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GSM and Smart Antennas for Wi-Fi Routers

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***Abstract*— This paper suggests the G-Fi technique which deals with the improvement in the signal flow of the Wi-Fi routers. All present day routers have Omni directional antennae, which equally radiates the signal in every direction possible and thus it will scatter the signals in all directions, thereby increasing the beam width pattern of the signal. So the signal tends to become weak as they go beyond a limit. The G-Fi technique will be using "SMART ANTENNAE" or Adaptive antenna array and "GSM "to overcome the above mentioned impairment. It will operate in real time without any manual control. This technology will basically involves "SPACE DIVISON MUTIPLE ACCESS (SDMA)" and "TIMING-ADVANCE" technique which helps to pin point the location of the Wi-Fi users and then with the help of the beam forming capability of the smart antenna we will direct the beam to only to particular directions.**

***Index Terms*— GSM, Smart Antennae, SDMA, TA &Wi-Fi Router**

I. INTRODUCTION

Wireless Communication is an enormously growing industry, and recently with the advancement in technologies the RF communication sector's progress is exponentially rising up. With all the new generation communication services coming in the market the radio frequency band is getting used up and there is a growing demand of faster data rates and more efficient and less power consuming techniques.

The first disadvantage with wireless communications "Rayleigh fading". When a signal is passed through the transmitter it follows multi-path because of the reflection from the physical objects and due to scattering. Because of the multi- path the signals in different paths will be out of phase with each other and thus when the signal reaches the receiver side it gets distorted in both time and frequency domain. And when the transmission is wide band the effect is more. And the second impairment is the co-channel interference. Many studies have been done to make improvements in wireless communication sector. One indispensable technique is to program the transmitter and receiver with the environmental condition. And this is the basic idea behind the "SMART ANTENNAS" or mostly known as "DIGITAL BEAM FORMING ANTENNA".

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II. TECHNOLOGIES USED IN EXPERIMENT:

A. SMART ANTENNAS

A smart antenna can be basically defined as a real time live antenna which transmits the signal without any consideration of the surrounding environment. A smart antenna is an array of antenna elements which are connected to a DSP processor. Each individual element of the array watches over a particular propagation path of the signal. Thus it helps the collection of elements to distinguish individual paths with better accuracy and resolution. Thus it can encode each path with a unique stream of data and thus the data rate gets increased and also it can enforce surplus amount of encoded data onto the path which suffers from more interference than any other path and which avoids a calamitous distortion of signal at the receiver side and thus provide a wide gain of the signal and prevents the co-channel interference.

B. BEAM FORMING OF SMART ANTENNAE:

A Beam former is an array of sensors which can do spatial filtering. The objective is to estimate the signal arriving from the desired direction in the presence of noise and other interfering signals. A beam former does spatial filtering in the sense that it separates two signals with overlapping frequency content originating from different directions. The aim of the project was to study the different beam forming techniques and use the Constrained Least Mean Squares (LMS) filter for spatial filtering. An array of microphones was simulated in MATLAB and a simple delay and sum beam former was implemented. The results were compared with that of a single microphone and it was observed that beam forming definitely gives a significant SNR improvement. A Constrained least mean square algorithm (also known as Frost Beam former) was derived which is capable of iteratively adapting the weights of the sensor array to minimize noise power at the array output while maintaining a chosen frequency response in the look direction.

Spatially propagating signals encounter the presence of interfering signals and noise signals. If the desired signal and the interferers occupy the same temporal frequency band, then temporal filtering cannot be used to separate the signal from the interferers. However the desired and the interfering signals generally originate from different spatial locations. This spatial separation can be exploited to separate the signals from the interference using a beam former. A beam former consists of an array of sensors in a particular configuration. The output of each sensor is properly filtered and the filtered outputs of all the sensors are added up. Typically a beam former linearly combines the spatially sampled waveform from each sensor in the same way a FIR filter linearly combines temporally sampled data. When low frequency signals are used an array of sensors can synthesize a much larger spatial aperture than that practical with a single physical antenna. A second very significant advantage of using an array of sensors is the spatial filtering versatility offered by discrete sampling. In many applications it is necessary to change the spatial filtering function in real time to maintain effective suppression of interfering signals. Changing the spatial filtering function of a continuous aperture antenna is impractical. Typical uses of beam forming arise in RADAR, SONAR, communications, imaging, Geophysical exploration, Biomedical and also in acoustic source localization.

