Draka

Receiving success: Draka RF Solution

Mobile Radio Cables, 50 Ohm cables, Antenna cables and special solutions transmitted by Draka

How can we help you build your network?

Who is Draka Communications?

Draka Communications – a member of Draka Holding N.V. located in Amsterdam – offers a versatile and reliable range of copper and optical fibre cables for the transmission in the data and telecommunication industry.

Our long-lasting expertise in cable and fibre business has been the basis for us holding a major market position today.

Draka Communications is located in more than 32 countries in Europe, Asia, North America and South America.

For many decades, we have been designing, developing, manufacturing and selling a variety of high-quality copper and optical fibre cables in order to offer you cable solutions for present and future challenges - Let it be standard products or tailor-made special cables.

In the communication infrastructure, our well proven products are always in use wherever it is a question of professional and undisturbed data, voice, audio and video transmission.

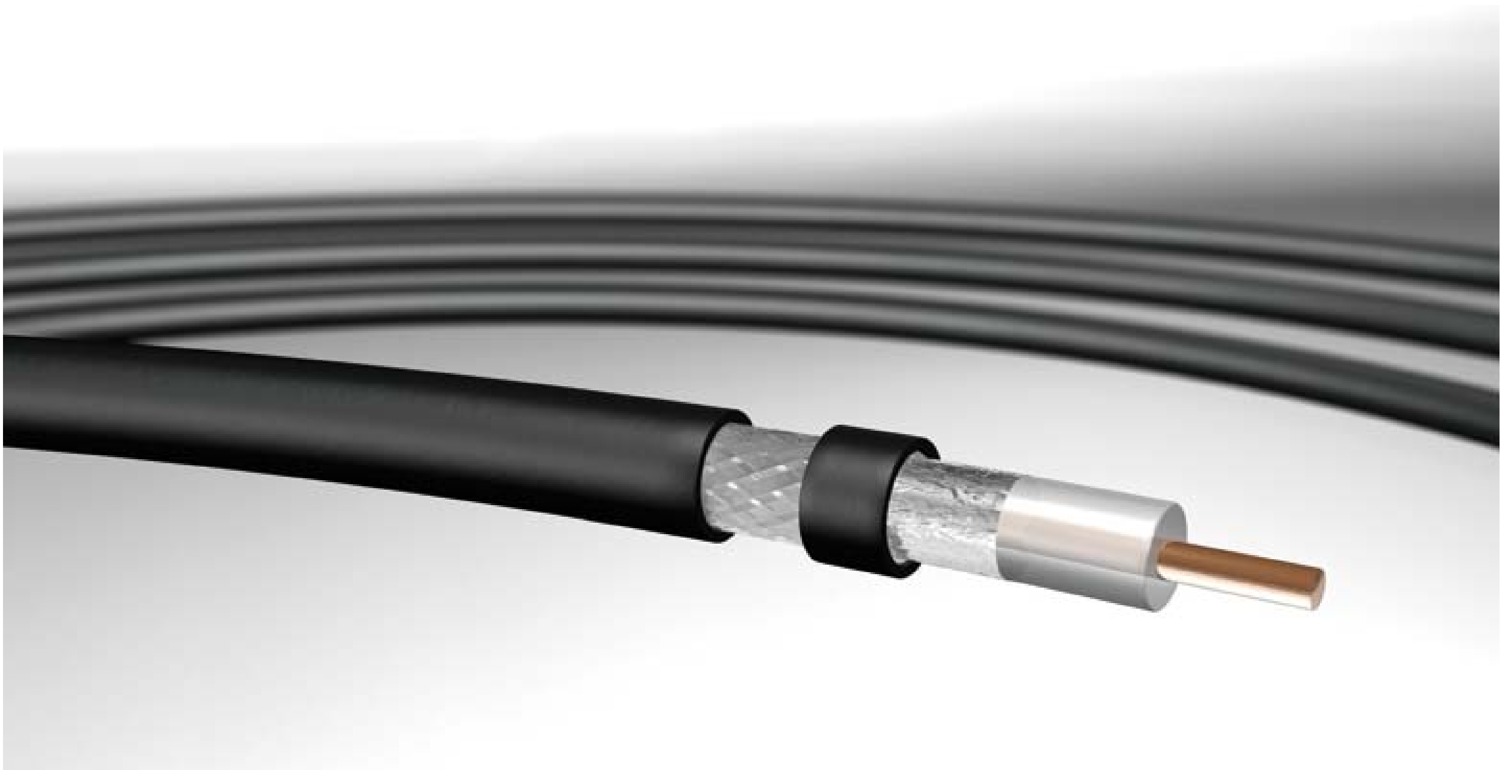
RF cables: Radio Frequency cables for general and wireless application

We are your partner for high-quality data transmission cables, control cables for audio/video signals, switching cables for central office and high-performance Radio Frequency cables for general and wireless application. Our comprehensive product scope combined with quick and flexible logistic services is your link to the digital future.

Radio Frequency cables:
Beside some general information, this brochure contains our standard programme in flexible coaxial braided cables according to US Military Specification MIL-C-17F and mainly 50 Ohm Transmitter and Receiver cables according to EN and IEC standards for wireless telecommunication application. From more than 100 RG types we have selected the most common cables for various fields of application.
A special feature of cables in accordance with Military specifications is their very high quality. All criteria regarding material, construction and electrical properties are specified in MIL-C-17F. We guarantee that the quality of our products conforms with these specifications.

New telecommunication standards are released in shorter intervals; WLAN technology, UMTS and further implementation of "Hot Spots" are the basis of permanent mobility and higher bandwidth for more information. Due to these developments the frequency range increases more and more. Dependent on this, the requirements as to the performance of RF cables will also increase.

Beside the standard range of 50 Ohm cables according to EN and IEC Standards, Draka Communications has developed a new range of Mobile Radio cables (MRC) for the above mentioned application.



RG cables according to MIL-C17F and MIL-C17G

RG cables are used in the whole field of commercial electronics and radio frequency engineering where high quality is required.

RG cables with PE insulation

Cable type		RG6	RG11	RG11-Triax	RG58	RG59	RG174	RG213	RG214	RG216	RG223
Construction											
Inner conductor		Copperclad steel wire bare	Stranded copper wires tinned 7 x 0.39	Stranded copper wires tinned 7 x 0.39	Stranded copper wires tinned 19 x 0.18	Copperclad steel wire bare	Stranded coppercladded steel wires bare 7 x 0.16	Stranded copper wires tinned 7 x 0.75	Stranded copper wires tinned 7 x 0.75	Stranded copper wires tinned 7 x 0.39	Stranded copper wires silver-plated
	Ø mm	0.73 ± 0.01	1.2	1.2	0.9	0.59 ± 0.01	0.48	2.25	2.25	1.2	0.90 ± 0.01
Insulation		PE,	PE,	PE,	PE,	PE,	PE,	PE,	PE,	PE,	PE,
	Ø mm	4.7 ± 0.05	7.25 ± 0.05	7.25 ± 0.05	2.95 ± 0.05	3.70 ± 0.05	1.52 ± 0.05	7.25 ± 0.05	7.25 ± 0.1	7.25 ± 0.05	2.95 ± 0.05
Outer conductor		Copper braid, silver-plated	Copper braid, bare	Copper braid, bare	Copper braid, tinned	Copper braid, bare	Copper braid, tinned	Copper braid, bare	Copper braid, silver-plated	Copper braid, bare	Copper braid, silver-plated
Shielding		Copper braid, bare		Copper braid, bare					Copper braid, silver-plated	Copper braid, bare	Copper braid, silver-plated
Sheath material		PVC	PVC	PVC	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Sheath material	Ø mm	8.4 ± 0.15	10.1 ± 0.20	13.5 ± 0.50	4.95 ± 0.10	6.15 ± 0.10	2.7 ± 0.10	10.3 ± 0.15	10.8 ± 0.15	10.8 ± 0.15	5.4 ± 0.1
Sheath colour		black	black	black	black	black	black	black	black	black	black
Weight	kg/km	115	134	270	37	54	11.2	153	200	185	60
Electrical Properties											
Impendance	Ω	75 ± 3	75 ± 3	75 ± 3	50 ± 2	75 ± 3	50 ± 2	50 ± 2	50 ± 2	75 ± 3	50 ± 2
Attenuation	10 MHz	3.0	1.8	1.8	4.2	3.5	9.8	1.8	2.0	1.8	4.4
(dB/100m) nom.	100 MHz	9.8	6.5	6.5	15.7	11.0	31.0	6.8	6.9	6.5	13.9
	400 MHz	20.0	14.1	14.1	34.5	24.0	74.0	14.4	15.1	14.1	29.3
	1000 MHz	32.0	25.2	25.2	60.0	38.0	120.0	24.7	26.5	25.2	50.1
	2000 MHz	47.0	43.0	43.0	90.0	60.0	170.0	36.4	38.1	43.0	80.0
	3000 MHz	60.0	59.0	59.0	120.0	78.0	210.0	46.6	48.6	59.0	98.0
Max. Power	10 MHz	1600	2800	2800	750	1100	240	2300	2200	2800	765
rating at 40°C	100 MHz	500	810	810	230	340	68	920	875	810	240
	400 MHz	220	370	370	110	180	32	380	360	370	115
	1000 MHz	150	200	200	65	90	18	210	200	200	70
	2000 MHz	70	120	120	40	58	11	140	135	120	45
	3000 MHz	50	100	100	30	45	9	100	95	100	35
Mutual capacitance	pF/m	67	67	67	100	67	100	100	100	67	100
Velocity ratio	%	66	66	66	66	66	66	66	66	66	66
DC resistance											
Inner conductor	Ω/km	105.0	21.0	21.0	36.7	158	315.0	5.7	5.7	21.0	29.1
Outer conductor	Ω/km	6.5	4.0	4.0	12.9	8.5	37.3	6.2	10	4.4	13.5
Return loss at 1000 MHz	dB	> 22	> 24	> 24	> 23.5	> 26	> 19.5	> 23	> 25	> 22	> 23
Operating voltage	kV.rms.	2.4	3.6	3.6	1.8	1.7	1.1	3.7	3.7	3.7	1.4

Connectors and grounding kits are also supplied by DRAKA.

