ECCOSORB® MFシリーズ

Lossy, Magnetically Loaded, Machinable Stock

for Round bar, Square bar and Sheet type

ECCOSORB® MF

ECCOSORB MF is a series of right magnetically loaded epoxy stock, which can be machined for use as absorbers, attenuators and terminations in waveguide, coaxial or stripline applications. With products such as these, it is necessary to be conversant with the dielectric and magnetic properties of the materials, which are listed in this technical bulletin, the values given are normalized with respect to free space, see Products table in last page.

Most of the definitions of several symbols and the details of fomula in this application note are explained in later page, which is originated by Emerson & Cuming publication in 70s : "ENERGY PROPAGATION IN DIELECTRIC AND MAGNETIC".
In this technical bulletin, M' is used for the real part of the Magnetic permeability and M" for the Magnetic loss factor.
The definition of dB/CM (dB/IN) is included in reference, both in mathematical form and in word. The value is useful in comparing one material against another to determine which offers the most loss independent of interface reflection coefficients.
|Z|/Zo, the normalized impedance magnitude ratio, can be used as a qualitative measured of the impedance match between free space and the material. An impedance raio that is closest to 1 is the most desirable because at that ration, the impedance match between the material and free space is perfect.
These characteristics are not in themselves directly applicable to the calculation of transmission and reflection coefficients as they are defined on point 3 & 4 of "Energy Propagation in Dielectric and Magnetic Material". For these calculations, the complex dielectric constant (K' - jK' tan D) and complex magnetic permeability (M' - jM' tan M) are used as listed in the table.

Please refer the Product Type # in table. Some of them, we have asked Volumed MOQ.

The key factor of MF series, Attenuation at 10GHz is as follows,

MF	110	112	114	116	117	124	175	190
dB/CM	2.2	5.6	13.2	32	56	67	69	75
dB/ＩN	5.6	14.2	33.5	81	142	170	175	190

Application at the low frequencies,

At radio frequencies, MF series have been used effectively as a high-Q inductor-core material in such devices as sulg tuners. The material is useful also in many other magnetic components. Simple RF filters can be formed for example, by passing vacuum tube filament leads through small blocks of ECCOSORB MF, or by casting appropriate sections of the material around such leads by using one of the electrically equivalent castable versions.

Physical Properties

Service Temperature	< 180℃
Density	1.6-4.9 g/cc
Hardness Shore D	85°
Tensile Strength	55 MPa
Thermal Expansion per ℃	~30×10^{-6}
Thermal Conductivity	1.44 W/mK
Water Absorption % 24hours	< 0.3
Outdoor Exposure Tolerance	GOOD
Machinability	GOOD

Electrical Properties

Volume Resistivity	> 10^{11} ohm-cm
Dielectric Strength	> 25 volts/mil

Product Size ；

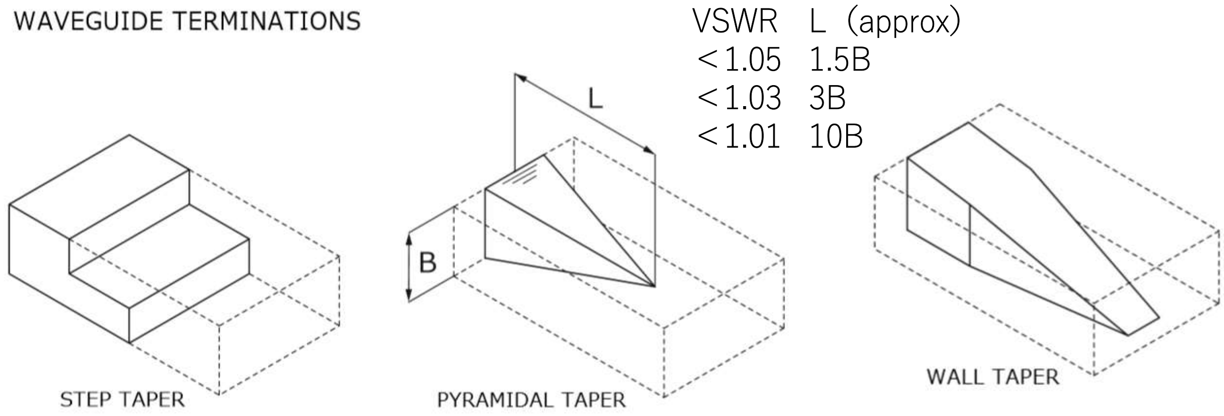
Sheets 30.5cm (12in) x 30.5cm (12in)
thicknesses 1.27cm, 1.91cm, 2.54cm, 3.81cm, 5.08cm (1/2in, 3/4in, 1in, 3/2in, 2in)

