BROAD BAND ANTENNA SYSTEM

Filed May 22, 1947 4 Sheets-Sheet 1

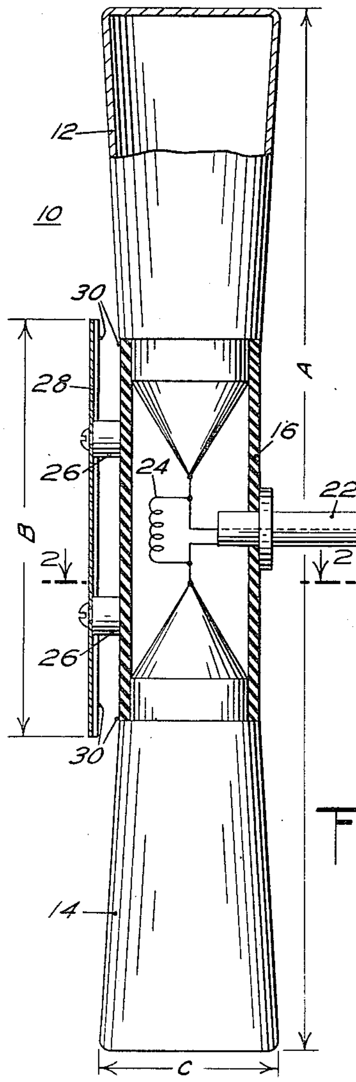

Fig. 1.

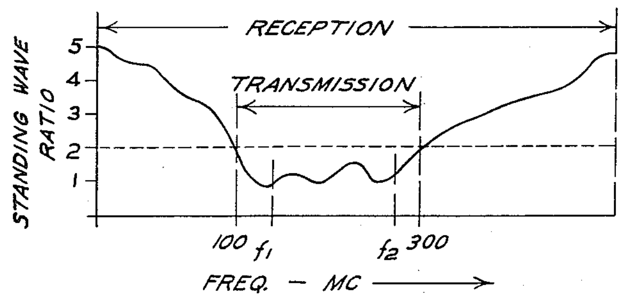

Fig. 3.

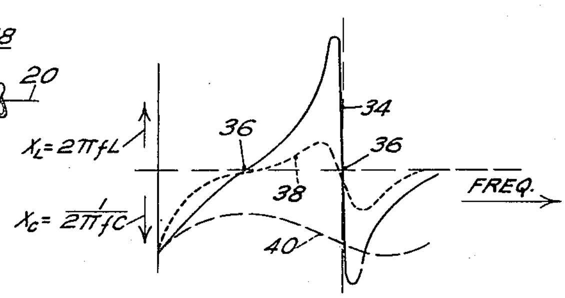

Fig. 4.

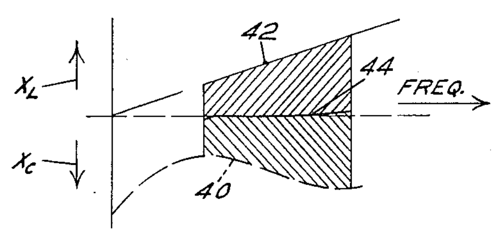

Fig. 5.

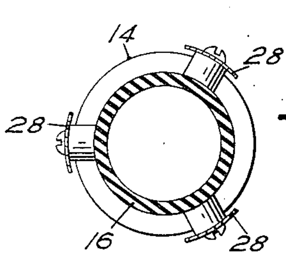

Fig. 2.

INVENTOR
FREDERICK A. KOLSTER
BY
Woodcock and Phelan
ATTORNEYS

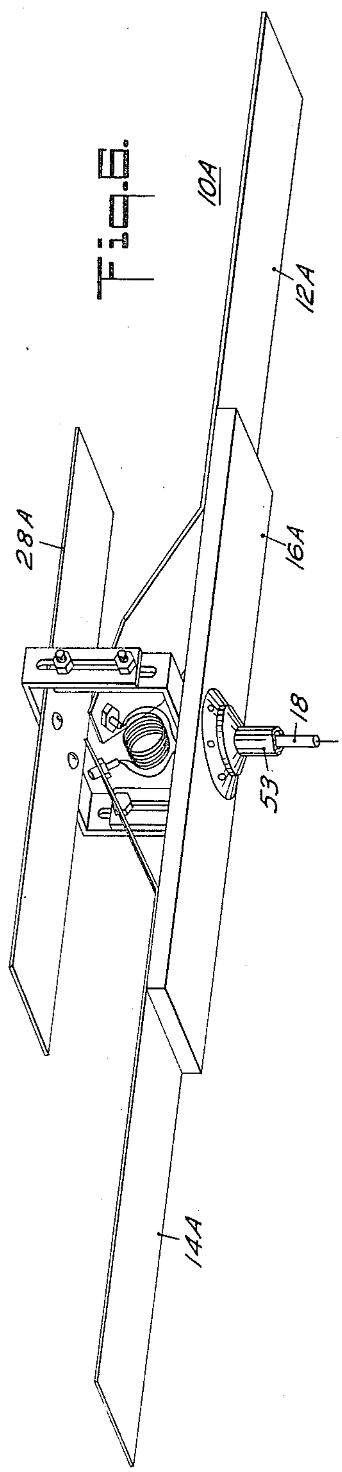

Fig. 6.

