

# An Interactive Smith Chart

Sanjeev Baskiyar, PhD  
Assistant Professor  
Dept. of Computer Science and Software Engineering  
Auburn University  
Auburn, AL 36849  
*baskiyar@eng.auburn.edu*

## Abstract

*Smith* is an instructional, interactive, menu driven program that offers the use of *Smith Chart* on a personal computer. Using the *Smith Chart* is greatly simplified by providing the user with a “tracking mode” in which the cursor is tracked, showing the normalized resistance and reactance as well as distances from source and load. Also, construction lines such as radius, diameter and circles can be drawn and erased. The position on the *Smith Chart* corresponding to any point on the transmission line can be determined by simply specifying the input impedance at that point. The software can also be used to plot the Standing Wave Ratio (*SWR*) over the desired frequency range.

## 1 Introduction

Many transmission line problems can be solved to a desired accuracy for most practical purposes using a *Smith Chart*. It has been a proven tool for many decades. The *Smith Chart* has been used for matching a transmission line using a single or a double stub. *Smith Chart* is taught in almost all EE curriculums. The software *Smith* facilitates an interactive use of the *Smith Chart*. It makes learning to use the *Smith Chart* fun and easy.

Using the *Smith Chart* is greatly simplified by providing the user with the tracking mode in which the cursor is tracked, showing the normalized resistance and reactance as well as distance from source and load corresponding to the cursor's position. Also, construction lines can be drawn and erased. The position on the *Smith Chart* corresponding to any point on the transmission line can be determined by simply specifying the input impedance.

In the next section we describe the features of the software package *Smith* and in the following section we make some concluding remarks.

## 2 Description

Let  $G$  represent the complex reflection coefficient at any point on the transmission line. It is defined as the ratio of the complex amplitudes of the reflected voltage wave to that of the incident voltage wave on the transmission line. The *Smith Chart* consists of circles and arcs of normalized resistance,  $r$ , and normalized reactance  $x$  on the  $G$  plane. We call the area within the  $r = 0$  circle as the bound of the *Smith Chart*. The intersection of the  $r = 1$  circle and the  $x = 0$  circle, which is a horizontal straight line since its radius is infinity, is called the center of *Smith Chart*.

The main window of *Smith* is named *Smith Chart* and is shown in Figure 1. The child window on the left of the main window is used to display the *SWR* versus frequency graph. The main window has eight menu items: *Draw*, *Erase*, *Parameters*, *Convert*, *LocateImp*, *Label*, *Track* and *SWR*. The menu items *Draw* and *Erase* have pop-up menu items. The pop-up menus of *Draw* are: *Circle*, *Radius* and *Diameter*. The pop-up menus of *Erase* are *Circle*, *Radius*, *Diameter* and *Point*. Below we discuss the features of the software *Smith* by describing the operation of each of the menu items.

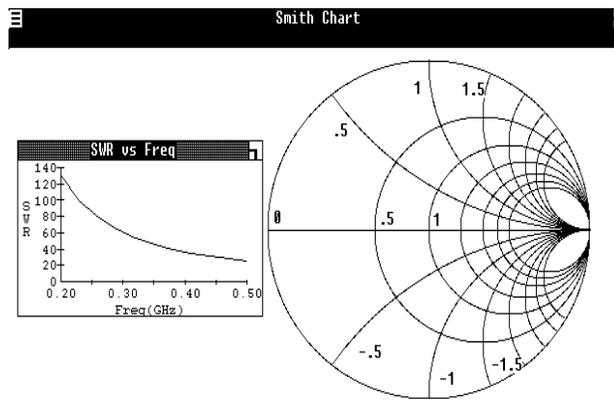


Figure1: The Main Window of *Smith*

## 2.1 Actions using menu items

One can draw and erase construction lines on the *Smith Chart* by using the menu items. To draw a circle one has to specify its center and a point on its circumference by clicking at those points. If you select one of the points such that any part of the resulting circle will lie outside the bounds of the *Smith Chart*, the circle will not be drawn. In other words, when you are in the *Draw Circle* mode you can double click outside the bounds of the *Smith Chart* if you decide not to draw a circle, and wish to exit this command. Similarly you can draw a radius/diameter passing through the center of the chart and any chosen point within the bounds of the *Smith Chart*. The above constructions can be selected and erased using the *Erase-Circle*, *Erase-Radius*, *Erase-Diameter* commands available from the menu items. The user can also erase any point that he/she had located using *LocateImp*.

