Multi-Band Driven-Element

ROTARY BEAM

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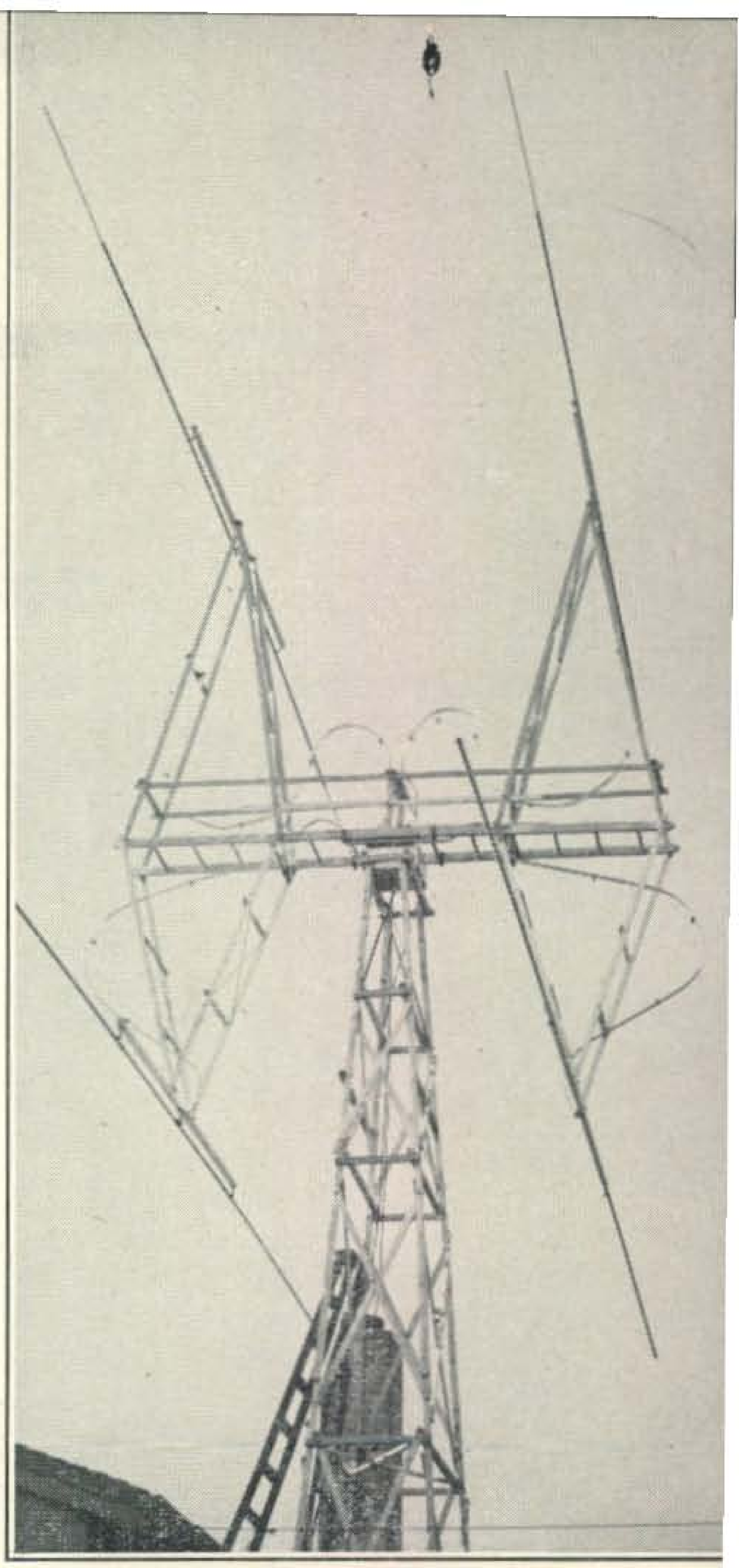
A proponent of the driven-element school comes up with an effective beam for 10, 11, 15 and 20.



