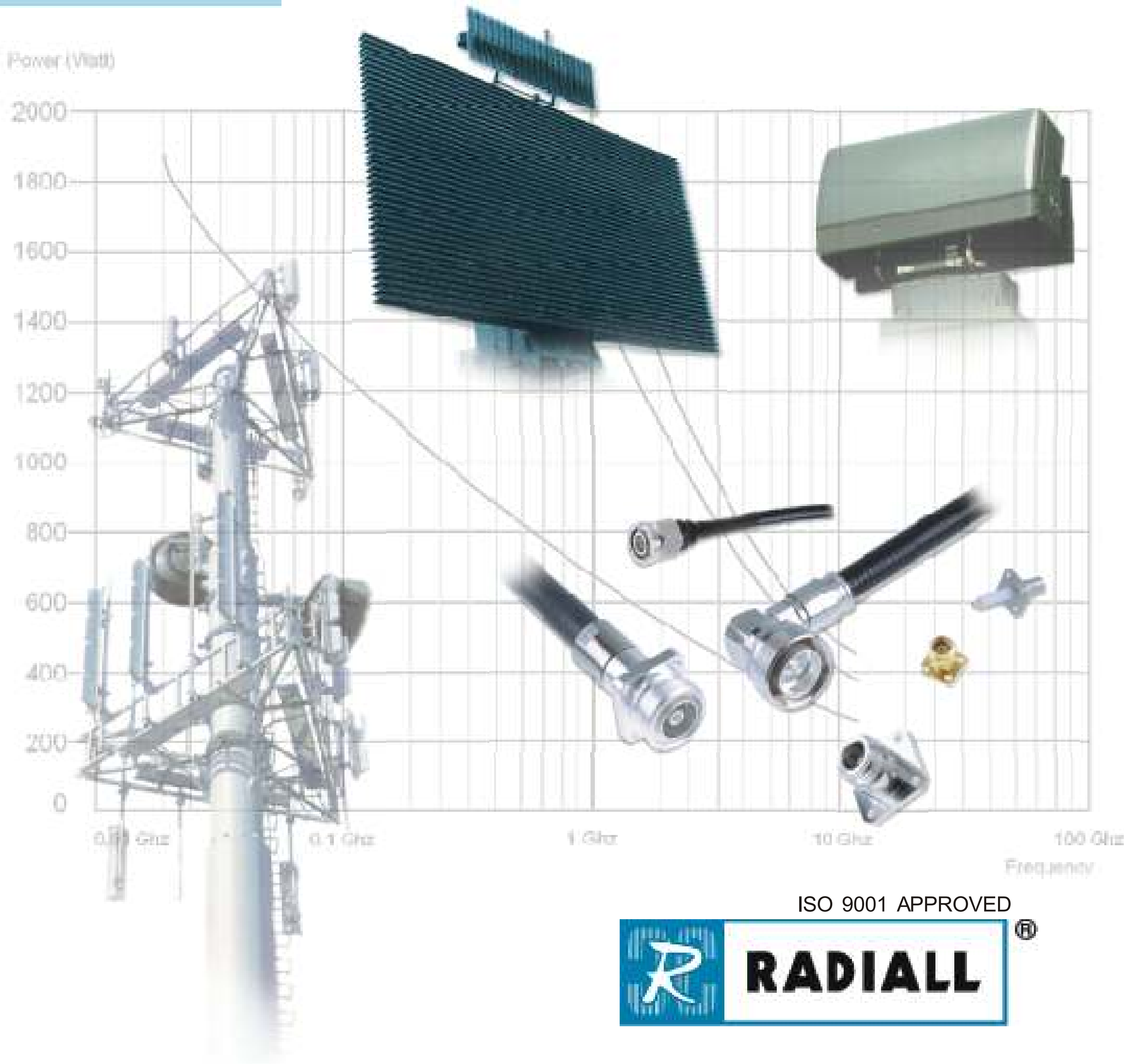
RF INTERCONNECT PRODUCTS

Technology guide for power calculation



ISO 9001 APPROVED

RADIALL ®

CONNECTOR RF POWER WITHSTAND

The maximum power conveyed through a coax connector is limited by two factors : **heat** and **dielectric strength**.

I - MAXIMUM PERMISSIBLE HEAT POWER

Part of the power conveyed through the connector turns into heat due to the dielectric and ohm losses of the materials involved.