C. BEAMFORMER CLASSIFICATION:

Beam formers are classified as either data independent or statistically optimum, depending on how the weights are chosen. The weights in a data independent beam former do not depend on the array data and are chosen to present a specified response for all signal and interference scenarios. The weights in a statistically optimum beam former are chosen based on the statistics of the array data to optimize the array response. The statistics of the array data are not usually known and may change over time so adaptive algorithms are typically used to determine the weights. The adaptive algorithm is designed so the beam former response converges to a statistically optimum solution. The weights in a data independent beam former are designed so that the beam former response approximates a desired response independent of the array data or data statistics. This design objective is same as that for a classical FIR filter design. The simple Delay and sum beam former is an example of the data independent beam forming. In statistically optimum beam former the weighs are chosen based on the statistics of the data received at the array. The goal is to optimize the beam former response so that the output signal contains minimal contributions due to the noise and signals arriving from directions other than the desired direction. The Frost beam former is a statistically optimum beam former. Other statistically optimum beam formers are Multiple Side lobe Canceller and Maximization of the signal to noise ratio.

D. DELAY AND SUM BEAM FORMING:

The underlying idea of sum-and-delay beam forming is that when an electromagnetic signal impinges upon the aperture of the antenna array, the element outputs, added together with appropriate amounts of delays, reinforce signals with respect to noise or signals arriving at different directions. The delays required depend on the physical spacing between the elements in the array. The geometrical arrangement of elements and weights associated with each element are crucial factors in defining the array's characteristics. In delay-and-sum beam forming, delays are inserted after each microphone to compensate for the arrival time differences of the speech signal to each to each microphone (Figure 3-1). The time aligned signals at the outputs of the delays are then summed together. This has the effect of reinforcing the desired speech signal while the unwanted off-axis noise signals are combined in a more unpredictable fashion. The signal-to-noise ratio (SNR) of the total signal is greater than (or at worst, equal to) that of any individual microphone's signal. This system makes the array pattern more sensitive to sources from a particular desired direction. The major disadvantage of delay-and-sum beam forming systems is the large number of sensors required to improve the SNR. Each doubling of the number of sensors will provide at most an additional 3 dB increase in SNR, and this is if the incoming jamming signals are completely uncorrelated between the sensors and with the desired signal. Another disadvantage is that no nulls are placed directly in jamming signal locations. The delay-and-sum beam former seeks only to enhance the signal in the direction to which the array is currently steered.

E. FROST BEAM FORMER:

The *Constrained Least Mean Squares* or *Constrained LMS* algorithm is a simple stochastic gradient algorithm which requires only that the direction of arrival and the desired frequency response in the look direction. In the adaptive process, the algorithm progressively learns statistics of noise arriving from directions other than look direction. The algorithm is able to maintain a chosen frequency response in the look direction while minimizing output noise power. Consider the array processor shown in Figure 4.1. The processor has K sensors and J taps per sensor. So there are KJ weights. Out of these J weights determine the look direction frequency response. [In the figure the delays after each sensor are not shown. The array processor is assumed to be steered to the required look direction by appropriate delays after the sensors as in the case of Delay and Sum beam forming.] The remaining KJ – J weights may be used to minimize the total power in the array output. Minimization of the total output power is equivalent to minimizing the non-look direction noise power as long as the signal and the noise is uncorrelated which is a reasonable assumption. As far as the signal is concerned, the array processor is equivalent to a single tapped delay in which each weight is equal to the sum of the weights in the vertical column of the processor. These summation weights in the equivalent tapped delay line must be selected so as to give the desired frequency response characteristic in the look direction

III. ADAPTIVE ALGORITHM FOR FROST BEAMFORMER

To find the optimum weights the input correlation matrix R_{XX} is not known a *priori and* must be learnt by an adaptive technique. Direct substitution of a correlation matrix estimate into the optimal weight equation requires a number of multiplications at each iteration proportional to the cube of the number of weights. The complexity is due to the inversion of the input correlation matrix. The adaptive algorithm described below requires only a number of multiplications and storage locations directly proportional to the number of weights.

