PROCESS TOMOGRAPHY Ltd.

ELECTRICAL CAPACITANCE TOMOGRAPHY SYSTEM

TYPE PTL300

ECT32v2

TWIN-PLANE ELECTRICAL CAPACITANCE TOMOGRAPHY

SOFTWARE FOR WINDOWS

USER GUIDE

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APPENDICES

1. INTRODUCTION

Electrical Capacitance Tomography (**ECT**) is a measurement technique which is normally used to obtain the **concentration distribution** of a **mixture of 2 dielectric (insulating) materials**.

The **PTL300E** is a computer-controlled twin-plane **ECT measurement system** for capturing and viewing capacitance and image data at either one or two measurement planes. This equipment is controlled by the **PTL ECT32v2** software, which is a comprehensive **suite of programs** which allows a **PTL300E ECT system** to be set up, calibrated, used to capture capacitance data files and to convert them into image files at user-defined speeds. It also allows captured **capacitance** and **permittivity image data** to be replayed

This **USER GUIDE** gives an introduction to the **use of the ECT32v2** software **for replaying and viewing** captured capacitance data files **only.** A full set of **operating instructions,** covering the use of the **ECT32v2 software** for controlling the **PTL300E capacitance measurement hardware** can be found in the **PTL300E Operating Manual.** The **ECT32v2** software operation is demonstrated in this **User Guide** using a number of **sample data files** which are supplied with the software. This **User Guide** should be read in conjunction with the **PTL Introductory Notes** document and the **PTL300E ECT System Operating Manual**.

After a brief summary of the functionality of the **ECT32v2** software **(section 2)**, a set of **Quickstart** instructions (**section 3**) describing the operation of the software for playing back previously-captured data are given, based on the use of sample capacitance data files which are supplied with the **ECT32v2** software.

The **User Guide** concludes with a comprehensive **reference section** (sections 4 to 6) which describes the functionality of the **ECT32v2** software in detail.

Throughout the guide, references are made to the appropriate sections in the **PTL300E Operating Manual** *(PTOM*), where additional and more detailed information on the topics under discussion is given.

2. SUMMARY OF SOFTWARE FEATURES AND FUNCTIONALITY

The **ECT32v2 software** allows **one** or **two ECT sensor planes** of a **PTL300E ECT system** to be controlled either **separately** or **together.** The software also allows both **live data** and **captured capacitance data files** to be converted into **permittivity images,** which can be viewed either **live** or **off-line**. The software is configured and controlled using a number of **user interfaces**, including an **initial configuration window**, **control menus** on the **menu bar** at the top of the **ECT32v2 desktop window**, **control icons** on a **toolbar** and **control buttons** on a separate **Control panel window**.

The main **control screen** is the **ECT32v2 Desktop window** and other important windows are the **ECT32v2 Configuration** and **Calibration** Windows. A comprehensive set of **Toolkit** software is also included which allows diagnostic checking and updating of the **firmware** within the **PTL300E** unit to be carried out. An additional option allows **Capacitance data** to be exported **on-line** via an ethernet link to a remote PC.

Options included in the software allow **Permittivity Images to be co**nstructed using a number of different **physical sensor models. Capacitance d**ata can be **captured** and **played back** at **different frame rates,** and displayed as **permittivity images, normalised capacitances** or any combination of these.

Image pixels can be **truncated** or **inverted**. The **image gain** can be set by the user and a **permittivity offset** can also be applied to the image to allow **small variations** about a **preset value of permittivity** to be displayed.

Capacitance data from a **number of frames** can be **averaged** on a **rolling or fixed basis** to reduce the effect of noise for slowly-changing images and the **averaged data** can be used to produce a **Reference frame** (see next para**.**).

A set of data can be stored in a **reference frame** and **subtracted from all subsequent data frames** to allow enhanced viewing of **changes in experimental conditions**. **Simple on-line correlation of data from a twin-plane system** can be implemented to measure **the velocity of materials** under relatively steady-state flow regimes.

Measured capacitance data can be saved in **binary format** and converted to a range of other data files in **ASCII** format. **Sequential binary capacitance data files** can be generated automatically. **Calibration of twin plane systems** can be carried out for **each plane individually** and a **composite calibration file** can be generated from the individual calibration files.

Data capture can be triggered by or synchronised with other instruments.**Advanced facilities** are provided which allow the **fundamental measurement time constants** to be optimised to allow increased data capture speeds at the expense of increased system noise levels. This may be advantageous in some specific applications.

This **User Guide** covers the operation of the **ECT32v2** software in **Playback Mode** only.

3. QUICK START INSTRUCTIONS

This **Quickstart** section illustrates some of the important functionality of the **ECT32v2** software in **Playback mode**, using a number of **sample data files** which can be found in the **C:\ECT32v2\working\examples\data files** folder. Brief details of the **sample data files** are given in **Appendix 2**.

3.1 SOFTWARE INITIALISATION AND CONFIGURATION

1. Install the **ECT32v2 software** as described in the **Introductory Notes document**.

2. Double click on the **ECT software icon** on the **Windows Desktop**. The **ECT software group window** will open and will ressemble that shown in **figure 3.1(a)**.

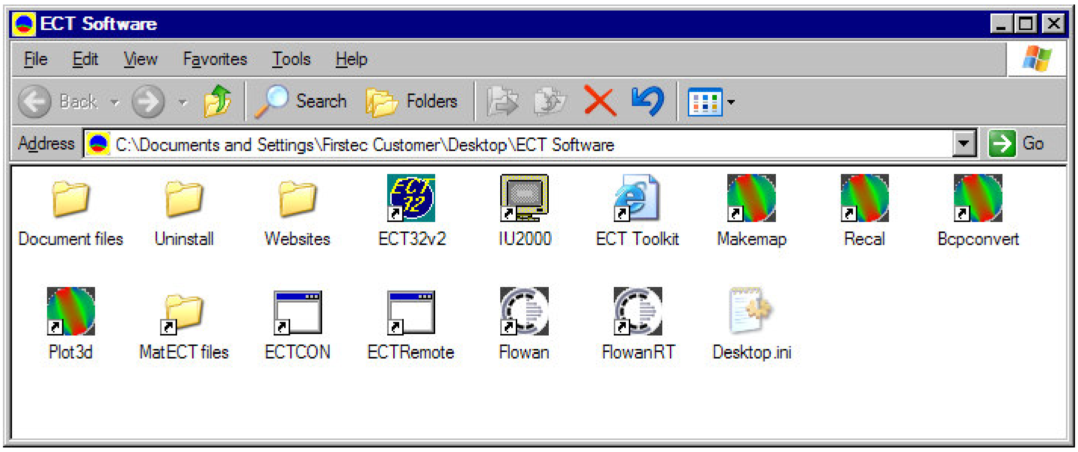


Figure 3.1. ECT Software Group window

Double click on the **ECT32v2 icon** in the **ECT program group window**. If this is the first time the software has been run, a **Registration Window** will appear as shown in **figure 3.1(b).**

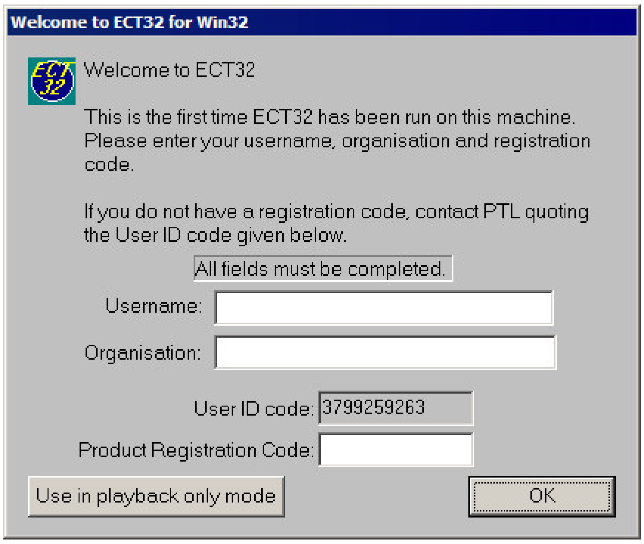


Figure 3.1(b) Registration Window.

For on-line use of the the **ECT32** software with the **PTL300E** instrument, a product activation user code must be obtained for the software before it can be used. However, in off-line **Playback** mode, this user code is not required. In this case, there is no need to input any registration data and the program can be used in **Playback only** mode by clicking on the **Use in playback only mode** button in the **Registration window**.

3.2 LOADING A DATA FILE USING THE CONFIGURATION WINDOW

1. The **Configuration window**, shown in **figure 3.2**, appears each time the **ECT32v2 software** is run and allows some of the important software set up parameters to be defined and/or initialised.

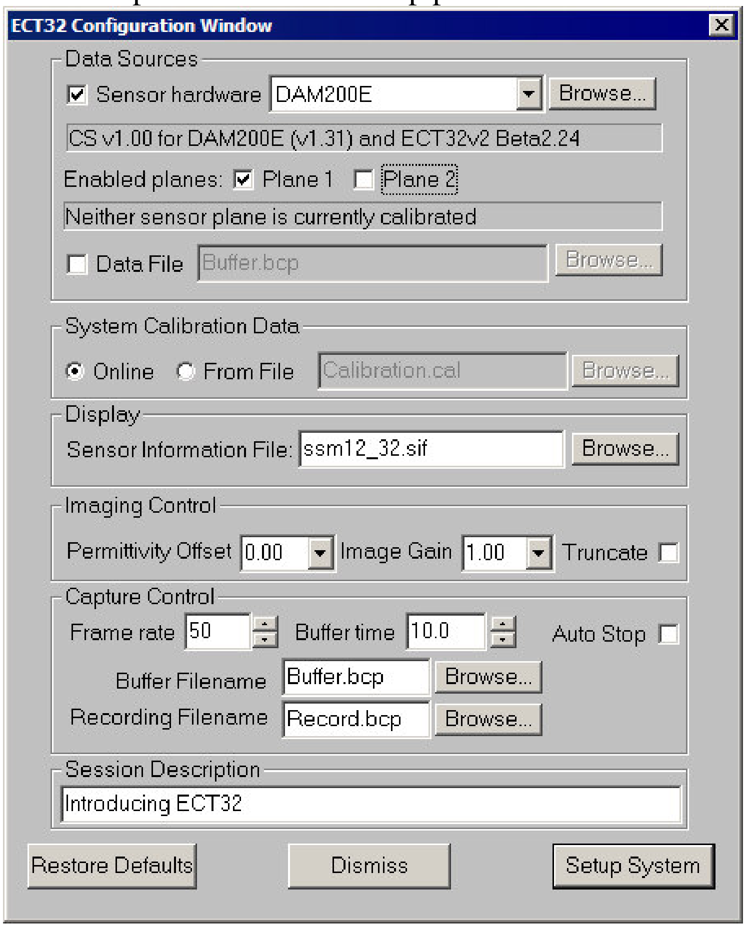


Figure 3.2. ECT32v2 Configuration Window

2. Left click the **Restore Defaults** button at the **bottom** of the **Configuration window**. This resets the **Configuration window** to a fixed set of default parameters.

3. Click on the **Sensor Hardware** selection box to **de-select it** and then click on the **Data File box** to **select it**. This operation tells the **ECT32v2** software to expect input from a **data file** rather than from the **measurement hardware**.

4. Use the **Data file browse button** to select the sample data file **12_rodpoly_sp.bcp,** which can be found in the **C:\ECT32v2\working\examples\Data Files** folder. This file contains 10 seconds of captured data for a simple dielectric rod moving inside a 12-electrode sensor.

5. In the **Display section**, use the **Browse button** to select the sensor information file **ssm12_32.sif**, which is in the **c:\ect32\configure folder**.

6. The **Configuration window** should now ressemble that shown in **figure 3.3**.

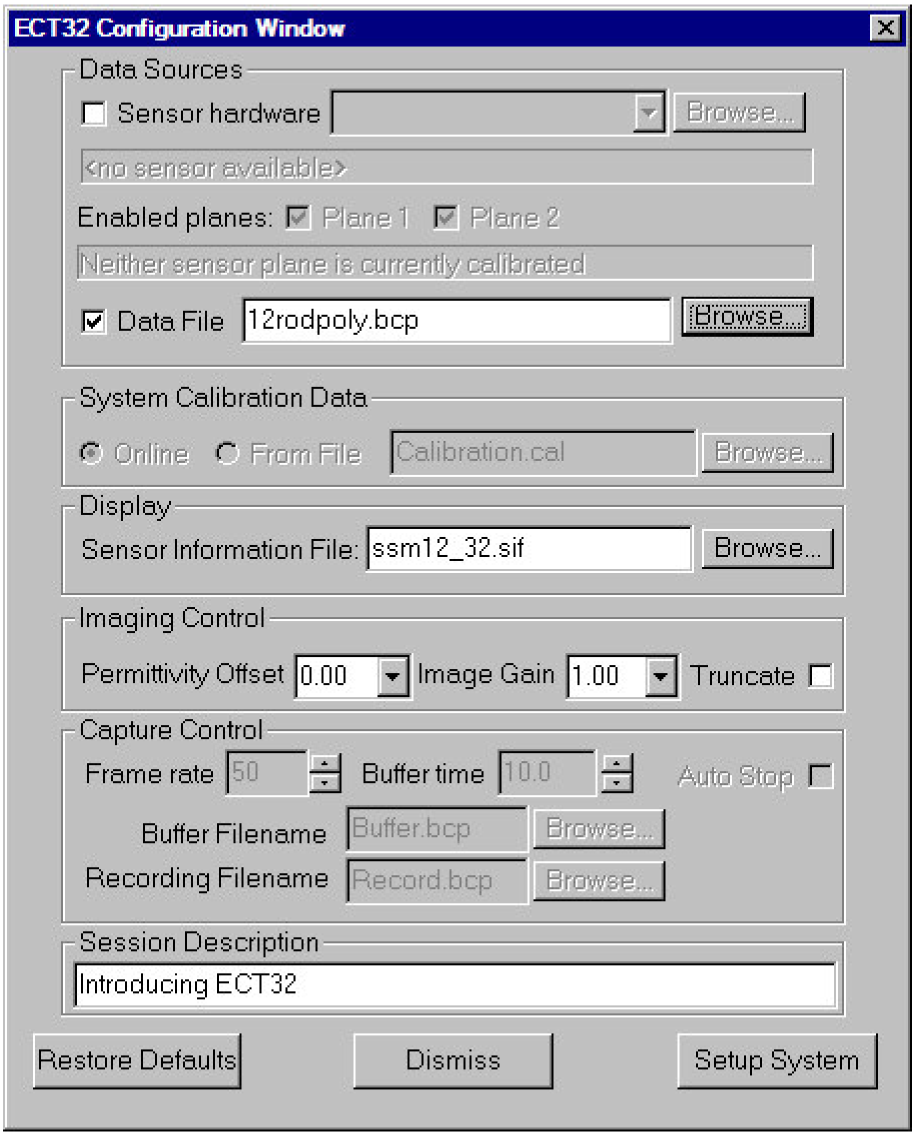


Figure 3.3. Configuration window for sample data file.

7. Check the parameters in the **Configuration window** and, if necessary, modify any parameters which differ from those shown in **figure 3.3**.

8. Left click the **Setup System** button at the **bottom RHS** of the **Configuration** window. The screen changes to the Main **ECT323v2 desktop window,** shown in **figure 3.4**.

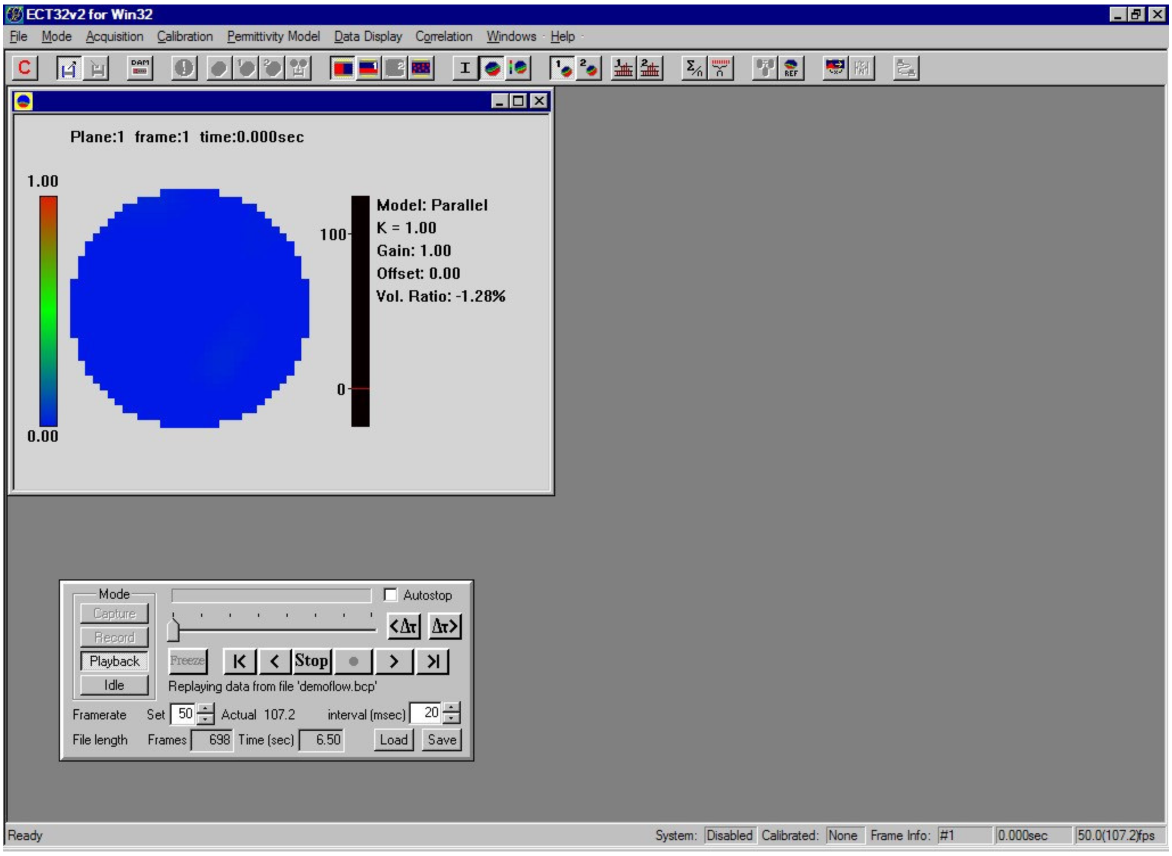


Figure 3.4. Main ECT32v2 software window

Note that in figure 3.4 there are **2 separate areas** inside the **main ECT32v2 window**. The first of these is the **Plane 1 image window** (showing a blue image of an empty sensor in figure 3.4) and also the **Control Panel**, located at the lower left hand side of the screen in figure 3.4. The functionality of the **Control Panel** is described in section 3.3.2 and also in section 4.2.4 of the **Reference** section of this **User Guide**. As will be shown later, it is possible to have further multiple image displays within the main **ECT32v2** window.

The **ECT32v2 Desktop** window also includes (at the top) a **Menu Bar** and a **Toolbar** which includes a large number of **control icons** arranged in groups. A comprehensive list of the **menu options** and **toolbar icons** are given in **sections 4.2.2** and **4.2.3** in the **Reference section** of this guide. There is also a **Status Bar** at the bottom of the window whose functionality is explained in **section 4.2.5.** The **Status Bar** only appears when the **ECT32v2 desktop** window is maximised.

The next section (3.3) explains how a **captured data file** can be **replayed** and **viewed** and illustrates how the choice of **permittivity (concentration) model** and **image reconstruction algorithm** changes the **ECT image** and associated parameters. This is an important feature of **ECT image reconstruction** and emphasises the need to select the **most appropriate reconstruction algorithm and permittivity model** for the specific application. Further information can be found in chapter 12 of the ***PTOM*** manual.

