An Experimental All-Band Nondirectional Transmitting Antenna

Some Possibilities Offered by the Tilted Folded Dipole

BY G. L. COUNTRYMAN, * W1RBK, W3HH

FEW improvements in antennas for the lower-frequency bands have been forthcoming for several years. The arrangement to be discussed is not entirely original with the autor but was based on some Navy antenna studies. Initial tests indicate that it may provide an acceptable solution to amateur multiband operation.

Briefly, it is an aperiodic system that will give uniform output over a frequency of approximately a 5-to-1 ratio with nondirectional characteristics and without critical adjustment. In fact, the only adjustment is to couple the final tank to a 600-ohm line.

The practical experiments conducted by the author are incomplete, but it is hoped that the publication of the data contained herein will encourage experimenting by other amateurs.

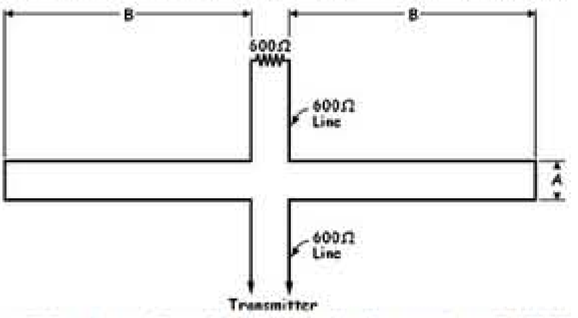

Fig. 1 General diagram of the terminated folded dipole. Dimensions for A and B are suggested in the text.

There are many questions unanswered: measured variation in standing-wave ratio over a given frequency range, loss in power attributable to the resistance termination, experimentally-obtained radiation patterns, etc.

Essentially, the system shown in Fig. 1 is a nonresonant folded dipole. It is fed with a 600-ohm line. This antenna, if horizontal, will be quite directional at right angles to its axis, with pronounced minima off the ends. As the antenna is tilted with respect to ground, this pattern gradually changes until at an angle of 30 degrees it becomes nondirectional for all practical purposes. Translated into terms of amateur construction this means that only one mast is required, together with a short pole six feet or so in height

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• Those hams who are experimentally inclined will no doubt be interested in the possibilities that this antenna system suggests. Practical tests by the author have show that the single antenna may be operated over a frequency range as great as 5 to 1 with a relatively small change in the standing-wave ratio on the line and that the pattern is essentially nondirectional.

supporting the low end. There seems to be no marked advantage in an increase in over-all height of the antenna. On the contrary, reports from a distance indicate that signals are definitely better with one end of the antenna only six feet from the ground, perhaps because of a resulting lower angle of radiation.

Because complications are introduced by the resistance termination, it is difficult to make an adequate analysis or evaluation of a terminated folded dipole by conventional methods. It becomes necessary to measure performance experimentally.

One of the Navy laboratories has investigated the performance of this type of antenna and has reported unfavorably upon it. However, the laboratory study was based upon a vertical monopole erected over a metallic ground plane, using conventional measuring instruments, and the characteristics obtained were applied mathematically to arrive at theoretical characteristics for the resistance-terminated folded dipole. Operational tests were not made by this laboratory and their theoretical findings are not borne out by the limited practical tests conducted by the author.

It is of interest to note that the standing-wave ratios estimated by the laboratory for various frequencies from 4 to 22 Mc. ranged from a minimum of 1.4 to a maximum of 2.6, with an average close to 1.7. These ratios compare favorably with average s.w.r.s found in amateur installations. It should be remembered that these standing-wave ratios were not measured but where arrived at by calculation.

Dimensions

Fig. 1 gives a general idea of the system with the important dimensions indicated except for

the angle of tilt. Fig. 2 indicates the required tilt with a suggested pole arrangement and dimensions pertaining thereto. Two particular sizes should be of interest to amateurs, one of which will have maximum efficiency from 3.5 Mc. to

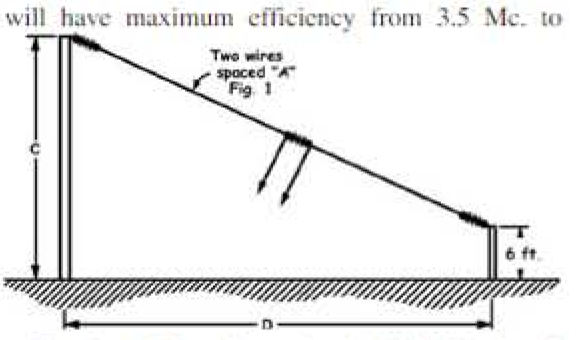

Fig. 2 Tilting the terminated folded dipole tends to make the pattern nondirectional. For dimensions C and D, see text.

