Antenna Back to Basics – Balance vs. Symmetry

How are balance and symmetry the same?
How are balance and symmetry different?

How to measure and who requires them?

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Symmetry vs. Balance

ANSI C64.4 vs ANSI C63.5

Antenna Symmetry

Antenna symmetry measurements are intended to determine whether received signals on both element sides are similar across the usable frequency range of the antenna. The measurement is used to determine if mechanical or electrical differences can affect the AF values.

History of Symmetry Requirement

In the ANSI C63.5-1998 version of the standard for the calibration of antennas used for radiated emissions measurements, a very rudimentary procedure for checking the balance of the balun in an antenna was introduced. It was not a requirement for the calibration of an antenna but was viewed as prudent to be checked. The procedure essentially was used to verify consistency in the measured signal and cross-polarization rejection minimums as the antenna was rotated from 0° through 270°.

The subsequent version, ANSI C63.5-2006, maintained a similar procedure, but introduced it under a new subsection titled *Antenna Symmetry* where the "balance" of symmetrical antennas was to be checked. The cross-polarization minimums were not included in that procedure. It required that the TX antenna be positioned vertically, and the RX antenna rotated 180°. If the received signal was within 1.0 dB of the antenna in the original 0° position, then the antenna was considered balanced. Should the result be larger than 1.0 dB then the antenna was considered unbalanced. This was the introduction of the terms *symmetry* and *balance*. Balance is used to describe the measurement variation between the 0° and 180° positions, and symmetry is used to describe the antenna topology's symmetrical design both physically and electrically.

The symmetry requirement for the selected hybrid antenna is introduced formally with the release of ANSI C63.4-2014. Surprisingly, this standard is not specific to the calibration of antennas but rather the methods for making emissions measurements. In experiments, it was demonstrated that there was a large number of cases where significant measurement errors were observed when using hybrid antennas. These errors were observed when the hybrid antenna was used from 30 MHz up to 300 MHz, and at certain test distances.

A hybrid antenna is defined in ANSI C63.4 Annex N as an antenna that is constructed with the combination of both a broadband dipole antenna (biconical or bowtie) elements and log-periodic dipole array elements.

ANSI C63.4-2014 Annex N

The annex offers two different conditions that could be used to validate a specific hybrid antenna to be suitable for final compliance measurements at a specific test site. The test site-specific hybrid antenna qualification procedures and acceptance criteria specified in the ANSI C63.4 apply only over the restricted nominal frequency range from 30 MHz to 300 MHz.

ANSI C63.4-2014 Annex N Condition A

- N.2 Size Limitation – 1.5m maximum dimension. No part closer than 25cm to ground plane in either polarization at 1m. Overall length front element to rear element not to exceed 1.5m
- N.3 VSWR – an attenuator (hybrid antenna impedance matching pad - HAIMP) may be used during the test site-specific hybrid antenna qualification procedure. 10:1 or higher in the frequency range of 30 MHz – 200 MHz
- N.4 Test site-specific hybrid antenna qualification procedures
- N.4.2a – near free-space antenna factors (in accordance with ANSI C63.5, over the frequency range 30 MHz to 200 MHz) must be available for the hybrid antenna under investigation.
- N.4.2b - Two nominally identical biconical antennas are required (both of which must have baluns) of the same nominal impedance. Free-space antenna factors must be available for the receiving antenna.
- N.4.2c – two 10 dB impedance matching attenuators are required. One connected on the input connector of the transmit antenna. The second to be connected to the input connector of the EMI receiver or spectrum analyzer.
- N.4.2d – an external preamplifier is required if the laboratory wishes to employ the external preamplifier when making measurements on products.
- N.4.3.1 – biconical antennas a horizontally polarized, placed 3m apart. Scan the RX biconical antenna from 1m to 4m while sweeping 30 MHz to 200 MHz. Exchange the receiving antenna with the hybrid (HAIMP may be included). This shall be within ±2.5 dB. Note – the procedure is different for a 10m site.
- N.5.1 – in the frequency range of 30 MHz to 200 MHz, the difference in results of measurements performed in accordance with N.4, must be less than or equal to ±2.5 dB at all measured frequencies.
- N.6.1 – qualification interval may be up to 3 years.

