Development of portable navigation combination unit

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Abstract

Fujitsu Ten released the world's first AVN and created a new market centering on Japan. Meanwhile, from a global viewpoint, PND (portable) has become widely used in countries other than Japan. When considering the characteristics of the overseas market, we perceived the possibility of a new market incorporating the element of PND, as well as conventional AVN, and so we planned and developed the portable navigation combination unit.

We introduced this product in January 2007, and released it also in Europe and Australia, starting with release in North America as an ECLIPSE product in May of the same year. Furthermore, we have started to deliver the same model to Toyota Europe and the product has attracted a great deal of attention as a new-category product in car navigations.

In this article, we introduce the concept / summary of product, hardware / software technology and implementation method.

1 Introduction

In the Japanese domestic car navigation market, high added value/multi-function AVN (Audio Visual Navigation: "installed-type" all-in-one navigation) units still occupy a significant amount of market share.

Recently, however, sales of more simplified navigation units, called PNDs (Portable Navigation Devices), a markedly different type of navigation unit compared to the AVN style of navigation in which Fujitsu Ten specializes, have been rapidly increasing in the overseas car navigation market. In response to this trend, we initiated the "Supercat" project (development code name) in April 2006, using keywords and concepts such as "rapid" (as in, "rapid delivery of products that can compete in an ever-changing market"), "affordable" (as in, "lowering costs in order to provide affordable products"), and "trimmed down" (as in, "trimming down excessive usage of development resources by promoting the use of common design, while satisfying the needs of a broad range of customers") to drive the development process of a new product, primarily targeted to tap into the overseas market.

Fujitsu Ten unveiled this new product to the press in January 2007, and released it, under the ECLIPSE brand name, in North America (under the "AVN2210p" model name) in May 2007, and later in the European and Australian markets as well (under the "AVN2227P" and "AVN2210p" model names, respectively). Furthermore, Fujitsu Ten has started supplying the same product to Toyota Europe where it has been attracting a great deal of attention as establishing a new product category in the car navigation market.

In this article, we provide a basic product concept/overview of the product, as well as the underlying hardware/software technology and the methods of implementation of said technology.

2 Project Background and Development Objectives

2.1 Market Trends

Although the market for car navigation continues to expand worldwide, a noticeable trend has been the rapid increase in sales of PNDs (Portable Navigation Devices), alongside "installed-type" all-in-one car navigation systems in which most Japanese manufacturers specialize. In 2006, PND annual sales exceeded 10 million units in the world market, establishing a brand new category in the navigation market. A PND is a simplified navigation unit consisting of a liquid crystal display panel of 5-inches or less and using flash memory to store map data. The portability and affordability of PNDs has led to broad acceptance by consumers in the overseas (mainly European) market. Responding to this trend, companies large and small, both domestic and overseas, have expanded their PND lineups, making the fledgling market more and more competitive. As a result, suppliers like Fujitsu Ten, which had been specializing in multi-function/high-end "installed-type" car navigation units, have been struggling to compete.

At the same time, in the new car market, the ratio of cars fitted with "installed-type" car navigation units, at factory, to total cars produced, has gradually increased to the point where it now constitutes a market of significant size. For products in this market segment, integration of the navigation unit controls with that of the automobile itself has become a key factor for success.

From a global standpoint, it can be said that the recent market for car navigation systems has been polarized into two segments, one for multi-function/high-end "installed-type" car navigation units which are highly integrated with vehicle-side controls and vehicle audio setup, and another rapidly growing segment for relatively affordable PNDs.

Also, in terms of the overseas in-vehicle multimedia market, the need for increased connectivity and compatibility with various devices continues to increase. Specific needs include, Bluetooth, a wireless communication standard that allows for hands-free cell phone usage (that is on its way to becoming a standard feature for in-vehicle devices mainly in Europe and the US), RDS-TMC (Traffic Message Channel), a European traffic information communication standard based on RDS, connectivity and integration with portable music players (mainly iPod), digital satellite radio (such as SIRIUS and XM), and connectivity with PCs and/or mobile phones. Realizing these needs and providing customers with products that meet them is a mandatory requirement for all in-vehicle device manufacturers that wish to survive in such a competitive market.

