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FUNCTIONAL DESCRIPTION OF THE APOLLO UNIFIED S-BAND DATA TRANSMISSION LINKS

BY

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SUMMARY

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This document contains a functional description of the Data Transmission Links required at several Apollo S-Band Telecommunications and Tracking Stations. Two (2) data transmission systems will be discussed in detail. The first is a microwave system which will be installed at the Madrid, Canberra and Goldstone stations. The other is an RF Coaxial cable system which will be installed at the Bermuda, Hawaii and Corpus Christi stations.

author

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1.0 INTRODUCTION

1.1 Objective of the Report

At the present time, documentation exists on the Apollo Unified S-Band Telecommunication and Tracking System which provides a reader with a complete and comprehensive functional description of the basic system in its entirety.[1] Documentation also exists on many of the individual subsystems of the Unified S-Band (USB) System.[2] However, no such documentation presently exists on the Data Transmission Links required at several Apollo Tracking stations. This report is intended to provide this documentation for the Data Transmission Link in its present state of development. The development, at present, is far enough along to indicate that the difference between the system description given in this report and the final system configuration will be minor.

1.2 History and Function of the System

The world-wide network of Apollo telecommunication and Tracking stations in addition to an intricate communication network and Control Center comprise what is called the Manned Space Flight Network (MSFN). The individual stations are sometimes referred to as MSFN sites. Those stations utilizing 85-foot antennae are referred to as MSFN 85-foot sites. Those utilizing 30-foot antennae are referred to as MSFN 30-foot sites. Similarly, Jet Propulsion Laboratory (JPL) has a world-wide network of deep space telecommunication and tracking stations called the Deep Space Network (DSN). The DSN is comprised of seven (7) deep space stations called the Deep Space Instrumentation Facilities (DSIF) and an operations control center.

To support the Apollo mission during the trans-lunar and lunar phase, the National Aeronautics and Space Administration (NASA) is installing three (3) MSFN 85-foot stations located at Madrid, Canberra, and Goldstone. Also at each of these locations, JPL has in operation a DSIF site equipped with an 85-foot diameter parabolic antenna. In the early stages of the Apollo program, it was agreed that these three (3) DSIF sites would be used to provide back-up support to the MSFN 85-foot sites. At that time the back-up support function of the DSIF sites and hence the required equipment to provide this support could

[1] John H. Painter and George Hondros — Unified S-Band Telecommunications techniques for Apollo, Volume I, NASA TN D-2208.

[2] Apollo Unified S-Band Technical Conference. July 14-15, 1965, NASA SP-87.

not be specifically defined. However, it was known that some sort of Data Transmission Link would be required to relay signals between the DSIF and the MSFN sites. In 1965 results of studies conducted on the network implementation and management revealed that it would be most efficient to utilize the DSIF sites as extensions to the MSFN 85-foot sites. This meant that the data processing equipment located at the MSFN sites would be utilized to support S-Band Transmitting/Receiving equipment at the DSIF sites. As a result the signals to be relayed between these sites were defined and thus the configuration of the data link to transmit these signals was initiated.

For this purpose two (2) data transmission systems were studied, an RF cable system and a Microwave system. Due to the relatively long distances between the sites (5 to 14 miles) a cable system would require several repeater amplifiers. It was felt that the repeater amplifiers would cause reliability and maintenance problems. On the other hand the reliability of a microwave link for the transmission of data signals over these distances is quite good. As a result a microwave link was selected for the 85-foot sites.

At the 30-foot Bermuda, Hawaii and Corpus Christi sites, the ground station consists of two (2) buildings separated by several thousand feet (1500 to 6300 feet). One building called the S-Band building contains the Unified S-Band Transmitting/Receiving equipment and the other, called the Telemetry and Control (T&C) building contains the data demodulators and the data processing equipment. For these sites a data transmission link must be installed to transfer up-link and down-link data signals from one building to the other. Due to the relatively short distance between buildings repeater amplifiers would not be required for a cable system. Thus, an RF Coaxial cable data transmission link was selected.

Table I lists the locations of the stations requiring a data transmission link, the distances data is to be relayed and the type of transmission link at each site. Also listed in Table I are the cable dimensions for the cable links. A 1 5/8" diameter Coaxial cable will be utilized at the Hawaii Station rather than the 7/8" cable as at the Bermuda and Corpus Christi stations because of the additional losses in the longer run (6300 feet).

TABLE I

Station Location	Distance Between Buildings	Type of Data Transmission Link
Madrid	6 miles	Microwave
Canberra	14 miles	Microwave
Goldstone	5 miles	Microwave
Bermuda	1500 feet	Coaxial Cable-7/8" Dia.
Hawaii	6300 feet	Coaxial Cable-1 5/8" Dia.
Corpus Christi	2700 feet	Coaxial Cable-7/8" Dia.

2.0 THE BASIC MICROWAVE LINK

At the 85-foot stations all of the up-link signals (signals transmitted from ground to spacecraft) originate at the MSFN site. All of these signals, with the exception of Range Code, must be transferred to the S-Band equipment at the DSIF site and transmitted to the Apollo spacecraft during certain phases of the Apollo mission. (Range Code transfer is not necessary since the ranging system at the DSIF site will be used). In addition to the up-link signals some of the information function on the down-link telemetry must be decommutated at the MSFN site and relayed back to the DSIF site. These information functions; spacecraft automatic gain control (AGC) and static phase error, are used to indicate the operational status of the spacecraft receiver.

A similar situation exists for the down-link signals (signals transmitted from spacecraft to ground). All the down-link signals, with the exception of turn-around range code, must be relayed from the DSIF to the MSFN site for demodulation and processing.

Figure 1 is a highly simplified block diagram which shows how the microwave link integrates with the equipment at the DSIF and MSFN sites. This figure applies to the three (3) 85-foot stations at Madrid, Canberra and Goldstone since these stations are all identical. Also shown in this figure are the signals and their form (baseband, etc.) that are transmitted via the microwave links.

A simplified block diagram of the basic microwave link is shown in Figure 2. As indicated in this figure as well as in Figure 1 all the data signals will be transferred between the DSIF and the MSFN sites on six (6) radio frequency (RF) channels. Each RF channel contains a separate transmitter and receiver. The outputs of the microwave transmitters at each site is summed before propagated. At the receiving end the receivers are selectively tuned to pass specific RF channels. Thus only one directional (parabolic) antenna is required at each site. Due to the terrain between sites passive repeaters or reflectors will be required (one at each station).

Table II lists the signals transmitted on each RF channel as well as the transmitting direction of each channel. (This information is also indicated in Figure 1). Not all of the signals transmitted in the DSIF to MSFN direction are down-link signals. The exceptions are up-data verification, up-voice verification and the 24 voice channels. However, since the down-link signals are the more important ones, all of the signals transmitted in this direction are usually referred to as down-link signals. Similarly, all other signals relayed in the MSFN to the DSIF direction are referred to as the up-link signals.

TABLE II

MICROWAVE LINK DATA SIGNALS

RF Channel	Data Signals	
1	50 Mc IF #1	
2	50 MC IF #2	
3	PM Video #1 and 2 Up-Data Verification #1 and 2 Up-Voice Verification #1 and 2 24 Voice Channels	DSIF to MSFN Down-Link Signals
4	Frequency Diversity for Channel 3	
5	Up-Data #1 and 2 Up-Voice #1 and 2 S/C Static Phase Error #1 S/C AGC #1 24 Voice Channels	MSFN to DSIF Up-Link Signals
6	Frequency Diversity for Channel 5	

Since the microwave link is not in the primary path of information flow between the MSFN ground site and the Apollo spacecraft, (except in the lunar stay phase) a complete backup link is not required. However, as indicated in Table II and in Figure 1, frequency diversity transmission will be used on some of the signals in order to improve the propagation and equipment reliability for these signals. Also only two (2) each of the four (4) 50 Mc IF and PM video signals will be relayed from the DSIF to the MSFN site.

3.0 THE BASIC CABLE LINK

As stated in Section 1.2 the 30-foot sites at Bermuda, Hawaii and Corpus Christi consist of two (2) buildings, the S-Band building and the Telemetry and Control (T&C) building, which are separated by several thousand feet. All the up-link signals, with the exception of range code, originate in the T&C building. These signals must be transferred to the equipment in the S-Band building for transmission to the Apollo spacecraft. In addition to the up-link signals, some of the information functions transmitted on the down-link telemetry must be decommutated in the T&C building and transferred back to the S-Band building. As in the case of the microwave link these information functions; spacecraft AGC and static phase error, are used as operational status indications of the spacecraft receiver.

A similar situation exists for the down-link signals. The down-link signals with the exception of turnaround ranging code must be relayed from the receivers in the S-Band building to the equipment in the T&C building for demodulation and processing.

Figure 3 is a highly simplified block diagram which shows how the cable link integrates with the equipment at the Bermuda and Corpus Christi stations. These stations, so called "single stations", utilize a single 30 foot parabolic antenna, a single power amplifier and two (2) receivers. Figure 4 shows the same for Hawaii, a so-called "dual station". This station utilizes a single 30 foot parabolic antenna, a single power amplifier and four (4) receivers. The signals to be relayed via the cable link and their form (baseband, etc.) are also shown in these figures. The RF cable transmission system utilizes frequency division multiplex techniques for the transmission of the various data signals between buildings.

Table III lists the signals and quantities to be transmitted on the cable link at each of the 30-foot sites. This list differs slightly from the corresponding list for the microwave link given in Table II. The difference is that no voice communications will be relayed on the cable link. Ordinary telephone wire will be used for this purpose at the 30-foot sites.

A simplified block diagram of a basic RF cable link for a single 30-foot station is shown in Figure 5. This figure also applies to the dual 30-foot station at Hawaii except that the number of 50 Mc IF converters, modulators and demodulators must be doubled. As indicated in this figure all of the signals will be

TABLE III

CATV LINK DATA SIGNALS

T&C to S-Band Building		
	BERMUDA CORPUS CHRISTI	HAWAII
50 Mc IF Signals	2	4
PM Video Signals	2	4
Up-Voice Verification	1	2
Up-Data Verification	1	2
S-Band to T&C Building		
Up-Voice	1	2
Up-Data	1	2
S/C AGC	1	2
S/C Static Phase Error	1	2

simultaneously transmitted in both directions on one cable. Simultaneous transmission in both directions is accomplished by using splitting filters on both ends of the cable which divide the cable spectrum into two (2) parts as shown in Figure 6. The low frequency portion of the spectrum is used to transmit the up-link data signals from the T&C building to the S-Band building. The upper half is occupied by the down-link signals transmitted from the S-Band building to the T&C building. Each input signal is first converted or AM modulated to a higher frequency and summed together in the combiner prior to transmission over the cable. The spectral position of the converted signals were chosen to minimize signal distortion and interference. At the receiving end the signals are stripped out by splitting (bandpass) filters and down converted or demodulated to their original form.

Since the cable link is in the primary path of information flow between ground and spacecraft, a backup cable transmission link will be installed at each split site. In the event of an equipment or cable failure in one cable link the data can be switched to the backup link by a single control switch. Coaxial relays will be utilized to select the primary or backup cable link. Although a signal patch panel is provided at the terminal ends of the cable equipment for selective connecting into the S-Band equipment, repatching will not be necessary when switching from the primary to the backup link or vice versa.

4.0 DETAILED SYSTEM DESCRIPTION

4.1 Microwave Link

The microwave equipment will be described in detail by discussing the individual equipment in the signal flow path from input to output for each signal transmitted on the microwave link. As a result, the following section is divided into two parts. The first part discusses the microwave equipment related to the down-link signals transmitted from the DSIF to MSFN site. The second part deals with the equipment related to the up-link signals transmitted from the MSFN to DSIF site. For this discussion, Figure 7, which shows a block diagram of the microwave equipment, should be referred to from time to time.

4.1.1 Down-link Signals

4.1.1.1 50 Mc i.f. Signals. The 50 Mc i.f. signal contains all of the information functions transmitted from the spacecraft on the down link carrier. These information functions are: Television, Telemetry, primary voice, biomedical data, backup voice, and emergency key.

The 50 Mc i.f. signals from the S-band receiving equipment are converted to 70 Mc, passed through an AGC amplifier and then applied to channels 1 and 2 of the microwave rf transmitting subsystem. Since the amplitude of the 50 Mc i.f. is expected to vary over a considerable range, the AGC amplifier is used to maintain the power output of the transmitting TWT relatively constant at five (5) watts. The 50 to 70 Mc conversion is done to facilitate the use of standard microwave transmitting equipment. A detailed block diagram of a microwave channel for the 50 Mc i.f. signals is shown in Figure 8.

The 70 Mc signal is up converted by a microwave varactor diode which effectively modulates the 70 Mc signal onto the rf carrier (carrier frequence range 7.125 to 8.4 GC). The output of the up converter is then applied to the TWT for power amplification. The rf energy from the TWT is then combined with the rf energy from all of the other rf channels in the transmitter waveguide and propagated to the DSIF site.

At the receiving end, the desired signal is selected by an 8-cell waveguide filter. This signal is then mixed with the output of a local oscillator microwave source and translated to 70 Mc for amplification and detection. The preamplifier contains filters for selectivity and phase equalizers to reduce intermodulation noise. The output from the 70 Mc i.f. amplifier is then fed to the 70 Mc to 50 Mc converter. The 50 Mc converter output, identical in form to the 50 Mc i.f. signal from the S-band receiver, is then fed into the S-band Signal Data Demodulators.

The output of the 70 Mc i.f. amplifier is also down converted to 12 Mc and fed to an automatic frequency control unit comprised of the limiter and discriminator shown in Figure 8. The DC output from the discriminator is used as an error voltage for L. O. automatic frequency control in the receiver.

4.1.1.2 PM Video Signals. The PM video signal contains all of the information functions transmitted from the spacecraft on the PM down-link carrier. These information functions are: turn-around range code, telemetry, primary voice, biomedical data, backup voice and emergency key.

The microwave link picks up the PM video signal at the output of the S-band receiver. This signal is amplified and then split into two signals by two passband filters. The first filter, which has a passband from 500 kc to 1.5 Mc, is used to strip out the telemetry and biomedical/voice subcarriers. The second filter is low pass to approximately 4 kc and is used to strip out backup voice. The stripped out backup voice signal is fed to the voice multiplexing equipment and transmitted to the MSFN site on one of the 24 voice communication channels. Two voice channels are used since there are two backup voice signals.

The other signal (stripped out telemetry and biomedical/voice signal - also referred to as the PM video signal) is fed into a combiner where it is summed with the second PM video signal and other down-link signals. As shown in Figure 7, the second PM video signal (PM video #2) is first up-converted to 2.5 Mc center frequency before being combined with PM video #1.

