# REDUCED EMC TEST METHOD FOR RADIATED EMISSION AND RADIATED SUSCEPTIBILITY

## ESCC Basic Specification No. 24500

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**1**  **PURPOSE**

This specification describes a test approach which allows for the characterisation of Electromagnetic Compatibility (EMC) performance of RF components, in respect of:

- A reduced test for radiated emission (RE), called a "Sniff" test.
- A reduced test for radiated susceptibility (RS), called a "Spray" test.

Such tests are typically performed on passive RF components such as isolators and circulators, power dividers and couplers. These tests may also be performed on active equipment, such as amplifiers and frequency converters.

The Sniff and Spray tests described in this specification are to be performed with an antenna made of a coaxial-to-waveguide transition fitted with a dielectric spacer, duly calibrated in order to ensure a constant distance between the probe and the device under test (DUT). The dielectric spacer can be made of PTFE rods attached to the flange of the coaxial-to-waveguide transition. A simpler solution may be used with just one dielectric spacer. These configurations are illustrated in the figures below:
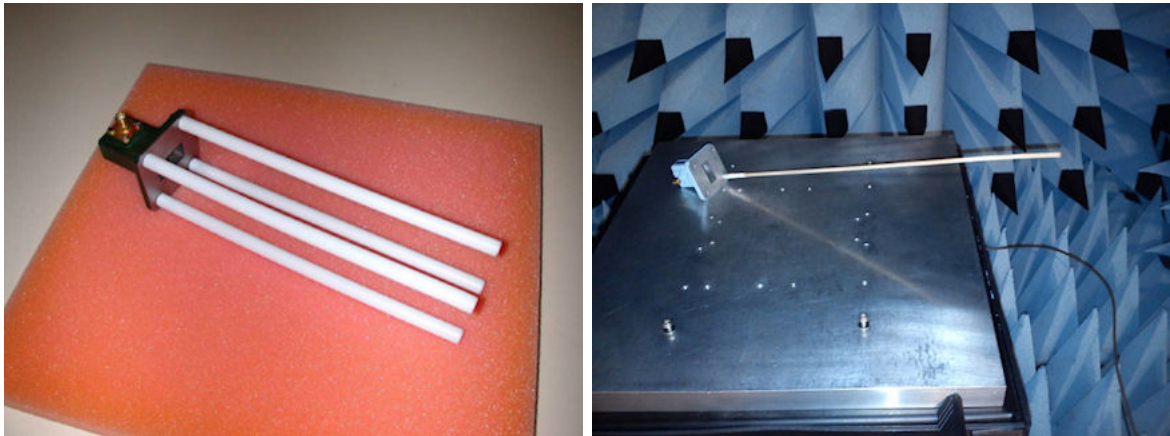


The length of the dielectric spacers shall be such that far field condition is reached:

$$\frac{2(a^2+b^2)}{o}<d$$

Where "a" and "b" are the dimensions of the aperture of the waveguide transition, "d" is the distance between the probe and the junction / DUT and "λ" refers to the centre of the pertinent measurement band, as described in paragraph 3.1

1.1    SCOPE

This specification provides a simplified test method which may be used to conduct EMC characterisation of passive RF components such as those specified in ESCC Generic Specifications No. 3202 and No. 3404. The validity of such a simplified approach, when compared with standard EMC tests, i.e. those performed in a reverberation chamber, can only be ensured through the correct calibration of the set-up which is also addressed in this specification.

The test approach is similar to EMC compatibility verification tests used for RF payloads with the intention to measure the shielding effectiveness of RF equipment or subassemblies, as described in ECSS-E-HB-20-07. However, the implementation of this simplified approach at the level of individual EEE components does not imply conformance with general space system requirements, such as those derived from ECSS-E-ST-20-07 for electromagnetic compatibility control, which may have to be verified at higher levels of integration in any case.

The test method described in this specification makes use of a test antenna made with a rectangular waveguide transition. An alternative approach might use a horn antenna instead of a waveguide transition. That case is not addressed in this specification and the useful frequency band for measurement and gain will depend on the applicable horn antenna calibration sheet.

This specification does not intend to address the methods or procedures necessary for the protection of personnel or equipment against the effect of electromagnetic radiation, for which the reader should refer and respect the applicable local regulations. However, it may be noted that, for safety reasons, the general practice is to keep waveguide-adapters at more than 0.3m distance from human heads and to avoid looking into the waveguide, as eyes shall not be heated with microwave radiation. Similarly, the signal generator should only be in RF-ON mode if and while the adapter is pointed away from the test engineer.


2    **RELATED DOCUMENTS**

The following documents form part of, and shall be read in conjunction with, this specification. The relevant issues shall be those in effect at the date of the test.


2.1    APPLICABLE DOCUMENTS
- No. 21300, Terms, Definitions, Abbreviations, Symbols and Units
- No. 21500, Calibration System Requirements
- No. 22800, ESCC Non-Conformance Control System
- No. 24900, Minimum Requirements for Controlling Environmental Contamination of Components


2.2    REFERENCE DOCUMENTS
- ECSS-E-ST-20-07, Electromagnetic Compatibility
- ECSS-E-HB-20-07, Electromagnetic Compatibility Handbook
- IEC Publication No. 60153-2 (Part 2), Hollow Metallic Waveguides - Relevant Specifications for Ordinary Rectangular Waveguides.

3    **TERMS, DEFINITIONS, ABBREVIATIONS, SYMBOLS AND UNITS**

The terms, definitions, abbreviations, symbols and units specified in ESCC Basic specification No. 21300 shall apply. In addition, the following shall apply:

Terms:

- Electromagnetic Compatibility  : Ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

- Emission  : Electromagnetic energy propagated by radiation or conduction.

- Radiated Emission  : Radiation and induction field components in space.

- Spurious Emission  : Electromagnetic emission from the intended output terminal of an electronic device, but outside of the designed emission bandwidth.

- Susceptibility  : Malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification in response to other than intended stimuli.

Abbreviations and Units:

- EMC  : Electromagnetic compatibility.

- $L_c$  : Insertion loss of coaxial cable in test set-up, in dB.

- $P_{ASA}$  : RF Power measured with a Spectrum Analyser, in dBm.

- RE  : Radiated emission. The component specification with regards to RE shall be expressed in dBµV/m.

- RS  : Radiated susceptibility.

- SE  : Shielding effectiveness, in dBi.

3.1 TEST ANTENNA - WAVEGUIDE NAMES

As explained above, the test method described in this specification makes use of a test antenna made with a rectangular waveguide transition. Standard rectangular waveguides have been defined in various systems. For convenience, this specification uses the "WR" nomenclature, where WR stands for Waveguide Rectangular and the number that follows is the inner dimension width of the waveguide, in hundredths of an inch. The cross-reference of the waveguide definitions used in this specification with their IEC designation, and the identification of the frequency band for which such waveguide should be used, for the purpose of tests specified herein, are included in the following table:

| Waveguide Rectangular | IEC 60153-2 Designation | Recommended for Tests on Bandwidth (GHz) |
|---|---|---|
| WR650 | R14 | 1.12 - 1.70 |
| WR510 | R18 | 1.44 - 2.19 |
| WR340 | R26 | 2.2 - 3.3 |
| WR229 | R40 | 3.3 - 4.9 |
| WR137 | R70 | 5.67 - 8.1 |
| WR112 | R84 | 6.97 - 10z |
| WR75 | R120 | 9.75 - 14.6 |
| WR62 | R140 | 12.40 - 18.00 |
| WR51 | R180 | 15.0 - 22.0 |
| WR42 | R220 | 18.1 - 26.1 |
| WR34 | R260 | 22.0 - 33.0 |
| WR28 | R320 | 26.1 - 39.5 |
| WR22 | R400 | 33.0 - 50.0 |

## 4 REQUIREMENTS

The formulas in this specification assume free space conditions. It may be noted that performing the tests described below will give different results for both emission and susceptibility depending on mirroring/reflections in the ground plane; hence consideration shall be given to the material of the table or support board used to hold the test set-up. A metal ground plane is in general preferred (though it may not always be necessary) and may allow for the cooling of some components, if necessary during the test, by connecting the DUT to a heat sink. It is also not possible to specify the size of the ground plane in this specification, as the difference between a small or large ground plane will not be as significant as aperture leakage on the DUT.

