May 20, 1947. R. C. MOORE 2,420,967

TURNSTILE ANTENNA

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Fig. 3.

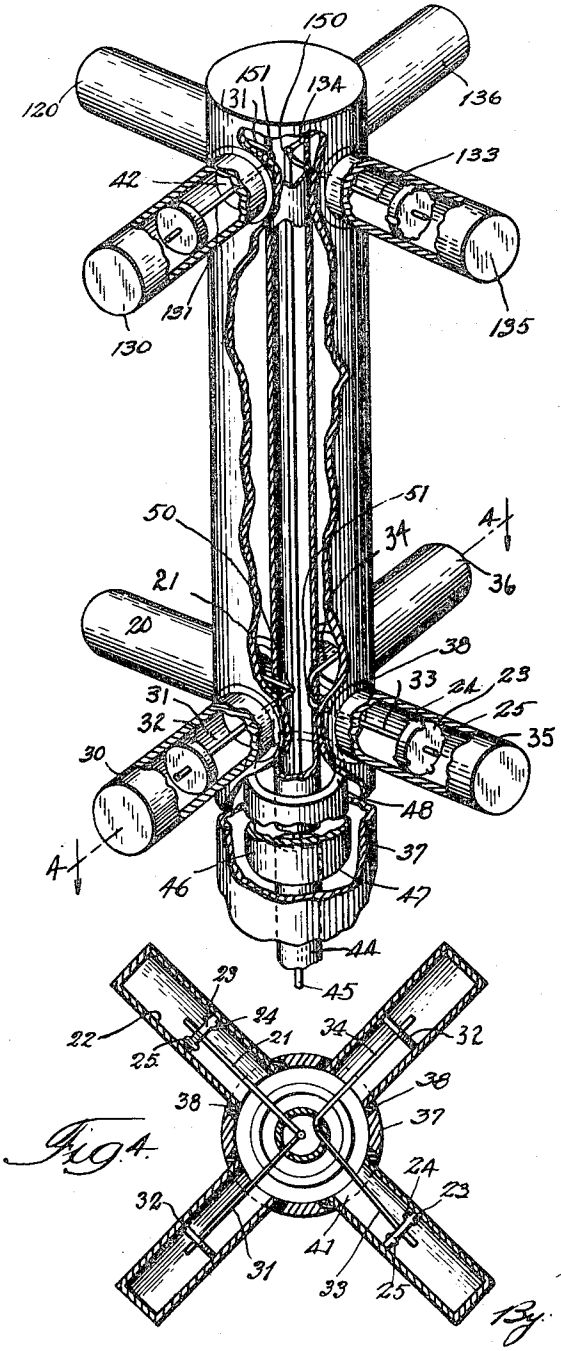


Fig. 4.

Fig. 1.

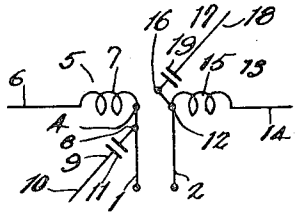
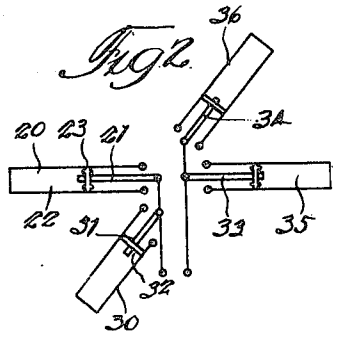


Fig. 2.



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TURNSTILE ANTENNA

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9 Claims. (Cl. 250—33)

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This invention relates to an electrical apparatus and particularly an antenna system. In particular, the invention relates to a turn-stile antenna system for ultra-high frequencies whereby a more compact and desirable system is provided. As is well known, a turn-stile type of antenna system may include one or more banks or bays of a group of two or four antennas. A group of four antennas for a bay may be disposed in a generally horizontal plane with a 90 degree geometrical and electrical angle between adjacent antennas to obtain a generally circular radiation pattern in azimuth. Two superposed groups of two antennas for a bay may also be provided. Such turnstile antenna arrays are used to some extent at high frequencies for frequency modulation transmission, some television work, and similar purposes.

