PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

PULSED ELECTRIC DIPOLE FIELD SCATTERING BY A DIELECTRIC BODIES OF REVOLUTION IN MULTIFREQUENCY CONDITIONS

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Abstract

Some results of the investigations of time- and frequency characteristics (FC) of dielectric spheroid with various absorption in a case of pulsed electric dipole (PED) excitation are presented. The scattered fields spectra are investigated. Scatterer oscillations eigenfrequences are determined and field resonances shaping mechanism is studied. Weighted frequency characteristics (WFC) and responses of spheroid in far zone are also investigated.

1. Problem statement and solution method

Development and adoption of various dielectric units and equipment operating in a broad frequency range requires to investigate FC and time responses of simple model objects.

Let us consider the PED field scattering from prolate dielectric spheroid with semimajor axis $C = 0.50$ and semiminor axis $A = 0.25$ which is locate in a free space in a case when exciting dipole is locate on the axis of revolution on the distance $d = 0.20$ from the surface of the object. The dipole moment is polarized along the axis of revolution. The geometry of the problem is shown in Fig.1.

In frequency domain the problem was solved by the auxiliary sources method (ASM) [1]. For the purpose of increasing of the accuracy of the boundary problem solution and CPU time minimization the auxiliary sources are located in the singularities regions of the fields extended inside the scatterer [1]. For solving of this concrete problem the effective modification of ASM based on the axial symmetry [2] is used.

The frequency characteristic of spheroid was calculated over the interval $0.05 \le k_0L \le 20.0$ with increment $k_0L = 0.05$ ($L = 2C$ and "k_0" is the wave number in free space). Normalized residual of boundary condition over considered frequency interval is less then 0.001 .

2. Investigation of frequency characteristics of dielectric spheroid

Here we investigate the spectrum of field scattered by spheroid with permittivity $\epsilon^i = 8.0 + i\cdot 0.0$. Here we assume that permeability $\mu^i = 1$ and frequency dispersion is neglected. Because of limitation of this paper volume we consider scattering along one direction with observation angle $\theta = 30°$.

Scattered field spectrum is shown in Fig.1. Let us divide (conventionally) considered frequency range into three intervals: low frequency (LF) range $0.05 \le k_0L \le 5.00$, medium frequency (MF) range $5.05 \le k_0L \le 15.00$ and high frequency (HF) range $15.01 \le k_0L \le 20.00$. From the presented spectrum one can observ that the resonance oscillations superimposed over the interference one. Spectrum behaviour in LF range is determined basically by standard difraction mechanism of field dependence on k_0L parameter. In MF range occurs the resonance peaks. When increasing of incident field frequency high mode oscillations are exciting. However, in this case, because of closed cavity resonatores FC flatness and resonance peak finite width, resonance peaks overlaps and at some angles of observation resonance peaks are not clearly highlighted. This effect arise in FH range.

Let us investigate scattered fields in near zone at the resonance frequency and in small vicinity of it. Here we consider frequences corresponding to $k_0L = 14.00$ and $k_0L = 14.45$ (resonance frequency). Scattered field patterns are shown in Fig.2 and 3. One can observ strong disturbance of field inside and outside the scatterer in a case of resonance frequency (Fig.3). A new oscillation arise in this case and that is a characteristic attribute of a resonance. This new oscillation causes to new lobe arising in scattered field pattern in far zone (Fig.4). After passing the resonance frequency field pattern becomes "stable" and field amplitude decreases.

Similar effects exists for the rest of resonance frequences.

Let us consider now strongly absorbing spheroid of the same geometry and dimensions with permittivity $\epsilon^i = 8.0 + i\cdot 8.0$. Scattered field spectrum at $\theta = 30°$ is shown in Fig.1. Here we analyse changes that occurs in this case. From the comparision of non-absorbing and absorbing spheroids fields spectra one can observ following effects:

1) dominating of interference mechanism over the resonance one in spectra formation,
2) small shifting (increasing) of resonance frequences over the whole frequency range
3) strong decreasing of considered resonator Q-factor.

