COMPLEX SOURCE POINT BEAMS AND SURFACE WAVES IN URBAN PROPAGATION MODELLING

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INTRODUCTION

In radio propagation along a street, reflection is usually more significant than diffraction. Consequently most models for radio wave propagation in densely urban environments are simplified by assuming omnidirectional sources and plane wave reflection from plane lossy building surfaces. The complex dielectric constant of the building surface may be deduced for the model by comparison with experimental results for propagation loss along a similar street. Diffraction by building corners, if included, is usually for perfectly conducting buildings, because scattering by a dielectric corner presents mathematical difficulties.

In spite of their physical inconsistencies these simplified urban propagation models may yield satisfactory results for situations where the source directivity and its proximity to a building surface do not significantly affect excite surface waves or even where the surface wave fields do not significantly excite the receiver. It appears that most measurements of urban propagation are made in the street, rather than near the building surfaces, where surface waves are often more likely to be significant, at least near the source. Surface wave dominance of the received signal would be expected, for example, around the corner from a source in the shadow of direct and reflected fields.

In this paper we confine our analysis to two dimensions to determine situations where source directivity and lossy dielectric surfaces can affect the scattered field in urban propagation modelling. For source directivity we apply the complex source point technique to a uniform geometrical theory of diffraction solution for scattering by a right-angled impedance wedge The complex dielectric constant of the wedge is selected from that deduced from propagation measurements in Manhattan, New York. Solutions for both E and H - polarization are investigated. While both cases exhibit surface wave effects, of course those for H polarization are found to be more significant. Indeed it is found that that for a source near a building surface, as is usual, surface waves occur near the building surface and tend dominate the signal there in the near field of the source. Source directivity can slightly effect this, but it has usually a minor effect. Of considerably greater significance when the source is near the building is surface wave excitation, which strongly affects the scattered far field signal near the direction of specular reflection. This appears to be a situation requiring inclusion in urban propagation modelling.

Arrays of complex source point beams can be used to simulate radiation from aperture antennas, and their scattering by local impedance wedges used to further examine the effect of source directivity in urban propagation modelling. The effects observed are similar to those already mentioned for a single beam source.

ANALYSIS

Uniform theory of diffraction (UTD) expressions for the diffracted and surface wave fields near a line source parallel to the edge of a wedge with impedance boundary conditions different on the two wedge faces were obtained in [1] by asymptotic evaluation of the exact Maliuzhinets [2] far field plane wave spectrum integral. Complete expressions and numerical results were given only for right-angled wedges perfectly conducting on one face, with an impedance boundary on the other. Numerical results were presented to show uniformity of the UTD solution. This analysis was extended to a right-angled wedge with identical impedance boundaries on both faces in [3]. Although both E and H polarizations were analyzed, only for H - polarization (magnetic field H_z parallel to the edge) were surface waves significant in the numerical examples. Thus only H - polarized fields are dealt with here.

Fig. 1 shows the geometry for the magnetic field at r,ϕ from the edge of a right-angled wedge due to a magnetic line source at r_0,ϕ_0 parallel to the edge. Either source or field point may be arbitrarily close to the edge but the sum of their distances must be large in wavelengths. Both wedge surfaces have the impedance boundary condition [4],

$$\frac{1}{r}\frac{\partial H_z}{\partial \phi} - jk\frac{\eta}{Z_o}H_z = 0, \tag{1}$$

where η is the surface impedance of the wedge, k is the free space propagation constant and $Z_0 = 120\pi$ ohms is the wave impedance of free space. Solutions for the geometrical optics and diffracted fields, which includes both incident and reflected fields and the diffracted field from the edge, arising from real singularities in the integral, are given in [1, Part I]. There are also four terms associated with complex singularities in the integral. Edge diffraction produces surface wave fields on both faces. Also any source near an impedance surface produces a surface wave, which is reflected on the illuminated side of the wedge and transmitted on the shadow side. Diffracted waves also are launched from the edge due to surface wave excitation. The first is by a surface wave incident from the illuminated face. The second comes directly from the source due to the impedance boundary condition. Expressions for these fields resulting from surface wave excitation are defined in [1, Part II] and [3]. The expressions for diffracted fields are in terms of complex Fresnel integrals, providing a uniform solution.

DIRECTIVE SOURCES

Although source directivity has only a minor effect in the numerical examples chosen, it can easily be included by assigning appropriate complex coordinates to the source position.. Complex coordinates r_s, ϕ_s are related to real source coordinates by

$$r_s = \sqrt{r_0^2 - b^2 - 2jr_o b\cos\left(\beta - \phi_o\right)} \ , \tag{2}$$

$$\phi_s = \cos^{-1}\left(\frac{r_o\cos\phi_o - jb\cos\beta}{r_s}\right), \tag{3}$$

where kb defines the beam width and β the direction of the beam from the x axis. Then the far incident field is modified by a factor $\exp\left[kb\cos\left(\phi-\beta\right)\right]$, making it paraxially Gaussian with a half power beamwidth (HPBW)

$$HPBW = 2\cos^{-1}\left(1 - \frac{\ln 2}{2kb}\right). \tag{4}$$

When the real source coordinates are replaced by complex values all related field quantities become complex, including the arguments of Fresnel integrals. Their evaluation is then in accordance with their relation to the complementary error function, as in [5].

