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Advanced Highly Reliable and Accurate Automated Billing System Using Spread Spectrum Technique

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Abstract

Spread spectrum as suggested in this report provides avenues for highly reliable and accurate automated billing system. The approach detailed in this research report allows the use of advanced technologies to be incorporated in the billing procedures in super markets (eg Walmart etc.) to extract higher degrees of operational efficiencies. The system proposed makes use of the PN sequences to represent the different items (or products) in the super market. The PN sequences are the tags for the products in the super market. The discrimination between the spread spectrum tags assigned to different products is a limiting factor in the design of the tags. The phased array reader antenna scans the cart containing PN sequence tags (of products) by energizing the tags with focused electromagnetic energy. The directivity or the gain pattern of the reader antenna should be such that it should not accidently read the adjacent cart. The article finally concludes the research findings of this project effort.

Keywords: PN Sequences, Spread Spectrum, Super Market Billing, Phased array antennas.

I. INTRODUCTION

Accuracy in automated billing process and inventory management are crucial deciding factors in the operation of a large Retail Stores like “Walmart”. Currently the industry is dominated by POS (Point Of Service) equipments which are labour intensive and hence vulnerable to operational errors. These retail operations are also affected by the use of archaic management systems that do not model the billing process accurately. This problem becomes a serious issue during the festival seasons when the number of customers visiting the large store exponentially increases. In this research it is our objective to introduce advanced technologies like Spread Spectrum and Antenna Arrays for the Billing Process Automation resulting in speeding up the billing process and servicing more customers in less time.

Many attempts in the recent years to automate the billing process have been focussed on solutions incorporating RFID Tags and readers, Li-Fi (Optical laser illumination and tag reading) etc. The use of RFID tags to represent products and eventual reading of these tags by RFID readers (passive tags is alluded in this implementation) have been suggested in [1]. A microcontroller based system implementation using RFID is used to control inventory in the shelves and eventual recognition of the products purchased at the billing counter. One of the limitations of this approach is that the products can be only sequentially read by the RFID reader there by requiring human intervention. This implies that 100% automation at the billing process cannot be possible as suggested in [1]. Authors of [2] have suggested an alternative approach to use a hybrid process (use of RFID and Li-Fi) where the product identification is achieved using RFID-RFID reader combination and backend processing is completed using Li-Fi based high speed processing. All these modules are brought together by a microcontroller based system that integrates the functional behaviour of these processing devices.

In our approach as suggested in this research article 100% automation of the billing process is possible as the tag (here we call them as spread spectrum PN sequence tags) utilizes the ability to spread PN sequence codes (with a standard reference data) in to the noise floor. This is exactly followed in spread spectrum applications like CDMA based second generation wireless systems. In CDMA the users are identified by the individual PN sequence codes. Like wise in our architecture the PN sequences are used to identify the individual products. As far our investigation such an approach have not been published in the literature for billing process automation. In this system the antenna structure at the billing counter energizes the passive spread spectrum tags and are read by the reader. The reader uses a sequence of PN codes to identify the products in the trolley brought to the billing counter of the super market by the customer. The products are identified by their unique PN sequences.

II. SYSTEM ARCHITECTURE

The salient feature of the architecture suggested is the use of advance technologies like spread spectrum processing of useful data. The architecture includes a spread spectrum reading antenna that energizes the spread spectrum tag making it possible to read and recognize the PN sequence coded inside tag. The system consists of the following sub components:

1. PN sequence coded spread spectrum tags attached to the products in a trolley.
2. A phased array antenna scheme to energize the PN tags and read the PN sequence in the noise floor &
3. Back end processing systems using high speed computers to maintain inventory in the super market shelves.

A. PN Sequence coded spread spectrum tags

Individual PN sequence numbers are assigned to each product types e.g. Branded Soaps, Fresh Breads etc. and are spread spectrum modulated with a reference ONE bit symbol. This ONE bit symbol is common for all PN sequences coded in to the tag. The working principle of the PN tag is as follows. The PN tag actually consists of the PN sequence and a dc component circuitry (It is the ONE bit symbol or pulse) together with the modulation circuitry. Once the tag is energized by the antenna system, the modulated signal (The PN sequence code and the ONE bit pulse) is launched in to the noise floor. Please refer to figure 1 for a pictorial view of the architecture used.

The reading antenna receives the spread spectrum datum (PN sequence modulated with ONE bit pulse) and steps through the PN sequences stored in its processing data base. When the same PN sequence is used for the demodulation process a ONE bit must be decoded from the antenna system. If a ONE bit is received it is a confirmation that the PN sequences are matching and hence can be identified in the data base as a specific type of product e.g. Fresh Bread etc.

The antenna based spread spectrum reader sequentially steps through the various PN sequences in the data base and it is designed to detect the ONE bit pulse when the PN sequences match. This process repeated for all the stored PN sequences in the data base and the existence of the ONE bit is detected. If a ONE bit is detected (corresponding to the PN sequence) an entry is made in the bill generated for the customer for his collection of purchased items. Automatically the bill can be generated and submitted to the customer for his remittance of the money.

B. A phased array antenna scheme to energize the PN tags and read the PN sequence in the noise floor

A phased array antenna system deployed in this architecture scans the trolley with the customer purchased items. The scanning process energizes the passive spread spectrum PN sequence coded tags to emit the ONE bit into the noise floor. This ONE bit information is extracted by the demodulation process in the reader and the purchased item of the customer bill is updated accordingly. This is a fully automated billing procedure and is guaranteed to be highly accurate.

