Feb. 11, 1969 A. G. KANDOIAN ET AL 3,427,622

VOR ANTENNA

Filed Feb. 14, 1967

Sheet 1 of 2

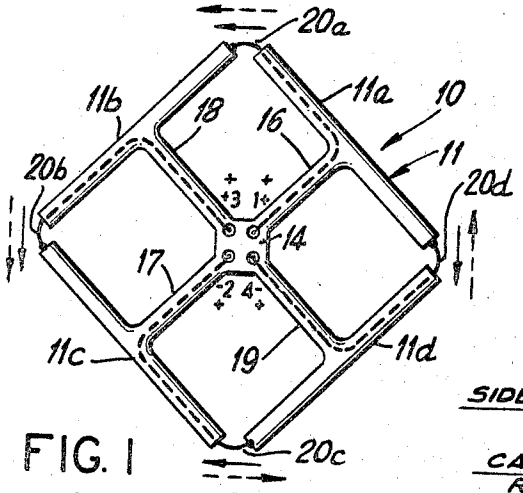


FIG. 1

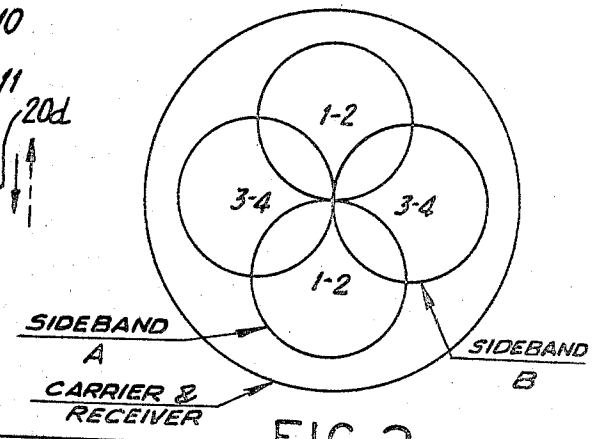


FIG. 2

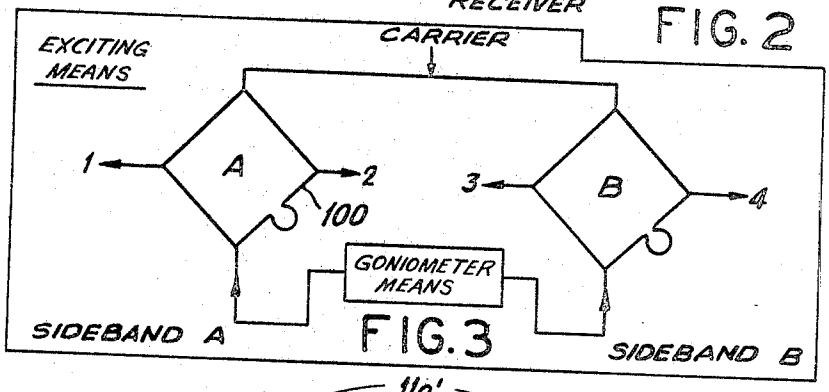


FIG. 3

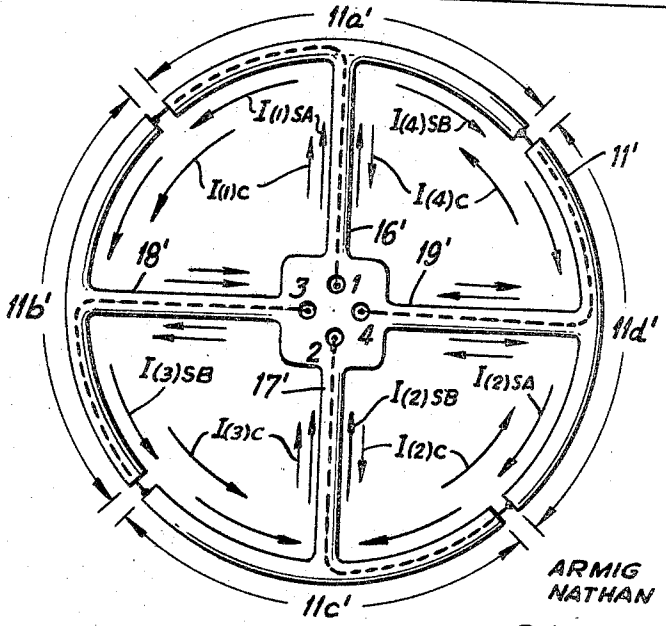


FIG. 4

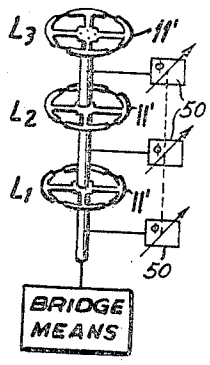


FIG. 5

INVENTORS
ARMIG G. KANDOIAN
NATHAN MARCHAND

BY Hofgood & Calimafde
ATTORNEYS

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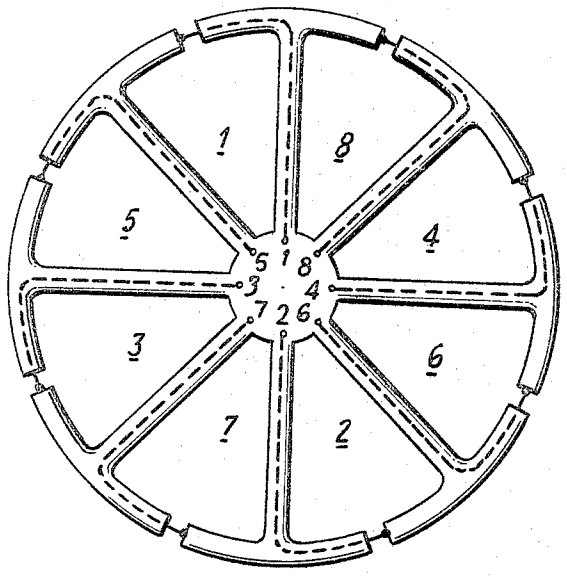


FIG. 6

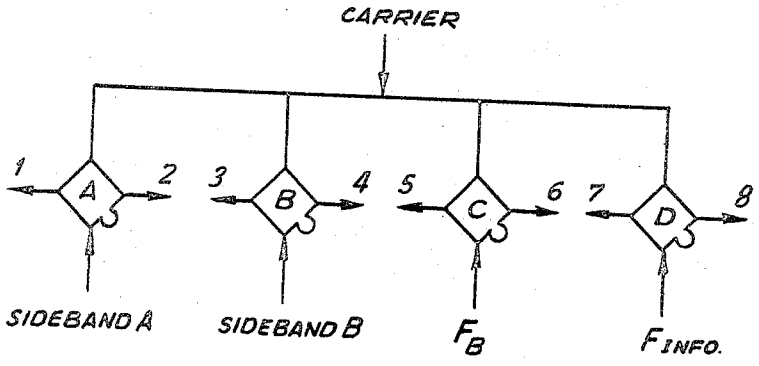


FIG. 7

INVENTORS
ARMIG G. KANDOIAN
NATHAN MARCHAND

BY Hopgood & Calimafde
ATTORNEYS

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VOR ANTENNA

Armig G. Kandoian, Ridgewood, N.J., and Nathan Marchand, Greenwich, Conn., assignors to Communication Systems, Incorporated, Paramus, N.J.

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Int. Cl. G01s 1/44

ABSTRACT OF THE DISCLOSURE

An ominidirectional and direction loop antenna is provided having one or more stacked loops. Each loop comprises an outer loop and radially connecting spokes and a central feed defining subloops. Gaps are provided in loop between the spokes. The feed comprises wires passing internally through the spokes and the adjacent loop section and are fastened externally to the loop section adjacent the gap.

