Sept. 21, 1937. W. M. HAHNEMANN 2,093,886

ANTENNA STRUCTURE

Original Filed Aug. 13, 1932 5 Sheets-Sheet 1

Fig. 1

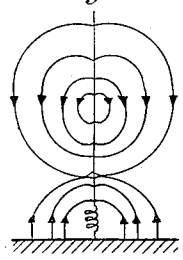


Fig. 2

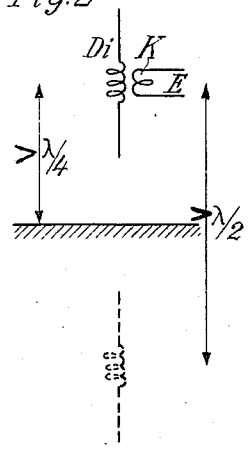
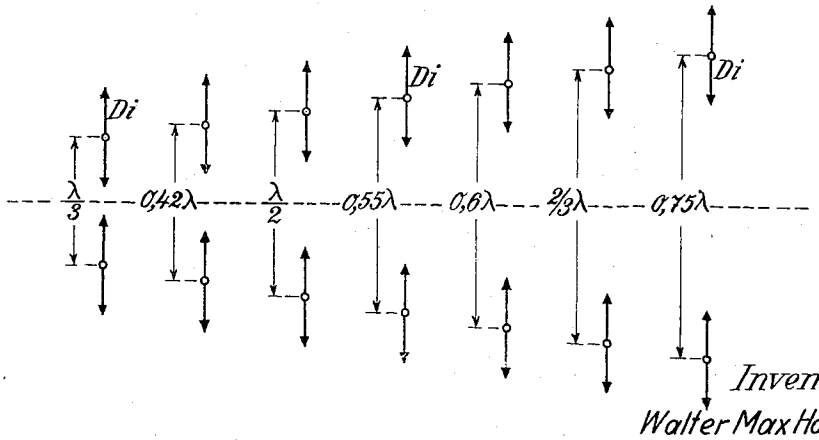


Fig. 3



Inventor:
Walter Max Hahnemann
by R C Hopgood
Attorney.

