The introductory study for MIMO techniques over satellite systems

Yeonsu-Kang*, Kunsuk Kang*, and Doseob Ahn*

요 약

본 논문에서는 MIMO (multi input multi output) 기술의 위성 통신에 적용을 위한 연구에 대해 논하고자 한다. 위성은 광역 커버리지의 장점을 활용하여 DVB-S/S2, DVB-SH와 같은 방송 서비스 및 지상망 커버리지 외각에 대해 음성 및 데이터 fill-in 서비스 제공하여 왔다. 한편 최근의 지상망은 MIMO 기술을 적용하여 높은 전송 효율 및 전송 커비러지를 넓히는 것을 가능하게 하였다. 이러한 관점에서, 위성 시스템의 지상망과의 효율적인 공존 및 4세대 통신에서 요구하는 유비커터스 환경에 부합하기 위해서는 지상망의 핵심 기술인 MIMO 기술의 위성 시스템 적용을 위한 연구가 필요하다. 이에 본 논문에서는 위성 및 IMR (intermediate module repeater) 환경에서의 효과적인 MIMO적용을 위한 여러 시스템 시나리오들을 소개하고 각각의 시나리오 모델에서 필요로 하는 기술적 요구사항 및 적용 가능성에 대해 논하고 대략적인 실험 결과를 통해 그 가능성을 확인 하고자 한다. MIMO기술은 크게 Space time coding (STC)기법과 Spatial multiplexing (SM) 기법으로 나눌 수 있는데, 위성 통신에서는 STC 의 위성 및 IMR환경에서 전송 효율 및 IMR cell 커버리지를 증가 시키기 위해 사용되었으며, SM의 경우 IMR환경에서 위성에서 전송된 방송 외에 IMR cell지역의 지역 방송을 multiplexing 하기 위한 형태로 형태로 활용 되었다.

Key Words : Satellite, MIMO, space time code, spatial multiplexing, repeater

ABSTRACT

In this paper, the introductory study of the multi input multi output (MIMO) techniques for satellite communication systems is presented. Because of the advantage of wide coverage of satellite, it has been considered for broadcasting services and fill-in services. On the other hand, state of the art multi input multi output (MIMO) techniques such as space time code (STC) and spatial multiplexing (SM) makes the terrestrial system increase link performance and their coverage, and also increase the link throughput. For these regard, in order to satisfy the requirements of the next generation communications and coexists with terrestrial systems harmoniously, the studying about satellite MIMO techniques is necessary. In this paper, we introduce some system model and scenarios to apply MIMO technique to intermediate module repeater (IMR). The possibility of these techniques and technical requirements are also considered. Especially, Space time code is used to enhance IMRs coverage and increase the link performance, and space time multiplexing is utilized to multiplex satellite broadcasting signals with local broadcasting signal in IMR cell.

I. Introduction

In the B3G and 4G systems, the major role of satellites will be providing terrestrial fill-in service and efficient multicasting/ broadcasting services. As the terrestrial fill-in services, satellite systems provide services and applications similar to those of terrestrial systems as much as possible in the outside of the terrestrial coverage area[1]. In this regard, in order to enhance the coverage given by satellite layer in urban and sub-urban, introducing intermediate module repeaters (IMR) is considered as a solution. However, in present IMR environments, multipath propagation similar to that experienced in the terrestrial channels. On the other hand, for the terrestrial systems, recent state of the art communication technique improves the link reliability, spectrum efficiency, and coverage of wireless networks [2][3]. Especially, the use of multiple antennas at receiver and/or transmitter, usually called as multi input multi output (MIMO) technique, offers a powerful tool to improve system performance

* Electronics and Telecommunications Research Institute, Broadband Wireless Transmission Research Team (yskang@etri.re.kr)

※ This work was supported by the IT R&D program of MIC/IITA. [2005-S-014-02, Development of Satellite IMT-2000+ technology].).

under wireless environments, and some aspects of this technique have already been included in 3G mobile standards or for the future systems. In this regard, it is necessary that the study for future satellite systems can take advantage of MIMO technique. This paper demonstrates some introductory conceptual systems model applying MIMO technique to the future satellite models including some ground components such as IMR.

The paper is organized as follows. We mention the general MIMO system in Section II. In Section III space-time coding based satellite MIMO scenario is introduced. Section IV gives satellite system models based on spatial multiplexing and we make conclusion in Section V.