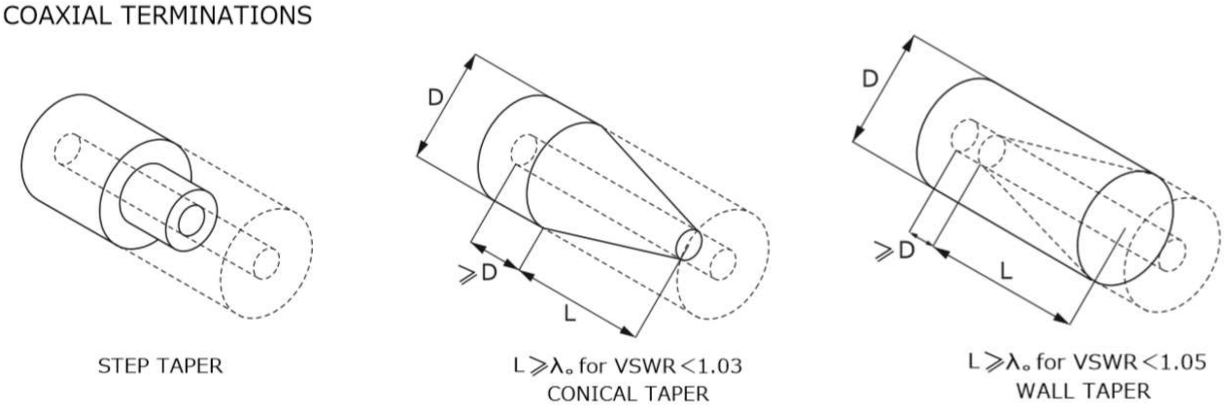
Bars Length 30.5cm
In squares 1.27cm, 1.91cm, 2.54cm, 3.81cm, 5.08cm

Rods Length 30.5cm
Diameters (cm) 0.64, 0.95, 1.27, 1.59, 1.91, 2.54, 5.08
(IN) 1/4, 3/8, 1/2, 5/8, 3/4, 1, 2,

Other sizes, shapes, thickness and configurations are available on special order.

Termination Design Considerations ;





The most widely used member of the ECCOSORB MF series is 117. It is an excellent material to start experimentation. Most designs of termination and attenuating elements depend heavily upon cut-and-try procedures. A preliminary design is established by experience or rough estimates of probably satisfactory dimensions, a piece of ECCOSORB MS is machined and tested for VSWR and/or attenuation and the design is them modified as required.

In coaxial, waveguide and strip-line terminations, either step-tapered or uniformly tapered configurations can be used.

Step-tapered terminations are narrow-banded and highly critical dimensionally. They are recommended only where essentially single frequency operation is anticipated. Increasing the number of steps beyond two can increase the usable band-width and such designs are helpful when limited length is available in the direction of propagation. Reproducibility of the performance of step-tapered terminations may be difficult because of their sensitivity to small changes in magnetic and dielectric properties.

Uniformly tapered terminations are generally preferred because of the low VSWR which is possible to achieve over a wide frequency range. Dimensions are reasonably non-critical and performance is reasonably insensitive to magnetic and dielectric properties. In general, the more gradual the taper, the lower the VSWR. A length-to-base-width ratio of 10 : 1 is highly desirable for VSWR as low as 1.01 over a full waveguide frequency band, particularly with materials having the higher value of M' and K'. A sufficiently long taper must be used so that very little energy reaches the base mounting plate where it can be reflected back into the line. The one-way attenuation should be at least 25dB for VSWR as low as 1.01.

Wall-type uniform tapers offer maximum heat-transfer efficiency and are recommended for high-power applications.

