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Beamforming Showing Effect on BER with Change in Antenna Configuration

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ABSTRACT
This work investigates the improvement in Bit Error Rate (BER) with different antenna configuration using beamforming technique. In this paper Linearly Constrained Minimum Variance (LCMV) beamforming is used and based on this BER graph is plotted. The idea is to show improvement in BER performance with increasing number of antenna and also to show that the data rate can be increased if BER is brought to a lower value. In this paper antenna configuration with linear array of 5,7 and 9 elements are shown.

Keywords
BER,LCMV, Shanon's Capacity, Beamforming.

1. INTRODUCTION
Beamforming is a general signal processing technique used to control the directionality of the reception or transmission of a signal on a antenna array. It is used to denote an array processing technique for estimating one or more desired signals[1]. The output provided by each antenna element is weighted according to a certain criterion in order to distinguish the spatial properties of a signal of interest from noise and interference. The name beamforming comes from the early forms of antenna arrays that were used to generate pencil beams, so as to receive signals from a specific direction and attenuate signals incoming from other directions. From this primary meaning related to propagation environments characterized by a low angular spread, beamforming has been extended to rich scattering scenarios and, at present, this term is used to denote the antenna processing techniques operating both in low and high-rank channels. In a low-rank environment, depending on the level of sophistication of the adopted processing algorithm, beamforming techniques can be subdivided in two main groups: fixed beamforming and adaptive beamforming[2]. In the first case the interference is mitigated but not suppressed and the system can be usually realized at a reasonable cost. Adaptive antennas, instead, require the adoption of complex signal processing algorithms in order to steer the main lobe towards the desired direction and to suppress the undesired sources. This second approach leads to optimal performance, but is more expensive and needs considerable implementation efforts.

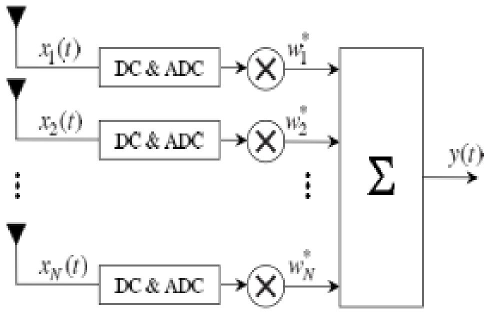

Fig.1 Digital Beamforming at receiving end[1]

A narrowband beamformer is a processor operating on the input signals at the N antennas as a single linear combiner with coefficients equal to the antenna weights

$w=[w_1,\ldots..w_N] \in C^{N\times 1}$. Therefore, the array output can be expressed as:

$$y(t) = \sum_{K=1}^{N} w^*_k\, x_k(t) = w^H x(t) \ldots.(i)$$

where $x(t)=[x_1(t),\ldots\ldots x_N(t)]^T$ is the received signal vector at the N antennas.

In this paper the author has shown digital beamforming at the transmitting end. All the weight assignment techniques are same as beamforming at receiving end. The figure below will clear the image of transmit beamforming.

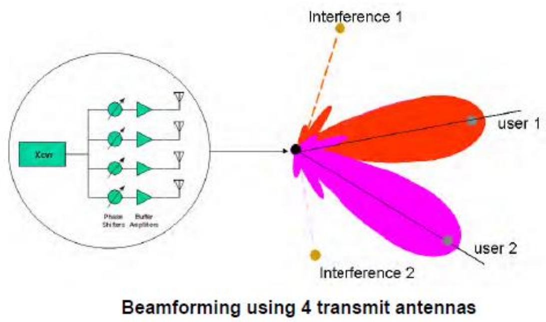

Fig. 2.Digital Beamforming at transmitter end

In the above diagram the overall transmission beam can be adjusted in different directions by applying different phase shifts to the signals to be transmitted on the different antennas.The adjustments are generally based on estimates of the direction to the target receiver.

There are several beamforming techniques like linerar Constraint Minimum Variance (LCMV) technique, Least Mean Square (LMS) technique, Q-R Decomposition (QRD) technique, Recursive Least Square (RLS) technique. In this paper the author has discussed about LCMV technique of beamforming using uniform linear array (ULA) antenna.

2. LCMV BEAMFORMING

The concept of “beamforming” refers to multichannel signal processing techniques that enhance the acoustic signals coming from a particular a priori known position, while reducing the signals coming from other directions. A number of beamforming techniques also exist. In this paper, the author has discussed about linearly constrained minimum variance (LCMV) beamformers, which are widely used in acoustic array processing. The class of the LCMV beamformers is general enough to form a common framework to design beamforming algorithms for various physical setups.

In LCMV beamforming Signals from the direction of interest are passed without distortion and it preserves the desired signal while minimizing the contributions from interfering signals and noise[5]. Antenna of linear array type is considered in this type of beamforming.

