Peeking into the secret of particle and wave through the reactive power of a transformer

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Abstract

Traditionally, there is only one kind of electromagnetic radiation. It’s electromagnetic waves. The author’s research shows that electromagnetic radiation can be subdivided into two different types. One is self energy radiation, the other is mutual energy radiation. The two kinds of radiation have different properties. First of all, let’s make the primary coil of the transformer, the transmitting antenna and the charge of the emitter all become the emission source of radiation. The secondary coil of the transformer, the receiving antenna and the charge of the absorber are all called the radiation absorption sink. The source can emit electromagnetic energy, and the sink can receive electromagnetic energy. The author thinks that both the source and the sink have electric current running on them, so they produce electromagnetic waves. The wave produced by the source is the retarded wave, and the wave produced by the sink is the advanced wave. The self energy radiation is the radiation from only one source or sink. The self energy radiation satisfies one set of Maxwell equations. Mutual energy radiation is the radiation of a system containing at least one pair of source and sink, which must satisfy a pair of sets of Maxwell equations. One set of the Maxwell equations corresponds to the source and one to the sink. Two sets of Maxwell equations must be solved simultaneously. The simultaneous solutions are equivalent to the mutual energy principle. In addition, mutual energy radiation must satisfy the law of conservation of energy (Here energy conservation law is not the Poynting theorem but a generalized mutual energy theorem). From this we can deduce the theorem of mutual energy flow theorem. The properties of mutual energy flow are consistent with that of photons. Therefore, the theory of mutual energy radiation is also the theory of photons. In the author’s theory, it is speculated that since there is no other object to absorb the self energy radiation, this part of energy can not go out of the universe, so it should be returned. Therefore, the concept of time reversal wave is proposed. That is to say, although self energy radiation brings energy to the whole space, this part of energy returns to the source. The return process is completed by the reverse collapse of the wave. The reverse collapse of a wave is accomplished by a time reversal wave. The time reversal wave satisfies the Maxwell equation of time reversal. Through the study of the reactive power of the transformer primary coil, it is found
that the reactive power is actually the energy of the electromagnetic field
emitted by the transformer primary coil to the whole space, but the energy
collapses back. In fact, the transmitting antenna has the same reactive
power as the primary coil of the transformer. This part of radiation is
self energy radiation. Besides reactive power radiation, the transmitting
antenna also has active power radiation. Mutual energy radiation belongs
to active power radiation. This article studies the relationship of the self
energy radiation, mutual energy radiation, reactive power radiation, ac-
tive power radiation. The conclusion is the self-energy radiation does not
carry energy. The mutual energy radiation can carry the energy through
the mutual energy flow.

Keywords: Poynting; Maxwell; Schrödinger; Self-energy; Mutual en-
ergy; Mutual energy flow; Reciprocity theorem; Radiation; Newton's third
law; Action; Reaction; Retarded wave; Advanced wave; Photon; Electron;
Wave particle duality; Transformer; primary coil; Secondary coil; Active
power; Reactive power; Transformer; Antenna;

1 Introduction

There have always been two views on whether electromagnetic waves are independent or inseparable from radiation sources. The first view is that electromagnetic waves can be separated from their sources and propagate independently in space. In this way, the current induces a magnetic field, \( \nabla \times \mathbf{H} = \mathbf{J} \). The magnetic field can produce an electric field, \( \nabla \times \mathbf{E} = -\mu_0 \frac{\partial}{\partial t} \mathbf{H} \). The electric field can produce a magnetic field again, \( \nabla \times \mathbf{H} = \frac{\partial}{\partial t} \mathbf{E} \). The magnetic field further induces an electric field. This spread step by step. Therefore, the elec-
tromagnetic field is independent of its source. People who hold this view include
Faraday and Maxwell. Maxwell believed that electromagnetic fields could travel independently in the ether. This view is accepted by most electromagnetic text-
books. Therefore, if we want to calculate the direct electromagnetic radiation from the transmitting antenna to the receiving antenna. Firstly, the elec-
tromagnetic field emitted by the transmitting antenna is calculated to make the electromagneti
c field propagate freely to the receiving antenna in space. Then consider the effect of the electromagnetic field on the receiving antenna.

Another view is that, electromagnetic wave can be calculated by retarded potential and advanced potential, so both magnetic field and electric field are generated by current passing through the sources or the sinks. First, vector potential and scalar potential are generated, \( \mathbf{A}(\mathbf{x}, t) = \frac{\mu_0}{4\pi} \iiint_V \frac{J(\mathbf{x}', t-r/c)}{r} dV \), \( \phi(\mathbf{x}, t) = \frac{1}{4\pi \varepsilon_0} \iiint_V \frac{\rho(\mathbf{x} - \mathbf{x'}, t-r/c)}{r} dV \), where \( r = |\mathbf{x} - \mathbf{x'}| \), \( c \) is speed of light. The electromagnetic fields can be calculated from vector potential and scalar potential, \( \mathbf{E} = -\nabla \phi - \frac{\partial}{\partial t} \mathbf{A} \), \( \mathbf{B} = \nabla \times \mathbf{A} \). Therefore, the electromagnetic field cannot be separated from its source.

Weber and Newman are typical representatives of this view in the 19th century. In the 20th century, there were K. Schwarzschild, H. Tetrode, A. D. Fokker [11,13,6]. Richard Feynman and John Wheeler [11,2] Wheeler and Feynman believe that electromagnetic fields have no degrees of freedom of their own. The
electromagnetic field is just a record of the action-at-a-distance. Electromagnetic field is the assistant of the action-at-a-distance. Wheeler and Feynman think that there must be reaction if there is action, so there must be at least two objects. Another example is the emitter charge and absorber charge. Moreover, the retarded wave is generated by the emitter charge and the advanced wave is generated by the absorber charge. Current element can produce both retarded wave and advanced wave. It can also produce half retarded wave and half advanced wave. Based on Wheeler and Feynman absorber theory, John Cramer proposed a transactional interpretation of quantum mechanics. This interpretation recognizes the advanced wave as an objective existence. John Cramer called the retarded wave the offer wave, and he called the advanced wave the confirmation wave. The offer wave of an emitter trades with the confirmation wave of an absorber. The offer wave can only trade with one of the thousands of confirmation waves. It is said that at one meeting, Feynman with Wheeler explained their theory about advanced waves. Wolfgang Ernst Pauli attended the meeting and opposed Feynman’s view. Einstein also attended the meeting. Pauli is attempt to unite Einstein against Feynman and Wheeler’s theory was rejected by Einstein. Einstein explicitly supported Feynman Wheeler’s theory of advanced waves. He also mentioned that he and Walther Ritz had a debate in 1910 about whether time could be retrieved. At that time, Einstein supported the inversion of time in microscopic phenomena, and Ritz believed that there must be a physical law to block the reverse movement of time.

In early 1987, the author proposed the mutual energy theorem of the electromagnetic field [8],

$$-\iiint V E_2^*(x, \omega) J_1(x, \omega) dV = \iiint V E_1(x, \omega) J_2^*(x, \omega) dV$$  \hspace{1cm} (1)

In 1989, the mutual energy theorem was further extended [15][17]. Later this author learned that Rumsey actually put forward the same formula in 1963 [13]. Welch put forward a similar formula in 1960 [16].

$$-\int_{t=-\infty}^{\infty} dt \iiint V E_2(x, t) J_1(x, t) dV = \int_{t=-\infty}^{\infty} dt \iiint V E_1(x, t) J_2(x, t) dV$$  \hspace{1cm} (2)

de Hoop put forward a similar formula at the end of 1987[5],

$$-\int_{t=-\infty}^{\infty} dt \iiint V E_2(x, t + \tau) J_1(x, t) dV = \int_{t=-\infty}^{\infty} dt \iiint V E_1(x, t) J_2(x, t + \tau) dV$$  \hspace{1cm} (3)

Welch’s theorem is a special case of de Hoop’s. The Fourier transform of de Hoop’s theorem is the author’s mutual energy theorem or Rumsey’s reciprocity theorem.
Welch, Rumsey and de Hoop call their theorems as reciprocity theorems. If it is the reciprocity theorem, only one of the two quantities in the theorem is the physical quantity of the theorem. Another electromagnetic field can be mathematical, or virtual electromagnetic field for auxiliary calculation. Reciprocity theorem is often used to calculate electromagnetic field or antenna directivity patterns. The mutual energy theorem tells us that the energy received by the receiving antenna is exactly equal to the energy transmitted by the transmitting antenna to the receiving antenna. Because this formula involves advanced waves. As a reciprocity theorem, there is no problem in choosing the virtual electromagnetic field as the advanced wave. As an energy theorem, two quantities in the formula are required to exist physically. Therefore, if one of the waves is an advanced wave, the advanced wave must exist objectively.

In 2014, the author noticed the viewpoint of Wheeler Feynman’s absorber theory, which was greatly inspired. In particular, Wheeler Feynman’s epistemology that the advanced wave is an objective physical entity has greatly encouraged the author. The author began to study the mutual energy and related theories. Includes Welch’s reciprocity theorem. In 2017, the author proposed the mutual energy principle, self energy principle, the mutual energy flow theorem and mutual energy interpretation of quantum mechanics [2]. In 2020, the normalized theory of mutual energy flow is published [10]. In addition, the theory is extended to quantum mechanics [11]. Feynman’s absorber theory, Cramer’s quantum mechanics transactional interpretation, are qualitative theories about interaction and reaction. The author’s theory of mutual energy is Wheeler Feynman’s absorber theory and Cramer’s further quantitative theory of quantum mechanics.

If the mutual energy theory is used to solve the problem of electromagnetic radiation, what is the main difference with the electric field theory in today’s teaching books?

1. Admit that the advanced wave is an objective existence. Receiving antenna, absorber charge radiate the advanced wave.

2. There are two kinds of electric field radiation. Self energy radiations and mutual energy radiations.

3. Self energy radiation satisfies Maxwell’s equations. The radiant energy does not interact with any other object. This part of energy returns to the source through the time reversal wave. The wave returning to the source is a time reversal process, which satisfies the time-reversal Maxwell’s equations.

4. Mutual energy radiation, at least one transmitting antenna and one receiving antenna in a system, transmitting antenna transmits retarded wave and receiving antenna transmits advanced wave. The interaction between the two waves must be considered. \( N \geq 2 \) sets of Maxwell’s equations must be solved simultaneously.

5. If the retarded wave is synchronized with the advanced wave, the retarded wave and the advanced wave can produce mutual energy flow. The mutual energy flow includes both retarded wave and advanced wave. The mutual energy flow is responsible for carrying energy from the radiator to the absorber or from the transmitting antenna to the receiving antenna.
6. The normalized mutual energy flow is consistent with the properties of photons. Therefore, photons can be regarded as normalized mutual energy flow.