### 4.1 SNIFF TEST

The test aims to characterise the component with regards to the Radiated E field. The test shall be performed at ambient temperature and pressure.

### 4.1.1 Test Set-Up

The test set-up is shown in the figure below. The choice of the sniff antenna's waveguide size shall be made based on the targeted range of frequencies to be measured, as per paragraph 3.1
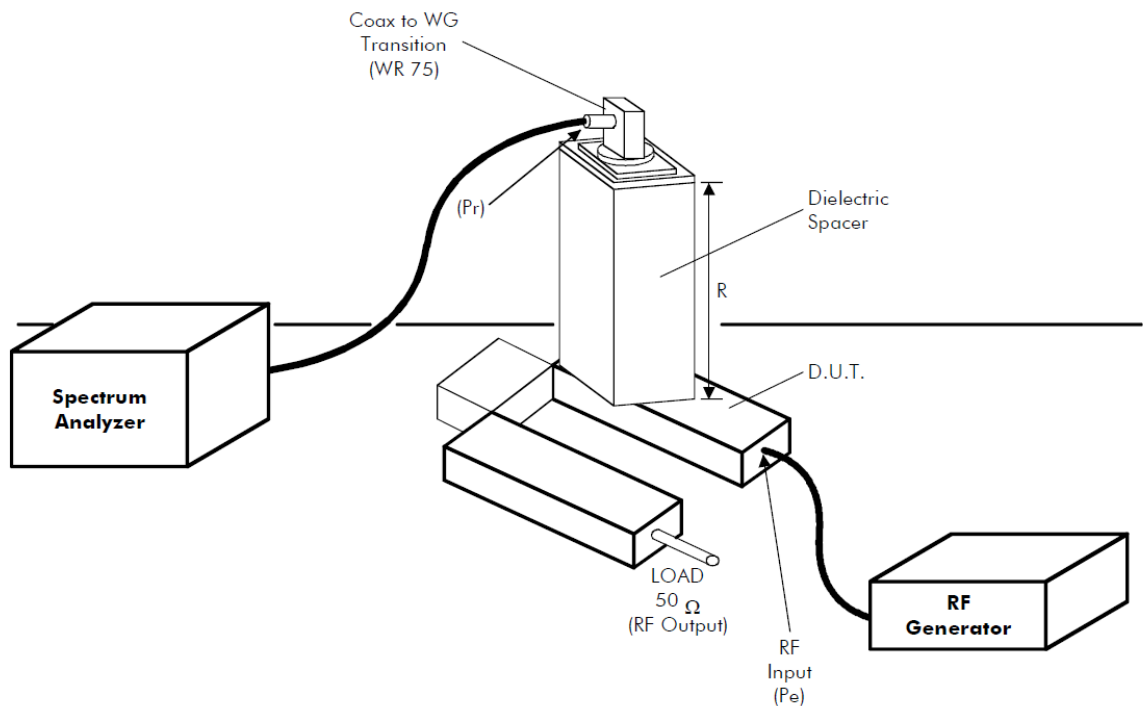


The electric field is measured at distance R from the DUT by means of the sniff antenna (coaxial-to-waveguide transition).
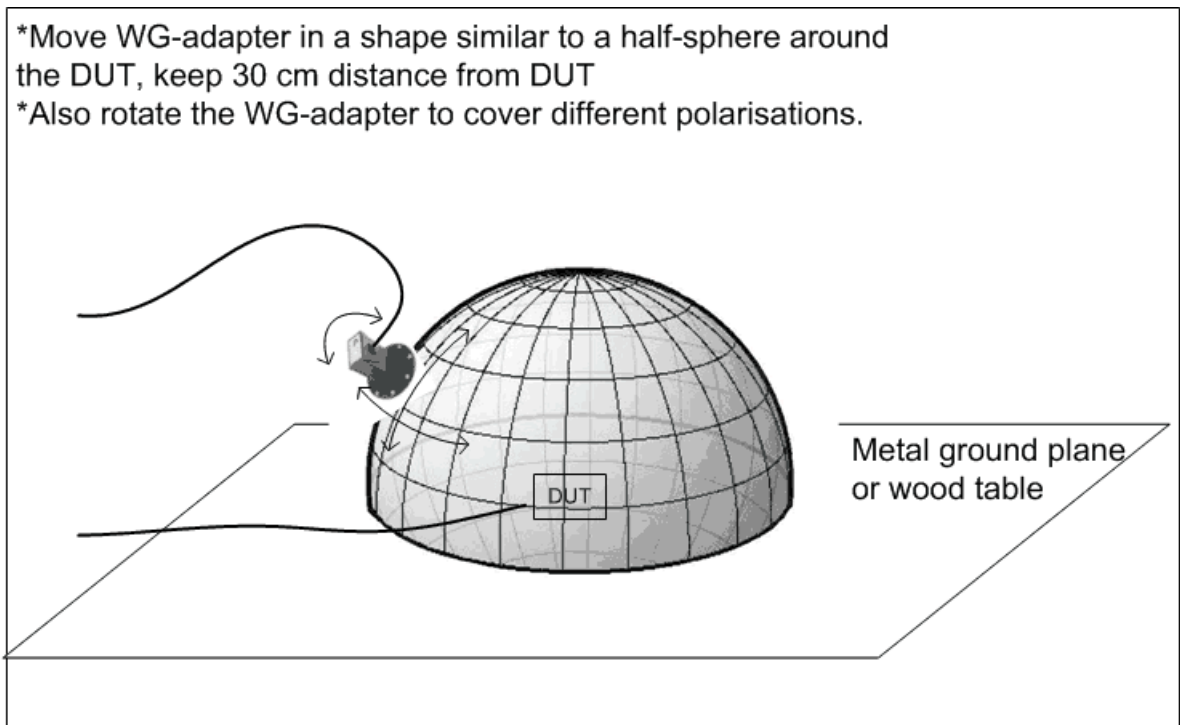
4.1.2    Sniff Test Description

The actual magnitude measured in the test set-up above is the RF Power at the Spectrum Analyser, $P_{ASA}$. This quantity is related to the RF Power at the transition, $P_r$, as follows:

- $P_{ASA}$ (dBm) = $P_{rmax}$ (dBm) – $L_c$ (dB)                                           Eq. 1

where $L_c$ amounts to the insertion loss of the coaxial link between the transition and the analyser.

The maximum value radiated by the DUT, $P_{rmax}$, is found by moving the sniff antenna around the component and by rotation of the antenna, in order to take into account the polarization of the E field. A representation of this is shown in the figure below:



*Move WG-adapter in a shape similar to a half-sphere around the DUT, keep 30 cm distance from DUT
*Also rotate the WG-adapter to cover different polarisations.

DUT

Metal ground plane or wood table

 The $P_{rmax}$ calculated with Eq. 1 may be related to the radiated emission as follows:
Let a coaxial-to-waveguide transition have a free-space gain G at frequency f. When receiving through its open waveguide aperture, the power picked up from an incident plane wave can be expressed as:

- $P_r$ (dBm at 1m) = E (dBµV/m at 1m) + G (dB) – 20log f (MHz) – 77.21                Eq. 2

4.1.3 <u>Sniff Antenna Gain Calibration</u>
The gain G will be calculated (see results in paragraph 5) or measured using two identical transitions facing each other at a distance of 1 meter. One probe will be used in transmission, the other in reception. If $P_1$ is the transmitted power and $P_2$ is the received power, then the Gain G can be calculated using the following formulas:

- $$G = \frac{4\pi\,D\,f}{C}\sqrt{\frac{P_2}{P_1}}$$      Eq. 3

where D is the distance between the two coaxial transitions.

and:

- G (dB) = 10log G      Eq. 4

The sniff antenna's gain G will be plotted for each frequency range, and the calibration curves thus obtained shall be kept with the test results.

