Title: "The Site VSWR Procedure for the Validation of EMC Emission Test Sites in the 1 GHz to 18 GHz frequency range"

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Abstract:

Until 2007, radiated disturbance measurements in accordance with CISPR had only been defined for the 1 GHz frequency range. The full standards which are now available describe the measurement of emissions in the 1 GHz plus frequency range as well as the requirements for the test site necessary to do this. A new procedure ("Site VSWR") was developed to characterise the test site which is described in the following paper. The requirements made on the validation broadband omnidirectional antenna are stringent. ARC developed and patented a precision antenna of this type.

Introduction:

Measuring the radiated disturbance of an EUT is an integral part of any EMC test since the EMC Directive came into force more than 10 years ago in Europe. The frequency limits which it specifies were easily identifiable. Below 30 MHz, the emissions are negligible as the EUT together with the cabling is small compared to the wavelength whereby the radiation of electromagnetic waves is inefficient. Measurements above 1 GHz were not required as at the time there were no emissions in this frequency range. Typical microcomputer clock speeds were below 100 MHz - it was possible in any case to record the tenth harmonic.

Things are different today: processors in modern PC systems run at speeds of up to 4 GHz. The introduction of standardised radiated disturbance measurement for the 1 to 18 GHz frequency range is absolutely necessary and is described in CISPR 16-2-3 [1]. The new procedure to determine the influence of the test site is also inextricably linked to the new emission measurement technology. Similarly, the new CISPR 16-1-4 [2] provides a procedure below 1 GHz which can be used to assess the properties of anechoic rooms. A limit is also specified which distinguish between suitable and unsuitable anechoic chambers.

Anyone operating an EMC test house will be aware of the procedure to measure normalised site attenuation (NSA) in the 30 MHz to 1 GHz frequency range. The motivation behind the NSA can be easily explained: an attempt is made to simulate an omnidirectional EUT via a test antenna/signal generator combination. The test antenna is positioned at various locations and polarisation levels at the test volume, and the field strength is measured with the receiving antenna. The deviation from the target value, which may not exceed ± 4 dB, is determined by using calibration data.
It would be advantageous if this idea could be retained above 1 GHz, however, this is not feasible because of a certain number of physical effects.

CISPR 16-2-3 emission procedure:

The measurement procedure to determine the field strength of radio disturbance in the 1 GHz to 18 GHz frequency range is described in the CISPR 16-2-3 standard. In contrast to emission measurement below 1 GHz where an open area test site or absorber chamber with a reflective ground plane is used, another test environment is used for this measuring procedure. In this case, fully anechoic rooms or an open area test site with absorber layout on the ground plane are used - this means that open air conditions can be simulated. This has the advantage that a height scan of the receiving antenna is not required between 1 m and 4 m, as there is no reflection caused by the ground plane. However, the intention is not to dispense entirely with the height scan. According to the directivity of the antenna – or its half power beam width w at the test location – a differently sized part of the test piece is sampled, see Figure 1. If an EUT is measured which is higher than w, then the receiving antenna must be adjusted to a height in order to cover the test piece height.
The measuring distance is reduced from 10 m to 3 m because the coupling between the test piece and receiving antenna is negligible in this frequency area.
A preliminary measurement procedure is described in the standard: the EUT is turned in increments of 15° and the field strength is scanned with the test receiver at each receiving height. The receiver is operated with the peak detector and in max hold mode.
At the time of the final measurement, the receiving antenna must be turned and height-adjusted until the actual emission maximum is found. The product committee

CISPR/I, responsible for CISPR 22 [3], has defined two different limits, one for peak and one for average detector.

a) b)

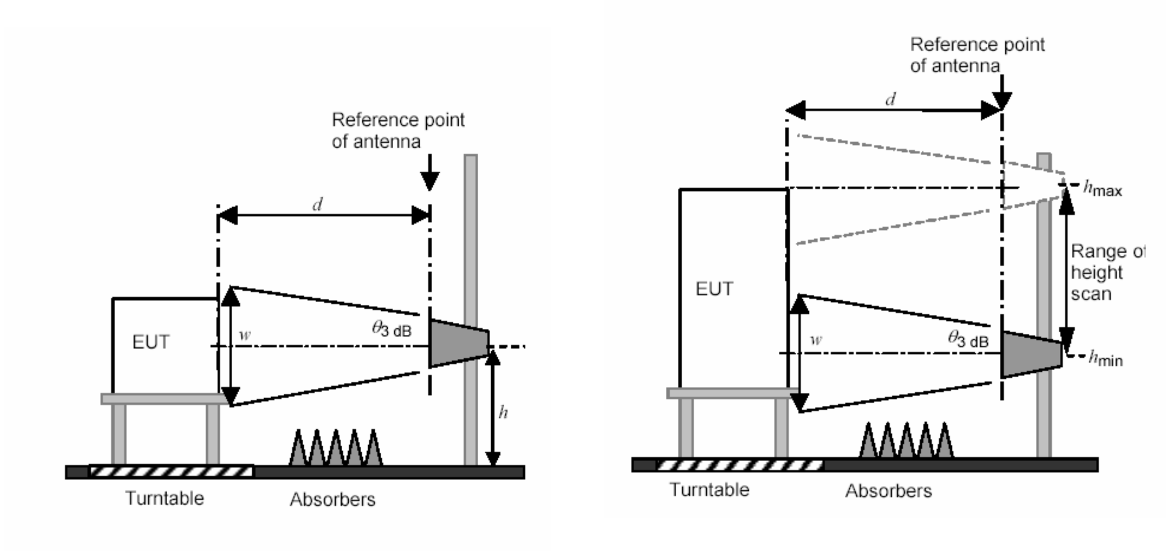


Figure 1: Emission test setup a) height scan not required b) height scan required (from [1])