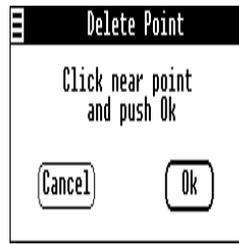


Figure 2: The Delete Point Dialog Box

The *Parameters* menu item allows one to enter the parameters of the transmission line and those of any matching stub using the dialog box in Figure 3.

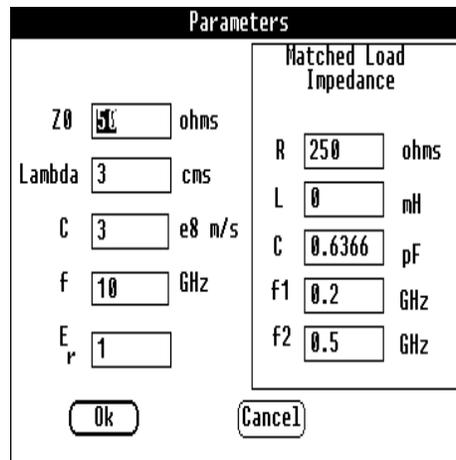


Figure 3: The *Parameters* Dialog Box

You can specify the characteristic impedance of the transmission line  $Z_0$  and the wavelength of operation  $\lambda$ . The value of  $\lambda$  can be specified either by directly entering it in its edit box or by entering a consistent combination of values of  $c$ ,  $f$  and  $\hat{\epsilon}_r$ . The parameters  $c$ ,  $f$  and  $\hat{\epsilon}_r$  represent the velocity of electromagnetic waves on the transmission line media, the frequency of operation and the relative permittivity of the transmission line medium respectively.

The values in the Matched Load Impedance box in Figure 3 are required only when a transmission line has been matched and one is interested in the *SWR* of the matched transmission line over a band of frequencies. The parameters  $R$ ,  $L$ , and  $C$  represent the resistance, inductance and capacitance at any point on the stub (and of the transmission line). The parameters  $f_1$  and  $f_2$  represent the frequency interval within which a plot of *SWR* versus frequency is desired. The *SWR* versus frequency graph will be plotted when *SWR* is selected from the menu item.

The *Convert* menu item displays the *Convert* dialog box shown in Figure 4. Using this dialog box one can change actual impedance values to normalized impedance values and vice versa.

One can also change lengths in meters to multiples of wavelengths and vice versa. As soon as a value is entered in any of the edit boxes the converted value appears in the corresponding box.

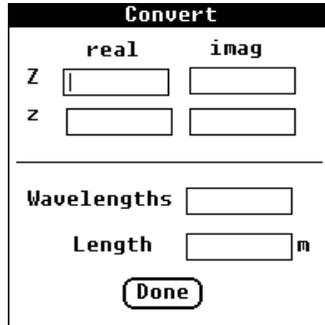


Figure 4: The *Convert* Dialog Box

The *LocateImp* menu item helps to locate an impedance value on the *Smith Chart*. On selecting this menu item the dialog box shown below appears:

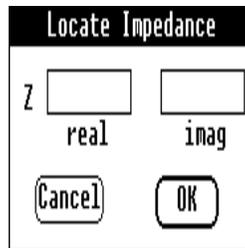


Figure 5: The *Locate Impedance* Dialog Box

The real and imaginary parts of impedance can be entered in the boxes provided. On activating OK the program divides these values by  $Z_0$  to get the corresponding normalized values and marks the point on the *Smith Chart* representing these values with a '+' sign. The point located by a *LocateImp* command can be labeled with an alphanumeric character by selecting the *Label* menu item.

