Application Note #41A
Update on the Latest Release of IEC 61000-4-3, Edition 3

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The European Union's EMC directive 2004/108/EC and its predecessor 89/336/EEC mandate the Electromagnetic compatibility of products placed on the European market. While the directives provide broad base goals, product specific standards and in insolated cases when product standards do not exist, generic standards are used to define specific test levels and frequencies that apply. These standards in turn call out a set of unique EMC "Basic" standards that define in detail test procedures that must be successfully accomplished before a CE mark can be affixed to products shipped to the EU. The basic test standard that addresses radiated electromagnetic field immunity is the ***IEC 61000-4-3***. While product standards provide test level severity, specific test frequencies, and any variance to the referenced basic standards, the object of this basic test standard is to establish a common reference to radiated RF immunity caused by any source. In particular, electronic products must be designed and tested to insure immunity to intentional transmitters such as walkie-talkies, digital cell phones, and other unintentional RF emitting devices such as electric motors, thyristors, and welders, to name but a few RF interference sources.

This application note is offered as supplemental background information and highlights the changes introduced with the latest edition of IEC 61000-4-3 and the impact the changes have on the EMC test system. Always refer the latest IEC basic standard (IEC 61000-4-3: Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test) for guidance when conducting RF immunity tests.

Edition 3 has been approved and released ahead of schedule. The status is shown in the table below:

Stage Code	Meaning	Actual Date
CDIS	Final draft issued for final vote	11-4-05
APUB	Draft approval for publication	1-13-06
BPUB	Print of the publication	2-07-06
PPUB	Issue of the final standard	2-07-06

Major Changes in IEC 61000-4-3 Edition 3.0:

- New Harmonic distortion requirement of test setup: better than -6dBc
- New Linearity check to ensure RF amplifiers are not operating in compression
- New extension of frequency range up to 6GHz
- New test table material requirement

The above changes may seriously impact EMC test facilities and the test equipment used.

Harmonic distortion

RF test system nonlinearities result in harmonic distortion of the test signal. For EMC test systems, the amount of distortion is the difference between the amplitude of the fundamental and the level of the largest harmonic. Since the validity of an EMC immunity test are seriously compromised by RF signal impurity, the IEC has mandated that the harmonic distortion for the ***total*** test system must not exceed -6dBc. This means that all the harmonics present in the RF test signal transmitted from the antenna must be at least 6dB below the level of the fundamental test frequency. Since RF power amplifiers are major contributors to signal distortion, the new harmonic distortion requirement may prove difficult to accommodate in some situations. This is especially true when RF amplifiers are driven well into compression or when using Traveling Wave Tube (TWT) amplifiers. While the harmonic distortion of most solid-state RF amplifiers is minimal when operated in or near the linear region, distortion can become unacceptable as the output power reaches compression. On the other hand, TWT amplifiers typically exhibit harmonics in excess of that acceptable for EMC testing applications and if they are used, special measures must be taken to reduce the harmonics. TWT amplifiers have been historically used for testing above 1GHz when high power is required and offer significant cost/performance benefits, especially at very high power levels. Since the introduction of solid-state amplifiers in this frequency range many of the limitations of TWT amplifiers have been overcome. Furthermore, considering the need to minimize harmonics, some EMC TWT amplifiers either combine tubes or use built-in filters to keep harmonics within acceptable levels. RF Immunity systems that fail to meet the -6dBc mandate may still be used for EMC testing by attaching RF filters at the output of the RF amplifiers to block unwanted harmonics.

A case in point is shown in Figure 1 where the harmonic content of a typical low power TWT amplifier is contrasted with that of a solid-state amplifier. Note the startling contrast in harmonic distortion. The solid-state amplifier has an excellent harmonic distortion level of -24dBc while the TWT amplifier has a harmonic distortion of only -0.8dBc. Clearly, external filters would be required if the TWT amplifier were used for EMC testing.

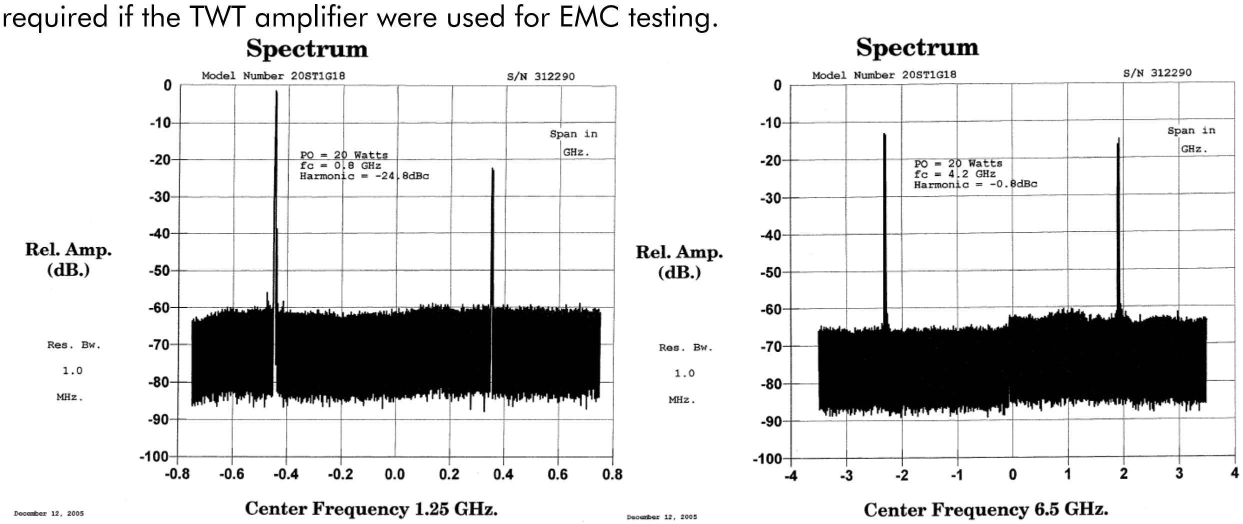


Figure 1: AR 25S1G 4A solid-state module vs. the AR 20T4G18A TWT amplifier module

If the TWT amplifier show above were to be used in violation of the IEC mandate, the high harmonic level would result in at least two major error components that would render the test results suspect. First of all, since a broadband RF field probe is used to determine field level, the TWT harmonic will contribute significantly to the measured calibration level. This occurs because the RF field probe can not distinguish between the desired fundamental test signal and the undesired harmonic. Furthermore, frequencies in excess of a field probes stated operating range will register to some extent, further contributing to erroneous field measurements. Clearly high levels of harmonics result in a major error component when attempting to establish the proper test level. A second consideration that exacerbates this error component is that the effective antenna gain typically increases with frequency. Antenna gain at the harmonic frequency can exceed that seen at the fundamental test frequency by 5dB or greater. In the example above where the harmonic is just -0.8dB below the fundamental, a 5dB boost will result in a test field dominated by the harmonic, thus introducing even more error in the test. And finally, an even more subtle adverse effect of high levels of harmonics is that the Equipment Under Test (EUT) may actually be susceptible at these higher frequencies. Since the test personnel assume they are testing at the fundamental frequency, any failure will be incorrectly recorded as occurring at the fundamental frequency rather than at the harmonic. Furthermore, it is entirely possible that the harmonic may be outside the intended test frequency range, and therefore should not even be part of the test. From the EUT manufacturer's point of view, harmonics are undesirable since they may result in unwarranted product failures.

Given the adverse effects of high levels of harmonics and considering what level of distortion is reasonably achievable, lets work backwards to determine a safe level of harmonic distortion.

Maximum difference in antenna gain between harmonic and fundamental	= 5dB
Other adverse effects from setup and room (safety factor)	= 3dB
Required by the new IEC 61000-4-3 spec	= 6dB
Total	=14dB

Therefore, factoring in "real-life" considerations, a more conservative figure of merit for RF power amplifier harmonic content would be -14dBc. By adopting this conservative requirement for all the RF power amplifiers, one can guarantee an acceptable system harmonic level when the actual EMC test is run.