Construction

Construction, material and tolerances of the inner conductor are the determining factors for the mechanical and electrical properties of a cable. The individual wires are drawn from electrolytic copper with very close tolerances and are used bare, tinned or silver-plated as solid or stranded inner conductor. Cables with a stranded inner conductor are highly flexible.

Due to the higher tensile strength, copper-clad steel wires are used for very thin inner conductors. Temperature behaviour, attenuation, voltage strength and flexibility of a cable are essentially determined by material and construction. Polyethylene (PE) is preferably used due to its good cold-bending resistance and dielectric properties.

Polytetrafluorethylene (PTFE) is a particular high-grade cable insulating material with a high temperature resistance and excellent dielectric properties.

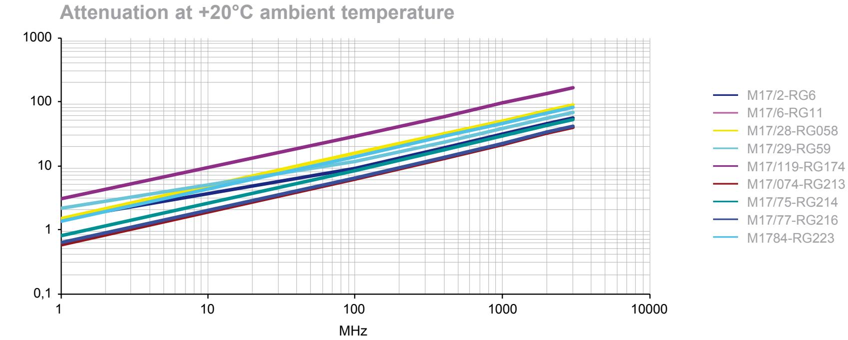
Air-space insulated cables have a lower attenuation. The outer conductors of all RG cables consist of bare, silver-plated or tinned copper wires. They are designed in accordance with MIL-C-17F and achieve a high coverage and screening efficiency.

Cable types with particularly stringent screening requirements must be provided with a double braid. RG cables have a weatherproof sheath as outer protection which is classified into quality groups according to MIL-C-17F. Cables with PVC sheaths according to MIL-C-17F, i.e. PVC with plasticisers of a low migration degree, are very resistant to aging, i.e. the attenuation increase through aging is negligible. The sheath materials applied here correspond to sheath type IIa for PVC and to sheath type IX for FEP (according to MIL-C-17).

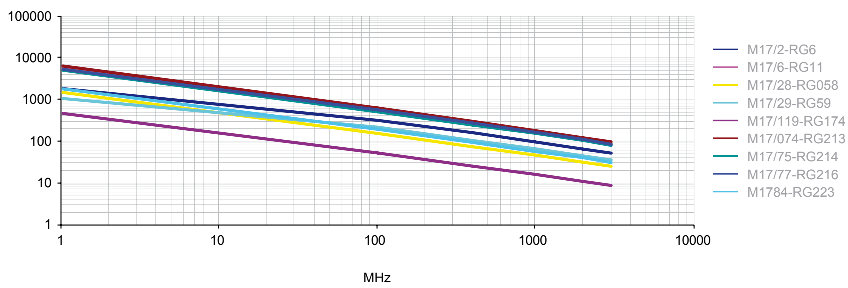
Properties

Temperature range for cables with PE insulation and PVC sheath
-40°C up to +85°C
With PTFE insulation and FEP sheath
-55°C up to +250°C
Fire propagation test
acc. to IEC 60332-1 and VDE 0472 part 804 class B

Attenuation at +20°C ambient temperature



Maximum Power Handling at +40°C ambient temperature



RG cables according to MIL-C17F and MIL-C17G

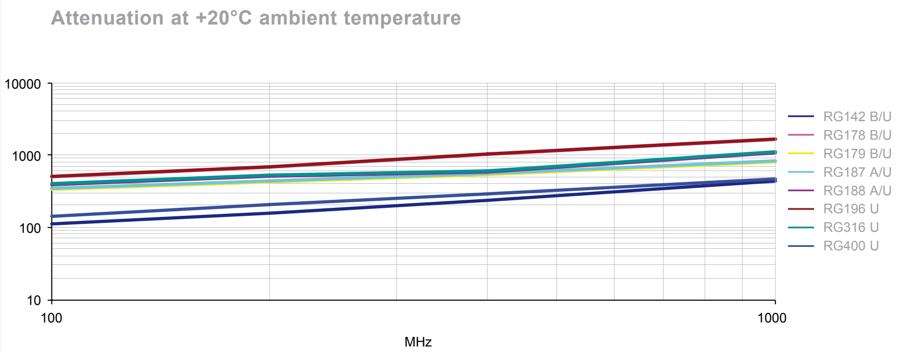
RG cables are used in the whole field of commercial electronics and radio frequency engineering where high quality is required.

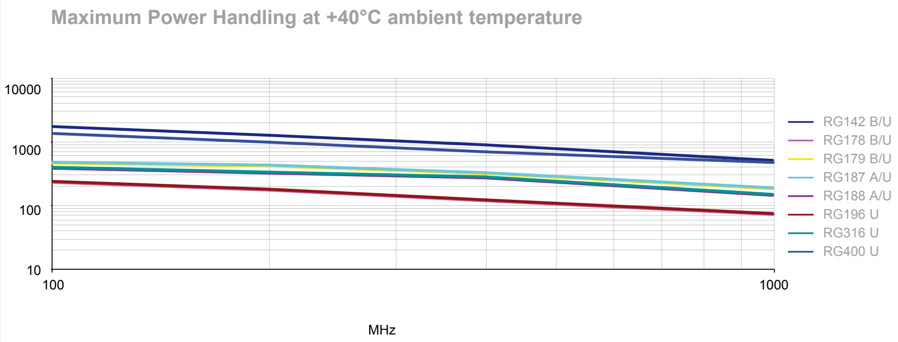
RG cables with PTFE insulation

Cable type		RG142 B/U	RG178 B/U	RG179 B/U	RG187 A/U	RG188 A/U	RG316 U	RG196 U	RG400 U
	Standard	MIL-C-17F	MIL-C-17F/17G	MIL-C-17F/17G	MIL-C-17F/17G	MIL-C-17F/17G	MIL-C-17F/17G	MIL-C-17F/17G	MIL-C-17F/17G
Construction									
Inner conductor		Copper-clad steel wire, silver coated,	Stranded copper-clad steel wires, silver coated 7 x 0.102	Stranded copper-clad steel wires, silver coated 7 x 0.102	Stranded copper-clad steel wires, silver coated 7 x 0.102	Stranded copper-clad steel wires, silver coated 7 x 0.17	Stranded copper-clad steel wires, silver coated 7 x 0.17	Stranded copper-clad steel wires, silver coated 7 x 0.102	Stranded copper wires, silver coated 19 x 0.203
	Ø mm	0.94 ± 0.01	0.31 ± 0,01	0.31 ± 0,01	0.31 ± 0,01	0.51 ± 0,01	0.51 ± 0.01	0.31 ± 0,01	1.01 ± 0.01
Insulation		PTFE,	PTFE,	PTFE,	PTFE,	PTFE,	PTFE,	PTFE,	PTFE,
	Ø mm	2.95 ± 0.05	0.84 ± 0.05	1.60 ± 0.05	1.60 ± 0.05	1.52 ± 0.05	1.52 ± 0.05	0.84 ± 0.05	2.95 ± 0.05
Outer conductor		Copper braid, silver coated	Copper braid, silver coated	Copper braid, silver coated	Copper braid, silver coated	Copper braid, silver coated	Copper braid, silver coated	Copper braid, silver coated	Copper braid, silver coated
Screen		+Copper braid, silver coated							+Copper braid, silver coated
Sheath material		FEP	FEP	FEP	PTFE	PTFE	FEP	PTFE	FEP
Sheath	Ø mm	4.95 ± 0.13	1.80 ± 0.10	2.54 ± 0.13	2.54 ± 0.13	2.49 ± 0.10	2.49 ± 0.10	1.80 ± 0.10	4.95 ± 0.13
Weight	kg/km	68	9.0	16.5	17.0	17.5	16.0	9.5	63

Electrical Properties									
Characteristic impedance	Ω	50 ± 2	50 ± 2	75 ± 1.5	75 ± 1.5	50 ± 2	50 ± 2	50 ± 2	50 ± 2
Attenuation	100 MHz	11	46	33	33	37	37	46	14
(dB/100m) nom.	200 MHz	15	62	41	41	47	47	62	20
	400 MHz	23	92	52	52	55	55	92	28
	1000 MHz	43	151	79	79	102	102	151	46
Max. Power rating	100 MHz	1800	240	480	480	400	400	240	1400
at 40°C (Watts)	200 MHz	1300	180	420	420	325	325	180	1000
	400 MHz	900	120	320	320	275	275	120	720
	1000 MHz	530	75	190	190	150	150	75	490
Mutual capacitance	pF/m	96	96	64	64	96	96	96	96
Velocity ratio	%	70	70	70	70	70	70	70	70
DC resistance									
Inner conductor	Ω/km	± 638	± 800	± 800	± 800	± 275	± 275	± 800	± 31
Operating voltage	kV Peak	1.9	1.0	1.0	1.0	1.2	1.2	1.0	1.4

Connectors and grounding kits are also supplied by DRAKA.


Attenuation at +20°C ambient temperature
10000
1000
100
10
100
1000
MHz
RG142 B/U
RG178 B/U
RG179 B/U
RG187 A/U
RG188 A/U
RG196 U
RG316 U
RG400 U


Maximum Power Handling at +40°C ambient temperature
10000
1000
100
10
100
1000
MHz
RG142 B/U
RG178 B/U
RG179 B/U
RG187 A/U
RG188 A/U
RG196 U
RG316 U
RG400 U

Coaxial RF cables according to IEC 61196-1

The Radio Frequency cables are used in transmitter and receiver installations in radio communication as well as in the entire field of commercial radio frequency technology and electronics. This product family includes only 50Ω cables.

