NOTE 2
INVISIBLE ABSOLUTE
E-FIELD PROBE

by
R.E. Partridge
Los Alamos Scientific Laboratory

February 1964
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 $v_0$ if the gain $G$ is
identically unity. We assume that the first-order effect of $G$ on $v_0$ 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 tech-
nique to assure that $v_0$ is identical to $v_i$. Then, if $Z$ can be made to approach
infinity, \( v_0 \) will be \( E_h \). 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

\[ C_s = \frac{\varepsilon \cdot \text{Area}}{h} \]

Figure 2
\[ Z = -\frac{2K + 2(\omega + iK) + 4\alpha}{\pi} \]

**Figure 3**