Impact of Moisture Content on RFID Antenna Performance for Wood-Log Monitoring

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***Abstract*— In recent years, the use of RFID technology has gained popularity in the timber industry for wood-log monitoring. Harvested wood-logs are stored for different time periods before being processed. As a result, the moisture content in the stored wood-logs varies compared to the freshly-cut wood and it must also be noted that the moisture content of freshly cut wood differs from one log to another. Apart from storage time period of wood-logs, the environmental factors such as temperature, rain, snow and sun also contributes to the variation in the moisture content of the wood-logs. This variation of the moisture content changes the dielectric constant of the wood and hence, influences the characteristics of the RFID antenna. In this paper the impact of variations in moisture content in wood and its effect on the performance of the RFID antenna are studied.**

I. INTRODUCTION

Today, the use and deployment of RFID in the timber industry is growing [1]. Each RFID transponder often called a “tag” is made up of a chip, an antenna and a casing to protect the operating components against mechanical and environmental stress. Tags are either active which rely on an external battery for operation or passive which does not have a battery and relies on the energy radiated from the reader in order to trigger the chip and send back needed information. Since passive tags rely on the performance of the antenna, it is worthwhile studying the variations in antenna specifications and performance according to environmental changes.

II. RFID TECHNOLOGY IN TIMBER INDUSTRY

The wood supply chain from the forest to the factory is shown in Fig. 1. Marking of the logs is done by the collectors once the logs have been piled. The numbers stamped on the logs contain information that will be used for further processing of the logs. Usually each pile will be transported in two or more parts, and hence the numbers should be stamped in a way that each shipment contains at least one marked log. As a rule, at least 20 percent of the logs in a pile should be stamped, but in practice it is difficult to stamp the logs in a way that the 20 percent is evenly distributed among the pile. Hence the use of RFID technology reduces the labor of marking the logs in large quantities and guarantees that each shipment is marked correctly.

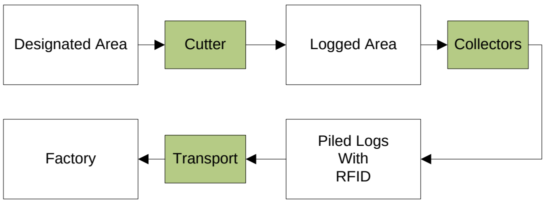

Fig. 1. The wood supply chain with RFID technology

All the operations shown in Fig. 1 are usually completed in a period of three to five weeks. During winter period, the process can take up to 15 weeks [1] and hence, the moisture content of the wood logs will vary according to different weather and environmental conditions [2]. As a result, the dielectric constant of the wood will also vary [3]. Since the antenna of the RFID tag is placed in proximity of the wood, the dielectric constant variations will influence the antenna characteristics.

III. THE EFFECTS OF MOISTURE CONTENT VARIATION ON DIELECTRIC PROPERTIES OF WOOD

Experimental data relating to the values of the dielectric properties of spruce and Birchwood measured at super high frequencies, negative temperatures and at moisture contents from 41% to 62% shows that in negative temperatures, the value of dielectric constant to some extent increases with increasing temperature, but it is less subject to the influence of moisture content than positive temperatures. Due to the fact that moist wood has a high ionic conduction, dielectric constant is higher at low frequencies. From data given in [3] it can be understood that the loss tangent of wood also changes at different frequencies and different moisture content. At frequencies below 10^3 Hz and moisture content varying from 20% to 100%, loss tangent increases with an increasing in frequency. From 10^3 Hz to 10^8 Hz loss tangent decreases by increasing frequency and at frequencies above 10^8 Hz it increases by increasing frequency [3].

IV. Design and Simulation Results

A. Antenna Design

For RFID application, since an omni-directional pattern is desired to achieve good readability a dipole antenna is used. The design in this study is a folded dipole, mounted on a polyamide substrate with a relative permeability (ε_r) of 4.3 and loss tangent of 0.004. The antenna is encapsulated in a casing of the same material as the substrate.

A schematic view of the whole setup is shown in Fig. 2.

