Bob's TechTalk #15
by Bob Eckweiler, AF6C

Impedance – Part I

Antennas and feedline cannot be discussed without hearing the word impedance. What exactly is impedance and where and why is it important? This month we'll try to answer these questions.

Looking at the input terminals of an antenna, that antenna can be represented closely by the circuit in figure one. The values of the three components, a resistor, a capacitor and an inductor determine the impedance of the antenna. The impedance is made up of two parts, resistance and reactance. Let's look more carefully at each of these parts. The resistive part is what does the work and is called the real part. It absorbs the energy from the antenna, turning it into either a radiated signal (good!) or heat (not good!). The inductive and capacitive components combine to determine the reactive part. The reactive part of the impedance absorbs no energy and is thus referred to as the imaginary part. The reactive part causes the voltage and current peaks to occur at different times in a cycle; this is called phase shift (See Sidebar).

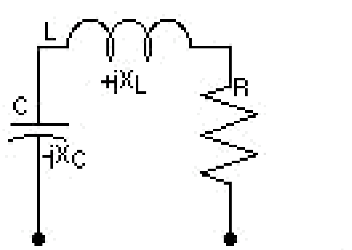

Figure 1

The reactance of an inductor is a positive value while the reactance of a capacitor is a negative value; both measured in ohms. The total reactance of an inductor and capacitor in series is the sum of these values. (Note that when you add the capacitive reactance you are adding a negative number.)

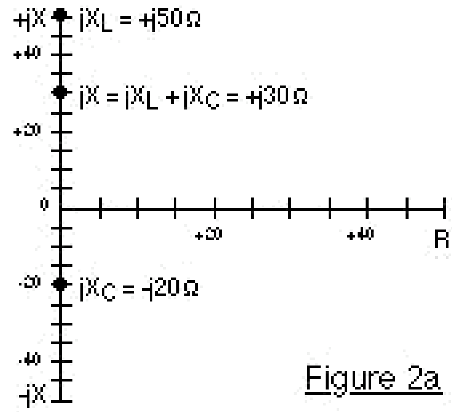

Figure 2a

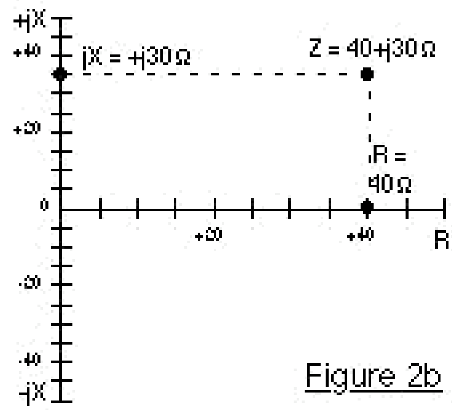

Figure 2b

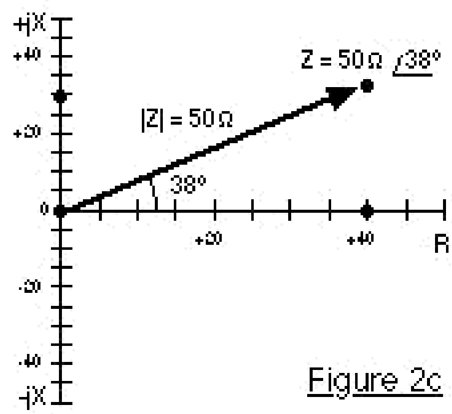

Figure 2c

Figure 2a is a simple graph. The horizontal axis represents the resistive part of the impedance and the vertical axis represents the reactive part. The horizontal axis starts at zero at the left, since the resistance cannot be negative. The reactance can be positive or negative so the vertical axis passes through the zero point of the horizontal axis. Inductive reactance is plotted above the horizontal axis and capacitive reactance, being negative, is plotted below it. The horizontal axis is labeled R for Resistance and the vertical axis is labeled jX for reactance. (Remember that reactance doesn't absorb any power and is the imaginary part. Since the symbol "i" was taken to represent current, "j" is used to signify "imaginary".) We'll talk more about "j" more in a future article. For now don't treat it as part of the equation; instead think "an imaginary". When you see " -j20Ω" say "minus 'an imaginary' twenty ohms".

