# A STUDY ON MATHEMATICAL MODELS OF ELECTROMAGNETIC FIELDS

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**ABSTRACT**

Most of the electromagnetic field calculation methods for high-voltage transmission overhead lines assume that the three-phase conductors are horizontal long straight wires. Therefore, the derived electromagnetic field model will be different from that in the real environment. The geometry of the overhead line has a great influence on the electromagnetic field calculation, especially at the centre point of the cable between the two towers, where the cable sags to the lowest point in space. The study followed byEMRs like IR, MW and RF could be used for unit operations like blanching, drying and microbial load reduction of food products to retain high product quality. However, is impossible to achieve this without putting forward new approaches to the current converter study. Since the output signal of the current converter mainly depends on the position of the conductive conductor in the magnetic circuit window and on the structural parameters of the magnetic circuit.Finally, the presents electronic components that can process these signals. Some are passive, others are active.The technical and economic requirements for electrical devices are increasing, mainly aiming at ease of operation, increased efficiency and measurement accuracy, as well as cost reduction. These requirements can be met by conducting a comprehensive study of the components of each designed device and their characteristics.

**Keywords:** electromagnetic field, magnetic circuit, electronic components, real environment, electrical devices.

## INTRODUCTION

Electromagnetic fields were studied physically during the study of light in the seventeenth century. The phenomenon of electromagnetic radiation is a form of linear energy transfer. The electromagnetic wave is one of the representations of the phenomenon. Photons are another representation. In addition, the wave theory of light was mainly developed. Then Augustin Fresnel developed the notions of interference and wavelength. In 1860, the great theoretical advance was the synthesis of the laws of electromagnetism by James Clerk Maxwell. His equations predicted the existence of electromagnetic waves, and their speed, allowing the hypothesis that light is an electromagnetic wave. Maxwell's equations constitute the basic postulates of electromagnetism, with the expression of the Lorentz electromagnetic force. These formulas show that in stationary conditions, the electric and magnetic fields are independent of each other.A bearingless motor is a new type of magnetic levitation motor that integrates rotary drive and rotor levitation functions. It not only overcomes the shortcomings of AC motors with magnetic bearings, such as low power density, high power consumption of the control system, and high cost, but also has the advantages of a high critical rotational speed and ease of microminiaturization. Therefore, it has broad application prospects in the fields of advanced manufacturing, flywheel energy storage, aerospace engineering, etc. Currently, bearingless motors generally adopt a dual-winding structure; that is, the torque winding and levitation winding are simultaneously embedded in the stator to achieve radial levitation and rotational

drive control of the bearingless rotor, respectively. However, the existence of independent levitation windings reduces the slot occupancy rate of torque winding, thereby reducing the motor power density.

## LITERATURE REVIEW

**Tuka Biaba Samuel Garcia (2024)**The study of Electromagnetic Compatibility is essential to ensure the harmonious operation of electronic equipment in a shared environment. The basic principles of Electromagnetic Compatibility focus on the ability of devices to withstand electromagnetic disturbances and not produce disturbances that could affect other systems. Imperceptible in most work situations, electromagnetic fields can, beyond certain thresholds, have effects on human health. The objective of the present article is focused on the modeling analysis of the influence of geometric parameters of industrial static converters radiated electromagnetic fields using Maxwell's equations. To do this we used the analytical formalism for calculating the electromagnetic field emitted by a filiform conductor, to model the electromagnetic radiation of this device in the spatio-temporal domain.

**Anthony Bassesuka Sandoka Nzao (2022)**The actions and health effects of electromagnetic fields in the radio frequency (RF) domains, referred to as radio frequencies and HV transmission networks have been studied for several decades. Following the appearance of questions and debates within the population, the actions and potential effects of radiofrequency and HV transport networks on health, in connection with the development of new wireless technologies, are generating a certain revival of interest. Thus, the increasing exposure to electromagnetic fields and the concerns of the public have led health organizations to undertake large-scale research programs to respond to the concerns expressed. The objective of our research is focused on the analysis, sources, and study of the biological consequences of electromagnetic pollution.

