4-4 BFN Operating System

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Numerous parameters are required for the setup of Beam-Forming Networks used in phased-array antenna systems. For this reason, a fixed BFN operating system was established with the aim of increasing efficiency and saving labor. This system manages the various parameters required for the employment of a BFN unitary, resulting in the more efficient use of BFN.

Keywords
Beam-forming network, Command, Telemetry, Operation

1 Introduction

The ETS-VIII (Engineering Test Satellite-VIII) is equipped with phased array antennas that use large deployable reflectors as primary mirrors. Setup commands must be executed for the controller (BFC) of the beam-forming network (BFN1; for related details, see an article "3-6-3 Beam-forming network" of this special issue.) used. Setup of the BFC involves a variety of data, including phase and amplitude parameters required for beam formation, necessitating the execution of a large number of commands. To render BFN operation more efficient and to save labor in the setup process, a fixed BFN operating system (BFNOS) has been established. The BFNOS manages, in a unified manner, the various parameters required to run the BFN1. The BFNOS controls the BFN1, constructs array weight tables, and displays beam pattern simulations. Together these functions combine to yield greater operational efficiency.

2 System configuration

The hardware for the BFNOS consists of a commercially available personal computer running under a JAVA-based software development environment.

The BFNOS is a dedicated element for an experimental telemetry and command system (T&C system, see an article "4-3 Telemetry and command processing system for experiments" of this special issue.) and is connected via LAN to the T&C system through a TCP/IP network adapter. RAID-based network storage within the T&C system ensures the coordination of data between the BFNOS and the T&C system, incorporating the commands generated from within the BFNOS and the telemetry data transmitted from the satellite.

3 Main functions

Numerous parameters must be set to enable operation of the BFN1, including the phase and amplitude parameters required for beam formation, BFN1 error correction data, reflector data, and antenna coordinate data. The BFNOS manages these various types of data via personal computer, generates the necessary command streams, and transmits the commands through the T&C system. The BFNOS also displays the telemetry data for the BFN1 and the BFC, calculates array weight, and simulates beam patterns. In short, the BFNOS controls nearly all of the data required for operation of the phased array antennas of the ETS-VIII. However, BFNOS manages only a packet command. The power on/ off operations for the BFN1 and BFC are executed by the T&C system.

The BFNOS has five main functions as follows. The parameter input and settings of each function are input via a graphical user interface (GUI) for a simplification over traditional command-line input troublesome.

3.1 Command generation

This function involves the generation of commands required to transmit data to the satellite. Data to be transmitted include settings for the operation mode of the antenna feed system, various operational parameters, the array weight table, and the on-board software. Table 1 lists the various BFC commands.

In the MMIC used to set array weight—the main circuit component of the BFN1—there are numerous semiconductor switches to control phase and set amplitude. Accurate setup of the BFN1 requires advance recording, in the BFN error correction table, of phase and

