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

REPLY TO ATTN OF: GP

June 30, 1971

MEMORANDUM

TO: KSI/Scientific & Technical Information Division
Attn: 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 contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, 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. : 3,417,400

Corporate Source : Hughes Aircraft Company

Supplementary Corporate Source :

NASA Patent Case No.: XGS-02290

Gayle Parker

Enclosure:
Copy of Patent

FACILITY FORM 602

N71-28809 (ACCESSION NUMBER) (THRU)

6 (PAGES) 00 (CODE)

(NASA CR OR TMX OR AD NUMBER) 07 (CATEGORY)

Dec. 17, 1968 W. W. BLACK 3,417,400

TRIAXIAL ANTENNA

Filed April 25, 1966 3 Sheets-Sheet 1

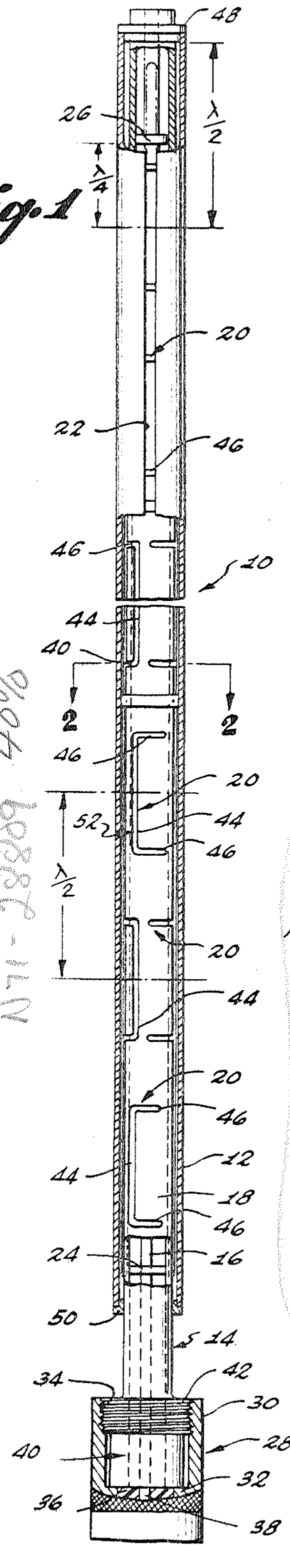

Fig. 1

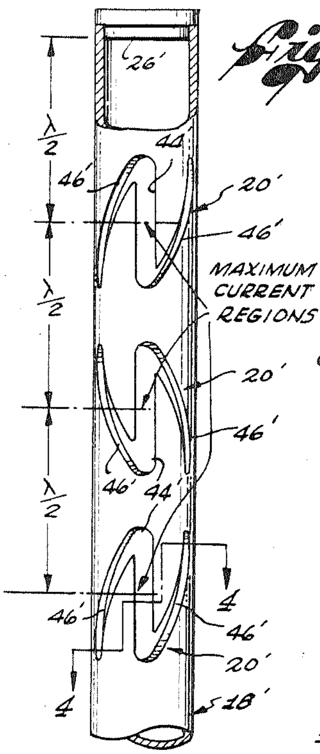

Fig. 3

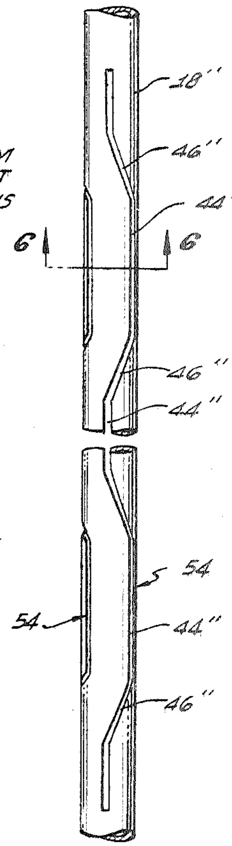

Fig. 5

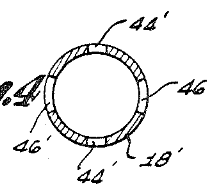

Fig. 4

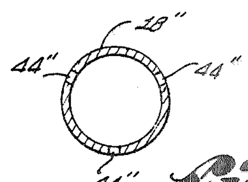

Fig. 6

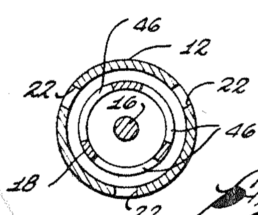

Fig. 2

INVENTOR.
WOODROW W. BLACK
BY J. K. Haskell
ATTORNEYS

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TRIAXIAL ANTENNA

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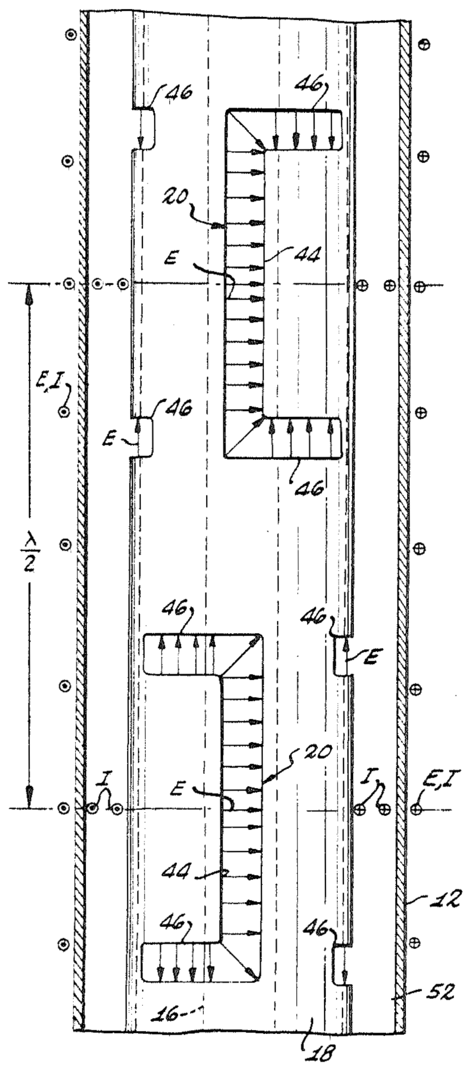

Fig. 7

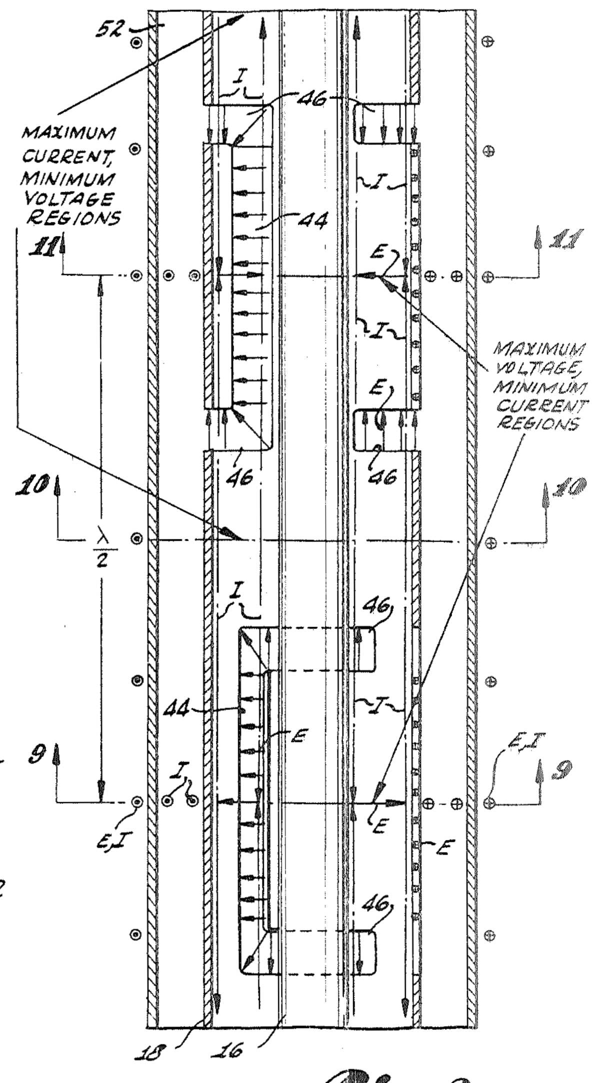

Fig. 8

INVENTOR.
WOODROW W. BLACK
BY J. K. Haskell
ATTORNEYS

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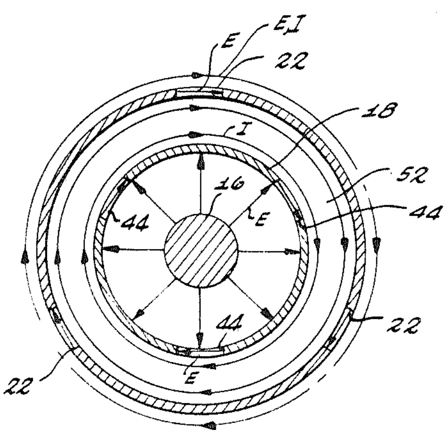

