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NOTICE

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METHOD FOR IMPROVING ELECTROMAGNETIC SHIELDING

PERFORMANCE OF COMPOSITE MATERIALS BY ELECTROPULSING

This patent application is co-pending with related patent application entitled "Method for Improving Electromagnetic Shielding Performance of Composite Materials By Electroplating" filed on the same date as this application.

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for Governmental purposes without the payment of any royalties thereon or therefor.

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BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates generally to electromagnetic (EM) shielding, more particularly to an electropulsing method for improving the EM shielding performance of a composite material having semi-conductive or conductive filler particles suspended in a non-conductive resin.

(2) Description of the Prior Art

The EM environment encountered in commercial/military applications grows ever more "noisy" as the number of electronic components on a given platform increases. Further, the current desire to use strong, lightweight materials in

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1 construction of shielded structures provides an incentive to
2 develop composite materials offering good EM shielding
3 performance that will not degrade over time. To be useful for
4 a range of applications, the composite must have a low
5 resistivity, be resistant to chemical attack, immune to shock
6 (both thermal and mechanical), machinable, moldable and usable
7 in high temperature environments (e.g., greater than 200° C).
8 The composite must further be capable of being utilized in
9 commercial and military applications to include aircraft and
10 shipboard environments. Accordingly, the composite must be
11 lightweight, corrosion resistant when connected to metal
12 structures (e.g., aluminum) and must provide an EM shielding
13 performance at least as good as the present compounds that
14 incorporate aluminum, carbon, stainless steel and nickel-plated
15 carbon fillers. Composites incorporating these materials have
16 been shown to severely degrade over time and exposure to
17 marine/corrosive environments.

18 Prior U.S. Patent No. 5,066,424 issued to Dixon et al.
19 discloses certain oxides and catalytic behaving materials that
20 "self-adjust" their electrochemical electromotive force. Such
21 adjustment is either by oxygen manipulation or other charge
22 transfer thereby making them extremely attractive in minimizing
23 corrosion due to the dissimilar galvanic potentials. These
24 composites display good EM shielding properties when connected
25 to materials that are dissimilar with respect to the galvanic
26 table. Because the performance of the composite material is

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1 not as good, larger quantities of composites are needed for
2 similar shielding properties of the device. This negates any
3 light weight advantages of using the plastic composites.
4 However, still higher levels of EM performance are desirable
5 before these composites will be accepted as replacements for
6 pure metals and alloys in terms of EM shielding performance.

8 SUMMARY OF THE INVENTION

9 Accordingly, it is an object of the present invention to
10 provide a method of improving the EM shielding performance of a
11 composite material.

12 Another object of the present invention is to provide a
13 method of improving the EM shielding performance of a composite
14 material that will be used in a marine environment.

15 Other objects and advantages of the present invention will
16 become more obvious hereinafter in the specification and
17 drawings.

18 In accordance with the present invention, a method of
19 improving the electromagnetic (EM) shielding performance of a
20 composite material is provided. The composite has conductive
21 and semi-conductive filler particles suspended in a non-
22 conductive resin. The filler particles make up 0-40 weight
23 percent of the composite. The composite is subjected to an
24 exponentially decaying pulse from an energy source such that
25 the energy of the pulse is less than that required to cause
26 localized melting of the composite. In a preferred embodiment,

1 the resin is a preselected weight percent of a matrix material
2 selected from the group consisting of a polyether etherketone
3 (PEEK) polymer and a polycarbonate polymer, and the filler
4 particles are made up of 0-10 weight percent conducting nickel
5 flake particles and 0-20 weight percent of non-corrosive semi-
6 conducting indium tin oxide particles. In the preferred
7 embodiment, the pulse is a 5 MHz continuous wave pulse having a
8 damping factor in the range of 10-20 and a total energy of
9 approximately 1.5 millijoules.

