EasyChair Preprint

№ XXX

Novel Innovative Approaches to Spatial Modulation

Rama Murthy Garimella

December 29, 2019

NOVEL INNOVATIVE APPROACHES TO SPATIAL MODULATION

Garimella Rama Murthy,

Mahindra Ecole Centrale, Hyderabad, India

ABSTRACT

In most cellular communication systems**,** it is practical to be able to control the geometry of antennas at the Base Station. Hence, Spatial Modulation (SM) on downlink can be facilitated by using angular indices of antennas in 2-dimensions and the spherical coordinates of antennas in three dimensions. It is concluded that the performance measures such as spectral efficiency improve with this innovative SM schemes. Further, the implementation of these ideas in real world communication systems is really feasible

1. INTRODUCTION:

With the proliferation of mobile communication devices, deployment of technologies such as Internet of Things (IoT), Cyber Physical Systems (CPS), demand for electromagnetic spectrum is constantly increasing. Hence, there is urgent need for transmission technologies which increase the spectral efficiency, energy efficiency and other related measures. Cognitive Radio technology is an effort in this direction (in which the electro-magnetic spectrum is shared by licensed as well as unlicensed users in an opportunistic manner). More interestingly, other innovative ideas to increase the utilization of available channels are actively explored.

Spatial Modulation is a digital modulation technology which increases spectral efficiency, energy efficiency and at the same time the implementation is relatively simple. Even though this technology did not receive much attention in the early years, it is being realized in the past few years that the advantages attainable by Spatial Modulation (SM) are numerous. In this research paper, we propose innovative ideas to increase spectral efficiency achievable by Spatial Modulation schemes.

This research paper is organized as follows. In Section 2, known research literature is briefly reviewed. In Section 3, Spatial modulation with polar coordinates of the antennas (in 2-dimension) as indices is discussed. It is reasoned that the spectral efficiency increases. Also, by utilizing the spherical coordinates of antennas as indices, Spatial Modulation schemes are

proposed. In Section 4, implementational considerations are briefly discussed. The research paper concludes in Section 5.

2. REVIEW OF RELATED RESEARCH LITERATURE:

The concept of Spatial Modulation (SM) was introduced by Mesleh et. Al [1], [2]. With the survey research papers [3], [4], the concept of SM began to attract the attention of large number of researchers. Related concepts such as Space Shift Keying (SSK), index modulation were also studied [5], [6]. Researchers also proposed various other variants of SM such as Generalized Spatial Modulation (GSM), Quadrature Spatial Modulation (QSM), Differential Spatial Modulation (DSM) etc. These variants were reasoned to provide better performance in terms of factors such as spectral efficiency.

3. SPATIAL MODULATION: POLAR, SPHERICAL CO-ORDINATES:

To illustrate our idea, we consider the following simple transmission problem, with four antennas placed in two dimensions. We consider the Spatial Modulation (SM) scheme.

- Let the binary information be *explicitly* transmitted using QPSK. Thus, two bits of information is transmitted explicitly.
- Let the binary information be *implicitly* transmitted by selecting the index of one active antenna for each channel use (as in traditional SM scheme). Thus, two bits of information is transmitted *implicitly.*
- *Also, let the antenna geometry be the corners of a square, with the transmitter being located at the center of the square. With such a geometry of antennas, they are angularly located (polar coordinate based representation) at* $\{45^0, 135^0, 225^0, 315^0\}$. *This angular information is utilized as "another index".* ($This\ is\ the\ beginning\ of\ innovative\ idea$). *Thus, implicitly 2 two bits of information is transmitted. In general, if there are 'L' antennas located in 2-dimension, using angular location information (with respect to the transmitted located at the center),* $\lfloor log_2 L \rfloor$ *bits can be transmitted implicitly.*

