An Advanced Co-Channel Operation Method for Multiple Wireless Gate

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Abstract

An advanced co-channel allocation system for use 2.45 GHz multiple wireless gates in a train station has been developed. It is desirable to use a co-channel allocation system when designing a multiple gate system to effectively utilize frequency resources. The new co-channel allocation system doesn't need to phase lock. Each transmitter has a highly stable oscillator. The installation cost of this co-channel operation system is lower than old model which needs to phase lock. The interferences in a multiple wireless gate using this new co-channel system are discussed and compared with experimental results. The operation of advanced model has been successfully tested with the newly developed highly stable PLL DR oscillator.

1. Introduction

A simple transmission system has been developed for a 2.45 GHz wireless automatic passenger gate system with multiple gates, and the effectiveness of this system has already been reported[1].

The transmission system consists of a simple modulation/demodulation scheme for stable data transmission and a co-channel allocation system for use with multiple gates. It is desirable to use a co-channel allocation system when designing a multiple gate system to effectively utilize frequency resources.

However, the co-channel operation system needs to connect each transmitter with semi-rigid coaxial cable to phase lock each transmitter's oscillator as shown in Fig. 1. As a result, the installation cost of this multiple gate system in a train station is expensive. Therefore, we have developed an advanced co-channel allocation system, which doesn't need to phase lock or have semi-rigid coaxial cables installed. Each transmitter has a highly stable oscillator. The installation cost of this co-channel operation system is lower than old model.

This paper describes an outline of the wireless gate system, discussion of interference signals and their suppression, design of the highly stable oscillators for use in the advanced system, and experimental results.

2. Outline of The Wireless Card System

In Japan there are a maximum of 16 gates in an automatic magnetic card gate system. The distance between the gates is about 75 cm and the height of the gate is about 85 cm, as shown in Fig. 2.

As shown in Fig. 1, in a wireless card system, the transmitter/receiver equipment (TRE) is installed on each gate, which are the same size as the magnetic card system's gate. When a person passes through a gate he passes his wireless card over the TRE with his hand.

The distance between the card and the TRE is less than 30 cm. The sequence of data transmissions between the card and the TRE is shown in Fig. 3. This sequence must be completed during the time the card passes through the communication area above the TRE.

The modulation system of the TRE is ASK, and the card's modulation system is PSK using a subcarrier. The transmission rate of the digital signal is 64 kbps and the subcarrier frequency is 500 kHz.

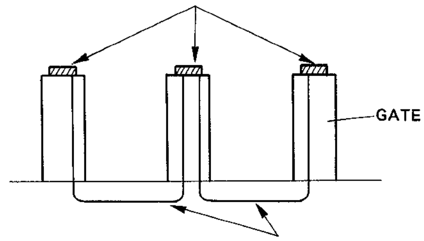

Fig.1 Phase Locking System of Multiple Gate Operation

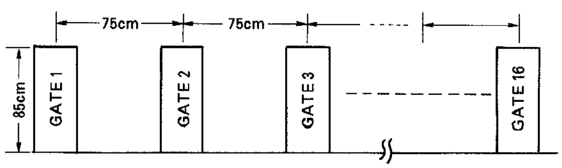

Fig.2 Multiple Gate of Magnetic Card System (maximun 16gate)

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Fig. 4 shows the spectrums of the modulated RF signal of the TRE and the card. The spectrum energy of the TRE's modulated RF signal concentrates around the carrier frequency fo while the energy of the phase modulated RF signal from the card is around the offset frequency fm (subcarrier frequency).

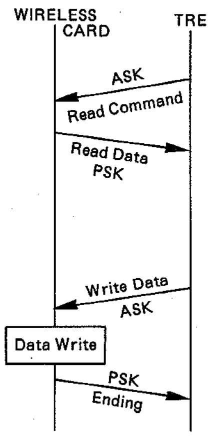

Fig.3 Sequence of The Data Transmission

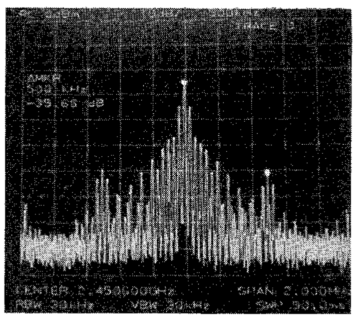

Fig.4 Spectrum of moduloted RF Signals of The TRE and The Cand

3. Interference Signal and Their Suppression

As shown in Fig. 5, when the TRE(A) and the card(A) are communicating with each other according to the sequence, there are interference signals [Pu_T] and [Puc] from neighboring TREs and cards. These interference signals are received along with the desired signal and detected by the TRE(A) and the card(A). At TRE(A), the desired signal is [Pdc] from the card(A) and the interference signals are [Pu_T] and [Puc]. At card (A), the desired signal is [Pd_T] from the TRE(A) and the interference signals are [Puc] and [Pu_T].

