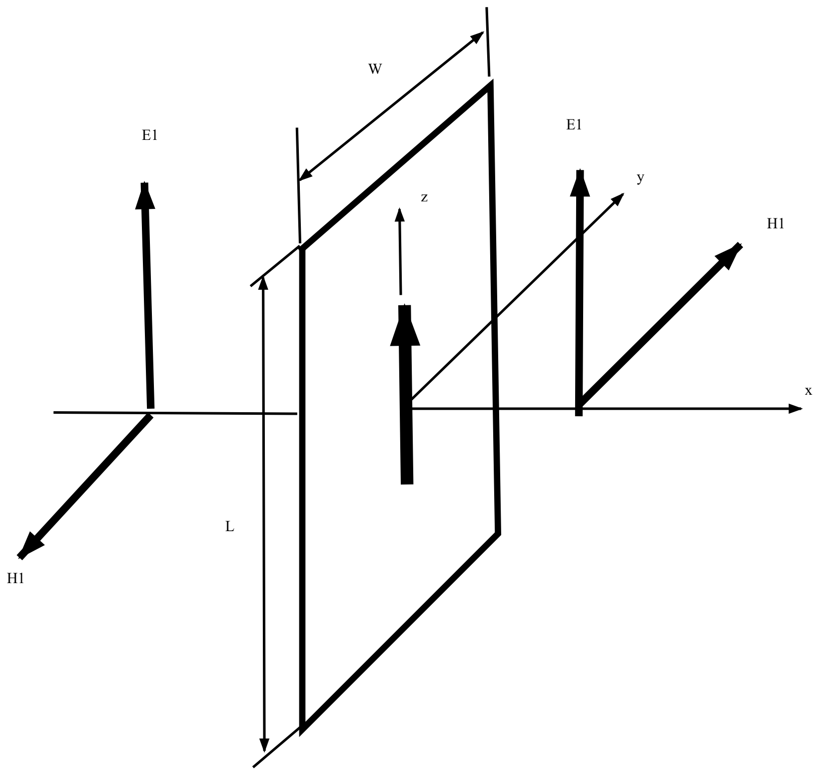

Figure 1: Plane Current Sheet $\boldsymbol{J}_1$ Generated Electromagnetic Field, $\boldsymbol{E}_1$, $\boldsymbol{H}_1$.

are all reactive power waves, these waves do not consume energy. Some currents look like a source of radiation because the advanced waves they emit are reactive power, emitting and returning to the source, just like no advanced waves are emitted. Some current elements are like sinks because their retarded waves are reactive power, it is sent out, and returned to the sinks. Same as not emitting retarded waves.

Both the source and sink randomly emit electromagnetic waves. If a retarded wave emitted by a certain source reaches a distant sink, and the sink happens to emit an advanced wave, the retarded wave is synchronized with the advanced wave. Synchronous formation of mutual energy flow. The mutual energy flow is a photon.

1. Assuming that the Source and Sink are Very Close

The following figure 1 shows a plane current sheet. The size of the current sheet is finite, with a width of W and a length of L. The current density is $\boldsymbol{J}_1$. The generated electromagnetic field is $\boldsymbol{E}_1$, $\boldsymbol{H}_1$, refer to the figure 1.

We first assume that the source and sink are very close. The source is a current element,

$$\boldsymbol{J}_1 = J_{10}\hat{z} \tag{105}$$

The electric field generated by this current is first obtained based on the magnetic vector potential under quasi-static conditions,

$$\boldsymbol{E}_1 = -j\omega \boldsymbol{A}_1 \tag{106}$$

$$\boldsymbol{A}_1 = \iint_\sigma \frac{J_{10}\hat{z}}{r} \tag{107}$$

$$\boldsymbol{E}_1 \sim -jJ_{10}\hat{z} \tag{108}$$

"$\sim$" means proportional. The symbol $\sim$ is only interested in phase and direction, and it is not interested in numerical magnitude. The magnetic field follows the ampere's circuital law,

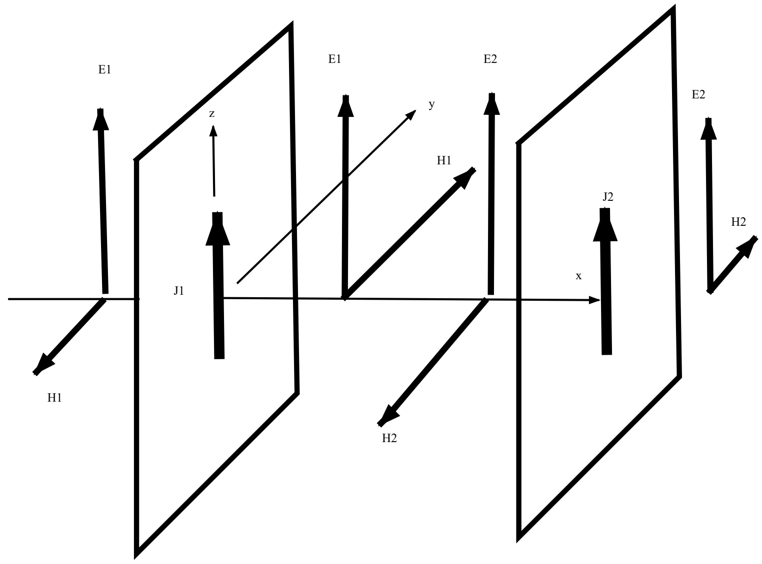

Figure 2: Two Plane Currents $\boldsymbol{J}_1$, $\boldsymbol{J}_2$ Generated Electromagnetic Field, $\boldsymbol{E}_1$, $\boldsymbol{H}_1$ and $\boldsymbol{E}_2$, $\boldsymbol{H}_2$.

$$\boldsymbol{H}_1 \sim J_{10}\hat{y} \tag{109}$$

There is,

$$\Re(\boldsymbol{E}_1 \times \boldsymbol{H}_1^*) \sim \Re((-jJ_{10}\hat{z}) \times (J_{10}\hat{y})^*)$$
$$= \Re(jJ_{10}J_{10}^*\hat{x}) = 0 \tag{110}$$

