International Journal For Technological Research In Engineering
Volume 4, Issue 1, September-2016 *ISSN (Online): 2347 - 4718*

DESIGN AND PERFORMANCE ANALYSIS OF SMART ANTENNA SYSTEM

Rahul Mishra[1], Bhushan Salunke[2]
[1]Assistant professor, [2]PG Student [DE], Dept. of ECE, Central India Institute of Technology, Dewas Road, Indore, India.

Abstract: Digital Enhanced Cordless Telecommunication (DECT) can be a latent solution for wireless local loop (WLL) based communication system planning. However DECT performs poorly in multipath propagation scenarios. To overcome the difficulties and utilize the advantages of DECT systems, smart antennas can be introduced. In this paper, the design and simulation of a smart antenna system for DECT radio base stations in WLL is presented. A 8x8 planar micro strip antenna array is designed and associated signal processing signal processing techniques for one and two dimensional cases of smart antenna system are analyzed. Two different algorithms are used for Direction-of-arrival (DOA) estimation using the 8x8 array parameters, these are Multiple signal classification (MUSIC) and Estimation of Signal Parameters via Rotational Invariance Techniques (ESPRIT). Simulation results and performance comparison of these two algorithms for optimum output are incorporated. For adaptive beam forming, Least Mean Square (LMS) algorithm is used here. Radiation characteristics, gain and return loss of the fixed beam planar array antenna are simulated using Zeland IE3Dsoftware. Signal processing simulations are run in MATLAB. This smart antenna system is designed for DECT system in 1.881.90GHz frequency band.
Index Terms: DECT, LMS, MUSIC, WLL, Planar array, smart antenna system.

I. INTRODUCTION

To exploit the dramatic advent of information and communication technology (ICT) into distant areas Wireless Local Loops (WLL) plays a vital role besides mobile communications. In contrast to Plain Old Telephone System (POTS) or broadband internet connection where copper wires are used to connect end users to backbone network, WLL uses wireless link as the last mile solution. Consequently it can provide very cost effective and rapid deployment over vast area which is particularly essential to extend the ICT sector in developing countries like Bangladesh, India, Kenya etc. Using advanced digital radio technologies, WLL can provide a variety of data services and multimedia services as well as voice. DECT system can also be used for outdoor applications; it may be university campus established within large areas, industrial areas in remote places, oil/gas field or suburb/rural area. DECT is also considered WLL, when a public network operator provides wireless service directly to the user via this technology. WLL has two standards – mobile and Fixed or local area network. Several technologies are used for WLL in fixed or local area network like DECT (local loop), LMDS, IEEE 802.11, WiMAX or 802.16 etc. DECT has the advantage of low cost equipment at both user and service provider end. Moreover, it doesn't require the valuable cellular spectrum as operates in 1880-1900 MHz band. DECT is recognized by the ITU as fulfilling the IMT-2000 requirements and thus qualifies as a 3G system [1]. It is also one of the leading cordless technology [2].So for rapid deployment of PSTNs (public switched telephone networks) DECT can be a promising candidate. A simplified model of DECT used as WLL described in reference [3]. The problem is that DECT requires Line of Sight (LOS) communication which might not be as feasible in urban areas as in suburb/rural areas. To significantly improve the communication link in multipath scenario Smart Antenna System can be deployed. Smart antennas have the potential to provide enhanced range and reduced infrastructure costs in early deployments, enhanced link performance as the system is built-out, and increased long-term system capacity [4]. Smart antenna system consists of an array of radiating elements able to steer the main lobe beam towards the desired signal and to locate suitable nulls of the radiation pattern in the direction of interferences. Many works have been done on smart antenna system references [5] [9] are some of these. In reference [5] a complete Smart antenna system was presented for Mobile Ad-Hoc Networks (MANETs). References [6][9] describes DOA algorithms and smart antennas for uniform linear array (ULA) and considering signal arrivals in one dimension only. Also the numbers of antenna elements/ sensors are small. Contrasting to most of the earlier published work that cover only one dimensional conditions for DOA estimations and smart antennas, this paper presents an inclusive effort on smart antennas that incorporate planar antenna array design, the development of signal processing algorithms for angle of arrival estimation (both azimuth and elevation angle) and adaptive beam forming techniques. We use two different algorithms (MUSIC and ESPRIT) for both one and two dimensional cases and make relevant comparisons of these two algorithms. LMS algorithm is used for adaptive beam forming techniques for both of these DOA algorithms. The main goal of this paper i s to design smart antennas for DECT system in WLL in 1.88 GHz— 1.90GHz. One essential component of smart-antenna is its sensors or antenna elements. These antenna elements play an important role in shaping and scanning the radiation patterns and constraining the adaptive algorithm used by digital signal processor. Micro strip antennas gain popularity for its simple and inexpensive manufacturing using modern printed-circuit technology. This type of antenna is mechanically robust when mounted on rigid surfaces. As micro strip antenna has many advantages, we considered micro strip antenna for antenna array design. We designed a 64 element planar array antenna for the smart antenna system as planar array antenna could control the radiation pattern both azimuth and elevation directions. The performance of an adaptive antenna array is strongly affected by the electromagnetic characteristics of antenna array. An important electromagnetic characteristic of an antenna array is the mutual coupling between its elements [10]. There are several publications arrays [10] [12]. The presence of mutual coupling between the array elements degrade the array performance and reduce the speed of responses of an adaptive array [10]. So, we consider mutual coupling of antenna array elements to compensate the weights of Adaptive beam forming algorithm (Least Mean Square Algorithm).

II. ANTENNA ARRAY DESIGNING.

For micro strip antenna array we use corporate feed network. The corporate–feed network is used to provide power splits of 2 (i.e., n=2, 4, 8, 16, 32, etc.). This is accomplished by using either tapered lines or using quarter wavelength impedance transformers. With this method the designer has more control of the feed of each element both in amplitude and phase. Let us assume that we have × identical elements, M and N being even, with uniform spacing positioned symmetrical in the. The array factor for this type of planar array with its maximum along, for an even number of elements in each direction can be written as [13]

$$[AF(\theta,\phi)]_{M\times N} = 4\sum_{m=1}^{M/2}\sum_{n=1}^{N/2} w_{mn}\cos[(2m-1)u]\cos[(2n-1)v] \quad (1)$$

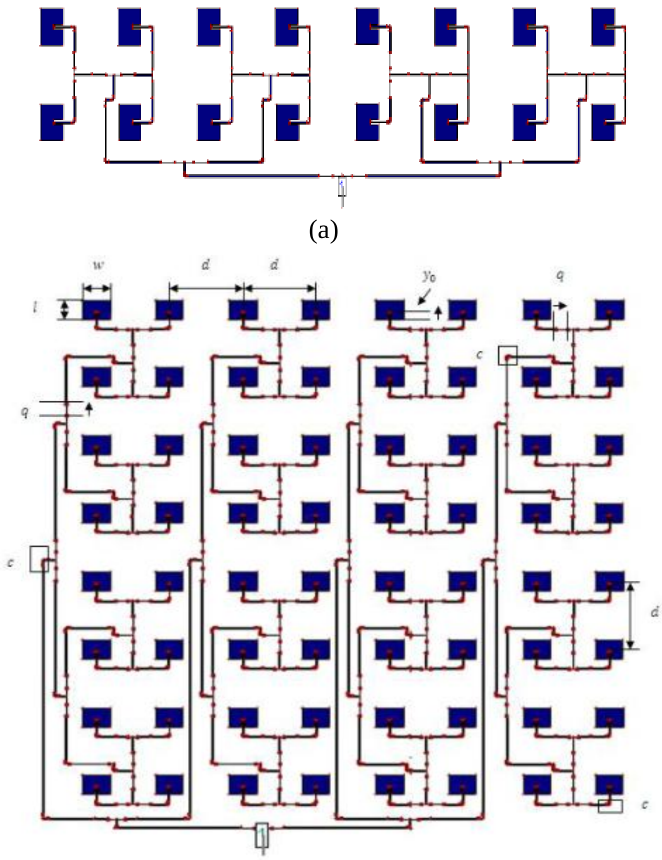
$$u = \frac{\pi d_x}{\lambda}(\sin\theta\cos\phi - \sin\theta_0\cos\phi_0)$$

