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DEVELOPMENT OF A MOBILE SATELLITE COMMUNICATION UNIT

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ABSTRACT

This paper describes a compact (210(W) x 280(H) x 330(D) mm) mobile terminal capable of transmitting voice and data through L-band mobile satellites. The Voice Codec can convert an analog voice to/from digital codes at rate of 9.6, 8 and 4.8 kb/s by an MPC algorithm.

The terminal functions with a single 12 V power supplied by a vehicle battery. The equipment can operate at any L-band frequency allocated for mobile uses in a full duplex mode and will be soon put into a field test via Japan's ETS-V satellite.

1. Introduction

The WARC Mobile 87 has opened a wide path for land mobile satellite communications using L-band frequencies. It is highly expected that satellite systems will take major roles for mobile communications because of their extremely wide coverages[1]. Field data on L-band radio propagation have been accumulated[2] making the mobile satellite services highly realistic. Developments projects for such equipments or systems are going on in various organizations[3,4,5,6,7].

2. Basic Design Philosophy

Demands for mobile satellite communications are versatile[6,7,8] and the transmission paths characteristics are often under frequent changes.

Considering above factors, the mobile satellite communication equipments must possess multi-functional capabilities. Such highly adaptive equipments can be most easily implemented by application of DSP (Digital Signal Processing) techniques[8].

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3. Basic Design Parameters

3.1 Link Budget and Basic Design

Table 3-1 shows link calculations for communications through Japan's ETS-V satellite[6] between the Base Earth Station (BES) located at KASHIMA and Mobile Earth Stations (MES) on board automobiles moving around central area of Japan. The calculation is made for the data rate of 9.6 KBPS and for two types of antennas, i.e. omnidirectional (4 dBi gain) and directional (12 dBi gain). The structure and front view of the mobile equipment is each shown in Fig. 3-1 and Photo 3-1.

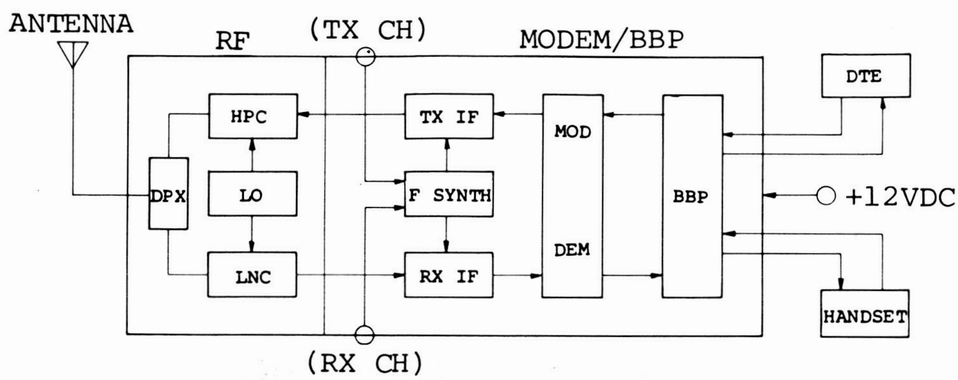


Fig. 3-1 Structure of the Mobile Equipment

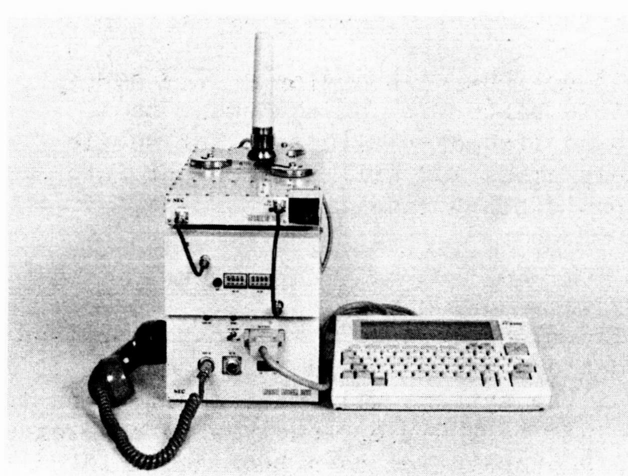


Photo 3-1 External View of the Mobile Equipment

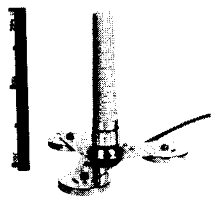
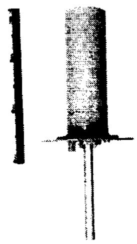
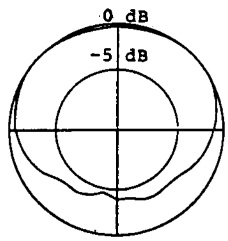
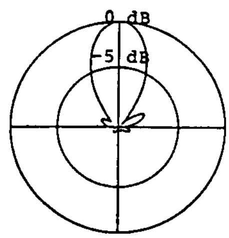
3.2 ANTENNA

