UDC 621.396.62

Network Follow System

● Yoshihisa Mizuno ● Takashi Nagamitsu

To keep up with the latest sophisticated advances in automotive sound systems, automotive radio receivers require performance improvement. One technique to improve reception is automatic following and tuning to adjacent stations broadcasting identical program material. As the vehicle moves out of the broadcast range of one station, the receiver automatically searches for and locks onto the stronger signal of another station broadcasting the same material. This technique is currently used in Europe for RDS network broadcasts.
Working with the Toyota Motor Corporation, we have developed a similar tracking system called the Network Follow System.
This paper introduces the basic operating principle of the system, and focuses on its audio signal comparison circuit.

1. Introduction

In Japan, widely scattered radio stations and repeater stations transmit the same broadcast at different frequencies. Commercial broadcasts are geographically limited in coverage, but NHK (Nippon Hoso Kyokai), Japan's equivalent of the American Public Broadcast Service (PBS), provides nationwide AM and FM service. To continue receiving the same broadcast, the driver of a vehicle must manually scan the broadcast band and tune in to another stronger station as the vehicle moves from one area of converage to another.

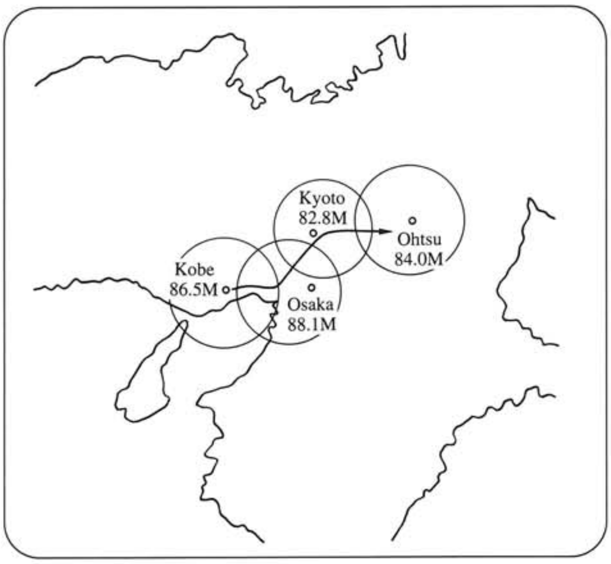

Figure 1. Service areas of NHK FM broadcast stations

Figure 1 shows the service areas covered by NHK FM broadcast stations. In this example, the driver of a car traveling from Kobe to Ohtsu would have to tune his receiver from 86.5 MHz to 88.1 MHz, to 82.8 MHz, and then to 84.0 MHz to receive the same NHK broadcast.

The Network Follow System developed by Fujitsu TEN eases laborious and annoying manual tuning and improves reception outside service areas by automatically evaluating the conditions of radio transmission and seeking the station with the strongest signal.

This paper describes the basic principles of operation of the Network Follow System, focussing on the audio signal comparator circuit that identifies FM broadcast signals.

2. Market trends

2.1 Network tracking overseas

The Radio Data System (RDS) has been in service mainly in European countries for the last six or seven years. The RDS uses empty FM broadcast channels to provide a wide range of information, including radio reception data, traffic information, and radio text. A main function of the RDS is its network tracking facility, which uses alternative frequency data (AFD).

2.2 Network tracking in japan

In Japan, radio text services from radio stations, such as the RDS, are not yet available. Receivers require a function enabling similar broadcasts to be identified. Some manufacturers offer system implementations that use a single tuner to compare broadcasts, but these systems have not been widely accepted because of their limited practical usefulness.

3. Network tracking

3.1 Circuit configuration

There are two circuit configurations that can be used to implement a network tracking function: the single-tuner and double-tuner. The single-tuner system involves an interruption in audio reception while searching for the same broadcast. If it were to identify a broadcast without interrupting audio reception, it would take too much time to gather the necessary information to achieve identification, and thus detract from smooth network tracking. The double-tuner system, on the other hand, has one tuner (main tuner) dedicated to audio reception, receiving broadcasts, and generating audio at all times, with the other tuner (subtuner) being readied for seeking the same broadcast as the one currently being received. It thus offers speedy network tracking without interrupting audio reception, and the double-tuner system is considered best for achieving a network tracking capability.