3.3 REPLAYING CAPTURED DATA

3.3.1 The Control Panel

Capacitance data (**.bcp**) files captured using the **ECT32v2** software and a **PTL300E ECT system** can be replayed and viewed using the **ECT32v2 Control Panel** shown in **figure 3.5.**

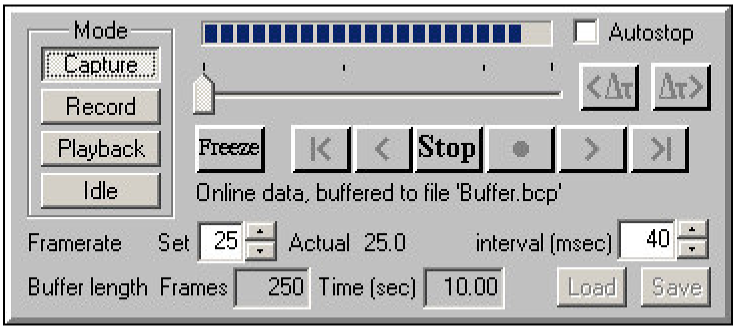


Figure 3.5 The ECT32 Control Panel

3.3.2 Basic LPP Image reconstruction (*PTOM Chapter 9*)

1. Click the **forward play** [>] button on the **Control panel** (second button from the right in figure 3.5). The **permittivity images** will be constructed from the **captured capacitance** data file and displayed in sequence in the image window. The **current image frame number** and the **time from the start of data collection** are displayed at the top of the image window and also on the right hand end of the **status bar** at the **bottom** of the window. The data in the sample data file was obtained by moving a small **circular dielectric rod** inside the sensor and **figure 3.6** shows a screenshot for **frame number 300**.

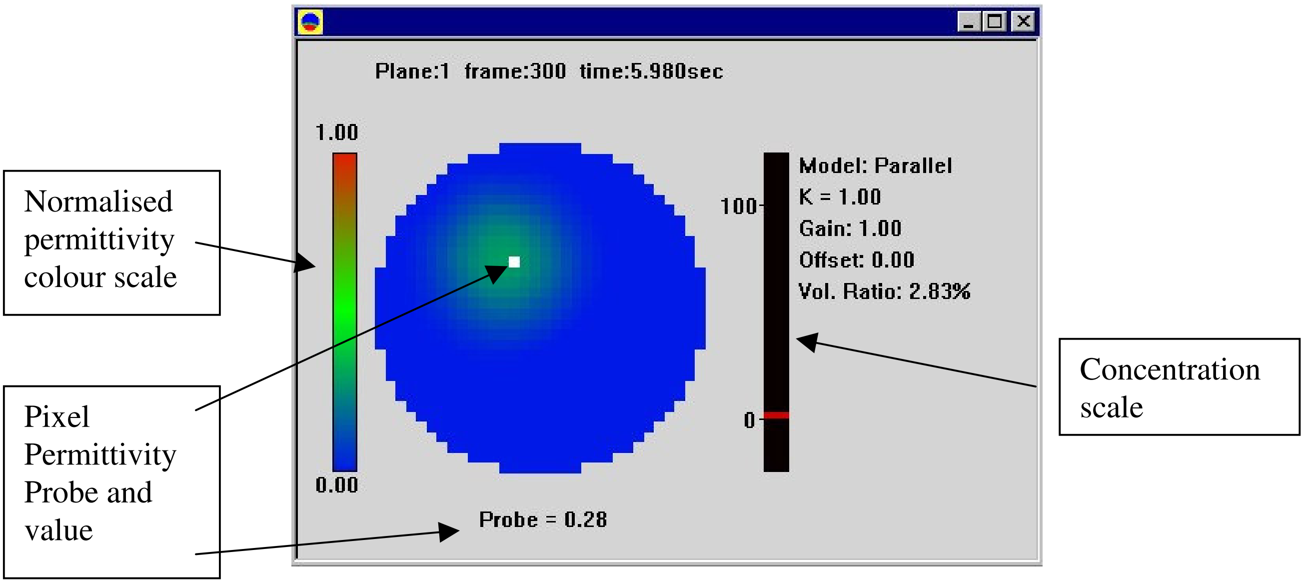


Figure 3.6. ECT image constructed using LBP and the parallel model

The **ECT image shows the normalised permittivity** distribution, displayed as an approximate circular image and based on a grid of 32 x 32 square pixels and a permittivity colour scale which extends from blue (normalised permittivity = 0), through green, to red (normalised permittivity = 1).

The image of the rod shown in figure 3.6 has been constructed using **the LBP algorithm** and a **simple parallel capacitance concentration/permittivity model** (*PTOM section 4*) . Note that the image is fairly faint and indistinct.

2. Click the **Stop button** on the **Control Panel** and then click the **reverse play** [<] button (to the left of the **stop** button) on the **Control Panel.** The captured data will be replayed in **reverse sequence.**

3. Click the **Go to last frame [>|]** and **Go to first frame** [|<] buttons at the edges of the **control panel** in turn**.** Note that these set the **displayed image** to the **last** and **first** captured **frames** respectively.

4. Click the **increment one frame** button [**Δτ>**]. The image will advance to the next frame. Similarly, click the **decrement one frame** button [**<Δτ**]. The image will change to the previous frame.

5. Finally, note that the **image frame** can be selected by **dragging** the **control panel slider button** using the **mouse**.

3.33 Using different concentration/permittivity models (*PTOM Chapter 12*)

1. Use a combination of the **Control Panel** buttons to set the display to show **frame 300** (as in figure 3.6).

2. Position the **mouse cursor** inside the **image** of the rod and left click the cursor. The **pixel under the cursor** is highlighted as a **white square** (the **pixel probe**) and the **normalised pixel permittivity** is displayed at the **bottom of the image** (in this case = **0.28** in **figure 3.6**). The overall **volume ratio** (the volume of the sensor space occupied by the rod) is given in a **text dialogue** at the RHS of the image (in this case the **Vol.Ratio** is **2.83%**).

3. Use the ***Permittivity Model > Set Permittivity Ratio*** menu sequence (**figure 3.7)** to set the **permittivity ratio** to 2 then click on the **OK** button. The ECT image should remain unchanged.

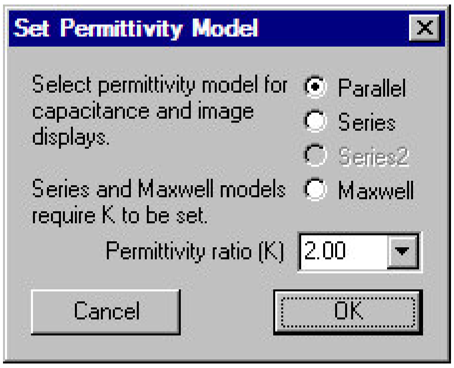


Figure 3.7. Set Permittivity Model Window

4. Click on the **Series Permittivity Model** icon button  on the **ECT32v2 Toolbar**. This is the second button (labelled "1") in a group of 4 buttons on the **Toolbar**, located immediately below the "**Data Display**" heading on the **Menu bar**. In **figure 3.8** below, it is the second icon from the left.

Figure 3.8. Image Control Icons

The ECT image changes to that shown in **figure 3.9**.

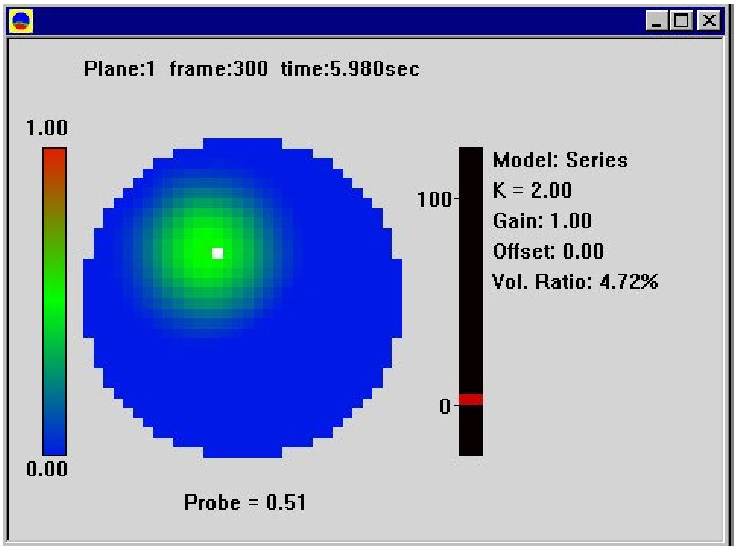
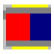
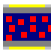


Figure 3.9. ECT image constructed using LBP and the parallel model

5. Note that the **rod image** becomes more intense and the **pixel probe** and **Volume Ratio** figures increase to 0.51 and 4.72%. The **image** is now being reconstructed using the **series capacitance model**. Click on the **Parallel Capacitance model icon button**  (immediately to the left of the **Series model** button on the **Toolbar**) to confirm that these values have changed from the original parallel model values of 0.28 and 2.83%.

6. Click on the **Maxwell model icon**  (RHS button in Model icon group) and note that the figures change again to 0.37 and 3.55% respectively.

7. Move the **mouse cursor** outside the image and click again to **turn off the pixel probe**.

3.34 Using iterative reconstruction techniques (*PTOM Chapter 13*)

1. Open the **Image Display Controls window** using the ***Data Display > Image Display Parameters*** menu sequence.

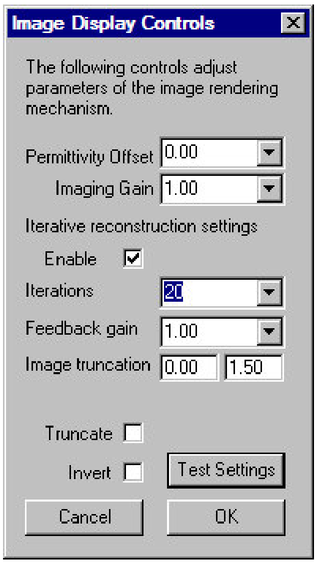
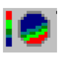


Figure 3.10. Image Display Controls Window.

Note that this window can also be obtained by using the **modify image display parameters icon**  , which is in the group of 3 icons on the section of the toolbar shown in **figure 3.8.**

2. Enable **iteration** by clicking the **enable check box** in this window and set the **limits** in the image truncation boxes to 0 and 1 repectively.

3. Set the **number of iterations** to 20 and click in the **Truncate box** to enable **image truncation**. The window contents should now be as shown in **figure 3.10**. Click on the **OK button**. The ECT image now appears as shown in **figure 3.11**.

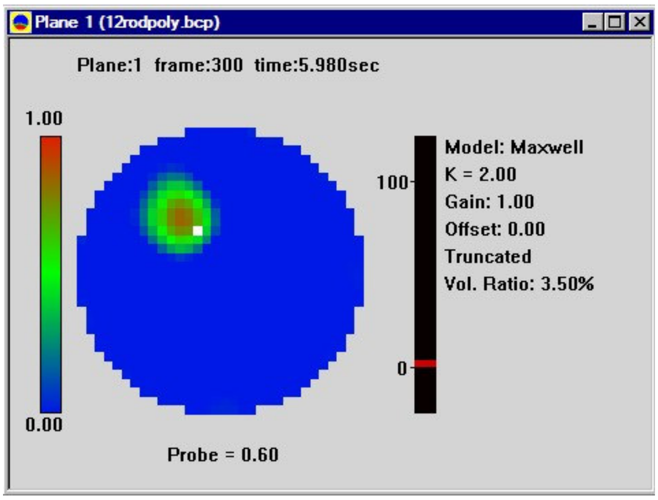
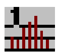


Figure 3.11. ECT image constructed using iteration and the Maxwell model

Note that the rod image has further intensified and that the figures have again changed (to 0.60/3.50).

3. Reselect the **Series** and **Parallel** models in turn (section 3.3.3) and note the changes in the image.

3.35 Displaying normalised capacitances. (*PTOM Chapter 7.3*)

1. Left click the **Plane 1 capacitances icon**  (2nd icon from right on the section of the toolbar shown in figure 3.8). This will open a new window, displaying the **normalised capacitances** as shown in **figure 3.12.**

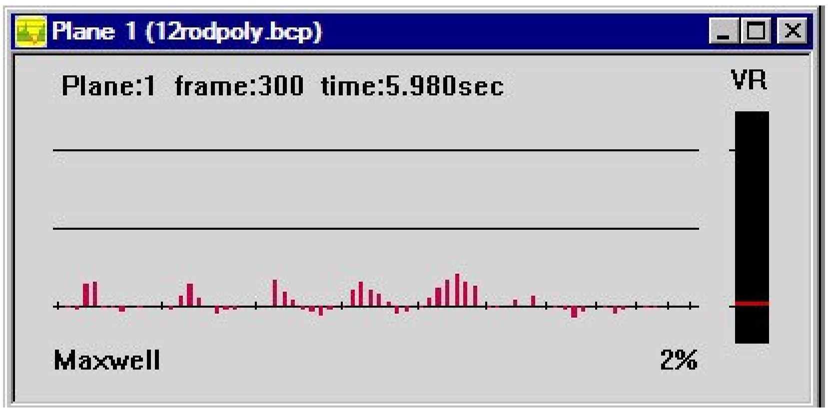


Figure 3.12. Normalised Capacitances

The capacitances are displayed as sets of **vertical lines** (with a gap between each set) where each line represents the **normalised capacitance** on a nominal scale from 0 to 100%, with facilities for 30% over and under-range values. The first set of lines are the capacitances C_{12} to C_{1E} in order (where E is the total number of electrodes), the second set is C_{23} to C_{2E} and so on. The **volume ratio** calculated from the normalised capacitances is displayed on a scale at the right hand edge of the capacitance window.

This completes a brief initial look at some of the the main features of the **ECT32v2** software. To **exit** the **ECT32v2** software, click on the **X box** at the **top right hand corner** of the screen. The system will prompt with the message "**Do you really want to exit from ECT32?**" Respond by clicking the **Exit ECT32** button.

The next few sections give further examples of the software functionality using some of the other example data files supplied with the ECT system.

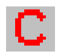
3.4 PLAYING BACK DATA FROM OTHER EXAMPLE FILES

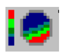
Now that the basic functionality of the **ECT32v2** software has been demonstrated, it can be used to view and play back some of the remaining data files in the **examples\data files** folder,

Note that these file have been named to indicate the type of sensor used to capture the data. For example, the file already used (**12_rodpoly_sp.bcp)** was captured using a **12-electrode single-plane** sensor and shows the image of a thin-walled tube filled with polypropylene beads. A full set of details of the example data files can be found in Appendix 2,

The important point to note here is that the **Sensor Information file** used to construct the image must match the geometry and number of electrodes on the sensor. The following sections explain how to use the **ECT32v2** software to display data from some of the remaining example data files, with comments on the data as appropriate.

3.4.1 Polypropylene beads in 12-electrode demonstration sensor

Either restart the **ECT32v2** software or select the **Configuration screen** using **icon 1**  . Repeat the steps listed in sections 3.2 and 3.3, but this time, select the **12_demo.bcp** file. This data file was generated using a standard 12-electrode **PTL demonstration sensor** of the type supplied with each ECT system for demonstration purposes. This sensor has an internal diameter of 50mm and is half-filled with polypropylene beads. The test data shows the effect of tilting the sensor first to one end and then to the other. This can be seen by playing the data back as described in section 3.3.

Open the **Image Display Controls window** using **icon**15  . Now set the **permittivity ratio** to 2, the permittivity model to **Maxwell** and use the **Control Panel** buttons to move through the data to **frame 493**, when the displayed permittivity image should ressemble that shown in figure 3.13.

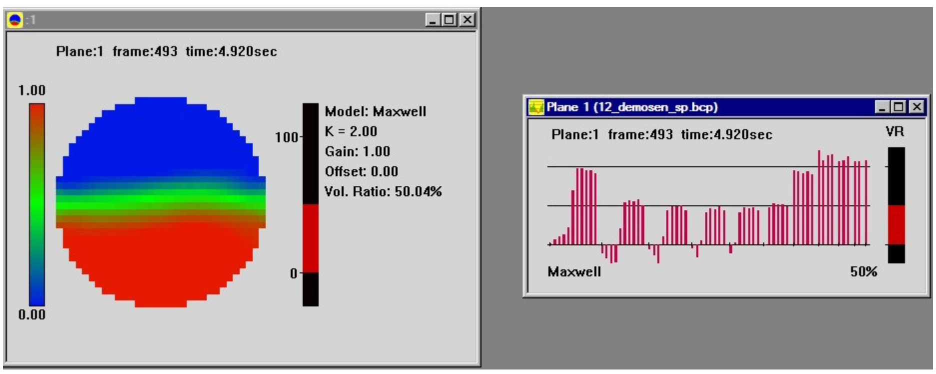
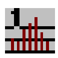


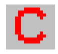
Figure 3.13 Sample data for demonstration 12-electrode sensor.

Click on the **Plane 1 capacitances icon**  (section 3.3.5) to view the normalised capacitances as well as the permittivity image. Note that the **Volume Ratio** scale in both windows reads approximately 50%, which agrees with the image of a half-full sensor.

Try selecting the other **permittivity models (Parallel** and **Series**) in turn and note how the **Volume Ratio** figure changes.

Now click the **pixel probe** in the blue and red areas above and below the centre line of the image. Note that the **pixel values** are outside the nominal normalised permittivity limits of 0 and 1. This is caused by a combination of the soft field effect and the simple linear image reconstruction algorithm used and is typical of what happens when there is a severe permittivity contrast inside the sensor. In this situation, it is necessary to use more complex non-linear image reconstruction methods to obtain accurate images.

3.4.2 Multiple test objects

Either restart the **ECT32v2** software or select the **Configuration screen** using **icon 1**  and repeat the steps listed in sections 3.2 and 3.3, but this time, select the **8_4rod_sp.bcp** data file. This data file was generated using a set of **four tufnol dielectric rods**, each of diameter 12mm, located inside an 8-electrode sensor of internal diameter 100mm. The sensor was calibrated using air and polypropylene beads. As the **data file** was generated using an **8-electrode** sensor, the **Sensor information file** must be changed to suit the sensor. This is done by selecting the Sensor information file **ssm8_32.sif** in the **Display group** of the **Configuration window**.

Once the required **Data** and **Sensor information files** have been selected in the **Configuration screen**, click on the **Setup System** button in the **Configuration screen**.

Note that the following **warning message** will appear if the **Sensor Information file** has been changed from that set when the **ECT32v2** software was used previously.

