Coexistence of Overlapped MIMO Radar and Communication Systems using MATLAB

by

Ahmed Abdelhadi

Review Article with MATLAB Instructions
2019

University of Houston
# Table of Contents

List of Tables  
List of Figures  

Chapter 1. Introduction  
1.1 Motivation, Background, and Related Work  
1.2 Radar and Communications Systems  

Chapter 2. Overlapped MIMO Radar in Coexistence Scenarios  
2.1 System Model  
2.1.1 Projection Algorithm  

Bibliography
List of Tables
List of Figures

2.1 System Model ......................................................... 4
2.2 Overall Gain (dB) .................................................... 8
2.3 Overall Gain with NSP (dB) ................................. 9
Chapter 1

Introduction

This report is a MATLAB simulation tutorial for the plots in [1]. The report starts with a background on the radar communications coexistence prior work and the importance of coexistence scenarios on the performance of communication systems. Then, it provides a code tutorial for plotting the figures in [1].

1.1 Motivation, Background, and Related Work

In our model, we utilize the advantages of Multiple input multiple output (MIMO) radars. MIMO radars show better performance compared to phased-array radar [2–4] due to inherent degrees of freedom in waveforms. In the future, MIMO radars will replace phased array radars currently deployed by the military [5–10]. Due to the waveform diversity of MIMO radars, they are more suitable for coexistence scenarios over phased-array radar [11–22]. For this report, we consider overlapped MIMO radar which is a hybrid between MIMO radar and phased-array radar with detailed description of it presented in [1].

In [23], the President Council of Advisers on Science and Technology (PCAST) recommended the commercial mobile network service share the spectrum of shipborne radar [24–26] as this will have significantly technological and economical benefits to the United States. Similar statement from the Federal Communications Commission (FCC) points to sharing of the shipborne radar spectrum [27,28] with commercial wireless spectrum [29,30]. More studies on the effects of radar and communications coexistence on interference was performed by the National Telecommunications and Information Administration (NTIA) [31–33] and by researcher in [34–37] and authors in [38–40] showed
Given the growing demand for wireless services, the need to a significant boost to the throughput of wireless communication networks is increasing [41–44]. With MIMO communications systems [45–49], the exploitation of spatial dimension led to an increase of the wireless throughput [50–54]. However, there is still growing demand that needs to be met with spectrum sharing of underutilized radar spectrum to further improve quality of service (QoS) [55–57] and quality of experience (QoE) [58,59]. Prior work on QoS of Open Systems Interconnection (OSI) Model for network layer is in [60–63], for physical layer is in [64,65], and for application layer is in [66,67]. Energy efficiency considerations and game theory tools were presented in [68–70], and [71–74], respectively, applied to Long Term Evolution (LTE) third generation partnership project (3GPP) [75–77], Universal Mobile Terrestrial System (UMTS) [78–80], Mobile Broadband [81,82], and Worldwide Interoperability for Microwave Access (WiMAX) [83–85]. Enhancing QoS with cross-layer design was shown in [86,87], while battery life and embedded-based systems inclusion was provided in [88–92], and scheduling and shaping in [93–99].

Coexistence scenario benefits both radar and wireless communication systems. On the wireless communication side, resource allocation algorithms with coexistence provide better throughput and overall QoE for delay-tolerant applications [100–103]. Some resource allocation techniques for delay-tolerant applications are proportional fairness [104–106], max-min fairness [107–110], and optimal allocation [111–114]. More importantly the bandwidth demanding real-time applications [115–123] can significantly benefit from coexistence scenarios. Prior resource allocation for real-time applications are either approximate solutions such as the work in [124–126] or optimal solutions as in [127–134] using optimization techniques [135–140]. Mergence of resource allocation with coexistence is emphasized in carrier aggregation techniques [141–145]. With optimal performance can be achieved by convex optimization techniques [146–149].

Tools developed in this work can benefit other areas such as ad-hoc networks [150–153], multi-cast networks [154], machine to machine (M2M) communications [155–157], and other wireless networks [158–162].
1.2 Radar and Communications Systems

In the simulation of results in [1], uses the following system model. We start the MATLAB code by clearing and closing other programs using. In MATLAB:

```matlab
close all;
clear all;

The simulation parameters for our model are:

In MATLAB:

```matlab
M = 20;
M_r = 20;
no_subarrays = [1 5 10 20]; % {1, 5, 10, 20} corresponds to number of elements in Overlapped MIMO subarray
```
Chapter 2

Overlapped MIMO Radar in Coexistence Scenarios

2.1 System Model

In [1], we consider a coexistence scenario where the communication system has MIMO antennas and the radar system has overlapped MIMO antennas. The radar system is assumed to be shipborne on military ships on the east or the west coasts of the US as shown in Figure 2.1. The radar uses null space projection (NSP) as in [163–165] to avoid interference with the communication system.
2.1.1 Projection Algorithm

We provide a MATLAB code for coexistence that utilizes the hybrid MIMO radar introduced in [166] with MATLAB code in [167] and is extended in [1] for overlapped MIMO coexistence.

- Implement singular value decomposition (SVD) on the channel between radar and communications systems followed by null space projection to mitigate harmful interference.

In MATLAB

