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MULTI USER DIVERSITY IN A SPECTURM SHARING USING CO EXISTENCE IN OFDM

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ABSTRACT :
The fifth-generation (5G) cellular mobile communications look promising with features that can help improving consumer experience and satisfaction. The feasibility of spectrum sharing between a Multiple-Input Multiple- Output radar system and a MIMO cellular system, comprising of a full duplex base station serving multiple downlink & uplink users at the same time and frequency is investigated. Spectrum is, however, a finite and scarce resource, and it can be allocated to a new service only when the spectral coexistence with other incumbents is ensured. New waveforms for 5G that differ from the conventional orthogonal frequency-division multi-plexing (OFDM) are required in order to have a superior performance in terms of out-of-band emissions and to be able to utilize the fragmented spectrum in different bands. While a joint transceiver design technique at the CS's BS and users is proposed to maximise the probability of detection of the MIMO RS, subject to constraints of QOS of users and transmit power at the CS, null-space based waveform projection is used to mitigate the interference from RS towards CS.

INDEX TERMS MIMO, CS, RS, BS, QoS, scarce, incumbents.

1. INTRODUCTION

The electromagnetic radio spectrum is one of the most precious and scarce natural resource. Wireless networks today follow a fixed spectrum assignment strategy. Actual measurements by FCC support this fact by showing a severe underutilization of the licensed spectrum by the licensed or Primary User (PU). Due to limited availability of radio spectrum and high inefficiency in its usage, new insights into the use of spectrum have challenged the traditional approaches to spectrum management. A cognitive radio is an intelligent wireless communication system that relies on opportunistic communication between unlicensed or Secondary Users (SU) over temporarily unused spectral bands that are licensed to their PUs. The FCC suggests that any radio having adaptive spectrum awareness should be referred to as Cognitive Radio.

A cognitive radio is a "smart" radio platform. White spaces change over time. A cognitive radio used for dynamic spectrum access "jumps" from one chunk of spectrum to another. Figure 1.1 represents the different actions taken by a cognitive radio as well as its interaction with the outside environment. The main functions of a cognitive radio used for accessing the spectrum opportunistically are

- Spectrum Sensing
- Spectrum Allocation
- Reconfiguration
- Transmission

The cognitive radio reconfigures itself to transmit in the open band, potentially changing its carrier frequency, transmit power and modulation scheme (to better match the available band).

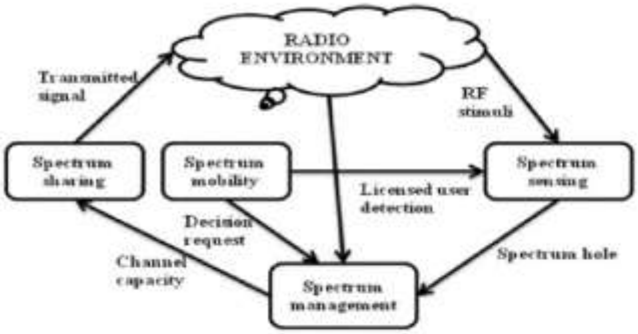


Figure 1.1 Cognitive Radio Cycle

Cooperative sensing is a solution to the "hidden node problem". The hidden node problem occurs when a primary user is far away from the cognitive transmitter but close to the receiver. The receiver will not receive the samples correctly because the cognitive transmitter and primary user transmit on the same band.

