MODELLING AND IMPLEMENTATION OF ITS CHANNEL ESTIMATION AND IMAGING RADAR: AN IMPACT ON REMOTE SENSING AND ITS SYSTEM

1 NIRMALENDU BIKAS SINHA, 1 MANISH SONAL, 2 R. BERA and 3 M. MITRA

2 Sikkim Manipal University, Majitar, Rangpo, East Sikkim, India.
3 Bengal Engineering and Science University, Shibpur, Howrah, W.B, India.

ABSTRACT

We are proceeding towards a broadband age both for the communication as well as remote sensing. Recently, CALM standard has already been formulated by ITU with objectives of collision avoidance between car to car as well as car to roadside communication and safety by utilization of Sensor-friendly vehicle. Millimetre wave radar is mandatory in every car to locate accurate position. Lots of works can be thought of relating to the radar. In radar, a target is characterized by its radar cross section (RCS) function. RCS measurements and its system developments at UHF and Low frequency range are the challenging assignments for the Engineers. The antenna beam width is poor at such low frequency ranges. So, lots of additional constraints from the channel will pollute the system performance. Proper design, waveforms, and signal processing are very important for the system designer. Implementation of modern SDR in the system may be the best choice. Correlation based system design is also another preference for the system designer. Of course some additional advantages are also there and some portion of the objects which were previously invisible at high frequencies now will become visible. In this paper a multifunctional operations in system realization for radar & communication technology has been tried for moving vehicle application. The system is tested at the laboratory and also in the open test bed. Field trial is yet to be undertaken in vehicles for ensuring a reliable communication and collision avoidance as intelligent transport system. SDR based design approach is tried for the individual and total system. However, at the initial phases, conventional non SDR based methods were tried for individual systems. Observation leads to the fact that in each type of receivers, e.g., radar and communication; for target identification, radio noise detection and reception of transmitted signal respectively, demand autocorrelation method to be adopted as one of the performance enhancement techniques implemented separately

Keywords: ITU, UHF, SDR, ACC, AWGN.

1. INTRODUCTION:

Dispersions in signal are very common phenomenon, particularly when the signal is radiated in space with its modulated carrier and as a consequence, the radio system is severely affected resulting in performance degradation of the system. During design of imaging radar for collision avoidance of Cars in ITS (Intelligent Transportation System) application, the authors have worked a lot in this direction so that their radar system will not be disturbed from environmental effects. This will ensure reliability and is highly essential as it relates to ACC (Automatic Cruise Control) of Car. Transmitted radar signal may suffer from all types of dispersions namely i) Time dispersion ii) Frequency dispersion and iii) Spatial/angular dispersion. Time dispersion will be effective when antenna is exposed to multipath environments whereas frequency dispersion relates to step frequency operation of the imaging radar. When one broad beam width antenna is looking to the multiple cars on the road or multiple MIMO antennas are looking to a single car; the radar signal will face the angular dispersion. So the dispersion effects are required to be measured accurately and proper equalization techniques to be implemented in the system for restoration of the performance.
2. THE IMAGING RADAR SYSTEM

The SS-SF (SS = Spread Spectrum; SF= Step Frequency) imaging radar system is designed as per the ITS requirement. SS waveform composed of a 13 bit barker code with waveform duration of 200 nsec with a pulse repetition of 6.5 µsec. The Radar will be operational at center frequency of 5.8 GHz with SF of 5 MHZ, total bandwidth of 2000 MHZ and with the total step of 2000/5 = 400 points. A good quality image is the objective to recognize the vehicle on the road which is possible with 400 points of radar operation.

3. THE ITS CHANNEL ESTIMATION

Different preambles can be added in radar waveform considering severe dispersion effects from ITS channel. Those preambles composed of known vector signals or coded pulses which are referred at the receiver for solving different channel related problems like multipath, interference, time, frequency and angular dispersions. Here, the authors are motivated to cascade preambles in time. Preamble1 will be the several cycles of CW Pilot signal to be referred at the receiver for multipath energy exploitation resulting in Chan_est1 whereas Preamble 2 will be PN codes places next in time frame extracted at the receiver for correlation with reference PN code resulting in Chan_est2 to be used to avoid Interference and frequency dispersion. The same preamble 2 will be used for multiple antenna configuration (MIMO) resulting in Chan_est3 to be used to avoid angular dispersion.

3.1 SIMULATION OF TIME DISPERSION FOR ITS CHANNEL

3.1.1 THE SCHEME FOR THE CHANNEL ESTIMATION

A pilot symbols as in Fig .1a and 1b that are used to sound the channel and provide an estimate of the momentary channel state (value of the weighted phasor) for a particular multipath finger. Then the received symbol is rotated back to the reference direction using PLL, so as to undo the phase rotation caused by the channel. The following Fig. 1b may be referred for it. The reference vector with amplitude of 1 volt and reference phase of 45 degree may be useful for the channel estimation for the removal of time dispersion from the measured target data. A phase lock loop composed of i) a multiplier ii) a low pass filter iii) a variable integer delay and iv) a loop which will measure the phase error and position the spectra in bore sight direction. In this way use of PLL in each finger, all the signal components from prominent multi path fingers will be positioned at the reference vector directed to the bore sight target direction.

