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Prolate-Spheroidal IRAs for Illuminating and Diagnosing Targets in Lossy Dielectric Media

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Abstract

IRAs have been developed for variety of applications in the far field region. However, in this paper we use prolate-spheroidal IRAs in the near field region for diagnosing targets close to the ground in lossy dielectric media to obtain better resolution. We use brewster-angle concepts for above-ground (or above-biological-media) antennas to match the fields into the second media in which the target is buried.

1. Introduction

Prolate-Spheroidal Antennas can be used for buried-target identification. Our motivation in this paper is transmitting a fast transient electromagnetic wave from a prolate-spheroidal IRA into the earth to scatter from the buried target close to the surface and be received by the same kind of antenna as a receiver for processing to find the aspect –independent complex resonant frequencies appearing in the singularity-expansion-method (SEM) representation of the target scattering [1]. The emphasis here is on the influence of the air/soil, air/water or air/tissue on antenna location and orientation depends on the application. This antenna system can be used for either target identification as a radar for buried targets close to the ground [2,3] or as a biological radar [4] for skin cancer tumor identification.

2. Designing IRA System

The geometry for this prolate-spheroidal antenna system is presented in Fig. 1.

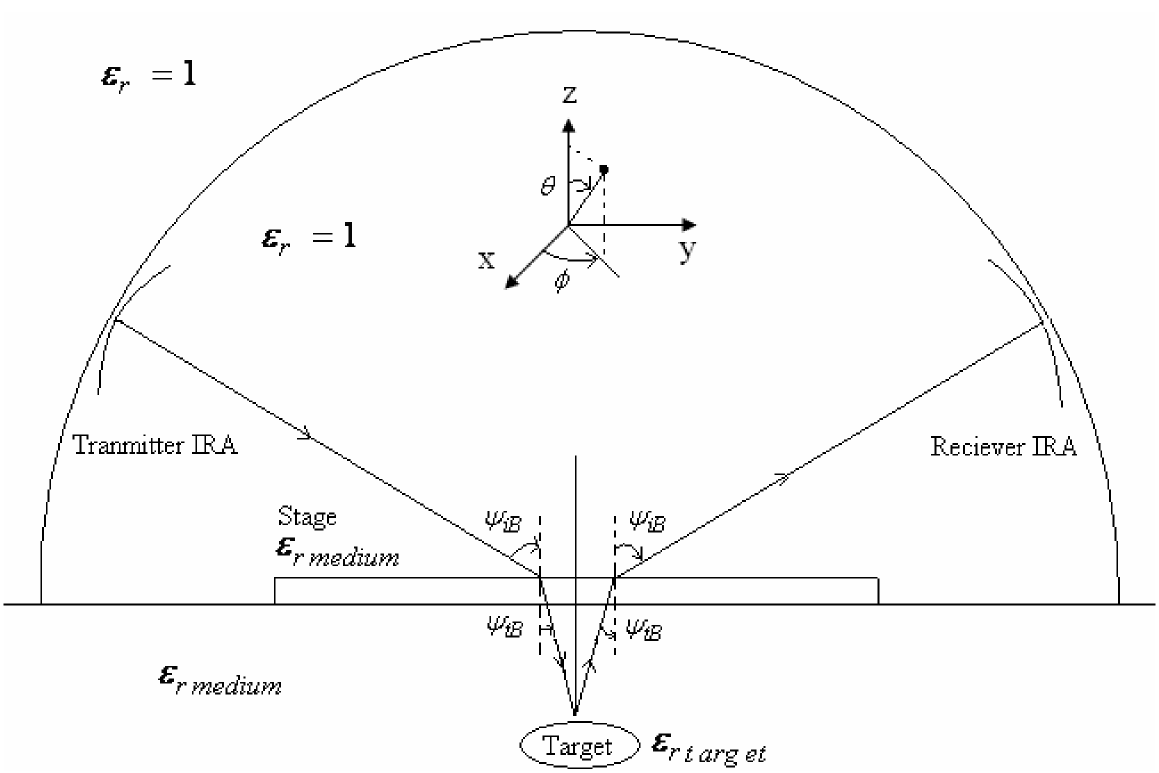

Figure 1. Prolate-spheroidal antenna system for target identification

ϕ is the azimuth angle and θ is the polar angle. We design a flexible mechanical system that allows us to locate our IRAs in a region as

$0 < \theta < 90^0,$
$0 < \theta < 360^0,$ (1)

As seen from Fig. 1 we use a stage which has a dielectric constant of $\varepsilon_{r\,medium}$ for transmitting our signal to the target. Figure 2 shows the mechanical system that allows us to move our antennas in ϕ (azimuth) and θ (polar) angles.

