DETECTION OF OIL SPILL POLLUTION ON WATER SURFACE USING MICROWAVE REMOTE SENSING TECHNIQUES BY EXPERIMENTAL WORK

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Abstract - Oil spill pollution is a major threat to ecosystem of different water surfaces, therefor many researches and resources were deployed and still to monitor and detect oil spills on water surfaces. Ocean and river pollution monitoring mainly oil spills is performed by using microwave energy due to its ability to operate during day and night and its capability of penetration through fog and clouds, therefor this study is focused on the mechanism and parameters used to detect oil spills through microwave energy. In this study experimental work conducted to detect Iraqi crude oil characteristics by microwave energy and find the radar cross area values of the Iraqi oil and other materials as well that commonly exist in the same medium with the crude oil on water surfaces. The results and data set produced is very useful to further researches on the same field as no previous researches were conducted on the same field with data set.

Keywords - Oil Spill Pollution, Microwave Energy, Iraqi Crude Oil, Radar Cross Section

I. INTRODUCTION

Oil spill pollution is a major threat to ecosystem of different water surfaces, the increase in oil industry and demand led to the increase in oil products shipping around the world using sea and ocean and connected water channels as a mean to transport goods including crude oil and oil products around the world. Iraq is not a different case considering it's ranking as global oil exporter with heavy production and exporting in the south portal of it.
A quick glance at Iraq in terms of oil production and exporting clearly shows that this country still have strong position among the leading rich of oil countries. According to oil and gas journal, Iraq's proven oil reserves are 115 billion barrels with additional increase 45 to 100 billion barrels (bbls) of recoverable oil.

The main technology used commonly worldwide in the field of oil spills detection on water surface is the radar sensors through microwave energy. Beside its technical features, it's considered as the most cost effective, covering wide areas and ease of access that brought it to this level of popularity in this field. Previous studies concluded many recommendations on this regard, detection of oil spills on water surface and the distinction between the existence of oil on sea water can be achieved by EM waves targeting the oil-water medium as the reflection coefficient parameter can be extracted as the reflection values change with the range of the EM frequencies[6].

Yuanming Shu found that the use of spatial density thersholding on the dark spots detection from SAR images is countable and productive and time effective to be adopted as a process for oil spills detection on water surfaces in real events [7]. Different types of oil should be tested and listed in databases as references for future studies and assessment of oil spills risks as recommend by Jagos Radovic [8].

II. THE STUDY FOCUS

Oil spills happen on frequent bases either due to operational cause or accidental cause or in some cases due to illegal discharges from oil tankers. Based to the knowledge of the author, the current processes and protocols used to detect oil spills in Iraq are based on visible observations. We aimed to study the oil spill detection on water surface using microwave energy. Despite that other tools and technology are available for the same purpose, but one of the most reliable and commonly used tools is the radar satellite images depending on microwave energy because of its usability in all-weather types and without the need to sunlight where it can be used during night time.This study employed one experimental work on submitting samples of Iraqi crude oil, ships engine oil, pure and contaminated water to microwave energy with a predefined set of frequencies to create a foot print of Iraqi crude oil RCS and the other materials as well so it can be used as foot print when working on SAR image to extract RCS and compare with the foot print for validation. The importance of this study comes from that lack of previous work on such field in Iraq and being important due to the available free technology to detect oil spills on water surface by SAR images and image processing applications like sentinel 1 application platform where such work can be matched with the foot print table for validation.

III. OIL SPILL DETECTION IN REMOTE SENSING

Within the different applications of remote sensing in the use of environmental studies, remote sensing in

oil spill detection became essential within the development of sensors, technology and soft wares to minimize costs and time. Since the 80's a great progress have been achieved in this field. And now tools and resources are available even for free access to the aim of oil spill detection on oil surfaces. Oil spill detection in remote sensing deployed different equipment and tools for that purpose including (aircrafts, visible sensors,infrared,Ultraviolet, Laser Fluor sensors and Microwave Sensors), however radar remain the main tool to be used in the application of oil spill detection on water surface, due to its ability of covering wide areas and operational property to work all day without any dependency on sun light or clear weather conditions [3].

Sea surface characters like color, temperature, roughness and reflectance are detected by remote sensors, two types of sensors act in this regard, passive and Active. Remote sensors work by detecting sea surface propertiesSuch as color, reflectance, temperature and roughness (SEOS, Introduction 2008).

