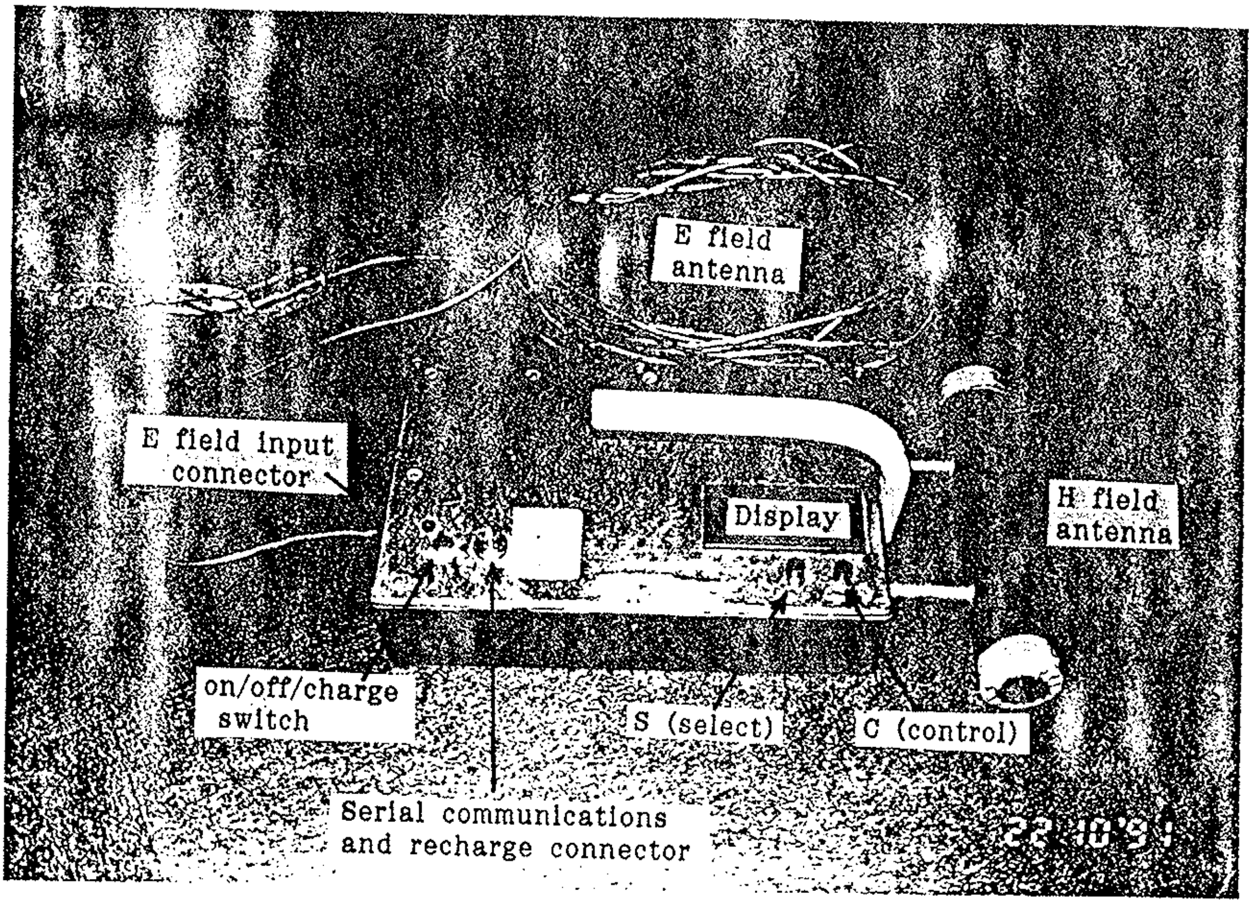
Kim Frankcombe

TSIM USERS MANUAL
(Version 92/1)

CONTENTS:


E field
antenna
E field input
connector
Display
H field
antenna
on/off/charge
switch
S (select)
C (control)
Serial communications
and recharge connector
22 10 '91

1.0 PRINCIPLES OF OPERATION

1.1 Introduction:

VLF (very low frequency) surface impedance measurements constitute one method of electromagnetic (EM) geophysical prospecting. The technique is described in standard geophysics books and papers some of which are listed at the end of this section. While the earlier VLF-EM techniques used magnetic field wave tilt measurements to search for laterally defined anomalies in the conductivity of the earth near the surface, VLF surface impedance measurements can be used to not only locate anomalies but also to make absolute conductivity measurements in areas where the earth is laterally uniform. The technique has been used successfully in coal basins and in ice covered regions in addition to a wide range of mineral deposits and ground water search.