$$v = \frac{\pi d_y}{\lambda}(\sin\theta\sin\phi - \sin\theta_0\sin\phi_0)$$

is the amplitude excitation of the individual elements. It is the that the adaptive beam forming algorithms adjust to place the maximum of the main beam toward the signal of interest and nulls toward the signal not of interest. Substrate material of this antenna array is considered R03010 (ϵ_r =10.2), high dielectric constant is taken for size reduction because the operating frequency of the antenna is 1.88GHz 1.90GHz. In these range of frequency antenna size is usually large unless high dielectric constant substrate is not used for antenna design. Recessed micro strip line feeding techniques is used as this gives a good impedance matching at inputs of the radiating elements. Feed networks in general have certain undesired characteristics that must be carefully monitored in order to minimize any adverse effects on array performance. These characteristics include conductor and dielectric losses, surface wave loss, and spurious radiation due to discontinuities such as bends, junctions and transitions. These losses constitute the overall insertion losses of the feed system affecting the maximum obtainable gain of the array [14]. For this simulated antenna, chamfered bend is used to compensate for excess capacitance [15]. Simulated antenna layout is shown in Fig.1 and dimensional parameters of the simulated antenna are given is Table 1. In Fig. 1(b) indicates chamfered bend and antenna dimension is 700 (l) × 691 (w) ×1.58(h) mm. After Simulation we found that return loss is 33.10dB at 1.88GHz. Return loss of -10dB or below is found from 1.855GHz to 1.907 GHz, so it is suitable for use in 1.88/1.90GHz frequency band. 2.77% bandwidth is found for this antenna. Figure 2 shows the return loss curve. Side lobe level (SLL) of the antenna is more than 15dB lower than main lobe. Fig. 3 and 4 gives the radiation pattern of the simulated antenna. Fig. 5 gives the gain of the antenna at different frequencies. Simulated gain and directivity of the antenna is 21.0dBi and 23.39dBi respectively. After the antenna array receives the incoming signals from all directions, the DOA algorithm determines the directions of all incoming signals based on the *time delay which*, for a × planar array can be computed using following equation [13]

$$\tau_{mn} = \frac{md_x\sin\theta\cos\phi + nd_y\sin\theta\cos\phi}{v_0} \quad (2)$$

Where V0 is the speed of light in free space.



(a)

(b)

Figure 1. Layout of the simulated antenna.

TABLE I: DIMENSIONAL PARAMETERS OF THE ANTENNA.

ٹ	୍	○	γ	ب□
34mm	25mm	88mm	15.6mm	10.13mm

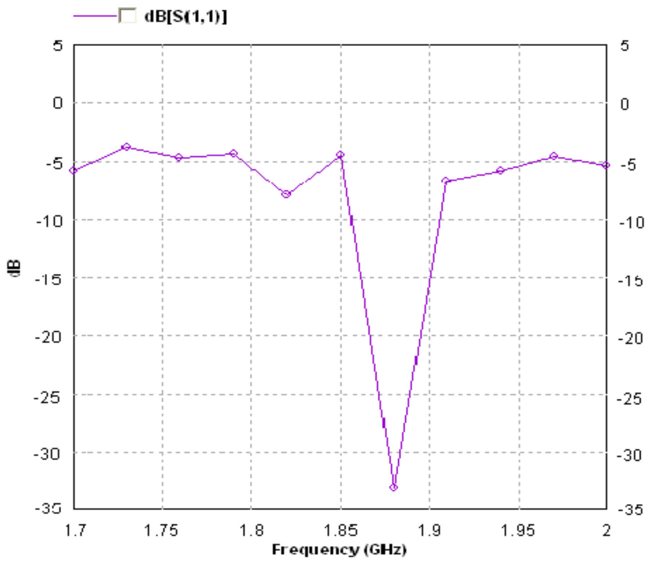


Figure 2. Return loss of the array antenna (64 elements).

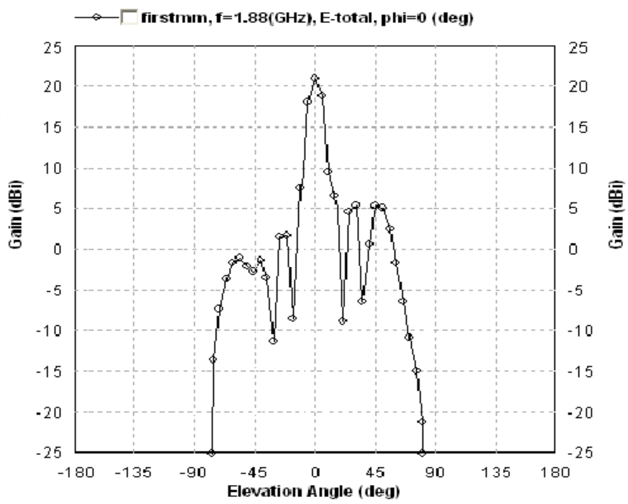


Figure 3. Radiation pattern of the array antenna.

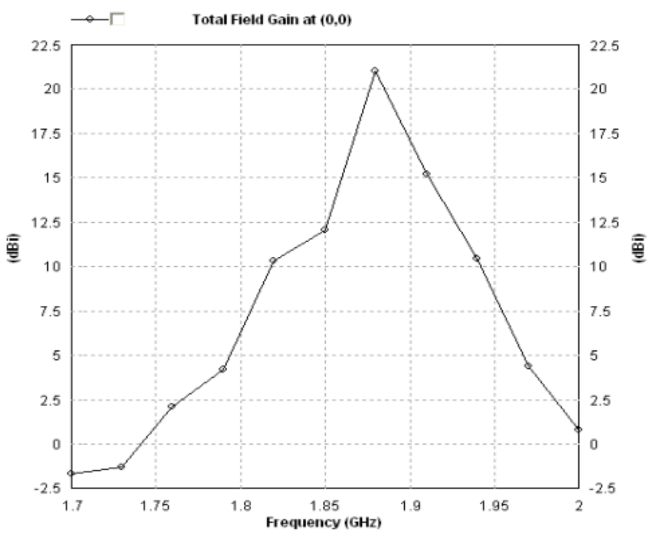


Figure 5. Simulated gain of the antenna at different frequencies.

