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AP2000

Biconical Antenna

AP3000

User manual

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1. User instructions

1.1. General features

Antenna AP2000 / AP3000 (Figure 1) is a biconical passive antenna operating in the 60-2500 MHz band (AP3000 in the 85-3000 MHz band), designed and built in Calzavara - Clampco Sistemi's NIRLab laboratory. If used with the ferrite bead coaxial cable supplied by Calzavara and with the ortho-angular tilted support, it allows reliable measurement of electromagnetic environmental impact in the vast majority of practical cases.

Figure 1a: AP2000 biconical antenna

Figure 1b: AP3000 biconical antenna

1.2. Use of the ortho-angular tilted support

Firmly secure the base of the support to the ball joint on the light wooden tripod (Figure 3), use the ¼" brass threaded insert or an M5 nylon screw respectively.

Insert the cylindrical antenna rod into the support sleeve, locking it by means of the threaded knob. The knob need only be tightened gently to achieve adequate locking. Correct positioning is achieved by aligning the base of the antenna rod with the bottom end of the support sleeve; then rotate the antenna in the sleeve until the dipole axis is in a vertical plane (Figure 2). Now the antenna can be moved to three successive, mutually orthogonal positions, maintaining the physical centre of the antenna in the same spatial position. In fact the three components of the field being measured (E_x, E_y, E_z) can be measured in sequence by manually rotating the elbowed support through 120° in relation to the base of the support (Figure 2), moving it successively to the three positions marked with the letters X, Y, Z and signalled by a

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mechanical click. Normally, it is best to perform this operation while holding the support base with one hand to prevent it from also rotating on the stand.

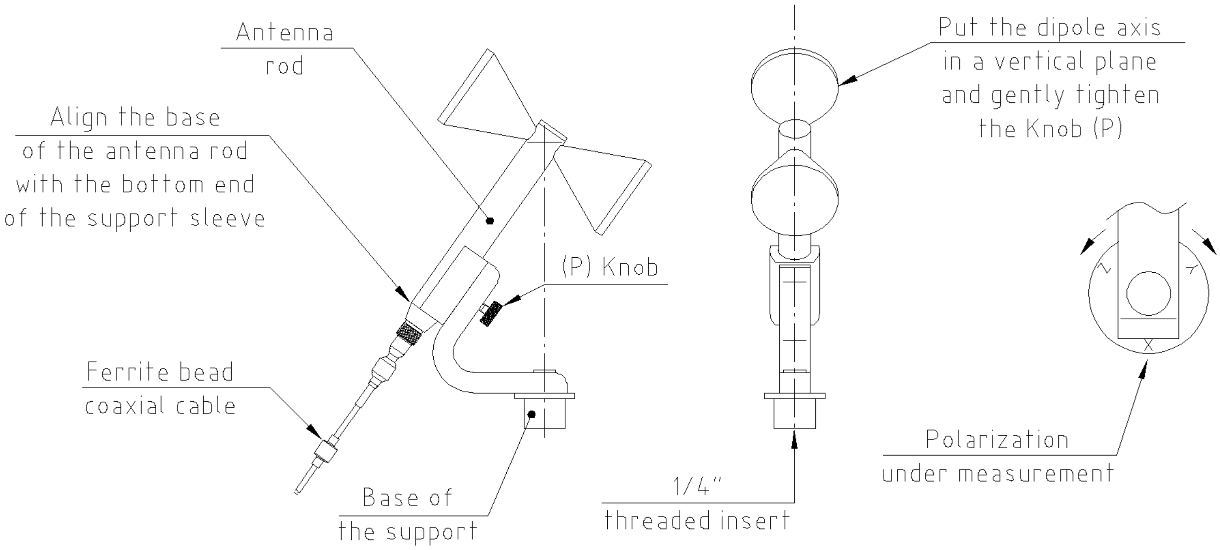

Figure 2: Correct position of the antenna using the ortho-angular support

The ferrite bead cable must be connected to the antenna with the beaded end connected to the mouth of the antenna. Always make sure that the connectors are well tightened to avoid poor contacts: after measuring has been completed, always check that the connectors are still tight.