Two single-section 14-mc 8JKs stacked three-eights wave on 20 and fed 180° out of phase with Q bars enables operation on 10, 11, 15 and 20.

When short skip sets in, the locals frequently get together for round tables on problems of mutual interest. Antennas, as always, are high on the list of topics gone over. The writer, as a staunch advocate of the driven-element type of rotary, has been the center of considerable controversy from the equally vigorous proponents of the parasitic type of array.

The beam described in this article was built as the "final" answer to the parasitic advocates. The driven-element beam, while impressive to look at, is even more impressive when one examines its performance statistics. Here is a single beam that will perform very efficiently without any retuning or switching on 10, 11, and 20, and also gives satisfactory performance on 15!

Basically, the driven-element beam consists of two Johnson Q-type, single-section, 20-meter 8JKs, stacked three-eighths wave on that band. The Q-bars are so arranged that the impedance at the feed point is identical whether the array be used on its fundamental on 20 or on its first harmonic on the 10-meter band. On 10 meters it becomes two *double-section* 8JKs, stacked approximately five-eighths wave. Looking at it from the front, it is two complete Lazy Hs, one 10 feet behind the other, fed 180° out of phase. If feeder length is properly adjusted, the array will also resonate on 15 meters as two extended-Zepp 8JKs stacked one-half wave.

Theory and Mathematics Involved

Most authorities on the subject agree that the impedance at the center of a single-section 8JK is approximately 21 ohms, where the elements are spaced somewhere between an eighth and a fifth of a wavelength. Optimum gain with two driven elements fed 180° out of phase is obtained with spacing between a seventh and a fifth wavelength, so we chose 10 feet spacing as giving optimum efficiency on 20 meters while still not too far out of line for 10-meter operation. These same experts seem to agree that the center impedance increases to approximately 1200 ohms when the array is operated on its second harmonic.

Two formulas are employed in computing the physical characteristics of the quarter-wave matching sections needed for 20-meter operation. The formula to ascertain the impedance necessary in a quarter-wave section to match the center of the antenna to a given feed line is as follows:

$$Z_m = \sqrt{Z_l \times Z_a}$$

where Z_m is the characteristic impedance of the quarter-wave section, Z_l is the impedance of the transmission line going to the transmitter, and Z_a is the center impedance of the antenna. The formula used to determine the physical spacing and size of the elements needed for such a quarter-wave matching section is

$$Z_m = 278 \log_{10} \frac{2D}{d}$$

where D is the spacing between the centers of the elements and d is the diameter of the conductors utilized in the matching section.[1]

These formulas are intended primarily for those who might want to use different diameter tubing than we did. If ½" aluminum tubing is used, a spacing of 1" center to center gives the 158-ohm

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1 The presence of the second 8JK stacked 10 feet above the lower section changes the impedance of the array due to the mutual impedance between the elements. However, since WØNNI obtains a low SWR on the basis of impedances mentioned the practical change evidently is not too great.

impedance needed in the quarter-wave sections, and 3 1/16" spacing gives the 300-ohm impedance for the feeder line.

On 20 meters the 158-ohm quarter-wave transformer increases the 21-ohm center impedance of each element to 1200 ohms at the center of the array. Connecting the feeders on each side in parallel and then transposing the connection between these brings four 1200-ohm impedances together, resulting in an impedance of 300 ohms where we attach the feed line. On 10 meters the Q sections become ½ wave and serve as a one-to-one transformer. The 1200-ohm center impedance for each element with second harmonic operation is transformed to 300 ohms at the beam feed point. Large diameter elements will tend to make the array broad enough to resonate also on 11 meters. A standing wave ratio may appear on 11, and will appear on 15-meter operation where we adjust feeder length to have a current maximum at the transmitter link connection. But 10 and 20-meter operation offers no such irregularities. The beam at WØNNI dips a grid meter at the link end at approximately 14,300, 28,500, and 21,350 kc, and will take the full output available on any frequency in the 20, 15, 11, or 10-meter bands.[2]