Table 1 *List of BFC parameter setup commands*

ID	Sub ID		Size	contents
1	1～5	1～31	80	MMIC correction table
				Phase correction
				Gain correction
				Attenuation
2	1～2	0	248	SSPA(LNA) correction
				Phase-temperature gradient
				Gain-temperature gradient
3	0	0	62	MMIC for fixed weight
				Phase, Attenuation
4	1～5	0	248	Initial weight of MMIC
				Phase, Attenuation
5	1～5	0	248	Gain-temperature curve of BFN
				coefficient of temperature
6	1～5	0	248	Phase-temperature curve of BFN
				coefficient of temperature
7	1～2	0	336	Antenna parameters
				Focal length
				Defocus length
				coefficient of beam tilt(x)
				coefficient of beam tilt(y)
				coordinates of feed element(x)
				coordinates of feed element(y)
				coordinate conversion matrices
				(SAT. → reflector)
				(reflector → feeder)
				(attitude → SAT.)
8	1～5	0	8	Beam tilt angle
				Az、El
9	1～5	0	14～602	Program tracking parameters
				Number of beam scan replications
				Number of beam scan angle data
				step intervals
				Beam tilt angle (Az, El)
10	0	0	1	Beam operation start
				Beam N scan ON/ OFF
11	0	0	0	Forced termination of beam scan
12	0	0	8	REV parameters
				Phase rotation step (deg)
				Phase rotation time interval (multiples of control period)
13	1～5	1～31	0	REV start
14	0	0	0	Forced termination of REV
15	0	0	27	Operation control parameter
				Operation mode
				Temperature compensation for beam #i ENA/ DIS
				Attitude compensation for beam #i ENA/ DIS
				Temperature sensor #i ENA/ DIS
				Output port for Beams #i ENA/ DIS
16	0	0	310	MMIC control bit setting
				Phase shifter and attenuator statuses
17	0	0	MAX 724	Reprogramming
				Reservation
				Number of patches
				Address
				Number of data
				Data
				Check sum
18	0	0	1	Telemetry mode switching
				Telemetry mode
19	0	0	2	Telemetry request
				Telemetry ID
				Telemetry Sub ID
20	0	0	6	Memory dumping
				Address
				Data size
21	0	0	0	Reprogramming execution

amplitude errors attributable to these switches. This data must be transmitted prior to operation of the BFN1, with the initial transfer characteristics as the initial setting parameters. Thus, the command for each parameter setting is generated in advance using the GUI command generation and edit function and stored in the hard disk as a command file. Fig.1 shows a screen shot of the MMIC error correction table of an example command generation and edit screen. It is also possible to generate array weight setup commands for beam-pattern formation and to verify this pattern using the antenna beam simulation function described below.

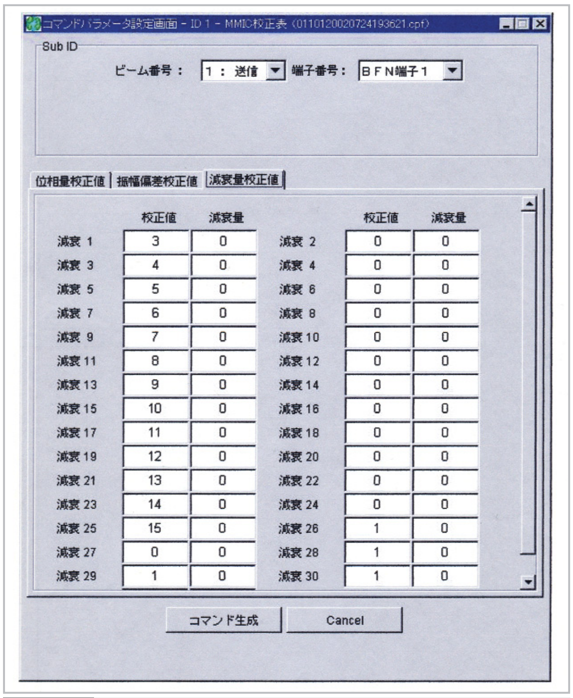

Fig.1 *MMIC error correction table setup screen*

Other command files are also created for other commands in addition to those for the MMIC settings. Fig.2 shows the antenna system coordinate setup screen.

3.2 Command transmission

The command transmitting function stores the generated command and antenna beam pattern information to the RAID disk of the T&C system, and transmits a command through the T&C system.

