RADIO FREQUENCY TECHNIQUE FOR ANALYSIS OF UREA CONTENT IN SOIL

Sulaxana R.Vernekar[1], Ingrid Anne P. Nazareth[1], Jivan S. Parab[2], Gourish M. Naik[3]
[1]Ph.D Scholar, [2]Assistant Professor & [3]Professor and Head,
Department of Electronics, Goa University, India.

ABSTRACT
The paper presents a novel approach for determining soil nutrient content using Radio Frequency signals. The study is conducted to obtain the frequency response of urea. A shielded cell is designed for obtaining the frequency response of urea solution. A signal generator and a spectrum analyzer are used to obtain the RF responses of urea with different concentrations in the range of 10MHz – 4.4GHz. It is observed that at certain frequencies, the response of urea to RF changes in accordance with the changes in the concentration of urea and at other frequencies, it has a flat response. These results can be used for the prediction of unknown concentration of urea based on a multivariate system. The variation in the RF response can be fed to a multivariate system analyzer to estimate the concentration of urea in an unknown sample.

KEYWORDS: *RF, urea, multivariate analysis.*

I. INTRODUCTION

To enhance agricultural production, soil should contain proper nutrients required for the plant growth. Agricultural production throughout the world has tremendously increased due to the use of commercial N, P and K fertilizers. However, it has also been observed that excessive use of these fertilizers has created a lot of problems such as contamination of surface and groundwater. In order to avoid such problems, we can use precision farming technique, which is based on the application of just the right amount of nutrients at the right location based on the crop requirements. This technique is called as Site Specific Crop Management (SSCM) and aims to improve the profitability and it can also help in protecting soil and water resources. Kitchen et al have shown how precision farming techniques can increase profitability [1].

Soil nutrient testing is one method which is used to determine the available nutrient status of soil and the efficient use of fertilizers. Soil testing has been instrumental in determining insufficient or excess nutrients levels. Hergert et al have shown how the economic environment of crop production has changed substantially since the introduction of soil fertiliser recommendations [2]. However, conventional soil testing methods are found to have many limitations such as the number of samples analyzed per field, the cost effectiveness and time consumption. Hence, it is difficult to characterize spatial or temporal variability in soil nutrient concentrations within fields. At National University of Miryang, Korea, H.Kim et al have done extensive studies on soil sensor development and an excellent comprehensive study has been published elsewhere[3]. For e.g. accurate monitoring of soil nitrate has been limited by the relatively long turn-around time of laboratory analysis because soil nitrate can be easily lost by leaching and denitrification between the time of testing and plant uptake. To reduce this turnaround time Ehsani et al have suggested PLS and PCR technique for signal processing [4]. Mi Yeon Cho have used poly (ethylene oxide)-urea complex film to understand the electrical characteristics as a function of urea concentration [5].

In this manuscript, the various methods of estimating soil parameters are given under soil nutrient sensing approaches. The experimental setup gives the construction of urea cell and also the technique used for measurement of RF absorption. Section III gives the results and discussions where in the response of urea with different concentrations are plotted against the frequencies. The concluding section gives the present scope of the research work and also gives the future direction of the research work.

1.1 Nutrient sensing approaches

Many sensing techniques are available for the measurement of soil macronutrients (N, P, and K). These techniques are based on one of the two measurement methods:

- Optical sensing that uses reflectance spectroscopy to detect the level of energy absorbed/reflected by soil particles or nutrient ions
- Electrochemical sensing that uses ion-selective electrodes which generate a voltage or current output in response to the activity of selected ions [6].

This paper describes a novel method of estimating urea content in soil based on FPGA using multivariate system.

II. EXPERIMENTAL SETUP

In order to acquire the signals from the soil a contact type sensor based on the four probe method is used. Lund eta al discusses the techniques that are used for soil EC mapping [6]. Traditionally, a four probe method is used to measure the resistivity of materials accurately by injecting current in the sample from outer electrodes and measuring the potential difference developed in the sample due to the passage of current between the intermediate electrodes, which eliminates all the errors due to ohmic contact. This method can also be used for measurement of soil contents by injecting high frequency signals at outer electrodes and measuring the signal strength at intermediate electrodes. The schematic of the designed cell is as shown in Figure 1.

