11. CONTROLLED-SOURCE AUDIO-FREQUENCY MAGNETOTELLURICS

11.1   INTRODUCTION

Controlled Source Audio-frequency Magnetotellurics or CSAMT is an enhanced frequency domain EM program using synchronous stacking and averaging, and Fourier integral methods to improve the signal to noise ratio.

The standard frequency range of the CSAMT program is 0.015625 (1/64) to 8192 Hz.

Both electric (Ex, Ey, Ez) field measurements and magnetic (Hx, Hy, Hz) field measurements are utilized with this method. A calibrate buffer is provided for the magnetic antenna calibrates, and is labeled **Antenna Cal** in the calibrate buffer area. The standard system calibrate buffer is labeled **Freq Domain Cal**.

The program has a digital telluric filter, which we call a moving average or MAV filter, for rejection of low frequency tellurics. This filter is installed for frequencies from 0.015625 (1/64) to 1.0 Hz.

This manual is written in generic form for 16 channels. If your receiver has less than 16 channels, only information for the number of channels contained will be displayed.

Go to *Section 6* for information concerning calibration, synchronization and generic operation of all programs.

Go to the end of this *CSAMT program manual* for suggestions on connecting the receiver for field measurements.

11.2   FIXED FUNCTION KEYS

One of the differences between the GDP-32^{II} and its predecessor, the GDP-32, is the addition of six fixed function keys located below the six soft function keys (**F1** through **F6**) at the bottom edge of the LCD.

These keys are activated with the same menus as before, and are denoted as follows, from left to right:

DATA F7   By pressing this key you enter the field data cache and can view data, escape back to other menus to initialize or view other data caches, or output data to a PC from the data caches. See ***DATA Section 7*** for more details.

EXIT F8   Exit the data taking routine and return to the main menu for selection of other programs by pressing **F2**. When exiting the program at this point, the main menu will display **Back** above the **F2** function key to enable the operator to return to the **CSAMT** program, if desired.

CAL F9   Press this key to enter the calibrate and system checking program. See ***GDP Section 6.1, Calibration*** for more details.

GAIN F10   Press this key to enter the automatic or manual gain setting and SP buckout menu.

*Note: The CSAMT program does not automatically enable the front-end gain stage (G0). For the best results in weak signal environments enable the receiver to use G0. The receiver will do it automatically if Option 7 of the **GAIN** program is used.*

SP F11   Pressing this key will automatically buck out any self potential (SP) or amplifier offset, for any channel that is turned on.
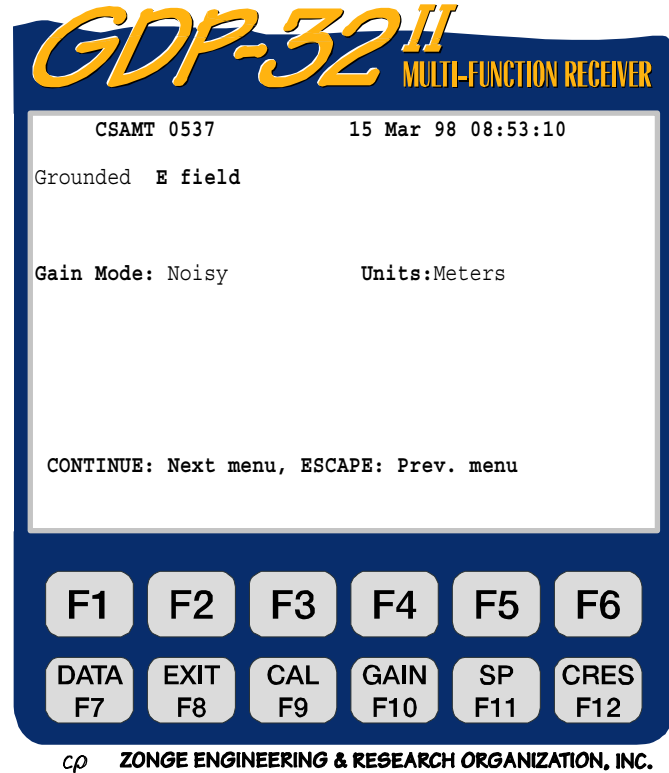
CRES F12   Press this key to measure the contact resistance or coil output resistance. See ***GDP Section 6.3, Measuring Contact Resistance*** for more details.

11.3 CSAMT PROGRAM OPERATION

MENU 1:

In all of the following menu descriptions, the **bold fields** in the boxes are the parameters that can be changed by the operator.

```
   CSAMT 0537              15 Mar 98 08:53:10

Grounded   E field



Gain Mode: Noisy           Units:Meters




CONTINUE: Next menu, ESCAPE: Prev. menu
```

GDP-32^{II} MULTI-FUNCTION RECEIVER

F1	F2	F3	F4	F5	F6
DATA F7	EXIT F8	CAL F9	GAIN F10	SP F11	CRES F12

$c\rho$ ZONGE ENGINEERING & RESEARCH ORGANIZATION, INC.

The **DATA F7** key is active.

CSAMT 0537.   Program name and version.

15 Mar 98.   Date.

08:53:10.   Time.

Grounded.   There are two choices for Electric field sensors:

  Grounded   **AMT**
  Insulated   **ISL**

The grounded configuration is the standard option, while the insulated configuration is included with this program as a research tool. Our field testing to date indicates that E-field magnitudes measured with the insulated dipole are one-half the values measured with a grounded dipole.

When the insulated dipole option is selected, the E-field values are adjusted by a factor of two to make the resistivities identical between the two methods.

Gain Mode.   The default mode is "**Noisy**", which limits the gains to obtain a maximum voltage of 1.0 Volts, leaving sufficient voltage range for SP drift and random noise spikes. The other option is "**Standard**", which adjusts the gains for a maximum voltage of 3.0 Volts. *See Section 6.*

Units.   The operator can select meters or feet. The default is meters.

MENU 2:


```
        CSAMT 0537          15 Mar 98 08:53:40

OPER JOHN.DOE  TX ID Z-30  A-SP    100
JOB 94007 LINE AJO ROAD N  SPREAD  1







CONTINUE: Next menu, ESCAPE: Prev. menu
```
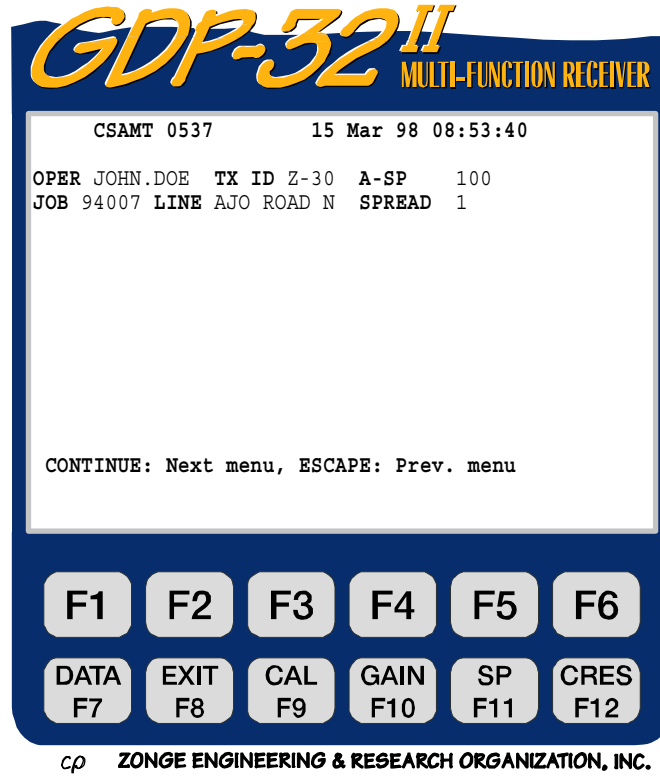
The **DATA F7** key is active.

OPER. User defined identification. Alphanumerics permitted.

TX ID. User defined identification. Alphanumerics permitted.

A-SP. E-field dipole size in meters (a-spacing). E-field dipoles can be of different sizes - see Menu 3 below.

JOB. User defined identification. Alphanumerics permitted.

