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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: GP

NOV 29 1973

TO: KSI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,769,623

Government or Corporate Employee : Caltech Pasadena, CA

Supplementary Corporate Source (if applicable) : JPL

NASA Patent Case No. : NPO-13171-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes [X] No [ ]
Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

Elizabeth A. Carter

Elizabeth A. Carter
Enclosure
Copy of Patent cited above

United States Patent [19]

Fletcher et al.

[11] **3,769,623**

[45] **Oct. 30, 1973**

[54] **LOW LOSS DICHROIC PLATE**

[76] Inventors: **James C. Fletcher**, Administrator of the National Aeronautics and Space Administration with respect to an invention of; **Richard T. Woo; Arthur C. Ludwig**, both of La Canada, Calif.

[22] Filed: **Sept. 21, 1972**

[21] Appl. No.: **290,915**

[52] **U.S. Cl.** **343/909,** 343/781

[51] **Int. Cl.** **H01q 15/02**

[58] **Field of Search** 343/755, 781, 909, 343/911

[56] **References Cited**

UNITED STATES PATENTS

3,148,370 9/1964 Bowman 343/909

3,165,749 1/1965 Cushner 343/909

Primary Examiner—Eli Lieberman
Attorney—Monte F. Mott et al.

[57] **ABSTRACT**

A low loss dichroic plate is disclosed for passing radiation within a particular frequency band and reflecting radiation outside of that frequency band. The dichroic plate is comprised of a configuration of dipole elements defined by slots formed in a conductive plate. The slots are dimensioned so as to pass radiation of a selected frequency and are shaped so as to minimize the relationship between that frequency and the tilt angle of the plate relative to the direction of radiation. The slots are arranged so as to minimize signal power loss due to cross polarization effects.

9 Claims, 8 Drawing Figures

(NASA-Case-NPO-13171-1) LOW LOSS DICHROIC PLATE Patent (Jet Propulsion Lab.) 7 p CSCL 17B N74-11000

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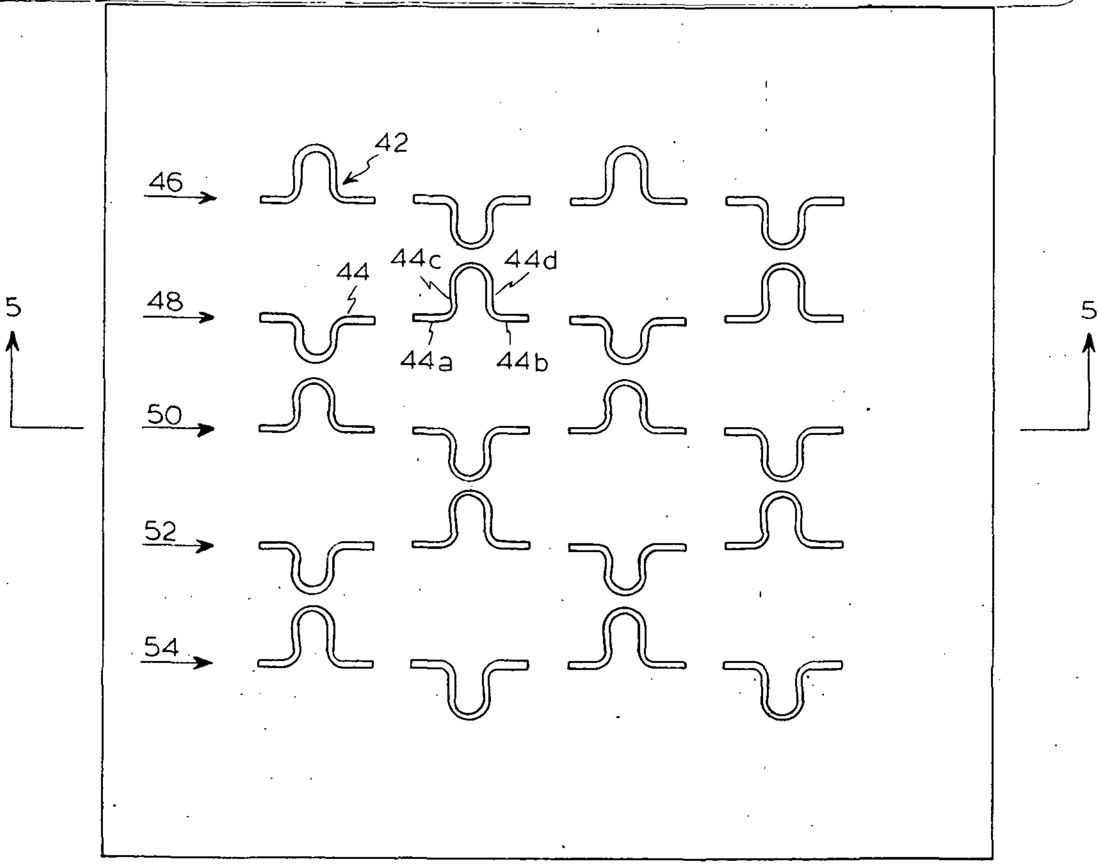

