INTERNATIONAL JOURNAL OF ADVANCED RESEARCH
International Peer-Reviewed Research Journal
ISSN (Online): 3106-7980 | ISSN (Print): 3106-7972
Volume 3 • Issue 2• June 2026

RCS ANALYSIS OF PEC HALF PLANE EMBEDDED IN NEAR ZERO INDEX MATERIALS

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DOI: https://doi.org/10.5281/zenodo.2368391

Keywords
Perfect Electric Conductor, Radar Cross Section, DNZ, ENZ, MNZ

Article History
Received: *01 May 2026*
Accepted: *15 June 2026*
Published: *30 June 2026*

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Abstract
In this paper, we study the scattering breadth of a half plane that is a perfect electic conductor (PEC) in near zero metamaterials. The solution of the problem is in close form. To see how the scattering width of the PEC half plane behaves, the amplitude of the Radar Cross Section (RCS) has been examined for various electric permittivity and magnetic permeability values. The impact of RCS is examined for a range of permeability and permittivity (double) near zero (DNZ), permeability (mu) near zero (MNZ), and permittivity (epsilon) near zero (ENZ) parameters. The numerical outcomes of the analytical solution have been examined and contrasted with the existing literature, and are found in good ageement.

INTRODUCTION

In this paper, an attempt has been made to study the diffracted field and and backscattered echo width by a PEC half plane embedded in near zero metamaterials. The close form solution of PEC half plane given in [2-6]. The answer is given in terms of Fresnel integrals for both electric and magnetic polarizations. By extending the article for DNZ, MNZ and ENZ metamaterial medium, the purpose of this paper is to examine the diffracted field and scattering breadth of a PEC half plane. The significance of RCS in the radar system and its applications are described in detail in the various books. The main characteristics of the Radar Cross Section (RCS) are the ability to identify and evaluate an object's size, shape, range, and effective capture area [8]. There have been viable research efforts in the field of meta-materials [1]-[6]. They are the artificial structures that exhibit unusual properties but not readily exist in nature. On the basis of real part of the values of refractive index, the optical meta-materials may be divided into two categories. The first one is negative refractive index while the other is near-zero index materials. The negative refractive index metamaterials are also known as *left-handed* materials. They are artificial composites with negative effective value of refractive index and have sub-wavelength features [7]-[8]. The basic characteristics of the first type of metamaterials is the negative phase velocity of the plane waves, propagating in the negative index mediums [9]. They have many applications in the field of science such as super lens, the reversal of Snell's law, reduction of the size of patch antennas, invisible cloaking, perfect absorber and the

photonic band gaps with averaged zero refractive index [9]-[15]. The second type of metamaterials having a near-zero refractive index have been thoroughly discussed in [16]. The electromagnetic fields in this type of medias are dynamic in time but remain static in space. A remarkable work has been done for metamaterials with a near-zero refractive index (NZI) for visible and infrared wavelengths. Electromagnetic waves (EM) inside such materials have large phase velocity and experience no spatial phase change [17]-[18]. These type of materials have several applications such as super reflection [19], cloaking [19]-[21], funnelling [22] and tunnelling [23]-[26]. In scattered fields the use of near-zero index materials may give phase distribution from various geometries such as cylindrical shells, planar slabs and lenses with various exit faces.

Among the metamaterials, the near-zero constitutive parameters are of great interest [26]. Three different classes of near-zero-parameter materials can be described as:

- ENZ (epsilon-near-zero) is the class of metamaterials whose relative permittivity is near zero.
- MNZ (mu-near-zero) is the class of metamaterials whose relative permeability is near zero.
- DNZ (Double-near-zero) is the type of metamaterials where both permittivity and permeability are near to zero.

ENZ mediais realized by electrically adding small metal particles in the dielectric material and DNZ mediums may be realized as tuned photonic crystal in order to obtained a Dirac-like cone dispersion at the τ-point in the photonic band structure [27, 28] under some suitable conditions [28]. In order to realize (MNZ) medium with one component of permeability near to zero, the transmission-line metamaterials are used. The properties of an isotropic and inhomogeneous (MNZ) metamaterials are investigated in cylindrical and Cartesian coordinate system which show excellent potential results for transmission line in implementation of novel transmission optics devices [29-32]. In this article we apply near zero index materials to visualize the radar cross section of PEC half plane.