The spectral position of the two PM video signals after combining is shown in Figure 9. Figure 9 also shows the spectral position of the other signals in the baseband spectrum of microwave channels 3 and 4 (combiner output). The 8.5 Mc spectral line is a pilot tone used for diversity selection in the microwave receiver. This tone is transmitted only on RF channels 3 through 6.

The output from the combiner is FM modulated onto two rf carriers and transmitted to the MSFN site. As previously stated, two microwave transmitting channels are used for frequency diversity transmission. The power output from each transmitter is one (1) watt.

At the receiving end, the transmitter signals are down converted to baseband by two identical receivers and fed into a switch combiner. The signals from both receivers are identical except for possibly the signal-to-noise ratios which may differ due to the propagation peculiarities of each rf channel. The function of the switch combiner is to select the best of the two signals based on signal-to-noise ratio of the received 8.5 Mc pilot tone. The selected signal is then amplified and fed to the demultiplexing equipment where the individual signals are stripped out and fed to the S-band processing equipment.

PM video #1 is stripped out by a 500 kc to 1.5 mc band pass filter, summed with the back/up voice #1 signal from the voice demultiplexing equipment, amplified and fed to the S-band data demodulator. PM video #2 and back/up voice #2 are handled in an identical manner except that PM video #2 is first down converted prior to summing with backup voice #2.

At the input to the microwave link, the PM video from the S-band receiver was split into two signals and transmitted as such. This was done to eliminate a portion of the PM video spectrum between 4 kc and 500 kc and thereby remove a considerable amount of undesired noise and range code power. At the receiving end, these signals must be recombined since the S-band data demodulators can only accept the PM video as one signal.

4.1.1.3. UP-Data Verification. The microwave link picks up the up-data verification signal at an auxiliary output from the verification receiver. This output connects into the verification receiver just before the receiver's baseband demodulator (second i.f.). The output signal at this point is the sum of the 70 kc and 30 kc up-data and up-voice subcarriers respectively.

As shown in Figure 7, the 70 kc up-data verification signal is stripped out from the composite 70 kc + 30 kc signal by a band pass filter. This signal is then up converted, summed with the other down-link signals in the combiner, and transmitted to the MSFN site. The spectral positions of the two up-data verification signals are shown in Figure 9.

At the receiving end, the up-data verification signals are stripped out, down converted to 70 kc, and converted to baseband by the 70 kc FM discriminators. These outputs are then fed to the S-Band up-data buffer where it is compared with the up-data from the 642B computer for verification.

4.1.1.4 Up-Voice Verification. The microwave link picks up the two up-voice verification signals in baseband form from the two (2) S-band verification receivers. These signals are transmitted to the MSFN site on two of the 24 voice channels.

4.1.1.5 Voice Channels. A total of 24 two-way voice channels will be available for communications between the MSFN and DSIF sites. These, of course, are required for the coordinated operation of the two sites during the Apollo mission. The spectral position of the 24 voice channels in the DSIF to MSFN direction (24 one-way voice channels) is shown on the baseband spectrum for microwave channels 3 and 4 in Figure 9. Actually a spectral bandwidth for 60 one-way voice channels is shown in this Figure. This means that the equipment will be wired to handle 60 voice channels, however, electronics will be supplied for only

24 channels. Thus, depending upon future requirements, the microwave link can be expanded to handle up to 60 voice channels by merely purchasing additional voice multiplexing and demultiplexing plug-in modules.

The voice equipment uses frequency division multiplexing, single sideband, suppressed carrier techniques. The bandwidth of each channel and the separation between the center frequency of adjacent channels is 3 kc and 4 kc respectively. In order to demodulate at the receiving end, the carrier frequency which was suppressed at the transmit end must be reinjected into each voice channel. For this purpose, a 308 kc pilot tone is transmitted with the multiplexed voice signals. At the receiving end this pilot tone is stripped out and used to synchronize the voice channel carrier generating equipment.

It was previously stated that the two backup voice signals and the two up-voice verification signals are relayed from the DSIF to MSFN site on four of the 24 voice channels. Also as shown in Figure 7, a fifth voice channel is used for equipment status and fault reports. As a result, only 19 of the 24 voice channels can be used for one-way voice communications from the DSIF to MSFN site.

4.1.1.6 Equipment Status and Fault Reports. As indicated in Figure 7, one of the 24 voice channels is used to relay to the MSFN site the status and condition of the S-band and microwave equipment at the DSIF site. Up to 80 on-off or relay type control functions can be relayed on the one voice channel. Approximately twenty (20) of these 80 control functions will be used to monitor the status and condition of the microwave equipment at the JPL site. Time division multiplexing is used to transmit these functions on the one voice channel.

At the receiving end (MSFN site) the time multiplexed signal is used to control 80 lamps and operate 80 relays which are located in the microwave terminal equipment. The relays are used to operate remotely located lamps.

4.1.1.7 Microwave Service Channel. A single sideband service channel provides voice communications between the microwave terminal equipment at the two sites. This channel operates over a narrowband centered about 30 kc as shown in Figure 9 and is independent of the normal voice multiplexing equipment.

4.1.2 Up-Link Signals

4.1.2.1 Up-Data. At the DSIF site, the microwave link picks up the two 70 kc up-data signals at the output of the S-band subcarrier oscillator units. The two signals are first up converted to 3.4 Mc and 3.8 Mc and then summed together along with other up-link signals in a combiner. The combiner output is then FM modulated onto two microwave carriers and transmitted to the DSIF site. The spectral content of the combiner output is shown in Figure 10. Two (2) RF channels (channels 5 and 6) are used to transmit these signals in order to increase propagation and equipment reliability. The power output from each transmitter is one (1) watt.

At the receiving end, the rf transmitted signals are down converted to baseband by two identical receivers and fed to a switch combiner. The switch combiner selects the best of the two input signals, based on signal-to-noise ratio, and feeds it to a distribution amplifier. The two up-data signals are then stripped out by band pass filters, down converted to 70 kc, amplified and fed to the S-band equipment for transmission to the Apollo spacecraft.

4.1.2.2 Up-Voice. At the MSFN site, the two up-voice signals are fed into the microwave link in baseband form and transmitted to the DSIF site on two of the 24 multiplexed voice channels. At the DSIF site, these signals are demultiplexed and restored to baseband and fed to the S-band subcarrier oscillator units. In the subcarrier oscillator, up-voice is FM modulated onto a 30 kc subcarrier which in turn is PM modulated onto the up-link carrier and transmitted to the Apollo spacecraft.

4.1.2.3 Spacecraft (s/c) AGC and Static Phase Error. The automatic gain control (AGC) and static phase error signals of the spacecraft receiver are transmitted to the ground station on the down-link telemetry. At the ground station, the telemetry signal is removed from the PM video or 50 Mc i.f. signal by the data demodulators and fed to the PCM telemetry decommutator where all the information functions contained in the PCM telemetry are decommutated or stripped out and converted to analog voltages. Two of these functions; s/c AGC and static phase error, must be relayed to the DSIF site via the microwave link.

As shown in Figure 7, these signals are FM modulated onto subcarriers, summed together along with the other up-link signals, and transmitted to the DSIF site on microwave channels 5 and 6. The spectral positions of these signals are shown on the baseband spectrum of microwave channels 5 and 6 in Figure 10.

At the DSIF site, these signals are stripped out, FM discriminated to baseband, and fed to the S-band equipment for metering. Metered indications of s/c AGC and static phase error are useful to the operation of the S-band transmit/receive equipment, particularly during the acquisition of the Apollo spacecraft.

4.1.2.4 Voice Channels. The 24 one-way voice channels in the MSFN to DSIF direction comprise the second half of the 24 two-way voice system to be used for communications between the two sites. The first half was discussed in section 4.1.1.5. The characteristics discussed in section 4.1.1.5 also apply to the 24 voice channels in the MSFN to DSIF direction and will not be discussed here.

4.2 Cable Link

In section 4.1 the microwave link was described in detail by discussing the individual equipment in the signal flow path from input to output for each signal relayed via the link. The discussion was presented in two parts: (1) Down-Link Signals, and (2) Up-Link Signals. The same procedure will be followed in describing the cable link equipment.

A detailed block diagram of the cable link at Bermuda and Corpus Christi is shown in Figure 11. Figure 12 shows a block diagram of the cable equipment at Hawaii (dual site). Two complete cable links (primary and backup links) are shown in these figures in order to show their interconnections. Since the cable link performs the same function as the microwave link described in section 4.1, a large part of that discussion also applied to the cable link. As a result in the discussion that follows emphasis is placed on characteristics of the cable equipment not in common with the microwave equipment. For this discussion, Figures 11 and 12 should be referred to periodically.

4.2.1 Down-Link Signals

4.2.1.1 50 Mc i.f. Signals. The cable equipment in the S-band building picks up the 50 Mc i.f. signals at the output of the S-band receivers. These signals are then translated to an RF spectrum assignment, combined with the other down-link signals, amplified and transmitted on the Coaxial cable to the T & C building. At the receiving end, these signals are stripped out by filtering in the signal splitter, down converted to 50 Mc and fed into the S-band data demodulators.

The spectral position of the up converted 50 Mc i.f. signals on the Coax cable is shown in Figure 13. At Bermuda and Corpus Christi the two 50 Mc i.f. signals are placed on the cable each in a 10 Mc bandwidth centered at 117 and 143 Mc. The two additional 50 Mc i.f. signals at the Hawaii station are centered at 169 and 195 Mc.

In Figures 11 and 12, splitting filters are shown at both ends of the cable. The purpose of these filters is to divide the cable spectrum into two sections (see Figure 6). The lower section includes frequencies out to 20 Mc and is used for the transmission of the up-link signals from the T & C building to the S-band building. The other section includes frequencies from 20 Mc and up and is used for transmitting down-link signals from the S-band building to the T & C building. Employment of this method allows for the simultaneous transmission of signals in both directions on a single cable.

The cable driver amplifiers at both ends of the cable are required for amplification, cable impedance matching and to compensate for the frequency tilt characteristic of the cable (increasing attenuation as frequency increases). The amplifier has linear phase characteristic. However, compensation for phase distortion primarily due to the filters at both ends of the link, may be required. This will be accomplished, if necessary, by a phase equalizing network placed at the receiving end for each signal.

4.2.1.2 PM Video Signals. The PM video signal is picked up at the output of the S-band receiver and fed into a notch filter. The function of this filter is to remove that portion of the PM video signal spectrum between 4 kc and 500 kc. Removal of this portion of the spectrum is done to remove a considerable amount of undesired range code signal and noise before up-converting and transmitting. The output from the notch filter is then amplified and fed to two AM modulators.

At the single stations (Figure 11) the PM video signal #1 is AM modulated onto 130 Mc and 156 Mc carriers in two (2) separate modulators. The output from each modulator is then combined with the other down-link signals and transmitted to the T & C building. The 156 Mc signal is transmitted on the primary cable while the 130 Mc signal is transmitted on the backup cable. The PM video signal #2 is handled in an identical manner as PM video signal #1 up to the input to the two (2) respective modulators for this signal. From there it is treated slightly different as indicated in Figure 11. In each modulator the PM video signal #2 is summed with the 30 + 70 kc up-voice and up-data verification signal. This composite signal is then AM modulated onto 130 Mc and 156 Mc carriers by the respective modulators, combined with the other down-link signals and transmitted to the T & C building. In this case the 130 Mc signal is transmitted on the primary cable while the 156 Mc signal is transmitted on the backup cable. Note that the frequency assignments (spectral position) of PM video signals #1 and 2 on the primary cable are reversed on the backup cable.

At the Hawaii dual station (Figure 12) four (4) PM video signals are transmitted to the T & C building. In this case PM video signals #1 and 3 are transmitted over the two (2) Coaxial cables in an identical manner as the PM video signal #1 at the single stations discussed above. PM video signals #2 and 4 are handled the same as the PM video signal #2 at the single stations also discussed above. The AM carrier frequencies for the four (4) PM video signals are 130 Mc, 156 Mc, 182 Mc and 208 Mc as indicated in Figures 12 and 13.

At the receiving end, the PM video signals are stripped out by filtering in the signal splitter, demodulated to baseband and fed to the S-band data demodulators.

4.2.1.3 Up-Voice and Up-Data Verification Signals. The up-voice and up-data verification signals are picked up at an auxilliary output (second i.f.) from the verification receiver as one composite signal comprised of the sum of the 30 kc up-voice subcarrier and the 70 kc up-data subcarrier. This composite signal is fed into the cable link equipment where it is filtered, summed with a PM video signal in the PM modulator and transmitted to the T & C building along with the PM video signal as discussed in the previous section. The spectral position of these signals is shown in Figure 14.

At the receiving end, the 30 kc + 70 kc signal is separated from the AM demodulator output and fed in parallel to two FM discriminators, centered at 30 kc and 70 kc. The output from the 30 kc discriminator (up-voice verification) is fed to the station intercom system. The output from the 70 kc discriminator (up-data verification) is fed to the up-data buffer.

4.2.2 Up-Link Signals

4.2.2.1 Up-Voice Signal. In the T & C building up-voice is picked up from the station intercom system in baseband form, FM modulated onto a 30 kc subcarrier, summed with the other up-link signals and transmitted through the cable to the S-band building. The spectral position of this signal and for all the other up-link signals is shown in Figure 15. At the Hawaii station the second 30 kc up-voice signal is first AM modulated on a 3.4 Mc carrier prior to transmission on the cable as indicated in Figure 15.

At the receiving end, the 30 kc up-voice signal is stripped out by a band pass filter and fed to the S-band mode selector module (part of the S-band subcarrier oscillator unit) for transmission to the Apollo spacecraft.

4.2.2.2 Up-Data. The cable equipment picks up the up-data signal at the output from the up-data buffer unit (located in the T & C building), FM modulates it onto a 70 kc subcarrier, and transmits it to the S-band building. The second up-data signal at the Hawaii station is AM modulated onto a 3.8 Mc carrier prior to transmission.

At the receiving end, the 70 kc up-data signal is stripped out and fed to the S-band mode selector unit for transmission to the Apollo spacecraft.