TSIM is a small portable battery powered VLF receiving system designed to make and log VLF surface impedance measurements. The radiation sources used for measurements are the VLF navigation transmitters located around the world. As the propagation distances are very long (often over 1000kms), it is unwise to attempt measurements at times of local dawn and dusk as the signal undergoes rapid fading.

The transmitters radiate a vertically polarized radio wave which travels great distances with very little loss. When the radiation strikes the ground at your place of measurement, most energy is reflected, however, some energy propagates vertically downwards (i.e. perpendicular to the local surface). The interaction of this portion of the field with the earth is the basis of surface impedance measurements. The surface impedance parameter Z_s is defined as

$$Z_s = E_x/H_y$$

where E_x is the horizontal electric field measured in the direction of the transmitter, H_y is the horizontal magnetic field measured perpendicular to the direction to the transmitter. H_y is primarily a measure of the total field strength of the radiation, and so Z_s is essentially unaffected by field strength variations. The TSIM unit uses a coil to measure H_y and a trailing insulated wire to measure E_x. The surface impedance is a complex number and so there is usually a phase shift between these two field components.

When the earth is uniform both laterally and vertically (i.e. a homogeneous half space), the magnitude of the surface impedance is proportional to the resistivity squared: i.e.

$$Z_s =.$$

where is the angular frequency of radiation, is the magnetic permeability, j = $\sqrt{-1}$;
and the phase

$$\text{Arg}(Z_s) = 45 \text{ degrees.}$$

When the earth is horizontally layered, then it is usual to assign an "apparent resistivity" to the earth which is dependent on the thickness of the various layers and the resistivity contrast between them. The phase is no longer 45 degrees.

When the earth is laterally anisotropic, then the apparent resistivity can no long be interpreted in terms of the horizontal layers. The wave is scattered from the lateral boundary and an enhanced apparent resistivity is measured. This latter effect is used to establish the location of geological features such as faults, contact planes, dykes etc.

The reader is referred to the publications listed at the end of this chapter for further information.

1.2 Transmitter characteristics

There are two types of transmission sequence: a continuous wave transmission at a fixed frequency, and the Omega transmitters whose output is pulsed at a number of different frequencies over a 10 second period. The two transmitters on Australian soil are at North West Cape (Western Australia) and the Omega transmitter at Sale in Victoria. The locations and frequencies of the transmitters are given in Appendix 1. For VLF work in Australia the usual frequencies are 22.3kHz for North West Cape (continuous except during switch-off periods which usually occur on Mondays during the day-light hours), and Omega (Australia) at 13.0kHz.

1.3 References:

Collett, L.S., and O.G. Jensen (eds), 1982. "Geophysical applications of surface wave impedance measurements", Geological Survey of Canada, paper 81-15.

Nabighian, M.N., (ed.) 1992. "Electromagnetic methods in applied geophysics", Volume 2: Application part B. S.E.G., pp571-640.

Thiel, D.V., 1990. "VLF surface impedance changes in the vicinity of an abrupt lateral boundary at the earth's surface". IEEE Trans GRS-28, pp 500-502.

Thiel, D.V., 1988. "VLF electromagnetic prospecting", in The Encyclopedia of Field and General Geology, ed: C.W. Finkl, Jn., van Nostrand Reinhold: pp855-862.

2.0 PLANNING A TSIM SURVEY

In order to maximize the impact of a survey, and to minimise the amount of time wasted needlessly, here are a few hints for most effective surveying.

(a) Use pegged grids. A single traverse line should be pegged at a maximum spacing of 25 metre intervals if a station separation of 5m is to be used. As a general rule, use no more than 5 measurement stations between each survey point.