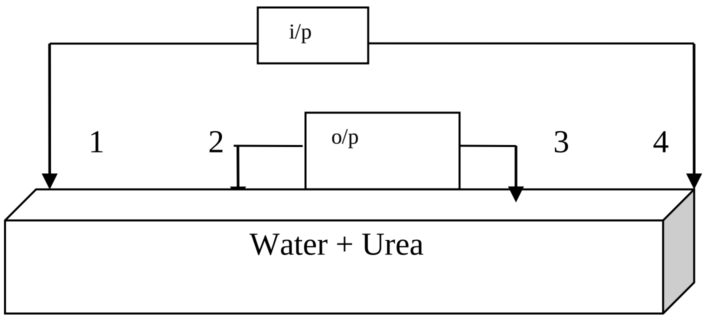


Figure1. Schematic of the designed cell

The cell is made up of acrylic material and has dimensions 7.5”x0.5”x1.125”. The outer two electrodes are made using stainless steel plates and the inner two electrodes are made up of stainless steel mesh. This is done so that the signal flow is not hampered.

The cell is connected to the instrument with RF cables and SMA connectors. This was done to prevent any attenuation in the signal due to wires. The input signal is applied between the first electrode and the fourth electrode whereas; the output is taken at two points, i.e. at electrode no. 2 & at electrode no. 3. It was observed that, there was a lot of noise due to the random signals (radiation tower etc.) introduced in the frequency response. These factors were minimized by shielding the cell in an iron container and properly grounding the same. A Signal Hound tracking generator USB-TG44A and a Signal Hound spectrum analyzer USB-SA124B were used for obtaining the response. The cell was tested for noise free measurement using standard RG cable of similar attenuation as that of the cell. The response of the cable was found to be similar to the attenuation levels as per the specifications provided by the manufacturer. The experimental setup is as shown in Figure 2.

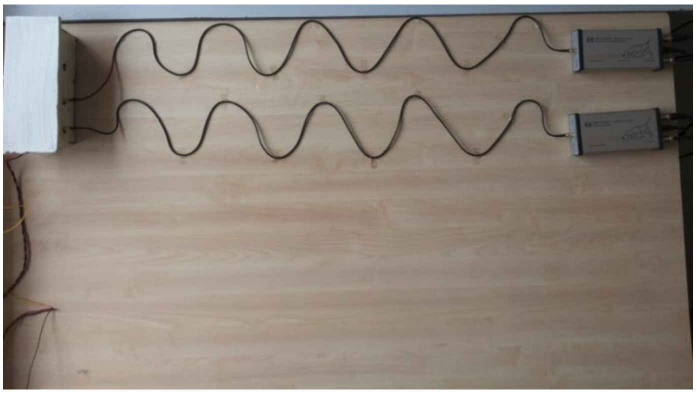


Figure2. Experimental setup

From literature, it is observed that, urea content in normal Goan soil is of the order of 43.43kg/ha. Based on this, urea samples were prepared. Different concentrations of urea mixed with distilled water were taken and placed in the cell. Signal is injected between electrode no.1 with ground at electrode no.4. Signal reaching at electrode no. 2 is measured w.r.t ground. The cell should have an impedance matching to that of the signal generator so that there is no reflection. The cell has a provision to vary the impedance of the sample column to match the source impedance. The impedance can be varied by changing the level of the liquid in the cell or changing the width of the cell. Signals of varying frequencies are applied and the output is observed.

III. RESULTS AND DISCUSSIONS

Figures 3 to 10 describe the results obtained in the form of graphs. The graphs show the responses of water and urea solutions of different concentrations at various frequency ranges. The concentrations of urea are denoted as 0.5Urea which corresponds to 150mg of urea in 20ml of distilled water, 1Urea corresponds to 300mg of urea in 20ml of distilled water, 2Urea corresponds to 600mg of urea in 20 ml of distilled water and 3Urea corresponds to 900mg of Urea in 20ml of distilled water. It may be noted that figures are shown only in the range where there is observable response. Figures with flat response are not shown.

