DEVELOPMENT OF 19-MULTIBEAM ARRAY ANTENNA FOR DATA RELAY SATELLITE

Tasuku TESHIROGI*, Wataru CHUJO*, Hideo KOMURO*
Akira AKAISHI** and Haruzo HIROSE**

* Satellite Communication Division, Radio Research Laboratories, Ministry of Posts and Telecommunications, Koganei, Tokyo, Japan

** Mitsubishi Electric Corporation, Kamakura Works, 325 Kamimachiya, Kamakura-shi, Kanagawa, Japan

1. Introduction

For future satellite communication, a multibeam antenna (MBA) is considered as an essential device in order to realize simplification of ground terminals.

Along the line of Japan's scenario of technology development for future mobile satellite and inter-satellite communications, RRL (Radio Research Laboratories) has carried out the development of a scanning single beam / fixed multibeam S-band array for multiple access link of an inter-satellite data relay system. For this antenna system, the following critical components are newly developed:

- New wideband microstrip subarrays of low profile and light weight.
- A simplified IF beam forming network which realizes precise beam forming characteristics.
- RF module, phase shifter and 10-W power amplifier.

2. Configuration of MBA

The specifications and performances of the multiple access link of the data relay system are shown in Table 1. The receiving system employs a MBA for multiple access, and fixed 19 beams arranged on triangular lattices cover the field of view of 20 degrees (altitude below 1000 Km). Cross-over levels between adjacent beams are from 2 to 2.5 dB. On the other hand, the transmitting system employs single beam phased array with time sharing.

A block diagram in Fig. 1 shows the configuration of data relay satellite system with multibeam array. Fig. 2 shows the developed multibeam antenna which is a ring array of 19 elements. 12 elements are shared for both transmission and reception, and remaining 7 elements are dedicated to receive.

Fig. 3 shows 3 dB receiving gain contours of 19 simultaneous beams of overall multibeam antenna.

3. Characteristics of Components

As a radiating element, a new wideband microstrip subarray of low profile and light weight has been developed. The element is composed of seven circular patches printed on a circular honey-comb-core substrate of 10 mm thickness and 288 mm in diameter as shown in Fig. 4.

A feature of this antenna is that each element has two small notches so as to cancel cross polarized component generated due to asymmetrical feed structure. Fig. 5 and Fig. 6 show the effect of the notches on improvement of gain and axial ratio respectively.

Fig. 7 shows developed intermediate frequency BFN of resistive matrix type and this BFN forms 19 beams at 70 MHz. A new design concept was adopted which enables the number of the nodes (coupling points) of the matrix to be reduced to about a quarter of that in a conventional BFN by utilizing the symmetry of element and beam-arrangements. Table 2 presents the summary of the results.

Furthermore, RF module, small sized 4-bit PIN diode phase shifter and 10-W solid-state power amplifier in S-band have been developed. Table 3 presents the summary of RF module.

4. Conclusions

Since 1980, RRL has continued research and development of a MBA of array type, and has been studying on future mobile satellite and inter-satellite communications systems. On the basis of these R&D, a breadboad model of the MBA has been manufactured and its evaluation test has been successfully carried out.

5. References

(1) T. Teshirogi, W. Chujo and K. Inamiya, "A multibeam antenna for satellite communications", IAF-82-61 (Paris, Sept., 1982).

(2) T. Teshirogi and N. Goto, "Recent phased array work in Japan", ESA phased-array workshop (Noordwijk, June, 1983).

(3) T. Teshirogi, W. Chujo, H. Komuro, A. Akaishi and H. Hirose, "Development of a Multibeam Array Antenna for Satellite Communications", 14th ISTS (Tokyo, 1984).

