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The Deep Space Network Tracking System, Mark IV-A, 1986

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The DSN Tracking System provides highly precise measurements of spacecraft Doppler and range. It was recently extensively modified as part of the Mark IV-A implementation. ~~This article describes~~ the DSN Tracking System as currently implemented, its performance in support of Voyager 2, and plans for new implementation, are described.

I. Introduction

The Deep Space Network (DSN) Tracking System is composed of the hardware, software, personnel and procedures required to perform the following primary functions:

(1) Acquire and maintain the communications link with the spacecraft;

(2) Generate radio metric data (consisting of doppler, range and angle measurements) at each Deep Space Station (DSS);

(3) Format and transmit radio metric data;

(4) Validate the radio metric data to assure that performance requirements are being met.

The data generated by the Tracking System are used for spacecraft orbit determination, gravity wave studies, and relativity experiments, among other usages.

This article describes the current Mark IV-A configuration of the Tracking System, discusses system performance and problem areas during the recent Voyager Uranus encounter, outlines modifications scheduled for delivery in the current fiscal year (FY 86) and describes several major implementations planned for the near future.

II. Functional Description

The subsystems and major assemblies that comprise the Tracking System and the data flow between them are illustrated in Figs. 1 and 2.

Using cesium and hydrogen maser standards, the Deep Space Communications Complex (DSCC) Frequency and Tuning Subsystem (FTS) distributes highly stable timing pulses and reference frequencies to elements of the Tracking System.

The generation of doppler and range measurements utilizes a closed loop between the DSS and the spacecraft. To provide this link, the Exciter Assembly (EXC) of the DSCC Receiver-Exciter Subsystem (RCV) generates a 2.1 GHz (S-Band) signal. The frequency of this signal is controlled by the DSCC Tracking Subsystem (DTK). When ranging, the uplink signal is modulated by a ranging signal generated by the Planetary Ranging Assembly (PRA).

The uplink signal is amplified by the DSCC Transmitter Subsystem (TXR) to power levels of 20 kW (34-m STD DSS) or up to 400 kW (64-m DSSs). As part of Mark IV-A, a high power transmitter controller was installed at each 64-m DSS to allow the Signal Processing Center (SPC) to control and monitor the transmitter.

The amplified signal is provided to the DSCC Antenna Microwave Subsystem (UWV) which directs the signal to the antenna for radiation to the spacecraft.

Tracking of the apparent motion of the spacecraft is accomplished by the DSCC Antenna Mechanical Subsystem (ANT). This subsystem was extensively redesigned as part of the Mark IV-A implementation. All antennas at the DSCC are under control of a single Antenna Pointing Assembly (APA), while antenna dependent activities are controlled and monitored by the Angle Data Assembly (ADA) which interfaces with the APA. Antenna pointing is accomplished using predictions generated by the NOCC Support Subsystem (NSS) corrected by conical scanning, angle correction tables, and manual offsets.

Received 2.3 GHz (S-Band), 8.4 GHz (X-Band), and 1.5 GHz (L-Band) signals are focused by the antenna and amplified by the UWV. These signals, appropriately up-converted (for 1.5 GHz) or down-converted (for 8.4 GHz at the 34-m DSSs), are provided to the RCV where they are tracked using phase-locked loop receivers. Doppler is extracted and provided to the Metric Data Assembly (MDA) for counting. Received ranging modulation is provided to the PRA which generates the range measurements.

The MDA formats the doppler and range measurements and provides them to the Ground Communications Facility (GCF) for transmission to the Network Operations Control Center (NOCC). Also at each DSCC, the Meteorological Monitor Assembly (MMA) continuously accumulates local weather data and Faraday Rotation angle measurements from geostationary spacecraft tracking. These data are also provided to the GCF which transmits them to the NOCC.

The DSCC Monitor and Control Subsystem (DMC) provides control and configuration data for all elements of the TRK located at the DSCC. It also generates displays of status, configuration and performance data received from the subsystems. The DMC was the centerpeice of the Mark IV-A implementation, providing a new, centralized method for controlling subsystems and receiving and distributing monitor data required by each subsystem.

