JMR *Survey By Satellite*

THE JMR-1 DOPPLER SURVEY SET

DESCRIPTION & APPLICATION

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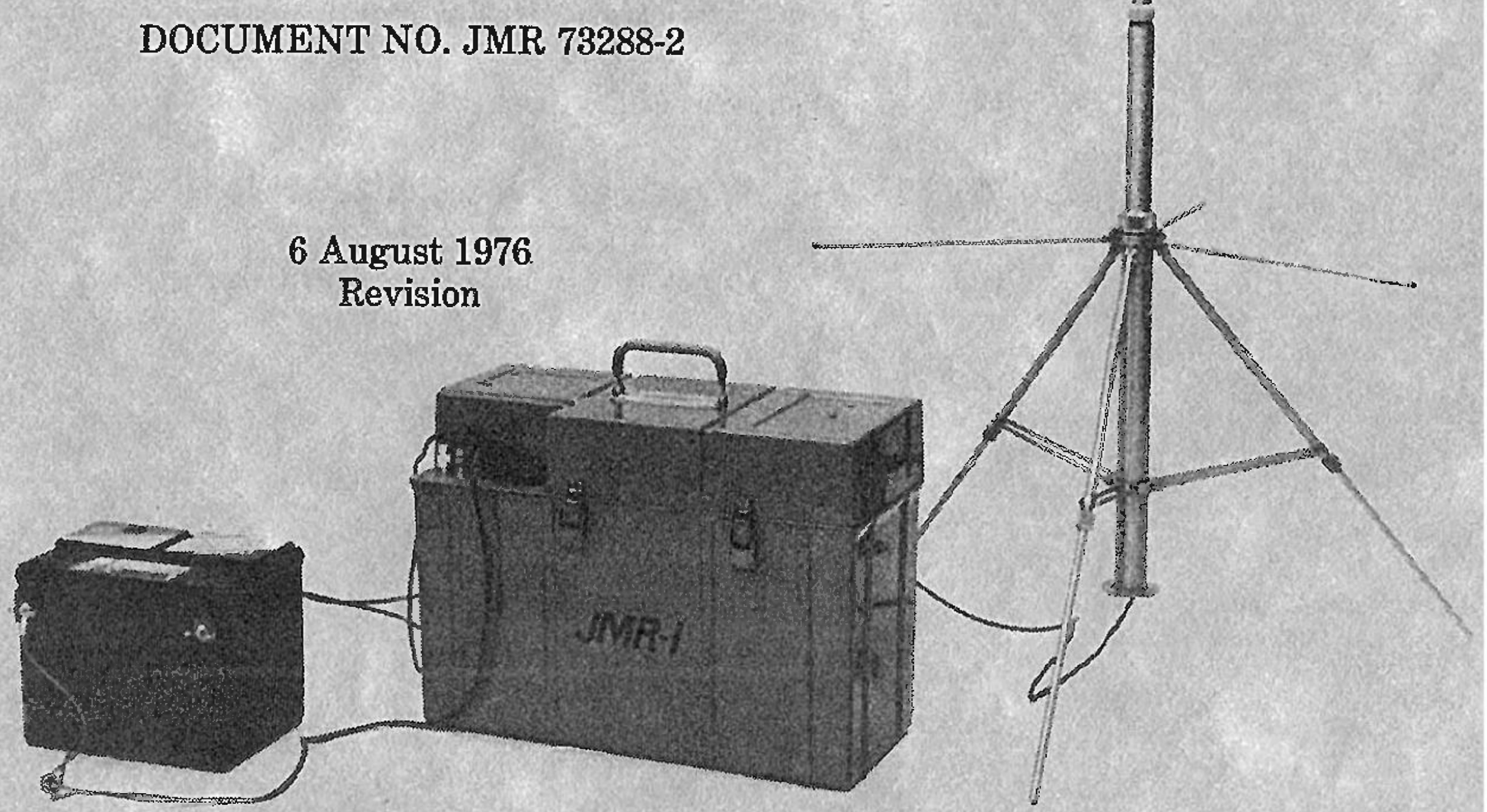

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FOREWORD

The primary objective of this document is to provide a general description of the JMR-1 Doppler Survey Set, how it is operated, and the data which it records. Additional documents which relate to the application of the JMR-1 are:

(1) JMR-1 Data- Handling & Preprocessing

(2) JMR Survey Software

(3) JMR-1 Warranty, Training & Service

(4) A precise Azimuth Measurement using the JMR System

THE JMR-1 DOPPLER SURVEY SET

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THE JMR-1 DOPPLER SURVEY SET

1.0 INTRODUCTION

The JMR-1 Doppler Survey Set is a portable receiving and data recording system which receives Navy Navigation Satellite System (NNSS) transmissions and records orbit and doppler information for later processing in a digital computer. The entire set can be readily moved to an extremely remote area by jeep or helicopter, backpacked to the actual site, set up, and operated by one man. The set will automatically record adequate data for a precision survey in one or two days of unattended operation. Major features of the JMR-1 are:

(a) When positioned and operated in a remote area, the data recorded by the JMR-1 can be processed to establish the geodetic longitude, latitude and elevation of the position without requiring a reference to any other point on the Earth's surface.

(b) For more precise measurements, relative to a known marker, a JMR-1 Set can be located up to 1,000 km from a second set at the nearest survey control, with no radio or visual contact required. This technique is called "Translocation."

(c) Property access problems which are experienced with conventional survey techniques are essentially eliminated since traverse is not required.

(d) Position accuracy is essentially unaffected by geographic location, weather or time of day or night.

(e) Fully automatic operation reduces operating costs and eliminates the possibility of operator error.

(f) Ownership and operating costs are less than any other first order survey technique; less than all other techniques for distances of 100 km or more from a control point.

(g) On-site data verification techniques allow a positive check of the recorded data.

(h) Recorded data is fully compatible with the use of both the predicted ephemeris from the Navy tracking network.

1.1 Satellite Signal Transmission and Detection

The JMR-1 Doppler Survey Set uses the U.S. Navy Navigation Satellites as its only references in determining the precise, three-dimensional position of a point on the Earth's surface. This satellite system has been operationally used for precise positioning, world-wide, for over 10 years. Six operational satellites are now in polar, 600 n. mile, circular orbits, some of which have been operating continuously for over seven years. The satellites transmit information on a continuous basis and their signals may be received and used by anyone who has appropriate instrumentation.

The track of the satellite in its orbit must be precisely known as it is the surveyor's position reference. The data which describes the satellite position as of each two minutes into the future is predicted by the U.S. Navy and stored in the satellite's memory. The satellite is programmed to transmit this data, as modulation on its carrier frequencies, in the appropriate time slots for reception by user's equipment. The orbit data is correlated with satellite-transmitted time marks. The accuracy of this prediction data has been periodically improved over the past ten years and continuing improvement is anticipated. Orbit data of greater precision is computed by the U.S. Naval Surface Weapons Center from tracking data obtained by its tracking network during the time period of the survey.

The JMR-1 Set receives the two coherently-related satellite-transmitted signals, at frequencies of approximately 150 MHz and 400 MHz, and extracts and records timing information, predicted satellite ephemeris, and doppler shift data. The timing and ephemeral information may be taken from either signal.

The doppler shift data, which is used to determine the position of the receiving station relative to the satellite, is detected from both signals and combined in analog circuitry to accomplish a first-order correction for ionospheric refraction. The zero-crossings of the resulting "offset doppler" cycles are counted in approximate 4.6 second "satellite time" increments and recorded.

