
DUET
TRANSMITTER
DUET
RECEIVER
VERSION 2.5

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Propagation Analysis of Digitally-Modulated Signals

Digitally-modulated signals at PCS frequencies manifest unique characteristics when signal reflections are encountered. These reflections cause unphased additions of data symbols which can cause bit errors in the received data. Paradoxically, unmodulated signal strength measurements (using narrow bandwidth signals such as CW) are deceptive because the signal appears to be strong, although there may be poor BER (Bit Error Rate) performance. The culprit is often multipath reflections. This is better known as time dispersion of the RF carrier. Time dispersion or delay spreading is induced by multipath reception (two or more signals of the same origin, but some components are delayed by traveling a longer path) caused by reflections and scattering in the propagation environment. These potential distortions must be considered when planning and optimizing high-rate digital radio systems.

Characterizing the delay spread of an RF channel determines whether the radio channel is flat-fading or frequency-selective fading the energy. Flat fading means that all frequency components transmitted through the bandwidth of the channel will experience the same magnitude of fading. Conversely, frequency-selective fading, means some part of the band within the channel bandwidth will have greater fading than other parts (differential fading) of the channel band. If the channel is not flat, then a signal equalizer is required at the receiver to maximize system performance for any given data rate and carrier frequency. Generally, a channel is considered flat when Y/T is less than 0.1 (where Y is the RMS delay spread and T is the symbol period).

Higher frequencies and digital wireless developments have made it necessary for RF engineers to broaden their knowledge of radio propagation. Today's designers are finding it necessary to have a greater depth of knowledge in propagation of digitally modulated RF signals to keep current with these now better understood phenomena. Actual propagation measurements provide data from which time dispersion effects and path loss can be calculated. Time dispersion can be characterized by excess delay (X dB), mean excess delay, and RMS delay spread. The path loss exponent ***n*** and standard deviation σ can characterize path loss with a simple statistical model in a log-normal shadowing environment.

The rationale for advanced tools

Simple fading (also known as small-scale multipath) of received signals are rapid fluctuations of the amplitude over brief instances of time or distance. These variations in amplitude are often so significant that the natural deterioration of signal strength caused by the relative path loss from the transmitter to the receiver becomes inconsequential by comparison. Often engineers believe that the communications link has good integrity with relatively strong signal strength readings. Good BER performance is far more critical.

In almost all cases, short-term fading is caused by the environment, where two or more copies of the originally authored signal arrive at the receiver, but at different times. These radio waves are then known as multipath waves, and when they combine at the antenna, they vary widely in both phase and amplitude. There are generally three properties that affect the character of the RF waves that arrive at the antenna. They are distance, propagation time and bandwidth of the transmitted signal. The signal strength has been the most traditional measurement for quality of the link. In an ideal environment, it has a predictable relationship to distance, and has been used to determine overall coverage in analog communication system designs.

The adverse effects of multipath reception are:

(i) rapid changes in the received RF amplitude

(ii) some frequency modulation of the signal caused by the Doppler shifts on more than one path

(iii) echoes (time dispersion) cause the carriers to add and subtract vectorially from each other causing data symbols to cancel each other.

There are three methods of quantifying small-scale multipath. They are ***direct pulse measurements, swept frequency measurement, and spread spectrum sliding correlator measurements.***

Direct pulse measurement is the simplest way to characterize an RF channel. In practice, a rapid pulse is transmitted close to the frequency of interest, then received and demodulated, usually with an envelope detector. The minimum resolvable distance in time between paths is governed by the width of this stimulus pulse. The relative bandwidth consumed however, is quite wide and consequently noise immunity is poor due to the wide filters which must be used in the receiver. Also, an exact capture of this asynchronously transmitted pulse is difficult because blocking (interference) or severe fading may occur. The leading edge of the received energy might be below the noise, making it difficult to trigger an oscilloscope precisely at the start of the impulse waveform.

The swept-frequency channel sounding technique sweeps the channel with an RF signal in discrete steps and through post-processing converts this information from the frequency domain to the time domain using a inverse discrete Fourier transform. This form of channel sounding requires rather exact calibration and unfortunately the results are not available in real-time. The rate of sweeping can also effect the quality of measurements. In order to reduce the adverse affects of rapid fades on this measurement system, fast sweeps are used, however the granularity of the time dispersion is correspondingly reduced. Although simple to implement, the swept-frequency form of measurement for multipath analysis has only been effective in indoor environments.

The most universal but sophisticated form of multipath analysis is the sliding correlator spread spectrum channel sounder. For spread spectrum wireless engineers, this approach has been an additional benefit because it mimics the type of transmission and reception hardware that is used in Code Division Multiple Access (CDMA) telephone systems. In practice, the RF transmitted stimulus signal and the analysis receiver are tuned to within the band to be measured and the results are calculated and displayed in real-time. Since the receiver uses relatively narrow bandwidth filters and has processing gain, the system's sensitivity is superior.

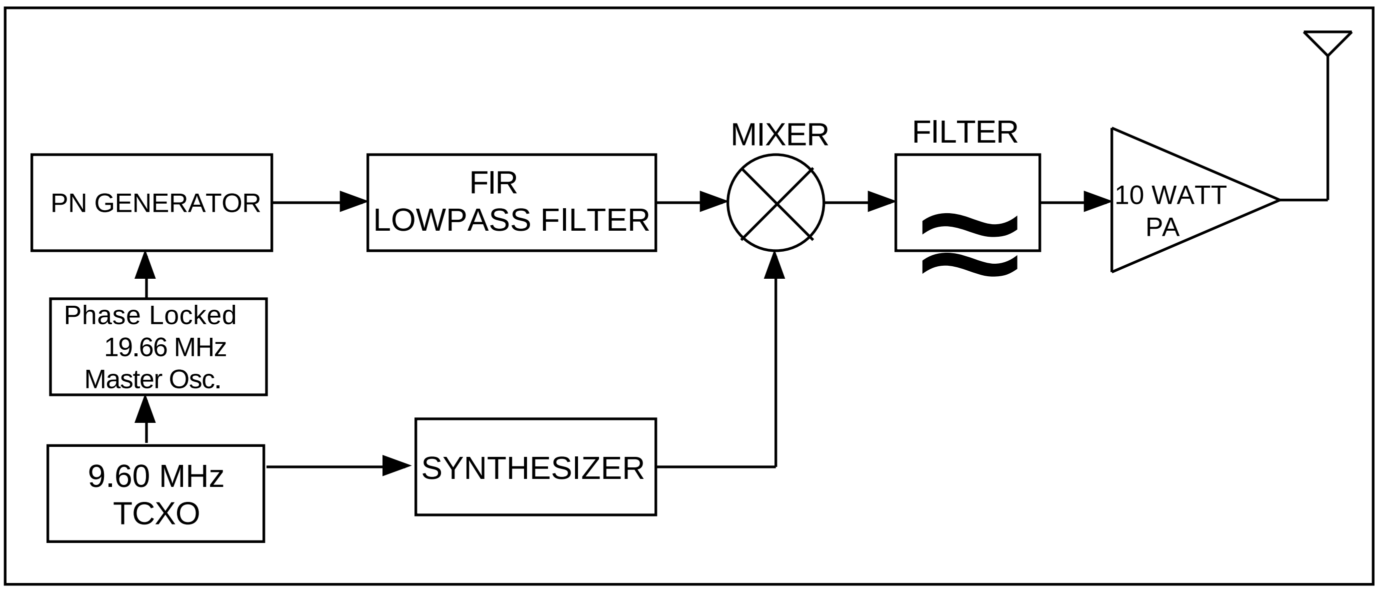
An improved version of the "sliding correlator sounder" is a **sequential correlating channel sounder.** The codes between the transmitter and receiver do not "slide" by each other (have different frequencies). Instead, they step from one phase alignment to another. This technique has considerably less noise, since the codes are not becoming misaligned during correlations. This synchronous technique is used in the Duet, and avoids a "smearing" of correlated data over long symbol analysis.

The ***Duet*** channel sounder provides insight into propagation analysis in the presence of fades, noise and multipaths for the PCS band. ***Duet*** allows the user to transmit a digitally-spread signal and examine the spectrum, received multipaths, signal strength, and bit error rate at the receiver similar to the way the system will operate when deployed. The ***Duet*** system is comprised of a 10 watt stimulus transmitter and companion correlating receiver, equipped with an 8-channel, differential GPS receiver for geographical position and time coordinates. The system has remote access and control, to allow forward or reverse link propagation studies. The receiver includes data logging capabilities to track a selectable number of paths and provide information on the magnitude and delay of each path, BER for any path, RSSI, position and time. This tool is specifically designed to meet the requirements for practical propagation analysis for TDMA or CDMA formats in the PCS band.

Transmitter

The ***Duet*** transmitter produces a user selectable direct digital spread signal in the PCS frequency band (primarily for use with the ***Duet*** receiver). A functional block diagram of the transmitter system is shown in figure 1.

These code generators are 15 bit (can produce codes with lengths up to 2^{15}) and can be programmed to produce any 15 state (or less) linear codes. However, Pseudo-noise (PN) codes, which are a subset of all linear codes, are most desirable for spread spectrum and CDMA applications. The ***Duet*** transmitter and receiver allow the user to select among a number of predefined PN codes of different lengths. Included in this selection are PN codes and chip rates that have the same bandwidth and spectral properties as Qualcomm's published I or Q pilot signals. Future versions of the software will permit ***Duet*** to be used for Walsh encoding, data encoding, and the generation of unique Gold Codes. The output of the code generator is over sampled to bring the sampling rate up to approximately 20 MHz (this is a minimum of 4 times over sampling). This data stream is then low pass filtered with a sixty four stage FIR filter to eliminate out-of-band components. The FIR filter is programmable and the user may also select a filter that produces a multipath, in order to test the Duet receiver. The output of the filter drives a D/A converter and



is sent to the I/Q modulator.

The I/Q modulator is used to produce a BPSK modulated signal. This signal resembles the I and Q pilot signal for Qualcomm's CDMA and well as other (such as W-CDMA IS-665) formats. The signal is then up converted to the PCS frequency band and amplified to a maximum of 10 Watts RF output. This output to the antenna is monitored with an internal forward and reverse VSWR detector. This not only determines the amplifier-to-antenna SWR match, but also regulates the transmitted power to maintain it at a constant level, irrespective of load or match from 1:1 to 1:6 SWR.

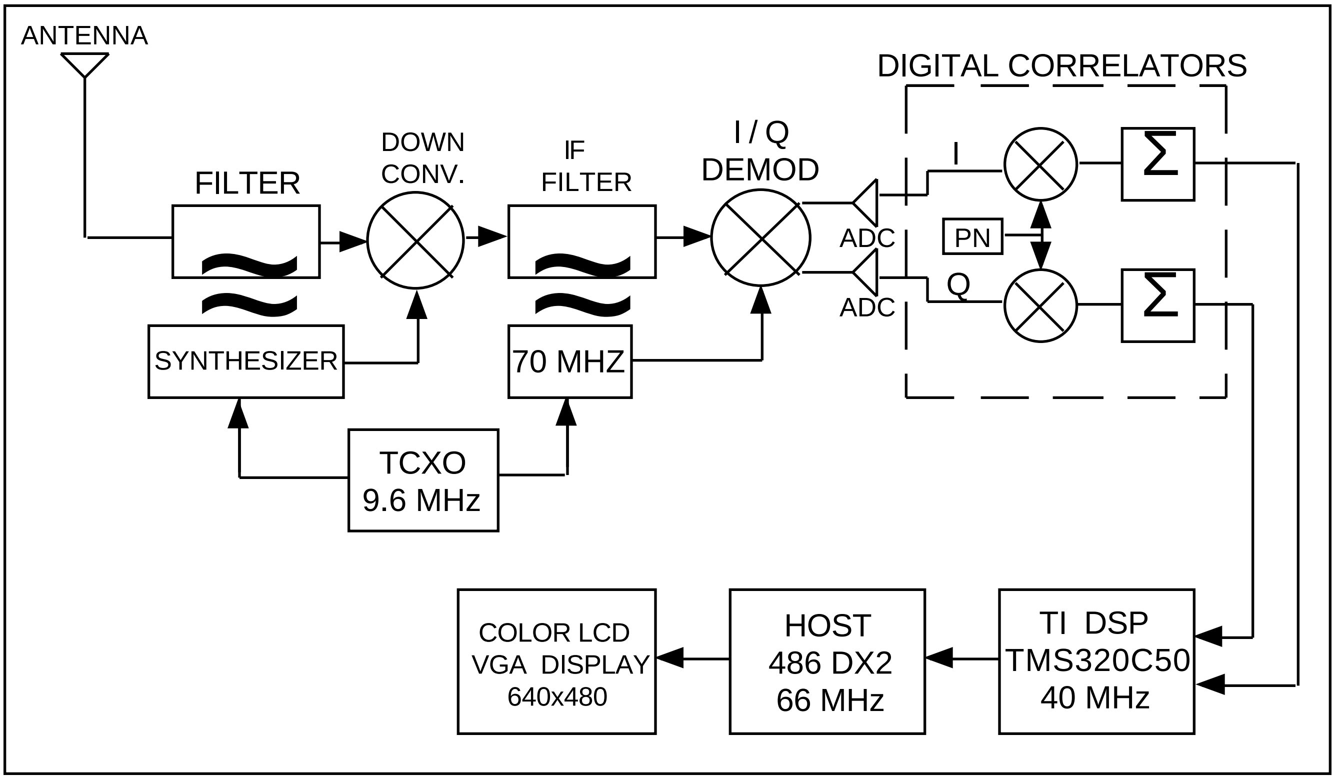
The heart of the ***Duet*** transmitter's control logic is an Intel 80C31 microcontroller. In addition to controlling the data stream, the microcontroller interacts with the display, a phone interface with internal modem, and an optional differential GPS receiver. The DTMF decoder and modem can be used for remote operation.

Receiver

The ***Duet*** receiver is a wide bandwidth spread spectrum receiver with ability to identify and track CDMA signals and their multipaths, report signal strength (in a spectrum analyzer like display), and perform bit error analysis for arbitrary signal paths. The functional block diagram for the receiver system is shown in figure 2.

The received spread signal is down converted to an intermediate frequency (70 MHz) (IF). The IF amplifier and receiver signal strength indicator (RSSI) is used as a signal strength detector with a narrow bandwidth to plot the signal strength across frequency, and as an AGC during multipath analysis.

The output of the IF amplifier goes to an I/Q demodulator. The I/Q demodulator is used to receive a signal regardless of incoming RF phase (this is essential in CDMA reception and multipath analysis). The output of the I/Q demodulator is sampled with a pair of A/D converters at a sampling rate of



approximately 20 MHz.

The pair of digitally sampled data streams is then fed to four independent correlators. The correlators are used to search for the signal and its multipaths. The correlators work together with the programmable code generators. These code generators differ from the code generators in the transmitter only in that they can be made to instantaneously jump to a different code phase without stopping - a property that is required for searching. Each of the power correlators can be controlled independently and can take their source from either code generator. This allows one or more of the power correlators to be used as a demodulator for bit error analysis, while freeing the remaining correlators to be used as high-speed delay lock loops (DLL) to keep the demodulator locked to a path. The DSP tracks the slowly drifting phase errors due to differences in clocks between the transmitter and receiver as well as compensates for any Doppler drifts that may occur due to motion of either end of the link.

The detection hardware is directly controlled by a digital signal processor (DSP TI-TMS320C50 running at 40MHz), which performs high speed computations and control of the digital logic. Collected and processed data is then transferred to a 486-DX (66 MHz), which controls the supervisory functions, display, logging, and communications. The display is a color VGA LCD. Data can also be logged to a non-volatile PCMCIA memory card, for post-processing. The magnitude, time dispersion (or delays, both positive and negative) of all the received paths and bit error rate (BER) for any path is calculated, stored and displayed.

The bit error (BER) is calculated based on how a CDMA receiver actually demodulates a symbol from a code channel. In a non coherent communication system, a correlation is performed on the pilot to estimate the RF phase of the signal so that the upright and inverted symbol phases can be determined. Symbols correlated from the code channel are then decoded with the estimated RF phase to determine if they are correct or inverted. In the Duet's BER calculation, the pilot itself is considered to be a channel with constant data. A moving average of several symbols is used to estimate the RF phase of the present path. The phase of each individual symbol is compared to that of the estimate. If the symbol phase is within ±90 degrees of the estimate, the symbol is considered correct. This measurement is functionally equivalent to a pre-corrected BER.

The Duet really has three measurement modes for multipath information; the normal measurement, the fast fade mode and the OPTIONAL download waveform.

In the **normal measurement** mode, the Duet records power of the largest thirteen (13) peaks, the time of arrival difference of each of the peaks, the total RF power in the IF pass band, the GPS time and position, and if enabled, the BER, the time offset the BER measurement is at, and the power of the component of the signal arriving at the BER measurement position. This information is updated at a rate of approximately 5 times a second.

In the **fast fade** mode, the power of the thirteen (13) strongest peaks are recorded along with the PN code position in 1/2 chips, and the GPS time and position. With this mode, the measurement rate is 100 times per second. A 2 Meg PCMCIA card can save 12 minutes of data in this mode, serial port storage is limited only by the size of the PC disk (in order to save data using the serial port, DATA LOGGING must be ON and baud rate set to 38.4k).

Fading data is measured using the 127 PN (Transmitter must also be set to 127 PN) and times 2 over sampling (multipath measurement uses times 4 oversample). Data saved is the raw peak values in ascending order and time offsets of each peak.

In the OPTIONAL waveform download mode, data for all the possible PN positions (lengths of 255 only) are in one-quarter chip increments, and saved to the on-board PCMCIA card or sent to a PC via the serial port at rates from 9.6 to 38.4kb/second. If the DUET used for waveform capture is equipped with an SRAM CARD, waveform data is measured and sent via the serial port after the &TRG sequence is received. There is no additional acknowledge sent (&ACK is not sent in the serial capture mode).

Duet Transmitter Specifications

frequency range in 50kHz steps	continuous tuning from 1850 to 1910 MHz or 1930 to 1990 MHz	
chip rates (selectable)	1.22880 MHz	
	2.45760 MHz	
	4.91520 MHz	
	9.83040 MHz	
PN code lengths and taps (selectable)	127	(7, 6)
	255	(8, 6, 5, 4)
	255	(8, 5, 3, 1)
	511	(9, 8, 5, 4)
	1023	(10, 5, 2, 1)
	2047	(11, 9)
	4095	(12, 6, 4, 1)
	8191	(13, 4, 3, 1)
	16383	(14, 13, 12, 2)
	32767	(Qualcomm I)
	32767	(Qualcomm Q)
baseband output filter	64 stage programmable FIR filter	

modulation:	BPSK
RF output power	250 mW to 10W adjustable in 1 dB steps using rotary knob or direct keypad entry via keypad
frequency stability	±500 Hz
amplifier type	Class A linear operation
harmonic output	-60 dBc, maximum
spurious frequency output	-60 dBc, maximum
VSWR monitoring	amplifier shutdown protection @ VSWR > 6:1
RF output connector	type N female, 50 ohms
power requirement	
AC	90 to 260 VAC auto switching, frequency from 47 to 63 Hz
DC	13.4 to 16 volts DC, 8 amperes (internally regulated)
display	240 by 64 pixel Super Twist Numeric Graphic LCD with vacuum fluorescent back lighting
modem	built in Bell 212A (full duplex) 1200 baud via RJ-11 jack on rear panel
remote control	
Data	front panel functions via modem
Audio	DTMF control of RF power level in 1 dB steps and simple "on-off" functions only
auxiliary port	general purpose (DB-15-F) port for controlling any generic user hardware (such as antenna direction)
size	18" (wide) by 15" (deep) by 7" (high)
temperature	
storage:	-30 to + 70 C
operating:	-10 to + 50 C
transmitter weight	25 pounds
options	built-in 8 channel, differential GPS receiver (standard equipment on Genlock models)

* Note: Some caution should be made to prevent transmitter from automatically shutting off due to excessive heat. Be sure to make certain that the intake and output cooling fans are clear of obstructions, and the unit has unrestricted airflow.