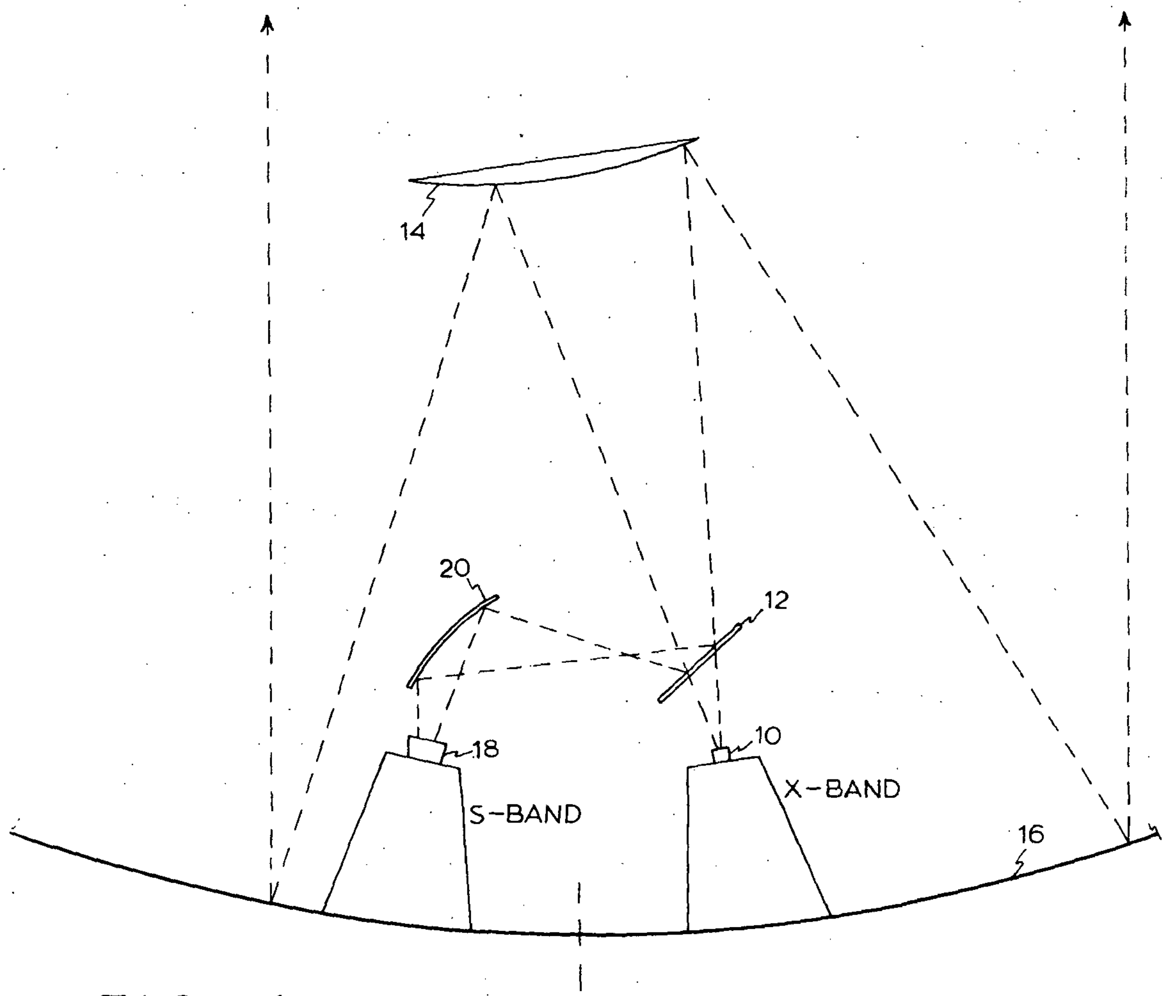

FIG. 1

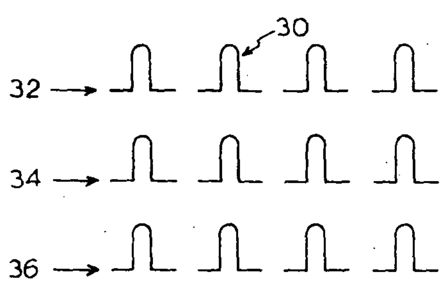

FIG. 2

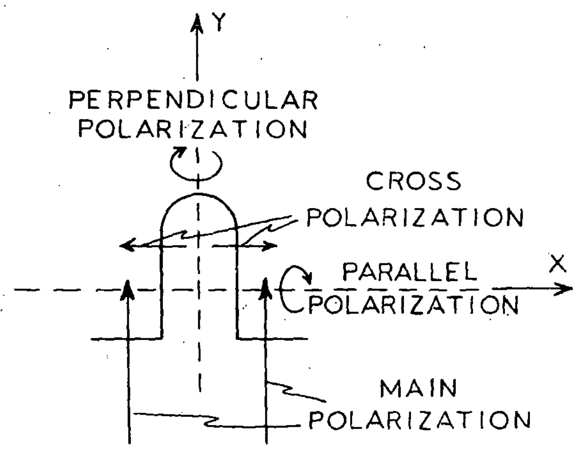