At the NOCC, the NOCC Tracking Subsystem (NTK) receives radio metric and MMA data and provides displays of data and warning messages to allow real-time validation of the data. The NOCC Support Subsystem (NSS) generates prediction data using input received from the NOCC Navigation Subsystem (NAV) and the flight project navigation teams and transmits them to the DMC for dissemination and archiving.

Orbit data files and state vectors received from NAV are transmitted by NSS to external users such as the European Space Operations Center, located in Darmstadt, Germany; the German Space Operations Center, located at Oberpfaffenhofen, Germany; and the Tracking and Control Center, located at Tsukuba, Japan.

The NAV uses radio metric data to compute the orbits of those certain deep space missions and earth orbiters supported on a reimbursable basis. NAV was newly implemented with Mark IV-A to provide this capability. Additionally, NAV preprocesses radio metric data to generate orbit data files for delivery to the flight project navigation teams.

III. Tracking System Performance

Immediately following the Mark IV-A implementation at each DSCC, the quality and quantity of radio metric data being delivered to the flight projects, especially Voyager, took a significant downturn. By March 1985, concern about the poor performance was serious enough that a team was formed at JPL to monitor data quality and recommend changes to hardware, software and procedures (at both the DSCCs and JPL) to improve the data return. In parallel, work continued in the Mark IV-A project to improve the operability of the Mark IV-A configuration.

Figure 3 illustrates the percentage of usable doppler and range data provided to Voyager from April 1985 through February 1986. As can be seen, the percentage of usable data was unstable prior to December 1985.

It should be noted that the scheduled tracking passes rarely provided the level of support required by the Support Instrument Requirements Document (SIRD). Thus, minor problems were typically magnified by the lack of tracking time.

Encountered problems that had significant impact on data quantity and quality were:

(1) Procedural – including incorrect entry of range parameters, frequently incorrect configuration of the doppler reference frequencies and incorrect flagging of doppler mode;

(2) Software – including halts of the Metric Data Assembly, Area Routing Assembly, Antenna Pointing Assembly, frequent occurrences of the antenna driving off point, missing data blocks (especially the uplink tuning data) and erroneous transmitter status flags in the data;

(3) Hardware – including transmitter failures and PRA failures.

These problems all were given special attention by the Mark IV-A implementers. By the beginning of the encounter period the majority of the problems had been resolved.

The Performance Analysis Group of the DSN Control Center Operations Section and the Multimission Navigation Support Team of the Navigation Systems Section worked closely to identify causes of problems and to recover data through special processing.

The excellent quality of data during the encounter period was, according to the Voyager Navigation Team chief, a strong contributor to the successful flyby of the Uranian moon, Miranda, and to the Uranus encounter.

The team established to monitor the data will continue this activity at a reduced level to attempt to ensure that data quality levels remain high.

IV. Planned FY 86 Implementations

During the current fiscal year, a multitude of changes have been planned which will continue to improve the operability of the Mark IV-A Tracking System. These modifications include (by subsystem):

(1) Antenna Mechanical – improvements in CONSCAN signal tracking, improved angle data and predicts displays, and high-level control of the Angle Data Assembly.

(2) DSCC Tracking Subsystem – redesign of the MDA-DCO (Digitally Controlled Oscillator) interface and displays, new interface with the Transmitter subsystem; and a doppler reference frequency monitor;

(3) NOCC Tracking Subsystem – addition of data monitoring for 26-m DSS radio metric data;

(4) DSCC Monitor and Control Subsystem – improved display handling, transmission of logs to JPL, and text file handling capability;

(5) Transmitter Subsystem – automation of the 20 kW transmitter and new MDA interface.

Transfer of the upgraded software and firmware is planned to be completed by September 30, 1986.

V. Future Major Implementations

Current planning calls for several major capabilities to be implemented during the next four years. These capabilities include X-Band uplink, the Media Calibration Subsystem, a real-time navigation interface, and the Sequential Ranging Assembly.

A. X-Band Uplink

This project is well underway towards a January 1988, operational date at DSS-45. A key feature of this implementation is the installation of a complete Tracking System at the 34-m High Efficiency (HEF) Antennas. This capability will provide coherent 7.2 GHz/8.4 GHz doppler and ranging capability for use during the upcoming Galileo, Magellan, and Mars Observer missions.

