CONVERGENCE OF WIRELESS COMMUNICATION AND DIGITAL RADAR SYSTEM FOR REMOTE SENSING IN INTELLIGENT TRANSPORTATION

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ABSTRACT

Among the emerging active sensing radar technology, Multiple Inputs Multiple Output (MIMO) radar has given a new path for imaging and remote sensing techniques. This paper deals with the comparison of performance analysis for various topologies of multiple antenna systems in radars and then compares the obtained result with analogous communication system. This paper also introduces the concept of statistical MIMO radar which exploits the special diversity of target scattering to improve detection and performance due to absence of target fades compared with other types of array radars, analyse various topologies of multiple antenna systems in radars into its analogous multi antenna communication system(AMCM). This new novel detection approach is more tractable than conventional 'probability of detection analysis' to track the detection capability of radars and is based on modelling of radar target as a modulator in an analogous communication system. This AMCM method leads to a quantitative and qualitative comparison of the fidelity of MIMO radar and quantifies 'detection' as being inversely proportional to bit error rates (BER) of the resulting communications channel. The fundamental difference between statistical MIMO radar and other radar array systems is that the latter seek to maximize the coherent processing gain, while statistical MIMO radar capitalizes on the diversity of target scattering to improve radar performance. Coherent processing is made possible by highly correlated signals at the receiver array, whereas in statistical MIMO radar, the signals received by the array elements are uncorrelated. In this paper the convergence of wireless communication and digital radar is being investigated and their performance is evaluated additionally a system realization between radar & communication technology has been tried for moving vehicle application. The results are found to be encouraging in real life remote sensing system and can be simultaneously used for ITS (intelligent transport system).

Keywords: *MIMO,AMCM,SER and ITS.*

1. INTRODUCTION

Scientists and Technologists involved in the development of radar and remote sensing systems all over the world are now trying to involve themselves in saving of manpower in the form of developing a new application of their ideas in ITS. The MIMO systems have gained popularity and attracted attention of late for their ability to enhance all areas of system performance. Inspired by the success of MIMO systems in communications, several publications have advocated the concept of MIMO Radar [1][2] from the system implementation point of view [3], as well as for processing techniques for target detection and parameter estimation[4].Target parameters of interest in radar systems include target strength, location, and Doppler characteristics. MIMO radar [1][5]-[10] systems employ multiple antennas to transmit multiple waveforms and engage in joint processing of the received echoes from the target. Elements of MIMO radar transmit independent waveforms result in an omnidirectional beam pattern or create diverse beam patterns by controlling correlations among transmitted waveforms [11]. MIMO radar may be configured with its antennas co-located or widely distributed over an area and able to provide independent diversity paths. In conventional radar, the target's radar cross section (RCS) fluctuations are regarded as a nuisance parameter that degrades radar performance. The novelty of MIMO radar is that it provides measures to overcome those degradations or even utilizes the RCS fluctuations for new applications. It is shown that with noncoherent processing, a target's RCS spatial variations can be exploited to obtain a diversity gain for target detection and for estimation of various parameters, such as angle of arrival and Doppler. For target location, it is shown that coherent processing can provide a resolution far exceeding that supported by the radar's waveform. MIMO radar systems have been shown to offer considerable advantages over traditional radars in various aspects of radar operation such as more degrees of freedom than systems with a single transmit antenna support flexible time-energy management modes [12], lead to improved angular resolution [8], [13], clutter interference rejection capability [6] [7], improve parameter identifiability [14], enhanced flexibility for transmitting beam pattern design [9][10], medium-high range of detection probability , exploiting RCS diversity [15], handle slow moving targets[8][13] by exploiting Doppler estimates from multiple directions , and support high resolution target localization[8] [16] ,the ability to identify and separate multiple targets [10], [11], and in the estimation of target parameters such as direction-of-arrival (DOA) [8], [10].

In this paper the performance of spatial diversity in MIMO radars has been analysed. The target is modelled as a modulator in an analogous communication system. The radar performance is compared by calculating the symbol error rates (SERs) of the respective analogous communication links. SER calculations can provide the same information as the miss-detection probability of a target under a given radar architecture. This method leads to a quantitative and qualitative comparison of the fidelity of various kinds of radars and the application of MIMO radar to the problem of direction finding and target detection. Through analysis and numerical results, we demonstrate that radar greatly improves detection and estimation performance due to the reduction in target fades as compared to MIMO communication system.

