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The Rhombic Antenna

The rhombic antenna has been used as a directive antenna system almost as long as "Wireless" or radio broadcasting. Phil Rand W1DBM, first built and operated a rhombic for amateur communications way back in 1931!

The purpose of this article, therefore, is not to bring you a new antenna development, but rather to acquaint, or re-acquaint you with the construction and operation of this outstanding antenna.

No single antenna array, regardless of its size, shape, or electrical characteristics, is capable of producing the ultimate in gain and/or directivity, when operated over a wide span of frequencies. The rhombic however, probably comes closer than any other antenna to meeting these criteria. **Fig. 1** lists the gain of rhombics of various leg lengths.

Before continuing further let's define just what a rhombic antenna is. A rhombic antenna is a form of long wire antenna, or to be more exact, a combination of long wires, so constructed as to produce maximum gain per unit of length. This long wire type antenna can be considered as two V beam antennas placed end to end, or two obtuse angle V beam antennas placed side by side to form a rhombus, or diamond. (See **Fig. 2**).

leg length (wave lengths)	*db gain*	*leg length (wave lengths)*	*db gain*
2	7.4	7	13
3	9	8	13.5
4	10.5	9	14
5	11.5	10	14.5

Fig. 1. Approximate gain (in decibels) for maximum output rhombics compared to a half wave dipole at the same elevation.

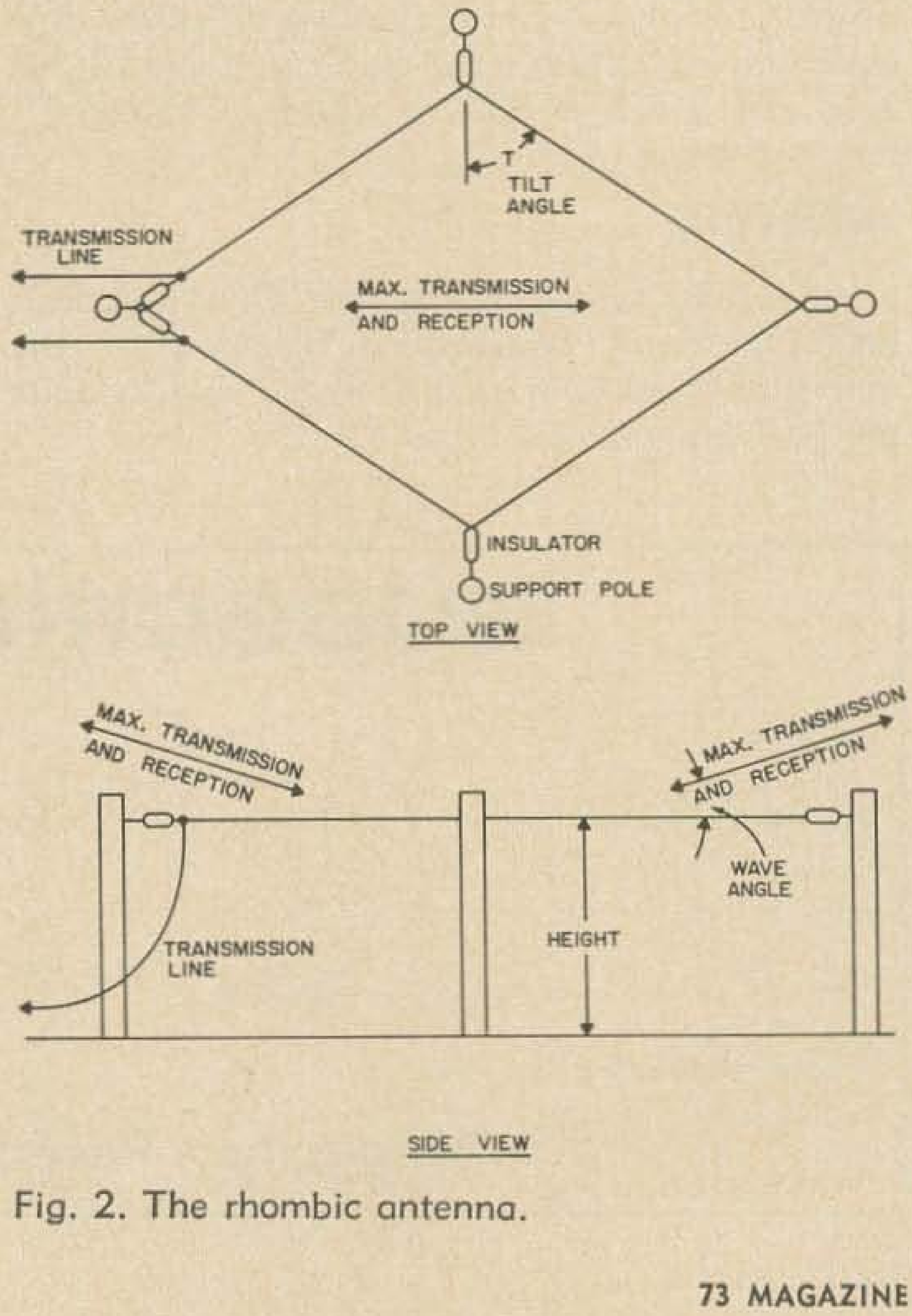


Fig. 2. The rhombic antenna.