7. The retarded wave cannot exist independently from the radiator. The advanced wave cannot exist independently of the absorber. But mutual energy flow can transfer energy from the radiator to the absorber. Photons are mutual energy flow, so photons can leave the source of radiation and be transferred from the emitter to the absorber.

8. The mutual energy current cannot exist in space independently without retarded wave and advanced wave. Therefore, the mutual energy radiation cannot exist independently from the self energy radiation. Mutual energy radiation must have self energy radiation. On the contrary, it does not hold. Self energy radiation can exist independently of mutual energy radiation.

9. The wave collapse is composed of two processes. (A) The retarded wave collapses backward to the radiation source. The advanced wave collapses backward to the absorber. The backward collapse is completed by a time reversal wave. (B) The mutual energy flow transfers energy from the emitter to the absorber.

The second chapter of this paper reviews the theory of mutual energy. The two kinds of radiation should also be explained in detail. In this review, we can see that the backward collapse of self energy flow is due to the consideration of energy conservation and self consistency of Maxwell's equations. These are still speculation.

In the third chapter, the concepts of time reversal wave and reactive power of wave are connected. The author proves that if the power of a wave is reactive power, the wave will radiate energy into space. But eventually this part of the energy radiated into space will return to its source through the time reversal wave. Therefore, the wave containing reactive power can be called a reactive wave. Reactive waves are composed of retarded wave and its corresponding time-reversal wave. According to the traditional theory, reactive waves are a kind of near-field effect. That is to say, a reactive wave does only output energy around the antenna, and does not radiate energy to the whole space. In fact, this is not true. The reactive wave does radiate energy to the whole space, but this energy returns to the radiation source from infinity.

It is worth mentioning that reactive waves radiate energy to the whole space. If another receiving antenna, or an absorber, is intended to receive this part of energy, the absorber releases the advanced wave when the retarded wave reaches it. The advanced wave and the retarded wave release extra energy synchronously, and produce the mutual energy flow. The energy of mutual energy flow is the energy other than that of retarded wave and advanced wave. Therefore, no matter whether the mutual energy flow is generated or not, the self energy flow must backward collapse. The self energy flow is reactive power. Previously, we speculated that the time reversal wave is emitted at the same time as the retarded wave. With the concept of reactive power wave, in fact, in a wave period $\left[ -\frac{T}{2}, \frac{T}{2} \right]$, there are two sub-periods of time, the wave is a retarded wave, and there are two sub-periods of time, the wave is a time reversal wave. A similar theory can also be applied to the advanced wave of self-energy radiation.
2 Review of the theory of mutual energy

2.1 The mutual energy formula

Recent years (2014) this author realized that the mutual energy theorem [8] is closely related to the absorber theory of Wheeler and Feynman [11, 12], the transactional interpretation of quantum mechanics [3, 4]. Hence, this author re-worked at the concept of the mutual energy and further introduced the mutual energy principle, the self-energy principle and the mutual energy flow theorem [9]. This author also introduced the concept that the photon is nothing else but the normalized mutual energy flow [10]. The concept of mutual energy flow and mutual energy principle and self-energy principle are also widened to the quantum mechanics [11, 12]. In the following we quickly review the most important concept of the mutual energy principle and the self-energy principle.

2.2 The Energy conservation of \( N \) charges

We know that a source for example a charge with current \( J_i \) in the field of another charge \( E_j \) can consume the power, \( \int \int V J \cdot E dV \). Since if charge \( i \) offers charge \( j \) some energy, the energy of charge \( i \) will be reduced, but some time latter the energy of the charge \( j \) will increase, hence the energy of the system will not increase or reduce. Assume in the space there is \( N \) charges, we have,

\[
\sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \int_{-\infty}^{\infty} dt \int \int V J_i(t) \cdot E_j(t) dV = 0
\]  

(4)

This is the energy conservation law for \( N \) charges. In the author’s theory it will be applied as an axiom, instead to derive it from Maxwell equations. Since if we derive it from Maxwell equations this author needs to first assume the existence of the advanced wave. This author believes that the above energy conservation law is self-explained would like to first assume the energy conservation law. In this way later the advanced wave can be derived as a theorem. This wave will easily to introduce the concept of advanced waves.

2.3 A Green function for Maxwell’s equations

Maxwell equations(dynamic part),

\[
\begin{align*}
-\frac{\partial}{\partial t} \varepsilon_0 E + \nabla \times H &= J\\
-\nabla \times E - \frac{\partial}{\partial t} \mu_0 H &= 0
\end{align*}
\]  

(5)

Or in matrix expression,

\[
L \xi = \tau
\]  

(6)

where

\[
L = \begin{bmatrix}
-\varepsilon_0 \frac{\partial}{\partial t}, & \nabla \times \\
-\nabla \times, & -\mu_0 \frac{\partial}{\partial t}
\end{bmatrix}
\]  

(7)
\( \xi = [E, H]^T, \tau = [J, 0]^T \). Superscript \( T \) is matrix transfer. We can prove the following mathematical formula is established,

\[
-(\xi_1, \xi_2) = \iiint_V (\xi_1 \cdot \mathbf{L} \xi_2 + \xi_2 \cdot \mathbf{L} \xi_1 + \frac{\partial}{\partial t} u_{12}) dV
\]  

(8)

where \((\xi_1, \xi_2) = \oint_{\Gamma} (E_1 \times H_2 + E_2 \times H_1) \cdot \hat{n} d\Gamma\) and \(u_{12} = \varepsilon_0 E_1 \cdot E_2 + \mu_0 H_1 \cdot H_2\). The above Eq. (8) is a kind of Green function for Maxwell’s equations.

2.4 Mutual energy principle of \( N \) charges

Assume in the space there is two charges or two antennas, they should satisfy the Maxwell equations,

\[
L \xi_1 = \tau_1, \quad L \xi_2 = \tau_2
\]  

(9)

Substitute the Maxwell’s equations Eq. (9) to the Green function Eq. (8) we have

\[
-(\xi_1, \xi_2) = \iiint_V (\xi_1 \cdot \tau_2 + \xi_2 \cdot \tau_1 + \frac{\partial}{\partial t} u_{12}) dV
\]  

(10)

where \((\xi_1, \xi_2) = \oint_{\Gamma} (E_1 \times H_2 + E_2 \times H_1) \cdot \hat{n} d\Gamma\). The above formula can be written as,

\[
-\sum_{i=1}^{2} \sum_{j=1, j \neq i}^{2} \oint_{\Gamma} (E_i \times H_j) \cdot \hat{n} d\Gamma
\]

\[
= \sum_{i=1}^{2} \sum_{j=1, j \neq i}^{2} \iiint_V (E_i \cdot J_j + (\varepsilon_0 \frac{\partial}{\partial t} E_i \cdot E_j + \mu_0 \frac{\partial}{\partial t} H_i \cdot H_j)) dV
\]  

(11)

This is the mutual energy principle of \( N = 2 \). If there are \( N \) charges, the above formula can be written as,

\[
-\sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \oint_{\Gamma} (E_i \times H_j) \cdot \hat{n} d\Gamma
\]

\[
= \sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \iiint_V (E_i \cdot J_j + (\varepsilon_0 \frac{\partial}{\partial t} E_i \cdot E_j + \mu_0 \frac{\partial}{\partial t} H_i \cdot H_j)) dV
\]  

(12)

The above is referred as the principle of the mutual energy principle for \( N \) charges, which is sufficient and necessary conditions of \( N \) group Maxwell equations,

\[
\nabla \times E_i = -\frac{\partial}{\partial t} B_i, \quad \nabla \times H_i = J_i + \frac{\partial}{\partial t} D_i \quad i = 1, \cdots, N
\]  

(13)
Figure 1: Comparison of the solution set of the Maxwell equations and that of the mutual energy principle. The solution of Maxwell’s equations can be retarded waves or advanced waves. Only very small part of Maxwell’s equations, they are pairs with one is retarded and another is advanced and synchronized together will be the solution of the mutual energy principle.

The mutual energy principle is equivalent to a system with \( N \) charges, and all waves of the charges are synchronized together. Hence, the mutual energy principle is not equivalent to a single Maxwell’s equations for example Eq. (3). This is the reason that this author would like to put the mutual energy principle as another new axiom of electromagnetic field theory. The mutual energy principle can replace \( N \) groups Maxwell’s equations Eq. (13).

The mutual energy principle can only have two groups of Maxwell’s equations, one is used for the primary coil, another is used for the secondary coil. The two groups of Maxwell equations need to be synchronized. This is clear that the primary coil needs to work together with the secondary coil. This also means the mutual energy principle is not equivalent to Maxwell’s equations. Hence, the mutual energy principle is suitable to be referred to as a principle independent of the Maxwell’s equations. Mutual energy principle can be applied in the following situation, a transformer with a primary coil and a secondary coil; an antenna system with a transmitting antenna and a receiving antenna; a photon system with an emitter and an absorber. Figure 1 shows the difference of the solutions of Maxwell’s equations and the solution of the mutual energy principle.

Another reason the mutual energy principle can be applied as a new axiom is because with this new axiom that the solution set can be reduced. Any conditions can that reduce the set of the solutions can be seen as an independent condition and should be applied as a new axiom.