III. DECT SYSTEM IN WLL AND RAYLEIGH-FADIANG CHANNEL

DECT system may have various different physical implementations depending on its actual use. Different DECT entities can be integrated into one physical unit entities can be distributed replicated etc. A good DECT system architecture model is given in ref. [3] and [16]. DECT system use GFSK (Gaussian Frequency Shift Keying) modulation techniques (BT=0.5).It's bit rate is 1.152Mbps, frame cycle time is 10ms and TDD duplex method is used. Wireless communication systems are characterized by time-varying multipath propagation channels, which are typically modeled as fading channels. In mobile radio channels, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component [17]. Fig. 6 shows a typical Rayleigh fading envelope at 1890MHz, frequency within DECT range and receiver speed is considered 15. The BER (bit error-rate) of GFSK modulation is evaluated over Rayleigh fading channel where received signal is corrupted by obstacles and causes multipath propagation as shown in Fig. 7. DECT has been used for Fixed Wireless Access as a substitute for copper pairs and provides a cost efficient means to establish the final drop in a public telecommunication network (Fig. 8). Wireless system always affected by multipath fading and interference; signal processing techniques can be used to improve this adverse condition. Smart antenna system is a solution to combat this problem. Smart antenna (adaptive array) work in the following way: First digital signal processor receives signals collected from each antenna element; it computes the direction of arrival
(DOA) of the signal of interest (SOI). It then uses adaptive beam forming algorithms to produce a radiation pattern that focuses on the SOI, at the same time as tuning out any signal not of interest (SNOI). Fig. 9 shows the functional block diagram of a smart antenna system.

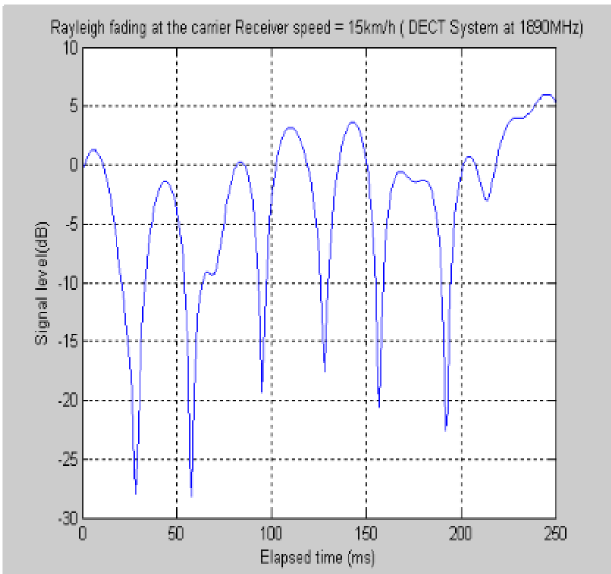


Figure 6. Rayleigh fading envelope at 1890MHz

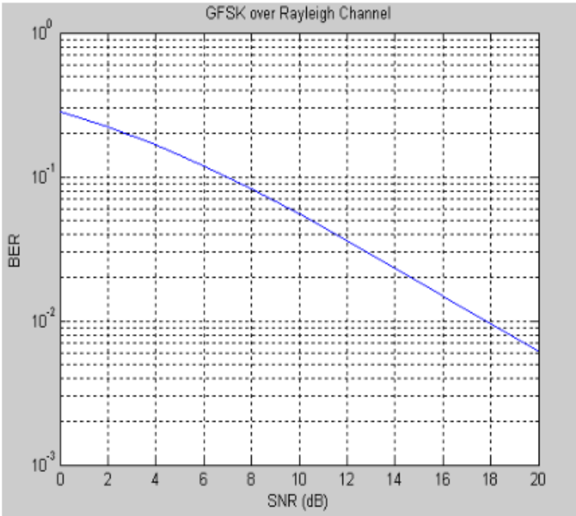


Figure 7. BER over Rayleigh fading channel for GFSK modulation

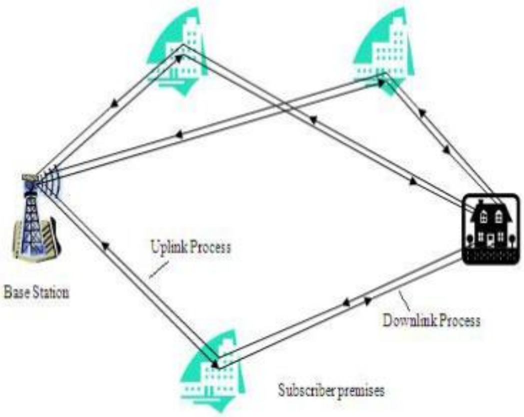


Figure 8. Block of DECT system for last mile solution.

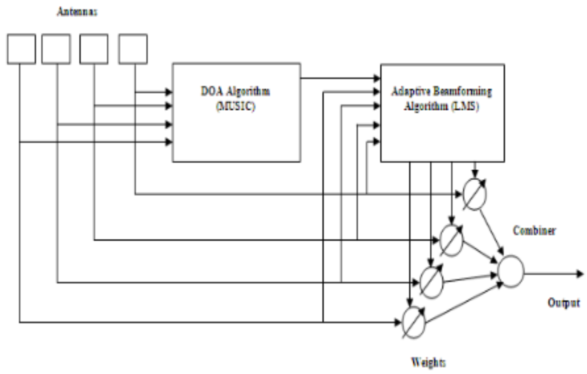


Figure 9. Block Diagram of a Smart Antenna System.

IV. DOA ESTIMATION ALGORITHM

Subspace-based methods exploit the structure of the received data, resulting in an impressive improvement in resolution. Multiple signal classification (MUSIC) algorithm falls into this category [13]. In our analysis we first consider MUSIC algorithm for DOA estimation using 8 element linear array (only azimuth angle). MUSIC is the first subspace-based DOA estimation approach (Schmitt, 1986). MUSIC promises to provide unbiased estimates of the number of signals, the angle of arrival and the strengths of the waveforms. It makes the assumption that the noise in each channel is uncorrelated making the noise correlation matrix diagonal and the incident signals may be somewhat correlated creating a no diagonal signal correlation matrix [18]. MUSIC algorithm can be described in the following way: Considering the number of signals is D and number of array elements is M. So the number of signal Eigen values and eigenvectors is D and the number of noise eigenvalues and eigenvectors is MD (M>D). Receive signal from M antennas can be written as follows:

$$x_k = [\ a(\theta_1)\ \ a(\theta_2)\ \ \dots . a(\theta_D)\ ].\begin{bmatrix} s_1(k) \\ s_2(k) \\ s_3(k) \end{bmatrix} + \bar{n}(\mathrm{k})$$

$$= \bar{A}.\bar{s}(k) + \bar{n}(k) \quad (3)$$

$$y_k = \bar{w}^T.\bar{x}_k \quad (4)$$

$$\bar{\boldsymbol{R}}_{xx} = \boldsymbol{E}[\bar{x}.\bar{x}^H] = \boldsymbol{E}[(\bar{A}\bar{s} + \bar{n})(\bar{s}^H\bar{A}^H + \bar{n}^H)]$$
$$= \bar{A}\boldsymbol{E}[\bar{s}.\bar{s}^H]\bar{A}^H + \boldsymbol{E}[\bar{n}.\bar{n}^H] = \bar{A}\bar{\boldsymbol{R}}_{ss}\bar{A}^H + \bar{\boldsymbol{R}}_{nn}$$
$$= \bar{A}\bar{\boldsymbol{R}}_{ss}\bar{A}^H + \sigma_n^2\boldsymbol{I} \quad (5)$$

$$\bar{\boldsymbol{E}}_{\boldsymbol{N}} = [\bar{e}_1 \quad \bar{e}_2 \quad \dots \dots \ \bar{e}_{M-D}] \quad (6)$$

$$\boldsymbol{P}_{\boldsymbol{MU}}(\theta) = \frac{1}{|\bar{a}(\theta)^H\bar{\boldsymbol{E}}_{\boldsymbol{N}}\bar{\boldsymbol{E}}_{\boldsymbol{N}}^{\boldsymbol{H}}\bar{a}(\theta)|} \quad (7)$$

