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(54) **ELECTRONIC TIMEPIECE**

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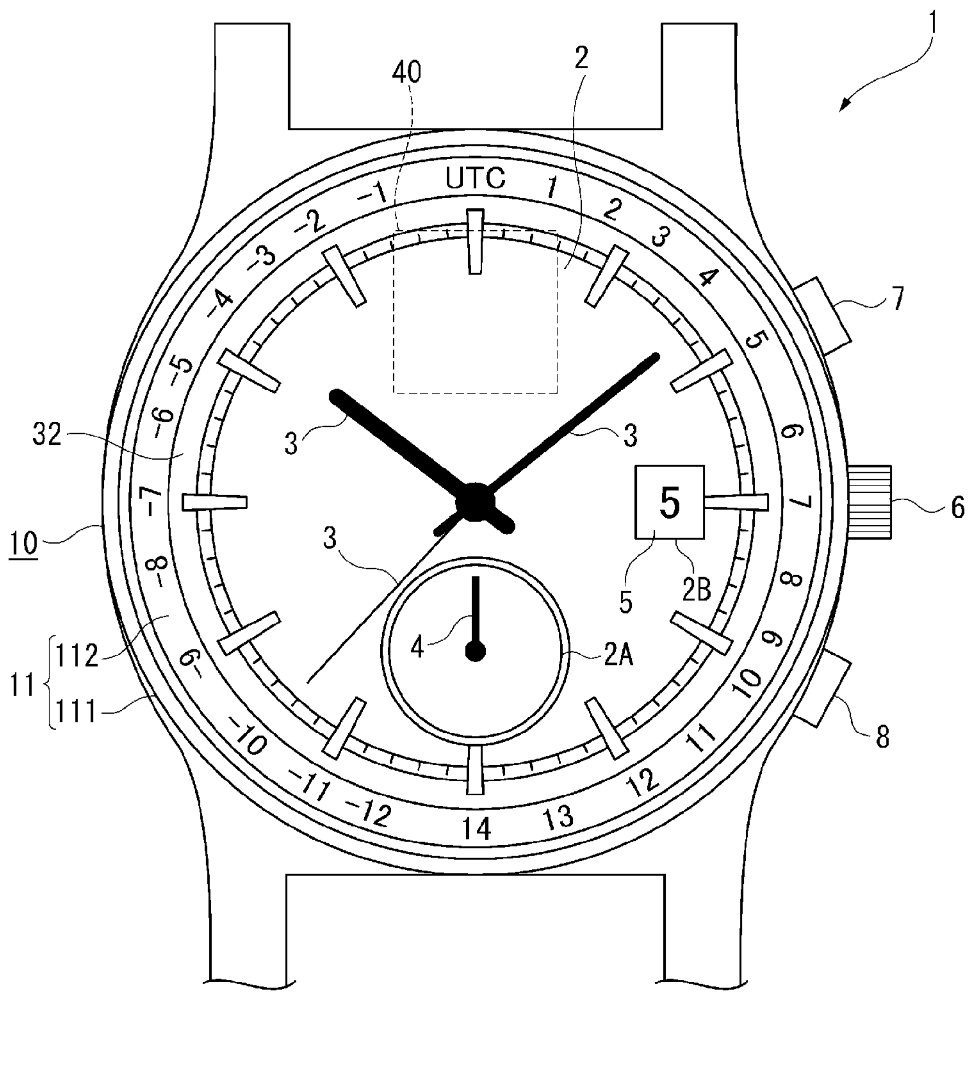
(57) **ABSTRACT**

An electronic timepiece has a base plate made from a non-conductive material, and a planar antenna disposed on the back side of the base plate. The planar antenna has a dielectric substrate and an antenna electrode disposed to the base plate side of the dielectric substrate. An exposed area not superimposed with the antenna electrode **42** is formed on the surface of the dielectric substrate. The base plate has a through-hole overlapping at least part of the antenna electrode in plan view, and a cover part overlapping at least part of the exposed surface in plan view.



