

HARDWARE & SOFTWARE FOR BDA TRACKING SYSTEM

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ABSTRACT

Second phase of the BDA will consists of array of 26 antennas located 300m away from control room. Intelligent Motion Technology Pvt. Ltd., Pune (India) is providing a control system & software for this system. In the abstract we have described main features of Hardware and Software used in the system. Antennas are controlled through motion controllers connected to Ethernet port. System Control software will be operated from a computer stationed in control room. Computer communicates to each motion controller through Ethernet port.

HARDWARE DETAILS

Block diagram

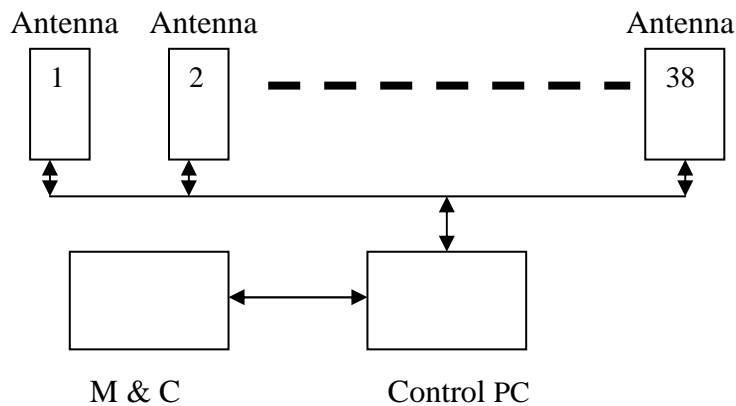


Fig. 1 - Overall Block Diagram.

This is overall block diagram of the BDA. In this each antenna is connected to the control PC via Ethernet. Each antenna is equipped with two drives for driving AZ & EL axes & one motion controller to control the axis motion. Control room PC will get the look-up table from Monitor & control PC. This lookup table contains the data of AZ angle & elevation angle with respect to time. The Servo software will download the required AZ & EL position to selected antennas respect to time.

Block Diagram of single Antenna

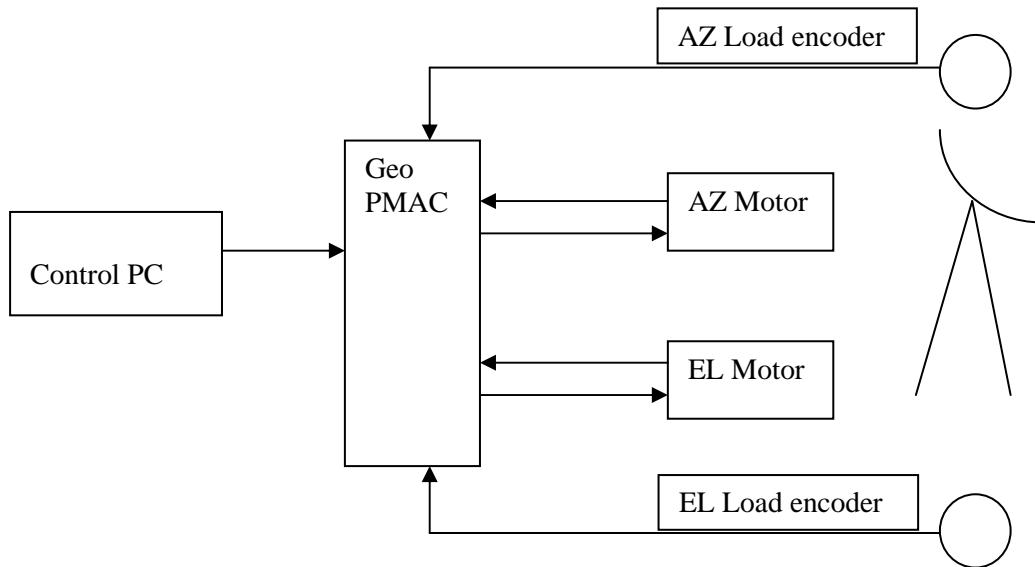


Fig. 2 - Block Diagram of single antenna.

Block Diagram Description

One antenna consists of AZ & EL axis. This AZ & EL axis are driven by Servo motors through gear box. To drive the motors we need two amplifiers or drives. To control the motion of AZ & EL as per time we require some motion controller. We have selected GEO PMAC. This GEO PMAC is powerful state of art controller with built in drives. GEO PMAC communicates with Control PC on Ethernet Port.

We need two load encoders to close the position loop. These load encoders are to read the exact position of the antenna. There are two ways to read the antenna position; one method is to use encoder or resolver on the motor. So with some gear ratio calculations we can display the antenna angle. In this method we cannot get exact reading because of exact gear ratio value & backlash in the gears. To avoid this load encoders are used.

