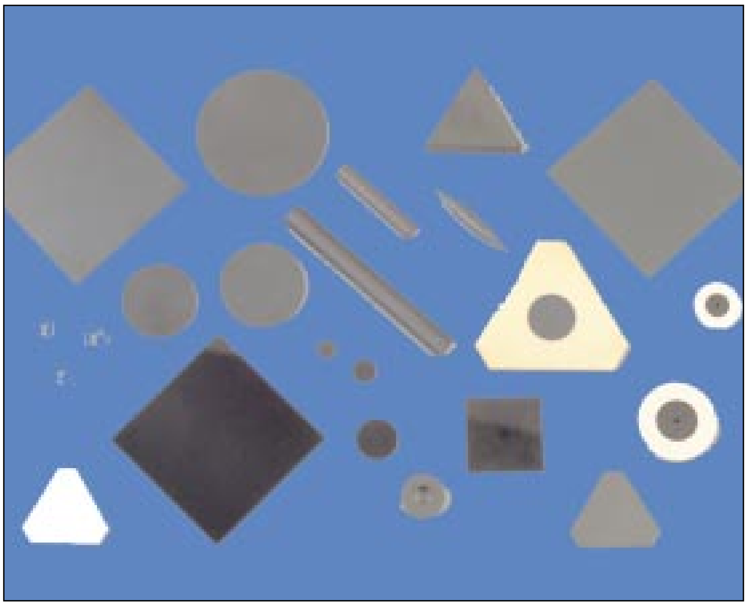
MICROWAVE FERRITE MATERIALS

CONTENTS



PAGE

PRODUCTION & QUALITY SYSTEM ISO9001-2000 4

SYMBOLS 5

BASIC PROPERTIES AND MATERIAL CHARACTERIZATION 6

IRON GARNETS 13

SPINEL FERRITES 21

HOW TO ORDER? 25

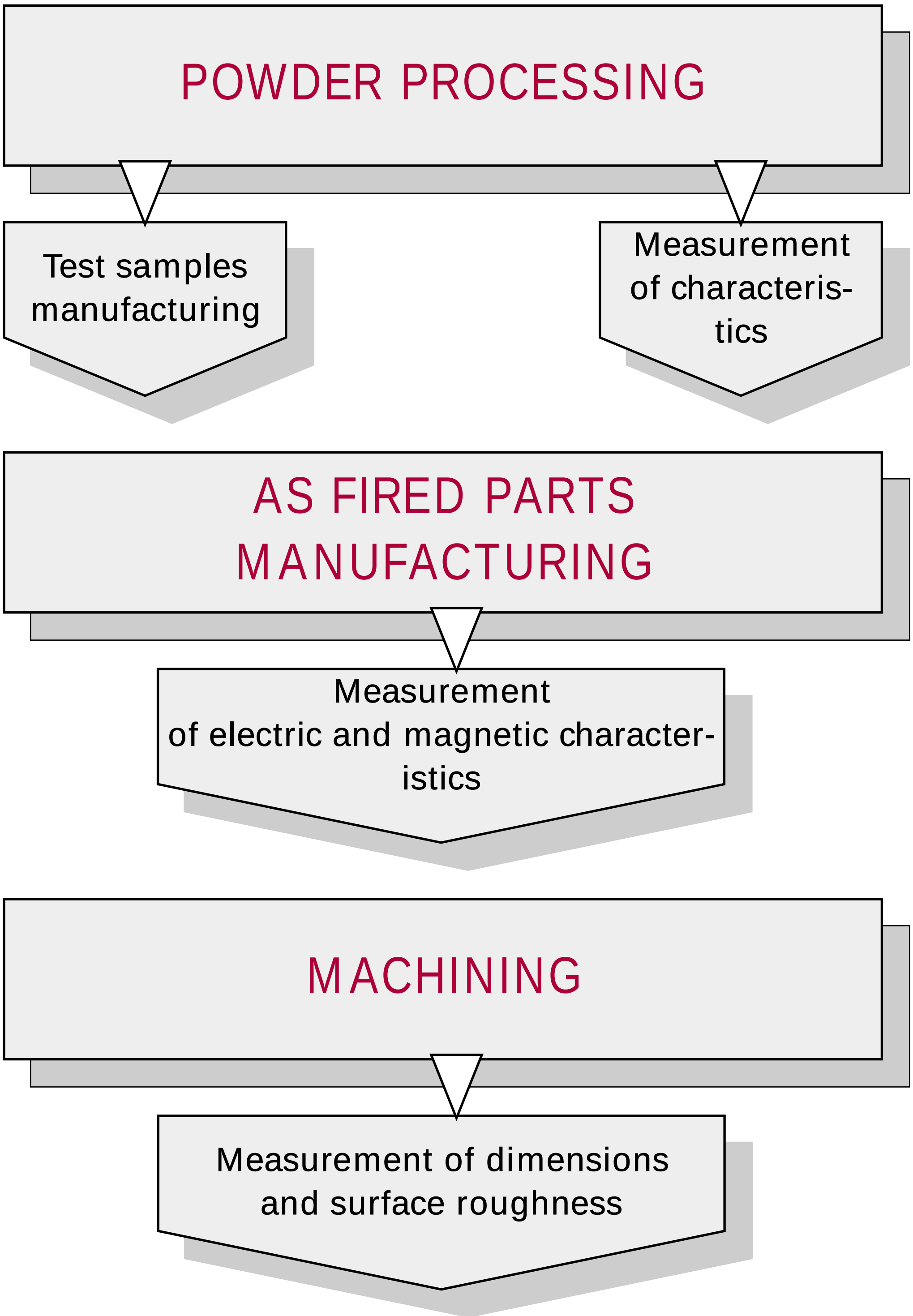
BASIC TECHNICAL NOTES 26

MICROWAVE FERRITE MATERIALS

Production and quality system

Production and Quality System ISO 9001-2000

Ferrite Materials



SYMBOLS

$\propto$	. . . .	magnetization temperature coefficient
B	. . . .	magnetic induction (Gauss)
B_m	. . . .	maximum induction at 5 H_c (Gauss)
B_r	. . . .	remanent induction (Gauss)
B_r / B_m	. . . .	squareness ratio
ΔH	. . . .	ferromagnetic resonance line width (@-3dB)(Oersted)
ΔH_{eff}	. . . .	effective line width (Oersted)
ΔH_k	. . . .	spin wave line width (Oersted)
ϵ'	. . . .	relative permittivity (real part)
ϵ''	. . . .	relative permittivity (imaginary part)
tan δ	. . . .	dielectric loss tangent = ϵ'' / ϵ'
ϵ_r	. . . .	relative complex permittivity
f	. . . .	frequency
γ	. . . .	gyromagnetic ratio
g_{eff}	. . . .	Landé factor
H	. . . .	applied magnetic field (Oersted)
H_c	. . . .	coercive force (Oersted)
h_c	. . . .	microwave critical field (Oersted)
$4\pi J_s$	. . . .	saturation magnetization (Gauss units)
χ	. . . .	diagonal constant of the susceptibility tensor
μ	. . . .	diagonal constant of the permeability tensor
Ra	. . . .	average surface roughness (µm)
T	. . . .	temperature
T_c	. . . .	Curie temperature

MICROWAVE FERRITE MATERIALS

General information

BASIC PROPERTIES AND MATERIAL CHARACTERIZATION

Selecting a ferrite for a given microwave application is a difficult challenge; the range of devices to be produced is wide, the parameters numerous. In the case of a three-port circulator for example, we can list the following parameters:

- Forward and backward insertion loss, midband frequency, bandwidth temperature range, average and peak power, dimensions, weight and cost effective design.

With both reciprocal (phase shifter) and non-reciprocal devices (isolator, circulator), the microwave appliances make use of the permeability of the ferrite, which is determined by the phenomenon of magnetic resonance. Thus, the permeability depends on one hand, on the magnetization and the applied static magnetic field and on the other hand, on the frequency and polarization of the electromagnetic wave, with respect to the static field. With a circularly polarized wave propagating parallel to the static field, the permeability will depend on the sign of polarization (positive or negative refers to the direction of rotation of the base vectors with respect to the direction of propagation):

$$\mu \pm = 1 + \chi_{\pm}$$

$$\chi = \chi' - j\chi''$$

Where χ' is the susceptibility
Where χ'' represents the loss
In case of saturated materials

$$\chi'_{\pm} = M_S \frac{(H_r \mp f/\gamma)}{(H_r \mp f/\gamma)^2 + (\Delta H/2)^2}$$

$$\chi''_{\pm} = M_S \frac{(\Delta H/2)}{(H_r \mp f/\gamma)^2 + (\Delta H/2)^2}$$

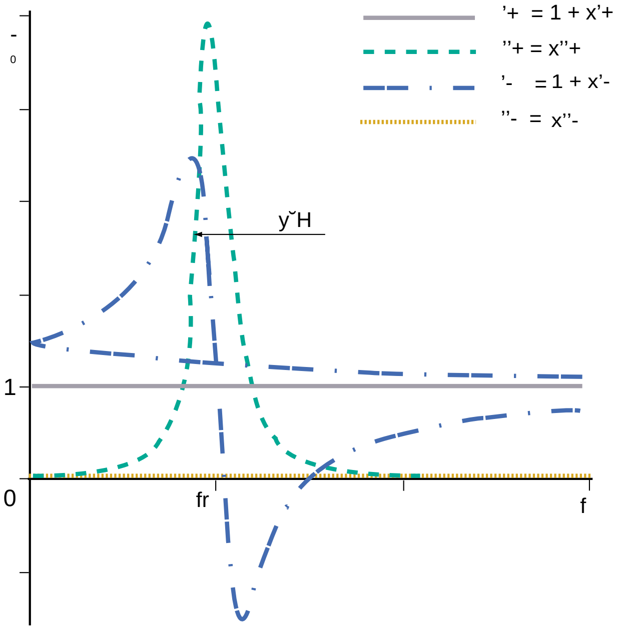


Fig. 1

Where f is the operating frequency
H_r is the applied field
γ is the ferromagnetic ratio

$$\gamma = g_{eff} \cdot 0.01759 \text{ MHz.m/A}$$
$$= g_{eff} \cdot 1.4 \text{ MHz/Oe}$$

M_S is the saturation magnetization
ΔH is the mid point width of the Lorentz curve
χ''_{+} (f) centered around $f_r = \gamma H_r$

Within a given frequency range, it is possible to find values of H such that the permeability μ'_{+} and μ'_{-} are substantially different, while μ'_{+} and μ''_{-} have very low values (Fig. 1). This property is used in the construction of non-reciprocal devices. The applied field H can be either lower or higher than the resonant field H_r. The first solution is often preferable, for size reduction, since the magnets required are smaller, and optimization of some characteristics.

