Notes on the Beverage Antenna

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This article is intended for the amateur interested in better point-to-point communication such as relaying messages. Due to its directional characteristics and efficiency many relay workers have already adopted it with marked success.

THE Beverage or wave antenna, one of the comparatively recent achievements of radio engineers, is probably the most efficient type of antenna for reception purposes evolved to date, and because of certain marked properties which operate to materially reduce interference, the system holds more than ordinary interest.

Theoretically, the current induced in a wire suspended in space will travel along that conductor at a velocity equal to that of light, namely, 300,000,000 meters per second, this velocity being a constant determined by the capacity and inductance per unit length of conductor. In practice, however, a wire must be suspended in proximity to the earth, hence, the capacity increases in greater ratio than the inductance decreases and the velocity of currents along a conductor near the earth becomes less than the velocity of light, this being more strictly true of currents of low frequencies, though currents of frequencies in the order of 1500 kilocycles or more travel along a conductor in proximity to the earth at frequencies closely approaching that of light.

An electro-magnetic wave moving along a conductor suspended above the earth is capable of inducing in that conductor two currents, one of which moves along the conductor with the radio wave and builds to a maximum at one end of the conductor, and the other which travels in a direction opposite to that taken by the radio wave becomes practically zero as it approaches the other end of the conductor. If the end of the conductor at which the current is a maximum is grounded through a suitable coupling transformer, the current induced in the conductor by the radio wave is capable of operating through the coupling device and reception apparatus to produce a signal. Such a system may be represented schematically by the heavy lines in Fig. 1.

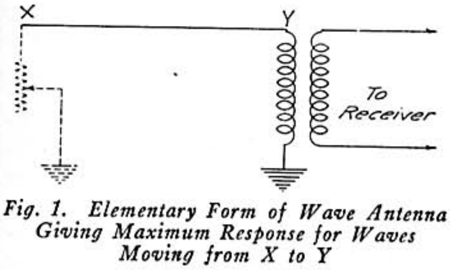

Fig. 1. Elementary Form of Wave Antenna Giving Maximum Response for Waves Moving from X to Y

Heretofore we have considered currents induced in a conductor by waves moving in the direction X to Y (referring to Fig. 1), but it is evident that waves moving in the direction Y to X will induce currents in the conductor which will build up to a maximum at the X end of the conductor. These currents will be reflected back from the open end of the conductor to the coupling transformer where they will tend to act through the receiving apparatus to produce signals. These signals, however, will not be of the intensity of those produced by waves moving from X to Y, as the horizontal plane intensity curve in Fig. 2, Detail A, indicates. This

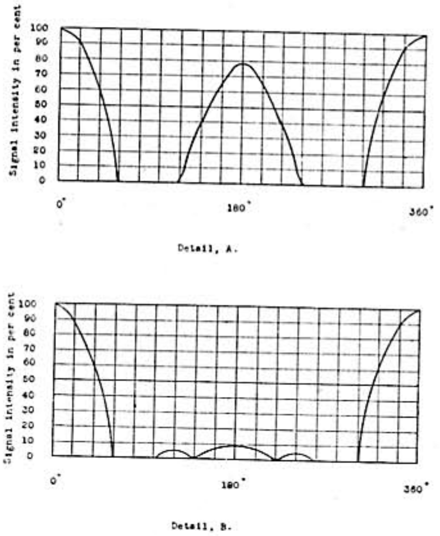

Fig. 2. Horizontal Plane Intensity Curves for Simple Wave Antenna, With and Without Damping Resistance

curve also shows the bi-directional properties which this system would possess.

By preventing the reflection of currents from the open end of the conductor, the system can be made to respond only to waves which originate in the direction toward which the open end of the conductor is pointing. This can be accomplished by grounding the open end of the conductor through a non-inductive resistance equal to the surge impedance of the conductor, this resistance being indicated by the dotted lines in Fig. 1. Theoretically, the surge impedance of a conductor is equal to $Z = \sqrt{L/C}$, L and C being the inductance and capacity per unit length. In practice it is not usually feasible to calculate this value and the damping resistance is made variable within certain limits so that it can be adjusted until the best response is secured from the system.

