DESIGN AND PERFORMANCE ANALYSIS OF FLEXIBLE MICROSTRIP PATCH ANTENNA WITH RUBBER SUBSTRATE AT 2.45 GHZ

BY

AHMAD ALHADI BIN RUSLAN

A thesis submitted in fulfillment of the requirement for the degree of Master of Science (Communication Engineering)

Kulliyyah Engineering
International Islamic University Malaysia

DECEMBER 2021

ABSTRACT

In this work, a flexible antenna using rubber substrate is proposed to operate at 2.45 GHz within the ISM band for Medical and Wi-Fi/WLAN application. Several rubber materials with different carbon filler composition have been selected as the substrate in designing the antenna which include (1) natural rubber, (2) rubber with 20% carbon filler, (3) rubber with 25% carbon filler and (4) rubber with 50% carbon filler. The performances of these antennas are simulated and analyzed based on the return loss, bandwidth and gain. In addition to that, the performance of the antenna is not just simulated on a flat condition. A bending condition with different bending radius and direction are simulated as well. Based on the simulation results of the initial design, antenna with 25% carbon filler exhibit the best overall performance. The conclusive factor is the fact that the antenna exhibits a wide bandwidth (81 MHz) with acceptable gain (1.91 dB) compared to the other antennas. The return loss for this antenna is -35 dB which is considered good. Despite the good results obtained on a flat condition, the performance of the antenna at 2.45 GHz degraded when the antenna is bended which leads to the antenna modification by increasing the thickness of the substrate to improve the performance. With the first modified design, antenna with 25% carbon filler also exhibit the best performance overall among the others with a wide bandwidth (876.46 MHz) and considerably high gain (5.31 dB). The return loss for this antenna is -25.85 dB. On bending condition, it is observed that the return loss value at the intended frequency which is 2.45 GHz remain below -10 dB with acceptable bandwidth and gain, despite the direction and cylindrical radius of the bending. This proved that the antenna is usable at 2.45 GHz even under the bending condition. Second modification has been done by replacing the rectangular patch with circular patch to further prove that the method used by increasing the height of the substrate will also produce a wider bandwidth regardless of the design. With the second modified design, antenna with natural rubber also exhibit the best performance overall among the others with a wide bandwidth (1147.1 MHz) and high gain (7.36 dB). On bending condition, it is also observed that the return loss value at the intended remain below -10 dB with acceptable gain and bandwidth. Comparing the best modified rectangular patch antenna (rubber composited with 25% carbon filler) with the best modified circular patch antenna (natural rubber), it can be concluded that the modified circular patch antenna using natural rubber exhibits the best antenna performances. The design modification of the antenna to cope with the bending effect by increasing the height of the substrate can be considered as a success.

خلاصة البحث

في هذا البحث، تم تقديم هوائي مرن بركيزة مطاطية للاستخدام في التطبيقات الطبية وتطبيقات Wi-Fi / WLAN بسرعة 2.45 جيجا هرتز في نطاق ISM. تم اختيار ركيزة الهوائي من مجموعة متنوعة من المواد المطاطية بتركيبات مختلفة لحشو الكربون، بما في ذلك (1) مطاط طبيعي، (2) مطاط بنسبة 20٪ كربون حشو، (3) مطاط مع حشو كربون بنسبة 25٪، و (4) مطاط مع حشو كربون بنسبة 50٪. على أساس خسارة العودة وعرض النطاق والكسب، تتم محاكاة وتحليل أداء الهوائيات. علاوة على ذلك، فإن أداء الهوائي ليس مجرد نموذج في بيئة مسطحة. يتم أيضًا محاكاة حالة الانحناء، مع اختلاف نصف قطر الانحناء والاتجاه. استنادًا إلى نتائج المحاكاة الأساسية للتصميم، يتمتع الهوائي المملوء بنسبة 25٪ بالكربون بأفضل أداء إجمالي. العامل الحاسم هو حقيقة أن للهوائي عرض نطاق عريض (81 ميجاهرتز) وكسب معقول (1.91 ديسيبل) مقارنة بالهوائيات الأخرى. هذا الهوائي لديه خسارة عودة تصل إلى –35 ديسيبل، والتي تعتبر جيدة. على الرغم من النتائج الجيدة التي تم الحصول عليها على سطح مستو، ساء أداء الهوائي عند 2.45 جيجا هرتز عندما تم ثنيه، مما استلزم تعديل الهوائي عن طريق زيادة سماكة الركيزة لزيادة الأداء. مع التصميم الأول المعدل، يتمتع الهوائي المزود بحشو كربون بنسبة 25٪ أيضًا بأفضل أداء إجمالي من بين الآخرين، مع عرض نطاق عريض (876.46 ميجاهرتز) وكسب مرتفع بشكل ملحوظ (5.31 ديسيبل). تبلغ خسارة عودة هذا الهوائي –25.85 ديسيبل. على الرغم من اتجاه الانحناء ونصف قطره الأسطواني، تظل قيمة خسارة العودة عند التردد المستهدف البالغ 2.45 جيجا هرتز أقل من –10 ديسيبل مع عرض نطاق مناسب وكسب في حالة الانحناء. أظهر هذا أنه يمكن استخدام الهوائي عند 2.45 جيجا هرتز حتى عند الانحناء. كان التغيير الثاني هو استبدال الرقعة المستطيلة برقعة دائرية، مما يدل على أنه بغض النظر عن التصميم، فإن رفع ارتفاع الركيزة ينتج نطاقًا ترددیًا أوسع. مع التصميم الثاني المعدل، يُظهر الهوائي بالمطاط الطبيعي أيضًا أفضل أداء بشكل عام من بين الآخرين بنطاق ترددي عريض (1147.1 ميجاهرتز) وكسب مرتفع (7.36 ديسيبل). تظل قيمة خسارة العودة عند المطلوب أقل من – 10 ديسيبل مع كسب وعرض نطاق كافيين في ظل ظروف الانحناء. عند مقارنة أفضل هوائي رقعة مستطيل معدل (مكون من المطاط بنسبة 25٪ حشو كربون) بأفضل هوائي رقعة دائري معدل (المطاط الطبيعي)، من الواضح أن هوائي التصحيح الدائري بالمطاط الطبيعي لديه أفضل أداء للهوائي. يمكن اعتبار تعديل تصميم الهوائي للتعامل مع تأثير الانحناء عن طريق زيادة ارتفاع الركيزة ناجحًا.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Communication Engineering)

