BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

Record 1986/36

BMR MAGNETOTELLURIC SYSTEM :

EQUIPMENT AND SOFTWARE, 1985

by

T.Barton, L.Allen, P.Gardner

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SUMMARY

This record describes the Bureau of Mineral Resources (BMR) magnetotelluric (MT) data acquisition system (DAS) as used in field operations during 1984.

This document will assist in the rebuilding of this system should a requirement arise for further BMR MT surveys. It was considered important to document the system and software that was operating in 1984 following the outcome of a review into the BMR MT program. The review examined staff movements, which had resulted in a loss of expertise in this field, and the suitability of this method to the BMR's present scientific programs. Subsequently the BMR MT program was suspended.

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1. INTRODUCTION

The data acquisition and processing system used by BMR for MT investigations has evolved over a number of years. This document has been written to assist in the rebuilding of the system should it be required for use at some future time. Included in this document are brief descriptions of the system components and details of the data acquisition software. All software was written using the Hewlett-Packard RTE-A.1 operating system and supercedes that previously given by Cull & others (1981) and Spence & Kerr (1982). A bibliography of BMR MT related publications is also included.

The MT system may be conviently divided into four parts; data acquisition, data processing, data manipulation and data interpretation. This paper deals with the equipment and software for the first two of these.

2. THE MAGNETOTELLURIC METHOD

The MT method is a geophysical tool for mapping subsurface electrical conductivity. Observations are made of the natural transient magnetic field together with the induced electric field. A detailed description of the method is given by Vozoff (1972).

The MT technique depends on electromagnetic energy reaching the earth's surface from two major sources. Signals with a frequency of less than about 1 Hz are usually due to ionspheric currents at heights of 75 km or greater. Frequencies about 1 Hz and greater are usually produced by electrical or thunderstorm activity in the atmosphere. It is assumed in the MT method that these sources are remote; calculations are based on the assumption of plane waves but adequate results can be obtained using curved waves with a radius of curvature greater than several times the "skin depth" of penetration of the earth at that frequency. These conditions occur most of the time in sedimentary basins in Australia, but it has been found on some occasions that plane wave conditions do not occur, and this complicates the processing of the data.

When plane electromagnetic waves strike the earth's surface they may do so at an angle; they are then partially reflected (at an angle equal to the angle of incidence) and partially refracted at the air/ground interface. The angle of refraction depends on the angle of incidence of the wave and the relative velocity of the wave in the air and earth; typically this velocity ratio will be many orders of magnitude, so the refracted wave will always be propagated nearly vertically downwards into the earth. At the point of reflection on the earth's surface, the reflected magnetic component of the wave is in-phase with the incident component, while the electric field undergoes cancellation due to phase reversal. The magnetic field at the air/earth interface is therefore nearly twice its value in free-space, but the electric field component is reduced by many orders of magnitude over its free-space value, and may be ignored.

The MT technique relies on this vertically-propagated alternating magnetic field, and the measurement of currents induced in a conducting medium (the earth) by that field. Penetration of the wave is determined by its frequency of oscillation and the conductivity of the medium, which together cause energy loss due to eddy currents. The ratio of induced electric to magnetic field at various frequencies is used to calculate apparent resistivity (i.e. the resistivity of a uniform earth which gives the measured E/H ratio) as a function of frequency. Apparent resistivity curves are then used to produce one-dimensional (1D) layered models and finally in some cases, two dimensional (2D) resistivity models.

In the MT technique the horizontal magnetic field (H field) is usually measured with the corresponding induced electric field (E field) in two orthogonal directions on the Earth's surface. In practice the H field is measured by the use of three orthogonal induction coil magnetometers (Hx,Hy,Hz) and two electrode pairs (Ex,Ey). Each pair is 600m in length centred on the magnetometer array location.

The signals are amplified, filtered and recorded using a computer based data acquisition system (DAS) which also provides a facility for preliminary in-field data processing. All data is then stored on magnetic tape for further processing prior to final interpretation.

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3. MAGNETOTELLURIC DATA ACQUISITION SYSTEM HARDWARE

3.1 OVERVIEW

The methods used for recording MT data depend to a large extent on the spectra of the signals being measured. Magnetic field strengths decrease rapidly at high frequencies, to the order of 1 picotesla (1 pT), however with the use of induction coil magnetometers a dynamic range of 100 dB is accommodated, providing increased sensitivity at higher frequencies. These low signal levels determine the critical design parameters for the analogue portion of the equipment. The magnetometer coils are buried underground to reduce noise interference and to provide thermal stability. This requires two trenches 50 cm deep for the x and y components and a vertical auger hole 2 m deep for the z component. The H preamplifiers are required to have extremely low noise levels (typically 0.03 uV) and include guarded differential inputs for chopper stabilisation to eliminate DC drift.

The E field is measured with electrodes 600 m apart. These consist of cadmium rods inserted in porous pots containing supersaturated cadmium-chloride solution. These are placed in contact with moist earth in a covered hole to prevent enviromental disturbance and maintain a satisfactory ground to porous pot contact. Multistrand copper wire is used to connect the electrodes to the E preamplifiers. Shielding is not necessary because of the low source impedances involved. The wire to the electrodes must be laid in a manner such that induced EMF's are not caused by wind moving the wires. A complete description of field procedures is given by Word & Hopkins (1971),and Vozoff (1972).

The digital portion of the equipment is a computer-based DAS with an interactive terminal. The data are recorded in files on a disc memory and transferred to magnetic tape at the completion of recording at each site.

Recording at an MT site with the BMR system consists of collecting data over specific frequency bands. These bands were selected on the basis of dynamic range and economy in the number of data points collected. The frequency bands, digitising interval, and number of data points collected are given in Table 1. These factors determine the maximum bandwidth that may be recorded. A site is normally occupied for a period of two days, during which time up to 160 data files would be recorded onto disc. The recorded data are usually processed to the stage of producing a plot of period versus apparent resistivity to ensure that sufficient data of good quality have been collected before vacating the site.

TABLE 1
FREQUENCY BANDS AND SAMPLING RATES

FREQUENCY BAND (Hz)	NO. POINTS PER FILE	DIGITISING INT. (msec)	TYPICAL NO. OF FILES COLLECTED
0.001 - 0.012	2048	4096	10
0.01 - 0.033	1024	2048	10
0.03 - 0.12	1024	1024	10
0.1 - 0.55	1024	256	25
0.5 - 2.5	1024	64	35
2.5 - 12.5	1024	8	35
10.0 - 40.0	1024	4	35

3.2 HARDWARE

This section contains brief information on each component used in the BMR MT system. A block diagram of the equipment used in the 1984 survey (Barton,1986) is shown in Fig. 1 and their rack positions in Fig. 2. The following information is included in this document as an aid for rebuilding the system should a requirement arise for future BMR MT investigations.

3.2.1 H-FIELD SENSOR COILS

Type	: Geotronics Model MTC-4SS	
	S/No.s 1005,1006,1007	(coil set 1)
	1014,1015,1016	(coil set 2)
Dimensions	: overall length 2045 mm	
	case O.D. 76 mm	
	cap flange O.D. 114 mm	
	weight 38.6 kg	
BMR vocab no.	: MMM-025	
Operating temp.	: -40°C to +100°C	

The model MTC-4 sensor is an induction coil magnetometer. The coil itself is wound on a laminated moly-permalloy core, then potted in polyurethane rubber and encased in a stainless steel jacket. There is a Farady shield between the case and coil.

The two coil signal terminations are made with special copper binding posts; the shield terminal is a standard binding post. All three terminals are mounted on a phenolic header located in the end of the coil. The cable is connected to the terminals via a self-sealing cap which is bolted to the head of the coil.

The sensor cable, Geotronics type H36-003, consists of three individually shielded twisted pairs of untinned, stranded copper wire. The cable and individual pair jackets are made of polyurethane rubber and the conductor insulation is polyethylene. Connections between the coils and the H-preamplifiers are made directly to the copper binding posts of the respective instruments.

In field operations the sensors were used as follows :

H COMPONENT	SERIAL No.s	CONNECTIONS (+)	(-)
Hx	1005, 1014	Yellow	Green
Hy	1006, 1015	Brown	Black
Hz	1007, 1016	Red	Orange

The output terminal marked + is positive for an increasing positive H-field directed from the terminal end to the opposite end of the sensor.
The coil sensitivity is given by :

$$k = 137 \frac{\text{microvolt}}{\text{gamma-Hz}} \pm 3\% \text{ on the low frequency asymptote.}$$

Plots of the transfer function amplitude and phase vs. frequency are given by Word & Hopkins (1971).

3.2.2 H-FIELD PREAMPLIFIER

Type	: Geotronics Model MTH-4 S/No.4H-003
Number of channels	: 3
Connectors	: Front panel Input : 2 copper binding posts Input guard shield : yellow post Signal common : black post Calibration : red(+) & green(-) posts Rear panel Output : 2 paralell BNC connectors
Gain steps	: 1800, 18000, 180000
Filter	: 4-pole, 4-zero, band reject filter with notch centred on 50 Hz.
Noise	: 0.20 uV pp rti 0.002-25 Hz : 0.10 uV pp rti 0.002-2 Hz : 0.05 uV pp rti 0.002-0.125 Hz (rti = referred to input)
Chopper frequency	: 2 KHz
Input voltage	: $\pm$ 5mV (undistorted) $\pm$5 V (abs.max)
Output voltage	: $\pm$5 V (max)
Input impedance	: 1.45 kohm // 10 mf
Common mode rejection	: 150 dB at 1 Hz 143 dB at 10 Hz 124 dB at 100 Hz
Power requirements	: 115 V AC, 50 Hz, 30 W (max.)
Operating temp.	: 0°C to 50°C
BMR vocab no.	: MMA-025

The H preamplifier is a low noise, guarded differential input, chopper-carrier amplifier. Three gain settings are available for each of the three channels. Each channel also has two signal monitors. One is a zero centre volt-meter thath reads the preamplifier output. The other is simply a red light that will latch on if either the chopper-carrier amplifier or the output DC amplifier approach saturation. It is reset by an adjacent push button. Two paralell-connected outputs are provided for each amplifier, one for connection to the postamplifier and one for signal monitoring.

Input connections are as per the sensor coils.