The MUSIC algorithm in general can apply to any arbitrary array regardless of the position of the array elements [18]. Now we consider signal received from both azimuth angle and elevation angle. In this case signals are collected by an array made up of m × n antennas with direction of arrival. Is the azimuth angle and is the elevation angle. Receive signal from m × n antennas can be written as follows:

$$x_k = [\ a(\theta_1, \phi_1)\ \ a(\theta_2, \phi_2)\ \ \dots . a(\theta_D, \phi_D)\ ]\ .\ \begin{bmatrix} s_1(k) \\ s_2(k) \\ s_3(k) \end{bmatrix} + \bar{n}(\mathrm{k})$$

$$= \bar{A}.\bar{s}(k) + \bar{n}(k) \quad (8)$$

The antenna array output can be described in the following form:

$$y_k = \bar{w}^T.\bar{x}_k \quad (9)$$

$$a(\theta_D, \phi_D) = [1\ e^{-\mathrm{jk}(\cos\theta_k\ .\ \cos\phi_k\ +\ \cos\theta_k .\ \sin\phi_k)} \dots\dots$$
$$e^{-\mathrm{jk}[(M-1)\cos\theta_k\ .\ \cos\phi_k + (N+1)\cos\theta_k . \sin\phi_k]}\ ] \quad (10)$$

Where, m and n are the element number for and axis respectively. Applying the same estimation method that is used for one dimension, the pseudo spectrum of MUSIC algorithm is as follows:

$$\boldsymbol{P}_{\boldsymbol{MU}}(\theta, \phi) = \frac{1}{|\bar{a}(\theta,\phi)^H\bar{\boldsymbol{E}}_{\boldsymbol{N}}\bar{\boldsymbol{E}}_{\boldsymbol{N}}^{\boldsymbol{H}}\bar{a}(\theta,\phi)|} \quad (11)$$

We used MUSIC algorithm for uplink condition. We assumed that a smart antenna is only employed at the base station, and not at the subscriber unit. Consider signal arrival from four different directions in different angles; these angles are randomly taken as the incoming signals are random in nature. Fig .10 illustrates the pseudo spectrum of MUSIC with four different angle of arrival for 8 element linear array antenna with SNR value of 18dB. Fig. 11 shows the possible radiation pattern of the beam former of that antenna considering azimuth angle. Fig. 12 gives the MUSIC pseudo spectrum for 8×8 planar array antenna considering both azimuth and elevation angles with SNR value of 18dB. Fig. 13 illustrates the possible radiation pattern of that antenna. We see that in both cases some phase errors are introduced in the radiation pattern of the beam former (Fig. 11 and Fig. 13). Mutual coupling effect between the antenna element and improper calculation of weights in LMS algorithm can cause this problem. From Fig 10. We can realize that if two sources (angle-of-arrival at 15.4105 and 13.4023) are very close then MUSIC algorithm is unable to resolve this source.

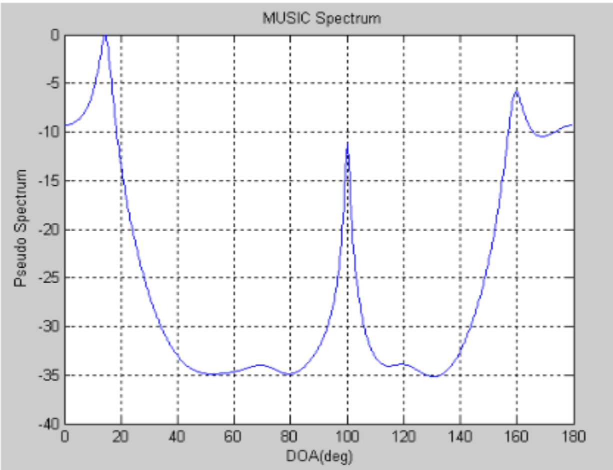


Figure 10. Pseudo spectrum of MUSIC with angle of arrival (azimuth direction) at 15.4105 , 13.4023 , 100.1832 , 160.3601 and SNR is 18dB.

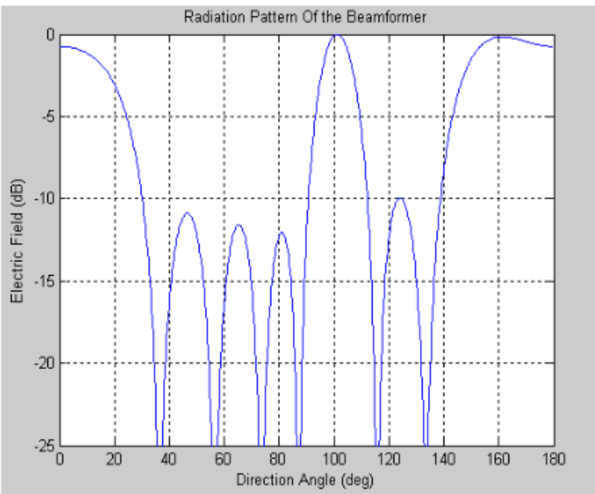
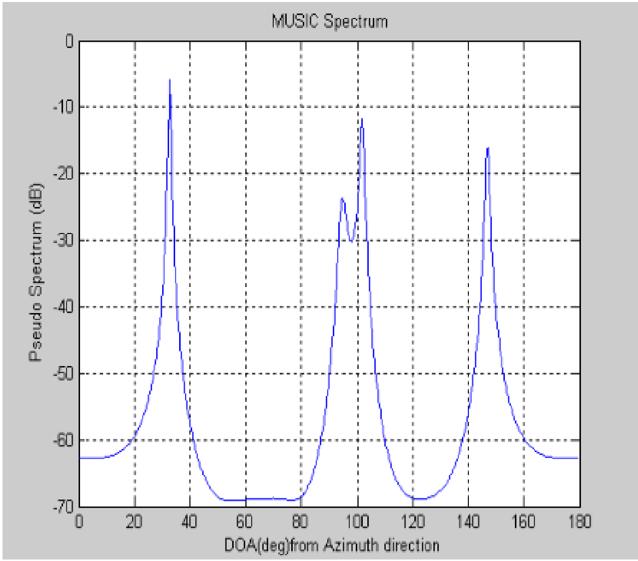


Figure 11. Possible Radiation pattern of the beam former for signal arrival (azimuth direction) at 15.4105, 13.4023, 100.1832, 160.3601 and SNR is 18dB.