The form of radiation beam in LCMV depends on the knowledge of the received desired signal. Moreover, LCMV technique can estimate the source of interference and control radiation lobe in order to accumulate high power to the desired direction.. Although this system does not have to know the radiated power of the desired signal or direction of interfence and white noise, it is capable of suppressing the disturbances as much as possible. The total signal is given by

$$X_{TOTAL} = X_S(t)+X_I(t)+X_N(t) \dots\dots\dots\dots (ii)$$

Where X_S is the desired signal, X_I is the interference signal, X_N is the noise signal added from Gaussian noise, and X_I+X_N is the undesired signal.

The array output can be written as follow

$$Y=W^H X \dots\dots\dots\dots (iii)$$

The output power is given by

$$P=\{E \ I\ Y\ I^2\}= E\{ W^H X X^H W\}=W^H E\{ X X^H W \}= W^H R \dots\dots\dots\dots (iv)$$

where R is the covariance matrix for the received signal X.

The LCMV algorithm depends on the steering vector, based on the incident angle that is obtained from the incident wave on each element. The optimum weights are selected to minimize the array output power while maintaining unity gain in the look direction.[6]

2.1 Unifrom Linear Array

All the individual radiators of an array are usually similar, with the most common array element being the half-wave dipole. The radiation pattern of an array in free-space depends on four factors:

a) The relative positions of the individual radiators with respect to each other

b) The relative phases of the currents of fields in them

c) The relative magnitudes of the individual radiator currents or fields

d) The patterns of the individual radiators.

The basic theory of arrays is developed in terms of the first three factors. The fourth factor assumes that the individual radiators are fictional isotropic point sources. An isotropic point source is one that radiates with uniform intensity in all directions and has no physical size and also no ‘electrical’ size, hence, it does not block or otherwise affect the radiation of the other elements of the array. An array radiation pattern can be calculated on the basis of these assumptions and then a correction to it can be made to take into account that in reality the individual radiators do affect each other and do not radiate isotropically.

When more than two elements are used in an array, the principle of calculating the pattern (from which in turn the beamwidth and directive gain can be computed) is the same as for a two-element array. Except that the fields of all the elements must be superposed at the field point. The simplest type of multi-element array is one in which all the radiators are in a line, with equal spacing between adjacent pairs. This is shown in Figure 3 below. The method of analysis is suggested by showing a field-point P joined by ray lines to each element. Such an array is called a linear array. When all the elements are radiating with equal intensity and the phase difference between adjacent elements is constant, the array is called uniform. The applet provided demonstrates a uniform linear array of up to nine elements.

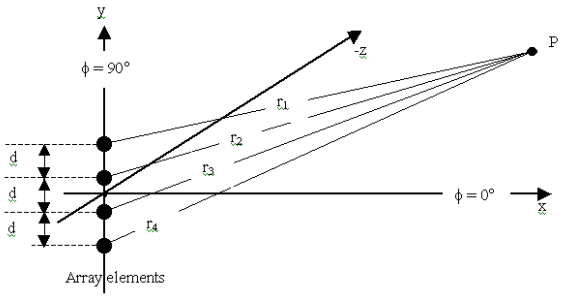

Figure 3 – Linear array of four radiating elements

In this paper the author have used uniform linear array of antenna length 5,7 and 9.

The simulation pattern of those antennas with the above stated number of array is shown below.

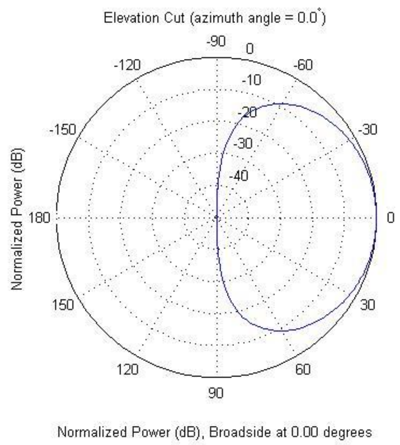

Fig. 4 Radiation pattern of a single antenna

As a component of linear array, cosine antenna elements are used and the radiation pattern is shown in above plot.