Figure 3: light wooden tripod

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2. Execution of measurement

The measurement of electric fields which have environmental impact is a complex activity that falls within the scope of Italian technical standard guide for the measurement and evaluation of electromagnetic fields in the frequency range 10 kHz ÷ 300 GHz, with reference to human exposure.

It is therefore advisable to refer to this standard when defining the numerous operating details (spatial and time averages, receiving instrument settings, correction factors, periods of observation, …) which constitute a common protocol for measurement.

On an international scale, it is recommended that the following be consulted:

IEC 61566 Measurement of exposure to radiofrequency electromagnetic fields- Field strength in the frequency range 100kHz-1GHz

ICNIRP Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields up to 300 GHz

To obtain repeatable measurements in real conditions it is advisable to use software tools for controlling the spectrum analyser, thereby relieving the operator of repetitive operations and reducing the occurrence of errors.

Calzavara - Clampco Sistemi has developed the SW3000 software package under Windows, which is currently being updated to the most recent national and international standards. This package can in particular be used for spatial averaging of fields at different heights in relation to the ground. A user manual is available for further details.

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3. Antenna characteristics

3.1. Radiation diagrams

Antenna AP2000 / AP3000 is a short dipole antenna with linear polarisation. Its geometrical structure makes it possible to obtain a transduction coefficient that is sufficiently high at low frequencies while maintaining an omnidirectional type radiation diagram even at the highest frequencies in the band

The importance of this characteristic for the isotropy of the field measurement is well known. The invariability of the result of the sum in power of the three field components Ex, Ey, Ez, in relation to the tri-axial orthogonal set- up selected for making the measurement, is totally reliant on the availability of an antenna with omnidirectional diagram, i.e. described, in terms of polar coordinates, by the formula $G(\theta, \varphi) = k \sin(\theta)$.

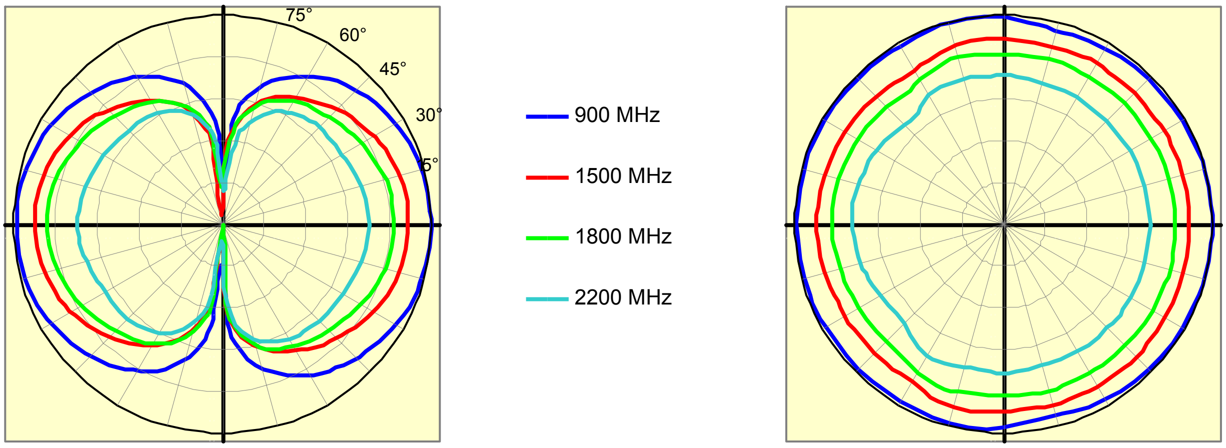

Figure 4a: AP2000 (E-plane and H-plane) experimental radiation diagrams.

