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 MK IV-A Telemetry System. This system is currently being implemented at all signal processing centers. The Mark III Telemetry System is the predecessor of the Mark IV-A System.

I. Introduction

Implementation of the DSN MK IV-A Telemetry System (Ref. 1) has been proceeding for the past two years and is nearly complete at all signal processing centers. The Deep Space Communications Complex (DSCC) portion of the DSN Telemetry System has been changed in two major ways as a result of the Mark IV-A DSN implementation. The Mark III Telemetry System is the predecessor of the Mark IV-A System and is described in Ref. 2.

(1) One 34-meter antenna has been added to each DSCC at Goldstone and Canberra. A 34-meter antenna will also be added at the Madrid Complex in June 1987. The arraying of this additional antenna with the existing 64- and 34-meter antennas at X-band will provide a relative gain of 1.84 dB (assuming a 0.2 dB array loss) as compared to a single 64-meter antenna, or a relative gain of 1.07 dB as compared to the arraying of the existing 64- and 34-meter antennas. To accomplish this, equipment has been added to provide baseband combining of signals from the three antennas.

(2) The telemetry system has been configured to support three missions simultaneously, with one or two of them being highly elliptical earth orbiters. Highly ellipitical orbiter (HEO) missions will have coded data at rates up to 211.2 ksps, manchester coded, modulated directly on the carrier.

Implementation of these changes, combined with previous capabilities, has prepared the network to support Deep Space and HEO missions.

The Deep Space missions are the following:

- Pioneers 6 through 9
- Pioneers 10 and 11
- Pioneer Venus
- Voyager
- Galileo
- Ulysses
- Giotto

The HEO missions are the following:

ICE (International Cometary Explorer)

AMPTE (Active Magnetospheric Particle Tracer Experiment)

- CCE (charge composition Explorer)

IRM (Ion Release Module)

UKS (United Kingdom Spacecraft)

II. Key Characteristics

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

(1) Coded data at rates up to 250 kilobits per second (kbps).

(2) Baseband combining for up to 7 antennas.

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

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

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

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

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

(8) Production of 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 handling of increased data rates and demodulation of NRZ or biphase data modulated directly on the carrier 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 29.9 kbps at Uranus encounter. The ICE mission also requires three-input baseband combining; two signals from the 64-m antenna (one right circularly polarized, one left) and one from the standard 34-m antenna. This will enable the data rate to be maintained at 1024 bps during encounter with the Giacobini-Zinner comet. New equipment for baseband combining allows a data rate increase to 250 kbps from the previous peak of 135 kbps. The provision for four groups of telemetry equipment at each SPC responds to the requirement to provide telemetry support to three projects concurrently.

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 Biphase (Manchester coding) modulation directly on the carrier was met during the Mark IV-A implementation.

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, Ulysses and Giotto. 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 and two 34-meter antennas (with the exception of the second Madrid 34-m antenna as noted earlier). The 64-meter and 34-meter standard antennas will be able to receive an S-band plus an X-band carrier simultaneously. The 34-meter High-Efficiency antennas will receive one X-band carrier; they are not useful for receiving S-band telemetry carriers for deep space missions because of high system noise temperature (115 K). Table 3 gives the RF reception characteristics for these antennas and indicates the distribution of masers and FETs. The 64-meter antennas will be equipped exclusively with masers whereas the 34-meter antennas will also have FETs. At the 34-meter antennas the masers will provide deep space support, and the S-band FETs will support HEOs with their broader (2200-2300 MHz) reception bandwidth requirements. New Block II-A X-band masers have been provided for the 64-m antennas at Goldstone and Canberra, giving lower X-band system temperatures than in the Mark III DSN. Also, the new 34-meter high-efficiency antennas will provide increased X-band gain compared with the existing 34-meter standard antennas.