2.5 Theorem for the advanced waves

Advanced waves are real waves. Make a time integral to the mutual energy principle of \( N \) charges Eq. (12).
\[- \sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \int_{-\infty}^{\infty} dt \oint_{\Gamma} (\mathbf{E}_i \times \mathbf{H}_j) \cdot \mathbf{n} d\Gamma \]

\[= \sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \int_{V}^{\infty} dt \iiint_{V} (\mathbf{E}_i \cdot \mathbf{J}_j + (\epsilon_0 \frac{\partial}{\partial t} \mathbf{E}_i + \mu_0 \frac{\partial}{\partial t} \mathbf{H}_i) \cdot \mathbf{H}_j) dV \]

(14)

Consider,

\[\sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \int_{-\infty}^{\infty} dt \iiint_{V} (\epsilon_0 \frac{\partial}{\partial t} \mathbf{E}_i \cdot \mathbf{E}_j + \mu_0 \frac{\partial}{\partial t} \mathbf{H}_i \cdot \mathbf{H}_j) dV \]

\[= \int_{-\infty}^{\infty} dt \frac{\partial}{\partial t} U = U(\infty) - U(-\infty) = 0 \]

(15)

where \(U = \iiint_{V} \sum_{i=1}^{N} \sum_{j<i}^{N} (\epsilon_0 \mathbf{E}_i \cdot \mathbf{E}_j + \mu_0 \mathbf{H}_i \cdot \mathbf{H}_j) dV\) is the mutual energy in the space. \(U(\infty)\) is the mutual energy of the system after the process, hence, \(U(\infty) = 0\). \(U(-\infty)\) is the mutual energy before the process, hence \(U(-\infty) = 0\). Substitute Eq. (15) and energy conservation law Eq. (4) to Eq. (14), there is,

\[\sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \int_{-\infty}^{\infty} dt \oint_{\Gamma} (\mathbf{E}_i \times \mathbf{H}_j) \cdot \mathbf{n} d\Gamma = 0 \]

(16)

If \(N = 2\) there is,

\[(\xi_1, \xi_2) = \int_{-\infty}^{\infty} dt \oint_{\Gamma} (\mathbf{E}_1 \times \mathbf{H}_2 + \mathbf{E}_2 \times \mathbf{H}_1) \cdot \mathbf{n} d\Gamma = 0 \]

(17)

Surface \(\Gamma\) can be chosen as a big sphere with its radius as infinitely large. The above two formulas Eq. (16, 17) tell us the mutual energy flow should not go to the outside of the surface. If \(\xi_1, \xi_2\) are all retarded wave the above formula normally cannot satisfied. If \(\xi_1, \xi_2\) are all advanced waves, the above formula can also not be satisfied. Only when \(\xi_1, \xi_2\) one is retarded wave and another is advanced wave the above formula can be satisfied. This is because, the retarded waves reach the surface \(\Gamma\) in a future time. The advance waves reach the surface in a past time. The two waves are not nonzero at the same time, Hence, the surface integral will be zero. This means in order to satisfy the above formula, \(\xi_1, \xi_2\) one have to be the retarded wave, another have to be the advanced wave. This also means the advanced wave has to be a real wave instead of a virtual wave.

In case there are \(N\) charges, the retarded wave and the advanced wave must be paired. In this case Eq. (16) can be satisfied. This also means advanced waves
have to be a real wave. Hence, the transmitting antennas send the retarded waves, the receiving antennas send the advanced waves. The emitter radiates the retarded wave. The absorber radiates the advanced waves. The two waves are synchronized.

2.6 Mutual energy flow theorem

From the mutual energy principle Eq. (12) and the energy conservation law Eq. (10), the mutual energy flow theorem can be derived, which can be written as following,

$$ - \int_{t=-\infty}^{\infty} dt \iiint_{V_1} J_1(t) \cdot E_2(t) dV = (\xi_1, \xi_2) = \int_{t=-\infty}^{\infty} dt \iiint_{V_2} J_2(t) \cdot E_1(t) dV \quad (18) $$

where is inner product of two electromagnetic fields $\xi_1$ and $\xi_2$,

$$(\xi_1, \xi_2) \triangleq \int_{t=-\infty}^{\infty} dt \iiint_{\Gamma} S_{12} \cdot \hat{n}_{12} d\Gamma = \int_{t=-\infty}^{\infty} dt \iiint_{\Gamma} (E_1 \times H_2 + E_2 \times H_1) \cdot \hat{n} d\Gamma \quad (19)$$

Where $\Gamma$ is any surface separate the $V_1$ and $V_2$. $\Gamma$ can be the surface $\Gamma_1$ or $\Gamma_2$ which are sphere surfaces. $\Gamma$ also can be an infinite plane separating the two volumes. The above is the mutual energy flow theorem. $S_{12} = E_1 \times H_2 + E_2 \times H_1$ is mixed Poynting vector which are energy flow intensity. $\iiint_{\Gamma} S_{12} \cdot \hat{n}_{12} d\Gamma$ is the mutual energy flow. $\int_{t=-\infty}^{\infty} dt \iiint_{\Gamma} S_{12} \cdot \hat{n}_{12} d\Gamma$ is the energy go through the surface $\Gamma$. The mutual energy flow is shown in Figure 2.

It should emphasize that the “mutual” can be dropped. The above formula is not only the mutual energy flow theorem it is the energy flow theorem. This is because the self-energy does not carry energy that will be shown in the following.

2.7 Poynting theorem of $N$ charges

The Poynting theorem (17) can be derived from the above Maxwell equations,

$$ - \iiint_{\Gamma} E \times H \cdot \hat{n} d\Gamma = \iiint_{V} (J \cdot E + \frac{\partial}{\partial t} D + H \cdot \frac{\partial}{\partial t} B) dV \quad (20) $$

The superposition principle tell us if there are $N$ charges, the superposed electromagnetic field is,

$$ E = \sum_{i=1}^{N} E_i, \quad H = \sum_{i=1}^{N} H_i \quad (21) $$

Substitute the superposition principle to the Poynting theorem we have the Poynting theorem of $N$ charges,
Figure 2: The mutual energy flow theorem, the energies going through any surface $\Gamma$ between a and b are same. The surface $\Gamma$ can be a sphere surface surrounding the source $a$ or a sphere surface surrounding the sink $b$, or an infinite plane separated $a$ and $b$.

$$\sum_{i=1}^{N} \sum_{j=1}^{N} \oint_{\Gamma} E_i \times H_j \cdot \mathbf{n}d\Gamma = \sum_{i=1}^{N} \sum_{j=1}^{N} \iiint_{V} (J_i \cdot E_j + E_i \cdot \frac{\partial}{\partial t} D_j + H_i \cdot \frac{\partial}{\partial t} B_j) dV$$

Poynting theorem of $N$ charges is an energy theorem.

2.8 Self Energy principle

Now we have obtained a $N$-charge Poynting theorem Eq.(22) and a mutual energy principle Eq.(12). These are two energy formulas, they all tell us the energy of the whole system. If $N$ is the number of our universe. These two formulas all tell us the all radiation energy of our universe. Hence, these two formulas should be equal. However, they are not equal. The difference of the energy formula is,

$$\sum_{i=1}^{N} \oint_{\Gamma} E_i \times H_i \cdot \mathbf{n}d\Gamma = \sum_{i=1}^{N} \iiint_{V} (J_i \cdot E_i + E_i \cdot \frac{\partial}{\partial t} \epsilon_0 E_i + H_i \cdot \frac{\partial}{\partial t} \mu_0 H_i) dV$$

The above are all self-energy terms. Eq.(22) and Eq.(12) are equivalent. If all self energy terms do not transfer the energy, the two system energy formulas Eq.(22) and Eq.(12) can be equivalent. Hence all self-energy terms should do
not transfer the energy. That means,

\[
\oint_{\Gamma} \mathbf{E}_i \times \mathbf{H}_i \cdot \hat{n} d\Gamma = 0
\]

(24)

\[
\iiint_{V} (\mathbf{J}_i \cdot \mathbf{E}_i) dV = 0
\]

(25)

\[
\iiint_{V} \left( \mathbf{E}_i \cdot \frac{\partial}{\partial t} \epsilon_0 \mathbf{E}_i + \mathbf{H}_i \cdot \frac{\partial}{\partial t} \mu_0 \mathbf{H}_i \right) dV = 0
\]

(26)

However, if the above 3 formula is established, we will obtained, \(\xi_i = [\mathbf{E}_i, \mathbf{H}_i]^T = 0\). Zero solution is not what we want. We know \(\xi_i \neq 0\). If \(\xi_i = 0\) there is no any electromagnetic field on the space. This is not what we like. We know the source \(\mathbf{J}_i \neq 0\), hence the electromagnetic field \(\xi_i\) can not be all zeros. This conflict led the author introduce the time-reversal wave, which can cancel the energy terms of all Eq. (24,25,26), i.e.,

\[
\oint_{\Gamma} \mathbf{E}_i \times \mathbf{H}_i \cdot \hat{n} d\Gamma + \iiint_{V} \mathbf{e}_i \times \mathbf{h}_i \cdot \hat{n} d\Gamma = 0
\]

(27)

\[
\iiint_{V} (\mathbf{J}_i \cdot \mathbf{E}_i) dV - \iiint_{V} (\mathbf{j}_i \cdot \mathbf{e}_i) dV = 0
\]

(28)

\[
\iiint_{V} \left( \mathbf{E}_i \cdot \frac{\partial}{\partial t} \epsilon_0 \mathbf{E}_i + \mathbf{H}_i \cdot \frac{\partial}{\partial t} \mu_0 \mathbf{H}_i \right) dV - \iiint_{V} \left( \mathbf{e}_i \cdot \frac{\partial}{\partial t} \epsilon_0 \mathbf{e}_i + \mathbf{h}_i \cdot \frac{\partial}{\partial t} \mu_0 \mathbf{h}_i \right) dV = 0
\]

(29)

In the above formula \(\mathbf{e}_i, \mathbf{h}_i\) are the time reversal wave, which satisfy the time-reversal Maxwell’s equations. The time-reversal Maxwell’s equations are not Maxwell’s equations. The time-reversal Maxwell’s equations can be obtained by the time-reversal transform

\[
\frac{\partial}{\partial t} \rightarrow -\frac{\partial}{\partial \tau}
\]

(30)

Consider \(\mathbf{J} = \rho \mathbf{v} = \rho \frac{\partial \mathbf{e}}{\partial \tau}\), hence there is the transform for \(\mathbf{J} \rightarrow -\mathbf{j}\), the time-reversal transform is

\[
\mathbf{E}, \mathbf{H}, \mathbf{J} \rightarrow \mathbf{e}, \mathbf{h}, -\mathbf{j}
\]

(31)

The Maxwell’s equation after the above transform becomes,

\[
\nabla \times \mathbf{e} = \mu_0 \frac{\partial}{\partial \tau} \mathbf{h}
\]

\[
\nabla \times \mathbf{h} = -\mathbf{J} - \epsilon_0 \frac{\partial}{\partial \tau} \mathbf{e}
\]

(32)

This is the time-reversal Maxwell equation. The corresponding Poynting theorem for the time-reversal wave can be written as,
\[ -\sum_{i=1}^{N} \oint_{\Gamma} \mathbf{e}_i \times \mathbf{h}_i \cdot \mathbf{n} d\Gamma = -\sum_{i=1}^{N} \int_{V} (j_i \cdot e_i + e_i \cdot \frac{\partial}{\partial t} \varepsilon_0 \mathbf{e}_i + h_i \cdot \frac{\partial}{\partial t} \mu_0 \mathbf{h}_i) dV \] 

This leads to the energy term of the electromagnetic waves being canceled by the corresponding time-reversal waves, that is the reason we have Eq. \([27, 28, 29]\). These 3 formulas are referred to as the self-energy principle. The self-energy is sent to space, however there is a time-reversal wave bringing all energy back to the source. The retarded wave returns to the source. The advanced wave returns to the sink.

