Effect of Adaptive Beamforming Upon Varying Interference Level

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***Abstract*— In this era the demand for high data rates and all-time connectivity has elevated to a higher level. In order to fulfill these demands a hybrid system that utilizes the already terrestrial networks for the users situated in the urban areas and the satellite networks for the rural area users. The same spectrum could be reused by both the networks. This reusing of spectrum introduces Co-Channel Interference in to the system which could be reduced by adaptive beamforming. A system based on OFDM is simulated using matlab and the number of antenna elements and interference level are varied to observe the difference.**

Keywords—Beamforming, Co-Channel Interference Level, Quadrature Phase Shift Keying, Orthognal Frequency Division Multixplixing Etc

I. INTRODUCTION

In today's period the requirement for wide-reaching connectivity and an elevated system aptitude has amplified to a greater stage [1][2].

In order to meet the requirements of higher data rates the existing networks are not adequate enough [3]. A hybrid system is the answer to these issues. In a hybrid communication system the users positioned in the rural areas are served by the already deployed satellite networks and the users positioned in the urban areas are provided services by the existing terrestrial networks [4]. This sharing of spectrum introduces Co- Channel interference [5]. In order to reduce this interference adaptive beamforming is applied at both the receiver and sender end [3]. Pre-FFT beamforming based on OFDM is incorporated. The system's performance is checked by passing the data with varying interference levels and number of antenna elements. At the receiver the original data is recovered by applying complex weights to the signal. Least Mean Square algorithm is used for weight updating.

A system which is also hybrid but that system is supported on (CDMA) and is anticipated by Mobile Satellite Ventures (MSV) [3]. This anticipated MSV design is capable of providing coverage in urban areas by incorporating Ancillary Terrestrial Components (ACTs) and it serves the rural areas by employing satellite links. The drawback associated with this design is that it does not deploy the already existing terrestrial system. For the purpose of precision between these services two satellites are employed and space diversity is used for link margin [3]. This precision commences the CCI in to the system and for its reduction adaptive beamforming is incorporated which is based on CDMA. Similarly the demand for higher data rates has made the researchers to move to the 4^{th} generation terrestrial networks. 3GPP projected Longer Time Evolution, which is OFDM, based and as we know that OFDM is bandwidth efficient.

Utilizing adaptive beamforming in an OFDM based system produces enhanced outcome hence improving the system output. So for the purpose of obtaining high capacity and compatibility with the 4^{th} generation networks, the mobile satellite design must be OFDM based. Usually there are two types of adaptive beamforming algorithms utilized for an OFDM system. The one is Post Fast Fourier Transform (PFFT) and the next is Pre-Fast Fourier Transform (Pre-FFT). Most of the work carried out is on terrestrial networks.

Frequency Re-use at the Satellite end:-

The concept of the reuse of the frequency spectrum at the satellite is in research since 1970. The total bandwidth available at a satellite could be increased by reusing the same frequency band in multiple beams towards earth [6].

Frequency reuse is utilized with the help of multiple spatially isolated beams and dual polarization has been incorporated by a number of commercial communication satellite systems. Several techniques exist to achieve frequency reuse antenna beams [7].

The frequency reuse in satellite provides for dual polarization and spatial reuse of transmit and receive beams to provide for a twelve-fold increase in the effective bandwidth and number of users that may be supported by the satellite system [8].

Adaptive Beamforming:-

Adaptive beamforming is a signal processing technique [9]. Beamforming is a technique of signal processing that is incorporated to organize the route of the signal within an array of transducers either the signal is sent or received [10]. The process of beamforming when integrated would direct majority of the signal in a precise direction transmitted from a group of transducers which could be an audio speaker or an antenna [11].