17.5 Mc. and the other being optimum from 7 Mc. to 35 Mc. Dimensions may be developed using the formulas set forth to cover higher-frequency bands, but at 28 Mc. and higher frequencies directional arrays are easy to construct and preferable because of the increased gain. The following dimensions are applicable to the frequency ranges selected above:

Dimension (Figs. 1 and 2)	3.5 to 17.5 Mc.	7 to 35 Mc.
A	2 ft. 10 in.	1 ft. 6 in.
B	46 ft. 10 in.	23 ft. 5 in.
C	56 ft. 0 in.	32 ft. 0 in.
D	80 ft. 0 in.	44 ft. 0 in.

For an impedance of 600 ohms, the center-to-center spacing of the feeder wires, divided by the diameter of the feeder wires, must equal 70. This means that No. 12 wire spaced six inches will be acceptable. Six-inch spreaders are readily available and the wire will not stretch unduly. No. 10 wire should be spaced 7 inches and No. 16 wire should be spaced 3 ½ inches.

Terminating Resistor

The terminating resistor should be non-inductive and have a minimum rating equal to 35 per cent of the input power to the final stage. It may be a carbon or graphite rod, adequately protected from the elements, or merely a long 600-ohm transmission line constructed of resistance wire. If the latter is used, the line may be carried vertically down from the center of one leg of the antenna to a short pole and then, if required, extended to one of the masts and doubled back and forth between the masts. If a carbon resistor is used, there is apparently no difference whether the rod is connected directly into the antenna as shown in Fig. 3, or at the end of a transmission line, as shown in Fig. 1. However, it is easier to adjust the resistance and protect it from the elements when it is installed at a fixed location on the ground than when it is suspended across an insulator in the antenna wire.

Formulas

The following formulas will be of assistance in developing antennas for different frequency coverages:

$$\text{Antenna-wire spacing (A) for lowest frequency} = \frac{3{,}000}{f\text{ (kc.)}} \times 3.28$$

$$\text{Antenna length, each half (B) for lowest frequency} = \frac{50{,}000}{f\text{ (kc.)}} \times 3.28$$

To convert decimal parts of one foot into inches, multiply by 12.

One meter = 3.28 feet.

$$\text{Frequency (kc.)} = \frac{300{,}000}{\text{(meters)}}$$

The length of the antenna and the wire spacing may well be the object of further experiments but initial tests indicate that the first two formulas shown above are reasonably accurate and that the system is operable over a 5-to-1 frequency range as previously mentioned.

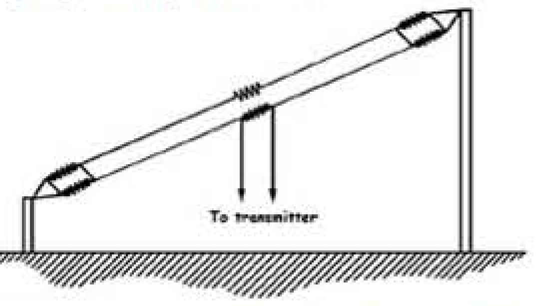

Fig. 3 The terminating resistor may be placed directly in the antenna, or at the end of a transmission line as indicated in Fig. 1.

Initial tests with these antennas indicate no change in signal strength on 40 meters at a distance of 2000 miles when compared with a conventional half-wave antenna, center fed with tuned feeders and carefully adjusted for optimum output at one selected frequency. Good reports were received on both 20 and 80 meters but comparative reports are not available because of the lack of antennas specifically designed for those bands. Transmitter loading was normal.

Performance of the Terminated Folded Dipole

G. L. COUNTRYMAN, W3HH*

Every once in awhile an antenna comes along that could be put to good use by the average amateur. The Terminated Folded Dipole (also known as the T2FD) is just such an antenna. Unfortunately, it has not been given its due publicity. This article is designed to clarify some of the points on the construction, as well as, report upon experimental results. —Editor.

INITIAL EXPERIMENTS with a terminated tilted folded dipole antenna were described by the author some two years ago.[1] This antenna has omnidirectional characteristics and a 5 or 6 to 1 frequency ratio which means that one "untuned" antenna is all that is required for operation on from three to five amateur bands.

The antenna has a definite application in connection with emergency communications in the lower frequency bands.

1. One antenna is all that needs to be erected for operation on several bands.
2. Only one elevated point (pole, tree or house gable) is required
3. Less space along the ground is needed for any given frequency as the flattop portion is shorter than the usual one-half wavelength.