(a)

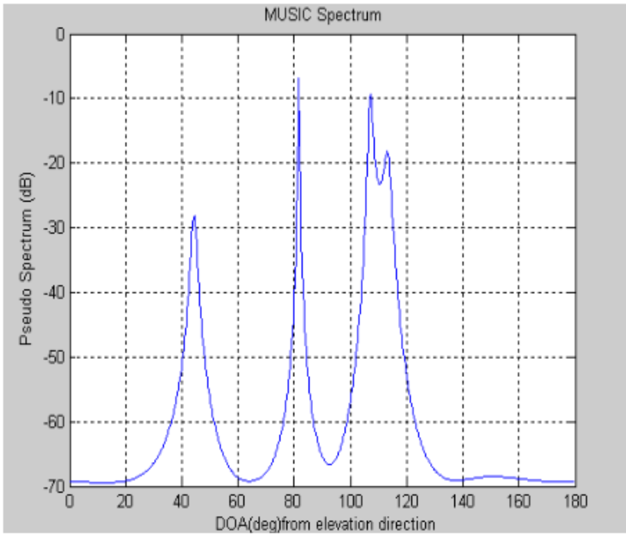
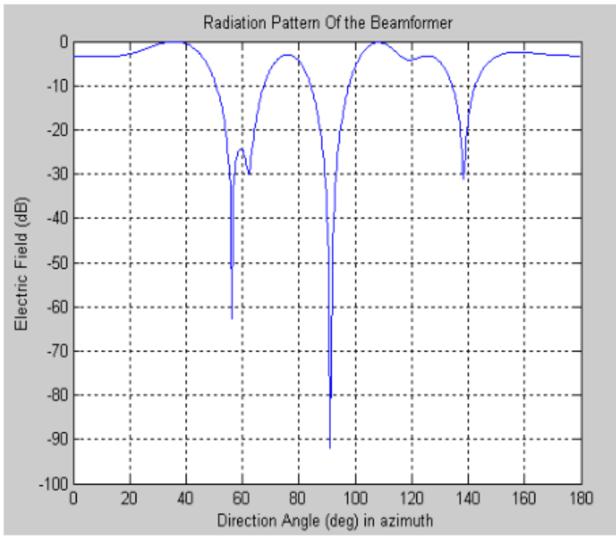


Figure 12. Pseudo spectrum of MUSIC with angle of arrival at (95.6564, 81.6510), (147.6541, 113.4150), (36.1061, 44.1702), (101.4183, 107.0332) and SNR is 18dB



(a)

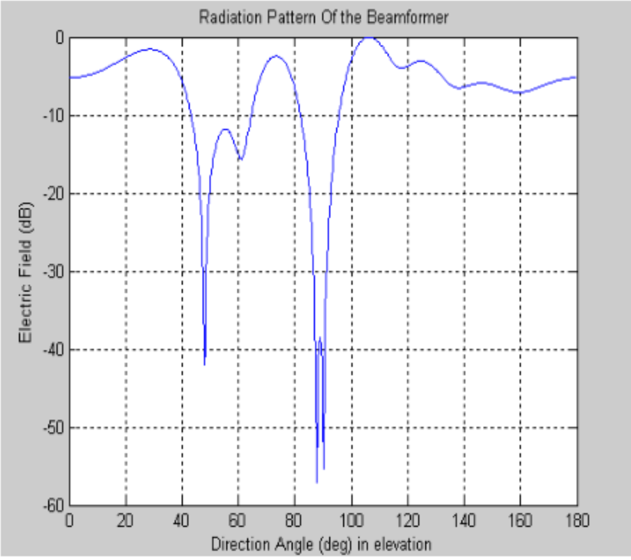


Figure 13. Possible Radiation pattern of the beam former for signal arrival at (95.6564, 81.6510), (147.6541, 113.4150),(36.1061,44.1702),(101.4183, 107.0332) and SNR is 18dB.

Another subspace based method is ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques) which gives some advantages over MUSIC algorithm like less computationally intensive, requires much less storage, does not involve an exhaustive search through all possible steering vectors to estimate the direction-of-arrival. First we consider the ESPRIT algorithm for one dimensional condition (azimuth angle). The goal of the ESPRIT techniques is to exploit the rotational invariance in signal subspace which is created by two arrays with a translational invariance structure [18]. As like MUSIC, ESPRIT assumes that the number of signal D is less that number of antenna element M (M > D). The idea behind ESPRIT is to divide the array in two equivalent sub arrays separated by a known displacement d. Here we consider eight element linear arrays that are composed of two identical five element sub arrays or two doublets. The signals induced on each of the arrays can be described by following equations:

$$\bar{x}_1(k) = [\ a(\theta_1)\ a(\theta_2)\ \dots a(\theta_D)\ ].\begin{bmatrix} s_1(k) \\ s_2(k) \\ : \\ . \\ s_3(k) \end{bmatrix} + \bar{n}_1(k)$$

$$= \bar{A}_1.\bar{s}(k) + \bar{n}_1(k) \qquad (12)$$

Similarly,

$$\bar{x}_2(k) = \bar{A}_2.\bar{s}(k) + \bar{n}_2(k)$$
$$= \bar{A}_1.\bar{\Phi}.\bar{s}(k) + \bar{n}_2(k) \qquad (13)$$

$$\bar{x}(k) = \begin{bmatrix} \bar{x}_1(k) \\ \bar{x}_2(k) \end{bmatrix} = \begin{bmatrix} \bar{A}_1 \\ \bar{A}_1.\bar{\Phi} \end{bmatrix}.\bar{s}(k) + \begin{bmatrix} \bar{n}_1(k) \\ \bar{n}_2(k) \end{bmatrix} \qquad (14)$$

$$\bar{\boldsymbol{R}}_{xx} = \boldsymbol{E}[\bar{x}.\bar{x}^H] = \bar{A}\bar{\boldsymbol{R}}_{ss}\bar{A}^H + \sigma_n^2\bar{\boldsymbol{I}} \qquad (15)$$

$$\bar{\boldsymbol{R}}_{11} = \boldsymbol{E}[\bar{x}_1\bar{x}_1^H] = \bar{A}\bar{\boldsymbol{R}}_{ss}\bar{A}^H + \sigma_n^2\bar{\boldsymbol{I}} \qquad (16)$$

and

$$\bar{\boldsymbol{R}}_{22} = \boldsymbol{E}[\bar{x}_2\bar{x}_2^H] = \bar{A}\bar{\boldsymbol{R}}_{ss}\bar{A}^H + \sigma_n^2\bar{\boldsymbol{I}} \qquad (17)$$

Using the above two equations we can construct the signal subspaces E1 and E2. The entire array signal subspecies. A matrix composed of signal eigenvector Can be constructed Now a 2 × 2 matrix can be formed using the signal subspace that is as follows:

$$\bar{C} = \begin{bmatrix} \bar{E}_1^H \\ \bar{E}_2^H \end{bmatrix} [\bar{E}_1\ \bar{E}_2] = \bar{E}_c\bar{\Lambda}\ \bar{E}_c^H \qquad (18)$$

$$\bar{E}_c = \begin{bmatrix} \bar{E}_{11} & \bar{E}_{12} \\ \bar{E}_{21} & \bar{E}_{22} \end{bmatrix} \qquad (19)$$

$$\bar{\Psi} = -\bar{E}_{12}\bar{E}_{22}^{-1} \qquad (20)$$

$$\theta_i = \sin^{-1}\left(\frac{\arg(\lambda_i)}{kd}\right) \qquad (21)$$

After calculation of the eigenvalues we can estimate the angle of arrival.