Duet Receiver Specifications

frequency range	continuous tuning from 1850 to 1910 or 1930 to 1990 MHz in 50 kHz steps

chip rates (selectable)	1.22880 MHz 2.45760 MHz 4.91520 MHz 9.83040 MHz (optional high-speed model)
PN code lengths and taps (selectable)	127 (7, 6) 255 (8, 6, 5, 4) 255 (8, 5, 3, 1) 511 (9, 8, 5, 4) 1023 (10, 5, 2, 1) 2047 (11, 9) 4095 (12, 6, 4, 1) 8191 (13, 4, 3, 1) 16383 (14, 13, 12, 2) 32767 (Qualcomm I) 32767 (Qualcomm Q)
sensitivity	-100 dBm (< 1% BER with 64 chips per bit)
dynamic range	-30 to -100 dBm (CDMA modulation)
AGC range	±1.5 dB, 40 dB dynamic range (CDMA modulation)
error frequency	worst case difference between transmitter and receiver ± 1 kHz + 80 mph vehicle speed
RSSI accuracy	±1 dB, over 80 dB dynamic range
oscillator stability	± 1.5 ppm for both digital clocks and RF frequencies
multipath delay resolution	(near) distance 200 ns (60 meters at 4.9152 Mchips/s) 100 ns (30 meters at 9.8304) for optional 10 Megachip model (far) distance 100 µsec (> 30,000 meters at 4.9152 Mc/sec)
power requirement	12 to 16 volts DC, 5 amperes
size	18" (wide) by 15" (deep) by 7" (high)
receiver weight	25 pounds
temperature	storage: -30 to + 70 degrees C operating: -10 to +60 degrees C

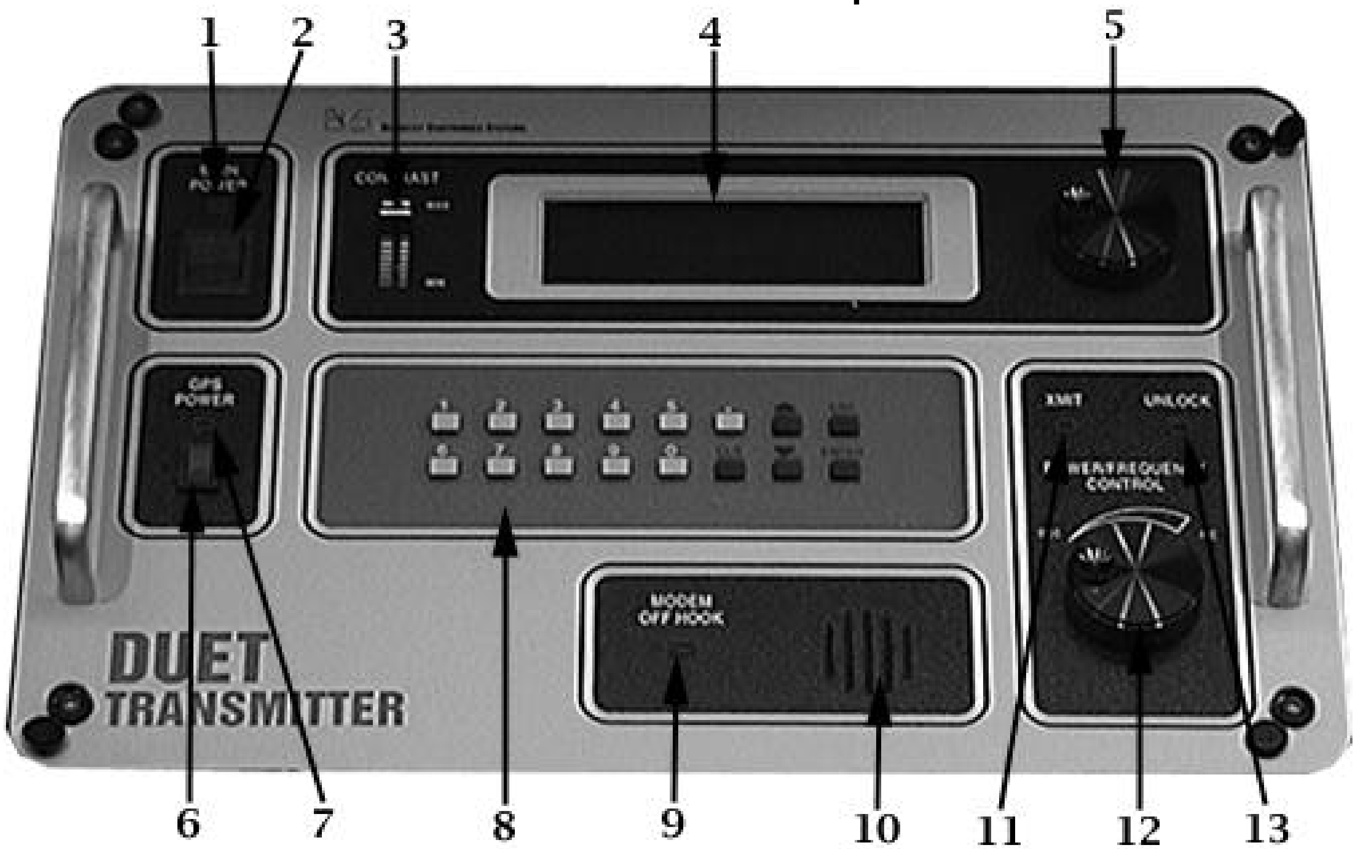


Figure 1
Duet Transmitter Front Panel

1 main power on light (green)

2 main power on-off switch (for both AC or DC operation)

3 display contrast control lever

4 LCD with vacuum fluorescent back lighting

5 control dial for positioning cursor on display

6 GPS power "on-off" switch for internal (optional) GPS receiver GENLOCK option, this switch is bypassed with models equipped with GPS and always should be on.

7 GPS power "on" light (green) indicates internal GPS receiver power is on

8 transmitter keypad for entering transmitter control settings

9 modem "off-hook" light (yellow) indicates connection of modem to line

10 speaker for audio monitoring telephone line

11 transmit light (green) indicates transmitter RF output

12 RF power output level and frequency adjust rotary control dial

13 unlock light (red) indicates synthesizer PLL is not locked

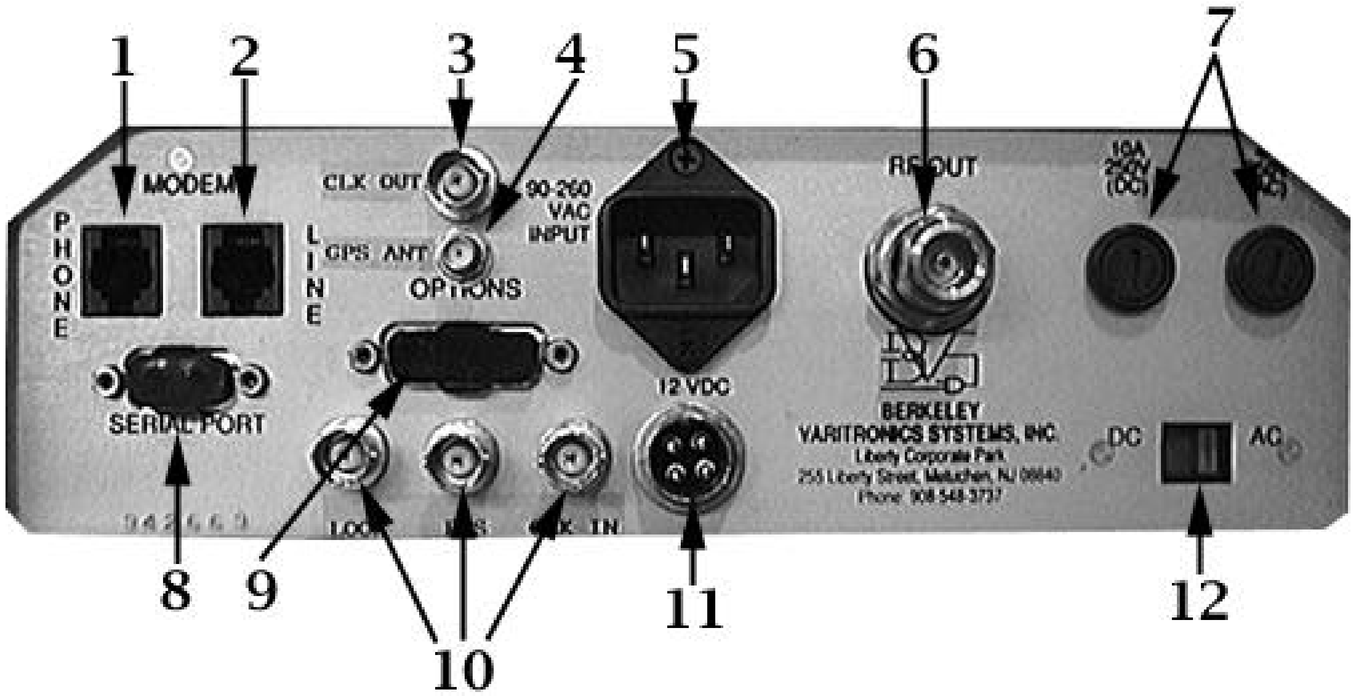


Figure 2
Duet Transmitter Installation

1	Phone Hand Set (RJ-11) In
2	Phone Jack (RJ-11) In
3	External Clock Out (BNC Male) (optional)
4	GPS Antenna In
5	110 VAC In (use supplied cable)
6	RF Out
7	AC and DC Fuses
8	Serial Port DB-9 Male To/From PC (use supplied cable)
9	Optional DB-15 PN Slave/Master Lock To/From 2nd Transmitter (optional)
10	External Clock Source In (BNC Male) (optional)
11	12VDC In (use 13.6VDC-16VDC for remote power)
12	DC/AC Power Source Switch

Power Input

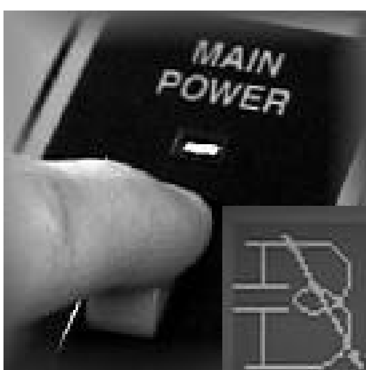
The transmitter will operate from either an AC or DC power source. Both AC and DC power connectors are located on the rear panel. Use the cables provided with the transmitter. A slide switch for selecting AC or DC operation must be set, and is located on the rear panel. AC operation is from 90 to 260 VAC and is auto switching inside the Duet, from 47 to 63 Hz. DC power for the transmitter is 13.6 to 16.0 volts DC, at 8 amperes. The power source should be as noise free as possible. When the transmitter is to be used in a vehicular installation, and it is connected after the ignition switch, turning the engine on and off will interrupt transmitter operation.

PCS transmitting antenna

Following the manufacturer's instructions, keep the transmission line as short and straight as possible. Connect antenna lead to the transmitter rear panel female type N connector labeled "RF Out." The nominal output impedance is 50 ohms. We recommend mobile mark model IMAG-5 for 1800-1900 MHz operation or model IMAG5 for 1900 MHz-2 GHz operation.

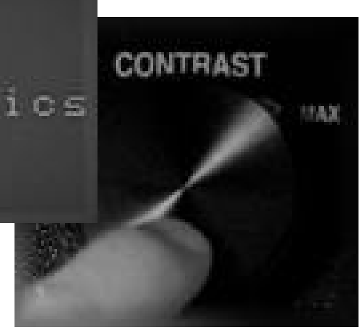
Duet Transmitter Operation

Before operating the Duet Transmitter, check power source voltage, minimum antenna VSWR, and the proper installation of accessories. See the transmitter front panel diagram and become familiar with the switches, panel lights, controls, keypad and LCD display.



Startup Screen

Pressing the rocker switch will turn the Transmitter on. A power up screen is displayed for a few seconds, followed by the main screen. Adjust the contrast control for maximum display legibility. Optimum RF carrier stability is achieved within 10 minutes of operation.

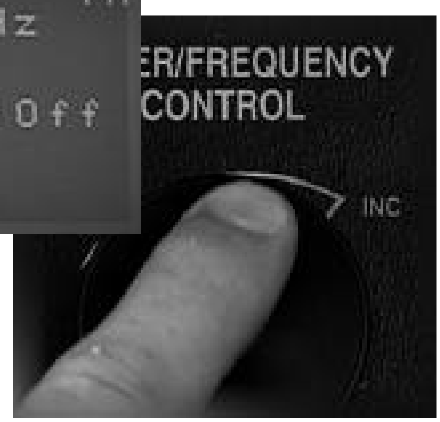


Setup Menu

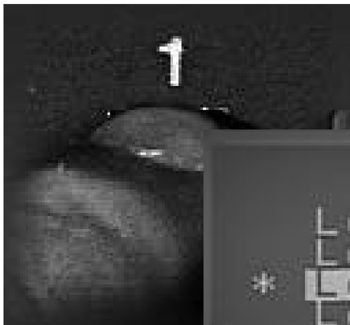
Press ESC when in the Main Screen and you will access the Setup Menu. Use the numbers on the keypad to choose between the 9 items or press **ESC** to return back to the Main Screen.

Setting the Transmitter Frequency

Press ESC at any time in the Setup Menu to exit and enter the Main Menu. Rotate the SELECTION control or use the ↑ and ↓ keys to move the display highlight to Carrier Frequency. Rotating the POWER / FREQUENCY control dial increases or decreases the frequency in 1 MHz steps. The transmitter carrier frequency is displayed as it is changed. The carrier frequency can also be changed by using the number keys. The frequency must be between 1930.00 and 1990.00 MHz. Press the **ENT** key to change to the new frequency. If an invalid frequency is entered, the frequency will return to the last valid entry made. The main screen shows the current carrier frequency in MHz, RF power out in dBm PN length, chip rate (bandwidth) in MHz, transmitter RF power ON - OFF status test mode status and GPS latitude and longitude (optional) in degrees and decimal minutes.



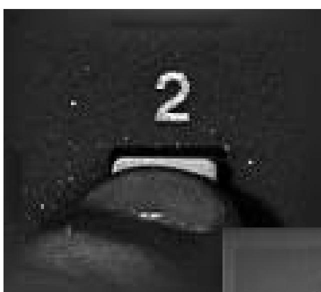
Note: When the transmitter is "ON", all controls are locked out except the transmitter "OFF" control.



Setting the Transmitter PN Length

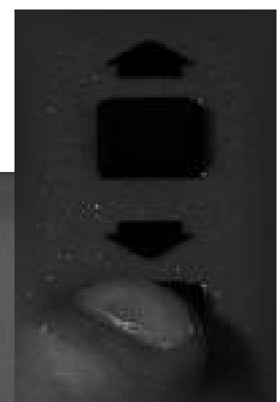
Press the **ESC** key to change to the SETUP MENU screen. Then press the **1** key to change to the SELECT PN LENGTH screen. An asterisk to the left of a

PN code shows the current setting. Pressing the ↑ and ↓ keys will move the highlight through the selections. Pressing th ↑ and ↓ key will change the current setting to the highlighted selection. Press the **ESC** key to return to the SETUP MENU.



Setting the Transmitter Chip Rate

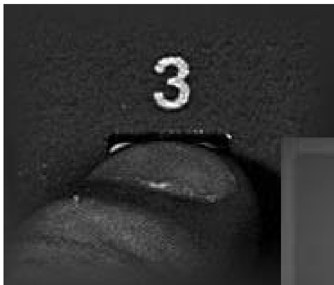
Press the **2** key to change to the SELECT CHIP RATE screen. An asterisk indicates the current chip rate. Pressing the ↑ and ↓ down arrow keys will move the highlight thı ↑ and ↓ e selections. Press the **ENT** key to change the current setting to the highlighted selection.

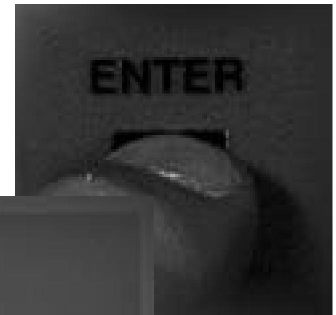


Pressing the **ESC** key will return you to the SETUP MENU. There are several additional options under the receive "chipping rates". These extend the usefulness of the instrument, and are in addition to those listed in the manual. 1,2,4,8,etc.

10 MHz Chip Rate Option

This options increases the Duet's maximum chip rate to 9.8304 MHZ, and allows the Duet to differentiate close-in multipaths. Specifically, the Duet's resolution on the time axis is increased by a factor of two. This option is very useful to characterize environment where shorter multipath components are significant or systems with fast baud rates that may be corrupted by shorter multipath.



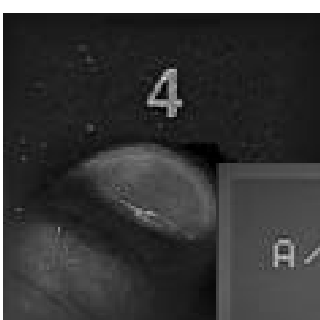


Initializing the GPS Receiver (optional)

When an optional GPS receiver is first installed, initialization of the receiver is necessary because the old latitude and longitude were stored. This process can take as long as 30 minutes when the unit has been transported a large distance. Turn the GPS receiver front panel power switch on (transmitter front panel diagram.) The green GPS power light should light. While in the SETUP MENU, press the **3** key to change to the GPS INIT screen. [The initial process of the GPS receiver locking to signals received from satellites and computing and displaying GPS data and can take several minutes.] If the GPS receiver has already been initialized, the GPS receiver will display latitude and longitude. If the GPS has not been initialized, press **ENT** to initialize. Press the **ESC** key to return to the SETUP MENU. The next time the GPS receiver is used, acquisition will be completed in less than 1 minute.

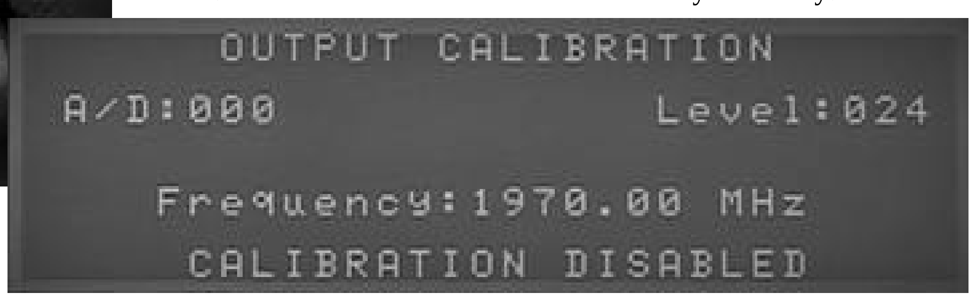
To operate the optional GPS receiver, the front panel GPS power switch must be on. Latitude and longitude are displayed on the lower right corner of the main screen.

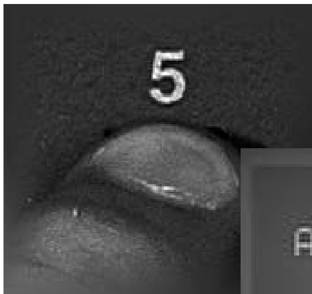
Note: The initial process of the GPS receiver locking to signals received from satellites and computing and displaying GPS data and can take several minutes.



Output Calibration Screen

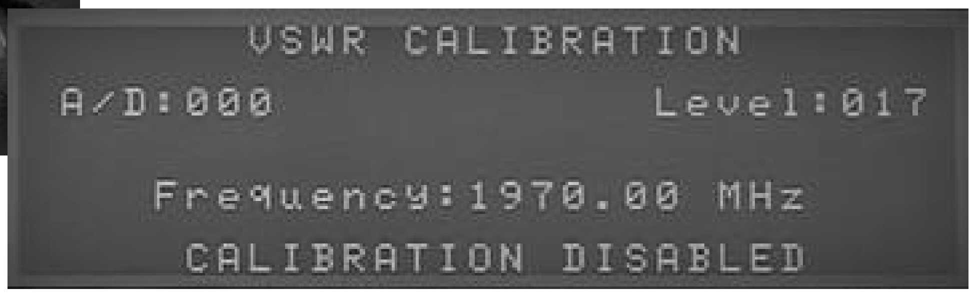
Pressing the **4** key in the Setup Menu will bring up the OUTPUT CALIBRATION screen. This screen is intended for factory use only. Press the **ESC** key to return to the SETUP MENU.



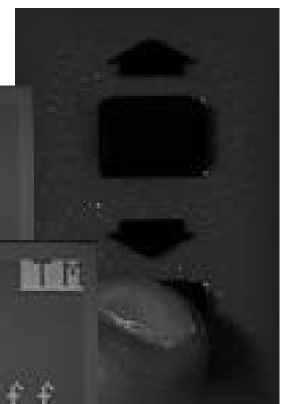


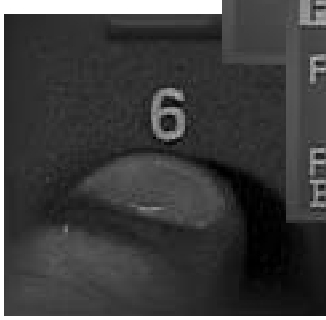
VSWR CalibrationScreen

Pressing the **5** key while in the Setup Menu will bring up the VSWR CALIBRATION screen. This screen is intended for factory use only. Press the **ESC** key to return to the SETUP MENU.