LINE. Two fields available: **xxxxxxxx** defines the line number and **N, E, S, W, NE, SE, SW, NW** designators are available by using the **SELECT UP** Home and **SELECT DN** End keys. Alphanumerics are permitted for the line number field.
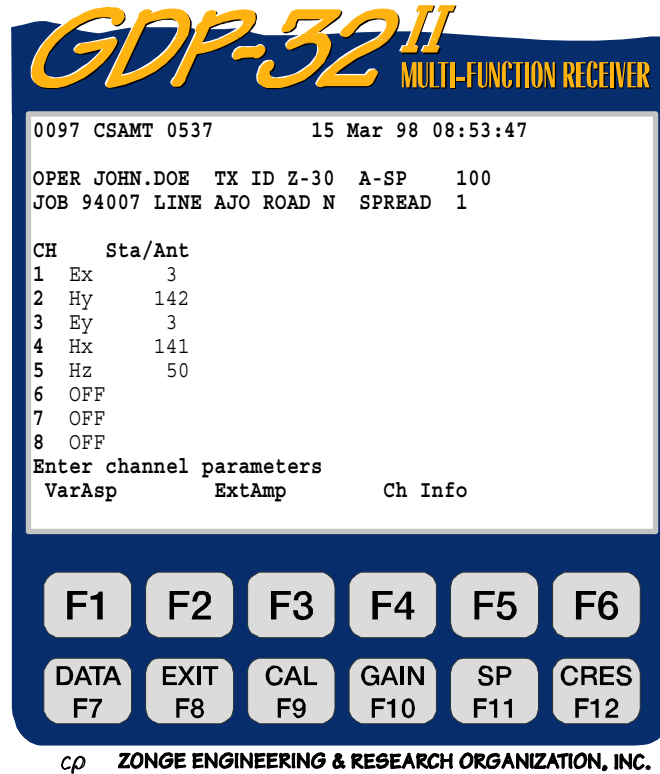
SPREAD. User defined identification, a subdivision of the **LINE** designator above. Alphanumerics are permitted.

MENU 3:

The following example is for a single station vector setup - two E-fields and three H-fields.

The <kbd>DATA F7</kbd> function key is active.

> **CH.** Any channel designator other than **OFF** will turn the channel **ON**.
>
> > **Ex, Ey, Ez** - Electric field designators
> >
> > **Hx, Hy, Hz** - Magnetic field designators
> >
> > *NOTE: For computing the Cagniard resistivity from the E and H fields, the program matches orthogonal pairs of fields. For this example Channels 1 and 2 will be used to calculate RHOxy and channels 3 and 4 will be used to calculate RHOyx. Data for Hz are acquired and put into the data cache without any calculations being done on the value, other than removal of calibrates.*

> **Sta/Ant.** Dual usage field:
>
> 1. H-field designator: Identifies the magnetic field antenna used for that channel. The number in this field must have an exact matching number in the antenna calibrate cache.
>
> 2. E-field designator: Identifies the station number for multiple E-field measurements.

Antenna Data

NNNC **NNN** is the antenna designator or serial number. **C** is the channel number or antenna type. For example:

141 Two channel ANT/2, serial number 14, using channel 1 of two channels.

142 Two channel ANT/2, serial number 14, using channel 2 of two channels.

50 Single channel ANT/1, serial number 5. 0 indicates single channel.

500 Single channel ANT/1, serial number 50.

189 Single channel TEM/3, serial number 18.

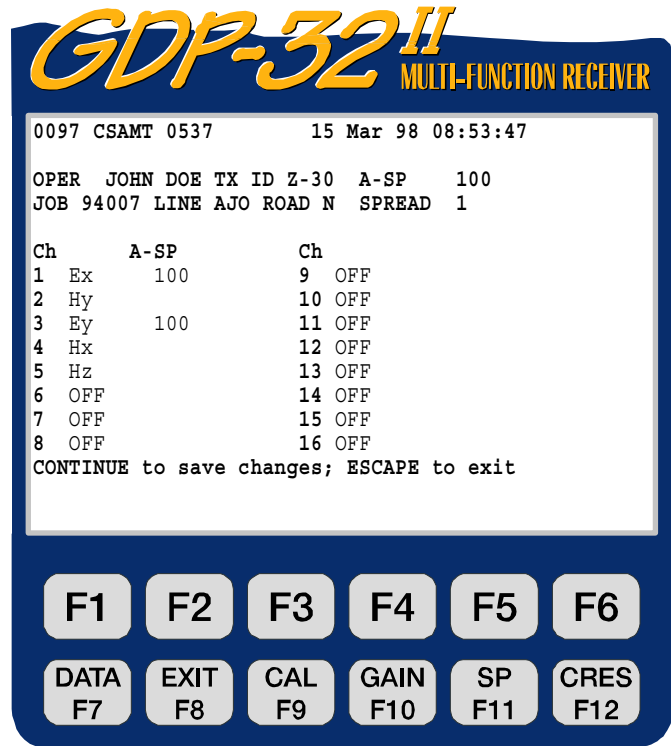**144** MT/AMT antenna, serial number 14.

Notice that the H-field antenna designator is offset by one space to the right when compared to the E-field designators. This has been done to easily differentiate between the two types of numbers. When the STA field is used with the E-field designators, the value is not used in any calculations. However, we use this field to indicate the station number for multiple E-field measurements. See ***Section 11.7, Restrictions*** for more information.

At this point, pressing the soft function keys in Menu 3 will result in the following:

VarAsp. Pressing [F1] will put the operator in the variable A-spacing input routine as shown below. The default A-spacings are set to the values entered in Menu 2 (100 meters):

MENU 3A

ExtAmp. Pressing [F3] enables input for preamplifier gains, such as the SC-8 Signal Conditioning box. In this example we have set all E- and H-field channels to a gain of 1.

```
0097 CSAMT 0537         15 Mar 98 08:53:47

OPER  JOHN DOE TX ID Z-30  A-SP    100
JOB 94007 LINE AJO ROAD N  SPREAD  1

Ch      A-SP        Ch
1  Ex    100        9  OFF
2  Hy               10 OFF
3  Ey    100        11 OFF
4  Hx               12 OFF
5  Hz               13 OFF
6  OFF              14 OFF
7  OFF              15 OFF
8  OFF              16 OFF
CONTINUE to save changes; ESCAPE to exit
```

GDP-32 II MULTI-FUNCTION RECEIVER

F1	F2	F3	F4	F5	F6
DATA F7	EXIT F8	CAL F9	GAIN F10	SP F11	CRES F12

cρ ZONGE ENGINEERING & RESEARCH ORGANIZATION, INC.

MENU 3B

```
0097 CSAMT 0537        15 Mar 98 08:53:47

OPER  JOHN DOE TX ID Z-30  A-SP    100
JOB 94007 LINE AJO ROAD N  SPREAD  1

Ch   External Amp     Ch   External Amp
1  Ex       1         9  OFF
2  Hy       1         10 OFF
3  Ey       1         11 OFF
4  Hx       1         12 OFF
5  Hz       1         13 OFF
6  OFF                14 OFF
7  OFF                15 OFF
8  OFF                16 OFF
CONTINUE to save changes; ESCAPE to exit
```

F1	F2	F3	F4	F5	F6
DATA F7	EXIT F8	CAL F9	GAIN F10	SP F11	CRES F12

cρ **ZONGE ENGINEERING & RESEARCH ORGANIZATION, INC.**

Ch Info. By pressing [F5], you can access data on the analog cards that are installed. For example:

1 DiffAmp Notch+60,3-5,9 S/N   67 Passed
2 DiffAmp Notch+60,3-5,9 S/N 127 Passed
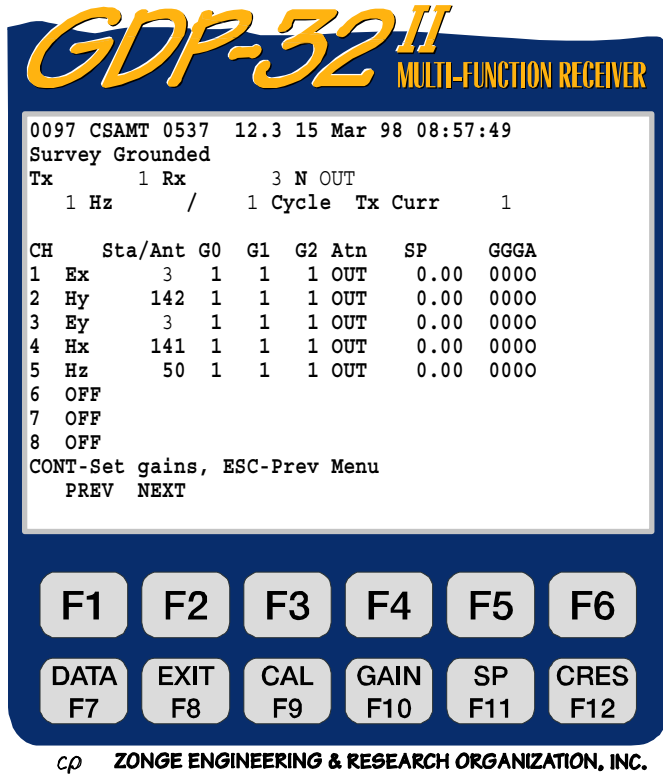**3 DiffAmp Notch+60,3-5,9 S/N 256 Passed**
                    Etc.

Here **DiffAmp** indicates the input plug-in card is a differential amplifier, the powerline notch filter is a 60/180/300/540 Hz filter, (the "+" indicates a modification level), the three board serial numbers are 67, 127, and 256.

Note that a number (**0097**) is visible before the program designator (**CSAMT 0537**). This number is the label of the last data block written to the data cache. The next time a block of data is written to the cache, it will be numbered **0098**.

MENU 4:

Upon pressing [CONTINUE / Enter] after the parameters are set up in Menu 3, the following screen will be displayed. This is a combination of Menu 3 and Menu 4.

```
0097 CSAMT 0537  12.3 15 Mar 98 08:57:49
Survey Grounded
Tx        1 Rx        3 N OUT
   1 Hz      /     1 Cycle  Tx Curr    1

CH    Sta/Ant G0  G1  G2 Atn   SP    GGGA
1  Ex      3   1   1   1 OUT   0.00  0000
2  Hy    142   1   1   1 OUT   0.00  0000
3  Ey      3   1   1   1 OUT   0.00  0000
4  Hx    141   1   1   1 OUT   0.00  0000
5  Hz     50   1   1   1 OUT   0.00  0000
6  OFF
7  OFF
8  OFF
CONT-Set gains, ESC-Prev Menu
   PREV  NEXT
```

← We have selected Grounded E-field array

Soft function keys [F1] and [F2] are active.

PREV/NEXT   Pressing [F1] and [F2] will permit the operator to scroll the channel parameters up and down, so that all 16 channels can be accessed. These labels will not be displayed if the receiver has 8 channels or less.
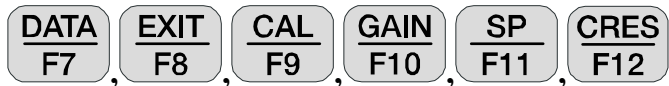
All function keys are active: [DATA F7], [EXIT F8], [CAL F9], [GAIN F10], [SP F11], [CRES F12].

Tx.   Transmitter designator. Normally only changed when you have more than one transmitter location per line or survey. The field for Tx designation is **±NNNNNNN**.

Rx.   Receiver location. For multiple E-field surveys, we normally set Rx equal to the station location at which the receiver is set up. In this example, we are only occupying a single station, so the station number (**Sta**) and **Rx** are the same. The field for Rx designation is **±NNNNNNN**.

N.   Powerline notch filter switch. You have several possible selections here, depending upon the configuration of your receiver. For this example, we have two options.

Use [SELECT UP / Home] or [SELECT DN / End] to change.

OUT - All notch filters bypassed.

60 - 60 and 180 Hz notch filters enabled.

60,5 - 60, 180, 300 and 540 Hz notch filters enabled.

Other standard selections are:

50 - 50 and 150 Hz notch filters enabled.

50,5 - 50, 150, 250 and 450 Hz notch filters enabled.

50/60 - 50, 150, 60 and 180 Hz notch filters enabled

Hz. Frequency selection - use [SELECT UP / Home] or [SELECT DN / End] to change.

Cycle. Specify the number of cycles to average. Increments are in binary steps from 1 to 16,384. Use [SELECT UP / Home] or [SELECT DN / End] to change. As the system acquires data, the cycle count will be updated in real-time to the left of the number input by the operator.

Tx Curr. Transmitter current in amperes.

Sta/Ant. The **Sta**(tion) field (station numbers for individual E-fields) can be changed in Menu 4, but the **Ant**(enna) numbers are accessible only in Menu 3. In Menu 4, the cursor will skip over any channels labeled with an H-field designator.

NOTE: Our standard data processing programs sort first on station number, second on Rx and third on Tx. To ensure proper sorting in data processing the operator must make sure the station numbers are entered properly.

G0, G1, G2. Gain stages 0, 1 and 2. In this example, all gain stages are set to unity gain by default. Upon pressing [CONTINUE / Enter], the program will automatically set the gains and SP buckout if the auto-gain mode is selected as denoted by the message at the bottom of the screen: **CONT-Set gains, ESCAPE-Prev menu**. (This is the default mode).

Atn. The attenuator is bypassed (set to **OUT**). The other option is **IN**.

SP. Self Potential or offset in millivolts. Initially set to 0.00. Will be set to the actual value upon pressing [CONTINUE / Enter].

GGGA. Gain settings for stages 0, 1 and 2 (in powers of 2). The attenuator setting is **A**, **I** for **IN**, **O** for **OUT**.

NOTE: Some values are not registered in the computer memory until you exit the parameter field by pressing [PREV FIELD / Pg Up], [NEXT FIELD / Pg Dn], or [CONTINUE / Enter]. Exceptions to this rule are the Hz (frequency) field and powerline notch filters. Whenever you change the frequency it is automatically changed through the timing card. However, the anti-alias filter is not changed until just prior to data acquisition. Upon pressing continue to gather data or set gains, the computer will automatically set the anti-alias filter as defined by internal look-up tables.

Notice also that the battery voltage (12.3) has now been inserted between the program version number and the date.

11.4 GATHERING DATA

Upon pressing [CONTINUE Enter] after the parameters are set up in Menu 4 the following screen display is an example of what you will see with a signal connected to channels 1 through 5. The battery voltage is measured and the A/D converter is automatically calibrated before each measurement cycle.

For this example we have set the frequency to 1 Hz, and the number of cycles to acquire to 4. The signal source is an LDT/10 Laboratory Transmitter with an RC network as a load.
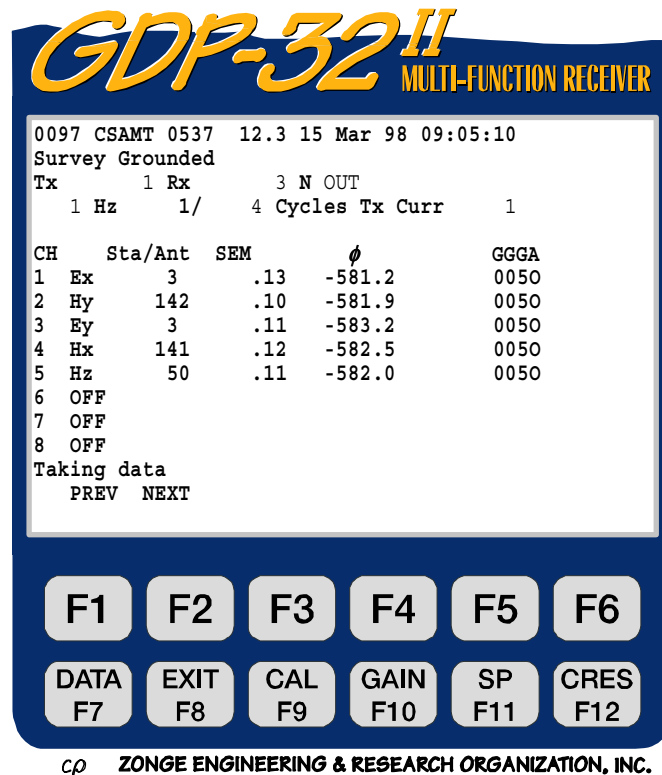
The program will first set up the gains, buck out the SP automatically, calibrate the A/D converters, and then gather data. Since we are operating in the default "noisy" gain mode, all of the necessary gain is put into G2 first. (See Section 6, Setting Gains, for additional information).

