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TRACKING AND DATA RELAY SATELLITE SYSTEM (TDRSS) FREQUENCY PLAN

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GSFC

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GREENBELT, MARYLAND

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Greenbelt, Maryland

PREFACE

This document is an updated version of the original Tracking and Data Relay Satellite System (TDRSS) Frequency Plan, (Doc. 16151/1-2.3.6/4.9.2) submitted to the IRAC in October of 1973. The format utilized corresponds to that specified in para 8.3 of the Manual of Regulation and Procedures for Radio Frequency Management as issued by the Office of Telecommunication Policy (OTP).

The TDRSS configuration specified in this document is the same as that defined in the TDRSS definition phase study. Because the TDRSS will be provided by a contractor under a leased service type of arrangement, the actual configuration of the system may differ from that defined by the definition phase study; however, the system capabilities and service levels will be as specified.

ACRONYMS AND ABBREVIATIONS

b/s	bits per second
CCIR	International Radio Consultative Committee
chip rate	bit rate of PRN code
dB	decibel
dBW	decibel referred to 1 watt
EIRP	effective isotropic radiated power
FDM	frequency division multiplex
FM	frequency modulation
FOV	field of view
GHz	gigahertz
G/T	gain over temperature
IF	intermediate frequency
K	degrees Kelvin
kb/s	kilobits per second
LCP	left circular polarization
$M	millions of dollars
MA	multiple access
Mb/s	megabits per second
Mch/s	megachips per second
MHz	megahertz
NASA	National Aeronautics and Space Administration
ppm	parts per million
PRN	pseudorandom noise
PSK	phase shift keying
RCP	right circular polarization
RF	radio frequency
RFI	radio frequency interference
SA	single access
Signal EIRP	EIRP in the direction of the user
STDN	Spaceflight Tracking and Data Network
T&DA	Tracking and Data Acquisition
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TT&C	tracking, telemetry, and command
TWT	travelling wave tube

1. SYSTEM PURPOSE

The purpose of the Tracking and Data Relay Satellite System (TDRSS) is to provide telecommunications service between the ground and NASA satellites in earth orbit (up to 12000-km altitude) via a NASA Tracking and Data Relay Satellite (TDRS) in geosynchronous orbit.

2. INFORMATION TRANSFER REQUIREMENTS

The TDRSS telecommunications service will provide the capability to transfer tracking, telemetry, commands, two-way voice, and digital and image data between ground and low earth-orbiting vehicles. The TDRSS, when operational, will become an integral part of the Spaceflight Tracking and Data Network (STDN). As such, the TDRSS will perform the same functions as any other network station, i.e., transmit signals to, and receive signals from, earth-orbiting user spacecraft, and provide data from which user spacecraft ephemerides can be calculated.

The command data rates to the orbiting spacecraft range from 100 b/s to 10 kb/s. The telemetry and/or digital data rates range from 1 kb/s to approximately 300 Mb/s. Image data may be transferred in digital (up to 30 Mb/s) or analog form on both the forward and return links. Voice will be transferred in digital format using a 32-kb/s delta modulation technique. Range information will be obtained by using either:

a. A Pseudorandom Noise (PRN) digital code.

b. Tone digital.

Doppler information will be obtained by using a reconstructed carrier component from the transmitted signal. The quality of the majority of digital data will be maintained at 10^{-6}, or better, bit error rate. The quality of analog image data has not yet been defined.

3. SYSTEM CONFIGURATION

The current TDRSS configuration (see figure 1) consists of two operational NASA TDRS's in geosynchronous orbit and an associated ground terminal located in the continental United States. The two operational TDRS's will be placed approximately 130 degrees apart at 41 degrees west and 171 degrees west longitude, in orbits inclined 7 degrees or less. Additionally, the system includes two spare satellites: one in orbit positioned midway between the two operational TDRS's, and one in configuration for a rapid replacement launch. A bent-pipe concept is used in the design of the TDRS telecommunications service system (i.e., all communication signals received at the TDRS are translated in frequency and retransmitted). Currently, it is planned to locate the TDRSS ground terminal at the White Sands, New Mexico area. The TDRSS ground terminal will have three antennas, each approximately 18 meters in diameter.

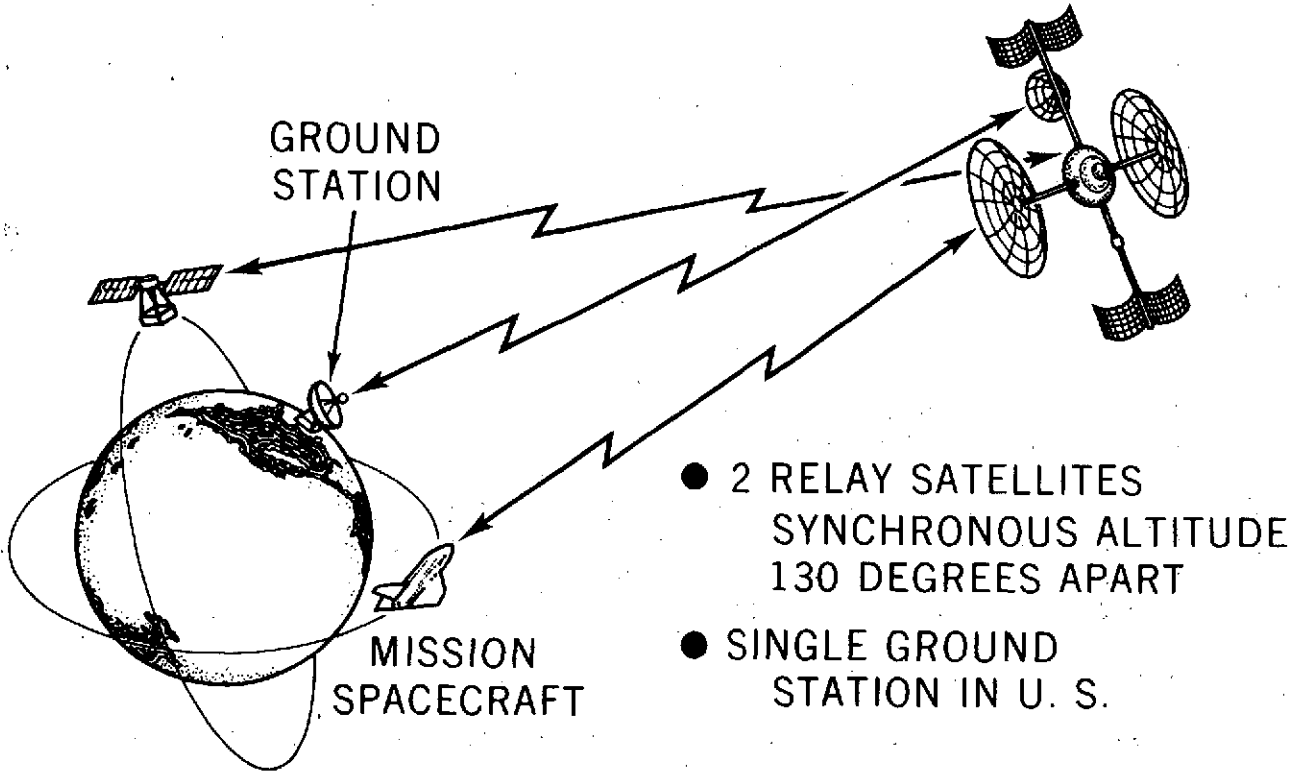


Figure 1. Tracking and Data Relay Satellite System

Each TDRS provides two types of communication service: Multiple-access (MA) service and Single-access (SA) service. These services will support the following three types of users (see figure 2):

a. MA users.

b. SA S-band users.

c. SA Ku-band users.

Note

The Shuttle and manned orbiting vehicles may be both MA and SA users simultaneously.

The telecommunications link from the ground terminal to the TDRS to the user spacecraft is called the forward link and will be used to carry user command data, tracking signals, voice, and digital data. The link from the user spacecraft to the TDRS to the ground terminal is called the return link and will be used to carry user telemetry data, tracking signals, voice, and image data. Both the forward and return links consist of two segments:

a. Space-to-space link, defined as the link between the TDRS and the user spacecraft.

b. Space-to-ground link, defined as the link between the TDRS and the TDRSS ground terminal.