(b) Orient every traverse in a direction parallel to the direction to the transmitter. This minimizes the time required to re-orient the instrument accurately at every station. If this is not possible, it is still possible to use the instrument at an angle of up to 30 degrees either side of the transmitter line providing the instrument does not change alignment along the traverse.

(c) Always work in the same direction; i.e. always towards the transmitter or away from the transmitter.

(d) It is preferable that the major axes of the features being mapped lie at approximately 45 degrees to the transmitter line. Thus, if possible, choose a transmitter which has approximately this bearing angle.

(e) It is essential that both the instrument and the trailing antenna lie on the earth's surface (regardless of the incline of the terrain), so choose cleared areas and road-ways if possible.

Note that reliable, repeatable results require

(1) very tight grid control

(2) consistent instrument orientation

(3) no touching the instrument during measurement

and (4) the E field antenna lying as close as possible to the earth's surface along its entire length.

3.0 HOW TO MAKE A MEASUREMENT

(a) Place the instrument on the ground.

(b) Orient the chassis for maximum H field.

(c) Stretch the E field antenna out in a straight line in line with the instrument and the transmitter line.

(d) Lie the antenna as close as possible to the ground; (If necessary part the undergrowth.)

(e) Make the measurement by pushing S at the Monitor Display Screen (as explained in the next section). Wait for the Monitor Display Screen to return and then move to the next station. If the traverse lies in the direction of the transmitter, the measurements can be made quickly and easily by simply trailing the antenna behind the instrument.

3.1 The firmware:

TSIM has been designed to make the measurement procedure as simple as possible for the operator. The unit has a microprocessor based data logger which provides some filtering and a logging facility for later data collection by computer. The procedure for making a measurement can be trialed anywhere, and it is a good idea to go through the full procedure before attempting a field survey. A flow chart is given in Appendix 2.

There are two only input controls: a S (sample) button and a C (control) button. The C button allows the user to move the cursor around the LCD display, and the S button allows the user to select a particular action or input.

The measurement procedure is as follows:

Switch the instrument on (toggle switch to the rear of the instrument).

The LCD display should show

```
CLEAR MEMORY ??
YES          NO
```

C allows the user to put the cursor on YES. S implements the command.

The LCD now reads

```
TSIM91 V1.0
PRESENT SETTINGS
```

Either C or S then allows you to examine the current settings of the instrument. For example the display might look like this (depending on last use)

```
AAAA  2230  0001
12:00 10/12
```

where AAAA is a four character traverse label (only letters)
2230 is the frequency in tens of Hz i.e. 22.3 kHz
0001 is the step size of the traverse
12:00 is the user entered time (There is NO real time clock)
10/12 is the user entered date (There is NO real calander)

This display is for information only and the settings cannot be altered at this point.

Either C or S then allows you to examine the current field strengths at this frequency via a display which updates 4 times per second. This is referred to as the "**Monitor Display Screen**".

TR:AAAA POS:0001
E0005 H0214 P091

where TR:AAAA is the traverse title
POS:0001 is the position in the traverse
E0005 is the E field level which is changing
H0214 is the H field level which is changing
P091 is the phase value which is changing

Pressing S will take a data point via the following sequence:

PLEASE STAND
BACK FROM TSIM

Touching the unit during a measurement can change the reading significantly

SAMPLING
PLEASE WAIT

The unit is acquiring data and finding a mean value for all three parameters. You are then returned to the Monitor Display Screen.

Pressing C results in

NEW COMS/THRESH
CLEAR EXIT

where NEW allows you to start a new traverse with a new name/time/date etc
COMS/THRESH allows you to start the download procedure and also to set the threshold for measurements
CLEAR allows you to clear the memory
EXIT allows you to exit from this screen.

To select one of these headings use C. When the cursor rests on the appropriate heading, then use S.

You can switch the instrument off at any time without loss of data.

3.1.1 Changing the settings:

From the Monitor Display screen use C and choose the NEW option (using C) and then S. The display is

AAAA 2230 0001
12:00 10/12 EXIT

Use C to move to the traverse label. At each letter, S is used to step through the alphabet. When you arrive at the desired letter use C to move to the next etc. The same is required for a frequency change, step size change, time change and date change. When all settings are correct, place the cursor on EXIT and S.

