Development of Space-saving Type Film Antenna for GPS/ Terrestrial Digital Broadcasting

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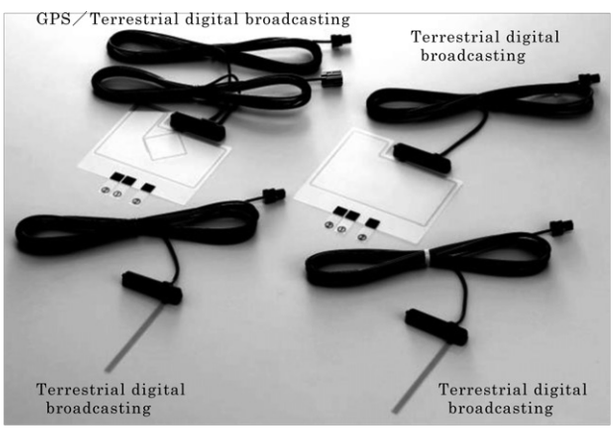
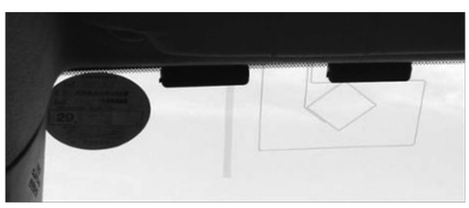
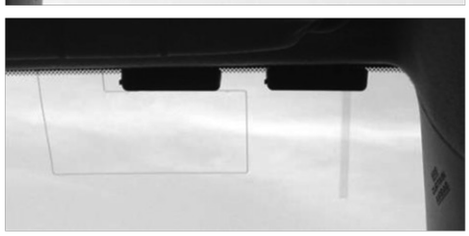






Abstract

FUJITSU TEN has introduced film antennas installed on the front windshield which are currently widely used into the dealer option market and aftermarket with model changes including support for terrestrial digital broadcasting for about 18 years since we commercialized a film antenna for analog TV as early as in 1998. As a result, the upper part area of the front windshield is now recognized as the installed place of film antennas.

However, recently equipment installed on the front windshield such as cameras for automatic braking and antennas for communication equipment has been increasing. Therefore, the space available for installation is becoming smaller so that significantly space-saving film antennas are required.

Thus, in order to respond to changes in the market environment, we have newly developed space-saving type film antennas for GPS/terrestrial digital broadcasting which ensure good reception performance.

This paper introduces the method for realizing the reception performance as a feature of this developed model and efforts to improve appearance/ serviceability/ robustness.

1 Introduction

TV function is almost essential for domestic dealer option/aftermarket navigation and the needs for good reception of full-segment terrestrial digital broadcasting are growing because of the recent big screen and the spread of the rear seat display.

Furthermore, GPS antennas for dealer option / aftermarket navigation were patch antennas (box-shape and floor-standing antennas) installed on the roof or instrument panel in past days. However, film antennas aiming for improvement of appearance and workability are penetrating into the market.

FUJITSU TEN commercialized a film antenna for analog TV installed on the front windshield in 1998 and has provided film antennas for GPS/analog TV since 2004 and film antennas for GPS/terrestrial digital broadcasting since 2008 to the market. FUJITSU TEN is a pioneer who introduced film antennas installed on the front windshield into the market. Especially, FUJITSU TEN introduced film antennas for both GPS and analog TV into the market faster than anyone. The cumulative shipments of film antennas installed on the front windshield have amounted to about 11 million units by FY 2015.

2 Outline of film antennas for GPS/ terrestrial digital broadcasting

Function block is, as shown in Fig. 1, broadly divided into an antenna element part for receiving radio waves, an antenna amplifier part for amplifying received radio waves and a cord part connected to a navigation body. The antenna amplifier part is placed close to the antenna element part and is commonly called "pick-up part". **(Fig. 2)** Film antennas for dealer option / aftermarket navigation to be installed on the vehicle later are generally installed on the upper part of the front windshield from the aspect of an easy place to receive radio waves in a space inside the vehicle and a reduction in the burden of wiring work.