50Ω cables with PE insulation

Cable type		MRC 200	MRC 240	MRC 300	MRC 400	MRC 600	1.0/2.95 AF	1.35L/3.6AF	1.85L/5.0 CF	2.7/7.3 CF	2.6/7.3 AF	2.7/7.3 AF
Construction												
Inner conductor		Copper wire bare	Copper wire bare	Copper wire bare	Copper wire bare	Copper wire bare	Copper wire bare	Stranded copper wires bare 7x0.45	Stranded copper wires bare19x0.37	Copper wire bare	Copper wire bare	Copper wire bare
	Ø mm	1.12 ± 0.01	1.42 ± 0.01	1.78 ± 0.01	2.74 ± 0.01	4.42 ± 0.01	1.05 ± 0.01	1.35	1.35	2.715 ± 0.005	2.61 ± 0.01	2.71 ± 0.005
Insulation		Foam-PE,	Foam-PE,	Foam-PE,	Foam-PE,	Foam-PE,	Foam-PE,	Foam-PE,	Foam-PE,	Foam-PE,	Foam-PE,	Foam-PE,
	Ø mm	2.95 ± 0.05	3.81 ± 0.05	4.83 ± 0.05	7.24 ± 0.05	11.56 ± 0.05	2.95 ± 0.05	3.6 ± 0.05	5.0 ± 0.05	7.25 ± 0.1	7.3 ± 0.05	7.25 ± 0.1
Outer conductor		Al-PET-foil, bonded to the dielectric + copper braid, tinned	Al-PET-foil, bonded to the dielectric + copper braid, tinned	Al-PET-foil, bonded to the dielectric + copper braid, tinned	Al-PET-foil, bonded to the dielectric + copper braid, tinned	Al-PET-Al-foil + copper braid, tinned	Al-PET-Al-foil + copper braid, tinned	Al-PET-Al-foil + copper braid, tinned	Cu-PET Cu foil + copper braid, bare	Cu-PET Cu foil + copper braid, bare	Al-PET-Al-Folie + copper braid, tinned Al-PET-Al-foil	Al-PET-Al-foil + copper braid, tinned
Sheath material		PE	PE	PE	PE	PE	PVC alt.FRNC	PVC alt. PE	PE	PE	FRNC	PE
Sheath material		4.95 ± 0.15	6.1 ± 0.2	7.6 ± 0.2	10.3 ± 0.2	15.0 ± 0.3	5.00 ± 0.2	5.40 ± 0.2	7.3 ± 0.2	10.3 ± 0.2	10.3 ± 0.2	10.3 ± 0.2
Sheath colour	Ø mm	black	black	black	black	black	black	black or white	black	black	black	black
Weight	kg/km	33	47	65	133	283	42 / 46	42 / 40	80	136	166	136
Electrical Properties												
Impendance	Ω	50 ± 2	50 ± 2	50 ± 2	50 ± 2	50 ± 2	50 ± 1,5	50 ± 2	50 ± 2	50 ± 2	50 ± 2	50 ± 2
Attenuation	30 MHz	5.8	4.4	3.5	2.2	1.4	6.2	5.0	3.5	2.1	2.4	2.4
(dB/100m) nom.	900 MHz	32.6	24.8	19.7	12.8	8.2	34.2	28.6	23.5	12.0	15.5	14.6
	1800 MHz	46.6	35.6	28.4	18.6	12.1	49.8	41.3	33.2	17.9	21.7	18.6
	2500 MHz	55.4	42.4	33.9	22.2	14.5	58.2	49.6	39.0	21.4	25.6	22.2
	5200 MHz	81.9	63.3	51.3	33.6	22.5	85.2	75.3	59.0	32.9	38.7	34.1
	5800 MHz	86.5	66.8	54.2	35.5	23.8	89.9	80.2	62.3	35.4	40.8	36.1
Max. Power	30 MHz	1020	1140	2100	3330	5510	939	980	2100	4907	2997	3000
rating at 40°C	900 MHz	180	260	360	580	930	167	221	292	839	457	499
	1800 MHz	130	180	250	400	630	122	151	217	558	333	400
	2500 MHz	110	150	210	330	520	104	124	175	475	280	330
	5200 MHz	74	105	137	222	338	71	86	116	226	188	218
	5800 MHz	70	100	130	210	320	67	80	110	311	178	207
Mutual capacitance	pF/m	80	79.5	79	79	77	82	80	80	79	80	79
Velocity ratio	%	83	84	85	85	86	80	81	84	84	81	84
DC resistance												
Inner conductor	Ω/km	17.6	10.5	7.0	4.6	1.2	20.3	16.5	8.9	3.1	3.2	3.1
Outer conductor	Ω/km	14	12.8	8.6	5.4	3.9	12.0	22.5	7.3	5.5	3.9	4.7
Return loss at 1000 MHz	dB	> 23	> 23	> 23	> 23	> 23	> 18	> 23	> 23	> 23	> 23	> 23
Operating voltage	kV.rms	0.8	1.0	1.0	1.2	1.5	0.8	1.0	1.0	1.2	1.2	1.2

Connectors and grounding kits are also supplied by DRAKA.

Construction

The inner conductors which essentially determine the mechanical and electrical properties of the cables are drawn from electrolytic copper with very close tolerances and can be supplied bare, tinned or silver-plated. Highly flexible cables are manufactured with stranded inner conductors. For very thin inner conductors, copper-weld wires are used due to their higher tensile strength.

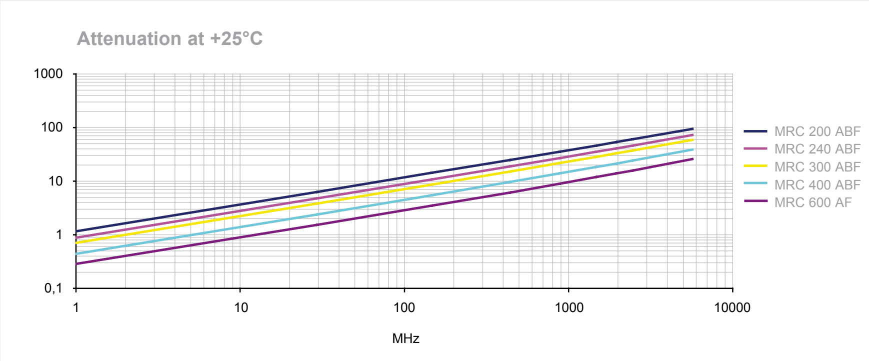
As insulation material, stabilised polyethylene is almost exclusively used. Foam-PE insulation is only required for cables with exceptionally low attenuation and capacity.

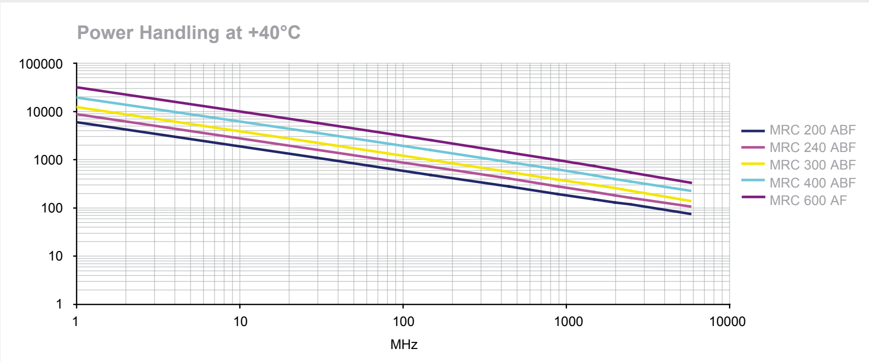
The outer conductors of Radio Frequency cables are almost exclusively made of a copper braid with a high coverage or of longitudinal double Al-PET foil and a tinned copper braid.

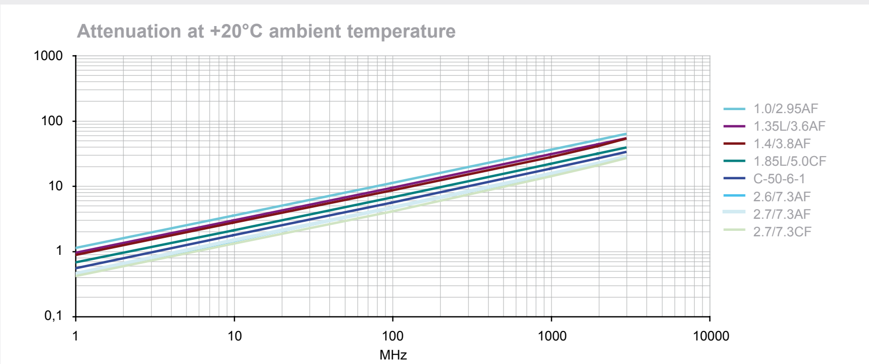
As recommended in the IEC standard, the cable sheaths are manufactured in the standard design with a highly resistant, flame retardant PVC sheath or a flame retardant, non-corrosive sheath of copolymer (FRNC).

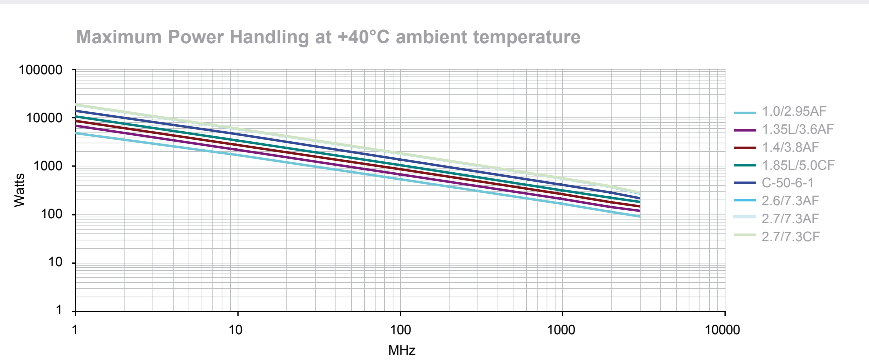
Properties

Temperature range
-30°C up to +70°C
Fire propagation test for FRNC cables
≤ 4,5 mm acc. to IEC 60332-1
≥ 4,5 mm acc. to IEC 60332-3-24
Corrosivity for FRNC cables acc. to IEC 60754-2









RF cables: Coaxial cable transmission theory

In coaxial cables, the transmission circuit is formed by three functional elements: inner conductor, dielectric and outer conductor. All three elements are concentric, i. e. they have the same central axis. The materials and dimensions of these three elements determine the transmission and the other electrical characteristics of the coaxial cable. Figure 1.1 shows these basic functional elements of a coaxial cable. Every coaxial cable also has a plastic sheath around its outer conductor and may have some other constructional elements depending on the application of the cable. In chapter 1.3, cable constructions are described in more detail.