It can be seen that $[\boldsymbol{E}_1;\boldsymbol{H}_1]^T$ is the reactive power. On the left side of the current $\boldsymbol{J}_1$, the electric field remains unchanged and the magnetic field turns,

$$\boldsymbol{E}_1 \sim -jJ_{10}\hat{z} \tag{111}$$

$$\boldsymbol{H}_1 \sim -J_{10}\hat{y} \tag{112}$$

Hence there is,

$$\begin{cases} \boldsymbol{E}_1 = -jJ_{10}\hat{z} \\ \boldsymbol{H}_1 \sim \begin{cases} J_{10}\hat{y} & x > 0 \\ -J_{10}\hat{y} & x < 0 \end{cases} \end{cases} \tag{113}$$

We assume that at the vicinity of the current $\boldsymbol{J}_1$ there is a current element $\boldsymbol{J}_2$. The distance d between them is very small, $d \cong 0$. Refer to the figure 2. Therefore, there are,

$$\begin{cases} \boldsymbol{E}_2 = -jJ_{20}\hat{z} \\ \boldsymbol{H}_2 \sim \begin{cases} J_{20}\hat{y} & x > d \\ -J_{20}\hat{y} & x < d \end{cases} \end{cases} \tag{114}$$

At $0 < x < d$

$$\boldsymbol{S}_m = \boldsymbol{E}_1 \times \boldsymbol{H}_2^* + \boldsymbol{E}_2^* \times \boldsymbol{H}_1$$
$$= (-jJ_{10}\hat{z}) \times (-J_{20}\hat{y})^* + (-jJ_{20}\hat{z})^* \times (J_{10}\hat{y})$$
$$= ((jJ_{10})(-J_{20})^* + (jJ_{20})^*(J_{10}))\hat{x}$$
$$= ((j)(-1)^* + (j)^*)J_{20}^*J_{10}\hat{x}$$
$$= -2jJ_{20}^*J_{10}\hat{x} \tag{115}$$

We assume that the current I_2

$$I_2 = \frac{\mathcal{E}_{2,1}}{R_2 + j\omega L_2} \sim \frac{\mathcal{E}_{2,1}}{R_2} \sim \mathcal{E}_{2,1} \sim \boldsymbol{E}_1 \tag{116}$$

Assuming $R_2 \gg \omega L_2$. So the phase and direction of I_2 is consistent with E_1,

$$\boldsymbol{J}_2 \sim \boldsymbol{E}_1 = -jJ_{10}\hat{z} \tag{117}$$

$$J_{20} \sim -jJ_{10} \tag{118}$$

According to (115)

$$\boldsymbol{S}_m = \boldsymbol{E}_1 \times \boldsymbol{H}_2^* + \boldsymbol{E}_2^* \times \boldsymbol{E}_1$$
$$\sim -2jJ_{20}^*J_{10}\hat{x} \sim -2j(-jJ_{10})^*J_{10}\hat{x}$$
$$= 2J_{10}^*J_{10}\hat{x} \sim \hat{x} \tag{119}$$

$$\boldsymbol{S}_m \sim J_{10}^*J_{10}\hat{x}, \quad 0 < x < d \tag{120}$$

It can be seen that the mutual energy is active power. At $x > d$, the sign of the magnetic field $\boldsymbol{H}_2$ will change. At $x < 0$, The sign of the magnetic field $\boldsymbol{H}_1$ will change. So, outside the interval $0 < x < d$, the two terms in the mutual energy flow, $\boldsymbol{S}_{12} = \boldsymbol{E}_1\boldsymbol{H}^*_2$ and another $\boldsymbol{S}_{21} = \boldsymbol{E}_2^*\boldsymbol{E}_1$ is offset.

Therefore, there are,

$$\boldsymbol{S}_m \sim \begin{cases} 0 & x < 0 \\ \hat{x} & 0 < x < d \\ 0 & x > d \end{cases} \tag{121}$$

It can be seen that the mutual energy flow density $\boldsymbol{S}_m$ generated at $x = 0$ and annihilated at $x = d$. It is generated at the source and annihilated at the sink. $\boldsymbol{S}_m$ having the properties of photons.

2. Assuming that the Distance between the Source and Sink is not Close

J1 , J2 are two plane current sheets. J1 is a radiation source that generates retarded wave electromagnetic fields E1, H1 , J2 is a sink that generates advanced wave electromagnetic fields E2,H2. The advanced wave guides the retarded wave. The retarded wave guides the advanced wave. Therefore, both retarded and advanced waves propagate like in a waveguide. Refer to the figure 3.

Now let's consider that d is not very small, as shown in Figure 3. In this case, the author believes that as the distance increases, both the electric and magnetic fields have a phase retardation. Note that in the author's theory, both electric and magnetic fields are determined based on the retardation of the field, rather than the vector potential retardation. such

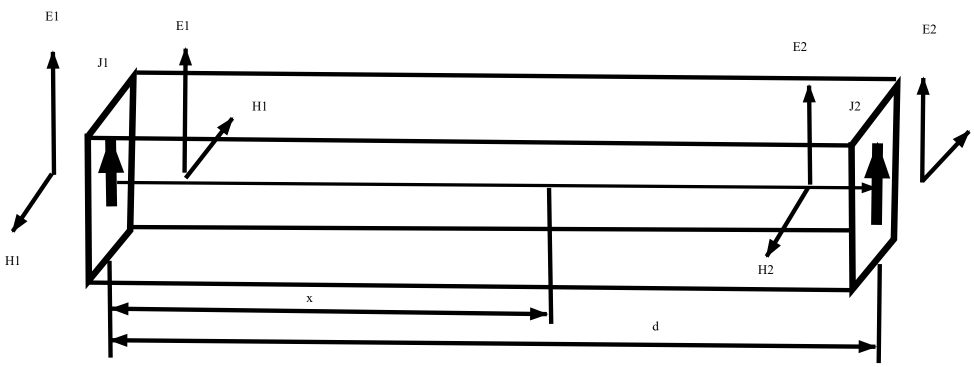

Figure 3: The source and sink form a waveguide to transmit a photon.

$$\begin{cases} \boldsymbol{E}_1 = -jJ_{10}\hat{z}\exp(-jkx) \\ \boldsymbol{H}_1 \sim \begin{cases} J_{10}\hat{y}\exp(-jkx) & x > 0 \\ -J_{10}\hat{y}\exp(-jkx) & x < 0 \end{cases} \end{cases} \tag{122}$$

$$\begin{cases} \boldsymbol{E}_2 = -jJ_{20}\hat{z}\exp(-jk(x-d)) \\ \boldsymbol{H}_2 \sim \begin{cases} J_{20}\hat{y}\exp(-jk(x-d) & x > d \\ -J_{20}\hat{y}\exp(-jk(x-d) & x < d \end{cases} \end{cases} \tag{123}$$

In the above equation, we assume that on the left side of the current $\boldsymbol{J}_1$ and current $\boldsymbol{J}_2$ the radiation are the advanced waves. On the right side the current $\boldsymbol{J}_1$ and current $\boldsymbol{J}_2$, the radiation is retarded waves. Therefore, the current generates waves that propagate to the right. In fact, the current also generates waves that propagate to the left. But those waves are reactive power waves and hence invalid waves. Only two waves propagating to the right of the current are synchronized, which can form a mutual energy flow. Therefore, we only retained the wave propagating to the right.