Basically, the antenna is the hypotenuse of a right angle triangle, one leg of which is along the ground, as shown in *Fig. 1*. The spacing between the folded dipole wires, in feet is equal to 3,000 divided by the frequency in kilocycles, and the result multiplied by 3.28. The length of each leg in feet (from either end to the center insulator or resistor) is equal to 50,000 divided by the frequency in kilocycles, and the result multiplied by 3.28. The terminating resistor should have a wattage rating equal to 35% of the power input to the final stage, and should have a resistance equal to the impedance of the two wire feeder system—usually 600 ohms.

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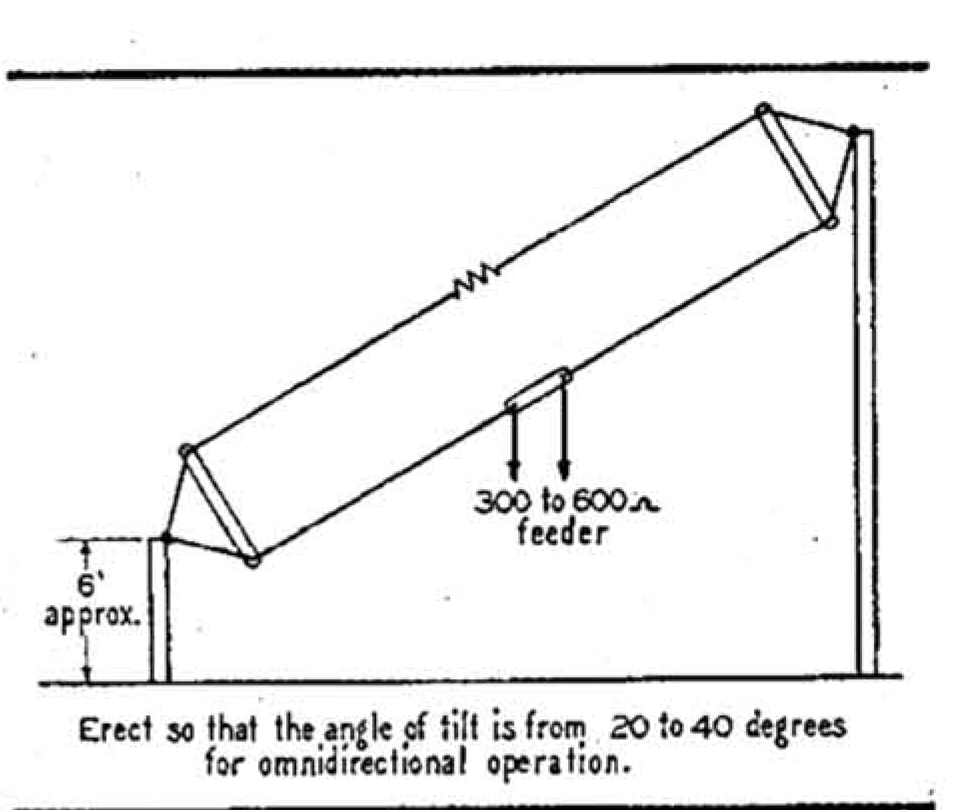


