

EXAMINER

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May 31, 1966

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3,254,345

ARTIFICIAL DIELECTRIC USING INTERSPERSED RODS

Filed July 5, 1963

2 Sheets-Sheet 1

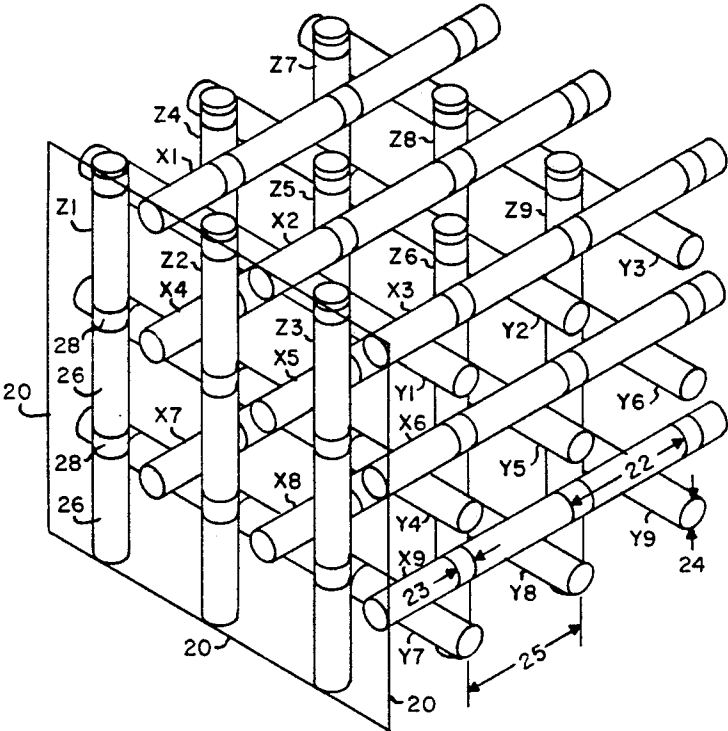


FIG. 1

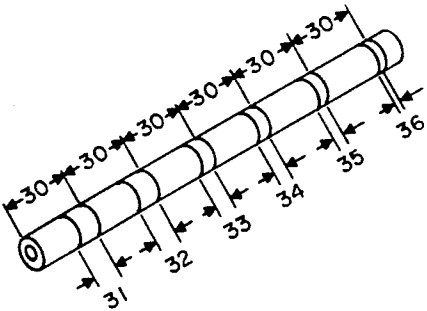


FIG. 2

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2 Sheets-Sheet 2

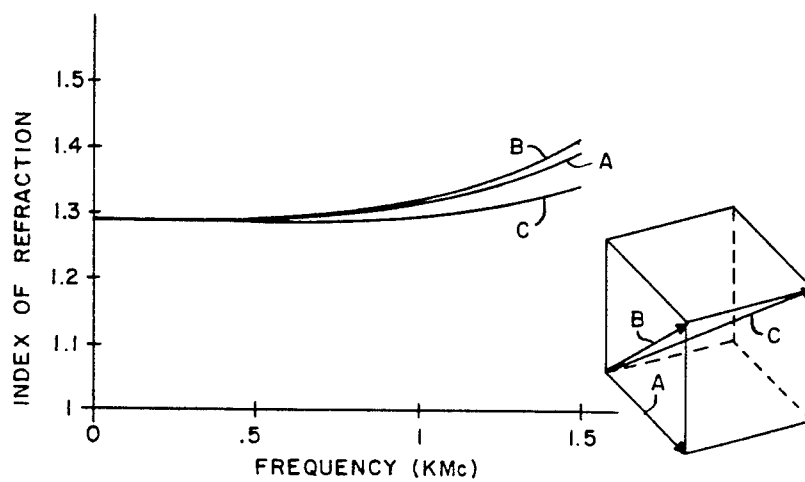


FIG. 3

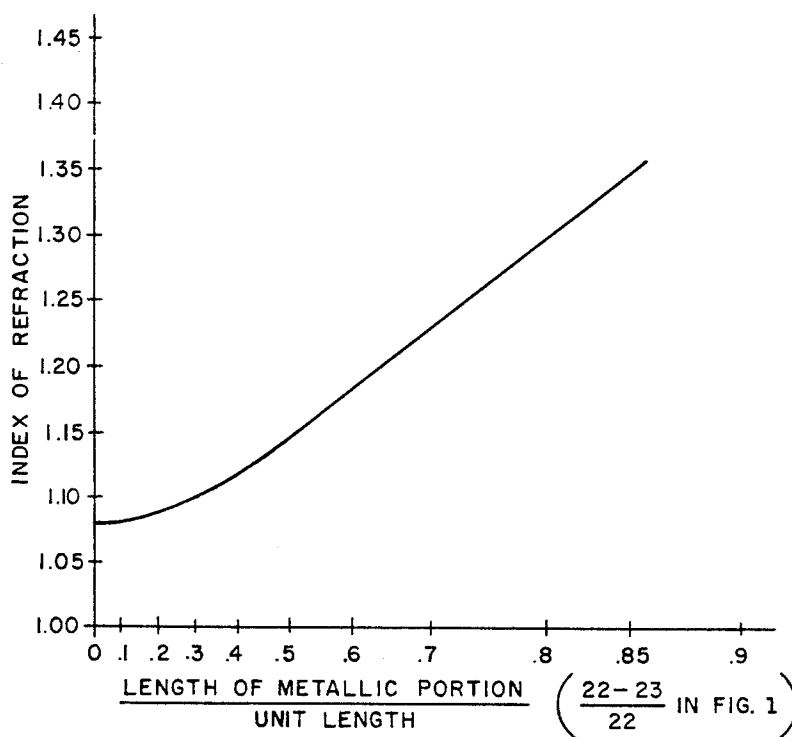


FIG. 4

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ARTIFICIAL DIELECTRIC USING INTERSPERSED RODS

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This invention pertains to artificial dielectrics and more particularly to artificial dielectrics composed of three sets of interspersed rods. Each rod may be all dielectric or all metal or may comprise a series of metal sections separated by gaps of dielectric material for example.

In a microwave antenna employing a lens it is desirable to minimize the weight and expense involved in a dielectric material. It may also be necessary to provide a controlled variation of the refractive index with position in the lens. An artificial dielectric composed of metal or dielectric elements can achieve these results.

Unfortunately, the electrical properties of an artificial dielectric are likely to be poor compared with those of a natural dielectric. Some of these defects are anisotropy (different refractive indexes for some wave directions and polarizations), random errors in refractive index (caused by random errors in packing the elements) and perhaps also excessive reflection (in a metal loaded delay medium having a wave impedance lower than that of a natural dielectric with the same refraction index).

The objects of this invention are to provide artificial dielectrics which avoid defects of prior artificial dielectrics, which have improved electrical properties, and which at the same time are practical to construct both structurally and economically.