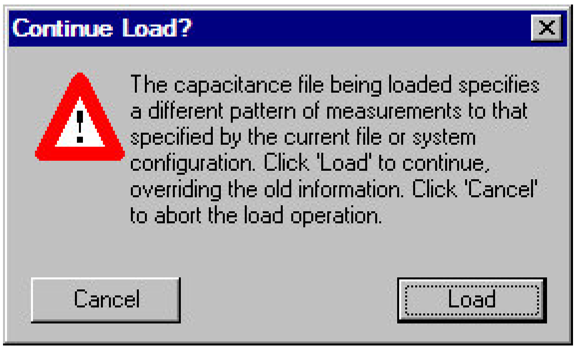


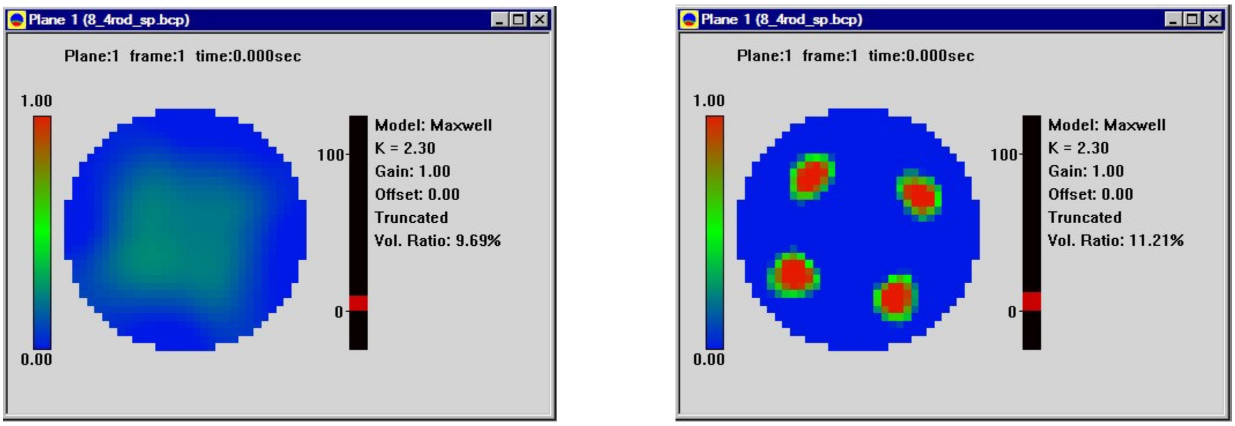
Figure 3.14 Sensor information file warning message

Click on the **Load** button and the new data file and sif file will be loaded.

As the **ECT32v2** software defaults to displaying the data as an image generated using the LBP algorithm, the parallel permittivity model and no iteration on startup, the **ECT32v2 desktop** will show a faint and very blurred image of the rods, as shown in figure 3.15(a).

However, by selecting the **Maxwell** model and using **100 iterations**, the image changes to that shown in figure 3.15(b), where the individual rods can be clearly seen.

To obtain the image shown in figure 3.15(b), select the **Maxwell** permittivity model (section 3.33), set the **permittivity ratio** to **2.3** and set the **Image display window** (section 3.3.4) to **enable iteration,** with **100 iterations** with **truncation** enabled.



(a) Without iteration **(b) after 100 iterations**

Figure 3.15. ECT images of 4 dielectric rods without and with iteration.

Replay the data and note that the dielectric rods are initially stationary and are then rotated inside the sensor. This data file shows that ECT can differentiate between a number of different discrete objects located inside the sensor.

The changes in the image caused by **iteration** can be demonstrated by clicking on icon 13a which **toggles iteration** on and off.

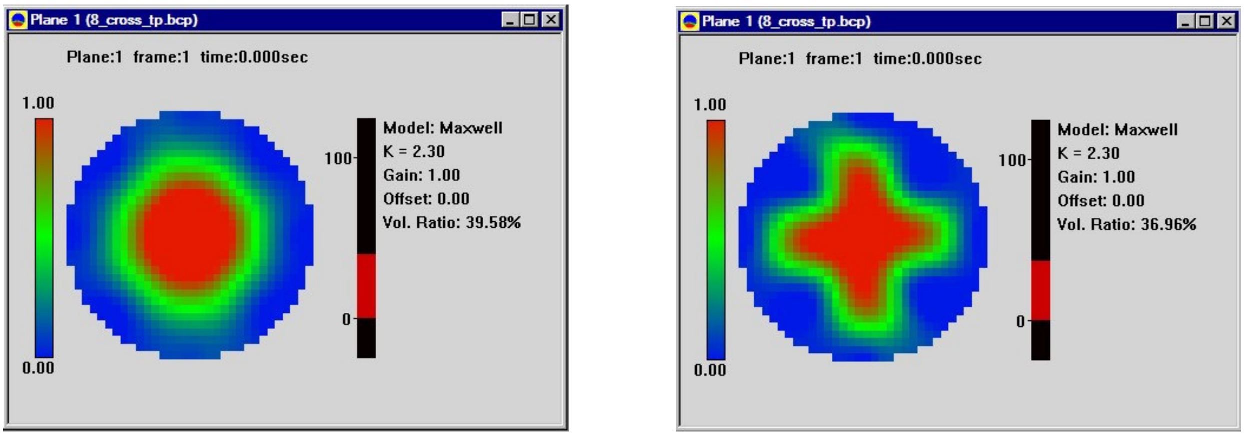
Note that the **nominal volume ratio** of each rod is (12/100)^2 * 100% = 1.44%. So the **overall volume ratio** of the 4 rods is (4 * 1.44) = 5.76%. However, the **ECT image** shows a value of 11.2% for the volume ratio of the iterated images.

The reason for this discrepancy is that the relative permittivity of the (tufnol) rods (2.3) is higher than the permittivity (1.6) of the polypropylene beads used to calibrate the sensor.

The correct volume ratio of the rods can be obtained by dividing the calculated volume ratio by the normalised permittivity of the rods, that is by (2.3 - 1)/(1.6 - 1) = 2.17. In this case, the displayed volume ratio (11.2) becomes 11.2/2.17 = 5.16%, which is close to the correct value of 5.76%.

3.4.3 Complex test object

The example data file **8_cross_sp.bcp** was obtained by placing an object having a section in the form of a cross with axes of length 48mm inside a circular 8-electrode sensor of internal diameter 60mm. The cross image can be obtained using iteration.



(a) without iteration **(b) after 100 iterations**

Figure 3.16 Images of a perspex cross without and with iteration

3.4.4 Fluidised bed

The data file **8_fb200_tp.bcp** was captured using a **twin-plane 8-electrode sensor** of internal diameter 60mm, with a spacing of 32mm between the centres of the 2 sets of measurement planes. The sensor was located on the outside of a vertical 60mm OD perspex tube which was partially filled with dry sand. The sand was fluidised by air blown from below.

Load the data file in the usual way, select a permittivity ratio for sand of 3.0 and use the control panel to select frame 171. The ECT images will be displayed as shown in figure 3.17, where Plane 1 is the upper measurement plane and Plane 2 is the lower measurement plane.

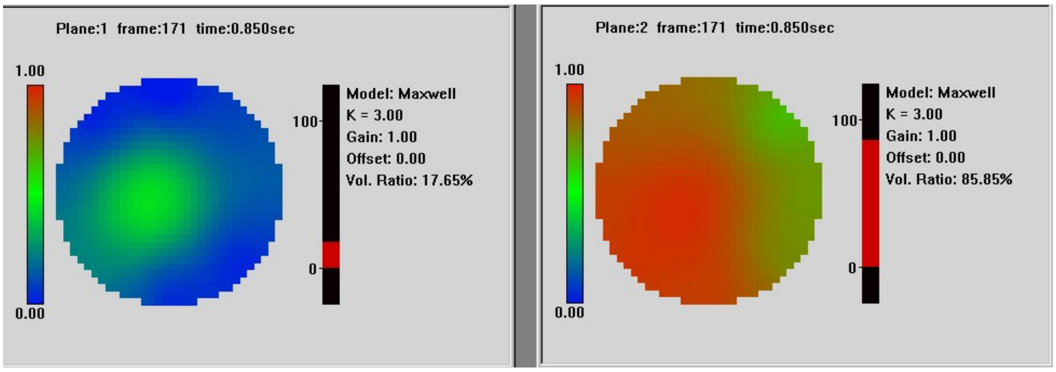


Figure 3.17. Fluidised bed images. plane 1 fillimg, plane 2 almost full

Note that the images show that Plane 2 (the lower plane) is almost full of sand (86%), whereas plane 1 (the upper plane) is fairly empty(17.7%). Now click on the **increment one frame** button **[Δτ>]** on the **control panel** and advance the frame count one frame at a time. The progress of the slug of sand up the sensor can be clearly seen.

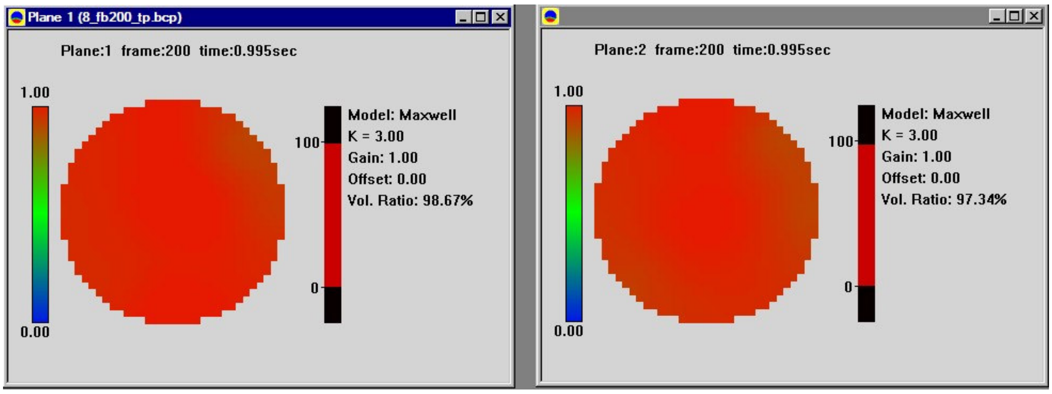


Figure 3.18 Fluidised bed images, both planes full

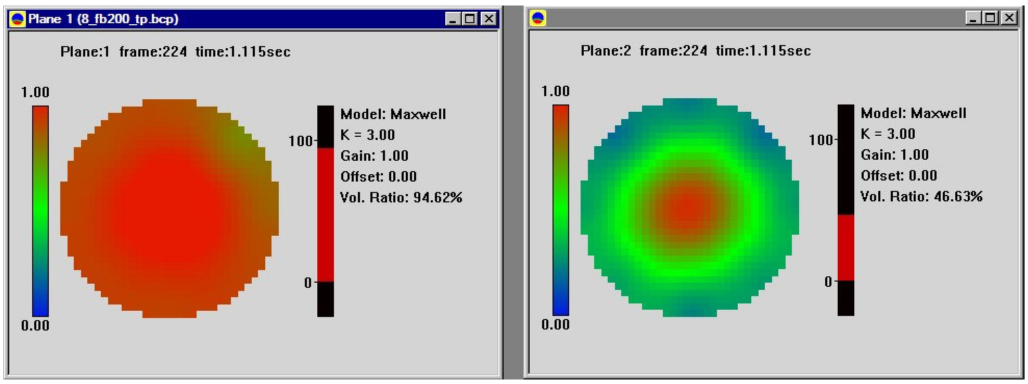


Figure 3.19 Fluidised bed images, plane 1 full, plane 2 emptying.

Figure 3.18 shows the situation at frame 200, where both planes are now filled with sand while figure 3.19 shows the situation at frame 224, where plane 2 has started to empty.

3.4.5 Other example data files

Several other **example data files** are supplied with the **ECT32v2** software and can be used to demonstrate its operation. These include single-plane data for a dielectric tube (**8_tube_sp.bcp**), data for gravity flow in a twin-plane 8-electrode sensor (**8_gravityflow_tp.bcp**), the passage of a ball down a vertical tube (**8_golfball_tp.bcp**) and a single dielectric rod inside an 8-electrode sensor (**8_rod_sp.bcp**).

3.5 CONVERTING CAPACITANCE DATA FILES INTO ASCII DATA

The **captured capacitance data files** are stored in **binary format** to reduce the size of the files. These files can be converted into **ASCII text** format if required for use with other software. Details are given in section 6.3 of the **Reference section** of this guide. The following section shows how a **binary capacitance data file** can be converted into a file of **absolute capacitances** in ASCII format.

3.5.1 Generating an absolute capacitance data file in ascii format

1. Select the **Generate ASCII data files** option from the **File** menu.

2. Click on the **OK** button, which will open the **ASCII file generation window** shown in **figure 3.20.**

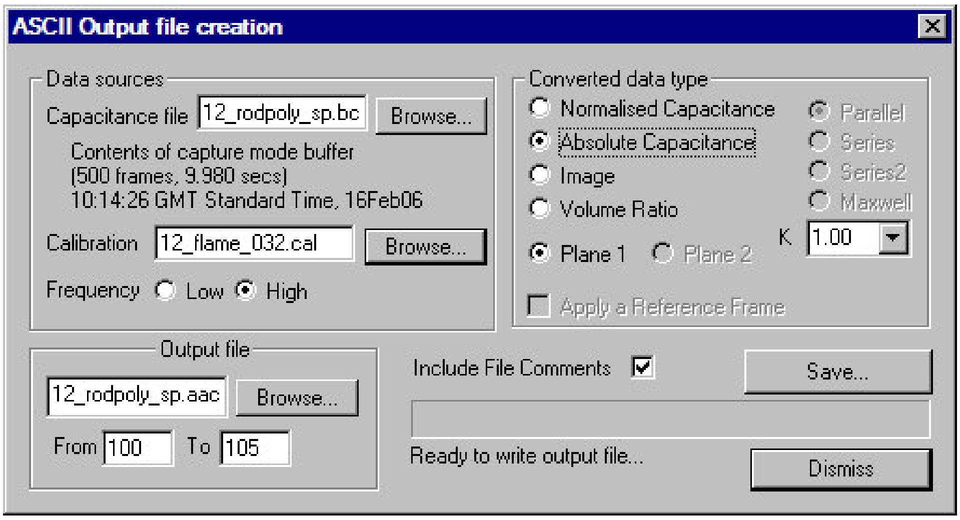


Figure 3.20. ASCII output file creation window

3. In the **Data sources** parameter group, locate the required **capacitance data file** (**12_rodpoly_sp.bcp)** in the **Capacitance File** box using the **Browse** button. This file is in the **c:\ect32v2\working\examples\data files** folder.

4. Similarly, use the **Calibration Browse button** to select the **calibration file** used to produce this data file in the **Calibration** file box. In this case, the required file is **12_flame_032.cal**, which is located in the **c:\ect32v2\working\examples\calibration files** folder.

5. If necessary set the **frequency** option to the setting used to generate the original capacitance data (normally high).

6. In the **Output file** parameter group, use the **Browse button** to select a folder for the **output file** which is to contain the **absolute capacitance** data and then click on **Save** without entering a file name. An output file with the same name as the input data file, but with a new file extension will be generated automatically. In this case, the output file name will be **12_rodpoly_sp.aac**.

7. Set the **range of capacitance frames to be converted** in the **From** and **to boxes.** Suggested values are 100 and 105, which will convert 6 frames of data.

8. In the **Converted data file list,** select (check) the **Absolute Capacitance** option.

9. When all of the above parameters are correct, click on the **Save** button. The data will be converted and written to the **output file** which will be given the file extension **.aac** (**ASCII Absolute Capacitance**) and a **finished** message will appear. To exit this window, click on the **Finished** button.

10. The **converted data file** (**12_rodpoly_sp.aac)** will be saved in the location specified in the **Output file** box and can be viewed with a suitable word-processor such as Microsoft Word as shown below.

Similar techniques can be used to convert the data files into other file formats and full details can be found in **section 6** of this guide.

3.5.2 Example of converted absolute capacitances data file (5 frames).

```
## Absolute capacitance data file
## Created by: ECT32v2 for Win32 2.32 (Jan 12 2005 14:39:26)
## Source: 12_rodpoly_sp.bcp
##    Description: Contents of capture mode buffer
##    Date: 10:14:26 GMT Standard Time, 16Feb06
## Electrodes = 12, Measurements = 66
## Data for Plane 1


## frame 100 (1980 msec)
228.37 32.16 14.67 10.88 7.82 3.94 1.74 3.16 8.93 35.19 234.67
227.05 29.41 9.02 8.08 8.51 8.76 9.35 9.95 13.65 33.50
233.29 31.78 13.97 9.72 8.09 7.78 7.71 8.60 14.18
229.37 33.89 14.26 8.10 6.39 6.60 7.50 8.05
252.27 34.84 13.00 6.93 6.00 7.27 5.72
253.39 32.18 11.93 5.96 5.68 4.68
248.62 32.46 12.91 6.55 5.94
246.76 32.07 10.15 8.11
244.26 28.06 13.63
232.90 32.21
235.21

## frame 101 (2000 msec)
228.30 32.25 14.76 10.84 7.90 4.03 1.74 3.25 9.07 35.15 234.61
227.11 29.47 9.09 7.96 8.51 8.88 9.35 9.94 13.80 33.51
233.29 31.71 13.96 9.69 8.17 7.91 7.73 8.78 14.15
229.49 33.86 14.32 8.17 6.53 6.62 7.33 8.04
252.27 34.78 12.94 6.81 5.83 7.29 5.75
253.32 32.24 12.05 5.95 5.82 4.79
248.69 32.43 12.88 6.67 6.10
246.83 32.12 10.19 8.23
244.12 28.15 13.63
232.83 32.22
235.15

## frame 102 (2020 msec)
228.37 32.18 14.65 10.89 7.94 3.92 1.69 3.14 8.91 35.13 234.54
227.05 29.53 8.99 8.03 8.65 8.92 9.47 9.97 13.72 33.47
233.42 31.69 13.96 9.57 8.11 7.84 7.60 8.67 14.09
229.37 33.81 14.32 8.30 6.33 6.51 7.50 7.94
252.41 34.72 12.87 6.76 5.79 7.20 5.69
253.26 32.13 12.03 6.06 5.78 4.77
248.69 32.38 12.91 6.47 5.96
246.70 32.00 10.37 8.20
244.33 28.21 13.56
232.90 32.13
235.15
```

```
## frame 103 (2040 msec)
228.37 32.14 14.63 10.97 8.01 3.89 1.59 3.14 8.98 35.18 234.61
227.05 29.50 8.99 8.08 8.47 8.82 9.49 9.94 13.84 33.41
233.35 31.71 13.97 9.58 8.06 7.80 7.75 8.58 14.18
229.56 33.97 14.27 8.06 6.49 6.67 7.39 7.99
252.34 34.84 12.87 6.91 5.94 7.35 5.77
253.39 32.10 12.00 6.07 5.85 4.72
248.82 32.49 12.84 6.59 6.00
246.76 32.05 10.41 8.28
244.12 28.33 13.62
232.83 32.18
235.21

## frame 104 (2060 msec)
228.43 32.25 14.74 10.91 7.96 4.03 1.54 3.10 9.05 35.23 234.61
227.11 29.49 8.92 7.98 8.58 8.88 9.45 9.94 13.75 33.45
233.29 31.72 13.96 9.62 8.04 7.80 7.61 8.70 14.12
229.31 33.88 14.34 8.14 6.40 6.60 7.33 8.04
252.27 34.78 12.91 6.69 5.92 7.39 5.81
253.32 32.26 12.05 5.93 5.97 4.69
248.56 32.37 12.93 6.45 6.04
246.70 32.09 10.23 8.26
244.19 28.29 13.46
232.76 32.31
235.35

## frame 105 (2080 msec)
228.43 32.21 14.76 10.78 7.84 3.89 1.72 3.21 8.88 35.05 234.61
227.11 29.36 9.06 8.03 8.55 8.90 9.53 9.84 13.72 33.57
233.29 31.74 14.00 9.57 7.95 7.85 7.48 8.74 14.19
229.62 33.92 14.29 8.04 6.47 6.49 7.47 8.13
252.13 34.84 12.97 6.81 5.75 7.29 5.73
253.39 32.35 11.97 6.04 5.95 4.74
248.69 32.42 12.99 6.63 6.02
246.70 32.07 10.23 8.20
244.12 28.31 13.49
232.76 32.11
235.08

##EOF
```

3.6. TO EXIT THE ECT32 SOFTWARE

This completes the **quick tour** of the **ECT32V2 software**.

To e**xit** the software, click on the **X box** at the **top right hand corner** of the screen. The system will prompt with the message "**Do you really want to exit from ECT32?"** Respond by clicking the **Exit ECT32** button.

An **overview of the software** functionality has already been given in section 2. A detailed explanation of the individual software components which are operative in **Playback mode** is given in the following **Reference sections (4 to 6)**.