Reception of terrestrial digital broadcasting includes reception of one-segment broadcasting by one antenna and reception of full-segment broadcasting mainly composed of four antennas and four tuners.

This paper introduces the development of a system with four antennas for reception of full-segment broadcasting.

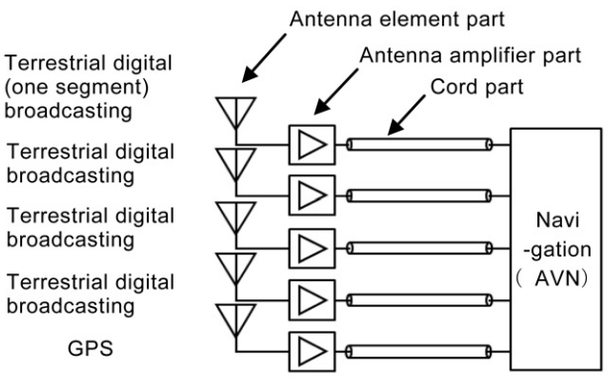


Fig. 1 Function Block Diagram

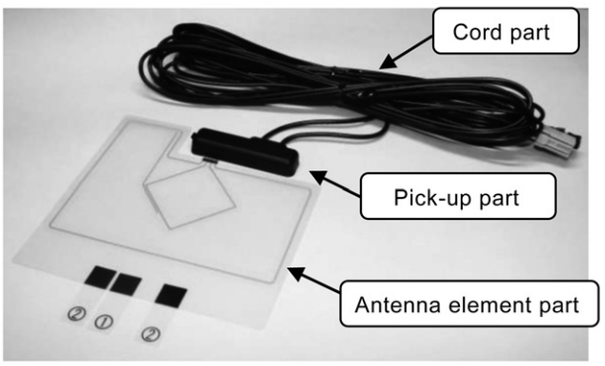


Fig. 2 Antenna Region

3 Background of development

In the past, equipment installed on the front windshield included film antennas for GPS / terrestrial digital broadcasting, Drive Recorder, antennas for mobile communication and ETC antennas and these could exist together.

However, recently, in addition to installing safety equipment such as a sensor for automatic braking (camera / laser) on the front windshield as standard equipment, the increase of antennas with faster mobile communication, the addition of antennas for ITS equipment such as vehicle-to-vehicle / road-vehicle communication equipment and the addition of antennas for new broadcast-

ing (V-Low multimedia broadcasting) are further expected in the future. It suggests that all the equipment mentioned above cannot be installed on the upper part of the front windshield while maintaining the conventional size.

Against this background, we have developed a space-saving type of the film antennas for GPS / terrestrial digital broadcasting which took up a large space.

4 Aim of development

The aim of development can be summarized to the following four points.

(1)Ensuring performance while saving space

A smaller space for installing antennas makes it very hard to ensure the performance of antennas.

As for conventional product, since all the four antennas for terrestrial digital broadcasting adopt one wavelength loop antenna method or monopole method which requires a long GND pattern (including the effect of shorter wavelength due to the dielectric constant of the windshield), the antennas take up a large space especially in the width direction of the vehicle. (Refer to "Conventional product" in the top column of **Fig. 6** in Section. 5)

As measures for saving space, it was difficult to ensure the performance of antennas by simply downsizing antennas or placing antennas closer to each other. Therefore, without changing the configuration of four antennas for reception of full-segment terrestrial digital broadcasting, we optimized the method, installation place and shape of antennas in order to ensure the performance equivalent to the conventional product while saving space.

Fig. 3 shows a target space compared to the conventional product as an example.