Transmitter Test Signal Operation





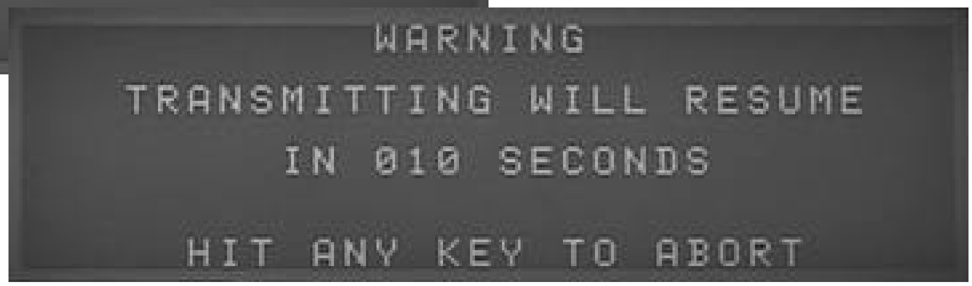
Press the **6** key while in the Setup Menu and the TEST MODE screen will appear on the display. The current on or off setting will be highlighted. Use the ↑ and ↓ keys to move the highlight from **off** to **on**. Pressing the **ENT** key changes the test mode from the current setting to the highlighted setting. Press the **ESC** key to return to the SETUP screen. The "TM" in the upper right corner indicates test mode. When the "TM" blinks, the transmitter is in the test mode.

The TEST MODE is used to check receiver operation. In this mode, the transmitter sends a simulated multipath signal to be used in conjunction with the Duet receiver. When the transmitter is in the TEST MODE, the main screen will display 'TM' in the upper right corner of the screen.

Note: The test mode included on the transmitter provides a convenient way to check the system on the bench before doing any drive studies. It is recommended to install at least -60 dB of power attenuators between the transmitter and the receiver to insure that the level at the input of the receiver is safe (-35 dBm maximum rating). Since the transmitter is capable of outputting up to 18 watts (CW power), be sure to use attenuators rated at at least 20 watts continuous for this test. The TEST MODE changes the FIR baseband filter to produce three (3) peaks in the Duet transmitter. Two (2) of these signals are the same PN signal, but advanced (5 chips positive time dispersion) and delayed (by 5 chips) respective of the primary signal. Their amplitude should be exactly -6 dB of the reference signal.

Power Up (Default)

By pressing **7** in the Setup Menu, the Power Restore menu will be displayed. This feature, when



enabled, will allow the Duet transmitter to resume transmission 10 seconds after power returns. This is particularly useful when the system is powered from gas powered generators that may run out of fuel or unstable power sources. A loud "beep" will provide warning that the transmit output will resume in 10 seconds. This warning is also annunciated on the LCD screen.

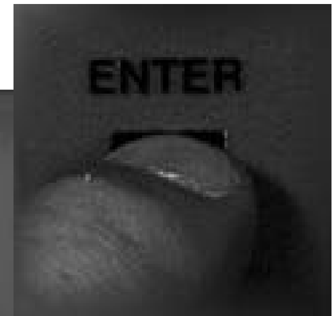
GPS GENLOCK

Press **8** in the Setup Menu to enter the GENLOCK menu. Use the SELECTION dial to toggle the GENLOCK On/Off and press ENTER to select the highlighted item.

This function will allow a synchronized Duet Receiver to monitor signals

from multiple base stations (or multiple Duet Transmitters). This feature is especially useful for handoff analysis. The GPS Lock system can be bypassed (menu function) leaving the reference oscillator free running, as in the base Duet model, or bypassed and substituted by an external 9.6 MHz clock. The GPS reference provides long term coherency of the RF as well as synchronization of the PNs in Duet's Transmitter and Receiver. The short term stability of PN phase is determined by the GPS PPS and does not exceed a half of the chip period at 1.2288 Mchips per second, the PPS jitter after the GPS is locked is specified as <150 ns. The synchronization of Tx and Rx PNs allows users to determine the real time of arrival of the direct and the reflected signals. Another important advantage of the synchronization is the ability to incorporate Duet Tx as a part of a deployed PCS without interference by a proper offset of the pilot PN.

PN Synchronization of Two DUET Transmitters



Pressing **9** calls up the Sync Mode screen. Two DUET Transmitters can be operated in a special mode, where the PN of one transmitter is synchronized with the other. This is done via the DB-15 Options connector located on the transmitter rear panel, between the GPS input and the GPS diff. input connectors. Both transmitter cases should be at ground potential. A special DB-15 cable connecting the two transmitters together is required for operation. See the appendix for a detailed drawing of this cable.

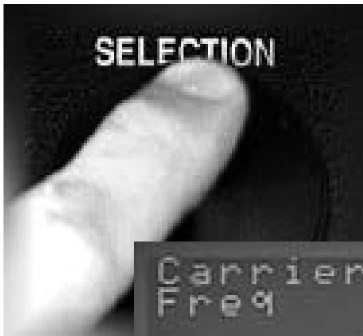
When two DUET transmitters are operated in this mode, one is designated as master and the other is designated as slave. Turning the master transmitter RF power output on will turn the slave transmitter's power on. The PN generator of each transmitter will begin at the same time. To activate this, press **9** in the Setup menu. The SYNC MODE screen w ill then appear. An asterisk indicates the current setting. To change the setting, use the ↑ and ↓ arrow keys to move the highlight to a new selection. Press the **ENT** key to change the highlighted selection to the new selection. Press the **ESC** to return to the main menu. In this mode, be certain to set one transmitter to slave mode and the other to master mode.

Press **ESC** and return to the main screen. Turning the master transmitter on and off will also turn the slave transmitter on and off.

For normal operation, and when a transmitter is to be operated independently, the transmitter must be set to the MASTER mode.

Setting the Transmitter RF Output Power Level

Select RF Output Power from the main menu. Rotate the SELECTION control to move the display highlight to Power Out . Then rotate the POWER/FREQUENCY control dial to adjust the RF power output level, shown on the display. The RF power out can be adjusted over the range in 1 dB from 24 dBm to 40 dBm.



Turning the Transmitter RF Output Power On and Off

Rotate the SELECTION control to move the highlight to the ON or OFF label. Pressing the **ENT** key will toggle the transmitter RF output on or off. When the transmitter is "ON", only the transmitter "OFF" selection is allowed. The green

front panel XMIT light will light when the transmitter output power is on. The red front panel UNLOCK light should not light. If it does light, it is because the transmitter's synthesizer is unlocked and the transmitter's power amplifier will not be activated, to prevent spurious transmission. The unit needs to be serviced. The transmitter will not turn on if GENLOCK is enabled and the transmitter GENLOCK circuit is not locked. The status of GENLOCK is displayed on the main screen when GENLOCK is "ON".

Note: When reacquiring synchronization with a transmitted PN, be sure to match the sequence of the transmitter with the receiver.

Remote DTMF Control of the DUET Transmitter

The DUET Transmitter may be controlled by a remote touch tone telephone. The transmitter must be connected to a telephone line at the rear panel as shown in figure 2, the transmitter installation diagram. The transmitter's main power switch must be on. Carrier frequency, PN length, and chip clock rate must also be set.

To change the DUET transmitter's RF power output level and RF output **on-off** status using a remote telephone:

1.) Dial the number that the transmitter is connected to.

2.) Wait for the transmitter to answer. The transmitter answers with two beeps.

3.) Within five seconds, press the # key to access the transmitter's DTMF answer mode.

If the # key is not pressed within five seconds, the transmitter's modem will be activated, and an answer tone will begin DTMF operation will then be disabled. If this occurs, hang up and repeat steps 1, 2 and 3 before proceeding with step 4.

4.) After successfully accessing the transmitter's DTMF answer mode,
use the following telephone keys to control the transmitter functions shown:

Key: **Function:**

1	turns transmitter RF output on
0	turns transmitter RF output off
3	increases transmitter's RF output power level by +1 dB
9	decreases transmitter's RF output power level by - 1 dB

The transmitter will respond with **three beeps** after successfully receiving and executing a command. The transmitter will not respond to an invalid command such as pressing the **2** key on the telephone keypad.

Note: All the controls are "locked" during **transmit on**, to prevent erroneous frequency, output power or modulation from being transmitted. To change any parameter, first **turn off** the transmitter, then make any adjustments required.

Remote Control via a Modem

The DUET transmitter has a built in standard Bell 212A Modem. The baud rate is 1200. The format uses 1 start bit, 1 stop bit and no parity bit.

Use the following command set to get the attention of the internal modem. The ampersand (&) is used in concert with two characters followed by an enter key according to the following examples:

To set the transmitter carrier frequency, type &FS,XXXX.XX **<ENT>** where, "&" is attention, "FS" means frequency set, and XXXX.XX is the frequency in MHz. and <**ENT**> is the Enter key.

To set the transmitter power level, type &PS,XX <**ENT**> where, "&" is attention, "PS" means power set, and XX is the power level in dB, and **<ENT>** is the Enter key.

To turn the transmitter on, type &TG <**ENT**>, where "&" is attention, and "TG" is transmitter go, and <**ENT**> is the Enter key.

To turn the transmitter off, type &TS <**ENT**>, where "&" is attention, and "TS" is transmitter stop, and **<ENT>** is the Enter key.

These commands can also be used via the transmitter's serial port, but run at 9600 bps with the same ASCII convention.

Figure 3
Duet Receiver Front Panel

1 color VGA LCD with vacuum fluorescent back lighting

Note: A faint line at the midpoint of this screen is normal, due to the mode of graphic display used in Duet

2 main power on light (green)

3 main power on-off switch

4 charging light for use with an external battery charging system (yellow)

5 battery low light, for use with an external battery charging system (red)

6 GPS receiver power on light (green)

7 GPS power on-off switch

8 direct entry keypad

9 cursor control for moving the position of measurement cursors

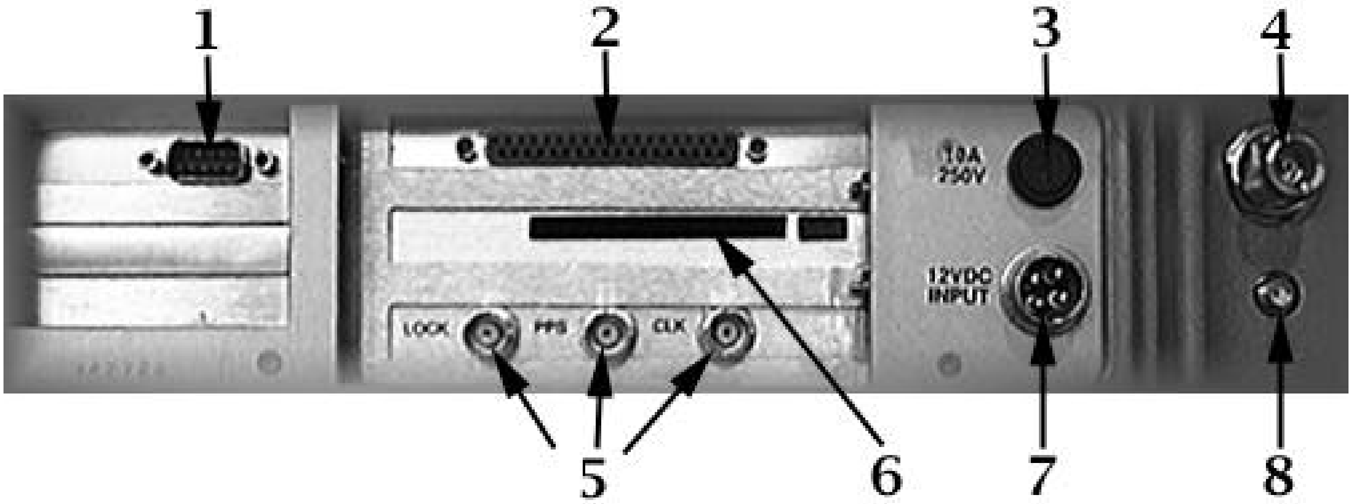


Figure 4
Duet Receiver Installation

1 Serial Port DB-9 Male To/From PC (use supplied cable)

2 VGA Monitor Output

3 10 Amp Fuse

4 RF In

5 External Clock Source In (BNC Male) (optional)

6 ATA Flash/PCMCIA Memory Card Slot

7 12 VDC Power Input

8 GPS Antenna Input

Power input

The receiver must be connected to a clean 12 to 16 volts DC power source, capable of delivering at least 5 amperes. The receiver voltage is internally regulated. Of course, power source should be as free of excessive ignition or power line noise. If the power source is a vehicle battery system, and the power is connected after the ignition switch, turning the engine on and off will reset the Duet receiver.

PCS receiving antenna

Following the antenna manufacturer's instructions, keep the antenna lead-in as short as possible. Locate the antenna and lead-in cable away from sources of ignition noise and avoid sharp bends.

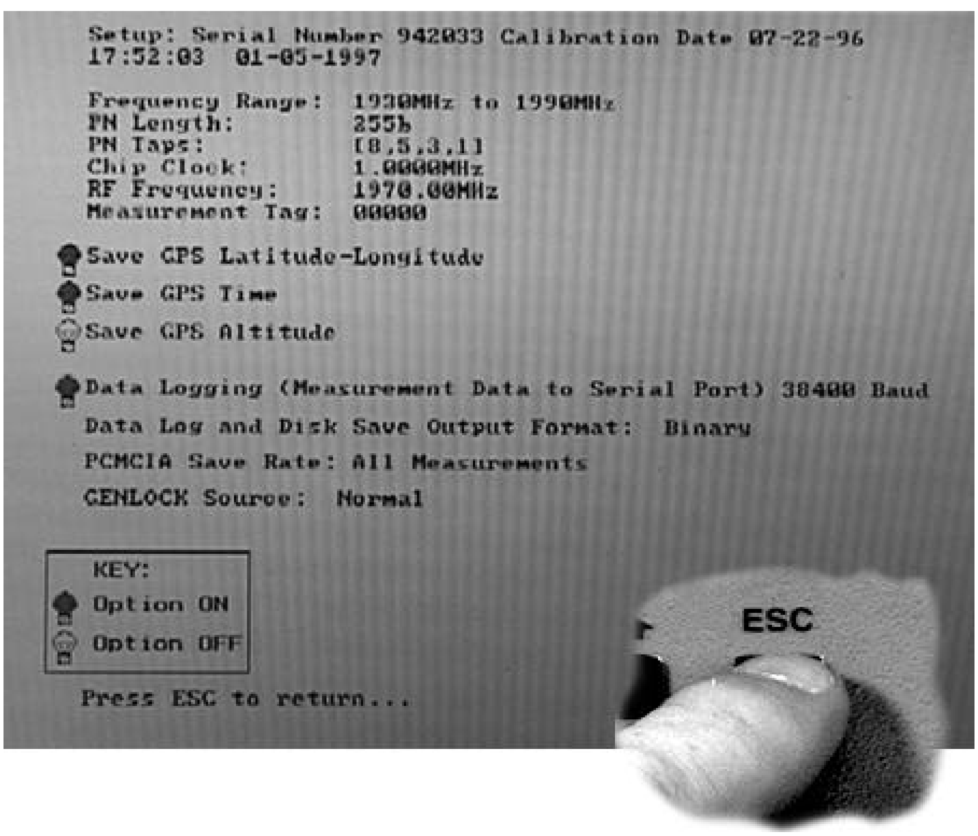
GPS antenna

Place the antenna in a location where it can have the greatest amount of sky visibility for maximum satellite reception. This is often in the center of the vehicle's roof. Follow the same guidelines used for the receiving antenna.

Duet Receiver Operation

Before operating the Duet Receiver, check for proper installation of the DC power input, receiving antenna, GPS antenna, and accessories. The Duet Transmitter should match the parameters set for receiver operation. Remote control of the transmitter is recommended. The receiver must be set to the same frequency, chip clock rate, and PN length. Turn the Receiver on, and the main menu will appear on the display:

The time and date are displayed at the top of the screen. To reset, see the section 'Setting the Time and Date. GPS data will be displayed if the GPS receiver is in operation. See the GPS Receiver Operation section. PCMCIA card capacity is displayed by a green bar graph. The length of the bar graph represents memory capacity available. When the PCMCIA card is full, the bar graph will read 'PCMCIA FULL.'



Checking Current Receiver Setup

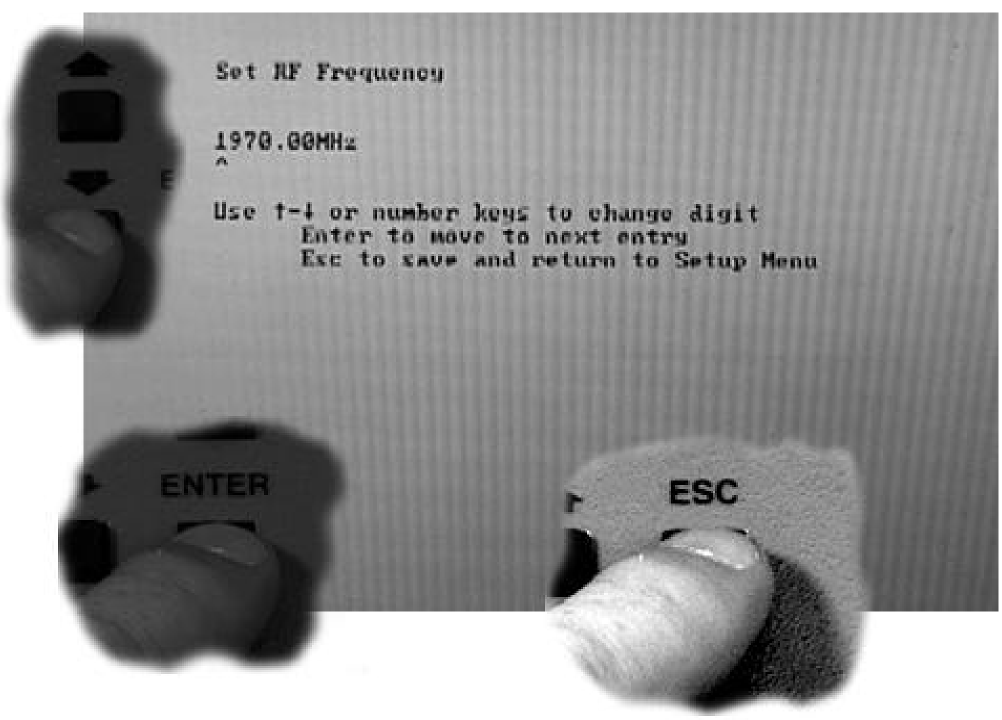
Press **1** on the keypad to select the Display Setup Screen:

This screen shows the current receiver settings. To change any of the settings, refer to the section, Changing Receiver Settings. To take multipath-BER measurements, remember the receiver frequency, PN settings and chip clock rate must be the same as the settings on the Transmitter. Press the **ESC** key and return to the Main Menu.

Changing Receiver Settings

Press **2,** and Change Setup will appear on the display:

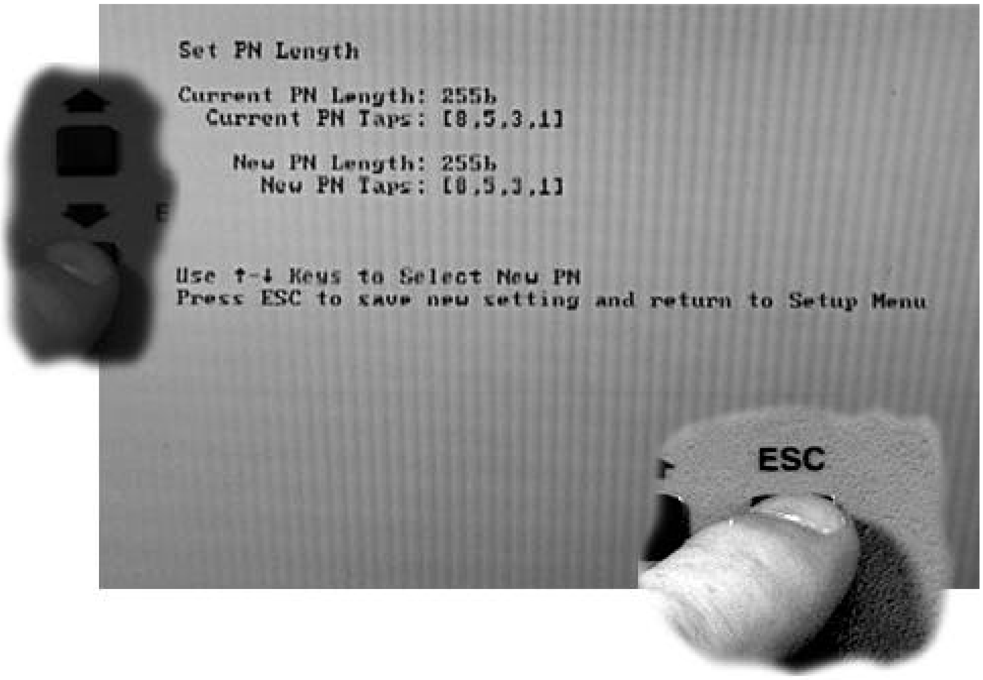
Notice that pressing **1** will bring back the Display Setup Screen to review current Duet Receiver setup status. To make setup changes, choose from options **2** through **0** shown on the screen, and press the corresponding key to set RF frequency, PN length, chip clock rate, GPS options, modem phone number, date and time, respectively.