Fig. 9

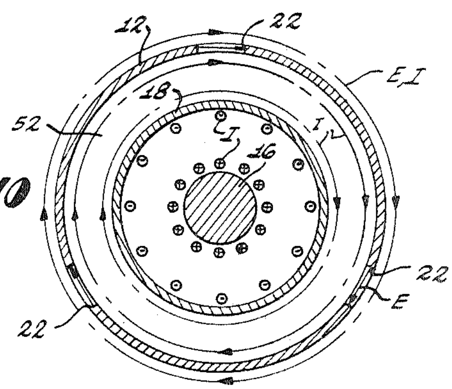

Fig. 10

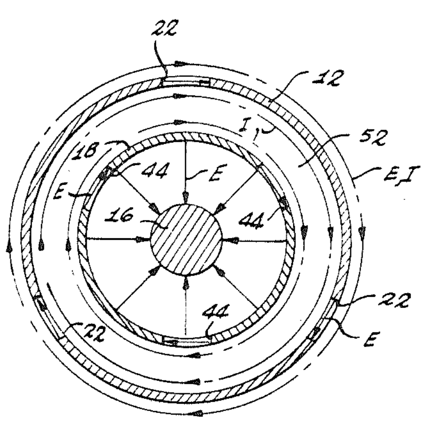

Fig. 11

INVENTOR.
WOODROW W. BLACK
BY J. K. Haskell
ATTORNEYS

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3,417,400
Patented Dec. 17, 1968

3,417,400

TRIAXIAL ANTENNA

Woodrow W. Black, Los Angeles, Calif., assignor, by mesne assignments, to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration

Filed Apr. 25, 1966, Ser. No. 544,895
9 Claims. (Cl. 343—771)

The present invention relates to improvements in antennas, and more particularly to a novel, transversely polarized triaxial antenna.

Prior art antennas are of a variety of configurations, including coaxial antennas having post feed slots and the clover leaf type of antennas. Although these antennas have presented certain improvements in the art still further improvements are needed.

In this respect the present invention is directed to a horizontally polarized antenna arragement of simplified construction providing improvements in pattern and impedance matching.

One object of this invention is to provide an improved transversely or horizontally polarized antenna.

Another object of this invention is to provide an improved antenna of the character referred to applicable in the construction of a phased array transmitting antenna.

Another object of the present invention is to provide a simple, compact, transversely polarized antenna of improved construction which is inexpensive and relatively easy to manufacture.

A further object of this invention is to provide an improved antenna of the character referred to which is capable of generating an omnidirectional radiation pattern.

The foregoing and other objects and advantages of this invention are achieved in a triaxial antenna construction according to this invention comprising a shorted, coaxial, TEM mode transmission line which includes an elongated inner conductor, a tubular intermediate conductor disposed about the inner conductor and provided with predetermined feed slot configurations. This transmission line is disposed within an outer tubular conductor which is provided with at least one elongated radiating slot which substantially parallels the inner conductor. The antenna is designed to provide a toroidal pattern with gain perpendicular to the axis of the antenna. It is horizontally or transversely polarized which minimizes reflections from adjacent antenna elements. The pattern has low side lobes and can be made to approach the maximum gain-bandwidth configuration. The feed slots of the intermediate tubular member of the antenna excite one or more long radiating slots in the outer tubular member or conductor of the antenna. The feed slots may be of various configurations characterized by having a portion such as a center section portion which is in line with or substantially parallel to the axis of the antenna element. The slots may be arranged to define a slot path around the intermediate conductor or pluralities of the slots may be arranged in axially spaced positions. The length of the radiating slot or slots may be expressed as

$$\frac{M}{2}\lambda$$

where M is any whole number, for example, 1, 2, 3, etc.

The foregoing as well as other objects and advantages of the present invention may be more clearly understood by reference to the following detailed description when considered with the drawings which, by way of example only, illustrate different forms of antenna construtcion embodying the advantages and features of the present invention.