Material for the R-F Portion

The radiating portion of the beam requires light self-supporting 10-meter elements, with a good degree of stiffness. We employed Dural pipe, 24ST, 1 1/8" in diameter, each 16' 3" in length. Some of the new tapered and corrugated light steel elements, such as are available from Premax would be excellent. Weight is quite a factor in an array of this size and every effort should be made to keep it down. In addition, four Q transformers, quarter-wave on 20 meters and 158 ohms characteristic impedance, are needed. 16' 5" half-inch diameter surplus duraluminum tubes, spaced 1" center to center with Johnson variable spacing bars No. 136–33, were employed in our installation. From the center connection of the beam to the transmitter in the shack, 300-ohm line is needed. The most convenient, of course, is Amphenol Twin-Lead. The most efficient would probably be some more ½" duraluminum tubing with the same Johnson variable spacers set to make the spacing 3 1/16" center to center. The latter type feeder spacing could be varied with a Micro-Match hooked in for a more exact match. In our case, the Amphenol was employed for convenience. Since the element and Johnson Q dimensions will vary slightly with height above ground, the really particular fellow may want to make them slightly adjustable and resonate them for the favorite frequency with a grid dip meter.

Framework to Support

The headaches and the backaches in the building of super-duper dream beams generally occur in this phase of the operation, and our experience was no exception. The design employed appears to be sufficiently strong, lends itself well to either wood or metal construction, and is also conveniently arranged for raising and placing in position on the top of the tower. It can best be described in words as a rectangular center boom of sufficient diameter to carry the end weight involved, with 4 block triangles mounted on the ends projecting both skyward and groundward from the center boom. The elements are mounted along the line that constitutes the extremities of the triangular sections.

The framework was constructed of 2 x 2 and 1 x 2 lumber with aluminum strengtheners ¾" wide

[2] This is not just a function of beam design. Length of feeder and most important, the output coupling system employed must be considered. The output coupling system at WØNNI uses conventional link coupling.

