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AN INNOVATIVE PORTABLE ULTRA WIDE BAND STEREOPHONIC RADIO DIRECTION FINDER

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Abstract—A portable ultra wide band radio direction finder has been constructed based on the principle of stereophonic direction recognition of sound by human ears. The instrument consists of two log periodic antennas having identical electrical properties. They are positioned in a plane, preferably parallel to the ground. The directivities of the antennas are aligned at slightly different directions with respect to each other. Their output powers are compared at the source frequency for the respective polarizations. The back lobes of the antennas have been reduced by symmetrically positioning two metallic plates (reflectors) behind the antennas. The antennas, reflectors and a compass are mounted over a video camera stand such that they could be manually positioned in the azimuth. Since the antennas are of identical make, ideally the radiation pattern of either antenna-reflector combination should behave as a flipped image of the other set. For any particular polarization and frequency, the outputs from the antennas are compared with each other. The antenna assembly is rotated between 0 and 360° in the azimuth until the power difference gets minimized. This position relates to the direction of the source and is indicated on the compass, provided there exits a single radio source at that frequency.

1. INTRODUCTION

Radio direction finding is an old field starting way back in 18th century. It has wide applications like navigation of ships, aircrafts, missiles, radar, tracking satellites and other astronomical radio sources. In the field of communications, certain requirements could be to cross check the intensity, direction and positioning of transmitters employed in a cluster of a GSM network [1]. It might be used to locate the radio sources temporarily jamming any communication network. It is also used extensively in spectrum management for checking the growth of transmitters in specific regions like radio astronomical observatories, etc. [5].

Several radio direction finders have been built in the past [1–14]. Different techniques have been employed in different instruments. These instruments could be broadly classified under *vector-type* or *scalar-type* of radio direction finders. The *vector-types* require both amplitude and phase information of the electromagnetic field at the antenna aperture, while the *scalar-types* require only amplitude information. In general, these instruments employ these measurements at various points in the three dimensional space. The direction of the radio signal is determined by applying some algorithms on these measured values. The direction finding could be either online or offline or both. The detected object may be a radio source or a passive device illuminated by electromagnetic radiations (like in RADAR). Majority of these instruments operate with small or medium bandwidths. With the increase of spectrum allotment to the communication channels and their growing numbers, the requirement ofband coverage in radio direction finding has increased. Attempts have been made in recent years to broaden the frequency coverage [5]. In certain instruments based on the principle of radio interferometer [12], the intensity of the signal plays an important role in phase detection. If the signal to noise ratio is weak, the phase information might not be recovered correctly, especially when the source of the signal is amplitude modulated. On the other hand, the scalar-type radio direction finders might not be significantly accurate in pointing the direction, but might work at relatively low signal to noise ratios, and could also cover very wide range of frequencies [5].

With the development of algorithms for categorically analyzing the terrestrial spectrum [15], a requirement from the low frequency radio astronomy community grew for having a portable ultra wide band radio direction finder. This requirement was for cross verification of the direction of narrow and broad band radio sources. Based on the requirement, a scalar type of online radio direction finder was designed, developed and tested by the authors. The first model with some results was presented in a conference [16]. For better functionality, certain changes were introduced, especially in the RF circuits. An SPDT RF-switch was introduced, the power combiner was removed, and extensive frequency dependent directional calibrations were done in the low frequency radio astronomy range. In this article we present the current model along with the detailed characteristics and results. The usage is limited within VHF and UHF frequency bands. The theory of operation is explained in Section 2. Section 3 describes the block description of the system. In Section 4, the constructional details of the antenna system have been presented. Section-5 describes the system setup and operation.

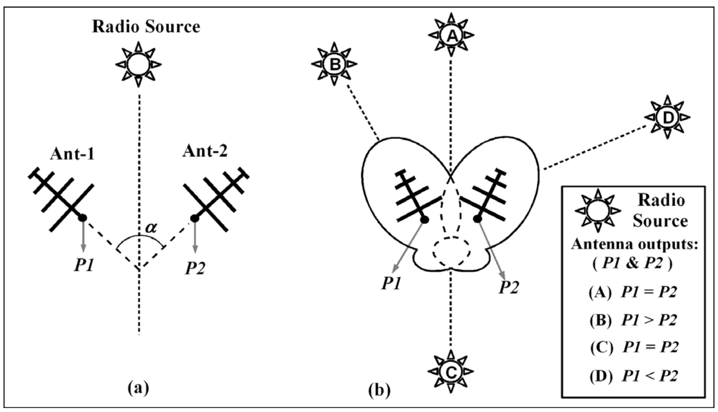

Figure 1. Stereophonic detection of radio direction using two electrically identical antennas. (a) Two antennas are positioned in geometrical symmetry with respect to the source. Hence they receive equal powers. (b) Explanation of direction finding using radiation patterns.