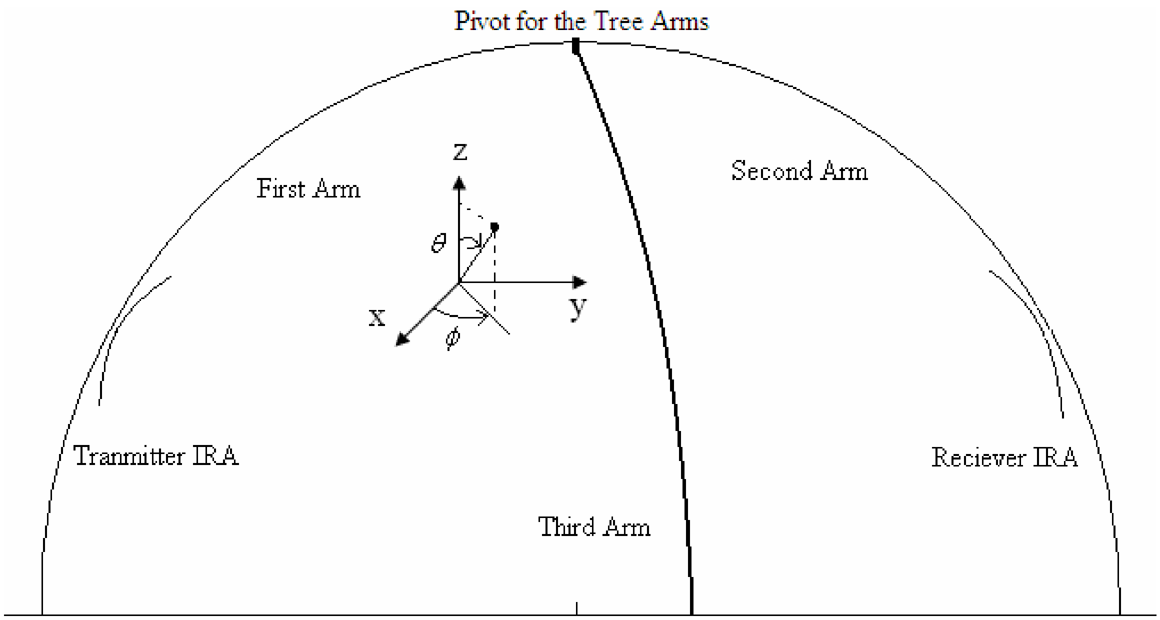

Figure 2. The mechanical system for antenna motion in ϕ (azimuth) and θ (polar) angles.

As indicated in Fig. 3, the antennas can be located at various places on a hemisphere centered on the target while maintaining the any chosen orientation (polarization) with respect to the target. If we move the receiver to the opposite side from the transmitter, we can observe the ground-surface scattered wave in the receiver. One can avoid this effect by keeping the antennas closer (nearby ϕ locations), however in this case one will observe interference. A lossy metarial can be used between these antennas to increase the signal-to- noise ratio.

To maximize the signal associated with the aspect-independent natural frequencies, one can also change the position of antennas to take advantage of the aspect dependence of the pole residues [1]. Utilizing the Brewster angle for transmission through the earth surface, the polarization is constrained to be vertical. If one uses horizontal polarization as well, so as to obtain more aspect information, the target-scattered signal will be reduced by scattering of the waves at the earth surface (both on entering and leaving the soil).

