A 2.45 GHz Wireless IC Card System for Automatic Gates

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Abstract

A 2.45 GHz wireless IC card system has been developed for a non-contact type train station automatic gate system. This system consists of a compact transmitter-receiver equipment and non-contact wireless IC cards. The newly developed technology used in this system comprises a small-size dual-port slot antenna for the card, a modulation-demodulation scheme for stable data transmission, and a co-channel carrier allocation system for operation with multiple gates. Operation of this wireless card system, with its newly developed technology, has been successfully demonstrated.

Fig. 1: Automatic Gate System in a Train Station (Manufactured by Nippon Signal)

Introduction

At present, automatic gate systems (AGS) using magnetic cards are widely used in train stations, as shown in Fig. 1. Magnetic cards, magnetic-coated tickets or commuter tickets are typically used, and in some systems, stored-fare magnetic cards can also be used. In these systems, passengers must insert their card into the slot in the gate and retrieve it from the ejector after they pass through the gate. Therefore, passengers with commuter or stored-fare cards must take the card out of their pocket case before passing through the gate and insert it into the slot. At peak commuter times (rush hours), the majority of passengers use commuter cards, and are therefore inconvenienced each time they pass through the gate.

In response to this, several companies in Japan have recently developed non-contact type wireless IC card systems (WICS) [1] [2] [3]. With a wireless IC card (WICC), the passenger simply passes the card over the transceiver at the gate, without inserting it into a slot. The WICC has greater memory capacity than a magnetic card, and can incorporate a CPU, which allows it to be applied to more sophisticated system, such as post-payment card system.

However, the need still remains for more stable data transmission between the card and the transmitter, and for a reduction in the cost of the card.

We have developed a 2.45 GHz WICS with a very compact transmitter using new technology that comprises a stable data transmission system, a small-size dual-port slot antenna for the WICC, and a single-carrier allocation system for use with multiple gates.

The Nippon Signal Company has developed a new AGS, shown in Fig. 2, which incorporates this newly developed WICS and accepts both magnetic cards and WICCs.

This paper describes primarily the microwave section of the 2.45 GHz WICS; the transmitter-receiver equipment, the small-size dual-port slot antenna, the modulation system used to realize stable data transmission, and the single-carrier allocation system for use with multiple gates.

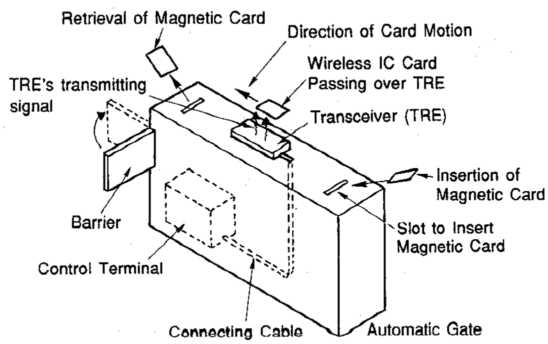

Fig. 2: 2.45 GHz Wireless IC Card System Built on a Magnetic Card System Base

Outline of the Wireless IC Card System

The new WICS comprises a compact transmitter-receiver equipment (TRE) connected to a control terminal, and a WICC, as shown in Figs. 3 and 4. Block diagrams of the TRE and WICC are given in Fig. 5, and specifications are given in Table 1.

The TRE is very compact and radiates 100 mW of microwave power at 2.45 GHz from a circularly polarized patch antenna, which has a gain of about 6.0 dBi, using a highly stable DR oscillator. The WICC is passed over the TRE by hand, as shown in Fig. 3, at which point the WICC detects the 2.45 GHz microwave CW signal and activates a CPU mounted in the WICC. The CPU starts to send a 64 kbps digital signal to a phase modulator, (Fig. 5) which is mounted in the WICC and has a very simple design based on a varactor diode. (The WICC's design has been made simple to realize cost reductions.) The phase modulator modulates the 2.45 GHz CW microwave signal, which is received by an antenna mounted in the WICC's substrate. The WICC then re-radiates the signal through the same antenna. (Fig. 5) The antenna's polarization is linear. Therefore, the angle between the WICC and the patch antenna mounted in the TRE can vary freely without disrupting communication, as shown in Fig. 3, and either side of the WICC can be used.

The TRE receives the phase modulated signal re-radiated from the WICC, and demodulates it with a homodyne detection system. When the data transmission from the WICC to the TRE and the data processing in the terminal are finished, the TRE starts to send AM modulation signals modulated by a 64 kbps digital signal from the terminal. The WICC detects this signal and writes the data to its memory.

Small-size Dual-port Slot Antenna [4]

Fig. 6 shows the newly developed small-size dual-port slot antenna for use in the WICC. The pattern at the center of the antenna acts as a loading capacitor to lower the resonant frequency of the slot antenna. This, in turn, reduces the size of the antenna.

