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Application of Array Processing for Mobile Communications

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Abstract: *Digital Signal Processing (DSP) is about a mathematical equation and mathematical operations. It is described by the significations of discrete period, discrete frequency, or supplementary discrete area signals by a order of numbers or signals and the processing of all the signals that related. Digital Signal Processing applications consist of the signal processing for communication. For example is the array processing for the mobile communications. Signal processing is a extensive area of scrutiny that extends from the easiest form of 1-D signal processing to the convoluted form of M-D and array signal processing. This report presents the theory and thoughts about array processing, the ideology of the array processing and appliance of the array processing.*

Keywords- *Digital Signal Processing, Array Processing for Mobile Communications*

1. INTRODUCTION

Array configuration can be identified as a set of sensors that are spatially separated for example is antennas[1]–[5]. There are three techniques of the array processing. The frank setback that needs to be focus to resolve by employing array processing techniques is to verify the number and the locations of the energy-radiating sources (emitters)[6], [7]. Secondly is to boost the signal to noise ratio SNR "signal-to-interference-plus-noise ratio (SINR)". Lastly is to detect several affecting sources. In such a context, the digital signal processing is the enabling technology. The block diagram of the digital radio receiver is shown in figure 1. The analogue front end includes essentially some demodulation, filtering and automatic gain control functions.

The block diagram is consists of the analog front end, the A/D , the equalisation, the estimation, the detection, the speech decoder, the data decoder, the power supply, the synthesiser, the phase lock loops and lastly is the monitoring and control [6]–[15].

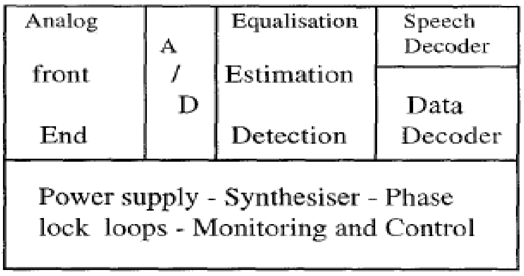

Figure 1: Block diagram of a mobile radio communication

2. VECTOR CHANNEL MODEL

From the multipath transmission and user motion, the consequences of the channel in a celullar radio link is arise. This consequences make unique challenges for STP. The key to initialy successful STP algorithms is a throughout perceptive of channel features. The main characteristics of a mobile wireless channel are illustrates into several parts. The first features is propagation loss and fading. As the signal propagate to the base station, the mobile loses strength during te signal radiated. From slow and fast fading and from the mean propagation loss, it makes the losses is arise. The square law spreading, absorption by foliage and the effect of vertical multipath is about the mean propagation loss. Slow fadding is effected from shadowing by buildings and natural elements and is generally classify to 8dB. Fast fadding is effected from multipath spreading in the surrounding area of the moving mobile. It is also known as Rayleigh distributed [16]-[19].

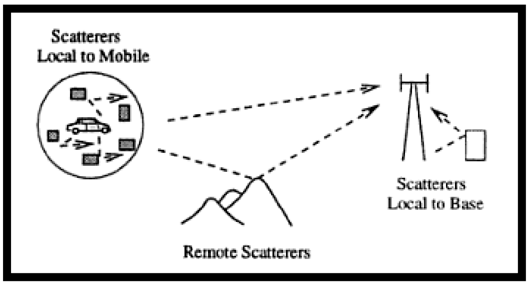

Figure 2: Multipath propagation

In the figure 2, is about the second features which is multipath effects. There three parts for the multipath propagation. The multipath propagation are the scatters local to mobile, the remote scatters and lastlt is the scatters local to base. The third features are the spatial and temporal structure. The structure can help determine a (ϴ1) if the angles of arrival ϴ1 are known or can be estimated. For the temporal structure, it relates to the properties of the signal u (t) and includes modulation format, pulse shaping function and symbol constellation.