Figure 2 is a block diagram of the Network Follow System thus developed. The main circuit components of the system consist of the following:

① FM receiver (two circuits)
② AM receiver (two circuits)
③ Audio signal comparator
④ Control microprocessor

3.2 Principles of operation

Figure 3 schematically shows the network tracking process. Each time the subtuner detects a station while scanning the reception frequency band, it uses the audio signal comparator to compare its broadcast with the one being received by the main tuner and stores the station information in memory if its broadcast is determined identical to the one being received. When a search through the entire reception band is complete, the subtuner receives the stations stored in memory again to measure their field strength. This procedure is iterated until a station having a field strength higher than that of the station being received by the main tuner is found. When tuning conditions are established, audio signal comparison is performed again for the station to be tuned in. The station frequency is tuned in to complete the network tracking process only if the broadcast is determined identical to the one being received by the main tuner.

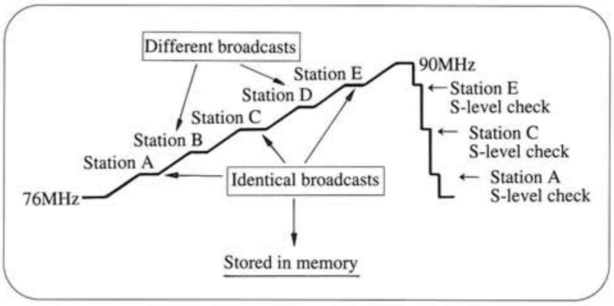

Figure 3. Network tracking schematic

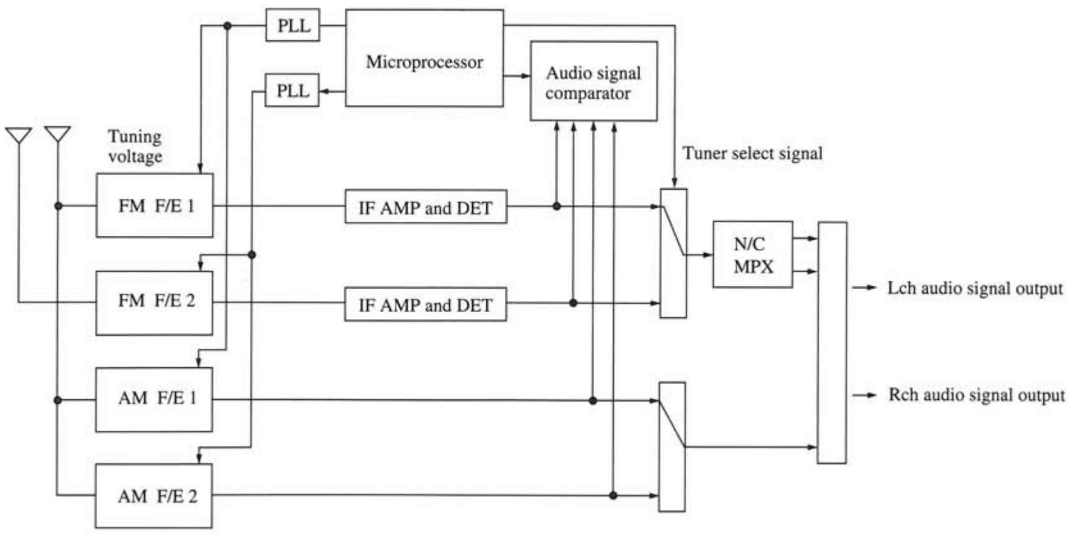

Figure 2. Network follow system configuration

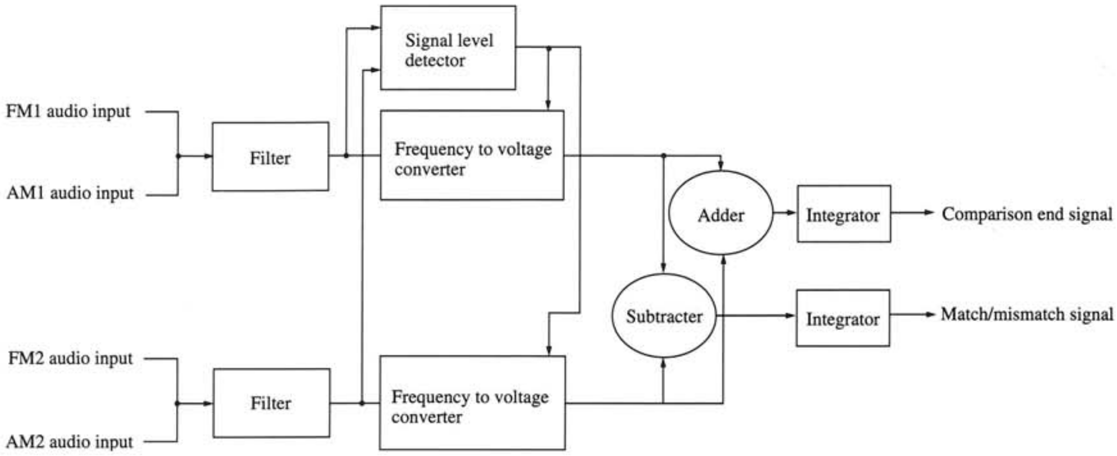

Figure 4. Audio signal comparator circuit configuration

4. Principles of audio signal comparison

4.1 Outline