Test site requirements in accordance with CISPR 16-1-4:

The measurement procedure to validate the test site in the 1 GHz to 18 GHz frequency range is described in the CISPR 16-1-4 [2] standard.
In this frequency range the procedure for measuring the normalised site attenuation is no longer applicable. Owing to the small wavelength - ≈ 16 mm at 18 GHz – the positioning of the measuring antennas is very sensitive. Adjustments in the mm range can cause fluctuations in the reception field strength in the dB range. A procedure which follows the principle used for less than 1 GHz is not appropriate owing to the poor reproducibility.
Other chamber characterisation procedures in the microwave area were already developed decades ago as they were required for measuring radar antennas. In contrast to the NSA method which refers to an absolute calibration, relative measurements are used here. Extensive literature on these techniques is available under the key words Free Space VSWR procedure [4] or Field Probe Test [5].
The procedures are based on the superposition principle between direct and reflected waves, see Figure 2. By summation of these two signals, the signal at the

receiving antenna fluctuates sinusoidally when the phase between wanted and unwanted signals changes due to adjustment of the position of the transmitting antenna (transmit section). The magnitude of the reflected signal can be established from the average site attenuation and the amplitude of the sine wave.

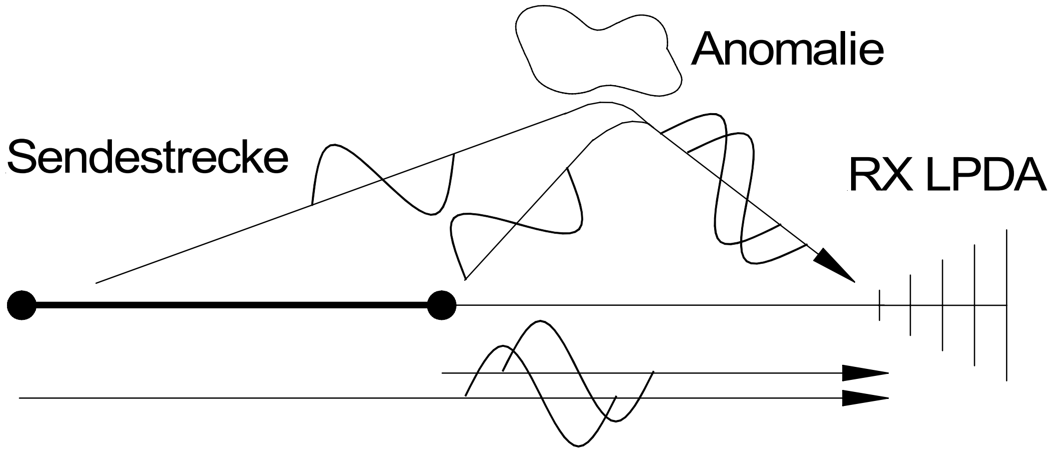


Figure 2: Sketch showing the relative measuring procedure for chamber validation

In the model shown, reflected waves are generated by anomalies. By anomalies we mean objects which reflect electromagnetic waves, such as lamps or cameras as well as the absorber walls themselves which are never perfect.

These procedures are only suitable for narrow band signals. If one wishes to characterise the absorber chamber in a larger frequency range, the verification must be carried out using many individual frequencies. The procedure for EMC technology is therefore unsuitable due to the long measuring time.

For this reason the standardisation committee developed a new validation procedure called "Site VSWR". You could also describe this technique as the broadband version of the classic procedure. Instead of continuously scanning the transmit section, measurements are taken at six discrete points. In turn, the network analyser or signal generator and spectrum analyser, measures within a very fine frequency spacing of just 50 MHz. This allows for the spatial undersampling to be compensated by oversampling in the frequency domain. This is the most important point to be considered when interpreting Site VSWR results. The standing wave maximums and minimums are not found at all the 341 frequency points. For this reason, results should only be analysed by octaves and not by frequency points.