2. THEORY OF OPERATION

The method employed is similar to the stereophonic identification of sound's direction by human beings using their ears. As shown in Figure 1(a), two antennas possessing identical electrical properties† (Ant-1 and Ant-2) with polarizations aligned and directivities subtend an angle α, are positioned symmetrically with positioned in geometrical

† By identical electrical properties, it is meant that the antennas possess identical bandwidths and for every frequency, the radiation patterns, gains, polarizations and impedances are identical.

symmetry with a radio source. The antennas subtend equal angles ($\alpha/2$) with the source, and hence the powers received by these antennas from the source should be equal. A more detailed picture is available in Figure 1(b) with radiation patterns shown.

Consider one of the four radio sources 'A', 'B', 'C' and 'D' to exist at a time and influence the antennas. If $P1$ and $P2$ are the powers received by the antennas Ant-1 and Ant-2 respectively from the radio source 'A', then $P1 = P2$. Similarly for the radio sources 'B', 'C' and 'D', the antenna output powers could be related as $P1 > P2$, $P1 = P2$ and $P1 < P2$ respectively. To be noted that the condition $P1 = P2$ occurs if the source is either 'A' or 'C'. This is because the radiation patterns cross each other at two points, viz. one using the front lobes and other involving the back lobes. If the intensities and distances of each of the sources from antenna system are assumed to be identical, then the absolute values of powers received from source 'A' would be more than those received from source 'B'. In other words, $(P1_{\mathrm{A}} = P2_{\mathrm{A}}) > (P1_{\mathrm{C}} = P2_{\mathrm{C}})$, where the subscripts 'A' and 'C' represent the radio sources. For any other position of the radio source $P1$ not equal to $P2$. The back lobes of the antennas could be further reduced by placing geometrically symmetric reflectors behind each antenna, such that $(P1_{\mathrm{A}} = P2_{\mathrm{A}}) \gg (P1_{\mathrm{C}} = P2_{\mathrm{C}})$. This could enable one to identify the position of the source (whether at front or at back). In the design, the angular separation α between the two antennas is chosen such that the gains of the major lobes at the points of intersections are is less than 3 dB. The back reflector plates are attached behind each antenna such that the gain ratio of front to back intersection points is at least 5 dB or higher.

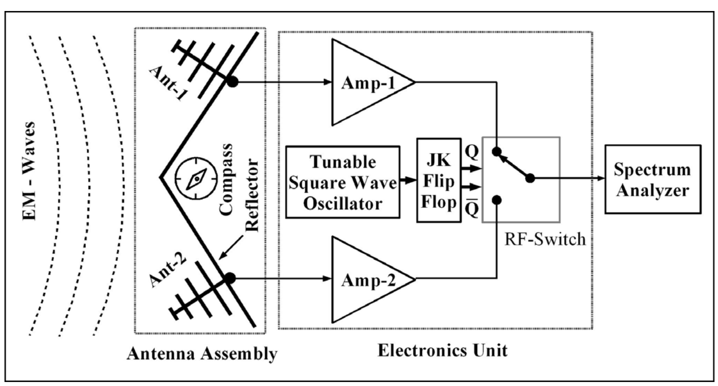

Figure 2. Block diagram of the ultra wide band VHF/UHF radio direction finder.

3. BLOCK DESCRIPTION OF THE SYSTEM

Figure 2 shows the block diagram of the system. Two electrically identical ultra wide band log periodic dual polarized antennas are mounted in an angle and backed by a common V-shaped reflector, such that the radiation pattern of either antenna is the mirror image of the other. The entire assembly of the antennas could be manually rotated between 0 and 360° for locating the radio source. A compass is attached to this assembly to indicate the direction of the source.

The outputs from the antennas are amplified by two RF ultra wide band amplifiers‡. The amplified signals are selected one at a time and fed to a spectrum analyzer. This is achieved using an SPDT RF switch controlled using a JK flip-flop. The clock to the JK flip-flop (or the switching frequency) is controlled by a manually tunable square wave oscillator. The spectrum analyzer is set to the required frequency range of observation. Table 1 lists the specifications of the devices and modules used.