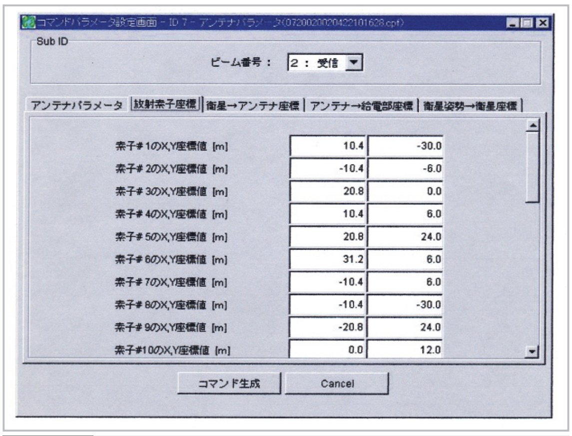

Fig.2 *Antenna-satellite system coordinate setup screen*

This function enables transmission of the command files described in the previous subsection, including those for the initial setting parameters and the MMIC setting parameters. It also allows for the transmission of commands for any array weight table setting generated using the beam forming function described in the next subsection. This function thus facilitates modification of array weight.

3.3 Antenna beam formation

The antenna beam formation function calculates the array weight of the antenna feed system using the set parameters (including satellite position, central coordinates of the antenna beam, and specifications of the feed system and the reflector) and generates the corresponding array weight table. When calculating array weight, the gain constraint points must be specified in order to secure the required service area and to provide isolation between adjacent beams. Specifying a given center of beam directivity on the map indicated in Fig.3 automatically sets 13 constraint points in accordance with the ETS-VIII mission specifications. Although operation is simplified in this manner, it is also possible to edit constraint point data using the edit screen shown in Fig.4. Further, this antenna beam formation function can generate the array weight for any given beam pattern. Fig.5 shows an example of the array weight table edit screen.