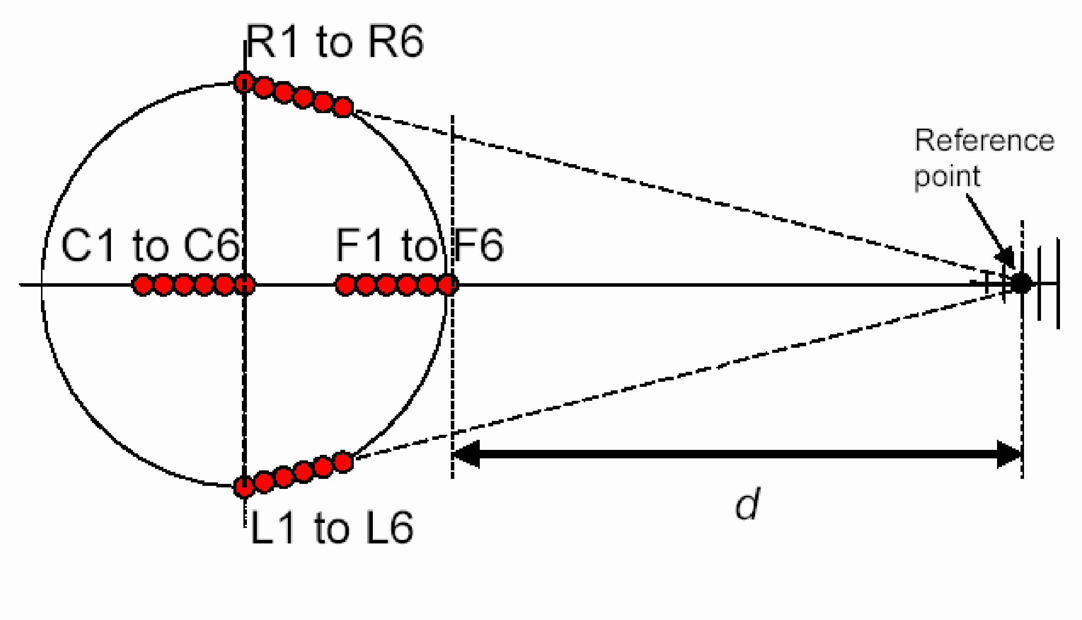
In Figure 3, the test setup conforming to the standard is displayed. The measuring distance d is measured between the extent of the test volume and the antenna reference point. In the test volume, five test positions are defined: Position Front (F), Centre (C), Right (R) and Left (L) to height h1 and a further front point (H) to height h2. Height h1 is in the middle of the test volume, however, 1 m at the highest. The second height, h2, is equal to the height of the volume. The receiving antenna is always mounted at the same height as the transmitting antenna and always directed at the centre of the test volume.

Each of the test positions consists of six test points which are distributed unequally along a length of 40 cm. The first point is the one which is closest to the receiving antenna. From this point on, the other points are positioned at distances of 2 cm, 10 cm 18 cm, 30 cm and 40 cm on a line. The received RF voltage or RF power is determined for each of these points. Using formula 1

$$S_{VSWR_{dB}} = 20\log\left(\frac{V_{max}}{V_{min}}\right) = V_{max_{dB}} - V_{min_{dB}} \tag{1}$$

the result for the particular test position is determined from the six points. It is permissible here to correct the different levels based on the differing distances to the receiving antenna. The maximum permissible Site VSWR value is + 6 dB.

a)



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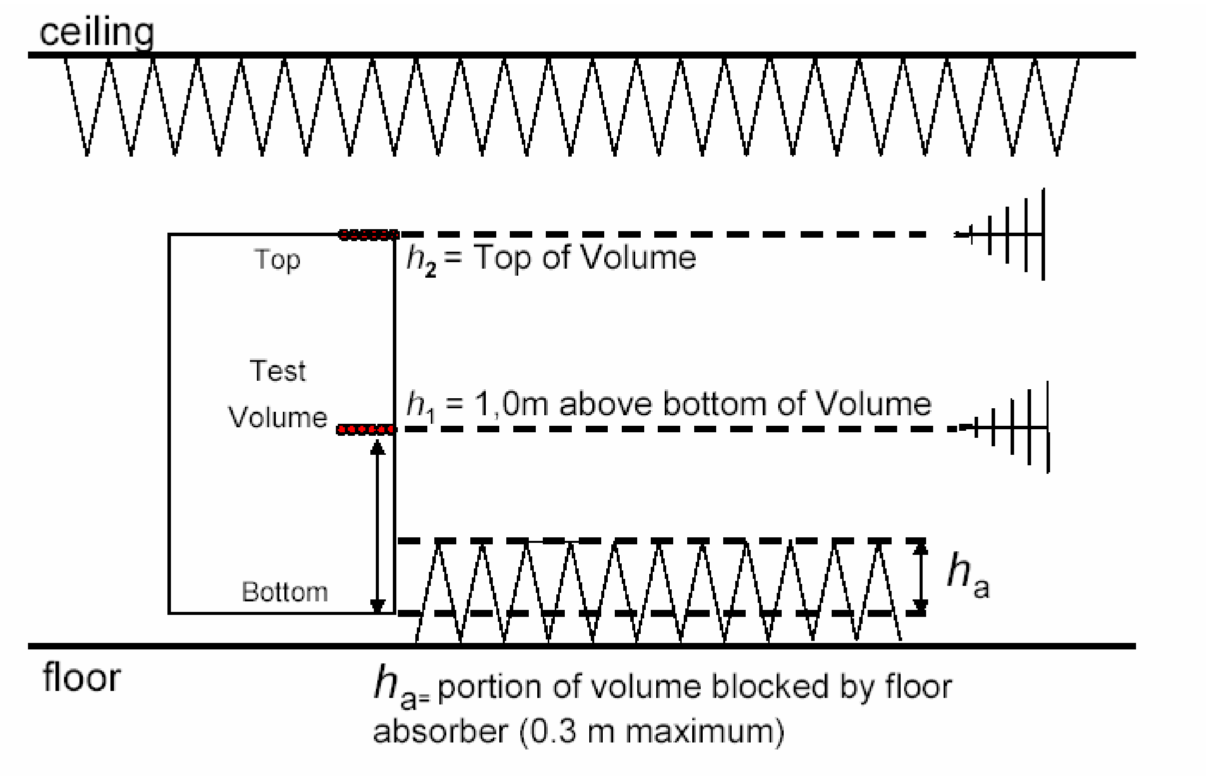


Figure 3: Test setup for Site VSWR a) top view b) side view (from [2])

According to the size of the test volume, it is permissible to omit some of the points. The decision tree required for this is shown in Figure 4. In the case of test volumes below 1.5 m in diameter, the centre point can be omitted. If the test volume is smaller than 1 m, the measurement at the second height can be omitted too.

