COIL TUNING RANGE NOMOGRAM

By DONALD W. MOFFAT

An accurate calculation of the amount of capacitance required to resonate a coil to a given frequency, taking into account the distributed capacitance and the value of the true inductance.

WHEN a variable capacitor is used to tune a coil to resonance over a selected range of frequencies, the actual tuning range usually measures lower than the calculated values. The difficulty arises when the standard resonance formula is applied to calculate inductance by using a known external capacitor and the measured frequency at which they resonate. Then, attempting to calculate the capacitance which would be required to resonate at other frequencies leads to trouble because the inductance value found in that manner is the *apparent* inductance, a value that varies with frequency. Dependable answers are obtained only if *true* inductance is used.

This nomogram allows an accurate calculation of the conditions at various frequencies, automatically correcting for true inductance, although it does not require that true inductance actually be determined.

A quick look at the meaning of the two kinds of inductance should give an appreciation of the reasons why idealized coils cannot be assumed. Because a coil in a circuit represents an impedance, there will be an over-all voltage drop and a resultant turn-to-turn voltage difference appears to the designer in the form of a distributed capacitance. Therefore, a practical coil must be analyzed as an ideal inductance in parallel with a capacitor, causing a coil by itself to have a self-resonant frequency, f_0.

When a known capacitor is connected across a coil to find a resonant frequency with which to calculate inductance, the calculation will therefore yield a value of inductance which is too high because of the effect of the distributed capacitance. Such calculations will yield a different value of inductance at every frequency, making it difficult to design a circuit which will tune over a specified frequency range.

This nomogram permits a quick calculation of actual tuning conditions, using a value of distributed capacitance which can be determined by any of several means. (See instructions and Manual of Radio Frequency Measurements, *Boonton Radio Corporation.*) Or, the nomogram can be worked twice: once to determine distributed capacitance and the second time to evaluate the frequency and capacitance for the selected resonance.

First, it will be assumed that the coil's distributed capacitance has already been determined. Find the coil's self-resonant frequency, f_0, with an instrument such as a grid-dip meter, and locate this value on the horizontal scale at the bottom of the nomogram. Next, locate on the f_1 scale, the frequency at which it is desired to resonate the circuit. Draw a straight line through these two points. From the point where this line intersects the horizontal axis of the curve, proceed straight up to the curve, using the dashed lines as guides. At the curve, turn and proceed straight out to the vertical axis, again using the dashed lines as guides. Draw the final straight line from the vertical axis to the correct value of distributed capacitance, C_0, and this line will cross the C_1 scale at the correct external capacitance which will tune the circuit to frequency f_1.

If distributed capacitance has not been found by other means, the first step will be to work the nomogram in a different sequence so as to evaluate C_0. Find the self-resonant frequency of the coil alone and then connect a capacitance, C_1, across the coil and find a new resonant frequency, f_1. Locate these two frequencies on the appropriate scales of the nomogram, draw a straight line through them, and proceed straight up to the curve as in the preceding instructions. Turn at the curve and go straight out to the vertical axis. The final line is then drawn through the known value of C_1. Distributed capacitance is read where this line crosses the C_0 scale. This value of the coil's distributed capacitance is then used in working the nomogram, as first described, to calculate external capacitances which will cause resonance at given frequencies.

It is not necessary to perform the steps in the sequence described. For instance, this procedure has assumed that a capacitance is to be found which will cause resonance at a given frequency. The nomogram can be worked in the other direction if it is desired to determine the frequency at which a circuit will resonate when a given capacitor is connected across the coil. Let us now consider an example of how the nomogram is used.

