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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

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

Antenna	Spot beam antenna shared with MM-wave and Ka-band (shared with feeder link antenna for inter-orbit communication) Diameter : 2 m. Circular polarization, Antenna pointing system
Beam	Two Ka-band beams (Tokyo and Nagoya beams) One MM-wave beam (Tokyo beam)
Frequency	Ka-band : 30.75-30.85 GHz (uplink) 20.98-21.07 GHz (downlink) MM-wave : 46.87-46.90 GHz (uplink) 43.75-43.78 GHz (downlink)
Transponder	Ka-band : 2 (20W and 10W SSPA) MM-wave : 1 (20W TWTA)
Operation mode	IF repeater : 2 x 2 matrix beam interconnecting by IF filter bank Wide band filter (8 MHz) and narrow band filter (500 kHz) Regenerative transponder : 8 ch SCPC (uplink) / TDM (downlink) Beam interconnecting by baseband switching

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 dB. 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 milli-

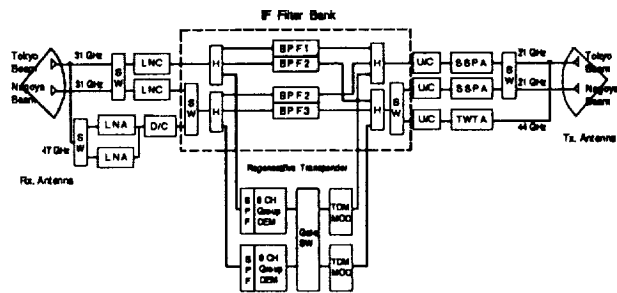


Fig.3 Block Diagram of a Transponder

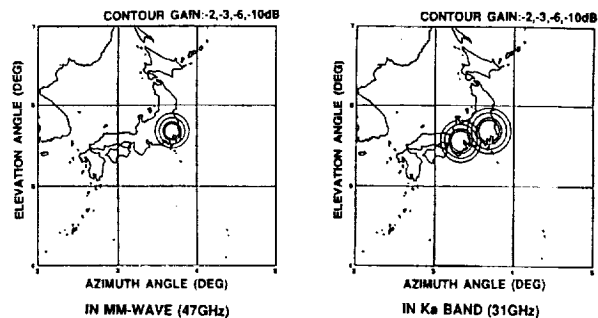


Fig. 4 Footprints of COMETS Receive Antenna.

meter-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 2×10^{-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

Table 3 Outline of a Regenerative Transponder

Uplink	: SCPC
Downlink	: TDM
Number of channels	: 8 ch / beam 6 ch for continuous signals 2 ch for packet signals (including 1 ch for channel assignment)
Transmission Rate	: 24 kb/s or 4.8 kb/s
Modulation	: BPSK
Demodulation	: Polyphase-FFT filter bank and Discrete BPSK demodulation
FEC	: Rate 1/2 convolutional code Viterbi decode

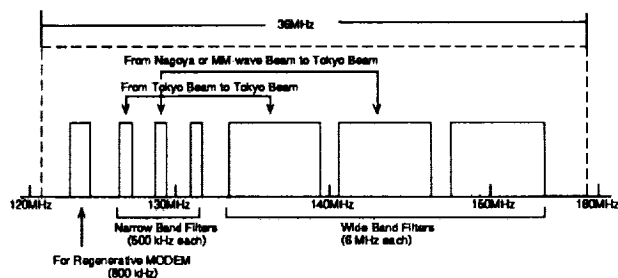


Fig.5 IF Frequency Allocation for Ka-band Tokyo Beam.

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

Table 4 Earth Stations for Experiments

	Antenna Diameter	Transmitting Power	Typical Data Rate
Base Station	3~5 m	more than 20 W	
VSAT	about 30 cm	about 4 W	300 kbps
Mobile Terminal	10~20 cm	about 2 W	24 kbps
Handy Terminal	5~10 cm	about 0.5 W	4.8 kbps

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.

Table 5 Example of Link Budget

Operation mode		IF repeater			Regen.Trans.
Frequency		Ka-band	Ka-band	MM-band	Ka-band
Transmission rate	kb/s	24	4.8	4.8	24/192
Tx. earth station					
Tx. power	W	0.48	0.41	0.82	1.05
Tx. antenna diameter	cm	20.0	10.0	10.0	10.0
Tx. antenna gain	dB	30.2	24.2	27.8	24.2
Pass loss	dB	214.3	214.3	218.0	214.3
Rain margin	dB	5.0	5.0	7.0	5.0
S/C (receiving)					
Rx. antenna gain	dB	47.4	47.4	45.8	47.4
Rx. power	dBm	-115.1	-121.6	-122.2	-117.5
No	dBm/Hz	-169.7	-169.7	-169.7	-169.7
Uplink C/No	dB · Hz	54.6	48.1	47.5	52.2
S/C (transmitting)					
Transponder gain	dB	140.0	145.0	145.0	-
Tx. power	W	0.31	0.22	0.19	4.20
Tx. antenna gain	dB	45.0	45.0	47.8	45.0
Pass loss	dB	211.4	211.4	217.8	211.4
Rain margin	dB	2.5	2.5	4.0	2.5
Rx. earth station					
Rx. antenna gain	dB	28.4	22.3	28.7	22.3
Rx. power	dB	-115.6	-123.2	-122.4	-110.4
No	dBm/Hz	-171.5	-171.5	-171.5	-171.5
Downlink C/No	dB · Hz	55.9	48.3	49.1	62.1
Required C/No	dB · Hz	52.2	45.2	45.2	-
Location of earth station : Center of Tokyo beam BPSK, Required Eb/No=8.4 dB (BER=10 ⁻⁴)					

