

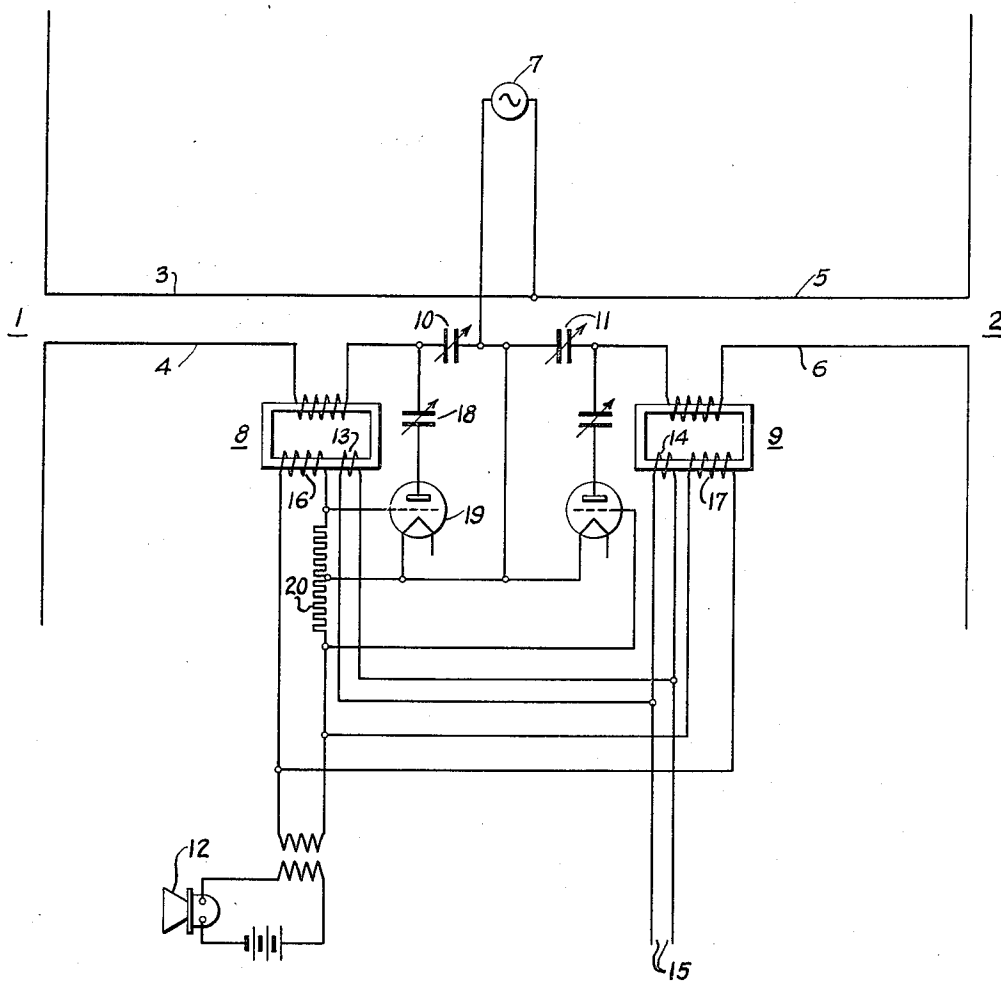
Oct. 12, 1937.

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2,095,774

METHOD OF MODULATION FOR RADIO TRANSMISSION

Filed May 4, 1934



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2,095,774

METHOD OF MODULATION FOR RADIO
TRANSMISSION

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Application May 4, 1934, Serial No. 723,881

4 Claims. (Cl. 250—17)

My invention relates to systems for propagat-
ing electromagnetic waves, and particularly to
systems for radiating signals and programs of
music or speech by means of electromagnetic
waves in the ether.

One object of my invention is to provide a
system in which the shape of the field pattern
about an antenna is varied from instant to in-
stant while the total power radiated from the
antenna may remain constant. In all or sub-
stantially all directions from the antenna the
wave is modulated but by making the phase of
the modulation different in different directions
there may be little or no modulation of the total
energy radiated from the antenna, so that the
oscillator may work to full capacity at all times.
In the system in use in the prior art the field
pattern changes in size but not in shape with
modulation. In the system of my invention the
field pattern changes in shape but not in size
with modulation.

One object of my invention is to provide a
system in which electromagnetic waves will have
one intensity in one direction at any particular
instant and a different intensity in another direc-
tion, and in which the direction of maximum
intensity may be made to change from one such
direction to another periodically.

Another object of my invention is to provide
a broadcasting system in which the maximum
intensity of the radiated electromagnetic wave
varies in direction periodically, so that although
any given direction is traversed at one time or
another at maximum intensity, this maximum
intensity does not occur in every direction at the
same instant of time. For many purposes the
requirement for satisfactory operation is that the
maximum instantaneous intensity of the broad-
cast wave must not fall below a certain value;
and this requirement can be fulfilled by my sys-
tem with a lower expenditure of total power than
with arrangements in which the maximum in-
tensity of the electromagnetic field is the same
in all directions.

Another object of my invention is to provide
a broadcasting system in which a given maximum
instantaneous intensity of magnetic field is at-
tained, regardless of direction, but the instan-
taneous power output of the transmitting antenna
system is reduced to a value less than that in
conventional broadcasting systems of the prior
art.

Other objects of my invention will become
apparent upon reading the following description
taken in connection with the drawing in which

the single figure is a diagrammatic representa-
tion of a broadcasting system embodying the
principles of my invention.

In broadcasting speech, music or telegraph
signals the receiving instrument in general re-
sponds to periodic forces, usually of audible fre-
quency, and the loudness of the indication or
response is, in general, proportional to the maxi-
mum instantaneous energy of the electromag-
netic field at the receiving system. Where receiv-
ing systems may be located in any direction in
the area surrounding the broadcasting system,
this requires that maximum intensity of the
electromagnetic field should be substantially the
same regardless of direction. In ordinary broad-
casting systems this condition is met by trans-
mitting systems in which the electromagnetic
field varies, in accordance with the signal or
sound being broadcast, periodically in respect to
time but is fairly uniform and invariable at any
particular instant as respects direction about the
broadcasting station. In contrast to the fore-
going I provide a transmitting system which pro-
duces an electromagnetic field which varies in
time periodically at the signal frequency as re-
spect to direction relative to the transmitting sta-
tion. It can be shown, as regards such an elec-
tromagnetic field, that while the maximum in-
stantaneous intensity of the electromagnetic field
in any particular direction is the same as the
maximum intensity in any other direction, and
accordingly that the loudness of the response of
any receiving instrument will be the same re-
gardless of its direction, the total power which it
is necessary for the broadcasting system to radi-
ate may be, even where the variation of field
intensity with time at every receiving instrument
is sinusoidal, as low as 50 percent of the power
output of a broadcasting system of the conven-
tional type in which the electromagnetic field
varies periodically with respect to time and not
with respect to direction; and when this sinu-
soidal limitation does not exist, may be for less
than 50 percent.

In general, a transmitter of the above described
type can be produced by arranging two electro-
magnetic radiators or antennae separated from
each in space by a substantial fraction of a wave
length, supplying them respectively with periodic
electric currents of proper frequency for radia-
tion, and producing periodic variations of the
phase of these currents relative to each other at
a frequency corresponding to the sound or a
signal which it is desired to transmit.

Referring particularly to the central figure of

the drawing, 1 and 2 are antennae, preferably of the duplex or balanced type and of the same size, which are spaced apart from each other, this spacing being preferably although not necessarily equal to a quarter of the wave length of the radio frequency current supplied to these antennae. The two antennae 1 and 2 are supplied with current of the same frequency from any desired source or sources; this may conveniently be done by supplying them through lines 3-4, 5-6 leading from the single source of radio frequency current source 7. Certain of the lines 3-4, 5-6 may be provided with variable impedance elements 8-9, 10-11 by means of which the speed of propagation of alternating current waves from the source 7 to the antennae 1 and 2 may be adjusted at will. Since the phase of the radio frequency current in the antenna 1 relative to the phase of the radio frequency current in the antenna 2 will depend upon the speed of propagation along the respective lines 3-4, 5-6, this relative phase relationship may be adjusted to any desired value at any instant by making the value of the impedance 8-9 differ from the value of the impedance 10-11 by a suitable amount.

When the speed of propagation of the electric current over the line 3-4, 5-6 is greater than the speed of propagation of the electric current lines 5-6, 9-11, the currents in the antenna 1 will lead in phase the currents in the antenna 2; and vice versa. As an example, suppose the radio frequency current in the two antennae are equal in R. M. S. value and that this lead in phase of the currents in antenna 1 over the currents in antenna 2 is 90 electrical degrees. An electromagnetic wave radiated from antenna 2 and travelling in space in the direction of antenna 1 will reach the latter after an interval equal to

$$\frac{x}{Ia}$$

where x is the distance between the antennae 1-2, I is the wave length of the radiated wave, and a is the time period of a radio frequency cycle. This means that the phase of this electromagnetic wave at antenna 1 is 360

$$\frac{x}{I}$$

electrical degrees behind the phase of the current in antenna 2. If the distance between antennae 1 and 2 is a quarter wave length, this radiated wave at antenna 1 is 90 electrical degrees behind the phase of the current in antenna 2. If, as in this example under discussion, the phase in the current of antenna 2 is 90° behind the phase of the current in antenna 1, the electromagnetic wave emanating from antenna 2 is $(90^\circ + 90^\circ) = 180$ electrical degrees behind the wave radiated from antenna 1. At all points to the left of antenna 1 in the drawing on the imaginary line connecting it with antenna 2, the two radiated waves just combine their energies 180° out of phase; i. e. they substantially neutralize each other, and the electromagnetic field intensity is zero.

In contrast to this, consider the wave radiated from antenna 1 travelling toward antenna 2. In accordance with the foregoing discussion, the phase at antenna 2 will be 90 electrical degrees behind the phase of the current in antenna 1; but in accordance with our example the current in the antenna 1 is 90 electrical degrees ahead of the current in the antenna 2 and accordingly

the phase difference between the wave radiated from antenna 1 and that radiated from antenna 2 at points to the right of antenna 2 in the drawing is zero; i. e., the energies of the two waves are added to each other, with a resultant equal to substantially twice that of either one alone.

Summarizing the foregoing, radio frequency currents bearing the phase relation just described in the respective antennae 1 and 2 produce an electromagnetic field having a maximum intensity twice that due to either antennae alone at points to the right of antenna 2, and produce substantially zero electromagnetic intensity at points to the left of antenna 1.

Now suppose that the respective phases of the currents of antennae 1 and 2 relative to each other are altered in any way; for example, by increasing the impedances 8-10 and decreasing the impedances 9-11 to such a degree that the radio frequency current in antenna 1 lags behind the radio frequency current in antenna 2 by 90°, their R. M. S. value still being equal however. Considerations similar to those just discussed will show that the electromagnetic field to the left of antenna 1 in the drawing is double the intensity of the field which would be due to antenna 1 alone; and at points to the right of antenna 2 the electromagnetic field intensity is substantially zero.

If the respective impedances 8-10 and 9-11 are varied periodically at the audio frequency of the sound to be transmitted, as by means of the microphone 12, an electromagnetic field, having an intensity double that due to either antenna alone will be displaced at the same periodicity and will sweep around in space about the antenna system 1-2. The intensity of the response of any receiving instrument in the space swept over, being dependent upon the maximum instantaneous value of this electromagnetic field, will accordingly be proportional to twice the intensity of the field emanating from each antenna alone.

Where it is desired that the maximum intensity of the field, referred to in the preceding paragraph as sweeping around in space, shall be of constant magnitude, and that the field energy shall not be wasted partly in an ancillary beam of lower intensity than the main field, the range of variation of the phases of the currents in the respective antennae should not extend beyond plus or minus 90 electrical degrees from coincidence with each other.

It may be shown by considerations similar to those just applied that for antennae spaced a distance x apart traversed by currents differing in phase by g electrical degrees the two antenna radiations are

$$\left(360 \frac{x}{I} + g\right)$$

electrical degrees apart in phase beyond one antenna and

$$\left(360 \frac{x}{I} - g\right)$$

electrical degrees apart beyond the other.

If, instead of antennae 1-2, a single antenna were used, it would produce a maximum intensity of electromagnetic field equal to twice that of a single one of my antennae (i. e. it would produce the same maximum field intensity as was just described above) provided it carried twice the radio frequency current supplied to the latter. In accordance with well known principles of electromagnetic fields, the rate of energy radiation from an antenna of given dimension is pro-

portional to the square of radio frequency current. The power required for this single antenna would accordingly be four times as great as that supplied to each antenna in my system, and correspondingly be twice as great as the combined power required for my antennae 1 and 2. It is accordingly seen that my system produces the same intensity of response in a distant receiver as a conventional signal antenna of the prior art with only half the power input required by the latter.

In order to permit the microphone 12 to control and periodically vary the impedance of reactors 8—9, these are provided with similar windings 13—14 supplied from a source of direct current 15. These reactor cores 3 and 9, also respectively provided with windings 16—17, are traversed by periodic current controlled by microphone 12; the winding 16 being arranged to magnetically oppose its associated winding 13 at the same time that the winding 17 magnetically assists its associated winding 14. With such an arrangement, the reactance of reactor 8 will be a maximum when the reactance of reactor 9 is a minimum, and this relationship will be reversed when the direction of the periodic current set up in these windings 16 and 17 by microphone 12 reverses. In order that the current in each antenna shall not decrease when the reactance 8 increases, as is desirable though not essential for certain fields of use, I may provide a condenser 18 connected through a grid controlled high vacuum or gas-filled tube 19, in shunt to condenser 10; and control the grid potential of the tube 19 so that its reactance to the radio frequency decreases to compensate the increase of reactance 8 and vice versa. This may be done by connecting the cathode of tube 19 to the mid-point of a resistor 20 in series with winding 16, and the grid of tube 19 to that end of this resistor 20 which is positive at the time winding 16 magnetically aids winding 13. A similar arrangement of a condenser and tube should shunt condenser 11, except that the grid of the latter tube should be connected to the other end of resistor 20.

The foregoing arrangement for periodically and oppositely varying the impedances 8, 9, 10, and 11 is merely illustrative, and other known arrangements for varying impedances or for equalizing the antenna currents may be substituted therefor. For example, condensers 10—11 might be arranged to be altered in capacity in opposite senses by a microphone diaphragm governed by microphone 12; for example, condensers 10, 11 might be the capacity between end plates on opposite sides of a diaphragm displaced in accordance with the vibrations of the diaphragm of microphone 12. Other types of variable condenser such as that illustrated in C. T. Allcutt Patent No. 1,716,161 might also be controlled by the voice frequency currents such as those generated by microphone 12; and in general substantially any known variable reactance or condenser capable of being made responsive at audio frequencies might be employed for controlling the rate of propagation in the lines 3—4, 5—6.

I have described a simple form of antenna arrangement adapted to make use of the principles of my invention; but it will be understood that this is only illustrative and that other antenna arrays capable of concentrating electromagnetic radiation in a desired direction, together with arrangements for periodically orientating this direction, may be employed and may be desirable where greater elaboration is commercially justified. Likewise it should be recognized that the particular phase relationships and space displacements of the antennae described in the foregoing example are illustrative only, and my invention is not limited thereto by such illustrations.

In accordance with the patent statutes I have described one particular embodiment of the principles of my invention, but this is intended to be illustrative only and I accordingly desire that the following claims be given the broadest interpretation of which they are susceptible in view of the limitations imposed by the prior art.

I claim as my invention:

1. In combination, an antenna and means for supplying it with radio frequency current, a second antenna supplied with current of the same frequency and distant from said first antenna by a quarter wave length of said radio frequency current, and means for progressively varying the phase of the current in said first antenna from 90 electrical degrees ahead to 90 electrical degrees behind that of the current in said second antenna.

2. In combination, an antenna and means for supplying it with radio frequency current, a second antenna supplied with current of the same frequency and distant from said first antenna by a quarter wave length of said current, and means for progressively varying the phase of the current in said first antenna relative to the current in said second antenna in accordance with a signal to be transmitted, whereby a beam of radiation is progressively swept around in space through approximately 360 degrees.

3. In combination, an antenna and means for supplying it with radio frequency current, a second antenna supplied with current of the same frequency and distant from said first antenna by a quarter wave length of said radio frequency current, and means for progressively varying the phase of the current in said first antenna with a periodicity equal to a signal frequency from 90 degrees ahead to 90 electrical degrees behind that of the current in the second antenna.

4. In combination, an antenna and means for supplying it with radio frequency current, a second antenna supplied with current of the same frequency and distant from said first antenna by a quarter wave length of said current, and means for progressively varying the phase of the current in said first antenna relative to the current in said second antenna periodically at an audio frequency of the signal to be transmitted, whereby a beam of radiation is progressively swept around in space through approximately 360 degrees.

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