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Microwave spectroscopy modelling for geophysical parameter retrieval using synthetic aperture radar (SAR) dataset

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The microwave spectroscopy is an extremely powerful tool for synoptic observation of the object on the earth or planetary bodies. One of the best microwave spectroscopy imaging system is the synthetic aperture radar (SAR) remote sensing. It operates in all weather conditions, though there is change in environmental conditions. In the present study microwave L band SIR-C SAR dataset has been used. The various modellings have been used to classify and analyze the geophysical parameters on the earth or planetary bodies. The modelling makes the process of estimating information beyond the real observation range for data interpretation. In the present paper two most widely used modeling techniques for microwave SAR spectroscopy, i.e., empirical model and an integral equation model (IEM) have been discussed. The aim of the present work is accurate, reliable and skillful measurements of geophysical parameters. In the present work, surface roughness, soil moisture, dielectric constant (ε) and backscattering coefficients (σ^0) etc. geophysical parameters have been measured with the help of the statistical parameter and occurrence plane estimated from the microwave SAR image.

Keywords: Microwave spectroscopy, SAR, Geophysical parameters, Modelling

1 Introduction

Microwave spectroscopy is the study of the interaction of matter and electromagnetic radiation in the microwave region of the spectrum. The synthetic aperture radar (SAR) is an active remote sensing system, which acquired very high-resolution images of the earth or planetary bodies. It has the capacity to penetrate through clouds, fog, smoke, etc. though there is change in environmental condition and capable to sense the object on the Earth during the day or night[1]. The modelling makes the process of estimating information; beyond the original observation range is possible in data interpretation. The land geophysical parameters like surface roughness, soil moisture, dielectric constant (ε) and backscattering coefficients (σ^0) etc. will be retrieved by using modelling techniques.

The measurement of soil-moisture content is one of the most important targets of remote sensing, and significant amounts of experimental and theoretical studies have been carried out since the late 1970s. The soil dielectric constant (ε) at microwave frequencies exhibits a strong dependence on the soil moisture content. The radar backscatter is sensitive to soil moisture content. Surface roughness is the other disturbing factor that significantly affects the measurement of soil moisture. This quantity has also been the subject of many investigations. In general, it has been stated that backscatter is more sensitive to this factor than emission. The variation of soil moisture affects the both dielectric constant (ε) and backscattering coefficients (σ^0) calculation[2,3].

The surface roughness can be interpreted as the topography of the surface nature on a scale of a few meters to centimetres[4]. One of the common approaches for soil moisture retrieval is the development of direct models by simulating the radar observations in terms of the soil attributes, such as the dielectric constant and the surface roughness, of an area with known characteristics. Dielectric constant and roughness are the primary features that govern the interaction of electromagnetic radiation with a bare natural surface[5]. The dielectric constant is directly dependent on soil moisture and soil texture

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constituents. Among all said geophysical parameters the surface roughness is very important parameter, because the roughness of the surface affects almost all other geophysical parameters. The present study covers both empirical model and an Integral Equation Model (IEM). These modelling is useful for the retrieving of the geophysical parameters[6].

The present modelling applied to microwave SAR image of microwave L band SIR-C SAR image. The dataset is freely available on the United States Geological Survey website[7]. USGS is a scientific agency of the United States government. The statistical parameter like Mean, Median, Standard Deviation, Coefficient Variance and Equivalence Number of Look (ENL) is estimated. Based on this the image accuracy is fixed and geophysical parameter is retrieval calculations have been done. The modeling of microwave dataset will be done by using PolSARPro Ver. 5.0 software. PolSARpro is a European Space Agency (ESA) open source toolbox for polarimetric SAR data processing and education. The software handles dual polarisation and full polarisation data from a wide range of SAR space and airborne missions. It contains tools for data import, data conversion, basis change, speckle filters, data processing, calibration, data simulation etc.[8].

2 Microwave Spectroscopy Modelling

The modelling makes the process of estimating, beyond the original observation range is possible in data interpretation. Let's consider the Y output measurement as:

$$Y = f(x)+\varepsilon \quad \ldots (1)$$

where ε measurement error, x is geophysical variable and f is the remote sensing model.

2.1 Empirical model

Empirical models are the most common in interpreting the satellite measurements, although some physical models have also been used. But these measurements can also be combined with remote sensing observations to enhance retrieval accuracy. The knowledge of the underlying physics increases; more and more accurate physical models are developed. The development of empirical models has been studied both as a first approach to study the relationship between backscatter and soil moisture[9]. It's determined from experimental data and simple formulations as,

$$\frac{\partial S}{\partial b} = \sum_{i=1}^{m} 2(y_i - ax_i - b)(-1) = 0 \quad \ldots (2)$$

where, a and b are unknown parameter.