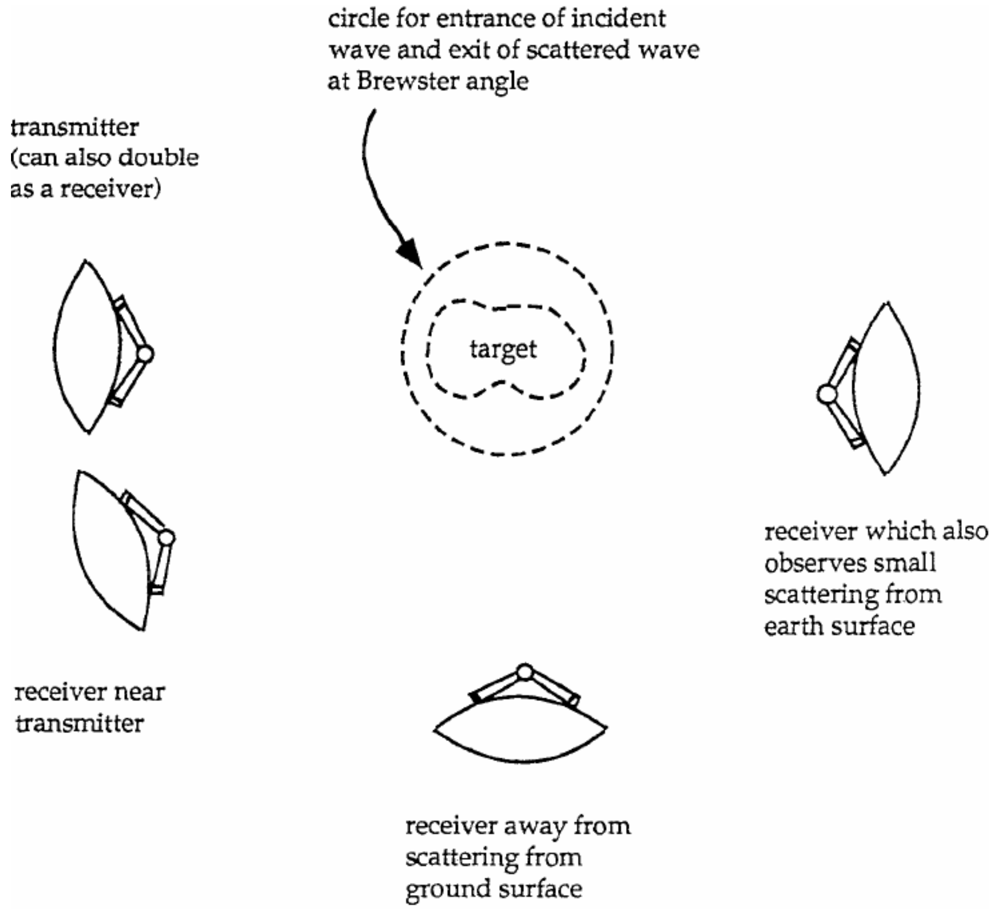

Figure 3: Transmitting and Receiving Antennas Oriented at Brewster Angle: Top Wiew [2]

The basic problem of this system is matching waves into the $\varepsilon_{r\,medium}$ region. We can utilize the approximate Brewster angle (vertical polarization) for the air and the $\varepsilon_{r\,medium}$ region. The Brewster angle can be defined as

$$\tan(\psi_{iB}) = \left[\frac{\varepsilon_{r\,medium}}{\varepsilon_{r\,air}}\right]^{1/2} = \cot(\psi_{iB}), \tag{2}$$
$$\psi_{iB} + \psi_{iB} = \pi/2.$$

3. Designing IRA System with Lens

To obtain better focusing and resolution, one can use a spherical-dielectric-graded lens as shown in Fig. 4 and the detailed discussions are presented in [5].