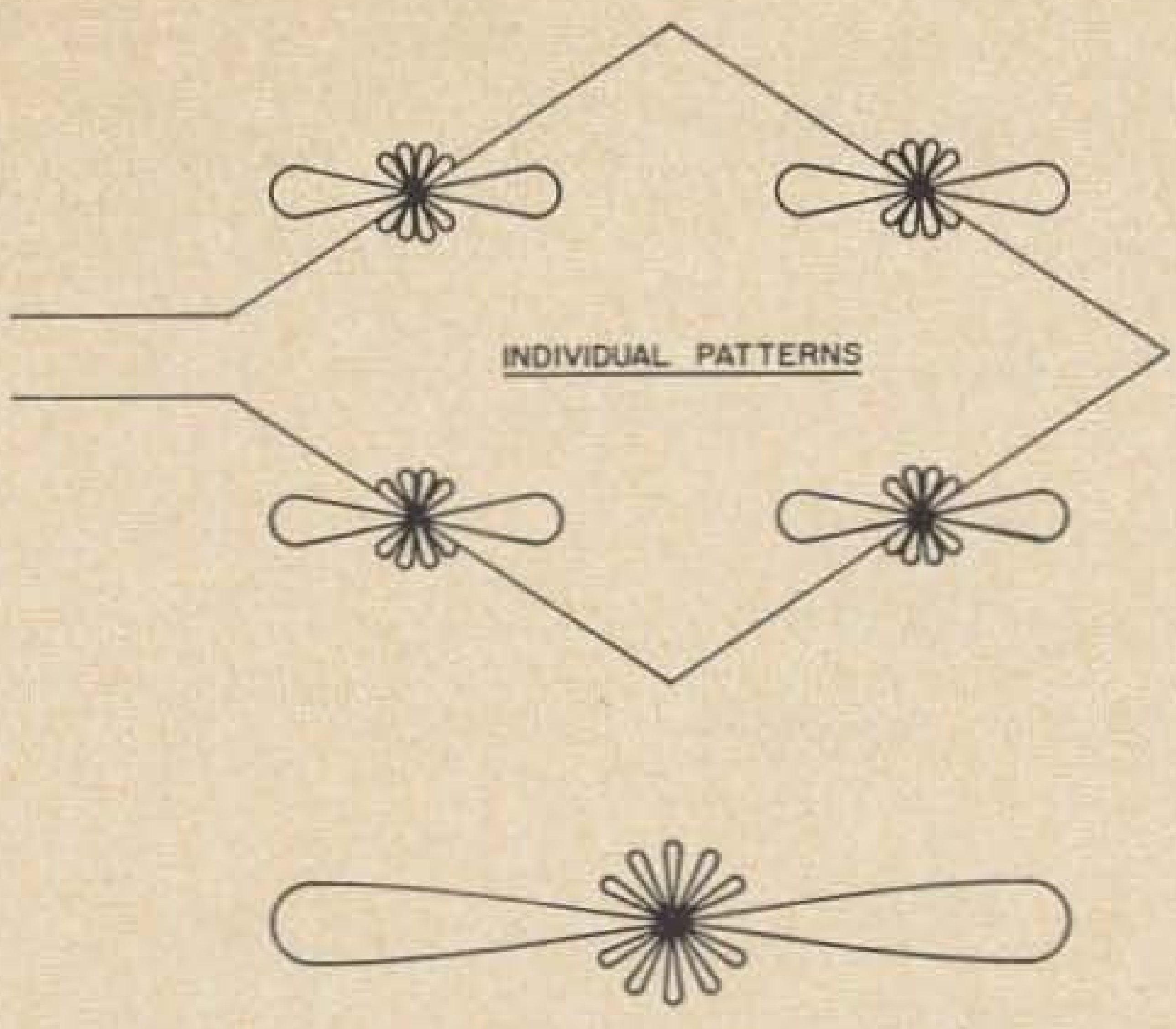


Fig. 3. Bi-directional rhombic.

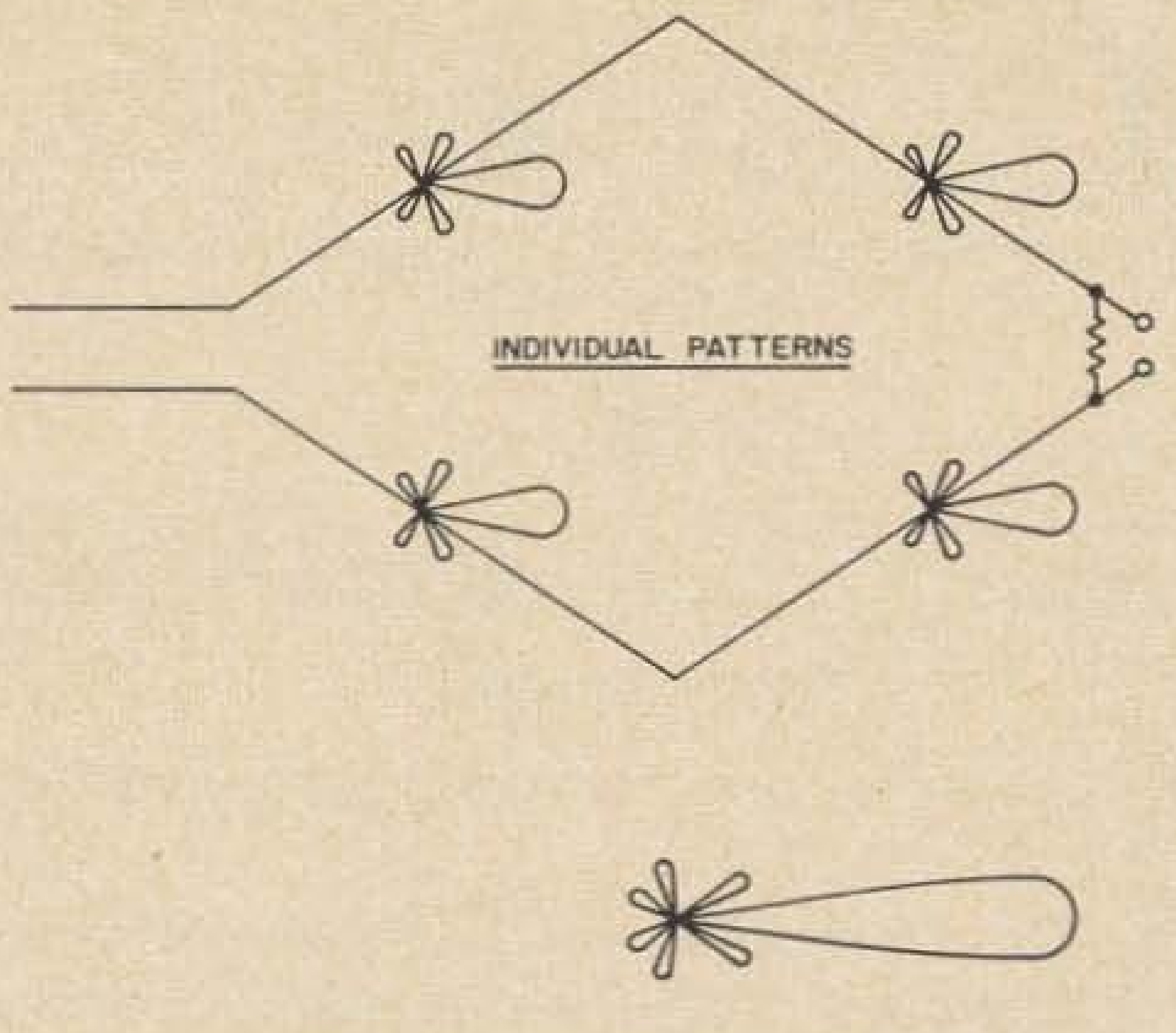


Fig. 4. Uni-directional rhombic.

