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Experimental Communication Payload Project of the ROCSAT-1 Satellite

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ABSTRACT

In this paper, an experimental communication payload (ECP) project of the Republic of China's ROCSAT-1 satellite program is introduced. The objective of the project is to study implementation techniques of the low earth orbit Ka-band satellite communication systems and to conduct Ka-band satellite communication experiments to study the performance of the video/voice/data/fax transmission and Ka-band propagation effect. The ECP consists of three subsystems, termed the ECP space segment (ECPSS), ECP ground segment (ECPGS), and ECP Science Data Distribution Center (ESDDC). The ECPSS provides a Ka-band bent-pipe transponder and a downlink beacon. The ECPGS is comprised of a fixed ground station with both transmitting and receiving capabilities and a transportable receive-only ground station. The ESDDC is responsible for scheduling the execution of various experiments, setup of configuration parameters of ECP, and dissemination of the pre-/post-experiment data.

(Key Words: Ka-band satellite communication, Ka-band propagation effect, Rain fade compensation)

1. ECP SYSTEM OVERVIEW

The ROCSAT-1 satellite [1], a low-earth-orbit (LEO) satellite developed by the National Space Program Office (NSPO) of the Republic of China (ROC), is scheduled to be launched in January 1999. The Experimental Communication Payload (ECP) project is one of the three science projects of the ROCSAT-1. Its purpose is to study implementation techniques of the LEO Ka-band satellite communication systems and to conduct Ka-band satellite communication experiments to study the performance of the video/voice/data/fax transmission and propagation effect of the Ka-band satellite link.

The ECP system, shown in Figure 1, is composed of three subsystems: (1) the ECP space segment (ECPSS), (2) the ECP ground segment (ECPGS), and (3) the ECP Science Data

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Distribution Center (ESDDC). The ECPSS, consisting of transmit and receive antennae and a Ka-band bent-pipe transponder with a downlink beacon, provides a platform for performing satellite communication experiments [2]. The ECPGS consists of a remote ground terminal (RGT) and a transportable ground terminal (TGT) [3]. The RGT is a fixed terminal with two-way (transmit and receive) communication capability and will be installed at Tainan, and the TGT is a transportable receive-only terminal. Both the ECPSS and ECPGS provide the necessary point-to-point link for various experiments. The ESDDC is established at NSPO in order for scheduling the execution of experiments, setup of the ECPSS and ECPGS ground terminal parameters, and dissemination of the pre-/post-experiment data. The communication between the ECPGS and ESDDC is through the terrestrial network.

There are only six orbits during which the spacecraft is within the line of sight from Taiwan area perday, and the average contact time per pass is about 6 minutes for 15° elevation. Thus, the total time duration that we can conduct communication experiments is only about 438 hours (18.25 full-days) for the entire 2 year mission period.

2. ECP EXPERIMENTS

At the beginning of the ECP project, three categories of experiments were considered:

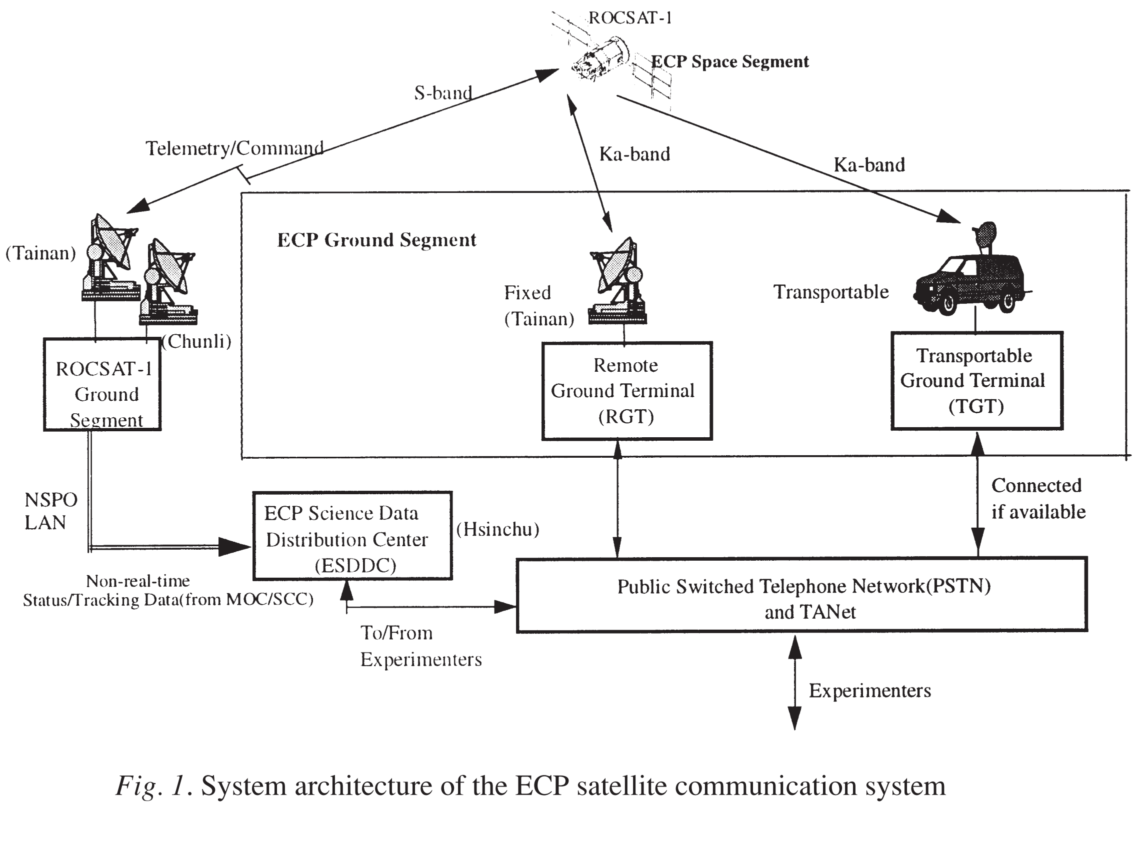


Fig. 1. System architecture of the ECP satellite communication system

A. Technology Demonstration Experiments:
- In orbit loop-back testing to measure EIRP, G/T and link quality
- Ka-band antenna tracking(antenna tracking loop C/No), Doppler compensation performance and antenna acquisition characteristics measurement
- Transponder characteristics verification
- LEO satellite operation experiments

