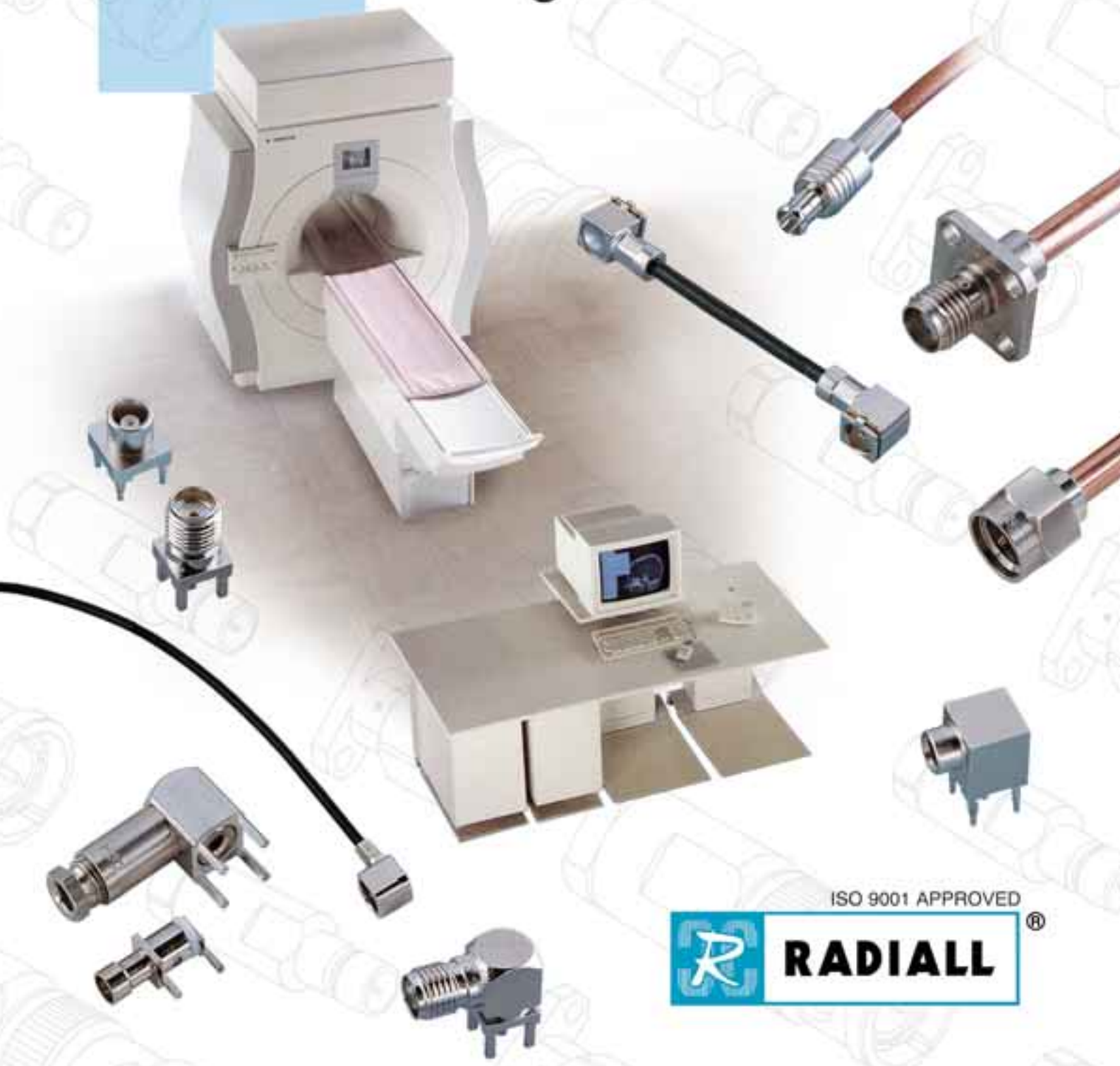
COAXIAL CONNECTORS

Application guide
for non magnetic connectors



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INTRODUCTION

The market for MRI (Magnetic Resonance Imaging) is rapidly evolving. The performance requirements for electro-mechanical components are becoming increasingly tougher. Until now, industry standard "non-magnetic" type coaxial connectors have been unable to meet the stringent level of non magnetic performance required.

