

Development of Antenna for Global Telematics

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ABSTRACT

Based on a concept of global compatibility, a telematics antenna unit has been developed that integrates antenna elements for mobile communications and for satellite positioning in order to respond to the increasing global application of telematics services.

Taking into consideration the differences in the frequencies used by each mobile network provider in any specific country and the frequency range stipulated by regulations, a bowtie antenna was employed as the antenna for mobile communications. This made it possible to realize an ultra-wide-band characteristic from 698 to 3800 MHz. The antenna for satellite positioning is compatible with both the US GPS and Russian GLONASS systems, and the use of a built-in signal divider and power supply selector switch has made it possible to split satellite signals between the telematics system and other systems. The volume of the antenna unit has been reduced by 50% against conventional antenna units, increasing the degree of freedom available for fitting in the instrument panel.

1. Introduction

Telematics is well known as an information service employed in the automotive and transportation industries. The word “telematics” itself was coined from a combination of “telecommunications” and “informatics.”

Today, attention is being focused on examples of the large-scale collection of driving logs from individual vehicles, and their use in big data analyses for the public benefit. One such case is the social contribution made following the Great East Japan Earthquake by the use of a service employing Honda’s InterNavi Floating Car System⁽¹⁾ to provide map data concerning roads that were in use by system users, enabling rapid communication of information regarding passable roads to other users⁽²⁾.

Current telematics services can be broadly classified as follows:

- (1) Transmission of information that is of use to vehicle users while driving, including information on traffic congestion and weather information;
- (2) Serving as a means of providing information to national and regional emergency response systems, for example as an emergency reporting system; and
- (3) Maintenance and management of vehicle performance, including electric vehicle battery data and charging station data.

Emergency reporting system is one of the means of

informing emergency lifesaving organizations as described above, thereby promoting formulation of official standards and/or establishment of mandatory regulations.

In Europe, the European Road Transport Telematics Implementation Coordination Organization (ERTICO), a public-private sector organization, has been the central actor in the formulation of European technological standards⁽³⁾ based on multi-stage verification of systems in public proving trials (e.g. HeERO1/HeERO2 and eCall). These standards make the fitting of telematics units mandatory in new model vehicles from March 31, 2018.

Separately to the European standards, Russia has also made it mandatory to fit telematics systems in all new model vehicles from January 1, 2015, and in all newly marketed vehicles from January 1, 2017. The use of the Russian satellite positioning system GLONASS to provide vehicle position data for emergency reporting is an essential condition for these telematics systems.

In response to this global diffusion of telematics services, the specifications of the conventional antennas used for telematics have been adapted to the characteristics of the frequencies used by mobile network providers in different countries and regions. As a result, the number of variations in antennas developed for specific countries and regions has increased in direct proportion to the global diffusion of telematics, and this has simultaneously increased costs for users.

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2. Development Goals

In order to address these issues, the research discussed in this paper set out to develop a new type of telematics antenna based on a concept of global compatibility, a unit able to be used in any country or region, and one that could assist in controlling the increase in antenna variations with the diffusion of telematics.

The antennas employed in telematics services are made up of an antenna for mobile communications (TEL ANT), making it possible to connect to mobile wireless telecommunications networks, and an antenna for satellite positioning (GNSS ANT), making it possible to obtain vehicle position data. The development targets for the new antenna were set as follows:

- (1) TEL ANT: Able to cover basically the entire frequency band specified by the Long-Term Evolution (LTE) standard, which is currently being advanced globally;
- (2) GNSS ANT: Compatible with the Russian satellite positioning system in addition to the conventionally used US system, and able to share satellite signals with other systems that employ satellite positioning; and
- (3) Realization of reduced size in order to increase the degree of freedom of fitting in the instrument panel.