In accordance with the invention, an artificial dielectric comprises a first set of rods, whose properties vary along their length, arranged in a spaced array with all rods substantially parallel to each other, a second set of rods, whose properties vary along their length, regularly interspersed with but spaced from the rods of the first set and arranged so that all rods of this second set are substantially parallel to each other and substantially perpendicular to the rods of the first set, a third set of rods, whose properties vary along their length, regularly interspersed with but spaced from the rods of the first and second sets and arranged so that all rods of this third set are substantially parallel to each other and substantially perpendicular to the rods of both the first and second sets and means for supporting all these rods in the resulting interspersed, spaced, three dimensional array; whereby there is formed an artificial dielectric whose characteristics of refractive index relative to position in the volume of artificial dielectric are determined by the rod construction.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings, FIG. 1 represents a small portion of an artificial dielectric constructed in accordance with the invention; FIG. 2 shows a single rod, for use in artificial dielectrics in accordance with the invention, whose dimensions vary along its length; and FIGS. 3 and 4 are curves useful in describing the operation of the invention.

The basic structure involves three sets of rods or cylinders oriented in three orthogonal directions, each set being interspersed with equal spacing from the other sets. Each rod may for example, be constructed entirely of dielectric material or entirely of metal or it may be made up of a series of metal sections separated by gaps of air or dielectric material. It should be understood that the

rods or cylinders need not be circular in cross section, but may be of rectangular, elliptical or any other desired cross section.

