SHUNT EXCITED BROADCASTING ANTENNA*

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ABSTRACT. A theoretical study has been made of the effect on the intensity of the field radiated from a shunt excited antenna when the point of excitation is gradually altered. From the knowledge of the distribution of current in the upper and in the lower parts of the antenna, mathematical equations have been obtained for calculating the intensity of the field radiated from it. Field strengths for quarter, half and full wave long antennae have been calculated at a ground distance of one wave-length from the base and suitable points for excitation have been indicated.

INTRODUCTION

The shunt excited antenna recently developed by Morrison and Smith[1,2] has very closely drawn the attention of radio engineers due to its various advantages. Such an antenna offers a high economy in the cost of erection, owing to the elimination of base insulators and tower lightning chokes which are always associated with the insulated tower antenna so widely used for commercial broadcasting purposes. The shunt excited antenna is essentially a vertical antenna efficiently grounded and excited at a suitable point on it above the ground. It may be mentioned that this type of antenna is of recent origin and much work has not been done as yet with it. Baudoux[3] has lately studied theoretically the radiation, resistance and space radiation characteristics of such an antenna. It has been incidentally observed by the previous workers that the situation of the excitation point changes the field characteristics of such an antenna, though detailed and systematic results are still lacking.

In view of the importance of such an antenna, it has been felt necessary to study the various aspects of this in a more elaborate manner. The present communication deals with the effect on the intensity of the field radiated from a shunt excited antenna when the excitation point is gradually altered. Considering the distribution of current in the lower and upper parts of the antenna, the portion of it above the excitation point is assumed to behave like an insulated system. Equations have been obtained for the computation of the radiated energy

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following the method of Carter[4] and subsequently developed by Banerjee.[5] The present method possesses the advantage of being able to calculate the field strength for antenna of any length and for the excitation point being situated at any point above the ground. The field strengths due to quarter, half and full wave antennae at a distance of one wave-length on the ground have been calculated and their variation with the alteration of feeding point has been graphically shown. It may be noted that in the case of a quarter wave antenna the radiated field strength is not affected by changing the excitation point as the current distribution along the antenna remains unaltered by a change of the feeding point.

METHOD OF CALCULATION

Let AB in Fig. 1 be an antenna of length l grounded at its base B. Let it be excited at a point C in it which is at a height h_0 above the ground.

If I donotes the maximum amplitude of the current and i the instantaneous current at an arbitrary point on the antenna at a vertical distance h from the ground, it can be shown that the instantaneous current i_u at a point in the upper part of the antenna AC is given by,

$$i_u = \mathrm{I} \sin m\,(l-h)\, e^{j\omega t}$$

where $m = 2\pi/\lambda$,

and ω = the angular frequency of the wave.

Similar current, i_l at a point in the lower part of the antenna, BC, is given by

$$i_l = \mathrm{I}' \cos mh\, e^{j\omega t}$$

where $\mathrm{I}' = \mathrm{I} \cos m\,(l-h_0)/\sin mh_0$.

In view of the above distribution of current, the field strength at any point P in space can be calculated from the resultant of the fields radiated by the part AC of the antenna which may be treated as insulated and by the part BC which is a grounded antenna.

We shall first find out the field strength due to the lower part BC of the antenna in which the distribution of the current is given by

$$i = \mathrm{I}' e^{j\omega t} \cos mh \qquad \ldots \quad (1)$$

If ρ denotes the charge density at any point on the antenna and i the current at the same point, both in the electrostatic units, then according to the law of continuity we may write,

$$\frac{\partial \rho}{\partial t} = -\frac{\partial i}{\partial h},$$

from which we get
$$\rho = -j\,\frac{\mathrm{I}'}{c}\, e^{j\omega t} \sin mh, \qquad \ldots \quad (2)$$

where c = velocity of light.

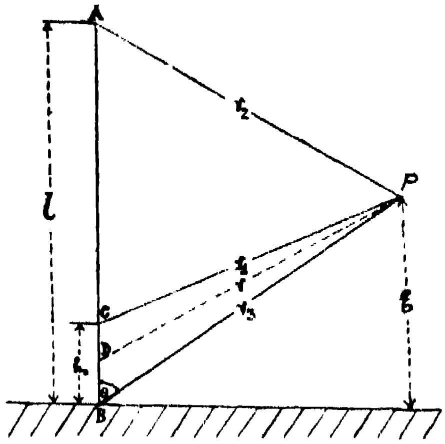

FIGURE 1

The electric force E_z at P (Fig. 1) parallel to the length of the antenna and due to the length BC may be determined from the retarded vector and scalar potentials V and A respectively from the relation,

$$E_z = -\text{grad}_z\, V - \frac{1}{c}\frac{\partial A}{\partial t} \qquad \cdots (3)$$

where

$$V = \int_0^{h_0} \frac{[\rho]_{t-\frac{r}{c}}}{r}\, dh \qquad \cdots (4)$$

and

$$A = \int_0^{h_0} \frac{[i]_{t-\frac{r}{c}}}{r}\, dh \qquad \cdots (5)$$

From equations (1), (2), (4) and (5), after putting sin mh in the exponential form, we get,

$$V = -\frac{I'}{2c} e^{j\omega t} \int_0^{h_0} \left[\frac{e^{-jm(r-h)}}{r} + \frac{e^{-jm(r+h)}}{r} \right] dh \qquad \cdots (6)$$

and

$$A = -\frac{I'}{2c} e^{j\omega t} \int_0^{h_0} \frac{\partial}{\partial z} \left[\frac{e^{-jm(r-h)}}{r} - \frac{e^{-jm(r+h)}}{r} \right] dh \qquad \cdots (7)$$

It can be shown from Fig. 1 that $\frac{dr}{dz} = -\frac{dr}{dh}$.

