New Radio Identification System

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Abstract

As supply chains become more complex, RFID deployment is needed for efficient item identification and tracking. A system simulation of RFID is constructed in this paper. RFID systems consist of tags and readers. Tags are components that store the information and are physically attached to each item. The tag transmits information back to the reader by modulating an RF signal in the UHF frequency range. The reader recovers data to identify the tag. In this paper, the system is simulated by electrical models. The tag is represented by a simple model. A wireless channel with path loss and variable environmental factors establishes the reader-tag link. The reader has a mono-static architecture. Performance of the whole system can be studied as function of the operation distance. System modeling can be optimized by modifying the parameters of the building blocks. Finally, simulation results showing code recovery are also included in this paper.

Keywords: *RFID, UHF, Tag, reader*

Resumen

Cada vez son más complejas las cadenas de suministro y por ello el desarrollo de RFID (***R****adio* ***F****requency* ***ID****entification*) está en pleno auge en estos momentos. Es necesario e importante este tipo de sistemas de identificación para ayudarnos a catalogar de forma correcta y permitir el seguimiento eficiente de los productos. En este artículo se presenta una simulación de un sistema RFID constituido por etiquetas a las que se deben identificar y lectores (constituidos por los trasmisores y receptores del sistema que nos permite realizar la detección). Las etiquetas son los componentes que almacenan la información y se encuentran unidas físicamente a cada artículo. Cuando el lector las interroga (mandando una señal), estas etiquetas transmiten la información almacenada al lector (dicha señal está modulada en RF en la gama de frecuencia UHF). Por otro lado, el lector recupera datos enviados por la etiqueta o tag e identifica a la misma. En este artículo, se propone un sistema RFID simulado utilizando los modelos eléctricos del sistema. La etiqueta es representada por un modelo simple, el canal wireless con pérdida de trayectoria y factores ambientales variables simulan la unión entre el lector (con una arquitectura monoestática) y la etiqueta. Además, la eficacia del sistema completo la podremos expresar en función de la distancia de funcionamiento. Finalmente, en los resultados de simulación de este artículo, se muestra la recuperación del código por parte del lector.

Palabras clave: *RFID; lector, UHF, etiqueta.*

1. Introduction

Radio Frequency IDentification (RFID) is an emerging technology which is expected to impact the development of supply chain management. A typical system is composed of Readers (active remote sensing devices) and Tags (transponders) whose operational power is supplied by the active Reader. Tags contain the information to be remotely sensed. Normally, the information contained in Tags is items identification codes and other relevant information. Thus, supply chain management, the main driver of the RFID technology, could become highly automated as the RFID systems become fully operational. One of the main concerns in such a system is the efficiency and reliability of the communication channel between the Reader and Tags. Passive Tags lack their own power source and are low cost, not bulky, and appropriate for one time use. However, there operational distance is limited and is on the order of one meter (Finkenzeller,2003; Kraus, 2001).

The characteristics of the Reader and Tag antennas and the propagation channel properties are of concern for a reliable RFID system (Nikitin,2008). Path loss and fading statistics are two elements that need to be addressed. A detailed discussion on RFID Tags is found in reference (Leonid,2007).

In this paper, an electrical model is presented for the whole RFID system. Although promising, RFID is not without its challenges. Researchers and industry are both involved in responding to these challenges. Important advances have been made in antennas, modulation or demodulation, digital signal processing, analogue to digital converters, and in the power management of RFID systems. Simulations are verification tools that are needed before the actual implementation of such a system (Han, 2006; Rutschlin,2006; Leong ,2006). These numerical simulations verify the proof of concept, reduce overall cost, and shorten deployment time. In essence, the impact of environmental variables and potential system limitations are evaluated ahead of the actual implementation of the system.

This paper begins with an overview of RFID system. After briefly describing UHF-RFID principle and presenting the mono-antenna reader, the simulated electrical model of the system is introduced. Its blocks are then defined. Modeling results are followed by a brief conclusion.

2. UHF-RFID principle

Figure 1 shows an overview of an RFID system.

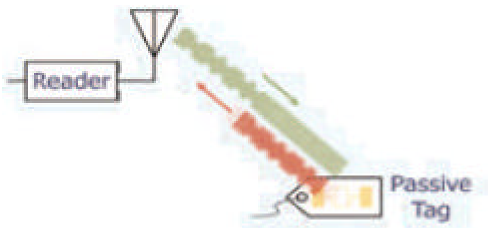

Figure 1. Overview of RFID systems .

