THE OPTIMIZED IMAGE OF AN OSCILLATING MAGNETIC DIPOLE NEAR AND NORMAL TO A CONDUCTING SPHERE

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Abstract

The optimized images of a low frequency electric dipole near a conducting sphere are known [1][2]. This paper studies the corresponding image for a normally oriented magnetic dipole. Interesting and simple properties of the image are interpreted.

I. Introduction

Field expressions from images are frequently simpler than those from other methods. For example an exact point charge image is found for a source point charge placed near a grounded sphere. The field expression is simply a sum of the Coulomb fields from the source and image charges.

An exact image is also frequently hard to find, an example is an oscillating electric dipole near a conducting sphere. Happily an approximate image can be found for low frequency dipole by placing image electric and magnetic dipoles inside the sphere. The complex amplitudes and locations of these dipoles can be obtained through a computer optimization routine minimizing the boundary errors. The method is called the "optimized simulated images", and the above example has been studied in recent papers [1][2].

Such optimized images are useful in studying mutual coupling between rain drops in electromagnetic scattering.

The coupling study is incomplete without the corresponding image of a magnetic dipole near a conducting sphere. This paper will study only simpler cases of a normally oriented magnetic dipole at low frequency. The tangentially oriented dipole will be more complicated and will be discussed in a later paper.

II. The Exact Image in the DC Case

The images can be point or line dipoles of the electric or magnetic type. The convergence in the optimization will be fast only if the suitable images are used. At low frequencies, the suitable images should be similar to those at DC.

The image of a DC magnetic charge near a conducting sphere is equivalent to that of a fluid source near an impenetrable sphere [3]. An exact solution for the latter is available. Thus, with the image of the magnetic charge obtained the DC image of a magnetic dipole is obtained. Fig. 1 shows the strength W' and location c of the magnetic dipole image from a normally oriented source magnetic dipole, with

$$W' = W\left(\frac{a}{b}\right)^3 \qquad (1)$$

$$c = \frac{a^2}{b} \qquad (2)$$

where a is the radius of the sphere and b the distance of the source dipole

W from the center of the sphere.

III The Low Frequency Images

As the frequency increases from DC, the magnetic dipoles (source and image) are oscillating. Because of the orientation of the normal magnetic dipole, the image remains as the magnetic type, no electric dipole images are excited.

The location, amplitude and phase of the oscillating magnetic dipole image are shown in Fig. 2, 3 and 4.

Fig. 2 shows that the location c of the image does not vary much from the DC case for any source-to-sphere-center distance b, as long as the sphere remains small in wavelengths, say $ka < 0.5$ where a is the one meter radius of the sphere and k, the propagation constant.

An examination of Fig. 3 shows that the amplitude W'/W of the image follows $(1/kb)^3$ until $kb = 1$, then it follows $(1/kb)^2$. This is easily understood from the relative strengths of the induction terms of the source dipole. The radiation term is nearly zero because of the orientation of the source dipole.

A similarly simple interpretation is possible for the phase of the image in Fig. 4.

IV Conclusion

In view of the simple observation and interpretation of the dipole image simple formulas for the properties of the image dipole can be constructed.

This paper studies only the normally oriented magnetic source dipole near a sphere. By the same optimized simulated image approach, a corresponding set of nearly as simple formulas, can be constructed for the tangential magnetic dipole.

With the formulas for the magnetic dipoles known, together with those for electric dipoles [1], the couplings between scattering rain drops and other similar problems may be solved without much difficulty.

References

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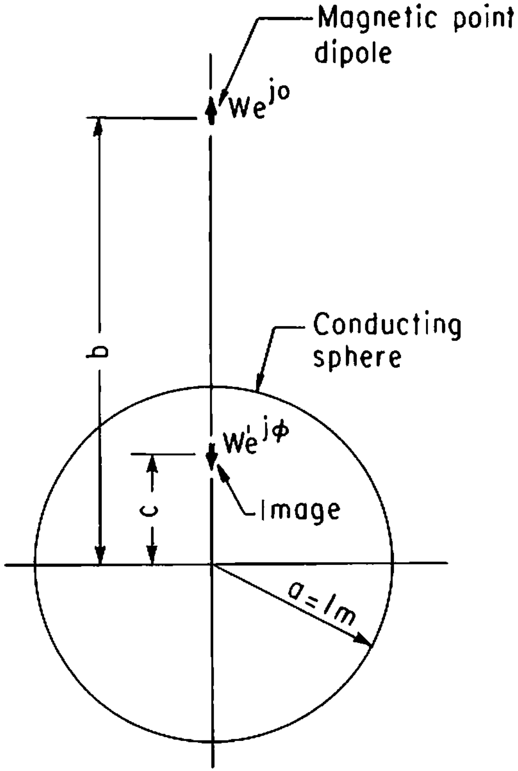

Fig. 1 A magnetic normal point dipole located near a conducting sphere.

