An Introduction to the Smith Chart for Amateur Radio

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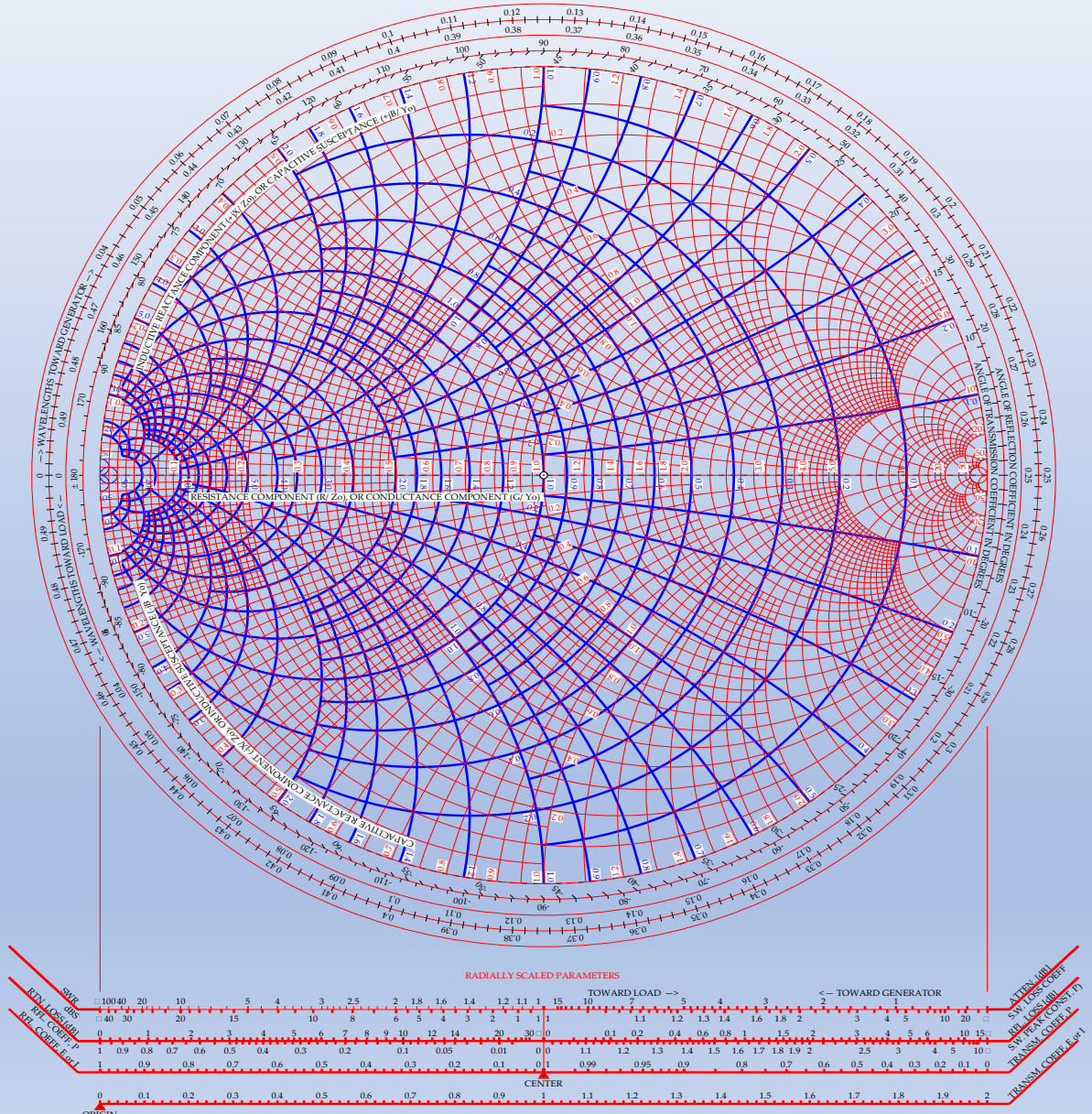
The Smith Chart