There are many types of RFID systems. Throughout this paper a special emphasis is placed on the UHF RFID applications following the EPC-Class 1- Generation2. The reader interrogates tags which transmits information back to the reader by modulating an RF signal in the 860-960 MHz frequency range. Tags are components that store the information and are physically placed upon each item. Typically, these tags consist of an antenna and a backscatter modulating circuit (Figure 2).

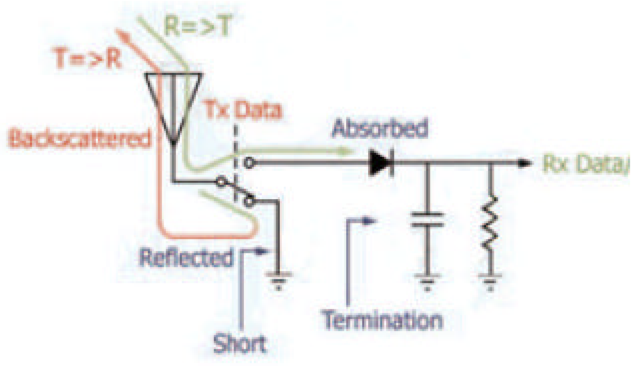

Figure 2. RFID tag.

The passive tag backscatters the reader's Carrier Wave (CW), modulating it by changing absorption characteristics of the antenna. The passive tag also rectifies the RF energy to create a small amount of power to run the tag. About the reader, it can be a bi-static one having two transmitting and receiving antennas. It can also have a mono-static architecture. Models for the bi-static reader can be found in the literature (Bottani,2008). For a European project purposes, we are interested in the mono-static architecture which is represented in Figure 3.

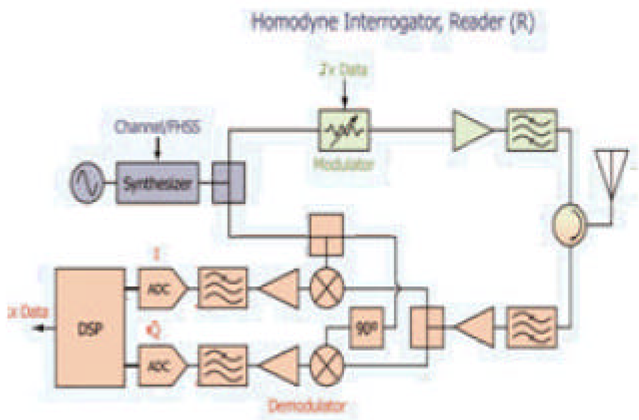

Figure 3. Mono-static architecture

A generator delivers the modulated signal to actívate the tag and the CW to interrogate it. The CW is splitted by a power divider into two parts: the first is amplified by a power amplifier, filtered and transmitted by the antenna. For reception, the antenna captures a signal backscattered by the tag, filtered by a band-pass filter, amplified by a Low Noise Amplifier (LNA), demodulated by a direct IQ demodulator. After lowpass filtering, analog to digital conversion and digital signal processing algorithms, data representing the code of the tag is regenerated. The mono-static architecture is simpler than the bistatic since it needs only one antenna for both transmission and reception. In counterpart, this architecture suffers from the isolation leakage of the circulator which can reach an optimal value of 25 dB in best cases. Due to this isolation, part of the transmitted CW will be detected on the receiving path in addition to the signal backscattered by the tag and received by the reader's antenna.

3. UHF-RFID electrical model

Unlike RFID system modeling found in the literature (Han,2006), and due to the importance of electromagnetic simulation and parameterization in the RFID design process as discussed in (Rutschlin,2008), this paper uses electric models to simulate all components of the system. In addition, the simulated reader has a mono-static architecture which is not widely explored so far. Figure 4 presents an electrical model of an RFID system functioning at 869 MHz and simulated by HPADS. This scheme is simulated in the time –domain using the simulator “Envelope”.

