Study on Multiple Antenna Combining for Sequentially Switched Antenna Array Receivers

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***Abstract*— The traffic from many smartphones in a bullet train is increasing and there is a fear of the capacity lack in the train-unit entrance circuit. In the Sequentially Switched Antenna Array Receiver, the array antenna elements fix the receiving point against the travel of the bullet train. In addition, it is necessary to synchronize the switching with the sampling period. We propose a multiple antenna combining scheme that satisfies the requirements for the sequentially switching, and show its effectiveness by computer simulations using experimental data.**

Keywords—switched antenna; high speed vehicle; array antenna; sequentially switched antenna array receivers

I. INTRODUCTION

Recently, the traffic from many smartphones is increasing. Smartphones reside densely in a train, therefore for improved spectral efficiency, it is better to communicate by way of a repeating device in a train rather than with each individual smartphone to the base station outside the train [1]. In this work, the continuous Sequentially Switched Antenna Array Receiver (SSAAR) technique for linear moving super high speed train is considered [2]. Antenna switching should be synchronized with the symbol rate to receive the OFDM signal. On the other hand, the physical limit of the interval between antenna elements is longer than the length determined by wavelength.

In this paper, we propose a multiple antenna combining scheme to satisfy the requirements for the sequentially switching, and show its effectiveness by computer simulations and by measurements.

II. PROPOSED METHOD

A. Principle of SSAAR

The array antenna on a high speed train receives signals from the base station via a high speed multipath fading channel. Fig. 1 shows the concept of the array antenna switching for the SSAAR. The train is lined on the railway (one-dimensional road) with many antenna elements. Receiving antenna elements are selected in order of the opposite direction of the moving train. Ideally the channel fading can then be canceled.

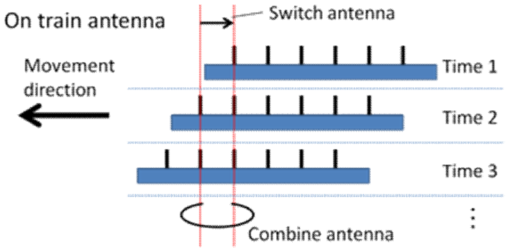


Fig. 1. Schematic diagram of switching antenna

B. Multiple Antenna Combining for SSAAR

The notch frequency change during a frame time length can be negligible in the case of a normal speed car or train. However, the notch frequency changes within a frame time length, in the case of a high speed train. The notch frequency changing rate depends on the train speed. We assumed that the acceleration is negligible within a frame period and that the speed of the train can be measured using preambles. Therefore, the notch frequency moves linearly. Ideally, the notch frequency of the selected antenna element does not change in the case of sufficiently short antenna element spacing. However, there is a physical interval limit in antenna element spacing due to antenna coupling. To investigate the above problem, we propose the combining scheme of multiple antenna elements. The first step is to select multiple antenna elements from all of the array antenna elements. The second step is to combine the received signals from selected elements with controlled weights. These steps are repeated every OFDM symbol.

Define T as symbol cycle, V as speed of bullet train, d as interval of antenna elements, and w is the minimum unit of weight as shown in (1). Also, if θ is known, V can be calculated from (2) by using Doppler shift. Here, θ is arrival angle of electromagnetic wave. c is light velocity, f_a is receiving frequency including Doppler shift, f_b is transmitting frequency.

$$w = (V \times T)/d \tag{1}$$

$$f_a = f_b\sqrt{1-(V/c)^2}\,\big/\,(1 - V\cos\theta / c) \tag{2}$$

Here, define S_1 and S_2 as the received signal of selected neighbor antenna elements and as a complex number. S is the combined signal from selected antenna elements given by (3).

$$S = S_1 + (S_2 - S_1) \times n \times w \qquad (3)$$

Where n is an integer number. When n changes, the position of the receiving point can be adjusted. On the other hand, when $n \cdot w$□1, choices of two elements are changed for S_2 and S_3 because $S = S_2$, and this treatment is repeated.

III. SIMULATION RESULT

Several receiving antennas on a bullet train in the running direction are arranged. The radio wave is transmitted from the base station to the array antennas on this bullet train. The distance between transmitting and receiving antennas is 50m, the bullet train speed is 350km/h, and the distance between array antennas is $\lambda/3$ (λ is wavelength). The transmitting signal is IEEE 802.11g which is OFDM in the 2.4GHz spectrum. In this model, the symbol cycle is 4μs and the spectrum of one channel is 2.400~2.416GHz.