In constrained gradient-descent optimization, the weight vector is initialized at a vector satisfying the constraint say $W(0) = C(C^T C)^{-1} F$, and at each iteration the weight vector is moved in the negative direction of the constrained gradient. The length of the step is proportional to the magnitude of the constrained gradient and is scaled by a constant μ .After the kth iteration the next weight vector is

$$
\begin{aligned}
W(k+1) &= W(k) - \mu \, \nabla_W H[W(k)] \\
&= W(k) - \mu [R_{XX} W(k) + C\lambda(k)]
\end{aligned}
$$

The Lagrange multipliers are chosen by requiring W (k+1) to satisfy the constraint

$$F = C^T W(k+1) =$$
$$C^T W(k) - \mu C^T R_{XX} W(k) - \mu\ C^T C\lambda(k)$$

Solving for the Lagrange multipliers λ(k) and substituting into the weight-iteration equation we have

$$W(k+1) = W(k) - \mu\left[I - C(C^T C)^{-1} C^T\right]$$

$$R_{XX} W(k) + C(C^T C)^{-1}\left[F - C^T W(k)\right]$$

Defining the KJ dimensional vector

$$\tilde{F} = C(C^T C)^{-1} F$$

and the KJ x KJ matrix

$P = I - C(C^T C)^{-1} C^T$,the algorithm may be written as

$$W(k+1) = P\left[W(k) - \mu R_{XX} W(k)\right] + \tilde{F}$$

A simple approximation for R_{XX} at the kth iteration is the outer product of the tap voltage vector with itself:

The stochastic Constrained LMS algorithm is

$$W(0) = \tilde{F}$$

$$W(k+1) = P\left[W(k) - \mu\, y(k) X(k)\right] + \tilde{F}$$

IV. GSM:

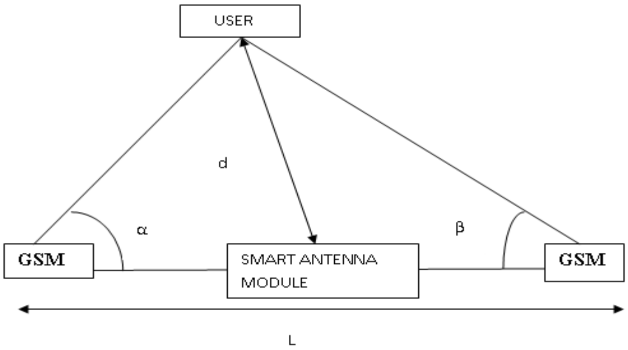
A. *TIMING ADVANCE:*

In a standard GSM Device, this technique is used to find out the distance of the GSM device from the base station. A Timing Advance (TA) is used to compensate for the propagation delay as the signal travels between the Mobile Station (MS) and Base Transceiver Station (BTS). The Base Station System (BSS) assigns the TA to the MS based on how far away it perceives the MS to be.

B. *Modified GSM Triangulation System:*

Traditional GSM triangulation systems consist of three GSM Antennae, where the location of the user can be determined by the intersection of the three wave spheres. However since the use of three antennae are expensive and also because in this case the distance between the antennae can be accurately known, a two antennae system is sufficient. The two GSM two antennae are placed with the Wi-Fi smart antenna linearly between them. The two antennae record both horizontal and vertical angles of the user's device with respect to the antennae and the corresponding loci of distances vectors from the Wi-Fi smart antenna are calculated using the following formula.