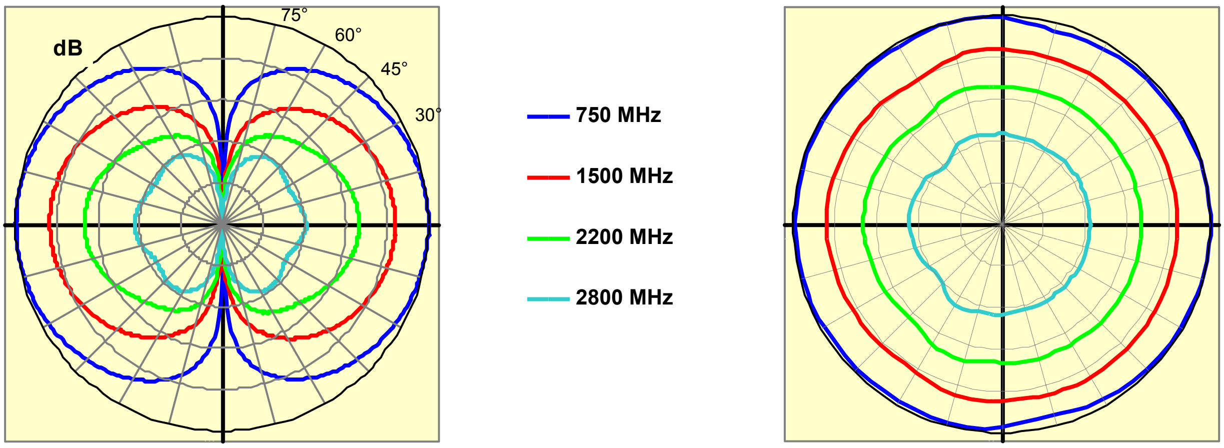

Figure 4b: AP3000 (E-plane and H-plane) experimental radiation diagrams.

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In particular, a deviation from the symmetrical behaviour of the antenna in the H-plane is due to the presence of the cable, the dipole carrier rod and the antenna support itself: these effects are lessened by the presence of the ferrite beads on the outside of the coaxial cable and by the ferrite beads on the antenna rod, under its plastic cover. Deviation from the ideal diagram form in the E-plane is due to the presence of the cable and of the dipole carrier rod, the conical shape of the dipoles and their size in relation to the wave length, which can no longer be ignored at the higher band frequencies. These characteristics are inherent to this type of antenna: to improve this aspect, it is advisable to use active devices with optical fibre outputs, i.e. without the RF connection cable (see Calzavara - Clampco active sensors) and, if necessary, smaller dimensions.

It should be noted that the stochastic measurement error due to deviation from the omnidirectional characteristics (anisotropy) is calculated on the quadratic sum of the three components. This means that over and under-estimates of the individual component are normally compensated by reducing the error on the total field.

It should in fact be borne in mind that factor K is normally defined in a calibration with a wave striking the antenna in a single given direction.

3.2. Antenna impedance

The diagram below represents the typical return loss coefficient of antenna AP2000 and AP3000. As one can see it is low enough to get negligible error due to stationary waves in the cable.

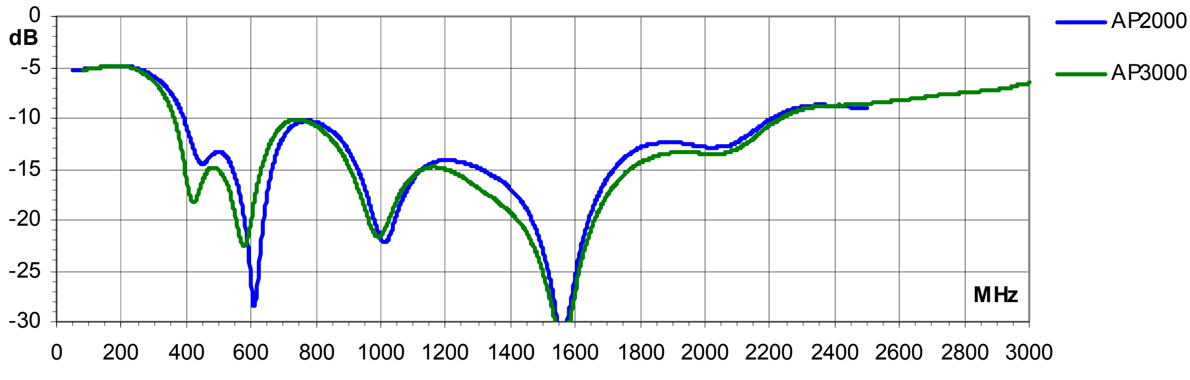

Figure 5: AP2000 and AP3000 return loss (typical)