11 BRIEF DESCRIPTION OF THE DRAWING(S)

12 Other objects, features and advantages of the present
13 invention will become apparent upon reference to the following
14 description of the preferred embodiments and to the drawings,
15 wherein:

16 FIG. 1 is a time domain trace in terms of voltage and
17 current of an exponentially damped 5 MHz continuous wave pulse
18 used in a preferred embodiment of the present invention;

19 FIG. 2 is a time domain trace in terms of power of the
20 exponentially damped 5 MHz continuous wave pulse shown in
21 FIG. 1;

22 FIG. 3 is a graph of shielding effectiveness before and
23 after pulsing for the ITO, nickel flake, PEEK example;

24 FIG. 4 is a graph of shielding effectiveness before and
25 after pulsing for the ITO, nickel flake, polycarbonate example;

1 FIG. 5 is a graph of shielding effectiveness before and
2 after pulsing for the graphite fiber, polycarbonate example;

3 FIG. 6 is a graph of shielding effectiveness before and
4 after pulsing for the graphite fiber, nickel flake,
5 polycarbonate example; and

6 FIG. 7 is a graph of shielding effectiveness before and
7 after pulsing for the nickel coated graphite, polycarbonates
8 example.

9
10 DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

11 The composite material improved by the method of the
12 present invention is comprised of a filler molded into a resin.
13 The filler is composed of conducting and semi-conducting oxide
14 particles, fiber or flakes suspended in the resin comprised of
15 a polymeric material matrix. A class of such composite
16 materials is disclosed by Dixon et al. in U.S. Patent No.
17 5,066,424, which is hereby incorporated by reference. However,
18 it will be readily understood by one of ordinary skill in the
19 art that other composite materials will have their EM shielding
20 performance improved by the method of the present invention.
21 Several examples of additional composite materials will be
22 given in the description to follow.

23 In accordance with the present invention, the composite
24 material of choice is subjected to an EM pulse from a
25 controllable source of such energy. The choice of energy
26 source is not a limitation of the present invention. The

1 pulsing frequency may range from DC to light, however, pulsing
2 at or near DC may infuse too much heat energy into the
3 composite material. It is critical that the total energy
4 imparted by the EM pulse be less than what would be required to
5 cause any localized melting within or on the surface of the
6 composite. Further through experimentation, it was found that
7 the greatest improvements in shielding performance were
8 achieved when the EM pulse was a rapidly or exponentially
9 decaying pulse. In this way, a high peak current would be
10 applied to the composite while the exponential decay of the
11 pulse maintained total energy within the critical limits.

12 In the examples and results to follow, the resin was
13 selected to be either a polyether etherketone (PEEK) polymer or
14 a polycarbonate polymer. Fillers which were evaluated included
15 graphite fibers and flake, nickel-coated graphite fibers,
16 carbon particles, iron oxide, indium/tin oxide (ITO) particles,
17 ITO particles with graphite fibers, ITO/Ni-flake, and
18 combinations of the above. Based on the composites tested, the
19 preferred filler composition consists of two elements: (1)
20 nickel because of its inherent low resistivity and its
21 corrosion resistance properties in combination with the ITO,
22 and (2) ITO which along with the nickel provides excellent
23 corrosion resistance. The semiconductor (ITO) also increases
24 the overall conductivity of the composite thereby increasing
25 the EM shielding effectiveness. The preferred percentages of
26 the fillers by weight for the nickel are from 0% to 10% and for

1 the ITO are from 0% to 20%. Preferred percentages by weight of
2 other fillers mentioned above are from 0% to 20%. It is
3 expected that other combinations of metallic and semi-metallic
4 filler particles (such as silver-coated nickel, silver-coated
5 aluminum, 400 series stainless steel, etc.) and polymers may
6 also have their EM shielding performance similarly improved.

7 For all of the examples, the EM pulse was generated using
8 a 5 MHz damped cosine (or other continuous wave) EM current
9 source simulator capable of subjecting the composites to a peak
10 current of 150 amperes. The EM pulse current was injected into
11 the samples in such a way that the entire 150 amp peak current
12 flowed through the sample. The 5 MHz current was exponentially
13 damped with a damping factor (Q) of 15 ± 5 . In this way, the
14 majority of the current occurred within the first 3
15 microseconds (μsec). A longer duration of high level currents
16 may cause the composite to overheat and melt. The overheating
17 would be undesirable, therefore a 3 μsec or less duration was
18 used. The resulting total energy imparted by such an EM pulse
19 is 1.43 millijoules. The time domain trace of the
20 exponentially damped 5 MHz pulse used is shown in FIG. 1 in
21 terms of voltage and current, and is shown in FIG. 2 in terms
22 of power. It is to be understood that other waveforms,
23 frequencies and powers may be used depending on the sample size
24 (i.e., larger sample sizes can dissipate more heat energy than
25 smaller sample sizes) and application. Note that the above
26 described exponentially decaying damped cosine waveform is

1 typical of (naval) shipboard EM coupled currents and voltages
2 and is also representative of industrial/commercial EM levels.
3 However, other EM pulses are expected to provide similar
4 improvement in material performance.