1.1 Cognitive Radio Features

Cognitive Radio systems have been seen as a promising solution to improve the current spectrum underutilization while accommodating the increasing amount of services and applications in wireless networks. Cognitive radio technology could potentially allow a complete SU system to simultaneously or opportunistically operate in the same frequency band as the PU. The inherent feature of these CR systems would be their ability to recognize their communication environment and adapt the parameters of their communication scheme to maximize the Quality of ServiceQoS) for the SUs while minimizing the interference. CR systems need to have a high degree of flexibility in order to overcome high variation in channel quality and interference. It will be built over Software Defined Radio (SDR) due to implicit realization of these characteristics in SDR transceivers are awareness of the radio environment, dynamic adaptability and highly efficient cooperative or non-cooperative behavior. A number of new mechanisms within these layers such as measurement of network parameters, reliable spectrum sensing (detecting un used spectrum), spectrum mobility (maintaining seamless transition to a new spectrum), coexistence (with PUs and other CR networks), spectrum management, reliability (in terms of QoS), resource allocation (such as transmit power allocation and dynamic spectrum sharing (DSS)) and so on, have to be designed for most efficient and practically harmless access and sharing of opportunistic radio spectrum. In addition, it is critical to best optimize these mechanisms for different situations in order to enhance network performance. Since PU channels have to utilize by secondary users in a CR network without causing any degradation in service to PUs, Orthogonal Frequency Division Multiplexing (OFDM) has been identified as a potential transmission technology for future CR systems. This is mainly due to its great flexibility in dynamically changing spectral environments and allocating unused spectrum among SUs, which allows for simple adaptation of sub-carriers to fast changing conditions in radio spectrum.

1.2 MIMO RADAR IMPACT ON MIMO COMMUNICATION SYSTEM

With increased bandwidth demands, spectrum scarcity has become a serious challenge, particularly regarding commercial utilization. In order to accommodate these growing bandwidth demands, many regulators and operators have taken the initiative of exploring a secondary access to very-high frequency/ultra-high frequency (VHF/UHF) bands occupied by radar. Spectrum sharing between the commercial cellular system and radar systems is a proposed solution to the spectrum-scarcity problem. This approach has been highly promoted by the National Telecommunications and Information Administration (NTIA) and Federal Communications Commission (FCC) in order to make use of the underutilized spectrum.

As a solution to the increased bandwidth demand problem, this approach promises enormous economic and social prospects but also brings in new challenges for the optimal operation of the incumbent radar systems and commercial cellular users. The spectrum-sharing approach also brings new challenges such as electromagnetic interference to the radar system or communication system. Traditionally, radar systems have high transmit power and high-peak side lobes, which have a negative effect on the communication system receivers that typically operate at lower power levels. This work considers multiple-input multiple-output (MIMO) radar waveforms as an interference to a MIMO communication system and the impact such interference has on the communication system with respect to the transmit power of radar waveforms, target reflection coefficient, and target direction.

2. RADIO INTERFERENCE MODELING FOR COEXISTENCE STUDY

In modeling radio frequency interference for coexistence study, three basic methods can be applied. The first method is the minimum coupling loss (MCL) method which is very simple and static as well as deterministic in nature as it analyses a single interferer and a single victim].

It takes relatively very short time to implement. Despite the merits of this method, it produces very pessimistic results which cannot be entirely relied on for establishing the feasibility of coexistence. Secondly, the Monte Carlo (MC) method is accurate and very reliable as it analyses
multiple interferers and victims. It models the system in a stochastic fashion to compute the aggregate interference. Its implementation is time consuming. The enhanced MCL (E-MCL) method is an intermediate between the MCL and the MC.

The results produced by the E-MCL method are more accurate than the MCL but less reliable as compared to the MC method. The A-MCL method is an extension
of MCL with PSD analysis, which is a basic framework for
this study. Radio frequency interference, which is the signal emitted from an undesired transmitter could degrade performances of a victimreceiver. where P_T is output power of the transmitter in dBW, $L_{FL,T}$ is feeder link losses between output of the transmitter and input of the transmitting antenna, G_T and G_R are gains of the transmitting and the receiving antennas, $L_{FL,R}$ is feeder link losses between output of the receiving antenna and the receiver input, L_{POL} is loss due to polarization mismatch of the receiving antenna, L_P is propagation loss (incorporating clutter loss) between transmitting and receiving antennas, and L_{FDR} is loss due to FDR.