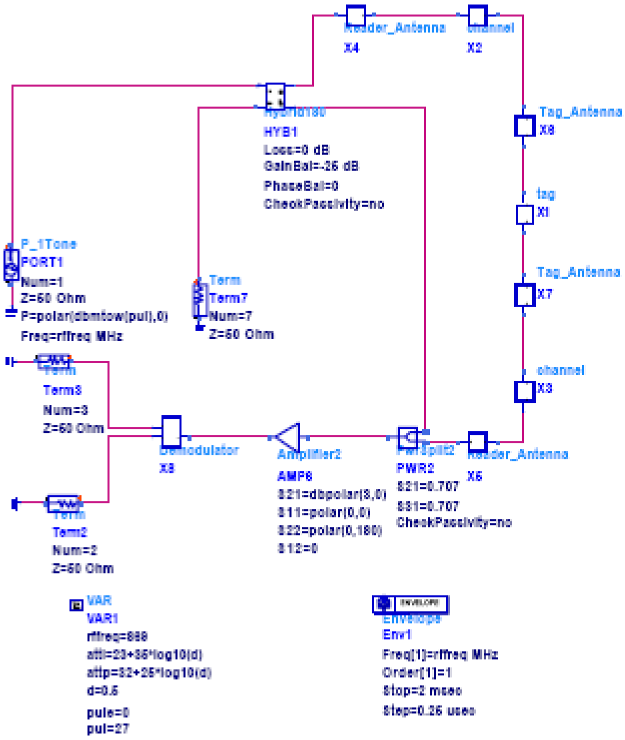

Figure 4. UHF -RFID simulated system.

A generator delivers a CW signal at the RF frequency of 869MHz. A non ideal power detector characterized by no insertion loss and an isolation of 25 dB splits this signal into two parts: One signal will be transmitted by the reader antenna (Figure 5), via the propagation channel (Figure 6) and will be captured by the tag’s antenna (Figure 7). The tag will modulate the received CW signal by its code and then backscattered the RF modulated signal to the reader (Figure 8), using the tag antenna. The RF modulated signal crosses back the propagation channel to reach the reader antenna. As previously mentioned, this model simulates a mono-static reader which transmits and receives signals by a unique antenna. The imperfect isolation of the introduced power divider will model the circulator effects in the mono-static reader. At reception, the leaked CW and the backscattered signal are added by the combiner with an insertion loss of 3 dB. This loss is compensated for by the amplifier of gain 3 dB. The RF signal is then detected by an IQ demodulator (Figure 9). The reader antenna can be simply modeled by an amplifier having a gain equal to that of the antenna and a 50 W resistor, as presented in figure 5.

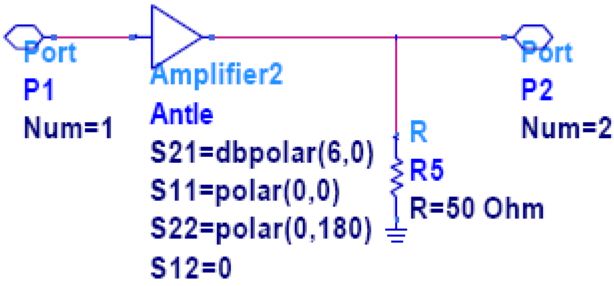

Figure 5. Reader antenna.

In (Leong, 2006), a wireless channel model with path loss and variable environmental factors establishes the readertag link. It defines propagation effects as function of the distance separating the reader from the tag. This channel can be simulated using a switch whose state is controlled by the distance d and selects one of the two parallel paths. Two attenuation values can be respectively obtained by one of the two amplifiers as shown in figure 6.

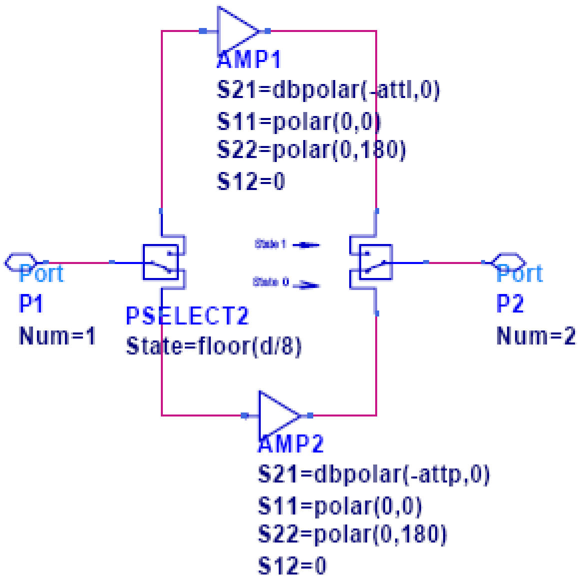

Figure 6. Propagation channel model.