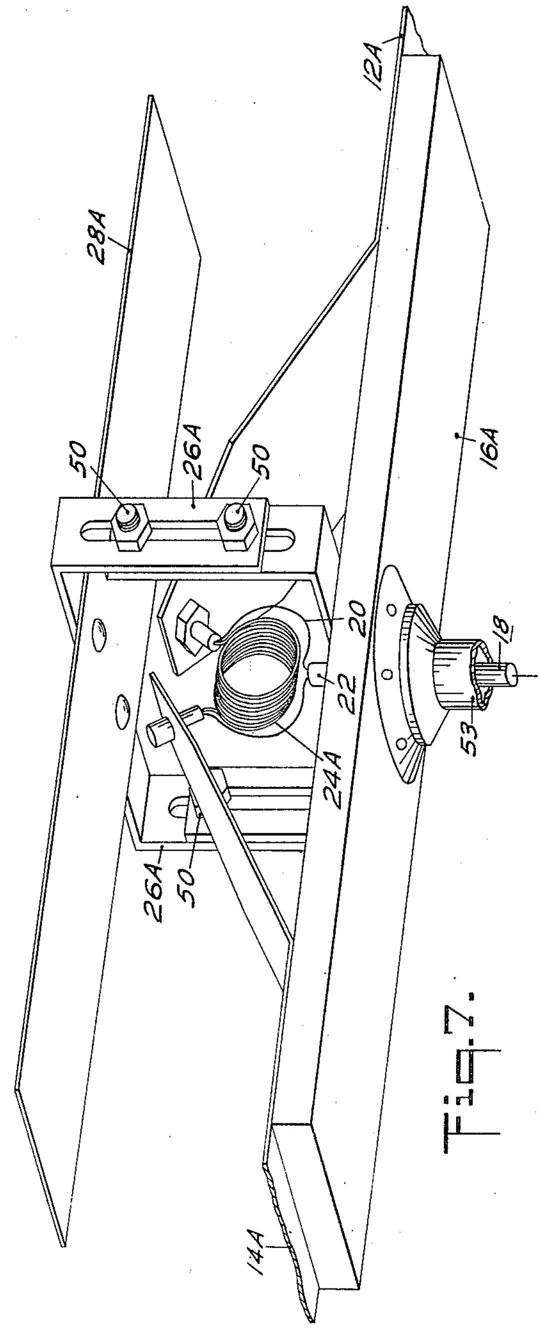

Fig. 7.

INVENTOR

FREDERICK A. KOLSTER

BY

Woodcock and Phelan

ATTORNEYS

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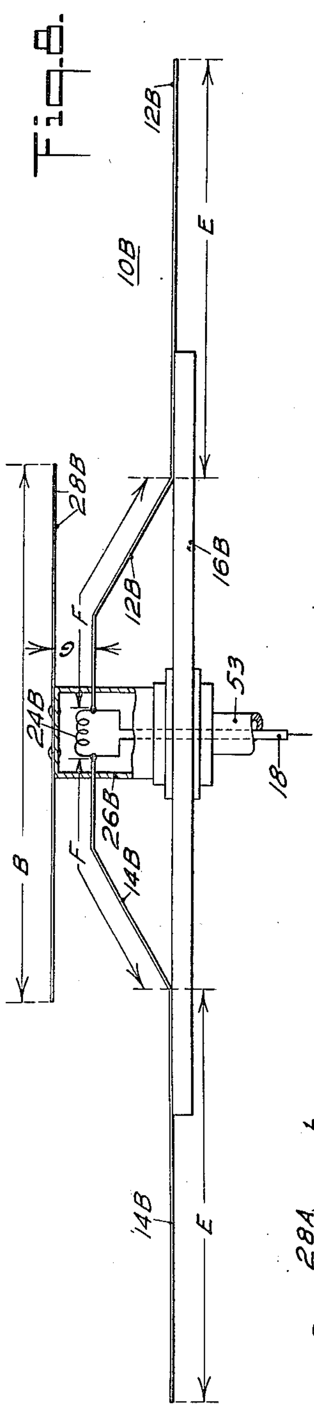

