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Molecular Magnets – Addressing Defence Signature Needs in 2010

by

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Abstract

Canadian ships must be protected from weapons that can damage or destroy the vessel. Ships are identified and targeted according to their signatures. One of these signatures, the radar cross section, may be reduced through the use of radar absorbing materials.

Ideal radar absorbing materials have equal permittivity and permeability. Unfortunately, although there are materials available having permittivity few materials having permeability are available. But two novel material types could be investigated for EM signature control. The first type, molecular magnets, is polymer-like materials being developed currently for their data storage capabilities. The second type is materials having negative permeability and/or negative permittivity. These materials are left-handed and have unique properties. An investigation of these materials will be undertaken in the search for EM signature control materials. Of further consideration are the potential advantages these novel radar absorbing materials might have over current technology.

MOLECULAR MAGNETS - ADDRESSING DEFENCE SIGNATURE NEEDS IN 2010

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OUTLINE

- Purpose
- Defence Relevance
- Initial Material Goals
- Types of Molecular Magnet Systems
- Description of Collaborative Effort
- Theoretical Results
- Conclusions
- Future Work

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PURPOSE

- To fabricate a stable polymer-like organic magnet with a T_c higher than room temperature.
- Direct research and development toward energy absorption (imaginary μ) in the gigahertz region.

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DEFENCE RELEVANCE

- Useful radar absorbing materials would have adjustable permittivity and adjustable permeability.
- Current materials having significant permeability tend to have high permittivity as well.
- Need improved performance in terms of frequency range and attenuation.

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LONG-TERM DEFENCE GOALS

- To develop an environmentally stable magnetic material with high permeability but low permittivity for EM signature control
- Will be developed through a collaboration amongst molecular magnetism experts for defence purposes

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DESCRIPTION OF COLLABORATIVE EFFORT

- We are requesting funding from the Office of Naval Research (ONR) for this collaborative effort.
- This funding would be in addition to a currently funded TIF – a more generalized effort to develop materials for EM signature control through DL(P).
- Approximately 25 molecular magnetism experts will work together to develop a room temperature stable molecular magnet to be used for EM signature control.
- This effort is a unique concept of academics collaborating because they will be sharing ideas before they are published.

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BENEFITS TO GROUP ARRANGEMENT

- Molecular magnets for signature control should be developed by the experts in molecular magnetism in conjunction with the experts in signature control.
- Research into molecular magnetism is not a technology that needs to be developed in-house.
- Able to use current research (used for mass storage) as a stepping stone for defence purposes.

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INITIAL MATERIAL GOALS

- Magnetic moments equal to or greater than that of iron oxide (Fe_3O_4 6000 gauss).
- Permittivity less than that of current magnetic materials (5 + 0j).
- Tc greater than room temperature, preferably above 340K.
- Coercivity at that temperature.
- Air stability.

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TYPES OF MOLECULAR MAGNET SYSTEMS

- Organic, organometallic, inorganic, liquid crystals and Langmuir-Blodgett films.
- Tc for purely organic systems less than 50K.
- Very few systems have Tc's greater than 150K.
- Few systems are available that are air stable at room temperature.

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PERMITTIVITY AND PERMEABILITY GOALS

- Would expect complex permeabilities of 3 and loss tangents of 1-3
- Permittivities would not be expected to have any imaginary parts but to have real values of approximately 5

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CAPABILITIES

- Hypothetically, what types of materials is it possible to develop? Can materials be fabricated that will reduce reflections by 50-60 dB?
- Are there other considerations for these materials, such as thickness, weight, and frequency range coverage?

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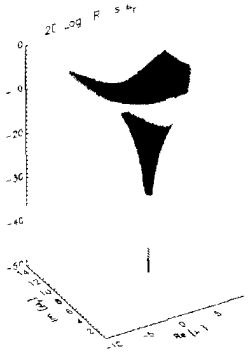
REFLECTIVITY VERSUS PERMEABILITY

$D/\lambda = 0.1$

F=10 GHz

$\varepsilon=5-j0$



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EFFECT OF NEGATIVE VALUES

- Until recently, materials with negative permeability were theorized to exist.
- But fabrication of materials having negative permittivity and negative permeability is now possible.
- The effect these materials will have on EM signature control in terms of frequency coverage and attenuation cannot be predicted.

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CONCLUSION

- If materials could be fabricated with any values of real and imaginary permeability, EM signature control performance can be improved.

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FUTURE WORK

- Continue theoretical calculations but develop permittivity and permeability equations that are frequency dependent allowing a more realistic view.
- As a consequence, be able to follow values of permittivity and permeability over 1-20 GHz.

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