The most important factor in the implementation of a network tracking function is the audio signal comparator. If two broadcasts carry exactly the same audio signal, subtracting their waveforms would yield 0, thus determining similarity between the two broadcasts. In reality, however, the audio signals transmitted from different stations involve some level differences or phase shifts such that subtraction often does not settle at 0.

To accommodate phase shifts, a comparator has been formed to deal specifically with the audio frequency distributions in which the signal change is slow. The comparison of the frequency distributions permits waveforms with level differences to be compared and evaluated.

4.2 Audio signal comparator

Figure 4 is a block diagram of the audio signal comparator. The audio signal comparator is composed of the following circuit blocks:

① Filter
② Signal level detector
③ Frequency-to-voltage converter
④ Adder
⑤ Subtracter
⑥ Integrator

4.2.1 Filter

Because automotive radios are typically exposed to sources of noise, noise components can affect evaluation in the audio signal comparison process. A filter is used, therefore, to cut off frequencies on which noise ranging several tens of hertz or lower or several kilohertz or higher is likely to be superimposed.

4.2.2 Signal level detector

With an audio signal like that shown in Figure 5, the noise component would not only be totally meaningless for audio signal comparison, but could affect the evaluation. Therefore, the audio signal is envelope-detected as shown in Figure 5 (c), so that signals lower than the dotted-line level are excluded from the comparison information to lessen the effects of noise. Raising the minimum detection level to an excessively high level, however, would remove wanted information as well, and would result in a prolonged evaluation time and other undesirable effects. The optimum detection level was established after repeated test runs.