3. TEL ANT

3.1. Issues of Conventional TEL ANT

Since the appearance of car telephones, onboard TEL ANT have been fitted in areas including the trunk lid, the rooftop, and the instrument panel. The main antenna elements in use for onboard TEL ANT are $\lambda/4$ monopole elements, $\lambda/2$ T-monopole elements, $\lambda/2$ dipole elements, and elements derived from these. The linear antenna elements resonate with standing waves⁽⁴⁾.

Due to their principle of operation, resonant antennas have a resonant frequency, and are restricted to use within a frequency band in which they are able to display their prescribed performance. In terms of the figure given by their upper limit frequency divided by their lower limit frequency, the antennas are generally used within a range of around 1.05 to a maximum of 1.1.

Government authorities in each country and region of the world grant licenses to mobile network providers for the frequency bands that can be used for mobile communications based on the global standards specified by the Third Generation Partnership Project (3GPP). These frequency bands are broadly divided into low bands (below 1 GHz) and high bands (1 GHz and above), and the bands used depend on the communications environment and the nature of the communications.

For the third-generation mobile phones that have been the mainstream since 2000, the main frequency ranges in use in the North American region are the low band from 824 to 894 MHz and the high band from 1850 to 1990 MHz. In the regions of Europe and Asia, the main

frequency ranges are the low band from 880 to 960 MHz and the high band from 1710 to 1880 MHz or from 1920 to 2170 MHz. These frequency bands are all in a frequency ratio of 1.1 or below. Resonant antennas with their resonant frequencies adjusted to each frequency band are employed as TEL ANT⁽⁵⁾. Two methods of manufacturing antennas are in use: A method that uses two elements, for the low and the high bands, respectively (Fig. 1); and a method that uses only a single element, a low band element, with the high band resonating as the third harmonic of the low band.

The wavelength of radio waves is calculated by dividing the speed of light (3.00×10^8 m/s) by the frequency of the wave. For example, the wavelength at 824 MHz, the lowest frequency of the low band, is 364 mm. The basic length of a TEL ANT element that resonates with this wavelength would be 182 mm in the case of a $\lambda/2$ dipole element, and 91 mm in the case of a $\lambda/4$ monopole element.

The frequency range used by the majority of fourth-generation mobile phones is broad, with the lower limit for the low band set at 698 MHz, and the high band ranging from 1427 to 1510.9 MHz, from 1744.9 to 2200 MHz, and from 2500 to 3800 MHz. The wavelength at 698 MHz is 430 mm. The basic length of resonating TEL ANT elements for this wavelength would lengthen the unit by 215 mm in the case of a $\lambda/2$ dipole element, and 107 mm in the case of a $\lambda/4$ monopole element.

As indicated above, mobile network providers are allotted specific frequency ranges from these frequency bands and are licensed to use these ranges by government authorities. When Honda establishes telematics services in different countries, the resonant frequencies of the antenna elements that are employed are adjusted to the frequency bands for which the mobile network providers that the company contracts with hold licenses.

As this indicates, the number of variations of conventional TEL ANT increases with the number of mobile network providers with which contracts are

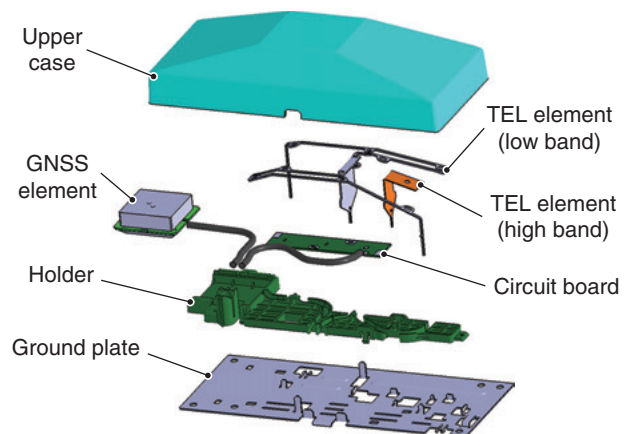


Fig. 1 Conventional antenna

established. Even if the contracted mobile network provider is not changed, if the company newly adds a frequency to its range, it will be necessary to either add or readjust an antenna element, which will further increase the number of TEL ANT variations.

