VARIATION OF ELECTROMAGNETIC PROPERTIES OF SOILS OVER FREQUENCY RANGE OF 1MHZ TO 10MHZ

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ABSTRACT

The effect of EM waves on the natural sources such as sand can be calculated by using skin depth and SAR. Skin depth is the measure of how closely electric current flows along the surface of a material. The present paper investigations have been made to estimate the effect of skin depth and SAR on various types of sand at different frequencies Results are obtained for electromagnetic characteristics conductivities, permittivity and permeability for different frequency bands of sand.

Keywords: EM waves, Skin depth, SAR

Introduction:

Soils are characterized by its physical appearance such as colour , texture, landscape position. Light soils have better structure and are easy for cultivation. Soil texture is an important characteristic of soil that drives crop production and field management.The texture of the soil is dependent on the percentage of sand,silt and clay. Soils can be classified into four major types i.e., Sands, Silts , Loams and Clays. A clay soil is a fine-textured soil whereas sandy soil is coarse textured soil. Soil texture determines the rate at which water moves freely through the soils. Clay soils have higher water holding capacity.

Soil is a light dense medium compared to the air, which produces great absorption and attenuation to electromagnetic waves. Electrical conductivity and relative dielectric permittivity are two independent physical properties that characterize the behaviour of soil when excited by electromagnetic fields. As stated in the open literature [1-5] the electrical conductivity and permittivity of the constituent minerals are the controlling factors of the electrical properties of soils.

Formulation:

Propagation of electromagnetic waves in radio frequency is described mathematically by Maxwell's equations with respective boundary conditions. The electrical characteristics of materials influence EM field distribution.The electrical characteristics may be expressed by three parameters : magnetic permeability(μ),electrical permittivity(ε) and electrical conductivity(σ).

Magnetic permeability is the ability of a material to support the formation of magnetic field within itself in response to the applied magnetic field.It is defined as the ratio of magnetic flux density B by magnetic field strength. Electrical permittivity is ability of material to oppose the electric field. It is defined as the ratio of electric flux density D by electric field strength E. Electrical conductivity is the ability of the material to conduct the electric current.

It is the ratio of current density in the material by electric field that causes current flow.The extent to which the EM waves effect the electrical characteristics of water and sand depends upon the penetration depth δ, which is defined as the depth at which the amplitude of the field strength of electromagnetic radiation inside a material falls to 1/e (about 37%) of its original value at the surface.

$$\delta = \left(\frac{1}{\omega}\right)\sqrt{\frac{\mu\epsilon}{2}\sqrt{1+\frac{\sigma^2}{\epsilon^2\omega^2}}-1} \qquad (1)$$

ω=angular frequency=2πf

μ= relative permeability= $\mu_0\mu_r$

$\mu_0=4\times\pi\times10^{-7}(N/A^2)$

ε=Relative permittivity=$\varepsilon_0\varepsilon_r$

$\varepsilon_0=8.854\times10^{-12}$ (F/m

There are various methods which are used to calculate Specific Absorption Rate[6]. The first one is Finite Difference Time Domain (FDTD) method and second one is Method of Moments method. SAR is related to physical and electrical properties of absorbing object by following equations[7]:

Specific Absorption Rate = SAR= $\frac{dP_a}{dm}$ = $\frac{\sigma E^2}{\rho}$(w/kg)

$$SAR=\frac{3\sigma\delta^2}{2\rho}(w/kg) \qquad (2)$$

Where σ = conductivity of the sand (S/m) , ρ = density(kg/m3),E = magnitude of electric field at the inspection point (V/m), δ is the penetration depth (mm)

Soil	Permeability
Gravel	10^0
Coarse sand	10^0 to 10^{-1}
Medium sand	10^{-1} to 10^{-2}
Fine sand	10^{-2} to 10^{-3}
Silty sand	10^{-3} to 10^{-4}
Silt	1 x 10^{-5}
Clay	10^{-7} to 10^{-9}

Table :Permeability of soils

Results and Discussions:

The skin depth of Gravel, Coarse sand, Medium sand , Silt, Silty sand, Silt and Clay using Equation(1) and values at different frequencies i.e., 2MHz to 10MHz are presented in fig(1) –(4).