In general, the use of this product as a transmitting antenna <u>is not advisable</u> for powers above 2 W. You should however consult the manual of the generator or amplifier used regarding the maximum return loss coefficient permissible for the load.

Note: In order to reduce the uncertainty of measurement associated with the possible presence of stationary waves in the coaxial cable used, it is advisable to use a minimum value for the attenuator on the spectrum analyser input, typically 5 or 10 dB.

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3.3. Antenna balun

In an ideal biconical antenna, the signal at the mouth of the antenna is picked up only by the cones. In a real antenna, part of the signal picked up can also come from the inevitable RF currents that develop on the antenna rod or on the outer surface of the coaxial cable (antenna unbalance). The antenna balun and the ferrite beads eliminate or at least limit the effects of these currents on the signal picked up. To test the effectiveness of the balun, rotate the antenna through 180° in the support sleeve, bringing each cone to the spatial position previously occupied by the other cone. The difference between the two signals is a measurement of the balun unbalance error. This test must of course be carried out without altering any of the other radio-electric environmental parameters. Normally, calibration of this antenna is performed using the average value of the readings obtained in the above two positions, so that the associated error is symmetrical. If calibration is performed by measuring factor K in the two positions and using, at each frequency, the average value of the two readings, the error illustrated in the graph below can occur. Alternatively, it is possible to identify the single effective orientation of the antenna used for calibration, but the uncertainty associated with antenna unbalance must still also be calculated.

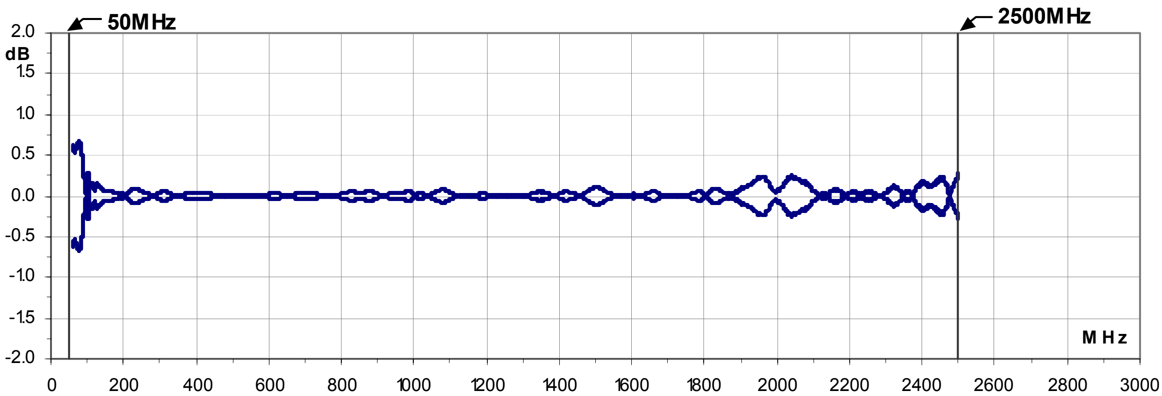

Figure 6a: AP2000: Antenna experimental symmetry error (typical)

