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COMPACT WIDE BAND ANTENNA SYSTEM

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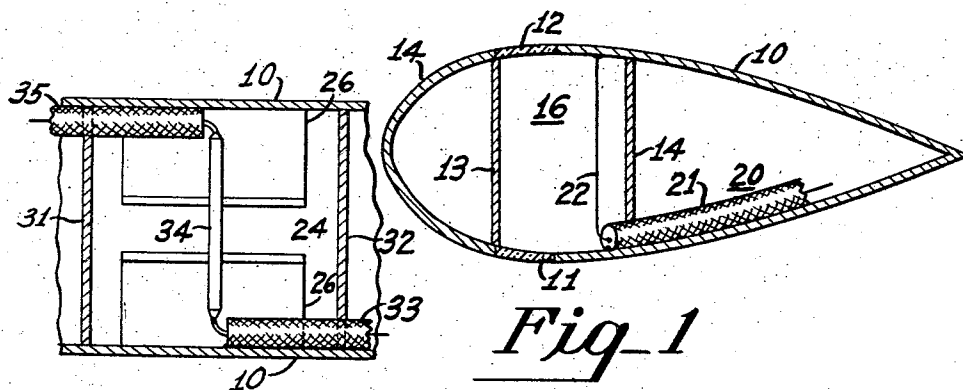
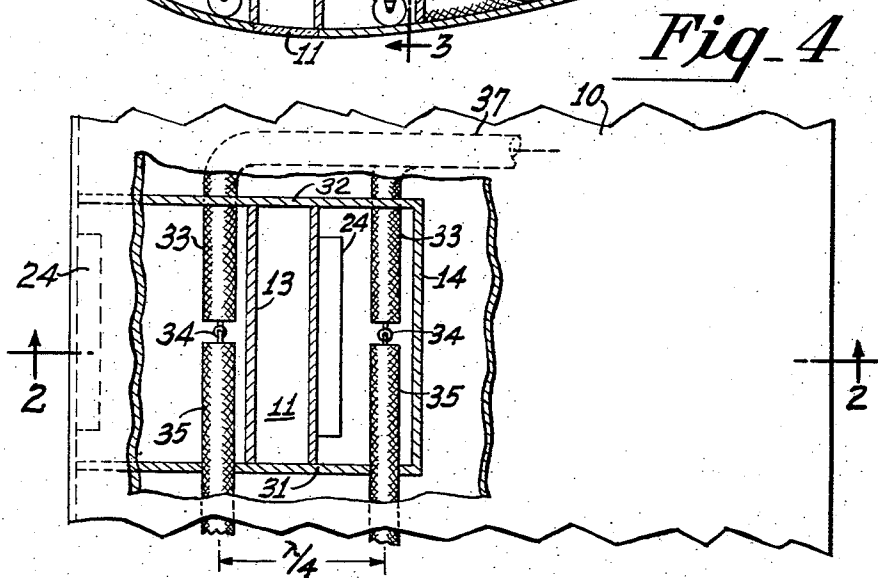
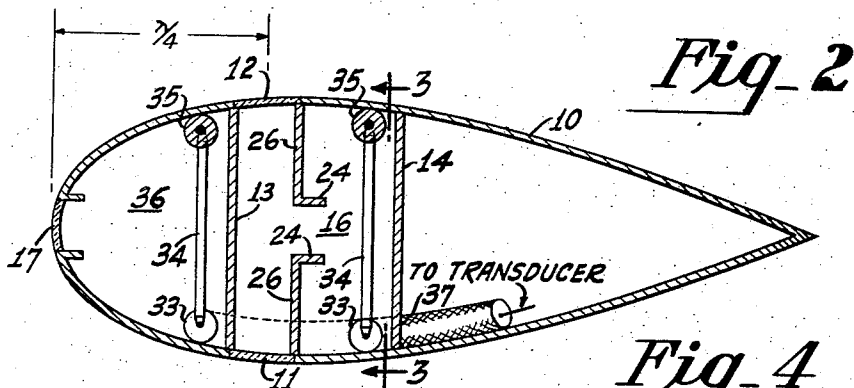


Fig. 3

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COMPACT WIDE BAND ANTENNA SYSTEM

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7 Claims. (Cl. 250—33)

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The invention relates to antenna systems and it particularly pertains to wide band very high frequency antennas for locations imposing restricted space requirements, especially as in aircraft installations.

