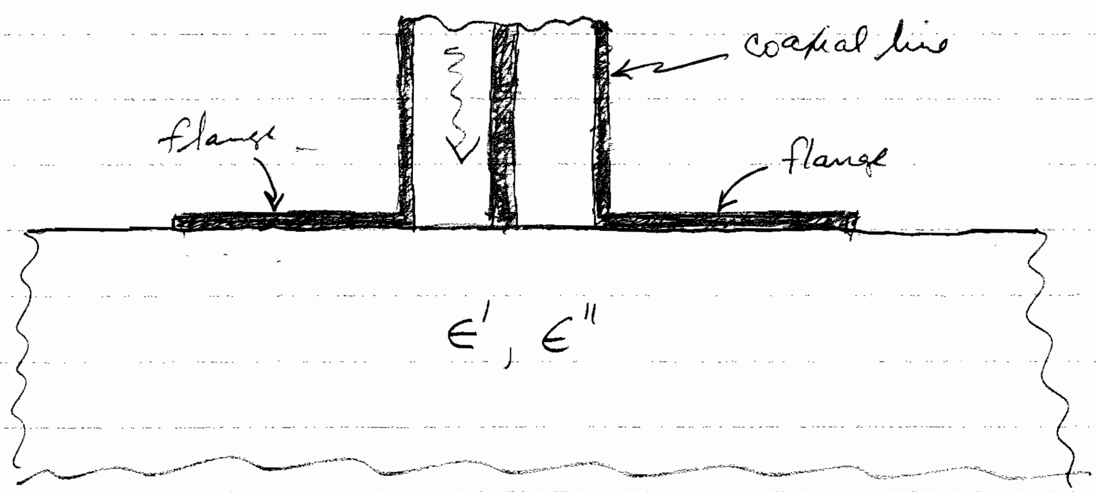
Open-Ended Coaxial Probe

A popular one-port method for measuring permittivity is the open-ended coaxial probe. Unlike the previous methods, the specimen is not necessarily backed by a conducting plane, nor is the specimen entirely surrounded by a conductor.

For these types of measurements, a flanged, open-ended coaxial line is placed onto a flat specimen face:



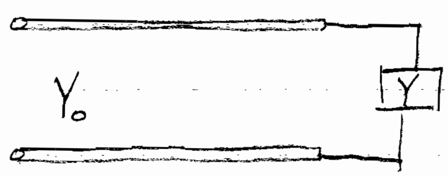
A signal is launched down the coax, and the reflected signal is measured back at the VNA, for example. So like the previous method, we have only a reflected signal from which to extract one material parameter, in this case complex ϵ.

But this open-ended coaxial probe geometry is a <u>much</u> more difficult problem to solve analytically.

Why is this? The primary reason is we no longer have a <u>separable geometry</u>. That is, the b.c.'s of this problem no longer lie on complete coord. surfaces of a separable coord. system. (For the shorted coax, the b.c.'s are on cylinders and planes inside the coax. These coord. surfaces in cyl. coord. system.)

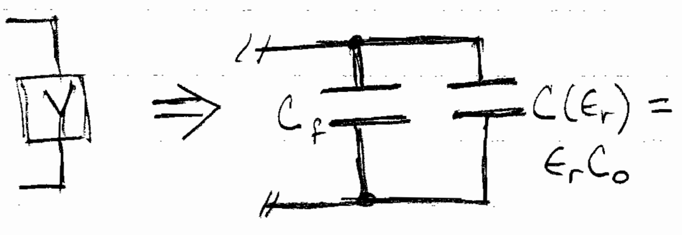
Another reason is that the fields in the specimen are not TEM. Cannot model these fields by TL's. Much more difficult problem!

There are a number of approximate models listed in Section 3.2.1 of your text, and the references contained therein. Assuming the freq. is low enough that only TEM mode propagates in the coax and an infinite flange, a common model is:



The "load" admittance assumes a range of expressions that have been developed over the years:

- "Lumped-parameter model" Fig 3.4 :

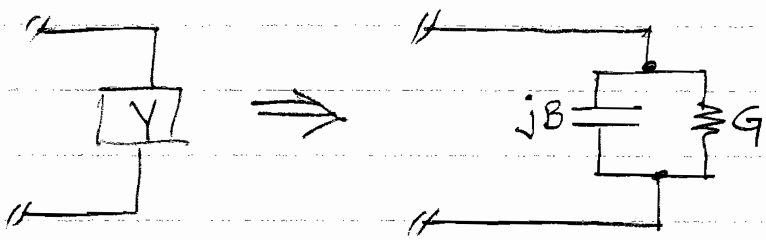


C_0 = capacitance of probe in air.

An expression for ϵ_r is given in eqn. (3.14). The capacitances C_f & C_0 are determined by calibration, measuring a fluid w/ known properties (such as distilled water).

Works best for relatively low frequencies

- Marcuvitz's approximation: From N. Marcuvitz, "Waveguide Handbook," London: Peter Peregrinus, 1986.



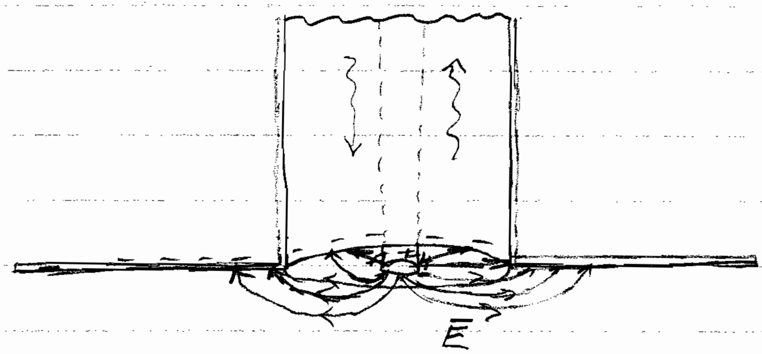
See Misra, et al., "Noninvasive Electrical characterization of materials...," IEEE Trans MTT, vol. 38, no. 1, pp. 8-14, 1990.

This paper presents an interesting study comparing the use of these two model's. Bottom line is Marcuvitz's approx. is preffered.

- Numerical solution for probe admittance: use mode-matching or method of moments to solve for the probe admittance Y. Very slow since numerical solution required for each guess of ϵ' & ϵ''! The CEM solution needs to be done to very high accuracy to reduce errors in ϵ to typically acceptable levels.

There are a couple of important potential sources of significant error when using the coaxial probe:

1. <u>Gap between probe and sample</u>: The model we've shown here assumes the probe has intimate contact with the sample. Any gap will likely cause significant error to measured ϵ. Hence, probe good for fluids & semi-solids. Can still use on solids, but need extremely flat surface.



Because of the axial component of $\bar{E}$, in addition to its radial component, the discontinuity of E_n across the probe-to-air and air-to-specimen interfaces will produce bound surface charge layers that turn out to greatly affect the measurement of ϵ.

See J. Baker-Jarvis, et al, "Analysis of an Open-ended coaxial probe with lift-off for nondestructive testing.

2. Cable movement – Another substantial source of error is cable movement after calibration. We've found that even the smallest cable movement during or after calibration can produce substantial error in ϵ.