SATELLITE AND SPACE COMMUNICATIONS **SSC**

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IEEE COMMUNICATIONS SOCIETY

SSC Newsletter **Vol. 26, No. 2, December 2016**

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The Satellite and Space Communications (SSC) Committee is a volunteer group actively involved in advancing satellite and space communication technologies within the IEEE. This committee is approved by the IEEE Communications Society and is governed by the constitution and bylaws of the IEEE as well as the other twenty-three Technical Committees in the Society. The committee belongs to the Technical Committee Clusters of Communication/Signal Processing (C/SP).

SATELLITE & SPACE

- JOIN US -

All conference attendees are welcome to join us in the SSC Committee meeting.

Location: GLOBECOM'16, Washington, DC USA

Northwest, Lobby Level, Washington Hilton Hotel

Date: Wednesday Dec. 7, 2016

Time: 12:30-14:00

Future SSC Meetings

June 2017, Paris, France

Dec. 2017, Singapore, Singapore

June 2018, Kansas City, USA

GLOBECOM 2016 SSC Committee Activities:

Symposium on Selected Areas in Communications:

Monday, 5 December 2016, 14:30 - 16:00
Room: Holmead East - Lobby Level
SAC-SSC.1: Routing and Caching
Chair: Tomaso De Cola (German Aerospace Center (DLR), Germany)

Tuesday, 6 December 2016, 16:00 - 17:30
Room: Holmead West - Lobby Level
SAC-SSC.2: System
Chair: Ana Pérez-Neira (CTTC, Spain)

Wednesday, 7 December 2016, 16:00 - 17:30
Room: Holmead West - Lobby Level
SAC-SSC.3: Signal Processing
Chair: Daniele Tarchi (University of Bologna, Italy)

Wednesday, 7 December 2016, 11:00 - 12:30
Room: Columbia Foyer - Terrace Level
IS-SAC: Interactive Session: Selected Area in Communications
Chair: Tingting Yang (Dalian Maritime University, P.R. China)

HOW TO JOIN SSC COMMITTEE AND MAILING LIST

If you like to join SSC Technical Committee: Please send your name and e-mail address to the SSC Secretary, optionally include your mail address, telephone and fax numbers.
If you like to join SSC Mailing List: Instructions on how to subscribe/unsubscribe are available at http://lists.scnl.dist.unige.it/listinfo/ssc/.

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MESSAGE FROM THE CHAIR

Dr. Tomaso de Cola

It is my immense pleasure to convey my message in this column for the very first time as the Chair of Satellite and Space Communications (SSC). I would like to take this opportunity to express my deep thanks towards the SSC TC Officers Selection and Nomination Committee for nominating me as one of the candidates for the Chairperson and also towards the SSC members who have placed their trust by selecting me for this privileged position. I would also like to state that I will do my level best to carry out the duty as the SSC Chair. Furthermore, my thanks especially go to our former Chair, Prof. Igor Bisio and former secretary, Prof. Song Guo, for their valuable contributions to sustain the activities of our TC in the past years. In particular Prof. Igor Bisio served as chair with a double mandate lasting four hours, ferrying the technical committee across an era of important changes, which also influenced the business of our committee. The achievements collected in his mandate are certainly one of the best lessons learnt that will be used as starting point for this new mandate.

According to the outcome of the election held in July earlier this year, Prof. Song Guo and Prof. Pascal Lorenz are to serve as Vice Chair and Secretary of SSC for the next two years' term, respectively. We appreciate your continuing support and really look forward to your valuable opinions so that we may make our TC even better and active in future.

As diligently carried out by my predecessors, my task as new SSC chair will be to consolidate the visibility of the technical committee, by attracting more members and increase the level of activity of the committee, in order to continue the success stories started with the previous chairs. In this respect, the important editorial initiatives commenced by Prof. Igor Bisio as former SSC chair represent a clear path to keep in order to disseminate the value of research and industries activities performed in the context of SatCom. Moreover, distribution of tasks within the TC to dedicate workgroups is an important achievement, which will be further exploited in the next two years to improve the quality of some important tasks.

