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Primary Modeling For Electromagnetic Waves Transmission In Extreme Weather Conditions

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ABSTRACT: Telecommunication plane-transverse wavelets of short wavelength and high frequency are industrially used for modern communication systems. There are extent variety of models for transmission and dispersive energy loss determination from emission to reception points. The dependence of the electrical and magnetic coefficients σ , ϵ , and μ , conductivity, dielectric constant and magnetic permeability in the Helmholtz wave equations are essential—non-conducting and conducting medium. These Maxwell parameters, dependent on chemical composition of wavepath matter, have influence for determination of magnitude of energy conservation—namely, the Poynting vector. The physical-mathematical development of the wavelets equations parameters have also an important role in this modeling. However, in heavy rain conditions the media is formed both by air and water with a high proportion of water vapour, facts that imply special constraints for telecommunication conditions. This paper deals with a primary approach to model the wavelet transmission and reception in these extreme dispersive rainy-weather environment. The mathematical model was made with Fresnel equations and Fourier transform integrals simplified. Bayesian calculus for intersection of probabilities were developed for the stochastic function of the model. The continuous interaction with large number of curtains of water created by chains of falling closely drops is taken into account stochastically. As a result, a group of primary mathematical equations are presented and computational-numerical simulations performed.

KEYWORDS: Wave Equations, Conductivity, Dielectric Constant, Magnetic Permittivity, Maxwell Equations, Optimization, Mathematical Modelling.

I. INTRODUCTION

Electromagnetic waves/wavelets emission-reception constitutes the most used communication system in all branches of information structures and modern telecommunication devices. Based on Maxwell equations, [1], this type of waves obey these four basic equations with subsequent modifications for frequency, media conductivity, electrical and magnetic permittivity, and complementary constraints, [2]. The energy loss formulation for model was selected by the simple quotient of electric field modulus, [9]. Far-field corrections were not applied in this case, [3]. Approximations were geometrical and numerical with probabilistic productory functions. Probabilistic functions were obtained from stochastic modelling fundamentals, [14]. In summary, an initial model for transmission of electromagnetic waves and wavelets was presented with power energy calculations. The power of the transmitted field is essential to determine the probability of fair reception. This point was the main objective of the model development.

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II. THEORETICAL ELECTRODYNAMICS MODEL FRAMEWORK

The beguine of the theoretical commences with the mathematical development of the Helmholtz wave equation from the initial setting of Maxwell equations, [1,2]. It is a simple vector calculus demonstration, but the concept of wavelets is set sharply through the mathematical proof. Starting with Maxwell equations,

$$\begin{aligned} \nabla \cdot \vec{B} &= 0 \\ \nabla \cdot \vec{D} &= 0 \\ \nabla \times \vec{E} + \frac{\partial \vec{B}}{\partial t} &= 0 \\ \nabla \times \vec{H} - \frac{\partial \vec{D}}{\partial t} &= 0 \end{aligned} \tag{1}$$

For wavelets, E and B are vectors depending on time, t, and frequency, ω . Such as,

$$\vec{D} = \epsilon \vec{E}; \text{ and } \vec{B} = \mu \vec{H}; \tag{2}$$

These equations are linear although [1,2] permittivities, electric and magnetic for waves, could easily be nonlinear functions. For the interest of getting learning of fundamental waves equation, not detailed in [1,2], it is developed here the vectorial calculus for getting the [2] equation,

$$\left[\nabla^2 + \mu \epsilon \omega^2 \right] \times \begin{vmatrix} \vec{E} \\ \vec{B} \end{vmatrix} = 0; \tag{3}$$

The upper term proof is developed, and the lower follows straightforward with the same demonstration technique. One basic equation in vector analysis to carry out the proof is,

$$\nabla \times \left[\nabla \times \begin{vmatrix} \vec{E} \\ \vec{B} \end{vmatrix} \right] = \nabla \left[\nabla \cdot \begin{vmatrix} \vec{E} \\ \vec{B} \end{vmatrix} \right] - \nabla^2 \begin{vmatrix} \vec{E} \\ \vec{B} \end{vmatrix}; \tag{4}$$

Subsequent application of Eqs. (4) to Maxwell equation,

$$\nabla \times \left[\nabla \times \vec{E} + \frac{\partial \vec{B}}{\partial t} \right] = 0; \tag{5}$$

Thus, it follows, decomposing Eq. 5, and form Eq. (4),

$$\nabla \times \left[\nabla \times \vec{E} \right] + \nabla \times \left[\frac{\partial \vec{B}}{\partial t} \right] = \nabla \left(\nabla \cdot \vec{E} \right) - \nabla^2 \vec{E} + \nabla \times (-i\omega) \vec{B} = 0; \tag{6}$$