2.2 Product Concept

In the midst of such market conditions, Fujitsu Ten saw an opportunity to develop a new market overseas by embarking on the planning and development of the aforementioned "Supercat" project. The main objective of project "Supercat" was to create an innovative car navigation design, which combined elements of both the "installed-type" car navigation units and PNDs.

For project "Supercat", Fujitsu Ten proposed a new style of product, with a detachable navigation unit (that can be used independently as well), housed in an all-in-one double-DIN size main unit (refer to Figure 1). In addition to combining the multi-functionality usually seen in "installed-type" navigation units with the convenience of a PND, Fujitsu Ten also focused on promoting the usage of common design where possible, so that the end product could be versatile enough to be easily deployed to a wide-range of markets such as North America/Europe/Australia, and as both an OEM and aftermarket product, while maintaining an affordable price.

For development of the detachable navigation unit, Fujitsu Ten selected TomTom N.V. (Netherlands), which holds an overwhelming share in the PND market in Europe and the US, as its partner. Between the two companies, Fujitsu Ten assumed responsibility of the overall planning/development of the product, while TomTom was responsible for development of the navigation unit.

Fig.1 Outline View of AVN2210p

2.3 Project Objectives

The aim of this project is to make a significant impact on the overseas navigation market, which is currently being shaped by further intensifying competition, in regards to both product features and price. To this end, Fujitsu Ten has developed a product which offers the wealth of features usually seen in "installed-type" navigation units while taking advantage of PND portability, and at the same time increasing usage of common design so that the product can be redesigned to meet differing customer needs in different markets.

Furthermore, Fujitsu Ten aims to regain market share of the rapidly changing overseas navigation market and eventually shift consumer demand back to the AVN type navigation units in which Fujitsu Ten specializes.

3 *System Overview*

3.1 Introduction of Features

The abovementioned product is an audio, all-in-one type car navigation equipped with a 3.5 inch TFT display with touch panel capability. The product includes an SD card containing a map database for the appropriate region. The detachable navigation unit (PND) comes equipped with GPS antenna/speaker/battery, and it can operate as an individual navigation unit even when detached from the main unit. As such, the PND can be used in multiple cars regardless of whether or not the main audio unit is present, and can be used in such situations as when the user rents a car while traveling, or when the user wants to perform a destination search at home. When attached to the main audio unit, the PND begins charging its internal battery automatically. Other benefits include better integration with vehicle console/car interior, as opposed to conventional PNDs, which require visible wiring, and mounting in a position that could obstruct the driver's line of sight.

Using their PCs or mobile phones, users can update the navigation software, and download contents such as weather, traffic reports, map database etc. (taking full advantage of TomTom web services).

Users can also enjoy audio features such as radio, CD/CD-R/RW playback etc. even when the navigation unit is detached. Additionally, this product offers excellent connectivity as seen in features such as direct playback of MP3 files stored in USB flash drives, touch panel iPod playback/control, built-in Bluetooth module for hands-free cell phone capability, the availability of an optional unit for reception of digital satellite radio (available in North America), reception of traffic reports over RDS-TMC (available in Europe), etc.

At the same time, this product also incorporates features integrated with standard vehicle-side functions, not available in typical PNDs, such as: switching between daytime and nighttime screens depending on vehicle-side illumination, position correction of route guidance using vehicle-side speed pulse information (ex. for usage inside tunnels), compatibility with variable intensity rheostat illumination controls and steering remote controls.

3.2 System Architecture

A system block diagram of this product is shown in Figure 2. The navigation unit (PND) and the main unit is connected by a special docking connector (denoted as "※1" in Figure 2). The connector provides various signal lines (power supply, audio signal, data communication lines, detachable unit detection signals etc.), by which the main audio unit can control the navigation unit. Main unit audio feature controls, and transmission/reception of speed pulse signals, illumination signals, etc. are performed over a dedicated serial communication link. As such, we required TomTom to develop a new PND design that could meet the above criteria.