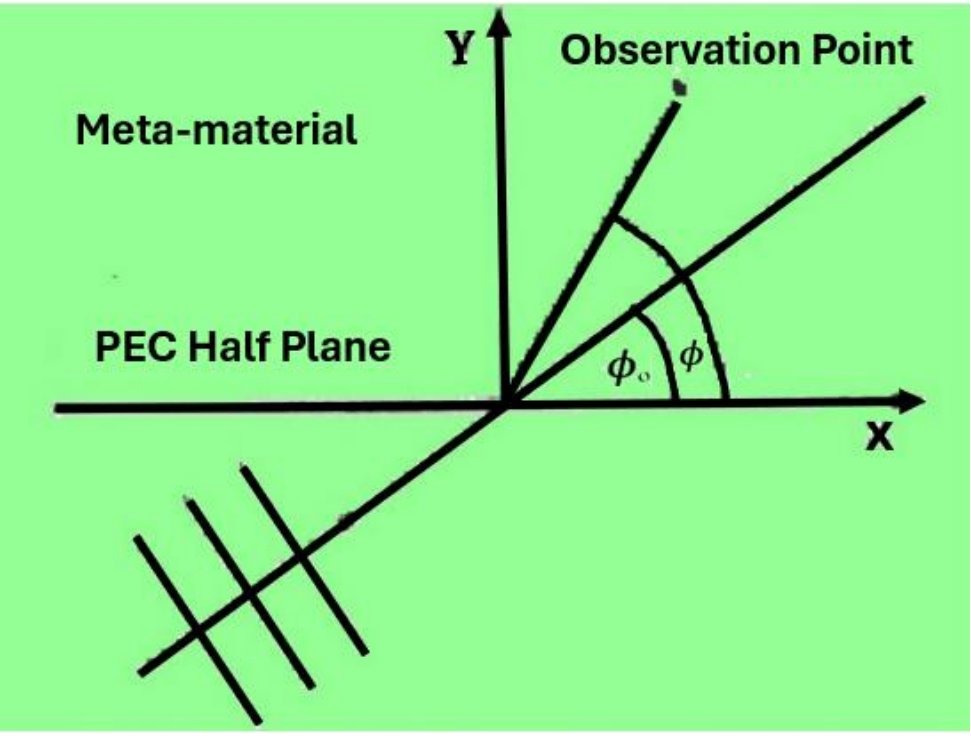


Figure 1: Plane wave diffraction by a semi-infinite half plane placed in Near Zero Metamaterials

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2 Problem Description

The issue raised in [2] has been examined in relation to lossy media. As seen in Fig. 1, this two-dimensional geometrical problem involves a plane wave impinging on a PEC half plane. Only the *z*-component of incident field is taken, which is given as,

$$E^{\text{inc}} = e^{-ik\rho\cos(\phi-\phi_0)} \tag{1}$$

where k is the wave number and ϕ_0 is the incidence angle. Fig. 1 defines the observation point's coordinates (ρ,ϕ). $\exp(j\omega t)$ is the time dependence. There is just one z component in the incident magnetic field H^{inc} for magnetic polarization, which is given by [2].

The exact total electric field E and magnetic field H are given by:

$$E = (\pi)^{1/2} e^{i(\pi/4-k\rho)}[\Psi_1(\rho,\phi) - \Psi_2(\rho,\phi)] \tag{2}$$

$$H = (\pi)^{1/2} e^{i(\pi/4-k\rho)}[\Psi_1(\rho,\phi) + \Psi_2(\rho,\phi)] \tag{3}$$

where

$$\Psi_1(\rho,\phi) = F\left[(2k\rho)^{1/2}\sin\left(\frac{\phi-\phi_0}{2}\right)\right]$$

and

$$\Psi_2(\rho,\phi) = F\left[(2k\rho)^{1/2}\sin\left(\frac{\phi+\phi_0}{2}\right)\right]$$

The Fresnel-type integral is defined as in [2]:

$$F(z) = e^{iz^2}\int_z^{\infty} e^{-it^2}\,dt \tag{4}$$

For lossless media, k in equations (1)–(3) is real.

