

July 1, 1958

R. H. DICKE
DIELECTRIC STRUCTURES

2,841,786

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2 Sheets-Sheet 1

FIG 1

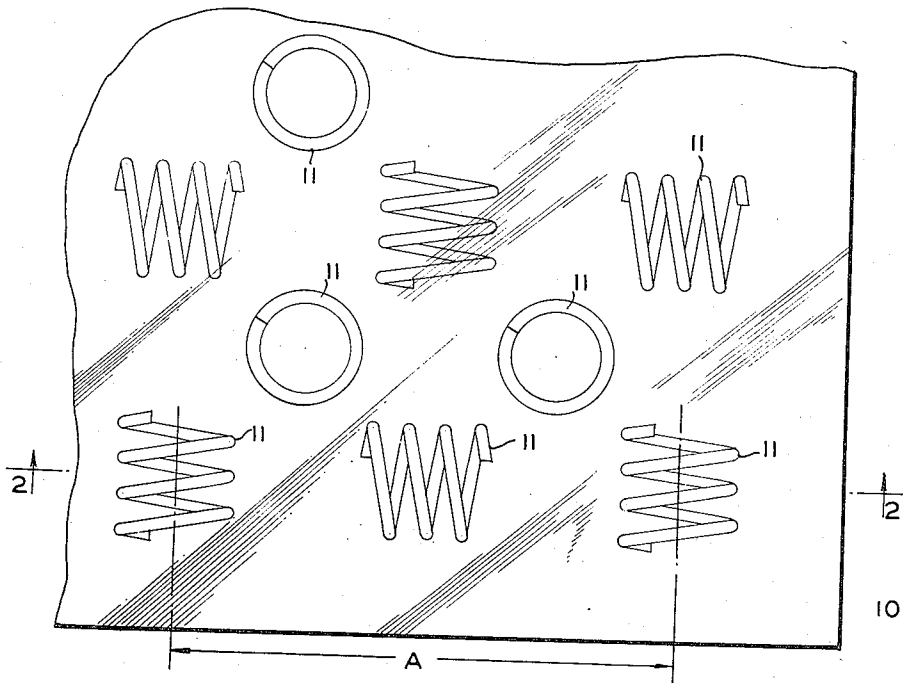


FIG 2.

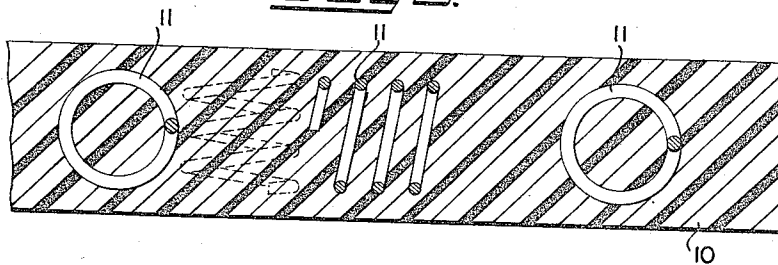
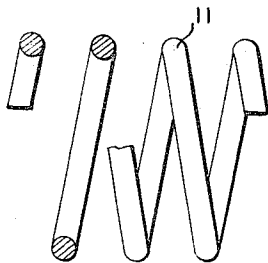


FIG 3.



INVENTOR
ROBERT H. DICKE

BY *Harold T. Stowell*

ATTORNEY

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FIG 4.

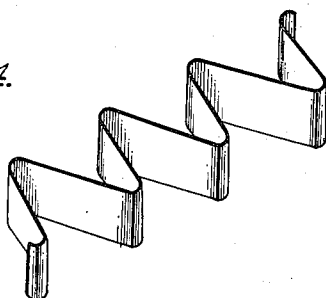


FIG 5.