II. PROPOSED METHOD

OFDM SYSTEM MODEL:-

The representation of an OFDM setup is offered in the figure 1. The beamforming is present at the satellite side. The first part is the source data generation block, random data is produced here. The next block is the modulator; its purpose is to modulate the data in accordance with the data design utilized. The modulation schemes utilized in this scenario are QPSK and BPSK, so they are going to be scrutinized. After the modulation insert the pilot process. Pilots are data that are already identified to the receiver; this is carried on for channel estimation. The insertion of pilots could be between data sequence with definite period. We have slot in five pilots in out system's data sequence. When we slot in the pilots into the mapped data, then we represent the output which is in the frequency domain in a multiuser case

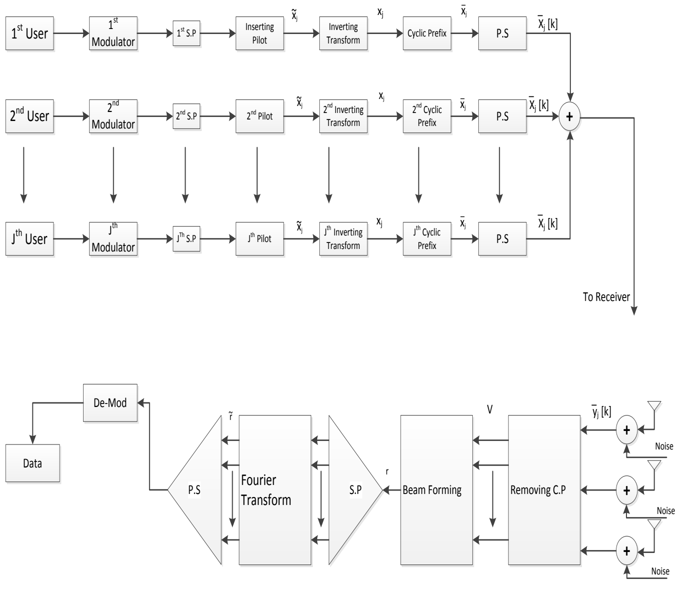

Fig. 1. Model of OFDM

Upto this part the signal exists in the frequency domain but when we slot in the pilot, and then the signal is altered to time realm by the application of Inverse Fast Fourier Transform.

$$\mathbf{x_j} = \mathbf{F}^{H}\tilde{\mathbf{x}}_\mathbf{j} \tag{1}$$

In the above equation the x_j represents the time domain figure of an OFDM system.

$$F = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ 1 & e^{-j2\pi(1)(1)/N} & & e^{-j2\pi(1)(N-1)/N} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & e^{-j2\pi(N-1)(1)/N} & \cdots & e^{-j2\pi(N-1)(N-1)/N} \end{bmatrix} \tag{2}$$

F is the matrix

$(.)^{H}$ is the Hermitian or complex conjugate transpose.

When the signal is transformed from time domain to frequency domain, then is the phase of adding the cyclic prefix. This extension periodically shifts the symbol. The rationale of including this extension is to prevail over the cause of Inter Symbol Interference (ISI). The cyclic prefix incorporated here is $1/4^{th}$ of the symbol length. The method of introducing guard interval is

$$\bar{\mathbf{x}}_j = \begin{bmatrix} \mathbf{I}_{N,G} \\ \mathbf{I}_N \end{bmatrix} \mathbf{F}^{H}\tilde{\mathbf{x}}_j \tag{3}$$

ADAPTIVE Beamforming :-

Now for the attainment of interference mitigation, the beamformer applies complex weights to the symbols thus processing the output antenna elements. This practice could be shown as

$$r = w^{H}\ V \tag{4}$$

it is clear from the block diagram that after applying the techniques of beamforming then comes the block of serial to parallel conversion. When the data is altered from serial to parallel form then it is altered in to the frequency domain by the application of FFT.

$$\tilde{r} = Fr^{H} \tag{5}$$

r is acknowledged as the symbol of OFDM which is obtained and it lies in the domain of frequency . For the purpose of renewing the weight, the beamformer takes both the transmitted and received pilot sequences. Evaluates both of them and then finds out the error vector. Now the adaptive algorithm which is supported on Mean Square Error for the then symbol calculates the subsequent weight by taking into consideration the error vector.

The error vector is represented below

$$\tilde{e}^{p} = \tilde{r}^{p} - \tilde{x}_{d}^{p} \tag{6}$$

A terrestrial communication system based on OFDM is first implemented. Then adaptive beamforming is applied to both the ends. Interference in the form of interferers is introduced in to the system. The antenna elements in the system are varied along with the interference and the performance is checked.