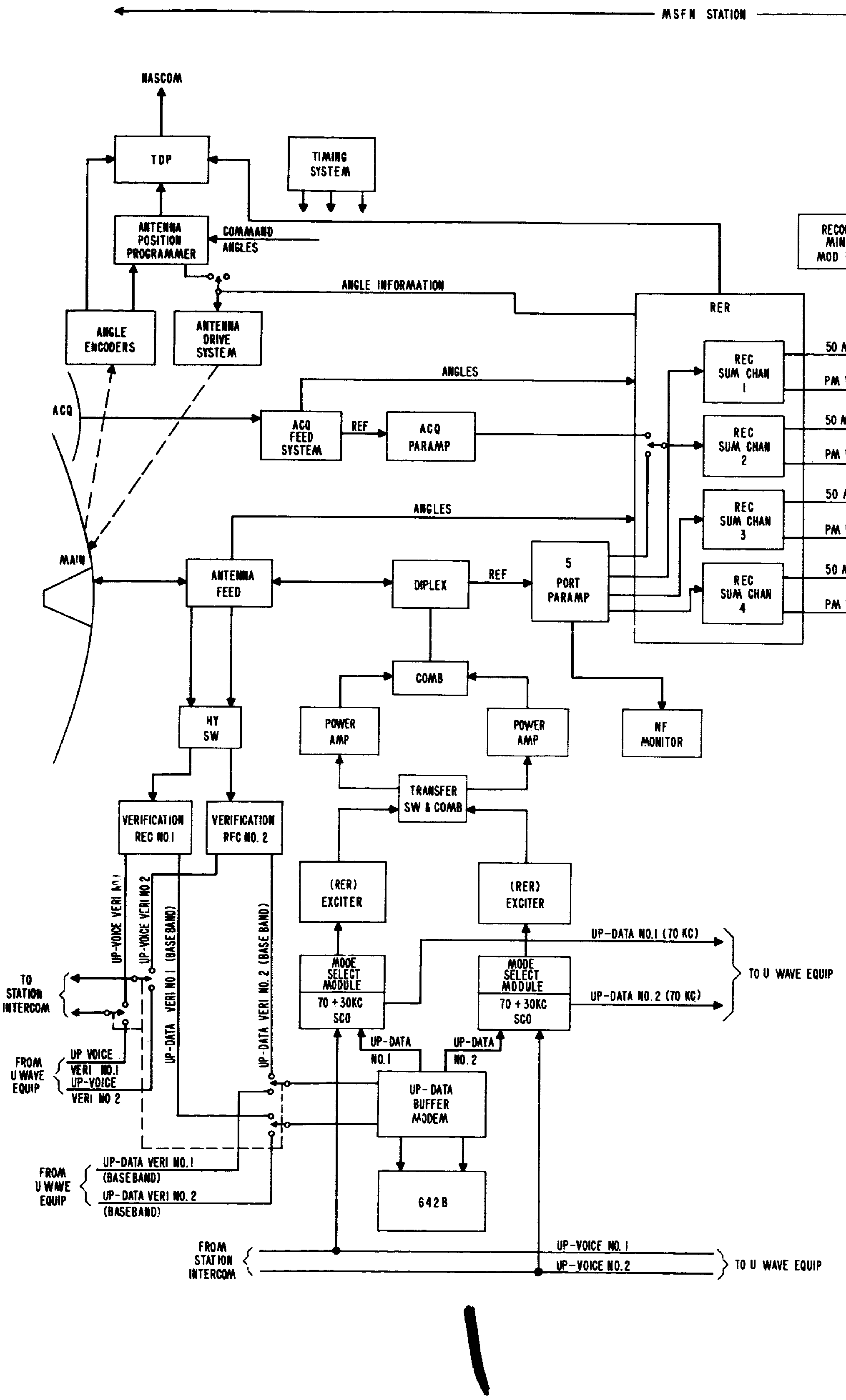
4.2.2.3 Spacecraft AGC and Static Phase Error. These signals are picked up at the output of the PCM decommutator located in the T & C building, FM modulated onto telemetry VCO subcarrier, and transmitted to the S-band building. The spectral positions of these signals are shown in Figure 15. At the receiving end, these signals are stripped out, FM discriminated to baseband, and fed to a metering panel located on the S-band transmitter console.

5.0 CONCLUDING COMMENTS

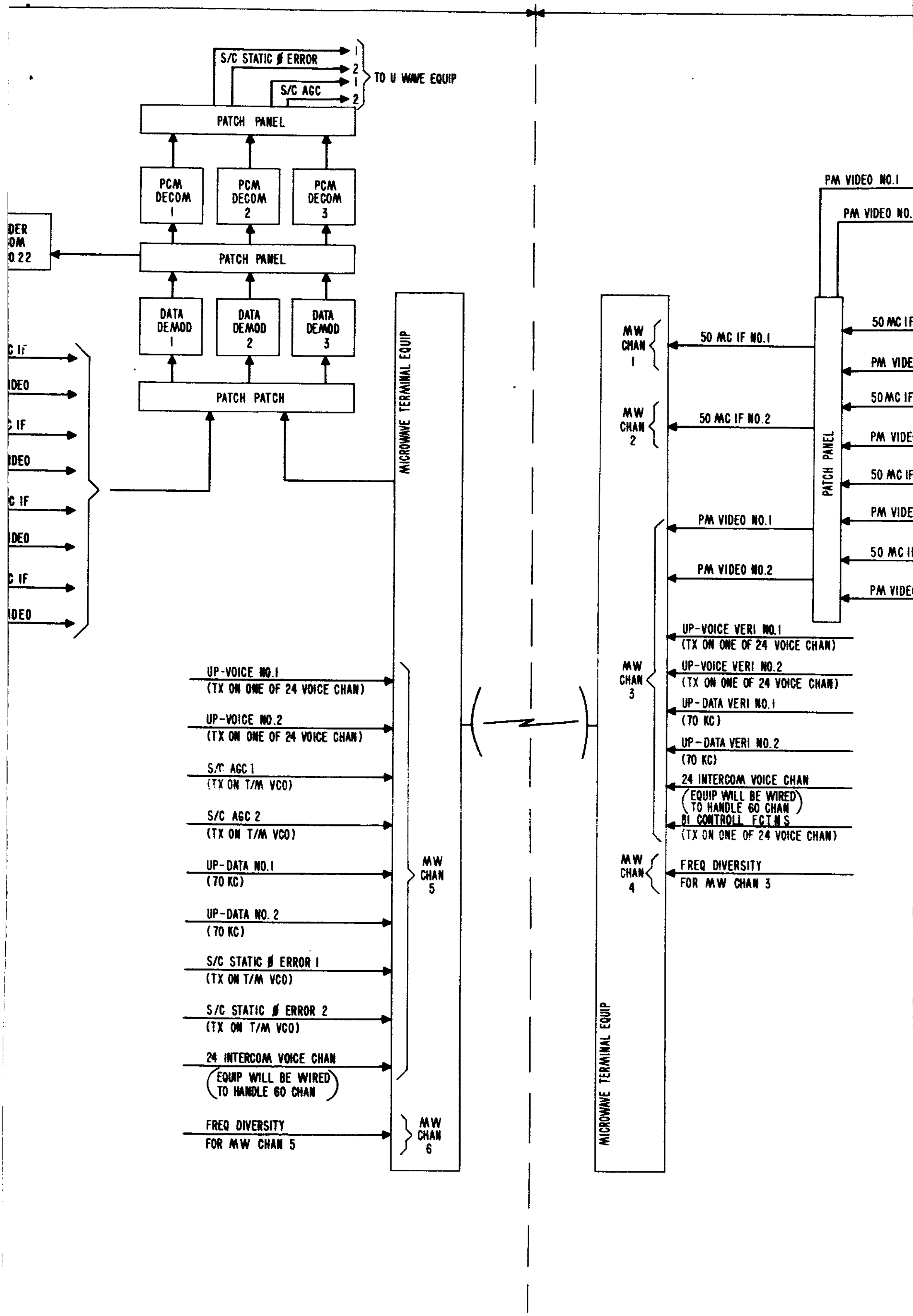
As stated in section 4.1.1.6 the microwave link, as specified during the writing of this report, has the capability of transmitting 80 on-off or relay type control functions only in the DSIF to MSFN direction. However, at this time, the use of one of the voice channels in the MSFN to DSIF direction for transmitting 27 equipment status and fault reports is being considered. Also being considered at this time is to provide all the microwave links with an Automatic Signaling capability to some of the voice channels. As presently configured the microwave links do not have this capability with the exception of the Canberra station which has Automatic Signaling on ten (10) of the 24 voice channels. Thus the final configuration of the microwave links may very well include these capabilities.

At the end of section 3.0 it was stated that the primary or backup cable transmission link can be selected by a single switch. Coaxial relays in both buildings (S-Band T & C) are controlled by this switch which is located in the T & C building. To remotely control the Coaxial relays in the S-Band building with this switch it will be necessary to run seven (7) wires from the T & C building to the S-Band building. Two additional switches will be provided with the cable transmission link for local control of the Coaxial relays in each building in the event the remote switch fails. A patch panel at each end of the link provides a capability of selecting any of the data link signal just prior to the Coaxial relays.

A final comment concerning the microwave links. At the MSFN site the down-link data signals from the JPL site via the microwave link terminate at a patch panel and also connect into Coaxial relays which are controlled by a single switch. The corresponding signals from the S-Band equipment at the MSFN site can be selected by patching and connected to these same Coaxial relays. Thus, the operator at the MSFN site can select either set of down-link signals by a single switch or by patching.



MSFN STATION
NASCOM
TDP
TIMING SYSTEM
ANTENNA POSITION PROGRAMMER
COMMAND ANGLES
ANGLE INFORMATION
ANGLE ENCODERS
ANTENNA DRIVE SYSTEM
RER
REC SUM CHAN 1
REC SUM CHAN 2
REC SUM CHAN 3
REC SUM CHAN 4
ANGLES
ACQ
ACQ FEED SYSTEM
REF
ACQ PARAMP
MAIN
ANTENNA FEED
DIPLEX
5 PORT PARAMP
COMB
HY SW
POWER AMP
POWER AMP
NF MONITOR
TRANSFER SW & COMB
VERIFICATION REC NO 1
VERIFICATION REC NO. 2
(RER) EXCITER
(RER) EXCITER
MODE SELECT MODULE
70 + 30KC SCO
UP-DATA NO. 1 (70 KC)
UP-DATA NO. 2 (70 KC)
TO U WAVE EQUIP
UP-VOICE VERI NO 1
UP-VOICE VERI NO 2
UP-DATA VERI NO 1 (BASEBAND)
UP-DATA VERI NO. 2 (BASEBAND)
TO STATION INTERCOM
FROM U WAVE EQUIP
UP VOICE VERI NO. 1
UP-VOICE VERI NO 2
UP-DATA NO. 1
UP-DATA NO. 2
UP-DATA BUFFER MODEM
642B
UP-DATA VERI NO. 1 (BASEBAND)
UP-DATA VERI NO. 2 (BASEBAND)
FROM STATION INTERCOM
UP-VOICE NO. 1
UP-VOICE NO. 2


S/C STATIC ∅ ERROR
S/C AGC
TO U WAVE EQUIP
PATCH PANEL
PCM DECOM 1
PCM DECOM 2
PCM DECOM 3
PATCH PANEL
DATA DEMOD 1
DATA DEMOD 2
DATA DEMOD 3
PATCH PATCH
MICROWAVE TERMINAL EQUIP
UP-VOICE NO.1
(TX ON ONE OF 24 VOICE CHAN)
UP-VOICE NO.2
(TX ON ONE OF 24 VOICE CHAN)
S/C AGC 1
(TX ON T/M VCO)
S/C AGC 2
(TX ON T/M VCO)
UP-DATA NO.1
(70 KC)
UP-DATA NO. 2
(70 KC)
S/C STATIC ∅ ERROR 1
(TX ON T/M VCO)
S/C STATIC ∅ ERROR 2
(TX ON T/M VCO)
24 INTERCOM VOICE CHAN
(EQUIP WILL BE WIRED TO HANDLE 60 CHAN)
FREQ DIVERSITY
FOR MW CHAN 5
MW CHAN 5
MW CHAN 6
PM VIDEO NO.1
PM VIDEO NO.2
MW CHAN 1
50 MC IF NO.1
MW CHAN 2
50 MC IF NO.2
PATCH PANEL
PM VIDEO NO.1
PM VIDEO NO.2
UP-VOICE VERI NO.1
(TX ON ONE OF 24 VOICE CHAN)
MW CHAN 3
UP-VOICE VERI NO.2
(TX ON ONE OF 24 VOICE CHAN)
UP-DATA VERI NO.1
(70 KC)
UP-DATA VERI NO.2
(70 KC)
24 INTERCOM VOICE CHAN
(EQUIP WILL BE WIRED TO HANDLE 60 CHAN)
81 CONTROLL FCTNS
(TX ON ONE OF 24 VOICE CHAN)
MW CHAN 4
FREQ DIVERSITY
FOR MW CHAN 3
MICROWAVE TERMINAL EQUIP