Existing Block III and Block IV receivers will be used to receive and detect baseband signals. The Block III receivers were modified to support HEO frequencies and provide a broad (4 MHz) baseband output to the Telemetry Subsystem. The Telemetry Subsystem is arranged to provide four telemetry groups, any of which can process data from any receiver and therefore 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). The MCDs were modified to change the node synchronization algorithm to achieve better performance at low signal-to-noise ratio for Voyager Uranus encounter. Telemetry Groups 3 and 4 are 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 combination 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 is performed from the TPA with no manual intervention required. The BBA is designed to accommodate NRZ-L, NRZ-M or Biϕ-L symbol formats, subcarriers up to 2 MHz and data rates from 4 s/s to 1 Ms/s with subcarrier, up to 4 Ms/s (NRZ) without subcarrier or up to 2 Ms/s for Biϕ-L. Operation with the BBA, including combining the 64-m and two 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 1 and 2 include modified Mark III Subcarrier Demodulator Assemblies (SDA) and Symbol Synchronizer Assemblies (SSA) as well as an MCD and TPA. Therefore, hardware in Group 1 and Group 2 closely resembles the Mark III Telemetry Subsystem. The SSAs were modified to decode Biϕ-L (Manchester coded) data so that Groups 1 and 2 can support HEO missions without using Spaceflight Tracking and Data Network (STDN) bit synchronizers as proposed in Ref. 3. New software was 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 3 or Telemetry Group 4. 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 1 and 2) or to either Baseband Assemblies (Groups 3 and 4).

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 5, respectively. When comparing Table 1 with Tables 4 and 5, note that Data Stream 1 in Table 1 is processed by Channel 1, while Data Stream 2 is processed in Channel 2. Also note that Groups 3 and 4 provide higher data rate capability (for example, for convolutionally coded data: 250 kb/s vs 135 kb/s) and higher subcarrier frequency capability (2 MHz vs 1 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 a wider bandwidth in the receivers, MCD replacement, provision for high rate recording, and quick look. Future planned missions will require these additional improvements, as well as adding a Reed-Solomon Decoder.

References

1. Burt, R. W., "Mark IV-A DSCC Telemetry System Description," in *TDA Progress Report 42-68*, January and February 1982, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1982, pp. 130-138.

2. Gatz, E. C., "DSN Telemetry System Mark III-77," in *DSN Progress Report 42-49*, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1979, pp. 4-9.

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, pp. 3-7.

Table 1. Single link requirements for HEO missions

Mission	Data Stream 1	Data Stream 2
ICE	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 105,600 b/s	Uncoded NRZ-L; 3300 b/s; subcarrier: 429 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	

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: 32.768 kHz; S-band or Convolutionally coded; K=32, R=1/2, NRZ-L; 8 to 2048 b/s; subcarrier; 32.768 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; 46.667 b/s; subcarrier: 360 kHz; combined X-band or Uncoded; NRZ-L; 46.667 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
Ulysses	Convolutionally coded; NRZ-L; K=7, R=1/2; 128 b/s to 8,192 b/s; subcarrier: 65,536 Hz for rates up to 1024 b/s, 131,072 Hz for rates of 2,048 b/s or greater; X-band	
Giotto*	Convolutionally coded; NRZ-L; K=7, R=1/2; Subcarrier: 46.080 kHz for data rate of 360 b/s, 276.480 kHz for data rates of 5,760 b/s, 23,040 b/s and 46,080 b/s; S- or X-band or Reed-Solomon and convolutionally coded; NRZ-L; K=7, R=1/2; Subcarrier: 276.480 kHz for data rates of 5,760 b/s, 23,040 b/s, and 46,080 b/s; S- or X-band	Uncoded; NRZ-L; Subcarrier: 46.080 kHz for data rate of 360 b/s; S- or X-band or Reed-Solomon coded; NRZ-L; Subcarrier: 276.480 kHz for data rates of 5,760 b/s, 23,040 b/s, and 46,080 b/s; S- or X-band

*Reed-Solomon data are not presently decoded by the DSN; only convolutionally encoded data are decoded by the DSN.

