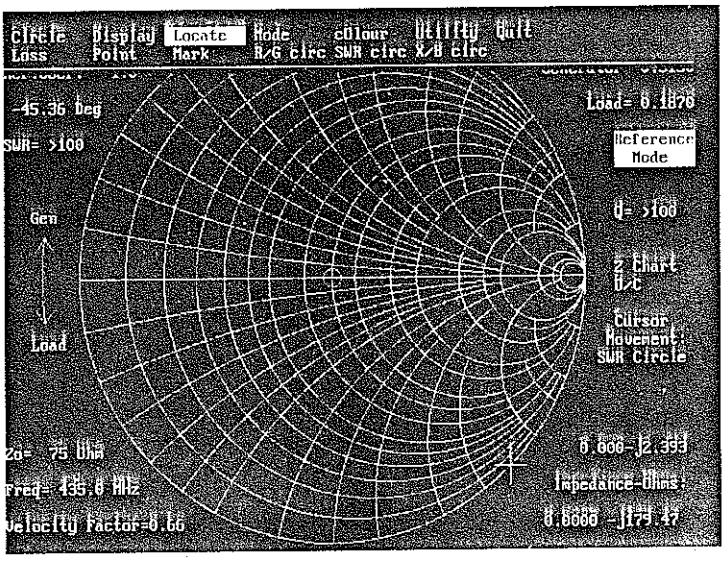
Z-MATCH II — A REVIEW

by Mike Wooding G6IQM

Z-MATCH II is a Smith chart RF design software package. Quoting from the supplier, Number One Systems: '*In spite of the availability of modern design aids, such as the hand-held programmable calculator, sophisticated circuit simulation and Computer Aided Design (CAD) software, the Smith chart is still widely used as a radio frequency circuit design tool. The Z-MATCH II program enables the Smith chart design process to be performed easily and accurately on a personal computer.*'



For those of you who have never seen a Smith chart, the following is going to seem like white man's magic! However, I shall attempt a short explanation of what a Smith chart is, and how one is used. This is not going to be the easiest thing for me to do, as it is a very long time since I learnt how to use them. Therefore, with the kind permission of Number One Systems Limited, I am going to reproduce, in part, the introductory explanations of Smith charts and their uses from the Z-MATCH II instruction manual.

Smith chart circles

The Smith chart is made up of two sets of circles; one set represents the resistive part, R, of a complex impedance, the other set represents the reactive part, X.

Normalised resistance and reactance

In order to avoid the need for a different chart for each characteristic impedance, Z_0, the paper Smith chart uses normalised values of resistance and reactance circles. The normalised impedance, Z_n, is given by:

$$Z_n = Z/Z_0 = (R/Z_0) + j(X/Z_0)$$

Where Z, R and X are the actual values of impedance, resistance and reactance respectively.

Series impedance values

The impedance of any point on a transmission line can be represented by a point on a Smith chart.

The series impedance value of a point on the chart is found by reading the values of the intersecting resistance and reactance circles. The Z-MATCH II program displays the series impedance value corresponding to the cursor position on the chart.

Parallel admittance values

An admittance value (Y-) Smith chart can also be drawn. The circles on this chart represent values of constant conductance ($1/R$) and constant susceptance ($1/X$). By using a Y-chart overlay on an impedance chart, it is possible to convert from series impedance to equivalent parallel admittance.

Standing wave ratio (SWR)

A circle that is concentric with the centre of a Smith chart has a fixed value SWR. The SWR of such a circle is equal to the value of R/Z_0 at the point where the circle crosses the horizontal axis on the right-hand side of the chart.

Intersections of the SWR circle with the horizontal axis on the left of the circle represent points of voltage minimum, intersections on the right represent voltage maxima. Moving round a constant SWR circle is equivalent to travelling along a lossless transmission line; successive values of impedance indicated on the chart correspond to the impedances seen along a lossless line with the same SWR.

Wavelengths towards generator and load

The distance moved on a transmission line is directly proportional to the angle of rotation around a constant SWR circle; one revolution is equal to a half wavelength movement.