2

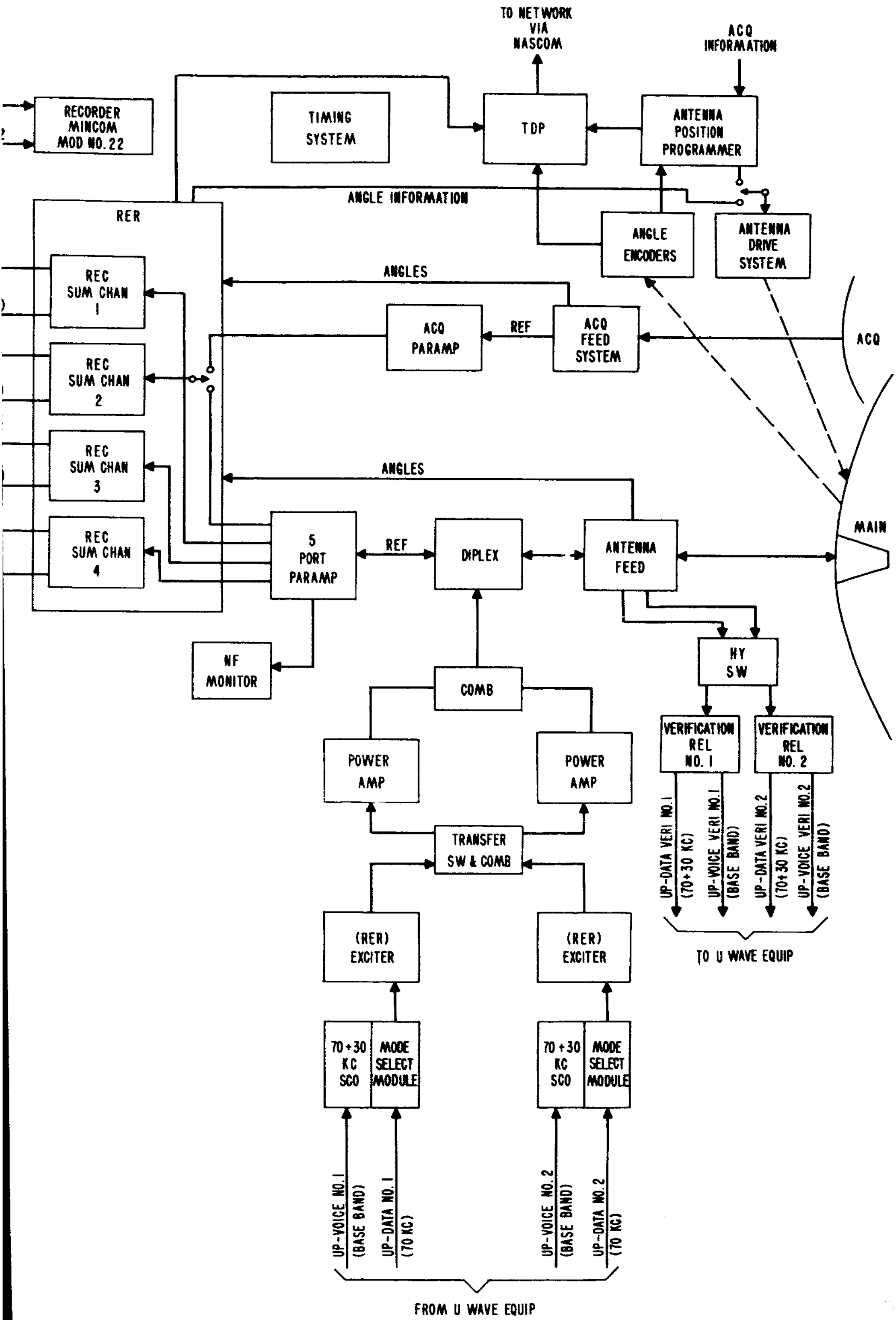


Figure 1. 85 Foot Stations — Madrid, Canberra and Goldstone

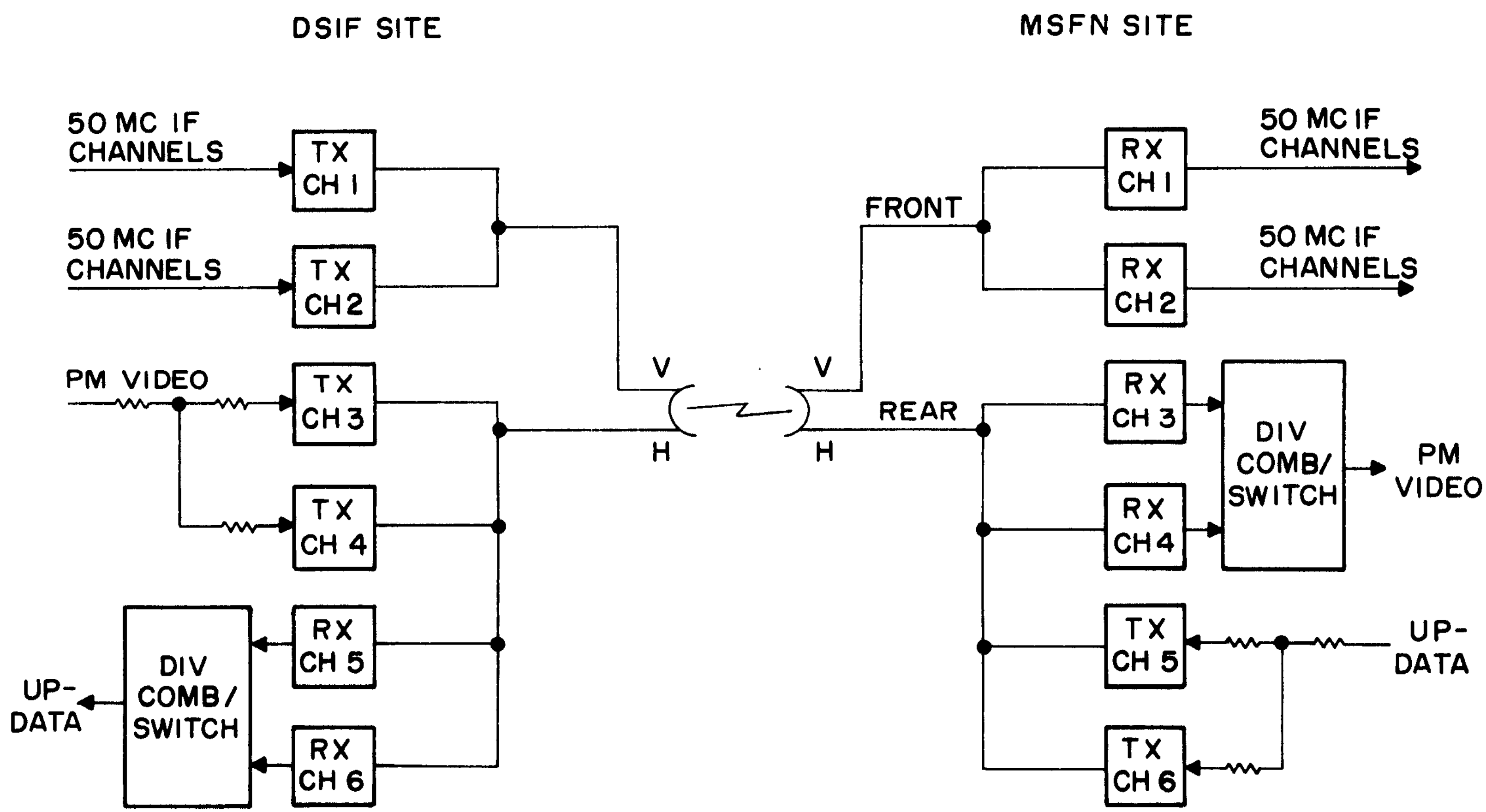
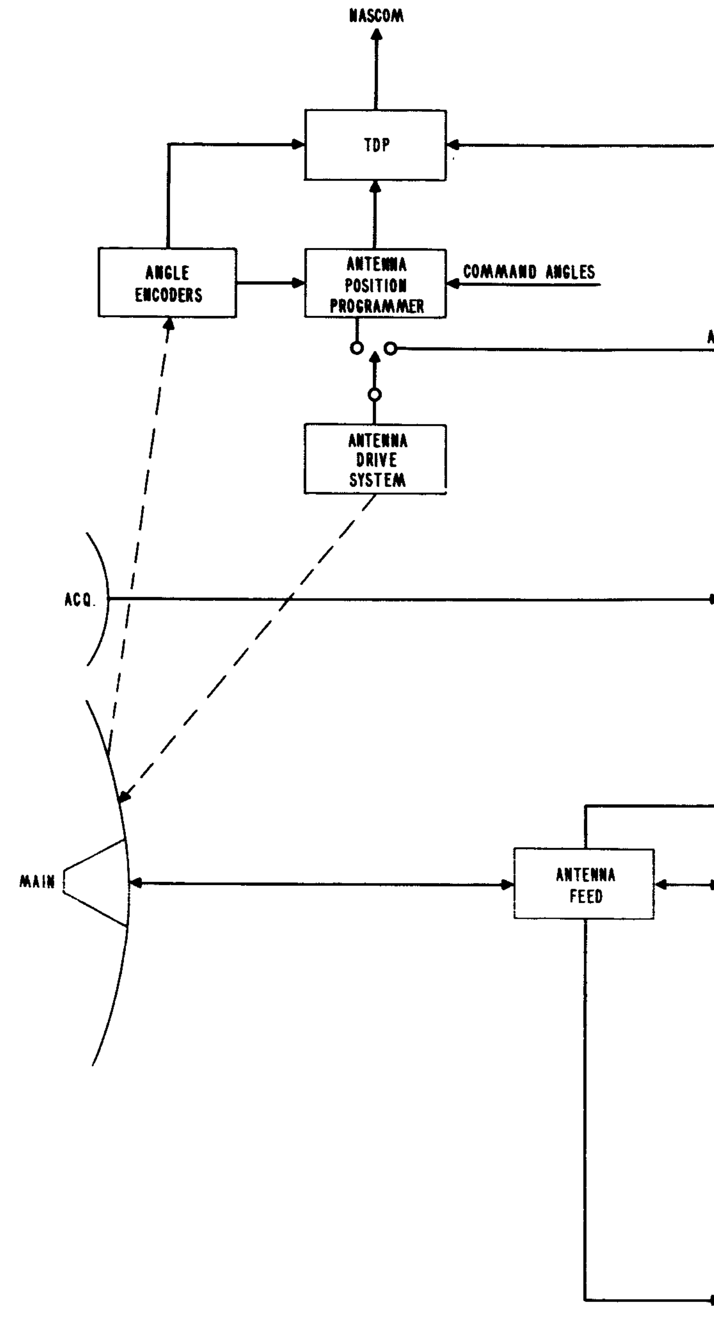
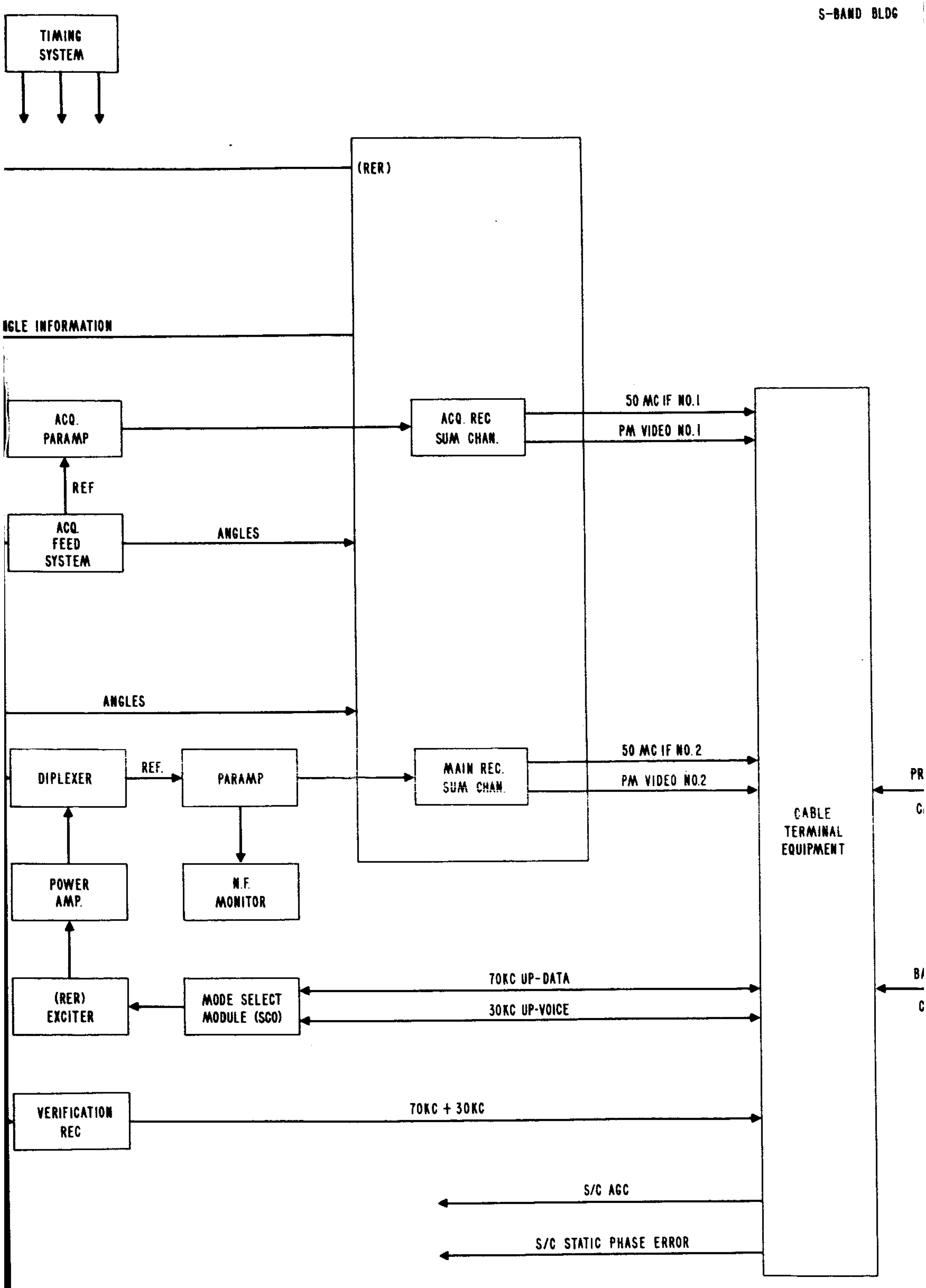


Figure 2. Basic Microwave Link



NASCOM
TDP
ANGLE ENCODERS
ANTENNA POSITION PROGRAMMER
COMMAND ANGLES
ANTENNA DRIVE SYSTEM
ACQ.
MAIN
ANTENNA FEED



S-BAND BLDG
TIMING SYSTEM
(RER)
GLE INFORMATION
ACQ. PARAMP
REF
ACQ. FEED SYSTEM
ANGLES
ACQ. REC SUM CHAN.
50 MC IF NO. 1
PM VIDEO NO. 1
ANGLES
DIPLEXER
REF.
PARAMP
MAIN REC. SUM CHAN.
50 MC IF NO. 2
PM VIDEO NO. 2
CABLE TERMINAL EQUIPMENT
POWER AMP.
N.F. MONITOR
(RER) EXCITER
MODE SELECT MODULE (SCO)
70KC UP-DATA
30KC UP-VOICE
VERIFICATION REC
70KC + 30KC
S/C AGC
S/C STATIC PHASE ERROR