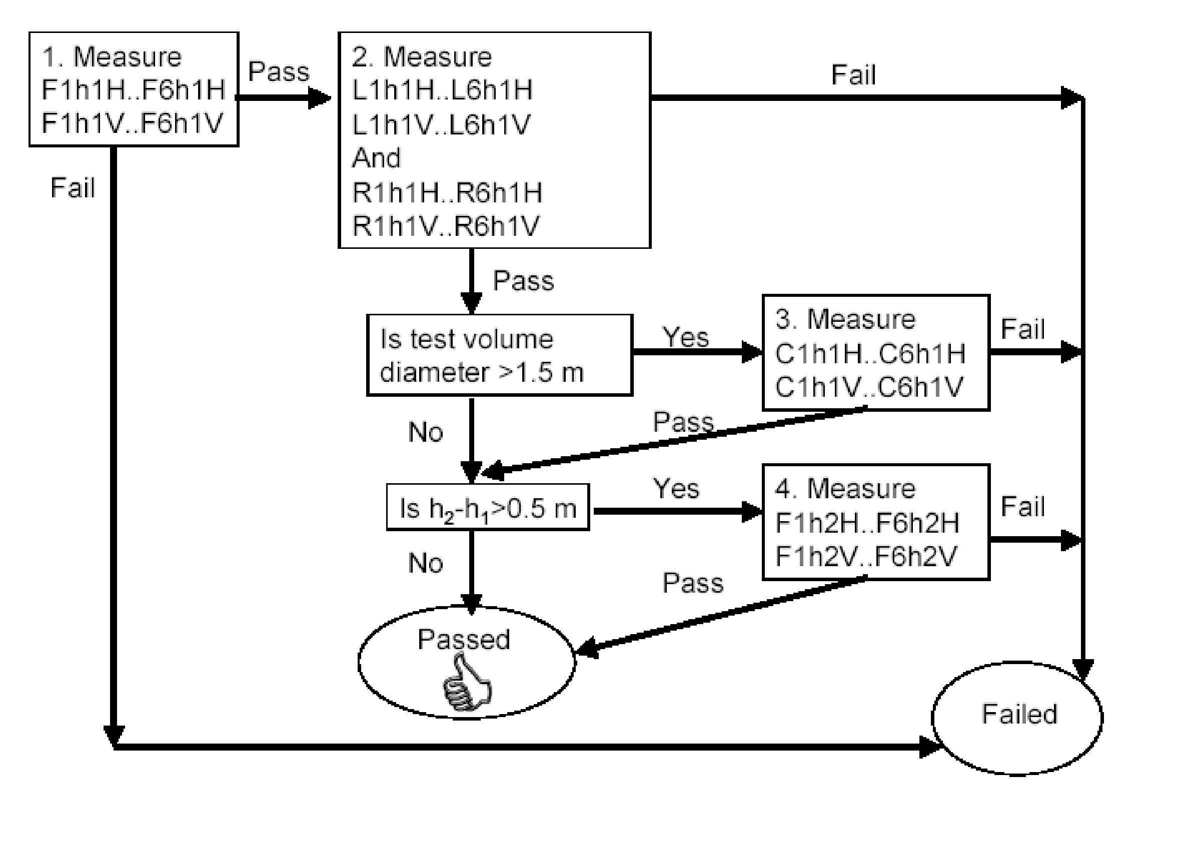


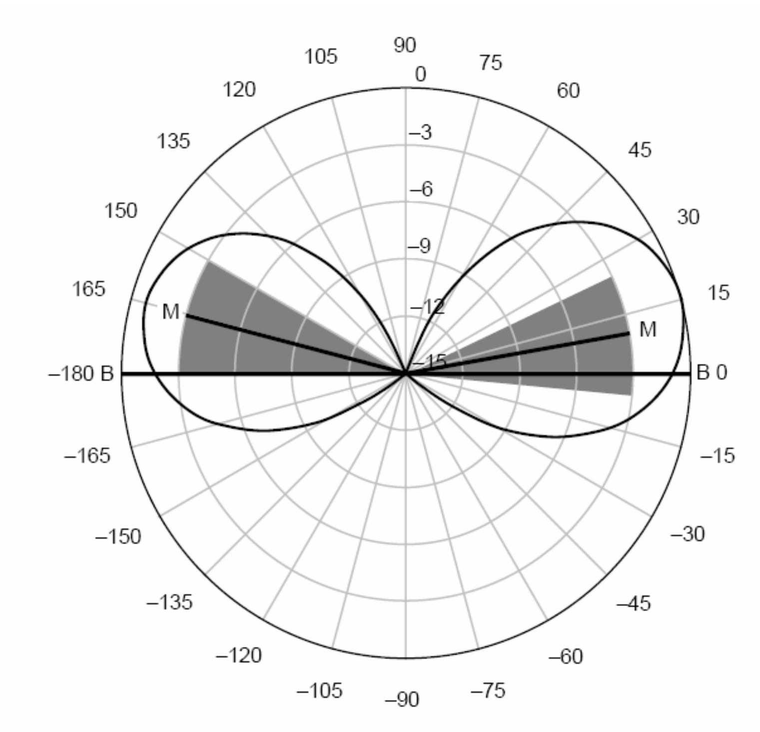
Illustration 4: Decision tree for required measurement configuration (from [2])