4.1.4 <u>RE Specification Adaptation</u>
If the RE specification of the DUT is given at 1m distance, it shall be scaled down for the purpose of acceptance limits during the Sniff Test, as follows:

- For L and S-band measurements (and because the RE Sniff Test shall be performed at R = 30cm with WR510 and WR340 transitions), a quantity equal to -20log 0.30, or 10.46dB, shall be added to the value specified at 1m, which, combined with the equation Eq. 1 above, gives:

  o $P_r$ (dBm at 30cm) = E (dBµV/m at 1m) + G (dB) – 20log f (MHz) – 66.75      Eq. 5

- For C, X, Ku and Ka-band measurements (and because the RE Sniff Test shall be performed at R = 15cm with WR229, WR137, WR112, WR75, WR42 and WR28 transitions, respectively), a quantity equal to -20log 0.15, or 16.48dB shall be added to the value specified at 1m, which combined with the equation Eq. 1 above, gives:

  o $P_r$ (dBm at 15cm) = E (dBµV/m at 1m) + G (dB) – 20log f (MHz) – 60.73      Eq. 6

4.1.5 <u>Alternative Specification - Shielding Effectiveness</u>
The RE specification of a component (E field radiated at 1m distance) may also be implied by an alternative magnitude, namely its shielding effectiveness (SE). In such a case, both magnitudes are related by the following equation:

- E (dBµV/m at 1m) = $P_e$ (dBm) – SE (dBi) + 10log Z      Eq. 7

Where $P_e$ is the maximum (input) power level allowed into the DUT and Z is the impedance.

4.2 <u>SPRAY TEST</u>
The test aims to characterise the component with regards to the Radiated Susceptibility. The test shall be performed at ambient temperature and pressure.

4.2.1    Test Set-Up

An idealized version of the test set-up is shown in the figure below. The choice of the spray antenna's waveguide size shall be made based on the targeted range of frequencies to be measured, as per paragraph 3.1
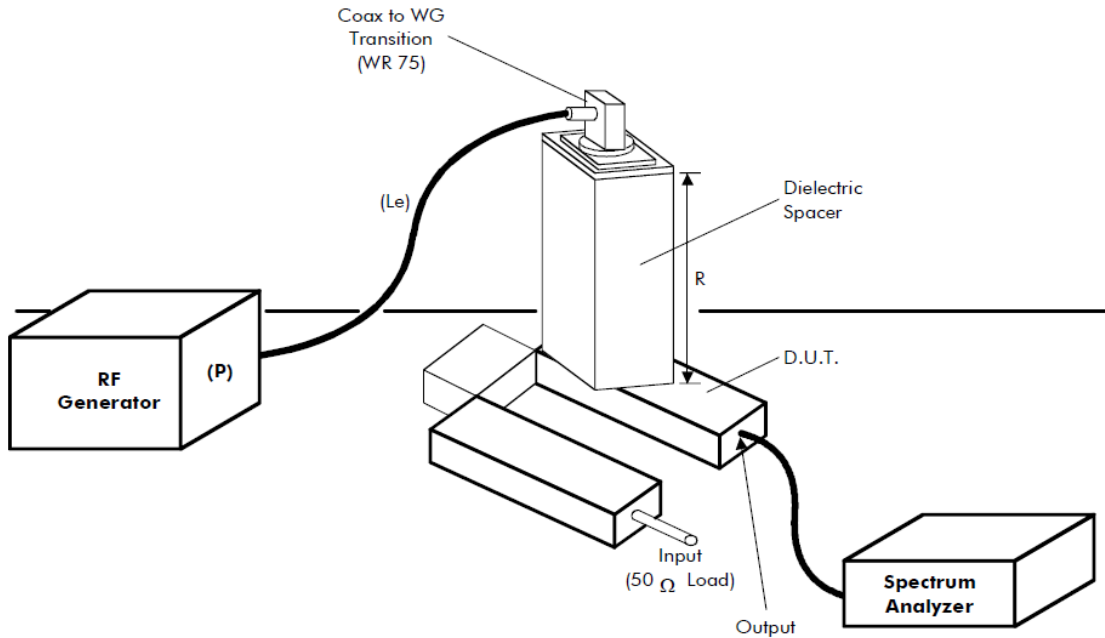


However, it must be noted that the set-up above may suffer from the applied electromagnetic field leaking into the spectrum analyser. Depending on how well the spectrum analyser is designed with respect to shielding effectiveness, it may be necessary to use anechoic material between the DUT and the spectrum analyser. A semi-rigid cable is preferred for the good shielding effectiveness performance.
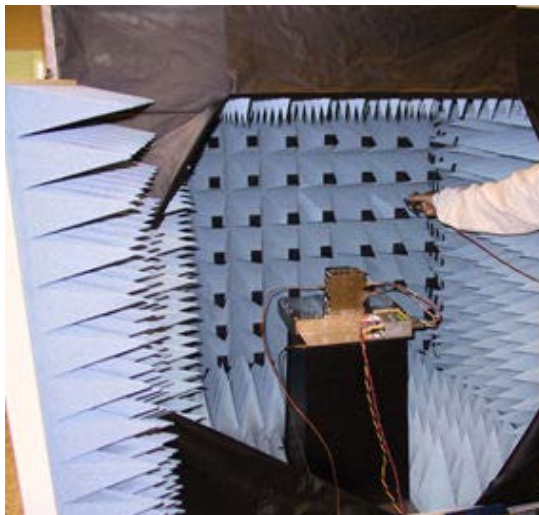


An RF signal is generated and fed into the coaxial-to-waveguide transition. As a result, an electric field is radiated by means of the spray antenna (coaxial-to-waveguide transition), its source being placed at distance R (resulting from the dielectric spacer length) from the DUT. The distance R can be chosen by the operator but shall never be in area of near field.

4.2.2    Spray Test Description
In this set-up, an electric field is applied to the DUT which is considered as a spurious receive antenna whose maximum gain, i.e. its shielding effectiveness, may be obtained by varying the position, orientation and polarisation of the spray antenna while keeping this at a constant distance (this is ensured using the coaxial-to-waveguide transition with a fixed dielectric attached, as described elsewhere in this specification

The component's specification with regards to RS will typically set a maximum $P_s$ (the power leaked into the component, or the component's output RF power, as measured by the Spectrum Analyser, in the set-up above) when the component is submitted to an external E field (the one emitted by the spray antenna) at a certain distance.

The required emission of E field by the spray antenna will comply with:

- $$\mathrm{EIRP} = \frac{\mathrm{E}^2 \cdot \mathrm{R}^2}{30}$$                                           Eq. 8

Effective isotropic radiated power, EIRP, is the product of the power radiated by the spray antenna (as measured at the input of the transition) by the gain G of this transition in the direction of the DUT so that:

- EIRP (dBm) = 20log E (V/m) + 20log R (m) + 15.23                              Eq. 9

The Power P (in dBm) to be generated by the RF Generator in the test set-up in order to achieve the E field required by the RS specification, will be set in accordance with the following expressions, depending of the distance R to be used for measurement:

If R = 0.30m – distance usually used for antennas with WR510 and WR340:

- P (dBm) = 20log E (V/m) + Coax. Losses (dB) – G (dB) + 4.77                    Eq. 10

Whereas, if R = 0.15m – distance usually used for antennas with WR229, WR137, WR112, WR75, WR62, WR51, WR42, WR28 or WR22:

- P (dBm) = 20log E (V/m) + Coax. Losses (dB) – G (dB) – 1.25                    Eq. 11

where the Coax. Losses correspond to the insertion loss of the coaxial link between the RF generator, and the coaxial transition and the gain G shall be calculated (calibrated) as specified in Para. 4.1.3

4.2.3    Alternative Specification - Shielding Effectiveness
The RS specification of a passive component may also be implied by an alternative magnitude, namely its shielding effectiveness (SE). In such a case, the magnitude and the maximum power leaked into the component, $P_s$, are related by the following equation:

- $P_s$ (dBm) = 20log E (V/m) – SE (dBi) – 20log f (MHz) + 42.78                    Eq. 12

where E is the field to be applied for a certain RS specification and f is the signal measurement frequency.

## 5    CALCULATED WAVEGUIDE TO COAXIAL TRANSITION CALIBRATIONS

The gain will always be between 4 to 7.5dB for any standard waveguide transition. The rest of this paragraph includes data for some of the WR transitions mentioned in this specification.

