



شبكة المعلومات الجامعية

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ





شبكة المعلومات الجامعية



# شبكة المعلومات الجامعية

## التوثيق الالكتروني والميكرو فيلم

# جامعة عين شمس

التوثيق الالكتروني والميكرو فيلم

## قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها  
علي هذه الأفلام قد اعدت دون أية تغيرات



## يجب أن

تحفظ هذه الأفلام بعيداً عن الغبار

في درجة حرارة من 15 – 20 مئوية ورطوبة نسبية من 20-40 %

To be kept away from dust in dry cool place of  
15 – 25c and relative humidity 20-40 %



شبكة المعلومات الجامعية



# بعض الوثائق الأصلية تالفة



شبكة المعلومات الجامعية



بالرسالة صفحات  
لم ترد بالأصل

**DESIGN AND SIMULATION OF FREQUENCY MODULATED  
CONTINUOUS WAVE RADAR TRANSCEIVER**

**By**

**Ahmed Mohamed Ali Moussa**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirement of the Degree of  
**MASTER OF SCIENCE**  
In  
Electronics And Electrical Communications Engineering

**Under The Supervision Of**

**Prof. Essam A. Hashish**  
Electronic And Communications  
Department  
Faculty Of Engineering  
Cairo University

**Dr. Ahmed Ibrahim Khalil**  
Electronic And Communications  
Department  
Faculty Of Engineering  
Cairo University

**Dr. Amr Nabil Hafez**  
Electronic And Communications  
Department  
Faculty Of Engineering  
Cairo University

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
March 2006**



**DESIGN AND SIMULATION OF FREQUENCY MODULATED  
CONTINUOUS WAVE RADAR TRANSCEIVER**

**By**

**Ahmed Mohamed Ali Moussa**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirement of the Degree of  
**MASTER OF SCIENCE**  
In  
Electronics And Electrical Communications Engineering

**Approved by the  
Examining Committee**

**Prof. ElSayed Mostafa**

\_\_\_\_\_  
**Prof. Magdi Fikri**

\_\_\_\_\_  
**Prof. Essam A. Hashish**

\_\_\_\_\_  
**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
March 2006**



1. The first part of the paper is devoted to a general discussion of the problem of the existence of solutions of the system of equations (1) and (2) under the assumption that the functions  $f_i(x)$  and  $g_j(x)$  are continuous and satisfy certain conditions.

2. In the second part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are linear.

3. In the third part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are quadratic.

4. In the fourth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are cubic.

5. In the fifth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of higher order.

6. In the sixth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order.

7. In the seventh part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

8. In the eighth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

9. In the ninth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

10. In the tenth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

11. In the eleventh part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

12. In the twelfth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

13. In the thirteenth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

14. In the fourteenth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

15. In the fifteenth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

16. In the sixteenth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

17. In the seventeenth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

18. In the eighteenth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

19. In the nineteenth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

20. In the twentieth part, we consider the case when the functions  $f_i(x)$  and  $g_j(x)$  are of arbitrary order and satisfy certain conditions.

# Contents

|                                                   |    |
|---------------------------------------------------|----|
| <b>CHAPTER 1</b>                                  | 1  |
| <b>Introduction</b>                               | 1  |
| 1.1 Motivation                                    | 1  |
| 1.2 Vehicular applications                        | 2  |
| 1.3 Overview                                      | 3  |
| <b>CHAPTER 2</b>                                  | 4  |
| <b>Theory Of Radar System</b>                     | 4  |
| 2.1 Introduction To Radar Fundamentals            | 4  |
| 2.2 Frequency Bands                               | 5  |
| 2.3 The Radar Equation                            | 6  |
| 2.4 Radar Cross Section                           | 11 |
| 2.5 Types Of Radar Systems                        | 12 |
| 2.5.1 Pulsed Radar                                | 12 |
| 2.5.2 Continuous Wave Radar                       | 13 |
| 2.5.2.1 Doppler Radar                             | 13 |
| 2.5.2.2 Frequency Modulated Continuous Wave Radar | 15 |
| <b>CHAPTER 3</b>                                  | 21 |
| <b>Analysis of FMCW Transceiver</b>               | 21 |
| 3.1 Introduction                                  | 21 |
| 3.2 System Overview                               | 21 |
| 3.3 System Performance Definitions                | 23 |
| 3.3.1 Noise                                       | 23 |
| 3.3.2 Linearity                                   | 25 |
| 3.3.2.1 1dB Compression Point                     | 25 |
| 3.3.2.2 Third Order Intercept Point               | 26 |
| 3.3.5 Receiver sensitivity                        | 28 |