During first phase installation & in last two years we have learnt many things. We have changed the hardware in second phase so that all these problems can be avoided.

Difference between First Phase & second Phase

In the first phase only 5 antennas were controller. The communication bus was RS 485. Looking at the third phase distances & communication speed of RS485 we decided to change the communication from RS485 to Ethernet. In third phase the longest antenna can be communicated via Ethernet by fiber optic link.

In the first phase antenna pointing was done with the help of resolver on the motor & load encoder reading was compared with the required reading. In second phase, position loop is closed on the load encoder.

The load encoder resolution in first phase was sufficient for 4 min of arc accuracy. Now this

resolution of load encoder is increased by 4 times to get better accuracy.

The brake operation feedback was not considered in the first phase. In second phase we have used brake protection modules. Because of this antenna will stop in case of brake failure.

Features of GEO PMAC Controller

Geo PAMC is a very powerful standalone controller with built in drives. It can communicate on USB & Ethernet. With dual feedback facility we can close the loop on load encoder. Built-in safety features like following error, max acceleration limit, max velocity limit, Software limits, Hardware limits etc. can be used to protect antenna structure. Different types of feedbacks can be interfaced like

Resolver, Absolute encoder, incremental etc. Very fast Servo update rate; which is 440 micro seconds. Linear, circular interpolation can be done. Maximum 256 motion programs can be saved. It has 36 bit position range.

Geo PMAC is available with single axis & two axis models. We have selected the two axis module which is working on 230 v AC 50 Hz supply. With this we can eliminate two drives from the first phase configuration.

Built-in drive is protected with following faults.

- Over voltage
- Under Voltage
- Over Current
- Over temperature
- Short Circuit

Features of Baldor Make Servo Motors

To drive AZ & EL axis we have selected Baldor make servo motor. Motor specifications are same as motors used in phase 1. Baldor Model No is BSM 90 C 2250DA. Following are the specifications.

- | | | |
|----------------------|---|---------------|
| • Stall Torque | - | 5.2 Nm |
| • Cont. current | - | 2.51 amps |
| • Peak Torque | - | 15.6 Nm |
| • Peak Current | - | 6.3 amp |
| • Rated Speed | - | 1200 rpm |
| • Feedback | - | Resolver |
| • Brake Supply | - | 24 V |
| • Thermal Protection | - | @155° C |
| • Oil Seal | - | At shaft end. |

Some protections are provided. In first phase it was found that water is going inside from the shaft. So oil seal is added in this model. Motor is with built-in thermal contact. This contact will operate when motor temperature goes beyond 155° C. This thermal contact is connected to controller input.

Homing

This Homing term is related to referencing of the antenna. When we power on the antenna we have to move the antenna to home position. This home position is nothing but the known degree of AZ & EL. This can be done with the help of limit switch. This Homing operation is required as we have

used the incremental encoder on the load side. During initial setting of the antenna we have to find out the AZ & EL degrees at this limit switch. After each power on we have to do the homing operation. Once this is done the reference position is valid up-to next power fail. This can be avoided either by using absolute encoders or by UPS power supply to controller.

Error Budget

As we are closing the loop on load encoder we will get the required accuracy. But it is necessary to find out the error budget. We have used 10000 PPR load encoder.

For one rotation of AZ/EL will get 10000 X 4 counts in controller

$$\begin{aligned} 360^\circ &= 40000 \text{ counts} \\ 1 \text{ encoder count} &= 360/40000 \\ &= 0.009 \text{ deg (0.54 min of arc)} \end{aligned}$$

Tuning of the system will decide the accuracy of the system. In worst case even if we do the tuning of the system in 4 counts, the accuracy will be 0.036 deg (2 min of arc).

Protections

Protections from Lightning: In first phase heavy lightning is observed at BDA site. Due to this some component failure is observed. This failure is mainly of 232 to 485 converter. Another component which is mounted outside is load encoder. This can be failed during lightning. To avoid this failure we have suggested lightning arresters / surge protection devices. We have suggested model no. D-UFB-V24/S-DSUB 9/SB-B

Brake protection: As discussed in previous sections we have observed the brake failure in first phase. To avoid this we have developed Brake protection module. This module will sense the current flowing through brake. Because of any reason if current stops flowing, immediately antenna will stop its motion indicating brake failure message on GUI.

SOFTWARE DETAILS

Tracking software is loaded on Servo control PC. This software will communicate with all selected antenna. This software is developed under VB.net platform. once we open the software the Main screen will get open.

On Main Screen five command buttons are provides.

Communication: this command button will open screen for communication.