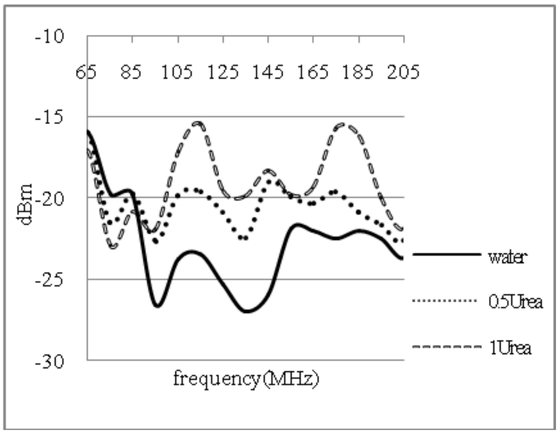


Figure3. Frequency response of urea in the range of 65-205MHz

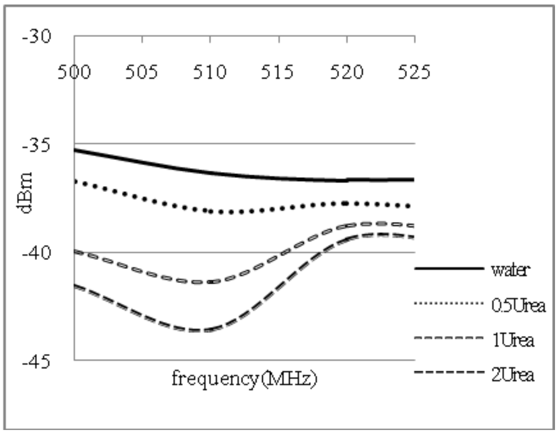


Figure4. Frequency response of urea in the range of 500-525MHz

In Figure 3 above, it is observed that variations in the frequency response are obtained according to the changes in the concentration of urea. At 75MHz, the attenuation increases as the concentration of urea is increased. At 95MHz, it is seen that the attenuation decreases as the concentration of urea is increased. Same can be observed at 115MHz, 145MHz and 175MHz.

Figure 4 shows that the attenuation is increasing with increase in the concentration of urea over a frequency range of 500-525MHz. A trough is observed at 510MHz which tend to sharpen as the concentration of urea is increased.

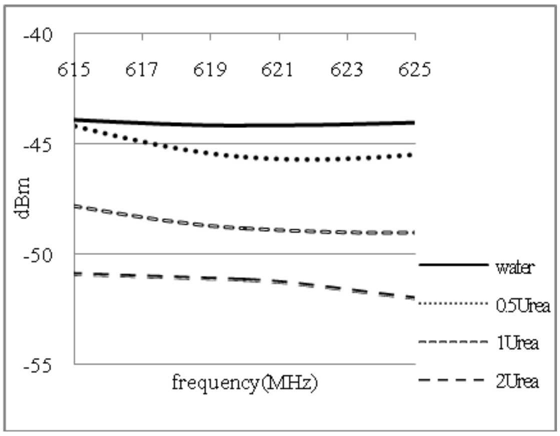


Figure5. Frequency response of urea in the range of 615-625MHz

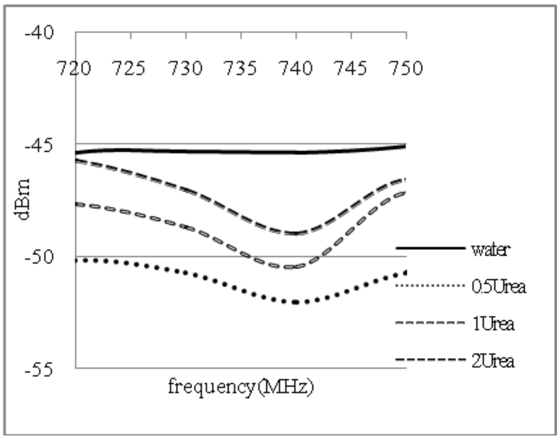


Figure6. Frequency response of urea in the range of 720-750MHz

Figure 5, gives the frequency response of urea in the range of 615-625MHz. It is observed that, as the concentration of urea increases the attenuation increases.

In Figure 6, it is observed that the attenuation increases as the concentration of urea increases and a trough is observed at 740MHz.