This invention relates to a VOR antenna and more particularly relates to a compact single-loop antenna providing a complete VOR pattern. In one aspect, this invention relates to a single loop antenna providing an omnidirectional pattern and the two rotating figure-eight patterns. In a broader aspect, the single loop may provide an omnidirectional pattern, two rotating patterns, fixed beacons and other selected radiation patterns.

Prior RF VOR antenna systems have employed five antennas or a five-loop VOR comprising a four-loop antenna radiating two rotating figure-eight patterns. Here a single antenna is positioned effectively in the center thereof to create an ominidirectional pattern for the reference signal.

In another embodiment, a four-loop antenna is used to create the rotating field and the omnidirectional pattern is created by means of a double RF bridge circuit. This four-loop antenna and bridge are described in "The Four-Loop VOR Antenna," by Anderson et al., Technical Development Report No. 210, Civil Aeronautics Administration, June 1953.

A serious problem exists in these prior VOR antennas because of substantial ground reflections causing errors. The ground reflections provide a cancellation vector or field which reduces or distorts the transmitted patterns. Pattern distortions can cause substantial errors in aircraft navigation, becoming in certain cases, a safety problem.

Proposals have been made to reduce ground reflections involving either complex antenna arrangements or requiring extensive site area clearance. Site area clearance is expensive. In areas where mountains surround a landing field, site clearance is impossible and therefore an improved antenna arrangement is necessary.