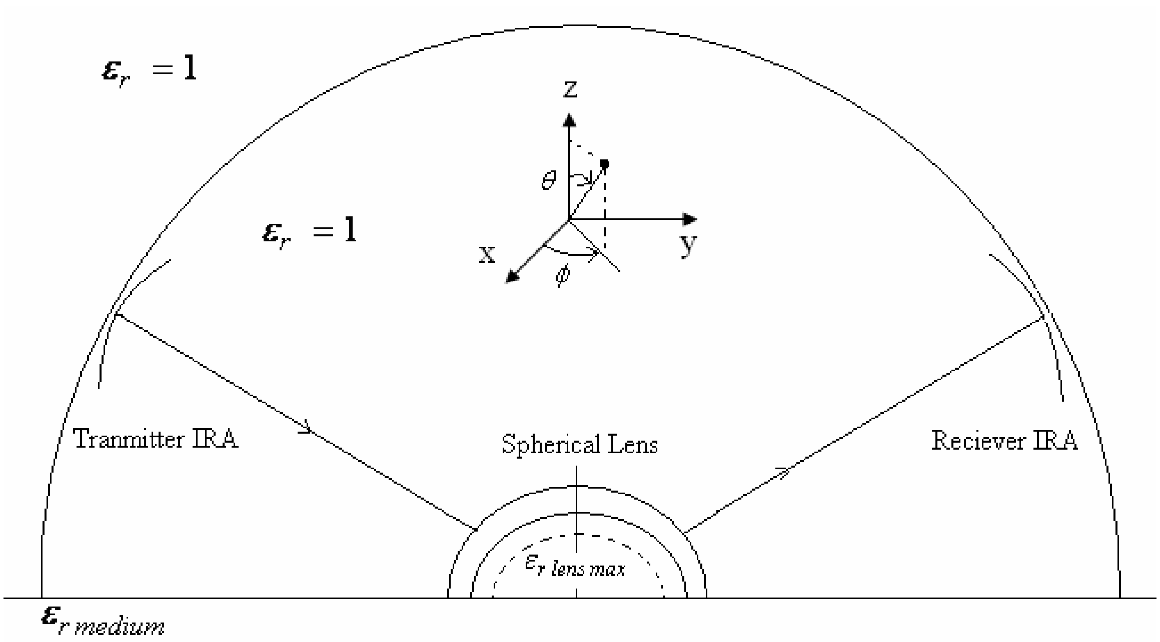

Figure 4. Prolate-Spheroidal Antenna System with Lens

The lens has a variation of ε_r from 1 to $\varepsilon_{r\ lens\max}$ and using this lens gives us two options for the Brewster-angle concept.

1. $\varepsilon_{r\ lens\max} = \varepsilon_{r\ medium}$, no need a Brewster-angle because there is no reflection.

2. $\varepsilon_{r\ lens\max} < \varepsilon_{r\ medium}$, Brewster-angle can be calculated from (2) as

$$\psi_{iB} = \mathrm{atan}\left[\frac{\varepsilon_{r\ medium}}{\varepsilon_{r\ lens\max}}\right]^{1/2} . \qquad (3)$$

One can see from (3) that the polar angle θ can be changed by changing $\varepsilon_{r\ lens\max}$ to obtain more suitable polar angles θ for geometrical-location purposes. Furthermore, this configuration, by experimentally finding the Brewster angle (minimum vertical-polarization reflection), can be used as a device for measuring the $\varepsilon_{r\,medium}$.

Conclusion

In this paper we transmit a fast transient electromagnetic wave from a prolate-spheroidal IRA into the dielectric medium to scatter from the buried target close to the surface, and receive by the same kind of antenna in the near-field region for illuminating and diagnosing targets close to the ground surface in lossy dielectric media to obtain better resolution. This antenna system can be used for either target identification as a radar for buried targets close to the ground [2] or as a biological radar [4] for skin cancer tumor location and identification. The Brewster- angle concept is used for above-ground antennas to match the fields into the second media in which the target is buried.

Using a graded lens is discussed to obtain better focusing and resolution. This lens also helps us to modify the antennas locations. Lenses change the Brewster angle by replacing $\varepsilon_{r\,medium}$ by $\varepsilon_{r\,medium} / \varepsilon_{r\,lens\,\max}$ as in (3). Brewster angles, $\psi_{iB}\,(\text{Degrees})$, for water, soil and different biological tissues are calculated from (2) and presented in table 1.

Table 1. Brewster angles, $\psi_{iB}\,(\text{Degrees})$, for water, soil and different biological tissues.

	Water	Muscle	Tumor	Skin	Soil	Fat
$\varepsilon_{r\,medium}$	81	70	50.74	34.7	12	9.8
ψ_{iB} (Degrees)	83.6	83.2	82	80.4	74	72.3

References

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