

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

## Variation of Electromagnetic Properties of Soils Over Frequency Range of 1 MHz to 10Mhz

M.Usha Rani<sup>1</sup>, Dr.V.S.S.N.Srinivasa Baba<sup>2</sup>, Dr.Srivalli Gundala<sup>3</sup>, J.Sampath Kumar<sup>4</sup>

Assistant Professor, Department of Electronics and Communication Engineering, ACE Engineering College,  
Ankushapur(V), Hyderabad, India<sup>1</sup>

Professor, Department of Electronics and Communication Engineering, ACE Engineering College, Ankushapur(V),  
Hyderabad, India<sup>2</sup>

Assistant Professor, Department of Electronics and Communication Engineering, G Narayanamma Institute of  
Technology and Science for woman, Shaikpet, Hyderabad, India<sup>3</sup>

Assistant Professor, Department of Electronics and Communication Engineering, ACE Engineering College,  
Ankushapur(V), Hyderabad, India<sup>4</sup>

**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

### I.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. Dielectric permittivity is a complex function which have both real and imaginary parts. The real part of dielectric permittivity is dielectric constant( $\epsilon_r$ ) which is ratio of storage capacity of electric field to material in free space. The imaginary part is dielectric loss which gives attenuation and dispersion. Dielectric loss is negligible for low conductivity materials . So, the real part is only the primary component for dielectric permittivity.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

## II.PROPOSED METHODOLOGY

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( $\mu$ ), electrical permittivity( $\epsilon$ ) and electrical conductivity( $\sigma$ ).

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  $\delta$ , 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.

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

$\omega$ =angular frequency= $2\pi f$

$\mu$ = relative permeability=  $\mu_0\mu_r$

$\mu_0=4\pi\times 10^{-7}$  (N/A<sup>2</sup>)

$\epsilon$ =Relative permittivity= $\epsilon_0\epsilon_r$

$\epsilon_0=8.854\times 10^{-12}$  (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[6-12]:

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

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

Where  $\sigma$  = conductivity of the sand (S/m) ,  $\rho$  = density( kg/m<sup>3</sup> ), E = magnitude of electric field at the inspection point (V/m),  $\delta$  is the penetration depth (mm).

Table1:Permeability of different soils

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	$1 \times 10^{-5}$
Clay	$10^{-7}$ to $10^{-9}$

