

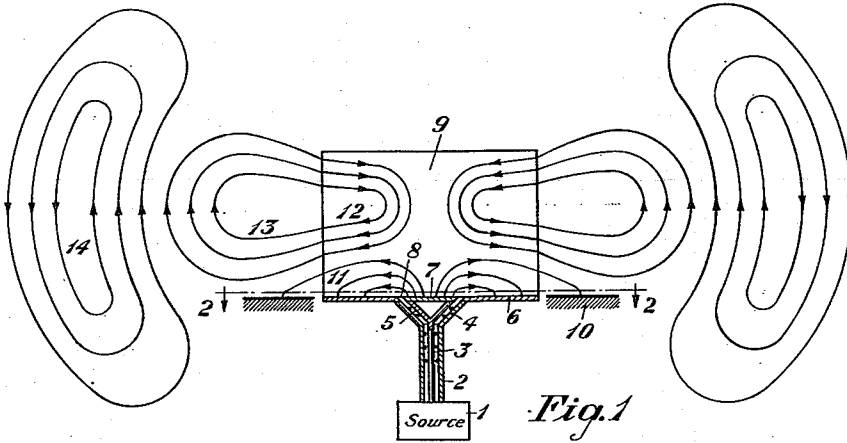
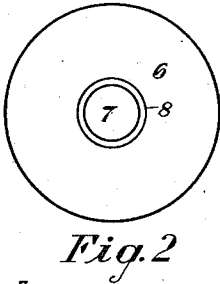
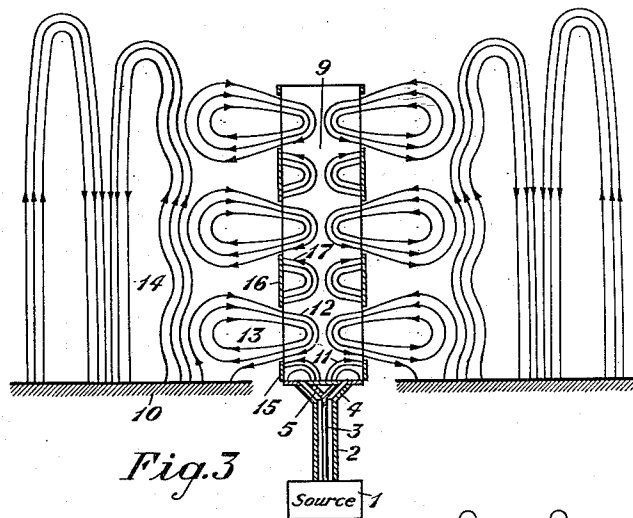
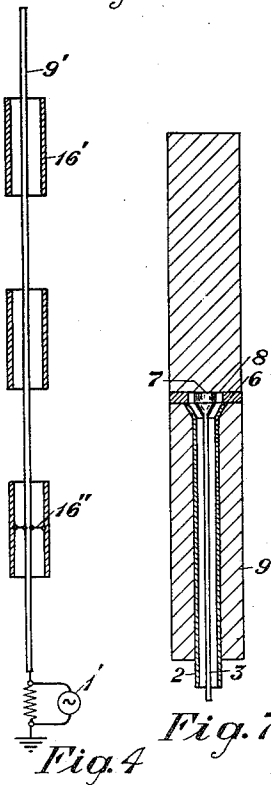
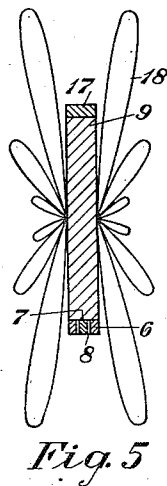
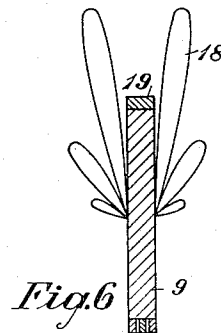
July 9, 1940.

G. C. SOUTHWORTH
SHORT WAVE RADIO SYSTEM

2,206,923

Filed Sept. 12, 1934

6 Sheets-Sheet 1



INVENTOR
G.C. Southworth
BY *Carl A. Richmond*
ATTORNEY

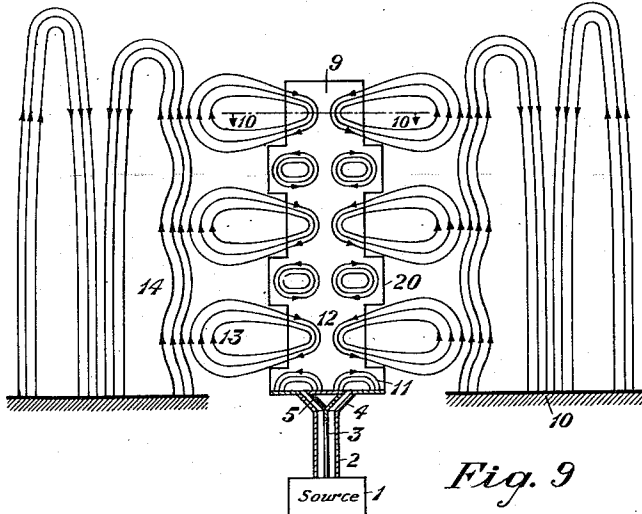
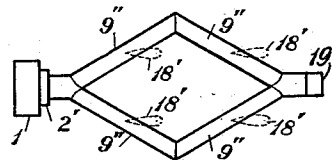
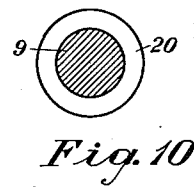
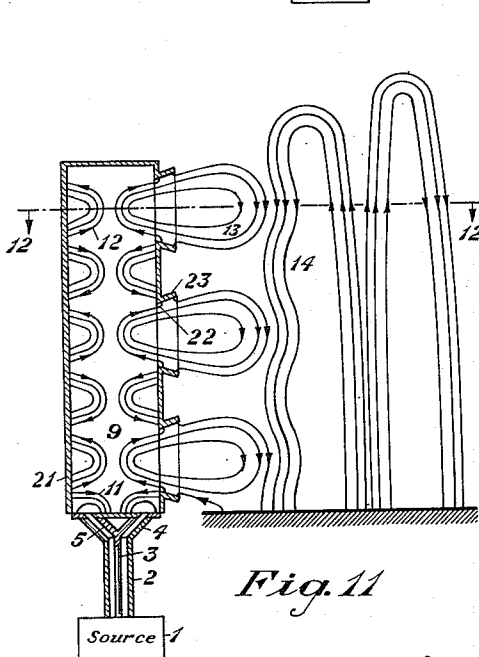
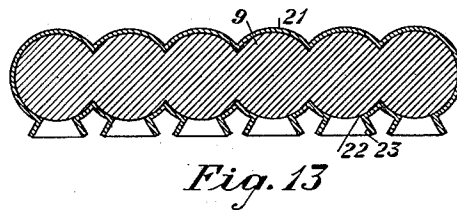
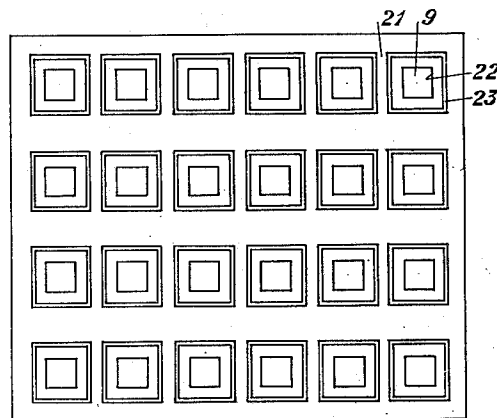
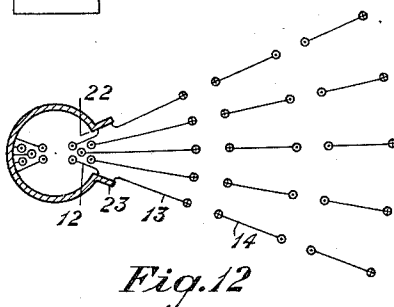
July 9, 1940.

G. C. SOUTHWORTH
SHORT WAVE RADIO SYSTEM

2,206,923

Filed Sept. 12, 1934

6 Sheets-Sheet 2



INVENTOR
G. C. Southworth
BY *Carl A. Richmond*
ATTORNEY

July 9, 1940.

