Sea-Air Systems Division
Sippican, Inc.

W-9000

Meteorological Processing System
Theory of Operations

Document Number 9010-212 Version 4.2A

ZEEMET

Sippican, Inc.

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METEOROLOGICAL PROCESSING SYSTEM

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Chapter 1.0 System Overview

1.1 System Description

The ZEEMET W-9000 Meteorlogical Processing System is the fourth generation of equipment for upper air atmospheric measurement. The W-9000 has proven features from past systems with many new capabilities made possible by significant advances in hardware, software, and radiosondes. With the compatible ZEEMET MarkII MICROSONDE, the W-9000 system performs an automatic synoptic sounding to WMO specifications. Embodying an open architecture concept, the W-9000 system supports industry standard specifications that permit two-way communications among computers, peripherals, and other products. With such flexibility, a system can be configured for a variety of requirements with a minimum of custom hardware or software. The system has three parts:

- Data acquisition devices such as radiosondes, radiotheodolites, and radar
- ZEEMET Rack: a modular unit for signal reception and conditioning
- Standard microcomputer(486 PC) with associated peripherals for analyzing and processing data

The ZEEMET Rack is the heart of the system. It is a standard Eurorack Rack assembly containing plug-in modules interconnected via the parallel P90 Bus and a dual antenna system. Most ZEEMET Rack modules perform two-way communication with the common bus and are controlled by the System Computer via the System Interface Module. Meteorological and wind data can be archived to maintain a complete record of system operation over a given period of time.

Transmissions from MarkII MICROSONDES are received via the 403 MHz Synthesized Receiver or through the 1680 MHz Down Converter in the case of a radiotheodolite system. Meteorological and Navaid data are passed onto the system computer through the RS-232 system interface.

Tracker modules are used to determine sonde position. The capability exists for Omega, VLF, Loran-C, and cross-chain operation, and they may be used simultaneously to track multiple Navaids.

Position information may also be generated by the system radiotheodolite and passed onto the system interface via Radiotheodolite Interface Module. Azimuth and elevation information is generated by the radiotheodolite, which, when combined in height (calculated from the meteorological data) gives precise location of sonde position.

The system interface employs two 9600 baud RS-232 channels. The first controls the actions of the ZEEMET Rack modules using a command/response protocol. The second is for interrupt-driven output of meteorological and Navaid data.

The system computer controls the ZEEMET Rack modules and processes data for display and output. System operation is menu-driven. A full complement of WMO messages are available to you.

With version 4.0 of the W-9000 software, the serial connection to the system computer in systems with a GPS module is provided by the GPS Module. The GPS module connects to the 403 Receiver module or Decoder module and to the Interface module. If a GPS module is not used, the system computer connects to the interface as in earlier versions of the W-9000 system. See Figures 1-1, 1-2 and 1-3.

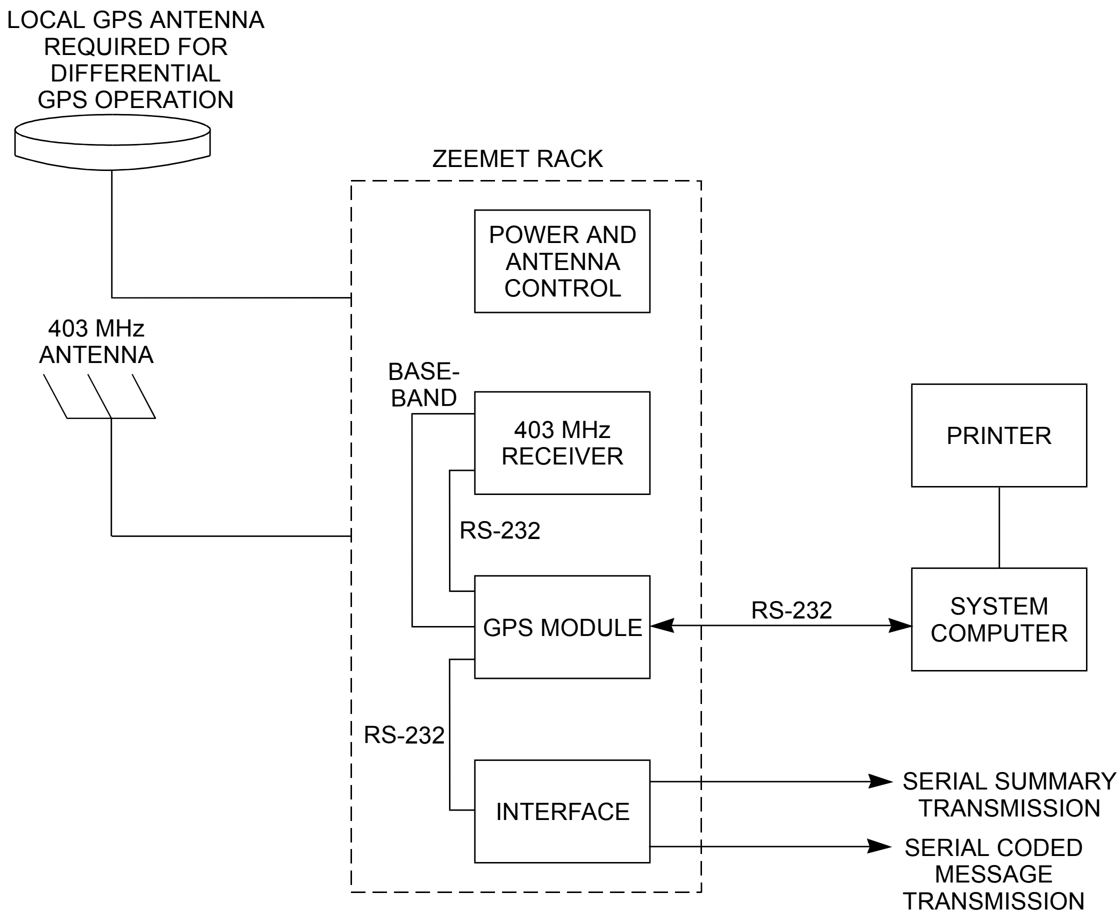


Figure 1-1. GPS System with GPS Radiosonde

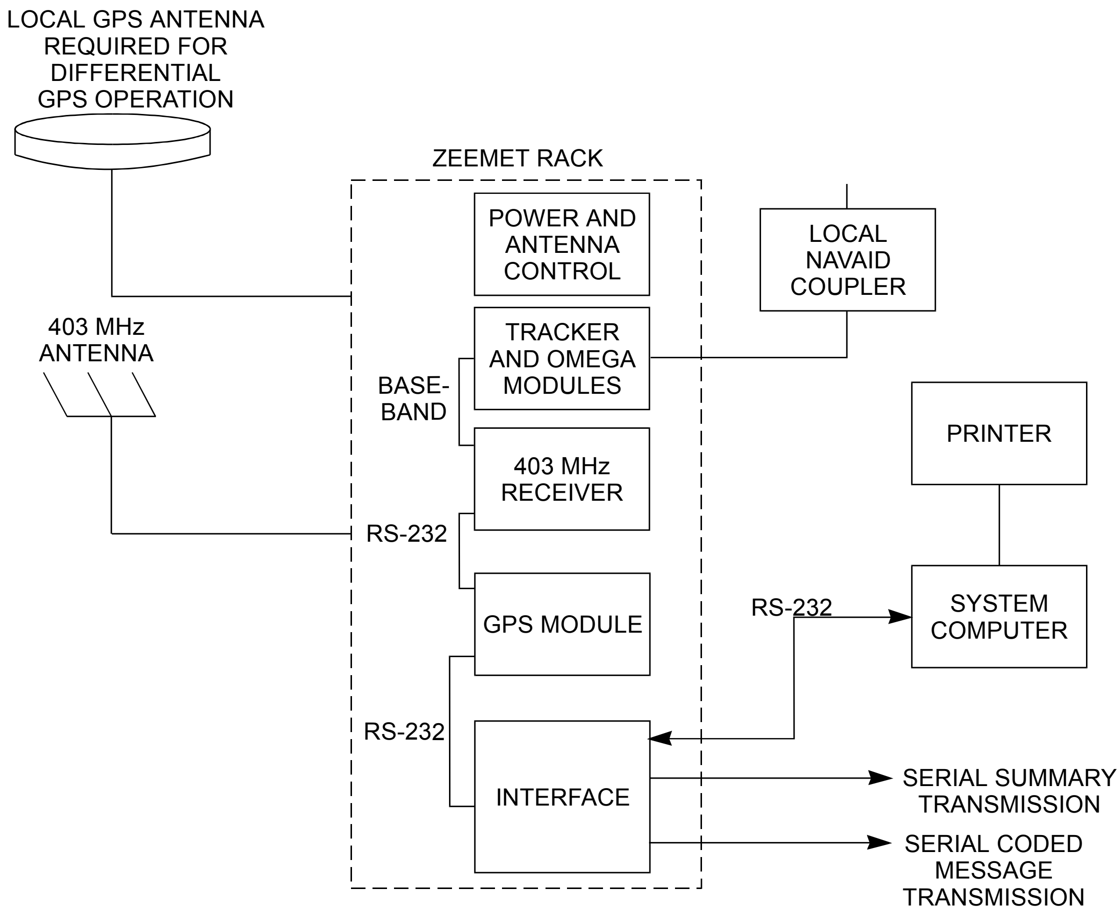


Figure 1-2. GPS ZEEMET Rack, Non-GPS Radiosonde, Block Diagram

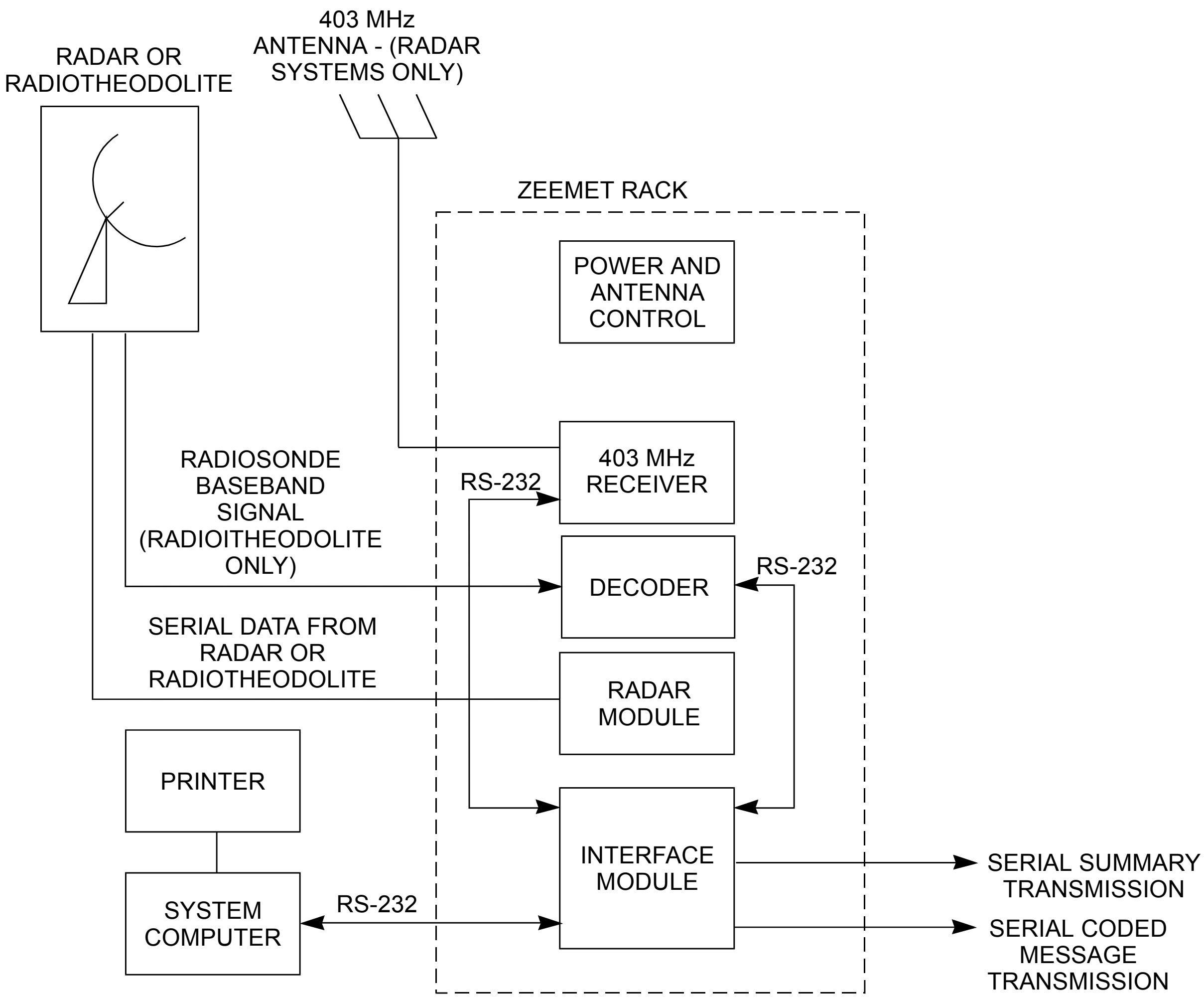


Figure 1-3. Radar/Radiotheodolite System, Block Diagram

1.2 Applicability

This version of the W-9000 Meteorological Processing System Theory of Operation manual is for operation with version 4.2 and later software.

Chapter 2. Technical Description

2.1 Mark II Microsonde

The Mark II is the next generation of the Microsonde that has been used extensively since it was introduced in 1981. It is a digital sonde that uses the same sensor technology for the temperature and humidity elements that has been standard with Sippican for all radiosondes for many years. The pressure sensor has been replaced with a continuous reading capacitive aneroid constructed from materials similar to those used in the conventional baroswitch, of which over 5,000,000 have been fabricated.

Physical Construction

The sonde consists of three subassemblies contained in a molded foam case. The sensor assembly holds the pressure and humidity sensors and provides the mount for the thermistor temperature element arm. The transmitter assembly contains a high stability transmitter. The third assembly provides the balloon to sonde cord and a mechanism for controlling its rate of payout. This assembly also provides for the Navaid antenna for those sondes equipped with a Navaid receiver.

In order to provide the appropriate environment for the carbon humidity sensor, the sonde package includes a duct. This eliminates solar heating of the element and provides satisfactory protection from direct impingement of rain. In addition the sonde contains the train dereeler and cord. These together increase the volume to 0.0017 cubic meters. The sonde weight is 250 grams. The lower weight and somewhat higher volume enhances the frangibility and reduces the risk of damage to aircraft.

Performance Characteristics

Sippican radiosonde sensors have been tested in many intercomparisons. The Sippican carbon element humidity sensor and the rod thermistor have been tested and compared with sensors of other manufacturers and also against themselves. The Microsonde humidity duct was part of the sensor environment tested in these trials. The MARK II MICROSONDE incorporates this sensor technology which is described in more detail under the appropriate paragraph.

The pressure sensor employed in the MARK II MICROSONDE is a continuously variable capacitive aneroid. The device, is manufactured from materials (Nispan-C for example) that has been procured and processed for many years for the manufacture of baroswitch aneroids. These units were the subject of intercomparisons.

Pressure Sensor

The Pressure Sensor is constructed from cold rolled, heat treated and exercised Nispan-C for zero temperature coefficient. Cold rolled internal capacitive plates resistance welded to specially constructed glass feed-throughs. Aneroid halves electron beam welded at 10 microns to form a precision butt weld. The capsule is calibrated with the interface electronics in similitude to provide polynomial coefficients. This procedure takes into account the temperature profile to which the sonde is to be exposed during a synoptic sounding.

Temperature Sensor

This is extruded from a mined iron oxide that has remained consistent for many years. The oxide is fired, treated, plated at both ends and thin wire leads added. Following a curve tracking test and the determination of resistance *lock in* value, the thermistors are coated with a reflective material. Lastly a surface coating is applied to encourage water droplets to coalesce and drop off after the passage through rain and clouds.

Sippican continually improves its sensors by ongoing research and development. This has resulted in smaller rod thermistors having the same resistance and reflection/absorption characteristics. A smaller version of the standard rod thermistor is employed in the Mark II MICROSONDE.

Humidity Sensor

Humidity is measured by the change in resistance of a carbon film deposited on an acrylic substrate. The substrate is provided with conductive stripes along each edge. Once prepared the elements are subjected to exercising through different humidity before calibration at 33% RH. Recently, an additional calibration point has been incorporated at 11% RH. A linear interpolation between the 33% calibration point and the 11% calibration provides good results at lower humidity.

Operating Environment

The Mark II MICROSONDE is designed to conduct a full synoptic sounding to balloon burst, which is typically 10 hPa. The sensors, battery, and other components withstand this environment and telemeter atmospheric parameters to the specified accuracy over this range.

In addition to the sensed parameters of the atmosphere, the Mark II MICROSONDE transmits frames of digital data that include the sonde serial number, values of reference resistors and capacitors, and calibration constants for the sensor polynomials. The reference components are time-multiplexed with the sensors to provide transfer standards during the radiosonde ascent.

To provide protection for the sensitive circuits within the sonde from both internally and externally generated radio frequency interference, internal shielding is employed. This is effective in shielding the sonde circuitry from various RF interference sources.

Transmitter

The transmitter in the Mark II MICROSONDE is a multistage circuit of high stability. It is effectively isolated from the sonde antenna, thereby reducing the effects of handling on frequency pulling while being prepared for launch. To minimize the range of temperatures seen by the transmitter, it is located in foam to retain the heat dissipated in the transmitter.

Radio Frequency

To address the need of covering the 400-406 MHz band, the transmitter is tunable, from outside the case, over the entire range.

The frequency of transmission of the sonde is received by the ground station. The W-9000 system includes a synthesized UHF receiver whose local oscillator is referenced to a crystal oscillator. This allows the transmitted frequency to be measured to an accuracy of the synthesized step of 33 KHz. The exact frequency is displayed on the system Computer.

Transmission Characteristics

The sonde transmits a 400 baud biphase digital data stream with CRC-16 error checking for data integrity. In addition, each data frame is sent twice to improve data capture during fades that may occur at long ranges when the sonde swings. The 400 baud data stream frequency modulates the carrier with a peak-to-peak modulation of 300 KHz. Pressure, temperature, and humidity are sent twice every second. This is one line of a frame of nine lines. Calibration information is complete in one frame and is sent continuously throughout the flight. Other words of the data stream contain reference resistance and capacitor information. Space is allotted to spare channels when additional sensors are required. A synchronizing Barker word is transmitted at the commencement of each line for ground equipment synchronization.

In addition to the above, the sonde transmits its serial number so that the ground station can accept or reject the transmission. This is an important feature that prevents the ground receiving system locking on to the wrong sonde.

The digital transmission is one of the most important features of the Sippican sonde/ground station system. The ability to transmit and receive data without error makes it unnecessary to smooth, edit, or filter data. Quality control of the incoming data is achieved with the CRC-16 check sum technique. This preserves the time constants of the sensors and permits an accurate representation of the atmosphere to be made.

The sonde includes a navigation receiver that determines wind without a radar or radiotheodolite and transmits a complex signal of data and Navaid information. When this occurs sidebands of the navigation information determine the transmitted bandwidth. This can be kept under 200 KHz for the Omega/VLF Navaid and 300 KHz for Loran-C.

The transmitter radiated power is nominally 250 milliwatts and has a tolerance of 50 milliwatts.

Modulation

The 400 baud biphase signal is a binary representation of the formatted data containing meteorological, calibration and other data. This is applied to the transmitter so as to change the carrier frequency by approximately 150 KHz, creating a transmission that has all the characteristics of a minimum shift keyed (MSK) modulation. The peak to peak deviation is 300 KHz and the rate of frequency shifting is that of the 400 baud modulating signal.

When the sonde is supplied with a navigation receiver, Navaid signal output together with atmospheric noise is added to the meteorological data stream. Extreme care is taken in the design for the navigation receiver in the sonde to preserve the Navaid signal phase integrity while limiting its output. This dual requirement is necessary to retain wind accuracy and to prevent over-modulation of the transmitter.

Battery

The battery system supplied with the Mark II MICROSONDE is the standard water activated battery used for many years in radiosondes. While there is adequate energy to power the sonde for one hour on the ground and two hours in flight, it is recommended that the sonde is turned on only when required, thereby preserving the energy for the last stages of the flight when maximum power is required.

Meteorological Sensors

The sonde is provided with three meteorological sensors and has the channel capacity to add a further three if required. This optional spare channel capacity has proved to be most useful for the evaluation and comparison of sensors and the addition of other sensors such a ozone, thermal and nuclear radiation.

The pressure, temperature and humidity sensors are all manufactured in high volume on the premises of Sippican. Tight control is maintained with all aspects of material purchase and inspection, process control and sensor calibration. Reference standards are maintained in the company, all traceable to primary standards held by the National Bureau of Standards.

To satisfy the current requirements for computer calibration of sensors and the new generation of automatic systems, Sippican has installed a computer network that touches all phases of sonde production, permitting data, serialization, quality and test information to be readily available to work and assembly stations as required.

Pressure

Pressure is measured with a continuously variable capacitive aneroid sensor. This is installed on the sensor assembly printed circuit board. The aneroid is made from similar material which undergoes the same processing that has been used successfully by the company in the production of well over 5,000,000 aneroid capsules. Capacity is measured between two parallel plates located within the aneroid. Connection to the plates is made through two glass seals. These seals are surface treated on the outside to make them non-hygroscopic.

The aneroid halves are joined together under vacuum using electron beam welding. A small flange is provided on the shell halves before welding that has just sufficient metal to create a vertical butt weld. This creates a mechanically rigid frame for the diaphragm action of the aneroid, thereby minimizing hysteresis and drift.

Temperature compensation of the aneroid assembly is achieved during manufacture by careful control of the heat treatment of the Nispan-C. The objective of this process is to produce a capsule of zero temperature coefficient. Since there is always a residual temperature effect, this is removed during the calibration process which is performed in similitude. The resulting coefficients used in the calibration polynomial will effectively remove the effects of temperature.

The range of pressures covered by the sensor extend from 1060 hPa to 3 hPa.

Temperature

A shortened version of the standard rod thermistor is used for the temperature sensor. This follows the identical temperature-resistance relationship as the larger unit. The coating is identical and the thermistor exhibits a similar solar radiation and emissivity performance as the larger rod.

Solar radiation is minimized by the coating employed. Water retention on the thermistor is reduced by a surface treatment during manufacture. This causes the water that is accumulated during passage through rain or a cloud, to bead and drop off, thereby minimizing the wet bulb effect.

The range of measurement of the sonde/ground processing system complies with the requirement for a range of +50C to -100C. The thermistors are manufactured to comply with a specified temperature-resistance law and then locked in to this curve at the time of calibration. This relationship holds for the required range to within 0.2C.

Humidity

The carbon element is well known for its superior performance at high humidity but there has been a limited evaluation of the performance below 20%. There is a reason for this. The largest user of the carbon element is the US National Weather Service who, by directive, have always cut off the humidity requirement at 20%. There has been only a small amount of interest to explore the characteristics of the sensor below 20%. This has now changed and Sippican is providing elements and equations for their use at low humidity.

The humidity element is installed in a duct that is integral with the sonde case. The purpose of the duct is to prevent direct solar radiation from warming the element and to avoid direct impingement of rain on the sensitive carbon film. Response of the carbon element exceeds the requirement of less than two seconds at +20C and 1000 hPa. Typical response time of the element under these conditions is less than one second.

Sampling Rate

The meteorological parameters (pressure, temperature, humidity, and three spare channels) are sampled and transmitted once per second. Each sampling is transmitted a second time for added reliability. If the ground system loses a frame of data because of interference, it can recover the data using this redundancy feature.

Calibration

Calibration of the sonde sensors is performed at the factory. Calibration information is held in the sonde electrically erasable programmable read only memory (EEPROM) and is transmitted on a continuous basis from the sonde. Upon receipt of the transmission, the ground equipment uses the information for the processing of data derived from the sonde sensors. Under normal circumstances there is no requirement for operator-input of sensor data; however, in the event that it is required to modify lock in values of the humidity element or thermistor, provision is made in the operator interface for manual override. Pressure information from a reference barometer may be input manually to provide a base line reference for the aneroid pressure element. A base line check box is not necessary for verification of the factory calibration of the humidity and temperature sensors.

Production Quality

Quality Assurance Record

Assurance of product quality for radiosondes and more recently, ground equipment, has been Sippican's policy for over 30 years. During this time over 5,000,000 sondes have been produced and flown. Quality assurance equipment updates, equipment calibration and personnel training are basic actions taken by the company for sustaining and improving quality.

Quality Assurance Procedures/Tests

Procedures are in place and are used by engineering, purchasing, production, and quality assurance to verify product quality. The Quality assurance manual contains the policies and requirements comprising the Quality Assurance Program at Sippican, Inc. and is commensurate with the U.S. military specifications MIL-I-45208A, MIL-Q-9858A and National Weather Service Specifications.

Thermistor

The temperature sensor quality is assessed immediately after firing using statistical sampling procedures. Each sensor is tested at two temperatures by use of temperature controlled baths, under computer control, with working standard sensors for comparison. Working standards are periodically compared against a Rosemont platinum temperature standard which in turn is calibrated by an independent calibration laboratory with traceability to the National Bureau of Standards (NBS). Those units that meet the acceptance criterion are categorized into lots and are put under lot-control. Individual lots are tested along the temperature curve from +40oC to -70oC. Additional mechanical tests are performed on a statistical basis and tests for reflectivity are conducted.

Humidity Elements

The carbon humidity elements are cycled through a range of humidity to exercise the sensitive carbon film. Individual units are cut-in to a specified resistance. Units are canned and stored for 30 days, following which a sample is tested in a two-pressure humidity chamber (this is an NBS design that has been reproduced at Sippican). The two pressures are measured by a calibrated Ruska pressure gauge. High pressure saturated air is isothermally expanded to the lower pressure. By taking the ratio of the pressures, the humidity can be determined. This is a fundamental relationship and is directly related to the accuracy of pressure measurement. The Ruska unit has direct traceability to the NBS. Computer analysis is made of the of the samples and lots are accepted or rejected based on the results. Samples are also set aside for future historical data checks.

Pressure Sensors

The capacitive aneroid cells are fabricated from heat treated and cold worked material, electron beam welded under high vacuum. They are then exercised and exposed to temperature extremes to relieve inherent latent stresses and are then maintained in lots. A lot is set aside for 30 days for further aging and leak detection. Sample pressure sensors are installed into electronic circuits, calibrated and retested at temperature extremes. Upon lot acceptance, every unit is built into the electronics and then individually calibrated. Accuracy of the calibration chamber is determined by comparing pressure to a secondary standard traceable to the NBS. Sippican maintains seven precision Ruska pressure gauges. Periodically these are returned to the manufacturer for calibration against a primary standard traceable to the NBS. When returned to Sippican other Ruskas are then compared against this latest calibration. A sample (MIL-Std.-105) from the calibrated lot is recalibrated at ambient and cold temperatures to assure repeatability in flight.

Batteries. Batteries for the Mark II MICROSONDE are manufactured by Sippican and sample tested with dummy loads under operating conditions, using computer aided test chambers. Samples from each lot are retained and stored for historical testing.

Electronic Parts. Electronic piece parts are verified (or tested) to assure specification compliance. Certified material reports are required wherein Sippican testing is not feasible.

Mechanical Parts. All mechanical parts, whether purchased or manufactured in house, are inspected in accordance with approved procedures.

Subassemblies. All subassemblies are tested and serialized prior to sonde installation. All sondes are 100% tested and serialized after final assembly. Samples from lots are also tested by Quality Assurance for ambient operation and flight similitude. Sippican also maintains a flight facility at the factory for sample flight testing.

Sonde Final Test. Each sonde is production tested on a final test stand to assure that all circuits operate properly. The radio frequency will be set at this time using a high frequency counter. Transmitter deviation will also be set using a discriminator and oscilloscope. Quality assurance then samples (MIL-STD-105) the sondes at ambient and in flight similitude. Sample sondes are flight tested using the company flight facility.

Calibration Laboratory

The Sippican Quality Assurance Laboratory maintains secondary standards traceable to the National Bureau of Standards (NBS). Frequency is verified by radio and navigation transmissions. The laboratory complies with the requirements of MIL-STD-45662A. The laboratory calibrates all gauges and precision measuring instruments used for acceptance and these items are on periodic recall for calibration.

Radiosonde Life

The radiosonde is designed for storage of at least two years before use. The humidity element is sealed in a vial and is not exposed to the atmosphere until an operator removes the vial. The temperature element is stable and does not shift lock-in with time. The pressure sensor is exercised many times during the manufacturing process and receives a ground truth reference at the time of launch.

2.2 Wideband Navaid Coupler

Purpose

The Wideband Navaid Coupler performs the interface between the free-space signals in the area of the coupler and the W-9000 computer/ZEEMET Rack. Utilizing a whip antenna, the coupler multiplexes, filters, and amplifies the VLF and Loran-C signals which are in the location of the system. The coupler will interface with all of the W-9000 Navaid heads via a commercially available 50 ohm coaxial cable.

Operation

The Wideband Navaid Coupler is designed to operate outdoors. When installing the coupler, some thought should be given to the surrounding environment. As in any antenna installation, the coupler should be mounted in a clear, unobstructed area. This area should be free of cables or any other metal structure which would interfere with Navaid reception. Since the coupler is amplitude-sensitive, high noise sources such as generators, power lines, air conditioners and fluorescent lights should be kept away from the coupler. Power to the Wideband Navaid Coupler is supplied via the coaxial cable from the Navaid Amplifier.

Technical Description

An E-field (whip) antenna provides the input signals to the coupler. This antenna is electrically short and therefore has a very high impedance. To accommodate this high impedance, the coupler uses a transformer that steps the antenna impedance down to a level that will interface with the low pass filter, shown in Figure 2-1.

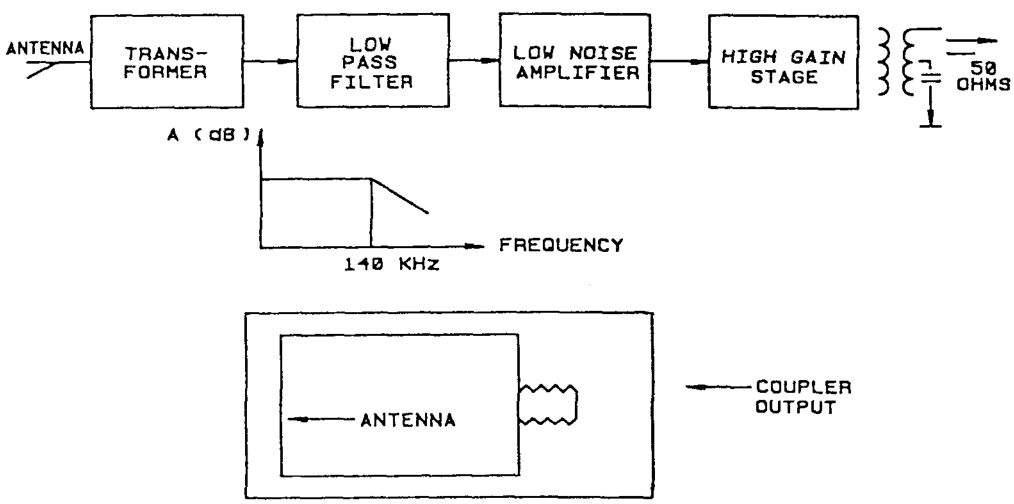


Figure 2-1. Wideband Navaid Coupler Block Diagram

The low pass filter provides a band width of 10 KHz to 140 KHz. This band width obviously covers the Omega band of 10-30 KHz as well as Loran-C (100 KHz). The low pass filter is the only bandwidth reduction used in the coupler. A low noise JFET provides the first block of gain in the coupler. The JFET provides high input impedance (megohms) with low noise (1 dB noise figure).

The output of the JFET stage is coupled to an integrated circuit that provides the additional gain required to:

- Convert the high antenna impedance to 50 ohms.
- Overcome the losses in the input networks.
- Override the amplifier noise in the W-9000 Navaid head.

An output transformer can be configured for balanced or unbalanced service (unit is delivered unbalanced). Power for the coupler is provided by the Navaid head and is fed into the coupler via the center inductor of the 50 ohm coaxial cable.

2.3 403 MHz Antenna System

Purpose

The purpose of the 403 MHz Antenna System is to collect signals during flight and send them onto the 403 MHz Synthesized Receiver for processing.

Operation

Signals collected by the antennas are amplified by the preamplifier, before they are passed along to the 403 Receiver. The 403 Receiver in turn provides DC power to the Electronic Switch Module which contains a preamplifier. See Figure 2-2.

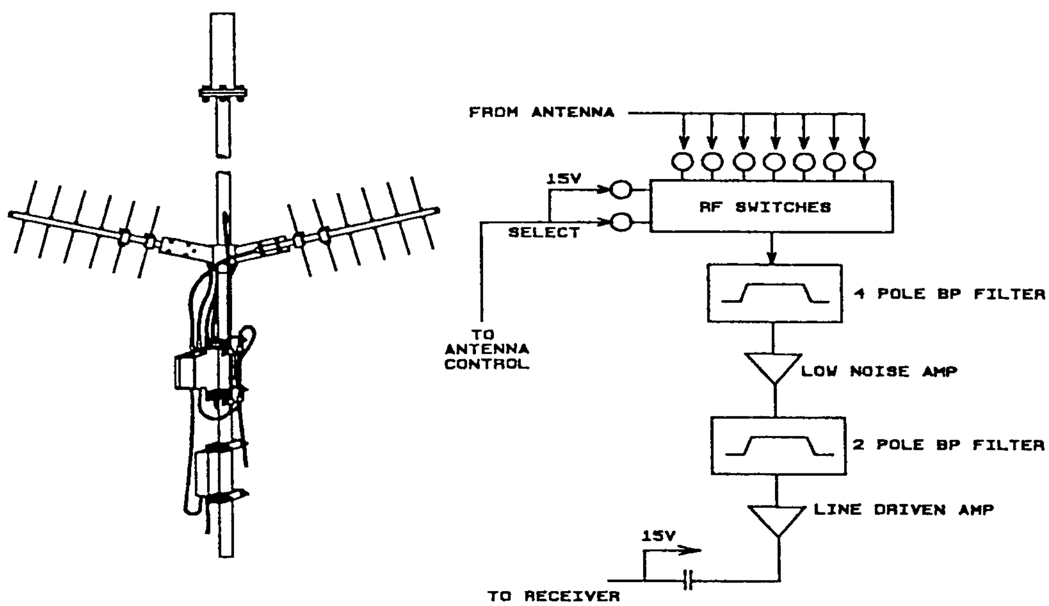


Figure 2-2. 403 Mhz Antenna System Block Diagram

In normal launch conditions, an omni-directional quadrafile antenna, is used for receiving the signal at launch. The signal comes down through the center part of the mast into the preamplifier, which is mounted the antenna. It is amplified and then sent into the receiver. At some time into the flight (usually about 10-20 minutes) as the signal becomes less distinct, the software switches the system over to the Yagi antennas, which are directional, (10 dB gain with a 20 dB front-to-back ratio). There are six Yagi antennas arranged in a circular pattern spaced 60^o apart to cover 360^o of the horizon.

The choice of which of the Yagi antennas to switch in is made by the Antenna Control/Power module based on wind information coming from the computer. The switches used in the Electronic Switch module are ultra low noise GaAs FET type solid state devices arranged in such a way as to allow either single or adjacent pairs of Yagi antennas to be used.

Some systems are configured with only an omnidirictional antenna that does not require an Antenna Control/Power module or the Electronic Switch module, but require a Preamplifier module and Power module.

Technical Description

Omni/Yagi Antenna System

There are nine cables normally connected to the Electronic Switch module: six cables are the feeds for the directional Yagi antennas, one is the feed for the omni-directional quadrafile helix antenna, one is the receiver coaxial cable which takes the signal from the preamplifier to the receiver, and one comes from the Antenna Control/Power module to control the solid state switches. The receiver supplies DC power via the coaxial cable to the Electronic Switch M
module preamplifier section. Power is applied to the switches via the antenna control cable.

The Yagi antenna is constructed of T6061 aluminum. The Omni antenna is constructed of fiberglass and can stand winds of over 100 miles per hour.

Omni-Only Antenna Systems

Some W900 systems are configured with only an Omnidirectional quadrifillar antenna for various reasons. This antenna system requires only a single input and single output from the preamplifier. This antenna system functions in the same manner as described above but without any software controlled switching action between antennas.

2.4 Electronic Switch Module

Electronic Switch modules are supplied with Omni/Yagi Antenna systems. They contain a preamplifier and solid state switching gear for antenna selection. When a single omnidirectional quadrafile helix antenna is supplied only a Preamplifier module is needed. The Preamplifier module contains only the preamplifier section of the Electronic Switch module.

Operation

Antenna selection (Omni/Yagi) is made at the computer. A bank of solid state switches in the Electronic Switch module is powered from the W-9000 through the MS3452L10SL-3P connector supplied with the unit. Omni-Only antenna systems do not have this.

Technical Description

Omni / Yagi Antenna systems

Refer Figure 2-2 for the following discussion. A combination of high frequency, low loss, solid state switches selects the appropriate antenna source. The possible combinations are:

- The quadrafile helix (omni) antenna alone (high elevation angle).
- One of the Yagi antennas alone (low elevation angle).
- An adjacent pair of Yagi antennas (low elevation angle).

Depending on the position of the radiosonde in flight as resolved by the wind-finding function of the system the Antenna Control Module will select the appropriate switches.

A four pole slab-line bandpass filter follows the solid state switch and provides filtering of the spectrum. This filter also provides impedance matching from the antennas to the amplifier outputs.

The gain is obtained from the cascade of three amplifier stages. The preamplifier has a gain of 35 dB to compensate for a long run of cable.

To further reduce interference a two pole filter follows the gain stages. The two pole filter is a Butterworth design whose characteristics provide high attenuation to out-of-band signals.

Power to the preamplifier is obtained from the center conductor of the coaxial cable connected to the receiver module in the ZEEMET Rack. Separation of RF and DC power is performed in the preamplifier.

Omni - Only Antenna Systems

A Preamplifier Module is supplied with Omni Only Antenna Systems. It is the same internal design as that described above and achieves that same function with one exception. The case provides for a single input and a single output.

2.5 1680 MHz Down Converter (Optional)

Purpose

The 1680 Converter frequency shifts signals from the 1680 MHz range to the 403 MHz range. This signal shift enables the use of the 403 MHz Synthesized Receiver. One further purpose of the 1680 Converter is that it enables using a lower down frequency from the antenna, thereby enabling the use of less expensive cables and the elimination of booster amplifiers.

Operation

The 1680 MHz Down Converter is a self-contained RF module. Since the 1680 Converter covers the 1660 to 1700 MHz band (roughly four times the 403 receiver bandwidth) a shift technique is used. The 1680 Converter local oscillator is shifted in four bands. Codes from the W-9000 system establish the band which the 1680 Converter tunes to. Power (+15vdc) and band codes are injected through the MS connector ,which is on the 1680 MHz Down Converter housing.

Technical Description

Refer to Figure 2-3. Signals from an antenna or from another RF source are filtered in a bandpass filter. The filter output is coax-connected to a low noise amplifier. A second amplifier provides the additional boost to overcome losses of the following modules. With an overall gain of 20 dB (two stage amplifier) the 1680 MHz signal is further bandwidth conditioned. A second four-pole filter couples the signal to a double balanced mixer (DBM). The Local Oscillator input to the DBM heterodynes the 1680 MHz signal into the 403 MHz board.

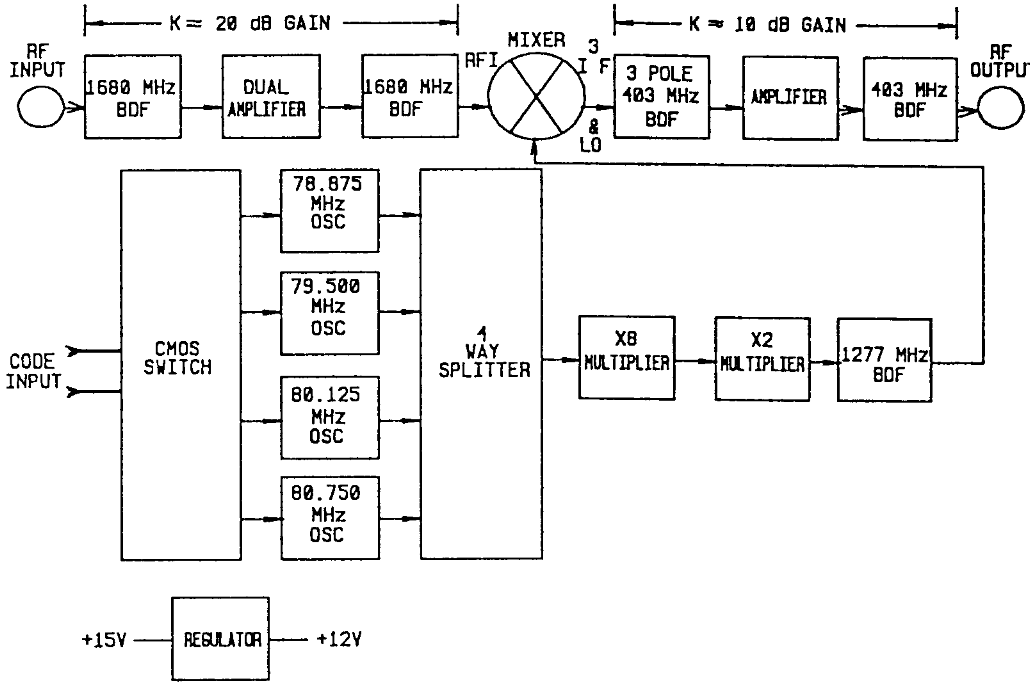


Figure 2-3. 1680 MHz Down Converter Block Diagram

A 403 MHz bandpass filter further signal conditions the received signal. The filter output drives an amplifier (gain 14 dB) whose output is filtered in a 403 MHz bandpass filter.

The local oscillator in the 1680 Converter consists of four crystal oscillators, followed by a times sixteen (<F128M>÷<F255D>16) frequency multiplier.

The <F128M>÷<F255D>16 frequency multiplier is obtained through a cascade of four overdriven bipolar amplifiers.

A decoder precedes the crystal oscillator, and one of four code selects which crystal oscillator is activated. The meteorological band (403 MHz) is broken up into 10 MHz increments. Each of the increments is scanned by the 403 MHz receiver. Dynamically the 1680 Converter will interface with the W-9000 system software. During a synoptic sounding the computer will measure the frequency of the 403 MHz Synthesized Receiver and will make the code correction to ensure that the received signal is kept in the center of the 403 MHz pass band.

2.6 ZEEMET Rack Assembly & Antenna Control/ Power Module

Purpose

The ZEEMET Rack Assembly is a modular enclosure which provides a parallel signal interface (P90 Bus) for a modular system. The 403 MHz Antenna Control / Power Module is included as part of the ZEEMET Rack only when the system is configured with a directional antenna system (Yagi).

Technical Description

The Antenna Control consists of two modules in one housing. The first half of this module provides an AC interface to the DC power supply and AC primary voltage to the antenna rotator transformer; (24 vac at 6 amps). The AC power is fused at 3.5 amps and the 24 vac is fused at 6 amps.

The Antenna Control consists of two printed circuit boards: the antenna interface card (to interface to the P90 Bus) and the serial interface card which contains the drivers for the solid state antenna switches.

This part of the module serves several functions in the W-9000 system:

- It provides a way to communicate to the antenna system via the P90 Bus through the system computer. See the Antenna Control Commands section.
- It provides a means to read the position of the Yagi Antenna.
- It provides a way to select the Yagi or Chu antenna.
- It provides a means to communicate to the 1680 MHz Down Converter.

AC Power

AC power enters the module via the three-pin bulk-head AC connector; AC line, AC neutral and AC ground. The AC line (hot) then passes though the 3.5 amp slow-blo to the front mounted panel switch which switches both the line and neutral leads. A Neon indicator within the switch provides visual confirmation of AC power to the system.

AC power then leaves the system by a 6-pin connector on the rear of the system to power the System DC supply and the 24 vac supply for the antenna rotator.

2.7 Power Module

Purpose

When Systems are supplied with a single omnidirectional antenna no antenna control functions are necessary. In such instances only the power handling and distribution tasks described in section 2.6 are achieved. These functions are taken care of by a Power module.

Technical Description

The Power module serves as the input for AC power and routes this power to the DC power supply and any other devices that require remote AC power inputs (such as portable or built in computers and printers when supplied). The DC power supply is a switching unit and is located directly inside of the power module. Hence the Z-MET rack DC voltages are fed directly from this module to the rest of the ZEEMET rack.

2.8 P90 Bus

Purpose

The purpose of the P90 Bus is to provide power and signal exchange between ZEEMET modules.

Technical Description

The back plane on which the P90 Bus is implemented consists of 64 pins (A and C rows of a DIN 41612 C female connector), interconnected in a parallel bus configuration by a printed circuit board. All bus connectors have wire-wrapped pins which extend through the back plane, permitting additional customized interconnections. The wire-wrapped posts on the first and last connector are gold-plated to allow for extension cables to be added to the bus.

Sub-Buses

The P90 Bus is subdivided into several sub-busses or functional sections, as follows:

- Power supply bus lines--provide +5V, + 15V, and +5V standby. These bus lines provide the power required by the system modules.
- Navaid Signal bus lines--provide the path to transfer Navaid signals (Omega, Loran-C, or VLF) from the Navaid Amplifier Module to the tracker module(s). The eight Navaid signal lines and their associated returns are identical in hardware design. For convenience, four have been predefined as Local Loran, Remote Loran, Local Omega, or Remote Omega.
- Bus lines--This is the most complex part of the P90 Bus. See the SBus Section which follows.
- Audio Bus Lines--2 audio lines provide (a) base-band telemetry signals, and (b) audio signals which are used to power the system loudspeaker.

Miscellaneous Bus Lines

- 16 MHz clock signal and return provides 16 MHz frequency reference to system modules as required
- System Synchronization provides a means of time synchronization for system modules.
- Reset provides logic reset signals to all system modules. Sources and uses of the reset is jumper selected on all processing boards.

Purpose of the SBus

The purpose of the SBus is to communicate serially between modules placed on the bus. The protocol permits the exchange of data between two intelligent or microprocessor-based modules and between an intelligent module and a dumb or non-microprocessor-based module in either asynchronous or synchronous format.

Operation

All intelligent modules may function as either bus master or bus slave. The intelligent modules are those which are microprocessor-based—for example, the System Interface, the Navaid Tracker, and the 403 and VLF Receivers. The dumb modules (those without microprocessors) operate as slaves. These include the Antenna Control module, the synthesizers on the VLF heads, and the control cards for the 1680 MHz antenna-mounted 1680 MHz Down Converter.

When an intelligent module communicates with another intelligent module, the communications may be either synchronous or asynchronous, but usually the asynchronous mode will be used. In either case, the addressing scheme uses a word imbedded in the serial data stream passed from the master to the slave. When a master communicates with a slave, the master module places an address on the Sbus which is directly decoded by the slave, simplifying the address decoding process.

Using P90 serial bus protocol, it is possible for any master module in the ZEEMET Rack to address any other serially interfaced module on the bus. Thus, for example, it is possible for the System Interface, the Navaid Tracker, and the 403 Receiver to control the 403 MHz Antenna Control module. The intelligent module assigned to actual control of a peripheral, such as the antenna rotator, is determined by the software loaded into the various modules.

Because it is possible for any master module to attempt to claim the serial data interface at any given time, a bus access protocol has been devised to prevent simultaneous access by two masters. Once the master has claimed the serial interface bus, it may continue to use the bus until data transfer is completed. Potential conflicts between competing master cards is resolved by assigning a bus access priority to each card in the system. This priority, which is assigned as a part of the overall system configuration, provides a variable delay between the time which a master first requests the bus and the time at which it finally takes control of the bus. If, during the interval between the time the use of the bus is requested and the time at which the bus may be claimed, a higher priority card seizes the bus, the lower priority master withdraws its request and tries again later.

Bus Terminator Card

A printed Circuit card is attached to the bus back plane located in the ZEEMET rack. This card serves as a master 16 MHz clock for Navaid processing. A Temperature Compensated Voltage Controlled 16.00000 MHz crystal oscillator is located on the board. In addition, a microprocessor and related digital circuitry are located on board to provide a control interface to this TCVCO.

2.9 403 MHz Receiver

Purpose

Radiosonde transmissions in the 400 to 406 MHz band are signal-processed by the 403 MHz Synthesized Receiver. Data on the 403 MHz carrier consists of meteorological and navigation signals. This data is provided by the receiver to the ZEEMET Rack for further processing in the W-9000 system.

Operation

The 403 Receiver is operated from the computer. Antenna and/or preamplifier signals are injected into the receiver and all receiver functions are performed via the computer card which is an integral part of the receiver.

Technical Description

Refer to Figure 2-4. Radio signals are injected into the receiver's input via a type N connector. The injected signal is bandpass filtered in a two-pole Butterworth network. A low noise amplifier provides gain at the receiver's input. A two-pole bandpass filter provides additional filtering prior to the receiver's first signal conversion.

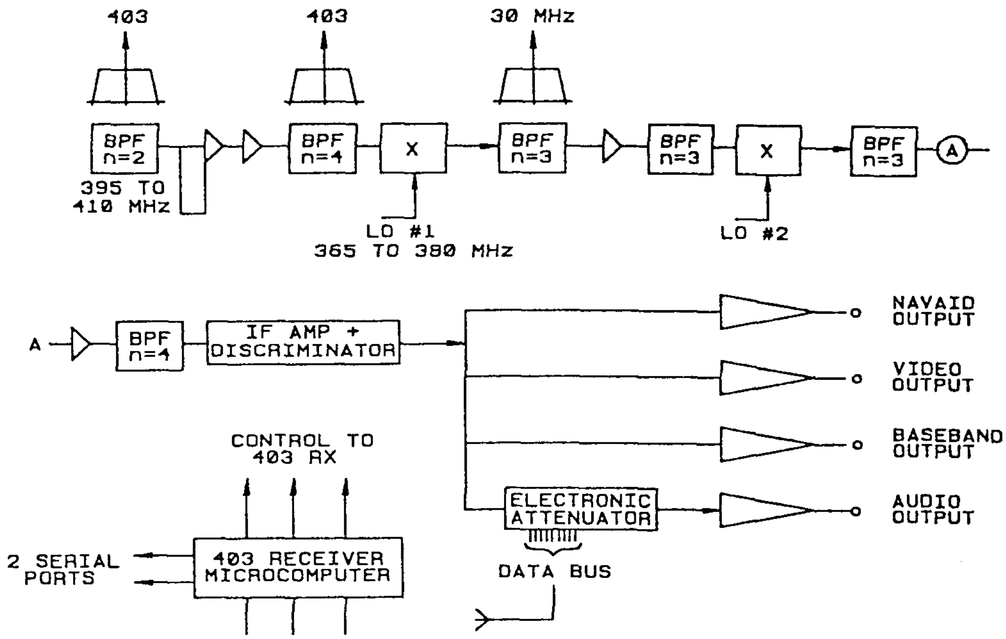


Figure 2-4. Synthesized Receiver Block Diagram

A double balanced mixer provides the conversion of the 400 to 406 MHz signal to the first IF (intermediate frequency) of 30 MHz. A local oscillator signal covers the frequency range of 365 MHz to 380 MHz. This local oscillator is generated in a Phase Lock Loop network. See Figure 2-5 for a description of Local Oscillator #1.

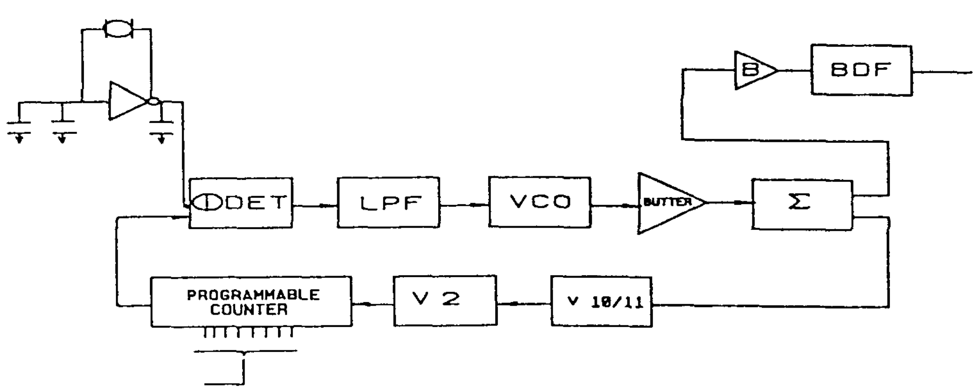


Figure 2-5. Local Oscillator Block Diagram

At the mixer output, a three pole filter selects the IF signal of 30 MHz. The bandpass filtered signal is amplified and filtered by a second bandpass filter.

A second double balanced mixer converts the 30 MHz IF to 12 MHz. Again, as in the first IF, a cascade follows the second mixer of two-pole filters and gain to further signal condition the down-converted signal. The local oscillator (LO2) injection is obtained from a Phase Lock Loop. See Figure 2-6 for a description of Local Oscillator #2.

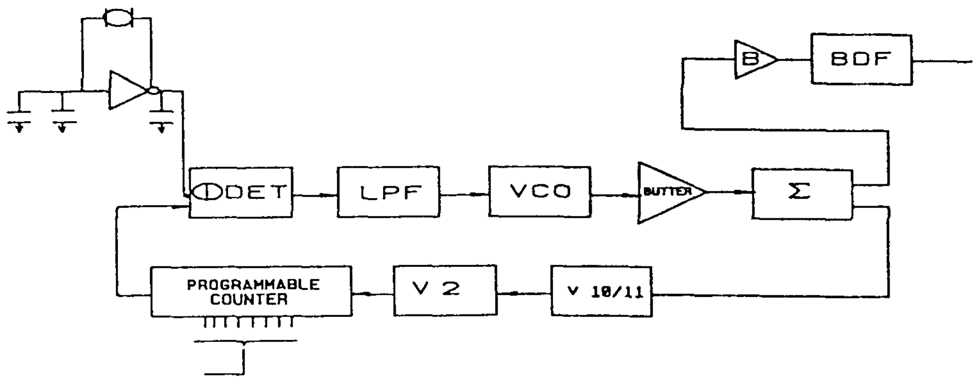


Figure 2-6. Local Oscillator #2 Block Diagram

Final signal conditioning is provided by an integrated circuit IF discriminator network. This conversion produces the baseband or meteorological data for the W-9000 system. Baseband output is buffered and drives four receiver outputs. These outputs are Navaid, video, baseband, and audio. With the exception of the audio output, the remaining outputs are buffered with wide band signal conditioning. These three outputs, Navaid, video, and baseband, can drive an impedance level of 50 ohms. All four of the signals are available on the receiver front panel.

In the 403 Receiver, there is one microcomputer to control the receiver, and to buffer and validate the sonde data. All of those functions in the receiver are enabled/disabled by the system computer through the serial port on the front panel.

The overall Receiver architecture is modular in nature. The Local Oscillator and RF/IF functions are located within housings inside of the overall receiver case. The microcomputer card and low frequency analog processing card are mounted together and are easily separated. This modular nature allows for easier servicing and troubleshooting.

Signals and DC power are carried between these boards via a separate bus inside of the receiver case. This bus consists of a small circuit card with connectors mounted on it which is mechanically secured to the back of the receiver case. All of the circuit cards can therefore be snapped into place and removed easily without having to de-solder connections.

2.10 Loran-C Amplifier

Purpose

The purpose of the Loran-C Amplifier Module is to convert the analog signals at its input to digital signals (TTL) for further processing in the Navaid Tracker module.

Operation

Navaid signals to the Loran-C Amplifier are from three sources: the Wideband Navaid Coupler, the 403 MHz Synthesized Receiver module or the Automatic Notch Filter module. In the case of the coupler, the Loran-C Amplifier provides the power to the coupler via the BNC coaxial input connector on the front end of the module.

A linear output is available on the front panel of the Loran-C Amplifier and is factory set to be equal to the Navaid signal at the amplifier's input. The analog Loran-C signal is amplified to limiting and converted to a TTL level. This TTL signal is present at the rear of the module and can be routed to 1 of 8 lines on the P90 Bus by DIP switch selection. The Loran-C Amplifier output is signal conditioned to interface to the Tracker module.

Technical Description

Refer to Figure 2-7 for the following discussion. Loran-C signals are signal conditioned in the amplifier module by amplifying and filtering. The source of the signals is from the coupler or from the 403 MHz receiver. The signals from either of these sources have amplitude variations of 40 to 60 dB. These signals are in a band width of 10 to 120 KHz. By a process of gain and filtering, the amplifier module compresses the band width and amplifies the signals into limiting. This limited signal is level shifted to a logic level, which for this system is TTL.

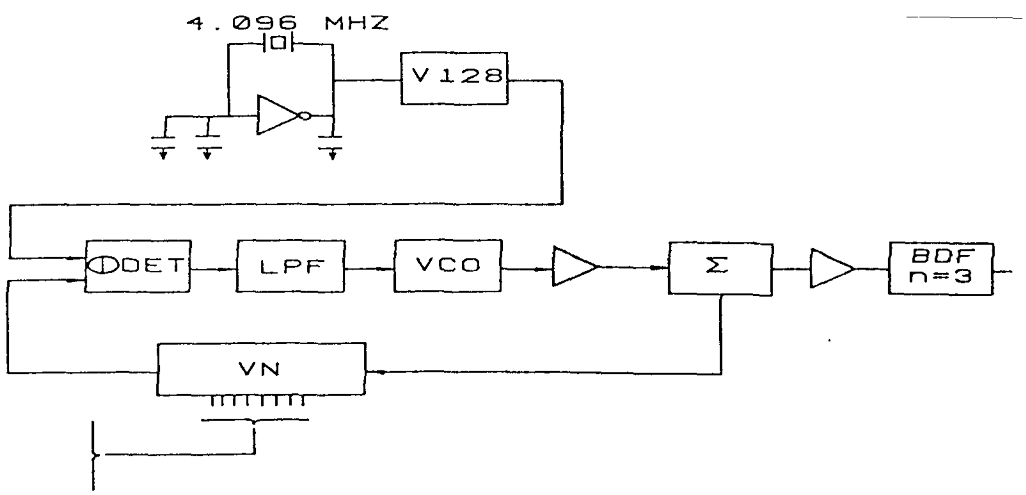


Figure 2-7. Loran-C Amplifier Block Diagram

Wide band signal input is coupled into the amplifier via the front panel connector. This input is transformer-coupled to the first gain stage of the amplifier. The transformer can be configured for either balanced or unbalanced input. Phase stability is extremely important in the signal processing of the Loran-C signals since any imbalance in the gain process will cause zero crossing errors which will affect the wind's data. U1 is a quad OP amp and is configured for low gain, to reduce errors discussed above. Gains in the first sections of the amplifier U1A are configured, as shown in Figure 1, to cover losses, PV and to provide buffering for notch filters and the bandpass filters. U1B, the fourth section of the quad, is looped back to the front panel of the amplifier and provides gain and drive capability for 50 ohm load impedance. This linear output is AC coupled and as such can be used to drive another navigation amplifier.

Section U1C drives a four-section notch filter. These notch filters are set at the factory. If your system has an Automatic Notch Filter then the notch filters in the Amplifier should not be adjusted. If your system does not have the Automatic Notch Filter it is possible that the Loran-C Amplifier will not lock. The notch filters can be optimized in the field by adjusting the four notch filters to reduce excessive noise on the signal. The amplifier has four adjustable notch filters for increasing the signal-to-noise ratio (SNR). Two of the notch filters tune the range of 75 to 90 KHz while the second pair of notches tunes the band of 110 to 150 KHz. Design of the notch filters provides for notch depths in excess of 20 dB. High band notch adjustments are indicated as 1 and 2 on the amplifier while the low band adjustments are indicated as 3 and 4.

Section U1D provides a buffer for the notch filters and drives the first filter section of the amplifier. Amplifier filtering is provided by a three-pole bandpass. The bandwidth of the filter is 20 KHz at the three dB points and provides an 18 dB/octave response in the stop band. U2 is a wideband amplifier which is used as an amplifier detector in FM receivers. The section of this IC that is used for the Loran-C signal provides 60 dB of voltage gain. For strong signals this amplifier limits and compresses the signals. Due to the wide bandwidth of the devices, a low phase distortion vs. amplitude is achieved in this first gain section. A second three-pole bandpass filter provides additional output of band rejection for the amplifier. To provide the necessary gain for the low level signals, a second amplifier U3 provides an additional 60 dB of gain. This cascade provides the gain limiting for the signals as well as the noise.

Overall gain up through U3 is in excess of 120 dB. To interface the amplifier to the P90 Bus, one last signal conditioning is required and this is accomplished at U4. U4 is a high speed (nanosecond) comparator which converts the analog amplitude signal to a logic level of TTL.

To provide a bus flexibility the amplifier output is fed to a DIP switch which enables system configuration of a Loran-C amplifier output to one of eight lines on the P90 Bus.

Loran-C Amplifier Front Panel BNC Connectors

The top BNC connector on the front of the local Loran-C amplifier is used for receiving the local Loran-C signal from the antenna. The cable is attached from the BNC connector to the Loran-C antenna.

The bottom BNC connector is used for signal output.

2.11 Omega Amplifier Modules

Single Frequency Omega Module (Omega Switch Module)

Purpose

The purpose of the Omega Switch module is to convert the analog signals at its input to digital signals (TTL) for further signal processing in the Navaid Tracker module.

Operation

The Omega Switch module's input is from the Wideband Navaid Coupler and from the 403 MHz Synthesized Receiver. The Omega Switch module provides power for the coupler through the front panel coaxial connector and also provides a linear output which is equal in level to the input signal. The linear output is located on the front panel and is a BNC connector. The amplifier's output is DIP switch selectable at the rear of the amplifier module. The amplifier output is signal-conditioned to interface to the tracker module.

An internal software controlled switch is used to select between the local and remote Omega signals. This action happens automatically at the arm for launch point of flight preparation. Prior to this the switch puts the processed local omega signals coming from the Wideband Navaid Coupler onto the bus for processing by the tracker module. After the switch position is changed the local omega signals coming from the receiver are put onto the bus.

Technical Description

Omega signals are signal-conditioned in the amplifier module by amplifying and filtering the input signals. Of interest in this configuration is the 13.6 KHz Omega signal. By a process of gain and filtering, the amplifier restricts the bandwidth to 250 Hz centered at 13.6 KHz, and amplifies the signals into limiting. This limited signal is level shifted to a logic level, which for this system is TTL.

See Figure 2-8 for the following discussion. Operation is the same for both local and remote Omega signals once the signal source has been selected via the software controlled switch.

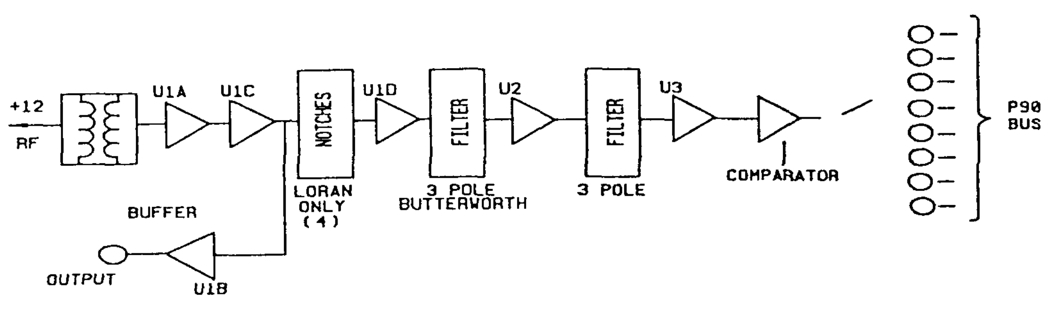


Figure 2-8. Omega Switch Module

Wide band signal input is coupled into the amplifier via the front panel connector. This input is transformer-coupled to the first gain stage of the amplifier. DC power is inserted into the center tap of the transformer. The transformer can be configured for either unbalanced as shown in the figure or balanced input. Phase stability is extremely important in the signal processing of the Omega signals since any imbalance in the gain process will cause zero crossing errors which will affect the wind's data. U1 is a quad operational amplifier and is configured for low gain to avoid the errors discussed above. Gains in the first section of the Amplifier (U1A, C, D) are configured as shown in the block diagram to cover D filter losses. U1B, the fourth section of the quad is looped back to the front panel of the amplifier and provides gain and drive capability for 50 Ohm load impedances. This linear output is AC coupled and as such can be coupled to another navigation amplifier such as Dual Omega, Loran-C, or VLF. The output of U1D drives a three-pole bandpass filter. The filter is designed with Butterworth constants and therefore provides a flat response with frequency over the passband of the filter. A three-pole network provides a filter response of 18db/octave. The three dB response of the filter is nominally 250 Hz. This bandwidth has proven to be good for out of frequency rejection and reduced effects due to spheric response. U2 provides 60 dB of voltage gain and is the first limiting amplifier in the cascade of gain. As previously discussed, the Omega Switch module must amplify signals in the microvolt region into the logic levels required in the system. To achieve this requirement, the amplifier utilizes a second three-pole filter and a second low distortion amplifier U3. This cascade provides a gain limiting not only on the input Omega signal, but also the noise in the system.

Overall gain up through U3 is in excess of 120 dB. To interface the amplifier to the P90 Bus, one last signal conditioning is required and this is accomplished at U4. U4 is a high speed (nanoseconds rise times) comparator which converts the analog amplitude limited signal into a logic level of TTL.

To provide bus flexibility, the amplifier output is fed to a dip switch which enables system configuration of an Omega Switch Module output to one of eight lines on the P90 Bus.

Multi-Frequency Omega Amplifiers

Purpose

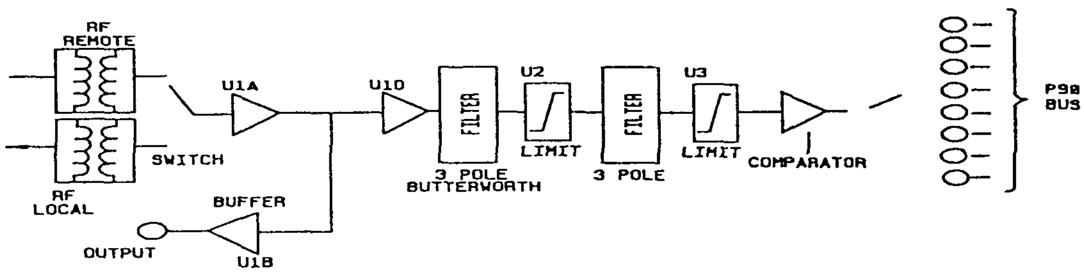
The purpose of the Multi Frequency Omega Amplifier modules is to convert the analog signals at their input to digital signals (TTL) for further signal processing in the Navaid Tracker module. There are two distinct amplifier modules associated with Multi Frequency Omega Reception. The first is the Omega Switch module and the second is the Dual Omega module. The operation of the Omega Switch is discussed in section 2.11. The operation of the Dual Frequency Omega module is discussed in this section.

Operation

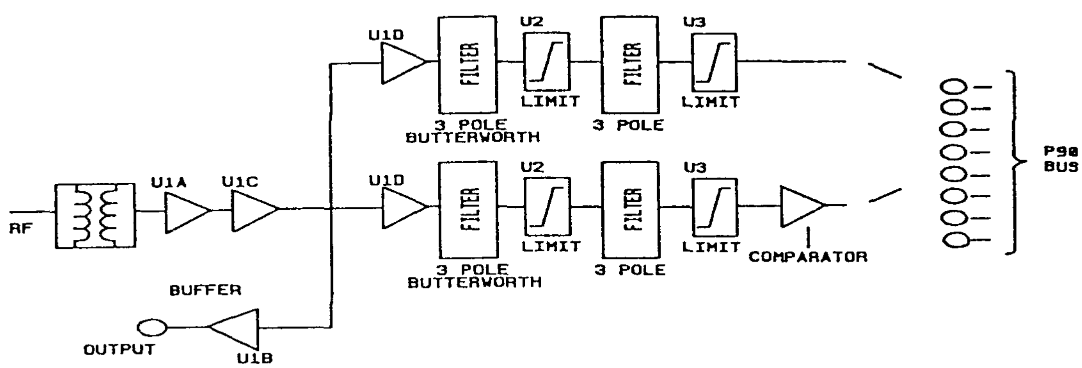
The Dual Frequency Omega module input is from the output of the Omega Switch module.. The Dual Frequency Omega module provides a linear output which is equal in level to the input signal. The linear output is located on the front panel and is a BNC connector. The amplifier outputs are DIP switch selectable at the rear of the amplifier module. The amplifier outputs are signal-conditioned to interface to the tracker module. The Dual Frequency Omega module has two distinct channels and two outputs to the bus. The channels provide filtering and gain for the Omega signals located at 10.2 KHz and 11.3 KHz.

Technical Description

See Figure 2-9, for the following discussion. Wide band signal input is coupled into the amplifier via the front panel connector. This input comes from the Omega Switch front panel connector. This input is transformer-coupled to the first gain stage of each channel of the amplifier. From here on the processing is exactly the same as that described for the Single Frequency Omega Module (Omega Switch) earlier in this chapter, except that instead of the bandwidth of each channel being centered at 13.6 KHz, the channels are located at 10.2 KHz and 11.3 KHz.



Single Omega Switch Module



Dual Omega Switch Module

Figure 2-9. Omega Switch Modules

To provide bus flexibility, each of the amplifier outputs is fed to a DIP switch that enables system configuration of a Dual Frequency Omega Module output to one of eight lines on the P90 Bus.

2.12 VLF Synthesized Receiver (Optional)

Purpose

The VLF Synthesized Receiver provides the necessary signal conditioning to Navaid signals in the 10 KHz to 30 KHz frequency range. This signal conditioning includes the filtering, mixing and amplification of the selected input signal to a compatible logic level (TTL) for the W-9000 system. By utilizing a unique synthesizer, this module will select any of the VLF signals in one Hz steps.

Operation

Tuning of the VLF Receiver module is via the W-9000 computer. Navaid signals in the microvolt to millivolt range are coupled to the receiver input. Frequency selection of these Navaid signals is from the

P90 Bus. With these two inputs, Navaid signal and Frequency selection, the VLF Receiver will process any of the Navaid signals in the 10 - 30 KHz frequency.

Technical Description

Refer Figure 2-10 for a block diagram of the VLF Synthesized Receiver. Navaid signals are injected into the VLF Synthesized Receiver via the front panel BNC connector. This input signal can be from the local coupler or from the telemetry receiver. For either input the parameters of the information are signals whose levels are microvolts to millivolts and in a bandwidth of 10 KHz to 150 KHz. A broad band amplifier amplifies and splits the input signal into two branches. One branch is a loop back which enables the user to cascade other modules into the W-9000 family. The second branch provides additional signal conditioning of the wideband (10 KHz to 30 KHz) Navaid signals.

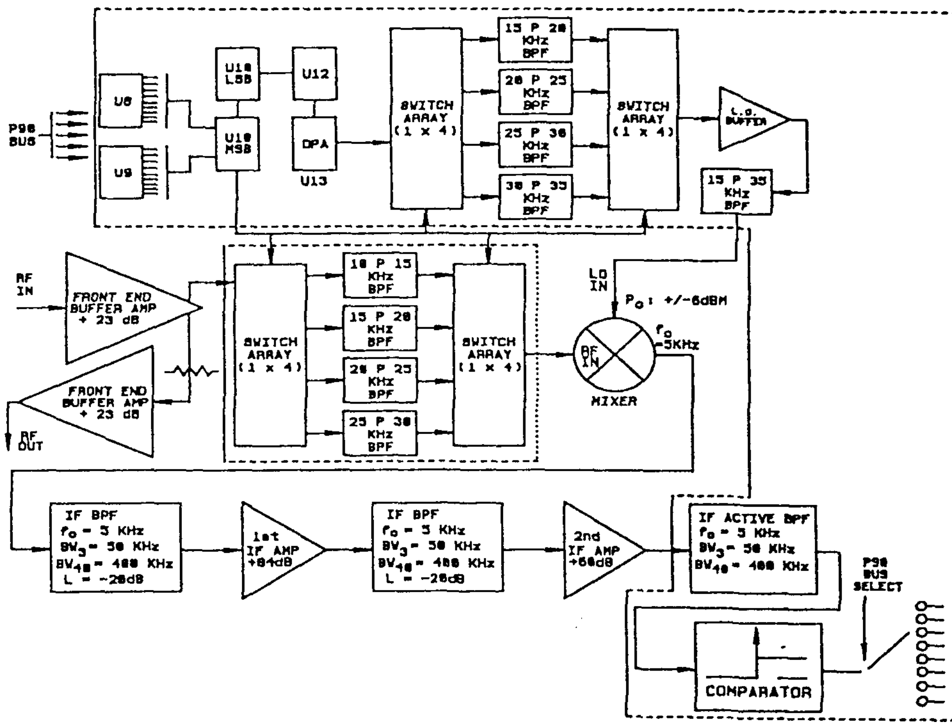


Figure 2-10. VLF Synthesizer Receiver Block Diagram

As can be seen in the block diagram the band of VLF signals is bandpass filtered by one of our banks of filters. Each of the four filters band-limit the VLF spectrum into 5 KHz spectrums. The filters in this section of the receiver are elliptic (Cauer) networks. The order of these filters is seven poles. Solid state FET switches are programmed via the P90 Bus to select the portion of the VLF spectrum which will be processed.

After this band reduction, the selected VLF spectrum is injected into a Doubly Balanced Mixer (DBM). The second injection into the DBM is from the synthesized local oscillator section of the VLF receiver. A difference frequency is generated in the mixer and the 5 KHz resultant is filtered in a passive three-pole Butterworth network. This filtered output is amplified at integrated circuit U4. High level VLF signals are limited in this first IF amplifier. Further filtering is provided by a second three pole network which further band limits the signal. To put all signals in limiting a second amplifier, U5, (identical to U4), provides the necessary gain.

At this point in the signal processing, the bandwidth has been reduced to 100 Hz and the VLF signal has been amplitude limited. Since the VLF information is narrow in bandwidth a final filter provides signal to noise enhancement. This final filtering is pre-formed in an active bandpass filter whose bandwidth is 50 Hz.

Now that the signal has been selected, bandwidth compressed and amplified into limiting, the final processing is implemented. A comparator converts the narrow band signal to a TTL level for processing in the W-9000 system.

To select the line which makes the VLF Receiver data available to the P90 Bus, a DIP switch is set. This DIP switch allows the TTL to be on one of eight lines and is physically located on the VLF receiver card.

Local Oscillator

A local oscillator is required in the VLF Receiver to select the desired signal in the VLF spectrum. Since the phase of the selected signal is processed in the W-9000 system, the local oscillator stability is of extreme importance. Equally important is the frequency agility required of the receiver to process any of the signals which are in the VLF spectrum.

To accomplish these requirements the W-9000 system utilizes a synthesized local oscillator. Frequency synthesis can be accomplished in many ways. The technique implemented in the W-9000 system is a digital synthesis which provides a local oscillator with one Hz steps covering a band of 15 to 35 KHz.

Digital synthesis is accomplished by integrated circuits U8, 9, 10, 11, 12, and 13. U13 is a PROM which has been programmed with the Sine of angles from 0o to 360o in 3,906 points. The Digital synthesizer addresses this PROM and provides the sine function output. What follows is a more detailed discussion of the synthesizer network.

Synthesizer Network

U10 and U11 are Programmable Logic Arrays configured as the phase accumulator, adder and P90 Bus arbitrator. The signals from the external bus are buffered by U8 and U9. U11 performs the bus decoding for device selection, serial to parallel conversion of bus data for synthesizer programming, and the clock decoding for the phase accumulator.

U10 comprises the phase accumulator and adder. At each clock interval generated by U11, the accumulator is incremented by the programmed number of degrees. When an overflow condition reached is greater than 360^{o}, 360^{o} is subtracted from the result to initiate the next cycle. The relationship of the increment rate and step value determines the output frequency.

A PROM, U12, contains a sine lookup table to convert the accumulator phase angle value to an amplitude value.

A digital to analog converter, U13, converts the table value to an analog voltage. As the D/A increments with the phase angle, a sinusoidal wave is generated. U14 performs impedance buffering between the D/A output and the filter section of the LO.

The output of the D/A is switched between one of four filter sections. Each filter section has a 5 KHz bandwidth to divide the LO range into its four channels: 15to 20 KHz, 20 to 25 KHz, 25 to 30 KHz, and 30 to 35 KHz. The filters eliminate harmonic distortion generated by the sampling technique of the synthesizer.

The four LO channel filters are selected and switched in or out by analog multiplexer (mux) switches U15 and U16. U18 performs signal level conversion from the channel select port of U11 to drive the mux switches. Serial data on the P90 Bus programs the synthesizer output frequency, and also contains the channel select data.

The output of the filter select, U16, is again buffered by Q1 and Q2 to drive the final LO bandpass filter. This filter has a pass band of 15 to 35 KHz. The pass band provides the LO inject to the IF mixer on the RF board assembly.

2.13 Navaid Tracker Module

The Navaid Tracker Module can be configured to track Loran, Omega, or VLF Communications signals, depending on the user's system. When needed, dual trackers can be installed to track Navaid signals from two sources simultaneously, and if needed, several trackers can be integrated into a multi-tracker system.

Loran Tracking

The Loran system consists of a coordinated network of four or five stations called a chain. Each chain transmits a series of pulses at the frequency of 100 KHz, in a specific sequence, with the master station transmitting first, and the secondary stations following in a predetermined order with a predetermined time lapse. When all stations have transmitted, there is a final predetermined delay, after which the master station again begins the cycle. This cycle of transmissions from master and secondary stations happens at a rate of about ten times per second.

The Loran tracker module function is to lock-on to each of the stations in the chain. The tracker will observe each station, and report the time at which each station is received in relation to the master station. This data, when gathered from the master and at least two secondary stations, can precisely fix the geographical location of the receiver, which is located in the radiosonde. As the radiosonde moves, the time delays reported for the several Loran stations tracked will change, and the system computer will translate this time change into geographical movement, and hence into wind.

The high accuracy of the Loran system is due to the high frequency of transmission (100 KHz) and the rapid repetition interval (about 10 opportunities per second to make a measurement of position).

Omega Tracking

The Omega navigation system consists of eight transmitters operating on three primary frequencies: 10.2 KHz, 11.33 KHz, and 13.6 KHz. Each transmitter transmits on each of these frequencies once in each ten second period. The order of transmission never varies: Japan, Norway, Liberia, Hawaii, North

Dakota, LaReunion, Argentina, and Australia. Each station transmits for approximately one second on each frequency. At the end of the ten second period, the cycle is repeated.

The Omega system synchronizes the tracker module on the frequency or frequencies of interest. The system will take a measurement of the observed time of arrival (actually, the phase relative to an internal clock) of the Omega signals. Since the Omega sequence is well defined, the tracker will lock-on to this sequence and take measurements on each of the eight transmitters. After taking data on these stations, the relative time-of-arrival of the stations is compared. This comparison yields a navigational fix which changes as the radiosonde moves in location, allowing the system computer to precisely locate the receiver's location, and its rate of movement. The extraordinary coverage range of these systems is due to stable, reliable propagation of these very low frequencies throughout the world.

VLF Tracking

The VLF navigation network consists of a series of transmitters operating in the frequency range of 15 to 30 KHz. These stations are not coordinated as are the Omega and Loran stations: each is a private transmitter on a unique frequency with a task assigned by the owner of the station. Because of the stable nature of these transmitters they may be used for navigational purposes similar to the Omega system. The wind accuracy of VLF is about the same as for Omega.

The VLF system synchronizes the tracker module on the frequencies of interest for a short period of time. This time is long enough to allow the system to take a measurement of the observed time-of-arrival (actually the phase relative to an internal clock) of the signal. After a measurement is taken, the tracker is locked onto another frequency, for another measurement. In this way one tracker module can do the duty of several separate modules. After taking data on several stations, the relative time-of-arrival of the stations is compared. This comparison yields a fix which changes as the radiosonde moves in location, allowing the system computer to precisely locate the radiosonde and its rate of movement.

Operation

The Navaid Tracker module is operated from the computer. In a standard W-9000 System, communications between the tracker and the computer are conducted via the System Interface module. Other systems may be configured differently, with direct communications between the tracker and the computer.

Technical Description

Refer to Figure 2-11, throughout the next discussion. The Navaid Tracker module uses hard-limited signal processing techniques to track all types of Navaid signals. Due to the variety of Navaids which must be tracked, the tracker hardware has been reduced to those functions which are common to all Navaids and which could not be implemented in the software.

The Navaid Tracker module is configured around the Hitachi HD6303Y microprocessor. In addition to the processor core, the tracker hardware provides two serial communication ports, a dual output comparison timer, an interval timer, and an input capture timer.

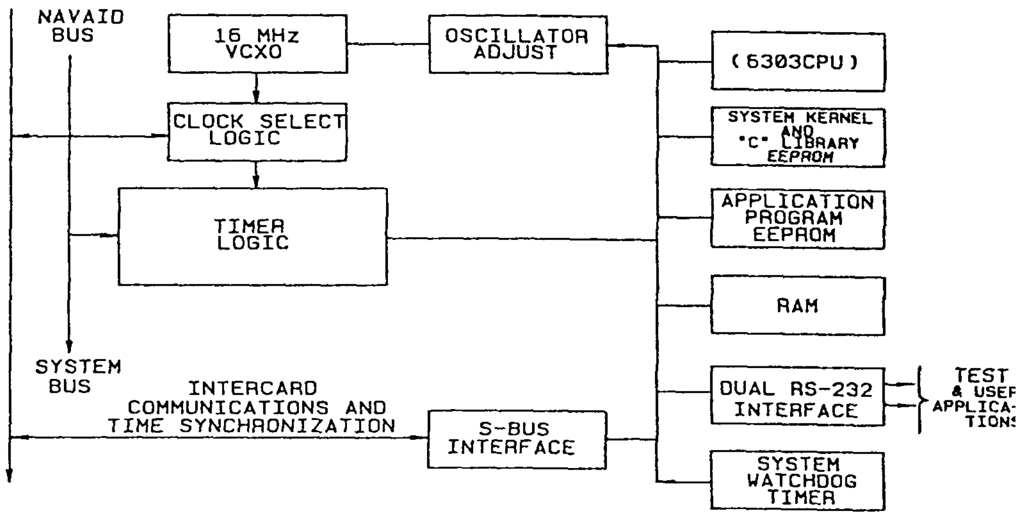


Figure 2-11. Navaid Tracker Block Diagram

The timer functions are implemented using an ALTERA 2100 gate programmable logic array and two 16-bit counters. All timing signals are derived from a 16 MHz temperature-compensated quartz oscillator which is frequency-adjusted under software control. The timer accepts input from one of eight hard-limited Navaid signal sources placed on the Navaid bus by appropriate Navaid heads.

The selected signal is processed by logic which is software-configured to provide either dual polarity samples or a linear phase measure. In the linear mode, the counters are used to measure the relative phase of the selected signal with respect to the system clock. In the polarity mode the 16 bit timers separate the two polarity timers.

The system memory is divided into three parts: EPROM, EEPROM, and RAM. The EPROM includes all the fixed software elements including priority tasking, I/O functions, a library of user callable C language functions, and a system monitor. The EEPROM contains the user/application program and may be loaded and/or reloaded using the serial ports. The RAM memory is used to store variables and to buffer data.

2.14 System Interface Module

Purpose

The purpose of the System Interface Module is to provide a communications interface between the various system components integrated within the ZEEMET Rack and the host computer. The System Interface module permits all data acquisition and the associated command and control communications to take place over two full duplex RS232 serial data ports. By serving as an intelligent data concentrator, the System Interface module decreases both the number of communications ports required and the volume of data which must be handled by the host computer.

Typical system components controlled by the System Interface module include the 403 MHz telemetry receiver, up to four Navaid Tracker modules, and the 403 MHz Antenna Control module.

In addition to its communication functions, the Interface also hosts a master system clock. This clock provides a common software adjustable time base to all system components, permitting improved cross Navaid tracking, for example., cross-chain Loran-C and various combinations of VLF and Omega signals. All Interface software functions are programmed in the C programming language, assuring both efficiency of memory usage and a structured programming environment. The use of non-volatile re-programmable applications memory permits the Interface to be reprogrammed via an RS-232 port, eliminating the need to replace EPROMs in the field.

Technical Description

The System Interface Module is designed around the Hitachi 63BO3 CMOS microcomputer. The module provides extensive serial communications capabilities including four full-function RS232 asynchronous communications ports and a synchronous/asynchronous SBus port. The SBus port provides for communications between the Interface module and other modules. The inclusion of the synchronous SBus mode permits the Interface to directly control and access data from non micro-computer based modules such as the Antenna Control.

The master system clock provides a 16 MHz time reference and a low frequency time tick to the P90 Bus. These signals are derived from a low power, high stability quartz crystal oscillator which is adjustable by the microcomputer. This permits the system time reference to be adjusted automatically, based on frequency measurements made using the highly stable, locally received Navaid signals.

Additional microcomputer resources include:

- A permanently programmed EPROM memory which contains system startup and maintenance programs and a complete library of C language support routines.
- A nonvolatile, re-programmable EEPROM memory used to store applications programs.
- RAM memory for the storage of measured data.

The System Interface module memory is configured at system integration by the use of a programmable logic memory decoder. The maximum system memory is 65536 bytes. This includes 256 bytes I/O and up to 32768 bytes each of EPROM, EEPROM, and RAM memory.

An extension power monitor/watch dog circuit provides for the protection of the EEPROM during power turn-on and turn-off cycles and for automatic system recovery following a low voltage condition or other detected system abnormalities

2.15 System Computer (Optional)

The ZEEMET W-9000 System Computer controls the meteorological data acquisition and executes all programs for data editing, display, message generation, and output. The standard computer is an 80486 IBM compatible computer operating at a minimum speed of 20 MHz. It is configured with a Virtual Graphics Adapter (VGA) and supplied with a full color Virtual Graphics Display (VGD). In addition to running the ZEEMET applications software, the computer can be used to write custom processing software, process custom sensor data using the spare channels of the Mark II MICROSONDE, generate

report documents, formulate spreadsheets, communicate via modem, and operate any of the many commercially available software programs.
Many other configurations exist for the computer, however, and relevant information to the specific computer shall be found in the Manufacturers manuals.

2.16 Software

The extensive system software is designed for high performance, completeness of processing, ease of use, and effective high resolution presentation of graphics. The software is highly modularized and configurable to meet specific requirements. All raw and processed flight data and meteorological messages are written to files for archiving. Saved data can be re-flown for further analysis, or it can be used as input to other software packages. For example, a utility to set up the data for input to a spreadsheet program is provided. Multiple choice menus, storage of custom configurable default choices in files, and on-line help screens make the system easy to operate without reference to manuals. The operator may press the F1 key at any time to obtain help related to the current display screen and its operation.

The system operating software produces a real-time trace of the wind and meteorological data. The meteorological display is a plot of temperature and humidity versus geopotential height. The left-hand ordinate is graduated to show pressure over the range of data displayed. These traces contain highlighted data points automatically selected by the system as mandatory or significant levels, interpolated humidity values are shown in a different color, and missing data which is represented by five hash marks [/////]. All selections and interpolations are done in accordance with WMO criteria. The scale of the plot can be changed to show the entire sounding or portion as small as one km high by 10<198> C wide.

The operator can connect the selected mandatory and significant levels with a join line. In this way, the profile to be reported can be viewed on a T-log P format (as called for by WMO) and allows the operator to instantly determine if the selected levels do indeed represent the sounding. If not, the operator can quickly and easily make additional selections in order to more accurately depict the flight. In addition to join lines, the operator can apply tolerance bars to the data to see if all the data points fall within the WMO allowed tolerance.

Two other data examining aids include the use of Dry Adiabatic Lapse Rate (DALR) line and tropopause (trop) scales. The DALR line can be moved up and down the temperature trace if the slope of the trace is less than the slope of the indicator, then a super dry adiabatic lapse rate exists. The WMO rules for selecting a tropopause do not always select the correct level. Accordingly, the tropopause scales can be moved from trop to trop and the critical lapse rates for each selection shown.

At any time during the sounding, the operating software can produce a summary of selected points, standard isobaric levels, and any tropopauses selected by the system. At the initiation of the operator, the system will automatically produce all standard meteorological messages in compliance with WMO requirements. Any custom coding of regional messages is easily accomplished because of the open, modular nature of the system software.

The system produces a tephigram display that includes grids for pressure, temperature, the dry-adiabatic lapse rate, the saturated adiabatic lapse rate (under 100 hPa only) and the saturation mixing ratio. The saturation mixing ratio isopleths are given in two colors: pink for saturation with respect to water, and blue for saturation with respect to ice. Each of the five grids can be displayed in high intensity, low intensity, or removed from the screen entirely, allowing the operator to highlight the grid(s) he is most interested in at the time.

The system operating software computes wind and meteorological data in real-time. Message composition and transmission, meteorological data display and editing, and system performance evaluation can all be done during a flight.

Both WMO and military messages can be automatically generated and transmitted at the earliest time in a flight. Messages may also be manually generated, viewed and edited.

Display and editing of meteorologic and wind data is fully supported. User specified graphs and reports can be generated and printed. Significant level selections can be graphically displayed and edited.
The performance of the ground system can be evaluated by viewing a journal of events during the flight. Communication with the ZEEMET Rack can be tested. There are also displays for evaluating antenna selection and pointing, receiver operation, and NAVAID reception.

All raw and processed flight data and messages are written to files for archiving. Saved data can be re-flown for further analysis, or it can be used as input to other software packages. For example, a utility to set up the data for input to a spreadsheet program is provided.

The system software is designed for high performance, completeness of processing, ease of use, and effective high resolution presentation of graphics. The software is highly modularized and configurable to meet specific requirements. Multiple choice menus and the ability to customize default choices make the system easy to operate without reference to manuals.

2.17 Global Positioning System (GPS)

GPS Antenna

Purpose

The Global Positioning System (GPS) Antenna is part of the Sippican W-9000 System Ground Station. It is required for differential GPS operation. This antenna is an environmentally sealed, dual frequency unit designed especially for high precision applications. The antenna collects signals received from the GPS transmitting satellites. These signals will be used as references together with the GPS receiver signals from the radiosonde.

Operation

The GPS Antenna minimizes noise and phase error to significantly reduce multipath errors. Its choke slot ground plane provides a highly capacitive surface to reduce re-radiation of surface currents.

The antenna element is a dual-feed microstrip patch based on a ceramic-loaded plastic dielectric. The dielectric is selected for its thermal stability to resonance frequency drift with temperature variations. Phase error, as compared to a conventional patch antenna, is much less. The antenna is O-ring sealed to withstand severe weather conditions. The radome provides excellent ultraviolet and abrasion resistance.

The antenna amplifier is equipped with four high-Q filters that prevent suppression of the GPS signal, even when in close proximity to transmitting systems.

403 Mhz Electronic Switch

Purpose

The W-9000 System Electronic Switch (Switch), Figure 2-12, is a PIN diode device that is designed to control steerable antenna arrays with no moving parts. The Switch selects signals from the antenna arrays and transfers them to a preamplifier for subsequent processing by the Ground Station 403 MHz Receiver.

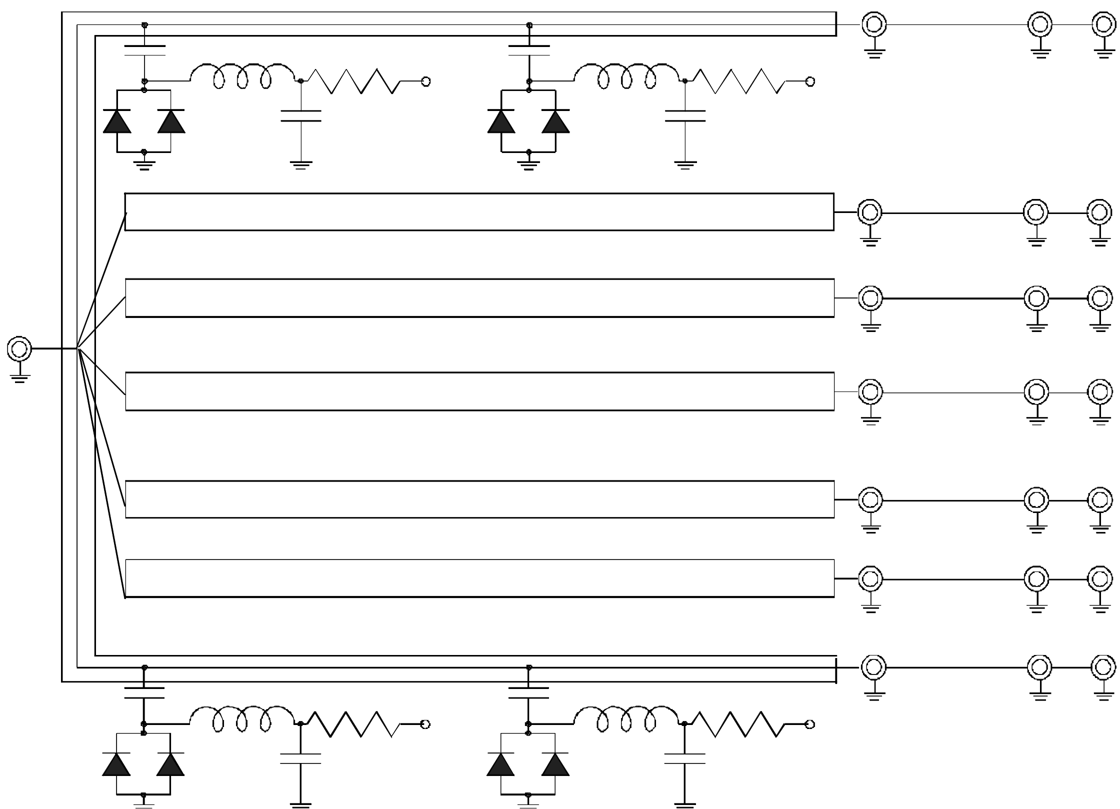


Figure 2-12. Electronic Switch, Simplified Schematic Diagram

Operation

Six of the elements connect to an array of six yagi antennas directed radially outward from a center point at 60-degree intervals, and a single quadrifilar helix that points upward. Each yagi antenna has a 3 dB beam width of 60 degrees in azimuth. The Switch can select one of the antennas, or it can combine two adjacent yagi antennas in phase, resulting in a pattern similar to that of a single antenna, but with the direction of maximum radiation midway between the two. The quadrifilar helix antenna is used for omnidirectional operation.

As shown in Figure 2-12, each of the seven Switch circuits contains a quarter-wavelength microstrip line; each line has a characteristic 70-ohm strip line; each line has a characteristic 70-ohm impedance. The end of each microstrip line is connected to an antenna. The output ends are all connected together at a common point.

Figure 2-13 is a simplified representation of a microstrip line. A PIN diode is connected between the input end of each microstrip line and ground. The diodes corresponding to the antennas that are not being used are biased on to short the end of these lines. The short circuits are seen as open circuits at the output (common) end, where all the microstrip lines connect together.

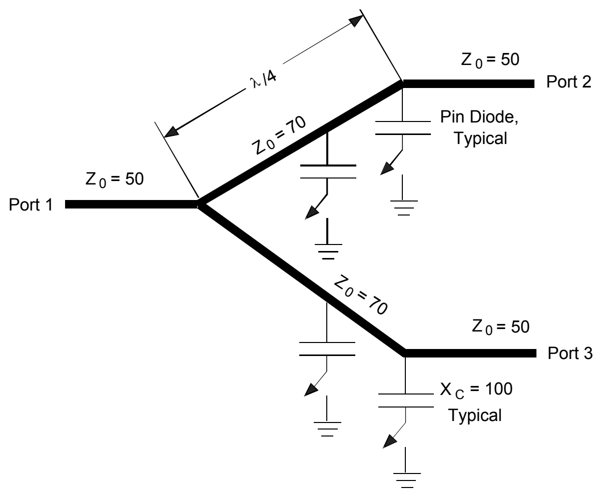


Figure 2-13. Microstrip Line, Simplified Schematic Diagram

If two adjacent yagi antennas are being used, the 7-ohm microstrip lines transform the 50-ohm antenna impedances up to 100 ohms. The two, 100-ohm impedances are then connected in parallel at the common port for a 50-ohm output impedance. The pin diodes located at the center of the 70-ohm lines are turned off (open circuit) and have no effect.

If only one antenna is used, a PIN diode at the center of the line is biased on. The second PIN diode is connected in series with a capacitor to ground. This capacitor has a reactance of 100 ohms at the operating frequency, and the addition of this capacitor causes the impedance reflected to the common port to be transformed back to 50 ohms.

To minimize losses through the Switch, each of the seven circuits includes a blocking capacitor in series with the PIN diodes. The value of the blocking capacitor has been selected to tune out the series inductance of the diodes. The value of the impedance matching capacitors has also been selected to compensate for the series inductance of the associated diodes.. The values of the choke inductors has been selected to resonate with the junction capacitance of the PIN diodes, result in a virtual open circuit when the diode is biased off.

403 Mhz Receiver Preamplifier

Purpose

The Receiver Preamplifier filters and amplifies signals from the Electronic Switch and provides these signals to the 403 MHz Ground Station Receiver.

Operation

Figure 2-14 is a simplified block diagram of the Receiver Preamplifier. It is designed for 403 MHz operation in an outdoor environment and has ultra-low noise features. The preamplifier consists of a filter and a low noise amplifier packed in an environmentally safe enclosure. The filter rejects signals outside of the 403 MHz band. The low noise amplifier (LNA) amplifies the received signal. A Radiosonde operating in the 400 to 406 MHz band at 300 milliwatts and 25 feet from the receiving antenna will not cause signal degradation to the preamplifier. Power for the preamplifier is provided from a cable from a DC feed located in the ground site building.

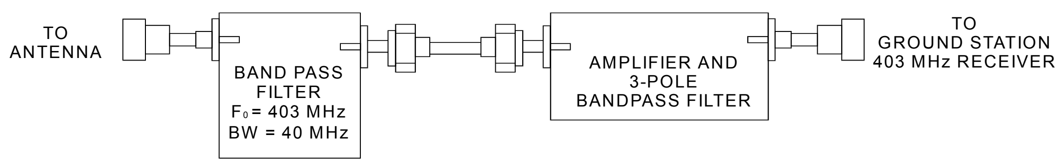


Figure 2-14. Preamplifier, Simplified Block Diagram

GPS Module

Purpose

The Global Positioning System (GPS) module is part of the Sippican W-9000 System Ground Station. As shown in the Figure 2-15, the GPS module interfaces with the 403 MHz Ground Station Receiver and the internal Local GPS Receiver. It also interfaces with the standard Sippican Interface Module and the Processor Module.

Operation

Information from the 403 MHz Ground Station Receiver consists of two channels of recovered GMSK baseband data. The input from the Local GPS Receiver consists of two channels of RSSI data. The baseband data contains GPS Radiosonde meteorological temperature and humidity, and GPS time and pseudo-range information. RSSI data from the Local GPS Receiver is in RS-232 serial format.

The GPS Module processes the baseband and serial RSSI data to recover the GPS and meteorological data. This data is then passed to the Main Processor module.

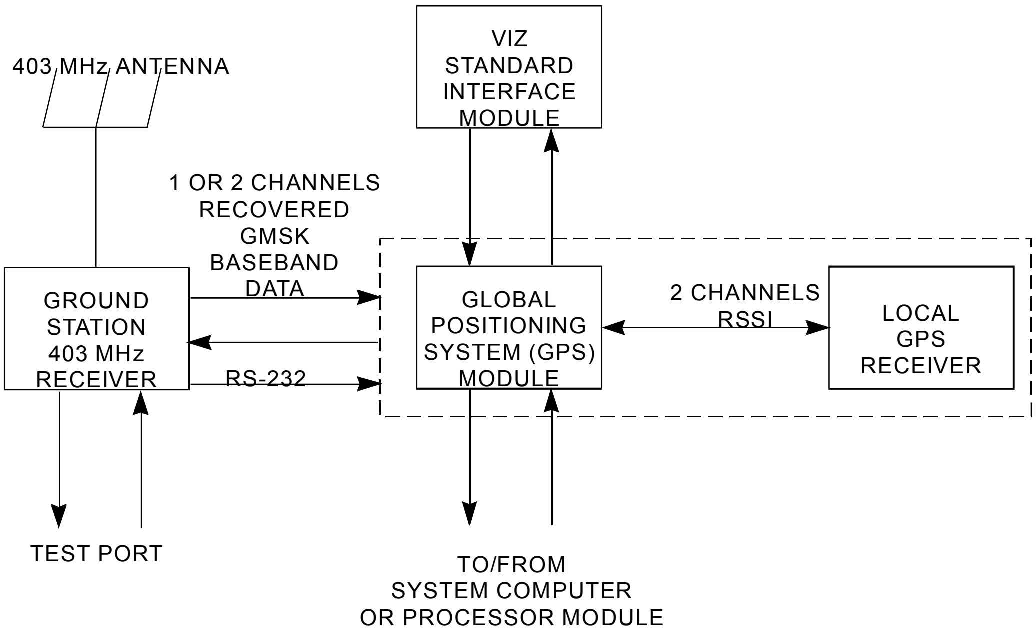


Figure 2-15. Global Positioning System, Functional Block Diagram

Physical Construction

The GPS module consists of a radio frequency (RF) section and a digital section. The RF section receives data from the GPS Antenna system. The digital component of the GPS Module processes the output of the RF section for use by the Main Processor or System Computer in conjunction with data from the 403 Mhz Receiver.

1.

3.0 Specifications

3.1 ZEEMET Rack

Power Input	105-124 Vac, 60 Hz or 210- 250 Vac, 50Hz
Internal Power Supply:	+5 Vdc, 6 Amps
+15 Vdc, 1.3 Amps	
-15 Vdc, 1.3 Amps	
+24 Vdc, 6 Amps	
Line Regulation:	±0.05% for 10% input voltage change
	±.05% for 50% load change
Temperature Range:	0° to 70°C operating
Short Circuit and Overload Protection	
Dimensions:	14.6 cm H x 47.0 cm W x 41.2 cm D

3.2 Telemetry Receiver

Type:	FM, low noise, dual conversion, synthesized receiver
Tuning Band:	395 to 410 MHz
Tuning Steps:	32 KHz
Noise Figure:	Less than 3 db (preamplifier needed)
Input Impedance:	50 ohms nominal
Sensitivity:	-94 dBm, 20 dB quieting
Data Outputs:	Receiver Status
	Demodulated Met data as ASCII character string
Analog Outputs:	Audio for loudspeaker
	Navaid 50 Ohm, 1.5 V peak to peak
	Video 50 Ohm, 1.5 V peak to peak
	Raw data to tape recorder

3.3 1680 MHz Down Converter (Optional)

Gain:	17 dB low, 34 dB high
Impedance:	50 ohms
Frequency:	1660 - 1700 MHz (4 selectable bands)
Noise:	5 dB max, includes cable loss
Bandwidth:	5 pole filter, 40 MHz min at 1 dB
Temperature Range:	-30°C to 50°C

3.4 Loran-C Amplifier Module

Type:	Limiting (tuned RF)
Input Impedance:	50 ohms balances
100 ohms unbalanced	
Input Levels:	5 microvolts - 0.5 V
Equivalent Noise Level:	10 nanovolts/Hz, 50 ohm input
Output:	TTL compatible drive levels, open collector
Phase Stability:	Phase stability vs input level less than □ 1 centicycle over any 60 dB portion of the specified input range.
Bandwidth:	3 pole Butterworth filter. 15 KHz, 3 dB bandwidth minimum, 90 KHz, 40 dB bandwidth 4 notches, field tuneable 70 - 130 KHz

3.5 Omega Amplifier Modules

(Includes both Dual Frequency and Omega Switch)

Type:	Limiting (tuned RF)
Input Impedance:	50 ohms unbalanced
Input Levels:	5 microvolts - 0.5 V
Equivalent Noise Level:	10 nonovolts/Hz, 50 ohm input
Output:	TTL compatible drive levels, open collector
Phase Stability:	Phase stability vs input level less than +/- 1 centicycle over any 60 dB portion of the specified input range.
Bandwidth:	3 pole Butterworth filter. 250 Hz, 3 dB bandwidth minimum

3.6 System Interface Module

Function:	Provides communication interface between ZEEMET Rack P90 Bus and the system computer

3.7 Navaid Tracker Module

Function:	Accepts preprocessed analog signals from system navaid modules and digitally processes them to provide a measure of relative signal time of arrival.
Synchronization:	Automatic

3.8 UHF Antenna and Preamplifier

OmniDirectional Antenna:	Quadrafile Helix
Directional Antenna:	Yagi
Polarization:	
Yagi:	Vertical
Quadrafile Helix:	Circular
Preamplifier	
Gain:	35 dB high
Impedance:	50 ohms
Frequency:	395 - 410 MHz
Noise Figure:	3 dB max.
Temperature Range:	-30^{o} to 70^{o}C

3.9 VLF Antenna and Wide Band Navaid Coupler

Type:	Whip
Frequency:	10 - 100 KHz
Impedance:	50 ohms
Temperature Range:	-30^{o} to 70^{o}C

3.10 GPS Module, Receiver and Processor

General**:**	
Voltage	9 to 15 Volts
Current	100 mA, nominal
Temperature Range	-30^{o}C to 60^{o}C
Clock Frequency	16.000 MHz
Processor	Motorola MC68332
Interfaces**:**	
Local GPS Receiver I/O	4800 Baud, RS-232 levels
Processor Module Data	RS-232 input/output port, programmable baud rate
Interface Module Data	RS-232 input/output port, programmable baud rate
Receiver:	
Baseband 1	4800 Baud, GMSK 0 volt = logic low; 1 volt = logic high
Baseband 2	4800 Baud, GMSK 0 volt = logic low; 1 volt = logic high
J1 Interface Port	RS-232 input/output port, programmable baud rate
Front Panel**:**	
Reset	Normally open pushbutton switch
LED	Two green, two red

(continued)

3.10 GPS Module, Receiver and Processor *(continued)*

Mechanical:	
Size	Compatible with Sippican ZEEMET rack
Weight	
Mounting	Compatible with Sippican ZEEMET rack
Environmental	Refer to the Sippican ZEEMET rack

3.11 System Computer (Optional)

Type:	486 PC
Microprocessor:	80486
Operating Speed:	16 MHz (minimum)
RAM:	4 Mbytes (minimum)
Disk Drives:	1.2 Mbytes 360 Kbytes
Hard Drive:	40 Mbytes (minimum)
Serial Ports:	3 RS232 (minimum)
Parallel Port:	1

3.12 Printer

Print Method:	9 pin, dot matrix impact
Paper:	Perforated form feed or single sheet
Character Set:	Full ASCII character set, 32 special international characters (13 international character sets), 96 alternate italic characters
Buffering:	8 K data buffer

3.13 Video Display

Variable Frequency Display (VFD)
Video Graphics Array (VGA)

3.14 Messages

Type:	Standard WMO TEMP and PILOT messages

3.15 Models

WL-9000	Loran-C
WO-9000	Omega
WT-9000	Radiotheodolite
WR-9000	Radar

3.16 Radiosonde

ZEEMET Mark II	
MICROSONDE	See Data Sheet Ref. No. DS002

3.17 Options

Plotter/Printer (9140)
Punch (9150)
Surface Sensors (9160)
Launch Indicator Module (9130)
Uninterruptible Power Supply (9180)
Field Spares (9190)

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