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

## III.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).

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

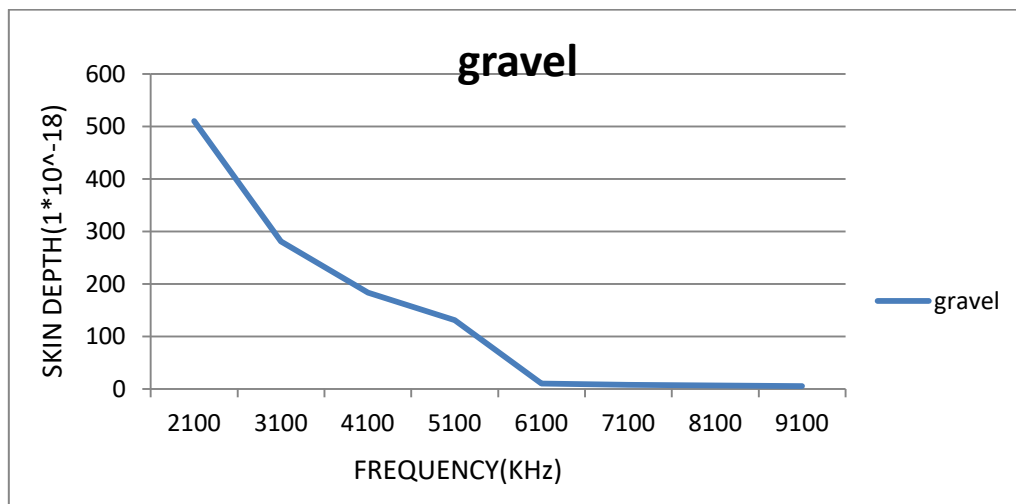


Fig1 : Skin Depth effect on Gravel

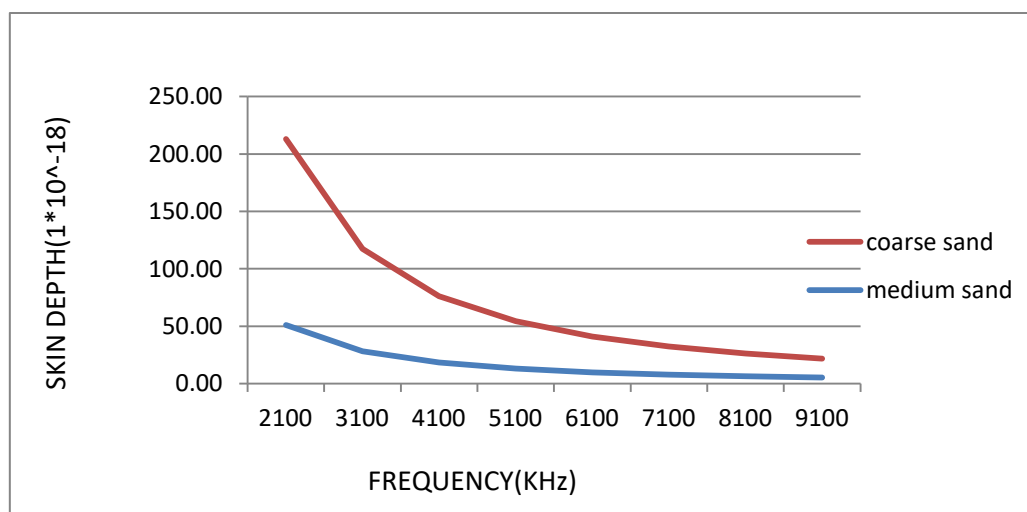


Fig2: Skin Depth Effect on Coarse sand and Medium sand

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

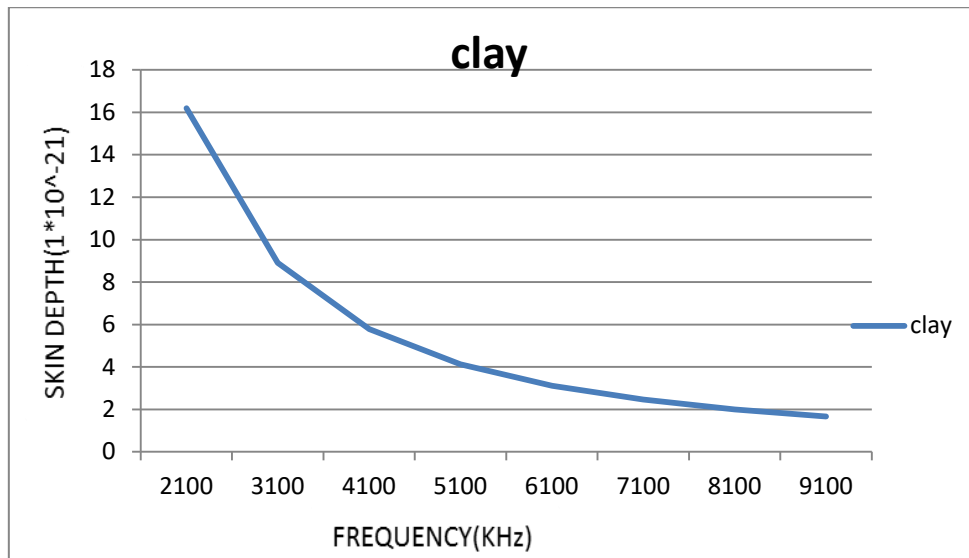


Fig3:Skin Depth Effect on Clay