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The temporal structures are divides into several parts which are the constant modulus (CM), Finite Alphabet (FA), the distance from Gaussianity, Cyclostationarity and lastly the temporal manifold. The temporal manifold confines the temporal pulse-shaping task data. The temporal manifold is definite as the sampled response of a receiver to an incoming pulse with delay. The temporal manifold can be probable with good accuracy because it depends only on the pulse shaping function.

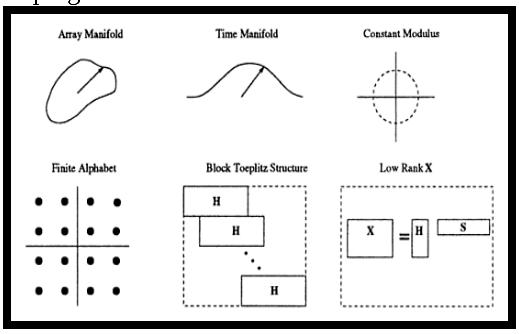

Figure 3 Space Time Structure

The figure 3 shows the space time structure. The time structure is consists of the array manifold, the time manifold, the constant modulus, the finite alphabet, the block toeplitz structure and lastly is low rank X. The figure is about the different structures and properties inherent in the signal model[20]-[26].

3. ALGORITHMS FOR STP

Beginning four decades ago, a signal processing arrays was first introduced in world history, and now it began to be used to adjust the antenna. For the detection of an antenna, the merger has been combined with a technique using the phase-lock loop start was introduced by Howells in which he was raised to the idea of prevention sidelobe nulling adjustments and Applebaum process is for developing feedback control algorithms for maximizing the SINR. In addition, an algorithm has also been proposed that the LMS algorithm by Widrow. Another idea proposed by Capon where he proposed adaptive antenna system is going to use the face constraints that can minimize the variance distortionless beamformer. Subsequently, other progress has been made by Frost, and Jim Griffiths among several others.

In addition, under algorithms for STP also have explained about two aspects that are single-user and multi-user also example of simulation. For single-user are discuss about ST-ML and ST-MMSE algorithms. Some of methods also has been study such as training signal methods, blind methods, spatial structure or DOA-Based methods, temporal structure methods and polyphase methods. The second aspect is multi-user algorithms which is are discuss about Multi-User MLSE and MMSE, Multi-User Blind Methods, Finite Alphabet (FA) Methods Finite Alphabet – Oversampling (FA-OS) Method, and Multi-User CM.

3.1 Single-User ST-ML and ST-MMSE

It explains that the concept of ST-MLSE and ST-MMSE is an extension of the space-time MMSE and ML algorithms. Maximum Likelihood Sequence Estimation (MLSE) is actually referring to the maximum Likehood (ML) where it is the first criteria in the space-time processing. ST-MLSE seeks to estimate the sequence of data sent and received signal vectors given. In addition, there are other criteria that is used is the minimum Mean Square Error (MMSE). For ST-MMSE concept we obtain an estimate of the signal to be transmitted as the number of space-time weighted received signal. In addition, it seeks to minimize the mean square error between the estimated and the actual signal at each instant of time.

3.1.1 ST-MLSE

In previous equation, the channel model is described and it is assumed that the noise N is the spatial and temporal white and Gaussian and no interference occurs. Problem for MLSE can be shown to reduce to find S that satisfy the following criteria:

$$\min_{S} \|X - HS\|_F^2 \qquad \text{eqn. 1}$$

The equation 1 which describes the channel H is assumed to be known and ‖ . ‖ F denotes Frobenius norm. It is a standard problem MLSE where it refers to space and time. Thus, by using space-time known Viterbi algorithm (VA) by the equation 1 it is used for conducting searches carefully and efficiently as in the figure below. MLSE criteria can be formulated with the new metric to address the problem in the presence of co-channel interference in which both spatial and temporal work (which caused the delay spread).

