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Microwave Based Classification Of Material : A Statistical Approach

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Abstract: In this paper we present a method for classification of material based on their electromagnetic property. Microwave radar has emerged as useful tool in many remote sensing applications. When microwave propagates from one medium to other, it causes reflections depending on permittivity and permeability of medium. Microwave in X-band range is used for scanning the sheets of various materials like Copper, Metal, Plywood and Acrylic in free space. Depending on their electromagnetic property, reflections from each are measured over the region of interest and finally radar image of reflections from each sheet is obtained using Digital Image Processing tools in MATLAB.Further various statistical features such as Entropy, Standard deviation, Mean and Energy etc are extracted for classification as Metal or Non metal. Results show good performance.

Keywords: Radar, Radar image, Remote Sensing.

I. INTRODUCTION

Material classification and recognition in uncontrolled environment is an important task in remote sensing application as well as in industrial application. The utility of passive polarimetry for material classification was first demonstrated by [1]. He showed it is possible to distinguish between metals and dielectrics by recording the polarization state of specularly reflected light using passive polarimeter. His method involves a threshold based discrimination procedure that relies on polarization Fresnel ratio. In [2], the concept of phase of polarization of light wave was introduced for discrimination between materials according to their intrinsic electrical conductivity based on principle that metal retard orthogonal components of light upon reflection while dielectric do not. In [3], the proposed algorithm is built on iterative model based method material classes to recover the complex index refraction of specular target from multiple passive polarization measurements and the extracted parameters were used to discriminate between materials. Stationary electric charge that is built upon material surface and different material attract different amount of static electricity charge due to its conductive characteristics. By using static electricity charge sensor target classification can be performed. Ultra-Wide Band radar was used to obtain high resolution image of target and image based features were used for classification [4].

Ground Penetrating Radar (GPR) is to detect buried objects like land mines, conduit pipe location, oil and gas explorations. Performance of GPR largely depends on dielectric contrast between object and soil surrounding it [5].This technique uses classification based on concept of different amount of reflection from different material having distinct dielectric constant. When microwave reflections over a region of interest are collected a radar image of target can be obtained. This image can be used for classification. This paper is organized as follows Section-II, describes the methodology in which experimental set up, data collection is given. Section-III, describes preprocessing for microwave image formation, section-IV, describes feature extraction for classification. In section-V, results are illustrated, finally concluding remarks are given in section-VI.

II. METHODOLOGY

The developed technique comprises data collection, preprocessing and filtering, image formation and feature extraction.

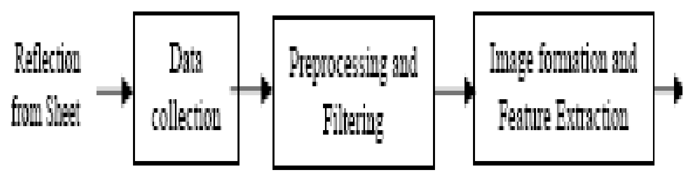

Figure. 1. Block diagram of processing stages.

The experimental set up shown in Fig.2, It uses *X- band radar* consists of reflex klystron as a microwave source, isolator, crystal detector, circulator and horn antenna. Circulator provides isolation from one port to other and used to route outgoing and incoming signal between antenna, transmitter and receiver. A single horn antenna placed on platform, was used for transmission as well as reception. It can slide both in horizontal and vertical direction.

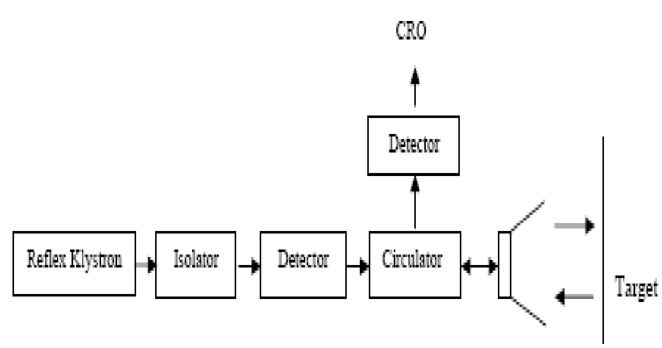

Figure.2. Block diagram of experimental set up.

*A. **Data collection:***

In this process reflections from each sheet were observed by scanning each sheet by plane polarized wave incident normally A region, also called a grid of size one meter by one meter was taken for observation and sheet was placed exactly at centre of scanning area at a range of approximately 30cms. from platform and reflections were observed at space of five cms. along X and Y direction over a length of one meter as shown inFig.3.[6].

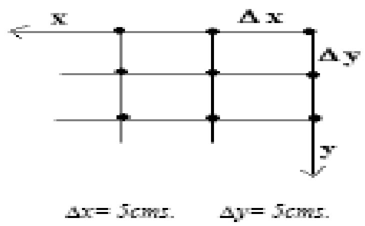

Fig.3. Grid for scanning

The dot shows the point where antenna was placed for data collection thus a data vector of size 20*20 was measured for each sheet of material, size of sheet was 30cms.*33cms.taken for observations. The reflections collected by horn can be detected by crystal detector, it's output is directly proportional to reflected power hence it can be observed on CRO.