Ⅱ. Space time wireless systems

There are three different categories to exploit multiple antennas in wireless communication systems; antenna array gain, diversity gain and spatial multiplexing. Array gain refers to the SNR

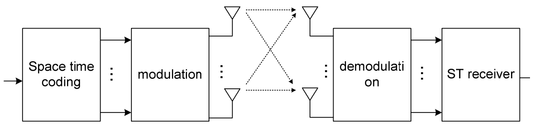

Fig. 1 Schematic of a ST wireless system.

increase at the receiver resulting from the coherent combining of multiple antennas at the receiver or transmitter. However, this technique has some technical limits to apply to satellite systems. Diversity gain is used to overcome the fading in wireless channel. Lastly, multiplexing offers an increase in the transmission capacity for the same bandwidth without no additional power. In our study, we focus on last two multiple antennas techniques; space time coding (STC) and spatial multiplexing (SM). STC and SM are basically based on the assumption that a MIMO system has multiple independent channel paths. From a satellite point of view, this assumption is not sensible because of the characteristic of satellite channels such as line of sight and high correlation at receiver antennas. For this reason, we introduce ground component such as repeater or inter modular repeater in order to apply the MIMO technique.

Ⅲ. Space time coding based models

This section outlines candidate space time (ST) wireless system configuration scenarios to be considered in the paper. Referring schematic of a ST wireless system shown in fig.1, main system assumptions, that will be common in all scenarios, include; OFDM Transmission (based on Wi-Max or DVB-SH standards) and focusing on the downlink.

III. I Scenario 1: Performance Enhancement through Space-Time Coding (STC) in IMR Link

In this scenario it will be assumed that an IMR site has two (or more) antennas and is employing some STC technique in order to enhance the link performance /cell coverage in the non-LOS multipath propagation environment. State of the art STC techniques make the terrestrial system enhance their coverage and increase link performance. For this regard, it is also necessary to apply STC techniques to the IMR site in order to enhance commonality between satellite networks and terrestrial networks. Figure 2 shows the system model for scenario 1. We don't care the satellite signal because it is relatively too weak in the IMR coverage. The performance is comparable to the performance of the terrestrial's, because all the system environment is quite similar with the terrestrial's, and the performance is closely depend on the channel state which is also almost same with terrestrial model. This model, therefore, can be considered the basis model for studying satellite STC technique, and is useful for unicast systems as well as broadcasting or multicasting systems.

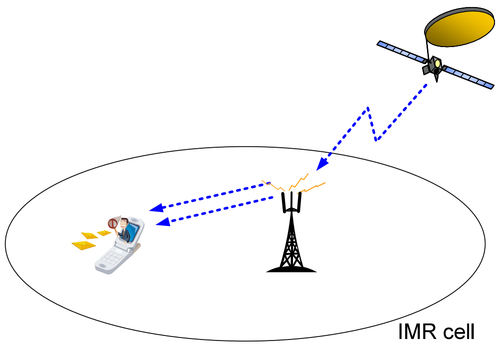

Fig. 2. System model of the scenario 1

III. II Scenario 2: Co-operative IMR and Satellite Transmission for Enhanced Peripheral Urban Coverage

Although satellite signal is ignored in the scenario 1, satellite signal is worth being considered at the edge of IMR coverage since IMR signal power is also weak comparatively. We, thus, apply STC for a co-operative fashion between with satellite signal and IMR signal mainly in order to enhance the coverage at the edges of urban regions. Figure 3 shows the system model for the second scenario. In this scenario it is assumed that the satellite to IMR link is at some high (fixed satellite services) band, while the satellite can also reach directly mobile users by transmitting at some lower frequency band. Therefore, we consider that the two signals of satellite to user (StU) link and IMR to user (ItU) link are perfectly synchronized by introducing the assumption that some mechanism is in place to synchronize satellite and IMR transmissions. This model has considerable meaning for the broadcasting system not for the unicast systems, because the synchronization between StU and ItU is quite difficult in case of unicast systems. Figure 4 shows the preliminary simulation results of the scenario 2 that is improvement in performance are achieved relative to isolated satellite or IMR transmissions. In fig. 3, ρ indicates the power ratio of ItU link and StU link. Comparing to typical terrestrial networks utilizing the STC technique, satellite MIMO systems, considered in the paper, has a different feature that satellite signal power can be considered additional signal power at the area at which IMR is implemented. For example, in case of terrestrial networks, they divide transmit power as the number of transmit antennas. However, in case applying STC between satellite and IMR, satellite signal can be considered as additional signal power gain because these two systems have independent power source such as satellite and IMR. As shown in simulation results, we can achieve an additional SNR gain comparing to IMR or satellite only networks. The SNR gain depends on not only K-factor but also signal ratio between satellite and IMR signal power.