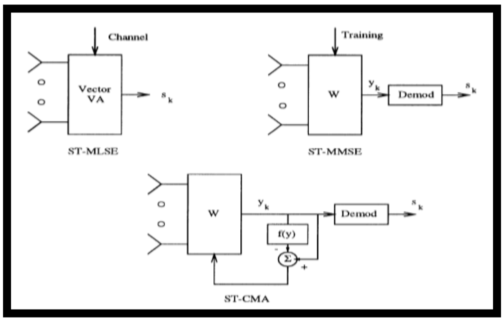

Figure 4 Different structures for space-time processing

3.1.2 ST-MMSE

ST-MMSE receiver is A strong interest to delay spread in the presence of CCI which the receiver is collecting input in space and time to get the output to minimize the error between itself and the desired signal. Before discussing further, will be introduced to some of the preparations. For equalizer cum beamformer, a space-time filter have been write in W form :

$$W(k) = \begin{bmatrix} w11(k) & w1M(k) \\ wm1(k) & wmM(k) \end{bmatrix} \qquad \text{eqn. 2}$$

For space-time filter output, to obtain convenient formulation was introduce the quantities W (k) and X (k) as above :

$$X(k) = vec\left(X(k)\right) \quad (mMx1) \qquad W(k) = vec\left(W(k)\right) \quad (mMx1) \qquad \text{eqn. 3}$$

The operator vec (.) was defined as :

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$$vec\ ([v1 \ldots vM]) = \binom{v1}{vM} \quad \text{eqn. 4}$$

The scalar equalizer output y (k) defined as

$$y(k) = WH_{(k)}X(k) = T_r\ (W^H\ (k)X(k)) \quad \text{eqn. 5}$$

which $(.)^H$ was defined as complex conjugate transpose. The space-time filter weights was choose by ST-MMSE to get the minimum mean square error. For example :

$$\min_W E\ \|W^H X(k) - s(k-\zeta)\|_2^2 \quad \text{eqn. 6}$$

Z is defined as delay which choose to center the space-time filter (it will effects of the performance). There are some theorem of the solurtion a least squares (LS) problem.

$$E(X(k)(X^H(k)W - s*(k-\zeta))) = 0 \quad \text{eqn. 7}$$

$$W = \{E(X(k)X^H(k))\}^{-\prime}\ E\ (X(k)s*(k-\zeta)) \quad \text{eqn. 8}$$

which is * superscript as complex conjugate.

$$E\left(X(k)s*(k-\zeta)\right) = [0 \ldots 0\ vec^T(H)0 \ldots 0]T_{=\bar{H}} \quad \text{eqn. 9}$$

The number of zeros before and after refer to $vec^T(H)$ was depends on choose of ζ. The space-time $mN \times mN$ and covariance matrix $R_{XX} = E(XX^H)$ was defined. Otherwise, Eqn 8 takes form as below.

$$W = R_{XX}^{-1}\bar{H} \quad \text{eqn. 10}$$

From the eqn.10 $M = N, \bar{H} = vec\ (H)$ was defined. Some technique are may used to solve eqn.10 such as the least mean square (LMS) or the recursive least square (RLS). It may have some different of computational complexity, tracking capability and steady-state error. For method Sample Matrix Inversion (SMI) or known as block method may used which is separate and use $\bar{H}$ to find W and calculate $R_{XX}^{-1}\bar{H}$.

The nature of channel, dominance of CCI and ISI are influenced by performance of ST-MLSE and ST-MMSE schemes. In this situation, the Viterbi equalizer is difficult to do if the CCI controlled channel and multi-direction. At the same time, the MMSE will be required. But, if the situation occurs propagation delay, the ISI will be controlled. This shows that MLSE has a natural advantages.

From the review of the basic approaches to space-time processing, now will start to discuss and study about two important issues: there are blind vs non-blind and single vs multi-user approaches.

a. <u>Training Signal Methods</u>

These training signals are function for the MLSE or MMSE receivers which is to estimate the channel that are needed. For some application mobile communications such as GSM and IS-54, there are separate signal to insert inside TDMA data bursts which is used a training signal.