Related Products

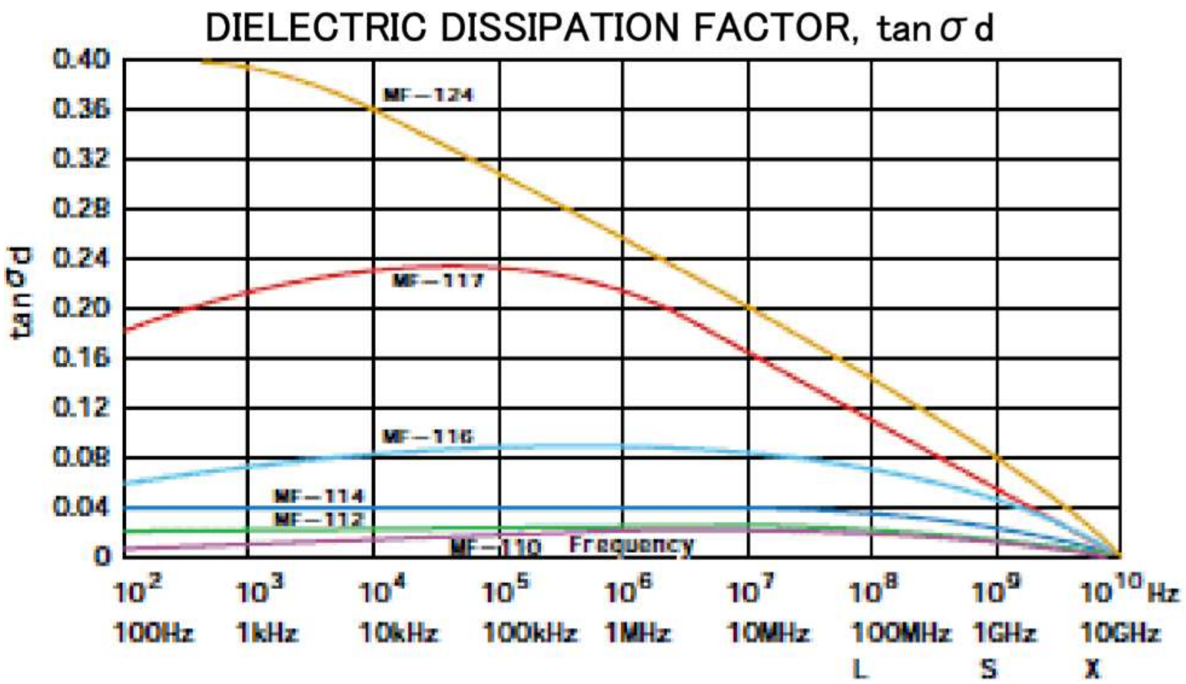
The following products have equivalent properties of ECCOSORB MF series with the availability of high-temperature, castable and molding-powder.

<u>ECCOSORB MF500F ;</u>
Increases temperature capability to 260 degC for MF110 through MF124 electrical properties. Sheet, bar and rod sizes as for ECCOSORB MF

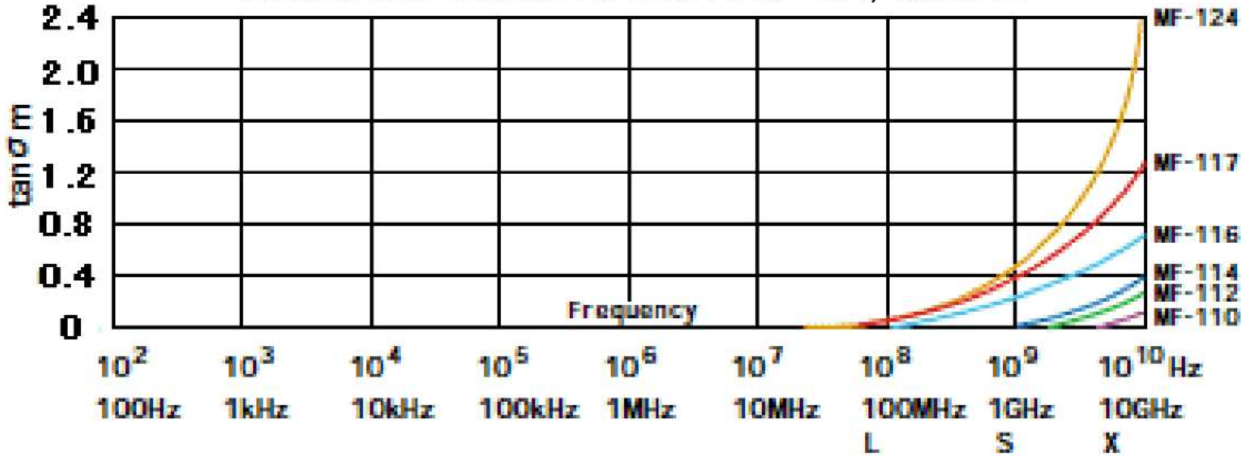
<u>ECCOSORB CR ;</u>
Epoxy casting-resin version for rigid shapes with electrical properties of ECCOSORB MF. Good to 180 degC. For intricate shapes or cavity filling.

