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WAREHOUSE STOCK MANAGEMENT USING RF ATTENUATION SYSTEM

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ABSTRACT

In the modern era of management, one of the biggest challenges is to manage a large stock at the warehouse with the latest technology. Warehouse Management systems may be standalone or cloud-based or integrated Enterprise Resource Planning based. In the warehouse, a manual or robotic system is used to check the status of stock. The proposed method is an innovative method to check the status of stored stock using the RF Attenuation system. Radio Frequency (RF) signals get attenuated due to many environmental phenomena such as reflection, refraction, diffraction, fading, scattering, and mainly due to the nature of the medium. The proposed Radio Frequency communication system consists of a 433MHz RF transmitter with 27 dBm transmitting power, a Radio Frequency receiver, and a Radio Frequency power meter. The research carried out to study the effect of the stock of storage items like cloths, books, and wheat grain inside a closed metal container on RF attenuation. It is observed that the RF signal gets attenuated is proportional to the stored stock. This study can be implemented in the warehouse to check the status of the stock where a manual or robotics systems fails.

Keywords: *Warehouse, Radio Frequency, Attenuation, Stock Management.*

Introduction

Stock management is one of the essential steps in any warehouse management system. Inaccurate information about the stock leads to such consequences which directly impact the business profit. The fulfillment of the demand of the customer is only possible if the stock is available. Whenever the correct information about the low amount of stock is conveyed to the supplier and all the necessary steps like purchase order, and demand letter has been taken on time, the warehouse can always have a sufficient amount of the stock. Hence, a very powerful stock management system is the backbone of any business. The paper is an outcome of research to provide a stock management system that will provide an accurate % stock at any time and can send an alert if the available % stock is less than 10% of stock as shown in the Figure 2 Flow diagram of the proposed Stock Management System. The stock management system proposed in this paper is based on the famous Beer-Lambert's law. When RF wave travels through any media, a part of it gets absorbed in it which decreases its amplitude. This decrease in amplitude of received RF power is called RF attenuation. Beer-Lambert's law gives the relation between the intensity of the absorbed radiation signal with the thickness of the absorbing medium and also on the concentration of the medium through which the signal travels.

$\mathbf{A=\varepsilon bc}$ --- equation 1

In equation 1, A is the absorbance of the medium, C is the concentration of the medium, ε is the molar extinction coefficient and b is the thickness of the medium. Ber-Lambert's law can also be expressed by equation 2, where I is the received intensity of the signal, I0 is the intensity of the incident radiation, μ is the absorbance coefficient, and x is the depth of the medium in meters.

$\mathbf{I=I_0\ e^{-\mu x}}$ ---equation 2

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Beer-Lambert law is used in analytical chemistry to measure the concentration of the solution using a spectrophotometer. Beer-Lambert model can be modified and applied in many fields that used an optical technique. Here we are using RF signal which can travel through the cloths, the books, and the wheat grain of different volumes as shown in Figure1. The main objective of the study is to compare the relation between RF power loss with the % increase in the stock as well as the % decrease in the stock. The proposed stock management system should provide the correct % of available stock by measuring the Received RF strength.

Literature Survey

Many research papers used Beer-Lambert's law for a variety of applications. Baker et al. (2014) used a Beer-Lambert model for blood flow using diffuse correlation spectroscopy (DCS) measurements. F. Erchiqui (2014) validated Beer-Lambert law for all of the wood species which are studied under different conditions. Daniel Koohmarey (2019) proposed a system using RF transceivers for the estimation of the food waste in the dustbin by measuring the Received Signal Strength Indicator (RSSI). Some stock management systems implemented by other researchers are studied. Sungkon Moon (2018) proposed an RFID system for material management during the construction project. Divyendu (Oct 2019) described demand forecasting using a linear regression line, and pivot table in the excel sheet which is explained in the case study, and suggested a Periodic Review Policy for the small inventory calculations. This paper gives an overall idea about how a warehouse management system is so important for companies to forecast the demand by having the correct data on the stock. E. Žunić (2018) explained the complete warehouse workflow like initial product placement, stock planning, transfer from stock to pick zone, order picking process, transport, and tracking. Anas M. Atieh (2015) developed a software program that will automatically generate the serial range according to the FIFO manner, but data of the stock is managed manually.

