FLOCK OF BIRDS®

SIX DEGREES-OF-FREEDOM
MEASUREMENT DEVICE

TECHNICAL DESCRIPTION
OF
DC MAGNETIC TRACKERS

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1.0 INTRODUCTION

Flock of Birds (Flock) * is a patented magnetic-transducing technique developed and manufactured by Ascension Technology Corporation for interactive computer graphics applications. It overcomes many of the operational weaknesses -- especially operation in metallic environments -- associated with earlier generation AC electromagnetic systems. It also overcomes the occlusion and noise problems associated with optical and acoustic tracking technologies.

The Flock measures the position and orientation of one or more receiving antenna sensors, typically located on a user's head, hand or body, with respect to a transmitting antenna, which is fixed in space. The transmitting antenna is driven by a pulsed, direct current (DC) signal. The receiving antenna measures not only the transmitted magnetic field pulse but also the earth's magnetic field. A microprocessor is used to control the transmitting and receiving elements and convert the received signals into position and orientation outputs.

Initially developed for use in mobile military vehicles as a head-tracking device, the Flock is currently available in a militarized version from Ascension's British licensee, GEC-Marconi, Ltd., of Rochester. Tests in the F-16 and other platforms, ranging from a Huey helicopter to a M47 tank, demonstrate that the Flock is five times less sensitive to metal than AC electromagnetic technologies. This sensitivity reduction reduces the need for costly mapping and compensation in most environments.

Commercially, the Flock is used in numerous applications in which humans interact with computers. Prominent uses include:

- head tracking in flight simulators/trainers
- head, hand and body tracking in virtual-reality games
- full body tracking for virtual prototyping, visualization, and virtual walkthroughs

* *This description applies also to all other pulsed DC magnetic trackers: pcBIRD, miniBIRD models 800 & 500, and MotionStar.*

- real-time control of 3D images in computer graphics workstations
- measurement of medical instruments and biomechanical measurement of anatomical parts
- manipulation of telerobotic controls
- real time interaction with virtual images
- measuring a pilot's line of sight for aiming weapon systems and interacting with helmet-mounted displays

2.0 PRODUCT DESCRIPTION

Fig. 1 depicts the Flock's major elements. It includes a transmitter, transmitter driver circuit, sensor, and signal processing electronics. The transmitter is typically located within one to eight feet of the sensor(s). It consists of three individual antennae arranged concentrically to generate a multiplicity of DC magnetic fields that are picked up by the sensor. The sensor measures the position and orientation of the object to which it is attached. The sensor consists of three axes of antenna that are sensitive to DC magnetic fields. The transmitter driver provides a controlled amount of DC current to each axis of the transmitter. The computer controls the amount of DC current provided by the driver to the transmitter axis. The signal output from the sensor travels to the signal processing electronics. It controls, conditions and converts the analog sensor signals into a digital format that can be read by the computer. The Flock's algorithm next computes the position and orientation of the sensor with respect to the transmitter and then outputs this information to the user's host computer.

Fig. 2 presents the details of the transmitter drive electronics. Its purpose is to provide DC current pulses to each antenna of the transmitter -- one antenna at a time. The transmitter consists of a core about which the X, Y, and Z antennae are wound. While a given transmitter antenna is being provided with current, readings are taken from the antennae of the sensor. Initially the transmitter is shut off so that the sensor can measure the x, y, and z components of the Earth's magnetic field. In operation the computer sends to the digital-to-analog (D/A) converter a digital number that represents the amplitude of the current pulse to be sent to the selected transmitter antenna. The D/A converter converts this amplitude to an analog control voltage. This control voltage goes to the multiplexer (MUX) which connects it to either the X, Y, or Z transmitter current source.