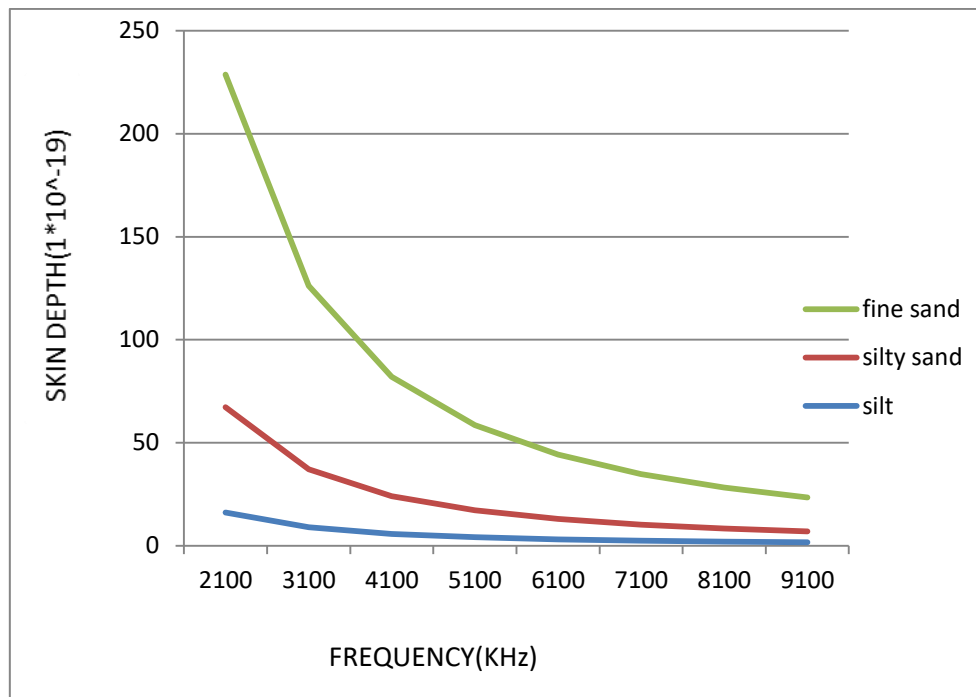


Fig4: Skin Depth Effect on SiltySand , Fine Sand and Silt

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

As observed in Figure 4 that skin depth values vary from  $1.62 \times 10^{-17}$  to  $1.66 \times 10^{-18}$  m for fine sand,  $1.62 \times 10^{-18}$  to  $1.66 \times 10^{-19}$  m for silt,  $5.11 \times 10^{-18}$  to  $5.24 \times 10^{-19}$  m for the frequency range of 2MHz to 10MHz

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).