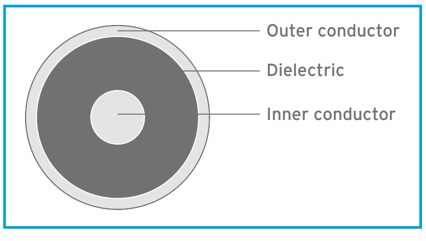


Figure 1.1: Functional elements of a coaxial cable

Field analysis

Transmission in a coaxial cable can be studied by using two analytical methods. These are:

- electromagnetic field analysis based on Maxwell`s equations
- distributed circuit analysis based on voltages and currents

The electromagnetic field pattern in a coaxial cable is based on the so-called TEM mode. The TEM mode is a propagation mode with electric and magnetic fields all being transverse to each other and to the direction of the conductors. The abbreviation TEM stands for Transverse Electro Magnetic.

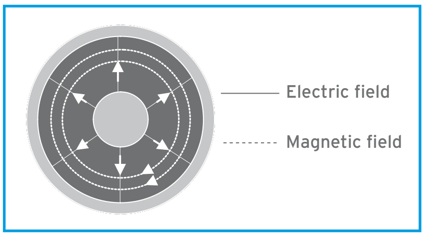
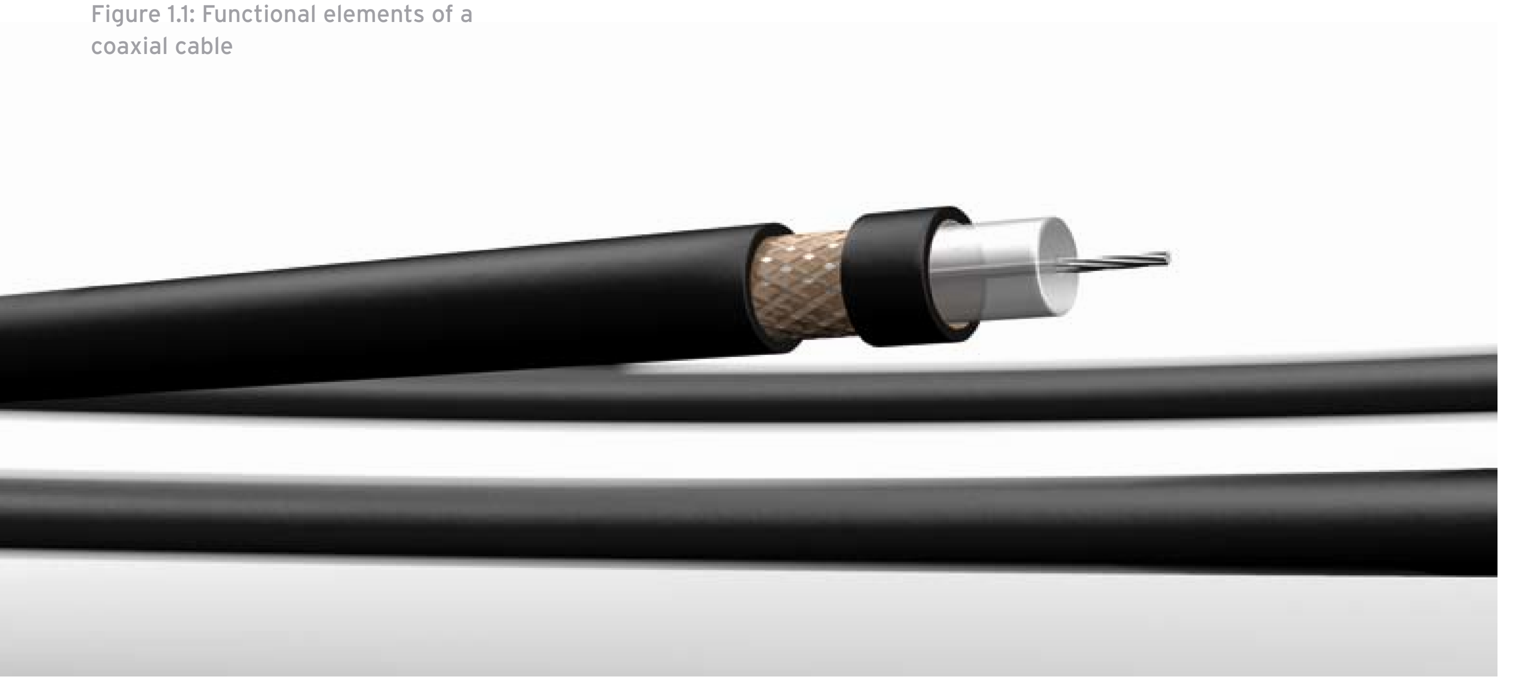


Figure 1.2: Electromagnetic field pattern for the TEM mode in a coaxial cable

According to the electromagnetic field theory, all the energy in the TEM mode propagates in the direction of the cable axis. This propagation is characterised by the basic transmission properties of the cable, such as characteristic impedance and attenuation.
Up to a certain frequency the TEM mode is the only propagation mode in a coaxial cable. This frequency depends on the dimensions and dielectric characteristics of the cable and is called cut-off frequency. At higher frequencies, other propagation modes such as TE and TM modes are excited. In coaxial transmission, these higher modes are unwanted and



therefore it is important to know the cut-off frequency and to use the cable at frequencies below. The cut-off frequency can be calculated by means of the following formula:

$$f_c = \frac{2c}{\pi\sqrt{\varepsilon_r(d+D)}}$$

fc = cut-off frequency
C = speed of light in vacuum
ε_r = relative permittivity of dielectric
d = diameter of inner conductor
D = inner diameter of outer conductor

Discontinuities in the cable can also excite higher modes below the cut-off frequency, but they are affected by high attenuation.
The TEM mode is the only wanted mode in a coaxial cable and all the transmission characteristics of a cable are based on this mode.

Figure 1.2 also shows another interesting fact concerning the electromagnetic fields in a coaxial cable. In a coaxial cable with closed outer conductor the TEM wave propagates.

If the outer conductor is completely closed there is no electromagnetic coupling between the interior of the cable and the external environment. The cable neither transmits nor receives any radiation. This means that a coaxial cable with closed outer conductor does not cause any radio frequency interference to other systems and it is also immune to any radio frequency interferences caused by other systems.

Conclusion

In the operating frequency range (below cut-off frequency) the only propagation mode is the TEM mode and all the energy is propagated in the direction of the cable axis. This propagation is characterised by the transmission properties of the cable, such as characteristic impedance and attenuation. In a coaxial cable with a closed outer conductor all the electromagnetic energy propagates inside the cable and there is no electromagnetic coupling between the interior of the cable and the external environment.

Distributed circuit analysis:
While the electromagnetic field analysis states the spatial conditions of electric and magnetic fields, the distributed circuit analysis deals with voltages, currents, impedances and other parameters used in electric network theory.

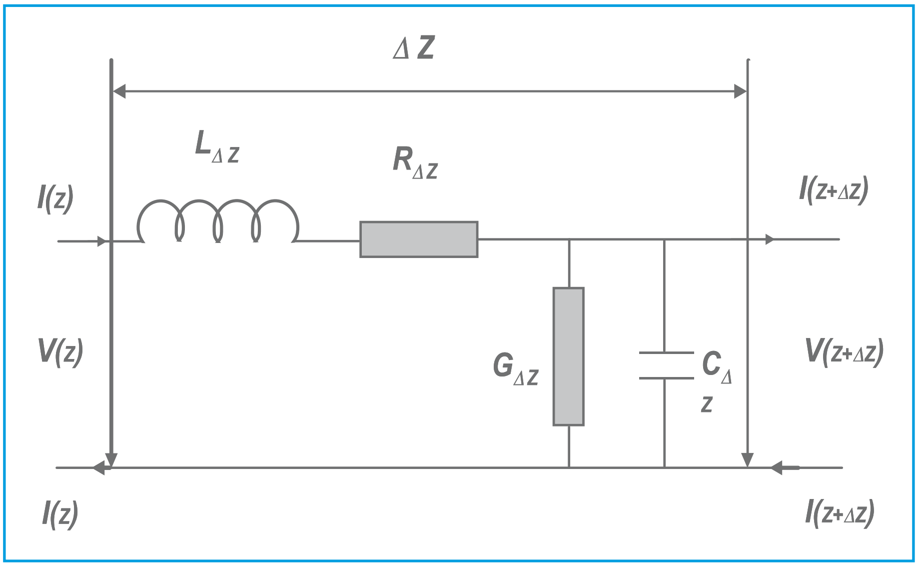
Every transmission line can be described with an equivalent circuit of a two-port network. The so-called primary parameters are continuously distributed along this circuit.

The four primary parameters are:
L = Inductance per unit length
R = Resistance per unit length
G = Conductance per unit length
C = Capacitance per unit length

Voltage at the input of the circuit is V(Z) and at the output V(Z + ΔZ). The respective values of current are I(Z) and I(Z + ΔZ).
As can be seen, the output voltage differs from the input voltage. This is caused by series of voltages across the inductance and resistance. Also the output current differs from the input current. This is caused by the shunt currents through the conductance and capacitance. In a homogeneous transmission line, however, the ratio of voltage and current remains constant.