2.2 Integral equation model (IEM)

The IEM is widely used in inversion procedures of SAR images for retrieving soil moisture content and roughness. However, geophysical parameter estimations require the use of a radar backscattering model that is capable of correctly modelling the radar signal[10]. The SAR image is converted from the provided format in the digital number (DN) values, to the backscattering intensity information also known as the σ°:

$$\sigma^0 = 10X\log 10(DN)^2 + CF \quad \ldots (3)$$

where σ° is the backscattering intensity, represented in decibel units (dB) and CF (equal to −83.4) is the calibration factor for the data obtained, depending on the observation period and polarization. Dielectric permittivity (ε) is a complex function with real and imaginary components. The real and imaginary parts of the complex dielectric constant of different soil texture in different land cover with varied moisture content have been expressed as,

$$\varepsilon = \varepsilon' - j\varepsilon'' \quad \ldots (4)$$

where j is the square root of −1. The real part (ε') is often expressed as the relative permittivity (ε_r). The imaginary part (ε") of the dielectric permittivity is usually expressed in terms of dielectric losses. The IEM reproduces radar backscattering coefficient[11]. The IEM model proposed for rough surface scattering, which has been extensively applied to microwave remote sensing as:

$$y(x) = g(x) + \int_a^b k(x,t)y(t)dt \quad \ldots (5)$$

where, the function $g(x)$ and $k(x,t)$ is given and unknown function $y(t)$ is to be determined.

3 Results and Discussion

The microwave SIR-C SAR image was in MLC (multi look complex) format, hence initially it is converted into the ground range using a multilooking process after importing the data in PolSARPro 5.0 software. Figure 1 shows the original quad pol SIR-C image [Lat-21^0 52' 58.80" N to 22^0 45' 07.20" N;

Lon-87^0 51' 7.60" E to 88^0 35' 06.00" E, MLC Level-1 dataset. Date of acquisition: 05/10/1994 with incident angle: 32.87^0, Kolkata, India]. The data filtered with 5×5 window size by using Lee filter. Refined speckle filter, because speckle noise degrades the quality of SAR image.

Then decomposition parameters like entropy (*H*), and Alpha (α) images are generated as shown in Fig. 2(a,b), respectively. Figure 2(c) shows Pauli RGB image and the H-alpha classified image is shown in Fig. 2(d).

The H Alpha classified image shows the eight classes shown in Fig. 2(d), in which the four-major class, *viz*., water, open land, vegetation and settlement are studied. These results further used for more finding of the geophysical parameters because each class has variation.

From Fig. 3 and Table 1 it is observed that the H Alpha has a less standard deviation, i.e., 1.4656 and coefficient variance less than 1, i.e., 0.5362, hence the σ^0 is more accurately retrieved. This value is further useful for the calculation of geophysical parameters. However, due to the moisture level of surface and the dielectric constant ε of the object, the value of σ^0 is varied. Later, both empirical and IEM models applied on the classified image and from this the occurrence plane are generated, which gives the anisotropic information present in the image. Figure 4 shows occurrence plane for H Alpha classified image.

It is observed that in Fig. 4, the anisotropic particle present in H alpha classified image is high. This indicates that the more moisture level and high dielectric constant value, due to object present in the image. However, the dataset is L band having a lower frequency with the wavelength of 15-30 cm therefore the less backscattering is occurred, and surface appeared as dark, which indicates the surface is smoother.

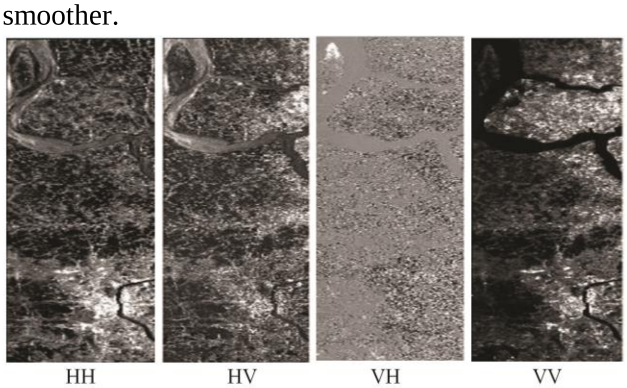

Fig. 1 — Microwave L-band SIR-C satellite SAR dataset with quad polarization.