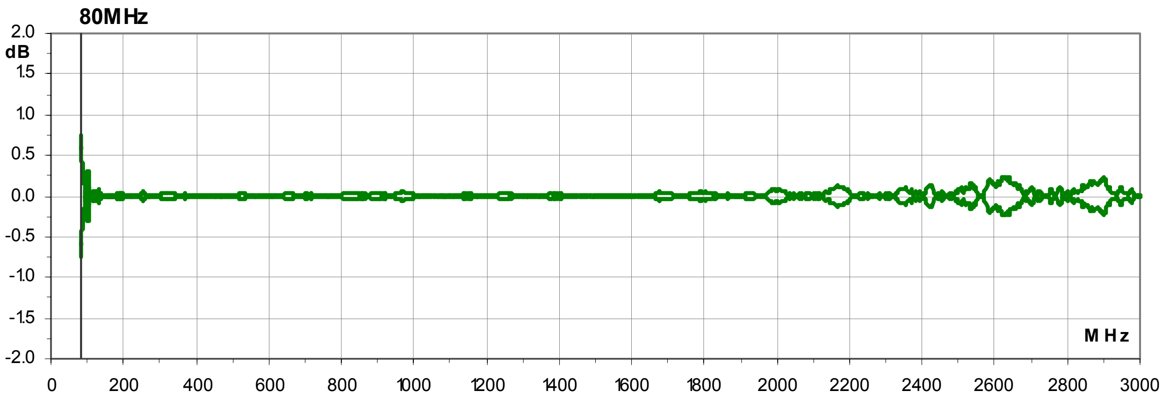

Figure 6b: AP3000: Antenna experimental symmetry error (typical)

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3.4. Antenna factor

To keep things simple, let us assume that the antenna is struck by a monochromatic, plane and uniform wave whose polarisation coincides with the axis of the dipole. The system consisting of the antenna and ferrite bead coaxial cable returns a signal whose amplitude is proportional to the amplitude of the electric field being measured. The proportionality factor depends on the geometric-electrical characteristics of the dipole, of the internal balun and of the cable. If we ignore slight variations of the transfer characteristics in this chain due to temperature variations, drift of the construction component characteristics and variations in the condition of the connectors and cables, the frequency of the incident wave remains the only parameter free of this transfer. We can therefore characterise the antenna-ferrite bead cable system by means of a table that shows the numerical value of such transfer for a significant set of frequencies.

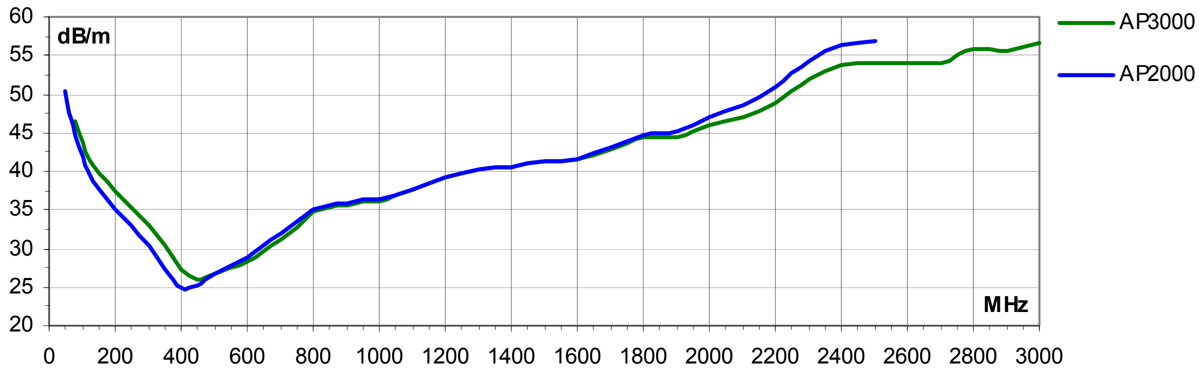

Figure 7: AP2000 and AP3000 Antenna factor (typical)

For the convenience of those who use the system connected to a spectrum analyser, the transfer characteristic of the system described above is usually represented in terms of *antenna factor*, i.e., of the value to be added to the indication in dBμV of the signal received by the spectrum analyser, in order to obtain the intensity value of the incident electric field on the antenna in dBμV/m. For example, if a certain signal at the frequency of 1GHz appears on the spectrum analyser with an amplitude of 84 dBμV (about –22 dBm), and the calibration table supplied with the system shows an antenna factor = 36 dB at 1GHz, then the amplitude of the incident field is equivalent to 84+36=120 dBμV/m, or 1 V/m.