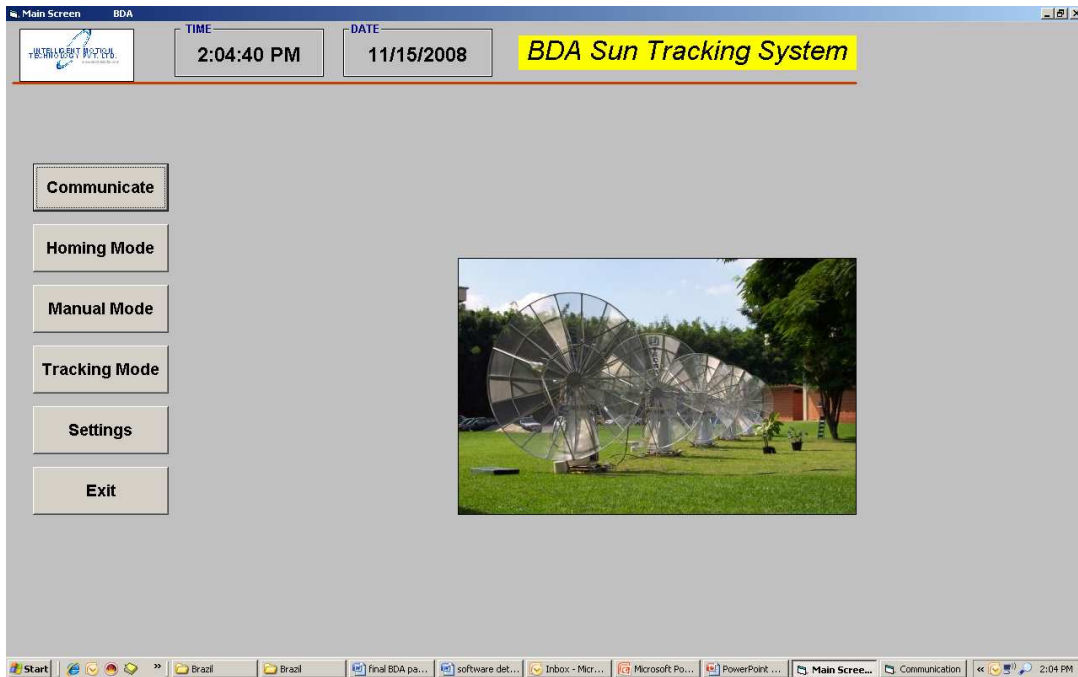
Homing: This command button will open screen for homing.

Manual: This command button will open screen for manual mode movement.

Tracking: This command button will open screen for tracking mode.

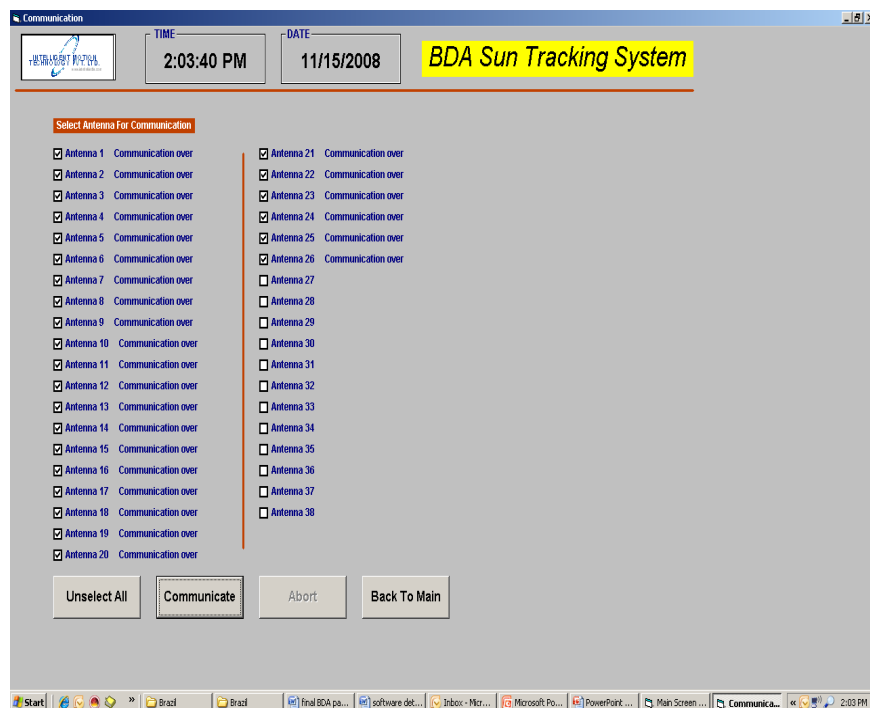
Settings: This command button will open screen for settings.

BDA tracking system



Communication Screen

Following figure shows the proposed version of the program screen.