Finally, a special note has to be dedicated to the number of submissions of papers to ICC and Globecom that has become quite stable in the last years. In spite of this good result, it is always important to target higher submission numbers in order to increase the visibility of satellite topics in ComSoc flagship conferences and hence increase the overall awareness of satellite in nowadays society. We are now entering an era where the penetration of mobile and terrestrial infrastructure technologies under the umbrella of 5G will be even more predominant than in the past. Nevertheless, the role of the satellite will still stay pivotal as experienced in the past years to enable communication services in specific sectors, such aeronautical and maritime, where mobile connections can be hardly exploited. Moreover, typical disaster management scenarios also rely on satellite communication to ensure efficient communication between coordination center and first responders. Finally, the very same integration with terrestrial infrastructures will become even more important because of the stringent service requirements characterizing 5G architectures, whereby the support of complementary technologies like the satellite will be of paramount importance to guarantee high levels of QoE/QoS and simultaneously make efficient use of the available network resources. From this standpoint, it is immediate to see the important role that satellite expected to play in the next years; therefore important research and industry disseminations are foreseen in the very next ICC and Globecom conferences and then further emphasized in the daily business of the SSC technical committee.

Dr. Tomaso de Cola, Chair
Satellite and Space Communications TC

SCANNING THE WORLD

Prof. Song Guo

The second half of year 2016 shows a particular interest towards networking in space by the announced progress in establishing a high-speed worldwide cloud storage network of space-based data centers, which is envisioned by Cloud Constellation Corp. and called the "SpaceBelt". As a satellite industry startup, Cloud Constellation has designed-SpaceBelt network as Low Earth Orbiting (LEO) data centers for cloud service providers with needs for highly secure communications, not relying on leased lines, Internet cable, or any other network to function. With SpaceBelt, Cloud Constellation would serve enterprise and government customers around the world requiring to transport sensitive and mission-critical information that requires high levels of security. The first spacecraft is hopefully to reach orbit by late 2018. According to the latest progress, the SpaceBelt Information Ultra-Highway is detailed as a hybrid cloud that evolved as a way to protect and manage critical data on private, on-premises infrastructure and enable organizations to host customer-facing applications in the cloud.

Other exciting news reveals that the private rocket launch service SpaceX is requesting government approval to operate a massive satellite network that would provide high-speed, global internet coverage, according to newly filed documents with the US Federal Communications Commission (FCC). As the FCC filings showed, the proposed satellite network system would begin with the launch of about 800 satellites to expand internet access in the United States, including Puerto Rico and the US Virgin Islands. Such a system is designed to provide a wide range of broadband and communications services for residential, commercial, institutional, government and professional users worldwide. Once the establishing is completed, it would provide a space-based alternative to cable, fiber-optics and other terrestrial internet access currently available. Similar internet-via-satellite networks are under development by privately owned OneWeb and by Boeing Co.

Another important topic that is emerging in the satellite domain regards that the global satellite Machine-to-Machine (M2M) and Internet of Things (IoT) market will reach 5.96 million in-service satellite M2M/IoT terminals by 2025, according to Northern Sky Research's (NSR) "M2M and IoT via Satellite, 7th Edition M2M7" report. These terminals correspond to approximately $2.5 billion in annual retail revenues, a doubling over 2015. As noted by a NSR's latest report, operators cannot stand still as increasing competition aims to take advantage of the growing demand for M2M/IoT. The growing cellular footprints, greater terrestrial reliability, and the rollout of 5G and Low-Power Wide Area (LPWA) networks are increasing competition within the M2M/IoT market globally. Although competition will increase, opportunities also exist, such as dual-mode solutions, enabling operators to tap into new markets. Beyond this, with the growth of dedicated terrestrial IoT LPWA networks, such as Sigfox and LoRa, markets for satellite participation will open up. The compelling value proposition to provide satellite IoT backhaul for such networks will enable new revenue sources in the longer term, once these networks are rolled out globally. As reported, a large opportunity in satellite IoT is going to be the significant growth in areas such as location and tracking devices. This will come in spite of the dominance of terrestrial connections.

