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Article

Theoretical Insights Manifested by Wave Mechanics Theory of Microwave Absorption—Part 1: A Perspective

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Abstract: The wrong theory of impedance matching theory in microwave absorption research has dominated the field for a long time because it was believed that the theory was supported by experimental reports and was consistent with transmission line theory which is fundamental in electromagnetism. Thus, when the correct wave mechanics theory for microwave absorption opposing impedance theory was recently developed, pointing out that the wrong theory involved a misunderstanding of transmission line theory, and in fact the published experimental data disproved the theory rather than supporting it, little notice was taken with the result that the wrong theory still dominates the field as material scientists are reluctant to acknowledge the new theory. It shows here that in contrast to impedance matching theory, the new wave mechanics theory rediscovers the real microwave absorption mechanism that had already been revealed by transmission line theory and now has been developed further with many new concepts. The principles used in this part apply to Part 2 where a perspective derived from a question and answer session with DeepSeek is provided. This work also reveals that theoretical research is important to correct the wrong conclusions obtained from experimental observations.

Keywords: wave mechanics theory; transmission line theory; microwave absorption film; theoretical insights

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1. Introduction

In the field of microwave absorption material, the film and the material have been confused [1–7], characterized by not distinguishing the input impedance Z_{in} of film from the characteristic impedance of material Z_M [8,9] and represented by confusing the interface in its isolated state from that in film [10] and the two parallel interfaces in a film from the interfaces between material particles [11]. In addition, concepts such as first and second reflection losses have been wrongly defined [4,12–15]. Inaccurate theories such as impedance matching theory [10,16–18] and the quarter wavelength theory [19–22] were used to develop the wrong absorption mechanisms for film and material [23–25] which have been established over the years since their inadequacies were not recognized and corrected. Over the years, many experiments have been carried out which are described as supporting the wrong theories instead of correcting them even though the inconsistences should have been easy to spot. Material scientists believe that their theories are based on transmission line theory and thus do not accept they can be wrong [26–31].

Recently a new theory of wave mechanics has been developed for microwave absorption for film [22,24,32] which identifies and explains the problems in current theories. Indeed, it is found that the experimental data reported previously were in fact inconsistent with the wrong theories which were based on misunderstanding transmission line theory. However, the scientific community continues using the wrong theories within a large number of publications with only a few exceptions [14,33,34] mentioning the opposite new theory [35–41]. Discrediting commonly accepted ideas is often difficult

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to achieve in a scientific community [42], particularly when a theory had been accepted for many years.

Scientific paper is to solve problem. There are two kinds of such research. One is solving problems against the current theory. Such work pushes science forward. Related to this kind of research with this present work is that it has been established by many publications [8,10,16–25,32,36,38] from different perspectives, including reviews and correcting errors commonly occurs in publications, that the current dominant theories in microwave absorption are wrong and should be replaced by the new wave mechanics theory which is correct. Indeed, when a theory is wrong, it is wrong from every perspective, and a correct theory is correct in whatever perspectives.

The other kind of research is solving problems using accepted theory. Such work is still considered novel and most of the papers published fall in this categorify. This present work of Parts 1 and 2 addresses the problem as to why the replacement of the wrong theories with the new correct wave mechanics theory has not yet happened in that the current theories still dominant publication and the wave mechanics theory has not been accepted by the research community. This is the important problem needs to be solved. This present work is based on the correct wave mechanics theory. Thus, Parts 1 and 2 of this present work belong to the second kind of the research that focused on the problem needs to be solved.

Wrong and junk papers can easily be published just because they conform to accepted theory. Indeed, 90% of the published papers are wrong [43] and 95% are junk [44]. Even junk papers from essay mill can easily get published [45,46]. However, those manuscripts against accepted theories, even they have solved real problems and important because they push science forward, are difficult to be accepted for publication. There are serious problems in publication [47]. As Planck [42] said: "*A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it*". Even in modern time, history repeats itself remarkably. Indeed, "*some scientists wondered how a questionable line of research persisted for so long … experts were just too timid to take a stand*" [48] and "*Can so many scientists have been wrong over the eighty years since 1925? Unhappily, yes. The mainstream in science, as any scientist will tell you, is often wrong. Otherwise, come to think of it, science would be complete. Few scientists would make that claim, or would want to. Statistical significance is surely not the only error in modern science, although it has been, as we will show, an exceptionally damaging one. Scientists are often tardy in fixing basic flaws in their sciences despite the presence of better alternatives* [49]". It was argued that peer review is when your peers have the ability to prevent the world from learning about your work and enables the professional class to turn the process of gatekeeping information into a safeguard for their own status [50–53].

