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Adaptive Arrays for Mobile Radio Communications

A Thesis submitted for the degree of M.Sc.

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ABSTRACT

An analysis to the high-altitude platforms communications system is done with the application of adaptive antenna arrays indicating the radio coverage parameters and the main factors that affect the system performance. Several coverage schemes are proposed based on switched-beam antennas for the macrocellular regions that need large area radio coverage with the expectation that the users may exist at any location within these regions. These schemes have shown a reduction in the power consumption, increase in user location accuracy and efficient utilization of the spectrum. Of these approaches, the beam splitting one sequentially splits wider coverage beams into narrower sub-beams, which when compared with the other possible schemes can be considered as a compromise between hardware requirements and processing complexity.

Regarding the positional instability of the platform and the resulting problems of handovers and location updating, a novel cellular structure is proposed that adopts ring-shaped cells instead of the traditional hexagonal cells configuration. This innovated structure can be achieved by adaptive antenna arrays at the platform. The array pattern constituting these cells is resulted from a scanning operation of multiple of beams, which is named as multi-beam scanning approach in which a number of azimuthally equispaced beams scan in the azimuth plane with constant elevation angle. Definitions of the beam scanning rate and beam visiting time are deduced. This new cellular structure improves the system performance, as it is capable of reducing the transmitted power, simplifies the location updating and handover algorithms and rates. The adaptation of the cell area to meet teletraffic changes from hour to hour is easier with this structure than utilizing the conventional hexagonal one.

LIST OF PUBLICATIONS

[1] M. Hadhoud, M. Dessouky, M. Nofal, **Y. Albagory**, "Two-dimensional switched-beam smart antennas for stratospheric platform cellular communications", Proceeding of The IEEE International Conference on Software, Telecommunications, and Computer Network (SoftCOM 2001), Split – Dubrovnik, Croatia, Ancona – Bari, Italy, pp. 279-285, 9-14, October 2001.

[2] M. Nofal, M. Dessouky, M. Hadhoud, **Y. Albagory**, "A novel cellular structure for the stratospheric platform mobile communications," Proceeding of The Nineteenth National Radio Science Conference (19^{th} NRSC' 2002), Alexandria, Egypt, pp. 354-362, 19-21 March 2002.

*Also has been accepted for presentation and publication in the 6^{th} World Multiconference on Systemics, Cybernetics and Informatics (SCI 2002), Orlando, USA, July 14-18, 2002.

[3] M. Nofal, M. Dessouky, M. Hadhoud, **Y. Albagory**, "Performance and feasibility of different switched-beam antennas for the stratospheric platform mobile communications covering newly developing regions," Proceeding of The Nineteenth National Radio Science Conference (19^{th} NRSC' 2002), Alexandria, Egypt, pp. 133-140, 19-21 March 2002.

*Also has been accepted for presentation and publication in the 6^{th} World Multiconference on Systemics, Cybernetics and Informatics (SCI 2002), Orlando, USA, July 14-18, 2002.

[4] M. Hadhoud, M. Dessouky, M. Nofal, **Y. Albagory**, " Smart Antennas for High Altitude Platforms Wireless Communications," has been accepted for presentation and publication in the Wireless 2002 Conference in Calgary, Alberta, Canada, July 8-10, 2002.

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INTRODUCTION

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The demand for mobile communications services is growing at an explosive rate with the anticipation to provide any one, anywhere, and at anytime with services at low cost, high quality, high data rates supporting multimedia, with little mobile handset. These demands will put the system operators and researchers in a challenge with the system resources in digging for solutions for increased capacity demands at an affordable cost. Mobile communications faced evolutionary path starting with first-generation analog systems, second-generation digital system, and recently the way to apply third-generation system. All the technology improvements aimed the above demands. The last decade has a great research activity on the application of antenna arrays at the base stations. This approach named *smart antenna technology* and has a great effect on the system performance. Many studies [1]-[6] indicate the feasibility of antenna arrays in mobile radio communications indicating the improvements in performance as it is capable of reducing the cochannel interference level, reducing the cluster size, tracking mobiles for handover reduction and others that will be discussed in detail later. But there are more needed requirements such as flexibility in system design, reconfiguration, adaptability for teletraffic demands and cost effective deployment, which form a great impact especially with the conventional terrestrial systems. Mobile satellite communications although covering large area, it offers a limited solution and suffers from several problems such as Doppler spread, complicated handover schemes, limited capacity, and extraordinary system cost.

1.1 A Promising Future with High Altitude Platforms

Recently, the idea of high altitude platforms (HAP) communications system [7] has a great interest especially for mobile and wireless data communications. Since 1992, un-manned aerial platforms have been proposed, where Steele [8] (Royal

Society meeting in London) proposed the use of stationary stratospheric platforms to handle teletraffic hotspots and peaks saying, "The Platforms will be tethered to the earth and located up to 30 km in height and placed between the aircraft flying lanes. Barely visible from earth they will be able to deliver many services. They will held on station by power conveyed to them via their tie-lines, and these lines will also house the fibers that convey the teletraffic with the network. Alternatively these platforms could be untethered, hovering, and therefore capable of being rapidly re-deployed. The hovering platforms will be able to track 'solitons of the teletraffic', rather than force the task on the terrestrial networks. For example, the platforms could handle the teletraffic from high-speed trains, highways, aircraft and ships. They can be rapidly deployed when disasters occur, for example, the rapid provision of communications to a city, which has been devastated by an earthquake" and latter the application of aerial platforms for cellular communications in [9].

The platforms consist of multi-layer skin airship having buoyant helium-filled cells, a station-keeping system, solar panels for daytime power supply, and regenerative fuel cells for nighttime. Station-keeping with the new technology of corona ion engines make these platforms to be practically available as well as global positioning system (GPS) for accurate positioning and ultra-thin fabric hulls for long duration buoyancy [10]. The HAPs are stationary therefore, no Doppler frequency shift results as in low-earth-orbit satellites. The HAP communications is basically a line-of-sight as it is used with higher elevation angles. Due to the lower altitudes (few kilometers to 70 km high), the path loss is low and is similar to that of conventional macrocells.

Worldwide regulatory approval for the use of stratospheric platforms was granted by the International Telecommunications Union in November 1997 and by the U.S. Federal Communications Commission earlier that year. Many current systems employ and designing to apply HAPs in mobile communications and wireless networks such as SkyStation International Inc.[11], which announced the starting to deploy its global