The precise time of the beginning and ending zero-crossing of each increment of doppler cycles is also recorded from the JMR-1's internal digital clock. This digital clock is epoch-synchronized with a received satellite time mark at the beginning of each satellite pass, then read out at succeeding satellite time marks to allow a

smoothed estimate of the time of arrival of the time mark. Since the local clock is relatively noise-free, and the ending zero-crossing of one doppler counting interval is the beginning zero-crossing of the next interval, a precise, noise-free, and continuous measure of the period of the "integral doppler" samples throughout the pass is obtained.

All doppler samples which are obtained are not of equal value in position determination. Their relative value is influenced by the geometry of the satellite pass, signal propagation effects and received signal strength. Weighting of each doppler data point in the computation may be accomplished from information which is automatically recorded on the tape. Satellite pass geometry is readily computed using the received and recorded orbital information. Errors due to signal propagation through the troposphere are corrected in software. The JMR-1 allows entry of local pressure, temperature and humidity in the header data of each recorded pass. This information can be used by software to refine the tropospheric correction. And indicators of minimum received signal strength are recorded by the JMR-1 with each doppler count.

1.2 Application of the JMR-1

The JMR-1 is a truly "application oriented" instrument. The first step in the development of the JMR-1 concept was to establish the characteristics and functions required by the end-item user for accomplishing an accurate survey at minimum cost. The results of numerous experimental survey applications of previously-developed NNSS user equipments were available and provided excellent guidelines for this purpose. Careful review of these previous results and extensive interviews with the users has established the following:

(a) The instrument must detect and record NNSS data which is compatible with currently-available and proven techniques, both for "quick look" positions and for more sophistocated high precision processing. The recorded data must also have the potential of being re-processed with advanced software of the future for continuing refinement of the survey without the necessity of repeating the field data-gathering operation. To assure achievement of the highest quality data record, the JMR-1 developers solicited the advice of the most qualified in NNSS data analysis and processing. As a result, the JMR-1 data detection and recording process has been reviewed and confirmed by a number of recognized authorities in the U.S. and Canada.

JMR-1 data has been processed by several of these authorities to confirm that the desired results have been achieved.

(b) The major cost of most surveys is the day-by-day operating expense rather than the original equipment cost. Therefore the instrumentation must be designed and applied so that the data gathering time is minimized and so that uncertainties in predicting the required data gathering time are eliminated. An equipment design which will minimize the on-site data gathering time requires, first, reliable performance. To achieve this objective, only high quality parts are used in the design, and extensive environmental and field testing have been accomplished. However, possible failure of any electronic equipment must be anticipated, particularly during its first few months of operation. If a failure does occur, loss of valuable data gathering time can be prevented if the failure can be quickly recognized and if the repair can be rapidly accomplished.

Isolation and repair of a failure in sophisticated electronic equipment can be difficult, even for a highly-trained technician. Even recognizing that a fault exists can be difficult and may require interpretation of test results. The JMR-1 field operating technique eliminates these difficulties by using a procedure which has proven, from experience, to be most effective and positive. This technique utilizes two identical Sets operating from the same antenna and the same reference oscillator, thus producing the same data. These two Sets are called the "Primary Set" and the "Auxilliary Set." All that is required of the operator is to compare the data between the two sets as often as he elects to do so. This comparison is made during actual satellite data collection, rather than by the use of a simulated signal. The data is presented on a highly reliable digital display as it is being recorded.

If a failure is detected, it is not necessary to identify the source of the fault and change a module. Instead, the "Auxilliary Set" is merely switched online. This idealistic operating technique has been made practical by designing a small, low-cost instrument, and by achieving an extremely low standby power consumption so that the Auxilliary Set is ready for operation at all times.

(c) The user of the equipment is a surveyor and not an electronics expert. He should be concerned only with the quality of the survey data, and not with the diag-

nosis and repair of malfunctioning electronic equipment. In addition to simplifying the process of fault detection and eliminating any fault isolation and module replacement in the field, the entire problem of repair by the user has been eliminated by the Auxilliary Set concept. The failed unit is shipped back to the factory for repair (or to the nearest JMR Agent). A low-cost service contract is offered which allows a replacement unit to be shipped to the user as soon as the failure is reported.

(d) Transportation of survey equipment is a major cost item, making equipment size and weight an important consideration. The size and weight of the power generating equipment is most significant in this regard. The basic on-site JMR-1 System consists of two Sets plus batteries. The two Sets weigh 16 kg each, or 32 kg total. A battery to support the operation for 20 to 30 passes weighs about 16 kg. If a second back-up battery is also provided at 16 kg, the total weight of survey equipment taken to the site is 64 kg (141 lbs.).

The power requirement for operating the set is held at a minimum by using the most modern, low-current integrated circuits which are available, and by only powering the circuits when they are needed. Further power saving is accomplished by the Pass Selector, which applies power to the receiver circuits only when a pass is available, and can be programmed to ignore undesirable passes.

1.2.1 Translocation Operation

In this mode of operation, two or more sites are instrumented. One site is at a reference survey mark and the one or more additional sites are at the unknown locations which are to be determined relative to the reference site. The accuracy of the survey is improved, particularly when using the satellite-transmitted "predicted" ephemeris, as the data at the several sites is being gathered simultaneously and errors in prediction of satellite position are, in general, common to all sites. The results of a translocation survey are directly related to the reference survey mark and its coordinate system.

If a large number of control points are to be established by translocation, it may be more economical to instrument 4 or 5 sites simultaneously, thereby reducing the field operating time required. Also, a higher degree of precision is attainable by simultaneous adjustment of several sites in the computation process, particularly

if the satellite orbits are also allowed to adjust.

For translocation operations where transportation between sites is practical one or two times daily, the Auxilliary Set may be used to support two or more sites, thus reducing the total complement of equipment which is required.

1.2.2 Typical Survey Mission Events

Additional insight to the application of the JMR-1 Set is made available by postulating the events which might take place during a survey mission. A typical sequence of events which might occur in using the JMR-1 is as follows:

(1) Before leaving on the mission a data verification check is performed on all sets. If the sets have been set up for tracking satellite passes while awaiting their next application, additional checks may not be necessary.

(2) Fresh cassettes are installed in the JMR-1 digital cassette recorders.

(3) The sets are disconnected from their 12-volt charging source. This charging source is used to maintain full charge on the internal standby battery during the period between missions. The internal battery maintains power to the reference oscillator and the clock during transportation to a survey site or between sites.

(4) The display panel access cover is latched on each set and the sets are loaded for transport to the survey site.

(5) Set-up on site consists of removing the antenna from its stowage compartment, setting it up for operation, and connecting the battery to the set.

The antenna is set up on the point to be surveyed, 8 to 60 meters from the survey set. Antenna set-up is about a five-minute operation. Basic performance checks and header entries are made during this operation, as detailed in Section 2.3.

(6) Operation of the set from this point on is fully automatic. The surveyor may desire to observe the front panel indicators and the data verification display during the first satellite pass to assure proper operation. At other times the panel power is turned off to conserve battery life. The set may be operated with the panel cover closed for protection from the weather.

(7) Since the time of each available satellite pass is predictable in advance (before leaving home base) the required duration of the on-site data gathering can be predetermined. A period of from 6 hours to several days may be required on site, depending on the desired accuracy and the survey mode in use.

(8) Shut-down procedure is the reverse of the set-up procedure. The antenna is stowed, and the battery is disconnected.

(9) During transport to the next site, the internal battery maintains clock time and oscillator stability.

(10) Upon arrival at the second site, the procedure is the same as for the first site except that the surveyor must enter different tape header and pass header information.

(11) One cassette has the capacity for about 40 passes, so attention to recorder tape supply is normally required only during transport between sites.

(12) Upon completion of the survey mission the cassettes, appropriately marked as to site numbers, are delivered to the computer lab for processing.

(13) A cassette tape reader unit is used in conjunction with the mini-computer for data entry directly from the cassette. If a large computer is being used for processing the data, JMR will work with each individual customer to design and implement the most advantagous method of data entry for his computer system.

