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Adaptive Array Antennas for Mobile Earth Stations: A Review

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Abstract: satellite-mobile communication is currently one of the most growing areas in the field of telecommunications. However, the interference and the multi-path fading are still considered as major problems for receiving a dependable signal in such systems and this can generally lead to a significant degradation in their performance. One interesting solution to mitigate this problem is to utilize adaptive antenna array systems on the mobile user terminals. These systems will be used to steer the radiation pattern towards the satellite signal and to dynamically put nulls in the direction of the interference and the multi-path signals. This will be done in the real time by using smart signal processing algorithms; which are the key elements of the adaptive array antenna systems. These algorithms will be used to determine spatial signal parameters such as direction-of-arrivals (DOAs) of incoming signals and also to form the beams and steer them in the desired directions. In this paper, the adaptive antenna array systems for satellite-mobile communications has been discussed in terms of its advantages to the operator. The working principle of these systems, its applications for satellite-mobile communications, and also the drawbacks that may hinder its large-scale use have been discussed in details.

Keywords: Satellite-mobile communication, adaptive antenna array, phased antenna array, beam-steering.

1 Introduction

A satellite-mobile communication systems, which provides global reach to a great variety of services and across transnational boundaries, still face multiple obstacles especially those concerned with stations user terminal, the space segment, challenges in work organization, as well as technical issues such as traffic allocation, quality of wanted service (QoS) and the accompanied grade of service (GoS) [1-3].

Actually, the interference and the multi-path fading are still considered as major problems for receiving a dependable signal in satellite-mobile communications. This is because most mobile earth stations usually use omnidirectional or circularly-polarized antennas; which are normally designed with a low gain. Hence, these mobile stations are particularly more vulnerable to noise interference and multi-path effects as they receive signals from all directions [4-7].

One proposed solution to mitigate this problem is to use an adaptive antenna array systems mounted on the mobile terminal. These systems can eliminate the interference and trace the satellite automatically while revolving around the sky [4].

In this paper, we disused the adaptive antenna array systems for satellite-mobile in terms of its advantages to the operator. we disused the working principle of these systems, its applications for satellite-mobile communications, and also the drawbacks that may hinder its large-scale.

2 Antenna Classification

Typically, antennas can be categorized as Omni-directional, directional, phased array, and adaptive array [8].

An Omni-directional antenna has the same gain in all directions while a directional antenna has more gain in particular directions and thus less in others. The direction where the gain of these antennas reaches the maximum is normally known as boresight direction of the antenna. The directional antenna has a gain along the boresight direction more than that of omnidirectional antennas and this gain is usually measured with regard to the gain of the omnidirectional antennas [8]. The radiation pattern of a directional antenna and an omnidirectional antenna are shown in Fig. 1.

A phased array antenna (PAA) uses an array of antennas. Each antenna constituting the array is referred as an element of the array. By collecting the signals of the different array elements, we shape the array output and this process is called beam-forming. The direction where the array has the greatest gain is controlled by setting the phase difference between the elements of the array. After setting the phases, the contributions from the array elements due to a source in the direction where high gain is wanted will then be added in phase. This phase manipulation leads in an array gain equal

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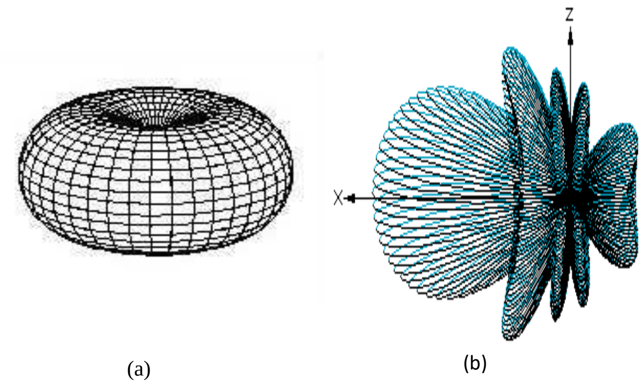

Fig. 1. (a) Radiation pattern of an omnidirectional antenna and (b) Radiation pattern of directional antenna.

