Reconfigurable Tunable Microwave Devices Using Liquid Crystal

by

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DEDICATION

"I dedicate this thesis to my wife, Hedy, for without her love and support none of this would have happened".

"To my parents and sister whom always supported me both emotionally and financially".

Contents

Abstract

During the past decades, the applications of communication devices have extended widely, from AM radio receivers initially to newly developed GPS, smart mobile phones, radars, wireless LANs, satellite communications and implantable medical devices. The shortage in the available frequency spectrum for radio communications, the demand for portable wireless devices, and the requirement for more functionality in an even smaller volume, requires the development of new concepts in RF technology. One ideal pathway towards development of such new concepts is reconfiguration.

Today, due to the rapid progress in material science and electronic technology, there is great possibility in designing reconfigurable portable wireless devices which are frequency tunable, flexible and consume low energy. In this thesis, the anisotropic properties of liquid crystals in their nematic phase are exploited as a low-voltage (< 35 V) mechanism for designing tunable wireless devices at a low microwave frequency (L to C-band). To demonstrate the possibility of using liquid crystal technology, three different design approaches were pursued: a liquid crystal tunable resonator, a tunable band-pass liquid crystal filter, both at S-band, and liquid crystal tunable frequency selective surfaces operating at C-band. The results from full-wave electromagnetic simulations, lumped-element circuit models and prototype measurements in all cases indicate around 3.1 to 8.2% of continuous frequency tuning with low insertion loss (< 1 dB).

Given that liquid crystals material are transparent, commercially obtainable and are the only liquid material with tunable characteristics at microwave frequency, they could be ideal, in conjunction with flexible electronics, for designing either external or internal implantable microwave devices where flexibility is of great concern.

Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Signed

Date

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P. Yaghmaee

Conventions

Typesetting This thesis is typeset using Microsoft word, 2007.

Referencing The IEEE style is used for referencing and citation in this thesis.

Spelling Australian English spelling is adopted, as defined by the Macquarie English Dictionary (Delbridge 2001).

System of units The units comply with the international system of units recommended in an Australian Standard: AS ISO 1000-1998 (Standards Australia Committee ME/71, Quantities, Units and Conversions 1998).

Physical constants The physical constants comply with a recommendation by the committee on Data for Science and Technology: CODATA (Mohr and Taylor 2005).

Frequency bands Microwave frequency bands are defined according to "IEEE Standard Letter Designations for Radar-Frequency Bands," IEEE Std 521-2002 (Revision of IEEE Std 521-1984).

Publications

[1] **P. Yaghmaee,** O. H. Karabey, B. Bates, C. Fumeaux, and R. Jakoby, "Electrically tuned microwave devices using liquid crystal technology," *International Journal of Antennas and Propagation*, vol. 24, pp. 25-35, September 2013. (Chap. 1-2), Journal

[2] **P. Yaghmaee**, T. Kaufmann, B. Bates and C. Fumeaux, "Effect of polyimide layers on the permittivity tuning range of liquid crystal," *IEEE European Conference on Antennas and Propagation (EuCap)*, pp. 3579-3582, March 2012. (Chap. 3), Conference

[3] **P. Yaghmaee,** C. Fumeaux, B. Bates, A. Manabe, O. H. Karabey and R. Jakoby, "Frequency tunable S-band resonator using nematic liquid crystal," *IET Electronics Letters*., vol. 48, no. 13, pp. 798-800, June, 2012. (paper was selected for the "in brief" section of the journal, under Wireless Communications - Body Tuning) (Chap. 4), Journal

[4] **P. Yaghmaee**, A.K. Horestani, B. Bates and C. Fumeaux, "A multi-layered tunable stepped impedance resonator for liquid crystal characterization," *IEEE Asia-Pacific Microwave Conference (APMC)*, PP. 776-778, December 2012. (Chap. 5), Conference

[5] **P. Yaghmaee**, W. Withayachumnankul, A.K. Horestani, A. Ebrahimi, B. Bates and C. Fumeaux, "Tunable electric-*LC* resonators using liquid crystal," *IEEE International Symposium on Antenna and Propagation (AP-S/USNC-URSI)*, July 2013. (Chap. 6), Conference

[6] **P. Yaghmaee,** B. Bates, and C. Fumeaux, "Liquid crystal tunable frequency selective surfaces for microwave frequency switching," in preparation. (Chap. 6), Journal

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[8] A. Ebrahimi, **P. Yaghmaee**, W. Withayachumnankul, C. Fumeaux, S. Al-Sarawi and D. Abbott, "Interlayer tuning of X-band frequency-selective surface using liquid crystal," *IEEE Asia-Pacific Microwave Conference Proceeding (APMC)*, pp. 1118-1120 November 2013. (Future work), Conference

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[10] A. Ebrahimi, and **P. Yaghmaee**, “A new enhanced differential CMOS colpitts oscillator,” *Journal of Circuits, Systems, and Computers*, November 2013.* Journal

Note: Articles with an asterisk are not directly relevant to this thesis

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