Advanced Mobile Satellite Communications
Using COMETS Satellite in MM-wave and Ka-band

Shingo Ohmori, Shunkichi Isobe,
Makoto Takeuchi, and Hideyuki Naito
Communications Research Laboratory
Ministry of Posts and Telecommunications
Koganei, Tokyo 184, Japan
Tel. +81-423-27-7504
Fax. +81-423-27-6825

ABSTRACT

Early in the 21st century, the demand for personal communications using mobile, hand-held and VSAT terminals will rapidly increase. In a future system, many different types of services should be provided with one-hop connection. The Communications Research Laboratory (CRL) has studied a future advanced mobile satellite communications system using millimeter-wave and Ka-band. In 1990, CRL started the Communications and Broadcasting Engineering Test Satellite (COMETS) project. The satellite has been developed in conjunction with NASDA and will be launched in 1997. This paper describes the COMETS payload configuration and the experimental system for the advanced mobile communications mission.

INTRODUCTION

Early in the 21st century, the need for personal communications will rapidly increase in fixed and mobile satellite services. In this environment, a mobile satellite communication system will become place, not only for use in airplanes, ships and automobiles but also in hand-held terminals and portable VSATs. Personal services offered will include many different types of transmission, from low-bit-rate data such as information of message or voice to the high-bit-rate data of still picture or band-compressed video. In to offer wide variety of services, it will be important to provide a function of one-hop connection among mobiles and VSAT terminals. It will also be necessary to develop essential techniques and devices such as beam interconnecting and hand-held terminals to realize low-cost and user-friendly systems.

The 1990's will be an era of commercial mobile satellite communications, following upon the research and development phase in the 1980's such projects as the ETS-V in Japan, PROSAT in Europe and MSAT-X in USA. In some countries, research on future mobile satellite communications systems using millimeter-wave and Ka-band has already started. For example, the ACTS program in the U.S.A. is a well-known satellite program in this category [1].

In Japan, the Communications and Broadcasting Engineering Test Satellite (COMETS) project was authorized by the government in 1990. A COMETS satellite is scheduled to be launched by an H-II rocket at the beginning of 1997. Its mission is to provide a test bed in the development of advanced technologies for the future satellite communications and broadcasting systems. One of the main purposes of COMETS is to study the feasibility of advanced mobile communications systems in millimeter-wave and Ka-band. This study will be carried out on the basis of the vast amount of research experiences of Communications Research Laboratory (CRL), such as the ETS-V and ETS-VI satellite programs [2][3].

This paper describes the COMETS payload configuration and the experimental system for the advanced mobile communications mission.

MISSION OF AN ADVANCED MOBILE SATELLITE COMMUNICATIONS

COMETS Project

The COMETS is a joint project of CRL and Japan's National Space Development Agency (NASDA). COMETS has three mission payloads. The first is an advanced mobile satellite
communications system using millimeter-wave and Ka-band, which is developed by CRL. The purpose of this mission is to develop basic technologies to realize advanced mobile satellite communications systems. The second is a 21 GHz band advanced broadcasting system developed by CRL and NASDA. The third is an inter-orbit communication system developed by NASDA using S-band and Ka-band.

Figure 1 shows a conceptual sketch of the COMETS satellite and Table 1 shows its major characteristics of COMETS. The COMETS is a three-axis stabilized geostationary satellite and has three deployable antennas and about 32 m from tip to tip along a solar arrays. Its mission life is three years and the in-orbit weight is about two tons.

Fig.1 Conceptual Sketch of COMETS satellite.

Objectives of Advanced Mobile Satellite Communications Mission

Figure 2 shows a service image of an advanced mobile satellite communications system. This system has an on-board multibeam antenna, the beams of which must be connected each other. With this system, it will be possible to offer many different types of services as voice or message communications using handheld terminals, TV phone or facsimile services using mobile terminals, and TV conference services using VSATs.