B. Propagation Experiments and Rain Fade Compensation:
- Rain attenuation
- Uplink power control
- Site diversity
- Modulation and coding (time diversity)

C. Application Experiments:
- Modulation and coding
- Direct broadcasting experiment
- Interactive multimedia experiment
- Low-rate video/voice/data/fax transmission experiment
- Digital communication experiment
- Mobile (receive-only) communication experiment

The ECP team of the NSPO will perform the first category of experiment. The last two categories of experiments are open to domestic universities. An "Announcement of Opportunity" was issued in May 1995 to solicit proposals from universities to conduct ECP experiments. After review of all proposals, three experiments were selected: (1) Direct Broadcasting Experiment of Digital TV and High-speed Multimedia Signals to be executed by a research team from National Tsing Hua University (NTHU) [4], (2) Integrated Voice/Data/FAX/Low-Speed Video Transmission Experiment to be executed by a research team from National Cheng Kung University (NCKU) [5], and (3) Ka-Band Propagation and Rain Fade Compensation Experiments to be executed by a research team from National Central University (NCU) [6].

2.1 Direct Broadcasting Experiment of Digital TV and High-speed Multimedia Signals

This experiment will demonstrate the possibility of broadcasting compressed TV and high-speed multimedia signals via LEO Ka-band satellite link. In this experiment, the NTHU team will also study the performance of various source coding (video/audio compression) algorithms for digital TV and high-speed multimedia signals in order to develop a robust codec of optimum source coding structures for the Ka-band satellite communication system [6].

This experiment will use the RGT to transmit and receive the compressed digital TV and high-speed multimedia signals. The maximum data rate is as high as 6.6 Mbps. Since Ka-band satellite link is vulnerable to weather conditions, the data rate may be reduced to 3.3Mbps or lower in order to achieve the same 10^{-6} bit error rate (BER) performance.

2.2 Integrated Voice/Data/FAX/Low-Speed Video Transmission Experiment

This experiment will use the RGT to transmit and receive the low speed data signals. The

NCKU team will study robust source coding (video/voice compression) structure for integrated low rate video and voice services in the video-phone application, which is suitable for the characteristics of the LEO Ka-band satellite link [5]. To combat rain attenuation for the Ka-band satellite link, a scalable structure which can adaptively change the transmission rate for keeping the BER acceptable was developed. Four types of digital signals (low-speed video, digital voice, fax and data) are to be generated in real-time fashion and transmitted using a Frequency Division Multiplexing (FDM) scheme.

2.3 Ka-Band Propagation and Rain Fade Compensation Experiments

This experiment will study the propagation characteristics and quantify the attenuation in the Ka-band satellite communication downlink due to rain fall and atmospheric absorption for the Taiwan area [7].

During the first phase of study [8], much meteorological data, such as rain fall rate, rain particle size, rain cell pattern and principal axis, the height of Troposphere and Stratosphere, atmospheric background noise temperature, etc., have been collected by radiosonde, rain gauge, MST radar, C-band microwave meteorological radar, Distrometer, and radiometer. Some of these statistical data are used to calculate the atmospheric deflective index and effective earth radius which is essential in determining the satellite propagation length and the satellite acquisition direction. After the satellite has been placed into orbit, the experimenters will use the RGT and TGT to measure the power of the ECP Ka-band downlink beacon signal under various weather conditions. Based on these measurement data along with previously collected statistical data, extensive studies of rain attenuation and tropospheric scintillation in the Taiwan area will be performed.

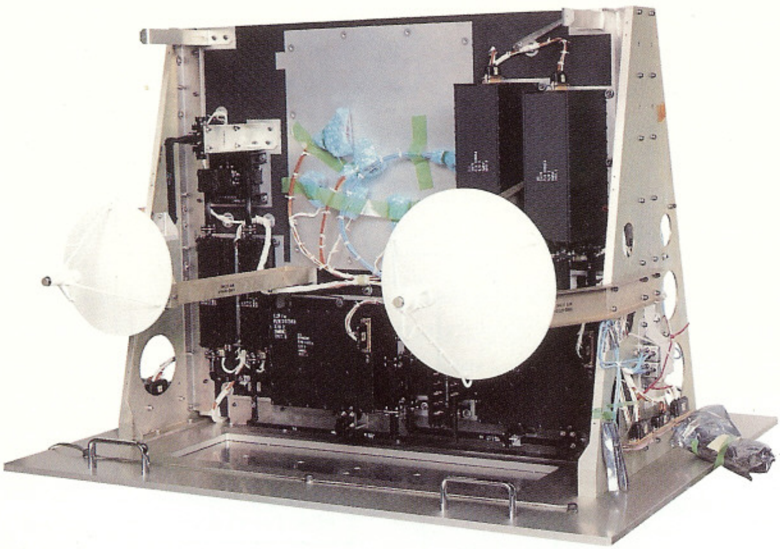
Rain fade compensation is also an important task in this experiment. The mitigation technique of compensating the rain fade, using site diversity, will be studied. In order to achieve site diversity, both the RGT and the TGT will be used. The TGT will be placed outside the rain cell area after the rain cell pattern has been detected by the C-band microwave radar to calculate the diversity gain.

3. SYSTEM CHARACTERISTICS

3.1 The ECPSS

The ECPSS consists of a Ka-band bent-pipe transponder and an antenna subsystem including transmit and receive antennas [2]. The ECPSS is shown in Figure 2 and its functional block diagram is shown in Figure 3.

The key components of the Ka-band transponder are input and output switches, Ka-band receiver, transmitter, Traveling Wave Tube Amplifier (TWTA), beacon transmitter, and beacon output switch. The receiver, transmitter, TWTA, and beacon transmitter each have the two same parts: one is selected primary and the other is redundant. The switch can be switched to either primary or redundant side. All of them are commandable. Based the combination of these key components, there are 16 configurations for operation. Only one of them can be configured for operation for each flight contact.