In the drawings:

FIGURE 1 is an elevational view, fragmentarily in section, of one embodiment of the antenna of the present invention showing a triaxial configuration comprising an inner conductor, an intermediate tubular conductor and an outer tubular conductor;

FIGURE 2 is a sectional view taken on the line 2—2 of FIGURE 1;

FIGURE 3 is an enlarged elevational view, fragmentarily in section, of a portion of an intermediate tubular conductor illustrating a feed slot configuration differing from that of FIGURE 1;

FIGURE 4 is a sectional view taken along the line 4—4 of FIGURE 3;

FIGURE 5 is an elevational view drawn to the scale of FIGURE 1 of a portion of an intermediate conductor usable in the construction of FIGURE 1 and showing a different configuration of feed slots;

FIGURE 6 is an enlarged sectional view taken along the line 6—6 of FIGURE 5;

FIGURES 7 and 8 are enlarged longitudinal sectional views, respectively, of selected portions of the antenna construction illustrated in FIGURE 1 for the purpose of demonstrating the theoretical concept explaining how energy which is propagated axially of the inner and intermediate conductors is transformed into energy radiating transversely and circumferentially from the outer conductor;

FIGURES 9, 10 and 11 are sectional views taken along the respective sectional lines 9—9, 10—10 and 11—11 of FIGURE 8 illustrating the current and voltage conditions within the antenna construction in planes placed in quarter wavelength intervals from each other.

In the drawings, the triaxial antenna construction is represented generally by the numeral **10** and comprises a tubular, outer conductor **12** receiving one end of a shorted, coaxial, TEM mode transmission line **14**. The transmission line **14** includes an elongated inner conductor **16** and a tubular intermediate conductor **18** having a series of complex feed slots **20** formed therein. In the operation of the antenna **10**, the feed slots **20** excite one or more axial, radiating slots **22** in the outer conductor **12** causing the outer conductor to circumferentially radiate electromagnetic energy transverse to the axis of the antenna **10**, and preferably in an omnidirectional radiation pattern in a plane perpendicular to the antenna axis.

More specifically, in the form of the shorted coaxial line **14** illustrated in FIGURE 1, the inner conductor **16** is an elongated cylindrical metal body, while the intermediate conductor **18** is a hollow metal cylinder surrounding the inner conductor and separated therefrom by a plurality of insulating rings **24**. An electrical short **26** is connected between the intermediate and inner conductors **18** and **16** adjacent one end thereof and preferably takes the form of a metal ring stationed around the inner conductor with an outer edge bearing against the inner wall of the intermediate conductor.

Ends of the inner and intermediate conductors **16** and **18** opposite the electrical short **26** are received by a connector **28** for coupling energy to the antenna **10**. The connector **28** is of a conventional type and includes an outer sleeve **30** having an internal collar **32** and an internally threaded end portion **34**. The collar **32** supports an annular insulating bead **36** for holding an end portion **38** of the inner conductor **16** within the connector **28**, and acts as an end stop for an enlarged end portion **40** of the intermediate conductor **18**, including an externally threaded collar **42** mating with the internally threaded portion **34** of the sleeve **30**. Electrical energy applied to the connector **28** causes the coaxial transmission line **14** to transmit TEM modes while the electrical short **26** establishes a standing wave pattern within the line including two separate series of one-half wavelength separated maximum current and voltage regions, the maximum current regions being spaced one-quarter wavelength from the maximum voltage regions and the electrical short **26** being located at a maximum current region.

It is well known that the TEM mode will not excite axial slots, such as the axial radiating slots **22** in the outer conductor **12**. Therefore, to excite the radiating slots, the intermediate conductor **18** includes one or more series of complex feed slots **20**. In the form of the antenna **10** illustrated in FIGURE 1, three series of feed slots are included and are equally spaced from each other around the intermediate conductor.

Generally speaking, the feed slots **20** are substantially one-half wavelength long and each includes an axial portion **44** substantially parallel to the inner conductor **16** and a transverse portion **46** extending from the associated axial portion and lying immediately adjacent a maximum current region. Also, the feed slots **20** are spaced substantially at multiples of one-half wavelength along the intermediate conductor **18** and transverse portions of even multiple feed slots are reversed in direction from transverse portions of odd and multiple feed slots (if any).

More particularly, in FIGURE 1, the feed slots **20** are generally U-shaped having relatively long axial portions **44** and relatively short transverse portions **46** at opposite ends of and substantially normal to the axial portions. Also, corresponding feed slots **20** in the three series of slots are aligned as groups with the transverse portions **46** of slots of each group extending in the same direction around the intermediate conductor **18**.