There are many possible applications involving the use of antennas which impose severe limitations as to physical dimensions of the antenna while at the same time imposing severe electrical requirements as to directivity of the beam and usable frequency band width of the radiated energy. Such installations are found principally, but by no means entirely, in the field of aircraft radio installations, where it is often highly advantageous, if not absolutely necessary, to arrange antennas in wing sections, in tail assembly sections, and in sponsons, where the available space is exceedingly limited.

It is known to utilize such available space to a high degree of efficiency by use of a slot radiator antenna. For example, there is the arrangement disclosed in copending U. S. application Serial No. 612,685, filed August 25, 1945, thereafter issued on October 30, 1951, as U. S. Patent 2,573,460, or one of the arrangements shown and described in U. S. Patent 2,414,266 issued January 14, 1947. However, there are numerous desirable installations which require antennas which are either omnidirectional or sharply directive having a band width greatly in excess of that possible with heretofore known arrangements.

Therefore, it is an object of the invention to provide an improved antenna system having small physical dimensions and a relatively wide band width.

It is another object of the invention to provide a compact antenna in accordance with the foregoing object for convenient and efficient installations in the constricted structural portions of aircraft without impairing the aerodynamic characteristics thereof.

It is still another object of the invention to provide an antenna system in accordance with the foregoing objects which is highly directive.

It is a further object of the invention to provide an efficient but simple means for exciting the antenna elements of such a system.

These and other objects of the invention which will appear as the specification progresses are attained by means of antenna systems having a plurality of slot radiators. Novel feed means are obtained by having the slots arranged in such manner that one of said radiators forms an edge slot antenna and the remaining slot radiators serve as primary radiation sources, energizing

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sets of two-way slots in phase opposition. To obtain a highly directional system a plurality of antennas are arranged with slot radiators spaced apart one behind the other a distance of a quarter wavelength at the mean operating frequency and excited in phase quadrature. Thus increased directivity in the direction of principal radiation of the edge slot antenna is obtained along with the improved band width.

The invention will be described in detail with reference to the accompanying drawing forming a part of the specification and in which:

Fig. 1 is an illustration of a plural slot radiation omnidirectional antenna according to the invention;

Figs. 2 and 3 form an illustration of alternative feed and tuning arrangements for an antenna installation according to the invention; and

Fig. 4 is an illustration of a highly directive antenna system according to the invention.

Referring to Fig. 1, there is shown a structural section 10 of conductive surface elements arranged in streamlined form such as would be found in aircraft struts, wings, rudder post structures, and the like, in which it is desired to install an antenna. For purposes of explanation, the invention will be described as though the aerofoil body of the aircraft were of simple monocoque construction and the antenna structures integrally incorporated therein to form a combined structure. It should be borne in mind, however, that more practical embodiments are realized by a construction in which the antenna system is fabricated as a complete unit or group of units, readily removable from the aircraft or other vehicle in which it is installed.

On either side of section 10 are elongated slots 11 and 12 arranged in registry and shown here as being covered by insulating material in order that the aerodynamic characteristics of section 10 remain unimpaired. The longitudinal axis of slots 11 and 12 is perpendicular to the plane of the paper in this view. Wall portions 13 and 14 in the form of planar conductive surface elements are arranged in conductive relationship to section 10 and about slots 11 and 12 to form a cavity resonator structure enclosing resonant cavity 16 in conjunction with end wall portions 31 and 32 located at the ends of slots 11 and 12 as shown in the drawing. It is not at all necessary to have the wall portions so located but limitations of space will dictate that the walls be near the ends of the slots. Wall portion 13 is preferably but not necessarily close to one edge of each of slots 11 and 12 as shown in Fig. 1.