The rhombic antenna is usually oriented in the horizontal plane, and in its basic form, produces a horizontally polarized bi-directional pattern, with maximum radiation occurring at some vertical angle above the plane of the antenna. This angle of radiation, or lobe, is called the wave angle, and is shown by the Greek letter delta (Δ). The *tilt* angle, or *T*, is one half angle between the two legs making up one side of the antenna.

Fig. 3 shows the rhombic with a bi-directional pattern. This bi-directional pattern results because a part of the energy traveling from the input, or feeder end of the antenna, toward the far end of the antenna, is reflected back, producing standing waves on the antenna legs. Because of these standing waves, this type is known as a resonant rhombic.

In order to make a rhombic uni-directional, it must be terminated with a non-inductive resistance of the proper value. The function of this terminating resistance is to absorb any energy that might be reflected back toward the feeder, or input end of the antenna. The terminated rhombic, therefore, is non-resonant. Termination of the rhombic, in addition to making it uni-directional, provides a feed, or input impedance which is constant over a wide range of frequencies. (See **Fig. 4**)

We will get back to the fine points of termination, and other aspects of design and layout of the rhombic, but right now, let's take up the advantages of this antenna array.

Some of the advantages of this antenna are as follows:

a. Produces excellent results over a frequency range of 4 to 1 (80–40–20–15 meters, for example).

b. Is easier to erect and maintain than other antennas of comparable gain and directivity.

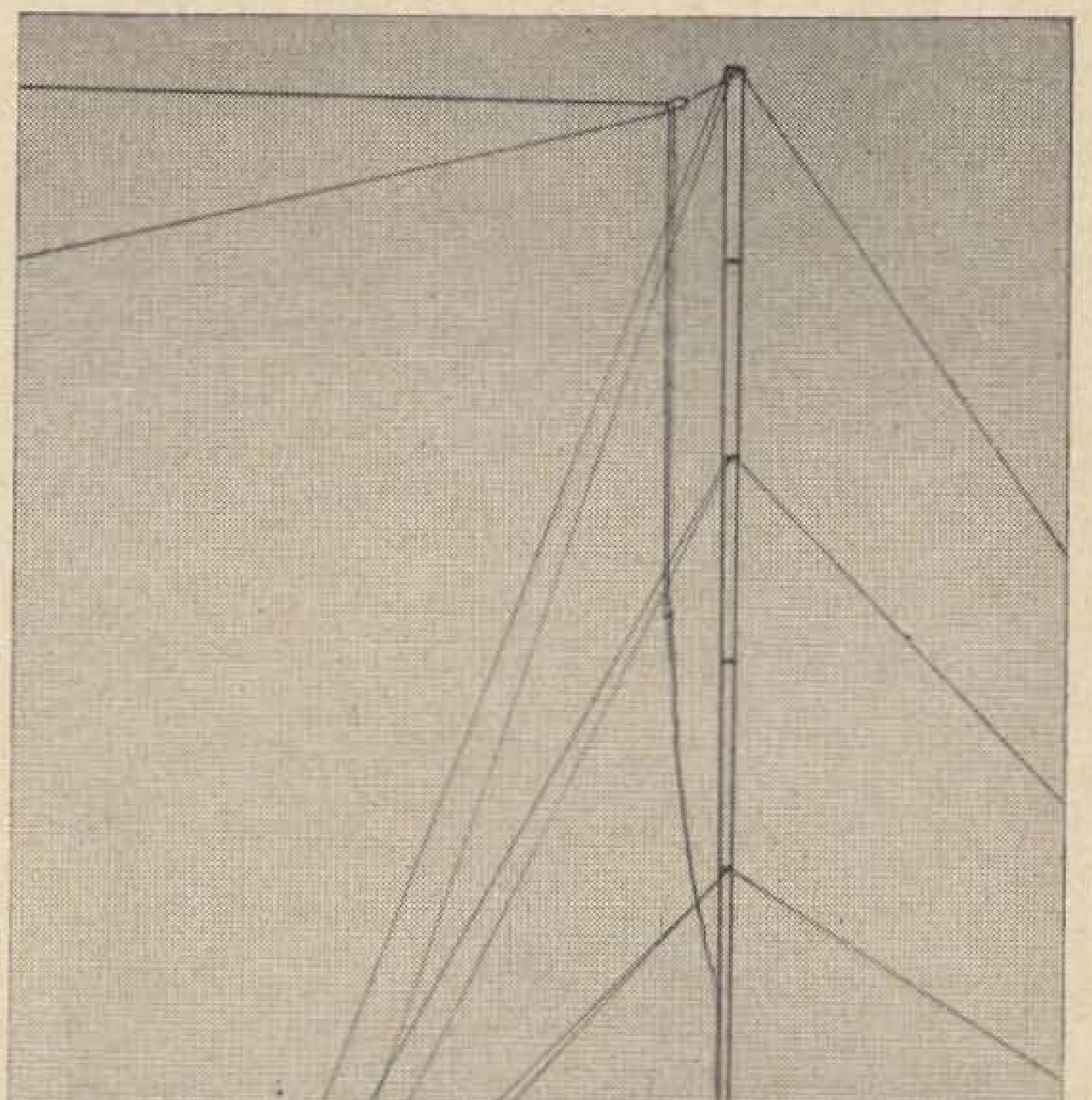
c. Is non-critical in operation and adjustment (broad tuning).

d. Can be made uni-directional by use of a terminating resistance.

On the disadvantage side, these are some of the factors to consider:

a. A large space is required for erection.

b. When terminated with a resistance, approximately 35 to 45% of the power fed to the antenna is dissipated in the termination resistance.



Rear pole with ¼ wavelength stub and coax balun for DL5UW's 20 meter rhombic.

