Mark IV-A DSCC Telemetry System Description

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This article provides an update to the description of the Deep Space Communications Complex (DSCC) portion of the Mark IV-A Telemetry System. This system, first described a year ago in this document, is currently being designed as a replacement for the Mark III.

I. Introduction

The present DSN Telemetry System, the Mark III, is described in Ref. 1. The DSN is undertaking a major modification of the Mark III. The modified Network, described in Ref. 2, will be called the Mark IV-A and will be implemented between 1983 and 1985. The DSCC portion of the DSN Telemetry System will be changed in two major ways as a result of the Mark IV-A DSN implementation:

(1) Two 34-meter antennas will be added to each Deep Space Communications Complex (DSCC). The arraying of those antennas with the existing 64- and 34-meter antennas will provide the equivalent of two separate 64-meter antennas or two 64-meter antennas arrayed together. To accomplish this, the DSCC will be modified to provide baseband combining of three 34-meter antennas and one 64-meter antenna.

(2) The Telemetry System will be configured to support either two deep space missions and one highly elliptical orbiter or two highly elliptical orbiters and one deep space mission. Highly elliptical orbiter (HEO) missions will have data rates up to 202 ksps modulated directly on the carrier.

Implementation of these changes, when combined with the existing capabilities, will prepare the network to support both DSN and HEO missions.

The DSN missions will be the following:

Pioneers 6 through 9

Pioneers 10 and 11

Pioneer Venus

Viking

Voyager

Galileo

ISPM (ESA) (International Solar Polar (European Space Agency))

The Highly Elliptical Orbiter (HEO) missions will be the following:

ISEE-C (International Sun Earth Explorer)

AMPTE (Active Magnetospheric Particle Tracer Experiment)

– CCE (Charge Composition Explorer)

– IRM (Ion Release Module)

– UKS (United Kingdom Spacecraft)

TDRS (Tracking Data Relay Satellite)

GOES G, H, I (Geostationary Operational Environmental Satellite)

II. Key Characteristics

The key characteristics of the DSCC portion of the Mark IV-A Telemetry System are:

(1) *Data rates up to 500 kilosymbols per sec (ksps).*

(2) *Baseband combining for up to 7 antennas.*

(3) *Deletion of analog recording.*

(4) *Four complete groups of telemetry equipment at each complex*, each with the capacity to support one of the above missions.

(5) *Demodulation of Manchester coded (Biϕ-L)* or NRZ-L data modulated directly on the carrier.

(6) Maximum likelihood decoding of short-constraint-length convolutional codes and sequential decoding of long-constraint-length convolutional codes.

(7) Precise measurement of received signal level and system noise temperature.

(8) Centralized control by (and real-time reporting to) the Monitor and Control Subsystem.

(9) Production of a digital telemetry Original Data Record (ODR) at each telemetry group with playback via local manual control or in automatic response to GCF inputs; reduced playback rate for higher data rates as required.

The characteristics that reflect new or modified capabilities due to Mark IV-A design requirements are italicized. The handling of increased data rates and demodulation of NRZ or biphase data modulated directly on the carrier directly responds to a requirement for telemetry support of HEO spacecraft. Baseband combining provides for improved sensitivity to high data rate X-band signals in support of deep space telemetry and is driven by the Voyager project requirement for support of 19.2 kbps at Uranus encounter. New equipment for baseband combining allows a data rate increase to 500 ksps from the previous high of 250 ksps. The provision for four groups of telemetry equipment at each SPC responds to the requirement to provide telemetry support to three projects concurrently. The absence of project requirements for analog recording allows that function to be removed. Characteristics which are not italicized exist presently in the Mark III and are discussed in Ref. 1.

III. Project Data Rate and Coding Requirements

HEO missions are compatible with the existing DSN capabilities. This is illustrated in Table 1, which defines the single link data handling requirements for the HEO projects included in the Mark IV-A mission set. A telemetry single link can be defined as all of the functional elements, from the antenna(s) through an SPC telemetry group, that have been selected for support of a project. The requirement to detect Biϕ-L (Manchester coding) modulated directly on the carrier is not supportable by existing DSN capabilities.

Requirements for new and existing deep space missions are listed in Table 2. The new missions to be supported during Mark IV-A are Galileo and ISPM-ESA. The next section shows how HEO and deep space mission requirements will be met.