2.9 Summary

The advanced waves as a real thing is introduced by Wheeler and Feynman\([1, 2]\), John Cramer\([3, 4]\). However, most scientists and engineers still do not accept them. The advanced wave violates the causality consideration. This author introduced the energy conservation law which is easy to be accepted since it is self-explained. The mutual energy principle can be derived from \(N\) groups of Maxwell's equations. However, the solution set of the mutual energy principle is not equal to the solution set of Maxwell's equation. Only the paired electromagnetic fields which contains one retarded wave and one advanced wave are the solution of the mutual energy principle. Both retarded wave and advanced wave are the solutions of the Maxwell's equations. Considering this, this author thought it is better to put the mutual energy principle also as an axiom of the electromagnetic fields. With the two new axioms, (1) the advanced wave can be proved as a real wave instead of a virtual wave; (2) the mutual energy flow theorem can be proved; (3) self-energy principle can be introduced.

This author believes there are two kinds of different radiations. One is the self-energy radiation which can be solved with Maxwell's equations. The self-energy principle shows that this kind of radiations does not transfer the energy, because even the self-energy is radiated to the whole space, but it is returned through the time-reversal wave. The energy flow of the self-energy radiation is canceled by the energy flow of the time-reversal wave. The second of radiation is the mutual energy radiation, this kind of radiations is the solution of the mutual energy principle. The solution of mutual energy principle are pairs of waves, one pair includes a retarded wave sent form the source and an advanced wave sent from the sink. The mutual energy flow theorem can be derived from the mutual energy principle. The mutual energy flow consists of a pair of waves, a retarded wave and a advanced wave. Photons can be described by the normalized mutual energy flows.
Figure 3: (a) A transformer with a primary coil and a secondary coil. (b) The current in the primary coil is \( I_1 \). The current of the secondary coil is \( I_2 \). (b) it is the equivalent circuit. The emf of the current \( I_1 \) act to the secondary coil is \( \mathcal{E}_{2,1} \). The emf of the secondary coil to the first coil is \( \mathcal{E}_{1,2} \).

3 The theory of the mutual energy for the transformer

The following figure 8 shows a simple transform with a primary coil and a secondary coil. Assume the transformer is ideal, that means there is no heat energy loss. Here, \( I_1 \) and \( I_2 \) are currents of the primary coil and the secondary coil. The emf in the secondary coil produced by the current of the primary coil is \( \mathcal{E}_{2,1} = -M \frac{dI_1}{dt} \). The emf in the primary coil produced by the secondary coil is \( \mathcal{E}_{1,2} = -M \frac{dI_2}{dt} \). \( M \) is mutual inductance. The up-part of the Figure 8 shows a transformer with a primary coil and a secondary coil. The down-part of the Figure 8 shows the equivalent circuit of the transformer. In the primary coil, there is a power source.

3.1 The power transferred by the transformer

Considering alternating current (AC) situation, assume \( I_1 = I_{10} \exp(\omega t) \). The current \( I_2 \) can be calculated,

\[
I_2 = \frac{\mathcal{E}_{2,1}}{R_2} = -\frac{1}{R_2}M_{2,1}\frac{dI_1}{dt} = -\frac{1}{R_2}M_{2,1}I_{10}\omega \exp(\omega t) \tag{34}
\]

\[
p_2 \triangleq \mathcal{E}_{2,1}I_2^* = I_2I_2^*R_2 = \left| -\frac{1}{R_2}M_{2,1}I_{10}\omega \exp(\omega t) \right|^2 R_2
\]
\[ W_{2,1} = \frac{\omega^2 M_{2,1}^2 I_{10}^2}{R_2} \]  

(35)

\( W_{2,1} \) is the power of the primary coil offers to the secondary coil. It is the power consumed by the secondary coil. Now let us calculate the power of the primary coil. \( \mathcal{E}_{1,2} \) is the electromagnetic motive potential on primary coil produced by current \( I_2 \).

\[ \mathcal{E}_{1,2} = -M_{1,2} \frac{dI_2}{dt} = -M_{1,2} \left( \frac{d}{dt} \left( \frac{1}{R_2} M_{2,1} I_{10} \omega \exp(j\omega t) \right) \right) \]

\[ = -\frac{1}{R_2} (M_{1,2} M_{2,1}) I_{10} \omega^2 \exp(j\omega t) \]  

(36)

In case of for a transformer

\[ p_1 \triangleq I_1 \mathcal{E}_{1,2}^* = (I_{10} \exp(j\omega t)) \left( -\frac{1}{R_2} M_{1,2} M_{2,1} I_{10} \omega^2 \exp(j\omega t) \right)^* \]

\[ = -\frac{(M_{1,2} M_{2,1})^* I_{10}^2 \omega^2}{R_2} \]  

(37)

If the the secondary coil is close to the primary coil, we have

\[ M_{2,1} = M_{1,2} = M = \frac{\mu_0}{4\pi} \oint_{c_1} \oint_{c_2} \frac{dl_1 \cdot dl_2}{r} \]  

(38)

\[ p_1 = -\frac{M^2 I_{10}^2 \omega^2}{R_2} \]  

(39)

\( W_{21} \) is the power of the secondary coil offers to the primary coil. This power is negative, that means actually the primary coil offers energy to the secondary coil.

Comparing Eq. (33) and (38) we obtained,

\[ -\mathcal{E}_{21}^* I_1 = \mathcal{E}_{12}^* I_2^* \]  

(40)

This is agree with the energy conservation law Eq. (4) for the situation \( N = 2 \). The energy transferred from the primary coil to the secondary coil is active power. This results can also widen to an antenna system the energy transferred from the transmitting antenna to the receiving antenna is active power. Active power means the energy is really go from transmitting antenna to the receiving antenna.

### 3.2 The secondary coil has a distance with the primary coil

In this situation, the secondary coil has a distance with the primary coil. Hence, in the mutual inductance the retarded and advanced effect should be considered. \( M_{2,1} \) should be retarded,

15
\begin{align*}
M_{2,1}I_1 &= \frac{\mu_0}{4\pi} \oint_{C_2} \oint_{C_1} \frac{1}{r} d\mathbf{l}_2 \cdot \mathbf{I}_1 d\mathbf{l}_1 = \frac{\mu_0}{4\pi} \oint_{C_2} d\mathbf{l}_2 \cdot \oint_{C_1} \frac{I_1}{r} d\mathbf{l}_1 \\
&= \frac{\mu_0}{4\pi} \oint_{C_2} d\mathbf{l}_2 \cdot \iiint_{V} \frac{J_1(x', t - r/c)}{r} dV \\
J_1(x', t) &= J_1(x') \exp(j\omega t) \\
J_1(x', t - r/c) &= J_1(x') \exp(j\omega(t - r/c)) \\
&= J_1(x') \exp(j(\omega t - \frac{\omega}{c} r)) = J_1(x') \exp(j(\omega t - kr))
\end{align*}

(41)

where \( k = \frac{\omega}{c} \).

\begin{align*}
M_{2,1}I_1 &= \frac{\mu_0}{4\pi} \oint_{C_2} d\mathbf{l}_2 \cdot \iiint_{V} \frac{J_1(x')}{r} dV \exp(j(\omega t - kr)) \\
&= \frac{\mu_0}{4\pi} \oint_{C_2} d\mathbf{l}_2 \cdot \iiint_{V} \frac{J_1(x') \exp(j(\omega t))}{r} dV \exp(j(-kr)) \\
&= \frac{\mu_0}{4\pi} \oint_{C_2} d\mathbf{l}_2 \cdot \iiint_{V} \frac{J_1(x', t)}{r} dV \exp(j(-kr)) \\
&\to \frac{\mu_0}{4\pi} \oint_{C_2} \oint_{C_1} \frac{d\mathbf{l}_2 \cdot I_1}{r} d\mathbf{l}_1 \exp(j(-kr)) \\
&= MI_1 \exp(j(-kr))
\end{align*}

(44)

where,

\[ I_1 = I_{10} \exp(j\omega t) \]

\[ M = \frac{\mu_0}{4\pi} \oint_{C_2} \oint_{C_1} \frac{d\mathbf{l}_2 \cdot d\mathbf{l}_1}{r} \]

Hence, we have

\[ M_{2,1}I_1 = MI_1 \exp(j(-kr)) = MI_{10} \exp(j(\omega t - kr)) \]

(45)

In the above \( \exp(j(-kr)) \) is the retarded fact.

\begin{align*}
\mathcal{E}_{2,1} &= -\frac{d}{dt}(M_{2,1}I_1) = -\frac{d}{dt}(MI_{10} \exp(j(\omega t - kr))) = -MI_{10}j\omega \exp(j(\omega t - kr))
\end{align*}

(46)
\[ p_2 = \mathcal{E}_{2,1}^* I_2^* = \mathcal{E}_{2,1}^* \frac{1}{R} = -M I_{10} j\omega \exp(j(\omega t - kr))^2 \frac{1}{R} = \frac{M^2 I_{10}^2 \omega^2}{R} \]  

(47)

\[ M_{1,2} \text{ should be advanced,} \]

\[ M_{1,2} I_2 = \frac{\mu_0}{4\pi} \oint_{C_1} dl_1 \cdot \iiint_{V_2} \frac{J_2(x', t + r/c)}{r} dV \]  

(48)

Similarly we have

\[ M_{1,2} I_2 = M I_2 \exp(j(+kr)) \]  

(49)

\[ \mathcal{E}_{1,2} = -\frac{d}{dt}(M_{1,2} I_2) = -\frac{d}{dt}(M I_2 \exp(j(+kr))) = -\frac{d}{dt}(M \frac{\mathcal{E}_{2,1}}{R} \exp(j(+kr))) \]

\[ = -\frac{d}{dt}(M \frac{-M I_{10} j\omega \exp(j(\omega t - kr)) \exp(j(+kr))}{R}) = -I_{10} M^2 \omega^2 \frac{\exp(j(\omega t))}{R} \]  

(50)

\[ p_1 = I_1 \mathcal{E}_{1,2}^* = I_{10} \exp(j(\omega t))(-\frac{I_{10} M^2 \omega^2}{R} \exp(j(\omega t)))^* = -\frac{I_{10}^2 M^2 \omega^2}{R} \]  

(51)

This means that,

\[ -p_1 = p_2 \]  

(52)

or

\[ -I_1 \mathcal{E}_{1,2}^* = \mathcal{E}_{2,1}^* I_2^* \]  

(53)

or

\[ -\oint_{C_1} E_2^* \cdot I_1 dl = \oint_{C_2} E_1 \cdot I_2^* dl \]  

(54)