In response to this highly demanding market, RADIALL has developed a new technology that meets the non-magnetic requirements of MRI and still maintains the same high level of electrical and mechanical integrity found in all our coaxial connectors. These new products are called COAXI-CORE. Their magnetic susceptibility is one hundred times better than standard "non magnetic" connectors.

ADVANTAGES

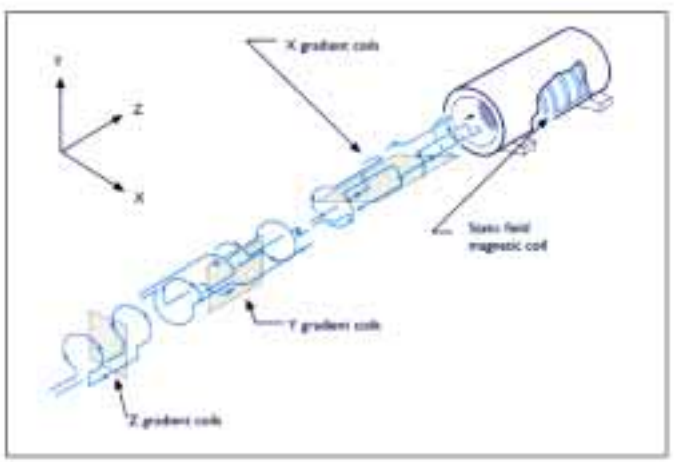
- Connection inside the field core
- Minimal distortion of the field
- Field homogeneity preserved
- High signal to noise ratio
- Multi-series technology
- Quality and repeatability guaranteed

INTRODUCTION

THE CHALLENGE

MRI medical equipment consists of :

- one magnet or electro-magnet to create an intense and homogenous magnetic field (1.5 – 2 Tesla) in the chamber where the patient lies.
- "gradient coils" to position into the space the area under analysis.
- two high frequency coils, one transmitting the excitation impulsions of the atomic nucleus contained in the area under analysis, and the other receiving like a true signal captor that constitute the image after treatment.



The quality of the picture depends above all on the homogeneity of the magnetic field and on the signal to noise ratio. To avoid any perturbation of the field homogeneity, any equipment located inside the magnetic field should be transparent relative to the field, that means its relative permittivity should be equal to 1.

The various coils placed inside the magnetic field (gradient coils and RF coils) are connected to electronic feeding or treating equipment that are far enough outside the field to prevent from any distortion.

The connectors set on these coils have to be made of non magnetic materials that show a μ_r relative permittivity close to 1, and at the same time meet the mechanical characteristics required of any reliable coaxial connector.

THE MAGNETIC MAGNITUDES

The main magnetic magnitudes are :

B : magnetic induction (Tesla)

H : magnetic field (A/m)

M : magnetization (A/m)

χ : magnetic susceptibility

μ_0 vacuum magnetic permittivity

μ_r material relative permittivity

In vacuum : $B = \mu_0 . H$

(with $\mu_0 = 4\pi 10^{-7}$ H/m)

In practice, under a H_{ext} external magnetic field, a material will get a M magnetization such as :

$$M = \chi H_{ext}$$

The magnetic induction that stands inside this material is equal to :

$$B = \mu_0 (M + H_{ext})$$

$$B = \mu_0 (1 + \chi) H_{ext}$$

Thus : $B = \mu_0 \mu_r H_{ext}$

EXAMPLES

- the Earth's magnetic field is about 0.5 x 10^{-4} T.
- the strength of electromagnets used in junk yards is about that of MRI machines 1.5 – 2.0 T.

UNIT CONVERSION

There is a second unit system you can find in older articles. It is the C.G.S system.

	Conversion	C.G.S
B	1 G = 10^{-4} T	Gauss (G)
H	1 Oe = $\frac{10^3}{4\pi}$ A/m	Oesterd (Oe)
M	1 G = 10^3 A/m	Gauss (G)
χ	$\chi_{USI} = \chi$ u.e.m/g/Oe x 4π $\chi_{USI} = \chi$ u.e.m/g/atom x $\frac{4\pi d}{M_{mol}}$ (*)	u.e.m/g/Oe u.e.m/g/atom

(*) with d density and M_{mol} molar masse.