G. C. SOUTHWORTH

2,206,923

SHORT WAVE RADIO SYSTEM

Filed Sept. 12, 1934

6 Sheets-Sheet 3

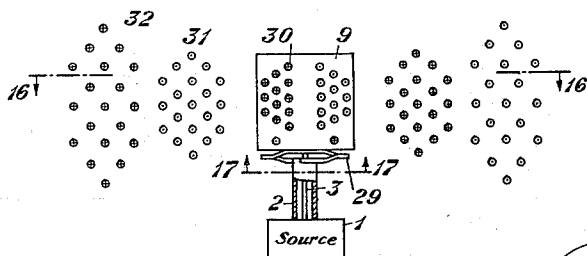


Fig. 15

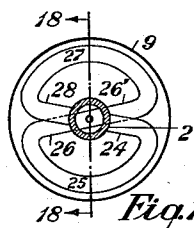


Fig. 17

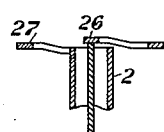


Fig. 18

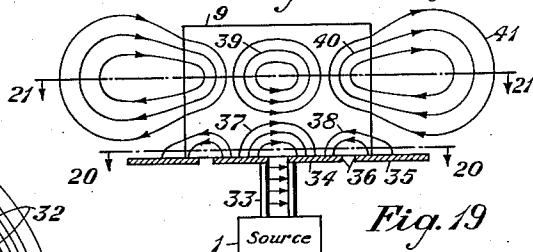


Fig. 19

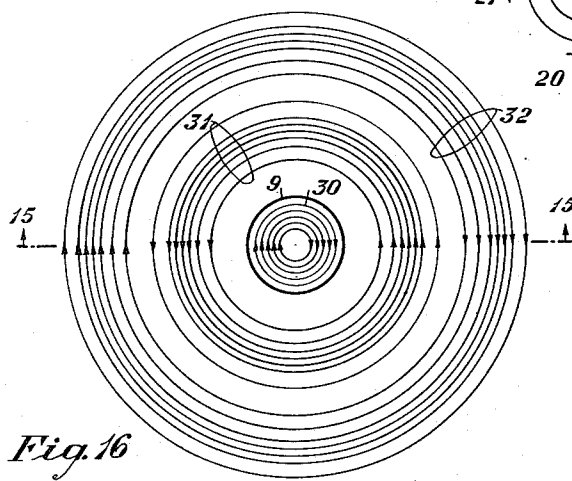


Fig. 16

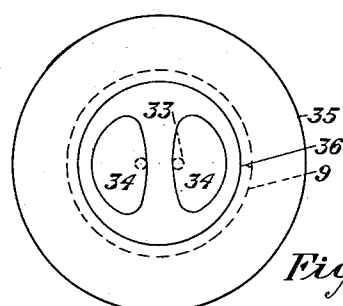


Fig. 20

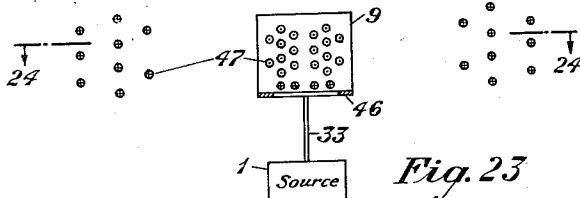


Fig. 23

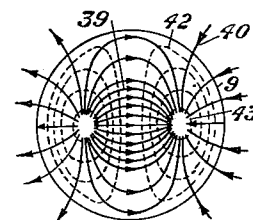


Fig. 21

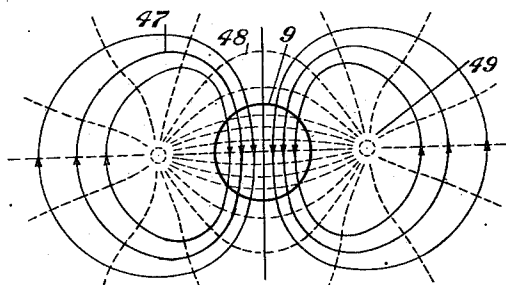


Fig. 24

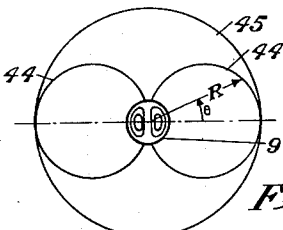


Fig. 22

INVENTOR
G.C. Southworth
BY
Carl A. Richmond
ATTORNEY

July 9, 1940.

G. C. SOUTHWORTH

2,206,923

SHORT WAVE RADIO SYSTEM

Filed Sept. 12, 1934

6 Sheets-Sheet 4

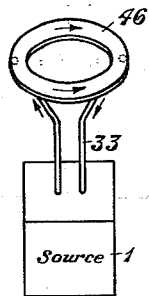


Fig. 25

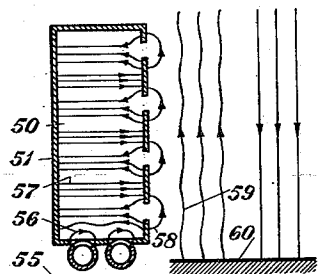


Fig. 26

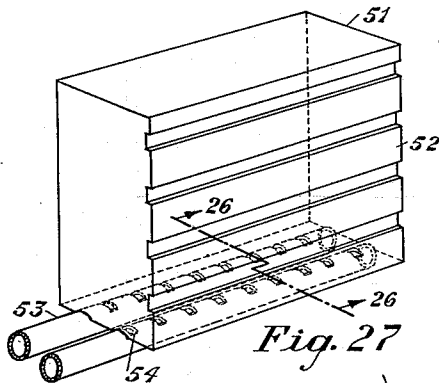


Fig. 27

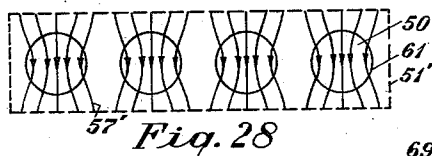


Fig. 28

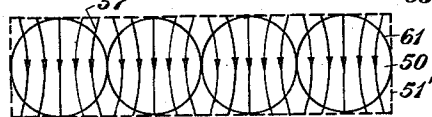


Fig. 29

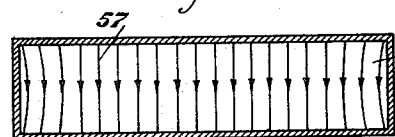


Fig. 30

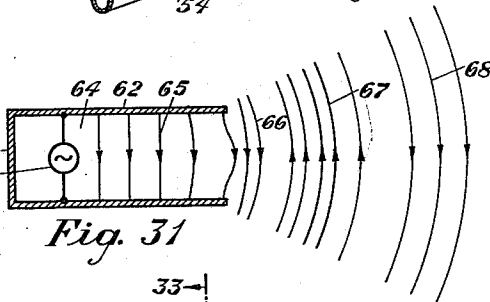


Fig. 31

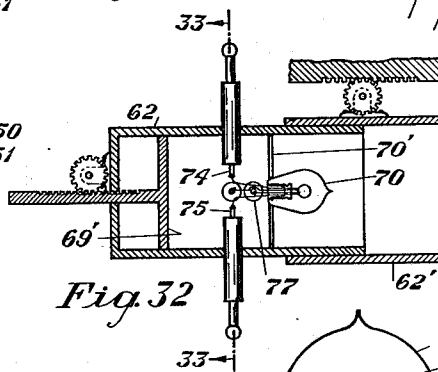


Fig. 32

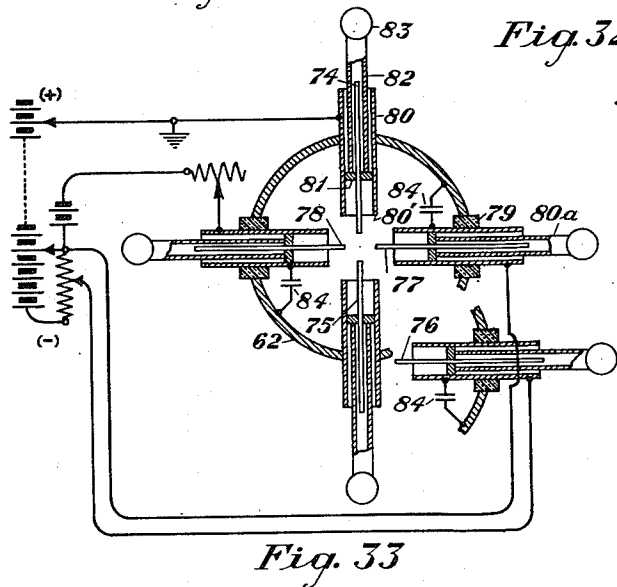


Fig. 33

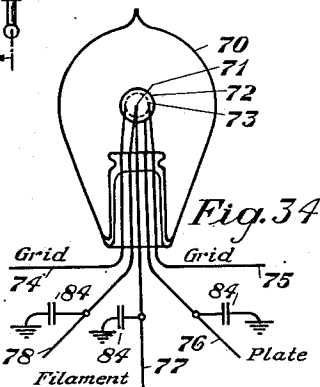


Fig. 34

INVENTOR
G. C. Southworth
BY
Carl A. Richmond
ATTORNEY

July 9, 1940.

G. C. SOUTHWORTH

2,206,923

SHORT WAVE RADIO SYSTEM

Filed Sept. 12, 1934

6 Sheets-Sheet 5

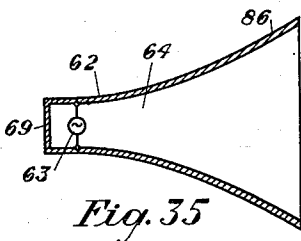


Fig. 35

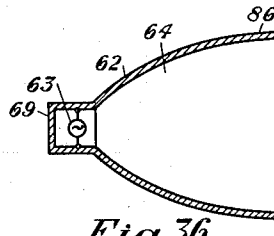


Fig. 36

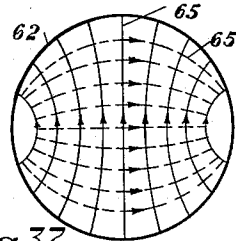


Fig. 37

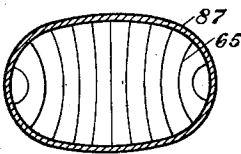


Fig. 38

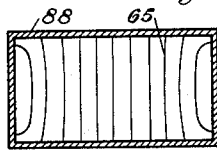


Fig. 39

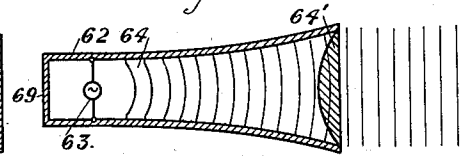


Fig. 40

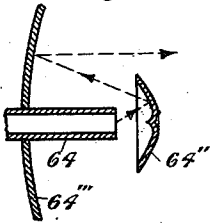


Fig. 41

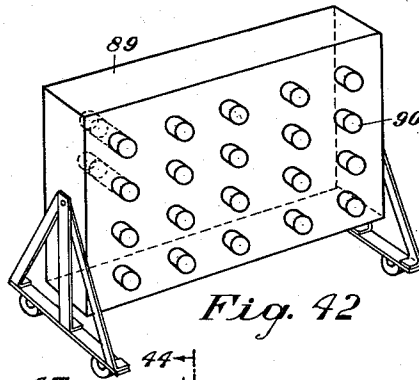


Fig. 42

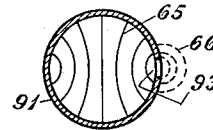


Fig. 45

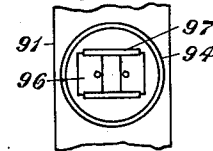


Fig. 46

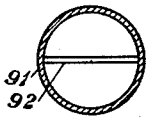


Fig. 47

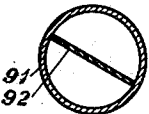


Fig. 48

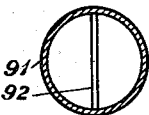


Fig. 49

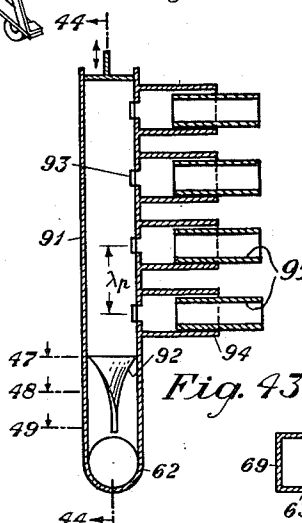


Fig. 43

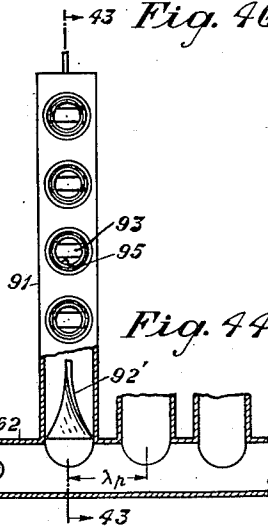


Fig. 44

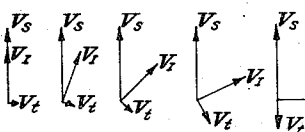


Fig. 50

INVENTOR
G. C. Southworth
BY
Carl A. Richmond
ATTORNEY

July 9, 1940.