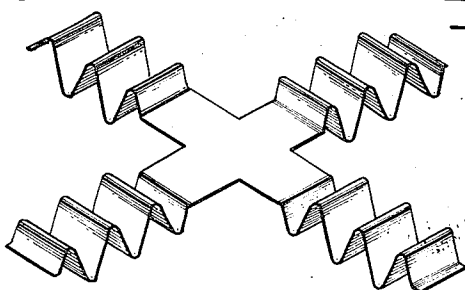


FIG 6.

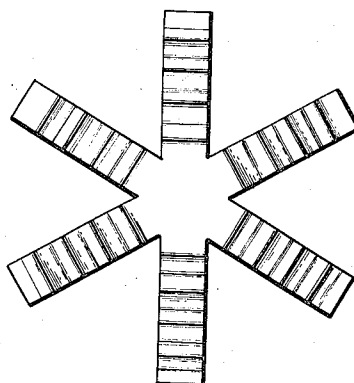
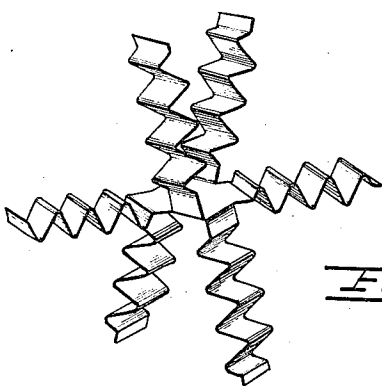


FIG 7.



INVENTOR
ROBERT H. DICKE

BY *Harold T. Stowell*

ATTORNEY

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DIELECTRIC STRUCTURES

Robert H. Dicke, Princeton, N. J., assignor to the United States of America as represented by the Secretary of the Navy

Application February 3, 1956, Serial No. 563,255

3 Claims. (Cl. 343-18)

This invention relates to dielectric structures having very low effective dielectric constants with respect to high frequency electromagnetic wave lengths in the frequency range commonly referred to as microwave frequency.

The invention is based on the discovery that by imbedding in a mass of dielectric material a regular lattice array of resonator elements having a resonance frequency less than the microwave frequency and spaced apart a distance not substantially greater than one-fourth the microwave wave lengths, the dielectric constant of the resulting structure is substantially less than that of the unloaded dielectric medium.

This effect may be explained as follows: The dielectric constant ϵ of a material at a given frequency is equal to $1 + 4\pi\delta$ where δ is the dipole moment induced in a cubic centimeter of the material by a unit electric field strength. If a system of charges can be added to the dielectric material of such character that the charges move in the opposite direction from that of the dielectric charges, the contribution of the added charges to the dipole moment per unit volume will be of opposite sign from the dipole moment of the material, hence they will reduce the effective δ of the aggregate and reduce the dielectric constant. A proper mixture of the two types of dipoles could thus be made to give a zero or even negative δ and a dielectric constant of unity or less.

A system of electric dipole resonators tuned to a frequency below the operating frequency contributes a negative susceptibility to the medium, for the reason that, while the displacement of a simple harmonic oscillator is in phase with the impressed force at frequencies below the resonant frequency, it is 180° out of phase as frequencies above the resonance frequency.

The resonator elements should be small, in terms of the wave length of the operating frequency, and should be closely packed, preferably in some type of regular crystal lattice. For dielectric structures to be used in thin sheets, for example, as radomes, the resonators should be arranged in the form of a two dimensional lattice.

The resonators should radiate substantially only as electric dipoles and the magnetic dipole and electric quadrupole moments should be small. One form of resonator elements useful in the structures of the invention are small wire coils arranged in the dielectric medium with their axes regularly oriented in three mutually perpendicular directions. Another form of resonator elements is provided by small metal strips, crimped or corrugated transversely of their longest dimension. The latter form of resonator has a lower magnetic dipole moment than the coil resonators.

The dielectric material may be any of the commonly used dielectrics, such as organic thermoplastic or thermosetting resins, including polymerized olefines, such as polystyrene, polychlorostyrenes, polymethacrylate esters, and their copolymers, and condensation polymers such as the phenol-formaldehyde resins, and polyester resins.