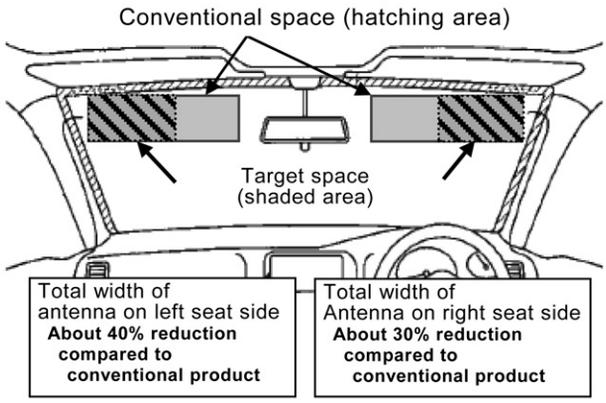


Fig. 3 Installation Space of Film Antenna

As for the target space, we calculated the size required for antennas by analysis of storage data of FUJITSU TEN and performing activities of the working group with automotive manufacturers and other peripheral manufacturers after careful consideration of the size of other equipment which are expected to be added in the near future.

Furthermore, in view of driver's visibility, we aimed to place four antennas only on the upper part of the front windshield as in the past.

(2)Improvement of appearance

In the dealer option market, automotive manufacturers delivered an opinion that the appearance from the driving position may become worse depending on the shape of the antenna element. Therefore, we adopted a superfine metal mesh film by which the antenna element is inconspicuous instead of a conventional metal paste printing film so as to improve appearance. **(Fig. 4)**

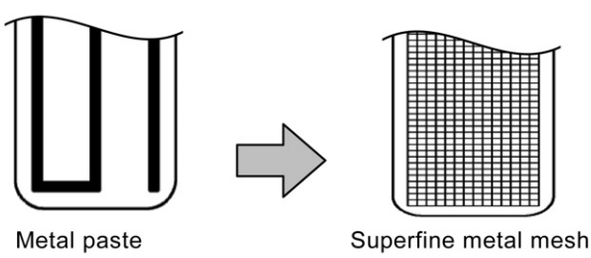


Fig. 4 Configuration of Antenna Element

(3)Improvement of serviceability

In the conventional product, when the windshield was damaged, since the antenna element part was adhered to the pick-up part (including

the cord part) with a double-stick tape so that they could not be separated from each other, all the product needed to be replaced. Thus, the customer's cost burden and the dealer's burden of replacement of product were large.

Therefore, we aimed to adopt a removable fitting method for the attachment structure of the antenna element and pick-up element instead of an adhesion method. (**Fig. 5**)

By this method, for example, if the windshield is damaged, only the antenna element part should be replaced, and if disconnection is caused in the cord part, only the pick-up part (including the cord part) should be replaced. In this way, the replacement of the antenna element part or the pick-up part can be minimized as needed.

(4)Improvement of robustness

The attachment portion between the antenna element part and the pick-up part is important in quality, because the signals are transferred by the contact of elements with spring terminals on the pick-up part side.

In the conventional product, this attachment depended on the attaching work with the double-stick tape by dealers and customers. However, the present product which integrates the antenna element part and the pick-up part has ensured contact quality of terminals on the manufacturer side to improve robustness.