2

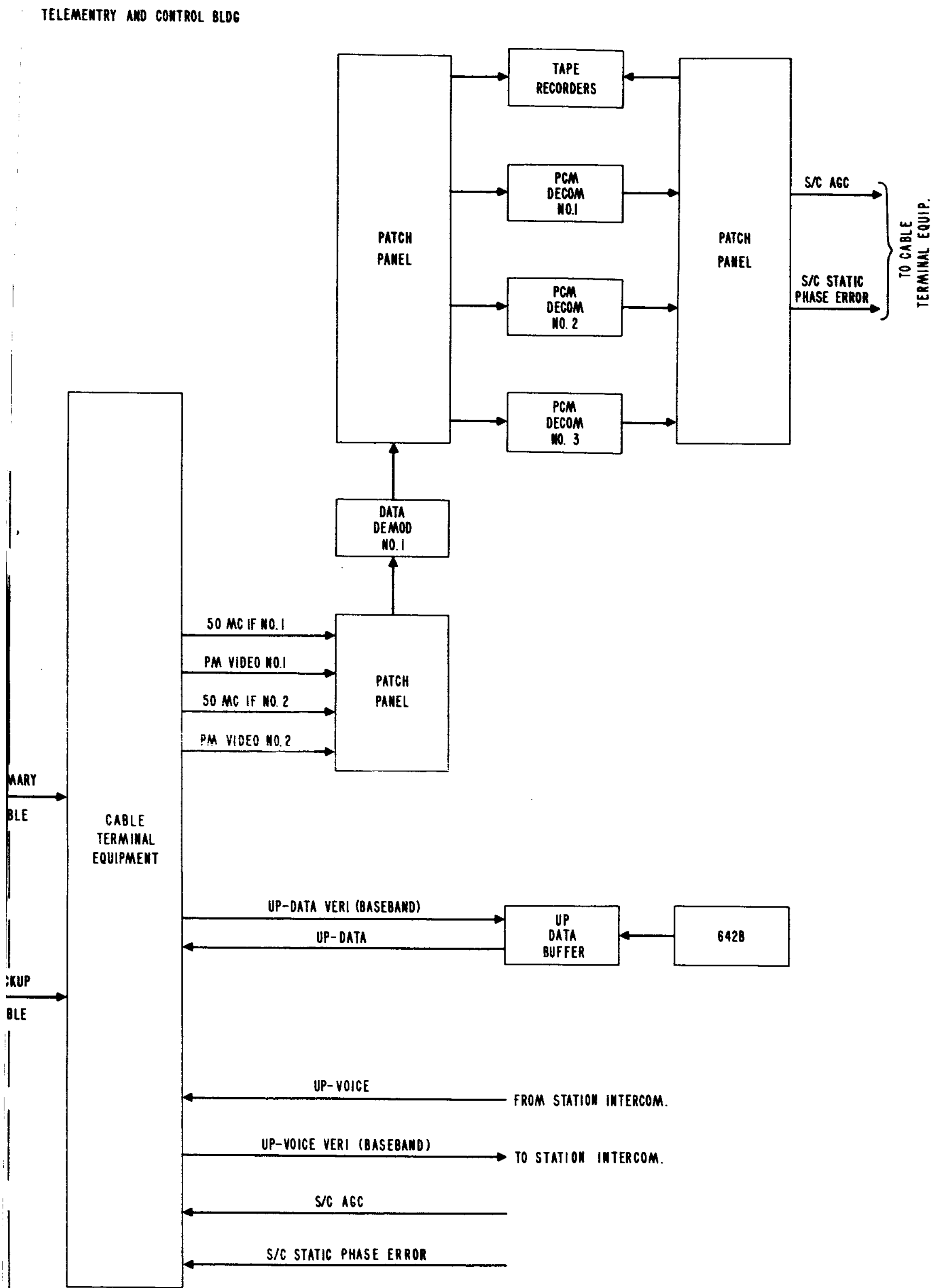
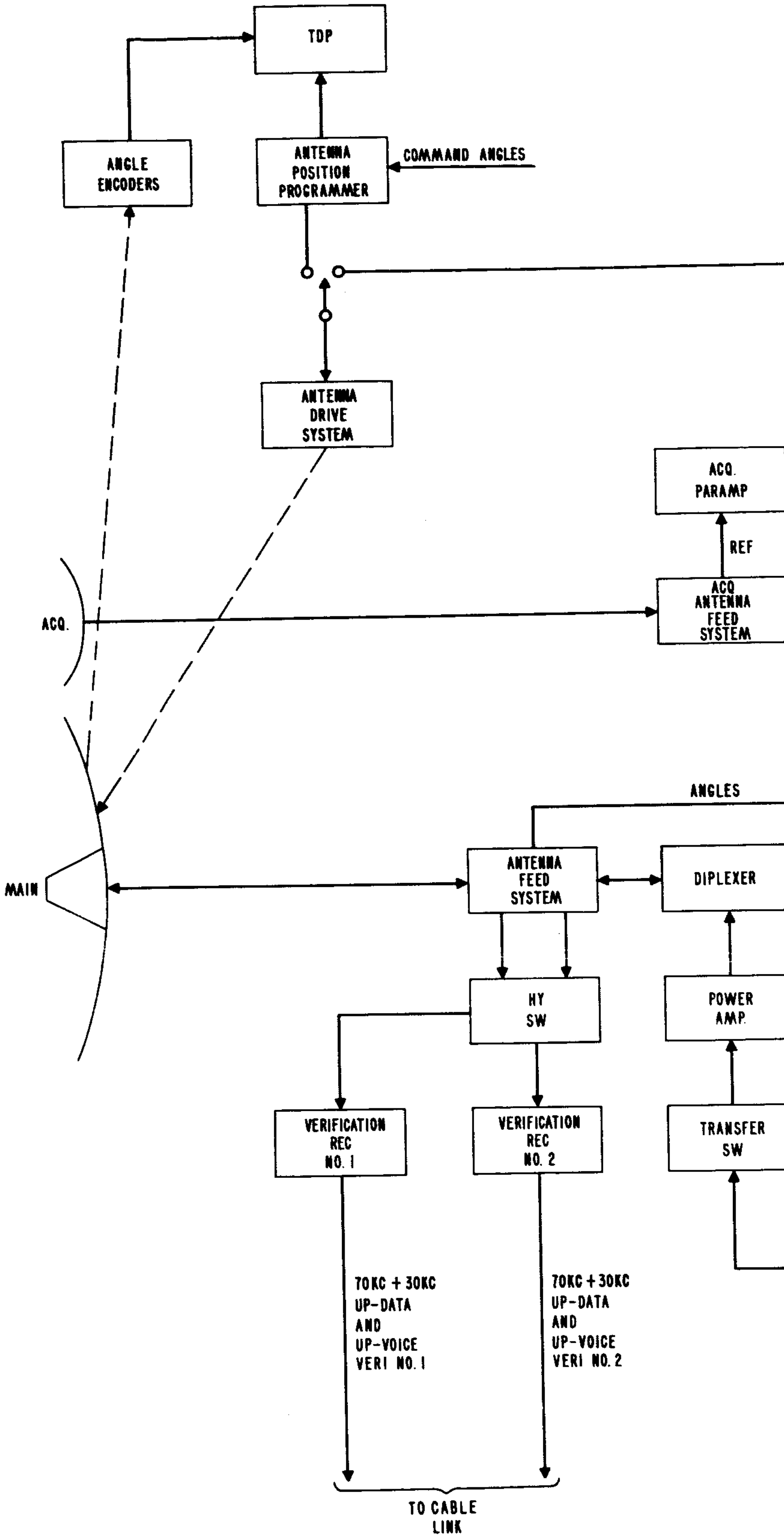
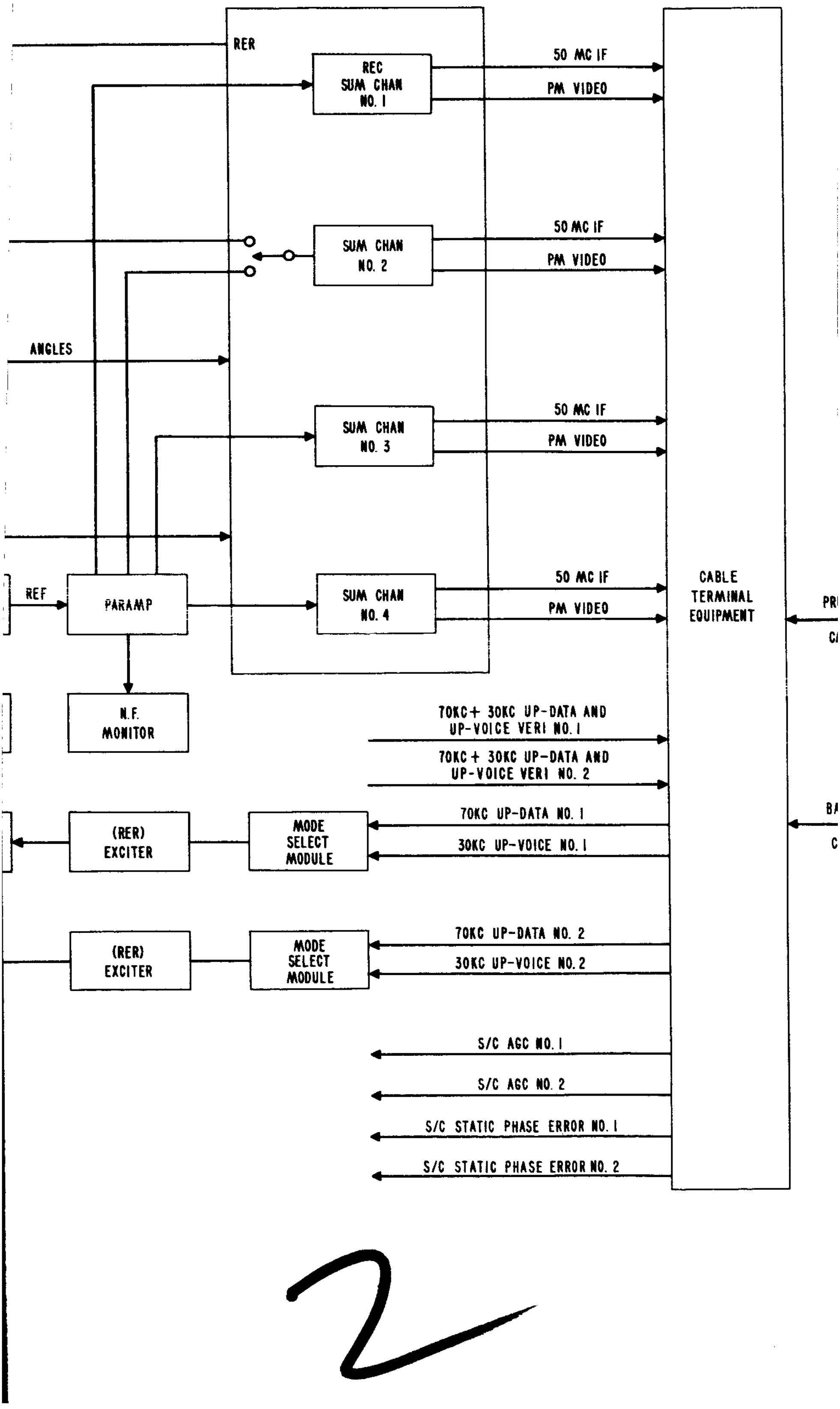


Figure 3. 30 Foot Single Station — Bermuda, Corpus Christi


TDP
ANGLE ENCODERS
ANTENNA POSITION PROGRAMMER
COMMAND ANGLES
ANTENNA DRIVE SYSTEM
ACQ. PARAMP
REF
ACQ ANTENNA FEED SYSTEM
ACQ.
ANGLES
MAIN
ANTENNA FEED SYSTEM
DIPLEXER
HY SW
POWER AMP.
VERIFICATION REC NO. 1
VERIFICATION REC NO. 2
TRANSFER SW
70KC + 30KC UP-DATA AND UP-VOICE VERI NO. 1
70KC + 30KC UP-DATA AND UP-VOICE VERI NO. 2
TO CABLE LINK

S-BAND BLDG


RER
REC SUM CHAN NO. 1
50 MC IF
PM VIDEO
SUM CHAN NO. 2
50 MC IF
PM VIDEO
ANGLES
SUM CHAN NO. 3
50 MC IF
PM VIDEO
REF
PARAMP
SUM CHAN NO. 4
50 MC IF
PM VIDEO
CABLE TERMINAL EQUIPMENT
N.F. MONITOR
70KC + 30KC UP-DATA AND UP-VOICE VERI NO. 1
70KC + 30KC UP-DATA AND UP-VOICE VERI NO. 2
(RER) EXCITER
MODE SELECT MODULE
70KC UP-DATA NO. 1
30KC UP-VOICE NO. 1
(RER) EXCITER
MODE SELECT MODULE
70KC UP-DATA NO. 2
30KC UP-VOICE NO. 2
S/C AGC NO. 1
S/C AGC NO. 2
S/C STATIC PHASE ERROR NO. 1
S/C STATIC PHASE ERROR NO. 2
2

