HONEYSUCKLE CREEK APOLLO SIMULATION SYSTEM

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SUMMARY: The reduced frequency together with the increased complexity of Apollo Missions added considerably to the problems of staff training and station equipment checkout. This paper describes the simulator developed to simulate all Apollo communication interfaces with the Honeysuckle Creek Apollo Complex. During missions the simulator provided a convenient means of readily assessing Station equipment performance and data flow without having to change the station configuration prior to a pass.

1. INTRODUCTION

The Apollo Stations form a world wide relay network to enable the Mission Control Centre (MCC) in Houston, U.S.A., to maintain continuous communication with the Apollo spacecraft out to lunar distances.
Honeysuckle Creek Tracking Station (HSK) is part of NASA's Spaceflight Tracking and Data Network (STDN) and is operationally responsible for STDN activities at the Tidbinbilla Deep Space Communications Complex (TDSCC).

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* Standard Telephones & Cables Pty. Ltd., Canberra.

and Parkes sites during Apollo Missions. The Tidbinbilla DSCC is part of NASA's Deep Space Network (DSN) and the 85ft antenna, together with associated equipment, is used to support STDN activities such as Apollo missions.

The CSIRO's 210ft antenna at Parkes, N.S.W., supports STDN Apollo missions by agreement with NASA.

2. MISSION CONFIGURATION

The normal mission configuration with the Honeysuckle Creek (HSK) Complex is shown in Fig 1. The Apollo communication links with a typical ground station are shown in Fig 2.

2.1 Mission Control Centre (MCC) to Spacecraft Link. (Fig 1)

Upvoice and data is transmitted from MCC in Houston U.S.A. via commercial international circuits to the Deakin Switching Centre in Canberra, then to HSK. The information is processed and modulated onto S-Band carriers (2.1 - 2.2 GHz) which are transmitted as required to the Command Service Module (CSM), Lunar Module (LM) or the Lunar Communications Relay Unit (LCRU). The LCRU is the communications package carried on the Lunar Roving Vehicle (LRV).

Both Honeysuckle and Tidbinbilla are equipped with two independent 20 KW transmitters. The usual practice is for one station to support CSM and the other station the LM and LCRU, leaving a backup transmitter at each

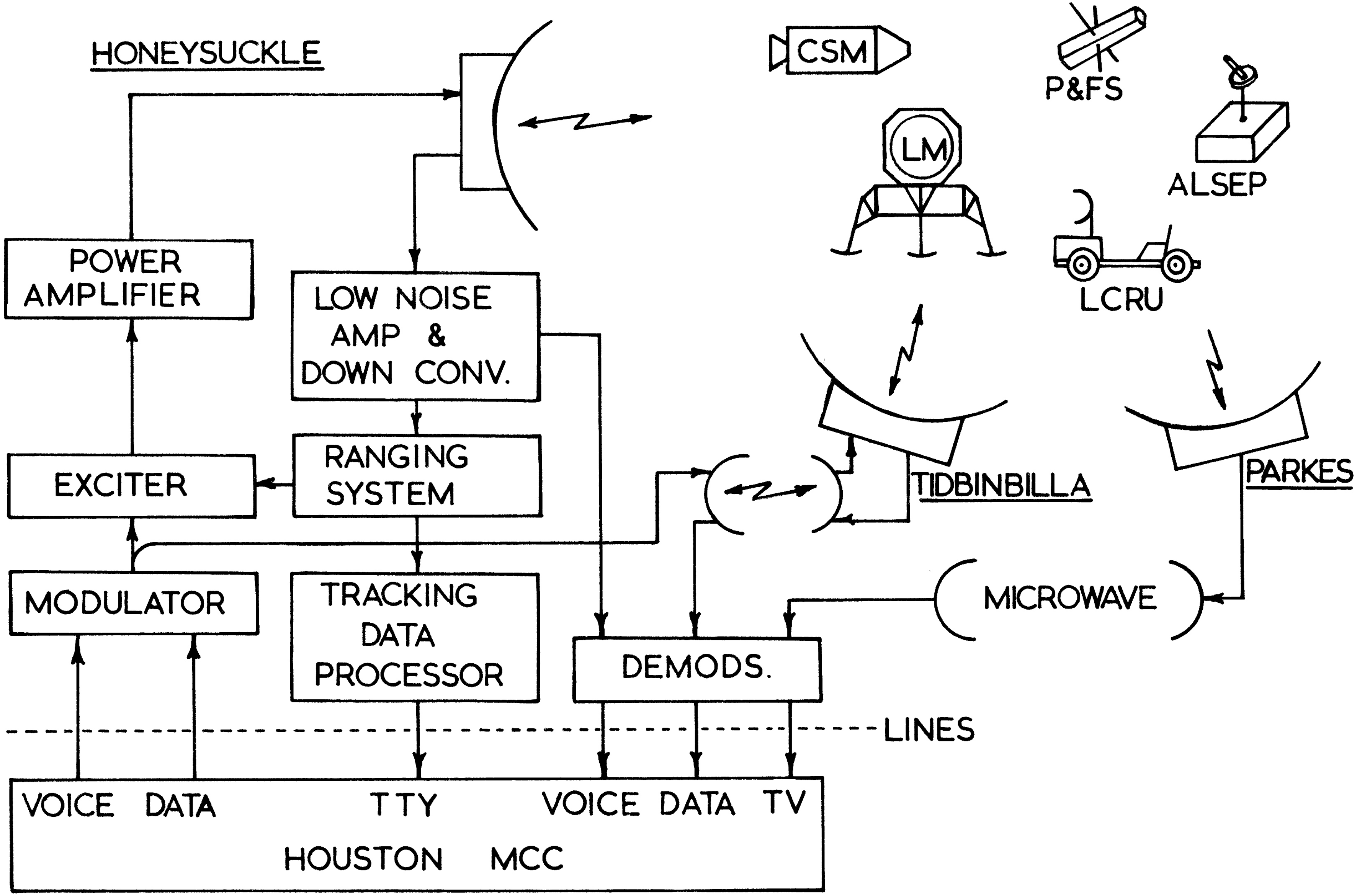


FIG.1 APOLLO MISSION CONFIGURATION.

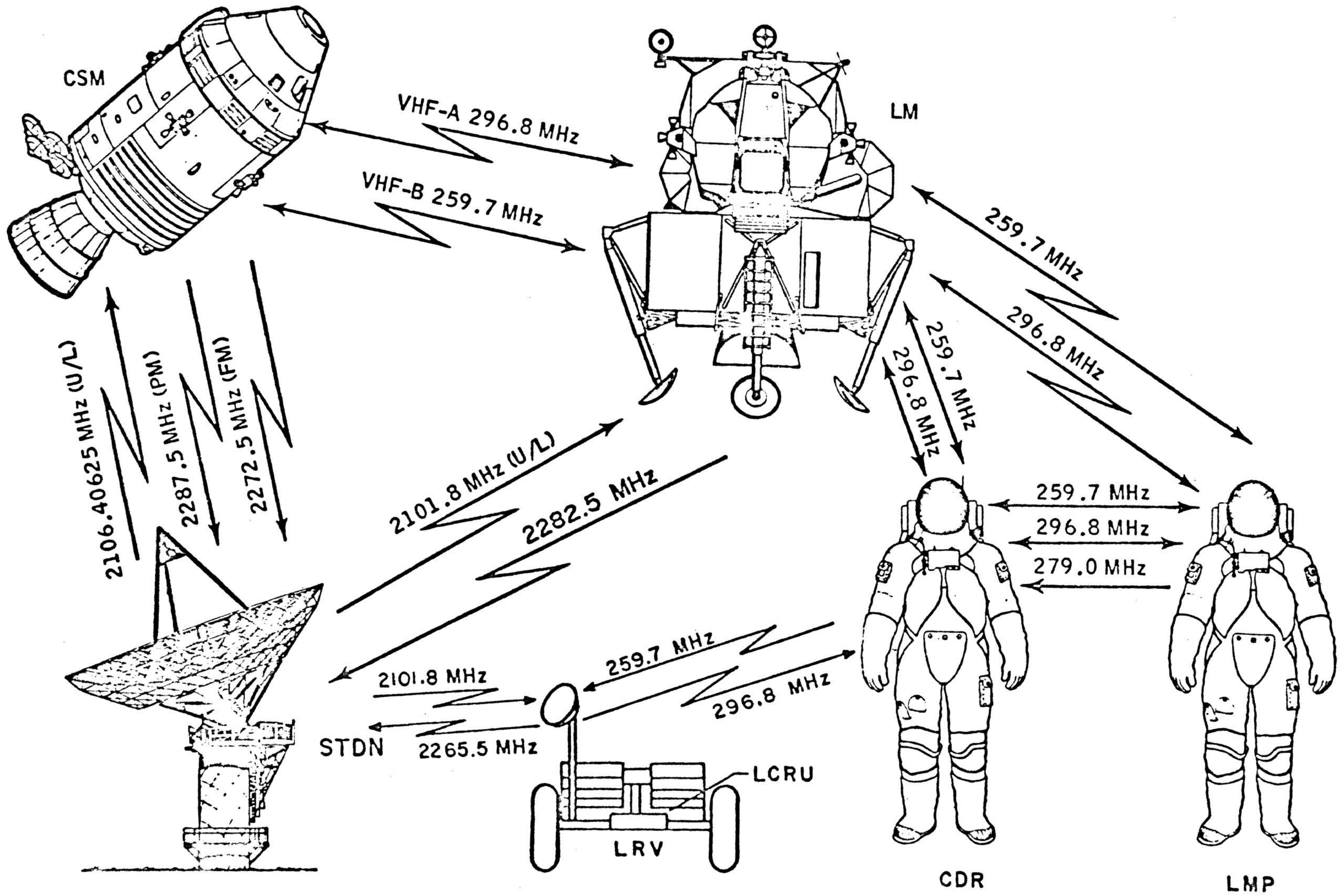


FIG.2. APOLLO COMMUNICATIONS LINKS.

site. The LM & LCRU use the same uplink carrier frequency so the data is vehicle addressed. Upvoice, updata and verification signals are transferred between Honeysuckle and Tidbinbilla on a two-way broad-band redundant microwave system.

The remaining two spacecraft shown are the Particles and Fields Subsatellite (P & FS) which is on the same frequency as the LM, but is not put into orbit around the moon until after the LM has impacted. The second is the Apollo Lunar Surface Experiment Package (ALSEP). These are the scientific experiments left behind on the moon's surface by the astronauts of which there are now five operating on different S-band frequencies.

2.2 Spacecraft to MCC Link (Fig 1)

Downlink voice, data and TV from the Apollo vehicles is received on S-band frequencies at Honeysuckle, Tidbinbilla and Parkes. The signals from Tidbinbilla are transferred by the microwave link mentioned in para 2.1, while the signals from Parkes are transferred by PMG microwave links via Sydney to Honeysuckle. There are four receivers at Honeysuckle, four at Tidbinbilla and two at Parkes so the 'best source' from each vehicle is processed by the demodulators at Honeysuckle, then transmitted back to the MCC via commercial circuits.

Angle tracking data from the Honeysuckle and Tidbinbilla antennas is sent via Teletype (TTY) to Houston.

3. SIMULATION SYSTEM

In order to produce realistic Apollo Simulations it is necessary to provide all MCC and spacecraft functions plus simulated Parkes and Tidbinbilla interfaces, as these stations are not always available for simulations. A block diagram of the simulation configuration is shown in Fig 3.

3.1 Simulation Director.

The overall activities involved in a simulation are co-ordinated by the Sim. Director. These include planned and sometimes unplanned contingencies. He also provides assistance when additional sections in Houston or other stations need to be in simulated voice contact during simulations.

3.2 Houston Simulator.

Honeysuckle is manned by two shifts of up to 12 hours duration during Apollo Missions. During simulations, one shift is exercised while members of the remaining shift are used to man the simulation system. The following Houston positions are manned as follows:

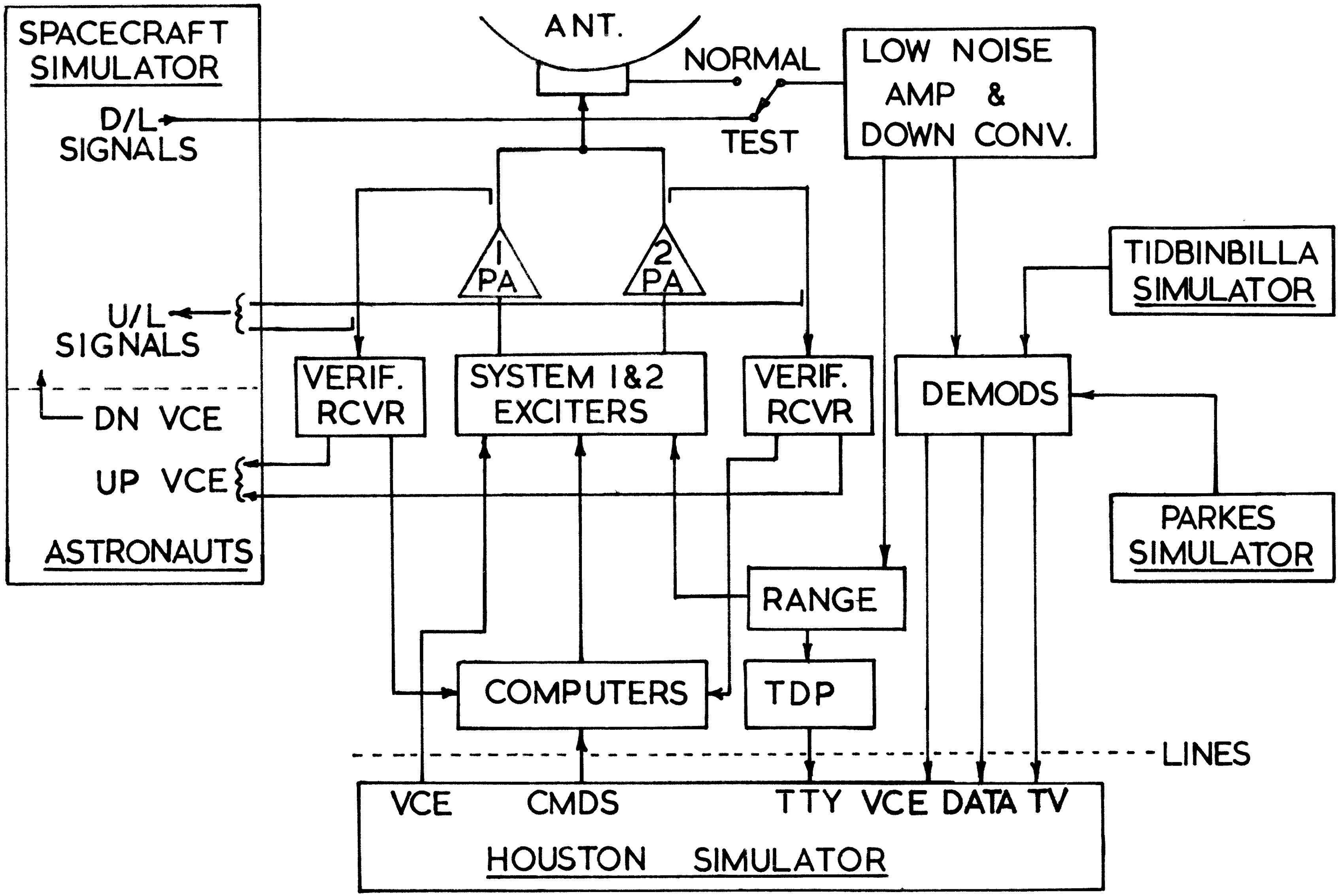


FIG.3. APOLLO SIMULATION CONFIGURATION.

a) Capsule Communicator - is the only person who talks directly with the astronauts.

b) Real Time Command (RTC) operator - uses a spare HSK computer to generate Houston commands and provide appropriate verbal response. Data from the station is monitored to ensure correct station action.

c) Communications Technician (Comtech) - interfaces with the station Comtech. He also simulates line problems, sends TTY messages to the station and ensures that correct messages and responses are received from the station.

3.3 Observers.

Observers are placed in each section of the station and are in direct contact with the Sim. Director. They observe station action and provide constructive criticism during the debrief held after each sim.

3.4 Astronauts.

Two sim. astronauts simulate the three mission astronauts. Either of the sim astronauts is able to select himself to any of the vehicles as required.

As the Sim. Director, Houston personnel and astronauts are all in direct contact in the sim. area, this allows realistic co-ordination of all sim. events. For instance, although the Houston commands are not decoded in the simulated spacecraft, the astronauts are able to provide correct responses by switching modes etc., for realism.

4. SPACECRAFT SIMULATOR

The equipment is housed in a modified console which was originally used in one of the Gemini programme tracking ships. A photograph of the 'sim. console' as it is referred to, is shown in Fig 4. A block diagram of the CSM, LM & LCRU Uplink and Downlink interface is shown in Fig 5.

4.1 CSM Phase Modulated (PM) Link.

The CSM PM uplink (Fig 7) is received on a modified Apollo transponder from the station 1 or 2 transmitter via a 3 db hybrid (Fig 5). The PM downlink (Fig 8) from the transponder is fed into the station receivers via a test cable immediately behind the antenna (Fig 3). The combinations of CSM data and astronauts voice modulated onto the transponder downlink is selected from the CSM control panel. A block diagram of the modified transponder is shown in Fig 6.