Using the *Track* menu item one can track the cursor's location on the *Smith Chart* as mentioned earlier. On activating the *Track* menu item the Position dialog box shown in Figure 6 appears.

Position	
<input type="checkbox"/> z	
r	0.120 × 0.323
Tr	-0.6493 Ti 0.47557
Wavelengths toward source	
	0.05031
load	
	0.44969
<input type="checkbox"/> ref point: 0	SWR 9.24823

Figure 6: The Position Dialog Box

This command tracks the values of the normalized resistance,  $r$ , and reactance,  $x$ , corresponding to the cursor's position on the *Smith Chart*. It also tracks the wavelengths toward the source and load (the distance of the point on the transmission line from the source and the load). Unless the reference point is changed the source and load are assumed to be at the normal reference point '0' on the *Smith Chart*. The distances from the source and load are shown in fractions of wavelengths. The distances cycle at each half wavelength. To track the reflection coefficient  $G = T_r + j T_i$  and  $SWR$  on the transmission line one locates the load impedance on the *Smith Chart*. One then draws a circle passing through the above point and the center of the *Smith Chart*. Moving the cursor on the circle tracks  $G$  and  $SWR$  on the transmission line as a function of distance. The tracking mode can be changed from impedance to admittance by toggling the check box labeled  $z$ . On doing so  $z$  changes to  $y$  indicating the impedance mode. Also,  $r$  and  $x$  change to  $g$  and  $b$  and the values in these boxes give the conductance and susceptance corresponding to the cursor position. The normal reference '0' at which the source and load are located on the *Smith Chart*, can be changed by using the 'ref point' check box in Position dialog box. When the position box is displayed the menu item *Track* is changed to *EndTrack*. One can terminate the track mode by selecting *EndTrack* whereupon the Position dialog box disappears and the menu item *EndTrack* is changed to *Track*.

### 3 Conclusion

The software *Smith* allows ease of use of the *Smith Chart*. It interests students in learning about the *Smith Chart*. The features of tracking the cursor, showing the normalized resistance and reactance, distance from the source and the load, the reflection coefficient and the  $SWR$  has been liked by many. One does not need to strain the eye to find the above values, which could be the case on a small paper *Smith Chart*. The software features the ability of drawing and erasing radius, diameter and circles. The facility of automatic location of impedance and conversion of values has also been very well received.

### References

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BIODATA OF AUTHOR

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Sanjeev Baskiyar received the PhD and MSEE degrees (major: Electrical (Computer) Engineering, minor: Computer Science) from the *University of Minnesota*, Minneapolis in 1993 and 1988 respectively and the BE (Electronics and Communications) degree from the *Indian Institute of Science*, Bangalore in 1984. He received the BS degree in Physics with honors and distinction in Mathematics in 1981. He was a recipient of the competitive National Merit Scholarship, the State-merit Scholarship (twice) and the Indian Institute of Science Scholarship. He ranked in the top quartile in JEE/IIT. He was nominated for the *Best Teaching Assistant Award of the Year* in the ECE dept. at the University of Minnesota, Minneapolis. He has taught courses in the areas of Real-time and Embedded Computing, Computer Systems Architecture, Operating Systems, Microprocessor Programming and Interfacing and VLSI Design. His research interests are in the areas of Computer Systems Architecture, Distributed Computing and Task Scheduling. His experience includes working as an Assistant Professor at Western Michigan University, as a Senior Software Engineer in the Unisys Corporation, as a Programmer in IBM's *ProjectWoksape*, as a Project Manager in U of M, St. Paul and as an Assistant Computer Engineer in Tata Engineering and Locomotive Company Ltd., India. He has published in the areas of Computer Systems Architecture and Task Scheduling on Multiprocessors (*web site—<http://www.eng.auburn.edu/users/baskiyar>*).