2. MIMO COMMUNICATION VS. MIMO RADAR SIGNAL MODEL:

Radar is an electromagnetic system for detection and location of a particular object. It operates by transmitting a narrow rectangular –shape pulse waveforms S (t) modulating a sine wave carrier which is known to the receiver and observing a return signal r (t).

$$r(t) = s(t-\tau) + \text{ noise} \ldots\ldots (1)$$

Estimate the target range (R) from its relation to the time delay

$$\tau = \frac{2R}{c} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

If target has range rate (velocity) v_0, then r (t) will acquire a Doppler shift,

$$f_d = \left(\frac{2v_0}{c}\right) f_0 \quad \ldots\ldots (3)$$

So equation (1) from the frequency shift

$$r(t) = s(t-\tau)e^{j2\pi f_d (t-\tau)} + \text{ noise} \ldots. (4)$$

Target angle can be estimate by utilising a directional antenna or antenna array.The performance of the detection can be improved by transmitting higher power and spread spectrum gain. Improve range resolution and cross-range resolution by transmit higher bandwidth waveform and larger aperture antenna respectively.

2.1 MIMO RADAR SIGNAL MODEL

MIMO radar architecture (Fig.1) employs multiple transmit waveforms and has the ability to jointly process signals received at multiple antennas ,iindependent waveforms are omnidirectional beam pattern and diverse beam patterns created by controlling correlations among transmitted waveforms. Antenna elements of MIMO radar can be co-located or distributed. The MIMO radar scheme is based on a system with M transmitting radars and N receiving radars, widely distributed. It is assumed to be both time and phase synchronized. MIMO radar offers the potential for detection/estimation performance through diversity gain and resolution performance through spatial resolution gain. The performance enhancement of the different radar signal detection is considered from an aspect of improving the SNR, and is to utilize the best modulation techniques for only AWGN channel over the whole process. The rank of the channel matrix can be used to determine the number of dominant scatterers or the number of targets in the range resolution cell. With suitable processing, this property of MIMO radar can be applied to enhance radar resolution by allowing the measurement of one scatterer at a time.