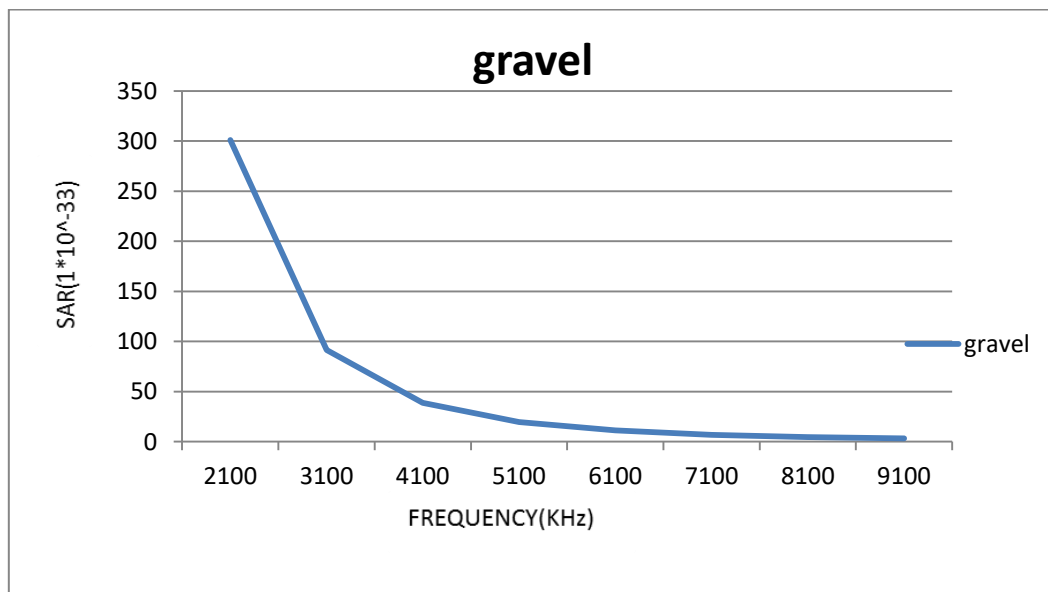


Fig5:SAR effect of Gravel

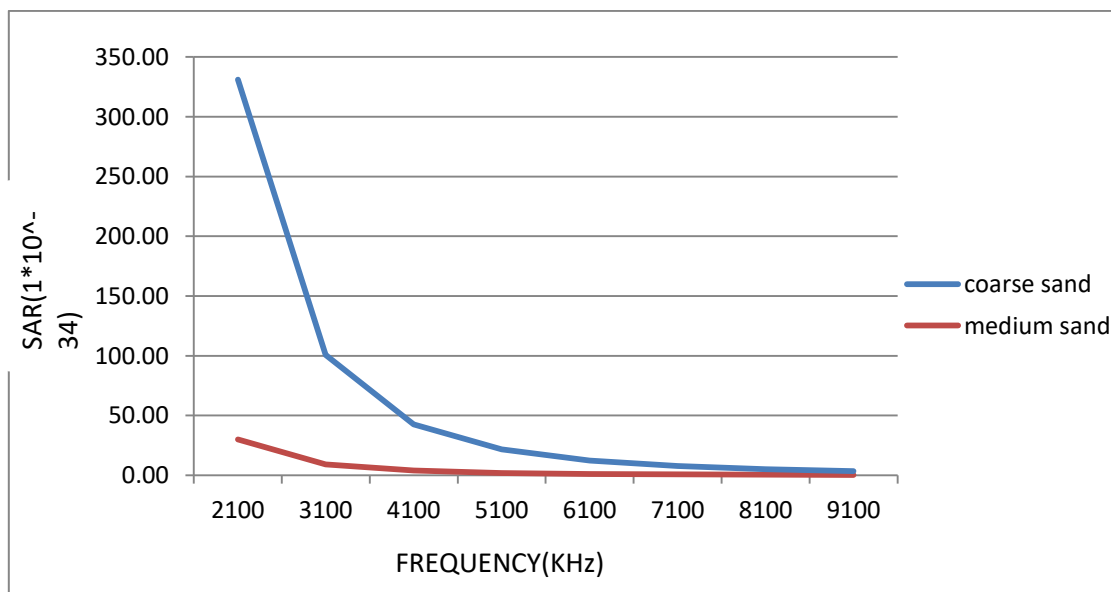


Fig6:SAR effect of Coarse Sand and Medium Sand

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

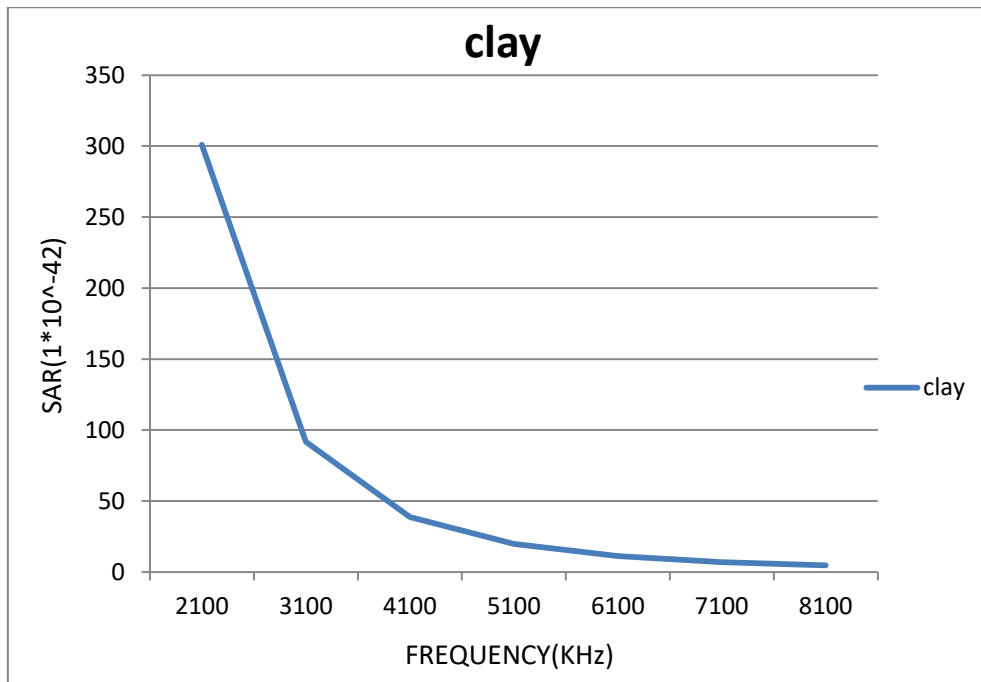


Fig7: SAR Effect of Clay

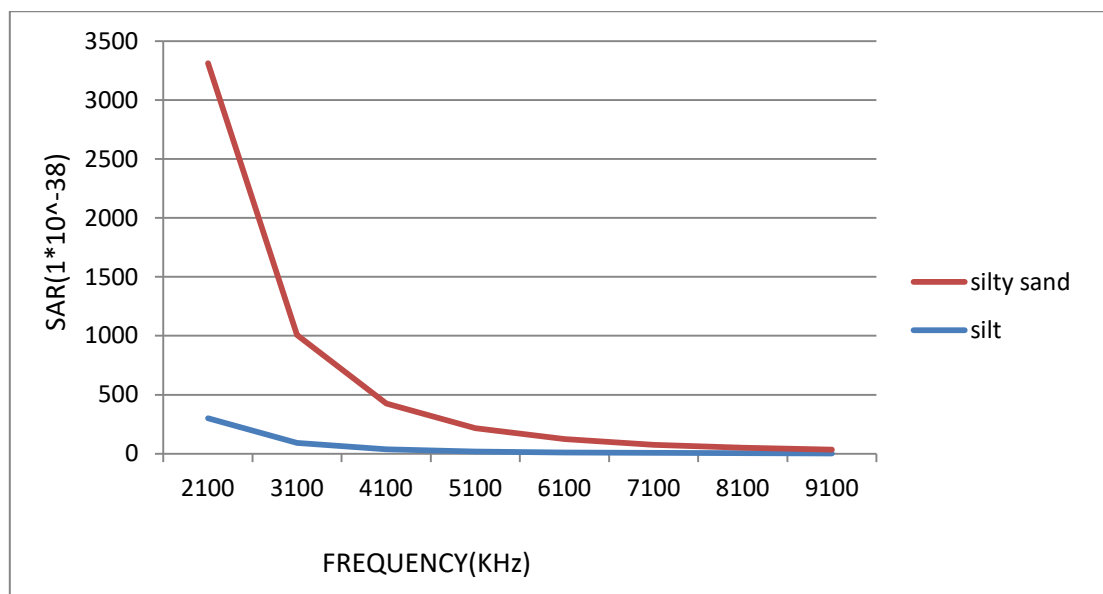


Fig8:SAR Effect of silty sand and silt

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

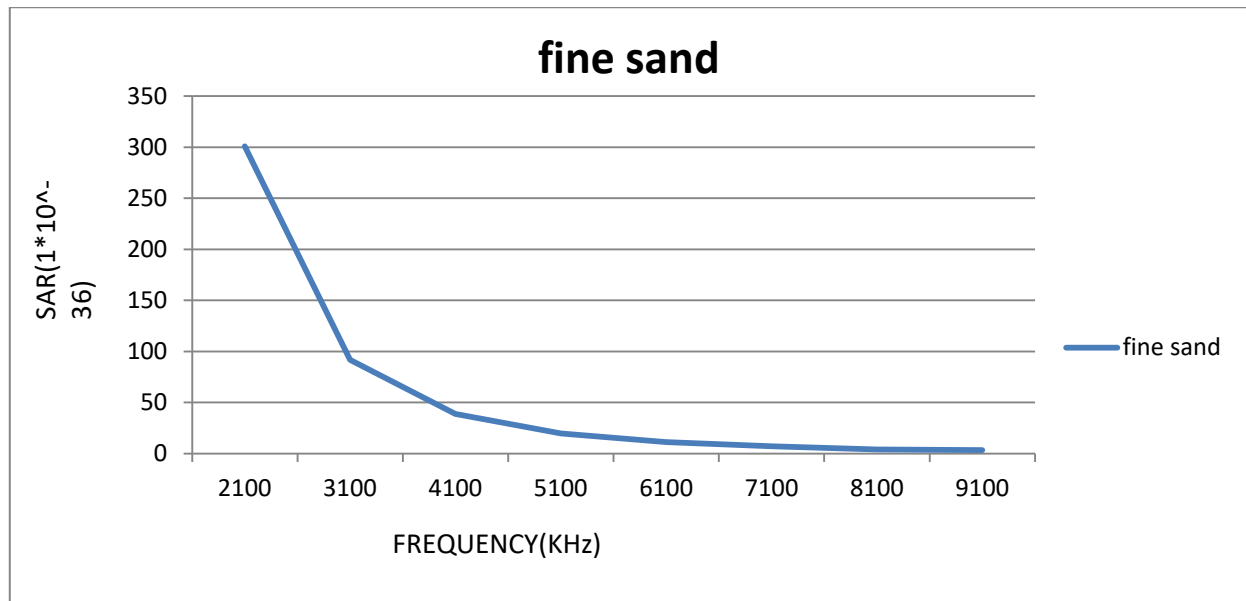


Fig9:SAR effect on fine sand

It is seen from the figures (5)-(9) the SAR value varies  $3.01 \times 10^{-31}$  to  $3.17 \times 10^{-33}$  (w/kg) for gravel,  $3.01 \times 10^{-32}$  to  $3.17 \times 10^{-34}$  (w/kg) for coarse sand,  $3.01 \times 10^{-33}$  to  $3.17 \times 10^{-35}$  (w/kg) for medium sand,  $3.01 \times 10^{-40}$  to  $3.17 \times 10^{-42}$  (w/kg) for clay,  $3.01 \times 10^{-36}$  to  $3.17 \times 10^{-38}$  (w/kg) for silt,  $3.01 \times 10^{-35}$  to  $3.17 \times 10^{-37}$  (w/kg) for silty sand,  $3.01 \times 10^{-34}$  to  $3.17 \times 10^{-36}$  (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