During missions the ground transmitted uplink is swept in frequency to capture the spacecraft receiver phase lock loop (PLL), which has a bandpass of about 700 Hz. Once the PLL is locked, it is used to generate a phase coherent downlink, in order to provide accurate spacecraft range and doppler data. In the modified transponder

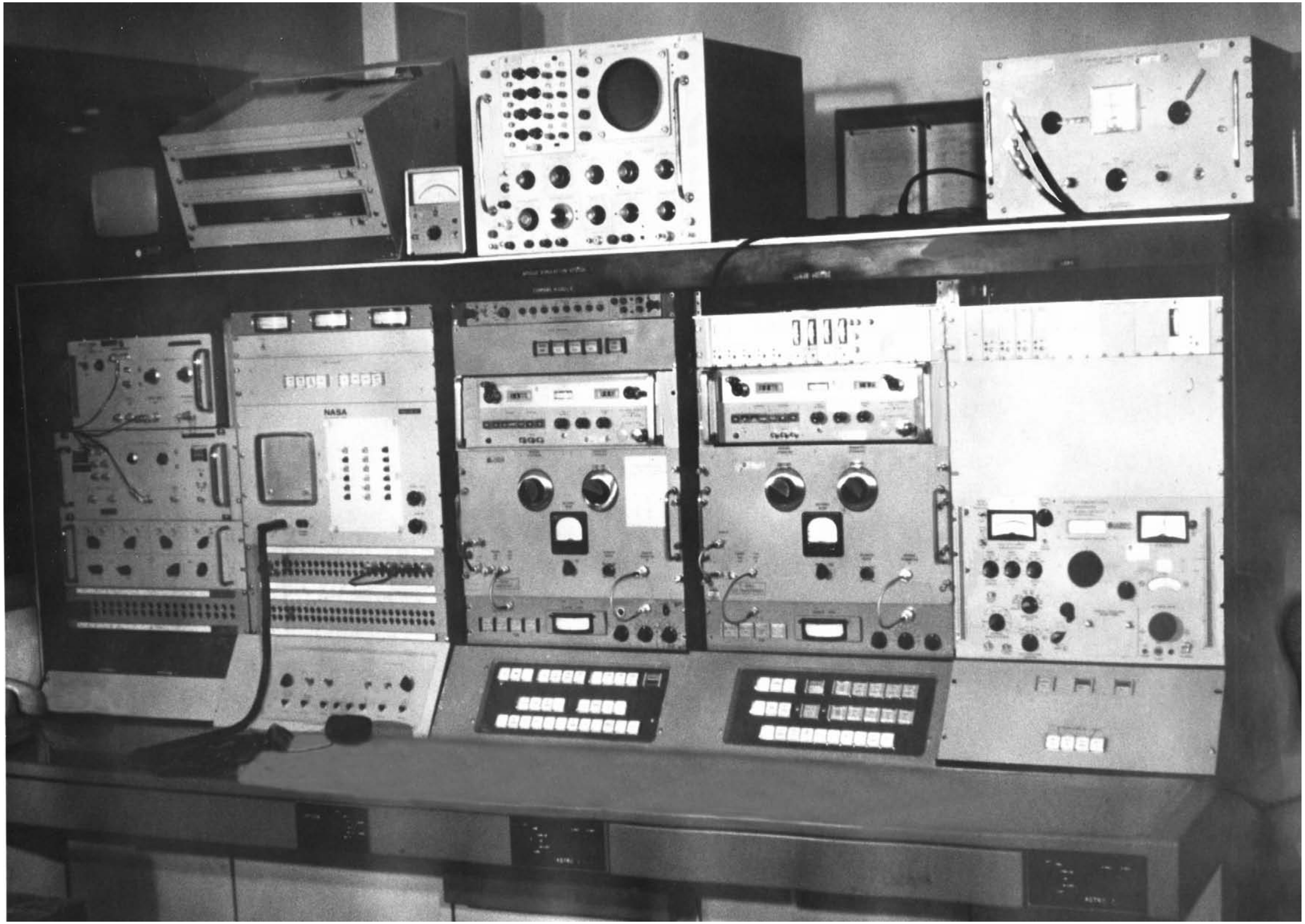


Fig. 4

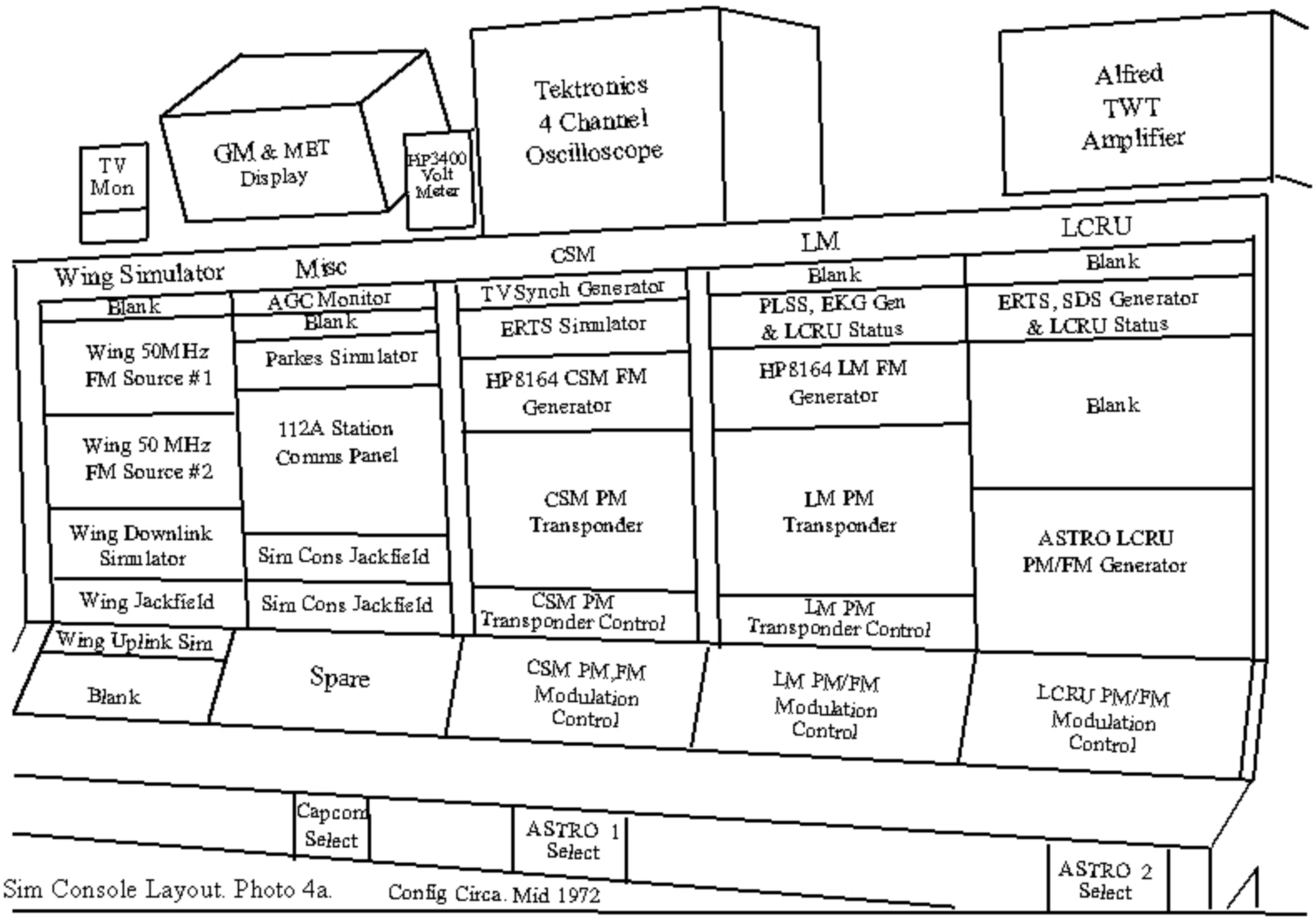

TV Mon
GM & MET Display
HP3400 Volt Meter
Tektronics 4 Channel Oscilloscope
Alfred TWT Amplifier
Wing Simulator
Misc
CSM
LM
LCRU
Blank
AGC Monitor
Blank
TV Synch Generator
Blank
Blank
Wing 50MHz FM Source #1
Parkes Simulator
ERTS Simulator
PLSS, EKG Gen & LCRU Status
ERTS, SDS Generator & LCRU Status
Wing 50 MHz FM Source #2
112A Station Comms Panel
HP8164 CSM FM Generator
HP8164 LM FM Generator
Blank
Wing Downlink Simulator
CSM PM Transponder
LM PM Transponder
ASTRO LCRU PM/FM Generator
Sim Cons Jackfield
Wing Jackfield
Sim Cons Jackfield
CSM PM Transponder Control
LM PM Transponder Control
Wing Uplink Sim
Blank
Spare
CSM PM,FM Modulation Control
LM PM/FM Modulation Control
LCRU PM/FM Modulation Control
Capcom Select
ASTRO 1 Select
ASTRO 2 Select
Sim Console Layout. Photo 4a.
Config Circa. Mid 1972

Fig. 4a

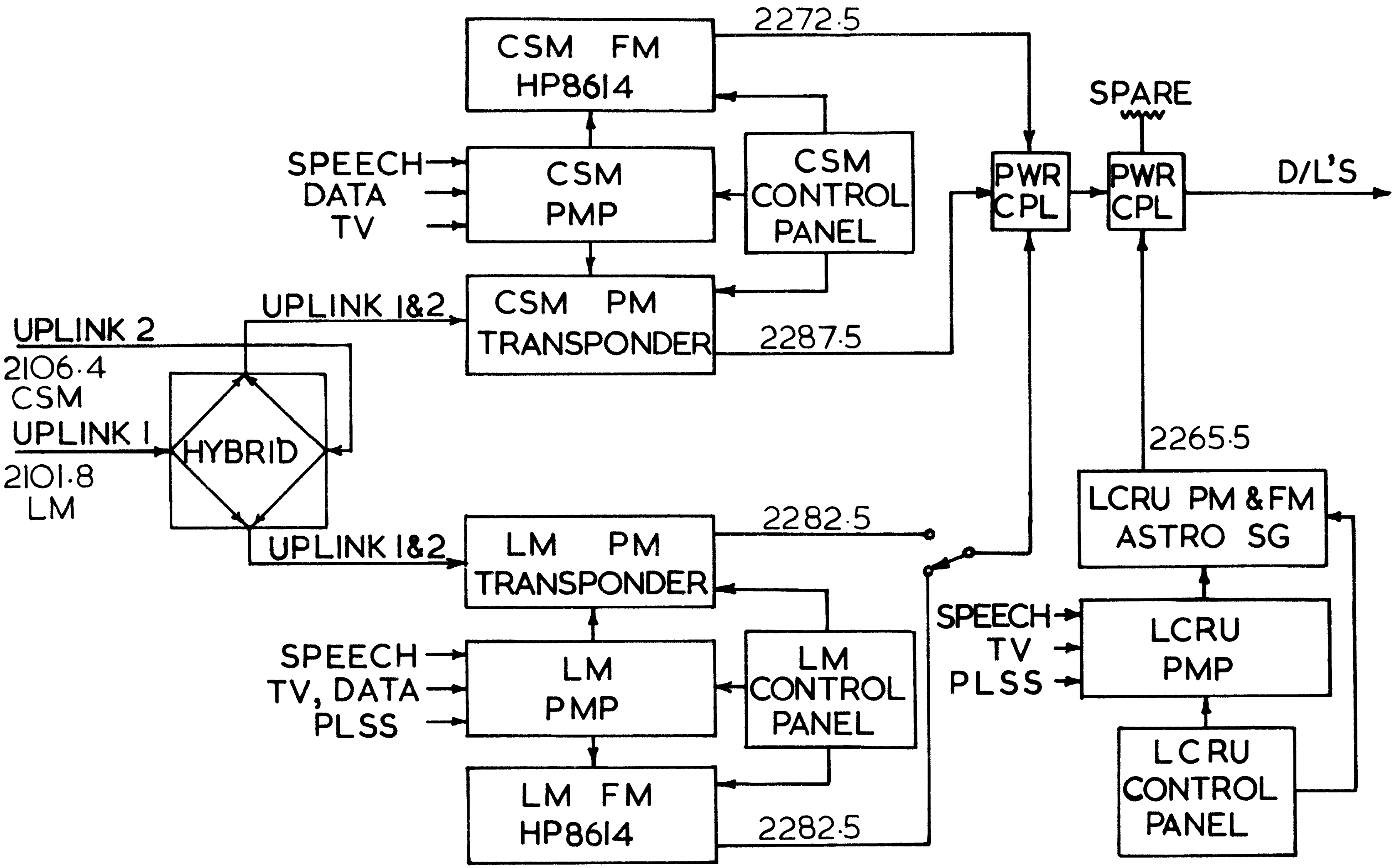


FIG. 5. SPACECRAFT SIMULATOR.

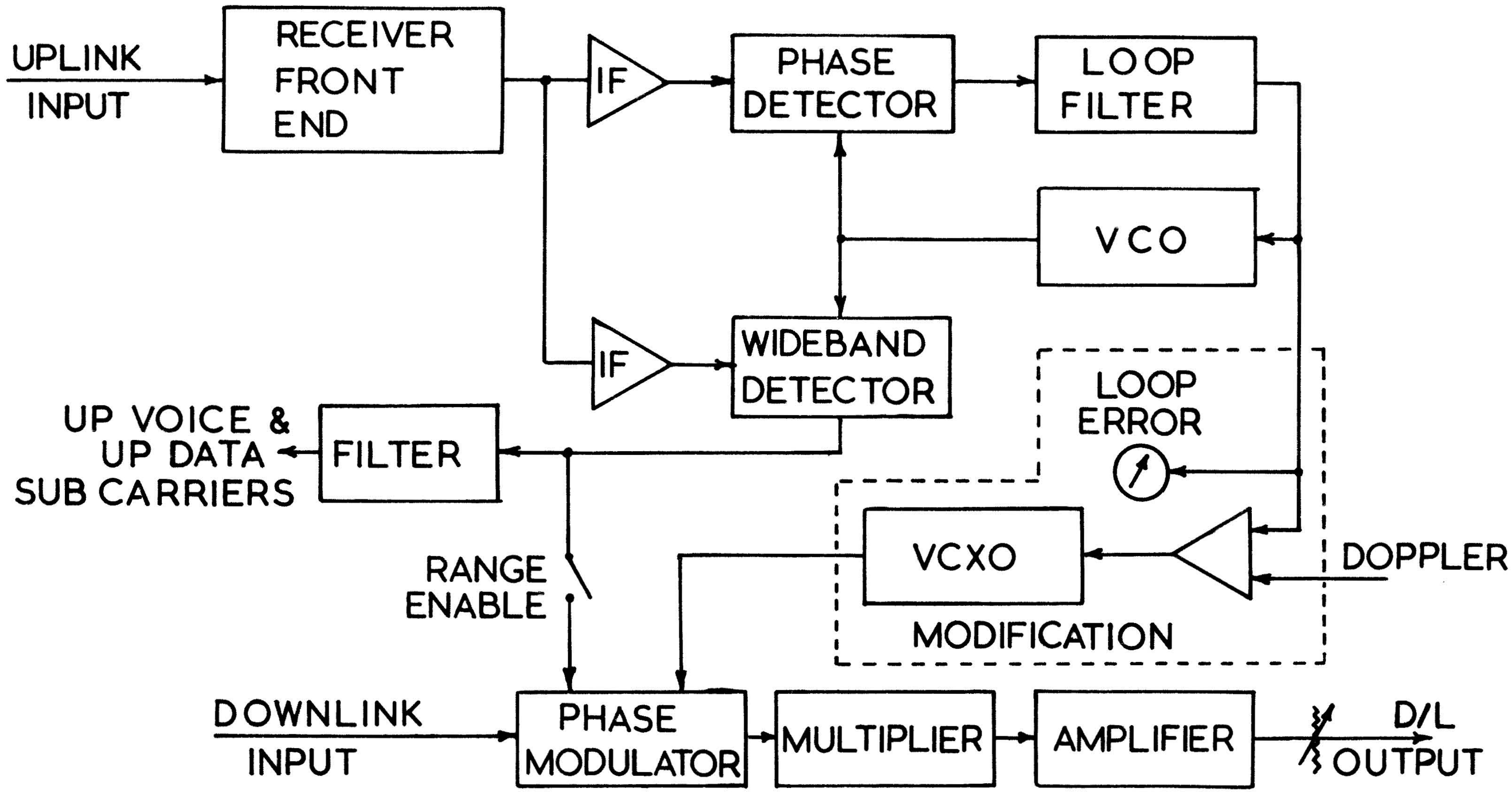


FIG.6. MODIFIED TRANSPONDER.

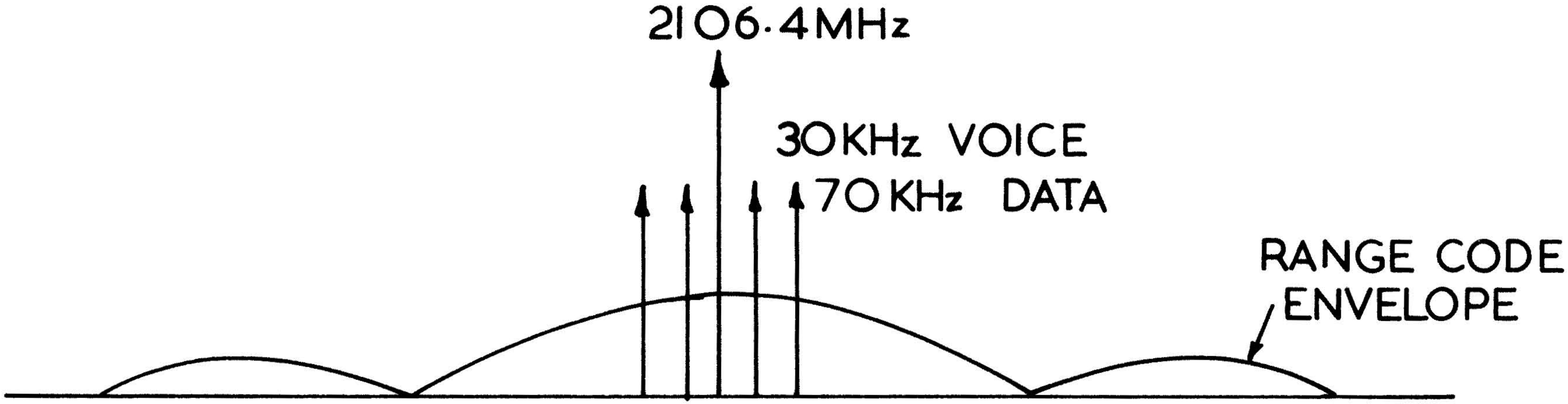


FIG.7. CSM UPLINK SPECTRUM

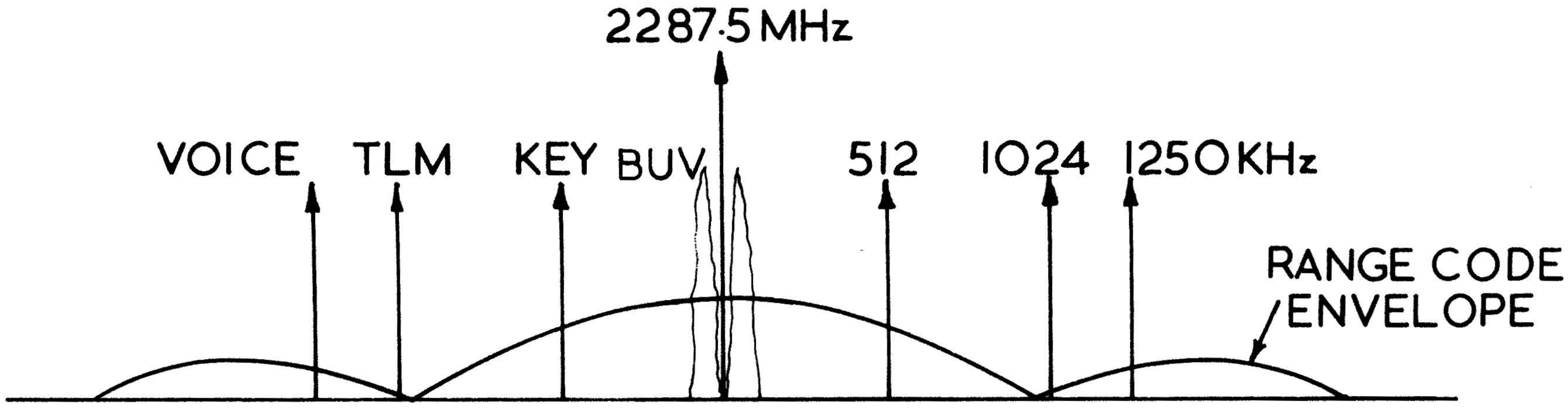


FIG. 8. CSM PM DOWNLINK SPECTRUM

the downlink is generated from a voltage controlled crystal oscillator (VCXO) so the transponder is not coherent. The error voltage from the PLL is, however, fed to the VCXO so it appears to produce a coherent downlink. When the uplink frequency is swept, once the PLL has locked, the downlink will then sweep in sympathy thus indicating a lock of the spacecraft receiver in the normal manner. However, as the downlink is derived from the VCXO, a separate voltage may be summed with the error voltage to simulate doppler on the transponder downlink. This allows the simulation of doppler out to lunar distances and is controlled from the transponder control panel.

The CSM PM uplink spectrum generated by the station (Fig 7) comprises, astronauts voice modulated onto the 30 KHz subcarrier, which in turn is modulated onto the S-Band carrier and command data modulated onto the 70 KHz subcarrier. As mentioned previously, the data normally transmitted to the simulated spacecraft is not used, so it is not therefore necessary to demodulate the subcarrier. When the commands are sent from the simulated MCC in the Sim. Area, any commands requiring a response on the downlink are manually co-ordinated (E.G. switching antennas requires a change in downlink signal strength, switching modes requires a change on the CSM control panel etc. including the $2\frac{1}{2}$ sec. delay at lunar distances). The Range code envelope is also transmitted on the uplink consisting of a 497 KHz clock modulated by a psuedo-random code. This is demodulated in the transponder (Fig 6) fed via the range enable switch and remodulated onto the downlink. The transmitted and received range codes are compared in the station and by measuring the delay the distance to the vehicle may be determined.