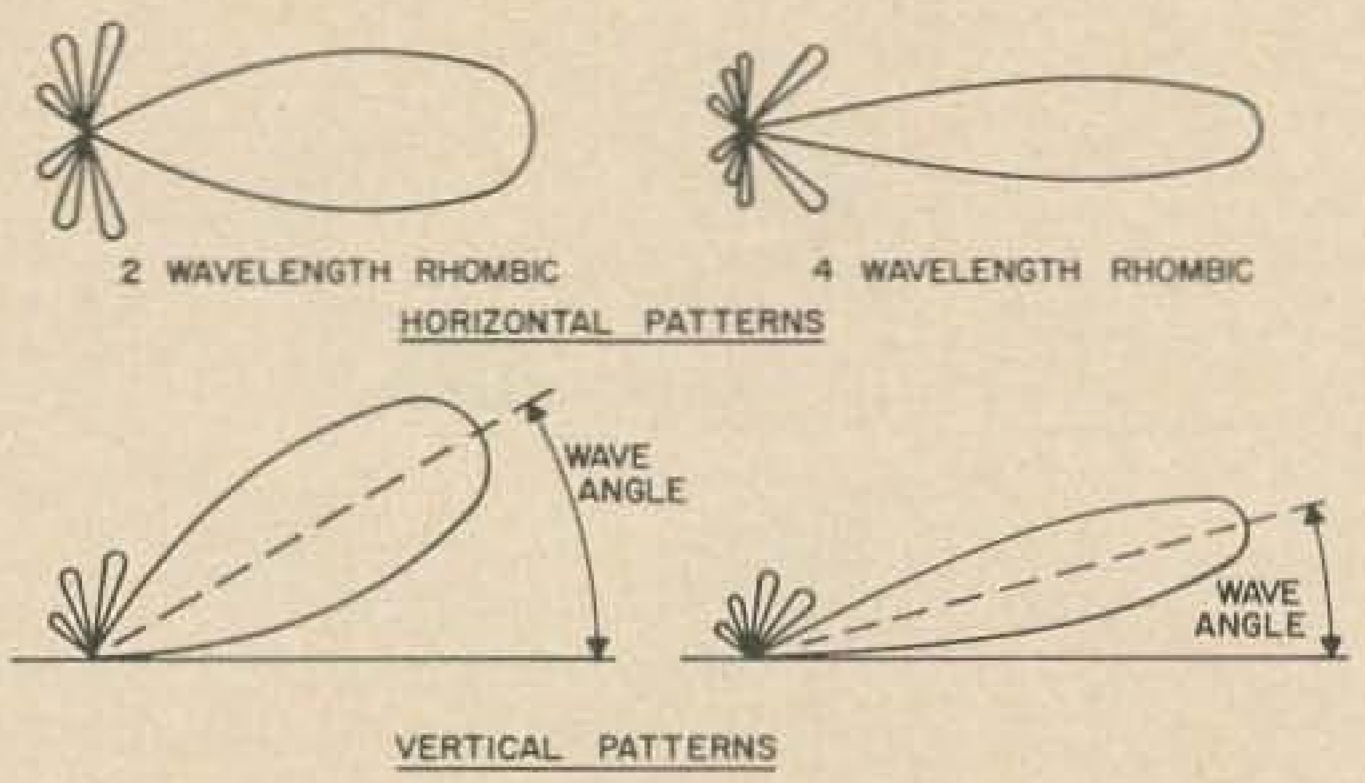


Fig. 5. Vertical and horizontal patterns of rhombics.

c. The horizontal and vertical patterns are interdependent, thus, for example, a rhombic designed to produce a narrow horizontal beam will have a fairly sharp and low vertical pattern. (See **Fig. 5**).

There are two main types of design for a rhombic antenna. One is known as the maximum output design, and the other as the alignment design. As the name implies, the maximum output design rhombic produces maximum gain if certain design parameters are adhered to. If, for example, we desire to cover a 4000 mile path, with a two-hop skip, we might choose a vertical wave angle of 15 degrees and design the antenna around this figure. In order to have the antenna produce maximum power at this vertical wave angle of 15 degrees, we must use certain valves of leg length, tilt angle, and height above ground. Any variation from these valves, will reduce the gain at the desired wave angle.

These computations for a maximum output rhombic, with a 15 degree wave angle are as follows:

$$\text{H (Height in wave lengths)} = \frac{1}{4\sin\Delta}$$

$\sin\Delta = .25882$

$4\sin\Delta = 1.03528$

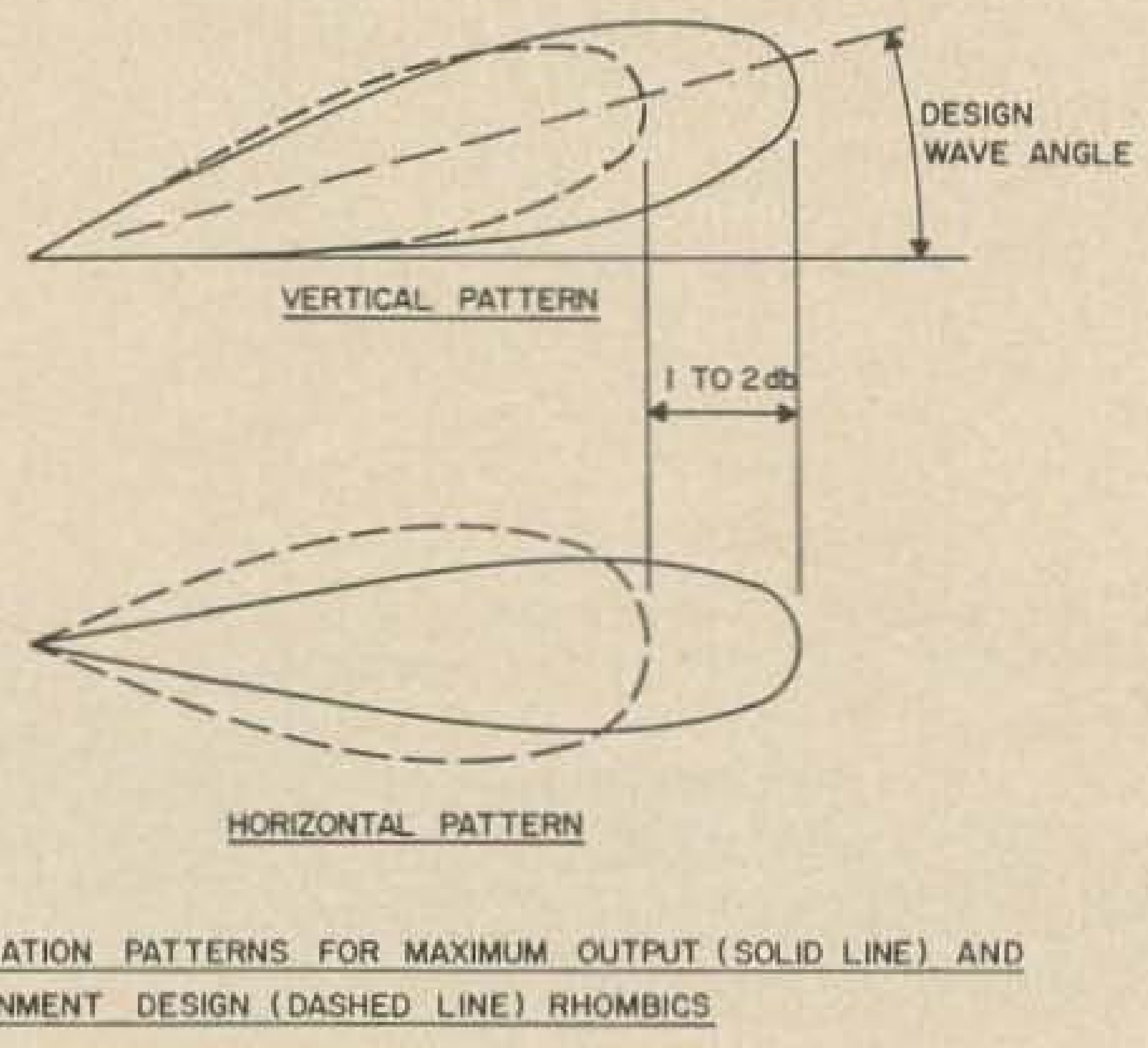


Fig. 6. Differences in patterns between maximum output and alignment rhombics.

$$H = \frac{1}{1.03528}$$

$H = .97$

$$\text{L, leg length} = \frac{1}{2\sin^2\Delta}$$

$\sin\Delta = .25882$

$\sin^2\Delta = .066466$

$2\sin^2\Delta = .13398$

$$L = \frac{1}{.13398}$$

$L = 7.4649$

Tilt Angle, or ϕ (PHI) $= 90° - \Delta$

$\phi = 90° - 15°$

$\phi = 75°$

When a sufficiently large antenna site is not available for a maximum output rhombic, the leg length can be made about 74 precent of the maximum output leg length, or by

$$\text{formula L, or leg length} = \frac{.371}{\sin^2\Delta}$$

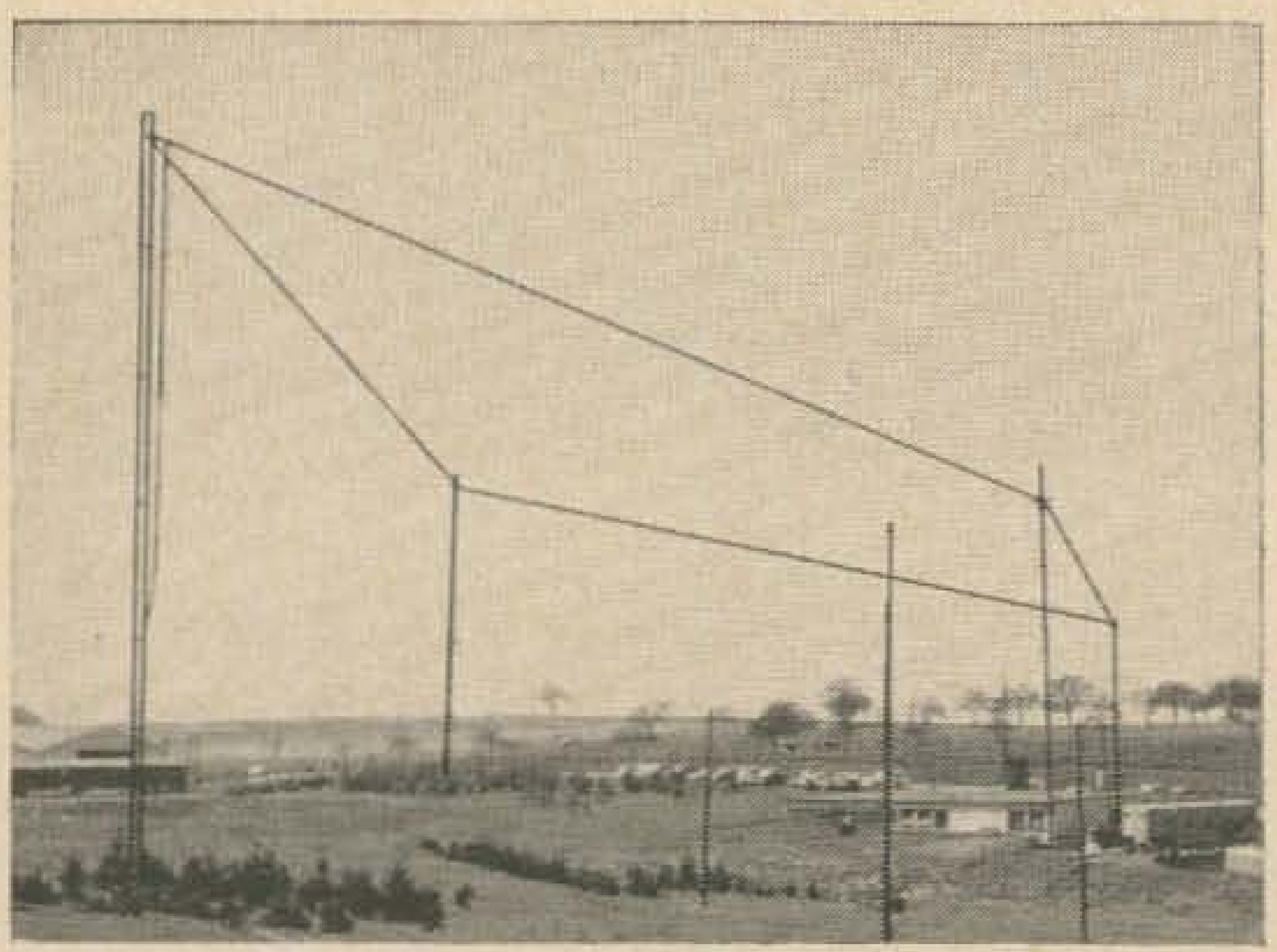
This shortened leg rhombic is known as the alignment design rhombic. The height, and the tilt angle are the same for any given wave angle for both maximum output and alignment designs.