L = d/tanα + d/tanβ

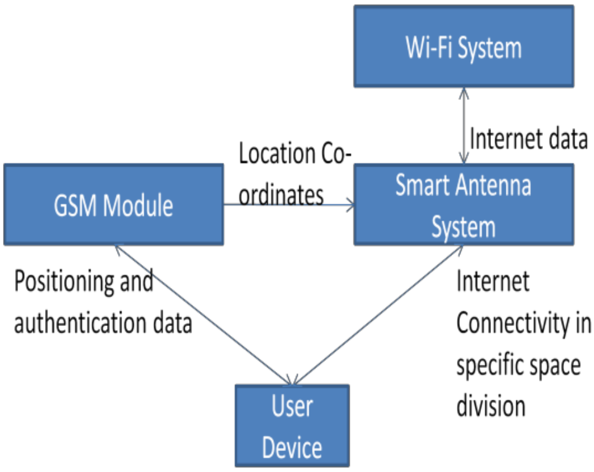


These loci distance vectors individually represent two circles perpendicular to each other with the same radius. The intersection of these circles represents the location of the user in three dimensional space.

C. *PROCEDURAL SETUP:*

The G-Fi consists of two GSM locator modules which locate the user using the modified geometric triangulation and the Wi-Fi router placed linearly in between the two GSM location modules.

V. ARCHITECTURE:



It is to be considered that the moving Wi- Fi user is equipped with the GSM receivers and that location data is transmitted between the user and the base GSM server using a GSM network. And one more consideration that has to make is that the connection between the client and server is continuous.

The operation consists of three processes:

a) Authentication and location of users:

When the user request Wi-Fi connectivity the GSM modules detect the request and authenticates the user and stores the IMEI for future reference. Now using the two GSM antennae, the location of the user is determined using geometric triangulation. The location of the user here is determined not as a point however as a circular front indicating that the user's device can be somewhere in the circular front.

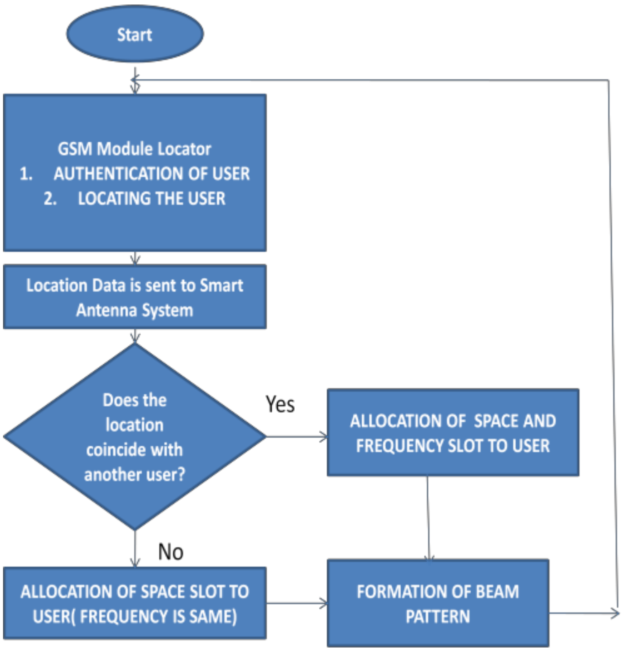
b) Transfer of location data from GSM module to Wi-Fi smart antenna:

This information is converted into a coordinate and then passed on to the Wi-Fi smart antenna module. The GSM module provides continuous input to Wi-Fi smart antenna system containing the various locations coordinates of the users

c) Formation of the beam pattern:

The coordinate values received from the GSM module is processed by the DSP processor of the adaptive multi beam smart antenna array and this input is then fed to the smart antenna array which produces the corresponding beam pattern.

VI. FLOW CHART:



VII. CONCLUSION:

Thus at a whole it can be concluded that this G-Fi system will be more efficient in terms of power consumption, bandwidth distribution and range of the Wi-Fi routers. In future more adaptive algorithm can be used to enhance the system efficiency to a great extent.

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