One of the objectives of the advanced mobile satellite communications mission is to develop key technologies and devices for application in the future systems. These technologies and devices are the following:
(a) One-hop connection between handy, mobile and VSAT terminals
(b) Very small millimeter-wave and Ka-band antennas for handy and mobile terminals (e.g. active phased array), and antenna tracking techniques
(c) A multi-beam interconnecting technique
(d) A link-control system for a regenerative transponder
(e) New applications for mobile satellite communications

The COMETS will develop the millimeter-wave and Ka-band frequencies for advanced mobile satellite communications. These frequencies are suitable for future mobile satellite communications because antennas of an earth terminal can be made small enough for handy terminals and they have sufficient bandwidth to provide a large capacity for a great number of terminals including personal users.

ADVANCED MOBILE SATELLITE COMMUNICATIONS MISSION PAYLOAD

### Table 1 Outline of COMETS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch date</td>
<td>in Beginning of 1997</td>
</tr>
<tr>
<td>Launch vehicle</td>
<td>H-II rocket</td>
</tr>
<tr>
<td>Orbit position</td>
<td>121° E longitude</td>
</tr>
<tr>
<td>Mission life</td>
<td>3 years</td>
</tr>
<tr>
<td>Shape/dimensions</td>
<td>Rectangular parallelepiped (approx. 2 x 3 x 3 m)</td>
</tr>
<tr>
<td></td>
<td>Approx. 32 m length along solar arrays</td>
</tr>
<tr>
<td>Weight</td>
<td>for Launch: 3.8 tons</td>
</tr>
<tr>
<td></td>
<td>for Initial geostationary position: approx. 2 tons</td>
</tr>
<tr>
<td>Power</td>
<td>Approx. 5.4 kW or more at end of life</td>
</tr>
<tr>
<td>Attitude stabilization</td>
<td>Three axes stabilization</td>
</tr>
<tr>
<td></td>
<td>(feed forward compensation when the antenna is driven)</td>
</tr>
</tbody>
</table>
Outline

Table 2 shows an outline of the mission payload of advanced mobile satellite communications mission of the COMETS. The antenna has three beams; two adjacent Ka-band beams (Tokyo and Nagoya beams) and a millimeter-wave beam (Tokyo beam). As shown in Figure 3, the payload consists of the multibeam antenna, millimeter-wave and Ka-band transmitters and receivers, an IF filter bank and regenerative MODEMs which have a function of 2x2 matrix beam interconnecting.

The frequencies used in the COMETS system are 47/44 GHz bands for millimeter-wave communications and 31/21 GHz bands for Ka-band communications.

Table 2 Outline of Mission Payload

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Spot beam antenna shared with millimeter and Ka band (shared with base link antenna for inter orbit communication) Diameter: 2 m. Circular polarization, Antenna pointing system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam</td>
<td>Two Ka band beams (Tokyo and Nagoya beams) One millimeter beam (Tokyo beam)</td>
</tr>
<tr>
<td>Frequency</td>
<td>Ke band: 30.75-30.85 GHz (downlink) 20.56-21.07 GHz (downlink) Millimeter: 48.67-49.0 GHz (downlink) 43.78-43.79 GHz (downlink)</td>
</tr>
<tr>
<td>Transponder</td>
<td>Ke band: 2 x 20W and 10W SSPAs Millimeter: 1200W TWTA</td>
</tr>
<tr>
<td>Operation mode</td>
<td>IF repeater: 2 x 2 matrix beam interconnecting by IF filter bank Wide band base (5 kHz) and narrow band base (100 kHz) Regenerative transponder: 8 ch SCPC (uplink) 120M (downlink) Beam interconnecting by baseband switching</td>
</tr>
</tbody>
</table>

Multibeam Antenna

The 2-m-diameter antenna is used for both millimeter-wave and Ka-band communication. Figure 4 shows footprints of the COMETS's receiving antenna. The antenna has one spot beam in the millimeter-wave, of which the maximum gain is 55 dBi. It has other two spot beams in the Ka-band, which cover Tokyo and Nagoya areas, respectively. Maximum gains of the receiving antenna are 48.3 dBi for the Tokyo beam and 45.4 dBi for the Nagoya beam. The Ka-band two beams are located close to each other for purposes of an experiment on interbeam interference. The 3 dB contour diameter of each beam is about 300 km. The antenna has an antenna pointing system which tracks a beacon signal transmitted by an earth station.