```matlab
%%

N_R = 5; % No of receive Antennas

%% VIRTUAL ARRAY W/O A_R

P = []; % No of receive Antennas
H = randn(N_R, no_subarrays * M_sub) + j * randn(N_R, no_subarrays * M_sub);
P = null(H) * ctranspose(null(H));
v_sv2 = [];

for kk = 1:no_subarrays
    for mm = 1:M_sub
        v_temp2 = [];
        w_u = W_u(mm,kk);
        for jj = 1:length(Theta)
            v_temp2 = [v_temp2, (w_u' * Tx_sv(kk + mm -1, jj))];
        end
        v_sv2 = [v_sv2; v_temp2];
    end
end
```
v_sv2_P = P * v_sv2;

v_sv3 = [ ];
for vv = 1:no_subarrays * M_sub
    v_temp3 = [ ];
    for jj = 1:length(Theta)
        v_temp3 = [v_temp3, (v_sv2_P(vv, jj)) * Rx_sv(:,jj)];
    end
    v_sv3 = [v_sv3; v_temp3];
end

%%% For Projection case uncomment %%%%%

v_sv = v_sv3;

%% Code for plotting of Overall Gain without NSP is shown below and plotted in Figure 2.2.

In MATLAB:

Theta = Theta_grid;
plot(Theta*180/pi,1.02*Rx_pattern_conv(2,:),'g',
    Theta*180/pi,Rx_pattern_conv(3,:),'b',Theta*180/
    pi,Rx_pattern_conv(4,:),'k--',
    grid
axis([-40 40 -100 30])
xlabel('Angle (deg)')
ylabel('Overall Gain (dB)')
Code for plotting of Overall Gain with NSP is shown below and plotted in Figure 2.3.

In MATLAB:

```matlab
figure;
Theta = Theta_grid;
plot(Theta*180/pi,1.02*Rx_pattern_conv_proj(2,:),'g',Theta*180/pi,Rx_pattern_conv_proj(3,:),'b',
    Theta*180/pi,Rx_pattern_conv_proj(4,:),'k--','linewidth',2),grid
axis([-40 40 -100 30])
xlabel('Angle (deg)')
ylabel('Overall Gain (dB)')
legend('Overlapped-MIMO Radar w/ NSP (K=5)','Overlapped-MIMO Radar w/ NSP (K=10)',
    'MIMO Radar w/ NSP (K=20)')

%%%%%%%%%%%%%%%%%%

• Code for plotting of Overall Gain with NSP is shown below and plotted in Figure 2.3.

In MATLAB:

```
Figure 2.2: Overall Gain (dB)
Figure 2.3: Overall Gain with NSP (dB)
Bibliography


[45] M. Brady, M. Mohseni, and J. Cioffi, “Spatially-correlated jamming in
 gaussian multiple access and broadcast channels,” in Information
 Sciences and Systems, 40th Annu. Conf. on, Mar. 2006.

[46] D. Chi and P. Das, “Effects of jammer and nonlinear amplifiers in
 MIMO-OFDM with application to 802.11n WLAN,” in Military Com-

[47] Y. Cho, J. Kim, W. Yang, and C. Kang, “Mimo-ofdm wireless commu-

 jamming strategies in gaussian mimo channels,” in Vehicular Technology

 of carrier frequency offset synchronization for MIMO-OFDM systems,”
 in Wireless, Mobile and Multimedia Networks, 2006 IET International
 Conference on, November 2006.

 of carrier interferometry/OFDM,” in Wireless And Mobile Computing,
 Networking And Communications. IEEE Int. Conf. on, Aug. 2005.

 of SLM based DFT spreading OFDM system for active anti-jamming

 in partial-band noise jamming,” in Information Sciences and Systems,
 44th Annu. Conf. on, pp. 1 –6, Mar. 2010.

[53] M. Han, T. Yu, J. Kim, K. Kwak, S. Han, and D. Hong, “An efficient
 channel estimation algorithm under narrow-band jamming for OFDM

 brid ARQ Schemes of 3GPPLTE OFDMA System,” in Personal, Indoor


[78] European Telecommunications Standards Institute, “UMTS; LTE; UTRA; E-UTRA;EPC; UE conformance specification for UE positioning; Part 1: Conformance test specification,” 2012.

[79] European Telecommunications Standards Institute, “UMTS; UTRA; General description; Stage 2,” 2016.


[82] IXIACOM, “Quality of Service (QoS) and Policy Management in Mobile Data Networks,” 2010.


