POS1-25

Study on an intrusion detecting method using TV broadcasting waves

#Yuichiro Okugawa[1], Yoshiharu Akiyama, Hiroshi Yamane, Kimihiro Tajima
NTT Energy and Environments Systems Laboratories
9-11, Midori-cho 3-chome Musasino-shi, Tokyo 180-8585 Japan
[1]okugawa.yuichiro@lab.ntt.co.jp

1. Introduction

In recent years, the demand for security services has increased in response to the rising number of crimes of intrusion. The most important thing to construct security system is the capability to sense an intruder. Present security systems generally use infrared or vibration sensors. However, an infrared sensor cannot provide complete coverage because it has strong directivity. Therefore, we must use many sensors to fully cover an area. Another problem is that infrared sensors sometimes work incorrectly when the air temperature is close to body temperature.

To solve these problems we are investigating a method of detecting intruders by using radio waves. A radio wave sensor can detect an intruder who enters an out-of-sight area because of its diffraction and permeation characteristics. Such sensors will enable us to reduce the number of sensors that must be installed and reduce the number of malfunctions induced by air temperature.

Intruder detecting method using radio waves can be categorized into two types. One uses actively transmitted waves (active type), while the other uses only reception waves already present in the environment such as TV broadcasting waves (passive type). One example of an active sensor is the Doppler sensor. However, passive-type sensors have some advantages compared with active ones in that they do not worsen the electromagnetic environment, are less limited in terms of available frequency, and can reduce power consumption. Therefore, we are developing a passive sensor that uses TV broadcasting waves.

2. Detection method

2.1 Detection principle and problems

First, we explain the principle of detecting intruder using TV broadcasting waves. TV broadcasting waves, which come from a broadcasting station, and propagate inside a room and form multiple paths by reflecting off the walls and furniture in the room. When a moving object such as a person enters the room, the multi-path condition changes because the waves are also reflected by the moving objects. As a result, the voltage received by an antenna changes in proportion to the speed of the moving object. Thus, this sensor can detect intrusion if the changes in received voltage are analyzed.

In a conventional detection method, the sensor during a period of about 16 seconds detects if the voltage changes by 2 dB [1]. However, changes in TV broadcasting waves can be caused not only by changes in the multi-path condition, but also radio path (for example, by moving airplanes or cars). Like the method in Ref. [1], if the method simply uses a threshold for time differences in the received voltage, false positives may be generated by sudden changes in the received voltage produced by other causes, such as changes of in the ratio path.

Therefore, we investigated an algorithm for reducing incorrect detection caused by external factors. When this algorism was used, we investigated the frequency characteristics of a radio wave sensor, installation point characteristics, and ways of improving the sensitivity.

2.2 Algorithm

First of all, the measuring instrument measures the voltage received by the antenna at regular intervals of time. The received voltage at measurement time t is denoted V_t, and received

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voltage measured one time slot before is denoted V_{t-1}, Thus, the time difference in received voltage is given by

$$\delta_t = |V_t - V_{t-1}|. \tag{1}$$

If the sensor tries to detect intrusion by using only (1) and judging the threshold, it false positives could be generated by sudden changes in received voltage. We decided to use the characteristics of changes in received voltage caused by human movement, and we sum the time differences during a fixed time width. The number of measurement times P is given by

$$P = \frac{T}{\Delta t}, \tag{2}$$

where T is the time width of summation and Δt is the measurement time interval.

Using (2), we obtain the sum $I(t)$ at time t as

$$I(t) = \sum_{i=t-P+1}^{t} \delta_i \qquad (t \geq P). \tag{3}$$

3. Settings of major parameters

To use this algorithm, we should consider the following parameters:

- measurement time interval of the receiver (Δt)
- summation time width
- resolution band width (RBW) of the receiver

Measurement time interval Δt is set to the minimum value of the receiver because this detection method uses multi-path phasing, and the changes in receiving voltage have a very short cycle. So, we set this parameter to 50 ms, which is the limit of the used receiver. Then, the summation time width T is set to 1 s, considering that human movements usually take more than 1 s from start to finish.

On the other hand, we obtained an optimised value of resolution band width (RBW) by changing the RBW of the receiver because it is a significant parameter related to measuring changes in received voltage precisely.

