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ATTENTION SIGNAL SYSTEM FOR EMERGENCY ALERT BROADCASTING

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SUMMARY

An Emergency Alert Broadcasting System which promptly and effectively conveys emergency notices, such as predictions or warnings of imminent and potentially disastrous earthquakes and tsunami warnings, has been developed at the NHK Technical Research Laboratories. It works through conventional broadcasting systems by automatically actuating alert receivers.

This paper describes the signal format and the method of reception of attention signals for emergency alert broadcasting. The signal is a frequency shift keying (FSK) coded signal using two frequencies in the middle of audio frequency range with a bit-rate of 64 bit/s. The alert receiver can be actuated within a few seconds by transmission of the signal even under severely affected receiving conditions.

The signal can be applied to any broadcasting medium, such as AM radio, FM radio or television.

1. INTRODUCTION

An emergency alert broadcasting system notifies the entire relevant audience of important and urgent information, such as predictions of imminent and potentially disastrous earthquakes or tsunami warnings in a prompt and accurate manner. If, therefore, a specific control signal could be sent from a broadcasting station in advance of the start of an emergency broadcast, and if an alert receiver could be actuated automatically by this signal, the audience would be able to receive without fail the emergency announcement which follows. For this kind of system, various proposals have been put forward and practical equipment is being developed. In the United States of America, several systems are already in operation. In Japan, too, various emergency alert broadcasting systems have been proposed for making announcements of earthquake predictions to the audience and field tests are also being conducted.

This paper describes a general concept of an emergency alert broadcasting system and a system using a digital code signal for its control signal. In section 2, the concept of emergency alert broadcasting system and how it differs from that of other communication systems are set out, and the various signal systems that have been proposed are reviewed in section 3. In section 4, an attention signal system which uses a digital code signal for its control signal is proposed, and the signal format is explained. And the receiving method of the attention signal system and the operating characteristics of the code detector circuit are described in section 5. And in section 6, the results of the field test of the experimental system are given.

2. EMERGENCY ALERT BROADCASTING SYSTEM

The composition of a typical emergency alert broadcasting system is as shown in Fig. 1. The control signal to specify the beginning of the emergency broadcast is inserted by intermitting the program signal, and is sent from the transmitter. The alert receiver always supervises control signal reception, whether the signal is being sent or not, by supplying a

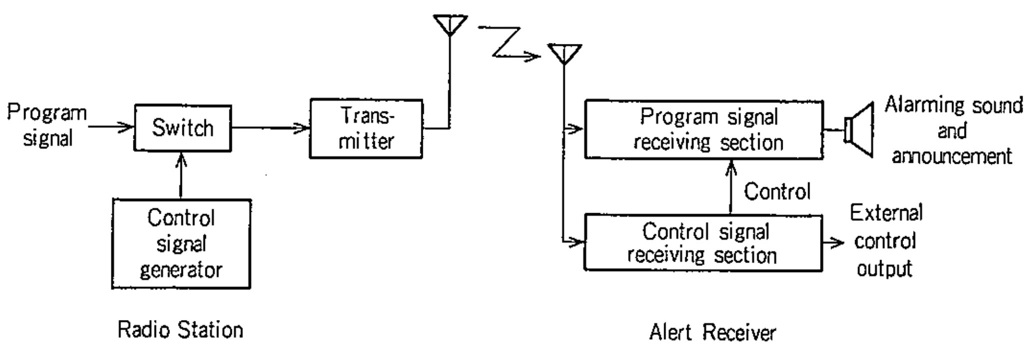

Fig. 1 Composition of emergency alert broadcasting system.

small amount of power to the control signal receiving section. Receiving a control signal specifying the beginning of an emergency broadcast program, the power source of the audio amplifier is switched on automatically, and the emergency program can be heard. When a series of emergency broadcast programs is over, an end-control signal is transmitted from the station. By this control signal, the power source of the audio amplifier is turned off and the alert receiver returns to the waiting condition again. This system is considered to be available for either radio broadcasting or television broadcasting.