Setting RF Frequency

Press **2,** and the RF Frequency Setup screen will appear on the display:

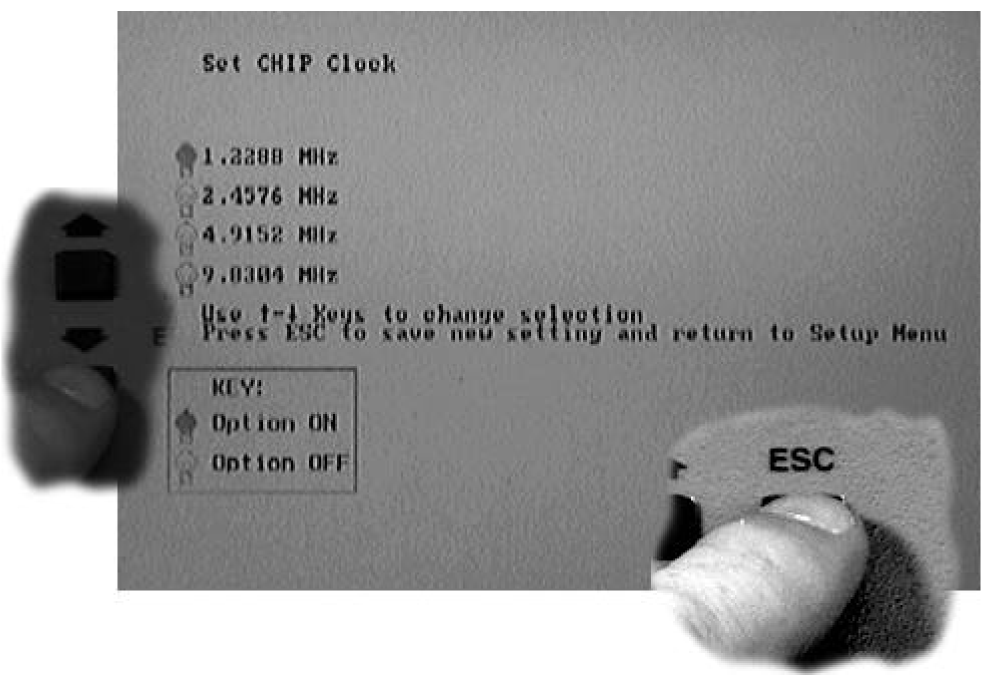
Use ↑ and ↓ or number keys to change digits, indexed by "^". Press the **ENTER** key to move to the next position. Press the **ESC** key to save change and return to main menu.



Setting PN Length

Press **3,** and the Set PN Length screen will appear on the display:

Use the ↑ and ↓ arrow keys to select a new PN length or PN taps. Press the **ESC** key to enter the new PN length and to return to the Setup Menu.

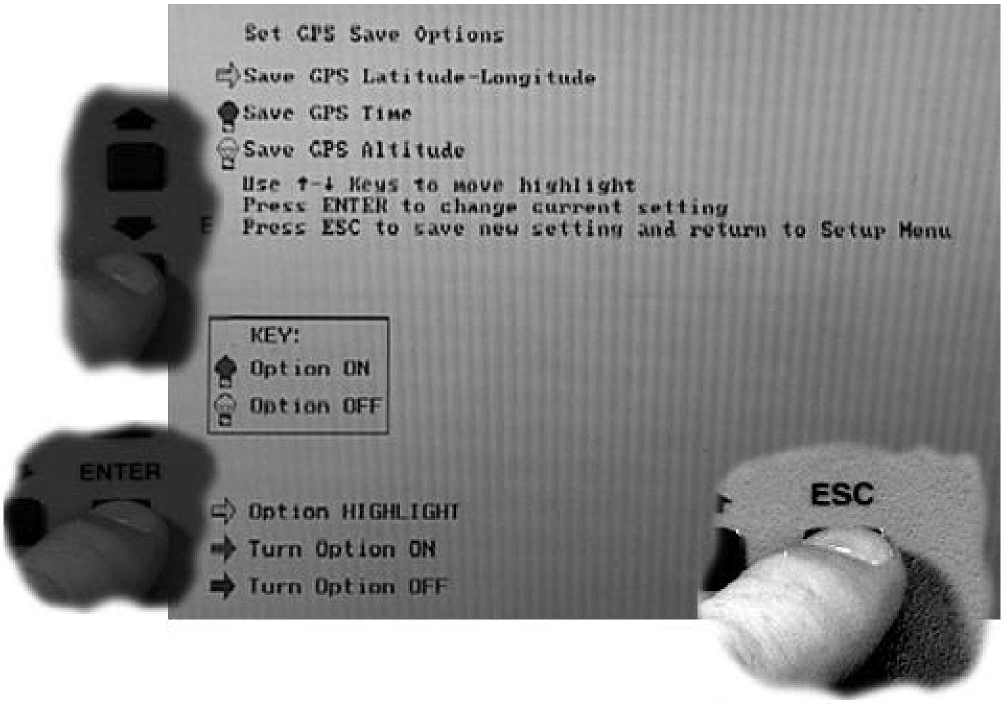


Setting Chip Clock Rate

Press **4**, and the Set Chip Clock screen will appear on the display:

Use the ↑ and ↓ arrow keys to select the Chip Clock Rate. Press the **ESC** key to enter the new Chip Rate and to return to the Setup Menu.

Note: The 9.8304 MHz setting is not available on the standard unit.



Changing GPS Receiver Save Settings

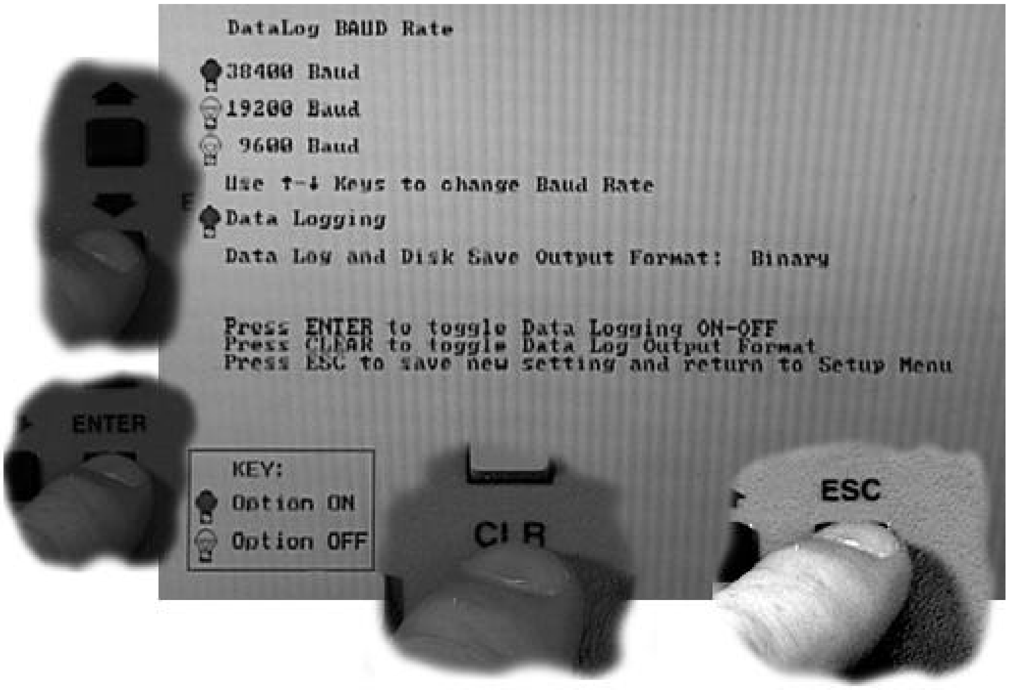
Press **5** while in the Setup Menu and the GPS Save Options screen will appear on the display:

GPS Receiver Operation

The built in GPS receiver receives signals from special satellites and uses the information to compute the receivers location. The satellites also broadcast precise time information in UTC. Note that GPS time can differ from the internal clock time displayed at the top of the main menu screen. In order to compute location, the GPS receiver must receive signals from three or more satellites.

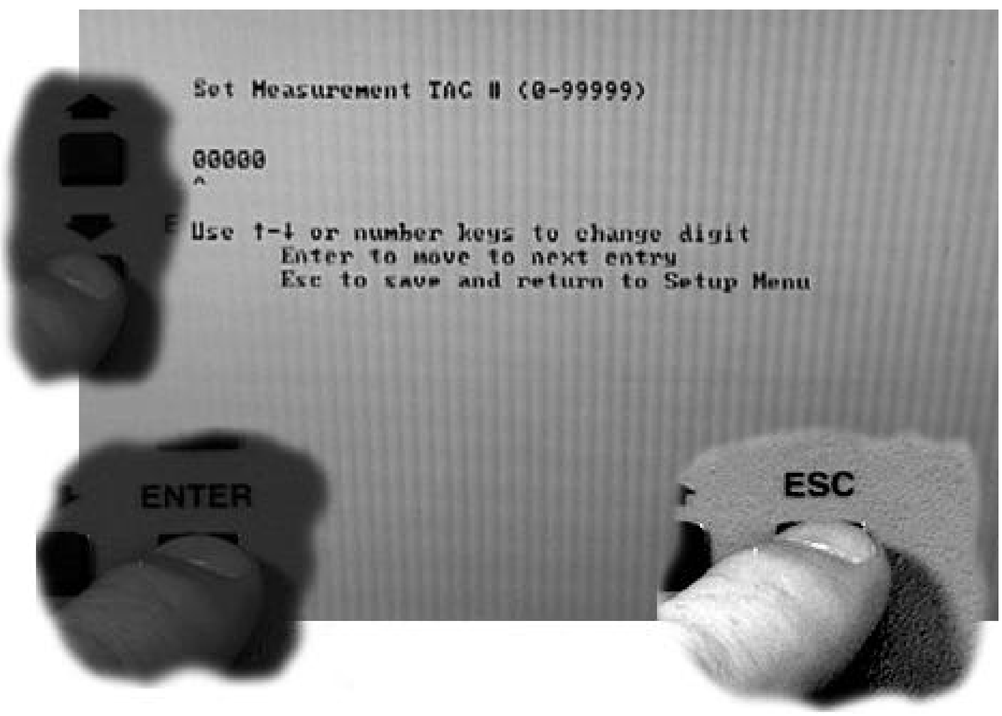
To use the GPS receiver, turn the front panel GPS power switch "on." The green light next to the switch should be lit. The main menu, and other screens show GPS status. The status can be "off", "unlocked", "locked.

GPS status:	meaning:
Off	The GPS receiver power switch is off.
Unlocked	The GPS receiver power switch is on, but the GPS receiver has not received and processed enough satellite information to compute its location. Latitude, longitude, altitude and time are not displayed.
Locked	The GPS receiver has successfully received signals from enough satellites and has computed its location. Latitude, longitude, altitude, and time are displayed. The GPS data will be saved only if the individual GPS save settings are made.



Data Logging to a PC

To access measurement data present on the receiver's serial port, or for logging data on a PC, the data logging function must be turned on, and the baud rate must be set. Press **6** for the data logging screen:



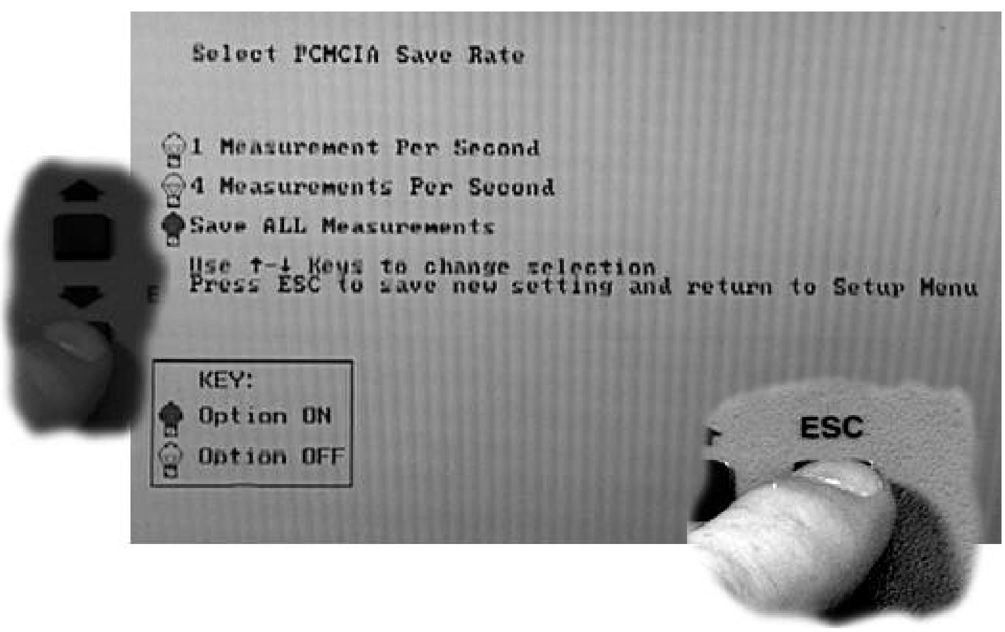
Setting Measurement Tag

Entering a Measurement Tag # for data identification, a 5-digit user-definable tag number can be assigned to data for future reference. This measurement tag # can be checked on the Setups screen before data is taken. The number will appear on the PCMCIA replay screen when data is reviewed. To use this function, press **7**. The Set Measurement Tag Number screen will appear on the display. Use the ↑ and ↓ keys to change the digits. Use the **ENTER** key to move to the next position, indexed by a "^". Press the **ESC** key to save the new measurement tag number and to return to the Setup Menu.

Setting the Time and Date

Press **8** and the Time and Date screen will appear on the display:

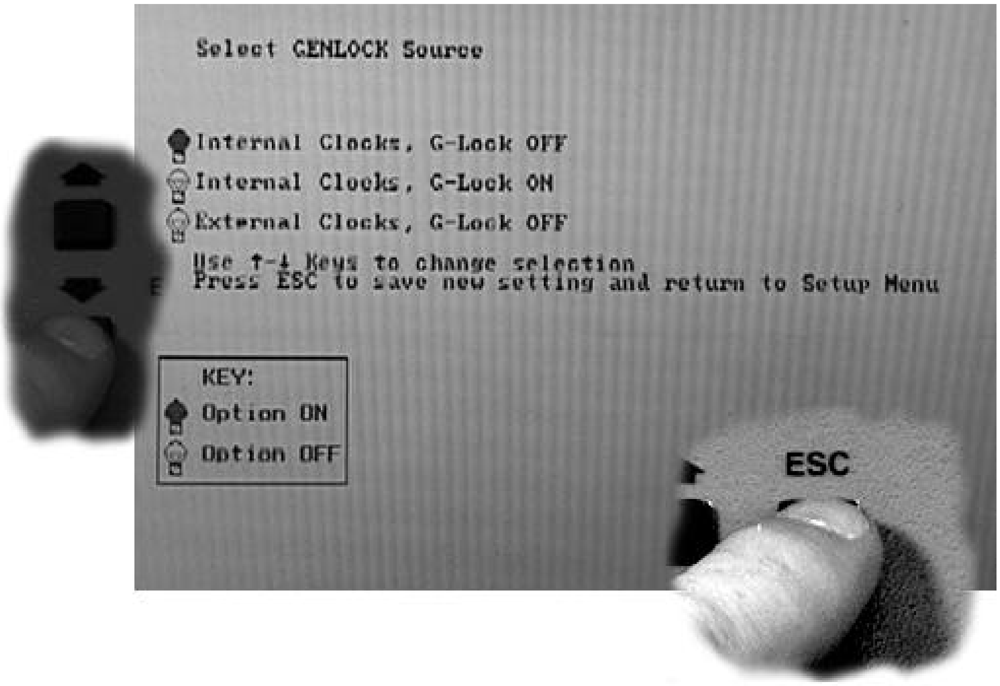
Use the ↑ and ↓ arrow keys to change the digits. Use the **ENTER** key to move to the next position, indexed by a " ^ ". Press the **ESC** key to save the new time and date and to return to the Setup Menu. Press **1** to display the current Receiver Setup. When the Receiver Setup is correct, press the **ESC** key to return to the Main Menu.



Select PCMCIA Save Rate

Press **9** and the Select PCMCIA Save Rate Menu will appear:

Note: The rate of multipath measurements is effected by the display mode of the Duet. Changing the X scale magnification has the greatest effect on this rate. This in turn will effect the rate at which the data is written to the card and serial port. The new PCMCIA Save Rate option will write as many measurements as possible to the card up to the number selected per second. This means that in some instances, less than the number selected will be written.



Selecting the GENLOCK Source

Press **0** and the Select GENLOCK Source Menu will appear:

Internal Clocks- GENLOCK OFF

This internal mode uses the Duet's internal oscillator as a frequency source. The Duet's DSP uses a search and tracking algorithm to stabilize the screen.

Internal Clocks- GENLOCK ON

This mode locks the Duet's internal clock to the internal GPS. Upon starting a multipath measurement, the DSP centers the strongest path to the center of the screen and does not track the path. Peak times recorded when GENLOCK is on are referenced to the initial time position of the strongest peak, (the center of the display screen).

External Clocks- GENLOCK OFF

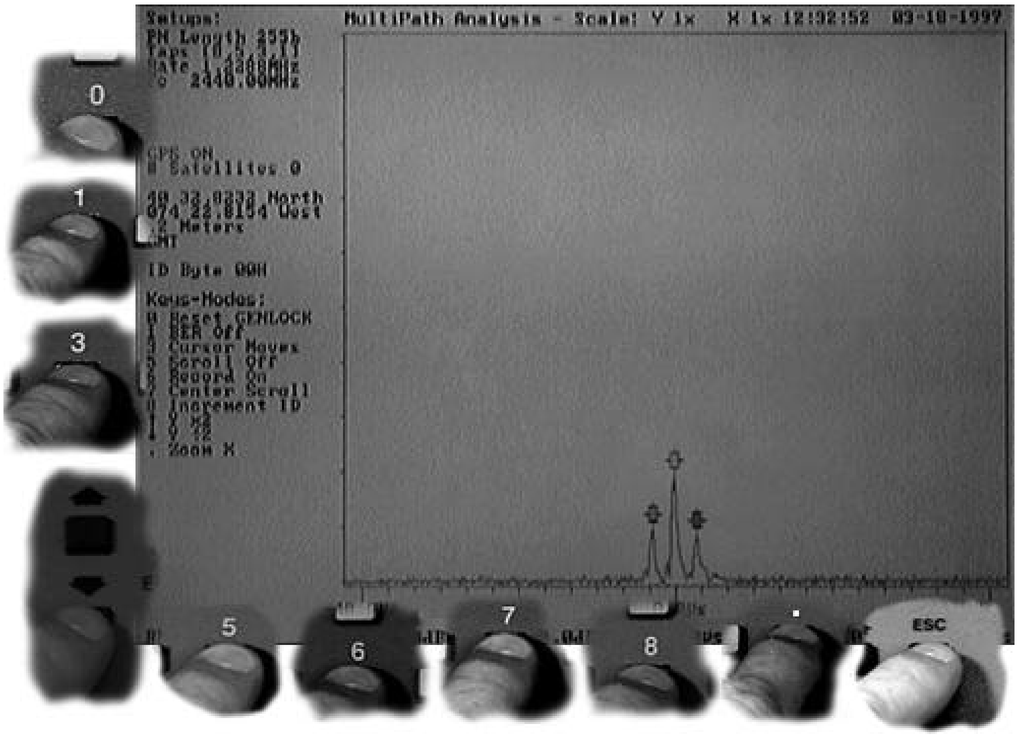
This mode requires the user to provide a clock PPS and lock signal via the external BNC connectors.

Clock-In: 1 Vpp AC coupled 9.6 MHz sine wave. The source should have 56 Ω impedance.

PPS- Pulse Per Second- TTL input. Duet detects a rising edge.

Lock- Indicator that the external clock source is locked. TTL input high is an indicator of lock.

Note: This menu is valid only for units equipped with GENLOCK.



Measuring Multipath and BER

Press **6** when in the Main Menu and the Multipath Analysis screen will appear on the display. Upon starting a multipath measurement, the DSP centers the strongest path to the center of the screen and tracks it with a narrow search window.

To measure BER, position the green movable cursor to the point of interest and press **1**. A yellow BER cursor will also appear on the screen, and lock in that position. The respective BER measurement will be computed and appear on the bottom of the screen. Press **1** again to exit the BER measurement mode.

Description of Multipath Analysis Screen

The left hand side of the Multipath Analysis screen displays:

PCMCIA capacity remaining bar graph (E - F)
GPS receiver on-off,
number of satellites locked in,
locked-unlocked status,
GPS latitude
GPS longitude
GPS altitude
GPS time (UTC)
modem on-off line status,
cursor mode (fixed or moving),
PN length and taps,
chip clock rate,
RF carrier frequency,
explanation of key functions

The center of the screen displays:

Real-time graphical representation of the strongest correlated signal and to its left (positive) or right (delayed) any multipath signals

Green cursors show the signal strength of the main correlated signal and the relative signal strength and delay time of any multipath signals

A yellow cursor shows the location of the BER measurement

Along the top of the screen shows:

Y axis magnification

Current internal clock time and date

At the bottom of the screen is shown:

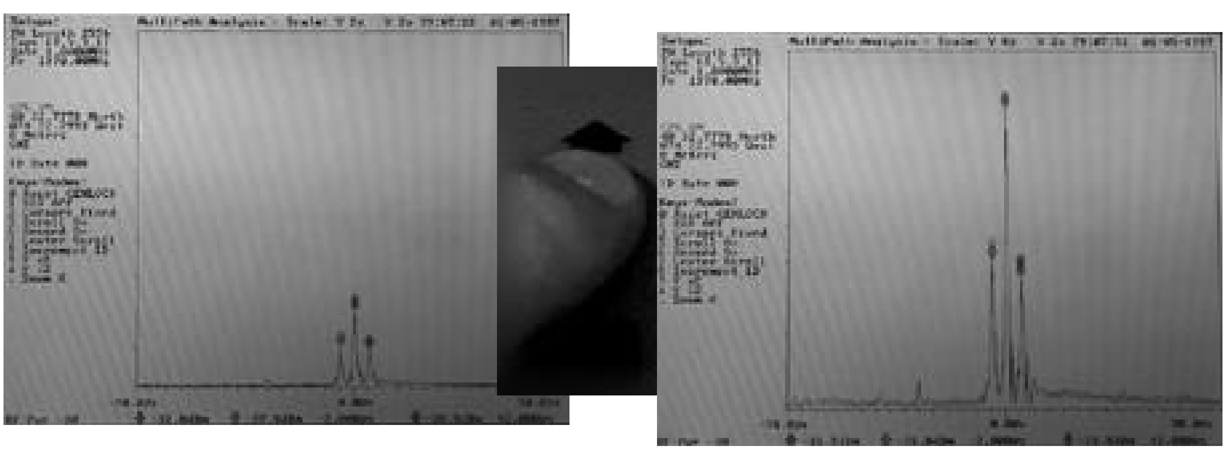
delay (1) time and relative strength of the second strongest signal delay (2) time and relative strength of the third strongest signal BER (Bit Error Rate)

Receiver Keypad Functions

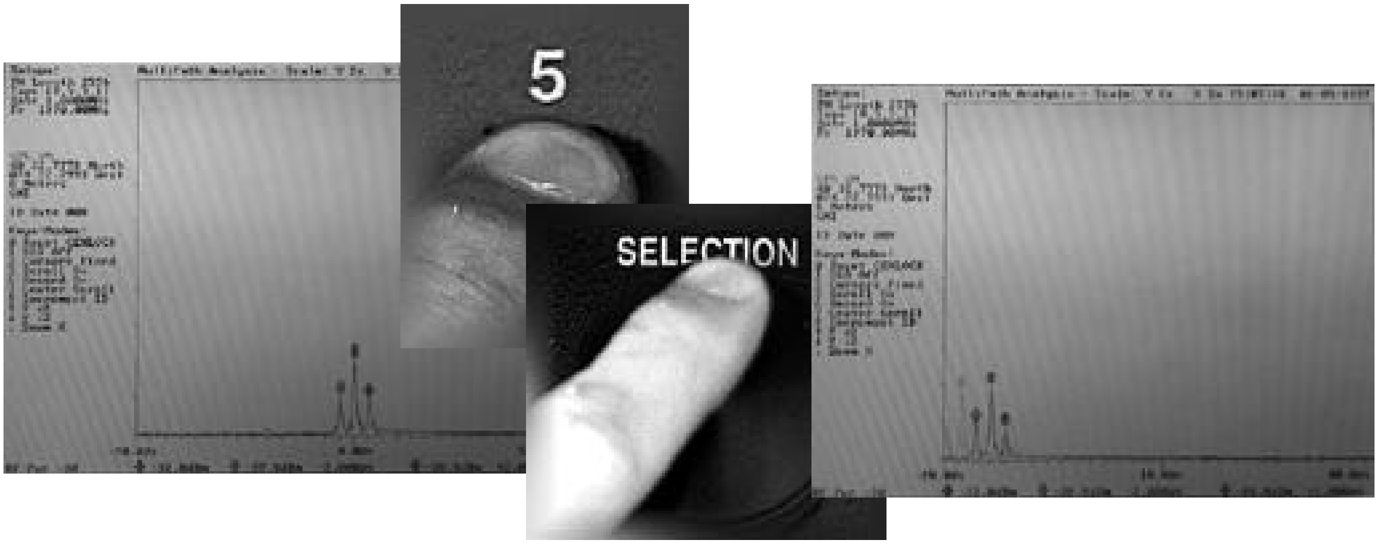
The following receiver keypad functions effect the VGA display screen <u>only</u>:

Key

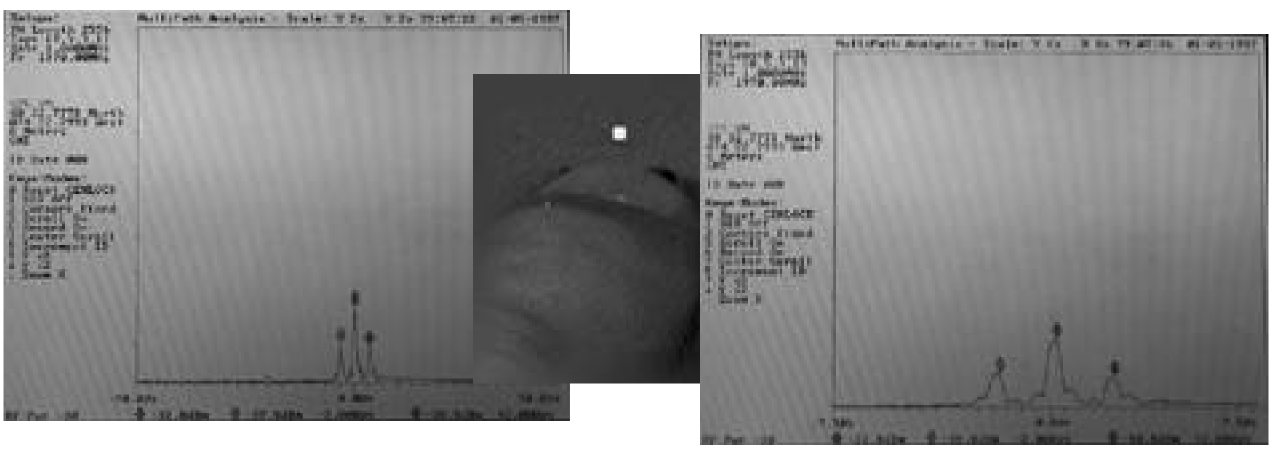
0	Resets the GENLOCK
1	Toggles BER measurement On or Off at position of the movable cursor (receiver must be in movable cursor mode).
3	Toggles between 3 peak mode or movable cursor modes.
5	Toggles scroll function ON or OFF.
6	Toggle record On and OFF to the PCMCIA
7	Reset scroll - display main peak at center of screen (scroll must be on.)
8	Increment ID number
9	Save screen to PCMCIA card (only appears if 2 Meg PCMCIA Card is enabled)
↑	increase magnification of signal magnitude (Y axis) by : (1X, 2X, 4X, 8X, 8X, 16X, 32X, 64X, 128X, 256X .)
↓	decreases magnification of signal magnitude (Y axis)
.	cycles through zooms by 2X; in the order of 1X, 2X, 4X, 8X and if pressed a fourth time, the X axis magnification returns to 1X mode.



The Y axis can be magnified or de-magnified by using the up and down arrow keys on the keypad. This can be helpful in determining precise incoming power levels.



The position of the X axis can be shifted from the center to the left or right on the screen by first pressing **5** to toggle center scroll off and then using the **Selection** dial to move the peak signal level and all its related multipaths in the direction that the dial is turned. This feature is useful in determining precise time correlated data between related multipaths. By pressing **5** again, the display will readjust the strongest signal to the center of the screen.



The time delay spread on the X axis can be magnified further by pressing the **.** key incrementally. The magnification is reset back to 1X upon pushing the **.** key a fourth time.

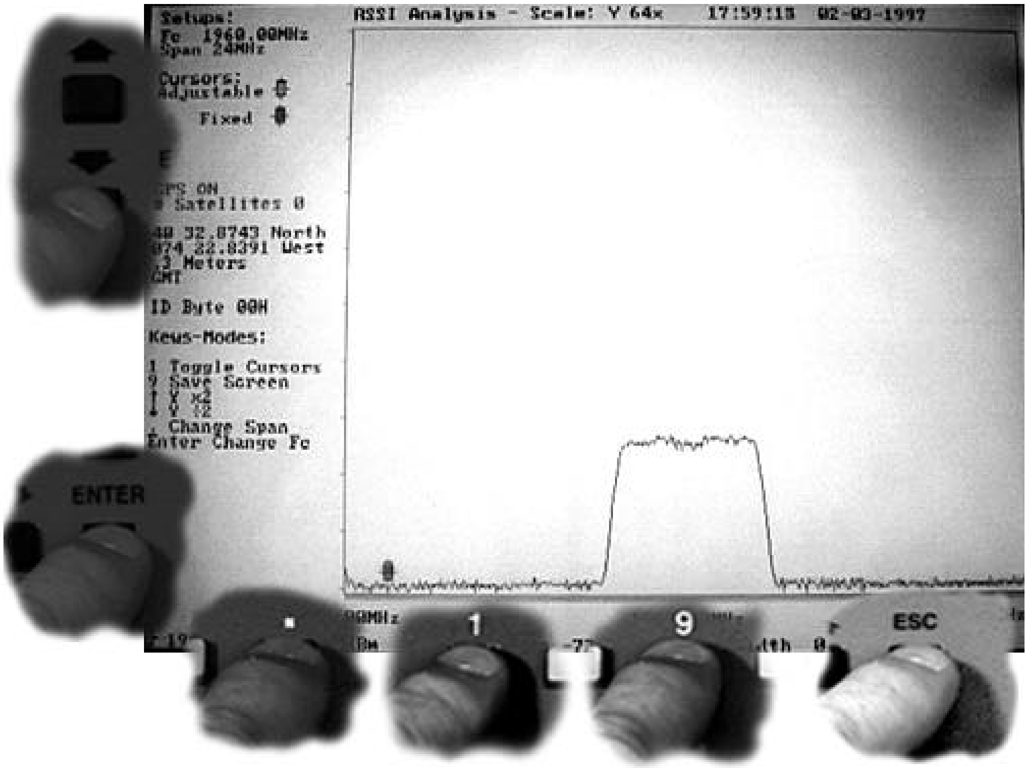
Fast Fade Measurement

Press **7** while in the Main Menu to enter the Fast Fade screen. When in this mode of operation, the Duet can measure and save the strongest 13 peaks 100 times per second on the PCMCIA or ATA Flash card and send to serial port (if DATA LOGGING is ON). 2 Meg PCMCIA card can save 12 minutes of data, serial port storage is limited only by the size of the PC disk (in order to save data using the serial port, DATA LOGGING must be ON and baud rate set to 38.4k). Press the **6** key to toggle the PCMCIA record On or Off. Press the **8** key to increment the ID number of the current study.

Fading data is measured using the 127 PN (Transmitter must also be set to 127 PN) and times 2 over sampling (multipath measurement uses times 4 oversample). Data saved is the raw peak values in ascending order and time offsets of each peak.

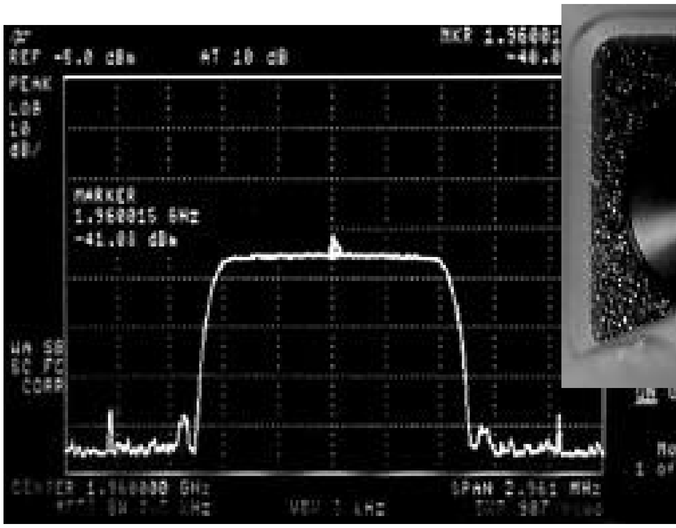
Measure RSSI Screen

Received Signal Strength Indictation (RSSI) is a measure of RF channel power. If your Duet has this option, the instrument behaves much like a spectrum analyzer. The RSSI option includes a narrow bandwidth (30 kHz) IF sub-system branching off the wideband CDMA IF (6 MHz or 12 MHz depending on the model) channel. When operated in this mode, the narrowband receiver steps across the entire spectrum of interest and the amplitude at every 50 kHz measurement point is plotted on the VGA screen.

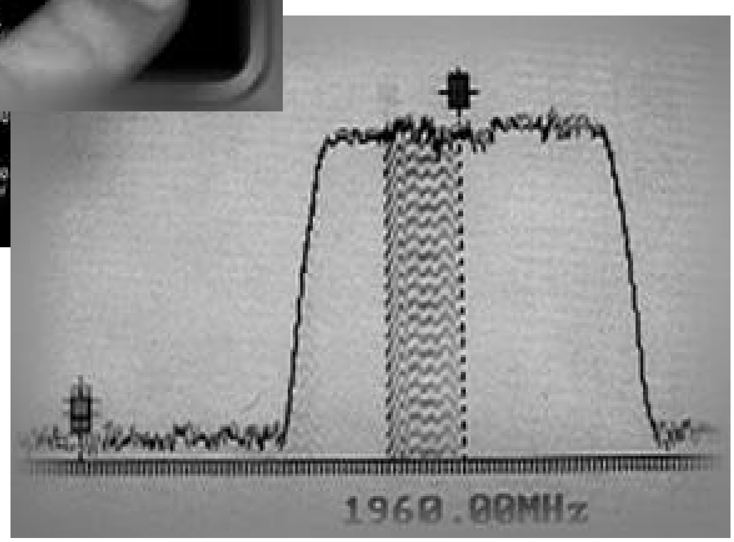


RSSI mode

In the RSSI mode, selection **8** on the main menu, the Duet scans the spectrum and displays RF signal strength across frequency. This display is very similar to the display of a spectrum analyzer. And included provisions to measure RF power in a selectable bandwidth and to measure frequencies and frequency spans. All of this is done with a few simple controls.



The Toggle Cursor function selects which one of the two measuring cursors (red and green) is controlled by the cursor knob. The cursors are used to measure frequencies, and to set the bandwidth for power measurements. This screen is



similar to the display on a spectrum analyzer. At the bottom of the screen the frequency, power per 50 kHz are show for each cursor. The difference in cursor frequencies and the total power in that bandwidth are also displayed at the bottom of the screen. The Change Span function changes the total frequency range of the X axis of the display. Pressing the button repeatedly rotates through several selections.

Controls for RSSI screen

Seven keys are active in the RSSI screen:

Key	Function
1	Toggle Cursor
9	Save Screen
↑	Y scale times 2
↓	Y scale divided by 2
.	Change span
ENTER	Enter new center frequency
ESC	Return to Main Menu

Using the ATA Flash Card

ATA card capacity is displayed by a green bar graph (like a gas gauge). The length of the bar graph represents memory capacity available. When the ATA card is full, the bar graph will read ATA FULL.

The ATA card must be initialized when used for the first time. The card should also be checked for capacity before taking measurements and initialized if necessary. Initializing the ATA card erases all data and reformats the card.

24 Meg ATA Flash Card

The ATA Flash card installed in the Duet receiver acts like a DOS compatable disk drive and can be read with any PCMCIA card reader that supports DOS formatted ATA cards.

Installing the card

To use an ATA Flash card, insert it into the PCMCIA slot in the rear of the Duet. The Duet receiver automatically recognizes that a card has been inserted and displays "New Card" in the area of the screen where the card status (a bar graph indicating the relative card space used) is normally displayed.

Storing data on the card

If a ATA FLASH card is installed in the PCMCIA slot, all subsequent measurements will be logged to the card. The card should not be inserted while a measurement is in progress. The Change Setup Menu, option **2** of the Main Menu, contains several items that control how the data is stored on the ATA card.

Displaying files stored on the card

A directory of the ATA FLASH card is available by selecting **3**, ATA FLASH Disk File Directory in the Main Menu. When this option is selected, the Volume name of the disk, the total size in bytes of the card, and the space remaining in bytes are displayed on the top of the screen, Below that is an entry for each file on the card, including the filename, size, data, and time. This display is similar to the one produced by a DOS directory command.

Removing the card

To remove the ATA card from the Duet, return to the main menu and select item **4**, Remove ATA FLASH Disk. The display will indicate that it is safe to remove the ATA card. Do not remove the card while the unit is powered without selecting this function.

Using the data on the ATA card

The ATA card can be read with any PC or laptop that have a PCMCIA card slot that supports DOS formatted ATA cards. Once the card is installed, it acts like a normal DOS disk drive and files can be read and copied from it. Old files can also be deleted.

Downloading the PCMCIA to a PC

To download the contents of the Receiver's PCMCIA card to a PC, the supplied DB9 cable must be connected from the Receiver's serial port to the PC. The DOS program DUET.EXE must be installed on the PC. After the PC program has been loaded, press **D** to download the DUET receiver PCMCIA card contents. The program will request a filename. Enter up to 8 characters, a "." and a 3 character extension. To begin downloading, press **5** on the Receiver keypad. When downloading has been completed, press the **ESC** key on the Duet Receiver keypad to return to the Main Menu.

Notes on DUET equipped with ATA FLASH DISK CARD:

a) There is no download option in the DUET main menu. Use option 4 to remove the ATA FLASH DISK and transfer data directly using the PC PCMCIA slot.

b) Make sure the card is formatted before using it with DUET.

c) NEVER remove the card during a measurement. To remove the card, stop the measurement and use the main menu **4** option to safely remove the card.

d) Do not power down the DUET during a measurement, all data from the current measurement will be lost.

e) To measure without saving to the card, remove the card prior to starting the measurement.

f) File names are created automatically by the DUET as follows:

1) If MULTI PATH measurement, the first letter of the file name is 'M'.

2) If FADE measurement, the first letter of the file name is 'F'.

3) If WAVEFORM CAPTURE measurement, the first letter of the file name is 'W'.

The next three characters are a 3 digit file number that is incremented after every measurement. When a new card is inserted into the DUET, the next file number is determined.

The file extension is set to '.txt' if the OUTPUT MODE is set to ASCII TAB DELIMITED. See section in manual on setup of DATA LOG.

The file extension is set to '.bin' if OUTPUT MODE is set to BINARY.

The file extension is set to '.bin' if in either FADE or WAVEFORM CAPTURE.

Diagnostics Menu

By selecting **9** in the Main Menu, you will enter the Diagnostics screen. This screen is used primarily by the BVS staff for display and calibration purposes. This menu was created for easy access to receiver settings so it may be accessed by the user.

DGPS

The "standard" configuration for Duet pair does not include differential (DGPS) receiver in the transmitter. This is optional, and one can be put in if a customer requires it. Normally, the Duet transmitter would be positioned in a known location and left there, while the receiver would be moved around. In the event a user chooses to post process its absolute position to differential GPS resolution, the optional GPS receiver for the transmitter should be ordered to collect the corrective information, and negate the Selective Addition installed by the US Government. It is rumored that this deliberate error signal added to GPS (to foil unauthorized use by the enemy) will be lifted, to provide full resolution to single-ended users.

Note: The term "differential GPS receiver" means the receiver is capable of correcting for Selective Addition errors. To actually realize the increased accuracy of DGPS, the user must have another piece of equipment, a special radio receiver that can demodulate a reference signal from a known location that is broadcast by a company that offers this service. The special receiver outputs a baseband data signal that is automatically detected by the DGPS receiver and used to improve the location resolution to 1 meter accuracy or better. The format must be compatible with RTCM SC-104, from the correction receiver.

GENLOCK Option

The optional GPS Lock system provides several additional functions not included in the basic Duet system. The upgrade includes a second GPS 8-channel, differential receiver installed in the transmitter along with oscillators and phase-locking circuits on a new PC card mounted near the receiver to:

- lock the PN frequency and phase to a GPS one pulse per second 1 PPS
- lock the RF reference frequency to the GPS 1 PPS output
- present via rear mounted BNC connectors the system master clock, 1 PPS strobe, master/slave output for multiple transmitters or signals from an external source. This bypasses the internal Duet timing oscillator circuits.
- The GPS reference provides long term coherency of the RF as well as synchronization of the PN data streams in Duet's Transmitter and Receiver. Standard Duet models use a TCXO oscillator, while systems configured with the optional GPS Genlock modules use an oven controlled reference, achieving accuracy of up to 1 part in 10,000,000 (0.1 part per million).
- The short term stability of PN phase is determined by the GPS IPPS output and is less than one-half the chip period at 1.2288 Mchips per second. The 1 PPS jitter after the GPS is locked is specified as <150 ns.
- The synchronization of Transmitter and Receiver PNs allows measurement (in real time) of the time of arrival for both the direct and reflected signals. The system also permits the synchronization of multiple Duet Transmitters with proper offset of the Pilot PN phase.
- With forthcoming optional software, operators may synchronize the Duet receiver to Qualcomm base stations and measure signals from multiple base stations (or multiple Duet Transmitters). This feature is especially useful for handoff analysis.
- The GPS Lock system can be bypassed (menu function) leaving the reference oscillator free running, as in the base Duet model, or bypassed and substitute by an external 9.6 MHz clock.

Setting the GENLOCK Mode

This menu appears for units equipped with the GPS GENLOCK option. Choose one of the following modes:

GENLOCK ON: This option can be selected only when the sync mode is Master Internal. This mode locks the internal clocks to the internal GPS.

GENLOCK OFF: Locking is disabled.

In the OPTIONAL waveform download mode, data for all the possible PN positions (lengths of 255 only) are in one-quarter chip increments, and saved to the on-board PCMCIA card or sent to a PC via the serial port at rates from 9.6 to 38.4kb/second.

Base Station Offset

The Base Station Offset option synchronizes the Duet's transmitter to GPS time. This allows several Duet transmitters to operate in the same environment. The transmitters may be installed in a cell-like pattern at candidate sites. The Duet receiver can track and measure main signal and multipaths from multiple transmitters at the same time and at the same frequency. The measured data can be analyzed to predict coverage of the multiple transmitters, interference from other transmitters and hand-off areas. In this mode, the Duet transmitters resemble and simulate CDMA Base Stations with different Offsets. This option is of particular interest to carriers and installers of CDMA systems. Set-up transmitters at Base Station Candidate sites that modulate with a PN pilot signal and have base station offsets, measure coverage of the pilot, multipath reflections, check neighbor lists and plan PN offset reuse patterns before construction of any site.

This option also allows operation of the Duet within an operating CDMA system. Install the transmitter at a candidate site with a PN offset and make the measurements listed above before construction of the site.

Note: This option requires the GPS GenLock option.

Setting the Sync Mode

This menu appears for units equipped with the GPS GENLOCK option. Choose one of the following modes:

Master Int - Uses the Duet's internal clock oscillators and internal GPS

Master Ext - Uses an external clock (1 PPS rate) and external GPS lock signals. These must be supplied by the user via the external BNC connectors. Intended for users with a precision base station time reference.

Internal GPS - Uses and external clock and internal 1 PPS reference. The user must supply this clock via the external BNC connectors. This feature is intended for users with a high precision oscillator source available.

Slave - Allows two co-located transmitters to be synchronized. Contact factory for operating details.

Clock-In: 1 Vpp AC coupled 9.6 MHz sine wave. The source should have 56 Ω impedance.

PPS- Pulse Per Second- TTL input. Duet detects a rising edge.

Lock- Indicator that the external clock source is locked. TTL input high is an indicator of lock.

SYNC Channel Option

This option adds a second CDMA channel to the Duet transmitter. The channel added is an IS-95A or PCS JED-008 SYNC Channel. A single transmitter or multiple transmitters arranged in a cell like pattern can be measured with the Duet's receiver or a CDMA phone in the test mode. Use the phone in test mode to evaluate coverage, neighbor lists and PN reuse patterns. Also, use the Duet's receiver for collecting more and unique data, multipath reflections, unwanted interference from other system transmitters and hand-off areas.

This option includes a second FIR filter, Walsh generator, data circuits and a combiner that adds the SYNC channel to the Pilot Channel.

Note: This option requires GPS GenLock and Base Station Offset options.

Telephone line connection (for modem or DTMF control)

Connect a standard telephone line with RJ-11 plugs from a telephone wall jack to the transmitter rear panel RJ-11 jack labeled LINE for remote operation. Connect a telephone set with a standard telephone cable with RJ-11 plugs to the transmitter rear panel RJ-11 jack labeled “PHONE”, for regular telephone operation when the modem is not in use. Use land line or cellular phone line for receiver remote control. While the Duet Receiver is designed for portable operation, care should be taken to minimize exposure to water, extreme heat and cold, dust, shock and severe vibration.

External Computer Port

This option consists of a A DB9 connector labeled 'Serial Port' and is located on the transmitter rear panel for connection to a PC. This port transmits and receives data at 9600 baud.

10 MHz Chip Rate Option

This options increases the Duet's maximum chip rate to 9.8304 MHZ, and allows the Duet to differentiate close-in multipaths. Specifically, the Duet's resolution on the time axis is increased by a factor of two. This option is very useful to characterize environment where shorter multipath components are significant or systems with fast baud rates that may be corrupted by shorter multipath.

ATA Flash Disk Card Option

a) There is no download option in the DUET main menu. Use option 4 to remove the ATA FLASH DISK and transfer data directly using the PC PCMCIA slot.

b) Make sure the card is formatted before using with DUET.

c) NEVER remove the card during a measurement. To remove the card, stop the measurement and use the main menu 4 option to safely remove the card.

d) Do not power down the DUET during a measurement, all data from the current measurement will be lost.

e) To measure without saving to the card, remove the card prior to starting the measurement.

f) File names are created automatically by the DUET as follows:

1) If MULTI PATH measurement, the first letter of the file name is 'M'.

2) If FADE measurement, the first letter of the file name is 'F'.

3) If WAVEFORM CAPTURE measurement, the first letter of the file name is 'W'.

The next three characters are a 3 digit file number that is incremented after every measurement. When a new card is inserted into the DUET, the next file number is determined.

The file extension is set to '.txt' if the OUTPUT MODE is set to ASCII TAB DELIMITED. See section in manual on setup of DATA LOG.

The file extension is set to '.bin' if OUTPUT MODE is set to BINARY.

The file extension is set to '.bin' if if either FADE or WAVEFORM CAPTURE.

Waveform Capture Option

For DUET's equipped with ATA FLASH DISK CARD, waveform data is saved to a flash dik file. For units equipped with the SRAM PCMCIA card, waveform data is collected using the serial port.

Special Characters:
'&' - the ampersand character - 26H
'CR' - carriage return - 0DH

If not using the supplied PC software, use the following procedure to capture waveform data:

To start the waveform capture mode, make sure the receiver is displaying the main menu and that the PC and DUET are set to the same baud rate.

Send the following character sequence to the DUET receiver:

'&' 'S' 'W' 'C' 'CR'

The DUET screen will change to the WAVEFORM CAPTURE screen.

To trigger a measurement send the following character sequence:

'&' 'T' 'R' 'G' 'CR'

Flash Card Save

The DUET will measure and save the results to the ATA FLASH DISK (file name will begin with the letter 'W').

After the data is saved, the DUET will respond to the PC with the following 5 character sequence:

'&' 'A' 'C' 'K' 'CR'

NO OTHER data is sent from the DUET over the serial link, ALL measurement data is saved on the FLASH DISK.

Serial Port Save

If the DUET used for waveform capture is equipped with an SRAM CARD, waveform data is measured and sent via the serial port after the &TRG sequence is received. There is no additional acknowledge sent (&ACK is not sent in the serial capture mode).

V1.15 Dual Data Collect Option D

Before using the Dual Collect option, both receivers should be set to the same frequency, chip rate and PN. Also, to assure that the data collected remains in sync, the X and Y scales should be set to the same values for both receivers and PCMCIA cards removed from both units. Manually start each receiver and set the X and Y scales to the same value before using the D option.

Once the units have been setup, select the D option and enter a file name for the binary to be saved in when prompted. After the file name is entered, both receivers will be started in the standard 13 peak mode. The following data for both receivers is displayed while the dual collect is running:

Time, RF frequency, Chip Clock, PN, GPS data, Genlock status and the dBm value of the strongest peak and total power for both receivers.

Press the '1' key to increment the ID number for both receivers during measurement, press Esc to stop the measurement.

To convert the data collected to ASCII, use Main Menu Option 4 (Duet File Operations). The ASCII file created will contain the data from receiver 1 on odd lines (1,3,5...) and data from receiver on the even lines (2,4,6,...).

Option Codes

The number after the V 1.10 is the firmware revision number.

Option Code Letter	Option Installed
F	ATA Flash Disk PCMCIA
S	SRAM PCMCIA
1	4.9152MHz Chip Clock
2	8MHz Chip Clock
3	9.8304MHz Chip Clock
R	RSSI
G	GENLOCK
W	Waveform Capture
D	Dual Data Collect

DUET Receiver Remote serial commands

Command Format:&xxdCR

&	first character - command marker
xx	2 letter ascii command (upper case)
d	ascii data (number of char depends on command)
CR	carriage return (0x0d)

Commands:

SU	- returns duet setup structure
PN	- set PN length (followed by PN letter code)
PNA	- set 127 PN
PNB	- set 255a PN
PNC	- set 255b PN
PND	- set 511 PN
PNE	- set 1023 PN
PNF	- set 2047 PN
PNG	- set 4095 PN
PNH	- set 8191 PN
PNI	- set 16383 PN
PNJ	- set Qualcomm I1 PN
PNK	- set Qualcomm Q1 PN
PNL	- set Qualcomm I2 PN
PNM	- set Qualcomm Q2 PN
PNN	- set Qualcomm I4 PN
PNO	- set Qualcomm Q4 PN
PNP	- set Qualcomm I8 PN
PNQ	- set Qualcomm Q8 PN

CCc	- set chip clock (followed by chip clock digit)
CC1	- set clock freq 1
CC2	- set clock freq 2
CC3	- set clock freq 3
CC4	- set clock freq 4

FC - set rf frequency (followed by freq in MHz (4 ascii digits), decimal point, followed by the last 2 digits (hundred, tens KHz)

FC1960.00 set rf frequency to 1960MHz

ID - set ID byte
Follow ID command with binary value of ID.

Format for ID values other than CR is IDvCR where v is 8 bit id value. If value of ID is equal to CR is IDCR

SM	- start measurement
SMM	start multipath measurement
SMF	start fast fade measurement

EM - end (stop) measurement

CTllhh - Change Tag # to llhh where llhh is a binary number range 0-32767, ll low byte, hh high byte

CM0 - set output mode to BINARY
CM1 - set output mode to ASCII

BE - start BER measurement at main peak

IS - init setup
a) 3 cursor mode
b) chip clock freq 1
c) PN 127
d) Freq = Base Freq
e) tag = 0
f) GPS - save LAT,LON

NOTE: CM0,CM1 only effect output of multi-path measurement. Fast Fade measurement is always in binary. Use the PC software to convert Fast Fade binary data into ASCII.

Only start,end and id commands are accepted during measurement. Other setup command are accepted only when DUET is in its main menu.

Be sure that both the PC and DUET are at the same baud ratefor data logging and remote features.

V1.10 Commands

SWC Enter Waveform Capture mode (and open waveform capture file if ATA FLASH DISK).

TRG Trigger Waveform capture, send data to PC (or write to file if ATA FLASH DISK).

EWC End Waveform Capture mode (and close waveform capture file if ATA FLASH DISK).

SCROLL mode - use the cursor knob to change the center of the data displayed.

Key:

1 - Toggle BER measurement ON-OFF at position of movable cursor if movable cursor mode. If fixed 3 cursor mode, BER is measured at main peak (red cursor).
3 - Toggle between 3 peak mode and movable cursor mode.
5 - Toggle SCROLL ON-OFF (Scroll overrides movable cursor).
7 - Reset SCROLL - display main peak at center of screen (SCROLL must be ON).
9 - Save Screen to PCMCIA card (screen turns yellow during save operation, measurement is paused).
. - zoom X scale
↑ and ↓ - zoom Y scale

PC Software - Firmware Update

DUET PC software can be used to update DUET receiver firmware. Connect the Duet to the the PC in the same manner as when using RF data log. From the PC main menu, press U and then turn on the DUET as prompted. Two files will be transfered to the DUET from the PC:
a) duet.bin
b) dsp.bin
These file(s) must be in the same directory as duet.exe and are supplied by BVS.

NOTE: In some cases only one of the files above is needed to update the DUET, in these cases only the required file will be supplied.

After upload is complete the DUET main menu is displayed. At this point (BEFORE doing ANY measurements), enter the diagnostic menu (press 9) and init the default settings (press 9 again when the diagnostic menu is displayed). This function will reset the setup flash rom to a known state for the new firmware. Before starting any measurements, use the DUET setup menu to restore setups required.

Duet Download File Structure

The format for binary data files saved by the Duet PC software is described below. This format description is for both the Download (PCMCIA Card) and Serial Transfer data files. The only difference between the two file types is the additional Card ID record in the Download file.

The General structure of the file is shown first. Values enclosed by "< >" will always be present. Values enclosed by "[ ]" may or may not be present. If the optional items are present, the order is as indicated. The Save Flag indicates which, if any, of the Data fields are present. A Save Flag equal to EOM (End of Measurement) appears at the end of each measurement. Two consecutive Save Flags of value EOM indicate the end of file.

File Structure

```
[ Card ID ]
        < Save Flag >
                [ Data : Set up]
                [ Data : Date ]
                [ Data : Time ]
                [ Data : GPS Status ]
                [ Data : GPS Lat/Lon]
                [ Data : GPS Time ]
                [ Data : GPS Altitude]
                [ Data : Peaks ]
                [ Data : BER ]
                [ Data : ID ]
                [ Data : Calibrate]
                [ Data : Fade ]
        <Save Flag>
                .
                .
                .
        <Save Flag : EOM>
                .
                .
                .
        <Save Flag : EOM>
        <Save Flag : EOM>
```

Save Flag Values

Every data record begins with a Save Flag word. The Save Flag indicates the Data fields that will be included in this record. The Save Flag value is a logical OR of values from the following table. The EOM value (Save Flag = 0) is a special case and marks the end of a measurement and the end of the file.

Data Type	Save Flag Value (Hexadecimal) 16 bit
Setup	0001
Date	0002
Time	0004
GPS Status	0010
GPS Lat/Lon	0020
GPS Time	0040
GPS Altitude	0080
Peaks	0100
BER	0200
Fade	0400
ID	0800
Calibrate	1000

Data Fields

A particular Data field exists in a record if the corresponding bit in the Save Flag word for that record is set. The Data fields are always in the order indicated in the File Structure section; however, the Data fields not indicated in the Save Flag value are skipped (not written to the file). The content of each field follows. A "char" is one byte, a "word" is two bytes, and "int" is two bytes, a "long" is four bytes, and a "float" is four bytes.

```
Setup {
        Chip Clock                  byte
        Data Clock                  byte
        Walsh Select                byte
        Phone Number                17 char
        Seed 0                      5 words
        Seed 1                      5 words
        Measure Mode                word
        GPS Save                    word
        Magnify                     int
        Setup Index                 int
        RF Frequency                word
        T Color                     int
        D Color                     int
        B Color                     int
        Background                  Color  int
        Measurement Tag             long
        Measurement Marker          long
        Data Log                    int
        Baud Rate                   word
}

Date                                3 bytes

Time                                3 bytes

GPS Status                          word
```

GPS Lat/Lon {
Latitude Integer Degrees — float
Latitude Decimal Degrees — float
Direction — char - N for North, S for South

Longitude Integer Degrees — float
Longitude Decimal Degrees — float
Direction — char - E for East, W for West
}

GPS Time — float

GPS Altitude {
Altitude — float
Units — char - M for meters
}

Peaks {
Peak #1 in dB — float
Peak # 2 in dB — float
Peak # 3 in dB — float

Time from peak 1 to 2 — float
Time from peak 1 to 3 — float
}

BER {
Level of peak being tested in dB — float
Bit Error Rate (ratio) — float
time from peak #1 to this peak — float
}

ID — byte

Calibrate {
Serial Number of unit — 7 char
Calibration date — 7 char

Power Calibration Table 1{
AGC Value — word
Power factor in dB — float
} — 80 Times

Power Calibration Table 2{
AGC Value — word
Power factor in dB — float
} — 17 Times

RSSI Calibration Table1 — 90 words - Not Implemented
RSSI Calibration Table2 — 17 words - Not Implemented
}

Fade {

AGC Value	word	
Fade Measurement {		
Peaks {		
Level	word	
Position	byte	
}	13 Times	- one for each peak
}	100 Times	
}		

Card ID Record

Only PCMCIA Download files contain the Card ID record.

Card ID {	
ID	16 bytes
ROM Version	8 bytes
Next Free	long
Size	long
}	

Connect instruments as shown in Figure 18 and setup as follows:

Duet Transmitter setup:

1) PN to 255A
2) Chip Clock to 1.2288 MHz
3) Frequency to 1960.0 MHz
4) Power to 24 dBm
5) Test Mode OFF
6) Turn the output ON

Duet Receiver setup:

1) PN to 255A
2) Chip Clock to 1.2288 MHz
3) Frequency to 1960.0 MHz

HP 8593E Spectrum Analyzer setup:

1) Press Meas/User button
2) Select Power Menu
3) Select Setup
4) Set CHANNEL BANDWIDTH to the Chip Clock Value (in this case 1.2288 MHz)
5) Set Center Frequency to 1960 MHz
6) Return to Power Menu and measure channel power
7) Connect output of the Duet transmitter to the HP 8593E and verify the output power level (HP should display -46 dBm)

Duet Receiver:

1) Connect the output of the Duet transmitter to the Duet receiver. Start the MultiPath Measurement (press 6, Receiver Main Menu.)

2) Observe the Peak dBm value (Red Cursor.) The indicated value should be the same as the HP +-1 dBm.)

Note: The above example assumes no loss in the cable used to connect the transmitter to the HP/Duet. Use the same cable to measure power with both instruments so that any cable loss will be recorded by both devices.

Waveform Capture Commands

This mode of capture is for Duet systems equipped with ATA FLASH Disk Cards 24 megabytes or greater in size. When using this mode, a PN length of 255a or 255b must be specified. To start the waveform capture mode, make sure the receiver is displaying the main menu and that the PC and Duet are set to the same baud rate. If you are not using the BVS supplied PC software, use the following procedure to capture waveform data:

Send the following character sequence to the Duet receiver: '&' 'S' 'W' 'C' 'CR'.

The Duet screen will change to the Waveform Capture screen displaying a message: 'Waiting for PC Trigger...'

To trigger a measurement, send the following character sequence: '&' 'T' 'R' 'G' 'CR'

The Duet will measure and save the results to the ATA FLASH Disk (the file name will begin with the letter 'W'). After the data is saved, the Duet will respond to the PC with the following 5 character sequences: '&' 'A' 'C' 'K' 'CR'

Note: No other data is sent from the Duet over the serial link. All measurement data is saved on the ATA FLASH Disk.

Duet Main Menu V1.10 Selections

Press:

1 Communications Setup and Testing

2 Remote Control of Duet Receiver

3 Remote Logging of Duet Data

4 Duet File Operations

5 Update Duet Receiver Firmware

Esc to Exit

To access the Communications settings, press **1** in the Main Menu

Communications Menu

1 Display Communications Settings

2 Set PC Baud Rate for Data Log

3 Test PC to Duet Serial Link

ESC to return to Main Menu

To access the Remote Control settings, press **2** in the Main Menu:

Duet Remote Control

1 Change PN
2 Change Chip Clock
3 Change RF Frequency
4 Change output mode (ASCII or BINARY)
5 Set Tag #
6 Set ID

I Initialize setups

S Get Duet setup and display

M Start multi path measurement and save to disk - Binary
A Start multi path measurement and save to disk - ASCII
F Start fast fade measurement and save to disk

W Waveform capture and save to disk

Esc Return to main menu

1-Use to change PN sequence used by receiver. BOTH receiver AND transmitter must use the SAME PN for proper operation.

2-Use to change the chip clock (data rate). BOTH receiver AND transmitter must use the SAME Chip Rate for proper operation.

3-Change RF frequency. Again, BOTH receiver AND transmitter must use the same frequency for proper operation.

4-Change DUET output mode to ASCII or BINARY.

5-Set measurement TAG number. This number can be used to identify a drive test. Set this number before starting to collect data.

6-Set ID number. This number can be used to tag events that occur during a drive test. Set this number before starting to collect data.

I-Initialize DUET setups.

S-Display current DUET setups.

M-Remote Start the multipath measurement in the BINARY output mode.

A-Remote Start the multipath measurement in the ASCII output mode.

F-Remote Start the multipath FAST FADE measurement.

W-Enter the Remote Control WAVEFORM capture mode.

Esc-Return to main menu

To access the Remote Logging settings, press **3** in the Main Menu:

Duet Receiver Remote Logging

Remote logging records measurements on the PC that are started on the Duet. Data Logging must be enabled on the Duet and set to the proper type, ASCII or BINARY.

1 Log data to BINARY file

2 Log data to ASCII file

ESC to return to Main Menu

To access Duet File Operations, press **4** in the Main Menu:

Duet File Options

1 Review data file and convert to ASCII

2 Plot Multipath binary data file

3 View Waveform Capture file

ESC to return to Main Menu

To Update Duet receiver Firmware, press **5** in the Main Menu:

Duet Firmware Updating Instructions

1. Copy the entire contents of the disk into a directory on the hard drive of the computer that will be used to update or run from the floppy drive.

2. Connect the Duet to be updated to the computer with the Duet receiver serial cable.

3. Run the program "UPDATE" by typing 'UPDATE' followed by enter. (Run the program in DOS, not Windows). To run from the floppy drive, place the supplied disk in the 'A' drive and type "A:" followed by enter. Then run "UPDATE" as described above.

4. When prompted, enter the number of the serial port being used to update (1 or 2, the one connected to the serial cable).

5. When instructed, turn on the Duet power switch.

6. There will be a delay as the Duet starts up.

7. The PC screen will display a message while the update is in progress, and a message when complete.

8. The Duet will execute the new program when the update is done, the main menu version will be 1.10

V1.15 Dual Data Collect

This version of PC software assumes that one DUET receiver is connected to PC COM1 and another DUET receiver is connected to PC COM2. To test that both receivers are connected properly to the PC, use Main Menu option 1 (Communication Setup and Testing).

Use option 3 (Test PC to Duet Serial Link) of the Communication Menu to check that both Duet receivers are communicating with the PC.

Main Menu option 2 (Remote Control of Duet Receiver) contains the options used to collect and setup the DUET receivers via. the PC serial ports. The following describes the new additions:

Option:	Function:
D	Use to collect binary 13 peak data from both receivers.
R	Use to select the receiver for the following commands: 1,2,3,4,5,6,I,S. The currently selected receiver for these commands is diplayed at the top of the menu.

To setup (options 1,2,3,4,5,6,I) one of the receivers, first use the 'R' command to select the receiver, then use the setup option.

Data collect options M,A,F,W and X use the Duet receiver connected to COM1 and are not available for the Duet receiver connected to COM2.

Waveform Capture Data Format
(AS SAVED BY FLASH CARD or SERIAL PORT)

Name	Size	#bytes	Value or content
----	----	------	----------------
Save FLAGS	word	2	see below
Hours	byte	1	rtc hours
Minutes	byte	1	rtc minutes
Seconds	byte	1	rtc seconds
milli sec	byte	1	rtc milli seconds
GENLOCK STATUS	word	2	see below
GPS STATUS	word	2	see below
deg_lat	float	4	latitude degree
dec_lat	float	4	latitude decimal minutes
qlat	char	1	'N' or 'S'
deg_lon	float	4	longitude degree
dec_lon	float	4	longitude decimal minutes
qlon	char	1	'E' or 'W'
trig_tot_pwr	byte	1	total power
trig_data[1020]	byte	1020	waveform db data array

trig_tot_pwr: total RF power measured, to convert to dBm, use
total RF power (dBm) = trig_tot_pwr * (-1);

trig_data: to convert each waveform point (byte) to dBm, use
dBm[i] = trig_data[i] / (-2);

For ALL BINARY DATA (including WAVEFORM CAPTURE)
\

GPS STATUS WORD::

bit #	set	clear
11	gps ON	gps OFF
10	gps LOCKED	gps WARN
7-0	# of satellites	

GENLOCK STATUS WORD:

bit #	set	clear
14	Internal LOCK	Internal WARN
13	External LOCK	External WARN

For all DUET data saved in the binary format (multipath, fast fade and waveform capture), the elements saved for each measurement are indicated by bits set in the save flags word. The procedure for reading and decoding a binary saved measurement are as follows:

step 1) read the SAVE FLAG word

step 2) if the word is zero, the measurement was stopped. Go back to step 1, if the next word is also zero, there is no more data in the file, else continue to step 3.

step 3) check each bit in the same order as listed below starting at bit 0 (SAVE_SETU). If the bit is set, read the data structure listed under the "Save Structure" column.

Bit name	Bit #	Data	Save Structure
SAVE_SETU	0	setups	struct setup
SAVE_RDAT	1	date	3 bytes (mon, day, yr)
SAVE_RTIM	2	time	4 bytes (hrs, min, sec, msec)
SAVE_GLS	3	genlock status	word
SAVE_ST	4	gps status	word
SAVE_GLL	5	lat/lon	struct lat_lon
SAVE_GTIM	6	gps time	float
SAVE_GALT	7	gps altitude	struct altitude
SAVE_NPEAK	12		13 peak data struct n_save_peak_data
SAVE_BER	9	BER data	struct save_ber_data
SAVE_ID	11		ID byte byte
SAVE_TRIGGER	13		Trigger data struct save_trigger_data
SAVE_CALIBRATE	14		Calibrate data
SAVE_FADE	10		FADE record
SAVE_SCREEN	15		Screen

Waveform Capture ASCII Data Format

40.5477,-74.3811,4,0,13:01:23,650,-51,-87,..-88 CR LF

40.5477,	Latitude (deg, negative if South)
-74.3811,	Longitude (deg, neagative if West)
4,	GPS Lock status
0,	Genlock Status
13:01:23,	Time (DUET RTC)
650,	Time (DUET RTC)- milli seconds
-51,	Channel Power
-87,	dBm - waveform sample 1
.	.
.	.
-88	dBm - waveform sample 1020
CR	carriage return (0DH)
LF	carriage return (0AH)

Note: The time between each waveform capture sample (1 thru 1020) is 1/4 chip time.

Tsample = (1/chip clock frequency)/4

Binary Save Structures

```
struct setup {

        byte chip_clock;        /* chip clock setup */

        byte num_chip_clk;
        float base_chip_clk;
        float cur_chip_clk;
        dword base_freq;
        dword top_freq;

        byte data_clock;        /* data clock setup */
        byte walsh_select;      /* walsh code setup */

        char phone_number[17];          /* modem phone # */

        word seed0[5];                  /* pn seed 0 */
        word seed1[5];                  /* pn seed 1 */

        word measure_mode;              /* cursor mode */
        word gps_save;                  /* gps save flags */

        int magnify_y;                  /* y scale mag factor */
        int magnify_x;                  /* x scale mag factor */

        int setup_index;                /* index into dsp_set_table[] */

        dword rf_freq;                  /* rf frequency */

        int t_color;                    /* text color */
        int d_color;                    /* draw color */
        int b_color;                    /* border color */
        int bck_color;                  /* background color */

        long meas_tag;                  /* measurement tag # */
        long meas_marker;               /* measurement marker */

        int data_log;                   /* data log on-off */
        int output_mode;                /* 1 = ASCII, 0 = binary */
        word baud_rate;                 /* data log baud rate */

        word rom_ver;                   /* v1.05 - rom version added */

        word gen_lock;                  /* v1.08 - genlock option */
};

        struct lat_lon {
                float   deg_lat;                // deg lat
```

```
        float   dec_lat;                // decimal minutes
        char    qlat;                   // quad ('N' or 'S')

        float   deg_lon;                // deg lon
        float   dec_lon;                // decimal minutes
        char    qlon;                   // quad ('E' or 'W')
};


struct altitude {

        float   alt;                    // altitude
        char    ualt;                   // 'M' - meters
};

struct n_save_peak_data {

        float sp_db[13];        /* peak data dbm */
        float sp_t[13];         /* delay times relative to strongest peak */

        float sp_cur_db;        /* db level at moving cursor */
        float sp_cur_t;         /* delay time relative to strongest peak */

        byte sp_tot_pwr;        /* v1.08 rom - total power */
        byte sp_resv;           /*   "       - reserve */
};

struct save_ber_data {

        float ber_db;           /* ber level */
        float ber_avg;          /* ber */
        float ber_t;            /* ber time relative to peak 1 */
};

struct save_trigger_data {

        byte trig_tot_pwr;      /* total power */
        byte trig_data[1020];   /* trigger data db */
};
```

Fast Fade Measurement

Measure and save the strongest 13 peaks 100 times per second and save on the PCMCIA card and send to serial port (if DATA LOGGING is ON). 2 Meg PCMCIA card can save 12 minutes of data, serial port storage is limited only by the size of the PC disk (in order to save data using the serial port, DATA LOGGING must be ON and baud rate set to 38.4k).

Fading data is measured using the 127 PN (Transmitter must also be set to 127 PN) and times 2 over sampling (multipath measurement uses times 4 oversample). Data saved is the raw peak values in ascending order and time offsets of each peak.

example of data saved in fast fade, 1 peak

```
struct fade {
        word level;     /* peak sample value */
        byte posit;     /* position in time */
};
```

The total measurement consists of 100 sets of 13 peaks each as follows:

```
struct fade_rec {
        word agc;
        struct fade fm[100][13];
};
```

The 'agc' word is used to convert each peak 'level' into signal strength (dBm).

Calibration data required to convert the peak to dBm is included with the saved data.

Computing signal strength in fast fade measurement:

1) use the AGC value passed in the data to find the associated conversion factor Si.

2) for each peak level in the data compute:

```
db = 20log10(level)
```

3) compute signal strength:

```
ss = db + Si;
```

example in C (see duet.c)

```
/***************************/
float compute_level(lev, agc)

word lev, agc;

{

float Si;
float db;
double l;
int i;
        if(lev == 0)
                return(-120.0);

        /* find Si using agc */

        for(i = 0; i < (NUM_AGC_POINTS - 1); i++)
                if(agc >= cd.p_cal[i].agc_cal)
                        break;
        Si = cd.p_cal[i].pwr_conv;
        l = (double)lev;
        /* compute 20log10(level) */
        db = (float)log10(l);
        db *= 20.0;
```

```
        /* compute final signal strength by adding Si */
        db = db + Si;
        return(db);
}
```

Computing time fast fade measurement:

Time = 1/chip clock * 2

example - chip clock = 4.9152 MHz

Time = 1/4.9152*2
Time = .102us

To compute time between peak 1 and 2, sample 1:

```
peak1 = fade.fm[0][0].posit;
peak2 = fade.fm[0][1].posit;
```

T = (peak2 - peak1) * Time

To compute time between peak 1 and 3, sample 100:

```
peak1 = fade.fm[0][0].posit;
peak3 = fade.fm[99][2].posit;
```

T = (peak3 - peak1) * Time

ASCII file format for Fast Fade data (v1.12 PC software)

3\t	GPS Lock status
40.546\t	Latitude (deg, negative if South)
-74.380\t	Longitude (deg, neagative if West)
131920.00\t	GPS Time (if selected in DUET GPS SAVE SETUP)
13:04:25\t	Time (DUET RTC)
150\t	Time (DUET RTC)- milli seconds
82\t	Id byte (2 character Hex)
0	v1.12 - Genlock Status
LF	line feed (0AH)
-72.5\t 0.000\t	Sample 1, main peak dBm (delay 0.0000)
-90.0\t 15.055\t	Sample 1, peak 2 dBm, delay to main peak
-96.6\t 33.366\t	Sample 1, peak 3 dBm, delay to main peak
-108.1\t 45.573\t	Sample 1, peak 4 dBm, delay to main peak
-108.1\t 10.173\t	Sample 1, peak 5 dBm, delay to main peak
-108.1\t-27.262\t	Sample 1, peak 6 dBm, delay to main peak
-108.2\t -2.848\t	Sample 1, peak 7 dBm, delay to main peak
-108.2\t -9.766\t	Sample 1, peak 8 dBm, delay to main peak
-108.3\t-13.021\t	Sample 1, peak 9 dBm, delay to main peak
-108.4\t 2.848\t	Sample 1, peak 10 dBm, delay to main peak
-108.4\t 29.297\t	Sample 1, peak 11 dBm, delay to main peak
-108.5\t -4.476\t	Sample 1, peak 12 dBm, delay to main peak

-108.5\t-41.504	Sample 1, peak 13 dBm, delay to main peak
LF	line feed (0AH)
.	
-72.5\t 0.000\t	Sample 100, main peak dBm (delay 0.0000)
-90.0\t 15.055\t	Sample 100, peak 2 dBm, delay to main peak
-96.6\t 33.366\t	Sample 100, peak 3 dBm, delay to main peak
-108.1\t 45.573\t	Sample 100, peak 4 dBm, delay to main peak
-108.1\t 10.173\t	Sample 100, peak 5 dBm, delay to main peak
-108.1\t-27.262\t	Sample 100, peak 6 dBm, delay to main peak
-108.2\t -2.848\t	Sample 100, peak 7 dBm, delay to main peak
-108.2\t -9.766\t	Sample 100, peak 8 dBm, delay to main peak
-108.3\t-13.021\t	Sample 100, peak 9 dBm, delay to main peak
-108.4\t 2.848\t	Sample 100, peak 10 dBm, delay to main peak
-108.4\t 29.297\t	Sample 100, peak 11 dBm, delay to main peak
-108.5\t -4.476\t	Sample 100, peak 12 dBm, delay to main peak
-108.5\t-41.504	Sample 100, peak 13 dBm, delay to main peak
LF	line feed (0AH)

note: '\t' = TAB character

GPS Lock status: 0 if GPS not locked, 3-6 if gps locked, number indicates # of satellites used to compute fix.
GENLOCK status: 0 if not locked, 1 if locked

NOTE: GPS latitude-longitude,time and altitude are saved if they are turned ON using the Duet GPS save option menu. 13 peak plus position of cursor data saved. If Moving Cursor is OFF, Moving Cursor dBM and delay return value of 0.0

ASCII output during multipath measurement

Each measurement sends an ASCII TAB delimited line as follows:

05-24-96\t	Date
12:39:23\t	Time of measurement
150\t	Time of measurement - milli seconds (v1.10)
3\t	GPS Lock status
40.546\t	Latitude (deg, negative if South)
-74.380\t	Longitude (deg, neagative if West)
101112.00\t	GPS Time (GMT)
107.0\tM\t	GPS Altitude in Meters
-72.5\t	dBm - main peak
-90.0\t	dBm - second peak
-96.6\t	dBm - third peak
.	.
.	.
-110\t	dBm - peak 13

0.000\t	delay - main peak (0.0)
+2.528\t	delay in micro sec, main peak to second peak
-2.683\t	delay in micro sec, main peak to third peak
.	
.	
+16.123\t	delay in micro sec, main peak to peak 13

-72.5\t	cursor dBm
0.000\t	delay - main peak to cursor, micro sec.
f1\t	Id byte (2 character Hex)
1234\t	TAG # (v1.10)
0\t	Genlock Status
-42	Channel Power
CR	carriage return (0DH)
LF	line feed (0AH)

GPS Lock status: 0 if GPS not locked, 3-6 if gps locked, number indicates # of satellites used to compute fix.

GENLOCK status: 0 if not locked, 1 if locked

ASCII output during multipath measurement
BER On

05-24-96\t	Date
12:39:23\t	Time of measurement
150\t	Time of measurement - milli seconds (v1.10)
3\t	GPS Lock status
40.546\t	Latitude (deg, decimal minutes, direction)
-74.380\t	Longitude (deg, decimal minutes, direction)
101112.00\t	GPS Time (GMT)
107.0\tM\t	GPS Altitude in Meters
-72.5\t	dBm - main peak
-90.0\t	dBm - second peak
-96.6\t	dBm - third peak
.	.
.	.
-110\t	dBm - peak 13
0.000\t	delay - main peak (0.0)
+2.528\t	delay in micro sec, main peak to second peak
-2.683\t	delay in micro sec, main peak to third peak
.	
.	
+16.123\t	delay in micro sec, main peak to peak 13
-72.5\t	cursor dBm
0.000\t	delay - main peak to cursor, micro sec.
-90.0\t	dBm - at BER cursor
0.496093750\t	BER value
+2.528\t	delay in micro sec, main peak to BER cursor
f1\t	Id byte (2 character Hex)
1234\t	TAG # (v1.10)
0\t	Genlock Status
-42	Channel Power
CR	carriage return (0DH)
LF	line feed (0AH)

GPS Lock status: 0 if GPS not locked, 3-6 if gps locked, number indicates # of satellites used to compute fix.
GENLOCK status: 0 if not locked, 1 if locked

Notes on using DATA LOG Serial output

1) PC must be setup and ready to receive data log BEFORE Duet measurement is started. This will assure that data sent ONLY at the beginning of the measurement is captured. Setup data and calibrate data (Fast Fade) are only sent once at the beginning of the measurement.

Duet Receiver - Main Menu

Extended Version Number

The version number displayed on the main menu has been extended to include the options included in the unit as follows:

BVS DUET Receiver V1.10-F1RGW

The number after the V (1.10 in the example above) is the firmware revision number. The characters after the dash ('-') are the option code letters (F1RGW in the example above).

Option Code Letter	Option Installed
F	ATA Flash Disk PCMCIA
S	SRAM PCMCIA
1	4.9152MHz Chip Clock
2	8MHz Chip Clock
3	9.8304MHz Chip Clock
R	RSSI
G	GENLOCK
W	Waveform Capture

To convert binary data from the DUET to ascii, select PC software main menu option 4 (Duet File Operations). When the PC screen displays the Duet File Options Menu, select option 1 (Review data file asnd convert to ASCII).

When prompted

BINARY Disk File Name:

Enter the name of the binary data file to convert to ASCII.

When prompted

ASCII TAB Delimited File Name [enter for none]:

Enter the name of the file for the converted ASCII data.

(If no file name extension is entered, the extension .txt will be appended to the file name if MAPINFO or WIZARD output format is selected. The extension .xl will be appended to the file name if EXCEL format is selected).

When prompted

Press: W for TEC CELLULAR WIZARD format
E for EXCEL TAB Delimited format
M for MAPINFO-PLANET TAB Delimited format ?

Press the appropriate letter (W or E or M) to select the desired ASCII format.

NEXT:

When prompted:

Press: 1 pause display after each measurement
2 pause display at ID byte change
3 pause display with space bar

Select 3 so that the program will not pause during ASCII conversion.

The program will now display in text the data from the supplied binary file and convert it to ASCII. Press the ESC key to stop the process at any time.

Data converted up to the point the ESC key was pressed will be present in the ASCII file.

To convert the entire nbinary file to ASCII, wait for the display to stop with the message

...Press Any Key... on the top line.

Press the space bar and exit the PC program. The ASCII file is now ready for use.

TEC Cellular *Wizard* ASCII Format

FREQ	Line 1 indicates Channel measured is saved in MHz. Line 2 is blank.

Each from line 3 till the end of the file contains the following COMMA delimited data:

1,	Sequence Number
40,	Lat degrees
32,	Lat minutes
47.33,	Lat seconds
N,	Lat Hemisphere (N or S)
74,	Lon degrees
22,	Lon minutes

51.28,	Lon seconds
W,	Lon Hemisphere (E or W)
1960.00,	Channel measured in MHz
-50,	Total RF power (channel power dBm)
-50.0,	Peak 1 dBm
-63.0,	Peak 2 dBm
-64.0,	Peak 3 dBm
.	.
.	.
.	.
-77.0,	Peak 13 dBm
+0.000,	Delay of peak 1 relative to peak 1 (always 0)
+1.221,	Delay of peak 2 relative to peak 1
-1.017,	Delay of peak 3 relative to peak 1
-1.628,	Delay of peak 4 relative to peak 1
.	.
.	.
.	.
-3.255,	Delay of peak 13 relative to peak 1
97,	year
06,	month
05,	day
09,	hour
55,	minute
50.25	seconds

Note: The Sequence Number starts at 1 and is incremented on each successive line.

To create a wave form capture ascii file, select the PC main menu option 4 (DUET FILE OPERATIONS). Then select 3, VIEW WAVEFORM CAPTURE FILE. When prompted, enter the name of the file to contain the ascii data (if no extension is supplied, the extension .txt is appended to the file name supplied). If no name is entered, no ascii file is created.

Once the ascii has been specified, the waveform capture data is displayed. Press the SPACE BAR to pause the display, Esc to stop the display.

PN Setting	Length	Minimum Multipath Resolution ns			Max Unambiguous Delay			Cross-correlation S/N
		1×	2×	4×	1×	2×	4×	dB
127	127	810	400	200	103 ns	51.7 ns	25.8 ns	∞
255A	255	810	400	200	207 ns	103 ns	51.8 ns	∞
255B	255	810	400	200	207 ns	103 ns	51.8 ns	∞
511	511	810	400	200	415 ns	208 ns	104 ns	22.5
1023	1023	810	400	200	833 ns	416 ns	208 ns	16.7
2047	2047	810	400	200	1.66 ms	833 ns	416 ns	15.9
4095	4095	810	400	200	3.33 ms	1.67 ms	833 ns	13.6
8191	8191	810	400	200	6.66 ms	3.33 ms	1.67 ms	14.7
16383	16383	810	400	200	13.3 ms	6.67 ms	3.33 ms	14.7
QC I	32767	810	400	200	26.7 ms	13.3 ms	6.67 ms	15.1
QC Q	32767	810	400	200	26.7 ms	13.3 ms	6.67 ms	14.7

Table I - Receiver PN Characteristics

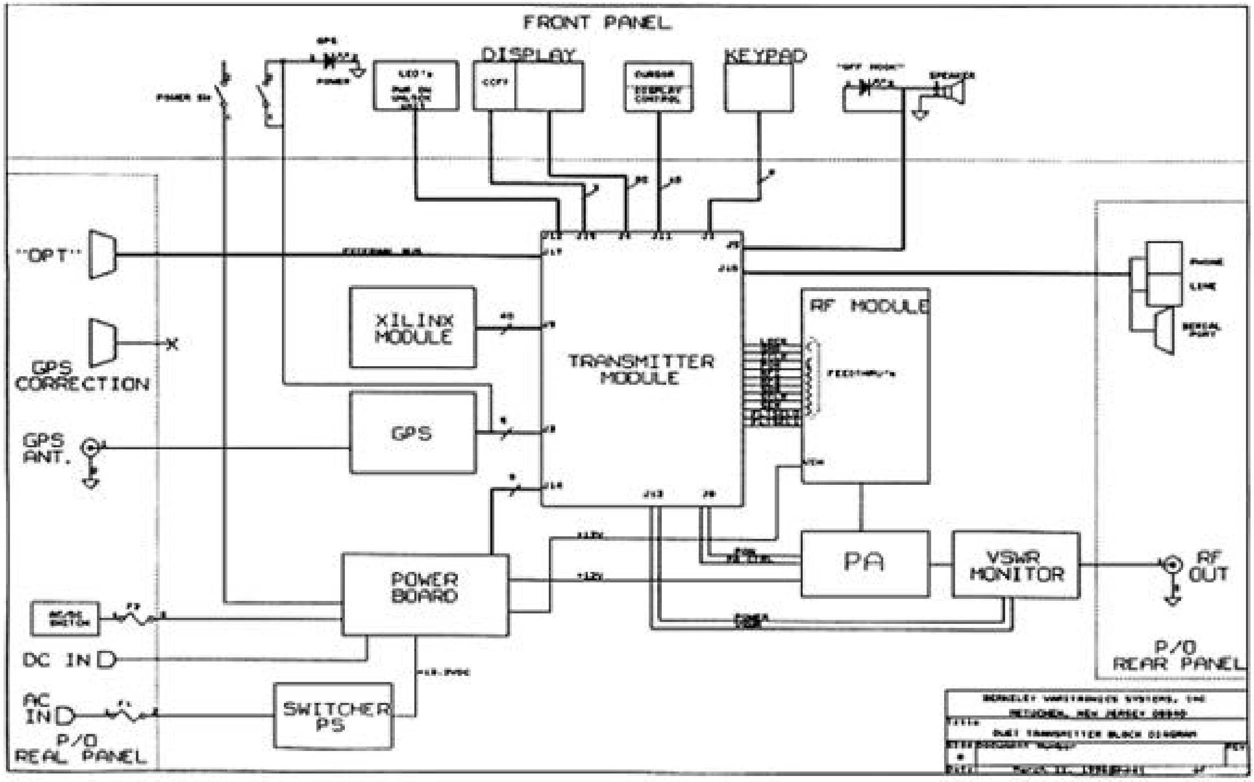


Figure3 Duet Transmitter Functional Block Diagram

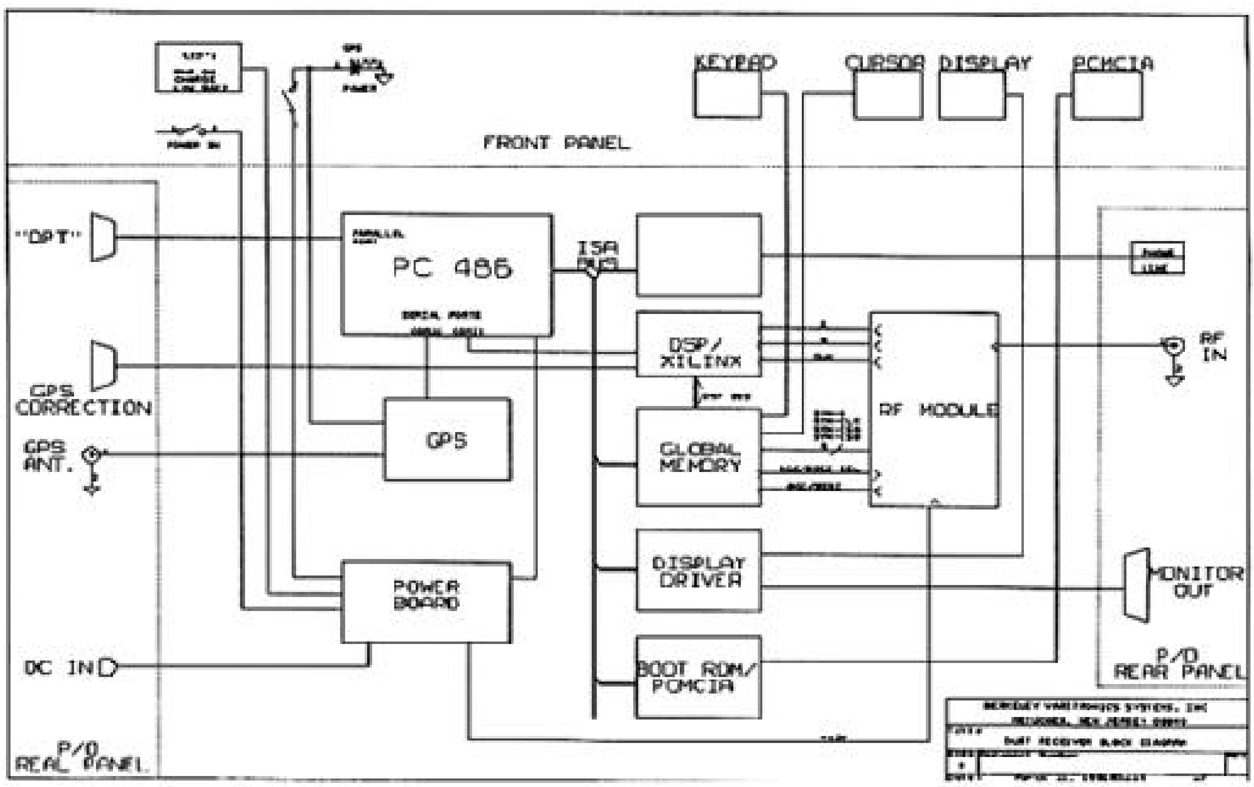
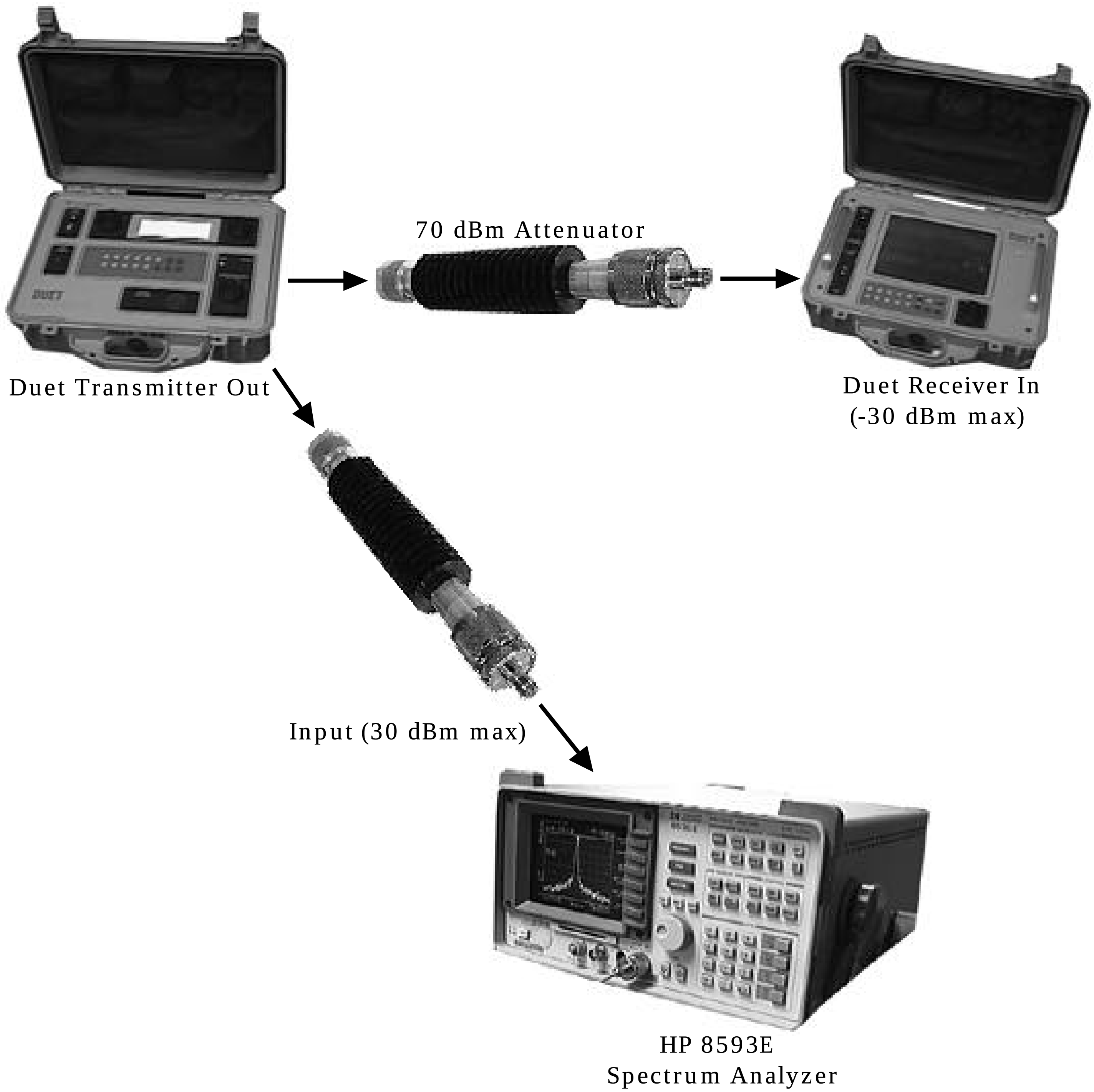


Figure 4 Duet Receiver Functional Block Diagram

Verifying Duet Receiver Calibration

Follow the following diagram if you wish to verify calibration on your receiver without assistance from BVS. BVS does provide this service free of charge to all Duet customers.



VP Oncore GPS Receiver

General Characteristics	Receiver Architecture	6 channel LI 1575.42 MHz C/A code (1.023 MHz chip rate) Code plus carrier tracking (carrier aided tracking)
	Tracking Capability	6 Simultaneous satellite vehicles
Performance Characteristics	Dynamics	Velocity: 1000 knots (515 m/s) > 1000 knots at attitudes < 60,000 ft. Acceleration: 4 g jerk: 5 m/s
	Acquisition Time (Time To First Fix, TTFF)	20 sec. typical TTFF (with current almanac, position, time and ephemeris) 45 sec. typical TTFF (with current almanac, position and time) 2.5 sec. <u>typical reacquire</u>
	Positioning Accuracy may invoke Selective	Less than 25 meters, SEP (without SA) [DoD Availability (SA), potentially degrading accuracy to 100 m (2dRMS)] DGPS accuracy 1-5 meters typical
	Timing Accuracy (1 Pulse Per Second, I PPS)	130 nanosec. observed (1 σ) with SA on In position hold mode, < 50 nanosec. observed (1 σ) with SA on
	Antenna	Active micro strip patch Antenna Module Powered by Receiver Module (25mA @ 5 Vdc) Passive antenna configuration (see optional features)
	Datums	49 std. datums, 2 user defined, default WGS-84
Serial Communication		Output Messages Latitude, longitude, height, velocity, heading, time, satellite tracking status (Motorola Binary Protocol) NMEA- 0183 Version 2.00 (selected formats) available Software selectable output rate (Continuous or Poll) Broad list of command/control messages TTL interface
Electrical Characteristics	Power Requirements	5 + 0.25 Vdc 50 mvp-p ripple (max)
	"Keep-Alive" BATT Power	External 2.5 V to 5.25 V 15pA (typ.) 6OpA (max) 3V on-board battery@ 15pA (typ.) 60@A (max)
	Power Consumption	1.1 W@5v

Physical Characteristics	Dimensions	Receiver 2.00 x 3.25 x 0.64 in. [50.8 x 82.6 x lb.3 mm]
		Active Antenna Module 4.01 (dia.) x 0.89 in. [102 (dia.) x 22.6 mm]
	Weight	Receiver 1.8 oz. (51 g) Active Antenna Module 4.8 oz. (136.2 g)
	Connectors	Data/Power: IO pin (2x5) unshrouded
	header on 0. 100" centers	
		RF:Right Angle OSX (subminiature snap-on)
	Antenna to Receiver	Single coaxial cable (for active antenna-6 dB max loss at L1
	Interconnection	1575.42 MHz)
Environmental Characteristics	Operating Temperature	Receiver Module -30'C to +85'C
	Humidity	95% noncondensing +30'C to +60'C
	Altitude	60,000 ft. (18 km) (max) > 60,000 ft. (18 km) for velocities < 1000
	knots	
Miscellaneous	Optional features	1 PPS timing output Raw measurement data On Board Rechargeable Lithium battery On board LNA option for use with passive
	antenna	
	DGPS	Differential GPS-standard software feature RTCM-104 format (remote input) Motorola custom format (master output and remote input)

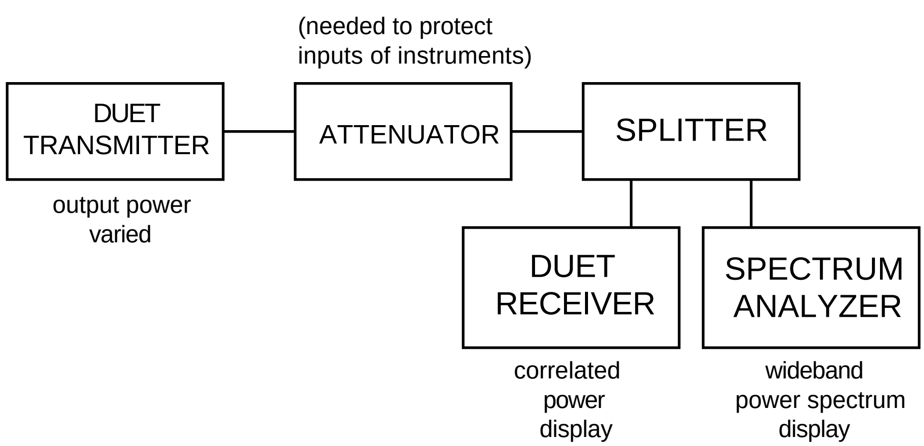
Duet Receiver vs. Spectrum Analyzer

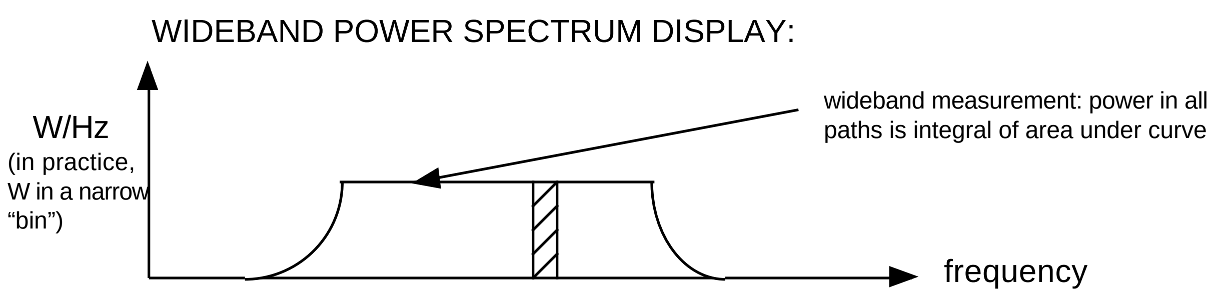
The Duet signal is a PN-coded, shaped BPSK waveform. The spectrum analyzer display should show an approximately rectangular spectrum whose bandwidth is approximately the chip rate of the PN code. Actually, modern spectrum analyzers perform and FFT and the display is of the magnitude of the FFT coefficients-estimates of the power contained in a small “bin” or frequency interval.

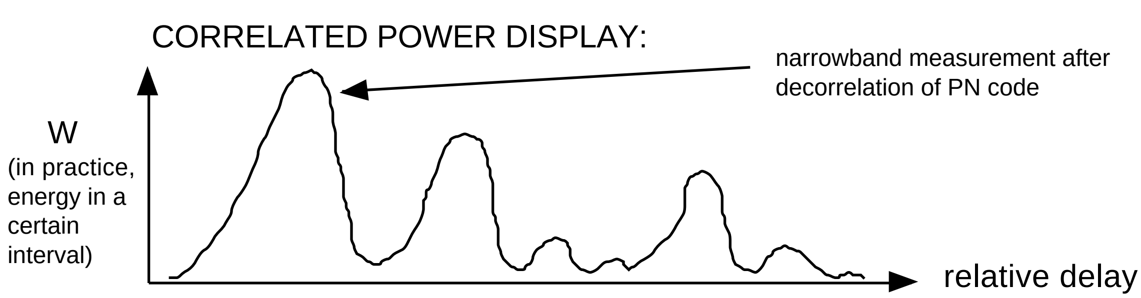
The spectrum of the Duet signal contains all the multipaths on top of one another. An average power measurement of their sum will theoretically be the sum of the powers in the paths, but over a short term there can be fluctuation due to interference between the paths.

The Duet receiver acquires the PN-coded Duet transmitter waveform by correlating it with the same baseband PN-coded waveform that was sent. The time of the first arrival is taken as a reference, and the Duet receiver displays a measure of the magnitude of the correlation between the received waveform and the local replica of the PN code. Multipath components show up as correlations at nonzero displays.

The value of the correlation measurement depends on the interval over which the correlation is performed. The Berkeley Varitronics engineers have carefully calibrated the display so that the peak values of the correlated power display agree with the power in a single path as measured in the laboratory under carefully controlled conditions.







Magnet Mount Antenna Series (Pat-Pend.)

For PCS, ISM & High Frequency Applications (Recommended by BVS for use in their Duet CDMA package)

E Built in ground plane improves high frequency performance

_ 5 dBi Gain overcomes signal losses, Unity gain also available

_ Available from 1700 - 2600 MHz

_ Low Profile, 2" powerful magnet securely holds antenna

Applications
Mobile Mark's high frequency Magnet Mount antennas are useful for many applications including surveillance work, PCN/PCS, ISM/Data and other high frequency applications. It's unique design features allow the antennas to overcome many of the problems normally associated with higher frequency systems.

Unique Electrical Desiqn
These high frequency antennas have an integral ground plane imposed at the feedpoint. This design overcomes the typical ground decoupling that occurs at the higher frequencies. The 5 dB gain model also compensates for typical system losses that occur at these higher frequencies. Because the antenna has it's own built-in ground plane, it is not required that it be mounted on a metal surface. For appropriate applications, a unity gain (O dBi version is also available).

Low Profile Aerodynamic
These antennas are very small in design and appearance. A powerful mini magnet (only 2") holds the antenna securely at all times. The 3" round integral ground plane can serve as a removal handle. The Low profile 5 dB whip with close winding phasing coil reduces potential whistling noise. These antennas can be mounted on virtually any surface. A metal surface will provide best contact with the powerful magnet.

5 dB Gain Models	**Unity** Gain Models	**Factory tunable in range**
IMAG5-1800	IMAGO-1800	1700 - 1900 MHz*
IMAG5-1900	IMAGO-1900	1800 - 2000 MHz*
IMAG5-2400	IMAGO-2400	2400 - 2600 MHz*

* Please specify center frequency when ordering. Other frequencies available upon request, consult factory to discuss your unique requirements.

Product Specifications

Frequency:	1700 - 2500 MHz, factory set for center frequency	**Mount:**	ABS plastic & metal
Gain:	5 dBi or 0 dBi	**Whip Material:**	17-7 stainless steel with chrome plating
Bandwidth:	140 MHz @ 2:1 SWR		
Impedance:	50 Ohm nominal	**Cable:**	RG -BX low loss or better, 10 feet.
Maximum Power:	10 Watts		
Whip Length:	7 inches maximum - 5 dBi maximum - 0 dBi	**Connector:**	TNC standard, UHF or 2 inches N connector upon request

Glossary of Acronyms

AC	alternating current
A/D	analog to digital converter
AGC	automatic gain control
BER	bit error rate
BPSK	binary phase shift keying
BW	band width
CDMA	Code Division Multiple Access (spread spectrum modulation)
DC	direct current
D/A	digital to analog
dB	decibel
dBm	decibels referenced to 1 milliwatt
DOS	digital operating system
DSP	digital signal processing
FIR	finite impulse response
GHz	gigahertz
GPS	geographical positioning system (satellite based)
GPS diff.	GPS error correction signal which enhances GPS accuracy
IF	intermediate frequency
I and Q	In phase and Quadrature
kHz	kilohertz
LCD	liquid crystal display
LO	local oscillator
Mbits	megabits
MHz	megahertz
modem	acronym for modulator/demodulator
PCMCIA	personal computer memory card international association
PC	personal computer
PCS	personal communications service (1.8 to 2.1 GHz)
PN	pseudo noise
QPSK	quaternary phase shift keying, 4-level PSK
RF	radio frequency
RSSI	receiver signal strength indicator
UTC	universal coordinated time
VAC	volts alternating current
VGA	video graphic

If you require technical assistance, or service to your Duet Channel Sounder, please contact:

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