RF Section

The transponder consists of 20W and 10W Solid State Power Amplifiers (SSPAs) for Ka-band communications, a 20W TWTA for millimeter-wave communications, and LNAs. An HEMT-LNA with a very low noise figure of 2.5 dB has been developed for millimeter-wave communications. The transponders for the two Ka-band beams can be switched if a malfunction occurs in either one. The frequency converters have a common local oscillator which is adopted to make it easy to compensate for frequency drift in the satellite. A frequency of the local oscillator is 14 MHz and its temperature stability is 2 x 10^-7.

IF Filter Bank

Signals from an uplink beam are divided by the IF filter bank into three frequency sub-band, and each sub-band interconnects between Tokyo-Tokyo, Tokyo-Nagoya and Nagoya-Nagoya. Each frequency band is preassigned to each beam. With this simple and flexible method, various types of signals can be transmitted via a transparent transponder.

In using a transparent repeater, it is desirable to optimize a transponder gain and a frequency bandwidth in order to increase satellite transmitting power (EIRP) and reduce a noise power. In order to carry out communications experiments at various transmission speed,
transponders are equipped with two kinds of filters with bandwidths of 6 MHz and 500 kHz. The transponder gain can be changed within a 30 dB range.

Though the satellite has three beams, only two of them, i.e., the Tokyo beam in Ka-band, and either the Ka-band Nagoya beam or the millimeter-wave beam can be used at the same time. Then 2x2 matrix beam interconnection is achieved in the IF filter bank. Figure 5 shows the IF frequency allocation bound for the Ka-band Tokyo beam. The IF filters of each beam consist of two wide-band 6 MHz filters, and two narrow-band 500 kHz filters, and an 800 kHz filter for a regenerative MODEM. Therefore, the frequency bandwidth of each transponder is 36 MHz, including a guard band. All filters are SAW filters.

Regenerative Transponder

Table 3 shows an outline of a regenerative transponder. Eight-channel SCPC signals are received at one regenerative MODEM and a single TDM signal is transmitted. The SCPC signal transmission rate is 24 kbps or 4.8 kbps with a BPSK modulation. Eight-channel SCPC signals are demultiplexed by a digital polyphase-FFT filter and demodulated discretely. Convolutional coding with a rate 1/2 and a Viterbi decoding are used as a forward error correction (FEC).

A link control system must have such functions as channel set-up, and SCPC and TDM channel assignment. This control is achieved in the satellite by using one SCPC packet signal channel and one TDM signal time slot. The system has functions suitable for mobile satellite communications. In order to increase link occupancy, a set-up demand from an earth terminal is stored once in a satellite buffer memory with a capacity of 20-channels and signals are assigned to a vacant channel in order. In the case of land mobile communication, a link is held for a given period of time when the link is temporarily disconnected by shadowing, or the link is disconnected automatically after a limited time when, for example, an automobile goes through a tunnel. Such a link control algorithm is under study based on the experiences of the mobile satellite communication experiments using the ETS-V satellite in 1.6/1.5 GHz.

ADVANCED MOBILE SATELLITE COMMUNICATIONS EXPERIMENTS

Example of Link Budget

The earth stations shown in Table 4 are considered to be used in the experiment. The base station will be located in the Kashima Space Research Center of the CRL.