Figure 1

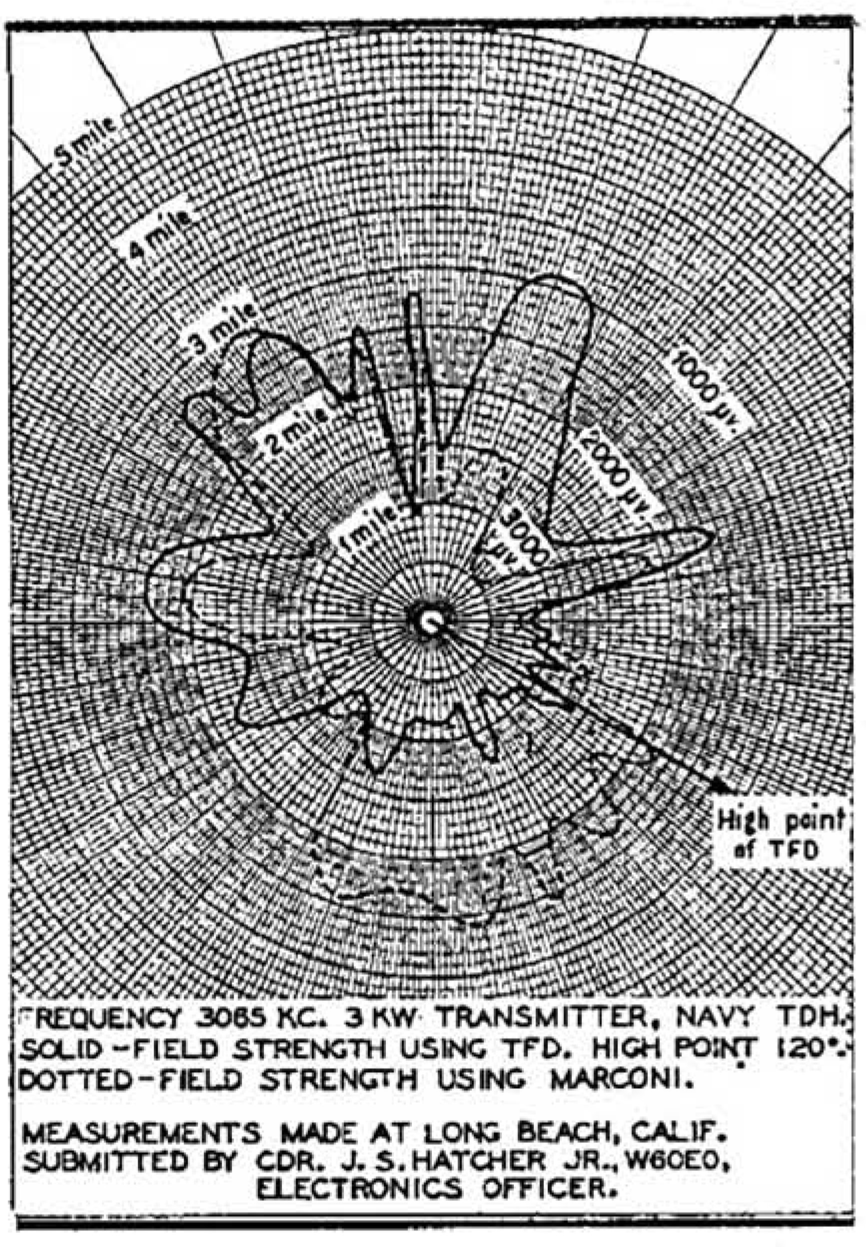


Figure 2

The formulas given are for the lowest frequency on which operation is desired. Applying these formulas, an antenna that will work well on the 10, 11, 15, 20 and 40 meter bands may have an overall length of forty-seven feet, with the two wires spaced about 17 inches.

During the past few months the response has indicated that there is considerable interest in, and several applications successful of the T2FD antenna. Some criticism from the theoretical gentlemen who dismiss the practicability with the statement; "It won't work," has also been received.

As far as the author is concerned, work on the antenna has progressed spasmodically, due to the

pressure of other duties, although additional tests continue to indicate that the formulae for length and spacing are accurate. Elsewhere, experimenters have reported advantages to be gained by spacing according to formula at the antenna ends, and doubling that spacing at the center. The author has found that this apparent advantage is realized only because a center spacer is needed that will keep the wires fixed in their relative positions. It definitely appears that a center spacer is a good idea, but the dimension should keep the two antenna wires parallel throughout their entire length.

Comparative Signal Strength at 3 Receiving Locations

Transmitting Antenna - Hitoyoshi

Local Time	1/2 wave doublet			W3HH Antenna - 30° tilt angle		
	Kagoshima	Miyazaki	Oita	Kagoshima	Miyazaki	Oita
0800	-	-	-	-	-	-
0900	4	2	2	4	2	3
1000	3	1	2	4	2	3
1100	2	1	1	-	-	2
1200	3	1		2	-	-
1300	2	1	2	-	-	-
1400	2	1	-	3	1	2
1500	3	1	-	-	-	-
1600	3	2	2	3	2	3
1700	2	1	3	2	2	-
1800	3	1	3	3	3	-
1900	2	3	1	-	-	-

Reception at Kagoshima and Miyazaki was on 2530 kcs.
Reception at Oita was on 3830 kcs.
- indicates no measurement due to QRM, QRN or other reasons.
Fractions in signal strength have been reduced to nearest whole number.

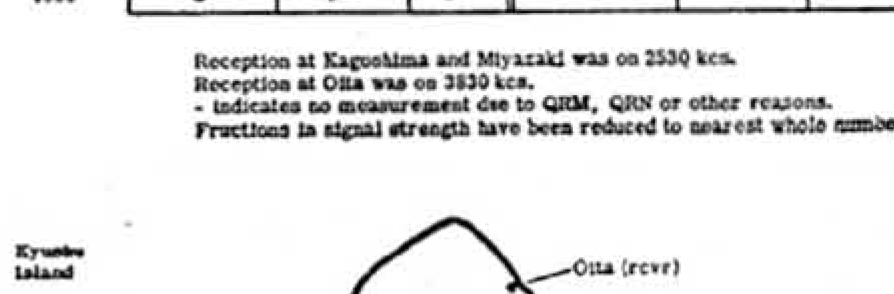


TABLE I

The only modification to the original data is that further experiments indicate the angle of tilt is not critical. Any tilt angle from about 20 degrees to about 40 degrees will radiate with omnidirectional characteristics. This greatly increases the flexibility of the system.