SAR of Gravel , Coarse sand, Medium sand, Silty sand ,Silt and Clay using equation(2) and values at different frequencies i.e., 2MHz to 10MHz are presented in fig(5)-(9).

From the results, it is observed that skin depth value is varying from 5.027*10^-16 to 5.24*10^-17 m for gravel, 1.62*10^-16 to 1.66*10^-17 m for coarse sand, 5.027*10^-17 to 5.243*10^-18 m for medium sand, 1.62*10^-20 to 1.66*10^-21 m for clay in the frequency range of 2MHz to 10MHz.

As observed in Figure 4 that skin depth values vary from1.62*10^-17 to 1.66*10^-18m for fine sand ,1.62*10^-18 to 1.66*10^-19 m for silt ,5.11*10^-18 to 5.24*10^-19 m for the frequency range of 2MHz to 10MHz.

It is seen from the figures (5)-(9) the SAR value varies 3.01*10^-31 to 3.17*10^-33(w/kg) for gravel,3.01*10^-32 to 3.17*10^-34 (w/kg) for coarse sand, 3.01*10^-33 to 3.17*10^-35 (w/kg) for medium sand , 3.01*10^-40 to 3.17*10^-42 (w/kg) for clay,3.01*10^-36 to 3.17*10^-38 (w/kg) for silt, 3.01*10^-35 to 3.17*10^-37 (w/kg) for silty sand ,3.01*10-34 to 3.17*10^-36(w/kg) for fine sand in the frequency range of 2MHz to 10MHz.

We have obtain the electromagnetic paramters of various soil samples.These physical parameters can be obtained cost-effectively without any distruption of the samples. This study and results are very useful for remote sensing applications.

