EMTP
Solutions

Calculable Antenna Processor

User Manual

Contents

Installation of CAP2010 - Steps 1 to 3

CAP2010 can be downloaded from the NPL website
www.npl.co.uk/software/calculable-antenna-processor

CAP2010 will run in Microsoft Windows XP with SP3, Vista, and Windows 7 operating systems.

1. Unzip the file CAP2010.zip.
2. Click on the setup.exe file.
3. Follow the on-screen installation instructions.

By default the installer will put the CAP2010 executable in the Program Files folder. It can be put elsewhere, but the string of subfolders must not be too long.

When the program is first run by clicking on the executable, it will create the data folders in a folder called CapData in the root directory on the current drive. This can be changed later if required (see Appendix 1).

This User Manual is included as html text in the software Help

Disclaimer of Warranty: The Software is provided on an "as is" basis without express or implied warranties of any kind (such as, but not limited to, implied warranties of merchantability and fitness for a particular purpose). Downloading, installing and using the Software is at the user's sole risk.

1.0 Introduction

The Calculable Antenna Processor (CAP) is a 'Moments Method' program for performing calculations involving models of wire antennas. The kernel of the program is based on a small subset of the Numerical Electromagnetics Code (NEC) produced by the Lawrence Livermore Laboratory [1]. The insertion loss between a transmitting antenna and a receiving antenna placed a chosen distance apart can be calculated, either in free space or above a perfect ground plane. The balun loss is included by incorporation of the measured balun S-parameters [2], see Appendix 2. If the antennas are identical, antenna factors are also calculated. These parameters can be calculated at a series of frequencies and at various heights above the ground plane. Varying the heights is more relevant in EMC applications.

A wire antenna is an antenna that can be described in terms of an interconnected system of cylindrical metal wires. Each wire is specified by its end coordinates in space and its radius. The data format for wires is that used by NEC. The moments method is used to calculate the current on each wire either when the antenna is subjected to an external field or when it is excited by a voltage source at its input terminal. In order that the current distribution on the wires may be calculated precisely, even in situations where there are several current oscillations, the wires are divided into segments and the current on each segment is determined. By representing the current on a segment as the sum of a constant term, a sine term and a cosine term it is possible to guarantee that segment currents are continuous along the wire and at wire junctions.

This software can be used at several levels of complexity. A small number of antenna models are built in. These are models of an NPL designed dipole antenna, a generic EMC biconical antenna, a Schwarzbeck miniature biconical antenna and a Teseq log-periodic dipole array (LPDA) antenna. Using these models it is possible to immediately investigate the variation of antenna factor with height, for example. The 'User Interface' described in section 2 allows this to be done. Frequency range, antenna polarisation and geometry can be selected together with the appropriate pairs of antennas and the results calculated by first clicking the 'Estimate Time' button and then the 'Proceed' button. CAP2010 is a powerful tool for modelling changes to antenna coupling and for providing generic correction factors, for example changes in coupling as a transmit antenna is moved throughout a volume, including the assessment of near-field effects. Another example is modelling the changes in biconical antenna coupling (or site attenuation) with one antenna at a fixed height above a ground plane and the other scanned in height from 1 m to 4 m.

One of the first questions that arise when using NEC to perform calculations is whether a sufficiently large number of segments have been chosen for each wire in the antenna model. If the numbers are too small the wire currents will not be computed accurately. Changing the segment numbers to investigate convergence is tedious in NEC. Using CAP this process is simple and is described in section 3.

The most complex process involves entering data for a new antenna. If NEC data is available for the antenna this is fairly straight-forward. The steps involved are discussed in section 5.

Many of the users of this software will be employing dipoles for site verification or as reference antennas when calibrating other antenna types. The principle of the dipole design is described in CISPR 16-1-5 [2], which also gives analytical formulae for calculating site insertion loss. This design was introduced to CISPR by NPL [3]. In this application it will be necessary to change the supplied antenna pairs files to reference the balun files (created using a Vector Network Analyser (VNA)) for the baluns at hand. Changing balun files is described in section 4.

The calculations made by the CAP2010 software agree to within ±0.03 dB of the analytical calculations described in CISPR 16-1-5:2003 [2] and agree with coupling measurements between pairs of dipole antennas at the UK National Physical Laboratory as described in [3] and [4].

References:

[1]   LOGAN, J.C. and BURKE, A.J., Numerical Electromagnetic Code, 1981, Naval Oceans Systems Centre, CA, USA.

[2]   CISPR Publication 16-1-5, Basic Standard, Specification for radio disturbance and immunity measuring apparatus and methods - Radio disturbance and immunity measuring apparatus – Antenna calibration test sites for 30 to 1000 MHz, www.iec.ch/searchpub.

[3]   SALTER, M.J. and ALEXANDER M.J., EMC antenna calibration and the design of an open-field site, Jnl. of Phys. E, Meas. Sci. Technol., 1991, 2, 510-519.

[4]   Alexander M J, Salter M J, Loader B G and Knight D A, Broadband calculable dipole reference antennas, IEEE Trans. EMC, Vol. 44, No.1, pp 45-58, February 2002.

2.0   User Interface

The first time CAP2010 is run after installation, a button must be pressed to create the data folders in a folder called CapData in the root of the current drive. There is also a short pause while the program assesses the speed of the computer by factoring a large matrix. This is followed by the appearance of the opening window. This window has seven frames where the simulation parameters are entered, two buttons and two menus.

   2.1 Simulation Parameters

      2.1.1   Controls Frame

      This frame contains two buttons and a drop-down box. The two buttons, labelled 'Create Antenna Pairs File' and 'Change Segmentation' relate to advanced uses of the program which are discussed later. The drop-down box allows the selection of an Antenna Pairs File. The format of these files is detailed in Appendix 3 but essentially they contain references to the antenna model files and baluns for the transmit and receive antennas and the frequency ranges over which they are to be used. A Pairs file may contain details of a number of antennas to be used over contiguous frequency ranges.

      2.1.2   Frequency Range

      A check-box can be used to turn frequency sweeping on or off. With frequency sweeping disabled only the first of the accompanying text entries boxes is relevant and is labelled 'Frequency', the others are greyed out. The single frequency, in MHz, at which calculations are to be performed, can be entered in this box. With frequency sweeping enabled the three text boxes are used to enter the Start Frequency, the End Frequency and the Frequency Step, all in MHz. (For frequencies other than integers the number of decimal places to be displayed for results can be set – see Appendix 1.)

      2.1.3   Receive Antenna

      A check-box can be used to turn height scanning of the receive antenna on or off. With height scanning disabled only the first of the accompanying text entries boxes is relevant and is labelled 'Height'. The height of the receive antenna, in metres, at which calculations are to be performed, can be entered in this box. With height scanning enabled the three text boxes are used to enter the Start Height, the End Height and the Height Step, all in metres. Note that height scanning and convergence cannot be investigated simultaneously. Convergence (see section 4) takes preference.

      2.1.4   Transmit Antenna

      The height of the transmit antenna can be arranged to track that of the receive antenna or it can be fixed. The Track Receive Antenna check-box controls this choice. When enabled, the heights of the two antennas are maintained equal as height scanning takes place. When disabled the Transmit Antenna Height must be specified.

      Note: The usage of the terms receive and transmit antennas is merely a helpful aid in distinguishing the two antennas. By the principle of reciprocity the same answer would be obtained by swapping the signal generator and receiver on the antenna ports.

2.1.5 Antenna Separation

The required separation of the transmitting and receiving antennas in metres is specified in the text-box in this frame. For extended antennas, such as log-periodic dipole antennas, the separation is from tip to tip.

2.1.6 Polarisation

The polarisation of the pair of antennas is set using radio buttons in this frame. When there is no ground plane present the results should be independent of the setting of the antenna polarisation.

2.1.7 Ground Plane

The radio buttons in this frame allow the choice between calculating insertion losses above a perfect (infinite area, perfectly conducting) ground plane, or calculating these losses in free space. When calculating free-space insertion losses the heights refer to heights above a virtual ground plane taken as the z=0 coordinate plane.

2.2 Control Buttons

2.2.1 Estimate Time

Clicking this button causes the first stage of calculation to commence. First, all the simulation parameters are checked for consistency. The second stage of checking consists of verifying that the antenna and balun files can be located and that the antennas are entirely above the ground plane, when present. Finally, a check is made that the total number of wire segments does not exceed the software-set limit, currently 4000. During this final check the total execution time is estimated. If there are no errors this estimated time is displayed in a new window, along with 'Proceed' or 'Cancel' buttons.

2.2.2 Exit

Clicking this button closes the program. If the simulation parameters have not been saved then the user if provided with the opportunity of saving them.

2.3 Menus

2.3.1 File Menu

This menu has the following six options:

New
    Sets all simulation parameters to their default values as specified in the Default Script.txt file. If changes have been made to the stored set of parameters the user is given the opportunity to save them.

Open
    Opens an existing file containing simulation parameters. An unsaved parameter set can be saved first, if necessary.

Save
    Saves the current parameters. If these parameters have not been opened from a file the 'Save as' menu is presented

Save as
    Allows the current parameter set to be saved under a new file name.

Exit
    Exits the front end and returns to the Windows environment

2.3.2   Help Menu

.   This menu has two options:
                            <u>C</u>ontents
                                    This option displays the HTML version of this manual.
                            <u>A</u>bout
                                    This option gives details of the programs origins.

3.0 Wire Segmentation

The NEC specification of a wire antenna consists of a series of so-called GW 'cards', one for each wire. The letters GW are followed by the tag (wire identifier), the number of segments (ns), the wire end co-ordinates and the radius. The wire end co-ordinates are used to calculate the length (l) of the wire and the wire is then divided into a series of sub-wires (segments) each of length l/ns.

3.1 Segmentation Rules

The length of a segment should be small compared with the wavelength corresponding to the frequency at which calculation of current is required. The length should also be large compared with the wire radius. CAP is mainly intended for the modelling of broadband wire antennas over wide frequency ranges and it then becomes more difficult to maintain these length requirements.

3.2 Convergence

The fundamental quantity calculated by CAP is the insertion loss between a pair of antennas. The value reported for this quantity depends on the segmentation of the wires and, in general, displays 'convergence' as the numbers of segments are increased. For a pair of dipole antennas, for example, modelled as single wires divided into ns segments, convergence is apparent after ns = 9 at resonance but not until ns > 35 a long way off resonance (say at one half or twice the resonant frequency).

3.3 Change Segmentation

CAP has provision for investigating convergence via the 'Change Segmentation' button. Clicking on this button results in a new window where four parameters may be set. It also has a text box in which guidance notes are provided. The four parameters are as follows:

3.3.1 Mode

If Mode has the value 1 (or any value other then 2) the wire segmentation is based on the segment numbers specified in the antenna data, i.e. on the GW 'cards'. The actual segment numbers used will depend on the other three parameters.

If Mode has the value 2 the initial segment numbers are calculated using

$$ns = 60 \text{ X wire length / wavelength}$$

Again the segment numbers used depend on the other parameters. (For log-periodic dipole array (LPDA) antennas this will result in a large number of segments on the longest elements (wires) when the insertion loss is being calculated at the highest applicable frequencies. This is slightly unfortunate since the tiny currents on these elements is effectively being computed with high precision and have little impact on the calculated insertion loss. A side effect is that the computation takes a long time! Mode = 2 is more suitable for dipole or biconical antennas.)

3.3.2 Start

The value of 'Start' is a multiplier for the segment numbers determined by Mode. For example, if Mode = 1 and Start = 1 then the segment numbers specified in the antenna data are used. If Start = 0.5 the segment numbers will be divided by 2. When 'Steps' (see below) is greater than unity Start is the first multiplier used. (If Start is set to a value <0.2 it is limited to 0.2.)

3.3.3   Increment

Increment is a parameter used in conjunction with 'Steps' to investigate convergence. The segment multiplier starts with the value set by 'Start' and is then increased at each step by the value of 'Increment'. There are three restrictions built into the program on the number of segments on a wire. It can never be less than 1. It must be odd. For a source/load wire with segment number set to three in the antenna data it is not altered since this is taken as a signal that the wire is already short compared with its radius.

3.3.4   Steps

'Steps' is the number of calculations to perform in checking for convergence. If it has a value of 1, calculations are performed once using the appropriate Mode and Start values. For values greater than 1 the calculations are repeated with the multiplier incremented at each step. In this case any height scanning called for is turned off. Only the initial receive and transmit heights are used. The insertion losses presented in the results table are presented in columns – one for each frequency. The rows are labelled by the values of the multiplier.

4.0 Changing Baluns

The CAP program requires that baluns are associated with all antennas. The balun used for a LPDA antenna is a pseudo balun. No impedance translation is involved so the S matrix parameters reduce to those of a straight-through connection of the transmission line to the antenna elements:

$$S_{11} = S_{22} = 0, \quad S_{12} = S_{21} = 1$$

For dipole and biconical antennas the balun performs the essential balanced to unbalanced transformation. The model of balun used in CAP also performs impedance translation. The NEC style model of the antenna does not involve a balun. A receive antenna, for example, is modelled connected to a 100 Ω load. The S matrix of an ideal balun in this situation is

$$S_{11} = S_{22} = 0, \quad S_{12} = \sqrt{2}, S_{21} = 1/\sqrt{2}$$

This balun is matched and lossless and performs the impedance translation to 50 Ω.

The S matrix parameters of baluns are measured using a vector network analyser (VNA). Details are given in Appendix 2. New transmit and receive baluns with the files designated as Newt.bal and Newr.bal could be introduced into the modelling as follows:

4.1 Create New Pairs File

When the 'Create New Pairs File' button is clicked a new window opens which has a drop-down text box and a single button marked 'Edit'

4.1.1   Drop-.down Box

This performs the same function as the drop-down box on the setup screen. It allows the selection of a Pairs file to use as a template. If the new baluns are to be used with the NPL set of four dipoles [4], see Table below, the file named 'Four NPL Calculable BB Dipoles.txt' should be selected. If they are to be used with the NPL biconical choose 'NPL Calculable Biconicals.txt'.

Table of dimensions of the four NPL dipoles covering 30 MHz to 1000 MHz

Resonant frequency, MHz	Length, mm	Radius, mm
60	2370	4.7625 (⅜" diameter)
180	791	1.5
400	355	1.5
700	201	1.5

4.1.2   New Filename

In the text box below the drop-down box the new filename of the Pairs file to be created should be entered. Ideally, the baluns used for the transmit and receive antennas should be included in the filename. Example

Four BB Dipoles using Newt & Newr.bal

If the filename does not end in .txt this filename extension will be appended.

4.1.3   Edit

Select the template Pairs file to be edited and enter a new Pairs filename, then click the button marked 'Edit'. This results in a copy of the template file with the new filename being opened in NotePad. The necessary changes are made as follows:

1. Click Edit and then click Replace

2. In the 'Find what' box, type   Transmit Balun File : CHD497.bal

3. In the 'Replace with' box, type   Transmit Balun File : Newt.bal

4.   Click the 'Replace all' button

Repeat this process for the receive balun. With the instructions given all four dipoles referenced in the pairs file will have the associated baluns changed to Newt.bal. In the highly unusual situation where different baluns are to be used with each dipoles pair, the editing would be more protracted; for example one pair of baluns for the frequency range 20 – 100 MHz and another pair of baluns for the range 100 – 1000 MHz.

5.0 New Wire Antennas

When using NEC a wire antenna is modelled as an array of interconnected cylindrical wires. Each wire is specified by its end co-ordinates in space and its radius. NEC has a number of ways in which a wire antenna can be constructed but, at present, CAP only supports the 'GW' and 'GM' cards. The antenna is described by a series of lines of text each of which starts with the letters GW. GW is followed by a tag (a wire identifier), a segment specification, the end coordinates and the radius. For example, a 180 MHz resonant dipole could be described as follows:

GW   1   31   0   -0.3955   0   0   0.3955   0   0.0015

Here the tag is 1, the number of segments into which the wire is to be divided is 31, the x, y, z coordinates of the start of the wire in space are 0 m, -0.3955 m, 0m, the x, y, z coordinates of the end of the wire in space are 0 m, 0.3955 m, 0 m and the radius is 0.0015 m. Complex antennas are described by numerous GW 'cards' where wires that join must have identical end coordinates. For the parameters used in GM cards refer to the NEC manual (for example see http://www.nec2.org/). The collection of GW and GM 'cards' is terminated by a GE 'card', i.e. the terminating line of the collection just has the letters GE. These GW, GM and GE lines constitute the second half of the CAP model of an antenna and are preceded by 9 lines which provide additional information to CAP about the NEC model.

5.1 The CAP Model

Antenna files are stored in the 'Antennas' folder. There is a template file in this folder which should be used when constructing a CAP model. This begins with 9 lines, is followed by two dummy GW lines which are to be replaced by the NEC GW 'cards', and is terminated by a GE line. The first 9 lines provide the following information;

      5.1.1   Antenna Title

      The template displays the dummy title 'Antenna Title'. This should be replaced by a suitable title such as 'Teseq LPDA UPA6109'.

      5.1.2   Additional Data :

      This text can be followed by any extra information that might be useful. For LPDA antennas there is an in-built function. In the sample Teseq UPA6109 Log-Periodic Dipole file the following is included:

            Additional Data : Log, 0.030, 0.085, 0.830, 0.749

      This is used to identify the antenna as an LPDA and provide details of the shortest and longest elements, in the form – distance from tip, total length (tip to tip). This data is used, when calculating free-space antenna factors, to allow for the motion of the phase centre. As a result the reported antenna factors are independent of separation until the distance between the (identical) antennas is less than about 1.5 m

      5.1.3   Axis of Symmetry : x

      When two antennas are modelled in NEC it is a convention to place them at two positions along the x-axis. For two LPDAs this would imply, if they are to be oriented for minimum insertion loss, that the dipole elements are parallel to the y-axis. Rotating either antenna through 360° about the x-axis would have no effect and is considered as the axis of symmetry. Very rarely, the axis of symmetry will be the y-axis and since CAP places the transmit and receive antennas along the x-axis it would be necessary to rotate the antenna in this circumstance.

5.1.4 Boresight Direction : positive

In order not to end up with the transmit and receive antennas placed back-to-back it is necessary to specify the 'direction of fire'. If the maximum signal (from an LPDA, for example) is directed in the positive direction along the x-axis then 'positive' should be specified. On the other hand if the maximum signal propagates from the origin along the negative x-axis, 'negative' should be specified.

5.1.5 Reference Centre : 0

For dipole and biconical antennas the reference centre is 0 (m). For an extended antenna, such as an LPDA, if the wire data is all relative to the manufacturer's mark at the centre then, again, the reference centre would be 0 (m). If the LPDA data is such that the tip of the antenna is at the origin and results are required when two LPDAs are placed d metres apart tip-to-tip then, once more, the reference centre is 0 (m). However, if results are required when the LPDAs are placed with d metres between the marked centres and the NEC data is referenced to the tip, the reference centre should be the distance from the tip to the marked centre. In this situation, when the software reports free-space antenna factors they will be independent of separation.

5.1.6 Antenna Height : 0

If the NEC data refers to an antenna placed h metre above the reference (z=0) plane then the antenna height should be entered as h. For example, the sample biconical data is referenced to a height of 1 metre. In use, CAP controls the antenna heights.

5.1.7 Scaling Factor : 1

This is the scaling factor permitted by NEC. For example, the sample LPDA data is all specified in cm, so to ensure that all antenna data is in metres a scaling factor of 0.01 must be used.

5.1.8 Segment Multiplier

If convergence tests have demonstrated that the numbers of segments specified in the GW cards in the antenna file are two small, a segment multiplier can be included which will ensure that for all uses of the antenna model the calculations will be accurate. For example, if a convergence test reveals that the segment numbers should be multiplied by 1.5 to achieve stable insertion losses then the segment multiplier should be set to 1.5.

5.1.9 Tag of Source/Load wire : 1

CAP needs to know where to attach a source (transmit antenna) and load (receive antenna). This is specified by giving its tag. The source/load will always be placed on the centre segment of the tagged wire. The segments for this wire must be an odd number.

Appendix 1: The Program Folders

At present the folders used by the program are placed in the folder called CapData on the drive containing the executable (called CAP2010.exe). Also included in this folder is a file called Config.txt which contains the complete path to the CapData folder. The data can be moved elsewhere on the computer as long as the initial CapData folder and included Config.txt remain in situ. Config.txt would need to be modified to include the complete, including drive, pathname. There are 7 folders:

1. Antennas

The structure of the antenna files is detailed in section 5.1 'The CAP Model'. The software is supplied with five antenna files and a template file.

    24 Dipoles.txt
    9116A.txt
    NPL Biconical.txt
    NPL Dipoles.txt
    Teseq UPA6109.txt
    Template.txt

2. Baluns

The structure of the balun files, which have the extension .bal, is presented in Appendix 2. As supplied there are three files and the folder 'Three Port' in this folder

    CHD497.bal
    Through.bal
    LossLess.bal

3. Defaults

This folder contains the following text files:

Excel Path.txt	The full pathname of Excel is specified in this file. To disable the use of Excel as the results viewer either change the name of the file or give an incorrect path.
Impedances.txt	This file lists the instrument, source and load impedances, all currently 50 Ω
Matrix Time.txt	A two-line file created at start-up containing the time it takes to factor the sample matrix. Knowing the times to fill and factor this matrix on a reference computer it is possible to estimate computation times. Filling goes as the square of the number of segments (the matrix is square and has rows/columns set by the total number of segments) and factoring goes as the cube of the number of segments. On the reference computer (a Pentium M) the factor time is 1.14 sec. It is estimated that to fill and factor a matrix with 4,000 rows and columns would take about half an hour on this computer.

Places.txt	By default the two lines in this text file are:
	        Decimal places for frequency : 0
	        Decimal places for SIL : 3
	These indicate that all frequencies will be treated as integers and insertion losses will be displayed with three decimal places. If more than 3 decimal places are specified for frequency it will be limited to 3 giving 1 kHz resolution. SIL is limited to 4 decimal places. Antenna factors are always presented to 2 decimal places.

4. Documentation

This folder holds the two versions of the manual

CAP User Manual.txt
CAP User Manual.mht

The latter is used when help is sought when running the software

5. Pairs

The structure of Pairs files is discussed in Appendix 3. Creating new Pairs files when new baluns are to be introduced is described in section 4. 'Changing Baluns'. The files supplied are:

PairsIndex.txt
Four NPL Calculable BB Dipoles.txt
24 NPL Calculable Dipoles.txt
NPL Calculable Biconicals.txt
Teseq Log-Periodic Dipoles.txt
UBA9116 & Calculable Biconical.txt

PairsIndex.txt contains the list of Pairs files and is updated when 'Create New Pairs File' is used.

6. Scripts

As supplied, there are three files in this folder:

Current Script.txt
Default Script.txt
Script Template.txt

Script files contain a complete list of the setup conditions. The file Default Script.txt is used when the program is started to fill all the fields (Start Frequency etc.). The Current Script.txt file is created just prior to computation. In the event of a catastrophic error this file can be analysed for the possible cause. Script files can be saved and loaded by the user. Changing the Default Script.txt file enables alternative start-up parameters to be loaded.

7. WorkSpace

The results files are created in this folder. Testing convergence produces a SegmentTest.csv file which gets overwritten (unless renamed) with each new test. Other results files are labelled Resultnnn.csv, where nnn takes on the values 001, 002 and so on (up to 999) as computations are carried out. The results files are displayed in NotePad or Excel and if regarded as important should be stored in a folder of the user's choice with a recognizable filename.

Appendix 2: Balun Files

Balun data may be entered in one of two ways:

1. In the 'Three Port' folder

This folder is contained within the 'Baluns' folder and is reserved for raw VNA S-parameter data. If the balun file to be introduced is called 'New.bal' then a file with this name must be created in the 'Three Port' folder listing the three sets of two-port data created by the VNA. These filenames must be in the order AB, AG, BG where port A is the unbalanced port (i.e. the antenna input) and ports B and G are the two balanced ports that are connected to each half of the dipole element.. An example .bal file is given below, for a balun named Balun1.
CAP processes these files by first searching for an input line containing the 'word' FREQ. It then skips a line and starts looking for the S parameter data. The data is similar to that described above but the order is different.

Frequency (MHz)   S11re, S11im, S21re, S21im, S22re, S22im, S12re, S12im

The files are terminated with the character ';'. The frequencies must be in order and it is essential that the same sets of frequencies occur in all three files.
An example .txt file is given below; re and im refer to the real and imaginary parts of the complex S matrix elements.

Where dipoles can be specified by a single GW 'card', a collection of such cards describing diploes to be used at different frequencies can be placed in a single antenna file (as with the Four NPL Calculable BB Dipoles). To indicate which dipole card is to be used the antenna filename is followed by the sequence number of the card in brackets.

Example content of Balun1AB.txt

```
; ********** HP8753 NETWORK ANALYSER 4-PORT MEASUREMENTS *********
;
; HOST CODE IDENTITY STRING:
;
; TITLE: Balun1AB
;
; TIME: Tue Jan 11 15:17:20 2011
;
; DATA: CORRECTED S-PARAMETERS
;
; CALIBRATION: Two port
;
; NETWORK ANALYSER IDENTITY: HEWLETT PACKARD,8753
;
; START=20MHz  STOP=1020MHz  (RAMP)
;
; POWER=0dBm   POINTS=651   AVG=4   ELEC.DELAY= (NONE)
;
; SWEEP TIME=12sec   IFBW=100Hz
;
;
; FREQ    S11                 S21                 S22                 S12
;MHz Re.        Im.        Re.        Im.        Re.        Im.        Re.        Im.
20.0 -0.114456 0.277313 -0.367065 0.251541 0.139656 0.075516 -0.367111 0.251602
21.0 -0.110016 0.266068 -0.351761 0.273270 0.137871 0.062721 -0.351761 0.273254
22.0 -0.106415 0.256042 -0.335327 0.293304 0.135529 0.051048 -0.335236 0.293320
24.0  etc
```

<u>Example content of Balun1.bal</u>

```
Balun1AB.txt
Balun1AG.txt
Balun1BG.txt
```

2. Alternatively, balun data may be entered directly in the 'Baluns' folder

CAP2010 processes the data in the Three Port folder to by condensing the three-port into a two-port [3] which is needed in order to integrate the balun data with the NEC output. Alternatively the two-port data can be generated by other software.

The two-port files have the extension .bal and the following format:

A sequence lines of data containing the frequency and S parameters separated by whitespace (spaces, carriage returns, etc. but not commas). The order of the S parameters is important

Frequency (MHz)   S11re, S11im, S22re, S22im, S12re, S12im, S21re, S21im

The frequencies must be in order. The file is terminated with EOF.

Appendix 3: Pairs Files

The structure of a Pairs file is best illustrated by an example 'NPL Calculable Biconicals.txt'.

```
1
First Antenna Pair
Title: Two NPL Calculable Biconicals
Comment:
Start Frequency (MHz): 20
End Frequency (MHz): 320
Transmit Antenna File : NPL Biconical.txt
Transmit Balun File : CHD497.bal
Transmit Balun Resistance (ohm): 100
Transmit Balun Reactance (ohm): 0
Receive Antenna File : NPL Biconical.txt
Receive Balun File : CHD497.bal
Receive Balun Resistance (ohm): 100
Receive Balun Reactance (ohm): 0
End
```

This file has a single entry covering the whole frequency range from 20 to 320 MHz. The file 'Four NPL Calculable BB Dipoles.txt' contains four entries all with the same structure each covering a (contiguous) subset of the frequency range.

The first line in the file holds an integer specifying how many entries there are in total. Each entry consists of 14 lines, the first of which is a somewhat arbitrary sequence indicator and the last always consists of the word 'End'

Most lines are self explanatory. When the balun files for transmit and receive are different, average antenna factors are calculated. The balun impedance should be (100, 0) for a real balun and (50, 0) when Through.bal is used.