DYNAMIC TUNABILITY ENHANCEMENT OF REFLECTARRAY ANTENNA USING NON-HOMOGENEOUS DIELECTRIC MATERIALS

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Sincerely dedicated to my beloved Mother and Father

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ABSTRACT

The conventional antenna systems require the mechanical movement of beam scanning antenna to meet the demands of emerging field of communications. To overcome the flaw of the mechanical movement an electronically tunable reflectarray antenna based on non-homogeneous properties of substrate materials has been introduced. This research study provides a thorough investigation on the tunability performance of reflectarrays designed in X-band frequency range. The objective of this work is to demonstrate the functionality of an active reflectarray antenna with optimized loss performance and enhanced dynamic phase range. Different types of reflectarray resonant elements such as rectangular, dipole and ring are discussed here with different design configurations based on their ability of frequency tunability and dynamic phase range. Commercially available computer models of CST Microwave Studio and Ansoft HFSS have been used to investigate the phase agility characteristics of reflectarray resonant elements printed above various non-homogeneous materials ($0.17 \leq \Delta\varepsilon \leq 0.45$). The analytical approach has been used to develop equations for progressive phase distribution and frequency tunability of individual reflectarray element which is validated by CST simulations. The results obtained from theoretical investigations have been further validated by experimental implementations. An optimized configuration of non-homogeneous Liquid Crystal (LC) material with 0.5 mm thickness below the resonant element has been designed and tested by waveguide scattering parameter measurements. An external bias voltage of 0V to 20V has been applied across the LC substrate of individual resonant elements in order to obtain the electronic tunability. The three resonant elements namely rectangular, dipole and ring offer a measured dynamic phase range of 95°, 153° and 197° respectively at 10 GHz using the proposed design configuration. Moreover, the ring element attains a 107% higher dynamic tunability with a 56% reduction in the reflective area as compared to rectangular element.

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LIST OF PUBLICATIONS

Journals:

(i) M. Y. Ismail and M. Hashim Dahri, "Tunability Performance of Reflectarrays Based on Non-Linear Material Properties", American Journal of Engineering and Applied Sciences, 2013, Volume 6, Issue 1, Pages 25-30.

(ii) M. Hashim Dahri and M. Y. Ismail, "Performance Analysis of Reflectarray Resonant Elements based on Dielectric Anisotropic Materials", in Procedia Engineering, Volume 53, 2013, Pages 203–207.

(iii) M. Y. Ismail and M. Hashim Dahri, "Tunable Reflectarray Resonant Elements based on Non-linear Liquid Crystals", in Journal of Advanced Materials Research, Volume 746, 2013, Pages 357-362.

(iv) M. Y. Ismail, M. Inam and M. H. Dahri, "Phase Characterization of Reconfigurable Reflectarray Antennas", in International Journal on Electrical Engineering and Informatics, Volume 5, Number 4, December 2013.

(v) M. Y. Ismail and M. Hashim Dahri, "Microwave Absorption Analysis of Passive and Active Reflectarray Resonant Elements", accepted for publication in International Journal of Electrical Engineering and Informatics.

Proceedings:

(i) M. Y. Ismail and M. Hashim Dahri, "Tunable Reflectarray Resonant Elements based on Non-linear Liquid Crystals", in International Conference on Material Science and Technology (ICMST 13), Hong Kong, 2013.

(ii) M. Y. Ismail, M. Hashim Dahri and W. N. Zaihasra, "Characterization of Material Properties for Tunable Reflectarray Antenna Design", in 2012 National Conference on Physics (PERFIK 2012), published in American Institute of Physics (AIP) Conference Proceedings 1528, pages 237-242.

(iii) M. Yusof Ismail and M. Hashim Dahri, "Analytical Investigation of Phase Agile Reflectarray Elements Based on Non-Linear Materials", in International Conference on Electrical, Computer, Electronics and Communication Engineering ICECECE 2012, Bali, Indonesia October 24-25, 2012.

(iv) M. Hashim Dahri and M. Y. Ismail, "Phase Distribution Analysis of Reflectarray Resonant Elements based on Linear and Non-linear Materials", in International Symposium on Telecommunication Technologies (ISTT2012), 26-28 November 2012 in Kuala Lumpur, Malaysia.