As illustrated most clearly in FIGURES 7 through 11, the centers of the axial portions **44** are immediately adjacent maximum voltage regions while the maximum current regions lie between the transverse portions **46** of adjacent feed slots **20**. Thus arranged, axial currents in the coaxial line **14** along the inner surface of the intermediate conductor **18** excite the transverse portions **46** of the feed slots **20** to induce voltage thereacross. Voltages induced across the transverse portions **46** are transposed 90° by the axial portions **44** of the feed slots to be of like instantaneous polarity in each axial portion and to induce circumferential currents of like direction around the outside of the intermediate conductor **18**. The fields resulting from the circumferential currents, in turn, excite the axial radiating slots **22** in the outer conductor **12** to circumferentially radiate electromagnetic energy transverse to the axis of the antenna **10** and preferably in an omnidirectional radiation pattern as the antenna is rotated.

In this regard, the outer conductor **12** is a hollow metal cylinder and the axial slots **22** are each a multiple of one-half wavelength. Also, electrical shorts **48** and **50** are included adjacent opposite ends of the outer conductor **12** and between the outer and intermediate conductors and preferably comprise annular metal plugs seated around the intermediate conductor **18** at the ends of the outer conductor. The plugs and outer conductor define an annular chamber **52** around the intermediate conductor **18** which is substantially a multiple of one-half wavelength long with the electrical short **48** being substantially a multiple of one-half wavelengths beyond the middle of the endmost feed slot **20**.

With the outer conductor **12** thus arranged, the circumferential currents between the intermediate and outer conductors excite the radiating slots **22** in the manner illustrated in FIGURES 7 through 11. In particular, a continuous sheet of current is induced along the outside of the outer conductor **12** which changes in direction at times corresponding to each half cycle, and electromagnetic energy radiates circumferentially from the outer conductor transverse to the axis of the antenna **10** and in an omnidirectional radiation pattern as the antenna is rotated around its longitudinal axis.

In the foregoing operation, the outer conductor **12** also acts as a polarizer for the antenna **10**, blocking the exit of any cross-polarized energy from the antenna, that is, energy other than that radiating circumferentially and substantially normal to the axis of the antenna.

From the foregoing, it is appreciated that the present invention provides a compact, transversely polarized, omnidirectional antenna design which is inexpensive and relatively easy to manufacture and assemble.

Within the basic framework of the triaxial antenna previously described, numerous changes and modifications may be made without departing from the spirit of the invention. For example, various numbers and combinations of feed and radiation slots may be employed. The length and angle of the slots may be altered relative to each other. Also, the design of the feed slots may be changed.

One such example of feed slot design change is illustrated in FIGURES 2 and 3 and another in FIGURES 4 and 5. In FIGURES 2 and 3, the feed slots **20'** are generally Z-shaped having transverse portions **46'** extending from opposite ends of and back along the axial portions **44'**. The Z-shaped slots are substantially one-half wavelength long and are spaced at multiples of one-half wavelength with the transverse portions of even multiple feed slots being reversed in direction from the transverse portions of odd multiple feed slots.

As in the U-shaped slots, the transverse portions **46'** are immediately adjacent maximum current regions. In fact, the maximum current regions are preferably located at the center of the axial portions **44'**. This means that for the Z-shaped slot configuration, the electrical short **26'** is spaced a multiple of one-half wavelength from the middle of the endmost Z-slot rather than an odd multiple of a quarter wavelength, as with the U-shaped feed slots.

With the Z-shaped slots and electrical short **26'** thus spaced along the intermediate conductor **18'**, the mode of excitation of the feed slots and hence of the antenna **10** is very similar to that previously described. In particular, axial currents in the maximum current regions along the inner surface of the intermediate conductor **18** excite the transverse portions **46'** to induce voltages thereacross. The voltages are transposed in direction normal to the antenna axis by the axial portions **44'** and become of like instantaneous polarity in each axial portion. The voltages in axial portions, in turn, induce circumferential currents of like direction around the intermediate conductor which excite the radiating slots **22** of the associated outer conductor as described in connection with FIGURES 7–11.