REFERENCE INFORMATION

In the following sections (4 to 6), the operation of the **Configuration window** and the **ECT32v2 desktop window** in **Playback mode** are described in detail. We have tried to identify **the relevant software menu headings and options** in the **ECT32v2** software which are relevant to the topics under discussion and have indicated these items in ***italics*** where appropriate.

Note also that where the acronym ***PTOM*** appears, it refers to a specified section or chapter in the **PTL300E Operating Manual** which should be referred to for further information about the topic.

4. SIMPLE PLAYBACK OF CAPTURED DATA

4.1 SYSTEM CONFIGURATION WINDOW (*Mode menu*, *Configure system*)

The **ECT32v2 software** has three main modes of operation, Data Capture, **Playback** and Record modes, together with an additional Idle mode, all of which are initiated following an initial **Configuration** process. This **User Guide** deals exclusively with the case where the **ECT32v2** software is used in **Playback Mode**.

The **Configuration Window** (shown in figure 4.1 below) appears each time the **ECT32v2** software is started up and is used to initialise the ECT system and software. The **Configuration window** can also be accessed after the software has been started, either by clicking on **icon 1** on the toolbar of the **ECT32v2 Desktop** or by selecting the **Configure System** option from **the Mode menu.**

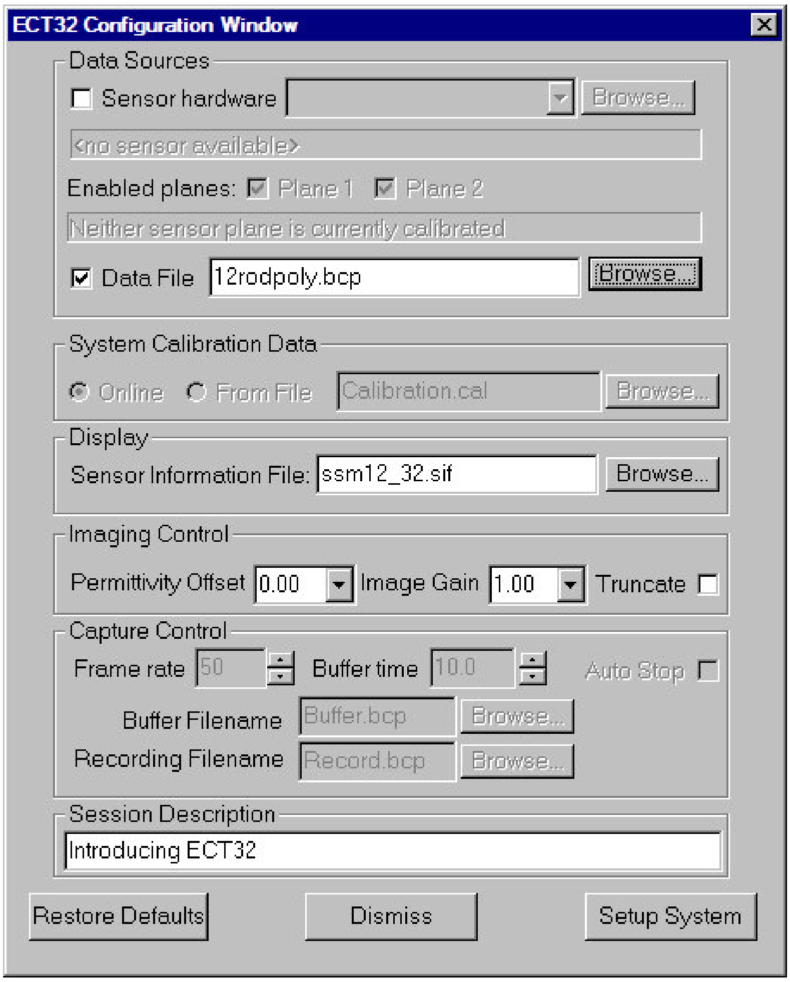


Figure 4.1 ECT32v2 Configuration window (playback mode)

The **Configuration window** contains a number of sets of **parameter groups** titled **Data sources, System Calibration Data, Display, Imaging control, Capture control** and **Session Description**. The text order in this **Reference section** of the **User Guide** follows the groupings of the controls and settings contained in the various parameter groups in the **Configuration window.**

4.1.1 Data sources group

This parameter group allows the user to select the basic mode of operation of the ECT system.

If the **Sensor hardware option** is selected, the ECT system will be set up to capture live capacitance data using a **DAM200E Capacitance Measurement unit**. The use of the **ECT32v2** software in this mode is not covered by this **User Guide**. Instructions for using the **ECT32v2 software** with the **DAM200E capacitance** measurement hardware are given in **section 5** of the **PTL300E Operation Manual**.

If the **Data File** option is selected, the **ECT32v2 software** operates **in Playback mode** with **captured data files** only. In this mode, data can be replayed from a captured **capacitance data file** which is selected using the **Browse** button. This **User Guide** deals exclusively with the **Playback** mode of operation.

4.1.2 System calibration data group

The parameters in this group are not used in **Playback mode**.

4.1.3 Display group (sensor information file) (***PTOM*** *Chapter 10*)

A suitable valid **sensor information file** (sensitivity map) must be selected using the **Browse** button before captured data files can be replayed as permittivity images. In the **normal mode of operation, permittivity images** are displayed by default, but the **normalised capacitances** can also be displayed on request. However, **permittivity images** can only be produced if **a valid sensor information file** has been selected. If no suitable file is selected, only the **capacitance data** can be displayed.

The **sensor information file** contains information which controls the operation of the **ECT32v2 software,** including the **number of electrodes**, **order of measurements**, and the **geometry and back-projection imaging** parameters for each **specific image format.**

A set of generic **sensor information (.sif) files** is supplied with each PTL ECT system, together with specific **.sif** files for any custom sensors supplied with the system and these files are stored in the **Configuration folder.**

The **standard sensor information files** are in the form: **SSMA_B.sif** where **A** is **the number of electrodes** and **B** is the **display resolutions in pixels per line**. These sensor information files can be used for most normal applications. For example, **SSM12_32.sif** is the standard sensor information file for a 12 electrode sensor to display an image at a resolution of 32 X 32 pixels. Note that **the number of electrodes** in use is defined by the **sensor information file** in the **Display** group**. Permittivity images** will be displayed as long as a valid **.sif** file is selected.

A second set of generic sensor information files have the form: **WSMA_B.sif**. These **.sif** files are for use with sensors having **external electrodes** and which are to be used for imaging **high permittivity** materials such as **water**. In these files, the coefficients corresponding to adjacent electrode measurements have been set to zero and the effect is to omit capacitance measurements made between adjacent electrodes. When images are displayed using the **water** sensitivity maps, the **pixels** corresponding to measurements between **adjacent electrodes** will display zero values of permittivity and should be ignored.

4.1.4 Imaging control group parameters

The parameters in this group allow the displayed **permittivity image** to be modified as follows:

Permittivity offset:

If a value other than zero is set here, the normalised permittivity image display will be offset by the value entered, in the range 0 - 1. This allows the **lower value** of the **normalised permittivity scale** to be **offset** from the **normal value of zero**. When used with the **Image gain control** this option allows **small variations in permittivity around a fixed value to be seen**. The **default offset value** is **zero**.

Image gain:

The normalised pixel permittivity values are multiplied by the gain value entered. The normal (default) value is 1.

Truncate:

If this option is checked, the displayed image pixel **permittivity values K** are **truncated** to lie within the range $0 < K < 1$. This facility can be used to alleviate the effect of severe field distortion.

4.1.5 Capture control group parameters

The parameters in this group are not used in **Playback mode**.

4.1.6 Session description group parameters

The parameters in this group are not used in **Playback mode**.

4.1.7 Function buttons

The **three buttons** at the **bottom of the Configuration window** have the following functions:

Restore Defaults: The **default values** for the C**onfiguration screen parameters** are used to replace all existing settings.

Dismiss: The **Configuration screen** is exited without implementing the settings in the screen.

Setup System: The **Configuration screen** settings are used to set up the **ECT32v2** software for **data replay**.

4.2 THE ECT32v2 DESKTOP WINDOW

4.2.1 Overview

Once the **ECT32v2 software** has been configured, the **ECT32v2 Desktop window** is displayed. This window is the main control and display window for the **ECT32v2** software and allows **capacitance data** to be **captured** and **permittivity images** to be displayed**.**

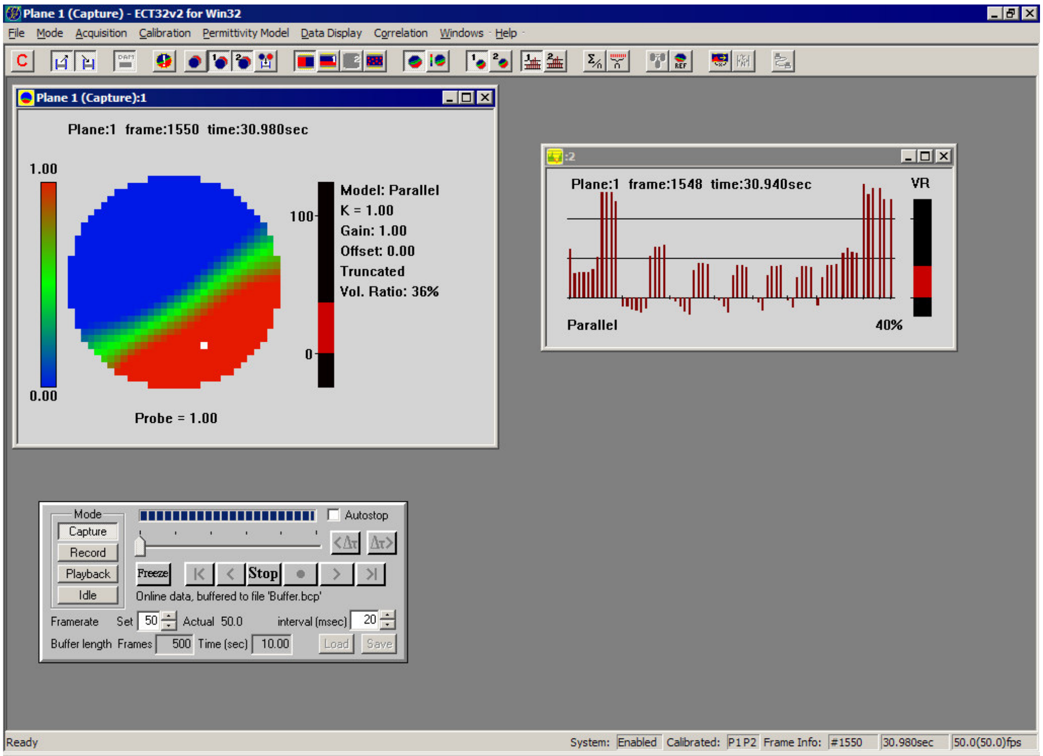


Figure 4.2. ECT32v2 Desktop window

The **ECT32v2 Desktop** (shown in **figure 4.2**), consists of a **title bar** (at the top of the window)**, a menu bar** (immediately below the **title bar),** a **toolbar** (immediately below the **menu bar**), a **display area** containing a **control panel,** below which is a **status bar** with **indicators** (at the bottom of the window). N.B. The **ECT32 Desktop window must be maximised** to display the **Status bar.** The **control panel** is shown separately and at a larger scale in **figure 4.3.**

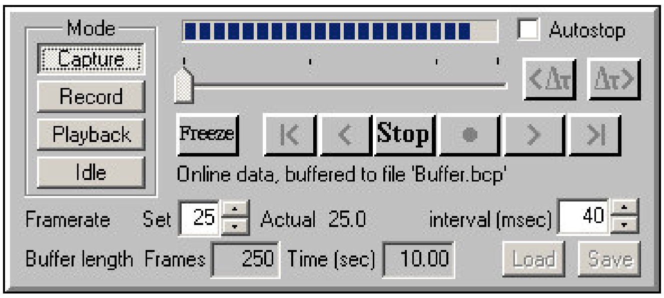


Figure 4.3. Control Panel window

Although the **Configuration** window offers a convenient way to set up the ECT system, the continuous operation of the software is normally carried out by the use of the **menus** on the **menu bar,** the **tool buttons** on the **toolbar** and the **control panel.** The detailed functionality of the **menu bar**, **toolbar**, **control panel** and **status bar** are described in the following sections.

4.2.2 The menu bar

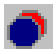
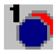
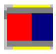
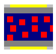
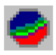
The **menu headings** on the **menu bar** control the major functionality of the **ECT32v2** software Most of the **Control menu** functions can be implemented by alternative means, either by the use of **tool buttons,** represented by **icons on** the **toolbar**, or by **function** buttons on the **control panel,** or by **parameters** set in the **Confguration** window.

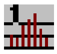
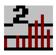
Section 4.2.2.1 lists the **menu** and **sub-menu headings** on the **menu bar** and gives details of any **alternative means** of implementing these menu functions by the use of the **Toolbar**, **Control panel** or **Configuration** window.

4.2.2.1 MENU BAR OPTIONS

Note that an asterix (*) in the list below, indicates that this option is not active in **Playback mode**.

Main Menu	**Sub-menu**	**Alternative implementation**
		(Numbers refer to toolbar **icons**)
File	Load Recorded Data	2 
	*Set Recorded Data filename	3 
	*Set Capture Mode Buffer Filename	Configuration window
	Save As...	Control Panel save button
	*Set Session Description	Configuration window
	Generate Ascii Data Files...	None
	*Data streaming Network Connection	26 
	Exit	None
Mode	Configure System	1 
	*Capture Mode	Control Panel Capture button
	*Record Mode	Control Panel Record button
	Playback Mode	Control Panel Playback button
	Idle Mode	Control Panel Idle button
***Acquisition**	*Enable/Disable Measurement System	4 
	*Select Sensor Planes	None
	*DAM200E Timing Parameters	None

Main Menu	Sub-menu	Alternative implementation
***Calibration**		(Numbers refer to toolbar **icons**)
	*Reset Baselineand Measurement freq.	5 
	*Calibrate Online (selected planes)	6 
	*Calibrate Plane 1 only	7 
	*Calibrate Plane 2 only	8 
	*Load Calibration File	Calibration window Load File
	*Save Calibration File	Calibration window Save File
Permittivity Model		
	Parallel model	10 
	Series Model	11 
	*Series 2 Model	12  (Not in use)
	Maxwell Model	13 
	Set Permittivity Ratio (K)	None
Data Display		
	Enable iterative image reconstruction	13(a) 
	Load Sensor Information File	14 
	Sensor Information File details	None
	Image Display Parameters	Configuration window
	Normal Image Display	None
	Quadrant Image Display	None
	Enable Continuous Averaging	20 
	Continuous Averaging Controls	21 

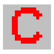
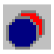
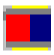
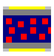
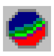
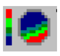
Main Menu	Sub-menu	Alternative implementation (Numbers refer to toolbar **icons**)	
Correlation			
	*Enable/Disable Correlation	24	
	*Sensor Spacing	None	
	*Correlation Controls	25	
	*Enable Reference Frame	22	
	Reference Frame Controls	23	
Windows	Display Plane 1 Permittivity Image	16	
	Display Plane 2 Permittivity Image	17	
	Display Plane 1 Capacitances	18	
	Display Plane 2 Capacitances	19	
	Tile Windows	None	
Help	About ECT32v2 for Windows	None	
	List of active windows		

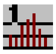
4.2.3 The tool bar

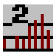
The functionality of the **control buttons** on the **toolbar** is shown in **the tool bar icon function list** on the next few pages. The **toolbar button functionality** can also be displayed on the PC screen by positioning the **mouse pointer** over **a toolbar button** for a second or so. In this case, information about the **functionality** of the button is displayed **next to the button** and also in more detail **at the left hand side** of the **status bar** at the **bottom** of the **ECT32v2 Desktop window**.

An asterix (*) in the list below, indicates that this option is not active in **Playback mode**.

4.2.3.1 Tool bar icon function list

	Icon	Function
1.		Displays the Configuration Window
2.		Loads recorded data file
3.		* Sets recorded data file name
4.		*Selects data capture subsystem hardware DLL
5.		*Resets Baseline and measurement frequency
6.		*Calibrates sensor (selected planes)
7.		*Calibrates sensor (plane 1 only)
8.		*Calibrates sensor (plane 2 only
9.		*Saves calibration data to file
10.		Selects parallel permittivity model (default setting)
11.		Selects series permittivity model 1 (requires permittivity ratio)
12.		*Selects series permittivity model 2 (no permittivity ratio required)
13.		Selects Maxwell permittivity model
13(a)		Enable/disable iterative image reconstruction
14.		Loads sensor information file (sensitivity map etc.)
15.		Modifies image display parameters (Gain, offset, truncation, inversion, iteration)
16.		Selects and displays plane 1 permittivity image
17.		Selects and displays plane 2 permittivity image

18.  Selects and displays plane 1 normalised capacitances

19.  Selects and displays plane 2 normalised capacitances

20.  Enables Continuous Averaging

21.  Accesses Averaging Controls

22.  Enables Reference Frame Option

23. 

Accesses Reference Frame Controls

24.  *Enables/Disables Cross-Correlation

25.  Accesses Correlation Controls

26.  *Sets up Network Connection

4.2.4 The control panel

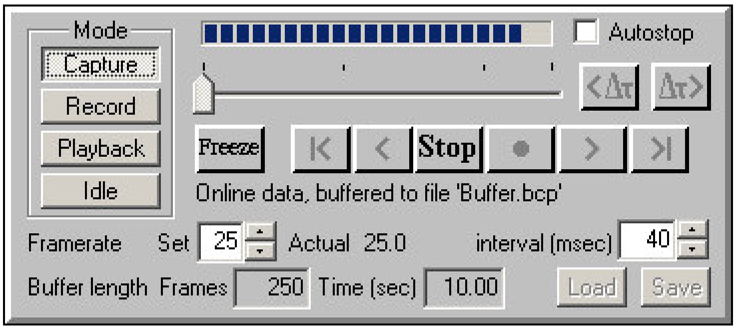


Figure 4.4 Control Panel

The **control panel** is shown in **figure 4.4** and the functions of the controls are as follows:

Note that an asterix (*) in the list below, indicates that this option is not active in **Playback mode**.

***Capture mode button.** This control button is not used in **Playback mode**.

***Record Mode Button.** This control button is not used in **Playback mode**.

Playback mode button. (*Alternative implementation, Mode menu, Playback mode*)

The contents of the **buffer file** or a selected **recorded data file** are replayed.

Idle mode button. This control button is not used in **Playback mode**.

***Freeze button**. This control button is not used in **Playback mode**.

***Autostop option**: This control button is not used in **Playback mode**.

Frame rate. This sets the nominal frame rate in **frames per second in Playback Mode**. The interval between frames, corresponding to the set frame rate, is displayed as **Interval (msec).** The **Frame rate** may also be set by inputting an integer directly into the **Interval data box**.

Note that the **frame rate** set in **Playback mode** sets the **playback mode frame rate** only.

***File length**. This parameter is not used in **Playback mode**.

Load button. (*Alternative implementation, File menu, Load Recorded data*)

This button loads a pre-recorded data file for viewing.

Save button. (*Alternative implementation, File menu, Save As...*)

This button saves the current buffer memory contents to a new file name.

[|<] **button**. Moves to the start of the data file.

[>|] **button**. Moves to the end of the data file.

[<] **button**. Reverse play button.

[>] **button**. Forward play button.

[Δτ>] **button**. Increment one frame

[<Δτ] **button**. Decrement one frame.

The **STOP** button halts the display without remembering direction.

At the top of the **control panel,** the **slider** control allows the **frame position** in the **file** to be forced with the **mouse**. The range of this **slider** is the **size of the file**. By holding the left mouse button down, the position of the slider indicator can be relocated by dragging it with the mouse.

4.2.5 The status bar

As well as giving detailed information about the tool button functionality on the left-hand end of the bar, the **status bar** also contains **indicators** which appear on the **right hand side** of the bar and show the current status of the following parameters:

System status: This will show the message **"disabled"** in **Playback mode**.