This emergency alert broadcasting system has the following special features in comparison with those of other broadcasting systems or many other communication systems; it is not designed merely for sending control signals to put the receiver into operation but also for satisfying very strict requirements.

(1) Moment of use cannot be foreseen

The receiver is always to be kept in a stand-by condition so that no important information may be lost, as it is impossible to foresee when such information is to be expected. In the case of broadcasting, a large number of receivers should be maintained in a reliable condition. However, we have insufficient experiences regarding this.

(2) Mistriggering must not occur

As this system is to be used only for announcing emergencies and very important information, mistriggering will cause chaos and hindrance to normal diffusion. (Here, mistriggering means that the alert receiver is actuated although no control signal has been sent from the broadcasting station. This occurs when the receiver misinterprets program sound or noise as the control signal or when an illegal signal is radiated.) Attention must be paid to this point not only in the system design but also in the manufacture of circuitry.

(3) Nontriggering must not occur

On the other hand, if nontriggering occurs, that is, if the system does not operate in spite of the control signal for emergency broadcasting being sent, the system loses its meaning. In the case of broadcasting, many receiving environments and unanticipated cases of usage may be postulated owing to the daily unconcern of the audience, thus many difficulties will exist.

(4) Power consumption must be low.

A weak current always flows in the control signal receiving section under the condition of stand-by, and the circuit must be designed so that the frequency of battery change is minimized to reduce maintenance work.

(5) Other requirements

In addition to the above, for notification of emergency information, there will be various points that must be considered; for example, the system must operate as quickly as possible provided that the reliability is maintained.

3. VARIOUS SIGNAL SYSTEMS

The principal control signals which have been proposed for multiplexing the signal onto radio or television sound can be classified as in Table 1. The table includes the control signals not only for emergency alerts but also for automatic reception of traffic information or news programs. These signals have a common nature in that they discriminate between types of programs. However, in the case of emergency alert signal, the standards for the design of the required characteristics are considered to be extremely demanding.

As shown in Table 1, there are more systems multiplexing the signal onto the baseband signal rather than directly modulating the carrier wave. Here, in the case of modulating the carrier wave of medium wave broadcasting, the relation to AM stereophonic broadcasting should be taken into account. With regard to the baseband signal, there are two choices: tone signal or coded signal. With either, when using a frequency band in common with the sound programs, the program sound and control signal must be fully discriminated at the receiver. Accordingly, in the case of the tone signal, it would be necessary to send this on a specific frequency for a sufficiently long duration, greater than any during which the same frequency tone is being used in the program. In the case of coded signals, on the other hand, it would be necessary to establish the bit length of the coded signal so that the probability of a specific code pattern occuring in the program sound coinciding with the prescribed code pattern will be sufficiently low. For instance, if the bit length of a code is 64, the probability of a random code pattern coinciding with a code pattern of 64 bits will be $1/2^{64}$. Therefore, the average time-interval of incidental coincidence will be as