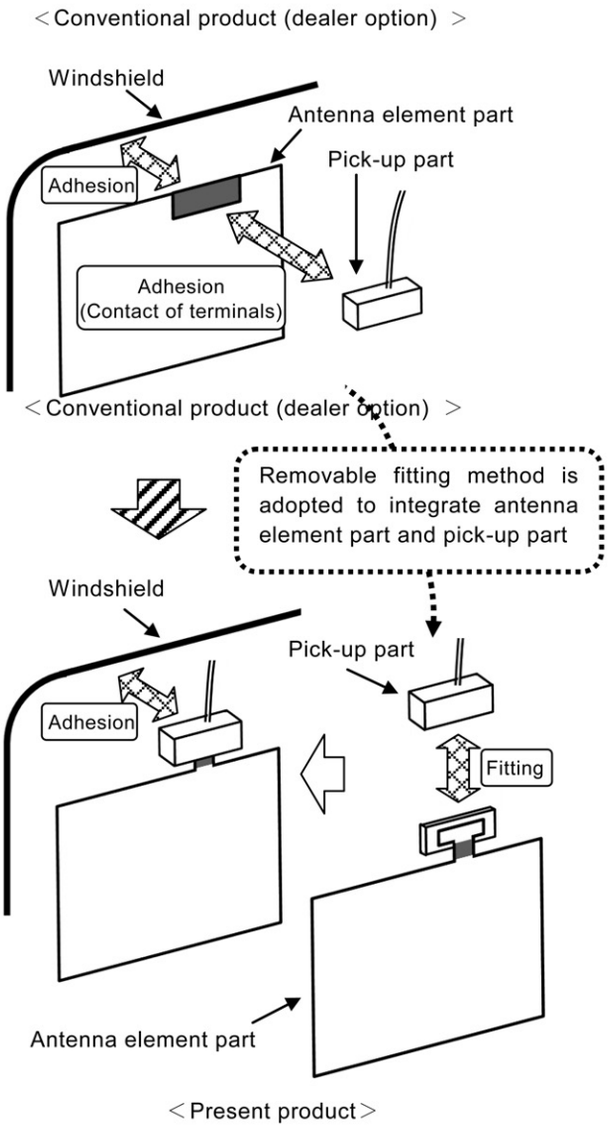


Fig. 5 Attachment Configuration of Antenna Element Part and Pick-up Part

5 Specific contents of efforts of development

The efforts of development can be summarized to the following four points.

(1)Ensuring performance while saving space

The configuration of the developed antenna is shown as follows. (**Fig. 6, Table 1**)

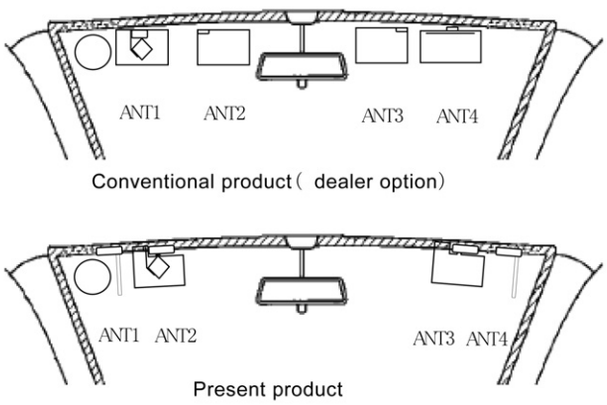


Fig. 6 Configuration of Antenna

The configuration of each antenna is as follows.

Table 1 Directivity of each antenna

	Conventional product		Present product	
	Method	Directivity	Method	Directivity
ANT1	Loop	Front	Monopole	Right
ANT2	Loop	Front (diagonally right)	Loop	Front
ANT3	Loop	Front (diagonally left)	Loop	Front
ANT4	Loop	Front	Monopole	Left

In order to avoid interference between antennas, the antennas close to each other should be the combination of a loop antenna (mainly for horizontal polarized wave) and a monopole antenna (mainly for vertical polarized wave) to achieve a polarization diversity configuration. Furthermore, as for the installation position of antennas, the monopole antenna is placed in the vicinity of a vehicle A pillar (metal) to improve directivity of horizontal polarized wave in the lateral direction of the vehicle due to reflection effect. (**Fig. 7**)

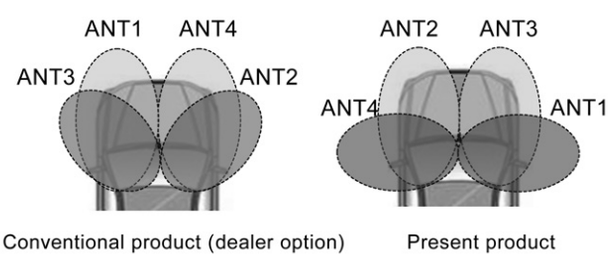


Fig. 7 Antenna Directivity (Horizontal Polarized Wave)

One side of the element of the monopole antenna is basically connected to ground (GND). However, in the present antenna, in view of installation in the vehicle, capacitance coupling caused by placing the element for GND close to the vehicle body (GND), instead of directly connecting them, ensures GND connection at high frequencies.