An extended source such as an aperture antenna can be treated as a linear array of beam sources[5] arranged in a Gabor lattice as in Fig. 2. Provided the beam spacing is less than half a wavelength [6], parallel beams suffice and the aperture field is

$$H_z\left(x, y_o\right) = \sum_{m=-M}^{M} A_m w\left(x - m\frac{\lambda}{2}\right), \tag{5}$$

in which w is the elementary beam function, a complex source point beam here. A_m is the beam amplitude, which can be determined from the aperture distribution. The total scattered field is

$$H_z\left(r,\phi\right) = \sum_{m=\_M}^{M} A_m B_m\left(r,\phi\right) \ , \tag{6}$$

where $B_m\left(r,\phi\right)$ are the scattered fields of each of the beams.

NUMERICAL RESULTS

Some numerical results are shown in Figs. 3a and 3b. These are for an H - polarized beam parallel to and directed at the edge of a right-angled wedge with an impedance boundary condition on both faces corresponding to data extracted from measurements on urban propagation in Manhattan [7]. They correspond to a building surface dielectric constant of 15 and conductivity of 7 S/m. at a frequency of 900 MHz. In these results the source is near the edge, but the receiver is at half its distance and that is why a total field maxima appears for small values of ϕ , where the receiver is nearest the source. Surface wave field contributions excited by edge diffraction and by surface wave scattering by the edge are indicated by the dashed lines in Figs. 3a and 3b and are most evident near the wedge boundaries and also just beyond $\phi = 180°$, This is particularly evident when the source is very near the impedance wedge surface, as in Fig.

3b. It is much less in a numerical example for $\phi_0 = 30^\circ$ and vanishes when $\phi_0 = 60^\circ$ with these parameters. It is important to note that this effect is also very significant in the far field with similar parameters [3, Fig. 8]. There surface wave effects along the boundaries are virtually negligible but for a source close to the wedge, the surface wave lobe launched by the edge is sharper and higher than the specularly reflected lobe.

Surface wave excitation also occurs for E - polarization but is so small with these parameters as to be negligible. In the case of extended H - polarized sources surface waves appear along the impedance wedge surfaces, but their launching and scattering by the edge is more simply shown for a single beam.

CONCLUDING REMARKS

We have assumed here a smooth right-angled impedance wedge as a model for the corner of a building. Of course building surfaces are usually not smooth but often indented with windows and other architectural features. For near-grazing incidence on modern buildings, however, such indentations should have negligible effect. Our results indicate that it is the edge of an impedance wedge that is critical in affecting the scattering pattern. If this is rounded on a building with a radius of curvature significantly large in wavelengths the results would be very different. Of course the assumption of uniformity in buildings and other approximations are essential in urban propagation modelling but care needs to be taken in two critical areas where surface waves of significant amplitude can be excited; that is for a horizontally polarized source (H - polarization) near the vertical edge of a building that can support surface waves. One is on the shadow side of the source near a building surface where the entire field may be that of a surface wave. The other is down the street near the direction of specular reflection. These situations are usually important in propagation modelling and when they occur surface wave effects need to be included.

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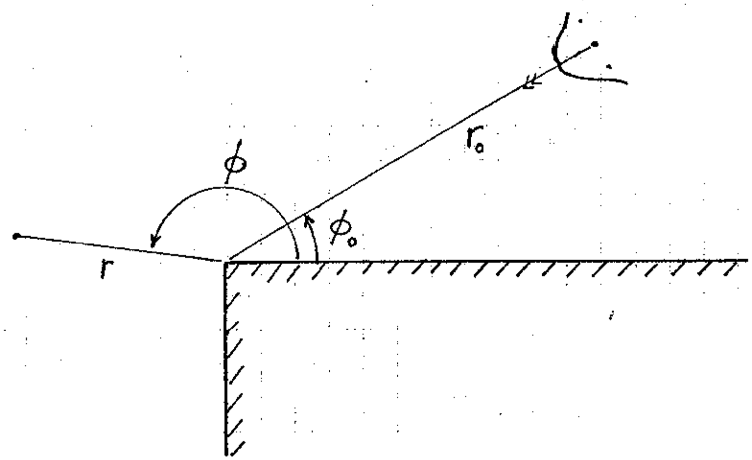


Fig. 1 Geometry for scattering from a right-angled impedance wedge.