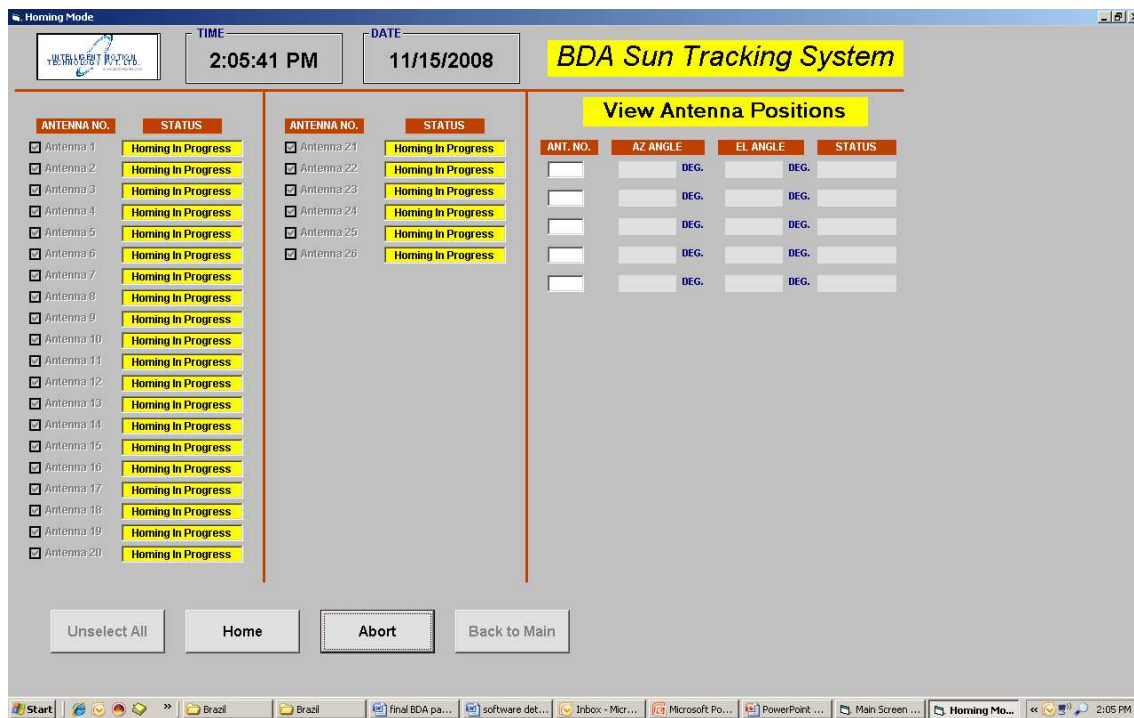
This screen will show the entire forty antennas. User can select the required antenna for

communication. If we select 5 antennas for communication; all other screens will show 5 selected antennas only. This software will work for 1 antenna to 38 antennas.

After selecting antenna user have to click on Communicate button to start communication. After successful communication Back to main button will appear on screen. User can abort the communication with Abort button.

Homing screen

Following figure shows the proposed version of the screen which is used for homing for all the selected antennas.



Homing screen will show only those antennas; which user has selected for communication. Select all antennas with Select All button. Click on Home command button. Homing of all antennas will start at a time.

One status window is provided in front of antenna no. this window will show following messages.

Homing required
Homing in process
Homing Over
Fault.

All messages will get displayed with different colors. If any fault occur during homing; Antenna will stop moving & status window will show FAULT message with red color.