Sept. 21, 1937. W. M. HAHNEMANN 2,093,886

ANTENNA STRUCTURE

Original Filed Aug. 13, 1932 5 Sheets-Sheet 2

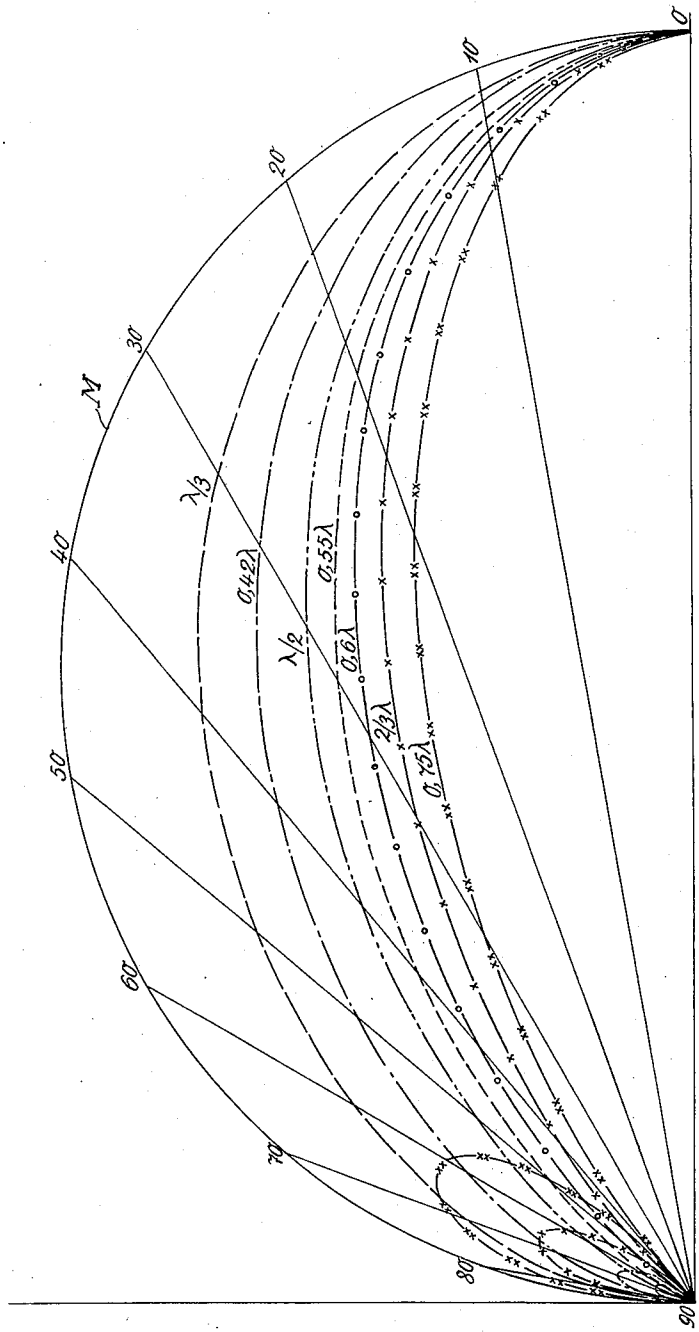


Fig. 4

Inventor:
Walter Max Hahnemann
by R. C. Hopgood
Attorney.