This constant is called impedance and is described as Z. This can be expressed by means of the following formula.

$$Z = \frac{V}{I}$$



It can be seen that Z depends on the primary parameters L, R, G and C according to the following formula:

$$Z = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

j = imaginary unit used in complex numbers
ω = 2πf
f = frequency

At high frequencies (f > 1 MHz) the following simplified formula can be used:

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)}$$

The propagation coefficient γ which is expressed by the following formula is an important parameter as well:

α = attenuation coefficient per unit length
β = phase coefficient per unit length

The natural unit of the attenuation coefficient is Np/m (Neper per meter). In practical engineering, however, the unit dB (Decibel) is used instead of Np. The following formula expresses the relation between dB and Np.
1 dB = 0.115 Np
1Np = 8.686 dB

The unit of the phase coefficient is rad/m (radians per meter)

$$Z = \sqrt{\frac{L}{C}}$$

$$\alpha = \frac{R}{2Z} + \frac{GZ}{2}$$

$$\beta = \omega\sqrt{LC}$$

Characteristic impedance, attenuation coefficient and phase coefficient are the three most important transmission characteristics of a transmission line. Their mathematical expression as shown above, however, is impractical for cable design and application purposes. In the following chapters, these transmission characteristics as well as some other important transmission related parameters are presented in a more practical and useful form for engineering purposes of coaxial cables.

Transmission characteristics

Characteristic impedance

The characteristic impedance is one of the most important properties of a coaxial cable. In a homogeneous coaxial cable, the characteristic impedance is constant along the whole length of the cable. It is important to specify the characteristic impedance,of the cable. The impedance of a terminating resistor should have the same value as the characteristic impedance of the cable. In radio communication applications, the most common characteristic impedance is 50Ω. Other values, such as 75Ω are used in other applications, e. g. in cable TV and video systems.

All equipment or passive components connected to the cable should have the same characteristic impedance as the cable. Differences in the characteristic impedances cause mismatch and reflections, thus distorting the transmission.

The characteristic impedance in a coaxial cable is determined by the dimensions of the conductors and the relative permittivity of the dielectric.

As can be seen in the formula above, the characteristic impedance 'Z' is a complex number which depends on the frequency. At high frequencies, the value of the characteristic impedance approaches a constant real number. Therefore, at frequencies above 5 MHz this value can be expressed by means of the following formula.

$$Z = \frac{60\Omega}{\sqrt{\varepsilon_r}} \ln \frac{D}{d}$$

- Z = characteristic impedance
- ε_r = relative permittivity of the dielectric
- D = inner diameter of the outer conductor, mm
- d = diameter of the inner conductor, mm

This formula shows that the characteristic impedance can be influenced by the choice of the conductor diameters and the dielectric permittivity. The relative permittivity depends on the dielectric material and its structure. The relative permittivity of air is 1. With solid polyethylene it amounts to 2.28 and with highly foamed polyethylene it can be as low as 1.25.

With a high-quality coaxial cable the characteristic impedance is very uniform and nearly constant along the whole cable length and within different manufacturing batches. Acceptable tolerance in most common applications is ± 2Ω.

Attenuation

A decrease of the electromagnetic power between two points of the cable is called attenuation (sometimes also called longitudinal loss). With cables, the attenuation is expressed in decibels per unit length, e.g. dB/100 m. The attenuation of a coaxial cable is determined by the characteristics of the conductors and the dielectric.

The attenuation can be expressed by the following formula:

$$\alpha = \alpha_1 \sqrt{f} + \alpha_2 f$$

- α = attenuation at given frequency (dB/100 m)
- α_1 = loss coefficient of conductors
- α_2 = loss coefficient of dielectric
- f = frequency (MHz)

The attenuation increases with an increasing frequency. This is caused by the so-called skin effect in the conductors and dissipation in the dielectric.

The loss coefficient of conductors is defined by the conductor's resistivity and its dimensions. The surface conductivity in both the inner and outer conductor should be as high as possible. Due to this skin effect, the inner conductor of a coaxial cable with a large diameter can be made of a copper tube.

The loss coefficient of the dielectric depends on the relative permittivity and the dissipation factor of the dielectric material. These parameters can be minimised by using foamed polyethylene as dielectric material. Foaming degrees of more than 80% can be achieved by applying the gas injection method during the insulation process. With this method, nitrogen gas is injected directly into the dielectric material in the extruder.

The process is also called physical foaming in opposition to chemical foaming by which only foaming degrees of 50% can be achieved. At frequencies above 10 MHz, the attenuation can be expressed by the following formula (see also Figure 1.4):

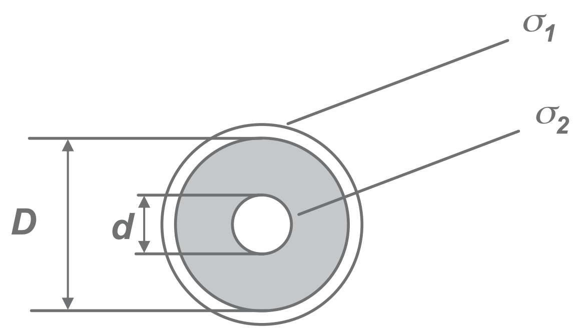
$$\alpha = \frac{4.85\sqrt{\varepsilon_r}\, f}{\ln \frac{D}{d}} \left(\frac{1}{d\sqrt{\sigma_1}} + \frac{1}{D\sqrt{\sigma_2}} \right) + 9.1\sqrt{\varepsilon_r}\, f \tan\delta$$

- α = attenuation, dB/100 m
- ε_r = relative permittivity of the dielectric
- D = inner diameter of the outer conductor, mm
- d = diameter of the inner conductor, mm
- σ_1 = conductivity of the inner conductor, MS/m
- σ_2 = conductivity of the outer conductor, MS/m
- tan δ = dissipation factor of the dielectric
- f = frequency, MHz

The attenuation depends on the temperature according to the following formula:

$$\alpha_T = \alpha\sqrt{1 + 0.0048T - 20}$$

- α_T = attenuation at temperature T
- α = attenuation at a temperature of +20°C
- T = Temperature



$$Z = \frac{60}{\sqrt{\varepsilon_r}} \ln \frac{D}{d} \qquad VF = \frac{1}{\sqrt{\varepsilon_r}} \qquad C = \frac{\sqrt{\varepsilon_r}}{3Z} 10^4$$

$$\alpha = \frac{4.85 \sqrt{\varepsilon_r f}}{\ln \frac{D}{d}} \left(\frac{1}{d \sqrt{\sigma_1}} + \frac{1}{D \sqrt{\sigma_2}} \right) + 9.1 \sqrt{\varepsilon_r} \; f \tan \delta$$

Figure 1.4: Basic transmission formulas

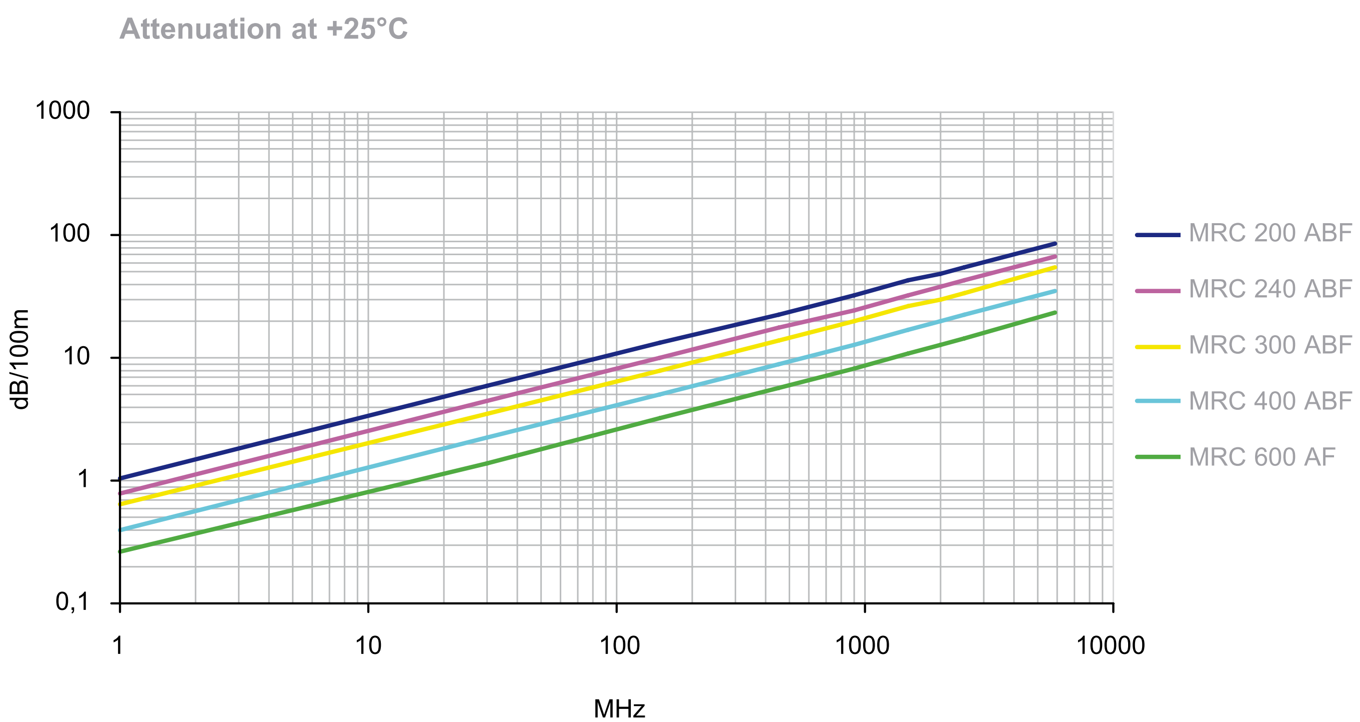


Figure 1.5: Typical attenuation curves of Draka MRC 50Ω cable types

Return loss and structural return loss

Reflection

In an ideal coaxial cable the characteristic impedance is uniform and constant along the whole cable length. In reality, the characteristic impedance slightly varies. This is due to slight variations of the conductor dimensions and the dielectric material during the manufacturing process. Furthermore, the cable connectors and joints cause small local changes of the characteristic impedance.

Each such slight variation of the characteristic impedance leads to a small part of the signal voltage reflecting backwards. The higher the variation of the impedance the higher the voltage reflection. Figure 1.6 illustrates the phenomenon.