DIMENSIONS

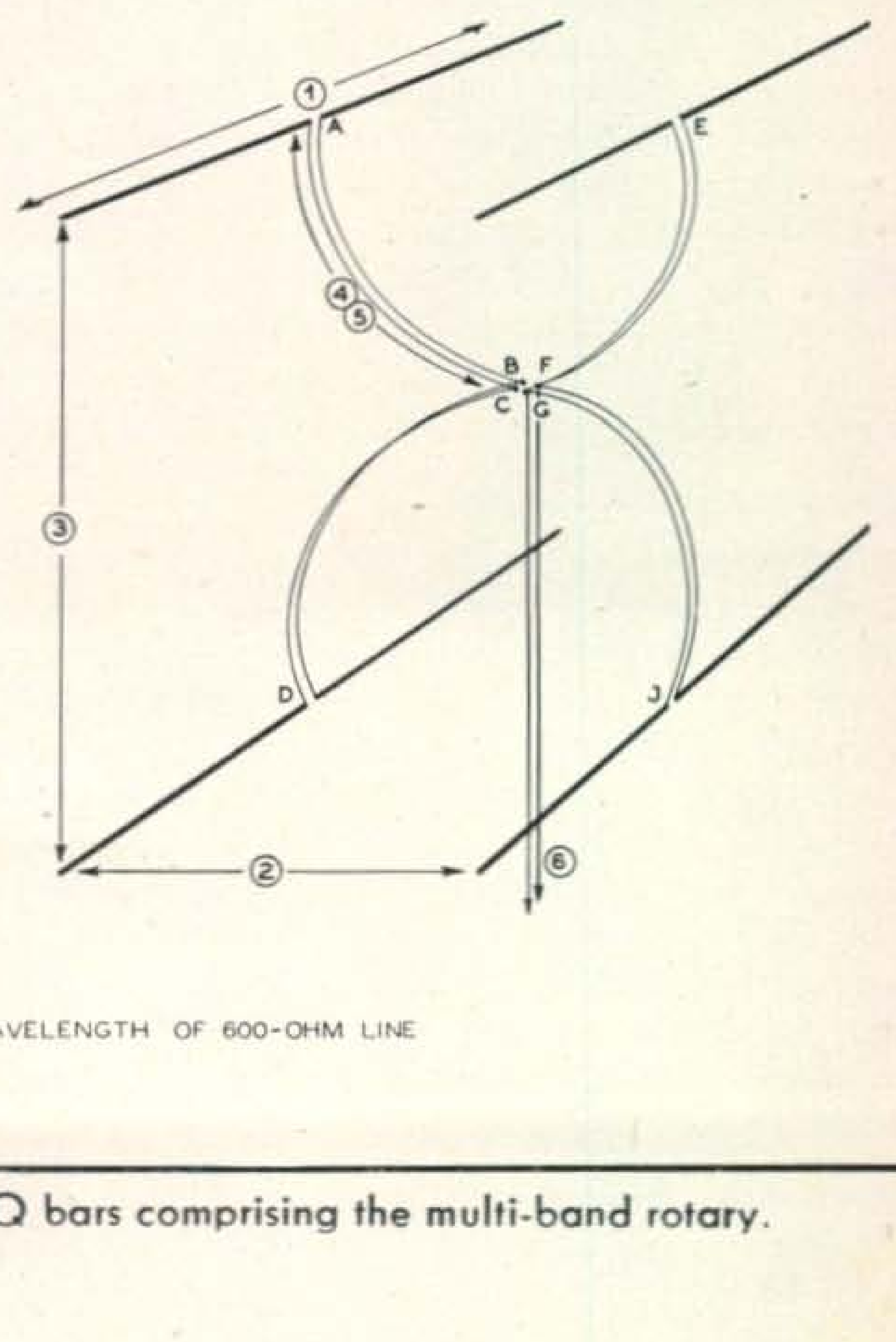
1. TOTAL LENGTH OF RADIATING ELEMENT = $464/F_{MC}$
USE LARGEST POSSIBLE DIAMETER TUBING
2. HORIZONTAL SPACING BETWEEN ELEMENTS = 10 FEET
3. STACKING FOR BEST OPERATION = 22 FEET
ANY DISTANCE 17 TO 24 FEET WILL WORK
4. ALL Q BARS (AB, EF, ETC.) ARE ONE-HALF INCH DIAMETER ALUMINUM TUBING SPACED ONE INCH CENTER-TO-CENTER
5. Q BAR SECTION LENGTHS ALL = $234/F_{MC}$
6. 300 OHM LINE TO TRANSMITTER CONNECTS AT THE JUNCTION OF EF AND GJ

DIRECTIVITY

FOR MULTIBAND BIDIRECTION PATTERN
JOIN BC AND FG WITH VERY SHORT CROSSOVER LINK TO OBTAIN 180° PHASING

FOR ONE-BAND UNIDIRECTIONAL PATTERN WITH A HIGH FRONT-TO-BACK RATIO
SUBSTITUTE FOR CROSSOVER LINK A QUARTER-WAVE LENGTH OF 600-OHM LINE

FOR ONE-BAND UNIDIRECTIONAL PATTERN WITH MAXIMUM FORWARD GAIN
SUBSTITUTE FOR CROSSOVER LINK A THREE EIGHTHS-WAVELENGTH OF 600-OHM LINE



The basic positioning of the elements and the Q bars comprising the multi-band rotary.

and 12" long, placed wherever a bolt through the 1 x 2 would be carrying a considerable amount of strain, especially in a high wind. Bolts were used throughout, with large washers, so as to secure all joints in a permanent fashion. The pieces making up the edges of the block Vs are 1 x 2s 12′ in length. Two triangles with common 5′ bases built of these 12′ strips produced a stack of 22 feet, the necessary 3/8 wave on 20 meters.

