Operating Manual

ADVANCED CHANNEL EMULATOR ACE9600

For use with ACE
firmware version 0.970

dBm

RF Test Equipment for Wireless Communications

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Preface

This manual contains operation instructions and reference information for the **dBm** ACE9600. The ACE9600 reproduces link effects found in communications between earth stations and satellites.

This manual is prepared as a reference source for engineers and technicians to use the ACE9600 as part of their earth station/satellite transceiver design and testing.

The ACE9600 operations manual is divided into the following sections:

- **Section 1: Introduction** shows the ACE9600 equipment, control and connector locations, and describes external interfaces.

- **Section 2:   Local Operation** describes how to operate the ACE9600 from the front panel.

- **Section 3: Remote Operation** shows how to operate the ACE9600 through the LAN interface.

- **Appendix A: Installation and Troubleshooting** describes installation procedures and lists error messages.

- **Appendix B: Description and Specifications** gives an overview of the ACE9600 technical design and provides technical specifications, and verification testing .

- **Appendix C: Maintenance and Warranty** describes the ACE9600 warranty and directs how to return the ACE9600 for repair or calibration.

Conventions Used in This Manual

Text Conventions

This manual uses the following text conventions:

- *Italic text* indicates new terms, directories and/or filenames.
- <u>Underlined Text</u> indicates ACE9600 selections or key presses.
- Monospaced text indicates ACE9600 commands entered through remote mode.
- **Bold monospaced text** indicates ACE9600 responses through remote mode.

Symbols

The following symbols appear in the manual.

See also,

This symbol and its "see also" text is placed next to subject matter in the manual to tell you where to find more information.

*This icon indicates a **warning**. Failure to follow the instructions given here may result in **personal injury** or **damage to the equipment**.*
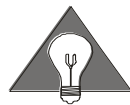
*This icon indicates a **tip**. Text marked this way may be an optional procedure for accomplishing a task, or a time-saving procedure for advanced or familiar users.*

Contacting **dBm**

We encourage you to contact us if you want more information or have any questions or concerns about this or any other dBm product or manual. Use any of the following methods:

Mail	dBm
	32A Spruce Street
	Oakland, NJ 07436
Telephone	(201) 677-0008
Fax	(201) 677-9444
E-mail—Technical Support	Info@dbmcorp.com
www	http://www.dbmcorp.com

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Introduction Section

Introduction

This section introduces you to the Satellite Link Emulator instrument and describes the physical interface and turn-on procedure.

Topics include:

- ACE9600 functional overview
- Front and rear and interior views.
- External power and cable connections.
- External Interface Descriptions
- Power-up and shutdown procedures.

General Information

Functional Overview

ACE9600 reproduces link effects that occur as signals propagate though the atmosphere and space. These link effects include propagation delay, carrier Doppler shift, chip rate shift, path loss, ionospheric scintillation, mutipath fading , and troposcatter effects. The ACE9600 reproduces those effects by generating time varying delay, attenuation, carrier Doppler shift, phase shift, AWGN, and 12 path multipath fading.

The ACE9600 also has the capability to emulate distortions caused by hardware. Those distortions include signal compression, intermodulation, and AM/PM that result from power amplifier non-linearities, additive phase noise that results from non-pure local oscillators and clocks, group delay slope and amplitude slope that result from band limiting filters and multiplexers, and spurious signals that may be generated in internal signal sources or from external interfering sources.

The ACE9600 allows the user to set these parameters to fixed values. This is the Static mode of operation. In Dynamic mode operation, delay, attenuation, Doppler shift, phase offset, AWGN, and multipath fading can be varied in real time to emulate changes in the relative position of communication platforms (the remaining parameters remain at a fixed setting during dynamic operation). The values of the parameters are controlled by data files that can be generated by the user or via SATGEN, an application that creates the files based on ephemeris satellite data, mobile and fixed ground terminals, ground vehicles, and aircraft. Carrier Doppler, attenuation, and additive white Gaussian noise can be varied at time intervals ranging from 1 msec to 1000 msec. RF frequency and multipath fading parameters can be executed at time intervals between 10 msec and 1 second. The number of points per file is limited only by the removable on-board SD card memory size. The RF output signal remains phase continuous during all dynamic updates. The time varying delay causes chip rate variations.