We assume that $\boldsymbol{J}_2$ and electric field $\boldsymbol{E}_1$ the direction and phase are consistent. The reason is the same as the formula (116). Therefore there is,

$$J_{20} \sim E_1(x = d) = -jJ_{10}\exp(-jkd) \tag{124}$$

$$\begin{cases} \boldsymbol{E}_2 \sim -j(-jJ_{10}\exp(-jkd))\hat{z}\exp(-jk(x-d)) \\ \boldsymbol{H}_2 \sim \begin{cases} (-jJ_{10}\exp(-jkd))\hat{y}\exp(-jk(x-d) & x > d \\ -(-jJ_{10}\exp(-jkd))\hat{y}\exp(-jk(x-d) & x < d \end{cases} \end{cases} \tag{125}$$

Or,

$$\begin{cases} \boldsymbol{E}_2 \sim jjJ_{10}\hat{z}\exp(-jkx) \\ \boldsymbol{H}_2 \sim \begin{cases} (-jJ_{10})\hat{y}\exp(-jkx) & x > d \\ jJ_{10}\hat{y}\exp(-jkx) & x < d \end{cases} \end{cases} \tag{126}$$

Considering the interval of $0 < x < d$,

$$\begin{aligned} \boldsymbol{S}_m &= \boldsymbol{S}_{12} + \boldsymbol{S}_{21} \\ &= \boldsymbol{E}_1 \times \boldsymbol{H}_2^* + \boldsymbol{E}_2^* \times \boldsymbol{H}_1 \\ &= (-jJ_{10}\hat{z}\exp(-jkx)) \times (jJ_{10}\hat{y}\exp(-jkx))^* \\ &\quad +(jjJ_{10}\hat{z}\exp(-jkx))^* \times (J_{10}\hat{y}\exp(-jkx)) \\ &= (-jJ_{10}\hat{z}) \times (jJ_{10}\hat{y})^* + (jjJ_{10})\hat{z})^* \times (J_{10}\hat{y}) \\ &= ((jJ_{10})(jJ_{10})^* + (-jjJ_{10})^*(J_{10}))\hat{x} \\ &= (jj^* + (-jj)^*)J_{10}J_{10}^*\hat{x} \\ &= 2J_{10}J_{10}^*\hat{x} \\ &\sim \hat{x} \end{aligned} \tag{127}$$

Consider at $x > d$ the magnetic field $\boldsymbol{H}_2$ change sign, at $x < 0$ the magnetic field $\boldsymbol{H}_1$ change sign, so there is a ($x < 0; x > d$) $\boldsymbol{S}_{12}$ and $\boldsymbol{S}_{21}$ offset. Therefore, there are,

$$\boldsymbol{S}_m \sim \begin{cases} 0 & x < 0 \\ \hat{x} & 0 \le x \le d \\ 0 & x > d \end{cases} \tag{128}$$

It can be seen that the mutual energy flow density $\boldsymbol{S}_m$ generated at x = 0 and annihilated at x = d. It is generated at the source and annihilated at the sink. In the region of 0 < x < d, the mutual energy flow $\boldsymbol{S}_m$ is active power.Sm have the properties of photons.

3. Generation and Annihilation of Photons

At the initial moment, the current element radiates spherical waves, which are electromagnetic waves that decay with distance. This type of wave can be referred to as electromagnetic waves in broadcast mode. According to the formula (60), this wave is a reactive power wave, and most of the waves emitted are invalid waves. Although the electromagnetic waves of the invalid wave were emitted, they returned as expected, so there was no energy loss. Therefore, the source can reemitted. Until the photon energy is emitted. Assuming that the retarded wave emitted by a certain source coincides with (or shakes hands with) the advanced wave emitted by a sink, a mutual energy flow is formed. The initial mutual energy flow can be calculated from the electromagnetic field emitted by the sink and source. If the distance between the source and the sink is very large, such as one light year, the electromagnetic waves emitted by the source decay with distance, and such electromagnetic waves reach the sink very, very weakly. Similarly, the advanced wave emitted by the sink arrivals the source is also very weak. But at this point, the retarded wave forms the waveguide of the advanced wave, and the advanced wave forms the waveguide of the retarded wave. The retarded wave continuously strengthens in the direction of the advanced wave, which is the direction of the sink. The advanced wave also continuously strengthens in the direction of the retarded wave, that is, in the direction of the source. The final retarded wave and advanced wave form a planar or quasi planar electromagnetic wave in the direction of the connection between the source and sink. This is why the previous section of this chapter can calculate the retarded and advanced waves emitted by the source and sink based on plane waves.

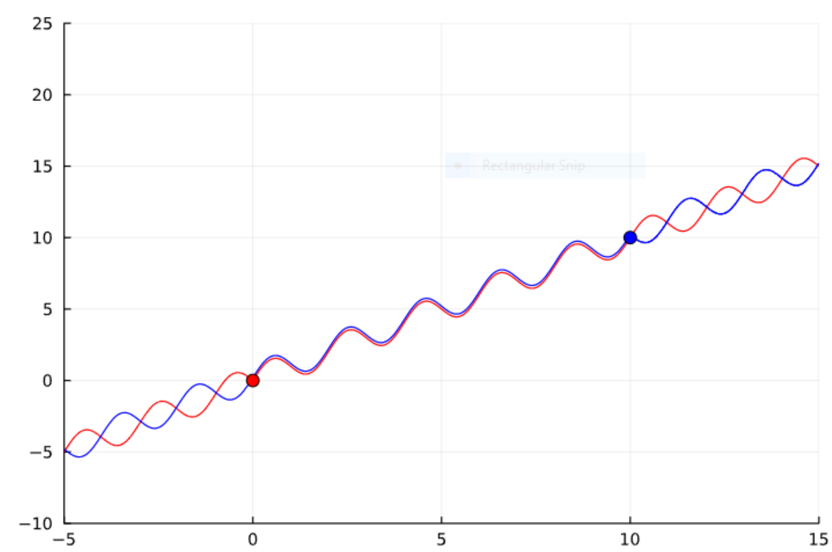

Figure 4: Cramer's Quantum Mechanical Model. The Horizontal Axis in the Figure is the Spatial Variable *X*, and the Vertical Axis is the Time *T*. The Red Dot is the Source of Radiation. The Blue Dot is the Sink. The Source Emits a Retarded Wave with Red Color Towards the Sink. The Sink Emits a Advanced Wave with Blue Color Towards the Source