Table 1. Classification of control signals multiplexed on sound broadcast signal

CLASSIFICATION				EXAMPLES OF PROPOSED SYSTEMS OR OPERATING SYSTEMS	
Baseband Signal	Program sound	Music, Time signal, etc.		Nippon Cultural Broadc. Co.,"System Q" (Japan)[1]	Arrangement of tone in theme music.
	Tone signal (continuous)	Single-tone	Single-tone	Old EBS (U.S.A.)	Two 5-sec. interruptions of the station carrier, and 15-sec. 1000-Hz tone.
			One-tone out of N	NOAA (U.S.A.)	1050 Hz: special weather warnings, 1650 Hz: routine updating of the weather report.
		Two-tone	Two-tone	EBS (U.S.A.)	853 Hz & 960 Hz, Time period for transmission: 20~25 sec., Time delay for activation: 8~16 sec.,
			Two-tone out of N	NHK (Japan)	Combination of two frequencies near 10 kHz, professional use.
		Three-tone	Three-tone out of N	Tokyo Broadc. System (Japan)[1]	Program identification. Combination of three frequencies out of five freqs. in 50~100 Hz.
	Tone signal (coded)	Single-tone	Single-tone	Kokusai Electric Co., "Warning system" (Japan)[3]	Beginning: 1900 Hz, 12 marks, total 22.5 sec. End: 5-sec. 1900-Hz tone.
			ASK	DIDS (U.S.A.)	e.g. 200 Hz, 12-bit code, duration 12 sec.
		Two-tone	ASK & Sync.	Nippon TV-Network Corp. (Japan)	"Emergency Warning System I" Low frequencies in audio band.
			FSK	NHK (Japan)[4]	"Emergency Alert Broadcasting System" Middle frequencies in audio band.
				Nippon TV-Network Corp. (Japan)	"Emergency Warning System II" Low frequencies in audio band.
		Three-tone	FSK & Sync.	Tokyo Broadc. System (Japan)	"Emergency Alert Broadcasting System" Middle frequencies in audio band.
	Subcarrier	AM	Modulated by one freq. out of N freqs.	ARI (West Germany)	VHF FM broadcasting, Subcarrier freq.: 57 kHz, Regional identification: one freq. out of six freqs. in 23~54 Hz, Traffic information: 125 Hz.
		FM	Frequency deviation	RTL (Luxembourg)	LF radio. News program identification. 2325-Hz signal frequency-modulated by a 115-Hz square wave. Frequency deviation: ±175 Hz for the opening signal and ±75 Hz for the closing signal. Duration: 1 sec.
Carrier Modulation	Interruption of main carrier			Shin-Etsu Broadc.Co., (Japan)[1] Old EBS (U.S.A.)	
	Phase modulation			Nippon Broadc. System Inc. (Japan)[1]	Station carrier is continuously modulated by a specific signal during programs (news, etc.)
	Frequency modulation			CARFAX (U.K.)	Modulating signal : tone signal (freq. deviation: ±2 kHz, duration: 0.5 sec.). Tone frequencies are 125 Hz for the opening signal and 200 Hz for the closing signal.

ASK: Amplitude shift keying FSK: Frequency shift keying.
EBS, DIDS, ARI, CARFAX: System's names.

long as $2^{64}/64=2^{58}$ seconds (about 91 hundred million years) in the case of comparison performed at a rate of 64 times a second. From the relation of this required bit length to bit rate, the time necessary for transmitting the coded control signal is determined. If a frequency in the middle or high bands of audio frequency range is used for modulating the control signal, the time required for transmitting the control signal could be made about one second because the bit rate could be raised higher than 100 bits/second.

4. CODED CONTROL SIGNAL TRANSMISSION SYSTEM

In the following, the coded control signal transmission system for which field tests were performed by NHK to investigate its function as an emergency alert broadcasting system will be explained.

4.1 Composition of Transmission Signal

The composition of the experimental coded control signal is shown in Fig. 2. This signal is composed of a sequence of unit signals which is a code of a specific pattern of 16 bits and is FSK modulated using two frequencies in the audio frequency range. Four of these continuous signals,