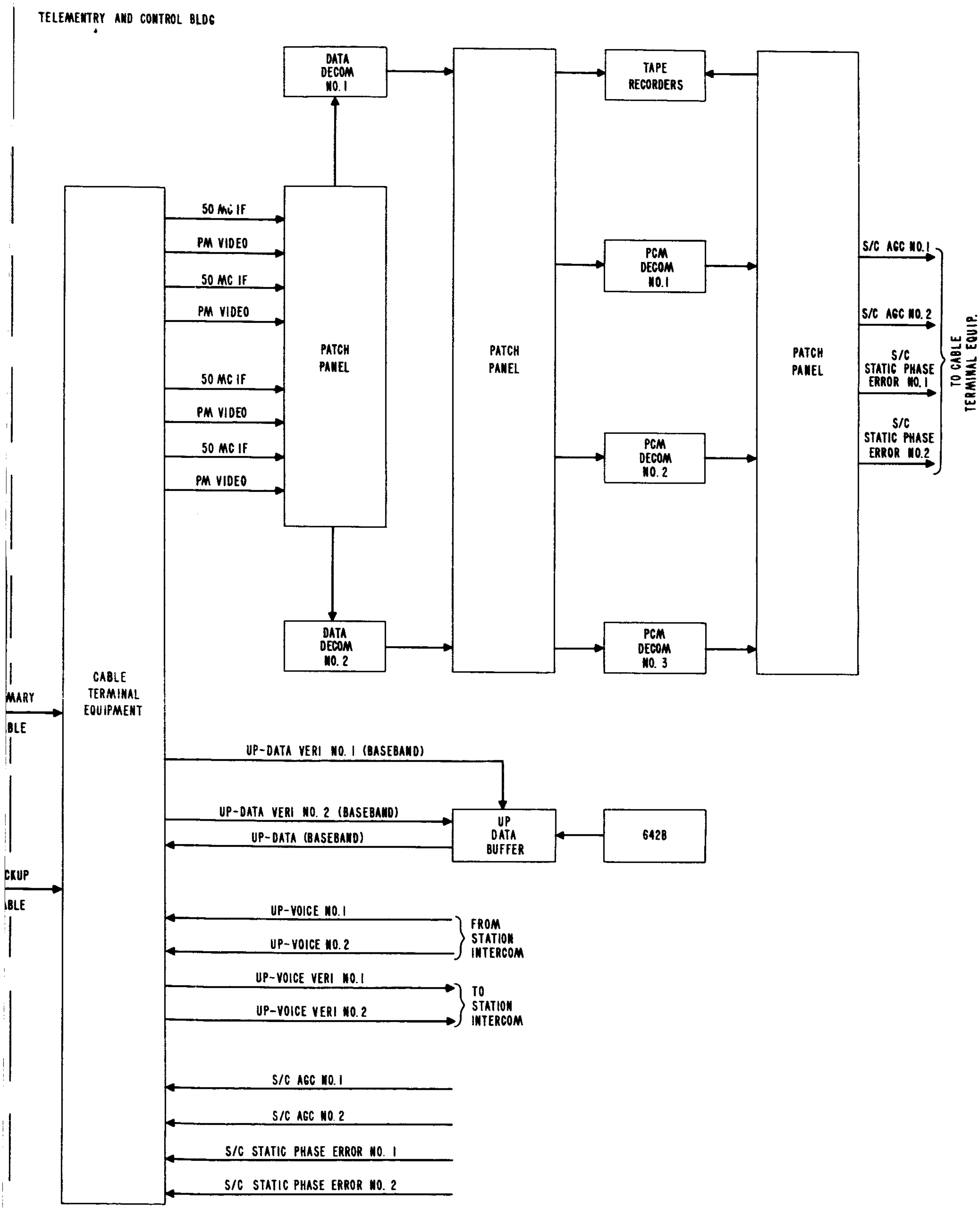


Figure 4. 30 Foot Dual Station — Hawaii

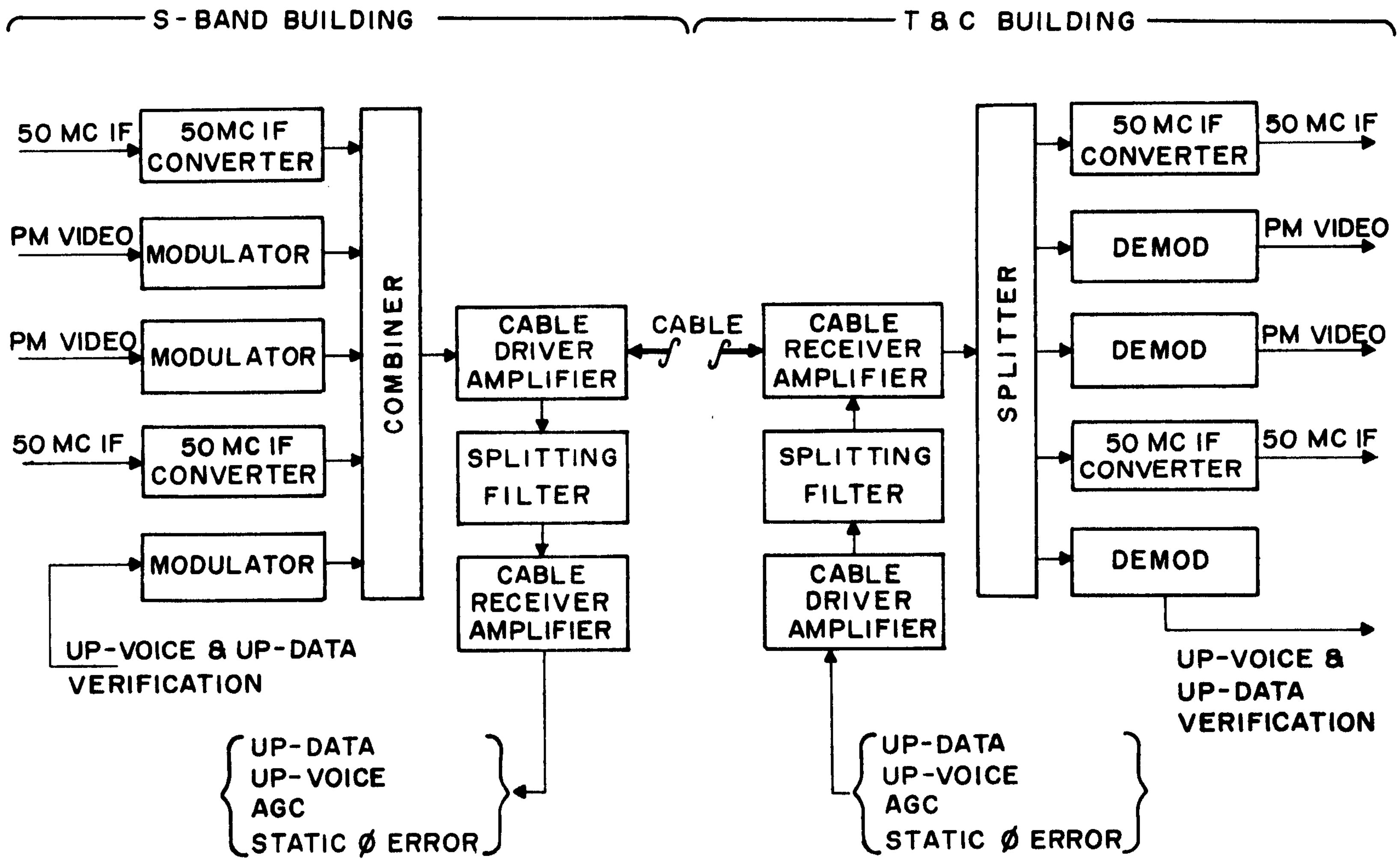


Figure 5. Basic Cable Link for a Single 30 Foot Station

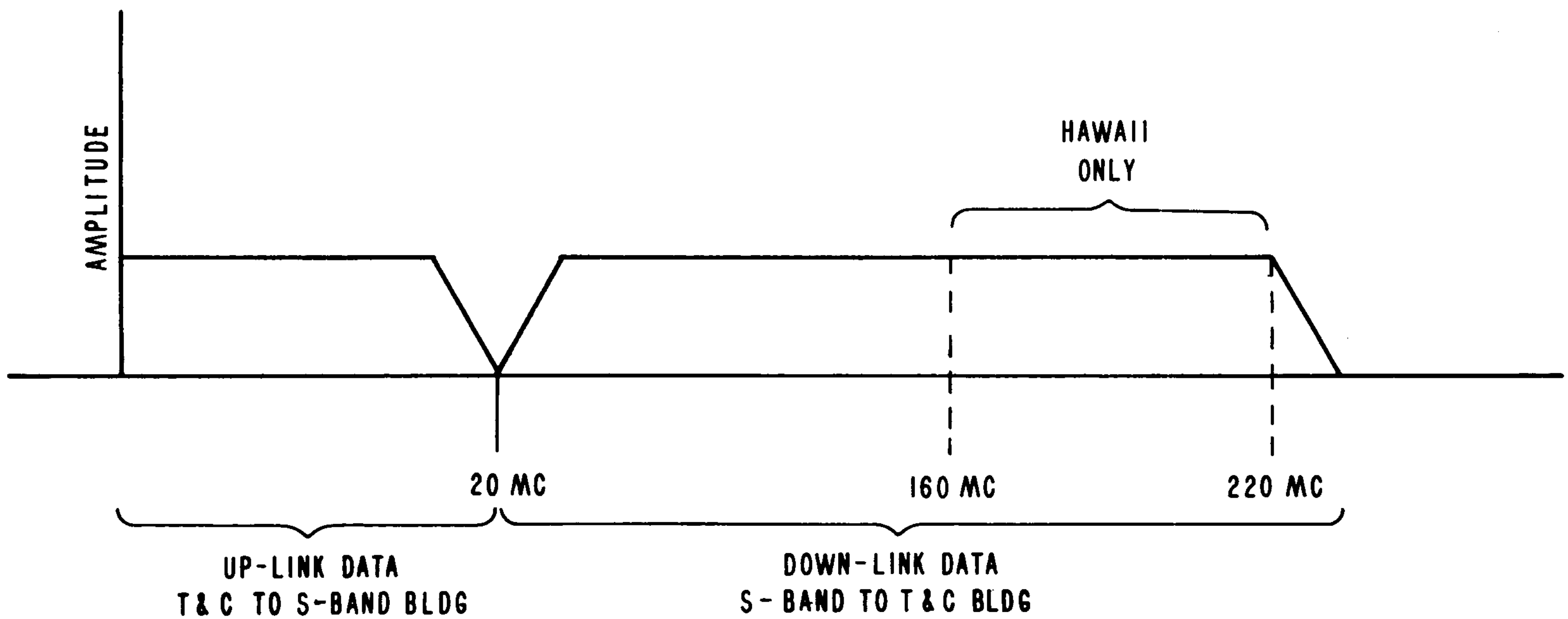


Figure 6. Cable Spectrum

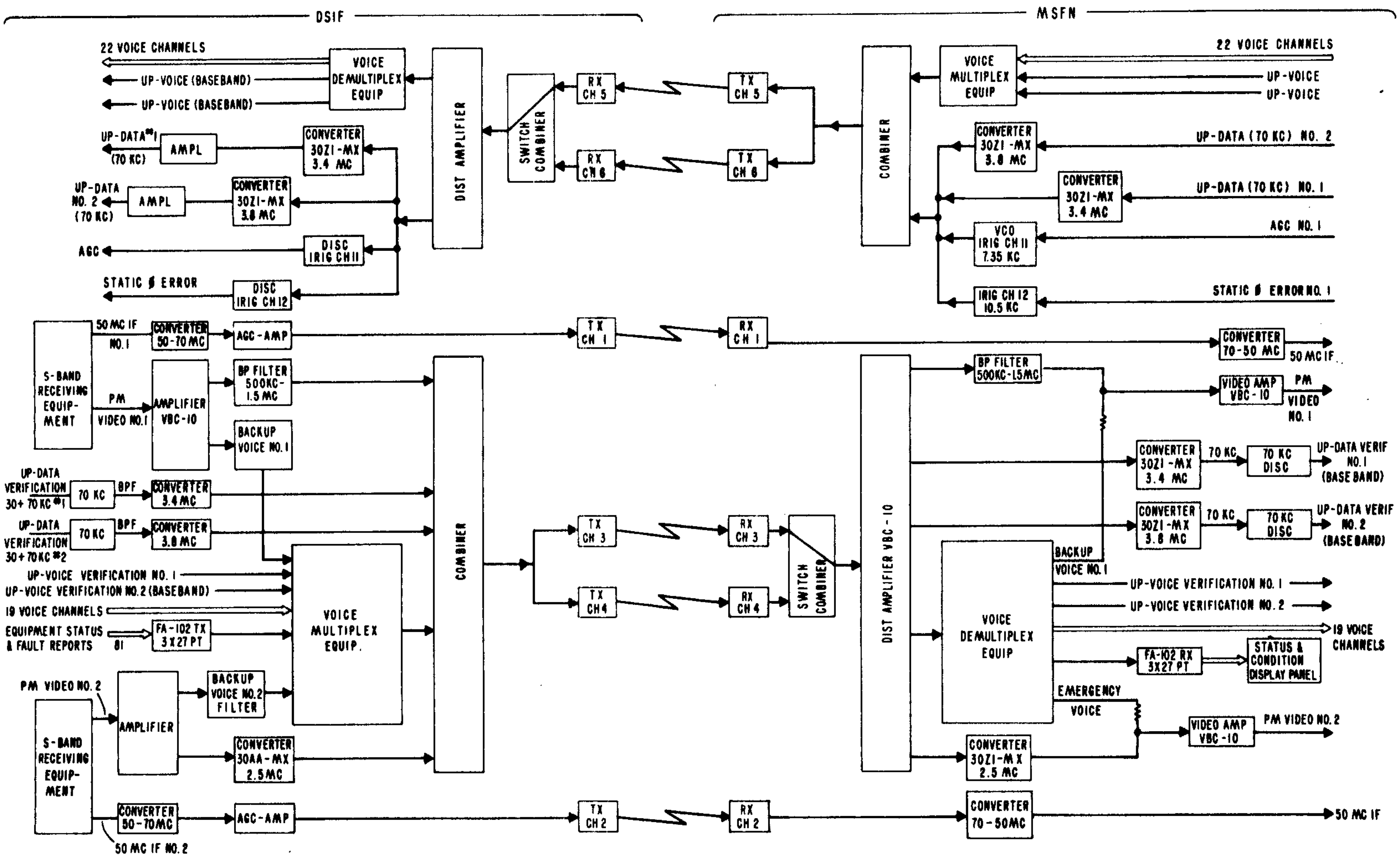


Figure 7. Microwave Data Transmission Link Goldstone, Madrid, Canberra