IV. DSCC Conceptual Description

The DSCC block diagram in Fig. 1 provides a conceptual description of the portion of the Mark IV-A Telemetry System to be located at the DSCC. At each complex there will be one 64-meter antenna, three 34-meter antennas, and a 9-meter antenna. The 64-meter and 34-meter transmit/receive antennas will be able to receive an S-band plus an X-band carrier simultaneously. One of the 34-meter Listen-Only antennas will receive either one S-band or one X-band carrier; the other will receive one X-band carrier. The 9-meter will receive 2 S-band carriers. Table 3 gives the RF reception characteristics for these antennas and indicates the distribution of masers, FETs and Paramps. The 64-meter antennas will be equipped exclusively with masers whereas the 34-meter antennas will also have FETs. At the 34s the masers will provide deep space support and the S-band FETs will support HEOs with their broader (2200-2300 Mhz) reception bandwidth requirements. The 9-meter antennas will be provided exclusively with Paramps. New Block II-A X-band masers will be provided, giving lower X-band system temperatures than in the Mark III DSN. Also, the new 34-meter antennas will provide increased gain compared with the existing 34-meter transmit-receive antennas.

Existing Block III and Block IV receivers will be used to receive the baseband signals. They will be modified to support HEO frequencies and provide a broad (~8 MHz) baseband output to the Telemetry Subsystem. The Telemetry Subsystem is arranged to provide four telemetry groups, any of

which can process data from either an HEO or deep space spacecraft. All groups will include the Mark III Maximum Likelihood Convolutional Decoder (MCD) and Telemetry Processor Assembly (TPA). Telemetry Groups 1 and 2 will also be equipped with a new Baseband Assembly (BBA) which will include the functions of baseband combining, subcarrier demodulation and symbol synchronization. Figure 2 is a functional block diagram of the BBA. Any combined set of receiver outputs can be input to either subcarrier demodulator; or any single receiver output can be routed to either subcarrier demodulator, bypassing the combining function. The monitor and control function will be performed from the TPA with no manual intervention required. The BBA will be designed to accommodate NRZ-L, M or Biϕ-L symbol formats, subcarriers up to 2 MHz and data rates from 4 s/s to 1 Ms/s without subcarrier or up to 4 Ms/s (NRZ) with subcarrier. Operation with the BBA, including combining the 64-m and all three 34-m antenna basebands, will result in a nominal system degradation at the highest data rates of about 0.3 dB. This includes an allowance for waveform, spectrum correlation and symbol timing losses and represents an improvement over the Mark III system of several tenths of a dB. Telemetry Groups 3 and 4 will include Mark III Subcarrier Demodulator Assemblies (SDA) and Symbol Synchronizer Assemblies (SSA) as well as an MCD and TPA. Therefore, hardware in Group 3 and Group 4 will closely resemble the Mark III Telemetry Subsystem. The SDAs will be modified to decode Biϕ-L (Manchester coded) data so that Groups 3 and 4 can support HEO missions without using Spaceflight Tracking and Data Network (STDN) bit synchronizers as proposed in Ref. 3. New software will be provided for the TPAs.

The 64- and 34-meter antennas can be arrayed by combining baseband signals and performing subcarrier demodulation and symbol synchronization in the BBA in either Telemetry Group 1 or Telemetry Group 2. The combined signal is then decoded in the Maximum Likelihood Convolutional Decoder and formatted for transmission to JPL in the Telemetry Processor Assembly. When combining is not required, outputs from an antenna may also be routed to a Subcarrier Demodulator Assembly (Groups 3 and 4) or to either Baseband Assemblies (Groups 1 and 2).

Any of the telemetry equipment groups can accept two data streams. In any group, one data stream is processed by Channel 1 and one by Channel 2. The performance parameters for Channels 1 and 2 are listed in Tables 4 and Table 5, respectively. Comparing Table 1 with Tables 4 and 5, it may be noted that Data Stream 1 in Table 1 is processed by Channel 2, while Data Stream 2 is processed in Channel 2. Also note that Groups 1 and 2 provide higher data rate capability (500 ks/s vs 250 ks/s and higher subcarrier frequency capability (2 MHz vs 1.2 MHz). This improvement is due to the BBA and wider receiver passband. However, the overall system will not support the highest BBA/receiver data rate capability until further improvements are made, including MCD replacement and provision for high rate recording and quick look. Future planned missions will require these additional improvements.