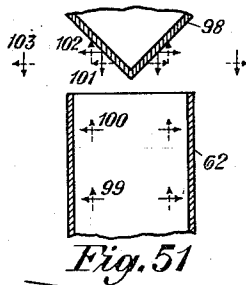
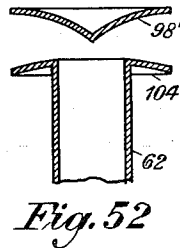
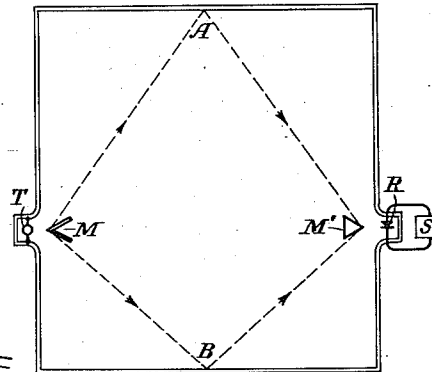
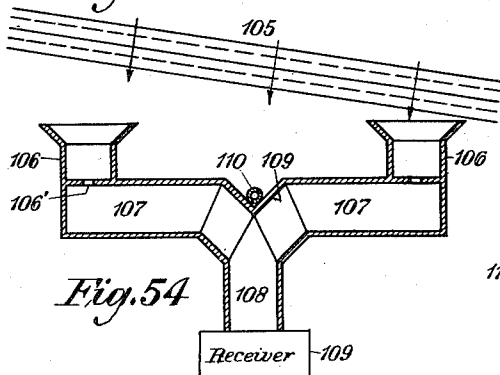
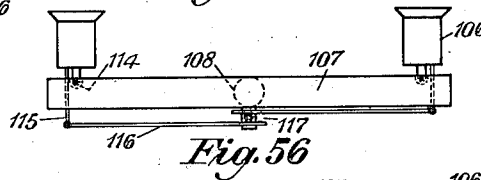
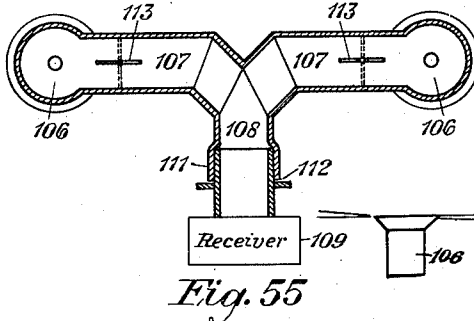
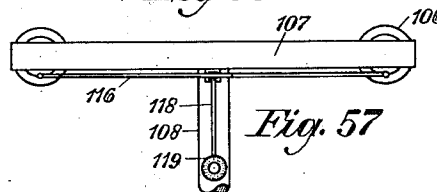
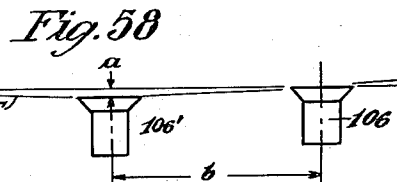
G. C. SOUTHWORTH

2,206,923

SHORT WAVE RADIO SYSTEM

Filed Sept. 12, 1934

6 Sheets-Sheet 6



INVENTOR
G. C. Southworth
BY *Carl A. Richmond*
ATTORNEY

UNITED STATES PATENT OFFICE

2,206,923

SHORT WAVE RADIO SYSTEM

George Clark Southworth, Ridgewood, N. J., assignor to American Telephone and Telegraph Company, a corporation of New York

Application September 12, 1934, Serial No. 743,753

69 Claims. (Cl. 250—11)

An object of my invention is to provide new and improved apparatus and a corresponding method for transmitting and receiving electromagnetic waves of very high frequency. Other objects are to establish a direction of maximum intensity in such waves and to practice directional selectivity in their reception. Another object is to generate high frequency electric waves in a dielectric guide and radiate them in space. Other objects have to do with attaining directional intensity and selectivity by means of arrays of unitary radiators and receptors energized in proper phase and intensity relation. In the practice of my invention waves of different types may be employed, electric or magnetic, symmetric or asymmetric, using these terms in the senses to be explained presently. In some principal examples of practice in accordance with the invention electromagnetic waves are radiated from the open end of a dielectric guide comprising a metallic pipe or from lateral openings in such a guide, or radio waves are received through such open end or openings. Other embodiments feature metallic horns for radiating or intercepting waves and their use in conjunction with dielectric guides and metallic chambers for improving and modifying the directional characteristics thereof. In one embodiment of my invention a wave front may be formed in a dielectric guide medium from a plurality of simple component waves and then launched from that medium into space. In one aspect my invention involves an intimate combination of a vacuum tube with a dielectric wave guide whereby the waves are generated and launched with the desired type and frequency. Other aspects of the invention involve shaping the wave front by means of refracting media and securing polarization in a proper desired transverse direction. Among the more specific applications of my invention disclosed herein are direction finders and range finders. All the foregoing objects and aspects, and many other objects and advantages of my invention will become apparent on consideration of a limited number of specific embodiments of the invention which I have chosen for presentation in the following specification and the accompanying drawings. It will be understood that this disclosure has relation principally to these specific embodiments of the invention and that its scope will be indicated in the appended claims.

Referring to the drawings, Figure 1 is a diagrammatic vertical section of a radiator having its principal intensity in all the directions of a

horizontal plane. Fig. 2 is a horizontal section on the corresponding line in Fig. 1. Fig. 3 is a diagrammatic vertical section like Fig. 1 but showing radiation from several sources arranged vertically one above another. Fig. 4 somewhat like Fig. 3 with the salient distinction that the radiator is a conductor guide instead of a dielectric guide. Fig. 5 is a vertical section of a dielectric guide radiator with a directional intensity diagram. Fig. 6 is a diagram corresponding to Fig. 5 but with suppression of part of the directions of maximum intensity. Fig. 7 is a diagram corresponding to either Fig. 5 or Fig. 6 showing how energy may be applied at the middle of the guide. Fig. 8 is a diagram showing units such as in Figs. 5, 6 and 7 assembled in a directive diamond radiator. Fig. 9 is a diagrammatic vertical section like Fig. 3 but with variation of diameter of the guide instead of the use of metallic bands as in Fig. 3. Fig. 10 is a horizontal section on the corresponding line of Fig. 9. Fig. 11 is a diagrammatic vertical section of a radiator consisting of a metal sheathed dielectric guide with "windows" to give radiation on one side only. Fig. 12 is a horizontal section on the corresponding line of Fig. 11. Fig. 13 is a diagrammatic horizontal section of an array of units like the one shown in Figs. 11 and 12. Fig. 14 is a front elevation of the same array. All the foregoing figures have relation to symmetric electric waves in the dielectric guide or guides. Fig. 15 is a diagrammatic vertical section of a radiator for symmetrical magnetic waves. Fig. 16 is a horizontal section on the corresponding line of Fig. 15. Fig. 17 is a section on the corresponding line of Fig. 15 looking up. Fig. 18 is a section on the corresponding line of Fig. 17. Fig. 19 is a diagrammatic vertical section of a radiator for asymmetric electric waves. Fig. 20 and Fig. 21 are sections on the corresponding lines of Fig. 19. Fig. 22 is a directional intensity diagram in a horizontal plane for the radiator of Figs. 19, 20 and 21. Fig. 23 is a diagrammatic vertical section of a radiator for asymmetric magnetic waves. Fig. 24 is a horizontal section on the corresponding line of Fig. 23. Fig. 25 is a perspective view showing the metallic conductor system by which energy is fed into the radiator of Fig. 23. Fig. 26 is a vertical section showing a multiple unit array of radiators adapted to send an approximately plane wave front. Fig. 27 is a diagrammatic perspective view of the same radiator shown in Fig. 26. Figs. 28, 29 and 30 are progressively modified diagrams showing how one horizontal radiator of Fig. 26 or Fig. 27 may be

regarded as built up of a row of units. Fig. 31 is a unitary radiator consisting of a dielectric guide having a metallic shell. Fig. 32 shows the same thing more in structural detail and with facilities for certain adjustments. Fig. 33 is a diagrammatic cross-section of the radiator shown in Fig. 32. Fig. 34 is a diagram showing the circuit connections for the vacuum tube employed in the device of Figs. 32 and 33. Fig. 35 is an axial section of a dielectric guide in the form of a flaring horn adapted to give directivity of transmission or to secure a proper electrical impedance match, as desired. Fig. 36 corresponds with Fig. 35, except that the flare of the horn is according to a somewhat different law. Fig. 37 is a transverse section of the horn of Fig. 35 showing the lines of electric and magnetic force. Figs. 38 and 39 are corresponding transverse sections showing alternative shapes. Fig. 40 is an axial section of a dielectric guide radiator with means to shape the wave to give it a flat wave front. Fig. 41 is a diagram showing the use of concave reflectors to give a flat wave front with a radiator of the type of Fig. 31. Fig. 42 is a diagrammatic perspective view of an array of units of the type shown in Fig. 31. Fig. 43 is a vertical section through one column of units comprising an array as in Fig. 42. Fig. 44 is a view partly in front elevation and partly in section of the same column of units shown in Fig. 43, together with certain associated elements. Fig. 45 is a horizontal section through one of the columns of Figs. 43 and 44. Fig. 46 is an elevation showing adjustable covers for the opening in one of the radiator units. Figs. 47, 48 and 49 are horizontal sections at different heights as indicated in Fig. 43. Fig. 50 is a set of vector diagrams to which reference will be made in explaining the mode of operation of the system of Figs. 43 to 49. Fig. 51 is a vertical section showing a dielectric guide radiating upwardly in combination with a conical reflector to change the radiation to substantially horizontal in all directions. Fig. 52 corresponds to Fig. 51 with some modification of detail. Fig. 53 is a diagram of a burglar alarm system. Fig. 54 is a horizontal section of a rotatable direction finder. Fig. 55 is a vertical section of a modified rotatable direction finder. Fig. 56 is a top plan view of a rotatable range finder. Fig. 57 is an elevation of this same range finder. Fig. 58 is a diagrammatic top plan view of a range finder operating on a somewhat different principle.

