

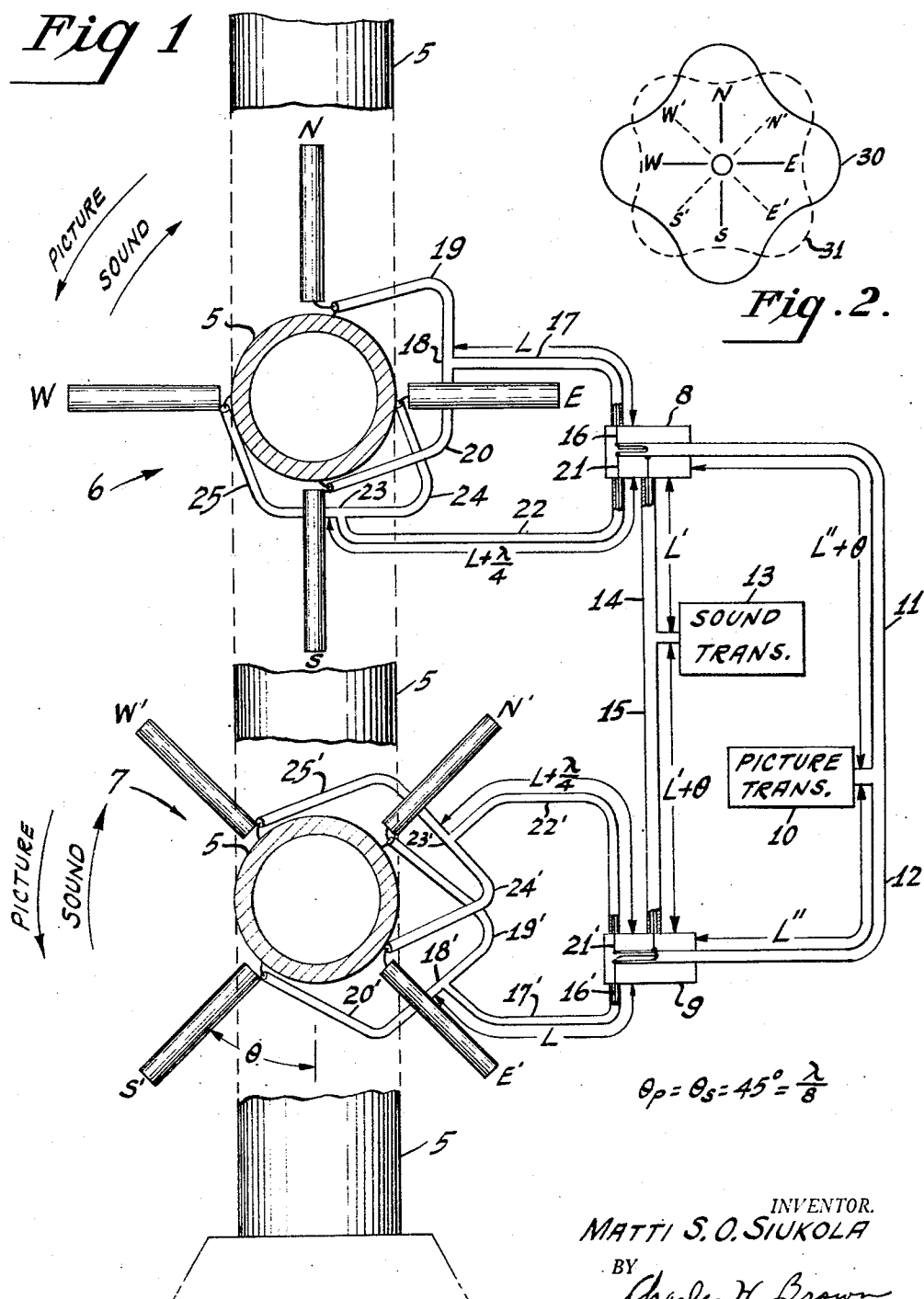
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TURNSTILE ANTENNA AND FEED SYSTEM THEREFOR

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TURNSTILE ANTENNA AND FEED SYSTEM THEREFOR

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The terminal fifteen years of the term of the patent to be granted has been disclaimed

9 Claims. (Cl. 343—797)

This invention relates to television broadcasting systems, and more particularly to a system including turnstile antennas for simultaneously broadcasting sound and picture signals so as to provide high antenna gain together with improved circularity in the radiated pattern.

A turnstile antenna consists of a pair of crossed dipoles which are fed in phase quadrature so that the phase of the energy radiated from the antenna rotates in a given direction at the carrier frequency rate. For a description of turnstile antennas reference is made to pages 424 et seq. of "Antennas" by John D. Kraus, McGraw Hill, 1950. Turnstile or quadrature-fed antennas are very useful in television broadcasting because the outputs of the picture transmitter and the sound transmitter may be applied thru a bridge diplexer to the turnstile antenna to radiate oppositely rotating picture and sound signals. Such a system is described in U. S. Patent 2,454,907 issued on Nov. 30, 1948 to G. H. Brown, entitled "Radio Frequency Network," and assigned to the assignee of this application. The contra-rotating picture and sound signals are radiated from the same turnstile antenna in such a way that the two signals are decoupled from each other, and cannot interfere one with the other.

In order to increase the gain of the antenna, a large number of turnstile antennas are mounted in spaced relation on a vertical pole or tower to provide an antenna array. The greater the number of turnstile antennas in the array, the greater the gain of the array.

At frequencies in the V. H. F. television band in the United States, turnstile antenna arrays have in practice been limited to arrays including no more than about twelve turnstile antennas. When more than twelve antennas are to be mounted on a vertical tower, at least the lower part of the tower must be of sufficiently large cross-section to provide the necessary mechanical strength. The required cross-sectional dimension to provide sufficient strength is too large, in terms of electrical wavelengths, to provide a circular radiation pattern in the horizontal plane. The larger the diameter of the tower, the more the radiation pattern resembles a four-leaf clover. When the cross-sectional dimension of the tower is very small, the radiation pattern approaches a perfect circle.

It is an object of this invention to provide a high gain turnstile antenna array utilizing more than twelve turnstile antennas and having a radiation pattern of improved circularity.

It is another object to provide an improved television broadcasting system for broadcasting picture and sound signals simultaneously from a single turnstile antenna array employing a multiplicity of turnstile antennas mounted on the same mast.

It is a further object to provide an improved turnstile antenna array having a large number of turnstile antennas and feed system therefor giving a higher antenna gain than has heretofore been possible while at the same time providing a substantially circular radiation pattern in the horizontal plane.

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In one aspect, the invention comprises an array of at least two turnstile antennas mounted so that the elements of one are oriented at an angle of 45 degrees with respect to the corresponding elements of the other. There is a bridge diplexer associated with each of the two antennas. The modulated radio frequency signal outputs of a picture transmitter and a sound transmitter are applied thru the diplexers to the respective antennas to cause the radiation of contra-rotating sound and picture fields. The sound signals radiated from both antennas rotate in synchronism and in phase, despite the angular relationship of the antennas, and similarly the picture signals radiated from both antennas rotate in synchronism and in phase but in the opposite direction, by reason of the construction whereby the couplings from the transmitters to the diplexers are adjusted in length to compensate electrically for the spacial relationship of the two antennas. A plurality of similarly-oriented turnstile antennas on the same tower may be fed from each one of the diplexers.

These and other objects and aspects of the invention will be apparent to those skilled in the art from the following more detailed description of the invention taken together with the appended drawings wherein:

Figure 1 is a diagrammatic representation partly in elevation and partly in cross-section of a television broadcasting system constructed according to the teachings of this invention; and

Figure 2 is a diagram of a radiation pattern which will be referred to in describing the operation of the invention.

In Figure 1, a vertical metallic conductive tower 5 is shown having two turnstile antennas mounted thereon at spaced points along the length of the tower. The turnstile antennas are shown as they would appear in cross-section thru the tower looking down. One turnstile antenna 6 includes a dipole N—S, and a second dipole W—E, the two dipoles being arranged at right angles with each other. The dipoles are mounted to extend radially from the tower 5 in insulated relationship therewith by any suitable construction (not shown). A similar turnstile antenna 7 having dipoles N'—S' and W'—E' is mounted on the pole 5 at a point vertically spaced from the antenna 6. It will be noted that the dipoles N'—S' and W'—E' of antenna 7 are oriented at an angle θ with respect to the dipoles N—S and W—E of antenna 6. In the present illustration, the angle θ is equal to 45 degrees.

A split balun bridge diplexer 8 is associated with antenna 6, and a split balun bridge diplexer 9 is similarly associated with antenna 7. Diplexers 8 and 9 may be of the type disclosed in Patent 2,454,907, supra. The output of a picture transmitter 10 is coupled over coaxial line 11 to an input of diplexer 8, and over a coaxial line 12 to an input of diplexer 9. The output of a sound transmitter 13 is applied over a coaxial line 14 to an input of diplexer 8, and over a coaxial line 15 to an input of diplexer 9. One output 16 of diplexer 8 is coupled thru a coaxial line 17 to a coaxial line T junction 18 from which a coaxial line 19 extends to the inner end of radiating element N, and from which a coaxial line 20 extends to the inner end of radiating element S. Lines 19 and 20 are of equal length.

The other output 21 of the diplexer 8 is connected thru coaxial line 22 to a coaxial line T junction 23 from which a coaxial line 24 extends to the inner end of radiator E, and from which a coaxial line 25 extends to the inner end of radiating element W. Lines 24 and 25 are of equal length and of the same length as lines 19 and 20. Line 17 has a length L, and line 22 has a length

$$L + \frac{\lambda}{4}$$

The antenna 7 is similarly coupled to the diplexer 9 thru elements bearing the same numerals as those of corresponding elements connected to antenna 6, but with prime

designations added. The only difference between the antenna 6 and 7 together with the respective couplings from the diplexers 8 and 9 is that the antenna 7 is rotated or skewed with respect to antenna 6 in a clockwise direction thru an angle θ which is equal to 45 degrees. The leads 16 and 21 constitute the two inputs to turnstile antenna 6, and the leads 16' and 21' constitute the two inputs to turnstile antenna 7.

In the operation of the invention, the sound signal from the transmitter 13 is applied over line 14 to the diplexer 8, and the sound signal appears in-phase on both of the output leads 16 and 21. The sound signal on lead 16 is applied over line 17 and line 19 to the antenna element N; and the sound signal on the lead 21 is applied over line 22 with an additional 90 degrees delay, and over line 24 to the antenna element E. Therefore, the antenna element E is energized 90 degrees later than the antenna element N with the result that the sound signal radiated by the antenna rotates in the clockwise direction. The antenna elements S and W are energized 180 degrees out-of-phase with elements N and E, respectively, and need not be considered in determining the direction of rotation of the radiated energy.

The picture signal from the transmitter 10 is applied over line 11 to the input of the diplexer 8, and outputs appear on the output leads 16 and 21 of the diplexer 8 with the picture signal on the lead 21 being 180 degrees delayed with respect to the picture signal on the lead 16. This results from the quarter wavelength slot in an intermediate conductor in the diplexer 8. The picture signal on the output lead 16 is applied over line 17 and line 19 to the antenna element N. The 180 degree delayed picture signal on output lead 21 of diplexer 8 is further delayed in line 22 by 90 degrees, and then is applied over line 24 to the antenna element E. Therefore, antenna element E is energized 270 degrees later than antenna element N or, stated another way, antenna element E is energized 90 degrees ahead of antenna element N. Consequently, the picture signal radiated by the antenna 6 rotates in the counter clockwise direction, being opposite to the direction in which the sound signal rotates.

The operation of the antenna 7 is the same as has been described in connection with the antenna 6. In both cases, the radiated picture signal rotates in a counter-clockwise direction and the radiated sound signal rotates in a clockwise direction.

Since the antennas 6 and 7 are relatively skewed or angularly related with each other, they cannot be fed from a single diplexer in the usual manner to produce an omni-directional pattern in the horizontal plane. It is necessary that the rotating picture signals in both antennas 6 and 7 rotate in exact synchronism and in phase with each other. Similarly, it is necessary that the rotating sound signals in both antennas 6 and 7 rotate in exact synchronism and in phase. The antenna 7 is skewed with relationship to the antenna 6 in order to improve the circularity of the pattern of the antenna array.

This important advantage is obtained by the use of two diplexers 8 and 9, and the manner of coupling the transmitters to the diplexers as will now be described.

The antenna 7 may be viewed as having been physically rotated in the clockwise direction thru an angle θ of 45 degrees with relation to the antenna 6. The physical relation of the antenna 7 is therefore displaced in the same direction as the radiated sound signal rotates, and in the opposite direction from which the radiated picture signal rotates. In order for the radiated sound and picture signals from antenna 7 to be in exactly the same phase as the radiated sound and picture signals, respectively, from antenna 6, the respective signals from the sound transmitter 13 and the picture transmitter 10 are phased in a compensating manner before application to the diplexers 8 and 9.

The line 11 from the output of the picture transmitter

10 to the diplexer 8 is longer than the line 12 from the picture transmitter to the diplexer 9 by an amount equal to the electrical angle θ . In the present example the angle θ is 45 degrees, the line 11 is an eighth wavelength longer than the line 12. Therefore, the picture signal applied to the antenna 6 is 45 degrees delayed relative to the picture signal applied to the antenna 7. Therefore with respect to the picture signal, any given antenna element in antenna 6 is energized 45 degrees later than the corresponding element in antenna 7. Bearing in mind that the direction of rotation of the picture signal is counter-clockwise, the result of the electrical delay in combination with the relative physical orientation of the antennas results in perfect synchronism between rotating picture signals radiated from antennas 6 and 7.

The line 15 from the sound transmitter 13 to the diplexer 9 is an eighth wavelength longer than the line 14 from the sound transmitter to the diplexer 8. Therefore with respect to the sound signal, any given antenna element in antenna 7 is energized 45 degrees later than the corresponding element in antenna 6. Since the rotation of the sound signal is in a clockwise direction, the electrical delay in the line 15 insures that the radiated sound signals from antennas 6 and 7 are always in exact synchronism and in phase with each other.

Figure 2 shows the radiation patterns of antennas 6 and 7 in the horizontal plane as viewed from above, with the tower 5 supporting solid line dipoles N—S and W—E, and also supporting dotted line dipoles N'—S' and W'—E'. The solid line dipoles produce the solid line radiation pattern 30, and the dotted line dipoles produce the dotted line radiation pattern 31. The patterns 30 and 31 result when the cross-sectional diameter of the tower 5 is relatively large as may be required for structural strength in an antenna array including a large number of antennas. It is apparent that the two patterns 30 and 31 add up to provide a nearly circular resultant pattern. In practice, an antenna array will, of course, include a large number of antennas similar to antennas 6 and 7. Additional antennas oriented like antenna 6 may be fed from the junction points 18 and 23 by replacing the T junction with a coaxial line junction having additional branches. Similarly, additional antennas oriented like antenna 7 may be fed from the junction points 18' and 23'.

Although two sets of turnstile antennas displaced angularly by $\theta=45$ degrees, as explained above, provide a better circularity than is required for all practical purposes in television broadcasting, still better circularities can be obtained. This can be done by having more than two sets of turnstile antennas, each one at its specified angular setting θ_n from the first set. The feed system principle above can be extended to apply by having as many diplexers as there are different angular positions of turnstile antennas and by providing proper phasing lengths between the transmitters and diplexers to obtain radiated field synchronism in phase for both transmitted signals. For example, there may be three sets of antennas equally spaced by the angle $\theta=30$ degrees and fed from two transmitters thru three diplexers.

It is apparent that according to this invention it is possible to construct antenna arrays having a large number of antennas so oriented and fed as to provide a substantially circular radiation pattern in the horizontal plane even though the supporting tower is required to have a large cross-sectional dimension for structural reasons.

What is claimed is:

1. A system for transmitting two radio frequency signals, comprising, an antenna array including at least first and second turnstile antennas mounted with a relative angular relation θ , first and second diplexers having outputs coupled to said first and second antennas, respectively, to provide quadrature feeds, means to apply a first signal to both of said diplexers with a phase difference θ ,

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and means to apply a second signal to both of said diplexers with a phase difference θ .

2. A system in accordance with claim 1 wherein said turnstile antennas are mounted one above the other on the same supporting mast on the same axis.

3. A system for transmitting two radio frequency signals, comprising, an antenna array including at least first and second turnstile antennas mounted with a relative angular relation of 45 degrees, first and second diplexers having outputs coupled to respective ones of said first and second antennas to provide quadrature feeds, means to apply a first signal to both of said diplexers with a phase difference of 45 degrees, and means to apply a second signal to both of said diplexers with a phase difference of 45 degrees.

4. A system for transmitting two radio frequency signals, comprising, an antenna array including at least first and second turnstile antennas mounted with a relative angular relation θ , first and second split balun bridge diplexers having outputs coupled to respective ones of said first and second antennas to provide quadrature feeds, means to apply a first signal to both of said diplexers with a phase difference θ , and means to apply a second signal to both of said diplexers with a phase difference θ .

5. A system for transmitting two signals, comprising, an antenna array including at least first and second turnstile antennas mounted with a relative angular relation θ , first and second diplexers having outputs coupled to said first and second antennas, respectively, to provide quadrature feeds, first and second transmitters, means to couple the output of said first transmitter to said diplexers over paths differing in electrical length by the angle θ , and means to couple the output of said second transmitter to said diplexers over paths differing in electrical length by the angle θ .

6. Means to apply the outputs of two transmitters to an antenna array of at least two turnstile antennas each having two inputs, said antennas being physically related with reference to each other by the angle θ , comprising two diplexers each having two outputs coupled to the two inputs of respective antennas, means to couple the output of one of said transmitters to both of said diplexers over paths differing in length to provide a phase difference θ , and means to couple the output of the other of said trans-

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mitters to both of said diplexers over paths differing in length to provide a phase difference θ .

7. In a television broadcasting system, means to apply the outputs of picture and sound transmitters to an array of at least two turnstile antennas each having two inputs to receive quadrature signals whereby to radiate contra-rotating picture and sound signals, said antennas being physically rotated with reference to each other thru the angle θ , comprising, two diplexers each having two outputs coupled to the two inputs of respective antennas, means to apply the output of said picture transmitter to both of said diplexers over paths differing in length to provide a phase difference θ , and means to couple the output of said sound transmitter to both of said diplexers over paths differing in length to provide a phase difference θ .

8. A broadcasting system comprising, first and second diplexers, first and second sets of four orthogonally related antenna elements, said sets having corresponding elements mounted at θ degrees with each other, quadrature feed means coupling outputs of said diplexers to respective sets of antenna elements, a first signal source, means to couple the output of said source to inputs of both of said diplexers with a phase difference θ , a second signal source, and means to couple the output of said second source to inputs of both of said diplexers with a phase difference θ .

9. A broadcasting system comprising, first and second diplexers, first and second sets of four orthogonally related antenna elements, said sets having corresponding elements mounted at 45 degrees with each other, quadrature feed means coupling outputs of said diplexers to respective sets of antenna elements, a first signal source, means to couple the output of said source to inputs of both of said diplexers with a phase difference of 45 degrees, a second signal source, and means to couple the output of said second source to inputs of both of said diplexers with a phase difference of 45 degrees.

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