The element for GND is structured by using a meandering (folded) structure to have loading effects (extension effects) so as to achieve a horizontal shortening. (**Fig. 8**)

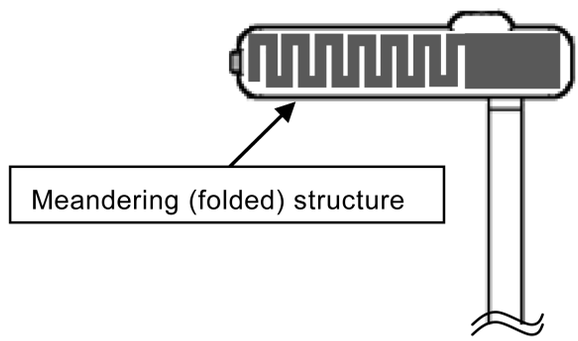


Fig. 8 Meandering Shape

Furthermore, by using meandering structure, the current phase difference with the adjacent loop antenna is increased to suppress coupling between the antennas. (Filed a patent application Patent Application Number: 2016-168365)

The loop antenna has a convex portion on the left upper part to ensure one wavelength and shorten its horizontal length compared to the conventional one. The convex portion is placed on black ceramics along the roof lining with consideration for the appearance. (**Fig. 9**)

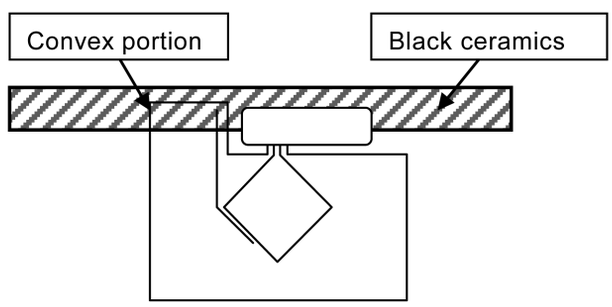


Fig. 9 Loop Antenna Shape

One example of performances of the presently developed product is shown as follows.

(Table 2, Fig.10)

It was confirmed that the present product had an average sensitivity equivalent to the conventional product, and as for directivity, the present product had a better directivity than the conventional product in the horizontal direction of the vehicle.

Table 2 Average sensitivity

4 synthesis average sensitivity [dBd]	Conventional	Present
Priority band [470MHz to 575MHz]	Criterion	+0.5
Overall band [470MHz to 710MHz]	Criterion	+0.2

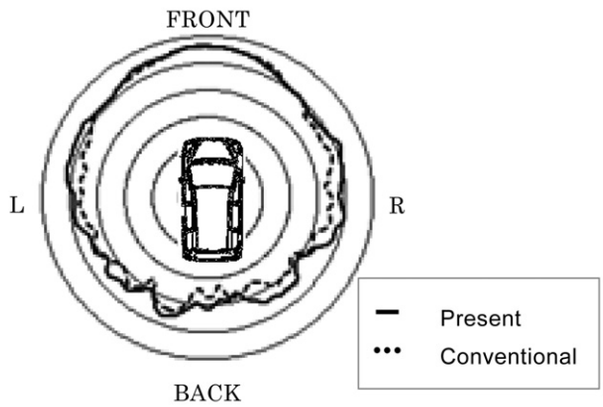


Fig. 10 Example of Directivity

In this way, by using a polarization diversity configuration and improving directivity, the performance equivalent to the conventional product while saving space could be ensured without changing the "placement of four antennas on the upper part of the front windshield".

