Abstract

For reliable and efficient use of communication links, it is important to efficiently manage Electro-Magnetic Interference (EMI) to minimize system susceptibility to other sources or being a source of service disruption in other systems. Effects of EMI are noticed in many of the electronic equipment which may act either as the source, or as the victim, or even both. Some common noticeable examples of EMI are:

- Cellular device interference in aircraft systems
- Interferences in bluetooth, wi-fi and other wireless devices
- Natural phenomenon

Increase in electromagnetic (*em*) interferences due to the rapid growth of recent complex electronic equipment and systems have led to the need for designing microwave absorbers which can sufficiently reduce these interferences. The electrical and/or magnetic properties of layers of microwave absorbing materials as well as geometry are customized to achieve desired absorption of microwave energy at discrete or broadband frequencies.

When an electromagnetic wave passes through a lossy medium, its amplitude decreases exponentially. This decay or absorption loss occurs because of currents induced in the medium producing ohmic losses and heating of the material.

The requirements for good microwave absorbing materials (MAMs) are:

- Minimization of reflectivity at the air-absorber interface
- Maximizing dissipation of radio frequency (rf) energy in the absorber

The modelling of electromagnetic wave propagation in bulk slabs can be done using the basic transmission line equations. Transmission line modelling (TL model) is a model based on temporal and spatial sampling of electromagnetic fields.

Objectives

The objectives for the work are as follows:

I. To design, fabricate and study single layer magneto-dielectric absorbers in X-band

II. To improve performance of single layer absorbers

III. To enhance the absorption bandwidth by multilayering

Based on the objectives, the title of the thesis is formulated as “Design, development & study of thin and lightweight nano-sized strontium ferrite-LLDPE magneto-dielectric composite as microwave absorber covering X- band”.

For achieving the objectives of the research work, literature survey is carried out first to obtain a contemporary overview of microwave absorbers and approaches of earlier works have been studied.

Linear Low Density Polyethylene (LLDPE) is chosen as the matrix material. LLDPE has linear chain and short side chain branching which disrupts the uniformity of the polymer thus preventing crystalline formation & permitting higher addition of filler %. It has good resistance to chemicals. Nano-sized strontium hexagonal ferrites are chosen as the filler material because of their high saturation magnetization, large anisotropy field, chemical stability and high loss.

Micro-structural analysis which includes SEM, XRD and TEM as well as physical characterization including density, water absorbance and magnetization measurements are carried out. Complex permittivity & permeability measurements in the X-band are also carried out for the absorbers developed.

Single layer microwave absorber is designed using TL model and is fabricated. This is followed by optimization of the thickness of the designed structure and microwave absorption measurements. A maximum reflection loss of -22.19 dB and -10 dB absorption bandwidth of 3.36 GHz (8.53 GHz-11.89 GHz) is observed for the composite with the wt. % of 60.

Single layer absorber using aluminium and cobalt doped strontium ferrite is modelled, fabricated and its performance experimentally investigated. A 5.96% increase in 90% absorption bandwidth is observed for cobalt doped strontium ferrite in the X-band.

Multilayered structures are designed and fabricated to cover the X-band. First, a double layered structure is designed and fabricated. An improvement in maximum reflection loss by 4.91% and enhancement of absorption bandwidth by 3.5% as compared to single layer absorber is observed.

Subsequently, sandwiched structures are designed and fabricated. The structure comprises of a dielectric layer (LLDPE/ expanded graphite) sandwiched between two magneto-dielectric layers. Wave attenuation is seen to increase as does the -10 dB absorption bandwidth, covering almost the entire X- band which can be attributed to matching of the permittivity values of the sandwiched layer with the two outer layers.

The work involves in development of thin, light weight absorber with a wide absorption bandwidth (absorption ≥ 90%) over the X-band. The process of development should be relatively easy and cost effective. In addition, the absorber performance should remain sufficiently consistent with variation of humidity.

Thesis outline

Mitigation of the electromagnetic radiations is essential for reliable communication of information. The challenges lie in achieving sufficiently good absorption over a broad range of frequencies. Considering the applications in airborne and handheld devices where light weight and thin absorbers are desired, in this dissertation, thin polymer- based microwave shields are developed to effectively suppress leakages covering almost the whole X-band i.e. 8.2-12.4 GHz.

The dissertation has been organized into five chapters.

In *chapter I*, microwave absorbers are introduced and desired requirements are detailed through a literature survey.

Chapter II focuses on development and study of single layer magneto-dielectric absorber using Strontium ferrite ($SrFe_{12}O_{19}$) nano-particles as fillers and fabrication of nanocomposites with LLDPE.

Doping of strontium ferrite using aluminium and cobalt is carried out and studied with LLDPE as composites. Absorption performance of $SrAl_xFe_{12-x}O_{19}$-LLDPE (x ranging from 1.0-3.0) and $SrCo_xFe_{12-x}O_{19}$-LLDPE (x ranging from 0.2-1.2) is studied in X-band. Enhancement of absorption bandwidth is observed in cobalt doped nano-sized strontium ferrite. This is included in *Chapter III.*

Chapter IV describes the further enhancement of absorption bandwidth by deploying multilayering technique. Two structures have been included in this chapter:

(i) A double layer structure using $SrFe_{12}O_{19}$-LLDPE and $SrCo_xFe_{12-x}O_{19}$-LLDPE composites as the two layers. Thicknesses of all the layers are optimized to achieve a broad absorption bandwidth.

(ii) A three layer structure, where LLDPE or expanded graphite (EG)-LLDPE composite is sandwiched between the two ferrite layers is studied as absorber in X-band. Again, the thickness of each layer is optimized to improve performance.

Concluding discussions on the objectives achieved and proposed future work are included in *Chapter V*.