Faculty of Electronic and Computer Engineering (FKEKK)

MULTI-BAND AND WIDE-BAND METAMATERIAL ABSORBER FOR RADAR CROSS SECTION REDUCTION OF AN ANTENNA

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A thesis submitted
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DEDICATION

Specially dedicated to my beloved husband, Zazale Bin Hassan and my dearest children; Muhammad Faiz, Muhammad Sallahuddin and also to my beloved special daughter Nur Quratul Ain Hanan for their love and support.

DECLARATION

I declare that this thesis entitled "Multi-band and Wide-band Metamaterial Absorber for Radar Cross Section Reduction of an Antenna" is the result of my own research except as cited in the references. The thesis has not been accepted for any PhD and is not concurrently submitted in candidature of any other PhD.

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APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality as a partial fulfillment of Doctor of Philosophy.

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ABSTRACT

Metamaterial is a periodically arranged of unit cells with adjustable electric permittivity and magnetic permeability, which is enabled the production of electromagnetic (EM) materials with properties not observed in nature. A few types of metamaterials are used for different applications; High Impedance Surface (HIS), Artificial Magnetic Conductor (AMC), Frequency Selective Surface (FSS) and Metamaterial Absorber (MA). The aim of the MA is to decrease EM wave reflect to source by minimizing the reflection and eliminating the transmission. The transmission is blocked by the ground plane while the reflection is minimized depend on the impedance matching between the surface impedance and free space impedance. The MA is applied in Radar Cross Section (RCS) reduction to be invisibly tracked by the radar. Unfortunately, the recent studies are successfully achieved RCS reduction with either maintained or decreased the gain of the antenna. Therefore, this research is focused on the designed of multi-band MA and wide-band MA with high absorption for RCS reduction at the same time to enhance the gain of the antenna. The multi-band MA is designed based on bar patch, which is printed on Taconic TLY-5 with the thickness of 1.52 mm. The bar patch is rotated anticlockwise from 0^o to 90^o in 15^o increment to understand the structure's absorption spectrum. At rotation of 45^o, the bar patch MA is slotted to develop a multi-band MA. The multi-band MA is successfully maintained high absorption at each resonances; 3.98 GHz, 4.81 GHz, and 5.80 GHz with absorption of 99.94%, 99.88%, and 99.66% respectively. Then, the wide-band MA is designed based on double arrow connected with a lump resistor, which is printed on Taconic TLY-3 with the thickness of 0.25 mm. Due to the inherent limitation during fabrication and utilization in real applications, the resistor is replaced by the thin line to connect both arrows to represent the lump element resistance. A wide-band MA is resonated from 3.87 GHz to 11.25 GHz with triple absorption peaks at 4.17 GHz, 6.09 GHz, and 10.30 GHz with absorption capability of more than 99%. Then, the Meandered Dipole Antenna (MDA) is designed at 5.80 GHz to integrate with multi-band MA or wide-band MA to study the RCS reduction and gain enhancement. Both integration are successfully achieved more than -25 dBsm of low RCS apart of enhanced more than 3 dB gain of the antenna. Therefore, the multi-band MA and wide-band MA with high absorption turns out to be suitable for a wide variety of potential applications for Low Observable Technology (LOT) in stealth communication technology.