The transfer functions for coil and preamplifier combinations are given by Word & Hopkins (1971).

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3.2.3 E-FIELD SENSOR ELECTRODE

Type : Geotronics Model MTE-2
BMR vocab no. : MME-015

The MTE-2 is a cadmium-cadmium chloride ($Cd\text{-}CdCl_2$) buffered type electrode. The electrode wire lead is connected to a cadmium rod This should be bound with Scotch 23 tape or similar to seal against moisture, which can cause electrolysis to occur between the copper lead wire and the Cd rod, subsequently causing signal degradation. The Cd rod is immersed in a saturated solution of $CdCl_2\text{-}H_2O$, which makes ultimate contact with the ground through a porous ceramic pot. Caution should be exercised in the handling of this solution as it is toxic.

Each electrode is placed in a hole about 40 cm in diameter and about 50 cm deep. Water is added to form a slurry to ensure a good porous pot to ground electrical contact. This arrangement is covered with a plastic bucket to prevent rapid drying of the contact area. The electrodes are checked on a daily basis and re-watered if required.

3.2.4 E-FIELD PREAMPLIFIER

Type	: Geotronics Model MTE-4 S/No.4E-003
Number of channels	: 3 (two used, one spare)
Connectors	: Input : 2 binding posts, blue(+), white(-) Input guard shield : yellow post Signal common : black post Output : 2 paralell BNC connectors
Gain steps	: 10, 100, 1000
Filter	: 4-pole, 4-zero, band reject filter with notch centred on 50 Hz.
Noise	: 3.0 uV pp rti 0.002-25 Hz
Chopper frequency	: 2 KHz
Input voltage	: $\pm$ 1 V (undistorted),$\pm$8 V (abs.max)
Output voltage	: $\pm$5 V (max)
Input impedance	: $>$ 100 kohm
Common mode rejection	: 100 dB at 1 Hz 86 dB at 20 Hz 74 dB at 200 Hz 60 dB at 2 kHz
Power requirements	: 115 V AC, 50 Hz, 25 W (max.)
Operating temp.	: 0°C to 50°C
BMR vocab no.	: MMA-020

The E preamplifier is essentially the same as the H preamplifier. The input electrode connections are shown below.

ELECTRODE	AMPLIFIER CHANNEL	TERMINAL
Ex+ (north)	1	RED
Ex- (south)	1	GREEN
Ey+ (east)	2	YELLOW
Ey- (west)	2	BLACK

The guard shield and the signal ground are left floating.

3.2.5 MT CALIBRATOR AND POWER MONITOR

Type	: Geotronics Model MTC-2 S/No. 2C-001
	: Hewlett Packard function generator Model 3300A S/No. 939-05086
Power requirements	: 115 V AC, & 240 V AC, 50 Hz
BMR vocab no.	: MMC-080

The MTC-2 is a system service unit that provides calibration voltages for the preamplifier inputs, monitors the AC line voltage and frequency, and serves as an auxilary DC power supply.

3.2.6 MT POSTAMPLIFIER POWER SUPPLY

Type	: BMR MTA-1
Power requirements	: 240 V AC, 50 Hz
BMR vocab no.	: MMP-055

The MTA-1 provides $\pm$ 15 V DC for the BMR designed and constructed preamplifiers and postamplifiers.

3.2.7 MT E & H POSTAMPLIFIERS AND FILTERS

Type	: BMR MTA-1 S/No.s 1,2,3,4,5,6
Number of channels	: 5
Connectors	: Input : BNC floating Output : BNC single ended Power : Cannon 14-P-5P
Gain steps	: 3, 10, 30, 100, 300, 1000, 3000
High pass filter (3 dB points)	: 0.001, 0.01, 0.03, 0.1, 0.5, 2.5, 10 Hz
Low pass filter (3 dB points)	: 0.012, 0.033, 0.12, 0.55, 2.5, 12.5, 40 Hz
Noise	: 1 uV pp rti 0.001-40 Hz
Output voltage	: $\pm$1.2 V (on recorder output terminal) $\pm$ 12 V (on CPU output terminal)
Input impedance	: 10 kohm
External Power requirements	: $\pm$ 15 V DC, 400 mA (max)
Internal Power requirements	: $\pm$ 12 V DC, $\pm$ 5 V DC
Operating temp.	: 0°C to 50°C
BMR vocab no.	: MMA-030

The MTA-1 postamplifier accepts outputs from the E and H preamplifiers. It performs bandwidth shaping and amplification. The output analogue signal is interfaced to the Phoenix analogue-to-digital converter and monitoring devices. Gain settings on all five channels are independent of each other, but they may be controlled by the CPU. High- and low-pass filter settings are slaved from channel 1, or may be controlled by the CPU. Logic controls for all five channels of filter and gain settings are sent via the digital multiplexer to the CPU for data logging.

A complete description of the MT postamplifiers is given by Lui (1983).

3.2.8 SIXTEEN-CHANNEL DIGITAL MULTIPLEXER

Type	: BMR XDM-1 S/No. 2
Power requirements	: 115 V AC, 50-400 Hz
BMR vocab no.	: XDC-CV7

The XDM-1 allows a number of devices to be connected to the CPU for input/output operations. For the MT system five channels were used as given below.

CHANNEL	INPUT
0	Ex & Ey Preamp gain and filter settings.
1	Hz, Hx & Hy Preamp gain and filter settings.
2 to 4	Postamplifier E & H gain and filter settings.

When this device is used with the Geotronics preamplifiers the inputs require voltage level translation to TTL compatability. To allow for this the inputs on channels 0 and 1 are optically isolated. Details on this are given by Devenish (1979). Optical isolation is not required if the BMR-constructed preamplifiers are used.

3.2.9 PROGRAMMABLE OSCILLATOR

Type	: BMR SPO-1
Power requirements	: 240 V AC, 50 Hz
BMR vocab no.	: SPR-130

The SPO-1 is a programmable oscillator that provides a number of output frequencies that are used to control the sampling rates (Table 1) for the analogue-to-digital conversion carried out by the Phoenix equipment. This device is controlled by the six least significant bits (LSB) of a 16 bit duplex register (i.e. bits 0-5). Bits 0-4 determine the output frequency whilst switching of the oscillator is by bit 5. With bit 5 at logic 1 (0 V) the output is enabled and disabled when bit 5 is logic 0 (+12 V). The cutoff frequency for an anti-aliasing filter is selected by the three LSB of the duplex register. Input settings of "000" or "111" disable the filter. The oscillator is interfaced with the CPU which provides the logic control for the output frequency selection.

3.2.10 PHOENIX DATA ACQUISITION SYSTEM

Type	: Phoenix Data Inc. Model 6915-3754 & Model PDI Standard Subsystem Interface
Power requirements	: 240 V AC, 50 Hz
BMR vocab no.	: XDI-DA3

The 6915 is an analogue-to-digital converter which is used in conjunction with the PDI Standard subsystem interface for the acquisition of MT data. The sampling rates are controlled by the CPU via the programmable oscillator and the digitised data is sent to the CPU for storage onto disc. Full details on this equipment is given by Phoenix Data Inc. (1976,1977).

3.2.11 MT PREAMPLIFIERS

Type	: BMR MT Preamplifiers S/No.s 1,2,3,4,5
Number of channels	: 5
Number of channels	: 5
Connectors	: Front panel Input : 2 red binding posts Signal common : silver binding post Rear panel Output : BNC Power : Cannon 14-S-5P A - +15 V B - -15 V C - 0 V
Gain steps	: 10, 100, 1000
Filter	: 50 Hz notch filter (38.6 dB)
Input Voltage	: ±1 V (undistorted)
Output voltage	: ±12 V
Input impedance	: 2.2 mohm
Common mode rejection	: 64.4 dB at 10 Hz
External power	: ± 15 V DC
Internal power	: ± 12 V DC, ± 5 V DC
Operating temp.	: 0°C to 50°C
BMR vocab no.	: MMA-026

These preamplifiers were designed and constructed by BMR to replace the Geotronics units. At the time of writing these preamplifiers had not been field tested. Should they be required it will be necessary to include an additional fixed gain field preamplifier situated with the magnetic sensor coils to increase the signal level to the recording cab. It will be necessary to determine the transfer functions for the magnetic and electric channels for the system under field conditions. This would allow the poles and zeros of the system to be calculated and included into the data acquisition software.

Design specifications required for the H-field pre-preamplifiers are given below.

Number of channels	: 3
Gain	: 100 (fixed)
Filter	: 0 - 100 Hz (fixed bandwidth)
Input impedance	: 1.45 kohm // 10 uf
Common mode rejection	: 120 dB (typical)
Internal power	: ± 6 V DC (batteries)
Max. noise	: 0.20 uV pp rti 0.002 - 25 Hz
Sensitivity	: 0.05 V/gamma (approx) when combined with the MTC-4SS coil

3.2.12 CPU

Type : Hewlett Packard A600 Series 1000
Model 2156A opt.015
S/No. 2309A00319
Power requirements : 240 V AC, 50 Hz
BMR vocab no. : XDC-DC30

The CPU included the following cards:

2 x HP5180 A600 memory control PROM card (ports 1 & 2)
1 x HP12101 A600 PROM processor card (port 3)
1 x HP12005A Asyncronous serial interface card for use with HP2623A VDU (port 4)
Select codes: U1 (1 to 8) CCCOCCCC
U21 (1 TO 8) OOOOCCOC
1 x HP12009A HP IB interface card for use with HP7908A Disc Drive (port 5)
Select code: (1 to 8) OCCOCOOO
3 x HP12006A Parallel interface card for use with:
Multiplexer (port 6)
Select code: (1 to 8) OOCOCCOO
Phoenix interface (port 7)
Select code: (1 to 8) OOCOCCCO
Programmable oscillator (port 8)
Select code: (1 to 8) OOCOCCOC
Note: R6 to R11 are removed to match ground true logic of the SPO-1 oscillator.

3.2.13 DISC AND TAPE DRIVE

Type : Hewlett Packard Model 7908A
S/No. 2208A00890
Power requirements : 240 V AC, 50 Hz
BMR vocab no. : XDC-DD12

The 7908A contains five disc cartridges (CR 16 to 20) for data storage, acquisition software and system control. The unit includes a cartridge type tape drive for data archival and system back-up use. For data archival 150 foot HP data cartridge tapes were used.