Two types of antennas are provided for land mobile satellite communications. One is a 3 dBic omni-directional quadrifilar helix type antenna. It can be attached on the vehicle roof easily with magnets and operates without tracking function. Another is a 12 dBic helical antenna for portable communications. It can be mounted on a tri-pod and manually steered for the satellite easily.

Table 3-1 Link Budget

DATA RATE 9600 BPS			
Feeder link earth sttion		Kashima	Kashima
TX power	dBW	14.0	14.0
Feeder loss	dB	3.5	3.5
Antenna gain	dB	54.7	54.7
FES nominal EIRP	dBW	65.2	65.2
Path losses (Kashima-SAT)			
Frequency	GHz	5.96	5.96
FES elevation agnle	degree	47.0	47.0
Range	Km	37289.0	37289.0
Free space path loss	dB	199.4	199.4
Atmospheric absorption loss		dB	0.2
47.1	47.1		
Satellite RX			
Antenna gain (Kashima)	dBi	21.5	21.5
Feeder loss	dB	3.2	3.2
Satellite RX Power	dBW	-116.1	-116.1
System noise temperature	K	440.0	440.0
Satellite No.	dBW/Hz	-202.2	-202.2
Satellit G/T	dBK	-8.1	-8.1
Up-link C/No	dBHz	86.1	86.1
Satellite TX			
Transponder gain (+0dB mode)	dB	127.7	127.7
Satellite TX power	dBW	11.6	11.6
Total TX power (MAX 11.6 dBW)	dWB	11.6	11.6
Feeder loss	dB	3.9	3.9
Antenna gain	dBi	23.0	23.0
Satellite nominal EIRP	dBW	30.7	30.7
Path losses (SAT-Land mobile)			
Frequency	GHz	1.54	1.54
MES elevation angle	degree	47.1	47.1
Range	Km	37302.7	37302.7
Free space path loss	dB	187.6	187.6
Atmospheric absorption loss		dB	0.1
37289.0			
Mobile earth station		Car	Car
Radome loss	dB	0.0	0.0
Tracking loss	dB	0.0	0.0
Antenna gain	dBi	4.0	12.0
Feeder loss	dB	2.0	2.0
MES RX power	dBW	-155.0	-147.0
System noise temperature	K	478.6	478.6
MES No.	dBW/Hz	-201.8	-201.8
MES G/T	dBK	-24.8	-16.8
Down-link C/No.	dBHz	46.8	54.8
Satellite link C/No.	dBHz	46.8	54.8
Required C/No.	dBHz	42.0	42.0
Margin	dB	4.8	12.8