Calibration status: This will show the message **"none"** in **Playback mode**.

Frame information: Shows current frame number, time stamp and frame capture rate

NB. The ECT32 Desktop window must be maximised to display the Status bar.

4.3 EXAMPLE OF REPLAYING CAPTURED DATA

As an example of how 10 seconds of previously captured data can be replayed and viewed, carry out the following instructions:

In the **Control Panel** window, select **Load** and browse to one of the **example data files** in the **ECT32v2/working/example files** folder. Load the selected data file. An image will appear similar to that shown in figure 4.5.

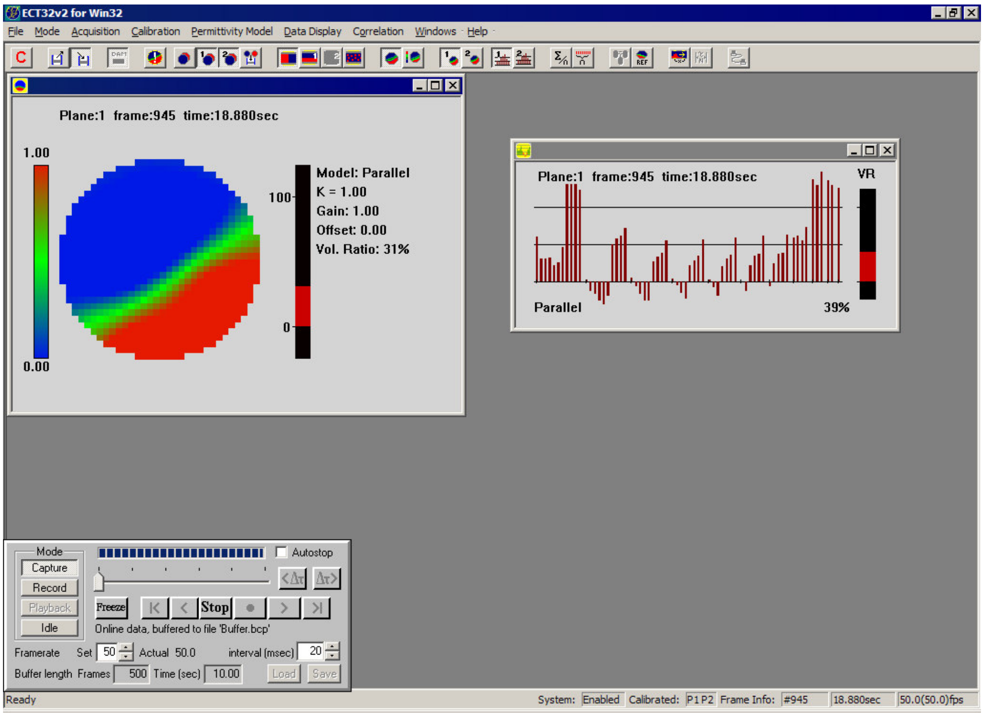


Figure 4.5 Single plane permittivity image and normalisedcapacitances.

The **ECT32v2 Desktop** can display up to **four image windows** comprising, **two permittivity images** and **two sets of normalised capacitances.** The **images displayed** will depend on the **number of sensor planes in use**, the **settings** in the **Configuration window** and whether or not the **capacitance display icons** on the **toolbar** have been enabled. Figure 4.5 shows a typical single-plane image display for both **permittivity** and **capacitance images.**

Click the **Playback mode button** and then click the **forward play [>]** button (2nd on right after **Stop** button) on the **control panel**. The **capacitance** and **image** data will be replayed and the **current image number** and the **time from the start of data collection** are displayed in both the **ECT image window** and also on the right hand end of the **status bar** at the **bottom** of the **ECT32v2 desktop** window.

2. Click the **reverse play [<]** button (to left of **stop** button) on the **control panel.** The captured data will be replayed in **reverse order.**

3. Click the **Go to last frame** [>|] and **Go to first frame** [|<] buttons on the **control panel** in turn**.** Note that these set the **displayed image** to the **last** and **first** captured **frames** respectively.

4. Click the **increment one frame** button [**Δτ>**]. The image will advance to the next frame. Similarly, click the **decrement one frame** button [**<Δτ**]. The image will change to the previous frame.

4.4 PERMITTIVITY IMAGE FORMAT (*Mode menu, Playback mode*)

In the ECT32v2 software, ECT images are displayed in a rectangular grid format (normally 32 X 32 pixels, depending on the sensor information file), using a **colour scale** from **blue** to **red**. **Blue** corresponds to **low value pixels** (0) and **red** corresponds to **high-value pixels** (1). The pixel **colour scale** is indicated by a **vertical bar** on the LHS of the image. The **volume ratio** of the image is displayed on a **gauge on the RHS of the image** in the range **0 to 100%,** where **0** corresponds to the case where the sensor is filled with the **lower permittivity material used for calibration** and **1** corresponds to the sensor filled with the **higher permittivity material**. A **pixel probe** controlled by the **mouse cursor** allows the values of **individual pixels** to be measured. Its operation is described below and in in **paragraph 3.32**.

If a valid **captured data file** and **configuration file** are loaded as described in section 4.3 and **Playback mode** is selected, the main **ECT32v2 window** will display an **image** of the normalised **permittivity distribution** of the sensor contents and an example is shown in figure 4.5.

In figure 4.5:

The **central circular area** of the **image window** displays the **permittivity image** using a **colour scale** from **blue** (normalised pixel value = 0, corresponding to the permittivity of the material used to calibrate the sensor at the lower level) via green (0.5) to **Red** (normalised pixel value = 1, corresponding to the permittivity of the material used to calibrate the sensor at the higher level). The overall **shape of the ECT imag**e (in this case circular) is determined by the **sensor information file**.

The **far left vertical bar** shows the **normalised permittivity** on a **colour scale** from low (blue) to high (red).

The right hand **vertical gauge** is the **volume fraction** of the image expressed in % in a scale from 0 to 100%, where 0% corresponds to the sensor full of the lower permittivity material and 100% corresponds to the sensor full of the higher permittivity material. The **volume fraction** is calculated from the image pixels.

For the situation where there is a mixture of two materials inside the sensor, **the normalised permittivity** can be interpreted as the **voidage** or **volume ratio** of the materials with which the sensor was calibrated. The **volume ratio** is shown on a scale at the **right hand side of the image window**. The **volume ratio** scale has a nominal range from **0 to 100%,** with the facility for displaying values 30% more or less than this nominal range.

Note that an **indicated volume ratio** of **100%** corresponds to the situation where the **sensor is full of the higher permittivity material** and **0%** corresponds to the situation where **the sensor is full of the lower permittivity material**. If, as is often the case in practice, the higher permittivity material is a mixture of air and solids, and the lower permittivity material is air, the **actual volume ratio** must be obtained by multiplying the **indicated volume ratio** by the **absolute volume ratio at the higher permittivity point** (typically 50 to 60% absolute volume ratio).

The **normalised permittivity** value of any **pixel** can be found by clicking the **mouse pointer** inside the **image** at the **required location**. The selected **pixel** is highlighted **and its value** is displayed at the **bottom of the image,** as shown in **figures 3.9** and **3.11**, in the **form probe = X**, where **X** is the **voidage or normalised permittivity**. This option is turned off by clicking the mouse cursor outside the image.

The **permittivity image** can be modified by changing the **image gain**, introducing a **permittivity offset**, **truncating** the image pixels and by the use of a number of different **voidage models**.

Any **Image display** window can be removed by clicking the **X** box in the top RHS of the window. It can be **retrieved** by either selecting the **Plane 1** or **Plane 2 image option** in the **Windows** menu or **alternatively** by using the **Plane 1** or **Plane 2 image** buttons (**icons 16** and **17**) near the **right-hand end** of the **toolbar**.

4.5 NORMALISED CAPACITANCE DISPLAY WINDOWS (*PTOM Chapters 6.5 and 7.3*)

If **icons 18** or **19** are selected on the **toolbar**, an additional window appears which displays the normalised values of capacitance. The **normalised capacitance data display** is in the form of a **histogram of inter-electrode capacitance measurements** in the nominal range (0.0 to 1.0).

The **capacitances** are displayed as **sets of vertical lines** (with a gap between each set) where each line represents the **normalised capacitance** on a nominal scale from 0 to 100%, with facilities for 30% over and under-range values.

The capacitances are displayed in the order C12, C13, '... C1E (where E is the number of electrodes), C23, etc. with gaps between the C1E, C2E, C3E.... sets of readings. The **first set of lines** are the **capacitances C_{12} to C_{1E}** in order (where E is the total number of electrodes), the second set is **C_{23} to C_{2E}** and so on.

The **normalised capacitances** window for a single plane sensor is shown at the RHS of figure 4.5. A similar window with two sets of capacitances is displayed in twin plane mode.

Capacitance display windows can be closed in the normal way by clicking on the X symbol in the top RHS of the **title bar**.

5. MODIFYING THE DISPLAYED IMAGES (*Data Display menu*)

This section explains how the basic image reconstructed from the capacitance measurements can be modified to produce more accurate images. This can be carried out using options available from the **Data Display drop-down menu.** The following options are currently avaIlable:

5.1 SENSOR INFORMATION FILE OPTIONS

The **Sensor Information Files** contain information, including the sensor sensitivity maps, which determines how the image is to be calculated. These files are stored in the **Ect32v2\Configure** folder.

5.1.1 Load Sensor Information File (*Data Display menu, Load Sensor Information file*)

The **Load Sensor Information File** option allows the **current sensor information file** to be replaced with a new file. This can also be implemented using **icon 14** on the toolbar. It opens the **Sensor Information File** window shown in figure 5.1.

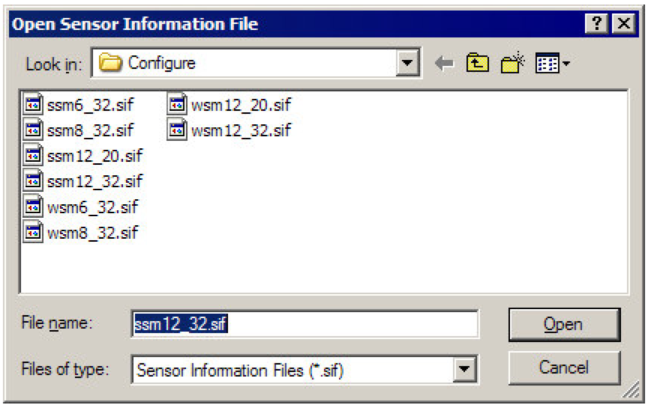


Figure 5.1 Open sensor information file window

Additional sensor information files, for example files for square or rectangular sensors or unique, more accurate files for individual sensors may be added as required to the **Configure** folder.

5.1.2 Sensor Information file details (*Data Display menu, Sensor Information file details*)

This option displays a window giving details of the current sensor information file. An example is shown in **figure 5.2.**

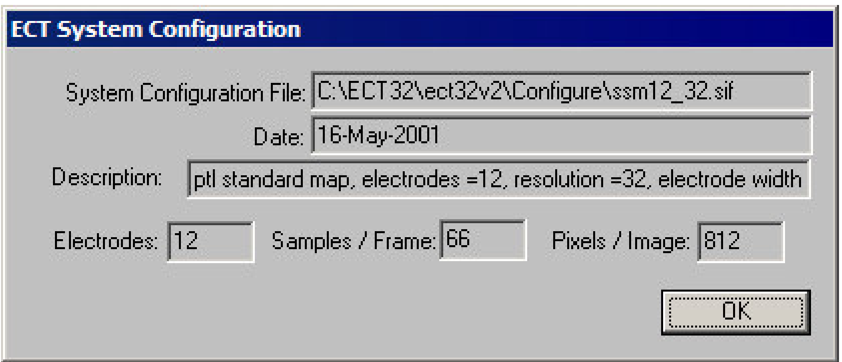


Figure 5.2. Sensor information file details window

5.2 IMAGE DISPLAY PARAMETERS (*Data Display menu, Image Display Parameters*)

This option (**icon 15**) opens the **Image Display Controls** window (**figure 5.3**) which allows a number of parameters in the **image reconstruction algorithm** to be modified. The original **capacitance measurements, and capacitance data files** are not affected in any way.

5.2.1 Image Display Controls

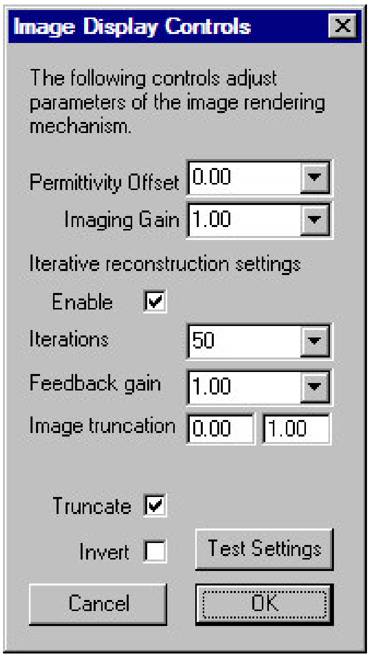


Figure 5.3 Image Display Controls window

The control parameters, which affect only the **displayed image,** are as follows:

Permittivity offset: The **Permittivity offset** parameter **OS** is normally set to zero, in which case the **displayed image** covers the **normalised permittivity range** from 0 to 1. If an offset value other than zero is entered (eg **OS**), in the range 0 to 1, **the permittivity range displayed** will be from **OS to 1 + OS**. The effect of this is to **offset** the **measurement range**. This facility can be used, for example, to display permittivity values which exceed the nominal maximum value of 1.

Imaging Gain: The **Image gain** parameter **G** normally has the value 1. However, if a value of G other than 1 is entered, the **permittivity value** of each pixel is multiplied by the **Image gain** factor **G**. The effect is to change the overall gain of the image. Note that the **colour scale bar** changes to reflect the effect of the new gain setting.

If both **Image gain** (**G**) and **Permittivity offset** parameters (**OS**) are in use, the permittivity scale will be modified to run from **OS** to **OS + 1/G.** This facility can be very useful for monitoring small permittivity changes.

5.2.2 Iterative Reconstruction settings (*PTOM Chapter 13*)

The 3 parameters in this group allow **images** to be reconstructed using **iterative techniques** in all operating modes.

The **Iterations** parameter sets the number of iterations to be performed for the construction of each image. If a large number of iterations are set, the image display rate may fall. Note that iteration can be enabled and disabled using the **Iteration** button on the **Toolbar** (icon 13a).

The **Feedback gain** parameter sets the feedback gain in the iterative algorithm. A value = 1 will result in a safe but slow convergence process. Values exceeding 1.5 may cause the iterative process to diverge rather than converge.

Image truncation parameters. If the **Truncate** option is selected, the **normalised image pixel values** are truncated at each **image iteration** to lie within the set range. The first figure is the **low permittivity truncation level** and the second figure is the **high permittivity level**.

Pixel inversion: If the **Invert** option is selected, the value of each pixel is multiplied by -1. This facility can be used for viewing the contents of sensors where the capacitances decrease below the calibration values. This often occurs when an earthed or partially-earthed sample is introduced inside the sensor following calibration.

5.3 IMAGE DISPLAY FORMATS

5.3.1 Normal image display (*Data Display menu, Normal Image Display*)

This option, displays the permittivity image in its **normal** format.

5.3.2 Quadrant image display (*Data Display menu, Quadrant image display)*

This option displays the image as **four isolated quadrants** as shown in **figure 5.4**. In this mode, the **volume ratios** of **each quadrant** are displayed separately.

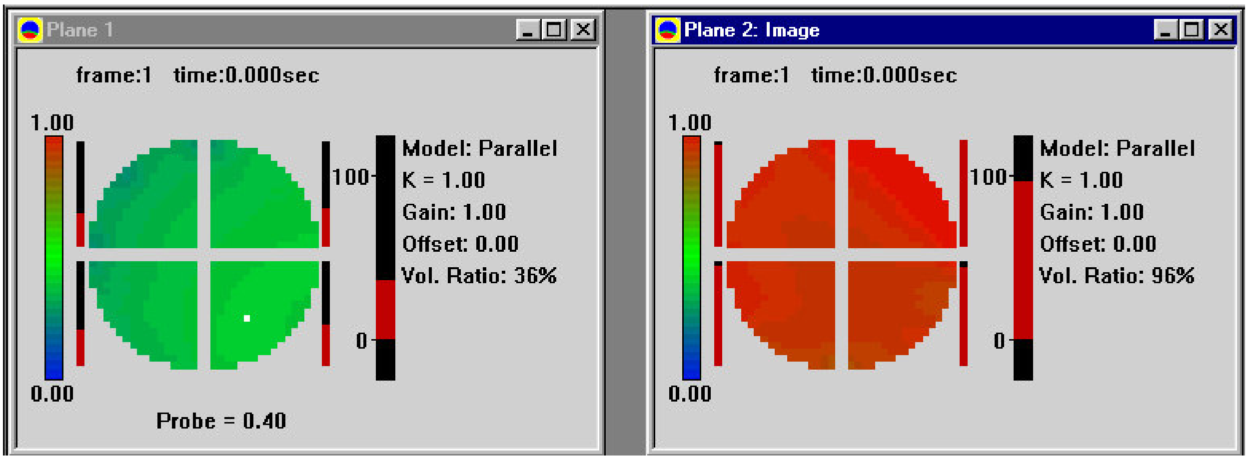


Figure 5.4 Quadrant image display window

5.4 CONTINUOUS AVERAGING CONTROLS

5.4.1 Enable Continuous Averaging (*Data Display menu, Enable Continuous Averaging)*

This option enables the **continuous averaging** of the **measured data** and can also be implemented using **icon 20** on the toolbar. The parameters used for averaging are set in the **Continuous Averaging Controls** menu (section 5.4.2).

5.4.2 Continuous Averaging Controls (*Data Display menu, Continuous Averaging controls)*

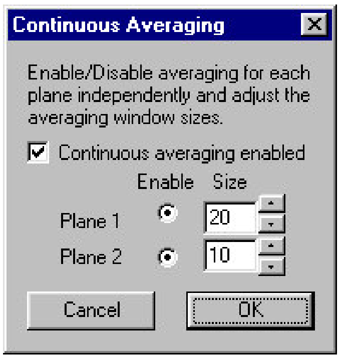


Figure 5.5 Continuous Averaging window

This option (which can also be implemented using **icon 21** on the toolbar) displays the **Continuous Averaging Window** shown in **figure 5.5**. If this option is enabled, the displayed images show the data **averaged over the number of frames selected in the Size boxes** on a **rolling basis**. The **parameters** for **plane 1** and **plane 2** can be **set independently**. **If no averaging** is required on **one of the planes only**, the **enable selection option** for this plane should be **disabled**. The example in **figure 5.6** shows data for **plane 1** averaged **over 20 frames** with that for **plane 2** averaged over **10 frames**. This technique is very useful for reducing noise levels in images for slowly-changing concentration distributions.