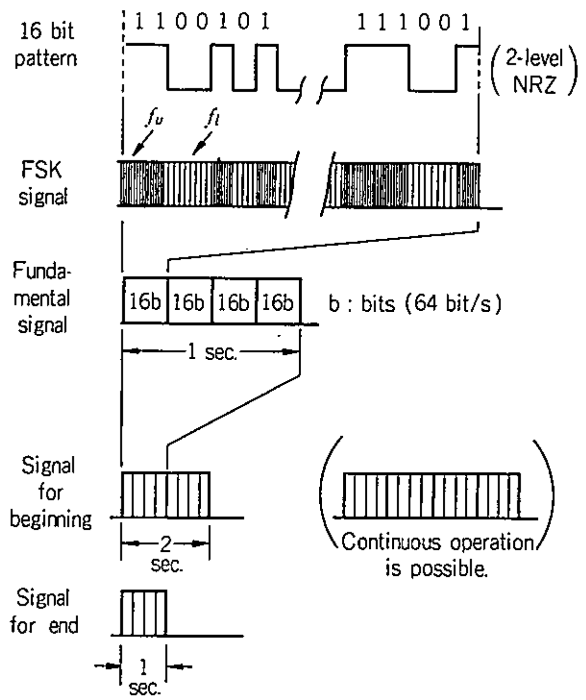

Fig. 2 Example of coded control signal for the experimental attention signal system.

composing a 64 bit signal, are named as the fundamental signal. The bit rate is 64 bit/s, accordingly, one unit of 16 bits pattern is 250 ms duration and the length of a fundamental signal of 64 bits is one second. For the frequency of an FSK signal, two frequencies near 1 kHz are used. For instance, the frequencies used for the experiment are 1024 Hz and 640 Hz; either is an integrated number of times of 64 Hz.

In the case of sending it as an alert signal, the above fundamental signal of one second duration could be combined (secondary coded) and further classified into several kinds of information to be used. For instance, in the experimental system, the signal for beginning is defined as a continuous signal of at least two seconds duration, as shown in Fig. 2, and the signal for end, a signal of one second of the fundamental signal followed by at least one second blank. In addition, as shown in the figure, these can also be repeatedly transmitted to increase the reliability of signal transmission. In this system, as the coded control signal itself is also acting as an alarm sound, which will be mentioned later, it would be practical to transmit the signal continuously for a duration of several seconds.

4.2 Features of the Signal System

The features of the signal system are as follows.

(i) As the middle part of the audio frequency range is used, the transmission characteristics are relatively stable, and failure of operation due to deterioration of transmission characteristics or variation occurring due to lapse of time will not easily occur. In addition, with this part of the frequency range being used, the coded signal can also serve as the alarm sound; if the power switch of an ordinary receiver is on, the alarm sound can arrest the attention of all those within hearing range. It is to be noted that the system is applicable to any broadcasting medium, such as AM radio, FM radio, or television because the audio frequency range is used.

(ii) As coded signals are appropriate, chances of mistriggering due to program contents can be reduced greatly for even a short duration of signal transmission. The tone signal of the EBS requires about 20 seconds, but, in this system about one second would be sufficient.

(iii) The alert receiver can be controlled by transmitting signals briefly, even under severely affected reception conditions.

(iv) By changing the specific code pattern (diagram at top of Fig. 2) a considerable number of different kinds of information can be established. For instance, separate regional codes may be adopted.

(v) As the system is based on digital techniques, the receiving circuit can easily be made of LSIs. Reduction in cost and high reliability can both be realized by mass production.

5. EXPERIMENTAL RECEIVER

5.1 Composition of Experimental Receiver

The basic composition of the alert receiver is shown in Fig. 3.

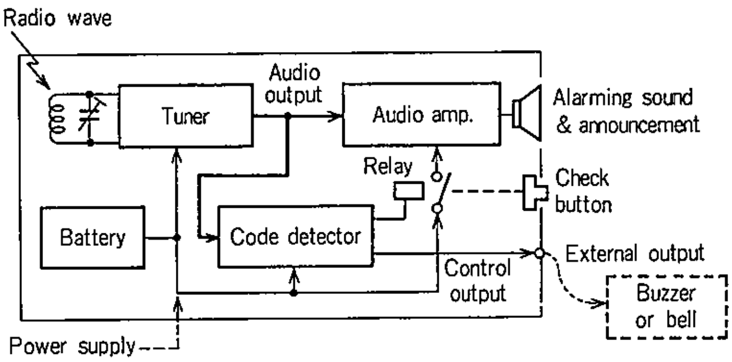

Fig. 3 Basic structure of alert receiver.