In order to feed properly the four antennas of a turn-stile group, it is necessary to advance or retard the phase of the current in each member of the group by 90 degrees progressively. Such a requirement has hitherto made it necessary to provide half wave stubs for obtaining the necessary phase correction. The use of such stubs in an antenna system of this character is objectionable for various reasons. For one thing, such antenna systems may be exposed to adverse weather where sleet and snow may collect. For another thing, the use of shorting stubs results in a mechanical system susceptible to vibrations and having some tendency to modulate transmission or reception of energy. In addition thereto, the use of half wave stubs creates additional tuning problems.

In accordance with the invention herein, a turnstile antenna system of the type having four arms to a bay is provided. This system is mechanically and electrically simple and efficient. The mechanical simplicity results in a streamlined structure which may be important when used at the top of a high building or in an exposed position. Electrically, the invention provides an antenna system which can accommodate an unusually broad range of frequencies.

In many instances, such as in television work, a wide range of frequencies must be used so that the band width of the system must of necessity be substantial. Considerable difficulty is experienced in designing an antenna system having a substantial band width at high frequencies due to the extremely sharp resonance characteristics of circuits at such frequencies.

In order to widen the band width of an antenna system, it has hitherto been the practice to decrease the ratio of length to diameter of the radiating elements. However, this alters the radiation resistance and input impedance of the system in cases where it is undesired. By virtue of the invention herein, the antenna system as a whole presents a substantially pure resistance to the feed lines and presents a substantially constant impedance over a wide band.

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The usual type of dipole customary in turnstile systems inherently has a narrow band width and thus cannot present a substantially constant impedance over any substantial band width. Because of this, the use of such antenna systems in television work has been greatly restricted.

Referring to the drawing:

Figure 1 is a schematic circuit diagram of a system embodying this invention.

Figure 2 is a diagrammatic illustration of an antenna system embodying the present invention.

Figure 3 is an elevation with certain parts broken away showing a practical antenna system embodying the invention.

Figure 4 is a section on 4—4 of Figure 3.

Referring first to Figure 1, a transmission line consisting of conductors 1 and 2 may be supplied with energy at high frequency either from a suitable transmitter or may be connected to supply energy to a suitable receiver, depending upon whether the antenna system is to be used for transmission or reception. If wires 1 and 2 are formed as an open line, it is understood that the spacing between them must be small in comparison to the wave length so that radiation from the line will be suppressed. Actually, wires 1 and 2 are merely symbolic and the transmission line which they represent may be an open line, a coaxial cable, as shown in Figures 3 and 4, or a wave guide. Inasmuch as feeding from transmission lines is highly developed and well known in the art, the substitution of one form of line for another may be effected readily.

Conductor 1 may have connected thereto terminal 4 of a radiating antenna unit generally designated as 5 and consisting of an antenna radiating arm 6 and inductive reactance 7. Inductive reactance 7 may in its physical form be incorporated in as part of radiating arm 6 or, if desired, may be separate and associated with radiating arm 6. Conductor 1 is also connected to terminal 8 of a radiating unit 9 consisting of an antenna arm 10 and capacitive reactance 11. As is the case with unit 5, unit 9 may have the reactance and radiating arm all together in one physical structure or be separate.

Conductor 2 is similarly connected to terminal

12 of unit 13 having radiating antenna arm 14 and inductive reactance 15. Conductor 2 is also connected to terminal 16 of unit 17 having radiating arm 18 and capacitive reactance 19.

It is understood that terminals 4 and 8 are fed in phase and that terminals 12 and 16 are similarly fed in phase. The reactance in each arm is approximately equal to the radiation resistance of that arm at the frequency of operation, particularly the center of the band. Thus a substantially 45 degree phase angle between resistance and impedance is provided. In the case of an inductive reactance, the voltage will lead the current by 45 degrees. With capacitive reactance, the voltage will lag the current by 45 degrees.