The sensor consists of three orthogonal antennae sensitive to DC magnetic fields. Many technologies can be used to implement the DC sensor. The Flock uses a three-axis fluxgate magnetometer. The output from the sensor goes to the signal processing electronics. As detailed in Fig. 3, the sensor signal processing electronics consists of a multiplexer (MUX), which, on command from the computer, switches the desired X, Y, or Z sensor antenna signal, one at a time, to the differential amplifier (DIFF). The differential amplifier subtracts from this antenna signal the previously measured component of the Earth's magnetic field. It outputs only that part of the received signal that is due to the transmitted field. The output from the differential amplifier is then filtered to remove noise and amplified. The analog-to-digital converter converts the DC signal to a digital format that can be read by the computer.

Fig. 4 shows the timing relationship between the current pulses provided by the transmitter driver to the transmitter and the signals received by the sensor. The transmitting and receiving sequence begins at time T_0 with all three transmitter antennae shut off. During the time period T_0 to T_1, the X, Y, and Z components of the Earth's magnetic field are measured by the sensor and read into the computer. The computer outputs these Earth field values to the signal processing electronics where they are subtracted from the nine measured values generated when the transmitter's X, Y, and Z antennae are turned on. At time T_1, a current pulse is supplied only to the X transmitter antenna. The rising edge of the pulse will cause an initial burst of eddy currents in nearby conductive material. After the pulse reaches its steady state value, however, no new eddy currents will be generated. Existing eddy currents then die out at an exponential rate proportional to the metal's conductivity, size and nearness. Sampling the transmitted signal close to its rising edge will thus result in a sensed signal containing large eddy current components.

Sampling the signal farther from the leading edge results in reduced eddy currents. As shown in Fig. 4, the sensor's X, Y, and Z antenna will measure the X, Y, and Z components of this transmitted magnetic field plus the Earth's magnetic field during the period T_1 to T_2. The amplitude of the measured signals is a function of the position and orientation of the sensor's antennae with respect to the transmitter's X antenna and the location and orientation of the sensor on the Earth's surface. During the T_1 to T_2 period, the Earth's field is subtracted from the sensor's X, Y, and Z signals and the resulting signals are read into the computer. The X transmitter antenna is then turned off. At time T_2, a current pulse is applied to the transmitter's Y antenna and again the sensor's X, Y, Z antennae values are read into the computer. Starting at time T_3, the same process is repeated for the transmitter's Z antenna. At the end of this period, twelve sensor values will have been read into the computer: three Earth field components, and three sensor values for each of the three-transmitter antenna. The entire sequence of turning on the transmitter X, Y, and Z antennae then repeats itself, as indicated above, continuing as long as measurements are required.

3.0 FLOCK OUTPUTS

The Flock outputs both position and orientation of the sensor, measured with respect to the transmitter's reference frame. The X, Y, and Z position of the sensor is output as three words that the user can scale to inches, meters or any other unit. The orientation of the sensor is output as either nine words that are the elements of a 3x3 orientation matrix, the three Euler angles: azimuth, elevation and roll, or the four quaternion elements.