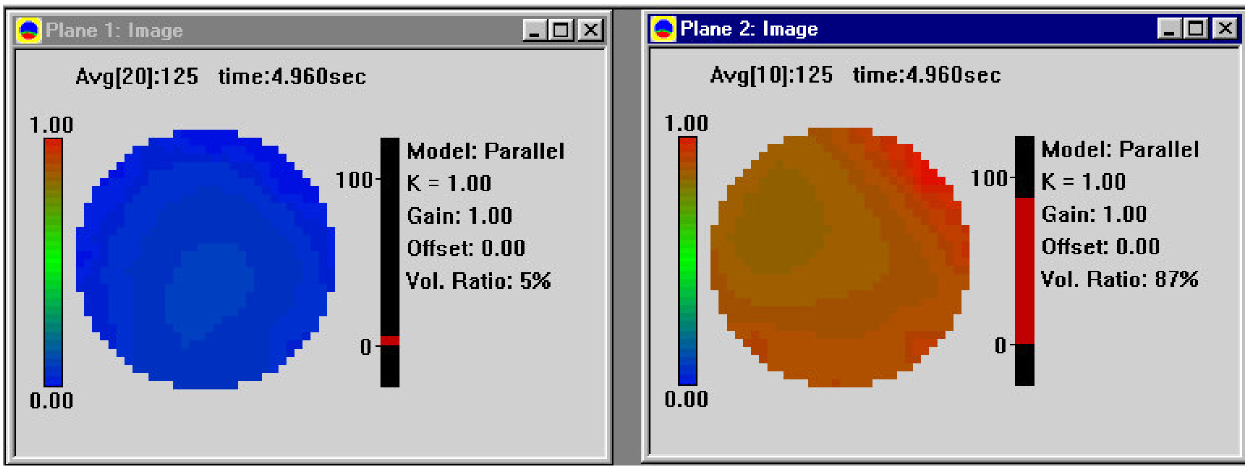


Figure 5.6 Permittivity Images in continuous averaging mode

Note that the standard text **"frame",** followed by the **current frame number**, located at the top of the **image display window** (eg as shown in **figure 3,9**) is replaced by the text **"Avg[X]",** where **X** is the **number of frames** selected in the **size box**, followed by the **current frame number**.

5.5. PERMITTIVITY MODELS (*PTOM Chapter 12*)

Before the captured **capacitance data** can be converted into **accurate ECT images**, it is necessary to decide how to convert these measurements into a **permittivity** or **voidage** image. Detailed information about this topic is given in **chapter 12** of the the **PTL300E Operating Manual.**

The method used will depend on the physical model chosen to represent the relationship between the **concentration distribution** of the 2 materials inside the sensor and the **measured capacitances.**

Selection of the **permittivity model** to be used is carried out either by the use of **the Permittivity Model drop-down menu** or alternatively, by the use of **icons 10** to **13**.

5.5.1 Parallel permittivity model (*Permittivity Model menu, Parallel Model*)

This is the **default** option in the **ECT32v2** software and assumes a **linear relationship** between the **concentration** of the materials inside the sensor and **the capacitance measured between any pair of electrodes**. This is known as the **parallel permittivity model** as it **combines the elementary capacitances inside the sensor as if they were connected in parallel**.

This simple model is useful for imaging fluids such as vertical columns of immiscible liquids where there may be true parallel paths across the sensor through the different dielectric materials. This option is selected by clicking on **icon 10** on the **tool bar** or by selecting the **Parallel model** option from the **Permittivity model** menu.

5.5.2 Series permittivity model (*Permittivity Model menu, Series model)*

The **Series** option assumes that the **elementary capacitances** inside the sensor contribute to the overall **capacitance measured between any pair of** electrodes as though they **were connected in series**.

The **Series model** is useful for imaging fluids such as powders or granules in fluidised beds where there will **normally not be a continuous path between electrodes through the higher permittivity material**.

The first series model option is selected by clicking on **icon 11** on the **tool bar** or by selecting the **Series 1 model** option from the **Permittivity model** menu. For this version of the Series model it is necessary for the user to know the approximate ratio **(K)** of the dielectric constants of the two materials used for calibrating the sensor. This value of **K** must be entered by selecting the **Set Permittivity Ratio (K) option** in the **Permittivity model** drop-down menu (see **paragraph 24.5**). A typical image display using the series model is shown in figure 5.7**.**

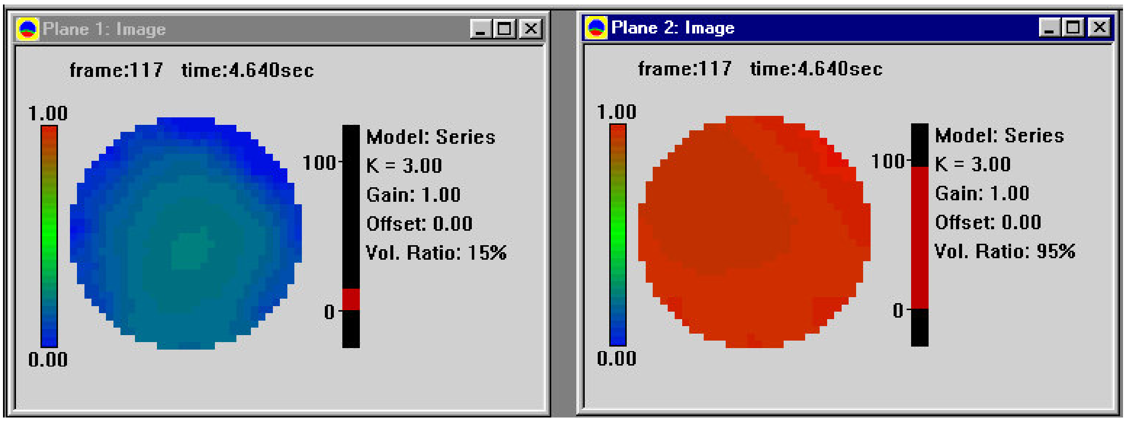


Figure 5.7. Permittivity image display window using series 1 model

5.5.3 Series 2 model (*Permitivity Model menu, Series 2 model)*

The second series model option is selected by clicking on **icon 12** on the **tool bar** or by selecting the **Series 2 Model** option from the **Permittivity model** menu. This version of the series model, deduces the permittivity ratio from the calibration data and there is therefore no need to enter a value for K.

NB This option is currently inoperative in the ECT32v2 software.

5.5.4 The Maxwell model (*Permittivity Model menu, Maxwell model)*

This is effectively a **composite parallel/series capacitance model** developed by **Maxwell** in the 19th century. It is a good compromise for most practical ECT applications. This option is selected by clicking on **icon 13** on the **tool bar** or by selecting the **Maxwell model** option from the **Permittivity model** menu.

5.5.5 Set permittivity ratio (k) (*Permittivity Model menu, Set Permittivity Ratio (K))*

This option displays the **Set Permittivity Model Window** (**figure 5.8**) and allows the **Permittivity ratio (K)** to be set or changed directly by the user.

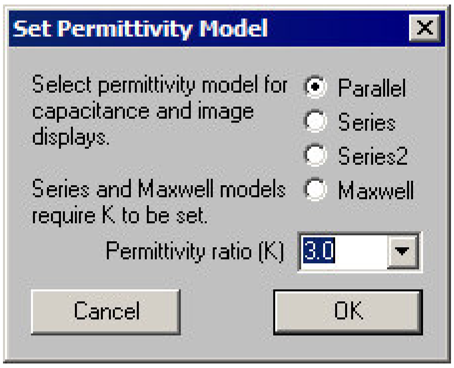


Figure 5.8. Set Permittivity Model window

5.6. REFERENCE FRAME OPTION

The **Reference frame** option allows a **set of measured capacitance data** to be defined as a **reference set**. If the **Reference Frame** option is **enabled**, this data is then subtracted **from all subsequent data frames**. This facility can be useful in a number of circumstances:

For example, it can be used to remove the effects of low-level calibration drift from the displayed images, or it can be used to view changes from a fixed point in an experiment.

The **Reference frame** can be derived from **current** or **previous measurement** data and can be derived from either a **single data frame** or the **average of a number of data frames**.

The operation of the **Reference Frame** facility is described below.

5.6.1 Enable Reference Frame (*Correlation menu, Enable Reference Frame)*

The **Reference Frame** facility is enabled either by selecting **option 4** on **the Correlation drop-down menu** or by clicking on **icon 22** on the **toolbar**.

5.6.2 Reference Frame Controls (*Correlation menu,Reference Frame controls)*

Click on the **Reference Frame Controls** option or **icon 23** on the **toolbar** to access the **Reference Frame Controls window,** shown in **figure 5.9.**

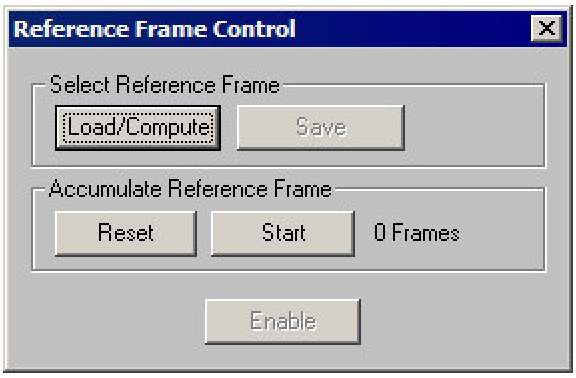


Figure 5.9 Reference frame control window

The **Reference frame** can be defined in two ways, either from a set of **previously-captured capacitance data** or from **on-line data**.

To define the **Reference frame** from previously-captured data, click on the **Load/Compute** button in the **Reference Frame Control** window. A new **Load/Compute Reference Frame window** will appear as shown in **figure 5.10**.

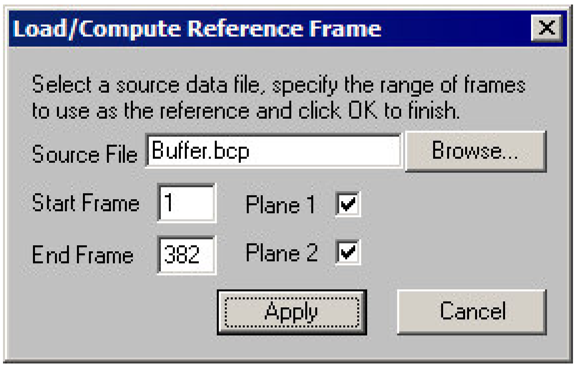


Figure 5.10 Load/compute reference frame window

Define the **Data file** to be used in the **Source File** box and the **range of frames to be averaged** in the **Start** and **End Frame** boxes. Insert the **same frame number** in **both boxes** to use a **single frame** of data for the **Reference Frame**. Then click on the **Apply button**.

Click on the **Enable** button to implement the **Reference Frame** option, then close **the Reference Frame Control window**.

A typical image display with the **Reference frame** option enabled is shown in figure 5.11.

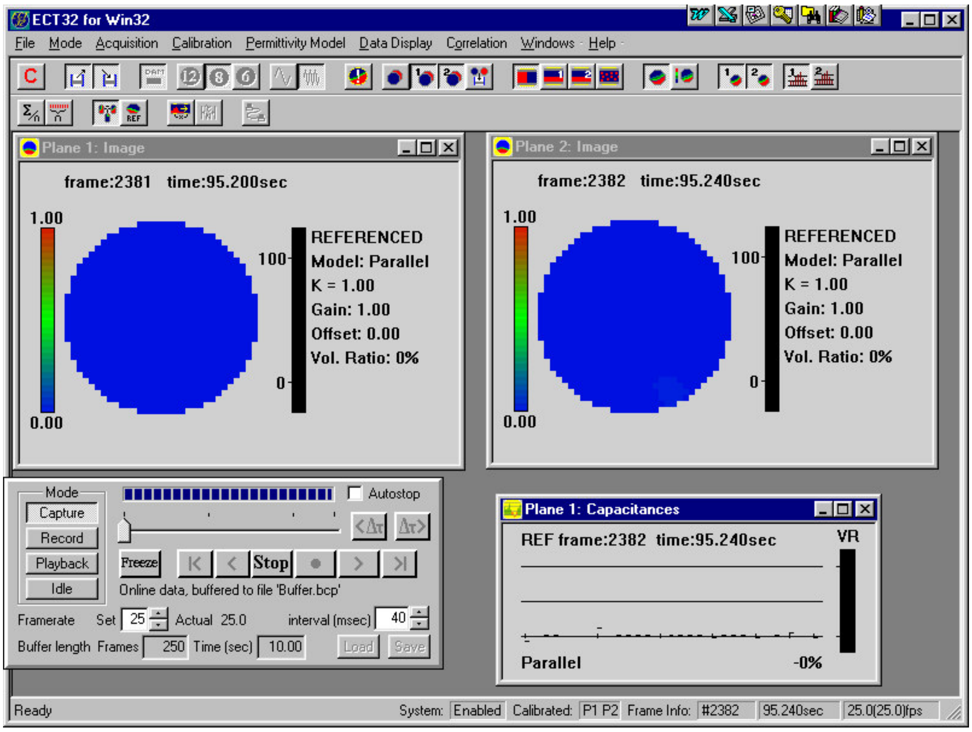


Figure 5.11. Image display with Reference Frame enabled

Note that when the capacitances are displayed when the reference frame is active, “ghost values” of the capacitances of the reference frame are shown as short horizontal lines in the capacitance window.

6. DATA FILES

6.1 FILE FOLDERS

The **ECT32v2 software** structure contains 3 service folders, a **Configure folder**, **Installation folder** and a **Working folder**. Users will usually only be concerned with the **Working** and **Configure** folders. The **Working** folder is used to store calibration files and capacitance data files and is also the target folder for any recording operation. The **Configure** folder holds the **sensor information files**. The **current folders** are **retained between subsequent uses** of the **ECT32v2 software**.

6.2 GENERATING ASCII FILES (*File menu, Generate ASCII files*)

Capacitance and **image** data can be saved and retrieved in a number of diferent formats.

When primary capacitance measurement data is captured to file, it is stored by default in **binary** format as **normalised inter-electrode capacitances.** This format is used to minimise the size of the stored data files.

However, facilties are provided to convert these **capacitance data files in binary format** (**.bcp files**) into a number of **different data types** (including **normalised** and **absolute capacitances**, **image files** and **voidage files**) which can then be saved in **ASCII (text) format**.

Binary capacitance data files (**.bcp files**) can be converted into **ASCII data files** in the following formats:

Normalised capacitance files (.anc files)

Absolute capacitance files (.aac files)

Image files (.aim files)

Volume ratio files (.avr files)

The format of the data in these files is described in **Appendix 1**.

The method for generating these data files is decribed in the following sections. In each case, it is assumed that data has been captured and stored to a suitable file and that, where appropriate, a **calibration data file** has also been saved.

6.3 ASCII FILE GENERATION DETAILS

The method for generating the data files is common to all data file types and is initiated by selecting the **Generate ASCII data files** option from the **File** menu. This brings up the **ASCII file generation window** shown in **figure 6.1.**

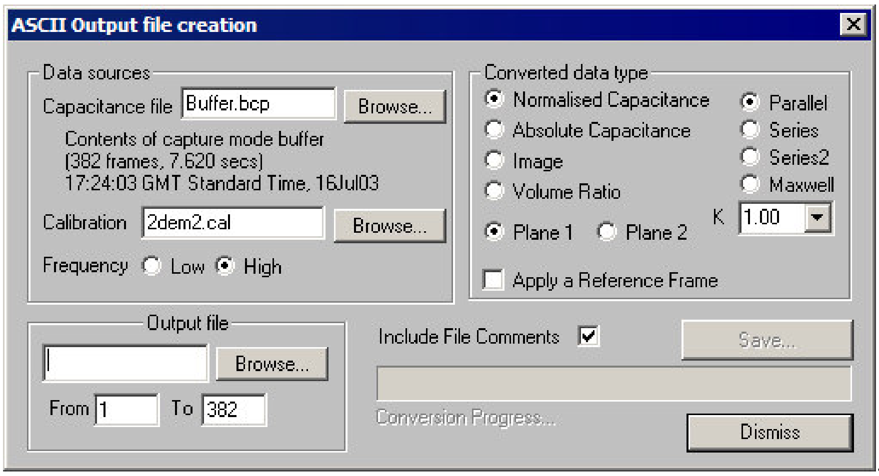


Figure 6.1. ASCII output file creation window

6.3.1 Normalised capacitance data files

1. In the **Data sources** parameter group, locate the required **capacitance data file** to be converted in the **Capacitance File** box using the **Browse** button.

2. In the **Output file** parameter group, use the **Browse button** to select a folder for the **output file** which is to contain the **normalised capacitance** data and then click on **Save** without entering a file name. An output file with the same name as the input data file, but with a new file extension will be generated automatically. Also select the **range of capacitance frames to be converted** in the **From** and **to boxes.**

3. In the **Converted data type** list, select **Normalised Capacitance** and also select the **measurement plane(s)** for which the data is to be converted.

4. When all of the above parameters are correct, click on the **Save** button. The data will be converted and written to the **output file** which will be given the file extension **.anc** (**ASCII Normalised Capacitance**) and a **finished** message will appear. To exit this window, click on the **Dismiss** button.

5. The data file will be saved in the specified folder and can be viewed with a suitable word-processor such as Microsoft Word. A typical converted data file is shown in **Appendix 1.**

6.3.2 Absolute capacitance data files

1. In the **Data sources** parameter group, locate the required **capacitance data file** to be converted in the **Capacitance File** box using the **Browse** button and also set the name of the **calibration file** used to produce this data in the **Calibration file** box. If necessary set the **frequency** option to the setting used to generate the original capacitance data.

2. In the **Output file** parameter group, use the **Browse button** to select a folder for the **output file** which is to contain the **absolute capacitance** data and then click on **Save** without entering a file name. An output file with the same name as the input data file, but with a new file extension will be generated automatically. Also select the **range of capacitance frames to be converted** in the **From** and **to boxes.**

3.3. In the **Converted data type** list, select **Absolute Capacitance** and also select the **measurement plane(s)** for which the data is to be converted.

4. When all of the above parameters are correct, click on the **Save** button. The data will be converted and written to the **output file** which will be given the file extension **.aac** (**ASCII Absolute Capacitance**) and a **finished** message will appear. To exit this window, click on the **Dismiss** button.

5. The data file will be saved in the specified folder and can be viewed with a suitable word-processor such as Microsoft Word. A typical converted data file is shown in **Appendix 1.**

6.3.3 Image data files

1. In the **Data sources** parameter group, locate the required **capacitance data file** to be converted in the **Capacitance File** box using the **Browse** button.

2. In the **Output file** parameter group, use the **Browse button** to select a folder for the **output file** which is to contain the **image** data and then click on **Save** without entering a file name. An output file with the same name as the input data file, but with a new file extension will be generated automatically. Also select the **range of capacitance frames to be converted** in the **From** and **to boxes.**

3. In the **Converted data type** list, select **Image** and also select the **measurement plane(s)** for which the data is to be converted.

4. Select the **permittivity model** to be used and the **permittivity ratio K** if appropriate.

5. When all of the above parameters are correct, click on the **Write** button. The data will be converted and written to the **output file** which will be given the file extension **.aim** (**ASCII Image**) and a **finished** message will appear. To exit this window, click on the **Dismiss** button.

6. The data file will be saved in the specified folder and can be viewed with a suitable word-processor such as Microsoft Word. A typical converted data file is shown in **Appendix 1.**

6.3.4 Volume Ratio data files

1. In the **Data sources** parameter group, locate the required **capacitance data file** to be converted in the **Capacitance File** box using the **Browse** button.

2. In the **Output file** parameter group, use the **Browse button** to select a folder for the **output file** which is to contain the **Volume Ratio** data and then click on **Save** without entering a file name. An output file with the same name as the input data file, but with a new file extension will be generated automatically. Also select the **range of capacitance frames to be converted** in the **From** and **to boxes.**

3.In the **Converted data type** list, select **Volume Ratio** and also select the **measurement plane(s)** for which the data is to be converted.

4. Select the **permittivity model** to be used and the **permittivity ratio K** if appropriate.

5. When all of the above parameters are correct, click on the **Save** button. The data will be converted and written to the **output file** which will be given the file extension **.avr** (**ASCII Volume Ratio**) and a **finished** message will appear. To exit this window, click on the **Finished** button.