**Hans-Jürgen Apell (2021)**Electromagnetic fields (EMFs) can interact with biological tissues exerting positive as well as negative effects on cell viability, but the underlying sensing and signaling mechanisms are largely unknown. So far in excitable cells EMF exposure was postulated to cause Ca2+ influx through voltage-dependent Ca channels (VDCC) leading to cell activation and an antioxidant response. Upon further activation oxidative stress causing DNA damage or cell death may follow. Here we report collected evidence from literature that voltage dependent anion channels (VDAC) located not only in the outer microsomal membrane but also in the cytoplasmic membrane convert to Ca2+ conducting channels of varying capacities upon subtle changes of the applied EMF even in non-excitable cells like erythrocytes. Thus, VDAC can be targeted by external EMF in both types of membranes to release Ca2+ into the cytosol. The role of frequency, pulse modulation or polarization remains to be investigated in suitable cellular models.

**Patrick Joly (2017)**In this work, we investigate mathematical models for electromagnetic wave propagation in dispersive isotropic media. We emphasize the link between physical requirements and mathematical properties of the models. A particular attention is devoted to the notions of non-dis-sipativity and passivity. We consider successively the cases of so-called local media and then of general passive media. The models are studied through energy techniques, spectral theory and dispersion analysis of plane waves. For making the article self-contained, we provide in appendix some useful mathematical background.

**Fang Yang (2017)**Aiming at the problem that the mathematical expressions in unstructured text fields of documents are hard to be extracted automatically, rapidly and effectively, a method based on Hidden Markov Model (HMM) is proposed. Firstly, this method trained the HMM model through employing the symbol combination features of mathematical expressions. Then, some preprocessing works such as removing labels and filtering words were carried out. The experimental results show that the proposed method can effectively extract the mathematical expressions from the text fields of documents, and also has the relatively high accuracy rate and recall rate.

**Electronic Components for Processing the ElectromagneticSignal**

An electromagnetic field appears as soon as electric charges are in motion. For example, any conductive wire in the presence of current generates a magnetic field. This paragraph is concerned with electrical components transforming current into another form of energy, such as heat or light; as well as electronic components controlling the movement of electrons to perform operations. A magnetic field can be detected via an antenna. It is transformed into electric current thanks to transformers such as coils. The electric current is processed via electrical and electronic components. Some are passive, others are active. Among the passive components, there are resistors, capacitors and coil. These components are passive because, they do not generate modifications in the electrical characteristics (current, voltage). In other words, they can only store or supply energy but cannot generate it. For example, they oppose the passage of current by presenting an inductive reaction. Some components, such as the resistor, dissipate the current in heat.

**Application: Brain Wave Treatment**

The brain waves are detected by detectors called electrodes for the EEG and SQUID for the MEG. They are always processed via electronic components and computer software to result in plots. But can they be treated differently? Brain wave treatment can mean a change in voltage or current or both. In the previous paragraph, we have described electronic components for processing electromagnetic signals. Some are passive, others are active. A treatment of electric waves detected by an EEG or of magnetic waves detected by a MEG may consist in the amplification of the waves via components such as transistors or the modulation of the frequencies via electronic components such as the zener diode.

**Comparative Analysis with Six-Phase CSW-6/2-BPMSM**

To verify the performance advantages of the six-phase DSW-12/2-BPMSM in terms of the amplitude and fluctuation of electromagnetic torque and radial magnetic levitation force waveforms, as well as the electromagnetic coupling rate between them, a detailed comparison was conducted with a six-phase centralized-winding BPMSM with 6 slots and 2 poles (six-phase CSW-6/2-BPMSM), which is frequently used in the field of low power. Since the slot number of the six-phase CSW-6/2-BPMSM is half of that of the six-phase DSW-12/2-BPMSM, the number of turns for each tooth coil in the CSW-6/2-BPMSM was set to twice that of the six-phase DSW-12/2-BPMSM. The selected slot type is a flat-bottomed groove with a larger area, and the other parameters are the same as those of the six-phase DSW-12/2-BPMSM.

**Electromagnetic fields inside a Mode-Stirred Chamber**

In the second part of this thesis we will investigate the electromagnetic fields inside a Mode-Stirred Chamber (MSC). One of the first papers in which the concept of a MSC was investigated is an Italian article written called" Valutazione ed impiegonormativodella camera reverberantedell'Istituo Universitario

Navale". After 25 years of almost continuous research, the same first author published a new article in which the early work is reviewed and some unsolved questions in the research of electromagnetic behavior of a MSC are discussed. Traditionally, EMC tests have been performed inside anechoic chambers. These chambers are designed such that they simulate a free-space environment, i.e. an environment in which only a direct contribution of the electromagnetic field of the source is present without reflected electromagnetic waves. Anechoic-chamber measurements are used for e.g. EMC testing and for measuring radiation patterns, radar cross sections, or the maximum radiated field strength of a device under test at a certain position. For many EMC tests, MSCs are superior to anechoic chambers due to the ability of generating a stochastic environment.