Fig. 8

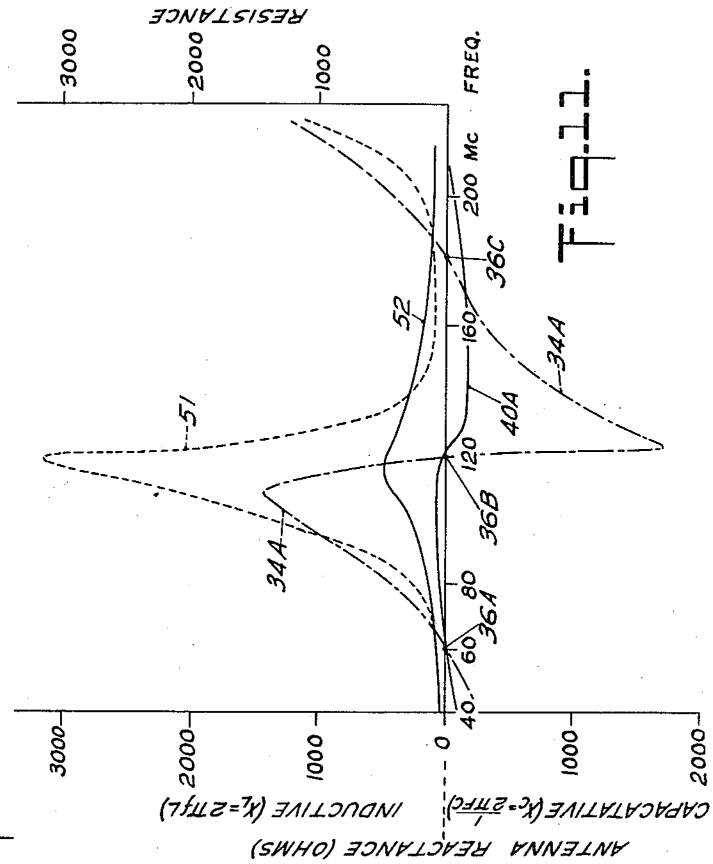

Fig. 11

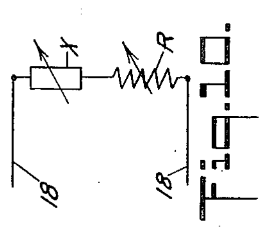

Fig. 10

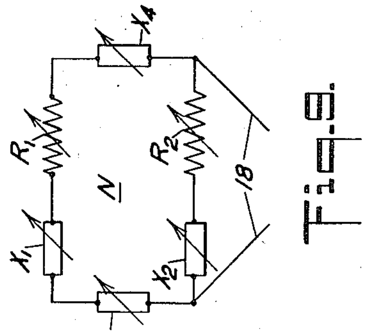

Fig. 9

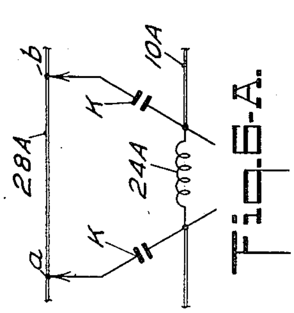

Fig. 6-A

INVENTOR

FREDERICK A. KOLSTER

BY

Woodcock and Phelan

ATTORNEYS

Jan. 1, 1952 F. A. KOLSTER 2,580,798

BROAD BAND ANTENNA SYSTEM

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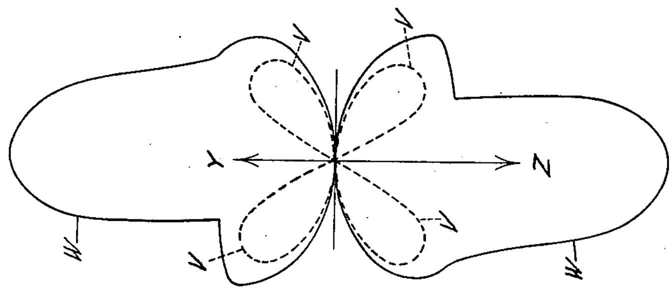


Fig.16.

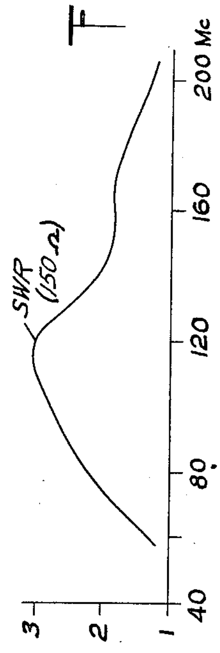
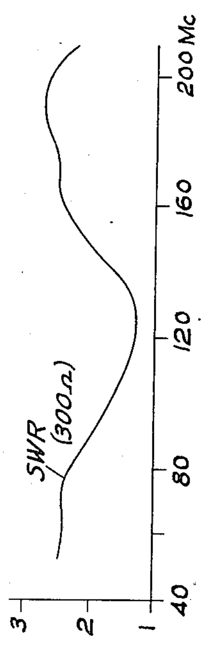
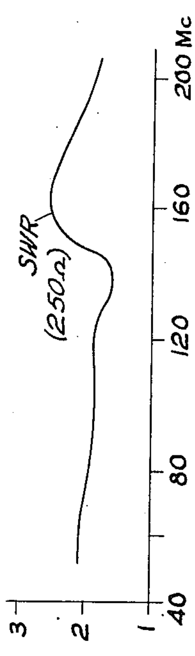


Fig.15.





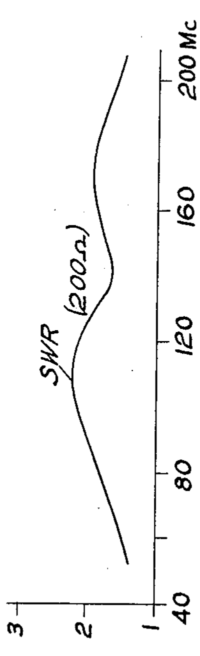


Fig.12.

Fig.13.

Fig.14.

INVENTOR

FREDERICK A. KOLSTER

BY

Woodcock and Phelan

ATTORNEYS

Patented Jan. 1, 1952 2,580,798

UNITED STATES PATENT OFFICE

2,580,798

BROAD-BAND ANTENNA SYSTEM

Frederick A. Kolster, San Francisco, Calif.; Muriel Kolster administratrix of said Frederick A. Kolster, deceased

Application May 22, 1947, Serial No. 749,699

15 Claims. (Cl. 250—33.59)

This invention relates to antenna systems, and particularly to antenna systems suited for efficient operation throughout, or anywhere within, a wide band of frequencies.

Generally in accordance with the invention, to provide an antenna system efficiently operative throughout a wide band of frequencies or at any frequency within a wide band, there are utilized two or more low "Q" dipoles of substantially different length so coupled that their net reactance as seen by the associated transmission line is low at all frequencies within that band.

More specifically, the self and mutual impedances of the dipoles effectively form a band-pass network which when reduced to its simple equivalent series circuit for each frequency of the band appears to the transmission line as a low reactance in series with a resistance of such magnitude that for all frequencies of the band the impedances of the antenna and line are suitably matched to insure a low standing wave ratio.

Further in accordance with the invention, the shorter dipole controls the amplitude and phase of current in the longer dipole, particularly at and near the harmonic frequencies thereof, to prevent occurrence of undesirable nulls in the field pattern of the antenna and so insure that throughout the wide frequency coverage of the antenna it always favors, or nowhere discriminates against, reception or transmission in the desired direction.

The invention further resides in features of construction and operation hereinafter described and claimed.

For an understanding of the invention and for illustration of embodiments thereof, reference is made to the accompanying drawings, in which:

Fig. 1, partly in section, illustrates one form of broad-band antenna;

Fig. 2 is a sectional view taken on line 2—2 of Fig. 1;

Fig. 3 is a frequency versus standing-wave-ratio curve discussed in connection with Fig. 1;

Fig. 4 comprises frequency versus reactance curves discussed in connection with Fig. 1;

Fig. 5 graphically represents modification of the antenna characteristic by addition of loading inductance;

Fig. 6 is a perspective view of another broad-band antenna embodying the invention;

Fig. 6A is an explanatory figure referred to in discussion of Figs. 6 and 8;

Fig. 7, in perspective and on enlarged scale, shows constructional details of the antenna of Fig. 6;

Fig. 8 is an elevational view of a further modified form of broad-band antenna;

Fig. 9 is a complex network referred to in discussion of Figs. 6 to 8;

Fig. 10 represents the series circuit equivalent of Fig. 9;

Fig. 11 is an explanatory figure referred to in discussion of the reactance-frequency and resistance-frequency characteristics of the antennae of Figs. 6 to 8;

Figs. 12 to 15 are frequency versus standing-wave-ratio curves discussed in connection with Figs. 6 to 8; and

Fig. 16 comprises field patterns discussed in connection with the antennas of Figs. 6 to 8.

In the embodiment of the invention shown in Figs. 1 and 2, the dipole 10 consists of two antenna elements 12 and 14 supported by tube 16 of suitable insulating material. The antenna elements are conductively connected to the associated receiving or transmitting apparatus by a transmission line 18 which may be, as shown, a concentric line consisting of an inner conductor 20 and an outer conductor 22 respectively connected to the adjacent ends of the antenna elements 12, 14.