References

1. Gatz, E. C., "DSN Telemetry System Mark III-77," in *DSN Progress Report 42-49*, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1979.
2. Gatz, E. C., "Networks Consolidation Program System Design," in *TDA Progress Report 42-63, March and April 1981*, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1981.
3. Burt, R. W., "Mark IV-A DSCC Telemetry System Description," in *TDA Progress Report, 42-63, March and April 1981*, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1981.

Table 1. Single link requirements for HEO missions

Mission	Data Stream 1	Data Stream 2
I SEE-C	Convolutionally coded; K=24, R=1/2; NRZ-L; 64 b/s; Subcarrier: 1024 Hz or Convolutionally coded; K=24, R=1/2; 512 to 2048 b/s: Biφ-L	
AMPTE-CCE	Convolutionally coded; K=7, R=1/2; Biφ-L 101,000 b/s	Uncoded NRZ-L; 3300 b/s; subcarrier: 404 kHz
AMPTE-IRM	Convolutionally coded; K=7, R=1/2; NRZ-L; 1.024 kb/s, 2.048 kb/s, 4.096 kb/s, or 8.192 kb/s; subcarrier: 131,072 Hz	
AMPTE-UKS	Convolutionally coded; K=7, R=1/2, or uncoded; Biφ-L; 1024 b/s, 2048 b/s, 4096 b/s, 8192 b/s, 16384 b/s, 32768 b/s	
TDRS		Uncoded; 250 b/s, 1000 b/s, 4000 b/s, NRZ; subcarrier: 1.024 MHz
GOES-G,H,I		Uncoded; 2000 b/s, Biφ-L

Table 2. Single link requirements for deep space missions

Mission	Data Stream 1	Data Stream 2
Pioneers 6-9	Uncoded; NRZ-M; 8 to 512 b/s; subcarrier: 512 Hz for 8 to 64 b/s, 2048 Hz for ⩾128 b/s; S-band	
Pioneers 10/11	Uncoded; NRZ-L; 8 to 2048 b/s; subcarrier: 32 kHz; S-band or Convolutionally coded; K=32, R=1/2, NRZ-L; 8 to 2048 b/s; subcarrier: 32 kHz; S-band	
Pioneer Venus	Uncoded; NRZ-L; 8 to 4096 b/s; subcarrier: 16 kHz; S-band or Convolutionally coded; K=32, R=1/2; NRZ-L; 8 to 2048 b/s; subcarrier: 16 kHz; S-band	
Voyager	Convolutionally coded; K=7, R=1/2; NRZ-L; 10 to 115,000 b/s; combined X-band; subcarrier: 360 kHz	Uncoded; NRZ-L; 40 b/s; subcarrier: 360 kHz; combined X-band or Uncoded; NRZ-L; 40 b/s; subcarrier: 22.5 kHz; S-band
Galileo	Convolutionally coded; K=7, R-1/2; NRZ-L; up to 134.4 kb/s; subcarrier: 360 kHz; combined X-band or Convolutionally coded; K=7, R=1/2; NRZ-L; up to 40 kb/s; subcarrier: 22.5 kHz for data rates up to 7.68 kb/s, 360 kHz for rates ⩾7.68 kb/s; S-band	Uncoded; NRZ-L; 40 b/s; subcarrier: 22.5 kHz; S-band
ISPM-ESA	Convolutionally coded; NRZ-L; K=7, R=1/2; 128 b/s–8,192 b/s; subcarrier: 65,536 Hz for rates up to 1,024 b/s, 131,072 Hz for rates of 2,048 b/s or greater; X-band	
Viking	Block coded; NRZ-L; 250 b/s to 1 kb/s; subcarrier: 228 kHz; S-band	Uncoded; NRZ-L; 8-1/3 or 33-1/3 b/s; subcarrier: 48 kHz; S-band