Any subject interaction with microwave energy is mainly related to the basic principle of radar and radar equation, which is related to the power received by the target, target parameters and radar parameters. Considering that path losses are neglected.One form of radar equation can be written as:

$$Pr=(P_tG_t/4\pi R^2)*(\sigma_{rt}*A_r/4\pi R^2)$$

Where,

- Pr received power at polarization r
- Pt transmitted power at polarization t
- Gt gain of transmitting antenna in the direction of the target at polarization
- R distance between radar and target
- σrt (radar cross section), the area intercepting that amount of incident power of polarization t which, when scattered isotropically, produce an echo at polarization r equal to that observed from the target.
- The EMR at the target given by $P_tG_t/4\pi R^2$
- The expression when multiplied by σrt indicates the total EMR scattered by the target which can be denoted by Ps.
- Pt, G and λ are parameters of the radar system

The equation for the received power indicates that Pt, G and λ are parameters of the radar system, and R is determined by the location of the radar with respect to the target. The design and operation of radar is such that these quantities normally either remain constant or are known during the use of radar. The factor that governance the average return power strength as a function of the way in which the incident EMR interact with the surface is therefore σrt. The scattering coefficient σ°, in general, is related to polarization, look angle, wavelength and interaction property of the target: geometric, dielectric and conductive. As transmitted power, antenna, wave length and polarization are fixed by the design of the system, only the average return power strength change with σ°.

Radar return from a target depends on the strength of transmit energy and the reflecting or scattering capability of the target. The targets of radar tend to scatter with different strengths and directions. And their scattering characteristics may be conveniently described in terms of their scattering, or reradation, patterns (plots of signal strength versus angle). The backscattering pattern is of particular interest to radar, it shows the return-signal strength in the opposite direction of the incident radiation.

Every material has a relative complex dielectric constant,ε, consist of real part, ε', and imagery part ε". By relative, we mean that ε is the dielectric constant of a material, normalized to the permittivity of free space, ε°. Often, ε' is referred to as the relative permittivity and ε" is referred to as the loss factor [5].

Radar scattering from water surface

Radar return from water is expressed in the terms of the average radar scattering cross-section per unit area (NRCS), or referred to as the scattering coefficient σ°.

Which is normally presented in terms of decibels as a function of the incidence angle for each associated wavelength and polarization condition [5].

IV. METHODOLOGY

The methodology used in this study was based on site visit to Basra (south of Iraq) to collect the samples of crude oil, engine oil, pure water and contaminated water figure [1]. Samples of each of the liquids mentioned were collected from the field and tested by vector analyzer network to measure it's interaction with microwave energy figure [2] [3]. The final results were a footprint and data set for each of the samples tests.

The concept of VNA is to hit the target with a microwave energy, in this experiment we used the range between 4.5 – 6 GHZ frequencies. And then we measure the S parameters (scattering), mainly s1 which indicate the permittivity of the target. The final results obtained were used as a reference for crude oil scattering behavior.



Figure 1 - samples of crude oil, engine oil, fresh water and sea water gathered from Basra city.



Figure 2 - VNA device that was used for the test.



Figure 3- the portal to measure S parameters

The crude oil used as sample in the lab experiment showed an interesting interaction with the microwave energy, during the experiment we started with a frequency of 4.5 GHZ and concluded with a frequency of 6.0 GHZ. The sample RCS was at its lowest in the frequency range 5.5 – 5.6 GHZ, which is very combatable with the recommendations of using a frequency range around 5.5 GHZ in oil spill detection sensors figure [4].

VI. RESULTS AND DISCUSSIONS

For the experimental work, the aim was to create data set for Iraq crude oil, to be used as reference in checking the radar image oil spill detection results, and to create a footprint of crude oil behavior in different microwave energy frequencies. From the figure [4] we can clearly see the behavior of oil to the different frequencies applied, for the frequency range between 5.5 to 5.6 ghz the db values range between -25 to -24 which is the optimal range for microwave sensors to detect oil spills in radar images.