The feed for units 5 and 9 is 180 degrees out of phase with the feed for units 13 and 17. Thus antenna radiating arms 10 and 18 will be oppositely poled and constitute the stubs of a dipole unit. The same is true of radiating arms 6 and 14. By virtue of the magnitude of reactance and radiation resistance, there will be a ninety degree difference in phase between the currents in the radiating arms progressively around an antenna bay. Thus dipole unit 10 and 18 will have a phase difference of ninety degrees as far as radiation is concerned with respect to dipole units 6 and 14. To be more specific, the current in dipole unit 10 and 16 leads the voltage by forty-five degrees whereas the current in dipole unit 6 and 14 lags the voltage by forty-five degrees. Thus a turnstile action results and radiation is provided.

In order to embody the antenna system of Figure 1 in a practical structure, it is preferred to utilize as radiating elements half dipole stubs as shown in Figure 2. Thus antenna arm 6, which has inductive reactance, may consist of metal tube 20. Within tube 20, center conductor 21 is provided, this center conductor being electrically joined to inside surface 22 of tube 20 by metal shorting disc 23. Shorting disc 23 may be provided with spring fingers 24 and 25 for engaging inner surface 22 of cylinder 20 and central conductor 21. (See Figures 3 and 4.)

It is understood that cylinder 20 is closed at the outer end. The position of disc 23 along conductor 21 inside of cylinder 20 may be determined by calibration or experiment and should be so chosen as to produce desired inductive reactance. The length of cylinder 20 will also be a factor in this. If desired, cylinder 20 may have a generally ovoid shape on the outside to control the band response characteristics. The major axis of the ovoid would naturally be coincident with the inside cylindrical axis of wall 22.

Capacitive antenna arm 10 has cylinder 30 of the same general construction as cylinder 20. Within cylinder 30, center conductor 31 may be provided and this may be maintained centered within cylinder 30 by means of suitable insulating beads 32 disposed in a manner to avoid undue reflection. If desired, the inside of cylinder 30 may be filled with dielectric such as polystyrene and conductor 31 disposed therein. Antenna arms 14 and 18 resemble antenna arms 6 and 10 respectively in their physical construction having center wires 33 and 34 inside of cylinders 35 and 36.

To support the structure, standard 37 may be provided. This standard may be made of metal pipe and may have insulating bushings 38 from which each antenna unit may be supported. The insulating bushings may be supported in the pipe

in any suitable fashion so that sufficient mechanical strength as well as insulation is provided. It is preferred to have the diameter of the standard as small as possible to reduce to a minimum the amount of metal and dielectric in the vicinity of the radiators. The actual diameter or size of pipe is not critical. By virtue of small size of pipe and dielectric, the radiation pattern will be less affected.

Bushings 38 may have apertures 41 into which each antenna arm unit is rigidly secured. A second series of apertures 42 may be provided for another bay, the two bays being preferably one half wave length apart.

While various means for feeding the antenna may be provided such as open line, balanced coaxial cables or even wave guide, a simple means using one coaxial cable is herewith shown. A coaxial cable ordinarily has the outside of the outer cable at ground potential and the two surfaces at radio frequency potential are not balanced with respect to ground. As used herein, however, it is desirable that the feed lines connected to the antenna arms be balanced to ground so that the antenna arms themselves will not be at different potentials with respect to ground.

In order to obtain a coaxial cable section that is balanced to ground, a balancing sleeve is used. Thus, the coaxial feed cable may have outer conductor 44 and inner conductor 45 spaced in a manner well known in the art, and having a predetermined ratio of diameters to provide a desired characteristic impedance. Outer conductor 44 is provided with sleeve 46, this sleeve having a length substantially a quarter wave along its axis. It is understood that bottom 47 of sleeve 46 is joined to outer conductor 44 so that an annular cup around outer conductor 44 is formed. Sleeve 46 extends upwardly toward the antenna arms and terminates in free edge 48.

Beyond sleeve 46, an open line may be used. However, a coaxial line is shown. The coaxial line extends beyond balancing sleeve 46 and, since the opposed conducting surfaces are balanced to ground, connections to the antenna arms may be made thereto. Thus, at point 50 on center conductor 45, leads 21 and 31 for radiating pipe members 20 and 30 may be connected. These leads pass through apertures in outer conductor 44. At point 51 on the inside surface of outer conductor 44, this point being opposite in polarity to point 50, connections to conductors 33 and 34 of cylinders 35 and 36 are made.