The screen will show:

MAKE A NEW FILE?
YES NO

The usual response is yes (chosen using C), and then implemented using S. You then return to the screen:

TSIM 91 V1.0
PRESENT SETTINGS

While duplicate traverse labels are stored, the MS-DOS program "TRANSLAT" will only output the last file with a particular name.

3.1.2 Changing the Threshold

In order to prevent data acquisition during periods of no signal; for example when using Omega transmitting stations, it is necessary to set the threshold above which data is considered valid. The threshold level refers only to the H field signal level. The following technique should be adopted:

Place the instrument on the ground with the screen set to show E, H and P changes continuously (the Monitor Display screen). Rotate the instrument slowly. When the instrument is aligned with the transmitter, the signal is a maximum. For Omega frequencies this is evident as one or more sudden periodic increases in H signal level every 10 seconds. Note the mean level during the non signal period and use twice this value as a threshold value. This can be set by positioning the cursor on the COMMS/THRESH position and using S. The screen is

BAUD9600 DUMP
THRESH 0000 EXIT

Use C to select the four digit threshold value, and use S to increment each digit as required. The next position is selected using C. Move the cursor to EXIT and use S to exit from this screen.

3.2 Field work (traversing)

Once the user has set the appropriate traverse identifier (4 characters), the step size, time and date, and returned to Monitor Display screen, the traverse can be started.

Place the instrument on the ground next to the first station (grid point). Orient the instrument in the direction of the transmitter and extent the E field antenna in a straight line on the ground behind the instrument. Make sure that the appropriate H level is evident on the display and press S. Wait for the instrument to return to the Monitor Display screen and move to the next location. Press S, wait and move on. Continue this procedure until the end of the traverse.

Note that the POS value updates after every S. This allows the user to ensure the correct position is kept.

The time required for each point depends on whether the VLF transmitter is continuous or of the Omega type, the noise in the vicinity and the threshold setting. If no satisfactory result is obtained after 256 samples the instrument will display

SIG<<THRESHOLD

If this happens it is wise to terminate the traverse and recheck the settings of frequency and threshold.

To complete a traverse press C and select NEW for a new traverse.

At the end of the day and during long breaks, switch the instrument off. All data is preserved regardless of position in the software.

4.0 HOW TO TRANSFER DATA

4.1 Changing the Communications speed

Enter the COMMS/THRESH screen and use C to place the cursor on BAUD9600. Using S steps through a number of preset communications speeds (300, 600, 1200, 2400, 9600). Once the desired value has been selected, move the cursor to EXIT using C and exist using S.

4.2 Dumping the data

Enter the COMMS/THRESH screen and use C to place the cursor on DUMP. Connect the communications cable to your computer and enter your up-load routine (e.g. PROCOMM on the MS-DOS disk provided).

After the set up has been completed, you will be prompted to

PRESS BUTTON TO
SEND DATA

Press either S or C to initiate the data dump. The data will be transferred in one block with each traverse in turn in the order in which they were recorded. There is no problem with duplicate traverse names until you use the program TRANSLAT.

COMMUNICATIONS ARE SET FOR 9600 Even Parity 7 bits 1 Stop

4.3 File Format

The data stream contains a file header with the traverse label, time, date, step size etc. Then follows tables of values of H, E and P.

The file dumped by the TSIM unit is an ASCII file with the following format:

```
TSIM 91 VERSION 1.0
NAME:-AAAA
Freq:-22300hz
Step:-0001 Metre
Time:-12:00 Date:-10/12
Step  E    H    P
0   0056 0124 0940
more data

NAME:-AAAB
Freq:-13000hz
Step:-0005 Metre
Time:-01:30 Date:-03/3
Step  E    H    P
0     0120 0110 0874
more data

END OF DATA
```

Note that the phase value (P) must be divided by 10 to be correctly calibrated. The E value must be multiplied by 30 for correct calibration. Thus

apparent resistivity = $(30E/H)^2$.

This scaling is performed by TRANSLAT.

4.4 MS-DOS software provided

Two programmes have been provided to assist in the preparation of TSIM data for use by any computer: a serial communications programme PROCOMM, and a data preparation routine called TRANSLAT. The programmes are designed to run on an IBM PC under MS-DOS. Copy the files onto a hard disk before running either program.