Pattern of field scattered by absorbing spheroid at resonance frequency corresponding to $k_0L = 14.95$ is shown in Fig.5. Scattered field practically don´t penetrate inside the scatterer and it concentrated in narrow zone near the surface of spheroid in a form of waves "flowing down" from top pole of spheroid to the bottom one. In this case the scatterer operates as a guided element. For more detail analyses of field distribution inside the scatterer with absorption in Fig.6 is shown only internal field.

Decreasing of Q-factor leads to field behaviour changing at resonance frequency and its vicinity. Changing frequency in the vicinity of the resonance peak one can observ that the resonance field amplitude only slightly exceeds field amplitude at frequences near the resonance and field pattern is practically invariable with the exception of field small concentration in bottom pole region and a little more uniform field distribution in above mentioned zone near surface of the scatterer.

3. Investigations of spheroid weighted frequency characteristics and its transient responses

Here we investigate FC of spheroid weighted by incident field spectrum. Let us consider non-modulated incident pulse with Gaussian envelope and duration $cT_0 = 1$ (here we use "ct" units, "c" is light velocity). WFC of non-absorbing spheroid corresponding to this pulse is shown in Fig.7 . One can observ clear resonance peaks but at the same time Gaussian pulse "gains" effect of spectrum LF an MF regions. Similar effect occurs in a case of absorbing spheroid (Fig.7). Main difference between these scatterers consists in interference mechanism dominating in a case of spheroid with absorption.

Let us consider transient responses of spheroids with $\epsilon^i = 8.0 + i\cdot 0.0$ and $\epsilon^i = 8.0 + i\cdot 8.0$ in a case of above considered pulse. We obtain time domain solutions by using the Fourier synthesis technique [3].

Responses of both scatterers at $\theta = 30°$ are presented in Fig.8. Let us analyse response of scatterer without absorption. Response consists of three different components: specularly reflected (SR) pulse, creeping wave (CW), and oscillations corresponding to field radiation on resonance frequences. The SR duration is equal to cT_0 and CW duration is slightly longer then cT_0. Time delay between SR and CW $t = 2.67$ that is more then corresponding quantity for perfectly conducting spheroid with the same parameteres that is concerned with decreasing of CW phase velocity in a case of dielectric scatterer. Response third component oscillations amplitudes are decreased with increasing ct because of energy losses by radiation.

Response of absorbing spheroid consists only of SR and CW components (this response for convenience is shifted by -10.0). SR practically completely correlate with SR of non-absorbing spheroid. Time delay between SR and CW is equal to 2.67 but CW amplitude is smaller then for $\epsilon^i = 8.0 + i\cdot 0.0$. Radiation at resonance frequences is absence becaus of strong absorption.

Conclusion

Let us briefly summarize presented results. Frequency characteristics for both non-absorbing and absorbing spheroids are investigated. Scattered field patterns in near- and far zones in the vicinity of a resonance frequences are analysed.

Relation between scatterers geometry, dimensions and permittivity from one side and time delay between SR and CW from another side is shown. Eigenfield radiation in time domain is also investigated.

Presented results demonstrated efficiency of using of combination of scatterer characteristics in the frequency- and the time domain in target identification and inverse scattering problems.

References

1. R.S. Zaridze et al., "A Method of Auxiliary Sources in Applied Electrodynamics", Proc. of URSI Int.Symp. on EM Theory, part A, p.104, Budapest, 1986.
2. Sveshnikov A.G., Eremin Yu.A, Orlov N.V., "Investigation of some mathematical models in the difraction theory by the method of nonorthogonal series", Radiotekhnika i Electronika, vol.30, No.4, pp.697-704, 1985 (in Russian).
3. E.M. Kennaugh, D.L. Moffat, "Transient and Impulse Response Approximations" Proc. IEEE, vol.53, pp.893-901, 1965.