Preferably and for reasons later discussed, an inductance 24 is connected in parallel with the transmission line at its antenna termination. The antenna may, however, be used without such inductance with realization of some but not all of the advantages attained when the inductance is used.

The insulating spacers 26 supported by cylinder 16 in turn support auxiliary dipole elements 28, each capacitively coupled at its opposite ends 30 to the transmission line 18 through the capacitance between the ends of the auxiliary dipole and the adjacent main dipole elements 12 and 14 respectively.

Though, as in Fig. 1, the main dipole elements may be somewhat conical in shape, they may be of practically any cross sectional form provided the average transverse section is sufficiently great to obtain a low "Q," and to enable adequate capacitive coupling at points 30. If desired, for example, the antenna elements may each be formed in the shape of a right circular cylinder, or may be of diamond or elliptical vertical section: preferably, as in later embodiments exemplified by Figs. 6, 7 and 8, they may be wide flat strips.

Though the auxiliary dipoles 28 are preferably longitudinal strip conductors, as shown in this and other modifications of the invention, they may be of other physical shape. The strips **28**, Fig. 2, may be increased in width circumferentially of the main dipole elements if desired. It is also possible to use but one auxiliary dipole **28** or to replace all of them by a cylindrical conductor of the same length disposed concentrically about the main dipole elements **12** and **14**. The band-pass characteristics of the antenna may be varied by bending the ends of dipoles **28** toward or away from the main dipole **10** to increase or decrease the capacity coupling between them.

For use in transmission, excitation is applied to the antenna through the transmission line **18**. Assuming the excitation frequency is in the neighborhood of the natural or fundamental resonant frequency of dipole **10**, it will radiate but since this frequency is much lower than the natural frequency of the auxiliary dipoles, they produce very little radiation at such frequency. However, because the dipoles **28** are capacitively coupled to both of the radiating elements **12** and **14**, the capacitance between the latter is effectively increased and the resonance band of dipole **10** is effectively widened.

Assuming now the excitation frequency is much higher (approximately the natural or fundamental frequency of the auxiliary dipoles **28**), the main dipole **10** produces very little radiation; however, the auxiliary dipoles **28**, each excited through the capacitance at points **30**, produce considerable radiation at such high frequency.

At all frequencies intermediate their natural frequencies, the dipoles **10** and **28** act in supplementary manner to produce satisfactory radiation or absorption characteristics of the composite antenna formed by them, and in fact, as later discussed in connection with Fig. 3, the antenna system of Fig. 1 has very satisfactory characteristics considerably below the natural frequency of dipole **10** and considerably above the natural frequency of dipole **28**.

In one physical embodiment of Fig. 1, the overall length A of the main dipole **10** was approximately 42 inches, the length of each auxiliary dipole was approximately 17 inches and the maximum diameter C of each main dipole element was approximately 8 inches. The antenna so dimensioned had satisfactory radiation characteristics throughout the range of from 100 megacycles to 300 megacycles which covers a large number of channels assigned to public, private and government services for many uses including television broadcast, frequency-modulated broadcast, and point to point communications. It should be noted the ratio of the terminal frequencies of this band is 3 to 1, whereas with previous so-called broad-band antennas the ratio of terminal frequencies was at best only about 1.25 or 1.5 to 1 and that obtainable only by recourse to dipole elements of excessively large cross-sectional dimensions, prohibitive, on shipboard for example, where space is at a premium and in all cases creating difficult mounting and construction problems. It should further be noted that the operating range of such previous so-called broad-band antennas did not extend through any harmonic or multiple resonance frequency of the antenna.

An antenna constructed in accordance with the invention is not dimensionally critical: that is, the shape and size of the dipole elements may be varied within reasonable limits without adversely affecting the radiation or absorption characteristics which can be adjusted for attainment of the desired band-pass by bending or deforming the auxiliary dipoles or by changing the value of inductance **24**.

For efficient transfer of energy between any antenna and the associated transmission line, the standing-wave-ratio, later herein defined, must be low and ideally is unity. However, an antenna is considered an efficient radiator if the standing-wave-ratio (SWR) does not exceed 2 or 3 and as a satisfactory absorber if the standing-wave-ratio is not much greater than 5.

Fig. 3 is the SWR curve of an antenna constructed in accordance with Fig. 1 and having the dimensions above given. The main dipole **10** was dimensioned to resonate at frequency f_1, somewhat higher than 100 megacycles and the auxiliary dipoles **28** were dimensioned to resonate at frequency f_2 somewhat lower than 300 megacycles. As shown in Fig. 3, the standing-wave-ratio, though varying within the limits 100 to 300 megacycles, did not, at any frequency within those limits, exceed 2 and did not exceed 5 throughout a much wider range of frequencies extending well below 100 megacycles and substantially above 300 megacycles. For this curve, the characteristic impedance of the line **18** used with the antenna was about 50 ohms.

During either radiation, for transmission, or absorption, for reception, the antenna of Fig. 1 acts as, and may be considered the operating equivalent of, a band-pass filter with broad-band characteristics. This is true not only of the particular construction shown in Fig. 1, but of all modifications including those later herein disclosed and described.

The curve **34**, Fig. 4, is exemplary of the reactive impedance characteristic of a dipole having small transverse cross section, for example, a wire or rod of small diameter. At each of points **36** where the curve **34** crosses the horizontal axis, the slope of the curve is steep, indicating sharp resonance. An antenna having such sharp resonance is wholly unsuited for efficient radiation at frequencies appreciably displaced from its fundamental resonant frequency because of the resulting large mismatch between its impedance and that of the associated transmission line.

Broadening the dipole elements into a large surface of revolution, as in Fig. 1, effects flattening of the reactive impedance of the antenna, generally as shown by curve **38**. The greatly decrease slope of curve **38** at each of points **36** where the curve crosses the horizontal line (zero reactance) indicates a condition of substantial resonance exists over a fairly broad band, insufficient, however, to attain the results here sought. The expedient of increasing the thickness or cross section of a single dipole cannot, practically be extended to attain band widths of the magnitude obtained by my composite antenna. By the further addition of capacitance by addition of the auxiliary dipoles **28** to the primary dipole **10**, there is produced the characteristic curve **40**, indicating my antenna, Fig. 1, has net capacitive reactance throughout the frequency range of 100 to 300 megacycles, and that the magnitude of the changes in reactance throughout the range is very materially reduced.