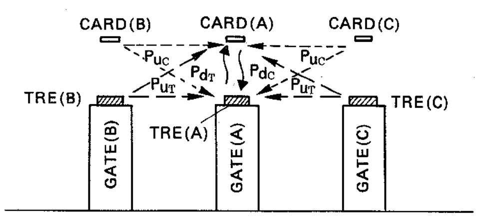

Fig.5 Multiple Wireless Card System and It's Interference Signals

The desired RF signal level [Pdc] received by the TRE(A) is expressed as following expression:

$$Pdc = (\lambda/4\pi h)^4 G_T{}^2 Gc^2 P_T/Lc$$

where [h] is the distance between TRE(A) and card(A), [G_T] is TRE (A) and (B)'s antenna gain, [Gc] is card (A) and (B)'s antenna gain, [P_T] is TRE's output power and [Lc] is the loss of the modulator of the cards. Fig. 6(a) and 6(b) show the antenna directivity of the TREs and the cards respectively.

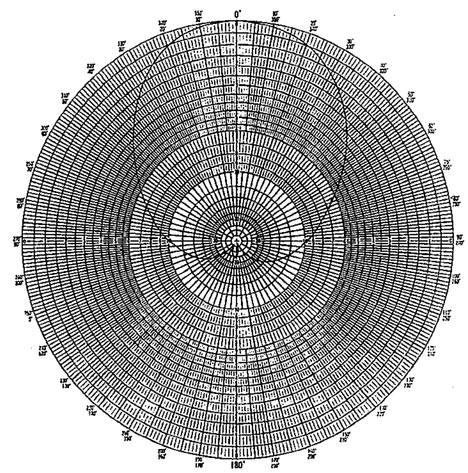

Fig.6 (a) TRE's Antenna Directivity

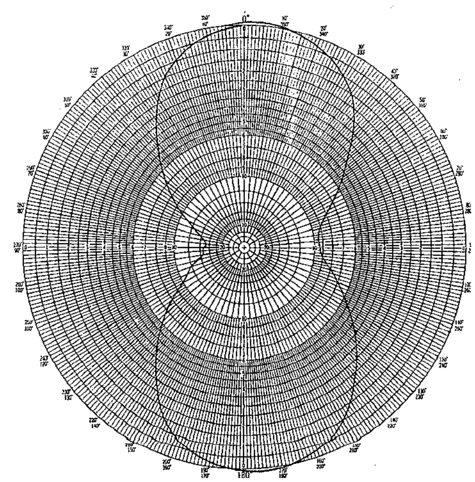

Fig.6 (b) CARD's Antenna Directivity

The interference RF signal level [Puc] from the card(B) received by TRE(A) is expressed by following expression:

$$Puc = (\lambda/4\pi h)^2 (\lambda/4\pi\sqrt{(h^2 + d^2)})^2 G_T{}^2 Gc^2 G_T b^2 Gcb^2 P_T/Lc$$

where [d] is the distance between TRE (A) and (B), [$G_T b$] is the TRE(A)'s antenna directivity gain of the direction to the card(B), its angle is [θb], and [Gcb] is that of card(B)'s directivity as shown in Fig. 7. Its angle is the same as [θb]. The interference RF level [Pu_T] from TRE(B), received by TRE(A) is expressed as following expression:

$$Pu_T = (\lambda/4\pi d)^2\ G_{TS}{}^2 P_T$$

where [G_{TS}] is the front side directivity of the TRE(A)'s antenna to TRE(B) from TRE(A), as shown in Fig. 7.

From these expressions, we can get the ratio of the interference signal to the desired signal as shown in Table 1. [D_{TS}] used in the expression of case 2 in Table 1 is [G_{TS}/G_T]. Table 2 shows the value of the antenna gains in both case: d = 75 cm and 1.5m.

In practice, there are other effects, such as that which occurs when a parson passes through the gate or the material effects of a parson's belongings. These effects are still under consideration and therefore, the expressions do not include them. We will present experimental results and an analysis of such effects in our next report.