Table 1. Specifications of the RF instruments and semiconductor modules used.

Device	Specifications
Log periodic Antenna	[locally designed] $G = 6$ dBi (avg.), 70 MHz–3 GHz
Low Noise Amplifier	ZX60-3018G [MiniCircuits] $G = 21$ dB (avg), NF = 2.7 dB, 20 MHz–3 GHz
RF SPDT Switch	ZX80-DR230+ [MiniCircuits] Ins. Loss = 0.9 dB, Min. Isolation = 45 dB, dc-3 GHz
Spectrum Analyzer	HP-8590L [HP-Agilent] 100 kHz–1.8 GHz

4. CONSTRUCTIONAL DETAILS OF THE ANTENNA SYSTEM

The mechanical mounting of the antenna system is shown in Figure 3. The top view, front view, back view and side view are respectively shown in (a), (b), (c) and (d) respectively. The log periodic antennas have been constructed on glass epoxy PCB substrate and are mounted over the V-shaped aluminum reflector. 'H' and 'V' indicate the

‡ At a given time, only one polarization (vertical or horizontal) of the antennas are selected manually.

horizontal and vertical polarization RF-connections for each antenna. These output connections are provided using chassis-mountable SMA-type 50 Ohm connectors. The compass has been mounted rigidly to the antenna system so that it rotates along with the assembly. A video camera stand has been used as the base of the antenna assembly. The antenna system could be manually rotated and positioned anywhere between 0 and 360° in the azimuth over the stand.

5. SYSTEM SETUP AND OPERATION

For any operation, either the vertically or horizontally polarized antenna pair is selected. Figure 4 shows the complete experimental setup. For detecting the radio direction of any signal, the spectrum analyzer's span is set such that the signal is clearly visible on the screen. The operator should stand behind the antenna assembly so that the radio source whose direction is under determination is not blocked. On the spectrum analyzer's screen, the power level of the transmitted signal would be seen to toggle in two states at the oscillator frequency. These two levels indicate the outputs from the two amplifiers. The reference level and the power scale of the spectrum analyzer might

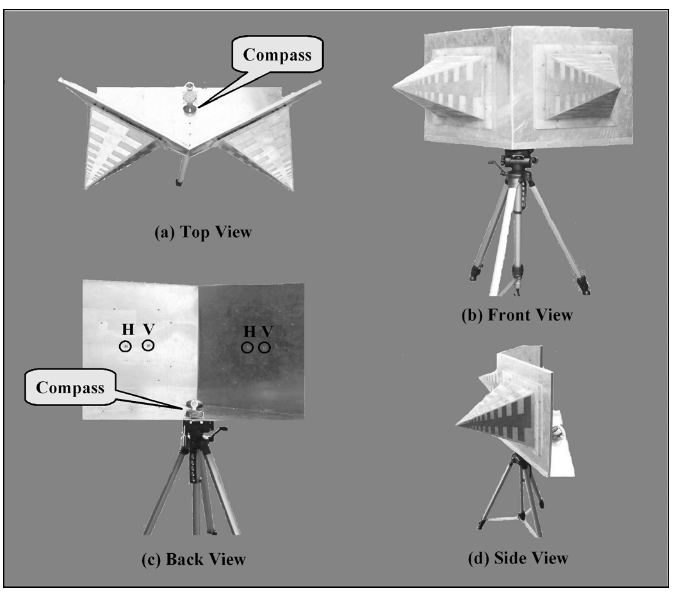

Figure 3. Details of the antenna assembly. (a) Top view. (b) Front view. (c) Back view. (d) Side view.

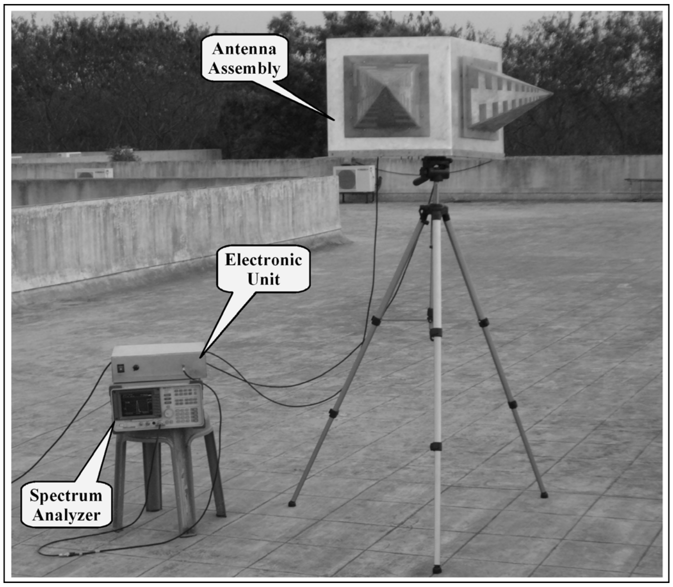

Figure 4. The complete experimental setup.