The RF interface of the ACE9600 can be configured as either a fixed IF frequency, or tunable over the L-band range of 800 – 2600 MHz. When L-band is included, the RF frequency can be set to a fixed value, or when dynamic mode is active, the RF frequency can also be varied in real time.

Front Panel View

All local control is done via a touch sensitive graphics panel.

Figure 1-1. Instrument Front Panel View

Front view shows a four channel model. Multiple channel models have two Type N (f) connectors for each channel.

For custom ACE9600 units, consult additional documentation provided with the instrument.

Rear Panel Connections

Figure 1-2. Instrument Rear Panel View

10MHz Ref input: BNC (f) connector, termination impedance: 50 ohms, AC coupled.

Input level: sine, 0 dBm to + 3dBm

(ACE9600 will automatically switch to its internal reference if no external reference is present)

Update Clock input: BNC (f) connector, termination impedance:130 ohms Thevenin equivalent to 1.3VDC, DC coupled.

Input level: Logic 0: -0.1V to +0.6V/Logic 1: 1.5V to 3.3V

Trigger input: BNC (f) connector, termination impedance:130 ohms Thevenin equivalent to 1.3VDC, DC coupled.

Input level: Logic 0: -0.1V to +0.6V/Logic 1: +1.5V to +3.3V

IEEE-802.3: RJ45 connector, TCP/IP LAN interface per the IEEE-802.3 standard.

RS-232: DB-9P connector, interface per RS-232. Pin 2: Tx, Pin 3, Rx, Pin 5, ground. All other pins are not used.

UART A/B/C: DB-9P connector. Proprietary interface to synchronize timing of up to four ACE chassis.

UART D: DB-9P connector. Proprietary interface to control external microwave frequency converters.

MLVDS A/B: Proprietary interface for high speed interchange of data between up to four ACE chassis.

USB: Factory use only

Start and Shutdown Procedures

Starting the ACE9600

Press the Line on/off switch on the rear panel. Move the front panel power switch to the on position. The LCD display will illuminate.

The instrument is usable immediately. However, it is recommended to allow approximately 30 minutes warmup, then press *Preset* for best performance.

Shutting Down the ACE9600

Move the front panel power to the standby position. There may be a short delay before the instrument powers off.
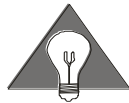
If the ACE9600 is going to be off for an extended period of time, you may wish to remove the main power by pressing the Line on/off switch on the rear of the instrument.

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Local Operation Section

Local Operation Overview

 The ACE9600 is a laboratory instrument designed to apply impairments to an RF signal, simulating the effects that are encountered in a space based and/or terrestrial wireless channel. The link impairments include a) delay, b) frequency offset (carrier Doppler shift), c) attenuation, d) phase offset, and optionally e) white noise f) frequency selective multipath fading, and g) tunable L-Band frequency control. The optional hardware impairments include a) distortion effects- AM/AM, AM/PM, harmonic distortion and intermodulation b) group delay variation, c) amplitude ripple variation, d) phase noise, and e) spurious signals.

The instrument is fully controllable from either the front panel or remotely via LAN. The local front panel control is implemented via an 8.4" touch display graphic display.

On power-up, the state of the instrument is static mode. The input signal will pass through the instrument, and the current effects, as displayed on the front panel, are applied to the signal.

When in dynamic mode, the user can select data files that control the impairment values, changing them at a given update rate. The user selects either an internal parameter update rate or applies an external update clock to set the time intervals. Each rising edge of the update clock causes the next point in the data file to be implemented. An external start signal can also be used to accurately trigger the execution of the data files.

Using the touch panel typically requires touching a soft key to enact its function, or touching a value field to enable editing of that value.

Operating States

Power up and Reset

Upon power-up or preset, the instrument is set to the default static state. The display will momentarily (10 sec) display a graphic while the hardware is initializing.

Static

Static (non-varying) values for link impairments are applied to the RF input signal. Additional optional link impairments include additive noise (AWGN), tunable L-band frequency control, and multipath fading. Optional hardware impairments include gain compression, AM/PM conversion, group delay distortion, amplitude ripple, phase noise, and spurious signals. The signal propagates through the instrument and appears at the output with the impairments applied. The user can modify any of the link impairments by entering a new value, or by using the Step+ key or Step- key. The step size is set in the Step Size menu.