### REFERENCES

- [1] Katherine A Klein, J. Carlos Santamarina, "Electrical Conductivity of Soils :Underlying Phenomena", Journal of Environmental and Engineering Geo- Physics, Dec 2003, Volume 8, Issue 4.
- [2] F.Girault, C.Poitou, F.Perrier, B.P.Koirala, M.Bhatarai, "Soil Characterization using patterns of magnetic susceptibility versus effective radium concentration", Natural Hazards and Earth System Sciences, doi:10.5194/nhess-11-2285-2011.
- [3] Virendrakumar N. Patel, Prahalada D. Chaudhary, "Variation Of electrical Parameters of soil with moisture and salinity over frequency range from 20 Hz to 2MHz", International journal of Scientific research and reviews, 2018, ISSN : 2279 – 0543.
- [4] George R .Jiracek, "Earth Electromagnetic Properties Plate Tectonics to Pure Fluids(Plates to Pores) "
- [5] R.Shenbhagavalli, K.Ramar, "Feature Extraction Of Soil Images For Retrieval based on Statistics ", International Journal of Computer Applications, Volume 88-No.14, February 2014.
- [6] R.J.Spiegel(1957)623, "A review of numerical models for predicting the energy Deposition and resultant thermal response of humans exposed electromagnetic fields", IEEE Trans .Microwave Theory Tech., 23.
