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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Information and Communication Technology

MATHEMATICAL MODEL OF ENERGY SAVING GLASS COATING SHAPE DESIGN USING BINARY HARMONY SEARCH FOR BETTER SIGNAL TRANSMISSION

Muhammad Izzuddin Bin Jasmi

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MATHEMATICAL MODEL OF ENERGY SAVING GLASS COATING SHAPE DESIGN USING BINARY HARMONY SEARCH FOR BETTER SIGNAL TRANSMISSION

MUHAMMAD IZZUDDIN BIN JASMI

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DECLARATION

I declare that this thesis entitle "Mathematical Model of Energy Saving Glass Coating Shape Design Using Binary Harmony Search for Better Signal Transmission" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Muhammad Izzuddin Bin Jasmi

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Master of Science in Information and Communication Technology.

Signature :

Name : Dr. Zuraida Abal Abas

Date :

DEDICATION

I would like to dedicate this toward to my parents, Tuan Haji Jasmi bin Shaari and Puan Hajah Hasnah binti Kamis, , beloved wife Nadiah Daud , brothers and sisters, Muhammad Naim, Nur Najihah ,Muhammad Irfan and friends who assist me on this journey of knowledge enrichment.

ABSTRACT

In recent years, buildings are designed using a special coated glass window. This glass serves as the outer shell that avoids the exposure of dangerous Ultra-violet rays; hazard light, direct sunlight and heat. Instead of being a normal window, this glass also acts to maintain the internal temperature of a building. Besides, this glass is known with the ability to save energy, which is an extensive technology of low-emissivity glasses that assist in reducing electricity usage. However, the use of this glass has impacted signal transmissions such as electromagnetic signal use in mobile communication by causing attenuation to the useful signals such as mobile phone (GSM, 3G), global positioning system (GPS), wireless network (Wi-Fi) and wireless broadband (LTE) due to the fabricated layer made of metallic-oxide on the window. Thus, engraving approach using a symmetrical shape design on the surface layer has shown improvement in reducing the attenuation problem. A well-designed algorithm is able to generate an optimized irregular shape design that can result in less attenuation on the transmission signal. Therefore, this study was conducted to propose a practical and effective irregular shape design that considers the property of coated layer and transmission signal. This approach is able to provide less attenuation problem and high efficiency of the signals through the coated glass. A model was developed to specify the requirement of coated glass on the energy saving glass. It determines the optimum irregular shape design, which is then integrated with Harmony Search (HS) optimization technique. By applying HS, an optimized shape design was generated, which met the objective of this study. HS generates a binary design representing bit ‘1’ and ‘0’. The obtained result were then simulated into a CST (Microwave) and tested on the S-parameter aspects, which are the return loss (S11) and transmission coefficient (S21). The efficiency of the irregular shape design was attained after the simulation process. Meanwhile, experimental result obtained in this study showed an irregular shape design generated by HS, hence showing an improvement in reducing the attenuation problem by 99.88% efficiency. The coated glass with optimized irregular shape design engraved on it can give a better signal transmission for mobile device, tracking system, wireless network and wireless broadband.