FIG. 3

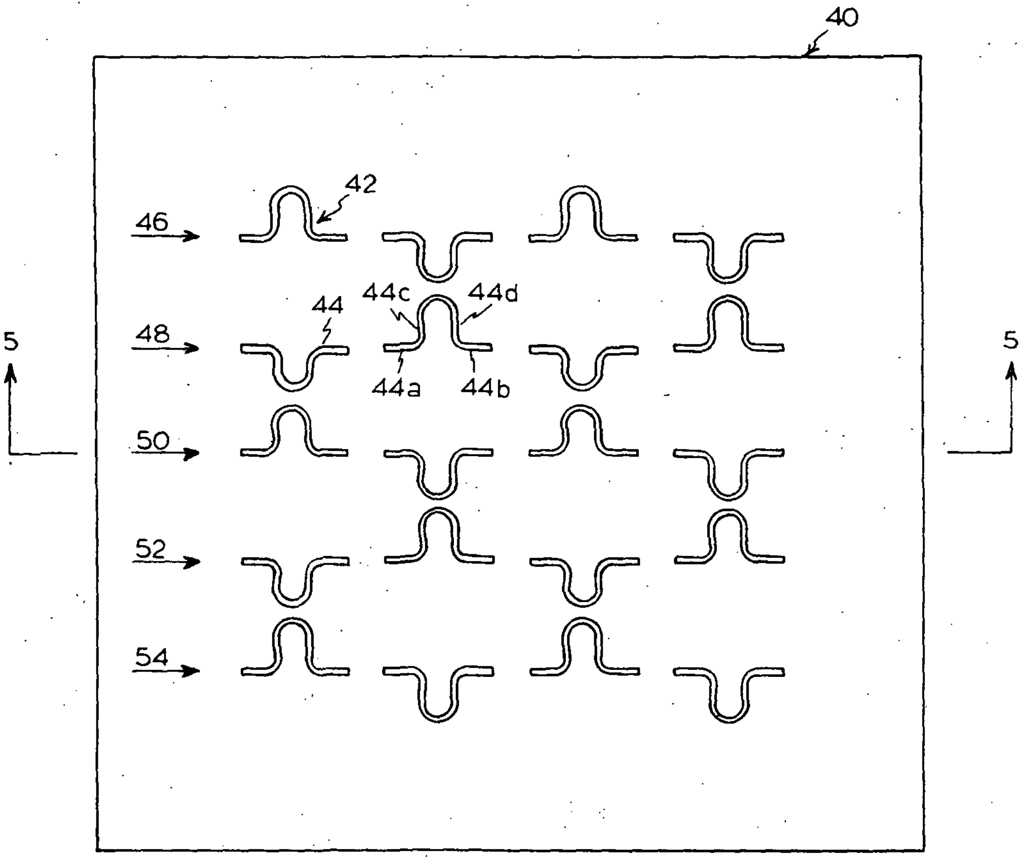

FIG. 4

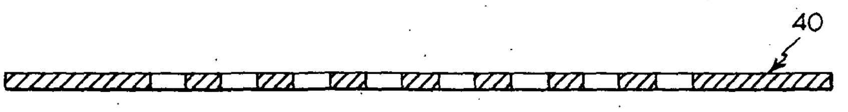

FIG. 5

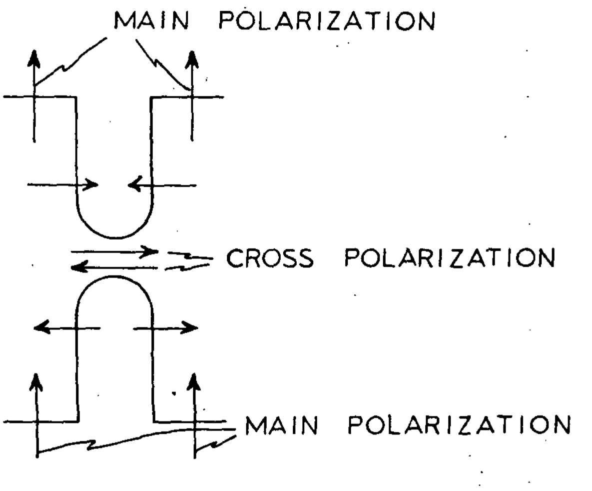