This work addresses the problem as to why this replacement has not yet happened and the current theories still dominant publication and the wave mechanics theory has not been accepted by the research community. To address this important issue, this Part 1 focuses on showing that the wave mechanics theory conforms with transmission line theory while the wrong theories originate from a misunderstanding of this fundamental electromagnetic theory. Part 2 focuses on the same problem with perspective based on interaction offered from DeepSeek. The work uses theories conforming to accepted wave mechanics theory to solve problems in the field of material. Many people believe that a particular theory must be wrong if theoretical and experimental conclusions are in conflict. However, this work demonstrates another perspective which shows the importance of scientific research in that it is possible to draw wrong conclusions from numerous sets of accurate experimental data particularly when the correct theory has not been established.

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2. Discussions Based on Transmission Line Theory

2.1. The Transmission Line Theory-Based Wave Mechanics Theory of Microwave Absorption

As shown by Figure 1, the incident microwaves represented by beam i enter the metal-backed film and the entered beam is reflected back-and-forth between the top and the bottom interfaces. r1 the is the reflected beam from the top interface and r2 is the total beam reflected from the bottom interface. Beam r is obtained from the superposition of beams r1 and r2.

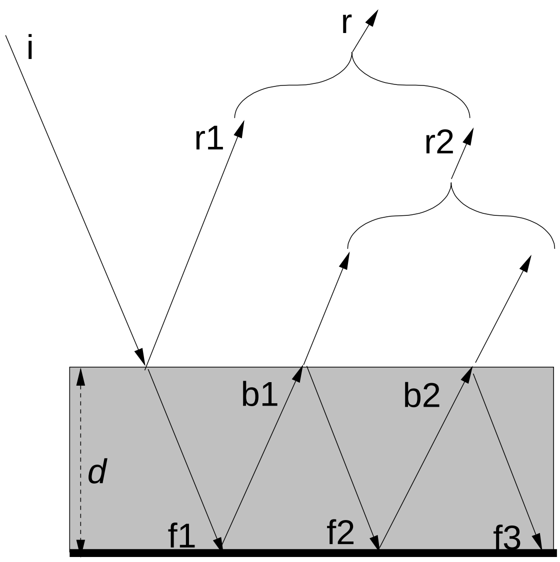

Figure 1. A metal backed film with thickness *d*. i indicates the incident beam and r1 is the reflected beam from the top interface. Part of the incident microwaves enters the film and reflected back-and-forth between the top and bottom interfaces. f1, f2, f3. etc. are the forward beams and b1, b2, etc. are backward beams in the film. r2 is the total reflected beam from the bottom interface. Beam r is the superposition of beams r1 and r2.

In transmission line theory, reflection coefficient RL is obtained from the superposition of individual beams [19,20,54] shown in Figure 1 as

$$RL = \frac{V_r}{V_i} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \tag{1}$$

$$Z_{in} = \sqrt{\frac{\mu_0 \mu_r}{\varepsilon_0 \varepsilon_r}} \tanh(j \frac{2\pi \nu d \sqrt{\varepsilon_r \mu_r}}{c}) = Z_M \tanh(j \frac{2\pi \nu d \sqrt{\varepsilon_r \mu_r}}{c}) \tag{2}$$

Z_{in} is the input impedance of the film. Z_M and Z_0 are the characteristic impedances of material and free space, respectively. The permittivity ε_0 and the permeability μ_0 are of free space, and ε_r and the μ_r are the relative permittivity and permeability of material. ν is the frequency, c is the velocity of light in a vacuum. V_k is the voltage of beam k. Thus, the "perfect impedance matching" situation [16] of RL = 0 at Z_{in} = Z_0 is the result of microwave penetration rather than an interface phenomenon without penetration.