Dynamic

Data files can be downloaded into the instrument through the LAN interface and stored on a removable SD card. These files control the values for each of the link impairment parameters. Each parameter type in each channel can be loaded with the internally stored parameter data files. Upon receipt of a Start command, the instrument sequentially executes the values in the parameter data files. There are seven file types per channel, and therefore up to twenty-eight files (for a four channel instrument) can be implemented simultaneously and synchronously with the same update clock. At each rising edge of the update clock, the next data point in each file is executed.

When the Start command is issued, the instrument begins executing the data files. A universal start command is simultaneously issued to all channel hardware to insure a synchronous start. If no parameter file is selected for a particular impairment, that parameter will remain at its static value. When the Reset command is received via the LAN or front panel, data implementation is immediately stopped and the instrument returns to the initial data point. When a Pause command is received via the LAN or front panel, data implementation is immediately stopped, parameters are halted at that point, and the current parameter values are displayed on the front panel of the ACE. When in pause mode the Step Fwd key or Step Back key can be used to step through the parameter files at a definable time increment. Pressing the *Start* key from the PAUSED or READY state begins execution from the current point in the file.

Front Panel Display Navigation:Link Emulation

Figure 2-1 illustrates the Static mode navigation keys found on all of the static mode displays.

The *Go To Dynamic* (and conversely the *Go To Static*) mode key is used to switch between Static mode and Dynamic mode.

The *Hardware Emulation* (and conversely the *Link Emulation*) key is used to access the hardware impairments and the link impairments respectively.

The *Preset* key resets the instrument to a known state.

Figure 2-1. Static Mode Navigation Controls (Delay key not shown)

Navigation in Static Mode

Soft touch keys are used to switch between four main menus, which are:
- Delay
- RF frequency (key is labeled *RF*)
- AWGN
- Multipath Fading (key is labeled *Fade*)

AWGN and Multipath Fading are optional features. The navigation keys will be visible even when the feature is not installed.

Navigation in Dynamic Mode

Soft touch keys are used to switch between three main menus, which are:

- Delay
- RF frequency (key is labeled *RF*)
- Multipath Fading (key is labeled *Fade*)

Figure 2-2. Dynamic Mode Navigation Controls (Fade key not shown)

Editing Parameter Values

Parameters are selected for editing by pressing the parameter field on the touch sensitive display. When touching a parameter, the instrument responds with an audible beep, and the background of the selected field is highlighted. The user then enters the new numeric value via the keypad, ending the entry with a units key (ms/MHz, us/kHz, or Enter for ms/Hz/dB). After a units key has been pressed, the new value is stored and editing is complete. Anytime a parameter field is highlighted, that field can be edited. If another parameter key is pressed prior to pressing a units key, the highlight immediately moves to the appropriate field and the original parameter is not overwritten.
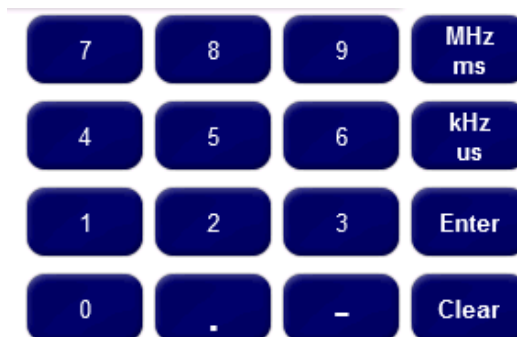
Figure 2-2. Keypad

Units Keys

When the data field to be edited is selected and a numeric value typed, the data must be entered by pressing one of 3 possible units keys. The key assigns the order of magnitude to the data entered as follows:

Key	*units*
Enter	ms, Hz, degrees, dB, dBm, dBm/Hz, ratio
us kHz	us, kHz
ms MHz	ms, MHz

Use of the Clear Key

The Clear key is used to delete a new numeric value prior to pressing an enter key.