5 EXAMPLES AND RESULTS

6 The improvement in EM shielding performance for five
7 examples will now be presented. The five example composites
8 are:

- 9 1) 10 weight percent nickel flake
10 15 weight percent ITO
11 75 weight percent PEEK
- 12 2) 10 weight percent nickel flake
13 15 weight percent ITO
14 75 weight percent polycarbonate
- 15 3) 40 weight percent graphite fibers
16 60 weight percent polycarbonate
- 17 4) 20 weight percent graphite fibers
18 10 weight percent nickel flake
19 70 weight percent polycarbonate
- 20 5) 15 weight percent nickel coated graphite fibers
21 85 weight percent polycarbonate

22 A reduced DC resistivity is one indicator of improved EM
23 shielding performance. Table 1 shows the before and after DC
24 resistivities for the five examples subjected to the EM pulse
25 described above and shown in FIGs. 1 and 2. Note that all five
26 examples improved substantially after pulsing.

Table 1. Comparison of Measured DC Resistivities of Samples
Before and After Pulsing Treatment

EXAMPLE NO.	MATERIAL	BEFORE RESIST. (Ω -cm)	AFTER RESIST. (Ω -cm)	IMPROVEMENT (dB)
1	ITO, Ni-Flake, PEEK	>2M	6.0	>100
2	ITO, Ni-Flake, Polycarbonate	123	10.2	22
3	Graphite, Polycarbonate	58.1	10.8	15
4	Graphite, Ni-Flake, Polycarbonate	293	9.9	29
5	Nickel Coated Graphite, Polycarbonate	>60K	245	>48

Shielding effectiveness (SE) is defined as the reduction in magnetic and/or electric field strengths caused by the shielding material. It is the measure of the quality of the EM performance of that material. Conventional units of SE are

decibels (dB). The SE of a material relies on three types of losses: reflection, absorption, and re-reflection of the EM fields. The losses are due to the reflection at the first boundary, absorption through the material, and reflection at the second boundary, respectively. Table 2 shows the post-pulsing SE improvement for each of the five examples at 1 MHz.

Table 2. Measured Shielding Effectiveness at 1 MHz

EXAMPLE NO.	MATERIAL	BEFORE SE (dB)	AFTER SE (dB)	IMPROVEMENT (dB)
1	ITO, Ni-Flake, PEEK	0	40	40
2	ITO, Ni-Flake, Polycarbonate	10	31	21
3	Graphite, Polycarbonate	2	20	18
4	Graphite, Ni-Flake, Polycarbonate	0	22	22
5	Nickel Coated Graphite, Polycarbonate	0	3	3

1 The improvement in shielding effectiveness over a range of
2 frequencies is given for examples 1-5 in FIGs. 3-7,
3 respectively. In FIGs. 3-7, each dashed line trace indicates
4 measured shielding effectiveness of the composite before being
5 subjected to the pulsing as described above, while each solid
6 line trace indicates measured shielding effectiveness after the
7 composite was subjected to the pulsing.

8 The advantages of the present invention are numerous. The
9 EM shielding performance of a composite material having
10 conducting and semi-conducting materials in a non-conducting
11 polymeric matrix is greatly improved by EM pulsing. Long-term
12 evaluation of pulsed examples indicates that the improvements
13 are permanent, i.e., EM characteristics do not change
14 appreciably over time or after exposure to marine/corrosive
15 environments.

16 It will be understood that many additional changes in the
17 details, materials, steps and arrangement of parts, which have
18 been herein described and illustrated in order to explain the
19 nature of the invention, may be made by those skilled in the
20 art within the principle and scope of the invention.
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1 METHOD FOR IMPROVING ELECTROMAGNETIC SHIELDING
2 PERFORMANCE OF COMPOSITE MATERIALS BY ELECTROPULSING
3 ABSTRACT OF THE DISCLOSURE

4 A method of improving the electromagnetic (EM) shielding
5 performance of a composite material is provided. The composite
6 has conductive and semi-conductive filler particles suspended
7 in a non-conductive resin. The filler particles make up 0-40
8 weight percent of the composite. The composite is subjected to
9 an exponentially decaying pulse from an energy source such that
10 the energy of the pulse is less than that required to cause
11 localized melting of the composite.