Additionally, by adding an external GPS antenna, navigation is made possible regardless of whether the PND is detached or housed in the main unit.

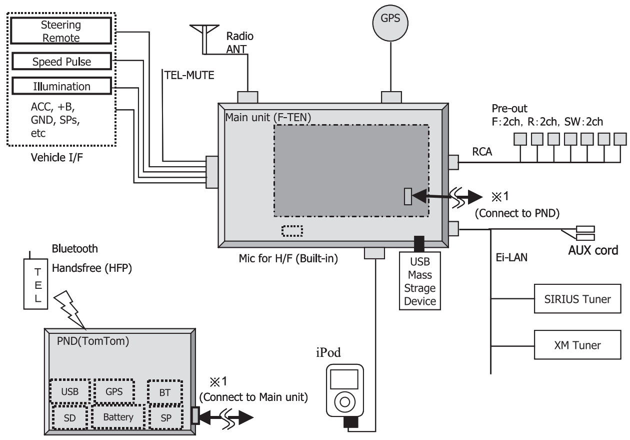

Fig.2 System Block Diagram of AVN2210p

4 PND Detachment/Attachment Technology

4.1 Development Objectives

Our main focus during development was to achieve the convenience of a detachable PND while maintaining the product performance of conventional PND and audio units, and at the same time observing the following three targets:

(1) The PND should allow for easy detachment; the user should be able to detach the unit using only one-hand and in a single movement. As a side note, conventional PNDs are designed so that that they are placed on a fixed stand and held in place by a lock mechanism, requiring the user to hold on to the PND with one hand while they push the release lever with the other hand. By designing a housing mechanism where the PND can be released using only one hand, we aimed to make the unit more convenient and safer to use for the end-user.

(2) The incline/decline angle range in which the PND can be detached without problem should be ±30° (refer to Figure 3). In this range, the PND should not fall out against the user's intentions, even when pushing the PND release button when the vehicle is headed uphill. Likewise, PND detachment must be performed relatively easily from the audio unit even if pushing the PND release button while the vehicle is headed downhill.

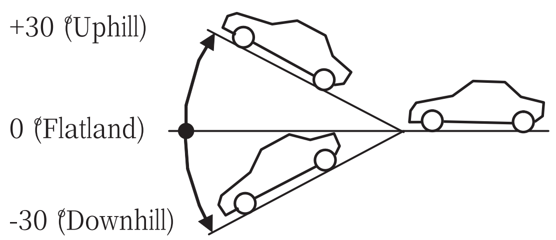

Fig.3 Inclination Angle Range

Not being able to meet this target will sacrifice either safety or convenience, therefore it will lead to an unsatisfactory product.

(3) To limit vibration of the PND while it is housed inside the main audio unit, the degree to which vibration is amplified as it transfers from the main audio unit to the PND should be within 1.2 times of the vibration originally applied to the main audio unit. This design tolerance (based on calculations from past evaluation results) was established to prevent any mechanical noise caused by friction between the PND and housing panel due to vibration, and to minimize sliding abrasion (fretting corrosion) of the dock connector connecting the PND with the main unit. At the same time however, applying excessive force to keep the PND fixed could cause difficulty for the user when detaching the PND.

4.2 PND Detachment/Attachment Mechanism

The housing panel has a depression in which to mount the PND. A PND fixing rib is positioned on the inner-left side of the depression, and it fits into a groove located on the left side of the PND. The PND detachment/attachment mechanism is located on the inner-right side of the depression in the housing panel, and a PND fixing tab locks the PND in place while the PND is attached to the main unit.

When the PND release button is pushed, the PND rotates using its left side as an axis, and then locks temporarily in a position where the drop-prevention pin activates (Refer to Figure 4).