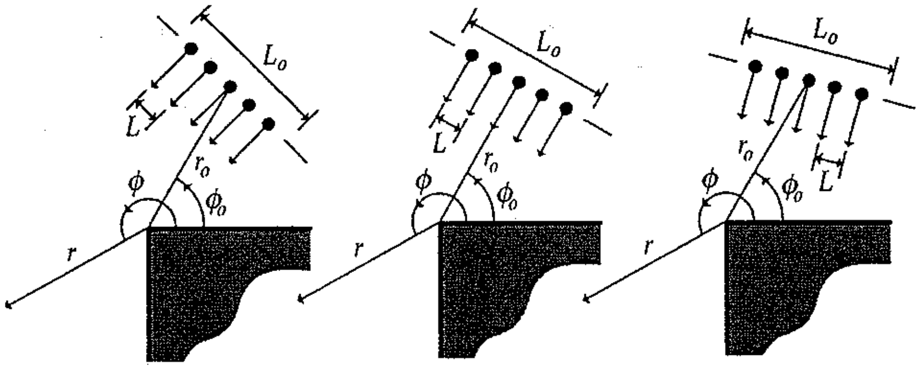
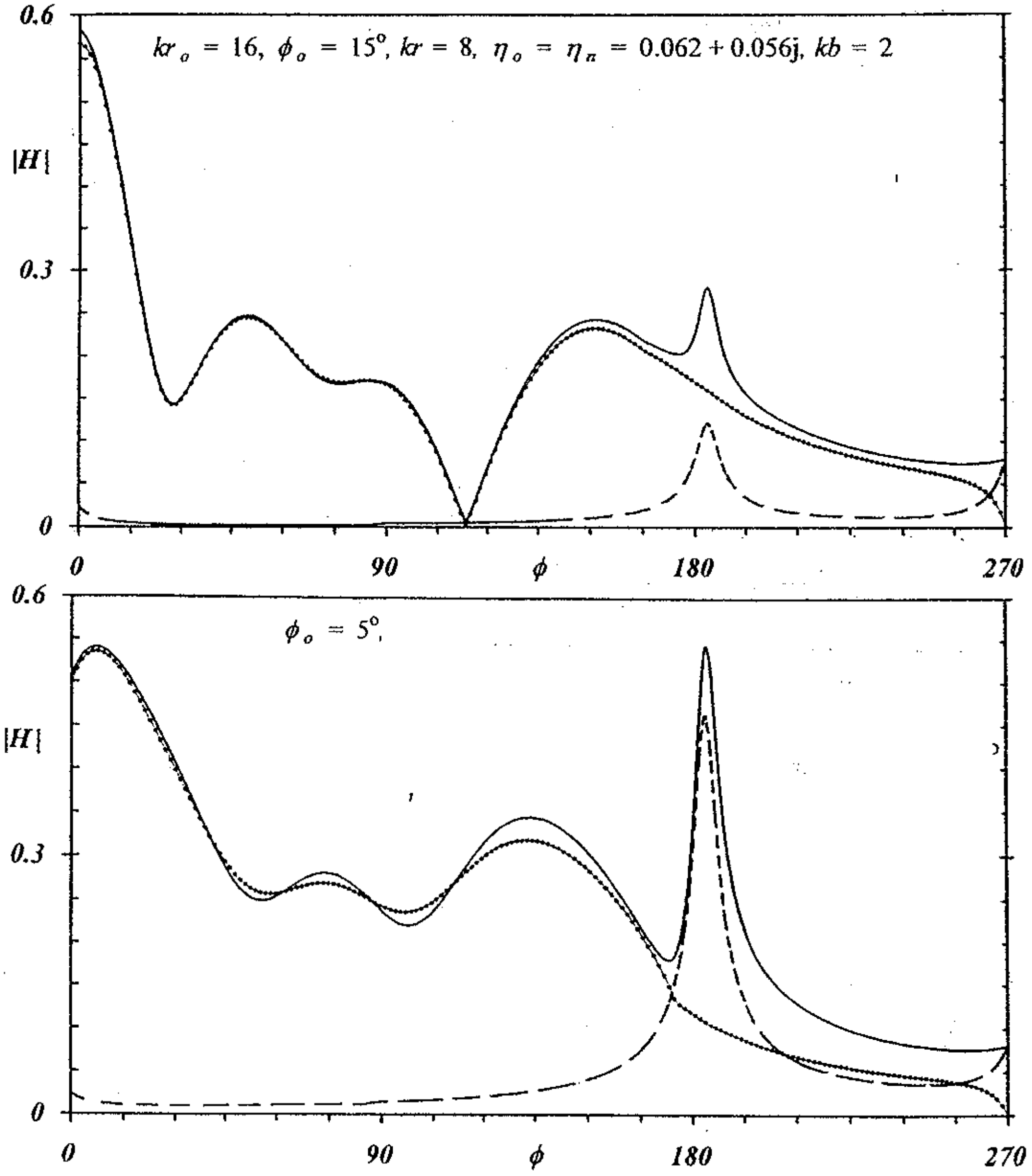


Fig. 2. Coordinates for beam array scattering by a right-angled impedance wedge with the beam axis of the array directed above, at and below the edge of the wedge.



Figs. 3. Surface wave-----, non-surface wave……. and total magnetic fields_________for a single beam parallel to the edge of a right-angled wedge with normalized surface impedance $\eta = 0.062 + j0.056$ on both faces. The source of $HPBW = 68.5^\circ (kb = 2)$ is directed at the edge and is at a distance $kr_0 = 16$. The receiver is at half this distance $(kr = 8)$. The source position is Fig. 3a is at $\phi_0 = 15^\circ$ and in Fig. 3b at $\phi_0' = 5^0$.