Using the alignment design, there is a small reduction in gain. This gain reduction amounts to about one to two db, in most cases. The horizontal pattern of the alignment design rhombic is some what broader, and the vertical pattern somewhat sharper than that of the maximum output design. In addition, the maximum output design rhombic produces a vertical radiation pattern which, in practice, falls a few degrees lower (or less) than the design angle. For example, our rhombic designed for a vertical angle of 15 degrees, will produce a vertical lobe centered on, perhaps 13 degrees (See **Fig. 6**).

Fig. 7 gives values for both the maximum output and alignment design rhombics.

In military point to point communications, we use several sizes of rhombics that can be utilized for amateur operation. These rhombics were designed to cover a frequency range of 4 to 22 mc. (See **Fig. 8**).

You will notice that the dimensions of these antennas do not necessarily conform to those listed in **Fig. 7**. The reason for this difference is that these rhombics utilize what is known as a compromise design. The compromise design



5 wavelength 20 meter rhombic at DL5UW.

provides good gain over a fairly wide frequency range, and at the same time employs reasonable physical sizes and heights.

In our discussion, and diagrams of various rhombics, we have used a single wire or conductor to form each leg of the antenna. Commercial, military, and in some cases, amateur rhombics employ multi-element legs. These multi-element legs are normally made up of three wires of equal length and fanned out from the rear and front poles so that they have a spacing of about 6 feet (vertically) at the point of attachment to the side poles. (See **Fig. 9**). The multi-wire or curtain rhombic has the following advantages over the single wire type.

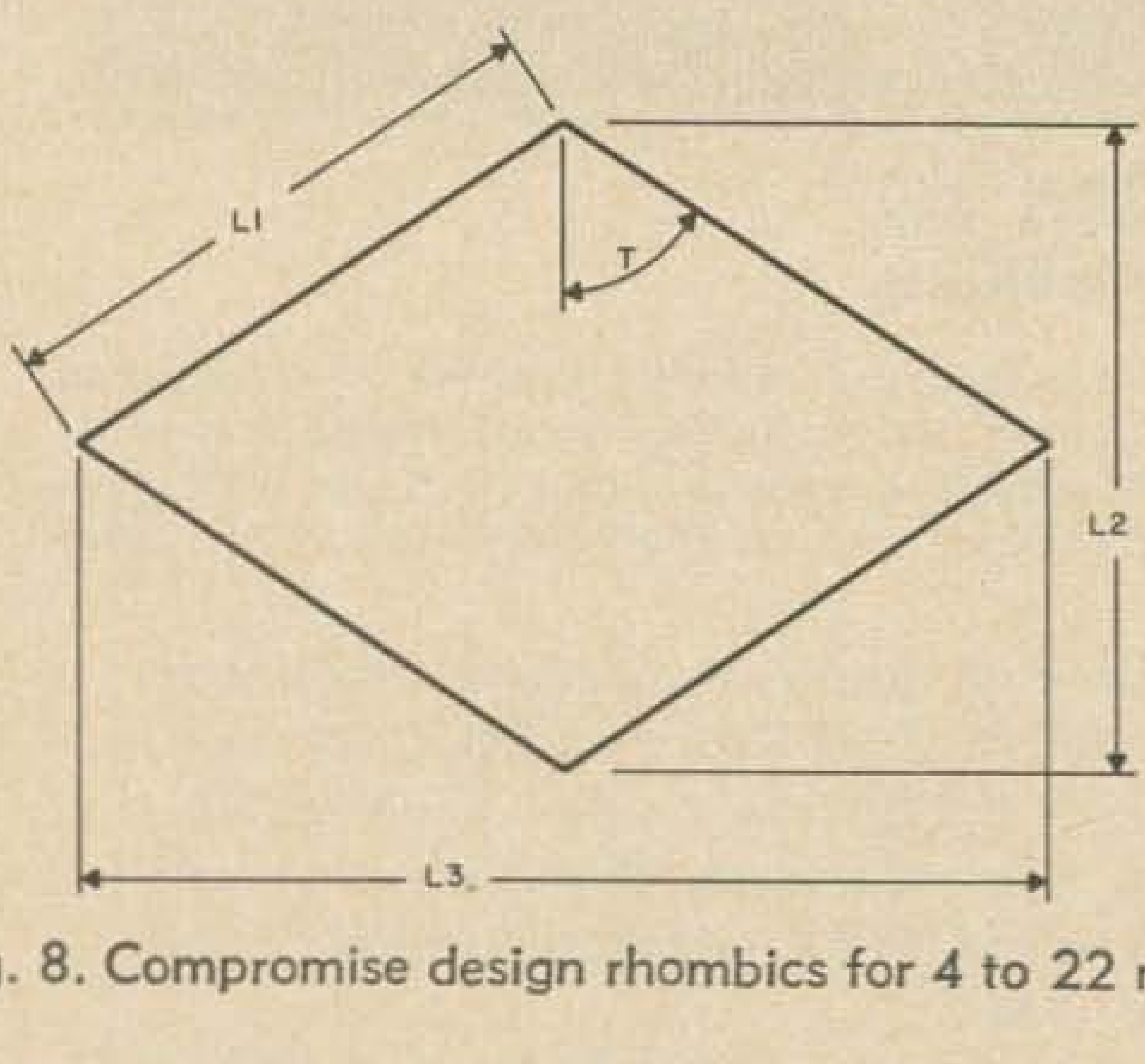


Fig. 8. Compromise design rhombics for 4 to 22 mc.

L1 Leg Length (feet)	L2 Width (feet)	L3 Total Length (feet)	T Tilt Angle (degrees)	H Height (feet)
* 375	256	705	70	65
350	241	658	70	60
315	221	590	70	57
290	222	537	67.5	55
270	228	490	65	53
245	226	437	62.5	51
225	225	391	60	50

* This is approximately the same antenna as the one used so successfully at DL4OV. Converting the 375 foot leg length to wavelengths, we have one wavelength per leg on 3.9 mc, 2½ on 7 mc, 5 on 14 mc and 8 on 21 mc.