At least as much cross-bracing as appears in the accompanying pictures should be used. In a location subject to high winds even more bracing might be advisable. The completed framework should be sufficiently rigid that it can be picked up by one corner without more than a few inches of give. Our center boom was made using a 14′ ladder for its bottom foundation, with 1 x 2s and 2 x 2s making up the posts and the four other stringers plus cross bracing, sufficient to give it the rigidity needed. The ladder, while heavy,[3] made a good solid place to which the Vs going both skyward and earthward could be solidly bolted, and also a solid foundation to which the channel iron or plate on the rotator could be fastened. Anyone constructing this framework should also note that the 12′ stringers making up the Vs begin at the same point of attachment on the center boom, namely on the lower stringer or ladder in our case. Thus, the large diameter of the boom helps to support that part of the structure above the rotator as well as furnishing vertical and horizontal rigidity for the whole array.

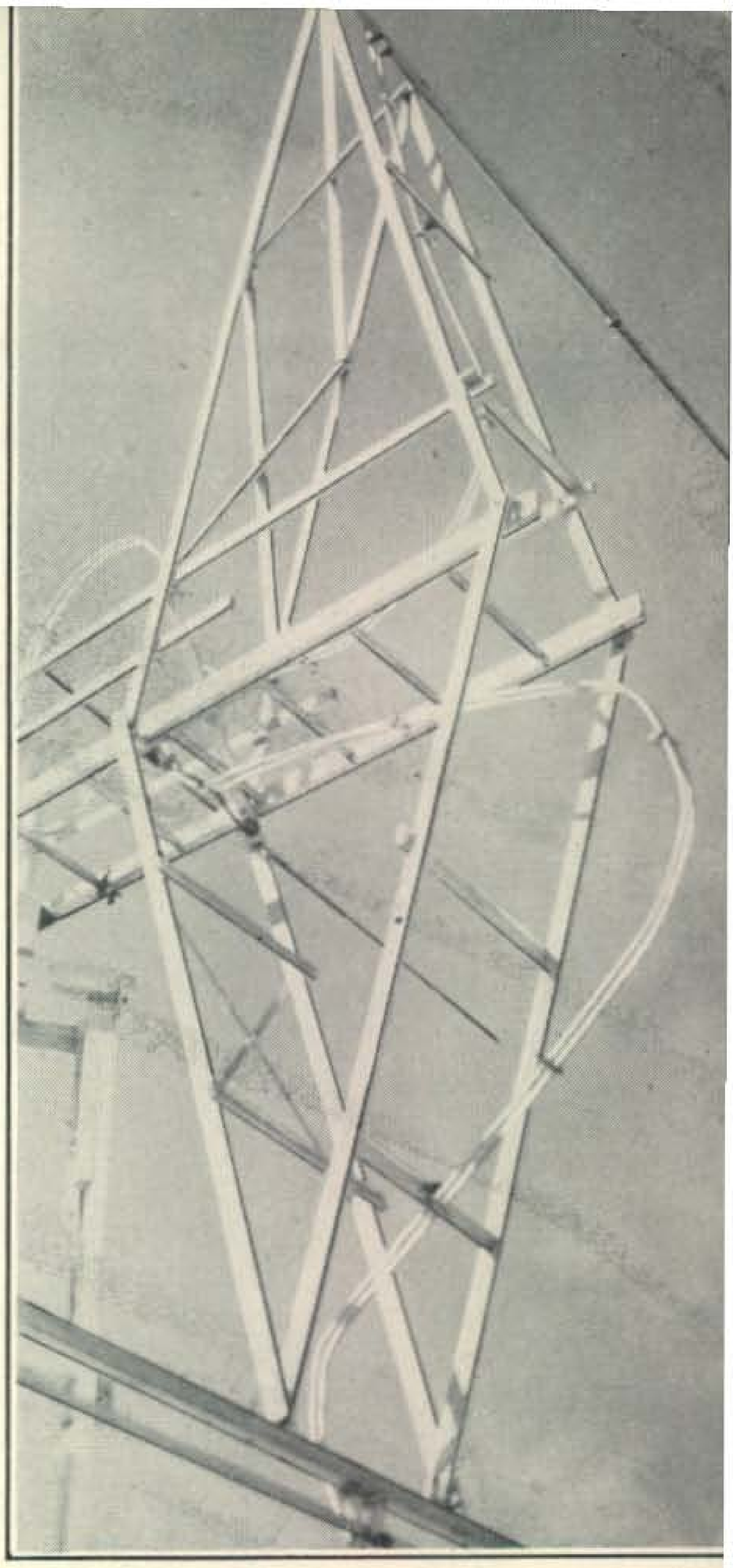
It is easy to understand why the 12′ Vs going earthward do not require so much support, since they hang from the boom, so to speak, with gravity helping to keep them in position. Only strength enough to counteract wind resistance is needed.