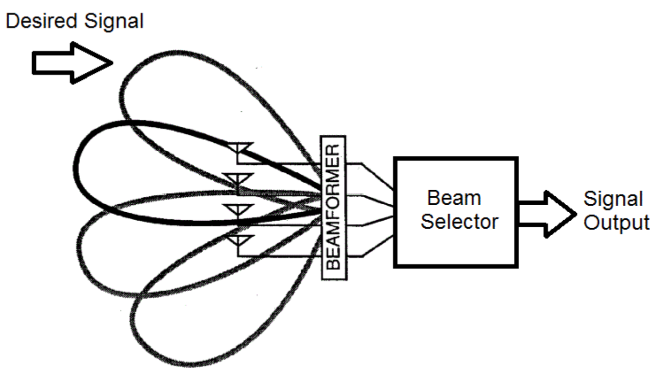

Fig. 2. Phased array antenna.

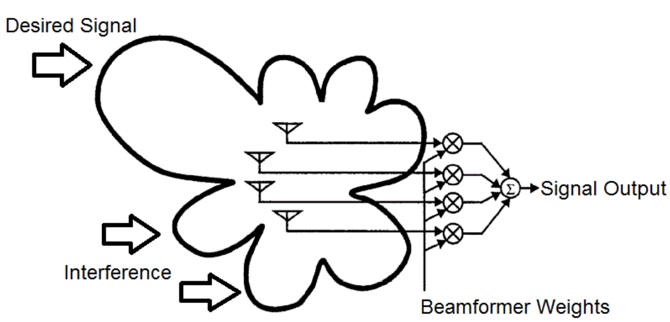

Fig. 3. Adaptive antenna array.

to the sum of all single antenna element gains [8]. Fig. 2 illustrates the phased array antenna system.

The term adaptive antenna array is used for the phased antenna array when the gain and the phase of the different array elements are weighed before collecting to dynamically adjust the array gain, as required by the system [9]. The amount of weighting on each element is not constant, but instead it is dynamically determined by the system to achieve required targets and this processing should always be done in the real time. In this way, the array radiation pattern adjusts itself to the current status and the process of adaptation is always driven by the system to dynamically decrease the multi-path and interference signals which in turn leads to enhanced desired signal reception [10]. Fig. 3 illustrates the adaptive antenna array concept.

3 Adaptive Array Antenna Systems

Adaptive array antenna is an antenna array provided with signal processing algorithms. These algorithms are used to determine spatial signal parameters such as the direction-of-arrival (DOA) of the incoming signal, and to form the beam and steer it in the desired direction while minimizing the interference. Thus, it can perform the following tasks:

1. Estimate the direction of arrival of all incoming signals including the interfering signals and the multi-path signals using the DOA algorithms such as Multiple Signal Classification (MUSIC) and Estimation of Signal Parameter via Rotational Invariance Techniques (ESPRIT) algorithms.
2. Determination and differentiation the intended signal from the rest of the unintended incoming signals.
3. Steer the beam pattern in the direction of the intended signal and track it while putting pattern nulls in DOA of interference and multi-path signals. This is will be done by dynamically updating the weights of both phase and amplitude of signal at the different array elements using adaptive algorithms such as Least-Mean-Squares (LMS) and Recursive-Least-Squares (RLS) algorithms.

As shown in the figure, the digital signal processor (DSP) is the key element of the adaptive array antenna systems. But before analyzing and processing the received signals by the DSP, it is necessary to down-convert the received signals to baseband frequencies by using the frequency down converters and digitize these down converted signals by using Analog to Digital (A/D) converters.

After down-converting the incoming signals and digitizing them, the DSP will be able to handle the received data information, calculate the complex weights, and multiply the weights to each antenna element. in order to optimize the array radiation pattern (i.e., producing maximum beam gain in the direction of the intended signal) and shape the radiation pattern to minimize the interference [11-12].