A half wave length beyond the region in standard 37 where the first bay occurs, a second bay may be provided. This second bay may consist of four arms symmetrically disposed and aligned with the four arms of the lower bay. These four arms are numbered 120, 130, 135 and 136 respectively. The corresponding parts in the two bays are similarly numbered with the difference of one hundred between the corresponding numbers.

For certain purposes, it is desirable that the corresponding arms be connected at points of opposite polarity, the bays being separated by one-half wave length. Thus arms 120 and 130 may have their center conductors 121 and 131 connected to point 151 on the inside surface of outer conductor 44. In the case where the center conductors of the antenna arm units connect to the inside surface of the outer conductor, such wires may pass through suitable apertures in outer conductor 44 and be soldered or joined thereto in a manner well known in the art. Radiating arms 135 and 136 have their center

conductors 133 and 134 joined to point 150 on center conductor 45.

It is understood that additional bays may be provided and, in fact, as many may be provided as may be deemed necessary. The spacing between adjacent bays may be a wave length if desired, in which case no reversal of polarity of corresponding superposed arms will be necessary. However, it is preferred to have adjacent bays separated by a distance of one-half wave length, as the radiation pattern appears to be more desirable.

Since bays are separated by a distance of one-half or in some instances one whole wave length, it is clear that all of the bays as seen at the input to the entire system are effectively in parallel. In some instances, it is possible that the wide frequency band over which the system is adapted to operate may result in some mismatching. Thus, it is clear that a separation of one-half a wave length between adjacent bays is true for only a narrow band of frequencies. Where the desired band width is substantial, the separation between adjacent bays may effectively be somewhat less or greater than one-half a wave length. In such case, some matching for the mid frequency is desirable, so that satisfactory operation over the entire frequency range will be had. In certain instances, it may be desirable to provide separate feed lines to each bay.

The outer radiating surface of each of the radiating arms is preferably of the order of one quarter wave length. The exact length is a complex function involving among other things the ratio of length to diameter, proximity of other arms, shape of cylinder arms and other factors. In the case where each arm has a transmission line section built in, as shown herein, it is clear that each arm has a transformer therein for imparting a predetermined magnitude of reactance.

It is possible to design the length of each of the radiating arms so that the radiating surface has a reactive component. In that particular case, the transmission line section within each arm would be entirely eliminated and a direct connection from the feed line to the radiating surface would be provided. It is also possible to have some reactance in each radiating arm and supplement this with a transmission line section within each arm so that the total reactance would combine to provide a desired magnitude.

It is understood that the diameter of the inner and outer conductor of each transmission line section within a radiating arm are properly proportioned to give a desired characteristic impedance as seen from the supply cable. Naturally, the thickness of each of the cylinder walls making up a radiating arm may be varied so that the ratio of diameters of the coaxial transmission cable within a radiating arm is independent of the dimensions of the arm itself. By proper design, the combination of the four arms of each bay may present a substantially pure resistive load as seen from the supply cable. Thus accurate matching for maximum energy transfer may be obtained.

The standard may terminate in an end cap as shown. Since the feed is substantially nonresonant, and since substantially perfect matching is presumed, it is clear that no special termination for the feed line or standard is necessary. The fact that the entire system presents a substantially pure resistive load is desirable,

particularly in the event that long open line feeders are used. In such case, substantially nonresonant lines may be used, and the variation in the length of line or variation in frequency will have little or no effect. A construction of this character may thus be pre-fabricated and pretuned.

It is understood that the use of the terms capacitive and inductive reactance herein refers to the phase angle between current and voltage. At the frequencies involved, the ordinary concept of inductance and capacitance is unsatisfactory. Thus it is well known that the same physical structure having a different electrical length may go from an inductive reactance through substantially pure resistance to a capacitive reactance.