The reason why retarded waves can strengthen in the direction of the source is that retarded waves are reactive power waves in other directions, and the energy flow of these waves can return to the source. This is the same as the principle of interference. The retarded wave is strengthened by interference in the sink direction. In other directions, it is interference cancellation. The advanced wave emitted by the sink also interferes and strengthens in the direction of the source, and cancels out in other directions.

The formula (121,128) explains the mixed Poynting vector corresponding to the mutual energy flow $\boldsymbol{S}_m$ is generated at source $x = 0$, $\boldsymbol{S}_m$ is annihilated at $x = d$. $\boldsymbol{S}_m$ has the properties of photons. This indicates that the mutual energy flow formed between the source and sink is generated at the source and annihilated at the sink. Therefore, we say to establish a photon between the source and the sink.

The performance of the author's mutual energy flow in this chapter is very close to the particle model in Cramer quantum mechanics transactional interpretation [3, 4]. The Cramer model, refer to Figure 4. Current $\boldsymbol{J}_1$ red point is the source of radiation, $\boldsymbol{J}_2$ blue point is the sink. The retarded wave emitted by the source is discribed with red color. The advanced wave generated by the sink is discribed with blue corlor. On the right side of the sink, the sink generates retarded waves, which have a phase difference of 180 degrees from the retarded waves of the source. Therefore, it precisely cancels out the retarded wave emitted by the source. On the left side of the source, the source generates a advanced wave, which has a 180 degree phase difference from the advanced wave generated by the sink. Therefore, it precisely cancels out the advanced wave emitted by the sink. Cramer's paper on the quantum mechanical transctional interpretation model [3, 4] has been cited by over 1000 people since its publication in 1886. It can be seen that there are many people supporting it.

In Cramer's quantum mechanical model, there is an superposition of retarded and advanced waves between the source and sink. Due to a phase difference of 180 degrees outside this range, they cancel out each other. The superposition or cancellation here are both the retarded wave and the advanced wave themselves. In the author's electromagnetic theory, superposition and cancellation are caused by mixed Poynting energy flow S_{12} and S_{21} completed instead of retarded waves and advanced waves. In addition, Cramer did not explain why the retarded wave emitted by the sink in his theory is exactly 180 degrees out of phase with the retarded wave emitted by the source. There is also no explanation for why the advanced wave emitted by the source is exactly 180 degrees from the advanced wave emitted by the sink. In the author's electromagnetic theory, the phase change of the retarded wave emitted by the sink is due to the fact that the magnetic field must be reversed on both sides of the sink current. The phase change of the advanced wave emitted by the source is also due to the reversal of the magnetic field direction at the source. Therefore, in the author's electromagnetic theory, the reason for the 180 degree phase difference in the Cramer model is perfectly explained. In addition, the author's electromagnetic theory can also be a three-dimensional electromagnetic field model, while the Cramer quantum mechanics transactional interpretation model is a one-dimensional model. Therefore, the author's theory is a further concrete implementation of Cramer's quantum mechanical transactional interpretation. The Cramer quantum mechanics transactional interpretation is based on the Wheeler Feynman absorber theory. The author's electromagnetic theory is also a development of the Wheeler Feynman absorber theory [1, 2]. In fact, the author was indeed influenced by the theory of absorbers.

VI. Macroscopic Electromagnetic Waves

1. Sliver-Müller Radiation Boundary Condition

In this chapter, we must distinguish between the symbols used in Maxwell's electromagnetic theory and the author's electromagnetic theory.We assume that the electromagnetic field defined by Maxwell's equation still uses the lowercase symbols $\boldsymbol{e}$ and $\boldsymbol{h}$. According to the author's electromagnetic theory, the electric and magnetic fields are written in capital letters $\boldsymbol{E}$ and $\boldsymbol{H}$.

We know that in Maxwell's electromagnetic wave theory, the far field is required to meet the Sliver Müller boundary condition. This condition is actually equivalent to requiring the boundary of the universe to have good absorption of electromagnetic waves. This condition is often simulated using a microwave anechoic chamber in antenna measurement, as shown in Figure 5. In the author's electromagnetic theory, good absorption implies the existence of sinks. The author needs to arrange sinks to absorb electromagnetic waves, as shown in the figure. Here we assume that there are countless sinks uniformly distributed outside the sphere of infinite radius. These sinks can completely absorb electromagnetic waves. Therefore, these sinks also serve as the Sliver Müller radiation boundary conditions.

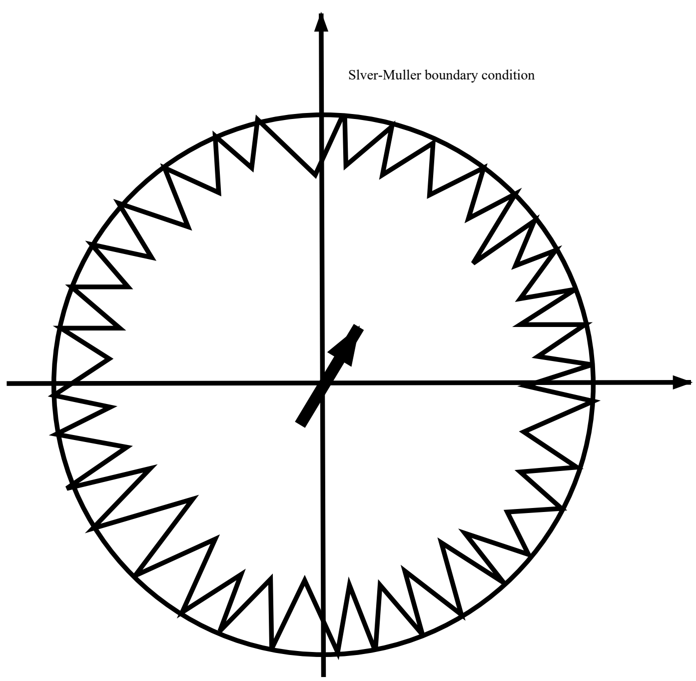

Figure 5: Microwave Darkroom. On a Sphere with a Radius of R, a Substance that Absorbs Electromagnetic Waves is Arranged, known as an Absorber