It is claimed that RL has been used to characterize absorption because "Obviously, there will be different RL calculation methods to characterize the absorber's absorbing performance. … when calculating the input impedance of the transmission line mode of the lossy absorber, it is assumed that the transmission end point of the EMW is known. … when the absorber is a high loss absorbing material, the EMW is difficult to pass through the absorber, and the input impedance is the

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characteristic impedance of the absorber. When the absorber is a low-loss absorbing material, EMW will penetrates the absorber and enter the free space. … it is difficult to determine whether the EMW can penetrate the multilayer material for the multilayer absorber … Because it is difficult to know whether the EMW will penetrate the material before the test, it is necessary to assume that the transmission end point of the EMW is known before the next calculation. On the one hand, the premise of this assumption may lead to inaccurate calculation results, on the other hand, the characterization of microwave absorption performance will not be unified. Therefore, in order to facilitate calculation and characterization, the transmission line model with absorber attached on the metal backing is often used." [55] Different absorbers such as material, films with and without metal-back need different parameters to characterize absorption. RL/dB can only be used to characterize the absorption of metal-backed film but cannot be used to characterize the absorption of material since powerful absorption in metal-backed film does not necessarily signify powerful attenuation of its material [18]. Metal-backed film is related to devices such as Salisbury screen and Jaumann absorber.

RL can be used to characterize metal-backed film whether the penetrated microwaves reach the end interface of the film or not [16]. Thus, That the metal-backed film has been used in microwave absorption research has nothing to do with the extent of penetration. The absorption peaks of film are related to wave cancellation, whether the film is metal-backed or not [38]. The absorption of the film without metal back is related to the absorption from the so-called Fabry-Pérot Resonance although this is not real resonance, rather it is the absorption peak from out-of-phase wave superposition. The back-and-forth reflections between the two parallel interfaces in the film are not resonance oscillations [56]. Indeed the concept of quarter-wavelength resonance [57] has in fact attributed the absorption peak wrongly as material resonance [58].

It is also claimed that "It is noted that no RL peak is found in all the $S_{11\text{-OPEN}}$ curves at various thicknesses. This proves that the RL peak cannot appear if the composite has no backed metal plate [59]." However, this conclusion is not justified as the absorption peak of metal-backed film is usually stronger than that of the film without metal back for the reason that some of the microwaves have been leaked from the other side of the film without metal back and thus do not participate in the wave cancelation process [38]. Because RL/dB has been mistakenly taken as a criterion for the absorption of material, the stronger absorption peak found with metal-backed film has led to the false conclusion that RL/dB should be used for material absorption.

In microwave absorption research, ε_r and the μ_r of the material is first measured from s_{11} and s_{21} of a film without metal-back, then they are used in Equations (1) and (2) to calculate the value of *RL*. [23] For the material CA3.5-4 reported by Guangbin Ji et al. [60], $\varepsilon_r = 12.35 - j3.08$ and $\mu_r = 1.14 - j0.12$ at $\nu = 4.00$ GHz, and $\varepsilon_r = 9.51 - j3.85$ and $\mu_r = 1.16 - j0.014$ at $\nu = 11.00$ GHz. The $|RL|$ values calculated using Equations (1) and (2) from these experimental data of ε_r and μ_r are plotted in Figure 2.

The incident energy is reflected back to the free space represented by $|RL|$ [2]. The rest is absorbed by the film represented by *A*(Film) and thus

$$A(\text{Film}) = 1 - |RL|^2 \tag{3}$$

The lowest peaks in $|RL|$ in Figure 2 represent the strongest absorptions by the film where beam r is at its weakest positions. It is claimed in the wave mechanics theory of microwave absorption that the absorption peaks occur when beams r1 and r2 are out of phase by π and this condition ensures that beam r is at its local weakest. This result can be verified by numerical calculations using Equations (4)–(6), which confirms that $|RL|$ peaks do occur when the phase difference between the reflection coefficient R_M of the top interface and that R_2 of the bottom interface in Figure 1 is indeed π. [20,23] The phase difference between beams r1 and r2 is the same as that between R_M and R_2 since both R_M and R_2 are calculated relative to the incident beam i.