Influence of the magnetization of the material

The magnetization is a multiplicative factor in all terms of magnetic susceptibility. The greatest efficiency is linked to the highest degree of magnetization. However, the phenomenon of natural resonance in unsaturated materials must be taken into account, as this leads to "low strength field loss". Consequently, for a given frequency f, the material selected must have a magnetization lower than f/γ, unless it has to be used above the resonant frequency.

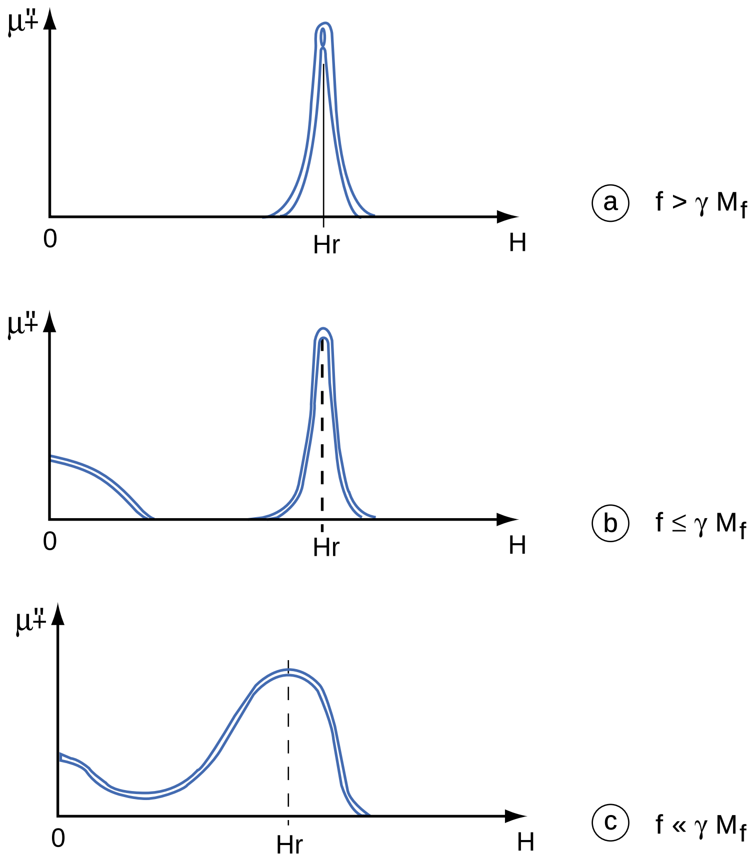


Fig.2 - Permeability μ"+ versus applied static field H

Influence of loss

One of the main preoccupations in the construction of ferrite components is the problem of reducing forward insertion loss. Loss from ferrite materials has two origins: dielectric and magnetic.
Modern technology produces microwave ferrites which have, depending on their composition, dielectric loss tangents at 10 GHz tg $\delta_\epsilon = \epsilon''/\epsilon'$ between 10^{-4} and 10^{-3}.
Two kinds of magnetic loss can be distinguished: at low and high microwave power level.

- **Low microwave power magnetic loss:**

Experiments show that the curve χ''_+ (H) is a Lorentz curve away from the resonant frequency with an effective line width $\Delta H_{eff} \leq \Delta H$.
On the other hand, near the resonant frequency, the line is broadened by several phenomena: doping ions porosity, magneto-crystalline anisotropy, impurities.

MICROWAVE FERRITE MATERIALS

General information

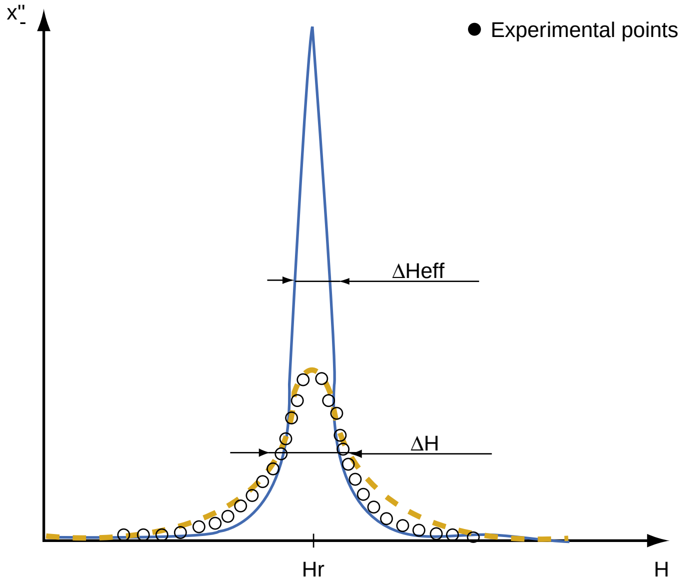


Fig. 3

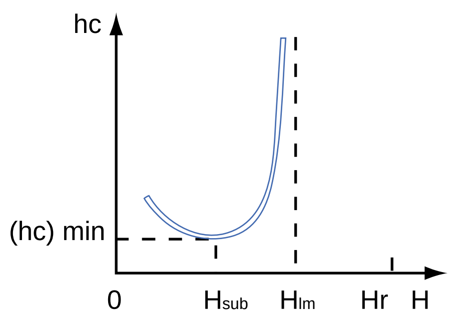
- **High microwave power magnetic loss:**

Above a certain microwave signal level, non linear phenomena take place resulting in additional magnetic loss that rapidly becomes prohibitive in the devices.

The critical microwave field h_c, from which such effects appear, depends on the applied static field. The non-linear effects are associated with the excitation of the spin waves, the attenuation of which is described by ΔH_k. For "below resonance" devices, non-linearity threshold of electromagnetic field is given by:

$$h_c \min = \Delta H_k \, 2f/\gamma \, M_s$$

The higher the value of ΔH_k is, the better the high-power behavior will be.



h_c 1st order non-linear effect critical field function of static field H.

Fig. 4

Characterization

MEASUREMENT METHODS

The methods used to measure the properties of ferromagnetic materials for microwave applications comply with the "Instructions for specifications relating to ferrites for use in microwave applications". (See publication 60556 at www.iec.ch) established by the International Electrotechnical Commission (I.E.C.) concerning "Ferrite and Magnetic Components". The magnetic characteristics are only given in the classic Gauss system (C.G.S. system) units.

- **Saturation magnetization, ($4\pi\ J_S$ in C.G.S.):**

Saturation magnetization is measured at room temperature by the Weiss method. A sample is moved out the air gap of a magnet delivering a magnetic field of 8000 Oe. The flux variation is read on an integrator with an accuracy of ± 1%.

- **Magnetization temperature coefficient, $\propto$:**

The average temperature coefficient of magnetization in the range –20° C, +60° C, is given by the following expression:

$$\propto = \frac{\Delta J_S}{J_S.\Delta T}$$

Where ΔJ_S represents the maximum magnetization level difference in the temperature range ΔT.

- **Ferromagnetic resonance line width, ΔH: Landé factor, g_{eff}**

The effective Landé factor (g_{eff}), and the ferromagnetic resonance line width (ΔH) are measured in a rectangular cavity at 9.3 GHz, at room temperature. The sample is a 1 mm diameter sphere, lapped using grain abrasive wheels. For materials with a low ΔH value, the sphere is polished to optical quality to eliminate disturbances caused by surface unevenness. The g_{eff} measurement accuracy is ± 1%. The accuracy of the ΔH values falls in two categories:

— For $\Delta H > 125$ Oe, accuracy is ± 5% ;
— For $\Delta H < 125$ Oe, accuracy is ± 2% with a limit of ± 0.5 Oe.

- **Effective line width, ΔH_{eff}:**

The effective resonance line width (ΔH_{eff}) is measured at room temperature in a cylindrical cavity at 9 GHz using a 2 mm diameter rod. The values of ΔH_{eff} are given for an applied magnetic field at 500 Oe. For materials with $4\pi\ J_S$ 2000 Gauss, ΔH_{eff} is measured above the resonant frequency (approximately 5000 Oe). The ΔH_{eff} measurement accuracy is ± 10% with a limit of ± 1 Oe.

MICROWAVE FERRITE MATERIALS

General information

- **Spin wave line width, ΔH_k:**

The spin wave line width (ΔH_k) is measured using a 3 mm diameter sphere, in a cylindrical cavity at 9.4 GHz, at room temperature, using parallel pumping with a pulse duration of 2.5 µs.
The ΔH_k measurement accuracy is ± 5% with a limit of ± 1 Oe.