|         |                                                  |    |
|---------|--------------------------------------------------|----|
| 3.4     | System Analysis of FMCW Radar                    | 29 |
| 3.5     | <b>Circulator</b>                                | 31 |
| 3.5.1   | Introduction                                     | 31 |
| 3.5.2   | Types Of Active Circulators                      | 32 |
| 3.5.3   | Basic Configuration of A Quasi-Circulator Module | 32 |
| 3.6     | <b>Antenna</b>                                   | 38 |
| 3.6.1   | Microstrip Quasi-Yagi Antennas                   | 38 |
| 3.6.2   | Antenna Dimensions                               | 40 |
| 3.6.3   | The power divider                                | 41 |
| 3.6.4   | The 180° delay line                              | 42 |
| 3.7     | <b>Low Noise Amplifier</b>                       | 42 |
| 3.7.1   | Introduction                                     | 42 |
| 3.7.2   | Stability Analysis                               | 43 |
| 3.7.3   | Noise and gain Circles                           | 48 |
| 3.7.4   | Constant Noise Figure Circles                    | 48 |
| 3.7.5   | Available power Gain Circles                     | 50 |
| 3.8     | <b>Dual – Gate Mixer</b>                         | 51 |
| 3.8.1   | Introduction                                     | 51 |
| 3.8.2   | Mixer Definitions                                | 53 |
| 3.8.2.1 | Conversion Loss                                  | 53 |
| 3.8.2.2 | Isolation                                        | 53 |
| 3.8.3   | The Principle Of Dual-Gate FET Mixers            | 53 |
| 3.8.3.1 | Dual-Gate I–V Characteristics                    | 55 |
| 3.9     | <b>Voltage Controlled Oscillator</b>             | 57 |
| 3.9.1   | Introduction                                     | 57 |
| 3.9.2   | Phase Noise                                      | 57 |
| 3.9.3   | Colpitt's Oscillator                             | 59 |
| 3.10    | <b>Wilkinson Power Divider</b>                   | 61 |
| 3.11    | <b>Band Pass Filter</b>                          | 62 |

|                                                  |                                               |           |
|--------------------------------------------------|-----------------------------------------------|-----------|
| 3.11.1                                           | Types of Microwave Filters                    | 62        |
| 3.11.2                                           | Hairpin Filter Design                         | 63        |
| <b>CHAPTER 4</b>                                 |                                               | <b>65</b> |
| <b>Design and Simulation of FMCW Transceiver</b> |                                               | <b>65</b> |
| 4.1                                              | Specifications of the FMCW radar transceiver  | 65        |
| 4.2                                              | Quasi Circulator Module                       | 66        |
| 4.2.1                                            | Implementation of the quasi circulator module | 66        |
| 4.2.2                                            | Gain of the designed quasi circulator         | 70        |
| 4.2.3                                            | Isolation of the designed quasi circulator    | 70        |
| 4.2.4                                            | Return Loss of the designed quasi circulator  | 71        |
| 4.3                                              | Antenna                                       | 72        |
| 4.3.1                                            | Design considerations                         | 72        |
| 4.3.2                                            | Length of Director                            | 74        |
| 4.3.3                                            | Distance Between Director and Driver          | 74        |
| 4.3.4                                            | Length of Driver                              | 75        |
| 4.3.5                                            | Distance From the Driver to the Reflector     | 76        |
| 4.4                                              | Low Noise Amplifier                           | 78        |
| 4.4.1                                            | Transistor Selection                          | 78        |
| 4.4.2                                            | DC biasing                                    | 79        |
| 4.4.3                                            | LNA Performance                               | 84        |
| 4.5                                              | Simulation of Dual Gate FET Mixer             | 87        |
| 4.5.1                                            | Biasing the Dual Gate FET                     | 87        |
| 4.5.2                                            | Dual gate FET performance                     | 91        |
| 4.6                                              | Colpitt's Oscillator Design                   | 94        |
| 4.7                                              | Wilkinson Power Divider                       | 105       |
| 4.8                                              | Hairpin Filter design                         | 108       |
| 4.9                                              | Simulation of The FMCW Radar Transceiver      | 114       |
| 4.9.1                                            | Linear FM Chirp Waveform                      | 112       |
| 4.9.2                                            | Doppler Target                                | 115       |

|                                    |     |
|------------------------------------|-----|
| 4.9.3 System simulation            | 117 |
| 4.9.3.1 Stationary target          | 117 |
| 4.9.3.2 Moving target              | 121 |
| <b>CHAPTER 5</b>                   | 125 |
| <b>Conclusions and Future Work</b> | 125 |
| <b>References</b>                  | 126 |
| Appendix A                         | 132 |
| Appendix B                         | 138 |
| Appendix C                         | 144 |
| Appendix D                         | 155 |

