NOTE 2

INVISIBLE ABSOLUTE
E-FIELD PROBE

by

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SENSOR AND SIMULATION NOTES II

"Invisible" Absolute E Field Probe

There is a need for a quasi-static electric field sensor which

(a) has a calculable absolute sensitivity so that it may be used as a reference element for other sensors, and/or

(b) creates a minimum of disturbance to the field in its vicinity. A sensor with these properties is sketched in Figure 1, where a uniform field E is assumed to exist above a reference (ground) plane. The probe plate P at height h above the reference plane would acquire a potential Eh in the absence of any loading by connecting leads or circuitry. The probe is connected by a doubly-shielded coaxial lead to the positive-unity-gain impedance-shifting amplifier G, whose input impedance is, in principle, infinite. The output of G is fed back to the inner coax shield to form a conventional guard system. (Note that the coax must be electrically short at the highest frequency of interest in order for the guarding to be effective.)

The probe end of the inner shield at potential Eh is attached to a metallic ring atop a resistive cylinder R, shown in section. Ideally the cylinder is fabricated from a uniform semiconducting material such as graphite in order to generate a uniform potential distribution from P to ground. In practice this probably would consist of a string of resistors and potential-dividing rings.

We see from the above that this probe leaves the field undisturbed in its immediate vicinity (even underneath the plate). However, to achieve an absolute calibration one must be more careful. Consider the equivalent circuit in Figure 2. The source capacitance of the plate need not be known accurately if the input impedance Z of the amplifier is made sufficiently high. If C_a is desired more accurately it can either be measured or computed using a rotation of the zeta-function curves of Figure 3. The input impedance Z may be made arbitrarily large either by conventional techniques or through the use of positive feedback. R and C_s, the capacitance between the inner and outer shields, are driven by the output impedance of G. The capacitance C_i between the inner coax conductor and the inner shield is only cancelled uniquely by the guard voltage v_o if the gain G is identically unity. We assume that the first-order effect of G on v_o can be measured and hence "calibrated out". Then the gain change due to loading of C_a by C_i becomes only a second-order effect if C_i is not large compared to C_a. Both of these effects can be eliminated by making G adjustable and using a null technique to assure that v_o is identical to v_i. Then, if Z can be made to approach infinity, v_o will be Eh. There seems to be some confusion regarding the raising of input impedance by positive feedback and the use of guard voltage. This will be discussed in another S and S note.

