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The V-Antenna on the Car roof for mobile Direction-Finding

The following article is based on one in "Biotelemetry" (1) in which the use of the V-antenna was described for tracking wild animals equipped with a radio transmitter. Since antennas are fundamentally interesting and mobile direction-finding is especially interesting, I have adapted this detailed description by the author with further technical information. DL3WR

1. INTRODUCTION

Gazelles, rhinoceroses and similar animals are easy to fit with radio transmitters while one grasps one of their horns. A skilled team can fit them up in 15 minutes. The antenna glued to the horn ends up normally in a vertical position, so one can reckon on vertical polarisation. The directional effect of common VHF aerials is generally less pronounced in the vertical plane than in the horizontal direction - the HB9CV is an example of this; using it one gets very good direction-finding results in horizontal polarisation, but poor ones used vertically (fig. 1).

To increase the directional effect one can use an antenna with more elements, but the size rapidly becomes unmanageable. An alternative is to invert the polar diagram to get good directionality with small antenna dimensions; this technique was used here.

2. THE V-ANTENNA

An arrangement of three elements was developed, composed of two radiators and one reflector and optimised for vertical polarisation. Since the horizontal projection of the three elements forms a "V", the designation "V-Antenna" was chosen. Fig. 2 shows it on a small wooden mast.

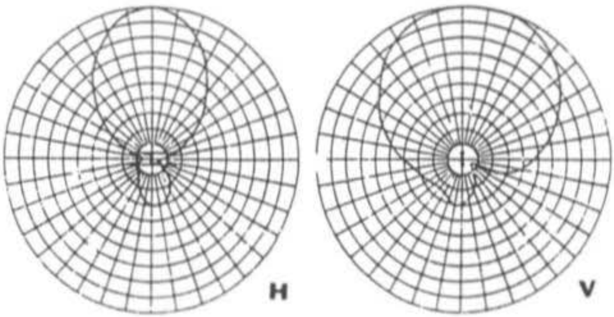

Fig.1 Directional diagrams of the HB9CV antenna
H = horizontal: V = vertical

If the RF energy received on the two radiators is added in a power combiner., we get the directional diagram shown in fig. 3a. If we put a suitable delay line in the two feeders the diagram shifts about 30 degrees to the left or right, as shown in fig. 3b. A comparison of the two voltages Vr and Vl gives a measure of the size and direction of declination between the two incoming wave fronts and of the antenna symmetry axis.

Switching between the two diagrams (directionality switching) and Vr/Vl comparison can be carried out electronically and the direction indicated on an instrument: this is like instrument navigation in a vehicle or aeroplane.

The radiators are connected to the gamma-matching elements with coaxial cable, so that the lower half of the V-antenna can be substituted by its mirror image without further ado. If desired, just the upper half can be mounted on a car roof, achieving the antenna sketched in fig. 4 without detriment to performance.

For an operating frequency of 174 plus or minus 1MHz the following dimensions and details apply:

Radiator length (i/c connector):	422mm
Reflector length (i/c connector):	470mm
Connector type:	PL259
Separation between radiators:	403mm
Separation between radiator and reflector:	403mm
Gain (including switching loss):	$4dB_d$
Matching:	SWR max. 2

The navigation arrangements comprise, apart from the V-antenna, three modules which are described next in detail: Directionality switch, Receiver Control and display circuitry.

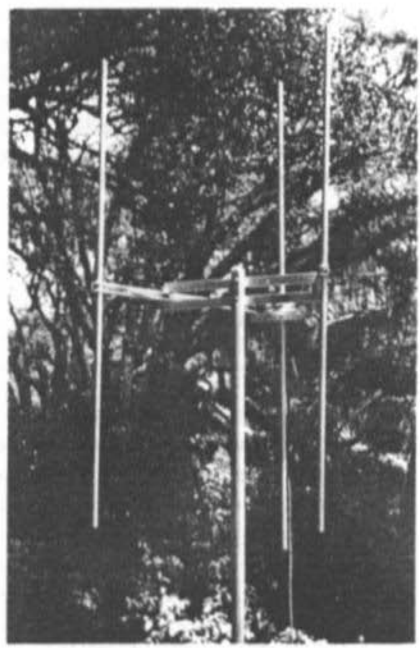

Fig.2 V-Antenna on wooden mast: cables are led down the reflector

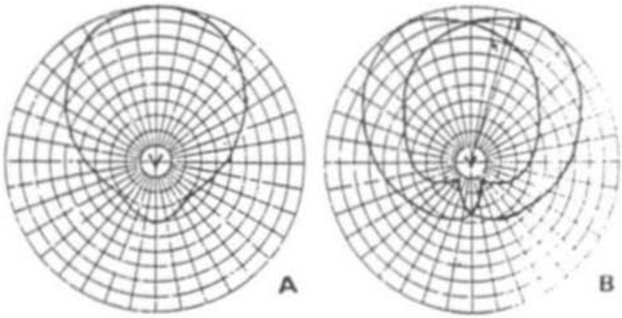

Fig.3 Directional diagrams of the V-antenna
A = zero degrees: B = plus or minus 30 degrees