Linearity Check

The linear region of an amplifier is the power range characterized by a 1:1 ratio in output power change in dB to the corresponding change in input signal in dB. Increasing the input signal further will continue to result in an output power change per the 1:1 ratio up to the point of output device current limitation. At this point, the amplifier is said to be saturated. Here a 1dB increase results in less than a 1dB change in output power. AR's solid-state amplifiers are specified at both a 1dB and a 3dB compression point. Below the 1dB compression point the amplifier is said to be operating in its linear region. Above the 3dB compression point the amplifier is in full compression.

An understanding of linearity is vital to insuring a viable EMC test. If RF amplifiers are driven into compression, the output signal is distorted. This can be clearly seen as a flattening of either the positive or negative alternations of the sine wave input. As the amplifier approaches full saturation, the output begins to resemble a square wave. A check of this signal in the frequency domain reveals a very high content of harmonics. A further complication of operating close to saturation is that there is little overhead to accommodate the amplitude modulation (AM) required of IEC 61000-4-3. The resulting signal distortion leads to a situation most feared by EMC engineers…unrepeatable test results.

Figure 2 is a power curve for the 25S1G4A at 1.5GHz. The orange triangle demonstrates how the 1dB compression point is determined (the point at which a 10dB input change results in a 9dB output change). The green triangle illustrates the 3dB compression point where a 10dB input change only results in a 7dB output change.

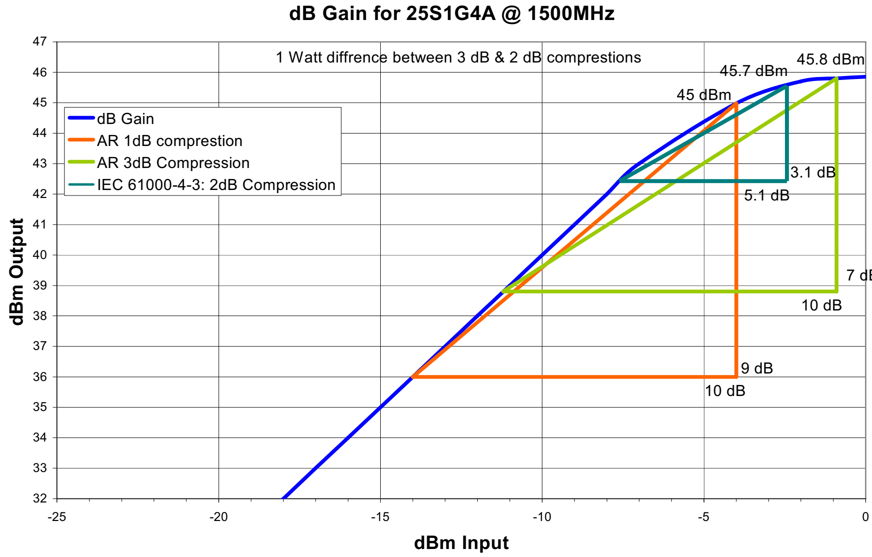


Figure 2: Linearity curve of a production unit 25S1G4A amplifier at 1 frequency

The new specification calls for a 2dB compression point check of the RF power amplifier while connected to the antenna. (See the aqua triangle) If the amplifier were driving a pure 50Ω rather that an antenna characterized by a complex impedance, amplifier manufacturers could easily specify this new 2dB compression point and it could be used as a reference when calculating your needs. Unfortunately, given the uncertainties of the vast variety of antennas available, coupled with the uncertainties normally encountered in complex systems, the 2dB compression point may very slightly in actual test configurations. To circumvent this problem, it best to size amplifiers based on the manufacturer's supplied 1dB compression point to allow for some margin of error. This may be a concern when using a TWT amplifier since they are normally not as linear as solid-state amplifiers. The 1dB compression point is typically 25% of rated power. Therefore a 20 Watt TWT amplifier will have a 1dB rating of about 5 Watts. By way of contrast, the 25S1G4A solid-state amplifier has a minimum output rating of 25Watts and a minimum 1dB compression rating of 20Watts. Since there is no formula for determining the various compression points, it is always best to check the amplifier's specification sheet or contact the manufacturer directly for actual test data and assistance with the selection of the product that will best meet your needs. As an example, while a 25S1G4A is specified to have a minimum 1dB compression ratio of 20 watts, the actual production test data of the one shown in Figure 3 shows a 1dB compression of 30 watts at 1.5 GHz.