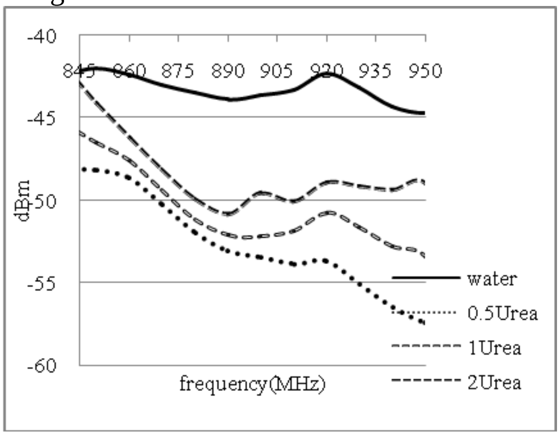


Figure7. Frequency response of urea in the range of 845-950MHz

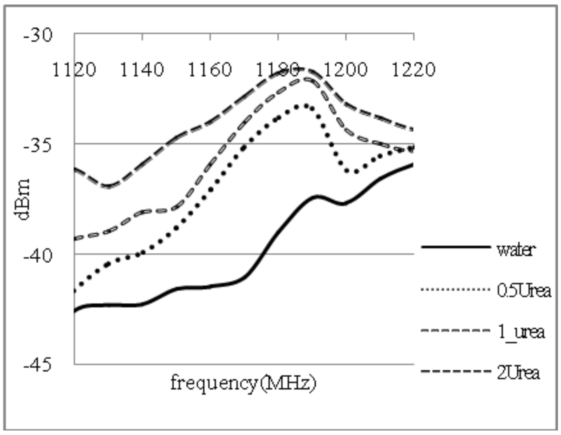


Figure8. Frequency response of urea in the range of 1120-1220MHz

Figure 7 shows that, for 0.5Urea two troughs are observed at 890MHz and 910MHz which disappear for 1Urea and 2Urea. A peak is observed at 920MHz for all the three concentrations of urea.

Figure 8 shows the response of urea for frequencies from 1120-1220MHz. We observe that there is a decrease in the attenuation as the concentration of urea is increased and a peak is observed at 1190MHz.

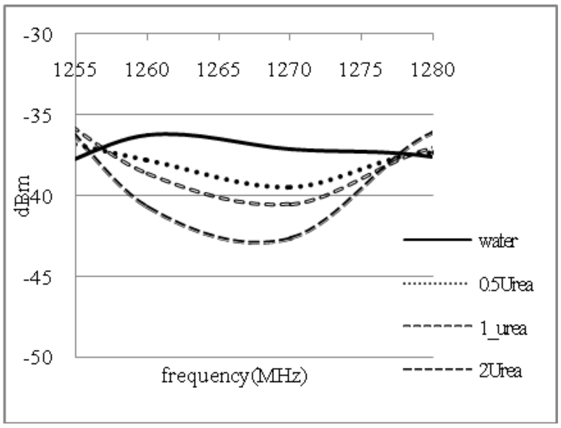


Figure9. Frequency response of urea in the range of 1255-1280MHz

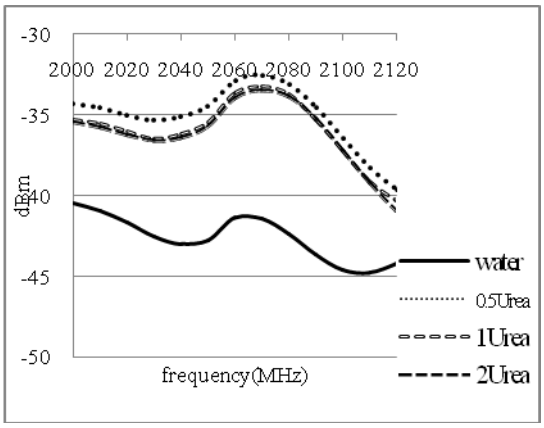
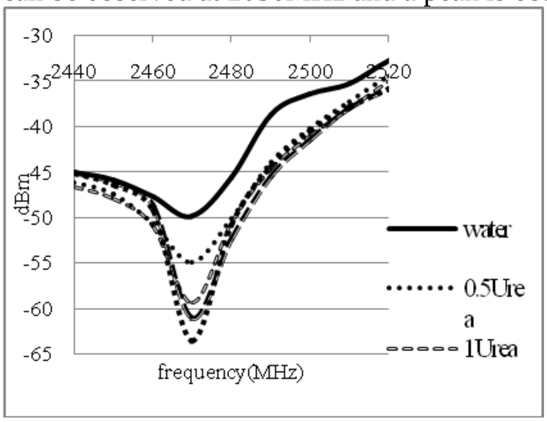


Figure10. Frequency response of urea in the range of 2000-2120MHz

In Figure 9, we see that the attenuation increases with the increase in the concentration of urea. Figure 10, the attenuation is found to decrease with increase in the concentration of urea. A shallow trough can be observed at 2030MHz and a peak is observed at 2070MHz.