When the correct adjustment of damping resistance is secured the wave antenna functions aperiodically over a comparatively great range of frequencies; a marked contrast to other antennae systems which require adjustment to resonance with the frequency of the waves being intercepted for the attainment of maximum results.

Since the damping resistance prevents the reflection of currents induced in the antenna by waves moving toward the end in which the damping resistance is placed, the system is uni-directional; the horizontal plane intensity curve in Fig. 2, Detail B, indicating the marked directional properties of which this system is capable.

The system just described (of which the diagram in Fig. 1 is representative) is the elementary form of wave antenna, and will prove very practical and efficient as an experimental or permanent installation, but the adjustment of the damping resistance is a serious disadvantage, since it must be located some distance from the receiving apparatus. This disadvantage is eliminated, however, in more advanced types of wave antennae which employ two parallel conductors, and locate the damping resistance at the same end of the antenna as the receiving apparatus is located.

The schematic arrangement of one type of two-wire wave antenna is shown in Fig. 3. The system consists of two

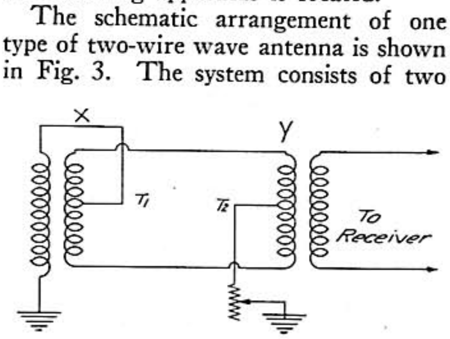

Fig. 3. Feed-back Transformer Type of Wave Antenna

parallel conductors connected at one end Y to a coupling transformer T_2, the primary of which is tapped at the midpoint and grounded through the damping resistance. At the other end of the conductors X is a feed-back transformer T_1, the primary of which is very closely coupled to the secondary. Waves moving along the conductors in a direction Y to X induce currents in each conductor that are in phase and which travel along the conductors to the transformer T_1 where they pass through the primary and secondary and to ground, but in passing through the secondary of the transformer they induce currents in the primary which circulates through the system of conductors in much the same manner as energy is transmitted over a power line. These currents as they pass through the coupling transformer

T_2 induce currents in the secondary which, operating through the receiver, produce signals. Currents induced in the conductors by waves moving from X to Y travel along the conductors in phase and, passing through the two halves of the primary of the coupling transformer, neutralize each other and induce no current in the secondary of the coupling transformer, thereby producing no effect in the receiving apparatus.

This system, like the one-wire wave antenna, is uni-directional, but it should be noted that the directional properties are the reverse of the simpler antenna. Because of certain losses which become more apparent at the very high frequencies of short wavelengths, this circuit cannot be recommended for short-wave reception.

Another two-wire wave antenna system is shown in Fig. 4. Electrically,

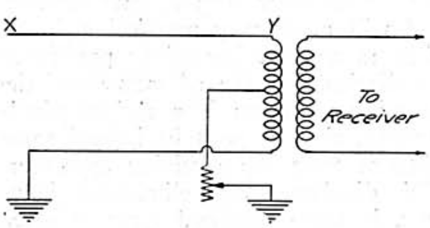

Fig. 4. Feed-back Wave Antenna Without Transformer

this circuit is similar to that of Fig. 3, but the feed-back transformer has been omitted, one of the conductors at the X-end being grounded, and the other left open. Waves moving along the conductors toward the Y-end induce currents in each conductor which are in phase and equal until reflection occurs; the reflected waves being 180 degrees out of phase, hence when they reach the coupling transformer they are capable of reacting through it to produce a signal in the receiving apparatus. This circuit, because of its simplicity and efficiency at high frequencies, is recommended for short-wave reception.

By inserting a variable condenser and an inductance in series with the damping resistance, better tuning can often be effected, since many times it is of advantage to make the damping reactance slightly capacitive or inductive to eliminate back-wave effects or interference.