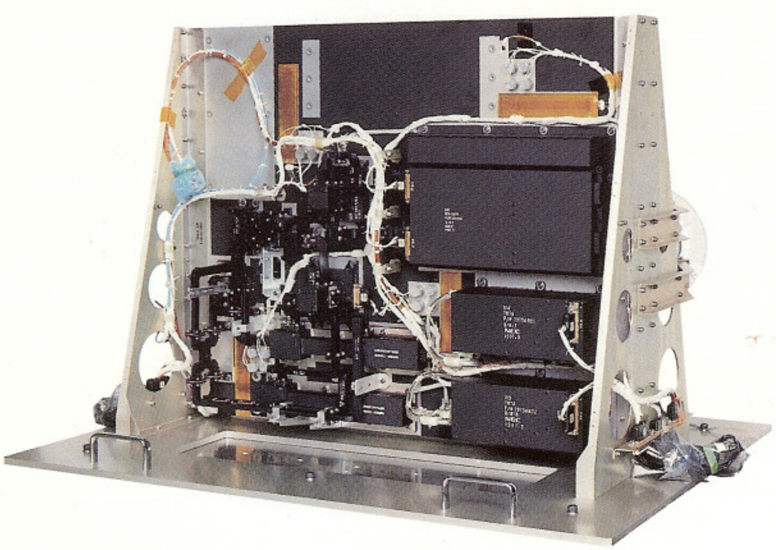


Fig. 2. The ECPSS (top:front view, bottom:back view).

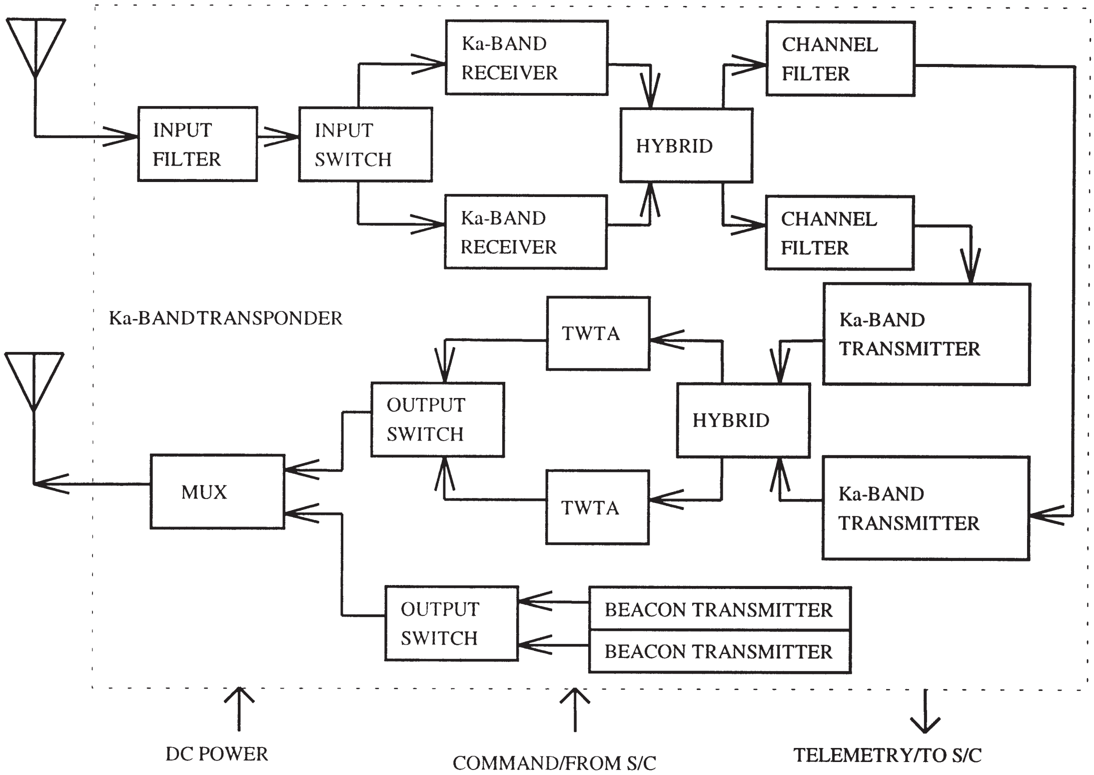


Fig. 3. Functional block diagram of the ECP space segment.

3.1.1 Antenna Subsystem

The ECPSS receiving (uplink) antenna is operated at a centered frequency of 28.25 GHz and the transmitting (downlink) antenna is operated at a centered frequency of 18.45 GHz. Each antenna consists of a hyperbolic-shaped reflector, a feed horn, and support assembly. The manufactured reflector of the receive antenna has a diameter of 20.3 cm, height of 16 cm, and weight of 0.54 Kg. The manufactured reflector of the transmit antenna has a diameter of 25.4 cm, height of 19 cm, and weight of 0.87 Kg. The antenna polarization is left-hand circularly polarized for downlink and right-hand circularly polarized for uplink. The feed horn is an axially corrugated horn. The coverage of the antennae provides the beam to illuminate Taiwan when the satellite is within the line-of-sight (LOS) of the Taiwan area at an altitude of 600 ± 50 Km. The elevation angle for the LOS is $\geq 15°$ for communication experiments and $\geq 10°$ for propagation experiments as well as satellite tracking.

3.1.2 Transponder Subsystem

For communication purposes, the transponder receives the uplink signal of 28.25GHz from the RGT through the ECPSS receive antenna and converts its carrier frequency to the downlink frequency of 18.45GHz. The signal is then amplified by the TWTA before being sent to the earth through the ECPSS downlink antenna. The range of transponder input power for single carrier saturation is from –95 dBW to –115 dBW. Transmitter gain can be commanded in steps the size of 5 dB maximum with a power control attenuator. The minimum transponder output saturated power is 10 dBW over 27 MHz in Ka-band. The downlink beacon is a continuous wave (CW) signal operated at 19.5GHz for the aid of antenna acquisition and propagation study. The beacon transmitter output power is at least 1.5 watts.

Table 1 lists major specifications of the ECPSS.

3.2 The ECPGS

Two ground terminals (RGT and TGT) were developed for ECPGS [3]. The RGT is a fixed terminal and equipped with transmitting and receiving capabilities and will be installed in the Aerospace Science and Technology Research Center at Tainan. The TGT, a receive-only terminal, is installed on two trucks, one for antenna equipment and the other for control equipment. They can be transported to various sites in the Taiwan area for propagation experiment.

The RGT consists of an antenna module, a tracking module, a Ka-band transmitting mod-

Table 1. Major Characteristics of the ECP Space Segment.