Table 3. RF reception characteristics

Parameter	Antenna			
	64-meter	34-meter Transmit/ Receive	9-meter	34-meter Listen-Only
Frequency range, MHz				
S-band	2270-2300	2200-2300	2200-2300	2200-2300[a]
X-band	8400-8440	8400-8440		8400-8435
Gain, dBi				
S-band	$61.7^{+0.3}_{-0.4}$	$56.1^{+0.3}_{-0.7}$	$43.8^{+0.4}_{-0.8}$	$55.8^{+0.0}_{-0.5}$
X-band	$72.1^{+0.6}_{-0.6}$	$66.5^{+0.3}_{-0.9}$		$67.3^{+0.5}_{-0.8}$
System noise temp, K zenith				
S-band with maser				
Diplex	18.5 ±3	27.5 ±2.5		
Listen-Only	14.5 ±3	21.5 ±2.5		
S-band with paramp[b]				
Prime			125 ±25	
S-band with FET				
Diplex		130 ±10		
Listen-Only				115 ±10[a]
X-band with maser	20 ±3	21.5 ±3		18.5 ±2

[a]One 34-m Listen-Only antenna per complex has this capability. Others are 2290-2300, X-band only.
[b]Diplexed operation.

Table 4. DSCC Telemetry Subsystem channel capabilities (Telemetry Groups 1 and 2)

Functions	Channel 1	Channel 2
Baseband combining	Up to six receivers	N/A
Subcarrier demodulation	Approximately 10 kHz to 2 MHz, squarewave or sine wave	Approximately 10 kHz to 2 MHz squarewave or sine wave
Sequential decoding	K=24, 32; R=1/2; frame length= variable 6 s/s to 10 ks/s	N/A
Maximum-likelihood	K=7; R=1/2 or 1/3	N/A
Convolutional decoding	10 b/s to 250 kb/s	N/A
Block decoding	Reed-Muller 32/6; up to 2 kb/s	N/A
Symbol rate	4 s/s – 500 ks/s[a]	4 s/s to 500 ks/s[a]
Uncoded rate	4 b/s – 600 kb/s[a]	4 b/s to 500 kb/s[a]
Data format	NRZ-L, M, Biϕ-L	NRZ-L, Biϕ-L

[a]Record with non-real-time playback from 250 to 500 ks/s.

Table 5. DSCC Telemetry Subsystem channel capabilities (Telemetry Groups 3 and 4)

Functions	Channel 1	Channel 2
Subcarrier demodulation	100 Hz to 1.00 MHz squarewave or sine wave	100 Hz to 1.00 MHz, squarewave or sine wave
Baseband combining	N/A	N/A
Sequential decoding	K=24, 32; R=1/2; frame length: variable, 6 s/s to 10 ks/s	N/A
Maximum-likelihood	K=7, R=1/2 or 1/3	N/A
Convolutional decoding	Reed-Muller 32/6, up to 2 kb/s	N/A
Symbol rate	6 s/s to 250 ks/s	6 s/s to 250 ks/s
Uncoded rate	6 b/s to 250 kb/s	6 b/s to 250 kb/s
Data format	NRZ-L, NRZ-M, Biϕ-L	NRZ-L, NRZ-M, Biϕ-L