FLOCK BLOCK DIAGRAM

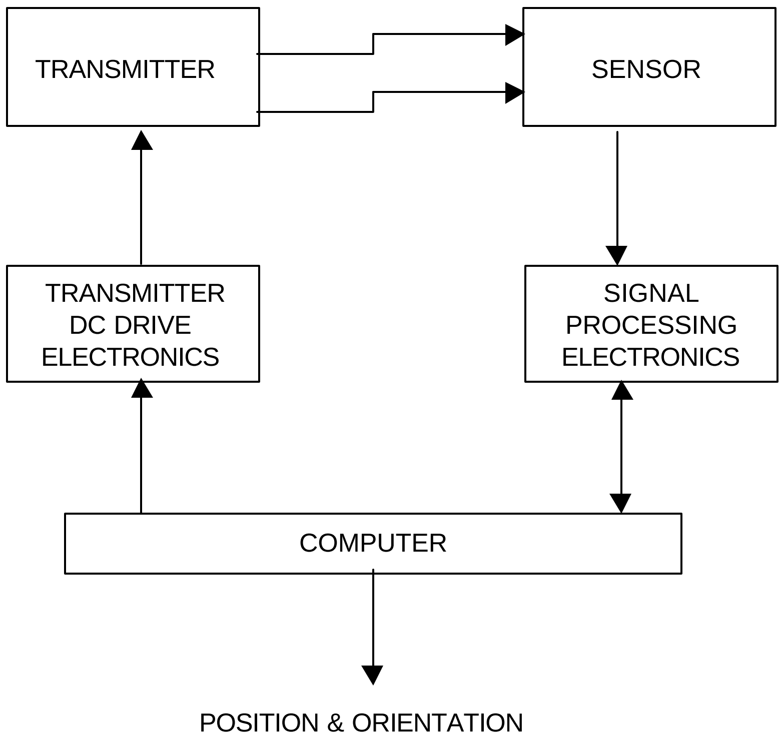

FIG. 1

TRANSMITTER DRIVER