3.2.14 COMPUTER TERMINAL

Type : Hewlett Packard Model 2623A
opt. 015,050,262
S/No. 2226V19232
Power requirements : 240 V AC, 50 Hz
BMR vocab no. : XDC-DT11

The 2623A is used for interactive control of data acquisition and processing. It includes a graphics capability and a thermal printer which allows hardcopy plots of processed data to be produced in the field.

3.3 SYSTEM RECONFIGURATION

The BMR MT data acquisition system was decommissioned during 1985. With the exception of the HP A600 computer system and the Phoenix equipment all components were placed in storage. Should this system be required the following points may be of assistance.

(i) All software is written under the RTE-A.1 operating system and is archived on HP1000 9 track tape and HP data cartridge format.

(ii) It will be necessary to design and construct pre-preamplifiers for the three magnetic channels. These would be located at the sensing coils and provide sufficient gain for the inputs of the BMR preamplifiers.

(iii) The BMR constructed preamplifiers were not field tested prior to the system being dismantled.

(iv) The transfer function for the complete system would have to be determined as the present poles and zeros information is not valid for the revised equipment. Software for data acquisition and interfacing cables are available for this replacement equipment.

4. MAGNETOTELLURIC DATA ACQUISITION SYSTEM SOFTWARE

4.1 INTRODUCTION

4.1.1 OVERVIEW

This chapter describes the magnetotelluric data acquisition system software (MT DAS) which used the HP RTE-A.1 operating system in an HP A600 computer with a 2623A graphics terminal and 7908A disc and cartridge tape unit. The software was written during the first quarter of 1984 at the BMR, and updated in early 1985 with the replacement of the Geotronics preamplifiers.

This software supercedes that which ran on the old HP E-series computer It has an enhanced user interface (program MAGTL) in addition to having a simplified program structure (modular programs written in FORTRAN 77), and a rationalised data file structure (i.e. no duplication of data items within data files along with the use of files with variable length records).

In addition to the MT DAS programs, there are several utilities which facilitate file manipulation, archiving and purging, as well as a help file, an answer file, a status file, and of course the data files.

All system software is archived on HP data cartridge and 9-track magnetic tape formats. Data processing software is given by Moore (1976,1977), and Spence & Kerr (1982).

4.1.2 DATA FILES

There are three types of data files:

MTnnnn files - Data files made by MAGTL on disc cartridge 19.
FTnnnn files - Fourier transform files made from MTnnnn files by program FFT. They are usually on disc cartridge 20, but can be on 16 and 17 as well. They have a security code of 50.
Tense files - These are the tensor rotation files ROTTEN and TIPPER. They are made by program TENSE from FTnnnn files. They normally reside on cartridge 18 and have a security code of 50.

The different input/output (I/O) system of the A-series CPU necessitated writing new interface drivers for the Phoenix analogue-to-digital converter, the SPO-1 programmable oscillator and the XDM-1 multiplexer.

All of the above components of the MT DAS are described in the following sections.

4.2 USERS GUIDE

4.2.1 SYSTEM INITIALISATION

After powering up all hardware components, the MT DAS system is booted up by typing:

%BDC0027BCF01 (or %BDC0027 for the development system)

and pressing carriage return. After the system has been booted up, the time must be set with the FMGR TM command,
e.g.

TM,hrs,min,sec,month,date,year

At the start of each new site, the following action must be taken:

1. Transfer control to procedure file PUDATA to archive and purge all data files from the previous site.
2. Run MAGTL and type IN to initialise the answer file.
3. Type UP to update the answer file.

The MT DAS system is then ready to use. User interface to the system is obtained by running program MAGTL, the main control routine, in FMGR.
e.g.

RU,MAGTL

MAGTL will clear the screen, write out a heading that includes the current version number and issue a prompt for a command input
e.g.

```
MAGTL - MT Data Acquisition System <861204.1423>
Type HE for help, EX to exit
MAGTL:
```

The valid inputs to MAGTL are:

AB - to abort data acquisition immediately and purge data file.
AQ - to start data acquisition.
BR - to break (abort) data acquisition at next file.
CU - to display the current answer file.
EN - to end MAGTL and disable printer if it was enabled.
EX - to exit from MAGTL, leaving printer status unaltered.
FI - to display the number of files collected in each frequency band.
HE - to display the MT help file.
IN - to initialise the MT answer file.
RE - to enable the printer for hard copy reports.
RX - to disable the printer.
ST - to display the MT survey status file.
UP - to update the MT answer file.

If MAGTL cannot recognize a command input, e.g. CC, it will respond in the following manner:

MAGTL: CC is an Illegal Input.

Type HE for help, EX to exit

The two character command inputs are not followed by a carriage return as there is an automatic data transmission whenever a two character command is typed.

4.2.2 ANSWER FILE INITIALISATION

The IN command should be used with caution as it will preset the answer file to an initial state. It is useful when the answer file is nonexistent.

4.2.3 ANSWER FILE UPDATE

After the UP command the user is prompted to update the answer file. This command operates by displaying in turn the current values for various data items, e.g. coil set used, electode resistance and frequency band to sample. For each displayed value a new value can be input or the return key pressed for no change.

To reset a value to zero, -1 must be typed as in this system a zero is equivalent to pressing the return key.

The answer file is contains a character string of 54 letters and several numeric items. The character string is used to contain details on the site. It can be updated with the aid of a restricted editor function that interprets a "/" by leaving that character position unalterd in the old string, and a "\" by deleting the character in that position from the old string.
e.g.

ANSWER FILE UPDATE
Survey Site is: FINAL TESTING OF MAGTL AT BMR 27-3-84
New Site or cr: //////////\\\/////////////////28/////.
New Site is: FINAL TEST OF MAGTL AT BMR 28-3-84.

The character string is updated first, followed by the following numeric items:

Azimuth (deg); Coil Set used; Ex Separation(m); Ey Separation(m);
Rx Resistance(ohms); Ry Resistance(ohms);
Effective Ex Separation (automatically calculated);
Effective Ey Separation (automatically calculated);
Next File No.; Freq.Band No.; No of Samples;
Dig.Int.(msecs); Files in band;
Post Amp.Gains;
E Preamp.Filters; E Preamp.Gains;
H Preamp.Filters; H Preamp.Gains;
Low & High Pass Filter Bands.

4.2.4 DATA ACQUISITION

Additional input is required after the AQ and UP commands. After the AQ command, MAGTL will ask for the number of data files to be collected. In the example below, two files are collected according to the information contained in the answer file.

```
MAGTL: Acquire how many files Doc?  2
       Data Acquisiton Started for 2 Files.
MAGTL:
```

4.2.5 ACQUISITION MONITORING

Once data acquisition has started, control returns to MAGTL and other commands can be entered. The answer file cannot be updated during an acquisition because the acquisition uses data from it. Hence if the CU or UP commands are entered their only action is to respond with:

DATA ACQUISITION IN PROGRESS NO ACCESS TO MTANS

Note also that the AQ command must not be entered again until after the current acquisition has finished. If AQ is accidently input to MAGTL, the user must ask for zero files and control will return to MAGTL without requesting an acquisition to start.

After each file has been acquired, a message is written on the status file (MTSTAT) saying what file was acquired and when it was completed. A message is output to the VDU saying how many files were recorded when an acquisition is finished.
e.g.

ACQUISITION COMPLETE FOR 2 FILES

It can be determined whether data acquisition is currently in progress by one of several means:

1. Observe the Phoenix A-to-D converter - the lights flash during data acquisition.
2. Enter CU or UP - these commands will indicate if acquisition is in progress.
3. In FMGR, enter PL and observe if program AQUIR is doing I/O to LU 30 (the Phoenix)
4. Type ST in MAGTL and check whether the last data file has been completed.

4.2.6 TROUBLE SHOOTING

If the MT DAS system cannot access any of the files it uses, it will report the appropriate FMGR error code. If any errors are reported, they should be investigated before re-running MAGTL. The following files are used by MAGTL and must exist:

MTANS::18 - the answer file
MTSTAT::18 - the status file
MTHELP:LA:18 - the help file

In addition to the above, MAGTL uses a temporary scratch file on disc cartridge 19 called 'NEWDAT'. This file should only exist during actual data acquisition and should only be opened to program AQUIR. After ACQUISITION COMPLETE FOR n FILES it will be purged.

If the A-to-D converter fails to stop on completion of the file acquisitions, down (DN,-31) then up (UP,-31) the programmable oscillator (SPO-1).

It is the users responsibility to manage the number of files on cartridge 19 and ensure that there is sufficient room for subsequent data acquisition. Several utilities exist to assist the user to do this. They are outlined in the next section.

The ST command in MAGTL can be used to determine how full data cartridge 19 is. It is displayed as a blinking percentage in the top right hand corner of the screen.

The first file acquired should always be checked to determine whether all wires have been connected properly.

4.2.7 DATA ARCHIVAL AND RETRIEVAL

For archival onto magnetic tape (LU 24) the following commands are used:

,PUDATA - Archives FTnnnn, MTnnnn, ROT---, and MTSTAT files onto tape using PURGE subroutine. These files reside on cartridge 17.
,UPDATA - Recovers files from tape using RTREVE subroutine.
,STDATA - Recovers all data files from tape using RECOVR subroutine.

These procedure files reside on cartridge 16 but if these are to be used for data files residing on cartridge 16 then STDATA and RECOVR should be moved to cartridge 20 and purged from 16 so as to avoid a cartridge lock-out error.

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This may be done as follows:

Copy files to another cartridge:

```
CO,namr::source-cr,dest-cr
```

Purge the file from the source cartridge:

```
PU,namr:sec-code:cr
```

Or if desired instead of purging the file may be renamed by:

```
RN,old-namr:sec-code:cr,new-namr
```

Other useful commands for tape handling are the File Copy (FC) commands:

```
LH,-24 - list tape header
LC,-24 - list comment file
DL,-24 - list all files on tape
```

Selected files on tape may also be transferred to a cartridge using the FC command:

```
CO,-24,namr::cr
```

4.2.8 FMGR-005 ERRORS

These occur when a file has been corrupted, e.g. due to filling up a cartridge (usually file ROTTEN:50:18)

This is remedied by purging the corrupt file and any other unwanted files on the cartridge (do a DL,cr,HP), packing the cartridge, and trying again.