Omnidirectional antennas are used as transmitting antennas in order to evenly illuminate the anechoic room. Only in this case is it possible to maximise the effect of reflections on the measurement result of the radiated disturbance measurement. The receiving antenna should be of the same type as the antenna used for the radiated disturbance measurement, to evaluate the reflections during validation and the emission test in an identical manner. If a high directive antenna is used, the side walls are largely masked out. In turn, during the height scan, the increment has to be reduced or a height scan will be necessary for small EUTs. This means a lengthening of the measuring time and thus more costs are incurred which can scarcely be offset by a more reasonably priced anechoic chamber.
The properties of the omnidirectional transmitting antenna are also defined, see Figure 5.

The radiation pattern in the E plane for an antenna with a simple linear polarisation can be measured in any one of a variety of cutting planes (constant azimuth angle) around the radiation sphere. The cutting plane of the radiation pattern being measured must be selected by the antenna manufacturer and stated in the description of the antenna properties. The plane which contains the connector and the cable is to be favoured.

The maximum of the radiation pattern is first normalised to 0 dB. The main beam direction M is then chosen and must be between 0° ± 15° und 180° ± 15°. Following this, the forbidden zone, which describes an angle segment of ± 15° and a length of -3 dB, is drawn symmetrically to M (on both sides of the radiation pattern). The E plane radiation pattern shall not enter the forbidden zone.

a)



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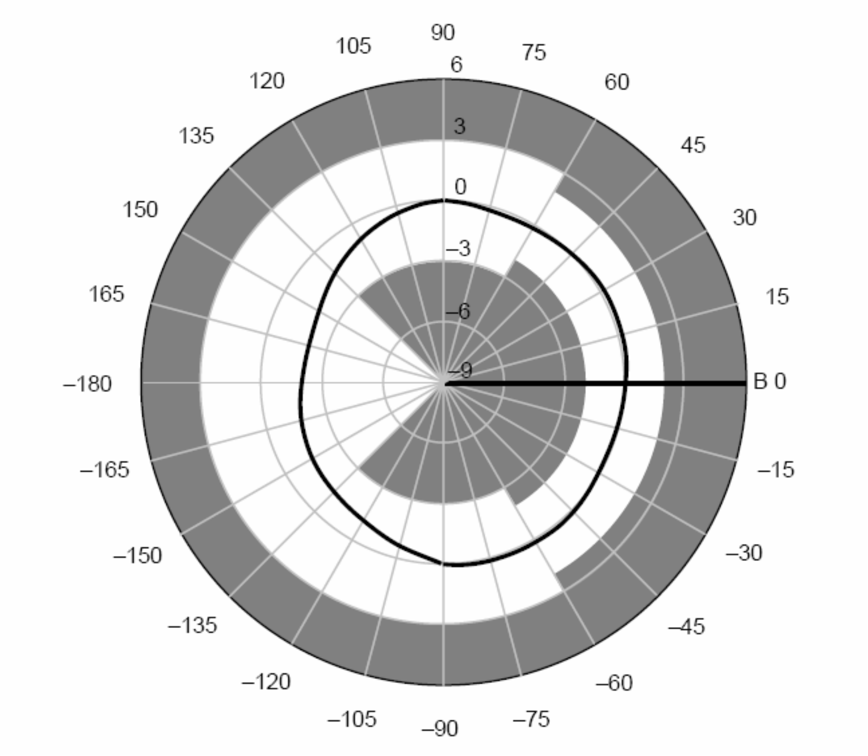


Figure 5: Requirements for the omnidirectional measuring antenna; The forbidden zone is drawn in grey. a) E plane b) H plane (from [2])

There is only one possible plane in which the H plane radiation pattern of a dipole antenna can be measured. This is the plane lying orthogonally to the dipole axis through the centre of the dipole.
The average of the radiation pattern is determined in the ±135° range from the main beam direction (=0°). The radiation pattern is then normalised to this average. The forbidden zone worked out in accordance with Table 1. The H plane radiation pattern shall not enter the forbidden zone.

Angles	**1 GHz to 6 GHz**	**6 GHz to 18 GHz**
–60° to 60°	±2 dB	±3 dB
–60° to –135°, 60° to 135°	±3 dB	±4 dB
–135° to –180°, 135° to 180°	< +3 dB	< +4 dB

Table 1: Definitions of the forbidden zone for the H plane

One other way of meeting these requirements is the use of what is known as the reciprocal procedure. Here, instead of the omnidirectional antenna, an omnidirectional field probe is used and the receiving antenna adapted to become the transmitting antenna. Pros and cons of this technology are described in Kriz [6].