If you want to pause between gain setting and data gathering, push [STOP AVG Escape].

The program will acquire four cycles of data for all enabled channels (unless the [STOP AVG Escape] key is pressed before completion) and the results will look similar to the following for real-time displays (while data are being acquired).

```
GDP-32 II MULTI-FUNCTION RECEIVER

0097 CSAMT 0537  12.3 15 Mar 98 09:05:10
Survey Grounded
Tx       1 Rx       3 N OUT
   1 Hz     1/    4 Cycles Tx Curr    1

CH    Sta/Ant  SEM       φ        GGGA
1  Ex      3      .13   -581.2    005O
2  Hy    142      .10   -581.9    005O
3  Ey      3      .11   -583.2    005O
4  Hx    141      .12   -582.5    005O
5  Hz     50      .11   -582.0    005O
6  OFF
7  OFF
8  OFF
Taking data
   PREV  NEXT
```

F1	F2	F3	F4	F5	F6
DATA F7	EXIT F8	CAL F9	GAIN F10	SP F11	CRES F12

$c\rho$ ZONGE ENGINEERING & RESEARCH ORGANIZATION, INC.

SEM.   Standard error of the mean, in milliradians, calculated after each cycle, or burst of cycles, based on the averaged phase.

ϕ **.**   Average Phase in milliradians without the machine calibrations removed.

After the selected number of cycles have been acquired (or

STOP AVG
Escape

 is pressed), the final display will be one of the following:

Display "A"


```
0097 CSAMT 0537   12.3 15 Mar 98 09:11:15
Survey Grounded
Tx        1 Rx         3 N OUT
   1 Hz      4/     4 Cycles Tx Curr      1

CH    Sta/Ant    MAG        φ      SEM  GGGA
1  Ex       3   675.4u  -256.7    .13 005O
2  Hy     142   124.8u -1789.6    .10 005O
3  Ey       3   702.2u  -179.4    .11 005O
4  Hx     141   223.9u -1838.9    .12 005O
5  Hz      50   154.4u -1849.6    .11 005O
6 OFF
7 OFF
8 OFF
CONTINUE to save, RESET to discard
    PREV  NEXT                   RHO
```
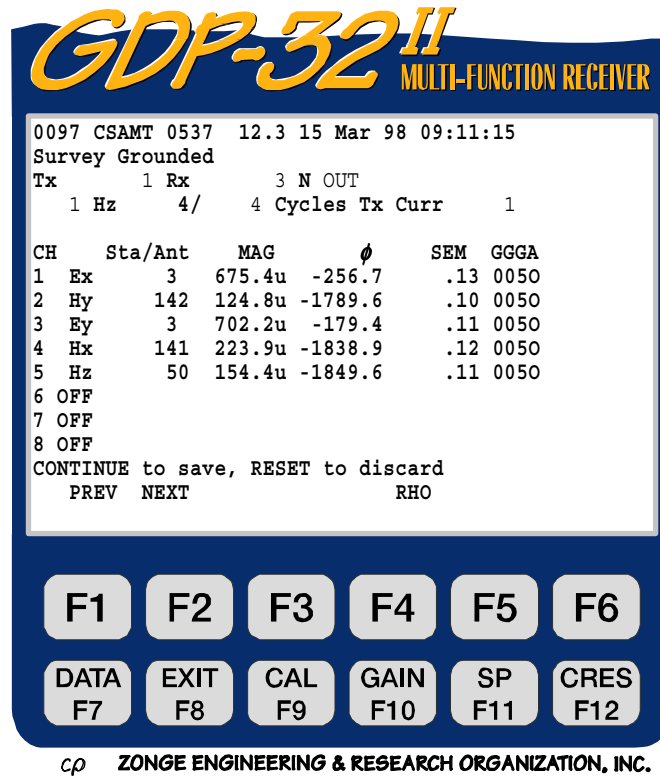
F1	F2	F3	F4	F5	F6
DATA F7	EXIT F8	CAL F9	GAIN F10	SP F11	CRES F12

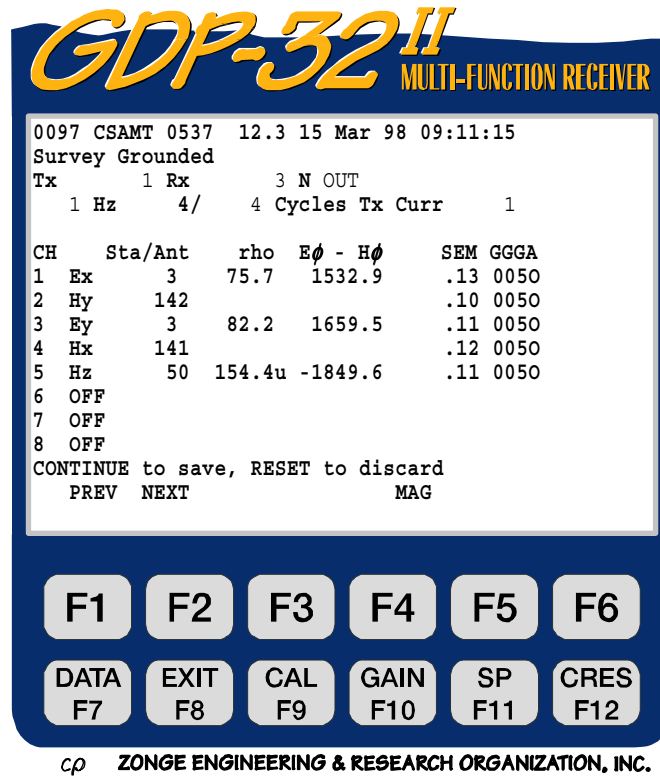*cρ* **ZONGE ENGINEERING & RESEARCH ORGANIZATION, INC.**

MAG. The decalibrated magnitude in volts for each E-field or kilogammas for each H-field component measured.

ϕ. The decalibrated phase for each E- or H-field component measured.

By pressing F5 (under the **RHO** label), the following is displayed:

Display "B"

```
0097 CSAMT 0537   12.3 15 Mar 98 09:11:15
Survey Grounded
Tx        1 Rx        3 N OUT
   1 Hz      4/     4 Cycles Tx Curr     1

CH    Sta/Ant    rho  Eφ - Hφ     SEM GGGA
1  Ex       3    75.7    1532.9    .13 005O
2  Hy     142                      .10 005O
3  Ey       3    82.2    1659.5    .11 005O
4  Hx     141                      .12 005O
5  Hz      50  154.4u -1849.6      .11 005O
6  OFF
7  OFF
8  OFF
CONTINUE to save, RESET to discard
   PREV  NEXT                 MAG
```

F1 F2 F3 F4 F5 F6

DATA F7 EXIT F8 CAL F9 GAIN F10 SP F11 CRES F12

cρ **ZONGE ENGINEERING & RESEARCH ORGANIZATION, INC.**

rho. This column displays the apparent resistivity in ohm-meters for each channel defined as an E-field channel (Ex, Ey) that has a matching orthogonal H-field channel (Hy, Hx). If the E- or H-field being measured on a particular channel does not have a corresponding orthogonal component (such as Hz, or Ex without a corresponding Hy), the value displayed will be the magnitude of the received signal in volts with the magnitude calibrates in **Freq Domain Cal** removed. For channels defined as H-field inputs, (Hx, Hy, Hz), the coil magnitude calibrates in **Antenna Cal** are also removed.

Eφ-Hφ. This column displays the phase difference in milliradians for each channel defined as an E-field channel (Ex, Ey) that has a matching orthogonal H-field channel (Hy, Hx). If the E- or H-field being measured on a particular channel does not have a corresponding orthogonal component (such as Hz, or Ex without a corresponding Hy), the value displayed will be the phase of the received signal in milliradians with the phase calibrates in **Freq Domain Cal** removed. For channels defined as H-field inputs, (Hx, Hy, Hz), the coil phase calibrates in **Antenna Cal** are also removed.