Assuming there is a current element $\boldsymbol{J}_1$ located at the center of the sphere Γ. We use Maxwell's electromagnetic theory and the author's electromagnetic theory to calculate the radiation of this current element, respectively. According to Maxwell's electromagnetic theory, the Sliver Müller radiation condition is satisfied on a spherical Γ . According to the author's electromagnetic theory, uniform sink current $\boldsymbol{J}_2$ is arranged on a spherical surface Γ . These currents can absorb all electromagnetic waves. Consider the Fourier transform of the mutual energy flow formula (46),

$$-\int_{V_1}(\boldsymbol{E}_2^*\cdot\boldsymbol{J}_1)dV$$

$$=\oiint_{\Gamma}(\boldsymbol{E}_1\times\boldsymbol{H}_2^*+\boldsymbol{E}_2^*\times\boldsymbol{H}_1)\cdot\hat{n}d\Gamma$$

$$=\int_{V_2}(\boldsymbol{E}_1\cdot\boldsymbol{J}_2^*)dV \tag{129}$$

Firstly, we know that according to the author's electromagnetic theory and Maxwell's theory, the electric field is still consistent,

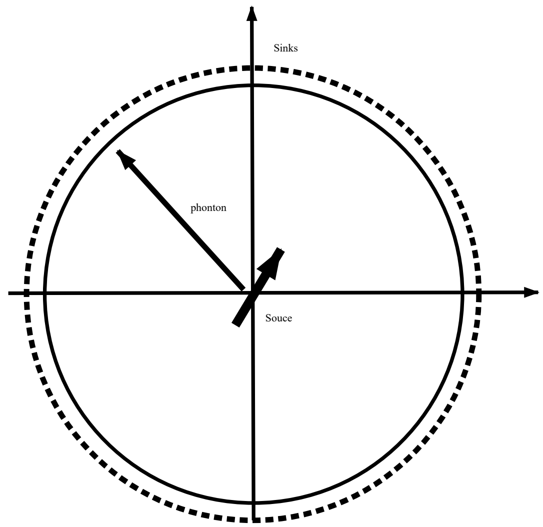

Figure 6: In the Author's Theory, the Sliver Müller Radiation Boundary Condition is Achieved by Arranging Countless Sinks onto a Sphere of Infinite Radius

$$\boldsymbol{E}_1\simeq\boldsymbol{e}_1 \tag{130}$$

$$\boldsymbol{E}_2\simeq\boldsymbol{e}_2 \tag{131}$$

We assume that V_2 is $r_2 > R$ area. R is the radius of the sphere Γ. $r_2=|\boldsymbol{x}_2|$, $\boldsymbol{x}_2$ is the location of the current density $\boldsymbol{J}_2$. $\boldsymbol{J}_2$ generats the advanced wave. These retarded waves and advanced waves sent from $\boldsymbol{J}_1$ and $\boldsymbol{J}_2$ are synchronized. This synchronization means that,

$$\boldsymbol{H}_2\sim\boldsymbol{J}_2\sim\boldsymbol{E}_1\sim\boldsymbol{e}_1\sim\boldsymbol{h}_1 \tag{132}$$

hence there is,

$$\boldsymbol{H}_2\simeq\boldsymbol{h}_1 \tag{133}$$

Hence there is,

$$\boldsymbol{H}_1\sim\boldsymbol{E}_2\simeq\boldsymbol{e}_2\sim\boldsymbol{h}_2 \tag{134}$$

$$\boldsymbol{H}_1\simeq\boldsymbol{h}_2 \tag{135}$$

Substitute (130, 131, 133 and 135) into the first half of (129),

$$-\int_{V_1}(\boldsymbol{E}_2^*\cdot\boldsymbol{J}_1)dV=\oiint_{\Gamma}(\boldsymbol{E}_1\times\boldsymbol{H}_2^*+\boldsymbol{E}_2^*\times\boldsymbol{H}_1)\cdot\hat{n}d\Gamma$$

$$=\oiint_{\Gamma}(\boldsymbol{e}_1\times\boldsymbol{h}_1^*+\boldsymbol{e}_2^*\times\boldsymbol{h}_2)\cdot\hat{n}d\Gamma$$

$$=\oiint_{\Gamma}(\boldsymbol{s}_{11}+\boldsymbol{s}_{22})\cdot\hat{n}d\Gamma \tag{136}$$

We know,

$$\boldsymbol{s}_{11}=\boldsymbol{e}_1\times\boldsymbol{h}_1^*,\quad s_{22}=\boldsymbol{e}_2^*\times\boldsymbol{h}_2$$

The effect of absorption should be consistent with emission, so there is,

$$\boldsymbol{s}_{11}=\boldsymbol{s}_{22} \tag{137}$$

We get,

$$-\int_{V_1}(\boldsymbol{e}_2^*\cdot\boldsymbol{J}_1)dV=2\oiint_{\Gamma}\boldsymbol{s}_{11}\cdot\hat{n}d\Gamma \tag{138}$$

We can compare it with Poynting's theorem,

$$-\int_{V_1}(\boldsymbol{e}_1^*\cdot\boldsymbol{J}_1)dV=\oiint_{\Gamma}\boldsymbol{s}_{11}\cdot\hat{n}d\Gamma \tag{139}$$

Firstly, we compare the right-hand side of formulas (138) and (139). (138) has an additional factor of 2. We should first address the issue of factor 2.

