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Safety Test Solutions
an L3 Communications Company

Applicaton Note

Antenna Parameters: Antenna Gain, Directivity, and Conversion Factor

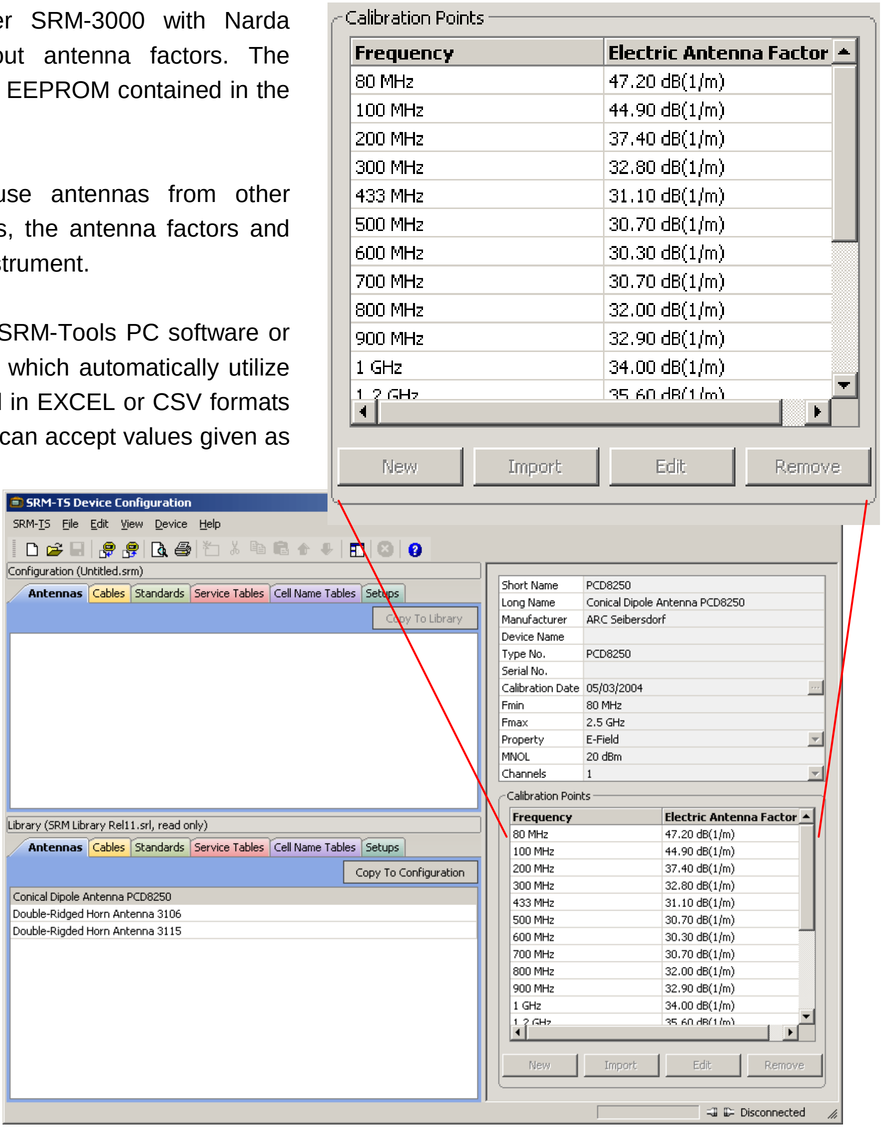
The background for combining various antennas with the Selective Radiation Meter SRM-3000

If you use the Selective Radiation Meter SRM-3000 with Narda antennas, you don't need to worry about antenna factors. The instrument automatically reads them from an EEPROM contained in the plug of the auxiliary control cable.

Sometimes, though, you may want to use antennas from other manufacturers with the SRM. In such cases, the antenna factors and correction values can be imported into the instrument.

This process is simplified by using the free SRM-Tools PC software or the more sophisticated SRM-TS application, which automatically utilize the tables of values that are usually provided in EXCEL or CSV formats by the antenna manufacturers. The software can accept values given as conversion factors, antenna factors, or antenna gain and then converts them automatically.

You don't need to worry about the conversion, either. Nevertheless, it is useful to know something about the physical and mathematical background to the conversion. This Application Note gives you a brief outline of this.