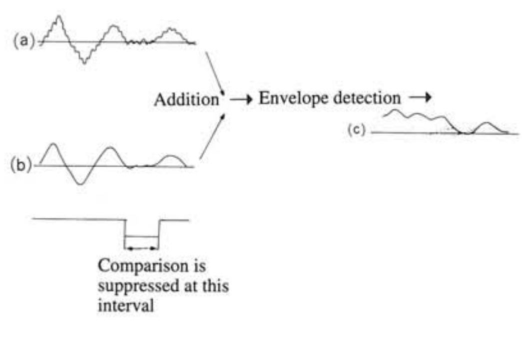

Figure 5. Signal level detector schematic

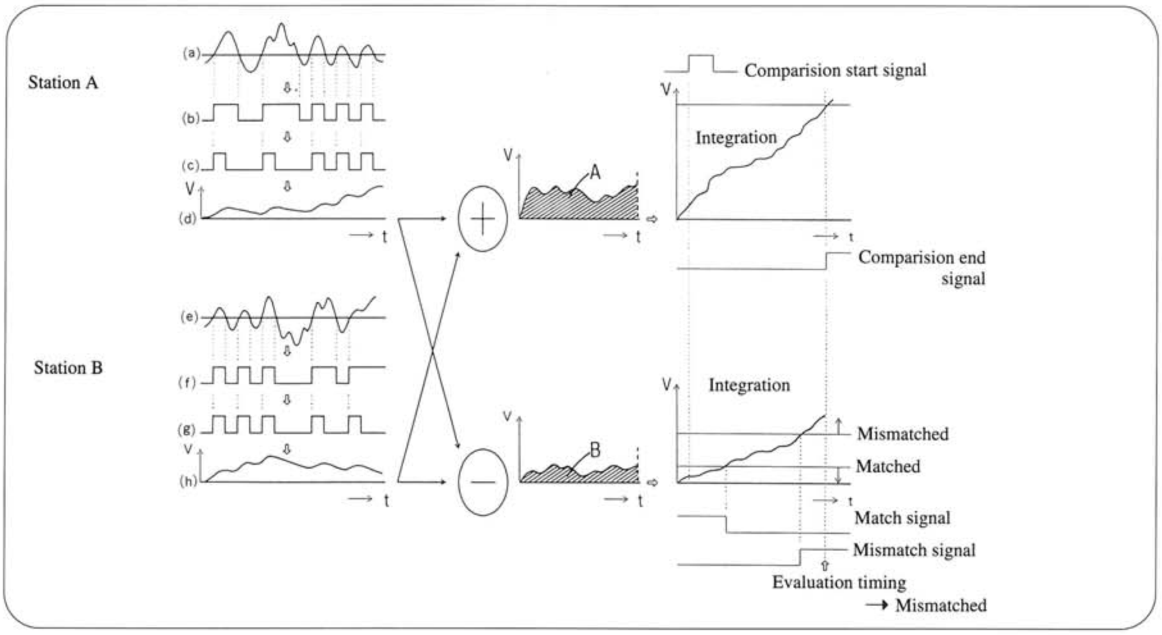

Figure 6. Principles of audio signal comparation

4.2.3 Frequency to voltage converter

Figure 6 illustrates the process of converting frequency to voltage to perform an audio signal comparison on frequency components. The audio signals transmitted from stations A and B are assumed to have the waveforms shown in (a) and (b), respectively. First, the waveforms are converted to square waves as shown in (b) and (f) at the zero crossings, shaped to fixed-width pulses (c) and (g) that are synchronized with the rising edge of the square waves, and then passed through a low-pass filter to generate analog voltages (d) and (h). This is how the frequency component of an input signal is converted to an analog voltage.

Because the waveforms are converted to square waves at the zero crossings, they are given a hys-teresis characteristic to narrow errors associated with noise and other effects.

For example, if the waveform shown in Figure 7 (a) were converted in part A without a hysteresis characteristic, the noise would be converted as shown in B, causing a data error. Given hysteresis at the level indicated by the dotted line, however, part B is eliminated, thereby lessening noise and other effects.

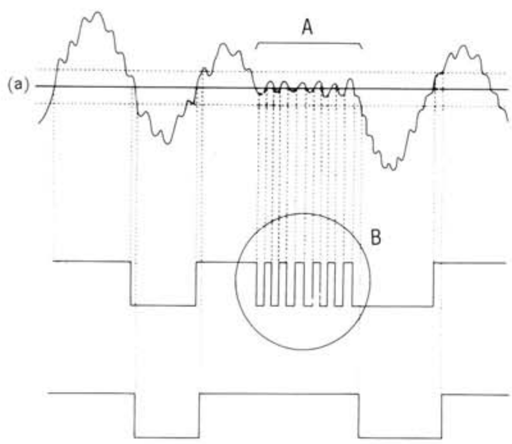

Figure 7. Signal conversion schematic

4.2.4 Adder and subtracter

The next step is to add and subtract the resultant analog voltages from each other. The result of subtraction would be small if the two audio signals carry the same broadcast. Thus, the two audio signals of interest can be determined identical or different depending on the size of the result of subtraction.

The result of subtraction alone, however, is not sufficient to determine whether the audio signals are matched or mismatched, for the result can be 0 even when the two waveforms compared are silent. A more precise means of comparative evaluation can be provided by checking the ratios of the results of addition and subtraction to see how much information the audio signals carry. However, some time is necessary to ensure comparison accuracy because different waveforms could give the appearance of similarity at any instant of time. An integrator is used to establish this length of time.