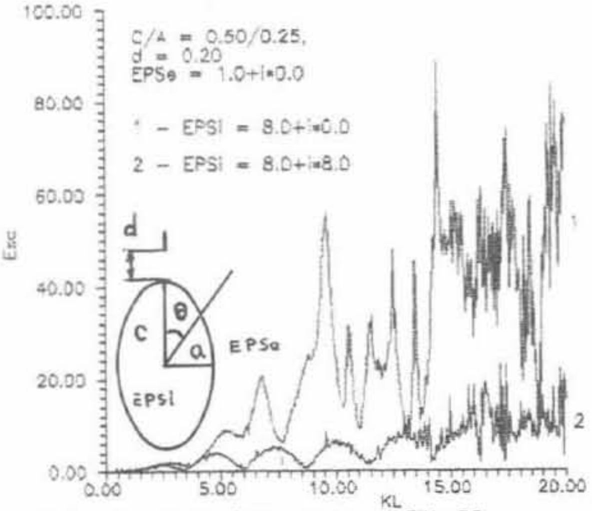


Fig.1 Scattered field spectra, THETA=30

Fig.2 Near zone field, EPSI=8.+i*0., K0=14.00

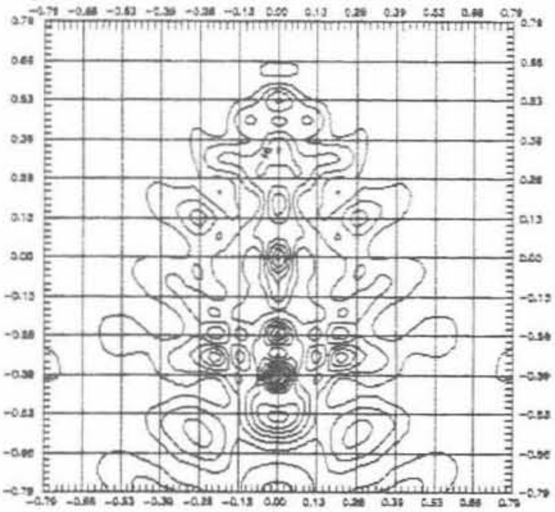
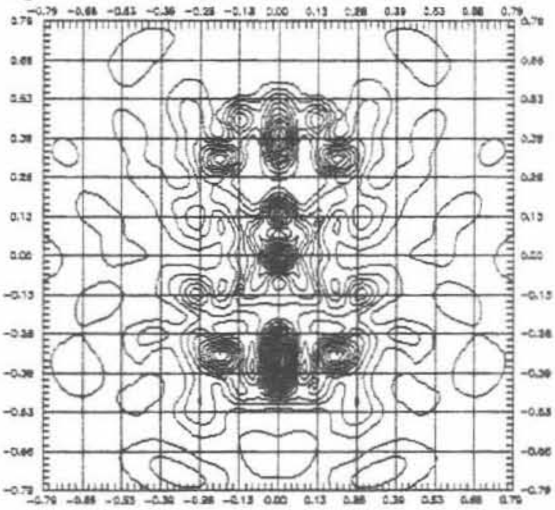


Fig.3 Near zone field, EPSI=8.+i*0., K0=14.45



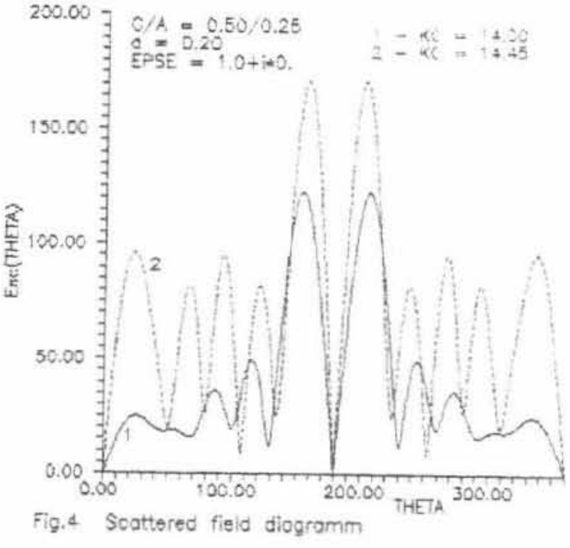
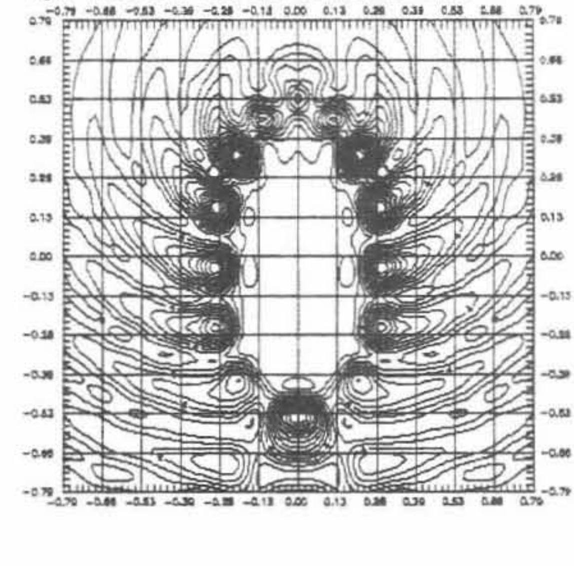


