MIMO Radio Providing Concurrent Vehicular Safety And Communication

D. Kandar[1] *and* *Rabindranath Bera* [1]

[1]Sikkim Manipal Institute of Technology, Sikkim Manipal University,Majitar, Sikkim, India 737132,
E-mail : dkandar @rediffmail.com, Phone: 09932778779; Fax: 03592-246112.

Abstract

In the development process of smart vehicle, communication and safety aspects are thought of. Systems are being developed using commercial WiFi N adapters and Matlab software. The performances are tested satisfactorily. For the betterment, the SDR kit is interfaced with the system replacing the commercial WiFi adapters. The innovative idea of exploiting the digital communication technology towards radar is being carried over. Lab models are almost ready and a Lab environment is created to simulate the road condition. The systems are being tested at the Lab both for concurrent Communication and safety aspects. Some preliminary testing on road was conducted.

1. Introduction

With the rapid growth of MIMO Technology [1]for wireless application and easy availability of several books on ' Smart Antennas' [2] [3] [4], a trend is noticed for the development of MIMO radar for smart car(Intelligent Transport System) ITS application. A recent trend is noticed towards space domain processing resulting in (Space Time Processing) STP. Putting multiple antennas both at transmitter and receiver along with (Direction of arrival) DOA estimation and antenna pattern synthesis (adaptive beam forming), the antenna beam may be focused to a particular targets. A multiple access in the form of SDMA can be thought of, for multiple targets detection and information using STAP/MIMO. DSP algorithms are smart enough to enable above mentioned technology with the result of improved target detection buried in clutter, interference and multi path condition. Considering the poor signal conditions at the radar receiver, authors are prompted to develop MIMO radar for Car collision avoidance.

2. Background Information

Digital array radars in the form of MIMO are the technological growth borrowed from wireless communication technology. Recently, the authors are well experienced with three PC adapters namely

1) AGP adapters (make: ATI. Model : 6800). This adapter when fitted within a PC has the features of composite 'Video Out' connectivity utilizing its own DAC.
2) TV Tuner Card Adapter (make: Frontech Model: JIL0606) . This adapter when fitted within a PC has the features of composite 'Video IN' connectivity utilizing its own ADC. We like to explore those DAC and ADC features for Pulse In/Out connectivity with our MIMO RADAR radio Unit.
3) IEEE 802.11 (Draft) N PCI adapters (make: D-Link Model : DWA547) [5]: This has the features of using 3 external antennas where antenna pattern synthesis can be done following DOA of signals from targets. Wi-Fi N routers & adapters are the new entry in the commercial market. The adapters consists of Two ICs namely a) MAC & base band processor b) Up-converter , Power Amplifier , Transmit and receive beam former for smart antenna , Down-converter & others operating in the frequency band 2.4 -2.48 GHz. Base band processing involves MIMO codec and OFDM modem using a 32 bit microcontroller. When fitted in a PC, the adapters are useful as a node serving the user with 300 Mbps data rate. The adapter uses PC resources for the other 5 layers in typical 7 layer based computer communication ISO architecture. The Data, address & control signals available from the MAC IC is normally utilized for feeding the application data from upper layers. A different varieties of multimedia data like voice communication, VOIP service, MPEG1, MPEG2 quality video services, data chatting, whiteboard services etc. can be easily channelized through this data bus external to the MAC IC.

   Those three PC adapters capabilities are explored here for the said development of MIMO radio utilizing the XPC target mode of MATLAB/ SIMULINK which is also providing the better RTOS.

3. MIMO Radio For Vehicular Communication

Authors The PC when fitted with 3 adapters are useful for providing car to car communication using its ADHOC mode of operation and supporting multimedia services. Additionally, Car to roadside Communication is also established by putting the wireless router at the road. The windows net meeting software is useful for such services.

4. MIMO Radar System Block Diagram

Instead of sending the multimedia communication data, the authors are encouraged to send data related to different complex radar waveform generation and reception which can be generated digitally through Matlab based PC programming. Alternatively, analog Pulse waveform can be transmitted. It necessities a DAC and ADC for analog pulse in and out to be fitted in the PC . The two PCI cards namely AGP and TV tuner card serve the above purpose. Fig 1. shows such a MIMO radar experimental configuration.

A MIMO system is formed by putting 3 antennas at the radio units which results in a good interference, clutter as well as multipath rejection with a better focus towards the target and higher SNR. The distant target is simulated at the laboratory using another WI-FI N adapter having the same configuration as in Fig.1 with a loop back at the 'Video In' and 'Video Out' terminal.

5. Software Procedures

i) Matlab is our development platform under windows

ii)A conversion of the matlab file from the *.m or *.mdl file to its next lower level *.c is required and real time workshop is helpful in this regard which is embedded with the Matlab.

ii)We required to load ' The Visual Studio V6.0 ' for conversion of *.c to *.rtb.

iii) This final *.rtb file is an executable file during boot up sequence of XPC target. Therefore, hard disc drive of the PC is required to be partitioned by two. Window based Matlab/ Simulink /Visual Studio is loaded in one partition .

iv) All the developments is carried out in one partition and the resulting three final files (Autoexec.bat, function.com and function.rtb) are copied in the C: drive of the second partition. By giving the proper choice at the Boot sequence of the PC, it is very easy to start the standalone mode of XPC target It will automatically load the RTOS kernel over which the application will reside.