This can be written as,

\[ -\iiint_{V} E_2^* \cdot J_1 dV = \iiint_{V} E_1 \cdot J_2^* dV \]  

(55)

Considered a inverse Fourier transform,

\[ -\int_{-\infty}^{\infty} dt \iiint_{V} E_2(t) \cdot J_1(t + \tau) dV = \int_{-\infty}^{\infty} dt \iiint_{V} E_1(t + \tau) \cdot J_2(t) dV \]  

(56)

Take \( \tau = 0 \),

\[ -\int_{-\infty}^{\infty} dt \iiint_{V} E_2(t) \cdot J_1(t) dV = \int_{-\infty}^{\infty} dt \iiint_{V} E_1(t) \cdot J_2(t) dV \]  

(57)
The above can be written as,

\[
- \sum_{i=1}^{2} \sum_{j=1, j \neq i}^{2} \int_{-\infty}^{\infty} \int_{V} E_j(t) \cdot J_i(t) dV = 0 \quad (58)
\]

Widen 2 to N we obtained,

\[
- \sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \int_{-\infty}^{\infty} \int_{V} E_j(t) \cdot J_i(t) dV = 0 \quad (59)
\]

The above is the energy conservation law. We obtained the energy conservation law. In the derivation of the above energy conservation law, We have assume \( M_{2,1} \) is retarded and \( M_{1,2} \) is advanced. That means we have assume the electromagnetic field of the primary coil \( I_1 d\) is retarded and We have assume the electromagnetic field of the secondary coil \( I_2 d\) is advanced. In this way we obtained the energy conservation law. It is clear if we assume the field of the secondary coil is also retarded, we cannot prove the system satisfy the energy conservation law. This means the energy conservation law need the field of the secondary coil is advanced. Hence, the secondary coil sends advanced wave.

Since the load of the secondary coil is a resistance, the power \( p_1 \) and \( p_2 \) are all real, this means the power sends from primary coil to secondary coil is still a active power.

### 3.3 The secondary coil with a inductance or capacity load

For the secondary coil, since the load is capacity, the current in the secondary coil is,

\[
I_2 = C \frac{d}{dt} \mathcal{E}_{2,1} \quad (60)
\]

\( \mathcal{E}_{2,1} \) is the induced potential of the secondary coil from the primary coil. We have known that,

\[
\mathcal{E}_{2,1} = -M_{2,1} \frac{d}{dt} I_1 \quad (61)
\]

and

\[
I_1 = I_{10} \exp(j \omega t) \quad (62)
\]

\[
\mathcal{E}_{2,1} = -M_{2,1} \frac{d}{dt} I_{10} \exp(j \omega t) = -M_{2,1} (j \omega) I_{10} \exp(j \omega t) \quad (63)
\]

\[
I_2 = C \frac{d}{dt} \mathcal{E}_{2,1} = C \frac{d}{dt} (-M_{2,1} (j \omega) I_{10} \exp(j \omega t)) \]

\[
= C(-M_{2,1} (j \omega)^2 I_{10} \exp(j \omega t)) = C M_{2,1} \omega^2 I_{10} \exp(j \omega t) \quad (64)
\]

Hence, The power of the secondary coil is,
Figure 4: Assume there is a current element $J_1$, it likes the primary coil of a transformer, $J_1$ is shown as red. Assume there is a secondary coil which have a distance to the primary coil. The secondary coil is shown as blue. Assume the load of the secondary coil is a resistance. The secondary coil can receive the active power.
Figure 5: Assume there is a current element $J_1$, it likes the primary coil of a transformer. $J_1$ is shown as red. Assume there is a secondary coil which have a distance to the primary coil. The secondary coil is shown as blue. Assume the load of the secondary coil is a capacity. The secondary coil can only receive the reactive power, that means it receive some power from the primary coil but return this power back to the primary coil.
\[ P_2 = \mathcal{E}_{2,1} I_2^* = (-M_{2,1}(j\omega)I_{10}\exp(j\omega t))(CM_{2,1}\omega^2I_{10}\exp(j\omega t))^* \]
\[ = -j\omega^3CM_{2,1}M_{2,1}I_{10}^2 \]

(65)

We can see the power of the secondary coil is pure imaginary. This means the power of the secondary coil is a reactive power. We have known that the reactive power does not really consume the energy. That means the power of the secondary coil received should be sent back to the primary coil. How this energy can send back from the secondary coil to the primary coil? The author thought it is through the reactive power send from the primary coil to the secondary coil. Hence it should be possible to send reactive power from the primary coil to the secondary coil.

Now let us to calculate the power of primary coil,

\[ \mathcal{E}_{1,2} = -M_{1,2} \frac{dI_2}{dt} \]
\[ = -M_{1,2} \frac{d}{dt}(CM_{2,1}\omega^2I_{10}\exp(j\omega t)) \]
\[ = -M_{1,2}j\omega(CM_{2,1}\omega^2I_{10}\exp(j\omega t)) \]

(66)

\[ P_1 = I_1\mathcal{E}_{1,2}^* \]
\[ = I_{10}\exp(j\omega t)(-M_{1,2}j\omega(CM_{2,1}\omega^2I_{10}\exp(j\omega t)))^* \]
\[ = jI_{10}^2M_{1,2}M_{2,1}C\omega^3 \]

(67)

\[ M_{2,1} \text{should be retarded,} \]
\[ M_{2,1}I_1 = \frac{\mu_0}{4\pi} \int \int \frac{1}{r} \frac{dI_2}{dt} \cdot I_1 dt_1 \]
\[ = \frac{\mu_0}{4\pi} \int \int \frac{dI_2}{dt} \cdot \int \int \frac{I_1}{r} dt_1 \]
\[ = \frac{\mu_0}{4\pi} \int \frac{dI_2}{dt} \cdot \int \int \int \frac{\mathbf{J}_1(x',t-r/c)}{r} dV \]

(68)

\[ \mathbf{J}_1(x',t) = \mathbf{J}_1(x')\exp(j\omega t) \]

(69)

\[ \mathbf{J}_1(x',t-r/c) = \mathbf{J}_1(x')\exp(j\omega(t-r/c)) \]
\[ = \mathbf{J}_1(x')\exp(j(\omega t - \frac{\omega}{c} r)) = \mathbf{J}_1(x')\exp(j(\omega t - kr)) \]

(70)
where \( k = \frac{\omega}{c} \).

\[
M_{2,1}I_1 = \frac{\mu_0}{4\pi} \oint_{C_2} dl_2 \cdot \iint_V \frac{J_1(x')}{r} dV \exp(j(\omega t - kr))
\]  

(71)

Similarly

\[
M_{1,2}I_2 = \frac{\mu_0}{4\pi} \oint_{C_1} dl_1 \cdot \oint_{V_2} \frac{1}{r} \frac{I_2}{r} dl_2 = \frac{\mu_0}{4\pi} \oint_{C_1} dl_1 \cdot \oint_{V_2} \frac{J_2(x', t + r/c)}{r} dV
\]

\[
= \frac{\mu_0}{4\pi} \oint_{C_1} dl_1 \cdot \iint_{V_2} \frac{J_2(x')}{r} dV
\]  

(72)

\( M_{1,2} \) should be advanced,

\[
M_{1,2}I_2 = \frac{\mu_0}{4\pi} \oint_{C_1} dl_1 \cdot \iint_{V_2} \frac{J_2(x', t + r/c)}{r} dV
\]

(73)

\[
M_{1,2}I_2 = \frac{\mu_0}{4\pi} \oint_{C_1} dl_1 \cdot \iint_{V_2} \frac{J_2(x')}{r} dV \exp(j(\omega t + kr))
\]  

(74)

Hence we have,

\[
M_{2,1}I_1 = MI_{10} \exp(j(\omega t - kr)) = MI_1 \exp(j(-kr))
\]  

(75)

\[
M_{1,2}I_2 = MI_{20} \exp(j(\omega t + kr)) = MI_2 \exp(j(+kr))
\]  

(76)

\[
M = \frac{\mu_0}{4\pi} \oint_{C_1} dl_1 \cdot \oint_{C_2} dl_2 \frac{V_2}{r}
\]

(77)

\[
I_1 = I_{10} \exp(j\omega t)
\]  

(78)

\[
I_2 = I_{20} \exp(j\omega t)
\]  

(79)

\[
M_{2,1} = M \exp(-jkr)
\]  

(80)

\[
M_{1,2} = M \exp(+jkr)
\]  

(81)

Considering Eq. (66) there is,

\[
P_2 = \mathcal{E}_{2,1} I_2^* = -j\omega^2 CM_{2,1} M_{2,1} I_{10} = -j\omega^2 CM^2 I_{10}^2
\]  

(82)

Considering Eq. (68) there is,

\[
P_1 = I_{1} \mathcal{E}_{1,2}^* = jI_{10}^2 (M_{1,2} M_{2,1})^* C \omega^3
\]  

(83)

Considering,

\[
M_{1,2} M_{2,1} = M \exp(-jkr) M \exp(+jkr) = M^2
\]  

(84)
We have,

\[ P_1 = jl^2_0 M^2 C \omega^3 \quad (85) \]

or

\[ -P_1 = P_2 \quad (86) \]

or

\[ -I_1 \mathcal{E}_{1,2}^* = \mathcal{E}_{2,1} I_2^* \quad (87) \]

or

\[ -\oint_{\mathcal{C}_1} \mathbf{E}_2^* \cdot I_1 dl = \oint_{\mathcal{C}_2} \mathbf{E}_1 \cdot I_2^* dl \quad (88) \]

This can be written as,

\[ -\iiint_V \mathbf{E}_2^* \cdot \mathbf{J}_1 dV = \iiint_V \mathbf{E}_1 \cdot \mathbf{J}_2^* dV \quad (89) \]

Considered a inverse Fourier transform,

\[ -\int_{-\infty}^{\infty} dt \iiint_V \mathbf{E}_2(t) \cdot \mathbf{J}_1(t + \tau) dV = \int_{-\infty}^{\infty} dt \iiint_V \mathbf{E}_1(t + \tau) \cdot \mathbf{J}_2(t) dV \quad (90) \]

Take \( \tau = 0 \),

\[ -\int_{-\infty}^{\infty} dt \iiint_V \mathbf{E}_2(t) \cdot \mathbf{J}_1(t) dV = \int_{-\infty}^{\infty} dt \iiint_V \mathbf{E}_1(t) \cdot \mathbf{J}_2(t) dV \quad (91) \]

The above can be written as,

\[ -\sum_{i=1}^{2} \sum_{j=1, j \neq i}^{2} \int_{-\infty}^{\infty} dt \iiint_V \mathbf{E}_j(t) \cdot \mathbf{J}_i(t) dV = 0 \quad (92) \]

widen 2 to \( N \) we obtained,

\[ -\sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \int_{-\infty}^{\infty} dt \iiint_V \mathbf{E}_j(t) \cdot \mathbf{J}_i(t) dV = 0 \quad (93) \]

The above is the energy conservation law. We obtained the energy conservation law. In the derivation of the above energy conservation law, We have assume \( M_{2,1} \) is retarded and \( M_{1,2} \) is advanced. That means we have assume the electromagnetic field of the primary coil \( I_1 dl \) is retarded and We have assume the electromagnetic field of the secondary coil \( I_2 dl \) is advanced. In this way we obtained the energy conservation law. It is clear if we assume the field of the secondary coil is also retarded, we cannot prove the system satisfy the energy
conservation law. This means the energy conservation law need the field of the secondary coil is advanced. The secondary coil sends advanced wave.