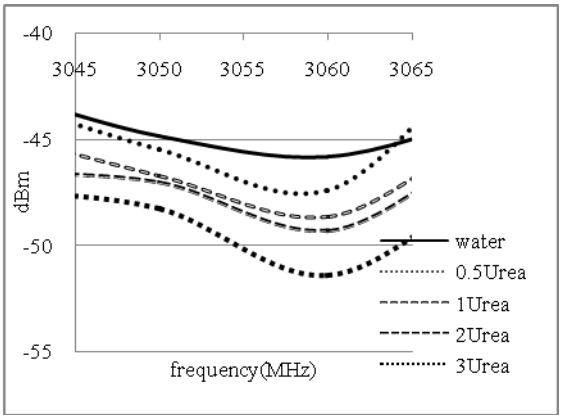


Figure11. Frequency response of urea in the range of 2440-2520MHz

Figure12. Frequency response of urea in the range of 3045-3065MHz

From Figure 11, we observe that there is a sharp trough at 2470MHz and the attenuation level increases with increase in the concentration of urea.

Figure12 shows a shallow trough at 3060MHz and the attenuation level is found to increase as the concentration of urea is increased.

Variations at certain frequencies are observed due to molecular absorption of urea however, molecular study of urea is not important here as we use analytical tools to estimate the quantities. It is observed that at some frequencies, attenuation increases with increase in the concentration of urea and at certain other frequencies the attenuation is found to be decreasing with increase in the concentration of urea.

The frequency response of urea is changing in accordance to the variations in the concentration of urea. These frequency points at which the variations are observed can be fed as input points to a multivariate system to predict the concentration of an unknown sample of urea.

IV. CONCLUSION

Preliminary studies are limited only to urea concentration and the same technique can be extended for finding the frequency responses of other soil components. These responses can be combined together and can be used for predicting unknown soil component based on multivariate analysis. This method can be of great significance in the field of agriculture, for predicting soil content in real time, thus aiding in SSCM. The new micro electronics techniques such as FPGA, can be used to incorporate multivariate block for signal processing and a user friendly device can be made available to farmers for soil analysis.

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AUTHORS

Sulaxana R. Vernekar is currently pursuing her Ph.D. in Electronics at Goa University. She is Assistant Professor in the Department of Computer Science at GGPR College of Commerce, Ponda-Goa and has 17years of teaching experience. She has participated in number of symposium / workshops and presented her research work. Her areas of interest are agricultural electronics, micro electronics and digital signal processing.

Ingrid Anne Nazareth born in Sharjah, U.A.E. is currently a Ph.D. Scholar in the Department of Electronics, Goa University (India). She completed her Masters in Electronics having secured the 1st place and is an awardee of the 'IV SERC School in Physics Gold Medal'. She was appointed a project fellow in the project "Design of Hyperspectral Smart Sensors using soft-core processors and IP cores". She was also a visiting faculty at the Goa University. Her research interest is in the field of Biomedical Electronics. She has attended a number of National Symposiums and Conferences where she has presented her research work.

Jivan S. Parab, Born in Goa, India on 26th March 1983. Obtained Bachelor and Master degree in Electronics from Goa University, Goa, India. He worked initially as Research Student on project 'Non-Invasive Glucometer', funded by Indian Council of Medical Research, New Delhi. He completed his Ph.D on the same topic and is currently working as Assistant Professor, Department of Electronics, Goa University. He has co-authored two books with Springer (Netherland), in the area of Embedded System and programming. His areas of interest are Digital Signal Processing, Embedded Systems, Digital communication.

Gourish Naik obtained his Ph. D from Indian Institute of Science, Bangalore (1987) and served the institute as research associate in the areas of Optoelectronics and Communication till 1993. For the last 15 years, he is associated with Goa University Electronics Program. He is the founding head of University Instrumentation Center and established Fiber optic LAN & Wireless Communication Network at Goa University. He is also coordinator of DEITI (an educational broadcast studio supported by Indian Space Research). His other commitments are regulating digitization Center at Goa University to support the various Digital repository projects like DIGITAP (Digital Repository for Fighter Aircrafts Documentation) of Indian Navy, Million Book project of Ministry of Information Technology and Antarctica Study Center (NCAOR). He has to his credit around 50 odd research papers published in National and International Journals and has presented research works at various National and International Forums. He has delivered several key note addresses and invited talks at various institutes and also authored a book on Embedded Systems published by Springer (Holland). He is a member of Goa State Rural Development Authority and also advisor for Directorate of Education. He is also the chairman of Goa University Technical Advisory Committee. Presently he is the Head of Electronics and Instrumentation division at Goa University.