Outline of Presentation

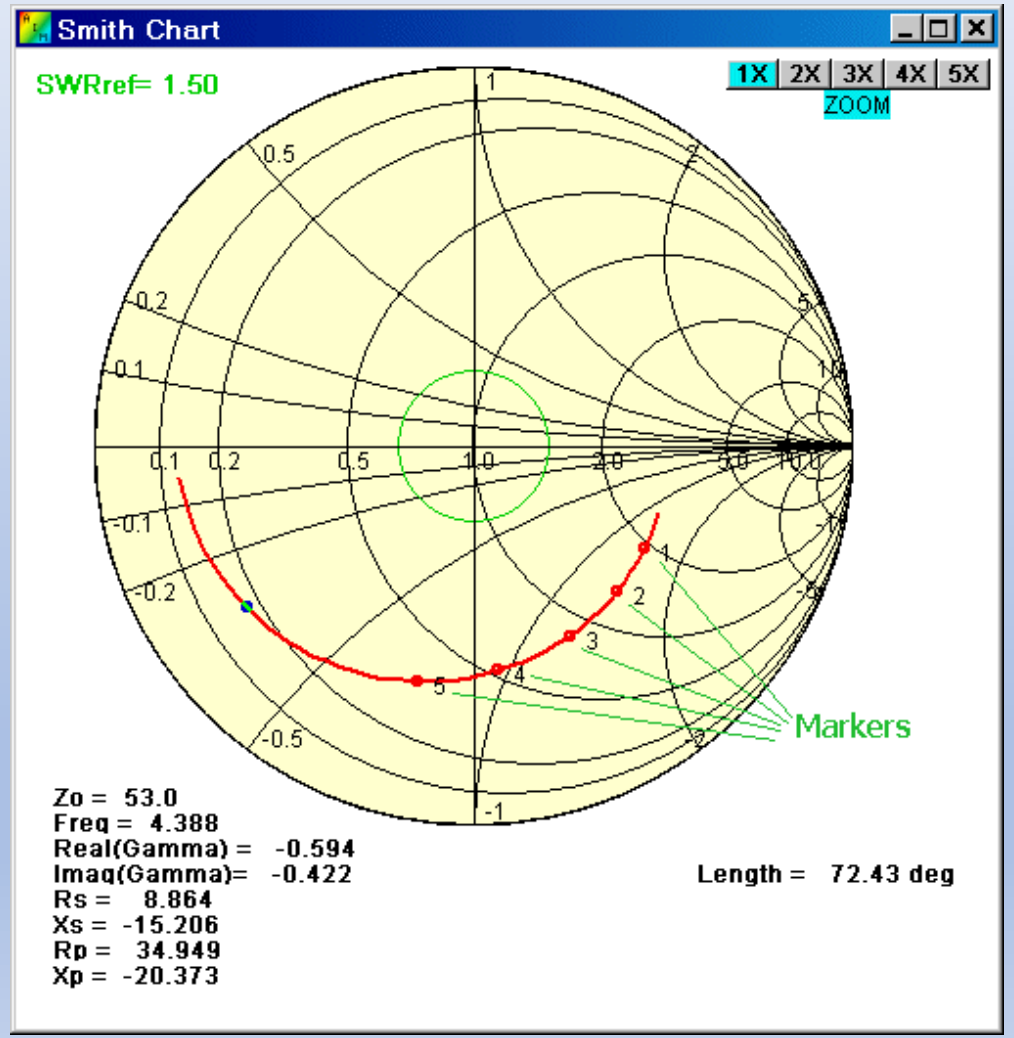
1. What is a Smith Chart?
2. Why should hams care?
    1. Understanding antennas, transmission lines, and circuits.
    2. Instrumentation marketed to the amateur community.
3. Some mathematical and physical basics
4. Exploring the Smith Chart
5. Representations on the Smith Chart
6. The Smith Chart on the computer
7. An impedance matching example using Smith Chart on the computer

What is a Smith Chart?

- The Smith Chart is a complex transformation of the transmission line equations on a polar plot with a loci of constant resistance and reactance lines superimposed on a polar plot of of reflection coefficients and angles of reflection coefficients.

- Why should the average ham care?
  - Instruments marketed to the ham community
  - Sometimes shown in amateur articles and books
  - Essential if you want to design your own amplifiers

Instruments Marketed to the Amateur Community



Mathematical and Physical Basics

- Scientific Notation
- MKS Units
- Radian Frequency
- Complex Operator
- Complex Impedance (Admittance)
- Normalization
- Lumped and Distributed Components
- Wavelength

Scientific Notation

- A compact way to express either very large or very small numbers as powers of 10. The most important quantities for Smith chart work:
  - Kilo 10^{3}
  - Mega 10^{6}
  - Nano 10^{-9}
  - Pico 10^{-12}
- MKS units are based on the meter, kilogram and second. Units used in Smith chart work (although they can be inconvenient) are Ohm (Ω), Farad (F), Henry (H), and Hz.

