

**Sudan University of Science and Technology**  
**College of Graduate Studies**



# **Interference Management for Downlink OFDMA Using Fractional Frequency Reuse**

**إدارة التداخل للوصلة الهابطة لتقسيم التردد متعامد الوصول  
المتعدد بواسطة إعادة استخدام التردد الجزئي**

**A Research Submitted in Partial Fulfillment for the Requirements of  
the Degree of M.Sc. In Electronics Engineering (Communications)**

**Prepared By:**

**Islam Elsiddiq Mustafa AbuElgasim**

**Supervisor:**

**Dr. Fath Elrahman Ismael Khalifa Ahmed**

**August 2015**

بسم الله الرحمن الرحيم

قال تعالى:

(( قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ ))

سورة البقرة آية (32)

## **DEDICATION**

I dedicate my thesis work to my family and my friends. A special feeling of gratitude to my loving parents whose words of encouragement and push for tenacity ring in my ears. I also dedicate this thesis to my friends support for their throughout my research course, I will always appreciate all they have done.

## **ACKNOWLEDGMENT**

I must acknowledge my parents as well the many friends, colleagues, students, teachers, and my loved ones who assisted, advised, and supported my research and writing efforts over the months at the top of them all my supervisor Dr. Fath-Elrahman. Especially, I need to express my gratitude and deep appreciation to Yasir and Rwah whose friendship, hospitality, knowledge, and wisdom have supported, enlightened, and entertained me over the many years of our friendship. They have consistently helped me keep perspective on what is important in life and shown me how to deal with reality.

## المستخلص

في تطور طويل الأمد للمشروع شراكة الجيل الثالث في الآونة الأخيرة تم التركيز بشدة نحو إعادة استخدام التردد؛لنتمكن من الحصول على العدد الأقصى داخل الخلية. مفهوم إعادة استخدام التردد التقليدي لإدارة التداخل لا يوفر تغطية ومعدل مرضيين بحيث تم اختيار إعادة استخدام التردد الجزئي. في أنظمة الاتصالات اللاسلكية اليوم هناك تحديات تتعلق نسبة الإشارة الي الضجيج بإعتبار ومعدل نقل البيانات مثل المسافة وإحتمالية التغطية الممكنة والمعدل المطلوب. بحيث يتم تقسيم التردد المعاد بشكل جزئي لدراسة المشكلة وإيجاد حلول أفضل.

هدف هذه الدراسة هو تقييم أداء إعادة استخدام التردد الجزئي علي الماتلاب ومقارنته مع إعادة استخدام التردد التقليدي من حيث الأداء والقدرات للعثور علي افضل حل.

يعتبر إعادة استخدام التردد الجزئي مقترح كوسيلة لإدارة التداخل نظراً للتقييم المقارن مع إعادة استخدام الترددات التقليدي على أساس ثلاثة مقاييس احتمال التغطية، احتمال معدل القبول وعامل إعادة استعمال التردد. كما إتضح أن إعادة استخدام التردد الجزئي له أفضل نسبة الإشارة الي الضجيج وتطور ملحوظ في كل من نسبة الإشارة الي الضجيج ومعدل نقل البيانات.

أظهرت نتائج المحاكاة التي ان إعادة استخدام التردد الجزئي له أفضل نسبة الإشارة الي الضجيج بالمقارنة مع طريقة إعادة استخدام الترددات التقليدي ومشابهة لإعادة استخدام الترددات التقليدي 3 كما أظهرت ان له تغطية تصل الي ضعف نظريتها في لإعادة استخدام الترددات التقليدي 3 عند نسب الإشارة الي الضجيج معينة. علاوة علي ذلك وجد ان إعادة استخدام التردد الجزئي له معدل نقل بيانات يترواح من الضعف الي الثلاث أضعاف مقارنة بكل من في لإعادة استخدام الترددات التقليدي 1 في لإعادة استخدام الترددات التقليدي 3 علي التوالي .