DATA RATE 9600 BPS			
Mobile earth station		Car	Car
MES nominal TX power	dBW	14.7	14.7
Feeder loss	dB	2.0	2.0
Antenna gain	dB	4.0	12.0
Tracking loss	dB	0.0	0.0
Radome loss	dB	0.0	0.0
MES nominal EIRP	dWB	16.7	24.7
Path losses (Land mobile-SAT)			
Frequency	GHz	1.64	1.64
0.2	MES elevation angle		degree
Range	Km	37302.7	30302.7
Free space path loss	dB	188.2	188.2
Atmospheric absorption loss	dB	0.1	0.1
Satellite RX			
Antenna gain	dBi	23.0	23.0
Feeder loss	dB	3.1	3.1
Satellite RX Power	dBW	-151.7	-143.7
System noise temperature	K	386.0	386.0
Satellite No.	dBW/Hz	-202.7	-202.7
Satellite G/T	dBK	-6.0	-6.0
Up-link C/No.	dBHz	51.1	59.1
Satellite TX			
Transponder gain (+5dB mode)	dB	132.7	132.7
Satellite TX power	dBW	-19.0	-11.0
Total TX power (MAX 8.5 dBW)	dBW	-19.0	-11.0
Feeder loss	dB	3.0	3.0
Antenna gain (Kashima)	dBi	19.9	19.9
Satellite nominal EIRP	dBW	-2.1	5.9
Path losses (SAT-Kashima)			
Frequency	GHz	5.23	5.23
FES elevation angle	degree	47.0	47.0
0.1	Range	Km	37289.0
Free space path loss	dB	198.2	198.2
Atmospheric absorption loss	dB	0.2	0.2
Feeder link earth station		Kashima	Kashima
Antenna gain	dBi	53.5	53.5
Feeder loss	dB	0.3	0.3
FES RX power	dBW	-147.3	-139.3
System noise temperature	K	113.0	113.0
FES No.	dBW/Hz	-208.1	-208.1
FES G/T	dBK	32.7	32.7
Down-link C/No.	dBHz	60.8	68.8
Satellite link C/No.	dBHz	50.6	58.6
Required C/No.	dBHz	42.0	42.0
Margin	dB	8.6	16.6

	Omni-directional	Directional
Outside View		
Gain	3 dBic	12 dBic
Polarization	LHCP	LHCP
Axial Ratio	Less than 2 dB	Less than 2 dB
Tracking	Unnecessary	Manual
Radiation Pattern (1625 MHz)		

3.3 RF Unit

Design concepts

i) Compactness
- The size 213.5(W) x 312(D) x 40(H) mm, and the weight 3kg.
- A heatsink with a fan keeps the temperature rise within 30°C in a continuous operation.
- Compact duplexer (108(W) x 12.5(D) x 20(H) mm) by dielectric resonator technique.

ii) High performance and flexibility for many experimental uses
- The high saturated transmit power and extended linearity achieved with power GaAs FETs (NE345L) usable for carriers of many modulation types.
- The low noise GaAs FET (25K569) for the preamplifier stage of the receiver improves the noise figure.
- Low phase noise synthesized local oscillators phase locked to a stable reference enable low rate communications.

Table 3.3 Major RF unit performance

HPC	
a) Input frequency	70 MHz band
b) Input level	0 dBm
c) Output frequency	1626 - 1661 MHz
d) Output power (at DUP output)	20W saturation
LNC	
a) Input frequency	1530 - 1559 MHz
b) Output frequency	70 MHz band

c) Gain — 80 dB nominal
d) Noise figure typical (at DUP input) — 2 dB at 25°C

DUP Loss transmit side 1.3 dB; receive side 1.4 dB
Power requirements — +12 - +15 V DC, 10A (when HPA on)

<u>High power converter</u>
The transmit BPFs including DUP attenuate more than 100 dB in the 1530 - 1551 MHz receive band to secure 60 dB D/U against local and negligible thermal noise leakages into receive amplifiers from HPC output. HPC output power linearity is shown in Figure 3-3-1.

<u>Low noise converter</u>
LNC gain and noise figure response is shown in Figure 3-3-2.