(14) The computer processes the data, producing a precise position in latitude, longitude, and elevation for each site.

2.0 DESCRIPTION OF THE JMR-1 SET

The JMR-1 Set is about the size and shape of a brief case or attache case. Its dimensions are 22 cm by 38 cm by 52 cm. A picture showing the general location of the various subassemblies is presented in Figure 2-1. The Set is designed to withstand rough handling and is completely enclosed in its watertight carrying case. A carrying handle is provided.

A panel cover provides protection for operator controls and displays. The panel is weatherproofed so that the controls may be operated in any kind of weather with the cover open. The cassette unit is mounted in a special hermetically-sealed, but accessible, compartment to provide environmental protection for the magnetic tape.

A 12-volt battery is required to power the set. An ordinary automobile battery may be used. However, for convenience in transporting, it may be more desirable to use a sealed, rechargeable battery.

2.1 JMR-1 Characteristics

A summary of the JMR-1 characteristics is presented in Table 2-1. These characteristics are designed to produce the following:

(a) A precision of position determination which is better than that from any NNSS receiving equipments which are currently available,

(b) An operating reliablility, under field environment, which is the best available for this application of today's state-of-the-art solid-state components and equipment design technology,

(c) A maximum of useable data from each satellite pass which is tracked,

(d) A system which requires no special skill to operate and maintain, and which requires a minimum of operator attention while it is in operation.

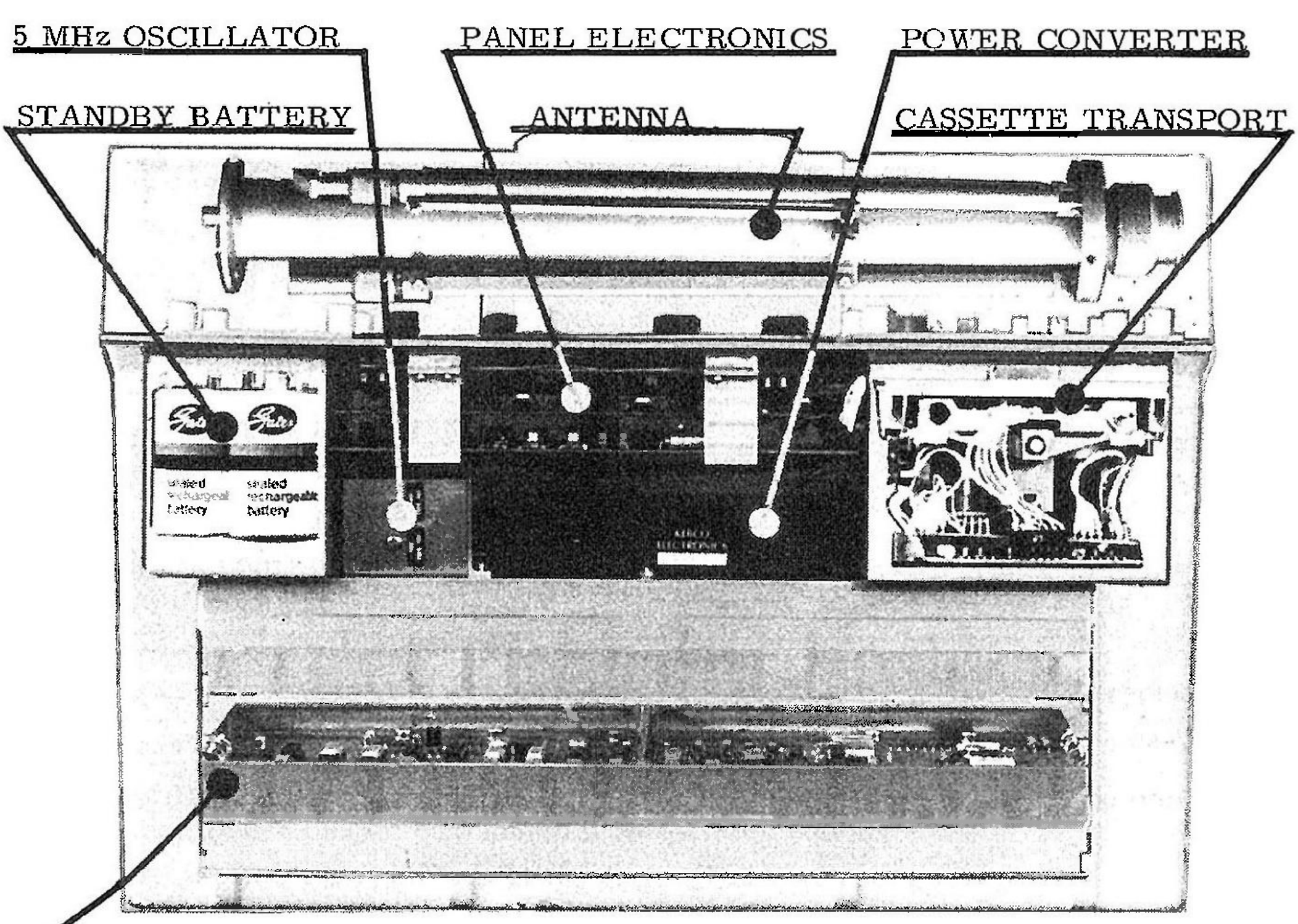


FIGURE 2-1: JMR-1 ASSEMBLY (Internal View)

TABLE 2-1

JMR-1 CHARACTERISTICS

ELECTRICAL	
1. Received signal frequencies	399.968 MHz ± 10 KHz and 149.988 MHz ± 3.75 KHz.
2. Doppler interval length	4.6 seconds; 234 satellite bits.
3. Reliability goal	8760 hours MTBF.
4. Down time due to failure	30 minutes maximum.
5. Verification of recorded data	Positive indication of data detection errors.
6. Message detection error rate	< 1bit in 10^3 at -135 dbm.
7. Data recording media	Magnetic tape; cassette.
8. Data recording error rate	<1 bit in 10^7.
9. Receiver time delay	Constant to within 50 microseconds.
10. Acquisition time	<30 seconds for r-f lock; 15 seconds additional for synchronization.
11. Reference oscillator stability	$<5 \times 10^{-12}$/100 sec. avg'g. time.
12. Reference oscillator aging rate	5×10^{-11}/day.
13. Standby time (internal battery)	> 30 hours at 2 watts.
14. Operate power	6 watts average: 10.8 to 12.8 vdc.
AUTOMATED FUNCTIONS	
1. Frequency search	6 KHz initial range; 6 KHz from frequency at unlock for "during pass" re-acquisition.
2. Signal acquisition	At least 9 times for 10 opportunities; immediate slave acquisition of second channel.
3. Frequency track	At >70Hz/second frequency rate.
4. Refraction correction of doppler	Analog correction in hardware.
5. Data demodulation	All message bits; from 400 MHz signal unless not locked, then from 150 MHz signal.
6. Data recording	Satellite pass data, pass header data, and tape header data.
7. Pass selection/rejection	Using Pass Selector.

TABLE 2-1 (cont.)

JMR-1 CHARACTERISTICS

MECHANICAL

1. Size	22 cm wide x 38 cm high x 52 cm long.
2. Weight	<16 kilograms.
3. Carrying provisions	Via handle or backpack attachment.
4. Packaging	Sealed against water and dust.
5. Shipping container	Padded transit case

ENVIRONMENTAL

1. Temperature, operate	-40°C to +55°C.
2. Vibration, transport	0 to 100 Hz, 0.25 mm peak displacement; 100 to 500 Hz, 0.025mm peak " ; 1 to 4 Hz, 125mm peak " ; 20 Hz, 1.25mm peak displacement; 5 g's maximum acceleration.
3. Shock, transport	10cm edge drop, all edges.
4. Weather, operate	Wind-driven rain, freezing rain, snow, sleet, blowing dust/sand.