Frequency (GHz)	Forward 2.1039 - 2.1089 Return 2.285 - 2.290
Date bit rate (Return)	> 3 Kbps (eirp of user satellite 10 dBW)
Modulation	Spread Spectrum (unique PN code)
Bandwidth	5 MHz
Field of View	20 degrees (altitude below 1000 Km)
Satellite	
Receiving antenna (Return link)	Fixed multibeam array antenna
Number of beams	19 (independent beams)
Minimum gain	> 25.5 dB (by beam synthesis)
Polarization (Transmit and Receive)	LHCP
Transmit antenna	Phased array (single beam)
gain	> 23 dB
Transmit eirp	> 34 dBW

Table 1 System Performances of the Multibeam Array

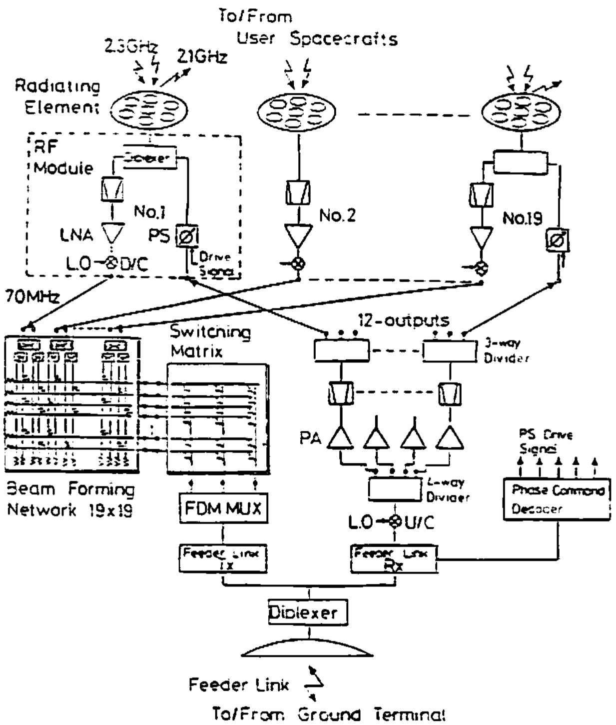

Fig. 1 System Configuration of Multiple-Access Link of Data Relay Satellite

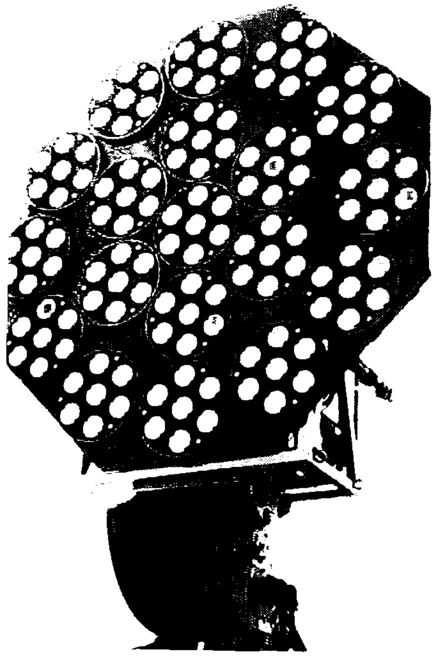

Fig. 2 19-Element Multibeam Array

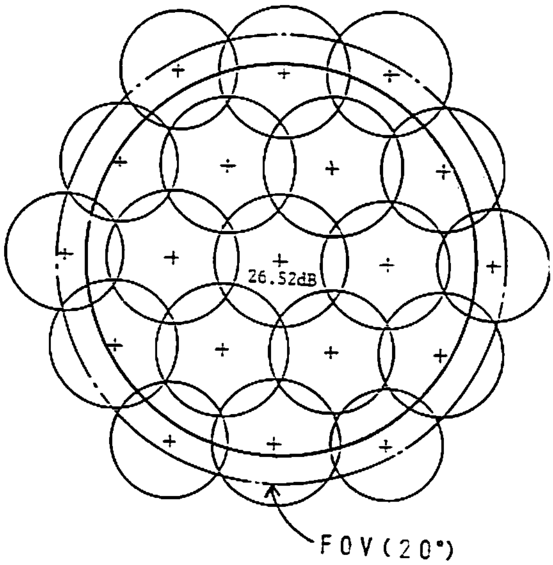

Fig. 3 Contours at -3dB Levels Relative to Peak Gain

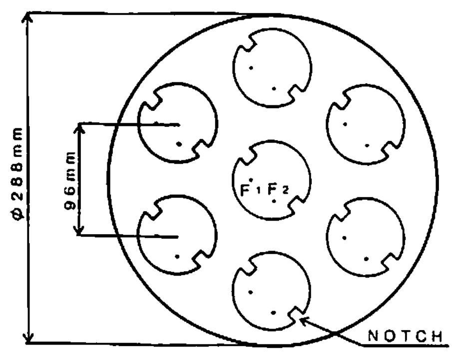

Fig. 4 Wideband Microstrip Subarray Composed of Notched Elements

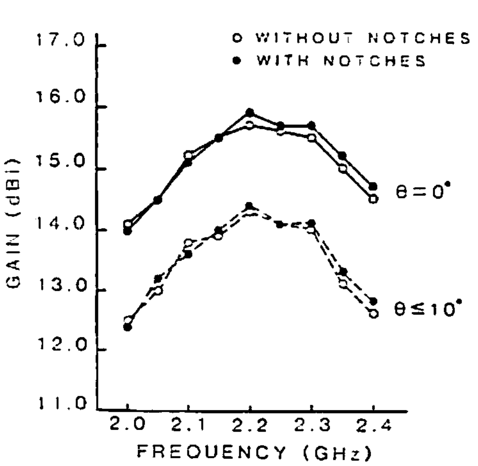