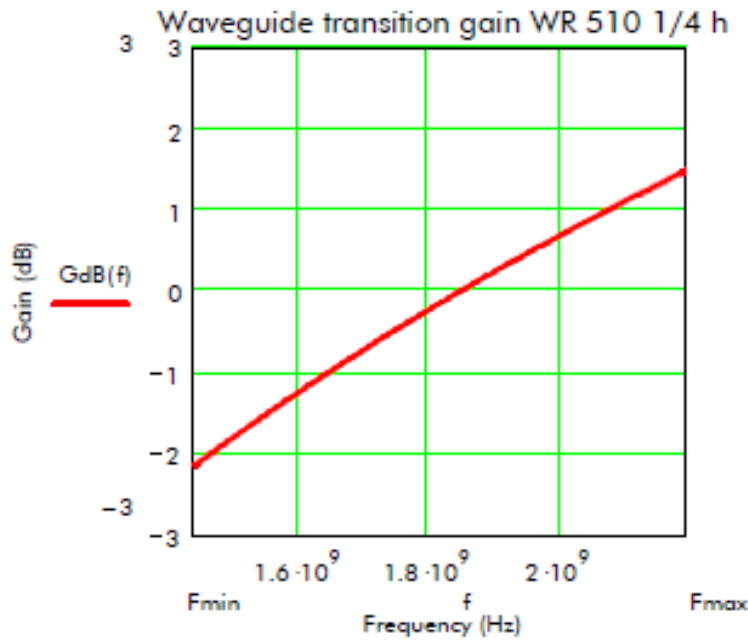### 5.1    DATA FOR THE WR510 TRANSITION (1.44 – 2.19GHZ)
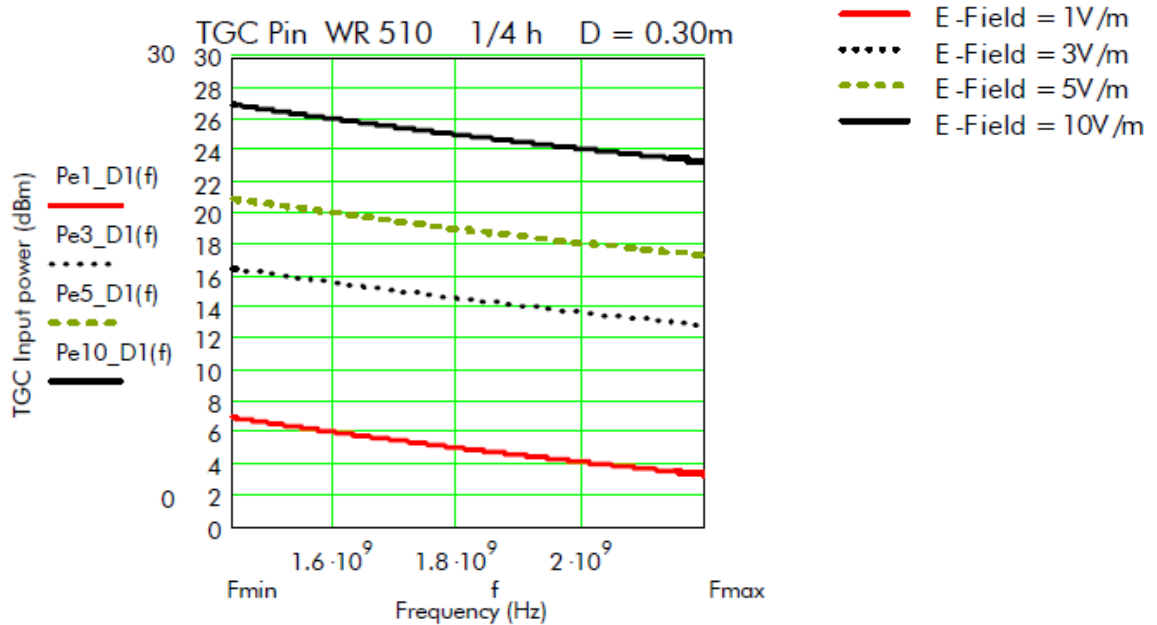
WR510 transition Gain calculation result:
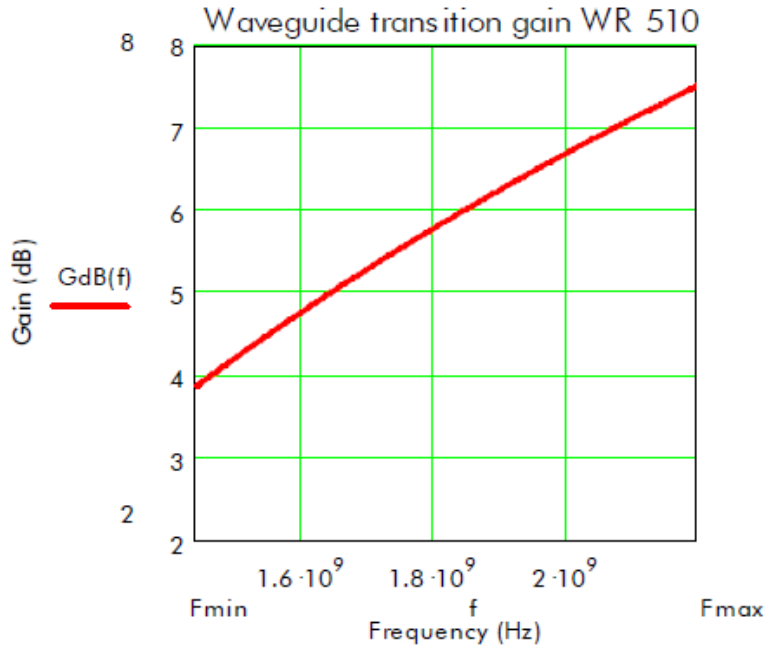