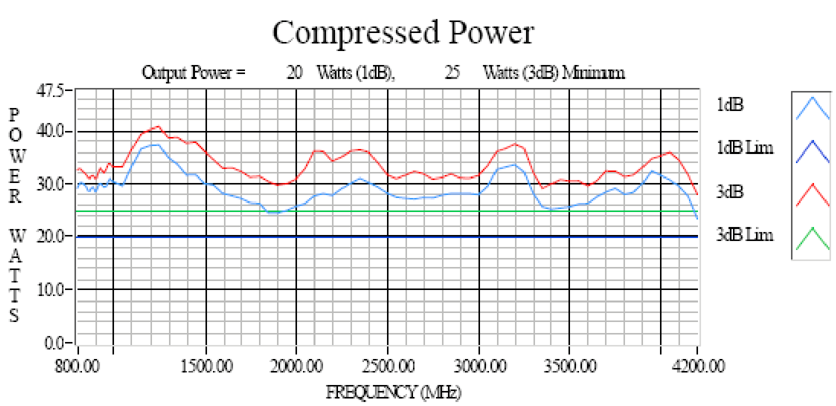


Figure 3: 25S1G4A solid state amplifier production data.

Increased Frequency Range

The increase in the upper test frequency limit from 2 GHz to 6 GHz is in response to the push by the communication industry into ever higher frequencies within the RF spectrum. The available RF spectrum is being parsed out by the countries of the world. The specific operating frequencies used within each country are governed by law. While products marketed worldwide must be tested at all pertinent frequencies. A product destined for a specific region need only be tested for immunity at the frequencies in use where it is expected to be put into service. In addition, not all communication standards use the same signal strengths. This is why the new IEC *test standard* leaves further definition up to forthcoming *product standards*. *Product standards* will specify the additional frequencies that apply in the communications bands: 800 to 960 MHz and 1.4 to 6 GHz. *Product standards* also specify test levels which may not be consistent throughout the bands. The current test requirements in the 80 MHz to 1 GHz frequency range should remain the same.

The requirement to test at higher frequencies may present a problem for some existing EMC test chambers. Ferrite lined chambers are very popular but have difficulty meeting the field uniformity requirements above 1 GHz. The ferrite material tends to loose much of its absorbent characteristics around 1 GHz and above and will reach a point where it reflects more RF energy more than it absorbs. Annex C of IEC 61000-4-3 Ed. 3 explains this situation and offers advice and options on correcting this problem. A fully lined anechoic chamber with ferrite and absorber material is the best choice when testing at these higher frequencies.

Non-conducting test table

The test table is now specified to be made of low permittivity material. Rigid polystyrene is one material that is suggested. In the past, many labs have used wood which is fine when testing at lower frequencies. Now that testing requirements can be as high as 6GHz, wood is unsuitable. At these frequencies wood becomes reflective. This undesirable property adversely effects field uniformity and the reflections are cause for less repeatable test results.

General test tips

The addition of the new requirements noted in this application note may require test labs to upgrade and purchase new equipment. The following helpful hints are offered to increase the likelihood of success.

If harmonic content is greater than desired…

- RF filters on the amplifier's output may reduce harmonics to an acceptable level.
  - Make sure the insertion loss of the filters do not force the amplifier into saturation.
  - Account for a loss of productivity since the switching out of filters entails additional test time.
  - High power absorptive harmonic filters may prove difficult, if not impossible to manufacture.