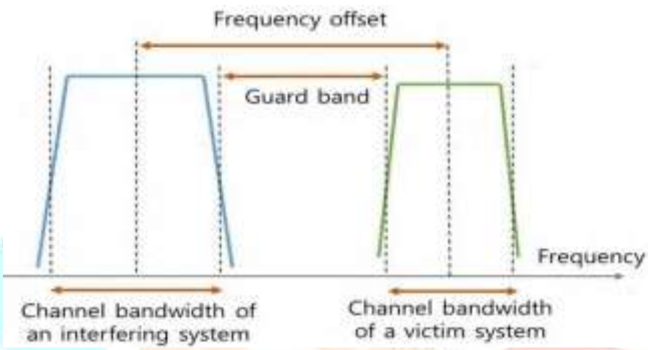


Figure 1.1 Cognitive Radio Cycle

3. SPECTRUM SHARING EFFORTS BETWEEN RADAR AND COMMUNICATION SYSTEMS

A study by the NTIA evaluated sharing of radar band with WiMAX systems and found that in order to protect WiMAX systems from radar interference huge exclusion zones up to tens of kilometers are required. This is due to high signal power used by radars and high-peak side lobes which saturate communication system receivers, which are traditionally designed to handle power levels in watts rather than kilo watts or megawatts. Such high peak powers are typical of airport surveillance radars, weather radars, and military phased array radars such as SPY-1 radar of Aegis system. On the other hand, due to highly sensitive radar receivers, designed to detect even the faintest of returned signal, has in the past mandated for exclusive rights to radio spectrum allocations since its operation can be affected by commercial wireless system interference.

The heterogeneous nature of devices sharing an RF band, radar and cellular sys- tem in our case, dictates the need for Electro Magnetic Interference (EMI) mitigation tactics for both systems since traditional interference mitigation tactics are meant for exclusive use of the same RF band. The emission pattern, both in space and time, of radar is significantly different from communication system. This point is also validated from a study by the NTIA, showing that radar receivers handle noise like interference from communications systems differently than the interference from other radars with former having detrimental effect on radar due to its continuous wide-band nature than the low duty cycle radar waveforms.

In the past, it has been made possible for wireless systems to share govern- ment bands such that they operate under a low-power constraint in order to pro- tect incumbents from interference. Example includes: Wi-Fi and Bluetooth in the 2450–2490 MHz band, wireless local area network (WLAN) in the 5.25–5.35 and 5.47–5.725 GHz radar bands, and recently the FCC has proposed small cells, i.e. wireless base stations operating on a low power, to operate in the 3550–3650 MHz radar band.

The 3550–3650 MHz band, currently used for military and satellite operations, is a possible candidate for spectrum sharing between military radars and broadband wireless access (BWA) communication systems such as LTE and WiMAX, according to the NTIA’s 2010 Fast Track Report. Electromagnetic interference to military radar operations is expected from spectrum sharing. However, one simply can’t relocate these federal radar systems to other bands since the nature of the said band contains many frequencies which work best for highly sensitive fixed, airborne, and maritime radar systems and are essential for superior performance. Moreover, cost to relocate can be unbearable. The problem of EMI mitigation is possible due to advancements in transmitter and receiver design technology, of cellular systems, which has made real-time spectrum reassignment possible.

In spectrum sharing perspective between radars and communication systems, EMI needs to be mitigated at both the systems. Communication systems due to their advancements give more freedom to mitigate interference from radar systems. Radar systems due to their sensitivity are more susceptible to interference from communication systems. So far, as previously discussed, in order to protect radar operations, communication systems operate on a low- power basis to avoid interference to radars or operate by sensing the availability of radar channel at a power level which doesn't exceed the allowed interference limit.

Radar systems are also evolving and with recent trend in design of MIMO radars and cognitive radars, radar systems are becoming more resilient in handling interference and jamming as they are more aware about their Radio Environment Map (REM). This has motivated researchers to propose beam forming approaches to mitigate interference from wireless communication systems to MIMO radar. In addition, spatial domain can also be used to mitigate MIMO radar interference to wireless communication system. One such technique was proposed which projected radar signal onto the null space of interference channel between MIMO radar and MIMO communication system.

