TRANSIENT RESPONSE BETWEEN DIPOLE ANTENNAS WITH A PARASITIC ELEMENT

Motoyuki Sato

and

Risaburo Sato

Dept. of Mining & Mineral Eng.
Faculty of Engineering
Tohoku University
Sendai 980 Japan

Dean, Faculty of Engineering Tohoku Gakuin University Tagajo 985 Japan

<u>Introduction</u>: The authors have been interested in a simple analytical method to give transient responses between two dipole antennas[1][2]. In this paper, we use the same technique to analyze transient responses between two dipole antennas with a parasitic element near the transmitting or the receiving antenna. This type of antenna is known as Yagi-Uda array antenna but its analysis in the time-domain is rare as far as the authors know.

Analysis: The configuration of antennas is shown in Fig.1. Two dipole antennas namely #1 and #2 are set parallel and coplanar to each other and are terminated by a resistance Z_0 . A parasitic element #3 is set parallel to #1 and #2 and the center of each element is on the same plane. Neglecting the back scattering from the other elements, we have

$$V_r = V_{pri} + V_{sec}$$
 (1)

where

$$V_{\text{pri}} = \frac{V_{\text{t}} Z_{0} Z_{21}}{(Z_{11} + Z_{0})(Z_{22} + Z_{0})}, \quad V_{\text{sec}} = \frac{-V_{\text{t}} Z_{0} Z_{31} Z_{23}}{(Z_{11} + Z_{0})(Z_{22} + Z_{0}) Z_{33}} (2)$$

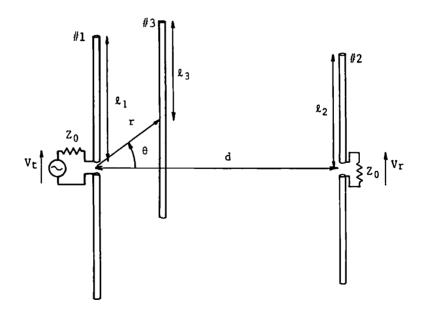


Fig.1 Dipole antennas with a parasitic element

which is the induced voltage of the terminating resistance of #2 in the frequency-domain. Here Zii is the self-impedance of #i and Zii ixi is the mutual-impedance between #i and #j respectively. Equation(1) can be separated into two components, namely the primary wave and the secondary wave as shown in (2). While the former propagates from #1 to #2 directly, the latter propagates from #1 to #2 via #3, i.e., the induced current on #3 re-radiates the secondary scattering wave to #2. Here we give the self-impedance of dipole antennas by the equivalent circuit shown in Fig.2[3]. This circuit is a modification of the conventional "Transmission-line approximation" but we have shown that it is valid not only for the reactance but also for the resistance of the input impedance of dipole antennas[3][4]. The circuit parameters of this equivalent circuit depend only on the radius of the antenna. When the radius is lmm, W = 685Ω , Zf = 3272Ω , Zt = 3125Ω are given[4] and we use these values for the numerical calculation in this paper. On the other hand, we give the mutual-impedance between antennas by electromotive force method[5]. Substituting these values into(2) causes divergence in the time-domain because of the difference of accuracy between the self- and the mutual-impedance of antennas. This error can be avoided by shifting all the poles of the mutual-impedance in the complex frequency-domain to coincide with those of the self-impedance[3]. Consequently we can carry out the inverse Fourier transformation of (1) analytically and have a closed-form formula for the responses in the timedomain.

Numerical results and measurement : The time history of the primary and the secondary wave defined in (1) and (2) are shown in Fig. 3. The primary wave is independent of the location of #3 but the secondary wave varies according to 0. The time history of the induced load voltage which can be given by the summation of the primary and the secondary wave is shown in Fig.4. Measured data is also shown in the same figure. We used a short video-pulse for the excitation voltage Vt and its duration is approximately 300ps. Refer to [1] for the detail of this measuring system. The receiving voltage is normalized by the peak amplitude of the exciting pulse Vt0 in all the figures. The theoretical results are given by the convolution integral of the impulse response given by (1) and the theoretically assumed pulse form in the time-domain. Although the accuracy of the results is not enough, we can explain every part of the change in the time-domain as the result of the varied geometrical distance between antennas. For instance, the maximum dip appears just after ct=2m in the measured time history can be expected to be caused by the superposition of the maximum dip of the primary wave and the small rise of the secondary wave which are shown obviously in the theoretical time history. Since the distance between #2 and #3 increases according to the increase of 6 from 0° to 180°, the appearance of the small rise delays and the maximum dip in the measured data increases as the result.

<u>Conclusion</u>: A closed form formula for the time history of the induced load voltage of the dipole antenna by another dipole antenna excited by a short video-pulse with a parasitic element was given. It enables us easy estimation of the peak-amplitude of the response in the time-domain. Wave forming by the geometrical configuration of antennas will also be possible.

Acknowledgment: The authors are grateful to Professor Shigeo Nishida of the Research Institute of Electrical Communication, Tohoku Univ.

References:

- [1] M.Sato, M.Iguchi and R.Sato, "Transient response of coupled linear dipole antennas," *IEEE Trans.*, Antennas Propagat., vol.AP-32, no.2, pp.133-140, Feb. 1984.
- [2] M.Sato and R.Sato, "Transient response between a V-antenna and a collinear dipole antenna," *IEEE Trans.*, Antennas Propagat., vol. AP-32, no.11, Nov. 1984.
- [3] M.Sato and R.Sato, "A new equivalent circuit representing electrical discontinuities of a dipole antenna," in *Int. EMC Symposium Dig.*, pp. 309-314, Tokyo, Oct. 1984.
- [4] M.Sato and R.Sato, "Analysis of transient response between coupled dipole antennas by using a simple equivalent circuit," to be submitted.
- [5] J.D.Kraus, Antennas, New York: McGraw-Hill, 1950.

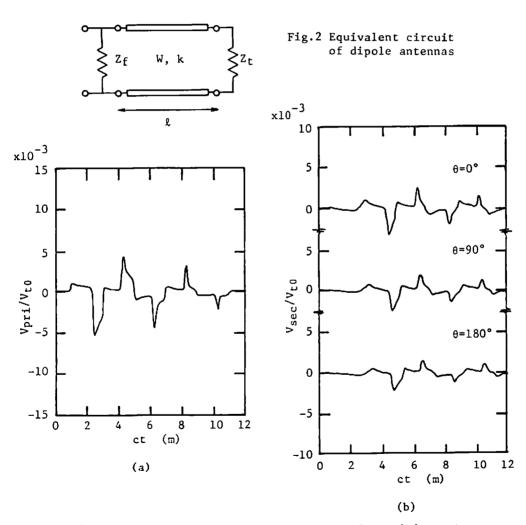


Fig. 3 Time history of induced load voltage of receiving antenna. (a) Primary wave, (b) Secondary wave $\ell_1 = \ell_2 = \ell_3 = 1 \text{m}$, d = 1 m, r = 0.2 m.

