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Validation of RKAS Soil Dielectric Model at C and X-Band Microwave Frequencies

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***Abstract*—In the present study an attempt is made to validate soil dielectric model which was formed to estimate the values of dielectric constant of dry and moist soil at various volumetric moisture contents at C and X-Band microwave frequencies. Eight Soil samples are collected from various parts of Haryana. Dielectric constants are measured using waveguide cell technique at C and X-Band microwave frequencies at varying volumetric moisture contents and then compared with estimated values obtained from model. The model has good accuracy and practicality.**

***Index Terms*—** Dielectric Constant, Haryana, Soil Dielectric Model.

I. INTRODUCTION

In the present era of technology, microwave remote sensing is a major tool to understand and analyze natural resources like soil. The soil has physical properties like porosity, bulk density, texture, grain size, color etc; Chemical properties like pH, organic matter, nutrients available, inorganic matter etc; Electrical properties like permeability, dielectric constant, dielectric loss, electrical conductivity etc. In microwave remote sensing of soil, its electrical parameters play important role as it depends on soil moisture, texture of soil and frequency at which measurements are made. Dielectric constant is a function that depends on texture of soil, moisture content and frequency at which observations are made [1]-[8] and play very important role to understand and analyze soil.

For the estimation of value of dielectric constant of soil from its physical constituents and volumetric moisture content present in it, a mathematical model was formed which is named as RKAS model [9]. In our previous study [9], the model is formed using results of six soil samples from Hisar, Ramgarh, Rohtak, Siswal, Balsmand and Naraingarh at various moisture contents and compared with *Hallikainen et al.* Model [10]. In the present paper, an attempt is made to validate the mathematical model for soil samples from eight different locations of Haryana with different textured soil. These eight locations are Kaithal, Rewari, Jind, Panipat, Sonipat, Jhajjar, and Mahendargarh and Sirsa districts of Haryana.

Testing of validation of the model is done in two steps:

1. Comparison of modeled results of dielectric constant at various volumetric moisture contents with measured results at different frequencies.
2. Comparison of modeled results of dielectric constant at various volumetric moisture contents with other available model at different frequencies.

II. EXPERIMENTAL DETAILS

Soil samples are collected from eight different locations of Haryana – Kaithal, Rewari, Jind, Panipat, Sonipat, Jhajjar, Mahendargarh and Sirsa. Texture of these eight samples are given in Table 1.

TABLE I. TEXTURE OF SOIL SAMPLES ON WHICH TESTING OF VALIDATION IS DONE

Area	Sand (%)	Silt (%)	Clay (%)	Texture
Rewari	82	12	6	Loamy Sand
Mahendragarh	80	13	7	Loamy Sand
Jind	66	18	16	Sandy Loam
Panipat	61	22	17	Sandy Loam
Jhajjar	68	18	14	Sandy Loam
Sirsa	72	16	12	Sandy Loam
Kaithal	51	31	18	Loamy
Sonipat	66	19	15	Sandy Loam

The samples of soil collected first sieved and coarse particles are removed. The texture structure of four samples is presented in Table 1 for which measurements are made. The fine particles obtained are then oven dried for several hours to remove moisture completely and make it dry. Now to prepare moist soil samples measured quantity of distilled water is added to dried soil. The gravimetric soil moisture content in percentage term is calculated using the following relation [11]:

$$w_c(\%) = \frac{w_w - w_d}{w_d} \times 100$$

Where w_w, is the weight of wet soil and w_d is the weight of dry soil.

A. Measurement of dielectric constant of soil

In the present work, technique used for the measurement constant is waveguide cell technique [12]. A microwave bench operating at C-Band is used at 5.3 GHz in TE_{10} mode with Gunn

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source at room temperature and another microwave bench operating at X-Band is used at 12 GHz in TE_{10} mode with reflex Klystron as microwave source were used for measurements. The microwaves are allowed to be incident on the sample. A part of incident signal reflects and superimpose with incident signal to give rise to standing wave pattern. The dielectric constant is measured by using the shift in minima of standing wave pattern that takes place due to the change in guide wavelength on the introduction of sample in the waveguide. Dielectric constant can be calculated using the following relation:

$$\epsilon' = \frac{g_\epsilon + \left[\frac{\lambda_{gs}}{2a}\right]^2}{1 + \left[\frac{\lambda_{gs}}{2a}\right]^2}$$

where g_ϵ is real part of admittance, λ_{gs} is wavelength in air filled guide, a = inner width of rectangular waveguide.