The cross arms which carry the elements are 2 x 2s 10′ long, bolted to the end of the 12′ stringers where they come together with 2" angle irons. The joining of the 12′ stringers at the end of the V is one of the places needing a strip of aluminum to distribute the strain back from the end of the wood employed.

Overcoming Excessive Rotor Strain

The rotator employed at WØNNI has a 1½" steel pipe, mounted in bearings 5" apart, which carries the plate and channel iron to which the beam is fastened. This has proven sufficiently strong to carry the beam without flexing in winds up to 25 mph. However, to assist the rotator in carrying the strain of such a large array, it was found necessary to build a block, fitted across the lower extremity, which would tie it to the tower at that point and thus remove the twisting motion and unusual strain to which the rotator would be subjected in case of high wind. With the bottom thus blocked in position the rotator has only to carry the side pressure and almost any type of side bearings will stand this strain.

This block was constructed from an 11-ft. 2 x 2 with holes drilled in each end large enough to fit down over extra long bolts fixed in the angle irons supporting the 2 x 2 element holder. Holes were then made in the 2 x 2 block bar to coincide with holes in cross pieces on the tower so that the beam could be blocked either in an east-west or north-south direction. We are thus able to employ the array in a fixed position regardless of the wind velocity. This blocking feature requires a convenient ladder up the side of the tower, together with a small platform step, 7" or 8" wide, installed at a point within reach of the point of attachment of this blocking bar.