Loop antennas heretofore made are relatively complex. The four-loop antenna referred to has employed four separate loops mounted at corners of a square, each diagonal pair being driven from a bridge circuit, using jumpers, transposition pieces, and noncentric feeding. Stacked loops have been suggested as a means for minimizing ground reflections, however, the mechanical stacking and electrical feeding problems become substantial.

From the construction viewpoint, a VOR antenna should be economical and easily assembled and transportable. In order to achieve a significant construction advance, we have provided a novel VOR loop which has only one center support and a center feed. In this way, the single antenna is easily mounted and stacked loops on a single supporting member becomes feasible.

One of the objects of this invention is to provide a simpler single-loop antenna and a novel bridge circuit

feed therefor to create a complete VOR antenna pattern.

An important object of this invention is to provide an improved four-loop antenna having an omnidirectional pattern and two rotating figure-eight patterns.

Another significant object is to provide a multi-loop antenna having more than four loops to provide a multiplicity of radiation patterns in which the separate loops are independently, controllably energized.

A further object of this invention is to provide an easily constructed, transported and erected VOR antenna.

Still another object of this invention is to provide a single balanced VOR loop to eliminate extraneous radiations and minimize polyarization errors.

A further object is to provide a series of stacked loops each providing the complete VOR pattern all mounted on a single supporting member to create a vertical pattern minimizing ground reflections.

Further objects, as well as a more complete description of this invention will be apparent from the following drawing, in which:

FIG. 1 is a diagram of the loop antenna of this invention.

FIG. 2 is a diagram of the radiation pattern.

FIG. 3 is a circuit diagram of the bridge circuit to the loop FIG. 1.

FIG. 4 is an alternate embodiment of the novel loop of this invention.

FIG. 5 is a diagram of a stacked array.

FIG. 6 is a diagram of an alternate multi-loop antenna.

FIG. 7 is a diagram of a feeding circuit for the multi-loop of FIG. 6.

Referring now to FIG. 1, there is shown a compact VOR antenna **10** comprising a substantially endless member or single loop **11** having a central feed **14** comprising four feed conductors **1**, **2**, **3**, **4**. The single loop creates both the rotating cardiod pattern and the reference omnidirectional radiation pattern as will be described.

Loop or peripheral member **11** is made of hollow outer sections **11***a*, **11***b*, **11***c*, **11***d* or any other type of hollow peripheral member, substantially endless. Four hollow crossed spokes **16**, **17**, **18** and **19** emanate from the common central portion of the feed **14**.

The feed conductors **1**, **2**, **3**, **4** are fed into the center portion and out radially and internally through spokes **16–19** to the outer loop **11**. The loop **11** is cut through in the center of loop sections **11***a*, **11***b*, **11***c*, **11***d* between each of the spokes to provide the antenna feed gaps **20***a*, **20***b*, **20***c*, **20***d*. The conductor from each feed is led internally within respective spokes and then internally through the peripheral member and across the gap fastening to and terminating at the peripheral member on the other side of the gap. The internal passages of spokes **16–19** communicate with the passages of the hollow sections of the loop as to the respective conductive walls. In this way, four loops are formed which are fed at the gap, a first loop comprising conductor **1**, the right side of **11***b* and spoke **18**; the second loop comprising conductor **2**, the left side of **11***d* and spoke **19**; the third loop comprises conductor **3**, the left side of **11***c* and spoke **17**; loop **4** comprises conductor **4**, the right side of **11***a* and spoke **16**.

The four feed conductors are fed by means of the double bridge circuit shown in FIG. 3. Bridge A comprises three equal arms and a fourth arm **100** including a 180 degree phase shifter. Bridge B comprises the same elements. Feed wires **1** and **2** are connected at terminals **1** and **2** of bridge A while feed wires **3** and **4** are connected to terminals **3** and **4** of bridge B. A carrier signal is applied directly to the common top terminals. A first sideband signal A is applied to a bridge A at the opposite bottom terminal and a second sideband signal B is applied to the opposite bottom terminal of bridge B.

It will be noted that the embodiment of FIG. 4 is essentially the same as that of the preferred embodiment of FIG. 1. The endless peripheral member here **11'** is a circular loop and comprises parts **11***a'*, **11***b'*, **11***c'* and **11***d'*. The operation of the loop of FIG. 1 and FIG. 4 will be explained in connection with the current arrows of FIG. 4.