During training burst, the received data defined as:

$$X = HT + N \quad \text{eqn.11}$$

By using LS, the eqn. can estimate H as:

$$H = XT\dagger \quad \text{eqn.12}$$

which is $T\dagger = T^H(TT^H)^{-}1$

by using eqn. 10, H already to be computed and W will be need. It happen in a ST-MMSE receiver.

b. <u>Blind Methods</u>

The blind methods are known as 'self-recoring' or 'unsupervised' which is not use training signals and it more to temporal structure such as non-Gaussianity, constant module(CM), finite Alphabet(FA) and spatial structure. When use blind methods will effect to validity and structural properties

c. <u>Spatial structure or DOA-Based Methods</u>

This methods are used for deternine the optimum beamformer by use DOA estimates. In the 1980, are developed in military application for reception. In 1979 by Schmidt the DOA estimation was first began with the MUSIC algorithm and launched 'subspace era'. Another study of DOA estimation techniques have been proposed ESPRIT algirithm by Paulraj which there have advantages compared to MUSIC but it still need specific array geometry. Doa-Based methods happen in third step, first the requires accurate of array manifold and the process calibration is expensive. Next, at the base station, the number of antenna varies 4-8 per sector. Finally, the theory of the modulation format do not achievement of the communication signal. In addition, both of time delay and multipath signal have a relationship in methods.The signal as above can be used to estimate directions-of arrival that are known as 'subspace approach'.

$$x(t) = Au(t) + n(t) \quad \text{eqn. 13}$$

there have A that is matrix (m×Q) which is for each wavefront are refer as array response and assume no multipath

$$A = [a(\theta 1) \ldots\ldots a(\theta Q)] \quad \text{eqn. 14}$$

$$u(t) = [\alpha 1(t)u1(t-\tau 1) \ldots \alpha Q(t)uQ(t-\tau Q)]T \quad \text{eqn. 15}$$

From the eqn, u(t) refer as fading signal from Q users and

$$uq(t) = \textstyle\sum_k Sq(k)g(t-kT) \quad \text{eqn. 16}$$

The model of sampled block signal as in the following form

$$X = AS + N \quad \text{eqn. 17}$$

The received data get from X to estimate the signal subspace and then matrix A for an (m×Q).

The signal subspace have a good estimate by first Q dominant eigenvectors of the convariance matrix $R_{XX} = E(xx^H)$. The subspace fitting will estimates A when E_s is a matrix of eigenvectors for minimize by eqn. 18

$$\min_A \|Es - AZ\|_F^2 \quad \text{eqn. 18}$$

From eqn. 18 the square matrix (Q×Q) get from the Z. From eqn. 19 uq(t) was identical from the MMSE and ML estimators.

$$wq = R_{xx}^{-1}a(\theta q) \quad \text{eqn. 19}$$

The beamformer (space only) is refer to wq.

3.2Multi-User Algorithms

The problem of extract multiple co-channel signal when user signals arrived at an antenna array are known as multi-user (MU) algorithms. For example, problem happen in different situations such as in channel reuse within cell (RWC) or the interference was demodulate to improve interference. There are example of the model :

$$X = HS + N \quad \text{eqn. 23}$$

which is H and S are defined as multiple users and dimension matrix of m×NQ and NQ×M.

3.2.1 Multi-User MLSE and MMSE

MLSE can be continued if all isayarat before arriving at the channel known for memodulatekan all user data sequence. It

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can also minimize the ML cost function in the sequence data of multiple users. Viterbi equalization techniques to be implemented effectively. Normally, each separate user signal is estimated by the MMSE for a single user. But in this situation, the MMSE has been treating the signals of other users is not known. Blind method or training signal is required for multi-user technique. The solution, multiple signal training should be designed to minimize cross-channel coupling.