In fact, it should be noted that the above calculation is only strictly valid if it is assumed that the RF cable connecting the antenna to the spectrum analyser has no attenuation. The value of the antenna factor indicated in the table in fact corresponds to a signal measured at the receiver output. To obtain the overall antenna factor of the system, including the RF cable, it is therefore necessary to add the value in dB of the attenuation on this cable - assessed at the respective frequencies and obtained from the relative certificate – to the antenna factor values shown in the table supplied with the system.

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3.5. System sensitivity

Selective field measurements normally rely on a "display" instrument with a wide range of setting possibilities: the spectrum analyser. It is therefore better to take into consideration the entire measuring system, including the spectrum analyser.

The thing that limits the display of low intensity signals is noise. Thermal noise has a uniform spectrum distribution with a value of about –174dBm/Hz at ambient temperature; to this must be added the contribution of the spectrum analyser, which depends on the processing chain of the signal from the sensor input (attenuators, IF amplifiers, sampling method…). This varies as the state of the analyser varies (input attenuation, reference level, sampling method, display filtering, display averages…). Finally, there is parameter RBW (resolution bandwidth) which, however, has a known value (10LogRBW).

It would be possible to establish an analyser noise figure and then add the RBW contribution but, for simplicity, it is better to consider a given state of the instrument. For example, the S.A. HP ESA E4407B with 0dB input attenuation, sampling of the "sample" type, reference level at –70 dB, RBW =1KHz and VBW=30Hz has a background noise of less than –115dBm at a frequency of 1GHz.

Ignoring a contribution from antenna noise, we can calculate the corresponding equivalent electric field at the point of measurement as follows: convert to dBμV (-115+107=-8dBμV) and add together the antenna factor and cable attenuation, in all about 37dB at 1GHz. This gives 29dBμV/m, corresponding to about 28 μV/m. This is the equivalent background noise in terms of field.

In order to identify a signal, we must obviously distinguish it from the noise. If we want an S/N ratio of at least 10 dB, the minimum clearly detectable signal is 39 dBμV/m, corresponding to about 89 μV/m.

The spectrum analyser set-up could of course be different. For example, with:

- RBW=10 kHz (which increases the noise by 10 dB compared with the previous example),
- VBW = RBW
- "peak" sampling (which increases the noise by roughly 5 dB),
- an attenuator inserted as a precaution, e.g. a 10 dB attenuator
- a higher reference level, e.g. 0 dBm
- a detector of the 'max hold' type

the background noise of HP E4407B becomes about 27 dBuV. With a value of 37 dB for antenna factor+cable and with a margin of 10 dB for clear detection of the signal, the minimum detectable signal becomes 74 dBuV, which is equivalent to about 5 mV/m

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If the operator wishes to control the entire band from 60 MHz to 2.5GHz and sets RBW =VBW =100 kHz, attenuation = 10dB, ref = 0dBm, we get background noise of 39dBuV and 20 mV/m detectable at 1 GHz. Finally, it should be noted that the antenna factor and the spectrum analyser's background noise vary with the frequency: in practice, all other parameters being equal, the lower the antenna factor the greater the sensitivity.

The user must therefore from time to time evaluate the background noise present by operating his measuring chain under the conditions in which he intends to perform measurements. With the procedure illustrated, he will be able to determine the minimum sensitivity threshold, still with the possibility of achieving very small sensitivity values by setting a low RBW value.

3.6. Periodic calibration

This passive device does not contain any parts whose characteristics deteriorate over time, regardless of use. Consequently, the recommended calibration interval depends on intensity of use or on undesired accidental events (falling, crushing, contact with liquids). The calibration procedure is carried out against the sample in an environment free of return losses. Calzavara - Clampco Sistemi supplies the antenna complete with a calibration certificate issued by our internal laboratory. This is obtained by comparison with the laboratory primary sample, calibrated in SIT accredited or equivalent (EA) laboratories.