4.4.1 Procomm

Run the program using the following command sequence (a help utility is available):

procomm	
PgDn	(to upload a file)
7	(to specify an ASCII file)
	(insert a file name when prompted)

At this point implement the Dump command on the TSIM. The data should be visible on the screen during the dump command.

ESC	(to terminate the upload)
Alt(X)	(to terminate procomm)
Y	(to exit to DOS).

4.4.2 Translat

This file converts the large continuous file (recorded by TSIM and uploaded using Procomm) into discrete files with appropriate scaling and the calculation of the apparent resistivity values. To run the programme type

translat

(enter the input file name when prompted)
(each file name is listed as it is processed)

The result is a set of traverse files with the traverse names (without extension). Note that duplicate files are overwritten. These files contain the calibrated data, the correct position and apparent resistivity values.

5.0 HOW TO CHECK IF THE INSTRUMENT IS OPERATIONAL

Before each survey, it is important that the user checks that the instrument is performing correctly. There are a number of simple tests to make sure that this is the case.

Set the instrument to the field reading Monitor Display Screen on the menu so that you can see the changing field strengths.

5.1 H field test:

This can be performed with or without the E field wire antenna connected. Place the instrument on the ground away from power lines and buildings. Rotate the instrument slowly through the compass bearings. The H field level should be a maximum in the direction of the transmitter, and be a minimum when the instrument is perpendicular to the transmitter. (The exact pattern is a figure of eight).

If the ratio between H maximum and H minimum is less than 1, then either:

(a) the transmitter is not on (and you will have to wait until it is!)

or (b) the incorrect frequency has been selected (and you must change the frequency)

or (c) the instrument is close to a high noise source (and you must move to a different location)

or (d) there is a fault in the instrument (and you must contact the Radio Science laboratory).

If the threshold has been set too high and the computer cannot obtain a reliable estimate of the data, the screen will display:

SAMPLING TIMEOUT
SIG<<THRESHOLD

In this case, either the threshold has been set too high or the transmitter has been switched off. (North West Cape transmitter is sometimes switched off for short periods of less than five minutes).

5.2 E field Tests:

With the E field antenna disconnected, note the E field reading. It should be less than 10. Use a metal object to touch the metal part of the E field connector. The field should increase slightly. This simple test demonstrates that the E field probe input is active.

With the E field antenna connected, stretch out the antenna in the direction of the transmitter (or away from the transmitter), and note the reading. Now slowly pull the antenna in towards the instrument. As the antenna gets effectively "shorter", the signal level should decrease. (The relationship is essentially linear).

Note that the E field antenna is simply a weighted insulated wire. It is likely to break at the input point from time to time through normal use. If this occurs simply strip back the wire a little and re-connect to the terminal. The length of the wire is approximately 10metres. Clearly, if the length is reduced by 1 metre, then a 10% error in E field results with a 20% error in the apparent resistivity.

6.0 HOW TO RECHARGE THE INSTRUMENT

The instrument when fully charged has a useable life of 10 hours continuous use. It is wise to recharge the batteries over night.

You have been supplied with a recharger. The connector used for communications is used for the recharger. Connect up the recharger and switch the toggle switch to charge; i.e. towards the LCD. The red light should light up. Leave the instrument to charge for 12 - 24 hours to ensure the instrument is totally charged for field work. Note that the instrument is shipped fully charged.

If the instrument batteries get too low during field use, the instrument will flash a warning during the Monitor Display Screen. After a period of time, the instrument will shut-down without loss of data. If this occurs, simply recharge the unit for 24 hours and the data will then be accessible.

7.0 HOW TO GET ASSISTANCE

TSIM was designed and manufactured at the Radio Science Laboratory at Griffith University. Limited assistance in the operation of the instrument is available by telephone or fax. Please address all enquiries to:

Assoc. Prof. David V. Thiel
Radio Science Laboratory
Faculty of Science and Technology
Griffith University
NATHAN Qld 4111
Australia

telephone: 61-7- 875 7794 (Laboratory)
61-7- 875 7192 (Office)
fax: 61-7- 875 7656

Appendix 1: Transmitter Details

from: United Airlines 1974. "Avionics Fundamentals", IAP Inc, U.S.A. pp 149-150.