- **Complex permittivity, $\in_r$:**

The complex permittivity ($\in_r$) is measured using a 1 mm diameter rod in a rectangular cavity at 8.3 GHz, at room temperature. The dielectric constant ($\in$') measurement accuracy is ± 1%. This gives a dielectric loss tangent (tan δ) accuracy of ± 20% with a maximum of $\pm 5.10^{-5}$.

- **Hysteresis loop:**

A toroidal sample fitted with a double winding is used as a transformer. The primary winding magnetizes the sample through a 50 Hz frequency signal. The applied field H is proportional to the primary current; the signal induced in the secondary winding is proportional to the magnetic flux variation and is integrated to obtain the magnetic induction B.

The induction value B_m is obtained for an applied field of 5 H_c. The measurement accuracy is as follows:

$$H_c \pm 2\% \; ; \; B_r, B_m \pm 10\% \; ; \; B_r/B_m \pm 2\%.$$

The temperature coefficients of inductions B_r and B_m and coercive field H_c in the temperature range ΔT (- 60° C, + 100° C), are given by the expressions:

$\alpha B_r = \Delta B_r/(B_r.\Delta T)$ $\alpha B_m = \Delta B_m/(B_m.\Delta T)$ $\alpha H_c = \Delta t_c/(H_c.\Delta T)$

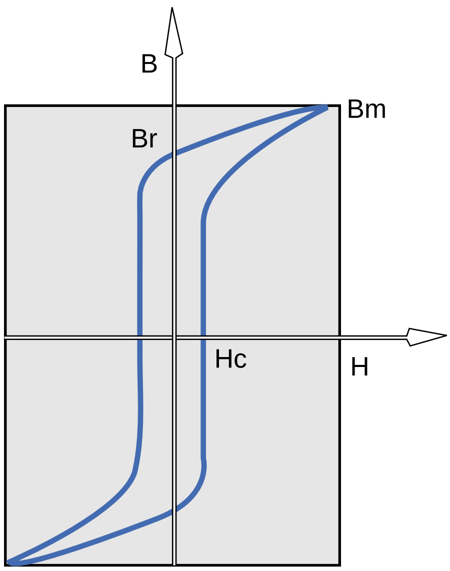


Fig. 5

USER GUIDE

Materials and applications

The table 1 here below shows how the parameters used in the catalogue meet the most common needs of the users.

Table 1

APPLICATIONS	CUSTOMER REQUIREMENTS	EFFECT ON CHOICE OF MATERIAL
Low level power circulator	Low insertion loss High directivity Compactness Widest possible frequency band Wide temperature range	ΔH_{eff} minimum ΔH minimum ϵ' maximum M_S adjusted to frequency α as low as possible
High level power circulator	Power behavior Low insertion loss Temperature stable M_S	ΔH_k high ΔH_{eff} and ΔH as low as possible compatible with ΔH_k
Isolator below resonant frequency circulator	Low insertion loss Narrow frequency band	ΔH_{eff} minimum M_S and ΔM_S function of frequency ΔH according to the required band

The diagrams shown in the catalogue are arranged in the table 2 here below. For each diagram, optimum use of the different parameters is shown.
For details of the possible materials corresponding to a given diagram, refer to the page indicated in the table.

Synoptical table 2

Crystal structure	TEMEX family	Chemical composition	Recommended band of operating frequencies	Temperature stability	Power behavior	Magnetic losses out of resonant frequency	Cycle squareness	Catalog page n°
Garnets	Y1xx	Y-Gd	1.55 to 10.90 GHz	* *	*	*		14
	Y2xx	CVG	1.55 to 10.90 GHz	* *	*	* * *		15
	Y3xx	Y-Al	0.34 to 6.20 GHz	*	*	* *		16
	Y4xxx		1.55 to 6.20 GHz	* * *	* *	* *		17
	Y7xx	Y-Gd-Al	0.34 to 6.20 GHz	*	* *	*		18
	Y9xx	Y-Gd-Al Co-doped	0.34 to 10.90 GHz	* *	* * *	*		19
	Dx	Y-Gd-Al Dy-doped	0.34 to 10.90 GHz	* *	* * *	*		20
Spinels	Uxx	Mn-Mg	1.55 to 36 GHz	*	*	* *	* *	21
	Axxx	Li	6.20 to 40 GHz	* * *	*	* * *	* * *	22-23
	Nxxx	Ni	1.55 to 40 GHz	* * *	* * *	*	*	24

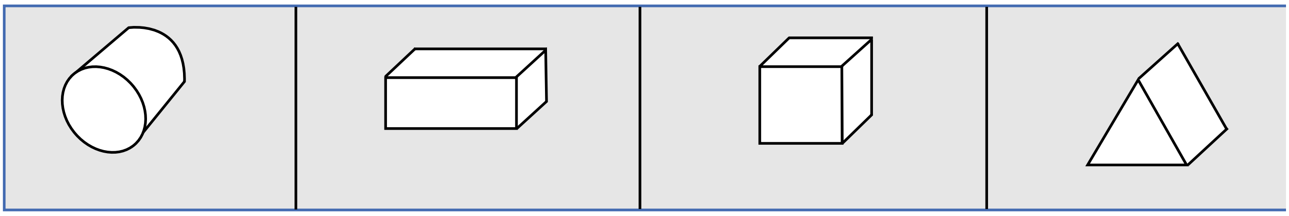
* Poor ** Fair *** Excellent

MICROWAVE FERRITE MATERIALS

User guide

Dimensioning

As-fired parts are produced from pressed powder fired at high temperatures (sintering).
A wide range of shapes can be produced.



Machined parts

Standard machining tolerances = ± 0.025 mm.
Tighter accuracy can be achieved on request.

A wide range of shapes and dimensions can be made according to the user's specification:

- **Disks** .... : Diameters = 1 mm up to 55 mm (typical values)
- **Substrates** .... : Max size = 50.8 x 50.8 mm
  Thickness = 0.5 mm to 3 mm (typical values)
- **Triangles**
- **Rods** .... : Max diameter = 12 mm (standard)
  Max length = 90 mm (standard)
  Other dimensions can be achieved on request.
- **Composite assemblies** .... : Ferrite and dielectric materials.

Note: Custom shapes are available on request. We can study all you requests.

Surface finishing

As-fired parts can be grinded, lapped and/or polished. The standard average peak-to-valley height (Ra) is specified here below:

Surface finishing	Ra micrometer		Ra microinch	
	min.	max.	min.	max.
Standard	0.6	0.8	24	32
"Finition"	0.4	0.6	16	24
"Super Finition"	0.2	0.4	8	16

Acceptable quality level requirements

TEMEX applies CEI410 (equivalent to MIL-STD-105) attribute sampling plan, General Inspection Level I, for the qualification of outgoing product. The following table provides the AQL criteria for typical product attributes.

Attribute	A.Q.L. Level I
Visual imperfections	1.5
Dimensions	1.5

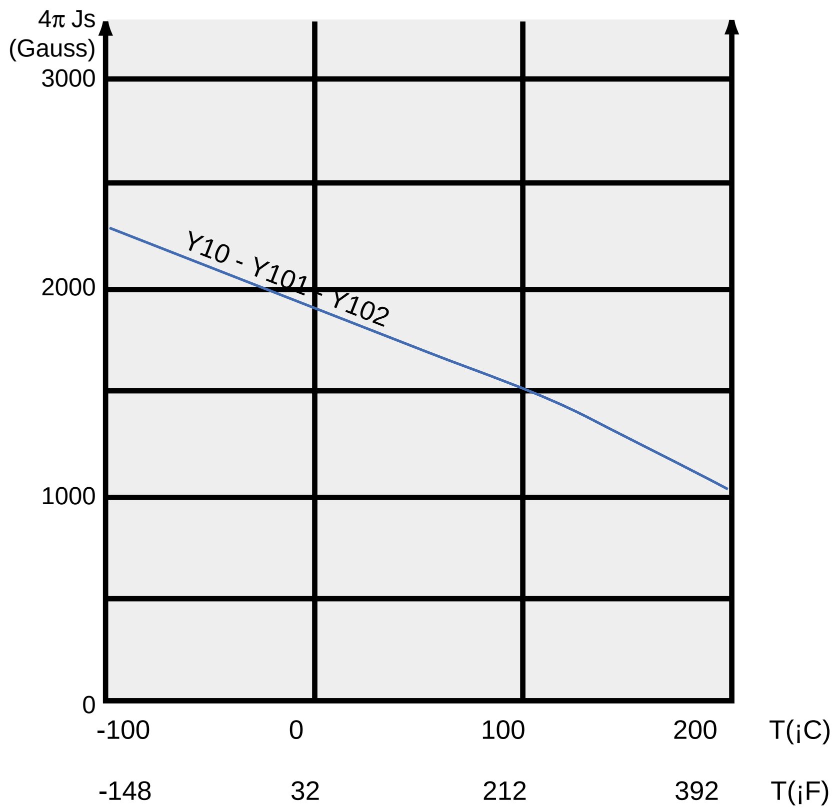
Outgoing products are qualified according to this A.Q.L., unless other A.Q.L. are specified by the customer before placing an order.