If there is still not enough room, then move files from this cartridge onto another using the procedure file MOVE. This will prompt for the "from" cartridge, security code, the "to" cartridge and the files to move. The user must precede the above answers with a ":", and terminate this procedure file with a ":,/E".

4.2.9 FMGR-019 ERRORS

These occur when running a program or a procedure file.

They are caused because the program involved has not been linked for the current operating system.

It is corrected by re-linking the program under the current operating system. (see the LINK manual)

4.2.10 FMGR-033 ERRORS

No room on cartridge 19.

This is remedied by examining the contents of cartridge 19 using DL,19. If there are only MTnnnn files on CR 19 then either sufficient data for the current site has been acquired, or the previous sites MTnnnn files have not been archived onto tape.

If there are any other files files on CR 19 (e.g.NEWDAT) they should be moved onto either CR 16 or 17, or purged if not wanted.

CR 19 should then be packed prior to restarting any further data acquisition.

4.3 MT UTILITIES

4.3.1 OVERVIEW

There are several utilities used in conjunction with the MT DAS There are procedure files, invoked from FMGR by typing a comma followed by the procedure file name, and programs, invoked with the RU command.

The procedure files are:

ARCH - to archive the system using the HP program called FC
PUDATA - to archive and purge data files from the MT DAS onto tape
STDATA - to restore data files from tape onto disc
PLINK - to relink a specified program for the MT DAS

While the programs are:

PUFT - purges FTnnnn files from the system.
PUMT - purges MTnnnn files from the system.
CHEK - checks the data from a specified channel on a specified MTnnnn file.
FFT - processes MTnnnn files into FTnnnn files.
TENSE - processes FTnnnn files into ROTTEN and/or TIPPER files.
MTPLT - produces plots of apparent resistivity vs. period, phase angle vs. period, and rotation angle vs. period.
SCREE - screens out scattered rotated tensor analysis and phase data.
SCRAV - averages screened data and formats it for 1D inversion.

The processing programs SCREE and SCRAV are described by Moore (1977) and wil not be dealt with in this document.

4.3.2 PUMT AND PUFT

PUMT and PUFT should be used with caution. Data files are not generally purged, but archived onto tape using the PUDATA procedure file. When PUMT or PUFT is run, a start file number and stop file number must be provided as run parameters. These programs will run faster if a cartridge number is specified as a third parameter.
e.g.

RU,PUFT,3,45,20

This will purge files in the range FT0003 to FT0045 from cartridge 20. PUMT and PUFT will display on the VDU the file names as they are purged.

4.3.3 CHEK

Checks the data in an MT file by a graphic display of the signal in a specified channel.
i.e.

```
RU,CHEK,MT0055
```

will check a channel of data on file MT0055. CHEK will open the specified file or terminate with an error if it can not be found on cartridge 19. The file name and its header record are then written on the screen. CHEK can be terminated, by typing EX, or continued by hitting the RETURN key.
e.g.

```
FMGR : RU,CHEK,MT0500
File MT0500 is BROKEN HILL 1984 SITE 14 YANCOWINNA CREEK
********** EX
FMGR:
```

Note that CHEK will clear the screen when run, and that it will not echo the EX typed in.

If it is continued by hitting the RETURN key, CHEK will ask for a channel number (only one channel can be looked at), an offset, and an X and Y scale factor.
e.g.

```
File MT0500 is BROKEN HILL 1984 SITE 14 YANCOWINNA CREEK
**********
Enter Channel:<3> (look at channel 3)
Enter Offset. Default is 1:<100> (start at sample 100)
Enter Y Scale. Default is 20000:<return> (Y scale defaulted)
Enter X Scale factor. Default is 1:<return> (X scale defaulted)
```

A Y scale factor of 20000 is usually adequate for all channels of MT data. A smaller Y scale will cause the displayed data to be magnified in amplitude, useful if the recorded signals are very weak. The X factor will stretch the X scale by the specified factor. A starting point other than the first bit of data may also be specified.

The file name, header, and plot of data is written on the screen which can then be hard-copied using the graph copy key on the terminal.

4.3.4 FFT

FFT is a fast fourier transform program, based upon program FFOUR as described by Spence & Kerr (1982), to process raw MT data files (MTnnnn) into fourier transform files (FTnnnn). FFT should be run under CMND. No indication is given when it stops. When running FFT, a start file number (nnnn) and the number of files to process (mm) must be specified.
e.g.

CMND: RU,FFT,0250,50

This will create files FT0250 to FT0299 from the raw data files MT0250 to MT0299. The original MT data files are retained after this operation.

When processing MT files acquired prior to 1985 the old version of FFT (FFT01) should be used as the structure of the MT file was changed in 1985 to accommodate data collected by the BMR preamplifiers.

4.3.5 TENSE

TENSE is a program which carries out the tensor analysis of the data. It is based on program TENSR as given by Spence & Kerr (1982). TENSE should be run in FMGR. TENSE will indicate on the VDU each FTnnnn file as it accesses it. When running TENSE, a start file number (nnnn), number of files to process (mm), and a processing parameter in octal must be specified.
e.g.

RU,TENSE,nnnn,mm,4540B	Produces rotated tensor analysis with no ROTTEN file produced.
RU,TENSE,nnnn,mm,4050B	Requires an input rotation angle and produces a ROTTEN file.
RU,TENSE,nnnn,mm,4040B	Calculates rotation angles and uses them to produce a ROTTEN file.

4.3.6 MTPLT

MTPLT is a program which produces plots of apparent resistivity (in ohm-m) vs. period (in sec.), phase angle (in degrees) vs. period (sec.), and rotation angle (degrees) vs. period (sec.). It uses a rotated tensor analysis (ROTTEN) file produced by TENSE as its input. TENSE is based on programs MTPLR, MTPLP and MTPLA as given by Moore (1976). The plots are displayed on the VDU and a hard-copy may be obtained using the graph copy key on the terminal. These are examined in the field to assess data quality and later to assist in the screening and averaging of the data. An example of running the program is given below.

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```
FMGR: RU,MTPLT

      OPTIONS: 1 RHO, 2 PHASE, 3 ROTATIONS (-'ve for points)
      1
      OPTIONS: 1 ROUTINE, 2 VARIATIONS
      2
      NPD, TCENTRE, COHLIM(2), SKEWLIM(2)
      10,1,0.7,0.8,1.0,0.5
      ERROR BARS: 0 NONE, 1 ST. DEVIATION, 2 ST. ERROR
      1
      "NAME OF INPUT FILE":
      ROTTEN
```

The above example would produce XY and YX plots of resistivity vs. period with standard deviation error bars. The VARIATIONS option allows the user to input the following, option ROUTINE uses the default values.

NPD	Number of data points per decade (default 10).
TCENTRE	Cutoff (or centre) period (default 10).
COHLIM(2)	Lower and upper coherency limits (default 0.8,0.8).
SKEWLIM(2)	Upper and lower skew limits (default 1,1).

4.4 DEVICE DRIVERS

Three drivers were written for the MT DAS
They are:

- The Phoenix driver - ID$57
- The SPO-1 oscillator driver - ID$70
- The XDM-1 MUX driver - ID$62

4.4.1 ID$57 - PHOENIX A-TO-D CONVERTER DRIVER

ID$57 is the RTE-A.1 interface driver used with the Phoenix 6915 analogue-to-digital converter and a Parallel Interface Card (PIC). It uses self-configuring Direct Memory Access (DMA) and the folowing system entry points:

$SELR - to select the correct map (1 of 32 - system or user)
$DIOC - to return the address of the Interface Table (IFT)
$DMPR - to report DMA parity errors
$IFTX - to return address of current interface extension

Read and Control EXEC request only are allowed. Write requests are rejected with the appropriate error code set.

The following error codes are returned in the A register:

0 - No error
1 - Illegal request (write)
2 - Illegal interupt on DMA
3 - Phoenix timed out

ID$57 uses DMA to read off LU 30, the Phoenix analogue-to-digital converter. It configures the Phoenix to read 5 channels of data (Ex, Ey, Hz, Hx, Hy) with external clocking in a sequential mode (see the Phoenix manual for more details). External clocking of the Phoenix is provided by the SPO-1 Programmable oscillator. ID$57 is used when data acquisition is in progress.

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ID$57 uses the following entry points into the Device Table (DVT).

DVT ENTRY POINT USAGE

ENTRY POINT	UPON ENTRY TO ID$57	UPON EXIT
$DVT15	contains EXEC request to select random/ sequential output & internal/external clock modes for the Phoenix	not used
$DVT16	contains EXEC buffer address	contains error code
$DVT17	contains EXEC buffer length	contains transmission log
$DVT18	contains optional Phoenix start and end channel address in lower and upper bytes respectivly	not used
$DVT19	not used (optional)	contains neg. DMA count

The subfunction in $DVT15 can have the following values:

0B - Puts Phoenix in Random output External clock mode
1B - Puts Phoenix in Sequential output External clock mode
2B - Puts Phoenix in Random output Internal clock mode
3B - Puts Phoenix in Sequential output Internal clock mode

In addition, ID$57 uses the following entry points into the Interface Table (IFT):

$IF5 - pointer to address of active DVT
$IF6 - pointer to IFT status

4.4.2 ID$62 XDM-1 MUX INTERFACE DRIVER

ID$62 handles I/O to the multiplexer on LU 32. NOTE that for historical reasons some wiring has been done back to front on this equipment, so the bit order of the incoming data from the filter switches has to be reversed in this driver

ID$62 is the RTE-A interface driver used with the BMR XDM-1 multiplexer and a Parallel Interface Card (PIC).

It uses the folowing system entry points:

$WRIT - to write 1 word into the users data buffer
$DIOC - to return the address of the Interface Table (IFT)

Read and Control EXEC request only are allowed. Write requests are rejected with the appropriate error code set.

The following error codes are returned in the A register:

0 - No error
1 - Illegal request (write)
2 - Illegal interupt
3 - MUX timed out

ID$62 is invoked by a user EXEC call with the following format :

```
CALL EXEC(1,ICNTWD,IBUFAD,NUMBER,IUNIT)
```

where:

1 - specifies a read
ICNTWD - specifies the MUX LU (32) in the lower 6 bits and the starting channel in the next 4 bits (6 to 9)
IBUFAD - is the buffer address where the driver will put the data read off the specified channels
NUMBER - is an option that specifies the buffer length and hence the number of channels to read. This defaults to 1.
IUNIT - is an option that specifies the unit number of the MUX where several MUX's are chained together. It is not normally used and will default to 0.

ID$62 uses the following entry points into the Device Table (DVT).

DVT ENTRY POINT USAGE

ENTRYPOINT	UPON ENTRY TO ID$62	UPON EXIT
$DVT15	contains EXEC request and subfunction to select starting channel number	not used
$DVT16	contains EXEC buffer address	contains error code
$DVT17	contains EXEC buffer length i.e. number of channel to read (default is 1)	contains transmission log
$DVT18	contains optional selection parameter (default=0)	

In addition, ID$62 uses the following entry points into the Interface Table (IFT):

$IF5 - pointer to address of active DVT
$IF6 - pointer to IFT status

4.4.3 ID$70 SPO-1 PROGRAMMABLE OSCILLATOR DRIVER

ID$70 controls the programmable oscillator. It outputs a function code to LU 31, which determines the oscillator frequency. The FMGR command CN can be used to control LU 31 via ID$70.