Having in mind the composite antenna including the auxiliary dipoles and widened main dipole has the frequency-reactance characteristic exemplified by curve **40**, the effect of the inductance **24** having the rising frequency-reactance characteristic **42** is evident from Fig. 5. It is pointed out the uncorrected antenna reactance characteristic **40**, throughout a wide range of frequencies, closely approximates a mirror image or reflection of curve 42 about the horizontal axis. Consequently, within that range and by use of suitable inductance 24, the resultant antenna reactance is a nearly straight line 44 practically coincident with the horizontal axis; otherwise stated the antenna has very small net reactance throughout a broad frequency band. To attain this characteristic with the antenna constants above given, the coil 24 had an inductance of about 0.3 microhenry.

The inductance 24 may, as shown in Fig. 1, be connected across the terminals of the transmission line 18; to improve the symmetry when the transmission line is, as preferably, of the concentric conductor type the outer conductor 22 of the line may be connected to the center of inductance 24, the other connections remaining unchanged.

Though the construction and operation of the antenna has been described with inductive reactance 24 connected between the main dipole elements, it has been found that a capacitive reactance, or condenser, may be so connected in lieu of coil 24. The effect of such insertion upon a dipole antenna having a characteristic such as exemplified by curve 38 of Fig. 4 is to reduce the upper or positive peak value and, with addition of auxiliary dipoles, the resultant characteristic will approximate curve 40. In other words, the antenna reactance with a condenser substituted for coil 24 is low.

From the foregoing, it is evident a broad band antenna need not have the excessive dimensions otherwise required in absence of the capacitive and radiating effects of the auxiliary dipoles 28. Moreover and from a mechanical standpoint, the antenna may be of simple durable construction, easily installed and can be manufactured inexpensively and without need to hold close tolerances.

The modification shown in Fig. 1 is disclosed in my copending application Serial No. 622,657, now abandoned, of which this application is a continuation in part.

Subsequent embodiments of the invention which are not only of even less expensive and simpler construction but which still further and very materially increase the frequency coverage are shown in Figs. 6, 7 and 8.

In the modification shown in Figs. 6 and 7, the main dipole 10A comprises two elements 12A, 14A each consisting of a wide flat strip of aluminum or other suitable metal. The inductance per unit length of each element is low and the capacitance per unit length is high, i. e., the ratio of inductance to capacitance per unit length is low. The "Q" of each dipole is therefore low, for example, of the order of 5 and preferably much less. The two strips 12A, 14A are held in axial alignment by their attachment to a strip or plate 16A of suitable insulating material. near their adjacent ends, the strips 12A and 14A are bent away from their support 16A to afford capacitive coupling to the auxiliary dipole 28A.

In this modification, like that of Fig. 8 later described, the ends of the auxiliary dipole are well away from the main dipole so that in effect each of the main dipole elements 12B, 14B is respectively coupled by capacity to an intermediate point of the overlying half of the auxiliary dipole. The band characteristic is generally that of two low Q dipoles 10A, 28A which are parallel throughout (Fig. 6A), but interconnected by condensers K, K to points a and b selected to obtain a satisfactory impedance match between the antenna and line at the higher frequencies of the band for which the auxiliary dipole is effective as a radiator or absorber.

The coupling capacities are also significant at the lower frequencies of the band. For example, the coil 24A may be selected so that with these capacities it forms a loop circuit which is resonant at about the frequency for which the main dipole exhibits fundamental resonance. Therefore, at that frequency, this loop circuit is the equivalent of a very high shunt impedance and the main dipole consequently performs much as a simple center-fed half-wave dipole. At lower and higher frequencies, this loop circuit exhibits inductive and capacitive reactance respectively so that the main dipole again becomes resonant at a frequency below its natural frequency and exhibits reduced impedance at frequencies above its natural frequency.

The auxiliary dipole 28A is also a wide strip of aluminum or other suitable metal having small inductance and large capacitance per unit length. It is supported centrally of the main dipole 10A with its longitudinal axis substantially in alignment with and parallel to the axis of the main dipole by a metal bracket 26A which comprises two U-shaped members respectively fixedly attached to dipole 28A and the support 16A and adjustably attached to each other as by bolts 50. The wide faces of the strips 12A, 14A and 28A are parallel to each other for large mutual coupling reactance of the dipoles. The adjustment afforded by the split bracket permits variation of capacitive coupling between the dipoles in empirical attainment of the desired band width.

The antenna assembly is supported by the mast 53, preferably tubular for enclosure of the transmission line. The mast may be fixedly or rotatably fastened at or near its base to a tower, roof, vehicle body or other fixed or mobile structure. In this and other modifications disclosed, the axis of the antenna may be vertical or horizontal in dependence upon the polarization of the waves to be transmitted or received.

Preferably and as shown, the adjacent ends of the main dipole elements 12A, 14A are connected to an inductance 24A having generally the purpose of coil 24 of Fig. 1. It is preferably included as one element of the broad band-pass network N, Fig. 9, comprising the self and mutual reactances of the two dipoles and their effective resistances. As is later more fully discussed in connection with the quite similar antenna construction shown in Fig. 8, this network as seen by the transmission line 18 is the equivalent of a reactance X and a resistance R in series, Fig. 10. The effective magnitude of the resistance R and the magnitude of the reactance X vary with frequency but the main and auxiliary dipoles are so dimensioned and coupled that the vector sum of the resistance and reactance remains quite constant throughout an extremely wide band of frequencies.

In the embodiment shown in Fig. 8, the main dipole 10B comprises two wide strips 12B, 14B of suitable conductors affording a dipole having a low "Q" and an auxiliary dipole 28B, also a wide conductive strip to obtain a low "Q." The auxiliary dipole 28B is supported by housing 26B in that position with respect to the main dipole 10B which by virtue of the dimensions of the dipoles and the coupling between them affords the desired band-pass characteristic. For that purpose, the housing 26B is suitably fastened to the supporting strip 16B of the main dipole. The housing 26B, preferably of good high-frequency insulating material, also forms an enclosure for the loading reactance 24B, and for the connections of transmission line 18 to protect them from weather conditions otherwise temporarily or permanently affecting the operating characteristics of the antenna.