$$R_M = \frac{V_{r1}}{V_i} = \frac{Z_M - Z_0}{Z_M + Z_0} \tag{4}$$

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$$R_2 = \frac{V_{r2}}{V_i} = RL - R_M = \frac{(R_M^2 - 1)e^{-\frac{j4\pi vd\sqrt{\varepsilon_r\mu_r}}{c}}}{1 - R_M e^{-\frac{j4\pi vd\sqrt{\varepsilon_r\mu_r}}{c}}} \quad (5)$$

$$Z_M = Z_0\sqrt{\frac{\mu_r}{\varepsilon_r}} = \sqrt{\frac{\mu_0\mu_r}{\varepsilon_0\varepsilon_r}} \quad (6)$$

The result shows that the new mechanics theory conforms to transmission line theory using the wave superposition derivation of the formula of *RL*.

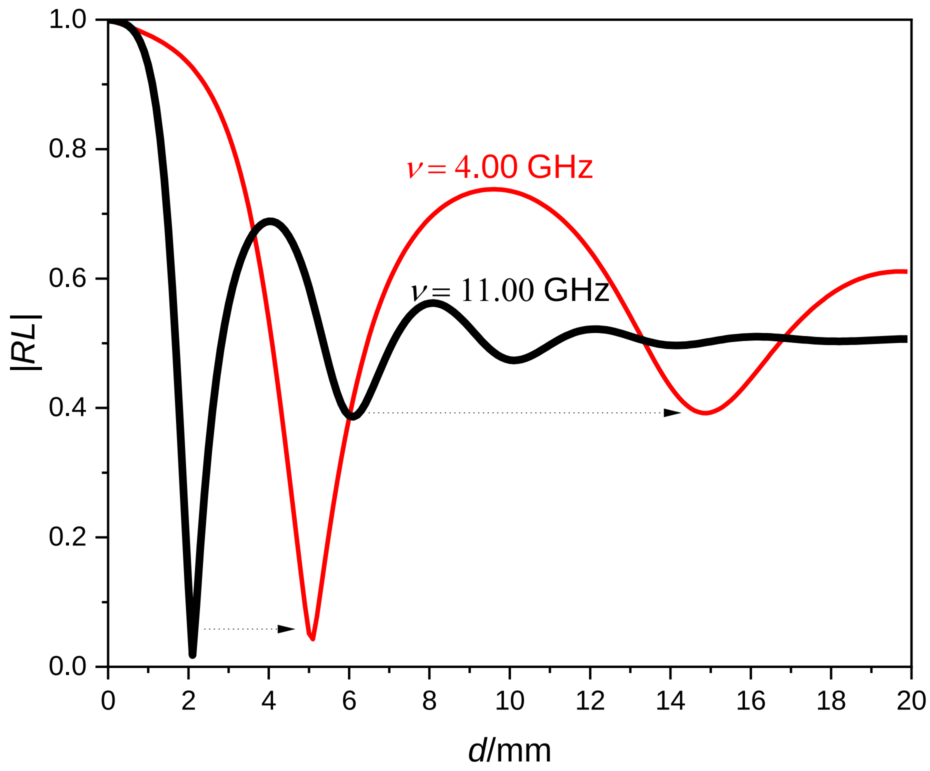

Figure 2. |*RL*| for the material CA3.5-4 reported by Guangbin Ji et al. [60] measured at 4.00 and 11.00 GHz, respectively.

2.2. The Misunderstanding of Transmission Line Theory

In the current dominant theory, it is believed from Equation (1) that when Z_{in} - Z_0 = 0, all the incident microwaves enter the film. Therefore, in the theory it is required by the absorption mechanism that most incident microwaves enter the film and that it is necessary to use material with significant attenuation to absorb the microwave energy along the optical path in the film. However, this theory is untrue [18,38] and it is based on a misinterpretation of transmission line theory. It is true that *RL* = 0 when $Z_{in} = Z_0$. [16] However, it has been proved that the absorption peak can occur when $Z_{in} \neq Z_0$ and can occur when $|Z_{in} - Z_0|$ reaches its maximum value if the peak is achieved at $Z_{in} \neq Z_0$. [20] The reason is that being a complex number, the denominator ($Z_{in} + Z_0$) in Equation (1) cannot be neglected if $Z_{in} \neq Z_0$. [20] It has further been proved that the absorption mechanism of film is not the same as that of material. The absorption of film does not originate from the attenuation power of the material along the zig-zag optical path. The absorption by the material along the optical path in the film should be *A*(Material) defined by Equation (7) other than by Equation (3). [32] The differences between the absorption of film and the attenuation power of material along its optical path are shown