Table 3. RF reception characteristics

Parameter	Antenna		
	64-meter	34-meter Standard	34-meter High-Efficiency
Frequency Range, MHz			
S-band	2270–2300	2200–2300	2200–2300
X-band	8400–8440	8400–8500	8400–8500
Gain, dBi			
S-band	$61.7^{+0.3}_{-0.4}$	$56.1^{+0.3}_{-0.7}$	$55.8^{+0.0}_{-0.5}$
X-band	$72.1^{+0.6}_{-0.6}$	$66.2^{+0.6}_{-0.6}$	$67.3^{+0.5}_{-0.8}$
System Noise Temperature, K			
Zenith			
S-band with maser			
Diplex	18.5 ±3	27.5 ±2.5	
Listen-only	14.5 ±2	21.5 ±2.5	
S-band with FET			
Diplex		130 ±10	
Listen only			115 ±10
X-band with maser	20 ±3	25.0 ±2.5	18.5 ±2

Table 4. DSCC telemetry s/s channel capabilities (telemetry groups 1 and 2)

Functions	Channel 1	Channel 2
Baseband Combining	N/A	N/A
Subcarrier Demodulation	100 Hz to 1 MHz, squarewave or sine wave	100 Hz to 1 MHz, squarewave or sine wave
Symbol Synchronization	6 s/s to 268.8 ks/s	6 s/s to 268.8 ks/s
Data Format	NRZ-L, NRZ-M, Biϕ-L	NRZ-L, NRZ-M, Biϕ-L
Sequential Decoding	K=24 or 32; R=1/2; frame length selectable; 16 s/s to 20 ks/s	N/A
Maximum Likelihood Convolutional Decoding	K=7; R=1/2 or 1/3 10 b/s to 134.4 kb/s	N/A
Uncoded	6 b/s to 268.8 kb/s*	6 b/s to 268.8 kb/s*

*Record only with non-real-time playback above 250 kbps

Table 5. DSCC telemetry s/s channel capabilities (telemetry groups 3 and 4)

Functions	Channel 1	Channel 2
Baseband Combining	Up to seven basebands	N/A
Subcarrier Demodulation	10 kHz to 2 MHz, squarewave or sine wave	10 kHz to 2 MHz, squarewave or sine wave
Symbol Synchronization	4 s/s to 4 Ms/s	4 s/s to 4 Ms/s
Data Format	NRZ-L, NRZ-M, Biϕ-L	NRZ-L, NRZ-M, Biϕ-L
Sequential Decoding	K=24 or 32; R=1/2; frame length selectable; 16 s/s to 20 ks/s	N/A
Maximum Likelihood Convolutional Decoding	K=7; R=1/2 or 1/3 10 bps to 250 kbps*	N/A
Uncoded	4 bps to 500 kbps*	4 bps to 500 kbps*