In adaptive array antenna systems, two major strategies are normally used [13]:

- In the first strategy, a training sequence will be used as a part of the desired signal and this training sequence should be also known at the receiver side, so in this case there is no need to use a DOA algorithm. This training sequence, which is correlated with the desired signal, will be then compared with what is received and the weights will be adjusted and updated such that error signal between the known and the received signal is minimized by using an adaptive algorithm. This scenario is usually appropriate for

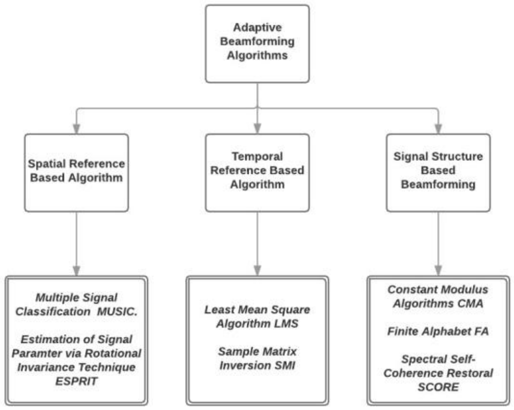

Fig. 4. An overview of the major algorithms used in the adaptive antenna array systems.

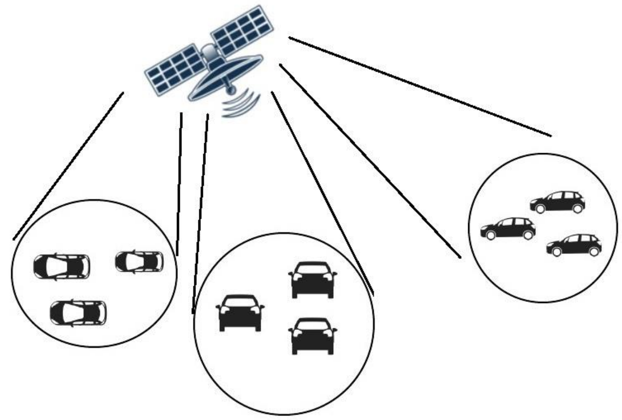

Fig. 5. Covering different service areas such that each area acts as a cell.

Non-Line-of-Sight (NLOS) environments.

- In the second strategy, a DOA algorithm should be used to identify the directions and the angles of arrival for all signals received by the array. Then, the weights will be adjusted to get a maximum beam gain towards the intended angle-of-arrival and null gain towards unintended signals by using an adaptive algorithm. This scenario is usually not appropriate for Non-Line-of-Sight (NLOS) environments where there are many reflectors close to the receiver which resulting in many DOA angles and then the DOA algorithm probably will fail to detect them correctly.

Fig. 4 provides an overview of the major algorithms used in the adaptive antenna array systems.

4 Adaptive Array Antenna Systems for Satellite-mobile Communications

Let us now consider the use of adaptive antenna arrays in satellite-mobile communication. In such systems, the mobiles directly communicate with the satellite. In the direct communication link, the adaptive antenna arrays actually may be utilized not only on the mobile but also on a satellite as we will see later in this paper [14].

4.1 The adaptive antenna array on mobile terminals

When an adaptive array antenna system is utilized on a mobile communicating directly with a satellite, the radiation beam should then be steered towards the satellite signal while putting nulls towards the interfering signals. As the direction of the satellite with respect to the mobile varies, the satellite will dynamically be tracked and the direction of the beam will be adjusted so that the main beam constantly points towards the satellite.

Based on the above, we can say that using adaptive antenna array can highly mitigate the multi-path fading and other noise interference which can lead to better Quality-of-Service (QoS) and consequently better overall system performance (i.e., increasing in the coverage, improvement of the link quality, increasing in capacity and improvement of the spectral efficiency).

Even though the advantages of using adaptive array antenna system on mobile user terminal are considered many, there also still exist some important disadvantages that may hinder its large-scale use. In fact, the adaptive array antenna system suffers from many drawbacks such as its high cost, large size, complicated mathematical calculations, and high power consumption.

4.2 The adaptive antenna array on satellites

Although this report is dedicated to talk only about the adaptive antenna array for mobile user, it was also important to mention that the adaptive antenna array for mobile user may be also utilized on the satellites.