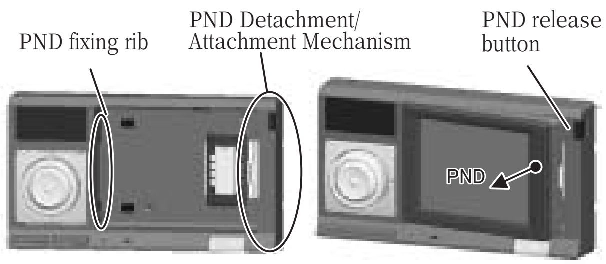

Fig.4 PND Detachable Structure

4.3 Measures for Meeting Design Objectives and Results

4.3.1 Structural Design for Easy Detachment

The structural parts for the PND detachment/attachment mechanism consist of a PND release button, PND fixing tub (shaft), PND extrusion arm (also referred to as the PND drop-prevention pin), and spring (Refer to Figure 5).

As a detaching mechanism, pushing the PND release button rotates the PND fixing tab (shaft), unlocking the PND. The PND extrusion arm is always in a position where it is pushing against the rear face of the PND due to the force applied by the spring. When the PND is unlocked, the PND pushes out forward until the drop-prevention pin activates, temporarily locking the PND in the position shown in Figure 6 (from which the user can manually remove the PND with relative ease).

This structural design makes it possible for the user to detach/attach the PND using only one hand because pushing the PND release button will push the PND out to a temporarily fixed position, whereupon the user can complete the detachment process by removing the PND with relatively little force.

As an additional advantage, this design allows for the user to detach the PND in less time compared to that of a conventionally mounted PND by using springs instead of a motor or gear for the mechanism to push out the PND.

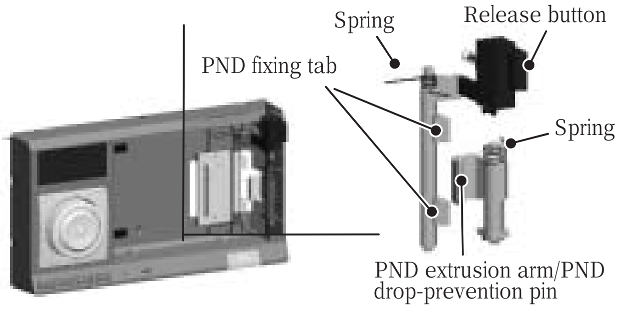

Fig.5 PND Detachable Mechanism

4.3.2 Inclination Angle Range

By adding a drop-prevention pin that catches a face on the PND backside upon detachment of PND, we were able to design a housing structure that can be titled downwards 75 ° without inadvertently dropping the PND.

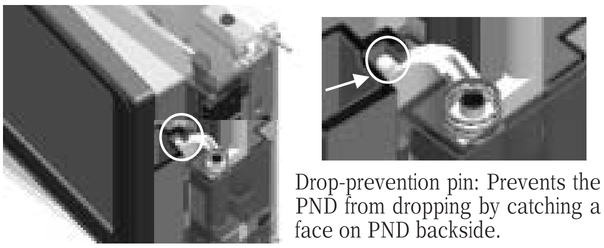

Fig.6 Structure for Dropping-Prevention

Furthermore, by applying spring force to the push-arm/drop-prevention pin we were able to design a housing structure that can apply sufficient force to properly eject the PND even when the unit is tilted upwards 80 °.

In regards to the range of tilting angle and its effect on detachment, the mechanical design of the extrusion arm is a key factor. If the spring constant to push out the PND is too small, the PND will not properly eject from the audio unit when the vehicle is on a decline (i.e. when the panel is facing upwards in direction); as a result, the user cannot properly remove the PND. On the other hand, when the vehicle is on an incline (i.e. when the panel is facing downwards), as opposed to flatland, if the spring constant is too large, there is a risk that the PND will have less contact resistance with the housing panel, and it could be inadvertently ejected and fall out without the user intending it to. Another approach to prevent the PND from inadvertently falling out of its housing would be to lengthen the dimensions of the drop-prevention pin, however if the pin is too long, it would hamper the easy removal of the PND by the user.

After repeated test simulations and optimization of design, we were able to resolve the aforementioned design issues for the push-arm mechanism.

4.3.3 Vibration Countermeasure

The design incorporates a flat spring to eliminate mechanical noise caused by friction between the PND and housing panel and minimize sliding abrasion of the docking connector, by controlling the range of motion of the PND.