IRON GARNETS

YIG

Yttrium - Iron garnet

TYPES	$4\pi J_S$ (Gauss) ± 5%	T_C (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	∈' ± 5%	10^4 tan δ	∝ $.10^3$ (°C^{-1}) −20, +60°C ± 0.2
Y10	1790	280	2.00	45	4	2	15.3	< 2	2.2
Y101	1820	280	2.00	20	4	2	15.4	< 2	2.2
Y102	1800	280	2.00	30	4	2	15.3	< 2	2.2



IRON GARNETS

Y - Gd

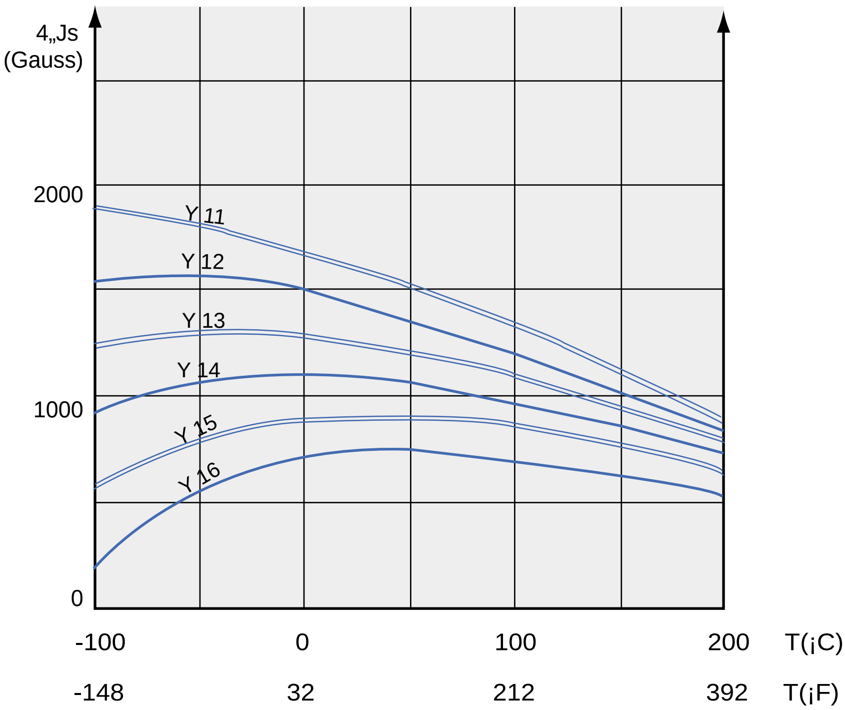
Y - Gd

Yttrium - Gadolinium

This Yttrium - Gadolinium garnet family is especially useful in applications where a high degree of temperature stability is required.

These materials can be used with a moderate level of peak power.

TYPES	$4\pi J_s$ (Gauss) ± 5%	T_c (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	ϵ' ± 5%	10^4 tan δ	$\propto .10^3$ (°C^{-1}) –20, +60°C ± 0.2
Y11	1600	280	2.00	60	5	3.0	15.3	< 2	1.8
Y12	1420	280	2.01	65	6	6.0	15.3	< 2	1.5
Y13	1250	280	2.01	75	8	8.0	15.3	< 2	1.0
Y14	1100	280	2.02	95	12	9.0	15.4	< 2	0.5
Y15	900	280	2.03	140	18	11.0	15.4	< 2	0.7
Y16	750	280	2.02	200	25	15.0	15.4	< 2	0.9

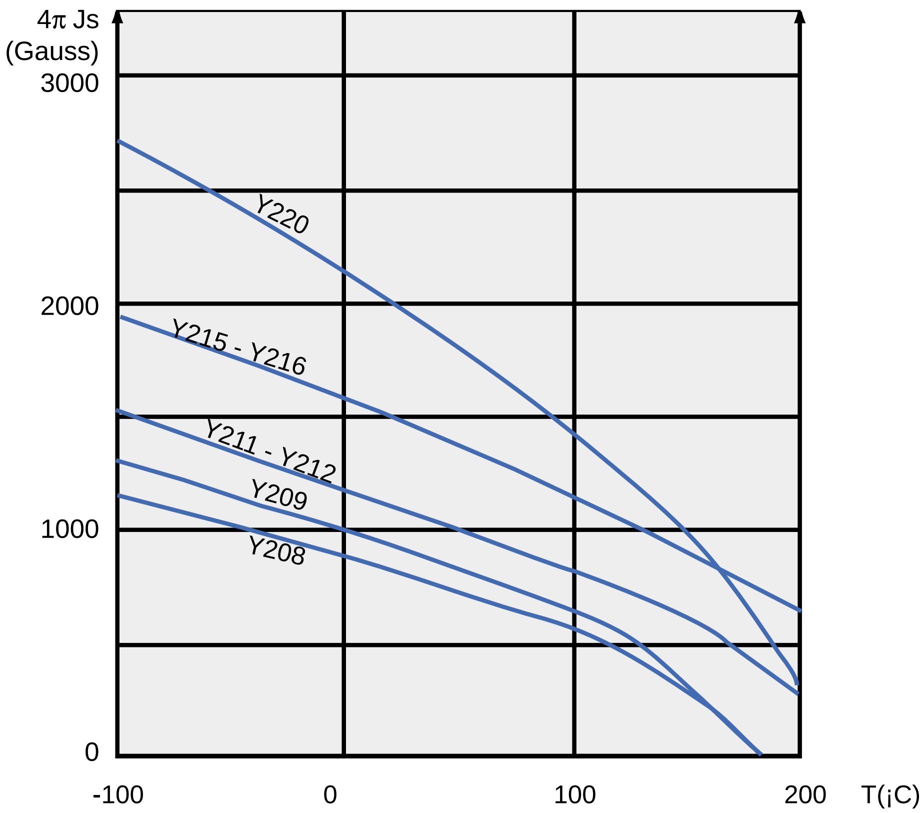


CALCIUM VANADIUM GARNETS (CVG)

Narrow line width materials

This family of materials have been specially designed and produced for low loss devices. Bandwidth improvements are obtained for beyond resonance applications.

TYPES	$4\pi J_S$ (Gauss) ± 5%	T_C (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	∈' ± 5%	10^4 tan δ	∝ $.10^3$ (°C^{-1}) −20, +60°C ± 0.2
Y220	1950	205	2.01	10	2	1	15.4	< 2	3.1
Y218	1850	215	2.01	10	–	–	14.8	< 2	2.6
Y216	1600	218	2.01	10	–	–	14.8	< 2	2.6
Y215	1450	215	2.01	10	2	1	14.7	< 2	2.7
Y212	1200	209	2.01	10	2	1	14.5	< 2	2.9
Y211	1100	205	2.01	10	2	1	14.4	< 2	3.0
Y210	1000	200	2.01	10	–	–	14.2	< 2	3.3
Y209	900	180	2.01	10	2	1	14.1	< 2	3.5
Y208	800	177	2.01	10	2	1	14.0	< 2	3.7



IRON GARNET

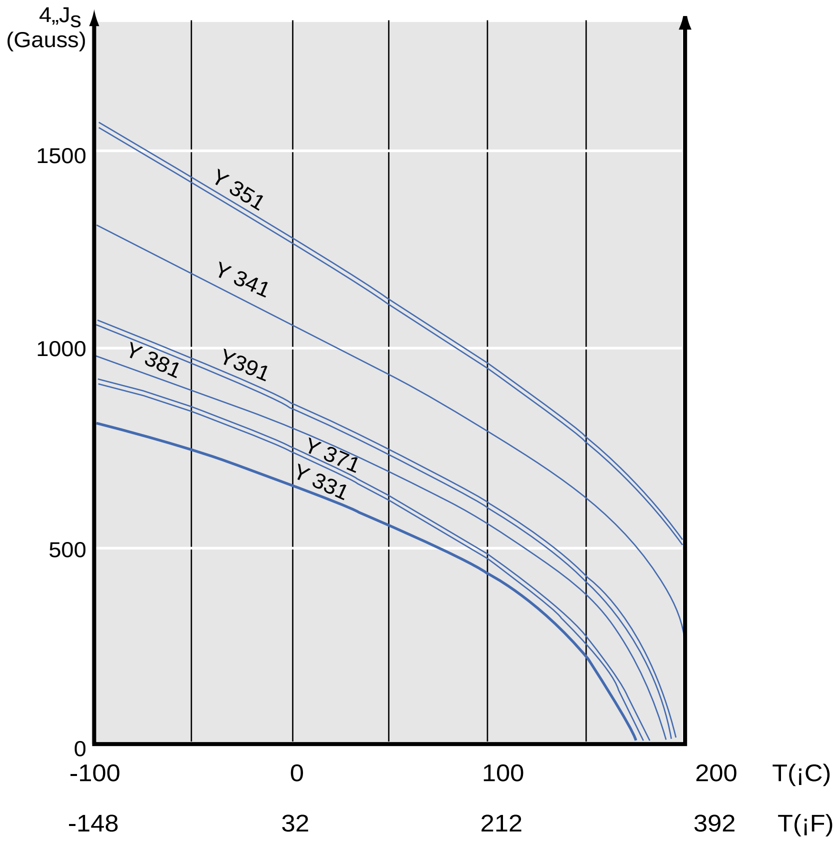
Y - Al

Y - Al

Narrow line width materials - Yttrium Aluminum

These garnets offer a wide choice of saturation magnetization covering most microwave applications for devices operating with very low loss in a wide band.