III. PREPROCESSING AND IMAGE FORMATION

Before information in raw images can be utilized correctly, it must be processed to remove undesired system and ground effect. To make observations independent of range, observed data has to be calibrated with metal sheet using "(1)"

$$E_0 = E / E_{metal} \quad (1)$$

Where, E_{metal} is reflections of metal sheet of size, one meter by one meter was taken for calibration , E_0 is calibrated data and E is observed data .Calibrated data was processed in MATLAB 7.7, using DIP tools and raw images are obtained as shown in Fig.4.

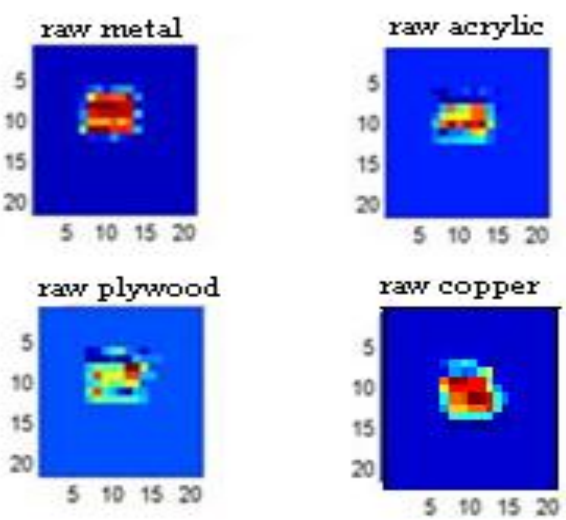

Figure.4.Raw Images

As there is overlapping of antenna swath during scanning so filtering was performed in spatial domain to overcome this effect. Finally thresholding technique was applied to discriminate between object and background [7]. Processed images, based on dielectric characteristics of material are obtained as shown in Fig.4.

IV. FEATURE EXTRACTION

Various image based features such as Entropy, Standard deviation, Energy and Normalized sum of image intensity etc. are calculated using ". (2) to (5) "respectively.

$$Entropy = \sum_{q=1}^{Q} P_q \log_2 P_q \quad (2)$$

Where, p_q is ratio of window image intensity to total image intensity.

$$Standard\ Deviation = \frac{1}{N}\sum_{q=1}^{Q}[f(x_q, y_q) - m] \quad (3)$$

Where, m is mean value of image $f(x, y)$, here $N = 400$.

$$Energy = \sum_{q=1}^{Q}|f(x_q, y_q)|^2 \quad (4)$$

Where, $f(x, y)$ is pixel intensity at position (x, y) in image.

$$Normalized\ sum\ of\ image\ intensity = \frac{\sum_{q=1}^{Q}|f(x_q y_q)|^2}{\left(\sum_{q=1}^{Q}|f(x_q y_q)|\right)^2} \quad (5)$$

Where, f (xq,yq) is pixel intensity at position (x,y) in image.

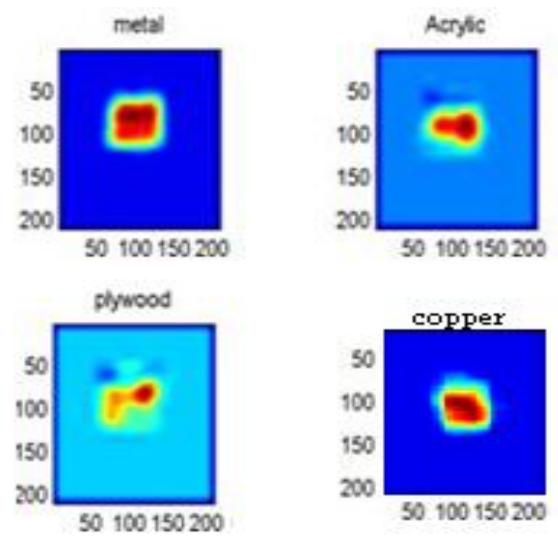

Figure.5 .Processed images

V. RESULTS AND DISCUSSION

After scanning the sheets of different material in free space with x-band radar, at frequency 8.5 GHZ, raw images of sheet of each material was obtained shown in Fig.4. Further filtering technique in spatial domain is adopted to obtain processed images of each shown in Fig.5.The image based features for each material is calculated and given in Table 1. There is large variation in features of metallic and dielectric material e.g. Energy of metal is much higher than dielectric, where as variation in acrylic and wood feature is small. It indicates that classification as Metal or Non metal can be done using image based features. It shows that the reflections from metal are more than that of dielectric material and all features are based on electromagnetic property (dielectric characteristics) of material.

Table 1. Image based features of target materials

Features	Metal	Acrylic	Wooden	Copper
Entropy	3.3789	2.8723	2.9199	3.5682
Std. Deviation	0.1495	0.0429	0.0286	0.1366
Energy	2.7301	1.3571	1.2619	2.7562
Normal Sum of Image Intensity	0.0045	0.0026	0.0024	0.0060

VI. CONCLUSION

In this work, classification of material based on their reflective property has been presented. This system allows discriminating different material having different dielectric constant. The experimental results show that implemented system exhibits good performance and success of image based classification depends on selection of feature. This method has just tested on small data sets , however more samples of metal and dielectric material can be taken for observation and work can be extended for classification using additional features such as electromagnetic and spectral features and combing them to use as input to classifier such as Support Vector Machine or Neural Network.

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