6. Experimental Results

Some interesting return is obtained from the distant target when placed at different distances.

i) We are able to resolve the nanosecond pulse delay providing the range information about the target

ii) Determination of target RCS:

The AGC is monitored at the received end which is useful for target gross RCS detection

Three Targets having the dimensions depicted in Table 1 are placed near the MIMO RADAR.

The net energy concentration of the incident radiation from the targets will be towards their focus as they are parabolic in nature. Accordingly the measured received beam patterns are tabulated in the Table 2.

A calibration curve is shown in Fig 2 which can be drawn out of those results and it will be useful in finding any unknown objects RCS of similar kind.

iii) Additionally, the moving target is discriminated from the static objects using Doppler frequency extraction from the pulse waveform.

With such success at the Laboratory, we are exploring the radar and its simulated target to put them in two moving cars and are trying to find the following on the road.

1. To nearest car detection
2. Measurement of the nearest car's velocity through its Doppler
3. Gross size of the nearest car which will help to monitor the types of cars passing by.

In this way, we are able to explore the MIMO radar for road situation and may be able to avoid the collision at the road.

7. Software Simulation For The Performance Analysis Of The IMO Radar.

The total simulation results are summarized as follows:

1. The performance of the MIMO CODEC in terms of BER vs. SNR plots.
2. The performance of the OFDM modem in terms of BER vs. SNR plots.

OFDM is the best performer as compared to others like spread spectrum modem which is effective in distributing the data over its multiple carriers lowering the effective data rate and improving the multi path performance.

3. The performance of the MIMO OFDM[1] (overall system) in terms of BER vs. SNR plots.

The performance is analyzed for 2x2 MIMO case and found to be highly depends on the convolution coding rate and the no. of FFT carrier. A BER performance of the order of 10^{-05} can be achievable for low S/N ratio within 2 dB for convolution code rate of ¾ which is never achievable before using traditional digital modulation and channel coding.

4. Pattern synthesis of the 3 antennas using DOA estimation by MUSIC algorithm , adaptive beam forming, OSTBC algorithm [6][7]. Fast DOA sensing is achieved which is really usable for SDMA systems.
5. Nulling the unwanted objects by Null steering beam formation

The nulling interference level of more than 80 dB is noticed which is adequate for good system performance.

6. Finding the limitation of MUSIC algorithm in terms of its spectral resolution and measuring its defocusing percentage .

We are able to measure the 'Q' value of the MUSIC and its gradual falling rate (defocusing percentage). The high resolution spectral estimation using MUSIC to be improved further as the 'Q' value of the MUSIC is not so sharp as expected.

8. Conclusion

Please The two Lab models are almost ready and a Lab environment is created to simulate the road condition. The systems are being tested at the Lab both for concurrent Communication and safety aspects. Some preliminary testing on road was conducted. The rigorous testing are yet to be conducted on the road.

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9. Acknowledgments

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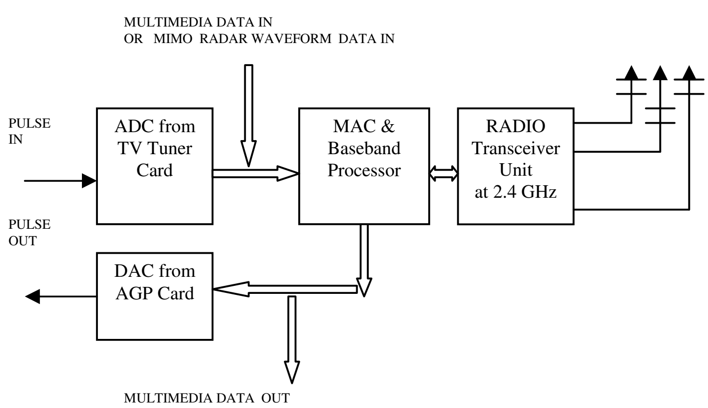

Fig. 1: A MIMO radar Block diagram utilizing a PC fitted with 3 PCI adapter cards.

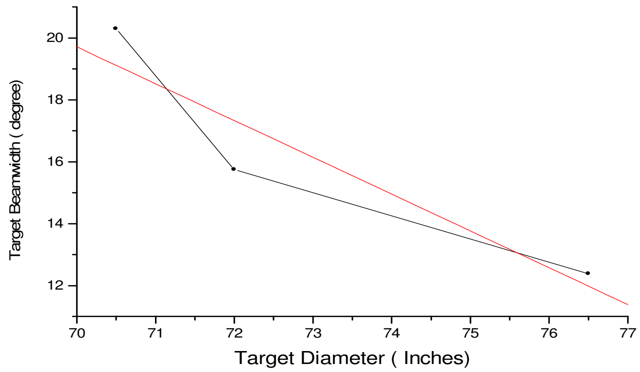

Fig 2 The Calibration Curve for RCS measurement of Azimuth angle.

Target Name	**Target Shape**	**Diameter of Major Axes A (inch.)**	**Curvature of Major Axes B (inch.)**	**Diameter of Minor Axes C (inch.)**	**Curvature of Minor Axes D (inch)**	**Remarks**
Target 1	Parabolic	76.5	78.5	76.5	78.5	Target is symmetric
Target 2	Parabolic	70.5	72	76.5	78.5	Target is asymmetric
Target 3	Parabolic	72	76.5	72	76.5	Target is symmetric

Table 1. Target placed near the MIMO RADAR

Target Name	3 dB Beamwidth in degree (Azimuth)	3 dB Beamwidth in degrees (Elevation)
Target 1	12.375	2.5
Target 2	20.3	27
Target 3	15.75	11

Table 2. Measured Received Beam Widths for the Targets.