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MEASUREMENT OF TARGET PARAMETERS USING THE DSSS RADAR

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Abstract—With the technological growth of broadband wireless technology like CDMA, OFDM and MIMO, a lots of development efforts towards wireless communication system and imaging radar system are well justified. It has been recently shown that multiple-input multiple-output (MIMO) antenna systems have the potential to dramatically improve the performance of communication systems over single antenna systems. Efforts are also being imparted towards a Convergence Technology. The convergence between a communication and radar technology which will result in ITS (Intelligent Transport System) and other applications. This motivates development of the present article. This is an effort in the direction to utilize or converge the communication technologies towards radar and to achieve the interference and clutter free quality remote images of targets.

1. INTRODUCTION

The author's past experience of development of an Imaging Radar Instrumentation system at W-band in a Closed Chamber reminds them the followings.

Firstly, narrow band operation of Network Analyzer (bandwidth 10 KHz) used for Radar Instrumentation restricts the image resolution.

Secondly, step frequency waveform over a bandwidth of 2 GHz center around 94 GHz and using 201 acquisition points improve the range resolution considerably. But the system becomes sluggish (typically a time of 20 minutes is required to complete a single measurement).

Thirdly, clutter effect outside the Quiet zone of the closed chamber are severe which results in some clutter energy distribution over the quite zone of the chamber.

Fourthly, this ultimately introduces extra Phase Noise in the system resulting weak target spot measurement sometimes unstable, particularly for small targets. For example , the radar return signal of a small sphere (used for the calibration of radar) -30 dBsm RCS value was found to be oscillatory from sweep to sweep and very difficult to predict the actual RCS value.

In the Imaging Radar Instrumentation system in the Open field, particularly the same clutter problem may become more serious and should not be allowed to repeat. Additionally, the Active Interference from Operational Radio system (mostly lies in the 300–3000 MHz Radio band) and man made noise are severe. So, a need arises to design and develop a suitable modern radar technology which will address all above problems.

2. PROBLEMS IN THE PHYSICAL LAYER

The communication system perturbed by the multipath effects due to environments and a fade depth of more than 30 dB are more common as shown in Fig. 1. This restricts data rate and goal of high end multimedia services are perturbed.

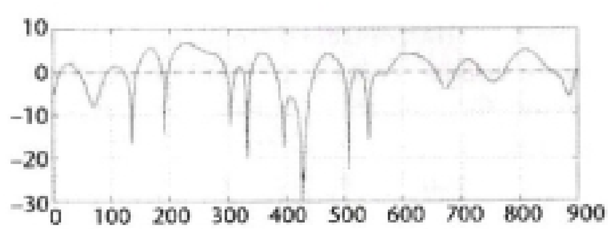

Figure 1. Signal fading due to multipath effect.

For radar based remote sensing case, every target is characterized by its RCS (RADAR Cross Section) function. A target's RCS function represents the amount of energy reflected from the target toward the receiver as a function of the target aspect with respect to the transmitter receiver pair. It is well known that this function is rapidly changing as a function of the target aspect [2]. Both experimental measurement and theoretical result demonstrate that scintillation of 10 dB or more in the reflected energy can occur by changing the target aspect by as little as one milli-radian. These RCS scintillation is responsible for signal fading, which can cause large degradations in the system's detection and estimation performances.

The aforesaid problems of SNR fluctuations both in mobile GIS, communication & radar services from the smart vehicle may be solved successfully with the use of MIMO technology. MIMO is a smart antenna array technology that uses broadband pulses of energy for remote sensing and communication application and may be best suited for such smart vehicle application.

3. DESIGN PHILOSOPHY

To achieve a data rate of 100 MBPS over mobile environment, it relates a total system bandwidth of 100 MHz. MIMO technology alone cannot tackle the problem rather the hybrid technologies to be explored. It is also well accepted that the OFDM (Orthogonal Frequency Division Multiplexing) is the enabler for the MIMO. So instead of MIMO alone, OFDM may be more useful. And the total spectrum will be subdivided over multiple simultaneous antennas which will be again divided over multiple carriers like 64 OFDM carriers or more.

In this way MIMO-OFDM combination will help tremendously to improve the data through-put by reducing the multipath effects. Also there are tremendous growth in CDMA based DSSS (Direct Sequence Spread Spectrum) technology which is superior in performance in terms of interference rejection. Therefore COFDM-MIMO (Coded OFDM) is the hybrid technology which is of immense interest to the authors. The simplified block diagram for the same is shown in Figure 2.