6. The data file will be saved in the specified folder and can be viewed with a suitable word-processor such as Microsoft Word. A typical converted data file is shown in **Appendix 1.**

7. ADDITIONAL IMAGE RECONSTRUCTION AND DISPLAY SOFTWARE

The **ECT32** software allows basic ECT images to be displayed both during data capture (**on-line**) and also during the replay of captured data (**off-line**). Two further sets of **off-line** image reconstruction and display software are also supplied with the ECT system. The **IU2000** software allows **2-D ECT images** to be reconstructed and displayed and the **Plot3D** software allows **2 and 3-D images** to be reconstructed and displayed. Details of these two sets of software are given in **Appendices 9 and 10** of the **PTL300E Operating Manual**.

APPENDIX 1 DATA FILE FORMATS

A1.1 INTRODUCTION

The following sections describe the general format of **calibration data** files, **sensitivity map** files, **captured data** files **image files** format and **capacitance** files, together with other more detailed information about the data in some of these files.

A1.2 MEASUREMENT SEQUENCE AND REPRESENTATION

When a set of inter-electrode capacitance measurements is taken, a notional inter-electrode capacitance matrix C can be formed from these measurements. For protocol 1, where measurements are made between single electrode-pairs only, this sequence reduces to:

Inter-electrode capacitance matrix **C:**

C11	C12	C13	...	C1e
C21	C22	C23	...	C2e
C31	C32	C33	...	C3e
.	.	.		.
Ce1	Ce2	Ce3		Cee

Where *Cxy* is the capacitance between electrodes ‘x’ and ‘y’ and e is the number of measurement electrodes.

Due to the symmetry in the matrix and the redundancy of the diagonal elements, only the upper or lower triangle of measurements need be measured and recorded. The elements where x = y have no physical meaning as capacitances and hence, choosing the "upper set" where y > x the sequence of actual measurements reduces to:

C12 C13 ... C1e C23 ... C2e C34 ... C(e-1)e

In ASCII file formats, a newline sequence is inserted at the end of each ‘row’, i.e. after element Cxe. Measurements in these files therefore appear in the following triangular form when displayed on a monitor or when printed:

C12	C13			...	C1e
C23	C24		...	C2e	
C34	C35	...	C3e		
.	.	.			
C(e-2)(e-1)	C(e-2)e				
C(e-1)e					

This matrix is known as the "measurement order" matrix. Detailed information about the file formats used for each type of data file are given in a separate document. Examples of data formats for each data type are given in the following sections.

A1.3 CALIBRATION DATA FILE

The calibration data file stores information necessary for the accurate operation of the DAM200E CMU using the two-point calibration technique.

A1.3.1 Data File Format

The default extension of a calibration file **.CAL** and the data is stored in **ASCII** format.The sequence of data stored in the calibration file for a 12-electrode sensor is as follows and follows the numbers in brackets to the right of each set of data in the sample data file shown on the next page.

1. Calibration file identifier code (D2CA). (1 parameter in total)

2. Number of measurement planes, number of electrodes, number of independent measurements. (3 parameters in total)

3. System zero balance count **M3BAL**. The value of the ADC count when the system gain is set to zero. (1 in total)

4. Zero (charge injection) offset counts **M10** (DAC values 0-1023). These are the readings in all measurement channels (2 to 11) with no excitation, i.e. no source electrode. (11 parameters in total)

5. Zero (charge injection) balance counts **M30** (ADC values 0-4095). (11 in total)

6. Low permittivity offset counts **M1L** (DAC values 0-1023). These integers are displayed in triangular measurement sequence (see above) with newline sequences separating rows. (66 in total).

7. Low permittivity ADC balance counts **M3** (ADC values 0-4095). These are values read from the DAM200 ADC while the sensor is filled with the low permitivity component for calibration. (66 in total)

8. High permittivity gain counts **M2H** (DAC values 0-1023). The system gain values set when the sensor is filled with the higher permittivity material. (66 in total)

9. High permittivity ADC counts **M3H** (ADC values 0-4095) when the sensor is filled with the higher permittivity material. (66 in total).

A sample single-plane 12-electrode calibration file is shown below.

CALIBRATION DATA FILE

Data type: ASCII

File extension: .CAL

Sample file: Single plane calibration file.

```
D2CA                                                                                      (1)
1      12     66                                                                          (2)
954                                                                                       (3)
216    219    217    227    229    225    227    217    216    217    176                 (4)
965    954    954    976    1048   1064   986    963    988    982    996                 (5)
422  237  225  234  233  229  230  221  224  237  324                                     (6)
 406  234  235  234  230  230  221  222  226  193
 409  244  238  231  231  220  220  223  184
 414  248  235  232  221  220  221  181
 413  246  234  222  220  220  180
 417  245  225  221  220  180
 427  234  224  221  180
 401  233  224  181
 401  234  184
 400  194
 362

978  997  968  778 1000 1008 1011 1025  974  993 1017                                     (7)
1025 1027  965 1033  984 1016  962  983  993  991
 990 1010  973 1032  968 1018 1037  976  979
 975 1000 1006 1016  960  982 1005 1016
1027  959 1127  981  979 1002 1019
 968 1007  967  965  956  990
1010 1026  958  971 1029
 998  985  982 1029
1000  981 1005
 981  980
1040

 512 1023 1023 1023 1023 1023 1023 1023 1023 1023  480
       (8)
 480 1023 1023 1023 1023 1023 1023 1023 1023 1023
 496 1023 1023 1023 1023 1023 1023 1023 1023
 512 1023 1023 1023 1023 1023 1023 1023
 480 1023 1023 1023 1023 1023 1023
 512 1023 1023 1023 1023 1023
 544 1023 1023 1023 1023
 464 1023 1023 1023
 424 1023 1023
 448 1023
 464

3303 2821 1833 1168 1496 1484 1519 1653 1835 2759 3296                                    (9)
3314 2919 1861 1689 1475 1502 1413 1558 1859 2721
3262 2903 1875 1683 1432 1483 1550 1523 1798
3292 2842 1922 1631 1395 1404 1469 1595
3285 2778 2159 1556 1437 1446 1506
3270 2846 1826 1520 1390 1421
3283 2897 1827 1551 1541
3289 2878 1898 1663
3278 2870 1919
3251 2809
3280
```

A1.3.2 Representation of Calibration file contents

The set of inter-electrode pair coefficients in data sets 6 to 9 form a triangular measurement sequence (the measuremenmt order) as displayed in the table below, in which 1-2 means the measurement which corresponds to the capacitance measured between electrodes 1 and 2 etc.

Electrode-pair combinations

1-2,	1-3,	1-4,	1-5,	1-6,	1-7,	1-8,	1-9,	1-10,	1-11,	1-12,
2-3,	2-4,	2-5,	2-6,	2-7,	2-8,	2-9,	2-10,	2-11,	2-12,	
3-4,	3-5,	3-6,	3-7,	3-8,	3-9,	3-10,	3-11,	3-12,		
4-5,	4-6,	4-7,	4-8,	4-9,	4-10,	4-11,	4-12,			
5-6,	5-7,	5-8,	5-9,	5-10,	5-11,	5-12,				
6-7,	6-8,	6-9,	6-10,	6-11,	6-12,					
7-8,	7-9,	7-10,	7-11,	7-12,						
8-9,	8-10,	8-11,	8-12,							
9-10,	9-11,	9-12,								
10-11,	10-12,									
11-12										

A1.3.3 Calibration file characteristics

In the case of the low-level permittivity balance coefficients, all of the data should be approximately equal to the the nominal ADC count for 1V (around 1000).

The low-permittivity offset coefficients required to achieve a nominal 1V output form a pattern. Each vertical column should contain approximately equal value coefficients, but these nominal values will differ for each column.

The high-level permittivity balance coefficients should ideally all be around the nominal value for 4V output. However, it will not be possible to achieve this output voltage for all combinations of electrodes because of the finite gain available.

The high level permittivity gain coefficients should again form a pattern, with similar nominal values in each vertical column. If all of the coefficients are 1023, this indicates that the system is working at maximum gain and that the nominal 4V level is not achievable.

The 11 zero balance coefficients should all be around the nominal value for 1V.

The 11 zero offset coefficients should have broadly similar values, but these will depend on the uniformity of the capacitance sensing electronic circuitry.

Large deviations from the expected values may be an indication of wrong connections of cables to electrodes, or of improper/unreliable connections, etc. Faulty electrodes can be identified by marking coefficients which deviate from the expected values and by using table 1 to identify the problem electrodes or channels. Alternatively, the Diagnostic test program can be used to rapidly identify faulty electrodes or measurement channels.

A1.4 SENSITIVITY MATRIX FILES

The **sensitivity matrix file**, which is created by external software, forms the basis of most linear image reconstruction methods. The sensitivity matrices are binary files with the generic names SSME-P**.SIF** where E is the number of electrodes in the sensor and P is the number of pixels in one line of the square pixel grid. At present, there are two sets of these files, one for normal use and one for use when imaging pure water. Sets of sensor sensitivity maps are held in the Configure folder of the ECT32 software.

A1.4.1 Data file format

The **sensitivity matrix** consists of **m** sets of **sensitivity maps**, each containing **n** pixels, where **m** is the **number of unique inter-electrode capacitance pairs** and **n** is **the number of pixels in each ECT image frame**.

Each sensitivity map corresponds to one pair of electrodes. Elements in a sensitivity map correspond to individual pixels in the image area including the 'corners' outside the imagein the case of circular vessels. In this case, only elements inside the circle (non-zero entries) are used, the others are ignored by the software.

Sensitivity maps for individual electrode pairs are stored in **measurement order** in the **sensitivity matrix**.

We use the following convention for naming sensitivity matrices:

(NAME)E_P.SIF

where:

Name is a suitable descriptor,

E is the number of measurement electrodes

P is the number of pixels along one row odf the image (= $N^{0.5}$ where N is the number of pixels in the image)

A1.4.2 Viewing sensitivity map files

Sensitivity matrix files can be viewed as sets of sensitivity maps, using a binary file editor such as "Norton Commander" or by using the ect_smapplot utility in the supplied MATECT software which runs under Matlab.

When the files are viewed on the screen in hex format, each coefficient is a group of 4 hex number pairs. The coefficients are listed in the order of pixels:

S1-2(k) (k =1 to 1024)
S1-3(k) (k =1 to 1024)
.
.
S11-12(k) (k = 1 to 1024)

The pixel number k refers to the pixel in the 32 X 32 grid shown in figure 17 in the following way:

Pixel 1 is at row 1, column 1
Pixel 2 is at row 1, column 2
.
.
Pixel 32 is at row 1, column 32
Pixel 33 is at row 2, column 1
.
.
Pixel 1024 is at row 32, column 32.

A1.5 CAPTURED DATA FILE

These files contain frames of normalised inter-electrode capacitance data and have the default extension **.BCP**. The data is stored in **binary format** as a series of 'data frames' preceded by a file header. The header contains sufficient information to permit the correct interpretation of the remaining data as frames and to replay them in the application's 'Playback' mode. Frames are stored as normalised capacitances rather than images, so that the original measurement data are saved. This allows images to be reconstructed retrospectively, using any desired image reconstruction algorithm and with arbitrary resolution. Capacitance values are normalised to the range 0-0xFFF. Negative values can occur in the file as well as values higher than 0xFFF.

As well as the stored capacitance values, the data files contain other information, including the number of electrodes, number of measurements in each frame, number of frames stored in the file, and the time between frames. Provision has also been made for storing the upper and lower calibration values of permittivity, although this feature is not functional at present.

The data is stored in binary format as a sequence of 8 bit bytes. As it is not easy to view these binary files directly, a file conversion facility is included in the ECT32 software to convert these files to ASCII format, which allows them to be viewed using a simple text editor.

A1.6 IMAGE DATA FILE

The image file is an **ASCII** file containing the numeric values of all pixels of a single frame or a series of frames. These files are produced by selecting **image** in the **converted data typ**e selection box which appears when the **Generate ASCII data files** option is selected in the **File** menu of the ECT32 software. The image file contains data for one or more images. The default extension of an image file name is .**AIM** (Ascii IMage) .

The format of the files is a set of **P X P** numbers corresponding to the numeric value of each pixel in the image, where **P** is the set resolution (eg 32 pixels). The numbers are formatted in a square table (number of columns and rows are equal), and separated within rows by **TAB** characters. The pixels are in row order, with the top left hand pixel at the start of the data file and the bottom right pixel at the end of the data file. For circular vessels, regions outside the sensor (with zero entries in the sensitivity map file) are filled with zeros. The numbers are stored with a precision of three digits after the decimal point.

The pixel data is normalised and lies nominally in the range 0 (lower permittivity limit) to 1 (higher permittivity limit). However, this situation will only apply if the sensor is full or empty when the simple linear back-projection image reconstruction algorithm supplied with the software is used. For partially-filled sensors, the electric field distribution will be distorted, causing errors in the images. In these circumstances, pixel values outside the range 0 - 1 will occur. Note, that negative values can occur in this file as well as values higher than 1. This is a result of the field distortion in the sensor which is highlighted by the backprojection reconstruction technique.

Each image frame is preceded by a pair of integer numbers, the frame number and a time stamp which shows the frame time in milliseconds from the start of data collection.

If the image file contains more than one image, subsequent data sets follow immediately without any delimiters.

A typical image file is shown on the following page.

Data type: ASCII

File extension: .AIM

The data in this file is the **normalised image pixel permittivity values** in the nominal range 0 to 1. Each frame starts with a time stamp giving the elapsed time in milliseconds from the first frame.