Max. Antenna Coverage Angle	±65° , conic
Duty Cycle	8% of one revolution around the earth
Transponder Bandwidth (1Db)	27MHz
Power Requirement	Operating power: 80Watts peak; in-orbit averaging power 25Watts
Mass	18.43 Kg
Volume	20 boxes plus one Tx Antenna with D=25.4cm and H=19cm, and one Rx antenna with D=20.3cm and H=16cm
Transponder Output Power	≥ 10 Watts
Beacon Output Power	≥ 1.5 Watts
Polarization of the Antennas	LHCP for Transmit, RHCP for Receive
G/T @ 0° boresight	-38dB/K (Range compensated up to ±65°)
EIRP @ 0° boresight	2 dBW (Range compensated up to ±65°)
Saturated Input Power Level	-115~-95dBW
Instrument Design Life	4 years in orbit
Reliability	0.95 for 2 years shelf +2 years on orbit

ule with uplink power control, a Ka-band receiving module including a beacon downconverter for antenna tracking and Doppler compensation, a communication module (including the data interfaces), a BER measurement module, a monitor and control module, a data acquisition module, a master time/frequency reference module, a power supply module, and an experiment support equipment module. As to the TGT, the transmitting capability is not included in the current design but is reserved for future expansion. Figures 4 and 5 depict the block diagrams of the RGT and TGT, respectively.

The receiving side of the ECPGS terminals is divided into three sub-bands for (1) the Communication Chain, (2) the Beacon Chain, and (3) the Radiometric Chain. The frequency assignment for the receiver front-end is as follows:

(1) Communication Chain: 18.2~18.7GHz

(2) Beacon Chain: 19.5GHz

(3) Radiometric Chain: 20.0~20.5GHz.

The communication chain is used to receive the downlink modulated signal from the ECPSS transponder. The beacon chain is used to receive the on-board beacon for antenna tracking and propagation measurement. The radiometric chain is used for an external passive radiometer to measure the background sky noise temperature.

To facilitate interfacing with external equipment, the commonly used 70MHz intermediate frequency (IF) is employed for the communication and beacon chains. For the TGT, the communication chain is terminated at the IF on the patch panel for future expansion.

3.2.1 Operation Modes of the ECPGS

The RGT and TGT are designed to be operated in three modes: (1) TEST Mode, (2) EXPERIMENT Mode, and (3) CALIBRATION Mode. The TEST mode is used for system diagnosis and trouble shooting purposes. In this mode the ground terminals will measure the link quality at low-rate and high-rate (up to 6.6Mbps) transmission, respectively; measure the antenna acquisition, tracking, and re-acquisition performance; measure the uplink and downlink Doppler compensation performance; measure the terminal acquisition (and re-acquisition) characteristics (e.g., antenna acquisition, modulation signal acquisition, etc.). In the EXPERIMENT mode, the high- and low-rate communication experiments and the propagation experiment will be conducted. The CALIBRATION mode is selected to calibrate the beacon receiver and the external radiometric receiver before an upcoming satellite pass, the ground terminal will be able to switch to a broadband calibration noise source input to the receiver front-end.

3.2.2 Antenna Tracking

To facilitate the satellite signal acquisition, the antenna tracking module is able to store and then make use of the predictive Keplerian ephemeris, supplied by ROCSAT-1 Ground Segment via ESDDC.

Antenna tracking is a crucial issue for low earth orbit satellites. To provide zenith tracking capability without key-hole, the antennae are equipped with a 3-axis tracking pedestal. This