The calculated value of this interference ratio by table 1 using the values of Table 2, is shown in Table 3. A desired interference ratio is under than –14 dB. If interference signals from both side are received, a single side's interference ratio

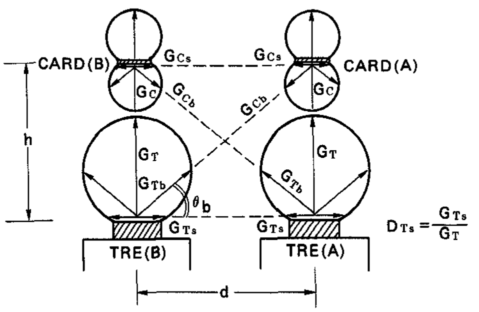

Fig.7 Gain and Directivity of Multipul Gate

Table 1. Expressions of Interference Ratio

	Interference Ratio	Expression
CASE 1	Pu_C/Pd_C	$G_{Cb} \cdot G_{Tb} \cdot (1+(d/h)^2)^{-1}$
CASE 2	Pu_T/Pd_C	$(h/d)^4 \cdot (D_{Ts}/G_C)^2 \cdot (4\pi d/\lambda)^2/L_C$
CASE 3	Pu_C/Pd_T	$G_C \cdot G_{Cs} \cdot (\lambda/4\pi d)^2/L_C$
CASE 4	Pu_T/Pd_T	$G_{Cb} \cdot G_{Tb} \cdot (1+(d/h)^2)^{-1}$

Table 2. Antenna Gain

d	θb	G_T	G_{Tb}	G_{Ts}	D_{Ts}	G_C	G_{Cb}	G_{Cs}
0.75m	22°	3.0^{dBi}	-3.0^{dBi}	-7.0^{dBi}	-10.0^{dB}	1.0^{dBi}	-5.5^{dBi}	-8.5^{dBi}
1.5	11°	3.0	–5.0	–7.0	–10.0	1.0	–7.0	–8.5

h=0.3m

Table 3. Caluculated Value of Interference Ratio

Interference Ratio		h=0.3m	
		d=0.75m	d=1.5m
CASE 1	Pu_C/Pd_C	-17.6^{dB}	-26.1^{dB}
CASE 2	Pu_T/Pd_C	5.8^{dB}	-0.2^{dB}
CASE 3	Pu_C/Pd_T	-51.2^{dB}	-57.2^{dB}
CASE 4	Pu_T/Pd_T	-17.6^{dB}	-26.1^{dB}

needs to be under than –17 dB. Therefore, we can see for co-channel systems, the distance between gates must be 1.5m or more, except for case 2.

In case 2, the energy of the detected desired signal's spectrum concentrated around the subcarrier frequency and the interference signal's spectrum is concentrated around a lower frequency band. Therefore, the interference signal can be rejected by using a high path filter (HPF), because the carrier frequency of the TREs are very close each other by using high stable DRO.

For example to keep a interference ratio under –14 dB, it needs to suppress more than 14.2 dB with the HPF.

The next gate of distance d = 0.75m needs a separate channel to remove the interference signal. This means this system needs two separate channels for multiple operation as shown in Fig. 8. Separate channel's interference can be rejected with a low path filter (LPF).

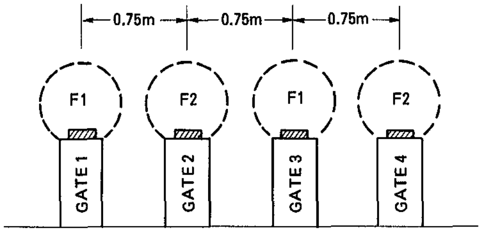

Fig.8 Channel Allocation

4. Design of Highly Stable Oscillator

A highly stable oscillator has been developed for the advanced co-channel operation system.

A compact size dielectric resonator of TE_{01} mode is used to realize high stability. The dielectric resonator's εr is 75 and Qo is 6000 at 2.45 GHz. The size is about 16.0 mmϕ and 8.0 mm thick. To get a more stable oscillator a PLL circuit is used. A PLL IC is 2.45 GHz band two modulas pulse swallow type and the reference Xtal oscillator is SM type, 14.4 MHz oscillation frequency, and its stability is 2.5×10^{-4} between –30°C and +75°C. Fig. 10 shows the characteristics of the developed DRO. The frequency stability is ±5.5 kHz between –20°C and +60°C.