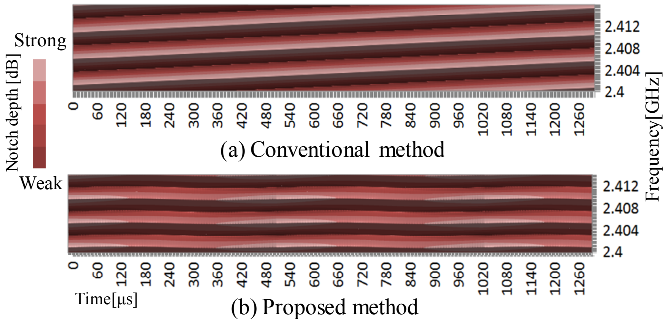
The simulation result for the case without using the proposed combining scheme is shown in Fig. 2 (a). The color of the graph represents the received signal strength. This result shows the notch frequency changes constantly. The result using the proposed combining scheme is shown in Fig. 2 (b). From this result, we confirmed that the notch frequency does not change significantly. This result means that the changing of notch frequency is less than the result obtained without the proposed method.

IV. EXPERIMENTAL RESULT

In this section, the experimental result of the proposed method stated above is considered. Fig. 3 shows the experimental setup used here. In this setup, the transmitter station and eight array antennas were aligned to the same height. As a first step, we defined that the transmitting frequency is 2.5GHz, and Rx array antennas (the distance between antennas is $\lambda/2$) move at 3.6km/h which is a lower scale-speed compared to the bullet train.

In this study, the experimental system which uses the proposed method shown in (1), (3) is constructed. In fact, this method uses a signal switched from the array antenna elements output in real time. But, in this experiment, signals from two antenna elements output were recorded in order to confirm the effect of the combined signal. We analyzed the composite signal on the basis of the experiment data. Fig. 4 shows the combining system. This system was constructed by LabVIEW software. Fig. 5 shows the calculated phase-time characteristics using the proposed method. From this result, we find that the phase variation becomes small. This indicates that the channel fluctuation can be decreased.

With the antenna spacing of 6cm and the moving speed of 3.6km/h it was possible to make the phase flat over a 60msec period. In future work, it is planned to extend this time. In addition, some of the reasons for the phase change of the proposed method are found. As one of the causes, although a constant moving speed was set in the proposed method, in



(a) Conventional method

(b) Proposed method

Fig. 2. Simulated receiving signal strength

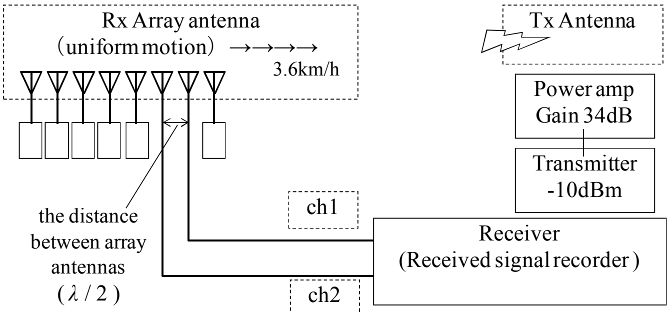


Fig. 3. Experiment structure

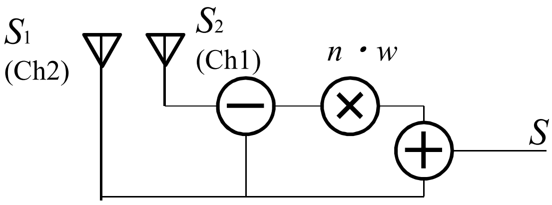


Fig. 4. Structure in proposed method

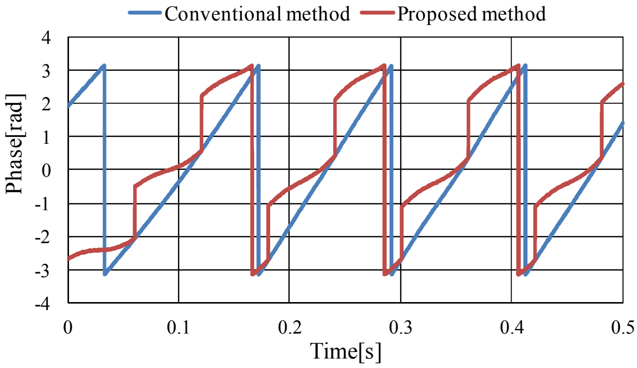


Fig. 5. Phase-Time characteristic

practice it is considered that there was an influence of error in the actual moving speed of this experimental system. It is necessary to get the exact and precise temporal moving speed using (2).

V. CONCLUSION

In this study, a new combining method using some array antenna elements and a weight average is proposed. From simulation and measurement results using the proposed method, we confirmed that the channel fluctuation condition can be improved.

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