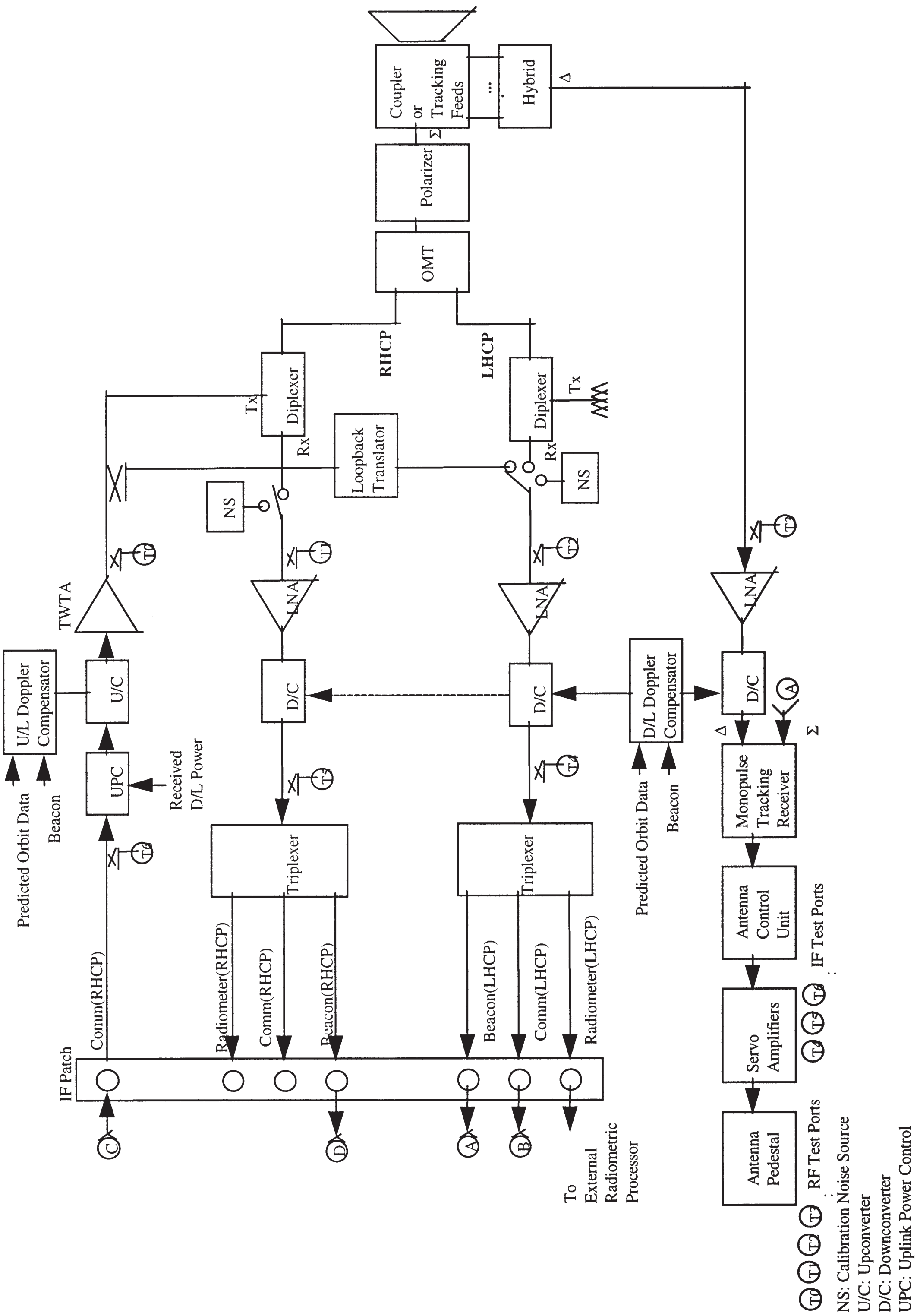
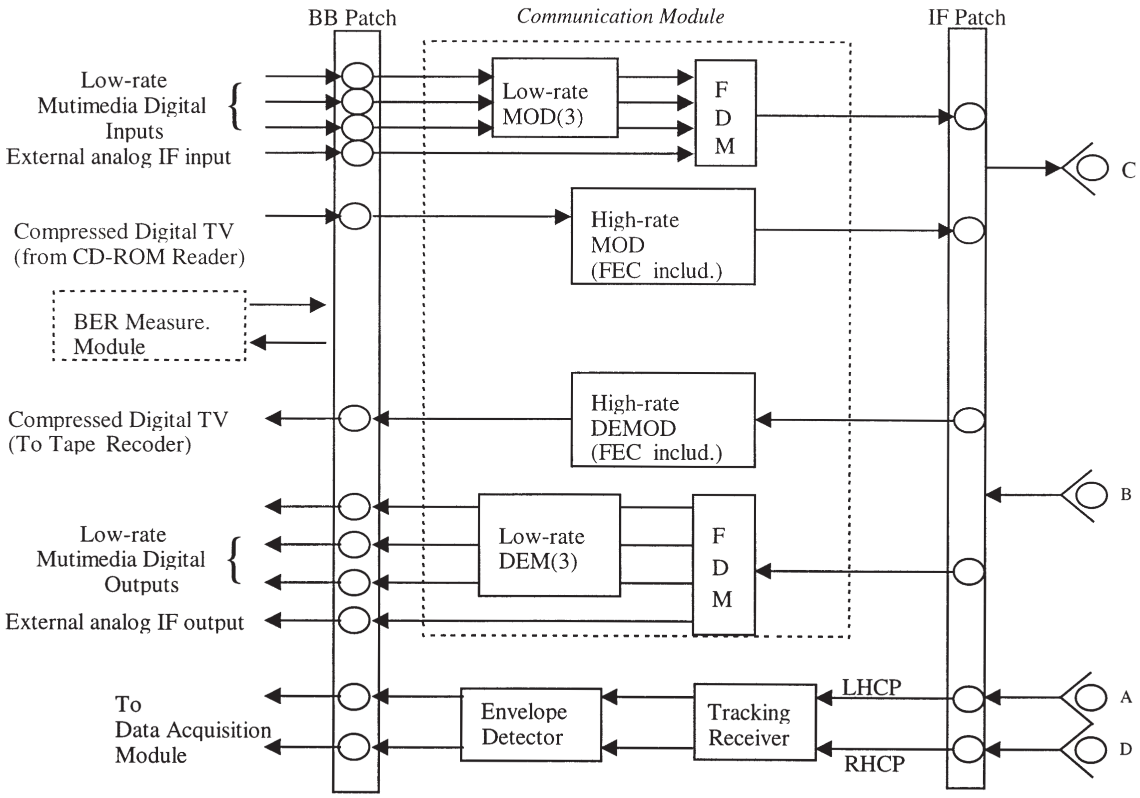


Fig. 4. Functional block diagram of the fixed ground terminal.



(Fig. 4. continued)

full motion antenna is able to travel 0~90 degrees in elevation and 0~360 degrees in azimuth.

In the ECPGS, pseudo-monopulse tracking algorithm is employed for autotrack. A sum-channel and a difference-channel with RF-sensing technique of high-order waveguide mode accomplish the tracking. When the autotrack system is faulty or interrupted for any reason, the tracking module will be able to switch to the program-track mode and return to autotrack mode upon re-acquisition of beacon signal. The ROCSAT-1 satellite is scanned with the aid of the acquisition knowledge box and predictive orbit data in the program track mode at 10 degrees elevation. As the signal strength surpasses the tracking threshold, the autotrack mode is initiated.

3.2.3 Doppler Tracking

Doppler tracking is another crucial issue for the LEO satellite especially for the Ka-band system. The Doppler tracking in the ECPGS is operated with the aid of predictive orbit data. It is also pre-compensated at the uplink side to make sure that the residual Doppler is within the carrier acquisition range of the satellite modems and beacon tracking loop.