2. Reasons for the Occurrence of Factor 2

We first noticed that the radiation energy flow calculated by formula (138) is twice as large as that calculated by formula (139). The factor of 2 is easy to understand. In Maxwell's electromagnetic theory, only the source of radiation produces an energy flow. However, in the author's electromagnetic field theory, the energy flow generated by the sink is added, so the calculated energy flow is doubled. This of course requires us to modify the formula (129). Firstly, considering the mutual energy flow theorem in Maxwell's electromagnetic theory, it should be modified to:,

$$-\int_{V_1}(\boldsymbol{e}_2^*\cdot\boldsymbol{J}_1)dV=\frac{1}{2}\oiint_\Gamma(\boldsymbol{e}_1\times\boldsymbol{h}_2^*+\boldsymbol{e}_2^*\times\boldsymbol{h}_1)\cdot\hat{n}d\Gamma=\int_{V_2}(\boldsymbol{e}_1\cdot\boldsymbol{J}_2^*)dV \tag{140}$$

The above equation is for the compression of mutual energy flow by %50. The above equation can be rewritten as,

$$-\int_{V_1}(\frac{1}{2}\boldsymbol{e}_2^*\cdot\boldsymbol{J}_1)dV$$
$$=\oiint_\Gamma(\frac{1}{2}\boldsymbol{e}_1\times\frac{1}{2}\boldsymbol{h}_2^*+\frac{1}{2}\boldsymbol{e}_2^*\times\frac{1}{2}\boldsymbol{h}_1)\cdot\hat{n}d\Gamma$$
$$=\int_{V_2}(\frac{1}{2}\boldsymbol{e}_1\cdot\boldsymbol{J}_2^*)dV \tag{141}$$

Consider the need to lower the electric and magnetic fields

$$\boldsymbol{e}'=\frac{1}{2}\boldsymbol{e},\quad \boldsymbol{h}'=\frac{1}{2}\boldsymbol{h} \tag{142}$$

This way (141) can be rewritten as,

$$-\int_{V_1}(\boldsymbol{e}'^*_2\cdot\boldsymbol{J}_1)dV=\oiint_\Gamma(\boldsymbol{e}'_1\times\boldsymbol{h}'^*_2+\boldsymbol{e}'^*_2\times\boldsymbol{h}'_1)\cdot\hat{n}d\Gamma=\int_{V_2}(\boldsymbol{e}'_1\cdot\boldsymbol{J}_2^*)dV \tag{143}$$

Rewrite (142) as,

$$2\boldsymbol{e}'=\boldsymbol{e},\quad 2\boldsymbol{h}'=\boldsymbol{h} \tag{144}$$

Consider the Maxwell equation,

$$\begin{cases}\nabla\times\boldsymbol{e}=-\frac{\partial}{\partial t}\boldsymbol{h}\\ \nabla\times\boldsymbol{h}=\boldsymbol{J}+\frac{\partial}{\partial t}(\epsilon_0\boldsymbol{e})\end{cases} \tag{145}$$

Substitute (144) into the Maxwell equation above to obtain,

$$\begin{cases}\nabla\times2\boldsymbol{e}'=-\frac{\partial}{\partial t}2\boldsymbol{h}'\\ \nabla\times2\boldsymbol{h}'=\boldsymbol{J}+\frac{\partial}{\partial t}(\epsilon_0 2\boldsymbol{e}')\end{cases}$$

Or

$$\begin{cases}\nabla\times\boldsymbol{e}'=-\frac{\partial}{\partial t}\boldsymbol{h}'\\ \nabla\times\boldsymbol{h}'=\frac{1}{2}\boldsymbol{J}+\frac{\partial}{\partial t}(\epsilon_0\boldsymbol{e}')\end{cases} \tag{146}$$

According to this Maxwell equation, it actually means that we have adopted half the retarded wave and half the advanced wave, which is

$$\boldsymbol{A}=\frac{1}{2}\frac{\mu_0}{4\pi}\int_V\frac{[\boldsymbol{J}]}{r}dV,\quad \phi=\frac{1}{2}\frac{1}{4\pi\epsilon_0}\int_V\frac{[\rho]}{r}dV \tag{147}$$

Or,

$$\boldsymbol{A}=\frac{1}{2}\frac{\mu_0}{4\pi}\int_V\frac{\{\boldsymbol{J}\}}{r}dV,\quad \phi=\frac{1}{2}\frac{1}{4\pi\epsilon_0}\int_V\frac{\{\rho\}}{r}dV \tag{148}$$

The square brackets represent retarded, $[\boldsymbol{J}]=\boldsymbol{J}(t-r/c)$. Curly braces indicate advanced, i.e.,$\{\boldsymbol{J}\}=\boldsymbol{J}(t+r/c)$

$$\boldsymbol{e}'=-\frac{\partial}{\partial t}\boldsymbol{A}-\nabla\phi \tag{149}$$

$$\boldsymbol{h}'=\frac{1}{\mu_0}\nabla\times\boldsymbol{A} \tag{150}$$

From this perspective, we have two options, (1) using (140). This indicates that we have reduced the calculated mutual energy flow pressure to 50%. The second option is to reduce the calculated electric and magnetic fields to 50% of the original value, referring to (147-150). This is also equivalent to reducing the current by 50%, refer to (146). The first choice is relatively simple in calculation. The second option is conceptually clear. The second choice clearly tells us that if we consider sinks, as they also generate energy flow, the correct Maxwell equation should be (146), which corresponds to half the retarded wave and half the advanced wave (147). The concept of half retarded and half advanced was proposed by Dirac and Wheeler Feynman. The author correctly applied this concept to electromagnetic theory for the first time.

According to the first choice, the mutual energy flow energy law of the author's electromagnetic theory corresponding to (140) is,

$$-\int_{V_1}(\boldsymbol{e}_2^*\cdot\boldsymbol{J}_1)dV=\frac{1}{2}\oiint_\Gamma(\boldsymbol{e}_1\times\boldsymbol{h}_2^*+\boldsymbol{e}_2^*\times\boldsymbol{h}_1)\cdot\hat{n}d\Gamma=\int_{V_2}(\boldsymbol{e}_1\cdot\boldsymbol{J}_2^*)dV \tag{151}$$

Replace (129) with (151), and the formula (138) becomes,

$$-\int_{V_1}(\boldsymbol{e}_2^*\cdot\boldsymbol{J}_1)dV=\oiint_\Gamma(\boldsymbol{s}_{11})\cdot\hat{n}d\Gamma \tag{152}$$

The results obtained from the author's electromagnetic theory are now closer to the results and formulas of Maxwell's electromagnetic theory (139). That is to say, if we consider half retarded wave and half advanced wave (138), the factor 2 disappears. This also indicates that Maxwell's electromagnetic theory does not allow sinks. To allow for sinks in Maxwell's electromagnetic theory, one must first solve the problem of the 2 or $\frac{1}{2}$ factor.