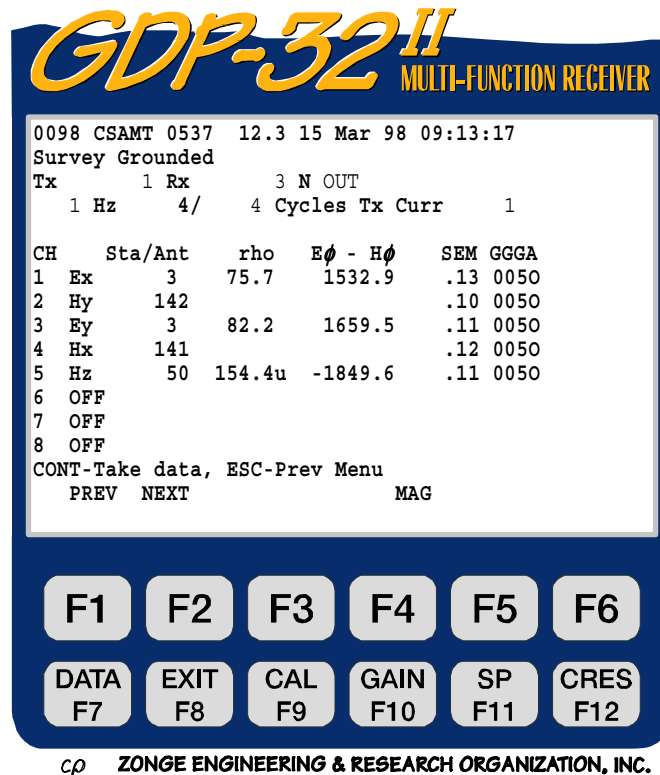By pressing F5 again (now under the **MAG** label) the operator will recall **Display A**. In whichever position the display is left, it will remain in that position for subsequent data acquisition, until changed again by the operator.

NOTE: *The data format is changed when the data are placed in the data cache. To obtain E - H phase for measurements which use more than one E-field for each H-field, you must manually subtract the H-field phase from the appropriate E-field phase. (This is done automatically in our data processing software). Apparent resistivities are calculated and saved on the E-field lines, and the phase difference between the H-field and the nearest orthogonal E-field is calculated and placed on the H-field line in the cache, as shown on the following page.*

NOTE: *The calibrations for both magnitude and phase are removed from the final displayed magnitudes and phases for all channels that are defined for H-field input, as long as a valid calibrate exists in the calibrate cache for the antenna defined in the* `Sta/Ant` *column. Therefore, you may notice large magnitude and phase differences between E-field and H-field channels when making system checks that use the same source for each channel. This difference in magnitude should also be kept in mind when observing received signal levels for field data. The magnitudes of the H-field channels have been normalized by the coil response. This means that the signal levels coming into the receiver are different than those being displayed in the data cache -- the difference being the antenna calibration factor.*

Upon pressing **CONTINUE / Enter** to save the data (or **STOP AVG / Escape** to discard the data), the screen will appear as follows, with the only difference in screens being the new block number (`0098`) and the bottom command line.

```
0098 CSAMT 0537   12.3 15 Mar 98 09:13:17
Survey Grounded
Tx        1 Rx        3 N OUT
    1 Hz     4/     4 Cycles Tx Curr      1

CH    Sta/Ant    rho     Eφ - Hφ    SEM GGGA
1   Ex      3    75.7     1532.9    .13 005O
2   Hy    142                       .10 005O
3   Ey      3    82.2     1659.5    .11 005O
4   Hx    141                       .12 005O
5   Hz     50  154.4u  -1849.6      .11 005O
6   OFF
7   OFF
8   OFF
CONT-Take data, ESC-Prev Menu
   PREV   NEXT                   MAG
```

F1	F2	F3	F4	F5	F6
DATA F7	EXIT F8	CAL F9	GAIN F10	SP F11	CRES F12

cρ   **ZONGE ENGINEERING & RESEARCH ORGANIZATION, INC.**

If you want to view the stored data, press the [DATA F7] key. It will display the last stack taken. See **Section 7.2, Viewing Data** for an explanation of the data mode. The data display is in the following format:
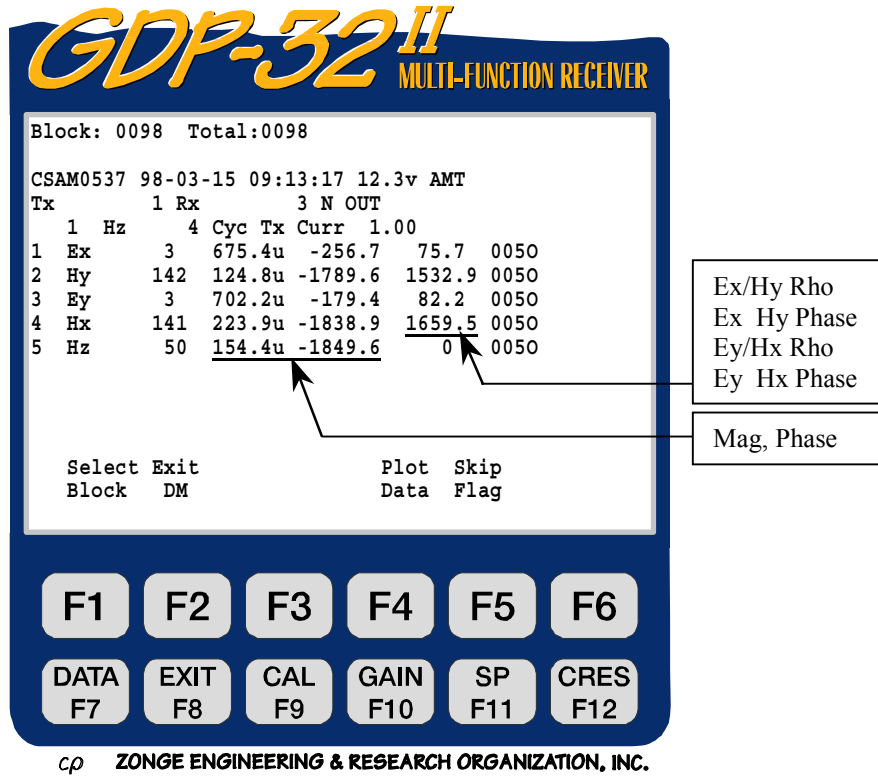
The SEM, SP contact resistance, external preamplifier gain, and A-spacing values have been saved, but are off of the screen to the right.

To view these numbers press ▶ several times to move to the right,

or press ◀ to move to the left.

Plot Data. By pressing [F5] you get into the plot routines. See **Section 14, Plotting Routines** for more information. Log-log resistivity versus frequency plots as well as magnitude or phase difference versus frequency plots are enabled for this version of CSAMT.

Skip Flag. By pressing [F6] an '**x**' is placed between the version number and the date in the header for the block being viewed. This flag is recognized by the plot routines and the flagged data will be skipped when averaging multiple blocks for plotting. Repeated pressing of [F6] will remove and replace the '**x**'.

11.5   A NOTE ON VARIABLE A-SPACING

When using variable A-Spacings, the key to getting the correct A-Spacing entered and used, is to remember two things: 1) the last field changed controls the A-Spacing value that is used, and 2) the A-Spacing that is used is ALWAYS the value in the Variable A-Spacing list.

For example, if the operator sets the A-Spacing value in the header to 50 M, then all of the numbers in the Variable A-Spacing list are set to 50 M. If the operator then gets into the Variable A-Spacing list and changes all of the values to, say, 25 M, then the A-Spacing value left in the header will still be 50 M but the actual values used will be 25 M - as shown in the Variable A-Spacing list.

The computer remembers where the latest changes were made and upon startup of the program. The A-Spacing in the header will still be 50 M, and the values in the Variable A-Spacing cache will still be 25 M. However, if the operator sets the A-Spacing in the header to, say, 100 M on startup, then the Variable A-Spacing values will all be set to 100 M.