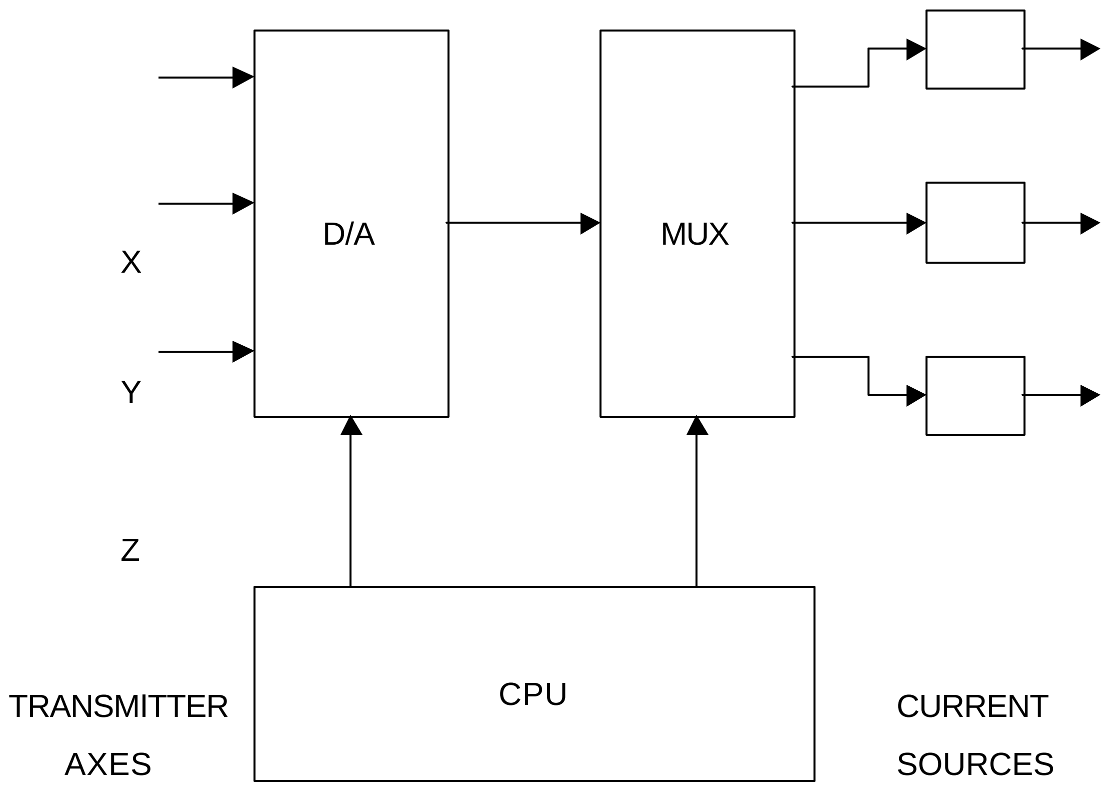

FIG. 2

SENSOR SIGNAL PROCESSING