The first term in the right side is null for Maxwell equations, and now it follows to prove,

$$\nabla \times (-i\omega) \vec{B} = \mu \epsilon \omega^2 \vec{E}; \tag{7}$$

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hence,

$$\nabla \times (-i\omega) \vec{B} = \nabla \times (-i\omega) \mu \vec{H} = \text{for Maxwell equations} = i\omega \mu \frac{\partial \vec{D}}{\partial t} = \mu \epsilon \omega^2 \vec{E}; \quad \text{Eq. (8)}$$

As it was wanted to demonstrate. Meshing Eqs. (5-8), it follows the first upper part of Eq. (3),

$$[\nabla^2 + \mu \epsilon \omega^2] \times \vec{E} = 0; \quad \text{Eq. (9)}$$

This demonstration was explained to set the direct consequences of Maxwell equations towards the fundamental wave equation. In other words, the physically invariant fundamentals of the four Maxwell equations is equally applied for waves equation. In next sections the model for rainy environment is developed with the waves equation related to electric field transmitted (refracted) power quotient.

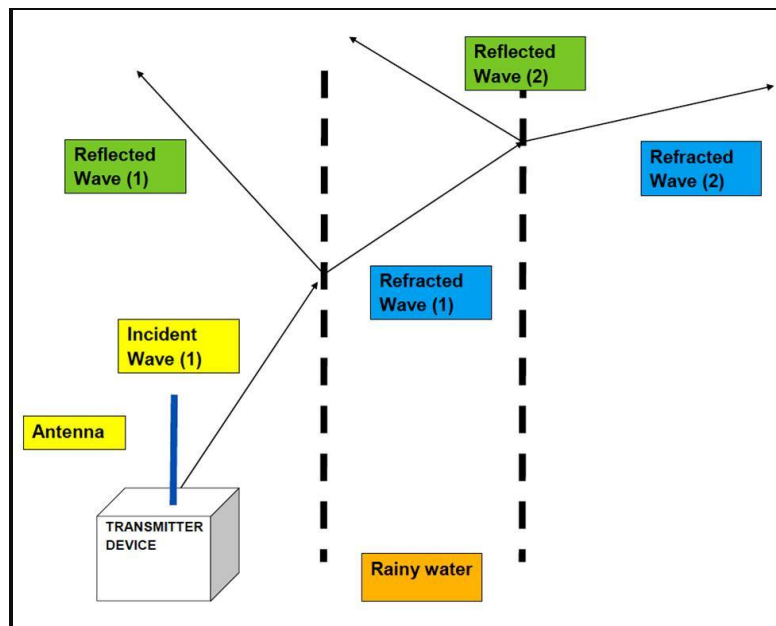


Figure 1.-Basic concept-sketch of the mathematical-electromagnetic model for emission-reception of the wavelet through curtains of rain-drops [Casesnoves, 2018].

III. MODEL CONSTRUCTION AND APPROXIMATIONS

What is intended in this primary approach for modelling in extreme rainy conditions is to set the energy variation through successive curtains of rain-water-particles. In Fig. 2 the geometrical shape approximation of a drop to a parallelepipedic volume is shown. There are approximately two surfaces separated by a distance of 10^{-11} millimeters, and n could vary according to the intensity of the weather phenomena. The model outbreak comes from the natural image of the rain that any individual can watch when it is raining. That is, a landscape formed by lines of water-particles falling from the sky towards the earth ground. The energy variation will be developed in a function of several variables. This function contains the energy of the transmitted wave from the previous incident field. The process of transmission constitutes a series of incident-refracted phenomenas through the subsequent drops of rain. The refraction occurs stochastically depending of the intensity of rain [13,14]. In other words, [14], Markov-Chain methods are applicable. That is, if for example the intensity of rain is high, the drops are almost together in every curtain, what means that the

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probability for a wavelet to incide over a drop could be 10% for not refraction and 90% for refraction energy loss. It is considered as a first approximation that a second refraction from the interior of the drop to the air does not happen.