3.2. Self-similar TEL ANT Elements

It is necessary for antenna elements to display a level of performance making it possible to apply them irrespective of which mobile network provider in any specific country a contract is established with. However, it is not an easy matter to obtain characteristics from conventional resonant antennas, which are operated at a frequency ratio of around 1.1, making it possible to apply them across the entire range of frequency bands. It was therefore decided that self-similar rather than resonant elements would be employed as the form of operation for the TEL ANT elements. Taking the degree of freedom of positioning the TEL ANT in the instrument panel into consideration, the use of a self-similar bowtie antenna would present the advantage of not having a solid, three-dimensional structure, but of having a pair of flat discs as its basic shape.

Examples of the use of bowtie antennas in ultra wide-band radar applications using millimeter wave pulses, for example underground exploration radar, have been reported⁽⁶⁾⁻⁽⁸⁾.

Biconical antennas, broadband antennas formed from two cones, have the basic shape of a pair of triangles arranged such that their vertices face each other (a planar projection configuration), like a bowtie. The actual dimensions of the antennas are known to affect the frequencies able to be employed (Fig. 2). The gain characteristics of the antennas in relation to frequency can be adjusted by modifying the hypotenuses of the triangles into quadratic curves or semi-circles⁽⁸⁾.

Because the polarized waves of the radiated electric field travel in the same direction as the axial direction of the triangular discs (the direction of the axis of rotation of the cones), the vertically polarized waves that are the main type used by second- and third-generation mobile phones were

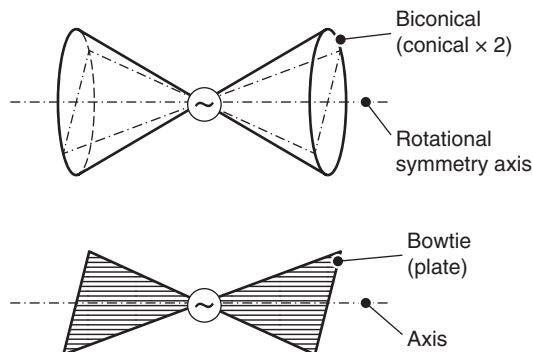


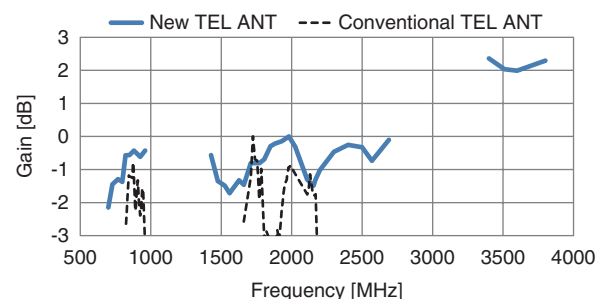
Fig. 2 Bowtie antenna

focused on, and the use of a vertical axis of alignment was selected as the basic form for the antenna.

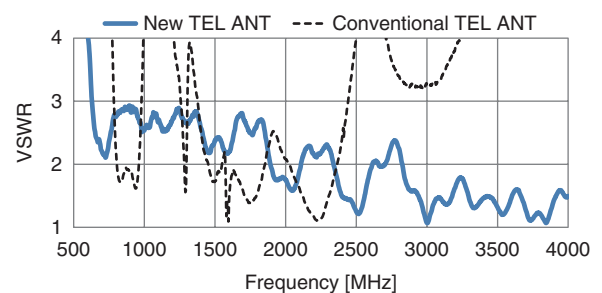
If it was not necessary to house the TEL ANT together with the GNSS ANT in the same case, a simple flat disc shape, like the shape of the antenna element, could be used for the external shape of the case; further consideration was necessary when the two antenna elements were housed together.

