Faculty of Electronic & Computer Engineering

A NEW TECHNIQUE TO DESIGN COATING STRUCTURE FOR ENERGY SAVING GLASS USING THE GENETIC ALGORITHM

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DECLARATION

I declare that this thesis entitled "A New Technique to Design Coating Structure for Energy Saving Glass Using the Genetic Algorithm" 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.

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APPROVAL

I hereby declare that I have read this thesis and my opinion this thesis is sufficient in term of scope and quality for the award of Master of Science in Electronic Engineering.

Signature :..

Supervisor Name :..

Date :..

DEDICATION

To my beloved husband, mother and father, mother and father-in-law, and Sofea Azzahra.

ABSTRACT

Energy saving glass is a specially coated glass with metallic-oxide coating that helps save energy by reflecting heat from the sun in the infrared region. Properties of an energy saving glass reflect the heat of infrared radiation while allowing visible white light to pass through the glass. Due to the presence of this metallic coating, some amount of useful radio frequency (RF) or microwave signals are attenuated. Magnitude for some wireless communication signals such as mobile phones (GSM, UMTS and 3G), global positioning system (GPS), wireless network (Wi-Fi), wireless broadband (WiMAX, LTE) are weaken. This limits the efficiency of the energy saving glass function in the wireless communication of microwave signals. In order to overcome this problem, currently there are three solutions; the first solution is to etch a structured design shape on the coated side of the glass, the second solution is by using different types of materials at the fabrication stage of energy saving glass process, and lastly, the common practice to address the signal attenuation is by employing numerous repeaters to improve signals. However, by changing materials during fabrication and having additional repeaters will incur extra cost through many aspects. Therefore this research focuses on the first solution that is to remove a portion of a structured design shape on the coated side of the glass. Currently, the shape is in the regular symmetrical forms such as square, triangle, circle, pentagon, rectangle, and octagon. This research proposed a modified regular shape which is based on the best selected regular shape, modified using genetic algorithm on the central processing unit (CPU). Genetic algorithm is a method which is easily transferred to the existing simulations and models. In order to evaluate the proposed approach, two different regular shapes are selected namely the Modified Single Square Loop (MSSL) and Single Square Loop (SSL). After modifying these shapes using the Genetic algorithm and Parallel Genetic algorithm, the outputs are simulated in the Computer Simulation Technology (CST) simulation software. Result shows that SSL with 10% coated part results -29.3044dB of return loss.

ABSTRAK

Kaca penjimatan tenaga adalah merupakan sejenis kaca yang disalut khas dengan lapisan logam-oksida yang membantu menjimatkan tenaga dengan memantulkan haba daripada matahari dalam lingkungan inframerah (IR). Sifat penjimatan tenaga bagi kaca ini memantulkan haba sinaran inframerah sementara cahaya putih dibolehkan melaluinya. Dengan kehadiran lapisan logam ini, beberapa jumlah frekuensi radio (RF) atau isyarat gelombang mikro menjadi lemah. Magnitud untuk beberapa isyarat komunikasi tanpa wayar seperti telefon bimbit (GSM, UMTS dan 3G), sistem kedudukan global (GPS), rangkaian tanpa wayar (Wi-Fi), jalur lebar tanpa wayar (WiMAX, LTE) juga lemah. Ini menghadkan kecekapan fungsi kaca penjimatan tenaga ini dalam komunikasi tanpa wayar bagi isyarat gelombang mikro. Bagi mengatasi masalah ini, terdapat tiga jenis penyelesaian; penyelesaian pertama adalah untuk menggores reka bentuk berstruktur di bahagian bersalut kaca, penyelesaian kedua adalah dengan menggunakan pelbagai jenis bahan-bahan pada peringkat fabrikasi penjimatan tenaga dalam proses pembuatan kaca, dan akhir sekali, praktis biasa untuk menangani masalah isyarat menjadi lemah adalah dengan menggunakan banyak pengulang untuk meningkatkan isyarat. Walau bagaimanapun, dengan menukar bahan semasa fabrikasi dan mempunyai pengulang tambahan akan melibatkan kos tambahan melalui pelbagai aspek. Oleh itu kajian ini memberi tumpuan kepada penyelesaian pertama iaitu untuk membuang sebahagian kaca dalam reka bentuk berstruktur di bahagian sebelah bersalut kaca. Pada masa ini, bentuk yg wujud hanya dalam bentuk simetri biasa seperti empat persegi, segitiga, bulatan, pentagon, segi empat tepat, dan oktagon. Kajian ini mencadangkan supaya bentuk diubahsuai berdasarkan bentuk biasa yang terbaik, ia diubah suai menggunakan algoritma genetik pada unit pemprosesan pusat (CPU). Algoritma genetik adalah satu kaedah yang mudah dipindahkan kepada simulasi dan model yang sedia ada. Dalam usaha untuk menilai pendekatan yang dicadangkan, dua bentuk biasa yang berbeza dipilih iaitu Modified Square Single Loop (MSSL) dan Single Square Loop (SSL). Selepas mengubah suai bentuk ini menggunakan algoritma genetik dan algoritma genetik selari, output disimulasikan dalam perisian simulasi Computer Simulation Technology (CST). Keputusan menunjukkan bahawa SSL dengan 10% bahagian bersalut hasil -29.3044dB kehilangan balasan.

