March 18, 1947. R. S. WEHNER 2,417,793

ANTENNA

Filed Aug. 1, 1944

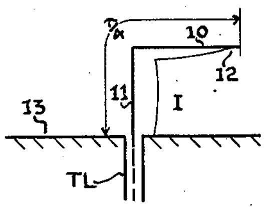


Fig. 1.

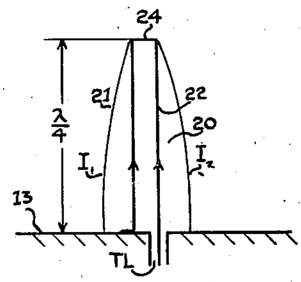


Fig. 2.

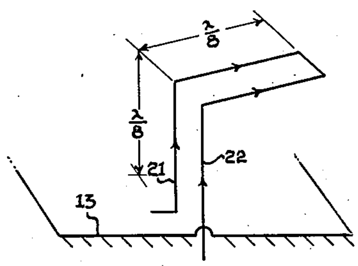


Fig. 3.

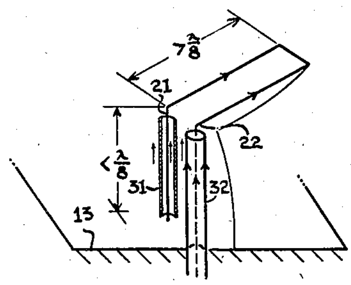


Fig. 4.

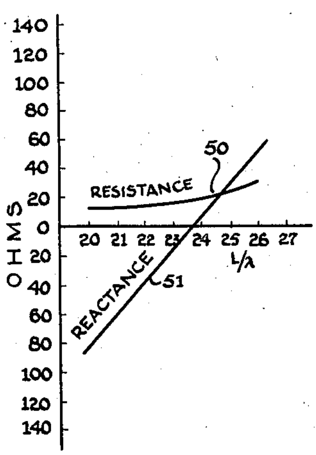


Fig. 5.

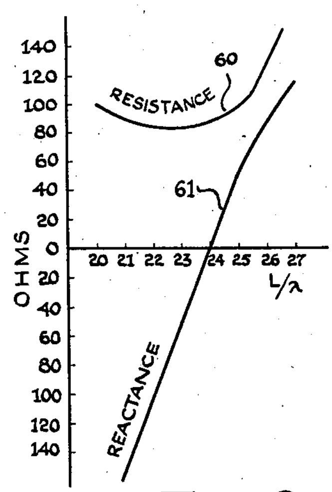


Fig. 6.

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Patented Mar. 18, 1947 2,417,793

# UNITED STATES PATENT OFFICE

2,417,793

## ANTENNA

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Application August 1, 1944, Serial No. 547,548

8 Claims. (Cl. 250—33)

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The present invention relates to broad-band antennas and, more particularly, to such antennas which are suitable for use on aircraft.

An object of the present invention is the provision of an aircraft antenna adapted to radiate vertically polarized radio waves.

A further purpose of the present invention is the provision of a broad-band aircraft antenna in which the vertical height, or maximum extension from the skin of the airplane, is of the order of or less than one-eighth of the resonant wavelength.

Another object of the present invention is the provision of an aircraft antenna providing a more nearly hemispherically symmetrical field pattern than is furnished by heretofore known antennae.

Still another object of the present invention is the provision of an aircraft antenna which may be conveniently energized from a conventional coaxial transmission line.

A further object of the present invention is the provision of an aircraft antenna which has good mechanical properties, one which lends itself to a mechanically strong mounting without danger of impairing its electrical properties.

The foregoing objects and others which may appear in the following detailed description are attained in accordance with the principles of the present invention by providing an antenna in the form of an inverted-L or bent quarter-wave mast antenna in which the L-shaped radiating element is in the form of a pair of parallel closely spaced conductors connected together at one end and fed in a series arrangement from the other end. As the two conductors are identical in cross-section, equal currents must necessarily flow in the conductors; but since only half of the total current flows into the driven element the input resistance at resonance is four times that of a conventional dipole.

The present invention will be more fully understood by referring to the following detailed description which is accompanied by a drawing in which Figure 1 illustrates in elevation and for the purpose of comparison only an inverted-L type antenna at present known in the art. Fig. 2 illustrates a folded-quarter-wave mast antenna utilizing some of the principles of the present invention, while Figures 3 and 4 illustrate in elevation and partly in section, inverted-L antennas combining the features of the folded-dipole shown in Figure 2 and the bent-dipole shown in Figure 1, while Figures 5 and 6 are curves illustrating graphically the electrical properties of the antennas of the present invention.

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Referring now to Figure 1, there is illustrated an antenna 10 in the form of an inverted-L having a vertical portion 11 and a horizontal portion 12. The antenna is mounted over a conductor sheet 13 constituting an electrically effective ground plane. This conducting sheet 13 may be a portion of the metallic skin or coating of the fuselage of an aircraft. Antenna 10 may be energized at the lower end of vertical portion 11 by means of a coaxial transmission line TL. The inner conductor of the transmission line TL is directly connected to the vertical portion 11 of antenna 10 while the outer shell of the coaxial transmission line TL is electrically connected to the ground plane 13. The current distribution along the length of the antenna 10 is indicated by curve I close to the adjacent conductors 11 and 12.