MAGNETIC MATERIALS CHARACTERISTICS

There are four types of materials :

- the diamagnetic materials
- the paramagnetic materials
- the superparamagnetic materials
- the ferromagnetic materials

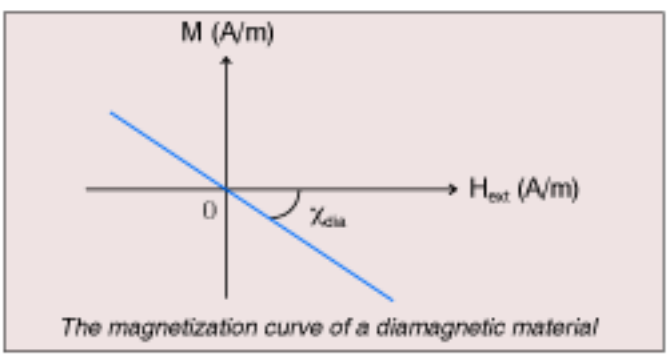
Dia- or para-magnetic materials feature rather weak magnetic properties and are linear.

The shemes, near the titles illustrate the effect of a magnetic material (grey circle) on the magnetic field flux lines (red).

DIAMAGNETISM

The characteristics of the diamagnetism are :

- The M Magnetization is proportional to the H field
- The χ_{dia} susceptibility is independent of temperature
- χ_{dia} is negative : M and H are opposite
- χ_{dia} is around -10^{-4}, -10^{-9}



The magnetization curve of a diamagnetic material

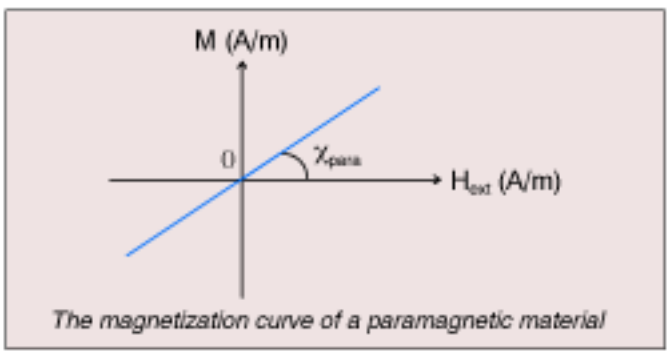
Main diamagnetic materials are :

- Cadmium
- Stain
- Copper + alloys
- Lead
- Gold
- Zinc
- Silver

PARAMAGNETISM

The characteristics of the paramagnetism are :

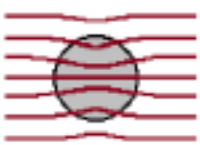
- The M Magnetization is proportional to the H field
- The magnetic susceptibility χ_{para} is proportional to T^{-1} (Curie law)
- χ_{para} is positive : M and H have the same sense
- χ_{para} is around :10^{-2},10^{-6}



The magnetization curve of a paramagnetic material

Among the most used paramagnetic materials there are :

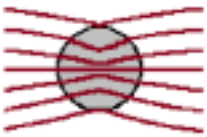
- Aluminum
- Palladium
- Chromium
- Platinum
- Manganese



SUPERPARAMAGNETISM

Superparamagnetic materials consist of individual domains of elements that have ferromagnetic properties in bulk.

The magnetic susceptibility is between that of ferromagnetic and paramagnetic materials.



FERROMAGNETISM

With a ferromagnetic material, M can not be linked to H or to B by a simple relation because of the hysteresis phenomenon.

The magnitude of the susceptibility of ferromagnetic materials is one thousand times greater than that of paramagnetic materials.

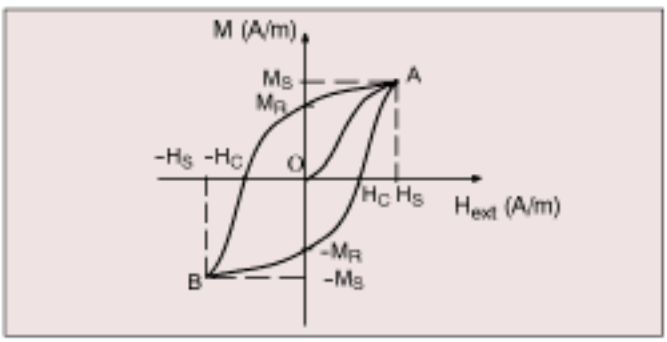
The magnetization curve of a ferromagnetic material is a hysteresis cycle.

(O.A) is called the first magnetization curve.

The (A.M_R.$-H_C$.B.$-M_R$.H_C) cycle is called hysteresis curve when the field varies alternatively from H_S to $-H_S$.