Example
- Press delay value to select that delay field. Type a value for delay.
- Press *ms/us/Enter*. The new value is entered.
- Press *Delay* and enter a value for delay. The characters appear as the new value is typed.
- Press *Clear*. The previous delay value appears.
- Press *Clear* again to disable editing

Change the sign of a value

Press "-" prior to a numeric value while editing a parameter to change the sign of the entered value.

Utility Keys
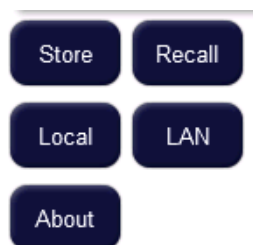
Figure 2-3. Utility Keys

The *Store* and *Recall* keys navigate to their respective settings display.

The *Local/Remote* key toggles the ACE between local front panel control and LAN based remote control. The text on the key will change to indicate the current state.

The *LAN* key invokes the instrument's ethernet configuration display.

The *About* key invokes the instrument's hardware configuration display.

To view the instrument's hardware configuration
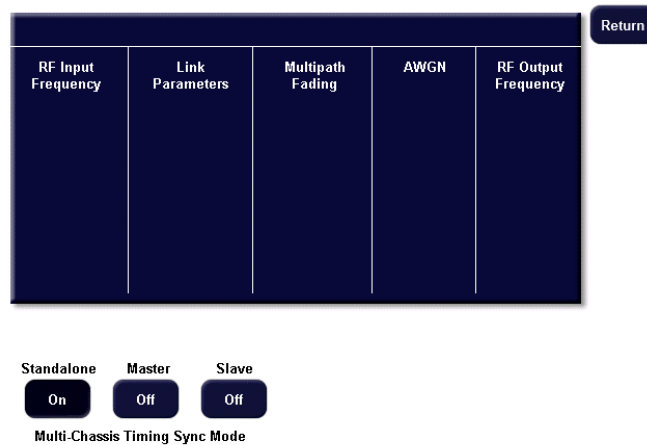
Figure 2-4. The About display

The Multi-Chassis Timing Sync Mode provides the ability to synchronously start up to four chassis' in dynamic mode. Press one of the three radio buttons to configure the instrument as Master, Slave, or Standalone. For a detailed description, see Multi-Chassis Synchronization under Dynamic Mode Control.

To store the instrument settings

Pressing *Store* activates the Store Settings display. A storage register contains all Instrument State settings, static parameter values, Update Rate, RF Center frequency, step sizes, and loaded Dynamic file names. It does not retain the current channel selection, Mode, elapsed time, or Start/Reset/Pause status.

1. Press the *Store key*. The store utility display appears. Press the number of the desired register to be updated. Store can be invoked from Static or Dynamic modes.
2. Press a number from 1-8, designating a register to store the current instrument settings. Register 0 (labeled *Preset State*) defines the power up and Preset state. The register is overwritten.

3. Press *Return* to exit the store utility menu. Note: Register 9 is not available to store settings as this always contains the factory defaults.
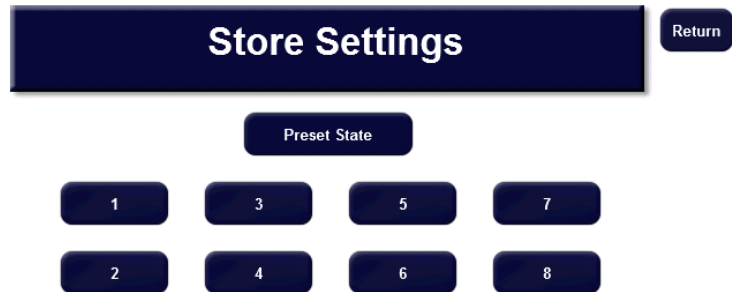
Figure 2-5. Store display

To recall a saved instrument setting

Pressing the *Recall* key activates the Recall Settings display. A storage register contains all Instrument State settings, static parameter values, Update Rate, RF Center frequency, step sizes, and loaded Dynamic file names. It does not retain the current channel selection, Mode, elapsed time, or Start/Reset/Pause status.