Sideband A and sideband B are the two outputs from a rotating goniometer. This yields in-phase RF modulated by a 30 cycle signal, the 30 cycles being derived from the r.p.m. of the goniometer rotor, here 1800 r.p.m. or 30 r.p.s. The goniometer yields a 90 degree difference in the modulation signal between sideband A and sideband B (this causes the cardiod in the ordinary VOR antenna to rotate). The four outputs of the balanced bridges, labeled **1**, **2**, **3** and **4** are connected with equal lengths of wire to the **1**, **2**, **3** and **4** inputs of the VOR loop, as shown in FIG. 1.

Referring to FIG. 3, it will be noted that the carrier signal outputs at outputs **1**, **2**, **3**, **4** are all in phase. This produces current components from the carrier I_c, in each of the loop sections in the same direction. These are shown by $I(1)_c$; $I(2)_c$; $I(3)_c$; $I(4)_c$ in FIG. 4. This produces the omnidirectional pattern shown in FIG. 2. Equal and opposite current components of I_c appear in each of the spokes and cancel out producing no resulting radiation and no induced vertical current in the pedestal or post supporting the loop, an important advantage referred to later.

Sideband A induces a current $I(1)_{SA}$ from output **1** of bridge A, and it will be noted that induced current $I(2)_{SA}$ is in the opposite direction, since output **2** is 180° out of phase.

Similarly, sideband B induces a current $I(3)_{SB}$ from output **3** of bridge B and it will be noted that induced current $I(4)_{SB}$ is in the opposite direction since output **4** is 180° out of phase. This creates a figure-eight pattern shown in FIG. 2. Since the two figure-eight patterns are modulated with signals 90° out of phase, a rotating cardiod results when the two figure-eight patterns are added to the carrier.

The ease with which these loops can be stacked is illustrated in FIG. 5. Three of such loops can be concentrically mounted on a post having a central coaxial feed. The bridge circuit means, illustrated in FIG. 3 may be conveniently positioned at the base or elsewhere as those skilled in the art desire. Since the feed is concentric, the mounting is extremely simple and the electrical connectors are easily made.

When the antenna elements are stacked, each can have an associated phase shifter **50**. Each phase shifter can be variably controlled to vary the beam angle of the pattern with respect to horizontal and such phase shifters comprise means for controlling the phasing of the stacked antennas. Considering for example, three stacked loops, L_1, L_2, L_3, the exciting means provides the same signal to each one of the four loops of main loops L_1, L_2 or L_3. Considering the loop section of FIG. 1 defined by conductor **1**, the right side of 11_b and spoke **18**, the same signal from the exciter is applied to the corresponding section of each of the stacked loops and a phase shifter is located between each of the respective loops. If each of the stacked loops L_1, L_2, L_3 is considered a multi-loop and the individual loops are defined as sub-loops, it can be said that the exciter means provides the same signal to each corresponding sub-loop one above the other except that the signal to each of the sub-loops will be controlled by individual phasing means to effect beam tilting.

The advantages derived from our invention are apparent. In prior structures, for example, those described in the C.A.A. article by Anderson discussed previously, techniques to reduce errors involved a large counterpoise, perhaps 35 feet in diameter and 15 feet in height. A polarizer was also mounted above the four loops. This polarizer was used to reduce vertically polarized radiations and comprised a parasitically excited array supported on the antenna pedestal. At least four vertical rods attached to a hub were required, which hub was fixed to the pedestal.

The pedestal was essentially a metal post which in some instances only served to aggravate the problem since vertically moving currents were induced in the post which in turn caused radiation error.

In our invention, the polarizer is not required, and the need for a large counterpoise is substantially, if not entiely, eliminated. The induced currents in the post are eliminated and the mechanical support and mounting problems are minimized. The mechanical support in this invention is simple and provided at the pattern null, whereas in the four loop antenna of the C.A.A. article, five posts were used, four being employed for the four loops.

In FIGS. 6 and 7, there are disclosed a multi-loop having more than four loops. As an example, eight loops are shown. Here the endless hollow member has eight gaps, and eight hollow radial spokes and separate conductors emanating from a central feed, passing radially to the endless member through the respective spokes and crossing respective gaps to be conductively attached to the endless loop. For simplicity, the feeders **1–8** may be considered as applying their respective outputs to loops **1–8**.

The signal source is shown in FIG. 7 and comprises bridges A–D. Bridges A and B operate as described previously and loops **1–2**, **3–4** may provide the omnidirectional carrier and the rotating cardiod.

It will be noted that the carrier signal passes through each of the radial spokes and cancels out as described previously.