Sept. 21, 1937. W. M. HAHNEMANN 2,093,886

ANTENNA STRUCTURE

Original Filed Aug. 13, 1932. 5 Sheets-Sheet 3

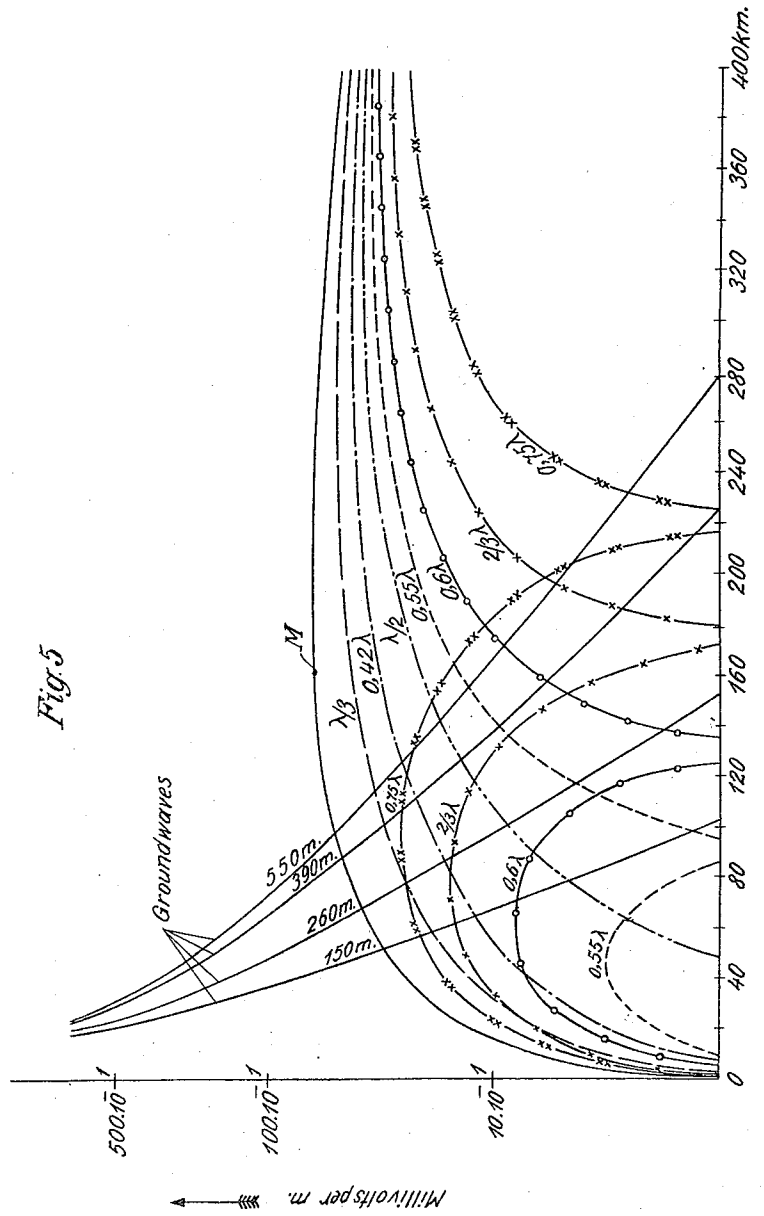


Fig. 5

Inventor:
Walter Max Hahnemann
by R. C. Hopgood
Attorney.

Sept. 21, 1937. W. M. HAHNEMANN 2,093,886

ANTENNA STRUCTURE

Original Filed Aug. 13, 1932 5 Sheets-Sheet 4

Fig. 6

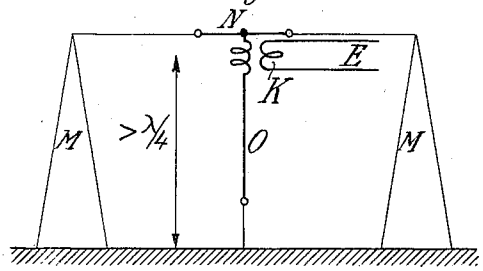
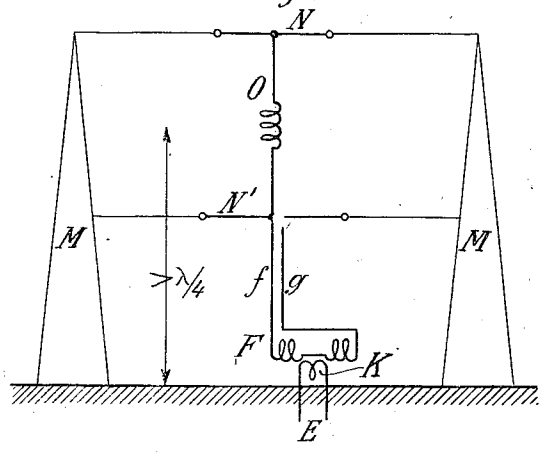


Fig. 7



Inventor:
Walter Max Hahnemann
by R. C. Hopgood
Attorney.