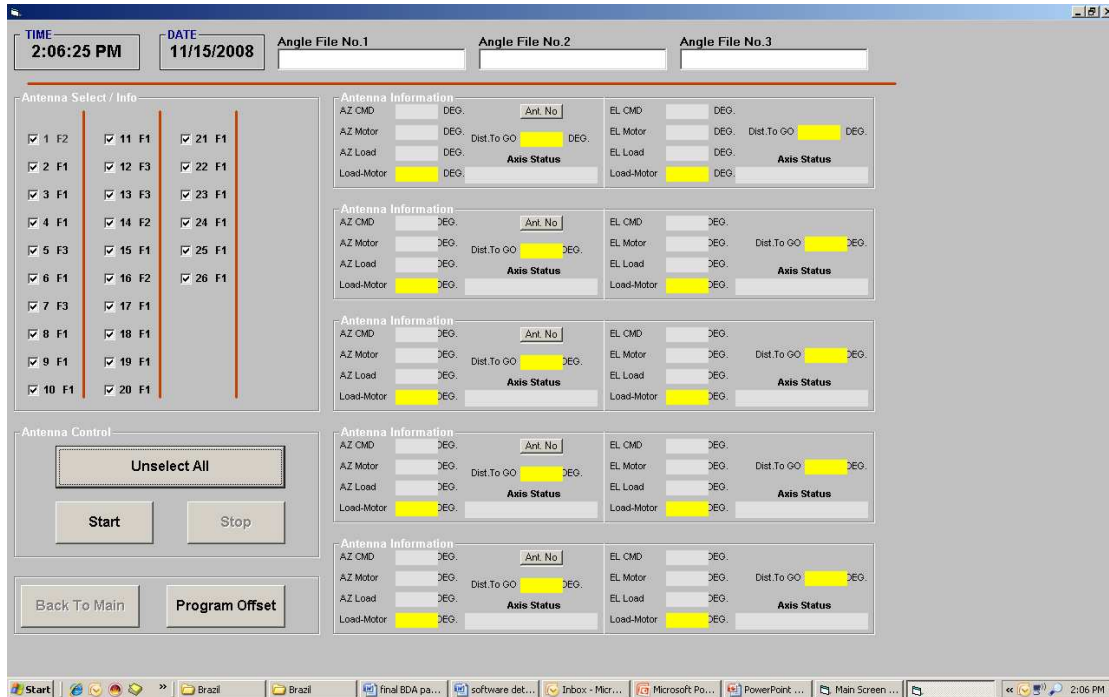
User can view the positions of the antenna in right side of the screen. User can view five antennas positions at a time. To view position user has to enter the antenna no in the window provided.

BDA tracking system

Once homing is over user can select tracking by going to main screen.

Tracking Screen

Following figure shows the proposed version of the screen which is used for Tracking operations.



This screen is mainly used for tracking purpose. On left side of the screen Antenna Select/Info screen is provided. With this user can select the antenna for tracking. User can select the tracking source. Beside the antenna no. User has to click on F1 & select the source. Tracking can be done for three different sources. Once tracking is on; all selected antennas will glow with green color. If there is some fault antenna no. will glow with red color. During tracking user can deselect a particular antenna to stop the tracking.

User can view the positions of 5 antennas at a time. In each position window, user has to enter the antenna no.

Position window will show following Information:

- AZ & EL command value
- AZ & EL motor encoder value
- AZ & EL Load encoder value
- Distance to go for AZ & EL - this is nothing but the difference between commanded & actual angle
- Load-Motor for AZ & EL - this is nothing but the difference between load encoder & motor encoder.
- Axis status for AZ & EL

To stop the tracking for all antennas user has to click on STOP command button. There is other

way to stop the antenna; program will check for the end time. This end time is entered by user on tracking screen.

During tracking user can enter the program offset for each antenna by selecting the program offset screen. This offset will not get stored in file. This offset is the difference between predicted & actual.

AZ Angle		EL Angle	
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

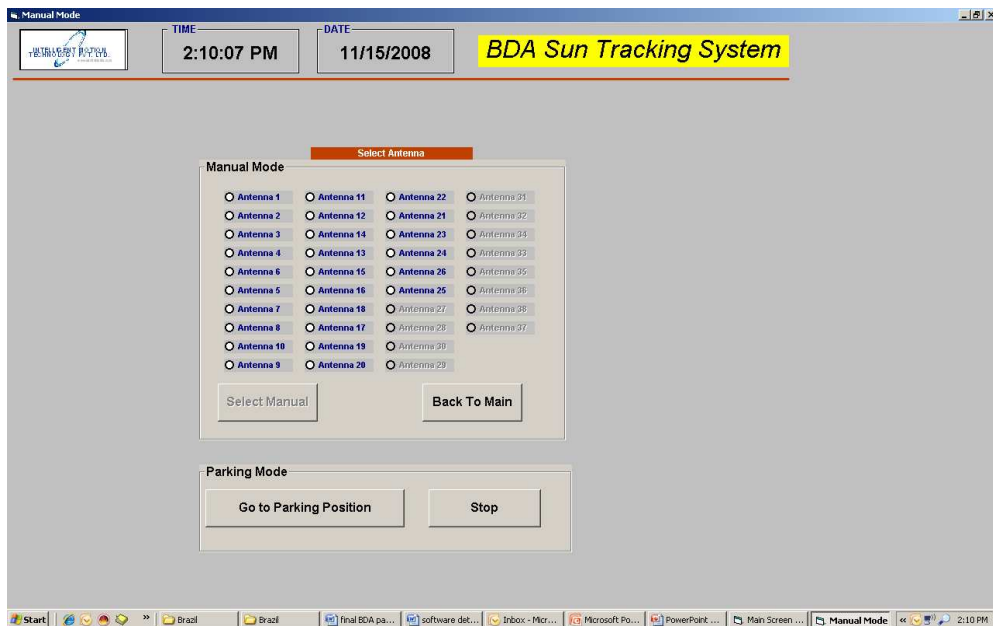
AZ Angle		EL Angle	
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			