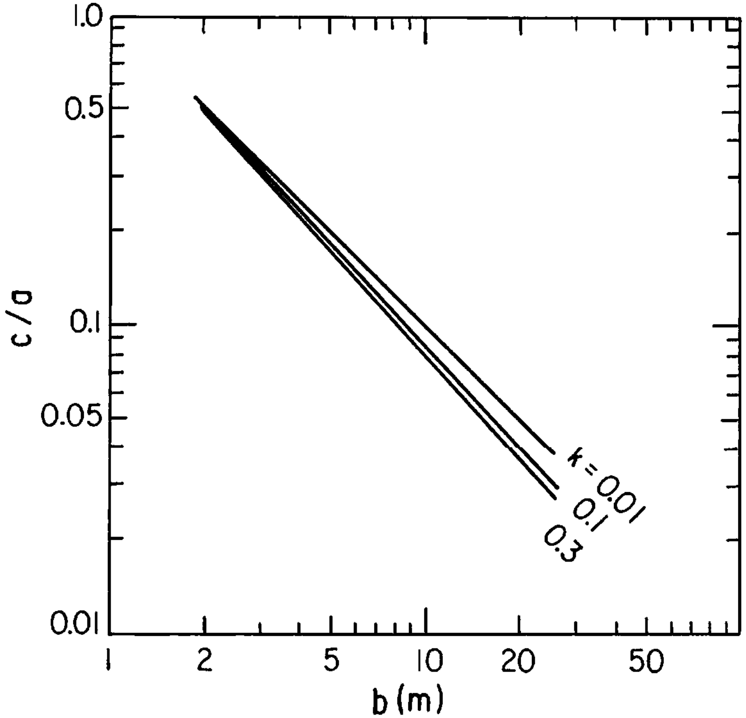

Fig. 2 The location of the image of a magnetic normal point dipole.

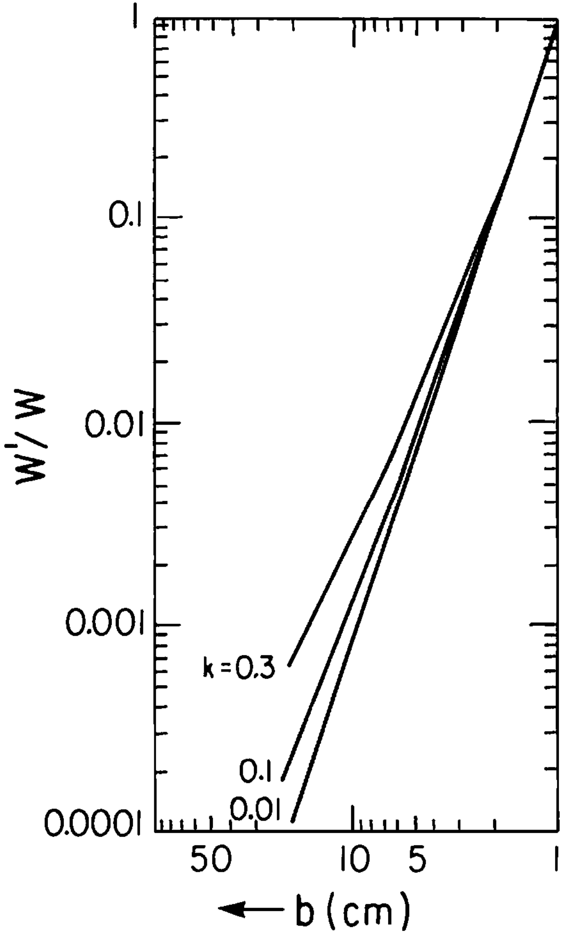

Fig. 3 The strength of the image of a magnetic normal point dipole.

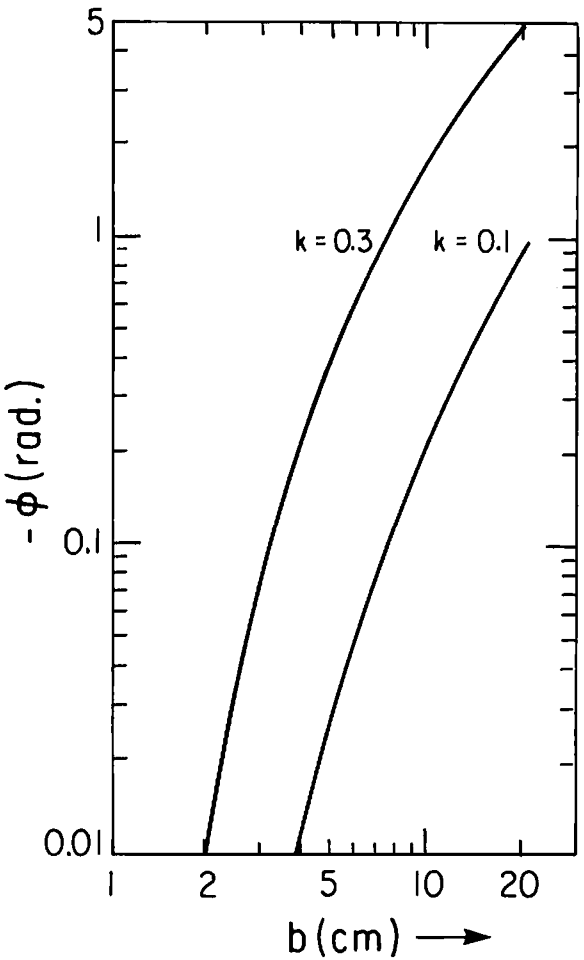

Fig. 4 The phase of the image of a magnetic normal point dipole.