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

BY

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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)

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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.

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

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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