Brief literature survey

The work carried out in the field of wireless communications systems and smart antennas by the researchers worldwide and published in various articles in National/International journals, reference books and IEEE conferences proceedings that provided the motivation for the present investigation, has been reviewed and presented here in brief.

C.A. Balanis [1] has introduced the fundamental principles of antenna array theory and techniques to apply them to the analysis, design and measurements of antenna arrays.

Raj Pandya [2], T.S. Rappaport [3] have covered the technical concepts which are the core of design, implementation, research and invention of modern wireless communication systems and standards. They also targeted at a clear understanding of the basic technology architecture and application associated with the current and future mobile communication system services and standards, and their evolution towards next generation system.

William C.Y. Lee [4], [5] has provided the design fundaments of early mobile radio systems while as Jochen H. Schiller [6] has covered the technical concepts of modern mobile communication systems.

Jack H. Winters [7], WTEC Hyper Library [8], G.V. Tsoulos [9], M. Cooper, M. Goldberg [10] have provided an over view of smart antennas in terms of benefits and challenges in the context of current 2G TDMA systems. They have advocated the use of four element adaptive array smart antennas in IS-136 or in GSM at all base stations to decrease the frequency reuse factor from 7 to 4 nearly doubling the capacity.

B. Widrow, P.E. Mantey, B.B. Goode [11] have suggested a system consisting of an antenna array and an adaptive processor that can perform filtering in both the space and the frequency domains, thus reducing the sensitivity of the signal receiving system to interfering noise sources. The adaption process is based on LMS algorithm which is slow in its convergence and hence not suitable for mobile wireless communication.

L.C. Godara [12] has provided a comprehensive review of various beamforming schemes, adaptive algorithms such as LMS, SMI, RLS CMA and various DOA estimation methods such as MVDR estimator, ML, CLOSEST, MUSIC, ESPRIT, WSF etc. He actually aimed to provide complete treatment of the subject area by extending coverage to topics that might not be directly relevant to mobile communications.

G. Tsoulos, J. McGeehan, M. Beach [13], Jack H. Winters and Jack Salz [14] have shown that it is possible with adaptive array smart antenna at base station of 2G wireless system to establish the required links and track the channels with an acceptable BER 10^{-3} for variety of operating but no attempt has been made for BER 10^{-4} which is acceptable BER for 3G CDMA system.

John S. Thompson, Peter M. Grant [15] have provided an introduction to the subject of antenna arrays for narrowband CDMA base station receivers in which adaptive array smart antenna can reduce the cellular interference levels and improve the capacity of reverse link. But nothing is suggested about how the forward link can handle the increased traffic that antenna arrays can offer on the reverse link.

David Cabrera, Joel Rodriguez [16] have proposed switched beam smart antenna for 3G CDMA cellular communication system with Gaussian windowed function which requires large number of array elements to keep main lobe beamwidth constant i.e. array size increases with Gaussian windowed function and hence not economical and practical to use at base station.

Simon C. Swales, Mark A. Beach, David A. Edwards and Joseph P. McGeehan [17] demonstrated that by employing smart antenna array to resolve the angular distribution of the mobile users as seen at the base station sites, and then using this information to direct beams towards the mobiles the amount of co-channel interference experienced from and by neighboring co-channel cells can be reduced which in turn increases the spectral efficiency or capacity of network. They have stated that there are various DOA estimation techniques and number of beam-forming algorithms but their utilization in mobile communication environment has yet to be fully appraised.

Ch. Shanti Rani, Dr. Subbaiah, Dr. Reddy [18] have suggested to use RLS beam forming algorithms for adaptive array smart antenna as RLS is more efficient and fastest in its convergence. But they varied inter element spacing of an array which is not acceptable for many applications.

A Kundy, S. Ghosh, B.K. Sarkar and A Chkrabarty [19] have proposed the use of adaptive array smart antenna in 3G CDMA system with MUSIC DOA estimation and

MVDR beam-forming algorithm to improve the capacity of 3G wireless system. The greatest advantage of MVDR beam-forming algorithm is that it does not require DOA of interfering signals. But this beam-forming algorithm generates significant amount of side lobe levels which in turn limits the capacity of 3G system.

Nidhal Odeh, Sabira Katun, Aliyan Ismail [21] have suggested that replacing the omni directional antenna by smart antenna system allows same codes to be reassigned to different users if they are spatially separated and this new system called CDMA-SDMA can improve the capacity of CDMA system.

J.C. Liberti, T.S. Rappaport [23] have given the mathematical treatment of various adaptive beam forming algorithms and DOA estimation techniques, their merits and demerits. They have mentioned that the use of smart antenna in 3G CDMA system improves its capacity but they assumed the side lobe level of about 10 dB, which limits the capacity and performance of 3G wireless system.

Ahmed EI Zoology [24] has provided an introductory discussion of the benefits and use of smart antennas in 3G cellular communication system.