<u>ECCOSORB CR-S ;</u>
Castable RTV silicon rubber like ECCOSORB CR. Electrical properties of ECCOSORB MF117 and MF124 only. Flexible, Tough and capability to 260 degC.

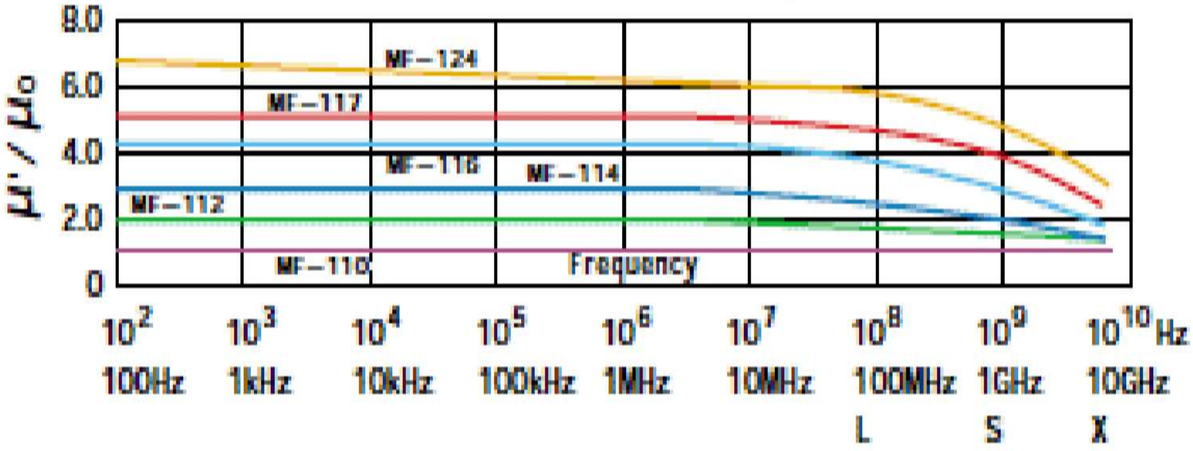
Each for Response



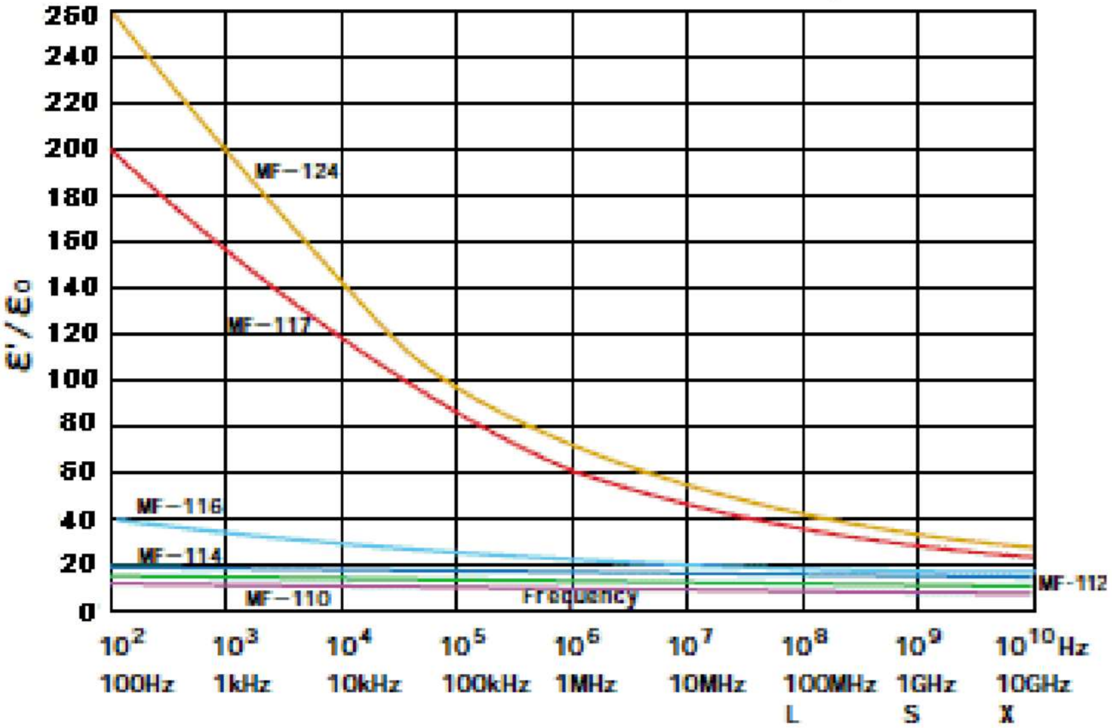
MAGNETIC DISSIPATION FACTOR, tanσm



PERMEATIBITY, μ' / μ_0



DIELECTRIC CONSTANT, $\varepsilon' / \varepsilon_0$



The significant features of the property table are :