1. Press the *Recall* key. The utility display appears. Press the number of the desired register to be loaded. Recall can be invoked from Static or Dynamic modes.
2. Press a number from 1-8, designating a register to recall instrument settings. Register 0 (labeled *Preset State*) contains the power up and Preset state. Register 9 (labeled *Default*) contains factory defaults.
3. Press *Return* to exit the Recall Settings display. If the recalled register invokes Dynamic file names that are no longer on the ACE internal memory, then a "file missing" error is displayed and those parameters are set to the default value.
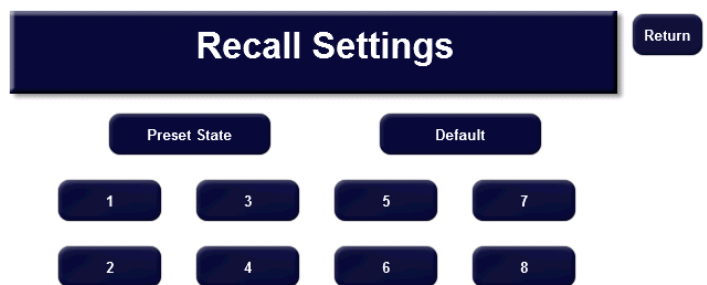
Figure 2-6. Recall display

To configure the instrument's LAN port

1. Press *LAN* key. The network utility display appears.

2. Press the IP address data field. Enter the desired IP address and then press *Enter*, or press <u>*Clear*</u> to revert to the previous value.
3. Press the Submask address data field. Enter the desired submask value, then press *Enter*, or press *Clear* to revert to the previous value.
4. If applicable, press and enter the Gateway address, then press *Enter*, or press *Clear* to revert to the previous value. Otherwise leave it at the default.
5. The MAC address is unique for every instrument, and cannot be modified.
6. After editing, press *Return* to store the new values and return to the main menu.
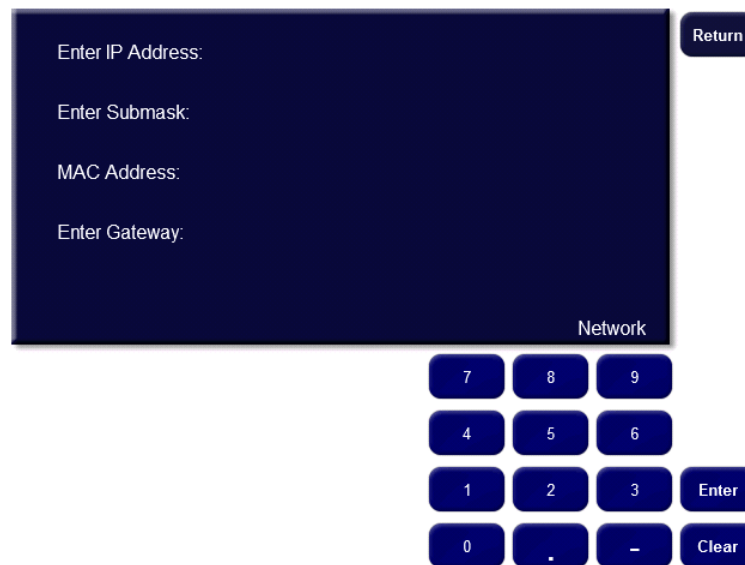
Figure 2-7. LAN display

To set the instrument to local or remote (LAN) control

The *Local/Remote* key toggles the instrument between local and remote. During remote LAN operation, all keys except *Local* are disabled. If currently in local mode, go to remote mode by pressing the *Local* key on the front panel. The key text will change to *Remote*.
If in remote mode, pressing the *Remote* key brings the instrument back to the local mode and activates the front panel keys. The key text will change to *Local*.
When a LAN socket is established, the instrument automatically changes to Remote mode.

To preset the instrument settings

Pressing *Preset* causes the instrument to return to the default state which is defined by the contents of the Preset State register.

Set Static Step Size (Delay, Attn, Freq Offset, Phase Offset, RF, and AWGN,)

The Step Size display allows static parameters to be incremented or decremented by a selectable delta.