Prof. Song Guo, Vice Chair
Satellite and Space Communications TC

FORTHCOMING GLOBECOM AND ICC CONFERENCES

COSPONSORING / RELATED CONFERENCES AND WORKSHOPS

ICC 2017
May 21-25, 2017, Paris, France
http://icc2017.ieee-icc.org/
The International Conference on Communications (ICC) is one of the two flagship conferences of the IEEE Communications Society, together with IEEE GLOBECOM. Each year the ICC conference attracts about 2-3000 submitted scientific papers, a technical program committee involving about 1500 experts provides more than 10000 reviews, the conference being finally attended by 1500 - 2000 professionals from all around the world. IEEE ICC is therefore one of the most significant scientific events of the networking and communications community, a must-attend forum for both industrials and academics working in this area. We invite you to submit your original technical papers, and industry forum, workshop, and tutorial proposals to this event. Accepted and presented papers will be published in the IEEE ICC 2017 Conference Proceedings and submitted to IEEE Xplore®. IEEE ICC 2017 will be held at Palais des Congrès - Porte Maillot, Paris, France, 21-25 May 2017. Located in the heart of the City of Lights, IEEE ICC 2017 will exhibit an exciting technical program, complete with 13 Symposia highlighting recent progress in all major areas of communications. IEEE ICC 2017 will also feature high-quality Tutorials and Workshops, Industry Panels and Exhibitions, as well as Keynotes from prominent research and industry leaders. We are now open for technical paper submission, proposal submission for Industrial Forum & Exhibition, proposal for Tutorials and proposals for Workshops.

MILCOM 2017
October 23-25 2017, Baltimore, USA
http://www.milcom.org
MILCOM 2017 celebrates the 36th anniversary of the premier international conference for military communications. At MILCOM, global security professionals face command, control, communications, computers and intelligence (C4I) challenges head on. They look at them from every angle and discuss them from end to end–research and development through future needs. The conference allows industry the opportunity to hear and understand the requirements, pace of change and state of play in a variety of C4I markets serving the military, federal agencies and multinational entities. Join military and industry communications professionals in this evolving conversation October 23-25 at the Baltimore Convention Center in Maryland. MILCOM features outstanding technical presentations, discussions and tutorials, as well as nearly 30,000 square feet of industry exhibits. Experts in C4I and cyber issues as well as science and technology developments will lead more than 300 unclassified and restricted sessions.

GLOBECOM 2017
December 4-8, 2017, Singapore, Singapore
http://globecom2017.ieee-globecom.org/about
IEEE GLOBECOM is one of two flagship conferences of the IEEE Communications Society (ComSoc), together with IEEE ICC. Each year the conference attracts about 3000 submitted scientific papers and dozens of proposals for industry events. A technical program committee of more than 1,500 experts provides more than 10,000 reviews, and from this a small fraction of the submitted papers are accepted for publication and presentation at the conference. The conference attracts roughly 2000 leading scientists, researchers and industry practitioners from all around the world. IEEE GLOBECOM is therefore one of the most significant scientific events of the networking and communications community, a must-attend event for scientists, researchers

and networking practitioners from industry and academia. IEEE GLOBECOM is a five-day event. Two days are dedicated to tutorials and workshops, while the remaining three days are dedicated to the IF&E program and the technical symposia. The program of the technical symposia includes oral or poster presentations of about 1000 scientific papers, grouped into 13 thematic symposia, and more than 15 parallel sessions. In addition to the technical program, IEEE GLOBECOM 2017 will feature an industry forum and exhibition (IF&E) program, including industry-focused workshops, tutorials, keynote talks from industrial leaders, panel discussions, a large exposition, and business and industrial forums.

CONFERENCES CALENDAR

CONFERENCE	DATE & LOCATION	INFORMATION
SPECTS 2017 International Symposium on Performance Evaluation of Computer and Telecommunication Systems	July 2017 Seattle, USA	http://atc.udg.edu/SPECTS2017/
ITC 2017 29th International Teletraffic Congress	September 4-8, 2017 Genoa, Italy	http://itc29.org/
ICTS 2017 International Conference on Computer, Information and Telecommunication Systems	July 21-23, 2017 Dalian, China	http://atc.udg.edu/CITS2017/
ICL-GNSS 2017 International Conference on Localization and GNSS	June 2017 Nottingham, UK	http://www.icl-gnss.org/2017/index.html
PIMRC 2016 IEEE International Symposium on Personal, Indoor and Mobile Radio Communications	Oct. 8-13, 2017 Montreal, Canada	http://sites.ieee.org/pimrc-2017/
Ka-Band/ICSSC The 23rd Ka and Broadband Communications Conference and the 34th AIAA International Communications Satellite Systems Conference (ICSSC)	October 16-19, 2017 Trieste, Italy	http://www.kaconf.org/
VTC-Spring 2017 2017 IEEE 85th Vehicular Technology Conference (VTC-Spring)	June 4-7, 2017 Sydney, Australia	http://www.ieeevtc.org/vtc2017spring/

To all SSC members: If your postal address, telephone or fax numbers have changed, please update them with the committee secretary. You can review our current records on our web page at http://committees.comsoc.org/ssc/.