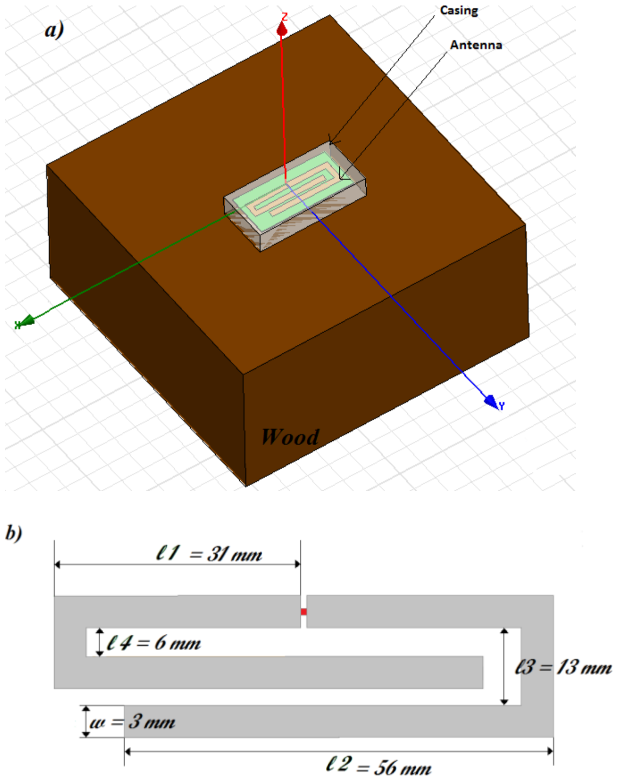

Fig. 2. Schematic view of antenna setup a) Antenna encapsulated in casing and mounted on wood block; b) Dimensions of simulated antenna

The antenna is designed to operate at 867 MHz when encapsulated and mounted on wood logs with dielectric constant of 3.2. The return loss at 867 MHz is -5.9dB with a peak directivity of 2.3 and radiation efficiency of 27%. This design was then tested on wood blocks with different dielectric constants and loss tangents according to different moisture content.

B. Read Range Calculations

The maximum reading range of the RFID was then calculated for each case using Friis transmission formula [4]:

$$R_{max} = \frac{\lambda}{4\pi}\sqrt{\frac{P_T\left(1-\eta^2{}_{reader}\right)Eff_{reader}D_{reader}\left(1-\eta^2{}_{tag}\right)Eff_{tag}D_{tag}\rho}{P_{tag\ min}}} \quad (1)$$

antenna parameters return loss (η_{tag}), radiation efficiency (Eff_{tag}) and directivity (D_{tag}) were extracted using Ansoft HFSS for the frequency of 867MHZ. The reader parameters for a hand held reader (XCODEIU9050 [5]) were return loss (η_{reader}) of 0.1, Radiation efficiency (Eff_{reader}) = 0.8, directivity (D_{reader}) = 0 dBi, transmitted power (P_t) = 29.5 dBm and polarization efficiency is assumed to be 1.

C. Simulation Results

The set-up shown in Fig. 2a. is simulated for six different moisture contents. The results of simulation are summarized in Fig. 3. Based on the simulation results the maximum reading ranges along with the percentage change are shown in Table I. Loss tangent, moisture content and dielectric constant data are taken from [3]. Based on data from [3] the read range calculations are done by using equation (1) and the results are represented in Table I which show that for a normal moisture content of 20% maximum reading range was found to be 2 meters. For 60% increase in moisture content maximum read range distance was reduced by 0.4 meters that is 20% change. With 10% reduction in moisture content the read range was reduced by 0.2 meters that is 10% change.

TABLE I

Antenna properties at different dielectric constants with the percentage change in reading range.

εr	Loss tg	Moisture Content	Max Range (m)	D_{tag}	Eff_{tag}	η_{tag}	Max Range% change
2.1	0.11	10%	1.8	2.23	30%	-3.7	10%
3.2	0.17	20%	2	2.36	27%	-5.9	-
4.5	0.2	30%	1.78	2.5	22%	-5	11%
5.3	0.19	40%	1.76	2.56	22%	-4.6	12%
8.8	0.15	80%	1.61	2.19	27%	-3.2	20%

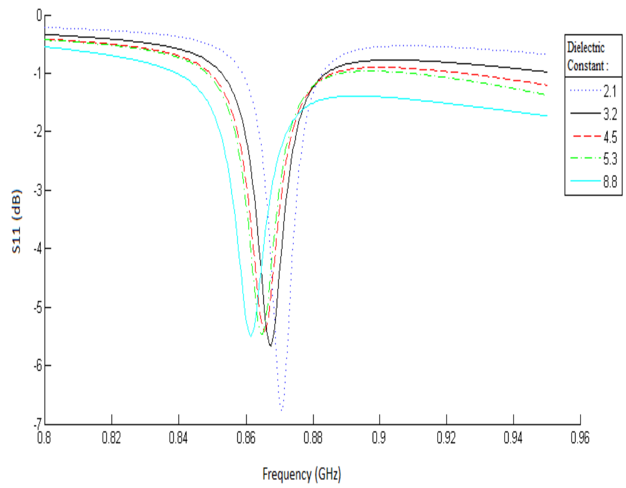

Fig. 3. Simulation results for return loss at different dielectric constants.

V. SUMMARY

The simulation results of the designed RFID antenna suggest that there is a decrease in the resonating frequency and return loss with the increase in moisture content of the wood. This variation also influenced the read range of the RFID tag and it is observed that the read range was varying from 10% to 20% for different moisture contents. Hence it can be concluded that the varying moisture content will influence the performance of the RFID antenna and tag.

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