Where i *=1,2,…,D* We now consider *ESPRIT* algorithm for two dimensional conditions (both azimuth angle and elevation angle). In reference [20], the unitary ESPRIT algorithm was presented for DOA estimation for uniform rectangular arrays. For a uniform rectangular array of × elements lying in the -*y* plane and equally spaced by in the *x* direction and in the y direction. The DOA of the source is specified by the pair where cosines with respect to the x and y axes, respectively. When a narrow band source impinges on the array from the direction the phase shifts between successive elements along the *x* and *y* axes respectively. vector formed by stacking the columns of uniform rectangular array outputs, *A* is the × DOA matrix (assuming *d* incident sources) is the vector of signal complex envelopes at the origin and ()is the stacked noise vector [21]. Here *A* can be expressed as [20]

$$A(\mu,\nu) = a_N(\mu)a_M^T(\nu) \qquad (22)$$

$$a_M(\nu) = \left[e^{-j\left(\frac{M-1}{2}\right)\nu}, \dots e^{-j\nu}, 1, e^{j\nu}, \dots, e^{j\left(\frac{M-1}{2}\right)\nu}\right]^T$$

$$D(\mu,\nu) = Q_N^H A(\mu,\nu)Q_M^* = Q_N^H\ a_N(\mu)a_M^T(\nu)Q_M^* = d_N(\mu)d_M^T(\nu) \qquad (23)$$

$$d_M(\nu) = Q_M^H a_M(\nu) = \sqrt{2} \times \left[\cos\left(\frac{M-1}{2}\nu\right), \dots \cos(\nu), 1/\sqrt{2}, -\sin\left(\frac{M-1}{2}\nu\right), \dots, -\sin(\nu)\right]$$

$D(\mu,\nu)$ satisfies the following equation,

$$\tan\left(\frac{\mu}{2}\right) K_1 D(\mu,\nu) = K_2 D(\mu,\nu) \qquad (24)$$

$$\tan\left(\frac{\mu}{2}\right) K_{\mu 1} d(\mu,\nu) = K_{\mu 2} d(\mu,\nu) \quad (25)$$

Where $K_{\mu 1}$ and $K_{\mu 2}$ are the $(N-1)M \times NM$ matrices

$$K_{\mu 1} = I_M \otimes K_1 \text{ and } K_{\mu 2} = I_M \otimes K_2 \quad (26)$$

$$\tan\left(\frac{\nu}{2}\right) D(\mu,\nu) K_3^T = D(\mu,\nu) K_4^T \quad (27)$$

where $K_3 = \mathcal{R}e\{Q_{M-1}^H J_2 Q_M\}$ and $K_4 = Im\{Q_{M-1}^H J_2 Q_M\}$ using the vec operator, we find the $d(\mu,\nu)$ satisfies

$$\tan\left(\frac{\nu}{2}\right) K_{\nu 1} d(\mu,\nu) = K_{\nu 2} d(\mu,\nu) \quad (28)$$

where $K_{\nu 1}$ and $K_{\nu 2}$ are the $N(M-1) \times NM$ matrices

$$K_{\nu 1} = K_3 \otimes I_N \text{ and } K_{\nu 2} = K_4 \otimes I_N \quad (29)$$

We simulated ESPRIT algorithm for both one and two dimensional cases. Fig. 14 gives the possible radiation pattern of the beam former (azimuth angle) for 8 element linear array antenna. Four random signals with different angle of arrivals are considered. Fig. 15 illustrates the possible radiation pattern of the beam former using 2 D ESPRIT algorithm considering both azimuth and elevation angles also in this case we consider four random signals with different directions. We simulated the program many times by taking random incoming signals and Fig. 15 is one of the simulation results. Simulation depicts that the phase errors in radiation pattern of the beam former is small for both 1 D and 2D ESPRIT algorithm than MUSIC algorithm although same adaptive beam forming algorithm (LMS algorithm) have been used. The most important thing that we investigated was the simulation time for 2 ESPRIT and 2 MUSIC algorithms MUSIC algorithm requires much time for simulation than ESPRIT for the same number of random incoming signals (angle of arrivals).

$$K_{\mu 1} D \Omega_\mu = K_{\mu 2} D \quad (30)$$

where, $\Omega_\mu = diag\{\tan\left(\frac{\mu_1}{2}\right), \ldots, \tan\left(\frac{\mu_d}{2}\right)\}$; similarly D satisfies the following equation,

$$K_{\nu 1} D \Omega_\nu = K_{\nu 2} D \quad (31)$$

where, $\Omega_\nu = diag\{\tan\left(\frac{\nu_1}{2}\right), \ldots, \tan\left(\frac{\mu_d}{2}\right)\}$.

Now , $E_s = DT$ where T is an unknown $d \times d$ real-valued matrix. Substituting $D = E_s T^{-1}$ into the (30) and (31) yields the signal eigenvector relations

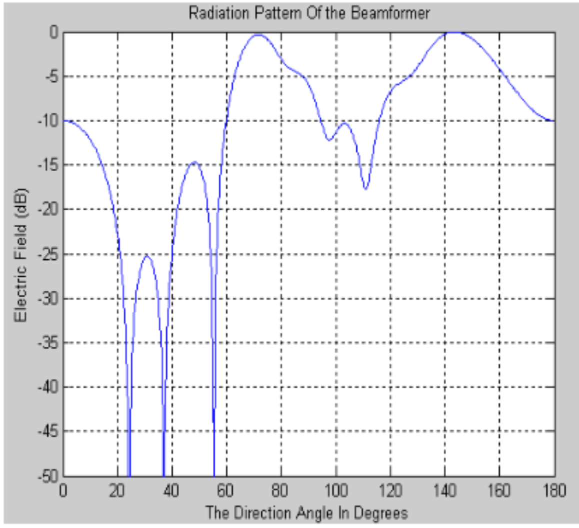
$$K_{\mu 1} E_s \Psi_\mu = K_{\mu 2} E_s \; ; \; \Psi_\mu = T^{-1} \Omega_\mu T \quad (32)$$

$$K_{\nu 1} E_s \Psi_\nu = K_{\nu 2} E_s \; ; \; \Psi_\nu = T^{-1} \Omega_\nu T \quad (33)$$

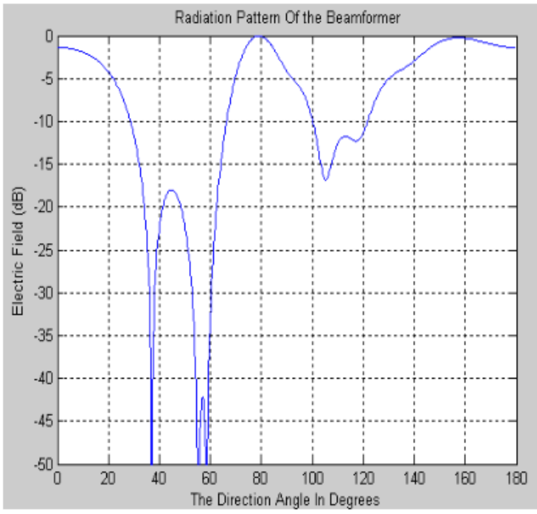
Thus, we can write $\Psi_\mu + j\Psi_\nu$ in following form,

$$\Psi_\mu + j\Psi_\nu = T^{-1}\{\Psi_\mu + j\Psi_\nu\} T \quad (34)$$

So ESPRIT algorithm can save valuable signal processing time for Smart antenna system.