This application is to some extent a continuation of my application, Serial No. 661,154, filed March 16, 1933, and of my application, Serial No. 701,711, filed December 9, 1933, which issued on September 13, 1938 as U. S. Patents No. 2,129,711 and No. 2,129,712.

In my aforementioned applications there are disclosed systems for the guided transmission of ultra high frequency electromagnetic waves through rods of dielectric material, metallic pipes containing only air or some other dielectric medium, and other wave guiding structures providing a dielectric path within a bounding medium of different electromagnetic properties. Such wave guides I have chosen to call dielectric guides. In accordance with these prior disclosures and as will appear hereinafter, the guided waves may assume different forms or types each having a characteristic spacial distribution or pattern of the component electric and magnetic fields. In all examples heretofore encountered in practice it has been found that for any par-

ticular type of wave in any particular dielectric guide there is a critical or cut-off frequency, more or less sharply defined, which must be exceeded for wave power to be transmitted through an indefinite length of dielectric guide. The cut-off frequency depends on the index of refraction of the dielectric medium and on the transverse dimensions of the guide, the diameter in the illustrative case of a guide of circular cross-section, and the velocity of propagation or the wavelength within the guide is likewise significantly dependent on these factors. It will be evident that separate conductors for the "go and return" flow of conducting currents, as in an ordinary wire line system, is not essential in a dielectric guide system.

Referring to Fig. 1 of the present case, the numerals 2 and 3 designate a conductor pair; one of the two conductors, 2, being a cylindrical shell, and the other conductor 3 being a rod lying in the axis of the shell 2. High frequency electromotive forces are applied from the source 1 across the lower ends of the conductors 2 and 3, and corresponding current waves travel up along the coaxial conductor system 2-3. The lines of force of these electric waves progressing up the coaxial conductor system 2-3, are directed radially and alternately outward and inward as the waves pass a fixed point.

At the top of the conductor pair 2-3, the axial core conductor 3 is expanded into a cone 5, and the cylindrical conductor shell 2 is expanded into a corresponding funnel 4, the cone 5 and the funnel 4 being spaced apart all around, and this space being a continued expansion upward of the space between the conductors 2 and 3. In a horizontal section at any height, the ratio is constant for the radius of the outer surface of the inner conductor 5 and the radius of the inner surface of the outer conductor 4.

The cone 5 has a flat metallic base 7 on top, and in the same plane therewith it is surrounded by a flat annulus 6, the central disc 7 and the flat annulus 6 being spaced by an annular gap 8, as seen in Fig. 2. It will readily be seen that the lines of force which extend radially between the conductors 2 and 3 will pass up between the flaring members 4 and 5 and will arch across between the plates 7 and 6 as indicated at 11 in Fig. 1. All of the lines shown in Fig. 1 are electric lines of force; generally the magnetic lines are circles around the vertical axis of the coaxial conductor system 2-3. Inasmuch as there is a component of the electric force in the direction of propagation, this type of wave is called an electric wave; and because it is the same in all horizontal directions around the axis it is called symmetric.

Standing on the plates or electrodes 6 and 7 is a cylinder 9 of dielectric material. This may be regarded as a short section of cylindrical dielectric guide with vertical axis. Surrounding the base of the dielectric guide 9 is a conductive platform 10.

The waves in the dielectric guide 9, represented by the lines of electric force 11, are broken off in loops and progress upwardly as indicated at 12. These lines of electric force extend out into the space surrounding the guide 9 and form completely closed loops as indicated at 13. These loops move out horizontally, as well as upwardly, and are detached as electromagnetic waves and radiated into space as indicated at 14. The lines shown at 14 in Fig. 1 are samples of such lines

lying all around the axis of the guide 9 on every side.

Generally the velocity of propagation in the material of the guide 9 will be less than in air or empty space. By a proper choice of diameter and material this velocity may advantageously be made about one-half that of ordinary light. This means that the wave length in the guide is one-half that in the surrounding medium. A specific set of data giving satisfactory results is to employ an operating frequency of 1,750 megacycles and make the guide 9 of an insulating material which has a dielectric constant of about 10, and hence, an index of refraction of about 3.16, which is the square root of 10. The wave length in the guide depends both upon the diameter and the index of refraction. The diameter of the guide-radiator 9 is chosen at 6.54 cms. so that the wave length in the radiator shall be about one-half that in the surrounding medium. The length or height of the cylinder 9 is about 4.5 cms., which is slightly more than one-half the wave length in the dielectric. All these dimensions and others may be in some degree determined by an experimental adjustment.

The apparatus of Fig. 3 differs from that of Fig. 1 principally in that the cylindrical dielectric guide 9 with vertical axis, has been much extended in a vertical direction and surrounded with a metallic band 15 at its base and other metallic bands 16 equally spaced along its height. As the waves represented by the lines of force 11 and 12 progress upwardly in the guide 9 of Fig. 3, part of their energy is radiated into the surrounding space between successive metal bands 15 and 16 as indicated at 13. But, as the waves 12 move up, the ends of the lines of force rest on a metallic band such as 16 as indicated by the lines 17, and in this state there is no radiation in the surrounding space. Then at the next stage higher up, between two successive metallic bands 16, there is more radiation, and so on. Farther out, all around, the lines of force such as 13, become detached and linked end to end to form the wave front 14. Presently these lines straighten out vertically and the radiated wave takes the form shown farthest out from the axis in Fig. 3. Vertical sections containing the axis of the guide 9 of Fig. 3 would show the same configuration of lines of force in any horizontal direction.

Assuming that the material and the dimensions are chosen in Fig. 3 so that the wave length in the guide is half that in the surrounding medium, then the radiating bands between the metal bands 16 will be spaced at intervals equal to the wave length in the guide. Thus, they will oscillate in the same phase, as indicated in Fig. 3.

In Fig. 4 there is shown a metallic conductor antenna 9' with like spaced cylindrical metal shields 16' along its length. These shields 16' are each as long as the alternating spaces between them. The frequency of the source 1' being such that the wave length in the conductor is twice the length of a shield, it follows that the unshielded radiating parts of the antenna 9' are in like phase and these parts contribute alike to send a horizontal beam of radiation, without interference from the shielded parts. The shields 16' may be supported conveniently on the antenna 9', especially if the latter is supported as a tower standing on an insulating base at its lower end. In the normal operation of the system of Fig. 4, there will be a voltage node at the middle of the height of each shield 16'; therefore the system will be electrically unchanged to

any substantial degree by metallic supporting connections as shown at 16'' in Fig. 4.

A guide such as 9 of Fig. 3, but without the metal bands 16, is shown in Fig. 5 capped by a metallic plate 17. Standing waves are set up in this guide and they build up an interference pattern to give different intensities in different directions. The loops of Fig. 5 are the loops of a polar intensity diagram. These show that the greatest intensities are nearly upward and downward, inclined a little to the axis of the guide. The diagram of Fig. 5 is based on the assumption that the dielectric losses in the guide 9 are relatively small, and the diameter of the guide is so chosen as to make the radiated component not too large. Suppose, on the other hand, that radiation produces considerable loss, and in addition, the cap as at 19 in Fig. 6, is of semi-conductive material so as to absorb all the wave power incident upon it from within the guide, then there will be no reflected wave at this end of the guide and no standing waves in the guide, and the polar intensity diagram will have the shape shown in Fig. 6.

It is assumed in connection with Figs. 5 and 6 that energy is fed into the guide 9 at its lower end, but the energy may be applied at the middle of the length of the guide according to the plan indicated in Fig. 7.

Referring to Fig. 8, this shows four guides 9'' connected in diamond shape and all supplied with energy from source 1 through connection 2'. By virtue of the energy sink 19', there is no reflection of energy. Each of the four guides has a principal loop of its polar intensity diagram as shown at 18' in Fig. 8. These loops 18' have their axes parallel and add vectorially with full resultant effect. Other loops, not shown in Fig. 8, have their axes in various directions and add vectorially to cancel out to a very great extent.

Instead of suppressing radiation at points along the height of the guide 9 by means of metal bands 16 as shown in Fig. 3, this effect may be attained as shown in Fig. 9 by spaced enlargements of the guide as at 20. Within each enlarged part 20 the lines of force are closed within the guide, but within each reduced part they break out into the surrounding space and break off and link together end to end to give the configuration indicated at 14.

Where the diameter is increased as at 20, this has the effect of reducing the speed of propagation along the guide which requires the radiating parts of the guide to be brought nearer together.

As shown in Figs. 11 and 12, the guide 9 may consist of a dielectric core within a cylindrical metallic shell, which is continuous except for a series of vertically spaced openings or windows 22. Around each window 22 is an outwardly directed flange 23 which partakes of the nature of a horn. This radiator sends out such waves as do the radiators of Figs. 3 and 9, but only on the side having the windows 22 so that in a horizontal plan view the radiation is as seen in Fig. 12.

Here and elsewhere throughout this specification the word "radiate" and its derivatives do not necessarily imply that there is divergence, such as shown in Fig. 12.

Radiation may be enhanced in one horizontal direction, with little or no divergence, by arranging radiators such as in Fig. 3 or Fig. 9 to stand side by side. In this case, an appropriate spacing between them would be half the wave length in air, though it may be as much as 0.7 times the

wave length in air. They should all be operated in the same phase.

Let a plurality of the radiators of Figs. 11 and 12 stand in a row side by side, partially united as indicated by the horizontal section of Fig. 13. This assembly or array will appear in front elevation as shown in Fig. 14. If the radiation from each vertical row of openings is of the character shown in Fig. 12, the interference pattern produced will give a plane wave front, and accordingly, the radiator will be more narrowly directed in intensity than in Fig. 12.