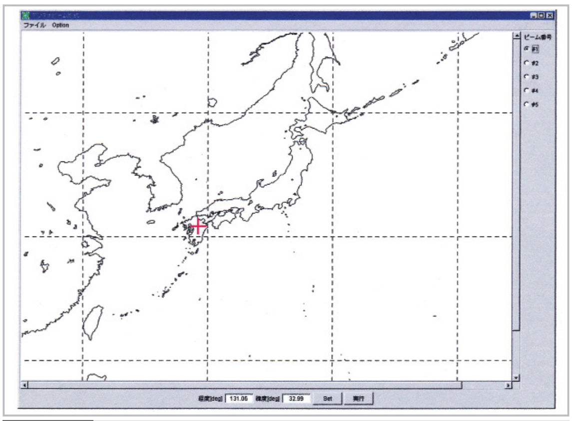

Fig.3 Beam center specification screen

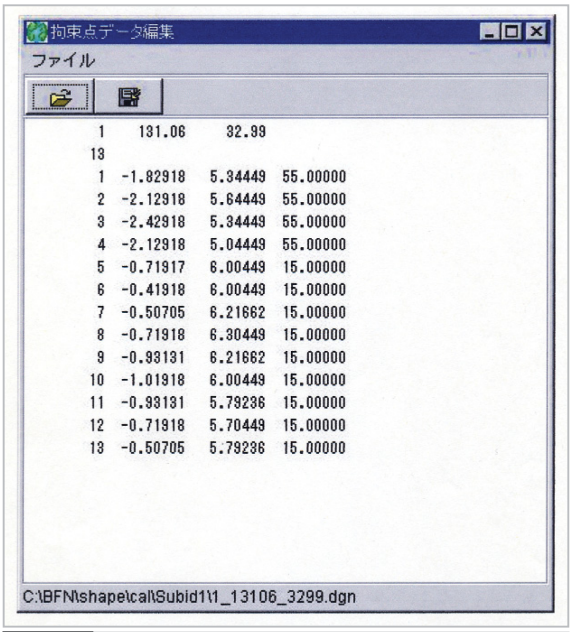

Fig.4 Gain constraint point edit screen

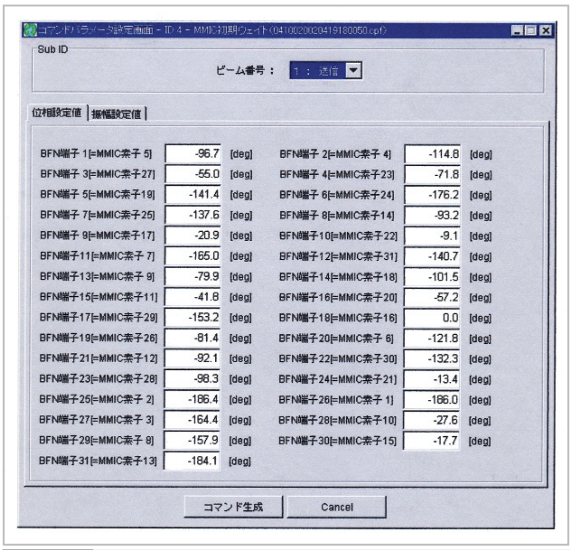

Fig.5 Example array weight table edit screen

3.4 Antenna beam simulation

The antenna beam pattern is simulated using the set parameters (including array weight and reflector specifications) and generates a contour map. Fig.6 shows an example of the displayed map. Using this function, the beam pattern constructed based on the array weight generated in the previous subsection can be verified on the map. As shown in Fig.7, two beam patterns can be displayed on the same screen, enabling evaluation of beam isolation and other characteristics.

The antenna beam pattern diagram displayed here can be transmitted to network storage within the T & C system and displayed similarly on a T & C system screen.

3.5 Telemetry display

The telemetry display function calls up data from the T&C system and provides BFC telemetry display. Table 2 provides a list of BFC telemetry data. Both the real-time process screen and the history display screen will display BFC setting status. The contents displayed based on this function are the same as the contents displayed using the telemetry display function within the T & C system.

4 Summary

A BFNOS has been established for the unified management of the parameters required for operation of phased array antennas. This BFNOS enables the efficient performance of transmission experiments using the large deployable antennas of the ETS-VIII, including the initial setup of the BFN1 and BFC elements, generation of array weight parameters, and antenna pattern simulations. At the time of writing of this article, satellite proto-flight test was underway, along with concurrent improvements to system software. By the time of initial satellite operation, the system will have undergone even further improvements to operability, including optimized parameter settings based on the results of final electrical performance tests.