Figure 2-8 Static Step Size display

Press the *Step Size* key once to invoke the step menu.
Press the desired parameter field to highlight the parameter. Use the keypad to enter a numeric value (valid ranges and resolutions are same as the corresponding parameter).
Press the appropriate units key to enter.
Press the *Return* key to return to the main display.
A unique step size is saved for each parameter type, and each parameter step size can be unique for each channel.
Note that if the entered step size exceeds the realizable limit, the value will be set to the valid limit.
The following step sizes may be defined

Delay	0.1ns to 2,000ns
Attenuation	0.10dB to 70dB
Frequency Offset	0.01Hz to 6,000MHz
Phase Offset	0.1 to 359.9 degrees
RF Frequency	1 to 2999 MHz
AWGN	0.1 to 60 dBm/Hz

Max delay change with slewing enabled

A threshold value can be entered to define whether delay changes are implemented as a linear slew or as an instantaneous step. A change in delay that is less than the threshold will be implemented via slewing. A change in delay that is greater than the threshold will be implemented in a single step. Delay slewing prevents phase discontinuities in the output signal. The delay slew rate is fixed at 2 msec/sec. The Delay

step function eliminates the transition wait time, but creates a phase discontinuity in the output signal. The threshold value for selecting slew versus step can be set from 0 to 700 msec.

Step + and Step - Keys

In Static mode, press the desired link parameter field. The background of that field will be highlighted. Then press the *Step +* or *Step –* key and the value changes by the selected Step size amount. Once stepping is completed, press *Clear* to exit the step mode.

Note: During operation, if step forces a parameter out of range, the value will be set to the allowable limit.

Static Delay Operation

When the mode is set to static, each of the link parameters is displayed and implemented immediately upon entering Static mode. The parameter values in each channel can be set independently of other channels.

A unique step size can be set for each of the link parameter types. The *Step +* and *Step -* keys change the parameter by its step size value.
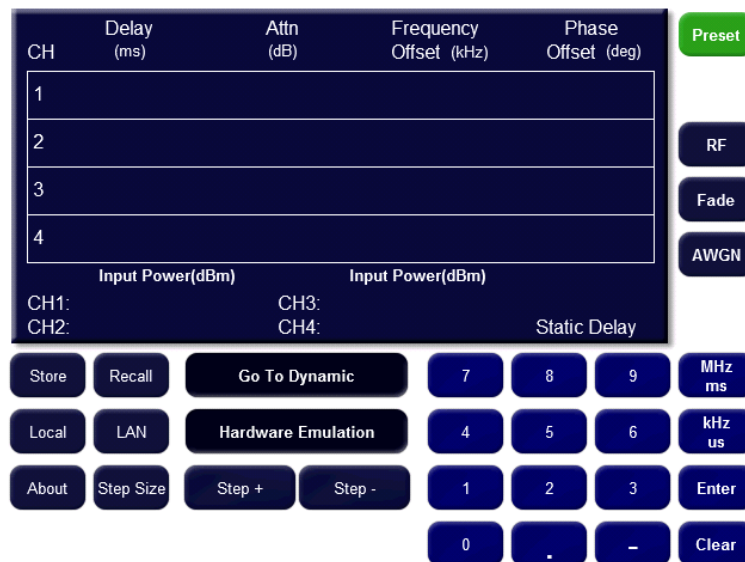
Figure 2-9 Static Delay display

Figure 2-9 shows the front panel display in static mode. Each of 16 parameter fields can be edited by touching near the center of the value.

The lower right hand corner of the parameter grid indicates the current Display name, in this case "Static Delay".

The measured signal input power is displayed for all installed channels.

Setting Delay Display Parameters

Set Delay

Press a delay field for the desired channel (valid during Static mode only)
Press numeric value of delay
Press *ms* or *us* or *Enter* (units of ms) to enter current value.

Set Frequency Offset

Press the frequency offset field for the desired channel (valid during Static mode only)
Press numeric value (valid range: 0 to +/- 6000 kHz, 0.01 Hz steps)
Press *MHz, kHz*, or *Enter* (units of Hz) to enter.

Set Attenuation

Press the attenuation field for the desired channel (valid during Static mode only)
Press numeric value (valid range: 0.0 to 70.0, 0.10 dB steps)
Press *Enter* (units of dB) to enter.

Set Phase Offset

Press the phase field for the desired channel (valid during Static mode only.
Press numeric value (valid range: 0 to 359.9 degrees, 0.1 degree steps)
Press *Enter* to enter.