The waves considered heretofore have been of the type which I call symmetric electric, with electric lines of force as shown by the continuous lines in Figs. 1, 3, 9 and 11. In the radiator of Figs. 15 and 16 the wave type is symmetric magnetic, the lines of electric force here being horizontal circles coaxial with the vertical axis of the radiator 9. These waves are called magnetic because the lines of magnetic force have a component in the direction of propagation, and symmetric, because they lie on all sides around the vertical axis of the radiator. The radiating element 9 of Fig. 15 is about 60% larger than the corresponding element of Fig. 1, for the same dielectric material and the same wave frequency. The source 1 supplies alternating electric currents of high frequency over the coaxial conductor system 2—3. At its upper end the tubular conductor 2 has two opposite radial arms 24 and 28 (see Figs. 17 and 18) which extend around through the parts 24—25—26 and 28—27—26', and meet on the extremity of the axial core conductor 3. In other words, the apparatus indicated generally in Fig. 15 by the reference numeral 29, and shown more in detail in the plan view looking up, of Fig. 17, is a figure-8 conductor with one cross-branch connected to one conductor 2 of the coaxial conductor system, and the other cross-branch connected to the other conductor 3 of the coaxial conductor system.

The waves that go up the coaxial conductor system 2—3 of Fig. 15, in the form of radially directed lines of force, are re-shaped by the 8-shaped member 29 and enter the dielectric guide 9 in the form of horizontal circles. These are radiated out laterally into space as shown by the diagrams of Figs. 15 and 16. Suppose that at a certain instant the shell 2 is positive at its upper end in Fig. 15 and the core 3 is negative; corresponding currents will flow in both arcs 25 and 27 directed the same way around the axis. Thus, it will be seen how the circular lines of electric force are thrown off and up into the dielectric guide-radiator member 9. In the same way that the elements of Fig. 1 may be arrayed to give horizontal directivity as in Figs. 3, 9, and 11, so may the elements of Fig. 15 be arrayed, likewise, for the same purpose.

For the radiation of asymmetric electric waves, two parallel conductor rods 33 are extended vertically upward from the source 1 as shown in Fig. 19. A high frequency alternating current is impressed across these conductors at their lower ends. At their upper ends they are terminated by the two plates 34 having the shape shown in Fig. 20. The lines of force extend across these plates 34 as indicated at 37 in Fig. 19. Also, some lines, as at 38, extend across from each electrode 34 to the annular bed plate 35. As the lines 37 and 38 become detached and float up to 39 and 40 respectively, the latter lines expand laterally as at 41 and spread out horizontally with the usual velocity of light in free space. The lines of

force 39 and 40 are gathered closer together within the space marked in Fig. 21 with the numeral 43, somewhat as if there were a conductor at this point. Therefore, this region may be referred to as a quasi-conductor, and this case may be looked upon as analogous to the case of two ordinary linear antenna elements standing vertically at the two plates 43 and spaced one-half wave length apart and oscillating in opposite phase.

The horizontal intensity diagram for the system of Figs. 19, 20 and 21 is shown by the curves 44 in Fig. 22. These indicate two maxima of intensity in two opposite horizontal directions with null intensity at right angles thereto. The same radiation of power measured in watts will give much more intensity in a preferred direction and its opposite, then when the same power is distributed uniformly in all horizontal directions. If the same power is radiated in both cases, the gain in the preferred direction with the characteristic 44 of Fig. 22 is about 3 decibels. This means that 1 watt of power is as effective in the preferred direction as 2 watts would be when radiated uniformly in all directions. The antenna of Figs. 19 and 21 is very useful when it is desired to avoid interference with stations in lateral directions by suppressing radiation in those directions. The units of Figs. 19 and 21 can be combined in arrays as heretofore described, to give enhanced directional selectivity.

Radiation of asymmetric magnetic waves may be effected by the system shown in Figs. 23, 24 and 25. Here the source 1 puts a high frequency alternating current across the two parallel conductor rods 33 which diverge at their upper ends and are connected to two diametrically opposite points of the horizontal conductor annulus 46. The lines of electric force extend substantially parallel with the diameter of the annulus that connects the upper ends of the two conductors 33. These lines are propagated upwardly in the dielectric guide 9, and outwardly therefrom, so that the wave shape pattern in plan view has the appearance shown in Fig. 24, in which the continuous lines represent electric lines of force and the dotted lines represent magnetic lines of force. Since the magnetic lines have components in the direction of propagation, this is called a magnetic wave, and a glance at Fig. 24 shows why it is called asymmetric. The elements of Figs. 23, 24 and 25 may be arranged in arrays to give directional selectivity as has been described for the other kinds of elements heretofore.

In the system of Figs. 26 and 27, asymmetric magnetic waves are propagated along the guides 53 with their lines of electric force extending across horizontally as indicated by the double headed arrows 55 at the bottom of Fig. 26. Each guide shell 53 has regularly spaced transverse openings 54 connecting with the block of dielectric guide material 50 standing above. At each opening 54 some lines of electric force escape through the opening upwardly and progress upwardly as waves in the block of dielectric material 50. This material 50 is encased in a metal shell 51 having a series of spaced horizontal slots in one face. The lines of force escape through these slot openings as shown at 58, and link together end to end as at 59, to give waves having a plane wave front with the direction of propagation horizontally to the right as viewed in Fig. 26.

The design of Figs. 26 and 27 and the mode of operation, may be apprehended by considering a series of cylindrical units side by side with their

axes parallel in one vertical plane, as seen at 50 in Fig. 28, which is a horizontal section. From each such unit 50 the asymmetric magnetic waves escape as indicated by the lines of electric force.

5 If these units are enlarged, we make the transition from Fig. 28 to Fig. 29. Further enlarging the units, so that they unite to form one large rectangular block 50, we have the diagram of Fig. 30 corresponding to a horizontal section through the guide shell 51 of Figs. 26 and 27.

10 While the system of Figs. 26 and 27 has been described for asymmetric magnetic waves, it could obviously be modified and adapted for other types. The openings 54 in the two guides 53 are staggered so that the guide material above them shall be utilized as nearly uniformly as practicable, and to the utmost advantage. These openings 54 are spaced along each guide 53 at wave length intervals as measured in the guide, so that the 15 waves will enter the guide material 50 in like phase all across its lower part. The slots 52 are spaced at one or an integral number of wave lengths as measured in the guide material 50 so as to get all parts of the radiated wave front 20 in like phase.

Another kind of a unit radiator is shown in Fig. 31. Here there is a cylindrical metal shell 25 62, more particularly a cylindrical shell of circular cross-section, closed across one end with a metal wall 69. Inside, at 63, is an oscillation generator connected to diametrically opposite points of the shell 62. This shell 62 may be filled with paraffin or any other suitable dielectric. When a dielectric guide comprises an enclosing metallic sheath, the dielectric may be any suitable medium, and as an important special case, it may be empty space, or its equivalent, air. Thus in Fig. 31 the dielectric medium within the shell 62 may be empty space or air. Accordingly, a hollow metal pipe may be made to function as a dielectric guide. The lines of electric force such as 65, extending across, parallel to a diameter, will establish asymmetric magnetic waves which will be propagated along toward the open end of the shell 62 and radiated therefrom, as indicated by the group of lines 66 in one direction, 67 in the opposite direction and 68 again in the first direction. The oscillator 63 may advantageously be placed at such distance from the end wall 69 that the waves reflected therefrom will reinforce the waves that proceed directly to the right from the oscillator.

A practicable form of the radiator of Fig. 31 may be made of a 12-inch length of pipe having its diameter 5" and containing air as the dielectric material. Operated at a frequency of 1,750 megacycles this gives a wave length in free space of about 17 cms.

60 In referring to the element 63 as an oscillation generator I contemplate that its frequency determining elements may or may not be included. Thus in Fig. 31, the frequency may be dependent, in some degree, on the dimensions of the guide around the source 63. Similarly, a three-electrode vacuum tube oscillator combined with frequency determining conductive circuits comprising inductance or capacity or both may be taken to be only the tube or the combination of the tube and the circuits. In any case, if it is important to know whether the term oscillation generator includes the complete frequency determining elements, I endeavor to make this clear in the context.

70 This same kind of a radiating unit of Fig. 31 is shown with certain facilities for adjust-

ment in Figs. 32, 33 and 34. The cylindrical side wall 62 has a telescoping extension 62' adjustable by means of a rack and pinion, and a movable end wall 69', also adjustable by rack and pinion.

Oscillation generator 70 is a three-electrode 5 vacuum tube having a transverse filament 71, a grid 73 in the form of a helix around the filament 71 as axis, and a cylindrical plate anode 72 outside the grid and having the same axis. This vacuum tube 70 is fixed by the support 70' in the center of the radiator. The direct current for heating the filament comes in over the diametrically opposite conductors 77 and 78. The direct current across the plate and filament is applied through the conductor 76 which lies beside the 10 conductor 77. The respective ends of the grid 73 are connected by means of the conductors 74 and 75 to diametrically opposite points of the shell 62, the diameter for these two points being at a right angle to the diameter for the conductors 77 and 78. 20

At the very high frequencies involved, oscillation generator 70 operates most effectively and advantageously when tuning devices are placed along its associated conductors. These tuning 25 devices are shown in Fig. 33. They exclude from the filament and plate leads certain parasitic high frequency currents which have been found to have very deleterious effects. The conductor 74, for example, lies along a radius of the shell 62. Around it, as axis, there is a cylindrical shell 80. The metallic plunger 81 is longitudinally displaceable, and fills the annular space between the axial conductor 74 and the surrounding cylindrical conductor 80 and establishes 30 conductive connection between these two members. This metallic plunger 81 is connected by a tube 82 to the handle 83 by which it may be displaced inwardly or outwardly. Thus, the effective length of the concentric conductor system between the plunger 81 and the end 80' of the tube 80 may be adjusted as desired. In this space a system of standing waves for a coaxial conductor pair will be set up and the most advantageous tuning secured in this way. All five conductors 74, 75, 76, 77 and 78 are connected for high frequencies to the shell 62, this connection being made through the condensers 84 in certain cases so as to block the direct currents. Where the condensers 84 are employed, insulating bushings 50 79 are used.