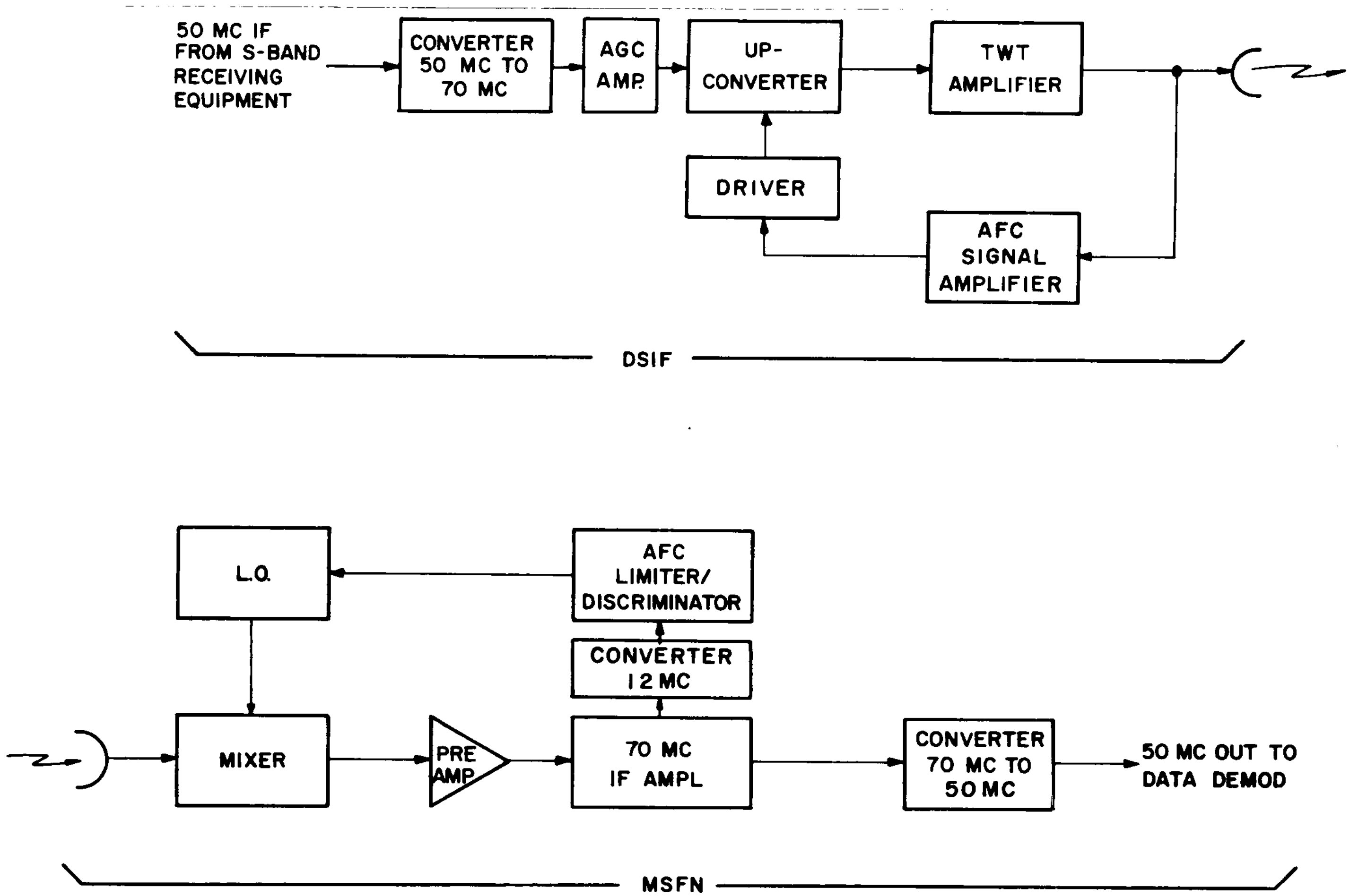


Figure 8. 50 mc if Microwave Channel

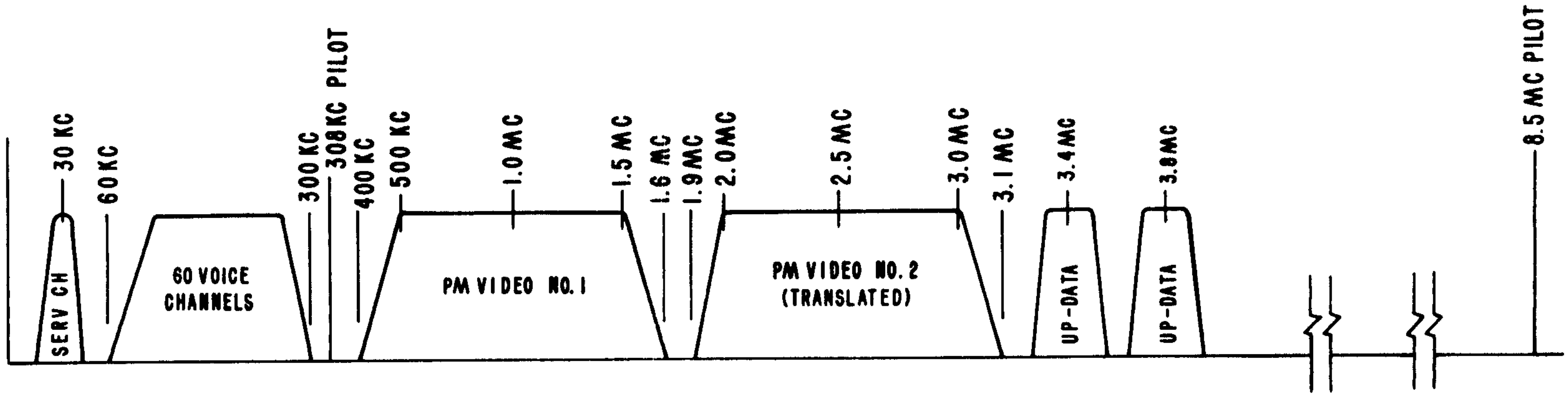


Figure 9. Baseband Spectrum Microwave CH 3 & 4

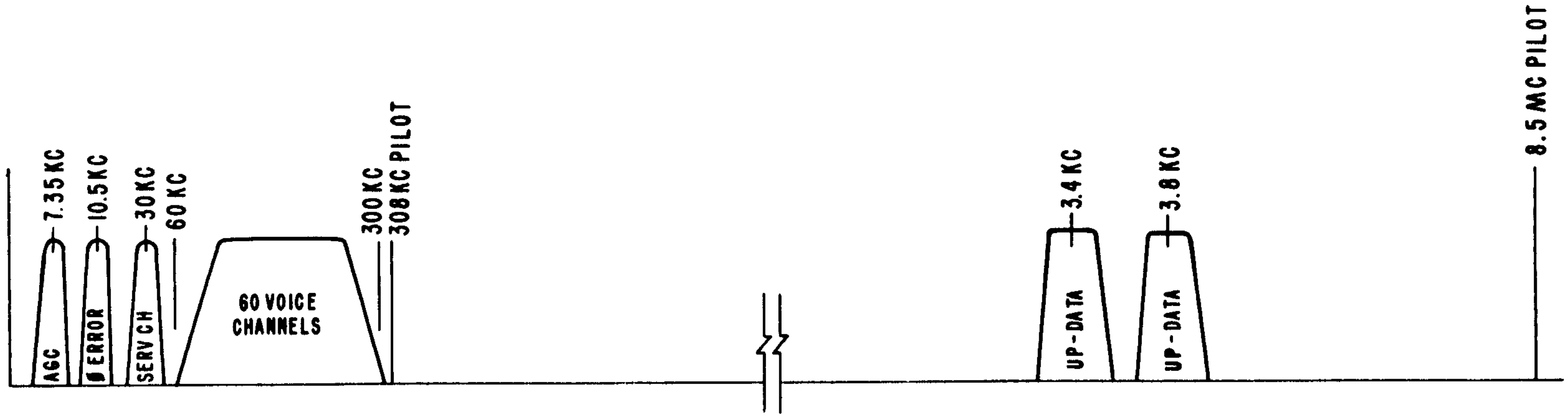


Figure 10. Baseband Spectrum Microwave CH 5 & 6

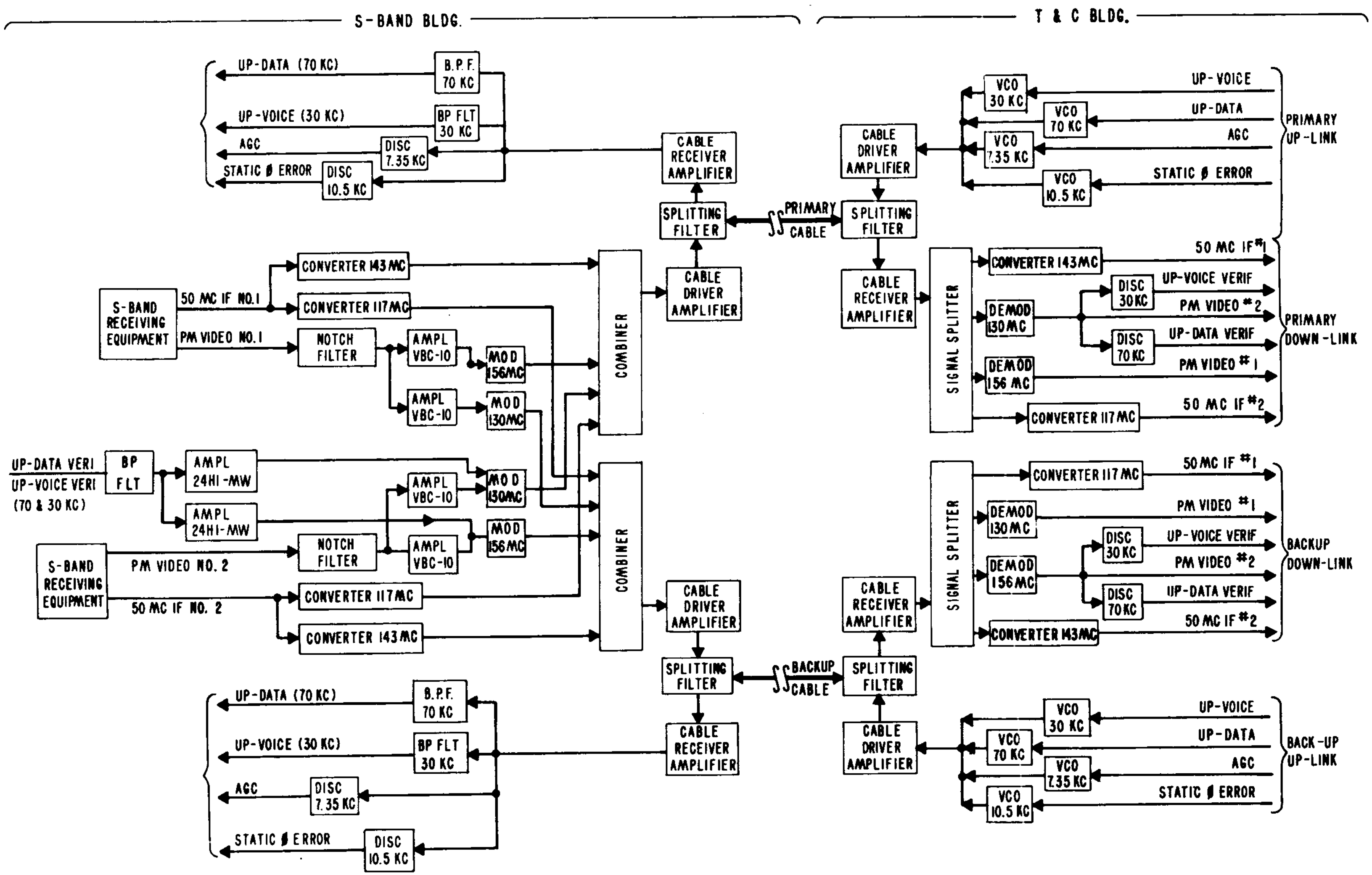
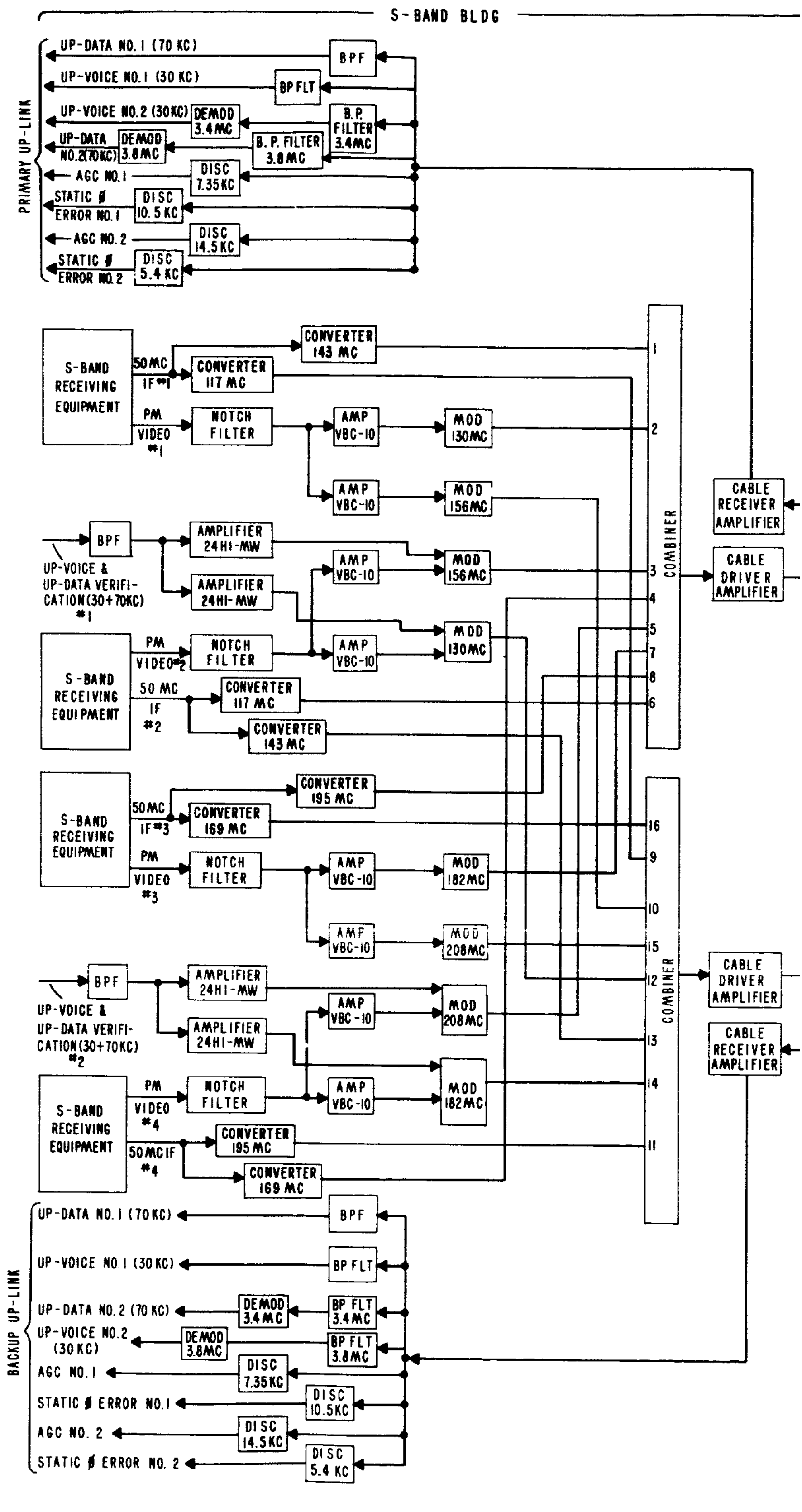