3. DIRECTIONALITY SWITCH

Fig. 5 shows the principal elements of the V-antenna and directionality switch. The feeders to the two radiators R1 and R2 must be the same length. The switches are formed of PIN-diodes, the delay line DL is a short length of 50-ohm cable and the power combiner. can either be made of coaxial cable or purchased as a ready-made hybrid.

If logic level H is present on the two control lines c1 and c2, all diode switches are "on" and one gets the directional diagram of fig. 3a. If only c1 is at "H", PDS 2 and 3 are switched on and the diagram turns to direction R1 (fig. 3b). The opposite turn is made if PDS1 and 4 are switched on (c2 at "H").

3.1. Switching details of the directionality switch

The complete circuit is very simple and is shown in fig. 6. The V arrangement of the antenna comprises three quarter-wave whips, which are installed on an electrically conducting surface of at least 1m x 1m. A car roof is normally large enough for this. If for all this no conductive material is available a groundplane of this size can be made of wire netting and fixed above or beneath the roof - it must be well connected to the antenna connectors and this means soldering! The four diode switches are simply four switching diodes of the type BA244, which have lower through attenuation than the PIN-diodes used previously, plus six capacitors and eight resistors for separating the RF and DC paths.

The 30 degree delay line is a twelfth-wavelength long piece of 50 ohm coaxial cable and the power combiner. consists of two quarter-wavelength pieces of 75 ohm cable.

The associated 100R resistor absorbs power of unequal phase. The twin-conductor, screened control cable comes from the control and display unit.

Fig.4 Halved V-Antenna in an African application

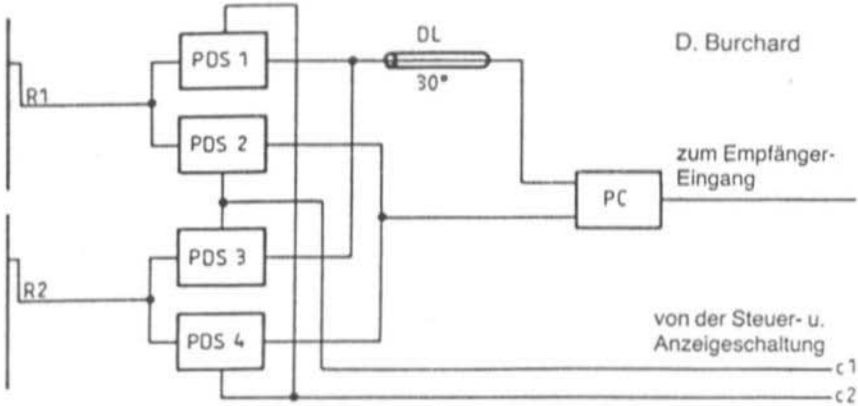

Fig.5 Principle of the Directionality Switch on the Antenna: R = radiator PDS = PIN-diode switch; DL = delay line; PC = power combiner

4. RECEIVER

Any kind of DF receiver with audio and trigger outputs can be used with the V-antenna if it has only slightly excess battery power. Automatic gain control is an advantage.

It is worth mentioning, to understand the necessary receiver characteristics, that the transmitters used in wildlife research operate in pulse mode in order to achieve an operating life of up to three years from a lithium battery. Typical values for pulse duration are 20ms, with a 1 second repetition rate.

Here we are using the model 287078 receiver made by B&R (W-7801 March-Buchheim, Germany) with the internal addition of the display circuitry (described in the next chapter) made on Vero-board and the display instrument glued to the side.

A more professional route would have been to construct a small additional housing for the electronics and mount this on the vehicle dashboard; this could be connected to the (unmodified) receiver by multi-core cable and connectors.

5. CONTROL AND DISPLAY CIRCUITRY

The block diagram in fig.7 should make things clear.

There is an analogue circuit section (above) and a digital one (below). Each pulse received activates the chain of timing elements (T1 - T3). Timing 1 is needed to start operation of the averaging filter, the other two are for switching the antenna diagram and for activating the sample and hold amplifier. The diagram is then shifted from the zero position to plus and minus 30 degrees, the analogue voltages proportional to Vr and Vl (fig. 3b) are stored in the two sample and hold amplifiers, and the difference indicated in the instrument.