POD 16 and POD 618 measurement antennas:

At the time when the standard was developed, there were no antennas on the market which met these strict requirements for the radiation pattern . For this reason, staff from the business unit radio frequency engineering of Austrian Research Centers GmbH – ARC, developed an antenna set for this application [7]. This consists of two antennas so that the 1 GHz to 18 GHz frequency range can be covered. The specified frequency ranges are clear simply from the descriptions, POD 16 (1 GHz to 6 GHz) and POD 618 (6 GHz to 18 GHz). Constructing an omnidirectional antenna which covers the entire frequency range is not possible according to today's state of the art. In the first few years after the new product standard for IT devices came into force, the emission limit was only specified up to 6 GHz. This meant that the frequency range which was important for EMC at the beginning could be covered with a single antenna.

In Figure 6, a comparison between the radiation pattern of an ideal dipole and two actual constructions of dipole antennas is given. In the case of the "classic" biconical design, the directional diagram in the area of the cable routing is deformed and does therefore not meet the requirements of the standard. However, the POD antenna shows a directional diagram which is very similar to that of an ideal dipole. The effect of the H plane deformation on the measurement uncertainty is calculated in Kriz [8] [9].

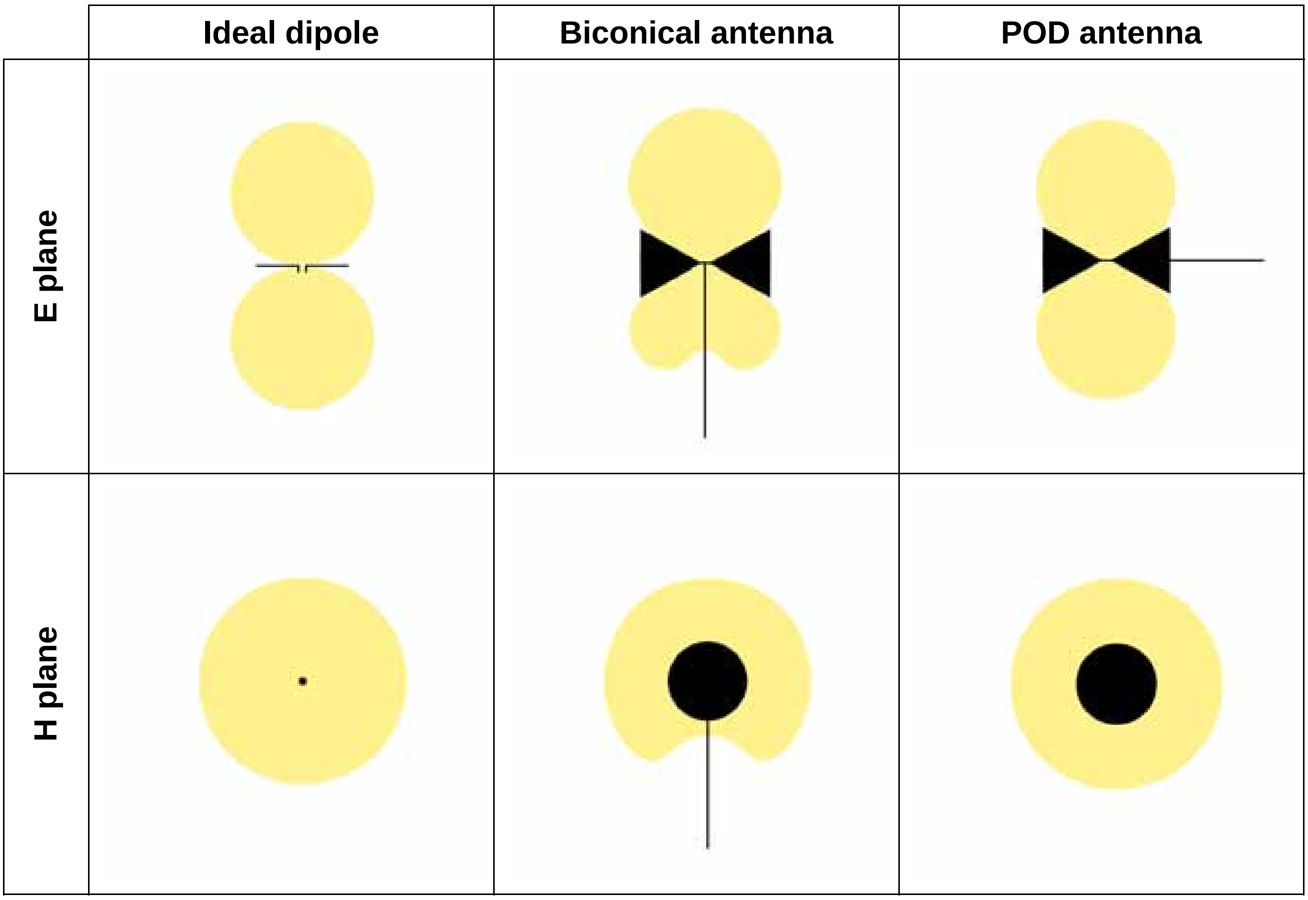


Figure 6: The radiation pattern (yellow) for various constructions of dipole antennas (black) in the E and H planes.