Table 5 shows an example of a link budget. The earth terminal is located at a point where the satellite antenna gain is the maximum. In the case of an IF filter bank, a 24 kbps or 4.8 kbps signal can be transmitted between land mobile earth stations with 20-cm or 10-cm-diameter antennas in Ka-band. In the case of a regenerative transponder, the required transmitting power of an earth terminal should be enough to satisfy only the uplink C/No, because uplinks and downlinks are independent. An earth terminal with a 10-cm-diameter antenna can transmit a 24 kb/s signal at 1 W in Ka-band.

The satellite antenna gain is not so high, however, it is sufficient for experiments to verify key technologies. At the crossover point
of two Ka-band beams, the satellite receiving antenna gain lowers by about 8 dB compared to the maximum. A communication experiment on crossing beams can be conducted when a lower transmission rate is used or the experiment is conducted on a fine day free from rain attenuation. Communications experiments with a few tens of terminals at the same time is possible under restrictions such as no rain attenuation and low bit-rate communications.

Experimental Items

Items of advanced mobile satellite communications experiments using COMETS are:
(a) Various communications experiments including personal communications
(b) Experiments on a link control and an interbeam connection
(c) Propagation experiments considering shadowing and rain attenuation
(d) Evaluation of the satellite antenna and the transponders
(e) Evaluation of the land mobile earth stations

CONCLUSION

In this paper, the payload configurations of the COMETS satellite for advanced mobile satellite communication experiments and the experimental system are described. As a mission of advanced mobile satellite communications, advanced technologies are onboard the satellite such as multibeam antennas, 20 W and 10 W SSPAs in an Ka-band, a 20 W TWTA, an LNA with an excellent noise figure of 2.5 dB in a millimeter-wave, an IF filter bank, and a SCPC/TDM regenerative MODEM. The characteristics of all these on-board equipment should be proved in space for the first time in the world.

The COMETS program is now in progress and the transponders are being developed.

Further studies on the satellite and earth terminals are being carried out to establish basic technologies in advanced mobile satellite communications in millimeter-wave and Ka-band.

ACKNOWLEDGEMENT

The authors would like to thank the member of the COMETS project of CRL and NASDA for their helpful discussions and continuous support.

REFERENCES

Session 12
Mobile Terminal Antennas

Session Chair—Lot Shafai, University of Manitoba, Canada
Session Organizer—Martin Agan, Jet Propulsion Laboratory, U.S.A.

Low Cost Antennas for MSAT Vehicular Applications
L. Shafai, University of Manitoba; and M. Barakat, InfoMagnetics Technologies Corp., Canada ................................................................. 557

K- and Ka-band Mobile-Vehicular Satellite-Tracking Reflector Antenna System for the NASA ACTS Mobile Terminal
Art Densmore, Vahraz Jamnejad, T.K. Wu and Ken Woo, Jet Propulsion Laboratory, U.S.A. ................................................................. 563

An Active K/Ka-Band Antenna Array for the NASA ACTS Mobile Terminal
A. Tulintseff, R. Crist, A. Densmore and L. Sukamto, Jet Propulsion Laboratory, U.S.A. ................................................................. 569

Microstrip Monopulse Antenna for Land Mobile Communications
Q. García and C. Martín, TeDeCe, Spain; J.C. del Valle, DCG Ingenieros, Spain; and A. Jongejans, P. Rinous and M.N. Travers, European Space Agency/ESTEC, The Netherlands ......................................................... 575

Isolated and Coupled Superquadric Loop Antennas for Mobile Communications Applications
Michael A. Jensen and Yahya Rahmat-Samii, University of California/Los Angeles, U.S.A. ................................................................. 581

L-Band Mobile Terminal Antennas for Helicopters
T.K. Wu, K. Farazian, N. Golshan, D. Divsalar and S. Hinedi, Jet Propulsion Laboratory, U.S.A. ................................................................. 587

Aeronautical Satellite Antenna Steering Using Magnetic Field Sensors
John Sydor and Martial Dufour, Department of Communications, Canada ................................................................. 593