Of the five conductors leading to and from the vacuum tube, all except the grid leads lie along equi-potentials of the electric field. For a specific example of the system shown in Fig. 32, a filament current of 5 amperes may be used with the grid voltage at 375 volts and the plate voltage at -40 volts. It is proper to regard the wave power as residing in lines of force produced by the acceleration of electrons back and forth through the spiral grid. These lines of force operate in virtue of the inductance property of the spiral grid to produce a substantial difference of potential between its opposite ends which is communicated to the diametrically opposite points on the inner wall of the shell 62 to which the ends of the grid are connected. 60

In such a device as that of Fig. 31, the waves are formed within a conductive chamber, and thereafter they are radiated out into neighboring space and away. To bring the waves to the desired form an appropriate shape may be given to the surrounding conductive chamber, as for example in Fig. 35. Here, to secure directivity, 75

the radiating unit of Fig. 31 may be modified by flaring to its open end. This will tend to make the wave front more nearly plane, so that it will be more narrowly directive. In other words, the Poynting vectors representing the flow of power will be more nearly parallel. The corresponding lines of force are shown by the transverse section of Fig. 37 in which the continuous lines are electric and the dotted lines are magnetic.

The horn of Fig. 35 may perform either or both of two functions. As one of these functions, it may be a wave shaping or directive device as has been explained. The other possible function is to serve as an impedance matching device. In the latter case it may be used to terminate a wave guide in its own characteristic impedance. It may have its contour modified as shown in Fig. 36, that is, the longitudinal wall section may be concave inwardly instead of convex outwardly.

It may be advantageous in shaping the wave front to depart from the circular section of Fig. 37, to an oval or elliptical shape, as in Fig. 38, or a rectangular shape as in Fig. 39.

Whatever the dielectric within the unit 62 of Fig. 35, it may be helpful, in order to get a plane wave front, to place across the opening a lens 64' of material having a different index of refraction; this is shown in Fig. 40. If the wave front is convex within, as at 64, then the lens should be convex or concave, according as its index is greater or less than at 64.

Another way to flatten the wave front from the open end of a guide 64 is by the use of two reflectors shaped and arranged as shown at 64'' and 64''' in Fig. 41.

Unitary radiators such as shown in Fig. 31, may be assembled in an antenna array to give a decidedly directional effect, as shown in a simple diagrammatic sketch in Fig. 42. Here the units are mounted in a frame 89 which is supported on rollers so that it can be turned in whatever direction the maximum intensity is desired. This frame 89 may be a solid block of metal, or a skeleton frame, or it may be of sheet metal with open end cavities as radiators. In the latter case the radiator units can be energized from a common source in the manner illustrated in Figs. 43 and 44. Fig. 43 is a vertical cross-section down through a column of the units, and Fig. 44 is a section partly in elevation at a right angle to the section of Fig. 43. The generator 63 sends asymmetric magnetic waves along the guide 62 to the right, as viewed in Fig. 44. From this horizontally extending guide 62, branch guides 91 extend upwardly. These are spaced a wave length apart. In the lower end of each vertical branch guide 91 is a metal plate 92 which is given a helicoidal form by a quarter turn twist. This is indicated by the sections in Figs. 47, 48 and 49. This changes the direction of polarity of the waves as they ascend in the branch guides 91, adapting them for further cooperation, as will be described presently.

At intervals of a wave length along each vertical guide, there are windows or openings 93 opening into horizontal branch guides 94, each with a telescopically adjustable extension part 95. The windows 93 permit some of the lines of force to escape through them as shown diagrammatically in Fig. 45. They may be covered by sliding metal plate doors 96 in guides 97 as shown in Fig. 46, so as to adjust the size of the openings.

From each unit 94-95 the waves come out in

like phase and coalesce to form a plane wave front which is radiated with a high degree of directional intensity.

Referring to the twisted helicoidal member 92 of Figs. 47, 48 and 49, this works best when its end on which the waves are incident, is perpendicular to the lines of electric force of that wave. This relation is shown by the last of the 5 vector diagrams of Fig. 50. In each of these diagrams the line V_e indicates the direction of the edge of the septum on which the waves are incident, the arrow V_i represents the direction of the electric lines of force at this point, and the line V_r represents the direction of the electric lines of force at the opposite end of the septum. The transmitted wave is always rotated 90 degrees in any one of these five cases, but it has its greatest magnitude in the case that has been described, most particularly shown at the right of Fig. 50.

For a frequency of 1,750 megacycles which corresponds to a wave length in free space of about 17.1 cms., the vertical branches may be spaced appropriately at about 22.2 cms. If each radiating unit is made about 12.5 cms. in diameter, then the horizontal separation from rim to rim of the adjacent units will be about 9.7 cms. This wave length within the guide of 22.2 cms. may be obtained by making it about 8 inches in diameter when using air for the dielectric.

If it is desired to radiate electric waves in all directions horizontally but without the spreading of intensity at angles up or down, a unit of Fig. 31 may be employed as indicated at 62 in Fig. 51, that is, having its open end directed upwardly with a conical reflector 98 above it. The dotted arrows represent the directions of progression of the electric wave, and the continuous line arrows represent a line of force as it makes such progress. Thus, we see a line of force progressing along the guide 62 from 99 to 100. At the reflector 98, it is shown partly reflected and partly not yet reflected, the reflected part being 101 and the part not yet reflected being 102; after reflection the wave advances horizontally and we see it at a later stage at 103.

The upper end of the unitary radiating wave guide may be flanged as at 104 in Fig. 52, and the conical reflector may be given a proper modifying shape as at 98' so as to hold the waves to the desired lateral direction of maximum intensity.

A radiator such as that of Fig. 51 or Fig. 52 will generally be best suited for operation with symmetric type waves, electric or magnetic. Such a radiator is adapted for a radio beacon when it is desired to have the emitted radiation distributed all around in a horizontal plane.

While the foregoing descriptions have had relation principally to transmitters, it will be readily understood how the principles involved are applicable for receivers.

The rectangular outline of Fig. 53 represents a room in horizontal section equipped with a burglar alarm system. A transmitter T like that of Fig. 35 is set in one side wall and a corresponding receiver R is in the opposite side wall. Double oblique mirrors M and M' are provided to establish the ray paths shown by dotted lines with reflection at A and B. The path via A is longer than that via B by an odd number of half waves so that normally there is a null effect on the receiver R. But if any one of the paths indicated by the four dotted line segments is interrupted, as by an intruder, there is an unbalance at R and an alarm signal is given on the device S.

A direction finder is shown in Fig. 54. A re-

celver wave front is represented at 105. Two unit tubular guides, each a cavity type resonator, are shown at 106 on the ends of transverse wave guides 107 which are pivotally mounted at 110 so as to rotate around a vertical axis. The received radiation in the guide unit 106 is admitted by windows 106' to the transverse guides 107. By means of the reflectors 109 the radiation from the guides 107 is directed into the main guide 108 and thence to the receiver 109.

The crests and troughs of an approaching wave to be received, are represented by the continuous and dotted lines, respectively, at 105. If the apparatus is turned so as to be directed accurately to receive these waves, the effects in the two resonators 106 will be in like phase and there will be a maximum of received intensity in the receiver 109. This will be 3 decibels higher than if only one of the chambers 106 had been operative.

A modification is shown in Fig. 55 in which the two resonating chambers 106 connect with the vertical main wave guide 108 which has a joint 111, so that the receiver 109 can remain stationary while the rest of the device rotates, and the angle can be read off on the scale at 112.

In either form of the device shown in Fig. 54 or Fig. 55, there will be several maxima and minima of intensity corresponding to a difference of wave path of an integral number of half-wave lengths. Generally, the intensity in the receiver will be less than when this difference is zero. However, to be certain that the maximum intensity depended upon corresponds to zero difference in wave path, one of the chambers is shut off by a butterfly valve such as 113 in Fig. 55, and the device is rotated through a wide angle to get the direction of maximum intensity with a tolerable degree of approximation. Then the valve 113 is opened and finer adjustments are made about the position previously ascertained, to get the direction more exactly. Two valves 113 are provided, one on each side as shown in Fig. 55, so that the electrical paths on the two sides will be matched and balanced.

A range finder is shown in plan view on Fig. 56, and in elevation in Fig. 57. The two resonant chambers 106 are pivoted on the cross-member 107. At the points 114 at the normal extreme of adjustment, the axis of each chamber 106 will be at 90 degrees to the cross-arm 107. By turning the knob 119 at the scale, the interposed mechanism 118—117—116—115 operates to incline the chambers 106 a little so that these angles become less than 90 degrees. The approaching wave front will be circular with its center at its source, and will be received with greatest intensity when the axes of the two resonating chambers 106 are directed along respective radii of such circles. The scale at the knob 119 may be calibrated to read the range directly.

In the modified form of range finder shown in Fig. 58 three resonating chambers are employed and the middle one 106' is adjusted forward or backward to get a maximum intensity in all three such chambers combined. At this intensity the three chambers will be equally distant from the source. With the source as center the arc c is drawn with b as its half chord or sine. The sagitta of the arc c is the length a , and the range is a function of a in relation to b , so that from the adjustment of the intermediate resonating chamber 106' the range can be ascertained. The formula is $d=b^2/2a$. If the wave

length is 1 cm. the displacement of the chamber 106' between maximum and minimum intensity would be 0.5 cm. This means that it would be easy to detect signal differences corresponding to sagittal differences as small as 0.1 cm. If the base b is 3 meters, then by substitution in the above formula we would get a distance to the source of 4500 meters.

I claim:

1. The method of transmitting electrical effects from one place to another place which comprises generating electromagnetic waves at the one place in a wave guide, said waves being of such character that they subsist within said guide at any frequencies above a critical frequency determined in part by a transverse dimension of said guide-but not at slower frequencies, passing said waves an appreciable distance through said guide and radiating them therefrom to the other place.

2. A combination for effecting translation of energy between radio waves of a given frequency and an electrical circuit, including a length of wave guide that comprises a laterally bounded dielectric medium, the interior of said guide being dielectrically connected with free space near one end for energy interchange with said radio waves, and means near the other end for energy interchange with said electrical circuit, said means being adapted for launching into said guide or receiving therefrom guided electromagnetic waves of such characteristic field pattern that energy transmission between said means and said one end can take place substantially at any frequencies exceeding a critical frequency functionally related to the transverse dimensions of said guide but substantially only at such frequencies, said transverse dimensions being such that the critical frequency lies below the frequency of said radio waves.