SIGNAL STATUS CODING

Printed Digit	Binary Record	Received Signal Condition
0	0000	unlocked
1	0001	< -145 dbm
3	0011	-145 to -135 dbm
7	0111	> -135 dbm

ON-SITE CHARACTERISTICS

1. Antenna Electrical Center	5cm above insulator ring at bottom of telescoping sections.
2. Antenna to Receiver Separation	8 meters without preamplifier; up to 60 meters with preamplifier.
3. Antenna to Receiver Cable	RG-223/U coax.

TABLE 2-1 (cont.)

RECORDED DATA EXPLANATION (reference diagram on opposite page)

1. Clock Readout: The clock is read out and recorded at the occurrence of MESSAGE SYNC which occurs 4915.6 microseconds before the first two-minute mark of the pass. This data is presented in Items (6), (7), (8) and (9) of the PASS HEADER. This readout provides a measure of clock drift since the previous pass. Then, upon the occurrence of the first received two-minute mark, the clock seconds and microseconds counters are zeroed and, if the minutes are odd, they are advanced to the next even minute.

At the occurrence of the first positive-going doppler crossover following the first two-minute mark, the two least significant digits of the microseconds counter are read out. This number will always be less than the period of one doppler cycle. This is shown as PASS HEADER (10) - FRACTIONAL COUNT.

The next clock readout is at the end of the 234th received satellite bit (end of message line number 1) and is shown as LINE 1 DATA (2) - CLOCK MICROSECONDS. This reading, plus 4 seconds, is the amount of clock advance since satellite bit "zero" was received (when the clock was set to an exact even minute). Item (3) is the clock's two least significant microseconds digits reading at the occurrence of the next positive-going doppler crossover after (2). From this the period of the number of cycles in LINE 1 (4) - DOPPLER COUNT can be determined. Using the numbers in the diagram, this period is 601036 - 29 = 601007 microseconds plus 4 seconds, or 4.601007 seconds for 141864 counts.

This procedure continues through the 25th message line of the first received two-minute interval. The readout at the end of the 26th line is held off until the second two-minute mark is received 19 bits later. At that time the entire clock is read out as shown in LINE 26 + 27 DATA (1) & (2). The LINE 26 + 27 DATA (3) - FRACTIONAL COUNT readout allows a measure of the period of the final 253-bit doppler count of the first two-minute interval.

The above procedure continues throughout the pass. The clock is synchronized to received satellite time only at the first two-minute mark of each pass, but is read out at the end of each line of the pass except for lines numbered 26, when the readout is held for 19 bits until the occurrence of the two-minute mark.

2. Doppler Readout: The initial count of the pass, Item (11) of the PASS HEADER, should always be a count of one, and merely indicates that the counter has been properly zeroed. All succeeding readouts are the integral number of counts occurring within a 234-bit period of received satellite time, except for the readout just prior to each received two-minute mark, which is the count for a 253-bit period. The doppler data which is being recorded has been corrected for ionospheric refraction in receiver analog circuitry. The doppler count is continuous. That is, no counts (or fractional counts) are missing between intervals. The last zero-crossing count of one interval is count "zero" of the next interval. The recorded doppler count is 55/64 of the true 400 MHz "vacuum" doppler count.

3. Signal Status: These two digits, which follow the doppler count record, indicate the signal status of the 150 MHz and 400 MHz channels respectively, as shown on page 10 under SIGNAL STATUS CODING.

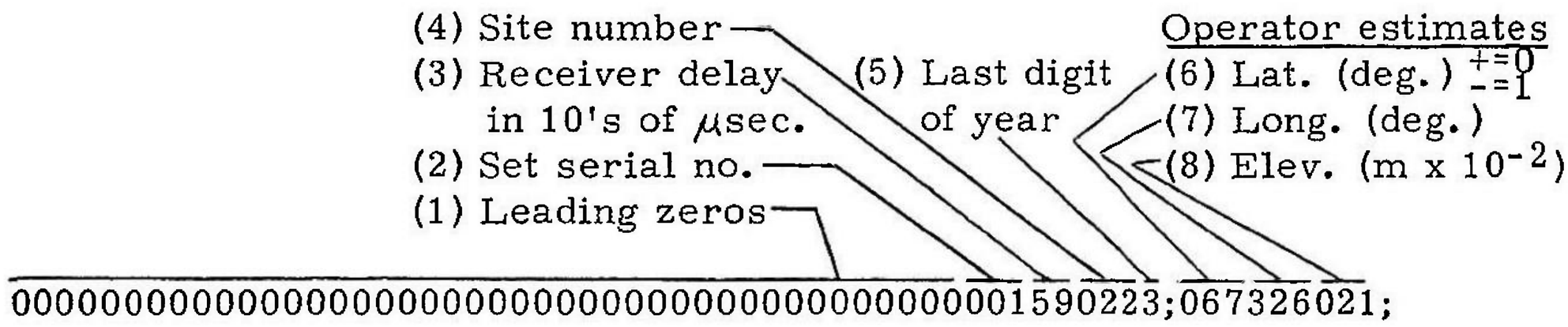
Since each doppler count is tagged with the weakest received signal condition which occurred during the time interval in which it was taken, all available doppler data is recorded and the computer program is required to select and/or weight the data which it uses. For example, if it is desired to use only data which was received while both channels were locked and receiving signals above -145 dbm, then any doppler counts having either or both signal status digits appear as 0 or 1 would be deleted from the computation.

TABLE 2-1 (cont.)

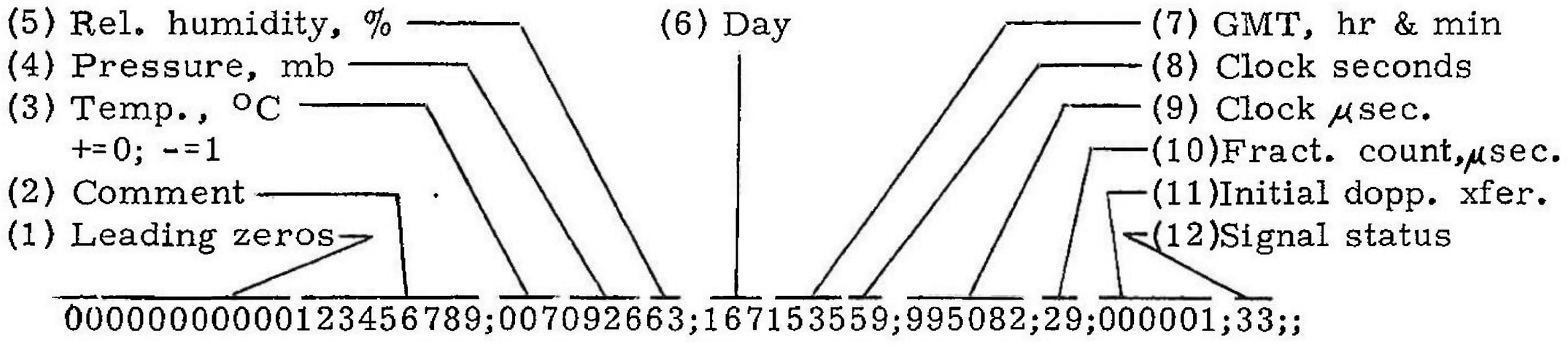
JMR-1 CHARACTERISTICS

RECORDED DATA (shown as a teletypewriter printout)