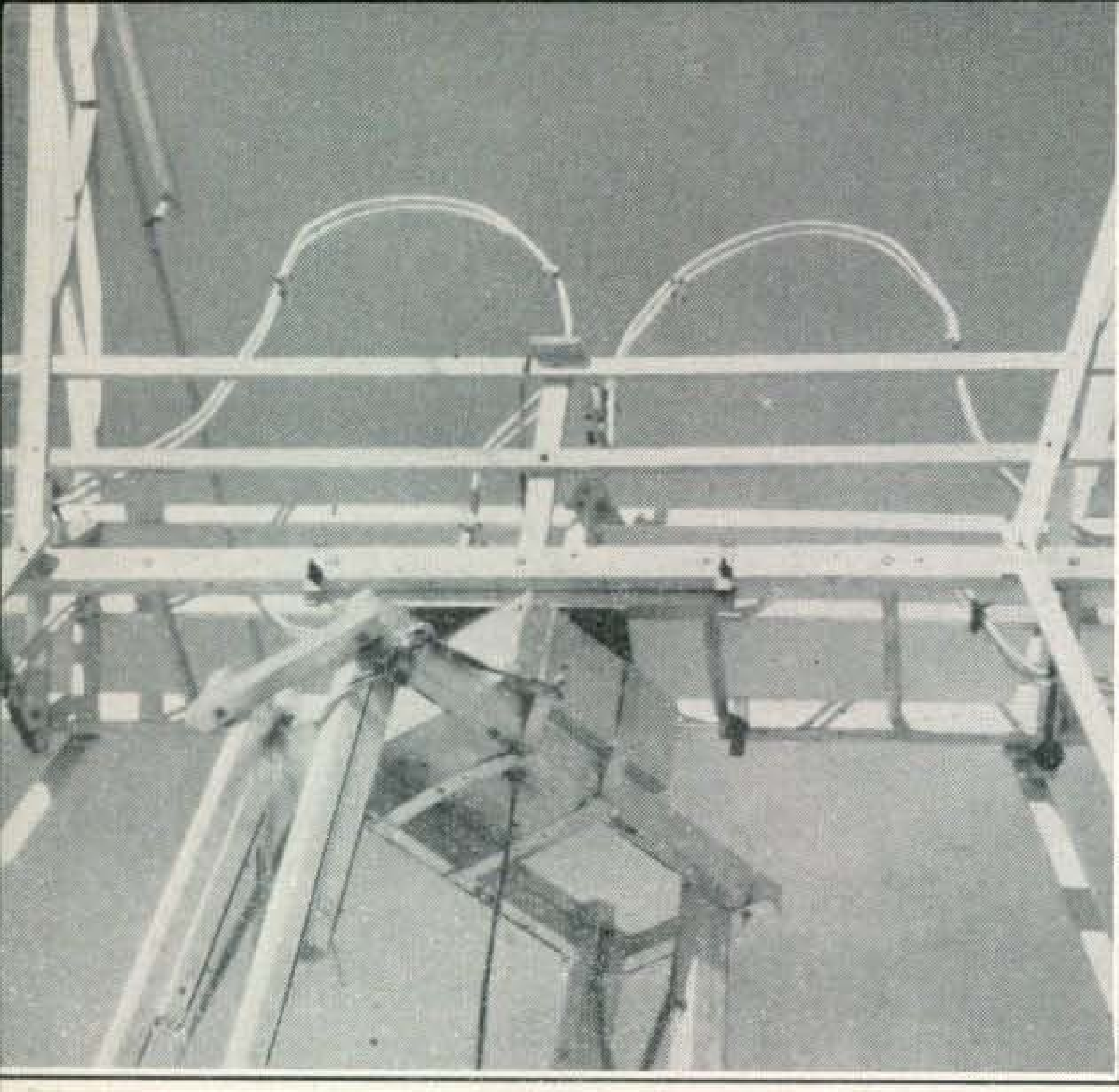
The method of supporting the Q bars and construction details of the supporting diamonds are identical for both of the 8JKs

Variations in the Pattern Obtainable

The transposition connector between the front and back element Johnson Qs recommended produces bidirectional gain on both receiving and transmitting on all bands. If a unidirectional pattern is required, and that is sometimes especially desirable on receiving, it can be accomplished by employing a 600-ohm quarter wave for the band in question in place of the transposition connector. The front then will lead the back elements by 90° phasing and a cardioid pattern as described in the August, 1947, issue of *CQ*[4] is obtained with the same gain concentrated in one direction as was previously realized in two directions and an infinite front-to-back ratio if the beam is properly adjusted. But if this change is made the antenna becomes a *one-band* array, since a change in the length of the inserted quarter wave is necessary to change bands. Some lumped inductance devices

[3] Aluminum and other light metal ladders are available from many sources. Montgomery Ward lists them in their current catalog.

[4] Harris, "The Cardioid Beam Antenna," *CQ*, Aug., 1947.



The center mounting of the beam must be husky to support the weight of the superstructure. The Q bars and 300-ohm ribbon are brought to a juncture at the top of the platform.

with plug-in connectors might make this not too impossible an obstacle.

The author's original objective while the beam was still on paper was 20-meter results equal to a 3 or 4-element 20-meter parasitic array and a 10-meter gain at least two Rs beyond the parasitic competition. It has lived up to these expectations and even exceeded them on the longer hops on 10 meters, due probably to the low angle of radiation accomplished by the stacking of elements involved. 11-meter results have been the same as those on 10. And results on 15, when we get that band, should fall somewhere between, and still be better than a 4-element on that band—and all this with multiband operation with no change of connection in the array!