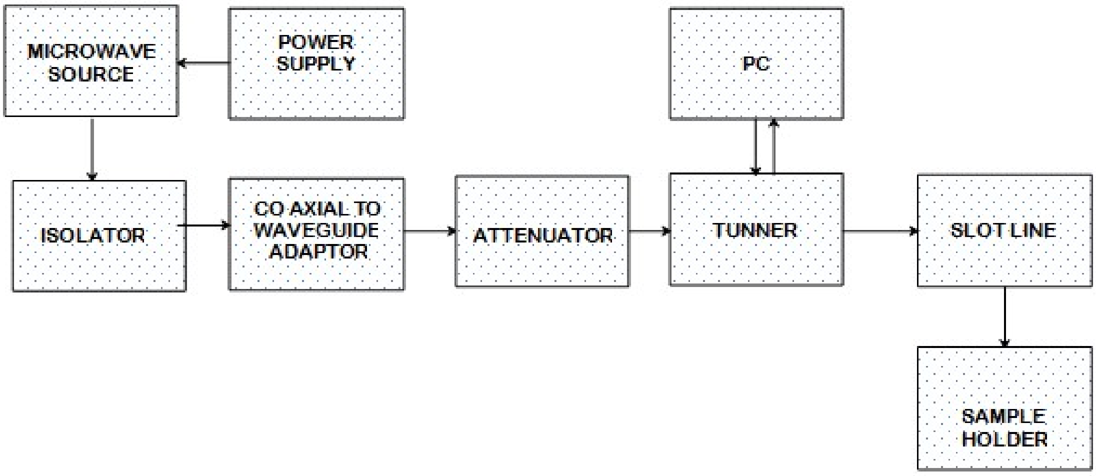

Fig. 1. Block Diagram of Experimental Set up of Microwave Bench.

III. RESULTS AND DISCUSSION

The plots showing variations of dielectric constant of soil of Kaithal, Rewari, Jind, Panipat, Sonipat, Jhajjar, Mahendargarh and Sirsa for 5.3 GHz are shown in Figs. 2 (a) to 2 (h) respectively. The observed values of dielectric constant of these soils at different volumetric moisture contents are compared with RKAS Model and Hallikainen model. Table II shows maximum and minimum errors in measurements for each sample. It is seen that the percentage error in the model are within allowable range. The percentage errors in the measurements of dielectric constant of soil are lesser in case RKAS model than Hallikainen model in six out of eight samples. In remaining two samples of soil, the differences in errors are not much significant and in can be neglected.

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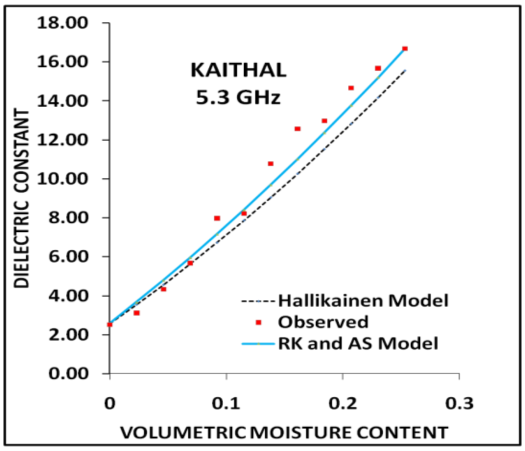
The plots showing variations of dielectric constant of soil of Kaithal, Rewari, Jind, Panipat, Sonipat, Jhajjar, Mahendargarh and Sirsa for 12 GHz are shown in Figure 2 (i) to 2 (p) respectively. The observed values of dielectric constant of these soils at different volumetric moisture contents are compared with RKAS Model and Hallikainen model. Table III shows maximum and minimum errors in measurements for each sample. It is seen that the percentage error in the model are within allowable range. The percentage errors in the measurements of dielectric constant of soil are lesser in case RKAS model than Hallikainen model in four out of eight samples. In remaining four samples of soil, the differences in errors are not much significant and in can be neglected.