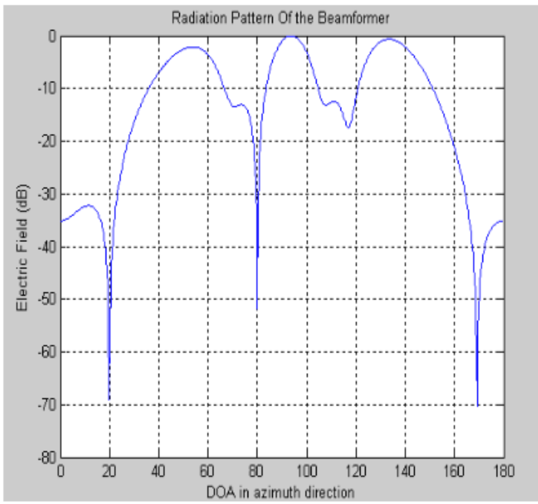


(a)

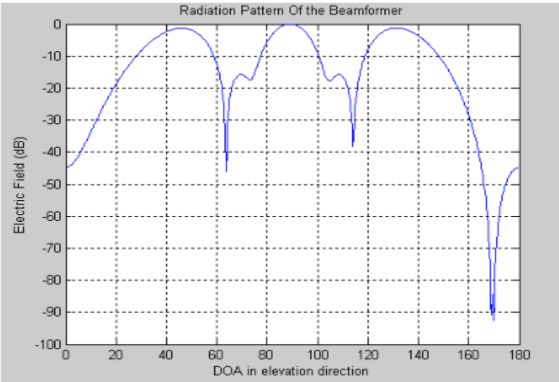


(b)

Figure 14. Possible radiation pattern of the beamformer for signal arrival at $74.2600^0, 140.4647^0, 158.4201^0, 10.9470^0$ and SNR is 18dB.



(a)



(b)

Figure 15. Possible radiation pattern of the beamformer for signal arrival at $(53.1242^o, 51.4569^o)$, $(92.2425^o, 41.40^o)$, $(125.5253^o, 90.0^o)$, $(136.5021^o, 130.1212^o)$ and SNR is 18dB.

V. ADAPTIVE BEAMFORMING TECHNIQUES

In adaptive beam forming, the target is to adapt the beam by adjusting the amplitudes and phases of signals such that an enviable pattern is formed. One of the simplest algorithms that are commonly used to adapt the weights is the Least Mean Square (LMS) algorithm. The LMS algorithm is a low complexity algorithm that requires no direct matrix inversion and no memory. It is an approximation of the steepest descent method using an estimator of the gradient instead of the actual value of the gradient, since computation of the actual value of the gradient is impossible because it would require knowledge of the incoming signals. As a result, at each iteration in the adaptive process, the estimate of the gradient is as follows [13].

$$\hat{\nabla}[J(\boldsymbol{w})]_k = \begin{bmatrix} \frac{\partial J(\boldsymbol{w})}{\partial w_0} \\ \vdots \\ \frac{\partial J(\boldsymbol{w})}{\partial w_L} \end{bmatrix} \quad (35)$$

$$x_k = [x(k)_1 \; x(k)_2 \; \ldots.. \; x(k)_L]^T \quad (36)$$

respectively, we also get a weight vector w

$$w = [\, w_1 \; w_2 \; \ldots \ldots \; w_L \,] \quad (37)$$

Then the output $y(k)$ for time step k is

$$y(k) = w^H \, x(k) \quad (38)$$

ε_k is the error between the desired signal d_k and the output signal of the array $y(k)$, can be expressed as,

$$\varepsilon_k = d_k - \boldsymbol{w}^H x_k \quad (39)$$

$$J_{MSE}(E[\varepsilon_k^2]) = d_k^2 - 2\boldsymbol{w}^H E[d_k \boldsymbol{x}_k] + \boldsymbol{w}^H E[\boldsymbol{x}_k \boldsymbol{x}_k^H]\boldsymbol{w} \quad (40)$$

$$J_{MSE}(E[\varepsilon_k^2]) = d_k^2 - 2\boldsymbol{w}^H r_{xd} + \boldsymbol{w}^H R_{xx} \boldsymbol{w} \quad (41)$$

where $\boldsymbol{r}_{xd} = E[d_k \boldsymbol{x}_k]$ and $\boldsymbol{R}_{xx} = E[\boldsymbol{x}_k \boldsymbol{x}_k^H]$ .Using steepest descent method, the iterative equation updates weights at each iteration; this can be expressed by following equation,

$$\boldsymbol{w}_{k+1} = \boldsymbol{w}_k - \mu\overline{\nabla}[J(\boldsymbol{w})]_k \quad (42)$$

where u is the step size related to the rate of convergence. This simplifies the calculation to be performed considerably and allows LMS algorithm to be used in real-time applications. LMS algorithm minimizes the MSE (Mean Square Error) cost function and it solves the Wiener-Hopf equation iteratively without the need for matrix inversion. The Wiener-Hopf equation is as follows,

$$\boldsymbol{w}_{opt} = \boldsymbol{R}_{xx}^{-1} \boldsymbol{r}_{xd} \quad (43)$$

The LMS algorithm computes the weights iteratively as,

$$\boldsymbol{w}_{k+1} = \boldsymbol{w}_k + 2\mu x_k (d_k - x_k^T \boldsymbol{w}_k) \quad (44)$$

In order to assure convergence of the weights, $\boldsymbol{w}_k$, the step size μ is bounded by the following condition

$$0 < \mu < \frac{1}{\lambda_{max}} \quad (45)$$

Where ymax is the maximum eigenvalue of the covariance Matrix, given is equation (5). The main disadvantage of the LMS algorithm is that it tends to converge slowly, particularly in noisy environment. Fig. 16 shows the simulated result of actual and estimated system output using LMS algorithm. Sixty-four weights are considered for simulation. Fig. 17 illustrates the error curve that gives error between the desired signal and output signal of the array. At last Fig. 18 describes the comparison of actual weights and estimated weights. The complex weights in equation (44) are the ideal weights if mutual coupling is not considered. These weights should be compensated according to mutual coupling in order to get better far field patterns. Compensation for mutual coupling can be accomplished by simply multiplying the received signal as given in equation (36) by the inverse mutual coupling matrix C [11]. The mutual coupling matrix can be expressed using following equations [11]

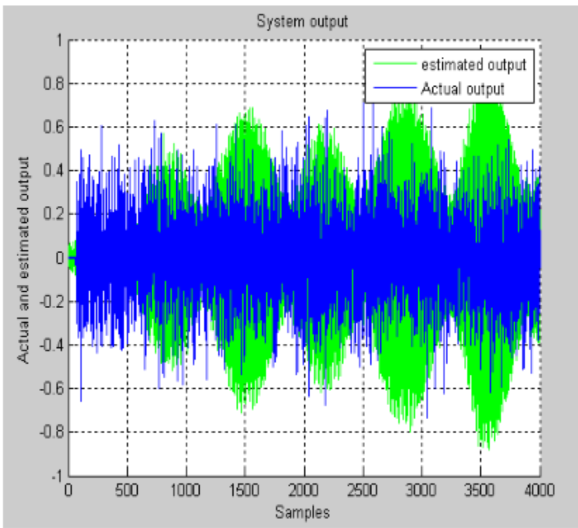


Figure 16. System output comparison of Actual value and estimated value.