Fig.4 Scattered field diagramm

Fig.5 Near zone field, EPSI=8.+i8., K0=14.95



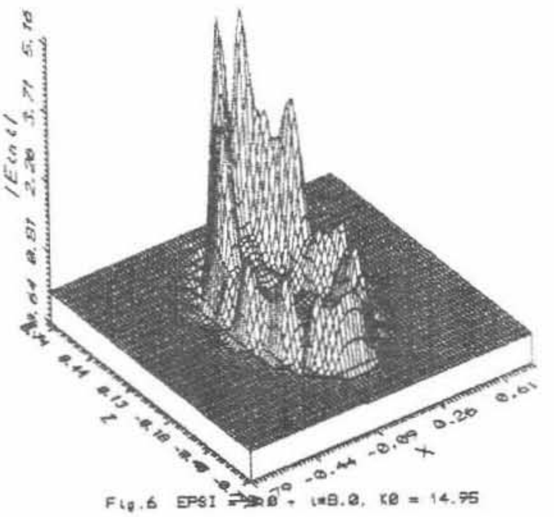


Fig.6 EPSI = 8.0 + i*8.0, K0 = 14.95

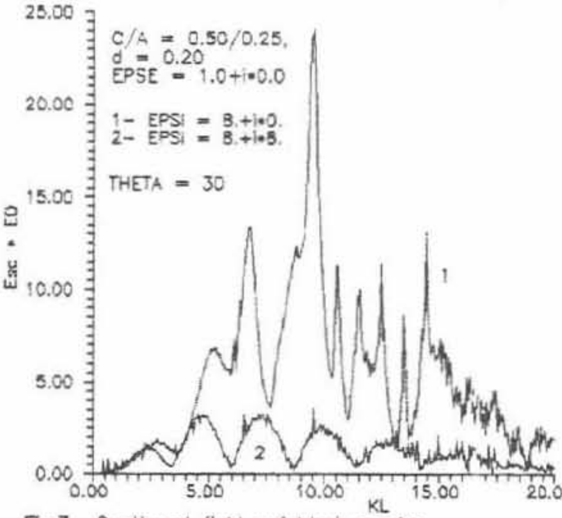


Fig.7 Scattered field weighted spectra

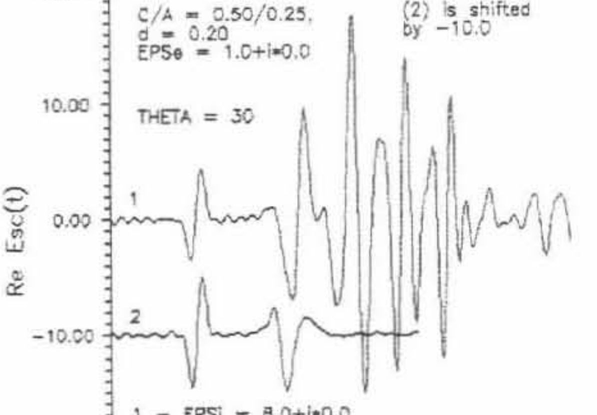


Fig.8 Far field responses