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ACO	-	Ant Colony Optimization
ALU	-	Arithmetic Logic Unit
CPU	-	Central Processing Unit
CST	-	Computer Simulation Technology
CT	-	Coated
CUDA	-	Compute Unified Device Architecture
CVD	-	Chemical Vapour Deposition
FDM	-	Finite Difference Method
FDTD	-	Finite Difference Time Domain
FEM	-	Finite Element Method
FSS	-	Frequency Selective Surfaces
GP	-	Genetic Programming
GPGPU	-	General Purpose Graphics Processing Unit
GPS	-	Global Positioning System
GPU	-	Graphic Processing Unit
GSM	-	Global System Mobile
IR	-	Infrared
ISM	-	Industrial, Scientific And Medical Bands
MSSL	-	Modified Single Square Loop
PSO	-	Particle Swarm Optimization

RWS	-	Roulette Wheel Selection
SSL	-	Single Square Loop
TS	-	Tournament Selection
UCT	-	Uncoated
UV	-	Ultraviolet

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, energy saving glass has become very popular in modern buildings and vehicles. It was proven to be very useful to maintain the temperature level inside a building or vehicle using the energy saving glass. This technology falls under the green technology category for it helps to contribute in saving the energy in a building or vehicles. It was in the late 1980s, when energy saving glass or low emissivity glass first began to contribute to energy saving through the window of a modern building design. It works by applying a very thin metallic oxide (e.g. silver oxide or tin oxide) on one side of the glass. It consists of multiple layers of metal and metallic oxides placed on the glass through a sputtering process in a special room called the vacuum chamber. A uniform thin (0.3-0.4 micron) layer of pyrolytic coating (hard coating) or metal oxide (soft coating) is fabricated on the glass substrate.

There are different processes available to fabricate these coatings, for example, a chemical vapour deposition (CVD) method. These windows are then capable to attenuate infrared frequencies while passing the ultraviolet band of the spectrum, due to the presence of this coating. Thermal insulation is maintained at an excellent level in a room that employs energy saving window while one can still easily see through the glass window without knowing the existence of this special coating. This shows that at room temperature, the coating layer is able to transmit visible white light while infrared radiations are reflected. This is due to the property of the energy saving glass.

IR insulation is thus achieved, when the energy saving glass is proven to be very helpful in saving electricity bills when buildings that incorporate this specially coated glass are warmer in winter and cooler during summer (Kiani *et. al.,* 2008). The following section presents the background of the research with the introduction of the problem as well as solutions to overcome the problem associated.

1.2 Problem Statement

There is one common drawback associated with these glass windows, in spite of being energy efficient in saving the electricity bills. Due to the presence of the metallic oxide coating, useful RF/microwave signals such as mobile phones, Wi-Fi, security and personal communication signals are attenuated. Useful signals in the wireless communication systems such as global positioning system (GPS), mobile communication system (GSM, UMTS, 3G), wireless network (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).

This limits the efficiency of the energy saving glass function in the wireless communication of microwave signals. In addition, the functional aspect of an energy saving glass is limited when most wireless communication signals are attenuated through the use of low-E glass. Wireless Local Area Network (WLAN) signals operating at 2.45 GHz and 5.25GHz are also attenuated. However, in terms of wireless security, this contributes to the advantage in security. A study (Sohail *et al.,* 2011) proved that the attenuation of GSM, GPS, UMTS, 3G, Wi-Fi signal leads to poor communication inside the building. Thus, the transmission is very low.