If the RF amplifiers are required to operate in compression…

- Reduce all RF losses in the system
  - Use good low loss RF Cabling and connectors
  - Make sure all connections are torqued to specification

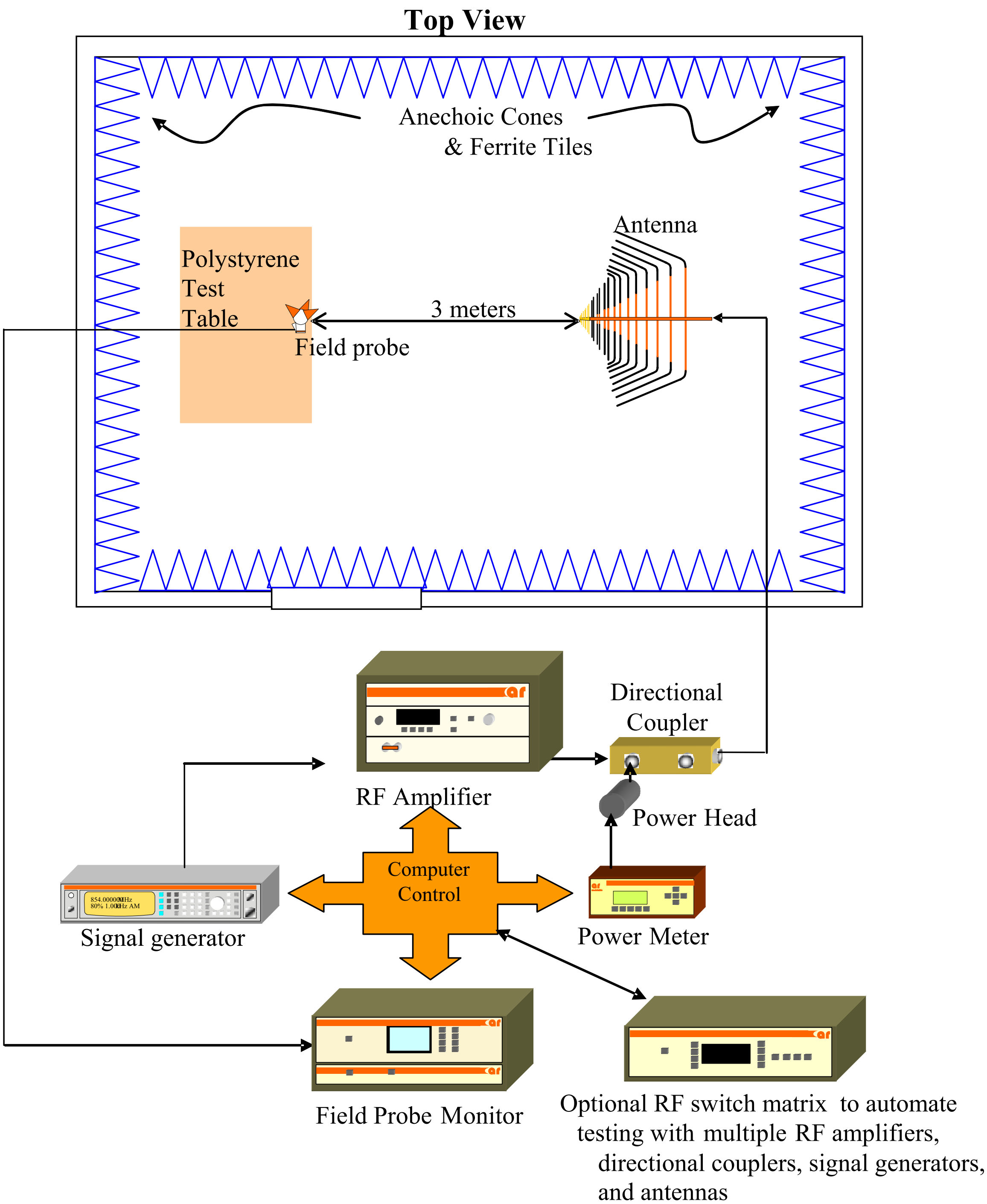
    - Insure all connectors are clean
    - Shorten RF Cabling (the amplifier may need to be moved closer to the antenna)
- Use a different RF antenna
    - Higher gain antennas will require less power
    - Keep in mind as antenna gain increases, the beamwidth decreases. A narrow beamwidth may not cover the full 1.5m x1.5m uniform field area calibration requirement. (See Appendix A for antenna coverage calculations)
        - Calibration to a smaller window is allowed above 1GHz.
    - Horn antennas will direct the energy forward better then Log antennas resulting in better field performance
- Move antenna in closer, but no less than 1 meter