3.7. Functional check and metrological validation

In general, since it is necessary to perform measurements of declared uncertainty which satisfy required repeatability and reliability criteria, it is always desirable to set up internal metrological validation procedures aimed at identifying and promptly resolving any problems with the devices used. Periodic calibration in itself provides an opportunity for metrological validation but the intervals for this – usually annual – are not frequent enough to guarantee the accuracy of all measurements performed in the intervening period. The chosen procedure, however simple or complex, must be aimed at least at identifying any potential serious faults in the equipment in order to prevent it being used and, if possible, should highlight any deviations from significant parameters which increase the total uncertainty of measurement. The above procedure, which must be repeated at intervals established by the user based on the relative requirements and the level of use of the device, naturally requires the availability of an RF generator, a receiver and one or more other antennas operating in compatible bands and, finally, the possibility of creating a measuring environment with radio-electric and environmental characteristics that are repeatable over time. In general, intervals of no less than one third of the calibration interval is recommended. The occurrence of a traumatic event for the device (impact, crushing, exposure to high temperatures, to rain or to corrosive agents) or the need to perform measurements of extreme importance

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or involving high costs if the measurement has to be repeated will, of course, require extraordinary metrological validation.

3.8. Near field measurements

When an antenna of this type is calibrated, it is normally struck by a radiative type field (plane wave or TEM mode), where the ratio between the electric field and the magnetic field has a known and defined value (377 ohm = wave impedance of the free space). This condition does not normally occur in the near field region of a transmitting station.
In general, a passive receiving antenna picks up energy from the electromagnetic field being measured and makes it available at the RF cable connector (50 ohm). This means that the signal actually measured at the spectrum analyser depends not only on the amplitude of the electric field being measured, but also on the associated magnetic field and its relative phase. Consequently, at a given frequency, the response of a passive antenna in two conditions of equal electric field but with a different associated magnetic field (i.e. with different wave impedance) is not necessarily identical. With regard to the usable band of the antenna in question, the problem arises in practice in the vicinity of dipole curtain FM radiant systems (where the near field zone is more extensive). In this case, the error will nevertheless be negligible because at these frequencies, antenna AP2000 or AP3000 has a high impedance.

More generally, however, it is advisable to compare near field measurements performed using passive antennas with other measurements obtained with instruments (active or wide band sensors) featuring a higher receiving antenna impedance. In particular, in the near field zone, it is advisable to measure the E and H components of the field separately using respective instruments of known and adequate rejection of the dual component.

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4. Maintenance

4.1. Functional check

Antennas AP2000 and AP3000 do not usually require any maintenance, except for general cleaning with a damp cloth. Do not use solvents on plastic components. The antenna cones in aluminium versions that are not anodised or treated may be cleaned with a polishing compound.

Please ask the manufacturer for assistance in the following cases:

- unsatisfactory result of metrological validation;
- variations of data on the calibration certificate compared with the previous certificate which are not justified by replacement of parts or up-dating of version;
- unsteady antenna connector;
- unsteady or misaligned dipoles;
- presence of dents indicating a heavy impact.

A simple check can be carried out using a normal resistance meter (ohmmeter):

- one of the two cones must have low impedance connection (less than 10 ohm) to the inner conductor of the antenna connector (N female); the other cone must have low impedance connection to the outer conductor of the connector. Between the two cones, there must be an open circuit for nn/03 series antennas, while a few hundredths of an ohm should be measured on latest series.
- if at least one of the above conditions is unsatisfactory, you should contact the manufacturer (beware of poor contacts at the tester tip on oxidised aluminium surfaces, because aluminium oxide is an excellent insulator).

4.2. Coaxial cable functional check

Visual check: check the cable, especially in the area close to the antenna connector. In general, exposed parts of the outer sheath are indicative of a damaged cable.