(2)Improvement of appearance

If the monopole antenna is composed of metal paste, since the tip of the antenna element gets close to the driver's view area, the appearance from the driving position may become worse.

Therefore, we considered adopting the superfine metal mesh pattern by which the antenna element is inconspicuous. In the conventional loop antenna, since the occupation area of the film part was large, there were cost problems to use the superfine metal mesh pattern in the shape of the film part. However, by developing the monopole antenna having a small occupation area of the film part, the superfine metal mesh pattern could be adopted in the present product. In order to adopt the superfine metal mesh pattern, the line width, pitch between lines, mesh shape, etc. were determined, aiming to achieve both high performance and good appearance. **(Fig. 11)**

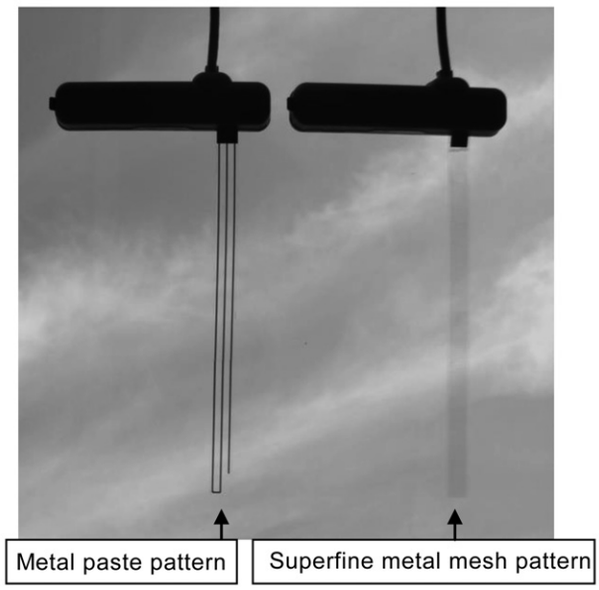


Fig. 11 Comparison between Metal Paste Pattern and Superfine Metal Mesh Pattern of Monopole Antenna

Furthermore, by changing the conventional metal paste pattern to the superfine metal mesh pattern, the conductor resistance is reduced to improve radiation efficiency of the antenna and contribute to the improvement of performance.

(3)Improvement of serviceability

As for the fitting structure of the antenna element part and pick-up part described above, by setting the main two targets, the specifications were determined.

①Easy removal and re-installation is possible without using tools.

②Never come off by the environmental load such as heat or the reaction force of the cord.

These two items,①Easy removal is possible and ②Never come off if it is not intended, are conflicting characteristics and both of them should be satisfied. Therefore, firstly, fitting parts were placed at both ends of the antenna element

part and a removal lever was set at one end. Consideration was made to ensure that the shape and the protrusion amount of the lever could be manipulated and Interior Fitting Regulation would not be violated.

Furthermore, the lever of all the four antennas was positioned on the left side to achieve the same workability in removal.

Next, the fitting part was placed not only at both ends of the antenna element part but also at the center of the pick-up part on only one side (one place) to improve fitting force. The purpose is that the pick-up part does not come off mainly by the reaction force of the cord. The fitting part was placed on the minimum one side to improve "①workability in removal and re-installation".

Since the fitting parts of these three places are composed of resin, resin with optimal heat resistance was selected to keep the pick-up part from not coming off by permanent deformation of the fitting part due to high temperature or inclination (deformation) of the fitting hook due to the reaction force of the cord. At the same time, by utilizing simulation and strength analysis, in order to prevent damage in removal and re-installation at the time of replacement, detailed specifications such as the hanging amount and the width of the hook were determined with consideration also for durability. (**Fig. 12**, **Fig. 13**)

