Progress In Electromagnetics Research Letters, Vol. 46, 83–87, 2014

Reply to the "Comments on 'FRINGE WAVES IN AN IMPEDANCE HALF-PLANE' by H. D. Basdemir, in *Progress In Electromagnetics Research*, Vol. 138, 571–584, 2013"

Husnu Deniz Basdemir

In [1], Hacivelioglu and co-authors criticize my paper, named "Fringe waves in an impedance half-plane" [2]. Unfortunately, the general scenario of the criticisms is based on misconceptions and lack of basic knowledge in the diffraction theory. Below we give our detailed rebuttals on their comments.

1. Our Rebuttals on Wave Terminology

In general, the objections of Hacivelioglu and co-authors are related with their misinterpretations on the basic concepts of the diffraction theory and bedevil the redear. For example

1) The term "asymptotic exact" is used in the beginning of p. 572 of [2]. It is clear from the whole sentence that the statement means **the asymptotic form of the exact solution**, which is the Maliuzhinetz's in this case if one does not scissor the phrase from the whole sentence as the authors do.
2) The objection of Hacivelioglu and co-authors to the phrase "exact geometrical optics (GO)" proves their real level of knowledge on the diffraction theory. The GO waves are exact, because they are directly obtained from the exact solution without any approximation. We can give the example of the exact reflected scattered waves from a half-plane with the Neumann boundary condition as
$$u_{rs} = e^{jk\rho\cos(\phi+\phi_0)} F\left[\xi_+\right] \tag{1}$$
for k is the wavenumber, ϕ_0 angle of incidence. F is the Fresnel integral,
$$F\left[x\right] = \frac{e^{j\frac{\pi}{4}}}{\sqrt{\pi}} \int\limits_x^\infty e^{-jt^2} dt \tag{2}$$
and ξ_+ is $-\sqrt{2k\rho}\cos[(\phi+\phi_0)/2]$. Eq. (1) can be decomposed exactly as
$$u_{rs} = e^{jk\rho\cos(\phi+\phi_0)} U\left(-\xi_+\right) + e^{jk\rho\cos(\phi+\phi_0)} sign\left(\xi_+\right) F\left[\left|\xi_+\right|\right] \tag{3}$$
where the first term is the **exact GO** and the second one is the **exact diffracted** waves [3]. I hope this example will be enough to enlighten Hacivelioglu and co-authors on the terminology that I used in [2]. Hacivelioglu and co-workers mention the GO wave as an asymptotic field in their comments. This shows that their interpretation of the diffraction theory is incorrect.
3) The **uniform** or **nonuniform** fringe currents mean that the fields that approach to infinity or have finite value at the transition regions respectively. The authors should have read the explanation, after Eq. (25) in p. 576 of [2] in order to understand the meaning of our terminology on uniform and nonuniform diffracted fields. I also advice them to read fundamental text books on the **uniform theory of diffraction** (UTD) in order to learn the basic terminology, used in the diffraction theory.

As a result, I stress the authors' lack of basic knowledge in the criticisms on my terminology.

Received 21 May 2014, Accepted 28 May 2014, Scheduled 4 June 2014
* Corresponding author: Husnu Deniz Basdemir (basdemir@cankaya.edu.tr).
The author is with the Electronic and Communication Department, Cankaya University, Ankara 06810, Turkiye.