FIG. 1

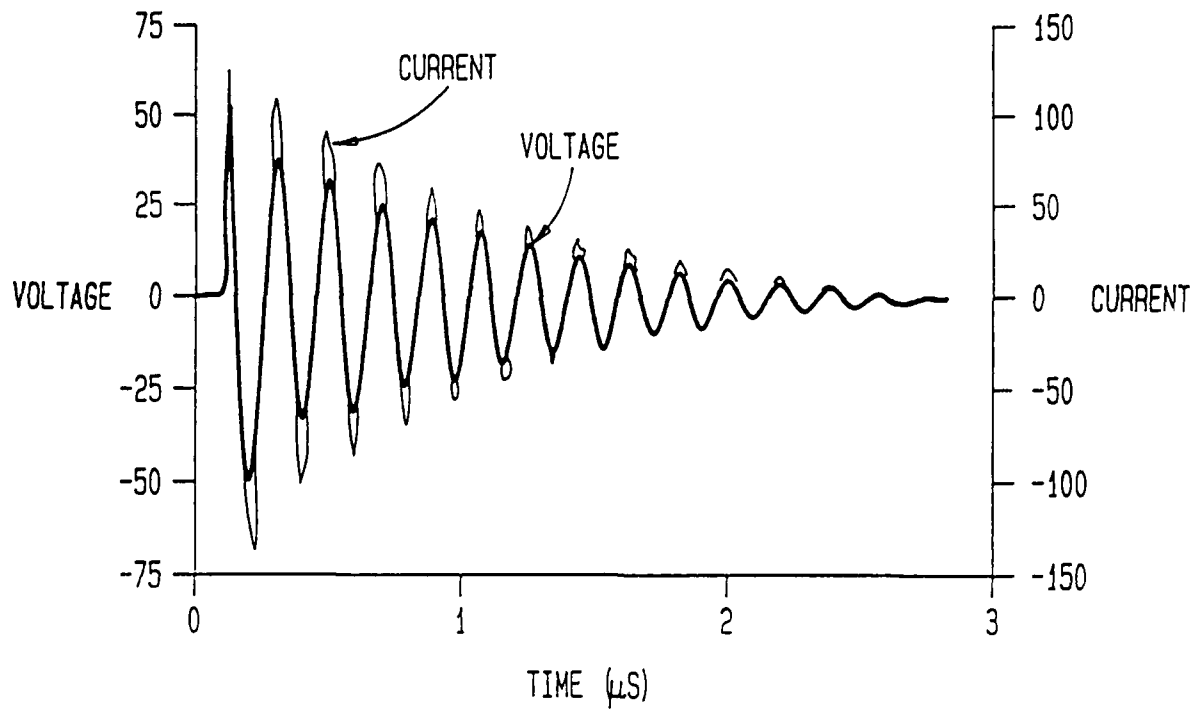


FIG. 2