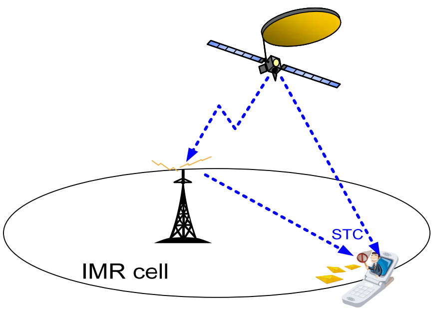

Fig. 3 System model 2

III. III Scenario 3: Co-operative transmission between two (or more) IMR for Enhanced IMR cell Coverage

This scenario is about architecture to enhance cell coverage of IMR. In this scenario, it is assumed that a ST code is applied for a co-operation between adjacent IMRs to enhance link budget at the edges of the cell coverage.

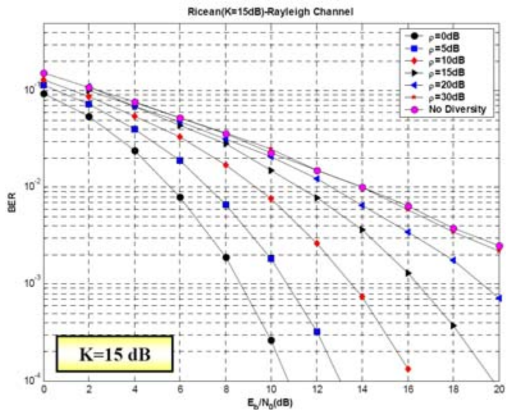

Fig. 4 BER performance of the scenario 3 with different power ratio and 15dB K-factor.

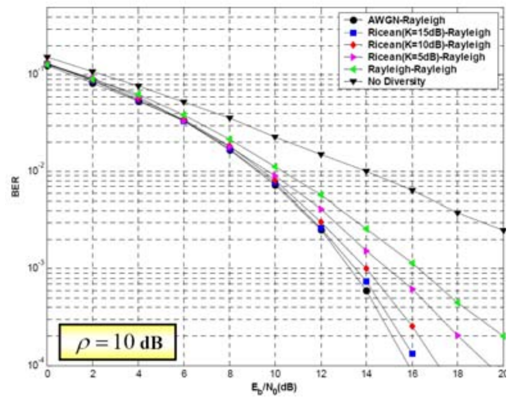

Fig. 5 BER performance with 10dB relative channel power.

The same assumption mentioned in scenario 2 about frequency band usage is considered. Synchronization among adjacent IMR cells, thus, is assumed as perfect. Figure 3 shows the basic concept of the scenario 3. The starting candidate code can be classical Alamouti technique that is currently supported by a lot of standard systems such as WIMAX standard and 3GPP LTE. As well known, Alamouti code is optimal only for two transmitter antenna. However, the satellite signal can not be ignored in the case. For this regard, advance study about the code optimization for three (or more) transmit antennas is required. A study about this issue have presented in [4].

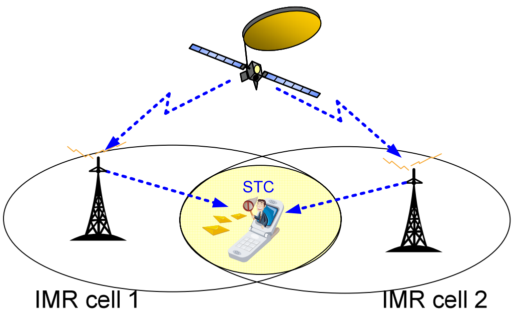

Fig. 6 System model for the multiplexing scenario 4

IV. Space time wireless systems

For the same bandwidth, spatial multiplexing linear increases the transmission rate in proportion to the number of transmit and receive antennas without additional power [2],[3],[5]. In this regard, we introduce a system model to enhance transmission capacity.

IV. I Scenario 4: IMR Link Throughput Enhancement through Spatial Multiplexing

In this scenario it is assumed that an IMR site is also equipped with two (or more) antennas and is applying space multiplexing in order to increase the link throughput, and it is mandatory to assume that the mobile terminal is equipped with multiple receiving antennas as well for the multiplexing. The same assumption mentioned in scenario 2 about synchronization is also considered. Figure 7 shows an example utilizing this scenario for the broadcasting. In this example, there is a mandatory broadcasting signal from satellite, and SM is implemented only IMR coverage of Urban areas with local contents. The additional capacity for the local contents is provided by the SM.