Beamforming in Satellite Communication Systems

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***Abstract* —Multi-beam Satellites have been widely adopted in current satellite communication systems due to its energy efficiency and potential for frequency reuse. Recently, array multi-beam antennas have drawn more atention for the possible applications of digital beamforming techniques. In this paper, we introduce several prospective applications of satellite beamforming technology. A practical work of Smart Communication Satellite (SCS), the Chinese first low-earth-orbit communication satellite, is presented briefly.**

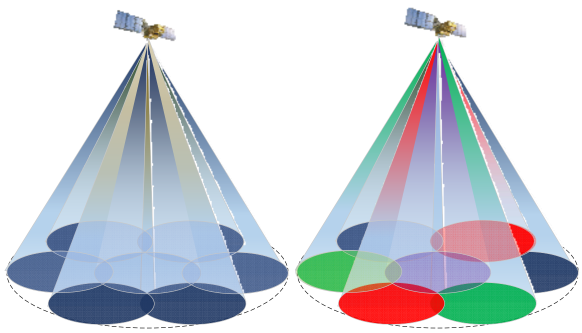
INTRODUCTION

The deployment of multi-beam satellites has increased during the last few years to cover designated areas with the minimum effective isotropic radiated power (EIRP). By projecting higher power density, narrow spot beams can provide higher data capacity for small user terminals. In recent developed multi-beam satellite systems, a large number of beams were employed, such as 228 beams in Inmarsat-4 and 500 beams in SkyTerra-1 [1]. Meanwhile, frequency reuse is possible in multi-beam satellite systems as long as the inter-beam interference can be carefully managed, which can significantly increase the spectrum efficiency [2].

Recently, array multi-beam antennas are drawing more attention for their superior performance of aperture efficiency and leakage loss. Digital beamforming techniques can flexibly construct beams of different shapes/sizes in different cases. Beamforming is one of the array processing methods of antenna arrays. By adjusting the weighting factors on antennas, it can steer nulls to mitigate co-channel interferences and forming independent beams toward different directions, which contributes to improve the performance of mobile communication systems [3]. Generally, it is not practical to equip user terminals with antennas arrays, while satellites and base stations are more applicable to do so. In mobile communication systems, transmit beamforming is a powerful mean of interference mitigation and capacity improvement by providing isolation among users in different directions.

In this paper, we give an overview of the application of beamforming in satellite communication systems. We introduce several prospective applications of satellite beamforming and provide test results of the Smart Communication Satellite (SCS), which is the first Low Earth orbit (LEO) satellite applying digital beamforming techniques in China.

PROSPECTIVE APPLICATIONS OF SATELLITE BEAMFORMING



(a) (b)

Figure 1. Multi-beam satellite system with frequency reuse factor of four and one.

A. Multi-beam Joint Processing

As stated in the introduction, frequency reuse is possible in multi-beam satellite systems as long as the inter-beam interferences can be carefully controlled. In current multi-beam satellite systems, the typical frequency reuse factor of four is generally adopted for the sake of inter-beam interference limitation, as illustrated in Fig. 1(a). Full frequency reuse, as illustrated in Fig. 1(b), can exploit higher spectrum efficiency with the reuse factor of one. However, the inter-beam interference maysignificantly deteriorate the system performance, especially in the overlap area of adjacent beams.

Multi-beam joint processing, which is based on the technique of digital beamforming, provides a possible way of full frequency reuse without significant performance loss [2]. Instead of each beam serving its users separately, signals of all users of all beams are joint precoded by means of beamforming, and then transmitted by all beams with full frequency reuse. The inter-beam interference can be mitigated by adjusting the beamforming weighting factors on antennas at the transmitting with the help of CSI. By utilizing the spatial orthogonality of users, higher spectrum efficiency can be exploited when digital beamforming techniques are adopted. Generally, the multi-beam joint processing is more potential to be adopted in the uplink case than the downlink case. For the downlink transmission of satellites, due to the power constraints, it may not be practical to serve all users with full frequency reuse simultaneously, in which user scheduling techniques need to be considered combined with frequency reuse techniques to optimize the system performance.

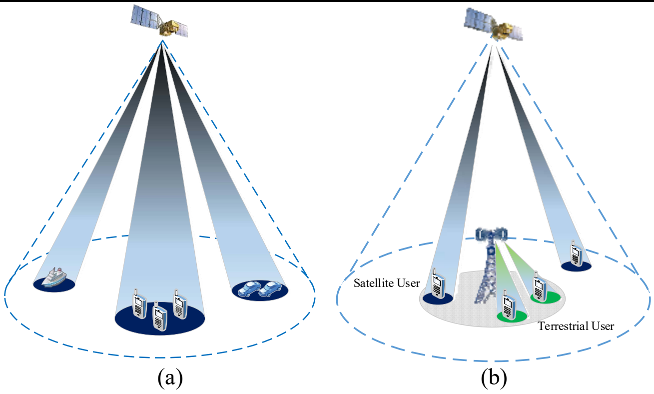


Figure 2. (a) Multigroup precoding satellite system, (b) Cooperative beamforming in terrestrial-satellite networks.

