Analysis of the Parameters of Symmetrical Multi – Fed Full – Wave Dipole Antenna

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Abstract

This paper demonstrates the analysis of the parameters of symmetrical full-wave dipole antenna based on multi – fed techniques. The current distributions were measured, followed by the measurement of parameters of antenna like gain, radiation patterns and input impedance. Based on these observations four equations for current distribution were eventually formulated. These equations were then used to compute the values of the same parameters of the antenna. Finally, the values of parameters obtained practically and theoretically were compared to analyse the validity of the developed equation.

Keywords: Full wave- Dipole Antenna, Symmetrical, Multi fed techniques, Radiated power and gain

1. Introduction

For a true harmonic operation, it is necessary that power is to be fed into the antenna at an appropriate point. A full wave dipole antenna was fed by various methods. These methods can be classified into three categories; namely, symmetrical dual feeding, asymmetrical dual feeding and symmetrical triple feeding. The analysis of the parameters of asymmetrical dual feeding full wave dipole antenna was discussed at Microwave Radar and Remote Sensing conference MRRS 2008 (Yahya, *et al*., 2008). This paper is focused on the analysis of the parameters of symmetrical dual and triple feeding full wave dipole antenna. The current distributions were measured using a shielded loop (Clenet, 2004; Collin, 1955; Balanis, 1997) protruding through a slit in the antenna surface along its axis, gives exact and accurate measurement rather than sinusoidal approximation. However, the sinusoidal distributions of current and voltage are approximations rather than exact descriptions (Edwards, 1963). Next the current distributions were modelled and formulated whose parameters were deduced from the measured current distribution by applying the current distribution data in models as derived by (IEEE standard, 1979). According to (Egashira, *et al*., 1985), it is difficult to apply directly measured data in the forms derived by same authors.

2. Practical Methods to Extract the Equations of the Current Distribution

This section presents results from an experimental investigation of current distribution test. This investigation serves to experimentally find the current distribution wave form, and to obtain formulas by using curve fitting and try and error. The relative magnitude of the current distribution along the antennas was measured and normalized with respect to maximum amplitude. The measurements were conducted firstly on half wave dipole which is well known in it is characteristics. Then on centre tap full wave dipole antenna. Finally on off centre full wave dipole. Figure 1 shows the current distribution for Symmetrical dual feeding in phase.

Curve fitting, and trial and error were used to obtain four Equations which were formulated and mathematically expressed. Equation 1, 3, 4 and 5 represent the mathematical expression of the current distribution for Symmetrical dual feeding in phase, Symmetrical dual feeding out of phase, asymmetrical dual feeding in phase, and asymmetrical dual feeding out of phase respectively

$$I(z) = \sin \beta(\frac{L}{2} - / z /) \tag{1}$$

3. Derivation of the Equations for Radiation Pattern, Gain, and Radiation Resistance

According to the thin wire approximation and Maxwell Equations, the z-component of the radiated electric field for infinitesimal dipole is shown in Figure 2 and depicted in Equation 2 (Balanis, C. A, 1997).

$$dE_\theta = \frac{j60\pi e^{j\omega(t-\frac{r}{c})} I(z)\sin\theta \; e^{jk(z\cos\theta)}}{\lambda r} dz \tag{2}$$

In pervious section the current distribution model obtained is presented in Equation 1. This Equations is used to derive the radiation pattern of antenna.

Referring to pervious section, the predicated Equation for the current distribution is:

$$I(z) = I_{\max} \sin\beta(\frac{L}{2} - /z/) \tag{3}$$

Where β =2 π / λ .

Expressions of the current distribution are as given below:

$$I = I_{\max} \sin\beta(\frac{L}{2} - z), z \ge 0 \tag{4}$$

$$I = I_{\max} \sin\beta(\frac{L}{2} + z), z \le 0 \tag{5}$$

Substituting Equations 3 and 4 in Equation 2, yields

$$E_\theta = \int_{\frac{-l}{2}}^{0} \sin[k(\frac{l}{2} + z)] e^{jkz\cos\theta} dz + \int_{0}^{\frac{l}{2}} \sin[k(\frac{l}{2} - z)] e^{jkz\cos\theta} dz \tag{6}$$

Using Equation 6 to solve the Equation 5 gives Equation (Hassan, 1987).

$$\int e^{\alpha x} \sin(\beta x + \gamma) dx = \frac{e^{\alpha x}}{\alpha^2 + \beta^2}[\alpha \sin(\beta x + \gamma) - \beta\cos(\beta x + \gamma)] \tag{7}$$

$$E_\theta = \frac{j\pi 60 I_0 e^{-j\omega(t-\frac{r}{c})}}{r} \left[\frac{\cos(\frac{\beta l}{2}\cos\theta) - \cos(\frac{\beta l}{2})}{\sin\theta} \right] \tag{8}$$