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in Figure 3. The absorption of thick film approaches the attenuation power of material [18] as the angular effects of the film are suppressed when *d* becomes large [23] since beam r2 is vanishing when *d* is large.

$$A(\text{Material}) = (1-|R_M|^2)(1-e^{-2\alpha_P d}) \quad (7)$$

$$\alpha_P = \text{Re}(|j\frac{4\pi\nu d\sqrt{\varepsilon_r\mu_r}}{c}|) \quad (8)$$

Re(x) is the real part of x.

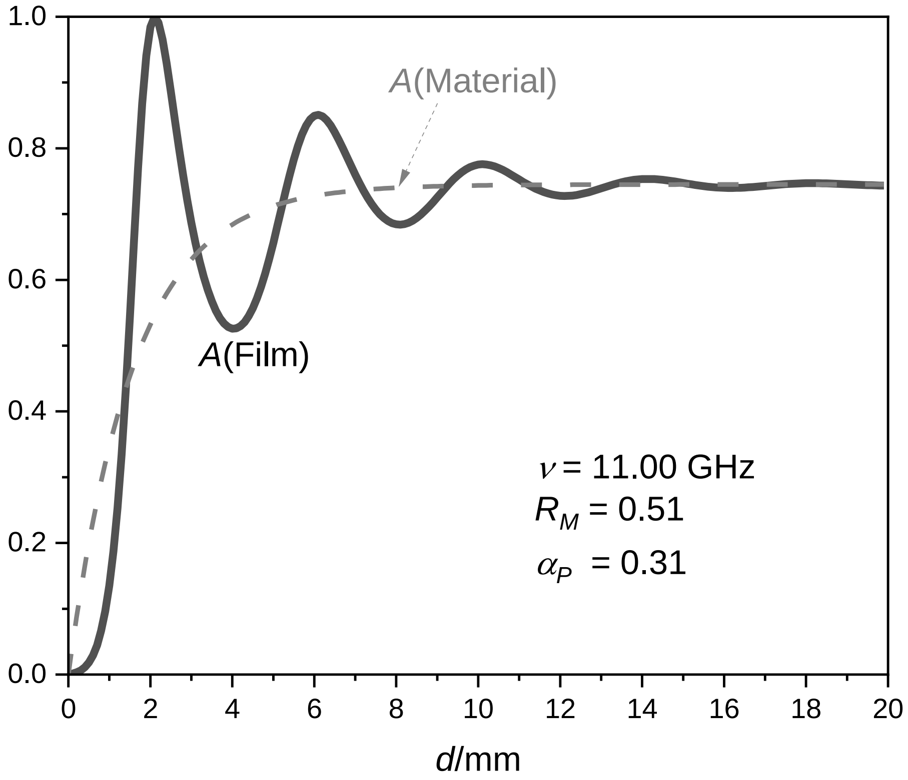

Figure 3. The difference between the absorption of metal-backed film *A*(Film) of material CA3.5-4 [60] and the attenuation power of its material *A*(Material) along the optical path.

The power of wave mechanics theory can be demonstrated by the fact that it can simply explain why the absorption peak does not occur exactly when the phase difference of beams r1 and r2 is π [22,24,38]. It can also be proved from the wave mechanics theory that film absorbs microwaves and interface does not [36].

2.3. The Flaws in Impedance Matching Theory Revealed from the Mechanics Theory

Although material is referred in microwave absorption research, it may be argued that it is acceptable what the authors means by "material" were referred really to film when *RL*/dB is applied to "the material". However, the problem is not only the ambiguous using of film and material but that the confusion between film and material has led to the wrong theory of impedance matching theory and the wrong absorption mechanism for film.

