A Comparison of Path Loss Variations in Soil using Planar and Dipole Antennas

Abdul Salam
Department of Computer and Information Technology
Purdue University, USA
salama@purdue.edu

***Abstract*—In this paper, an empirical investigation of propagation path loss variations with frequency in sandy and silty clay loam soils has been done using planar and dipole antennas. The path loss experiments are conducted using vector network analyzer (VNA) in sandy soil testbed, and greenhouse outdoor silty clay loam testbed for different operation frequencies and communication distances. The results show that the planar antenna can be used for subsurface communications in a wide range of operation frequencies. The comparison paves the way for development of sensor-guided irrigation system in the field of digital agriculture.**

I. INTRODUCTION

Digital agriculture [1], [2], [3], [4] is the area in which technology is used to effectively manage agriculture by understanding the temporal and spatial changes in soil, crop, production, and management through innovative techniques. The analysis of the communication path loss is vital for an efficient communication system design in sensor-guided irrigation management system. To investigate propagation loss variations, the path loss experiments are conducted in sandy soil testbed, and greenhouse outdoor silty clay loam testbed using a wideband planar antenna [5] and dipole antennas.

II. EXPERIMENT SETUP

In a sandy soil testbed [6], two planar antennas, are buried at $20cm$ depth at a distance of $1m$. The return loss and path loss measurements are taken. To analyze the effects of a planar in the middle of two planar, obstructing the communications, another planar antenna is buried in the middle at $50cm$ distance and same depth ($20cm$). Accordingly, the path loss and return loss measurements are taken again for $50cm$ distance and $1m$ distance.

In the greenhouse, another testbed of planar antennas is commissioned in silty clay loam soil. To compare the results of the experiment with sandy soil testbed, same empirical parameters are used. First, the path loss and return loss measurements are taken for planar buried at $1m$ distance at $20cm$ depth. Afterward, another planar is installed at $50cm$ distance and $20cm$ depth, and return loss and path loss measurements are taken, again, first for $1m$ distance and then for $50cm$ distance.

To compare the results of planar antennas with dipole antenna, a testbed of dipole antennas is developed outside of the greenhouse in silty clay loam soil. In this testbed, three dipole antennas are buried in soil at $50cm$ distance each and burial depth is $20cm$. The physical properties of sandy soil and silty clay loam soil are shown in Table I. The results of this empirical campaign are presented in Section III. The return loss of dipole and planar antennas are shown in Fig. 1. The comparison of dipole and planar return loss in same soil is given in Fig. 2.

TABLE I
PHYSICAL PROPERTIES OF TESTBED SOILS.

Textural Class	**Sand %**	**Silt %**	**Clay %**
Silty Clay Loam	13	55	32
Sandy Soil	86	11	3
Silt Loam	33	51	16

III. RESULTS

The planar antenna path loss at $50cm$ and $100cm$ in sandy soil and silty clay loam testbed is shown in Fig. 3(a) and Fig. 3(b), respectively. In sandy soil, there is 14dB difference in path loss when communication distance is increased from $50cm$ to $100cm$. Similarly, in silty clay loam soil, at frequencies higher than 500MHz path loss is increased from 19dB.

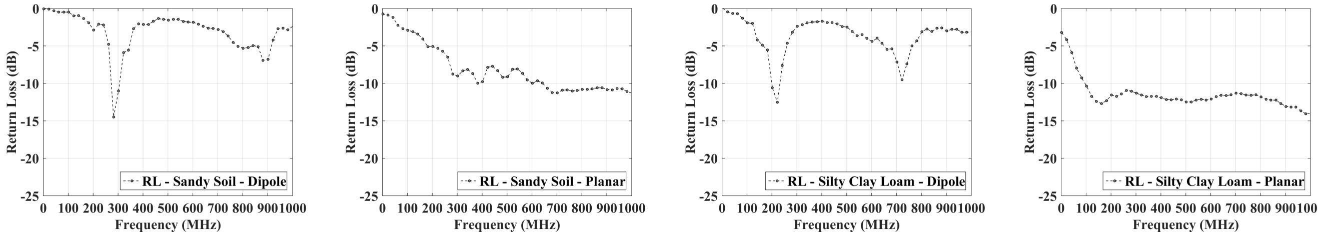
In Fig. 3(c), the path loss comparison of dipole and planar antenna is shown in sandy soil testbed at $50cm$. The variations in path loss with change in frequency, present in the case of dipole antenna, are not observed when measurements are taken using planar antenna. Similarly in Fig. 3(d), the path loss comparison of dipole and planar antenna is shown in silty clay loam testbed at $50cm$. As observed in sandy soil, the variations in path loss with frequency present in dipole antenna are not observed when using planar antenna.

The change in path loss when a planar is buried between planar antennas is shown in Fig. 4(a) for sandy soil and in Fig. 4(b) for silty clay loam. In sandy soil, difference of 8dB is observed at frequencies less than 400MHz, and in silty clay loam overall there is difference except 4-5 dB difference at 300 MHz and 800 MHz.