3. A combination for effecting translation of energy between radio waves and an electrical circuit, comprising a section of metallic pipe containing a dielectric medium, the interior of said pipe having a dielectric connection to free space at one end for energy interchange with said radio waves, means at the other end of said pipe for energy interchange with said electrical circuit, said means being adapted for energy interchange with guided waves within said pipe of such character that substantial translation of energy between said radio waves and said electrical circuit takes place only at frequencies exceeding a high-pass transmission cut-off frequency dependent on the transverse dimensions of said pipe.

4. A combination for effecting translation of energy between radio waves and an electrical circuit, comprising a section of metallic pipe containing a dielectric medium, the interior of said pipe having a dielectric connection to free space at one end for energy interchange with said radio waves, means at the other end of said pipe for energy interchange with said electrical circuit, said means being adapted for energy interchange with guided waves within said pipe of such character that substantial translation of energy between said radio waves and said electrical circuit takes place only at frequencies exceeding a critical cut-off frequency dependent on the transverse dimensions of said pipe, said dielectric connection to free space comprising means for matching impedances.

5. In combination, a wave guide comprising a metallic pipe containing only a dielectric medium, electrodes at one end of said guide, a

high frequency alternating current generator operatively connected to said electrodes, the frequency of said generator being sufficiently high relative to a transmission cut-off frequency dependent on an internal dimension of said pipe that progressive electromagnetic waves are established in said dielectric medium, said guide being open near its other end to radiate said progressive waves into space.

6. In a radio transmission system, a wave guide comprising a metallic pipe containing a gaseous dielectric medium, and means for launching into said guide or receiving therefrom high frequency electromagnetic waves of such characteristic field pattern that the guide presents to them the characteristics of a high-pass filter, the interior of said guide having an opening to free space at a distance from said means, whereby waves launched into said guide are radiated through said opening into space or radio waves intercepted at said opening are transmitted through said guide to said means.

7. A combination in accordance with claim 6 in which said pipe is open-ended, thereby providing said opening to free space.

8. In combination, a generator of high frequency alternating currents, a concentric conductor system connected thereto, a wave guide consisting essentially of a bounded dielectric medium the boundary of which separates said medium from a medium having different electromagnetic characteristics, a terminal structure at one point connecting said conductor system with said guide to set up progressive electromagnetic waves in said guide of a character such that they are readily transmitted through said guide only at frequencies exceeding a critical frequency functionally related to a transverse dimension of said guide, said progressive electromagnetic waves being radiated into space at another point of said guide.

9. In combination, a wave guide consisting essentially of a metallic pipe, a high frequency alternating current generator and means coupling said generator and guide in energy transfer relation comprising a terminal structure adapted to generate in said guide progressive electromagnetic waves characterized in that there is a substantial component of electric force in the direction of propagation and in that the field is symmetric about the axis of said guide, said pipe having an opening in at least one place for the radiation of said waves transmitted therethrough, the distance between said coupling means and at least one of said openings being great enough that substantial radiation occurs only at frequencies exceeding the transmission cut-off frequency of said guide.

10. In combination, a wave guide comprising a metallic pipe having an open end, a metallic horn surmounting the said open end of said pipe, electrical circuit means at a distance from said horn in energy transfer relation with said pipe, said means being adapted either for launching into said pipe ultra-high frequency electromagnetic waves of such characteristic field pattern that the pipe presents to them the characteristics of a high-pass filter or for receiving waves of such field pattern established in said pipe by incoming radio waves intercepted by said horn, the frequency of the waves so launched or received being substantially in excess of the transmission cut-off frequency of said pipe.

11. In a system for the radiation or reception of ultra high frequency electromagnetic waves,

a wave guide comprising a metallic pipe enclosing a dielectric medium, translating means within said guide adapted for the launching or reception of guided waves in which the electric field is roughly diametral, said pipe having a dielectric connection to free space at a distance from said translating means such that wave propagation takes place substantially only at frequencies exceeding a transmission cut-off frequency, and a signaling circuit connected to said translating means.

12. A combination in accordance with claim 11 in which said pipe is open-ended, thereby providing said dielectric connection.

13. A combination in accordance with claim 11 in which one end of said pipe is open and flared.

14. In combination, a wave guiding structure comprising a metallic pipe containing only a dielectric medium, a source of high frequency current and means within said guiding structure and coupled to said source for generating in said pipe progressive guided electromagnetic waves of asymmetric magnetic type, the frequency of said source being greater than a critical frequency below which said waves are propagated, if at all, only with great attenuation, said pipe having an opening at a point distant from said generating means through which said waves are radiated into space.

15. In a system for radiating electromagnetic waves, a wave guide comprising an extended body of dielectric of restricted cross-section, means for applying to said guide electromagnetic waves of a frequency so high as related to a transverse dimension of said guide that they are propagated through said guide and radiated therefrom, and means systematically spaced along said guide for inhibiting radiation so that the parts of uninhibited radiation are combined to give a directionally selective effect.

16. In combination, a dielectric guide, means to generate electromagnetic waves therein of frequency appropriate to its dimensions, said guide being adapted to radiate corresponding electromagnetic waves therefrom, and said guide comprising a metal sheath with regularly arranged openings therethrough for the radiation of electromagnetic waves and their combination with directionally selective effect.

17. A radiator of electromagnetic waves consisting of a dielectric guide that includes a metallic sheath having a row of windows along one side through which radiation may occur so that the parts of such radiation will combine to give directional selectivity, the transverse dimensions of said guide being appropriate for dielectrically guided wave propagation at the frequency of said waves.

18. A metal sheathed slab of dielectric material, a cylindrical metal sheathed dielectric guide adjacent to one edge of said slab, the sheaths between the slab and guide having interconnecting, regularly spaced, transverse slots, and the sheath of said slab having slots in one face parallel with said guide, whereby electromagnetic waves of sufficiently high frequency in said guide go therefrom through the first mentioned slots into said slab and then from the second mentioned slots to form a plane wave front in space.

19. A metal sheathed dielectric guide having one end open, the other closed, and an alternating current generator connected across two opposite points of the sheath near the closed end, whereby electromagnetic waves of a frequency

sufficiently high as related to the transverse dimensions of said guide may be radiated from the open end.

20. A metal sheathed wave guide, a generator
5 lying in its axis, said generator comprising a space discharge device having cathode, anode and grid electrodes, conductive connections from the respective ends of the grid to diametrically opposite points of the metal sheath, said sheath
10 having openings at the ends of a diameter at a right angle to the diameter of the grid connections, and cathode conductors passing respectively through said openings.

21. A metal sheathed dielectric guide, a three
15 electrode vacuum tube generator lying in its axis, said tube having a helical grid and a cathode, conductive connections from the respective ends of the grid to diametrically opposite points of the metal sheath, said sheath having openings
20 at the ends of a diameter at a right angle to the diameter of the grid connections, and conductors passing respectively through said openings for carrying current to heat said cathode.

22. A wave guide consisting essentially of a
25 metallic pipe, a high frequency oscillation generator within said pipe, a terminal structure connected to said generator for producing progressive electromagnetic waves in said pipe of a character such that there is a critical frequency related to the transverse dimensions of said pipe
30 separating the operative frequency range from a lower frequency range of zero or negligible transmission, and low frequency leads through the wall of said pipe to said generator, said leads
35 lying in an equipotential locus.

23. A metal sheathed dielectric guide, a three
40 electrode vacuum tube generator lying in its axis, said vacuum tube generator having a filament, a grid and a plate electrode, conductive connections from the respective ends of the grid to diametrically opposite points of the metal sheath, said sheath having openings at the ends of a
45 diameter at a right angle to that of the grid connections, filament conductors passing respectively therethrough and a plate conductor close to one of said filament conductors and insulated from said sheath.

24. A metal sheathed dielectric guide, a high
50 frequency alternating current generator in its axis, a radial conductor to said generator, a spaced metallic sleeve around said conductor, and a connector between said conductor and sleeve, said connector being longitudinally adjustable for tuning.

25. An electromagnetic wave guide consisting
55 essentially of a body of dielectric enclosed within a metal sheath, a high frequency alternating current generator in its axis, a radial conductor to said generator, a spaced metallic sleeve around
60 said conductor, and a conductive connector between said conductor and sleeve, said connector being longitudinally adjustable for tuning, and said sleeve passing through the sheath and being insulated therefrom.

26. A metal sheathed wave guide having one
65 end open and flared, the other closed, and an alternating current generator electrically connected across two opposite points of the sheath near the closed end, said generator being adapted
70 to operate at a frequency so high that electromagnetic waves may be radiated from the open flared end.

27. In combination, a dielectric guide consisting essentially of a hollow metallic pipe, means
75 to generate electromagnetic waves therein of fre-

quency appropriate to its dimensions, and an impedance matching termination for said guide adapted to radiate corresponding electromagnetic waves therefrom.

28. A combination for the directive radiation
8 of high frequency electromagnetic waves comprising an elongated metallic bounded chamber enclosing a dielectric medium, means for producing longitudinally progressive guided
10 waves in said chamber of a character such that the velocity of propagation is a function of a transverse dimension of said chamber, said chamber having an opening in the lateral boundary thereof for the emission and radiation of
15 waves guided through said chamber from said means to said opening, and said means being spaced a distance from an end boundary of said chamber that is optimum for maximum radiation of power through said opening.

29. A system for the radiation of electromag-
20 netic waves comprising a dielectric guide, means for generating in said guide displacement current waves of such field configuration that they are propagated through said guide substantially only at frequencies, but at any such frequencies,
25 exceeding a cut-off frequency functionally related to the transverse dimensions of the guide, said guide having a lateral dielectric connection at a distance from said generating means through which said waves are radiated into space.

30. A combination for the directive radiation
30 of high frequency electromagnetic waves comprising an elongated metallic bounded chamber enclosing a dielectric medium, means for producing longitudinally progressive guided waves
35 in said chamber of a character such that the velocity of propagation is a function of a transverse dimension of the chamber, said chamber having a plurality of openings in the lateral boundary thereof for the emission and radiation
40 of waves guided through said chamber from said means to said openings, said openings being spaced longitudinally of the chamber in a manner systematically related to the length of said waves within the chamber.

31. A system for the radiation of electromag-
45 netic waves comprising a metallic pipe and a dielectric medium enclosed thereby, means for launching electromagnetic waves within said pipe at a frequency exceeding a high-pass transmission cut-off frequency below which substantially
50 no power transmission can take place, said pipe having systematically spaced therealong a multiplicity of lateral apertures through which said waves are emitted.