The CSM downlink spectrum is shown in Fig 8. The main requirement is the transmission of the Astronauts voice and telemetry data to the ground. The data whether it be biomedical, attitude, acceleration or general housekeeping data is biphase modulated $\pm 90^{\circ}$ onto a 1.024 MHz subcarrier which is in turn phase modulated onto the S-band carrier. Either high 51.2 Kbs (HBR) or low 1.6 Kbs (LBR) data may be selected depending on the ground station received signal strength. An emergency Key mode is also provided where 512 KHz (the basic spacecraft clock frequency) is hand keyed directly onto the carrier. Normal voice is phase modulated onto a 1.25 MHz subcarrier, while Back-up Voice (BUV) is phase modulated directly onto the carrier to provide a lower threshold than normal voice. Various combinations of the above signals are provided to give a total of 16 different modes. These modes are selectable on the CSM control panel which in turn selects the correct modulation index for the combination in the Pre Modulation Processor (PMP) (Fig 9).

The square blocks at the bottom of Fig 9 represent diode switches to select the data, while the number in the block is the mod. index in radians. On the left are two BUV modes at 0.7 and 1.2 radians (r) with two normal voice modes at 0.7 and 1.2 r respectively and so on. The mod. index selection is determined by the combinations of HBR, LBR, Normal Voice BUV etc. so as to maintain equal thresholds on voice and data. The combinations are predetermined by the control panel switching logic which automatically selects the correct deviation. The composite baseband level out of the PM section of the PMP has been standardised at 1 volt/radian. The HBR and LBR live data is recorded on two tracks of a 14 track Magnetic Tape Recorder (MTR) selectable as required. A simplified block diagram of the diode switches is shown in Fig 10. +28V applied from the control panel enables the diodes which feed the selected level to the summing amp. Isolation through these switches is in the order of 60 db. The diode switches and summing amps are constructed on matrix board mounted in die cast boxes.

4.2 CSM Frequency Modulated (FM) Link.

As previously mentioned, the FM downlink and PM downlink

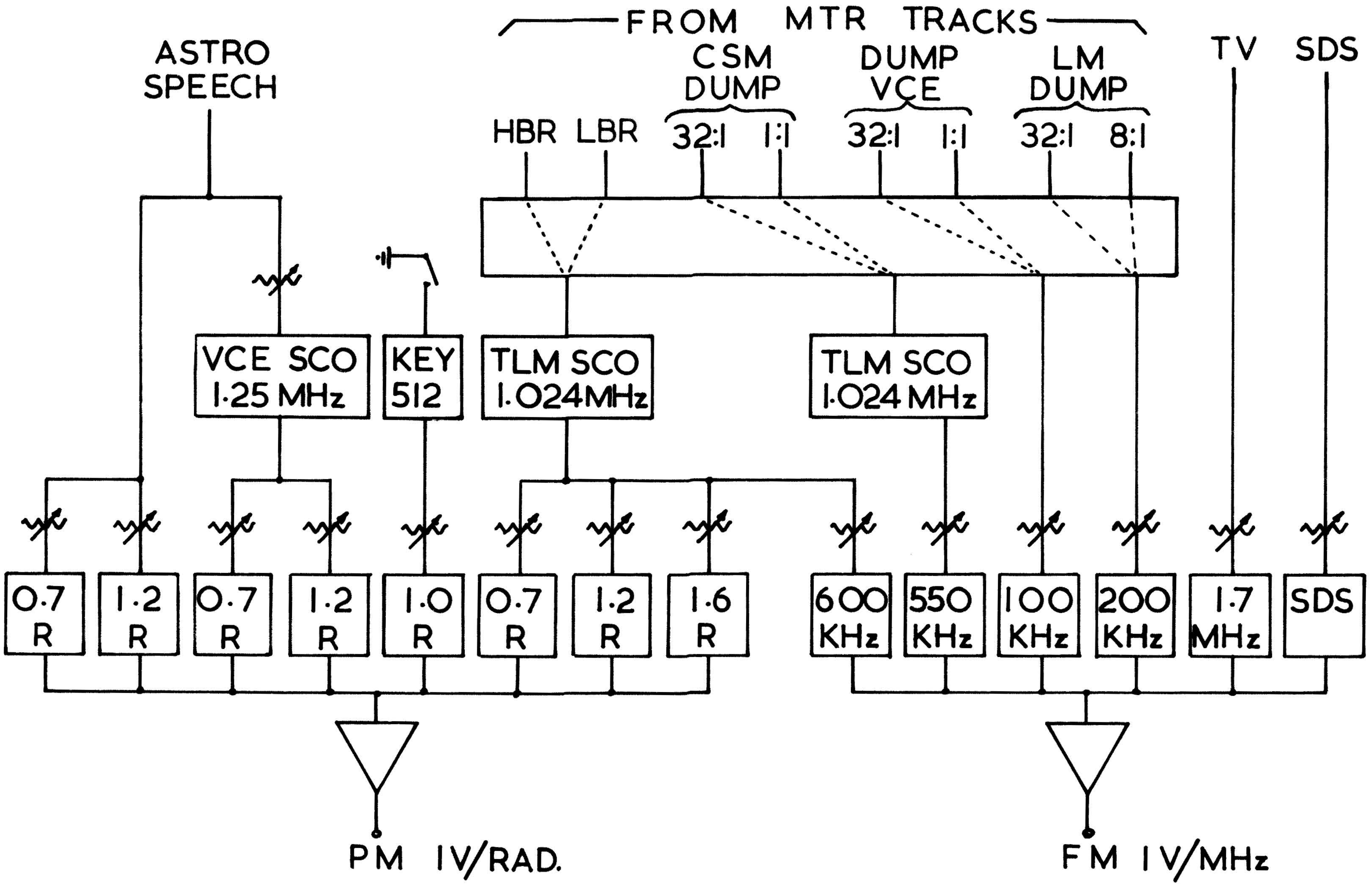


FIG.9. CSM PREMODULATION PROCESSOR.

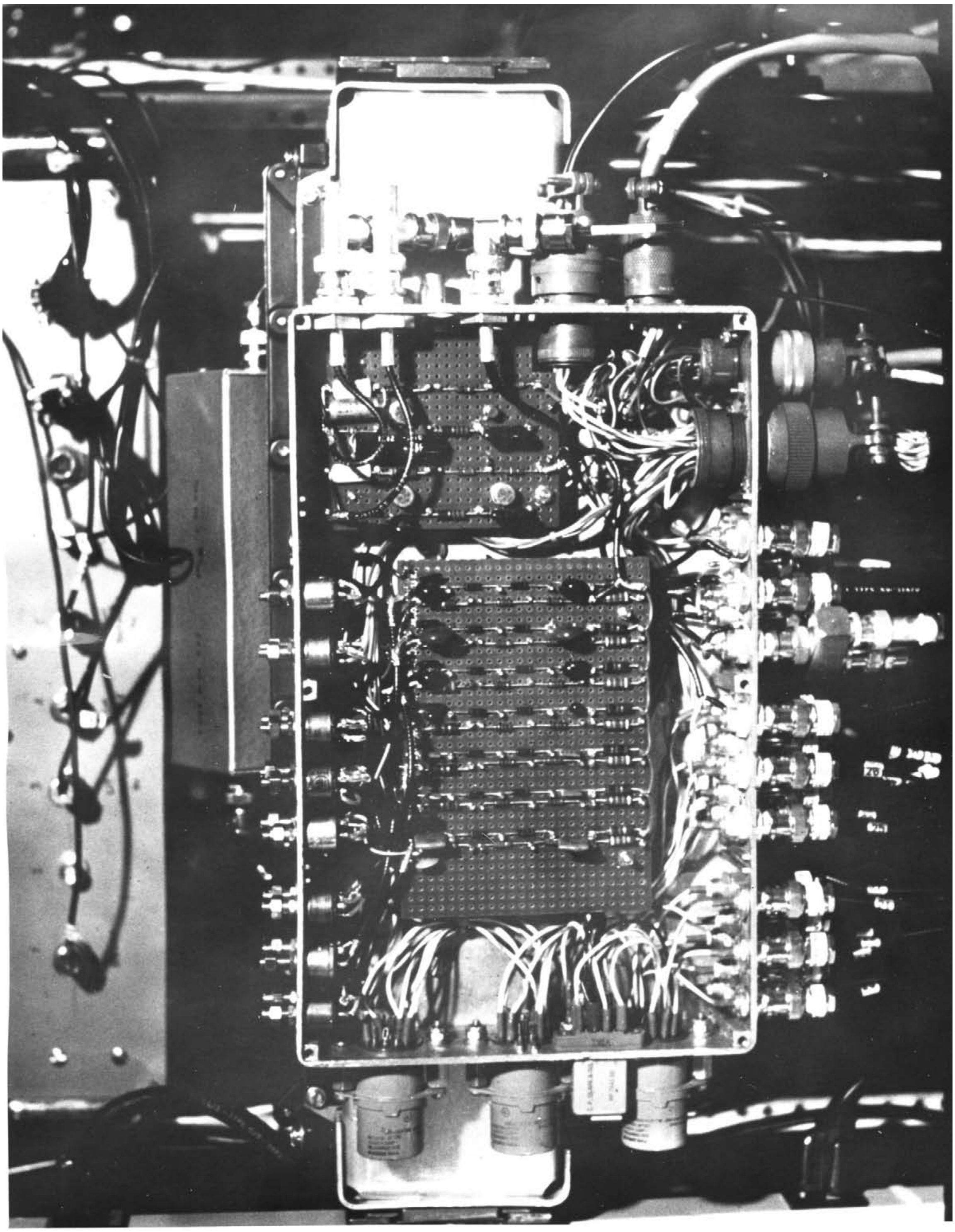


Fig. 9a CSM PREMODULATION PROCESSOR

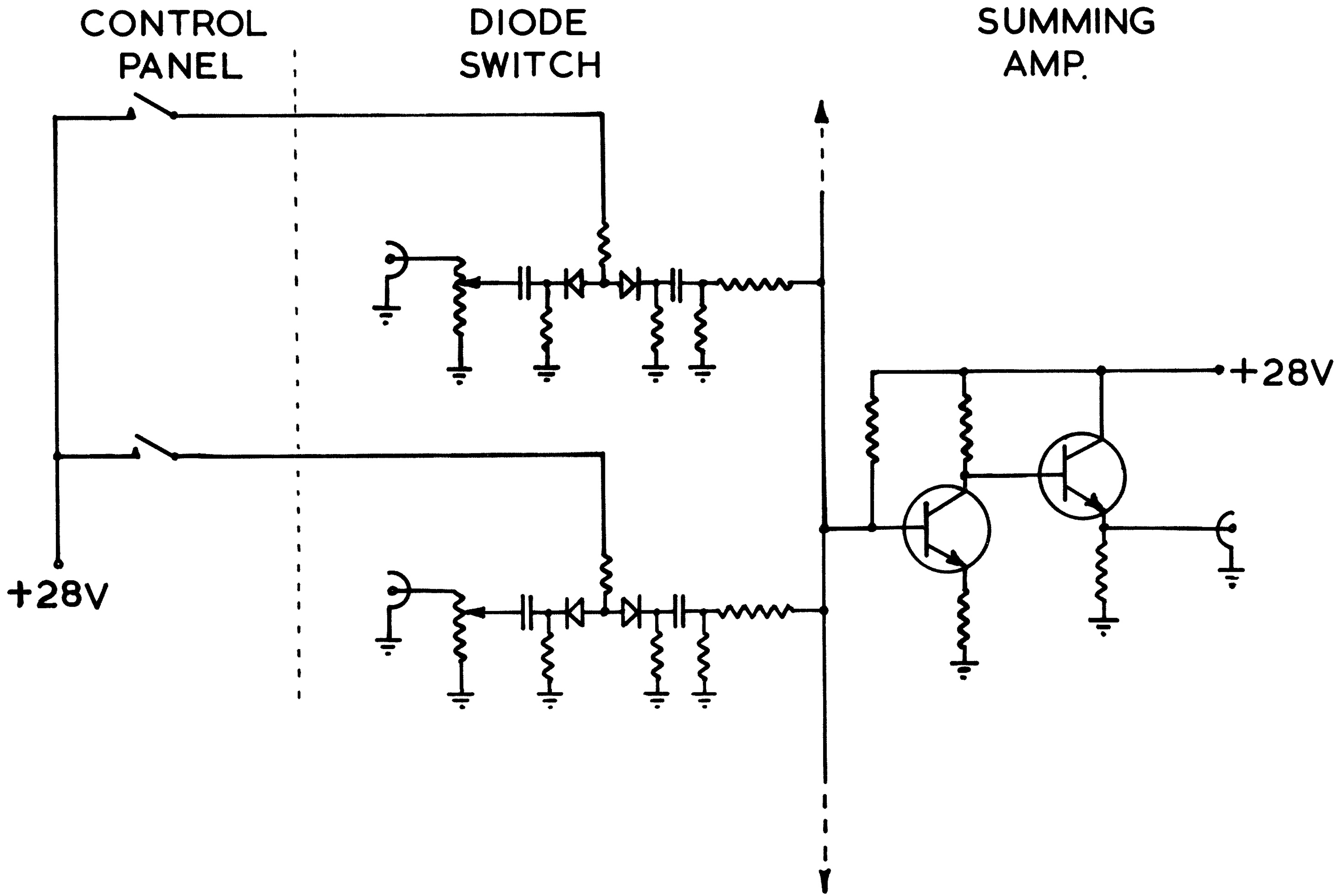


FIG.10. PMP DIODE SWITCHES

may be used simultaneously. The FM downlink is used to transmit wideband data such as TV (Standard ElA format with reduced bandwidth), playback of recorded voice and telemetry data (typically recorded when CSM is out of contact behind the moon) and since Apollo 14 data from the Scientific Data System (SDS) from the Scientific Instrument Module (SIM).

Playback data or Dump, as it is referred to, is shown in Fig 11. All combinations are shown but cannot be transmitted simultaneously. The modes are as follows.

CSM data on 1.024 MHz subcarrier HBR dump at 1:1 or LBR at 32:1 together with voice at 1:1. To reduce LM weight and power consumption, LM data may be recorded and dumped via the CSM. There are three LM Dump modes HBR and voice at 1:1, LBR and voice dumped at 32:1 which means the LBR will appear as HBR and the voice frequency range will be extended from 10 - 96 KHz, or Medium/Low BR where LBR and voice is dumped at 8:1 so LBR will appear at 12.8 Kbs and voice will occupy 3 - 24 KHz. It should be noted that LM data is dumped directly on baseband and not via the subcarrier as for CSM data.

The SDS spectrum (Fig 12) is the most complex comprising 7 subcarriers. The 165, 200, 300 & 400 KHz are FM.

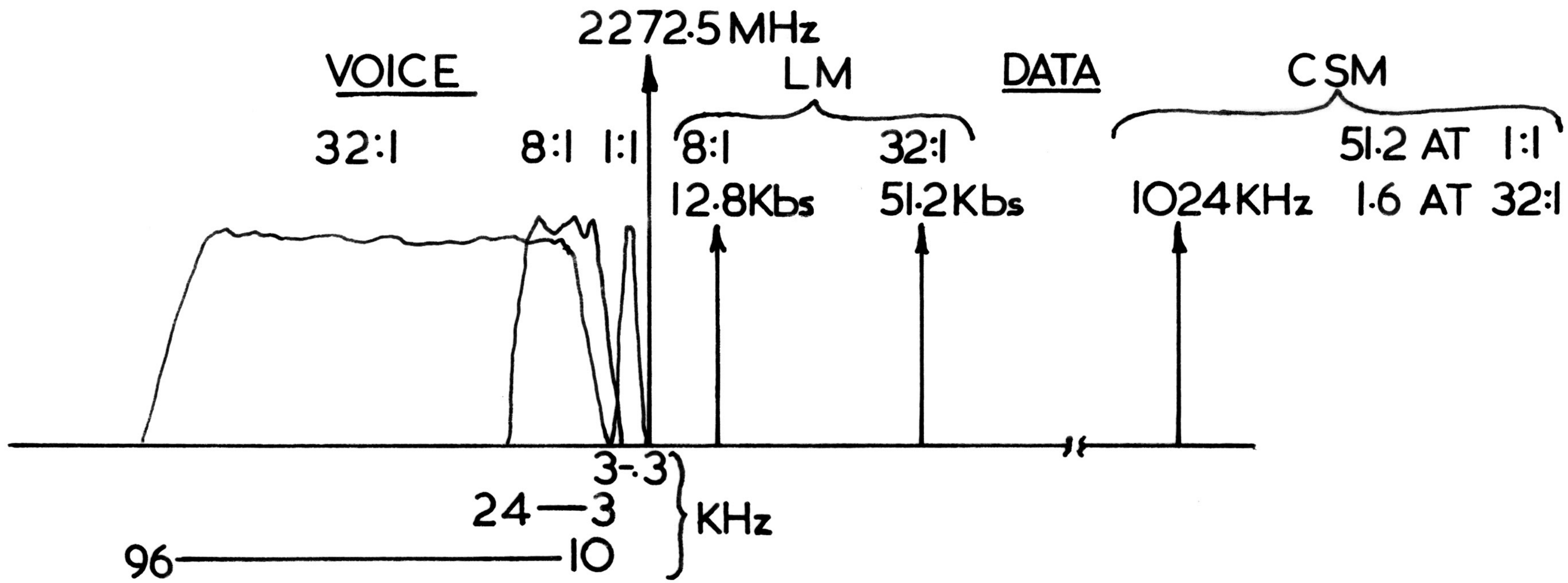


FIG.11. CSM FM DUMP DOWNLINKS

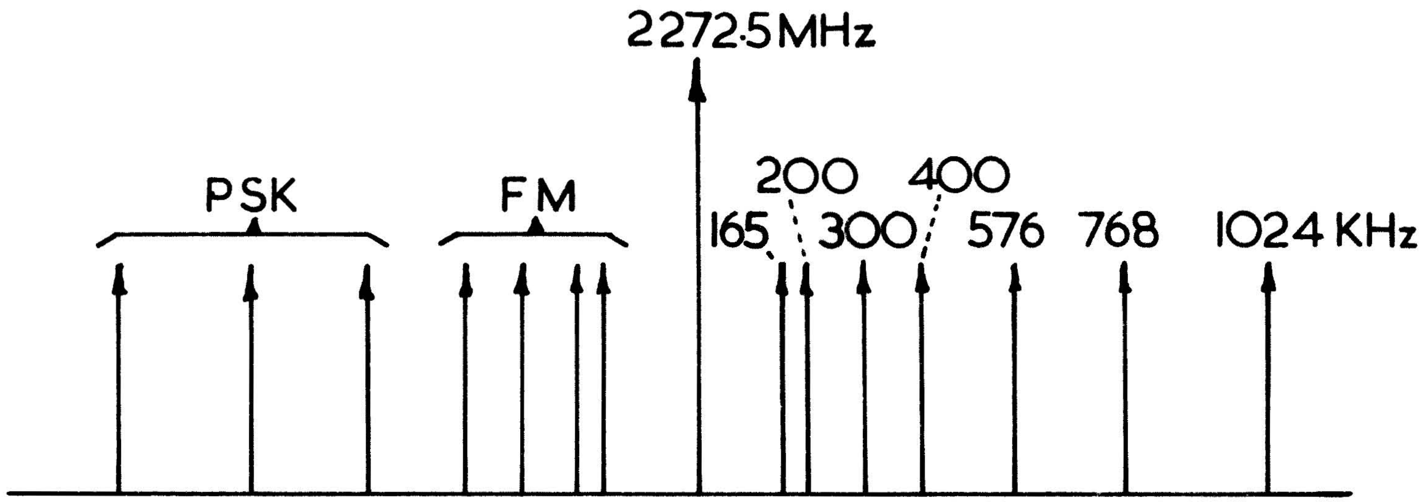


FIG. 12. SCIENTIFIC DATA SYSTEM

165 KHz is used for dump data, 200 KHz for real time data both of which are modulated at 3.906 Kbs. The 300 and 400 KHz subcarriers are present but have never been modulated. The remaining 3 subcarriers Phase Shift Keyed (PSK $\pm 90^{\circ}$ with 576 KHz for dump and 768 KHz realtime, both at 64 Kbs, and 1024 KHz, the normal CSM dump telemetry at 51.2 Kbs. Scientific data can only be dumped at 1:1.