This hysteresis curve is characterized by the following three magnitudes :

- the saturation magnetization M_S
- the remanent magnetization M_R, that is the magnetization inside the material with a nil field.
- the coercive force H_C to apply to get a nil magnetization.

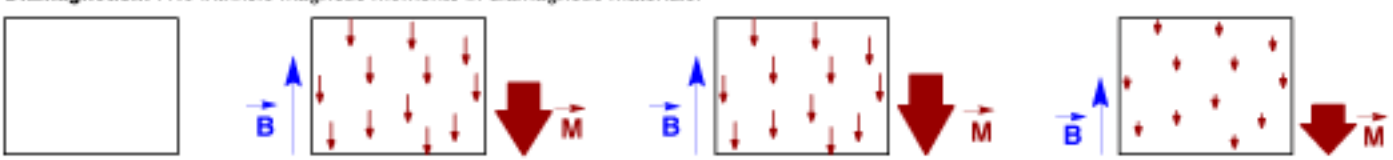


The materials below show a ferromagnetic behavior :

- Cobalt
- Iron
- Nickel

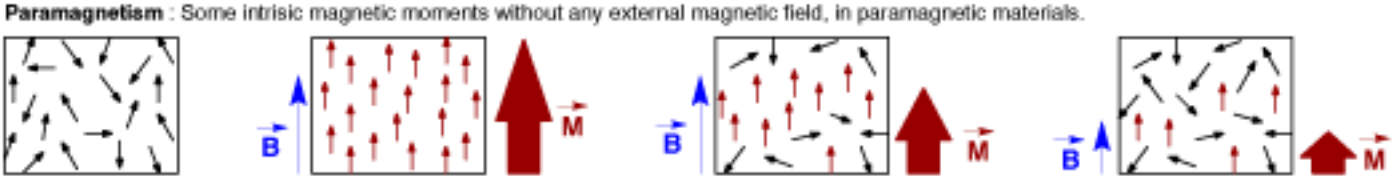
MATERIAL MAGNETIC BEHAVIORS

Diamagnetism : No intrinsic magnetic moments in diamagnetic materials.



B = 0 | B = 1 T, T = 0°K | B = 1 T, T = 300°K | B = 0.5 T, T = 300°K

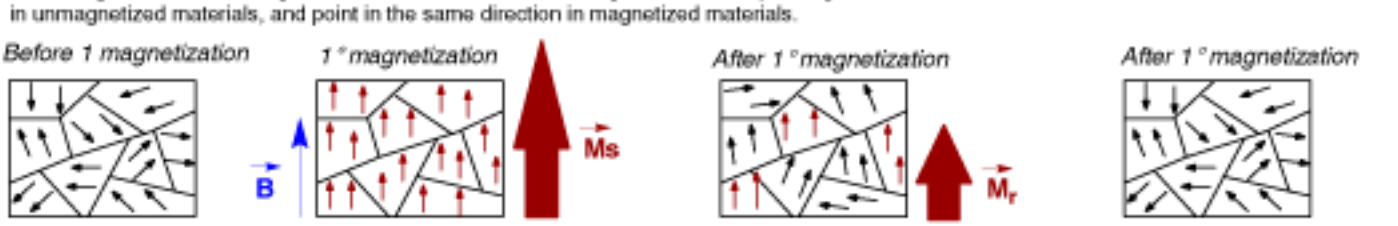
Paramagnetism : Some intrisic magnetic moments without any external magnetic field, in paramagnetic materials.



B = 0 | B = 1 T, T = 0°K | B = 1 T, T= 300°K | B = 0.5 T, T = 300°K

Ferromagnetism : Some magnetic domains that all have their magnetic moments pointing in the same direction. The moments of the domains are random in unmagnetized materials, and point in the same direction in magnetized materials.

Before 1 magnetization | *1° magnetization* | *After 1° magnetization* | *After 1° magnetization*



B = 0, M = 0 | B = 1 T, T = 0°K, M = M_s (Saturation magnetization) | B = 0, T < T_c (Curie temperature), M = M_r (Remnant magnetization) | B = 0, T > T_c (Curie temperature), M = 0

DISTURBING MAGNETIZATION

When an external magnetic field H_{ext} is applied, a magnetization M appears inside the material, here the connector.

This M magnetization generates a ΔH disturbing field, that disturbs the flux lines of the H_{ext} magnetic field. Thus the quality of the picture received is poor and many corrections have to be made.

The ΔH disturbing field, generated by the connector depends on :

1 - The **distance** between the connector and the point where it is calculated.