(v) M. Hashim Dahri and M. Y. Ismail, "Performance Analysis of Reflectarray Resonant Elements based on Dielectric Anisotropic Materials", in Malaysian Technical Universities Conference on Engineering & Technology (MUCET 2012), November 2012.

(vi) M. Y. Ismail and M. Hashim Dahri, "Microwave Absorption Analysis of Reflectarray Resonant Elements Based on Non-Homogeneous Substrate", 15th International Symposium of Antenna Technology and applied Electromagnetics (ANTEM) 25–28 June 2012 – Toulouse France.

(vii) M. Hashim Dahri and M. Yusof Ismail, "Performance Analysis of Reflectarray Antenna Elements Printed on Non-linear Dielectric Materials," Progress in Electromagnetic Research Symposium (PIERS 2012), Malaysia, March 2012.

(viii) M.Y. Ismail, M. Inam and M. Hashim Dahri, "Reconfigurable Reflectarray

Antennas: An Alternative Novel Solution for Satellite Communication Systems". Invited talk in 9th International Conference on Frontiers of Information Technology (FIT), December 2011, Islamabad, Pakistan.

(ix) M. Hashim Dahri and M.Yusof Ismail, "Phase Distribution Analysis of Reflectarrays based on Variable Material Properties," IEEE Student Conference on Research and Development (SCORED 2011), Malaysia, December 2011.

(x) M. Hashim Dahri and M. Yusof Ismail, "Tunability Performance of Reflectarray Elements based on Anisotropic Substrates," International Seminar on the Application of Science & Mathematics (ISASM 2011), November 2011.

(xi) M. Hashim Dahri and M. Yusof Ismail, "Phase Distribution Analysis of Reflectarrays Based on Isotropic and Anisotropic Substrate Materials," Malaysian Technical Universities International Conference on Engineering & Technology (MUiCET 2011), November 2011.

LIST OF AWARDS

(i) Silver Medal, "Tunable Microwave Absorber for Wireless Systems", International Technology Invention and Innovation Exhibition (ITEX 2012), May 2012, Kuala Lumpur Malaysia.

(ii) Silver Medal, "Non-Resonant Microwave Absorber for Mobile Radio Environment", Malaysia Technology Expo (MTE 2012), February 2012, Kuala Lumpur Malaysia.

(iii) Consolation Prize, "Non-Resonant Microwave Absorber for Mobile Radio Environment" Research and Innovation Compete, November 2011, UTHM.

(iv) Gold Medal, "Multi-function dynamic Steerable Flat Antenna", International Conference and Exposition on Invention of institutions of Higher Learning (PECIPTA 2011), September 2011, Kuala Lumpur, Malaysia.

CHAPTER 1

INTRODUCTION

Throughout the time, one thing that has distinguished humans from other creatures is their ability to exchange ideas and other information. That is, humans can communicate and share the information between each other. In ancient times, fire was first used as a communication tool by Chinese. Ancient Egyptians and Romans were able to use some sound making instruments to convey their messages at a distance. It is this capability that has played a big part in the development of human civilization. In fact, as our civilization continues to grow, the advancement in our communication capacity is required. The one of the first application of the new field of electricity was to extend our communication range. This was accomplished through the use of wires and telegraphy. Messages were sent by turning electrical currents on and off in accordance with a telegraph code. This system gradually evolved into the telephone system where the electrical currents are varied at audio rate. Thus the spoken word can be conveyed between two distant points. However, the telephone system still required wires, which limited its capabilities. Thus, the next development was to move towards "wireless" communications in the form of radio waves. This greatly extended the communication range, which was useful to communicate with ships at sea and remote areas of the world. Wireless or radio communications represented a significant advancement. The signals were brought to send into the free space without using any wired media with the help of a device called "Antenna".

Antenna is a device which converts electrical signals into the radio waves and make them capable to propagate into the free space (Balanis 2005). The idea of an antenna was first introduced by Heinrich Hertz in 1886, during his work to prove the existence of electromagnetic field which was first predicted by James Clerk Maxwell in 1873 (Pozar 2005). But it was Guglielmo Marconi who was able to send

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