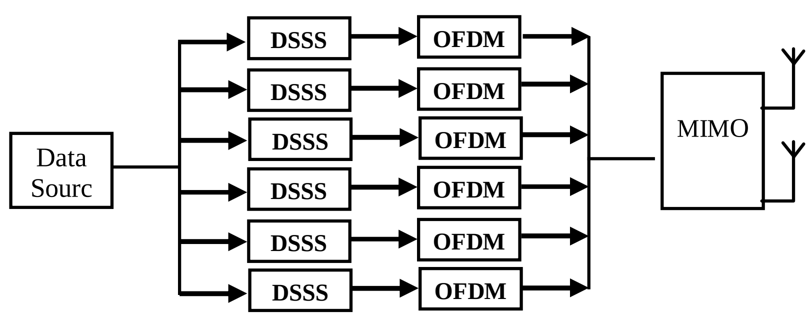

Figure 2. Simplified block diagram of COFDM-MIMO system.

4. THE DSSS RADAR

A DSSS Bi-Static Radar made up of Wi-Fi b PCI adapter as shown in Figure 3a fitted inside a PC is operational at SMIT (Sikkim Manipal Institute of Technology) using 2.4 GHz radio carrier. The received signal spectrum is as shown in Fig. 3b, having the following system parameters.

Figure 3a. Photograph of PCI Wi-Fi b/g adapter.

RF carrier Frequency = 2.4 GHz
Rate = 11 Mbps
RF bandwidth = 20 MHz
Spread with 11 bit Barker Code having sequence = [1; -1; 1; 1; -1; 1; 1; 1; -1; -1; -1]

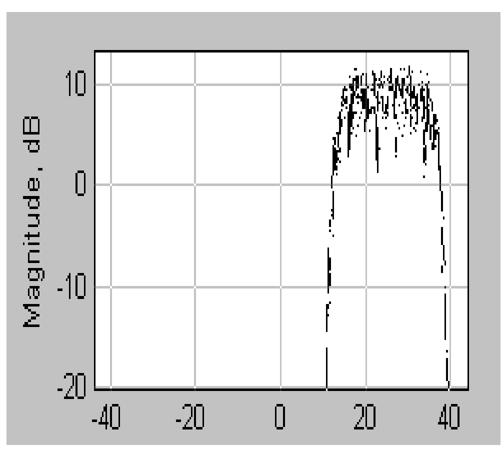

Figure 3b. The received signal spectrum from a DSSS system.

The total system is placed along with the target is as in Fig. 3c. The DSSS radar transmitter is placed at a long distance of 110 meter which radiates carrier using a dish antenna of diameter 6 ft with a horn at its focus. The horn is connected to Wi-Fi b adapter fitted inside a PC. At the further end the receiver with another Wi-Fi b adapter and a second horn is placed.

Three big targets of parabolic dishes of diameters 70.5, 72 & 76.5 inches respectively are placed near this receive horn and are shown in Fig. 3d. The targets are fitted on the proper mounting structure and can be rotated manually both in azimuth and in elevation angles which can be read out from the scale mounted at the back. Actually we have modified three commercial parabolic dishes (meant for the satellite reception) with their mounting structures and utilize them as targets. We have physically measured the 3 targets as depicted in Table 1.

Figure 3c. Photograph of the operational DSSS Radar at SMIT.