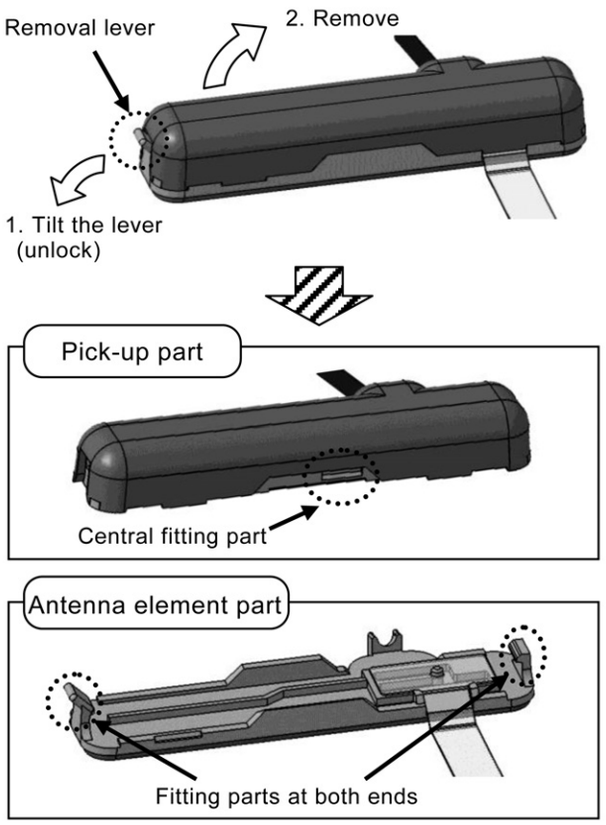


Fig. 12 Removal Structure and Detail of Fitting Region

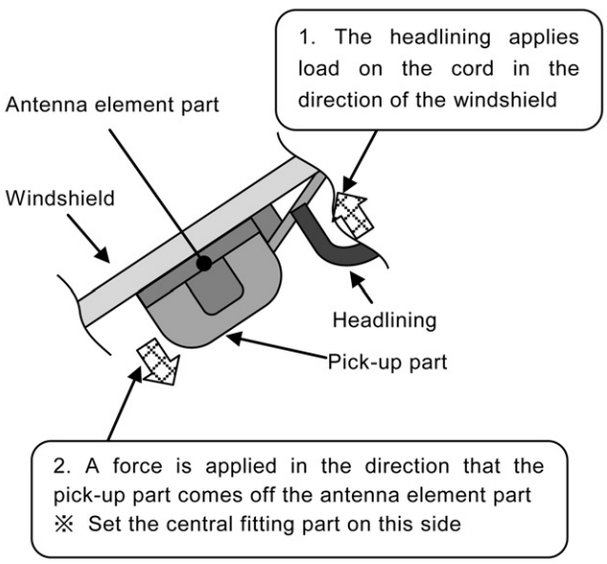


Fig. 13 Detail of Reaction Force Load of Cord

(4)Improvement of robustness

As for integration of the pick-up part and the antenna element part, contact part with a spring terminal on the board (commonly called a film land part) was included in the pick-up part. (**Fig. 14**)

The following three points were taken into consideration to realize this inclusion structure.

① Ensuring contact stability between the spring terminal and the film land

- In order to keep the fitting parts for fixing the board from not coming off by the reaction force of the spring terminal, the reaction force / heat analysis was conducted to determine its shape. In order to apply an optimal and stable contact load with the spring, the dimension between the board and the film was determined.
- The contact place between the spring terminal and the film land was plated to prevent deterioration such as rust.

As a result, resistance to instantaneous interruption or micro-sliding abrasion due to vehicle vibration was ensured.