The S&H and DA are set up for unity amplification. The pulse duration must be at least 13ms for correct display and the impulse amplitude must be constant. The AGC necessary for this must come into operation within 3ms including the internal trigger delay time of the receiver.

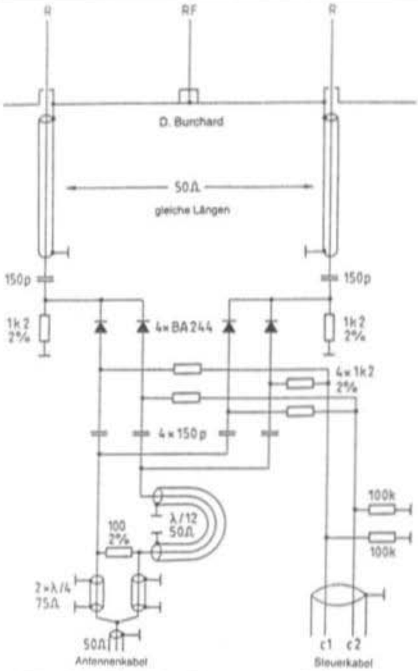

Fig.6 Circuit Diagram of the Directionality Switch

5.1 Details of the control and display circuitry

Fig. 8 shows a trial circuit with linear ICs and some CMOS logic. Only 5mA is drawn from the 12V operating voltage, most of which is taken by the switching diodes. Diverging from the block diagram, an internal trigger has been achieved, so that the DF receiver without its own trigger circuit can be employed.

The analogue circuit section - in the upper half of the diagram is equipped with low-power OpAmps all the way through. The first amplifier boosts the audio signal with amplification set coarsely by Rset and fine adjustment with P1.

The next two amplifiers form together a precision full-wave rectifier and the last is an active filter for averaging.

The output voltage of the filter is compared by the amplifier marked "trigger" with a DC voltage from P2. If the fixed level preset by P2 is exceeded, the LED lights up and the chain of timing elements is activated.

The output voltage of the filter also passes through electronic switches to two storage capacitors which are followed by OpAmps with high input impedances; these control the instrumentation. This circuit fulfils the function of the S&H/differential amplifier of fig. 7.

The last operational amplifier produces an auxiliary voltage of approx. 4.2V with low internal impedance.

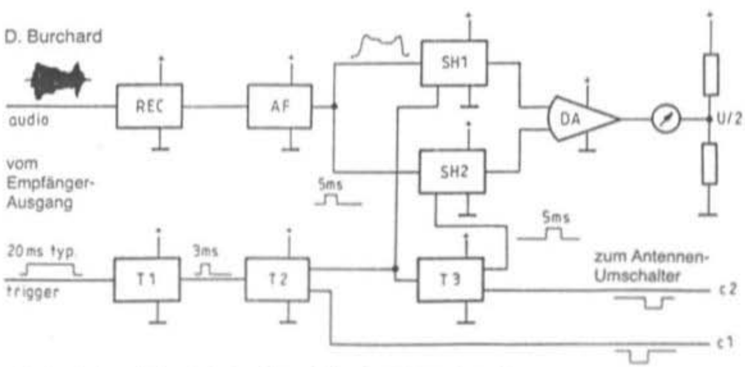

Fig.7 Principle of the Control and Evaluation circuit:
REC = receiver; AF = averaging filter; SH = scan/hold amplifier;
T = timing circuit; DA = differential amplifier