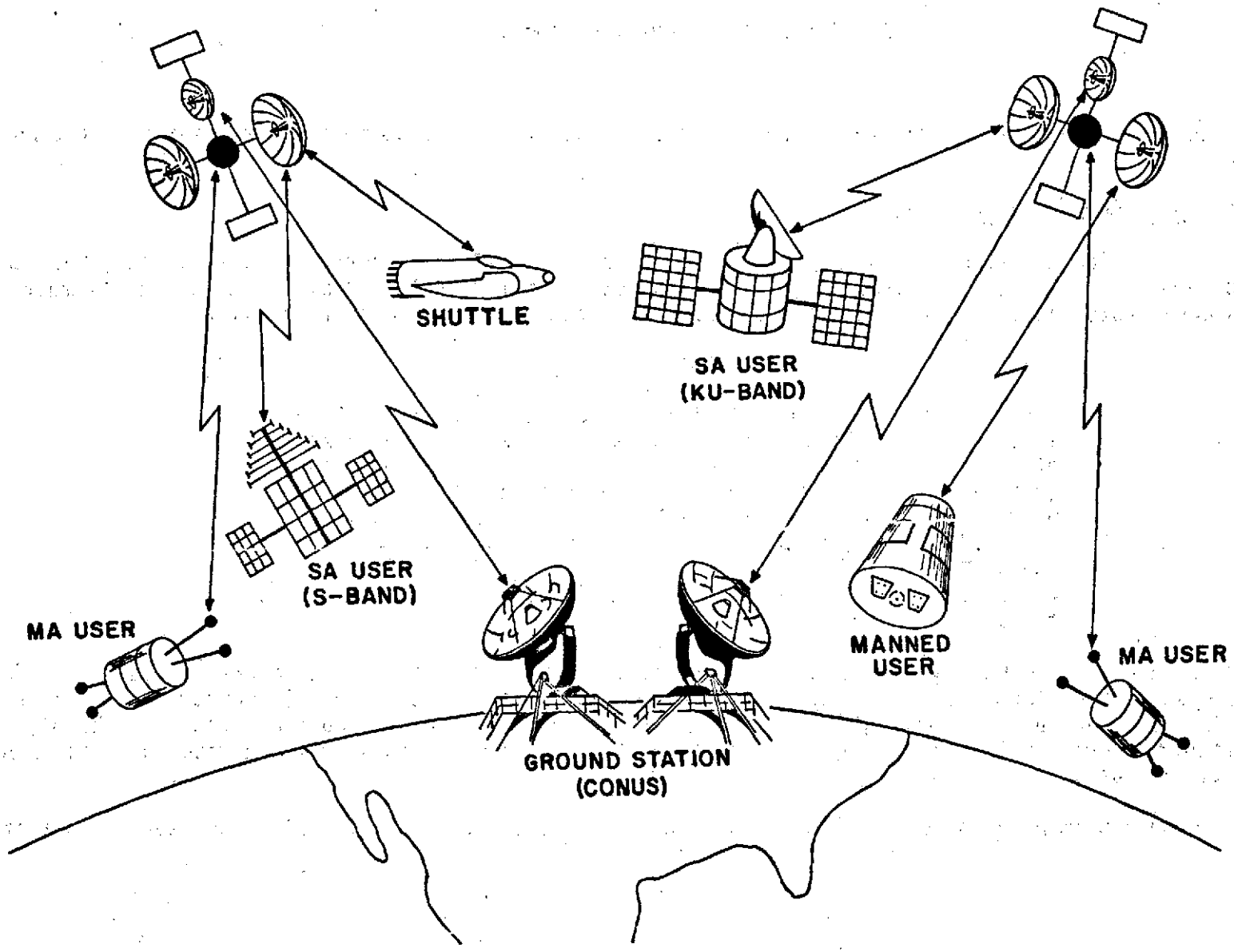


Figure 2. Tracking and Data Relay Satellite System Users

Each TDRS (see figure 3) contains the following antennas to support the space-to-space and space-to-ground communication links:

a. Space-to-space Communication Links

(1) 31- to 41-element S-band antenna system: One element is used to support the forward link; the remaining elements are used as an array antenna to support the return (telemetry) link of up to 20 users simultaneously. This antenna system is called the multiple-access system and is used to support MA users.

Note

The current design concept of the TDRS, shown in figure 3, is limited to a 31-element S-band MA antenna system because of the current weight estimates of the system and the weight constraints of the 2914 Delta launch vehicle. However, to provide for growth potential flexibility (i.e., possibly resulting from refined weight estimates or increased weight capability of the launch vehicle), the frequency plan presented in this document allows an increased capability of up to 41-elements on the MA antenna system.

(2) Two parabolic antennas operating at S- and Ku-band, each approximately 3.8 meters in diameter: Each antenna system is called a single-access system because each antenna normally will support one user at a time. However, each antenna can support two users simultaneously (one at S-band and one at Ku-band), provided both users are within the beamwidth of the antenna. These antennas will be used to support SA S- and Ku-band users.

b. Space-to-ground Communication Links. One parabolic Ku-band antenna, approximately 1.8 meters in diameter.

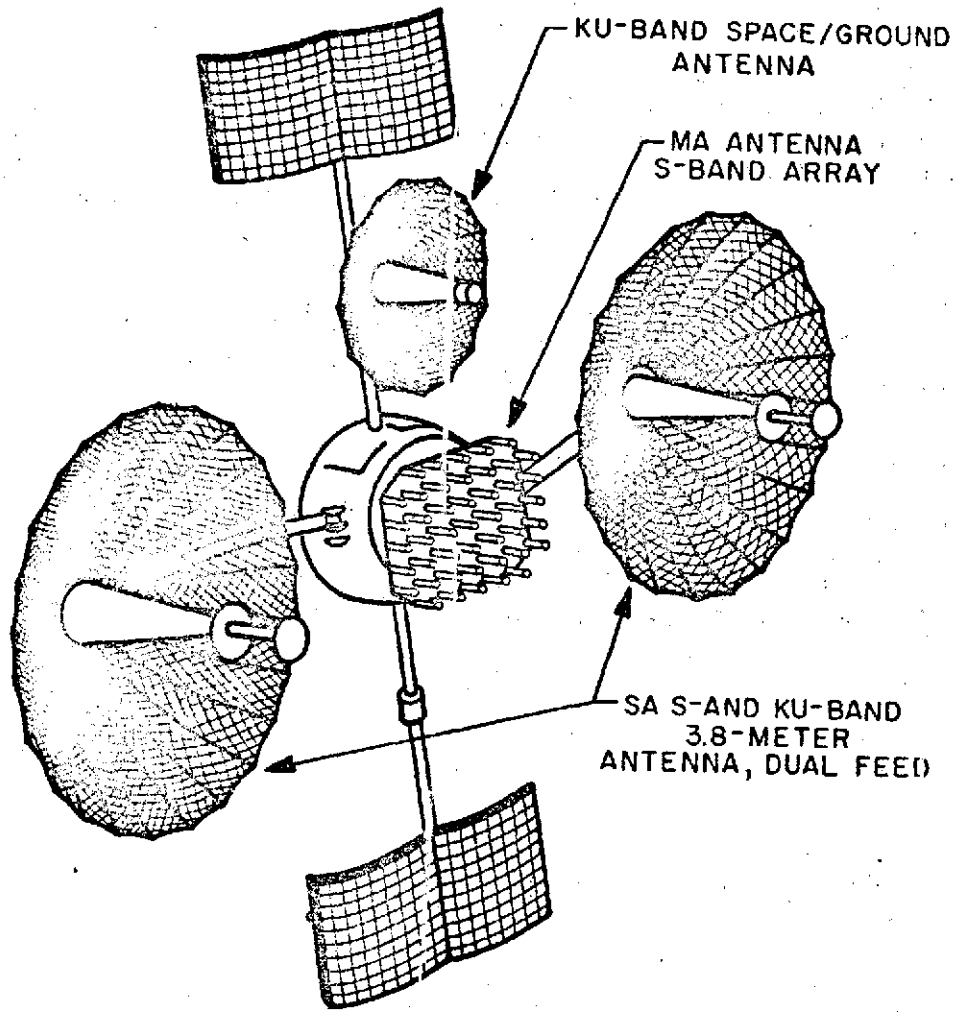


Figure 3. Three-axis Stabilized Spacecraft

The TDRSS frequency plan in figure 4 shows that the TDRSS ground terminal has the capability to transmit and receive in both the 2025- to 2120-MHz band and the 2200- to 2300-MHz band. The S-band TDRS Tracking, Telemetry, and Command (TT&C) links between the ground terminal and the TDRS will only be used: (1) to support the TDRS launch and initial positioning into synchronous orbit, and (2) as a backup TT&C capability during the operational phase of the TDRSS. The primary TT&C link supporting the TDRS's during the operational phase will be on the Ku-band TDRS/ground terminal links. The S-band TT&C link will require less than 1 MHz of RF bandwidth in the 2025- to 2120-MHz uplink band and the 2200- to 2300-MHz downlink band, with a turnaround ratio of 221/240.

The test and simulation links between the TDRS and ground terminal have been designed into the system to perform real-time and periodic checkout and tests of the entire system by locating an S-band MA and SA user transponder at the ground terminal.

Note that the proposed Ku-band frequencies supporting the up and down links between the ground terminal and the TDRS are reversed from the normal use of these bands on space-to-earth and earth-to-space links as indicated in the manual of regulations and procedures. Because the STDN is planning to augment its capability by 1980 to support high data rate users operating at Ku-band, a reversal of the Ku-band frequencies supporting the TDRSS space-to-ground links is considered to be the simplest method of: (1) permitting Ku-band STDN- and TDRSS-supported spacecraft to operate at Ku-band in the conventional manner, and (2) minimizing potential interference with other users in these bands.