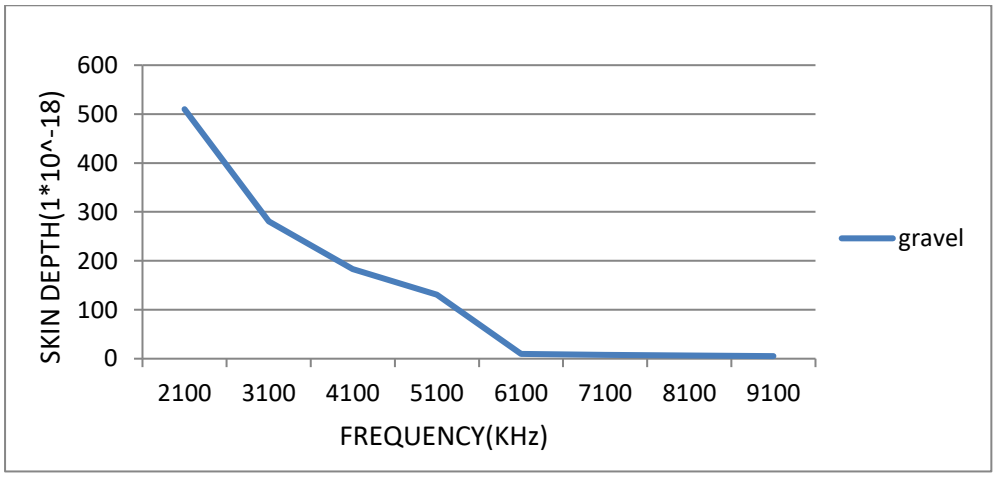

Fig1 : Skin Depth effect on Gravel

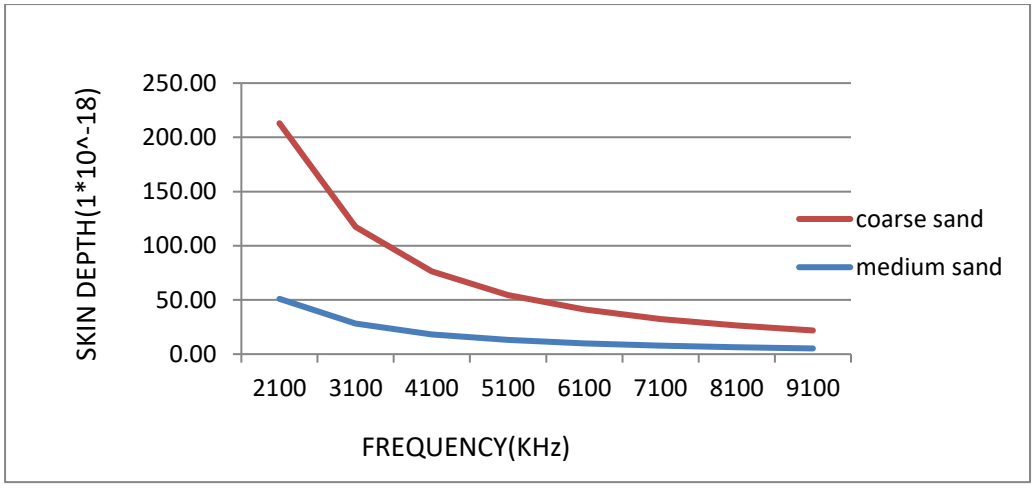

Fig2: Skin Depth Effect on Coarse sand and Medium sand