```
CN,31,25B,-3     - Starts the oscillator at a frequency
                   corresponding to -3
CN,31            - does a reset
CN,31,25B,-20    - will stop the oscillator
```

ID$70 is the RTE-A interface driver used with the SPO-1 Programable Oscillator and a Parallel Interface Card (PIC).

Control EXEC request only are allowed. Read and write requests are rejected with the appropriate error code set.

The following error codes are returned in the A register:

0 - No error
1 - Illegal request (read or write)
3 - SPO-1 timed out

ID$70 uses the following entry points into the Device Table (DVT).

DVT ENTRY POINT USAGE

ENTRY POINT	UPON ENTRY TO ID$70	UPON EXIT
$DVT15	contains EXEC request code & function	not used
$DVT16	contains frequency selection code	contains error code

The subfunction in $DVT15 can have the following values:

OB - to issue clear request to register 32 (to reset PIC)
25B - to select the frequency defined by parameter 1.

Parameter 1 can have the following octal values :-

11	To select an output frequency of 512	kHz
10	To select an output frequency of 256	kHz
7	To select an output frequency of 128	kHz
6	To select an output frequency of 64	kHz
5	To select an output frequency of 32	kHz
4	To select an output frequency of 16	kHz
3	To select an output frequency of 8	kHz
2	To select an output frequency of 4	kHz
1	To select an output frequency of 2	kHz
0	To select an output frequency of 1	kHz
-1	To select an output frequency of 500	Hz
-2	To select an output frequency of 250	Hz
-3	To select an output frequency of 125	Hz
-4	To select an output frequency of 62.5	Hz
-5	To select an output frequency of 31.25	Hz
-6	To select an output frequency of 15.625	Hz
-7	To select an output frequency of 7.8125	Hz
-10	To select an output frequency of 3.90625	Hz
-11	To select an output frequency of 1.953125	Hz
-12	To select an output frequency of 0.976563	Hz
-13	To select an output frequency of 0.488281	Hz
-14	To select an output frequency of 0.244141	Hz
-15	To select an output frequency of 0.122070	Hz
-16	To select an output frequency of 0.061035	Hz

i.e. the frequency (kHz) = 2^{n} ,where n = the parameter value

e.g. in FMGR - to select an output frequency of 125 Hz, do :

```
CN,31,25B,-3
```

4.5 DATA ACQUISITION SYSTEM SOFTWARE COMPONENTS

The Data Acquisition System (DAS) is controlled by the main control program MAGTL. MAGTL is a FORTRAN program that operates by executing the appropriate program upon receipt of a two character command. It also initialises the status file MTSTAT.

The initialization process is performed by MAGTL executing the program INITL upon receipt of the IN command. This is NOT done automatically. INITL simply sets up the MTANS file with default values.

The program UPDAT must then be run via the UP command to put meaningful site information into the MTANS file, including the switch settings on the amplifiers which are read from the MUX.

The actual data acquisition is performed by the program AQUIR executed via the AQ command. AQUIR creates the specified number of MTnnnn data files, placing the site information from the MTANS file at the head of each file followed by records containing the gain, poles and zeros for each channel as determined by the switch settings in the MTANS file. It also updates the status file MTSTAT.

Various programs exist to monitor the status of the system. CURNT displays the site information contained within the MTANS file. Any incorrect fields can then be corrected using UPDAT. STATS displays the data acquisition status, read from the MTSTAT file. FILES displays the number of files collected in each frequency band.

4.5.1 PROGRAM MAGTL

MAGTL is the main control routine for the MT DAS. It operates by ensuring that the MT status file (MTSTAT::18) exists, and prompts the user for a valid input.

Valid inputs are:-

AQ - Start data AcQuisition
AB - ABort data acquisition immediately
BR - BReak (abort) data acquisition at next file
EN - ENd MAGTL, disable printer if enabled
EX - EXit from MAGTL, printer will remain enabled if enabled
CU - Display CUrrent answer file
FI - Display FIles collected in each frequency band
HE - Display the HElp file
IN - INitialises the MT Answer File to 1's and 0's
RE - Enable the printer for hard copy REports
RX - Disable the printer
ST - Display survey STatus
UP - UPdate the answer file

It then performs the specified command, scheduling the appropriate program where necessary.

4.5.2 PROGRAM INITL

INITL is scheduled by typing IN, it opens the MTANS file and writes out the nine records below with default values for the fields. Some of the defaults are meaningless and thus MTANS must be updated prior to data acquisition using UP.

MTANS file format

Size	Name	
Record 1		
27	site information	- ASCII character string
Record 2		
1	AZIMUTH	- relative to magnetic North
1	ICOIL_SET	- coil set 1 or 2
1	Ex_SEPARATION	- in metres
1	Ey_SEPARATION	- in metres
2	Rx_RESISTANCE	- in ohms
2	Ry_RESISTANCE	- in ohms
2	NEXT_FILE_NO	- No. of next MTnnnn file
1	FREQ_BAND	- No. of freq. band
1	FILES_IN_BAND	- No. of files in each freq. band
1	No_POINTS	- No. of points collected
2	DIG_INTERVAL	- Digital interval in msec
7		- 7 frequency band counts
Record 3		
5	POSTAMP_GAINS(5)	- array 1-5 (Ex,Ey,Hz,Hx,Hy) = gain switch settings (1 to 7)
Record 4		
3	EPRE_FILTERS(3)	- array 1-3 (Ex,Ey,Ez) {Ez unused} = filter settings (not used)
Record 5		
3	EPRE_GAINS(3)	- array 1-3 (Ex,Ey,Ez) {Ez unused} = gain settings (1 to 3)
Record 6		
3	HPRE_FILTERS(3)	- array 1-3 (Hz,Hx,Hy) = filter settings (not used)
Record 7		
3	HPRE_GAINS(3)	- array 1-3 (Hz,Hx,Hy) = gain switch settings (1 to 3)
Record 8		
2	FILTER_PASSES(2)	- array 1-2 (LP filter, HP filter) = filter switch settings (1 to 7)
Record 9		
2	PRE_AMPS(2)	- array 1-2 (E preamps, H preamps) = 1 (old preamps) = 2 (new preamps)

4.5.3 PROGRAM UPDAT

UPDAT allows the user to update the contents of MTANS. MTANS contains data that will be used as input to the data acquisiton routine. Most of the data on this file ends up on the data file header. MTANS can be veiwed quickly using the ST command in MAGTL. UPDAT is scheduled in MAGTL by typing UP.

Fields AZIMUTH,..,NEXT_FILE_No,No_POINTS,DIG_INTERVAL and PRE_AMPS are all prompted for via one of the subroutines READI, READR or READM. The fields FREQ_BAND, POSTAMP_GAINS,...,FILTER_PASSES are taken from the switch positions read off the multiplexer and decoded using the assembler subroutines DECOD or DECID.

4.5.4 SUBROUTINE READI(OLD_DATA)

READI is a subroutine called by program UPDAT to read and update an integer variable.

One integer parameter (OLD_DATA) is passed to this subroutine.

It operates by reading a response from a users terminal into the INTEGER variable called NEW_DATA. READI then checks if NEW_DATA is non-zero, and if so, updates OLD_DATA according to the value in NEW_DATA. If NEW_DATA is negative, OLD_DATA is set to zero; if NEW_DATA is positive, OLD_DATA is set to the value of NEW_DATA.

4.5.5 SUBROUTINE READM(OLD_BUF,LEN)

READM is a subroutine called by program UPDAT to read and update an integer variable.

One integer array (OLD_BUF, of length LEN) is passed to this subroutine.

It operates by reading a response from a users terminal into the INTEGER buffer called NEW_BUF. READM then checks if NEW_BUF is non-zero, and if so, updates OLD_BUF according to the value in NEW_BUF. If NEW_BUF is negative, OLD_BUF is set to zero; if NEW_BUF is positive, OLD_BUF is set to the value of NEW_BUF.

4.5.6 SUBROUTINE READR(OLD_DATA)

READR is a subroutine called by program UPDAT to read and update a real variable.

One real parameter (OLD_DATA) is passed to this subroutine.

It operates by reading a response from a users terminal into the REAL variable called NEW_DATA. READR then checks if NEW_DATA is non-zero, and if so, updates OLD_DATA according to the value in NEW_DATA. If NEW_DATA is negative, OLD_DATA is set to zero; if NEW_DATA is positive, OLD_DATA is set to the value of NEW_DATA.

4.5.7 SUBROUTINE DECID(ICODE,IARRAY)

This subroutine will decode a 16 bit word (ICODE) read off the XDM-1 multiplexer and put values into a 5 word integer array (IARRAY) according to the following scheme:

```
bits 0 to 2 into word 1 of IARRAY    }
 "   3 "  5  "     "   2 "    "       }postamp
 "   6 "  8  "     "   3 "    "       }gain/filter
 "   9 " 11  "     "   4 "    "       }settings
 "  12 " 14  "     "   5 "    "       }
```

Data in the array is all right justified.

FORMAL PARAMETERS:

- ICODE - input data from the MUX
- IARRAY - decoded output

DECID is called as follows :