FIG. 6

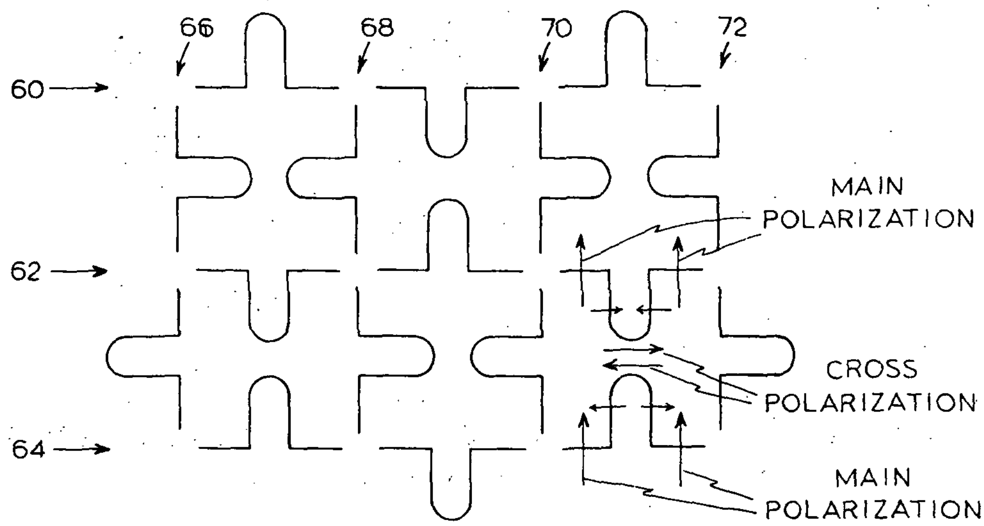
66
68
70
72
60
62
64
MAIN
POLARIZATION
CROSS
POLARIZATION
MAIN
POLARIZATION