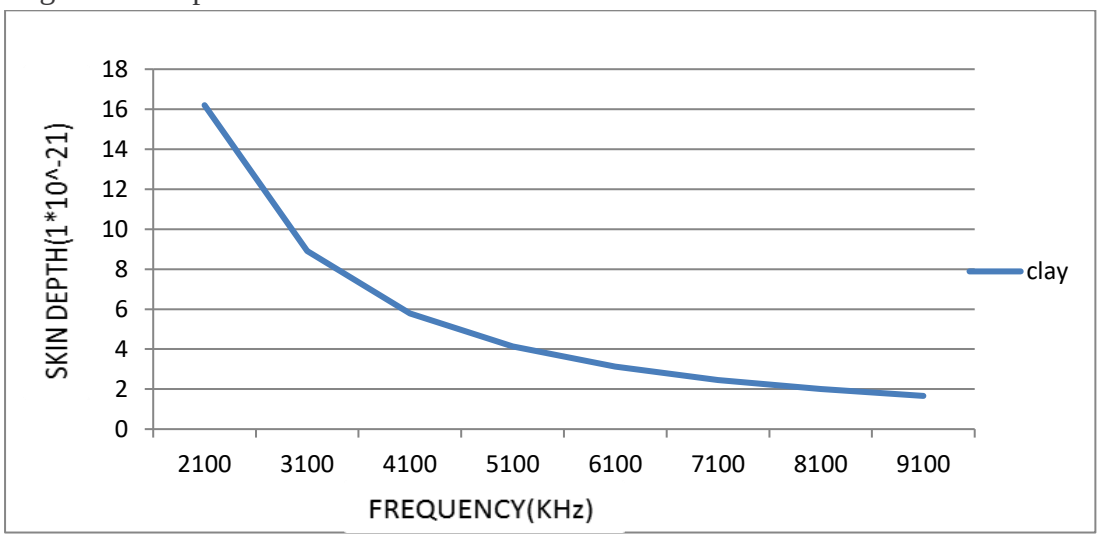

Fig3:Skin Depth Effect on Clay

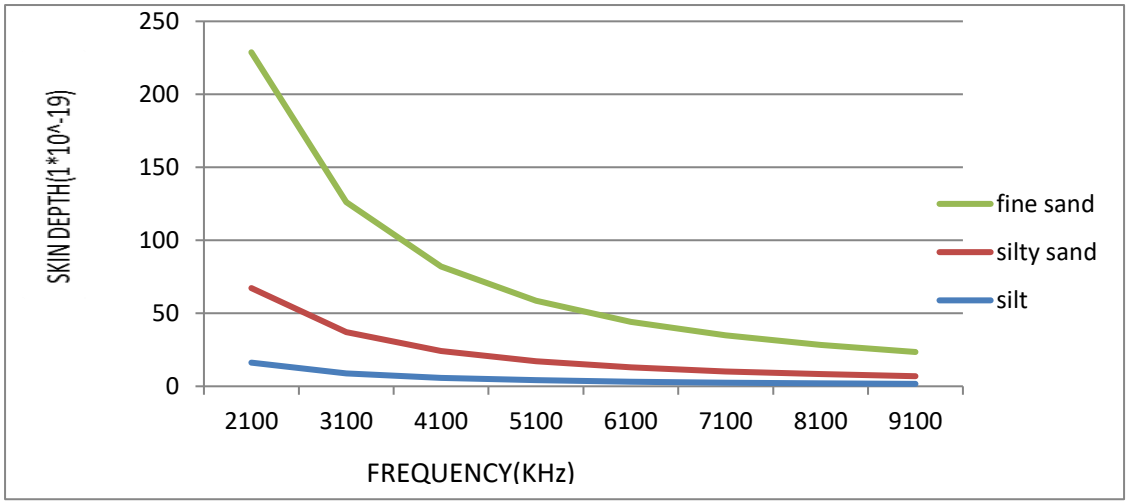

Fig4: Skin Depth Effect on Silty Sand , Fine Sand and Silt

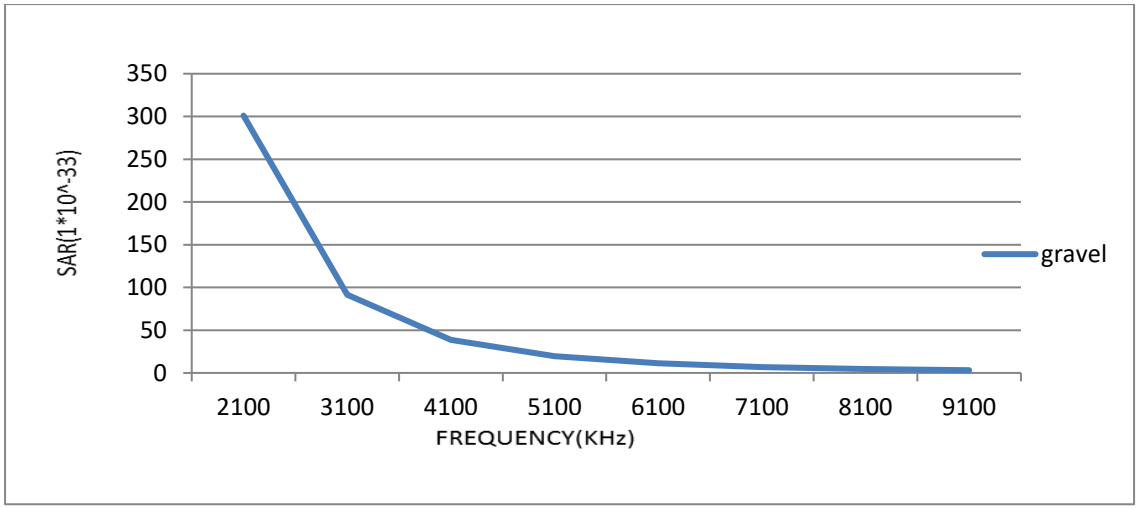