2. Rebuttals on Content

We give our rebuttals on the criticisms in [1] as

1) Hacivelioglu and co-workers see Eq. (2) as a big mistake. However this equation only represents the GO waves on the illuminated part of the half-plane as can be understood from Eqs. (1) and (3a). As the text advances, the evaluation of the diffraction fields is mentioned in detail. Thus the objection of the authors is baseless and inessential.
2) The authors mention that the replacement of the Hankel function by its Debye asymptotic representation leads to non-rigorous physical optics (PO) expression. Since the Debye asymptotic expression goes to infinity at $R = 0$. I deal with the high-frequency diffraction. For this reason I used the Debye asymptotic expression for $kR \gg 1$. But Hacivelioglu and co-workers would feel ashamed if they had basic mathematical knowledge on the chapter of special functions. The Hankel function can be written as
$$H_0^{(2)}(kR) = J_0(kR) - jN_0(kR) \tag{4}$$
where J_0 and N_0 are the zero order Bessel and Neumann functions. Although the Bessel function is finite at $R = 0$, the Neumann function goes to infinity at this point. Thus the claim of the authors is groundless. The Hankel function also goes to infinity as its Debye asymptotic expansion does at $R = 0$.
3) Equation (25) goes to infinity at the shadow boundary as does the geometrical theory of diffraction (GTD) fields do [4]. Because this equation shows a high-frequency asymptotic wave and this behavior is correct for a GTD field. In the transition region, the high-frequency condition of $k\rho \gg 1$ loses it validity, because the cosine term goes to zero. For this reason the GTD fields are named as **nonuniform** because they approach to infinity at the transition regions. If Hacivelioglu and co-authors read more carefully (with the basic knowledge on diffraction) the sentences after Eq. (25), they would learn this aspect of the incident diffracted wave.
4) In the related part of the paper, the method of UTD is used [5]. In the context of the physical theory of diffraction, this approach does not make sense. Because we apply the same approximations for both of the exact and PO solutions. Hence, the two nonuniform field expressions are multiplied by the same transition function of UTD.
5) I advise Hacivelioglu and co-workers to read [6] to gain a basic knowledge on UTD. These two objections show clearly that they have an important lack of knowledge on this subject. Furthermore, they refer the wrong equation (Eq. (47)). The uniform expressions of the diffracted fields by an impedance half-plane are given in Eqs. (44) and (45). This proves that they make their claims without seriously examining my paper.
6) Hacivelioglu and co-authors refer [7] to show that Umul's papers on the correct form of the fringe waves are incorrect. However when we read [7] (On the modified theory of physical optics), we see that this paper is absolutely misleading. The reasons can be summarized as follows:
   a) In [7], Hacivelioglu and co-workers state that the Green's function of the modified theory of physical optics does not satisfy the Helmholtz equation, but this statement is quietly flawed. In MTPO [8, 9], the Green's function is given in the form of
   $$G(P,Q) = \sin\frac{\beta+\phi_0}{2}\frac{e^{-jkR}}{\sqrt{kR}} \tag{5}$$
   which satisfies the Helmholtz equation of
   $$\frac{1}{R}\frac{\partial}{\partial R}R\frac{\partial G}{\partial R} + \frac{1}{R^2}\frac{\partial^2 G}{\partial \beta^2} + k^2 G = 0. \tag{6}$$
   b) This point shows that Hacivelioglu and co-workers manipulate the correct form of the Greens function, used in MTPO, in order to deceive the reader. This is a purely unethical behavior.

   The authors evaluate the wrong scattering integrals of MTPO for hard and soft half-planes in [7]. See [8, 9] for correct expressions.

   After these points, it can be seen that [7] is based on flawed mathematical and physical foundations and this reference can not be defended against Umul's papers.

7) I am finding it hard to reply such claims that are strain credibility, misleading and incorrect. They prove nothing in [7] as they prove nothing in their comments [1], since [7] is based on flawed and misleading interpretation of the MTPO as shown in the previous item. Hacıvelioglu and co-workers only study on the back scattering ($\phi = \phi_0$) but I study on my figures the more general case of bi-static scattering.

3. Rebuttal of Examples

First of all Hacivelioglu and co-authors confuse the reader by comparing the PO diffracted fields for $\rho = \lambda$ and comparing the fringe field at $\rho = 6\lambda$. Note that Umul uses the high-frequency asymptotic solutions and its uniform versions in order to construct the fringe fields. One important point is the fact that Eq. (1) of [1] does not exist in reference [6] of [1]. Furthermore in [8], Umul introduces the method of MTPO and there is nothing in that paper, related with the fringe waves. Thus the authors rest their claims on faked basis and try to mislead the reader on false statements on MTPO, which has nothing to do with the fringe fields. I found this attempt purely unethical.