TABLE II. COMPARISON OF MODELED AND OBSERVED VALUES OF DIELECTRIC CONSTANT AT C-BAND

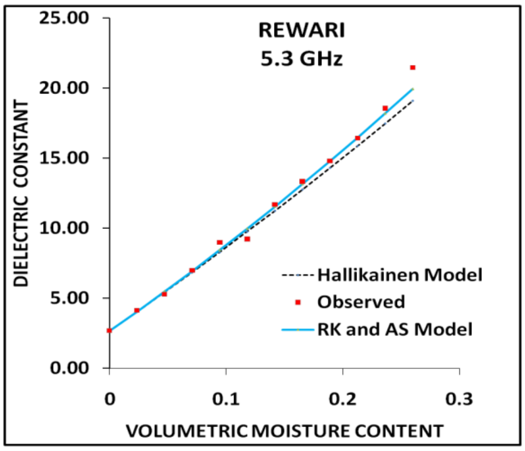
Area	f = 5.3 GHz			
	Percentage error			
	RKAS Model		Hallikainen model	
	Minimum	Maximum	Minimum	Maximum
Rewari	0.03	8.16	0.69	10.97
Mahendragarh	0.25	7.71	0.22	11.43
Jind	1.62	10.78	1.65	13.72
Panipat	0.67	20.43	1.54	27.47
Jhajjar	1.62	13.21	0.18	9.27
Sirsa	1.01	13.50	0.37	14.05
Kaithal	0.04	17.49	0.87	18.26
Sonipat	1.66	9.02	1.27	10.60

TABLE III. COMPARISON OF MODELED AND OBSERVED VALUES OF DIELECTRIC CONSTANT AT X-BAND

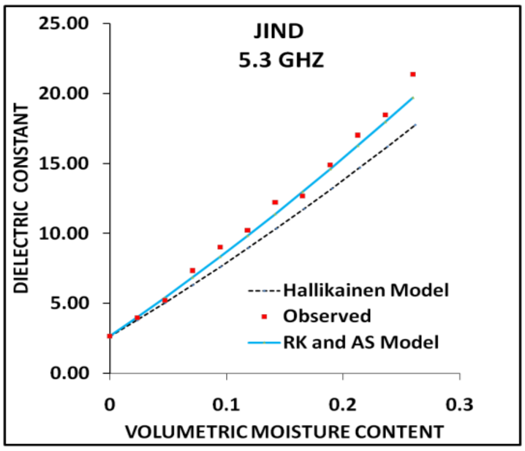
Area	f = 12 GHz			
	Percentage error			
	RKAS Model		Hallikainen model	
	Minimum	Maximum	Minimum	Maximum
Rewari	0.70	23.99	0.22	23.40
Mahendragarh	2.32	29.72	1.64	24.53
Jind	0.68	16.40	1.13	22.02
Panipat	0.60	23.14	0.41	20.59
Jhajjar	0.28	22.96	1.57	27.73
Sirsa	0.70	25.09	2.74	25.61
Kaithal	0.79	28.53	0.40	21.81
Sonipat	0.06	23.40	0.60	25.01


KAITHAL
5.3 GHz
DIELECTRIC CONSTANT
VOLUMETRIC MOISTURE CONTENT
Hallikainen Model
Observed
RK and AS Model

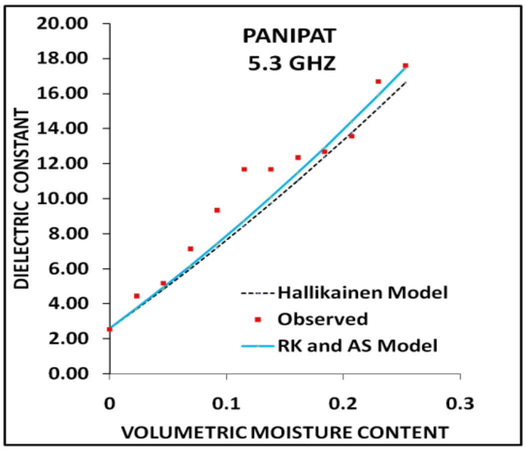
(a)