```
DIMENSION IARRAY(5)
        -
        -
CALL EXEC(1,100032B,ICODE,1)      !  READ FROM MUX
CALL DECID(ICODE,IARRAY)          !  INTO ICODE
```

4.5.8 SUBROUTINE DECODE(ICODE,IARRAY)

This subroutine will decode a 16 bit word (ICODE) read off the XDM-1 multiplexer and put values into a 6 word integer array (IARRAY) according to the following scheme:

```
bits 0 &  1 into word 1 of IARRAY    } E/H preamp
 "   2 "  3  "     "   2 "    "       } gain settings
 "   4 "  5  "     "   3 "    "       }

 "   6 to 8  "     "   4 "    "       } E/H preamp
 "   9 " 11  "     "   5 "    "       } filter settings
 "  12 " 14  "     "   6 "    "       }
```

Data in the array is all right justified.

FORMAL PARAMETERS:

- ICODE - input data from the MUX
- IARRAY - decoded output

DECODE is called as follows :

```
DIMENSION IARRAY(6)
        -
        -
CALL EXEC(1,100032B,ICODE,1)      !  READ FROM MUX
CALL DECODE(ICODE,IARRAY)         !  INTO ICODE
```


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4.5.9 PROGRAM AQUIR

AQUIR is scheduled by MAGTL to collect 5 channels of MT data. The data on each channel is as follows:

```
Channel 1 - Ex Data - induced telluric current in x plane
Channel 2 - Ey Data -    "       "        "     " y   "
Channel 3 - Hz Data - time varying magnetic signal in z plane
Channel 4 - Hx Data -   "     "       "        "    " x   "
Channel 5 - Hy Data -   "     "       "        "    " y   "
```

NOTE: Ez data (in the vertical plane) is not collected.

AQUIR uses 3 files - MTANS::18 (which must already exist); the actual data file (MTnnnn - where nnnn is a unique file number); and MTSTAT, which holds status information.

MTANS contains data that will be used as input to this program. It contains the site information, switch settings etc.

MTnnn has a header record copied directly from the MTANS file, the gains, poles & zeros records for each channel, and the collected data.

MTANS is written to at the beginning and end of each data acquisition.

AQUIR operates in the following manner:-

i) open MTANS - terminate if error.
ii) create MTnnnn - nnnn is NEXT_FILE_No of MTANS.
iii) set up MTnnnn file header using data in MTANS (record 1).
iv) call subroutine GAINS to select poles, zeros & gains.
v) set up status file record & output it to MTSTAT.
vi) write out the above values for 5 channels (records 2 & 3).
vii) start the Phoenix A-to-D Converter, and collect the specified number of files and samples at the given sampling rate.
viii) output status file record when acquisition is completed.

MTHEADR BUFFER FORMAT

Size words	MTHDR offset	Name	MTANS file record
27	1	site information	Record 1
1	28	AZIMUTH	Record 2
1	29	ICOIL_SET	" "
1	30	Ex_SEPARATION	" "
1	31	Ey_SEPARATION	" "
2	32	Rx_RESISTANCE	" "
2	34	Ry_RESISTANCE	" "
2	36	NEXT_FILE_NO	" "
1	37	FREQ_BAND	" "
1	38	FILES_IN BAND	" "
1	39	No. POINTS	" "
1	40	DIG_INTERVAL	" "
7	41	7X frequency band counts	" "
15	48	TIME	" "
5	63	POSTAMP_GAINS(5)	Record 3
3	68	EPRE_FILTERS(3)	Record 4
3	71	EPRE_GAINS(3)	Record 5
3	74	HPRE_FILTERS(3)	Record 6
3	77	HPRE_GAINS(3)	Record 7
2	80	FILTER_PASSES(2)	Record 8
2	82	PRE_AMPS(2)	Record 9

4.5.10 SUBROUTINE GAINS

GAINS is called by AQUIR in MAGTL to select all gains, poles and zeros for the switch settings used and write them to the MTnnnn file.

GAINS is passed the following parameters:

DCB_MT - DCB of MT file that Poles, Zeros, etc. are written to
MTHEADR - Contains passed switch settings from MTANS file

GAINS operates by setting up the filter, poles and zeros for channels 1 to 5 based on the switch settings found in MTHEADR and writing them to the MT file, one record for each channel.

All the poles and zeros data is read from an ASCII data file in list directed format. The option of the use of two sets ('old' Geotronics or 'new' BMR) of preamplifiers is allowed for by having four seperate 'P&Z' files, one for each possible combination of old or new E or H preamps:

P&Z11::17 - old E and H preamps
P&Z21::17 - new E and old H preamps
P&Z12::17 - old E and new H preamps
P&Z22::17 - new E and H preamps

A listing of each of these files is given in Appendix 2.

This feature is only temporary and can be easily removed by only allowing for one data file, i.e. P&Z22 for the new preamps.

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Poles & Zeros record : PoZ_BUF for each channel is written to the MTnnnn file.

POLES & ZEROS FILE FORMAT

PoZ_BUFF offset	Size words	Name	
1	2	GAIN	total gain for this channel
3	2	FUDG_P	gain normalisation for the poles
5	2	FUDG_Z	gain normalisation for the zeros
7	1	NO_P	No. of poles
8	1	NO_Z	No. of zeros
9	1	IDIST	wire length - E channels only
10	1	LX	No. of points
11	2	DELTA	digitising interval - in msec
13	120	POLES(30)	up to 30 poles
133	120	ZEROS(30)	up to 30 zeros

256 total

The above record is copied to the FT file by the FFT program, but is split into two 128 word records.

4.5.11 PROGRAM HELP

The function of program HELP is to display on the system console the contents of the MT Help file called 'MTHLP::18. If HELP cannot locate the MT Help file it will say so. HELP can be scheduled from FMGR or MAGTL by typing HE. Control returns to MAGTL when HELP finishes.

4.5.12 PROGRAM STATS

STATS displays the MT DAS status on the terminal by typing ST. MT survey status records are written onto a file called MTSTAT::18. STATS merely reads this file and writes it out.

STATS also reports on the %full of the data cartridge. It does this by temporarily creating a scratch file on the data cartridge to use all the unused space and then determines what percentage of the total cartridge was used for the scratch file. The scratch file is then purged.

4.5.13 PROGRAM FILES

FILES displays the number of files collected so far in each of the 7 frequency bands collected by the MT DAS by typing FI.

This information is kept on the MT answer file, MTANS, in record 2, words 14 to 20, i.e. 1 word for each channel.

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Geotronics Corporation, Austin, Texas, U.S.A.

APPENDIX 1

HEWLETT PACKARD MANUALS

The following is a list of manuals which relate to the computing equipment as used for the magnetotelluric data acquistion system. The print date shown, edition and update number were current at the time of the system being operational.

Manual Title	Part Number	Printed	Update	Date
Getting Started A-Series Computer	5955-8813	4/82		
Decimal String Arithmetic Routines	02100-90192	10/79		
HP 1000 L-Series Computer I/O Interface	02103-90005	4/82		
HP 1000 A600 Reference Manual	02156-90001	3/82		
HP 1000 A600 Installation & Service	02156-90002	3/82		
HP 2622A/2623A Display Terminals	02622-90008	6/81		
HP 2623A Graphics Terminal	02623-90001	7/81		
HP 12005A Asynchronous Serial Interface	12005-90001	1/80	3	4/82
HP 12006A Parallel Interface Ref. Man.	12005-90001	1/80	2	3/82
HP 12008A PROM Storage Module Ref. Man.	12008-90001	1/80	2	3/82
HP 12009A HP-IB Interface Ref. Man.	12009 90001	1/80	2	9/82
VIS User's Manual	12824-90001	1/83		
DOS/RTE Relocatable Library	24998-90001	10/81		
HP-IB in the HP1000 User's Guide	59310-90064	12/83		
MACRO/1000 Reference Manual	92059-90001	6/83		
Edit 1000 User's Manual	92074-90001	7/82		
RTE-A.1 Installation Instructions	92077-90001	2/82		
RTE-A.1 Operator's Guide	92077-90002	6/83	1	12/83
RTE-A.1 Utilities Manual	92077-90004	6/83	4	12/83
RTE-A.1 General Information	92077-90006	2/82	1	1/83
RTE-A.1 Programmer's Reference Manual	92077-90007	6/83	1	12/83
RTE-A.1 File Management Reference Manual	92077-90008	2/82	1	7/82
RTE-A.1 LINK Relocating Loader Manual	92077-90009	7/82	1	1/83
RTE-A.1 Debug Reference Manual	92077-90010	2/82		
RTE-A.1 Driver Reference Manual	92077-90011	6/83	1	12/83
RTE-A.1 System Design Manual	92077-90013	6/83		
RTE-A.1 Generation Planning Guide	92077-90014	2/82	4	1/83
RTE-A.1 Generator Reference Manual	92077-90016	2/82		
RTE-A.1 Software Installation Guide	92077-90018	2/82	4	1/83
RTE-A.1 Driver Designer's Manual	92077-90019	6/83		
RTE-A.1 Quick Reference Guide	92077-90020	6/83		
RTE-A.1 Generation Req. for Drivers	92077-90021	2/82	1	1/83
RTE-A.1 System Gen. & Installation Man.	92077-90034	8/83	2	12/83
RTE-A.1 LINK User's Manual	92077-90035	6/83		
RTE-A.1 Index & Glossary	92077-90036	6/83		
RTE-A.1 Relocatable Libraries Ref. Man.	92077-90037	12/83		
RTE-A.1 Primary System Software Install.	92077-90038	3/84		
RTE-A.1 FCO Utilty Manual	92077-90048	12/83		
FORTRAN 77 Reference Manual	92836-90001	12/81	1	4/82
Graphics 1000-II Reference Manual	92841-90001	1/83	1	7/83

APPENDIX 2

POLES & ZEROS FILES

FILE P&Z22::17:4

Ex Channel Preamps

```
3 1 0 0   ** Ex channel ** preamps- No poles, No fudgp's, No zeros, No fudgz's
(-70.07,70.07) (-186.605,0.0) (-13.40,0.0)  poles
2.5005E7          fudgp
                  no zeros
                  no fudgz's

