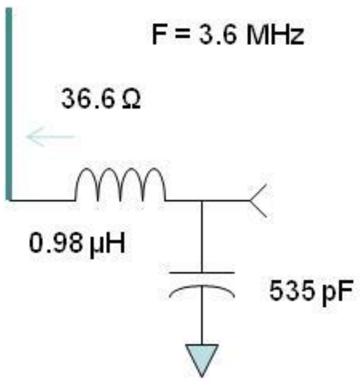
Example L-Networks

Consider the first impedance matching network below wherein we need to match 50Ω to a vertical input impedance of 36.6 Ω.



For the network to the left, the antenna itself presents an impedance of

$$Z_A = 36.6 + j0$$

Using ON4UN's software, a suitable L-network is designed and shown to the left. We perform the circuit analysis to determine the voltages and currents and compare to the program's outputs.

We can write loop equations for I_1 and I_2 and from there determine rating requirements for the parts.

$$V = I_1\left(50 + \frac{1}{j\omega C}\right) + I_2\left(\frac{-1}{j\omega C}\right)$$

$$0 = I_1\left(\frac{-1}{j\omega C}\right) + I_2\left(R_a + j\left(\omega L - \frac{1}{\omega C}\right)\right)$$

From these loop equations we determine the following:

$$I_1 = \frac{\begin{vmatrix} V & -\frac{1}{j\omega C} \\ 0 & R_a + j\left(\omega L - \frac{1}{\omega C}\right) \end{vmatrix}}{\begin{vmatrix} \left(50 + \frac{1}{j\omega C}\right) & -\frac{1}{j\omega C} \\ -\frac{1}{j\omega C} & R_a + j\left(\omega L - \frac{1}{\omega C}\right) \end{vmatrix}} \qquad I_2 = \frac{\begin{vmatrix} R_a + \frac{1}{j\omega C} & V \\ -\frac{1}{j\omega C} & 0 \end{vmatrix}}{\begin{vmatrix} \left(50 + \frac{1}{j\omega C}\right) & -\frac{1}{j\omega C} \\ -\frac{1}{j\omega C} & R_a + j\left(\omega L - \frac{1}{\omega C}\right) \end{vmatrix}}$$

The value of V is chosen such that when the 50Ω source is terminated in 50 Ω, 1500 watts is delivered to the 50 Ω. Doing these calculations in MatLab results in the following:

$$I_1 = 5.4758\ amps \qquad I_2 = 5.4763 - j3.3157 \qquad |I_2| = 6.4018\angle -31.194^o$$

$$V_{cap} = 273.93\,V \qquad P_{Ant} = 1499.2\,W \qquad P_{50\Omega} = 1500.0\,W$$

$$I_{cap} = j3.315\ amps$$

This does not agree with output from ON4UN's program. Nodal analysis and other analysis confirm my results as "the" accurate numbers.

Shunt-input L-networks are used when the resistive part of the output impedance is lower than the required input impedance of the network. The series-input L-network is used when the opposite condition exists.

Component Ratings[1]

[1] "Low-band DXing", Chapter 4

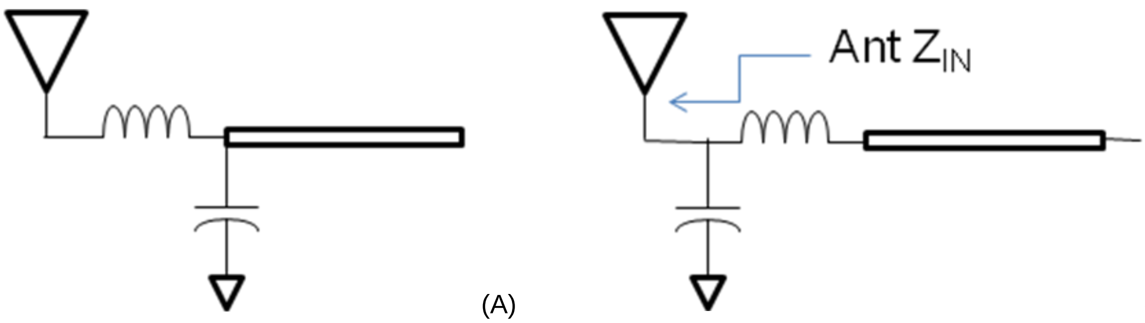
The transmitter power as well as the position of the component in the L-network will determine the voltage and current ratings that are required for the capacitor.

Suppose the capacitor is connected in parallel with the 50Ω transmission line (A). Assuming a 1:1 VSWR, the voltage across the capacitor is given by

$$P = \frac{E^2}{R} \qquad E = \sqrt{PR} \quad \text{Therefore for 1500 W, } E = \sqrt{1500 \times 50} = 274\ V_{rms}$$

In performing this simple calculation we make the assumption that a 50 Ω transmission line is feeding a 50 Ω load and the power developed in the "load" is 1500 watts.