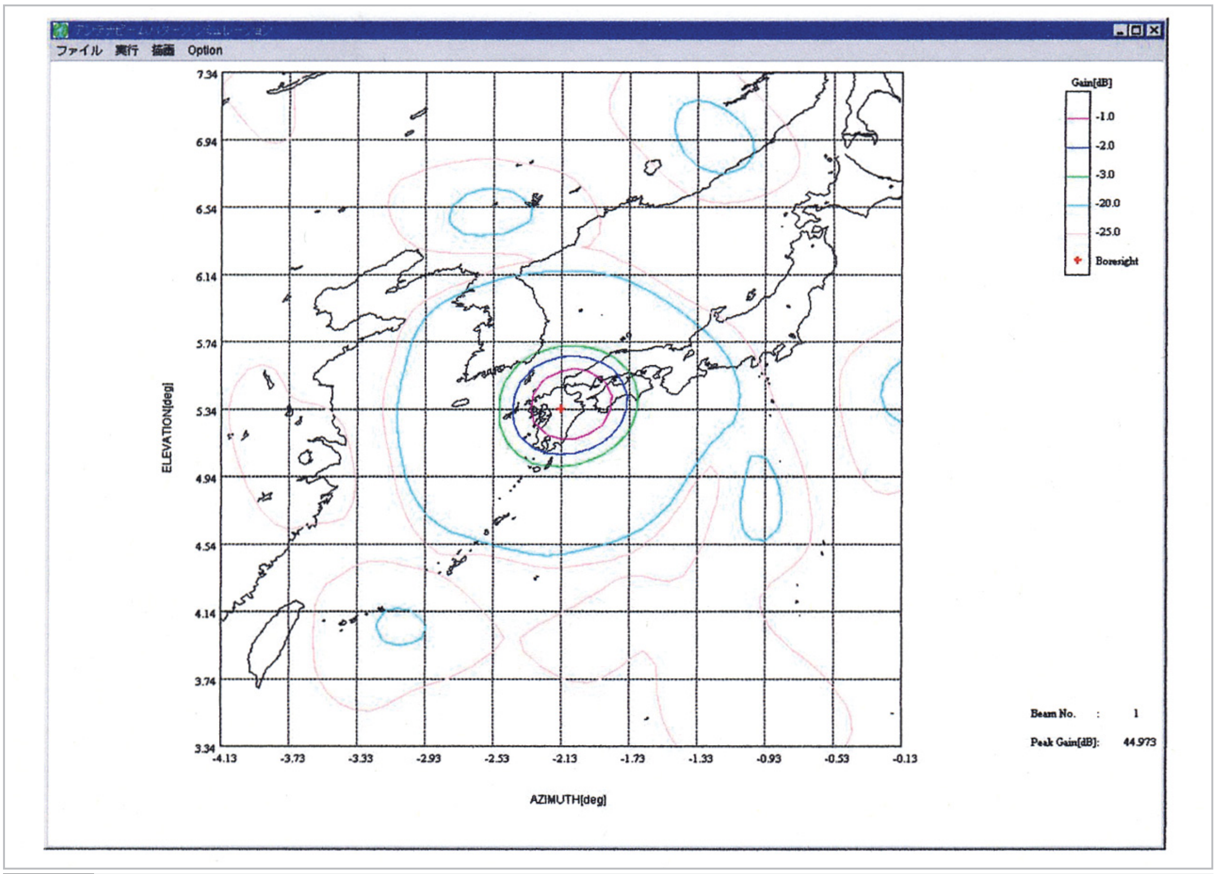

Fig.6 Example contour map

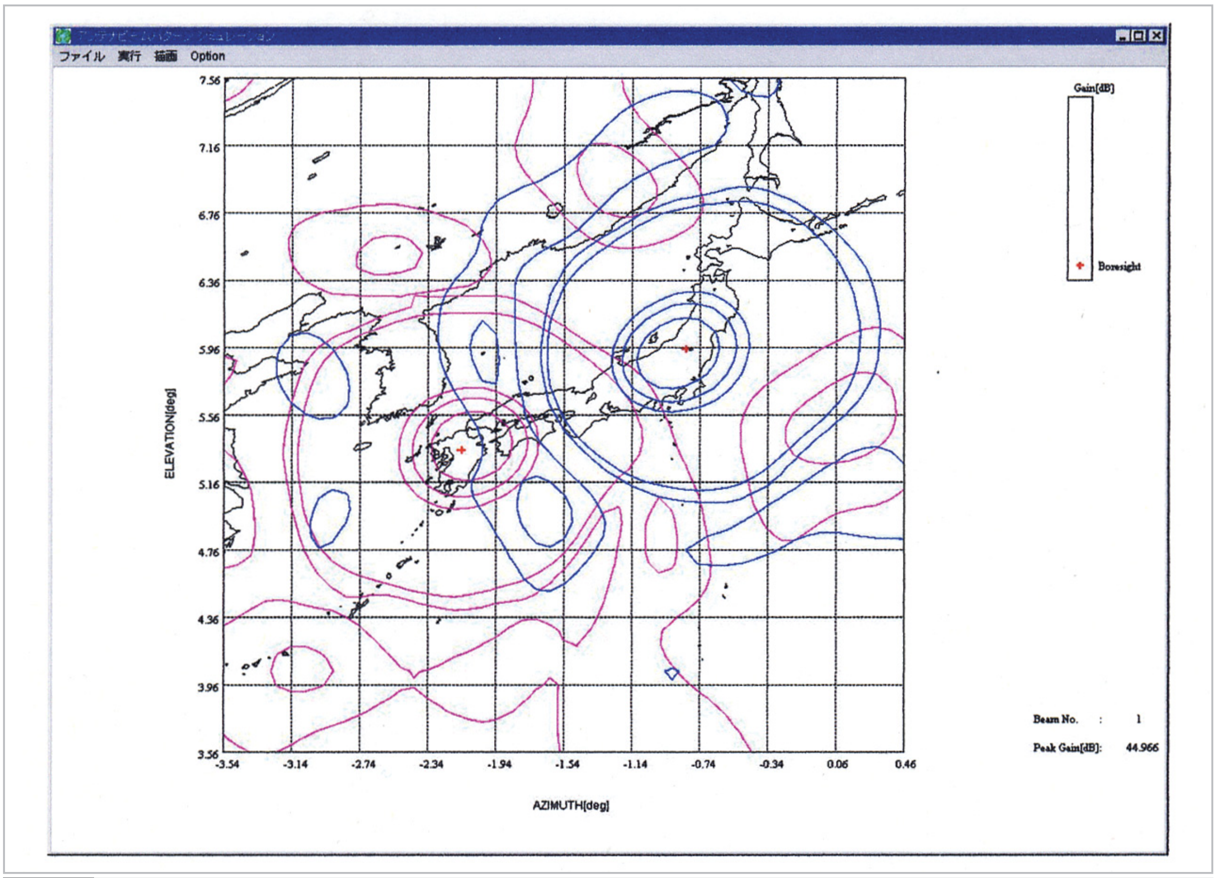

Fig.7 Example contour map with two beams

Table 2 *List of BFC telemetry data*

ID	Sub ID		Size	contents
1	1～5	1～31	80	MMIC correction table Phase, Gain, Attenuation correction
2	1～2	0	248	SSPA(LNA) correction Phase, Gain-temperature gradient
3	0	0	62	MMIC for fixed weight Phase, Attenuation status
4	1～5	0	248	Initial weight of MMIC Phase, Attenuation
5	1～5	0	248	Gain-temperature curve of BFN coefficient of temperature
6	1～5	0	248	Phase-temperature curve of BFN coefficient of temperature
7	1～2	0	336	Antenna parameters Focal length Defocus length coefficient of beam tilt coordinates of feed element coordinate conversion matrices (SAT. → reflector) (reflector → feeder) (attitude → SAT.)
8	1～5	0	8	Beam tilt angle Az、El
9	1～5	0	14 ～602	Program tracking parameters Number of beam scan replications Number of beam scan angle data step intervals Beam tilt angle (Az, El)
10	0	0	1	Beam operation start
11	0	0	0	Forced termination of beam scan
12	0	0	8	REV parameters Phase rotation step (deg) Phase rotation time interval (multiples of control period)
13	1～5	1～31	2	REV start