In this receiver, the tuner and code detector are always operating on a small amount of power. When a coded control signal indicating the beginning of an emergency alert broadcasting program is transmitted, a control output signal will appear in the code detector circuit of the receiver, by which the power source for the audio amplifier will be switched on automatically.

For actual working models, various types can be built; some exclusively for alert broadcasting purposes and some which can also be used as ordinary radio sets. Fig. 4 is an example of an experimental receiver.

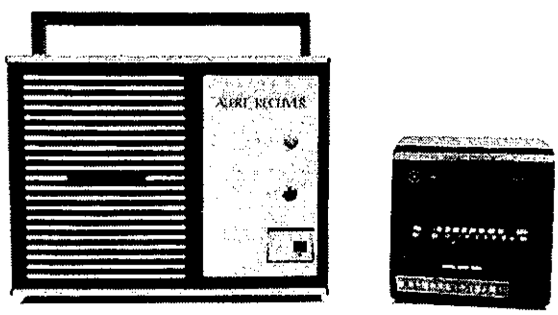

Fig. 4 Two types of experimental alert receiver.

The receiver operates on both batteries and normal power supplies because of the prerequisite that it must be able to operate even when power supplies fail.

5.2 Code Detector Circuit

The code detector circuit, as shown in Fig. 5, after demodulating the FSK signal, detects the coincidence of the code pattern and also discriminates the beginning and end signals to operate the relays, etc.
In the experimental receiver, a circuit as shown in Fig. 6 was adopted for the coincidence detector and the signal discriminator. The feature of the receiver circuit is that it uses an independent clock for inspecting the waveform of a received signal to find the coincidence of code pattern. This scheme is favorable because a waveform for reproducing the bit clock or a synchronization code is not included in the transmission signal.

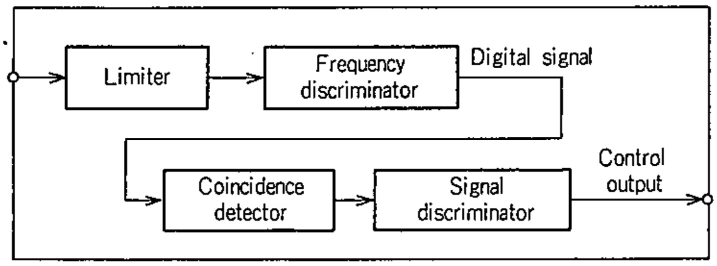

Fig. 5 Composition of code detector circuit.