Performance Review

Leo Carreras, W3EC, reports that one antenna has been used on the Model TCC transmitter at NDM for over a year on all frequencies with results superior to individual antennas on the various bands. The other antennas have since been removed. The Model TCC is a Navy 1 KW transmitter of modern design, with a frequency range from 2,000 to 18,000 kc.

Captain H. O. Crisp (RAF), now retired, reports highly satisfactory results and suggested a wide center spacing. He also reports excellent results on receiving—considerably greater than could be accounted for by the antenna and transmission line presentng a better input match to the receiver

Field Intensity in db at Various Horizontal Angles

Tilt Angle of Antenna

Horizontal Angle in Degrees	44°	36°	30°	24°	18°
0	122.5	120	120	119.5	120
10	121.5	121	121.5	120.5	120
20	121.5	121.5	121.5	121.5	120.5
30	120.5	121.5	121.5	121.5	120.5
40	120.5	120.5	120.5	121.5	120.5
50	121.5	120.5	121.5	120.5	120.5
60	121	121.5	120.5	120.5	120.5
70	120.5	120.5	120.5	120.5	120.5
80	119.5	119.5	119.5	119.5	116.5
90	119.5	119.5	119.5	119.5	117

The horizontal angle is taken relative to plane of antenna. Under the same conditions, the field intensity of a conventional Zepp Antenna was 115.5 at all horizontal angles.

TABLE II

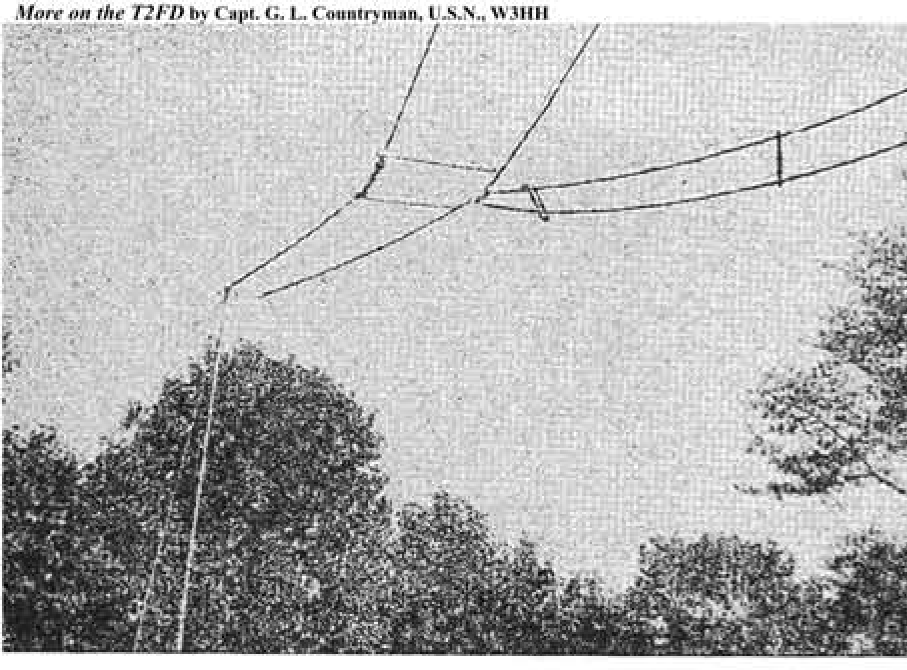
than a comparative single wire and "earth". He used an RCA AR88D in the receiving tests.

Commander H. E. Thomas, USN, W3AIU has reported that four of these antennas were erected at the Naval Station, Long Beach, California. Each T2FD was connected to a separate transmitter. They were used over the entire frequency range of the antenna with excellent results. The antennas were erected along the sides of a square with the building housing the transmitters in the center of the square. Poles were erected at each corner and each antenna ran from the top of one pole to a point near the bottom of the pole at the adjoining corner. *Figure 2* shows field strength measurements made at this station comparing the T2FD and the Marconi antenna formerly used.

Some of the most interesting observational material was from Mr. Yasuhiro Itahashi. Mr. Itahashi is a Radio Engineer for the Kyushu Electric Communication Bureau (Japan). After extensive tests Mr. Itahashi has recommended that the T2FD antenna be used for all coastal, emergency and domestic radio transmitting stations on Kyushu Island. His permission has been received to publish the results of some of their field strength checks and propagation tests.