Input Power

The rms input signal power is measured and displayed. The range of the measurement is 0 dBm to approximately -50 dBm. The displayed power is a true rms value, that is averaged over a period of approximately 1 second. The word "overflow" will be displayed next to the power measurement value when the signal power exceeds 0.25 dB below full scale.

Static RF Operation

Pressing the *RF* navigation key invokes the RF display, which allows modification of the input and output RF center frequencies when the optional L-band frequency converters are installed. For IF instruments, these settings will be fixed.

If the instrument is configured to operate at L-band, these settings will control the input and output center frequency of the L-band frequency converters.
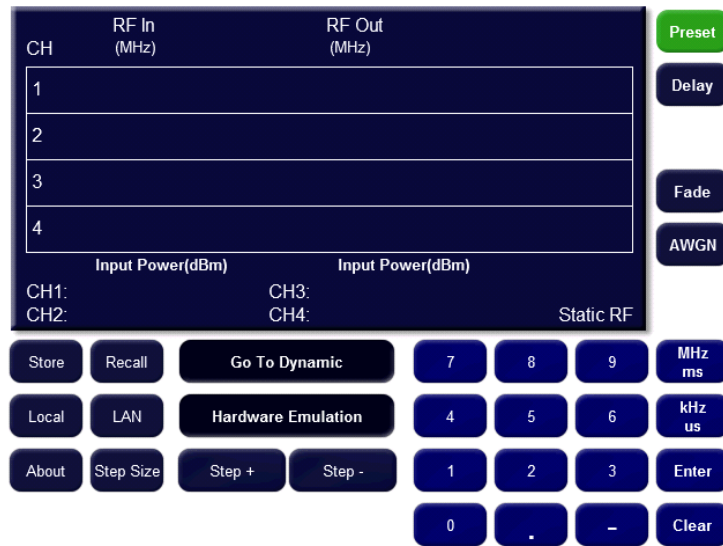
Figure 2-10. RF Frequency display

Setting RF Menu Parameters

Set the L-Band Input Frequency

Press the *RF in* frequency field for the desired channel
Enter a numeric frequency value (in MHz).
Press *MHz* or *Enter* to enter.

Set the L-Band Output Frequency (Option)

Press the *RF out* frequency field for the desired channel
Enter a numeric frequency value (in MHz).
Press *MHz* or *Enter* to enter.

Note that the output frequency is independent of the input frequency only if the instrument hardware is configured for independent input and output frequency. Otherwise, the input and output frequencies will track. For this configuration, modify the *RF in* value, and the *RF out* value will change automatically.

Static AWGN Operation (Optional Feature)

The optional AWGN feature adds white Gaussian noise to the user's signal. There are two modes of operation 1) Ratio mode that sets the noise density (N_o) based on an E_b/N_o ratio, the measured signal power, and the bit rate, or 2) Noise Density mode, that sets the noise density by direct entry, irrespective of the signal level. The noise has a constant power spectral density over the operating bandwidth of the instrument.

The ratio mode uses a true rms detector to measure the input signal power. Ratio and Bit Rate settings in combination with this measured power determine the applied noise density, such that the desired E_b/N_o ratio is achieved. The resultant noise density is displayed.

Mode is used to toggle between the two modes. Pressing the *on* or *off* value in the Enable column alternately enables and disables the noise output.

Figure 2-11. AWGN display
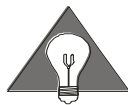
To avoid signal clipping, the power of the input signal when combined with awgn must be reduced to less than the instrument's normal maximum output power.When noise is applied, the maximum input signal amplitude (S_{max}) must be reduced to less than:
$S_{max}(dB) = 10*Log\{1-10^{\wedge(Pn/10)}\}-10$ *, where $P_n = No + 10*Log(NBW)$, and NBW is the noise bandwidth.. With AWGN at full scale, the noise power is typically -16 dBm, and the maximum applied signal power must be 10.1 dBc below full scale at the instrument input.*

Setting the AWGN Menu Parameters

Set Noise Density (Mode = N_o)
Press the noise density field for the desired channel
Enter a negative numeric value (in dBm/Hz).
Press *Enter* to enter.
Press on/off to enable/disable the noise.
If an out of range condition exists, the noise density value will be displayed with red characters.
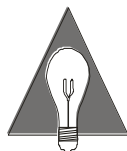
The range of control for the noise density is 60 dB. However, the usable range may be less, as it is limited by the maximum density the instrument can produce and the intrinsic noise floor of the instrument. Additionally, when AWGN is active, the channel attenuation should be limited to less than 32 dB.