Another thing is since the load of the secondary coil is a capacity, the secondary coil consume reactive power. \( P_1 \) and \( P_2 \) are all pure imaginary number. The energy transferred from primary coil to the secondary is a reactive power. The reactive power that means the power sends from primary coil to the secondary coil, however, the energy sends back from the secondary coil to the primary coil. The power sends back from secondary coil to primary coil is a time-reversal process. Because the energy sends from primary coil to the secondary coil spends a time \( T = \frac{T}{c} \), the energy sends back from the secondary coil to the primary coil spends a time \( -T = -\frac{T}{c} \). The total time of the energy go from primary coil to the secondary and together from the secondary coil to the primary coil is \( T + (-T) = 0 \). There is no time loss for the energy. The energy can be re-sends from the primary coil to the secondary coil.

### 3.4 Time reversal mutual energy flow

This author has assumed that there is a time-reversal mutual energy flow. The mutual energy flow is built by the retarded wave radiates from the source and the advanced wave radiates from the sink. The author has assumed there is the time-reversal wave corresponding to the retarded wave and there is the time-reversal wave corresponding to the advanced wave. The time-reversal mutual energy flow can be built by the time-reversal wave corresponding to the retarded wave sent form the source and the time-reversal wave corresponding the advanced wave sent from the sink [9]. The author believe the energy sent back from the secondary coil to the primary coil is the time-reversal mutual energy flow. In the reference [9] we have thought the time-reversal mutual energy flow can kill off the half photon or partial photon. If the energy is not enough to bring the electron from the lower energy lever to higher energy level, the energy can be brought back through the time-reversal mutual energy flow. In the example of last sub-section, we also found that if the load in the secondary coil is capacitive, the energy received by the secondary coil can be returned to the primary coil through a reactive power. For a reative power sends from the primary coil to the secondary coil, some time the power is positive in that case the energy sends from the primary coil to the secondary coil, some time the power is negative, in that case the energy sends back from the secondary coil to the primary coil.

In the figure [6] there is a source (red) current element. There is sink current element. The source sends the retarded wave and the sink sends the advanced wave. In the middle between the source and the sink can be seen as a plane waves (very close to a plane wave, but is is not a plane wave). The mutual energy flow between the source to the sink can be calculated by

\[
(\xi_1, \xi_2) = \iint_F (E_1 \times H_2^* + E_2^* \times H_1) \cdot \hat{z}d\Gamma
\]  

(94)

we know
Figure 6: Assume there is a source (red) current element, and a sink (blue) current element. Assume they have a large distance, hence in the middle between the source and the sink can be seen as plane waves.

\[ \mathbf{E}_1 = -E_1 \hat{y}, \quad \mathbf{H}_1 = H_1 \hat{x} \]  

(95)

and

\[ \mathbf{E}_2 = -E_2 \hat{y}, \quad \mathbf{H}_2 = H_2 \hat{x} \]  

(96)

hence,

\[ \mathbf{E}_1 \times \mathbf{H}_2^* = E_1 H_2^* \hat{z}, \quad \mathbf{E}_2 \times \mathbf{H}_1^* = E_2 H_1^* \hat{z} \]  

(97)

and there is,

\[ \langle \xi_1, \xi_2 \rangle = \oint \mathbf{E}_1 H_2^* + \mathbf{E}_2 H_1^* \, d\Gamma \]  

(98)

If \( \xi_2 = [\mathbf{E}_2, \mathbf{H}_2] \) and \( \xi_1 = [\mathbf{E}_1, \mathbf{H}_1] \) has a phase \( \frac{\pi}{2} \), \( \langle \xi_1, \xi_2 \rangle \) will be a pure imaginary number. This means the energy flow is also reactive. The energy flow will go back and forth from the primary coil to the secondary coil and from secondary coil to the primary coil.

### 3.5 The mutual energy flow with reactive power

Assume there is a source and sink and they have a very big distance. Assume now we are at the middle between the source and sink. The source sends the retarded wave, the sink sends the advanced wave. If the two wave is synchronized exactly, this mutual energy flow can bring active energy from the source to the
sink. However if the retarded wave and the advanced wave does not synchronized exactly but with, for example \( \frac{\pi}{2} \) phase difference. The mutual energy flow will bring a reactive energy from the source to sink. That means the energy is sent from the source to sink, but the energy is returned from the sink to source without time delay.

This also means the energy can vibrate between the source and sink. This can explain the phenomena of the interference of the electromagnetic field. For example assume there are two light sources (or the light produced by the double slits). It will produce white and black stripes on the light screen. We know that the energy of two sources should all reach the place of duck stripe, but why in the duck stripe there is no energy received by the screen? Actually the energy have received at the duck stripes, but the energy has been sent back from the light screen to the two sources. The energy re-sends from the two sources, in the process of re-sent, the energy will more likely to go to the place of white stripes. Figure 4 shows how the movement of the received energy can be implemented. In a light screen there is an absorber A which received the energy sent from the source. The energy is sent back to the light source by the time-reversal mutual energy flow. The energy is re-sent out again, perhaps the energy is received by B. The energy is sent back by the time-reversal mutual energy flow. The energy is sent forth and back until the energy is move from A to E on the screen. Assume in the place E the energy is enough for an energy of one photon \( \omega \hbar \). The energy is received by the absorber in the place of E. This shown the energy can move on the light screen.

If the energy can be vibrated between the source and the sink, if the sink received less the energy of one photon, the electron charge at the sink place can not spring from a lower level to a higher level, this energy will be returned to source. This is the reason why we can not obtained a half photon. All Half photon or patial photon be returned to the office. This solved the half photon problem.

4 Wave collapse and the wave with reactive power

In the last section the problem of mutual inductance or the mutual energy of a transform are studied. There are always a pair of coils. The same theory can be also applied to the antenna system with transmitting antennas and receiving antennas. However, if there is only one primary coil or only a transmitting antenna, what will happen? This will be discussed in this section.

The self-inductance of one coil can be calculated similar to the mutual inductance,

\[
M_{11} = \frac{\mu_0}{4\pi} \oint \oint \frac{dl_1 \cdot dl_2}{r}
\]

(99)
Figure 7: Energy move on the light screen. For example in the beginning the absorber A received the energy. Assume this energy is not enough as one photon. The energy is returned to the source. The source re-sends the energy. Perhaps the absorber B received this energy. The energy is sent back. In this way finally the absorber E received the energy of a whole photon.
The electromotive potential at the primary coil is,

\[ \mathcal{E}_{11} = -\frac{d}{dt} M_{11} I_1 \]  

(100)

$L_1 = M_{11}$ is the self-inductance of the primary coil.

### 4.1 The power of the primary coil

Assume there is only one coil, the primary coil. Assume $I_1 = I_{10} \exp(j\omega t)$ and assume $M_{11}$ is constant,

\[ \mathcal{E}_{11} = -\frac{d}{dt} M_{11} I_1 = -j\omega M_{11} I_{10}\exp(j\omega t) \]  

(101)

The power of the primary coil can be defined as,

\[ P_1 \triangleq \mathcal{E}_{11} I_1^* = (-j\omega M_{11} I_{10}\exp(j\omega t))(I_{10}\exp(j\omega t))^* = -j\omega M_{11} I_{10}^2 \]  

(102)

where superscript * is complex conjugate. The power $P_1$ is a pure imaginary number, this kind of power is referred as the reactive power. Hence, the primary coil has only reactive power. Reactive power does not consume energy. Hence, in the ideal situation, the primary coil does not consume the energy. Considering,

\[ \mathcal{E}_{11} I_1^* = \int_{C_i} \oint_{V_i} E_1 \cdot J_1^* \, dl \rightarrow \int_{V_i} \oint_{V_i} E_1 \cdot J_1^* \, dV \]  

(103)

\[ \oint_{V_i} E_1 \cdot J_1^* \, dV \] is a pure imaginary number. Considering the inverse Fourier transform, we have,

\[ \int_{-\infty}^{\infty} dt \int_{V_i} E_1(t+\tau) \cdot J_1(t) \, dV = 0 \]  

(104)

We can choose $\tau = 0$, and hence, there is

\[ \int_{-\infty}^{\infty} dt \int_{V_i} E_1(t) \cdot J_1(t) \, dV = 0 \]  

(105)

In time domain. This tell us, that the primary coil of the transformer does not send the energy out. This also means that if a antenna is put in the place where there is nothing surround the antenna, the antenna can not send the radiation wave out.

From Poynting theorem we know that,

\[ -\oint_{\Gamma} (E_1 \times H_1) \cdot \hat{n} \, d\Gamma = \int_{V_i} \oint_{V_i} E_1 \cdot J_1 \, dV + \int_{V_i} \oint_{V_i} \frac{1}{2}(\epsilon_0 E_1 \cdot E_1 + \mu_0 H_1 \cdot H_1) \, dV \]  

(106)
Considering,

\[
\int_{-\infty}^{\infty} dt \frac{\partial}{\partial t} \iiint_{V_1} \frac{1}{2} (e_0 E_1 \cdot E_1 + \mu_0 H_1 \cdot E_1) dV = \int_{-\infty}^{\infty} dt \frac{\partial}{\partial t} U_1
\]

\[
= U_1(\infty) - U_1(-\infty) = 0
\]

(107)

There is,

\[- \int_{-\infty}^{\infty} dt \iiint_{\Gamma} (E_1 \times H_1) \cdot \hat{n} d\Gamma = \int_{-\infty}^{\infty} dt \iiint_{V_1} E_1 \cdot J_1 dV\]

(108)

Considering Eq. (105) we should have,

\[
\int_{-\infty}^{\infty} dt \iiint_{\Gamma_1} (E_1 \times H_1) \cdot \hat{n} d\Gamma = 0
\]

(109)

\(\Gamma_1\) is any surface which surround the current \(J_1\). That means for a current in space for example of coil of a transformer should not radiate. However, we know the antenna can radiates. If there is a current in space \(J_1\), we can calculate the electromagnetic field \(\xi_1 = [E_1, H_1]\) by using the Maxwell equations. Then we can calculate the energy corresponding to the Poynting vector, that is real and also,

\[
\int_{-\infty}^{\infty} dt \iiint_{\Gamma_1} (E_1 \times H_1) \cdot \hat{n} d\Gamma > 0
\]

(110)

\[\int_{-\infty}^{\infty} dt \iiint_{\Gamma_1} (E_1 \times H_1) \cdot \hat{n} d\Gamma\] is 0 or not 0? According to the author’s mutual energy theory, Maxwell equations are mutual energy phenomena, it does not suit to self-energy phenomena. Poynting theorem is derived from Maxwell’s equations, if Maxwell’s equation does not suit to the self-energy radiation phenomena, the Poynting theorem does not too. Hence, we need other theory.