ANSI C63.4-2014 Annex N Condition B

- N.1b.1 – the hybrid antenna shall have a measured VSWR of 2.5:1 or less at all frequencies of operation. This may be achieved by using the permanent installation of a suitably chosen attenuator.
- N.1b.2 – the hybrid antenna shall have measured symmetry of ± 1 dB or less at all frequencies of operation (as per ANSI C63.5).
- N.1b.3 – the hybrid antenna shall satisfy all the size limitations of N.2
- N.1b.4 – the hybrid shall have been calibrated for antenna factors, VSWR, and symmetry by an ISO/IEC 17025-accredited laboratory that has the following items within its scope of accreditation:
  - i) – the Standard Site Method (SSM)
  - ii) – the Measurement of antenna VSWR
  - iii) – the measurement of antenna symmetry
  - Condition B is required from 30 MHz to its highest operating frequency

Current ANSI Requirements

The current version of ANSI C63.4-2014 has the symmetry specifications for the use of hybrid antennas, for final compliance measurements, defined in Annex N. It was written in ANSI C63.4-2014 that the upcoming ballot version of ANSI C63.5 was to have the contents of ANSI C63.4 Annex N incorporated.

The latest version of ANSI C63.5-2017 does incorporate a symmetry requirement for antennas to be measured between 30 MHz to 300 MHz in section 4.4.3 Antenna Symmetry Measurement, 30 MHz to 300 MHz, however this requirement is not the same and some aspects of the Annex N requirements are not required in ANSI C63.5.

ANSI C63.5-2017 seems to change the term and measurement reference from *balance* to *symmetry*. The terms get clouded even further when CISPR 16-1-4 is called out as part of the *symmetry* test requirements in ANSI C63.5. Another rather large variation between the requirements of the two regulations is that ANSI C63.5 puts the symmetry requirement on biconical antennas as well as hybrid antennas.

As mentioned above, ANSI C63.5 states the requirement that the antenna symmetry must be checked for hybrid and biconical antennas and references CISPR 16-1-4. Ironically, the referenced section of the CISPR document corresponds to the *balance of antenna*. So once again we find ourselves being bouncing between the terms symmetry and balance.

ANSI C63.5-2017 Clause 4.4.3 Antenna Symmetry

- 4.4.3.a – symmetry shall be checked for biconical and hybrid antennas. (refers to CISPR 16-1-4 section 4.5.4.1)
- 4.4.3.b – the antenna separation distance R shall be 10 m.
- 4.4.3.c – the frequency step size is defined in Table 2 of ANSI C63.5-2017.
- 4.4.3.d – cabling is installed as used for antenna calibrations.
- 4.4.3.e – the RX antenna (antenna under calibration) shall be placed at a height of 1 m above the ground plane.
- 4.4.3.f – a linearly polarized antenna is used as the TX antenna and is scanned in height.
  - ii) – the Measurement of antenna VSWR
  - iii) – the measurement of antenna symmetry

What does it all mean?

Our investigation into the symmetry versus balance discussion has led us through several regulations in which the terms are used almost interchangeably. But in addition to the terminology inconsistencies, we find conflicting requirements for the frequency range that the symmetry or balance checks are required.

Symmetry seems to be a requirement encompassing more than just the balanced response of 1 dB when the RX antenna is in the 0° and 180° positions. The symmetry of an antenna expands to include physical characteristics (size limitations) and VSWR requirements, in addition to the balanced measurement result.

Which is required for my needs?

If you intend to use a hybrid antenna for final compliance measurements as per ANSI C63.4-2014, then the antenna must meet the symmetry requirements called out in Annex N of the document. But which condition should be used to determine compliance? Condition A or Condition B? And what frequency range is required for the symmetry test?

Condition A requires that the antenna be validated specifically on the intended test site. In which case the frequency requirement only extends from 30 MHz up to 200 MHz. But this requirement requires an additional pair of biconical antennas to be used for the site-specific requirement and may not be possible for all laboratories.

Condition B allows for the antenna symmetry to be determined and verified by an outside accredited calibration laboratory. But the symmetry requirement extends up to 1 GHz when this option is selected.

Conclusions

The terminology differences between symmetry and balance are much more straightforward and easier to answer than the question of which condition is used for determining symmetry and what range of frequencies are required. The answer would vary depending on your point of view. The requirements if you are a regulatory laboratory, that is performing final compliance measurements, would be different than that of a calibration lab that is calibrating antennas for customers.

References

ANSI C63.4:2014 Standard

ANSI C63.5:1998 Standard

ANSI C63.5:2006 Standard

ANSI C63.5:2017 Standard

CISPR 16-1-4:2010+AMD1:2012+AMD2:2017 Standard