ABSTRAK

Kini, banyak bangunan yang direka menggunakan kaca bersalut khas sebagai tingkap. Kaca ini berfungsi sebagai kulit luar yang mengelak pendedahan sinar ultra-ungu berbahaya; cahaya bahaya, sinaran matahari dan haba. Berbeza dengan tetingkap normal, kaca ini bertindak dengan mengekalkan suhu dalaman bangunan pada keadaan yang sesuai. Selain itu, kaca ini dikenali dengan keupayaan untuk menjimatkan tenaga, yang merupakan teknologi cermin keberpancaran rendah yang membantu dalam mengurangkan penggunaan elektrik. Walau bagaimanapun, penggunaan kaca ini memberi kesan kepada penghantaran isyarat seperti penggunaan isyarat elektromagnet dalam komunikasi mudah alih dengan menyebabkan pegurangan dalam isyarat yang berguna seperti telefon bimbit (GSM, 3G), sistem kedudukan global (GPS), rangkaian tanpa wayar (Wi-Fi) dan jalur lebar tanpa wayar (LTE) kerana lapisan yang diperbuat daripada logam-oksida pada tingkap.Oleh itu, pendekatan dengan menggunakan reka bentuk simetri yang diukir dia atas lapisan tetingkap menunjukkan peningkatan dalam mengurangkan masalah pengecilan. Algoritma yang direka dengan baik mampu menjana reka bentuk tidak teratur yang optimum yang mampu mengurangkan pengecilan pada isyarat penghantaran. Oleh itu, kajian ini dijalankan untuk mencadangkan reka bentuk tidak teratur yang praktikal dan berkesan yang mengambil kira lapisan bersalut dan isyarat penghantaran. Pendekatan ini dilihat mampu mengurangkan masalah pengecilan dan meningkatkan kecekapan isyarat yang melalui kaca bersalut. Satu model dibangunkan bagi menentukan keperluan kaca bersalut pada kaca penjimat tenaga. Ia menentukan reka bentuk bentuk tidak teratur yang optimum yang kemudiannya disepadukan dengan teknik optimisasi Harmony Search (HS). Dengan menggunakan HS, reka bentuk bentuk optimum dijana dan memenuhi objektif kajian ini. HS menjana reka bentuk mewakili binari bit '1' dan '0'. Keputusan yang diperoleh kemudiannya disimulasi menjadi CST (Microwave) dan diuji pada aspek-aspek parameter S, iaitu pulangan kerugian (S11) dan pekali penghantaran (S21). Kecekapan reka bentuk bentuk tidak teratur dicapai selepas proses simulasi. Sementara itu, hasil eksperimen yang diperoleh dalam kajian ini menunjukkan reka bentuk bentuk tidak teratur yang dihasilkan oleh HS, sekali gus menunjukkan peningkatan dalam mengurangkan masalah pengecilan dengan 99.88% kecekapan. Kaca bersalut optimum beserta reka bentuk bentuk tidak teratur yang terukir di atasnya mampu memberikan penghantaran yang lebih baik untuk isyarat dalam komunikasi mudah alih seperti telefon mudah alih, sistem pengesanan, rangkaian tanpa wayar dan jalur lebar tanpa wayar.

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LIST OF ABBREVIATIONS

AC – Ant Colony

BW – Bandwidth

FSS – Frequency Selective Surface

GA- Genetic Algorithm

HM – Harmony Memory

HMCR – Harmony Memory Consideration Rate

HMS – Harmony Memory Size

HS – Harmony Search

HSA – Harmony Search Algorithm

PAR – Pitch Adjustment Rate

PSO – Particle Swarm Optimization

TS – Tabu Search

LIST OF PUBLICATIONS

1. M. I. Jasmi, Z. A. Abas, A. F. N. A. Rahman, & A. S. Shibghatullah, (2016). "Optimized Coating Design of Energy Saving Glass Using Binary Harmony Search for Better Transmission Signal". International Journal of Computer Science and Information Security (IJCSIS).

CHAPTER 1

INTRODUCTION

This study aimed to propose a new complex design for energy saving glass coating. It is driven by the increased use of energy saving glass to meet the demands of green-technology. This study is motivated to improve transmission signal and reduce the loss of signal by developing a new complex design of coating structure.

In this chapter, the background of the study is explained where there is a worldwide increase in demand of energy saving glass that can reduce the usage of electricity. The only issue lies in the efficiency of the glass in terms of transmitting and receiving radio frequency. Since energy saving glass is a combination of glass and coating layer, it may affect some radio frequency. The coating layer comprises compounds including metals that will attenuate and reflect useful signals. Nowadays, communication signals together with their applications are of high demand. Hence, this study is conducted to find a solution to the problems addressed and overcome the weaknesses of the current energy saving glasses.

1.1 Research Background

In today's technology, energy saving glass is a common material in manufacturing. This technology is commonly applied in automotive and infrastructure with the purpose of maintaining the temperature inside buildings and vehicle structures. It is considered as one of the green technologies that contribute to energy saving. It applies a thin metallic-oxide (silver oxide or tin oxide) on one side of the glass, which consist of different layer of metals and metallic-oxides. Pyrolytic coating (hard coating) or metal oxide (soft coating) fabricated in uniform thickness (0.3-0.4 micron) on the glass substrate is the technology developed since the late 80's. However, this technology has been only used as an energy saving material in modern buildings' window structure.

Different processes of fabrication are available in the industries; Chemical Vapour Deposition (CVD) is one of them. Due to the coating, the glasses are able to attenuate infrared frequencies while allowing the ultraviolet band of spectrum to pass through. The existence of this coating makes thermal insulation possible by maintaining a level of temperature inside the building while being transparent. This proved that at room temperature, these glasses are capable of transmitting visible white light and reflect Infrared Radiations (IR) by the materials of energy saving glass. IR insulation is considered successful when buildings using this special glass are warmer in the winter and cooler during the summer, hence proving the contribution of this glass towards energy saving (Kiani, Olsson, Karlsson, & Esselle, 2008). There are methods to overcome the attenuation problem on the energy saving glass that may still be issued; either the transmission has drastically improved or just an enhancement of signals.