REWARI
5.3 GHz
DIELECTRIC CONSTANT
VOLUMETRIC MOISTURE CONTENT
Hallikainen Model
Observed
RK and AS Model

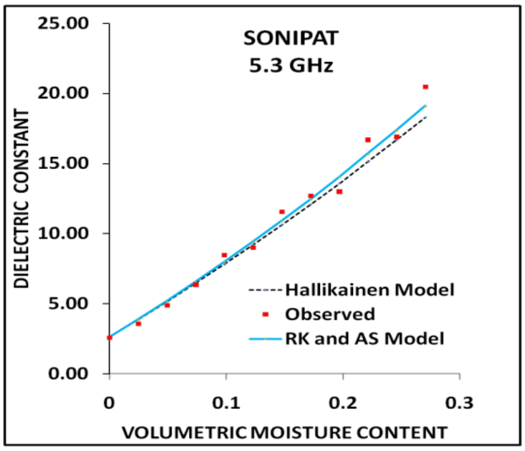
(b)


JIND
5.3 GHZ
DIELECTRIC CONSTANT
VOLUMETRIC MOISTURE CONTENT
Hallikainen Model
Observed
RK and AS Model

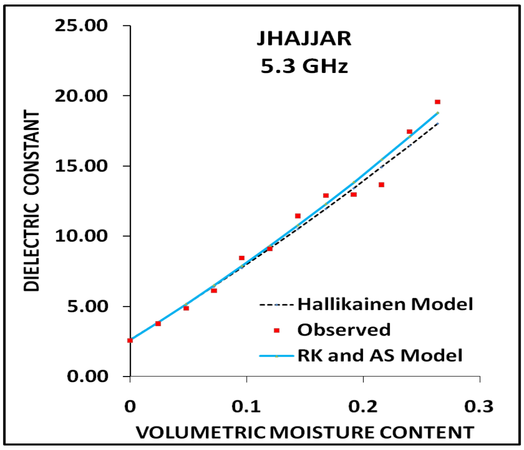
(c)


PANIPAT
5.3 GHZ
DIELECTRIC CONSTANT
VOLUMETRIC MOISTURE CONTENT
Hallikainen Model
Observed
RK and AS Model

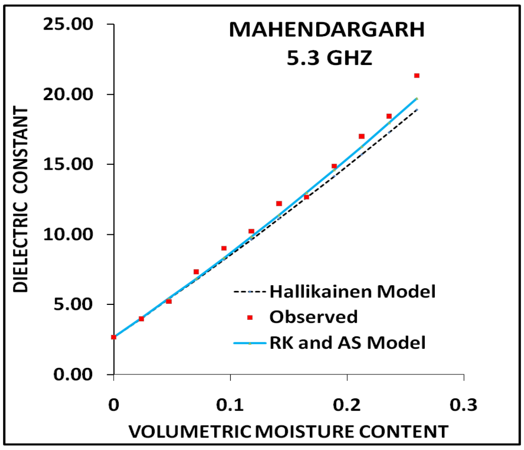
(d)


SONIPAT
5.3 GHz
DIELECTRIC CONSTANT
VOLUMETRIC MOISTURE CONTENT
Hallikainen Model
Observed
RK and AS Model

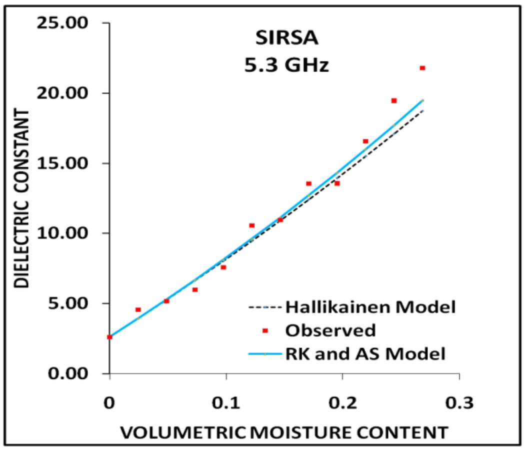
(e)