1. In every case, K’ decreases with increasing frequency.
2. Almost without exception, the dielectric loss Tan δ and dielectric loss factor decrease with increasing frequency, the exception occurs at the low end of the frequency band, and can be ignored in most applications.
3. The magnetic loading increases from a minimum in MF-110 to a maximum in MF-190. There is a corresponding increase in K’, K “, M’, M “, tan δ and μ.
4. The 0 value in the table indicate that the number is less than 0.01.
5. The values given in the table and response graphs are nominal values and should not be used by customers in the writing of procurement specifications.
   If specifications are needed, the customers should consult with the Sales Dept.

The use of dielectric/magnetic properties for Quality Control, i.e., incoming or outgoing inspection, is not recommended, because the measurement of these properties is very time consuming and complicated. It is recommended to monitor the density.

Notes ;

This information, while believed to be completely reliable, is not to be taken as warranty for which we assume legal responsibility nor as permission or recommendation to practice any patented invention without license. It is offered for consideration, investigation and verification.

The information on this data are provided for your Development, Research, Inspection, etc., we are pleased with your reference this data for your review.

< Table >

FREQUENCY (Hz)

Type #		10^2	10^3	10^4	10^5	10^6	10^7	10^8	10^9	3×10^9	8.6×10^9	10^{10}	1.8×10^{10}
MF-110	K'	18	16	15	13	11	9.0	7.0	5.0	3.2	3.0	2.9	2.8
	TAN D	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.04	0.04
	K''	0.18	0.16	0.30	0.30	0.33	0.27	0.28	0.20	0.16	0.15	0.12	0.11
	M'	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.0	1.0	1.0
	TAN M	0	0	0	0	0	0	0	0	0	0.10	0.10	0.20
	M''	0	0	0	0	0	0	0	0	0	0.10	0.10	0.20
	dB/CM	0	0	0	0	0	0	0.01	0.09	0.26	2.0	2.2	6.6
	dB/IN	0	0	0	0	0	0	0.03	0.23	0.66	5.0	5.6	17
	$\vert Z\vert/Z_o$	0.26	0.27	0.28	0.28	0.33	0.37	0.40	0.47	0.59	0.59	0.59	0.60
MF-112	K'	20	18	16	14	12	10	8	6	5.2	5.0	4.8	4.6
	TAN D	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.04	0.03
	K''	0.40	0.36	0.48	0.42	0.36	0.40	0.32	0.24	0.26	0.25	0.19	0.14
	M'	2.0	1.9	1.8	1.7	1.6	1.5	1.5	1.4	1.4	1.1	1.1	1.0
	TAN M	0	0	0	0	0	0	0.01	0.02	0.03	0.22	0.23	0.26
	M''	0	0	0	0	0	0	0.02	0.03	0.04	0.24	0.25	0.26
	dB/CM	0	0	0	0	0	0	0.02	0.16	0.59	4.9	5.6	10.1
	dB/IN	0	0	0	0	0	0	0.05	0.41	1.5	12.4	14.2	25.7
	$\vert Z\vert/Z_o$	0.32	0.32	0.34	0.35	0.37	0.39	0.43	0.48	0.52	0.47	0.48	0.47
MF-114	K'	22	21	19	18	16	14	12	11	9.9	9.8	9.7	9.6
	TAN D	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.05	0.05
	K''	0.88	0.84	0.76	0.72	0.80	0.70	0.60	0.55	0.59	0.59	0.49	0.48