The problems of the current theories were not identified until the establishment of the wave mechanics theory. In the current theory it is claimed that all the incident microwaves enter the film when $Z_{in} = Z_0$ and define this condition as impedance matching. However, this theory confuses Z_{in} and Z_M. [8] When $Z_M = Z_0$, the top interface in Figure 1 disappears and all the incident microwaves

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enter the film while this condition cannot ensure that all the incident waves enter the film since Z_M and Z_0 can be different even when $Z_{in} = Z_0$. [9] When $Z_M \neq Z_0$, the top interface still exists and not all the incident waves enter the film. The impedance matching theory uses the attenuation power of material to explain the absorption results represented by $|RL|$ and thus it does not account for the fact that all the incident microwaves have been absorbed when $Z_{in} = Z_0$ while not all of the waves enter the film since $Z_M \neq Z_0$,.

As shown by Figure, 3, beam r2 vanishes and $|RL| = |R_M|$ when d approaches infinity. Beam r1 vanishes and $|RL| = |R_2|$ when $Z_M = Z_0$. As shown by Figure 4, $|RL|$ is a monotonic decay function of d at 11 GHz when $\varepsilon_r = \mu_r = 5.51 - j3.85$ and $\varepsilon_r = \mu_r = [(9.51 - j3.85)(1.16 - j0.014)]^{1/2}$ to ensure $Z_M = Z_0$.

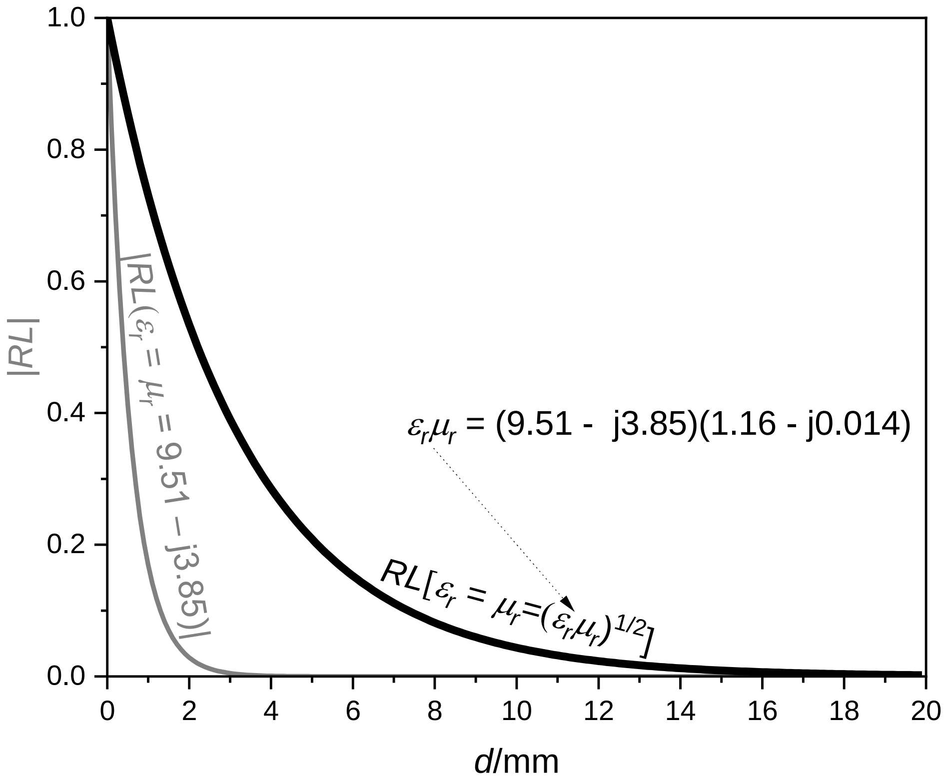

Figure 4. $|RL|$ calculated by Equation (1) or (5) with $\varepsilon_r = \mu_r = 9.51 - j3.85$ and $\varepsilon_r = \mu_r = [(9.51 - j3.85)(1.16 - j0.014)]^{1/2}$ at 11 GHz. [9].