(-0.01647,0.004934) (-0.01196,0.01510) 1.09685E-7 postamp LP filter 1
(-0.04528,0.01356)  (-0.0329,0.04156)  6.27717E-6    "     "      "   2
(-0.01647,0.04934)  (-0.1196,0.1511)   1.09777E-3    "     "      "   3
(-0.7547,0.2258)    (-0.5483,0.69248)  0.484135      "     "      "   4
(-3.4298,1.0270)    (-2.4924,3.1481)   206.664       "     "      "   5
(-17.157,5.1359)    (-12.469,15.739)   1.2925E+5     "     "      "   6
(-54.893,16.441)    (-39.868,50.365)   103548E+7     "     "      "   7

(-7.071E-4,0.0)     (-7.071E-4,0.0)    1.0        postamp HP filter 1
(-7.071E-3,0.0)     (-7.071E-3,0.0)    1.0           "     "      "   2
(-2.1214E-3,0.0)    (-2.1214E-3,0.0)   1.0           "     "      "   3
(-7.071E-2,0.0)     (-7.071E-2,0.0)    1.0           "     "      "   4
(-0.3536,0.0)       (-0.3536,0.0)      1.0           "     "      "   5
(-1.7678,0.0)       (-1.7678,0.0)      1.0           "     "      "   6
(-7.07,0.0)         (-7.071,0.0)       1.0           "     "      "   7
(0.0,0.0)           (0.0,0.0)          1.0        postamp HP filter zero
```

Ey Channel Preamps

```
3 1 0 0   ** Ex channel ** preamps- No poles, No fudgp's, No zeros, No fudgz's
(-70.07,70.07) (-186.605,0.0) (-13.40,0.0)  poles
2.5005E7          fudgp
                  no zeros
                  no fudgz's

(-0.01647,0.004934) (-0.01196,0.01510) 1.09685E-7 postamp LP filter 1
(-0.04528,0.01356)  (-0.0329,0.04156)  6.27717E-6    "     "      "   2
(-0.01647,0.04934)  (-0.1196,0.1511)   1.09777E-3    "     "      "   3
(-0.7547,0.2258)    (-0.5483,0.69248)  0.484135      "     "      "   4
(-3.4298,1.0270)    (-2.4924,3.1481)   206.664       "     "      "   5
(-17.157,5.1359)    (-12.469,15.739)   1.2925E+5     "     "      "   6
(-54.893,16.441)    (-39.868,50.365)   103548E+7     "     "      "   7

(-7.071E-4,0.0)     (-7.071E-4,0.0)    1.0        postamp HP filter 1
(-7.071E-3,0.0)     (-7.071E-3,0.0)    1.0           "     "      "   2
(-2.1214E-3,0.0)    (-2.1214E-3,0.0)   1.0           "     "      "   3
(-7.071E-2,0.0)     (-7.071E-2,0.0)    1.0           "     "      "   4
(-0.3536,0.0)       (-0.3536,0.0)      1.0           "     "      "   5
(-1.7678,0.0)       (-1.7678,0.0)      1.0           "     "      "   6
(-7.07,0.0)         (-7.071,0.0)       1.0           "     "      "   7
(0.0,0.0)           (0.0,0.0)          1.0        postamp HP filter zero
```

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Hz Channel Preamps

```
3 1 0 0   ** Ex channel ** preamps- No poles, No fudgp's, No zeros, No fudgz's
(-70.07,70.07) (-186.605,0.0) (-13.40,0.0)  poles
2.5005E7        fudgp
                no zeros
                no fudgz's

(0.5292,0.0) (-11.14,0.0) (176.25,0.0) (-9896.0,0.0) 2.009E7 coil set 1*
(0.5306,0.0) (-11.05,0.0) (179.13,0.0) (-4449.6,0.0) 9.262E6 coil set 2*

(-0.01647,0.004934) (-0.01196,0.01510) 1.09685E-7 postamp LP filter 1
(-0.04528,0.01356)  (-0.0329,0.04156)  6.27717E-6    "    "     "   2
(-0.01647,0.04934)  (-0.1196,0.1511)   1.09777E-3    "    "     "   3
(-0.7547,0.2258)    (-0.5483,0.69248)  0.484135      "    "     "   4
(-3.4298,1.0270)    (-2.4924,3.1481)   206.664       "    "     "   5
(-17.157,5.1359)    (-12.469,15.739)   1.2925E+5     "    "     "   6
(-54.893,16.441)    (-39.868,50.365)   103548E+7     "    "     "   7

(-7.071E-4,0.0)     (-7.071E-4,0.0)    1.0        postamp HP filter 1
(-7.071E-3,0.0)     (-7.071E-3,0.0)    1.0           "    "     "   2
(-2.1214E-3,0.0)    (-2.1214E-3,0.0)   1.0           "    "     "   3
(-7.071E-2,0.0)     (-7.071E-2,0.0)    1.0           "    "     "   4
(-0.3536,0.0)       (-0.3536,0.0)      1.0           "    "     "   5
(-1.7678,0.0)       (-1.7678,0.0)      1.0           "    "     "   6
(-7.07,0.0)         (-7.071,0.0)       1.0           "    "     "   7
(0.0,0.0)           (0.0,0.0)          1.0        postamp HP filter zero
```

Hx Channel Preamps

```
3 1 0 0   ** Ex channel ** preamps- No poles, No fudgp's, No zeros, No fudgz's
(-70.07,70.07) (-186.605,0.0) (-13.40,0.0)  poles
2.5005E7        fudgp
                no zeros
                no fudgz's

(0.5298,0.0) (-11.23,0.0) (182.70,0.0) (-3061.0,0.0) 6.0602E6 coil set 1*
(0.5260,0.0) (-11.26,0.0) (173.70,0.0) (-8541.0,0.0) 1.756E7 coil set 2*

(-0.01647,0.004934) (-0.01196,0.01510) 1.09685E-7 postamp LP filter 1
(-0.04528,0.01356)  (-0.0329,0.04156)  6.27717E-6    "    "     "   2
(-0.01647,0.04934)  (-0.1196,0.1511)   1.09777E-3    "    "     "   3
(-0.7547,0.2258)    (-0.5483,0.69248)  0.484135      "    "     "   4
(-3.4298,1.0270)    (-2.4924,3.1481)   206.664       "    "     "   5
(-17.157,5.1359)    (-12.469,15.739)   1.2925E+5     "    "     "   6
(-54.893,16.441)    (-39.868,50.365)   103548E+7     "    "     "   7

(-7.071E-4,0.0)     (-7.071E-4,0.0)    1.0        postamp HP filter 1
(-7.071E-3,0.0)     (-7.071E-3,0.0)    1.0           "    "     "   2
(-2.1214E-3,0.0)    (-2.1214E-3,0.0)   1.0           "    "     "   3
(-7.071E-2,0.0)     (-7.071E-2,0.0)    1.0           "    "     "   4
(-0.3536,0.0)       (-0.3536,0.0)      1.0           "    "     "   5
(-1.7678,0.0)       (-1.7678,0.0)      1.0           "    "     "   6
(-7.07,0.0)         (-7.071,0.0)       1.0           "    "     "   7
(0.0,0.0)           (0.0,0.0)          1.0        postamp HP filter zero
```

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Hy Channel Preamps

```
3 1 0 0   ** Ex channel ** preamps- No poles, No fudgp's, No zeros, No fudgz's
(-70.07,70.07) (-186.605,0.0) (-13.40,0.0)  poles
2.5005E7        fudgp
                no zeros
                no fudgz's

(0.5464,0.0) (-10.66,0.0) (183.90,0.0) (-9361.0,0.0) 1.935E7 coil set 1*
(0.5431,0.0) (-10.69,0.0) (182.30,0.0) (-7694.0,0.0) 1.581E7 coil set 2*

(-0.01647,0.004934) (-0.01196,0.01510) 1.09685E-7 postamp LP filter 1
(-0.04528,0.01356)  (-0.0329,0.04156)  6.27717E-6    "    "      "   2
(-0.01647,0.04934)  (-0.1196,0.1511)   1.09777E-3    "    "      "   3
(-0.7547,0.2258)    (-0.5483,0.69248)  0.484135      "    "      "   4
(-3.4298,1.0270)    (-2.4924,3.1481)   206.664       "    "      "   5
(-17.157,5.1359)    (-12.469,15.739)   1.2925E+5     "    "      "   6
(-54.893,16.441)    (-39.868,50.365)   103548E+7     "    "      "   7

(-7.071E-4,0.0)     (-7.071E-4,0.0)    1.0        postamp HP filter 1
(-7.071E-3,0.0)     (-7.071E-3,0.0)    1.0           "    "      "   2
(-2.1214E-3,0.0)    (-2.1214E-3,0.0)   1.0           "    "      "   3
(-7.071E-2,0.0)     (-7.071E-2,0.0)    1.0           "    "      "   4
(-0.3536,0.0)       (-0.3536,0.0)      1.0           "    "      "   5
(-1.7678,0.0)       (-1.7678,0.0)      1.0           "    "      "   6
(-7.07,0.0)         (-7.071,0.0)       1.0           "    "      "   7
(0.0,0.0)           (0.0,0.0)          1.0        postamp HP filter zero
```

NOTE: * Denotes that these values will need to be replaced with new poles and fudgp's when new H channel pre-preamps are built.

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APPENDIX 3

MT SYSTEM BOOT FILE

```
FILE BCF01::16:4

0001 EC
0002 $L
0003 EC
0004 *
0005 * DEFINE SYSTEM AND SNAP FILES
0006 SY,'OUTPUT:LA:16
0007 SN,SNAP:LA:16
0008 *
0009 MC,18
0010 MC,17
0011 MC,19
0012 MC,20
0013 MC,16
0014 *
0015 * DEFINE INITIALLY RP'ED PROGRAMS
0016 RP,D.RTR
0017 *
0018 RP,COMND
0019 *
0020 RP,FMGR
0021 ST,WE,LC,OM
0022 *
0023 * LINK EDIT TO ALLOW EDITING SYSTEM FILE
0024 *
0025 LK,EDIT
0026 *
0027 LK,FC
0028 *
0029 LK,LINK
0030 RP,HELP
0031 RP,CURNT
0032 RP,UPDAT
0033 RP,FILES
0034 RP,STATS
0035 RP,AQUIR
0036 RP,INITL
0037 RP,PUFT
0038 RP,FFT
0039 RP,TENSE
0040 RP,MTPLT
0041 RP,CHEK
0042 RP,MAGTL
0043 *
0044 * END RP/LK PHASE
0045 END
0046 *
0047 DEFINE SWAP FILES
0048 SW,SWAP:SW:-18
0049 *
0050 END
```

APPENDIX 4

SYSTEM BOOT FILE