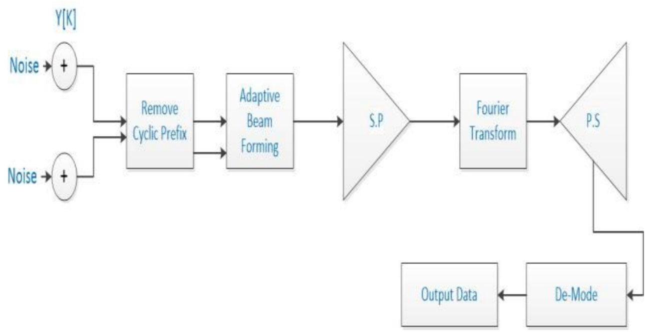

Fig. 2. Block diagram of the system

From figure 2 it is clear that after the introduction of noise in to the system, cyclic prefix removed and then apply the process of adaptive beamforming. After that process convert the data to parallel stream and then apply Fourier transforms [12]. Reset again from parallel to serial data stream and demodulate it.

III. SIMULATION RESULTS

Following are the simulation results. The Adaptive beamforming is applied and the output is checked in the form of gain. Interference level along with number of antenna elements is also varied and the output is checked.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 08, August-2016

System Parameters:-

The following are the system parameters utilized

System Parameters	
Modulation Scheme	QAM, BPSK, QPSK, 8-PSK,16-QAM
No. Of Subcarriers	32
Symbols	20,000
Antenna Elements	2,4
No Of Users	4
Interference power	-10dB

Note that all the modulation methods pointed out in the above table have been implemented single and multiuser OFDM system. But with the beamforming we have compared two modulation schemes that is BPSK and QPSK using 2 and 4 antenna elements.

Interference level -10dB:-

In the first scenario the modulation scheme employed is 8-PSK [13]. The desired user is located at 40 and the interferers are located at -8, -60, -30 and 70 degrees respectively. The numbers of antenna elements employed in this scenario are two.

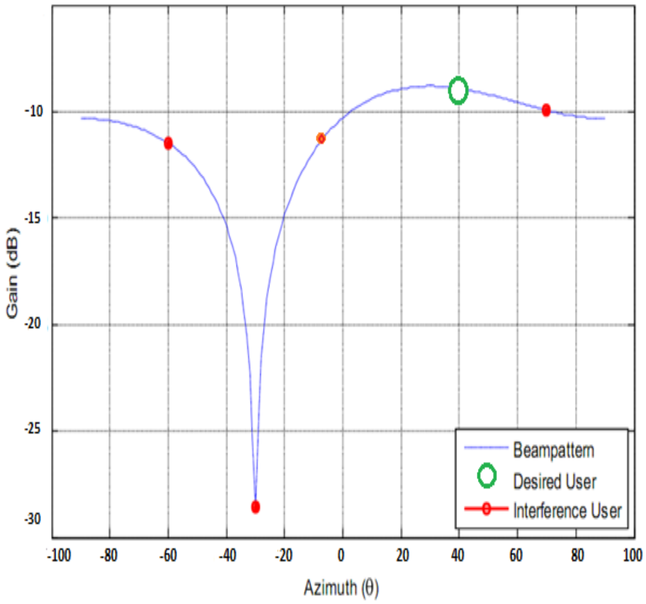

Fig. 3. Beampattern for 8-PSK for 2 antenna elements

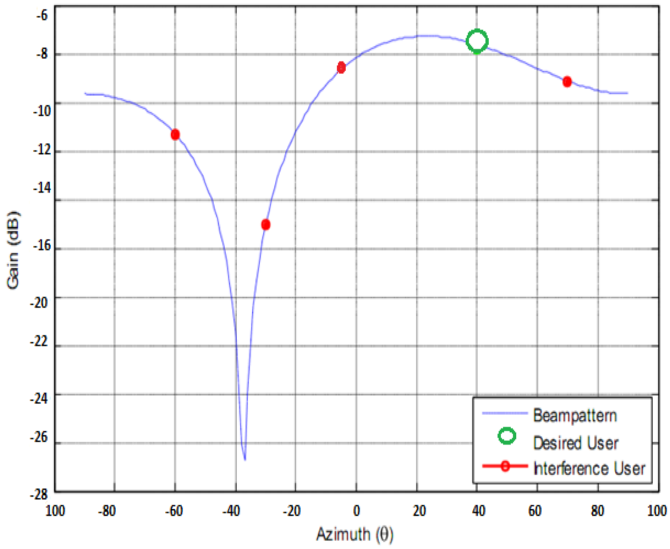

Fig. 4. Beampattern for QPSK for 2 antenna elements

From figure 4 manipulate QPSK modulation scheme for the same number of antenna elements and the same level of interference.