The proliferation of wireless devices and services along with static spectrum allocation have resulted in the dearth of spectral resources, which has empowered the vision of spectrum sharing between federal incumbents, such as radar (maritime, surveillance, weather, etc.) and commercial communication systems, such as Cellular Systems (CSs). Coexistence between radar and communication systems through technologies, such as Cognitive Radios (CRs), Licensed/Authorized Shared Access (LSA/ASA) and Spectrum Access Systems (SAS) has captured the attention of both academia and industry. However, irrespective of the technology being used, spectrum sharing between radar and communication systems brings a new set of challenges into picture, such as the harmful interferences generated by CSs towards the radar and vice-versa, which can potentially degrade the Quality-of-Service (QoS) of both systems.

For coexistence of MIMO and MIMO cellular communication they presented a two tier spectrum sharing framework.

1) Transceivers were jointly designed at a hardware impaired FD CS under imperfect CSI considerations.

2) Null space based waveforms were designed at MIMO RS under perfect CSI considerations.

3) In particular, the robust optimization in the CS led to an intractable problem, which was transformed into an equivalent tractable semidefinite programming problem.

4) Algorithms were proposed to suppress interference at both systems, thus maximizing the PoD of RS and also maintaining a specific QoS for each user in CS.

5) Finally, it was seen that to facilitate spectrum sharing, thereby providing the users of CS with QoS of 5×10−5 bps/user, the MIMO RS needs to spend an extra power of 1.5−4.5 dB depending on the number of antennas it uses.

6) Overall, the designed framework provides the essential understanding for successful development of future cellular systems in conjunction with federal incumbents that can operate under same spectrum resource

4. OVERVIEW OF PROPOSED SYSTEM

The proposed system optimizes the performance of PoD using **Energy harvesting scheme** through unused spectrum holders and transmission makes between users in both of RS and CS by maximizing its communication. Channel estimation with low complexity is reduces the interferences CCI (cochannel interference) and SI (self-interference) meanwhile the power optimization also considered. The number of sub carriers (QAM) monotonically increasing is leads to improvise the QoS in communication. Three tier communication implemented in proposed system for above parameters implementation.

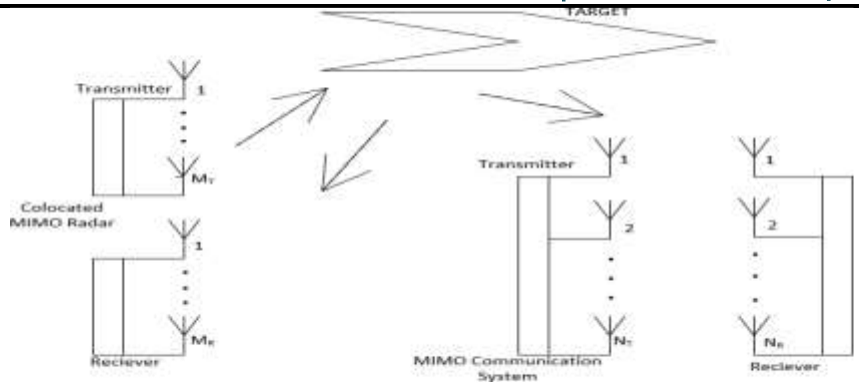
4.1 System model

This section describes both the MIMO communication system and the MIMO radar system. Figure 2 shows the coexistence of the two systems.

Hence, considering the i^{th} receive antenna j^{th} transmit antenna at the communication system and the k^{th} radar transmit antenna, the received signal can be written as

$$r_{ij} = \bullet \; {}_{ik} a_{ik} x_{ikr} + h_{ij} x_{ijN} ++ \bullet \; h_{il} x_{il} \cdot n_{ijl} \cdot \quad ....1$$

The radar component acts as interference to the communication system in addition to the interference signals from the remaining I_{th} transmit antennas at the communication system and the AWGN component. Hence, it is neglected. The propagation path traversed by the signal transmitted from the radar is usually characterized by the propagation loss factor and the target reflection coefficient.