2 - The connector **dimensions**. The larger the connector is, the greater the ΔH field is.

3 - The M magnetization of the connector, and thus, its χ **susceptibility** :

$$B = \mu_0 \mu_r H_{ext}$$

with $\mu_r = (1 + \chi)$.

The weaker the χ magnetic susceptibility of the connector is, the closer to 1 the μ_r relative permittivity is, the more the material is like vacuum and the less the material perturbs the magnetic field.
The connector is then transparent relative to the external magnetic field.

Conversely, the greater the χ magnetic susceptibility of the connector is, the farther from 1 μ_r is, and the more magnetic the material is.
The connector distorts the flux lines of the magnetic field.

DEMAGNETIZING FIELD

Under a H_{ext} external field, a H_d demagnetizing field appears inside the connector such as :

$$H_d = -n.M$$

n, demagnetizing coefficient, depends on the direction of the magnetization compared to the connector. $(0 < n < 1)$

The connector is subject to a total field :

$$H_t = H_{ext} + H_d$$

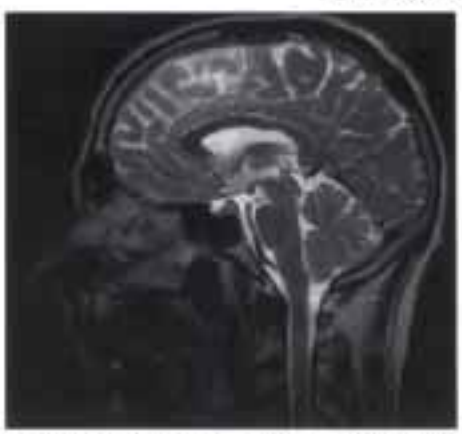
$$M = \chi.H_t = \chi.(H_{ext} + H_d) = \chi.(H_{ext} - n.M)$$

The magnetization is then : $$M = \frac{\chi.H_{ext}}{1 + r\chi}$$

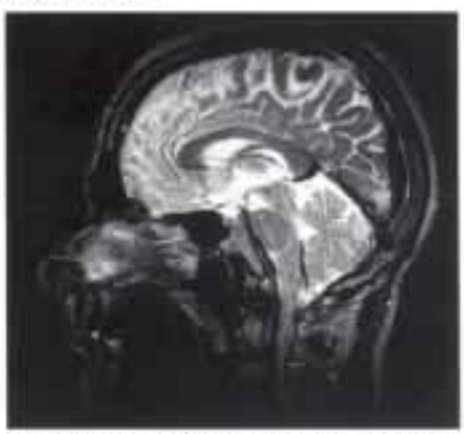
For $\chi << 1$, $M = \chi . H_{ext}$

The demagnetizing field is then negligible relative to the external field.

Examples of RMI brain images



Poor spatial resolution and low signal to noise ratio.



Good spatial resolution and high signal to noise ratio.

Thanks to RADIALL **COAXI-CORE** coaxial connectors, you can improve your spatial resolution.

THE SOLUTION : THE COAXI-CORE

PERFORMANCE

So far, the so-called "non-magnetic" coaxial connectors, have been designed by taking the sole precaution to use only non-magnetic materials (brass, gold, silver, bronze,...).

Because such "non-magnetic connectors" could not feature a sufficient level of non-magnetism for MRI, the solution has been to take the connections the farthest away from the magnetic field via long coaxial cable assemblies.

But this led to severe signal distortion or loss. Moreover this solution was not possible when the application required that the connection took place inside the magnetic field. But now, even placed inside the core of the magnetic field, the COAXI-CORE connectors, designed and manufactured by RADIALL, preserve the magnetic field homogeneity !

Indeed :

- The χ magnetic susceptibility of a COAXI-CORE is around $\mathbf{10^{-5}}$, that is over one hundred times less than that of a standard non-magnetic connector.

The μ_r relative permittivity of a COAXI-CORE can be compared to 1.