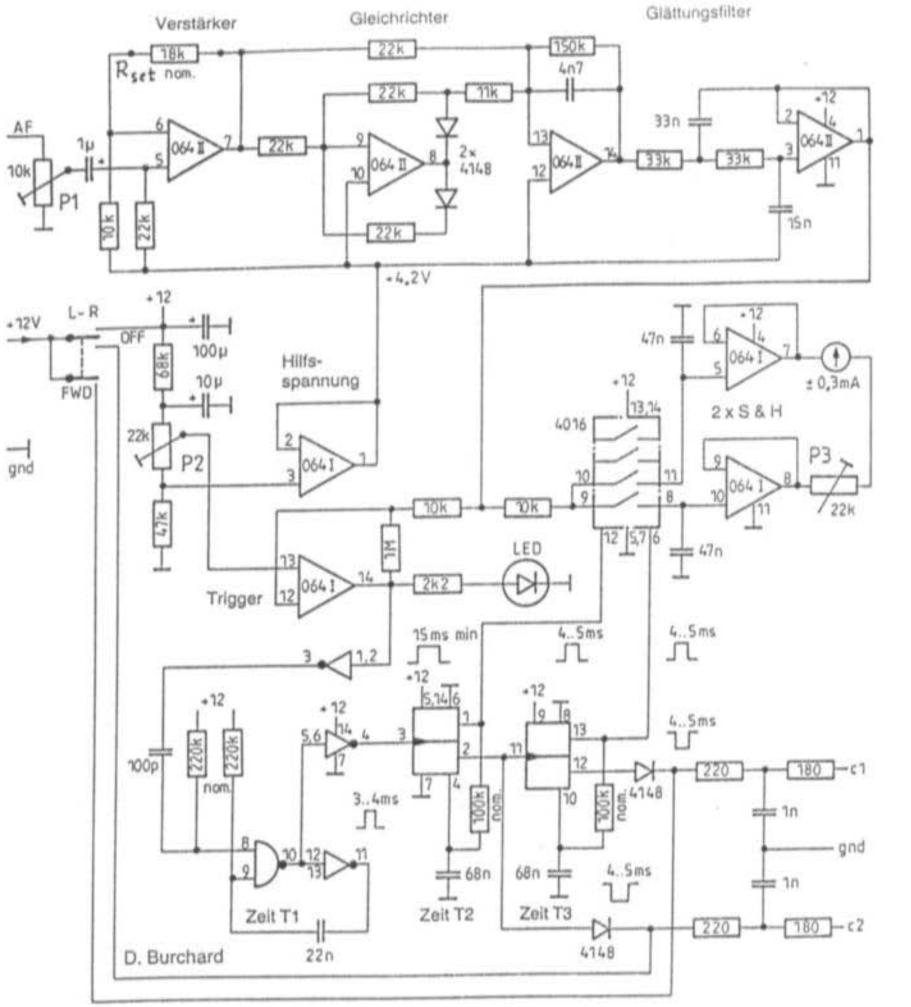

Fig.8 Circuit of the Control and Display electronics

Timing circuit T1 consists of two NAND gates of a 4011, the remaining two gates being employed as buffers before and after the circuit for regenerating the pulse edges. Timing circuits T2 and T3 are made up of D-type flip-flops, of which two are in one 4013. The Q outputs of both flip-flops control the electronic switch in the S&H circuit. The two bar-Q outputs control, via c1 and c2, the switching diodes in the aerial change-over switches. The R-C-R network in both control lines suppress high frequency interference from the digital circuit section.

When the double toggle switch is in the FWD (forward) position, battery voltage is applied to the two control lines and all diodes are switched for maximum sensitivity in the forward direction. With the toggle switch in the L-R (left-right) position, the control and display circuitry operates as follows.

The audio voltage at point AF is amplified, rectified and averaged - as already described. When the smoothed out voltage is sufficiently high, it triggers the timing circuit T1 via the comparator: T1 produces a pulse 3.5ms long and the LED lights up. The averaging filter needs this time to build up to the correct average value. After this timer T2 switched the antenna diagram into the -30 degree direction and switches the 4016 (or 4066) electronic switch shown top right to through-pass. After an operating time of 4.5ms the switched through voltage value is stored in the 47nF capacitor and read out on the side of the instrument.

Then, under the control of T3, the same thing happens with the +30 degrees direction and the lower S&H circuit, which now gives the stored voltage on the other side of the instrument.

The instrument gives the difference between both voltages, which gives a measure of direction of the oncoming wave front: with each pulse received a new direction value is displayed. The display sensitivity can be adjusted with P3.

6. OPERATIONAL EXPERIENCE

Open-air tests were carried out in the open bush land of the Kitangela Game Conservation Area. A tracking transmitter of the type 294079 (B&R) was used, with a radiated power of about 1mW (antenna height 0.5m).

The V-antenna was mounted on the back of a Land Rover, in such a way that it could be turned to pick up its diagram or orientated straight ahead for instrument navigation (fig. 9).

When we were at a distance of 10km from the transmitter the signal was far too weak (receive performance below -140dBm) to trigger the instrument's navigation, yet once heard we could track the direction coarsely (with the toggle switch in the FWD position).

At 5 or 6km distance the instrumentation tracking began to function but the instrument needle wavered about 5 degrees one way and the other because of the overloading receiver noise. Satisfactory results were achieved at 4km distance (receive performance above -120dBm), when the fluttering of the needle had reduced to less than 1 degree. With decreasing distance the display improved further, in which we determined with further tests that the instrument display was almost linear up to a tracking angle of more than plus or minus 20 degrees.

The system described takes about 10ms per tracking operation. Compared with the human method by ear, which takes at least 10 seconds per sounding, it is so fast that movement of the animals is almost inconsequential.

7. LITERATURE

(1) Burchard D.: The V-Aerial, A Navigation Aid for Tracking Down of Radio-Equipped Wildlife. Biotelemetry IX, pp 315-318, 1987.