	M'	2.8	2.8	2.7	2.6	2.5	2.4	2.3	2.1	1.9	1.3	1.1	1.0
	TAN M	0	0	0	0	0	0	0.04	0.08	0.13	0.33	0.40	0.45
	M''	0	0	0	0	0	0	0.09	0.17	0.25	0.43	0.44	0.45
	dB/CM	0	0	0	0	0	0	0.04	0.57	2.2	10.8	13.2	24.9
	dB/IN	0	0	0	0	0	0	0.10	1.4	5.6	27.4	33.5	63.2
	$\vert Z\vert/Z_o$	0.36	0.37	0.38	0.38	0.40	0.41	0.44	0.57	0.44	0.37	0.35	0.34
MF-116	K'	40	35	30	26	23	20	18	17	16.5	16.2	16.0	15.8
	TAN D	0.06	0.06	0.07	0.07	0.08	0.09	0.08	0.07	0.06	0.07	0.66	0.05
	K''	2.4	2.1	2.1	1.8	1.8	1.8	1.4	1.2	0.99	1.1	0.96	0.79
	M'	4.6	4.5	4.4	4.4	4.3	4.2	4.0	3.0	2.8	1.6	1.5	1.4
	TAN M	0	0	0	0	0	0	0.04	0.13	0.21	0.47	0.68	0.43
	M''	0	0	0	0	0	0	0.16	0.39	0.59	0.75	1.02	1.02
	dB/CM	0	0	0	0	0	0	0.09	1.3	5.0	21	32	57
	dB/IN	0	0	0	0	0	0	0.23	3.3	12.7	53	81	145
	$\vert Z\vert/Z_o$	0.34	0.36	0.38	0.41	0.43	0.46	0.47	0.42	0.42	0.33	0.33	0.33
MF-117	K'	195	158	120	85	62	48	38	28	22.9	21.4	21	20.6
	TAN D	0.18	0.21	0.23	0.24	0.22	0.18	0.12	0.09	0.06	0.02	0.02	0.02
	K''	35	33	28	20	14	8.6	4.6	2.5	1.4	0.42	0.42	0.41
	M'	5.0	5.0	5.0	5.0	5.0	5.0	4.8	4.1	3.4	1.2	1.1	1.0
	TAN M	0	0	0	0	0	0	0.1	0.20	0.39	1.36	1.5	2.0
	M''	0	0	0	0	0	0	0.48	0.82	1.33	1.63	1.7	2.0
	dB/CM	0	0	0	0	0	0.03	0.27	2.8	11	46	56	119
	dB/IN	0	0	0	0	0	0.08	0.69	7.1	28	117	142	302
	$\vert Z\vert/Z_o$	0.16	0.18	0.20	0.24	0.28	0.32	0.36	0.39	0.40	0.30	0.31	0.33
MF-124	K'	260	205	145	95	70	52	40	32	25.8	23.8	23.6	23.0
	TAN D	0.40	0.39	0.36	0.31	0.26	0.20	0.14	0.08	0.07	0.05	0.03	0.04
	K''	104	80	52	29	18	10	5.6	2.6	1.8	1.19	0.71	0.92
	M'	7.0	6.9	6.8	6.7	6.6	6.3	6.0	5.0	3.8	2.50	1.5	1.0
	TAN M	0	0	0	0	0	0	0.2	0.45	0.69	1.10	1.4	2.5
	M''	0	0	0	0	0	0	1.2	2.3	2.62	2.75	2.1	2.5
	dB/CM	0	0	0	0	0	0.03	0.48	6.5	20	63	67	149
	dB/IN	0	0	0	0	0	0.08	1.2	17	50	160	170	378
	$\vert Z\vert/Z_o$	0.16	0.18	0.21	0.26	0.30	0.32	0.39	0.42	0.42	0.39	0.33	0.34
MF-175	K'	320	250	170	105	78	56	42	36	27.0	25.0	24.0	24.0
	TAN D	0.50	0.49	0.46	0.41	0.36	0.26	0.16	0.06	0.05	0.03	0.02	0.02
	K''	160	123	78	43	28	15	6.7	2.2	1.35	0.75	0.48	0.48
	M'	8.0	7.9	7.8	7.7	7.6	7.3	7.0	6.0	4.40	1.80	1.3	1.1
	TAN M	0	0	0	0	0	0	0.4	0.6	0.80	1.40	1.6	3.0
	M''	0	0	0	0	0	0	2.8	3.6	3.52	2.5	2.1	3.3
	dB/CM	0	0	0	0	0.01	0.05	0.87	8.6	24	65	69	177
	dB/IN	0	0	0	0	0.03	0.13	2.2	22	61	165	175	450
	$\vert Z\vert/Z_o$	0.15	0.17	0.20	0.26	0.30	0.36	0.42	0.44	0.46	0.35	0.32	0.38
MF-190	K'	380	295	195	115	86	60	44	40	28.0	26.0	25.0	25.0
	TAN D	0.60	0.59	0.56	0.51	0.46	0.32	0.18	0.07	0.04	0.04	0.02	0.02
	K''	228	174	109	59	40	19	7.9	2.8	1.12	1.04	0.50	0.50
	M'	9.0	8.9	8.8	8.7	8.6	8.3	8.0	7.0	4.50	2.00	1.5	1.1
	TAN M	0	0	0	0	0	0	0.60	0.80	0.90	1.40	1.6	4.0
	M''	0	0	0	0	0	0	4.0	5.6	4.05	2.8	2.4	4.4
	dB/CM	0	0	0	0	0.01	0.06	1.3	12.6	27	70	75	217
	dB/IN	0	0	0	0	0.03	0.15	3.3	32.0	69	179	190	551
	$\vert Z\vert/Z_o$	0.14	0.16	0.20	0.26	0.36	0.36	0.46	0.47	0.47	0.36	0.34	0.43