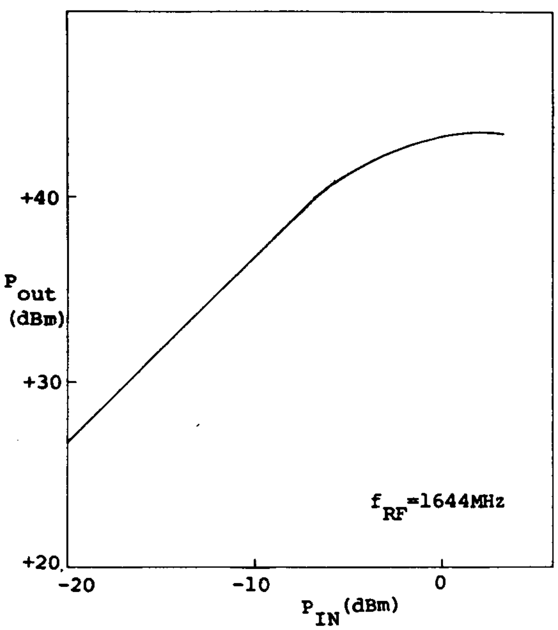


Fig. 3-3-1 HPC Output Power Linearity

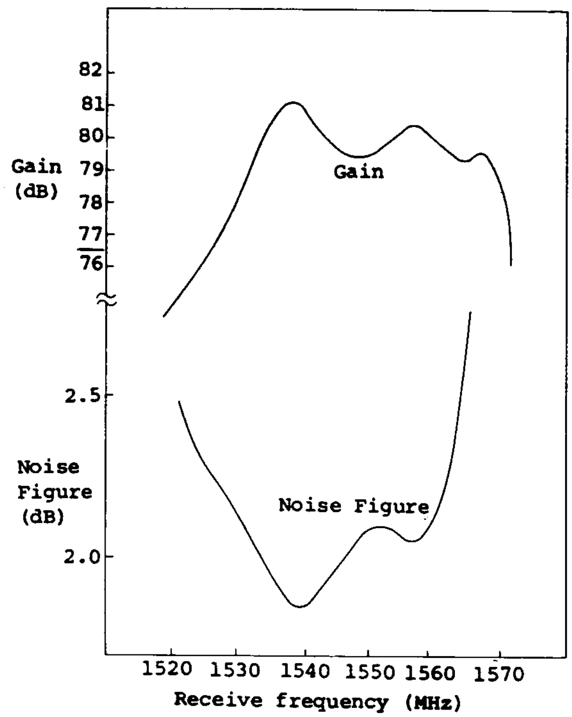


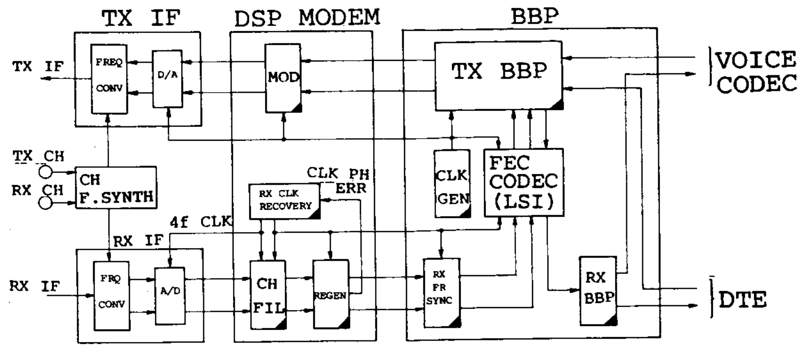
Fig. 3-3-2 LNC GAIN & NF Response

3.4 MODEM/BBP

Extensive uses of Digital Signal Processing (DSP) have realized a compact, rate variable MODEM/BBP as depicted in Fig. 3-4. The major design parameters are given in Table 3-4. For the demodulation of receive signals, a coherent detection was adopted because of its good BER performances in such poor C/N conditions as 5 dB E/No. A simple calculation shows that with the local phase noise specified for INMARSAT STANDARD-C system[7], a coherent detection still gives a better BER performance than differential detections in poor C/N conditions for data rates above 4800 BPS.

Table 3-4 MODEM/BBP Parameters

MOD	Modulation Type	QPSK
	Transmit clock Frequency (Hz)	9900 Hz for 9600 BPS DATA 8300 Hz for 8000 BPS DATA 5100 Hz for 4800 BPS DATA
	TX FILTER Type	Root NYQUIST
	TX IF FREQ (MHz)	70 + 15 (5 KHz step)
	TX IF Level	0 - -10 dBm/75
DEM	RX IF FREQ (MHz)	70 + 15 MHz (5 KHz step)
	RX IF Level	-50 dBm/Ch
	RX FILTER Type	Root NYQUIST
	Detection	Coherent Detection
BBP	Method of Word Synchronization	By Frame Synch.
	FEC	R=1/2 Convolutional Coding, Constraint Length; 4 bits, 3 bit soft decision, Viterbi Decoding, Coding Gain 3.5 dB at BER 10-4



Note; Symbol ◺ stands for a DSP (μPD77P20 by NEC)

Fig. 3-4 Structure of MODEM/BBP

3.5 VOICE CODEC

A 4.8 to 16 Kb/s high quality voice codec is implemented on NEC's single chip advanced floating point digital signal processor (ASP) UPD77230[9]. The codec is a multi-pulse exited linear predictive coder (MPELPC) based on a pulse search method which integrates the conventional cross correlation method [10] and the spectrum peak emphasis (SPE) method [11]. By adopting the SPE method, the segmental signal to noise ratio (SNR_{SEG})[12] has been improved by approximately 2.2 dB to 2.8 dB for bit rates below 7.2 Kb/s. The total coding delay is only 45 msec. This new codec can achieve speech coding at any rate between 16 and 4.8 Kb/s. Details of the codec specifications are shown in Table 3-5.