Briefly their experiments indicated that the tilted folded dipole was superior to the "Zepp" and one-half wave doublet types previously employed. Wide band characteristics were observed and the T2FD resulted in a 4 to 8 db increase in the signal at their various receiving locations. Tables I and II are self explanatory and should be of interest to antenna minded experimenters. Table I shows that reception from the tilted folded dipole gave an equal or louder signal at three widely separated locations, as compared to conventional dipoles. Table II shows the actual field intensity in db at five different tilt angles over a 90 degree horizontal pattern. The field strength from the same transmitter using a horizontal "Zepp" antenna was 115.5 db at all points. The distance from the field strength meter to the antenna was about two miles.

The author has had excellent practical results with the antenna. One big advantage to many hams who are not fortunate enough to live in an area permitting an "antenna farm" is that only one elevated point is required. Only 80 feet along the ground is required for operation on 75 and 80 meters, and only about 45 feet is required for a 40 meter T2FD. The 80 meter antenna will function equally well on 40 and 20, while the 40 meter job will give excellent results down to and including the ten meter band.



There is certainly nothing fancy or difficult in erecting a T2FD. This is the author's antenna. The peculiar photographic angle is due to the slope (coming towards the reader) of the antenna.

More on the T2FD

CAPT. G. L. COUNTRYMAN, U.S.N., W3HH

309 Windsor Street, Silver Spring, Maryland

While the average citizen walking down the street thinks and talks a lot about the weather, the average amateur radio operator is generally most concerned about his antenna. It, like another invaluable item, comes in an infinite variety and will probably never cease to attract interest and discussion.

About a year ago, CQ printed a little article on a type of folded dipole called the "T2FD." It was, in every sense of the word, a "sleeper." Those who put it up were amazed by its ability to load on three or more amateur bands. Others acclaimed its omni-directional properties, while a third group insisted that it radiated most of its energy at the most favorable vertical angles of radiation. Oddly enough, there still seemed to be some theory-bound skeptics who insisted that it couldn't work. For the benefit of those few, and for the fellows who haven't tried this unusual antenna, we append a few comments.—Editors.

"While looking for a compact antenna for my small backyard . . . I decided to give it a try.

"I put one up for 40 meters and the first night I worked all but the 6th district. Next night I thought I would see what would happen if I tried to load it on 80 meters. On first CQ I got a 579X report with only 40 watts input!"

W8IKB

"Saw your antenna just as I was about to put up the Zepp I use during the winter. Gave your plan preference and the next day . . . I casually asked for a report . . . and got 40 over S9 with doubts about my 450 watts. They said that the kilowatts were generally S6. This was on 75-meter phone.

"Next morning I tried 10-meters and heard more DX than on a beam at this location. In general, the T2FD surpasses anything I have used on 75-meter phone which included long wires up to 500 feet, center-fed and end-fed Zepps, and shortened center-fed Zepps with long feeders."

WØMIO

"I assisted VE1UL while erecting a T2FD and he found it to be one of the best antennas he had used."

VE1KQ

Several years ago the author experimented with a terminated, tilted, folded dipole that offered possibilities for ham use. The initial data appeared in *QST* for June 1949 on page 54. Apparently very few hams read the article, or, if they did, skimmed over it lightly. Certain communication services took it seriously, however, and the author continued to have excellent results with the system. Another article made its appearance in the November 1951 issue of *CQ*, and there is no doubt that this article was not only read, but that many brother hams went to the trouble of erecting a T2FD, and reporting its excellent performance.

Since then, more than a year has elapsed, and the mail continues to roll in. This article is now being published in self defense, as there is no time to answer the many letters. Most of these fall into two categories. First are the letters reporting excellent results with this "all-wave" omni-directional antenna. Next come the questions, and they all follow a general pattern. Here are the answers to the questions most frequently asked:

Question: Is the use of a non-inductive terminating resistor necessary?

Answer: No. However, if you use a wire wound resistor, the antenna is not aperiodic and will resonate at some frequency. The difference is that with a wire-wound resistor it will be necessary to use some form of antenna coupler depending on your installation, and the coupling will probably be different for the various bands. With a non-inductive resistor the system is aperiodic and one coupling method will be satisfactory for all bands. This advantage is offset to some extent by the fact that the resistance value is fairly critical and it is convenient to adjust a wire-wound resistor with slider. Sprague makes a non-inductive "Kool-Ohm" in a 120-watt size that will handle an input to the final of 350 watts. Rhombic non-inductive terminating resistors in larger wattage ratings are still available, now and then, at surplus outlets.*

T2FD Basic Design Data
(See Fig. 4)

1. The length of each leg from the center is equal to 50,000 divided by the lowest desired operating frequency (in kc.) and then multiplied by 3.28. The answer is in feet.
2. The spacing between radiating wires is equal to 3000 divided by the lowest desired operating frequency (in Kc.) and then multiplied by 3.28. The answer is in feet.
3. The sloping angle for a nondirectional pattern should be of the order of 30 degrees.
4. The terminating resistor should be non-inductive and have a rating equal to 35% of the transmitter input power. For further details see the text.