The Proposed System

The proposed system used for stock management is based on RF Through-beam system. In this system, a RF transmitter, a RF receiver, and a RF power meter are used. Figure 4 demonstrates the experimental setup of the proposed system. For RF transmitter and RF receiver pair, the Chinese transceiver model HR 1026 is used. HR 1026 RF transceiver can transmit and receive 433MHz RF signal. It can transmit RF signal of 27dBm strength and can receive RF signal up to -118 dBm. The whip antenna connected to the transceiver has 3dBi gain. When the RF signal travel in media, there is a decrease in amplitude is observed at the receiver end which is known as attenuation. The RF power loss can be measured at the RF receiver end with the help of RF power meter. Here the RF power splitter is used to pass the received RF strength to RF receiver and RF power meter simultaneously which is shown in Figure 5. RF attenuation can be calculated by equation 3.

RF attenuation in dB = RF transmitter power – RF receiver power +

(Transmitter Gain+ Receiver Gain) ------------------- equation 3

The proposed RF Through-beam system is installed on a metal container. The metal container is of cuboid shape with a height of 50 cm, a width of 31.5 cm, and a length of 31.5cm. The metal container is marked with 5cm apart inside it with the red dot shown in Figure 1. The stock is calculated from the volume of the cuboid. Table 1 gives the % stock calculation with respect to the capacity of the Metal container of cuboid shape. The stock of cloths, books, and wheat grain is considered here for the experimentation which is given in Figure 6. The proposed RF Through-beam system is considered according to the position of the transmitter antenna and receiver antenna. Figure 3 shows the RF Through-beam System in which the transmitter antenna is on the bottom and the receiver antenna is on top of the container. Figure 7 shows the RF Through-beam System in which the transmitter antenna is up and the receiver antenna is on the bottom of the container. The experiment is carried out to measure the received RF power during a stepwise % increase in the stock of cloths, books, and wheat grain. The measurement starts from the empty container to the fill the stock stepwise by considering the 5cm apart dot marked inside the container for both the cases when RF transmitter antenna is on the bottom, RF Receive antenna on Up of the container as well as when RF transmitter antenna is on the bottom, RF Receiver antenna on Up. The experiment is also carried out to measure the received RF power during a stepwise decrease in the stock of cloths, books and wheat grain from a 90% filled container to the empty container by considering a 5cm apart marked dot inside the container for both the cases when the RF transmitter antenna is on the bottom, the RF Receive antenna on Up of the container as well as when RF transmitter antenna is on the bottom, RF Receiver antenna on Up. Once we will get the relation between RF attenuation with respect to the % stock, we can predict the available % of stock by measuring the RF attenuation with RF Through-beam System. The system can be installed once within the warehouse of like items, it will give the correct information of available stock. We can develop an alarm system that can give an alert to the Stock manager when the available % stock is less than a threshold value such as 10%.

Results

The plotted Graphs here gives the relation between Received RF power in dB with % increase and % decrease in the stock when case I a) RF transmitter antenna is on Bottom and RF Receiver antenna is above the metal container, case II b) RF transmitter antenna is above and RF Receiver antenna is on bottom of the metal container. The received RF power for % increase in the stock of the cloths is indicated as PRxU I-Cloths and for % decrease in the stock of the Cloths is indicated as PRxU D-Cloths, when RF Receiver antenna is above and RF transmitter antenna is on the bottom of the metal container. The received RF power for % increase in the stock of the Books is indicated as PRxU I-Books and for % decrease in the stock of the Books is indicated as PRxU D-Books, when RF Receiver antenna is above and RF transmitter antenna is on the bottom of the metal container. The received RF power for % increase in the stock of the Wheat grain is indicated as PRxU I-Wheat and for % decrease in the stock of the Wheat grain is indicated as PRxU D-Wheat, when RF Receiver antenna is above and RF transmitter antenna is on the bottom of the metal container.