Table 1: Specifications of The Wierless IC Card System

Carrier Freq.		2.45GHz
Radiation Power of TRE		100mW
Size of TRE		175×70×25mm
Size of WICC		86×54×1.5mm
Antenna of TRE		Circular Polarized Patch Antenna
Antenna of WICC		Small-Size Slot Antenna
Communication Distance		0–50cm
Moving speed of WICC		2m/s max
Data Bit-rate		64kbps
Modulation	Data Read	Refrection type PM
	Data Write	AM

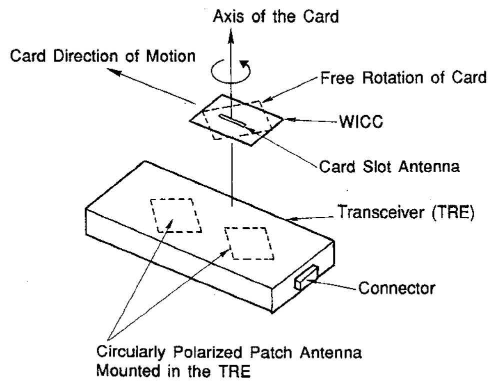

Fig. 3: Position of the WICC for the TRE

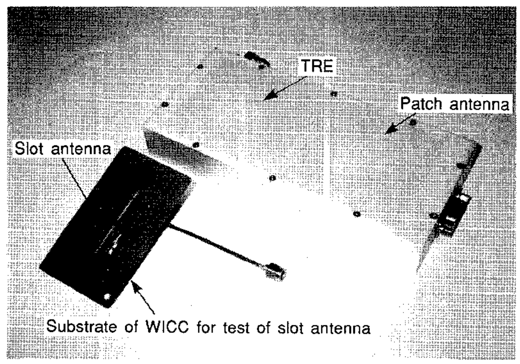

Fig. 4: Photo of TRE and Substrate of WICC for Test of the Slot Antenna

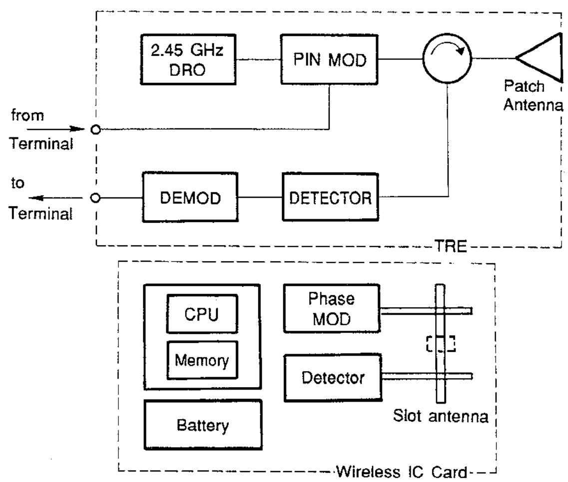

Fig 5: Block Diagram of TRE and WICC

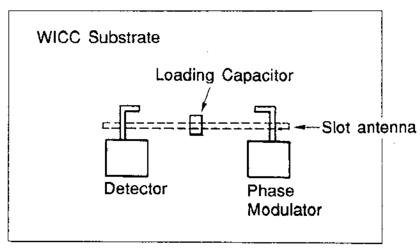

Fig. 6: A Small Dual-Port Slot Antenna Constructed on the WICC Substrate

One port of the antenna is used for detecting the 2.45 GHz microwave signal, and the other is used for receiving the 2.45 GHz microwave CW signal and re-radiating the phase modulated microwave signal. This small-size slot antenna was developed to leave more space for the WICC battery, since the battery's capacity determines the service life of the WICC.

The slot antenna's directivity is shown in Fig. 7. The gain is about 4.0 dBi for one port operation, but for dual port operation, the gain is about 1.0 dBi.

Modulation System for Stable Data Transmission [5]

At the TRE, the polarity of the demodulated signal is determined by the distance between the WICC and the TRE. This is a doppler effect, and is expressed by the following equation:

$$S(t) = A \cdot \cos \{\theta(s) + \pi(4/\lambda) \cdot d\}$$

where "S(t)" is the demodulated signal, "θ(s)" is the phase of the modulated microwave signal, "d" is the distance between the WICC and the TRE, "A" is a constant, and "λ" is the wavelength of the microwave signal.

From this equation, if $(4/\lambda) \cdot d$ is even, then $S(t) = A \cdot \cos \{\theta(s)\}$. If $(4/\lambda) \cdot d$ is odd, then $S(t) = -A \cdot \cos \{\theta(s)\}$. Therefore, when the WICC passes over the TRE, there are several positions at which the polarity of the demodulated signal reverses, due to the changing distance "d". At the moment of polarity reversal, the demodulated signal will become very small or zero. As a result, some signal errors will occur.

To get stable demodulated signals, a new and simple modulation system has been developed. In this system, θ(s) (64 kbps digital signal) is modulated by a high frequency signal, fm, as shown in Fig. 8(b). The signal received at the TRE is expressed by the following equation:

$$S(t)_N = A \cdot \cos \{\theta(s) \cdot (1-\cos (2\pi fm \cdot t))/2+\pi(4/\lambda) \cdot d\}.$$

The clock frequency of the CPU is 500 kHz, and has been selected to be fm. The demodulated signals for d = even, even + 1/2, and odd are shown in Fig. 8(c). Using these signals, θ(s) can be stably regenerated as shown in Fig. 8(d).

