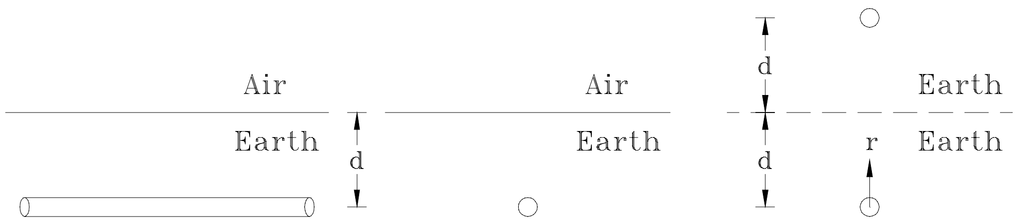
COMPUTATION OF COUNTERPOISE PARAMETERS

As shown in Appendix A, neglecting the internal impedance of the counterpoise, Z_I, the three essential counterpoise parameters which need to be known for analysis are: (i) capacitance (F/m), (ii) inductance (H/m), and (iii) leakance (℧/m). The electrical image method was applied to compute these three parameters (Fig.1). The air space above earth was removed, and the entire space was filled with soil. The image of the counterpoise was placed at a distance 2d vertically above the counterpoise, where d is the depth of burial of the counterpoise below the earth's surface. If the voltage, charge per meter and the current of the counterpoise are V, q and I, then the corresponding variables of the image will be -V, -q and -I.



(a) side view of counterpoise (b) cross-sectional view of counterpoise (c) counterpoise and its image

Fig. 1 Counterpoise and its image.

Counterpoise Capacitance

Invoking Gauss's law, the electric field at a distance, r, above the counterpoise will be:

$$E(r) = \frac{q}{2\pi\varepsilon_g r}\ , \tag{1}$$

where ε_g is the permittivity of the soil. Similarly, the electric field at the same point due to the image will be:

$$E_i(r) = \frac{q}{2\pi\varepsilon_g (2d-r)}\ . \tag{2}$$

Both fields will be in the same direction. The potential of the counterpoise with respect to the earth's surface (which is at zero potential) will be:

$$V = \frac{q}{2\pi\varepsilon_g}\left[\int_d^a \frac{dr}{r} + \int_d^a \frac{d(2d-r)}{(2d-r)}\right] = \frac{q}{2\pi\varepsilon_g}\ell n\frac{2d-a}{a} = \frac{q}{C}\ , \tag{3}$$

where a=radius of the counterpoise, and

$$C = \frac{2\pi\varepsilon_g}{\ell n \frac{2d-a}{a}} \approx \frac{2\pi\varepsilon_g}{\ell n \frac{2d}{a}} \ (F/m) \quad (4)$$

Counterpoise Inductance

If the counterpoise current is I, and that through its image is -I, then the total B-field vertically above at a distance r from the counterpoise will be:

$$B(r) = \frac{\mu_g I}{2\pi}\left[\frac{1}{r} + \frac{1}{2d-r}\right], \quad (5)$$

the B-fields of the counterpoise and its image being in the same direction. μ_g is the permeability of the soil. The magnetic flux enclosed between the counterpoise and the earth's surface is:

$$\phi = \frac{\mu_g I}{2\pi}\left[\int_a^d \frac{dr}{r} + \int_a^d \frac{d(2d-r)}{2d-r}\right] = \frac{\mu_g I}{2\pi}\ell n \frac{2d-a}{a} \quad (6)$$

$$L = \frac{\phi}{I} = \frac{\mu_g}{2\pi}\ell n \frac{2d-a}{a} \approx \frac{\mu_g}{2\pi}\ell n \frac{2d}{a} \quad \text{(H/m)} \quad (7)$$

Counterpoise Leakance

The current leaking out of the counterpoise to the earth will produce a current density with cylindrical symmetry. The electric field at a distance r from the counterpoise, taking leakance from the image into account, will be:

$$E(r) = \frac{1}{\sigma_g}\left[i(r) + i_i(2d-r)\right], \quad (8)$$

where σ_g is the conductivity of the soil, and

$$i(r) = \frac{I}{2\pi r}, \ and \ \ i_i(2d-r) = \frac{I}{2\pi(2d-r)} \quad (9)$$

Putting the values of i(r) and i_i(2d-r) from (9) into (8), and integrating E(r), the potential of the counterpoise above the earth's surface will be:

$$V = \frac{I}{2\pi\sigma_g}\left[\int_a^d \frac{dr}{r} + \int_a^d \frac{d(2d-r)}{2d-r}\right] = \frac{I}{2\pi\sigma_g}\ell n \frac{2d-a}{a} \quad (10)$$

$$G = \frac{I}{V} = \frac{2\pi\sigma_g}{\ell n \frac{2d-a}{a}} \approx \frac{2\pi\sigma_g}{\ell n \frac{2d}{a}}, \quad (\mho/,\text{m}) \quad (11)$$