A New Approach to Antenna Design

BY LARSON E. RAPP,* W1OU

• Every year or so, along about deadline time for the April issue, we receive from Mr. Rapp an erudite paper on some pressing problem in amateur radio. This leaves us no time to confirm some of Mr. Rapp's statements by laboratory tests, so we must confess that we haven't tested the revolutionary new antenna described in this paper. However, his reputation is such that we felt it was unnecessary in this case. All of the mathematical treatment included in the original has been deleted, in an effort to reach the largest possible audience.

The year 1948 was a good one in amateur radio. Several new techniques were introduced or suggested to keep the hobby alive, and there was no real need for this humble author to give the art a "shot in the arm," so to speak. So many amateurs were kept busy praising or denouncing (1) single-sideband receivers, (2) single-sideband transmitters, (3) double-sideband anything, (4) single-sideband anything, (5) the Clapp oscillator, and (6) the series-tuned Colpitts oscillator, that a healthy and rather jolly feeling prevailed throughout the better-informed *cognoscenti.* This was as it should be, of course.

However, it is about time that something was done about the antenna situation. Too many amateurs have been misled into believing that one needs a lot of ground and high supports for huge arrays to enjoy any success in amateur radio. So many amateurs have bought huge plots of ground and thousands of board feet of lumber that they are now considered in some circles to have been instrumental in bringing about the present housing shortage. In the field of parasitic arrays (originally designed for a small space), a recent tabulation shows that they have become increasingly complex. Starting originally with two-element beams, they have gradually evolved into 5- and 10-element menaces to aerial navigation. Any real DX is out of the question these days for anyone with less than 4 elements and *wide* spacing, if you would believe all of the stories.

A New Approach

This whole approach seems a little primitive. That "radio waves abhor a small conductor" can be shown from Maxwell's equations,[1] and it also can be proven experimentally. It is well known that a half-wavelength antenna cut for the high-frequency end of a band will work at the low-frequency end. But what seems to have escaped everyone is that it works slightly better! The reason, of course, is that the antenna is a little short for the frequency. Then, too, amateurs have been misled because when they have tried to work the antenna on the next lower frequency band, the results haven't been too good, and they have assumed that this was because the radiator was too short. *Au contraire,* it is because the wrong part of the now-shortened antenna had been cut off.

This is illustrated in Fig. 1. The diagram at A shows the normal current distribution on a half-wavelength antenna. When the antenna is shortened by removing the ends, the current distribution changes to that shown at B. But when the antenna is shortened by removing the *center* of the wire, the current distribution of Fig. 1-C is obtained, a very desirable condition indeed. While this may seem to be a puzzling effect at first, the explanation is quite simple. When the ends are removed, the remaining wire must replace it electrically, as is well known. But the corollary, that when the center is removed the ends take its place electrically, seems to have passed unnoticed.

This, then, is a step in the right direction, if we are ever to have antennas of reasonable size. However, as the antenna length is shortened, the radiation resistance goes down but the ohmic resistance remains the same. Thus when normal copper conductors are used, the efficiency of a really short antenna is not too good because of the low ratio of radiation resistance to ohmic resistance. Possibly this is one reason why such systems have never enjoyed any great vogue.

While casting about for a solution to the problem, the writer was called in (in an advisory capacity) on a project involving "super conductivity," and it became apparent that this might be the answer. It was!

As is well known, the resistance of any conductor decreases as the temperature is lowered. Signals are better in the winter than in the summer because the coils in receivers, transmitters and antennas have lower resistance. (This effect

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[1] Mr. Rapp did not submit this derivation. However, the principle was discovered independently by Dr. Scotten (*QST*, Feb., 1949, p. 46). Mr. Rapp apparently arrived at it by pure mathematics, which made it obvious that the law is valid for a three-dimensional space-time continuum, instead of the two-dimensional limit assumed by Dr. Scotten. Full credit goes to Dr. Scotten, however, because of his earlier disclosure. — *Ed.*

is more apparent in extreme climates and in unheated stations.) At absolute zero (−273.1° C.), any conductor has zero resistance and hence no loss. Currents once started flowing never stop unless radiated from the conductor.