3. Calculating the Output Power of Current

The right side of the formula (152) and the formula (139) are still different. The right side of both formulas represents the output power of the current $\boldsymbol{J}_1$. We first calculate this power based on Maxwell's electromagnetic theory

$$-\int_{V_1}(\boldsymbol{e}_1^*\cdot\boldsymbol{J}_1)dV\to-\int_{C_1}\boldsymbol{e}_1^*d\boldsymbol{l}I_1$$
$$=-\mathcal{E}_1^*I_1=-j\omega L_1I_1^*I_1 \tag{153}$$

The symbol "→" represents the transformation from volume current to line current. Consider the definition of electromotive force,

$$\mathcal{E}_1\triangleq\int_{C_1}\boldsymbol{e}_1^*d\boldsymbol{l} \tag{154}$$

Although the retarded effect should be considered for the electric field in the above formula, since we assume that the size of the current element is very small, the electric field on the current element $\boldsymbol{E}_1$, the retardation can be ignored. Therefore, the calculation formula for this electromotive force is,

$$\mathcal{E}_1 = -j\omega L_1 I_1 \tag{155}$$

It can been that the formula (153) takes a pure imaginary value. On the right side of (139) is the radiation of the current element according to Maxwell's electromagnetic theory, which is not zero, so the real part on the right side is not zero. Therefore, the formula (139) cannot be satisfied. This is an obvious loophole in Poynting's theorem. It is also an obvious flaw in Maxwell's electromagnetic theory. This is also one of the reasons why we need to establish a new electromagnetic theory.

If we use (152) to calculate the radiation of the current element,

$$-\int_{V_1} (\boldsymbol{e}_2^* \cdot \boldsymbol{J}_1) dV \tag{156}$$

We know the electric field $\boldsymbol{E}_1$ is,

$$\boldsymbol{e}_1 \sim -j\omega \boldsymbol{A}_1 \sim -j\boldsymbol{J}_1 \exp(-jkr) \tag{157}$$

The phase of current $\boldsymbol{J}_2$ should be consistent related to the electric field $e_1(r = R)$,

$$\boldsymbol{J}_2 \sim \boldsymbol{e}_1(r = R) = \boldsymbol{E}_1(r = R) \sim -j\boldsymbol{J}_1 \exp(-jkR) \tag{158}$$

Electric field $\boldsymbol{E}_2$ is an advanced wave,

$$\begin{aligned} \boldsymbol{E}_2 &\sim \boldsymbol{e}_2 \sim -j\omega \boldsymbol{A}_2 \sim -j\boldsymbol{J}_2 \exp(+jkR) \\ &\sim -j(-j\boldsymbol{J}_1 \exp(-jkR)) \exp(+jkR) \\ &\sim -j(-j\boldsymbol{J}_1) \sim jj\boldsymbol{J}_1 \sim -\boldsymbol{J}_1 \end{aligned} \tag{159}$$

Hence there is,

$$-\int_{V_1} (\boldsymbol{e}_2^* \cdot \boldsymbol{J}_1) dV \sim -\int_{V_1} (-\boldsymbol{J}_1^* \cdot \boldsymbol{J}_1) dV \sim \int_{V_1} (\boldsymbol{J}_1^* \cdot \boldsymbol{J}_1) dV \tag{160}$$

This indicates that the left side of (152) is also a real number, consistent with its right side. This indicates that the formula (152) overcomes the loophole in Poynting's theorem formula. The vulnerability is that (139) the left side is a pure imaginary number, and the right side is a real part that is not zero. Therefore, the formula (139) cannot hold true for antennas like short dipoles! This loophole is also a loophole in Maxwell's electromagnetic theory. This vulnerability has been corrected in formulas (152).

4. Factor of *sin* θ in the Directional Pattern of Dipole Antennas

Assuming there is a dipole antenna source. The dipole is located at the coordinate origin. The direction points towards the z-axis. Assuming that the photons released by this source are very rare, they are almost released one by one. Constitute a single photon light source. Assuming that the dipole source emits a photon exactly in the θ direction. Here, a photon is emitted along the θ direction, which means that the retarded wave emitted by the source is exactly synchronized with a sink on a sphere with an infinite radius of Γ, and the angle between this sink and the z-axis is. θ Obviously, we can project the dipole of the source in two directions. One is on the connection between the source and sink. One is in the direction parallel to the sink, as shown in 7. The dipole source in the direction of the connection is perpendicular to the sink, resulting in zero electromagnetic field. A dipole in the direction parallel to the sink can exactly produce a photon with the sink. The size of the dipole antenna in the direction parallel to the sink is,

$$\boldsymbol{J}_1 \sin(\theta) \tag{161}$$

Hence there is,

$$|\boldsymbol{E}_1| \sim \boldsymbol{J}_1 \sin(\theta) \tag{162}$$

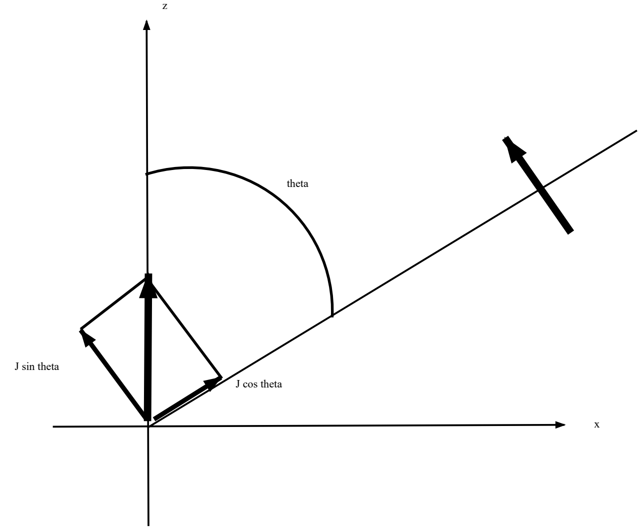

Figure 7: Schematic Diagram for Calculating the Directional Pattern of a Dipole Antenna

The electromagnetic field power of photons emitted along the source and sink will have a factor of $\sin^2(\theta)$. So the power in the θ direction is,

$$P(\theta)=|\boldsymbol{E}_1|^2 \sim \boldsymbol{J}_1 \boldsymbol{J}_1^* \sin^2(\theta) \tag{163}$$

We use Maxwell's electromagnetic theory to calculate the antenna pattern of dipole radiation, and there is also a dipole antenna with a power pattern that is just right, and there is a pattern factor of $\sin^2(\theta)$.

