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A SOLUTION
TO
SURFACE-WAVE EXCITATION PROBLEM

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INTRODUCTION

Electromagnetic energy can be transported in the form of surface waves along certain structures or lines. Such surface waves are often called characteristic waves or residue waves and are obtained, namely, as eigenfunctions of the structures. However, few solutions to excitation problems have been presented. This paper is mainly concerned with surface wave excitation problem of a periodic linear array of infinite length, especially that consisting of circular loops as shown in Fig. 1 to which no solution has been given.

CURRENT ON THE ELEMENT

In an arbitrary infinite periodic array, the active admittance $Y(\theta)$ when operated as a phased array is expressed by using the mutual admittance Y_{0m} between zero'th and m'th element as follows.[1]

$$Y(\theta) = \sum_{m=-\infty}^{\infty} Y_{0m} \exp(-jm\theta) \quad (1)$$

where θ is the phase difference between two adjacent elements and can be interpreted as a product of the phase constant β and the pitch p.

When the zero'th element is driven by a voltage source of unit voltage and the other elements are short-circuited, the driving-point current I_m of each element is given in the following integral.[2]

$$I_m = \frac{1}{2\pi} \int_0^{2\pi} Y(\theta) \exp(jm\theta)\, d\theta \quad (2)$$

Let $z = \exp(j\theta)$, and the above integral can be changed into a linear integral along the unit circle on the complex z-plane. In general the integrant of the above integral has poles in the complex z-plane on the unit circle[2] which correspond to surface waves. In the region where the integrant has poles, it takes a value of pure imaginary.

$$Y(\theta) = j/X(\theta) \quad (3)$$

Using this representation, I_m can be decomposed in two parts: surface wave I^s and attenuated waves I^d.

$$I_m = I_m^s + I_m^d \quad (4)$$

where

$$I_m^s = \frac{1}{-X'(\theta)} \exp(-jm\theta) \quad (5)$$

$$I_m^d = \frac{1}{2\pi} \int_0^{2\pi} \{Y(\theta) - P(\theta)\} \exp(jm\theta)\, d\theta \quad (6)$$

and $P(\theta)$ is a function including all the surface wave poles.

LAUNCHING EFFICIENCY

The launching efficiency of surface wave on the periodic structre can be defined as a ratio of the available surface wave power P_s to the total supplied power P_t from

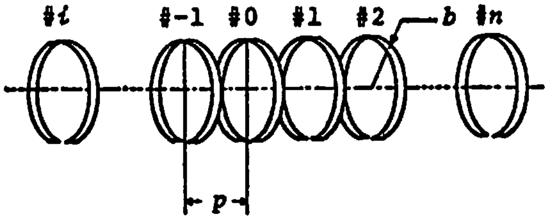

Fig. 1. An infinite periodic array of loop antennas. The loop radius and the pitch is b and p, respectively.

the driving point. The total supplied power is expressed in terms of the driving point current I_0 and voltage V_0 of the excited element.

$$P_t = \mathrm{Re}(\frac{1}{2}V_0 I_0^*) = \mathrm{Re}(\frac{1}{2}I_0^*) \quad (7)$$

where the applied voltage is assumed to be unity. The power associated to the surface wave is obtained from (4).

$$P_s = \mathrm{Re}(\frac{1}{2}I_0^{s*}) \quad (8)$$

Therefore the surface wave excitation efficiency η_s is evaluated as follows.

$$\eta_s = \frac{P_s}{P_t} = \mathrm{Re}(I_0^{s*})/\mathrm{Re}(I_0^*) \quad (9)$$

The surface wave excitation efficiency of an arbitrary periodic array of infinite length can be evaluated using the above formula.

NUMERICAL CALCULATION

Numerical calculations are carried out on circular loop array of infinite length as illustrated in Fig. 1.

The active admittance of the array is obtained using tape loop approximation.[2] The current amplitude of the surface wave is calculated by (5) and a typical values are shown in Fig. 2 for $p/b=\pi/4$. The amplitude increases rapidly when kb approaches to 1.0. When kb approaches to 1.0, the phase constant β of the surface wave increases. Therefore θ $(=\beta p)$ increases to take a value near π where $X(\theta)$ has stationary property. Accordingly, $X'(\theta)$ reduces to zero. The fact that the surface wave current tends to infinity has also been reported in the case of dipole array.[3]

The real part of the formula (6) does not vary very rapidly because it corresponds to the direct radiation from the excited element. Therefore, surface wave excitation efficiency takes a greater value for a greater kb.

CONCLUDING REMARKS

A formal expression is presented for the current distribution of surface wave on an infinite periodic array with one element excited and the others parasitic. The current distribution is proportional to the mutual admittance which is evaluated as Fourier components of the active admittance when the array is operated as a phased array. The values of amplitude and phase constant of the surface waves can be determined by finding the intensity and location of the poles of the active admittance. Stop bands for surface waves also appear as in the case of other ordinary periodic structures. The amplitude of the surface wave current tends to infinity when operating frequency approaches to the stop band edge. The amplitude of the surface wave current and the launching efficiency is evaluated for an infinite periodic loop array. The behaviour is similar to that of dipole arrays.

References:

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[3]R.J.Mailloux, Trans. IEEE *Antennas and Propagation*, AP-13,pp.719-724,(Sept. 1965).

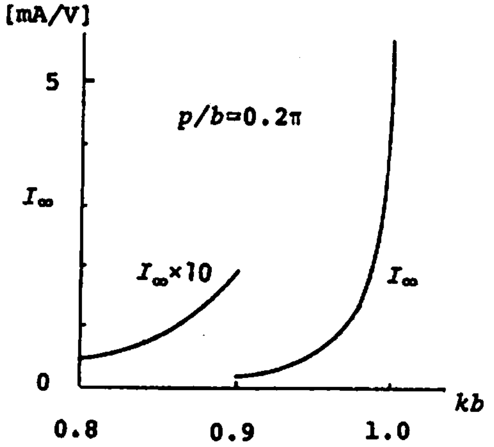

Fig. 2. Surface wave amplitude vs. kb, where k is the wave number of free space.