**RESEARCH METHODOLOGY**

The MW based microbial load reduction was carried out in a domestic MW oven (BPL, Mumbai, India) at two different power levels (663 and 800 W) and intensity of 40 W/g for up to 12.5 min. For all the experiments, the position of the Petri dish was maintained same on the turntable to minimize variation and the MW treated samples were transferred immediately to moisture free sterile collection bin.The uniform heating of black pepper was ensured by providing IR heating from both sides. The black pepper was transferred to a moisture free sterile collection bin, allowed to cool for 6-7 min to room temperature and packed immediately in presterilized polyethylene pouches. The RF based microbial load reduction was carried out in a pilot scale RF heater that consisted of two parallel plate electrodes. A small opening was provided at a top corner of the pouch (partially sealed) to facilitate the escape of water vapor from black pepper. Completely and partially sealed thermo-tolerant pouches containing black pepper was exposed to RF for 5-45 min.Black pepper was ground in a domestic mixer to fine powder with the intermittent ON and OFF sequence to prevent heating of material. The mixer jar was also wrapped outside with cloth dipped in cold water to prevent heat buildup.

**RESULTS AND DISCUSSIONS**

The TMAB, TYM, TC, Salmonella, Shigella and E. coli were reduced to 0.6±0.05, 0.42±0.03, 0.19±0.03 and 0.21±0.04 log cycles, respectively, when black pepper containing 11±0.4% (wb) moisture content was processed at a power level of 800 W and intensity of 40 W/g for 1 min. At increased treatment time (7 min), TC, Salmonella, Shigella and E. coli were reduced to an undetectable level (< 1 CFU/g) but TYM and TMAB were not reduced to the permissible level (Table 1).

**Table 1: Microbial load reduction in black pepper (11±0.4% moisture content in wet basis) during microwave treatment at 40 W/g and different power levels**

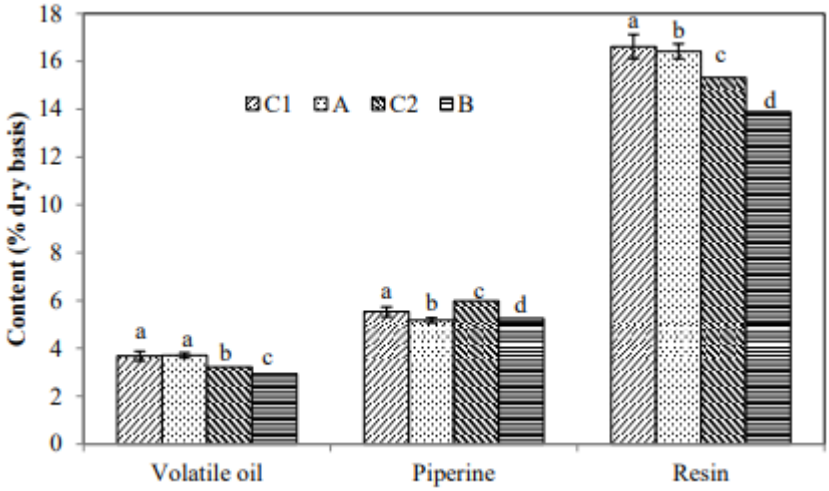
| MW power | Processing time (min) | Logreduction TMAB | TYM | TC | *Salmonella*, *Shigella*and *E. coli* |
|---|---|---|---|---|---|
| 800 W | 1.0 | 0.6±0.05[a] | 0.42±0.03[a] | 0.19±0.03[a] | 0.21±0.04[a] |
| | 3.0 | 1.97±0.11[b] | 1.29±0.13[b] | 0.57±0.05[b] | 0.63±0.07[b] |
| | 5.0 | 2.26±0.23[c] | 3.0±0.18[c] | Complete(6) | Complete(6) |
| | 7.0 | 3.35±0.14[d] | 3.65±0.12[d] | Complete(6) | Complete(6) |
| 663 W | 2.5 | 0.77±0.06[a] | 0.73±0.04[a] | 1.54±0.14[a] | 1.73±0.16[a] |
| | 5.0 | 1.53±0.13[b] | 1.42±0.18[b] | 2.98±0.19[b] | 3.48±0.21[b] |
| | 7.5 | 2.25±0.14[c] | 2.15±0.09[c] | 4.48±0.12[c] | 5.23±0.13[c] |
| | 10.0 | 3.02±0.23[d] | 2.87±0.19[d] | Complete(6) | Complete(6) |
| | 12.5 | 4.11±0.19[e] | 4.02±0.14[e] | Complete(6) | Complete(6) |