Sept. 21, 1937. W. M. HAHNEMANN 2,093,886

ANTENNA STRUCTURE

Original Filed Aug. 13, 1932 5 Sheets-Sheet 5

Fig. 8

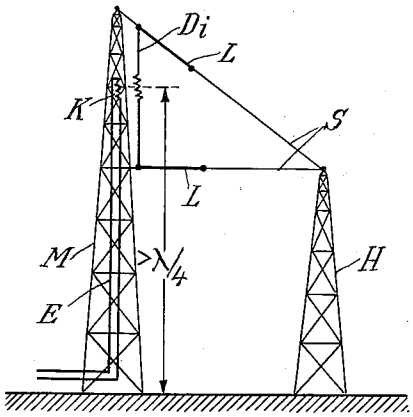


Fig. 9

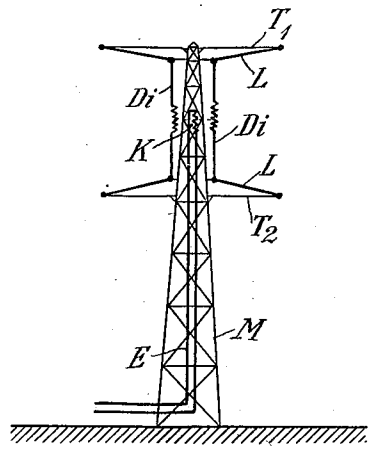
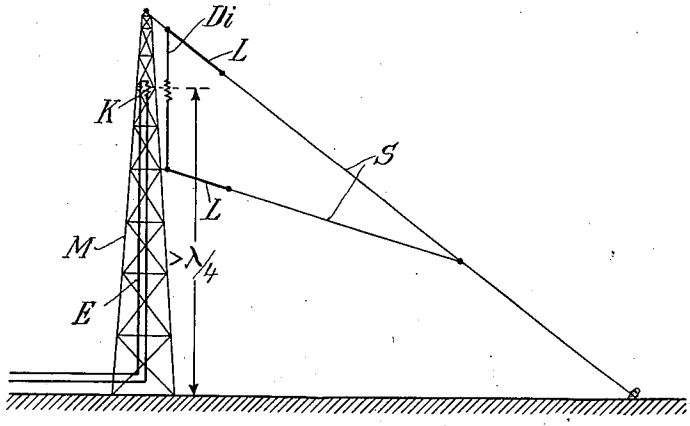


Fig. 8a



Inventor:
Walter Max Hahnemann
by R. C. Hapgood
Attorney.

Patented Sept. 21, 1937

2,093,886

UNITED STATES PATENT OFFICE

2,093,886

ANTENNA STRUCTURE

Walter Max Hahnemann, Berlin-Marienfelde, Germany, assignor to C. Lorenz Aktiengesellschaft, Berlin-Tempelhof, Germany, a company

Original application August 13, 1932, Serial No. 628,674. Divided and this application July 27, 1935, Serial No. 33,467. In Germany October 7, 1931

5 Claims. (Cl. 250—33)

This application is a divisional from the copending application Serial No. 628,674, filed August 13, 1932, for Antenna structures, and is intended for use with broadcast transmitters.

In order to avoid local fading phenomena in broadcast transmitters, i. e. to remove the field of fading as far as possible from the transmitter, antenna combinations have been suggested which produce the least possible space radiation and radiate as much energy as possible in the form of direct or ground radiation. Fading phenomena then only occur in an area in which the ground ray has lower intensity than the reflected space ray, i. e. at a substantial distance from the transmitter. To such end it has been proposed to extend a so-called Marconi antenna, i. e. a grounded aerial structure operating at about $\lambda/4$, vertically upward to such an extent that if possible it has a height of $\lambda/2$. λ denotes the operative wavelength.

Such arrangements operating at $\lambda/2$ have not had the desired result. This is obviously due to the fact that at the lower end of the antenna, that is to say in the vicinity of the ground, disturbing fields occur, which may be designated as reversal fields. These disturbing fields cause an oblique upward radiation which does not enable local fading to be overcome in a satisfying manner.

In accordance with the invention the antenna consists of a vertical dipole whose center of oscillation is somewhat more than a quarter of a wavelength above the earth's surface so that a radiation diagram results in which the ground radiation is predominating. The distance of the center of oscillation from the ground is so chosen that the secondary maxima, if any, are below a limit adapted to impair the reception. The magnitude of the secondary maxima depends upon the operative wavelength.

In the accompanying drawings Fig. 1 shows the occurrence of disturbing fields in the vicinity of the ground.

Some embodiments of the invention are shown in Figs. 2 to 9 of the accompanying drawings.

Fig. 2 is an elevation of one of these embodiments. Figs. 3, 4 and 5 are diagrams relating to the mode of action of the novel arrangement, Figs. 6, 7, 8, 8*a* and 9 are elevations of still other embodiments.

In the simplest case, which is shown in Fig. 2, a vertical antenna Di, vibrating as a dipole, is arranged over the electrically conducting layer of earth, preferably at such a height, that the center of oscillation is somewhat more than $\lambda/4$ from the ground.

With such a distance a very sharp ground radiation occurs in the case of a single dipole without harmful space radiations arising. E designates the transmission line from which the dipole is fed over a coupling device K.