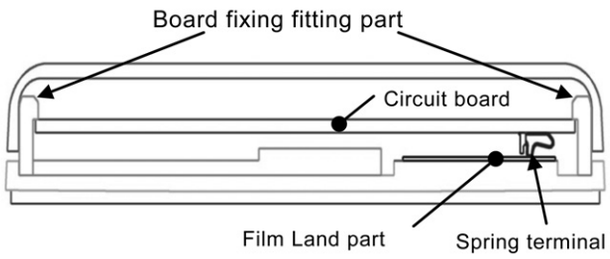


Fig. 14 Contact Structure of Terminal and Film Land Part

② Ensuring tensile strength of the film

By providing a hole in the film part and a boss on a bearing surface of a holder part, even if the film is pulled, the film does not easily come off. **(Fig. 15)**

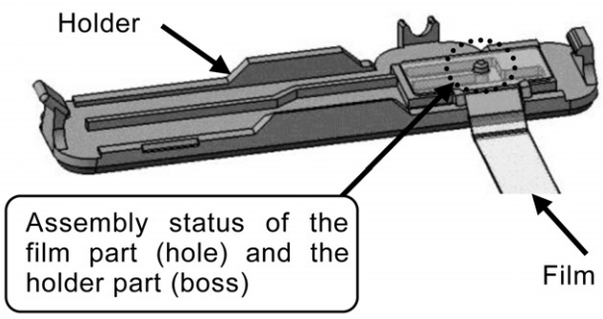


Fig. 15 Assembly Drawing of Film and Holder

③ Ensuring easy installation onto vehicles

When this product was installed on the vehicle, a paper pattern for installation was set in order to place two antennas on the left seat side and another two antennas on the right seat side at a target distance with good appearance (in parallel). This paper pattern was first placed on the front windshield and the pick-up part was placed according to the shape of the paper pattern so that two sets of two antennas could be installed on the left and right respectively at a target distance with good appearance. A paperboard for transportation was originally set for protecting the antenna element part. The paper pattern was integrated with this paperboard for transportation. The paper pattern was cut out and used for installation **(Fig. 16)**

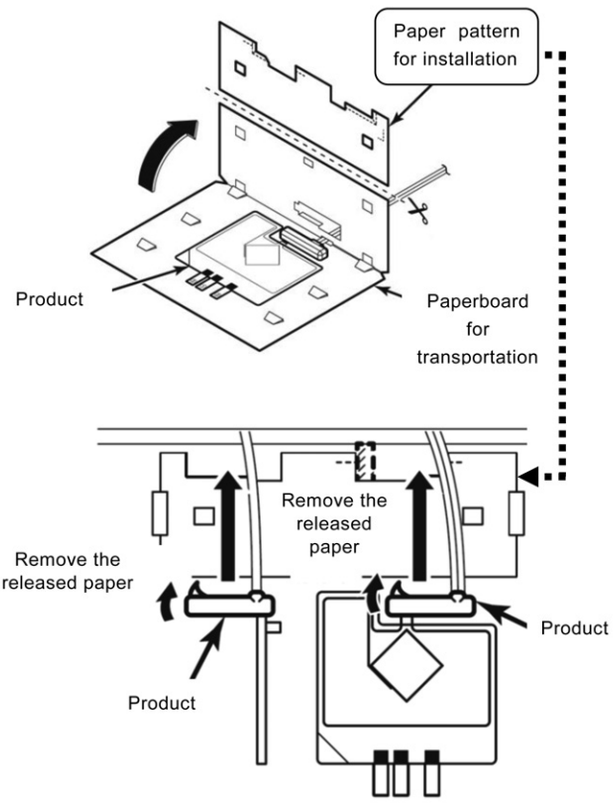


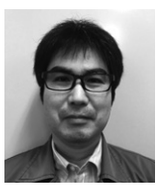
Fig. 16 Method of Installation on Vehicle Using Paper Pattern

6 Conclusion

By this development, commercialization of space-saving type film antennas for GPS / terrestrial digital broadcasting which ensure good reception performance has been realized. We think that we will make efforts to integrate these antennas into other media and improve performance, appearance and workability.

Finally, we would like to express our heartfelt gratitude to all concerned people inside and outside the company for their cooperation for the development of this product.

Profiles of Writers



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