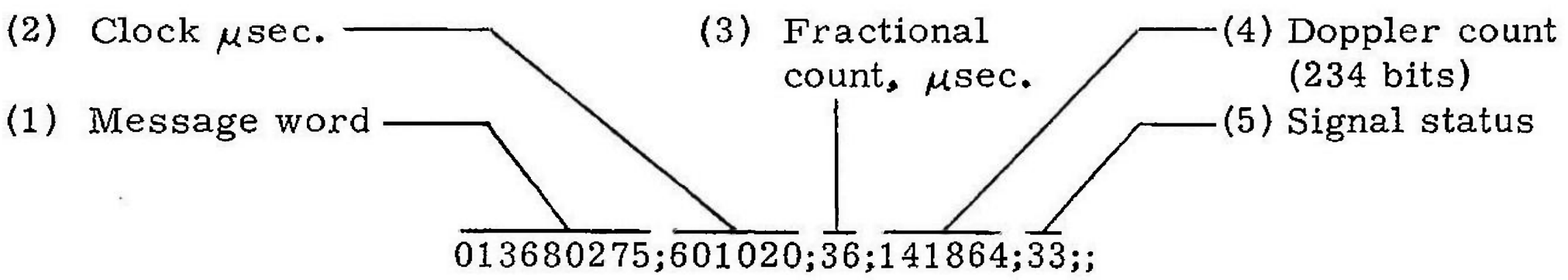
1. Tape Header (entered by operator at beginning and end of tape.



2. Pass Header (recorded automatically at beginning of each pass; items (2), (3), (4) & (5) are operator entries)

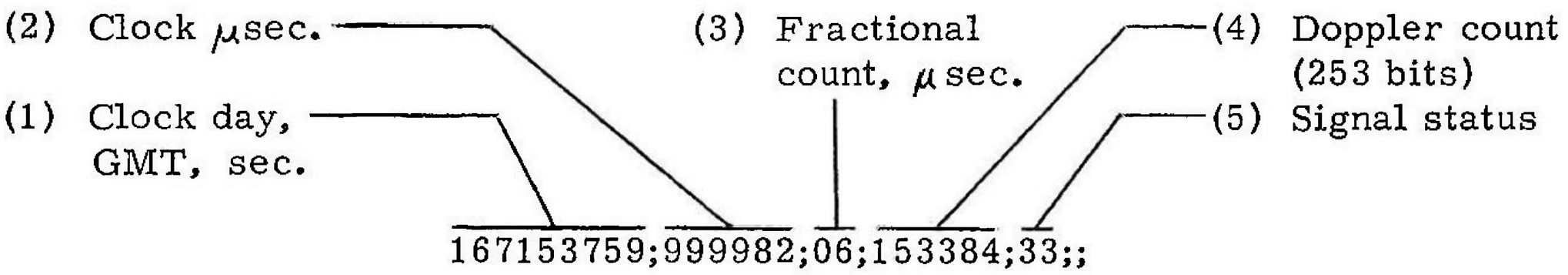


3. Line 1 Data (recorded during Line 3)



4. Line 2 Data through Line 25 Data } Similar to Line 1 Data

5. Line 26 + 27 Data (recorded during line 1 of second 2-minute interval)



Note: The semicolons (;) are not entered by the operator, but are recorded on the tape automatically.

If operator does not enter TAPE HEADER, set operation is not affected.

If PASS HEADER "operator entries" are not made, zeros will appear in the corresponding data spaces.

2.2 Functional Diagram

The functional elements of the JMR-1 Set are shown in Figure 2-2. The Set contains four major functional groupings; (1) Timing, (2) Receiving, (3) Data, and (4) Power.

The primary function of the Timing Group is to maintain information of the current GMT. This time information is presented to the Data Group for recording at specified times. The 5 MHz Reference Oscillator is a part of the Timing Group and provides a clock reference as well as being the source from which all receiver reference frequencies are synthesized. The Pass Selector is also a part of the Timing Group. Its primary output is a control signal to the receiver power switch.

The Receiving Group consists of an antenna and two phase-lock receiver channels. This Group receives the 400 MHz and 150 MHz signals which are transmitted by the NNSS satellites and outputs detected doppler, message, timing information and control signals to the Data Group.

The Data Group contains a phase-lock loop which locks to the received satellite clock rate (bit rate) and provides stable timing signals for data bit demodulation and for doppler count interval timing. This Group contains all circuitry for message data demodulation, doppler counting, and data formatting. It also includes the Cassette Recorder Unit and the Panel Displays.

The Power Group includes all power conversion and regulation, power switching and the Standby Battery. The Standby Battery maintains power to the oscillator and clock at all times. When an external bettery is connected to the Set, it provides a trickle-charge source for the Standby Battery as well as powering the Receiver Group, the Data Group, and the Display Panel. The Receiver continuously searches for a satellite signal when the Pass Selector is not used. Power is supplied to the Tape Recorder only when data is available to be recorded. The Panel Switch is actuated by the operator whenever he desires to check the operation of the Set. This switch also provides override control on the operation of the electronic switch.