14	0	0	0	Forced termination of REV
15	0	0	27	Operation control parameter Operation mode Temperature compensation for beam #i ENA/ DIS Attitude compensation for beam #i ENA/ DIS Temperature sensor #i ENA/ DIS Output port for Beams #i ENA/ DIS
16	0	0	310	MMIC control bit setting Phase shifter and attenuator statuses
17	0	0	1	Reprogramming (storage) Reprogramming execution (status)
18	0	0	1	Telemetry mode switching Telemetry mode
19	0	0	2	Telemetry request
20	0	0	Max 977	Memory dumping Address Data size Data Check sum
21	0	0	1	Reprogramming execution (status)
255	0	0	46	Periodic telemetry (control period) Angle of beam pointing *Az and El scan angle for beams 1–5* REV status *Beam number* *Radiation element number* *Phase rotation*
254	0	0	137	Periodic telemetry (once every 50 control periods) Angle of beam pointing REV status Temperature sensor A/D value Operation control parameters *Operation mode* *Temperature compensation for* *beam #i ENA/ DIS* *Attitude compensation for* *beam #i ENA/ DIS* *Temperature sensor #i ENA/ DIS* Output port #i for Beams 1–5 ENA/ DIS

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Satellite Onboard Antenna and Remote Sensing Equipment