11.6   A NOTE ON PHASE

The CSAMT program is an absolute phase program - that is, the program measures the absolute phase shift between the transmitted signal and the received signal. For normal operations at low frequencies, the real-time phase shift should be around -100 to -200 milliradians for the E-fields, and around $+\pi/2$ (1571 mr) for the H-fields. If the E-field phase is closer to π radians (3142 mr) then you have some wires reversed. You can get rid of the π radians of phase shift by either reversing the transmitter wires at the transmitter, or reversing the leads going into the receiver. For multi-channel receivers, it is easiest to make the change at the transmitter, and then maintain the same polarity through out the survey. If the phase for the H-field channels is negative $\pi/2$, you have a 180 degree phase shift. The easiest way to solve this problem is to rotate the H-field sensor by 180 degrees.

11.7   A NOTE ON SCALING

The following conventions are used for all measured and calculated parameters:
- E-field Voltage, (magnitude) displayed in volts.
- H-field Voltage, (magnitude) displayed in kilogammas when decalibrated with antenna cal.
- Current, displayed in amperes.
- Phase, displayed in milliradians.
- Apparent resistivity, displayed in ohm-meters.
- Dipole spacings, displayed in meters.
- Coil calibrate magnitudes, entered and displayed in millivolts per gamma.
- SP, displayed in millivolts
- SEM, displayed in milliradians

If scaling is necessary on these values, the following labels are appended to the end of the number string:

M - Mega units

K - Kilo units

m - milli units

u - micro units

11.8 RESTRICTIONS

The only restrictions on setting up the channels and using this program are to **make sure the E-field channels always precede the corresponding H-field channels**. In calculating Cagniard resistivities, the program first looks for an E-field channel, and then matches it up with the **first orthogonal H-field channel that it finds when going down the channel list**.

Following are some examples for connecting and defining the channels:

1. Reconnaissance Scalar CSAMT measurements on 7 separate stations:

Data displayed on LCD after acquisition:

```
CH     Sta/Ant   rho        Eϕ - Hϕ    SEM GGGA
1   Ex       1   RHOxy₁    Ex₁-Hy ϕ
2   Ex       2   RHOxy₂    Ex₂-Hy ϕ
3   Ex       3   RHOxy₃    Ex₃-Hy ϕ
4   Ex       4   RHOxy₄    Ex₄-Hy ϕ
5   Ex       5   RHOxy₅    Ex₅-Hy ϕ
6   Ex       6   RHOxy₆    Ex₆-Hy ϕ
7   Ex       7   RHOxy₇    Ex₇-Hy ϕ
8   Hy      30
```

Data stored and displayed in cache:

```
1   Ex       1   Ex Mag   Ex ϕ   RHOxy₁
2   Ex       2   Ex Mag   Ex ϕ   RHOxy₂
3   Ex       3   Ex Mag   Ex ϕ   RHOxy₃
4   Ex       4   Ex Mag   Ex ϕ   RHOxy₄
5   Ex       5   Ex Mag   Ex ϕ   RHOxy₅
6   Ex       6   Ex Mag   Ex ϕ   RHOxy₆
7   Ex       7   Ex Mag   Ex ϕ   RHOxy₇
8   Hy      30   Hy Mag   Hy ϕ   Ex₇-Hy ϕ
```

This example of scalar CSAMT, measures E-fields at 7 different stations, with the H-field antenna placed near the center of the array. This type of array is normally used for reconnaissance surveys.

The numbers 1 through 7 in the **Sta/Ant** field are used as station identifiers for data processing. The Rx value is commonly used to indicate the location of the GDP. These numbers can be any value from 0 to 99999. The number **30** on the **CH 8   Hy** line indicates that the calibrates for **ANT/1 Serial Number 3** are to be used. This exact number must identify the calibrates in the **Antenna Cal** antenna calibrate cache.

2. Four station scalar measurements, stations 1, 2, 3, and 4:

Data displayed on LCD after acquisition:

```
CH    Sta/Ant   rho      Eφ - Hφ   SEM GGGA
1   Ex       1   RHOxy₁  Ex₁-Hy₁ φ              1
2   Hy     240                                  1  Station 1
3   Ex       2   RHOxy₂  Ex₂-Hy₂ φ              2
4   Hy     250                                  2  Station 2
5   Ex       3   RHOxy₃  Ex₃-Hy₃ φ              3
6   Hy     260                                  3  Station 3
7   Ex       4   RHOxy₄  Ex₄-Hy₄ φ              4
8   Hy     270                                  4  Station 4
```

Data stored and displayed in cache:

```
1   Ex       1    Ex Mag   Ex φ RHOxy₁
2   Hy     240    Hy Mag   Hy φ Ex₁-Hy₁ φ
3   Ex       2    Ex Mag   Ex φ RHOxy₂
4   Hy     250    Hy Mag   Hy φ Ex₂-Hy₂ φ
5   Ex       3    Ex Mag   Ex φ RHOxy₃
6   Hy     260    Hy Mag   Hy φ Ex₃-Hy₃ φ
7   Ex       4    Ex Mag   Ex φ RHOxy₄
8   Hy     270    Hy Mag   Hy φ Ex₄-Hy₄ φ
```

This example of multiple station scalar measurements further defines the use of the station identifier for the E-fields in the **Sta/Ant** field. The notation used here is as follows: $RHOxy_2$ means the Cagniard resistivity is calculated using Ex_2 (channel 3) and the Hy from the next nearest channel (channel 4, which we label Hy_2). Likewise for the phase difference calculations, the phase for Ex_2 (channel 3) and Hy_2 (channel 4) are used to form the difference.

For this example we are using four single channel ANT/1's for the H-field measurements.

3. Two station vector measurements:

Data displayed on LCD after acquisition:

```
CH    Sta/Ant   rho      Eφ - Hφ    SEM GGGA
1  Ex       1   RHOxy₁   Ex₁-Hy₁  φ                1
2  Hy     141                                       1  Station 1
3  Ey       1   RHOyx₁   Ey₁-Hx1  φ                1
4  Hx     142                                       1
5  Ex       2   RHOxy₂   Ex₂-Hy₂  φ                2
6  Hy     151                                       2  Station 2
7  Ey       2   RHOyx₂   Ey₂-Hx₂  φ                2
8  Hx     152                                       2
```

Data stored and displayed in cache:

```
1  Ex       1    Ex Mag   Ex φ RHOxy₁
2  Hy     141    Hy Mag   Hy φ Ex₁-Hy₁  φ
3  Ey       1    Ex Mag   Ex φ RHOyx₁
4  Hx     142    Hy Mag   Hy φ Ey₁-Hx₁  φ
5  Ex       2    Ex Mag   Ex φ RHOxy₂
6  Hy     151    Hy Mag   Hy φ Ex₂-Hy₂  φ
7  Ey       2    Ex Mag   Ex φ RHOyx₂
8  Hx     152    Hy Mag   Hy φ Ey₂-Hx₂  φ
```

This example is just a rearrangement of the setup in Example 2 above to provide vector measurements, x and y components, at each of two stations.

For this example we are using two dual channel ANT/2's for the H-field measurements; Serial Number 14 (channels 1 and 2) and Serial Number 15 (channels 1 and 2).

4. Single station tensor measurements:

Data displayed on LCD after acquisition:

```
Tx        1   Rx        1   N OUT
  16 Hz    256 Cycles        Tx Curr      25

 CH     Sta/Ant   rho       Eφ - Hφ    SEM GGGA
 1   Ex        1   RHOxy₁   Ex₁-Hy₁  φ
 2   Hy       141
 3   Ey        1   RHOyx₁   Ey₁-Hx₁  φ
 4   Hx       142
 5   Hz       320 Hz Mag   Hz  φ
 6   OFF
 7   OFF
 8   OFF
```

Data from
Tx Antenna #1

```
Tx        2   Rx        1   N OUT
  16 Hz    256 Cycles        Tx Curr      21

 CH     Sta/Ant   rho       Eφ - Hφ    SEM GGGA
 1   Ex        1   RHOxy₁   Ex₁-Hy₁  φ
 2   Hy       141
 3   Ey        1   RHOyx₁   Ey₁-Hx₁  φ
 4   Hx       142
 5   Hz       320 Hz Mag   Hz  φ
 6   OFF
 7   OFF
 8   OFF
```

Data from
Tx Antenna #2

Remember, for full tensor measurements we need to make identical measurements from two orthogonally oriented transmitters. Hence the identical channel notation for the two transmitters. We identify the two different sources by using the **Tx** field as shown, and generating separate files with our data processing programs.