From the Graph 1, Graph2 and Graph 3, it is clear that RF power attenuates as the % of stock increases and there is increase in Received RF power as the % stock decreases. The coefficient of determinant R^2 of all the lines are more than 0.85. This shows all the lines shows the best fit curves. The linear equations of the lines in the form of y= mx + C is useful to know absorbance coefficient of all the cases. Here the average effect of Received RF power for % increase or % decrease in stock for given case is calculated by the formula 4.

Average slope= (m1+m2)/2 + or – |m1-m2| /2 -- equation 4

where m1 is slope of linear line corresponding to % decrease in the stock and m2 is the slope of the linear line corresponding to % decrease in the stock for the given case. Table2 gives the corresponding linear equations, R^2 and the average slope value for all the cases from Gaph1, Graph2 and Graph3. The equation 4 gives the average slope of combined effect of % increase and % decrease in the stock which will be helpful to calculate the amount of % stock if Received RF power is known.

Discussion

The concept of RF attenuation can be explained by Beer-Lambert's law. It states that the intensity of signal decreases exponentially with depth in the material and with the concentration of the material. In this research paper, the materials used are cloths, books and wheat grain through which the RF signal propagates. The depth of the material depends on he % of filled stock. More is the stock; more is the thickness and more is the absorbance of RF signal which leads to decrease in the received RF power. Ber-Lambert's law can be solved considering equation 2. It is solved to equation 5, in which I represents received power, I_0 represents transmitted power, μ represents absorbance coefficient and x represents % stock in our system.

$\log(I/I_0) = -\mu x$

$\log I = \log I_0 - \mu x$ ------------------------------equation 5

The absorbance coefficient is different for cloths, books and wheat grain as per the concentration of material. This is given by the average slope value calculated in Table2 for cloths, books and wheat grain. From equation 5, it is clear that the received RF power depends on transmitted power, absorbance coefficient as well as the % of stock. This will explain the decrease in received RF power measured by RF Through-beam System.

Conclusion

Any Warehouse Management System can implement this RF Through-beam Measurement System to have the exact status of % available stock for any type of like goods. This RF Through-beam Measurement System can also be used as an alert system for stock management in any warehouse as a good practice. This is used to check the available stock of goods randomly in the warehouse where no manual checking is possible. The advantages of using this RF Through-beam Measurement System are non-contact, economical, and power saving.

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Table 1: % Stock Calculation w.r.t. the Capacity of the Metal Container of Cuboid Shape

Height h in cm	Width w in cm	Length l in cm	Volume of Cuboid in cm^3 = h x w x l	% Stock
0	31.5	31.5	0	Empty=0
5	31.5	31.5	4961	10
10	31.5	31.5	9923	20
15	31.5	31.5	14884	30
20	31.5	31.5	19845	40
25	31.5	31.5	24806	50
30	31.5	31.5	29768	60
35	31.5	31.5	34729	70
40	31.5	31.5	39690	80
45	31.5	31.5	44651	90
50	31.5	31.5	49613	Full=100

Table 2: Linear Equations, R^2 and the average slope of combined graphs of % decrease and % Increase in the stock from Graph 1, Graph 2 and Graph 3

Graph number	Graph of	Linear Equations (slope m1) and R^2 for % Decrease in stock	Linear Equations (slope m2) and R^2 for % Increase in stock	m1+m2/2 + or - |m1-m2|/2
Graph 1	Rx power when Rx=Up, Tx=Bottom Vs % stock of cloths	y = -1.0594x - 52.07 R^2 = 0.9956	y = -0.2703x -64.29 R^2 = 0.9251	-0.66485 plus or minus 0.39455
	Rx power when Rx=Bottom, Tx=Up Vs % stock of cloths	y = -0.1315x - 57.33 R^2 = 0.9609	y = -0.2382x - 56.54 R^2 = 0.9351	-0.18485 plus or minus 0.05335
Graph 2	Rx power when Rx=Up, Tx=Bottom Vs % stock of books	y = -0.2552x - 63.65 R^2 = 0.9792	y = -0.2042x - 64.31 R^2 = 0.9944	-0.2297 plus or minus 0.0255
	Rx power when Rx=Bottom, Tx=Up Vs % stock of books	y = -0.2182x - 57.18 R^2 = 0.9731	y = -0.1648x - 57.65 R^2 = 0.9731	-0.1915 plus or minus 0.0267
Graph 3	Rx power when Rx=Up, Tx=Bottom Vs % stock of wheat	y = -0.2873x - 62.18 R^2 = 0.9777	y = -0.2915x - 65.39 R^2 = 0.8541	-0.2894 plus or minus 0.0021
	Rx power when Rx=Bottom, Tx=Up Vs % stock of wheat	y = -0.2267x - 56.11 R^2 = 0.9167	y = -0.3473x - 57.96 R^2 = 0.9792	-0.287 plus or minus 0.0603