It can be proved generally that $|RL|$ is a monotonic decay function when $\varepsilon_r = \mu_r$ where $R_M = 0$, as shown by Equation (9). [10,20] Although there may be an absorption peak with $Z_{in} = Z_0$ for film, $|RL|$ = 0 with $Z_{in} = Z_0$ for material can only be achieved when d is infinity.

$$|RL(\varepsilon_r = \mu_r)| = \left| \frac{R_M - e^{-\frac{j4\pi v d\sqrt{\varepsilon_r\mu_r}}{c}}}{1 - R_M e^{-\frac{j4\pi v d\sqrt{\varepsilon_r\mu_r}}{c}}} \right| = e^{-4\pi v d \varepsilon''/c}$$
$$= |R_2(\varepsilon_r = \mu_r)| = \left| \frac{(R_M^2 - 1)e^{-\frac{j4\pi v d\sqrt{\varepsilon_r\mu_r}}{c}}}{1 - R_M e^{-\frac{j4\pi v d\sqrt{\varepsilon_r\mu_r}}{c}}} \right| = e^{-4\pi v d \mu''/c} \quad (9)$$

where ε_r'' and μ_r'' are the imaginary parts of ε_r and μ_r, respectively.

The impedance matching theory was established to explain absorption peaks when $Z_{in} \neq Z_0$. However, as shown by Figure 2, the absorption of the film has a wave shape with absorption peaks while as shown by Figure 4, the accumulated attenuation of material is a monotonic decay function

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without absorption peak. When $Z_{in} \neq Z_0$, the absorption peak of the film usually cannot be achieved at the minimum of $|Z_{in} - Z_0|$ since the amplitude and the phase conditions for $Z_{in} = Z_0$ cannot be achieved simultaneously [17,37].

In impedance matching theory, microwave penetration is defined by amplitudes of individual beams with the value of $|Z_M - Z_0|$. [61] In fact, such penetration should be defined from energy penetration but it cannot be defined for film [10] unless all the incident microwaves enter the film or beam r2 vanishes.

It is believed in the current theory that the absorption peaks shown in Figure 2 are the resonance absorptions of the material [57,58]. This wrong concept leads to the investigation of the relationship between material structure and the value of $|RL|$, which is not relevant and to the investigation of the relationship between the attenuation power of material α_P and the value of $|RL|$, although in practice these terms are independent. Correct research should be based on clarifying the relationship between material structure and the values of ε_r and μ_r, and then investigating what values of ε_r and μ_r, can ensure the required value of $|RL|$ [18]. There is no simple relationship between material structure and the value of $|RL|$ nor one relating α_P to $|RL|$ as qualitatively discussed in the literature apart from the complex relationship represented by Equation (1). For example, at constant frequency, α_P is a constant while $|RL|$ is a function of d.

As can be seen from Figure 2 there is an absorption peak at d = 2.10 mm and ν = 11.00 GHz with $|RL|$ = 0.018. If this peak originates from material resonance, then it will become stronger if d increases to 5.10 mm. However, the value of $|RL|$ increases to 0.56 at d = 5.10 mm and ν = 11.00 GHz, which indicates a decrease in absorption with increase of film thickness.

This phenomenon can be understood by the wave mechanics theory. There is an absorption peak at d = 2.10 mm and ν = 11.00 GHz because the phase difference of beams r1 and r2 is π. When d increases with fixed ν, this phase difference is no longer π. To keep the phase difference at π, the frequency must decrease to ν = 4.00 GHz when d increases to 5.10 mm according to the inverse relationship between d and ν. [21] Thus, the origin peak at d = 2.10 mm and ν = 11.00 GHz shifts to the position at ν = 4.00 GHz with $|RL|$ = 0.043 when d increases from 2.10 to 5.10 mm. Similarly, the absorption peak at d = 6.10 mm and ν = 11.00 GHz with $|RL|$ = 0.39 shifts to d = 14.90 mm and ν = 4.00 GHz with $|RL|$ = 0.39. The result provides a real example that confirms the validity of the inverse relationship between frequency and film thickness which occurs when ε_r and μ_r are insensitive to frequency [21]. The ratios of the shifts of the first two peaks from 11.00 to 4.00 GHz in Figure 2 are both 0.41 within experimental error from 2.10/5.10 and 6.1.0/14.90 since both the peaks shift under the same frequency ratio of 4.00/11.00 = 0.36, quite near 0.41. If both ε_r and μ_r were invariant to frequency, the inverse relationship would have been rigorously obeyed.