For this example, an ANT/1 single axis magnetic antenna, Serial Number 32, is used for Hz. All other notation is as above in the previous examples.

11.9   SAMPLE DATA BLOCKS

|	
Grounded E-field dipole	Card status: Passed or failed QC test.

```
0010
CSAM0537 98-03-15 14:51:55 12.6v AMT
OPER    1 TX ID    1 A-SP     100
JOB 89001 LINE    1.0 N  SPREAD  1
1  DiffAmp Notch+60,3-50,3 S/N 185 Passed 1.00192
2  DiffAmp Notch+60,3-50,3 S/N 177 Passed 0.99835
3  DiffAmp Notch+60,3-50,3 S/N  61 Passed 0.99921
4  DiffAmp Notch+60,3-50,3 S/N  57 Passed 1.00329
5  DiffAmp Notch+60,3-50,3 S/N  60 Passed 0.99876
6  DiffAmp Notch+60,3-50,3 S/N  66 Passed 0.99586
Front Panel S/N   12, Cal S/N   6, Temp  23.2, Humidity 35.0, EPROM ZMT-32 Z201h
```

Gain factors for each card

Analog card information

EPROM version

```
0011
CSAM0537 98-03-15 15:00:11 12.6v AMT
Tx        1 Rx        3 N OUT
32 Hz     16 Cyc Tx Curr  2.10
1  Ex    1 134.58m  -79.6  106.8  031O    .00   2.96  1.23K    1    100
2  Hy   10 10.297m -1606.9 1527.3 031O    .00   0.12  100.8    1    100
3  Ex    2 133.86m  -79.3  151.9  031O    .00  -0.56  1.02K    1    100
4  Hy   20 8.5854m -1591.5 1512.2 031O    .00   0.15  105.1    1    100
5  Ex    3 133.43m  -79.5  120.8  031O    .00  -3.56  1.17K    1    100
6  Hy   30 9.5981m -1606.6 1527.1 031O    .00  -5.92  99.23    1    100
```

SEM's in mr

SP in mv

External preamplifier gains

Contact resistance in ohms

A-spacing

These data were acquired using an RC network and a constant current laboratory transmitter. The RC network is as follows:
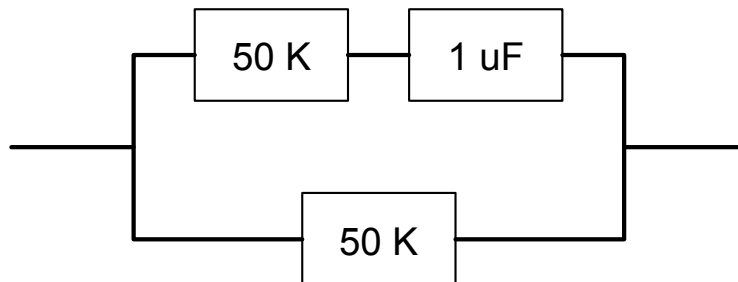
Block 0010 is the program header and is written to the data cache only when the operator goes between Menu 2 and 3.

Block 0011 is the main data block and is written at the end of each data acquisition cycle, when

CONTINUE Enter is pressed in answer to the instruction: "**CONTINUE to save, ESCAPE to discard**".

11.10   NOTES ON FIELD CONFIGURATIONS

When running multiple channel receiver systems, you must be very careful to avoid common mode problems. Common mode effects are caused by lack of a reference voltage or level (floating ground), or a reference level that exceeds common mode limits of the input amplifiers.

Common mode levels for the standard configuration of the GDP-32 are ±10 volts. With isolation amplifiers, this level can be extended to several thousand volts, but in exchange you have to contend with higher noise and a lower overall frequency response.

The best configuration that we have found is to install a **REFERENCE ELECTRODE** (standard copper/copper-sulfate electrode or equivalent), connected to analog ground (**COM** on the analog side-panel) and the case ground (**CASE GND** on the side panel), positioned next to the receiver and at least one meter distant from the nearest receiving electrode.

Another consideration is protection from static discharge and nearby lightning strokes. This protection is maximized by connecting the case ground to the **REFERENCE ELECTRODE** as well.

Additional protection in lightning-prone areas can be afforded by using a galvanized iron plate (or equivalent) as a **REFERENCE ELECTRODE**. This plate should be buried close to the receiver in a hole that has been well watered and the soil mixed to make good mud contact with the plate. Typical size for the plate would be 30 by 30 cm.

The following figures provide examples of receiver connections using the **REFERENCE ELECTRODE** or **REFERENCE POT** connected to both analog ground (**COM**) and case ground (**CASE GND**).

We have found that for most environments, the best noise rejection is obtained by connecting the analog ground (**COM**) to the case ground (**CASE GND**) on the **Analog I/O** side panel.

11.11   MAGNETIC COIL CONNECTIONS
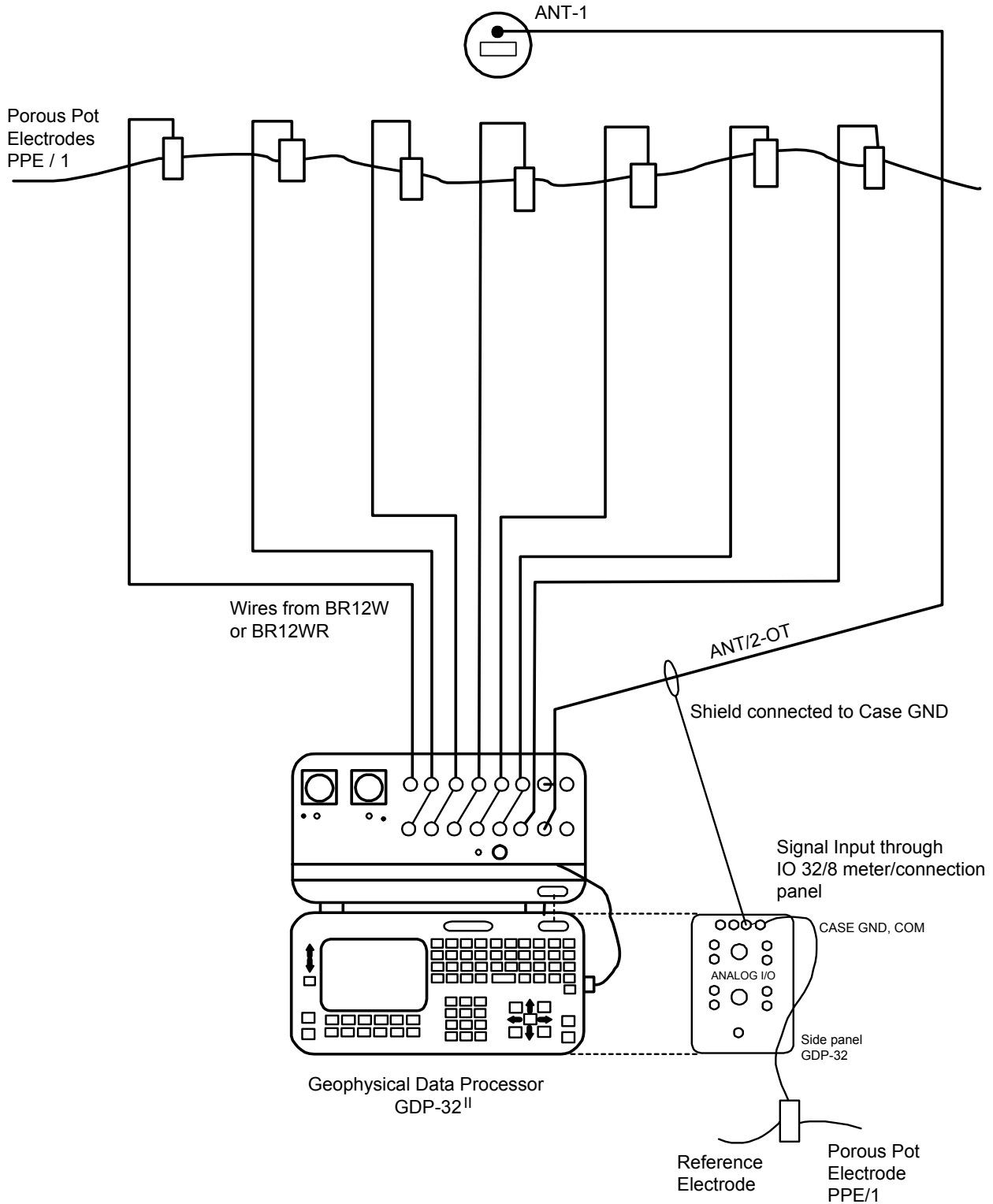
If the magnetic coil being used has a differential (3-wire) output, connect the two signal wires to the red and black input terminals, and the ground wire to **COM** on the **Analog I/O** side-panel.