The signal crosses the channel and is captured by the receiver antenna. Using (Paret,2008) and measurements made on tags in our laboratory allowed us to model the tag antenna by an amplifier of gain 6 dB equal to that of the antenna, followed by a resistor of 73 W, as shown in figure 7.

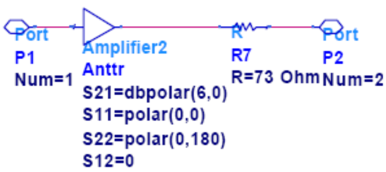

Figure 7. Tag antenna.

The tag modulates the CW by a load modulation. Its load impedance varies between two values following the code. (Paret,2008) indicates that this impedance can be simplified to a 73 W resistor for a bit “1” of the code, and to short-circuit for a bit “0”. The value of 73 W is not vital. It could be modified. The modulation is essentially made by the difference between a resistive impedance and a short-circuit. This difference produces 6 dB. This value will be demonstrated in the simulation results. HP-ADS simulates in transmission, i.e. every electrical scheme terminates by 50W. Fig. 8 shows a simulated Tag. A code following the form defined in the EPC - Class 1- Generation 2 (Specification for RFID Air interface,2005) is generated by a program written with Matlab and loaded via the Data Access Component. This code commands the switch to select the suitable impedance, and modulate the received CW. Negative resistances can be simulated by combining temporal and harmonic simulations in the “Envelope” simulator.

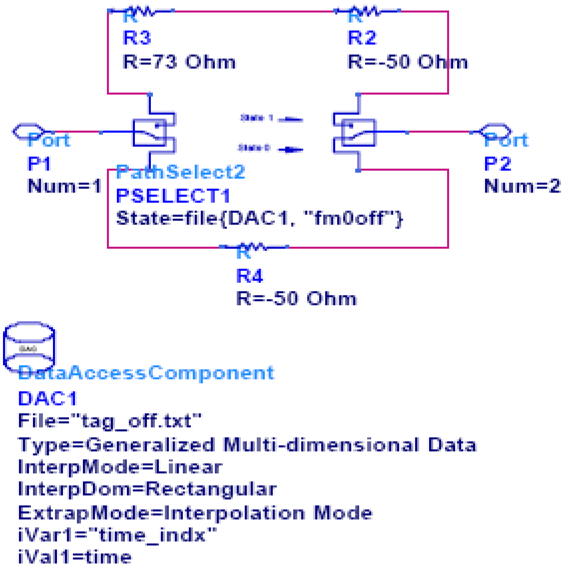

Figure 8. Tag’s model.

The tag backscatters the RF modulated signal by its antenna as previously described. After propagation toward the channel model, the signal is captured by the reader antenna. At reception, the RF modulated signal and the leaked CW delivered by the circulator are detected by an IQ demodulator simulated by two mixers, connected to two local oscillators in quadrature of phase as shown in figure 9. This model represents a homodyne receiver (fLO= fRF = 869 MHz) which is of simple architecture and widely used in RFID readers. The demodulator outputs I and Q should represent the regenerated code to correctly identify the tag.

In this receiver model, there is no LNA because the system already suffers from high power level of the carrier. In a future work, this model will be improved by introducing a new demodulator having a large dynamic range and that is able to detect signals with low level of data and high carrier level. An LNA will be inserted before the new demodulator.