Power in dBm on the WR510 transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.30m of the DUT:
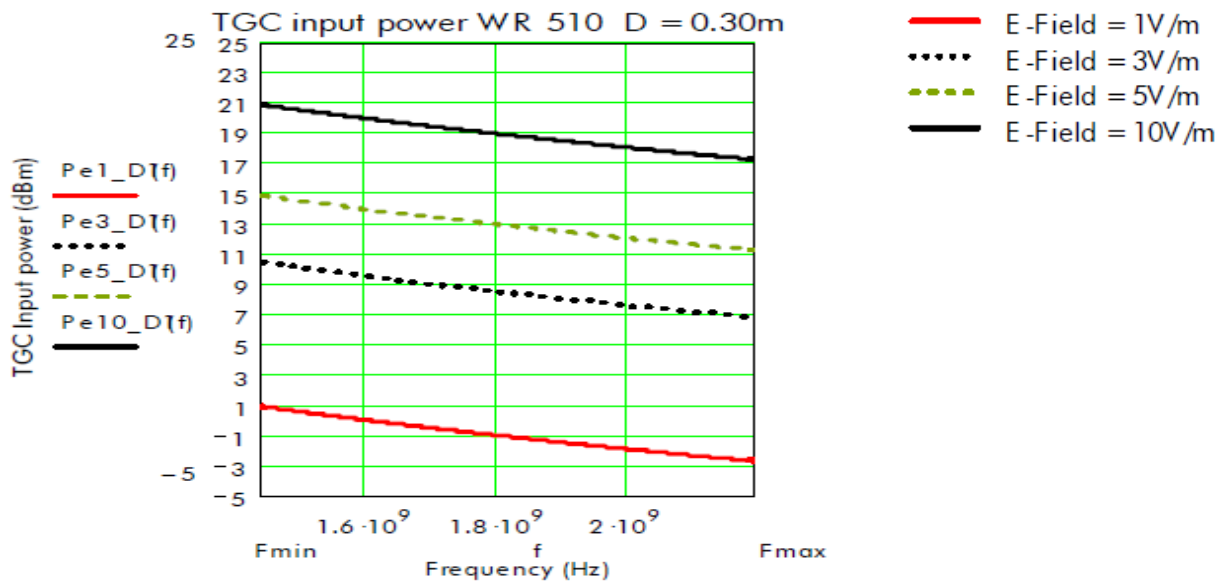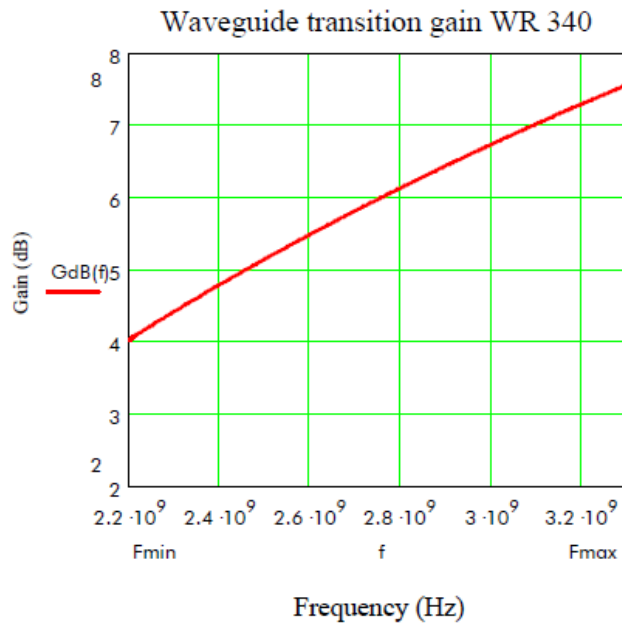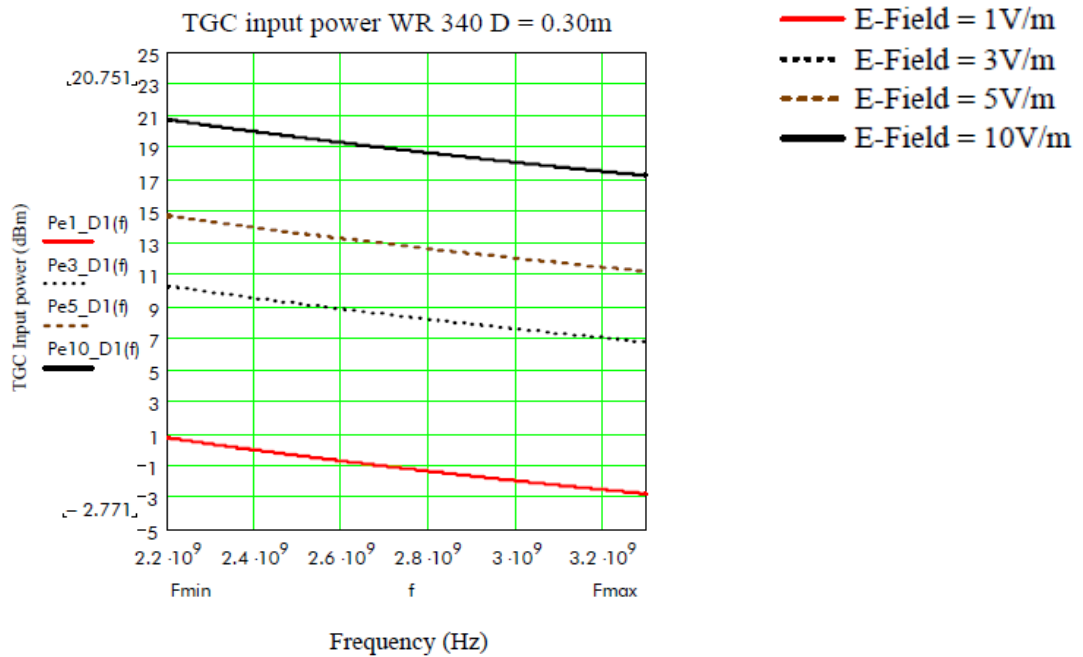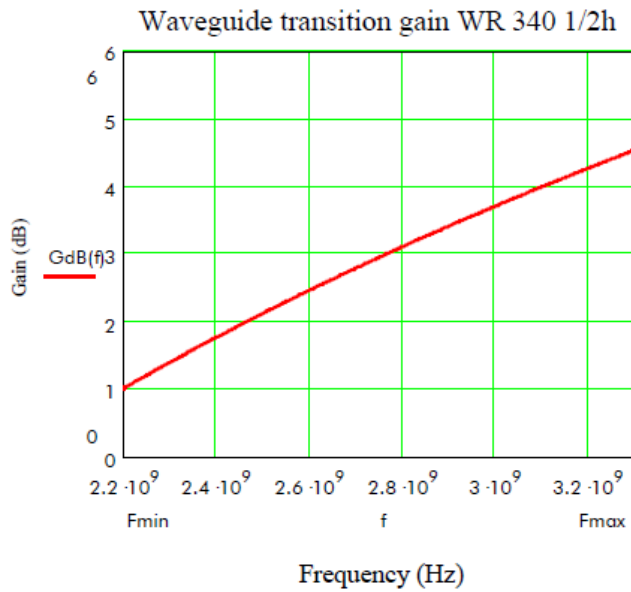
5.2     DATA FOR THE WR510 "1/4 HEIGHT" TRANSITION (1.44 – 2.19GHZ)
        WR510 "1/4 height" transition gain calculation result:
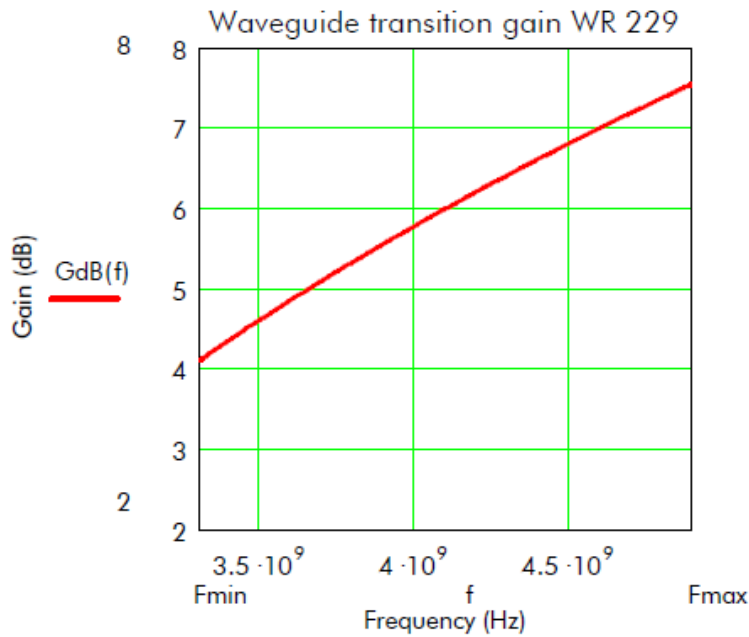