If the magnetic coil has a single-ended (2 wire) output, connect the signal wire to the red input and connect the ground wire (or shield, if it is a coaxial cable) to the black input.

11.12 FIELD CONFIGURATIONS

RECONNAISSANCE CSAMT SETUP

Reconnaissance CSAMT Setup with Six Electric Field Dipoles and One Magnetic Field Sensor

ANT-1

Porous Pot
Electrodes
PPE / 1

Wires from BR12W
or BR12WR

ANT/2-OT

Shield connected to Case GND

Signal Input through
IO 32/8 meter/connection
panel

CASE GND, COM

ANALOG I/O

Side panel
GDP-32

Geophysical Data Processor
GDP-32 II

Reference
Electrode

Porous Pot
Electrode
PPE/1

CSAMT TRANSMITTER SETUP

VR-CN/6 Cable

Voltage
Regulator
VR-I

Motor
Generator
ZMG-30

GGT-30-PW Cable

Transmitter
GGT-30

XMT-32-CN/6 Cable

XMT-32 Transmitter
Controller

✳ Wire from
BRI2W or
PR/I with
PW/I

Aluminum foil or
stake electrodes
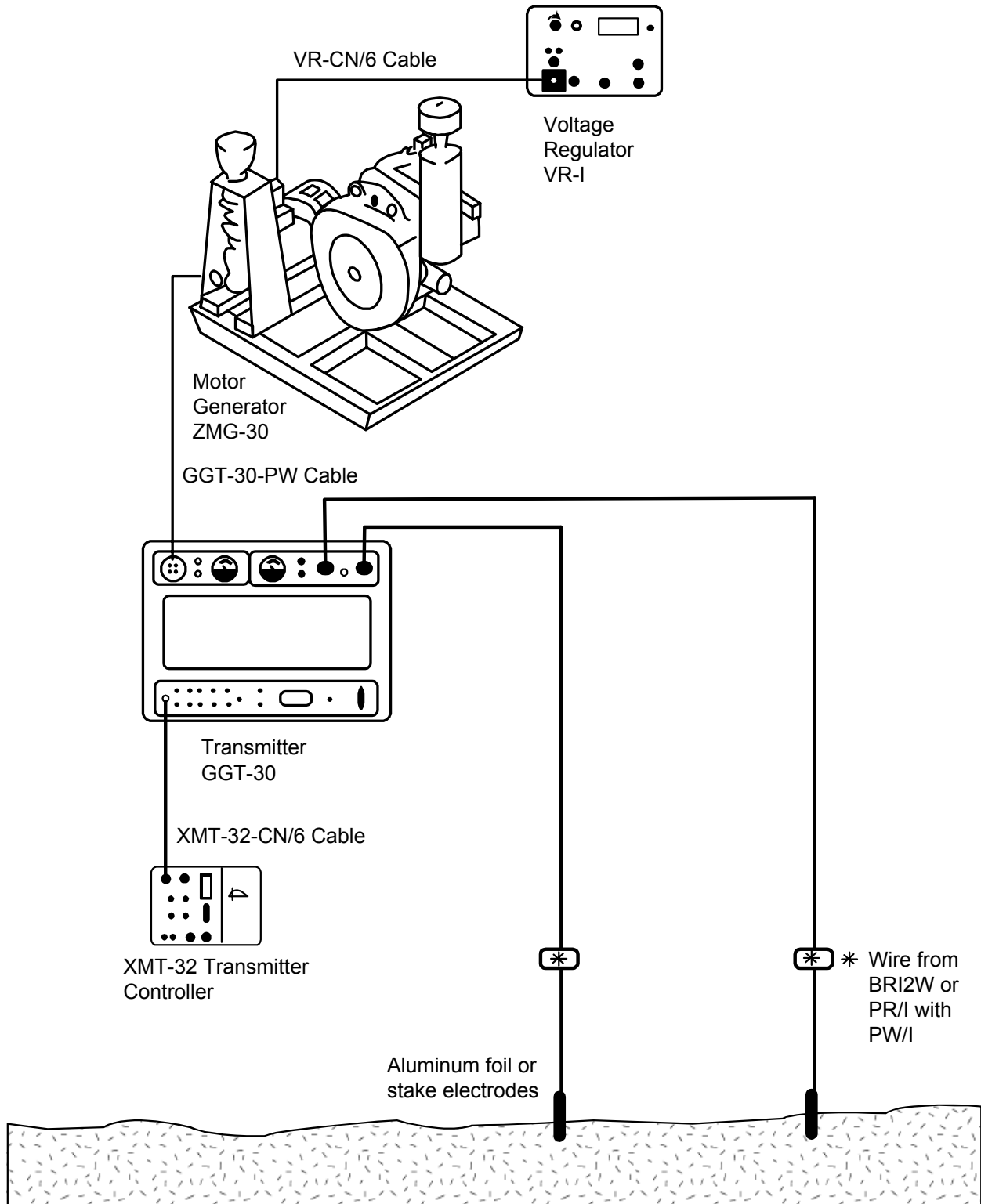
11.13   MAGNETIC SENSORS FIELD-CHECK

It is possible to field check the operation of an antenna by using the GDP calibrator as a signal source as follows:

1. Connect a 1 K ohm resistor between the Black and Red input terminals for channel 1.
2. Take a piece of wire or test lead and make a single turn around the antenna case as shown on the diagram. Connect one end of the wire to the Negative CALIBRATE output and the other end to the Negative (black) input terminal for Channel 1.
3. Connect a test lead from the Red CALIBRATE output to the Red Input for Channel 1.
4. Connect the coil output cable to the Channel 2 inputs as shown on the diagram.
5. Turn on the receiver and enter the CSAMT program. Set Channel 1 to Ex and Channel 2 to Hy with the antenna number set to 1.
6. Set the frequency to the lowest value you want to check - for instance 0.125 Hz.
7. Turn on the antenna.
8. Enter the calibrate program by pressing the **CAL F9** key. Then press 3) Auto System Check and then press 2) External. Press **CONTINUE Enter** to finish setting up the external calibrate system, and to begin taking data.
9. The program will automatically acquire data for each frequency, for example 0.125 Hz through 8192 Hz.
10. Enter the data mode by pressing the **DATA F7** key. Check to see the block number of the first data acquired. Then return to the last data block.
11. Enter the plot mode by pressing **F5**. Press 3) Magnitude Plot.
12. Enter the starting block number and press **CONTINUE Enter**.
13. Enter the starting channel number = 2 and press **CONTINUE Enter**.
14. The plot that you get will be the magnitude plot for the coil being tested. It should have the same shape as the calibration done in our test facility.
15. If you want to look at the difference between a calibrate stored in the receiver and the response from this test, go back to step 4 and set the antenna number to the proper value for the antenna under test. Follow the same steps as outlined above. The result when you plot the data will be a straight line.

Note: The reason for monitoring the current through the 1 K ohm resistor is to make sure that the signal level is constant over the frequency range being tested.

GDP-32^{II}

CAL+   CAL-   COM   CASE

Shield

Red
CH1   1K ohm
Black

Red
CH2
Black

Antenna with
one turn of wire
around middle

Cable from TEM/3
or ANT/* antennas