	Distortion $\Delta H/Hex$, at 10mm	Magnetic susceptibility χ
COAXI-CORE Non-magnetic connector	$\leq 5.10^{-7}$	$\approx 10^{-5}$
Standard Non-magnetic connector	$\approx 10^{-5}$	$\approx 10^{-3}$
Brass/Nickel connector	$\approx 10^{-4}$	$\approx 10^{-2}$

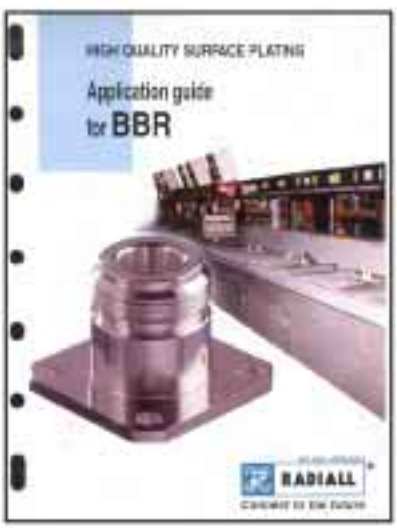
- the $\Delta H/H_{ext}$ relative distortion of a magnetic field of **1,5 T**, generated by a COAXI-CORE is only $\mathbf{5.10^{-7}}$ maximum, at a distance of **10 mm** from the surface of the connector !
- The magnetization of a COAXI-CORE is independent from temperature and from the connector position relative to the field. The distortion is the same whatever temperature and whatever position of the connector.
- The COAXI-CORE allow a high signal to noise ratio. They are adapted then to static MRI and also dynamic MRI where no picture averaging is possible.

MATERIALS

The COAXI-CORE bodies and center contacts are made of materials specially adapted to non-magnetism, each rod being selected based on a direct measurement with a vibrant magnetometer.

Center contacts are gold plated over a copper underplate and bodies are plated with BBR, diamagnetic alloy of copper-stain-zinc or with GBR, diamagnetic alloy of copper-stain-zinc with a gold strike.

To get more information about these two types of high quality surface plating, please ask for our BBR application guide (part number D1 030 DE) and our GBR leaflet (part number D1 031 DE).



PRODUCTION

Manufacturing a COAXI-CORE involves a special production, led in an appropriate environment where tools are allocated and where all precautions are taken to avoid any contact with ferromagnetic materials during the screw machining and cleaning process.

Their manufacture is directed by a Quality Assurance Plan whose documented rules are strictly applied throughout the production line. This Quality Assurance procedure (PAQ-C007A) guarantees the high level of non-magnetism and reproducibility for all our COAXI-CORE products.

ADVANTAGES OF COAXI-CORE CONNECTORS

CONNECTION INSIDE THE CORE OF THE FIELD

COAXI-CORE are the only ones that can even take place inside the core of the magnetic field. The field distortion they generate is so small that it meets the drastic requirements of the MRI type applications.

QUALITY

In order to guarantee that exceptional level of non-magnetism and its repeatability, every **COAXI-CORE** is manufactured through a strictly controlled production, led in an appropriate environment according to the Radiall Quality Assurance Procedure (PAQ-C007A).

MULTI-SERIES TECHNOLOGY

The **COAXI-CORE** technology is applicable to almost all our coaxial connectors series.

HIGH SIGNAL TO NOISE RATIO

Since the distance between the equipment and the magnetic field decreases, fewer signal distortions or losses appear. The signal to noise ratio rises, so that the sensitivity improves. Detection of very weak signals is then possible. Low-contrast anatomic features are visible.

COAXI-CORE are adapted to static MRI and even to dynamic MRI that forbids picture averaging.

FIELD HOMOGENEITY

The picture spatial resolution depends on the magnetic field homogeneity.
Since **COAXI-CORE** connectors do not disturb much this field homogeneity, the picture spatial resolution is good. Adjacent picture details can be distinguished other to another. There are fewer corrections to bring to the picture.

You wish to benefit from our technological advance ?

RADIALL introduces you its available **COAXI-CORE** connectors. Do not hesitate to consult us to develop any other **COAXI-CORE** model.

Series	Description	Part number
MMCX	Straight PCB receptacle with through-hole pins	R110 426 097
SMB	Straight plug crimp type for 2,6/50 and 2,6/75 cables	R114 082 097
SMB	Right angle plug crimp type for 2,6/50 and 2,6/75 cables	R114 186 097
SMB	Straight bulkhead mount jack crimp type for 2,6/50 and 2,6/75 cables	R114 313 097
SMB	Straight PCB male receptacle with through-hole pins	R114 426 097
SMB	Right angle PCB male receptacle with through-hole pins	R114 665 097
	Straight PCB feedthrought solder type for 2,6/50 and 2,6/75 cables	R280 220 007
	Straight PCB feedthrought solder type for .047 cable	R280 287 097

Unit packaging