4.2 MIMO Communication System

The MIMO communication system consists of N_T transmit antenna and N_R receive antennas. The received signal vector y(t) of dimension $N_R \times 1$ at the receive antenna of the communication system is

$$\mathbf{Y\ (t) = Hx\ (t) + n\ (t)}$$

Where H is the $N_R \times N_T$ Communications channel matrix, x(t) is the $N_T \times 1$ transmit signal vector from the N_T transmit antennas, and n(t) is the NT×1 Additive White Gaussian Noise (AWGN) vector of mean zero and variance one. The signals received on the N_R receive antennas from the N_T transmit antennas are desirable, and any other signals act as interference.

4.3 Spectrum Sharing

The received signal at the communication system is given by

$$r\ (t) = \square\ A(0)xr\ (t) + Hx(t) + n(t)$$

Hence, considering the i_{th} receive antenna j_{th} transmit antenna at the communication system and the k_{th} radar transmit antenna, the received signal can be written as

rij = αi k ai k xi k r + hi j xi j N++ hi l xi l α ni j l α j

The radar component acts as interference to the communication system in addition to the interference signals from the remaining I_{th} transmit antennas at the communication system and the AWGN component. Hence, it is neglected. The propagation path traversed by the signal transmitted from the radar is usually characterized by the propagation loss factor and the target reflection coefficient.

4.4 Propagation Loss Factor

The propagation loss depends on the target proximity (that is, distance from the transmit antenna to the target and also distance from the target to the receive antenna) and antenna properties. The propagation loss of the radar waveform from the K_{th} transmit antenna received at the i_{th} receive antenna of the communication system is given by

$$\mathbf{P_{i,k} = c} \ /\ d_{kt}\, d_{ir} \ \square\ A_{kt}\, A_{ir}$$

4.5 PROPAGATION PATH

Each propagation path between a set of transmitters, targets, and receivers has different characteristics, depending on path loss, target reflectivity, and phase errors.

4.6 TARGET REFLECTION COEFFICIENT

Suppose that the transmitters of the MIMO radar and the receivers of the MIMO communication system are separated far enough apart; then the reflection gains are independent. Also, if the target has a large number of small independent and identically distributed (i.i.d) random scatterers, then g_i would be i.i.d complex Gaussian vectors with a probability density function of mean 0 and variance □ 2 *I*. Hence, the target reflection gain vector for the receive antenna at the communication system is

g =[g , g , ... , g]T

5. MATHEMATICAL ANALYSIS

In this section, considering the work performed by Quack et al. the signal in equation received by the communication system is analyzed using a zero-forcing (ZF) equalizer at the receiver. The ZF equalizer applies the inverse of the channel to the received signal, to restore the signal before the channel. From the work of quoi et al., the ZF component is given by

rZF=(HHH)-1HH

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1M_T} \\ h_{21} & h_{22} & \cdots & h_{2M_T} \\ \vdots & \vdots & \vdots & \vdots \\ h_{M_R1} & h_{M_R2} & \cdots & h_{M_RM_T} \end{bmatrix}$$

Considering equations (11) and (20),

$$r_{ZF}^{ij} = \left(h_{ij}^{H} h_{ij}\right)^{-1} h_{ij}^{\ H} r_{ij}$$

$$r_{ZF}^{ij} = (h_{ij}^{H} h_{ij})^{-1} h_{ij}^{H} [\alpha_{ik} a_{ik} x_{ikr} + h_{ij} x_{ij} + \sum_{l \neq j}^{N_T} h_{il} x_{il} + n_{ij}]$$

$$r_{ZF}^{ij} = (h_{ij}^{H} h_{ij})^{-1} h_{ij}^{H} \alpha_{ik} a_{ik} x_{ikr} + (h_{ij}^{H} h_{ij})^{-1} h_{ij}^{H} h_{ij} x_{ij} + (h_{ij}^{H} h_{ij})^{-1} h_{ij}^{H} \sum_{l \neq j}^{N_T} h_{il} x_{il} + (h_{ij}^{H} h_{ij})^{-1} h_{ij}^{H} n_{ij}$$

$$SINR = \frac{1}{\frac{1}{g_{ij}^{H} g_{ij}} [\alpha_{ij}^{2} a_{ij}^{2} + N_T \sum_{l \neq j}^{N_T} g_{il} g_{ij}^{\ H} + 1]}$$