In [10] and [11], Umul states that it is more reasonable to evaluate the fringe waves by using the uniform field expressions instead of the GTD waves. In order to prove his statements, he uses the asymptotic form of the PO diffracted waves and the exact solution, which his method MTPO directly leads with the correct Green's function, introduced by him [8]. All the integrals, diffracted fields and their uniform versions are given and can be reproduced in Umul's papers in contrast of Hacivelioglu and co-workers. They should have explained how they plotted the PO and exact fields, given in the book of Ufimtsev.

Now I will explain the main features of the fringe waves, defined by Umul and mentioned by the authors in [1], in order to show that the fringe waves, evaluated by Hacivelioglu and co-workers are wrong.

The total field of the PO method for a soft half-plane can be written as

$$u_{tPO} = e^{jk\rho\cos(\phi-\phi_0)} - \frac{k\sin\phi_0}{2}\int\limits_0^\infty e^{jkx'\cos\phi_0} H_0^{(2)}(kR)\,dx' \tag{7}$$

for R is equal to $\sqrt{(x-x')^2+y^2}$. In order to obtain the PO diffracted fields, two approaches can be considered. The first one is to evaluate Eq. (7) by edge point technique for $kR \gg 1$ (high-frequency approximation). The second one is to subtract the incident and reflected GO waves directly from Eq. (7). Thus the asymptotic and direct diffracted fields can be given as

$$u_{dPO1} = \frac{\cos(\phi_0/2)}{\sin(\phi/2)}\left[e^{jk\rho\cos(\phi-\phi_0)} sign(\xi_-)\,F[|\xi_-|] - e^{jk\rho\cos(\phi+\phi_0)} sign(\xi_+)\,F[|\xi_+|]\right] \tag{8}$$

and

$$u_{dPO2} = e^{jk\rho\cos(\phi-\phi_0)} - \frac{k\sin\phi_0}{2}\int\limits_0^\infty e^{jkx'\cos\phi_0} H_0^{(2)}(kR)\,dx' - e^{jk\rho\cos(\phi-\phi_0)} U(-\xi_-) + e^{jk\rho\cos(\phi+\phi_0)} U(-\xi_+) \tag{9}$$

respectively. However, it is important to note that Eq. (8) is obtained from the PO integral

$$u_{tPO} = e^{jk\rho\cos(\phi-\phi_0)} - \frac{k}{2}\int\limits_0^\infty e^{jkx'\cos\phi_0}\frac{\cos(\phi_0/2)}{\cos(\beta/2)}\left[\sin\frac{\beta+\phi_0}{2} - \sin\frac{\beta-\phi_0}{2}\right] H_0^{(2)}(kR)\,dx' \tag{10}$$

that can be derived from Eq. (7) by using the relation of

$$\sin\phi_0 = \frac{\cos(\phi_0/2)}{\cos(\beta/2)}\left[\sin\frac{\beta+\phi_0}{2} - \sin\frac{\beta-\phi_0}{2}\right]. \tag{11}$$

For details refer to [11]. Thus Hacivelioglu and co-authors should have compared Eq. (7) with Eq. (10) for ρ=λ in Fig. 1 of [1].

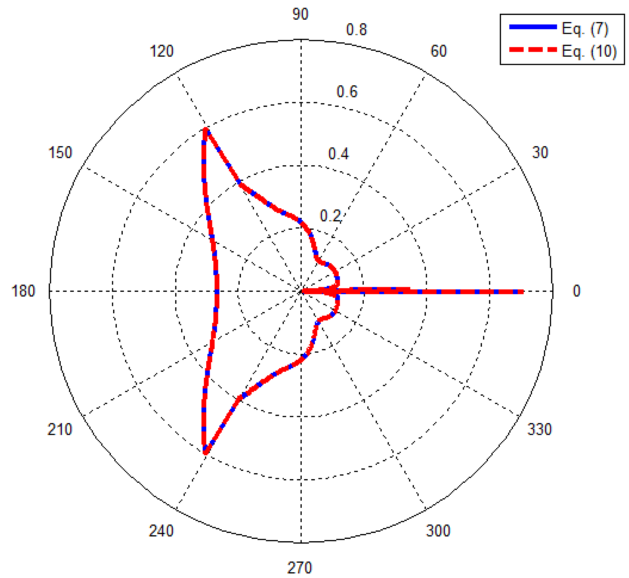

Figure 1. Diffracted fields for $\rho = \lambda$.