In order to overcome this problem, there are three solutions proposed to selectively improve the transmission of signal. The first solution is to etch a structured design shape on the coated side of the glass. There are regular and irregular shapes. It can be symmetrical and asymmetrical depending on the geometry constructions. However, according to the current work (Kiani, Olsson, Karlsson, & Esselle, 2010) using the Frequency Selective Surfaces (FSS), shapes that are symmetrical, are periodically arranged as patch elements or apertures. FSS is a periodic structure that works as a filter. Patches exhibit nearly the total reflection of signals, while an aperture refers to nearly the total transmission of signals.

The second available method used to develop an energy saving glass is through the type of coating used during the fabrication process. There are two different coating types available, (Ullah, 2012; Ullah, Zhao, & Habibi, 2011) which are hard and soft coating layers. Each has their own goods that benefit one another. Third method, the common practice to address the signal attenuation is by employing numerous repeaters to improve signals. However, establishing and operating additional repeaters will incur extra cost and electricity usage.

1.2.1 Current Solution to Energy Saving Glass Problem

There are three types of solutions found suitable to overcome the drawbacks with energy saving glass. The first proposed solution for this problem is to selectively improve the transmission of RF / microwave signals by etching a bandpass FSS on the coated side of the energy saving glass (Kiani *et al.,* 2010). The coating on the energy saving glass is usually etched in regular shapes.

There are some popular geometry shapes usually coated on the energy saving glass, such as cross dipole, circular loop, hexagon and square loop (Kianni, 2009). This structured coating works as a filter where the coated part will reflect IR while the etched part is left where the transmissions are allowed to pass through. Hence, the bigger the size of the coating the greater the signals and heat will be reflected.

This coating design structure is believed to have some effects on the transmission of signal, passing through this energy saving glass. Based on previous study, the coating design structure can be divided into three different categories. They are regular, modified regular and irregular shapes. Regular shapes can be referred as symmetrical shapes. There are a lot of regular shape designs such as square, triangle, circle, pentagon, rectangle, octagon and many more. Modified regular shapes as the name reflects, referred to shapes that are constructed from regular shapes. Irregular shapes are represented by a construction of shapes that are totally new and being randomly shaped. They are also not symmetrical. In other word, it is a complex design of shapes.

The second solution to this drawback can be solved during the fabrication process, where different types of materials are used at an early stage of energy saving glass process. Amongst the different coating types available are hard coating types. They are more robust and easier to handle. On the other hand, soft coating type provides higher IR attenuation but is easily broken if not handled with care. This is due to the soft metal oxide coating layer that is fabricated using either the sputtering process or CVD.

According to Ullah et al. (2011), hard coating layers attenuate up to 200dB within the same frequency band while soft coating could result in a 30dB attenuation (Suncool ™) within the RF microwave range. Another common practice to overcome the signal attenuation is by setting up a number of repeater amounts to enhance the useful signals.

However, installing and operating these additional repeaters are inefficient in terms of cost and consume more electricity. Furthermore this requires huge amount of works in money and manpower. These drawbacks will limit the efficiency of an energy saving glass function in terms of wireless communication. In order to optimize energy saving glass implementation in supporting the green technology, the work has to be environment-safe compliance. The current pattern of solution in overcoming the drawback with energy saving glass is by employing the regular shape patterns.

Results showed that the improvement in attenuation is at least at 25dB to 30dB. According to this situation, it can be assumed that the attenuation of signals with energy saving glass involves the use of low-e glass. Recently, a study also attested that the transmission of signals improved when at least 10% of metallic coating was removed, and the transmission loss of cross dipole for instance results around 25dB (Kianni *et al.,* 2011). As the size of the etched part coating gets bigger, the better the efficiency of the transmission signals. The smartest way to deal with this problem is by introducing a modified regular shape of coating. Other study using the regular shapes of cross-dipole for example, showed transmission loss at 25-30dB (G. I. Kianni, 2011).

It is positive that the shape of the coating represents most of the percentage of the coated area of an energy saving glass which contributes to the attenuation of useful signals. Until today, the coating of an energy saving glass still uses regular shapes as the structure of the low-e glass coating. Based on the study above, introducing a new modified regular shape of coating with less percentage of coating area is one of the ideas that may improve the efficiency of the microwave signal transmission. Currently there are two issues in proposing a modified regular shape. First, it is difficult to implement since a modified regular shape involves small pixels and it is complicated to optimize every single pixel.