OMEGA STATIONS

Letter	No.	Location	Latitude	Longitude
A	1	Aldra, Norway	66°25'N	13°08'E
B	2	Monrovia, Liberia	6°18'N	10°40'W
C	3	Haiku, Hawaii, USA	21°24'N	157°50'W
D	4	La Moure, North Dakota, USA	46°22'N	98°20'W
E	5	La Reunion	20°58'S	55°17'E
F	6	Golfo Nuevo, Argentina	43°03'S	65°11'W
G	7	Australia	38°29'S	146°56'E
H	8	Tsushima, Japan	34°37'N	129°27'E

Each station transmits three basic frequencies: 10.2 kHz, 11.33 kHz, and 13.6 kHz. To prevent signal interference between stations, transmissions are timed such that only one station is transmitting a particular frequency at a time.

VLF COMMUNICATION STATIONS

No.	Location	Latitude	Longitude	Freqency (kHz)	Pwr (KW)
1	Maine	44°39'N	67°17'W	17.8	1026
2	Japan	34°58'N	137°01'E	17.4	48
3	Washington	48°12'N	121°55'W	18.6	124
4	Hawaii	21°26'N	158°09'W	23.4	588
5	Maryland	38°60'N	76°27'W	21.4	588
6	Australia	21°49'S	114°10'E	22.3	989
7	Great Britain	52°22'N	01°11'W	16.0	40

Each station transmits a specific frequency.

Transmission Format

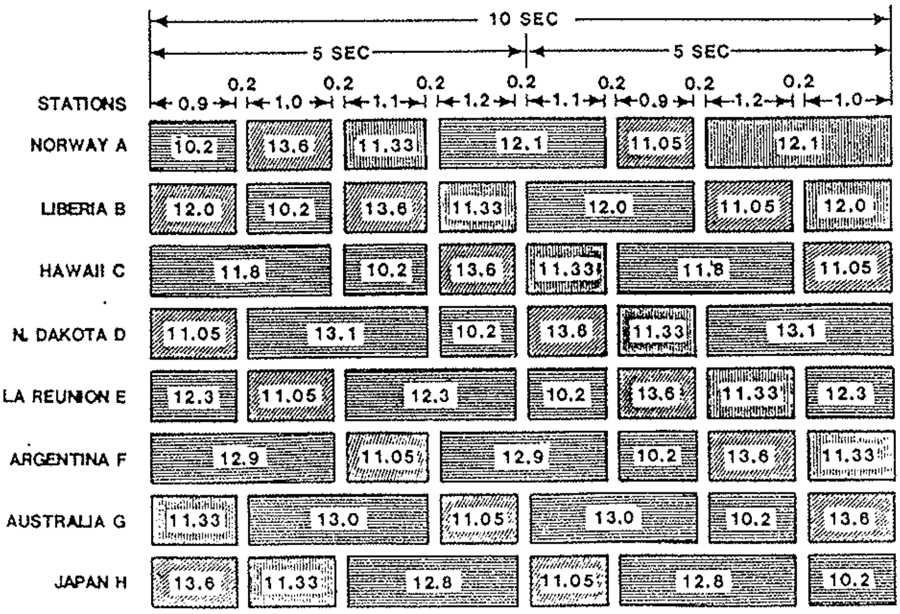
The transmission format of the eight Omega stations is shown in Figure 9-4. Each station transmits on four common frequencies and one frequency which is unique to that station. These signals are transmitted in a predetermined sequence and duration.

Let's take a look at Station "A", which is in Norway, and compare it to Station "C", which is in Hawaii. "A" transmits on three of the common frequencies of 10.2, 13.6, 11.33, then on its unique frequency of 12.1, followed by a common frequency of 11.05, and again on 12.1. All of this takes place in twelve seconds. Station "C" starts off with its unique frequency of 11.8, followed by the common frequencies of 10.2, 13.6, and 11.33 and so on.

You will notice that not only does it have a unique frequency, but also the duration of the common frequencies is not the same as for station "A".

This holds true for each Omega station. The airborne Omega unit has this information stored in its memory, so that it can properly identify each station as its signals are received.