Close

Manual Mode screen

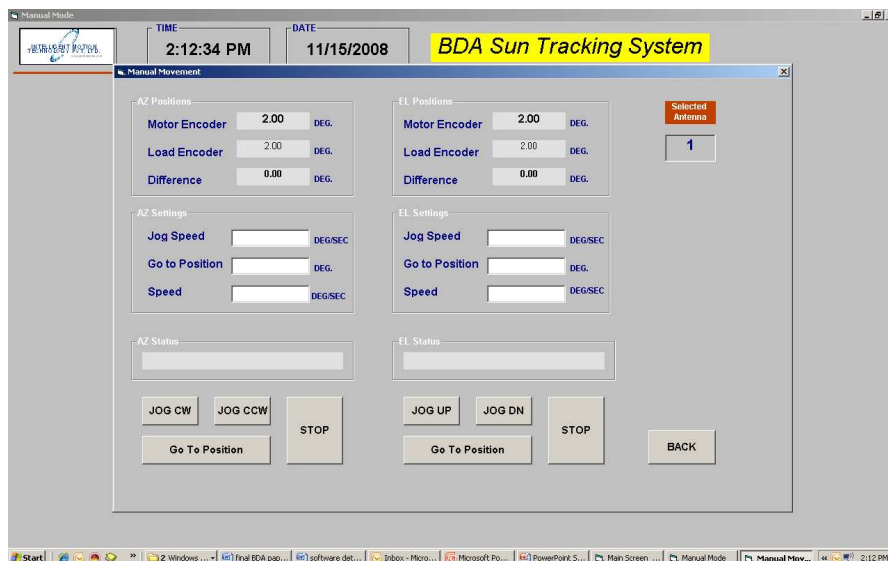
Following figure shows the proposed version of the screen which is used for Manual Mode operation.

BDA tracking system



Once manual mode is selected this basic screen will get displayed. This screen is only to select antenna for manual movement. At a time only one antenna can be selected for manual movement. After the tracking all selected antenna can be moved to Parking position. The parking position angle is common for all antennas. This angle can be defined in setting mode.

Once antenna is selected & SELECT MANUAL button is clicked; another screen gets open.



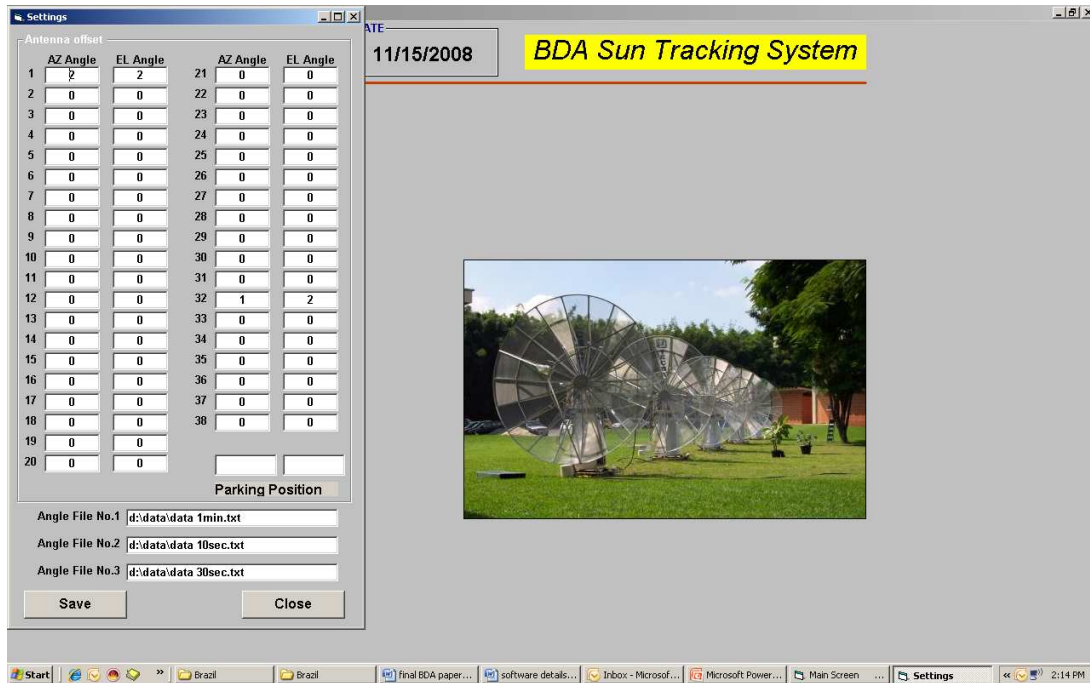
This screen will display the selected antenna no. In manual mode Jogging of AZ & EL axis is possible. This jogging speed can be entered in the window.