The flat spring load, which is set to 4 times the mass of the PND, was determined by taking into account product vibration specifications, the gap between the PND and housing panel and the range of movement of the PND within that gap (which also determines the degree to which vibration to the main unit would be amplified and as it is transferred to the PND), PND mass, etc.

By adding the flat spring we were able to reduce amplification of vibration to the PND by 25%, allowing us to meet our target of limiting amplification of vibration to the PND to just 1.1 times the vibration applied to the main audio unit (refer to Figure 7).

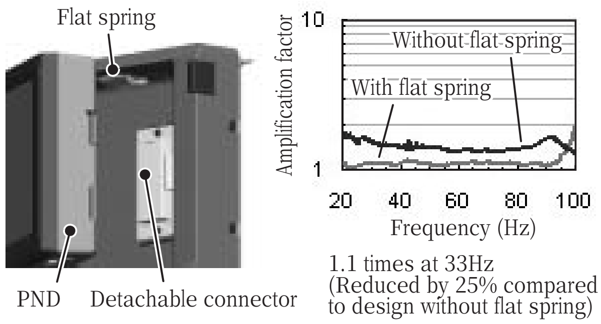

Fig.7 Effect of Countermeasure for Vibration

5 Electrical Interface

In this section, we explain the electrical interface that facilitates some of the detachable unit functions provided by the PND (which are key features of this product), when the unit is housed in the main audio unit.

5.1 Interface

The interface between the main audio unit and the PND consists of the following group of signals/lines:

- **Communication signals between main audio unit and PND**
- **Sound signals**
- **Power supply lines**
- **GPS signals (including GPS signal shield GND line/cable)**
- **Other signals**

Naturally, physical space restrictions affect the number of signal lines that we are able to use for the interface, so we were required to consult with TomTom N.V. in order to minimize the total number of lines for this particular interface.

5.2 Factors Affecting Design for Each Signal

Next, we explain factors that required consideration during design for each separate group of signals.

5.2.1 Communications Between Audio Unit and PND

UART (Universal Asynchronous Receiver Transmitter) was selected for the communication protocol between the main audio unit and the PND (details are described in section 6). Additionally, optional iPod communication, and communication with the RDS-TMC IC (only available in the European model) are carried out over a separate series of UART lines, for a total of three separate series of communication lines.

5.2.2 Sound Signal

There is one series of lines for communication of sound signals.

During USB playback, all file decoding is carried out on the PND-side, and the music is sent back to the main audio unit as an audio signal.

In addition, audio for navigation voice guidance and phone audio for hands-free calls are also sent over the same series, minimizing the total number of signal lines required. A diagram for the Ssound signal block is shown in Figure 8.

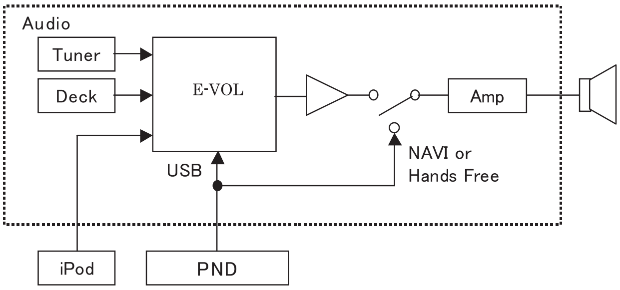

Fig.8 Circuit block diagram of Audio Signal Line

5.2.3 Power Supply Signal

There are two series of power supply lines: one series for charging the PND battery and providing power during operation of the PND when the engine is running (hereinafter referred to as PND_5V), and another series to provide enough power for the PND to retain its memory while the engine is stopped (hereinafter referred to as Bu_5V).

The Bu_5V has a two-level structure, which includes separate current-limiting circuits for when the engine is running and for when the engine is stopped (the latter in order to prevent the unit from draining the user's car battery).

In order to prevent drainage of the user's car battery, the main audio unit stops supplying PND_5V when the engine is stopped, as such, the PND battery cannot be charged during this time.

Furthermore, both series of power supply lines stop supplying voltage once the PND (a key feature of this product) becomes detached.