In author’s mutual energy theory, Maxwell’s equation must have \(N\) groups, here \(N \geq 2\). In self-energy situation, either there is time-reversal wave which can cancel the self-energy terms. That means, there is a time-reversal wave,

\[
\int_{-\infty}^{\infty} dt \iiint_{\Gamma_1} (E_1 \times H_1) \cdot \hat{n} d\Gamma + \int_{-\infty}^{\infty} dt \iiint_{\Gamma_1} (e_1 \times h_1) \cdot \hat{n} d\Gamma = 0
\]

(111)

where \(e_1, h_1\) is the time-reversal waves. The time-reversal wave have been introduced many times by this author [1, 11, 11, 12]. However there is also another possibility which will be introduced in next sub-section.
4.2 Reactive power

Another possibility is that a current element in space $J_1$, which can be seen as a self-inductance coil or transmitting antenna. We assume in the space there is nothing except this current $J_1$. Hence, if the $J_1$ radiates, since no thing can receive the energy radiates from the current element $J_1$, this energy cannot be sent out. This author has introduced one possibility to solve the problem by introducing the time-reversal wave which can cancel all self-energy terms. However, there is another possibility that the radiation is a reactive power. The reactive power does not carry energy, however the reactive power can still sends the energy to whole space. For the reactive power, the energy flow directions are changeable. The direction is point to front and back in each period two times.

We have known that for the Maxwell equations, they do not support reactive power in space. That is because, as far field, the electromagnetic field is looks like plane wave, for example, if the vector potential of the plane wave is,

$$A = A_0 \exp(j(\omega t - k \cdot x))$$  \hspace{1cm} (112)

Then, the electric field in transverse direction is,

$$E = -\frac{\partial A}{\partial t} = -(j\omega)A_0 \exp(j(\omega t - k \cdot x))$$  \hspace{1cm} (113)

The magnetic field is,

$$B = \nabla \times A = -jk \times A_0 \exp(j(\omega t - k \cdot x))$$  \hspace{1cm} (114)

The Poynting vector

$$S = \frac{E \times B^*}{\mu_0} = \frac{1}{\mu_0}(-j\omega)A_0 \exp(j(\omega t - k \cdot x)) \times (-jk \times A_0 \exp(j(\omega t - k \cdot x)))^*$$

$$= \frac{1}{\mu_0} \omega A_0 \times k \times A_0^* = \frac{1}{\mu_0} \omega |A_0|^2 k$$  \hspace{1cm} (115)

This means that Poynting vector of the Maxwell equation in far field is always a radiation field with active power, it is cannot send a reactive power. How a reactive power can be transferred in space? There is a possibility the boundary of our universe is like a many transform with a capacity load, from the boundary of our universe there is advanced wave sent back to the current element $J_1$. Assume $\xi_1 = [E_1, H_1]$ is a retarded wave sends from the current element $J_1$. Assume in the boundary of our universe, there is many small antennas with its load as a capacity, the current elements of the receiving antenna is $J_2$. $J_2$ sends back an advanced wave, $\xi_2 = [E_2, H_2]$. Assume $J_2$ uniformly distributes on the sphere $\Gamma$ which has a infinite radius. $J_2$ can be seen in Figure 8. $J_2$ sends the advanced wave back to the origin, however, this advanced wave looks very similar to the retarded wave sent from the source $J_1$. This means that $\xi_2$
is nearly same as $\xi_1$. But $\xi_2$ has $\frac{\pi}{2}$ phase compared to $\xi_1$. Hence, there is,

$$
(\xi_1, \xi_2) = \int_{\Gamma} (\mathbf{E}_1 \times \mathbf{H}_2 + \mathbf{E}_2 \times \mathbf{H}_1) \cdot \mathbf{n} d\Gamma = j\text{Im}(\xi_1(\xi_2)) \tag{117}
$$

Hence, this means that the self-energy radiation is actually composed with a mutual energy radiation. The advanced wave is sent out from the boundary of our universe, the advanced wave has an $\frac{\pi}{2}$ phase to the retarded wave of $\mathbf{J}_1$. See figure 8 for details.

Figure 8 shows the boundary of the universe where there is infinity of the capacities. These capacities will produced an advanced wave $\xi_2$. The $\xi_2$ has $\frac{\pi}{2}$ phase with the retarded wave send from the current element $\mathbf{J}_1$.

The author believes that, the self-energy radiation cannot be correctly described by Maxwell’s equations. The author believes the self-radiation, cannot send the power to the boundary of our universe. The reason is the author assume inside the universe there is nothing, and there is only the current element sits at the origin point, hence, there is nothing can receive the energy sent out from the current $\mathbf{J}_1$. However the energy must sent to the space, otherwise if in the space there is a receiving antenna with a resistance load, the energy should be received by the resistance load. The energy is sent to the whole space, if there
Figure 9: $\xi_1$ is retarded wave sends from the current $J_1$, $\xi_2$ is the advanced wave send back from the boundary of our universe. We have assume that the advanced wave looks similar to the retarded wave of $\xi_1$ but there is a $\frac{\pi}{2}$ phase difference. The power of the system is $P = (\xi_1, \xi_2)$ shown as green line is half positive and half negative. Positive means the energy is point to outside of our universe, negative means the power is point to the inside of the our universe.

is nothing, the energy have to go back to the source. There two method to allow the energy go back. One method is there is a time-reversal process which cancels all energy. Another method is like last section for the secondary coil, the load is a capacity, hence, a reactive power can be built between the source $J_1$ and the secondary coil $J_2$. We assume the secondary coils with capacity uniformly distribute on the boundary of our universe. This solved the problem. Any way, the self-energy radiation does not sends the energy out. This is the self-energy principle.

Figure 3 shows the power of the system which is,

$$P = (\xi_1, \xi_2) = \iiint \left( E_1(t) \times H_2(t) + E_2(t) \times H_1(t) \right) \cdot \hat{n} d\Gamma$$  \hspace{1cm} (118)

If this power is positive, there is energy point to the outside of our universe. Either there is a time-reversal wave cancel the energy flow the self-energy or self-energy radiation is actually a mutual energy radiation, in the boundary of our universe, there are many many receiving antenna with a capacity load, hence a reactive power is send to space. The reactive power can be positive and negative. If this power is negative there is an energy flow point to the insider of our universe. For a reactive power in the space,

$$P = (\xi_1, \xi_2) = \int_{t=-\infty}^{\infty} dt \iiint \left( E_1(\omega) \times H_2(\omega)^* + E_2(\omega)^* \times H_1(\omega) \right) \cdot \hat{n} d\Gamma = 0 \hspace{1cm} (119)$$

32
Hence, the self-energy flow do not contribute to the energy transfer. In this situation we still can say the self-energy first sends to the outside of our universe and then from the boundary of our universe collapse backward to the source current $J_1$.

### 4.3 Collapse of the wave

Last subsection we make clear why the self-energy flow does not carries energy. The self-energy flow is (1) with a time-reversal wave which cancel the energy flow of the self-energy flow; (2) the self-energy flow is actually a mutual energy flow between the source and the sink uniformly distribute at the boundary of our universe, the sink is a receiving antenna with a capacity load, hence the power of this mutual energy flow is reactive. Both situation the energy is sent from the source to the boundary of our universe, but the energy is returned with a time-reversal process. The process of the time-reversal process is also referred to as backward collapse of the wave.

The backward collapse of the wave is not the same as wave collapse. The wave collapse is a concept in quantum mechanics. The wave collapse is that the wave moves from the whole space to a target of the wave. For example an emitter radiates a wave and the wave suddenly moves from the whole space to an absorber. The absorber is the target of the wave. The wave collapse is a process where all waves suddenly move from the whole space to an absorber. The backward collapse of a wave is the wave sent from the emitter to the whole space, but suddenly moves back to the emitter by a time-reversal process.

The wave collapse cannot be described by any mathematical formula. The backward collapse of the wave can be described by the time-reversal process.

We have known that the energy can be transferred by the mutual energy flow. The mutual energy flow is responsible for transferring the energy. Two processes: The backward collapse of the wave combined with the mutual energy flow exactly described the wave collapse process. Hence, the wave collapse concept can be explained by a backward collapse of the wave and a process of the mutual energy flow. Figure [10] shows the collapse of the retarded wave.

Figure [11] shows, the implementation of the collapse by using the author’s mutual energy theory. First the retarded wave sends from the source backward collapse to the source. Second the mutual energy flow bring our energy of one photon from the source to the sink (target). Hence the wave collapse process is combined with two process: (1) wave backward collapse and (2) a mutual energy flow from the source to sink.

Figure [12] shows a particle, it can be a photon or an electron (the theory of mutual energy can be extended to quantum mechanics [11]). $a$ is the source of the particle. $b$ is the sink of the particle, the retarded wave radiates from the source. The advanced wave radiates from the sink. The two waves build the mutual energy flow which is the energy flow of the particle. The two waves backwardly collapse. If the retarded wave did not meet any the advanced wave, it does not find an advanced wave to match, it backwardly collapses to the source and can be radiated again from the source. If the advanced wave did not
Figure 10: Wave collapse. A retarded wave is sent from a source which is sit at the origin. The wave suddenly collapses to a target which is an absorber. This process cannot be described by mathematical formula.
Figure 11: In the author’s theory the wave collapse is combined by the two process: (1) The retarded wave backward collapsed (2) A mutual energy flow go from the source to the target which is a absorber.
Figure 12: A particle, for example a photon, a is a source, b is sink. The wave radiates from a. It looks like to collapse at b. But actually, the retarded wave radiates from a has backwardly collapsed to a. The advanced wave radiates from b has backwardly collapse to b. The mutual energy flow is built from the retarded wave from the source and the advanced wave radiates from b. The mutual energy flow bring the energy of photon from the source to the sink. The photon is the mutual energy flow. Together the two phenomena, the mutual energy flow and the two waves backwardly collapse, described the wave collapse phenomenon. This figure offers a particle, it can be a photon with an emitter or an absorber. It can also be an electron radiates form a source and reached at a sink.

meet a retarded wave, it backwardly collapses to the sink and can be radiated again from the sink.