Periodically check that the end of the inner conductor is not too far back from or projecting beyond the plane of the opening of the threaded ring on the male connector: this can respectively cause poor contacts or damage the female connector of the antenna or analyser.

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Check that there are no obvious signs of local deterioration of the cable. Even slight recurrent distortion of the cable (for example opposite the ferrite beads) can cause resonance and defective behaviour of the device at some frequencies.

The cable must be periodically calibrated to evaluate its attenuation (which is part of the measuring chain). It is also important to check the intrinsic return loss at the connectors, with a suitable load and a network analyser or equivalent device: a high return loss coefficient can in fact affect the overall measuring uncertainty. A metrological validation procedure for the individual cable significantly reduces the possibility of measuring unreliability: the simplest method is to have two similar cables and compare the results obtained when they are used successively. If in doubt, please do not hesitate to contact the manufacturer: the cost of cable maintenance is usually negligible.

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5. Technical Note

Specifications of Biconical Antenna AP2000

General Characteristics

Dimensions
172 mm x 270 mm x 74 mm

Weight
2,4 kg

Connectors
N-female

Material

Dipole
blue anodized alluminium

Balun
brass

Enclosure
PVC

Protection grade
IP42

Measurement characteristics

Antenna type
biconical (linear passive device) with RF absorbing boom

Polarization
linear, monoaxial

Frequency range
from 60 MHz to 2500 MHz

Maximum applicable field
> 300 V/m

Antenna factor and SWR
individually char, certificate included

Sensitivity
> 0,5 mV/m

Cross-polar component rejection*
> 22 dB

Isotropic error

up to 1,5 GHz	< 0,5 dB
from 1,5 GHz to 2,2 GHz	< 0,9 dB
from 2,2 GHz to 2,5 GHz	< 1,2 dB.

Balun symmetry

from 60 MHz to 80 MHz	< 0,6 dB
from 80 MHz to 2,5 GHz	< 0,2 dB.

Operating Condition

Temperature
From –30°C to +55°C.

Humidity
Max 95% at 50°C (without condensation).

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Specifications of Biconical Antenna AP3000

General Characteristics

Dimensions
144 mm x 270 mm x 74 mm

Weight
2,4 kg

Connectors
N-female

Material

Dipole
green anodized alluminium

Balun
brass

Enclosure
PVC

Protection grade
IP42

Measurement characteristics

Antenna type
biconical (linear passive device) with RF absorbing boom

Polarization
linear, monoaxial

Frequency range
from 85 MHz to 3000 MHz

Maximum applicable field
\> 300 V/m

Antenna factor and SWR
individually char, certificate included

Sensitivity
\> 0,5 mV/m

Cross-polar component rejection*
\> 22 dB

Isotropic error

up to 1,8 GHz	< 0,5 dB
from 1,8 GHz to 2,5 GHz	< 0,9 dB
from 2,5 GHz to 3,0 GHz	< 1,3 dB.

Balun symmetry

from 80 MHz to 90 MHz	< 0,6 dB
from 90 MHz to 3,0 GHz	< 0,2 dB.

Operating Condition

Temperature
From –30°C to +55°C.

Humidity
Max 95% at 50°C (without condensation).

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Biconical Antenna Kit Composition and codes

AP2000 Kit

n. 1	AP2000	Biconical passive antenna
n. 1	OCF010	10 meters cable with ferrit for biconical antenna
n. 1	SUPPORTAP2000	support 1/4" " 54,7 degrees bended for biconical antenna

AP3000 Kit

n. 1	AP3000	Biconical passive antenna
n. 1	OCF010	10 meters cable with ferrit for biconical antenna
n. 1	SUPPORTAP2000	support 1/4" " 54,7 degrees bended for biconical antenna

Accessories and Options

AT_WOODENTRIPODE	Wooden tripod with rotating joint and bag
AP_CARRYCASE	Carry Case for biconical antenna
SW3000	Measurement software for narrow band of electromagnetic fields