Referring now to Figure 2, there is shown a vertical mast antenna 20 in the form of a pair of closely parallel conductors 21 and 22 connected together at their top ends by a short bar 24. The antenna 20 is vertically disposed with respect to the conducting ground plane 13 similar to that shown in Figure 1. The lower end of conductor 21 is directly electrically connected to the ground plane 13 while the lower end of conductor 22 passes through an aperture in the plane 13 and is connected to the inner conductor of a coaxial transmission line TL. The transmission line TL may, of course, be connected to conventional transmitting or receiving equipment (not shown). Since conductor elements 21 and 22 are identical in cross-section, equal currents flow in them. The magnitudes of the currents are indicated by the light curves I—1 and I—2, while the instantaneous directions are indicated by the arrowheads on the conductors 21 and 22. The pair of conductors are so closely spaced that they radiate as a single conductor.

Since the current flowing into conductor 20 from the transmission line TL is only one-half of the total current flowing in the antenna, the input resistance presented to the transmission line TL at resonance is four times that of a conventional dipole. The higher input resistance is desirable in that it results in a greater intrinsic band width, as will now be shown by the following discussion.

The impedance characteristics of an antenna may be described in terms of three factors: namely, the value of its input resistance, the rate of change of resistance with frequency, and the rate of change of reactance with frequency. For series-resonant antennas the resistance is a much more slowly varying function of frequency than is the reactance; consequently the two important factors affecting the band-width obtainable with a given antenna are:

(1) the resonant resistance, called the impedance level and

(2) the rate of change of reactance with frequency, called the steepness of the reactance curve.

Other things being equal, a high-impedance-level antenna can be matched to a transmission line by means of a simple series matching section, over a much wider range of frequencies than can an antenna of low impedance. In other words, greater band-width can be obtained by means of a series matching section if that section is used to transform the antenna impedance down to the level of the impedance of the feed line than if the section must be used to transform the antenna impedance up to that of the line.

For a given impedance level greater band-width can be obtained with an antenna whose rate of variation of reactance with frequency is low, than with one whose reactance curve is steep. The truth of this statement is evident at a glance at any transmission line chart, and indeed is almost axiomatic: broad-band antennas are "flat" antennas.

While the foregoing discussion is believed adequate for enabling a complete understanding of the present invention, those interested in a more complete analysis are referred to my corresponding application #547,549, filed August 1, 1944.

The antenna of Figure 2 may be improved as shown in Figure 3 wherein the conductors 21 and 22 are bent at right angles at substantially their midpoints forming an inverted-L shaped antenna. Thus the advantages of the good field pattern and the small physical size are added to the inherently broad-band features of the antenna of Figure 2. The resonant resistance of the antenna of Figure 3 is very nearly four times that of the antenna of Figure 1, and even though the bent-half-folded dipole of Figure 3 has a reactance curve which is steeper than that of the inverted-L antenna of Figure 1, it may be more easily matched to a 50-ohm coaxial transmission line because of its much higher impedance level as mentioned above with respect to the antenna of Figure 2.

A preferred form of the present invention is that shown in Figure 4. Here both sides of the vertical portions of conductors 21 and 22 are surrounded by coaxial sleeves 31 and 32 extending up to nearly the bend in the antenna. The lower ends of both sleeves are electrically connected to the skin of the ship as indicated by ground plane 13. The purpose of sleeve 32 around conductor 22 is to shift the feed point of the antenna from a region of fairly high current and low resistance as at the bottom of conductor 22 on Figure 3 to a region of lower current and proportionately higher resistance, as at the bend in conductor 22. This results in a further step-up in the input impedance and makes possible also a reduction in vertical height without a loss in the intrinsic band width. As indicated in the drawing, the vertical height may be now less than one-eighth wavelength while the horizontal portion may be somewhat longer than one-eighth wavelength, in some cases as long as three-sixteenths of the operating wavelength.

In Figure 5, I have shown the effect on the impedance looking into the feed point of the antenna of Figure 1 caused by a variation in the ratio of the over-all length L to the operating wavelength $\lambda$. Curve 50 shows that the resistance varies from a value of the order of 16 ohms up to 25 ohms as the ratio $L/\lambda$ varies from .2 to .26. Over the same change in the ratio $L/\lambda$ the reactance varies as shown by curve 51 from a value of $-80$ ohms to a value of $+75$ ohms. It will be noted that, as compared to an ordinary quarter wave stub antenna, the impedance of the inverted-L is characterized by a low reactance and a steep reactance curve. Both of these features may be accounted for by considering that the effect of the bend in the antenna is to introduce a cooperative reactance due to the relationship between the horizontal member of the inverted-L and the ground plane in parallel with the impedance of the original vertical stub. Such a shunt capacity results in both a reduction in input resistance and an increase in the reactive value of the antenna.