The use of a bowtie antenna as the basic structure of a new TEL ANT would make the antenna compatible with the 698 to 3800 MHz frequency range scheduled for use by fourth-generation mobile phones, producing a frequency ratio of 5.4. In the case of conventional TEL ANT, gain declines rapidly outside the resonant frequency. Changing the frequency-gain characteristic of the new TEL ANT made it possible to realize an ultra-wide-band characteristic that maintains gain within a 2 dB amplitude in the range from 698 to 2700 MHz (Fig. 3). In order to simplify comparison of frequency-gain characteristics, in Fig. 3 the maximum gain in the range from 698 to 2700 MHz has been shown as a standard 0 dB.

The voltage standing wave ratio (VSWR) is an indicator expressing the impedance matching between an antenna and the feeder line. The ideal ratio is 1, and the radiation efficiency and other performance parameters of the antenna decline as this ratio increases. The figure increases rapidly and performance declines outside the resonant frequency in the case of conventional TEL ANT. The new TEL ANT realizes an ultra-wide-band characteristic in which VSWR is below 3 across the range from 698 to 3800 MHz.



(a) Gain (V-Pole)



(b) VSWR

Fig. 3 Frequency characteristics

4. GNSS ANT

GNSS antennas have long been employed in car navigation units. This has facilitated the civilian use of the Global Positioning System (GPS) operated by the United States. When car navigation units are used together with Telematics Control Units (TCU) to provide vehicle position data, it can be necessary to employ multiple GNSS ANT in the same vehicle.

In addition, in some cases there is an obligation to use a national satellite system, as in the case of Russia's GLONASS mentioned above. The frequencies for civilian use of GPS in the United States and GLONASS in Russia are 1575.42 ± 1 MHz and 1601.72 ± 4 MHz, respectively. Both systems use the L1 band, but there is a difference of approximately 30 MHz between them. Because of this, it was necessary to regulate the characteristic of an interference wave filter built into a low-noise amplifier (LNA) integrally supported directly below the GNSS element in order to make it possible to receive both frequencies.

Japan's Quasi-Zenith Satellite System (QZSS) is another satellite positioning system currently in operation, but the QZSS frequencies are basically identical to the GPS frequencies, making it possible to use the same antenna elements as are used for GPS.

In order to respond to the differences in specifications in relation to the use of the elements with navigation systems, a GNSS ANT element with a built-in GNSS signal divider was employed. A Wilkinson divider was used, implemented by forming an additional distribution circuit pattern on the circuit board of the LNA positioned directly underneath the GNSS element. This made it possible to share the GNSS ANT when a car navigation unit and the TCU were used simultaneously, eliminating the need to fit multiple GNSS ANT in the same vehicle (Fig. 4).

The LNA positioned directly below the GNSS element is operated using power supplied by the TCU or the car navigation unit. Car navigation units mainly supply a source voltage of between 4.5 and 5.0 V. In some cases, the voltage supplied by the TCU differs from the voltage supplied by the car navigation unit. This is because, taking emergency reporting of vehicle data as a representative case, it is necessary to attempt to ensure a minimum continuous operating time for the TCU using power from its inbuilt battery even if the power supply from the vehicle is completely exhausted; in such cases, it is normal to reduce power consumption by reducing the source voltage.

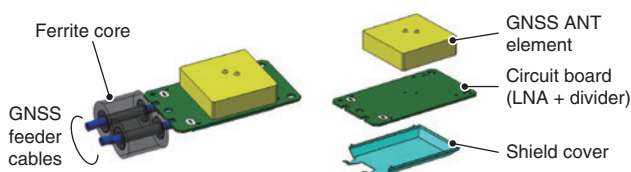


Fig. 4 GNSS ANT element and circuit board

The car navigation unit and the TCU monitor the current supplied to the LNA, and have been provided with a function for the detection of connection errors, disconnection, short-circuits, and other malfunctions. When there is a difference in supplied voltage between the units connected to the antenna with a built-in GNSS signal divider, it is not easy to attempt to ensure the correct functioning of monitoring of the supplied current when a simple backflow prevention device is employed as the means of responding to backflow to the power supply. A power supply selector switch has therefore been positioned on the LNA circuit board. When two systems are connected simultaneously, one is used as a power source for the LNA, and the other is connected to a dummy load (Fig. 5).