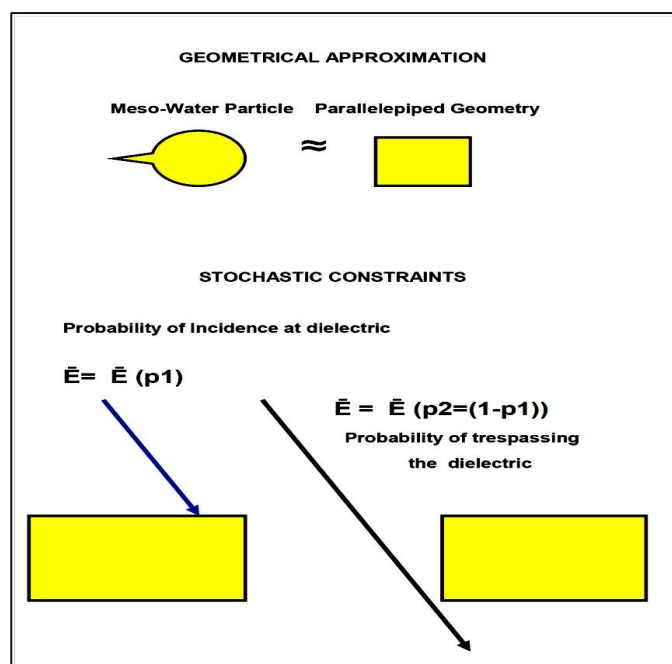


Figure 2.-Stochastic constraints sketch for the interaction between electromagnetic waves ad rain. There are two probabilities, namely, p_1 is probability of interaction with water, p_2 is probability of trespassing through the water curtain without incidence.

For Bayesian basics, $p_1+p_2=1$. Just to remark that water liquid could be in some magnitude proportion of an acid solution caused by environmental change reasons. The analysis of \vec{E} fields of incident-refracted wavelets is developed with basic electrodynamics formulation of classical texts and articles. It is intended set basis for future more rigorous development while making a substantial physics background. The proper characteristics of the model are its stochastic series occurrence and function construction settings. In Fig. 2 the principal hurdle of the rainy conditions is shown. Any electromagnetic field could interact either with water or trespass the air gap between two subsequent particles. If this probabilistic event happens n times, between the emitter and the receiver, the total probability is a Bayesian intersection of events probability. As a result it follows,

$$P = p_1 \times p_2 \times \dots \times p_n = \prod_{(i=1..n)} p_i \quad \text{Eq. (10). Probability Function (1).}$$

Suppose the probability of interaction is $1/5$, if it is calculated the probability of a field \vec{E} to reach receiver with continuous interaction with particles, no trespassing any gap, the total probability reads,

$$P = \prod_{(i=1..n)} p_i = [1/5]^n \quad \text{Eq. (11). Probability Function (2).}$$

The magnitude of the n could tend to infinite, or be a large-scale number, depending of the conditions. The model is developed with stochastic constraints [14], that is, the total probability if some m (total) interactions happen, $m-n$ collisions with particles and n trespassing events (\vec{E} passes through the gap of Fig. 2), the productory \prod of the stochastic probabilistic function, P_S , is as follows,

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$$P_S = \prod_{i=1..m} p_i = [1/5]^{m-n} \times [1-1/5]^n \quad \text{Eq. (12). Probability Function (3).}$$

These constraints are applied to the power loss of \vec{E} fields. In Fig. 3 the meso-scale of the field interaction in a particle with incident and refracted fields. When a incident field \vec{E}_0 of the wave incides ove the water particle occurs a reflexion and a refraction. A \vec{E}_{R1} , that is, field reflected is formed, and a \vec{E}_{T1} , a field refracted (transmitted, T) is formed. Within the particle, and at the subsequent interface water-air, the \vec{E}_{T1} incides, and generate two new fields. The first one is \vec{E}_{R2} , within the water liquid, and the second one is \vec{E}_{T2} , that emerges from liquid-particle material towards the air media. The probabilistic factors of Eqs. (10-12) multiply the magnitude modulus of these reflected and refracted fields. The probabilistic factors also multiply a field that collides with particles in m events, and sort the particles in n events, [14]. This is explained in Fig. 3 to pass onto the simulated formulation in the next section.

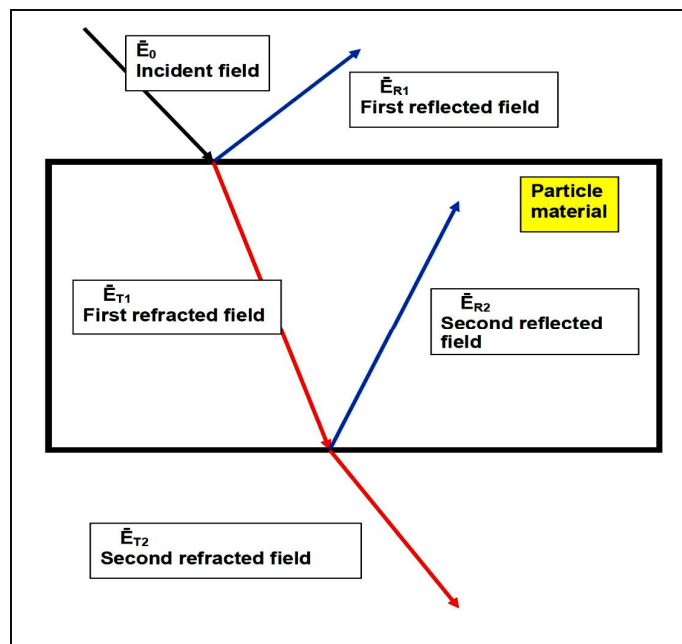


Figure 3.- Basic reflection-refraction phenomenas that occur when interacting the electric field of the wave. The reflected and refracted fields are detailed at sketch. The first approximation of Eq. (5) does not consider the refraction and reflexion within the particle.