In this study L=λ =1. Substituting λ =1 and simplifying Equation 8, yields

$$E_\theta = \frac{j60 I_0 e^{j\omega(t-\frac{r}{c})}}{r} \left[\frac{\cos(\pi\cos\theta) + 1)}{\sin\theta} \right] \tag{9}$$

$$H_\varphi = \frac{j60 I_0 e^{j\omega(t-\frac{r}{c})}}{2\pi r} \left[\frac{\cos(\pi\cos\theta) + 1)}{\sin\theta} \right] \tag{10}$$

Equations 9 and 10 represent the radiation pattern of E_θ and H_φ respectively for antenna A1.

The total radiated power is:

$$\frac{1}{2}\mathrm{Re}\int_0^{2\pi}\int_0^{\pi} E_\theta H_\varphi^* r^2 \sin\theta d\theta d\varphi \tag{11}$$

$$H_{\varphi} = \frac{E_{\theta}}{\eta_o}$$

Substituting Equations 9 and 10 in Equation 11, yields

$$P = 60 I_o^2 \int_0^{2\pi} [\frac{\cos(\pi \cos \vartheta + 1}{\sin \theta}]^2 \sin \theta d\theta \tag{12}$$

For numerical analysis and calculation, Matlab and MathCAD software were used to simplify Equation 12. The derivation of the gain is

$$E_{\max} = \frac{120 I_o}{r} \tag{13}$$

$$P = \int \frac{E^2}{120\pi} da$$

Where

$$da = 2\pi r^2 \sin \theta d\theta \tag{14}$$

$$P = \int_0^{2\pi} \frac{60^2 I_o^2}{120\pi r^2} \left[\frac{\cos(\pi \cos \theta) + 1)}{\sin \theta}\right]^2 2\pi . r^2 \sin \theta d\theta \tag{15}$$

$$P = 60 I_o^2 \int_0^{2\pi} [\frac{\cos(\pi \cos \vartheta + 1}{\sin \theta}]^2 \sin \theta d\theta \tag{16}$$

Let $\cos \theta = u, \sin^2 \theta = 1 - u^2, and \sin \theta d\theta = du$

$$P = 60 I_o^2 \int_{-1}^{1} \frac{(\cos(\pi u) + 1)^2}{1 - u^2} du \tag{17}$$

$$= 60 I_o^2 \int_{-1}^{1} [\frac{\cos^2(\pi u)}{1 - u^2} + \frac{2\cos(\pi u)}{1 - u^2} + \frac{1}{1 - u^2}] du \tag{18}$$

Lets $1 + u = \frac{v}{\pi}, du = dv / \pi$, $1 - u = \frac{v'}{\pi}, du = dv' / \pi$

$$= 60 I_o^2 \int_0^{2\pi} [\frac{\cos^2(v - \pi)}{v} + \frac{2\cos(v - \pi)}{v} + \frac{1}{v}] dv \tag{19}$$

$$= 60 I_o^2 \int_0^{2\pi} [\frac{\frac{1}{2}(1 + \cos 2v)}{v} - \frac{2\cos(v)}{v} + \frac{1}{v}] dv \tag{20}$$

$$P = 60 I_o^2 [2\int_0^{2\pi} (\frac{(1 - \cos v)}{v}) dv - \frac{1}{2} \int_0^{2\pi} (\frac{1 - \cos(2v)}{v}) dv] \tag{21}$$

$$P = 60I_o^2\left[2\int_0^{2\pi}\left(\frac{(1-\cos v)}{v}\right)dv - \frac{1}{2}\int_0^{2\pi}\left(\frac{1-\cos(2v)}{v}\right)dv\right] \tag{22}$$

$$P = 60I_o^2\left[2\int_0^{2\pi}\left(\frac{(1-\cos v)}{v}\right)dv - \frac{1}{2}\int_0^{4\pi}\left(\frac{1-\cos(y)}{y}\right)dy\right] \tag{23}$$

$$P = 60I_o^2[2(0.557+\ln(2\pi)-Ci(2\pi)) - \frac{1}{2}(0.577+\ln(4\pi)-Ci(4\pi))] \tag{24}$$

$$P = 60I_o^2[2(0.557+1.837-0.023) - \frac{1}{2}(0.577+2.531-0.006)] \tag{25}$$

$$P = 60I_o^2[3.319] = 199.1I_o^2 \tag{26}$$

$$P = 199.1I_o^2 = I_o^2 R_{rad} \tag{27}$$

$$R_{rad} = 199.1\Omega \tag{28}$$

To determine $E_{\max}$, the function $\left[\frac{\cos(\pi\cos\theta)+1)}{\sin\theta}\right]$ approaches its maximum as $\theta \to \frac{\pi}{2}$ and approaches zero as $\theta \to 0$ and π, thus