B. Multigroup Precoding

The channel between the satellite and terrestrial users is usually modeled as an AWGN channel or a Rician channel, which experiences small channel fluctuations. When terrestrial users distribute close to each other, it is difficult to separate different users by means of beamforming with full frequency reuse. In this case, instead of employing beamforming for each user separately, we can divide the users into groups according to the location distribution and employ multigroup precoding. As illustrated in Fig. 2(a), terrestrial users are divided into groups according to their locations and serviced by the satellite. For users in different groups, spatial orthogonality can be utilized, and beamforming is employed between groups when full frequency reuse is adopted. For users within the same group, since beamforming is difficult to be exploited due to small channel fluctuations, other multi-access techniques may be considered, such as time division multiple access (TDMA) or frequency division multiple access (FDMA).

Although beamforming techniques is difficult to be employed within each group to achieve frequency reuse, this problem can be avoided when it comes to multicasting. Multicast multigroup precoding is studied for satellite communication systems [4], in which users are divided in to groups and the same symbol is broadcasted to multiple users in the same group.Also, for users in different groups, digital beamforming techniques are employed to achieve full frequency reuse. Moreover, user scheduling methods can be exploited in this system to achieve higher multiuser diversity gaining.

Digital beamforming techniques are based on antenna arrays and CSI is needed when calculating the weighting factors on antennas. In next generation wireless systems, massive MIMO is attractive for its potential high data rates and energy efficiency based on large antenna arrays. However, when it comes to large antenna arrays, there exist several challenges especially in frequency division duplexing (FDD) cases. When the scale of antenna arrays increases, the number of CSIs required for beamforming also increases, leading to a large number of training symbols for channel estimation. Furthermore, in FDD systems, the CSI feedback will become a prominent problem if large scale of antenna arrays are equipped. To overcome these problems, the method of two-stage beamforming is proposed to reduce the CSI needed for beamforming in large antenna arrays systems [5]. Terrestrial users are divided into groups with approximately the same channel covariance matrix, and the beamforming process is then decomposed into two stages: the outer beamforming and the inner beamforming. In the two-stage beamforming, only the inner beamforming requires actual CSI, which has much smaller dimensions compared with the initial problem.

C. Cooperative Beamforming in Terrestrial-satellite Networks

The rapid growing data traffic brings more and more pressure to the wireless network, which is predicted to increase by over 10,000 times in the next 20 years.

Spectrum sharing has shown great potential for improving the capacity performance. For example, in the S-band, 1885-1980 MHz, 2010-2025 MHz and 2110-2170 MHz are allocated to the terrestrial communication systems IMT-2000 (International Mobile Telecom System-2000), while 1980-2010 MHz and 2170-2200 MHz are allocat-ed to satellite communication. Since the service in satellite systems is usually scheduled instead of burst, it is possible for terrestrial systems to share the satellite frequency band when the satellite frequency band is not occupied. Moreover, in the next generation wireless networks, the millimeter-wave (mm-wave) band of 30-90 GHz has drawn great attention for the large amount of possible bandwidth. Meanwhile, satellite communications have also shown interest in the mm-wave band for the sake of the increasing traffic demands, especially the Ka band of 26.5-40 GHz [6].

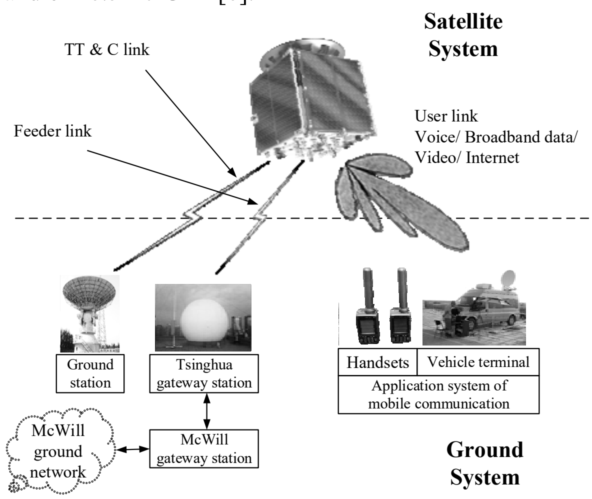


Figure 3. The composition of SCS experiment system.