Figure 11. Cable Data Transmission Link, Bermuda, Corpus Christi



S-BAND BLDG
PRIMARY UP-LINK
UP-DATA NO. 1 (70 KC)
UP-VOICE NO. 1 (30 KC)
UP-VOICE NO. 2 (30 KC)
UP-DATA NO. 2 (70 KC)
AGC NO. 1
STATIC ∅ ERROR NO. 1
AGC NO. 2
STATIC ∅ ERROR NO. 2
BPF
BP FLT
B.P. FILTER 3.4 MC
B. P. FILTER 3.8 MC
DEMOD 3.4 MC
DEMOD 3.8 MC
DISC 7.35 KC
DISC 10.5 KC
DISC 14.5 KC
DISC 5.4 KC
S-BAND RECEIVING EQUIPMENT
50 MC IF #1
PM VIDEO #1
CONVERTER 143 MC
CONVERTER 117 MC
NOTCH FILTER
AMP VBC-10
MOD 130 MC
MOD 156 MC
UP-VOICE & UP-DATA VERIFICATION (30+70 KC) #1
AMPLIFIER 24HI-MW
PM VIDEO #2
50 MC IF #2
50 MC IF #3
PM VIDEO #3
CONVERTER 195 MC
CONVERTER 169 MC
MOD 182 MC
MOD 208 MC
UP-VOICE & UP-DATA VERIFICATION (30+70 KC) #2
PM VIDEO #4
50 MC IF #4
COMBINER
CABLE RECEIVER AMPLIFIER
CABLE DRIVER AMPLIFIER
BACKUP UP-LINK
UP-DATA NO. 1 (70 KC)
UP-VOICE NO. 1 (30 KC)
UP-DATA NO. 2 (70 KC)
UP-VOICE NO. 2 (30 KC)
AGC NO. 1
STATIC ∅ ERROR NO. 1
AGC NO. 2
STATIC ∅ ERROR NO. 2
BP FLT 3.4 MC
BP FLT 3.8 MC

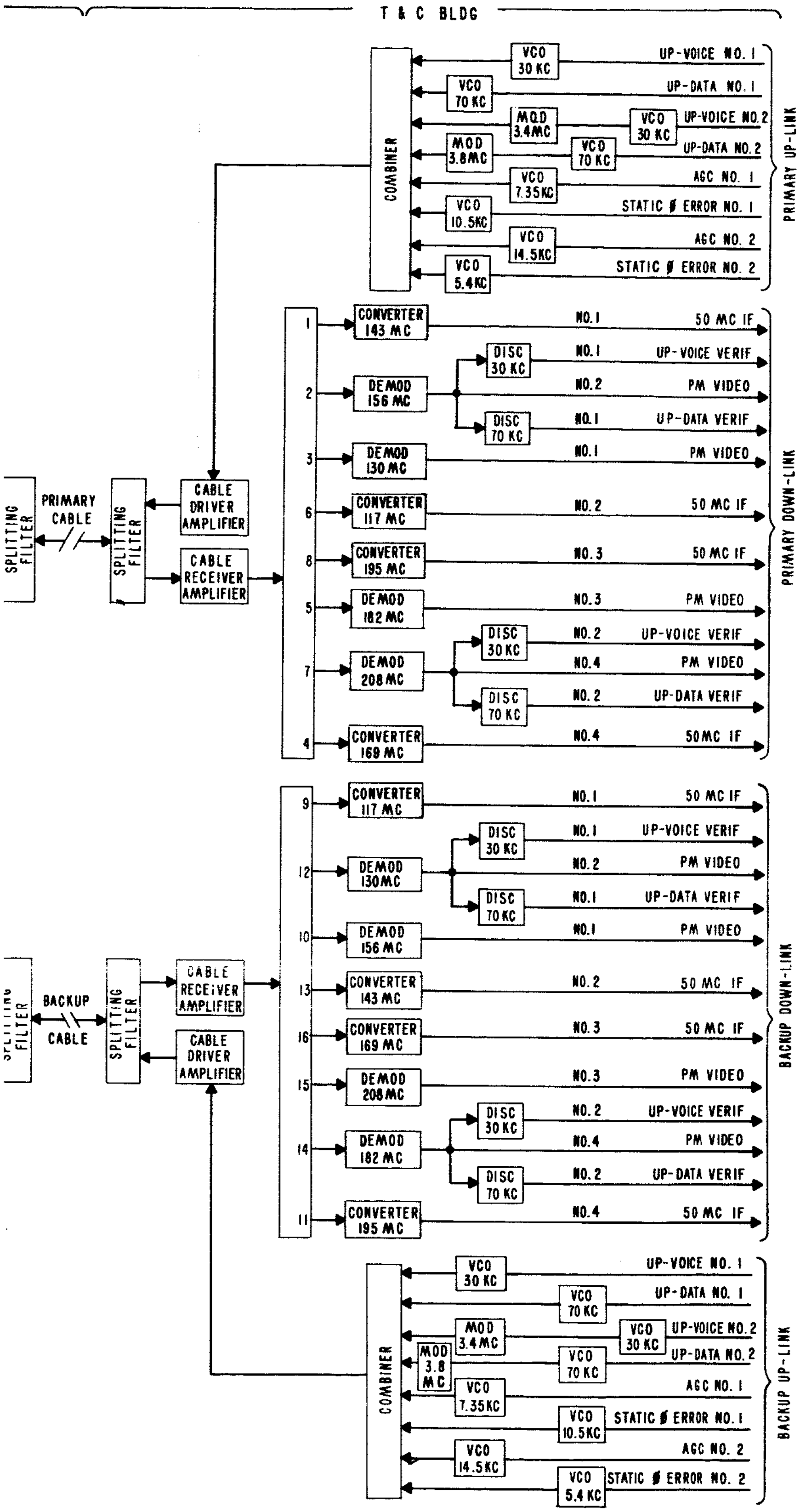


Figure 12. Cable Data Transmission Link Hawaii

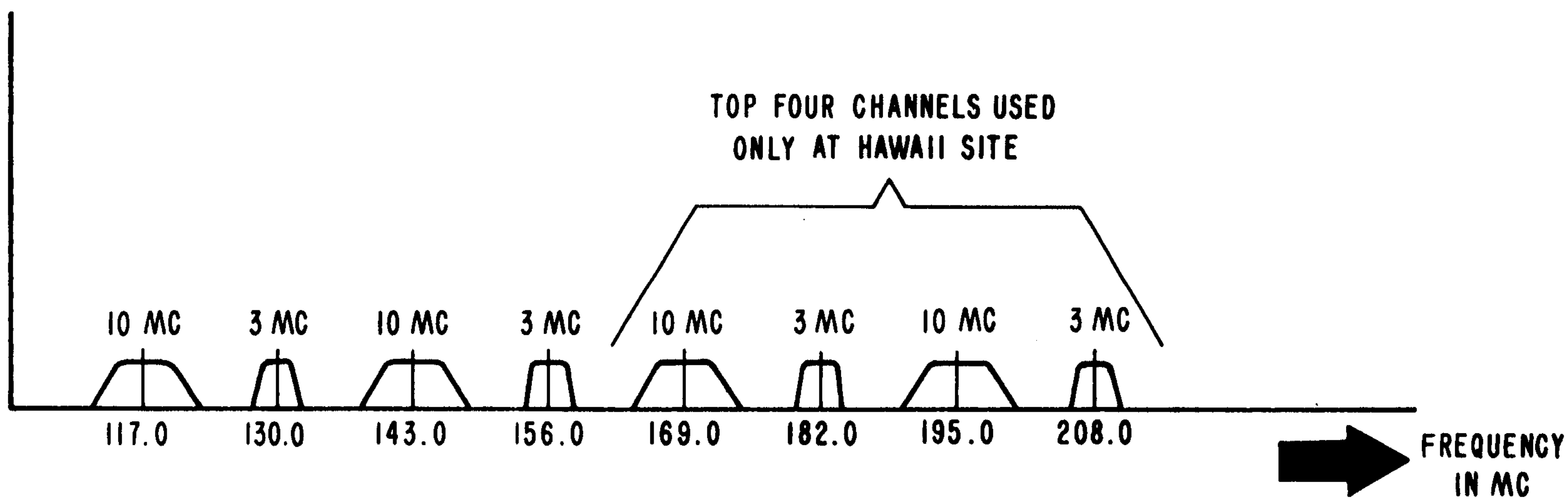


Figure 13. Down-Link Cable Spectrum

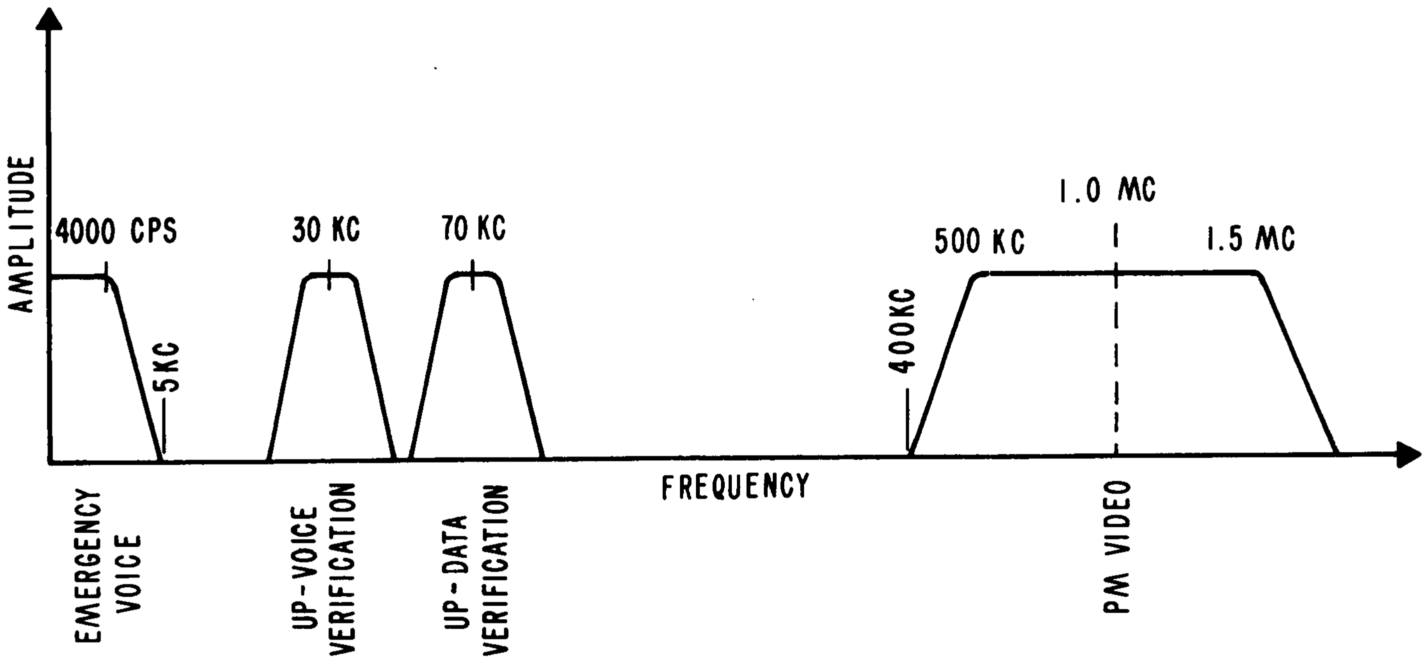


Figure 14. PM Modulator Spectrum

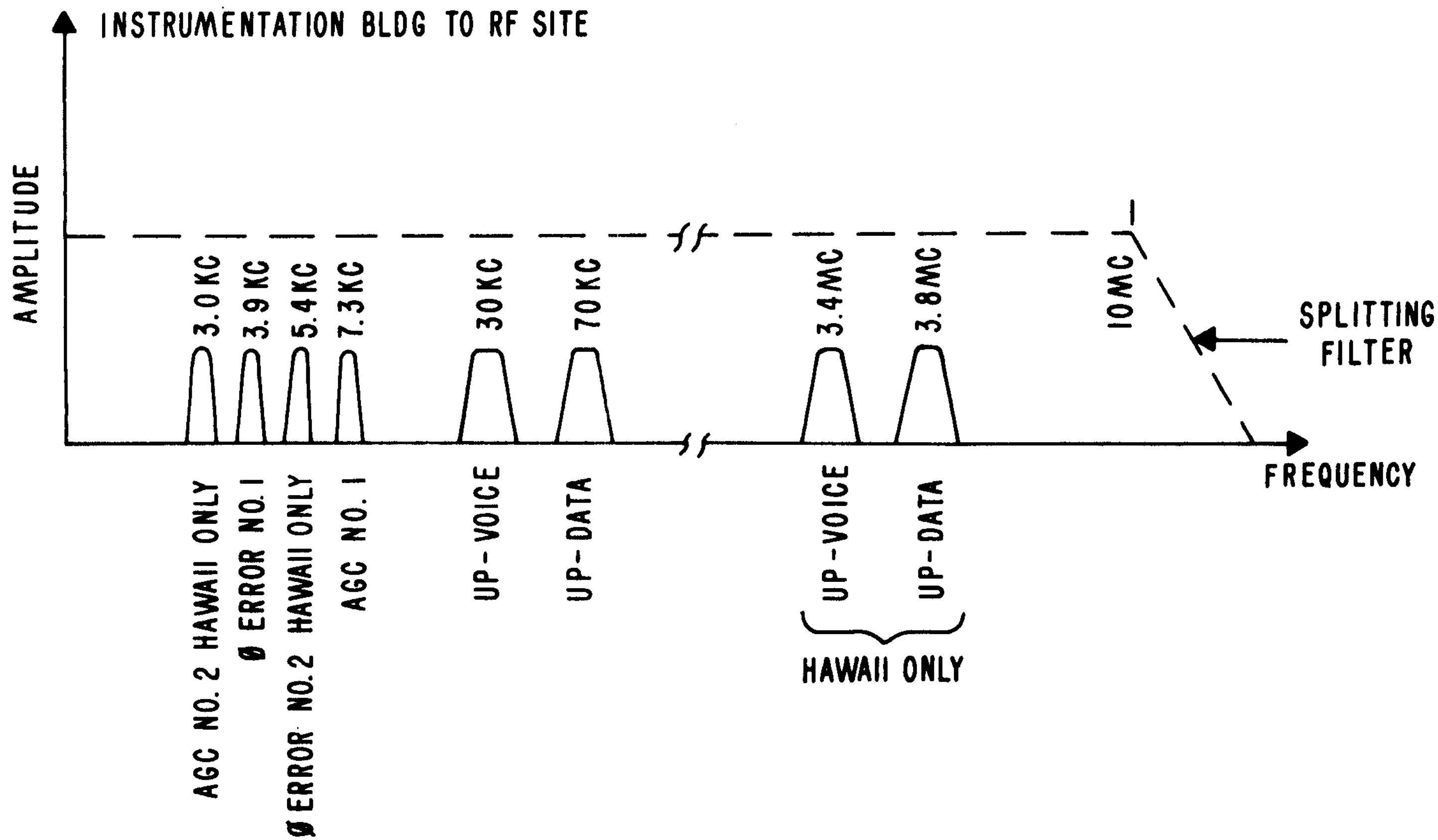


Figure 15. Up-Link Cable Spectrum