5.2.4 GPS Signal

Most popular methods of "self-reliant navigation" make use of GPS signals. However, in this case, since the GPS antenna was originally built into the PND, a problem arises when the PND is housed in the main audio unit, as this would prevent satisfactory reception of GPS signals. To counter this, we added an external GPS antenna as is typically used in conventional in-vehicle navigation systems.

The external GPS antenna is connected to the back of the installed main audio unit, and from there, the signal is routed to the PND while it is attached to the front panel housing. Since GPS signals are of an extremely high frequency (1572.42MHz), in typical applications, a shielding cable is added to accompany any exposed high frequency lines. However, in regards to this product, there was the added issue of shield performance deterioration, caused by repeated bending of the shield cable, which in turn is caused by movement of the front panel of the main audio unit whenever the tilt function is used (such as when CDs or other Disc media are inserted/ejected). To counter this potential problem, we opted to use a flex-cable for the front panel connection, for its resilience and resistance to damage even from repeated bending.

Upon selecting the flex-cable, we made repeated prototypes after performing extensive optimization using computer simulation analysis of the pattern shape, in order to create a design resistant to both deterioration of the signal connection and exogenous noise.

Furthermore, as we recognized that signal characteristics could deteriorate due to impedance changes of the GPS signal line, caused by contact between the metallic portion on the reverse face of the panel chassis and the flex-cable (Refer to Figure 9), we decided to add a spacer of non-woven fabric (branded as "Himeron") as an insulator.

Signal characteristics with and without the spacer are shown in Figure 10.

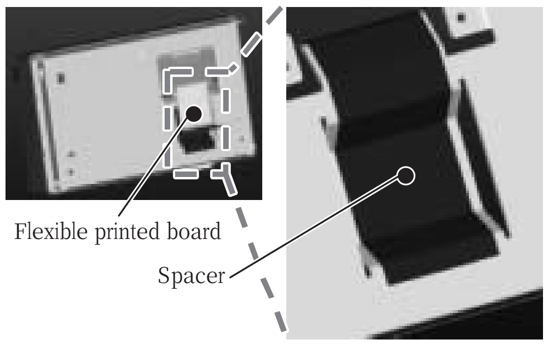

Fig.9 Application Area of Spacer

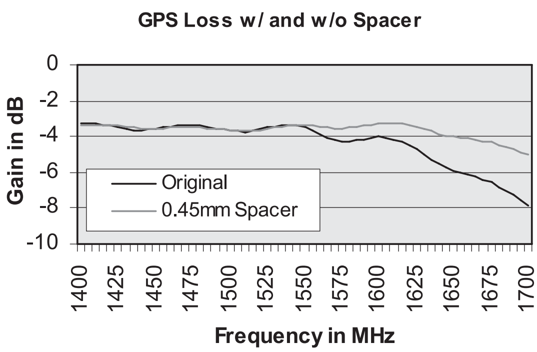

Fig.10 Performance of GPS Signal Loss

6 Software Development

In order to integrate the functions of both the PND and main audio unit (that make use of the GUI display and event communication), the development of a new communication interface was required (the first of its kind; attempting to connect and integrate the functions of a PND and a car audio unit). As this project required the simultaneous parallel development of software at two separate companies, establishing a common communication interface specification was necessary. Here, we explain the items that were considered during development of the new interface.

6.1 Selecting a Communication Method

After checking the past performance of both TomTom and Fujitsu Ten products which make use of UART, and discussing specific past cases where either company made use of UART etc., we selected UART for communications between the audio unit and PND.

6.2 Data Structure

While it was already understood that the software drivers were to transmit and receive data over UART, it was still necessary to establish how data in higher layers were to be handled.

In the past we had encountered a similar issue (in connecting a PND with a car audio unit), when we had dealt with a system where audio equipment and a TV display were connected via AVC-LAN. In the abovementioned case, the command format between the audio equipment and display was designed to conform to the AVC-LAN standard, and transmission/reception of data was conducted over AVC-LAN. Based on this past experience, we decided that it would be best to use the AVC-LAN command format for the data structure of communications between the PND and main audio unit, and to convert this data into the UART communication format for device driver level communication. This method offers the following advantages:

- All main audio unit-side transmission/reception of data is carried out via AVC-LAN and the data can be transmitted to the PND over UART, while preserving the command format of the data in its original AVC-LAN form. This cuts down on required man-hours because only the UART communication format needs to be modified.
- Although some of the AVC-LAN communications will contain information that is unnecessary to the PND, in this case we decided to keep this extraneous data. The main reasons for this is the possibility of software bugs that might arise from making unneeded changes to the data and the possibility of future designs allowing for the usage by the PND, of this otherwise extraneous data.