Radian Frequency

- In calculations on the Smith Chart, frequency must be expressed as Radians/Sec not Hz.
- Do not worry. The conversion is simple and it is, for the most part, transparent to the user.
- Radian frequency is expressed as ω, which is the lower case of the Greek letter Omega (Ω).
- Frequency in Hz is represented by f, and f and ω are related by

$$\omega = 2\pi f$$

The Complex Operator *i* (Actually *j*)

- Expressing many electronic quantities in terms of a complex number is a very powerful analysis technique. Mathematicians and physicists usually use i, where
  - $i = \sqrt{-1}$
- In electrical engineering the letter j is used to avoid confusion with i which is usually reserved for current. So
  - $j = \sqrt{-1}$
- Remember: It is the same thing

Complex Impedance (I)

- We will only be dealing with impedances, but the Smith Chart is both an impedance and an admittance chart.
- All complex impedance means is that an impedance consists of both a real (resistive) and an imaginary (reactive) part.
- When the reactive part is preceded by a +j, the impedance is inductive.
- When the reactive part is preceded by a –j, the impedance is capacitive.
- When the reactive part is 0, the impedance is real.

Complex Impedance (II)

- Complex impedance is expressed as

$$Z = R \pm jX$$

Inductive reactance

X_L=j ωL

Capacitive reactance

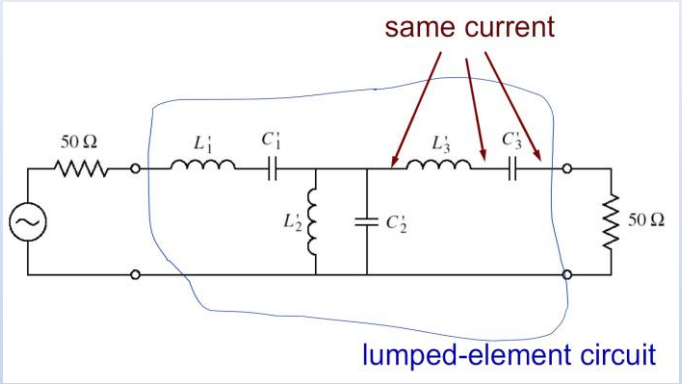
$$X_C = -j\frac{1}{\omega C}$$

Normalization

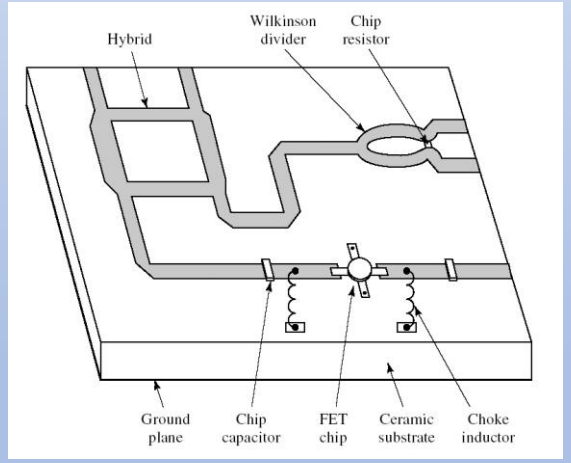
- The Smith chart is a general chart for all normalized impedances.
- The normalized impedance is the measured impedance divided by the characteristic impedance of the system, Z_o.
- 99.999% of the time, Z_o=50 Ω.
- At the end the results must un-normalized.

$$z_n = \frac{R \pm jX}{Z_o}$$

Lumped and Distributed Components



Lumped Components



Distributed Components

Wavelength

- Wavelength is equal to the speed of light divided by the frequency (always in Hz):

$$\lambda = \frac{c}{f}$$

Speed of light:

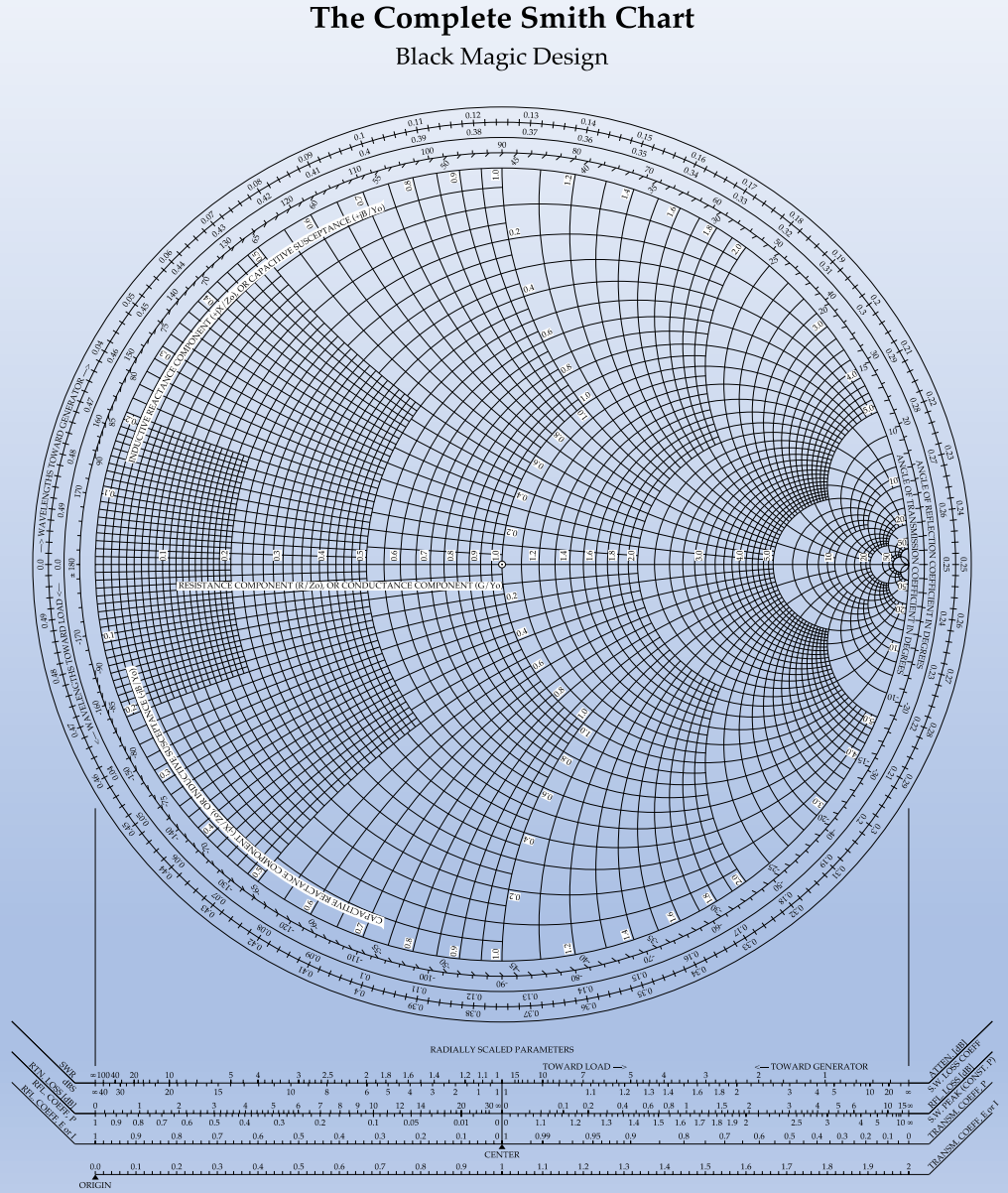
$$2.998\ x\ 10^{8}\ \frac{M}{S}$$

$$2.998\ x\ 10^{10}\ \frac{cm}{s}$$

$$9.836\ x\ 10^{8}\ \frac{ft}{s}$$

$$1.18x\ 10^{10}\ \frac{in}{s}$$

Smith Chart (Impedance Only)



The Smith Chart on the Computer

- There are a number of Smith chart programs available. One of the best is from Prof. Fritz Dellsperger of Bern University of Applied Sciences. The free version can handle 5 data points, which is usually enough for ham radio work. The full version is available to the ham market for $80 and a valid call sign.
- www.fritz.dellsperger.net

Matching Circuit Example

- Questions?