## **ABSTRACT**

The Long Term Evolution (LTE) of the Third Generation Partnership project (3GPP) has recently been focusing towards aggressive frequency reuse; so that maximum number of hands can be gotten within a cell. Traditional frequency reuse concept for interference management doesn't provide satisfactory coverage and rate, thus fraction frequency reuse is chosen.

In today's wireless communication systems there are challenges regarding SINR and data rate like distance, probability of coverage and probability of acceptance rate. Fractioning the number of reuse to study the problem and find better solutions.

The aim is to evaluate the performance of the FFR on MATLAB by comparing FFR with traditional reuse concerning their performance and capabilities of both as schemes to find the best solution.

FFR is purposed as a candidate for interference management and its comparative evaluation over traditional frequency reuse on the basis of three parameter metrics probability of coverage , probability of acceptance rate and frequency reuse factor are done and FFR has relatively better performance. Further improvements in both data rate and SINR can be achieved by FFR implementation .

The simulation results show that FFR has better performance in SINR than traditional reuse better, similar to reuse 3 and coverage around 200% more than it in particular SINR. Moreover the data rate value of FFR is more than 200% and nearly 300% regarding to reuse 1 and reuse 3 respectively.

# TABLE of CONTENTS

|                                                               |      |
|---------------------------------------------------------------|------|
| DEDICATION .....                                              | iii  |
| ACKNOWLEDGMENT .....                                          | iv   |
| ABSTRACT .....                                                | v    |
| المستخلص .....                                                | vi   |
| TABLE of CONTENTS .....                                       | vii  |
| LIST OF FIGURES.....                                          | x    |
| LIST OF TABLES .....                                          | xi   |
| LIST OF SYMBOLS .....                                         | xii  |
| ABBREVIATIONS .....                                           | xiii |
| Chapter One .....                                             | 1    |
| Introduction .....                                            | 1    |
| Preface .....                                                 | 1    |
| 1.1 Problem Statement .....                                   | 2    |
| 1.2 Proposed Solution .....                                   | 2    |
| 1.4 Objectives .....                                          | 3    |
| 1.6 Research Methodology .....                                | 3    |
| 1.7 Thesis Outlines.....                                      | 3    |
| Chapter Two.....                                              | 5    |
| Literature Review.....                                        | 5    |
| 2.1 Growth of Wireless Technology .....                       | 6    |
| 2.2 Evolution of Cellular Networks .....                      | 9    |
| 2.3 Cellular Network Planning and Optimization.....           | 13   |
| 2.3.1 Frequency Planning.....                                 | 15   |
| 2.3.2 Adaptive resource allocation in cellular networks ..... | 17   |

|                                                                                   |    |
|-----------------------------------------------------------------------------------|----|
| 2.3.3 Network Optimization.....                                                   | 17 |
| Chapter Three.....                                                                | 21 |
| Performance Analysis of Fractional Frequency Reuse .....                          | 21 |
| 3.1 Frequency Partitioning/Reuse Approaches .....                                 | 22 |
| 3.1.2. Hard Frequency Reuse:.....                                                 | 24 |
| 3.1.3 Fractional Frequency Reuse:.....                                            | 26 |
| 3.1.4. Soft Frequency Reuse: .....                                                | 28 |
| 3.2 System Model .....                                                            | 30 |
| 3.2.2 Parameters used: .....                                                      | 32 |
| Chapter Four .....                                                                | 33 |
| Results and Discussions .....                                                     | 33 |
| 4.1 Simulation Parameters .....                                                   | 33 |
| 4.1 Signal to Interference Noise Ratio (SINR) of Traditional Reuses and FFR ..... | 33 |
| 4.3 Data rate of Traditional Reuses and FFR.....                                  | 36 |
| 4.4 Data rate of to Traditional Reuses and FFR of Higher n=reuse size .....       | 40 |
| 4.5 Comparing Reuse Factors for FFR .....                                         | 41 |
| Chapter Five.....                                                                 | 43 |
| Conclusions and Recommendations .....                                             | 43 |
| 5.1 Conclusions.....                                                              | 43 |
| 5.2 Recommendations.....                                                          | 44 |
| 5.3 References.....                                                               | 44 |
| The appendix title .....                                                          | 48 |
| Appendix B .....                                                                  | 59 |