B. DSCC Media Calibration Subsystem (DMD)

The DMD will replace the existing MMA and Faraday Rotation equipment with a new MMA and receivers for tracking the Global Positioning System (GPS) satellites. Local weather data of improved quality and measurements of the differential phase and group delay from the dual frequency GPS downlinks will be generated by the DMD for use in computing ionosphere and troposphere calibration data. Implementation of the DMD is scheduled to begin in late 1988.

C. Real-time Navigation Interface

The current method for providing radio metric data to the flight project navigation teams requires that the data be logged in the Data Records Subsystem (GDR) and periodically written to tape as intermediate data records (IDRs). These IDRs are provided to the navigation teams for reformatting, preprocessing, and calibrating prior to their use in the orbit determination process. In October 1987, a dedicated NOCC Navigation Subsystem (NAV) computer with a real-time interface to the GCF for receipt of radio metric data will become operational. At that time, the IDRs will be replaced and the DSN will assume responsibility for providing preprocessed data to the flight projects. This implementation should improve the current radio metric data flow.

D. Sequential Ranging Assembly

The Sequential Ranging Assembly (SRA) will replace the current Planetary Ranging Assembly. The SRA will provide for coherent 7.2 GHz/8.4 GHz (X-Band) ranging as well as for the usual 2.3 GHz (S-Band) ranging. Key features of the SRA are automation of the Ranging Demodulator Assembly (RDA) configuration and calibration, automation of the pre-track DSS calibration, capability to change ranging parameters without loss of data and a capability to go eventually to higher ranging frequencies. The SRA is currently planned to be installed at DSS-14 in March 1987 for testing and evaluation with the first operational units planned for installation in October 1987.