The efficiency of MW heating depends on the dielectric properties of the material and with an increase in dielectric properties, the heating efficiency also increases. The dielectric properties of food material will be higher when the moisture content is more (Nelson, 1978). In order to improve the MW heating and also to compensate the moisture loss during MW treatment, initial moisture content of black pepper was increased to 26±0.3% (wb). The increase in moisture content resulted in a higher reduction of microbial load compared to black pepper treated without the external addition of moisture (Table 2).

**Table2: Microwave based microbial load reduction in black pepper (26±0.3% moisture content in wet basis) at 663 W and 40 W/g**

| Processing time (min) | Logreduction TMAB | TYM | TC | *Salmonella*,*Shigella and E. coli* |
|---|---|---|---|---|
| 2.5 | 1.22±0.1[a] | 1.13±0.12[a] | 3.13±0.11 | 3.24±0.13 |
| 5.0 | 2.42±0.14[b] | 2.26±0.11[b] | Complete(6) | Complete(6) |
| 7.5 | 2.88±0.12[c] | 2.57±0.14[c] | Complete(6) | Complete(6) |
| 10.0 | 3.38±0.22[d] | 3.02±0.21[d] | Complete(6) | Complete(6) |
| 12.5 | 4.31±0.17[e] | 4.17±0.23[e] | Complete(6) | Complete(6) |

The volatile oil content in control black pepper samples namely C1 and C2 was found to be 3.68±0.2% and 3.22±0.1% dry basis (db), respectively. After treating black pepper with 11±0.4% moisture content (wb) at 663 W and 40 W/g for 12.5 min, no loss in volatile oil was observed (3.71±0.11% in db).




**Graph 1: Effect of microwave treatment on quality parameters of black pepper (C1- Control with 11±0.4% moisture content (wb); A-Microwave treatment for 12.5 min with initial moisture of 11±0.4% (wb); C2-Control with 26±0.3% moisture content (wb); B-Microwave treatment for 12.5 min with initial moisture of 26±0.3% (wb)). Samples having different letters (a-d) are significantly different ($p < 0.05$).**

The content was found to be marginally higher than control (C1) that can be attributed to the increased extractability from the thermally treated material (Graph 1).But the volatile oil content in black pepper (26±0.3% moisture content in wb) treated at 663 W and 40 W/g for 12.5 min was 2.94±0.08% db (Graph 1). The reason for the loss of volatile oil (8.7±0.2%) in black pepper with high moisture content is may be because of the increased product temperature that in turn reflected in the higher microbial load reduction (~0.3 log cycle).

## CONCLUSIONS

The IR based processing of black pepper at 180°C for 10 min was effective in reducing the microbial load to permissible level without affecting product quality (volatile oil, piperine, resin and sensorial attributes) compared to conventional steam treatment. The improvement in MW and RF heating was observed in black pepper with increased moisture content. The moisture loss observed during IR, MW and RF treatment was also compensated by increasing the initial moisture content of black pepper. Radiofrequency wave was effective for in-pack microbial load reduction of black pepper without significantly affecting the product quality in terms of volatile oil, piperine, resin and colour. The energy requirement with IR (960 kJ/kg of material treated) was ~50% lesser than that required in steam treatment (1905.41 kJ/kg of material treated) of black pepper. The study showed that IR, MW and RF could be effectively used for unit opertions like blanching, drying and sterilization of food products. However, selection of raw material, pre-treatment and processing conditions significantly affect process efficiency and these parameters are to be carfully considered while adopting these techniques for food processing.The recent developments in the area of electromagnetic radiation (EMR) assisted enzyme inactivation, drying and sterilization of food products showed that it is a promising and efficient technique to attain products with superior quality.

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