Both the main dipole 10B and the auxiliary dipole 28B have small inductance and large capacitance per unit length so that considered individually neither of them exhibits sharp resonance at any frequency. The complex network N, Fig. 9, formed by the self and mutual reactances X_1, X_2 and X_3X_4 of the dipoles and their effective resistances R_1, R_2 may be represented by an equivalent circuit, Fig. 10, comprising reactance X and resistance R in series across the antenna end of the transmission line 18. The magnitudes of reactance X and resistance R are different for different frequencies, but in accordance with this invention the reactance X is low for all frequencies within a very wide band and at each frequency within that band the magnitudes of reactance and resistance are such that their vector sum closely approximates their vector sum at all other frequencies within the aforesaid wide band. The significant difference between the characteristics of my antenna system, Figs. 6, 7, 8, and that of the usual dipole can best be illustrated by specific examples based on measurements.

Referring to Fig. 11, the dot-dash curve 34A is the frequency-reactance curve of a dipole of ⅜'' diameter copper tubing which is a half-wavelength long at a frequency of about 60 megacycles. As evident from the curve, within a frequency range of from about 40 to 200 megacycles, the reactance varies from well over 1000 ohms (inductive) to well over 1000 ohms (capacitive) and rapidly changes with frequency particularly in the vicinity of points 36A, 36B and 36C corresponding with frequencies of about 60, 120 and 180 megacycles respectively.

Within the range of 40 to 200 megacycles, the reactance of the dipole swings back and forth in sign, that is, it changes to positive or inductive reactance from negative or capacitive reactance as the frequency is increased from below to above about 60 megacycles, reverses back to capacitive reactance as the frequency is increased from below to above 120 megacycles, and again shifts to inductive reactance as the frequency shifts from below to above 180 megacycles. In other words, the effective reactance of the dipole changes sign, and changes rapidly in magnitude, at frequencies corresponding with the fundamental and harmonic wavelengths of the dipole.

Furthermore, the effective resistance of the single thin dipole varies widely over this same range of frequencies; as shown by curve 51, Fig. 11, the effective resistance is low, less than 100 ohms, for frequencies at which the antenna is a half-wavelength long, but is very high, about 3,000 ohms, for frequencies at which the antenna is a full wavelength long.

Still referring to Fig. 11, the solid line curve 40A is the frequency-reactance curve of an antenna constructed in accordance with Fig. 8 and having the following dimensions for service as a transmitting antenna in the frequency range of from about 40 to 200 megacycles: each of the dipole elements 12B, 14B and 28B was a strip of aluminum one-eighth of an inch thick and four inches wide: the dimensions E and F of each main dipole element were 34 inches and 14 inches respectively: the length B of the auxiliary dipole was 28 inches: and the spacing G was 2½ inches.

Throughout the range of frequencies from 40 to over 200 megacycles, the equivalent series reactance X of that antenna system as evident from inspection of curve 40A, was low and nowhere in that range varied rapidly. Moreover, the effective resistance R of that antenna system, as shown by curve 52, Fig. 11, was throughout that range of frequencies of such magnitude at each frequency that the effect of the variations in reactance upon the effective antenna impedance was minimized. The variation in magnitude of the effective resistance with frequency is far less than the usual dipole throughout the frequency range of 40 to 200 megacycles.

In brief, my antenna system, and particularly as exemplified by Figs. 6, 7 and 8 comprises multiple low "Q" dipoles of different lengths so coupled that their self impedances and mutual impedances form a network (n, Fig. 9) which when reduced to its simple equivalent series circuit (Fig. 10) for each frequency will provide at the terminals of the transmission line a low reactance X and a series resistance R of such magnitude that for all frequencies throughout an extremely wide range, the effective antenna impedance

$$[Z=\sqrt{X^2+R^2}]$$

will so closely match the characteristic impedance of the transmission line that the stand-wave-ratio will be low throughout that wide range of frequencies.

The standing-wave-ratio (SWR) may be defined as

$$(1) \qquad SWR=\frac{1+K}{1-K}$$

wherein

$$(2) \quad K=\sqrt{\left[\frac{R^2-Z_0^2+X^2}{(R+Z_0)^2+X^2}\right]^2+\left[\frac{2Z_0X}{(R+Z_0)^2+X^2}\right]^2}$$

in which

Z_0=characteristic impedance of transmission line

R=equivalent series resistance of antenna (Fig. 10)

X=equivalent series reactance of antenna (Fig. 10)

By substitution in Equation 2 of the magnitudes of effective reactance and resistance ascertainable from curves 40A and 52 of Fig. 11 for the frequencies within the range of from 40 to over 200 megacycles, it is apparent the standing wave ratio is less than 3 when the characteristic impedance of the transmission line is 300 ohms. This was verified by actual measurements which as plotted resulted in curve SWR of Fig. 12. This antenna system is therefore efficient for transmission at any frequency within the range of 40 to well over 200 megacycles; i. e., over better than a 5 to 1 frequency coverage, and is efficient for reception over a much wider range.

Furthermore, and as evident from inspection of Figs. 13 to 15, the characteristic impedance of the transmission line 18 is not critical when this antenna is used. Throughout the same extremely wide frequency range, the standing-wave-ratio (SWR) is suitably low, less than 3, when the antenna is used with transmission lines having impedances of 250, 200 and 150 ohms, and also, as can be verified, with higher and lower impedance lines although if the line impedance is too far above 300 ohms or too far below 150 ohms, the standing-wave-ratio for this particular antenna will be excessive.

From the general rules above given, illustrated by specific example, those skilled in the art may readily design and construct other broad band antennas suited individually to cover a wide range in this and other portions of the radio frequency spectrum and which throughout that range will satisfactorily match the characteristic impedance of the associated transmission line.