Let's assume that, at a specific frequency, the components in figure one have the following values: R = 40Ω, XC = –j20Ω and X = + j50Ω. The resistance can be plotted on the horizontal axis as shown by 'R' in figure 2b. Before jX is plotted it must be calculated by adding the two values: + j50 Ω + (-j20 Ω) = + j30 Ω. This is plotted on the vertical axis as 'X' in figure 2b. A new point 'Z' can be plotted on the graph where lines drawn through the points and perpendicular to their axis cross. The point 'Z' represents the impedance and is often written in the form: Z = 40 + j30 Ω. Impedance always has two parts; here it's represented by a real part 'R' and an imaginary part 'jX'. Impedance can be represented in another way too, by its magnitude and the phase angle; we'll say more about that later.

Resonance

Earlier it was mentioned that reactance causes the voltage and current peaks to occur at different times in a cycle. Capacitive reactance will cause the current to peak before the voltage, and inductive reactance will cause the voltage to peak before the current. This difference (called phase shift) can be between –90° and +90° or up to a quarter of a cycle (one full cycle is 360°.) When the inductive reactance and capacitive reactance are equal they add to zero. When they do, the voltage and current peaks occur simultaneously, the phase shift is said to be zero and the impedance is purely resistive. This phenomena is said to be "resonance". At resonance the imaginary part becomes zero but is usually still included: Z = 50+j0Ω (Impedance is equal to 50 plus an imaginary zero ohms.) Whenever you see the j0Ω it signifies resonance.

In figure 2c a line has been drawn from where the two axes cross (the origin) to the point 'Z'. Look carefully at this line; notice that it has a difference length than either R or jX. This length is call the "magnitude" of the impedance. It can be calculated by Pythagorean's theorem (I'll leave solving this to the readers who care!) but the answer is 50Ω magnitude. If you again look carefully at the line you'll note that it makes an angle to the horizontal axis. This angle is called the phase angle and yes it is exactly the same phase angle we talked about above. What will this line look like at resonance? Think for a minute; we know that at resonance jX=j0, the phase angle is zero and the impedance is purely resistive. Thus the line must lie on the horizontal axis and must end at the point R. This impedance line is called a vector; it has two parts, magnitude and direction! Why is it called a vector? So mathematicians and engineers can impress and management and demand higher salaries!

Thus, the second way impedance may be specified is by its magnitude and phase angle and an impedance such as Z=40+j30Ω is often written as: * (Impedance is equal to a magnitude of 50 ohms at at phase angle of plus 38 degrees.)

Which representation of impedance you use depends on what you're trying to do or show. Usually one form makes computation easier than the other in a given situation.

Why is impedance important? The impedance of the antenna plays an important role in the transfer of power from the transmitter. We'll discuss this further in a future article.

Next month in *Bob's Tech Talk* we'll look at how the impedance at the antenna's terminals is affected by changes to the antenna, and why 'R' plays such an important part, especially for vertical antennas. This month we covered the heavy stuff (but hopefully did it lightly enough); next month we'll have some fun.

73, from AF6C

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Sidebar - Phase Shift

When an AC voltage is applied to a pure resistance the voltage and current peaks occur simultaneously, and the voltage and current are said to be **"in-phase"**. However, when an AC voltage is applied to an impedance that contains a reactive part, the current **'i'** and voltage **'e'** peaks occur at different times. This time difference is measured as an angle; where 360° is one full cycle of the AC voltage. The angle is referred to as **"phase-shift"** and is often designated by the symbol **'Ø'**. When the reactive part of the impedance is positive (inductive) the voltage peak occurs **before** the current peak (Figure 3a), and when the reactive part of the impedance is negative (capacitive) the voltage peak occurs **after** the current peak (Figure 3b).