This multi-loop may be used to advantage to provide multiple functions. For example, a fixed frequency F_B may be applied to bridge C so that loops **5** and **6** transmit a beacon, while another carrier may be modulated with information and applied to a bridge D to be transmitted from loops **7** and **8**.

The beacon can be used to provide a fixed course and may be used in conjunction with, or separately from, the rotating figure-eight VOR patterns.

It will also be understood that multiple loops may be employed for more than one beacon to define multiple fixed guide paths at separate identifiable signals.

Although the present invention has beeen described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art will readily understand. Such modifications and variations are considered to be within the scope of the invention and the appended claims.

What is claimed is:

1. A loop antenna means comprising:
- a loop including a hollow substantially endless conductive member,
- exciting means including central feed means having plural separate conductor means,
- plural conductive hollow spokes, each conductively coupled at one end respectively at said feed means and to said endless member at the other end respectively at equally spaced-apart intervals,
- said endless member having one gap in each section thereof between each pair of spokes,
- said separate conductor means diverging respectively from said center feed means and passing through a respective hollow spoke and then through a portion of said endless member and across a respective gap to be conductively joined to such hollow endless members adjacent said respective gaps.

2. The antenna means of claim **1** in which said loop is substantially circular.

3. The antenna means of claim **1** in which said loop is substantially square.

4. The antenna of claim **1** for providing a complete VOR pattern, in which said endless conductive member and said hollow spokes are horizontally disposed.

5. The antenna of claim 1 including exciting means providing separate fixed beacon signals and rotating signals.

6. The antenna means of claim 1 in which said exciting means includes first and second bridges,

said central feed means comprises four separate conductors, one for each subloop defined by respective pairs of spokes and the section of said endless conductive member between said respective pairs of spokes,

a carrier signal source means,

a first sideband source means,

a second sideband source means,

each of said bridges comprising four arms, three arms of identical electrical length and the fourth arm 180° greater than the other three,

said carrier signal being connected to each bridge between arms of equal lengths,

said first and second sideband source means being coupled to respective bridges between arms of unequal length and opposite to the connection of said carrier signal,

the other two bridge connections of said first bridge feeding conductors to opposite subloops,

the other two bridge connections of said second bridge feeding the two remaining opposite conductors.

7. The antenna means of claim 1 including a plurality of such loops, each including a hollow conductive member,

means including a post to support said loops as a stacked array,

said exciting means and said separate conductor means exciting respective stacked elements of each loop.

8. The antenna means of claim 7 in which the orientation of the pattern emitted from said stacked array is tilted upwardly including phase means coupled to each conductor for each hollow conductive member and means to control the amount of phase introduced thereby.

9. A VOR omnidirectional loop antenna comprising:

a hollow endless member,

four hollow spokes coupled to said endless member,

said endless member having at least four radial gaps located between said spokes,

a plural conductor central feed having at least four conductors, each conductor passing internally through a respective spoke and through the adjacent respective section of said endless member and connected externally to said endless member across the respective gap.

10. The antenna of claim 9 in which a carrier signal is applied to each of said conductors and at least one sideband signal is also applied to said conductors.

11. The antenna of claim 9 in which a plurality of said of said endless members are stacked to provide an array and means for controlling the phasing of said array.

12. The antenna means of claim 9 comprising:

an RF bridge circuit means for providing carrier and sideband output signal means, means coupling the carrier signal to each of said conductors,

means coupling said sideband signals to respective conductors to provide current distributions in said loop providing a figure eight radiation pattern.

13. The antenna of claim 12 in which a goniometer provides two sideband outputs to provide a rotating figure eight radiation pattern.

14. A compact antenna comprising:

a plurality of stacked loop means,

a coaxial center support for said loops,

said support including center feeding means for said loop means,

each of said loop means comprising,

a peripheral loop element,

a plurality of spoke elements connecting to said loop elements,

a plurality of gaps formed in said loop element, one gap formed between pairs of spokes,

means coupling said feeding means to said loop at said gaps through said spokes,

said feeding means including exciting means, said exciting means comprising two bridge circuits,

each bridge comprising three equal arms and a fourth arm including a 180° phase shifter,

carrier signal means coupling a carrier signal I_c at a common top terminal of each bridge circuit,

said feeding means and coupling means providing a unidirection carrier current component I_c in the endless loop and providing equal and opposite components of I_c in each of said spokes,

a first signal means coupling a first signal to the bottom terminal of said first bridge circuit,

means coupling a second signal to the bottom terminal of said second bridge.

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RODNEY D. BENNETT, *Primary Examiner.*

MALCOLM F. HUBLER, *Assistant Examiner.*

U.S. Cl. X.R.

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