The path loss difference using same antenna at $50cm$ and $100cm$ distance in different soils is presented in Fig. 4(c) and Fig. 4(d), respectively. A 28dB lower path loss is observed in sandy soil when compared to silty clay loam both at 50cm and 100cm distance. This happens because the sandy soil holds less bounded water which is the major component in soil that absorbs electromagnetic waves.

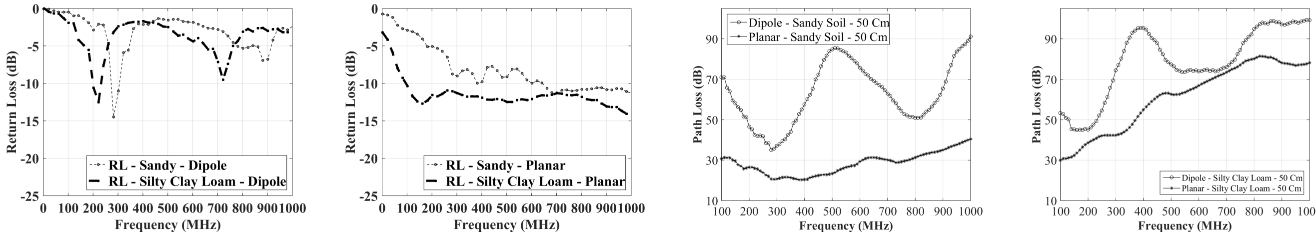
IV. CONCLUSIONS

A propagation path loss analysis has been presented using dipole and planar antennas in the sandy and silty clay loam. In



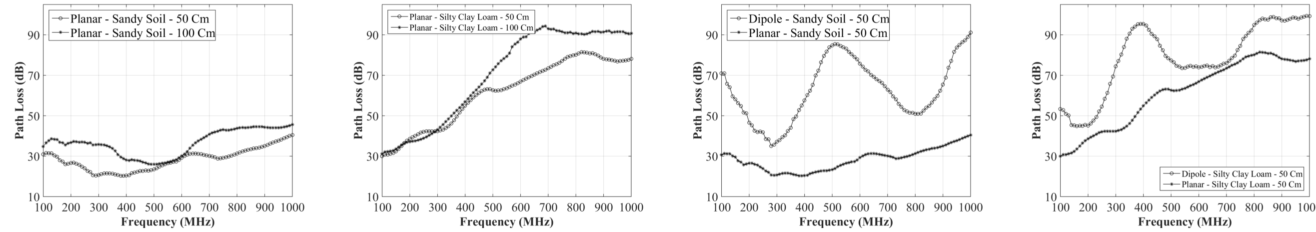
(a) (b) (c) (d)

Fig. 1. Return loss: (a) sandy soil dipole, (b) sandy soil planar, (c) silty clay dipole, (d) silty clay loam planar.



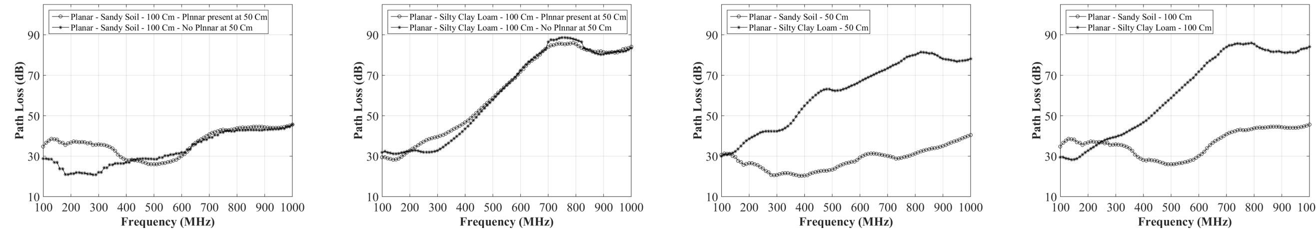
(a) (b) (c) (d)

Fig. 2. Return Loss Comparison: (a) Dipoles in Sandy and Silty Clay Loam Soil, (b) Planar antennas in Sandy and Silty Clay Loam Soil, (c) Dipole and Planar Antenna Path Loss Comparison in Sandy Soil at 50 Cm Distance, (d) Dipole and Planar Antenna Path Loss Comparison in Silty Clay Loam Soil at 50 Cm Distance.



(a) (b) (c) (d)

Fig. 3. (a) Planar path loss comparison in sandy soil at $50cm$ and $100cm$, (b) planar path loss comparison in silty clay loam at $50cm$ and $100cm$, (c) dipole and planar antenna path loss comparison in sandy soil at $50cm$ distance, (d) dipole and planar antenna path loss comparison in silty clay loam soil at $50cm$ distance.



(a) (b) (c) (d)

Fig. 4. (a) Effects of a planar between two planar antenna in sandy soil., (b) Effects of a planar between two planar antenna in silty clay loam soil, (c) Path Loss Comparison in Sandy Soil and Silty Clay Loam using Planar at 50 Cm, (d) Path Loss Comparison in Sandy Soil and Silty Clay Loam using Planar at 100 Cm.

the sandy soil, better radio wave propagation is observed. The results show that the planar antenna is more efficient for subsurface communications. The analysis is useful to determined inter-node distance in sensor-guided irrigation system.

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