Configuration (Untitled.srm)

Library (SRM Library Rel11.srl, read only)

Conical Dipole Antenna PCD8250
Double-Ridged Horn Antenna 3106
Double-Rigded Horn Antenna 3115

Short Name	PCD8250
Long Name	Conical Dipole Antenna PCD8250
Manufacturer	ARC Seibersdorf
Device Name	
Type No.	PCD8250
Serial No.	
Calibration Date	05/03/2004
Fmin	80 MHz
Fmax	2.5 GHz
Property	E-Field
MNOL	20 dBm
Channels	1

Frequency	Electric Antenna Factor
80 MHz	47.20 dB(1/m)
100 MHz	44.90 dB(1/m)
200 MHz	37.40 dB(1/m)
300 MHz	32.80 dB(1/m)
433 MHz	31.10 dB(1/m)
500 MHz	30.70 dB(1/m)
600 MHz	30.30 dB(1/m)
700 MHz	30.70 dB(1/m)
800 MHz	32.00 dB(1/m)
900 MHz	32.90 dB(1/m)
1 GHz	34.00 dB(1/m)
1.2 GHz	35.60 dB(1/m)

Antenna factors in the PC-Software SRM-TS

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Principles

It is useful in field strength measurements to characterize the receiving antenna by its conversion factor K_E as well as by the antenna gain. The relationship between them is described here.

The (lossless) receiving antenna used has a gain of G (or directivity) referred to a virtual isotropic receiver.
It has an absorption area of

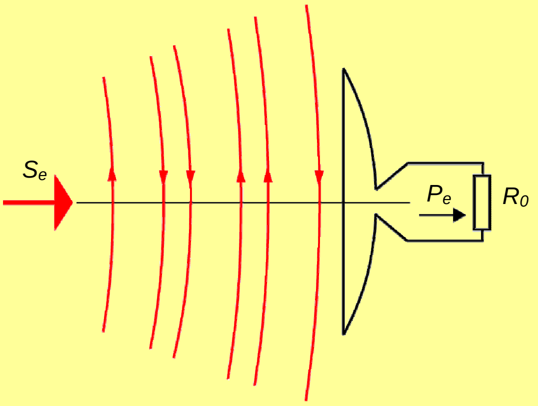
$$A_e = \frac{P_e}{S_e} = G \cdot \frac{\lambda^2}{4\pi} \qquad (1)$$

In the homogeneous far-field, the power density S_e gives the available receive power level:

$$P_e = S_e \cdot A_e = \frac{E^2}{\eta_0} \cdot G \cdot \frac{\lambda^2}{4\pi} \qquad \text{where } \eta_0 = 120\pi \ [\Omega] \qquad (2)$$

With impedance matching this results in a voltage U_0 across the load impedance $R_0 = 50\ \Omega$ of the receiver:

$$U_0 = \sqrt{P_e \cdot R_0} = E \cdot \sqrt{G \cdot \frac{\lambda^2}{4\pi \cdot \eta_0} \cdot R_0} \qquad (3)$$



Receiving antenna in an electromagnetic field

Conversion factor to gain conversion

The conversion factor K_E of the antenna is defined as the ratio of the electric field strength E to the output voltage U_0 at the measuring receiver with 50 Ω input impedance:

$$K_E = \frac{E}{U_o} = \frac{1}{\lambda} \cdot \sqrt{\frac{4\pi \cdot \eta_0}{G \cdot R_0}} = \frac{f}{c_0} \cdot \sqrt{\frac{4\pi \cdot \eta_0}{G \cdot R_0}} = \frac{f}{c_0 \cdot \sqrt{G}} \cdot \sqrt{\frac{480\pi^2}{50}} \qquad (4)$$

Using the speed of light in a vacuum $c_0 = 299.79 \cdot 10^6$ m/s, this gives the following equation between quantities:

$$K_E = \frac{f\,/\text{MHz}}{299.79} \cdot \frac{9.7339}{\sqrt{G}} = \frac{f\,/\text{MHz}}{299.79} \cdot \frac{9.7339}{\sqrt{G}} \qquad (5)$$

Since it is usually easier in field strength measurements to work with voltage and field strength levels, i.e. logarithmic quantities, it is practical to take the logarithm of the conversion factor:

$$k_E = 20 \cdot \log K_E \qquad \text{in units of dB (1/m)} \qquad (6)$$

The logarithm of the conversion factor is usually called the antenna factor (AF) even though strictly speaking it is not a factor but rather the logarithm of a factor.