The connector temperature becomes stable at about a value for which the heat generated by the dissipated power is equal to the heat released by the connector as radiation, conduction and convection.
Such temperature must remain lower than the acceptable limit for each material in the connector.
This determines the "**maximum permissible heat power**".

II - DIELECTRIC STRENGTH

Beyond a power threshold, the electrical field inside the connector causes the materials to wear out or fail early. This factor defines the "**maximum permissible voltage withstand power**".

Test bench

DEFINITIONS

Z_C system's characteristic impedance (Ω)

P power in watts. This is the peak power in pulse systems

U_{max} maximum voltage : in V

C_F **(frequency correction)** : this takes into account the skin effect and the dissipation part in the dielectric that varies according to the frequency.

C_T **(temperature correction)** : this takes into account the external environment temperature and its impact on radiation and convection. This coefficient is calculated for infinitely long revolution symmetry structures. Therefore, it does not apply to panel receptacles. However, even in this case, it provides a conservative approach.

C_R **(VSWR correction)** : this takes into account any standing waves present in the power transmission line. It is the system's V.S.W.R., but not the connector's V.S.W.R. For instance, in the case of a line operating in open or short circuit, the power present at each point of the connector can be multiplied by 4.

C_A **(altitude correction)** : this takes into account the convection decrease when the pressure drops, for instance in a non-pressurized area of a plane.

Please contact us for coefficient values relevant to a specific reference.

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I - MAXIMUM PERMISSIBLE HEAT POWER

The maximum permissible heat power depends upon several parameters :

1 - Internal Heat Generation

Parameters :

- Base materials and plating resistivity
- Contact area resistivity
- Dissipation in dielectric materials (Teflon, polypropylene, epoxy, etc.)
- Usage frequency
- Conveyed power and waveform
- Presence of standing waves

The higher these parameters, the higher the amount of heat released.

2 - Heat Released in the Surrounding Environment

Parameters :

- Heat exchange on the surface with the outside
- Outside surface emissivity (gold plated, passivated surfaces)
- Quality of thermal bonds with surrounding parts (heat bridges, panels, etc.)
- Air flow (free or forced convection, connector and cable position)
- Temperature and pressure of the surrounding environment
- Heat release path from the connector core to the outside.

The heat is released better when any of the above parameters increases, except for the temperature that has the opposite effect.

3 - Permissible Temperature Limits :

Parameters :

- Solder temperature at the center contact and ground contact
- Dielectric materials used in the connector and cable (Teflon, polypropylene, epoxy, etc.)
- Permissible surface temperature
- Material creeping or strain relief temperature

To determine the maximum permissible allowed heat power, it is necessary to know precisely the internal components of the connectors and cables, as well as the actual product usage environment. It is therefore essential that customer and supplier work together.

Simulation software

Several approaches are possible :

A) SIMPLE APPROACH : This approach provides some permissible power values for most popular connector series and their typical internal components.
This is the approach that we develop in this document. It is based on simple calculation models confirmed with some tests.
This is an indicative approach. It should be completed with a more realistic, theoretical or experimental approach.
The maximum conveyable power value is calculated as follows :

a → **Find the reference power P_{REF} ***
Refer to the tables in the following pages or contact us to get a value for a specific reference.

b → **Calculate correction factors ***
See formulas in the following pages

c → **Calculate the product of all these terms ***
$P = P_{REF} \times C_F \times C_T \times C_R \times C_A$

In the case of a repeated pulse signal, the power (P) calculated by the above formula is an average power. In such a case, check that the peak voltage remains acceptable.

Note : This is a rough calculation approach. It does not replace experimentation in the real world.