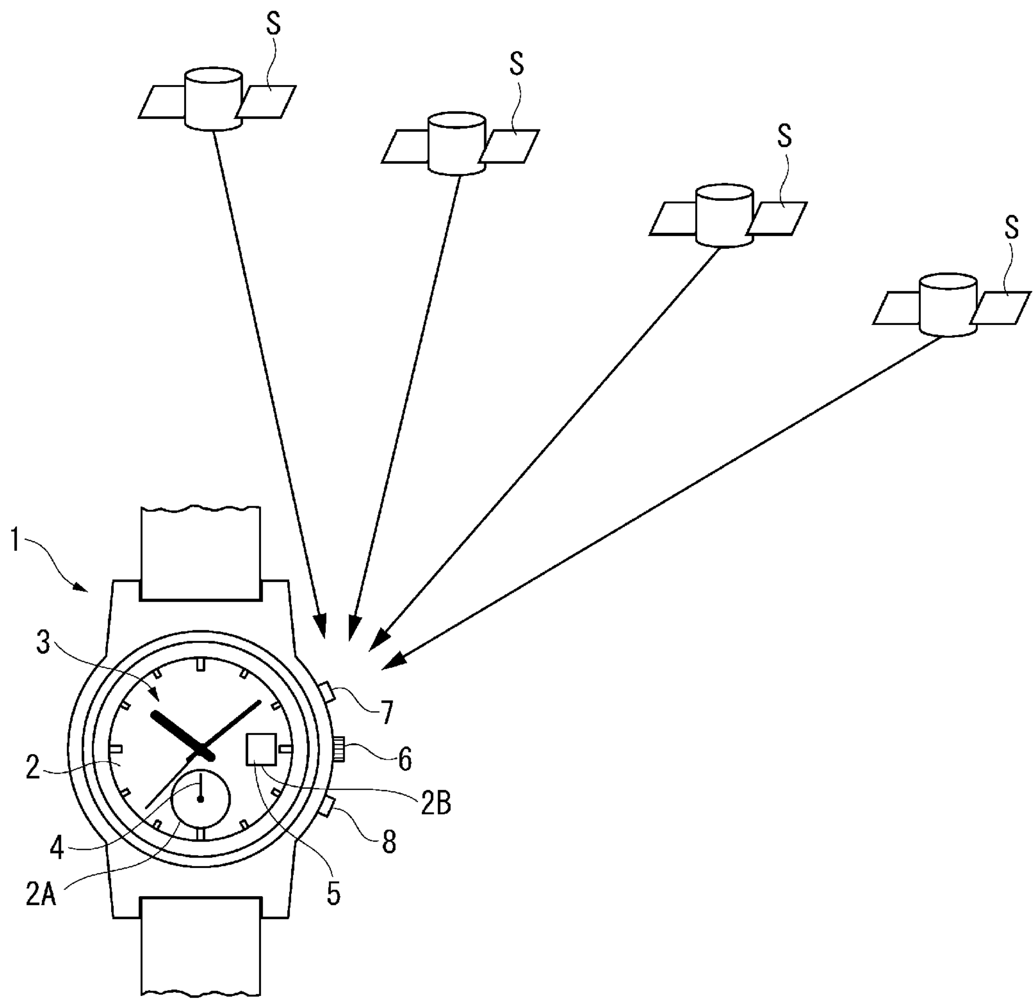


FIG. 1

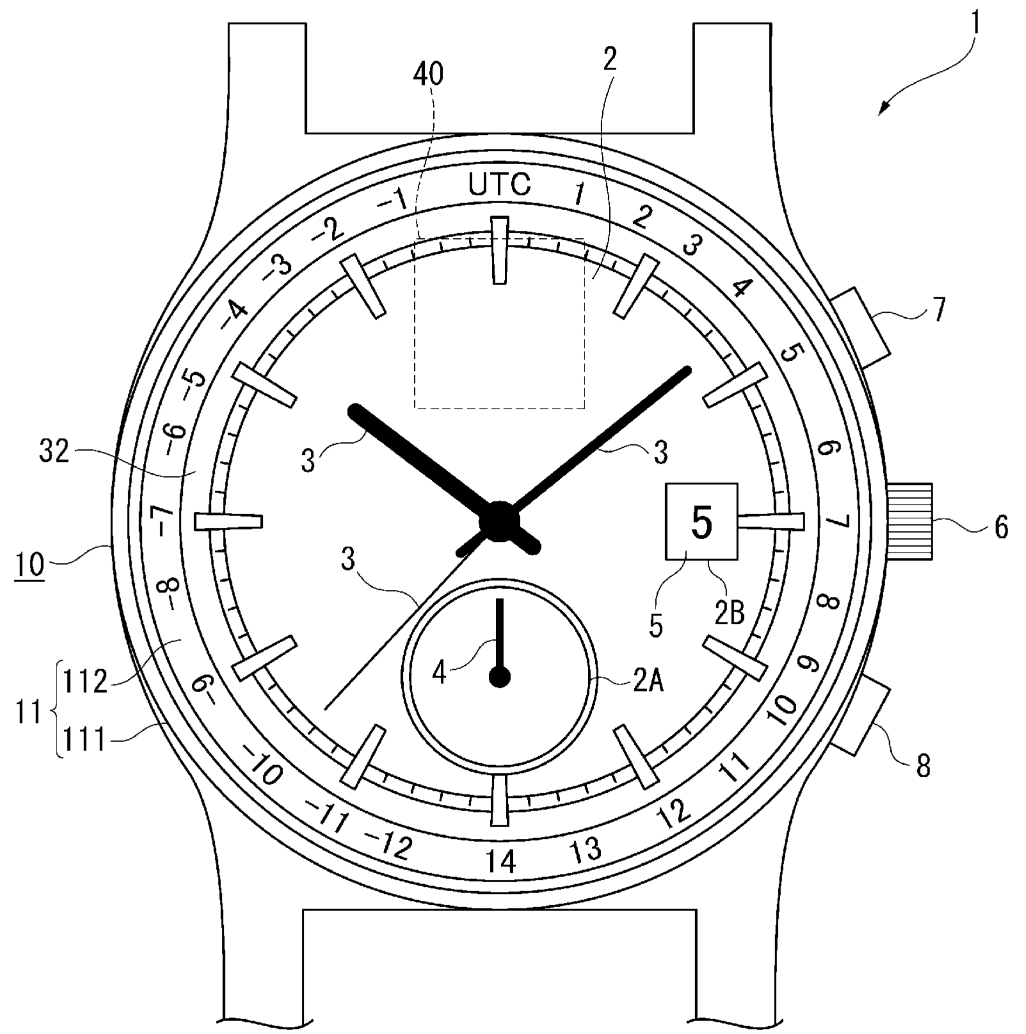
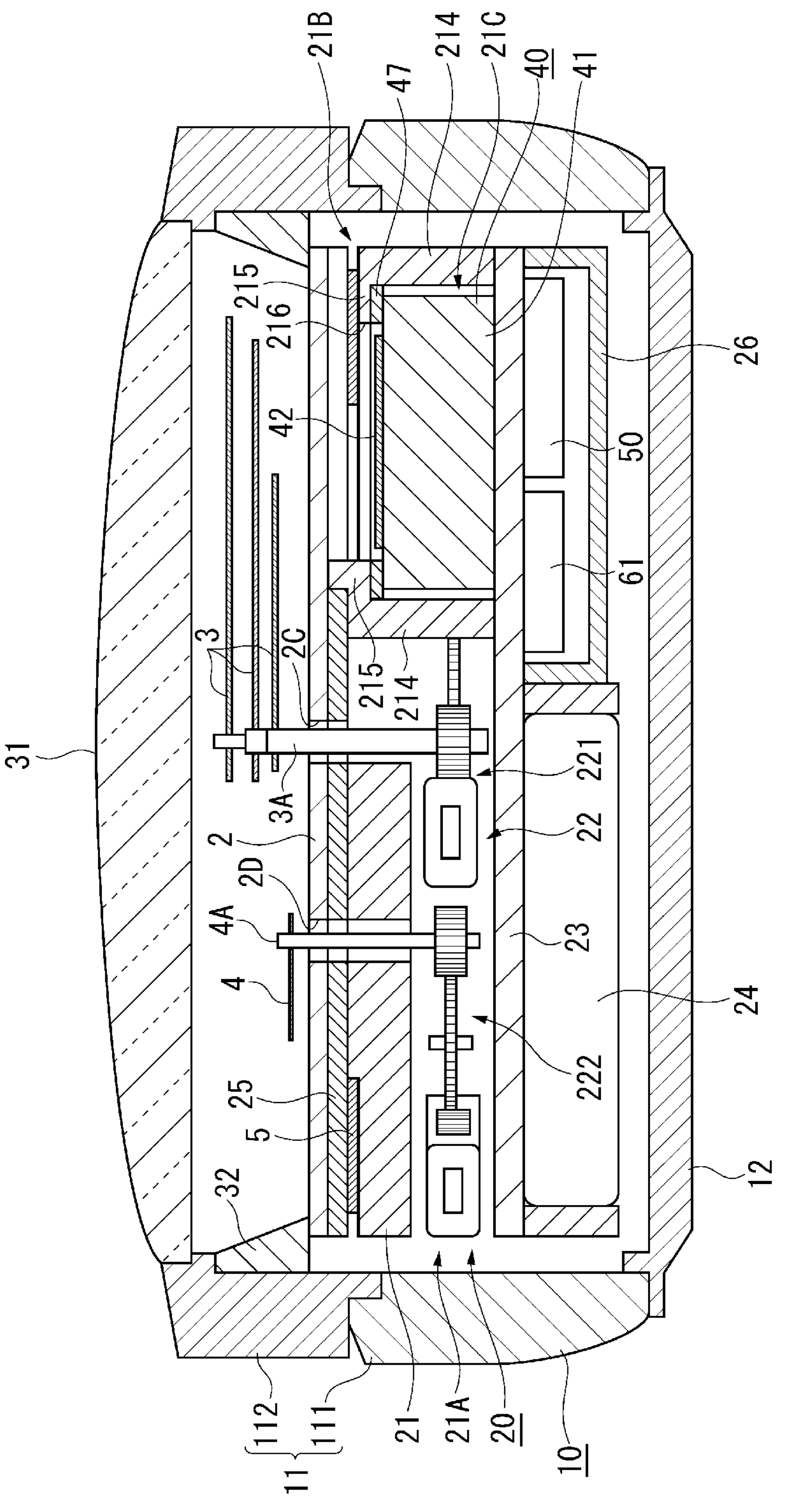


FIG. 2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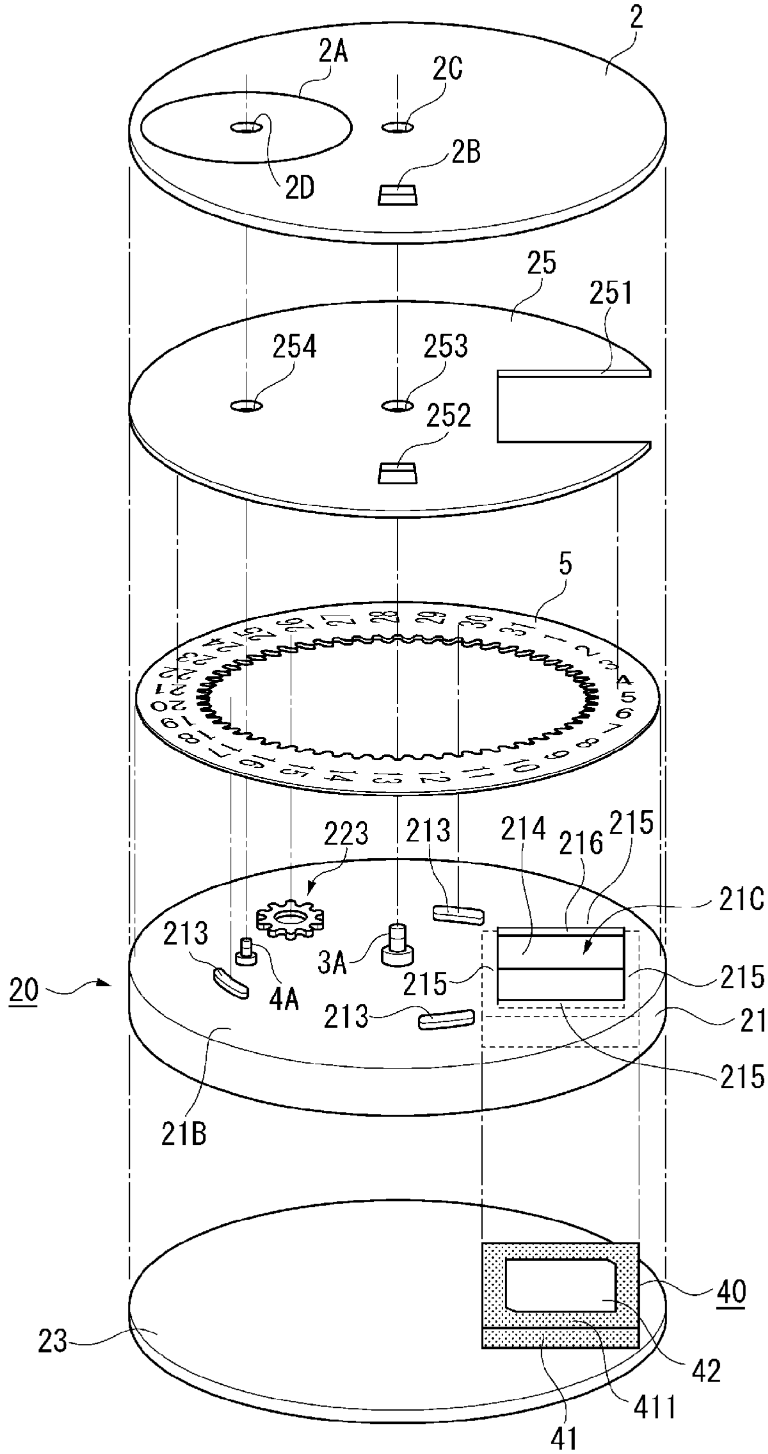
47
214
21C
40
41
215
216
42
26
50
61
3
2C
215
214
31
221
3A
22
2
2D
4A
23
4
24
222
25
5
32
12
112
111
11
21
21A
20
10