If the above considerations are taken into consideration and the requirements can still not be met a new higher power amplifier may be needed.

Conclusion

The increased frequency range of this standard has brought some common test problems to light as to their contribution to test error. Continuing efforts must be taken to maintain a consistently repeatable test. Both Harmonic distortion and amplifier linearity are issues that until now have been overlooked by this standard. All RF amplifiers will produce harmonics when operated in compression. If the test requires that the amplifier be driven into compression and if the antenna and cabling can not be improved upon, a higher power amplifier will be needed. If harmonic content becomes an issue, RF filters will be needed to block out the harmonics. With AR's solid-state amplifiers, filters are not required unless the amplifier is driven into hard saturation. It is always a good idea to ask manufactures for examples of test data taken from production units. This data can aid in product selection and provide a better level of confidence of the manufactures ability to meet their published specifications. Quality of testing and repeatability should be the goal of every EMC test lab. Repeatability is the primary goal of these international test standards.

Typical Radiated Immunity Setup Diagram



AR's Solution

1 Meter Distance of Antenna from the EUT

Test Level (cal level)	Product Description	Frequency ranges		
		80 – 1000MHz	1 - 4.2 GHz	4.2 – 6+ GHz
Level 1 1V/m (1.8V/m)	Amplifier Antenna Directional coupler	10W1000C AT6080 DC3001A	1S1G4A AT4418 DC7144A	1S4G11 Same DC7440A
Level 2 3V/m (5.4V/m)	Amplifier Antenna Directional coupler	10W1000C AT6080 DC3001A	1S1G4A AT4418 DC7144A	1S4G11 Same DC7440A
Level 3 10V/m (18V/m)	Amplifier Antenna Directional coupler	50W1000B AT6080 DC3002A	5S1G4 AT4418 DC7144A	5S4G11 Same DC7440A
Level X: Medical/Scooter 20V/m (36V/m)	Amplifier Antenna Directional coupler	150W1000 AT6080 DC6180A	25S1G4A AT4418 DC7144A	15S4G8A Same DC7440A
Level 4 30V/m (54V/m)	Amplifier Antenna Directional coupler	250W1000A AT6080 DC6180A	50S1G4A AT4418 DC7144A	35S4G8A* Same DC7440A

3 Meter Antenna Distance from EUT

Test Level (cal level)	Product Description	Frequency ranges		
		80 – 1000MHz	1 - 4.2 GHz	4.2 – 6+ GHz
Level 1 1V/m (1.8V/m)	Amplifier Antenna Directional coupler	10W1000C AT6080 DC3001A	1S1G4A AT4418 DC7144A	1S4G11 Same DC7440A
Level 2 3V/m (5.4V/m)	Amplifier Antenna Directional coupler	10W1000C AT6080 DC3001A	10S1G4A AT4418 DC7144A	5S4G11 Same DC7440A
Level 3 10V/m (18V/m)	Amplifier Antenna Directional coupler	150W1000 AT6080 DC6180A	50S1G4A AT4418 DC7144A	35S4G8A* Same DC7440A
Level X: Medical/Scooter 20V/m (36V/m)	Amplifier Antenna Directional coupler	500W1000A AT6080 DC6180A	100S1G4 AT4418 DC7144A	35S4G8A* AT4003A DC7440A
Level 4 30V/m (54V/m)	Amplifier Antenna Directional coupler	1000W1000C* AT6080 DC6280AM1	200S1G4A* AT4418 DC7144A	90S4G8* AT4003A DC7440A