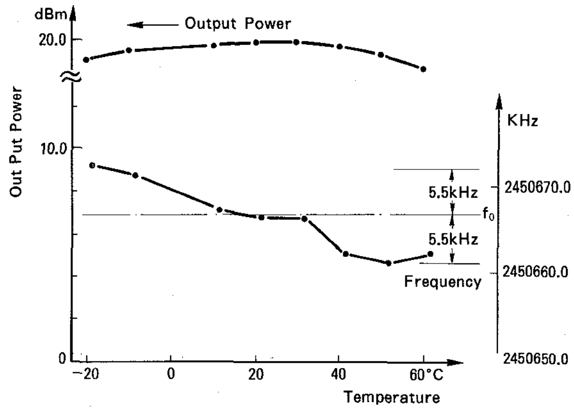

Fig.10 Stability of Frequency and Output Power of Developed DR Oscillator

5. Experimental Results

CASE 1:

Fig. 11 shows the measured values of the interference ratio and the value estimated by using the equation in Table 1. There are large differences between the measured value and the estimated value. This is caused by a difference between the antenna characteristics of the measurement environment and practical environment such as gain and directivity. We are investigating the cause of these differences.

CASE 2:

Fig. 12 shows the detected interference signal measurements at a two gate operation. The HPF used in the TREs to reject the interference signal has the same attenuation characteristics as old model to allow comparison of both. Fig. 13 shows the old model's characteristics. The amplitude of these interference signals detected has almost the same value for same distance gate. Therefore, we can get the same performance from a co-channel system as with the old model. The separate channel has been operated at 6 MHz separation with good interference suppression.

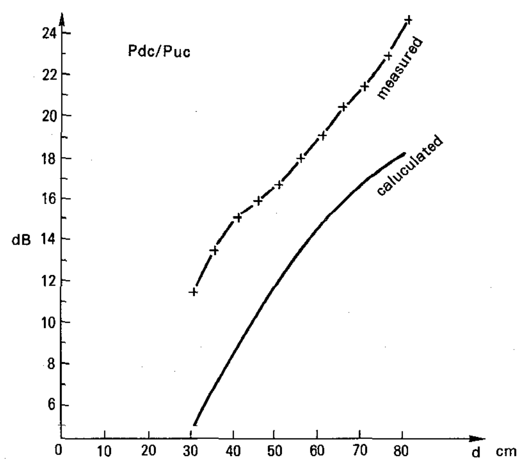

Fig.11 Interference Ratio of Case 1

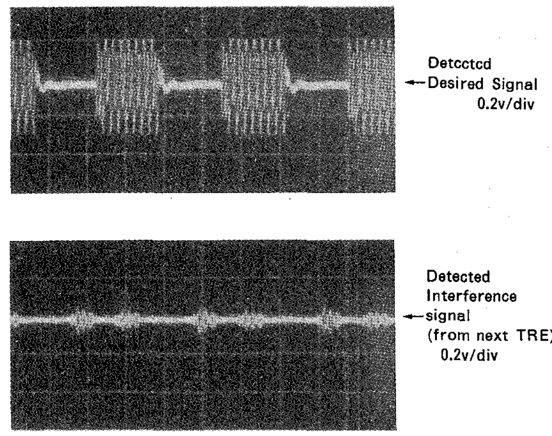

Fig.12 Detected Interference and Desired Signal of non Phase Lock System (new version)

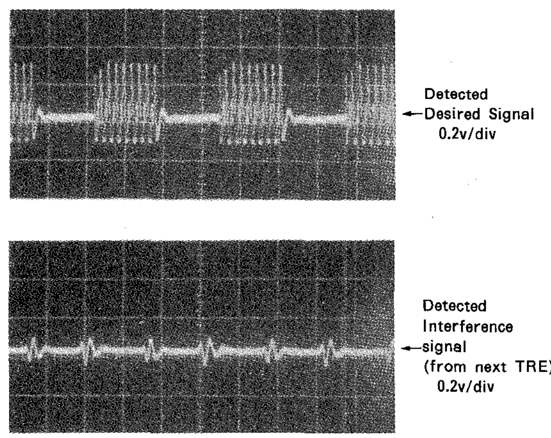

Fig.13 Detected Interference and Desired Signal of Phase Lock System (old version)

6. Conclusions

An advanced co-channel system has been developed. In comparison to old model, this system can be installed at a lower cost in a train station.

The interference ratio were discussed and measured values compared. The operation of advanced model has been successfully tested with the newly developed highly stable PLL DR oscillator.

Reference

[1] K. Konno, T. Kojima, "A Simple Transmission System for 2.45 GHz Multiple Wireless Gates", 1994 MTT-S International Microwave Symposium Digest, San Diego, pp. 1081–1084.