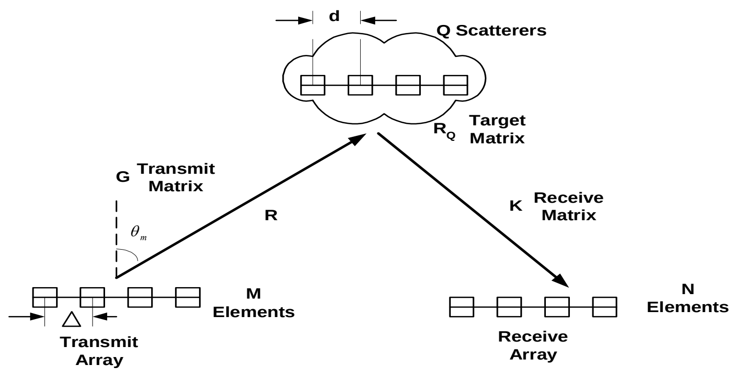

Figure 1 MIMO radar channel

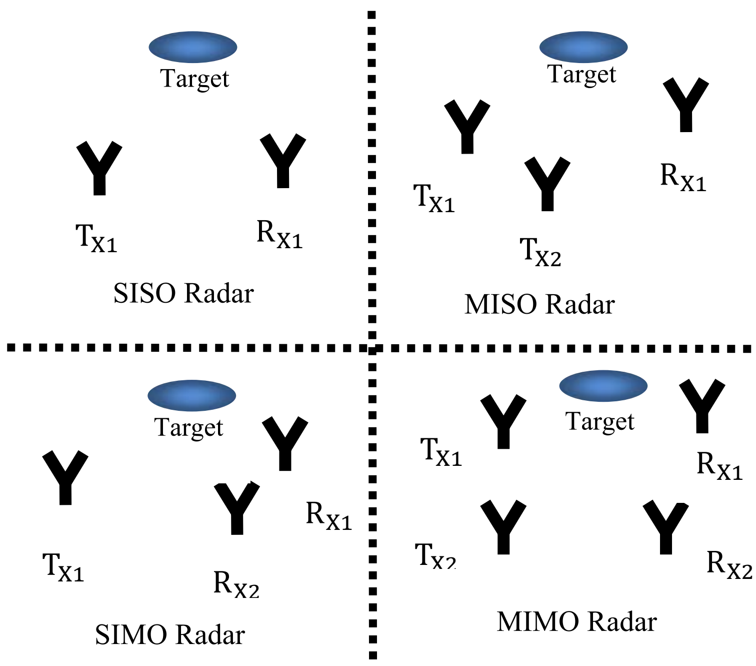

Figure 2 Different radar architectures showing various configurations of multi-antenna radars

For the SIMO system, we have N antennas at receiver and only one at transmitter. If the signals received on these antennas have on average the same amplitude, then they can be added coherently to produce an N^2 increase in the signal power. On the other hand, there are N sets of noise that are added incoherently and result in an N-fold increase in the noise power.

$$(SNR)_{SIMO} \approx \frac{N^2[Power]}{N[Noise]} = N.SNR_o \ldots\ldots(5)$$

where, SNR_o is the SNR of the SISO system. The SNR of the SIMO system is improved by N times comparing with the SISO system. In the case of multi-input single-output (MISO) system, the transmitter utilizes M antennas, and the transmitted power is distributed into M antennas. So

$$(\mathrm{SNR})_{\mathrm{MISO}} \approx \frac{\mathrm{M}^2[\mathrm{Power/M}]}{[\mathrm{Noise}]} = \mathrm{M.SNR_o} \ldots\ldots(6)$$

is improved by M times comparing with the SISO system. In case of MIMO system can be view in effect as a combination of the SIMO and MISO channels.

$$(\mathrm{SNR})_{\mathrm{MIMO}} \approx \frac{\mathrm{N}^2\mathrm{M}^2.\,\text{signal power}}{\mathrm{N.M.(noise)}} = \mathrm{M.N.SNR_o} \ldots\ldots\ldots\ldots(7)$$

The SNR of the MIMO is improved by M.N times comparing with the existing SISO system. In deterministic MIMO channel matrix is assumed to be non random, quasi-static and frequency non-selective. The channel for a MIMO system can be represented by The channel for a MIMO system can be represented by

$$\mathrm{H} = \begin{bmatrix} \mathrm{h}_{11} & \cdots & \mathrm{h}_{1\mathrm{N}_t} \\ \vdots & \ddots & \vdots \\ \mathrm{h}_{\mathrm{R}_1} & \cdots & \mathrm{h}_{\mathrm{N}_r\mathrm{N}_t} \end{bmatrix}$$

Where h_{ij} is the complex channel path gain between transmitter j and receiver i. The elements of the matrix H are unknown/ uncorrelated but their statistics are known.

Received signal of MIMO radar for point target located at a distance X is given by

$$r_i(t) = \sqrt{\frac{E}{M}}\sum_{j=1}^{M} h_{ij}\,(X)s_j(t-\tau_{ij}(X)+n_i(t)\ldots\ldots(8)$$

Where, E= signal energy, M and N= Number of transmit and receive antennas, $n_i(t)$= white Gaussian noise. For MIMO radar transmitted waveforms $S_j(t))$ are known to the receiver but channel coefficients are unknown

2.2 MIMO COMMUNICATION SYSTEM MODEL

The input /output a relation of a narrow band single-user MIMO wireless link is modulated by a complex baseband vector notation

$\mathrm{Y} = \mathrm{HX} + \mathrm{n}\ldots.(9)$. Where H is the channel matrix and n is the additive white Gaussian noise (AWGN) vector at a given instant in time channel noise.

Furthermore, as a commonly used structure for the MIMO system, V-BLAST shares some basic modules with our general multiple antennas.