The physical meaning of the diffracted fields in geometrical optics terms from equations (3) and (4) may be seen in [2], when $k\rho \gg 1$.

$$D_E(\rho,\phi) = E_d \simeq \frac{\cos\left(\frac{1}{2}\phi\right)\sin\left(\frac{1}{2}\phi_0\right)}{\cos\phi_0 - \cos\phi}\left(\frac{2}{\pi kr}\right)^{\frac{1}{2}} e^{-i\left(kr+\frac{\pi}{4}\right)} \tag{5}$$

$$D_H(\rho,\phi) = H_d \simeq \frac{\sin\left(\frac{1}{2}\phi\right)\cos\left(\frac{1}{2}\phi_0\right)}{\cos\phi_0 - \cos\phi}\left(\frac{2}{\pi kr}\right)^{\frac{1}{2}} e^{-i\left(kr+\frac{\pi}{4}\right)} \tag{6}$$

Additionally, a comparable solution may be found in [6] for the case η=0. For both E- and H-polarization, the backscatter echo width of a PEC half plane can be expressed as follows:

$$\sigma_E = 2\pi|D_E(\rho,\phi)|^2 \tag{7}$$

$$\sigma_H = 2\pi|D_H(\rho,\phi)|^2 \tag{8}$$

$$D_E(\rho,\phi) = D_H(\rho,\phi) = -\frac{e^{-i\pi/4}}{\sqrt{2\pi}}\frac{\sin\phi\sin\phi_0}{\cos\phi+\cos\phi_0} \times \frac{1}{\sqrt{1-\cos\phi}\sqrt{1-\cos\phi_0}}\frac{e^{ik\rho}}{\sqrt{k\rho}} \tag{9}$$

which is a diffracted field from a PEC half plane embedded in near zero metamaterials.

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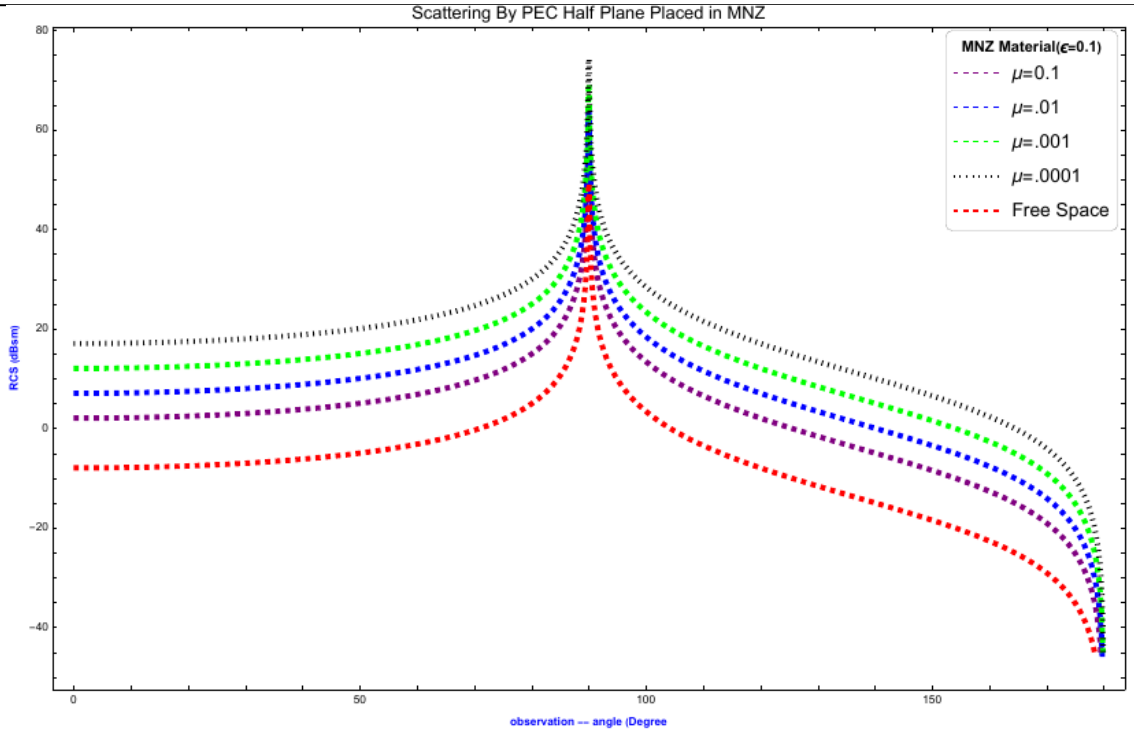