## LIST OF FIGURES

|            |                                                          |    |
|------------|----------------------------------------------------------|----|
| Figure 2.1 | Increasing in demand of mobile over the next years.....  | 9  |
| Figure 2.2 | Global development of ICT.....                           | 10 |
| Figure 2.3 | Evolution of cellular technology. ....                   | 15 |
| Figure 2.4 | An illustration of base station location.....            | 16 |
| Figure 2.5 | An illustration of frequency assignment.....             | 18 |
| Figure 2.6 | Interference Avoidance Schemes.....                      | 22 |
| Figure 3.1 | Full frequency reuse.....                                | 26 |
| Figure 3.2 | The most basic form of frequency reuse.....              | 28 |
| Figure 3.3 | Fraction frequency reuse.....                            | 31 |
| Figure 3.3 | SFR optimizes the full frequency reuse of resources..... | 33 |
| Figure 4.1 | SINR of Traditional Reuse 1.....                         | 38 |
| Figure4. 2 | SINR of Traditional Reuse 3.....                         | 38 |
| Figure 4.3 | SINR of Fraction Frequency Reuse 3.....                  | 39 |
| Figure 4.4 | Map of Traditional Reuse 1.....                          | 39 |
| Figure 4.5 | Map of Traditional Reuse 3.....                          | 40 |
| Figure 4.6 | Map of Fraction Frequency Reuse 3.....                   | 40 |
| Figure 4.7 | Data Rate of Traditional Reuse 1                         | 41 |

|             |                                                |    |
|-------------|------------------------------------------------|----|
| Figure 4.8  | Data Rate of Traditional Reuse 3.....          | 42 |
| Figure 4.9  | Data Rate of Fraction Frequency Ruse 3.....    | 43 |
| Figure 4.10 | Data Rate of Traditional Reuse 9.....          | 44 |
| Figure 4.11 | Data Rate of Fraction Frequency Reuse 9.....   | 44 |
| Figure 4.12 | SINR of Fraction Frequency Reuse Lower Rf..... | 45 |
| Figure 4.13 | SINR of Fraction Frequency Reuse Higher RF     | 46 |

## LIST OF TABLES

|           |                                                       |    |
|-----------|-------------------------------------------------------|----|
| Table 4.1 | Simulation Parameters .....                           | 37 |
| Table 4.2 | Probability of Acceptance rate (PAR) calculation..... | 43 |

## LIST OF SYMBOLS

|            |                                                                              |
|------------|------------------------------------------------------------------------------|
| $\alpha$   | Path loss coefficient                                                        |
| $\sigma^2$ | Noise power                                                                  |
| $i$        | Mobiles which are interfering with the mobile whose SINR is being calculated |
| $\tau$     | The achievable rate                                                          |
| $\lambda$  | User Equipment's intensity                                                   |
| 'i'        | Represents each of the mobiles which are interfering                         |
| $g$        | Statistical distribution and is fading value or value for fading             |
| $\mu$      | One over it gives the mean                                                   |
| $h$        | Exponential random variable( $h \sim \exp(\mu)$ ).                           |
| $r$        | Distance from mobile to its base station.                                    |
| $R$        | Distance from the mobile to other stations on same reuse assignment.         |
| $T$        | Target threshold SINR value.                                                 |