It is possible to utilize an adaptive array antenna system on board of a satellite and provide communication in many ways. For instance, different frequencies may be assigned to beams which covers different service areas such that each area acts as a cell. This allows frequency reuse similar to land communication cellular networks. Depending on the traffic conditions dictated by the positions of mobiles, the adaptive array antenna system may generate many spot beams of varying shapes and sizes to cover the service areas effectively, as shown in Fig 5.

5 Conclusion

It has been found that there are many advantages in using an adaptive antenna array for satellite-mobile communications particularly on the mobile terminal side. This includes mitigation the effect of multi-path fading, increasing in the coverage, improvement of the link quality, increasing in capacity, and improvement of the spectral efficiency. It has been also shown that these systems face some technical problems that may hinder its large-scale use such as its high cost, large size. However, the researches currently underway to overcome these drawbacks which may allow to widespread use of the technique in wireless communications.

References

[1] S. Iwasokun and M. Kolawole, " Interference mitigation in satellite personal communication networks using adaptive antenna arrays and filtering technique," *Wireless Engineering and Technology*, vol. 1, pp. 88–91, 2010.

[2] S. Iwasokun and M. Kolawole, " Interference suppression in satellite personal communication networks using adaptive antenna arrays and filtering technique," *Journal of Mobile Communication*, vol. 4, pp. 43–46, 2010.

[3] M. R. Bahloul, M. Z. Yusoff, A. Abdel-Aty, M. N. Saad and M. Al-Jemeli, "Modulation classification for MIMO systems: state of the art and research directions," *Chaos, Solitons & Fractals*, vol. 89, pp. 497–505, 2016.

[4] K. J. Lian, “Adaptive antenna arrays for satellite personal communications systems,” M.S. thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, 1997.

[5] M. R. Bahloul, M. Z. Yusoff, and M. N. Saad, “Robust and reliable modulation classification for MIMO systems” *Applied Mathematics & Information Sciences*, vol. 9, no. 5, pp. 2513–2519, Sep. 2015.

[6] M. R. Bahloul, M. Z. Yusoff, and M. N. Saad, “Efficient and low complexity modulation classification algorithm for MIMO systems” *Research Journal of Applied Sciences, Engineering and Technology*, vol. 9, no. 1, pp. 58–64, 2015.

[7] M. R. Bahloul, M. Z. Yusoff, A. Abdel-Aty, and M. N. Saad, “An efficient likelihood-based modulation classification algorithm for MIMO systems,” *Journal of Computational and Theoretical Nanoscience*, vol. 13, no. 10, pp. 7879–7885, Oct. 2016.

[8] L. C. Godara, *Smart Antennas*. Boca Raton, FL: CRC Press, 2004, pp. 19-22.

[9] L. C. Godara, “Applications of antenna arrays to mobile communications. I. Performance improvement, feasibility, and system considerations,” in *proceeding IEEE*, vol. 85, no. 7, Jul. 1997, pp. 1031–1060.

[10] C. A. Balanis and P. I. Ioannides, *Introduction to Smart Antennas*, Arizona: Morgan and Claypool Publishers, 2007, pp. 24-38.

[11] K. K. Shetty, “A novel algorithm for uplink interference suppression using smart antennas in mobile communications,” M.S. thesis, Florida State University, USA, 2004.

[12] C. S. Rani, P. V. Subbaiah, K. C. Reddy, and S. S. Rani, " LMS and RLS algorithms for smart antennas in a W-CDMA mobile communication environment," *ARPN Journal of Engineering and Applied Sciences*, vol. 4, pp. 77–88, 2009.

[13] G.V.S Karthik, M. Z. U. Rahman, and T. Anusha, " Algorithm for steering smart antennas: an application to wireless communications," *International Journal of Research and Reviews in Wireless Communications (IJRRWC)*, vol. 1, pp. 34–42, 2011.

[14] N. Blaunstein and C. Christodoulou, “Adaptive antennas for wireless networks,” in *Radio Propagation and Adaptive Antennas for Wireless Communication Links, Hoboken*, NJ: Wiley-Interscience, 2007, pp. 369–371.

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