require adjustments so as to keep both the toggling power levels within the screen. The toggling frequency could be controlled by manually tuning the oscillator such that they are distinctly visible to the human eye. The antenna assembly should be slowly rotated (in azimuth) until the difference between the two toggling power levels get minimized (preferably zero). Since there are two possible angles at which the power levels equalize (shown in Figure 1), care should be taken to choose the angle at which the individual antennas deliver larger powers. Under this condition, the reading on the compass would directly indicate the direction of the incoming signal.

6. RESULTS AND CONCLUSIONS

As seen in the Figures 5 and 6, the radiation patterns of the two antennas for every frequency do not produce identical gain at the zero axis of the antenna system. Thus the actual direction of the incoming signal might contain some error. These errors might be corrected manually from the radiation patterns. Table 2 lists some of the results of few radio, TV and GSM transmitters detected at the GMRT site. The measured directions and the actual directions have been compared and the percentage errors are calculated.

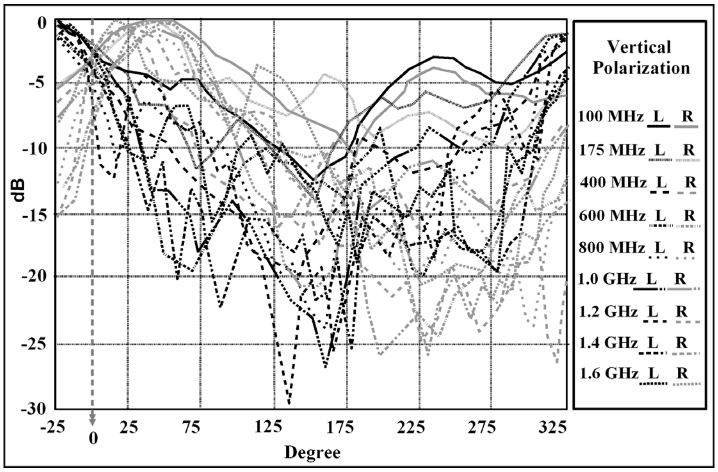

Figure 5. Radiation patterns for vertical polarizations of the left (L) and right (R) antennas at 100, 175, 400, 600, 800, 1200, 1400 and 1600 MHz.

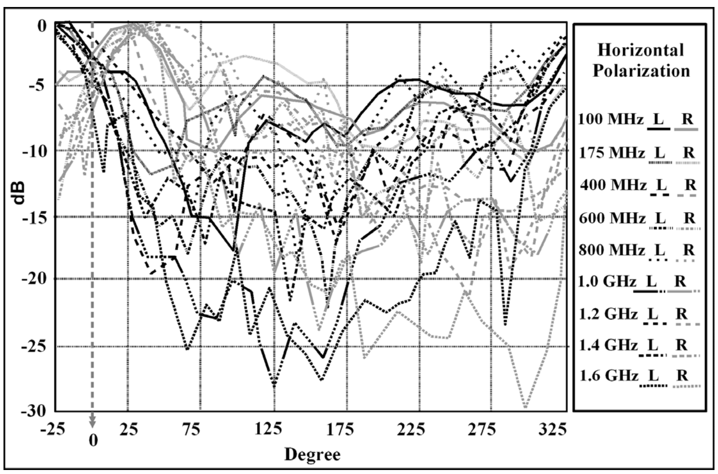

Figure 6. Radiation patterns for horizontal polarizations of the left (L) and right (R) antennas at 100, 175, 400, 600, 800, 1200, 1400 and 1600 MHz.

The instrument is extremely light in weight and could be carried in a car. It is speculated that this instrument would be very handy for field operations. A portable battery operated hand held spectrum analyzer might be preferable.

Table 2. Some of the detected radio sources at GMRT site.

Source (Type)	Freq. (MHz)	Measured Angle	Actual Angle	Error (%)
FM	101.1	224°	220°	−1.8
TV	175.25	202°	200°	−1.0
TV	535.25	246°	245°	−0.4
GSM	941	275°	274°	−0.4
GSM	1811	281°	275°	−2.2

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