C. Back end processing systems using high speed computers to maintain inventory in the super market shelves.

A high speed back end processing computers enable the coordination between the super market shelf inventory, the automated billing system and back end warehouse inventory is suggested in this article.

III. PERFORMANCE MEASURES OF THE AUTOMATED BILLING PROCESS

The automated billing process parallel reads all the tags by means of associating with them in the spread spectrum environment. The ability to read these tags and discriminate them as unique products is a crucial performance parameter to assess the system. In the following discussion an analysis is done to ascertain the ability of the system to discriminate between two PN sequence coded products by means of a probability of error criterion.

The received signal from the sample two PN sequence coded tags are represented as

$$r(t) = d(t)p_o(t) + n(t)$$
$$r(t) = d(t)p_1(t) + n(t)$$

Where p_o and p_1 are the PN coded tag information and concisely written as

$$r(t) = d(t)p_i(t) + n(t)$$

$$r_i(t) = \sum_{k=1}^{n} r_{ik}\emptyset_k(t)$$

Where “i″ corresponds to 0 and 1.

$$r_{ik} = \int_0^T r_i(t)\emptyset_k(t)dt$$

and

$$p_i(t) = \sum_{k=1}^{n} p_{ik}\emptyset_k(t)$$

Where “i″ corresponds to 0 and 1.

$$p_{ik} = \int_0^T p_i(t)\emptyset_k(t)dt$$

The reader initiates or performs a correlation receiver operation as given by

$$V = \sqrt{\frac{E_b}{T}} \int_0^T r(t)p_i(t)dt$$

Where $p_i(t)$ is an “n” dimensional PN sequence vector.

The integrand in the above equation can be expanded as

$$r(t)p_i(t) = [d(t)p_i(t) + n(t)]p_i(t)$$

Which can be reduced to

$$\frac{r(t)p_i(t) - d(t)}{p_i(t)} = n(t)$$

In the above equations n(t) is the additive white Gaussian noise.

Hence

$$P(r|p_i) = \frac{1}{(2\pi\sigma^2)^{1/2}} exp\left[-\frac{1}{2\sigma^2 p_i(t)}(r(t)p_i(t) - d(t))^2\right]$$

We decide p_i for which

$$A_i = [r(t)p_i(t) - d(t)]$$

is minimum. We choose the $p_i(t)$ in the above equation which makes $r(t)p_i(t)$ closest to d(t). Let

$$S_i(p) = r(t)p_i(t)$$

Where "i" corresponds to 0 and 1.

We choose $p_i(t)$ for which $S_i(p)$ is maximum but under the constraint

$$|S_i(p)| \leq d(t)$$

Hence we can write

$$r(t)p_o(t) = S_o(p) \leq d(t)$$

$$r(t)p_1(t) = S_1(p) \leq d(t)$$

Then the probability of error incurred in the process of detecting p_1 or p_o is given by

$$P_e = P\{B_1|B_o\}P\{B_o\} + P\{B_o|B_1\}P\{B_1\}$$

Where B_o and B_1 are the two hypotheses of selecting p_o or p_1 respectively. Assuming equal probability of occurrence of p_o and p_1 we have

$$1/2\,\{P\{B_1|B_o\} + P\{B_o|B_1\}\}$$

$$\frac{1}{2}[Pr\{S_1 > S_o|B_o\} + Pr\{S_o > S_1|B_1\}]$$

$$\frac{1}{2}[Pr\{S_1 - S_o > 0|B_o\} + Pr\{S_o - S_1 > 0|B_1\}]$$

Where $S_1$is $S_1(p)$ and S_o is $S_o(p)$ respectively.

Let

$$S(p) = S_1(p) - S_o(p)$$

substituting for $S_1(p)$ and $S_o(p)$in the above equation we get

$$S(p) = r(t)p_1(t) - r(t)p_o(t)$$

$$S(p) = r(t)[p_1(t) - p_o(t)]$$

$S(p)$ under B_o is given by

$$S(p)_{B_o} = d(t)p_o(t)[p_1(t) - p_o(t)]$$

which can be simplified as

$$S(p)_{B_o} = [p_o(t)p_1(t) - p_o{}^2(t)]$$

and

$$S(p)_{B_1} = [p_1{}^2(t) - p_o(t)p_1(t)]$$

S(p) is a Gaussian random variable for which

$$E\{S|B_o\} = E[d(t)p_o(t)\{p_1(t) - p_o(t)\}]$$

$$= E[d(t)p_o(t)] * E[p_1(t) - p_o(t)]$$

$$= p_o(t)p_1(t) - p_o{}^2(t) = -[p_o{}^2(t) - p_o(t)p_1(t)]$$

Therefore

$$E\{S|B_o\} = -[p_o{}^2(t) - p_o(t)p_1(t)]$$

and on similar calculation

$$E\{S|B_1\} = [p_1{}^2(t) - p_o(t)p_1(t)]$$

The variances are

$$Var\{S|B_o\} = Var[r(t)]Var[p_1(t) - p_o(t)]$$

$$= \sigma^2[p_1(t) - p_o(t)]^2$$

$$= \sigma^2\,\|p_1(t) - p_o(t)\|^2$$

And

$$Var\{S|B_1\} = Var[r(t)]Var[p_1(t) - p_o(t)]$$

$$= \sigma^2\,\|p_1(t) - p_o(t)\|^2 = Var\{S|B_o\}$$

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