For currents with more complex current distributions, the directional pattern can be obtained by superposition of dipole fields. Therefore, the directional pattern calculated according to the author's method should be consistent with the directional pattern calculated by Maxwell's electromagnetic theory. The photons emitted from the source to the sink are plane waves or quasi plane waves. That is, plane waves in photonic waveguides. Although this radiation energy does not decay. But if we average the radiation energy density on a sphere with a radius of R, the Poynting energy flow will be inversely proportional to the distance R^2, i.e.,

$$S \sim \frac{1}{R^2} \tag{164}$$

So for the average values of electric and magnetic fields,

$$E_f \sim \frac{1}{R}, \quad H_f \sim \frac{1}{R} \tag{165}$$

E_f, H_f is the far-field of the average value of electric and magnetic fields. The far-field pattern of the dipole antenna obtained by the author's one photon method is consistent with the far-field pattern obtained by Maxwell's electromagnetic theory. The attenuation of the average electromagnetic field and magnetic field with distance R is also consistent. As long as the antenna radiates a large number of photons, the far-field pattern cannot distinguish the difference between the two theories. But if the radiation energy of the antenna is reduced. We can observe that the sink is a collection of photons one by one. This situation is closer to the author's electromagnetic theory.

5. Summary

The macroscopic electromagnetic waves in Maxwell's electromagnetic theory are calculated by Maxwell's equations, and the calculation of electromagnetic fields requires considering the far field radiation boundary conditions of Sliver Müller. The far-field radiation power is calculated according to Poynting's theorem (139). In the author's electromagnetic theory, the Sliver Müller radiation boundary condition is replaced by sinks arranged on a sphere with an infinite radius. Then consider the random radiation retarded wave of the source. Each sink on the sphere with an infinite radius also randomly radiates advanced waves. Once the retarded wave synchronizes with the advanced wave emitted by a sink, this retarded wave and the advanced wave form a mutual energy flow. Once a mutual energy flow is formed, the retarded wave interferes and enhances in the sink direction, while the advanced wave interferes and enhances in the source direction. At this point, the retarded wave becomes the waveguide of the advanced wave, and the advanced wave becomes the waveguide of the retarded wave. Two waves synchronize, or shake hands, and form plane waves. Form a light waveguide between the source and sink. The energy of a photon travels along this waveguide from the source to the sink.

Although photons are emitted one by one, we can calculate the average radiation energy emitted from the source. If the source is a dipole antenna, due to the angle between the dipole antenna and the sink, the average radiation energy map will exhibit a pattern factor of sin2(). This pattern factor is also consistent with the far-field radiation pattern of a dipole antenna calculated using Maxwell's electromagnetic theory.

VII. Conclusion

In electromagnetic field theory, there exists a sink. The sink includes the coil of the transformer, the receiving antenna, and the absorber charge. The sink absorbs the energy of the electromagnetic field. Sinks also generate electromagnetic fields. This electromagnetic field is advanced waves. It is a controversial issue whether the receiving antenna generates advanced waves or not. But everyone will not object to the fact that the current in the secondary coil of a transformer also generates electromagnetic fields. However, the author's analysis indicates that once sinks are considered in Maxwell's electromagnetic theory, at least one point must be modified, which is to adopt the concept of half retarded wave and half advanced wave. That is to say, we need to add a factor of 1/2 to the current in Maxwell's equation (146).

Dirac first proposed the concept of half retarded wave and half advanced wave to explain the problem of self-force. Wheeler Feynman's theory of absorbers further developed the theory of half retarded wave and half advanced wave. Cramer further developed this theory and proposed a quantum mechanical transactional interpretation. But they did not truly implement the idea of half retarded and half advanced in electromagnetic theory. The author systematically implemented the electromagnetic theory of half retarded wave and half advanced wave. In the author's electromagnetic theory, the source produces a retarded wave, while the sink produces a advanced wave. These waves first need to be compressed by % 50. Otherwise, the calculated radiation intensity will exceed twice.

The author proposes a new electromagnetic theory, which is composed of several important laws: (1) The law of radiation not spilling out of the universe (2) The law of conservation of energy. (3) The law that the mutual energy flows are photons. (4) The current simultaneously radiates both retarded and advanced waves, whech must not cancel out on the surface of the current. (5) Electromagnetic theory should be a theory of retarded field rather than retarded potential.

The author believes that these retarded and advanced waves are both reactive power waves. Therefore, these waves propagate towards the entire space but can automatically return to the source or sink. That is to say, it will collapse in the opposite direction. But if the retarded waves emitted by the source reaches a certain sink, the sink also happens to emit a advanced wave, and this retarded wave is synchronized with this advanced wave. In Cramer's words, it is a handshake between retarded waves and advanced waves. The author believes that this synchronization or handshake process generates mutual energy flow. The mutual energy flow is a photon.

When the synchronization or handshake process is just beginning, the mutual energy flow is very weak. However, the retarded wave interferes more strongly in the direction of the advanced wave. The interference of the advanced wave strengthens in the direction of the retarded wave. Wave interference cancels in other directions. In this way, the advanced wave forms a waveguide for the retared wave. The retarded wave forms a waveguide for the advanced wave. Therefore, retarded waves and advanced waves become planar or quasi planar waves just like they propagate in a waveguide. Therefore, photons can be approximately described by plane waves.

In this way, we can assume that the source is emitting photons randomly, which is known as mutual energy flow. Adding up the energy flow of these photons is the energy flow of macroscopic electromagnetic waves emitted by the source. The author proves that the energy flow of these photons combined is exactly consistent with the energy flow corresponding to the Poynting vector. This proves that the electromagnetic theory proposed by the author, which is half retarded wave and half advanced wave, is equivalent to Maxwell's classical electromagnetic theory. At least the conclusions of the two theories are consistent in the far field of antenna radiation. When calculating the far field of an antenna, Maxwell's electromagnetic field theory uses the Sliver-Müller radiation boundary condition. In the author's electromagnetic theory, this radiation condition is achieved by arranging sinks on a sphere with an infinite radius.

In addition, there was originally a loophole in Poynting's theorem. The left and right sides of Poynting's law cannot be equal. This mistake has also been corrected in the auther's theory.

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