Figure 2: Diffracted Field by PEC Half Plane Embedded in MNZ Materials when $(\boldsymbol{\varepsilon = 0.1, \mu = 0.1, \mu = 0.01, \mu = 0.001, \mu = 0.0001})$ at incident angle $\boldsymbol{\phi = 90.}$

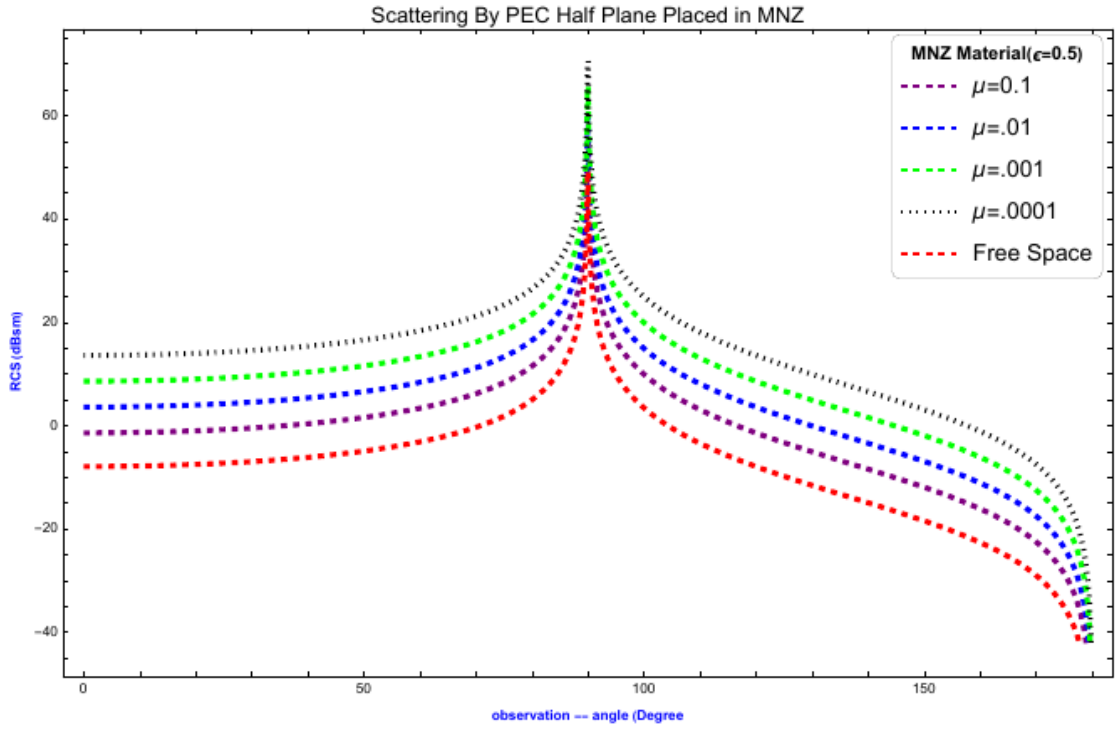


Figure 3: Diffracted Field by PEC Half Plane Embedded in MNZ Materials when $(\boldsymbol{\varepsilon = 0.5, \mu = 0.1, \mu = 0.01, \mu = 0.001, \mu = 0.0001})$ at incident angle $\boldsymbol{\phi = 90.}$