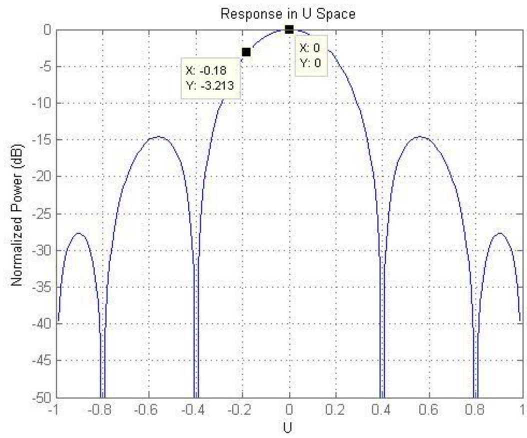

Fig.5 5 element antenna radiation pattern

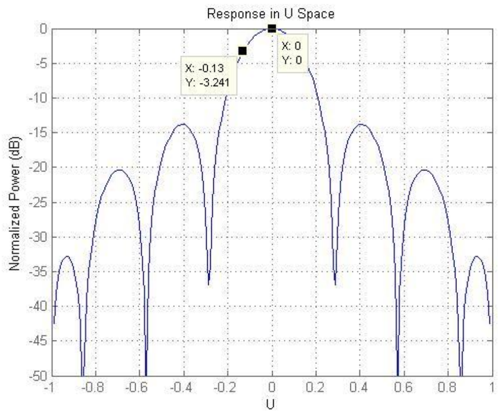

Fig.6 7 element antenna radiation pattern

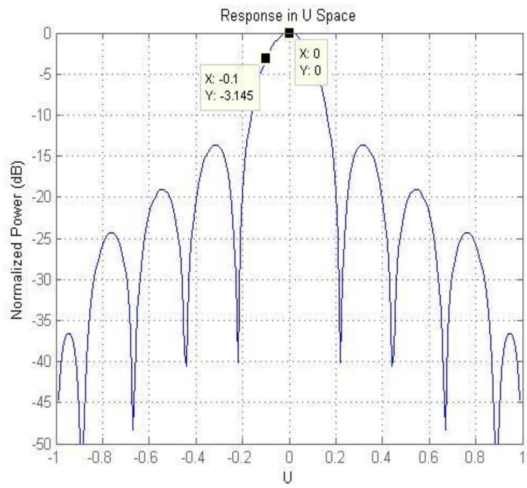

Fig.7 9 element antenna radiation pattern

In above figures , fig.5 is the radiation pattern for 5 element antenna array. The beamwidth as shown in the figure is 0.36 degress. fig.6 is showing the radiation pattern for 7 element antenna array and the beamwidth is 0.26 degress and that for 9 element antenna array(fig.7), it is 0.2 degrees. It shows that array directivity increases with increasing number of antenna.

3. SIMULATION RESULTS

Based on the above array configuration LCMV beam forming is applied on communication system in rician environment.

The BER plots are shown as under.

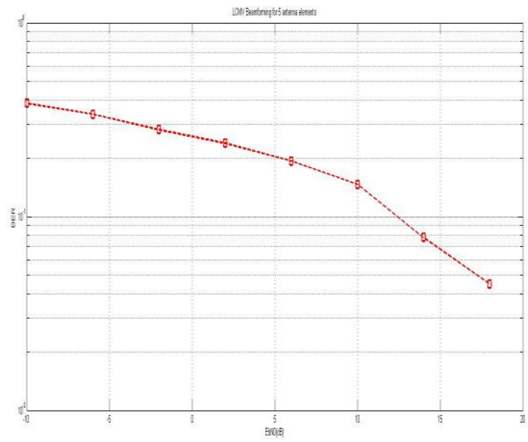

Fig. 8. BER plot using LCMV beamforming of 5 antenna element.

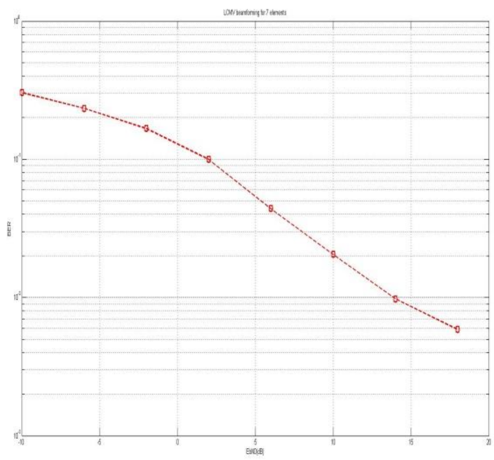

Fig. 9. BER plot using LCMV beamforming of 7 antenna element.

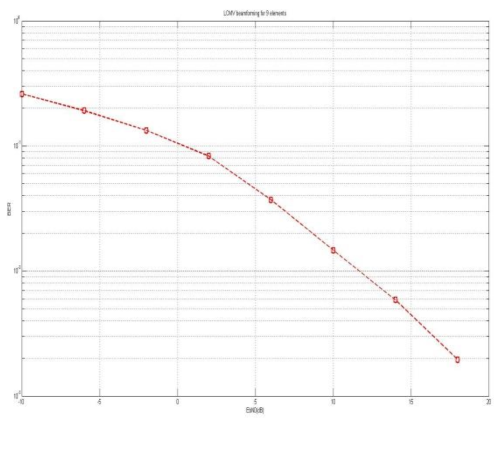

Fig. 10. BER plot using LCMV beamforming of 9 antenna element

Above plots shows the Bit error rate for different antenna configuration. Between 5 and 7 elements the difference is not much but the difference is clearly observed in case of 9 element array. Still the work is going on for another algorithms of beamforming with suitable equalizing technique.

4. REFERENCES

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