# WAVEGUIDE MINIATURIZATION USING NEGATIVE PERMEABILITY METAMATERIAL (ANALYSIS AND APPLICATION)

By

**Abdelmoniem Mohamed Alaa Eldeen Abdelmoniem**

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
**MASTER OF SCIENCE**
in
**Electronics and Communications Engineering**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

Prof. Dr. **Mostafa El Said Mostafa**

………………………………..

Professor of Electromagnetic Waves
Electronics and Communications Department
Faculty of Engineering, Cairo University

Prof. Dr. **Samir F.Mahmoud**

………………………………..

Professor of Electromagnetic Waves
Electronics and Communications Department
Faculty of Engineering, Cairo University

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Approved by the
Examining Committee

________________________________
Prof. Dr. **Esmat Abd ELfatah Abd Allah** (External Examiner)
**(Professor in Electronics Research Institute)**

______________________________
Prof. Dr. **Tamer Mostafa Abu ELfadl** (Internal Examiner)

________________________________
Prof. Dr. **Mostafa El Said Mostafa** (Main Supervisor)

______________________________
Prof. Dr. **Samir Fahmy Mahmoud** (Supervisor)

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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**Engineer:** **Abd Elmoniem Mohamed Alaa Eldien Abdelmoniem Hassan**
**Date of Birth:** **10 /6 /1988**
**Nationality:** **Egyptian**
**E-mail:** **eng_abdelmoniem_alaa@yahoo.com**
**Phone. :** **0122-7032490**
**Address:** **2 St. Mohamed Khatab- Maryotaya – Haram- Giza**

**Registration Date:** **1 /3 / 2013**
**Awarding Date:** **/ /**
**Degree:** **Master of Science**
**Department:** **Electronics and Communication (Waves)**

**Examiners:** **Prof. Dr. Esmat Abd Elfatah Abd Allah** (External examiner)
**(Professor in Electronics Research Institute)**

**Prof. Dr. Tamer Mostafa Abu ELfadal** (Internal examiner)

**Supervisors:** **Prof. Dr. Mostafa Elsaid Mostafa** (Main Supervisor)
**Prof. Dr. Samir Fahmy Mahmoud** (Supervisor)

**Title of Thesis:**

Waveguide Miniaturization Using Negative Permeability Metamaterial

(Analysis and Application)

**Key Words:**

Negative transverse permeability, Metamaterials, Backward Waves, Miniaturization of Waveguide, and Propagation below cut off.

**Summary:**

This research aims to study and analyze the electromagnetic phenomena of media with negative transverse permeability and how this leads into some physical phenomena such as the appearance of backward waves and the propagation below cutoff. This study and analysis is through the use of metamaterials of split ring resonator. The research has evidenced that the waveguide size can be miniaturize to smaller than its half. Also, the research has proved that the analytical determination of the electric and magnetic field inside the waveguide with the presence of the slab of dielectric permittivity and negative transverse permeability, and experimental Results of each case are shown clearly. Finally, it was shown how to achieve a high magnetic dipole to increase the negative transverse permeability, so that the losses can be decreased for a wider backward wave band.

# ACKNOWLEDGEMENT

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| | |
|---|---|
| **BC-SRR** | Broadside Coupled Split Ring Resonator |
| **DPS** | Double Positive Medium |
| **DPS** | Double Negative Medium |
| **EC-SRR** | Edge-Coupled Split Ring Resonator |
| **E.M.F** | Electromotive Force |
| **ENG** | Epsilon-Negative Medium |
| **MNG** | Mu Negative Medium |
| **NMPM** | Negative Magnetic Permeability Medium |
| **PEC** | Perfect Electric Conductor |
| **PMC** | Perfect Magnetic Conductor |
| **P.U.L** | Per Unit Length |
| **TEM** | Transverse Electromagnetic Field |
| **TE** | Transverse Electric Field |
| **TM** | Transverse Magnetic Field |
| **SRRs** | Split-Ring Resonators |

# LIST OF SYMBOLS

| | |
|---|---|
| $\varepsilon$ | Electric Permittivity |
| $\mu$ | Magnetic Permeability |
| $E_y$ | Electric Field Intensity in Y Direction |
| $E_y^{ext}$ | External Electric Field Intensity in Y Direction |
| $\beta$ | Wave Propagation Constant in Z Direction |
| $k_o$ | Free Space Propagation Constant |
| $f_{co}$ | Cutoff Frequency for empty waveguide |
| $f_c$ | Cutoff Frequency for totally loaded waveguide with metamaterial |
| $f_{cp}$ | Cutoff frequency for partially loaded waveguide with metamaterial |
| $f_o$ | Resonance Frequency |
| $k$ | Propagating Constant |
| $\omega$ | Angular Frequency |
| $\mu_o$ | Permeability in Vacuum |
| $\varepsilon_{eff}$ | Effective Dielectric Constant |
| $\varepsilon_O$ | Dielectric Permittivity in Vacuum |
| $\omega_c$ | Cutoff Angular Frequency |
| $\Phi$ | Magnetic Flux |
| $B$ | Magnetic Field Density |
| $B_x^{ext}$ | External Magnetic Field Density In X Direction |
| $m_x$ | Magnetic Dipole Moment In X Direction |
| $P_y$ | Electric Dipole Momentum in Y Direction |
| $\mu_l$ | Permeability in the Longitudinal Direction |
| $\mu_{tr}$ | Permeability in the Transverse Direction |
| $S_{21}$ | Transmission Coefficient |
| $m_z$ | Magnetic Dipole in Z Direction |
| $H_x$ | Magnetic Field In X Direction |

# Abstract

This research aims to study and analyze the electromagnetic phenomena of media with negative transverse permeability and how this leads into some physical phenomena such as the appearance of backward waves and the propagation below cutoff. This study and analysis is through the use of metamaterials of split ring resonator. The research has evidenced that the waveguide size can be miniaturize to smaller than its half. Also, the research has proved that the analytical determination of the electric and magnetic field inside the waveguide with the presence of the slab of dielectric permittivity and negative transverse permeability, and experimental Results of each case are shown clearly. Finally, it was shown how to achieve a high magnetic dipole to increase the negative transverse permeability, so that the losses can be decreased for a wider backward wave band.

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Negative transverse permeability, Metamaterials, Backward Waves, Miniaturization of Waveguide, and Propagation below cut off.