Figure 6 illustrates the variation in input impedance of the antenna of Figure 3 for a similar variation in the ratio of overall length to wavelength. While the overall resistance variation is somewhat greater as shown by curve 60, the mean value is also greater by a multiplying factor of approximately four, thus increasing the ease of matching the antenna to the transmission line. It will be noted that the resistance varies less than ten per cent plus and minus about a mean value of 90 ohms as the ratio $L/\lambda$ is varied from .2 to .26. For the same change in the ratio $L/\lambda$ curve 61 shows a variation in reactance from $-150$ ohms to $+120$ ohms. It is thus about twice as steep as curve 51 of Figure 5.

Application of the folded dipole principle to the inverted-L antenna really is a four-fold increase in impedance level and only a two-fold increase in the steepness of the reactance curve; while the benefit gained in the former effect is partially counteracted by the latter effect, there is still a considerable improvement in intrinsic band width.

While I have illustrated a particular embodiment of the present invention, it should be clearly understood that it is not limited thereto since many modifications may be made in the several elements employed and their arrangement, and it is therefore contemplated by the appended claims to cover any such modifications as fall within the spirit and scope of the invention.

What is claimed is:

1. A broad-band antenna in the form of an inverted-L disposed over a conductive sheet forming a ground plane, said antenna including a pair of closely adjacent parallel conductors bent at substantially their midpoint, one pair of adjacent ends of said conductors being connected together, and one of the remaining ends being connected to a conductor of a transmission line.

2. A broad-band antenna in the form of an inverted-L disposed over a conductive sheet forming a ground plane, said antenna including a pair of closely adjacent parallel conductors bent at substantially their midpoint, one pair of adjacent ends of said conductors being connected together, one of the remaining ends being connected to said conductive sheet, and the other passing through said sheet and being connected to a conductor of a transmission line.

3. A broad-band antenna in the form of an inverted-L disposed over a conductive sheet forming a ground plane, said antenna including a pair of closely adjacent parallel conductors bent at substantially their midpoint, one pair of

adjacent ends of said conductors being connected together, one of the remaining ends being connected to said conductive sheet, and the other passing through said sheet and being connected to the inner conductor of a coaxial transmission line, the other sheath of said line being connected to said conductive sheet.

4. A broad-band antenna in the form of an inverted-L disposed over a conductive sheet forming a ground plane, said antenna including a pair of closely adjacent parallel conductors bent at substantially their midpoint, one pair of adjacent ends of said conductors being connected together, and one of the remaining ends being connected to a conductor of a transmission line, the vertical portion of each of said parallel conductors being surrounded by coaxially arranged sheaths connected at their lower ends to said conductive sheet.

5. A broad-band antenna in the form of an inverted-L disposed over a conductive sheet forming a ground plane, said antenna including a pair of closely adjacent parallel conductors bent at substantially their midpoint, one pair of adjacent ends of said conductors being connected together, one of the remaining ends being connected to said conductive sheet, and the other passing through said sheet and being connected to a conductor of a transmission line, the vertical portion of each of said parallel conductors being surrounded by coaxially arranged sheaths connected at their lower ends to said conductive sheet.

6. A broad-band antenna in the form of an inverted-L disposed over a conductive sheet forming a ground plane, said antenna including a pair of closely adjacent parallel conductors, each having an over-all length of the order of one-quarter of the operative wavelength, one pair of adjacent ends of said conductors being connected together, one of the remaining ends being connected to said conductive sheet and the other passing through said sheet and being connected to a conductor of a transmission line, the vertical portion of said conductors having a length less than one-eighth of the operating wavelength.

7. A broad-band antenna in the form of an inverted-L disposed over a conductive sheet forming a ground plane, said antenna including a pair of closely adjacent parallel conductors, each having an over-all length of the order of one-quarter of the operating wavelength, one pair of adjacent ends of said conductors being connected together, one of the remaining ends being connected to said conductive sheet and the other passing through said sheet and being connected to a conductor of a transmission line, the vertical portion of said conductors having a length less than one-eighth of the operating wavelength, the vertical portion of each of said parallel conductors being surrounded by coaxially arranged sheaths, connected at their lower ends to said conductive sheet.



8. A broad-band antenna in the form of an inverted-L disposed over a conductive sheet forming a ground plane, said antenna including a pair of closely adjacent parallel conductors, each having an over-all length of the order of one-quarter of the operating wavelength, one pair of adjacent ends of said conductors being connected together, one of the remaining ends being connected to said conductive sheet and the other passing through said sheet and being connected to an inner conductor of a coaxial transmission line, the vertical portion of said conductors having a length less than one-eighth of the operative wavelength, the vertical portion of each of said parallel conductors being surrounded by coaxially arranged sheaths, connected at their lower ends to said conductive sheet, the outer sheath of said coaxial line constituting an extension of the sheath surrounding one of said conductors of said antenna.

ROBERT S. WEHNER.


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