The auxiliary dipole or dipoles not only provide for efficient radiation or absorption over a broad band of frequencies but may be dimensioned concurrently to insure that throughout the band the field pattern is free of nulls in the desired direction of reception or transmission. For example, with the particular composite antenna discussed in connection with Fig. 11, at each of various frequencies in the lower frequency portion of the band, say from 40 to 100 megacycles, at which the main dipole is primarily effective, the field pattern is approximately the same as those of an ordinary dipole; that is, it has two lobes forming a figure eight, affording best reception or transmission in a line of direction normal to the longitudinal axis of the antenna.

At the higher frequencies of the range, the field pattern of the main dipole, of and by itself, assumes different forms having marked nulls in the desired direction of operation. For example, the field pattern of the main dipole at about 120 megacycles is a four-lobed, or clover-leaf pattern exemplified by the broken line curve V of Fig. 16, having wide, deep nulls in both the Y and Z directions normal to the antenna axis. At still higher frequencies, say about 200 megacycles, the field pattern of the main dipole is a six-lobed figure similar to curve V plus two minor lobes normal to the line Y—Z.

At the higher frequencies, however, the auxiliary dipole becomes increasingly effective so that its individual directional characteristic modified that of the main dipole with the result that at all the higher frequencies at which undesirable nulls would otherwise occur, the combined field pattern of the dipoles is one affording satisfactory reception or transmission in the desired direction. For example, the radiation characteristic of the combined antenna system at 120 or 200 megacycles, as generally exemplified by the solid line curve W of Fig. 16, has substantial directional selectivity favoring reception or transmission in the desired line of direction Y—Z, whereas the main dipole itself, at that same frequency markedly discriminates against reception or transmission in that same line of direction.

Generally and in brief, the auxiliary dipole not only provides for proper matching of the antenna and its transmission line over a wide band of frequencies, but also controls the amplitude and phase of the current in the main dipole, particularly at its harmonic frequencies, thus to prevent serious lobing and appearance of undesirable nulls in the field pattern at any frequency within that wide band.

In view of the foregoing description of their dimensions, spacing and characteristics, the auxiliary dipoles of Figs. 1, 2, 6, 7 and 8 should not be confused with the directors or reflectors used in directional antenna arrays to attain enhanced directional selectivity at a particular frequency. In physical and electrical length, directors and reflectors differ only a few per cent, or less, from the associated driven dipole so that their individual field patterns at different frequencies and their individual frequency-reactance characteristics are practically identical with those of the main dipole. Consequently, unlike the auxiliary dipoles of this invention, reflectors and directors further increase the sharpness of resonance of the main dipole and so further reduce the already narrow frequency range in which it can efficiently radiate or absorb radio-frequency energy; moreover, reflectors and directors do not avoid nulls in the desired direction of reception or transmission should the antenna be used at harmonics of its fundamental frequency of resonance.

It shall be understood the invention is not limited to the specific embodiments disclosed and that changes and modifications may be made within the scope of the appended claims.

What is claimed is:

1. A broad-band antenna system for efficient transmission or reception throughout a wide band of frequencies including many channels and in a desired direction comprising mutually coupled low Q dipoles of such substantially different length that they respectively exhibit fundamental resonance at frequencies whose ratio is greater than 1.5, the field patterns of said dipoles complementarily combining at each of all frequencies of the band in avoidance of nulls in said desired direction and the self and mutual reactances of said dipoles combining at each of all frequencies of the band to provide an equivalent reactance which is low, said dipoles being spaced apart in parallel axial alignment to permit capacitive coupling therebetween, and a transmission line connected to the center point of the longer dipole.

2. A multi-channel broad-band antenna system for efficient transmission or reception in a desired direction and throughout a band the ratio of whose terminal frequencies is greater than 2 comprising mutually coupled low Q dipoles having substantially different lengths, an insulating support between said dipoles for maintaining them in parallel axial alignment and capacitively coupled, said dipoles respectively exhibiting fundamental resonance at frequencies corresponding with said terminal frequencies, the shape and relative size of the field patterns of the individual dipoles insuring the joint pattern at each of all frequencies of the band shall be free of a null in said desired direction, a transmission line connected to the center point of said longer dipole, an inductance connected in parallel across said transmission line of sufficient magnitude to compensate for the capacitive reactance of the coupled dipoles substantially through said band, the self and mutual impedances of said dipoles insuring the effective impedance of the antenna system is for each frequency of said band the equivalent of a reactance in series with a resistance, said reactance and resistance being of such a value that on a given transmission line the standing-wave-ratio will be low over a wide band of frequencies.

3. A multi-channel broad-band antenna system for efficient transmission or reception in a desired direction and throughout a band the ratio of whose terminal frequencies is greater than 2 comprising a pair of mutually coupled low Q dipoles of substantially different lengths, an insulating support between said dipoles for maintaining them in parallel axial alignment and capacitively coupled, one of said dipoles exhibiting fundamental resonance at a frequency in said band for which another of them exhibits harmonic resonance in avoidance of nulls in said

desired direction, and a transmission line connected to the center point of said longer dipole for effecting interchange of energy with said dipoles, an inductance sufficient to compensate for the capacitive reactance of said coupled dipoles connected in parallel across said transmission line, the self and mutual impedances of said dipoles forming a complex band-pass network whose series equivalent at the transmission line terminals appears at each frequency of said band to be a reactance in series with a resistance of such magnitude that the standing-wave-ratio is not greater than 3 for transmission or 5 for reception.

4. A multi-channel broad-band antenna system having low net reactance throughout a band of frequencies the ratio of whose maximum frequency to minimum frequency is greater than 1.5 comprising a first center-fed dipole resonant at a frequency substantially the said minimum frequency, a number of further dipoles circumferentially arranged about said first dipole, said number of further dipoles being greater than 2, said further dipoles being shorter in length than said first dipole and resonant at a frequency substantially the said maximum frequency, said further dipoles being capacitively coupled at their ends to areas intermediate the ends of the conductors of said first dipole.

5. A multi-channel antenna system broadly resonant over a band of frequencies the ratio of whose terminal frequencies is greater than 1.5 comprising a first center-fed dipole resonant at a frequency within said range, a second end-fed dipole capacitively coupled to said first dipole resonant at a substantially different frequency within said range, and inductance connected to the center of said first dipole of magnitude to compensate for capacitive reactance of the coupled dipoles substantially throughout said band.