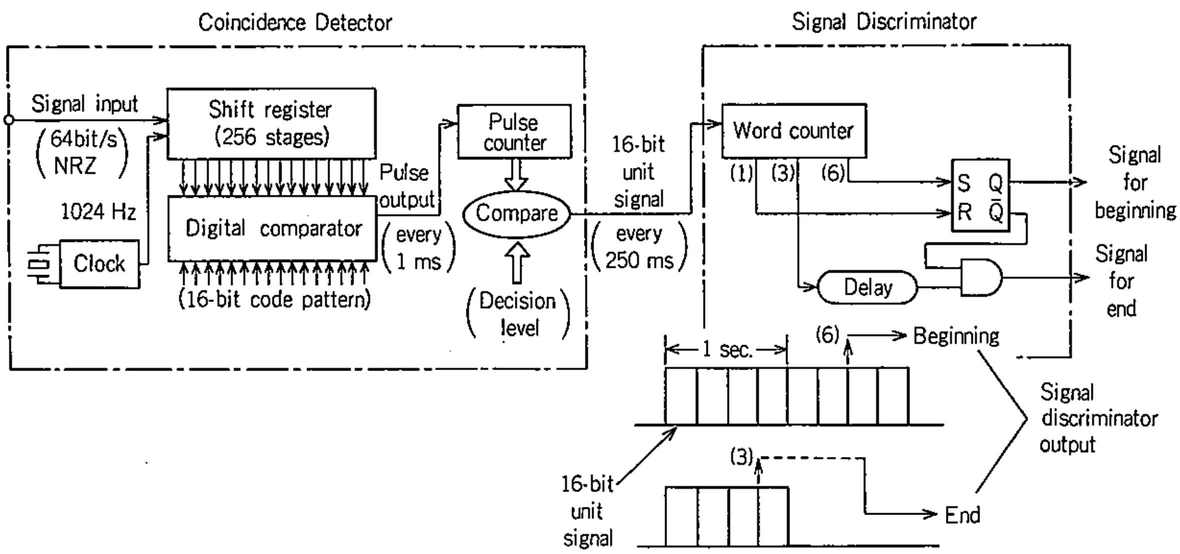

Fig. 6 Block diagram of coincidence detector and signal discriminator.

The operation of the circuit is as follows. First, the received code signal with a bit rate of 64 bits/sec is entered into the shift register at a clocking rate of 1024 Hz, which is 16 times as fast as the bit rate. In the shift register, one bit of input code will become 16 samples (accordingly, a 16 bit code becomes 256 samples) and these samples are stored and shifted sample by sample. If the bit pattern of 16 samples taken out at every 16th stage of the shift register coincides with the specific pattern which has been established in advance as the coded control signal, then a coincident pulse will come out from the digital comparator. Accordingly, if it coincides at each clock timing, coincident output pulses will repeatedly come out at about each 1 ms.

If the received code signal contains no noise components, and if the width of each bit is accurate and ideal, 16 pieces of coincident pulses will come out continuously. However, in practice, even when a correct code is received, coincidence of all of 16 pieces will be difficult due to the influence of noise and waveform distortion. A decision standard was therefore established. If, for instance, more than 8 out of 16 pieces coincide, it is decided that correct code has been received. If the decision standard level is lowered, nontriggering due to noise and waveform distortion can be reduced. However, on the other hand, as mistriggering due to program sound etc. can be reduced if the decision level is high, the level is to be determined in consideration of both. By such a method, if the correct code pattern continues, a detection pulse will be generated each 250 ms, and be sent to the following word counter and signal discrimination circuit.

The word counter and signal discrimination circuit discriminate the signal specifying the beginning and end. As shown in Fig. 6, the logic of the experimental receiver is such that when 6 pieces of unit signal are detected during a predetermined time, this is decided as the beginning signal, and when three pieces are detected and if this is not decided as the beginning signal after one second has elapsed, it will be discriminated as the end signal.

By the above-mentioned code detector, a control signal sent only occasionally can be discriminated immediately and accurately without using complicated circuits such as a bit clock extraction circuit or a frame synchronization circuit such as are used in ordinary digital data transmission systems. Namely, as a stable clock can be obtained over a long duration on the receiving side, it is considered that high reliability can be attained compared with the case of extracting a clock from the signals received under various transmission conditions. As for this clock frequency in the experimental receiver, a frequency divided from the frequency of 32.768 kHz for the crystal for a digital watch is used.

5.3 Operating Characteristics of Code Detector

As described in section 5.2, in the code detector of the experimental receiver, the detection of a code is performed by a method of sampling the input signal at a rate N times (N=16, for instance) as fast as the bit rate. In using this method, it is necessary to establish a decision level on the amount of coincident pulses coming out during one bit duration, to determine whether a correct code is being received or not. In this section, the operating characteristics of the receiver relative to mistriggering and nontriggering are considered, varying the value of the decision level, which is denoted as K.