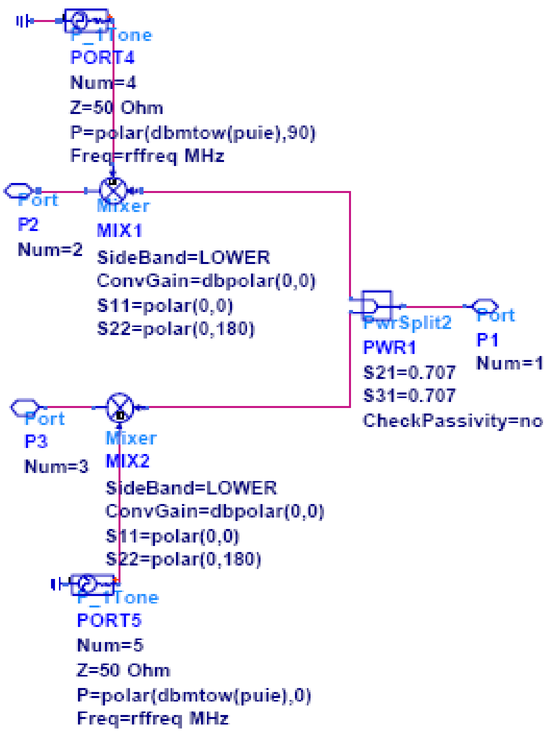

Figure 9. IQ demodulator.

4. Simulation results

The complete system was simulated with a transmitted CW power of 33dBm. The signal is attenuated by the channel as shown in figure 10 where the CW power is of -20 dBm at the tag's antenna. It should be mentioned that HP-ADS normalizes the frequency axis to that of the carrier.

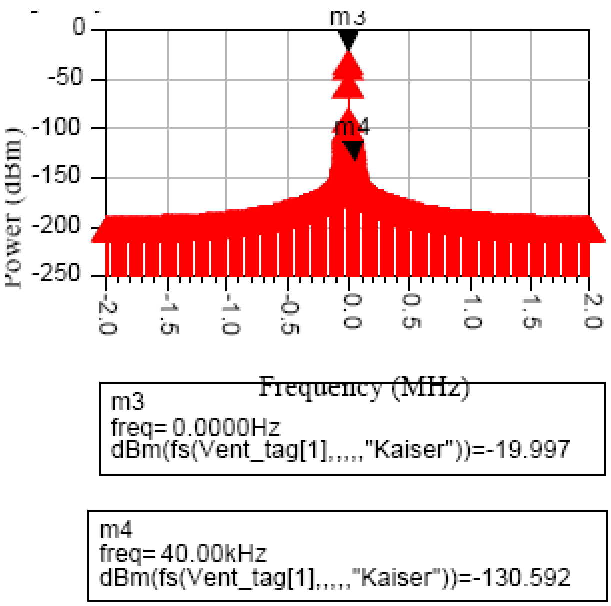

Figure 10. Spectrum at the tag's antenna.

The RF signal delivered by the tag is represented in figure 11. Due to mismatch between the characteristic impedance of 50 W and that of the tag, the carrier level is -10 dBm, and data with a bit rate of 40 KHz, have a power of -33 dBm.

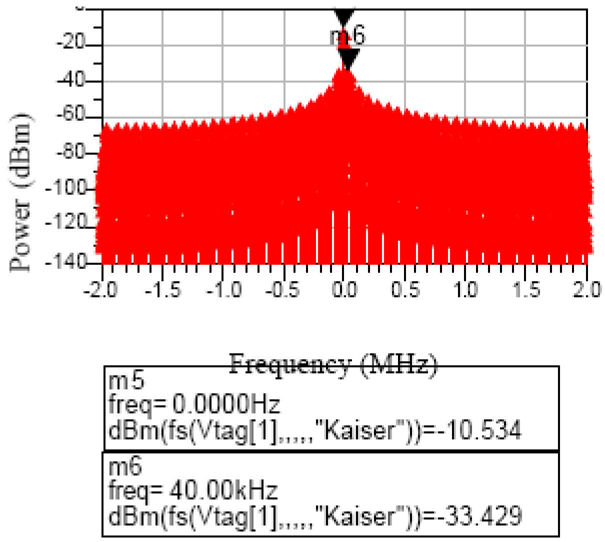

Figure 11. Spectrum delivered by the tag.

At reception, the spectrum is represented in figure 12. The high power level of the carrier and the attenuation of the data are both obvious.