It is clearly observed that the modulation scheme impose an almost negligible effect upon the gain. As we moved from higher order modulation schemes towards lower order modulation schemes and observed that there is not a noticeable difference in the gain.

Interference level -5dB:-

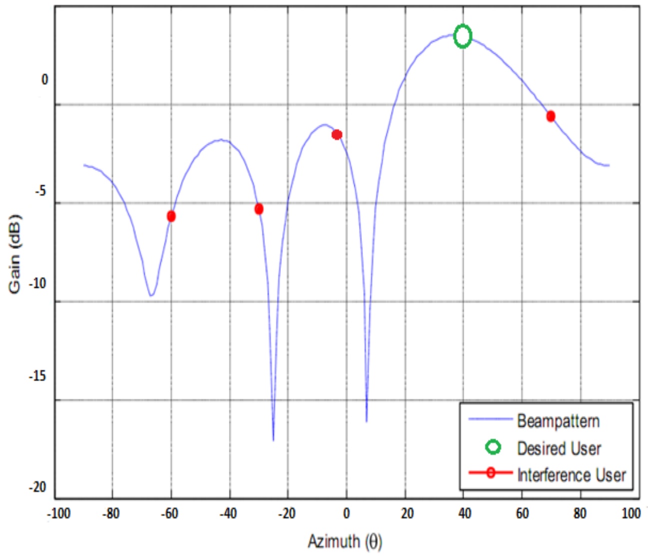

Fig. 5. Beampattern for 8-PSK for 4 antenna elements

Figure 5 represents a scenario with an increased number of antenna elements from two to four. The interference level is also increased from -10 to -5. But it is clearly observed that even with the increase in the interference level the gain has still increased. The reason is the increased number of antenna elements.

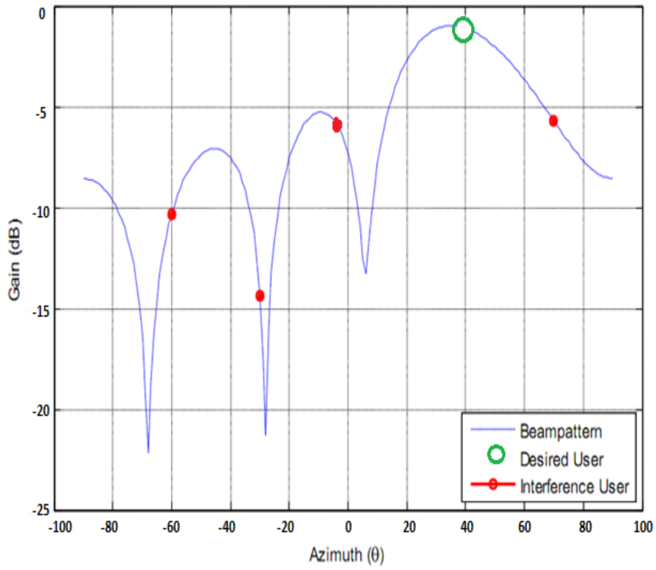

Fig. 6. Beampattern for QPSK for 4 antenna elements

In figure 6 the same scenario is with 4 antenna elements is checked with QPSK modulation scheme and it can be noticed that the gain has increased.

It is again observed that the modulation scheme has an almost negligible effect upon the gain.