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The antenna according to the invention is energized by means of a transmission line 20 having a sheath 21 and a center conductor 22 connected to provide instantaneously opposing potentials at corresponding edges of slots 11 and 12. The respective opposite edges of each of the slots being connected by conductor 13 must assume a neutral potential whereby the lines of flux emanating from slots 11 and 12 are all produced in the same direction and an omnidirectional field pattern is thereby produced about section 10. Conductors 21 and 22 are connected to section 10 at points where the impedance of transmission line 20 is substantially equal to, or closely approaches, the impedance of resonator 16.

Because there has been a tendency on the part of those skilled in the art to regard as necessary a symmetrical feed arrangement for cavity resonators of the type shown in the drawing, it is pointed out that this is by no means true. It is sufficient that the corresponding edges of the slot be at opposing instantaneous polarity. For example, referring to Fig. 1, the edge of slot 12 nearest the point of connection of conductor 22 will be positive at the instant the edge of slot 11 nearest the sheath 21 is negative. Due to conductive wall 13 the opposite edges of both slots will assume a potential intermediate the other edges and consequently a neutral polarity. In single slot radiator systems, the effect may be seen by considering the two edges of slots 11 and 12 nearest the feed points as described above as the slot radiator itself.

Provisions for adding capacitive reactance for tuning the system may be made as described in the above-mentioned copending U. S. application Serial No. 612,685, by appending flanges 24 to the edges of slots 10 and 11 by means of plates 25 as shown in Figs. 2 and 3. Certain advantages are derived by use of the structure shown as will be seen upon reference to the prior patent application. Conceivably flanges 24 may be adjustable in order to obtain optimum results.

In installations requiring wide bandwidth and highly directional rather than omnidirectional performance, the arrangement shown in Figs. 2, 3 and 4 may be advantageously employed. Slots 11 and 12 are located a quarter wavelength at the midband operating frequency, or an odd multiple thereof, behind the leading edge of section 10 and a slot radiator antenna 17 located thereat has the resonant cavity 36 of the cavity resonator structure thereof energized in phase quadrature to energization of the other resonant cavity 16.

Cavity resonators 16 and 36 may be energized by means of a coaxial cable assembly of the type disclosed in the above-mentioned copending U. S. application Serial No. 612,685, comprising an input transmission line 33, coupling bars 34 and compensating stubs 35. However, any of the alternative feed arrangements of the foregoing application may also be used if desired. The two input transmission lines 33 are connected in parallel to transmission line 37 leading to the associated transducer apparatus so that the line leading to cavity resonator 36 is a quarter wave longer electrically than the line leading to cavity resonator 16, whereby the resonators are energized in phase quadrature when each line terminates into a load equal to the line's characteristic impedance.

It may be advantageous to emphasize that a line a quarter-wave long operates as a true 90 degree phase shifter only if its characteristic impedance is matched by a terminating load of

equal resistive value. When two such lines are connected in series or in parallel, the common line must have a characteristic impedance equal to the series or parallel equivalent of the lines connecting to it. This difficulty is overcome in practice by inserting a quarter-wave line section having a characteristic impedance equal to the geometric mean between that of a combination of lines and that of the trunk line to which the combination connects. In this way the trunk line can be one having the same characteristic impedance as that of the individual branches. However, the various radiation elements, due to their particular location in the array, may not all require equal power. In such a case two alternatives are available. The arrangement of the slot radiator elements may be changed. If this is impractical, the elements requiring less power than the others may be combined in series or parallel with a resistive absorber which will consume the power difference. The resulting sacrifice of power, which usually would be slight, may sometimes prove very well worth while whenever it is important that a specified radiation pattern be closely adhered to.