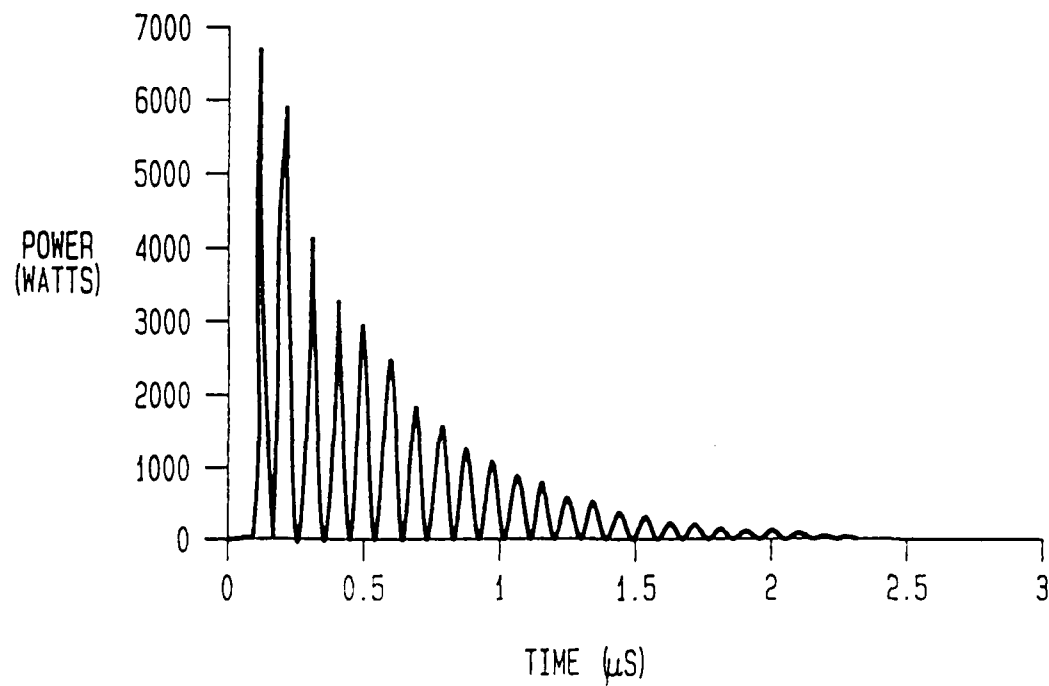


FIG. 3

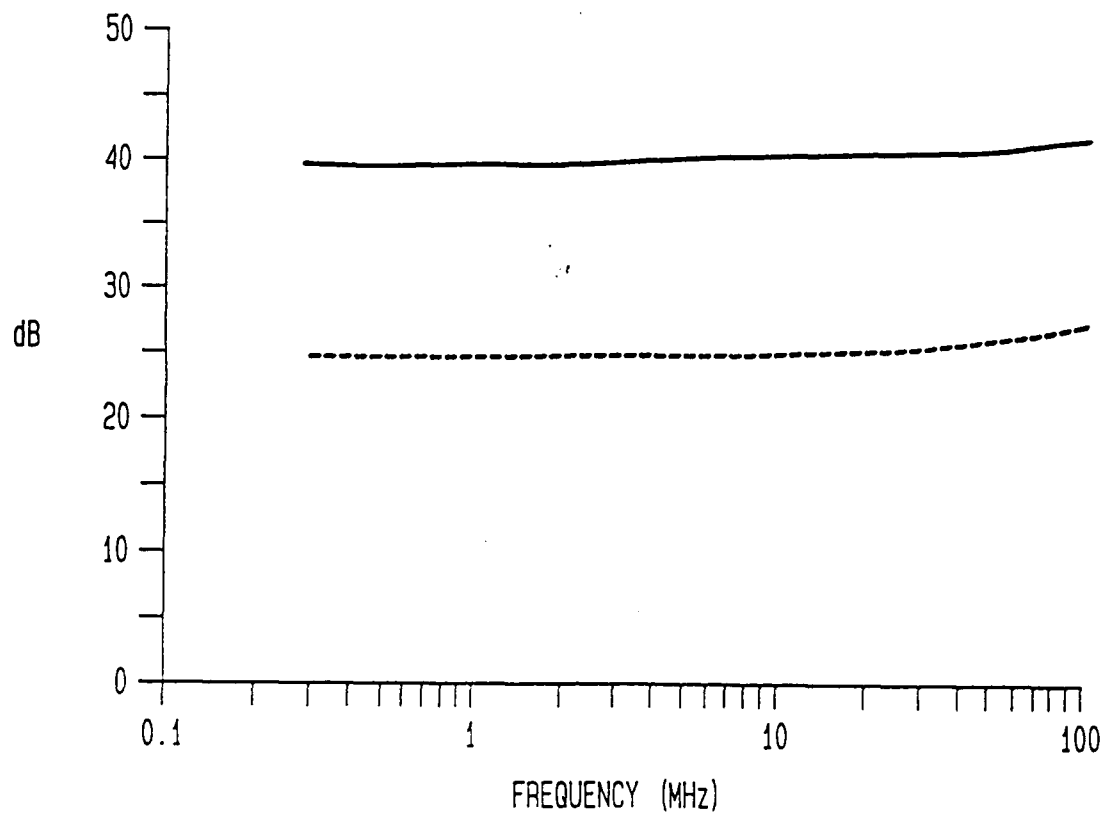


FIG. 4

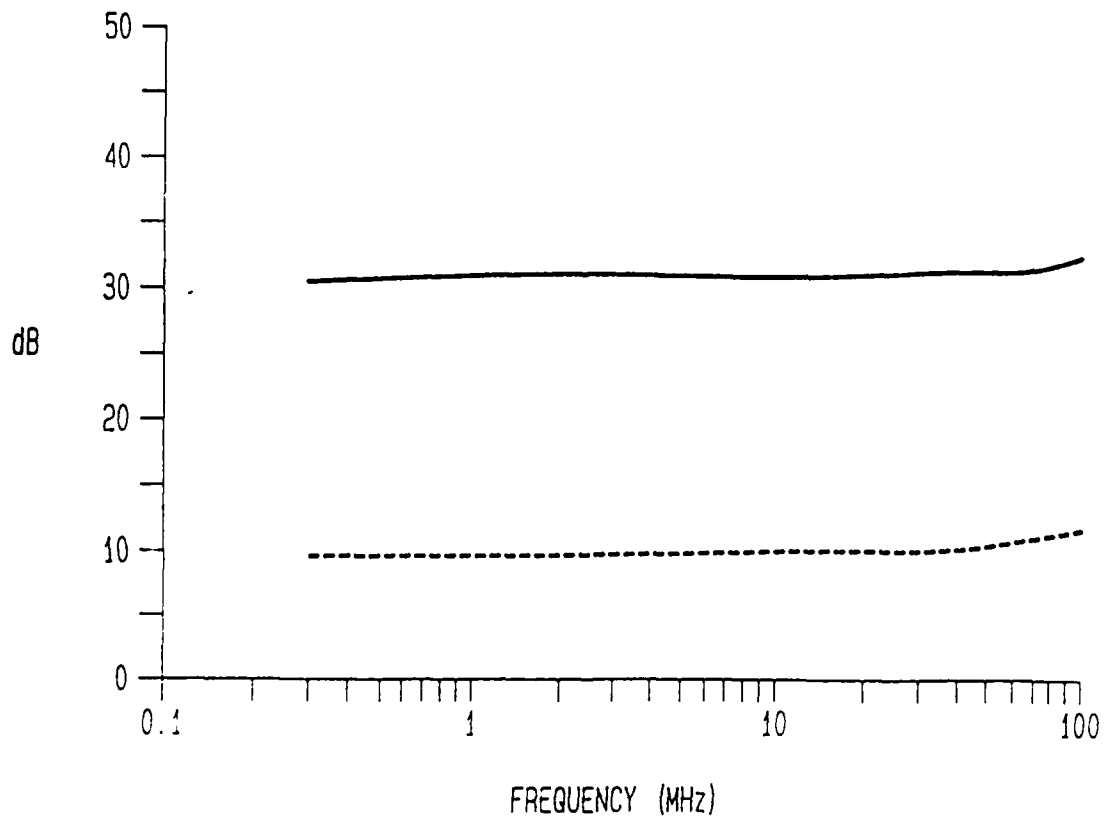


FIG. 5

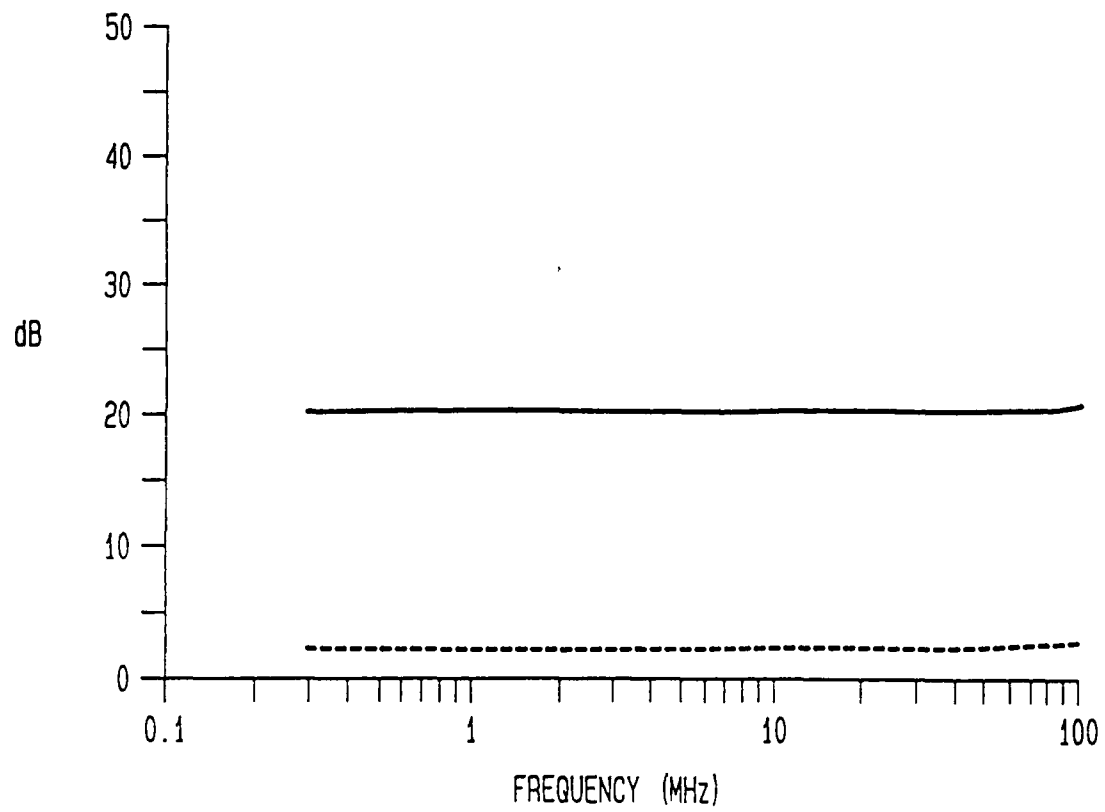


FIG. 6

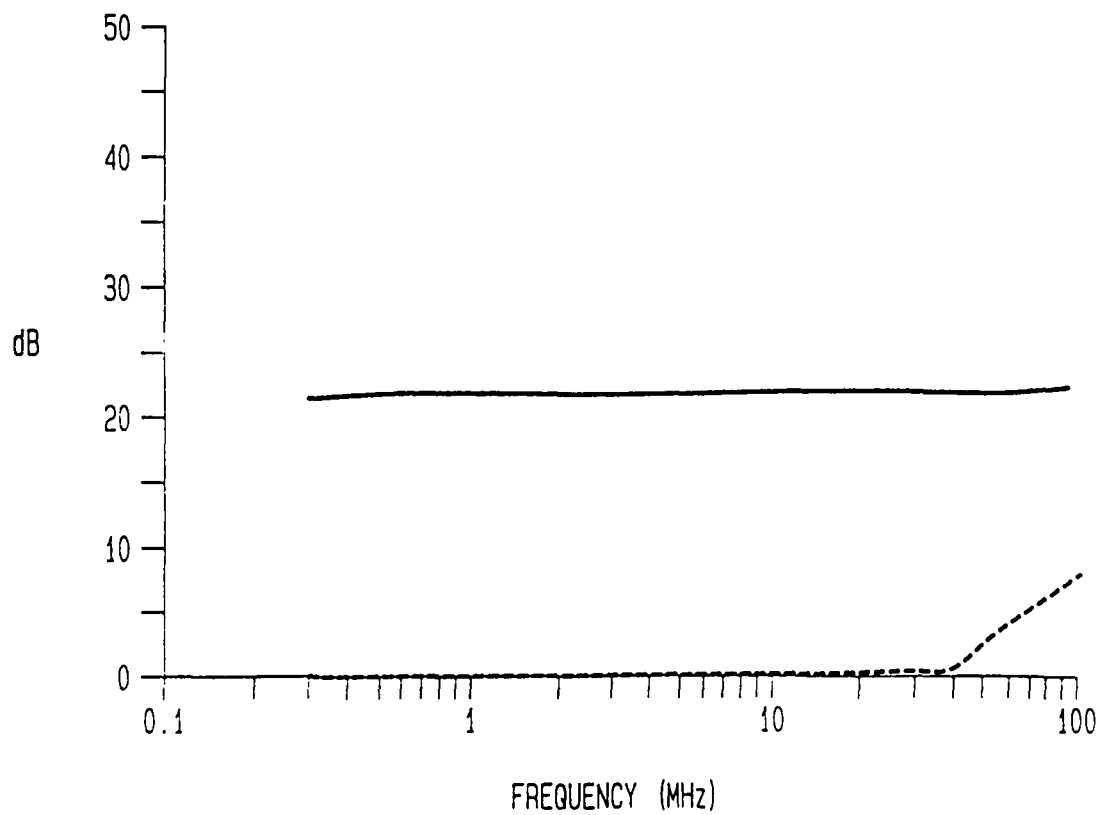


FIG. 7