4.2.5 Integrator

The integrator has a threshold level setting on the adder side to allow comparisons until the integral value equals this threshold level. This ensures that evaluations are always conducted with a fixed amount of information (in area A in Figure 6). To determine whether the audio signals of interest are matched or mismatched, matched and mismatched threshold levels are set on the subtracter side. The match signal will change from 1 to 0 when the integral value reaches the matched threshold level, or change from 0 to 1 when the integral value reaches the mismatched threshold level. Thus, the two audio signals of interest can be determined identical or different according to the status of the matched or mismatched signal, in effect, when the result of addition reaches the threshold level setting. In this way, audio signal comparisons are implemented on the basis of the ratios of areas A and B as shown in Figure 6.

5. Problems in the double-tuner system

The double-tuner system has disadvantages, as well as advantages in the implementation of a network tracking function. That is, as the subtuner scans the reception frequency band to seek stations carrying the same broadcast, the local oscillator frequency in the subtuner could interfere with the main tuner receiving the broadcast of interest, causing an abnormal sound like that shown in Figure 9 (b). This abnormal sound is generated when the frequencies received by the main tuner and the subtuner

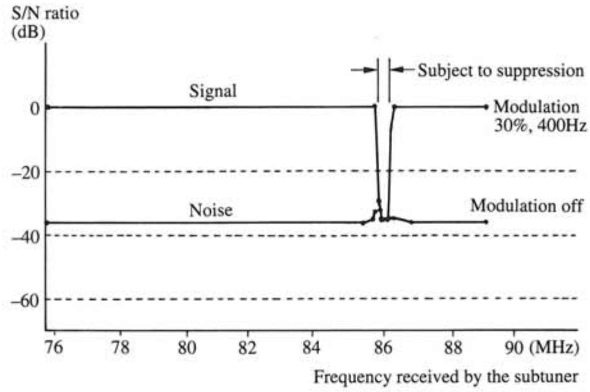

Figure8. Subtuner local oscillator frequency interfering with the main tuner

satisfy the following relation (Figure 8):

Frequency received by the subtuner
= Frequency received by the main tuner
+ 10.7 MHz ± a .... (1)

where

$0 \leqq a \leqq 0.2$ MHz

Because domestic receivers have the target frequency minus 10.7 MHz as their local oscillator frequency, and a transmission level of 100 dB V or higher, the target broadcast could be suppressed and the audio interrupted if its frequency matches the subtuner local oscillator frequency. Since the value of a in Eq. (1) is on the order of 0.2 MHz, suppression could occur in this range. This problem can be resolved by removing the frequency

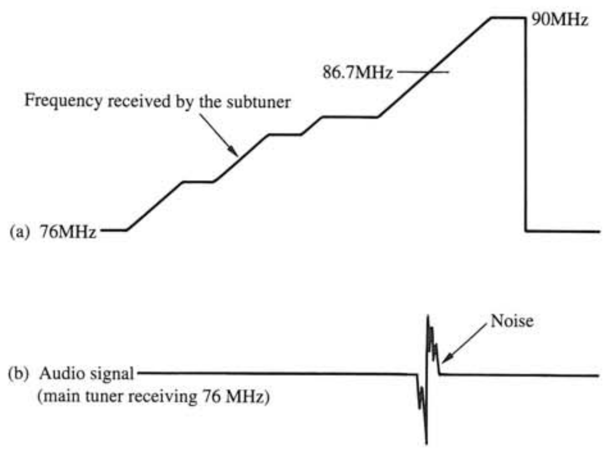

Figure 9. Noise caused by subtuneer local oscillator frequency interference (1)

received by the main tuner + 10.7 MHz ± a from the range of frequencies received by the subtuner.

In other words, network tracking is not carried out at the frequency received by the main tuner + 10.7 MHz ± a. Therefore, the nationwide radio broadcast frequencies were examined to suppress, as much as possible, network tracking where relation (1) is established. However, even though a network tracking suppression zone is provided, there is no way to eliminate abnormal sound completely because traversing of the frequency received by the main tuner by the subtuner local oscillator frequency is inevitable.