The invention is not limited to the use of but two radiator elements as shown. Any number consistent with space limitations can be so employed, the spacing being a quarter wavelength between elements and the elements being energized in phase quadrature steps. Radiation from slots 11, 12, and 17 is maximum parallel to the surrounding surface and outwardly free from the edge of section 10 whereby the radiation from the separate slots is additive in the forward direction of section 10 to provide increased directivity in the forward direction. Due to the quadrature feed, the band width of the overall system is likewise increased to a considerable degree.

It should be noted that directivity from an end-fire progressively fed array does not absolutely require that the elements be located at quarter- (or multiple thereof) wave spacing and fed in phase quadrature. They can be located in any space-sequence as long as they are fed in a corresponding phase-sequence. However, some dangerous combinations can result from spacing according to this general principle. If, for instance, the elements of the array should be spaced a full wavelength apart they would then have to be fed at a phase sequence of 360 degrees, or in phase. The array would then be quadruple directive; i. e., end-fire in both directions and broadside in both directions, or radiate in all four directions of a right angle system. Other incidents can occur for other sequence combinations. It is true, however, that if the spacing sequences are not multiples of a quarter-wave and if the phasing sequences, correspondingly, are not multiples of phase quadrature and if there is a sufficient number of elements in the array then the general principle will hold. The quarter-wave and phase quadrature sequential systems lend themselves, as a rule, to obtaining a desired directivity with a lesser number of radiators than the random system and are much more effective in obtaining wide band performance. It should be noted, however, that randomness does not detract from the ability of the signal components to add in the desired direction. The detriment from randomness is that there may be more radiation in undesirable directions. The signal energy will therefore be divided and less signal will be obtained in the desired direction as a secondary result. From the example given it can,

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however, be seen that the worse case is not obtained from random spacing and energizing but rather from a multiple quadrature spacing in which some adjacent multiples have been skipped. Such skipping is also very detrimental to bandwidth.

It should be understood that the antenna system according to the invention is equally operable for transmitting or receiving wave energy and that while the invention has been described in terms of several express embodiments, numerous modifications thereof will be suggested to those skilled in the art without departing from the spirit and scope of the invention.

The invention claimed is:

1. An antenna system including a first cavity resonator structure having a slot radiator element therein, a second cavity resonator structure having two slot radiator elements therein, each of the slot radiator elements of said second structure being arranged at equal space path distances from the slot radiator element of said first structure, and means to induce wave energy into each of said structures, said means comprising coaxial transmission lines having center and sheath conductors, said sheath conductors being connected to given walls of said structures and said center conductors extending substantially entirely across the interiors of said structure to the opposing walls thereby to energize opposing edges of the slot radiator elements in phase opposition to produce inphase addition of the components obtained from all of said slot radiator elements at the slot radiator element of said first structure to provide increased directivity of said antenna system in the direction of radiation of said first structure.

2. An antenna system including a first cavity resonator structure having a slot radiator element therein, a second cavity resonator structure having two slot radiator elements therein, each of the slot radiator elements of said second structure being spaced an odd multiple including unity of quarter wavelengths at the operating frequency from the slot radiator element of said first structure, and transmission lines coupled to said structures, said transmission lines differing in length by multiple including unity of a quarter-wave length at said frequency to induce energy into each of said structures said means comprising coaxial transmission lines having center and sheath conductors, said sheath conductors being connected to given walls of said structures and said center conductors extending substantially entirely across the interiors of said structure to the opposing walls thereby to energize opposing edges of the slot radiator elements in phase opposition to produce inphase addition of the components obtained from all of said slot radiator elements at the slot radiator element of said first structure to provide increased directivity of said antenna system in the direction of said first structure.