6.3 Communication Speed Issues

When defining a new communication specification, an optimum data transfer speed for communication between the PND and audio unit must be determined. In deciding the optimum communication speed, it is important to consider the following two factors:

1) To conform to the existing communication standard, commands must be sent with an interval of at least 100ms between each other. The maximum length of a command that can be transmitted at once is approximately 300bytes (which is composed of 30bytes of status information ＋ 260bytes of text), therefore the communication speed selected must be able to transmit 3000bytes in 1s.
2) Data must not be lost even if an interrupt process is executed during data transmission/reception. If the communication speed is too fast, the device receiving the data may not be able to keep up with the speed of data transfer and data may be lost in the process. For this design, the load time for the UART driver used is about 10μs per byte, which is fast enough that no problem should arise. However, even in this case, if the device receives an interrupt process, data could be lost because UART data acquisition cannot be conducted during the duration that the device is performing an interrupt process. Therefore the transfer speed should also take into account the time required for any interrupt processes that could occur. In other words, the transfer speed should satisfy the following:

Time required for interrupt process < Time required for data transmission/reception of UART communication + Load time

In the system in question, actual measurements show that the system architecture allows for interrupt processes requiring approximately 200μs. Therefore it is advisable that the load time be 190μs or more.

Taking into account the above conclusions, we were able to select the optimum communication speed from the available standard UART communication speeds (shown in Table 1). As one can see, the transfer speeds that satisfy our conditions are 28.8kbps and 38.4kbps. However it is important to note, that if continuous or repeated interrupt processes are performed, data could still be lost even at the optimum transfer speeds. With that in mind, we selected 28.8kbps, as the slower communication speed poses less of a risk in that regard.

Table 1 Study of Communication Speed

Transfer speed (kbps)	Transfer capacity (byte/s)	Transfer	Load time (μs/byte)	Loading
9.6kbps	1200	×	833	○
14.4kbps	1800	×	556	○
19.2kbps	2400	×	417	○
28.8kbps	3600	○	278	○
38.4kbps	4800	○	208	○
57.6kbps	7200	○	139	×
115.2kbps	14400	○	69	×
128.0kbps	16000	○	63	×

6.4 Collaborative Development with TomTom

Being that this was a first time effort, to collaboratively develop a new communication interface specification with a navigation manufacturer outside of Japan (TomTom N.V.), we conducted the following activities and initiatives to foster accurate communication and promote early detection of defects:

[Activities]

①Joint specification D/R (on July 21st and 24th in Amsterdam)
②Progress report meetings (once or twice a week) via conference calls/text-based meetings
③Joint cross-check sessions (First session: on September 20th to 22nd in Taipei, Second session: on November 27th and 28th in Kobe)
④In-vehicle on-road testing (on July 6th in Brussels)

[Results]

In the end, we were able to successfully guide the project to mass production launch despite the significant time difference (7 hours) and physical distance (11 hours by airplane) between the two development teams. Problems encountered and lessons learned from the development process include:

①Linguistic: to overcome our lack of English conversational proficiency, we made use of online chat/messenger clients. These proved extremely useful, as we were able to hold text-based conversations in real-time, while keeping records of all correspondence at the same time.
②Cultural: there were big differences in the general approach to work (delegating tasks, methods of task completion and problem solving) and in regards to the concept of "quality" between both parties due to differences in corporate/national culture. Persistent communication and understanding are required to overcome these issues. It is important to note however, that due to time constraints there were certain issues in this regard, that we were unable to address and should eventually be resolved in the future.