Experimental Antennas

The first antenna was a simple thing 142.2 cm. long, and it was cooled down to −268.4° C. Hot as it was (compared with absolute zero), it nevertheless showed amazing properties. Signal reports averaged 52 db. above S9 without preselectors on 14.23 Mc., and 67 db. above S9 on 3.94 Mc. The higher average on the lower frequency is readily explained by the fact that the same antenna was used on both bands, and it was shorter (in wavelengths) on the lower frequency.

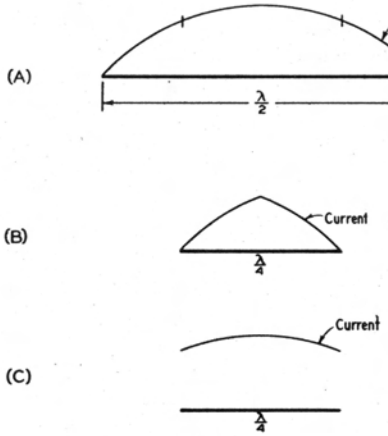

Fig. 1 **— Current distribution on various types of antennas. The current on a conventional half-wavelength antenna is shown at A. When the ends are cut off, the distribution is that shown in B, which is equivalent to the two end ⅛-wavelength sections of A moved together. When the center is removed, the distribution is as shown in C, which is equivalent to the center ¼-wavelength section of A. Comparing the current amplitudes shown in B and C, it is obvious which is the better radiator.**

Unexpectedly, it loaded well on any frequency between 30 and 3.5 Mc. and, when fed with 73-ohm coaxial cable, the standing-wave ratio never exceeded 1.07. A further unexpected development was that when fed with 300-ohm line, the s.w.r. never exceeded 1.07 over the entire range. In fact, when fed with 600-ohm line or with 52-ohm coaxial cable, the standing-wave ratio never exceeded 1.07, which leads to the conclusion that the antenna can be fed with any line and the s.w.r. will not exceed 1.07. This was a little difficult to explain at first, but the answer is really quite simple. It is the principle of "indefinite impedance" now rather widely used by amateurs without their knowledge. When they say "Cut the line to the length that loads best and you have eliminated the standing waves" they are doing the same thing but for one frequency. Obviously such a broad-band device as this antenna eliminates the need for a critical feedline length.

A second experimental antenna 94.3 cm. in length was cooled down to −269.9° C., and the results were even more amazing. Signal reports were even higher, and the s.w.r. was reduced to 1.06 at all impedance levels. But the results were not as consistent as they were with the first antenna, and this was finally traced to band conditions. When the bands were good and a large number of signals were coming through, their combined energies tended to heat the antenna and raise its temperature slightly! While this was disconcerting at first, it was decided that the effect might be used to indicate band conditions without turning on the receiver. Actually, this required only a sensitive thermometer calibrated in "signals per kilocycle." It works out quite well, although it doesn't show *where* the signals are coming from. An autoalarm, to indicate when there are sufficient signals coming through to justify turning on the transmitter and receiver, was used for a short time but added nothing to the enjoyment of other pursuits around the house, and several neighbors complained of the constant sounding of the alarm siren.

Further experiments showed conclusively that the antenna is indeed such a broad-band device that it works equally well over the entire radio spectrum.[2] In fact, it was found that there is *no* way to prevent the antenna from picking up weak harmonics from the transmitter and radiating them with quite high efficiency. Since this would only aggravate the TVI problem, it is felt that this is too dangerous an instrument to put in the hands of the amateur, and no disclosure of the constructional details will be made, despite the importunities of the editors of *QST*. Sorry.

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[2] Actually, the highest frequency at which tests were made was 27,000 Mc., so this is rather an extravagant statement. — *Ed.*

A.R.R.L. NEW ENGLAND DIVISION CONVENTION

Framingham, Mass. **April 30th**

The ARRL New England Division Convention, sponsored by the Framingham Radio Club, will be held on April 30th at Nevins Memorial Hall, in the heart of downtown Framingham, Mass. Registration will begin at 1:00 P.M. Registration tickets will be $2.00; combination registration-banquet tickets $4.50. To purchase tickets in advance by mail, contact Ed Parsons, W1BWJ, 35 Pitts St., Natick, Mass.