The action of such a dipole antenna is explained hereafter with reference to the diagrams shown in Figs. 4 and 5. It will especially be stated of what kind is the influence due to the distance between the center of oscillation and the earth. By "earth" is always meant the electrically active earth layer.

The radiation diagram may be calculated in the well known manner by resolving the radiation into radiation due to the dipole itself and radiation from an image of the dipole in the earth. The image is shown in dotted lines in Fig. 2. If the distance between the centers of oscillation of the dipole Di (Fig. 2) and the image dipole is chosen a little greater than $\lambda/2$, which corresponds to a distance somewhat greater than $\lambda/4$ above earth, then the ground radiation is a maximum while there is no disturbing space radiation. By increasing that distance still more the ground radiation is further increasing, but secondary maxima then occur which entail a disturbing space radiation and thus will impair the reception in the vicinity of the transmitter. When this distance is reduced a radiation diagram is obtained which corresponds more to the well known Marconi radiation diagram.

Fig. 3 shows dipoles arranged at progressively increasing distances from the earth. Here again the distance relationships are explained by means of the images of the dipoles. In Fig. 4 the radiation diagrams for the distances $\lambda/3$ to 0.75λ are illustrated.

In Fig. 4 the Marconi curve is designated M. The values $\lambda/3$ to 0.75λ, indicated in Fig. 4, show to which of the dipoles illustrated in Fig. 5 each radiation diagram, i. e. each of the curves inside the curve M relate. It will be seen that the distance $\lambda/3$ gives a radiation diagram which is substantially flatter than the Marconi curve M but has not yet the greatest flatness. Beyond $\lambda/2$, small secondary maxima occur. It will however be seen from the curve that with a value between $\lambda/2$ and $2/3\lambda$ the secondary maxima are still so small that disturbances in the vicinity of the transmitter, i. e. local fading phenomena, are not likely to occur. The secondary maxima are shown on the left in Fig. 4.

The decrease of local fading also depends upon

the wavelengths employed. In accordance with the wavelength the formation of the secondary maxima will be different. Therefore in Fig. 5 the field intensity curves of the space and ground radiations are shown for the different cases to which Figs. 3 and 4 relate. From the points of intersection of the field intensity curves it can be inferred from what distances fading phenomena are to be expected. It will be seen that the conditions depend upon the wavelengths employed. Hence it follows that the fading phenomena occur as soon as the space radiation happens to be in preponderance of the ground radiation. Therefore, in determining the distance between the center of oscillation and the earth it should be considered that this question also depends upon the distance within which the reception is to be free of fading. If for instance a wavelength of 260 meters is used, then with a distance of say $2/3\lambda$ disturbances result already at a distance of about 90 km. from the transmitter, since at this place the curve for $2/3\lambda$ intersects the curve of the ground wave of 260 meters. If however a wavelength of 390 meters is employed the curves only intersect at a distance of 180 km. from the transmitter.

In order correctly to keep to these relationships also in practice, an earth must be employed which is best adapted for the purpose and is of a constant character. To such end earth structures may be used which are composed of several small earths. The diameter of the earth structure should however be as great as possible and at least $\lambda/2$.

The dipoles need not be $\lambda/2$, but in order to save mast height, may be chosen substantially smaller and tuned by additional means of elongation. In order not to impair the radiation efficiency too much, however, unless special steps are taken, the reduction of the length must be kept within certain limits. In order to increase the efficiency it is therefore adapted for the purpose to arrange at the ends of the dipole short horizontal conductors which aid in the current distribution to the oscillating members.

The energization of the dipole can be effected either by current coupling, for instance by conveying the energy to them at the center by field action, or potential couplings can be used which permit energization at the ends of the antenna. Such kinds of energization are shown in Figs. 6 and 7.