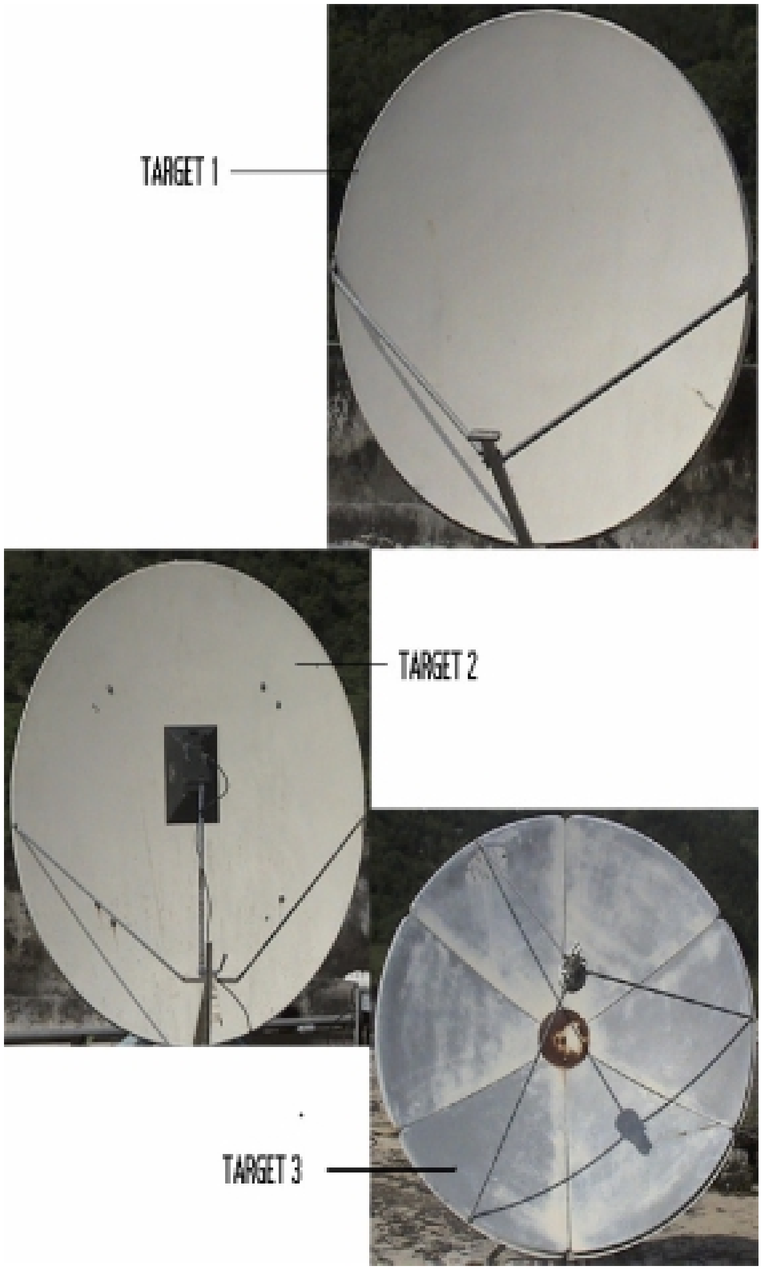

Figure 3d. The photographs of three different targets.

The Targets have the following dimension shown in Table 1.

Table 1.

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
Taget 1	Parabolic	76.5	78.5	76.5	78.5	Target is symmetric
Taget 2	Parabolic	70.5	72	76.5	78.5	Target is asymmetric
Taget 3	Parabolic	72	76.5	72	76.5	Target is symmetric

5. EXPERIMENTAL RESULTS

At every position of the targets we are noting down the values of target angular position with received signal strength. A typical table of Angular rotation Vs Rx signal strength of Target 2 is as shown in Table 2. We have plotted the received signal strength for the 3 different targets as shown in Figs. 3e, 3f & 3g respectively.

Table 2.

No. of Observations	Angular Rotation (in °)	Rx Signal (in %)	No. of Observations	Angular Rotation (in °)	Rx Signal (in %)
1	-39	40	12	0	100
2	-23	40	13	6.75	80
3	-18	40	14	8	80
4	-16.5	60	15	10	70
5	-14.5	80	16	11.25	60
6	-13.5	60	17	12	60
7	-12	80	18	15	60
8	-11.25	80	19	21	40
9	-6.75	60	20	28	40
10	-5.5	80	21	33.75	20
11	-4.5	90			

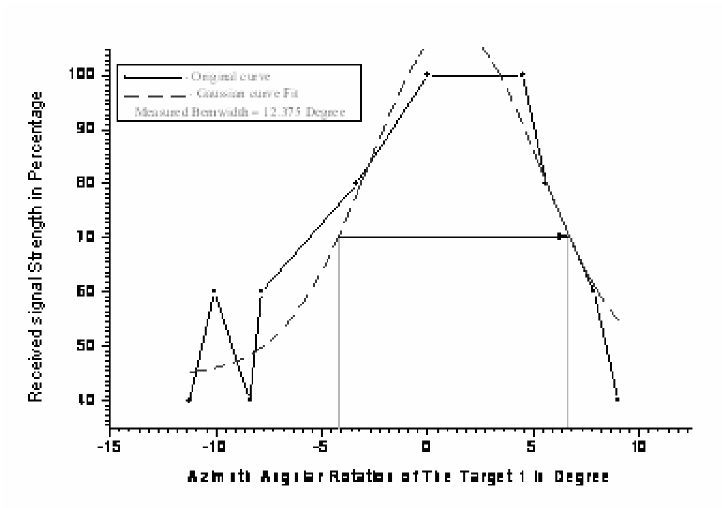

Figure 3e. Plot of azimuth angular rotation of Target 1.