The peak voltage is $E_{peak} = E_{rms}\sqrt{2} = 387\ V_{peak}$



(A) (B)

If the capacitor is connected between the antenna base and ground (B), we can follow a similar reasoning. In this case, however, we need to know the absolute value of the antenna impedance. Assume the feedpoint impedance is $90 + j110\,\Omega$, where R_r = 90. The magnitude of the antenna impedance is

$Z_{Ant} = \sqrt{90^2 + 110^2} = 142.1\,\Omega$ The voltage across the antenna feedpoint is given by:

$$E = I\,Z_{Ant} = \sqrt{\frac{P}{R_r}} \times Z_{Ant} = \sqrt{\frac{1500}{90}} \times 142.2 = 580\,V_{rms} = 820\,V_{peak}$$

Here we have made the assumption that 1500 watts is developed in the antenna "load" itself "after" the L-network. To do this we would be inputting more than 1500 watts into the input of the L-network. Let's work this out specifically.

Here are some additional details.

If the capacitor is the series element in the network, and if the parallel element is connected between the feedline and ground (transmitter side of the network), then the current through the capacitor equals the antenna current. Assume a new feed-point impedance of $120 + j190\,\Omega$. The magnitude of the antenna feed-point impedance is

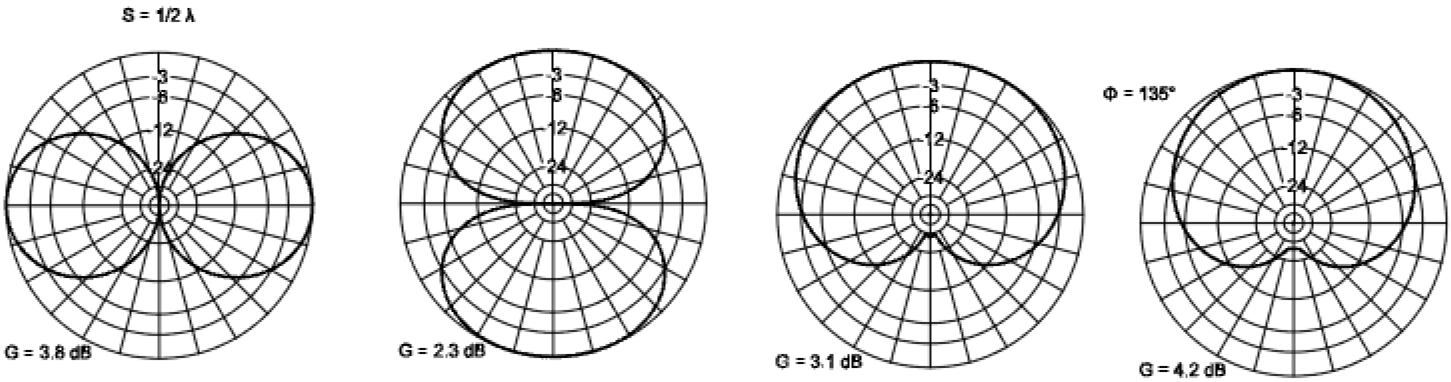
$$Z = \sqrt{120^2 + 190^2} = 225\,\Omega$$

Assume 1500 W, then the magnitude of the feed current is $I = \sqrt{\frac{P}{Z}} = \sqrt{\frac{1500}{225}} = 2.58\ A$

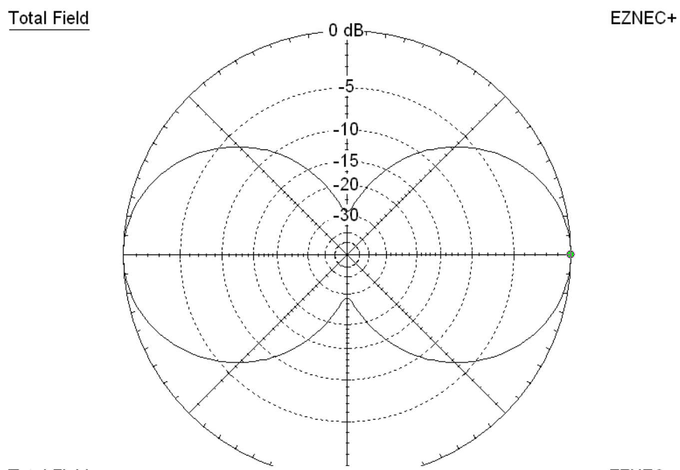
Assume the capacitor has a value of 200 pF and the operating frequency is 3.65 MHz, the impedance of the capacitor is