Three possible solutions were identified to overcome the deficiency of the energy saving glass. The first is to selectively improve the transmission of RF/ microwave signals by etching a bandpass FSS on the coated side of energy saving glass (Kiani et al., 2010). Usually, regular-shaped etchings are engraved on the energy saving glass coating material. There are a few popular geometric shapes that are usually coated on energy saving glass such as a cross dipole, circular loop, hexagon and square loop (G. I. Kianni, 2009). This coating structure serves as a filter with two parts; coating and etching. The coat functions as a reflector of IR, while the other part allows transmissions to pass through. It is worthy to note that increasing the coat surface area will result in signal and heat reflection.

The transmission signals passing through the glass may be affected by the coating design. A previous study showed that there are three categories of coating design, which are regular, modified regular and irregular shapes. Symmetrical shapes can be referred to as the regular shape. Meanwhile square, triangle, circle, pentagon, rectangle, octagon can be grouped as regular shapes. On the other hand, modified regular shape is defined as the opposite of regular shapes or a design constructed from a regular shape. A new construct design and random shapes are referred to as the irregular shape. It is a complex design of a shape which is different from symmetrical designs.

The second possible solution is by overcoming it during the fabrication process where various types of material are used during the early stage of energy saving glass production. There are many different types of coating, but the most common is the hard coating type since it is easy to handle and more robust. Moreover, soft coating may excessively attenuate IR and can be easily broken when the fabricated glass undergoes sputtering process or CVD.

Hard coating attenuates up to 200 dB while soft coating could result in a 30 dB attenuation (Suncool^{TM}) in the RF microwave range (Ullah et al., 2011). The way to overcome the signal attenuation is by engraving a number of repeaters to enhance the signals. However, this solution will incur a high cost and high electricity usage while installing and operating the repeaters. This deficiency is a limitation to the energy saving glass applications in wireless communication. In supporting green technology by implementing energy saving glasses, all work must be conducted in a safe environment. Nonetheless, implementing the current pattern, which is the regular shape, could also overcome the weaknesses of energy saving glass. As expected from (Ullah et al.,2011), result showed an improvement in attenuation of at least 25dB to 30dB.

Considering this, it can be inferred that the attenuation signal of energy saving glass involves the use of low-E glass. A previous study demonstrated that transmission signal can be improved when at least 10% of metallic coating is removed since transmission loss is occurred due to the use of cross dipole around 25dB (G. I. Kianni et al.., 2011). The efficiency of transmission signal depends on the size of coating on the carved surface. The bigger the surface is, the more efficient it will be to transmit signal. The smartest way to deal with this problem is by introducing a modified regular shape of coating such has that proposed by Kianni (2011), which is a regular shape cross-dipole etching that can cause only 25 -30 dB transmission loss.

The last solution is by using repeaters to amplify the signal to a desired frequency. This method is easy to be implemented, but the cost and electricity consumptions are high. By using energy saving glass in supporting green technology, it should be able to enhance the structural design, coating technique and improve the efficiency of microwave transmission. Similar method of designing a pixilated modified regular shape design is by using the genetic algorithm optimisation, which works with random binary chromosome strings.

Simulation package software including Computer Simulation Technology (CST) is also helpful in designing the modified regular shapes. However, the optimisation of shapes is not guaranteed even by using CST. The connectivity of the critical points would be problematic while designing the modified regular shape. This can result in different frequency characteristics between fabricated modified regular shape FSS and designed FSS at a specified band (M. Ohira et al., 2004) due to the contact of conductors at the critical points.

Therefore, an optimised coating shape design for the energy saving glass is of crucial to improve transmission signal.

1.2 Problem Statement

Despite the advancement in technology, there is yet a weakness in the energy saving glass. Radio frequency signals such as mobile phones, Wi-Fi and personal communication signals are attenuated because of the metallic-oxide coating in the application of regular shape design. The regular shape design applied is majorly coated while a minor part of it uncoated, which is the only area for signals to pass through. Useful signals in wireless communication systems such as the global positioning system (GPS), mobile communication systems (GSM, UMTS, 3G), wireless networks (Wi-Fi) and wireless broadBand (WiMax, LTE) are also attenuated due to the metal-oxide coating on the energy saving glass (Sohail et al., 2011).