Figure 1: Metal Container of Cuboid Shape with Markings 5cm Apart

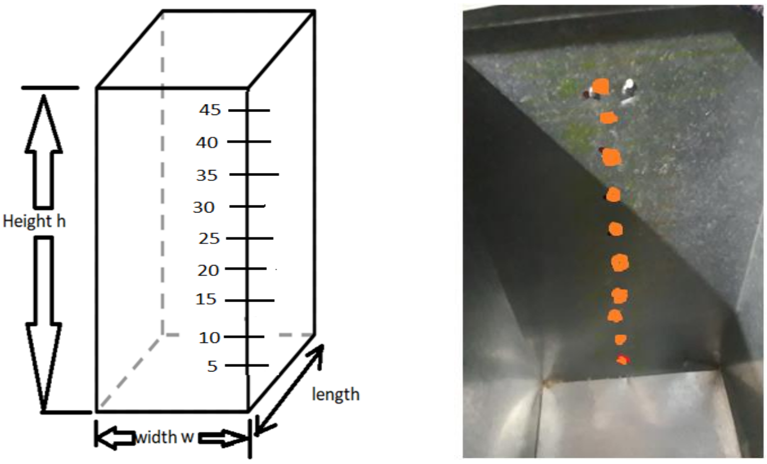


Figure 2: Flow Diagram of the Proposed Stock Management System

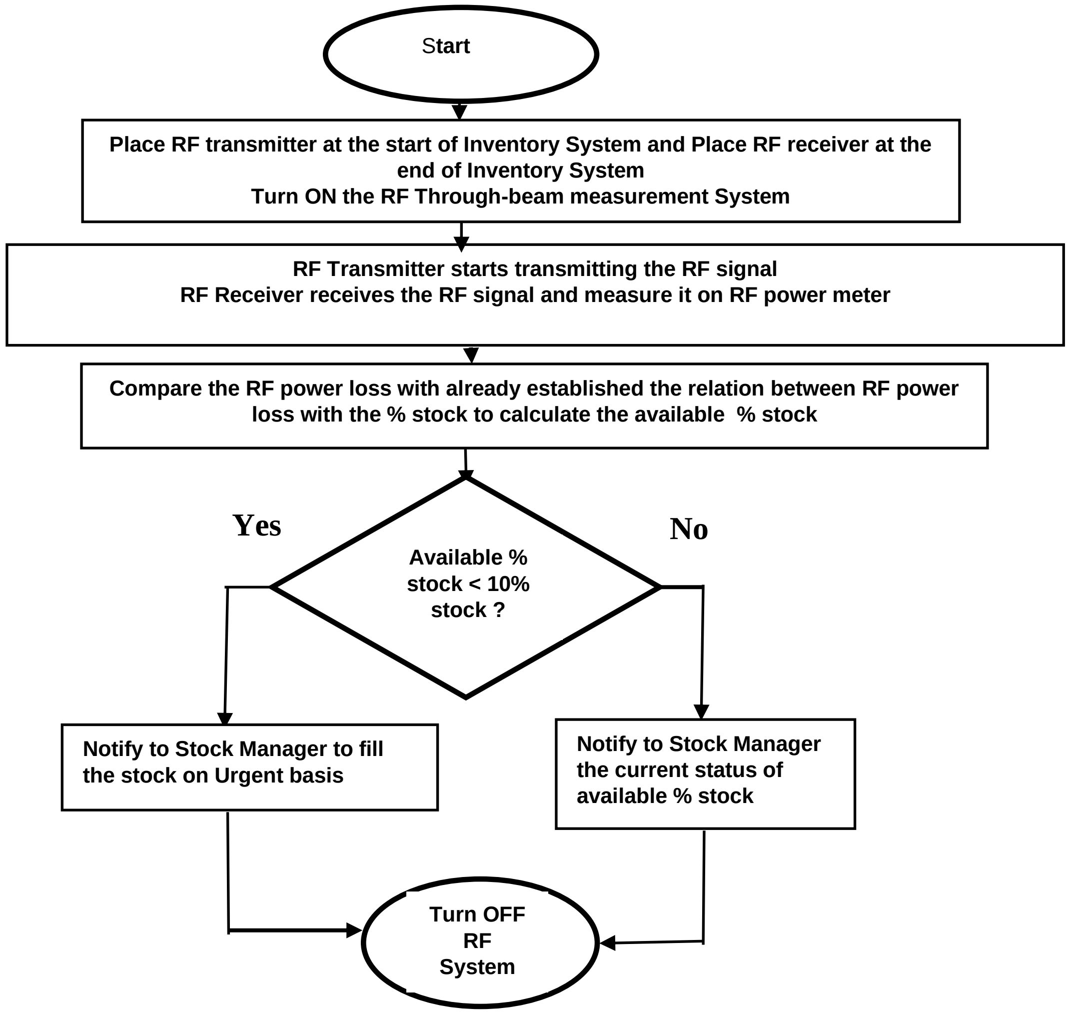


Figure 3: RF Through-beam System when RF Transmitter Antenna is on Bottom and RF Receiver Antenna on Top of Container