Note: All the antennas listed above were chosen for their broad beamwidth to meet the 1.5m x 1.5m uniform field requirement at 3 meters. While there are higher gain antennas available that require less power, their narrowband characteristics result in a uniform field that is less than that required. In general, beamwidth is inversely proportional to antenna gain. A case in point is the AT4003A recommended for level 4 testing from 4.2 GHz to in excess of 6 GHz. It is used without the gain enhancer attached to meet 1.5m x 1.5m field uniformity requirement.

*Please refer to Application Note 40A titled Subampability which explains the ability of these amplifiers to be combined to increase power and/or be separated to use sections in different locations.

Additional recommended equipment

MP06000 RF field monitor and laser power probe for 16 point field calibration
SG6000 Signal generator (100 kHz – 6 GHz)
PM2002 & PH2000 power meter and head for monitoring forward RF power from the amplifier
SC1000 RF System Controller switch matrix to facilitate system integration and reconfiguration
SW1006 RF Test Software to fully automate testing
Complete systems can be custom designed to meet your unique requirements. Please contact an applications engineer at 1-800-933-8181 to discuss your needs.

Annex A

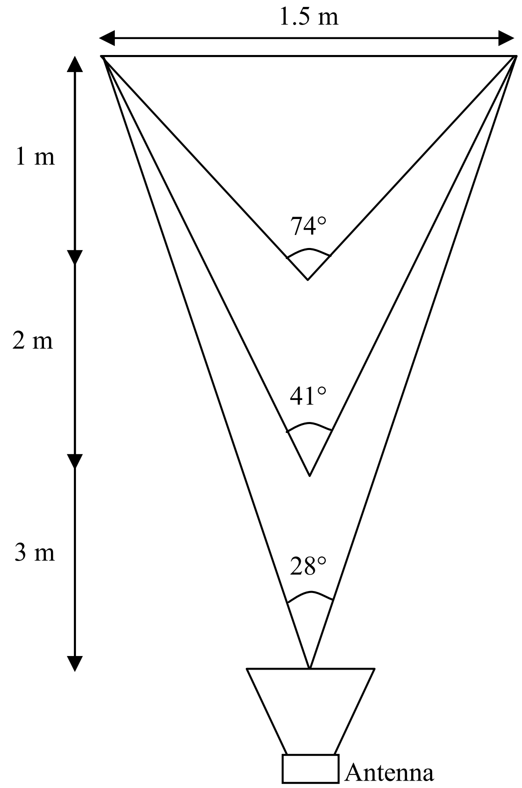
Using basic geometry we can calculate window size (spot size) from the 3dB beamwidth of the antenna.

$$\Theta = 2\tan^{-1}\left[\frac{W}{2D}\right]$$

$$W = 2D\tan\left[\frac{\Theta}{2}\right]$$

$$D = \frac{W}{2\tan\left(\Theta/2\right)}$$

$\Theta =$ 3dB beamwidth of the antenna at a specified frequency
$W =$ Window width
$D =$ Antenna distance



A selection of some of AR Worldwide's antennas:

Antenna	Frequency	3dB beam-width (deg)	Distance needed for 1.5 meter window	Window @ 1m	Window @ 3m
AT6080	1 GHz	38	2.2	0.69	2.1
AT6080	4 GHz	23	3.7	0.41	1.22
AT4418	6 GHz	37	2.2	0.67	2.0
AT4003A	6 GHz	33	2.5	0.6	1.8
AT4003A w/enhancer	6 GHz	18	4.7	0.3	0.9
AT4002A	4 GHz	13	6.6	0.2	0.7
AT4010	4GHz	26	3.2	0.46	1.4
AT4010	6GHz	16	5.3	0.28	0.84
AT4510	4GHz	20	4.2	0.4	1.0