A particle consists of 4 waves. The retarded wave radiate from the source. The advanced wave radiates from the sink. Two time-reversal waves corresponding to the retarded wave and the advanced wave. If the retarded wave and the advanced wave synchronizes, a mutual energy flow is produced which contains the energy flow of the particle. If the retarded wave and the advanced wave does not synchronize, the time-reversal waves cancel the retarded wave and the advanced wave. The source can radiate the retarded wave again next time. The sink can radiate the advanced wave again next time. Even if the mutual energy flow has been produced, the time-reversal wave still needs to clean the energy left in space.

In the above we have said that the source radiate a retarded wave and a time-reversal wave corresponding to the retarded wave. The sink radiates an advanced wave and a time-several wave corresponding to advanced wave. There is another possibility, the source sends a retarded wave. The sink sends an
advanced wave. However the advanced wave sends from the think has $\frac{\pi}{2}$ phase difference with the retarded wave. Hence, the mutual energy flow from the source to sink is a reactive power.

Since Maxwell equations do not support the reactive wave in far field situation, the reactive wave for self-energy phenomena actually build with a mutual energy phenomena. This mutual energy phenomena has a source sits at the origin, and a sink sits uniformly on the big sphere with its radius as infinity. The sink uniformly distribute to the big sphere. The sink is like receiving antenna (a secondary coil of the transformer) with a capacity load.

The reactive mutual energy flow can be divided as two energy flow (if the power of the mutual energy flow is positive), one is a normal mutual energy flow and one is a time-reversal mutual energy flow (if the power of the mutual energy flow is negative). Even if the reactive mutual energy flow does not transfer energy, it has brought the energy to the whole space, in case there is an absorber wanting to receive the energy, it can obtain the energy from this reactive wave. If there is no absorber or antenna to receive the energy, the reactive energy has no any loss for energy, because all energy sends to the whole space can backwardly collapse to the source.

There are two different explanation for the self-energy phenomena, even there are differences, however in general they are same, all means that the self-energy radiation do not carry energy. The radiation is only made with the mutual energy phenomena. In the mutual energy phenomena, the load for the receiving antenna has to be a resistance, for an absorber the energy level must spring from a lower level to a higher level.

4.4 Normalized the mutual energy flow

The mutual energy flow can be calculated with the retarded wave and the advanced wave. This is suitable to the system with a transmitting antenna and a receiving antenna. In situation of photon, when the retarded wave from the emitter to reach an absorber, it becomes very very wake. The calculated energy carried by the mutual energy flow will decrease with the distance between the emitter and the absorber. This is not correct. This problem has been solved with a normalized process. About the normalization process please see ref.10. After the normalization, it can be said that the photon is nothing else, it is the normalized mutual energy flow. In the normalization process, the mutual energy flow is normalized to $\omega \hbar$.

In quantum mechanics, for a photon or electron, it is often said that there is a wave which has been sent out from the emitter to the whole space and then the wave collapses to an absorber. Now, the corrected description is that there is a mutual energy flow bringing the energy from the emitter to the absorber. The self-energy flow is applied to help the mutual energy flow, without the self-energy flow, the mutual energy flow cannot be formed. The self-energy flow is a reactive wave which can be seen as a normal wave together with a time-reversal wave. The normal wave brings the energy to the whole space, the time reversal wave brings all energy left in the space back to the emitter. Hence, the
wave collapse process is explained. This author believes all waves for any other particles do the same.

5 transformers, antennas and photons

5.1 Antenna

In traditional textbooks, the teaching methods of antenna and transformer are very different. In the case of transformers, the signal delay from primary coil to secondary coil is ignored. Therefore, there is no retarded wave or advanced wave. For the antenna system, only the retarded wave of the transmitting antenna is considered. The influence of receiving antenna on transmitting antenna is omitted. For most engineers, these are OK. In this paper, the signal delay from primary coil to secondary coil is considered. The influence of receiving antenna on the transmitting antenna is also considered. In this way, the theory of transformers and antennas is unified. The same theory should be applied to both transformers and antenna systems. The energy flow theory of transformers is easy to explain. This article did it. However, this theory can be applied to antenna systems. In fact, the receiving antenna is same as a secondary coil with a certain distance to the primary coil in a transformer. Because of the distance, the receiving antenna usually has little influence on the transmitting antenna. However the receiving antenna obtained energy from the transmitting antenna. This energy is equal to the the energy of the transmitting antenna offering to the receiving antenna. This is the mutual energy theorem, it actually the energy conservation law for an antenna system.

The environment can also be regarded as some kind of receiving antenna. Most of the radiant energy is received by the environment. That is the reason the transmitting antenna always radiate energy. It is difficult to let the reader understand that if the environment is disappear, the transmitting antenna cannot radiates the energy out.

If two antennas are close to each other, such as microwave relay antennas, they are placed in pairs and face to face. In this case, the receiving antenna can receive a large amount of energy, such as 10% of the energy flow from the transmitting antenna. In this case, the influence of the receiving antenna to the transmitting antenna cannot be ignored. If the load of the receiving antenna changes, the transmitting antenna will fell the changes earlier, because the receiving antenna sends a advanced wave. Even if the receiving antenna is very far away from the transmitting antenna, the transmitting antenna and the receiving antenna must be considered as a whole system. For such a system, the electromagnetic field satisfies the mutual energy principle and the law of conservation of energy (mutual energy theorem). From these two principle or law, we derive two very important theorems: the theorem of mutual energy flow, and the existence theorem of advanced waves, and the energy do not spillover our universe.
5.2 Photon

Photons can be seen as a system with emitters and absorbers. A emitter can be thought of as an atom with a transmitting antenna inside. The absorber can be thought of as an atom with a small receiving antenna inside. In traditional textbooks. The emitter emits retarded waves to create the photon. The retarded wave collapses to an absorber, and the absorber receive a photon. The absorber gains the energy. However, the collapse process can not be described by any mathematical formula. This explanation is not satisfied by many scientists, including Einstein and Schrodinger. This author introduced the mutual energy principle, energy conservation law. The mutual energy flow theorem is derived from the mutual energy principle. If the energy of the antenna is transferred through the mutual energy flow, then the photon system can obviously do the same. For the antenna, the waves used to establish the mutual energy flow include the retarded wave sent from the source and the advanced wave sent from the sink, the two waves all collapse in the opposite direction. For photons, the retarded wave and advanced wave of photons should do the same as the retarded wave and advanced wave of the antenna, which are backward collapsed. Energy is transferred only through mutual energy flow. We can also say that photons are mutual energy flow. More precisely, photons are a normalized mutual energy flow.

5.3 Electron and other particle

Other particles are described by Schrodinger equation and Dirac equation. The author also introduces the principles of mutual energy and self energy corresponding to Schrodinger equation, to solve the wave particle duality [11]. The principle applicable to photons can also be applied to other particles. The waves of all particles are either reactive waves and do not carry energy or a wave with a time-reversal wave. A wave with a time-reversal wave is also some kind of reactive wave. The reactive wave is a wave which transmitting a reactive power. The reactive power do not carry energy or it carry energy but the energy is sent back through a time-reversal process.

Two kinds of waves, that is, the retarded wave from the source and the advanced wave from the sink, are all reactive waves. These waves come from the source or sink, but then collapse backward. In order to match the retarded wave with the advanced wave, the two waves must be synchronized. The synchronous retarded wave and advanced wave can produce mutual energy flow. Mutual energy flow carries the energy of particles from the source to the sink. The particle is a mutual energy flow. To be exact, the particle is a normalized mutual energy flow [10].

6 Conclusion

Based on Newman’s mutual inductance theory, electromagnetic field theory is derived again. In this process, the author found that there is a pair of Maxwell
equations; one for the primary coil and one for the secondary coil. This pair of
Maxwell equations must be considered together. If there is a certain distance
between the secondary coil and the primary coil, the retarded wave and advanced
wave should be considered. The primary coil radiates retarded wave and the
secondary coil radiates advanced wave. The two waves have to be synchronized.
In this way, the primary coil becomes a transmitting antenna and the secondary
coil becomes a receiving antenna.

The antenna system with transmitting antenna and receiving antenna can
be regarded as a transformer with primary coil and secondary coil, but the
distance between the two coils is very large. The energy provided by the primary
coil is equal to the energy received by the secondary coil. This is the mutual
energy theorem. This energy is transferred through the mutual energy flow.
The intensity of the mutual energy flow can be calculated by the retarded wave
radiated by the primary coil and the advanced wave radiated by the secondary
coil. The mutual energy flow satisfies the mutual energy flow theorem, that
is, the energy passing through any surfaces between the primary coil and the
secondary coil is all same.

If a transformer has only one primary coil or there is a secondary coil but the
secondary coil is open, this is the ease of the self induction. The self inductance
of the coil has reactive power. It emits reactive waves. Reactive wave is a kind
of wave with reactive power, that is, the wave is radiated to the whole space,
but it will not bring energy to outer space. It is found that the reactive wave
can be regarded as a combination of a normal wave and a time reversal wave.
The energy flows of the two waves cancel each other. We can also say that the
wave is sent out, but the wave collapses in the opposite direction.

The combination of the two processes (1) energy transfer through mutual
energy flow and (2) wave backward collapse can explain the wave collapse pro-
cess.

It is also possible that the self-energy phenomena is actually a mutual energy
phenomena, but the mutual energy flow is with a reactive power. This will
has the same effect to the self-energy phenomena, that means the self-energy
radiation do not carry energy (or it carry a reactive energy). The energy transfer
is only with the mutual energy phenomena, in which the sink has resistance load.

Photon is a system with an emitter and an absorber. An emitter can be
seen as an atom with a transmitting antenna inside. An absorber can be seen
as an atom with a small receiving antenna inside. Therefore, the above theory is
also applicable to the photon system. If photon waves can be explained in this
way, then all other particles can do the same. This means that for all particles,
including photons and electrons, the collapse of waves is a combined process,
(1) mutual energy flow transfers energy, (2) time reversal wave or backward
collapse.

Hence, we have unify the theory from a transformer system to an antenna
system, photon system any other particle for example electron system.

Therefore, the secret of wave particle duality, especially the collapse of waves,
has been seen clearly through the two coils of a transformer. The secret of
particles has been hidden on the transformer system.
References