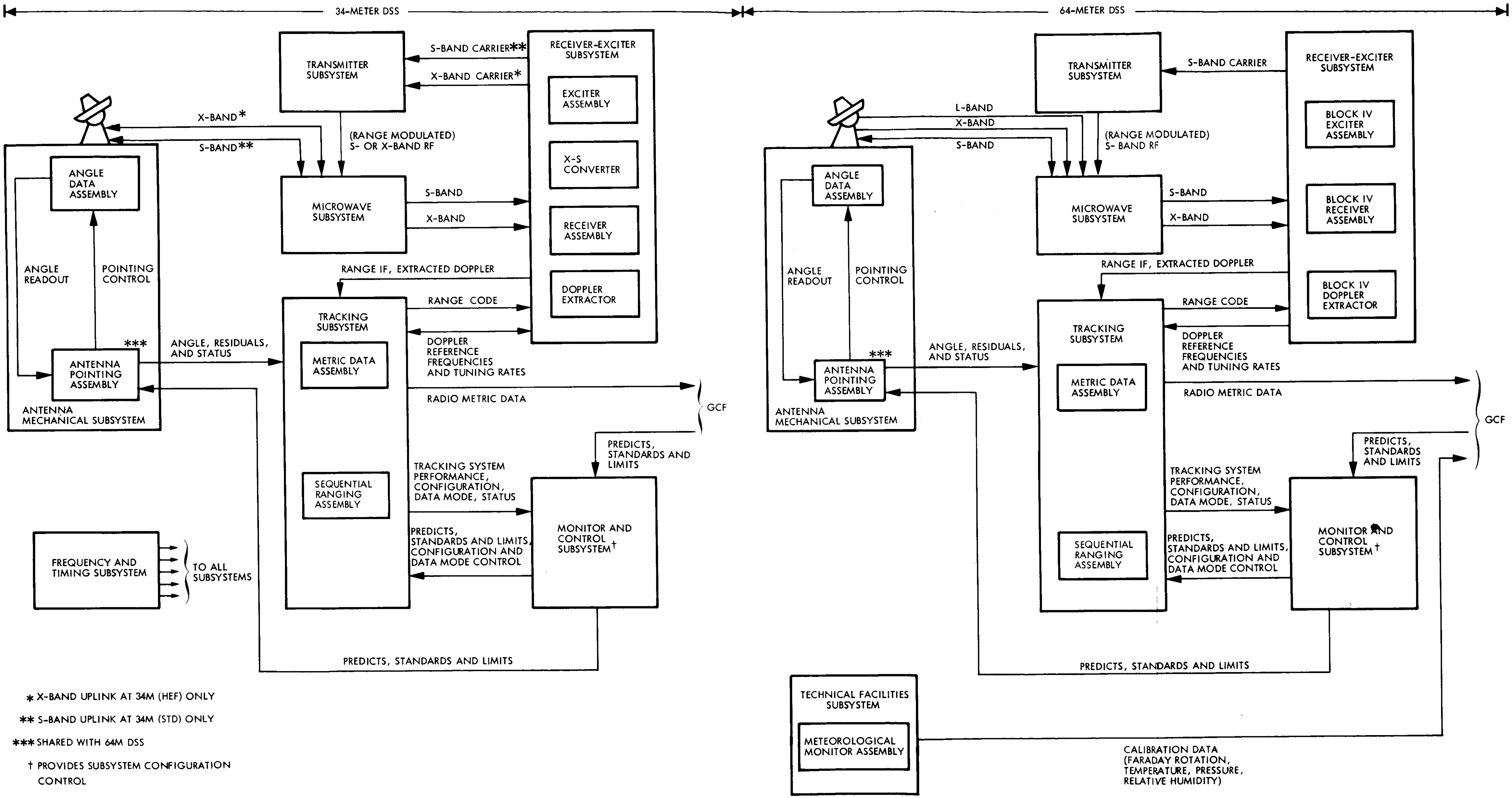

Fig. 1. Detailed block diagram of the DSN Tracking System at the 34- and 64-m DSSs