Referring now to FIG. 1. There is shown a portion of an artificial dielectric employing metal sections separated by gaps of dielectric material. The artificial dielectric shown in FIG. 1 includes a first set of rods which will be called set X, including rods X1 to X9 inclusive. Also included in the FIG. 1 arrangement is a second set of rods which will be called set Y, including rods Y1 to Y9, inclusive. Further included in FIG. 1 are a third set of rods which will be called set Z, including rods Z1 to Z9, inclusive. FIG. 1 finally includes means for supporting all three sets of rods in the resulting three dimensional array. In the illustrated configuration, these last means can be considered as taking the form of six sheets of thin transparent phenolic material, one appearing at each face of the cube shown in FIG. 1. In FIG. 1 the lines 20 are indicative of the edges of one of such sheets. Only one of such sheets is shown so as to indicate that actually a much larger volume of artificial dielectric may be utilized. In other arrangements the rods may be supported in the spaced relation by a low dielectric constant foam material.

Examining FIG. 1 in greater detail, it will be seen that all rods of set X are substantially parallel to each other. Also, all rods of set Y are regularly interspersed with but spaced from the rods of set X and the rods of set Y are arranged so that all of the Y rods are substantially parallel to each other and also substantially perpendicular to the rods of the X set. Also, the rods of set Z are regularly interspersed with but spaced from the rods of both set X and Y and the rods of set Z are arranged so that all these Z rods are substantially parallel to each other and substantially perpendicular to the rods of both sets X and Y. Thus, there results an interspersed, spaced three dimensional array of rods forming an artificial dielectric in accordance with the invention.

In operation, currents flow along the metal sections of those rods which are parallel to the electric field of an incident electromagnetic wave, creating a concentration of electric field in the appropriate gaps separating the metal sections of the rods. This results in the reduced wave velocity (refractive index greater than 1) that is usually desired in an artificial dielectric. Since the rods are equally dispersed in three orthogonal directions, this effect is isotropic provided the spacing of the metal elements is much less than a wave length. For example, the isotropic property would be essential in the case of a spherical Luneberg lens for an antenna operating in all directions. Furthermore, the dimensions of each gap do not depend on accidental factors as in a random packed artificial dielectric for example, but instead can be precisely measured and controlled. As a result, the refractive index can achieve a remarkable freedom from random errors, as is essential in any lens antenna intended to have a narrow beam.

Referring now to FIG. 2, there is shown a single rod of a different type than the rods included in the artificial dielectric shown in FIG. 1. It will be seen that the dimensions of the rod shown in FIG. 2 vary along its length. As shown, the dimension 30 (corresponding to 22 in FIG. 1) remains constant over the length of the rod. However, the gaps 31-36 grow progressively smaller from left to right. The physical construction of the rod shown in FIG. 2 may be considered similar to that of the rods in FIG. 1 except that the FIG. 2 rod is shown as utilizing a hollow dielectric cylinder rather than a solid cylinder as in FIG. 1. Using rods similar to the one shown in FIG. 2, artificial dielectrics can be constructed which have a refractive index which varies relative to position within the volume of artificial dielectric involved. The

dimensions of each rod in such an artificial dielectric would be determined by the particular variation of refractive index desired. Many different variations of dimensions along the length of rods are possible and FIG. 2 illustrates just one example.

In this metal section type of artificial dielectric, the rods are separated from each other and the metal elements occupy a relatively small portion of the volume; consequently, blocking of the magnetic field of the wave is small. As a result, the wave impedance and surface reflection is not appreciably worse than that of a natural dielectric. This property would also be important in any application involving discontinuous media, such as an ordinary lens or a stepped Luneberg lens. The interspersed geometry of the rods facilitates construction since each rod is physically independent of the others and there are no contact problems. Where light weight is essential, the metal elements can be thin-walled, hollow cylinders or strips, or small diameter solid cylinders supported by dielectric sections. Alternatively, the rods may comprise dielectric rods or hollow cylinders with pieces of metal foil wrapped thereon to form the metallic sections. The basic configuration is susceptible to modifications which simplify the production of large amounts of artificial dielectrics. In applications requiring very large volumes of artificial dielectrics, economic considerations are, of course, very important.

The all-dielectric rod type of artificial dielectric is useful where a simple, high power, nonresonant material is desired and where weight and cost are less important. The all-metal rod type is an advance rather than a delay medium and is useful for special applications. In the interspersed rod configuration, both of these types retain the features of isotropic and precisely controllable refractive index. In view of the extensive work which has been done in the field of artificial dielectrics the design of any of the aforementioned types of artificial dielectrics, in accordance with the invention, can be carried out by persons skilled in this art, once they have the present concepts clearly in mind and no discussion of the design principles is necessary here.