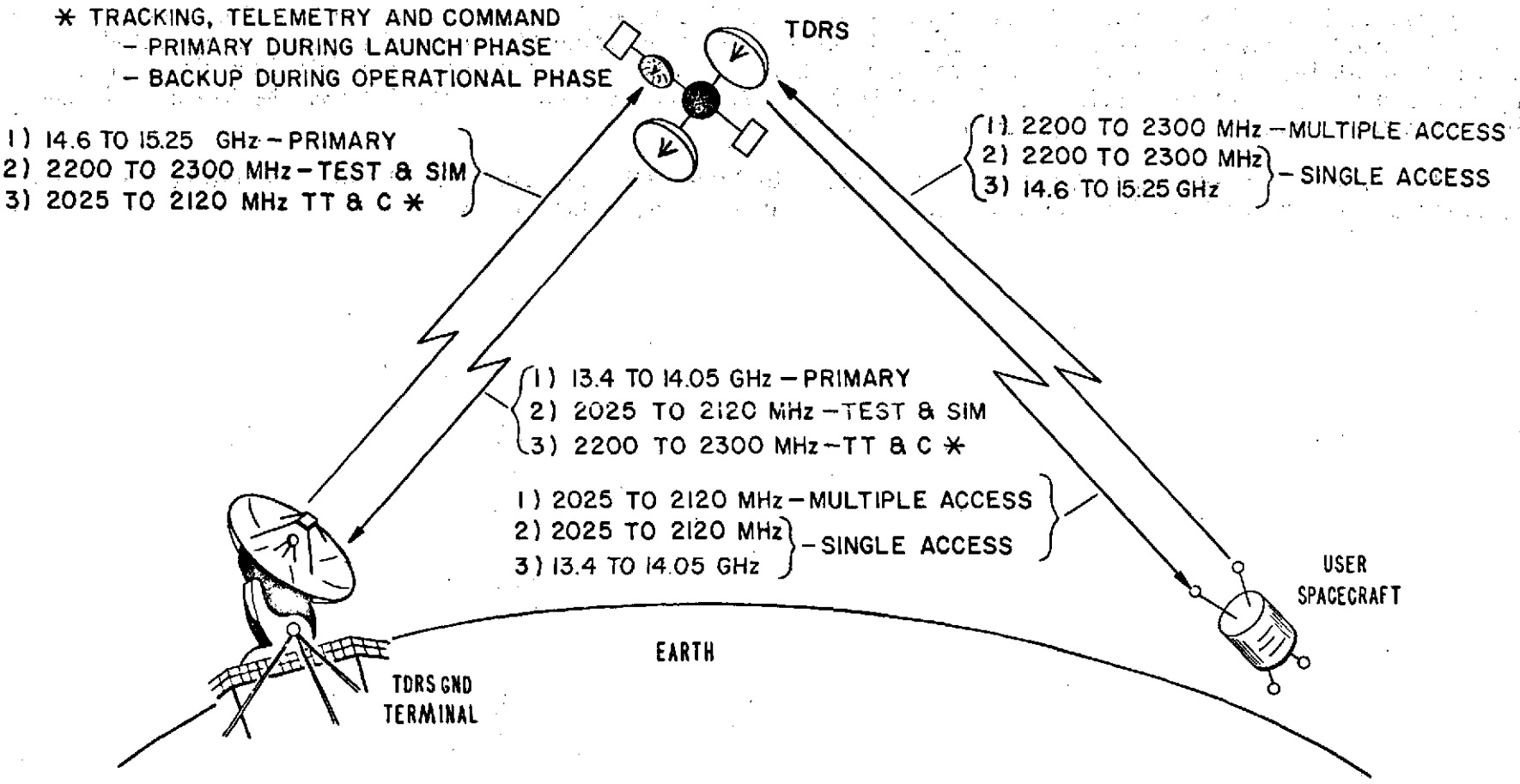


Figure 4. TDRSS Frequency Plan

Figures 5, 6, and 7 show the details of the spectrum utilization for all the links of the TDRSS at both S- and Ku-bands. These figures also indicate all the signals (including RF bandwidths) to be transmitted from and received at the TDRS. Figure 5 shows the spectrum utilization for all Ku-band transmissions from TDRS. Figure 6 shows the spectrum utilization for all Ku-band reception at TDRS. Figure 7 shows the S-band utilization for both transmission and reception at the TDRS.

Table 1 summarizes the characteristics for a two-satellite TDRSS and tables 2, 3, and 4 summarize the TDRS characteristics for the MA, SA S-band, and the SA Ku-band service, respectively.