In FIGURES 5 and 6, one or more axially extending zigzag slots **54** are spaced equally from each other around the intermediate conductor **18''**. The slots **54** have portions conforming to half wavelength feed slots with axial portions **44''** and transverse end portions **46''**. In fact, the slots **54** may be considered as being formed of a series of feed slots of the general design previously described joined end to end. That is, the feed slot portions are spaced one-half wavelength apart with the transverse portions **46''** of even multiple feed slot portions reversed in direction from the transverse portions of odd multiple feed slot portions. Also, the transverse portions are immediately adjacent maximum current regions in the conductor **18''** and the mode of exciting the slots to excite the radiating slots is as previously described for the U-shaped feed slots.

In viw of the foregoing as well as other changes and modifications which may be made in the illustrated forms within the spirit of the present invention, it is intended that the invention be limited in scope only by the terms of the following claims.

I claim:

1. A transversely polarized triaxial antenna, comprising:

a shorted coaxial TEM mode transmission line including an inner elongated conductor, a tubular intermediate conductor substantially coaxial with and receiving said inner conductor, and first short means adjacent a first end of said intermediate conductor and between said intermediate and inner conductors responsive to electrical energy applied to a second end of said line for setting up a standing wave pattern in said line including separate series of one-half wavelength spaced maximum current and voltage regions;

said intermediate conductor including a series of complex feed slots in its outer wall, each being substantially one-half wavelength long and each having an axial portion substantially parallel to said inner conductor and a transverse portion connected to said axial portion and lying immediately adjacent a maximum current region, said feed slots being located at multiples of one-half wavelength along said intermediate conductor with the transverse portions of even multiple feed slots being reversed in direction from the transverse portions of odd multiple feed slots;

a tubular outer conductor substantially coaxial with and receiving said intermediate conductor and having an axial radiating slot substantially parallel to said inner conductor, said radiating slot being substantially a multiple of one-half wavelength long;

and second and third short means adjacent first and second ends of said outer conductor and between said outer and intermediate conductors to define a chamber around said intermediate conductor, said chamber being substantially a multiple of one-half wavelength long and said second short means being substantially a multiple of one-half wavelength beyond the center of the endmost feed slot in said intermediate conductor.

2. The triaxial antena of claim 1, wherein said feed slots are generally U-shaped with the center of the axial portions being immediately adjacent maximum voltage regions in said coaxial line, maximum current regions being spaced at one-quarter wavelength intervals from said maximum voltage regions.

3. The triaxial antenna of claim 1, wherein said feed slots are generally Z-shaped.

4. The triaxial antenna of claim 3, wherein the center of the axial portions of said fed slots lie immediately adjacent maximum current regions in said coaxial transmission line and wherein said transverse portions of said feed slots extend from ends of said axial portions back along said axial portions toward said maximum current regions.

5. The triaxial antenna of claim 1, wherein said series of feed slots define a single, elongated slot comprising a plurality of substantially half wavelength feed slots joined end to end.

6. The triaxial antenna of claim 5, wherein said transverse portions extend axially from the opposite ends of sadi axial portions.

7. The triaxial antenna of claim 1, including a plurality of series of feed slots spaced equally from each other around said intermediate conductor.

8. The triaxial antenna of claim 7, wherein said feed slots are generally U-shaped with centers of said axial portions immediately adjacent maximum voltage regions in said coaxial line.

9. A transversely polarized triaxial antenna, comprising:

a shorted coaxial TEM mode transmission line including an inner elongated conductor, a tubular intermediate conductor substantially coaxial with and receiving said inner conductor, and first electrical short means adjacent a first end of said intermediate conductor and between said intermediate and inner conductors responsive to electrical energy applied to a second end of said line for setting up a standing wave pattern in said coaxial line including separate series of half wavelength spaced maximum current and voltage regions;

said intermediate conductor including a complex feed slot substantially one-half wavelength long and having an axial portion substantially parallel to said inner conductor and a transverse portion connecting to said axial portion and lying immediately adjacent a maximum current region;

a tubular outer conductor substantially coaxial with and receiving said intermediate conductor and having an axial radiating slot substantially parallel to said inner conductor, said radiating slot being substantially a multiple of one-half wavelength long;

and second and third short means adjacent first and second ends of said outer conductor and between said outer and intermediate conductors to define a chamber around said intermediate conductor, said chamber being substantially a multiple of one-half wavelength long and said second short means being substantially a multiple of one-half wavelength beyond the center of said feed slot.

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HERMAN KARL SAALBACH, *Primary Examiner.*

M. NUSSBAUM, *Assistant Examiner.*