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Attachment

PLASTICS/CERAMICS FOR ELECTRONICS

Emerson & Cuming, Inc.

MICROWAVE PRODUCTS DIVISION
CANTON, MASSACHUSETTS

ENERGY PROPAGATION IN DIELECTRIC AND MAGNETIC MATERIALS

THEORETICAL NOTES, DEFINITIONS AND CALCULATIONS

The following theoretical notes are based on sources such as Stratton "Electromagnetic Theory", McGraw Hill Book Company and Von Hippel "Dielectric Materials and Applications", Technology Press of M. I. T. and John Wiley and Sons.

The formulas and discussions are presented here for the convenience of the designer planning to use Dielectric Materials. Only the most practical formulas here have been selected, and an attempt has been made to simplify those presented. On the other hand, the use of many of the formulas requires the ability to manipulate complex numbers. (Emerson & Cuming, Inc. offers charts which give dielectric data on most commonly used electrical materials.)

It is important to note that the formulas presented here apply, with proper interpretations, equally well to -

1. a flat sheet in free space,

2. a slug which completely fills a section of coaxial transmission line, and

3. a rectangular solid which completely fills a rectangular wave guide operating in the TE_{10} mode.

DEFINITIONS

Complex Dielectric Constant

$$K^* = K - jK\tan\delta_d = \frac{\epsilon'}{\epsilon_o} - j\frac{\epsilon'}{\epsilon_o}\tan\delta_d$$

where K is the real part of the relative permittivity, $\frac{\epsilon'}{\epsilon_o}$ and $\tan\delta_d$ is the dielectric loss tangent.

Complex Relative Magnetic Permeability

$$K_m^* = K_m - jK_m\tan\delta_m = \frac{\mu'}{\mu_o} - j\frac{\mu'}{\mu_o}\tan\delta_m$$

where K_m is the real part of the relative permeability and $\tan\delta_m$ is the magnetic loss tangent.

d = thickness of flat sheet in free space or length of slug along the transmission line, either coaxial line or waveguide.

λ_o is free space wave-length.

Θ is incidence angle, the angle between the direction of propagation of signal impinging on the free space slab and the normal to the free space slab; Θ is always zero for the coaxial line; for wave guide in the TE_{10} mode.

$$\Theta = \arc \cos \frac{\lambda_o}{\lambda_g}$$

where λ_g is the wave guide wave-length and is given by

$$\lambda_g = \frac{\lambda_o}{\sqrt{1 - \left(\frac{\lambda_o}{2a}\right)^2}}$$

where a is the broad dimension of the wave guide.

$$\text{Impedance of free space} = Z_o = \sqrt{\frac{\mu_o}{\epsilon_o}} = 377 \text{ ohms}$$

Intrinsic impedance of a material =

$$Z = \sqrt{\frac{\mu^*}{\epsilon^*}} = \sqrt{\frac{\mu' - j\,\mu' \tan \delta_m}{\epsilon' - j\,\epsilon' \tan \delta_d}}$$

Relative impedance magnitude or absolute value of relative impedance =

$$\frac{|Z|}{Z_o} = \frac{|Z|}{377} = \left| \sqrt{\frac{\frac{\mu'}{\mu_o} - j\frac{\mu'}{\mu_o} \tan \delta_m}{\frac{\epsilon'}{\epsilon_o} - j\frac{\epsilon'}{\epsilon_o} \tan \delta_d}} \right| = \left| \sqrt{\frac{K_m - K_m \tan \delta_n}{K \quad - j\,K \tan \delta_d}} \right|$$

Attenuation in dB/cm:

The following equation may be used to calculate the attenuation constant for any material in terms of its dielectric and magnetic properties:

Attenuation constant =

$$\frac{db}{cm} = \frac{(2\pi)\ (8.686)}{\lambda_o} \sqrt{\frac{K'K_m}{2}\left[\sqrt{(1 + \tan^2 \delta_d)\ (1 + \tan^2 \delta_m)} - (1 - \tan \delta_d \tan \delta_m)\right]}$$

where λ_o = free-space wave-length in cm

The attenuation values tabulated or computed from the equation must be interpreted as in the following example. Suppose that a slug of lossy material completely fills a section of a coaxial transmission line. Once energy has entered the lossy material, it will be diminished at the given rate as it propagates in the section of line that is filled by the material. The tabulated or calculated rate does not include any effects of energy reflections at the input or output interfaces between the lossy material and any other materials such as air in adjacent sections of the line.