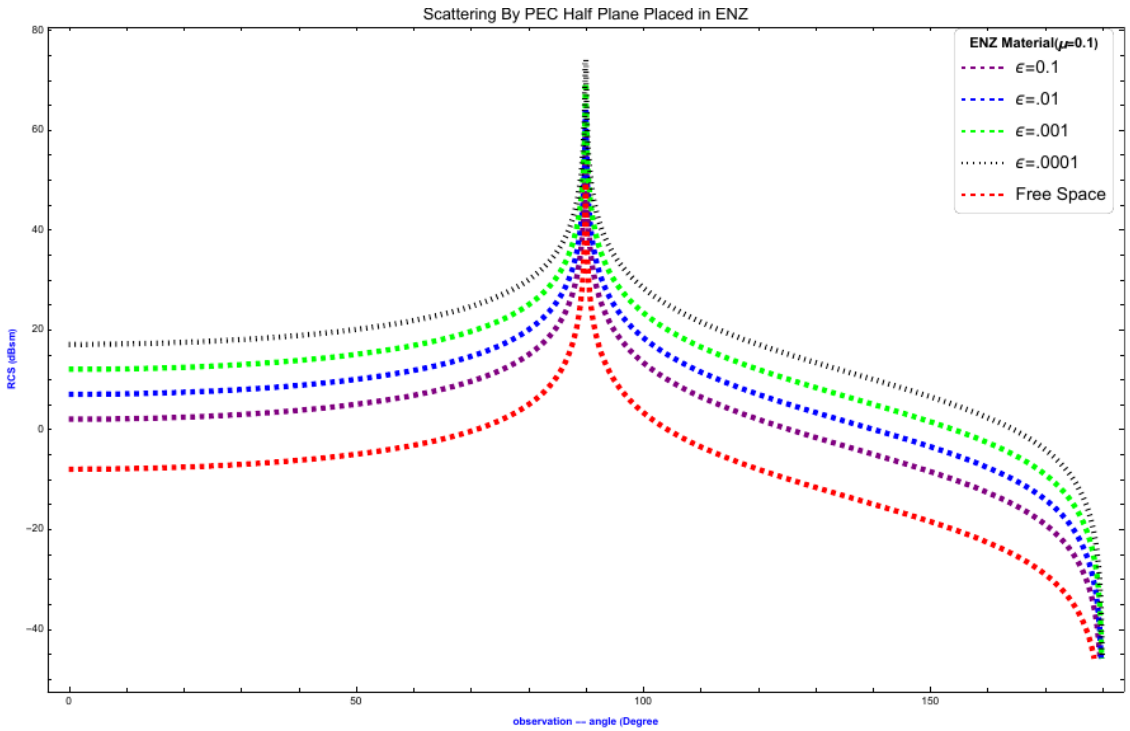


Figure 4: Diffracted Field by PEC Half Plane Embedded in ENZ Materials when $(\boldsymbol{\mu = 0.1, \varepsilon = 0.1, \varepsilon = 0.01, \varepsilon = 0.001, \varepsilon = 0.0001})$ at incident angle $\boldsymbol{\phi = 90.}$