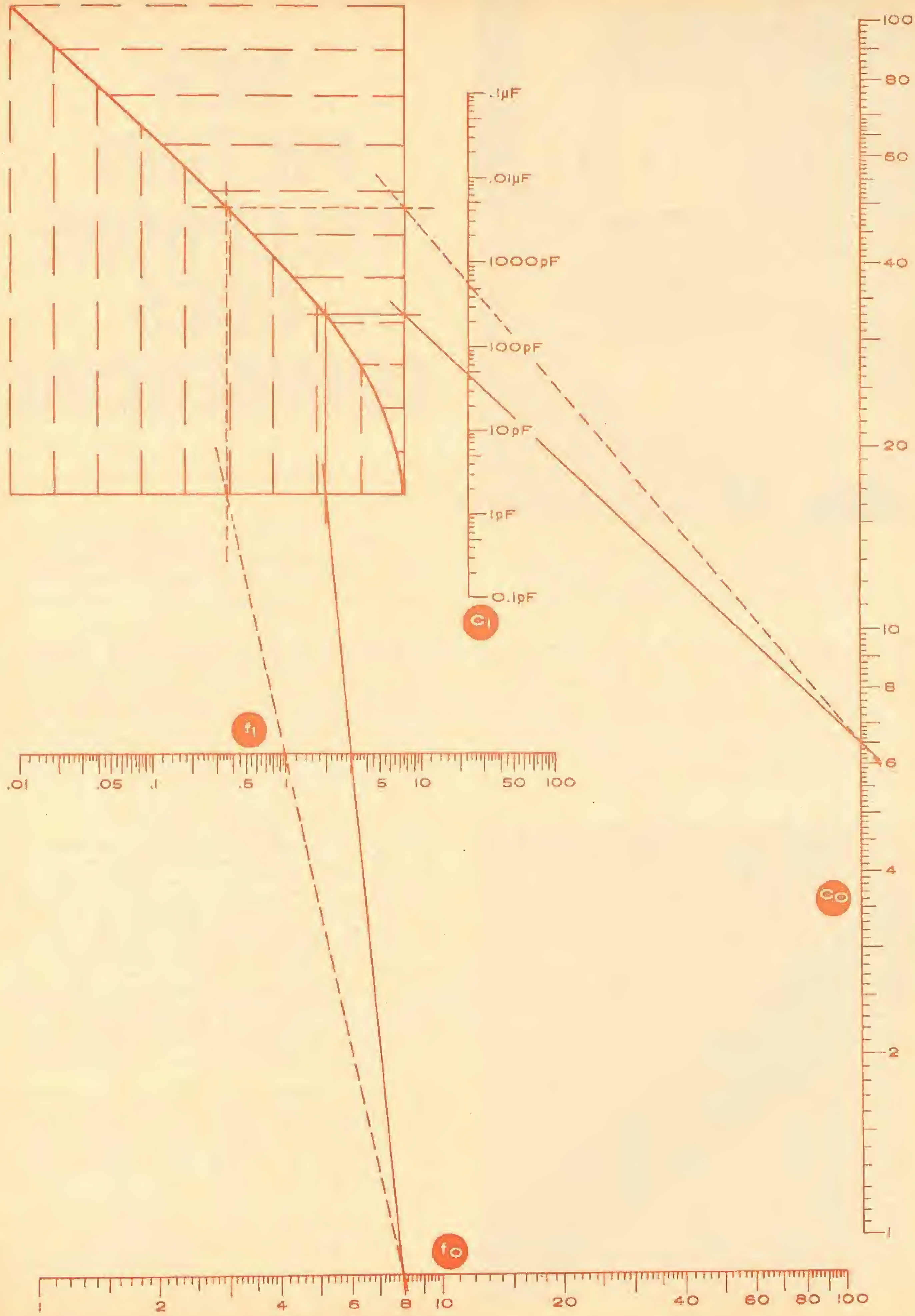
Example of Using Nomogram

This will be a complex example, showing how distributed capacitance can be determined first. Then the nomogram will be worked through again to calculate a tuning condition. The objective is to predict accurately the capacitance required to resonate a given coil to one megahertz. Three quantities are considered "knowns" at the start: self-resonant frequency (f_0) of the coil is 8 MHz and when a 47-pF capacitor (C_1) is connected across the coil, resonance moves to 3 MHz (f_1).

The nomogram will be worked first to determine distributed capacitance of the coil, using these given numbers, and then it will be reworked, using distributed capacitance as a known quantity, to find an external capacitor which will cause resonance at 1 MHz.

Locate 8 on the f_0 scale and 3 on the f_1 scale and draw a straight line (solid) through these two points. At the intersection of this straight line and the horizontal axis of the curve, proceed straight up (parallel to the nearby dashed line which serves as a guide) to the curve and then turn and proceed straight out to the vertical axis. The last line of this part of the calculation is drawn from the vertical axis, through 47 pF on the C_1 scale, to the C_0 scale. At this intersection, read a distributed capacitance of 6.5 pF.

Now that the coil's distributed capacitance has been determined, the nomogram can be worked in a different sequence to find a C_1 which will tune the coil to 1 MHz. Draw a line (dashed) through 8 on the f_0 scale (self-resonance of a coil is not affected by external connections) and 1 on the f_1 scale. This line crosses the curve's horizontal axis very near one of the dashed guide lines. Proceed straight up next to the guide line, to the curve, and then straight out to the vertical axis. Draw the last line from that point to 6.5 on the C_0 scale (distributed capacitance of this coil remains at 6.5 pF). This line crosses the C_1 scale at a little less than 600 pF, the capacitance which will tune with this coil to 1 megahertz. ▲


.1μF
.01μF
1000pF
100pF
10pF
1pF
0.1pF
C_1
f_1
.01 .05 .1 .5 1 5 10 50 100
100 80 60 40 20 10 8 6 4 2 1
C_0
f_0
1 2 4 6 8 10 20 40 60 80 100