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix}\ldots..(10)\ ,\mathrm{H} = \begin{bmatrix} \mathrm{h}_{11} & \ldots & \mathrm{h}_{1\mathrm{M}} \\ \mathrm{h}_{21} & & \mathrm{h}_{2\mathrm{M}} \\ \vdots & \ddots & \vdots \\ \mathrm{h}_{\mathrm{N}1} & \cdots & \mathrm{h}_{\mathrm{NM}} \end{bmatrix}..(11),$$

$$X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_M \end{bmatrix}\ldots.(12), \qquad n = \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_N \end{bmatrix}\ldots(13)$$

The time channel impulse response between the j-th $(j = 1,2,\ldots\ldots..\mathrm{M})$ transmit antenna and the i-th $(j = 1,2,\ldots\ldots..\mathrm{N})$ receive antenna is denoted as $\mathrm{h}_{\mathrm{i,j}}(\tau,\mathrm{t})$. This is the response at time t to an impulse applied at time $t-\tau$. The composite MIMO channel response is given by the N x M matrix H (τ, t) with antenna array.

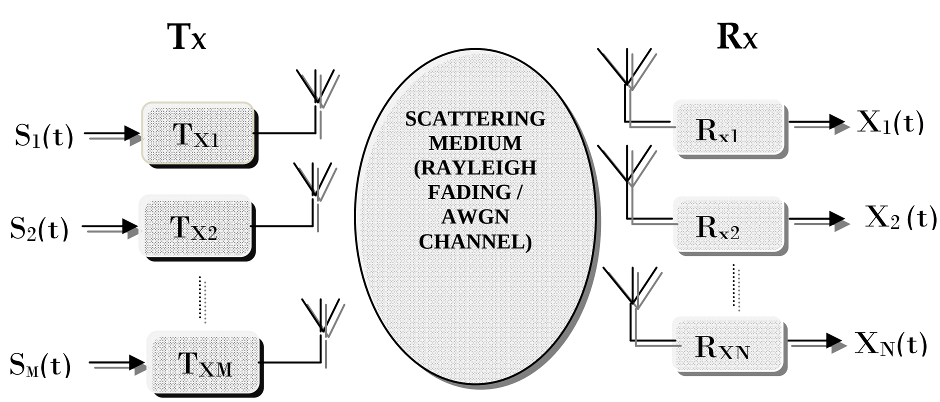

Figure 3 MIMO communication channel using M transmits and N receives antennas.

$$H(\tau,t) = \begin{bmatrix} h_{1,1}(\tau,t) & h_{1,2}(\tau,t) & \ldots\ldots & h_{1,M}(\tau,t) \\ h_{2,1}(\tau,t) & h_{2,2}(\tau,t) & \ldots\ldots & h_{2,M}(\tau,t) \\ \vdots & \vdots & \ddots & \vdots \\ h_{N,1}(\tau,t) & h_{N,1}(\tau,t) & \ldots & h_{N,M}(\tau,t) \end{bmatrix} \ldots (14)$$

The vector $\left| h_{1,j}(\tau,t)\ h_{2,j}(\tau,t) \ldots\ldots\ldots h_{N,j}(\tau,t) \right|^T$ is referred to as the spatio-temporal signature induced by the j-th transmit antenna across the receive Furthermore, given that the signal $s_j(t)$ is launched from the j-th transmit antenna, the signal received at the i-th receive antenna is given by

$$r_i(t) = \sqrt{\frac{E}{M}} \sum_{j=1}^{M} h_{ij}\, s_j(t-\tau) + n_i(t) \ldots\ldots..(15)$$

Where, $n_i(t)$ is additive noise in the receiver.For transmit/receive beam forming with the diversity of order M N, is considered as full diversity. On the other hand the antenna gain is; Max = {M, N} ≤ antenna gain ≤ M N. So for MIMO comm. antennas are co-located and scatterers are separated but for MIMO radar antennas are separated and scatterers are co-located which is depicted in Fig.3 and Fig.1

3. PERFORMANCE COMPARISONS OF RADAR DETECTION SYSTEMS

In statistical MIMO radar, all the array elements are widely spaced .Due to the target complex shape and distances between the array elements, every element observes a different aspect to the target. Therefore, the point source is not suited to depict the received signal in statistical MIMO radar. Consider radar target is composed of a finite but large number of small distributed scatterers. The target is located at some point $X(x_o, y_0)$ in space and it is stationary during observation time. We assume thatσ_n^2, target location, and noise levels are known in advance.