PENYERAP METAMATERIAL PELBAGAI JALUR DAN PENYERAP METAMATERIAL JALUR LEBAR UNTUK PENGURANGAN SEKSYEN SILANG RADAR ANTENA

ABSTRAK

Metamaterial adalah sel tunggal yang disusun secara berkala dengan pembolehubah keizinan elektrik dan kebolehtelapan magnetik, di mana boleh menghasilkan bahan elektromagnetik (EM) dengan ciri-ciri yang tidak terdapat secara semula jadi. Beberapa jenis metamaterial yang digunakan untuk aplikasi yang berbeza; Permukaan Rintangan Tinggi (HIS), Konduktor Magnet Tiruan (AMC) dan Permukaan Frekuensi Terpilih (FSS) dan Penyerap Metamaterial (MA). Tujuan MA adalah untuk mengurangkan gelombang EM yang dipantul semula kearah sumber dengan minimumkan pantulan dan hapuskan penghantaran. Penghantaran dihapus oleh satah bumi manakala pantulan diminimumkan bergantung kepada padanan antara rintangan permukaan dan rintangan ruang bebas. MA telah digunakan di dalam pengurangan Keratan Rentas Radar (RCS) agar tidak dapat dikesan oleh radar. Malangnya, kajian sebelum ini hanya berjaya mengurangkan RCS tetapi gandaan antena hanya dapat dikekalkan atau menurun daripada yang asal. Oleh itu, kajian ini memberi tumpuan kepada reka bentuk MA berbilang jalur dan MA jalur lebar dengan penyerapan yang tinggi untuk pengurangan RCS dan pada masa yang sama dapat meningkatkan gandaan antena. MA berbilang jalur direka berdasarkan bentuk tampalan segi empat tepat dengan menggunakan Taconic TLY-5 pada ketebalan 1.52 mm. Tampalan segi empat tepat diputarkan daripada 0^o hingga 90^o dengan kenaikan 15^o secara arah lawan jam untuk memahami spektrum penyerapan. Pada putaran 45^o, lengkungan diselitkan pada tampalan segi empat untuk mencipta MA berbilang jalur. MA berbilang jalur berjaya mengekalkan penyerapan tinggi pada setiap resonans; 3.98 GHz, 4.81 GHz, dan 5.80 GHz dengan penyerapan masing-masing sebanyak 99.94%, 99.88%, dan 99.66%. Kemudian, MA jalur lebar direka berdasarkan dua bentuk tampalan anak panah dengan perintang yang menyambungkan kedua-dua anak panah tersebut. Tampalan anak panah tersebut dicetak menggunakan Taconic TLY-3 dengan ketebalan 0.25 mm. Oleh kerana kekangan semasa proses fabrikasi dan penggunaan dalam aplikasi sebenar, perintang digantikan dengan garis nipis bagi mewakili unsur rintangan. MA jalur lebar yang terhasil bermula daripada 3.87 GHz hingga 11.25 GHz dengan mencapai tiga resonans penyerapan iaitu pada 4.17 GHz, 6.09 GHz dan 10.30 GHz dengan penyerapan yang menghampiri 99%. Kemudian, Antena Dwikutub Berliku (MDA) direka pada 5.80 GHz untuk diintegrasikan bersama MA berbilang jalur atau MA jalur lebar untuk mengkaji pengurangan RCS dan penambahan gandaan. Kedua-dua integrasi telah berjaya mencapai lebih daripada -25 dBsm nilai pengurangan RCS dan peningkatan gandaan antena melebihi daripada 3 dB. Oleh itu, MA berbilang jalur dan MA jalur lebar dengan penyerapan yang tinggi ternyata sesuai untuk pelbagai aplikasi Teknologi Kebolehperhatian Rendah (LOT) di dalam teknologi tersembunyi.

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LIST OF SYMBOLS

E	- Electric field
H	- Magnetic field
L	- Inductance
C	- Capacitance
R	- Resistance
n	- Refractive index
c	- Velocity of light in vacuum
λ	- Wavelength
ω	- Angular frequency
ε	- Permittivity
μ	- Permeability
η	- Impedance
h	- Thickness of the substrate
W	- Width of the patch
g	- Gap between adjacent patches
BW	- Bandwidth
f_U	- Upper frequency
f_l	- Lower frequency
f_r	- Response frequency
λ_o	- Free space wavelength

λ_g - Guided wavelength

Z_o - Characteristic impedance

Z_s - Surface impedance

Z_{TE} - TE slab impedance

Z_{TM} - TM slab impedance

B - Propagation constant

k_t - Transverse wave number

Γ - Reflection coefficient

δ - Tangent loss

P_R - Power receive

P_T - Power transmit

G_T - Gain transmit

G_R - Gain receive

P_{Loss} - Path loss

P_{LC1} - Power loss cable 1

P_{LC2} - Power loss cable 2

f - Resonant frequency

d - Distance between transmitting and receiving antenna

σ - Radar cross section

σsm - Structural mode radar cross section

σam - Antenna mode radar cross section

E_r - Reflected fields

E_i - Incident fields

A - Absorption

R_d - Detecting distance

LIST OF ABBREVIATION

LOW	- Low Observability Technology
EM	- Electromagnetic
TEM	-Transverse electromagnetic
TE	- Transverse electric
TM	- Transverse magnetic
RHM	- Right-handed materials
DPS	- Double positive
ENG	- Epsilon negative
DNG	- Double negative
MNG	- Mu negative
PEC	- Perfect Electromagnetic Conductor
AMC	- Artificial Magnetic Conductor
EBG	- Electromagnetic Band Gap
FSS	- Frequency Selective Surface
UWB	- Ultra Wide Band

TEM - Transverse Electromagnetic

CST - Circuit Simulation Technology

FBR - Front Back Ratio

RCS - Radar cross section

HIS - High Impedance Surface

JC - Jerusalem Cross

PMC - Perfect Magnetic Conductor

MA - Metamaterial Absorber

CA - Circuit analog

2D - 2 Dimensional

FR-4 - Flame resistance 4

SI - Split-I

SJC - Split jerusalem cross

RAM - Radar absorbing material

RF - Radio frequency

EMI - Electromagnetic interference

PET - Polyethelene terephtalate

ISM - Industrial, Science and Medical

LIST OF APPENDIXES