FIG. 3


2
2A
2C
2D
2B
25
251
254
253
252
5
223
213
214
216
215
21C
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3A
215
215
20
4A
213
21
215
21B
40
23
42
411
41

FIG. 4

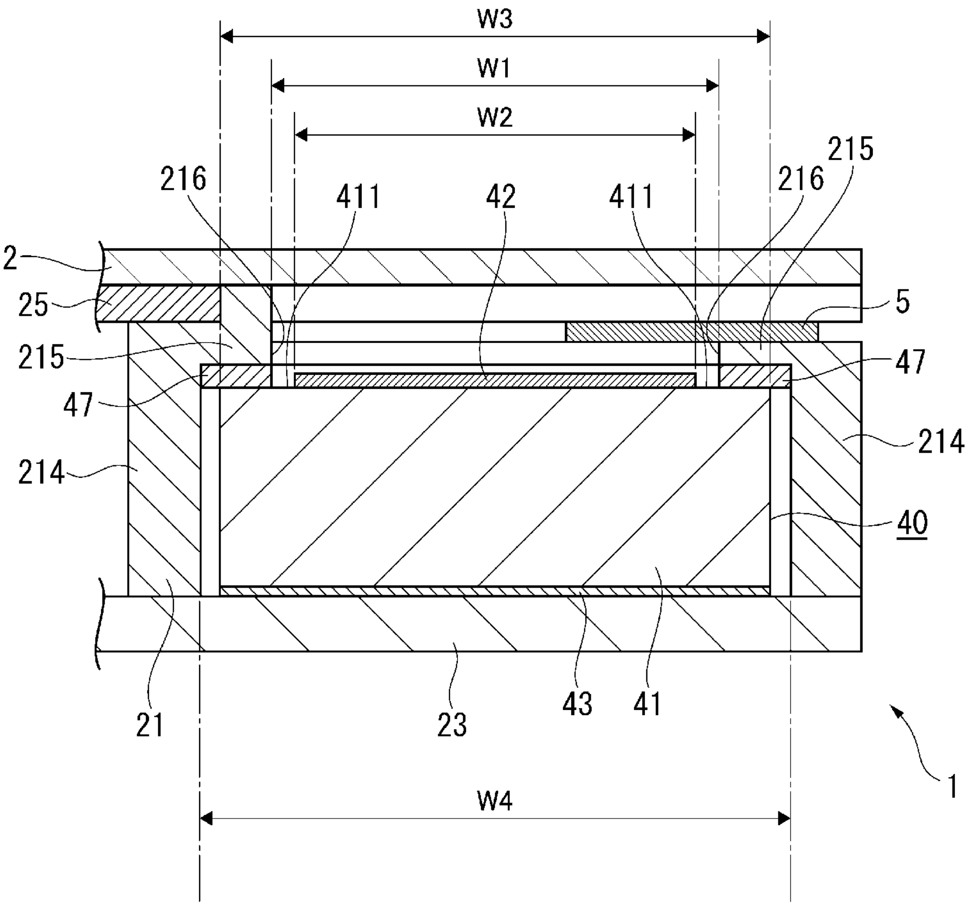

W3
W1
W2
216
411
42
411
216
215
2
25
5
215
47
47
214
214
40
21
23
43
41
1
W4

FIG. 5

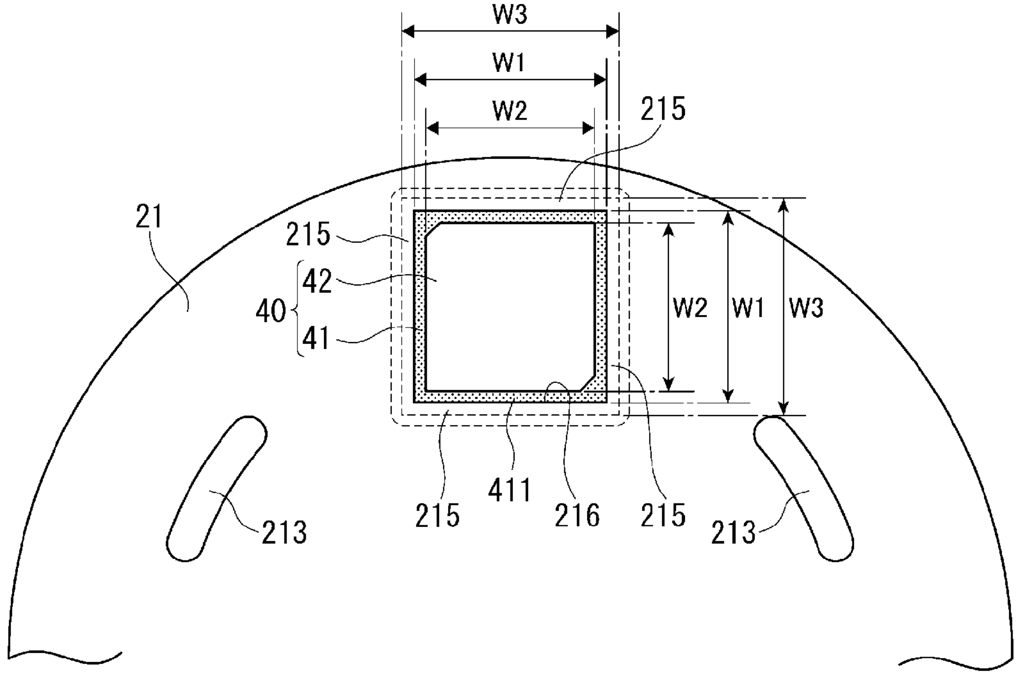


FIG. 6

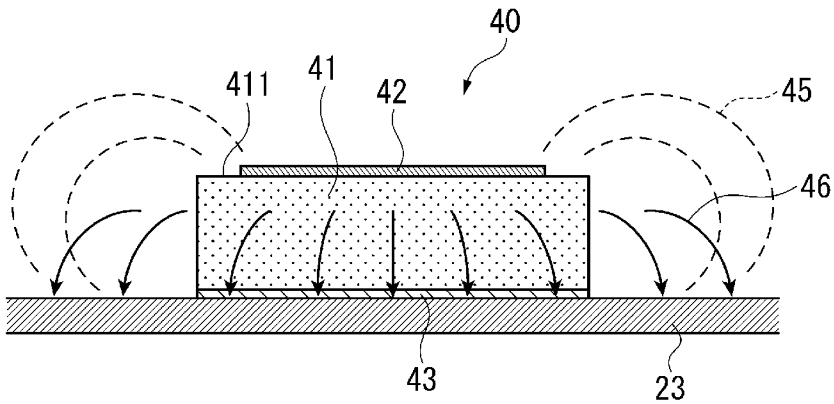
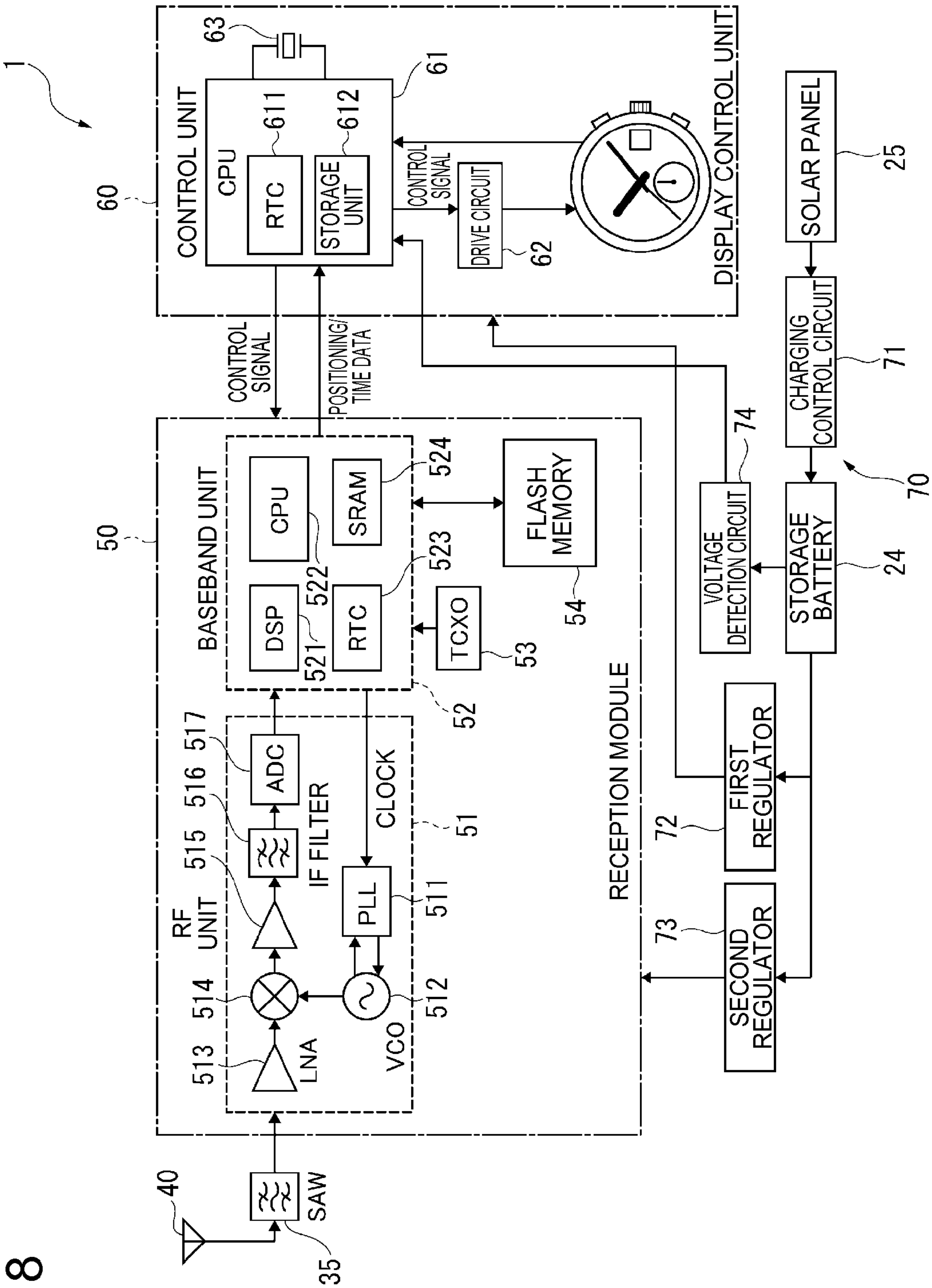


FIG. 7

FIG. 8


1
60
CONTROL UNIT
CPU
RTC
611
STORAGE UNIT
612
61
63
CONTROL SIGNAL
DRIVE CIRCUIT
62
DISPLAY CONTROL UNIT
SOLAR PANEL
25
CHARGING CONTROL CIRCUIT
71
70
CONTROL SIGNAL
POSITIONING/ TIME DATA
50
BASEBAND UNIT
CPU
SRAM
524
522
DSP
521
RTC
523
TCXO
53
52
FLASH MEMORY
54
74
VOLTAGE DETECTION CIRCUIT
STORAGE BATTERY
24
RECEPTION MODULE
FIRST REGULATOR
72
SECOND REGULATOR
73
517
ADC
516
IF FILTER
515
CLOCK
51
RF UNIT
PLL
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514
512
513
LNA
VCO
40
SAW
35

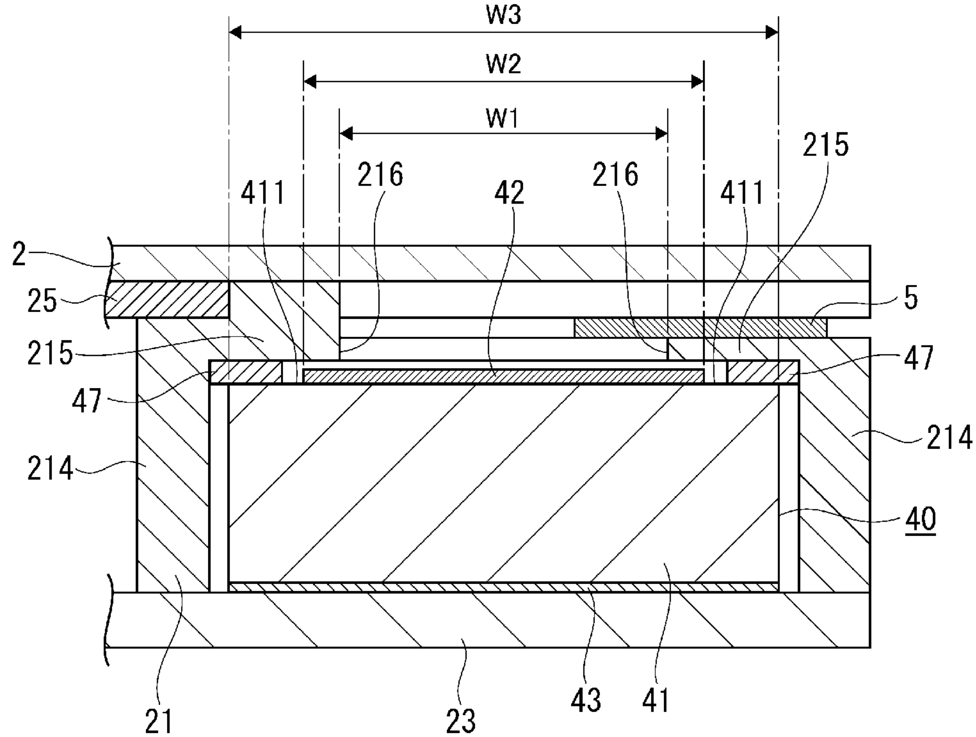
W3
W2
W1
411
216
42
216
411
215
2
25
5
215
47
47
214
214
40
21
23
43
41

FIG. 9

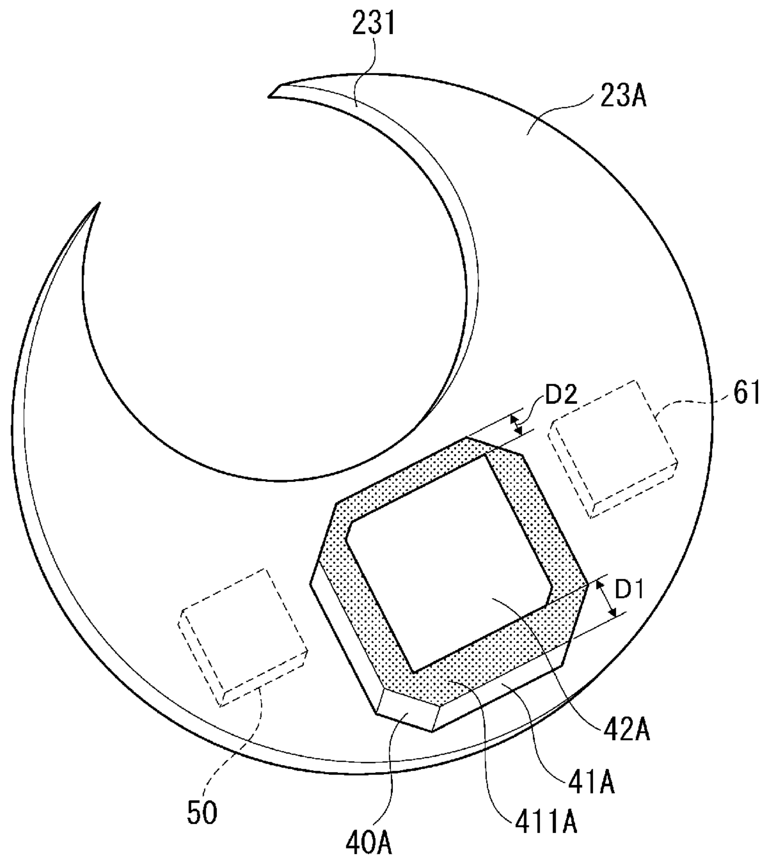

FIG. 10

ELECTRONIC TIMEPIECE

BACKGROUND

[0001] 1. Technical Field

[0002] The present invention relates to an electronic timepiece, and relates more particularly to an electronic timepiece with a planar antenna.

[0003] 2. Related Art

[0004] JP-A-2012-13627 describes an electronic timepiece with a planar antenna for receiving radio frequency signals transmitted from GPS (Global Positioning System) or other types of positioning information satellites.

[0005] The electronic timepiece in JP-A-2012-13627 has a planar antenna disposed on the back cover side of the dial, and suppresses loss of antenna sensitivity by separating the planar antenna from the metal case around the antenna.

[0006] Disposing the planar antenna closer to the base plate that is also disposed on the back cover side of the dial is desirable to make the electronic timepiece thinner. Because the base plate is made of plastic or other non-conductive material, the base plate does not interfere with radio waves, and the planar antenna can receive radio signals even with the planar antenna disposed adjacent to the base plate.

[0007] Because the base plate is a dielectric, however, a new problem of the antenna frequency shifting occurs if the gap between the base plate and the antenna electrode is too small. More specifically, the antenna frequency begins shifting if the gap between the base plate and the antenna electrode of the planar antenna is less than approximately 1.0 mm. The problem becomes particularly acute if this gap is 0.5 mm or less because the frequency shift increases with even the slightest change in the gap between the base plate and the antenna electrode, reception performance drops, and antenna characteristics are not stable.

SUMMARY

[0008] The present invention provides an electronic timepiece that is thin and maintains stable antenna characteristics.

[0009] An electronic timepiece according to a preferred aspect of the invention has a base plate made from a non-conductive material; and a planar antenna disposed on the back cover side of the base plate and including a dielectric substrate and an antenna electrode disposed to the surface of the dielectric substrate on the base plate side, and an exposed surface where the antenna electrode is not present formed on the surface of the dielectric substrate. The base plate has a through-hole overlapping the antenna electrode at least in part in plan view, and a cover part overlapping the exposed surface at least in part in plan view.

[0010] Because a through-hole that overlaps the antenna electrode of the planar antenna in plan view is formed in the base plate, less of the base plate or dielectric is in proximity to the antenna electrode when the planar antenna is placed close to the base plate than when a through-hole is not formed, the shift in the antenna frequency can be reduced, and antenna performance can be stabilized. Furthermore, because the planar antenna can be located near the base plate, the movement that houses the planar antenna can also be made thinner, and an electronic timepiece having the movement can be made thinner.

[0011] A cover part that overlaps at least part of the exposed surface in plan view is also formed to the base plate. As a result, movement of the planar antenna to the base plate side can be limited by the exposed surface directly or indirectly contacting the cover part. The planar antenna can therefore be prevented from passing through the through-hole in the base plate and striking the dial or other member in the event the electronic timepiece is dropped, for example.

[0012] An electronic timepiece preferably also has a shock absorber is disposed between the cover part and the exposed surface.

[0013] Because a shock absorber is placed between the cover parts of the base plate and the exposed surface of the dielectric substrate, the planar antenna can be precisely positioned in the height (thickness) direction of the electronic timepiece by setting the exposed surface of the planar antenna against the shock absorber. As a result, the positioning precision of the planar antenna to the base plate can be improved, change in the antenna frequency due to deviation in positioning precision can be further reduced, and antenna performance can be further stabilized.

[0014] Furthermore, because the exposed surface of the planar antenna contacts a sponge or other shock absorbing member, direct contact with the cover parts can be prevented. Damage to the ceramic dielectric substrate can also be prevented even if the dielectric substrate of the planar antenna is made from a hard, easily chipped ceramic because the dielectric substrate does not directly contact the base plate.

[0015] In an electronic timepiece according to another aspect of the invention, the through-hole is formed overlapping at least all of the antenna electrode in plan view.

[0016] In this aspect of the invention a through-hole formed in the base plate is made so that it does not completely overlap the antenna electrode in plan view. Because a through-hole in the base plate is therefore opposite the antenna electrode and the dielectric base plate is not opposite the antenna electrode, change in the antenna frequency can be further reduced and stable antenna performance can be achieved. In addition, the antenna electrode can be disposed in the through-hole in the base plate, and the thickness of the movement can be reduced.

[0017] An electronic timepiece according to another aspect of the invention also has a calendar wheel made from a non-conductive material and displaying calendar information; and the planar antenna is disposed to a position overlapping the calendar wheel in plan view.

[0018] Because the date wheel or other calendar wheel is made from a non-conductive material, there is no interference with signal reception even if the calendar wheel overlaps the planar antenna in plan view. Furthermore, because the pivots of the hour, minute, and second hands and other information indicators pass through the dial and base plate, the pivots must be disposed to plane positions outside the area of the date wheel and planar antenna. As a result, disposing the planar antenna to a position overlapping the calendar wheel in plan view affords greater freedom locating the pivots than a configuration in which the planar antenna and calendar wheel do not overlap, and thereby provides greater freedom designing the electronic timepiece.

[0019] An electronic timepiece according to another aspect of the invention preferably also has a solar panel disposed to the face side of the base plate not overlapping the planar antenna in plan view.

[0020] For example, the solar panel can be disposed not overlapping the planar antenna by creating a notch in the solar panel at a position superimposed with the planar antenna in plan view.

[0021] The solar panel includes electrodes, but because the solar panel and the planar antenna do not overlap each other in plan view in the invention, radio waves passing from the face side of the timepiece are picked up by the antenna without being obstructed by the solar panel. A solar panel can therefore be provided in the electronic timepiece without reducing reception performance.

[0022] Other objects and attainments together with a fuller understanding of the invention will become apparent and appreciated by referring to the following description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. **1** illustrates an electronic timepiece according to the invention.

[0024] FIG. **2** is a plan view of the electronic timepiece.

[0025] FIG. **3** is a section view of the electronic timepiece.

[0026] FIG. **4** is a partially exploded oblique view of the electronic timepiece.

[0027] FIG. **5** is a section view illustrating the relative positions of the planar antenna and a through-hole in the base plate of the electronic timepiece.

[0028] FIG. **6** is a plan view illustrating the relative positions of the planar antenna and a through-hole in the base plate of the electronic timepiece.

[0029] FIG. **7** is a section view illustrating the configuration of the planar antenna in the electronic timepiece.

[0030] FIG. **8** is a block diagram illustrating the circuit design of the electronic timepiece.

[0031] FIG. **9** is a section view illustrating the relative positions of the planar antenna and a through-hole in the base plate of an electronic timepiece according to another embodiment of the invention.

[0032] FIG. **10** is an oblique view illustrating the planar antenna and circuit board of the electronic timepiece according to another embodiment of the invention.

DESCRIPTION OF EMBODIMENTS

[0033] A preferred embodiment of the present invention is described below with reference to the accompanying figures. Note that the crystal **31** side of the electronic timepiece **1** according to this embodiment of the invention is also referred to as the face, front, or top side, and the back cover **12** side is also referred to as the back or bottom side of the electronic timepiece **1**.

[0034] As shown in FIG. **1** and FIG. **2**, the electronic timepiece **1** is a wristwatch with a time display unit for displaying the time using a dial **2** and hands **3**, an information display unit including a subdial **2**A of the dial **2** and a hand **4**, and a calendar display unit including a window **2**B in the dial **2** and a date wheel **5**.

[0035] The dial **2** is a disc-shaped member made of polycarbonate or other non-conductive material. The subdial **2**A is located at 6:00 on the dial **2**, and the window **2**B is located at 3:00 on the dial **2**. In addition to the subdial **2**A and window **2**B, the dial **2** has a through-hole **2**C through which the center pivot **3**A of the hands **3** passes, and a through-hole **2**D through which the pivot **4**A of the small hand **4** passes, as shown in FIG. **3** and FIG. **4**. Note that the information display unit comprising the subdial **2**A and hand **4** (small hand) may be used to indicate the current operating mode of the timepiece, the day of the week, the remaining battery capacity, or other information.

[0036] The hands **3** include a second hand, minute hand, and hour hand. The hands **3**, **4** and date wheel **5** are driven by a drive mechanism including a stepper motor and wheel train described further below.

[0037] The electronic timepiece **1** also has a crown **6** and buttons **7** and **8** as external operating members.

[0038] The electronic timepiece **1** receives satellite signals and acquires satellite time information from the plural GPS satellites S orbiting the Earth on known orbits, and can correct internal time information based on the acquired satellite time information.

[0039] Note that the GPS satellites S shown in FIG. **1** are just one example of positioning information satellites, and numerous GPS satellites S are in orbit. There are presently approximately 30 GPS satellites S in service.

[0040] External Structure of the Electronic Timepiece

[0041] As shown in FIG. **2** and FIG. **3**, the electronic timepiece **1** has a case **10** that houses a movement **20** described further below. The case **10** includes the main case **11**, and the back cover **12**.

[0042] The main case **11** includes a tubular outside case member **111**, and a bezel **112** disposed on the front side of the outside case member **111**.

[0043] The bezel **112** is shaped like a ring with the outside of the bezel **112** continuous to the outside of the outside case member **111**. The bezel **112** and outside case member **111** are connected by an interlocking tongue-and-groove structure formed on their mutual opposing surfaces, or by adhesive or double-sided adhesive tape, for example. The bezel **112** may also be attached so that it can rotate on the outside case member **111**.

[0044] The crystal **31** is attached to the inside of the bezel **112** as a cover member held by the bezel **112**.

[0045] A round back cover **12** is disposed to the back cover side of the outside case member **111** covering the back cover side opening to the outside case member **111**. The back cover **12** and the outside case member **111** screw together.

[0046] Note that the outside case member **111** and the back cover **12** are discrete members in this embodiment of the invention, but the invention is not so limited and the outside case member **111** and back cover **12** may be formed in unison as a single piece.

[0047] The outside case member **111**, bezel **112**, and back cover **12** are made of brass, stainless steel, titanium alloy, or other conductive metal material.

[0048] Internal Configuration of the Electronic Timepiece

[0049] The internal structure housed in the case **10** of the electronic timepiece **1** is described next.

[0050] As shown in FIG. **2**, FIG. **3**, and FIG. **4**, a movement **20**, planar antenna **40** (patch antenna), date wheel **5**, and dial ring **32** are housed in addition to the dial **2** inside the case **10**.

[0051] The movement **20** includes the base plate **21**, a drive module **22** supported by the base plate **21**, a circuit board **23**, a storage battery **24**, and a solar panel **25**.

[0052] The base plate **21** is made from plastic or other non-conductive material. The base plate **21** includes a drive module housing **21**A that holds the drive module **22**, a date wheel housing **21**B where the date wheel **5** is disposed, and an antenna housing **21**C that holds the planar antenna **40**.

[0053] The date wheel housing **21**B is a ring-shaped area on the outside side of plural guide parts **213** that protrude up from the face side (the dial **2** side) of the base plate **21**. Movement in the plane direction of the date wheel **5** disposed in the date wheel housing **21**B is limited by the guide parts **213**.

[0054] The drive module housing **21**A and antenna housing **21**C are disposed on the back side of the base plate **21**. As shown in FIG. **5** and FIG. **6**, the antenna housing **21**C has four walls **214** (only two shown in FIG. **5**) facing the four sides of the planar antenna **40**, and four cover parts **215** (only two shown in FIG. **5**) protruding from the walls **214** and opposing the front side of the planar antenna **40**. A through-hole **216** overlapping at least part of the antenna electrode **42** of the planar antenna **40** in plan view is formed between the cover parts **215**. Note that the four walls **214** are formed in unison, and the four cover parts **215** are formed in unison.

[0055] Because the antenna housing **21**C is at 12:00 on the dial **2** in plan view, the planar antenna **40** is also located at 12:00 as shown in FIG. **2**.

[0056] The drive module **22** is held in the drive module housing **21**A of the base plate **21**, and drives the time display unit, information display unit, and date display unit. More specifically, the drive module **22** includes a drive mechanism **221** with a stepper motor and wheel train for driving the hands **3**, a drive mechanism **222** with a stepper motor and wheel train for driving the hand **4**, and a drive mechanism **223** including a stepper motor and wheel train for driving the date wheel **5** (see FIG. **4**).

[0057] The top side of the circuit board **23** contacts the back side of the base plate **21**, and is attached to the base plate **21** by screw or other fastener. The planar antenna **40** is mounted on the face side of the circuit board **23**. A reception module **50** that processes satellite signals received from the GPS satellites S, and a control unit **61** that controls the drive mechanisms **221** to **223**, are mounted on the back side of the circuit board **23**. The reception module **50** and control unit **61** are located on the opposite side of the circuit board **23** as the planar antenna **40**. The reception module **50** and control unit **61** are also enclosed in a shield **26**. As a result, signals received by the planar antenna **40** are protected from noise produced by the reception module **50** and control unit **61**.

[0058] A lithium ion battery is used for the storage battery **24**. The storage battery **24** supplies power to the drive module **22**, reception module **50**, and control unit **61**. The storage battery **24** is also disposed to the back side of the circuit board **23** at a position not overlapping the reception module **50** and control unit **61** in plan view.

[0059] The surface electrode on the top side of the solar panel **25** is made from indium tin oxide (ITO) or other transparent electrode material to pass light. A amorphous silicon semiconductor thin film is formed as the photovoltaic layer on a plastic film base layer.

[0060] Because GPS satellite signals are high frequency signals of approximately 1.5 GHz, GPS signals are attenuated by even the thin transparent electrode of the solar panel, unlike the long wave standard time signals that are received by radio-controlled timepieces, and antenna performance drops. As a result, a notch **251** is formed in the disc-shaped solar panel **25** at the position overlapping the planar antenna **40** in plan view. The solar panel **25** therefore covers the face side of the base plate **21** but does not cover the planar antenna **40**. The planar antenna **40** can therefore receive radio waves through the notch **251** in the solar panel **25**.

[0061] Note that an opening **252** superimposed in plan view with the window **2**B in the dial **2**, a hole **253** through which the center pivot **3**A of the hands **3** passes, and a hole **254** through which the pivot **4**A of the small hand **4** passes, are also formed in the solar panel **25**.

[0062] The planar antenna **40**, which is a patch antenna (microstrip antenna), is disposed in the antenna housing **21**C. The planar antenna **40** receives satellite signals from GPS satellites S. The planar antenna **40** is described further below in detail.

[0063] The date wheel **5**, which is a ring-shaped calendar wheel having date numbers displayed on the surface, is held in the date wheel housing **21**B of the base plate **21**. The date wheel **5** is made from plastic or other non-conductive material. In plan view, the date wheel **5** overlaps at least part of the planar antenna **40**. Note that the calendar wheel is not limited to a date wheel **5**, and may be a day wheel showing the days of the week, or a month wheel showing the months.

[0064] The dial **2** is disposed to the face side of the base plate **21** covering the solar panel **25** and the date wheel **5**. The dial **2** is made from a material such as plastic that is non-conductive and transparent to at least some light.

[0065] Abbreviations or other markings can be disposed to the surface of the dial **2** overlapping the planar antenna **40** in plan view. To improve the reception performance of the planar antenna **40**, these parts are preferably made from plastic or other non-conductive material instead of metal.

[0066] Because the dial **2** is transparent, the solar panel **25** located on the back side of the dial **2** can be seen through the dial **2** from the front of the timepiece. The color of the dial **2** appears different in the areas where the solar panel **25** is present and where the solar panel **25** is not present. Design accents may be added to the dial **2** so that this color different is not conspicuous.

[0067] By forming the notch **251** in the solar panel **25**, the color tone of the dial **2** in the part overlapping the notch **251** appears different from the tone in other parts of the dial **2**. To prevent this, a plastic sheet of the same color (such as dark blue or purple) as the solar panel **25** may be disposed below the solar panel **25**, or the signal-blocking electrode layer may be removed only in the part overlapping the planar antenna **40** in plan view instead of cutting completely through the solar panel **25** so that the plastic film base layer remains and the color of the solar panel **25** is the same throughout.

[0068] A dial ring **32** that is made of a plastic non-conductive material in a ring shape is disposed to the face side of the dial **2**. The dial ring **32** is disposed around the circumference of the dial **2**, is conically shaped with the inside circumference surface sloping down to the dial **2**, and has **60** minute markers printed on the inside sloping surface. The dial ring **32** is held pressed against the dial **2** by the bezel **112**.

[0069] In plan view, the planar antenna **40** does not overlap the main case **11** (outside case member **111** and bezel **112**) and solar panel **25**, but does overlap the date wheel **5**, dial **2**, and crystal **31**, which are made from non-conductive materials. More specifically, all parts of the electronic timepiece **1** that are over the face side of the planar antenna **40** in plan view are made from non-conductive materials.

[0070] As a result, satellite signals passing from the face side of the timepiece pass through the crystal **31**, pass through the dial **2**, date wheel **5**, and base plate **21** without interference from the main case **11** or solar panel **25**, and are incident to the planar antenna **40**. Note that because the hands **3**, **4** overlap only a small area of the planar antenna **40**, there is no interference with signal reception even if the hands are metal, but the hands are preferably made from a non-conductive material because any interference with signal reception can be avoided.

[0071] Planar Antenna

[0072] GPS satellites S transmit right-hand circularly polarized satellite signals. As a result, the planar antenna **40** according to this embodiment is a patch antenna (also called a microstrip antenna) with excellent circular polarization characteristics.

[0073] As shown in FIG. **5**, the planar antenna **40** according to this embodiment is a patch antenna having a conductive antenna electrode **42** on a ceramic dielectric substrate **41**.

[0074] This planar antenna **40** is manufactured as described below. First, barium titanate with a dielectric constant of 60-100 is formed to the desired shape in a press and sintered to complete the ceramic dielectric substrate **41** of the antenna. Aground electrode **43** forming the ground plane (GND) of the antenna is made by screen printing a primarily silver (Ag) paste, for example, on the back side (the side facing the circuit board **23**) of the dielectric substrate **41**.

[0075] A radiating antenna electrode **42** that determines the antenna frequency and the polarity of the received signals is formed on the face side of the dielectric substrate **41** (the side facing the base plate **21** and dial **2**) by the same method as the ground electrode **43**. The antenna electrode **42** is slightly smaller than the surface of the dielectric substrate **41**, and an exposed surface **411** where the antenna electrode **42** is not present is disposed around the antenna electrode **42** on the surface of the dielectric substrate **41**.

[0076] FIG. **7** illustrates the operating principle of a planar antenna **40** (patch antenna). In FIG. **7** the dotted lines **45** represent radio waves received by the planar antenna **40**, and the arrows **46** represent the electric lines of force.

[0077] A square patch antenna resonates when one side is a half wavelength, and a round patch antenna resonates when the diameter is approximately 0.58 wavelength, but the size of the antenna size can be reduced by the wavelength shortening effect of a dielectric. A patch antenna works by the strong electric field around the edge of the patch (antenna electrode **42**) radiating from the edge into space, and the electric lines of force become stronger with proximity to the antenna and are easily affected by the effects of nearby metals and dielectrics. To receive GPS satellite signals, therefore, the distance between the metal outside case member **111** and the antenna electrode **42** must be at least 3 mm, and is ideally approximately 4 mm.

[0078] In this example, the walls **214** are located between the planar antenna **40** and outside case member **111**, and the planar antenna **40** is disposed to a position separated at least a specific distance from the inside surface of the outside case member **111**. As a result, a drop in reception performance due to the proximity of the planar antenna **40** to the metal outside case member **111** can be suppressed, and the reception performance required by the electronic timepiece **1** can be assured.