The radar detection problems have been investigated and analyzed in the past [16]. These variants differ by the assumed signal model, the unknown parameters, etc. In this section, we investigate the best achievable performance with phased array, and MIMO radars. We then compare the various systems and determine the best one.

The optimal detector in the Likelihood Ratio Test (LRT) detector is given by [16],

$$T = \log\left(\frac{f(r(t))_1}{f(r(t))_0}\right) \begin{matrix} > H_1 \\ < H_0 \end{matrix}\ \sigma \ \ldots\ldots\ldots..(16)$$

where $f(r(t))_0$ and $f(r(t))_1$ are the probability density functions (pdf) of the observation vector given the null and alternate hypotheses, respectively, and δ is a threshold, set by the desired probability of false alarm. H_0 : Target does not exist at delay τ.H_1 : Target exists at delay τ.

$$\sigma = \frac{\sigma_n^2}{2} F^{-1}_{x^2_{2MN}}(1 - P_{FA}) \ldots.(17)$$

4. NONCOHERENT MIMO RADAR

The optimal detector for non coherent MIMO radar is given by

$$T = \|X\|^2 \begin{matrix} >H_1 \\ <H_0 \end{matrix}\ \sigma$$

$$[X]_{iN+j} \triangleq \int r_i(t) s_j(t-\tau) dt \ldots\ldots\ldots(18)$$

Where, X is the output of a bank of matched filters. By proper processing, the detector creates MN virtual conventional radar systems, and adds their output noncoherently.

5. PROBABILITY DETECTION FOR MIMO RADAR

A useful measure of radar fidelity is probability of detection (PD). This has helped to obtain the parallel between probability of miss-detection (P_{MD} = 1- P_D) of a radar and SER of the AMCM, by plotting graphs of each of these quantities against the Fishler et. al [1] and modified equation as a function of the SNR can be given as:

$$P_{DMIMO} = 1 - F_{x^2(2pq)}\left(\frac{1}{\rho/_{p+1}} F_{x^2(2pq)}{}^{-1}(1 - P_{rFA})\right)..(19)$$

This is received signal-to-noise ratio (SNR) for every kind of radar under test. The PD for MIMO (P_{DMIMO}) radar and its variants has already been found by Where, $F_{x^2(2pq)}$ is the cumulative chi-squared probability distribution function with 2pq degrees of freedom (with p transmitters and q receivers), P_{rFA} is the false alarm rate (usually set constant), $= \frac{E_m}{\sigma^2}$.

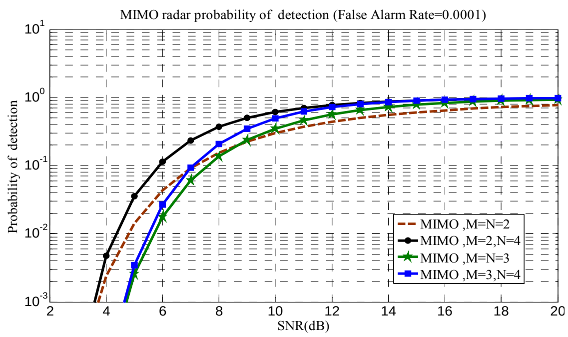

Figure 4, Probability of detection as a function of the SNR

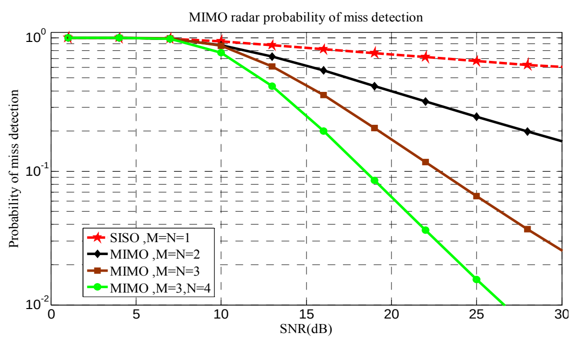

Figure 5, Probability of miss-detection as a function of the SNR

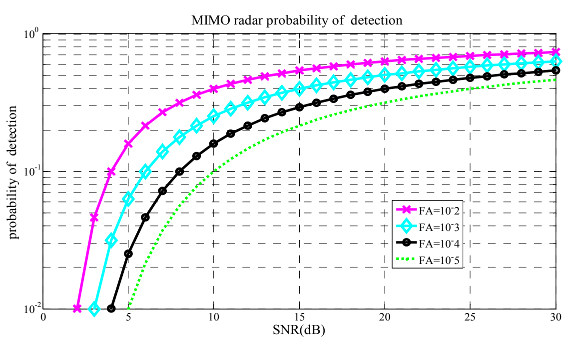

Figure 6, Probability of detection as a function of the SNR for variable false alarm rate