Fig.1a: The scheme for channel
Fig. 1.b: The Reference Pilot
A pilot symbols as in Fig. 1a and 1b that are used to sound the channel and provide an estimate of the momentary channel state (value of the weighted phasor) for a particular multipath finger. Then the received symbol is rotated back to the reference direction using PLL, so as to undo the phase rotation caused by the channel. The following Fig. 1b may be referred for it. The reference vector with amplitude of 1 volt and reference phase of 45 degree may be useful for the channel estimation for the removal of time dispersion from the measured target data. A phase lock loop composed of i) a multiplier ii) a low pass filter iii) a variable integer delay and iv) a loop which will measure the phase error and position the spectra in bore sight direction. In this way use of PLL in each finger, all the signal components from prominent multi path fingers will be positioned at the reference vector directed to the bore sight target direction.

### 3.2 SIMULATION OF FREQUENCY DISPERSION FOR ITS CHANNEL

The time dispersion and multipath problems are solved by above mentioned technique and the Rayleigh channel thus becomes AWGN channel. But still frequency dispersion effect persists due to SF mode of radar operation. A frequency domain equalizer as shown in Fig 2, utilizing a PN coded pilot may be more suitable to solve this problem. Initially the transmitter sends a training sequence, consisting of a standard set of symbols which are known to the receiver. With the reference and the transmitted training sequence the errors can be calculated exactly, and the equalizer coefficients are adapted in this training or reference-directed mode to provide a good initial solution. Depending upon the equalizer coefficients and by iterative processes the received signal is equalized.
3.3 SIMULATION OF ANGULAR DISPERSION FOR ITS CHANNEL

We can improve the performance of a system in term of minimizing ISI, improving SNR and equalization by using MIMO system as Fig 3a and 3b. These are the requirement for properly detecting the target or visualize them.

For a two antenna MIMO system we to send two training sequence with 180° phase difference between them as shown in Fig 3c for channel estimation. The block diagram for the channel estimation is shown in Fig 3d and at the output we get original data having constellation as shown in Fig 3b.

4. EQUALIZATION AND RESTORATION OF PERFORMANCE

4.1 EQUALIZATION AND RESTORATION OF PERFORMANCE FROM TIME DISPERSION

The corrupted data from channel time dispersion may be corrected to original target data utilizing the method of de-convolution. This can be easily implemented using a multiplier having channel estimation as one input and corrupted data as another input and output will result the recovered target data as shown in Fig. 4.
5. ITS CHANNEL MODEL SIMULATION AND IMPLEMENTATION

The authors have developed an ITS channel model simulator using MATLAB and XILINX Block sets. Different channel parameters are user defined and can be set through Matlab channel visualization tool. The dispersion effects as mentioned above can be visualized. FPGA Software Defined Radio based hardware can be built after porting the program to the SDR board. An outdoor V2V (Vehicle –to- Vehicle) experiment will be conducted after addition of RF part to the developed SDR subsystem. The field trial of the Imaging radar can be conducted at our later phases.

5.1 DATA SOURCE CONFIGURATION FOR THE ITS CHANNEL

In any channel estimation, we first go for the generation of data source and here the authors have taken the reference data source from the Xilinx Block sets. The ITS channel is priory fed by that data source [covariance matrix of 4X4] which is basically generated by a ROM (as depicted in Fig. 5). The element data of Co variance matrix will be out from the ROM sequentially with proper addressing to the ROM. It results in addressing sub blocks and additional Boolean control lines.

5.2 ITS CHANNEL MODELING USING DUAL PORT RAM

The 4 MIMO antennas are being considered here and they are in simultaneous frame data transmissions. So the propagation paths for each MIMO antenna would have to undergo the delays (due to multipath), pulse broadening effects, noise fading (Phase as well as Spectrum). All these considerations are being taken care of in our ITS channel estimations. At the source end, the whole data coming from 4 MIMO antennas are tactfully addressed to register themselves (element wise) in a ROM and stored as a covariance matrix. In the addressing technique, which is employed to pull out those elements that are being propagated throughout the ITS channel and facing the Delays (due to multipath), pulse broadening effects, noise fading (Phase as well as Spectrum). So these changed data are being registered in a dual port RAM.
which is equivalently reflecting the phenomenon of a Memory aided Raleigh channel. The Fig. 6 is depicting the reference of using a Dual Port RAM to establish the fact of ITS channel Delays (due to multipath), Pulse broadening & Noise fading.

6. TARGET RANGE/Delay MEASUREMENT USING SDR.

In our model we used two loops one for frequency variation and other for angle variation. The second one is nested to the first loop. All the measured data are stored in a matrix as shown in the previous fig. and two dimensional FFT is performed using “fft2” function of MATLAB and stored in another matrix. Now plotting this matrix against range (x-axis) and cross-range (y-axis) we obtain the 2D image of the targets and hence targets are separated.