IV. SIMULATION FORMULAS, CALCULUS OF PROBABILITIES, AND GEOMETRICAL-STOCHASTIC CONSTRAINTS

The present section deals with the principal formulas obtained for the model and brief of the main results. From [10] the normal-angle interaction between \vec{E} transmitted and \vec{E} incident is,

$$\left| \frac{\vec{E}_T}{\vec{E}_0} \right| = \frac{2\eta_t}{\eta_t - \eta_0}, \text{ with, } \eta = \sqrt{\frac{\mu}{\epsilon}}, \quad \text{Eq. (13)}$$

where E_T and E_0 are transmitted (refracted field) and incident, ϵ is electrical permeability, and μ magnetic permeability. Constant η_t corresponds to material of particle and η_0 to air (approximations). Thus, the Fraction of Power transmitted to the interior of the particle is,

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$$\left| \frac{\bar{E}_T}{\bar{E}_0} \right|^2 = \left| \frac{2\eta_t}{\eta_t - \eta_0} \right|^2, \quad \text{Eq. (14)}$$

It is possible approximate Eq. (6) for calculation, excluding a second interior refraction as Fig. 3 details. In this case, if modulus are taken to avoid complex exponential components of electromagnetic waves. The implementation of the P_s function results,

$$\left| \bar{E}_T \right|^2 = \left| \bar{E}_0 \right|^2 \left| \frac{2\eta_t}{\eta_t - \eta_0} \right|^2 P_s, \quad \text{Eq. (15, Algorithm 1 Casesnoves, 2018)}$$

Which is the model basic equation for power transmission that tends to zero if m of Eq. 4 is very high. The distance between the emission and reception roles an important part for the received signal not to be null. Corrections factors depend of the increase of incident field modulus to sort the P_s factor that reduces significantly the power fraction. P_s could be any Probabilistic Function of Eqs. (10-12). Subsequently, the second approximation is to consider the interior refraction and reflexion within particle. In this case we get the formula developing a series successive approximation in a induction method. The result, after some algebra, is as follows,

$$\left| \frac{\bar{E}_T}{\bar{E}_0} \right|^2 = \left| \frac{4\eta_t\eta_0}{(\eta_t + \eta_0)^2} \right|^{2m} \times \left| \prod_{i=1}^{i=m} p_i \right|^2, \quad \text{with, } \eta = \sqrt{\frac{\mu}{\epsilon}}, \quad \text{Eq. (16, Algorithm 2, Casesnoves 2018)}$$

Formulation more complicated that sets a productory depending on the Probabilistic Function. When m tends to infinite, that is a long distance between emitter and receiver, the signal power tends to zero. Corrections factors for the left side of the Eq. (16) are feasible although the Bayesian intersection of subsequent probabilities makes the productory to tend to zero fastly, [15]. All in all, these two formulas with respective approximations could be considered a first approach for the model. Just remark that the incidence has been taken as normal incidence, 90 degrees, and if the wave incidence over particles has an angle, formulas can be modified according to [10].

V. DISCUSSION AND CONCLUSIONS

The model presented constitutes a primary approximation for electromagnetic waves transmission in difficult weather conditions. It was shown as a base for next improvements since the variety of of electromagnetic waves is so large that specifications belong to further publications. The most important/applicable part is tee calculated fraction of power. The reason for that is a number of correction factors for power emission that could be implemented when weather conditions are not favourable. Humidity and rainy environment are hurdles for any type of electronic system, not only in the field of materials but also related to electromagnetic fields stability. Equations presented are formally developed in background, although important far-field conditions for electromagnetic waves are not implemented. More complicated equations, considering incidence at any arbitrary angle and setting complex numbers are feasible, [1,2,10,12,14]. Far filed approximations are very useful following [1,2,3,14]. In summary, an initial approach was initiated for further research with focus on industrial communication systems utility.

VI. ACKNOWLEDGEMENTS AND SCIENTIFIC ETHICS STANDARDS

This article is dedicated with sincere love and gratitude to my father. This study was carried out, and their contents are done according to the European Union Technology and Science Ethics. Reference, 'European Textbook on Ethics in Research'. European Commission, Directorate-General for Research. Unit L3. Governance and Ethics. European

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Research Area. Science and Society. EUR 24452 EN. The research was conducted by the authors, the software, calculations, images, mathematical propositions and statements, reference citations, and text is original for the author. The article also contains unique numerical data and special improved images together with algorithms. The introduction is the basis of the previous paper to understand mathematics and optimization of the present contribution. When something is taken from a source, it is adequately recognized. Ideas from previous publications were emphasized with an aim of clarification, [16,17].

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