Moving around an SWR circle in a clockwise direction is equivalent to travelling towards the generator, whereas moving anti-clockwise is the same as travelling towards the load. The wavelengths towards the generator and load (backwards and forwards respectively) are shown on the periphery of the standard paper Smith chart. These peripheral scales on the paper chart are used by drawing a straight line from the centre of the chart through the point of interest. The Z-MATCH II chart indicates directly the wavelength (or length in metres) corresponding to the cursor position.

By convention, the starting point for the wavelength scales is the left-hand minimum position; this is because in practice it is easier to accurately locate a voltage minimum than a voltage maximum on a line. The angle of the reflection coefficient is zero at the opposite, voltage maximum, point. Since the Smith chart repeats itself every half wavelength around a constant SWR circle, lines longer than half a wavelength are dealt with by subtracting multiples of a half wavelength from the actual line length.

Lumped L and C circuits

The Smith chart can also be used for the design and analysis of discrete L and C circuits. When a single component L, C or R is added to a network then either the resistance (R), reactance (X), conductance (G) or susceptance (B) parameter of that network will not change. The point representing the network impedance, or admittance, on the Smith chart will therefore move on a particular chart circle when a single component is added.

By switching between the Y and Z charts and moving the cursor on constant reactance or constant susceptance circles, it is possible to move from any one point on a chart to any other. Moving on a Y chart susceptance circle is equivalent to adding parallel inductance or capacitance to a network; moving on a Z chart reactance circle is equivalent to adding series inductance or capacitance. Using the Z and Y charts in this way, it is possible to build up networks to impedance match from any source impedance to any given impedance load.

The reference mode facility provided by the Z-MATCH II (see below) program is particularly useful in this type of process; the reference mode enables the value of inductance or capacitance required to move between any two points on a circle to be read directly.

With the conventional paper Smith chart the rules for the correct direction of movement on the constant parameter circle need to be known. Z-MATCH II simplifies the procedures involved considerably, by displaying directly the equivalent value of R, L and C at the operating frequency chosen. The change in L, C or R can therefore be seen as the cursor moves round any of the constant parameter circles.

Z-MATCH II

Z-MATCH II is a CAD package for designing and calculating Smith charts. The basic requirements to run the package are an IBM PC/XT/AT/386 or PS2 computer, or compatible clone, running under MS-DOS 2.0 or later; a col-

our graphics adaptor (CGA, EGA or VGA) and a colour monitor, and a minimum of 256k of free RAM. For hard copy of the output an IBM Graphics printer, or compatible, and adaptor card are required. Z-MATCH II does not require a maths co-processor to be installed, but it will increase the speed of operations substantially. A mouse may be used with the software, but, as will be seen later, owing to the necessity of precision locating of the cursor, this method is not wholly satisfactory.

User manual

The presentation of the package is very good. The user manual comes in an A4 ring binder, allowing for updates to be added easily. The software is supplied on one 5.25-inch 360k disk or one 3.5-inch 720k disc, both being supplied with the package.

The user manual begins with the usual software and copyright licence conditions and agreement, followed by the introduction, installation, running and basic operating instructions. The manual then continues with a brief description of what a Smith chart is and what it can be used for. This is, as is explained in the manual, by no means meant to be able to teach you the whats, whys and wherefores of Smith chart use, but is a general guide for those already conversant with the subject. For those less used to working with Smith charts, a tutorial section of worked examples is included later in the manual.

Following the initial section of the user manual is a comprehensive detailing of all the features of the package and explanations of all the features, menus and command key functions.

Cursor control

There are four methods of manipulating the cursor around the chart:

- in straight lines using the numeric keypad keys (2, 4, 6 & 8). The speed of movement can be changed by holding down the 'SHIFT' key simultaneously;
- if your keyboard is an enhanced version with separate cursor control keys, then these can also be used. In this case the shift key will not change the speed of movement with these keys, but the speed will always be opposite to that with the numeric cursor control keys;
- the 1 and 3 keys on the numeric keypad ('End' and 'Pg Dn') move the cursor around selected circles (see below). On the enhanced keyboard the separate 'End' and 'Pg Dn' keys also do this, but at the slower speed;
- using the mouse, by pressing the left-hand button, moving the pointer to the desired position and then releasing the mouse button. However, as previously noted, using the mouse to position the cursor is less accurate than using the cursor keys which is the recommended method.