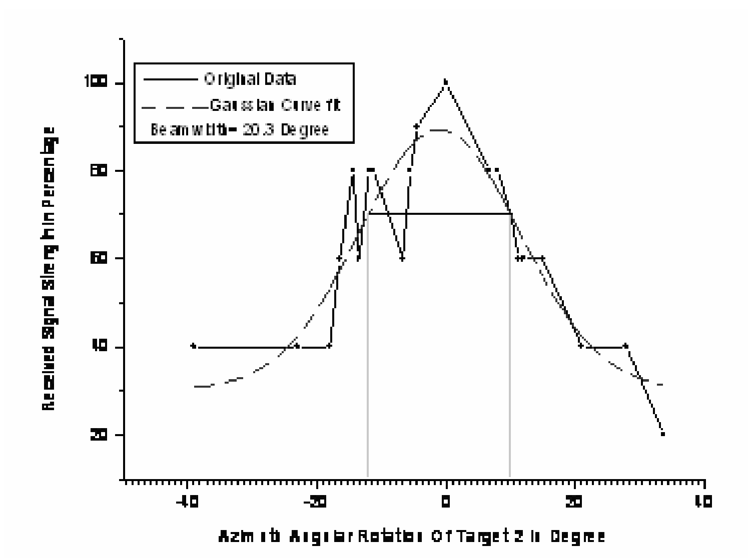

Figure 3f. Plot of azimuth angular rotation of Target 2.

6. DETERMINATION OF TARGET RCS

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 3.

Table 3.

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

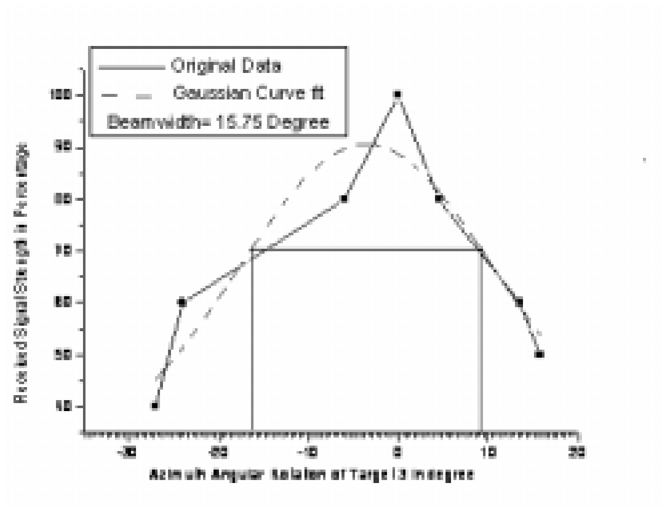

Figure 3g. Plot of azimuth angular rotation of Target 3.

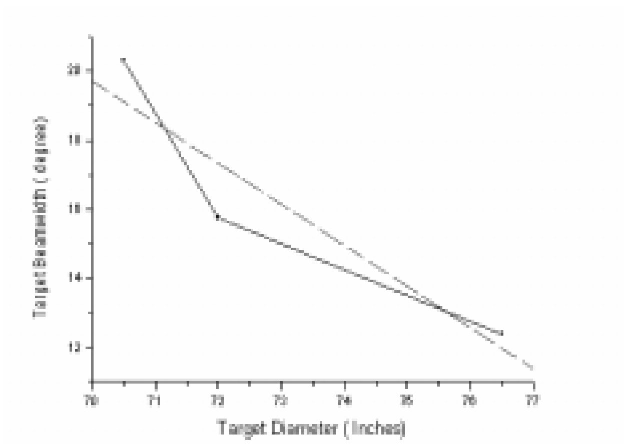

Figure 3h. The calibration curve for RCS measurement of azimuth angle.

A calibration curve is shown in Fig. 3h which can be drawn out of those results and it will be useful in finding any unknown objects RCS of similar kind as shown in Fig. 3h dotted line.

7. MIMO-OFDM SYSTEM

Motivated by recent developments in communication theory [3, 4], we introduce the concept of multiple-input multiple-output (MIMO) radar. MIMO communication systems overcome the problems caused by fading by transmitting different streams of information from several decorrelated signals. In MIMO communication system, the receiver enjoys the average signal to noise ratio (SNR) of the received signal is more or less constant, whereas in conventional system, which transmits all their energy over a single path, the received SNR varies considerably. The novelty of the MIMO RADAR is that, it capitalizes on target scintillations to improve the RADAR performance.

8. CONCLUSION

Both the DSSS and MIMO-OFDM system are operational at the laboratory of SMIT. The communication and radar modes are also explored for both the systems. The integration of the systems for COFDM-MIMO is still awaited. Both the systems are able to detect the targets for collision avoidance at the road. The DOA estimation is to be embedded to the systems. Soon we will be exploring the system for the field trial. We may expect a lot of further problems during field trials like the Doppler effects due to the motion of the vehicle. The Doppler extraction algorithm to be embedded to the system for determining the speed of the passing vehicles. In summary, the basic level of work has been carried out at the lab, but a lot of further efforts to be put in for actual operation condition.

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