When only Unit #1 or Unit #2 in Fig. 5 is connected, the connected unit supplies power to the LNA. When Unit #1 and Unit #2 are simultaneously connected, Unit #1 is used as a power supply for the LNA, and Unit #2 is connected to the resistor R, the dummy load.

This helps to ensure the operation of both the backflow prevention function and the supplied current monitoring function even when there is a difference in the voltage supplied by the units connected to the antenna.

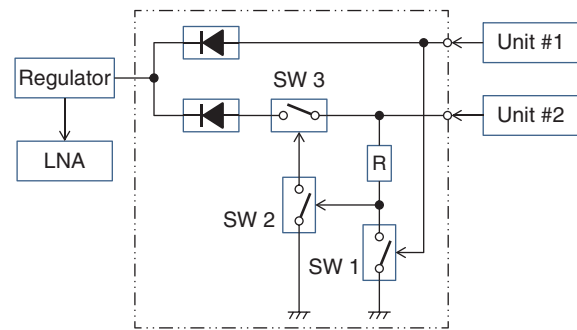


Fig. 5 Power supply switching circuit

5. Size Reduction

As indicated above, the axis of alignment of the triangular discs forming the bowtie TEL ANT element is a vertical axis. By contrast, the GNSS ANT element is a patch antenna with a built-in LNA, and is aligned horizontally, with the surface of the patch in the direction of the open vertex. When the alignment of the antennas was unified, an inverted L or T shape was produced, with the GNSS ANT element positioned along the upper section of the TEL ANT element. In this configuration, the horizontal width and height were determined by the TEL ANT element, and depth was determined by the GNSS ANT element. If both antenna elements were simply fitted together within the case, the space between the lower section of the GNSS ANT element and the TEL ANT element would be dead space. This would reduce the efficiency of space utilization,

and reduce the degree of freedom available in fitting the case in the instrument panel. To address this issue, the internal layout of the case was examined [Fig. 6(a)].

It is known that it is possible to reduce the size and adjust the wide-band characteristic of bowtie antennas via measures including modifying the shape of the elements or adding slots⁽⁶⁾. A configuration in which the upper element of the bowtie antenna was folded down was selected; a horizontal section was created that was aligned with the depth dimensions of the GNSS ANT element from the position at which the upper element of the TEL ANT element was folded down to the height of the GNSS ANT element, and finally the TEL ANT was folded upwards to the height of the GNSS ANT element. By this means, the sides of the GNSS ANT element were enclosed by two areas of the folded section of the TEL ANT, separated by predetermined intervals [Fig. 6(b)]. There was no necessity for the lower section of the bowtie antenna to overlap with the GNSS ANT element. Because of this, it was decided that the lower section of the antenna could be extended outside the case rather than being enclosed within it. The mounting section was extended downward from the bottom of the case, and the lower element of the bowtie antenna was inserted into it to hold it in place.

Multiple slots were added to the lower element, and some of these slots also served as holes to make it possible to secure the element in place.

The configuration described above made it possible to reduce the height of the case, while also creating a structure to hold the GNSS ANT element, increasing the space utilization efficiency in the case.

Coaxial cables are normally used as the feeder cables for high-frequency power from considerations of interference from radio disturbance, loss from power leakage, ease of wiring, and cost of manufacture.

Coaxial cables are unbalanced feeder cables, consisting of an external conductor and a core conductor. Bowtie antennas, however, are balanced antennas, with a basic shape formed from a pair of symmetrical elements. In cases in which balanced and unbalanced devices are connected, the use of a balance-unbalance transducer, or balun, is

available as a method of conversion between balanced and unbalanced⁽⁷⁾. However, it is not easy to apply a balun for the wide-band range represented by a frequency ratio of 5.4, due to the fact that the configuration of the unit tends to become more complex. In addition, it was feared that due to the use of a configuration that reduced size, in which the GNSS ANT element was fitted to a section of the TEL ANT element, leakage current might be induced in the external conductor of the GNSS ANT coaxial cable. The coaxial cables for both the TEL ANT and the GNSS ANT were therefore fitted with ferrite cores in order to control leakage current.

With regard to the shape of the ferrite cores, the internal diameter of the cores was determined by the finished exterior shape of the cable, and the external diameter and axial length of the cores were determined by magnetic properties. The case, which had been reduced in size by means of the process discussed above, contained one TEL ANT and two GNSS ANT, meaning that space would also be necessary for three ferrite cores. In creating the space for the external diameters of three ferrite cores, the cores were arranged on upper and lower levels, in order to control any increase in the size of the case. Space for the axial length of the cores was created by offsetting the axis of the bowtie antenna against the center of the case in the direction of lateral width. The effect of this offset of the axis of the bowtie antenna on its performance characteristic fell within a range that could be responded to by means of measures such as adjustment of the hypotenuses of the element [Fig. 6(c)].

These measures realized a reduction of approximately 50% in volume against a conventional antenna unit fitted in the instrument panel, increasing the degree of installation freedom.

Because it is possible to employ a unit without a built-in GNSS signal divider when it would not be used together with a car navigation system, there are three variations of the new antenna unit: (a) A unit with a GNSS ANT signal divider; (b) A unit without a GNSS ANT signal divider; and (c) A unit featuring a TEL ANT only.

The units with and without GNSS ANT signal dividers can be distinguished externally by the number of coaxial cables and the number of connector poles (Figs. 7 and 8).