JHAJJAR
5.3 GHz
DIELECTRIC CONSTANT
VOLUMETRIC MOISTURE CONTENT
Hallikainen Model
Observed
RK and AS Model

(f)



(g)



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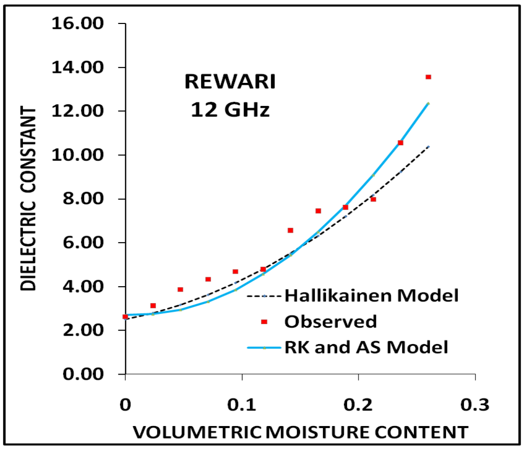
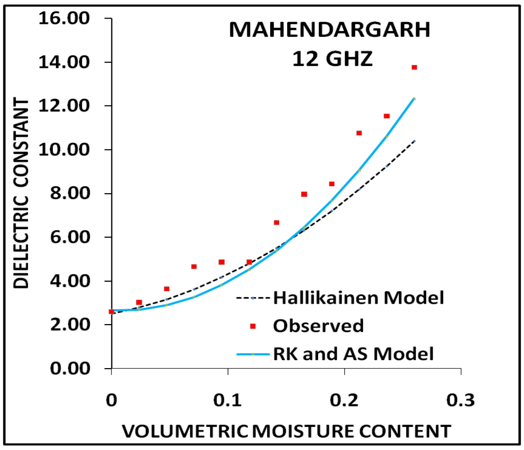
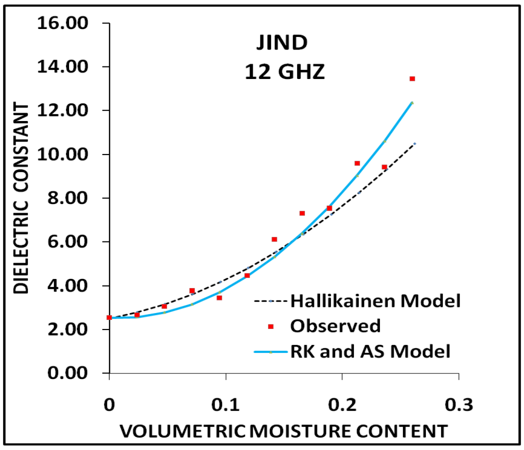


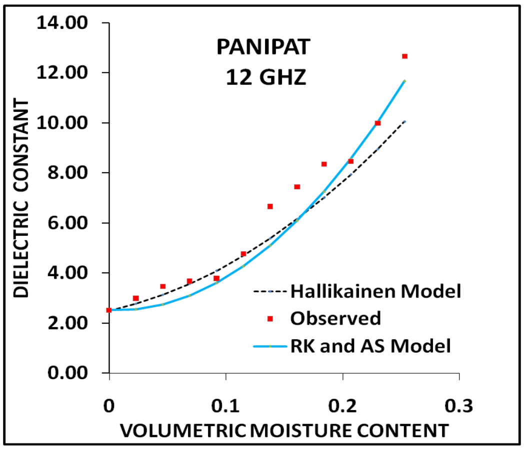
(i)



(j)



(k)



(l)