3.2.2 Multi-User Blind Methods

A technique where it is parallel to a single user and temporal blind method. Algorithms for multi-user spatial structure it is used according to the conditions previously discussed in the first part. The method used is the same where the initial estimate A subspace method and to eqn. 19 is wq beamformer for each users.

3.2.3 Finite Alphabet (FA) Method

The FA property was achieved from digitally modulated signals. From eqn.17 the model are given as above which is assuming no delay spread and multi-user synchronization.

$$X = AS + N \qquad \text{eqn. 24}$$

Which additive noise is assumed to be white and Gaussian and there have A and S are unknown value. The ML criteria is to reduce minimization problem.

$$\min_{A,S} \|X - AS\|_F^2 \qquad \text{eqn. 25}$$

To solve eqn. 25, the FA property are using to solve and estimate both of A and S. There have two techniques that are used such as ILSP and ILSE to minimization tractable. The problem of ML problem for single user can be formulated. The channel and data are estimate to jointly FA signal properties. The adaptive ML known as joint ML methods.

3.2.4 Finite Alphabet-Oversampling (FA-OS) Method

The FA algorithms are be used to estimate the space-time channel H and the spatial channel A. By using polyphase or oversampling method that are function to estimate the temporal channel. To combine with oversampling, eqn. 24 are needed to extend the multi-user data.

For example, assume at p samples per symbol is oversampling, and a new mP×M data matrix X was defined. The results was apply in the eqn. 26 as above :

$$X = HS + N \qquad \text{eqn. 26}$$

The eqn shows that dimension of X, H and S are (mp × M), (mp×NQ) and (NQ×M) respectively.

As in the eqn can estimate that H and S are used a joint-ML approach .

$$\min_{H,S} \|X - HS\|_F^2 \qquad \text{eqn. 27}$$

3.3 Simulation Example

Figure 5 shows the occurrence of STP in the mobile environment. For example the city was selected channel to channel model simulation. A total of four element linear array with spacing (λ / 2) was applied. Both interference signals arriving from the mean direction is needed for 0˚ and 45˚. Channel interface that used is IS-54. Section a shows the constellation have been received for a simple antenna. This implies that the eye is completely closed. Section b shows that a ST-MMSE equalizer are used to employing training signals and the same time it shows constellation after STP. From that, the received constellation have a dramatic improvement.

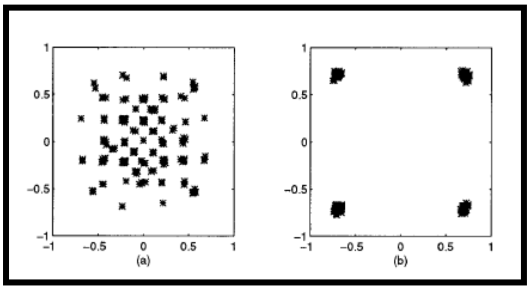

Figure 5: Interference cancellation by using STP

4. APPLICATIONS OF SPATIAL PROCESSING

In this section, three applications of antenna and STP in cellular base stations was described more details. Three application that are discussed switched beam systems, space-time filtering and channel reuse within cell.

For a description of the spatial filtering will be discussed in the application of spatial processing. In the channel delay spread which will produce a variety of processing in mobile communications. Thus, it can be used with signal processing in time (STP) and the space for co-channel interference and reduce interference between symbols as well as to maximize the SNR. It will be explained with the theory of a review of channel equalization. It started where initially only for demodulating the signal through a single user. Thus, the disorder has been treated from interfering with other users, known as additive noise. It is an intervention approach repression. Later in this topic will discuss the detection of a range of users as well as to detect all impinging signals with the next.