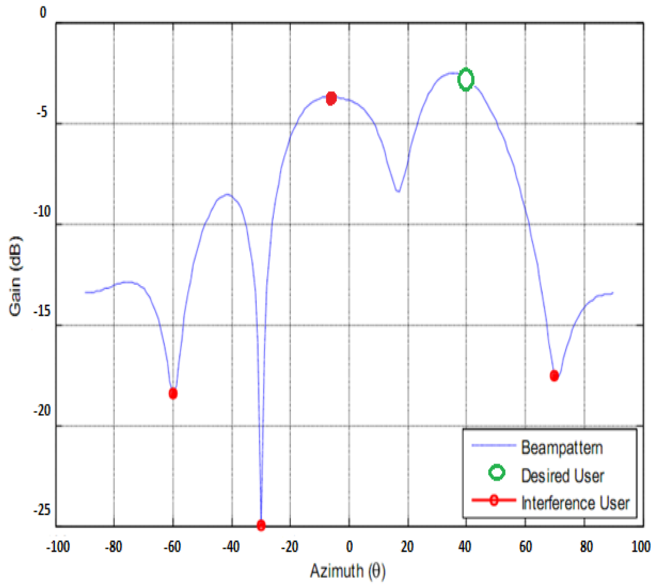

Fig. 7. Beampattern for QPSK for 6 antenna elements

In order to check the effect of antenna elements more effectively, figure 7 represents a scenario with 6 antenna elements and 8-PSK modulation scheme. In this scenario the desired user is at maximum gain and the interferers except the one at -8 are at complete nulls.

IV. CONCLUSION

In a hybrid network the CCI caused by the mobile user to the satellite end is reduced by the incorporation of Adaptive beamforming. The number of antenna elements has a great effect upon the gain. As the number of antenna elements increases so do the gain and the interference decreases. But by increasing the antenna elements the weight of the satellite increases and so does its power requirement, so there is a limit upon the number of antenna elements employed.

REFERENCES

[1] P.D. Karabinis, "Systems and methods for terrestrial reuse of cellular frequency spectrum," USA patent 6 684 057, January 27, 2004.
P.D. Karabinis, S. Dutta, and W. W. Chapman, "Interference potential to MSS due to terrestrial reuse of satellite band frequencies." [online]. Available: www.msvlp.com

[2] Ammar H. Khan, Muhammad A. Imran and Barry G. Evans, "OFDM based Adaptive Beamforming for Hybrid Terrestrial-Satellite Mobile System with Pilot Reallocation," International workshop on satellite and space communications IEEE pp 201-210

[3] C. K. Kim, K. Lee and Y.S. Cho, "Adaptive beamforming algorithm for OFDM systems with antenna arrays," vol. 46, no. 4, pp. 1052-1058, Nov. 2000.

[4] .Hamid, R. A. Qamar and K. Waqas, "Performance comparison of time-domain and frequency-domain beamforming techniques for sensor array processing," *Proceedings of 2014 11th International Bhurban Conference on Applied Sciences & Technology (IBCAST) Islamabad, Pakistan, 14th - 18th January, 2014*, Islamabad, 2014. Pp 379-385.

[5] J.C. Fuenzalida and E. Podraczky, "Reuse of the Frequency Spectrum at the Satellite", *Communications Satellites for the70's Systems, Progress. in Astronautics and Aeronautics*,1970..

[6] B. Claydon, A. Brunt, W English, and W. Bornemann. "Frequency re-use limitations of satellite antennas", *11th Communications Satellite Systems Conference, International Communications Satellite Systems Conferences* (ICSSC), 1986.

[7] Harold A. Rosen, Victor S. Reinhardt, Andrew L. Strodtbeck, Jennifer L. Vollbrecht, Frequency reuse technique for a high data rate satellite communication system "USA patent 5473601 A, Dec 5, 1995.

[8] T. Yang and W. Dong, "An Efficient Adaptive Beamforming Technique for Operation in Frequency-Selective Channels," *Wireless Research Collaboration Symposium (NWRCS), 2014 National*, Idaho Falls, ID, 2014, pp. 112-116.

[9] C. Fulton, M. Yeary, D. Thompson, J. Lake and A. Mitchell, "Digital Phased Arrays: Challenges and Opportunities," in *Proceedings of the IEEE*, vol. 104, no. 3, pp. 487-503, March 2016.

[10] T. M. Jamel, "Performance enhancement of adaptive beamforming algorithms based on a combination method," *Systems, Signals & Devices (SSD), 2015 12th International Multi-Conference on*, Mahdia, 2015, pp. 1-6.

[11] Z. A. Shaikh, S. V. Hanly and I. B. Collings, "Analysis of adaptive least squares filtering in massive MIMO," *Communications Theory Workshop (AusCTW), 2014 Australian*, Sydney, NSW, 2014, pp. 90-95.

[12] Gupta swati, "Types of Modulation Schemes used in Communication Systems, " *International research journal of commerce arts and science*, volume 5,Issue 1,2014.