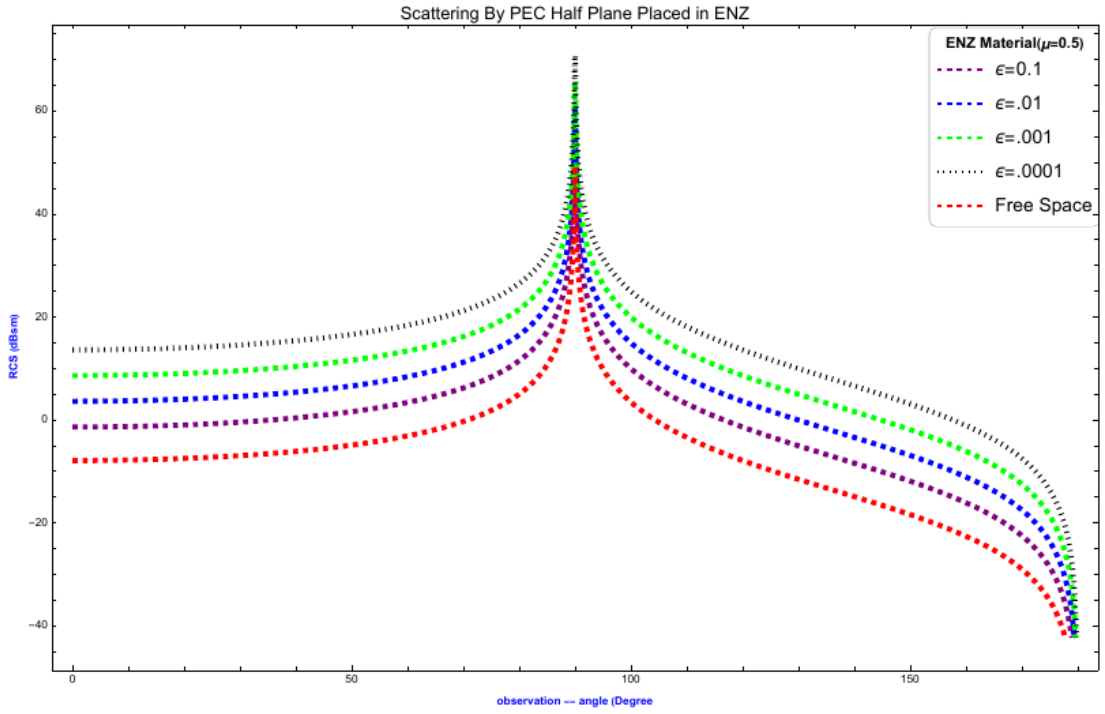


Figure 5: Diffracted Field by PEC Half Plane Embedded in ENZ Materials when $(\boldsymbol{\mu = 0.5, \varepsilon = 0.1, \varepsilon = 0.01, \varepsilon = 0.001, \varepsilon = 0.0001})$ at incident angle $\boldsymbol{\phi = 90.}$

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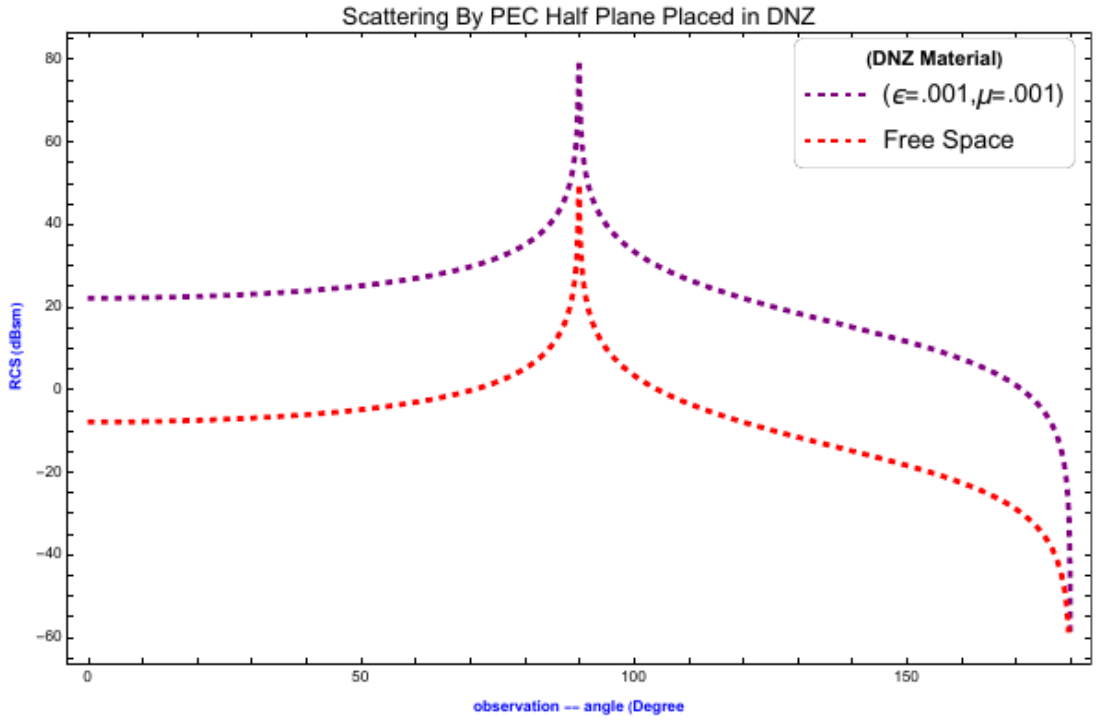