Question: Must the resistor be exactly the same resistance as the feed line impedance?

Answer: No. The value of the resistor is quite critical for optimum results, especially as the impedance of the feeder decreases. For example, with a 600-ohm line (No. 12 wire spaced 6 inches), a value of about 650 ohms seems best although operationally a 600-ohm resistor appears to be entirely satisfactory. When using 300-ohm twin-lead, the optimum resistance is 390 ohms, which results in a tremendous gain, approximately 30 db, over a 300-ohm resistor, although any value from 375 to 400 ohms gives excellent operational results. With 450-ohm line, a 500-ohm terminating resistor will be satisfactory. With lines of lower impedance including coaxial cable, reports indicate that for optimum results the value of the resistor is critical within about 5 ohms, although the author has used only open lines and twin-lead in his work.

*The PHOTOCON SALES (417 N. Foothill Blvd., Pasadena 8, Calif.) have advised us that they have the following available from stock, as this is being written.
300-ohm G.E. globar resistor (200-watt rating) new at $1.50 each.
600-ohm G.E. globar resistor (100-watt rating) new at $1.00 each.

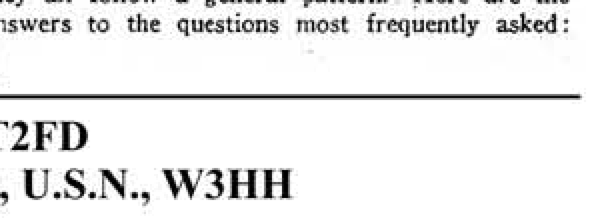


Fig. 1. The T2FD may be coupled to the final with a simple link. The use of a low-pass filter to prevent TVI is recommended.

Question: Is the antenna equally good on receiving and transmitting?

Answer: Definitely, provided the optimum resistance value is established and used. Rush Drake, W4ESK, reported that during the 1951 CQ DX Contest he "couldn't hear 'em on 80" with a hastily erected T2FD, but he had made no effort to establish an optimum value for the terminating resistor, and used the antenna only a few hours. (It's interesting to note that he won the contest!)

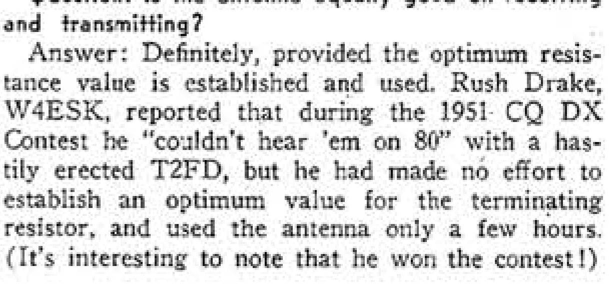


Fig. 2. This simple filter, when inserted as shown in Figure 1, has worked very well with 600-ohm lines.

Question: How is the transmission line coupled to the final amplifier?

Answer: If a non-inductive resistor is used, a simple link *(Fig. 1)* is all that is required. Remember that you must couple at your line impedance, otherwise your antenna will not load properly. For a 600-ohm line, a 3-turn link should be used for 20 meters and a 6-turn link will be a good match at 40 and 80. The B & W plug-in links are perfect in this application.

Question: How about TVI?

Answer: That's a good question! The usual precautions regarding parasitics, shielding, feedback into the a-c line, etc. should be taken. A low-pass filter in the line is best for all-band operation. If you operate on one band the half-wave "Harmoniker" type is better, but if you are on only one band, why worry about the T2FD? *Figure 2* shows a simple low-pass filter satisfactory for 300- to 600-ohm lines. Low-pass filters are available commercially for all line impedances.

Question: Should the two antenna wires be side-by-side or one over the other?

Answer: This is immaterial, although it usually is easier to erect them side-by-side, in the same plane as the surface of the earth.