Polarization

Before presenting transmission and reflection formulas, the two principal polarization cases for electromagnetic impingement on a flat sheet must be defined. These are perpendicular and parallel polarization, identified respectively in the formulas by the subscripts $\perp$ and $||$.

The terms refer to the direction of the electric field in a linearly polarized wave. They also refer to an incidence plane which is the plane formed by two lines, one of which is the normal to a flat sheet of material on which the wave is impinging, and the other which is the direction of propagation of the impinging wave. The incidence angle, Θ previously defined lies in this incidence plane. In a coaxial line the incidence angle is zero; therefore polarization does not apply. In the TE_{10} waveguide mode, the polarization is always perpendicular.

Interface Voltage Reflection Coefficients

There are two interface voltage reflection coefficients (r) one for each polarization:

for perpendicular polarization

$$r^*_{\perp} = \frac{K^*_m \cos\Theta - \sqrt{K^*_m K^* - \sin^2\Theta}}{K^*_m \cos\Theta + \sqrt{K^*_m K^* - \sin^2\Theta}}$$

for parallel polarization

$$r^*_{||} = \frac{\sqrt{K^*_m K^* - \sin^2\Theta} - K^* \cos\Theta}{\sqrt{K^*_m K^* - \sin^2\Theta} + K^* \cos\Theta}$$

Electrical Thickness, ϕ

This is the same for both polarizations and is given by

$$\phi^* = \frac{2\pi d}{\lambda_o} \sqrt{K^*_m K^* - \sin^2\Theta}$$

At normal incidence in free space and in a coaxial line, the last three formulas are simplified by the incidence angle, Θ being zero and become:

$$r^*_{\perp} = \frac{\sqrt{K^*_m} - \sqrt{K^*}}{\sqrt{K^*_m} + \sqrt{K^*}}$$

and

$$\phi = \frac{2\pi d}{\lambda_o} \sqrt{K^*_m K^*}$$

Transmission and Reflection

In terms of the interface reflection coefficient, r, and electrical thickness ϕ, we can now write the transmission and reflection equations for the flat sheet in free space, the solid slug in a coaxial line, and the rectangular solid in the waveguide.

Voltage Transmission Coefficient, T*

$$T^* = \frac{(1 - r^{*2})\, e^{-j\phi^*}}{1 - r^{*2}\, e^{-j2\phi^*}}$$

from which the insertion loss in decibels is given by

$$10 \log \frac{1}{|T^*|^2}$$

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and the insertion phase delay introduced by the sample over the distance occupied by the sample is given by

$$T' - \frac{2\pi d}{\lambda_o} \cos \Theta$$

where T' is the argument of T*.

Voltage Reflection Coefficient, R*

$$R^* = \frac{-r^*(1 - e^{-j2\phi^*})}{1 - r^{*2} e^{-j2\phi^*}}$$

from which the reflection loss in decibels is given by

$$10 \log \frac{1}{|R^*|^2}$$

and the reflection phase or delay due to energy lingering in the sample prior to reflection is simply R', the argument of R*.

Metal Backed Reflection Coefficient

If the dielectric material is backed by metal or short circuited, the reflection coefficient becomes:

$$R^*_{sc} = \frac{r^* - e^{-j2\phi^*}}{1 - r^* e^{-j2\phi^*}}$$

in which again reflection loss is given by

$$10 \log \frac{1}{|R^*_{sc}|^2}$$

Open Circuit Reflection Coefficient

If a quarter wave of air is placed between the dielectric material and the short circuit, the material is said to be open circuited, and

$$R^*_{oc} = \frac{r^* + e^{-j2\phi^*}}{1 + r^* e^{-j2\phi^*}}$$

and again reflection loss is given by

$$10 \log \frac{1}{|R^*_{oc}|^2}$$

This device is often used to take full advantage of the reflection loss potential in a lossy dielectric used for a termination.

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MARCH 1977