Fig 13 shows the method used to produce the SDS spectrum and this is fed to the CSM FM PMP (Fig 9) where it may be selected together with the normal 1024 KHz subcarrier. The respective deviations are shown in the blocks and the composite modulation from the FM baseband out of the CSM PMP is standardised at 1 volt/MHz.

The four SDS FM subcarrier oscillators (SCO's) are modified commercial units. These were modified from a much lower frequency which included the redesign of the output bandpass filter. As the 576 and 768 PSK modulators require low phase jitter, the basic frequency is derived from a crystal oscillator (Fig 14) on twice the final frequency. A regenerative divide by 2 stage was used to provide a sinewave, with total harmonic distortion less than 1%, to the modulator via

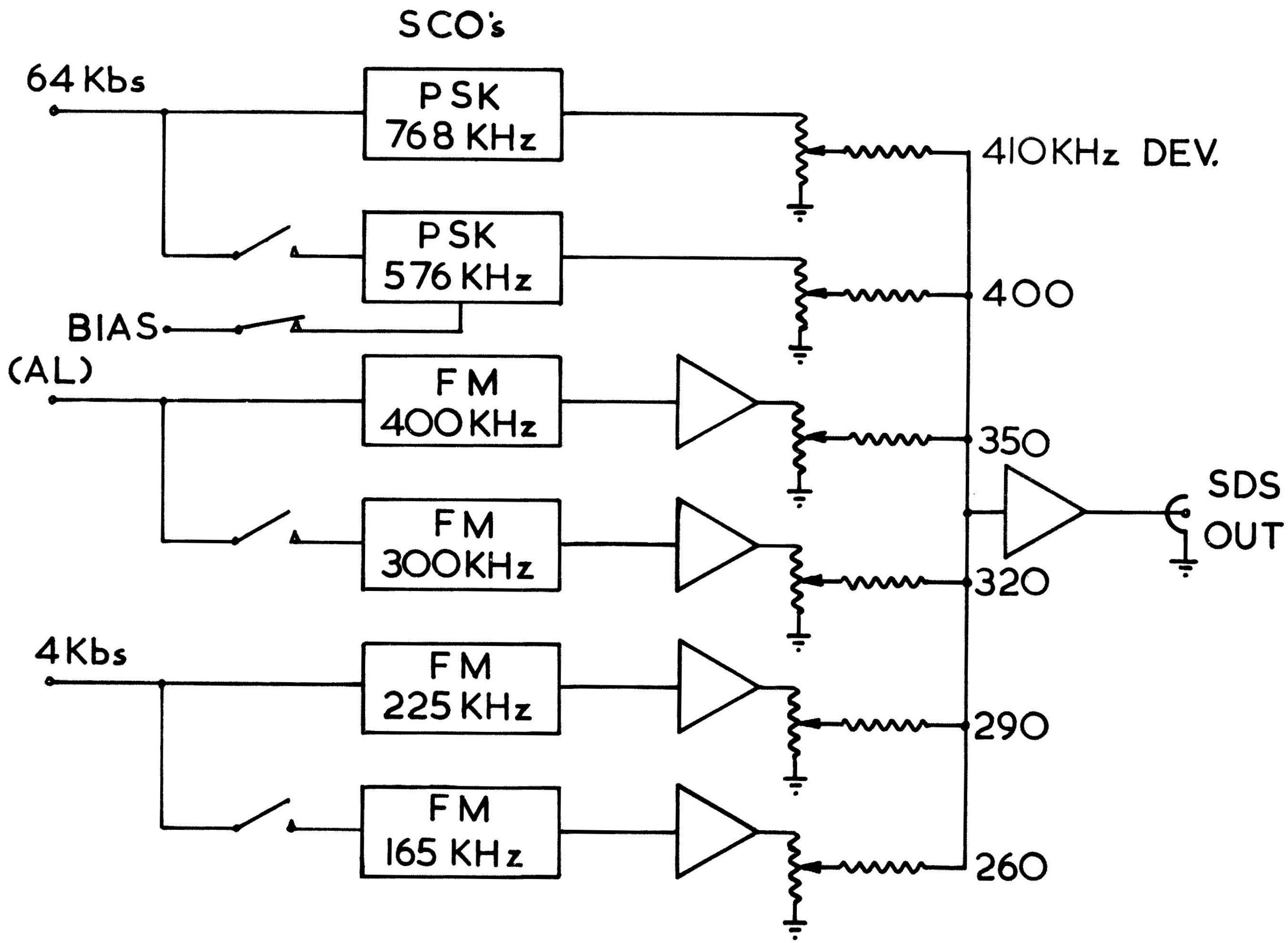


FIG.13. SDS PMP

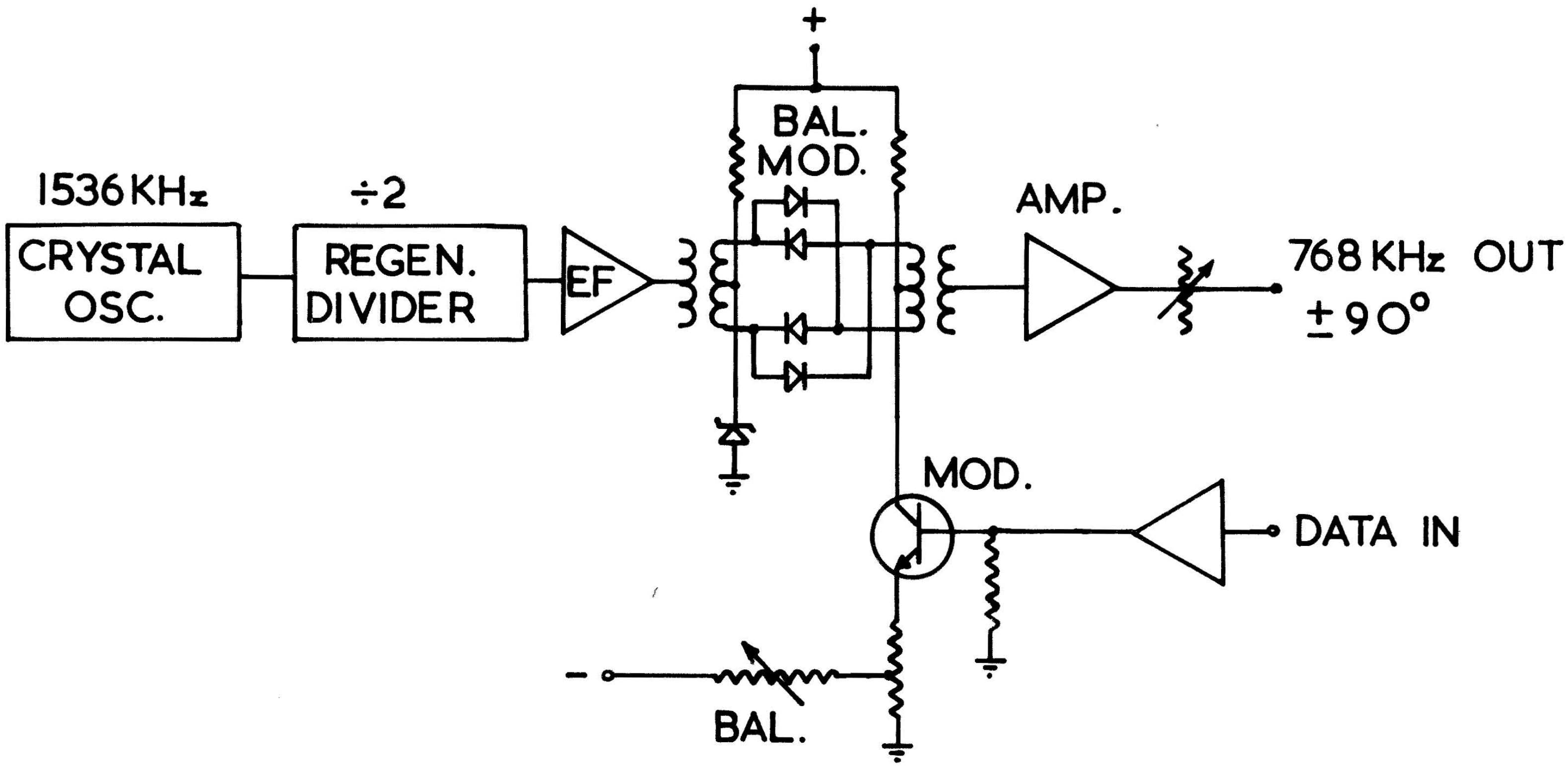


FIG. 14. PSK MODULATOR.

an emitter follower. Matching of diodes and the use of trifilar wound toroids provides carrier supression of 50 db set by the balance control in the emitter of the modulating transistor. The data (ones and zeros) selects either pair of diodes giving the desired $\pm 90^{\circ}$ phase shift.

The PSK modulators are built on printed circuit boards and housed in blank module cases similar to the FM SCO's. Data at 64 and 3.906 Kbs is obtained from another two tracks of the Sim. MTR, the same data being used for Dump and Realtime.

4.3 LM PM.

For reasons of power conservation, the LM can only transmit either PM or FM, consequently the same frequency is used for both. (Fig 5). The transponder modifications are identical to the CSM (Fig 6). Apart from the frequencies, the uplink (Fig 15) and downlink spectra (Fig 16) are identical to the CSM with one exception. When the Astronauts are suited up for critical descent, ascent or Extra Vehicular Activities (EVA), a careful monitor is maintained on consumables VIZ. suit coolant flows, temperature pressures etc., in each Astronauts portable life support system (PLSS).

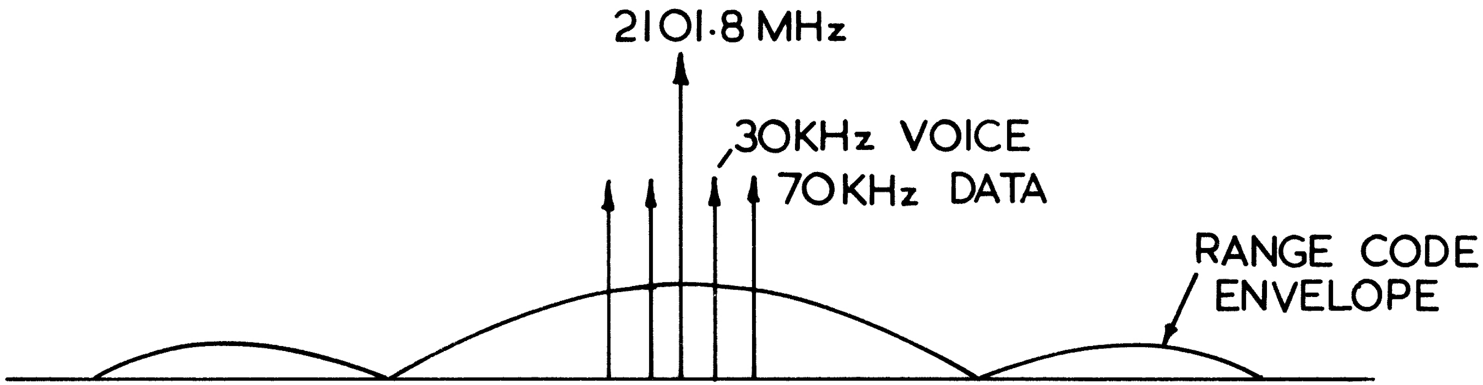


FIG.15. LM UPLINK SPECTRUM

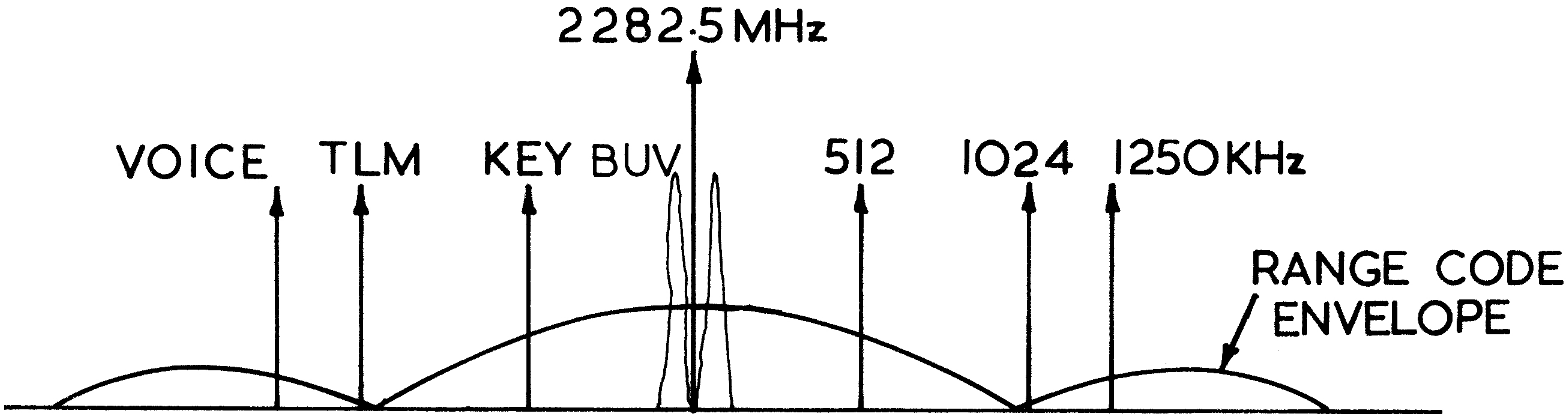


FIG.16. LM PM SPECTRUM

Also both astronauts heartbeats (EKG) are constantly monitored. This information is frequency multiplexed onto 5 subcarriers modulated onto the 1.25 MHz voice subcarrier together with the voice or when BUV is used direct on PM baseband. Reference to Fig 2 will show that similar VHF frequencies are used to link the astronauts to the LM and LCRU so that both astronaut voices will appear on the S-Band links. The data on the PLSS subcarriers (Fig 17) is allocated as follows, 3.9 KHz EKG2, 5.4 KHz EKG 1 astronauts 2 and 1 respectively, 7.35 KHz PAM 2, 10.5 KHz PAM 1 contains the suit data using 6 time division pulse amplitude modulated (PAM) channels on each subcarrier. The fifth subcarrier on 14.5 KHz LM EKG is used to monitor one of the LM astronauts heartbeats when out of their suits. When they are suited up this subcarrier is transmitted but unmodulated.

The LM PMP block diagram (Fig 18) shows how the PLSS signals are generated. The SCO's are commercial units on standard telemetry frequencies. The two identical EKG generators (Fig 19) are built into a blank module and allow independent adjustment of the simulated heartbeats. The station is able to remote this data live to the MCC and during Sims. it is

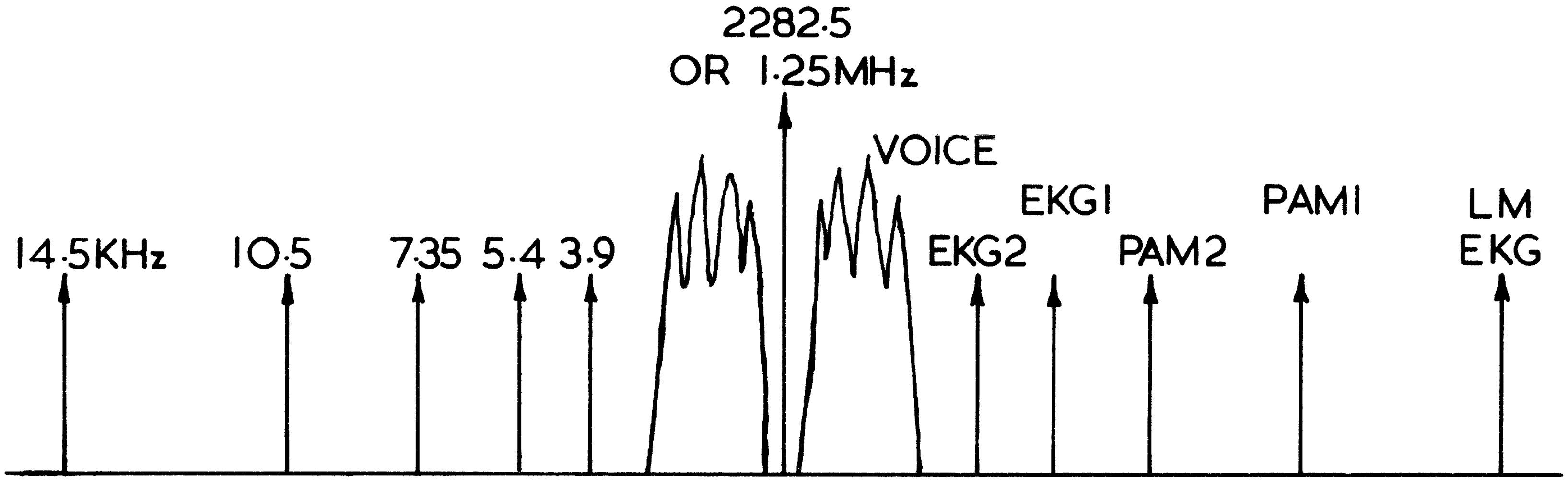


FIG.17. VOICE & PLSS COMPOSITE

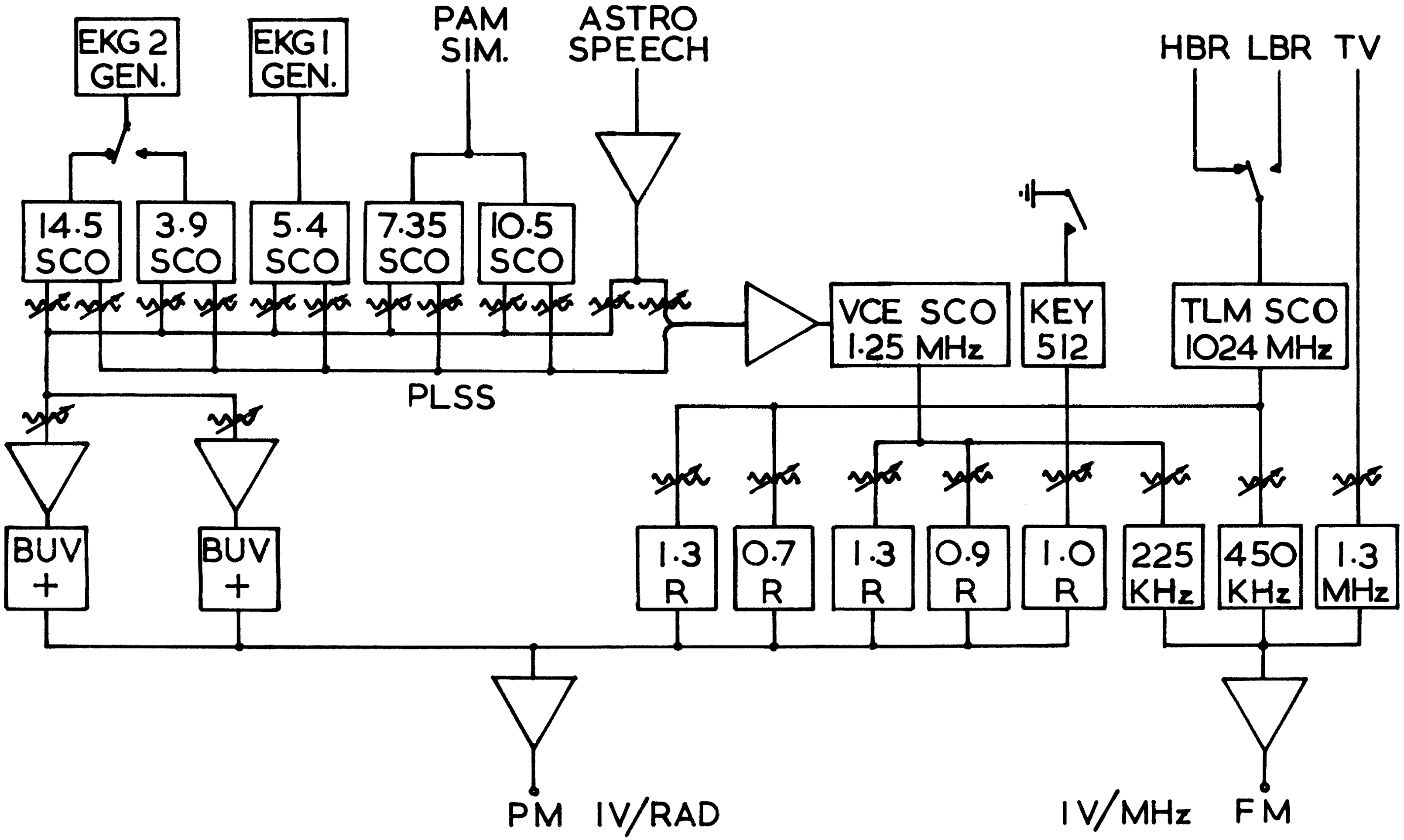

EKG 2 GEN.
EKG 1 GEN.
PAM SIM.
ASTRO SPEECH
HBR LBR TV
14.5 SCO
3.9 SCO
5.4 SCO
7.35 SCO
10.5 SCO
VCE SCO 1.25 MHz
KEY 512
TLM SCO 1024 MHz
PLSS
BUV +
BUV +
1.3 R
0.7 R
1.3 R
0.9 R
1.0 R
225 KHz
450 KHz
1.3 MHz
PM 1V/RAD
1V/MHz FM

FIG.18. LM PMP.