Fig. 5 Improvement of Gain

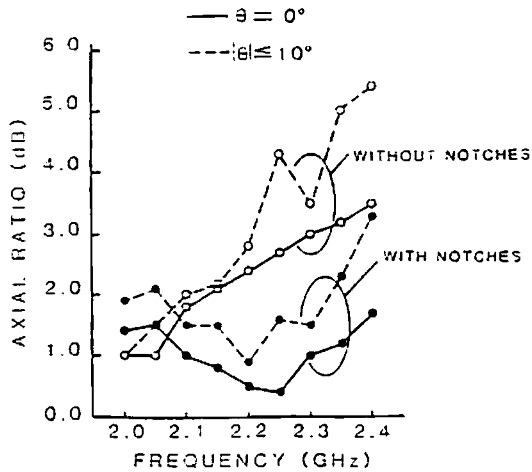

Fig. 6 Improvement of Axial Ratio

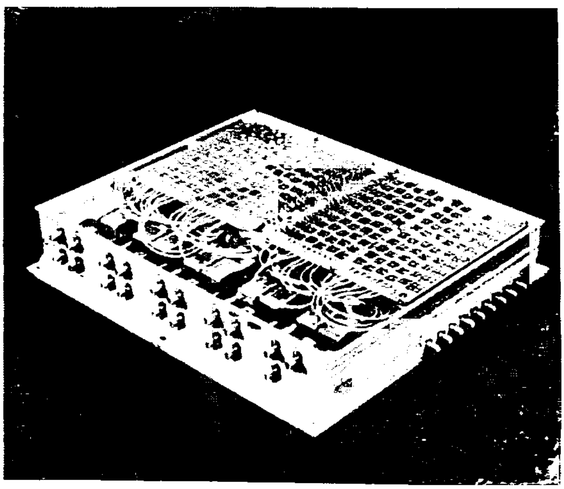

Fig. 7 The Developed Beam Forming Network

I/O Terminal	19 inputs x 19 outputs
Number of Coupling Resistors	166
Dimensions	319x275x57.5 (mm)
Weight	3350 g
Matrix Substrate	6-layer Glass-Epoxy (2 mm thickness)
Center Frequency	70 MHz
Phase Error Amplitude Error	σ = 4.1 (deg.) σ = 0.36 (dB)
VSWR (input) (output)	< 1.2 < 1.5
Bandwidth	20 MHz
Power Consumption	6.35 W

Table 2 Summary of Beam Forming Network

Receiving system		Power consumption	0.38 W
Input frequency	2.2875 GHz	Dimensions	
IF frequency	70 MHz	(Receive & Transmit)	240x77x95.7 mm
receiving gain	29.47 dB	(Receive only)	218x65x75.3 mm
gain deviation	+0.48 dB -0.26 dB	Weight	
gain flattness	0.32 max dB (5 MHz BW)	(R & T)	919.0 g
Transmitting system		(R only)	681.3 g
frequency	2.1064 GHz		
Insertion loss (Phase shifter & Diplexer)	2.68 max dB		
Phase shifter	4 bit PIN diode		

Table 3 Summary of RF Module