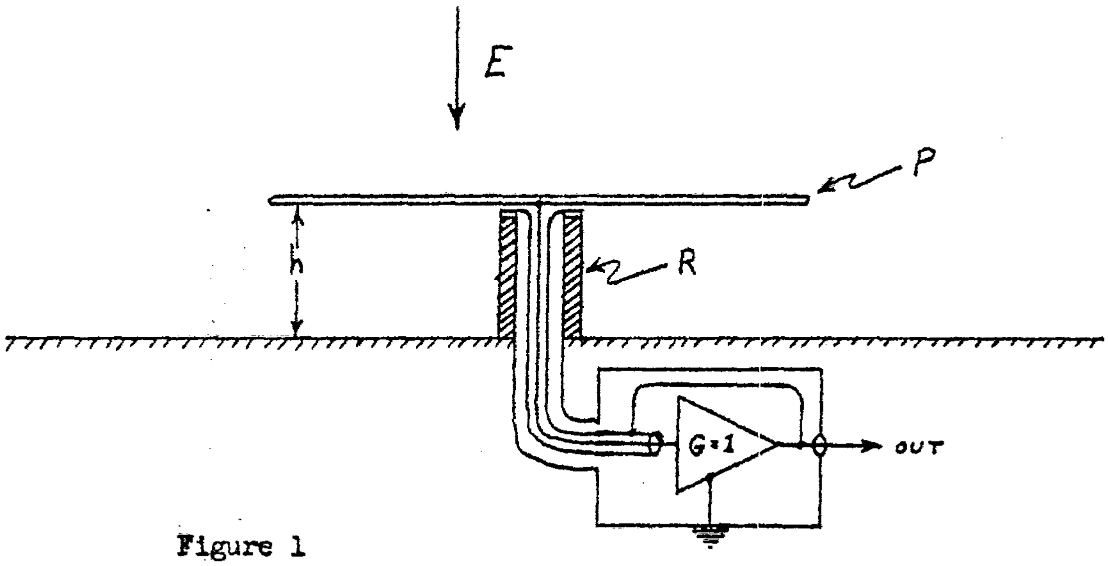


Figure 1

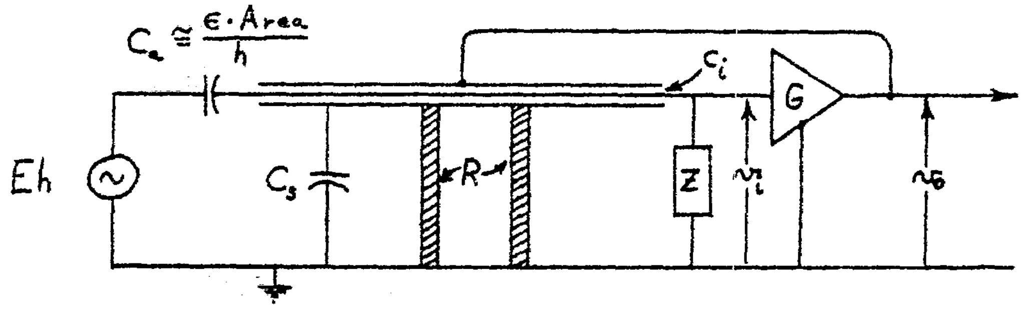
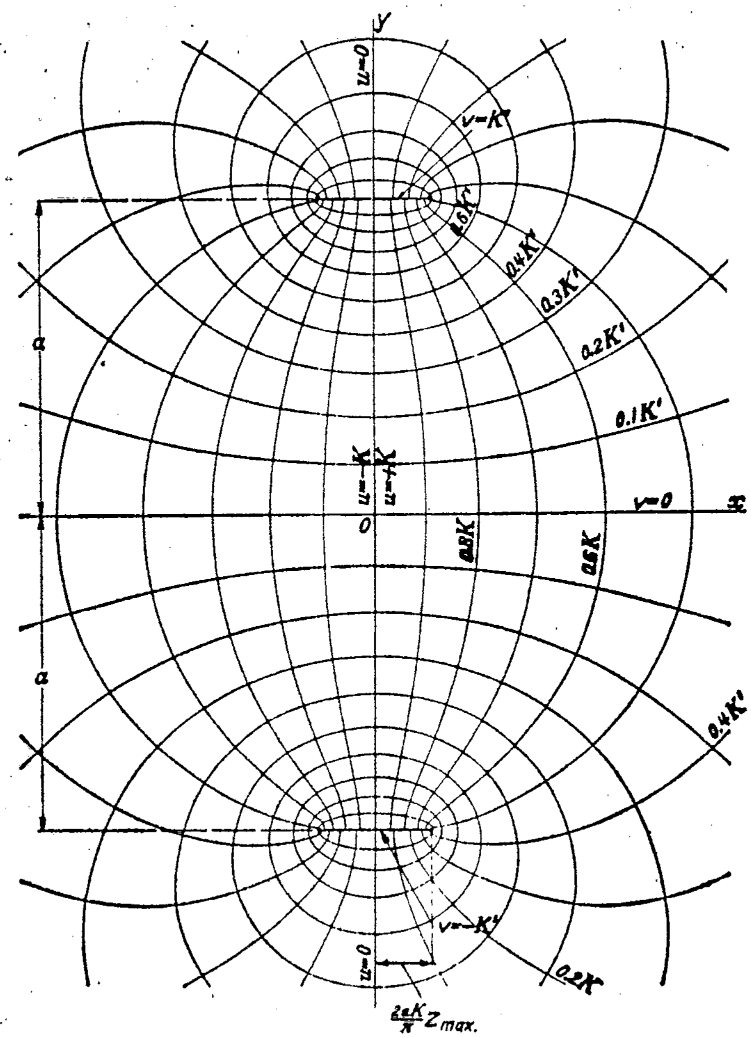


Figure 2



ζ-function curves, $\bar{z} = \frac{2Ka}{\pi} Z(w + iK) + ia$

FIGURE 3