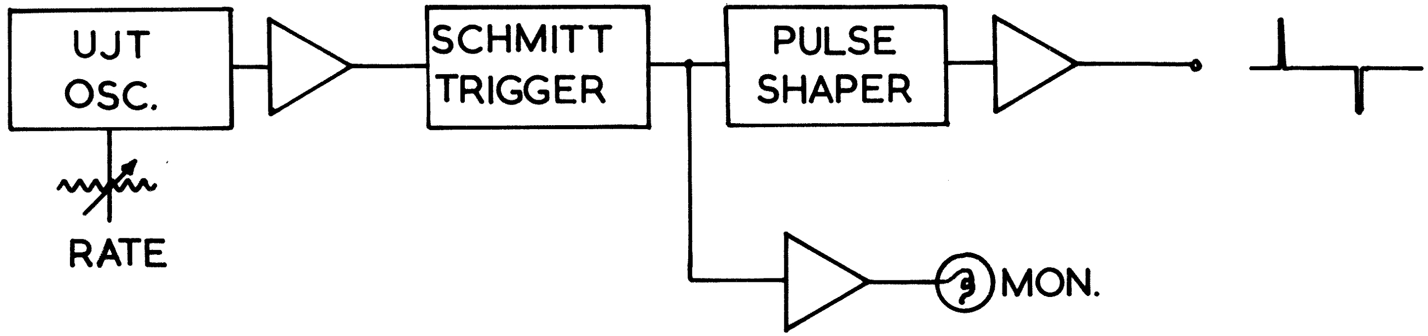


FIG.19. EKG GENERATOR.

possible to check, by varying the rate, that the correct data is being remoted. Apart from the different mod. indices the rest of the LM PMP is similar to the CSM PMP.

4.4 LM FM.

The main differences between LM & CSM FM are -

1. No dump data transmitted from the LM
2. LM FM and PM on the same frequency.
3. As only one downlink is transmitted from the LM, when LM TV is transmitted it is necessary to also transmit the telemetry and voice subcarriers (Fig 20). In recent missions the quality of LM TV has been improved by the use of subcarrier cancellation techniques to remove the subcarriers rather than filters used on early missions.
4. Realtime normal voice is transmitted on LM FM.
5. No BUV can be transmitted on LM FM. When marginal LM signals are received PM modes are used. When the LM High Gain Antenna is used sufficient margin is available for LM FM. Because of the above restrictions LM FM (Fig 20) is somewhat simpler than CSM FM (Fig 11 or 12).

4.5 LCRU PM

The LCRU modes are much simpler than either the CSM or LM. The PM uplink (Fig 21) is on the same frequency as

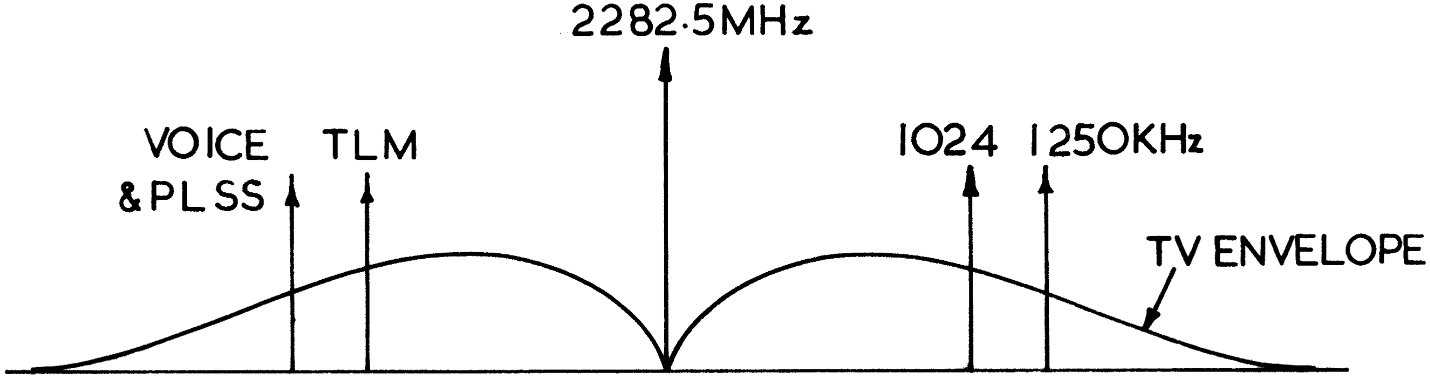


FIG.20. LM FM DOWNLINK SPECTRUM

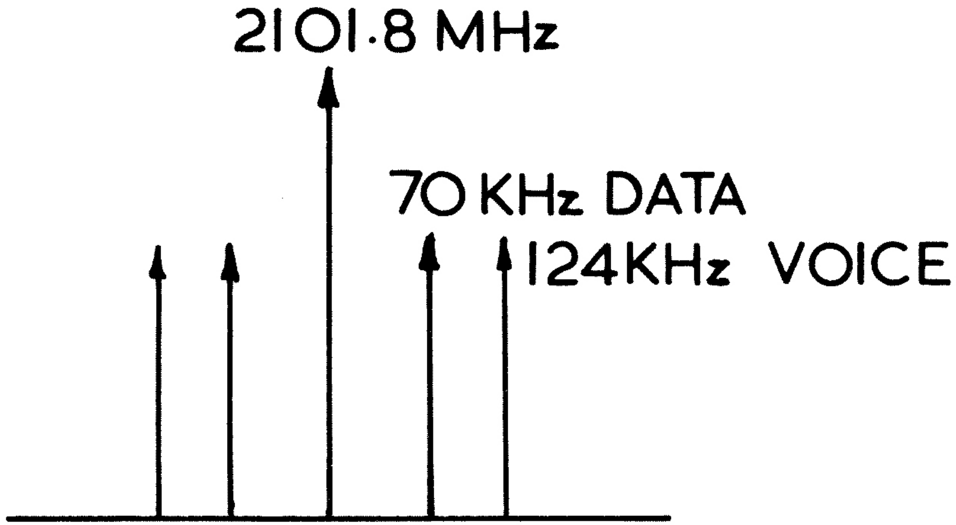


FIG.21. LCRU UPLINK SPECTRUM

the LM. Up-data is transmitted on the same 70 KHz subcarrier but is vehicle addressed. LCRU up-voice is however transmitted on a 124 KHz subcarrier (Fig 21) while the LM uses 30 KHz (Fig 15).

Only two PM downlink modes are provided namely normal voice with PLSS(Fig 22)or BUV with PLSS (Fig 23). In practice the astronauts voice and PLSS signals may be received via the LM and also via the LCRU when it is powered up(Fig 2). Therefore to simulate this condition the LM PLSS VCO's are used to feed the LCRU PMP. (Fig 24). The relative mod. indices of the LCRU PLSS subcarriers are different to that of the LM so it is necessary to provide another level combining network. A higher mod. index is used as the power does not have to be shared with a telemetry subcarrier. You will recall that the LM EKG 14.5 KHz SCO is unmodulated when the astronauts are suited up. Reference to Fig 23 will show an additional 14.5 KHz SCO for the LCRU. This is used to telemeter LCRU status, consisting of battery temperature and voltage from the LCRU in a 10 sec. plus 20 sec. cycle as shown in Fig 25. To simulate these a simple unijunction multivibrator is used with a single timing capacitor. A typical waveform at point A is shown. Assuming the left hand UJT to be conducting then C1 will be charging via R2 and when the voltage reaches the peak point the right

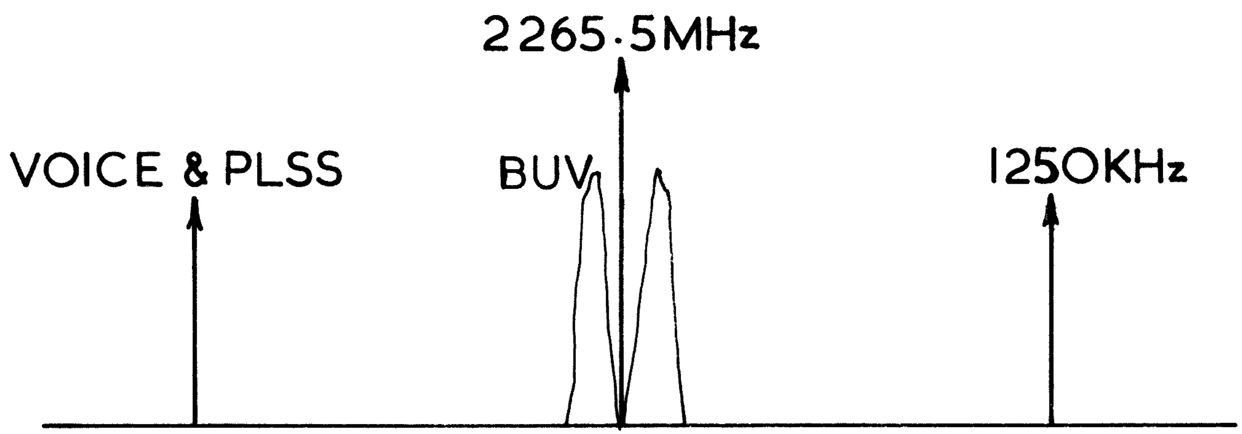


FIG.22. LCRU PM DOWNLINK

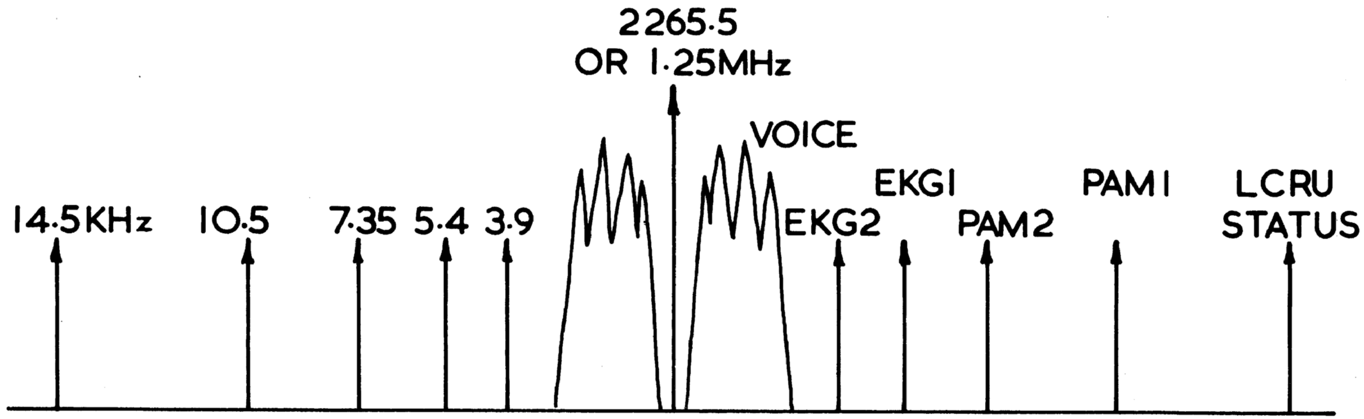


FIG. 23. LCRU BUV OR NORMAL VOICE DOWNLINK

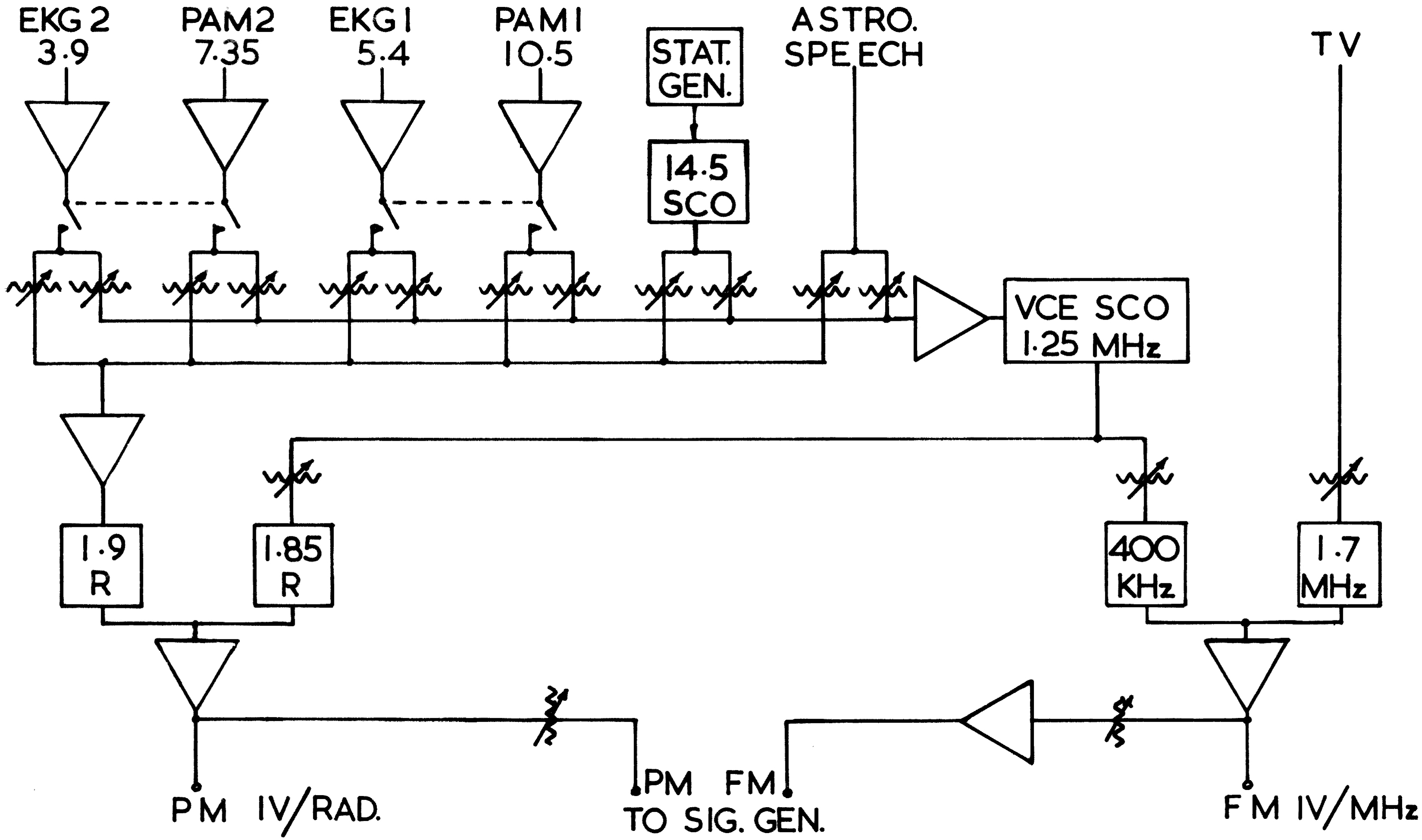


FIG.24. LCRU PMP.

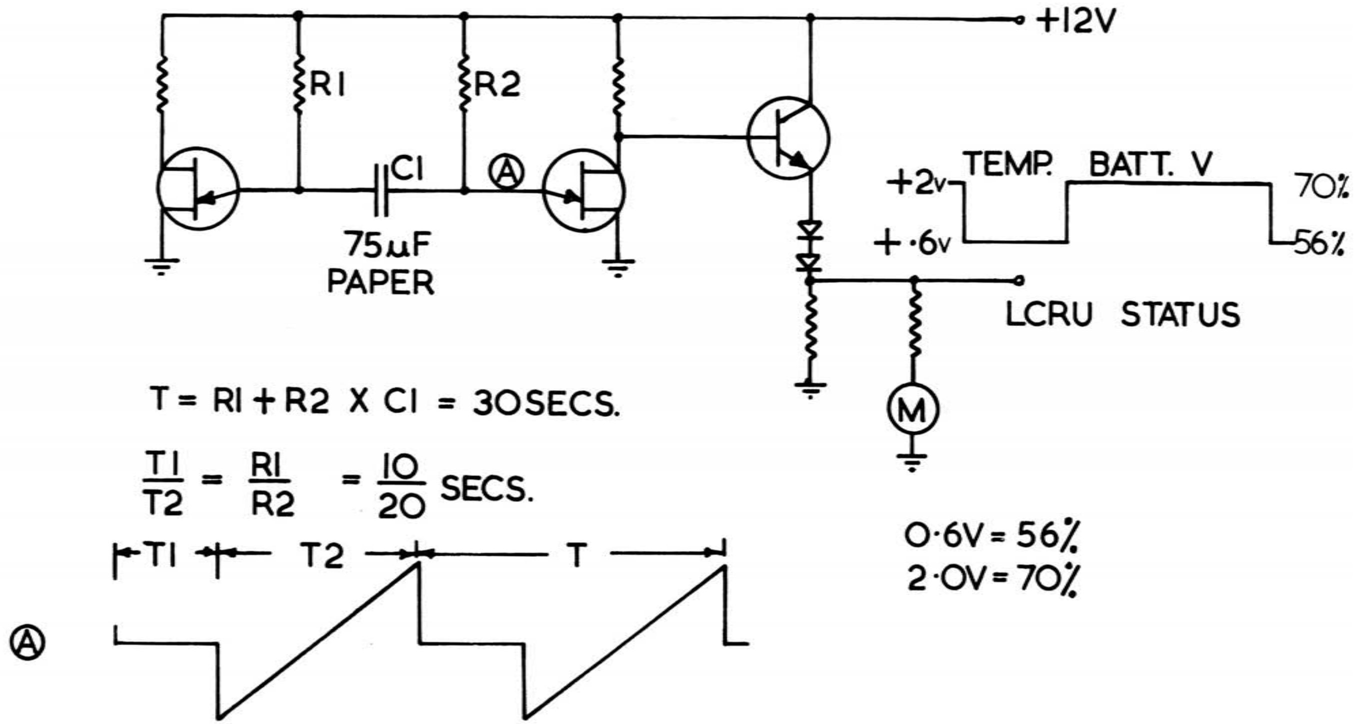


FIG.25. LCRU STATUS GENERATOR.

hand UJT conducts cutting off the left hand UJT and so on. An emitter follower isolates the output and diodes are used to set the level. When this voltage is applied to the SCO which has a -5 to +5 volt swing typical mission values shown in Fig 25 result.