From equation $g_{ij} = \sqrt{\beta_i} h_{ij}$. Hence, the SINR becomes

$$SINR = \frac{1}{\frac{1}{\beta_{ij}^{2} h_{ij}^{H} h_{ij}} [\alpha_{ij}^{2} a_{ij}^{2} + N_T \beta_{il} \beta_{ij} \sum_{l \neq j}^{N_T} h_{il} h_{ij}^{\ H} + 1]}$$

$$SINR = \frac{1}{\frac{1}{h_{ij}^{H} h_{ij}} [\alpha_{ij}^{2} a_{ij}^{2} + N_T \sum_{l \neq j}^{N_T} h_{il} h_{ij}^{\ H} + 1]}$$

5.1 WATER FILLING ALGORITHM

Develop a proposed water filling algorithm for MIMO fading channel (Rayleigh Fading channel). MIMO is a promising high data rate interface technology. It is well known the capacity of MIMO can be significantly enhanced by employing a proper power budget allocation in wireless cellular network.

The process of water filling algorithm is similar to pouring the water in the vessel. The un shaded portion of the graph represents the inverse of the power gain of a specific channel. The Shadow portion represents the power allocated or the water. The total amount on water filled (power allocated) is proportional to the Signal to Noise Ratio of channel.

Where Pt is the power urge of MIMO system which is allocated among the different channels and H is the channel matrix of system. The capacity of a MIMO is the algebraic sum of the capacities of all channels and given by the formula below.

Power allocated =pt+Σ(1/Hi) /Σ channel (1/-Hi)

$$\text{Capacity}= \sum_{i=1}^{n} \log(1 + PowerAllocated * H)$$

6. SOFTWARE ANALYSIS

MATLAB is a high-performance language for technical computing. It integrates computation, programming and visualization in a user-friendly environment where problems and solutions are expressed in an easy-to-understand mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows the user to solve many technical computing problems, especially those with matrix and vector operations, in less time than it would take to write a program in a scalar non interactive language such as C or FORTRAN. MATLAB features a family of application-specific solutions which are called toolboxes. It is very important to most users of MATLAB that toolboxes allow to learn and apply specialized technology. These toolboxes are comprehensive collections of MATLAB functions, so-called M-files that extend the MATLAB environment to solve particular classes of problems. MATLAB is a matrix based programming tool. Although matrices often need not to be dimensioned explicitly, the user has always to look carefully for matrix dimensions. If it is not defined otherwise, the standard matrix exhibits two dimensions $n \times m$. Column vectors and row vectors are represented consistently by $n \times 1$ and $1 \times$matrices, respectively. The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development and analysis. MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to *learn* and *apply* specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

7. RESULT AND FUTURE SCOPE

Spectrum sharing between the MIMO radar system and the MIMO communication system is promising in terms of mitigating spectrum scarcity; however, the effects of interference from the MIMO radar system to the MIMO communications system must be examined carefully. The target and target-scattering characteristic is of importance and should be look at closely. From the analysis and results, it can be concluded that the variation of transmitted power from the MIMO radar transmit antennas affects performance of the MIMO communications system. It is shown that when the radar transmit antennas transmit at unit power, the BER of the communication system is very high implying that performance at the MIMO communication system will be drastically reduced and the quality of service is increased along with the energy harvesting scheme.

The system model considered MIMO radar and a MIMO communication system with both ten receive and transmit antennas. Also, only a single point target was considered. With regards to the future research, the following points below will be taken into considerations: Firstly, instead of a single point target, the future research will consider multiple targets at different orientations (that is target range and target direction) with varying scattering power for each elemental scatter on the targets. Secondly, the future work will research advanced mitigation techniques to reduce the impact of the interference from the increasing number of targets and improve the performance at the communication system.

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