Figure 6: Diffracted Field by PEC Half Plane Embedded in DNZ Materials when $(\boldsymbol{\varepsilon = 0.001, \mu = 0.001})$ at incident angle $\boldsymbol{\phi = 90.}$

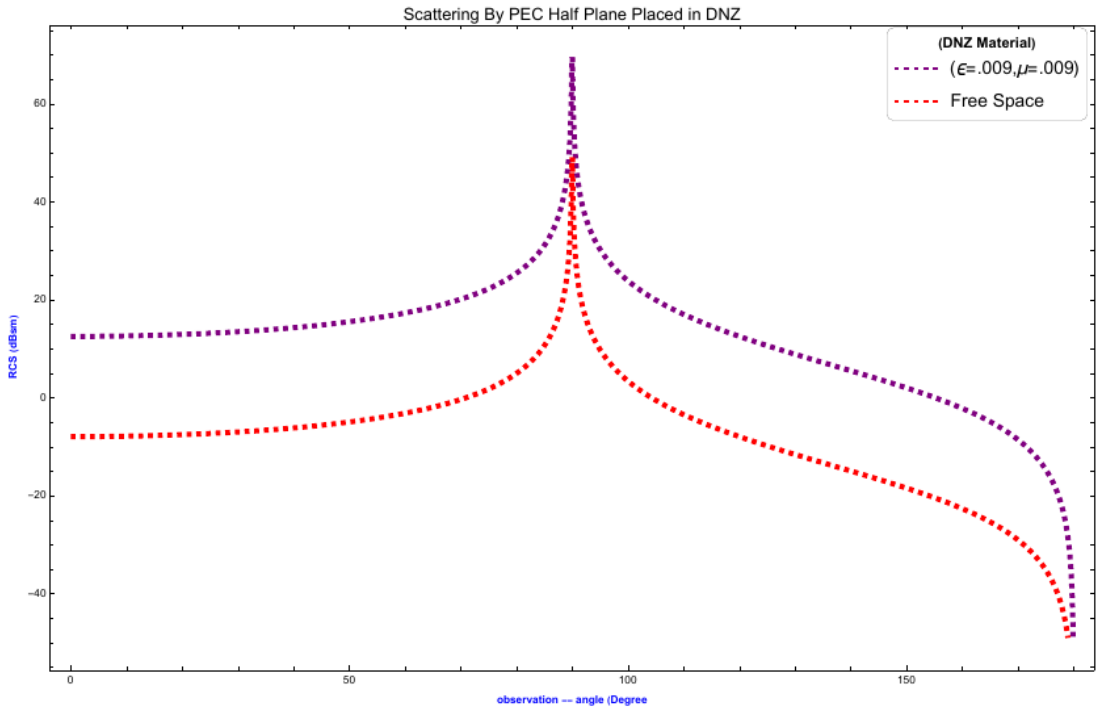


Figure 7: Diffracted Field by PEC Half Plane Embedded in DNZ Materials when $(\boldsymbol{\varepsilon = 0.009, \mu = 0.009})$ at incident angle $\boldsymbol{\phi = 90.}$