In this section the performance of various systems is compared through numerical examples. In this paper ,we consider the performance of various type of MIMO radars. Fig.5 depicts the probability of miss detection for both known and unknown noise levels, as a function of the SNR with M=N=1,M=N=2,M=N=3,M=3,N=4.The probability of false alarm was fixed at $P_{FA} = 10^{-6}$. We assume that the noise level is unknown; the receiver obtains 64 independent samples of the noise process. At high SNR, MIMO does extra ordinary performance as compared with MIMO communication system .Assuming all radars to be in transmit/receive mode and using the following parameters and autocorrelation function, resolution has been detected. Also analyze the performance of MIMO radar system for probability of detection as a function of SNR with fixed and variable false alarm rate. SISO performed worst in target detection in comparison with other digital array radar; when the detection probability reached over 90%, MIMO, MISO, and SIMO radar needed lower SNR than phased array radar. We find that the detection performance of MIMO radar improved as the increase in the number of T/R arrays when SNR>6.

6. CONVERGENCE BETWEEN MIMO COMMUNICATION AND MIMO RADAR SYSTEM

The convergence of MIMO communication to MIMO radar is already developed at the laboratory by assuming that no direct path exists between transmitter (T_x) and receiver (R_x) only modulating element for the radar signal is the target. In absence of target, noise is received by the received antenna (Fig. 7). Using the distances and the coordinates of the target Where, h_b is the channel just before hitting the target, h_a is the channel after heating the target, h_R is the channel just before reaching the receiver, ω is the angular frequency of the transmitted signal, T_1 and T_2 is the time taken for the signal to reach the target from the transmitter and target to receiver respectively, $r_1^{\rightarrow}$ and $r_2^{\rightarrow}$are the distances from T_x to target and target to R_x.

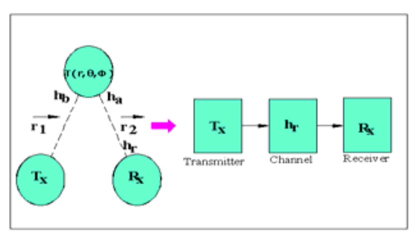

Figure 7 Block diagram of analogous multi-antenna communications system for radar

Now **e**fforts are also put to extend the above MIMO communication system towards MIMO radar. The MIMO radar complexity is involved in its signal processing. Therefore, works have been imparted towards processing of MIMO radar and its performance analysis for tracing probability of detection, SER(symbol error rate), PSD(power spectral density).

We convert the radar system into AMCM system by assuming that no direct path exists between T_X and $R_{x,}$ only modulating element for the radar

signal is the target. In absence of target, noise is received by the received antenna. The AMCM system is then used to calculate the symbol error rate (SCR) of the communication system.
Using the distances and the coordinates of the target (Fig.7) the following expression (20) was obtained for the channel just before hitting the target.

$$h_b = \frac{1}{\left|\vec{r_1}\right|}\, e^{j(\omega T_1 - K^{\rightarrow} r_1^{\rightarrow})} \;\ldots\ldots (20)$$

Channel after heating the target,

$$h_a = \frac{1}{\left|\vec{r_1}\right|}\, e^{j(\omega T_1 - K^{\rightarrow} r_1^{\rightarrow})} \;\ldots\ldots (21)$$

Channel just before reaching the receiver,

$$h_R = \frac{\sigma}{\left|\vec{r_1}\right|\left|\vec{r_2}\right|}\, e^{j\left(\omega(T_1+T_2) - K^{\rightarrow}(r_1^{\rightarrow} + r_2^{\rightarrow})\right)} \;\ldots (22)$$

where ω is the angular frequency of the transmitted signal, T_1 and T_2 is the time taken for the signal to reach the target from the transmitter and target to receiver respectively, $r_1^{\rightarrow}$ and $r_2^{\rightarrow}$are the distances from T_x to target and target to R_x.
Using this model, the 1x 1 SISO radar has only one channel in the AMCM. The 2x1 MISO and the 1 x 2 SIMO radars have two channels each and the 2 x 2 MIMO radar has four channels. This leads to the expressions for the received signal-to-noise ratios (SNRs) of each of these radars in terms of the respective channels:

7. SYMBOL ERROR RATE

Using this model, the 1 × 1 SISO radar has only one channel in the analogous communication system. The 2×1 MISO and the 1×2 SIMO radars have two channels each and the 2 × 2 MIMO radar has four channels and so on. This leads to the expressions for the received signal-to-noise ratios (SNRs) of each of these radars in terms of the respective channels:

$$(\mathrm{SNR})_{\mathrm{SISO}} = (\mathrm{H})^2 \frac{\mathrm{E_m}}{\sigma_n^2} \ldots\ldots\ldots\ldots (23)$$

$$(\mathrm{SNR})_{\mathrm{MISO}} = \frac{1}{2}(\mathrm{H})^2 \frac{\mathrm{E_m}}{\sigma_n^2} \ldots\ldots\ldots.. (24)$$

$$(\mathrm{SNR})_{\mathrm{SIMO}} = (\mathrm{H})^2 \frac{\mathrm{E_m}}{\sigma_n^2} \ldots\ldots\ldots (25)$$

$$(\mathrm{SNR})_{\mathrm{MIMO}} = \frac{1}{2}(\mathrm{H})^2 \frac{\mathrm{E_m}}{\sigma_n^2} \ldots\ldots. (26)$$

Where, $\mathrm{H} = \sum_{i=1}^{M}\sum_{j=1}^{N}\left|h_{ij}\right|$ .... (27)

Where, h_{ij} are the channels that are set-up in the respective analogous communication system and E_m is the signal power while σ_n^2 is the noise power spectral density. The SER of each of these systems is found using BPSK, QPSK and 16-QAM modulation schemes. In BPSK with an additive white Gaussian noise (AWGN), the SER is given by,

$$P_b = Q\left(\sqrt{\frac{2E_m}{\sigma_n^2}}\right) \ldots (28)$$

$$P_b = Q\left(\sqrt{\frac{E_m}{\sigma_n^2}}\right) \ldots\ldots (29)$$

$$P_b = \frac{3}{4} Q\left(\sqrt{\frac{E_m}{10\sigma_n^2}}\right) \ldots\ldots. (30)$$

Where, equation (29) and (30) are the SER of QPSK and 16 – QAM for AWGN respectively.

Where, $Q(x) = \frac{1}{2}\, erfc(x/1.414) \ldots\ldots\ldots\ldots (31)$

The target can occupy any position in space defined by azimuth-elevation space $\theta = [0,\pi]$ and $\varphi = [0,2\pi]$. (θ,φ) be the probability density function of the target positions. Then the SERs of each of the four radar systems using BPSK are given by,

$$P_{SISO} = \int_0^{2\pi}\int_0^{\pi} Q\left(\sqrt{2(H)^2\frac{E_b}{N_0}}\right) P(\theta,\varphi)\sin\theta d\theta d\varphi \ldots (32)$$

$$P_{MISO} = \int_0^{2\pi}\int_0^{\pi} Q\left(\sqrt{(H)^2\frac{E_b}{N_0}}\right) P(\theta,\varphi)\sin\theta d\theta d\varphi \ldots (33)$$

$$P_{SIMO} = \int_0^{2\pi}\int_0^{\pi} Q\left(\sqrt{2(H)^2\frac{E_b}{N_0}}\right) P(\theta,\varphi)\sin\theta d\theta d\varphi \ldots (34)$$

$$P_{MIMO} = \int_0^{2\pi}\int_0^{\pi} Q\left(\sqrt{(H)^2\frac{E_b}{N_0}}\right) P(\theta,\varphi)\sin\theta d\theta d\varphi \ldots (35)$$

By assuming uniform probability distribution for the target and an arbitrary fading probability distribution for the radar target reflectivity over all the azimuth-elevation space, the integrals in the above equations are evaluated numerically. Similar expressions can be derived for QPSK and 16-QAM modulation schemes. Fig. 8(a) and 8(b) shows the results of SER performances. For all SNR levels, MIMO system has the least SER and hence the highest probability of detection because the lower the error in the received signals, the higher is the detection.