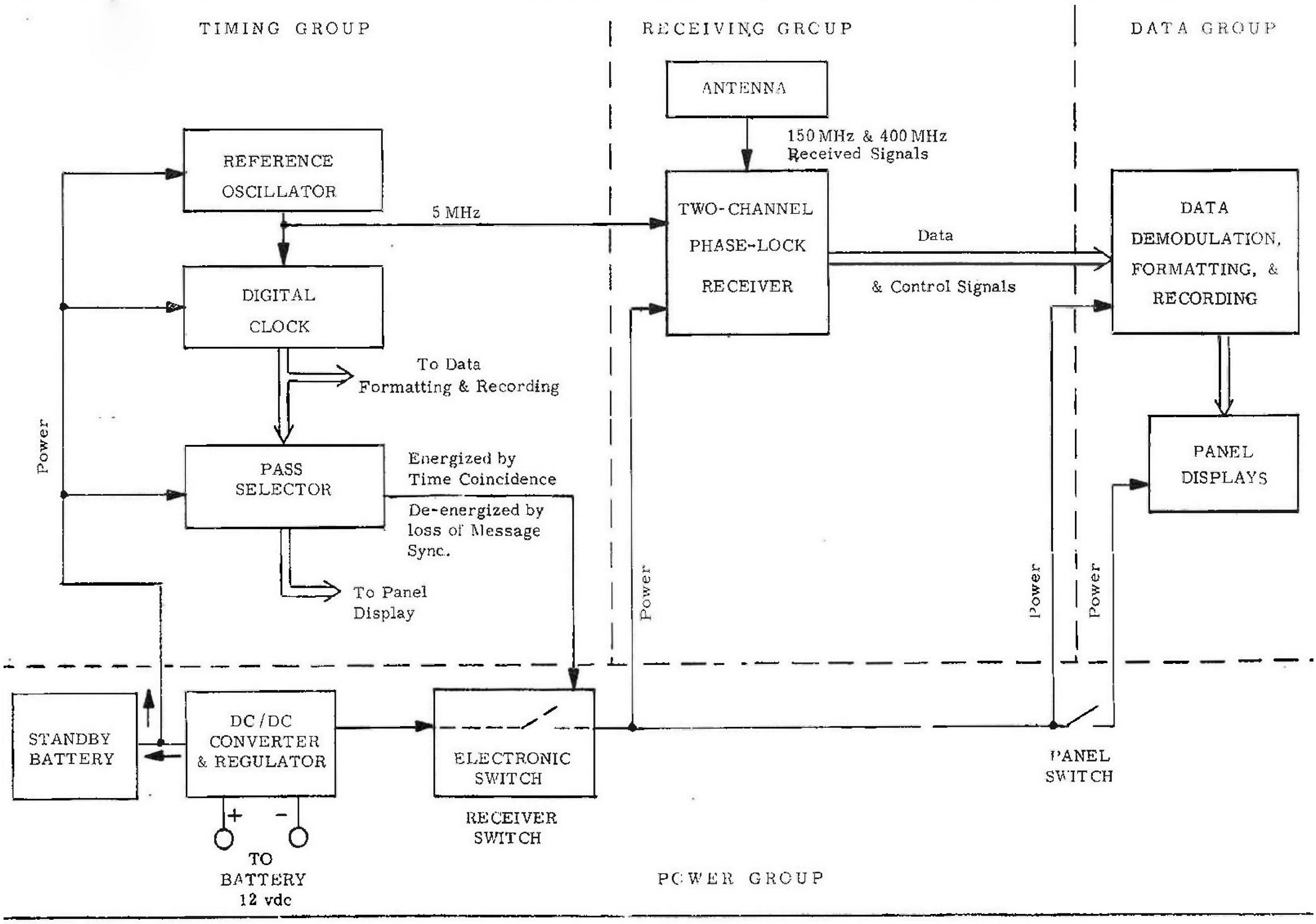


FIGURE 2-2: FUNCTIONAL DIAGRAM OF JMR-1 SET

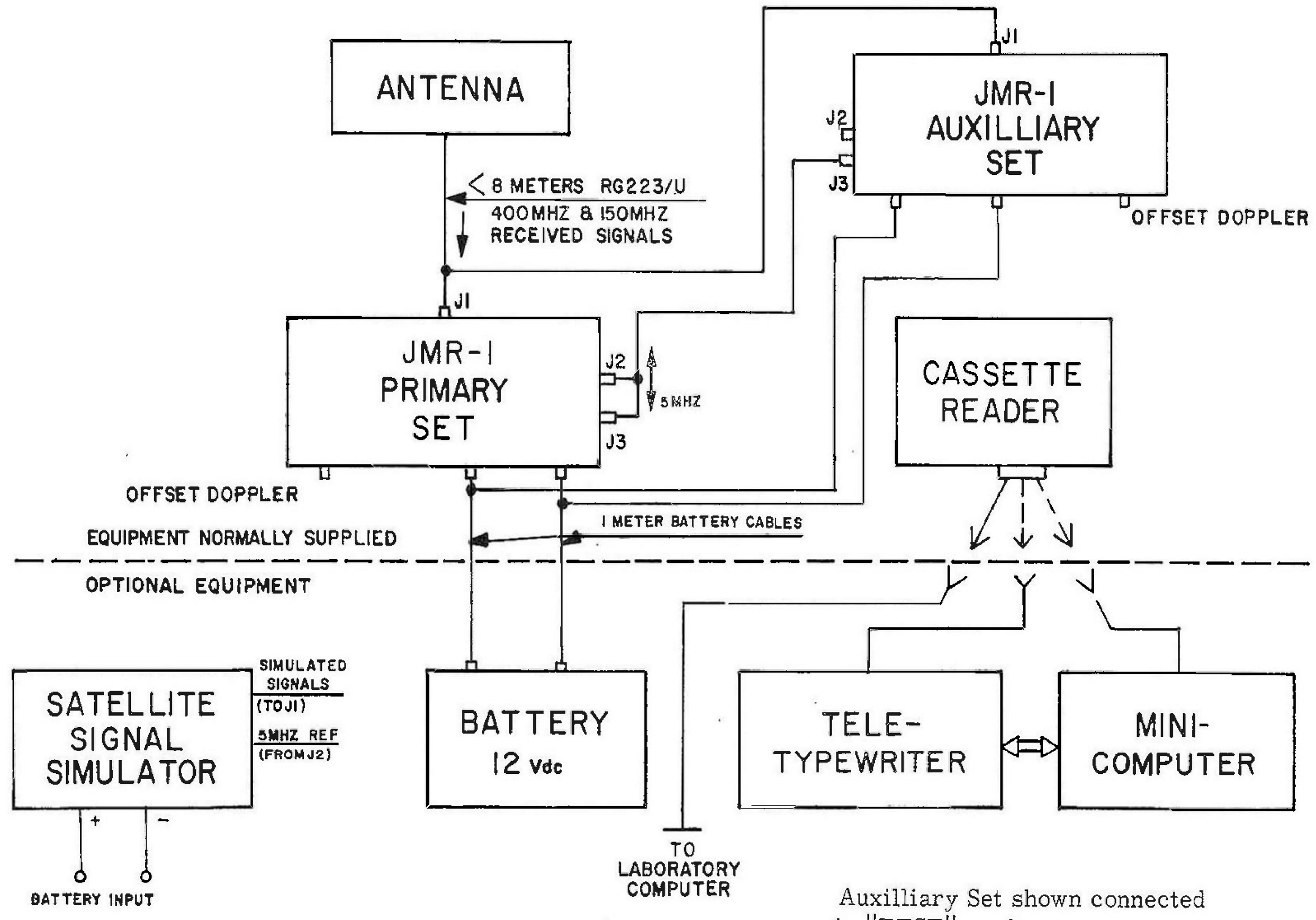


FIGURE 4-1:

THE JMR-1 SET & ASSOCIATED EQUIPMENT

Auxilliary Set shown connected in "TEST" mode.