Only the major points in the design of the wave antenna can be considered in these notes, these being the determination of the effective dimensions of the antenna, and a determination of the surge impedance. Of the effective dimensions the first to be considered must be length. For practical work, the length of the wave antenna, whether one or two wire, may be made equal to the wavelength of the signals which are to be received. As previously mentioned, the wave antenna will function over a wide band of frequencies, but in practical work there is usually but one wavelength employed and this can be made the determining factor of the length of the antenna. The length can, however, be varied within certain limits, though it should never be equal to less than one-half the wavelength to be received, nor greater than twice the wavelength. It should be remembered, in this connection, that with the longer antennae the directional properties are more pronounced and the antenna must be constructed to point either directly at or away from the transmitting station whose signals are to be intercepted, while with the shorter antennae a variation of as much as 20 degrees may be had without greatly affecting the intensity of the received signal. Generally speaking, signals received on short antennae are not of the intensity of those received on the longer structures.

The proximity of the wave antenna to the earth has a marked influence on its efficiency, the velocity of the currents along the conductor being greatly decreased when it is brought very close to the earth. It is, therefore, necessary to elevate the antenna some distance above ground, and for antennae to be used for intercepting waves of frequencies in the order of 1000 kilocycles or more, this height may be from 5 to 10 per cent the length of the antenna. Greater elevations add little to the efficiency of the system and tend to distort the directional characteristics of the antenna.

The most important factor in the design of wave antennae is the determination of the damping resistance. Since the damping resistance is equal to the surge impedance of the antenna, it is possible to calculate its value, as noted in the discussion of theory, but in practice the capacity and inductance of the conductors which form the antenna may vary widely from their predicted values, hence, a calculation is of little value unless the proper corrections for external influences are known and can be applied. By far the best method of obtaining the correct value of damping resistance is to make the resistance unit variable and make adjustments of the resistance while signals are being intercepted, until a maximum response is secured from the receiver.

If an oscillator of moderate output is obtainable, the damping resistance of a wave antenna can be determined by coupling the oscillator to the antenna and inserting an ammeter in the antenna lead. The damping resistance should then be adjusted to such a value that the antenna current will remain appreciably constant for a wide band of frequencies. Ordinarily, for short-wave antenna, the value of damping resistance will be from 200 to 500 ohms.

The foregoing notes treat of the directional characteristics and efficiency of the Beverage antenna. As these characteristics largely determine its use, it is necessary to make but brief mention of the applications to which it is peculiarly suited. For the reception of signals in point-to-point communication, the wave antenna is of prime importance, for, generally speaking, it permits the reception of signals from one source only, and tends to function at an efficiency much greater than obtainable with other antennae systems. Not only is the intensity of the received signals greater, due to the fact that the intercepted waves tend to operate through the antenna and receiving equipment to produce signals of maximum intensity, but the signal-interference ratio is greatly improved, with a resultant improvement in the quality of the received signals, this latter tendency being due to the directional properties of the antenna, which naturally would tend to eliminate a great deal of interference. Since point-to-point communication is employed in practically every field of radio work, from the relaying of amateur messages to trans-oceanic communication, the usefulness of the wave antenna can scarcely be said to be limited. Of course there are many exceptions to this statement, for it would be practically impossible to erect a wave antenna on a ship and get it to function at anywhere near maximum efficiency. Likewise, with broadcast listeners, unless they cared to favor some particular station, the wave antenna would find but little favor, but in communication between pre-established points the wave antenna is certain to find favor.

DIFFERENCE BETWEEN VARIOMETERS AND VARIO-COUPLERS

A variometer is a variable inductance coil used in a receiving set to give a continuous variation of inductance in a circuit. They are used for tuning to short wavelengths. They consist of two coils connected in series so that one can rotate inside of the other. As the inner coil rotates its inductance successively opposes, or is added to the inductance of the outer coil, thus giving a variation from minimum to maximum values.

A vario-coupler consists of two coils, one rotating within the other, without physical connection other than the induction between them. It is used to transfer energy from one circuit to another as from the primary coil in the antenna circuit to the secondary coil in the detector circuit. It is satisfactory only for short wavelengths. The primary coil is generally tapped so as to give the proper inductance for different wavelengths, corresponding to the variation secured by using different sizes of honeycomb coils.