[0079] The planar antenna **40** is mounted on the circuit board **23**, and is electrically connected to the GPS antenna module, which is the reception module **50** on the back side of the circuit board **23**. The circuit board **23** can also function as a ground plane by connecting the ground electrode **43** of the planar antenna **40** through the ground pattern of the circuit board **23** to the ground node of the reception module **50**. The outside case member **111** and back cover **12** can also be used as the ground plane by connecting the ground node of the reception module **50** through the ground pattern of the circuit board **23** to the metal outside case member **111** or back cover **12**.

[0080] The planar antenna **40** is held in the antenna housing **21**C by affixing the circuit board **23** to the base plate **21**. Because the planar antenna **40** receives high frequency 1.54542 GHz signals, and includes a ceramic dielectric substrate **41** with a high dielectric constant, the planar antenna **40** is susceptible to the effects of surrounding parts. The base plate **21** is plastic, but has a dielectric constant of 3-4, and affects the reception frequency if the gap between the base plate **21** and the antenna electrode **42** is less than approximately 1.0 mm. More specifically, the antenna frequency may shift and reception performance drop if the gap between the base plate **21** and the antenna electrode **42** varies even slightly.

[0081] As shown in FIG. **3** to FIG. **6**, a through-hole **216** is formed in the antenna housing **21**C of the base plate **21** in the surface opposite the antenna electrode **42** of the planar antenna **40**, that is, the surface on the dial **2** side.

[0082] The through-hole **216** in this example is formed overlapping all of the antenna electrode **42** in plan view. More specifically, because the antenna electrode **42** is substantially rectangular in plan view, the through-hole **216** is also rectangular in plan view when seen from the dial side of the electronic timepiece **1**.

[0083] The length W**1** of one side of the rectangular through-hole **216** is greater than the length W**2** of one side of the antenna electrode **42** and less than the length W**3** of one side of the dielectric substrate **41**. Note that as shown in FIG. **6** the length of each of the four sides of the through-hole **216** is the same, but the through-hole **216** may be formed as a rectangle with different length and width dimensions in plan view.

[0084] By thus providing a through-hole **216** superimposed in plan view on the antenna electrode **42**, the base plate **21** (dielectric) does not cover and is not closer than 1.0 mm to the antenna electrode **42**, and the antenna frequency is prevented from shifting due to variation in the gap between the antenna electrode **42** and the dielectric base plate **21**.

[0085] The length W**4** between the walls **214** is greater than length W**3** and is set to a dimension that accommodates the dielectric substrate **41** of the planar antenna **40**. The cover parts **215** protruding from the walls **214** are formed overlapping the exposed surface **411** of the dielectric substrate **41** in plan view.

[0086] A sponge or other type of shock absorber **47** is also disposed between the exposed surface **411** and the cover parts **215**. The position of the planar antenna **40** in the thickness direction of the timepiece is set by holding the dielectric substrate **41** against the shock absorber **47**.

[0087] The ceramic dielectric substrate **41** is also hard and easily chipped, but contact between the dielectric substrate **41** and the base plate **21** can be prevented by the intervening shock absorber **47**. Damage to the dielectric substrate **41** by collision with the base plate **21** can therefore also be prevented.

[0088] Part of the date wheel **5** is also disposed on the dial **2** side of the planar antenna **40**. Because the antenna electrode **42** and date wheel **5** are separated by at least the thickness of the cover parts **215**, the date wheel **5** is prevented from causing the antenna frequency to shift.

[0089] Circuit Configuration of the Electronic Timepiece

[0090] The circuit design of the electronic timepiece **1** is described next with reference to FIG. **8**.

[0091] As shown in FIG. **8**, the electronic timepiece **1** has a planar antenna **40**, a SAW filter **35**, the reception module **50**, a display control unit **60**, and a power supply unit **70**.

[0092] The SAW filter **35** is a bandpass filter that passes signals in the 1.5 GHz waveband. A LNA (low noise amplifier) may also be disposed between the planar antenna **40** and the SAW filter **35** to improve reception sensitivity.

[0093] Note also that the SAW filter **35** may be embedded in the reception module **50**.

[0094] The reception module **50** processes satellite signals passed through the SAW filter **35**, and includes an RF (radio frequency) unit **51** and a baseband unit **52**.

[0095] The RF unit **51** includes a PLL (phase-locked loop) circuit **511**, a VCO (voltage controlled oscillator) **512**, a LNA (low noise amplifier) **513**, a mixer **514**, an IF (intermediate frequency) amplifier **515**, an IF filter **516**, and an A/D converter **517**.

[0096] The satellite signal passed by the SAW filter **35** is amplified by the LNA **513**, mixed by the mixer **514** with the clock signal output by the VCO **512**, and down-converted to a signal in the intermediate frequency band.

[0097] The IF signal from the mixer **514** is amplified by the IF amplifier **515**, passed through the IF filter **516**, and converted to a digital signal by the A/D converter **517**.

[0098] The baseband unit **52** includes, for example, a DSP (digital signal processor) **521**, CPU (central processing unit) **522**, a RTC (real-time clock) **523**, and SRAM (static random access memory) **524**. A TCXO (temperature compensated crystal oscillator) **53** and flash memory **54** are also connected to the baseband unit **52**.

[0099] A digital signal is input from the A/D converter **517** of the RF unit **51** to the baseband unit **52**, which acquires satellite time information and navigation information by a correlation process and positioning computation process.

[0100] Note that the clock signal for the PLL circuit **511** is generated by the TCXO **53**.

[0101] The display control unit **60** includes a control unit (CPU) **61**, a drive circuit **62** that drives the hands **3**, **4**, a time display unit, and information display unit.

[0102] The control unit **61** includes a RTC **611** and storage unit **612**.

[0103] The RTC **611** calculates the internal time information using a reference signal output from a crystal oscillator **63**.

[0104] The storage unit **612** stores the satellite time information and positioning information output from the reception module **50**. Time difference data corresponding to the positioning information is also stored in the storage unit **612**, and the local time at the current location can be calculated from the time difference data and the internal time kept by the RTC **611**.

[0105] The electronic timepiece **1** in this example can also automatically correct the displayed time based on the satellite signals received from the GPS satellites S using the reception module **50** and display control unit **60** described above.

[0106] The power supply unit **70** includes the solar panel **25**, a charging control circuit **71**, the storage battery **24**, a first regulator **72**, a second regulator **73**, and a voltage detection circuit **74**.

[0107] When light is incident and the solar panel **25** produces power, the power obtained by photovoltaic generation is passed by the charging control circuit **71** to the storage battery **24** to charge the storage battery **24**.

[0108] The storage battery **24** supplies drive power through the first regulator **72** to the display control unit **60**, and supplies power through the second regulator **73** to the reception module **50**.

[0109] The voltage detection circuit **74** monitors the output voltage of the storage battery **24**, and outputs to the control unit **61**. The control unit **61** can therefore know the storage battery **24** voltage and control the reception process.

[0110] Operating Effect

[0111] By forming a through-hole **216** in the base plate **21** overlapping all of the antenna electrode **42** of the planar antenna **40** in plan view, the base plate **21** is not present near the antenna electrode **42**, and the antenna frequency is prevented from shifting due to the dielectric base plate **21** being close to the antenna electrode **42**. As a result, variation in the antenna frequency is reduced and antenna performance is stabilized.

[0112] Furthermore, because a through-hole **216** is opposite the antenna electrode **42**, the distance between the exposed surface **411** of the planar antenna **40** and the cover parts **215** of the base plate **21** can be reduced. As a result, the movement **20** housing the planar antenna **40** inside can be made thinner, and the electronic timepiece **1** can also be made thinner.

[0113] Furthermore, because cover parts **215** that overlap at least part of the exposed surface **411** of the planar antenna **40** in plan view are formed with the base plate **21**, the planar antenna **40** can be prevented from moving to the face side of the timepiece. The planar antenna **40** can therefore be prevented from passing through the through-hole **216** in the base plate **21** and striking the dial **2** or date wheel **5** in the event the electronic timepiece **1** is dropped, for example.

[0114] Furthermore, because a shock absorber **47** is placed between the cover parts **215** of the base plate **21** and the exposed surface **411** of the dielectric substrate **41**, and the exposed surface **411** of the planar antenna **40** is set against the shock absorber **47**, the planar antenna **40** can be precisely positioned in the height (thickness) direction of the electronic timepiece **1**. As a result, the positioning precision of the planar antenna **40** to the base plate **21** can be improved, change in the antenna frequency due to deviation in positioning precision can be further reduced, and antenna performance can be further stabilized.

[0115] Furthermore, because the exposed surface **411** of the planar antenna **40** contacts the shock absorber **47**, direct contact with the cover parts **215** can be prevented, and damage to the ceramic dielectric substrate **41** can be prevented.

[0116] Furthermore, because the date wheel **5** is made from a non-conductive material, a drop in reception performance can be prevented even if the date wheel **5** overlaps the planar antenna **40** in part in plan view because the satellite signals can pass through the date wheel **5** to the antenna.