From equation (5) we can then derive the following relationship between the antenna factor and the antenna gain g in dBi (referred to the isotropic receiver):

$$k_E = 20 \cdot \log\left(f/\text{MHz}\right) - 29.7707\text{dB} - g \tag{7}$$

where

$$g = 10\text{dB} \cdot \log\left(G\right) \tag{8}$$

Examples

Example 1:
Tuned λ/2 dipole
at its particular resonance frequency

	Gain (directivity)		Antenna factor (AF)
f [MHz]	G [1/m]	g [dBi]	k_E [dB(1/m)]
100	1.64	2.15	8.08
300	1.64	2.15	17.62
1000	1.64	2.15	28.08
3000	1.64	2.15	37.62

Tuned λ/2 dipoles
are suitable for precision measurements at a fixed frequency, The antenna gain gi of 2.15 dBi means they are very sensitive. They are not suitable, however, for multi-frequency environments such as are normally found where measurements for human safety limit values need to be made.

Example 2:
Biconical dipole antenna SBA 9113

	Gain (directivity)		Antenna factor (AF)
f [MHz]	G [1/m]	g [dBi]	k_E [dB(1/m)]
500	0.28	-5.46	29.67
600	1.09	0.39	25.40
750	1.12	0.51	27.22
1000	0.86	-0.67	30.90
2000	1.20	0.80	35.45
3000	0.82	-0.87	40.64

Biconical dipole antennas
provide high sensitivity with antenna gain g_i in the region of 0 dBi, but the frequency range covered is not as broad as that of a broadband dipole antenna (example 4).

Example 3: Log periodic antenna USLP 9143

	Gain (directivity)		Antenna factor (AF)
f [MHz]	G [1/m]	g [dBi]	k_E [dB(1/m)]
300	3.67	5.65	14.12
1000	5.05	7.03	23.20
2000	4.35	6.38	29.87
3000	3.82	5.82	33.95

Log periodic antennas
are extremely sensitive, having an antenna gain g_i of 5 to 7 dBi. At the same time, they are highly directional and have a relatively high bandwidth. They are therefore eminently suitable for determining the direction of radiation sources. If they are to be used for measuring the overall field exposure level in terms of human safety limit values, however, a complicated and very precise procedure is required if all radiation components are to be detected reliably.

Example 4:
Single-axis antenna 3531/01 for SRM-3000

	Gain (directivity)		Antenna factor (AF)
f [MHz]	G [1/m]	g [dBi]	k_E [dB(1/m)]
27	4.68E-06	-53.30	52.16
100	3.80E-04	-34.20	44.43
300	5.62E-03	-22.50	42.27
900	6.61E-02	-11.80	41.11
1000	8.32E-02	-10.80	41.03
1800	1.88E-01	-7.25	42.58
2100	1.74E-01	-7.60	44.27
2500	1.66E-01	-7.80	45.99
2800	1.41E-01	-8.50	47.67
3000	8.91E-02	-10.50	50.27

The single-axis E-field antenna 3531/01
covers an extremely wide frequency range from 27 MHz to 3 GHz. It is suitable for measuring overall field exposure levels using the pendulum method, and is the antenna of choice in applications where the sensitivity of the three-axis E-field antenna 3501/01 (example 5) is insufficient.

Isotropic measurements can also be made with the single-axis antenna. There is a special antenna holder available for this which allows you to place the antenna in a sequence of three defined positions. This method is supported by a wizard function in the SRM basic unit.

Example 5:
Three-axis antenna 3501/01 for SRM-3000

	Gain (directivity)		Antenna factor (AF)
f [MHz]	G [1/m]	g [dBi]	k_E [dB(1/m)]
100	1.00E-05	-50.00	60.23
300	5.62E-04	-32.50	52.27
900	1.29E-02	-18.90	48.21
1000	1.78E-02	-17.50	47.73
1800	5.62E-02	-12.50	47.83
2100	4.17E-02	-13.80	50.47
2500	2.82E-02	-15.50	53.69
2800	2.43E-02	-16.15	55.32
3000	2.16E-02	-16.65	56.42

The three-axis E-field antenna 3531/01
measures isotropically i.e. non-directionally, so it is a real “all-rounder” for practically all measurements determining limit values at a location or for human safety purposes. Its broad frequency range from 75 MHz to 3 GHz is obtained at the expense of relatively low sensitivity, but this is completly adequate for demonstrating equipment limit values and for most public area emission measurements.

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