Fig. 7: The Implemented DSP Block For Spreaded Symbol With One Delay Channel
7. 2D RADAR IMAGING

The basic data set needed for radar imagery consists of sets of coherent RCS patterns collected at regularly spaced frequency intervals. The measured data set (solid dots) may be padded with zeros (open dots) to artificially improve resolution or to expand the effective data set to integral power-of-two sampling. The measured data need not be confined to one corner of the padded array as shown here. We must apply FFT twice, once along the angle variation, and once along the frequency variation; it does not matter which one is done first. The resulting image is a set of complex numbers (amplitude and phase) that we must visually display for interpretative or diagnostic purposes.

\[
G(f, \theta) = \sum_{x} \sum_{y} g(x, y) \exp[i \frac{4\pi}{c}(xf\sin\theta + yf\cos\theta)]
\]

\(G(f, \theta)\) = a discrete set of coherent samples of a continuous function (the target RCS) that does not depend on how we sample it. \(g(x, y)\) = complex amplitude distribution of the target scatterers projected onto the plane of rotation = speed of light; \(f\) = the instantaneous frequency, \(x\) and \(y\) = the cross range and range locations of scattering centers in the scene.

Fig. 9. 2D RADAR imaging fundamental
Fig. 10. 1D cross range imaging for three point scatter Fig. 11. 1D range imaging for three point scatter

Fig. 12. 2D radar image for three targets

8. ITS CHANNEL VISUALIZATION

MATLAB is enriched to provide us the Communications Toolbox used to plot function that helps us to visualize the characteristics of a fading ITS channel using a GUI. We have completely utilized those toolbox to scope the several features of an ITS channel.

(i) Impulse Response: This plot shows the magnitudes of two impulse responses: the multipath response (infinite bandwidth) and the band limited channel response.

(ii) Frequency Response: This plot shows the magnitude (in dB) of the frequency response of the multipath channel over the signal bandwidth.

(iii) IR Waterfall: This plot shows the evolution of the magnitude impulse response over time.

(iv) Phasor Trajectory: This plot shows phasors (vectors representing magnitude and phase) for each multipath component, using the same color code.

(v) Multipath Components: This plot shows the magnitudes of the multipath gains over time, using the same color code.

(vi) Multipath Gain: This plot shows the collective gains for the multipath channel for three signal (i.e. Narrow bandwidth, Signal Bandwidth and Infinite Bandwidth) bandwidths.

We have been capable to use the above mentioned channel visualization tools provided by the MATLAB which are helping us in simulation environment. But with an objective to explore these facts into the real field at different cities and villages, necessarily a compatible hardware arrangement would be needed. So, we have our future focus to develop a SDR based subsystem in which we would reuse those MATLAB visualization tools having modified by the necessary Xilinx Blocks.

9. CONCLUSION

The enormous potential of the SDR based radar can thus be configured and tested enabling real time target detection on the road and decision on ACC can be invoked accordingly.
10. REFERENCES:


BIOGRAPHY:

Prof. Nirmalendu Bikas Sinha received the B.Sc (Honours in Physics), B. Tech, M. Tech degrees in Radio-Physics and Electronics from Calcutta University, Calcutta, India, in 1996, 1999, and 2001, respectively. He is currently working towards the Ph.D degree in Electronics and Telecommunication Engineering at BESU. Since 2003, he has been associated with the College of Engineering and Management, Kolaghat, West Bengal, India where he is currently an Asst. Professor with the department of Electronics & Communication Engineering & Electronics & Instrumentation Engineering. His current research interests are in the area of signal processing for high-speed digital communications, signal detection, MIMO, multiuser communications, Microwave /Millimeter wave based Broadband Wireless Mobile Communication, semiconductor Devices, Remote Sensing, Digital Radar, RCS Imaging, and Wireless 4G communication. He has published large number of papers in different national and international Conference and journals. He is currently serving as a reviewer for Wireless communication and RADAR system in different international journals.

Manish Sonal is pursuing B.Tech in the Department of Electronics & Communication Engineering at College of Engineering and Management, Kolaghat, under WBUT in 2010, West Bengal, India. His areas of interest are in Microwave /Millimeter wave based Broadband Wireless Mobile Communication and digital electronics.

Dr. Rabindranath Bera is a professor and Dean (R&D), HOD in Sikkim Manipal University and Ex-reader of Calcutta University, India. B.Tech, M.Tech and Ph.D. degrees from Institute of Radio-Physics and Electronics, Calcutta University. Field of Interests are in the area of Digital Radar, RCS Imaging, Wireless 4G Communication, Radiometric remote sensing. He has published large number of papers in different national and international Conference and journals.

Dr. Monojit Mitra is an Assistant Professor in the Department of Electronics & Telecommunication Engineering of Bengal Engineering & Science University, Shibpur. He obtained his B.Tech, M.Tech & Ph. D. degrees from Calcutta University. His research areas are in the field of Microwave & Microelectronics, especially in the fabrication of high frequency solid state devices like IMPATT. He has published large number of papers in different national and international journals. He has handled sponsored research projects of DOE and DRDO. He is a member of IETE (I) and Institution of Engineers (I).