Fig5: SAR effect of Gravel

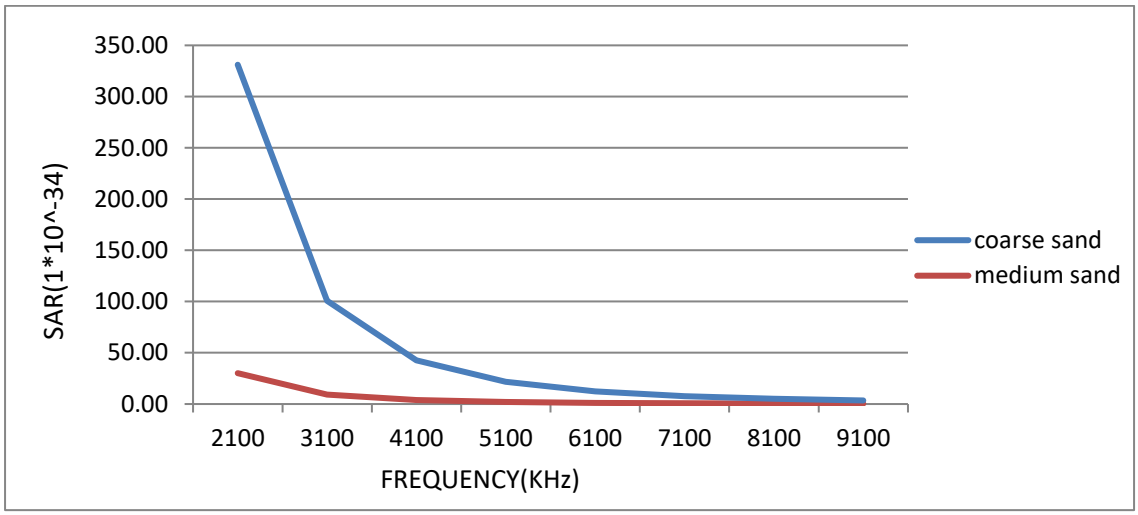

Fig6: SAR effect of Coarse Sand and Medium Sand

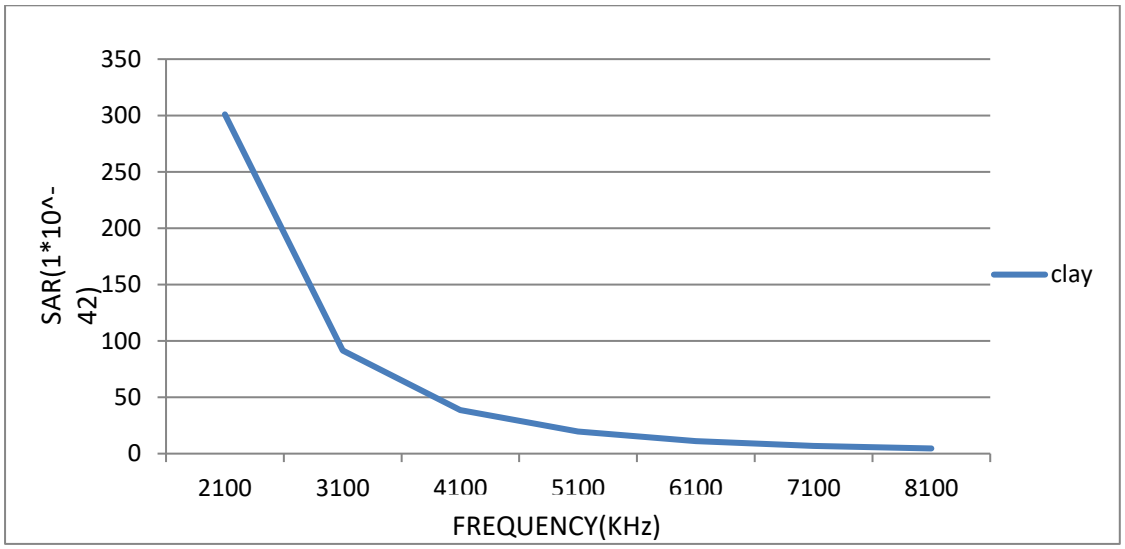

Fig7: SAR Effect of Clay