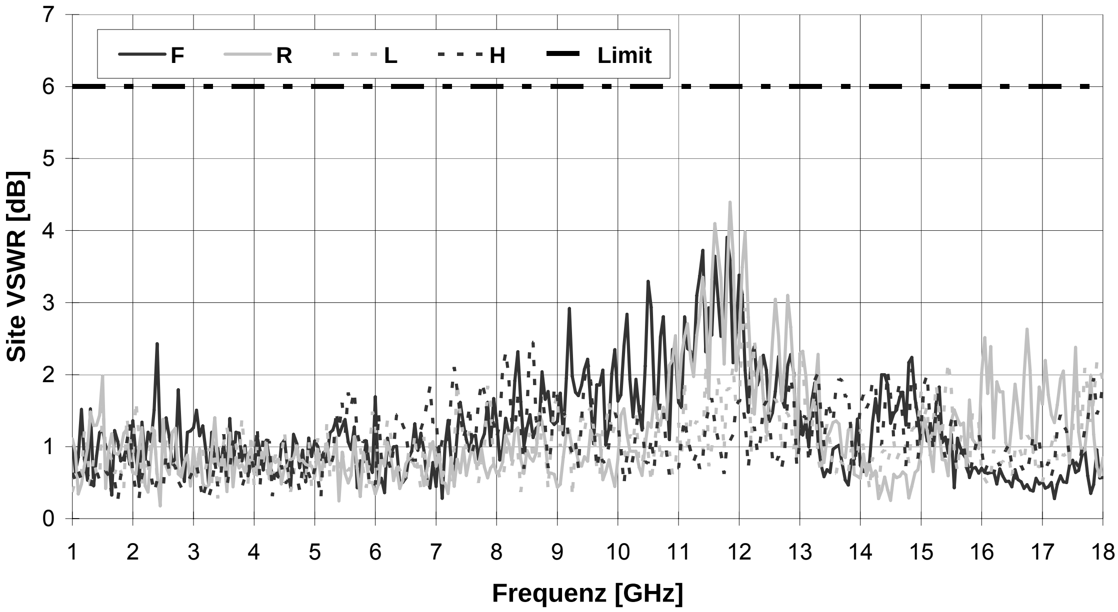
When mounting the antenna for Site VSWR measurement, care should be taken to ensure that the radiation pattern is not affected by the stand and cable routing. Therefore, staff from the business unit radio frequency engineering of Austrian Research Centers GmbH – ARC, constructed a special stand which meets this requirement, allows for simple change of the polarisation and is equipped with a positioning aid.

Measurement results:

Staff from the business unit radio frequency engineering of Austrian Research Centers GmbH – ARC, validated the anechoic room at the Seibersdorf EMC test centre in accordance with the Site VSWR procedure. This fully anechoic room which is now 15 years old, meets the requirements of the new standard and complies with the 6 dB limit. The measurements are shown in Figure 7.

The size of the screening is 8.5 m x 4.3 m x 4.3 m and it is lined with 36 inch or 26 inch absorbers (carbon-impregnated polyurethane foam) from Emerson & Cuming. The test volume has a diameter of 100 cm and a height of 160 cm. Because of the size of the test volume, validation is not required at the point centre, but rather at a second height.

a)



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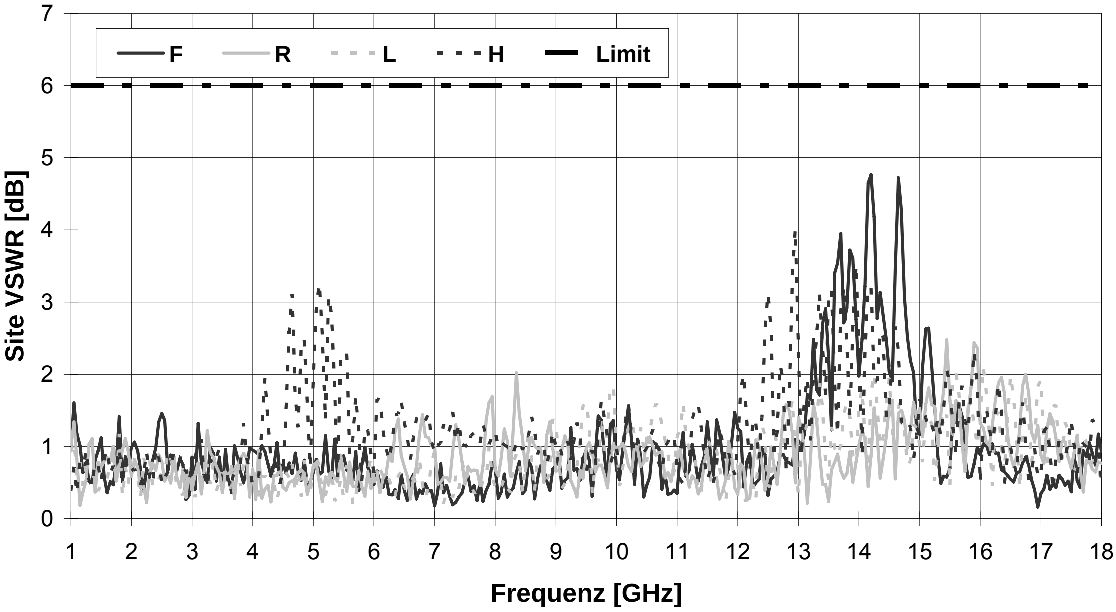
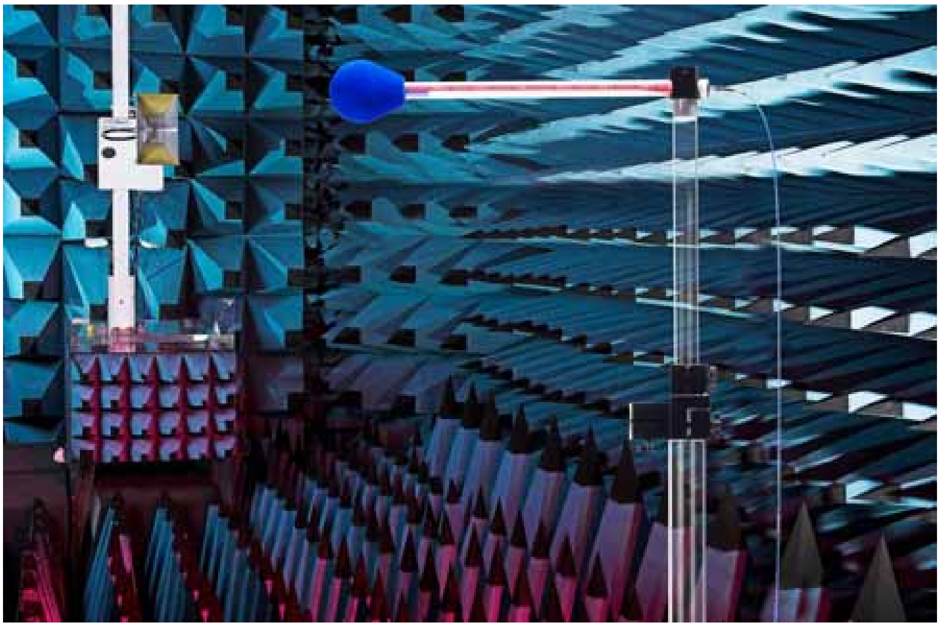