Wave Angle (degrees)	Leg Length (wave lengths)	Tilt Angle (degrees)	Height (wave lengths)
10	17	80	1.45
12	11.5	78	1.20
14	8.5	76	1.04
16	6.6	74	.91
18	5.3	72	.81
20	4.3	70	.73
22	3.7	68	.67
24	3	66	.62
28	2.3	62	.53
30	2	60	.50

Fig. 7A. Maximum output rhombic antennas.

Wave Angle (degrees)	Leg Length (wave lengths)	Tilt Angle (degrees)	Height (wave lengths)
10	12	80	1.45
12	8.5	78	1.21
14	6.3	76	1.04
16	4.9	74	.91
18	3.9	72	.81
20	3.2	70	.73
22	2.6	68	.67
24	2.3	66	.63
26	2	64	.57
28	1.8	62	.53
30	1.6	60	.50

Fig. 7B. Alignment design rhombic antennas.

a. The input impedance is more nearly constant over a wide range of frequencies.

b. The input impedance is reduced to a lower value, allowing a good match to 600 ohm open wire line feeders.

c. The 3 wire rhombic produces about 1 db greater gain than the single wire type.

The value for termination of a single wire rhombic is about 800 ohms. When this 800 ohm value is used, the input impedance of the antenna is approximately 700 to 750 ohms. This difference is caused by radiation losses in the antenna. The rhombic can be terminated with non-inductive resistors, such as the carbon type. These resistors are available in power ratings of 100 to 200 watts. One combination of resistors for a single wire rhombic is seven 100 watt, 5200 ohm carbon resistors paralled to make a 700 watt, 740 ohm termination resistance. This 700 watt rating will handle a transmitter running a full kilowatt and allow a 50 percent safety factor. Another type of termination consists of a dissipation line. Dissipation lines are sometimes constructed with a pair of number 15 AWG solid stainless steel wires, spaced to provide proper termination impedance. The advantages of this line is that it is 1000 feet long. A more suitable dissipation line can be constructed with number 24 to 26 nichrome wire 250 feet long, with a 20 watt 800 ohm carbon resistor across the far end of the line. (Ten 8000 ohm 2 watt carbon resistors in parallel, for example). Because of the power attenuation in the 250 feet of nicrome wire, the 20 watt resistor will not be overloaded.

The terminated rhombic can be made to switch its beam, or lobe direction by 180 de-

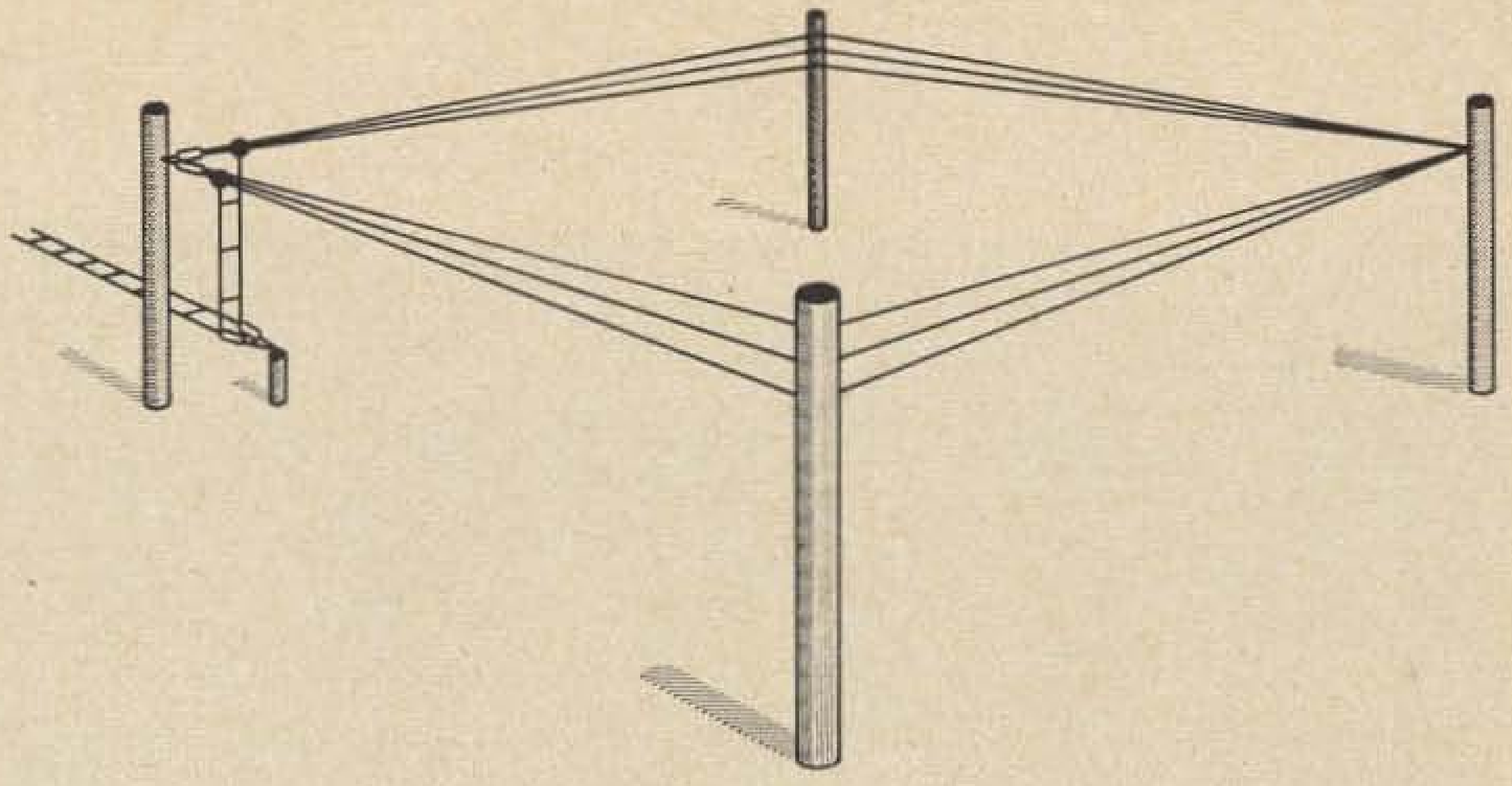


Fig. 9. Three wire rhombic.

grees when the following components are incorporated in the system. First, transmission lines are run from the transmitter to both ends of the rhombic. Then a dissipation line is constructed and the open end brought into the shack, or operating position. If two double pole double throw relays, or switches are employed, the proper transmission line, and the dissipation line can be connected for transmission in either of two desired directions. This switching system is shown in **Fig. 10**.