Fig. 7 shows the results of an experiment on the relation between the average word error probability in the presence of white Gaussian noise and the decision level K. The code length is 16 bits and receiving clock frequency is 1024 Hz (N=16). Here, for measuring the S/N ratio, the bandwidth of program sound is assumed to be 5 kHz, and the noise power in the

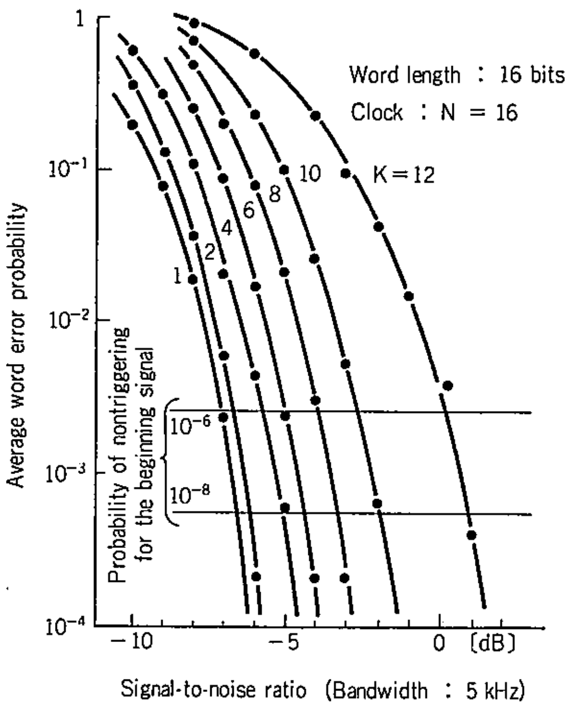

Fig. 7 Relation between the average word error probability and the decision level K, and the estimated value of nontriggering probability for the beginning signal.

same bandwidth of 5 kHz is measured*1. In this figure, the S/N ratio required to make the probability of nontriggering for the beginning signal (for discrimination when sent for two seconds and received for a duration of over one and a half seconds) of an emergency broadcast a value of 10^{-6}, 10^{-8} is indicated. It is clear from the result that the probability of nontriggering can be reduced by decreasing the decision level K.

Fig. 8 gives the measured results of the average time interval when white Gaussian noise*2 or the sound signal of a broadcast program was applied to the input of the code detector and received and discriminated as the specific code word. Each point (•) in the lower part of the figure shows the average time interval when the decoded pattern of random noise coincides with a specific 8-bit code pattern. And each point (•) in the upper part indicates the result in the case of a 16-bit code pattern. Both of these

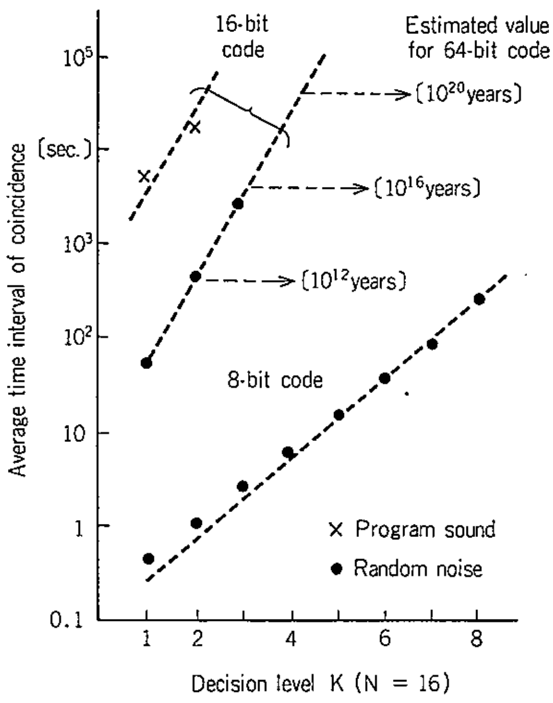

Fig. 8 Average time interval of coincidence of random signal to a specific code pattern.

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*1 For the bandpass filter in an FSK demodulator, an RC active filter is used and the Q is 6.8 (Center frequency is 1024 Hz or 640 Hz).