** see definitions page 3*

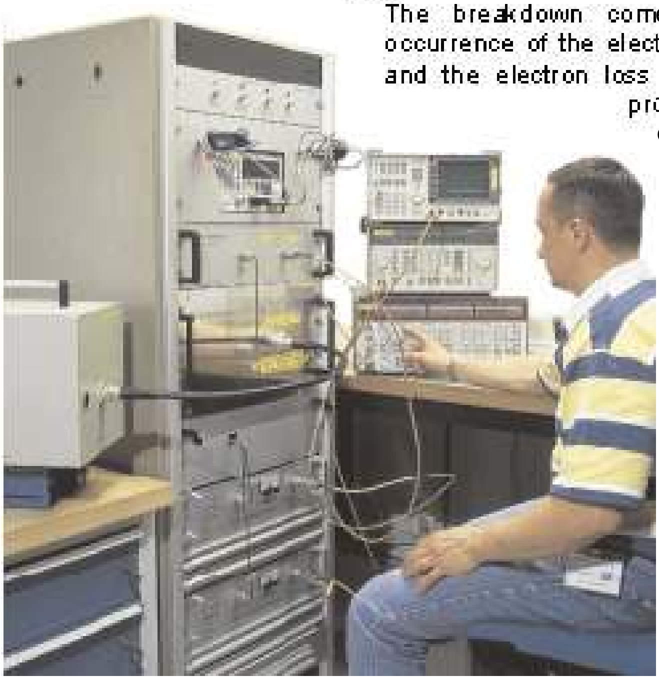
B) REALISTIC THEORETICAL APPROACH : This approach uses developed models, such as finite element methods. This requires having an accurate knowledge of the connector's environment and the material characteristics. This is a lengthy and costly approach. It can be used in difficult cases where experimentation is too complex. It also requires experimental adjustments but in conditions that are more accessible to experimentation.

C) EXPERIMENTAL APPROACH : The actual application is implemented using a specific material. Such an experimental approach is usually carried out by the final user.

II - DIELECTRIC STRENGTH

1 - The dielectric strength is based on some parameters

The insulation breakdown and the corona effect depend on the electric field inside the coax line. The type and consequences of the breakdown may vary according to the dielectric materials. In the case of a solid insulator, the breakdown will destroy the dielectric, which causes a conductive path to occur along the carbonized walls of the arc track. If the breakdown threshold is not reached, vacuum in the dielectric may cause local field reinforcements. This may lead to partial discharges. Over time, such discharges will erode the dielectric and cause early aging. In the case of a air insulator, the breakdown is not necessarily destructive. Such breakdown will occur depending on ambient pressure, type of gas, opposite surface cleanliness and line geometry (macro geometry : sharp edges ; micro geometry : surface finish, burrs). All of these phenomena have a complex dependency upon frequency.



Control bench

2 - Dielectric strength and pressure effect (air dielectric)

This is a well-known phenomenon : as pressure drops, disruptive voltage falls. It dips to a minimum for a critical value of the pressure multiplied by the distance between the electrodes. It then increases for very low pressure. The variation of the disruptive voltage according to the pressure follows the Paschen law. It provides that for a breakdown to occur, shocks between gas molecules and electrons must cause the electrons to multiply (the avalanche effect). The disruptive voltage is then directly related to the number of gas molecules between both electrodes. This number is proportional to the product of the pressure by the distance between both electrodes.
In the case of coax connectors, the field is not homogeneous and the Paschen law does not apply directly. However, it provides a qualitative assessment of the disruptive voltage according to the pressure.

3 - Dielectric strength and frequency effect (air dielectric)

In microwave, breakdown will occur according to much more complex rules. Electrons present between both conductors are driven by the alternating electromagnetic field.
The breakdown comes from the simultaneous occurrence of the electron production phenomenon and the electron loss phenomenon. The electron production is the result of free electrons colliding with gas molecules or conductors. It requires minimum kinetic energy. The electron loss is the result of electrons being spread and drained through conductors. The breakdown occurs when more electrons are produced than used. This is expressed by the Townsend criteria.

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At ambient pressure, the average free travel of electrons is very small, and there are many shocks but they are not effective for electron production. The breakdown occurs at a high voltage that is practically independent from the frequency.

Test installation

At low pressure, the average free travel of electrons increases. Electrons gain kinetic energy and ionize gas molecules more effectively. The breakdown voltage then falls to a minimum. At this minimum, there are two phenomena regarding the influence of frequency. First, if frequency is low and rising, the breakdown will occur at increasingly lower voltage levels (less electron drainage by the conductors). Then, if frequency keeps rising, the breakdown will occur at a higher voltage (because the electron oscillation magnitude becomes too low to ionize the gas molecules effectively).

For the range of distance between conductors in the connectors, note that a frequency increase does not have any influence at high pressure and it actually improves the dielectric strength at low pressure. This latest effect can not be quantified in a simple way.