## ABBREVIATIONS

|                |                                                       |
|----------------|-------------------------------------------------------|
| 1G             | 1st Generation                                        |
| 2G             | 2 <sup>nd</sup> Generation                            |
| 3G             | 3 <sup>rd</sup> Generation                            |
| 4G             | 4 <sup>th</sup> Generation                            |
| AMPS           | Advanced Mobile Phone Service System                  |
| APs            | Access Points                                         |
| BS             | Base Station                                          |
| CAPEX          | Capital Expenditure                                   |
| CCDF           | Cumulative Distribution Function                      |
| CCI            | Co Channel Interference                               |
| CDMA2000 1xRTT | Single-Carrier Radio Transmission Technology          |
| CoMP           | Coordinated Multi-Pointing Transmission/<br>Reception |
| D-AMPS         | Digital Advanced Mobile Phone Service System          |
| dB             | Deci-Bel                                              |
| DCA            | Dynamic Channel Allocation                            |
| DC-HSPA        | Dual-Carrier HSPA                                     |
| DFR            | Dynamic Frequency Reuse                               |
| EDGE           | Enhanced Data Rate For GSM Evolution                  |
| e-ICIC         | Enhanced Inter Cell Interference Coordination         |
| EUL,           | Enhanced Uplink                                       |
| FAP            | Frequency Assignment Problem                          |
| FAP            | Frequency Assignment Problem                          |

|         |                                                   |
|---------|---------------------------------------------------|
| FBSs,   | FemtoBSSs                                         |
| FFR     | Fractional Frequency Reuse                        |
| FH      | Frequency Hopping                                 |
| FRF     | Frequency Reuse                                   |
| GPRS    | General Packet Radio Service                      |
| GSM     | Global System For Mobile Communications           |
| GUI     | Graphical User Interface                          |
| HetNets | Heterogeneous Networks                            |
| HSCSD   | High-Speed Circuit Switched Data                  |
| HSDPA   | For High Speed Downlink Packet Access             |
| HSDPA   | High Speed Downlink Packet Access                 |
| HSPA+   | High Speed Packet Access Evolution                |
| ICI     | Inter Cell Interference                           |
| ICIC    | Inter Cell Interference Coordination              |
| ICT     | Information And Communication Technology          |
| IEEE    | Institute Of Electrical And Electronics Engineers |
| IS-136  | Interim Standard 136                              |
| IS-95   | Interim Standard 95                               |
| ITU     | International Telecommunications Union            |
| Kbps    | Kilo Bit Per Second                               |
| LTE     | Long Term Evolution                               |
| LTE-A   | LTE-Advanced                                      |
| MBS     | Macro Base Station                                |
| MIMO    | Multiple Input Multiple Output                    |
| NMT     | Nordic Mobile Telephone System                    |
| NTT     | Nippon Telegraph And Telephone                    |

|          |                                               |
|----------|-----------------------------------------------|
| OFDMA    | Orthogonal Frequency Division Multiple Access |
| OPEX     | Operational Expenditure                       |
| PAR      | Probability Of Acceptance Rate                |
| PDC      | System The Personal Digital Cellular.         |
| PSK      | Phase Shift Keying                            |
| QAM      | Quadrature Amplitude Modulation               |
| R10      | Release 10                                    |
| R5       | Release 5                                     |
| R6       | Release 6                                     |
| R7       | Release 7                                     |
| R8       | Release 8                                     |
| R99      | Release 99                                    |
| RAN      | Radio Access Network                          |
| RF       | Factor Radio Frequency                        |
| RRM      | Radio Resource Management                     |
| SAE      | System Architecture Evolution                 |
| SC-FDMA  | Single Carrier FDMA                           |
| SFR      | Soft Frequency Reuse                          |
| SFR      | Soft Frequency Reuse                          |
| SINR     | Signal To Interference Noise Ratio            |
| SIR      | Single-To-Interference Ratio                  |
| SNR      | Single-To-Noise Ratio                         |
| TACS     | Total Access Communication System             |
| TDMA     | Time Division Multiple Access                 |
| TD-SCDMA | Time Division Synchronous CDMA                |
| UEs      | Cell-Edge                                     |

|       |                                                    |
|-------|----------------------------------------------------|
| UMTS  | Universal Mobile Telecommunications System         |
| WCDMA | Wideband Code Division Multiple Access             |
| WiMAX | Worldwide Interoperability For Microwave<br>Access |
| X2    | Signaling Interface                                |