Power in dBm of the WR510 "1/4 height" transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.30m of the DUT:
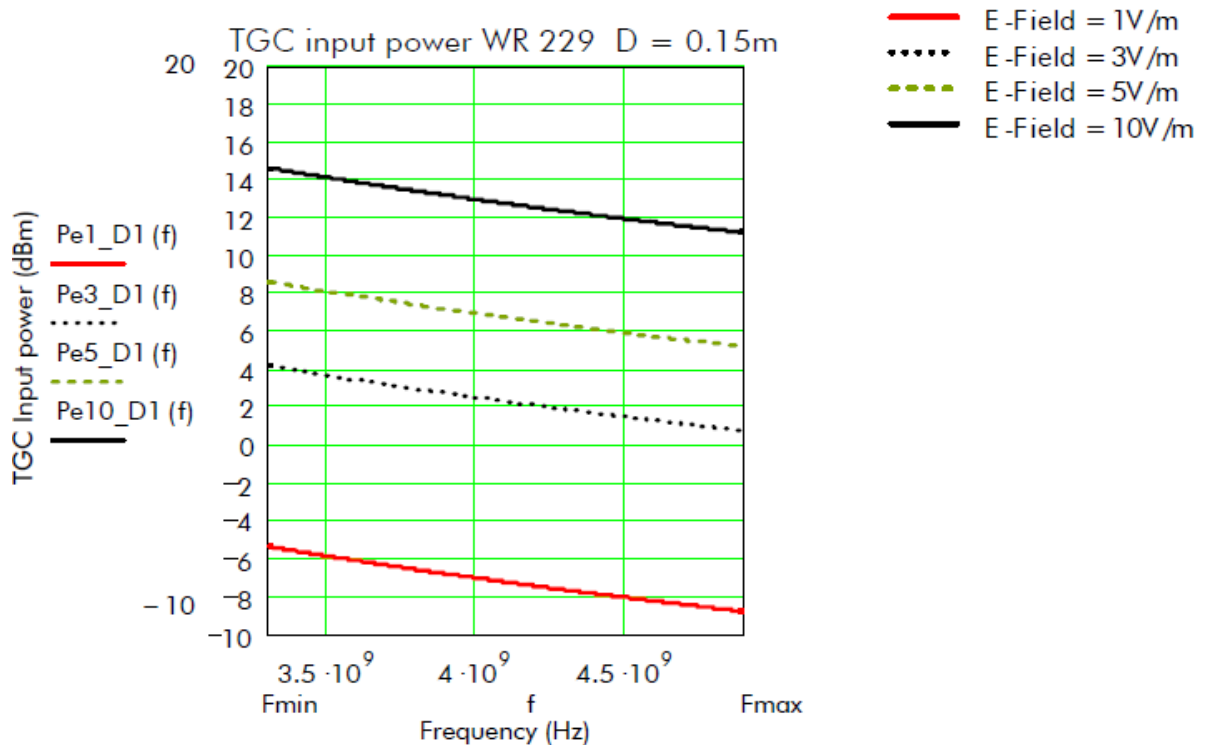
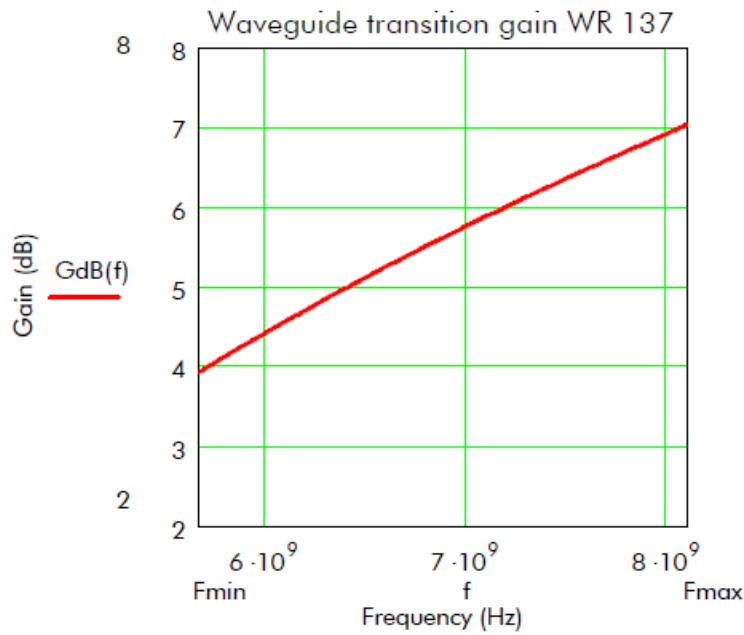5.3     DATA FOR THE WR340 TRANSITION (2.2 – 3.3GHZ)
        WR340 transition Gain calculation result:



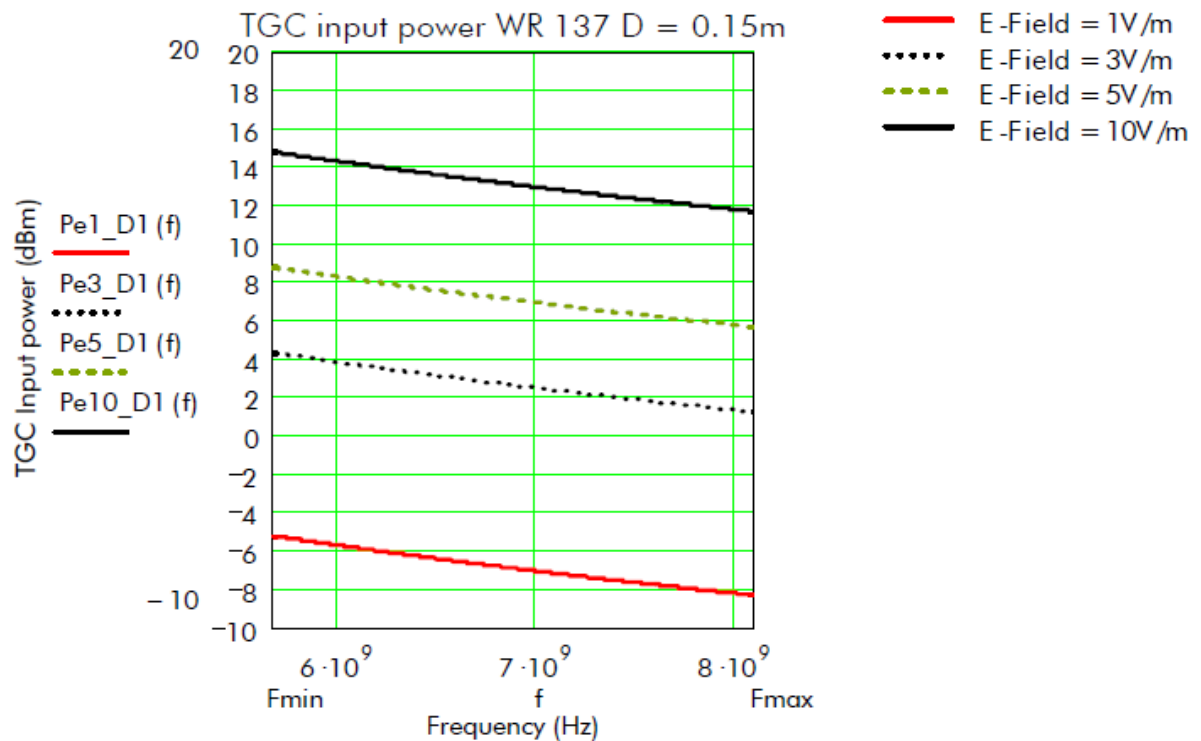Power in dBm of the WR340 transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.30m of the DUT:

5.4     DATA FOR THE WR340 "1/2 HEIGHT" TRANSITION (2.2 – 3.3GHZ)
WR340 "1/2 height" transition Gain calculation result:



Waveguide transition gain WR 340 1/2h

Power in dBm of the WR340 "1/2 height" transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.30m of the DUT:



TGC input power WR340 1/2h D = 0.30m
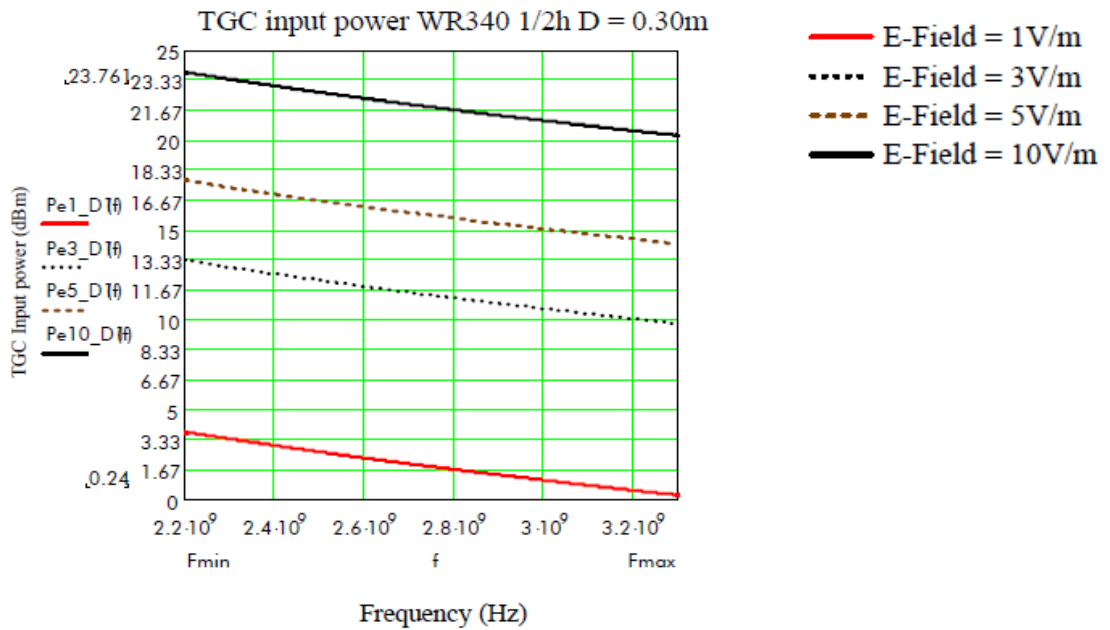
5.5    DATA FOR THE WR229 TRANSITION (3.3 – 4.9GHZ)
       WR229 transition Gain calculation result:



Power in dBm of the WR229 transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.15m of the DUT:

5.6    DATA FOR THE WR137 TRANSITION (5.67 – 8.1GHZ)
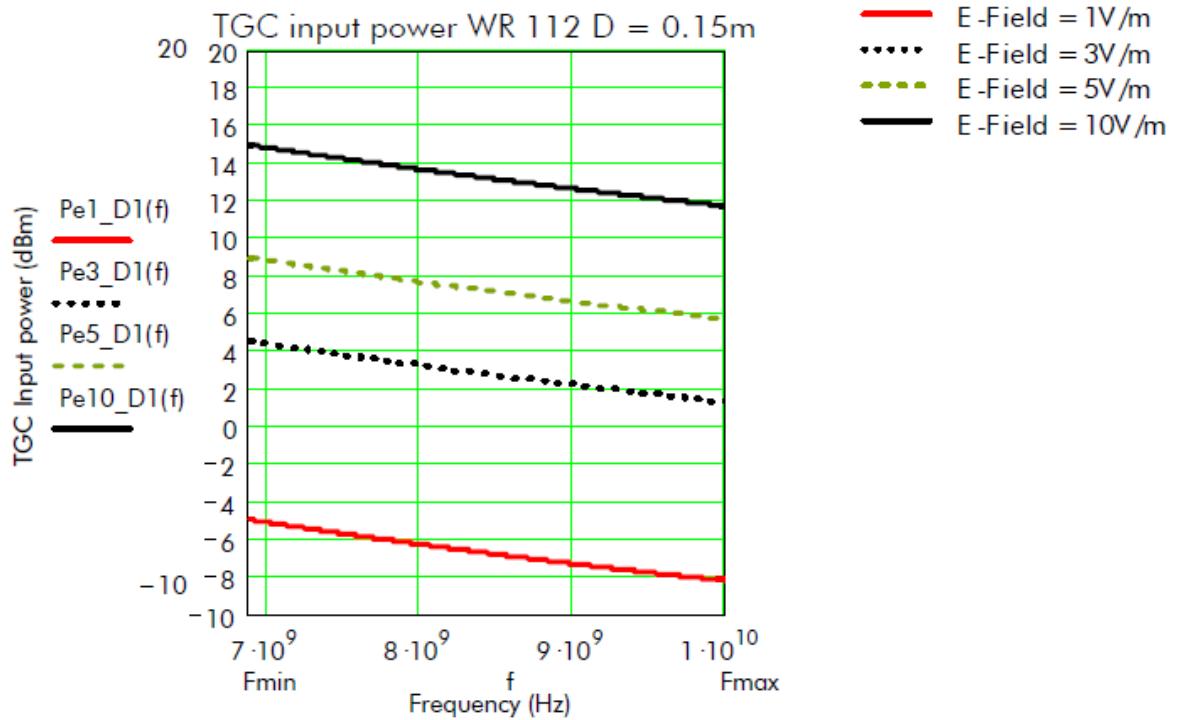
WR137 transition gain calculation result:



Power in dBm of the WR137 transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.15m of the DUT:
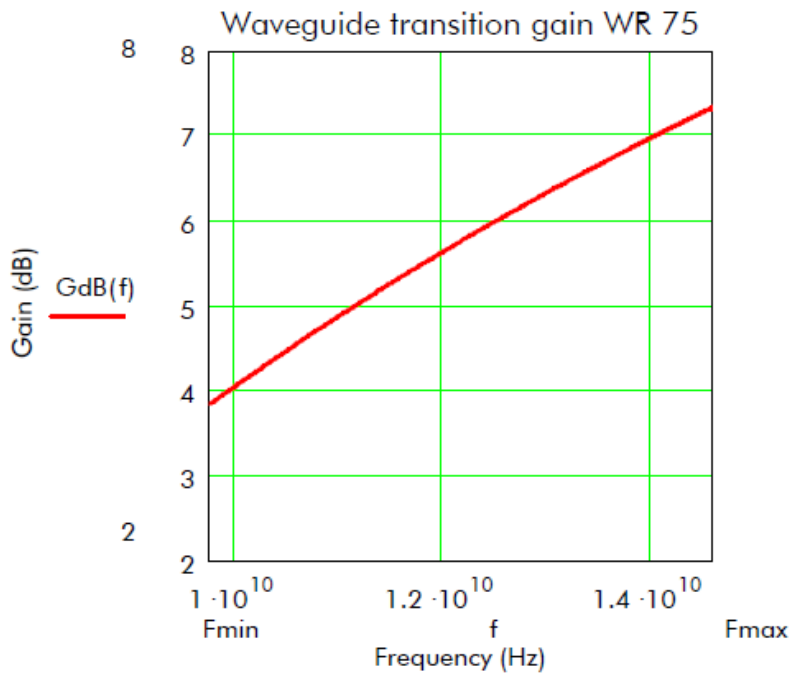
5.7    DATA FOR THE WR112 TRANSITION (6.97 – 10GHZ)
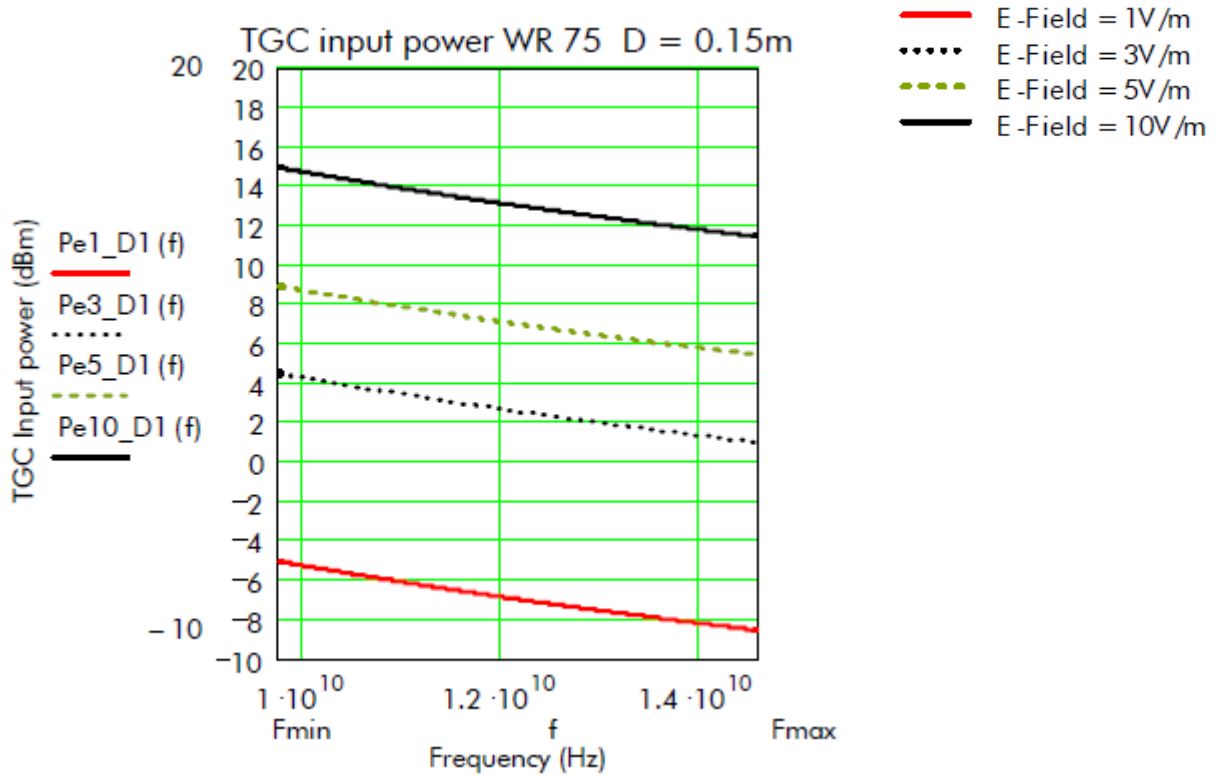WR112 transition gain calculation result:
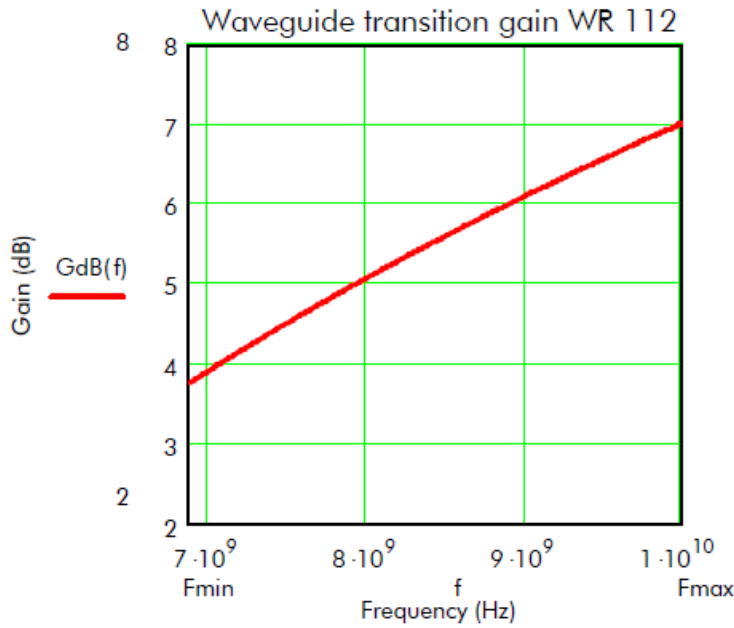