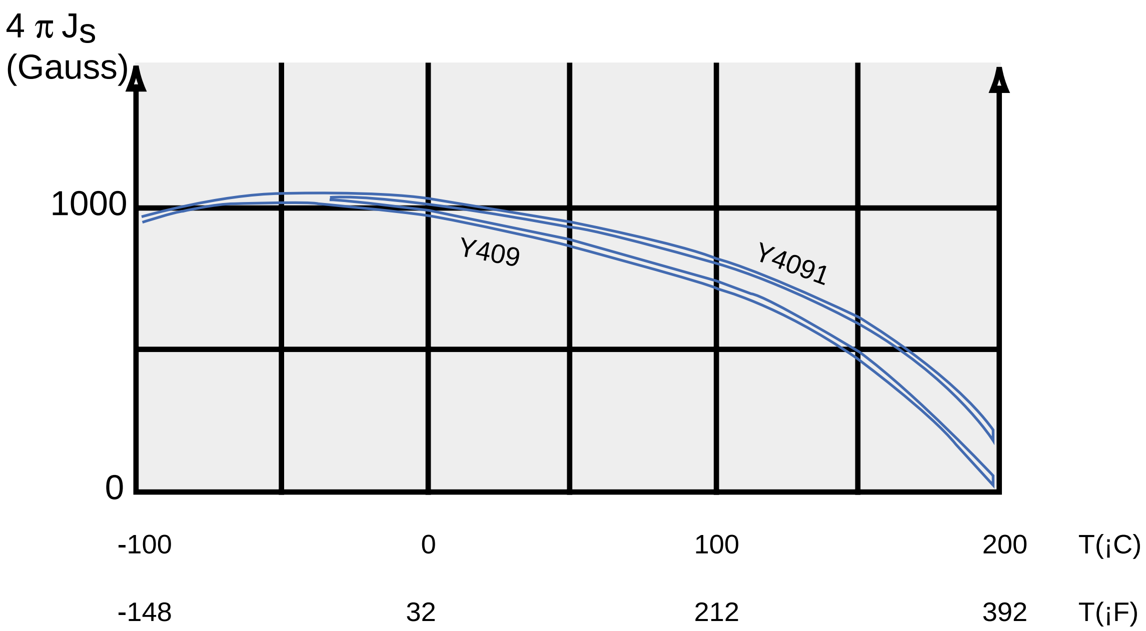
TYPES	$4\pi J_S$ (Gauss) ± 5%	T_C (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	∈' ± 5%	10^4 tan δ	∝ .10^3 ($°C^{-1}$) –20, +60°C ± 0.2
Y35	1200	225	2.01	40	4	2.0	14.9	< 2	2.6
Y351	1200	225	2.01	22	4	2.0	14.9	< 2	2.6
Y34	1030	210	2.01	40	4	2.0	14.8	< 2	2.7
Y341	1030	210	2.01	22	4	2.0	14.8	< 2	2.7
Y39	800	195	2.01	40	4	2.0	14.6	< 2	2.9
Y391	800	195	2.01	22	4	2.0	14.6	< 2	2.9
Y38	760	190	2.01	40	4	2.0	14.5	< 2	2.9
Y381	760	190	2.01	22	4	2.0	14.5	< 2	2.9
Y37	680	180	2.01	40	4	2.0	14.5	< 2	2.9
Y371	680	180	2.01	22	4	2.0	14.5	< 2	2.9
Y33	615	175	2.01	40	4	2.0	14.5	< 2	3.2
Y331	615	175	2.01	22	4	2.0	14.5	< 2	3.3
Y30	565	160	2.01	30	4	2.0	14.4	< 2	3.8
Y32	420	135	2.01	30	4	2.0	14.4	< 2	3.2
Y31	370	125	2.01	30	4	2.0	14.1	< 2	4.1
Y36	290	115	2.01	25	4	2.0	14.0	< 2	4.6
Y302	240	100	2.01	30	4	2.0	13.8	< 2	5.0



NARROW LINE WIDTH - TEMPERATURE STABLE MATERIALS

This family of materials has been specially designed and produced for low loss and temperature stable devices. It is possible to increase the bandwidth for beyond resonance applications.

TYPES	$4\pi J_S$ (Gauss) ± 5%	T_C (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	$\in'$ ± 5%	10^4 $\tan\delta$	$\propto .10^3$ (°C^{-1}) –20, +60°C ± 0.2
Y4091	960	195	2.02	35	12	9.0	15.2	< 2	1.4
Y409	920	223	2.02	50	18	12.0	15.2	< 2	0.8



IRON GARNET

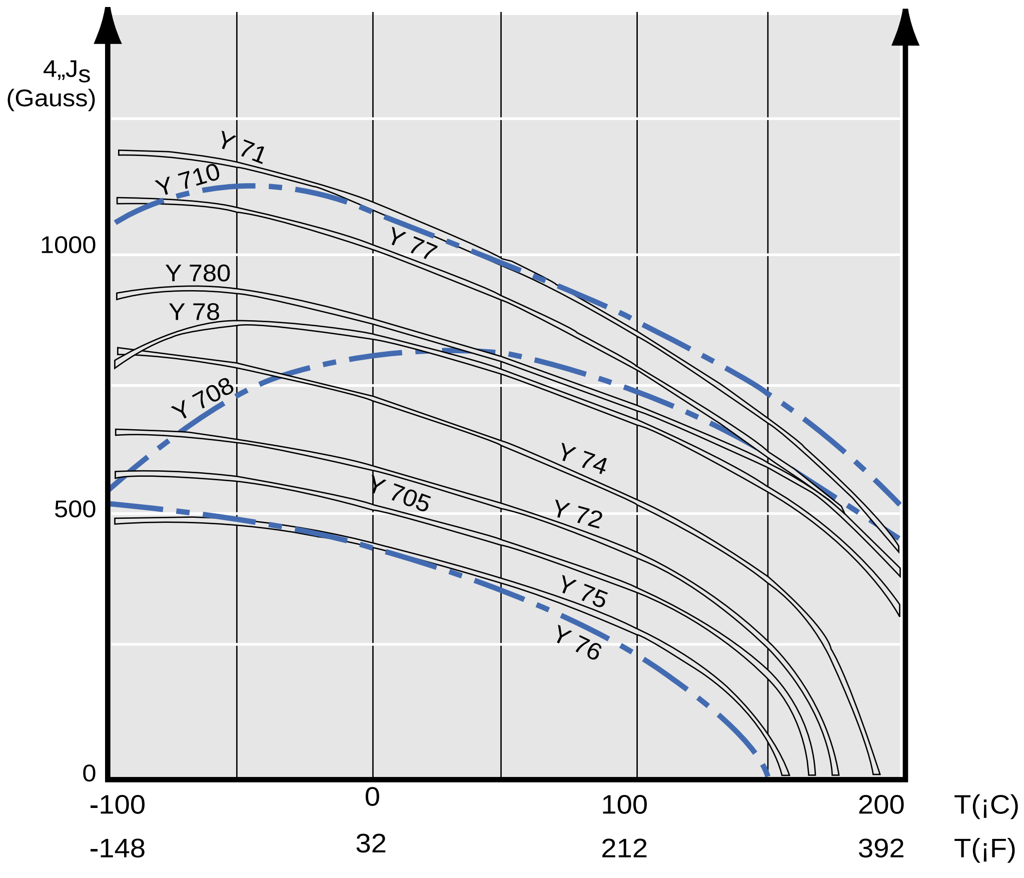
Y - Gd - Al

Y - Gd - Al

Yttrium - Gadolinium - Aluminum

The main feature of this family of products is its high temperature stability. These garnets are suitable for use at moderate peak power levels.

TYPES	$4\pi J_S$ (Gauss) ± 5%	T_C (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	∈' ± 5%	10^4 tan δ	$\propto .10^3$ ($°C^{-1}$) –20, +60°C ± 0.2
Y71	1020	235	2.01	60	7	5.0	15.0	< 2	2.2
Y710	1020	240	2.02	75	9	7.0	15.0	< 2	1.7
Y77	950	230	2.01	60	6	5.0	14.9	< 2	2.0
Y780	830	235	2.02	60	6	5.5	14.8	< 2	1.6
Y78	800	220	2.00	80	8	8.0	15.0	< 2	1.3
Y708	800	260	2.04	140	15	15.0	15.2	< 2	0.5
Y74	670	190	2.01	60	6	6.0	14.9	< 2	2.3
Y72	540	175	2.01	60	6	6.0	14.6	< 2	2.3
Y705	470	170	2.02	65	6	6.0	14.3	< 2	2.8
Y75	400	160	2.03	65	6	6.0	14.3	< 2	2.7
Y76	390	150	2.02	50	6	6.0	14.2	< 2	3.4