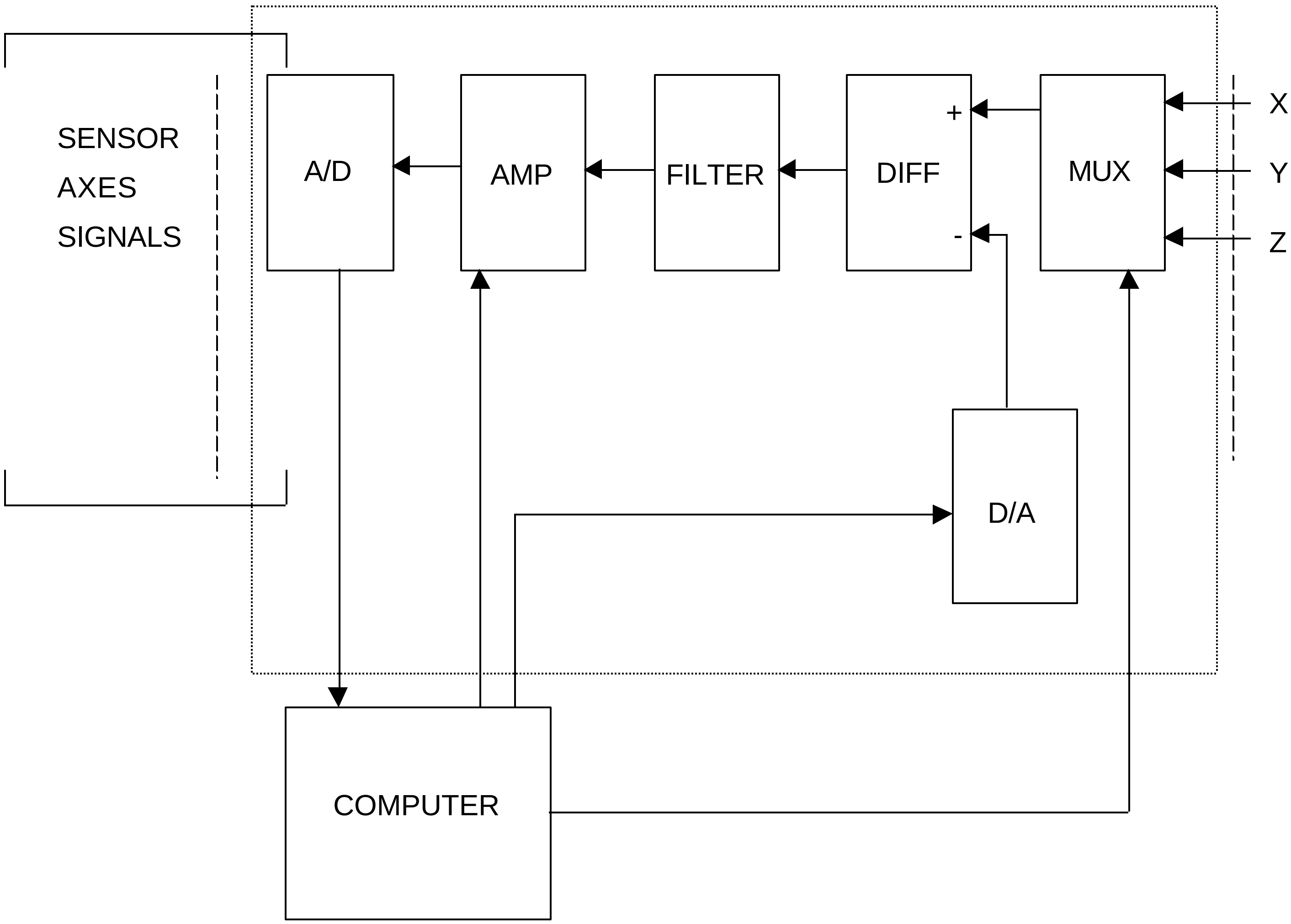

FIG. 3

SIGNAL TIMING

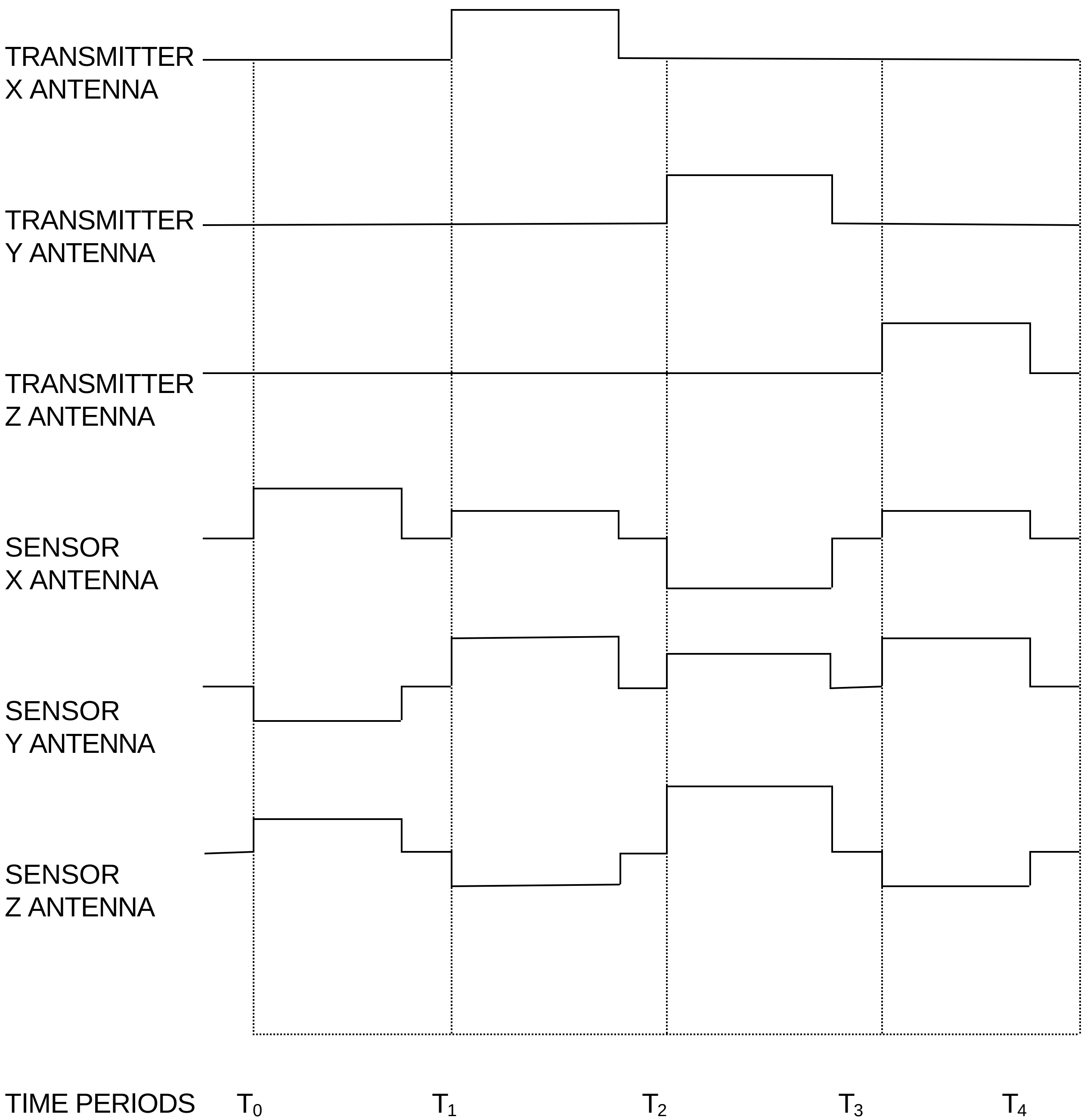

FIG. 4