FIG. 7

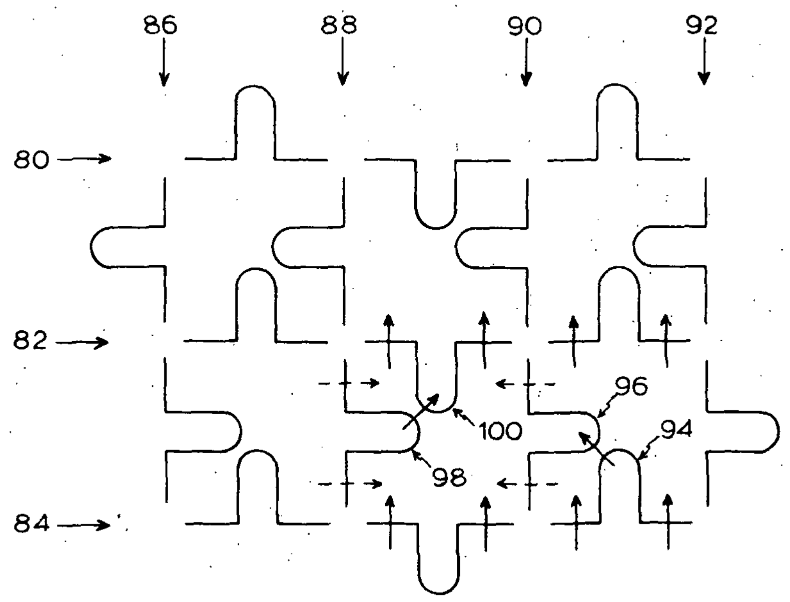
86
88
90
92
80
82
84
96
94
100
98

FIG. 8

LOW LOSS DICHROIC PLATE

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a low loss dichroic plate particularly useful in a dual frequency feed system for Cassegrainian antennas for passing polarized radiation within a selected frequency band.

2. Description of the Prior Art

U.S. Patent Application Ser. No. 290,022, filed on Sept. 18, 1972 by Dan A. Bathker, Samuel A. Brunstein, and Arthur C. Ludwig entitled "Dual Frequency Microwave Reflex Feed" discloses a feed system for a Cassegrainian antenna wherein X and S band signals are simultaneously transmitted or received along a common boresight of a single antenna. That system employs a dichroic plate able to reflect signals of a first frequency (e.g., S band) and pass signals of a second frequency (X band). Dichroic plates intended for use in such systems have been discussed in the literature; e.g., (1) Ohio State University Technical Report 2148-6, 1967 and (2) IEEE Transactions on Antennas and Propegation, volume 19, No. 5, September 1971 "Reflection Properties of Periodic Surfaces of Loaded Dipoles." The devices disclosed in the foregoing and other papers do exhibit appropriate dichroism and have proved satisfactory in certain applications. However, the need for dichroic plates exhibiting lower power loss has been recognized for certain applications.

OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is the provision of a dichroic plate capable of passing a signal of selected frequency with negligible power loss.