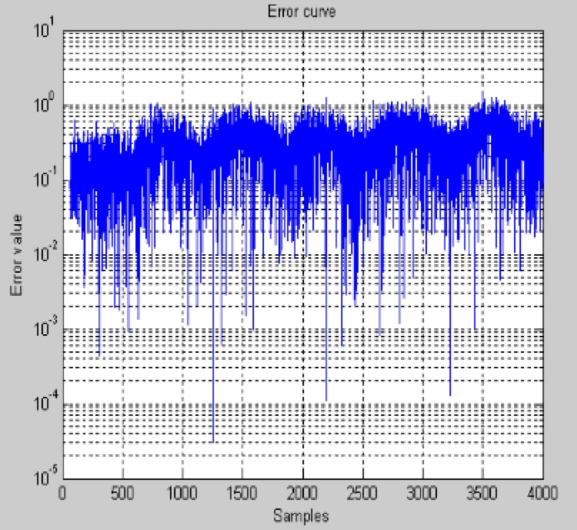


Figure 17. Error value between actual and estimated output.

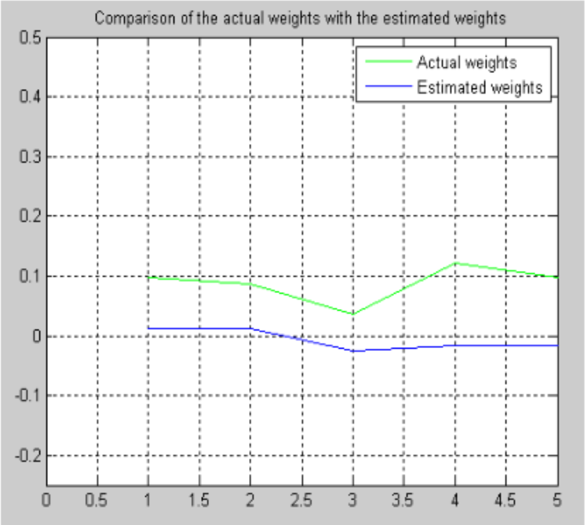


Figure 18. Comparison of Actual weights and the estimated weights, iteratively computes using equation (44).

VI. CONCLUSION

A smart antenna system has been designed to minimize the adverse effect of time-varying multipath propagation channel and improvement of the signal communication link for DECT RBS in WLL system. For signal processing we exploit MUSIC and ESPRIT algorithm considering both 1-D (azimuth angle) and 2-D (azimuth and elevation angle) angle of arrivals. LMS algorithm is used for adaptive beam forming as it requires low complexity. Using LMS algorithm we calculate the weights for adaptive beam forming in last portion we show the differences between actual weights and the estimated weights regarding LMS algorithm. Mutual coupling is considered as this gives more realistic results. At last we can conclude that for same input signal (angle – of arrival) and antenna array ESPRIT gives better performance than MUSIC algorithm. In future we want to work on the improvement of bit error rate (BER) using smart antenna for WLL and improvement of network throughput. Simulation of a 64 element micro strip antennas is very time consuming specially using low processing speed computer, Intel core 2 due CPU T8100 @ 2.10GHz , 2.09GHz is used for this task. Only 11 frequency points are considered from 1.7-2.0GHz for processing as more frequency points require more time. In simulation each frequency point takes approximately 2800sec and a total of 9 hours for 11 frequency points.

REFERENCES

[1] Friedhelm Hillebrand,"GSM and UMTS: The Creation of Global Mobile Communication", John Wiley & Sons Ltd, 2001.
[2] http:// www.dect.org
[3] Saifur Rahman, and Manisa Pipattanasomporn, "Alternate Technologies for Telecommunications and Internet Access in Remote Locations", In Proc. of 3rd Mediterranean Conference and Exhibition on Power Generation, Transmission, Distribution and Energy Conversion, Greece, November 2002.
[4] Joseph C. Liberti, JR and Theodore S Rappaport, "Smart Antennas for Wireless Communications: IS-95 and Third Generation CDMA Applications". Prentice Hall, Inc. 1999.
[5] Salvatore Bellofiore, Jeffrey Foutz,Ravi Govindarajual, srafil Bahçeci, Constantine A. Balanis , Fellow , IEEE, Andreas S.Spanias, Jeffrey M.Capone, Member , IEEE, and Tolga M. Duman, "Smart Antenna System Analysis, Integration and Performance for Mobile Ad-Hoc Networks (MANETs)", IEEE Transactions on Antennas and Propagation, Vol.50, No.5, May 2002.
[6] A. Kundu, S Ghosh, B.K.Sarkar and A. Chakrabarty,"Smart Antenna based DS-CDMA system design for third generation mobile communication" ,Progress In Electromagnetics Research M,Vol.4,6780,2008.
[7] S.N.Shahi, M.Emadi and K.Sadeghi,"High Resolution DOA Estimation in Fully Coherent Environments", Progress In Electromagnetics Research C, Vol.5, 135-148, 2008.
[8] L.Lizzi, F.Viani, M.Benedetti, P.Rocca , and A.Massa ,"The M-DSO-ESPRIT Method for Maximum Likelihood DOA Estimation", Progress In Electromagnetics Research, PIER 80,477-497,2008
[9] H. Wang and M. Glesner "Hardware implementation of smart antenna systems" Microelectronics System Institute, TU Darmstadt, Germany. Adv. Radio Sci. 4, 185-188, 2006 www.adv-radio-sci.net/4/185/2006/
[10] Inder J. Gupta and Aharon A. Ksienski, "Effect of Mutual Coupling on the performance of Adaptive Arrays", IEEE Transactions on Antenna and Propagation, vol.AP-31, NO.5.s, Sep 1983
[11] Hans Steyskal and Jeffrey S. Herd, "Mutual Coupling Compensation in Small Array Antennas", IEEE Transactions on Antenna and Propagation, vol.38, NO.12, December 1990
[12] Braham Himed and Donald D. Weiner, "A

Generalized Treatment of Mutual Coupling Compensation for ESPRIT", 1989 IEEE Int. Symp. Circuits Syst. pp. 296299.

[13] C.A. Balanis, Antenna Engineering, wiley, 3rd ed, 2005.

[14] Ramesh Garg, Prakash Bhartia, Inder Bahl, Apisak Ittipiboon, Microstrip Antenna Design Handbook, 2001 ARTECH HOUSE, INC.

[15] K.C.Gupta,Ramesh Garg, Inder Bahl, Prakash Bhartia, "Microstrip Lines and Slotlines",Artech House,2 ,1996.

[16] Jochen Schiller "Mobile Communications", 2nd ed. Pearson education Limited 2003.

[17] Theodore S. Rappaport, "Wireless Communication Principles and Practice"Prentice Hall, 2nd ed, 2004.

[18] Frank Gross, "Smart Antenna for Wireless Communication with MATLAB" The McGraw-Hill Companies, Inc. 2005

[19] Smair Mouheddin and Bel Hadj Taher Jamel "Indoor Characterization using High-Resolution Sihnal Processing Based on Five-Port Techniques for Signal Input Multiple Output System " American J. of Engineering And Applied Science 2(2): 365-371, 2009/

[20] Machel D. Zoltowski , Martin Haardt and Cherian P.Mathews " Closed-From 2-D Angle Estimation with Rectangular Arrays in Element Space or Beamspace via Unitary ESPRIT " IEEE transactions on signal processing, vol,44, no 2, February 1996.

[21] Cherian P.Mathews , Martin Haardt and Machel D. Zoltowski, "Implementation and Performance Analysis of 2D DFT Beamspace ESPRIT" IEEE Proceedings of ASILOMAR -29,1996.