We now briefly revise one of the advantages of single RF chain based spatial modulation system. When the number of transmit antennas is N_T and modulation order of the signal constellation is M, the spectral efficiency of SM i.e. S_{SM} is

$$S_{SM} = \ log_2 N_T + log_2 M \quad (\ bits\ per\ channel\ use\ ).$$

Now, for our approach (*with an index indicating the angular position of antenna in the plane*), the spectral efficiency is

$$S_{SM} = \ log_2 N_T + log_2 M \ + log_2 L \ \ (\ bits\ per\ channel\ use\ ).$$

Note: The spectral efficiency advantages for Generalized Spatial Modulation (with multiple antennas being active) systems (with the angular index information in the plane) can easily be worked out. Details are avoided for brevity.

- **Generalization to THREE DIMENSION**:

  Now, we consider antennas located in three dimensions (with the Base Station located at the center of antenna geometry). In addition to (x, y, z) coordinates (utilized in traditional SM) locating the position of antenna, the spherical co-ordinates (r, θ, φ) are available with respect to the Base station location.
- *The spherical coordinates are capitalized for arriving at the indices of the antennas transmitting the information. Thus, additional information is transmitted implicitly using the spherical coordinates*.

Note: The calculation of improvement in spectral efficiency in the 3-D case follows the same argument as in the case of antennas placed in two dimensions. Details are avoided for brevity.

Note: Also, as in the case of more generalized spatial modulation schemes , with angular antenna index in two dimensions and spherical coordinate based indices in three dimensions, spectral efficiency increases.

Note: With two/three dimensional antenna geometry, a group of antennas having the same angular index/indices can be activated (for transmission) as in the case of generalized Spatial Modulation (SM) schemes.

4. IMPLEMENTATION OF INNOVATIVE IDEAS:

The antenna geometry can be controlled at the Base station (for transmission on the downlink). Since the antenna geometry is static, the angular indices can easily be associated with the active antenna/antennas that are utilized for transmission. Hence the implementation of the ideas proposed in this research paper is relatively easy at the transmitted as well as receiver.

5. CONCLUSIONS:

In this research paper, the innovative idea of utilizing the spherical/polar coordinates of antenna position (in 2-D/ 3-D) as the indices for Spatial Modulation (SM) is introduced. It is reasoned that the performance measures such as spectral efficiency improve with the new idea. Also, it is reasoned that the implementation of such Spatial Modulation schemes and its variants is relatively straight forward.

REFERENCES:

[1] R. Mesleh, H. Hass, C.W. Ahn and S. Yun," Spatial Modulation-A new low complexity spectral efficiency enhancing technique," in Proceedings of IEEE International Conference on Communication Networking, China, Beijing, China, October 2006, pp. 1-5

[2] R. Mesleh, H.Haas, S. Sinanovic, C. W. Ahn and S. Yun,"Spatial Modulation," IEEE Transactions on Vehicular Technology, Vol. 57, No.4, pp. 2228-2241, July 2008

[3] M. Di. Renzo, H. Haas, A. Ghrayeb, S. Sugiura and L. Hanzo,"Spatial Modulation for Generalized MIMO: Challenges, Opportunities and Implementation," Proceedings of IEEE, Vol. 102, No. 1, pp. 56-103, January 2014

[4] M. Di. Renzo, H. Haas and P. M. Grant, "Spatial Modulation for Multiple Antenna Wireless Systems: A Survey," IEEE Communications Magazine, Vol. 49, No.12, pp. 182-191, December 2011.

[5] M. Di Renzo and H. Haas,"Improving the performance of Space Shift Keying (SSK) Modulation via opportunistic power allocation," IEEE Communications Letters, Vol. 14, No. 6, pp. 500-502, January 2010

[6] M. Di Renzo and H. Haas," Space Shift Keying (SSK -) MIMO over correlated Rician Fading Channels; Performance Analysis and new method for transmit diversity," IEEE Transactions on Communications, Vol 59, no.1, pp.116-129, January 2011.