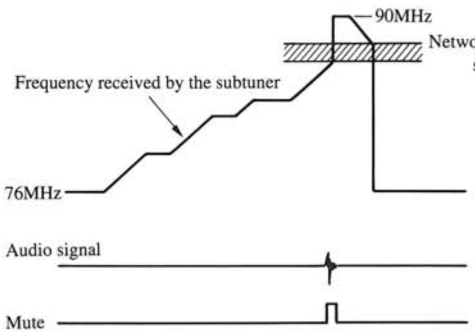

Figure 10. Noise caused by subtuner local oscillator frequency interfernce (2)

To minimize the time for which the subtuner local oscillator frequency traverses the frequency received by the main tuner, the search method shown in Figure 10 is used. This search is combined with muting enabled at the moment of frequency traversing to lessen the abnormal sound to virtually the zero level.

6. Field tests

Because the Network Follow System is difficult to evaluate in many respects by bench tests alone, it has gone through repeated field tests since its development stage. Figure 11 summarizes the results of field tests of an automotive radio receiver over the distance from Kobe to Shizuoka. Except for the area around Sekigahara where broadcasts were barely receivable, smooth switching was obtained and broadcasts were received continuously without resort to manual tuning. Switching was found to take place prior to the generation of noise due to multipath fades with reductions in field strength, thus improving broadcast reception.

For AM, smooth switching was also accomplished though the switching frequency was less than FM because of its wider station coverage.

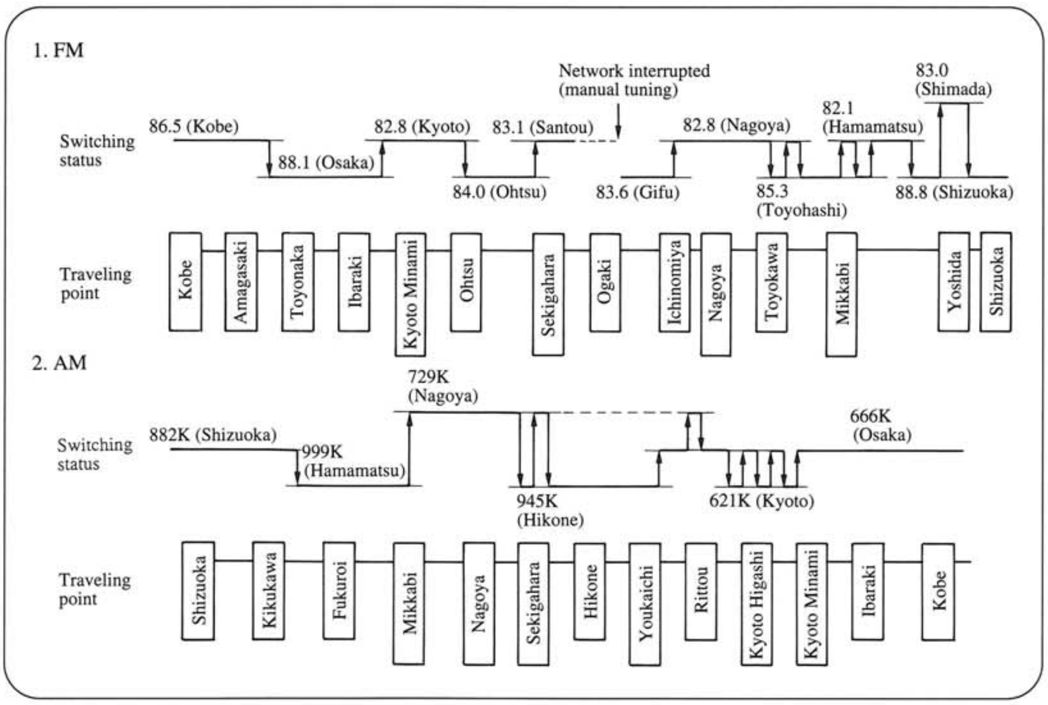

Figure 11. Field test results

7. Conclusions

The development of the Network Follow System has not only improved user convenience but enhanced broadcast reception performance in a rather unique way. Further market penetration should be pursued by feeding back market reviews to better the system. In the meantime, efforts should also be directed at reducing system cost.

Yoshihisa Mizuno

Employed by the company since 1984. Engaged in developing car audio systems. Currently in the Ist AV Engineering Department, AVC Division.

Takashi Nagamitsu

Employed by the company since 1980. Engaged in developing car audio systems. Currently in the System Research and Development Department, AVC Division.