- [7] M.E.Haque, A.A.Suman and M.M.Rashid, 2012, " Numerical Evaluation of Specific Absorption Rate and Skin Depth on Human Body Tissue Due To Electromagnetic Field Emitted From Mobile Phone Antenna", Proceeding of the International Conference on Electrical, Computer and Telecommunication Engineering, PI-0032
- [8] Robert Poretta, Fabio Bianchi, "Profiles of relative permittivity and electrical conductivity from unsaturated Soil water content models", Annals of Geo-Physics, 59, 3, 2016., G0320 doi:10.4401/ag-6990
- [9] J.E.Hipp, "Soil electromagnetic parameters as a function of frequency, soil density and soil moisture" , Proc. IEEE 62:98-103(1974).
- [10] J. R. Wang and T. J. Schmugge, "An empirical model for the complex dielectric permittivity of soils as a function of water content", IEEE Trans. Geosci. Remote Sens. GE-18:288–295 (1980).
- [11] A. M. Shutko, Microwave Radio Sensing of Water Surfaces and Soils, Nauka, Moscow, 1986 (in Russian).
- [12] L. V. Gonchariva, V. I. Barinova, U. M. Egorov and V. M. Fedorov, "Dielectric properties of disperse soils in microwave range, Proc. Int. Conf. Application of Microwave Energy in Technology and Science, Saratov, Russia, 1991, pp. 104–105 (in Russian).