These flaws limit the energy saving glass' efficiency in wireless communication. Moreover, the functional aspect is limited when signals are attenuated through the low-E glass. Low-emissivity glass is a special coated glass with the purpose of bouncing off heat energy from the surface of energy saving glass either in buildings or vehicles. In contrast, Wireless Local Area Network (WLAN) is attenuated at operating signals of 2.45 GHz and 5.25 GHz; however, this could actually be an advantage in wireless communication. Sohail et al. (2011) proved that the attenuation of GSM, GPS, UMTS, 3G and Wi-Fi signals lead to poor communication inside a building. Thus, the transmission is very low.

Due to this constraint, possible solutions were proposed to improve the transmission of signals. The first solution is to engrave the surface of the coated glass with a regular or irregular shape design. It also can be either symmetrical or asymmetrical depending on the geometric construction. By using Frequency Selective Surface (FSS), shapes that are symmetrical can be periodically arranged as patch elements or apertures. FSS is a periodic structure that acts as a filter. Patches exhibit nearly total reflection of signals, while apertures refer to a nearly total transmission of signals (G. I. Kiani, Olsson, Karlsson, & Esselle, 2010).

Ironically, the common practice to improve the signal is by utilising a large number of repeaters to address signal attenuation, which actually consumes a considerable amount of cost and electricity. .

1.3 Research Questions

Based on Section 1.2, the research questions in this study were derived as follows:

1. How to formulate a model for optimum shape design of energy saving glass coating structure?
2. How to apply the mathematical model using optimisation technique in obtaining the optimum shape design of energy saving glass coating structure?
3. How to design and verify the result of optimum shape design coating structure on the performance of energy saving glass?

1.4 Research Objectives

This study is expected to find the best solution for a modified regular shape design to replace the regular shape design and to improve the transmission of microwave signals so that it could penetrate into buildings that utilise the technology of energy saving glass. A latest optimisation technique, which is the harmony search, was implemented to overcome the weakness of this energy saving glass technology. This is a method commonly applied in music improvisation. Hence, this study has three main objectives as stated below:

1. To formulate the mathematical model of optimum coating shape design for energy saving glass.
2. To implement mathematical model using Harmony Search for optimum shape design of energy saving glass coating.
3. To verify the obtained design and analyse the performance of coating design in terms of efficiency towards useful transmission signal.

1.5 Significance of Research

Today, the use of cellular communication is very important as it has become one of the human needs. The most common wireless networks used are the Wi-Fi, 3G, Global Positioning System (GPS) and Long-Term Evolution (LTE), which work with 4G and requires a high-speed data transmission to be accessed anytime and anywhere. Thus, this study will benefit modern building infrastructures by implementing energy saving glass that allows more useful signals to pass through without any problems. By implementing new coating shape design of energy saving glass, it would improve the efficiency of microwave transmission signals.

1.6 Organisation of the thesis

This thesis is divided into six chapters. The structure of this thesis is as follows:

Chapter 1 – This chapter represents the introduction of study as it briefly explains the background of the study followed by the problem statement, current technology, research questions, research objectives and project significances.

Chapter 2 – The second chapter contains the literature review. The energy saving glass and harmony search are explained in detail. Comparison study to show the research gap is discussed.

Chapter 3 – The third chapter is the methodology of this study. It discusses the selected method to achieve the research objectives. In addition, the type of research method, research design, proposed methodology and proposed Harmony Search technique are explained in detail.

Chapter 4 – The fourth chapter is about the mathematical modelling. The section explained on how the model is develop to meet the problem of the research.

Chapter 5 – The fifth chapter is about the implementation phase. The problem analysis, design, coding and step by step implementation of harmony search and testing procedure are explained in this section.

Chapter 6 – The sixth chapter describes the result and analysis of the new coating design newly invented by implementing Harmony Search Algorithm.

Chapter 7 – The final chapter summarises the whole thesis from chapter 1 to chapter 6. Conclusion is made from the main objective of this study. Limitations and suggestions for future studies are also discussed in this chapter.

1.7 Summary

The introduction of this study describes the concerns regarding energy saving glass, its weaknesses, the design of coating structure and the use of metal oxide on the energy saving glass since it can cause wireless communications such as mobile communication system (GSM, UMTS, 3G), Global Positioning System (GPS), wireless network (Wi-Fi) and wireless broadBand (WiMax, LTE) to be attenuated. Most common approach, which