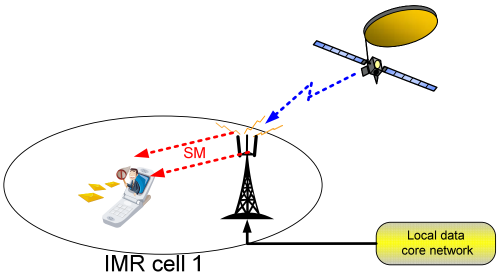

Fig. 7 System model for SM

IV. II Scenario 5: Multi-IMR Spatial Multiplexing for System Capacity Enhancement

This modeling of this scenario is very similar to scenario 4, but underlying system architecture assumption is a little different. In order to broadcast two independent services at the same time/frequency slots, this co-operative MIMO type of scenario requires overlapping cell coverage and possibly also bit-level synchronization between IMR transmissions. However in practice, the large physical separation between antennas result in highly-uncorrelated MIMO sub-channels and thus more available MIMO channel capacity compared to Scenario 4. Figure 9 shows a introductory simulation results for scenario 5 with various detection algorithms. The performance resulting from optimal detection gives a possibility of SM as advance satellite communication.

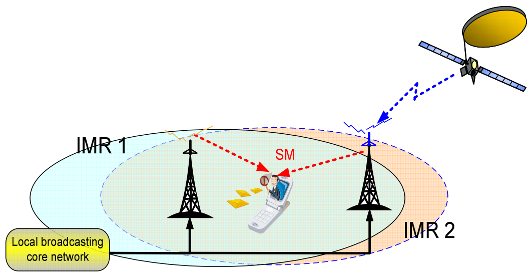

Fig. 8 SM on multi IMRs

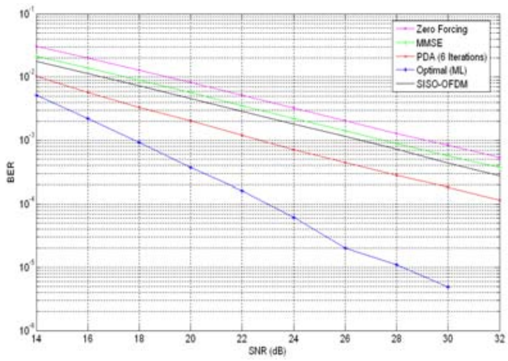

Fig. 9 Performance with various detection schemes

V. Conclusion

As far, various system models for satellite and IMR to utilize MIMO techniques have been introduced. Each model has its own advantages, and their application systems can be a bit different. STC is used to enhance the coverage of the IMR and the performance at cell edge. Space time multiplexing is considered to increase throughputs, and it can be utilize to transmit the satellite broadcasting date and local/terrestrial broadcasting data simultaneously. On the order hand, in order to achieve their benefits in their applications, some technical issues such as synchronization problem and code optimization should be overcome.

Reference

[1] B. Evans,, M. Werner, E. Lutz, M. Bousquet, G.E. Corazza, G. Maral, R. Rumeau, and M. Bousquet, “Integration of satellite and terrestrial systems in future multimedia communication”, IEEE tr. wireless comm. Oct. 2005, pp. 72-80.
[2] A. Paulraj, R. Nabar and D. Gore, “Introduction to Space-time Wireless Communications”, Cambridge, 2003.
[3] D. Tse, and P. Viswanath, “Fundamentals of Wireless Communication”, Cambridge, 2004 .
[4] H. Kim, K. Kang, and D. Ahn, “Distributed Space-Time Coded Tiransmission for Mobile Satellite Communication using Ancillary Terrestrial Component”, IEEE ICC, 2007.
[5] P.W. Wolniansky, G. J. Foschini, G. D. Golden, and R. A. Valenzuela, “V-BLAST: An architecture for realizing very high data rates over the rich-scattering”, in Proc. URSI Int. Symp. Signals, Syst. Electron., Sept. 1998, pp. 295-300.

저 자

강 연 수(Yeonsu Kang)

2002년: 동국대학교 전자공학과 졸업
2005년: 한국정보통신대학교 공학부 석사
2005년～현재: ETRI 광역무선연구그룹 광대역무선전송연구팀

<관심분야> 위성 통신, OFDM, MIMO, 채널추정, 동기

강 군 석(Kunseok Kang)

1997년 2월: 경북대학교 전자공학과 졸업
1999년 2월: 경북대학교 전기전자공학과 석사
1999년 2월～현재: ETRI 광역무선연구그룹 광대역무선전송연구팀

<관심분야> 위성통신, 다중반송파 전송

안 도 섭(Do-Seob Ahn)

1988년 2월: 경북대학교 전자공학과 졸업
1990년 2월: 경북대학교 전자공학과 석사
1990년 2월～현재: ETRI 광역무선연구그룹 광대역무선전송 연구팀 팀장

<관심분야> 위성통신, 성층권 통신