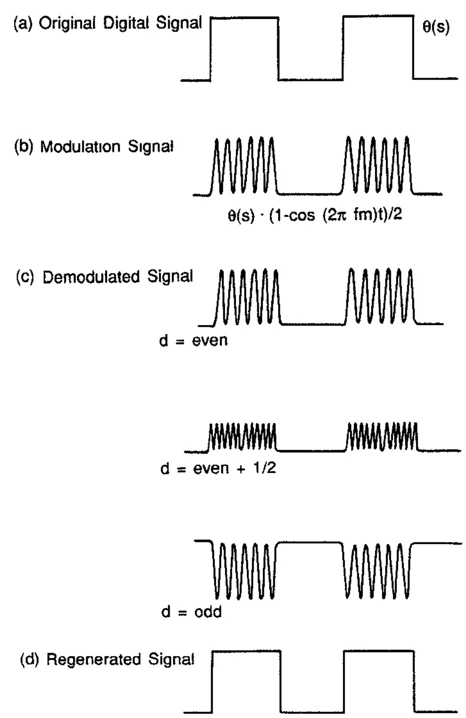

Fig. 8: Demodulated Signals of New Modulation System

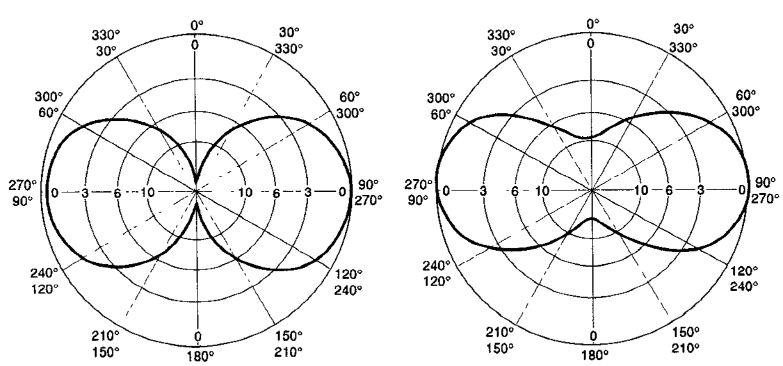

Fig 7: Measured Directivity of the Dual-port Slot Antenna

Single-carrier Allocation for Multiple Gate Operation

For operation of multiple gates, a co-channel allocation system has been developed to effectively utilize frequency resources. In this system, each oscillator is phase locked, as shown in Fig. 9. Therefore, each TRE uses a single carrier frequency. The spectrum for the received signal of one TRE (including the desired signal from the WICC, and the interference single, which is the other TRE's modulated transmitting signal) is as shown in Fig. 10. The interference signal's spectrum is in a lower frequency band, below about 150 kHz, whereas the desired signal is in a higher frequency band, with most of the energy around the 500 kHz fm. Consequently, the interference signal can be rejected by a high-pass filter inserted in the front end of the preamplifier of the demodulator.

Conclusions

A 2.45 GHz wireless IC card system has been developed. It comprises a compact transmitter-receiver equipment connected to a control terminal, a wireless IC card that contains a small-size dual-port slot antenna, a new modulation system for realizing stable data transmission, and a single-carrier allocation method for use with multiple gates. This wireless card system using these newly developed technologies has been successfully demonstrated, and the authors hope it will prove a useful advance in the field.

Acknowledgement

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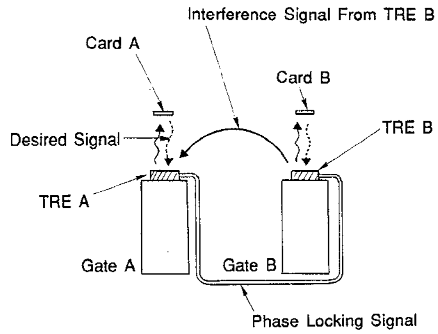
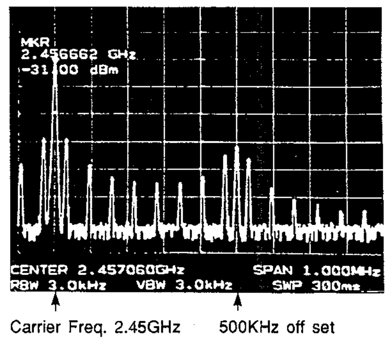
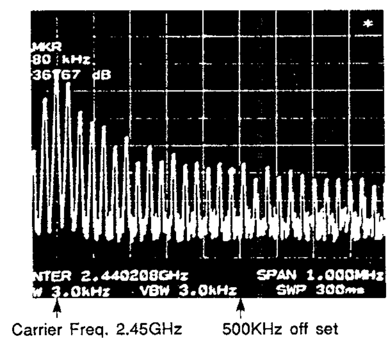


Fig. 9: Phase Locking System



(a) Spectrum of Desierd Signal (from WICC)



(b) Spectrum of Interference Signal

Fig. 10: Spectrum of Desierd and Interference Signal