…………………………………..
Sarah Yasmin binti Mohamad
Main Supervisor

…………………………………..
Norun Farihah binti Abdul Malek
Co-Supervisor

DR. SITI HAJAR YUSOFF
Assistant Professor
Department of Electrical and Computer Engineering
Kulliyyah of Engineering
International Islamic University Malaysia

…………………………………..
Siti Hajar binti Yusoff
Co-Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Communication Engineering)

…………………………………..
Farah Nadia binti Mohd Isa
Internal Examiner

…………………………………..
Fauziahanim binti Che Seman
External Examiner

This thesis was submitted to the Department of Electrical and Computer Engineering and is acceptable as a fulfilment of the requirement for the degree of Master of Science (Communication Engineering)

…………………………………..
Md. Rafiqul Islam
Head, Department of Electrical and Computer Engineering

This thesis was submitted to the Kulliyyah Engineering and is acceptable as a fulfilment of the requirement for the degree of Master of Science (Communication Engineering)

…………………………………..
Sany Izan Ihsan
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Ahmad Alhadi Bin Ruslan

Signature …………………………………… Date …28/12/2021……..

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

DESIGN AND PERFORMANCE ANALYSIS OF FLEXIBLE MICROSTRIP PATCH ANTENNA WITH RUBBER SUBSTRATE AT 2.45 GHZ

I declare that the copyright holder of this thesis is jointly owned by the student and IIUM.

1. Any material contained in or derived from this unpublished research may only be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purposes.

3. The IIUM library will have the right to make, store in a retrieval system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Ahmad Alhadi Bin Ruslan

……………………………. ……28/12/2021…..

Signature Date

Dedication -This thesis is dedicated to my parents for laying the foundation of what I turned out to be in life.

ACKNOWLEDGEMENT

All glory is due to Allah, the Almighty, whose Grace and Mercies have been with me throughout the duration of my program. Although, it has been tasking, His Mercies and Blessings on me ease the herculean task of completing this thesis.

I am most indebted to by supervisor, Dr Sarah Yasmin Binti Mohamad, whose enduring disposition, kindness, promptitude, thoroughness and friendship have facilitated the successful completion of my work. I put on record and appreciate her detailed comments, useful suggestions and inspiring queries which have considerably improved this thesis. Her brilliant grasp of the aim and content of this work led to her insightful comments, suggestions and queries which helped me a great deal. Despite her commitments, she took time to listen and attend to me whenever requested. The moral support she extended to me is in no doubt a boost that helped in building and writing the draft of this research work. I am also grateful to my co-supervisor, Dr. Siti Hajar Binti Yusoff and Dr Norun Farihah Binti Abdul Malek, whose support and cooperation contributed to the outcome of this work.

Lastly, my gratitude goes to my beloved parents and siblings; for their prayers, understanding and endurance while away.

Once again, we glorify Allah for His endless mercy on us one of which is enabling us to successfully round off the efforts of writing this thesis. Alhamdulillah

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ISM	Industrial, Scientific and Medical
CST MWS	Computer Simulation Technology Microwave Studio
EBG	Electromagnetic Band Gap

LIST OF SYMBOLS

c	Speed of light
dB	Decibels
ΔL	Length extension
e_r	Dielectric constant
er_{eff}	Effective dielectric constant
f_o	Resonant frequency
Ghz	Gigahertz
h	Height of the substrate
L	Length of the patch
L_{eff}	Effective length
L_f	Length of the feed
L_g	Length of the ground plane
L_s	Length of the substrate
n_o	Notch gap
mm	Millimeter
S_{11}	Return loss
%	Percentage
W	Width of the patch
W_f	Width of the feed
W_g	Width of the ground plane
W_s	Width of the substrate