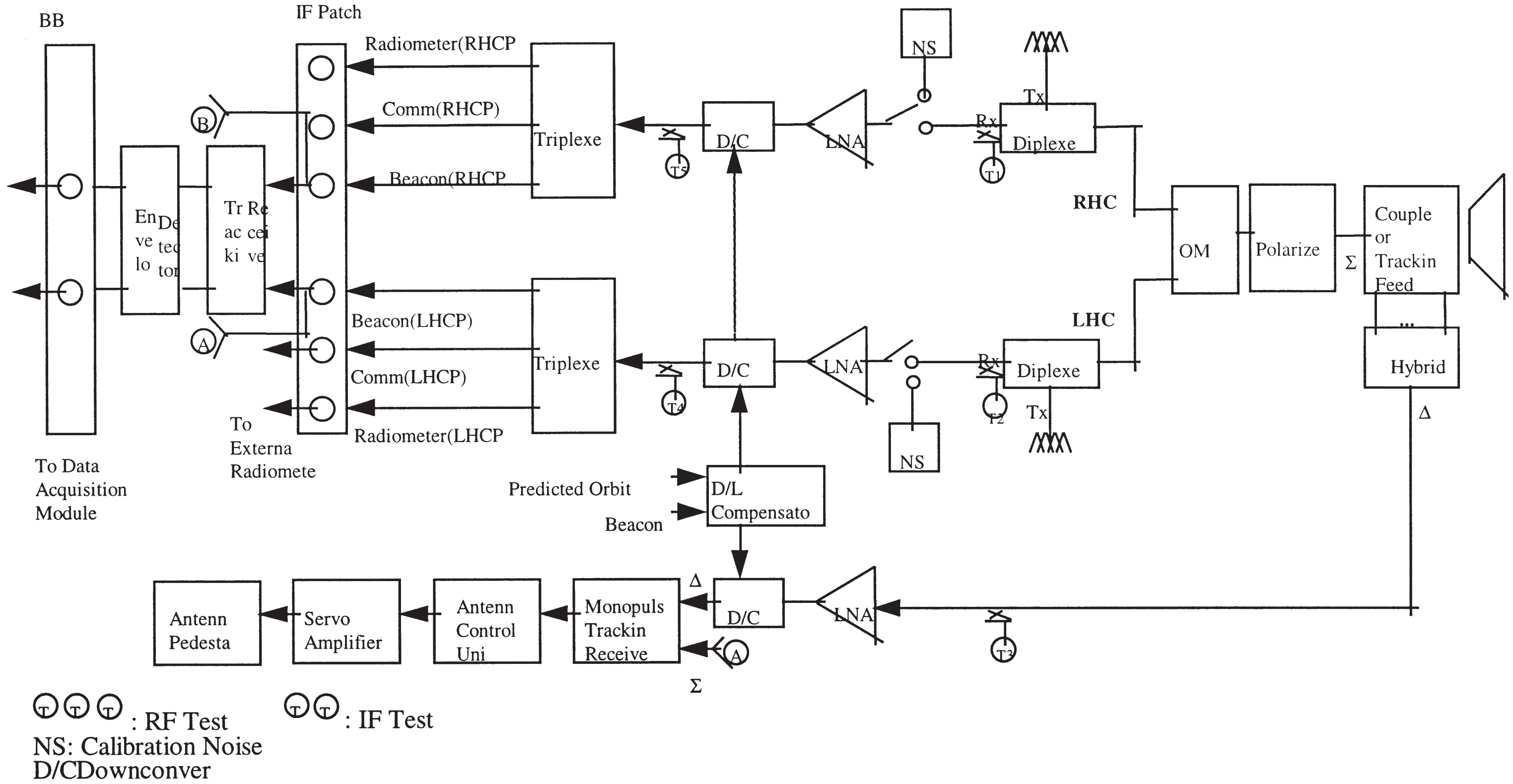


Fig. 5. Functional block diagram of the transportable ground terminal.

3.2.4 Satellite Modems

The RGT provides one high-rate satellite modem and three low-rate satellite modems, respectively, for high-rate communication experiments and low-rate ones. Figure 6 shows the functional block diagram of the communication module. No satellite modem is provided in the TGT but external interface is reserved for future expansion.

The high-rate satellite modem can operate at a data rate of up to 6.6Mbps. It can provide convolutional code (code rate=1, 1/2, 3/4 and 7/8 with constrain length of 7), RS code and its concatenated code for combating the error due to channel impairments. Interleaving depths of 1 and 4 are used in the modem. BPSK and QPSK modulations can be selected according to the experiment requirements.

For low-rate communication experiment requirements, FDM is used to combine three IF modulated signals. It also provides the capability of connecting external signals from other customer supplied equipment. The low-rate modems can operate at a data rate between 9.6kbps~256kbps. Both BPSK and QPSK modulation formats can be selected. Only convolutional codes (no RS codes) with code rates 1, 1/2, 3/4 and 7/8 are implemented for the low-rate modems.

3.2.5 Transmit and Receive Capabilities

The RGT and TGT are equipped with dual-polarization reception capability. RHCP and LHCP beacon signal components are measured and archived simultaneously for the propagation experiment.

A Ka-band 120Watt TWTA used for the RGT operates over the frequency range of 27.5~29.5GHz which overlaps the frequency band of 28.25GHz $\pm$ 13.5MHz. The output power measured at the output flange is at least 115Watts. The Effective Isotropic Radiated Power (EIRP) of the RGT with 3m antenna is at least 74.5dBW with stability within +/-1.0dB.

The Gain-to-System Noise Temperature (G/T) figures of RGT and TGT are at least 25.1 and 20.7dB/K respectively with stability to be within 1dB peak-to-peak at 10 degrees elevation in clear sky.

The major characteristics of the RGT and the TGT are summarized in the Table 2.

3.3 The ESDDC

Due to very limited communication time windows, it is very crucial that all experiments are scheduled to proceed efficiently and timely. Before actually executing the experiments, coordinations are required to resolve the schedule conflicts among science teams. The experimenter, particularly for the propagation experiment, needs to know the orbit trajectory of the spacecraft ahead of time for planning the experiment. Selection of either primary or redundant components in ECPSS has to be determined for each contact time. Finally, after the experiment, the experimenter needs to acquire the post-experiment data and associated housekeeping information from receiving ground terminals for post-processing and analysis. The ESDDC is required to carry out all these operations.