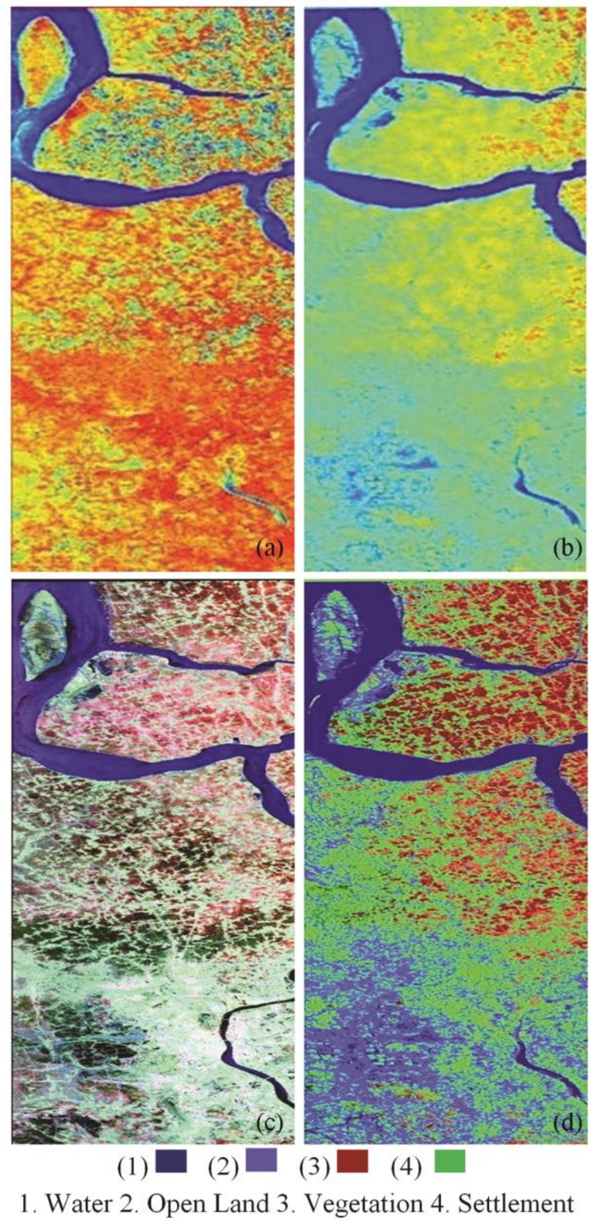

Fig. 2 — (a) Entropy (*H*) (b) alpha (α) image, (c) Pauli RGB and (d) H alpha classified image.

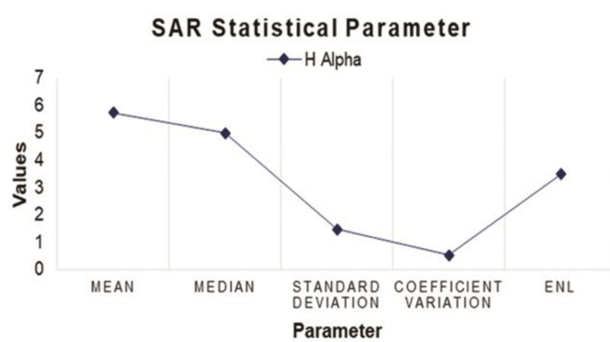

Fig. 3 — Graph of SAR statistical parameters.

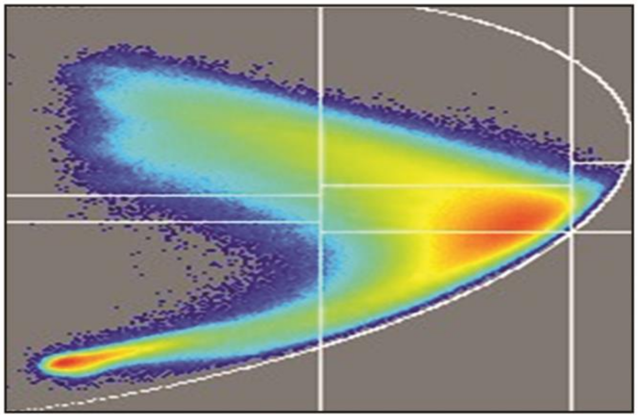

Fig. 4 — Occurrence plane for SAR statistical parameter of H Alpha classified image.

Table 1 — SAR statistical parameters.

Parameter	H alpha classification
Mean	5.7302
Median	4.9902
Standard deviation	1.4656
Coefficient variation	0.5362
ENL	3.4783

Table 2 — σ^0 and ε for H alpha classified SAR image.

Class	Moisture (%)	Standard (σ^0)	Observed (σ^0)	Standard (ε)	Observed (ε)
Water	100	-27.00 to -28.00	-27.526	80	76.3200
Open land	Oct-15	-12.00 to -20.00	-14.153	03-May	04.5060
Vegetation	50-70	-12.00 to -20.00	-18.232	5<	08.9010
Settlement	20-40	01.00 to 03.00	01.640	03-Apr	03.2600

Table 2 indicates that the σ^0 and ε for approximate soil moisture level measured with the help of software tool. Both σ^0 and ε parameters are found nearly same values compare with the standard values for the classes, *viz*., water, open land, vegetation and settlement. Therefore, the modelling retrieved the said geophysical parameters easily by using the occurrence plane.

4 Conclusions

The present paper discussed about two most widely used modelling techniques for microwave SAR spectroscopy, i.e., Empirical and IEM model. The geophysical parameters; soil moisture, dielectric constant (ε) and backscattering coefficients (σ^0) has been retrieved from the microwave SAR dataset. The statistical parameter and occurrence plane was very helpful for retrieving geophysical parameters from SAR dataset. From the overall paper work, it was concluded that the microwave spectroscopy modelling is a one of the realistic method for measurement of geophysical parameter of earth surface.

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