$$E_{\max} = \frac{j60I_0 e^{-j\omega(t-\frac{r}{c})}}{r}\left[\frac{\cos(\pi\cos\frac{\pi}{2})+1)}{\sin\frac{\pi}{2}}\right] \tag{29}$$

$$E_{\max} = \frac{j60I_0 e^{-j\omega(t-\frac{r}{c})}}{r}\left[\frac{1+1)}{1}\right] \tag{30}$$

$$E_{\max} = \frac{120I_o}{r} \tag{31}$$

Equation (32) can be used to calculate the gain (Idris and Hadzer, 1994; Idris, *et al.*, 1999).

$$G = \frac{E_{\max}^2 r^2}{30P} \tag{32}$$

Substituting Equations (27) and (31) in Equation (32), yields

$$G = \frac{E^2 r^2}{30P} = \frac{120I_o^2 r^2}{30I_o^2 199.1} = 2.41 \tag{33}$$

$$\text{G=10log (2.41) =3.82 dBi} \tag{34}$$

Half –power beam width is the angle between two solutions of Equation 8, (Idris, *et al.*, 1999; James, *et al.*, 1982; king & smith, 1981; Kraus, 1988).

$$\left[\frac{\cos(\pi\cos\theta)+1)}{\sin\theta}\right]=\frac{1}{\sqrt{2}} \qquad 0\le\theta\le\pi \tag{35}$$

Solving Equation (35) for θ and the numerical solution gives $\theta \approx$ 124° and 66°. The half-power beam width is 124° - 66° = 48°.

4. Conclusion

Expressions for the current distribution, gain, and radiation patterns of full-wave dipole antennas were developed. The relation of the current distribution with the feeding modifications and the polarity of feeding were numerically and experimentally investigated. The expressions for current distribution were developed, and validated, and compared with the experimental results. For symmetrical dual feeding in phase, the Equation of the current distribution is found to be similar to the conventional full-wave antenna Equation. For symmetrical dual feeding out of phase, the Equation follows the theoretical concept of the full-wave antenna (off-centre fed). However, the Symmetrical feeding in-phase achieved 3.82 dBi gains. In this paper, it was found that the full-wave antenna offers a high gain by devising the feeding and applying multi feeding instead of one. Novel design methodologies and implementation techniques for full wave antennas with dual and triple feeding are studied.

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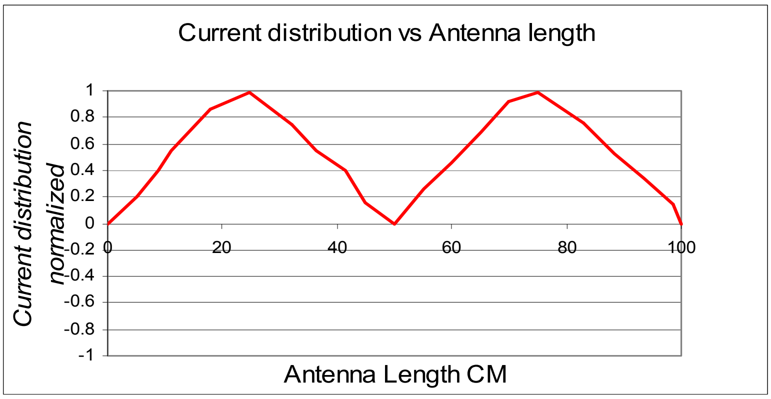

Figure 1. Measured current distribution for symmetrical dual feeding in phase

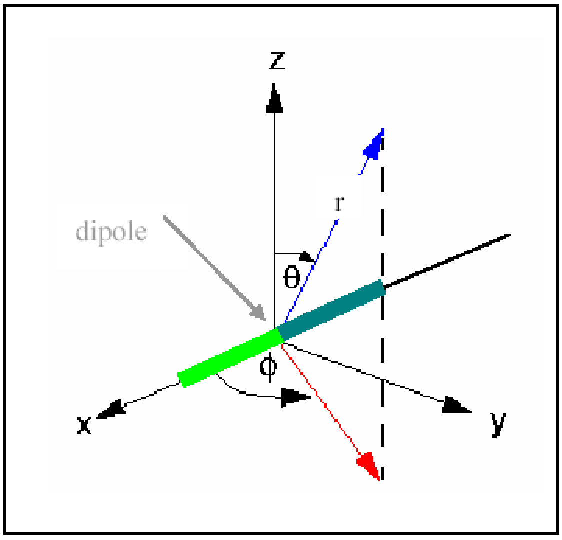

Figure 2. Coordinate System Used with Antennas