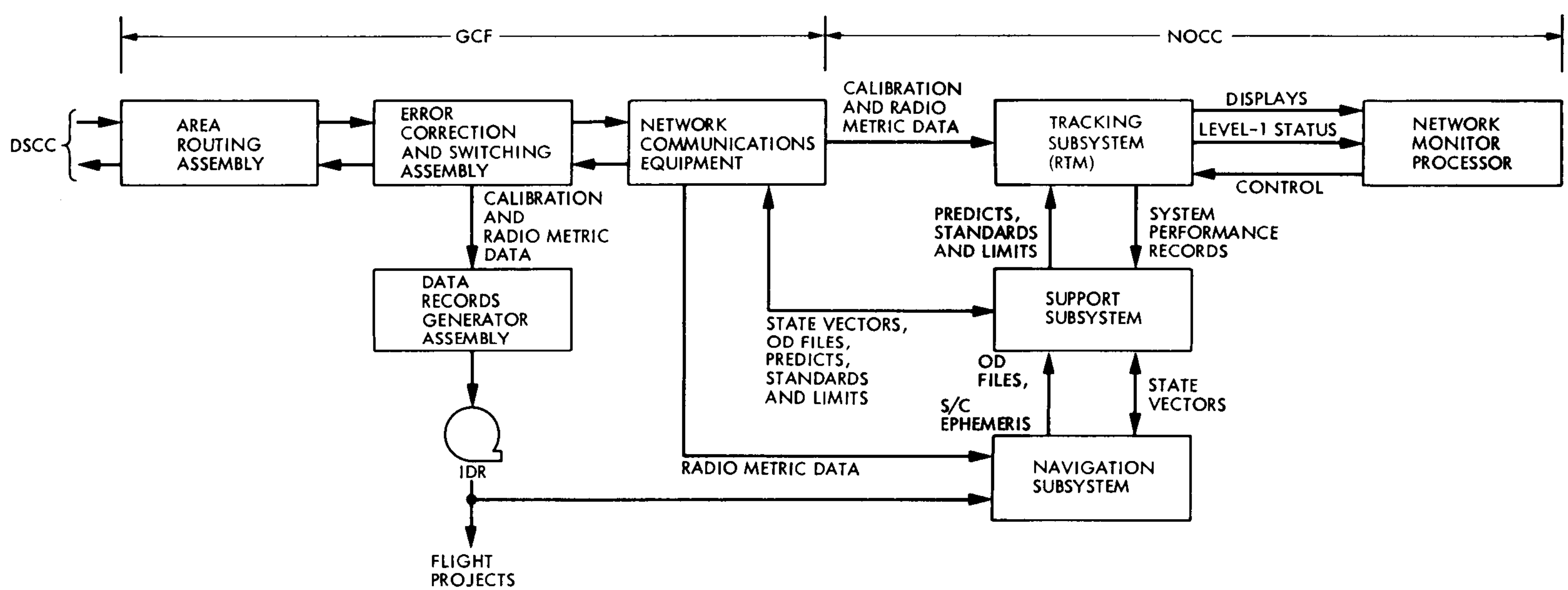

Fig. 2. GCF/NOCC functions and data flow within the DSN Tracking System

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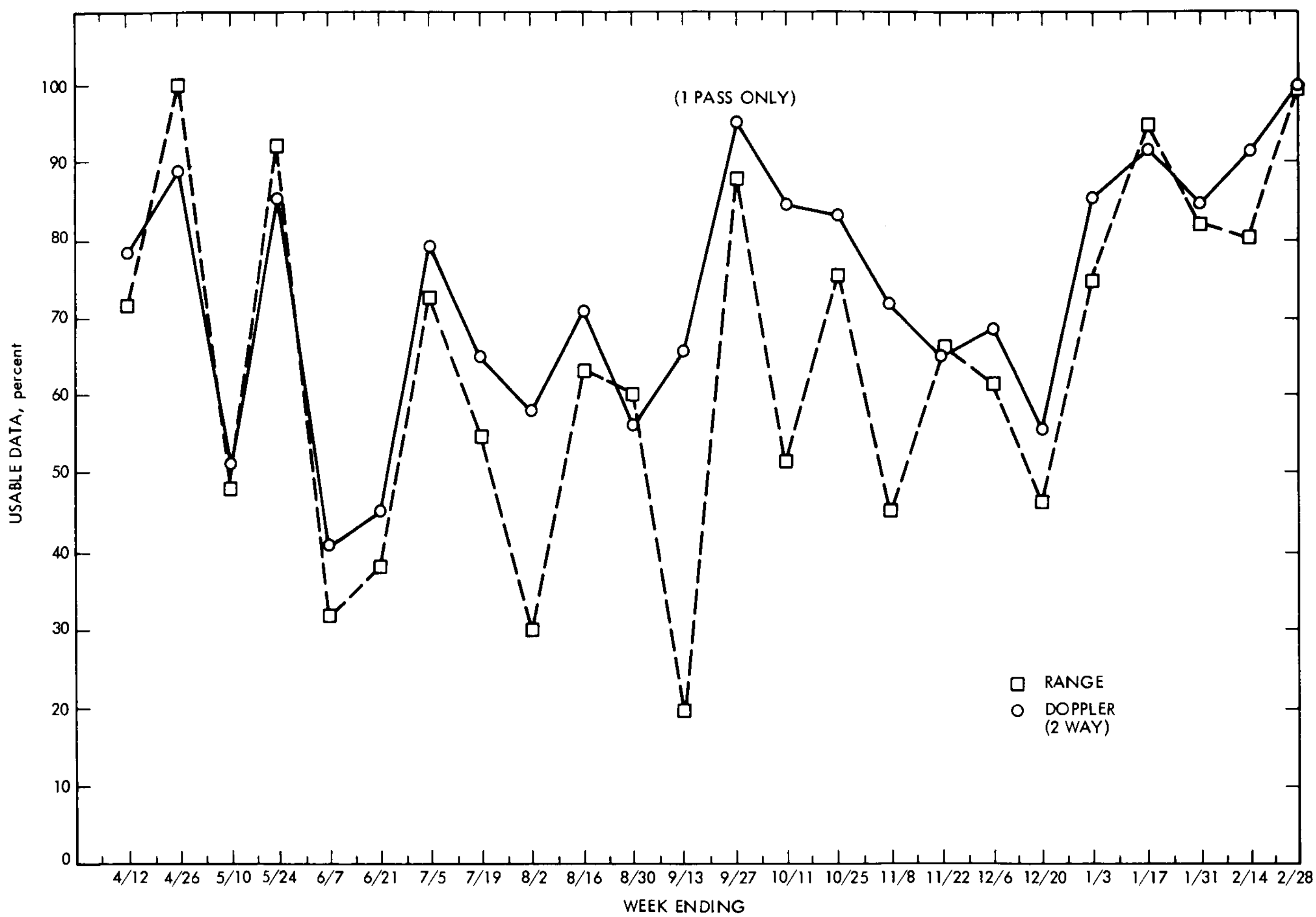

Fig. 3. Tracking System performance