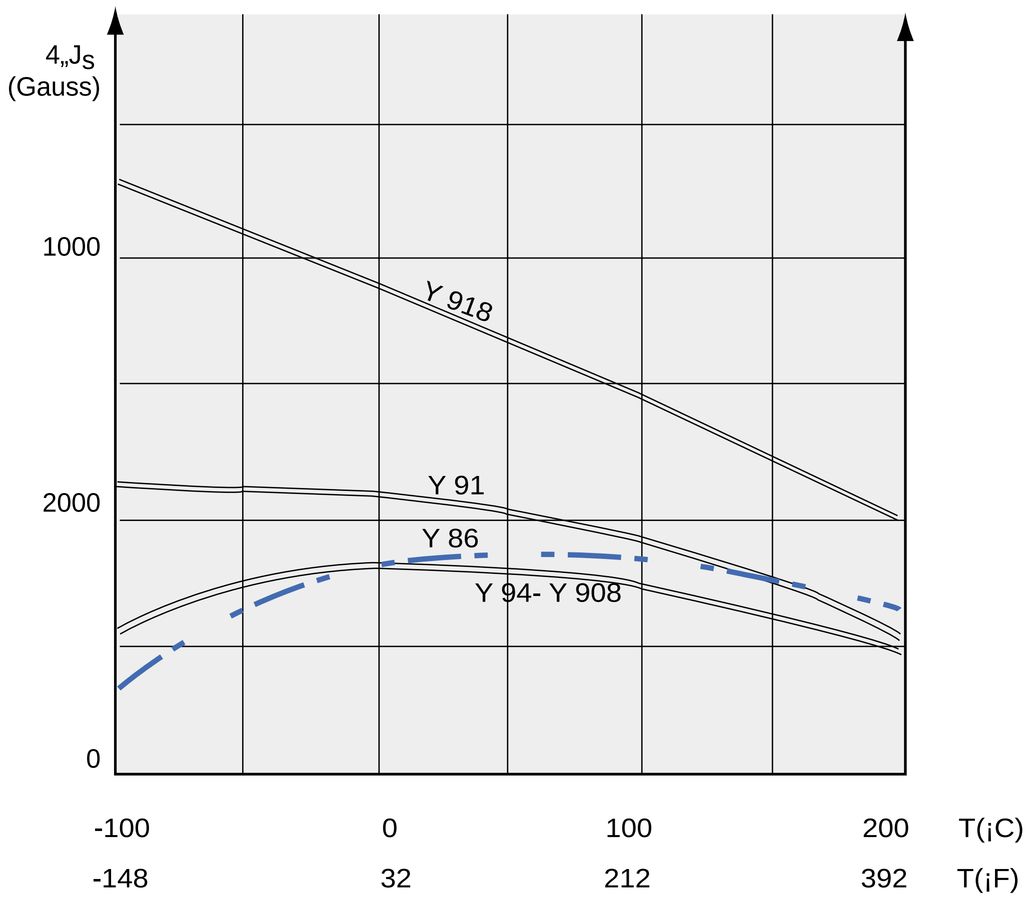


Y - Gd - Al Co OR Dy-DOPED

Yttrium - Gadolinium - Aluminum Cobalt or Dysprosium - doped power materials

These garnets are designed for high peak power level applications. Most of them have good temperature stability, which means that they can be used at high average output levels.

TYPES	$4\pi J_S$ (Gauss) ± 5%	T_c (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	ϵ' ± 5%	10^4 tan δ	$\propto .10^3$ (°C^{-1}) −20, +60°C ± 0.2
Y918	1760	280	2.02	85	12	20	15.0	< 2	2.2
Y91	1020	240	2.02	60	17	14	15.1	< 2	1.3
Y86	830	270	2.03	95	34	25	15.4	< 2	1.2
Y94	780	250	2.02	75	14	23	15.2	< 2	0.3
Y908	780	250	2.02	85	14	29	15.2	< 2	0.3
Y9081	780	250	2.02	120	14	35	15.2	< 2	0.3



IRON GARNETS

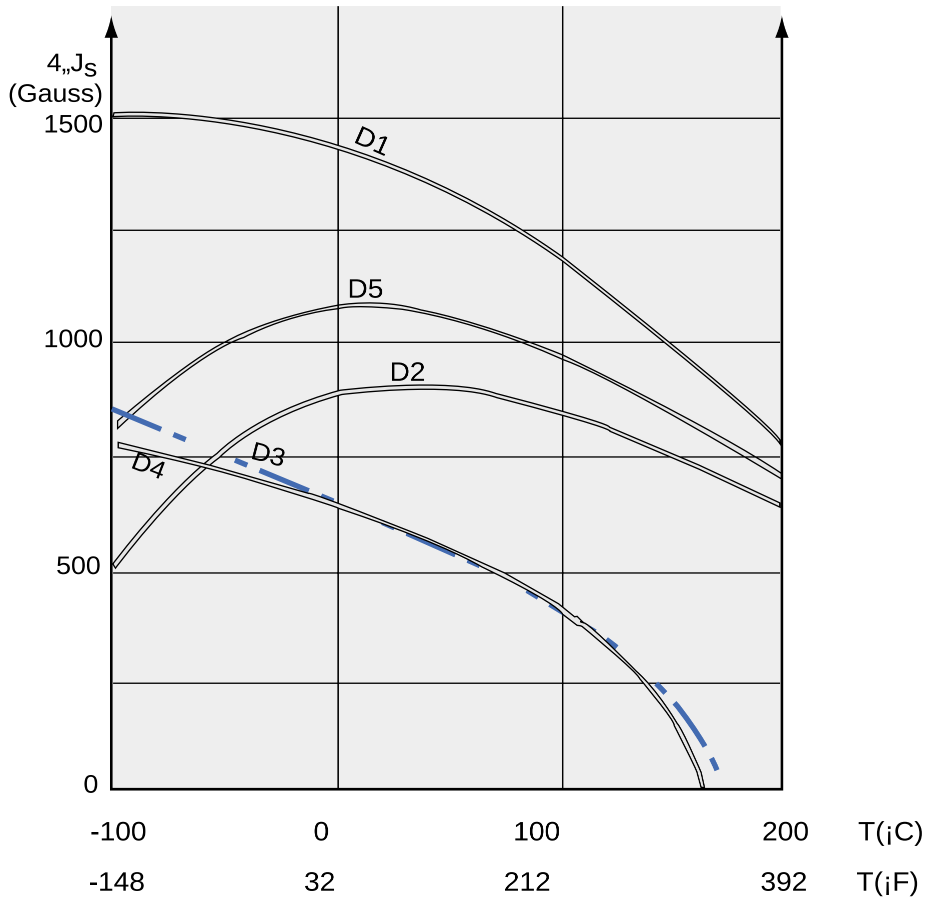
Dy-doped

DY-DOPED

Dysprosium-doped power materials

These garnets are designed for high peak power level applications. Most of them have good temperature stability, which means that they can be used at high average output levels.

TYPES	$4\pi J_S$ (Gauss) ± 5%	T_c (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	ϵ' ± 5%	10^4 $\tan\delta$	$\propto .10^3$ (°C^{-1}) –20, +60°C ± 0.2
D1	1400	270	2.00	110	34	16	15.5	< 2	1.4
D5	1070	270	2.02	150	36	23	15.5	< 2	0.5
D2	900	270	2.01	185	25	24	15.5	< 2	0.8
D3	590	175	2.00	85	16	19	14.5	< 2	3.5
D4	580	170	2.00	140	34	33	14.4	< 2	3.0



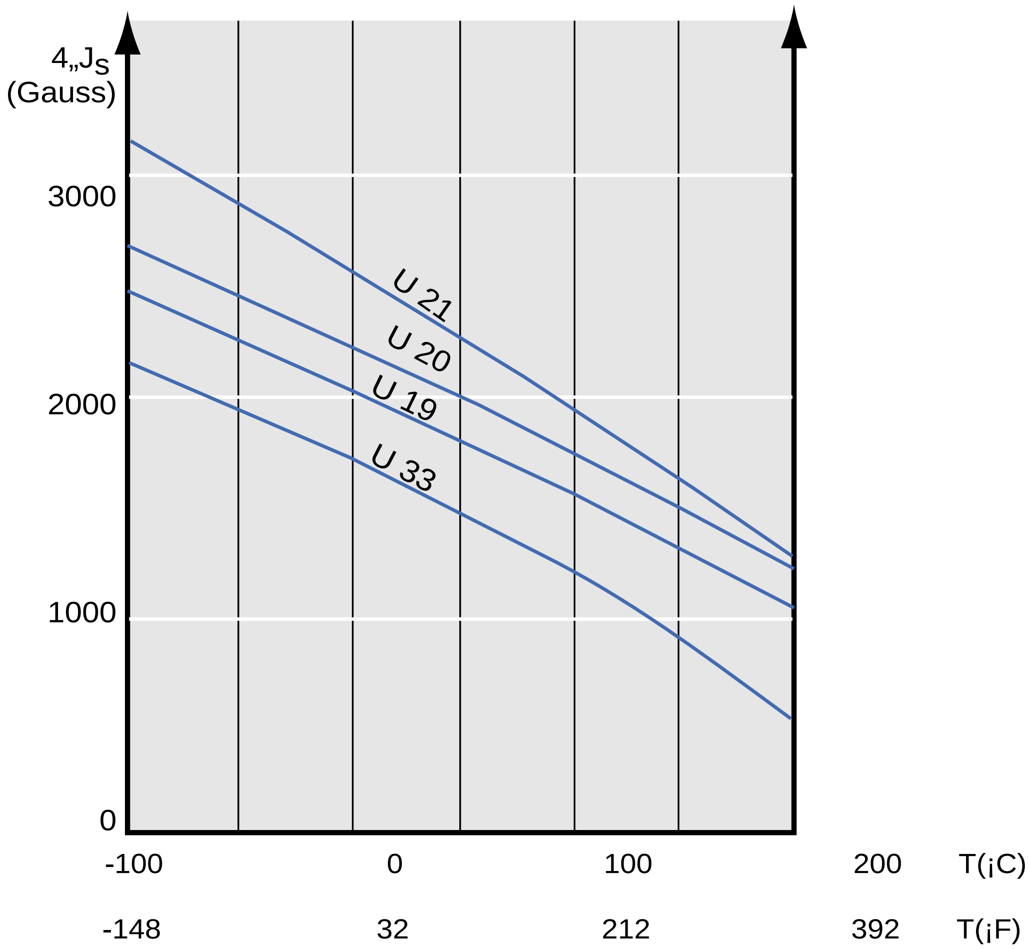
SPINEL FERRITES

Mn - Mg

Manganese- Magnesium

Manganese - magnesium ferrites are used in devices which must have low magnetic and dielectric losses.