Frank Gross [25] has explained that side lobes in array pattern of antenna array can be reduced to insignificant level by employing the window function. He also demonstrated that fixed beam arrays can be designed such that the array pattern consists of several simultaneous spot beams transmitting in fixed angular directions through the use of Butler matrices. This forms the basis of switched beam smart antenna. Frank Gross has also explored the various techniques employed to estimate DOA e.g. MUSIC, ESPRIT etc. and has laid foundation for understanding eigen structure methods. He has also explained and explored various adaptive algorithms e.g. LMS, RLS, SMI, CMA etc.

P.F Dricssion and G.J Foschin [27], David Gesbert, Mansoor Shafi and Ayaman Naguib [28] have given an overview of MIMO techniques.

F. E. Fakoukakis, S. G. Diamantis, A. P. Orfanides and G. A. Kayriacou [33], have proposed the development of four element and eight element switched beam smart antenna using Butler matrix. They have also proposed the idea of an adaptive smart antenna in azimuth and switched beam smart antenna in the elevation direction to keep the cost at an affordable level.

C. Jansen, R. Piesiewicz, D. Mittleman and Martin Koch [34], have described the effect of reflections from buildings on path loss and angular spread at mobile station and base station of mobile communication systems.

W. C. Y. Lee [35], has provided the path loss concept and diversity concept applicable to mobile radio environment.

Garret Okamota[36] and IEC [37], have investigated various methods of development of smart antennas and their advantages in wireless communication systems.

Iordanis Koutsopouls and Leandros Tassiuals C[38], Ung and R. H. Johnston [39] L. Hanzo, L. L. Yang, E. L. Kuan and k.Yen [40] have investigated the concept of SDMA using adaptive array smart antenna.

Nan-Jun Li, Jian-Feng Gu and Ping Wei [44],have compared MUSIC and ESPRIT algorithms and they have predicted that MUSIC is suitable for 1-D DOA estimation.

L. C. Godara [45] has showed how the smart antenna could be utilized in different configurations to improve the performance of mobile wireless communication system.

J. G. Proakis [46] has provided the basic principles of DSP.

2.1 Summary of Literature Survey, Objectives and Investigations

The articles reviewed in literature survey can be classified into three categories.

- Modern wireless communication system, their impairments and approaches to improve the capacity of these wireless systems.
- Smart antenna types, their benefits and challenges, the approaches suggesting algorithms for DOA estimation and beam forming of adaptive array smart antenna.
- The use of smart antenna to improve the capacity of 3G CDMA wireless system.

From literature survey it is concluded that the subject of smart antennas is gaining more and more popularity due to tremendous growth in all forms of wireless communication systems. In wireless communication smart antennas can be utilized to boost capacities, expand bandwidths, increase SINR, mitigate fading and improve MIMO communications. As stated in literature survey Frank Gross [25] has provided the fundamental understanding of smart antennas without a need to tie the treatment to any one specific application. He described the fixed beam arrays with butler matrix. We extended this concept to get switched beam smart antenna. When such antenna is windowed with Kaiser-Bessel window function, side lobe level is reduced and such new developed SBSA can be employed in 3G cellular mobile system to improve its capacity.

Frank Gross[25] and other researchers explained and explored various DOA estimation and adaptive algorithms..

The literature survey shows that many Researchers have investigated 4 element SBSA with 4x4 Butler matrix and it is widely used for 2G wireless communication. We extended this approach to 8 element SBSA with 8x8 Butler matrix for 3G wireless communication system.

The literature survey further shows that it is possible to use an adaptive array smart antenna at base station of 2G system to improve its capacity . we investigated and extended the use of an adaptive array smart antenna at the base station of 3G system and developed eight element adaptive array smart antenna with MUSIC and RLS algorithm to improve the capacity 3G system.

2.2 Investigation Methodologies

- For macro cells angular spread (AS) [24] at the base station is generally below 15° and upper bound on the number of elements in the array is about 8 for AS of 12°. Diversity gain and capacity improvement diminishes beyond the four elements in the array while as Beam forming performance improves as number of elements in array increases. Beam forming performance depends on high correlation values between the antenna elements and hence optimum separation between the antenna elements for high correlation is $d=\lambda/2$. With this view we assume antenna arrays with 8 elements with $\lambda/2$ separation between two elements.
- We assume desired coherent signals of suitable amplitude and sinusoidal in nature and noise signals of suitable variances impinging on elements of antenna array from various directions.
- The development platform used is MATLAB with associated tool boxes.
- After learning and understanding of mathematical intricacies involved in the development of smart antenna the same is implemented in software by writing script files in MATLAB.
- The results have been displayed in the form of radiation pattern of antenna arrays and represented in terms of tabular numerical data and graphs.

The above methodology that has been adopted in the present investigations is reported in the flowing chapters.