4.6 LCRU FM

Two modes are also available on LCRU FM (Fig 26). Mode 3 consists of TV plus the 1.25 MHz voice subcarrier with PLSS (Fig 23) or Mode 4 which is TV only and is used to provide the television spectacular of LM lift-off from the moons surface. The method used to generate the FM modes will be obvious from Fig 24.

4.7 Particles & Field Subsatellite. (P & FS).

After the LM has completed its mission and rendezvoused with the CSM it is then impacted on the moons surface to exercise the seismometers left behind by the astronauts. The LM frequency is then available for a small satellite ejected from the CSM and left in moon orbit. It uses the same LM uplink frequency with ranging and 70 KHz updata subcarrier. (Fig 27). The downlink frequency is the same as the LM with ranging but instead a 32.768 KHz squarewave subcarrier is used (Fig 28). The method used to generate the squarewave subcarrier is shown in Fig 29. The main difference from the sinewave CSM PSK modulator

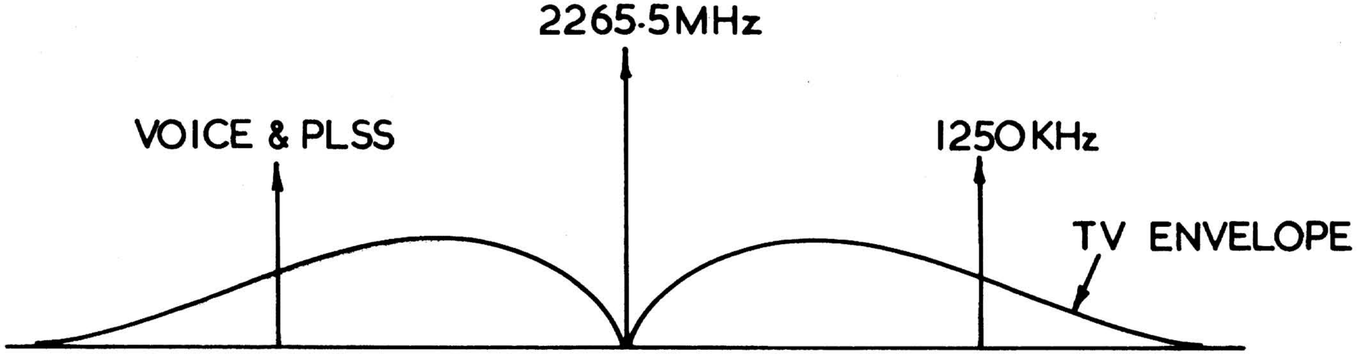


FIG.26. LCRU FM DOWNLINK SPECTRUM

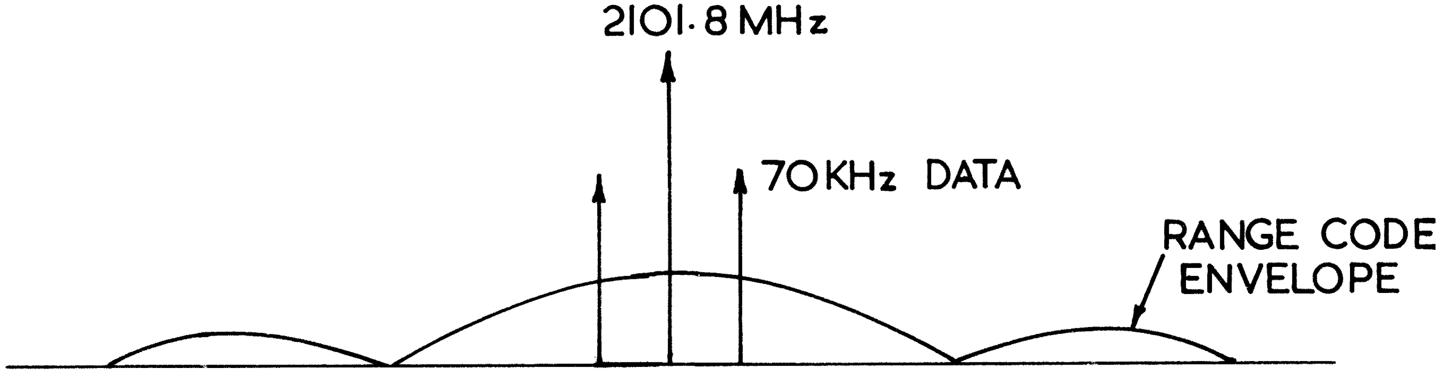


FIG. 27. P&FS UPLINK SPECTRUM

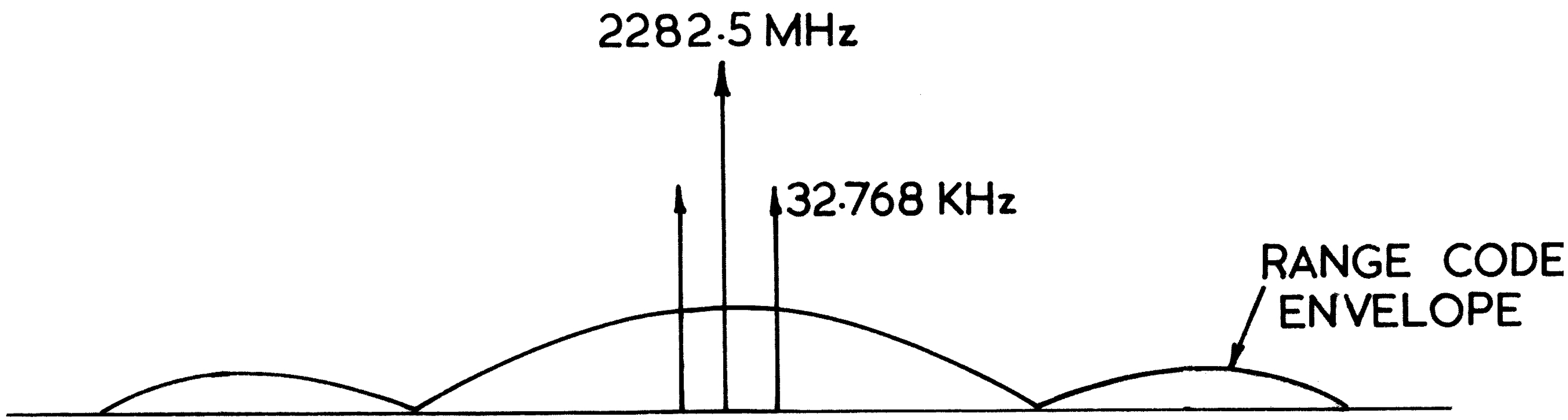


FIG.28. P & F S DOWNLINK SPECTRUM

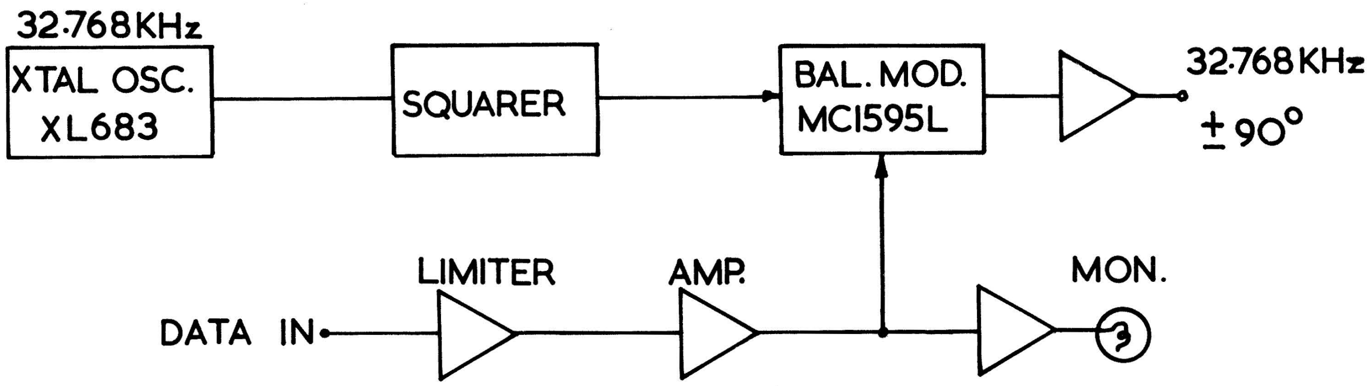


FIG. 29. P&FS PSK MODULATOR.

(Fig 14) is the use of a Motorola integrated circuit type MC 1595L for the modulator. It is also necessary to remove any amplitude changes from the data hence the limiter. This modulator produces a clean squarewave subcarrier with clean transitions on the keying.

4.8 Sim Astronaut Interface.

As only two astronauts are used to simulate the three mission astronauts it is necessary to provide a flexible switching arrangement. The method used is depicted in the simplified block diagram of Fig 30. Isolating amplifiers have been omitted for clarity. Basically there is a 4-way/4-wire bridge for each vehicle and these are used to combine the up, down and two astronauts. Two switches are provided, the first selects the vehicle and provides simulation of the various relay modes used in Apollo. For example when the LM is docking with the CSM it is necessary for the crews to communicate with each other as well as the ground. The VHF link between the CSM & LM (Fig 2) is used in parallel with the CSM & LM S-Band downlinks. To simulate this it is only necessary for the CSM and LM astronauts to appear on both downlinks,which is accomplished by feeding the CSM & LM bridges. Likewise when the astronauts are on the surface they will be heard via the LM and LCRU S-Band. The LCRU (only) position is provided to simulate the LCRU driving out of

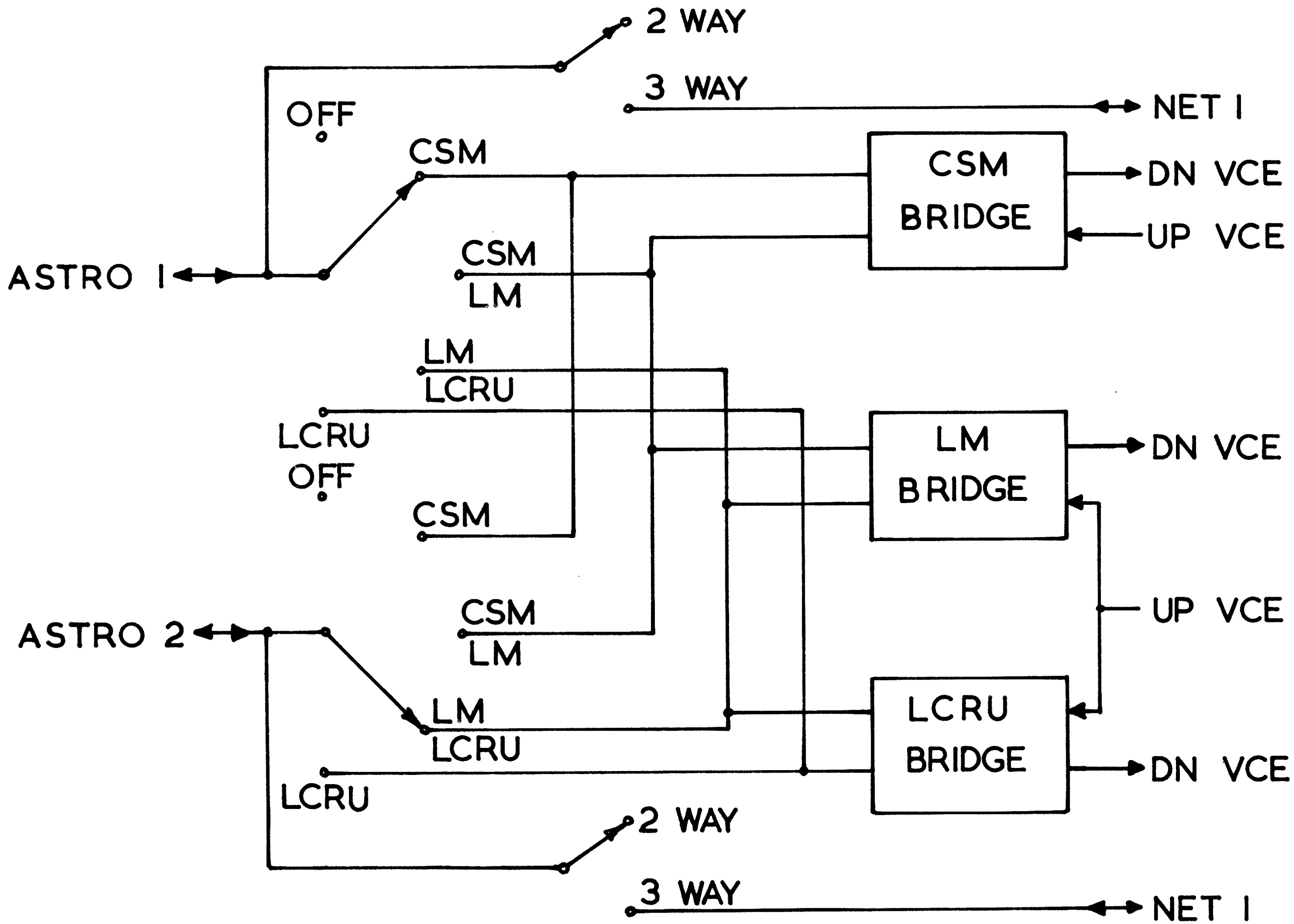


FIG.30. SIM ASTRO INTERFACE.

VHF line of sight with the LM when they will be heard only via the LCRU S-Band.

The second switch designated "2-way/3-way" provides the following function. During a mission, all Apollo stations are in conference on the main voice Net 1. Prior to acquisition of signal (AOS) at the station, the astronauts will be heard from another station via Net 1. Once the station acquires and has a 2-way circuit with the spacecraft then the downlink will be remoted from the 2-way site via Net 1. The separate switches are required as it will be possible for one vehicle to be 2-way and the other 3-way.

4.9 MCC Simulation

During a mission seven circuits, or nets, plus teletype interfaced with the station. These functions are simulated as shown in Fig 31. Except under fault conditions, Net 1 is used for communication with the astronauts. Nets 2 and 3 are normally used for MCC to site communications but when two Nets are required to communicate with the astronauts in separate vehicles Nets 1 and 2 are used leaving Net 3 for site communication.

For simulations, two MCC positions are provided, Wiretech and Capsule Communicator (Capcom). The Capcom position is fitted with Quindar Keying. When the Capcom depresses his press-to-talk key this transmits a short mark tone

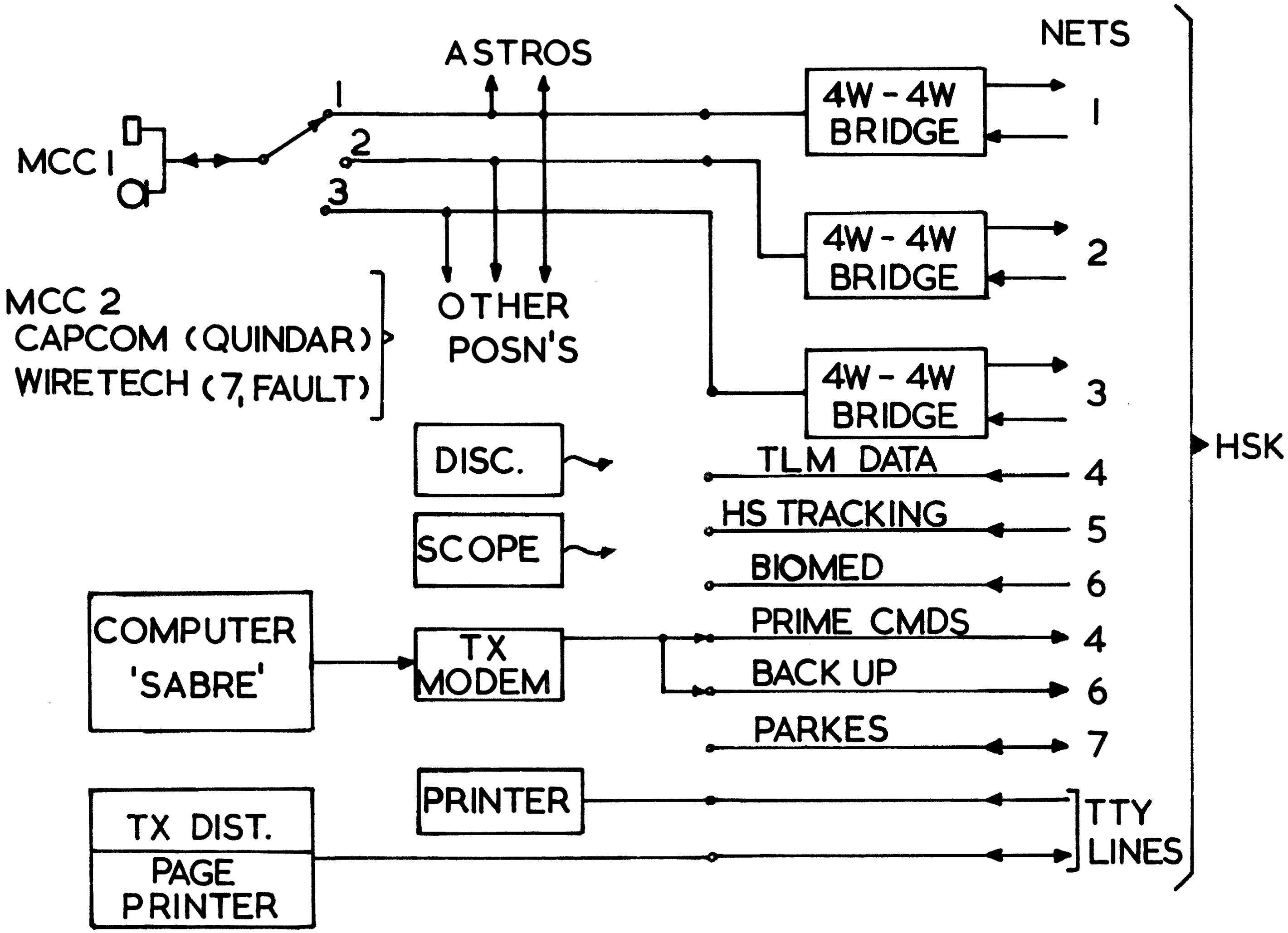


FIG. 31. SIM - SITE COMMS INTERFACE.

of 2.525 KHz enabling the Capcom onto the Uplink at the station and when he releases his key a short space tone of 2.475 KHz is transmitted which releases the circuit. The tones provide security by preventing anyone but the Capcom from uplinking to the spacecraft. Crystal oscillators are used to generate these tones due to the narrow bandwidth of the system filters. Net 4 carries telemetry data, Net 5 tracking data, Net 6 Biomed data from the station. A tuneable discriminator plus oscilloscope is fitted to monitor these circuits if required. Net 4, with Net 6 (as back-up) to the station, is used to transmit the commands from MCC to the site. The operating console of one of the spare station computers is moved into the sim. area and interfaced with Net 4 via a Transmit Modem. A special programme for simulations called "Sabre" has been devloped at Honeysuckle and provides a realistic workout for the site computers.