*Record only with non-real-time playback above 250 kbps

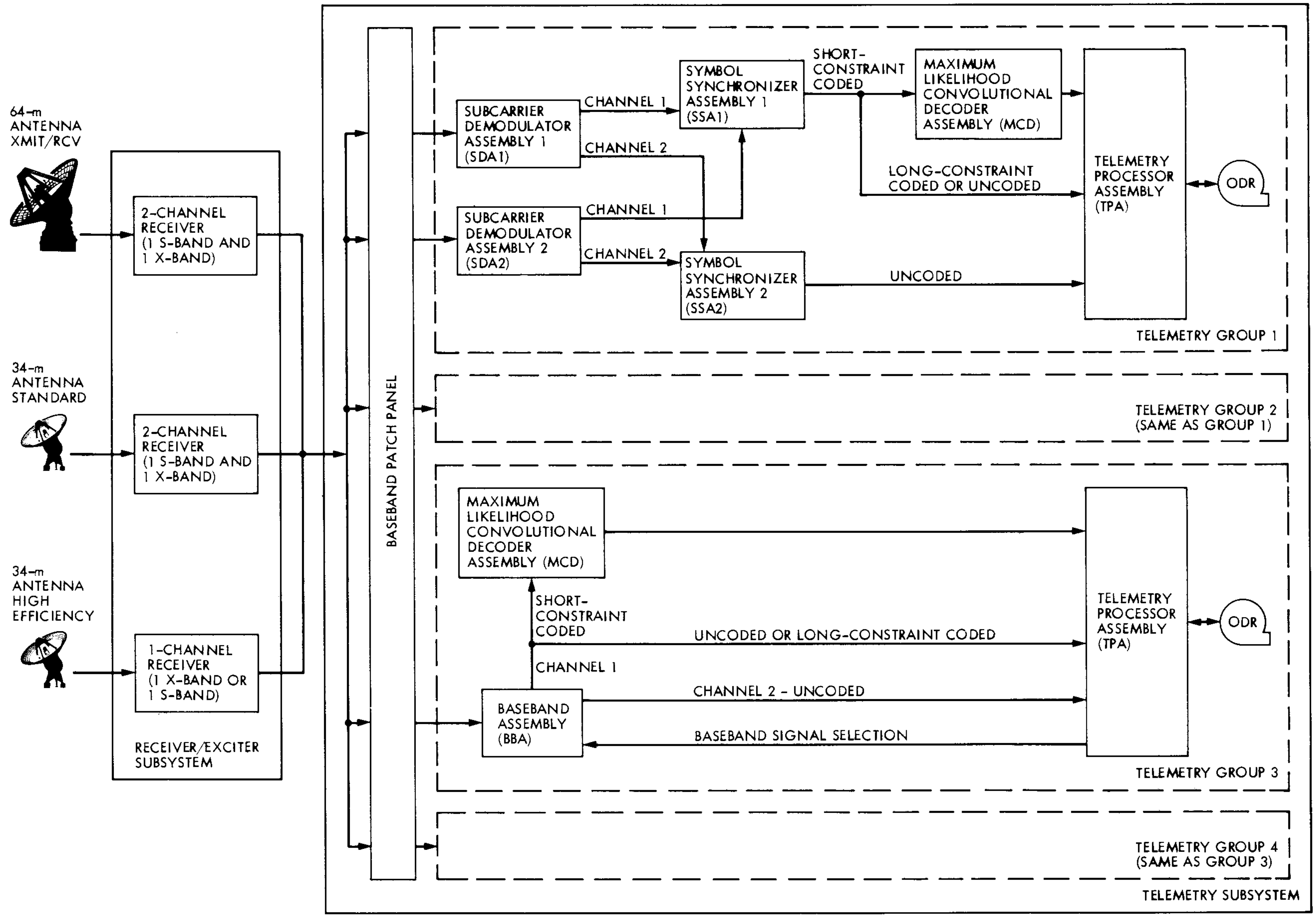

Fig. 1. Telemetry System: DSCC block diagram

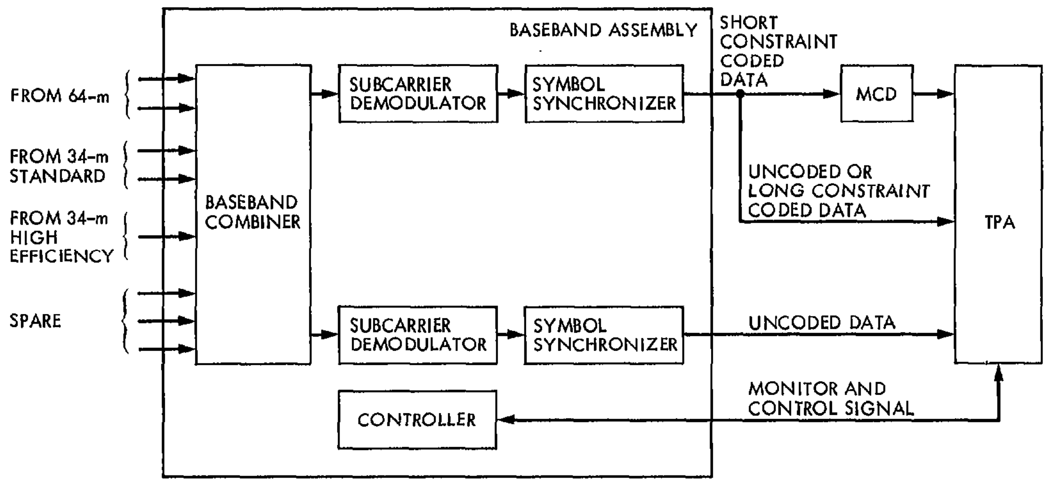

Fig. 2. Baseband Assembly functional block diagram