6.5 Development Issues

During PND interface development, we were required to create the communication interface and evaluate it without possession of the actual PND, as TomTom needed to develop a new PND design from scratch, that conformed to the newly created communication specifications, in parallel to our development process. In response to this problem, we made use of a PC simulator that served as a communication monitor, and could send pseudo data transmissions to simulate the behavior of the actual PND unit.

6.5.1 Overview of the PC Simulator

Without a PND unit, it would be impossible to conduct the necessary communication tests in order to develop the PND interface. To counter this issue, we made use of a PC simulator that served as a communication monitor, and could send pseudo data transmissions to simulate the behavior of a real PND unit.

The use of a PC simulator makes it possible to do the following:

- **Examine the contents of the data transmitted from audio unit to PND**
- **Compose and send pseudo commands to the audio unit**
- **Monitor the state of communication between the audio unit and PND**

6.5.2 Functions and Features of Simulator

[Functions]

- **Command transmission**

Allows the user to compose and send data from the PC over UART.

- **Command reception**

Automatically receives and removes the header from UART data transmitted from the main audio unit. Also stores/displays the received data as log data.

- **Data storage**

Logs data sent between the simulated PND and main audio unit, converts the data into a text file and stores it.

- **Data editing**

Allows the user to edit the data using a normal text editor.

[Features]

This simulator is specifically designed to simulate the communication of a PND unit. To elaborate:

・The simulator is designed to faithfully reproduce the data transmission/reception mechanism of a UART connection, while at the same time observing the data link layer communication specifications defined for communication between the PND and the audio unit. By eliminating the need to tweak detailed settings such as header or check sum, the users can check log data and create commands with relative ease.

- **Automatic ACK/NAK response**

In response to data transmitted from the audio unit, the simulator responds with the appropriate ACK/NAK replies automatically. According to the communication specification, the device receiving the data, must reply with an ACK/NAK response within 100ms. As it is impossible for the user to manually provide ACK/NAK responses within 100ms of receiving data, not to mention inefficient, considering the frequency of transmission/reception of data, the simulator automatically provides the necessary ACK/NAK response upon reception of data.

・Retry upon failure of transmission

If a device transmits data and does not receive an ACK reply within 100ms, it is determined that the transmission has failed, and the transmission-side device will resend the data up to three times. As it would be extremely tedious for the user to identify whether or not an ACK reply has been received and to manually resend the data, the simulator is designed to automatically recognize this condition and resend data up to three times.

・Byte stuffing

Upon receiving the first byte of data, which is also known as SYNC (fixed value), both the PND and audio unit recognize communication to have "started" and act accordingly. If the body of the data being sent contains a sequence which happens to be the same value as the SYNC value, the receiving device could misconstrue this as the start of a new data sequence. To avoid this misidentification, if the data being sent contains the SYNC value, then that sequence of data is converted into a form where it can be distinguished from a genuine SYNC response. This is called byte stuffing.

Since it is extremely difficult to intentionally create data that doesn't include the SYNC value, and doesn't require byte stuffing, the simulator automatically performs byte stuffing on the fly, during transmission of data.

By using this PC simulator, it was possible for us to perform communication testing even without the physical PND unit, and to finish development ahead of schedule, which allowed us to spend more time on early detection of software bugs.

7 Conclusion

After releasing commercial models in Europe and Australia, following an earlier release in North America, we have been receiving many favorable comments from our consumers in regards to the product concept. It is also important to note that, at the same time, several of our competitors had been planning products quite similar in concept, however due to our successful execution of an accelerated development process, we were able to be the first supplier to deliver this concept to the market as a finished product.

Regarding our first-time collaborative development project with navigation manufacturer TomTom, it is important to note that we were able to bring a product to market despite the numerous barriers between us, such as language, time difference, differences in design methodology and so on.

We aim to further expand and continue future product planning/development of this concept, so as to achieve further "customer delight".

In closing, through this publication, we would like to offer our deepest thanks to TomTom International BV, FTEG as well as all other companies that were involved with development for project Supercat.

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"Bluetooth" Bluetooth SIG, Inc.
"iPod" Apple, Inc.

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"AVN" Fujitsu Ten Limited

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