In impedance matching theory, a strongest absorption peak at $|Z_{in}| = |Z_0|$ is explained as a result of the most penetration occurred and the strongest attenuation of material, which has already been proved to be wrong [18]. The correct explanation can only be provided from wave mechanics theory that all the absorption peaks occur when beams r1 and r2 are out of phase by π and the strongest among them is the one that the amplitudes of Z_{in} and Z_0 are the closest [17]. Impedance matching theory was intended to explain the strongest absorption peak and has been proved to be failed in doing so while it is incapable of explain other aspects of the property RL represented such as why the absorption peaks deviated from the exact positions of $d = n\lambda/4$, n is an integer and λ is wavelength [10,21]. In contrast, the wave mechanics theory can reveal every detail of that represented by RL, including the exact value of numerical of RL, the shape of the RL curve, and revealing simply why the absorption peaks deviate from the positions where beams r1 and r2 are exactly out of phase by π [22,24,38].

2.4. The Roles Played by Theoretical Research

The flaws in current theories revealed above remained unidentified until the new wave mechanics theory [22,24,32] was established. Indeed, these wrong theories still dominate publications because many people cannot believe that accepted theories, such as the current dominant theory for microwave absorption [62], with plenty of accumulated experimental supports over a long period can possibly be wrong. Many researchers only believe experimental results and regard theoretical research as opinions, which leads to editorial policies such as "*Theories, commentaries, and non-systematic reviews are not eligible for preprinting*" [63].

To address this, we cite Ziliak and McCloskey "Can so many scientists have been wrong over the eighty years since 1925? Unhappily, yes. The mainstream in science, as any scientist will tell you, is often wrong. Otherwise, come to think of it, science would be complete. Few scientists would make that claim, or would want to. Statistical significance is surely not the only error in modern science, although it has been, as we will show, an exceptionally damaging one. Scientists are often tardy in fixing basic flaws in their sciences despite the presence of better alternatives. Think of the half century it took American geologists to recognize the truth of drifting continents, a theory proposed in 1915 by—of all eminently ignorable people—a German meteorologist. Scientists, after all, are human. What Nietzsche called the 'twilight of the idols,' the fear of losing a powerful symbol or god or technology, haunts us all" [49]

Conclusions from experimental results can be wrong and such wrong conclusions cannot be easily identified without the correct theory. The theory that the Earth moves around the Sun cannot be corrected without the guidance of a new theory which tells us that the experiment observations that seemly support the original theory do in fact disprove it. Without the correct theory, it is difficult to understand from experiment observation that the light object falling at the same speed as that of the heavier object in vacuum, and it is argued that "*he and his fellow travelers are proposing a major departure from the way we have done science since the time of Galileo. True, the Italian physicist himself largely engaged in theoretical arguments and thought experiments (he likely never did drop balls from the leaning tower of Pisa)*" [64].

Experiments without theory of logic like mathematical reasoning that only accumulate facts is not science [65]. In the heyday of alchemy, there was no science other than experimentation.

3. Conclusions

The data from ref. [60] have been used to show that published data used to support the current theories in fact disprove them. The inverse relationship between frequency and film thickness has also been confirmed from the real experimental data. Conclusive evidence has been provided that microwave absorption is rooted in transmission line theory while the current dominant theories originate from a misinterpretation of this electromagnetism theory. The details of reflection loss, including its exact value and the shape of its curve can be described exactly by the wave mechanics theory, However, such results cannot be achieved by impedance matching theory since it was only intended to explain the absorption peak represented by RL/dB. Nevertheless, it has been proved that this intended purpose has not reached by impedance matching theory. The wave mechanics theory is a much more powerful theory to describe all aspects of microwave absorption whether the film behaves as material or not. Unfortunately, the practice of using the wrong theories continues in modern research without open debate on the opposing wave mechanics theory because the wrong concepts have dominated the field for long. This situation might be related to the fact that many concepts established in the new theory, such as the importance of the angular effects unique to film, the fact that beam r2 reaches its maximum at absorption peak position, and that the amplitude of beam b2 can be larger than that of the incident beam, contradict the so-called common sense evoked in the wrong theories.

Data Availability Statement: Data sharing does not apply to this article as no new data were created or analyzed in this study.

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