Piezoelectricity induced electromagnetic radiation: Probable phenomenon for wireless sensing

A THESIS

Submitted by

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I would like to dedicate this to my parents (Sivarathri Siva Nageswara Rao and Bharathi) and brother (Uma Sankar) who have always supported and encouraged me for further studies in spite of many difficulties. I would also like to dedicate this to all my teachers and friends.

Declaration by the Research Scholar

This is to certify that the Thesis entitled **"PIEZOELECTRICITY INDUCED ELECTROMAGNETIC RADIATION: PROBABLE PHENOMENON FOR WIRELESS SENSING"**, submitted by me to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by me under supervision of **Dr. Vishal Singh Chauhan and Dr. Rajeev Kumar**. The content of this Thesis, in full or in parts, have not been submitted to any other institute or University for the award of any Degree or diploma.

Place:

Date: Signature:

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Declaration by the Research Advisor

This is to certify that the Thesis entitled **"PIEZOELECTRICITY INDUCED ELECTROMAGNETIC RADIATION: PROBABLE PHENOMENON FOR WIRELESS SENSING"**, submitted by **SIVARATHRI ASHOK KUMAR** to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by him under our supervision. The content of this Thesis, in full or in parts, have not been submitted to any other institute or University for the award of any Degree or diploma.

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Name of the Guide: Dr. Vishal Singh Chauhan

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Signature:

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Date:

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Abstract

Electromagnetic radiation is a physical phenomenon sourced by accelerating charges or time varying charge distribution which connects distinct points in the universe without a physical medium. It is propagation of electric and magnetic fields at speed of light normal to each other to the direction of propagation. Deformation of materials can result in acceleration of charges with in the material and emit EMR connecting mechanics of materials with electromagnetism. One such phenomenon is fracture induced EMR which is well-known and exhibited by wide range of materials. Metals can exhibit this phenomenon during plastic deformation as well.

Piezoelectric materials polarize and develop surface electrical charges when subjected to mechanical stress due to direct piezoelectric effect. A time-dependent mechanical load can setup time-dependent mechanical stress which causes development of time varying surface charges and leads to EMR emission which may be referred as piezoelectricity induced EMR (PiEMR). This phenomenon occurs under elastic deformation of piezoelectric material. In the present work, experimental detection of near-field EMR from a lead based piezoelectric material which is subjected to dynamic mechanical fields is carried out. Near-field EMR is detected under impact, periodic and structural loads from the cylindrical shape piezoelectric material and behaviour of EMR has been analysed. Under structural load category, piezoelectric material is placed in simple structures such as cantilever beams and EMR is detected from it as the structure is loaded. Frequency of the detected EMR signals is found to be matching with frequency of mechanical loading and strength of EMR is observed to increase with the applied load.

A mathematical analysis is carried out for the far-field and near-field EMR from the piezoelectric material subjected to dynamic mechanical loads by combining theories of piezoelectricity and electromagnetism. For analysing far-field EMR, dipole radiation theory is applied and electromagnetic power radiated from the piezoelectric material is obtained. A preliminary mathematical expression is obtained for near-field radiation by applying appropriate electromagnetic theory and a general mathematical description of near-field EMR is presented which shows the dependence of near-field EMR voltage on piezoelectric charge coefficient and applied load. Obtained model is qualitatively in phase with the experimental observations.