Construction Notes

Now for some helpful hints. The best connectors for the round end terminals of a resistor approxi-

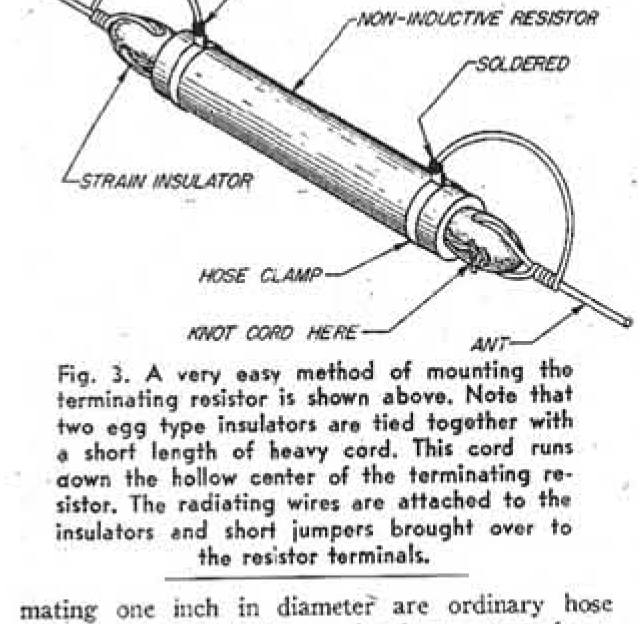


Fig. 3. A very easy method of mounting the terminating resistor is shown above. Note that two egg type insulators are tied together with a short length of heavy cord. This cord runs down the hollow center of the terminating resistor. The radiating wires are attached to the insulators and short jumpers brought over to the resistor terminals.

mating one inch in diameter are ordinary hose couplings, available in any hardware store for a dime. They won't rust and no soldering to the resistor is necessary, although the antenna should be soldered to the connectors.

No strain should be placed on the resistor. If it is hollow, and it usually is, a stout cord, similar to a venetian blind cord can be passed through it and a strain insulator used at each end, as shown in *Fig. 3.* Use spreaders at each end of a heavy resistor. A ⅜-inch diameter wood dowel is fine. Wipe them with oil before installing. A threaded ⅜-inch diameter brass rod is ideal for the high end and it serves both as a spreader and connector for the two antenna legs. At the low end it is usually easier to attach insulators to a short pole or building (far enough apart to give the proper separation) and solder a connecting wire between the two antenna legs.

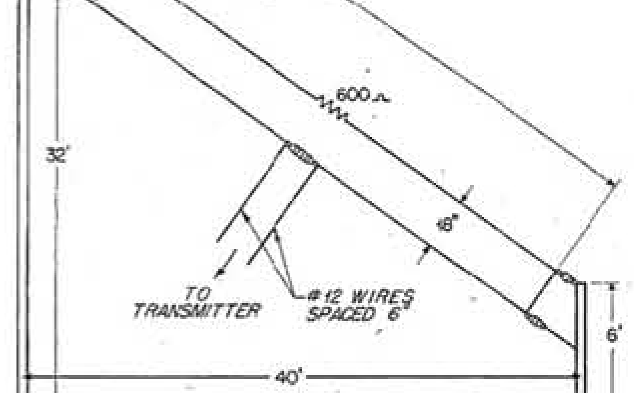


Fig. 4. This drawing represents the antenna that appears on the opening page of this article. Although it was cut for the 40-meter band it has been used on 80 meters with only a small

Further experimenting indicates that formulas for length and spacing previously published for the lowest frequency to be used remain the best. However, with negligible operational loss an antenna cut for 40 meters will, for example, load perfectly on 80. *Figure 4* shows the installation the author has used for some time on 20, 40 and 80 with excellent results. On 40, the band for which the antenna is cut, the T2FD is definitely superior to a "center-fed Zepp" for DX. Reports average two S-figures higher from Europe, South Africa and Australia even though the loading to the final amplifier is slightly less than with the tuned-feeder current-fed antenna used as a "standard."

There is a "mental hazard" with the T2FD that is hard to overcome. Upon seeing an antenna with one end only six feet from the ground (in contrast to the usual "higher the better" skywire), one experiences a natural reaction to the effect that "It won't get out." Don't be fooled. The T2FD will hold its own with other omni-directional antennas and normally out performs any of them when properly loaded.

This may be a good place to mention that the long-haired gents still cast a jaundiced eye at the "squashed rhombic." Admittedly it is theoretically inferior but it may be time to overhaul some of our theory! The U. S. Air Force finds it acceptable at Pacific Bases; the British RAF are well satisfied; our Navy uses it at certain locations; Japanese domestic communications on Kyushu use it exclusively, and some 200 Hams have taken the trouble to express to the author the excellent results they have obtained. It's not a "cure all" but if you want a simple unostentatious skywire, which requires little space, that will put out in commendable fashion on 3 or 4 ham bands and is omni-directional, you can't do better than put up a T2FD some Sunday afternoon.