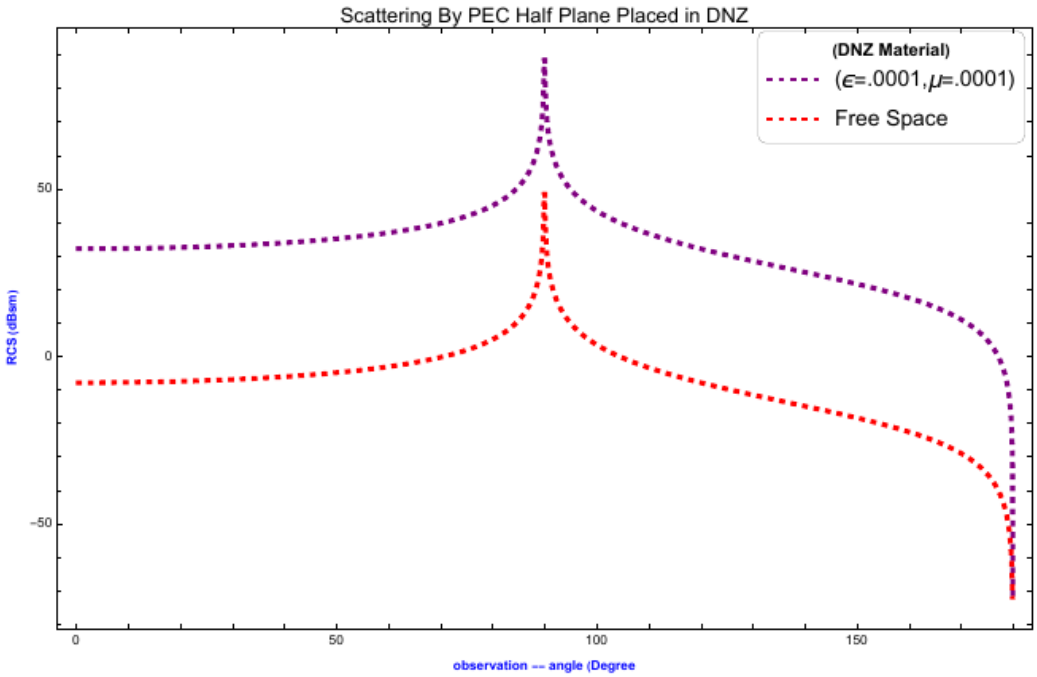


Figure 8: Diffracted Field by PEC Half Plane Embedded in DNZ Materials when $(\varepsilon = 0.0001, \mu = 0.0001)$ at incident angle $\phi = 90$.

Numerical Results and Discussion

Here we have applied a close form solution for the diffraction by PEC half plane and investigated the effects of near zero index materials MNZ, ENZ and DNZ to visualize the variation of RCS of the PEC half plane. We can a clear effects of near zero index materials. Fig.2 shows the diffracted Field by PEC Half Plane Embedded in MNZ Materials when $(\varepsilon = 0.1, \mu = 0.1, \mu = 0.01, \mu = 0.001, \mu = 0.0001)$ at incident angle $\phi = 90$. Fig.3 shows the diffracted Field by PEC Half Plane Embedded in MNZ Materials when $(\varepsilon = 0.5, \mu = 0.1, \mu = 0.01, \mu = 0.001, \mu = 0.0001)$ at incident angle $\phi = 90$. Fig.4 shows the diffracted Field by PEC Half Plane Embedded in ENZ Materials when $(\mu = 0.1, \varepsilon = 0.1, \varepsilon = 0.01, \varepsilon = 0.001, \varepsilon = 0.0001)$ at incident angle $\phi = 90$. Fig.5 shows the diffracted Field by PEC Half Plane Embedded in ENZ Materials when $(\mu = 0.5, \varepsilon = 0.1, \varepsilon = 0.01, \varepsilon = 0.001, \varepsilon = 0.0001)$ at incident angle $\phi = 90$. Fig.6 shows the diffracted Field by PEC Half Plane Embedded in DNZ Materials when $(\varepsilon = 0.001, \mu = 0.001)$ at incident angle $\phi = 90$. Fig.7 shows the diffracted Field by PEC Half Plane Embedded in DNZ Materials when $(\varepsilon = 0.009, \mu = 0.009)$ at incident angle $\phi = 90$. Fig.8 shows the diffracted Field by PEC Half Plane Embedded in DNZ Materials when $(\varepsilon = 0.0001, \mu = 0.0001)$ at incident angle $\phi = 90$. We see in each case as such metamaterial approaches near zero the radar cross section increases. That is why near zero index materials are very useful in radar apllications.

Conclusions

We conclude that the near zero index metmaterials MNZ, ENZ and DNZ materials as host medium visible effects on the diffracted field by PEC half plane. It enhances the amplitude of the diffracted field by PEC half plane. Due to the DNZ medium clocking of the objects becomes visible. Radar can easily detect invisible objects by the signal enhancement. As the diffracted field is proportional to the size of the scatterers.

Acknowledgement

The authors are thankful to the Department of Electronics, Quaid-i-Azam University, Islamabad for its hospitality during this research work.

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