User can enter per defined Position for AZ & EL. During this mode antenna will reach to

defined position. Speed for this can be entered in settings window.

Screen for Setting antenna offsets

These offsets are nothing but the antenna mounting offsets. This value can be different for different antenna.



These values can be changes during tracking also. After entering the value, user has to save these values with save command button. All values are stored in one text file. Angle data files for different sources can be stored anywhere in the PC. User has to define the full path in the setting window.

Data Log & Event Log

Once tracking gets started; software will start data logging & event logging. This logged data will get saved in one file automatically. Event data will get saved in different file. Both the files will get saved with date.

CONCLUSION

With this state of art tracking system, the tracking of the BDA antenna will be accurate & without any fault. For details of the BDA project see Sawant et al. (2008)

REFERENCES

Sawant, H. S. et al., INPE, 2008.

DIGITAL CORRELATOR SYSTEM FOR BRAZILIAN DECIMETRIC ARRAY (BDA)

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ABSTRACT

The basic principles of a digital correlator system are explained. A 30 channel one bit digital correlator system for the Brazilian Decimetric Array (phase I) and 1500 channel system for BDA (phase II) are described.

INTRODUCTION

Correlation means dependence, or the extent to which one thing depends on another. For example the pressure of steam in a boiler depends very much on the rate of fuel burning. In terms of signals, we say that correlation is a measure of the way in which one signal depends on another, or the way in which one part of the signal depends on another part of the signal. Radio interferometer system measures the complex cross – correlation function (fringe pattern) of the output of a pair of antennas (i, j). This quantity is defined as $R_{ij}(\tau) = \langle V_i(t) V_j(t + \tau) \rangle$ where the brackets indicate time average. The cross correlation function is related to the visibility function $V = |V| \exp(i\phi(\text{sky}))$ by $R_{ij}(\tau) = A |V| \Delta f \cos(2\pi \Delta f \tau(g) - \phi(\text{sky}))$ where A is the collecting area of the antenna, Δf is the IF bandwidth, $\tau(g)$ is the geometrical delay and $\phi(\text{sky})$ is the phase due to the source. This is a real function of the delay and can be estimated by a simple correlator. By Fourier transforming the visibility function the source brightness distribution can be obtained. The basic observables in the complex visibilities are: amplitude and phase as functions of baseline, time, and frequency. If $V_i(t)$ and $V_j(t)$ are narrow band signals centered at ν with a bandwidth of $\Delta \nu \ll \nu$, then $R_{ij}(\tau)$ is nearly sinusoidal with a period of $1/\nu$. At a given frequency, all we can know about the signal is contained in two numbers: the real and the imaginary part, or the amplitude and the phase. For measuring the amplitude and phase of the correlator output signal, 2 correlators are used one which multiplies the signal directly and another one with a 90 degree phase shift network. ie the output is Hilbert transform of the input. The 90 degree phase shift can be also effected by feeding the signal to 2 mixers with LOs in phase quadrature or by using a 90 degree hybrid at the output of the final IF filter. The combination of two correlators and the quadrature network is called a Complex correlator. The 2 kinds of correlators are XF and FX. In the FX correlator then signals are Fourier transformed and then multiplied. In the case of XF correlator, the signals are multiplied and then Fourier transformed.

PRINCIPLES OF A DIGITAL CORRELATOR SYSTEM

Digital correlator

Modern correlators are implemented digitally because digital operations are precisely defined and repeatable. Analog circuitry is subject to environmental conditions such as temperature and humidity. Digital circuits can be exactly replicated at low cost when many identical elements are needed. For long baseline (> 10 km for connected elements and 1000 Km for VLBI and wide bandwidths) only digital delay can be used. Accuracy of the delay depends on the accuracy of the timing pulse and long delays with Pico second accuracy can be achieved digitally. No distortion of the signal other than calculable effects of quantization occurs. Correlations with wide dynamic range are easily implemented digitally.

Quantization

The digital correlator must first convert the analog signals to digital form. This requires sampling which converts continuous time signal $V(t)$ to as discrete – time sequence of its samples $\{V(kt), k=0,1,\dots\}$ and quantizing which converts a continuous variable to one of a finite set of values. This combination of a sampling and quantizing device is called digitizer. The signal can be sampled and quantized or quantized and sampled. The samples of a continuous time (analog) signal have a continuous amplitude range. These signals are approximated to the nearest pre –fixed level in the case of digital correlator. This approximation of the signal to the nearest level is known as *Quantization*. The quantized digital samples are applied to an encoder. The encoder responds to each of the samples by generating a unique identifiable binary pulse pattern. The combination of the quantizer and the encoder is called an A/D converter. The quantization processes introduces an error which is the difference between the input signal $m(t)$ and the quantized signal $m_q(t)$. This error is called quantization noise by $Q_e(t) = m(t) - m_q(t)$. Quantization adds noise to the signal and therefore the S/N ratio decreases. For quantization to n bits, the amplitude range of the signal is divided into 2^n discrete levels, and each sample is quantized to the nearest bit level.