[0117] Furthermore, because the date wheel **5** overlaps the planar antenna **40** in plan view, there is greater freedom positioning the center pivot 3A and pivot 4A of the hands **3** and small hand **4** to avoid the date wheel **5** and planar antenna **40**, and the electronic timepiece **1** can be designed with a greater degree of freedom.

[0118] Furthermore, because the planar antenna **40** does not overlap the solar panel **25** in plan view, satellite signals passed from the face side of the timepiece are incident to the planar antenna **40** without being obstructed by the solar panel

25. A solar panel **25** can therefore be disposed to the electronic timepiece **1** without reducing reception performance.

[0119] Because the planar antenna **40** does not overlap the main case **11** (outside case member **111** and bezel **112**) in plan view when seen from the front of the timepiece, satellite signals pass from the front of the timepiece through the crystal **31** and are incident to the planar antenna **40** without being obstructed by the main case **11**. Metal or other conductive material can therefore be used for the main case **11** and back cover **12** without reducing reception performance, and the apparent quality of the electronic timepiece **1** can be improved.

[0120] Furthermore, because the bezel **112** is made from a conductive material, the bezel **112** can be manufactured more easily than when using ceramic, freedom of design can therefore be improved, and cost can be reduced. Furthermore, because the bezel **112** is metal, greater rigidity can be achieved in a smaller sectional area than with a ceramic bezel. The sectional width of the ring-shaped bezel **112** can therefore be reduced, the planar size of the crystal **31** can be increased, and

[0121] the freedom of timepiece design can be improved.

[0122] Furthermore, because the outside case member **111** and back cover **12** are connected to ground of the reception module **50**, they can also function as the ground plane. As a result, the area of the ground plane can be increased, antenna gain can be improved, and antenna performance can be improved.

Other Embodiments

[0123] The invention is not limited to the embodiment doves, and can be varied in many ways without departing from the technical scope of the invention.

[0124] The through-hole **216** formed in the antenna housing **21**C of the base plate **21** is preferably sized to overlap the entire antenna electrode **42** of the planar antenna **40** in plan view. As shown in FIG. **9**, however, the length W**1** of one side of the through-hole **216** may be made smaller than the length W**2** of one side of the antenna electrode **42**, and the cover parts **215** may be formed to overlap part of the antenna electrode **42** in plan view.

[0125] In this case, compared with when a through-hole **216** is not formed in the base plate **21**, less of the base plate **21** or dielectric body is close to the antenna electrode **42**, the effect of a dielectric causing the antenna frequency to shift can be reduced, and antenna performance can be stabilized.

[0126] As also shown in FIG. **9**, when the antenna electrode **42** and the base plate **21** (cover parts **215**) overlap in plan view, the area of overlap is preferably as small as possible to reduce the antenna frequency shifting effect, and the area of overlap is preferably 30% or less of the area of the antenna electrode **42**.

[0127] A circuit board **23**A and a planar antenna **40**A as shown in FIG. **10** may also be used. To make the electronic timepiece **1** thinner, a through-hole **231** is formed in the part of the circuit board **23**A overlapping the storage battery **24** in plan view. The thickness of the movement **20** can then be reduced by disposing the stepper motor, wheel train, and other parts of the drive module **22** to positions not overlapping the storage battery **24** in plan view.

[0128] The reception module **50**, control unit **61**, and other circuit components are mounted on the circuit board **23**A on the opposite side as the side on which the planar antenna **40**A is mounted. As a result, as described in the foregoing embodiment, the planar antenna **40** is shielded from digital noise from the reception circuit and power supply circuit, and reception sensitivity can be improved.

[0129] The antenna electrode **42**A on the surface of the dielectric substrate **41**A of the planar antenna **40**A is formed at a position offset toward the planar center of the circuit board **23**A, that is, offset toward the planar center of the electronic timepiece **1**. As a result, in the exposed surface **411**A on the surface of the dielectric substrate **41**A, the width D**1** of the exposed surface **411**A from the antenna electrode **42**A to the outside case member **111** side is greater than the width D**2** of the exposed surface **411**A from the antenna electrode **42**A to the planar center of the circuit board **23**A. More specifically, the planar center of the antenna electrode **42**A does not match the planar center of the dielectric substrate **41**A, and is closer to the planar center of the electronic timepiece **1** than the planar center of the dielectric substrate **41**A.

[0130] In plan view, the width D**1** can also be expressed as the distance from the side of the antenna electrode **42**A closest to the outside case member **111** to the side of the dielectric substrate **41**A closest to the outside case member **111**. Width D**2** can also be expressed as the distance from the side of the antenna electrode **42**A closest to the planar center of the electronic timepiece **1** to the side of the dielectric substrate **41**A closest to the planar center of the electronic timepiece **1**.

[0131] By disposing the planar antenna **40**A with the antenna electrode **42**A separated from the metal outside case member **111**, the radio frequency shielding effect of the metal outside case member **111** can be reduced.

[0132] The embodiment described above has a shock absorber **47**, but this shock absorber **47** may be omitted. In this case, the exposed surface **411** of the planar antenna **40** may be set in contact with the cover parts **215**. The exposed surface **411** of the planar antenna **40** may also be disposed not touching the cover parts **215** with a gap therebetween.

[0133] The main case **11** in the foregoing embodiment includes a outside case member **111** and bezel **112**, but the invention is not so limited. More specifically, the main case **11** may comprise only an outside case member **111**.

[0134] The bezel **112** in the foregoing embodiment is made from a conductive material, but the invention is not so limited. For example, the bezel **112** may be made of a ceramic such as zirconia (ZrO_2), which is a non-conductive material. Zirconia has high resistivity, does not adversely affect signal reception, is hard, offers excellent scratch resistance, and is outstanding when used as an external member of a timepiece. If the bezel **112** is ceramic, the bezel **112** and the antenna electrode **42** may overlap in plan view. As a result, there is no need to increase the diameter of the outside case member **111** so that the bezel **112** does not overlap the antenna electrode **42** in plan view, the diameter of the outside case member **111** can be reduced, and the plane size of the electronic timepiece **1** can be reduced.

[0135] The electronic timepiece **1** in the foregoing embodiment has a date wheel **5**, solar panel **25**, and dial ring **32**, but the invention is not so limited. More specifically, the electronic timepiece may be made without a date wheel **5**, solar panel **25**, and dial ring **32**.

[0136] The outside case member **111** and back cover **12** touch the ground of the reception module **50** in the foregoing embodiments, but the invention is not so limited. More specifically, the outside case member **111** and back cover **12** do not need to connect to the ground.

[0137] The electronic timepiece in the foregoing embodiments has a time display unit comprising a dial **2** and hands **3**, but the invention is not so limited. The electronic timepiece may be made with an LCD panel as the time display unit, for example. In this event, the drive module that drives the time display unit may be a drive unit that drives the LCD panel.

[0138] In this case, the electronic timepiece simply requires a time display function, and the time display unit need not be a display unit for displaying only the time. Examples of such electronic timepieces are wrist-wearable devices such as heart rate monitors that are worn on the user's wrist to measure the heart rate, and GPS loggers that are worn on the wrist and measure the user's current location while the user is jogging.

[0139] The foregoing embodiments are described with reference to a GPS satellite as an example of a positioning information satellite, but the positioning information satellite of the invention is not limited to GPS satellites and the invention can be used with Global Navigation Satellite Systems (GNSS) such as Galileo (EU), GLONASS (Russia), and Beidou (China). The invention can also be used with geostationary satellites in satellite-based augmentation systems (SBAS), and quasi-zenith satellites in radio navigation satellite systems (RNSS) that can only search in specific regions. The invention can also be used in configurations that receive and process satellite signals from multiple systems.

[0140] The invention being thus described, it will be obvious that it may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

[0141] The entire disclosure of Japanese Patent Application No. 2014-208140, filed Oct. 9, 2014 is expressly incorporated by reference herein.

What is claimed is:

1. An electronic timepiece comprising:

a base plate made from a non-conductive material; and

a planar antenna disposed on the back cover side of the base plate and including a dielectric substrate and an antenna electrode disposed to the surface of the dielectric substrate on the base plate side, and

an exposed surface where the antenna electrode is not present formed on the surface of the dielectric substrate;

the base plate having a through-hole overlapping the antenna electrode at least in part in plan view, and

a cover part overlapping the exposed surface at least in part in plan view.

2. The electronic timepiece described in claim **1**, wherein:

a shock absorber is disposed between the cover part and the exposed surface.

3. The electronic timepiece described in claim **1**, wherein:

the through-hole is formed overlapping at least all of the antenna electrode in plan view.

4. The electronic timepiece described in claim **1**, further comprising:

a calendar wheel made from a non-conductive material and displaying calendar information;

wherein the planar antenna is disposed to a position overlapping the calendar wheel in plan view.

5. The electronic timepiece described in claim **1**, further comprising:

a solar panel disposed to the face side of the base plate not overlapping the planar antenna in plan view.

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