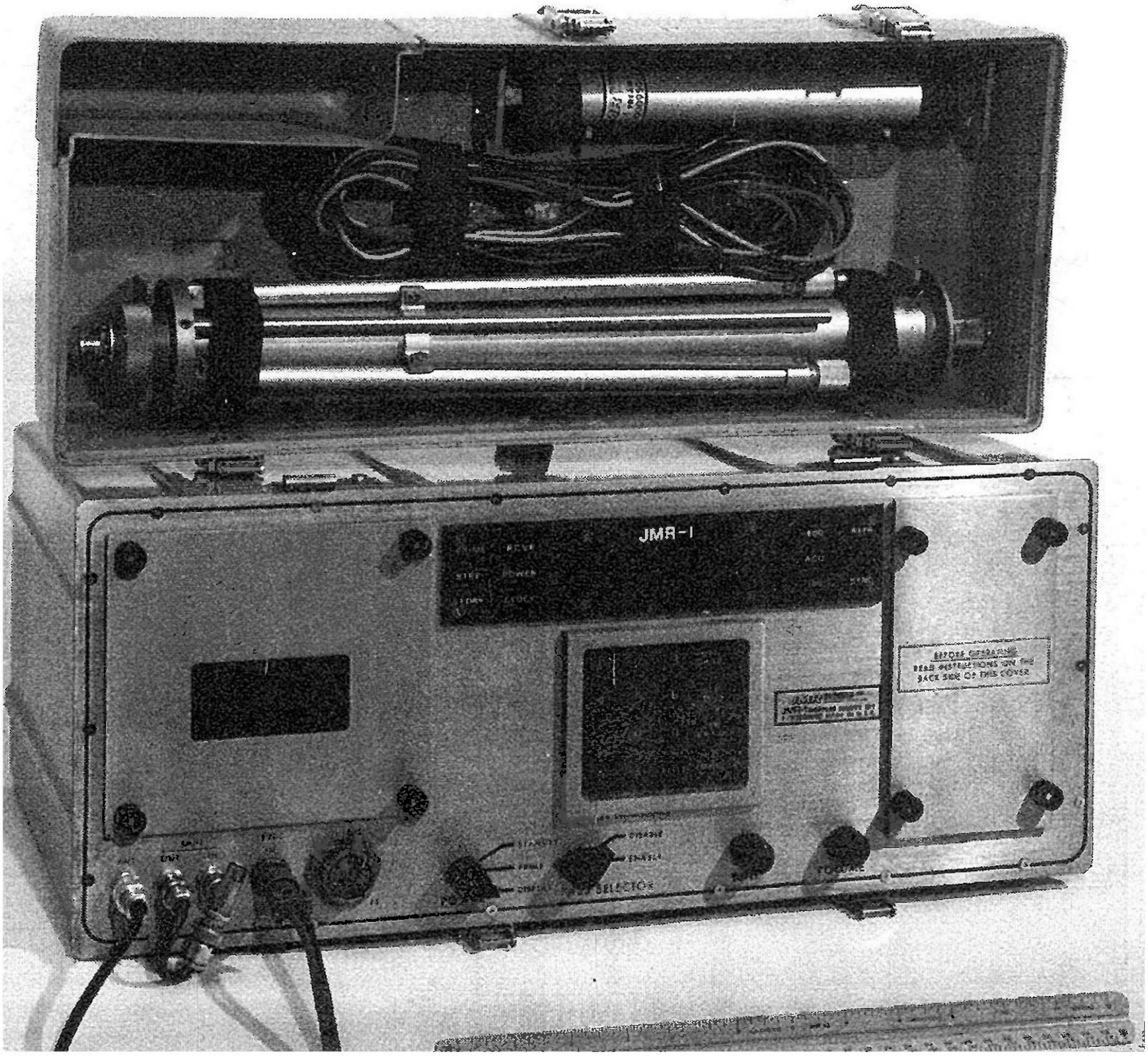


FIGURE 2-3: JMR-1 DISPLAY PANEL

2.3 The Display Panel

The JMR-1 Display Panel presents equipment status information to the operator. Controls are provided on the display panel to allow the operator to override some of the automatic functions of the equipment, and to enter data as required. Figure 2-3 is a picture of the JMR-1 Display Panel. Table 2-2 presents a brief description of the function of each display and control on the panel. The controls on the display panel have been selected for ease of operation by an operator who may be wearing heavy mittens. All keyboard switches can be operated using the eraser end of a lead pencil or any similar device.

The use of the Display Panel is explained by presenting a typical sequence of events, as follows:

(1) After arrival on site, and before the external battery is connected to the Sets, the POWER Switch on each set is turned to DISPLAY, thus activating the STDBY BTRY and the CLOCK POWER lamps. These lamps are observed to verify that adequate power has been available from the internal battery to maintain oscillator stability during transport. If not, a warm-up period will be necessary and the clock may need re-setting.

(2) The external battery is now connected to both the Primary Set and the Auxillary Set, and the PRIME BTRY lamp is observed to verify the charge of the primary battery. The RCVR Power lamp should also light.

(3) A single antenna is connected to both sets and the Auxilliary Set is connected to the 5 MHz output of the Primary Set.

(4) To verify the internal clock operation, the operator enters command 4, causing the digital display to present the internal clock time.

(5) The operator now enters the tape header information via the panel keyboard on both sets.

(6) If meteorological information is to be entered prior to each pass, it can be set up by the operator at any time prior to pass lock-on. If meteorological data is not required, the pass header entry is fully automatic and no operator action is required prior to each pass.

(7) At the time of lock-on to the first satellite pass, the panel lamps will indicate ACQ, SYNC and REFR, and the digital display will present the data as it is being

recorded. The operator observes that the message word digits are meaningful and that the words displayed by both sets are identical. He then enters command 3 and verifies identical doppler counts on both sets.

(8) As soon as correct operation has been verified, POWER is switched to STANDBY on the Auxilliary Set and to PRIME on the Primary Set. Thus the Primary Set will record satellite pass data and the Auxilliary Set will maintain charge on its internal standby battery.

(9) The cassette tape reels are visible through a viewing window for checking the amount of tape left on the cassette.

(10) In certain locations the possibility of a local interfering signal transmission may be suspected. If so, command 8 is entered to display the tuned frequency and the MNL switch is depressed to allow manual tuning of the 400 MHZ receiver across the operating frequency band while listening for zero-beat signals from the speaker.

(11) The procedure of (10) may be accomplished for the 150 MHz receiver channel by entering command 9.

The Pass Selector is operated as follows:

(12) Prior to the start of the survey mission, the rise times of the satellite passes which are to be recorded during the mission are computed and listed, with pass numbers assigned . These pass numbers and the associated rise times (day and GMT hour and minute) are then loaded into Selector memory. The listing of passes is also taken along on the mission.

(13) Upon arrival on site, the Pass Selector ENABLE/DISABLE switch is moved to ENABLE with the POWER switch at STANDBY. The Pass Selector is now in operation.

(14) The contents of any pass number location in Selector memory may be observed on the digital display by using command A9.

(15) The pass program which has been stored may be modified at any time by the operator using command A9, with the Pass Selector switch at DISABLE.

For detailed Pass Selector operating procedures, see page 23.

TABLE 2-2

JMR-1 DISPLAY PANEL FUNCTIONS

SWITCHES /INDICATORS

1. POWER	Main power switch
Standby	Only 5 MHZ oscillator, internal clock and Pass Selector are in operation.
Prime	Set is in full operation; panel controls & displays not operable.
Display	Energizes panel controls and displays; Set in full operation.
2. PASS SELECTOR	Pass Selector operating switch.
Disable	Pass Selector not operative; Pass Selector memory is loaded in this position.
Enable	Pass Selector in operation if POWER set to STANDBY.
3. BTRY-PRIME & STDBY	Indicator lamps (2) "ON" unless batteries are discharged.
4. POWER-RCVR & CLOCK	Indicator lamps (2) "ON" if Prime battery is charged and all DC voltages on receiver are present.
5. ACQ- 150 & 400	Indicator lamps monitoring signal acquisition status. "ON" if channels are locked to received signal.
6. SYNC	Indicator lamp "ON" when synchronized to satellite signal clock rate and two-minute mark.
7. REFR	Indicator lamp flashes at the refraction rate, assuring proper lock to both frequencies of the satellite.
8. VOLUME	Controls audio level from speaker.
9. TUNE	Manual tuning. Enabled while MNL button is depressed if POWER is switched to DISPLAY.

KEYBOARD COMMANDS

1 = DISPLAY MESSAGE	5 = SET CLOCK TIME	9 = DISPLAY 150 TUNING
2 = DISPLAY MICROSECONDS	6 = ENTER TAPE HEADER	A8 = REJECT SYNC.
3 = DISPLAY DOPPLER	7 = ENTER PASS HEADER DATA	
4 = DISPLAY TIME (from clock)	8 = DISPLAY 400 TUNING	A9 = SET/EXAMINE PASS SELECTOR.

Commands are entered by pressing the appropriate keys, followed by depressing NTR CMND. If a command initiates the entry of data, such as Commands 5, 6, 7, A9, the appropriate data is then entered by depressing the appropriate number keys followed by depressing NTR DATA. The header entries consist of 18 digits and are entered 9 digits at a time without re-entry of the command. Depressing CLR CMND freezes the display so that received data, such as doppler, may be observed for a longer period than the recording rate of one word each 4.6 seconds. CLR CMND also delets a command entry, and should be used at the end of each command operation. All data entry commands are automatically locked out during satellite data reception.

3.0 OPTIONAL FEATURES

The several optional features which may be purchased with the JMR-1 are presented in the following discussion.

3.1 Test Meter

The J5 connector on the JMR-1 panel is used as a test connector as well as a means of supplying functional signals to external devices. A pocket-size test meter is available which can be plugged into J5 for monitoring the test points. Direct monitoring on the test meter of the following switch-selectable points is provided.

D-C voltages; -12, +12, -6, +6, +5, +14 & +5s.
Operating signals; 150 ACQ, 400 ACQ, 150 AGC, 400 AGC & SYNC.

Other signals are available via pin jacks on the Test Meter, as follows:

1 MS	Goes to +5 vdc upon occurrence of Message Sync.
BR	Satellite bit rate signal.
Az DOPP	Offset doppler signal square wave.
Az $\overline{\text{DOPP}}$	Complement of Az DOPP.
DATA	"Real-time" output of data which is being recorded on the cassette. Serial BCD bits.
DATA CLOCK	Clock signal for the DATA bits.