The evening we got the beam up we were the loudest signal on 20 at Milwaukee, and the same on 10 meters at KH6AM in Honolulu. Whereas previously, with a 4-element beam, the R meter in Denver and Honolulu had always read the same on both ends of our many QSOs with KH6AM and his Sterba, since "beam day" we have consistently been 3 to 4 Rs louder there than he is in Denver.[5] Eight-hour WACs, and better, on 20 meters are commonplace—not a bad feat in inland mountain-bound Colorado. We regularly worked DX on ten during the summer before the regular openings for consistent foreign contacts occurred in early fall.

During the fall and this winter we have kept consistent schedules with Germany, Japan, Korea, Manila, Liberia, and South Africa, on both 10 and 20 meters with never a failure unless conditions were out altogether. Reports continue consistently above average on the band in use and we have never been bothered by QRM from our own district.

For the man with a stout tower and rotator, limited space, and a yen for multiband operation on the DX frequencies, here is the beam that will solve your radiation problems.

5 The free-space gain of the multi-band driven-element beam is as follows: On 14 mc the gain of the out-of-phase 8JK is 1.6 in field strength which is 2.56 in power, or 4.1 db. The stacking provides a gain of 1.2 in field strength or 1.44 in power, or 1.6 db. The free-space gain of the array then is 5.7 db on 14 mc. On 28 mc the gain is 2 db for the colinear elements, 3.8 db for the out-of-phase 8JK, and 4.86 db for the stacking. Hence the over-all 28-mc gain in free space is 10.66 db.

The 4-element (half-wavelength elements) parasitic array has a gain of the order of 8–9 db in free space. When the parasitic elements are one wavelength long and excited in phase (second harmonic operation) the gain of the 4-element parasitic array is 10–11 db in free space.

Electronic Navigation

Long range navigation has now become an electronic art. However, some systems are better for certain purposes than others. This is a resume of the better characteristics of the most important types.

Loran—operates near 1.95 mc. and uses pulses emitted from pairs of masters and slave ground stations. An airplane receives one of the pair before its mate in such a fashion that they may be displayed on a cathode-ray tube screen and the time difference measured. The distance range at sea is about 800 miles during the day and 1600 miles during the night. The last range suffers from some inaccuracy while errors in a normal fix probably do not exceed 3 to 4 miles.

Low-frequency Loran—Essentially the same system operating from 140 to 200 kc. The claimed daytime range is 2400 miles at best and 1200 miles at worst. Usually the system is good to within 10 miles and is capable of being operated in the polar regions. The ranges beyond 4000 miles are not useful because of a geometrical error.

Decca—a British system using phase comparison somewhat similar to Loran in manner of display. Has a very high order of discrimination and is known to be exceptionally accurate at short ranges. Operates around 100 kc and can be used to distances of 300 miles, but has no judgment factor beyond.

Sonne (Consol)—Uses a rotating loop and sense antenna as in the common direction finding equipment. A special circuit corrects for phase shift errors. Has the potential accuracy of direction finding equipment and is considered useful from 800 to 900 miles during the day and 1200 to 1400 miles at night. Operates at 300 kc and uses sky-waves entirely.

High-frequency Direction Finding—A fairly common method which operates between 20 and 40 meters. It employs sky waves and is thus considered unpredictable. Slowly becoming obsolete since it is possible to introduce errors from 2 to 5 degrees.

Gee—A British system using four transmitting stations at about 50 mc. Uses a variation of the Loran system, but is limited to a range of about 350 to 400 miles at an altitude of about 30,000 feet. Special equipment needed and the system is not too common outside of Great Britain.

BABS—European variation of Lorenz landing beacons. Operating mostly in the range 30 to 40 mc. it gives the pilot a good idea of the center of the runway. Used with an airbourne interrogator. Sometimes enables long range (300 miles or more) location of airport.