Sample file: (2 frames)

```
## Image (normalised permittivity) data file
## Created by: ECT32 for Windows95 Beta 1.05(Sep 14 1998 04:23:37)
## Source: demo1.cap
##    Description:
##    Date: 12:16:17 , 12Oct98
## Electrodes = 12, Measurements = 66, pixels = 820
## Data for Plane 1

## frame 0, 0 msec
0 0 0 0 0 0 0 0 0 0 0 0.998 0.999 1.005 1.007 1.012 1.012 1.010 1.006 1.000 0.991 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0.998 0.999 1.001 1.002 1.002 1.005 1.008 1.011 1.008 1.006 1.003 1.001 0.998 0.997 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1.002 1.005 1.004 1.002 1.001 0.999 1.002 1.006 1.008 1.009 1.008 1.006 1.001 1.000 1.001 1.003 1.008 0.995 0 0 0 0 0 0 0
0 0 0 0 0 0 1.005 1.007 1.007 1.003 1.002 1.000 1.001 1.001 1.000 1.003 1.005 1.004 1.002 1.002 0.998 0.999 0.994 0.995 0.999 0.998 0 0 0 0 0 0
0 0 0 0 0 1.001 1.003 1.005 1.008 1.003 1.007 0.999 0.999 0.996 0.999 1.000 1.000 0.999 0.993 0.992 0.989 0.991 0.993 0.998 0.981 0.968 0.949 0 0 0 0 0
0 0 0 0 0.999 0.997 1.003 1.002 1.008 1.001 1.007 0.998 0.999 0.993 0.992 0.987 0.988 0.986 0.983 0.982 0.979 0.982 0.967 0.968 0.959 0.951 0.933 0.921 0 0 0 0
0 0 0 0.996 0.996 0.998 0.998 1.000 1.003 0.996 1.000 0.994 0.990 0.986 0.982 0.978 0.976 0.967 0.963 0.961 0.956 0.951 0.937 0.933 0.928 0.925 0.905 0.904 0.895 0 0 0
0 0 0.997 0.997 0.996 0.993 0.995 1.000 0.996 0.997 0.993 0.989 0.983 0.975 0.969 0.961 0.954 0.942 0.932 0.929 0.921 0.919 0.900 0.903 0.886 0.891 0.872 0.883 0.861 0.854 0 0
0 0 1.000 0.997 0.995 0.994 0.992 0.993 0.989 0.991 0.983 0.985 0.971 0.960 0.949 0.937 0.927 0.914 0.905 0.893 0.883 0.868 0.850 0.855 0.836 0.849 0.824 0.842 0.833 0.862 0 0
0 1.000 1.001 0.997 0.994 0.990 0.987 0.986 0.985 0.981 0.979 0.970 0.959 0.946 0.930 0.909 0.899 0.866 0.867 0.836 0.819 0.826 0.841 0.813 0.814 0.825 0.818 0.850 0.853 0.858 0.866 0
0 1.001 1.000 0.997 0.992 0.989 0.985 0.980 0.977 0.973 0.967 0.955 0.944 0.924 0.908 0.877 0.863 0.847 0.840 0.825 0.789 0.760 0.786 0.782 0.805 0.795 0.803 0.806 0.855 0.865 0.900 0
0.989 1.000 0.998 0.993 0.988 0.984 0.979 0.975 0.971 0.966 0.955 0.937 0.926 0.909 0.884 0.874 0.838 0.828 0.792 0.769 0.768 0.749 0.766 0.739 0.781 0.781 0.833 0.847 0.893 0.906 0.920 0.938
0.997 0.997 0.994 0.991 0.984 0.981 0.972 0.969 0.960 0.956 0.944 0.936 0.907 0.896 0.860 0.846 0.800 0.788 0.769 0.755 0.745 0.728 0.754 0.752 0.801 0.816 0.837 0.865 0.908 0.927 0.951 0.952
0.994 0.993 0.990 0.985 0.979 0.974 0.967 0.966 0.953 0.948 0.927 0.919 0.891 0.878 0.847 0.825 0.801 0.775 0.739 0.729 0.737 0.734 0.754 0.764 0.783 0.835 0.885 0.908 0.939 0.956 0.968 0.982
0.991 0.989 0.986 0.981 0.976 0.970 0.961 0.956 0.943 0.939 0.926 0.908 0.900 0.864 0.826 0.800 0.785 0.748 0.747 0.749 0.746 0.756 0.768 0.803 0.841 0.884 0.911 0.939 0.957 0.985 0.987 0.991
0.990 0.989 0.984 0.978 0.971 0.970 0.962 0.953 0.950 0.931 0.928 0.896 0.889 0.848 0.837 0.787 0.822 0.772 0.744 0.755 0.764 0.787 0.805 0.842 0.868 0.915 0.935 0.974 0.983 1.005 1.005 1.014
0.990 0.988 0.982 0.982 0.975 0.965 0.959 0.943 0.942 0.921 0.920 0.896 0.891 0.842 0.847 0.831 0.774 0.781 0.770 0.789 0.805 0.824 0.849 0.887 0.916 0.948 0.971 0.996 1.001 1.013 1.011 1.013
0.994 0.993 0.987 0.978 0.970 0.967 0.963 0.951 0.941 0.928 0.918 0.892 0.890 0.866 0.845 0.826 0.808 0.793 0.802 0.813 0.832 0.858 0.880 0.912 0.948 0.971 0.997 1.015 1.014 1.013 1.010 1.010
0.996 0.995 0.994 0.988 0.978 0.973 0.959 0.946 0.935 0.933 0.916 0.908 0.886 0.881 0.858 0.851 0.828 0.830 0.836 0.848 0.867 0.888 0.921 0.942 0.979 0.999 1.015 1.016 1.019 1.013 1.008 1.006
0.996 0.998 0.992 0.988 0.975 0.969 0.964 0.961 0.943 0.944 0.920 0.922 0.897 0.893 0.872 0.865 0.858 0.855 0.856 0.866 0.892 0.915 0.951 0.973 1.004 1.015 1.031 1.026 1.022 1.013 1.005 1.004
0.998 0.998 0.995 0.990 0.980 0.976 0.964 0.961 0.943 0.947 0.935 0.928 0.908 0.906 0.894 0.886 0.879 0.873 0.889 0.902 0.921 0.942 0.971 0.996 1.017 1.028 1.038 1.030 1.023 1.012 1.004 1.022
0 0.996 0.993 0.989 0.980 0.976 0.971 0.969 0.963 0.954 0.944 0.934 0.927 0.924 0.910 0.902 0.896 0.901 0.912 0.917 0.939 0.959 0.989 1.011 1.026 1.040 1.045 1.034 1.025 1.014 1.008 0
0 0.993 0.995 0.990 0.988 0.980 0.978 0.971 0.967 0.963 0.955 0.941 0.938 0.933 0.918 0.924 0.915 0.919 0.927 0.944 0.958 0.984 1.003 1.024 1.034 1.043 1.041 1.039 1.029 1.019 1.012 0
0 0 0.995 0.992 0.990 0.982 0.983 0.975 0.975 0.963 0.963 0.957 0.955 0.947 0.942 0.938 0.932 0.939 0.936 0.955 0.967 0.990 1.010 1.027 1.040 1.052 1.047 1.044 1.033 1.026 0 0
0 0 0.992 0.994 0.995 0.991 0.990 0.982 0.983 0.974 0.973 0.965 0.961 0.958 0.954 0.956 0.948 0.953 0.953 0.971 0.983 1.003 1.020 1.034 1.049 1.049 1.047 1.045 1.038 1.024 0 0
0 0 0 0.996 0.997 0.995 0.994 0.989 0.981 0.980 0.977 0.977 0.974 0.970 0.968 0.966 0.961 0.965 0.966 0.977 0.987 1.004 1.018 1.039 1.048 1.051 1.054 1.047 1.040 0 0 0
0 0 0 0 0.998 0.997 0.996 0.992 0.987 0.986 0.980 0.980 0.977 0.976 0.977 0.977 0.972 0.972 0.975 0.978 0.996 1.015 1.019 1.042 1.047 1.054 1.048 1.053 0 0 0 0
0 0 0 0 0 0.999 0.997 0.997 0.990 0.988 0.986 0.987 0.986 0.986 0.986 0.981 0.981 0.976 0.983 0.983 0.997 1.014 1.022 1.045 1.049 1.054 1.053 0 0 0 0 0
0 0 0 0 0 0 0.995 0.995 0.992 0.991 0.988 0.990 0.990 0.992 0.994 0.990 0.989 0.984 0.990 0.992 1.001 1.012 1.019 1.039 1.047 1.053 0 0 0 0 0 0
0 0 0 0 0 0 0 0.996 0.992 0.991 0.990 0.994 0.996 0.998 0.999 0.998 0.992 0.991 0.994 0.996 1.001 1.014 1.026 1.036 1.030 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0.989 0.994 0.996 0.998 1.003 1.002 1.002 0.997 0.996 0.996 0.999 1.004 1.005 1.005 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 1.000 1.000 1.003 1.004 1.004 1.002 0.999 0.997 0.997 0.998 0 0 0 0 0 0 0 0 0 0 0

## frame 1, 33 msec
0 0 0 0 0 0 0 0 0 0 0 0.997 1.000 1.007 1.010 1.016 1.015 1.012 1.007 1.001 0.991 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0.994 0.996 1.000 1.002 1.003 1.007 1.011 1.014 1.010 1.007 1.003 1.001 0.998 0.996 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0.998 1.002 1.001 0.999 0.999 0.998 1.003 1.007 1.010 1.011 1.010 1.007 1.001 1.000 1.001 1.002 1.008 0.995 0 0 0 0 0 0 0
0 0 0 0 0 0 1.003 1.004 1.003 0.999 0.998 0.997 0.999 1.000 1.000 1.004 1.006 1.005 1.002 1.002 0.998 0.998 0.993 0.995 0.999 0.999 0 0 0 0 0 0
0 0 0 0 0 1.000 1.001 1.003 1.005 0.999 1.001 0.995 0.995 0.994 0.998 1.000 1.001 1.001 0.993 0.992 0.988 0.990 0.993 0.999 0.981 0.968 0.949 0 0 0 0 0
0 0 0 0 0.999 0.996 1.002 1.000 1.005 0.997 1.001 0.993 0.994 0.990 0.990 0.986 0.988 0.986 0.983 0.982 0.978 0.982 0.967 0.968 0.958 0.951 0.933 0.920 0 0 0 0
0 0 0 0.997 0.997 0.998 0.998 0.999 1.000 0.993 0.995 0.989 0.985 0.982 0.979 0.976 0.975 0.966 0.962 0.960 0.955 0.950 0.935 0.932 0.927 0.924 0.904 0.903 0.894 0 0 0
0 0 0.997 0.997 0.996 0.993 0.994 1.000 0.994 0.994 0.989 0.985 0.979 0.971 0.966 0.959 0.952 0.941 0.931 0.928 0.919 0.917 0.898 0.902 0.885 0.889 0.870 0.881 0.859 0.851 0 0
0 0 1.000 0.997 0.996 0.994 0.993 0.993 0.988 0.989 0.980 0.982 0.968 0.957 0.946 0.935 0.925 0.913 0.904 0.892 0.881 0.865 0.847 0.853 0.833 0.846 0.821 0.839 0.830 0.859 0 0
0 1.000 1.001 0.997 0.995 0.991 0.988 0.987 0.986 0.981 0.978 0.969 0.957 0.944 0.929 0.909 0.899 0.865 0.866 0.835 0.817 0.823 0.838 0.810 0.810 0.822 0.814 0.847 0.851 0.855 0.864 0
0 1.000 1.000 0.997 0.993 0.991 0.987 0.982 0.979 0.974 0.969 0.955 0.944 0.923 0.908 0.878 0.864 0.847 0.840 0.824 0.787 0.756 0.783 0.778 0.802 0.792 0.800 0.802 0.853 0.863 0.898 0
0.989 1.000 0.998 0.994 0.989 0.986 0.981 0.978 0.974 0.969 0.957 0.939 0.927 0.911 0.886 0.875 0.839 0.828 0.792 0.768 0.766 0.746 0.763 0.736 0.777 0.776 0.830 0.845 0.891 0.905 0.919 0.938
0.997 0.997 0.994 0.992 0.985 0.982 0.974 0.972 0.963 0.959 0.948 0.940 0.911 0.899 0.863 0.848 0.802 0.789 0.770 0.755 0.744 0.726 0.751 0.748 0.798 0.813 0.834 0.862 0.907 0.927 0.951 0.952
0.994 0.993 0.991 0.986 0.980 0.976 0.970 0.969 0.957 0.952 0.932 0.923 0.895 0.882 0.850 0.828 0.804 0.777 0.741 0.729 0.736 0.731 0.751 0.760 0.780 0.832 0.883 0.906 0.938 0.956 0.969 0.982
0.992 0.990 0.987 0.982 0.977 0.971 0.964 0.959 0.946 0.943 0.930 0.913 0.905 0.869 0.830 0.804 0.788 0.751 0.748 0.749 0.746 0.754 0.765 0.800 0.838 0.882 0.909 0.938 0.956 0.985 0.988 0.992
0.991 0.990 0.984 0.979 0.972 0.971 0.963 0.955 0.953 0.935 0.933 0.901 0.894 0.854 0.841 0.792 0.824 0.774 0.746 0.755 0.763 0.786 0.803 0.839 0.864 0.913 0.933 0.973 0.983 1.006 1.006 1.016
0.991 0.989 0.982 0.982 0.975 0.966 0.960 0.946 0.945 0.926 0.925 0.901 0.896 0.847 0.851 0.834 0.777 0.783 0.772 0.789 0.804 0.821 0.846 0.884 0.914 0.946 0.970 0.996 1.001 1.014 1.012 1.014
0.995 0.994 0.987 0.979 0.971 0.968 0.965 0.953 0.944 0.932 0.922 0.897 0.894 0.870 0.849 0.828 0.810 0.794 0.802 0.812 0.830 0.856 0.877 0.909 0.946 0.969 0.995 1.015 1.015 1.013 1.011 1.011
0.996 0.995 0.994 0.988 0.979 0.974 0.961 0.950 0.940 0.937 0.921 0.913 0.890 0.884 0.860 0.852 0.828 0.830 0.836 0.848 0.866 0.886 0.919 0.940 0.976 0.997 1.014 1.015 1.019 1.013 1.009 1.006
0.996 0.998 0.992 0.988 0.976 0.971 0.966 0.964 0.948 0.948 0.926 0.927 0.901 0.895 0.873 0.864 0.857 0.853 0.855 0.863 0.889 0.913 0.949 0.971 1.002 1.013 1.029 1.025 1.022 1.013 1.005 1.004
0.998 0.998 0.995 0.991 0.982 0.978 0.968 0.966 0.949 0.952 0.940 0.933 0.911 0.908 0.894 0.883 0.876 0.869 0.885 0.899 0.919 0.939 0.969 0.993 1.016 1.027 1.037 1.029 1.023 1.012 1.004 1.023
0 0.997 0.994 0.990 0.982 0.979 0.975 0.973 0.968 0.960 0.950 0.939 0.929 0.924 0.907 0.898 0.890 0.895 0.907 0.911 0.936 0.956 0.987 1.009 1.024 1.039 1.045 1.034 1.025 1.013 1.008 0
0 0.994 0.995 0.992 0.989 0.983 0.982 0.976 0.973 0.969 0.961 0.945 0.940 0.931 0.913 0.918 0.908 0.912 0.921 0.940 0.954 0.981 1.001 1.023 1.033 1.042 1.040 1.039 1.028 1.019 1.011 0
0 0 0.995 0.993 0.991 0.986 0.986 0.981 0.980 0.970 0.968 0.961 0.956 0.945 0.937 0.930 0.922 0.931 0.929 0.949 0.962 0.988 1.007 1.026 1.039 1.051 1.046 1.044 1.032 1.026 0 0
0 0 0.994 0.995 0.995 0.994 0.993 0.987 0.987 0.980 0.977 0.968 0.960 0.954 0.948 0.949 0.938 0.944 0.946 0.965 0.979 1.000 1.018 1.032 1.049 1.048 1.047 1.045 1.037 1.023 0 0
0 0 0 0.997 0.997 0.996 0.995 0.992 0.986 0.984 0.980 0.979 0.974 0.967 0.962 0.958 0.952 0.957 0.958 0.972 0.983 1.001 1.017 1.038 1.047 1.051 1.054 1.046 1.039 0 0 0
0 0 0 0 0.999 0.998 0.998 0.994 0.990 0.989 0.982 0.981 0.976 0.972 0.971 0.971 0.965 0.964 0.969 0.972 0.993 1.013 1.018 1.042 1.047 1.054 1.048 1.053 0 0 0 0
0 0 0 0 0 0.999 0.998 0.998 0.991 0.989 0.987 0.987 0.985 0.983 0.981 0.975 0.975 0.969 0.978 0.978 0.994 1.012 1.022 1.045 1.050 1.054 1.053 0 0 0 0 0
0 0 0 0 0 0 0.995 0.994 0.992 0.991 0.988 0.990 0.989 0.990 0.992 0.986 0.985 0.980 0.987 0.990 0.999 1.012 1.019 1.039 1.048 1.053 0 0 0 0 0 0
0 0 0 0 0 0 0 0.996 0.992 0.991 0.990 0.993 0.995 0.997 0.997 0.995 0.988 0.989 0.993 0.994 1.000 1.014 1.027 1.036 1.030 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0.988 0.994 0.996 0.998 1.002 1.001 1.001 0.995 0.995 0.995 0.998 1.004 1.005 1.005 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 1.001 1.000 1.001 1.001 1.000 0.999 0.997 0.995 0.996 0.998 0 0 0 0 0 0 0 0 0 0 0

##EOF
```

A1.7. NORMALISED CAPACITANCE DATA FILE

These files are produced by selecting **normalised capacitance** in the **converted data typ**e selection box which appears when the **Generate ASCII data files** option is selected in the **File** menu of the ECT32 software. The file cntains **ASCII** data for all normalised capacitances of a single frame or series of frames and the default file name extension is **.ANC** (Ascii Normalised Capacitance).

The capacitance values are normalised in the nominal range [0,1]. When the sensor is filled with the medium used for the low-permitivity calibration, the resulting capacitances are set to be equal to zero. The capacitance values are set to 1 when the sensor is filled the with high-permitivity medium used for calibration. The numbers are stored in measurement order in the file with rows separated by newline sequences. The precision of the numbers is 3 digits after the decimal point. If more than one frame of data is stored, subsequent frame records follow.

For a 12 electrode system, there will be 66 values of capacitance, stored in the order:

C12, C13, ...C1N
C23...C2N
C34... etc.

Each capacitance data frame is preceded by an integer number which is a time stamp which shows the frame time in milliseconds from the start of data collection. A sample data file containing 2 frames of data, is shown below.

Data type: ASCII

File extension: .ANC

The data in this file is the **normalised inter-electrode capacitance values** in the nominal range 0 to 1. Each frame starts with a time stamp giving the elapsed time in milliseconds from the first frame.

Sample file: (2 frames)

```
## Normalised capacitance data file
## Created by: ECT32 for Windows95 Beta 1.05(Sep 14 1998 04:23:37)
## Source: demo1.cap
##    Description:
##    Date: 12:16:17 , 12Oct98
## Electrodes = 12, Measurements = 66
## Data for Plane 1


## frame 0 (0 msec)
1.000 1.085 0.981 0.987 0.939 0.970 0.984 1.022 0.969 0.974 0.946
1.055 0.990 0.987 0.977 0.966 1.000 1.023 1.035 1.020 0.939
1.000 0.970 0.979 0.979 1.022 1.015 1.012 1.000 0.833
0.999 0.998 1.001 1.031 1.086 1.020 1.005 0.723
1.000 0.983 1.010 1.047 1.005 0.956 0.630
1.000 0.987 1.002 1.002 0.963 0.608
1.000 0.987 0.978 0.969 0.628
1.000 0.995 0.974 0.705
1.000 0.977 0.830
1.001 0.933
0.942

## frame 1 (33 msec)
1.000 1.086 0.980 0.975 0.939 0.972 0.995 1.016 0.973 0.975 0.946
1.055 0.986 0.980 0.988 0.980 1.005 1.002 1.037 1.022 0.935
1.000 0.964 0.980 0.966 1.027 1.019 1.035 1.002 0.822
0.999 1.005 1.001 1.022 1.067 1.012 0.991 0.715
1.000 0.986 1.012 1.051 1.021 0.963 0.642
1.000 0.985 1.005 0.998 0.970 0.603
1.000 0.987 0.987 0.971 0.619
1.000 0.993 0.973 0.711
1.000 0.971 0.813
1.001 0.932
0.942

##EOF
```

A1.8 ABSOLUTE CAPACITANCE DATA FILE

These files contain **absolute inter-electrode capacitance values** in **femtofarads** in ASCII format for one or more frames and are produced by selecting **absolute capacitance** in the **converted data typ**e selection box which appears when the **Generate ASCII data files** option is selected in the **File** menu of the ECT32 software. The file format is similar to the normalised capacitance file. The only difference is that the numbers are now absolute capacitances in femtofarads. The default file name extension is **.AAC**.

As for the normalised capacitance files, each capacitance data frame is preceded by an integer number which is a time stamp which shows the frame time in milliseconds from the start of data collection.

Data type: ASCII **File extension: .AAC**

A sample data file containing 2 frames of data, is shown below.

Sample file: (2 frames)

```
## Absolute capacitance data file
## Created by: ECT32 for Windows95 Beta 1.05(Sep 14 1998 04:23:37)
## Source: demo1.cap
##    Description:
##    Date: 12:16:17 , 12Oct98
## Electrodes = 12, Measurements = 66
## Data for Plane 1

## frame 0 (0 msec)
386.02 36.65 16.60 11.08 7.53 6.96 8.06 11.08 17.30 40.66 407.26
267.80 37.24 17.20 9.69 7.73 7.79 8.77 11.19 17.48 34.74
467.01 36.97 16.32 10.42 8.38 7.82 8.62 11.39 15.27
270.47 37.22 17.17 10.93 8.37 7.79 9.01 9.35
309.01 37.53 17.08 10.55 8.04 7.95 6.91
320.94 37.60 17.15 10.61 8.17 6.35
263.83 37.40 16.87 10.40 7.01
320.96 36.66 16.43 9.24
282.44 36.88 15.70
270.47 36.52
469.66

## frame 1 (33 msec)
386.02 36.67 16.59 11.04 7.53 6.96 8.10 11.06 17.33 40.68 407.26
267.80 37.18 17.15 9.73 7.78 7.80 8.71 11.20 17.49 34.69
467.01 36.88 16.32 10.37 8.40 7.83 8.70 11.40 15.20
270.47 37.32 17.17 10.89 8.31 7.76 8.96 9.32
309.01 37.57 17.09 10.57 8.10 7.98 6.95
320.94 37.57 17.16 10.60 8.19 6.33
263.83 37.40 16.93 10.40 6.98
320.96 36.64 16.42 9.26
282.44 36.80 15.60
270.47 36.50
469.66
```

A1.9 VOLUME RATIO DATA FILE

This file contains the volume ratio in % for each frame.

Data type: ASCII

File extension: .AVR

The data in this file is the **volume ratio (concentration)** for each frame of data. and these files are produced by selecting **volume ratio** in the **converted data typ**e selection box which appears when the **Generate ASCII data files** option is selected in the **File** menu of the ECT32 software.

The data is listed in groups of 3 numbers. The **first** number is the **elapased time** in milliseconds from the first frame, the **second** number is the **volume ratio % calulated from the normalised capacitances** and the **third** number is the **volume ratio % calculated from the image pixels**. The final 2 figures give the average volume ratios for all of the converted frames.

Sample file: (10 frames)

```
## Volume ratio data file
## Capacitance model: Parallel (K = 1.5)
## Created by: ECT32v2 for Win32 2.33 (Jan 12 2005 14:39:26)
## Source: 8_tube_sp.bcp
##    Description: Contents of capture mode buffer
##    Date: 15:29:18 GMT Daylight Time, 05Oct01
## Electrodes = 8, Measurements = 28
## Data for Plane 1

Time    CVR         IVR
0      16.68       19.20
20     16.80       19.34
40     16.83       19.37
60     16.81       19.35
80     16.78       19.31
100    16.96       19.52
120    16.75       19.27
140    16.76       19.30
160    16.91       19.46
180    16.76       19.30

#Ave   16.80       19.34


##EOF
```

APPENDIX 2

DETAILS OF EXAMPLE DATA FILES

The sample data files were generated by the following experiments:

12_rodpoly_sp.bcp: A PVC tube (OD 21mm, ID19mm) filled with polypropylene beads, moving inside an 8-electrode single-plane circular ECT sensor of ID 122mm.

12_demosen_sp.bcp: Polypropylene beads passing through a single-plane 12-electrode ECT sensor (OD 53, ID 50mm) in each direction in sequence.

8_4rod_sp.bcp: 4 dielectric tufnol rods (OD 12mm) inside a single-plane 8-electrode sensor (ID 100mm)

8_cross_tp.bcp: A perspex cross (48mm) located inside a twin-plane 8-electrode sensor (ID 60mm).

8_fb200_tp.bcp: Fluidised sand inside an 8-electrode twin-plane ECT sensor (OD 60mm. ID 50mm) with 3cm spacing between the electrode planes.

8_gravityflow_tp.bcp: Polypropylene beads falling under gravity through an 8-electrode twin-plane ECT sensor with 13cm spacing between electrode planes.

8_rod_sp.bcp: A dielectric rod located inside a single-plane 8-electrode ECT sensor.

8_tube_sp.bcp: A dielectric tube located inside a single-plane 8-electrode ECT sensor

8_golfball_tp.bcp; Plastic ball filled with polypropylene beads falling under gravity through an 8-electrode twin-plane ECT sensor with 13cm spacing between electrode planes.

Data file name	**Calibration file name**
12_rodpoly_sp.bcp	12_flame_032.cal
12_demosen_sp.bcp	12_demosen_032.cal
8_4rod_sp.bcp	8_bubsen_033.cal
8_cross_tp.bcp	8_fbed_031.cal
8_fb200_tp.bcp	8_fbed_031.cal
8_rod_sp.bcp	8_bubsen_033.cal
8_tube_sp.bcp	
8_golfball_tp.bcp	
8_gravityflow_tp.bcp	

Note: _sp means single plane data file, _tp means twin-plane data file