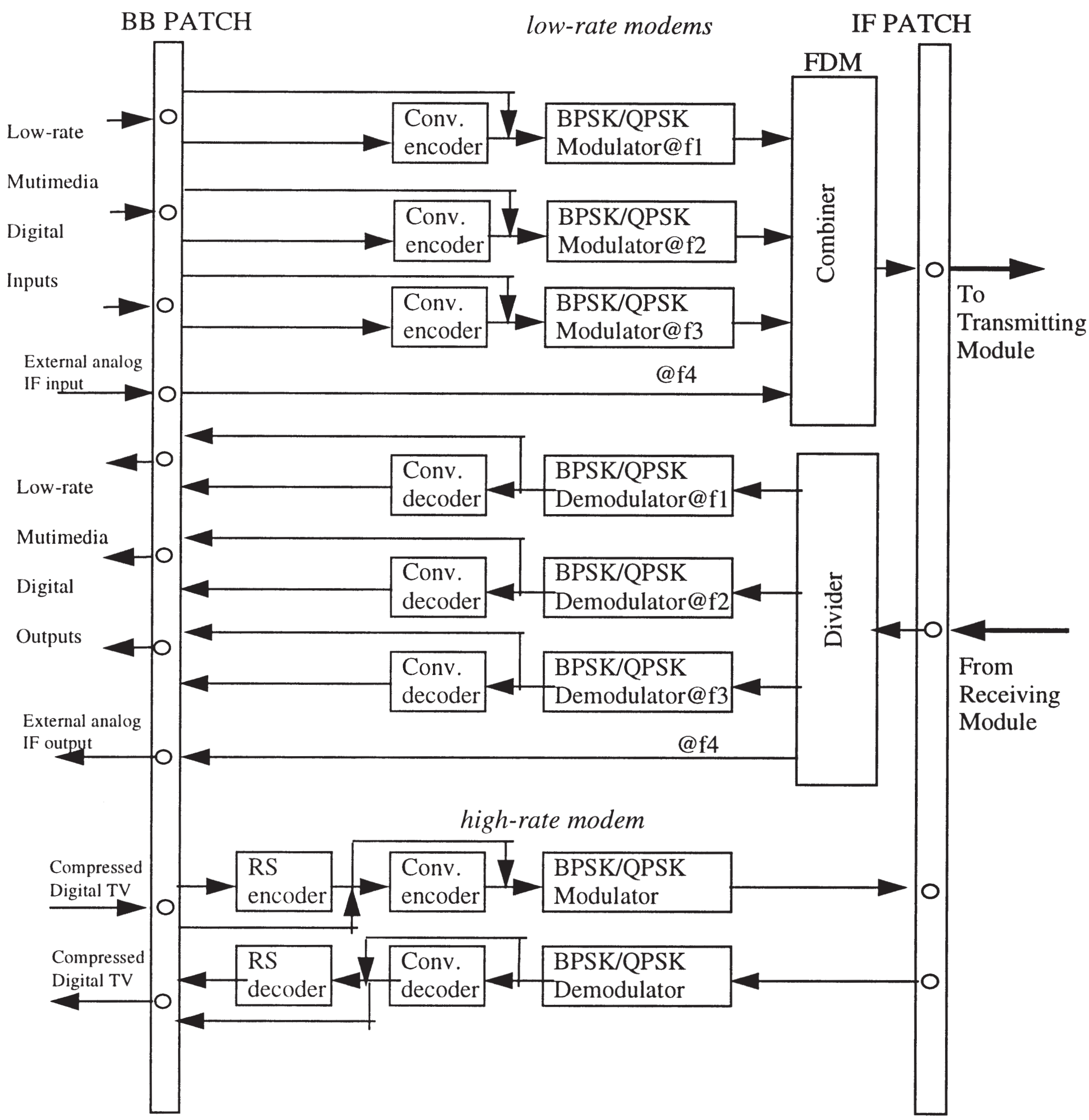


Fig. 6. Functional block diagram of the communication module.

3.3.1 Experiment Scheduling and ECP System Configuration Selection

According to the operation of the ROCSAT-1 Ground Segment (RGS), the predictive Orbit and Attitude Data can be generated at the RGS and be sent to the ESDDC every day. The predictive orbit ephemeris data covers up to a period of 30 days and will be updated every day after receiving the determinate spacecraft location from the TT&C station. The ESDDC will retrieve the predictive orbit ephemeris data for a new weekly scheduling cycle, pass this infor-

Table 2. Summary of RGT/TGT characteristics.

Item	RGT	TGT
Antenna Type	Cassegrain	Cassegrain
Antenna Main Reflector Diameter(in meters)	3.0m	1.8m
TWT Output Power(in Watts)	≥ 120 (>115 at flange output)	N/A
EIRP(in dBW)	≥ 74.5 (measured at diplexer output) in clear sky	N/A
G/T(in dB/K)	≥ 25.1@10 degrees Elev (clear sky)	≥20.7 @10 degrees Elev (clear sky)
Tracking Method	Autotrack(Monopulse)	Autotrack(Monopulse)
Antenna Mount	Three-axis(Az/El/X-El)	Three-axis(Az/El/X-El)
Antenna Gain	≥ 56.0dBi(Tx Band) ≥ 52.3 dBi(Rx Band)	≥ 51.6dBi(Tx Band) ≥ 48.0dBi(Rx Band)
Axial Ratio	<2.0dB for all bands < 1.5dB for beacon	< 2.0dB for all bands < 1.5dB for beacon
Polarization	Tx: RHCP or LHCP Selectable Rx: RHCP and LHCP Simultaneous	Tx: RHCP or LHCP Selectable Rx: RHCP and LHCP Simultaneous
Feed Horn	Corrugated Horn	Corrugated Horn
Tx/Rx Isolation	≥ 110dB	≥ 110dB
Tracking Threshold	≤ 43dB-Hz	≤ 43dB-Hz
Pointing Accuracy	≤ 0.07degree per axis	≤ 0.07degree per axis
Tracking Accuracy	≤ 1/8*HPBW	≤ 1/8*HPBW
Downlink Frequency Bands (contains three sub-bands)	18.2~18.7GHz for communication 19.5GHz for beacon 20.0~20.5GHz for radiometer	18.2~18.7GHz for communication 19.5GHz for beacon 10.0~20.5GHz for radiometer
Uplink Frequency Band	28.0~28.5Ghz	28.0~28.5Ghz(Terminated by dummy load)
Noise Figure of LNA	≦2.5dB	≦2.5dB

mation to all Principal Investigators (PIs) of ECP science teams, and request them to perform weekly experiment planning.

PIs plan the experiments including experiment duration, operation configuration of ECPSS and ECPGS, and detailed procedures, and send the plans to the ESDDC. The ESDDC review the proposed plans, resolve any schedule conflicts and finalize the experiment schedule for the entire scheduling cycle. The finalized "Approved Experiment Plans" will be sent to all PIs for their preparation. This process is to be performed once a week.

Five days prior to the planned experiment, the ESDDC sends a so-called "Science Acquisition Request" to the RGS. This request contains necessary information including:

(a) Reference Point for Instrument On/Off - There are 95 experiment reference points over the entire Taiwan area, one refers to the RGT and the others refer to the 94 possible experiment zones for TGT. The RGS will compute the Instrument Turn-On and -OFF times for each contact window according to the selection of the experiment reference point.

(b) ECPSS configuration - The ESDDC will determine whether the primary or redundant ECPSS components should be turned on during the contact window and requests the RGS to send a proper command sequence to configure ECPSS.

(c) Gain State of ECPSS Transponder – The ESDDC will decide the gain state from 0 through 6 of the ECPSS transponder based on the back off request from the experimenters. The RGS will follow the ESDDC's request to command the ECPSS transponder.

In response to the Science Acquisition Request, the RGS will generate and then send to the ESDDC an approved "Plans & Schedules." In case the approved schedule for using the ECPSS differs from the original plan, the ESDDC will re-arrange the experiment plans and inform all PIs.

The ESDDC will send 3 types of data to the ECPGS for each contact time window of the following day. They are (1) Orbit & Attitude Data, (2) Approved Experiment Plans (including system parameters), and (3) Experiment Data, for those experiments to be conducted in batch fashion. The Orbit & Attitude Data is used for pointing ground station antennae to acquire the spacecraft signal. The Approved Experiment Plans are used to setup the system parameters of the ground terminals for each contact time window of the following day. Lastly, the Experiment Data is for the readiness of the experiment if the real-time transmission is not possible.