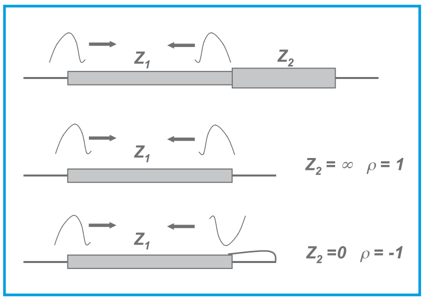


Figure 1.6: Reflection caused by a change of the impedance

An open-ended line (Z=∞) causes the whole signal voltage to reflect backwards, Thus, the reflection coefficient is 1. Also a short-circuit coaxial cable (Z=0) causes the whole signal voltage to reflect backwards, however, with a negative polarity; hence the reflection coefficient is -1. In other cases the reflection coefficient is between -1 and 1. Generally, when the characteristic impedance changes from Z1 to Z2, the reflection coefficient can be expressed by means of the following formula:

$$\rho = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

ρ = reflection coefficient
Z_1, Z_2 = values of characteristic impedance

Return loss

Return loss is defined as:

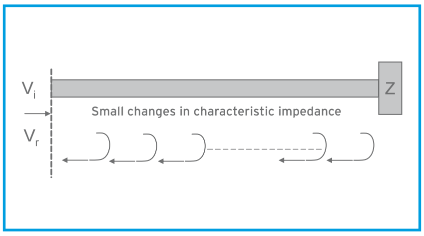
$$RL = 20 \lg \frac{1}{|\rho|} \quad \text{dB}$$

Figure 1.7 illustrates a situation where numerous slight variations of the characteristic impedance exist along the coaxial cable. Each such variation of the characteristic impedance leads to small reflections (voltages) which add up. The resulting signal can be measured at the cable input. The return loss at the cable input is defined as follows:

$$RL = 20 \lg \frac{V_i}{V_r} \quad \text{dB}$$

RL = return loss of the cable
V_i = input voltage
V_r = resulting reflected signal

Figure 1.7: Resulting reflected signal in a coaxial cable.



If the far end of a cable is terminated with an impedance equal to the characteristic impedance of the cable, no reflection is caused by the cable end.

With short cables, the return loss depends on the cable length. With cables the attenuation of which exceeds 6 dB, the return loss is practically independent of the cable length.

Occasionally, also a different expression is used instead of return loss. The so-called voltage standing wave ratio VSWR. It is defined as:

$$VSWR = \frac{1 + |\rho|}{1 - |\rho|}$$

Table 1.1 shows examples of the relationship between RL and VSWR.

RL dB	VSWR	RL dB	VSWR	RL dB	VSWR	RL dB	VSWR
16	1.374	21	1.193	26	1.105	36	1.032
17	1.329	22	1.171	28	1.082	38	1.025
18	1.285	23	1.151	30	1.064	40	1.020
19	1.251	24	1.133	32	1.051	50	1.010
20	1.220	25	1.118	34	1.040	60	1.000

Return loss and structural return loss

In order to define the level of the reflected signal, two return loss related terms are commonly used: return loss (RL) and structural return loss (SRL). Both expressions are useful, although there are some differences in their definitions and fields of application.

- Structural return loss (SRL) is used to show the structural effects of the cable itself relative to the characteristic impedance. With SRL the mismatch effects at the input and output of the cable have been eliminated.
  Therefore, structural return loss is useful for the cable evaluation.

- Return loss (RL) combines two causes of reflections. Firstly, the reflection is due to structural effects, and secondly, it is caused by the departure from the nominal impedance (e.g. mismatch). It is specified when the system performance is of primary interest.

The structural return loss (SRL) of a cable must be higher than the specified minimum value within the operating frequency range of the cable. A typical minimum requirement of a MRC 400 AFB cable is 21 dB. Figure 1.8 shows a typical SRL curve as a function of frequency.

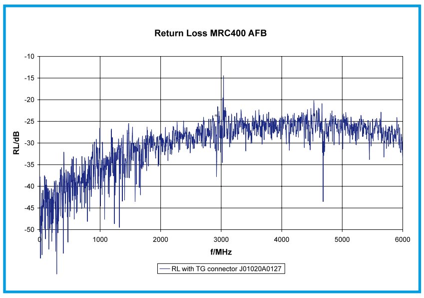


Figure 1.8: Typical structural return loss curve

By applying inverse FFT (Fast Fourier Transformation) to the frequency response of the SRL, the time response of impedance irregularities can be shown. The time response can be scaled to show the impedance irregularities as a function of distance in the cable.

In the following, the concepts of return loss (RL) and structural return loss (SRL) are discussed in more detail.

Effect of connections and installation quality on RL

Return loss (RL) is a system parameter which includes the effect of the following factors:

- transmitter mismatch
- connector mismatch at the input of the cable
- SRL of the cable itself (measured on the drum in the factory)
- installation quality
- connector mismatch at the output of the cable
- antenna mismatch

Transmitter mismatch and antenna mismatch depend on the difference between the output impedance of the transmitter or the input impedance of the antenna and the characteristic impedance of the cable. The characteristic impedance of MRC coaxial cables is 50Ω ± 2Ω. This impedance tolerance results in a corresponding RL value of 34 dB which is sufficient for any application.

The quality of the connectors and the installation are very important factors as they affect the resulting total RL. Connectors always have serial inductance and parallel capacitance which cause mismatch. The level of mismatch depends on the connector construction as well as the mounting method.

Only high-quality connectors should be used and the mounting instructions given by the connector supplier should be followed carefully.

For the installation of the cable (e.g. on a tower) good workmanship and skill are required. The RL can be dramatically degraded by improper handling of the cable and by poor installation quality. Limiting values, such as minimum bending radius and maximum pulling force should always be followed. Suitable clamps should be used for fastening the cable on the tower. Excessive crush and pressing should be avoided.
Geometrical deformations of the cable will result in an alteration of the characteristic impedance and degrade the RL of the cable. During all stages of the installation, the cable has to be handled carefully. Excessive crush, pressing onto sharp edges, rough surfaces excessive torsion of the cable and extra loops have to be avoided.

Periodic inhomogeneities and SRL

There are small structural changes along the cable length in every coaxial cable. They result from slight variations of the conductor dimensions and the dielectric material during the manufacturing process. Electrically, these effects appear as slight variations of the characteristic impedance. As described before, these variations lead to reflections of the signal. These voltages add up and the resulting signal can be measured at the cable input.

Although the individual changes of the impedance in the cable are very small, the reflections from periodic irregularities add in phase at certain frequencies. This results in peaks when measuring the return loss as a function of the frequency.

Reflections from periodic inhomogeneities of the cable accumulate to such an extent that the resulting structural return loss depends on the cable length. The longer the cable the more periodic inhomogeneities appear. along its length and the higher the reflected signal, and thus the lower the structural return loss.
With a longer cable, the reflections at the rear part of the cable, have attenuated more than those at the front section. Thus, in a very long cable the structural return loss is independent of the length. In mobile communication applications, the cable lengths significantly affect the level of the structural return loss.

The following formula shows the increase of the SRL level (in dB) depending on the cable length compared to the SRL of a cable with an infinite length:

$$\Delta SRL = 20\lg\left[\frac{1}{1-e^{-0.0023\alpha L}}\right]$$

ΔSRL = increase of SRL level, dB
α = attenuation coefficient, dB/100m
L = length of the cable, m

For an MRC 600 AF cable which has an attenuatin coefficient of 8.2 dB/100m at 900 MHz, this means an ΔSRL increase of more than 4 dB if the cable length increases from 50m to 500m. The lower the attenuation of a cable the better the ΔSRL.

Return loss characteristics of an installed MRC cable depend on many factors. The cable manufacturer guarantees minimum SRL values.

These values describe the cable itself and are measured on a drum in the factory. The SRL depends on the length and therefore a precise specification of the SRL requires information about the length of the cable.

The total RL of the feeder system is mostly affected by the connector and installation quality. The cable manufacturer guarantees the quality of the cable itself. The installer is responsible for the proper installation of the cable, thus ensuring that the RL of the transmission line is high enough.

Velocity Factor

In free space, electromagnetic waves propagate at the velocity of light.
The propagation velocity in coaxial cables depends on the material of the dielectric.
It is always lower than the velocity of light.
The ratio of the propagation velocity in a cable compared to the velocity of light in free space is called velocity factor (VF).

$$VF = \frac{v}{c}$$

VF = Velocity Factor
V = propagation velocity in the coaxial cable
C = velocity of light in free space

The velocity factor is needed for the calculation of the propagation time and the wave length. The wave length at a certain frequency can be calculated as follows:

λ = (c/f)VF
λ = wavelength
V = propagation velocity in the coaxial cable
C = velocity of light in free space

Furthermore, there is a relationship between velocity factor and the relative permittivity of the dielectric:

$$VF = \frac{1}{\sqrt{\varepsilon_r}}$$

A solid polyethylene dielectric has a velocity factor of 0.67. Highly foamed polyethylene can achieve velocity factors of up to 0.88.
VF= Velocity Factor
ε_r = relative permittivity of the dielectric