## LIST OF FIGURES

|             |                                                                   |    |
|-------------|-------------------------------------------------------------------|----|
| Figure 2.1  | Principle operation of radar systems .....                        | 4  |
| Figure 2.2  | Radar parameters .....                                            | 6  |
| Figure 2.3  | Monostatic and bistatic radar system .....                        | 10 |
| Figure 2.4  | Block diagram of pulsed radar system .....                        | 13 |
| Figure 2.5  | Block diagram of Doppler radar system .....                       | 14 |
| Figure 2.6  | Block diagram of FMCW radar system .....                          | 15 |
| Figure 2.7  | FMCW radar sweep .....                                            | 16 |
| Figure 2.8  | Frequency-time relationship for a stationary target .....         | 17 |
| Figure 2.9  | Frequency-time relationship for a moving target .....             | 18 |
| Figure 3.1  | FMCW radar block diagram .....                                    | 22 |
| Figure 3.2  | 1dB compression point .....                                       | 26 |
| Figure 3.3  | The effect of the second order intermodulation .....              | 27 |
| Figure 3.4  | The effect of the third order intermodulation .....               | 28 |
| Figure 3.5  | Simplified RF front-end receiver model .....                      | 29 |
| Figure 3.6  | Transmitter and receiver on the same antenna .....                | 31 |
| Figure 3.7  | Basic block diagram of quasi circulator module .....              | 33 |
| Figure 3.8  | Block diagram of the divider .....                                | 33 |
| Figure 3.9  | Block diagram of the combiner .....                               | 34 |
| Figure 3.10 | Block diagram of the circulator module .....                      | 35 |
| Figure 3.11 | Uniplanar quasi-yagi antenna .....                                | 39 |
| Figure 3.12 | Schematic diagram of quasi-yagi antenna .....                     | 40 |
| Figure 3.13 | Quarter-wavelength transformer and power divider .....            | 42 |
| Figure 3.14 | Amplifier block schematic .....                                   | 44 |
| Figure 3.15 | Output Stability Circle for $\Gamma_L$ plane .....                | 46 |
| Figure 3.16 | Conditions for unconditional stability for $\Gamma_L$ plane ..... | 47 |
| Figure 3.17 | Signals at inputs of mixer .....                                  | 52 |
| Figure 3.18 | Signals at outputs of mixer .....                                 | 52 |

|             |                                                                   |    |
|-------------|-------------------------------------------------------------------|----|
| Figure 3.19 | Conversion Loss of mixer                                          | 53 |
| Figure 3.20 | Dual gate FET Mixer                                               | 54 |
| Figure 3.21 | Transfer characteristics of DGFET                                 | 56 |
| Figure 3.22 | Schematic of a cascade FET                                        | 62 |
| Figure 3.23 | Output spectra of: (a) Ideal oscillator; (b) Practical oscillator | 58 |
| Figure 3.24 | Collpit's oscillator                                              | 59 |
| Figure 3.25 | Wilkinson power splitter                                          | 62 |
| Figure 3.26 | Hairpin resonator, schematic diagram                              | 63 |
| Figure 3.27 | Equivalent circuit for taped hairpin resonator                    | 63 |
| Figure 4.1  | The supposed quasi circulator module                              | 66 |
| Figure 4.2  | Schematic of the designed quasi circulator                        | 69 |
| Figure 4.3  | Gain of the designed quasi circulator                             | 70 |
| Figure 4.4  | Port isolation of the designed quasi circulator                   | 71 |
| Figure 4.5  | Return loss of the designed Quasi circulator                      | 71 |
| Figure 4.6  | Effect of the length of director                                  | 73 |
| Figure 4.7  | Effect of distance between director and driver                    | 74 |
| Figure 4.8  | Effect of the length of driver                                    | 75 |
| Figure 4.9  | Schematic diagram of quasi-yagi antenna from HFSS                 | 76 |
| Figure 4.10 | $S_{11}$ return loss of the Quasi-Yagi antenna                    | 77 |
| Figure 4.11 | Far filed radiation pattern ( $E_{\theta}$ )                      | 78 |
| Figure 4.12 | Cascaded two stages LNA schematics                                | 78 |
| Figure 4.13 | LNA schematic and biasing                                         | 80 |
| Figure 4.14 | Noise figure versus collector current for BFP420 transistor       | 81 |
| Figure 4.15 | First stage low noise amplifier                                   | 82 |
| Figure 4.16 | Output Stability Circle, Noise circles and Gain circles           | 82 |
| Figure 4.17 | Output impedance of the first stage                               | 83 |
| Figure 4.18 | Second stage block diagram                                        | 83 |
| Figure 4.19 | LNA Simulated returned loss                                       | 85 |
| Figure 4.20 | LNA Simulated Noise Figure                                        | 85 |