3.3.2 Experiment Execution and Experiment Data Archiving and Retrieval

Immediately prior to executing the experiment, the ESDDC will confirm with each of the ECP ground stations as to the readiness of the system setup. For the real-time experiment, the ESDDC will make a copy of the experiment data for archiving while the experiment data is being received. During the experiment, the ECPGS will monitor the quality of the communication link and the status of the entire operation. In the event that the link is corrupted due to severe fade or the experiment operation is aborted due to human errors or equipment failure, the ECPGS will immediately notify the ESDDC. Upon receiving any contingency notification from the RGS, the ESDDC will assess the situation, perform the diagnosis and decide to either terminate or halt the on-going experiment.

After the experiment is completed, the post-experiment data will be sent from the ECPGS to the ESDDC for archiving via terrestrial network or tape delivery. The TGT will include the position location data, obtained from the GPS receiver in its post-experiment data transmission. For each ground terminal and every experiment, the ESDDC will, for the purpose of future investigation and analysis, archive the pre-experiment data, post-experiment data and experiment-associated information, such as time tag, antenna pointing, Orbit & Attitude, and ground terminal location. The experimenter can retrieve at any time the experiment data (pre- and post-) and associated housekeeping data of the ground terminals from the ESDDC at any time by making a request.

3.3.3 Network Architecture of the ESDDC

The ESDDC is required to interface with RGS, ECPGS, and PI's university sites. In order to share the resources effectively and efficiently, the ESDDC has implemented a client-server type of Local Area Network (LAN). Figure 7 shows the block diagram of this network architecture. A router, two servers, one disk array, two graphical stations (for display), and printers (with printer servers) are included in the LAN. The router has a resident "fire wall" function and controls the security of the file flow into and out of the ESDDC. In addition to the ordinary security control of a regular LAN for preventing any unauthorized access, the router allows only the ingress of data flow from authorized users under normal conditions. In order to prevent the stored data from being destroyed or tampered with, the out-going of the data flow is only permitted subject to ESDDC consent.

Two servers are used for redundancy purposes. However, under normal working conditions, they can be used for different purposes to improve efficiency. One server is used to control the data flow to/from RGS and ECPGS, while the second server concentrates on handling the experiment plans and retrieval and archiving the data file. Since a lot of data need to be archived, a 25 Gbyte disk array with tape driver is utilized and connected to the servers. The servers and disk array are for operation control, the core function of the ESDDC. Thus, in order to ensure the availability of the system, this subsystem is designed to provide an automatic back-up capability. That is, in case one server is down or requires maintenance, another server can automatically take over the entire operation without interrupting the continuation of the service of the ESDDC.

The RGS interfaces to the first server through the NSPO LAN. The RGT is connected to the same server via T1 leased line and using ISDN as backup for sending back the post-experiment data and RGT housekeeping information to the ESDDC. This set-up is to avoid any collision with other traffic during the data transmission, because collisions here are not permitted. The RGT also interfaces with the first server through the NSPO LAN and TANet (Taiwan Academic Network) to exchange non-urgent data with ESDDC. Since the data transmission between university sites and ESDDC is very time-consuming, the packet switched network is much more desirable than PSTN or ISDN in terms of cost. Note that all universities in Taiwan area are connected to the TANet which has a node at the National Center of High-Performance Computing (NCHC) in Hsinchu, and that there is a FDDI network connecting NSPO and NCHC. Therefore, the university PIs can exchange their experiment plans and

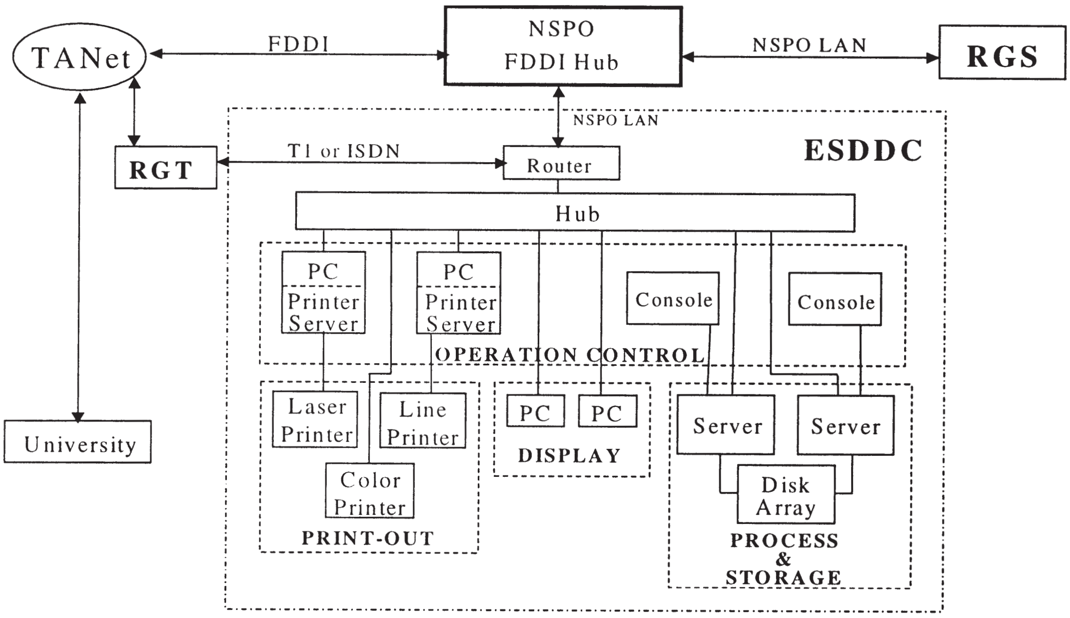


Fig. 7. Block diagram and network architecture of the ESDDC.

experiment data with the ESDDC through TANet and FDDI using E-mail (SMTP protocol) or file transfer (FTP).

4. CONCLUSIONS

The ECP system was developed to study implementation techniques of the LEO Ka-band satellite communication system and to conduct the Ka-band satellite communication experiments. In the ECP project, analyses and research of the Ka-band propagation effect have been conducted, and universities have also developed modem and coding/decoding techniques and rain-fade compensation algorithms. It is envisioned that, through the use of the ECP system, the characteristics of the LEO Ka-band satellite link will be better understood and the experiment results will benefit the design and operation of future Ka-band LEO communication satellites.

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