The codec is mounted on a single board as shown in Photo 3-5 and the structure illustrated in Fig. 3-5-1. The codec consists of a single ASP for digital signal processing, a single chip μ-LAW PCM codec for analogue interface, clock and timing circuits, and a digital line interface. The dimension of the board is 125 mm by 145 mm.

Fig. 3-5-2 shows the two SNR_{SEG} scores tested for eighteen short English sentences spoken by three American males and twelve short Japanese sentences spoken by two female and one male Japanese.

Table 3-5 Codec Specifications

NO	ITEM	SPECIFICATION
1	Sampling	8kHz (16K/9.6K/8K) 6.4kHz (7.2K/4.8K)
2	Quantization	8bits (255)
3	Frame Period	20 msec
4	LPC Analysis	Auto correlation method
5	LPC Order	12th (16K/9.6K/8K) 9th (7.2K/4.8K)

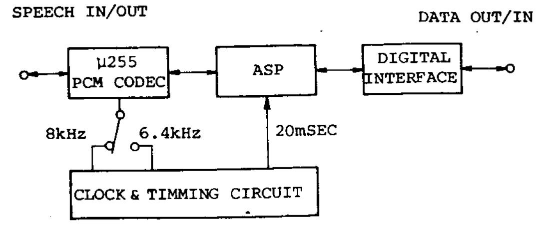
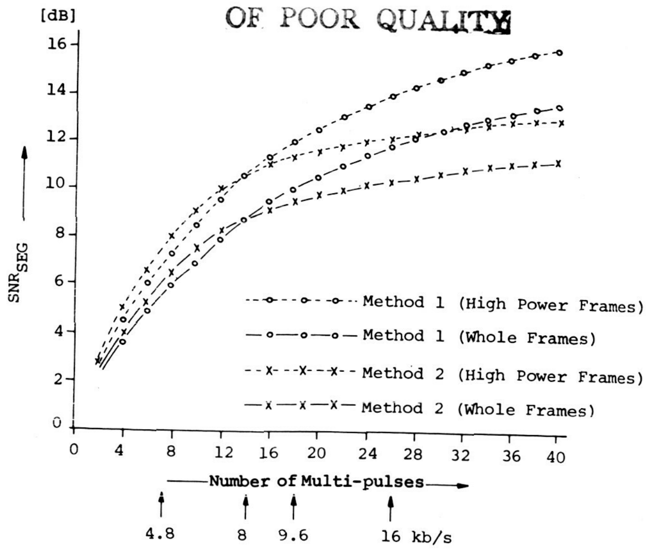


Fig. 3-5-1 The Block Diagram of Coder Hardware



Method 1: Crosscorrelation Method [22]

Method 2: SPE Method [23]

Fig. 3-5-2 Results of SNR_{SEG}

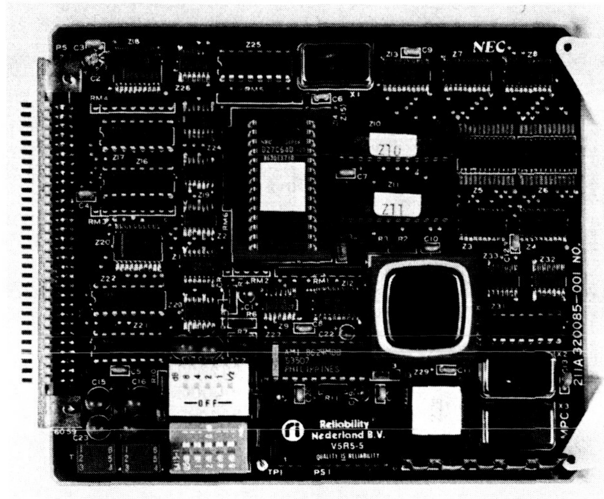


Photo 3-5 View of the New Codec Board

Conclusion

A compact multifunctional mobile terminal has been developed for field tests with Japan's ETS-V satellite.

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