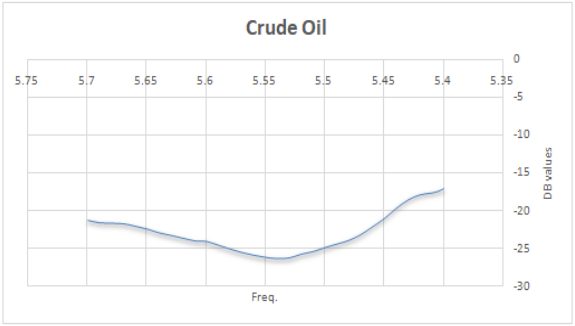


Figure 4- crude oil interaction with EM energy

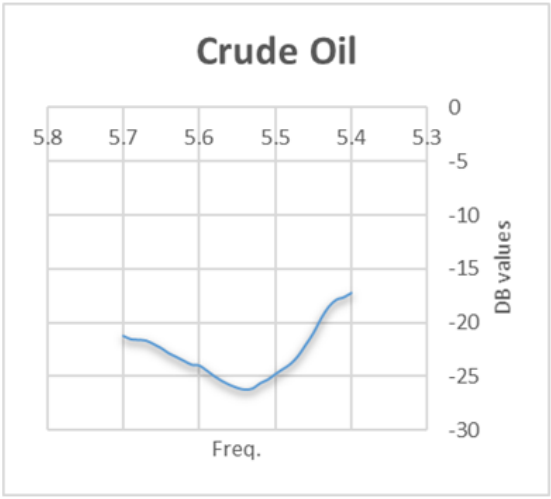


Figure 5 - the curve represents the readings of microwave energy on Iraq crude oil.

In order to provide reliable study for future development, we also tested other samples interaction with different microwave energy frequencies, thus to create a foot print for the liquids that are more likely to be in the same medium within the crude oil, such as ships engine oil, fresh water and sea water taken from Basra sea water figure [6,7,8].

The results shown in figures [5, 6,] can be used to further develop algorithms and mechanism in detecting oil spills out from enging oil spills and sea water on water surfaces.

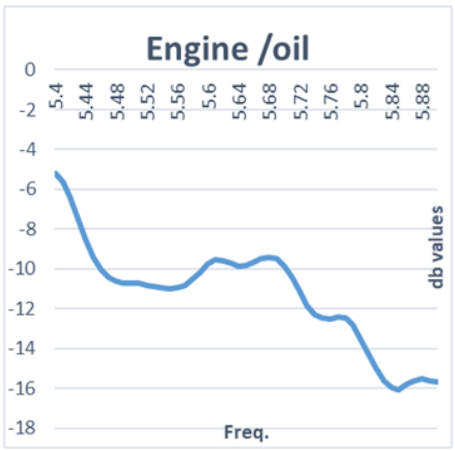


Figure 6- engine oil RCS interaction with microwave energy.

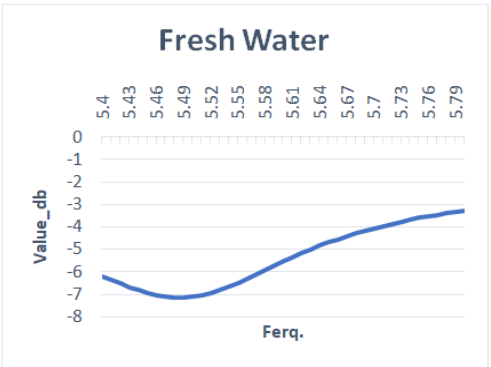


Figure 7 - sea water RCS interaction with microwave energy.

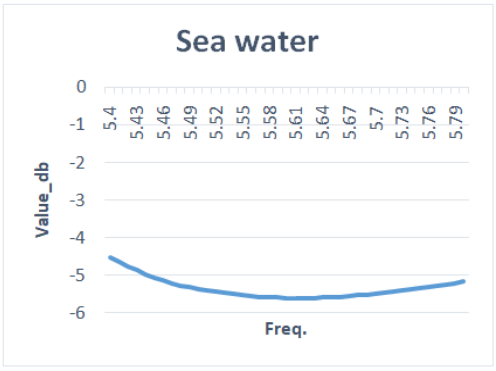


Figure 8- fresh water RCS interaction with microwave energy.

The tests approved that by using the microwave energy on specific frequencies, it's easier to distinguish the oil from engine oil and water on open water surfaces. The difference in dielectric property of each subject can be invested in the purpose of oil spill detection on water surfaces. Where this can be important in a specific range of EM frequency as each material has its own curve print and therefor it can be distinguished based on its RCS values.

VII. CONCLUSIONS

Our conclusion can be summarized in the following points:

1. Oil spill detection on water surfaces using microwave energy is the most reliable, cost effective, time saver and advantage technology to be used in that purpose.
2. A data set of crude oil NRCS was created based on experimental work plus other data sets as well to engine oil, pure water and contaminated water. The data set can be used as a footprint and reference for future use of oil spill detection applications on water surface to validate the results with actual ground truth values of Iraq crude oil.
3. This study can be used as a reference to serve the governmental and other agencies whom are in affiliation with the oil spills emergency response and detection.
4. It's advised to conduct further studies and researches on this topic since the use of the technology is now available for public access offered by ESA, furthermore the technology can be used to identify illegal oil exporting through coastlines, ships detection and monitoring and other applications as well.

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