4.1 Switched Beam Systems

Switched Beam Systems (SBS) containing the RF beamformer in the form of various (non-adaptive) beams. To get the best SINR is determined by a "sniffer" where the switch is used to choose the best one or two of the best beam on the receiver do. System that occurs is called unit dimanakepelbagaian applied to existing antenna will be replaced with the switch beam antenna system. Beamformer output was scanned with sniffer scanning where SBS operates two beams to detect where it is switched through the receiver. Methods to reduce the probability of incorrect selection of the beam, the output beam is confirmed by checking the color code before determining the best beam. For example (CDVCC in IS-54 or SAT tone in AMPS).

The advantages of using SBS is interference can be reduced and an increase in cell protection in addition to producing an array of reverse link gain and the sound quality is good. Moreover, the use of low factor can improve SINR to get better sound quality and also increase capacity. Beam initially established it is smaller than the beamwidth sector. When the desired signal and interference are separated in the corner and fell into different beam power minimization of interference will be obtained.

Several factors depend on the performance of SBS which is due to angular spread in different directions, from the angle-of-arrival signal and interference and topology array. Various profit performance in the SBS comes in a variety of ways, whether diversity gains, transmission efficiency and reduced interference.

4.2 Space-Time Filtering

Space-time filtering (STF) serves as a space-time processing to reduce the intersymbol and co-channel interference and maximize signal power. For each air interface standard, space-time processing is different from the example that proved the previous sections. In GSM, Channel equalization is needed where the slot is 0.577 ms with a 26-bit training and the symbol is 3.7µ Secs. Regulation by the ISI will complicate the equalization problem. In IS-54, the slot is 6.66 ms, which will cause a major change channels through the slot occurs. Therefore, it is to consider the probability of signal and interference channel is not changed in the slot. However, channel equalization is usually not needed then the symbol is 41.6µ Secs. Therefore, some means must be studied in architecture STF to detect the signal and interference channel in bursts by using blind techniques.

4.3 Channel Reuse Within Cell

Reusing channels or radio resources in a cell are referred to the reuse within cell (RWC) in which they exploit differences in the channel. This concept is similar to the use of spectrum in cellular systems where the use of a cell to a channel or source spectrum and another cell is separated by a sufficient distance so that interference with the channel is small enough. There is a comparison when RWC is used in TDMA or FDMA where in two or more cell users supported in a given channel, compared to the conventional cell for a single user only. Demodulation process with a number of users, used by antenna arrays and space-time processing with the assumption that users can be separated in the channels (direction). If there are two or more users on a continuous basis in a channel, it can not be separated and one of the users must be handed off to the frequency or time slot to another. To achieve the two reverse link RWC should work on both the front and links the signals can be separated.

When TDMA or FDMA is used in RWC challenges faced is to make a budget and keep track of the reverse and forward channel to a higher level of accuracy. Impact on the imbalance of power between users cause problems even more complicated when the ability to estimate and track the channel link depends on the angle spread, delay, and Doppler spread. When the spread increases to high, it will result in higher channel estimation error sources. Thus, the rural environment is flat with a score of angle and delay spreads lower than the city and microcells which uses antenna under the roof. We can predict the right channel again to link forward. It can be done with an open loop method which is used to predict the channel link back to the front channels. In rambangnya, feedback from the mobile can be used to estimate the forward channel. In FDD, the angle spread is a source of error in the open-loop method, while in TDD Doppler spread is a source of error. Consequently RWC is not promising technology in many applications TDMA and FDMA.

5. CONCLUSION

As a conclusion, in the application of digital signal processing and the use of array signal processing, better known as STP is a great application as well as the use of efficient techniques to improve wireless cellular network. In addition, STP can improve the quality of the links, improve cell coverage and increase the capacity of the system. Furthermore, the difference of the mobile channel will have a high impact that can cause delays in different directions and large angular spread. Aspects of each breeding environment and air interface should be emphasized for effective problem solving. However, futher study or work is needed to develop a more robust STP technique and achieve the characteristics of a good performance in all applications of digital signal processing.

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