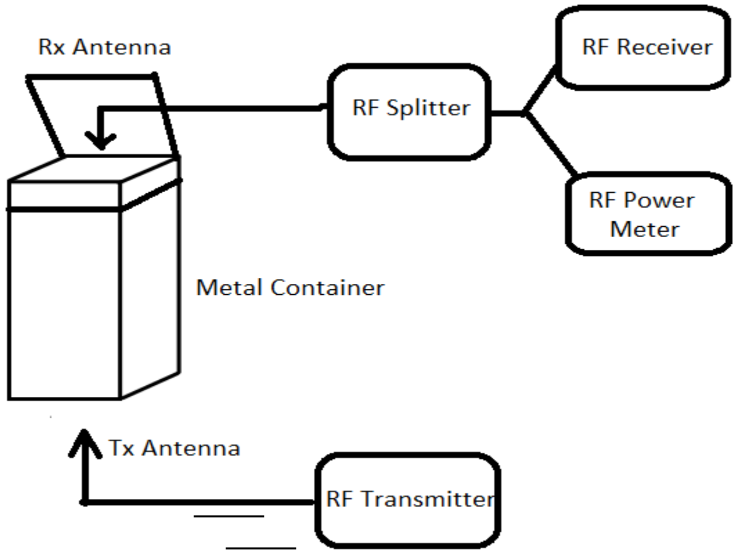


Figure 4: Experimental Set Up of RF through Beam System

Figure 5: RF Power Receiver with RF Power Splitter

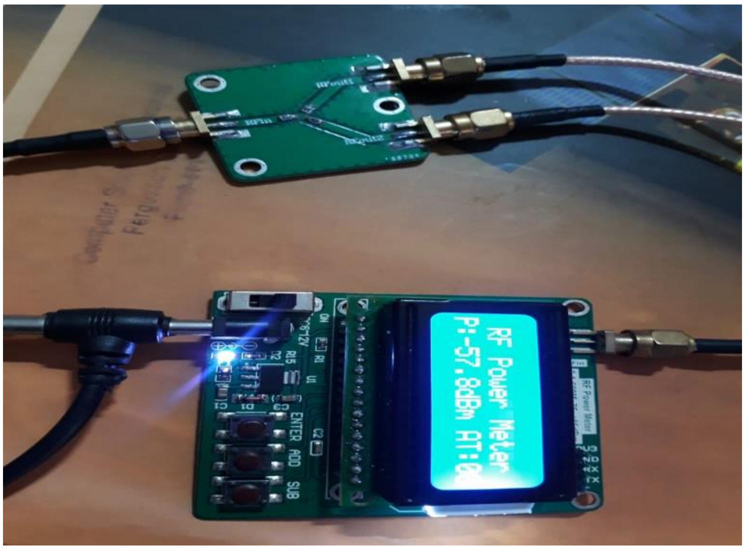