TYPES	$4\pi J_S$ (Gauss) ± 5%	T_C (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	ϵ' ± 5%	10^4 tan δ	$\propto .10^3$ (°C^{-1}) −20, +60°C ± 0.2
U21	2400	275	2.03	290	6.0	4	13.0	< 3	2.7
U20	2100	300	2.01	360	6.0	4	13.0	< 3	2.3
U19	1900	280	2.01	350	6.0	4	13.0	< 3	2.2
U33	1600	230	2.02	290	8.0	4	12.4	< 3	3.3



SPINEL FERRITES

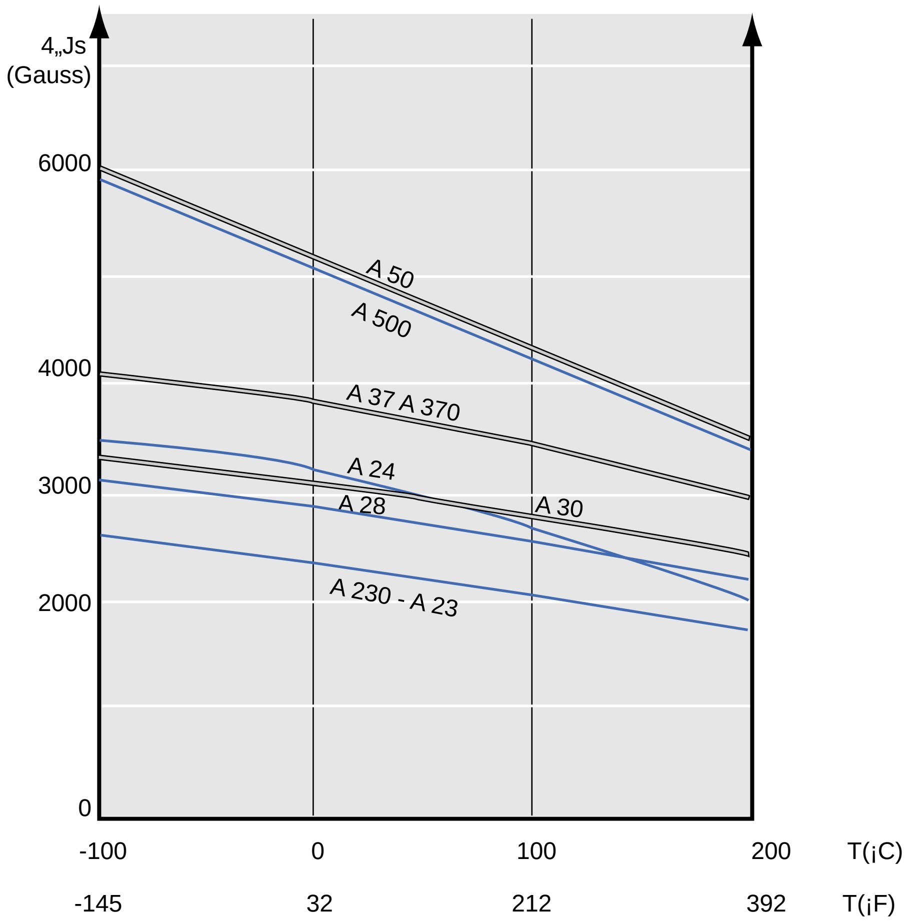
Li

Li

Lithium - Titanium - Zinc

These ferrites are used in the production of temperature stable components operating in and above the X band. A370 an A230 are power materials.

TYPES	$4\pi J_S$ (Gauss) ± 5%	T_C (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	ε' ± 5%	10^4 tan δ	∝ .10^3 * (°C^{-1}) −20, +60°C ± 0.2
A50	5000	450	2.06	170	4.0	3	15.3	< 5	1.6
A500	4900	450	2.06	200	9.0	10	15.3	< 5	1.6
A37	3700	565	2.08	400	4.0	3	16.0	< 5	1.0
A370	3700	565	2.07	400	7.0	6	15.9	< 5	1.0
A30	3000	555	2.08	450	4.0	3	16.4	< 5	0.8
A28	2800	540	2.08	450	4.0	3	16.6	< 5	0.9
A24	2450	390	2.08	250	4.0	3	16.8	< 5	–
A23	2300	505	2.08	450	4.0	3	16.8	< 5	1.2
A230	2300	505	2.08	450	9.0	8	16.7	< 5	1.2



Li

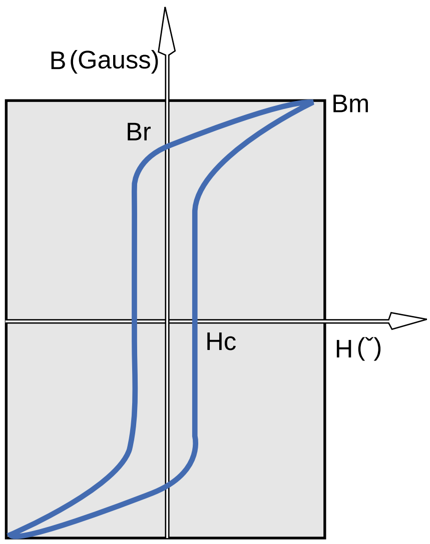
Hysteresis loop

TYPES	B_r / B_m (%)	B_r (Gauss)	$10^3 . \propto B_r$ (°C^{-1}) (–60, +100°C)	H_c (Oe)	$10^3 . \propto H_c$ (°C^{-1}) (–60, +100°C) ± 0.2
A50	92	2880	0.39	0.5	0.83
A37	96	2560	0.24	2.0	0.61
A30	97	1990	0.23	1.3	0.41
A23	98	1630	0.26	1.0	0.65
A230	97	1655	0.29	1.3	0.61

$\propto B_m = \propto B_r$

* $\propto B_r = \Delta B_r/(B_r.\Delta T)$

** $\propto H_c = \Delta H_c/(H_c.\Delta T)$



SPINEL FERRITES

Ni

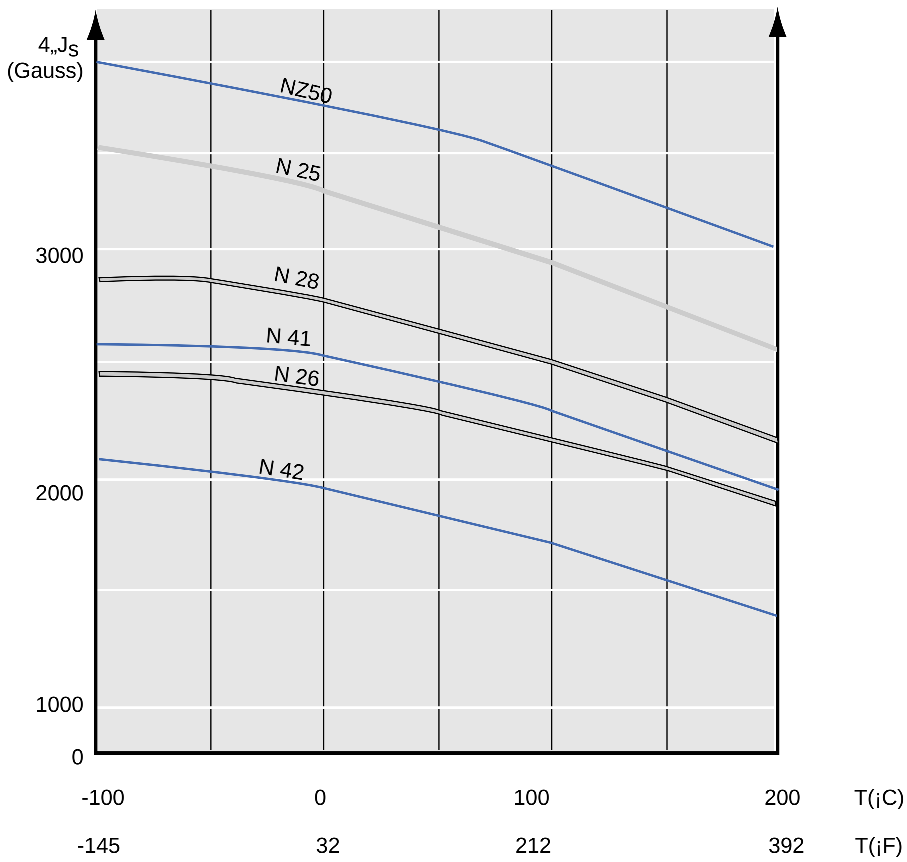
Ni

Nickel

These materials are used for high peak and average power applications.