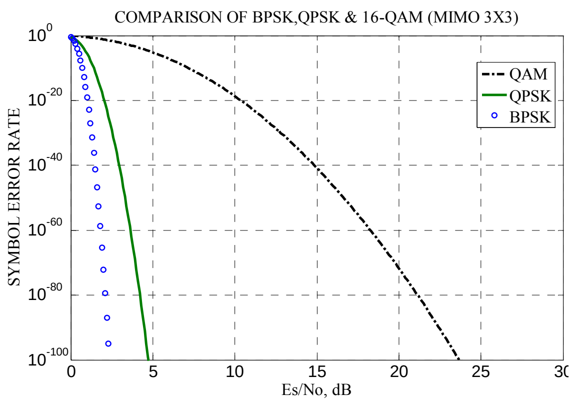

Figure 8(a) The performance of MIMO system with different modulation techniques.

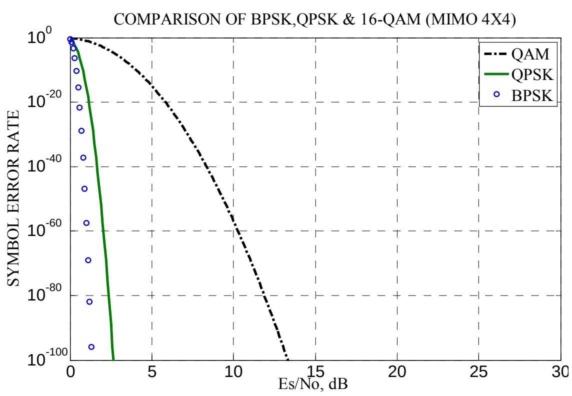

Figure 8(b) The performance of MIMO system with different modulation techniques.

Fig. 8(a) and 8(b) shows the overall system performances of MIMO system is better than other systems for different modulations due to its improvement of transmit and receive diversity. It is noticeable that the overall system performance of QPSK is better compare to other modulation schemes.For all SNR levels, MIMO system has the least SER, and hence the highest probability of detection because the lower the error in the received signals, the higher is the detection.

Comparing the results of P_{MD} (Fig. 4,5,and 6) and SER of AMCM (8(a)and 8(b) shows both analytical tools yield similar information. Hence the AMCM analysis can also be used to find out P_{MD} where the latter analysis becomes intractable. These results are in agreement with the analysis presented in [1].

8. CONCLUSION

We investigated and compared the inherent performance limitations of both analogous communication system of radar and the statistical MIMO radars. We derived the respective optimal detectors when the target and noise level are either known or unknown. We demonstrated that the MIMO radar outperforms the MIMO communication model. Fig. 5 shows variation of probability of miss error detection vs SNR for different types of radar system(MIMO,SIMO,MISO,SISO). The curve here clearly shows that among all the system MIMO radar system has least miss error detection probability i.e it's performance is better compared to other system. Additional it can be clear seen that SIMO radar has better performance that MISO radar i.e increasing receiver diversity helps in improving system performance. The probability of false alarm error rate was fixed at 10^{-6}. We assume that the noise level is unknown. The result find here is similar to that obtained in Analogous Communication System of Radar(ACSR). Fig.8(a) and 8(b) shows variation of System Error Rates of different types of radar (coherent)system(MIMO,SIMO,MISO,SISO) using QPSK,QAM and BPSK modulation. It clearly shows that as we increase no of either transmitting or receiving antennas the Symbol Error Rate(SER) decreases These curves clearly elucidate that for all SNR levels, MIMO system has the least SER, and hence the highest probability of detection because the lower the error in the received signals, the higher is the detection. MIMO is followed by SIMO, MISO and SISO with increasing SER. Comparing the results of SER of ACSR shows both analytical tools yield similar information.

The most important result that is obtained by comparing plot of SER vs SNR using BPSK and QPSK comes out that in QPSK modulation system the message can be transmitted with same accuracy as that of BPSK modulation scheme but it only consume half the bandwidth that is required in BPSK modulation scheme.

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