Fig. 6 shows an arrangement with the least possible mast height. Between two masts M an antenna is suspended which consists of a horizontal member N and a member O suspended perpendicular thereto. The energization takes place at the oscillatory center through current coupling and at a height greater than $\lambda/4$ above the earth. The antenna N, O is tuned as a dipole vibrating at $\lambda/2$. The masts M need only be slightly higher than the distance of the center of oscillation from the earth's surface, so that for the relatively long waves of the broadcasting range mast heights are obtained which do not exceed the height of the ordinary antennae.

In the device according to Fig. 7 two masts M carry a dipole consisting of two horizontal members N, N' and a vertical member O connected therewith. The transmission line E is coupled over a lead F with the dipole. This lead has two parallel wires *f*, *g*. The wire *f* is conductively connected with the dipole. The wire *g* ends free. The dipole has a potential loop at the point where wire *f* is connected to the member N'. The connection of the lead F to this point is therefore called a potential coupling. This is the so-called Zeppelin energization, the operation of which is based on the fact that the currents in *f* are co-phasal to the currents in *g*, so that the feeder F does not radiate, radiation being restricted to the dipole N, ON'. It may also be arranged that co-phasal currents which may be formed are cancelled in their effect. Coupling coils which are closely coupled together and are wound in appropriate directions may serve this purpose.

In the structure shown in Fig. 8 the dipole D*i* is so suspended on the mast M that the center of oscillation of the dipole is more than $\lambda/4$ above the earth. In order to save mast height the length of the dipole is reduced with respect to $\lambda/2$. To provide for the proper operation of the dipole there are arranged at its ends conducting members L which are as far as possible or approximately horizontally arranged. These members are guyed from the mast M to an auxiliary mast H by ropes S. The auxiliary mast H can be dispensed with if the upper rope S is anchored to the ground and the lower rope guyed to it, as shown in Fig. 8*a*. The feeding of the dipole takes place by a transmission line E which is erected in the mast M and coupled to the dipole by a coil K.

In the device according to Fig. 9 the mast M has cross members T1, T2 between which are arranged dipoles D*i*. These are fixed to the cross pieces T1, T2 by conducting members L which also act as bracing wires. The dipoles for example may be arranged in fours around the mast M and are jointly energized from the transmission line E over the coupling line K. As shown in the drawings the dipoles are spaced from the mast a distance small compared to the wave-length at which the dipoles are adapted to operate, this arrangement resulting in a reduction of the field to which the mast is subjected during operation of the antenna structure.

By the arrangement according to Fig. 9 a ground radiation is obtained which is of the same intensity on all sides.

What is claimed is:

1. An antenna structure comprising a plurality of vertically disposed dipoles arranged about and supported by a mast with the centers of oscillation of said dipoles positioned more than a quarter wavelength above the earth's surface but sufficiently close thereto to produce substantial ground radiation and means for jointly energizing said dipoles.

2. An antenna structure comprising a plurality of vertically disposed dipoles arranged in fours about and supported by a mast with the centers of oscillation of said dipoles positioned more than a quarter wavelength above the earth's surface but sufficiently close thereto to produce substantial ground radiation and means for jointly energizing said dipoles.

3. An antenna structure comprising a plurality of vertically disposed dipoles disposed around and supported by a mast, coupling means in each of said dipoles, and a feed line coupled to said dipoles by said coupling means, said dipoles being spaced from said mast a distance small compared to the wavelength at which said dipoles are adapted to operate.

4. An antenna structure comprising a pair of vertically disposed dipoles positioned at opposite sides of a supporting mast and spaced therefrom a distance small compared to the wavelength at

which said dipoles are adapted to operate, coupling means in each of said dipoles and a feed line coupled to said dipoles by said coupling means.

5. An antenna structure comprising a mast, a plurality of vertically disposed dipoles arranged in fours around said mast and spaced therefrom a distance small compared to the wavelength at which said dipoles are adapted to operate, coupling means in each of said dipoles and a feed line coupled to said dipoles by said coupling means.

WALTER MAX HAHNEMANN.