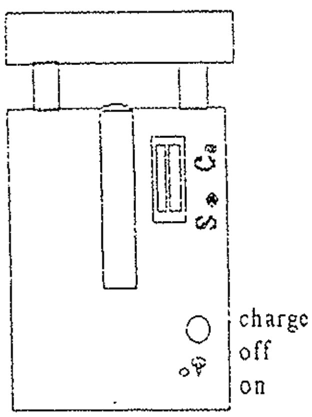
Figure 9-4



Appendix 2: TSIM flow chart

Use of Tsim 91

Operation:	Display:	Comments:
Power switch turned on	(blank)	The data lost message would normally only occur if tsim had been left off for longer than a week or so
	DATA LOST RESET MEMORY	
Identification	TSIM91 V1.0 PRESENT SETTINGS	Just shows the present settings being used.The time and date are entered for archival purposes. Freq is the operational frequency Dist is the distance traveled between consecutive measurements.
Any KEY file information	name Freq dist ABCD 1234 1234 12:34 12:07 time date	
Any KEY	TR:ABCD POS:0031 E0024 H0342 P110	MONITOR DISPLAY giving updated readings of amplitude and phase. Result of Ckey described later page
S key takes a sample and stores it to memory Note: Pressing the S key whilst already pressing the C key will REDO the measurement ie. Another measurement is done replacing the last and pos is not incremented.	S key PLEASE STAND BACK FROM TSIM	FLASHED WARNING: Standing or touching the TSIM during a measurement will affe the result.
	SAMPLING PLEASE WAIT	Ttsim will take the average of 6 valid readings. The duration wi vary on the threshold set.
	SAMPLING TIMEOUT SIG<<THRESHOLD	If the signal is weaker than the threshold set then the measurement will timeout after 256 tries
	TR:ABCD POS:0032 E0023 H0342 P110	The measurement is done and pos indicates the position of the next to be done.(ie. pos is incremented by one digit).



Use of Tsim 91

Control Menu | **Setup Changes** | **Comments**

```
TR:ABCD     POS:0032
E0023   H0342   P110
```

```
ABCD    1234       1234
12:34   12:07
```

result of S key see prev page

S key or CS key

C key

```
NEW     COMS/THRESH
CLEAR         [E]XIT
```

Cursor flashing at exit position pressing S key will exit back to information display and then to monitor display

C key

```
[N]EW   COMS/THRESH
CLEAR          EXIT
```

Cursor at new position. Pressing Skey now displays the present settings. These can be changed by using the Ckey to position the cursor on the digit of interest and using the Skey to increment it. Use the Ckey then to move on to the Exit posn and select it with the Skey. You are now presented with achoice to make a new file. This is selected similarlyand you then return to the monitor display via the settings display.

```
ABCD    1234     1234
12:34   12:07    [E]XIT
```

C key

```
NEW   [C]OMS/THRESH
CLEAR          EXIT
```

cursor at coms/thresh position
allows changes to baud rate,threshold,and allows dumping of data to remote computer. Set the threshold if using omega signals,otherwise set it back to a low value.

C key

```
NEW     COMS/THRESH
[C]LEAR        EXIT
```

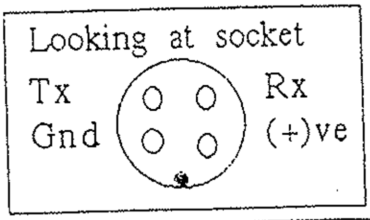
cursor at clear position:
use with CAUTION as this erases all data. use only after confirming that a dump remote computer is succesfull.

C key

```
NEW     COMS/THRESH
CLEAR         [E]XIT
```

Selection of Exit with Skey returns you to the monitor display via the settings display with no changes

Charging the TSIM.:connecting a DC voltage (12volts to 20 volts @0.5 amps) to the four pin connector will fully charge a flat TSIM in about 24 hours.LED indicates charging(lights for supply>13volts or so).



Appendix 3: Equipment List and Assembly Instructions

The instrument box should contain the following items:

1 TSIM unit

1 E field wire antenna (10 metres)

1 Battery charger

1 RS232 cable

1 MS-DOS floppy disk

1 TSIM Users manual

Assembly:

The TSIM unit is shipped fully assembled. The only assembly required is the attachment of the E field antenna via the screw terminal at the end of the instrument.