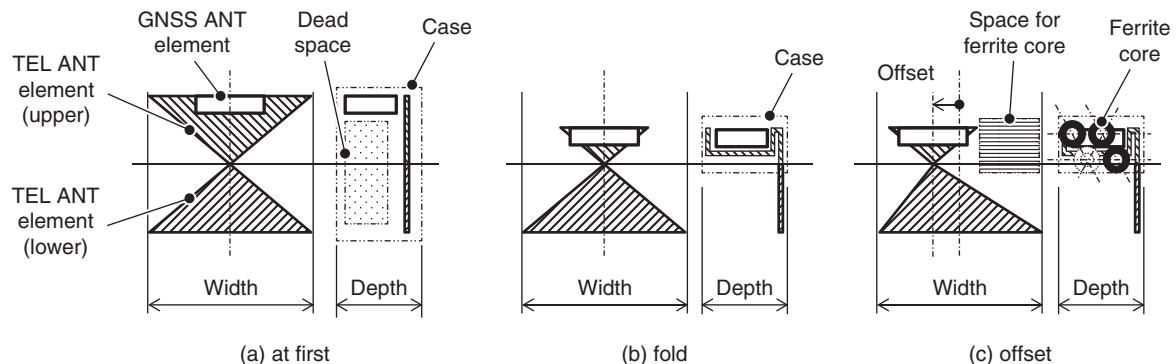


Fig. 6 Configuration concept for TEL ANT and GNSS ANT elements

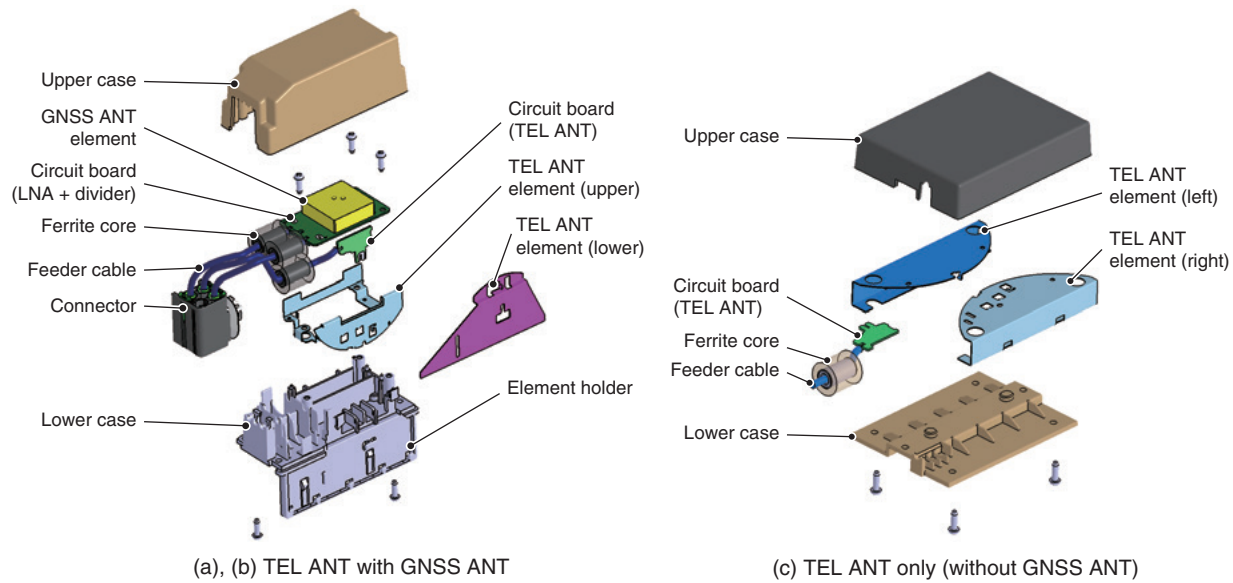


Fig. 7 Configuration of new antennas

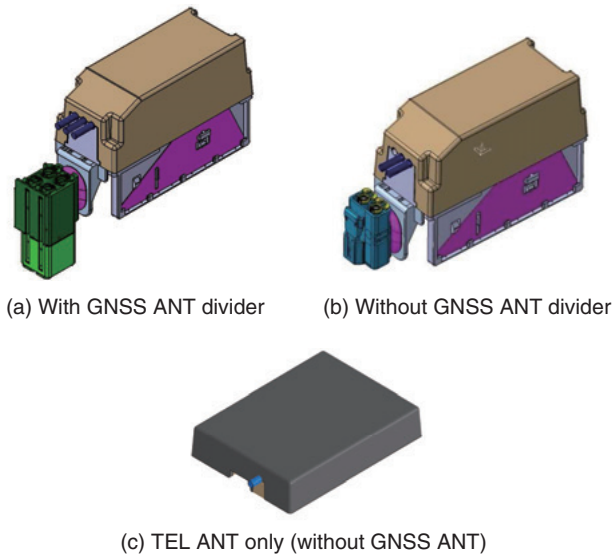


Fig. 8 Appearance of new antennas

6. Conclusion

A new telematics antenna unit has been developed that is capable of global utilization, irrespective of the frequencies licensed to a contracted mobile network provider.

The following development targets were set and achieved based on a concept of global compatibility.

- (1) A bowtie antenna was employed for the TEL ANT, compatible with a wide-band range of 698 to 3800 MHz (a frequency ratio exceeding 5), making it possible to cover the entire frequency range used in the LTE format.

- (2) The GNSS ANT is compatible with the Russian GLONASS satellite positioning system in addition to the US GPS system; providing the circuit board of the in-built LNA with a signal divider and a power supply selector switch has made it possible to split and share satellite signals with other devices using satellite positioning systems.
- (3) The volume of the unit has been reduced by 50% against a conventional unit, increasing the degree of freedom available in fitting the unit in the instrument panel.

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