*2 In this measurement, the noise level is set at a value so that the levels 1 and 0 occur equally at the demodulator output. This condition means that the average time interval will become shortest and the measured value will correspond to the most extreme cases.

results show that the average time interval of coincidence rapidly becomes longer with an increase in the value of K. The dashed line for the 16-bit code shows results estimated from the measured value for the 8-bit code. The measured values for the 16-bit code fit the dashed line well. In the same way, the value of the average time interval which could be mis-discriminated as a fundamental signal of 64 bits can be estimated and the results are also indicated in the figure. Each point (×) in the figure shows an example of the average time interval when the sound signal of a broadcast program coincides with a specific 16-bit code pattern. As the pattern of a sound signal is not always random, the chance of its coinciding with a code word, of which the bit pattern is random, is reduced.

From the results shown in Fig. 7 and Fig. 8, there is no problem in the values of both nontriggering and mistriggering probability. However, for maximizing the reliability in terms of mistriggering and nontriggering, it is recommended that the decision level K be chosen as $K=4\sim8$ for $N=16$.

6. FIELD TEST OF THE EXPERIMENTAL SYSTEM

The field tests on the experimental system were performed from February to March 1980, using NHK Radio 2 (693 kHz, 300 kW). The test wave was transmitted from midnight for about two hours after regular broadcasting was over, and reception tests were conducted at Tokyo, Kanagawa and Shizuoka for a total of 10 days. As for the transmission condition of test signals, the duration of the transmission time of the coded control signal and the transmission level were varied; that is, the duration of the signal for beginning was two seconds and 10 seconds, and modulation degree was 80% and 20%. The signals were received at several fixed points in urban and rural areas, and by a moving van.

It was shown by the results that the receiver would operate without fail in Tokyo and Kanagawa, which are in the direct service area of the Radio 2, and that there was no trouble at all even when the beginning signal was of two seconds duration and degree of modulation was reduced to 20%. At Shizuoka which is outside the service area, strong fading was observed at night time, and nontriggering occurred occasionally in receivers which were not provided with anti-fading circuitry. However, we came to the conclusion that if modulation degree is 80% and transmission duration is 10 seconds, the system will be completely operable even in these areas.

It is to be noted that no mistriggering occurred throughout both field tests and laboratory tests.

7. CONCLUSIONS

The general concept of an emergency alert broadcasting system and a coded control signal system has been explained. The composition of a receiver for the system and the operating characteristics of the code detector circuit have also been described. High reliability is particularly required for an emergency alert broadcasting system, and it was confirmed that a sufficiently reliable system can be realized by means of the coded signal and the receiving system described in this paper. And the duration of the transmission signal can be reduced to about one second when the system is used within the main service area. In emergency broadcasting, one premise is that the contents of an announcement must be conveyed perfectly. Accordingly, under such a condition, the nontriggering probability of a control signal becomes a value which can be ignored and the average time-interval of mistriggering occurrence is found to be a large value which can be also ignored.

It has been clarified, as mentioned above, that the proposed system can be used as a transmission system for transmitting the control signals of an emergency alert broadcasting system. However, this merely gives one fundamental form, and therefore, it will be necessary to make further considerations on other requirements for practical operation. For instance, for the code pattern in the system which is under deliberation by the Radio Technical Council of the Ministry of Posts and Telecommunications of Japan, a fixed code pattern of 16 bits and variable code pattern of 16 bits are combined. This variable code pattern is added for the purpose of coping with illegal radio transmissions, which may become the cause of mistriggering, and a plan for using codes corresponding to times and dates is being considered. In addition to such problems, it would be essential to consider many other points in developing the system for practical use, including, for instance, the organization and requirements of the operational system, the reliability and cost of receiver hardware, easiness of use, and furthermore, considerations to prevent mistriggering due to the illegal radio transmissions mentioned above and a check system to ensure reliability. Either case involves peculiar and difficult problems in the usage of an emergency alert broadcasting system. From now on, development of a synthetic system is to be planned on the basis of these considerations.

In ending this paper, we would like to express our gratitude to the engineers of the Laboratories and the Engineering Headquarters for their suggestions and cooperation in developing this system.

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