Power in dBm of the WR112 transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.15m of the DUT:
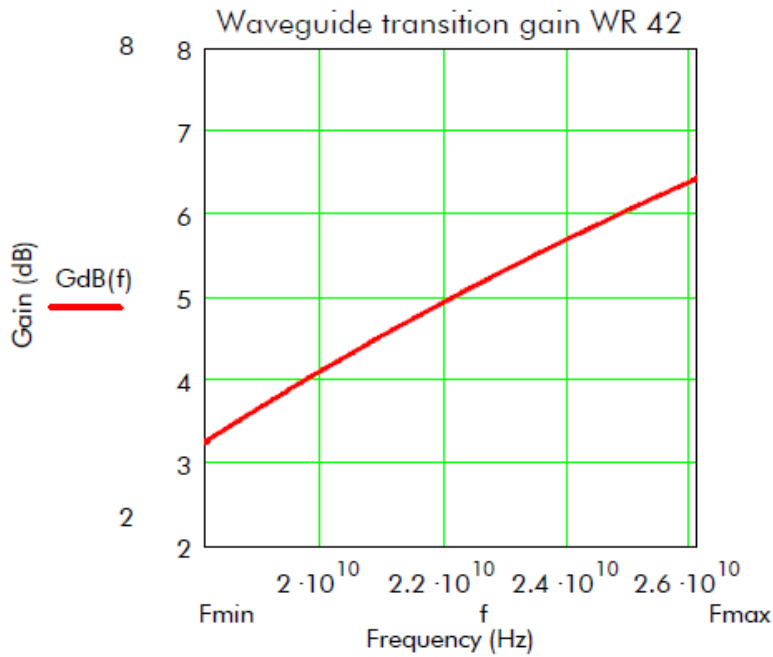
5.8    DATA FOR THE WR75 TRANSITION (9.75 – 14.6GHZ)
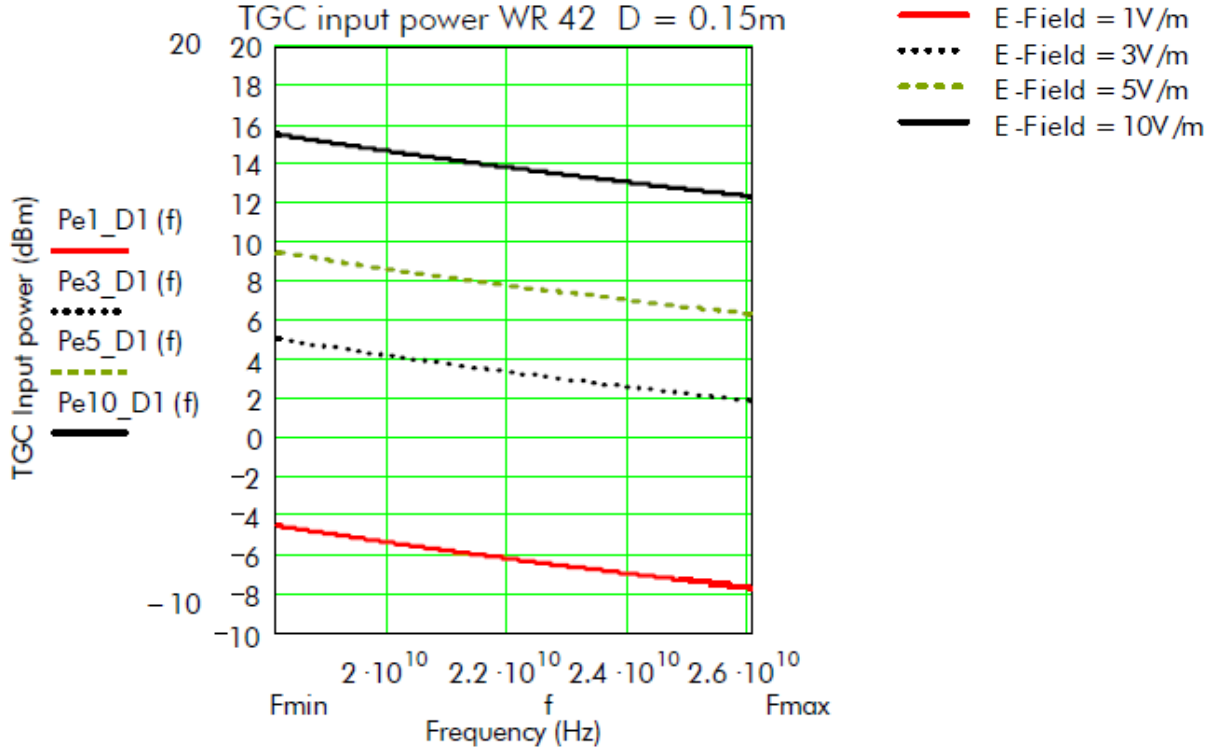WR75 transition Gain calculation result:



Waveguide transition gain WR 75

Power in dBm of the WR75 transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.15m of the DUT:



TGC input power WR 75  D = 0.15m

5.9    DATA FOR THE WR42 TRANSITION (18.1 – 26.1GHZ)
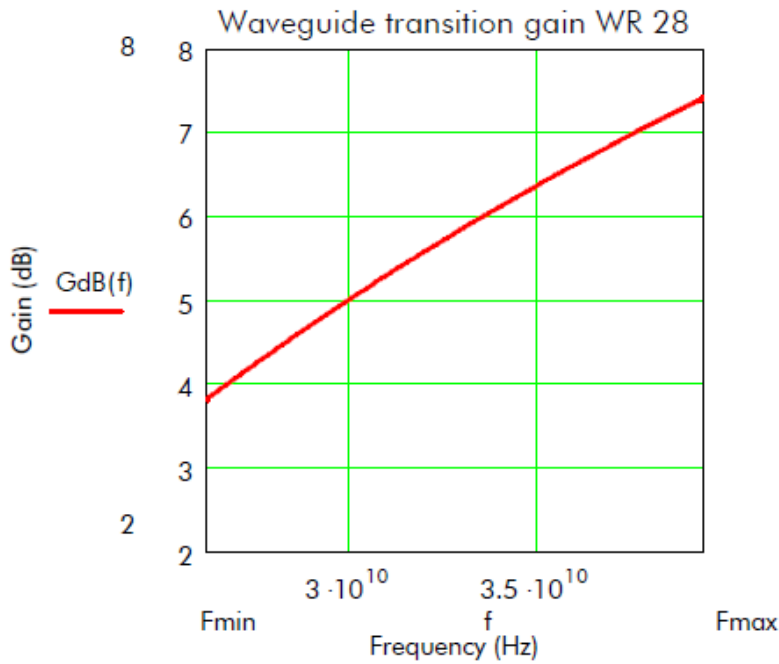
WR42 transition Gain calculation result:



Power in dBm of the WR42 transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.15m of the DUT:

5.10     DATA FOR THE WR28 TRANSITION (26.1 – 39.5GHZ)

WR28 transition Gain calculation result:



Power in dBm of the WR28 transition to obtain the radiated electric field of 1V/m, 3V/m, 5V/m and 10V/m at 0.15m of the DUT: