VICS Receiver for 3 types of Media

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Conditioning with economic growth, the number of automobiles in the world is increasing at an annual rate of about 5%, and now totals over 600 million. Accordingly, serious problems are arising which include increased traffic accidents and traffic jams and environmental damage. To solve these problems, the concept of the Intelligent Transport System (ITS) was generated.
ITS provides drivers with accurate, easy-to-understand, and real-time traffic information for safe, comfortable, and efficient driving. In addition, ITS enables automatic driving with the application of vehicle control technology.
In Japan, the Vehicle Information & Communication System (VICS), which is one of ITS systems, was implemented on April 23, 1996 to supply real-time traffic information, such as traffic jam information, to drivers. Fujitsu Ten developed a VICS receiver in a short time and has started delivering it to the Toyota Motor Corporation.
The VICS receiver is introduced in this paper.

1. Introduction

The vehicle navigation market is steadily expanding; 300,000 units were sold in 1994 and 500,000 units in 1995. As a result, more suppliers are entering this market. Today, multifunctional, low-priced navigation systems are becoming more common, and many suppliers are selling similar products.

When initially introduced, the navigation system was simply a vehicle location system. However, features such as route searching and audio guidance have since been added, and navigator-like devices are now available. Yet drivers still require a dynamic guidance feature that can handle accident and traffic jam information.

VICS, which is one ITS system, is a system that can deliver real-time traffic information. Ideal dynamic guidance is achieved by incorporating VICS features into a navigation system.

2. What is VICS?

2.1 Configuration of the VICS system

The configuration of the VICS system is shown in Figure 1. Traffic and parking lot information collected by the Japan Road Traffic Information Center and parking lot managers is processed and sent to three media centers by the VICS center (the Road Traffic Information Communication System Center). The three media centers send information to vehicle receivers via their respective media. Thus drivers can obtain information in up to three display modes.

2.2 Types of information and service coverage

The goals of VICS are to offer greater convenience to drivers, to reduce costs by decreasing transportation time, to improve safety by accurately assessing situations, and to protect the environment by enabling a smoother flow of traffic. To achieve these goals, VICS provides the following types of information:

① Traffic jam information: traffic jam areas and sections

② Driving time information: times required for driving between major locations

③ Traffic obstacle information: information on traffic accidents, obstacles, and construction

④ Traffic restriction information: information on road closings, speed restrictions, and lane restrictions

⑤ Parking lot information: information on the availability of parking lots, service areas, and parking areas

VICS now covers the main roads and highways in the Tokyo metropolitan area (Tokyo and Kanagawa, Saitama, and Chiba Prefectures) and the Tokyo-Nagoya and Nagoya-Kobe expressways. The operating area of VICS will be expanded to cover Osaka, Aichi, Kyoto, and Hyogo Prefectures by 1998, and will be further expanded to cover the whole country.

2.3 Information transmission (3 types of media)

Traffic information processed at the VICS center is transmitted by beacons and FM multiplex broadcasting.

Two type of beacons are used. One is based on optics (an infrared beam) and is installed along major trunk roads. The other type is based on radio waves (centimetric waves) and is installed along highways. In both cases, the traffic information required for each beacon installation area is provided. Traffic information to be delivered to a wide area is transmitted by FM multiplex broadcasting (with a subcarrier of 76 kHz).

2.4 Display of information

A driver can view VICS-provided real-time traffic information by using any of the three types of displays shown in Figure 2.

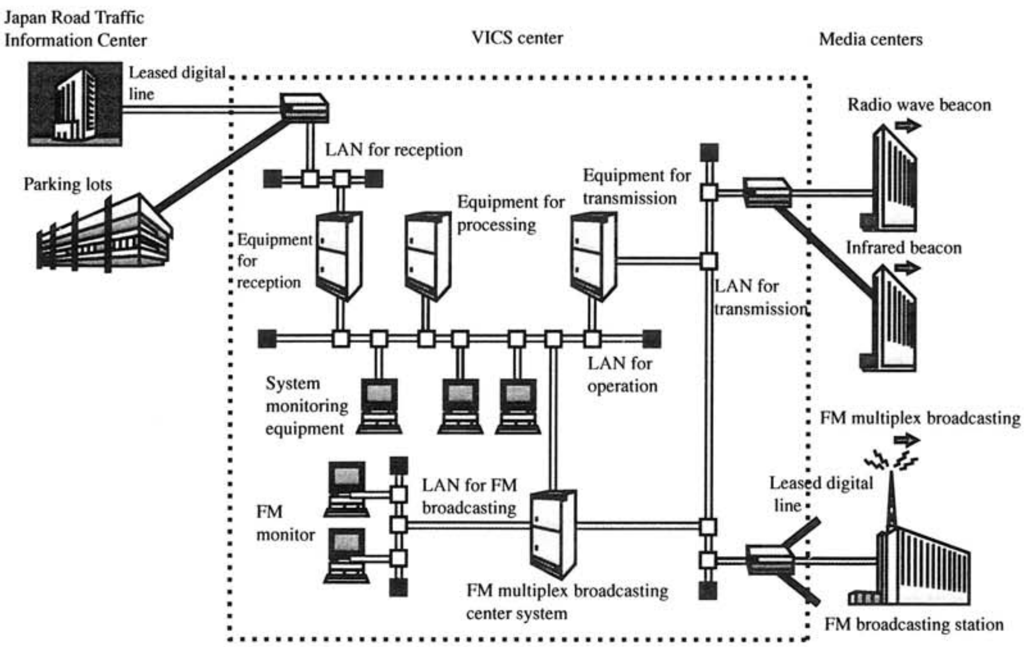
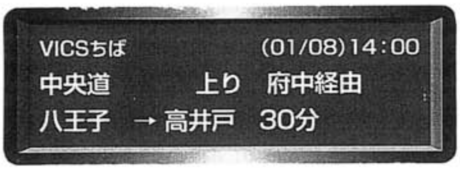
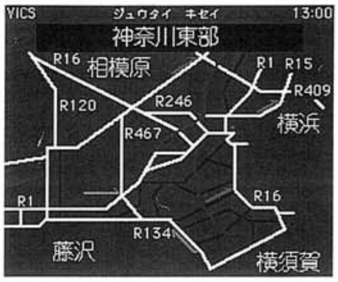


Figure 1. VICS system configuration

Level 1 (character display)



Level 2 (simplified graphics display)



Level 3 (map display)

Figure 2. Three display types

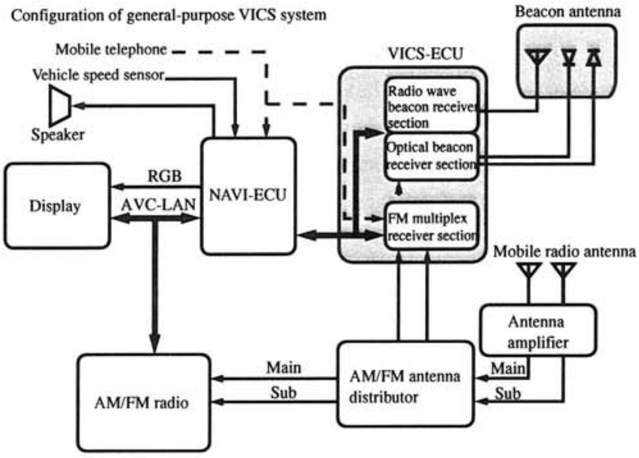


Figure 3. VICS receiver configuration

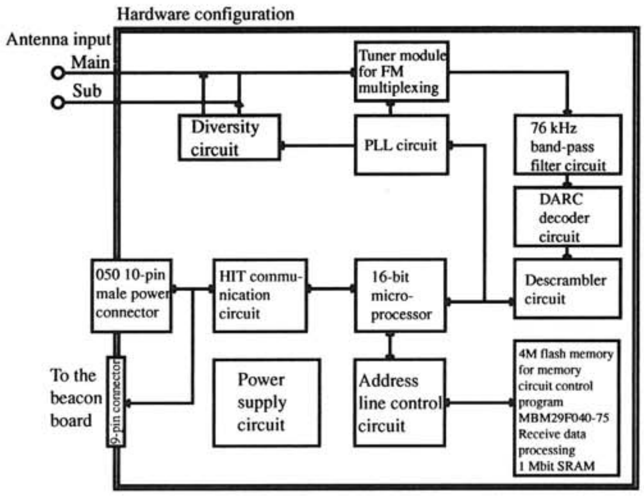


Figure 4. Block diagram of FM multiplex receiver

3. Overview of VICS receiver

3.1 Receiver configuration

The VICS receiver is connected as shown in Figure 3. VICS information is instantly transmitted using high-speed navigation communication at 64 kbps. The radio antenna of a vehicle is shared for the reception of FM multiplex broadcasting, and a distributor is inserted to prevent the level of both signals from being attenuated.

3.2 Hardware configuration

3.2.1 FM multiplex receiver section

A block diagram of the FM multiplex receiver is shown in Figure 4. The FM multiplex receiver has four features.

① To improve the performance of FM reception, a diversity antenna configuration is employed, and antenna switching is performed based on multi-paths and input levels.

② A tuner module dedicated to FM multiplexing is used, and a 15-MHz IF frequency is used to minimize interference on the existing radio equipment.

③ VICS broadcasting incorporates scrambling so that the signal output from the FM multiplex decoder is fed to a dedicated descrambler IC and then supplied to a microprocessor for data processing.

④ The FM multiplex receiver contains a 1 Mbit SRAM to temporarily store FM multiplex data, which is transmitted to the NAVI-ECU circuit via the conventional interface.

3.2.2 Beacon circuit section

As shown in Figure 5, the beacon circuit section consists of a beacon head section, a radio wave beacon receiver section, and a beacon signal processing section. Their features are listed below.

1) Radio wave beacon receiver section

This section employs a double superheterodyne system to perform a down-conversion and demodulates via frequency detection. This section also performs AM modulation to detect the vehicle's driving direction and beacon location.

2) Beacon signal processing section

When a radio wave beacon signal is received, the signal is first demodulated by the receiver section. Next, the signal is descrambled by the gate array and is then processed by the microprocessor.

When an optical beacon signal is received, the signal is first converted to an electrical signal of 1 Mbps data by the beacon head section. Next, the signal is Manchester decoded by the gate array, then is processed by the microprocessor. Moreover, an uplink signal is Manchester encoded for transmission at 64 kbps.

The beacon signal processing section also contains a 1 Mbit SRAM for temporarily storing radio wave beacon data and optical beacon data. Such data is transmitted to the NAVI-ECU circuit via the conventional interface.

4. Design considerations

4.1 Design objective

As mentioned earlier, VICS system involves three separate media. To receive all three kinds of signals, three types of receivers are required. Installing a separate receiver for each medium increases the mounting space and costs. The design objective was to build an integrated, compact receiver that can handle the three types of media and be mounted in any vehicle.

4.2 Methodology for compact design

4.2.1 Development of a beacon signal processing IC

To build a compact receiver, a common signal processing circuit was developed to process both radio wave beacon signals and optical beacon signals. In addition, a signal processing IC (gate array) with the features below was developed.

① A clock is regenerated from the received radio wave data and a CRC check is made after descrambling.

② Optical on-air data is biphase-demodulated. A CRC check is made after zeros inserted in the transmitter area removed.

③ A microprocessor interface common to radio wave data and optical data is provided for beacon data transfer one byte at a time.

④ Optical uplink data is Manchester encoded.

4.3 Methodology for general-purpose application

In determining the receiver structure, the following points were taken into consideration to make it mountable in as many types of vehicles as possible:

- Beacon antenna mounting angle adjustment feature and mounting angle check method
- Beacon antenna compactness required for installation

For the optical beacon antenna, optical axes of the light emitting device and photodetector of the antenna mounted on a vehicle must match those of the roadside beacons.

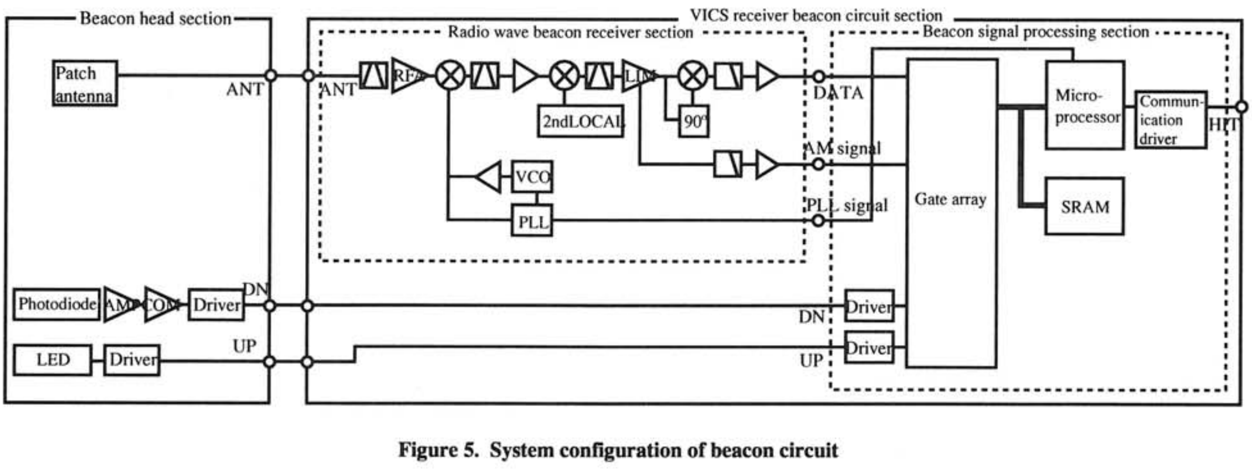


Figure 5. System configuration of beacon circuit

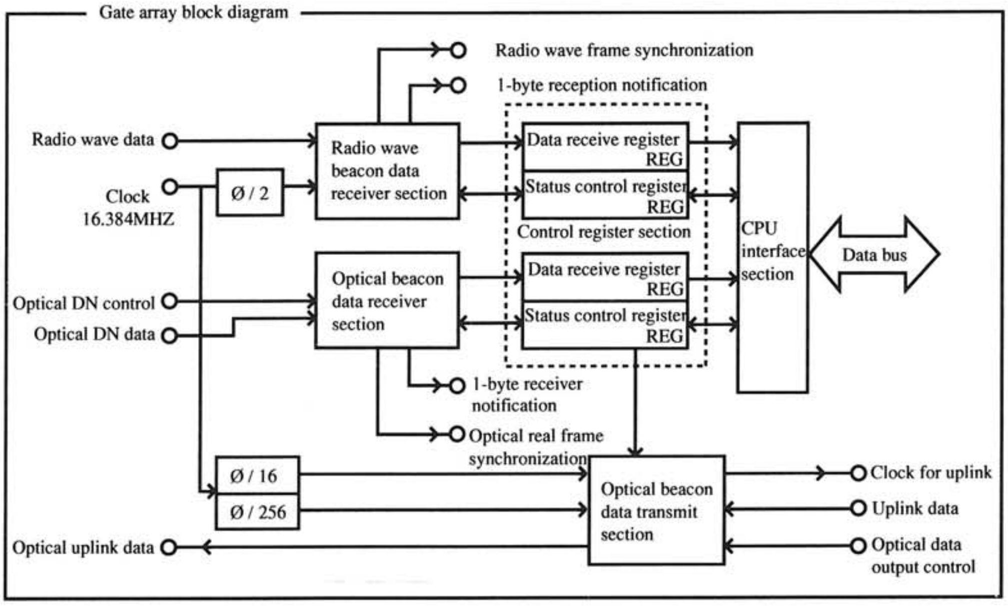


Figure 6. Block diagram of gate array

A roadside beacon is installed at a certain height. The dashboard of vehicles, where the antenna is installed, is slanted. Therefore, if an antenna is installed at a fixed angle, the axes of the light emitting device and photodetector surface of the antenna do not always match those of roadside beacons. Thus, communication with the beacons can fail.

To ensure that the optical axes of the vehicle antenna match those of the roadside beacon antenas, the vehicle beacon antenna needs to be adjustable in installation. So, an antenna angle adjustment feature is required to adapt to the angle of a dashboard.

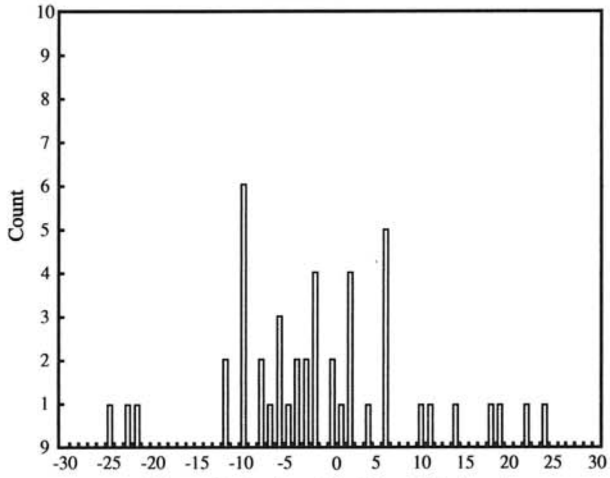
To determine the required adjustment range of this adjustment feature, we measured the forward to backward slant angles at the dashboard center of all models made by Toyota Motor Corporation.

Table 1 indicates the results of these measurements.

From the measurement results, we decided to set the light emitting device and photodetector surface to 45 degrees with an angle adjustment range of ±30 degrees. Similarly, we checked the left to right slant angles of the dashboards of all Toyota models. We found them all to lie within 2 to 3 degrees, a variation that does not affect optical performance or view quality. Consequently, no left to right adjustment feature was provided.

Figure 7 shows an antenna unit with an angle adjustment feature. With this feature, the head can be adjusted to the desired angle by using the screw provided on the left side panel.

Table 1. Slant angles of VICS beacon antenna installation locations



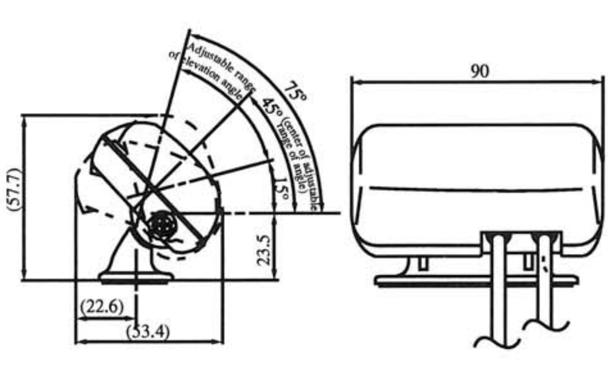


Figure 7. Antenna unit

This mechanical structure allows the antenna to be easily set to a desired angle within a variable range of ±30 degrees. However, the required angle needs to be determined easily and precisely by a dealer at, for example, an installation site.

To avoid such trouble as reception failures caused by incorrect settings, a jig is provided for adjustment, as shown in Figure 8.

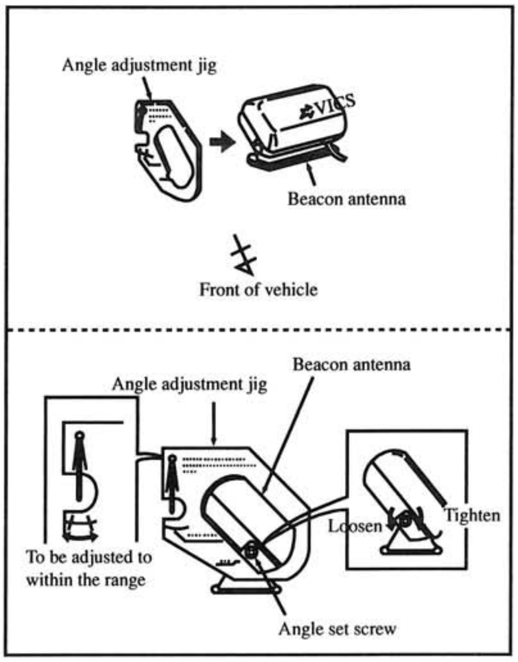


Figure 8. Adjustment jig

5. Evaluation of the receiver

We planned to introduce the receiver when VICS service starts, and we developed the receiver simultaneously with the preparation of the infrastructure and the development of the navigation system. Because of these restrictions, we needed to evaluate a prototype of the receiver. In particular, we needed to establish a method of bench evaluation and testing of the beacon circuit section because the infrastructure is placed on the roadside.

As a result, we developed a computer evaluation system that enables desk evaluation. The system consists of a radio wave beacon data output tool, an optical beacon data output tool, and a beacon test tool, as shown in Figure 9.

5.1 Radio wave beacon data output tool

Roadside radio wave beacon data is stored in the ROM of this tool. The data is output as a 64 kbps signal

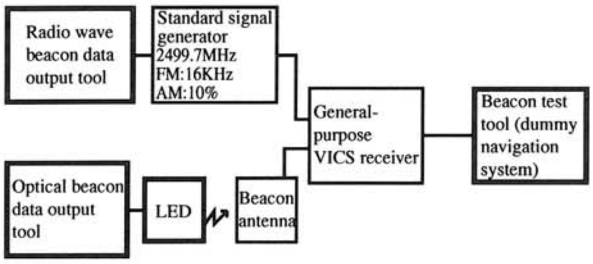


Figure 9. Beacon circuit section evaluation system

synchronous with an AM signal consisting of a 1 kHz rectangular wave. Both signals are modulated by the standard signal generator to transmit a 2499.7 MHz radio wave. The state of the radio wave beacon signal reception by the VICS receiver can be set by applying the output from the standard signal generator to the antenna connector of the VICS receiver. Moreover, the phase of the AM signal can be reversed with a switch to produce the state of a vehicle running just beneath a radio wave beacon.

5.2 Optical beacon data output tool

Roadside optical beacon data is stored in the ROM of this tool. The data is Manchester encoded, then a near-infrared beam is emitted from the near-infrared LED at a speed of 1 Mbps. The state of optical beacon signal reception by the VICS receiver can be set when the near-infrared beam is received by the beacon antenna.

5.3 Beacon test tool

The beacon test tool is a dummy-navigation system. This tool is connected via the conventional interface with the VICS receiver. This tool has the following functions.

① When the power is turned on, this tool initializes and checks the initial state of the VICS receiver and indicates its normal operation with an LED indicator.

② When the VICS receiver receives beacon on-air data, this tool request the received data.

③ The ROM of this tool holds the same on-air data as output from each beacon data output tool. This tool compares the received data with the ROM data and indicates whether the received data is correct with an LED indicator.

6. Results of development

Table 2 indicates the results of the general-purpose VICS receiver development. In general, the initial development goals have been achieved.

In actual installations of the VICS receiver on vehicles, the response time from the VICS information reception to being displayed is about three times faster (in the case of Level 2) than that of our competitors. (However, no particular requirement is defined for the response time.)

Table 2. Results of development

Item	Target	Result
Exterior dimensions	100×150×40mm	100×150×40mm
Data transmission speed	64kbps	64kbps
Radio wave beacon signal receiver sensitivity BER=1×10^{-2}	-90dBm or less	-95dBm
Radio wave beacon signal receiver bandwidth	100kHz or more	200kHz
Radio wave beacon image interference ratio	30dB or more	43dB

7. Conclusion

We initiated sales of our VICS receiver when VICS service began. For the time being, we intend to meet the demand of users for more compact, lower-cost receivers. In the long term, we expect to introduce three extended systems. The first system is a dynamic route guidance system (DRGS). The second one is a moving operation control system (MOCS) for supporting the operation management of vehicles for business use. The last system is a public vehicle priority system (PTPS) for ensuring open lanes for public vehicles. We will continue our efforts to contribute to the commercial application of these extended navigation and operation management systems.

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