$$\lambda = \frac{c}{f} VF$$

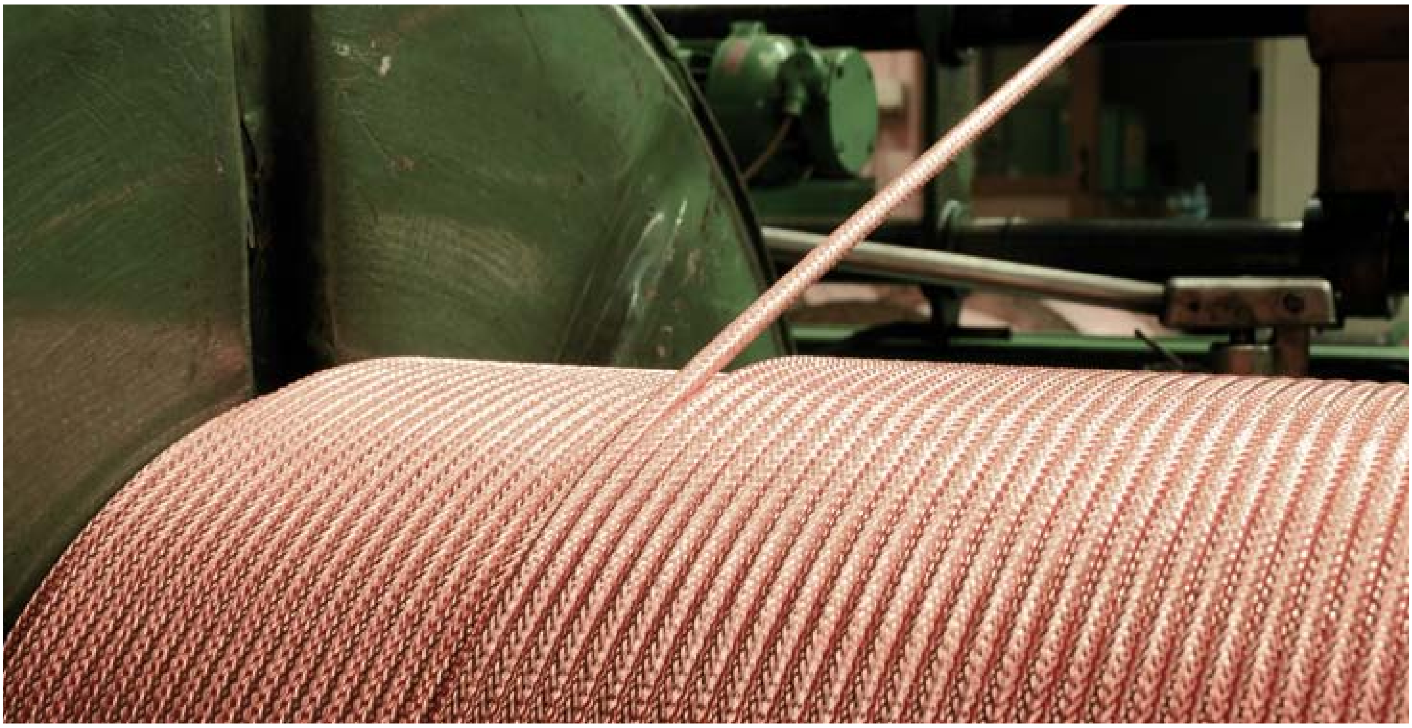
Capacitance

The effect of capacitance is included in the characteristic impedance and gives additional information about the cable.

The following relationship exists between capacitance, permittivity and impedance:

C = Capacitance
Z = Impedance
ε_r = relative permittivity of the dielectric

$$C = \frac{\sqrt{\varepsilon_r}}{3Z} 10^4 \,\mathrm{pF/m}$$



Power considerations of RF coaxial cables in mobile networks

Average and peak power rating

The power rating of a coaxial cable is defined as the input at any specified frequency, temperature and pressure which can be managed continuously when the cable is terminated by a load corresponding to the characteristic impedance.

The limitation may either be the maximum temperature of the inner conductor or the maximum permissible operating voltage of the cable. Thus, the power rating is divided into two categories:

- average power rating, limited by maximum permissible temperature of the inner conductor
- peak power rating, limited by maximum permissible operating voltage

Average power rating

Signal losses in cables cause a temperature rise in conductors. The inner conductor plays a more significant role than the outer conductor due to the resistance of the inner conductor being higher. The temperature rise in the inner conductor also affects the dielectric between the conductors. Therefore, the maximum permissible long-term operating temperature of the dielectric sets the limit for the power rating of the cable.

The average power rating of the coaxial cable depends on the following parameters:

- maximum permissible operating temperature of the dielectric (e.g. 100°C)
- thermal conductivity of the dielectric
- heat transfer characteristics of the cable surface
- ambient temperature (typically 40°C)

The average power rating decreases as the frequency increases, due to the increasing attenuation. Thus, a greater part of the power is converted into heat. At low frequencies, the average power rating may be limited by the voltage strength of the cable.

MRC transmission cables have an excellent average power rating due to the following facts:

- low attenuation: only a small part of the power is converted into heat
- high temperature stability of the dielectric
- high thermal conductivity of the dielectric

The average power rating of MRC transmission cables is defined for the following conditions:

- inner conductor temperature: 100°C
- ambient temperature: 40°C

The average power rating of each MRC transmission cable type has been calculated in accordance with the standard IEC 61196-0-1.
In mobile and other wireless communication applications the average power rating hardly ever causes problems.

When a cable is operated with a power level close to its average power rating, the cable should be installed with at least 50 mm free space around the cable.

If the ambient temperature is not 40°C the average power rating can be calculated as follows:

$$P_T = P_{40}\left(\frac{T_1 - T_a}{T_1 - 40}\right)^{1.14}$$

P_T = average power rating at temperature Ta
P_{40} = average power rating at ambient temperature 40°C
T_1 = maximum inner conductor temperature (100°C)

Peak power rating

Peak power rating is defined by the voltage strength of the dielectric between inner and outer conductor. Peak power rating may be a limiting factor for amplitude modulated signals at low and medium frequencies.
This is hardly ever a problem in mobile communication applications.

The peak power rating of MRC transmission cables is defined as follows:

- temperature: 20°C
- air pressure: 1 bar

In practical applications cables are always used with connectors.
At the interface of the cable and the connector always a gap of air dielectric remains. The peak power rating values given for MRC transmission cables include this effect and are therefore lower than the dielectric of the cable would allow.

Conclusion

MRC transmission cables are products which have been designed to fulfil the requirements of modern wireless and radio communication applications. The characteristics of the cables result from proper cable construction, suitable materials and sophisticated manufacturing processes. In addition to excellent transmission, mechanical and climatic characteristics also high power handling capacity has been one of the design targets.

The power handling capacity of MRC transmission cables is excellent and fulfils the requirements of most wireless and other radio communication applications with significant headroom. The wide range of MRC transmission cables allows for the use of an optimal cable for every application.

Passive intermodulation

Passive intermodulation is built up at the passive elements of the radio communication system. Passive elements are, for example, duplex filters, combiners, connectors, feeder or transmission lines, antennas, etc. The intermodulation is generated at the non-linear discontinuity points of the interfaces.

The space for the antenna at the tower of the base station may be limited. Thus, it may be obligatory to combine several transmitter and receiver signals to the same feeding line and antenna. Simultaneous high power transmitter carriers tend to interact at the non-linear points, thus causing an intermodulation interference with the receiving channels. Poor intermodulation characters may lead to a severe disturbance of numerous receiving channels. Passive intermodulation is related to the multiple transmitter duplex communication systems.

Non-linearity leads to harmonic frequencies. A combination of fundamental frequencies and their harmonic frequencies will result in intermodulation. All the removable contacts, e.g. connectors, are potential sources for such an intermodulation.

For example, non-linearity sources of connectors can be:

- ferromagnetic materials
- non-linear dielectrics
- dissimilar materials at the contact
- oxidized or improper surface of contact
- inadequate contact and low contact pressure leading to micro-arcing
- corrosion, dirt, dust, oil, grease, fingerprints

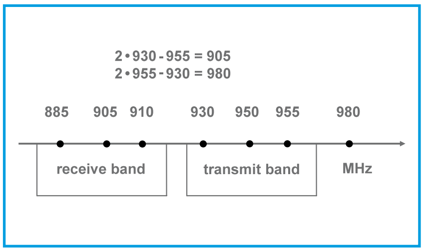
Intermodulation frequencies of two transmitted frequencies can be calculated with the formula:

$$f_i = \left| \pm m f_1 \pm n f_2 \right|$$

m and n = any positive integers
f_1 and f_2 = transmitter frequencies
The order of the intermodulation is (m+n)

Example of a third-order passive intermodulation at 900 MHz: The 930/885 and 955/910 transmitter/receiver signals are connected to the same transmission line.

The transmitter signals 955 and 930 may cause intermodulation products to 905 and 980. Thus the transmitting/receiving pair of 950/905 may be disturbed.



The third-order intermodulation attenuation is measured by using the two carriers at the standard level of 20 watts.

The intermodulation attenuation is the level difference between the test signal and the intermodulation product (Figure 1.9)

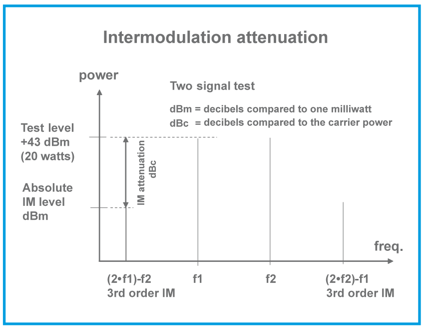


Figure 1.9: Intermodulation attenuation

Transfer impedance

One important element in the determination of the screening effectiveness of cables is the transfer impedance RK of its screen. It is defined in IEC 61196-1 and is measured in mΩ/m in accordance with the triaxial method. For an electrically short uniform cable it is defined as the quotient of the longitudinal voltage induced in the inner circuit of the cable under test and the current in the outer circuit.

The lower the transfer impedance the better the screening effectiveness of the coaxial cable. Figure 1.10 Principle circuit of Transfer impedance

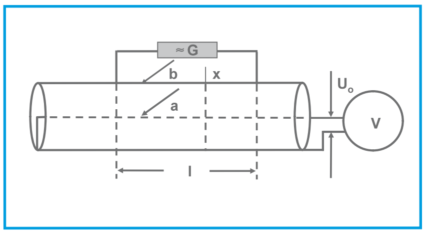


Figure 1.10: Principle circuit of Transfer impedance

a = inner conductor
b = outer conductor
l = effective length

The following formula describes the correlations between transfer impedance, longitudinal voltage induced in the inner circuit of the cable and the current in the outer circuit.

$$R_K = \frac{U_0}{lI}$$

R_K = transfer impedance
U_O = longitudinal voltage induced in the inner circuit
I = current in the outer circuit
L = effective length of the coaxial cable

A low transfer impedance has to be aimed at in consideration of an economic outer conductor construction. The optimisation of the transfer impedance and thus the screening effectiveness of the cables is achieved by matching different parameters for the outer conductor construction:

For example, for coaxial cables with braided screens only, these parameters are the ratio between the diameter of braid wire, braid angle, the diameter of insulation and the optimised electrical coverage of the braid.
The transfer impedance RK depends on the frequency. At frequencies below 100 KHz, the RK is roughly equivalent to the direct current resistance.

Figure 1.11 shows the typical trace of the transfer impedance of RF cables with an outer conductor of braid, foil and braid, or tube.