Net 7 provides liaison with Parkes and when Parkes is simulated this net is used. Normal TTY facilities are fitted in the Sim. area to enable the sending of messages as would occur in a normal mission. Typical messages are for example, Antenna pointing data, Station configuration and briefing messages etc.

5. TIDBINBILLA SIMULATOR

This simulator is separated into two parts consisting of uplink and downlink units. The normal mission interface is shown on the right hand side of Fig 32.

5.1 Tidbinbilla Uplink Simulator

The voice and data is transmitted from HSK to Tidbinbilla via the microwave system. At all Apollo sites the output of the transmitter is detected, the Upvoice Verification (UVV) recorded on a multitrack tape recorder and the Updata Verification (UDV) is compared bit for bit to ensure no errors are transmitted. The verification signals are fed back from Tidbinbilla over the Microwave to HSK. To simulate this path it is necessary to turn these signals around with amplification to obtain the correct levels.

Also the Tidbinbilla transmitter status is monitored by a telemetry system giving remote indications at HSK. The verification signals (left hand side of Fig 32) are controlled by an uplink simulator which simulates the telemetered indications and enables the verification turnaround when the correct modes, frequency, drive on and similar functions are selected. Basically the uplink simulator consists of two sets of switches for transmitter 1 & 2 together with logic to provide the verification turnaround and telemetered indications.

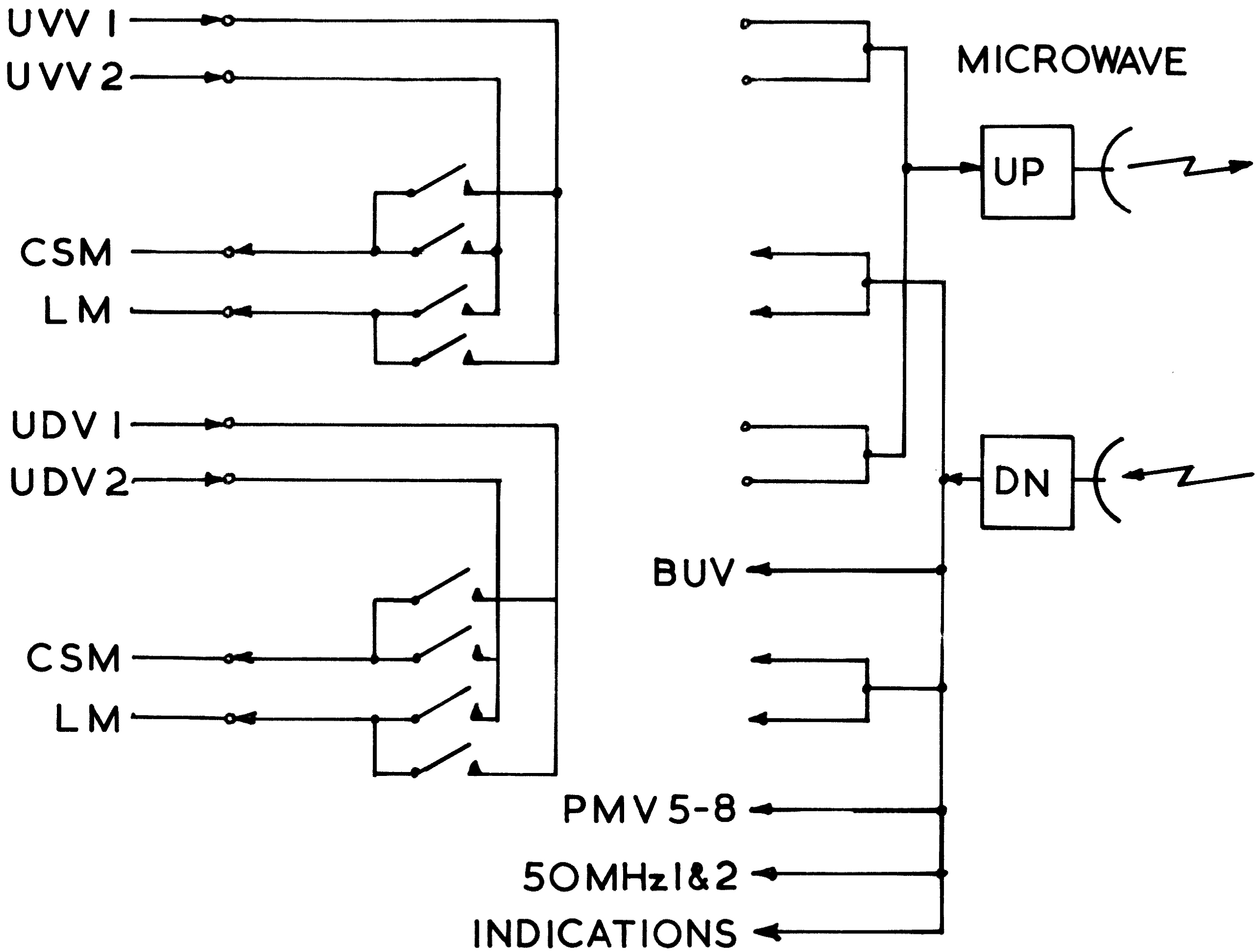


FIG.32. TIDBINBILLA SIMULATIONS.

5.2 Tidbinbilla Downlink Simulator.

The remaining functions shown on the right hand side of Fig 32 namely, BUV, PM Video (PMV) from the four receivers numbered 5 through 8 (Receivers 1 through 4 being the HSK receivers), and the two 50 MHz FM channels 1 & 2 are the normal downlink signals from Tidbinbilla. These are simulated by the downlink panel. The panel comprises of a matrix for the receiver video signals plus a second matrix for BUV (Fig 33). The composite modulation, either PM or FM from the CSM (Fig 8 & 11), LM (Fig 16 & 20) and LCRU (Fig 22 & 26) is fed to six separate bridging amplifiers, each fitted with six 50 ohm outputs. These outputs are fed to relay crosspoints that may be selected to feed the modulation to the four PM Video outputs or to the two 50 MHz FM modulators. The two modulators are required to simulate the wideband FM signals that are normally transmitted on separate microwave paths and demodulated at HSK. The output of the two modulators are switched via coaxial relays to simulate carrier on/off. The two 50 MHz FM channels and the four PMV signals are patched into the lines at the HSK end of the microwave link.

The BUV matrix (Fig 33) uses similar bridging amplifiers and relay switching but is fed with astronauts voice.

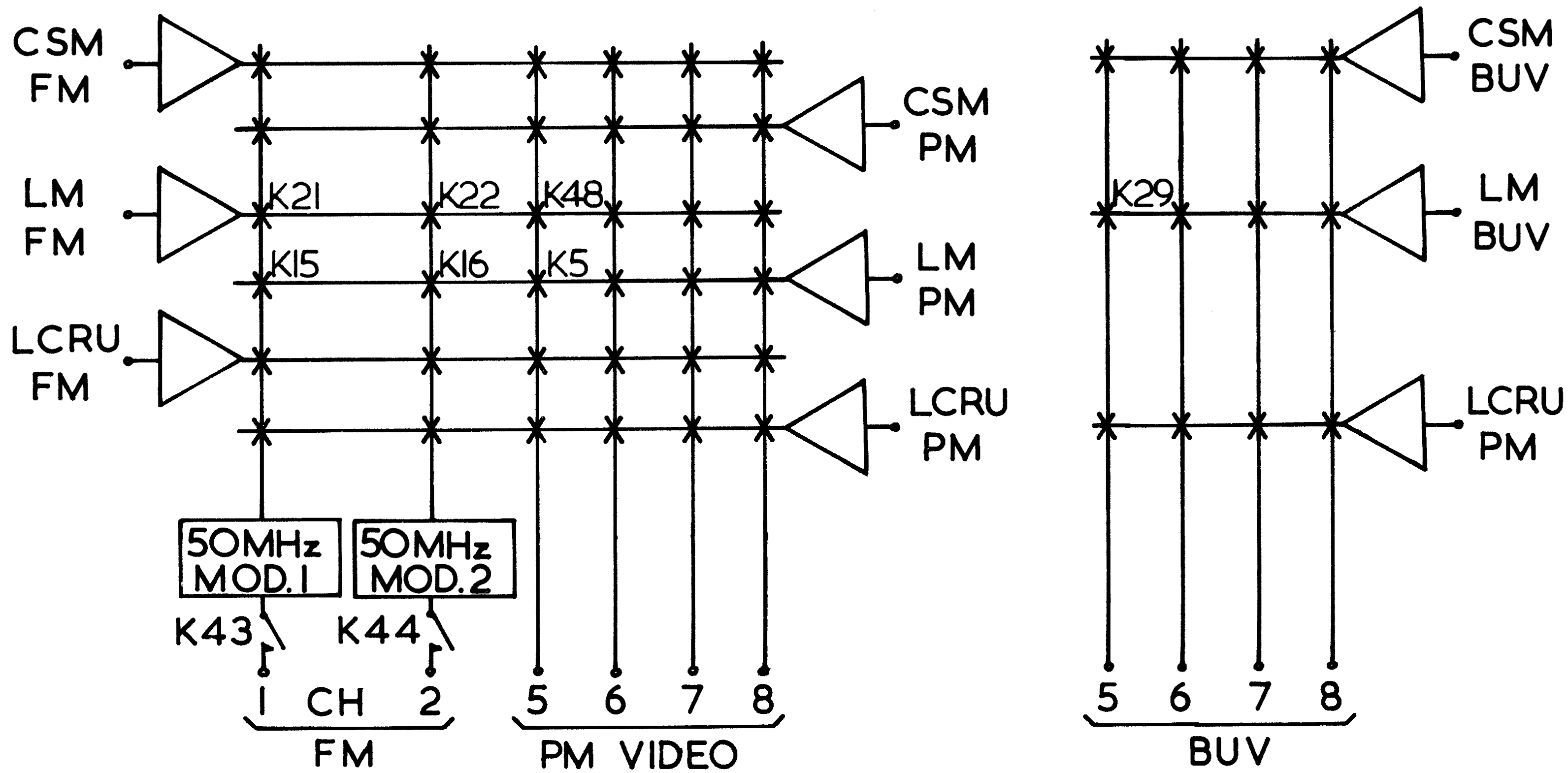


FIG.33. TIDBINBILLA SIMULATOR

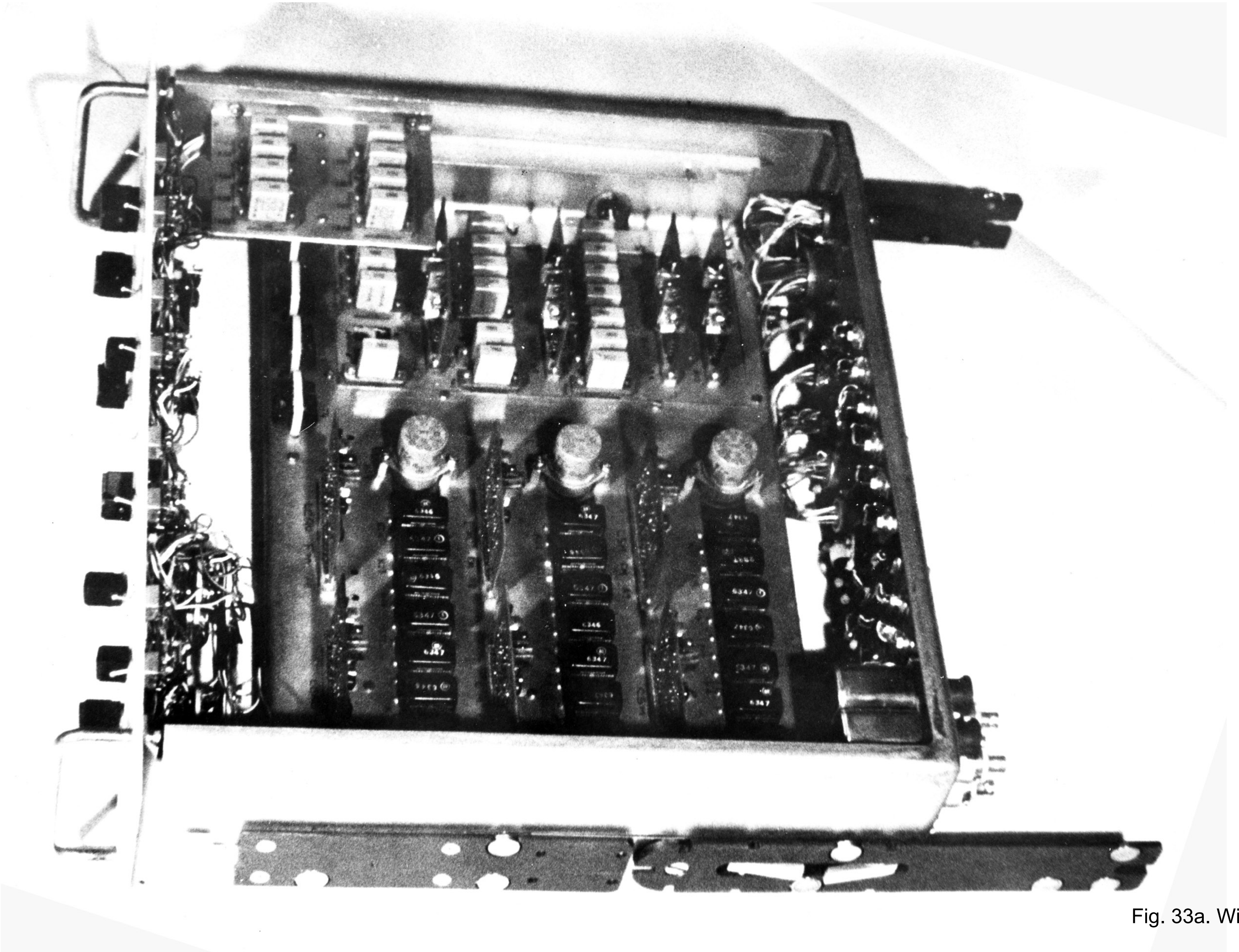
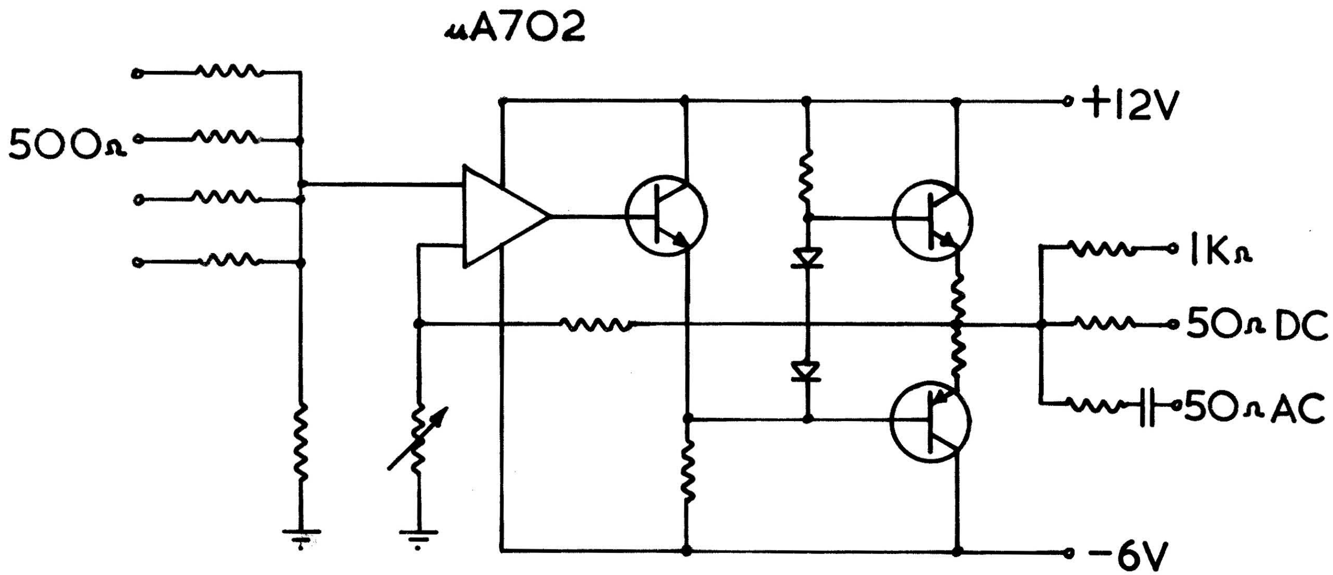


Fig. 33a. Wing Simulator

The BUV is normally transmitted from Tidbinbilla via voice channels on the microwave link so the BUV outputs from the simulator are patched into the output of these channels at HSK.

The bridging amplifiers referred to in the downlink panel are similar to the general purpose video amplifier shown in Fig 34. These are constructed locally on fibreglass printed circuit boards. A second version used in the downlink simulator differs in that the three outputs shown are replaced by six 50 ohm outputs. The amplifier is used to provide isolation between the six channels and also maintains a constant output impedance and level regardless of how many channels are selected.

While the PM, FM and BUV matrix selection is straightforward, the logic required to simulate normal operation requires some explanation. A section of the logic used to select receiver 5 LM FM or PM is shown in Fig 35. The relevant matrix relays are designated in Fig 33. Each simulated receiver is provided with frequency selection,CSM, LM or LCRU, mode selection FM or PM and a "lock" function which simulates the carrier lock



0 DBM IN -5 TO +10 DBM OUT

DC TO 5 MHz

+12V OFF ISOLATION >70DB

DISTORTION <0.5%

FIG.34. VIDEO AMPS.