Figure 6 Container filled with: empty, with cloths, with books, with wheat

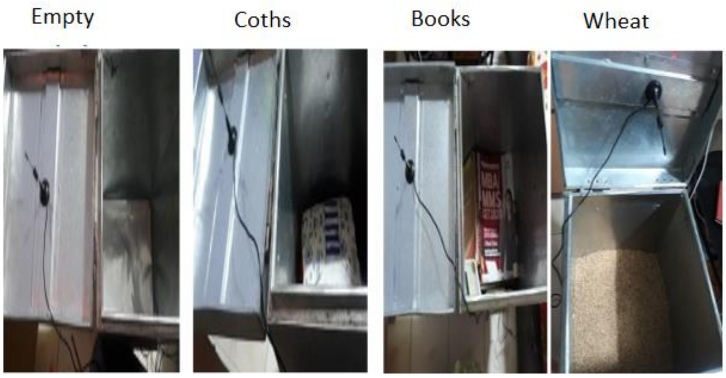
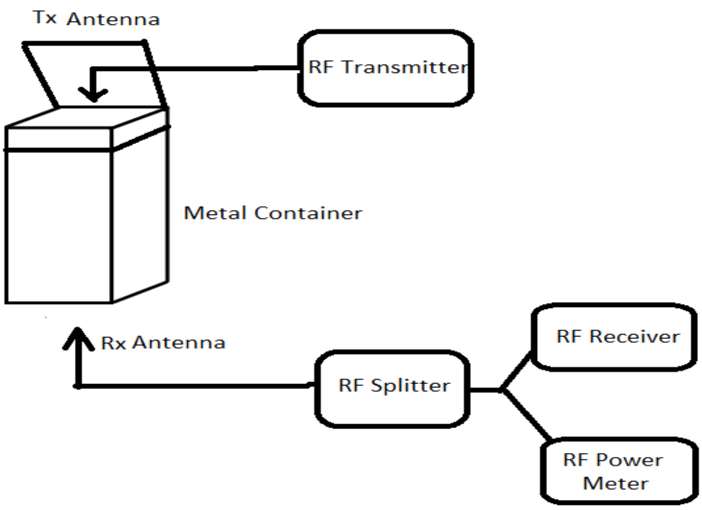
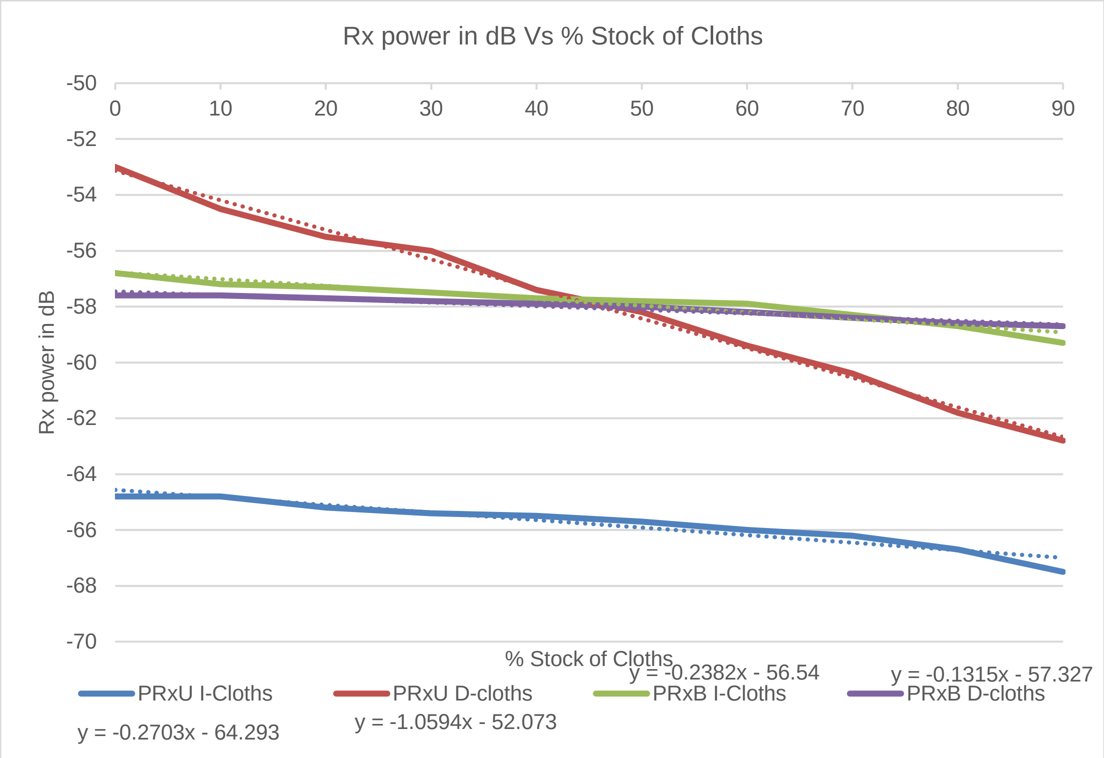