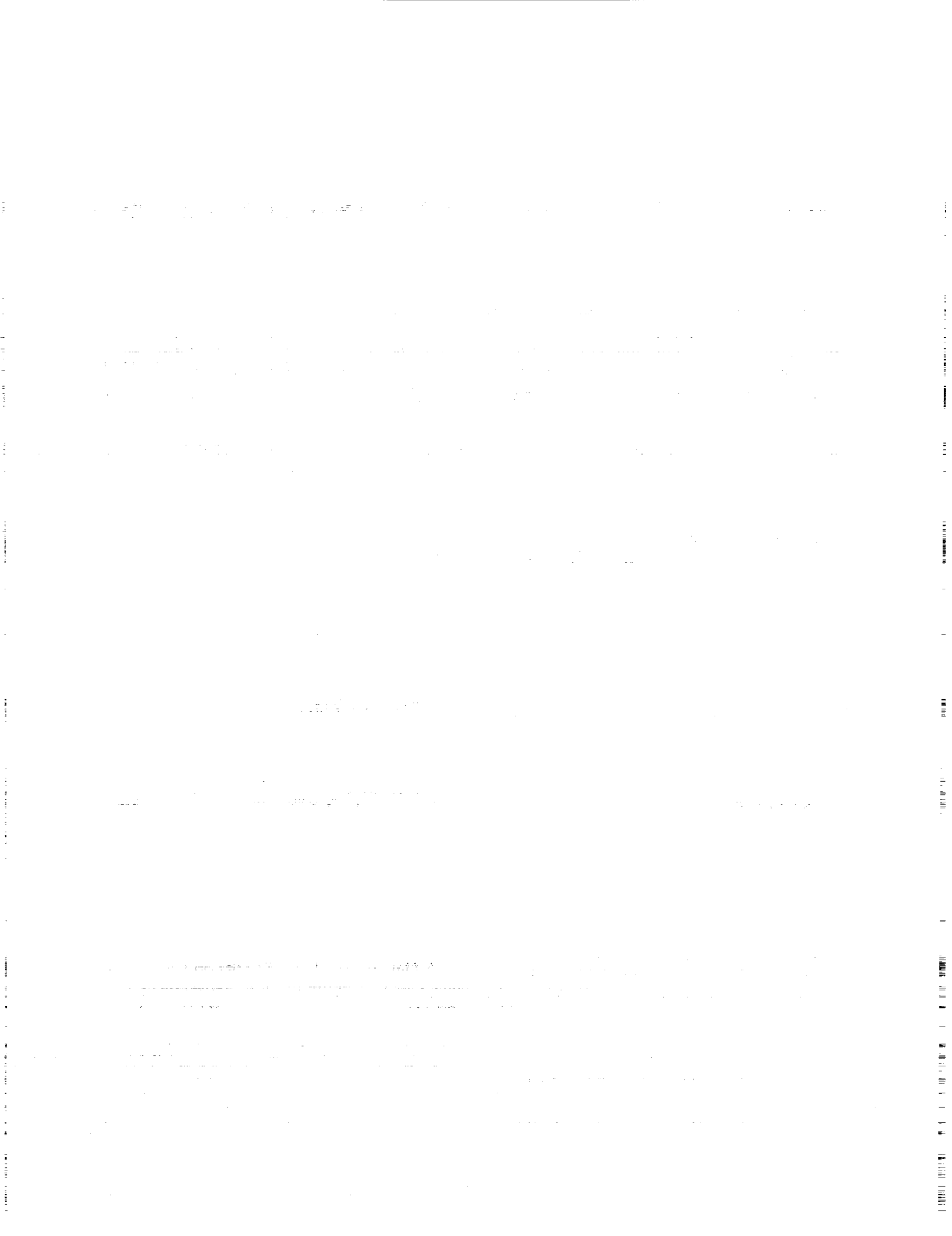
Further studies on the satellite and earth terminals are being carried out to establish basic technologies in advanced mobile satellite communications in millimeter-wave and Ka-band.

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