Sampling

A band – limited signal is a signal $f(t)$ which has no spectral components beyond a frequency B Hz. i.e. $F(s) = 0$ for $|s| > 2\pi B$. The sampling theorem states that a real signal $f(t)$ which is band limited to B Hz can be reconstructed with out error from samples taken uniformly at a rate $2B$ samples per second. This minimum sampling frequency $2B$ Hz is called the Nyquist rate or Nyquist frequency. In the synthesis telescope we are interested in the cross correlation function of 2 signals that are jointly obey Gaussian random process. For Gaussian noise signals, VanVleck (1966) showed that quantizing can be carried out to the extreme of recording merely the sign of the samples. The penalty paid for deleting the amplitude information in such one –bit correlator (Weinreb 1963) is loss of sensitivity by a factor $2/\pi$ relative to a continuous or analog correlator The advantage of one – bit sampling is that it is immune to variations in the input level thus eliminating the need for tight control of the correlator inputs. In a one – bit correlator, the samples are represented by a normalized values ± 1 .

The estimate of the normalized one – bit correlation function is

$$\rho_1(n \Delta t) = \{K_c(n) - K_a(n)\}/K \quad (1)$$

where $K_c(n)$ is the number of polarity coincidence and $K_a(n)$ is the number of anticoincidence observed in K products

$$\text{Since } K = \{K_c(n) + K_a(n)\} \quad (2)$$

$$\text{Therefore } \rho_1(n \Delta t) = [1 - 2(K_a(n)/K)] = [2(K_c(n)/K) - 1]$$

For a continuous correlation is generated using the Van Vleck (1966) relationship

$$\rho = \sin[(\Pi/2) \rho_1] \quad (3)$$

The S/N ratio can be improved by sampling the signal at a rate $>$ than the Nyquist rate.

Walsh switching

There can be DC offset in the comparator where the input analog signal is digitized. In a one – bit correlator the out put is 1 or 0 if the input analog signal is above or below the zero level of the comparator. In practice the zero level may not be perfect.

Due to this the out put of the comparator will be affected and there will be spurious correlations at the out put of the correlator which will affect the dynamic range of the synthesized images. Phase switching was used in earlier interferometers to remove the background. In correlator system of multiplications, phase switching is useful to remove small offsets in correlator outputs that can result from imperfections in circuit operations or from spurious signals. The latter are difficult to be removed from any complicated receiving systems. Such signals at levels too low level to detect by common test procedures can be strong enough to produce unwanted components in the output. Cross coupling of the signals between cables and circuits in the field also give cross talks. The 180 degree switching cycle is used to remove spurious signals that are correlated between antennas and introduced after the phase switch. Therefore switching is most effective if it is done as early as possible in the signal path. The demodulation of the phase switch is done by changing the sign of the data after sampling by adding and subtracting in the correlator accumulation hardware. After demodulation, the spurious signals will be modulated with the inverse of the switching and the signals before the phase switch (the desired sky signal) will not be modulated. If the switching functions has been chosen so that their product integrates to zero (functions are orthogonal) the correlator will remove the spurious signals as forms products and integrates.

Walsh switching period for different antenna are integral fraction of the integration time, the cross talks get averaged to zero as they are correlated half of the time + ve ly and other half – ve ly. Using the same Walsh functions (Beucahmp, 1975), this switching sequence is subsequently, removed at the output of the sampler, thereby eliminating the errors due to DC offsets in the A/D converter. Unwanted signals get averaged to zero only of it s amplitude is constant over a Walsh cycle. The effective removal of the unwanted cross terms depends on the ratio of the time difference between the on and OFF states of the switching pulse periods of the pulse. In the case of BDA the average value of the periods of the Walsh function is 100 msec and 10 microseconds in the time gap between the ON and OFF states of the switching pulse. The level of cross talk will be down by $10\log [(10 \times 10^6) / (100 \times 10^{-3})]$ is ~ 40 dB.

Total Power measurements

In a one bit correlator, the output of the quantizer is either high or low with no information on the absolute strength of the signal (like in correlator systems with an ALC loop), as only the sign of the input waveform is retained. Thus one – bit correlator measures the normalized correlation coefficient. The out put of a one – bit correlator is proportional to the ratio between the power of the correlated and the sum of the correlated and uncorrelated signal fed at the input. If T_s and T_b are the