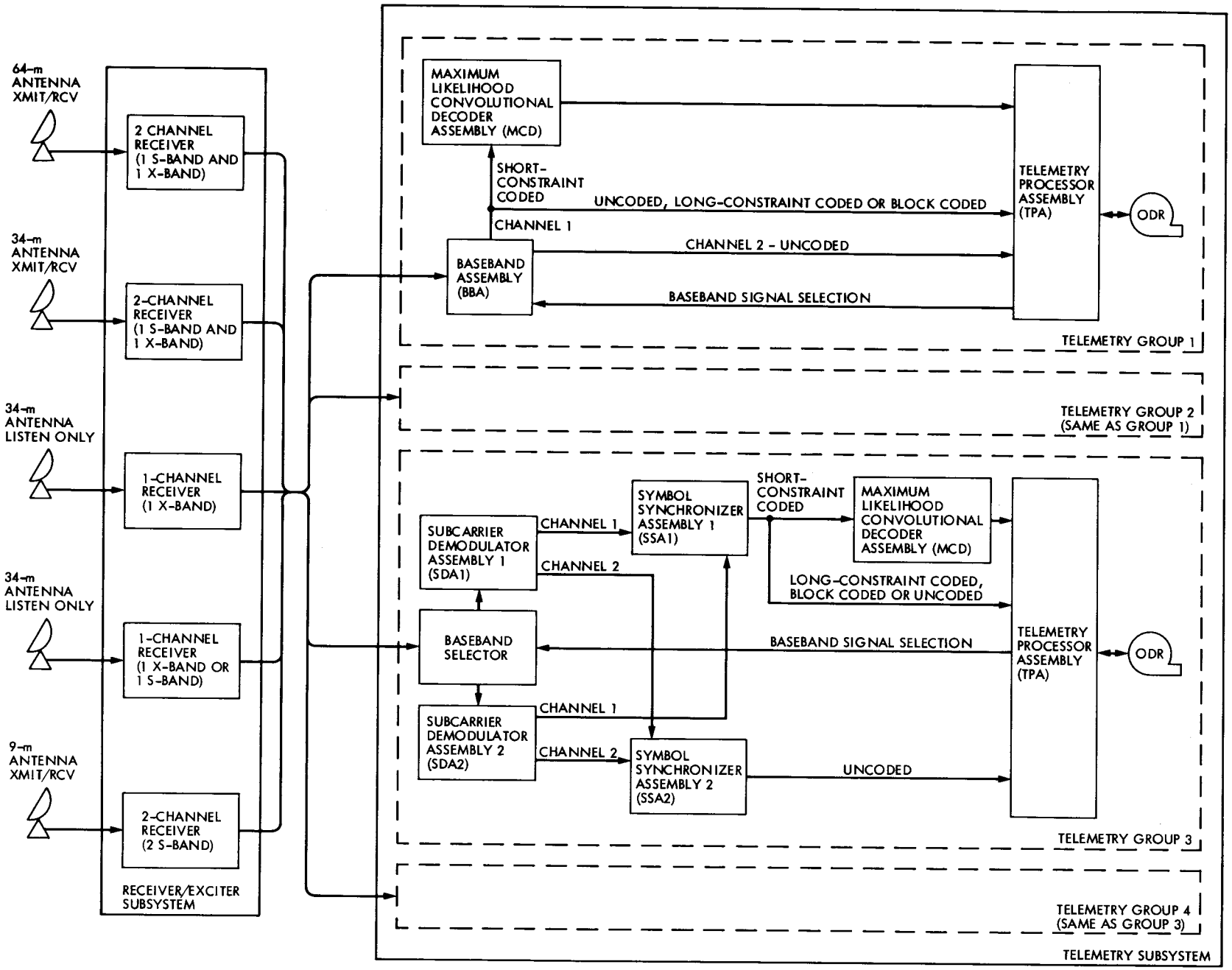

Fig. 1. Telemetry System: DSCC block diagram

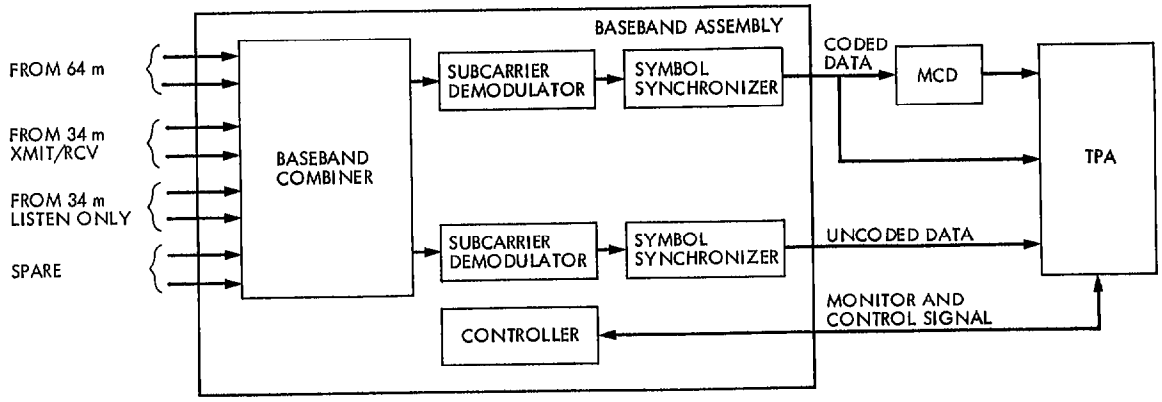

Fig. 2. Baseband Assembly functional block diagram