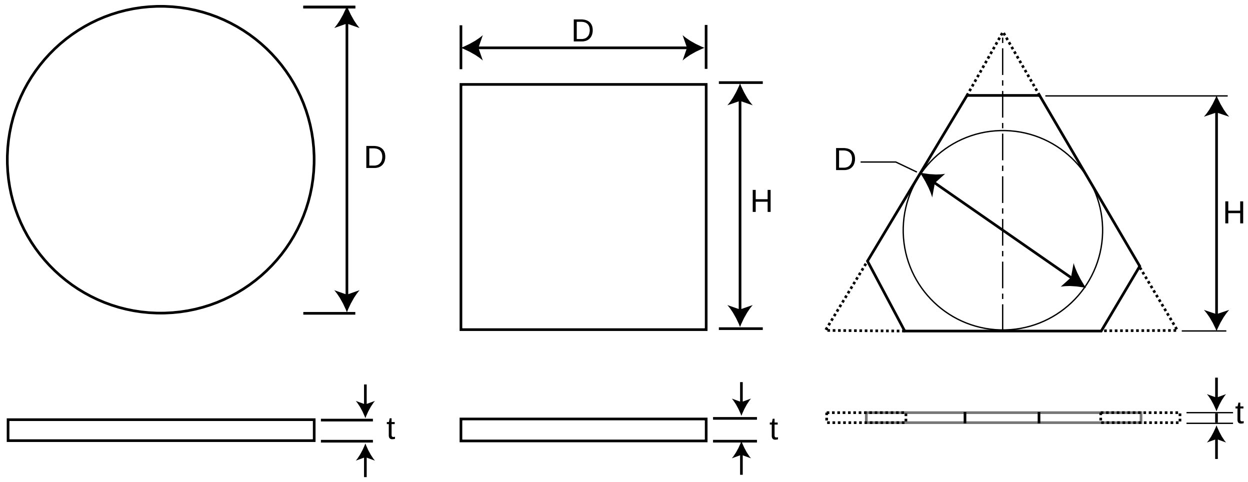
TYPES	$4\pi J_S$ (Gauss) ± 5%	T_c (°C) ± 5%	G_{eff} ± 5%	ΔH (Oe) ± 20%	ΔH_{eff} (Oe) ± 20%	ΔH_k (Oe) ± 10%	∊' ± 5%	10^4 tan δ	∝ .10³ (°C⁻¹) –20, +60°C ± 0.2
NZ50	5000	375	2.10	125	–	–	13.7	< 15	2.0
NZ40	4000	470	2.20	200	–	–	13.4	< 15	2.5
N25	3200	560	2.30	250	100	26	12.7	< 6	1.0
N28	2750	550	2.30	330	100	24	12.4	< 6	0.8
N41	2500	530	2.30	370	130	35	12.3	< 6	0.7
N26	2350	520	2.30	300	100	35	12.2	< 6	0.7
N42	1900	480	2.30	350	130	36	11.4	< 6	1.0

$\Delta H_{eff} >> \Delta H_{K}$



HOW TO ORDER?

TABLE 1: SHAPE TYPES



Shape code	Shape type
D	disc
T	triangular
S	substrate

TABLE 2: TOLERANCES ON DIMENSIONS

Tolerance type	Dimension tolerance (mm)	Dimension tolerance (inch)
Z	± 0.200	± 0.008
Y	± 0.150	± 0.006
X	± 0.100	± 0.004
W	± 0.050	± 0.002
V	± 0.025	± 0.001

Remark: as-fired parts (no machining requested, i.e. lower cost) are available for ±1% tolerance on the dimensions. Smaller tolerances for as-fired designs could be considered on request.

TABLE 3: METALLIZATION OPTION

Option type	Option
M	silver metallization
T	gold metallization

Examples:

Material see Types	Shape see Table 1	D * 100	D tolerance see Table 2	H * 100	H tolerance see Table 2	t * 100	tolerance see Table 2	Options see Table 3
Y101	D	2540	W	-	-	100	V	
Y216	T	1693	Y	2200	X	152	V	M
NZ50	S	5080	Z	5080	Z	100	W	

MICROWAVE FERRITE MATERIALS

Basic technical notes

TECHNICAL NOTES

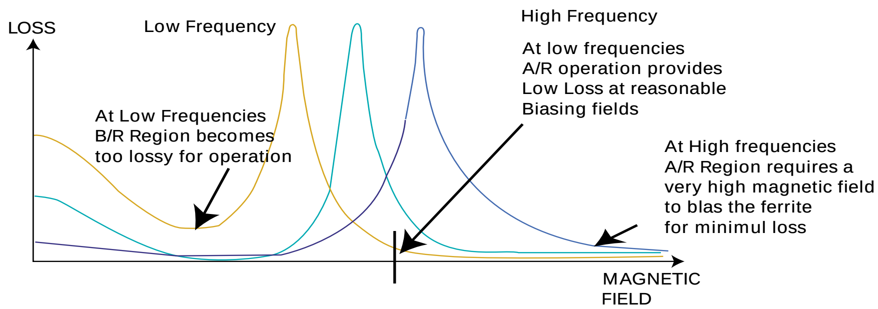
ELECTRON SPIN

As an electron spins about its own axis and revolves about the nucleus, it follows a strict set of rules. One is that the spin of the electron will be either left or right, depending upon where in the atom the electron is placed. Two additional rules that apply are:

- For closed orbits, there will be as many left-handed spins as right-handed spins,
- Only the electron in the outer-most orbits will cause magnetic effects.

As stated above, it is the spin of the electron that is the main cause of magnetization. In ferromagnetic materials, a predominance exists of either left or right-handed spins. Moreover, there is a restraining force that tends to keep electron near each other, spinning in the same direction. Ferromagnetic materials, also called cooperative materials, can retain their magnetic properties. This is due to the restraining force. Normally, in an unmagnetized state, the electron spins are randomly oriented so that the net sum of all the Bohr magnetrons is zero. When a magnetic field is applied, the material changes to the magnetized state, where all the tiny magnets line up and add together.

In an experiment, the sample is subjected to a microwave field of fixed frequency and to an applied static field, the magnitude of which is varied. At each field value, the reflected or absorbed power from the sample is measured. These may yield one or more minima and maxima, respectively, corresponding to resonance modes of the ensemble. The field, at which resonance occurs, the so-called resonance field, depends on several magnetic parameters.



VSWR PARAMETER

In the microwave field, transmissions of energy are not so easy. When you talk about transmitted power, you also talk about reflected power.

For example, when a signal goes from the source to the load, there is a reflected signal that comes from the load to the source. The value of this signal is based on the load reflection coefficient.
So, to characterize a device, one talks about the Voltage Standard Wave Ratio (VSWR) which is defined as follows:

$$VSWR = \frac{1+\Gamma}{1-\Gamma}$$

Where Γ is the reflection coefficient and given by the following formula:

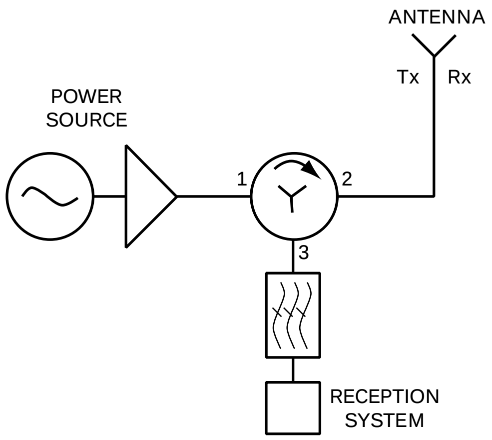
$$\Gamma = \frac{reflected\_energy}{transmitted\_energy}$$

If the device is perfectly matched, the VSWR value is 1:1 (i.e. Γ=0). But this is almost impossible to obtain, especially at low cost. So you have to live with this physical problem and try to minimize it. A very good VSWR is 1.05:1 (but this is still quite expensive to produce), standard values are around 1.10:1 and 1.20:1.

CIRCULATOR BASICS

The Y-junction circulator is a non-reciprocal device providing transmission of energy from one of its port to an adjacent port, while decoupling the signal from all other ports. It is based on the use of the gyromagnetic behavior of the elementary magnetic dipoles, or uncompensated electron spins, of the ferrite material.

A common application for this type of device (a duplexer) is described below:



A cost-effective solution for microwave signal transmission and reception is to use the same antenna for both operations. The operating principles to separate both channels (Tx and Rx) are listed below:

• The source signal, which is a high power one, comes from port 1 to port 2 and is transmitted by the antenna. The reception system, which is designed for low power, is then protected as nothing is transmitted from port 1 to port 3,

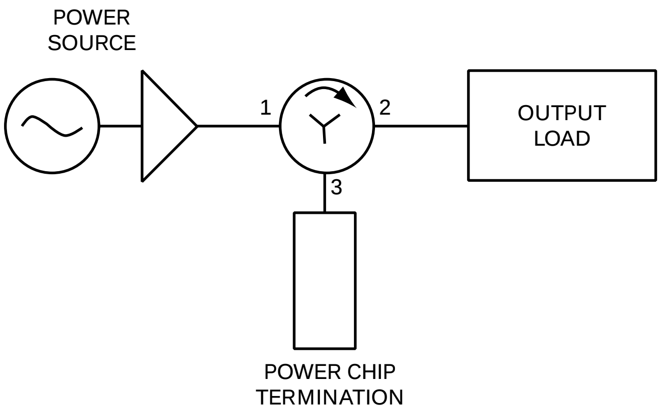
• When an incoming low power signal is received by the antenna, it comes from port 2 to port 3 up to the reception system for further processing and nothing goes from port 2 to port 1, which is necessary as the source doesn't like to receive any reflected signal.

MICROWAVE FERRITE MATERIALS

Basic technical notes

ISOLATOR BASICS

In microwave field, where power can be very high, it is necessary to protect the power source from any returned energy due to the VSWR of the output load. So, designers use isolators, which are basically circulators but with only two ports. The third port is then internally connected to a power chip termination.



Transmitted energy goes from port 1 to port 2 without any loss. A reflected signal, due to the fact that the VSWR of the output load is not 1:1, goes then from port 2 to port 3, which means there is nearly no power returned directly to the source. In fact you still have a small amount of the power that is returned to the source from port 2 to port 1, but with a high attenuation, -20dB for example.
However, you still have to dissipate the reflected energy exiting at port 3: that's when you need a power chip termination.