3.2 Satellite Pass SELECTOR

The Pass Selector allows advanced selection of those passes which are desired for use in the survey. When the Pass Selector is switched to disable, the JMR-1 set has its r-f section energized whenever it is connected to an external power source and is manually switched to the operate mode. Thus it is continually searching for a satellite signal and will track all satellite passes.

Use of the Pass Selector offers the following advantages:

(a) The watt-hours per site for operating the Set are 40% less, as the r-f section is powered only when a desired satellite pass is available. This power saving was calculated for days 134 and 135, 1973, at a site location of 35° latitude, rejecting all passes outside the elevation limits of 20° to 75°. A 48-hour period on site was assumed, with 29 passes tracked and 26 passes rejected, for a total of 55 available passes.

(b) The pass periods during which two satellites are simultaneously visible can lead to confusion of the data, resulting in an erroneous fix. The Pass Selector allows selection of the most desirable of the two passes or, in some instances, rejection of both passes. In the example of (a) above there were 7 occurrences of

simultaneous passes. These would be more frequent at higher latitudes.

(c) Depending on the method of processing used, manpower and computer time may be saved by selecting in advance only those passes which are most effective in achieving an accurate solution of position.

3.3 Compute Precise Azimuth from Satellite Signals (COMPASS)

The COMPASS option provides recorded data from which a precise azimuth can be computed. The option consists of a detection and data recording assembly which connects between the Primary Set and the Auxilliary Set and records azimuth data simultaneously with the position data recorder.

The antenna for the Auxilliary Set is placed over the azimuth marker whose direction from the Primary Set antenna is to be determined. The direction of the azimuth marker is computed in conjunction with the computation of the position of the Primary Set's antenna, using the data recorded by the COMPASS option.

The detailed performance characteristics of COMPASS have not yet been finalized, however it is expected that the accuracy of the azimuth computation result will be better than one minute of arc when using the data from a single satellite pass.

3.4 Antenna-Mounted Preamplifier

A dual-channel preamplifier is available as an option for all JMR-1 units purchased prior to July 1976 and is included in the purchase price for all units purchased after that time.

The JMR-1AMP preamplifier provides more than 3db improvement in system signal-to-noise ratio as the noise content of the doppler data is more than cut in half through elimination of all cable loss ahead of the first amplifier and also by improved noise figure in this first amplifier. The effect of possible interfering transmitters on JMR-1 performance is minimized by the JMR-1AMP, particularly in the 150 MHz channel which incorporates a 30 KHz bandwidth crystal filter. The preamplifier has been designed to retain the effectiveness of the JMR-1 signal strength indicators (which are recorded with each doppler count) when the 8-meter cable is replaced with the preamplifier and its accompanying 61-meter cable.

All the above-listed performance features have been achieved in a unit which is so small that it is completely concealed and mechanically protected inside the center support tube of the JMR-1 antenna tripod. The preamplifier components are fully encased in foam potting material for protection against water and extreme temperature change condensation.

4.0 ASSOCIATED EQUIPMENT

The basic JMR-1 Doppler Survey Set has been previously described. Certain additional equipment is available for use in the application of the JMR-1 Set, as shown in Figure 4-1. Basic to its use, of course, is a 12-volt power source. This source is normally a battery, but any other source of d-c power may be used provided it does not generate r-f signals which interfere with proper operation of the Set. The voltage provided by the d-c power source (or battery) should remain between the limits of 10.8 volts and 13.5 volts. A rechargeable battery pack may be ordered with the JMR-1 Set if desired.

Another piece of equipment which is essential in the application of the JMR-1 Set is a Cassette Reader Unit. This Cassette Reader Unit is available from JMR Instruments in a configuration to fit the needs of the user. The Unit includes an Interface which is compatible with the user's computer. The standard output format of the Reader Unit transfers the cassette data to the computer. Control signals, together with an appropriate data recording format, allow the computer to search for a particular pass on the cassette or to accept the data in recorded sequence, as desired. A Dual Reader Unit allows production of a second copy of a cassette recording or alternate entry of data from two cassettes. The standard output code used by the Reader Unit is ASCII. Other codes are available. The Cassette Reader Unit may also be used to print out the cassette data by direct connection to a standard ASR-33/35 or KSR-33/35 Teletypewriter or other similar devices at customer designated baud rates.

An optional equipment item, available from JMR, is the Satellite Signal Simulator. This unit provides simulated satellite signals at 400 MHz and 150 MHz which allow complete and controlled testing of the JMR-1 performance. The simulated signal is connected to the Set at J1, in place of the antenna input (alternately, the signal may be radiated to the antenna). The doppler counts and message words which are derived from this simulated signal by the JMR-1 Set are predictable and allow determination of the exact nature of any fault in the performance of the Set. The use of this unit facilitates pre-mission testing of the Set without connecting its antenna and waiting for a satellite pass.

APPENDIX

JMR-1 PASS SELECTOR

OPERATING PROCEDURE

1. Set Pass Selector switch (PSW) to "DISABLE".

2. Set Power Switch to "DISPLAY".

3. Location addresses in Pass Selector are:

00	10	20	30	40	50
01	11	21	31	41	51
⋮	⋮	⋮	⋮	⋮	⋮
07	17	27	37	47	57

4. To load, set location address and enter Pass Rise Time as follows:

Location	Last Digit of Day	Hour	Min	Seconds Filler
00	4	21	56	XX (any two digits)

The display will appear 0042156XX

Loading steps are:

(1) Press "CLR CMND"
(2) Press "A9"
(3) Press "NTR CMND"
The display will present all 0's.
(4) Press the entry desired and observe that display is correct.
(5) Press "NTR DATA"
The location which was addressed has now been loaded with a Pass Rise Time. To verify the contents of any location at any time, follow the same procedure as for loading, except substitute all 8's for the Pass Rise Time, as follows for location 15: 158888888
After pressing "NTR DATA," the display will respond with the contents of the location which was addressed.
(6) The selector will advance one location each second starting with location 00 when switched from "DISABLE" to "ENABLE", as follows:

Locations 00, 01, 02----------07
Locations 10, 11, 12----------17
⋮ ⋮ ⋮ ⋮ ⋮
Locations 50, 51, 52----------57

Then recycle back to location 00.
(7) After the Pass Selector is loaded, depress "CLR CMND", switch power switch to STANDBY, and pass selector switch to ENABLE. The pass selector will now compare one location each second with the JMR-1 internal clock time.
(8) When the JMR-1 clock advances to a stored time, the receiver will be automatically switched to "operate." After the pass, when "sync" is lost, the receiver is automatically switched to "standby" to await the next correspondence between the clock and a pass selector location.
(9) The panel power switch will override the pass selector.

(10) When loading or verifying all or sevéral locations in the Pass Selector, the procedure may be simplified, as follows:

(1) Press "CLR CMND."
(2) Press "A9"
(3) Press "NTR CMND"
(4) Set up the first entry as follows:

Location being addressed	Rise Time	Second Location to be addressed
00	42156	01

(5) Press "NTR DATA"
(6) Set up the second entry by merely pressing the "RISE TIME" digits for the second location to be addressed, followed by the digits of the third location to be addressed. The display will now appear

Second Location Addressed	Rise Time	Third Location to be Addressed
01	42243	02

(7) Press "NTR DATA"
(8) Continue this process until all desired locations are filled, then press "CLR CMND."
(9) The above procedure may be used to verify location contents by substituting five "8's" for the five "RISE TIME" digits, in each

(12) Any unused pass selector locations should have entered in them digits which are not any real time, such as "66666".