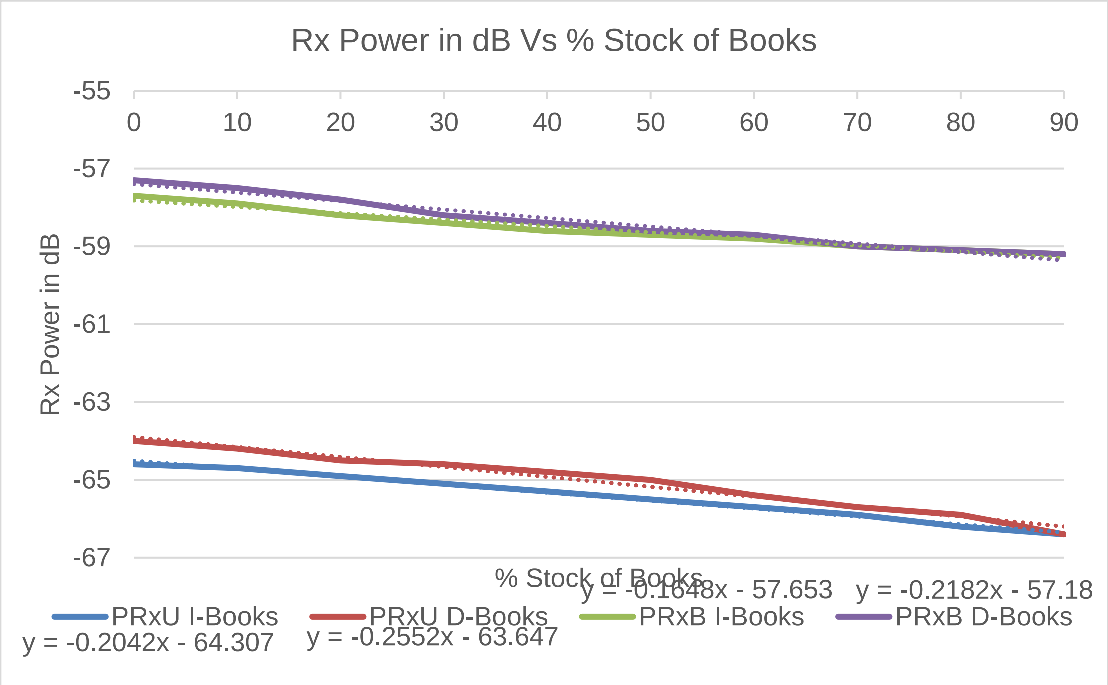
Figure 7: RF Through-Beam System when RF Transmitter Antenna is on Up and RF Receiver Antenna on Bottom of Container



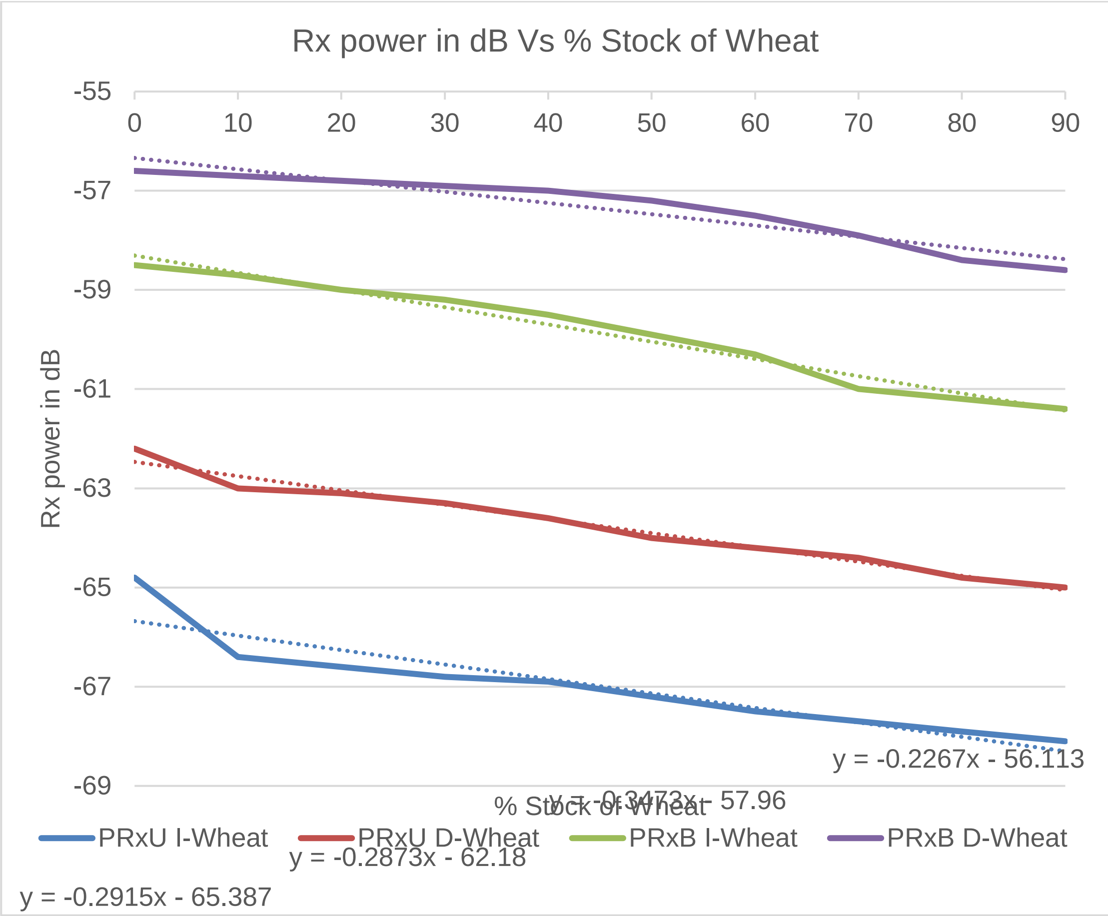
Graph 1: Graph of Received RF power in dB Vs % Stock of Cloths for a) Rx=Up, Tx=Bottom and b) Rx=Bottom, Tx=Up of the metal container



Graph 2: Graph of Received RF Power in dB Vs % Stock of Books for a) Rx=Up, Tx=Bottom and b) Rx=Bottom, Tx=Up of the Metal Container



Graph 3: Graph of Received RF Power in dB Vs % Stock of Wheat Grain for a) Rx=Up, Tx=Bottom and b) Rx=Bottom, Tx=Up of the Metal Container



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