How to Measure Sample Line Length and Characteristic Impedance

The new [73.151(c)] FCC rules contain a method for making accurate measurements of the length and characteristic impedance of the coaxial lines used for the antenna sample system.

These measurements require that the length of the line be determined by measurement of the frequency closest to the antenna system carrier frequency at which the line is an odd multiple of 90 electrical degrees in length. Then, having determined this frequency, the frequencies at which the line would be longer and shorter by 45 degrees can be calculated. The open-circuit measured impedance magnitudes at these two frequencies can then be combined by the square root of their product, giving the characteristic impedance at frequencies in the vicinity of the carrier frequency.

The first useful item of information is the approximate physical length of the lines. For new installations this is relatively easily determined, but for existing systems it may be necessary to estimate it. If sample loops are used, don't overlook the length of line in the sample isolation inductor. The lines will appear to be electrically longer, of course, because of the velocity of propagation, about 0.81 to 0.84 percent for the sizes of line used for sample systems.

The line should be open circuited at the far end, and measurements made at the antenna monitor end. Since the approximate length of the line is known with moderate accuracy, a frequency close to the antenna carrier frequency can be determined by simple algebra. (See attached sketch and sample calculation.)

Although network analyzers and RF generators with frequency counters will allow one to determine a frequency to 6 or 7 places, this degree of accuracy really isn't necessary for lines shorter than about 5 or 6 hundred meters. Potomac "bridge driver/receiver" units allow frequency selection to the nearest 500 Hz, and Delta units to the nearest 1 kHz. That's good enough for these purposes. For example, at 1.000 MHz 1 degree is 0.832757 m and at 1.001 MHz it's 0.831925 m, a difference of 0.000832 m. A line would have to be about 1/0.000832 = 1202 m in (equivalent electrical) length to have this difference in frequency be 1 degree at one MHz. The lower frequencies where sites are large have longer wavelengths, and conversely, and since we need to determine line length to 1 degree accuracy, half the 1 degree ambiguity is reasonable.

The next step is to determine the exact frequency by adjusting the equipment in small steps, searching for the "series-resonant" frequency close to the carrier frequency where the measured resistance is small and the measured reactance goes through zero. With the frequency where the line is 90 or 270 or 450 or 630 or 810 degrees long known, it's straightforward to calculate the length at the carrier frequency:

L (degrees @ carrier) = L (deg @ measured F)(Carrier F/Measured F)

Then, the next step is to calculate the frequencies above and below that frequency where the line is 45 degrees longer and shorter respectively. (Refer to the attached sketch and sample calculation.)

Then, set the measurement equipment to those frequencies and measure the impedances. The impedances will have both resistance and reactance, because the lines are not lossless. (If they were, the resistance would be zero!)

The characteristic impedances at each frequency are the magnitude of the measured impedance: $(R^2 + X^2)^{½}$. The average characteristic impedance is: $(Z_1 \times Z_2)^{½}$.

The FCC rules require that the sample lines be within 1 degree in length, and that they have characteristic impedances within two ohms of one another.

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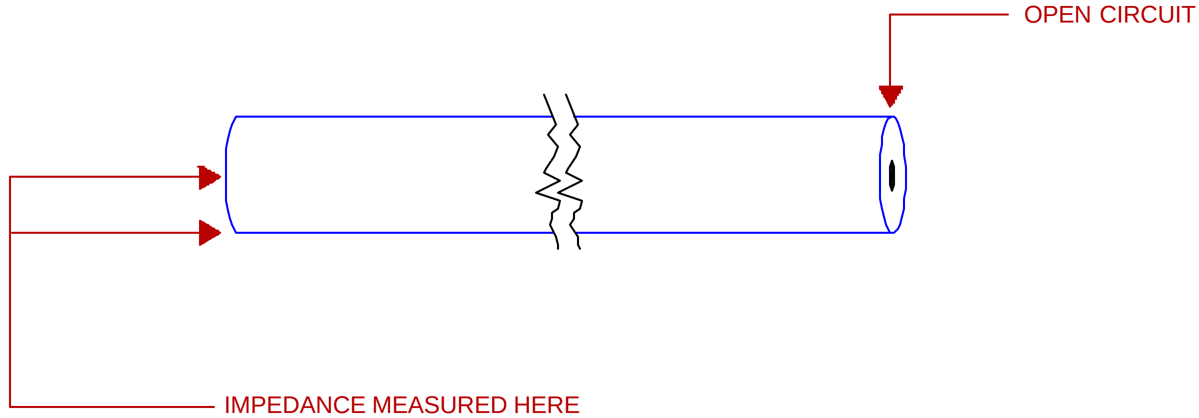
B. Dawson



SAMPLE CALCULATION

If the line is ~500' long, that is the equivalent of $\frac{500}{0.81}$ = 617' in free space.

617' (4/3) = 822.67

The line will be 270° long at a frequency where λ = 822.67' or 250.75m

or 250.75 = $\frac{299.792456}{\text{f(in MHz)}}$

$\frac{299.792456}{250.75}$ = 1.1956 MHz

If using a Delta bridge driver- the bridge will read its lowest reactance at 1.196 MHz

It will be 270° - 45° long at $\frac{235}{270}$ (1.196) = 1.041 MHz

and 270° + 45° = 315° long at $\frac{315}{270}$ (1.196) = 1.395 MHz