32. A metal-walled chamber enclosing a gaseous
55 dielectric medium and means for propagating ultra high frequency waves through said chamber, said chamber having a multiplicity of apertures systematically spaced apart in relation to the length of said waves so that said waves
60 emitted through said apertures are combined and radiated with directional effect.

33. A combination in accordance with claim 32
65 in which said apertures are provided with respective metallic horns of rectangular cross-section.

34. A combination for the radiation of electro-
70 magnetic waves comprising a metallic bounded chamber containing a dielectric medium, a plurality of metal-sheathed wave guides having openings therein connecting said guides and the said dielectric medium so that high frequency electromagnetic waves in said guides
75 are released into said chamber, the space-phase

relations of the waves escaping from said openings being such that the waves combine to produce a resultant wave having a substantially plane wave front, said chamber having at least one opening therein for the radiation into space of the waves therein produced.

35. A radiator of electromagnetic waves comprising a wave guiding structure consisting essentially of a metallic pipe, one end of said pipe being open, and means at the other end of said pipe for generating therein high frequency waves of such field pattern that they are guided through said pipe and radiated from said open end substantially only at frequencies above a high-pass transmission cut-off frequency dependent on a transverse dimension of said pipe.

36. A radiator of electromagnetic waves comprising a wave guiding structure consisting essentially of a metallic pipe, one end of said pipe being open, and means at the other end of said pipe for generating therein high frequency waves of such field pattern that they are guided through said pipe and radiated from said open end substantially only at frequencies above a critical frequency dependent on a transverse dimension of said pipe, said pipe being proportioned at said open end to effect an impedance match, whereby said waves are radiated substantially without reflection at said open end.

37. A radiator of electromagnetic waves comprising a wave guiding structure consisting essentially of a metallic pipe, one end of said pipe being open, and means at the other end of said pipe for generating therein high frequency waves of such field pattern that they are guided through said pipe and radiated from said open end substantially only at frequencies above a critical frequency dependent on a transverse dimension of said pipe, the open end of said pipe being terminated in a horn for reducing wave reflection at that point.

38. In combination, a wave guide comprising a metallic pipe, means for launching ultra high frequency electromagnetic waves within said pipe for progressive transmission therethrough, one end of said pipe being open, and a metallic horn at the end of said pipe for the radiation of said waves.

39. A combination in accordance with claim 38 in which said horn is proportioned to minimize reflection of said waves therefrom.

40. In a radio transmission system, a wave guide comprising a hollow metallic pipe containing a gaseous dielectric medium, one end of said pipe being open and the other closed, a metallic horn surmounting the open end of said pipe, and means near the closed end of said pipe for launching high frequency electromagnetic waves within said pipe for transmission to said horn and radiation therefrom or for receiving radio waves intercepted by said horn and transmitted through said pipe.

41. In combination, a wave guiding structure consisting essentially of metallic lateral bounding means and a dielectric medium enclosed thereby, the end of said structure being electrically connected with free space and said metallic means flaring as a horn, the mouth of said horn being of rectangular cross-section, and means at a distance from said end of said structure for launching therein high frequency electromagnetic waves for transmission therethrough and radiation through said mouth.

42. A combination in accordance with claim 41 in which said launching means is adapted to

generate an alternating difference of potential between points on opposite sides of the axis of said guiding structure.

43. A combination in accordance with claim 41 in which said launching means is adapted to generate asymmetric magnetic waves the electric field of which is aligned substantially perpendicularly to opposite sides of said horn at its mouth.

44. In combination, a wave guiding structure consisting essentially of metallic lateral bounding means enclosing a gaseous dielectric medium, the end of said structure being open to free space and said metallic means flaring as a horn, the mouth of said horn being of rectangular cross-section, and means at a distance from said end of said structure adapted either for launching therein high frequency electromagnetic waves for transmission therethrough and radiation through said mouth or for receiving such waves entering said mouth.

45. An electromagnetic wave radiator comprising an open-headed metallic chamber, a metallic horn flaring from the open end of said chamber, a high frequency conductor extending transversely through the interior of said chamber from one wall thereof to the other, and means for exciting said conductor with high frequency electromagnetic oscillations.

46. A combination in accordance with claim 45 in which said exciting means is electrically interposed in said conductor.

47. A combination in accordance with claim 45 in which said conductor is spaced a distance from a closed end of said chamber that is optimum for maximum radiation of power from said open end.

48. In combination, a cylindrical metallic chamber, a metallic horn surmounting an open end thereof, and means within the chamber adapted for launching ultra high frequency electromagnetic waves for radiation through said horn or for receiving such waves transmitted through space and intercepted by said horn.

49. A combination in accordance with claim 48 in which said launching means is adapted to generate or receive waves of asymmetric magnetic field pattern.

50. A section of metallic pipe, reflecting means closing one end thereof, a metallic horn opening from the other end and electromagnetic wave launching means within said pipe and spaced a distance from said reflecting means that is optimum for the radiation of said waves through said horn into space.

51. A cylindrical metallic chamber having one end closed and the other open, a metallic horn flaring from said open end, and means for generating ultra high frequency electromagnetic waves for directive radiation through said horn.

52. A combination in accordance with claim 51 in which said chamber and said horn are of circular cross-section.

53. A radiator or receiver of electromagnetic waves comprising a metallicallly-bounded apertured cavity portion and a metallic horn portion around the aperture, a high frequency conductor extending transversely through one of said portions and means for exciting said conductor with ultra high frequency waves or for receiving such waves induced in said conductor by intercepted radio waves.

54. In a radio transmission system, a section of metallic pipe, a metallic horn terminating one end thereof for the radiation or interception

tion of radio waves, wave reflecting means at the other end, a translating device and means electrically coupled thereto and disposed within the pipe for launching or receiving ultra high frequency electromagnetic waves, said reflecting means and said last-mentioned means being spaced apart a distance that is optimum for maximum interchange of power between said translating device and said radio waves.

55. In a short-wave radio system, a cylindrical metallic chamber, a metallic horn flaring from one end thereof, a terminal structure within said chamber adapted for launching or receiving waves of asymmetric magnetic type, and a high frequency translating device coupled in energy transfer relation with said terminal structure.

56. In combination, a section of metallic pipe one end of which is open and the other closed, a metallic horn flaring from one end thereof, a high frequency conductor spaced from said closed end and extending diametrically across said pipe from one side thereof to the other, and high frequency translating means coupled to said conductor for the reception or radiation of electromagnetic waves.

57. A metallic pipe one end of which is open and the other closed, a conductor disposed transversely within said pipe with the extremities thereof electrically connected with the walls of said pipe, and means interposed to said conductor for energizing it with high frequency currents, whereby at frequencies sufficiently high progressive electromagnetic waves are generated in said pipe and radiated from the open end thereof.

58. A radiator of electromagnetic waves comprising in combination, means providing a circular current conducting path, a diametral conductor connected across said path, a high frequency wave source electrically interposed at substantially the center of said conductor, and means spaced laterally in one direction from said conductor for efficiently directing the radiation therefrom.

59. A radiator or receiver of electromagnetic waves comprising a wave guiding structure consisting essentially of a gas-filled metallic pipe, one end of said pipe being open, and means at the other end of said pipe for launching therein or receiving therefrom high frequency waves of such field pattern that they are guided through said pipe substantially only at frequencies above a critical frequency dependent on a transverse dimension of said pipe, and means at the said open end of said pipe for modifying the directivity pattern with respect to waves radiated from, or entering, said open end.

60. A radiator of electromagnetic waves comprising a wave guiding structure consisting essentially of a metallic pipe, one end of said pipe being open, and means at the other end of said pipe for generating therein high frequency waves of such field pattern that they are guided through said pipe and radiated from said open end substantially only at frequencies above a critical frequency dependent on a transverse dimension of said pipe, and means at the open end of said pipe for modifying the intensity-direction pattern of the waves radiated therefrom.

61. In a system for the radiation of ultra high frequency electromagnetic waves, a wave guide comprising a metallic pipe and means for launching electromagnetic waves in said pipe for progressive transmission therethrough, said pipe

having an opening at a distance from said launching means for the emission of said waves, said launching means being adapted for the generation of waves of such field pattern that, first, they are propagated through said pipe and emitted through said opening substantially only at frequencies exceeding a cut-off frequency dependent on a transverse dimension of said pipe, and, second, substantial propagation and emission can take place at any frequency exceeding said cut-off frequency.

62. A system in accordance with claim 61 in which said launching means is adapted for waves of asymmetric type.

63. A system in accordance with claim 61 in which said launching means is adapted for waves of asymmetric magnetic type.

64. In combination, an open-ended metallic pipe, means within said pipe and removed from the open end for launching ultra high frequency electromagnetic waves of such characteristic field pattern that the pipe presents to them the characteristics of a high-pass filter, the frequency of the waves so launched being substantially in excess of the cut-off frequency, whereby said waves are propagated to said open end and radiated therefrom.

65. A combination in accordance with claim 64 in which said means is constructed and arranged to launch waves of the asymmetric magnetic type.

66. In combination, an open-ended metallic pipe, a metallic horn surmounting the said open end of said pipe, and means within said pipe and removed from the open end for launching ultra-high frequency electromagnetic waves of such characteristic field pattern that the pipe presents to them the characteristics of a high-pass filter, the frequency of the waves so launched being substantially in excess of the cut-off frequency, whereby said waves are propagated to said open end and radiated therefrom.

67. In combination, an open-ended metallic pipe, a flaring metallic portion at the said open end of said pipe, said metallic portion being of substantially rectangular cross-section, and means within said pipe and removed from the open end either for launching ultra-high frequency electromagnetic waves of such characteristic field pattern that the pipe presents to them the characteristics of a high-pass filter or for receiving radio waves to which the pipe presents said characteristics, the frequency of the waves so launched or received being substantially in excess of the cut-off frequency, whereby said waves in said pipe are freely propagated there-through.

68. A system for the radiation or reception of electromagnetic waves comprising an array of like-directed metallic horns, means constituting either a source or receiver of high frequency waves, and a metallic bounded transmission structure connecting said means and all of said horns for the transfer of energy in the form of guided waves, said structure enclosing only a dielectric medium and presenting to said guided waves the characteristic of a high-pass filter.

69. A system in accordance with the claim next preceding in which said horns are rectangular in cross-section, whereby the waves radiated therefrom are more effectively combined for directive transmission.

GEORGE C. SOUTHWORTH.