Cognitive ratio (CR) technique is considered as one of the spectrum-sharing techniques in terrestrial-satellite networks, in which the second user dynamically utilizes the spectrum when managing the interference caused to the main user. In CR networks, co-channel interference (CCI) management is the key problem, and thus interference mitigation techniques play an important role in the system performance. The digital beamforming technique, which is based on antenna arrays, can be ex-ploited for interference mitigation in terrestrial-satellite networks by utilizing the spatial orthogonality [6]. Cooperative beamforming is employed at the satellite when both the satellite users and terrestrial users are taken into consideration as constraints for beamforming. By carefully adjusting the weighting factors on antennas at the satellite, the satellite can share the spectrum with terrestrial networks while limiting the interference caused to terrestrial users, as illustrated in Fig. 2(b). Since the satellite generally has limited computation capability, for the sake of reducing complexity, one semi-adaptive beamforming technique is proposed for OFDM based terrestrial-satellite mobile system [7].

SMART COMMUNICATION SATELLITE

Smart Communication Satellite (SCS), the first low earth orbit (LEO) mobile communication experimental satellite of China, developed by Tsinghua University and Beijing Xinwei Telecom Technology Inc., was launched on 4th Sep. 2014 [8]. In line with the current developing trends of small satellites, SCS makes a lot of efforts in communication-oriented satellite design. Through tackling a series of challenges under the constraints of size, cost, and energy, SCS developed a payload centric technique and accomplished the 100Kg-class weighted micro-satellite applicable to communication and navigation services. Firstly, SCS demonstrates the concept of smart beamforming for small satellite. Secondly, by using large numbers of industrial-grade components, SCS achieves low-cost facilities from altitude determination to the house-keeping system, as well as the communication payload. Finally, SCS accomplishes the file management, software upgrading and Internet access by a Linux operating system, making it naturally with the ability for evolution with Internet development.

Table 1. The onboard experimental results of SCS.

Test Project	Test Results
Minimum elevation angle of devices	24°
Internetwork call setup time of handhold devices	≤ 300ms
Internetwork call setup time of handhold devices	≤ 400ms
Delay of vehicle devices	≤ 100ms
Uplink rate of handhold devices with single code channel	8 kbps
Uplink rate of handhold devices with double code channel	16 kbps
Downlink rate of handhold devices	Max 56 kbps
Uplink rate of vehicle devices	1024 kbps
Downlink rate of vehicle devices	1024 kbps

The composition of SCS experiment system is presented in Fig. 3. The entire experiment system can be divided into two parts: the satellite system and the ground system. The satellite system contains the platform system and the payload system, while the ground system contains the application system of payloads, ground station and gateway station. There are three links between the satellite and ground: S band TT\&C link, C band feeder link and S band user link. TT\&C link carries the telecontrol and telemetry information. Feeder link produces the high speed data download passageway for the flight logs and experimental data. Meanwhile, the feeder link connects the mobile communication payload and Tsinghua gateway station. If there is no support from ground station, the satellite forms communication links between users under its footprint through on-board switching.

The satellite communication has the feature of non-uniform services and uncertainty in user distribution. In the vast sea, land and space, the user requests are relatively concentrated but area-uncertain. SCS does not adopt the uniform coverage scheme as in the traditional mobile satellite communication system. Instead, after the users initiate the service request, it would calculate and adjust the beam direction in real time according to the position information of the satellite and the user. Then, by allocating the time, space, and frequency resources, the on-demand beamforming in vast coverage area is achieved, which is called as the smart beamforming. The smart communication system can be described as ``Smart beam, On-demand coverage", by which the Internet access and communication between the handsets users and vehicle terminals users under coverage area can be built. By providing directional services, SCS effectively increases the user's transmission rate, and meanwhile efficiently exploits the limited energy of small satellites. Table gives the onboard experimental results of SCS.

CONCLUSIONS

In this paper, we have introduced the digital beamforming techniques in satellite communication systems. When applying beamforming in satellite systems, combined with the special characteristics of satellite systems, prospective applications such as multi-beam joint. processing, multigroup precoding and cooperative beamforming in terrestrial-satellite networks are introduced. It is expected that in the near future, satellite communication systems and terrestrial networks can cooperatively provide "every place, every demand" services to the mobile users.

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