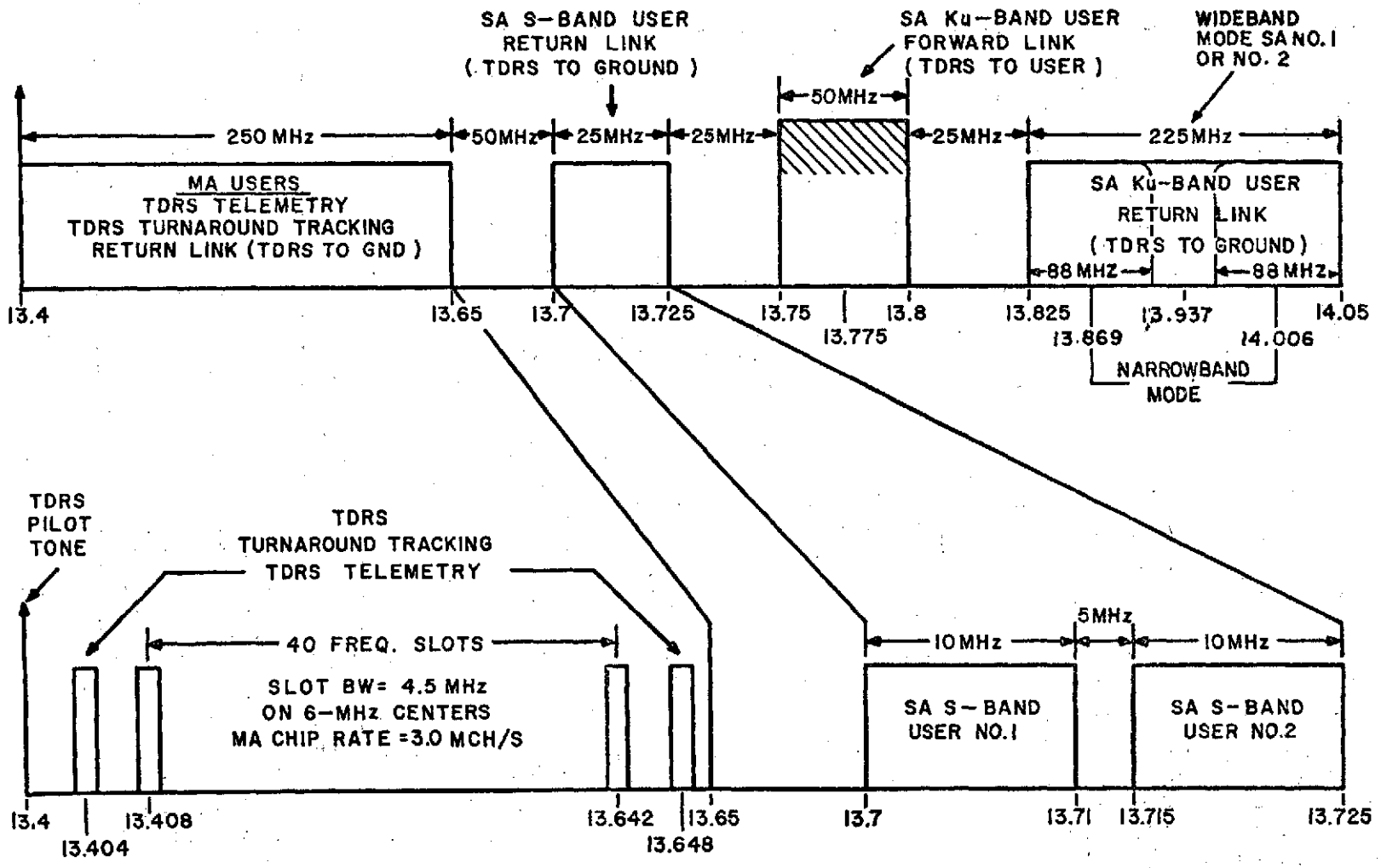


Figure 5. TDRS Ku-band Transmit Frequency Plan

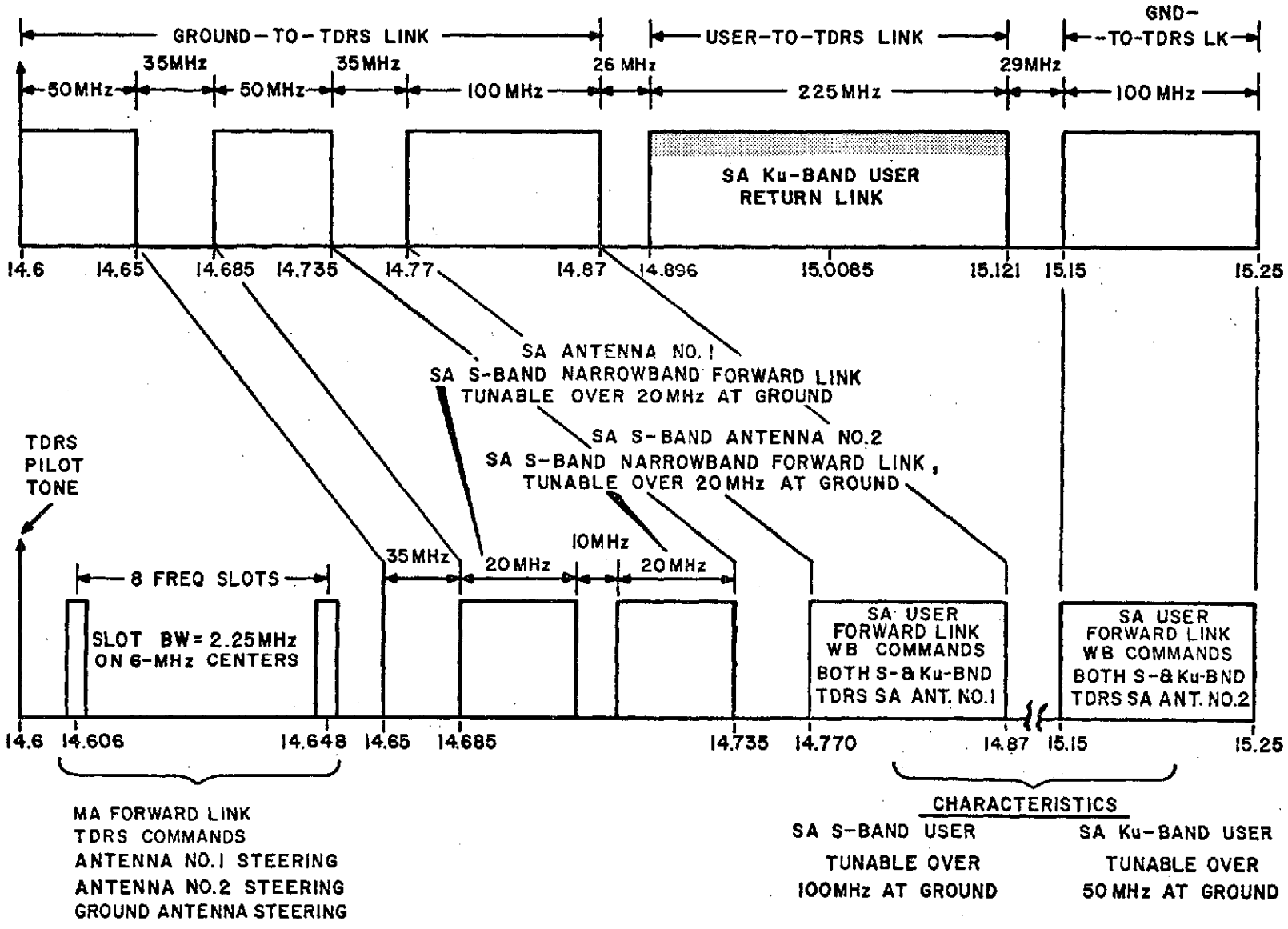
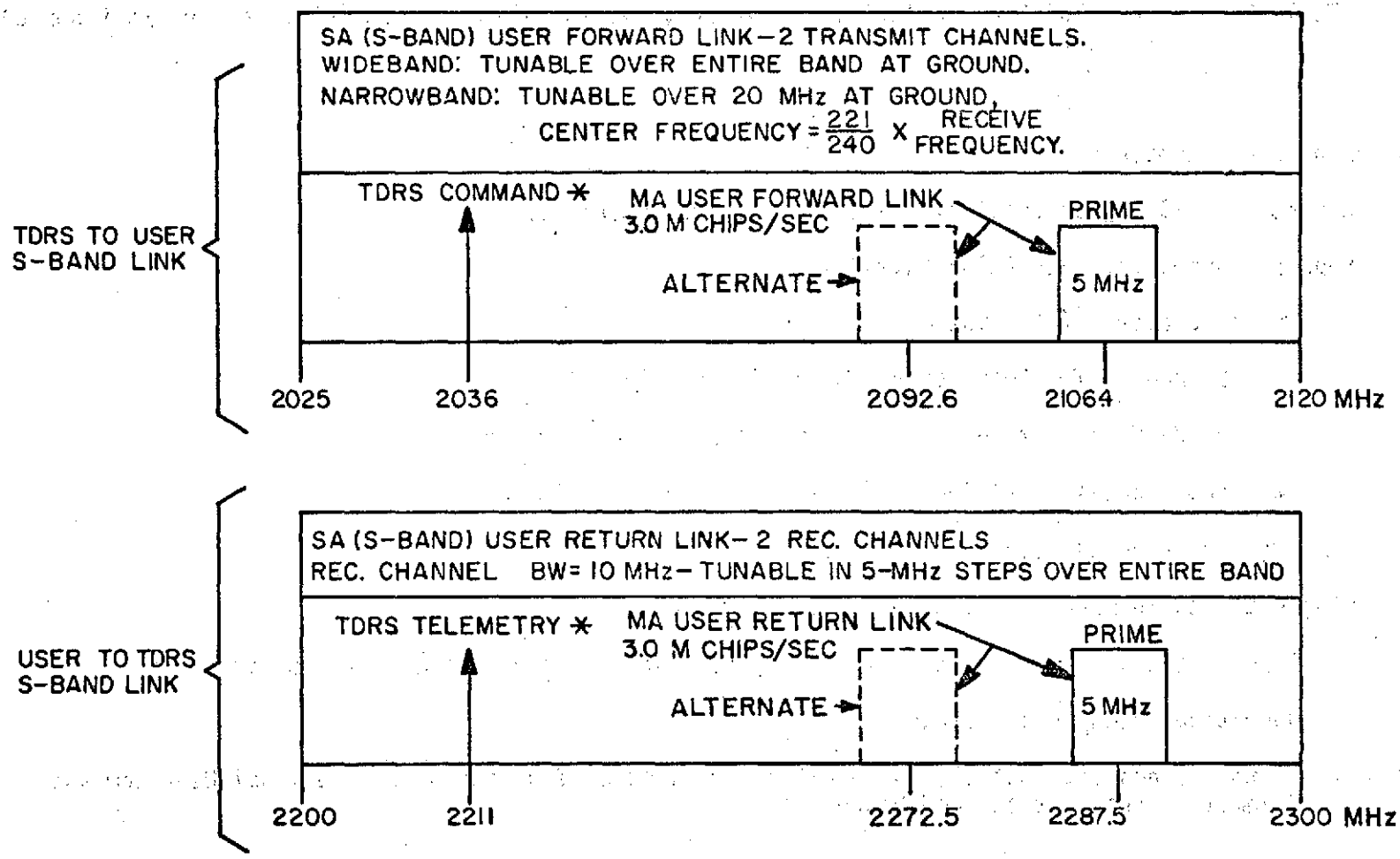


Figure 6. TDRS Ku-band Receive Frequency Plan



* TDRS TELEMETRY & COMMANDS
- •PRIME DURING LAUNCH PHASE
- •BACKUP DURING OPERATIONAL PHASE

Figure 7. TDRS S-band Frequency Plan

Table 1. Typical TDRSS Characteristics Summary, Two-satellite System (Plus One In-orbit Spare)

- Bent-pipe Repeater.
- Geometry: 130-degree Spacing, 85-percent Minimum Coverage.
- Support Capability (Per Relay Satellite)

  Multiple-access (MA) System

  20 MA User Telemetry Channels Simultaneously.

  One MA User Command Channel (Time-shared with 20 Users).

  Two Single-access (SA) S-band Users.

  Two Single-access (SA) Ku-band Users.
- Single Ground Terminal Located in CONUS (White Sands, N. M.)

  Three Antennas (Two Operational and one for Backup Spacecraft and Diversity).

  Operating Frequency: Ku-band.

  Perform Schedule, Control, and Monitor Functions of TDRS and Ground Terminal User Commands, Telemetry, Acquisition, and Handovers.

Table 2. Typical MA Service Characteristics

o FORWARD LINK	
ANTENNA:	NINE ELEMENT PHASED ARRAY, 9^{o} BEAMWIDTH.
FREQUENCY:	2106.4 MHZ (2092.6 MHZ ALTERNATE).
BANDWIDTH:	5 MHZ.
TDRS SIGNAL EIRP:	34 DBW AT $\pm 13^{o}$ OFF LOCAL NADIR.
DUTY FACTOR:	CONTINUOUS OPERATION.
USER COMMAND:	TIME-SHARED BETWEEN USERS. USERS SEPARATED BY UNIQUE CODE.
COMMAND RATE:	UP TO 1 KB/S.
MODULATION:	PRN SPREAD SPECTRUM (3.0 MCH/S), PSK ($\pm 90^{o}$) BIPHASE.
o RETURN LINK	
ANTENNA:	30- TO 40-ELEMENT PHASED ARRAY.
FREQUENCY:	2287.5 MHZ (2272.5 MHZ ALTERNATE).
BANDWIDTH:	5 MHZ.
G/T:	-1.1 DB (MINIMUM OVER 26^{o} FOV).
ARRAY BEAM FORMING:	ALL ELEMENT COMBINING/BEAM FORMING PERFORMED AT GROUND TERMINAL. SEPARATE ARRAY BEAM FORMED FOR EACH USER SIMULTANEOUSLY.
TELEMETRY RATE REQUIREMENT:	UP TO 48 KB/S.
RETURN LINK SIGNAL CHARACTERISTICS:	ALL USERS ON 2287.5-MHZ (2272.5 MHZ ALTERNATE) CARRIER FREQUENCY. CODE DIVISION MULTIPLEX/PRN SPREAD SPECTRUM MODULATION (3.0 MCH/S).

Table 3. Typical S-band SA Service Characteristics

o FORWARD LINK	
ANTENNA:	3.8-METER DIAMETER PARABOLIC REFLECTOR.
FREQUENCY:	2025 MHZ TO 2120 MHZ.
TDRS SIGNAL EIRP	
NORMAL POWER:	43.4 DBW.
COMMAND RATE:	UP TO 10 KB/S.
HIGH POWER:	46.0 DBW (50% DUTY FACTOR).
DATA RATE:	UP TO 216 KB/S (SHUTTLE).
NARROWBAND MODE	
CENTER FREQ:	$\frac{221}{240}$ X USER TRANSMIT FREQ.
BANDWIDTH:	20 MHZ IN TDRS.
WIDEBAND MODE	
CENTER FREQ:	INDEPENDENTLY CONTROLLED BY GROUND TERMINAL.
BANDWIDTH:	100 MHZ IN TDRS.
DUTY FACTOR:	SCHEDULED AS REQUIRED ON CONTINUOUS BASIS.
RETURN LINK	
ANTENNA:	3.8-METER DIAMETER PARABOLIC REFLECTOR.
FREQUENCY:	2200 MHZ TO 2300 MHZ.
BANDWIDTH:	10 MHZ.
G/T:	+6.9 DB (MINIMUM), +8.4 DB (MAXIMUM).
TELEMETRY DATA RATE:	UP TO 5 MB/S.

Table 4. Typical Ku-band SA Service Characteristics

o FORWARD LINK	
ANTENNA:	3.8-METER DIAMETER PARABOLIC REFLECTOR.
FREQUENCY:	13.75 GHZ TO 13.8 GHZ.
TDRS SIGNAL EIRP	
NORMAL POWER:	43.0 DBW.
COMMAND RATE:	UP TO 10 KB/S.
HIGH POWER:	49.0 DBW, (25% DUTY FACTOR).
DATA RATE:	UP TO 30 MB/S.
BANDWIDTH:	50 MHZ IN TDRS.
DUTY FACTOR:	SCHEDULED AS REQUIRED ON CONTINUOUS BASIS.
o RETURN LINK	
ANTENNA:	3.8-METER DIAMETER PARABOLIC REFLECTOR.
FREQUENCY:	14.896 GHZ TO 15.121 GHZ.
NARROWBAND	
CENTER.FREQ:	15.0085 GHz.
BANDWIDTH:	88 MHZ.
DATA RATE REQUIREMENT:	UP TO 50 MB/S (BIPHASE), 100 MB/S (QUADRIPHASE).
WIDEBAND	
CENTER FREQ:	15.0085 GHZ.
BANDWIDTH:	225 MHZ.
TELEMETRY RATE:	UP TO 150 MB/S (BIPHASE), 300 MB/S (QUADRIPHASED).

4. ESTIMATED TERMINATION DATE

The TDRSS is presently scheduled to be in full operation by the last half of 1979. The system will be used on a permanent basis to support NASA space programs.

5. ESTIMATED INITIAL COST OF THE SYSTEM

Intentionally deleted.