```
FILE SYSTEM::16:4


0001 * EC
0002 *
0003 * DEFINE SYSTEM AND SNAP FILES
0004 SY,PRMSYS
0005 SN,SNAP
0006 *
0007 MC,18
0008 MC,17
0009 MC,16
0010 *
0011 * DEFINE INITIALLY RP'ED PROGRAMS
0012 RP,D.RTR
0013 *
0014 RP,COMND
0015 *
0016 RP,FMGR
0017 ST,WE,LC,OM
0018 *
0019 * LINK EDIT TO ALLOW EDITING SYSTEM FILE
0020 *
0021 LK,EDIT
0022 *
0023 LK,LINK
0024 *
0025 * END RP/LK PHASE
0026 END
0027 *
0028 DEFINE SWAP FILES
0029 SW,SWAP:SW:-18
0030 *
0031 END
```

APPENDIX 5

LOGICAL UNIT (LU) TABLE

LU	DEVICE
16	7908A Disc cartridge 16
17	7908A Disc cartridge 17
18	7908A Disc cartridge 18
19	7908A Disc cartridge 19
20	7908A Disc cartridge 20
24	7908A Tape drive
30	Phoenix A-to-D converter
31	SPO-1 Programmable oscillator
32	XDM-1 Multiplexer

FIG.1 MT SYSTEM BLOCK DIAGRAM

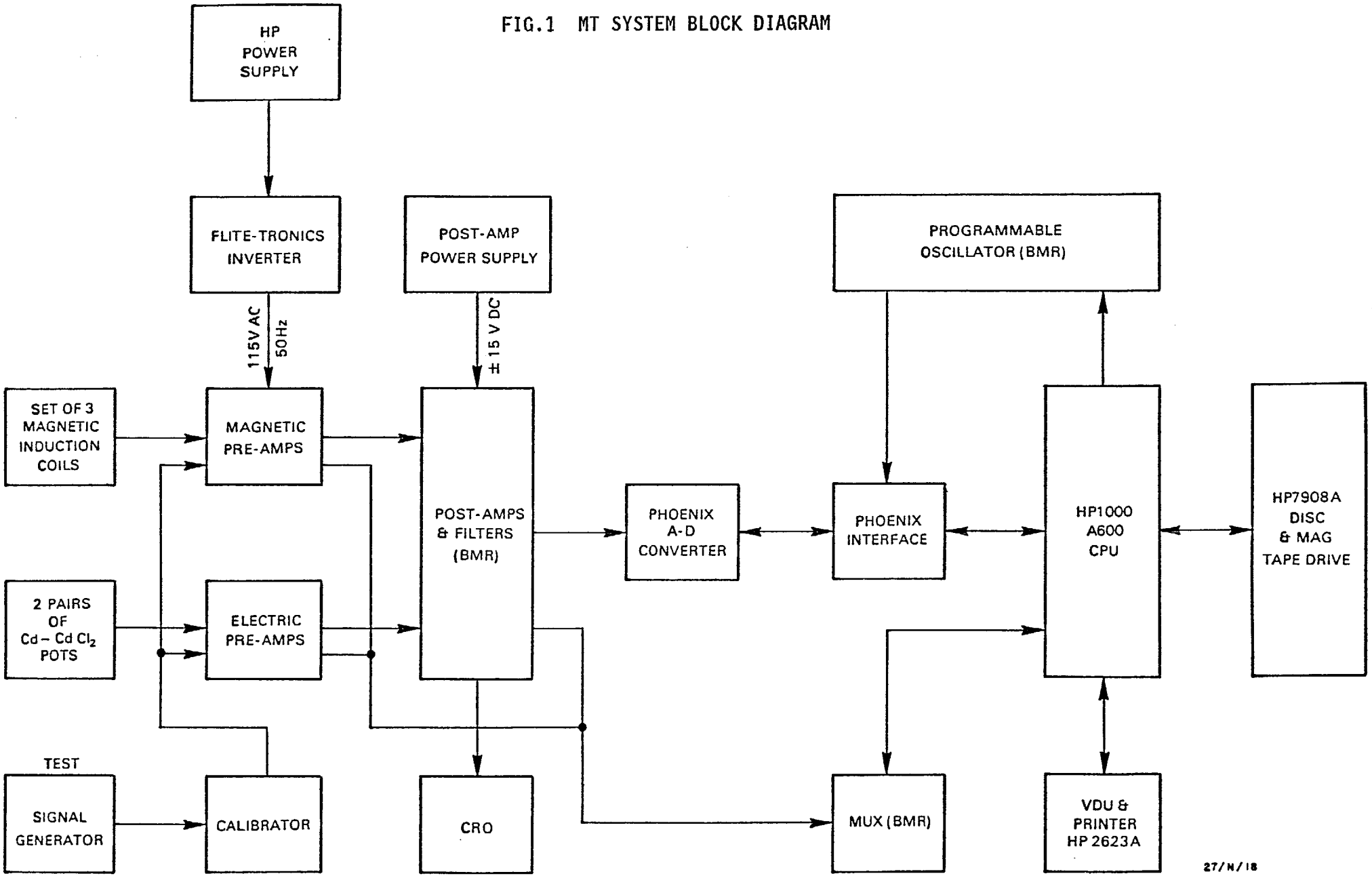
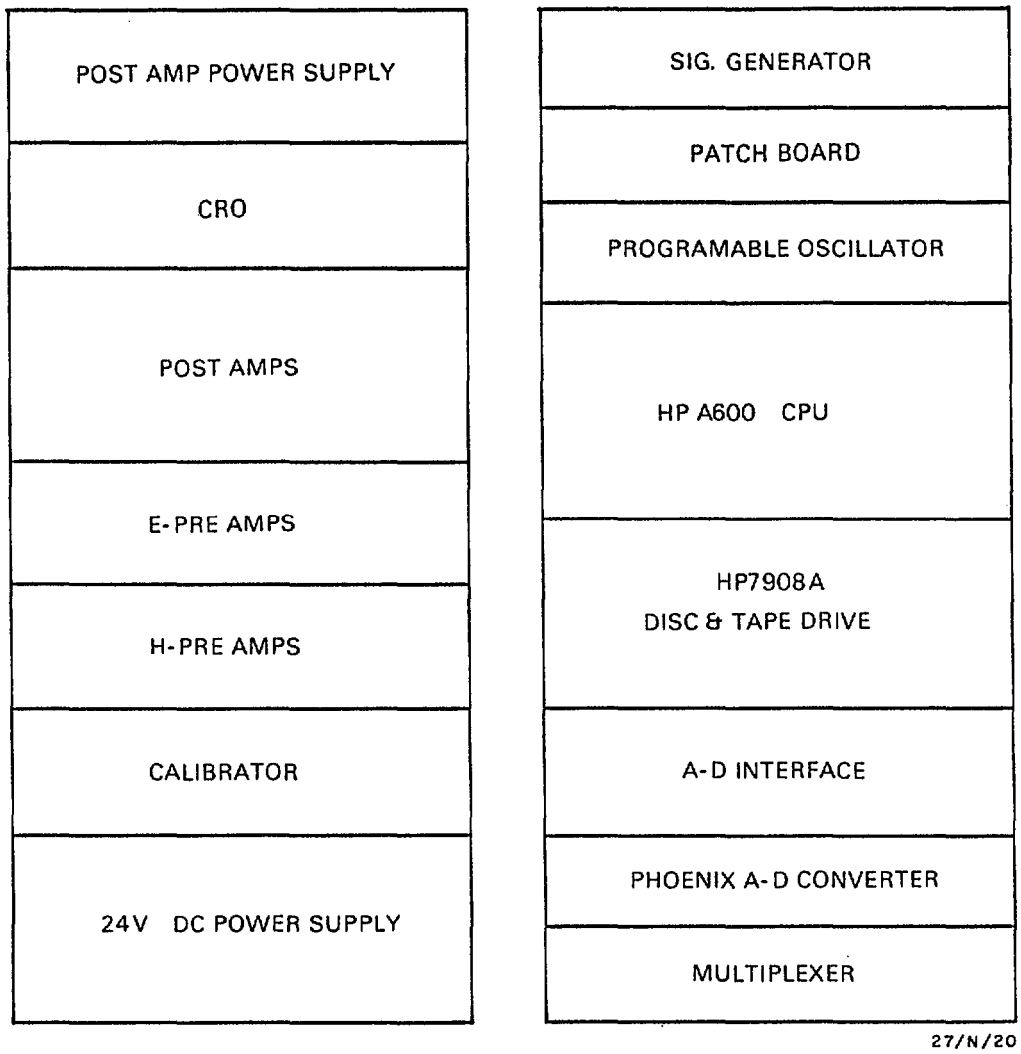


FIG.1 KEY

Magnetic induction coils	: Geotronics model MTC-4SS
Cd-$CdCl_2$ pots	: Geotronics model MTE-2
Signal generator	: Hewlett Packard model 3300A
Magnetic Preamplifiers	: Geotronics model MTH-4
Electric Preamplifiers	: Geotronics model MTE-4
Calibrator	: Geotronics model MTE-4
Postamplifier power supply	: BMR construction
Postamplifiers and filters	: BMR design and construction
CRO	: Tektronix model 5113
Phoenix A-to-D converter	: Phoenix model 6915-3754
Phoenix interface	: Phoenix model PDI Std. Interface
Programmable oscillator	: BMR design and construction
HP 1000 A600 CPU	: Hewlett Packard model A600
VDU and printer	: Hewlett Packard model 2623A
Disc and mag. tape drive	: Hewlett Packard model 7908A

FIG.2 MT SYSTEM RACK POSITIONS



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