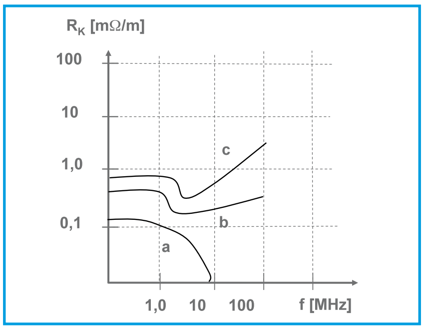


Figure 1.11: Typical traces for outer conductors: a = tube; b = foil and braid; c = braid

In order to rate the screening effectiveness at a lower frequency range (up to 50 MHz) the transfer impedance is applied, whereas at higher frequencies (as from 30 MHz) it is the screening attenuation.

The screening attenuation is defined as the logarithmic ratio of the power P1 fed into the cable and the radiated power P2.

$$a_s = 10 \log \frac{P_1}{P_2}$$

For electrically long cables – at a frequency range where the transfer impedance of the cable screen is proportional to the frequency – the screening attenuation is independent of the cable length and frequency.

In the past, devices were necessary for the measurement of the transfer impedance and the screening attenuation.

For example:
1. coupling measurement tube
2. absorbing clamp method equipment

With the newly developed triaxial testing procedure it is now possible to measure the transfer impedance RK up to 50 MHz as well as the screening attenuation from 30 MHz to 4 GHz. The triaxial system consists of coupling measurement tube and a network analyser. With this equipment it is possible to measure screening attenuation values higher than 125 dB and transfer impedance values lower than 1 mΩ/m.

The measurement methods are described in national and international standards as:
IEC61196-1
EN 50289-1-6
DIN 47250

The following graphics are some examples for transfer and screening attenuation measurements according to the above mentioned triaxial measurement method.

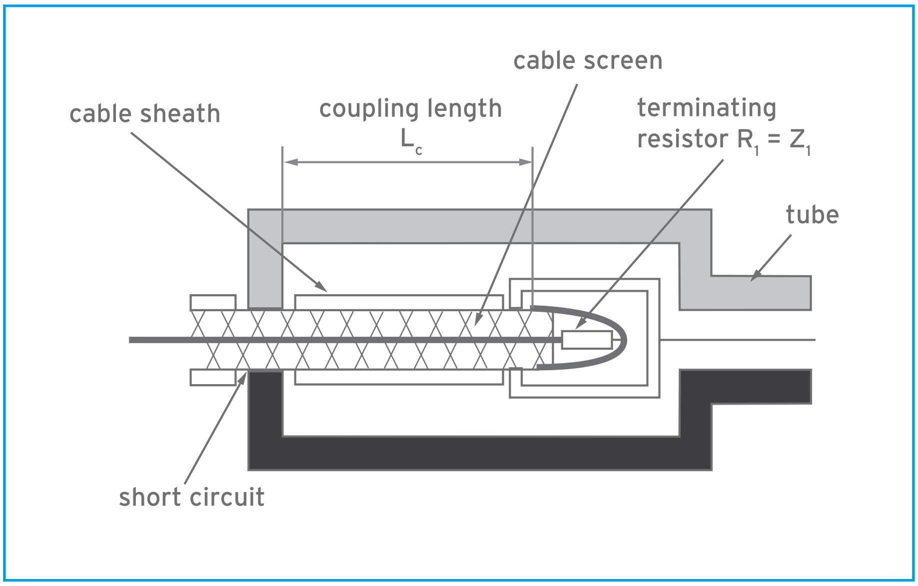


Figure 1.12: Connection of cable elements to the tube

Conclusion

RG cables according to MIL-C-17F and MIL-C-17G respectively, RF and MRC standard cables according to international standards of Draka Communications are products having been designed to fulfil the requirements of modern wireless and radio communication applications.

The characteristics of the cables result from the proper cable construction, suitable materials and sophisticated manufacturing processes. This results in excellent transmission and mechanical quality including a high screening attenuation, a low transfer impedance and a low attenuation.

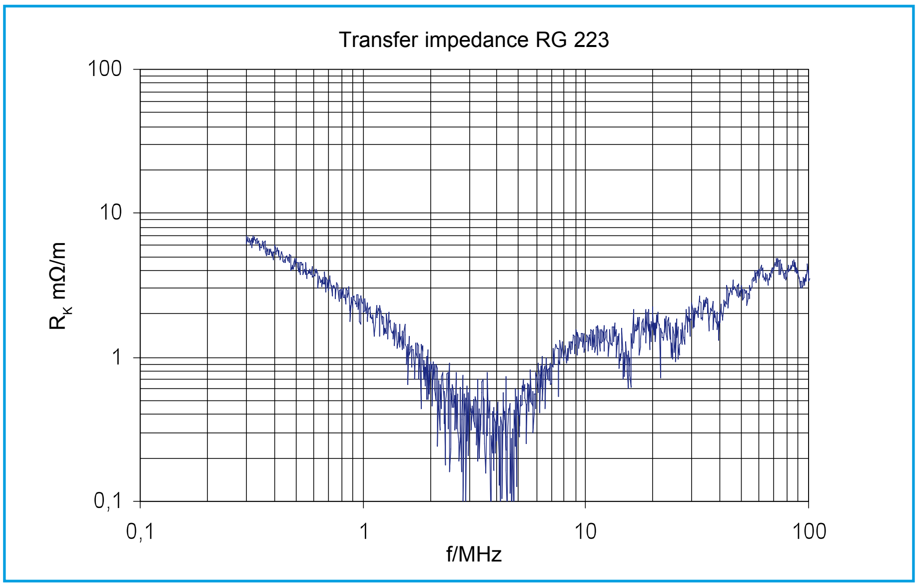


Figure 1.13: Transfer impedance of an RF cable according to American Military Specification type RG223

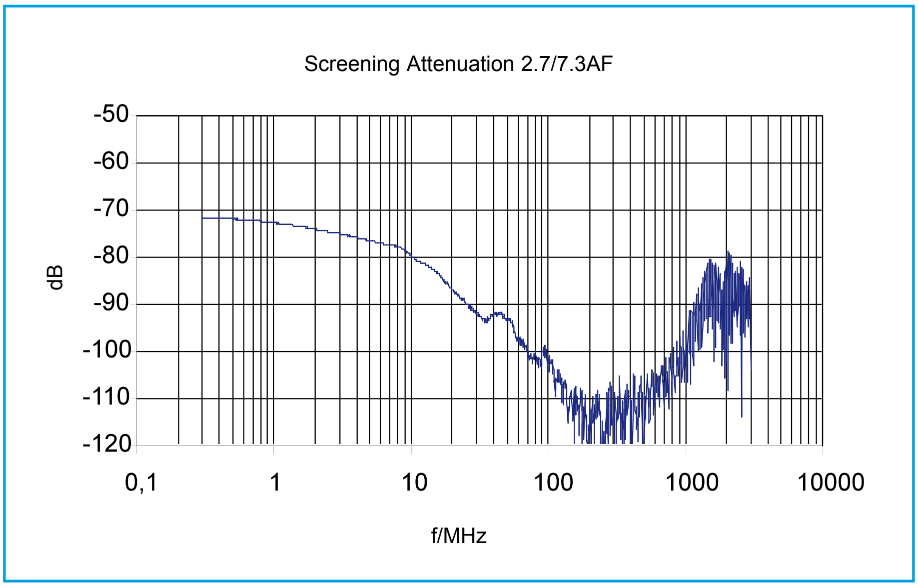


Figure 1.14: Screening attenuation of an RF cable according to IEC 61196-1 type 2.7/7.3AF

Mobile Network Cables

Antenna Line Products
Draka - Your Reliable Partner
Mobile Network Products

Jumper cable

Feeder cable + connector

Cable Clamp

Grounding kit

Feeder Cables

- RFA 1/4 "
- RFA 3/8 "
- RFA 1/2 "
- RFA 7/8 "
- RFA 7/8 " AL
- RFA 1 1/4 "
- RFA 1 5/8 "
- RFA 1 5/8 " AL
- RFA 2 1/4 "

Superflexible
and Extraflexible Cables

- RFF 1/4 "
- RFF 3/8 "
- RFF 1/2 "
- RFE 7/8 "
- RFE 1 1/4 "
- RFE 1 5/8 "

Coaxial Antennas

- RFX 1/2 "
- RFX 7/8 "
- RFX 1 1/4 "
- RFX 1 5/8 "
- RFX 7/8 "
- RFXT 1 1/4 "

Jumpers
Accessories

Draka Mobile Networks Division

Draka Mobile Networks Division offers a wide range of products with guaranteed compatibility and reliability. Furthermore, they supply feeder cables, coaxial antennas, superflexible cables and jumpers.

Draka provides a product range of leading connector and accessory manufacturers through an extensive network of partners. Draka feeder cables, flexible cables and coaxial antennas have an excellent performance in mobile telecommunication applications, such as GSM, WCDMA (UMTS), TDMA, D-AMPS, PCN, CDMA, TETRA and WiMAX.

Draka Mobile Network cables have been designed to transmit signal power between the transmission equipment and the antenna even in most demanding environmental conditions and thus meet the highest technical and environmental standards.

Coaxial Antennas

Draka coaxial antennas include two product families: RFX / RF2X and RFXT. RFX and RF2X cables are the best choice for multi- and broadband systems.

RFXT cables are ideal when certain selected frequencies are required; the performance of RFXT cables is optimised for antennas and provide a reliable way to build indoor coverage networks in buildings and tunnels. RFX and RF2X cables are coupled mode cables with a corrugated and milled outer conductor. RFX cables have slots in one line on the outer conductor, and RF2X have slots in two lines on the outer conductor.

These cables are also available with a suspension wire: RFXK and RF2XK. RFXT cables are radiating mode cables with a periodically slotted and over-lapped copper tape outer conductor.

The most important electrical characteristics of coaxial antennas are the longitudinal attenuation and the coupling loss. The excellent electrical performance of our RFX, RF2X and RFXT cables is achieved by continuous development and an extensive test program.

We make communication technology work, by serving you in every way to realize your leading edge network solution

Draka Communications has offices and production facilities all over the world.
To get in touch with us and find out how we can help you build your network, visit our website at **www.draka.com/communications** or contact us.

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