6. TARGET DATES

Intentionally deleted.

7. SYSTEM JUSTIFICATION

The TDRSS will provide improved Tracking and Data Acquisition (T&DA) services, at a reduced cost, to NASA spacecraft in low earth orbit. The improved T&DA results from the TDRSS (as defined in this document), providing 85-percent, and greater, contact coverage to orbiting spacecraft. The present STDN can provide a maximum of approximately 30-percent coverage.

8. REPLACEMENT INFORMATION

By 1975, the STDN will contain approximately 15 earth-based T&DA stations located both in the U.S. and abroad. These stations operate primarily at S-band (i.e., 2025 to 2120 MHz and 2200 to 2300 MHz). Based on the current projected NASA mission model, it is estimated that the TDRSS will be able to replace (i.e., close down) approximately 7 of the 15 STDN stations. The remaining stations will continue to operate in the S-bands previously cited.

9. EQUIPMENT CHARACTERISTICS

Note

All the equipment characteristics listed in this section are based on the current design concept of the TDRSS. To identify many of the equipment characteristics requested in this section, a detailed design of the TDRSS is required; however, this level of detailed design is not available at this time. The characteristics given below are based on the definition phase studies of the TDRSS program. Consequently, these characteristics are tentative and subject to change as the detailed design of the TDRSS develops.

a. Transmitters

(1) Nomenclature. The TDRSS transmitters can be divided into two categories:

Transmitters on the TDRS.

Transmitters at the TDRSS ground terminal.

Each category contains several transmitters. Figure 8 illustrates the transmit operating frequencies and RF bandwidths for the transmitters on the TDRS, while figure 9 illustrates similar information for the transmitters at the TDRSS ground terminal.

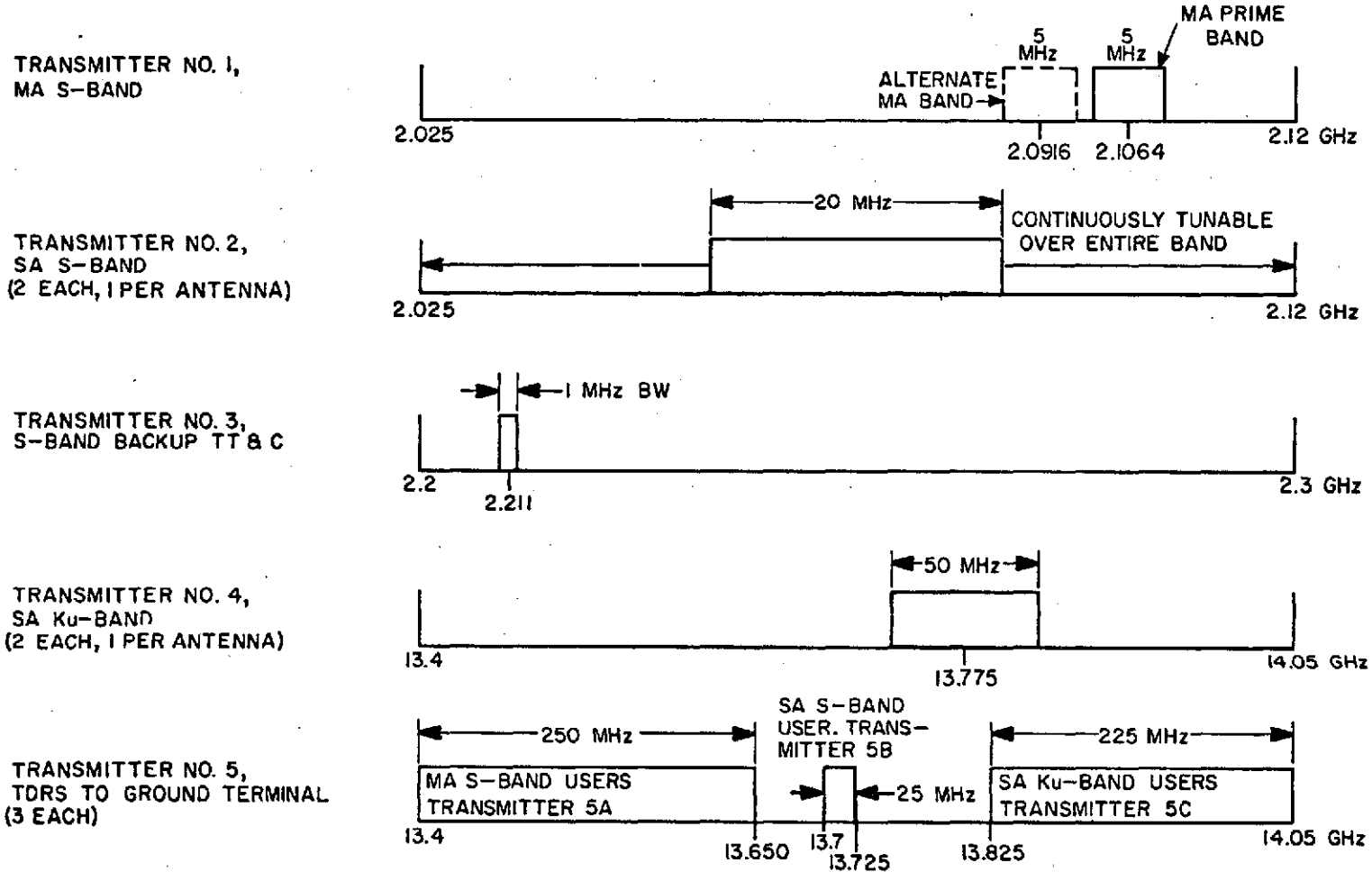


Figure 8. Transmitters on the TDRS, Operating Frequencies and RF Bandwidths

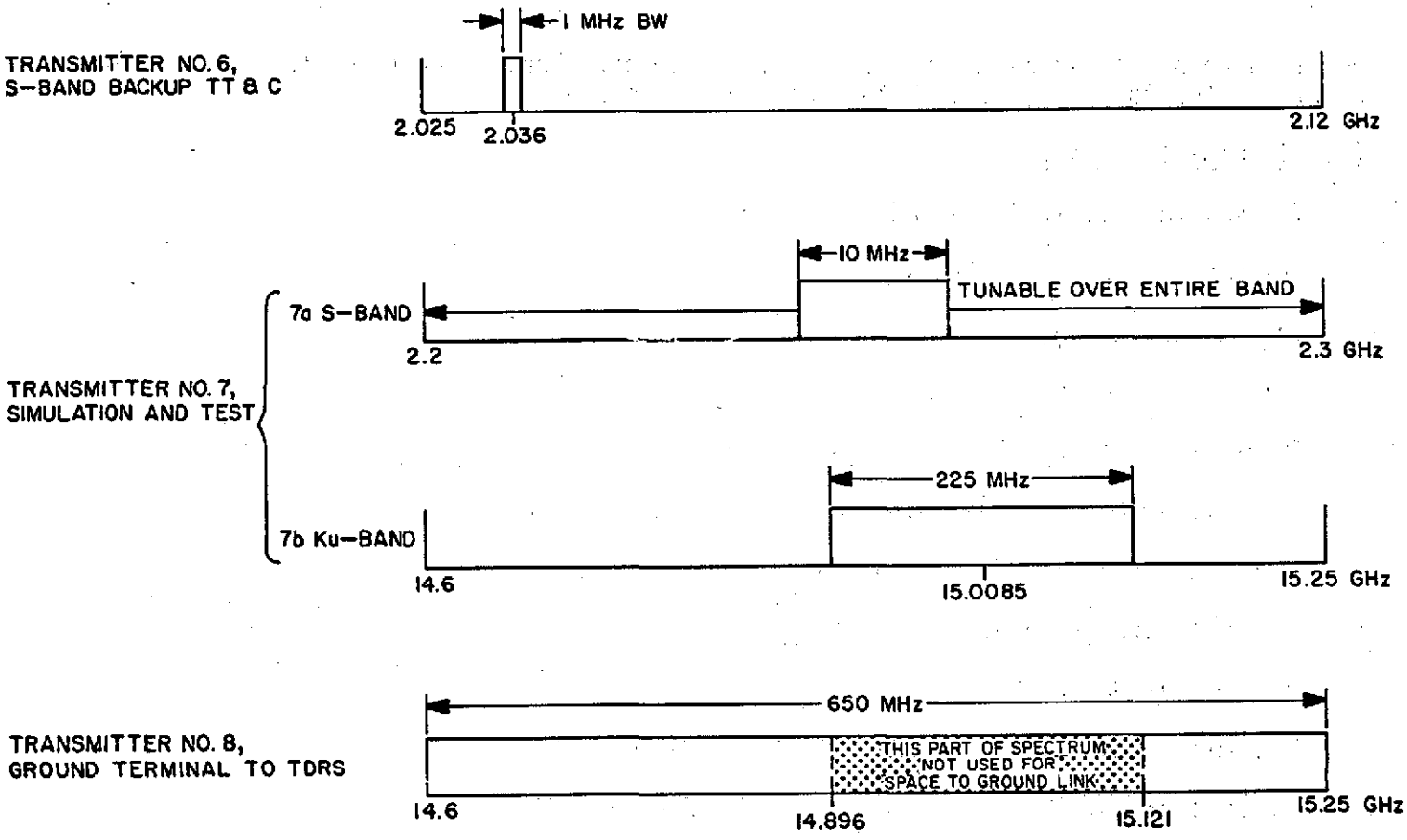


Figure 9. Transmitters at the TDRSS Ground Terminal, Operating Frequencies and RF Bandwidths

No standard nomenclature exists for the TDRSS transmitters; therefore, for the purpose of this document, the following nomenclature has been developed:

(a) Transmitters on TDRS

Transmitter No. 1, MA S-band.

Transmitter No. 2, SA S-band.

Transmitter No. 3, S-band Backup TT&C.

Transmitter No. 4, SA Ku-band.

Transmitter No. 5a, TDRS to Ground Terminal, MA.

Transmitter No. 5b, TDRS to Ground Terminal, SA S-band.

Transmitter No. 5c, TDRS to Ground Terminal, SA Ku-band.

(b) Transmitters at TDRSS Ground Terminal

Transmitter No. 6, S-band Backup TT&C.

Transmitter No. 7a, Simulation and Test, S-band.

Transmitter No. 7b, Simulation and Test, Ku-band.

Transmitter No. 8, Ground Terminal to TDRS.

Note

A transmitter is defined as a single power amplifier which transmits one or more FDM signals. See figures 5, 6, and 7 for the FDM signal structure (or spectrum utilization) for each transmitter.

(2) Manufacturer. All transmitters will be developed and fabricated by qualified industrial contractor(s) who will be selected on a competitive basis during the procurement cycle for the TDRSS.

(3) Type

(a) Transmitters on TDRS - Frequency translating repeater transmitters.

(b) Ground Terminal to TDRS - Fixed land-based station transmitter.

(4) Frequency Tuning Range

(a) Transmitters on TDRS

Transmitter No. 1, MA - Fixed center frequency at either 2106.4 MHz or 2092.6 MHz. At this time, the 2106.4-MHz center frequency is considered a first choice and the 2092.6 MHz an alternate. The final selection will be based on minimizing the RFI caused by earth-based emitters.

Transmitter No. 2, SA S-band - Continuously tunable across the 2025- to 2120-MHz band.

Transmitter No. 3, S-band Backup TT&C - Fixed at 2211-MHz center frequency.

Transmitter No. 4, SA Ku-band - Continuously tunable over 13.750 to 13.8 GHz.

Transmitter No. 5a, TDRS to Ground Terminal, MA - Fixed frequency.

Transmitter No. 5b, TDRS to Ground Terminal, SA S-band - Fixed frequency.

Transmitter No. 5c, TDRS to Ground Terminal, SA Ku-band - Fixed frequency.

(b) Transmitters at TDRSS Ground Terminal

Transmitter No. 6, S-band Backup TT&C - Fixed at 2036-MHz center frequency.

Transmitter No. 7a, Simulation and Test, S-band - Tunable over 2200 to 2300 MHz.

Transmitter No. 7b, Simulation and Test, Ku-band - Continuously tunable over 14.895- to 15.121-GHz band.

Transmitter No. 8, Ground Terminal to TDRS - Fixed frequency.

Note

The exact center frequencies for transmitters No. 3 and 6 above will be related by a $\frac{221}{240}$ ratio.

(5) Frequency Tolerance. .0001 ppm or better. All transmit frequencies will be generated from an atomic standard located at the TDRSS ground terminal.

(6) Power Output

Note

The numbers given below are the power levels out of the power amplifiers. The power output from the antennas will be approximately 2 dB lower due to the transmitter line losses, etc.

(a) Transmitters on TDRS

Transmitter No. 1, MA - 20 watts.

Transmitter No. 2, SA S-band

Low Power Mode - 14 watts.

High Power Mode - 26 watts.

Transmitter No. 3, S-band Backup TT&C - 5 to 15 watts.

Transmitter No. 4, SA Ku-band

Low Power Mode - 28 watts.

High Power Mode - 1.1 watts.

Transmitter No. 5a, TDRS to Ground Terminal*, MA - .14 to 1.4 watts.

Transmitter No. 5b, TDRS to Ground Terminal*, SA S-band - .2 to 2 watts.

Transmitter No. 5c, TDRS to Ground Terminal*, SA Ku-band - 2.5 to 25 watts.

(b) Transmitters at TDRSS Ground Terminal

Transmitter No. 6, S-band Backup TT&C - 100 watts.

Transmitter No. 7a, Simulation and Test, S-band - 10 to 100 watts.

Transmitter No. 7b, Simulation and Test, Ku-band - 10 to 25 watts.

Transmitter No. 8, Ground Terminal to TDRS* - 100 watts to 1 kW.

(7) Emission Designators. All transmissions will be F9, except in the 13.4- to 13.65-GHz band which will be A9.

(8) Baseband Bandwidth (FM Transmitters). No FM transmissions contemplated.

(9) Deviation Ratio (FM Transmitters). No FM transmissions contemplated.

(10) Pulse Characteristics. All transmissions will be digital signals.

(11) Other Modulation

(a) Transmitters on TDRS

Transmitter No. 1, MA S-band - One channel, Phase Shift Keyed (PSK) modulation using a Pseudorandom Noise (PRN) digital code. The chip rate of the PRN code is 3.0 Mch/s, one channel.

*The higher powers associated with the transmitters supporting the TDRS/ground link are used only to overcome rain attenuation.

Transmitter No. 2, SA S-band - One channel per 3.8-m antenna with PSK modulation using a PRN digital code. The PRN digital code is used to spread the spectral energy to meet the CCIR flux density guidelines. The chip rate of the PRN code is:

Normal Power Mode - 6.0 Mch/s.

High Power Mode - 11.0 Mch/s.

Transmitter No. 3, S-band Backup TT&C - One channel, PSK.

Transmitter No. 4, SA Ku-band - One channel per 3.8-m antenna, PSK modulation. The spectral distribution of energy will be spread sufficiently to meet the IRAC flux density guidelines, where appropriate. This will be accomplished by using a data rate which sufficiently spreads the transmitter energy to meet these guidelines or by using a PRN digital code. The approximate chip rate of the PRN code is:

Normal Power Mode - 3.5 Mch/s.

High Power Mode - 14.0 Mch/s.

Transmitter No. 5a, TDRS to Ground Terminal, MA - FDM, 42 channels.

Transmitter No. 5b, TDRS to Ground Terminal, SA S-band - FDM, 2 channels.

Transmitter No. 5c, TDRS to Ground Terminal, SA Ku-band - One channel.

(b) Transmitters at TDRSS Ground Terminal

Transmitter No. 6, S-band Backup TT&C - One channel, PSK.

Transmitter No. 7, Simulation and Test - One channel, PSK.

Transmitter No. 8, Ground Terminal to TDRS - FDM, 12 channels.

(12) Emission Fall-off Data, Emission Bandwidths. The following emission level values were theoretically calculated based on the sum (in dB) of the roll-off characteristics of the envelope of a $(\frac{\sin X}{X})$ spectrum, and the roll-off characteristics of a three-section Chebychev filter using a 5-percent (of center frequency) 3-dB bandwidth. The 3-dB bandwidth of the filter was, in general, selected to be 1.5 times the transmitted symbol (or chip) rate.

(a) Transmitters on TDRS

Transmitter No. 1, MA

3 dB - 2.4 MHz.

20 dB - 5.4 MHz.

60 dB - 14.4 MHz.

Transmitter No. 2, SA S-band

	Low Power	High Power
3 dB	4.8 MHz	8.8 MHz
20 dB	10.8 MHz	19.8 MHz
60 dB	28.8 MHz	52.8 MHz

Transmitter No. 3, S-band Backup TT&C - To be determined.

Transmitter No. 4, SA Ku-band

	Low Power	High Power
3 dB	2.8 MHz	11.2 MHz
20 dB	6.3 MHz	25.2 MHz
60 dB	16.8 MHz	67.2 MHz

Transmitter No. 5a, TDRS to Ground Terminal, MA - 42 channels FDM

3 dB - ≈ 250 MHz

20 dB
60 dB
} To be determined. The emission levels outside the 3-dB (250-MHz) bandwidth for the FDM signal (see figure 5) are caused by spillover from the end channel slots, and the internal products generated by the FDM multiplexer.

Transmitter No. 5b, TDRS to Ground Terminal, SA S-band - 2 channels FDM (assuming a 5-Mb/s data rate)

3 dB - < 25 MHz.

20 dB
60 dB
} To be determined. Comment for transmitter 5a applies.

Transmitter No. 5c, TDRS to Ground Terminal, SA Ku-band (assuming 150-Mb/s worst case data rate)

3 dB - 120 MHz.

20 dB - < 250 MHz.

60 dB - To be determined.

(b) Transmitters at the TDRSS Ground Terminal

Transmitter No. 6, S-band Backup TT&C - To be determined.

Transmitter No. 7a, Simulation and Test, S-band (assuming 1.5 Mb/s)

3 dB - 1.2 MHz.

20 dB - 2.7 MHz.

60 dB - 7.2 MHz.

Transmitter No. 7b, Simulation and Test, Ku-band (150-Mb/s maximum data rate, worst case)

3 dB - 120 MHz.

20 dB - < 250 MHz.

60 dB - To be determined.

Transmitter No. 8, Ground Terminal to TDRS

3 dB - ≈ 650 MHz.

20 dB
60 dB } To be determined. Comment for transmitter 5a applies.

(13) Harmonic Levels (dB of Attenuation). Equipment design characteristics are not sufficiently determined at this time to calculate harmonic levels.

(14) Spurious Levels (dB of Attenuation). To be determined.

(15) Special Circuitry. None.

(16) Output Tube Type

(a) Transmitters on TDRS

Transmitter No. 1, MA - Solid state.

Transmitter No. 2, SA S-band - Solid state (normal power), TWTA (high power).

Transmitter No. 3, S-band Backup TT&C - Solid state.

Transmitter No. 4, SA Ku-band - Solid state. (To be determined.)

Transmitter No. 5a, TDRS to Ground Terminal, MA - Solid state transistor.

Transmitter No. 5b, TDRS to Ground Terminal, SA S-band - Solid state transistor.

Transmitter No. 5c, TDRS to Ground Terminal, SA Ku-band - TWT.

(b) Transmitters at TDRSS Ground Terminal

Transmitter No. 6, S-band Backup TT&C - Solid state.

Transmitter No. 7a, Simulation and Test, S-band - Solid state.

Transmitter No. 7b, Simulation and Test, Ku-band - To be determined.

Transmitter No. 8, Ground Terminal to TDRS - TWT.

(17) Associated System(s) Nomenclature. None.

b. Receivers

(1) Nomenclature. The TDRSS receivers can be divided into two categories:

Receivers on the TDRS.

Receivers at the TDRSS ground terminal.

Each category contains several receivers. Figure 10 illustrates the receive operating frequencies and RF bandwidths for the receivers on the TDRS, while figure 11 illustrates similar information for the receivers at the TDRSS ground terminal.

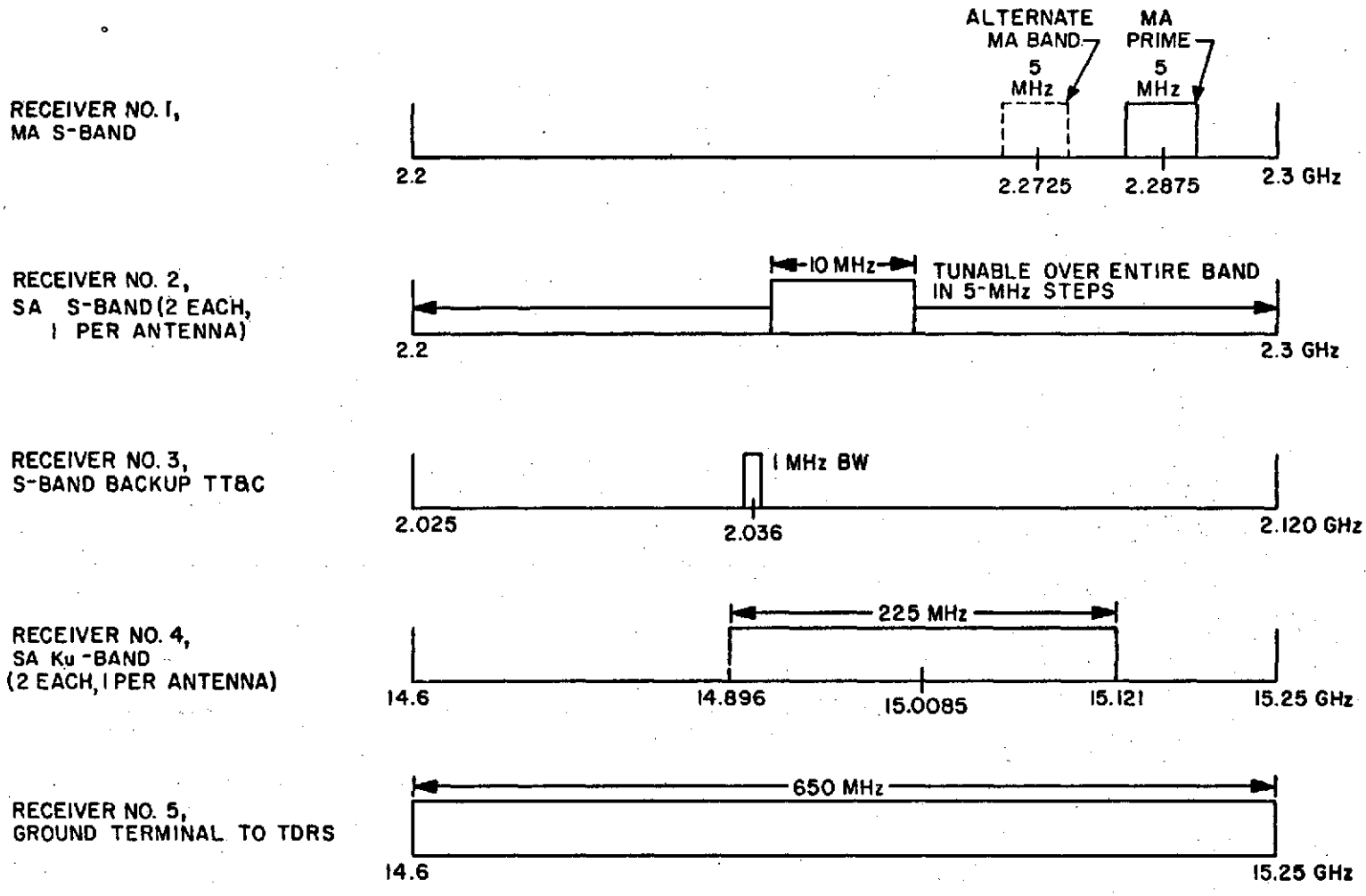


Figure 10. Receivers on the TDRS, Operating Frequencies and RF Bandwidths

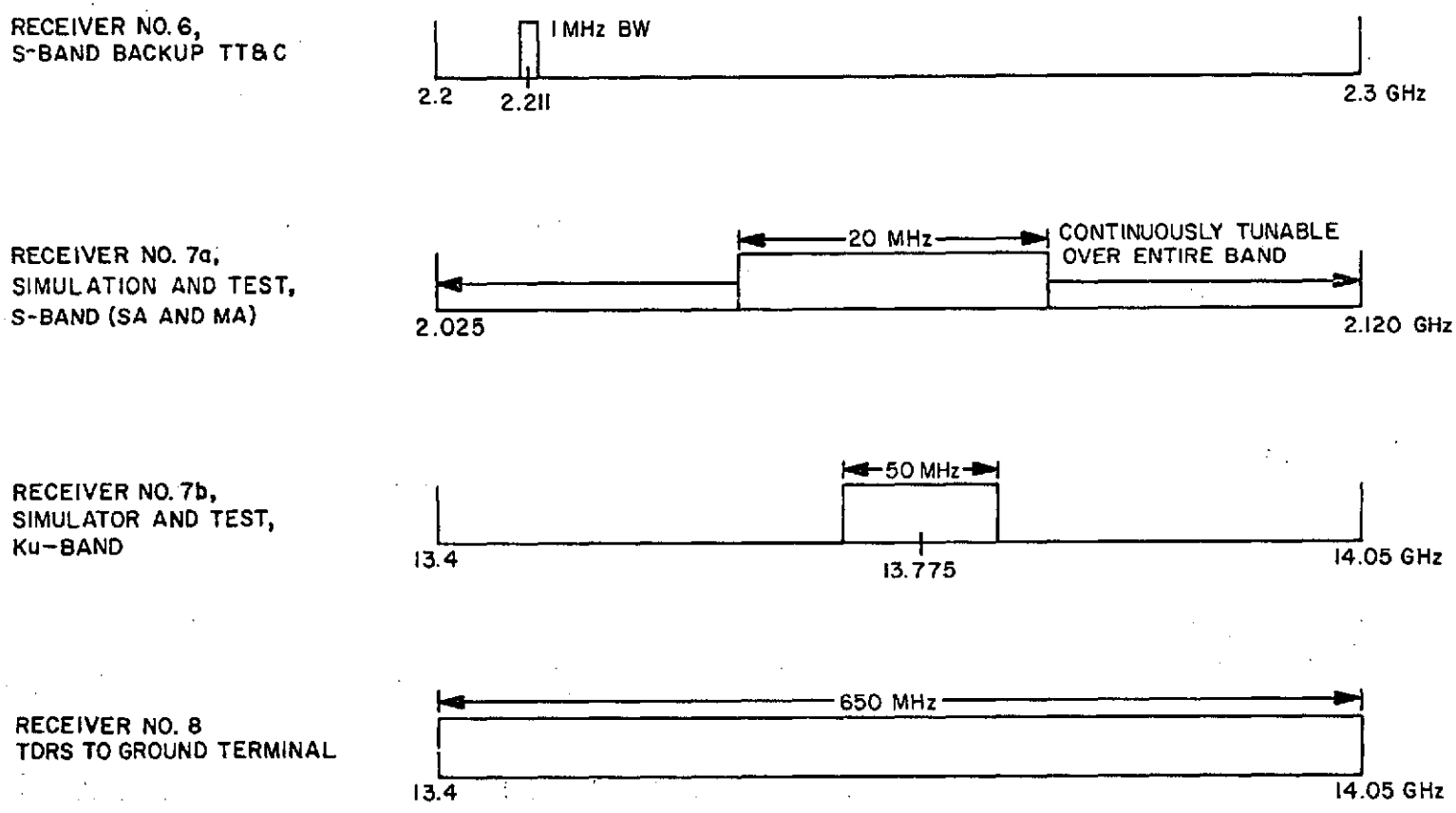


Figure 11. Receivers at the TDRSS Ground Terminal, Operating Frequencies and RF Bandwidths

No standard nomenclature exists for the TDRSS receivers; therefore, for the purpose of this document, the following nomenclature has been developed:

(a) Receivers on the TDRS

Receiver No. 1, MA S-band.

Receiver No. 2, SA S-band.

Receiver No. 3, S-band Backup TT&C.

Receiver No. 4, SA Ku-band.

Receiver No. 5, Ground Terminal to TDRS, Ku-band.

(b) Receivers at the TDRS Ground Terminal

Receiver No. 6, S-band Backup TT&C.

Receiver No. 7a, Simulation and Test, S-band.

Receiver No. 7b, Simulation and Test, Ku-band.

Receiver No. 8, TDRS to Ground Terminal, Ku-band.

(2) Manufacturer. All receiving equipment will be developed and fabricated by qualified industrial contractor(s) who will be selected on a competitive basis during the procurement cycle for the TDRSS.

(3) Type. All receivers are dual- and triple-conversion superheterodyne.

(4) Frequency Tuning Range

(a) Receivers on TDRS

Receiver No. 1, MA - Fixed center frequency at either 2287.5 or 2272.5 MHz. At this time, the 2287.5-MHz center frequency is considered a first choice and the 2272.5 MHz an alternate. The final selection will be based on minimizing the RFI caused by earth-based emitters.

Receiver No. 2, SA S-band - Tunable across 2.2 to 2.3 GHz in 5-MHz steps.

Receiver No. 3, S-band Backup TT&C - Fixed at 2036-MHz center frequency.

Receiver No. 4, SA Ku-band - Fixed center frequencies at 14.94, 15.0085, and 15.077 GHz.

Receiver No. 5, Ground Terminal to TDRS - Fixed frequency, 650-MHz RF bandwidth, from 14.6 to 15.25 GHz.

(b) Receivers at the TDRSS Ground Terminal

Receiver No. 6, S-band Backup TT&C - Fixed at 2036-MHz center frequency.

Receiver No. 7a, Simulation and Test, S-band - Continuously tunable over 2025- to 2120-MHz band.

Receiver No. 7b, Simulation and Test, Ku-band - Continuously tunable over 13.750 to 13.8 GHz.

Receiver No. 8, TDRS to Ground Terminal - Fixed frequency, 650-MHz RF bandwidth from 13.4 to 14.05 GHz.

(5) Emission Designators. F9.

(6) Sensitivity

Note

The values given below are the receiver temperatures referenced to the receiver input. These values do not include the noise temperature due to line losses and the antenna.

(a) Receivers on TDRS

Receiver No. 1, MA - 250°K.

Receiver No. 2, SA S-band - 100°K.

Receiver No. 3, S-band Backup TT&C - 250 to 750°K.

Receiver No. 4, SA Ku-band - 160°K.

Receiver No. 5, Ground Terminal to TDRS - 1000°K.

(b) Receivers at the TDRSS Ground Terminal

Receiver No. 6, S-band Backup TT&C - 250 to 750°K.

Receiver No. 7a, Simulation and Test, S-band - 250°K.

Receiver No. 7b, Simulation and Test, Ku-band - 150°K.

Receiver No. 8, TDRS to Ground Terminal - 150 to 350°K.

(7) Image Rejection. To be determined.

(8) RF Selectivity Data. To be determined.

(9) Spurious Response Rejection. To be determined.

(10) First IF Frequency. Exact values are yet to be determined. In general, the first IF for the S-band receivers will be in the 200- to 400-MHz range. The first IF for the Ku-band receivers will be in the 2000- to 3000-MHz range.

(11) Local Oscillator Tuning Position. To be determined.

(12) Overall IF Selectivity. To be determined.

(13) Other RF/IF Information. None.

(14) Baseband Bandwidth. No FM signals contemplated.

(15) Other Modulation Information

(a) Receivers on TDRS

Receiver No. 1, MA - One channel, PSK; PRN chip rate, 3.0 Mch/s.

Receiver No. 2, SA S-band - One channel per 3.8-meter antenna, PSK; PRN chip rate, 1.5 to 6 Mch/s.

Receiver No. 3, S-band Backup TT&C - One channel, PSK.

Receiver No. 4, SA Ku-band - One channel per 3.8-meter antenna, PSK; PRN chip rate, 1.5 to 15 Mch/s.

Receiver No. 5, Ground Terminal to TDRS - Four-channel FDM.

(b) Receivers at the TDRSS Ground Terminal

Receiver No. 6, S-band Backup TT&C - One channel, PSK.

Receiver No. 7a, Simulation and Test, S-band - One channel, PSK.

Receiver No. 7b, Simulation and Test, Ku-band - One channel, PSK.

Receiver No. 8, TDRS to Ground Terminal - Three-channel FDM.

(16) Special Circuitry. None.

(17) Associated System(s) Nomenclature. None.

c. Antennas

(1) Nomenclature. The TDRSS antennas can be divided into two categories:

Antennas on the TDRS.

Antennas located at the TDRSS ground terminal.

Each category contains several antennas. No standard nomenclature exists for the TDRSS antennas; therefore, for the purpose of this document, the following nomenclature has been developed:

(a) Antennas on TDRS

Antenna No. 1a, MA Transmit.

Antenna No. 1b, MA Phased Array.

Antenna No. 2, SA S- and Ku-bands (2 each).

Antenna No. 3, S-band Backup TT&C.

Antenna No. 4, Ground Link Antenna.

(b) Antennas at the TDRSS Ground Terminal

Antenna No. 5, S-band Backup TT&C.

Antenna No. 6, Simulation and Test (S- and Ku-bands).

Antenna No. 7, Ground Terminal Antennas (3 each).

(2) Manufacturer. Radiation, Inc. for the ground link and SA antennas on the TDRS. However, all TDRSS antennas will be fabricated by qualified industrial contractor(s) who will be selected on a competitive basis during the procurement cycle for the TDRSS.

(3) Antenna Type

(a) Antennas on TDRS

Antenna No. 1a, MA Transmit - 9-element S-band phased array. A 1.5λ helix is being considered for the element.

Antenna No. 1b, MA Receive Array - 30- to 40-element S-band phased array. A 1.5λ helix is being considered for the element.

Antenna No. 2, SA (2 each) - 3.8-meter (12.5-foot) diameter parabolic, unfurlable reflector.

Antenna No. 3, S-band Backup TT&C - Helix.

Antenna No. 4, Ground Link Antenna - 1.8-meter (6-foot) diameter parabolic, unfurlable reflector.

(b) Antennas at TDRSS Ground Terminal

Antenna No. 5, S-band Backup TT&C - To be determined.

Antenna No. 6, Simulation and Test (S- and Ku-bands) - Parabolic reflector.

Antenna No. 7, Ground Terminal Antenna (3 each) - (18-meter) parabolic reflector.

(4) Frequency Range

(a) Antennas on TDRS

Antenna No. 1a, MA Transmit - 2025 to 2120 MHz.

Antenna No. 1b, MA Phased Array - 2200 to 2300 MHz.

Antenna No. 2, SA 2025 to 2300 MHz and 13.4 to 15.25 GHz.

Antenna No. 3, S-band Backup TT&C - 2025 to 2300 MHz.

Antenna No. 4, Ground Link Antenna - 13.4 to 15.25 GHz.

(b) Antennas at TDRSS Ground Terminal

Antenna No. 5, S-band Backup TT&C - 2025 to 2300 MHz.

Antenna No. 6, Simulation and Test - 2025 to 2300 MHz and 13.4 to 15.25 GHz.

Antenna No. 7, Ground Terminal Antenna - 13.4 to 15.25 GHz.

(5) Fundamental Gain

Note

Values given below are on-axis peak gains @ the transmit frequency, except for the MA phased array.

(a) Antennas on TDRS

Antenna No. 1a, MA Transmit - 23 dB.

Antenna No. 1b, MA Phased Array - 31 dB (peak receive gain).

Antenna No. 2a, S-band - 35.4 dB.

Antenna No. 2b, Ku-band - 52.0 dB.

Antenna No. 3, S-band Backup TT&C - 0 to 11 dB (exact value to be determined).

Antenna No. 4, Ground Link Antenna - 45.8 dB (approximate).

(b) Antennas at the TDRSS Ground Terminal

Antenna No. 5, S-band Backup TT&C - To be determined.

Antenna No. 6a, Simulation and Test, S-band - 20 to 35 dB.

Antenna No. 6b, Simulation and Test, Ku-band - 30 to 50 dB.

} Exact values are yet to be determined.

Antenna No. 7, Ground Terminal Antenna - 66.4 dB (approximate).

(6) 3-dB Beamwidths

(a) Antennas on TDRS

Antenna No. 1a, MA Transmit - 9^{o}.

Antenna No. 1b, MA Phased Array - 5^{o}.

Antenna No. 2a, SA S-band - 3^{o}.

Antenna No. 2b, SA Ku-band - $.4^{o}$.

Antenna No. 3, S-band Backup TT&C - To be determined.

Antenna No. 4, Ground Link Antenna - $.8^{o}$.

(b) Antennas at the TDRSS Ground Terminal

Antenna No. 5, S-band Backup TT&C - To be determined.

Antenna No. 6a, Simulation and Test, S-band - 3 to 20^{o}.

Antenna No. 6b, Simulation and Test, Ku-band - .5 to 5^{o}.

Antenna No. 7, Ground Terminal Antenna - $.08^{o}$.

(7) Antenna Physical Characteristics

(a) Antennas on TDRS

Antenna No. 1a, MA Transmit - To be determined.

Antenna No. 1b, MA Phased Array - Square, $\approx$ 6 feet on each side.

Antenna No. 2, SA - 3.8-meter (12.5-foot) diameter reflector.

Antenna No. 3, S-band Backup TT&C - To be determined.

Antenna No. 4, Ground Link Antenna - 1.8-meter (6-foot) diameter reflector.

(b) Antennas at the TDRSS Ground Terminal

Antenna No. 5, S-band Backup TT&C - To be determined.

Antenna No. 6, Simulation and Test - 2-foot to 10-foot diameter reflector or equivalent.

Antenna No. 7, Ground Terminal Antenna - 18.3-meter (60-foot) diameter reflector.

(8) Polarization

(a) Antennas on TDRS

Antenna No. 1a, MA Transmit - Right Circular Polarization (RCP).

Antenna No. 1b, MA Phased Array - RCP.

Antenna No. 2, SA - RCP.

Antenna No. 3, S-band Backup TT&C - To be determined.

Antenna No. 4, Ground Link Antenna - Left Circular Polarization (LCP).

(b) Antennas at the TDRSS Ground Terminal

Antenna No. 5, S-band Backup TT&C - To be determined.

Antenna No. 6, Simulation and Test - RCP.

Antenna No. 7, Ground Terminal Antenna - LCP.

(9) Antenna Scan Characteristics (Total Scan Angle/Scan Slew Rate)

(a) Antennas on TDRS

Antenna No. 1, MA - N/A.

Antenna No. 2, SA - $62^{o}/1^{o}$/sec north-south axis, $45^{o}/1^{o}$/sec east-west axis.

Antenna No. 3, S-band Backup TT&C - N/A.

Antenna No. 4, Ground Link Antenna - N/A.

(b) Antennas at the TDRSS Ground Terminal

Antenna No. 5, S-band Backup TT&C - To be determined.

Antenna No. 6, Simulation and Test - 180^{o}/to be determined.

Antenna No. 7, Ground Terminal Antenna - 180^{o}/to be determined.

(10) Other Pattern Data. None.

(11) Associated System(s) Nomenclature. None.

10. RELATED ANALYSIS DATA

a. Rockwell International, Definition Phase Study, Final Report.

b. Hughes Aircraft, Definition Phase Study, Final Report.

c. Electromagnetic Systems Laboratories Reports.