6. A multi-channel broad-band antenna system comprising a first dipole consisting of a first radiating element of large transverse cross section and a second radiating element of large transverse cross section in axially-abutting relation, an insulating support joining said radiating elements, a plurality of shorter dipoles mounted on said support circumferentially and equally spaced about said radiating elements, a transmission line connected to the first and second radiating elements at their abutting ends, and an inductance connected across said transmission line in parallel with said radiating elements, the ends of said plurality of shorter dipoles being in capacitively-coupled relation respectively with areas intermediate the remote ends of said radiating elements and coacting therewith to provide for low net reactance of the antenna system over a band of frequencies whose maximum frequency to minimum frequency is greater than 1.5.

7. A multi-channel antenna system comprising a plurality of cooperatively associated main and auxiliary low Q dipoles of substantially different length and maintained in parallel axial alignment, said main dipole being of large transverse cross-section and said auxiliary dipoles being a plurality of shorter dipoles placed circumferentially and equally spaced around the large main dipole and capacitively coupled thereto at their ends, a transmission line connected to the center of said main dipole, and a lumped inductance at the center of said main dipole connected in parallel thereto across said transmission line, the reactances of all of said dipoles cooperating to produce a substantially resonant condition throughout a wide band of frequencies the ratio of whose terminal frequencies is greater than 2.

8. A multi-channel transmitting-receiving antenna construction forming a band-pass network comprising main and auxiliary low Q dipoles of substantially different length and maintained in parallel alignment, said dipoles being flat strips whose inductances per unit length are small and whose capacities per unit length are large, a transmission line connected to the center of one of said dipoles, lumped inductance at the center of one of said dipoles connected in parallel thereto across said transmission line, the ends of the auxiliary dipole being capacitivity coupled to the main dipole, all of said reactances cooperating to produce a substantially resonant condition throughout a wide band of frequencies, the ratio of whose terminal frequencies is greater than 2.

9. A multi-channel antenna system broadly resonant throughout a band of frequencies the ratio of whose maximum frequency to minimum frequency is greater than 1.5 comprising a pair of low Q dipoles of substantially different physical and electrical lengths, an insulating support between said dipoles for maintaining parallel alignment so that said dipoles are capacitively coupled, a transmission line center feeding one of said dipoles, and lumped inductance connected across said transmission line, said different lengths of said dipoles respectively corresponding with substantially different resonant frequencies within said band and having such individual and mutual reactances that said system exhibits low net reactance throughout said band.

10. A multi-channel antenna system broadly resonant throughout a band of frequencies the ratio of whose maximum frequency to minimum frequency is greater than 1.5 comprising dipoles individually resonant at substantially different frequencies, said dipoles being of substantially different length and positioned for capacitive coupling therebetween, a transmission line for center-feeding one of said dipoles, and inductance of magnitude to compensate for capacitive reactance of the coupled dipoles substantially throughout said band connected to said transmission line, said dipoles having such individual and mutual reactances that said system exhibits low and capacitive reactance throughout said band of frequencies.

11. A multi-channel antenna system broadly resonant throughout a band of frequencies the ratio of whose maximum frequency to minimum frequency is greater than 1.5 comprising dipoles individually resonant at substantially different frequencies, said dipoles being of substantially different length and positioned for capacitive coupling therebetween, a transmission line for center-feeding one of said dipoles, said dipoles having such individual and mutual reactances that said system exhibits low and capacitive reactance throughout said band of frequencies, and lumped inductance at the center of one of said dipoles connected in parallel across said transmission line compensating for said low capacitive reactance.

12. A broad-band antenna for efficient transmission or reception throughout said band comprising a pair of axially aligned broad strips forming a center-fed dipole, and a second shorter dipole exhibiting fundamental resonance at a frequency within said band for which said first-named dipole exhibits harmonics resonance, said second-named dipole comprising a broad strip

having its wide face parallel to and spaced from the wide faces of said pair of strips to provide mutual capacitive reactance which with the self-reactances of the dipoles insures low effective reactance at the center of said first-named dipole at all frequencies within said band.

13. A broad-band antenna comprising a pair of broad strips forming a low Q center-fed dipole, a transmission line connected to adjacent ends of said strips, an insulating support mechanically connecting said strips in axial alignment, an insulating housing on said support and enclosing said ends of said strips and the transmission line connections thereto, and a second shorter low Q dipole comprising a broad strip supported by said housing with its wide face parallel to the wide faces of said pair of strips to provide capacitive coupling thereto.

14. A broad-band antenna system affording a standing-wave-ratio not greater than 2 over a frequency band the ratio of whose maximum frequency to minimum frequency is greater than 1.5 comprising a first center-fed dipole having an inductance connected at its center in parallel across the feed line, a plurality of shorter dipoles placed circumferentially and equally spaced about said first dipole in parallel axial alignment therewith, said shorter dipoles being capacitively coupled to said first dipole at their ends, said first dipole being of length for acting as the primary radiator at the lower frequencies of said band and said shorter dipoles acting as the primary radiators at the higher frequencies of said band.

15. A broad-band antenna system comprising a first center-fed dipole of large average transverse cross section and having an inductance connected at is center across the feed line, a plurality of shorter dipoles positioned circumferentially about said first dipole, said shorter dipoles arranged about said first dipole in spaced parallel relation and capacitively coupled therewith to provide for low net reactance of said system throughout a band of frequencies the ratio of whose maximum frequency to minimum frequency is greater than 1.5.

FREDERICK A. KOLSTER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,044,779	Hanson	June 23, 1936
2,188,389	Cork et al.	Jan. 30, 1940
2,192,532	Katzin	Mar. 5, 1940
2,268,640	Brown	Jan. 6, 1942
2,287,220	Alford	June 23, 1942
2,289,856	Alford	July 14, 1942
2,297,329	Scheldorf	Sept. 29, 1942
2,311,364	Buschbeck et al.	Feb. 16, 1943
2,380,333	Scheldorf	July 10, 1945

FOREIGN PATENTS

Number	Country	Date
879,230	France	Nov. 10, 1942