With reference to FIG. 1, the dimensions of an artificial dielectric actually constructed are as follows:

	Inches
Spacing 22 -----	2
Gap 23 -----	.440
Diameter 24 -----	.500
Spacing 25 -----	2

The metal sections were formed by pieces of aluminum foil .00075 inch thick, such as 26, wrapped around solid polystyrene rods and the gaps, such as 28, were merely uncovered portions of the polystyrene rods.

Tests on the artificial dielectric having the dimensions just listed indicated that at or below one kilomegacycle the index of refraction was approximately 1.3 for all angles of incidence and all polarizations. The actual curves including these results are shown in FIG. 3. The curves A, B and C in FIG. 3 represented the characteristics measure with ray path directions as indicated by the arrows A, B, and C, respectively, shown relative to an outline of the artificial dielectric shown in FIG. 1.

Referring now to FIG. 4, there is shown a curve indicating the wide range of refractive indexes available by varying the dimension 22 relative to dimension 23. Thus, it will be appreciated that artificial dielectrics constructed in accordance with the invention, will possess characteristics of refractive index which are determined by the rod construction and spacings.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein

without departing from the invention, and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An artificial dielectric comprising:

a first set of rods, whose properties vary along their length, arranged in a spaced array with all rods substantially parallel to each other;

a second set of rods, whose properties vary along their length, regularly interspersed with, but spaced from, the rods of said first set and arranged so that all rods of this second set are substantially parallel to each other and substantially perpendicular to the rods of said first set;

a third set of rods, whose properties vary along their length, regularly interspersed with, but spaced from, the rods of said first and second sets and arranged so that all rods of this third set are substantially parallel to each other and substantially perpendicular to the rods of both said first and second sets;

and means for supporting all said rods in the resulting interspersed, spaced, three-dimensional array;

whereby there is formed an artificial dielectric whose characteristics of refractive index relative to position in the volume of artificial dielectric are determined by the rod construction.

2. An artificial dielectric comprising:

a first set of rods arranged in a spaced array with all rods substantially parallel to each other, said rods comprising sections of conductive material separated by sections of dielectric material;

a second set of rods regularly interspersed with, but spaced from, the rods of said first set and arranged so that all rods of this second set are substantially parallel to each other but perpendicular to the rods of said first set, said rods comprising sections of conductive material separated by sections of dielectric material;

a third set of rods regularly interspersed with, but spaced from, the rods of said first and second sets and arranged so that all rods of this third set are substantially parallel to each other but perpendicular to the rods of both said first and second sets, said rods comprising sections of conductive material separated by sections of dielectric material;

and means for supporting all said rods in the resulting interspersed, spaced, three-dimensional array.

3. An artificial dielectric in accordance with claim 2, wherein each rod is of substantially identical construction and comprises a cylinder of dielectric material covered at spaced intervals by encircling bands of conductive material;

and all rods are uniformly and repetitively spaced so that the resulting artificial dielectric has a substantially uniform refractive index throughout its volume.

4. An artificial dielectric in accordance with claim 2, wherein each rod is of substantially identical construction and comprises a hollow cylinder of dielectric material covered at spaced intervals by encircling bands of conductive material;

and all rods are uniformly and repetitively spaced so that the resulting artificial dielectric has a substantially uniform refractive index throughout its volume.

5. An artificial dielectric comprising:

a first set of rods, whose properties vary along their length, arranged in a spaced array with all rods substantially parallel to each other, said rods comprising sections of conductive material separated by sections of dielectric material;

a second set of rods, whose properties vary along their length, regularly interspersed with, but spaced from, the rods of said first set and arranged so that all

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rods of this second set are substantially parallel to each other but perpendicular to the rods of said first set, said rods comprising sections of conductive material separated by sections of dielectric material;

a third set of rods, whose properties vary along their length, regularly interspersed with, but spaced from, the rods of said first and second sets and arranged so that all rods of this third set are substantially parallel to each other but perpendicular to the rods of both said first and second sets, said rods comprising sections of conductive material separated by sections of dielectric material;

and means for supporting all said rods in the resulting interspersed, spaced, three-dimensional array.

6. An artificial dielectric in accordance with claim 5, wherein each rod is of substantially identical construction and comprises a cylinder of dielectric material covered at spaced varying intervals by encircling bands of conductive material providing gaps of exposed dielectric material of varying width along the length of the rod;

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and all rods are uniformly and repetitively spaced so that the resulting artificial dielectric has a substantially uniform refractive index throughout its volume.

7. An artificial dielectric in accordance with claim 6, wherein each cylinder of dielectric material is hollow.

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