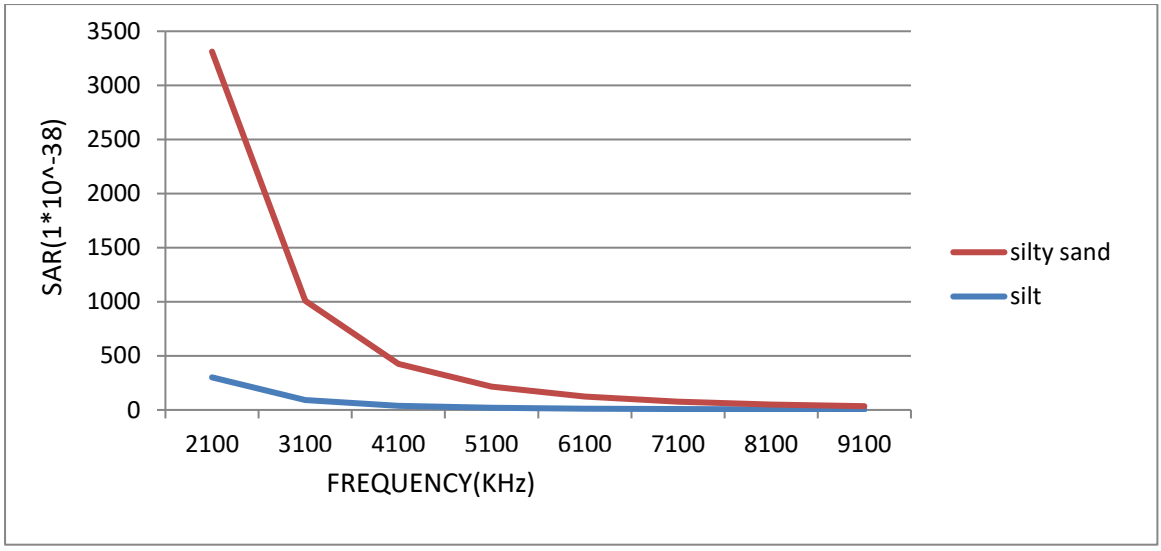

Fig8:SAR Effect of silty sand and silt

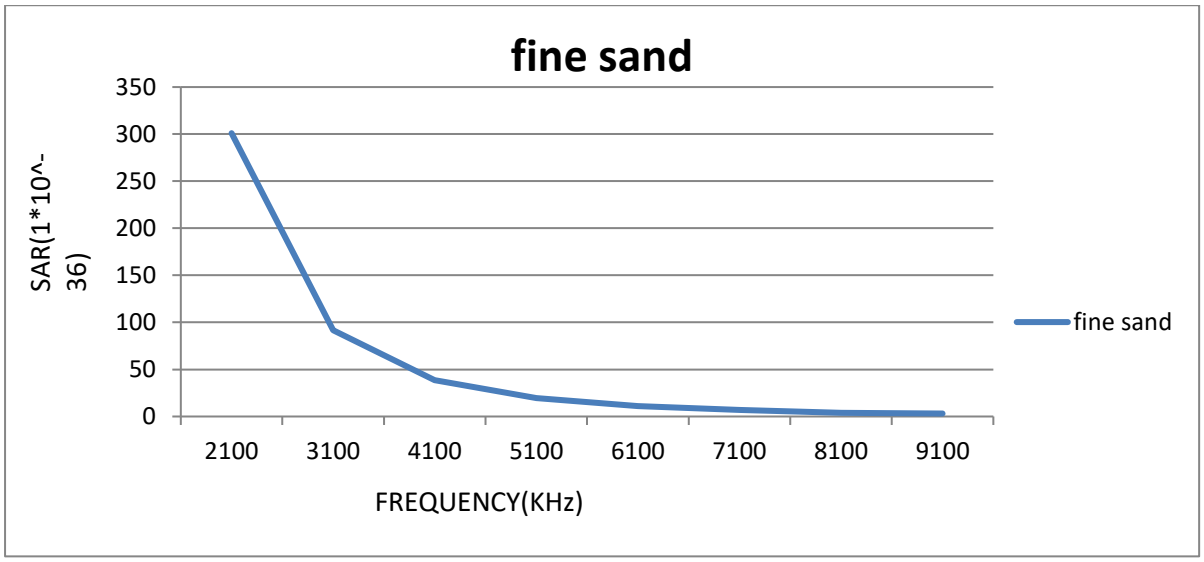

Fig9:SAR effect on fine sand

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