The resonant, or bi-directional rhombic, unlike the terminated model, must be fed with resonant, or tuned feeders, when operated on more than one band. Open wire line, such as number 14 AWG spaced 6 inches, tuned with a "match box" type of antenna tuner will do the job. When the resonant rhombic is operated on one band only, a matching stub and coaxial cable with a coaxial balun, can be used to feed the antenna.

Good engineering practice calls for a site, or plot of ground that is level and free of obstructions under, and near the rhombic antenna. This, of course, is an ideal situation for installing a rhombic, or any antenna, for that matter. If a rhombic is erected over ground

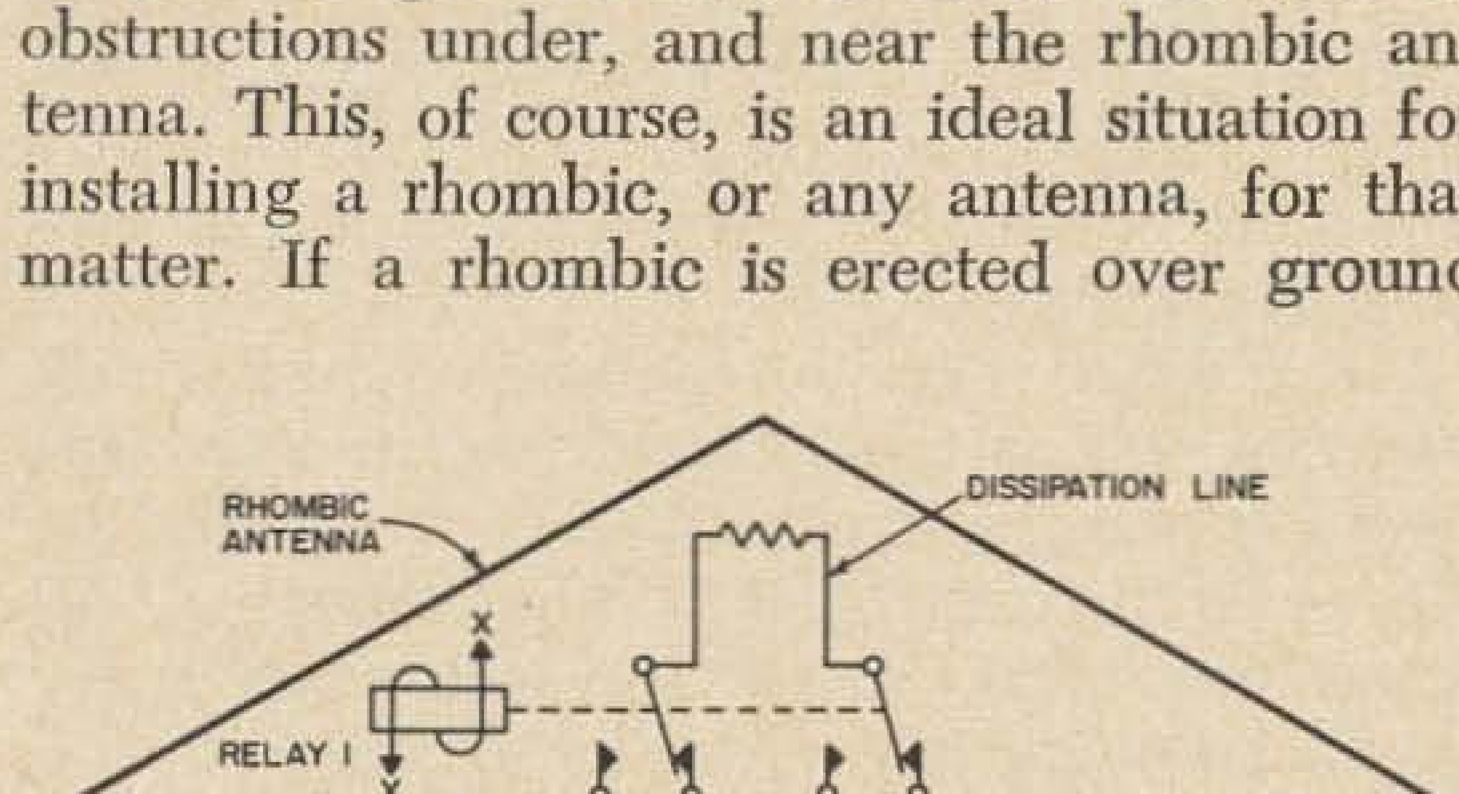


Fig. 10. Switchable terminated rhombic.

that slopes down evenly toward the front pole, the amount of slope, in degrees, is then subtracted from the design wave angle of the antenna. For example, if a rhombic designed for a 20 degree wave angle is erected parallel to the ground with a 5 degree downward slope, the resultant wave angle will be 15 degrees in the direction of the low end, and conversely the wave angle, if the antenna is bi-directional, will be 20 plus 5 degrees, or 25 degrees from the high end. Another variation, used frequently by radio amateurs, is erection of the rhombic over level ground employing poles of various heights, thereby tilting the entire antenna in respect to ground, in the direction that a lower wave angle is desired. For example, a rhombic with 290 foot legs, and a 67.5 degree tilt angle, (Approximately 493 feet from rear to front pole) when erected on level ground with a 70 foot rear pole, 50 foot side poles, and a 30 foot front pole, will have a slope or tilt in the horizontal plane of about 4.5 degrees.

Rhombics and V beams that are sloped, or tilted in the horizontal plane so as to produce a lower wave angle in on direction are very successfully operated by W1DBM, 5H3JR, W1BCR and the author, to name but a few.

Many of us are not fortunate enough to have the space required for a rhombic, but that place out in the country, that you've had your eye on, might just solve that problem. We will all be listening for that nice, big, fat signal from your new diamond shaped antenna. . . . WØSII