Figure 7: Site VSWR measurement results a) horizontal polarisation b) vertical polarisation

In broad frequency ranges the measuring result is below 2 dB. This is an indicator for the effective operation of the radio frequency absorbers used. In many positions, e.g. at approximately 5 GHz, 12 GHz and 14 GHz there are marked peaks in the results. It is not always easy to attribute causes conclusively. Reflections which occur at the second height can be attributed mostly to the lighting or cameras. Walkway absorbers or raised floors can sometimes be seen at the side points.
Photos from the chamber during the validation measurement can be seen in Figure 8.

a)



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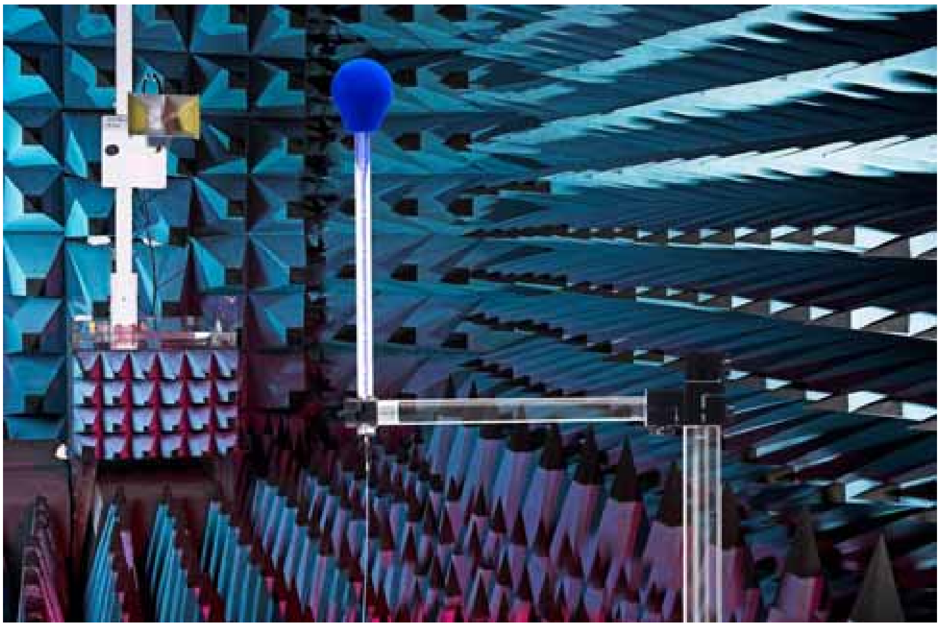

Figure 8: Photos of the Site VSWR measurement a) horizontal polarisation b) vertical polarisation. The POD 16 antenna on the stand, which was specially developed for this validation measurement, can be seen in the foreground (antenna and stand are ARC in-house developments).

Summary:

Carrying out radio disturbance measurements between 1 and 18 GHz, which is mandatory nowadays, requires two techniques: first, the measuring process itself and second, a process which verifies the suitability of the test site ("Site VSWR"

procedure). This is described in the new basic standards CISPR 16-2-3 and CISPR 16-1-4. Product standards from the CISPR/I committee set the emission limit and the detector to be used.
An omnidirectional antenna is used as the transmitting antenna for validating the test site. There are strict requirements placed on the radiation pattern which the POD 16 and POD 618 meet. Both antennas, which cover the frequency range from 1 GHz to 18 GHz, show radiation pattern similar to those of an ideal dipole.

References:

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