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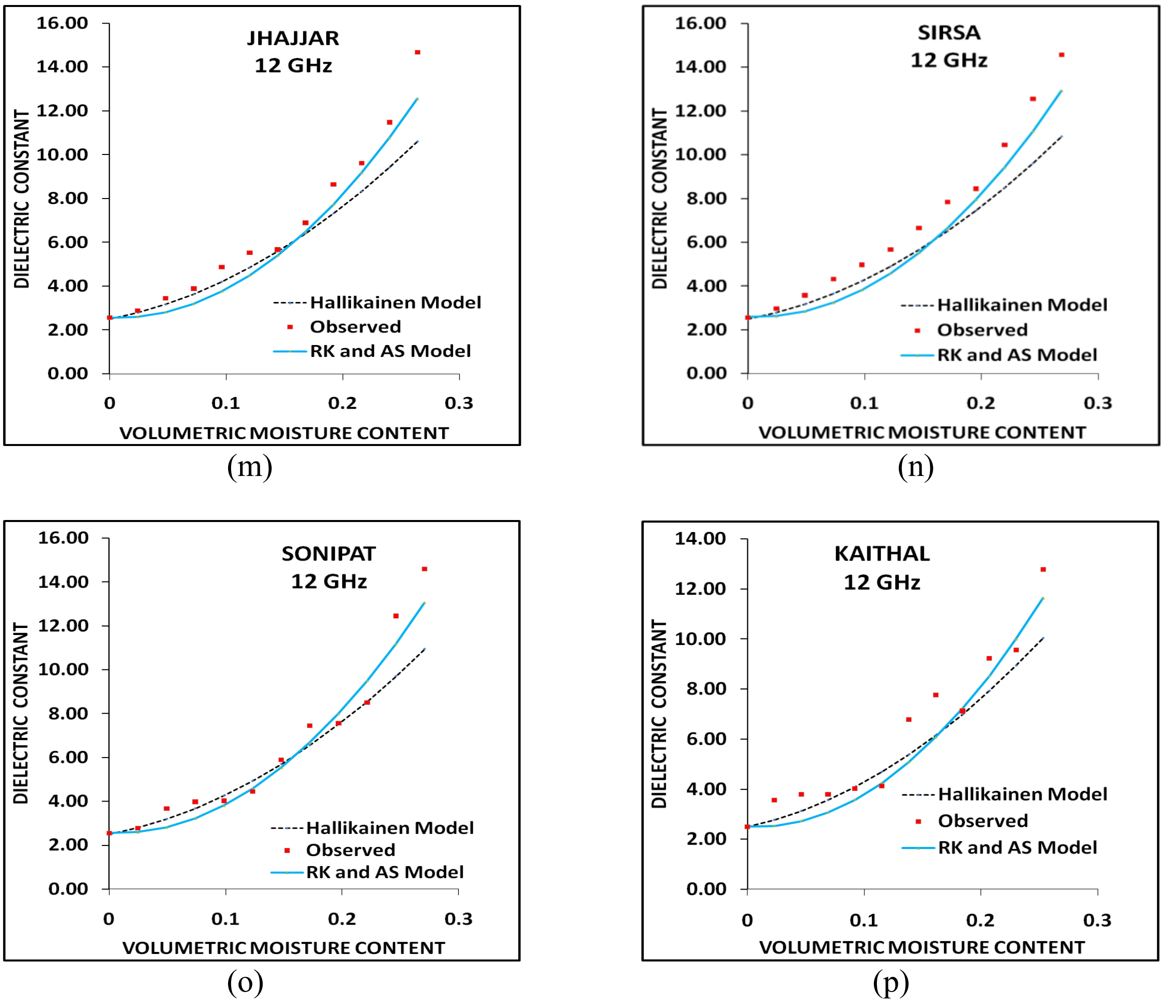

Fig. 2. Dielectric constant of soils.

IV. CONCLUSION

From the study on the variation of dielectric constant of soil with volumetric moisture content, it is found that dielectric constant is strongly depend on volumetric moisture content. Table 2 and Table 3 shows the variations of dielectric constant of soil of Kaithal, Rewari, Jind, Panipat, Sonipat, Jhajjar, Mahendargarh and Sirsa with volumetric moisture content at 5 GHz and 12 GHz. Values obtained under laboratory conditions and modeled values are presented here. The values obtained experimentally are compared with RKAS model as well as with Hallikainen model. It is seen that the values obtained from RKAS model are accurate and the percentage error is in allowable range.

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