3. An antenna system particularly for installations in an aerofoil body, including a first cavity resonator structure arranged in said body and having a slot radiator element therein located at the nose of the aerofoil, a second cavity resonator structure arranged in said body behind said first structure and having two slot radiator elements therein arranged on either side of said aerofoil, each of the slot radiator elements of said second structure being spaced an odd multiple including unity of quarter wavelengths at

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the operating frequency from the slot radiator element of said first structure, and transmission lines coupled to said structures, one of said transmission lines differing in length from the other by a multiple including unity of a quarter-wave length at said frequency, said coaxial transmission lines having center and sheath conductors, said sheath conductors being connected to given walls of said structures and said center conductors extending substantially entirely across the interiors of said structure to the opposing walls thereby to energize opposing edges of the slot radiator elements in phase opposition to induce energy into each of said structures to produce inphase addition of the components obtained from all of said slot radiator elements at the slot radiator element of said first structure to provide increased directivity of said antenna system in the direction of said first structure.

4. An antenna system including a hollow conductive surface member, two substantially planar conductive coextensive surface elements arranged in substantially parallel relationship within and extending across substantially normal to opposing portions of said conductive surface member, two further conductive coextensive surface elements arranged within and substantially normal to said opposing portions of said conductive surface member and substantially normal to said planar conductive surface elements to form a cavity resonator, said cavity resonator having a pair of slots arranged in registry in said opposing portions of said hollow conductive surface member, and a transmission line having sheath and inner conductors lying within said hollow conductive surface member and arranged to enter said cavity resonator, said sheath conductor being connected to said conductive surface member at one of said portions and said inner conductor extending entirely across said cavity resonator and being connected to the other of said portions of said conductive surface member.

5. An antenna system including a hollow conductive tubular member of relatively thin elliptical cross-sections, two substantially planar conductive surface elements arranged in substantially parallel relationship within and substantially normal to portions of said tubular member opposing each other across the thin dimension thereof, two further conductive surface elements arranged within and extending across substantially normal to the axis of said tubular member to form a cavity resonator, said cavity resonator having a pair of slots arranged in registry in said opposing portions of said hollow conductive surface member, and a transmission line lying within and contiguous to said hollow conductive surface member and having sheath and inner conductors arranged to enter said cavity resonator, said sheath conductor being connected to said conductive surface member at one of said portions and said inner conductor extending entirely across said cavity resonator and being connected to the other of said portions of said conductive surface member.

6. An antenna system including a conductive tubular member, having relatively short and long transverse axes, two substantially planar conductive surface elements arranged within and in substantially parallel relationship to the short axis of said conductive tubular member, two further conductive surface elements arranged within and extending across substantially normal to the longitudinal axis of said conductive tubular member to form a cavity resonator, said

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cavity resonator having a pair of slots arranged in registry in opposing portions of said conductive tubular member, and a transmission line lying within and contiguous to said hollow conductive surface member and having sheath and inner conductors arranged to enter said cavity resonator, said sheath conductor being connected to said conductive surface member at one of said portions and said inner conductor extending entirely across said cavity resonator and being connected to the other of said portions of said conductive surface member.

7. An antenna system including a conductive tubular member, having relatively short and long transverse axes, two substantially planar conductive surface elements arranged within and in substantially parallel relationship to the short axis of said conductive tubular member, two further conductive surface elements arranged within and extending across substantially normal to the longitudinal axis of said conductive tubular member to form a cavity resonator, said cavity resonator having a pair of slots arranged in registry in opposing portions of said conductive tubular member, a pair of planar conductive members arranged in said cavity resonator to one side of said slots and parallel to the longitudinal axis of said conductive tubular member to form a further tuning slot within said cavity resonator,

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and a transmission line having sheath and inner conductors lying contiguous to said tubular member and arranged to enter said cavity resonator, said sheath conductor being connected to said conductive surface member at one of said portions and said inner conductor extending entirely across said cavity resonator and being connected to the other of said portions of said conductive surface member.

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