What is claimed is:

1. A turnstile type of antenna comprising a support, four arms radiating from said support with said arms generally lying in a plane and having an angle of ninety degrees between adjacent arms, each arm comprising a metal member having a hollow interior, a conductor disposed within said interior and spaced therefrom, one pair of diametrically opposed arms forming a dipole and having a shorting member for each arm between the central conductor and the interior of said arm, the remaining two arms forming a dipole and having capacitive connections to their conductors, each of said arms having the interior functioning as a phasing sleeve, said arms and sleeves being so proportioned as to provide for a ninety-degree difference in phase between adjacent arms progressively around the four arms, and means for feeding the central conductors of two adjacent arms in phase and for feeding the central conductors of the remaining arms in opposed phase.

2. The system of claim 1 wherein said arms have the interior phasing sleeves so proportioned and so long that the pair having shorting members have inductive reactance and the open pair have capacitive reactance.

3. The system of claim 1 wherein said dipole arms are all the same length with each arm being substantially a quarter wave length long and wherein the phasing sleeves within one pair of dipole arms are so proportioned as to present an inductive reactance and wherein the phasing sleeves within the remaining dipole arms are so proportioned as to present a capacitive reactance, the inductive and capacitive reactances having a ninety-degree phase difference between adjacent arms.

4. A turnstile type of antenna comprising an insulating standard, at least one bay of antenna arms radiating from said standard with adjacent arms being electrically and geometrically ninety degrees apart, each arm including a metallic cylinder having an exterior radiating surface and having a cylindrical surface formed on the inside, opposing arms forming a dipole, each of said arms having a centrally disposed conductor within the interior thereof, the arms of one dipole having a shorting member within each arm between the center conductor and the interior metal surface, the arms of the remaining dipole having capacitive connection between each arm and the surrounding metallic surface, at least one transmission system within said standard, metallic connections between said transmission line to the center conductors of said arms, two adjacent arms being fed in phase and the remaining adjacent arms being fed in phase but oppositely poled, the center conductor and inside cylindrical

surface for each arm forming a phase sleeve having a predetermined length and dimension to provide a phase difference of ninety degrees between the two dipoles.

5. The system of claim 4 wherein each of said arms is substantially a quarter wave length long.

6. The system of claim 4 wherein each arm is substantially a quarter wave length long and wherein the phasing sleeves having metallic connection between the center conductor and surrounding cylinder wall provide an inductive reactance and wherein the remaining phasing sleeves provide a capacitive reactance.

7. The system of claim 4 wherein a pair of superposed bays spaced one-half wave length apart are provided, the corresponding arms of each bay being in the same vertical plane with corresponding arms being fed 180 degrees out of phase.

8. A turnstile antenna for use at high carrier frequencies, said antenna comprising four half-dipole radiator elements extending outwardly at 90 degree intervals from a common center, each one of said radiator elements comprising a hollow cylindrical conducting member, each pair of oppositely disposed radiator elements comprising a dipole element, each radiator element having an inner coaxial conductor extending part way only into said radiator element from the inner end thereof, the outer ends of the coaxial conductors in only one of said dipoles being shunted to the inner surface of the corresponding radiator elements through a path having low impedance at said carrier frequencies, means for energizing said dipoles in parallel from a common source of high frequency carrier wave energy, said means comprising connections between said source and the inner ends of said coaxial conductors, the length of said coaxial conductors

being such that a substantially 90 degree phase shift is effected between the currents in said dipoles.

9. A turnstile antenna for use at high carrier frequencies, said antenna comprising four half-dipole radiator elements disposed in a common plane and extending radially outward at 90 degree intervals from a common center, each one of said radiator elements comprising a hollow cylindrical conducting member closed at the outer end and open at the inner end thereof, each pair of oppositely disposed radiator elements constituting a dipole, each radiator element having an inner coaxial conductor extending part way only into said radiator element from the inner end thereof, the outer ends of the coaxial conductors in only one of said dipoles being connected directly to the inner surface of the associated radiator elements through a path having low impedance at said carrier frequencies, means for energizing said dipoles in parallel from a common source of high frequency carrier wave energy, said means comprising connections between said source and the inner ends of said coaxial conductors, the length of said coaxial conductors being such that a substantially 90 degree phase shift is effected between the voltages applied to said dipoles.

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