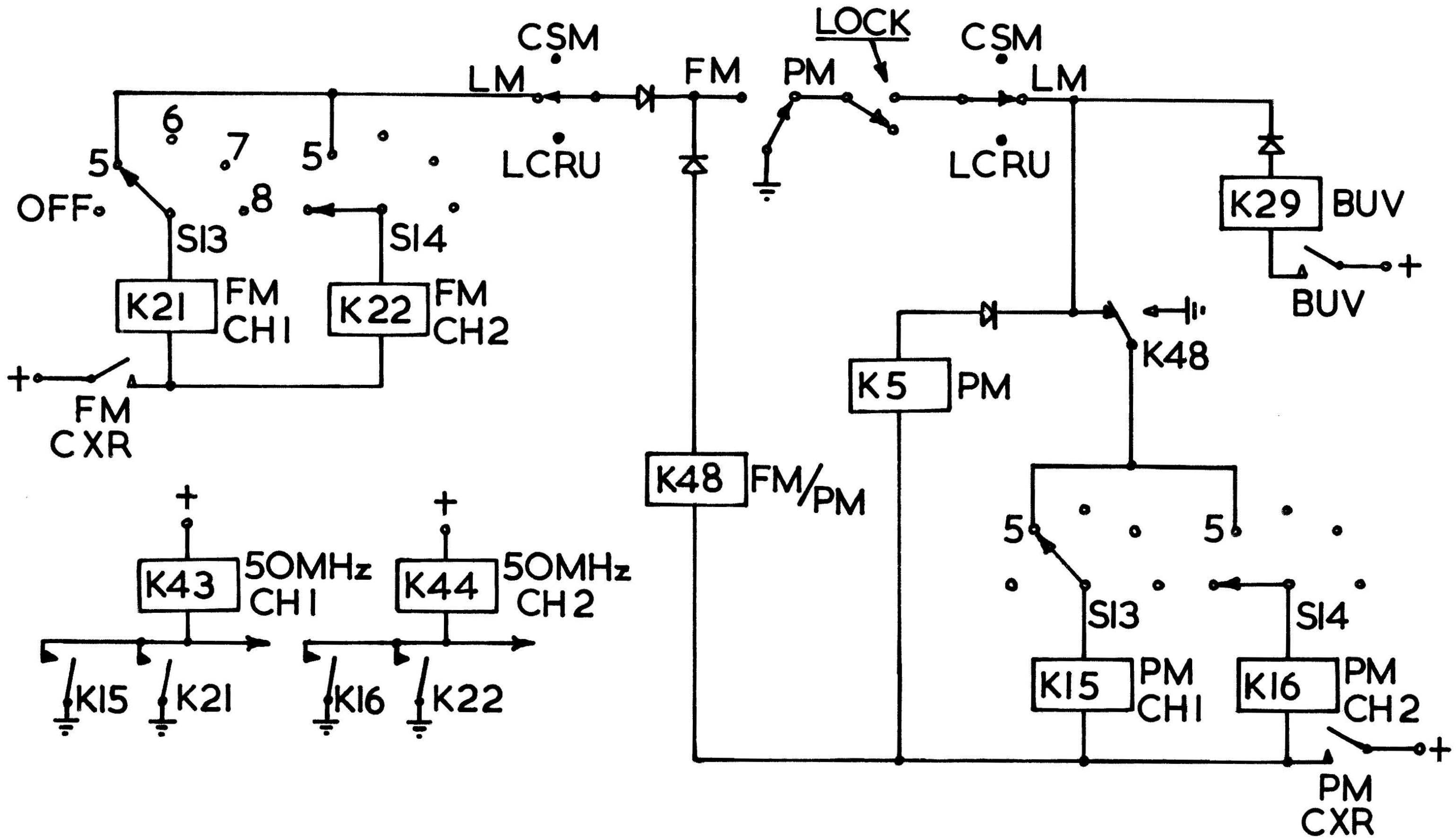


FIG.35. TIDBINBILLA SIMULATOR

indication of the PM receiver phase lock loop (PLL). Two additional switches S13 and S14, common to all four receivers, allows allocation of any two receivers to modulate the two FM channels CH1 (S13) and CH2 (S14).

Assuming it was desired to receive LM FM on Receiver 5 then the FM, PM switch would be selected to FM and the frequency switch to LM as shown Fig 35. Receiver 5 FM is shown selected to FM CH1 (S13) and FM CH2 is off but could be selected to Receiver 5 or any other receiver if required. This is how the receiver would be selected in practice and of course would not receive a signal until the LM FM transmitter was activated. In the simulator this is controlled by a separate switch for each spacecraft and is labelled "carrier ON". This switch controls all downlink signals generated for the vehicle. For instance, the S-Band carrier for HSK, the Tidbinbilla simulator and the Parkes simulator. A contact of this switch in Fig 35 designated "FM CXR" enables voltage to the relay logic and in case of receiver 5 operates K21 "FM CH1" which in turn operates K43 "CH1 50 MHz". Reference to Fig 33 shows that K21 selects LM modulation to the 50 MHz modulator and K43 applies the 50 MHz output of the modulator to the microwave tie line to HSK for processing. Additional relays for receivers 6 to 8 and for CSM and LCRU provide similar functions.

If receiver 5 is required to receive LM PM then the FM PM switch would be selected to PM. You will recall that the LM may only transmit FM or PM at any time. When the simulator control panel is selected to PM and the 'CXR ON' switch operated this will enable the 'PM CXR' contact on the lower right of Fig 35. However, nothing will happen until the operator decides he has a valid receiver lock and operates the 'Lock' switch. K5 will operate and apply LM PM modulation to receiver 5 PM video output Fig 33. As S13 is still selected to receiver 5 then K15 will apply LM PM modulation to 'CH1 50 MHz' and will also operate K43 enabling the carrier out of the 50 MHz Modulator. If a BUV mode has been selected on the LM control panel then a contact will operate K29 and apply LM BUV to receiver 5 BUV output on Fig 33.

A condition normally arises where a receiver has been selected to FM for example in anticipation of a TV transmission from the spacecraft but the spacecraft is still transmitting a PM signal. The station FM demodulators will demodulate the PM signal but will have a 6 db/octave slope and is therefore not normally used. The operators expect and look for this condition which is provided in the simulator by K48 "FM/PM". When the receiver is selected to FM with the spacecraft PM CXR ON then K48 will operate in turn operating K15 and K43 enabling the 50 MHz CH1 modulator input and output. When the spacecraft is selected to FM the 'PM CXR' contact will open releasing K15 etc. and K21 will operate as described above. As for the FM case additional sets of relays provide similar functions for receivers 6 to 8, CSM & LCRU.

All normal receiver functions have been simulated as closely as possible and the various functions are provided by the relay logic when the operator selects normal receiver functions. This reduces the amount of simulator operator training to a minimum and also reduces the possibility of "illegal" combinations and operator errors.

6. PARKES SIMULATOR

The Parkes Simulator is relatively simple in that only two microwave lines are available to HSK. Only one downlink may be received at a time and the demodulated baseband signals are normally sent via both microwave channels where the best path is selected at HSK.

A block diagram of the Parkes simulator is shown in

Fig 36. The simulator consists of an isolating Video amplifier Fig 34 from each of the spacecraft FM and PM composite baseband outputs. The front panel selections are CSM PM, CSM FM, LM & LCRU and line selection, Line 1, Line 2 and Line 1 & 2. When say, CSM PM is selected then +12V will be applied to the CSM PM bridging amplifier providing the CSM CXR ON switch has been selected on the console (i.e. the CSM PM Spacecraft is transmitting) CSM PM baseband signals will then appear on whichever line combination has been selected. Emphasis has been placed on facilities allowing preselection of most modes and functions with no signal outputs appearing until the appropriate spacecraft 'CXR ON' switch is operated. Thus it is possible to simulate a spacecraft transmitter on function or acquisition of signal when the spacecraft comes over the horizon with transmitter on.

7. POWER SUPPLY

Two supplies +28V and -28V 30 amp supplies (Fig 37) feed regulators providing the various voltages used throughout the simulator.

8. STATION READINESS TESTS (SRT's).

As the missions have become more complex, the time taken to test the station has become longer.

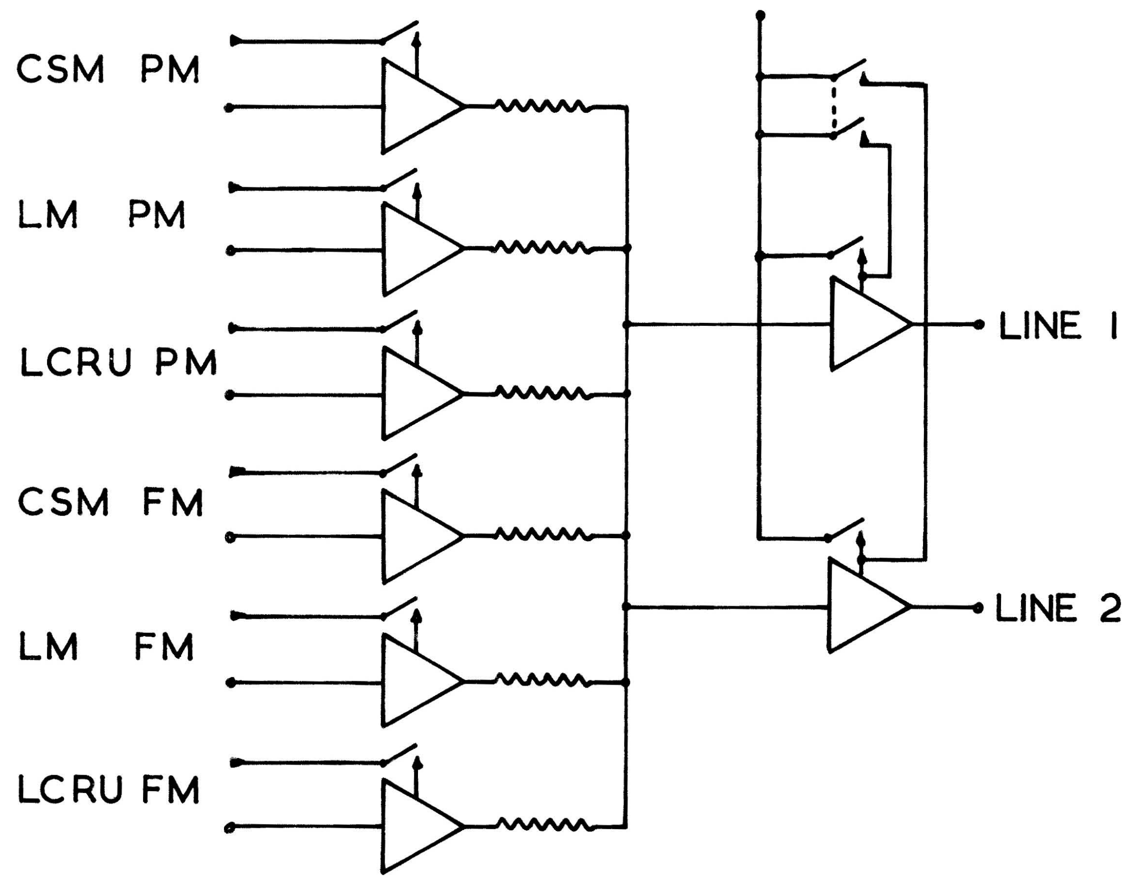


FIG. 36. PARKES SIMULATOR.

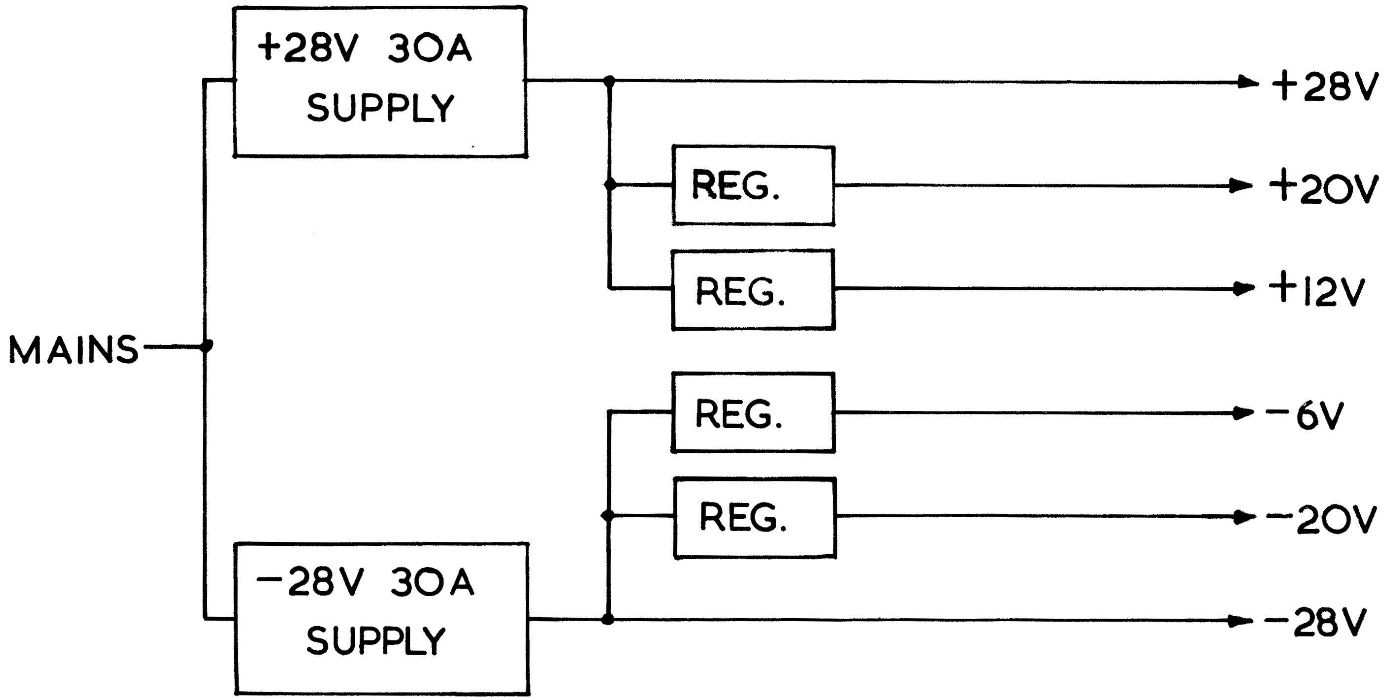
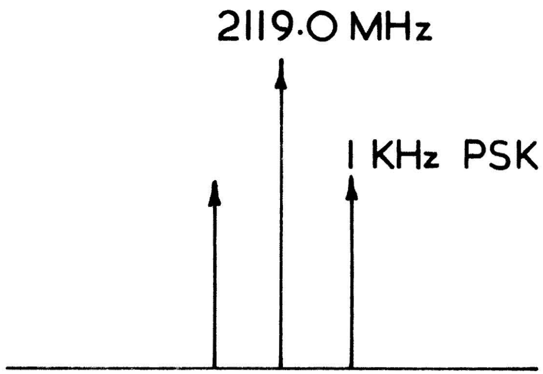
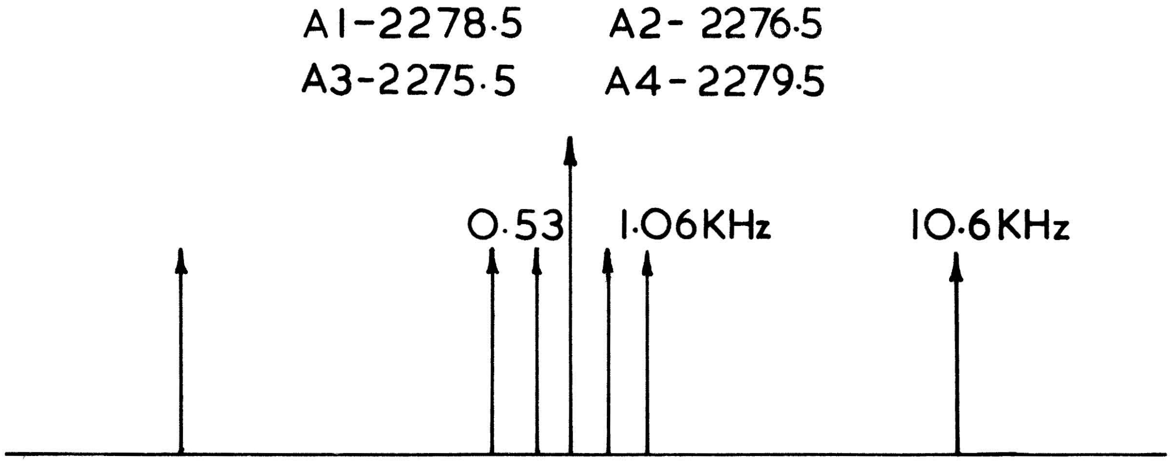


FIG. 37. POWER SUPPLY



ALSEP UPLINK



ALSEP DOWNLINK

An FM/PM S - band signal generator is provided for station testing. However, considerable time is required to set up the correct modulation indices in the numerous modes outlined. With additional patching and switching required to generate and route the signals there is also the danger of accidently interrupting part of the station configuration required for upcoming pass support.

All of the modes are available from the simulator so it is relatively simple to interface the modulation from the simulator to the S - band test generator. The main advantage is availability of signals at any time with minimum interruption of station configuration. The stability and quality of signals has proved adequate for station testing of bit error rate thresholds and signal to noise measurements etc.

At the completion of the engineering tests the simulator is used to check complete station end to end data flow in the configuration to be used on the next station pass. As all downlinks are simulated these confidence checks may be conducted in parallel to simulate all downlinks expected. The only station interface required is via the Test/Normal switch to inject the S -Band signals into the front end. During a pass all RF sources are disabled in the simulator to prevent any possible interference.

9. FUTURE DEVELOPMENTS

Work is currently in progress to simulate all the Skylab functions which include the present CSM plus several additional VHF links. The quality of these links must be suitable for SRT's.

10. CONCLUSION

The Apollo simulator has provided invaluable staff training of the A.C.T. Apollo Complex. The stability and reliability of the simulator has proved adequate for the testing of the station equipment.

11. ACKNOWLEDGEMENT

I wish to thank the Department of Supply Station Director, Mr. D. Gray, and Company Station Manager of Standard Telephones & Cables Pty. Ltd., Mr. W. Kempees, for permission to present this paper.

LIST OF ABBREVIATIONS WITH EXPLANATIONS

ALSEP	Apollo Lunar Surface Experiment Package. Moon scientific station.
AOS	Acquisition of Signal.
ASTRO	Astronaut, three per mission, one CSM and two LM
BUV	Back-Up Voice, voice modulated directly onto the carrier.
CAPCOM	Capsule Communication, in Houston talks directly with the Astronauts.
COMTECH	Communications Technician, responsible for voice in and out of site.
CSM	Command and Service Module, consists of Command Module and Service Module.
D/L OR DOWNLINK	Spacecraft to ground communications link.
DSCC	Deep Space Communications Complex, Deep space tracking station.
DSN	Deep Space Network.
EKG	Electro-cardiograph, telemetered heartbeat information.
EVA	Extra Vehicular Activities, Astronauts suited up outside spacecraft.
FM	Frequency Modulation.
FSK	Frequency Shift Keying.

HBR	High Bit Rate, high speed telemetry data.
HSK	Honeysuckle Creek Tracking Station.
LBR	Low Bit Rate, low speed telemetry data.
LCRU	Lunar Communications Relay Unit, communications package carried on Lunar Roving Vehicle.
LCRU STATUS	LCRU telemetered information - battery voltage and temperature.
LM	Lunar Module, Moon descent and ascent stages.
LM EKG	Monitoring EKG of one of the astronauts in the LM during sleep etc.
LRV	Lunar Roving Vehicle, used to explore moons surface.
MCC	Mission Control Centre, in Houston, U.S.A.
MTR	Magnetic Tape Recorder, multitrack data recorder.
NORMAL VOICE (OR VOICE)	Subcarrier modulated with astronauts speech.
P & FS	Particles and Fields Subsatellite, satellite in moon orbit.
PAM	Pulse Amplitude Modulation, telemetered data from Astros PLSS.
PCM	Pulse Code Modulation, coded telemetered data.
PLL	Phase Lock Loop.
PLSS	Portable Life Support System, Astronauts backpack worn during EVA's.
PM	Phase Modulation.
PMP	Premodulation processor, unit to combine and set subcarrier deviation.

PRN Psuedo Random Noise, unique code used for spacecraft ranging.

PSK Phase Shift Keying, phase shift modulation of telemetry data onto subcarrier.

RANGE CODE Unambiguous code used to determine spacecraft range (see also PRN).

RTC Real Time Command, computer commands sent to spacecraft.

SC Subcarrier or spacecraft.

SCO Subcarrier oscillator.

SDS Scientific Data System, scientific module in CSM.

SIM Scientific Instrument Module on CSM.

SIM. Simulation or Simulator.

SPEECH Astronauts unprocessed speech before modulation.

STDN Space Tracking and Data Network. Near earth spacecraft tracking network.

TLM Telemetry.

TRANSPONDER Spacecraft coherent PM receiver and transmitter.

U/L OR UPLINK Ground to spacecraft communications link.

VCO Voltage Controlled Oscillator, used to generate subcarriers.

VCXO Voltage Controlled Crystal Oscillator.

VOICE (OR NORMAL VOICE) Subcarrier modulated with Astronauts speech.

LIST OF FIGURES.

FIG. CAPTION.