Anechoïd chamber

4 - Dielectric strength and V.S.W.R.

The presence of mismatches at various points in a line leads to the occurrence of standing waves that increase the electrical field locally. The maximum voltage at any point will therefore be :

$$U_{max} = U_{inci} \cdot \frac{2\ \text{V.S.W.R.}}{\text{V.S.W.R.}+1}$$

Where V.S.W.R. is the V.S.W.R. of the system and U_{inci} is the incident voltage.
U_{max} will have to be compared to the maximum permissible voltage for the connector.

5 - How to calculate a maximum withstand voltage

a) At ambient pressure :
Just check that the maximum voltage does not exceed the permissible value for the series by following this formula :

$$U_{max} = \frac{2\ \text{V.S.W.R.}}{\text{V.S.W.R.}+1} \cdot \sqrt{P \times Z_C}\,*$$

b) At any other pressure :
The derating coefficient from the following table must be applied to the maximum permissible voltage.

Pression *(mbar)*	Derating	Altitude *(feet)*	Altitude *(km)*
1,000	1	0	0
480	0.5	20,000	6
200	0.25	40,000	12
80	0.12	60,000	18
59	0.10	70,000	21

* *see definitions page 3*

CALCULATION FORM

Values are given for a V.S.W.R. of 1 and an outside temperature of 20°C at sea level.

CALCULATION FORM

You must multiply the reference power of the used series (see table below) by the various correction factors (see the following page)

$$P = P_{REF} \times \underbrace{C_F \times C_T \times C_R \times C_A}_{\text{CORRECTION FACTORS}}$$

REFERENCE POWER

		P_{REF} *(Watt)*	F_{REF} *(GHz)*
MMS	FR4 coplanar line	40	.9
MMT	FR4 coplanar line		
MCX	right-angle on cable 2/50	100	
	right-angle "full crimp" on cable 2/50	120	
	on cable 2.6/50	150	
	right-angle "full crimp" on cable 2.6/50	200	
SMB	right-angle on cable 2/50	100	
	right-angle "full crimp" on cable 2/50	120	
	on cable 2.6/50	150	
	right-angle "full crimp" on cable 2.6/50	200	
SMA	on cable .141"	100	18
	on cable .141" microporous and SHF 8	130	
	with contact captivation by epoxy resin	40	
BMA	on cable .141"	100	
	on cable .141" microporous and SHF 8	130	
	with contact captivation by epoxy resin	40	
QMA	on cable 2.6/50/D	150	2.5
	on cable 5/50/D		
TNC	right-angle "full crimp" on cable 5/50 or 11/50*	350	11
TNC 18 GHz	on cable .141"	140	18
	on cable SHF 8	150	
	on cable SHF 5	170	
N	right-angle "full crimp" on cable 5/50 or 11/50*	350	11
N 18 GHz	male plug on cable .141" and cable SHF 8	170	18
	female jack on cable .141" and cable SHF 8	150	
QN	right-angle "full crimp" on cable 5/50 or 11/50*	350	2.5
7/16	on cable 11/50*	800	7.5

* *provided that the cable supports such power levels.*

Please consult us for other cables or series.