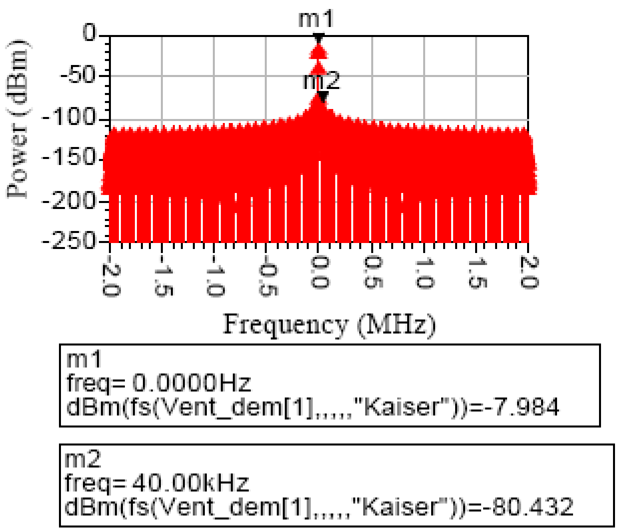

Figure 12. Spectrum at the receiver input

Figure 13 shows the signal representing the code and the regenerated I signal. The simulated system recovers the tag data. By its nature, the load modulation produced by the tag is a Binary Phase Shift Keying modulation. For this reason, regenerated data is only obtained on the In-phase output, and a negligible signal is detected on the Quadrature output as shown by the constellation diagram represented in figure 14.

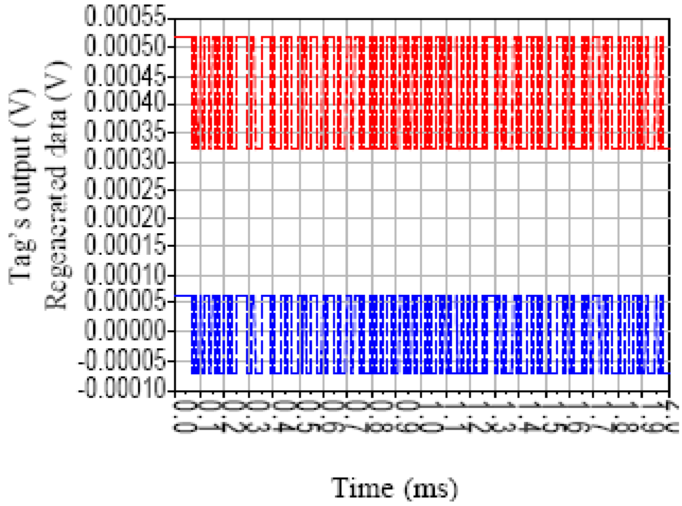

Figure 13. Code and regenerated data.

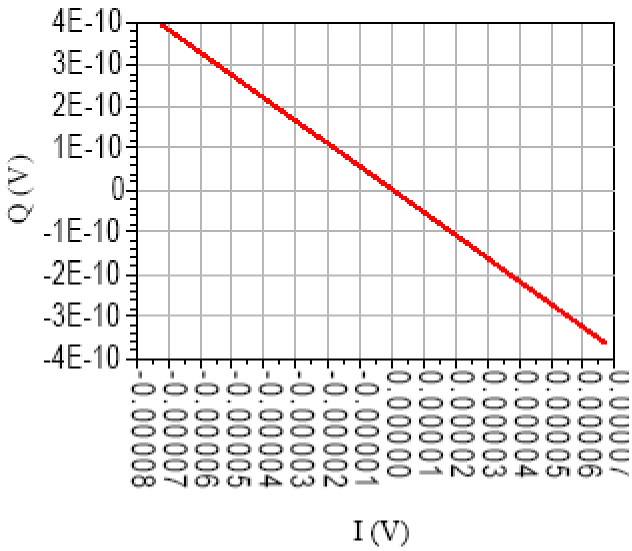

Figure 14. Data constellation diagram.

In (Specification for RFID Air interface,2005), the tag's code has the form represented in figure 15.

Preamble	CRC	Data

Figure 15. Tag data form.

We simulated a tag code by the text represented in figure 16. Table 1 show that the simulated RFID system recovers tag's code for distances lower than 10 m. For greater distances, the signal is highly attenuated and data is not recovered.

Preamble	S	T	0 0..	RFID

Figure 16. Simulated tag's code.

Distance (in m)	Code
0.5	ST RFID
5	ST RFID
10	YY0 0 0 0 0 0 0 0 0 0 YYYY

Table 1. Code recovery function of the distance.

5 Conclusions

The paper presented an electrical modeling simulation of a UHF RFID system. Starting from published models for the system components, it constitutes a basic for an electric and/or electromagnetic modeling for RFID. This approach has the advantage of being modularly based which facilitates the improvement or modification of model blocks. The tag data was successfully recovered using this approach.

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