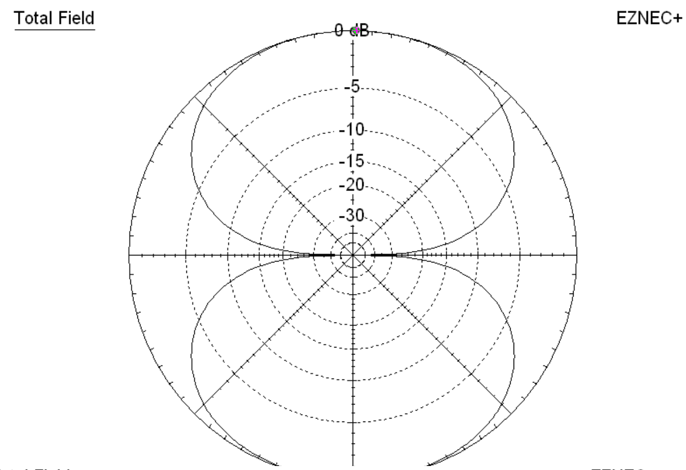
$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi\left(3.65\times10^{6}\right)\left(200\times10^{-12}\right)} = 218\,\Omega$$

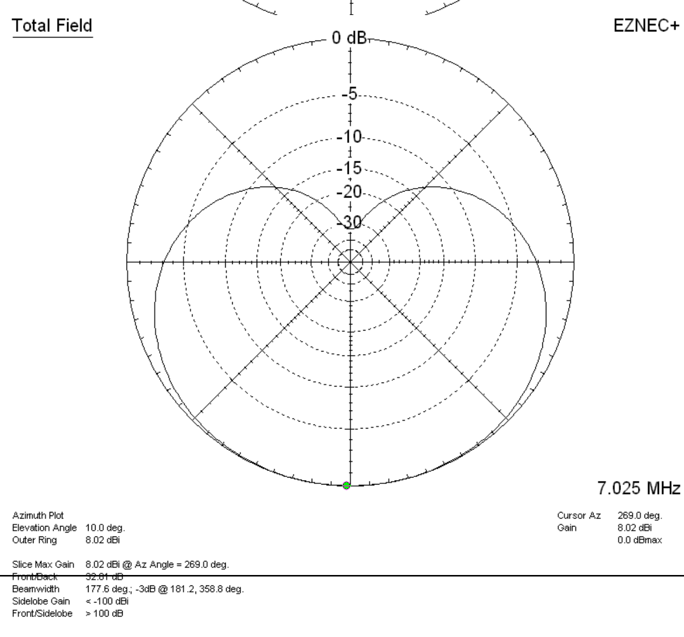
The voltage across the capacitor is $E = I\times Z = 2.58\times 218 = 562\,V_{rms} = 795\,V_{pk}$

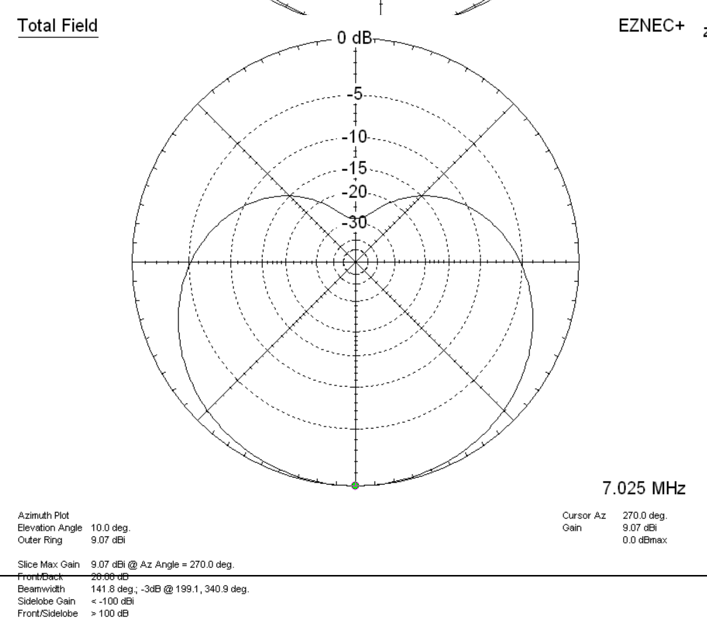


$0^{o}\ \Delta,\ d=\lambda/2$ $180^{o}\ \Delta,\ d=\lambda/2$ $90^{o}\ \Delta,\ d=\lambda/4$ $135^{o}\ \Delta,\ d=\lambda/8$









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