Using this relation, it can be shown after integration that

$$E_z = -j\frac{I'}{c} e^{j\omega t} \frac{e^{-jmr_1}}{r_1} \sin mh_0$$

As the part BC of the antenna is grounded, the actual field strength will be given by

$$E_z = -2j \frac{I'}{c} e^{j\omega t} \frac{e^{-jmr_1}}{r_1} \sin mh_0 \qquad \dots (8)$$

The distribution of current in the upper portion AC, which may be treated as insulated, is given by

$$i = Ie^{j\omega t} \sin m(l-h).$$

Proceeding in the same manner as above, it can be shown that field strength due to this part will be given by

$$E_z = j \frac{I}{c} e^{j\omega t} \left[\frac{e^{-jmr_1}}{r_1} \cos m(l-h_0) - \frac{e^{-jmr_2}}{r_2} \right]. \qquad \dots (9)$$

Assuming the feeder lines to be non-radiating, the total field strength at P due to the shunt excited antenna AB may be written from equations (8) and (9) as

$$E_z = j \frac{I}{c} \left[\frac{e^{-jmr_1}}{r_1} \cos m(l-h_0) - \frac{e^{-jmr_2}}{r_2} - \frac{2e^{-jmr_1}}{r_1} \cdot \frac{\cos m(l-h_0)}{\sin mh_0} \cdot \sin mh_0 \right]. \qquad \dots (10)$$

Taking only the real parts, equation (10) may be written as

$$E_z = -\frac{I}{c} e^{j\omega t} \left[\frac{\sin mr_1}{r_1} \cos m(l-h_0) + \frac{\sin mr_2}{r_2} \right] \qquad \dots (11)$$

For the sake of convenience of calculation, we may express the lengths involved in the above equation in terms of the wave length and thus we may write

$l = M\lambda$, $h_0 = N\lambda$ and $r_3 = K\lambda$, where M, N and K are some constants.

Therefore, $$r_2 = \lambda \sqrt{K^2 + M^2 - 2KM \cos\theta}$$

and $$r_1 = \lambda \sqrt{K^2 + N^2 - 2KN \cos\theta}$$

Equation (11) may then be written as

$$E_z = -A \left[\frac{\sin 2\pi \sqrt{K^2 + N^2 - 2KN \cos\theta}}{\sqrt{K^2 + N^2 - 2KN \cos\theta}} \cos 2\pi (M-N) + \frac{\sin 2\pi \sqrt{K^2 + M^2 - 2KM \cos\theta}}{\sqrt{K^2 + M^2 - 2KM \cos\theta}} \right] \qquad \dots (12)$$

where $$A = \frac{I}{c} e^{j\omega t}.$$

It should be mentioned that when the length of the shunt excited antenna is $\lambda/4$, the distribution of the current in both the parts is given by $i = I \cos mh$, and therefore the entire length of the antenna may be treated as one quarter wave earthed antenna The field strength due to such an antenna will then be given by

$$E_t = -2 \frac{I}{c} . e^{j\omega t} \frac{\sin mr_2}{r_2} \cos ml$$

and this is independent of the excitation point.

CALCULATED RESULTS

Fields radiated from antennae having half and full wave-lengths at a radial distance of λ from the base of them have been calculated by equation (12) for different excitation points. Tables I and II below show the results for half wave and full wave antennae resepectively. In order to compare the radiation from shunt excited antenna with that from the base insulated one of the same length, the intensities of the fields emitted from the latter type have been calculated. These values are shown at the bottom of the tables for the corresponding lengths of the antennae.

TABLE I

Half wave antenna

Height of excitation point from the ground in fractions of λ	Field strength in fractions of A
1/32	−.6046
1/24	−.5989
1/16	−.5930
1/8	−.0331
1/4	−.6046
1/3	−.7678
—	—
—	—
—	—
—	—
Insulated	−.6046

TABLE II

Full wave antenna

Height of excitation point from the ground in fractions of λ	Field strength in fractions of A
1/32	−.3639
1/24	−.3690
1/16	−.3753
1/8	−.3992
1/4	−.3639
1/3	−.2007
2/5	−.0145
1/2	+.2407
2/3	+.0326
3/4	−.3639
Insulated	−.3639

The variation of the field strength with the change of excitation point for the above antennae has been depicted graphically in Fig. 2, neglecting the direction of the field indicated in the tables. The continuous curve represents the field intensities for half wave antenna and that with the broken lines represents the same for full wave antenna.

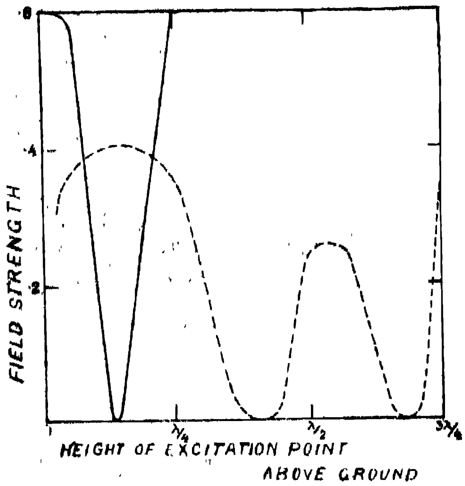

FIGURE 2

It will be observed from these curves that the radiated field strength from the half wave shunt excited antenna very rapidly falls when the point of excitation is lifted beyond the height of λ/4 from the ground. This kind of rapid fall, however, is not observed in the case of full wave antenna. Comparing the intensity of the fields radiated from a shunt excited antenna with that radiated from the insulated one of the same length, it may be concluded that the profitable point of excitation for the half wave antenna would be below λ/16 and above λ/4. Such points for the full wave antenna should be above the height of a quarter wave from the ground.

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