Another object of the present invention is the provision of a dichroic plate which is essentially insensitive to the variations in the tilt angle of the plate relative to the direction of signal radiation.

A more particular object of the invention is the provision of a dichroic plate capable of passing a polarized wave form and in which dipole elements are oriented so as to cancel cross polarization effects.

The foregoing and other objects of the invention are achieved in a preferred embodiment of the invention by providing a thin conductive plate having a matrix of slots formed therein, each slot defining a dipole element. Each slot is shaped to include an intermediate loop portion which loads the dipole element and thereby decreases the sensitivity of the plate's resonant frequency to tilt angle variations. In a linearly polarized embodiment of the invention, the matrix of slots is comprised of parallel rows in which the orientation of the slots in each row is alternated. As a consequence of the interaction between adjacent slots, either in the same or adjacent rows, the cross polarization effects produced by individual slots is compensated for resulting in a nulled net cross polarization. In a circularly polarized embodiment of the invention, the plate is provided with parallel columns extending orthogonal to the rows with the slots in each column also being alternated.

The novel features of the invention are set forth with particularity within the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings wherein:

FIG. 1 is a schematic diagram of a system in which a dichroic plate in accordance with the present invention can be advantageously utilized;

FIG. 2 is a schematic illustration of a known linearly polarized dichroic plate;

FIG. 3 is a diagram depicting the cross polarization effects occurring in the plate of FIG. 2;

FIG. 4 is a plan view of a linearly polarized dichroic plate in accordance with the present invention;

FIG. 5 is a sectional view taken substantially along the plane 5—5 of FIG. 4;

FIG. 6 is a schematic view depicting the polarization effects occurring within the slots of the dichroic plate of FIGS. 4 and 5;

FIG. 7 is a schematic illustration of a first circularly polarized dichroic plate embodiment in accordance with the present invention; and

FIG. 8 is a schematic illustration of an alternative circularly polarized dichroic plate in embodiment accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Attention is now called to FIG. 1 which illustrates a typical system in which embodiments of the present invention can be advantageously employed. The system of FIG. 1 includes a source of X band signals **10** which radiates X band energy through a dichroic plate **12.** The X band energy strikes a subreflector **14** and is reflected toward a Cassegrainian reflector **16.**

A source of S band signals **18** radiates S band energy toward an ellipsoid reflector **20.** The ellipsoid reflector reflects and focuses the S band energy in front of the dichroic plate **12.** By correctly orienting the tilt angle of the dichroic plate, the S band signals are reflected by it in line with the X band signals toward the subreflector **14.** The subreflector **14** reflects both the X and S band energy to the reflector **16** which in turn transmits both the X and S band signals along a common boresight.

The function of the dichroic plate **12** is to reflect the S band energy and to pass the X band energy with little degredation in either power or radiation pattern. These requirements necessitate that the dichroic plate have a low loss characteristic and be relatively insensitive to tilt angle, i.e., the angle of incidence of the X band energy on the plate **12.**

The present invention is directed to dichroic plate embodiments useful in systems of the type depicted in FIG. **1** for passing linearly and circularly polarized radiation of a selected frequency.

Attention is now called to FIG. **2** which schematically illustrates a known type of dichroic plate for passing linearly polarized radiation within a selected frequency band. More particularly, FIG. **2** illustrates a plurality of loaded dipole elements **30** arranged in parallel rows **32, 34, 36.** The dipole elements **30** may be formed, for example, by slots formed within a conductive panel such as a thin sheet of copper or aluminum. A dichroic plate of the type represented in FIG. **2** is discussed in the aforementioned paper appearing in the IEEE transactions.