Figure 1 shows the comparison of the diffracted fields obtained from Eqs. (7) and (11) by subtracting the GO waves as in Eq. (9). It can be seen that the two expressions fit exactly. For this reason, it is misleading to name Eq. (8) as Umul PO, since Umul did not obtain a new PO field in [10, 11]. Only he rewrote the classical PO integral by using Eq. (11). Hacivelioglu and co-workers also blame MTPO for the difference between their and Umul's fringe fields, but this attempt must also be rejected, since Eq. (10) is not the MTPO scattering integral. As can be seen from Fig. 1, it is an alternative representation of the PO integral.

As a result, the main features of our reply can be summarized as follows:

a) As can be seen from the above discussions (e.g., exact GO, Hankel function at $R = 0$, soft surface for $\sin\theta = 0$), most of the claims of Hacivelioglu and co-workers are based on flawed physical and mathematical assertions.
b) Hacivelioglu and co-workers try to support their claims with false references. For example References [3] and [6] of [1]. In those references, Umul does not deal with PTD or fringe fields, but authors cite these papers in order to support their wrong claims about Eq. (1) and Figs. 1 and 2 of [1]. They also cite [7] in order to denigrate MTPO, which is a more superior method than PTD. However, as is proven in p. 3 item 6 of this reply, [7] is based on flawed assertions and wrong calculations. Thus Hacivelioglu and co-authors cannot support their claims with strong references from the literature.

As a result, the claims of Hacivelioglu and co-workers must be rejected on scientific grounds.

REFERENCES

1. Hacivelioglu, F., L. Sevgi, and P. Y. Ufimtsev, "Comments on 'Fringe waves in an impedance half-plane'," *Progress In Electromagnetics Research Letters*, Vol. 46, 79–81, 2014.
2. Basdemir, H. D., "Fringe waves in an impedance half-plane," *Progress In Electromagnetics Research*, Vol. 138, 571–584, 2013.
3. Umul, Y. Z., "Equivalent functions for the Fresnel integral," *Opt. Express*, Vol. 13, 8469–8482, 2005.
4. Keller, J. B., "Geometrical theory of diffraction," *J. Opt. Soc. Am.*, Vol. 52, 116–130, 1962.
5. Kouyomjian, R. G. and P. H. Pathak, "A uniform geometrical theory of diffraction for an edge in a perfectly conducting surface," *Proc. IEEE*, Vol. 62, 1442–1461, 1974.

6. Volakis, J. L., "A uniform geometrical theory of diffraction for an imperfectly conducting half-plane," *IEEE Trans. Antennas Propag.*, Vol. 34, 172–180, 1986.
7. Hacivelioglu, F., L. Sevgi, and P. Y. Ufimtsev, "On the modified theory of physical optics," *IEEE Trans. Antennas Propag.*, 1–5, 2013.
8. Umul, Y. Z., "Modified theory of physical optics," *Opt. Express*, Vol. 12, 4959–4972, 2004.
9. Umul, Y. Z., "Modified diffraction theory of Kirchhoff," *J. Opt. Soc. Am. A*, Vol. 25, 1850–1860, 2008.
10. Umul, Y. Z., "Fringe waves radiated by a half-plane for the boundary conditions of Neumann," *Appl. Phys. B*, Vol. 93, 885–889, 2008.
11. Umul, Y. Z., "Fringe waves in wedge diffraction," *Optik*, Vol. 123, 217–222, 2012.