Measurement is done by setting the sensor system illustrated in Fig. 1 at the center of the measurement room illustrated in Fig. 2. The sensor system is composed of a 1/4λ monopole antenna, receiver, and personal computer for controlling the measurement instrument. The measurement room is 6 m x 4 m, three sides are concrete walls (one contains a metal door) and one side is a glass window. In this room, we receive TV broadcasting waves by using a 1/4λ monopole antenna located at the center of the measurement room. The TV broadcasting waves that we could receive were 7 channels in the VHF band (91.25 - 221.75 MHz), 2 channels in the UHF band (477.25MHz - 493.75MHz), and transmitted from Tokyo Tower located 18 km southeast of the measurement room. Each channel carries both video and audio signals. The audio signals use frequency modulation (FM) while the video signals use amplitude modulation (AM). For intrusion detection using changes in received voltage like this algorithm, we think that audio signals are better because they are FM waves and their amplitude is stable. This measurement used the audio signal (493.75MHz) of channel #16 which receiver was able to receive stably.

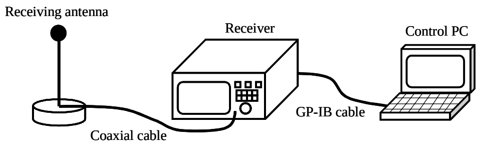

Figure 1: Measurement system

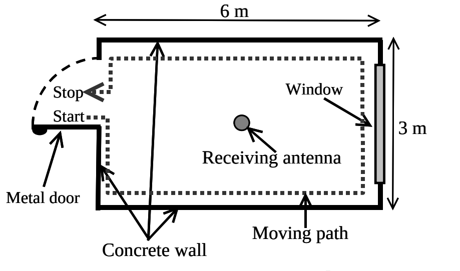

Figure 2: Measurement room and moving path

Here, we explain the method of measurement. First, a person stopped for 10 s at the start point shown in Fig. 2. Then the person moved to the stop point along the route indicated by the dashed line. Using (3), we calculated the average during the stationary period (0 - 10 s) as I_{ae0} and during movement (10 - 20 s) as I_{av10}, respectively. Measurements were conducted for RBW values of 200 Hz, 9 kHz, 120 kHz, and 1 MHz, and the relationship between the RBW and the average of the summation was evaluated. The RBW values were selected based on the available RBW of the receiver used for measurement.

The results are shown in Fig. 3. This figure shows the difference in the average of summation calculated from during the stationary and movement periods (I_{av0} - I_{av10}), namely, it shows the difference in average output value caused by the person's presence. As shown in Fig. 3, the wider RBW, the larger difference in sensor output value caused by the person's presence. A larger difference corresponds to higher intrusion detection precision. Therefore, we decided to use RBW of 120 kHz, which gave the biggest difference in this measurement.

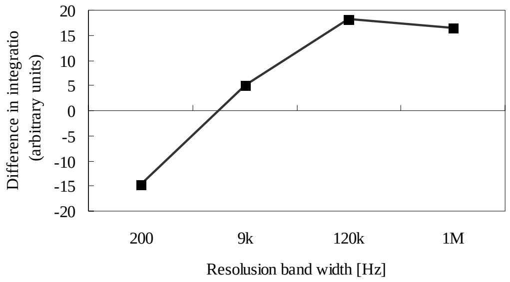

Figure 3: Relationship between difference in summation and RBW.

4. Evaluation of frequency characteristics

Using the parameters obtained in the previous section, we evaluated the frequency characteristics of the sensor. Specifically, the sensor shown in Fig. 1 was set in the measurement room shown in Fig. 2, and the difference in average was compared when the received frequency of TV broadcasting waves changed from 95.75 MHz (ch #1) to 493.75 MHz (ch #16). The person's sequence of movements was the same as for the RBW measurements.

The measurement results are shown in Fig. 4. The higher the frequency, the larger difference in average output. This is because multi-path phasing was stronger because the wavelength was shorter due to the higher frequency.

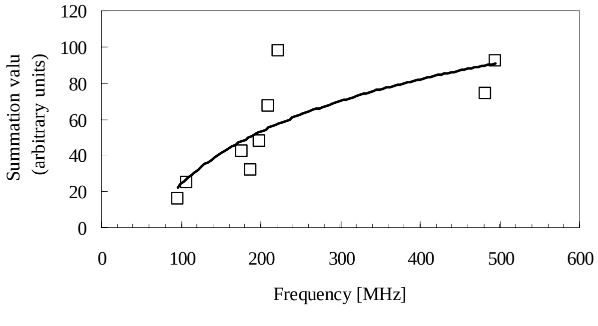

Figure 4: Frequency characteristics of the difference in average output value.