Experimentation with a slotted dichroic plate of the type illustrated in FIG. 2 was conducted including the measurement of transmission loss through the plate for various tilt angles. A high transmission loss characteristic was revealed in certain orientations. In the case of perpendicular polarization, transmission loss increased with angle of incidence θ to 2dB at $\theta = 60°$. On the other hand, losses were less than 0.5 dB for angles of incidence up to 60° in the case of parallel polarization. The difference in behavior of these two polarizations is attributable to cross polarization effects and can be explained with reference to FIG. 3. FIG. 3 illustrates a single, short, loaded dipole element. Normally, cross polarization excited in the legs of the loop of the dipole element is equal and opposite. When the dichroic plate is tilted about the X axis in FIG. 3, corresponding to the case of parallel polarization, cross polarization in the legs of the dipole element loop remains equal and opposite and thus no net cross polarization is produced. However, when the dichroic plate is tilted about the Y axis of FIG. 3, corresponding to the case of perpendicular polarization, the net cross polarization increases with angle of incidence because of the increased phasing between the legs of the dipole element loop.

The present invention is directed to embodiments of a dichroic plate which exhibits negligible transmission loss regardless of the angle of incidence. Transmission loss is minimized in accordance with the present invention by arranging the dipole elements so that adjacent elements effectively interract to cancel cross polarization effects.

Attention is now called to FIGS. 4 and 5 which illustrate a preferred embodiment of a linearly polarized dichroic plate in accordance with the present invention. The dichroic plate of FIGS. 4 and 5 consists of a thin panel **40** of conductive material such as copper or aluminum. In a typical application, the panel **40** would be square, on the order of 32 inches along each side and have a thickness of about 0.016 inches.

A plurality of dipole elements **42** are defined in the panel **40** by forming slots **44** extending therethrough. As shown, the slots **44** are arranged in parallel rows **46, 48, 50, 52,** and **54**. Each of the slots **44** is illustrated as including a pair of base portions **44*a*** and **44*b*** and a loop portion including legs **44*c*** and **44*d***.

As previously pointed out, dipole elements formed by slots with loops have been previously discussed in the literature, as for example, in the aforementioned IEEE article. The presence of the loop portion within a slot effectively electrically loads the dipole element and decreases the sensitivity of the plate's resonant frequency to tilt angle.

In order to null the net cross polarization effects discussed in connection with FIG. 3, the orientation of the slots are alternated in accordance with the present invention as shown in FIG. 4. Thus, proceeding from left to right along row **52** of FIG. 4, for example, it will be noted that the first slot has a loop pointing down, the second slot pointing up, the third slot point down, etc. In the adjacent row **54**, the first slot has a loop pointing up, the next slot pointing down, etc. As a consequence of the arrangement illustrated in FIG. 4, each slot projects toward an adjacent slot as is better shown in FIG. 6. The two slots illustrated in FIG. 6 produce opposite cross polarization effects which tend to cancel or null the net cross polarization. As a consequence, a dichroic plate constructed in accordance with the teachings of FIGS. 4–6 exhibits low transmission loss. A model constructed in accordance with the arrangement illustrated in FIG. 4 was built and tested and its measured cross polarization was at least 40 dB down for angles of incidence up to 60°.

It should be understood that the slots **44** formed in panel **40** should be packed with as great a density as is reasonable. The dimensions of each slot are of course, dependent upon the desired band pass frequency. More particularly, the integrated length of each slot should be approximately one half wave length. Thus, for a dichroic plate intended to pass 8.0 gigahertz radiation, the length of each slot should be approximately 0.7 inches. In the fabrication of a dichroic plate in accordance with the invention, it is important that the dimensions of the slots be uniform and thus very small tolerances, e.g., ±0.001 inches, are essential. The slots **44** can be formed within the plate **40** by various fabrication techniques such as precision machining or chemical etching.