CALCULATION FORM

CORRECTION FACTORS

<table>
<tr><th></th><th>C_F
Frequency *(GHz)*</th><th>C_T
Temperature *(°C)*
C_T max =1</th><th>C_R
max V.S.W.R.
view from connector</th><th>C_A
Altitude *(h in Km)*
for absolute vacuum,
$C_A = 0.2$</th></tr>
<tr><td>**MMS**</td><td rowspan="2">$C_F = .95 \times F^{-0.52}$
C_F max = 3</td><td rowspan="2">$C_T = 1 - \frac{7.55\ (T-20)}{1{,}000}$</td><td rowspan="13">$C_R = \frac{(V.S.W.R.+1)^2}{4\ (V.S.W.R.)^2}$</td><td rowspan="13">$C_A = 1 - .033 \times h$</td></tr>
<tr><td>**MMT**</td></tr>
<tr><td>**MCX**</td><td rowspan="2">$C_F = .96 \times F^{-0.36}$
C_F max = 20</td><td rowspan="5">$C_T = 1 - \frac{7.5\ (T-20)}{1{,}000}$</td></tr>
<tr><td>**SMB**</td></tr>
<tr><td>**SMA**</td><td rowspan="2">$C_F = 3.55 \times F^{-0.44}$
C_F max = 20</td></tr>
<tr><td>**BMA**</td></tr>
<tr><td>**QMA**</td><td>$C_F = 1.5 \times F^{-0.44}$
C_F max = 13</td></tr>
<tr><td>**TNC**</td><td>$C_F = 3.47 \times F^{-0.5}$
C_F max = 20</td><td>$C_T = 1 - \frac{5\ (T-20)}{1{,}000}$</td></tr>
<tr><td>**TNC 18 GHz**</td><td>$C_F = 3.55 \times F^{-0.44}$
C_F max = 20</td><td>$C_T = 1 - \frac{7.5\ (T-20)}{1{,}000}$</td></tr>
<tr><td>**N**</td><td>$C_F = 3.47 \times F^{-0.5}$
C_F max = 20</td><td>$C_T = 1 - \frac{5\ (T-20)}{1{,}000}$</td></tr>
<tr><td>**N 18 GHz**</td><td>$C_F = 4.47 \times F^{-0.52}$
C_F max = 20</td><td rowspan="3">$C_T = 1 - \frac{7.5\ (T-20)}{1{,}000}$</td></tr>
<tr><td>**QN**</td><td>$C_F = 1.58 \times F^{-0.5}$
C_F max = 20</td></tr>
<tr><td>**7/16**</td><td>$C_F = 2.51 \times F^{-0.46}$
C_F max = 15</td></tr>
</table>

ALTITUDE/PRESSURE (for information)

Altitude *(Km)*	0	6	12	18
Altitude *(feet)*	0	20,000	40,000	60,000
Pressure *(mbar)*	1,000	480	200	80

A complete range of power devices is also available.

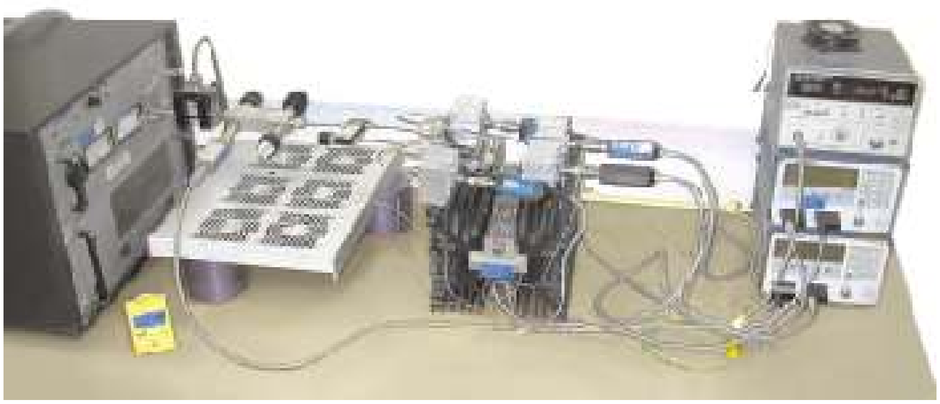
CATALOG P/N

COMPACT	D1 D004 BE
MMS	D1 C209 CE
MMT	D1 C210 CE
MCX	D1 C113 CE
SMB	D1 C114 CE
SMA	D1 C125 CE
BMA	D1 C128 DE

QMA	D1 C123 CE
TNC-TNC 18 GHz	D1 C143 CE
N	D1 C161 CE
N 18 GHz	D1 C163 CE
QN	D1 C164 CE
7/16	D1 C185 CE

RADIALL POWER BENCHES

RADIALL is equipped with two power benches : a 935MHz bench and a 17.6GHz bench. These measurement benches allow carrying out power tests on coax and microwave products at specified temperature or in space vacuum.



Power bench #1

Power bench #2

CHARACTERISTICS

	Bench #1	Bench #2
Frequency	935 MHz	17.6 GHz
Space vacuum encl. temperature	from -60°C to +100°C	
pressure	from ambient pressure to 10-5 mbars	
Max power	400 W	500W
Temperature station	16 channels -K thermocouple	

APPLICATIONS

- Standard coax cable assemblies
- SHF coax cable assemblies for space applications
- Switching products
- Microwave power products (loads, couplers, attenuators, etc.)