5. Evaluation of installation characteristics

The difference in the average of output value caused by the person's presence was compared when the sensor's installation points were changed among the three points shown in Fig. 5. Two TV broadcasting frequencies were selected: 209.75 MHz (ch #10) and 493.75 MHz (ch #16). The person's movement schedule was the same as for the RBW measurements.

The measurement results are shown in Fig. 6. When the sensor was installed at point 3, the difference in average output value was larger than when it was installed at point 1. This is because a strong multi-pass condition occurred away from the window, so the changes in received voltage were larger.

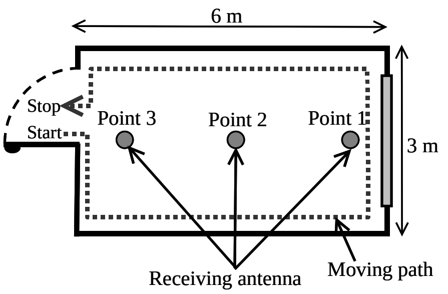

Figure 5: Location of receiving antenna.

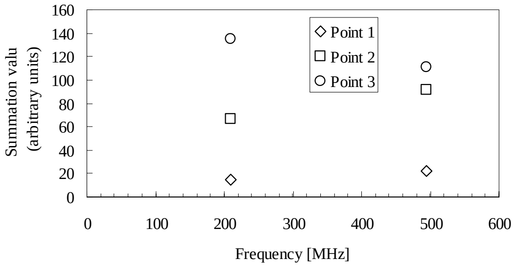

Figure 6: Installation characteristics.

6. Improvement in sensitivity

Finally, we investigated ways of improving the sensitivity by combining the received voltages from two antennas. The experimental system is shown in Fig. 7. Two monopole antennas were connected to a power combiner, and its output was connected to the receiver. The output value was measured for the condition shown in Fig. 2, and the results were compared with those for one monopole antenna. The measurement frequency and the movement schedule were the same as for the RBW measurements.

The results are shown in Fig. 8. When two antennas were used and their output voltages were combining, the difference in output value caused by the intruder was larger. This way of improving the quality of received signals is known as space diversity [2] in mobile communication systems. It is applicable to the situation under consideration here.

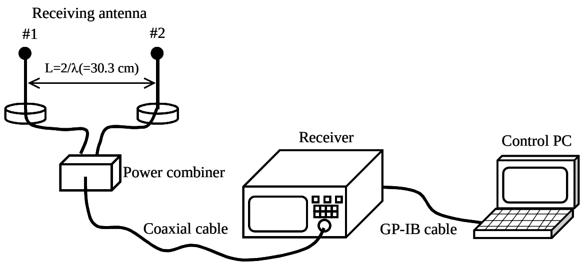

Figure 7: Measurement system

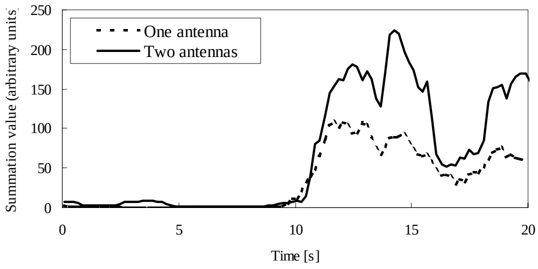

Figure 8: Measurement result using two receiving antennas

7. Conclusion

We investigated a method of detecting intruders by using TV broadcasting waves. First, we proposed an algorithm for reducing incorrect detection arising from changes in received voltage caused by external factors. Then, for this algorithm, we evaluated the frequency characteristics and installation position characteristics. We found that the difference in sensor output value caused by the person’s presence becomes larger when the frequency of TV broadcasting waves was higher, and when the installation points were further from the window. We also investigated possibility of using space diversity. We found that when we use two antennas and combining their output voltages, we obtained a larger output difference caused by a person’s presence.

In future, we plan to investigate a method of determining the threshold and evaluating the probability of detection.

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