The technique employed in the linearly polarized dichroic plate of FIG. 4 to cancel cross polarization effects is also applicable to the provision of a circularly polarized dichroic plate. More particularly, attention is now called to FIG. 7 which schematically illustrates a first embodiment of a circularly polarized dichroic plate in accordance with the invention. The dichroic plate of FIG. 7 consists of parallel rows of dipole elements **60, 62,** and **64** as well as parallel columns of dipole elements **66, 68, 70,** and **72**. It will be noted in FIG. 7 that the orientation of the successive slots is alternated along each row or column. As a consequence, cross polarization effects are cancelled as is represented in FIG. 7.

It should, of course, be recognized that arrangements of dipole elements other than those shown herein can be utilized in accordance with the present invention to achieve the net cancellation of cross polarization effects. These various arrangements are characterized by alternating the orientation of the elements along the rows and columns.

For example, one further arrangement of dipole elements in accordance with the invention is illustrated in FIG. 8 for forming a circularly polarized dichroic plate. Note that in FIG. 8 the orientation of the dipole elements is alternated along each of the rows and columns but, however, the orientation of the elements from column to column or row to row is not alternated. It is in this latter respect that the arrangement of FIG. 8 differs from the arrangement of FIG. 7.

FIG. 8 illustrates dipole rows **80, 82, 84** and dipole columns **86, 88, 90, 92**. Coupling between adjacent dipole elements, as **94, 96** produces a cross polarization component to the left along column **90**. However, coupling between elements **98, 100** produces an oppositely directed cross polarization component to the right along column **88**. As a consequence, the net cross polarization effect is nulled.

It has been found that dichroic plates built in accordance with the teachings of FIGS. 7 and 8 exhibit very low transmission losses for angles of incidence up to 60°. Even more significantly, however, such plates exhibit almost no pattern degradation which might otherwise lead to signal losses.

From the foregoing, it should now be appreciated that several embodiments of low loss dichroic plates have been disclosed herein for passing linearly or circularly polarized radiation within a selected frequency band.

What is claimed is:

1. Dichroic means for passing radiation within a selected frequency band and reflecting radiation outside of that band, said dichroic means comprising:

means defining a plurality of dipole elements each comprised of an elongated path including a first and second spaced base portions and a substantially U-shaped central portion interconnecting said first and second base portions, said elongated path having a length proportional to the wavelength at the center of said selected frequency band; and

means supporting said plurality of dipole elements in a plurality of parallel rows with the orientation of elements in each row being alternated.

2. The dichroic means of claim 1 wherein said supporting means supports some of said elements in a plurality of parallel columns interlaced with and extending orthogonal to said rows with the orientation of elements in each row being alternated.

3. The dichroic means of claim 1 wherein said means defining said dipole elements includes a thin panel of electrically conductive material having a plurality of slots extending therethrough, each slot forming said elongated path.

4. A low loss dichroic plate suitable for use in an antenna feed system for passing polarized signals within a first frequency band and reflecting signals outside of said first frequency band, said plate comprising:

a thin panel of electrically conductive material;

a first plurality of slots extending through said panel arranged in a plurality of parallel rows, each of said slots including first and second aligned and spaced base portions and a U-shaped central portion extending orthogonal to said base portions;

said slots in each row being arranged with the U-shaped central portions in adjacent slots extending in opposite directions.

5. The dichroic plate of claim 4 wherein each slot has a length substantially equal to one half wavelength at the center frequency of said first frequency band.

6. The dichroic plate of claim 4 wherein aligned slots in adjacent rows are oppositely oriented.

7. The dichroic plate of claim 4 including a second plurality of slots extending through said panel arranged in a plurality of columns interlaced with and extending orthogonal to said parallel rows, said slots of second plurality being shaped and dimensioned substantially identical to said slots of said first plurality and arranged along each of said columns with the U-shaped central portions in adjacent slots extending in opposite directions.

8. The dichroic plate of claim 7 wherein aligned slots in adjacent rows are oppositely oriented and aligned slots in adjacent columns are oppositely oriented.

9. The dichroic plate of claim 8 wherein each slot has a length substantially equal to one half wavelength at the center frequency of said first frequency band.

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