Features

Although, owing to the complexity of the software, I am unable to give a complete description of all the features available, I hope to briefly describe some of the major functions.

Circles

This function allows the user to draw various circles on the chart:

- a circle centred on the current cursor position;
- a constant conductance circle that passes through the current cursor position when in the impedance mode;
- a constant resistance circle that passes through the current cursor position when in the admittance mode;
- a constant Standing Wave Ratio (SWR) circle that passes through the current cursor position (this circle passes through all the impedance, or admittance, points that would be present on a half-wavelength of transmission line with the same SWR and Z_0 value);
- a unity conductance circle to be drawn on the chart when in the impedance mode.

Displays

This allows the method in which the parameters are displayed on the chart to be changed to suit the user's requirements in the following ways:

- a rectangular or polar coordinate display shown at the bottom of the screen. This process serves the same function as using a Carter chart overlay with a paper Smith chart;
- toggling between a wavelength scale from source and load to a distance in metres scale from source and load, depending on which constants or parameters are already known;
- redraw the entire chart, maintaining the values of frequency, Zo, etc., already entered, but clearing the display of any circles drawn, whilst maintaining the current cursor position;
- the ability to enter the various known parameters, i.e., characteristic impedance (Zo), frequency and dielectric constant or velocity factor.

Locate

This set of functions allows the user to easily manipulate the graphics cursor around the chart:

- the ability to compensate for transmission line loss, by simply entering the loss in dB, which updates the cursor to a new position, taking the loss into account and giving the corresponding SWR, impedance, etc.;
- the ability to move the cursor to a specific point on the chart relative to the prompted input of values for series impedance, parallel admittance, polar impedance or scattering parameter;
- the facility to permanently mark a cursor position on the chart for future reference;
- selection of cursor movement around constant resistance or conductance circles, SWR circles, or the constant reactance or susceptance circles.

Other facilities are available which allow the user to switch the program to reference mode, which enables further calculations to be made with reference to the current cursor position. Also, the display can be switched between series impedance and parallel admittance displays, using a single function key stroke. The background and drawing colours used in the display can also be user selected.

Main features of Z-MATCH II

Z-MATCH II displays a Smith chart which shows:

- Actual Impedance and Admittance
- Normalised Impedance and Admittance
- Polar Impedance
- Distance towards Generator and Load
- Reflection Coefficient
- Standing Wave Ratio
- Equivalent Inductance or Capacitance
- Z_0, Frequency and Dielectric Constant
- Network Q

Z-MATCH II provides these features:

- Conversion between Impedance and Admittance
- Circle drawing
- Determination of the effect of line loss
  Line Transformer calculations
- Location of any given Z, Y, S or Polar parameter
- Movement of the screen cursor on chart circles
- Amplifier design using S-parameters
- Display of ANALYSER II program output files

Note: ANALYSER II is an advanced AC Linear Analysis program that calculates and displays the steady-state AC frequency response of a circuit in terms of gain, phase, group delay and input/output impedances. It is also available from Number One Systems Limited at a cost of £195.00 exclusive of VAT and p&p. This package may also be reviewed at a later date.

Conclusions

I found the package easy to use and the results obtained were as accurate as those that could be obtained by manual charting, but much quicker and easier to obtain! The ability to quickly change parameters and observe the changes on the chart is an absolute boon to a designer.

I agree with the comment in the user manual that a mouse can be used but is not recommended. It is not really possible to place the cursor accurately enough using the mouse. However, moving around the chart with the mouse and then making final precise adjustments with the cursor keys worked fine.

Obviously aimed at the professional RF circuit designer, this package represents excellent value for money, especially when taking into account the time that could be saved using such a utility, instead of the 'Bob Crachett' method using quill and ink. Highly recommended.

I wish to thank Mr. Espin of Number One Systems Limited for his help and advice, and for the review software. ■

Z-MATCH II is priced at £195.00 + £4.75 p&p + VAT and is available from: **Number One Systems Limited, Harding Way, St.Ives, Huntingdon, Cambridgeshire PE17 4WR. Telephone: (0480) 61778. International: +44 480 61778. Fax: (0480) 494042.**