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The dielectric structures of the invention may be produced in plane or curved sheets, for example, for the construction of radomes, or may be in any other desired shapes adapted for use in microwave apparatus.

The invention will be further described with reference to the accompanying drawings in which:

Fig. 1 is a fragmentary plan view of a sheet dielectric structure embodying the principles of the invention;

Fig. 2 is a section on line 2-2 of Fig. 1;

Fig. 3 is an enlarged representation in partial section of a resonator element of the structure of Fig. 1;

Figs. 4 and 5 are perspective views of other forms of resonator element;

Fig. 6 is a plan view of a further variant of the resonator element in course of formation; and

Fig. 7 is a perspective view of the final form of the resonator element of Fig. 6.

In Figs. 1 and 2, 10 is a plate of dielectric material and 11 are coil resonator elements, arranged in plate 10 in a regular two dimensional array having a face-centered cubic lattice structure, with the longitudinal axes of the coils regularly disposed in three mutually perpendicular directions, two of which are in the plane of extension of plate 10 and one normal thereto.

In a typical construction, 10 is a polystyrene plate about 0.25 cm. in thickness. The coils 11 are made of copper wire 0.02 cm. in diameter wound into coils 0.126 cm. in outside diameter and about 0.12 cm. long, each turn being about 0.0525 cm. apart. The distance between centers of similarly oriented elements (dimension A in Fig. 1) is about 0.6 cm.

It is important that the coil dimensions, and particularly the wire length, be maintained as uniform as possible as these determine the resonance frequency. In general, the expression $2nL\pi r$, where n is the number of turns, L is the wire length and r is the coil radius, should be between 0.5λ and 0.7λ , where λ is the wave-length of the frequency of resonance.

The structure of Fig. 1 and 2 may be assembled by molding or milling an array of holes in a dielectric plate, shaped and positioned to hold a coil in the proper orientation at each location. The coils are placed in the holes and the holes are then filled up with a dielectric material, for example, a styrene monomer, which is then hardened to form a solid structure. Other methods of forming the structures will readily occur to those skilled in the plastic arts.

In a dielectric structure such as has been described above, the array of resonator elements acts as an isotropic resonator at microwave frequencies and, as has been set forth above reduces the effective dielectric constant of the unloaded dielectric material. For example, the dielectric structure just described, shows a reduction in amplitude of reflection at normal incidence of about 20 decibels compared with the unloaded dielectric material at a frequency of about 9400 mc.

In order to reduce the magnetic dipole moment of the resonator elements, they may be made by crimping or corrugating metal strips transversely to their longitudinal dimension as shown in Fig. 4. The crimping is desirable to reduce the overall length of the elements.

This type of resonator may also be made in the form of two crossed resonators by crimping the arms of a cross of sheet metal, as shown in Fig. 5.

An isotropic resonator of this type may also be made by cutting a sheet of metal into the form of three crossed strips and crimping the arms, as shown in Fig. 6. The crimped arms are then bent into mutually orthogonal positions as shown in Fig. 7.

The forms of resonators shown in Figs. 4 to 7 may be mounted in dielectric materials by methods such as are described above in connection with Figs. 1 and 2.

I claim:

1. A dielectric structure highly transparent to micro-
waves comprising a sheet of insulating material having
imbedded therein a regular lattice array of metallic
resonator elements, said resonators each having an
axis, each resonator element having a resonance fre-
quency less than the microwave frequency and being
spaced apart a distance not substantially greater than
one-fourth the microwave wave length, wherein said
lattice array is a mono-layer of said resonator elements
arranged with their axes regularly oriented in three mutu-
ally perpendicular directions. 5 10
2. A dielectric structure as defined in claim 1 wherein
the resonator elements are wire coils.
3. A dielectric structure as defined in claim 1 wherein
the resonator elements are corrugated metal strips. 15

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