Set Eb/No Ratio (Mode = E_bN_o)

Press the Ratio field for the desired channel.
Enter the desired ratio value in dB. Press *Enter*.
Press the Bit Rate field, type the desired value, then press *Enter*.
Enter the signal's bit rate. Press *Enter*.
Press the *Set Ratio* key to compute and set the noise density.
Press on/off to enable/disable the noise.
The resulting noise density is displayed, but cannot be modified directly.

The E_b/N_o ratio is set immediately when the *Set Ratio* key is pressed.
Prior to pressing the *Set Ratio* button, the Ratio value will be displayed in red characters to indicate that the input signal has not been measured. Once the measurement has been made, Ratio and bit rate can be modified, and the noise density will be adjusted accordingly, using the previous signal power measurement. If the applied signal power has changed, Set Ratio should be pressed again to re-measure the input signal power.
If an out-of-range noise density is computed, the noise density will be set to the nearest limit value, and the value will be displayed in red characters.

Static Multipath Fading Operation (Optional Feature)

The optional Multipath Fading feature applies up to 12 paths of multipath fading. Rayleigh and Rician distributions are available, as well as line of sight (Doppler shifted CW). Each path has control for the amount of spreading (via Doppler), path loss, path delay, and Angle of Arrival. Rician K-factor can be adjusted as well as correlation between paths.

From the Delay, RF, or AWGN displays, pressing the *FADE* navigation key will invoke the Multipath Fading display. Likewise, Delay, RF, or AWGN can be invoked from the Multipath Fading display by pressing the appropriate soft key.

In Static mode, the multipath display will appear as in the example figure below. Each of the Type, Doppler, Loss, and Delay parameters can be modified by pressing the touch sensitive display in the appropriate field.
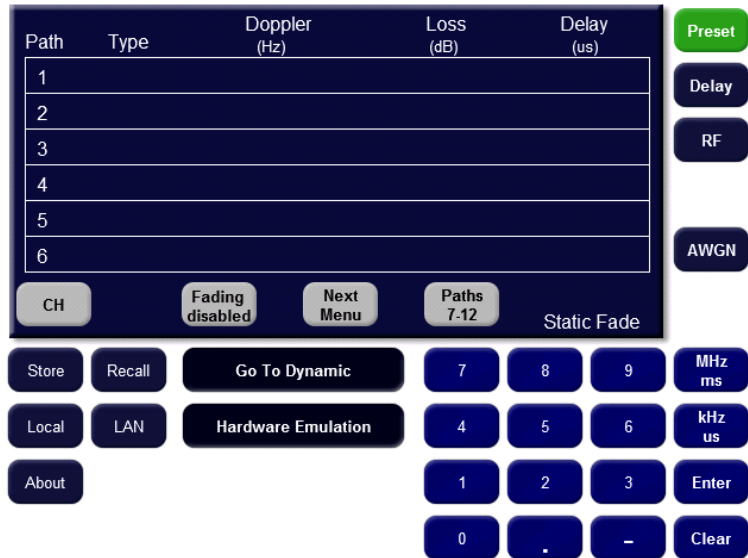
Figure 2-12. Main display for Static Multipath Fading
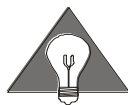
To avoid clipping when fading is enabled, the power of the signal under fading conditions must be reduced to less than the instrument's normal maximum power. When fading is enabled, the input signal must be limited to less than -6 dBm, and the resulting faded output signal power will be less than -19 dBm (dependent upon the path loss settings).

Setting the Multipath Fade Menu Parameters

Soft Keys

CH: To view settings for other channels, press the *CH* key to cycle through all installed channels. The current channel number is displayed at bottom left of the display.

Fading Disabled/Fading Enabled: Toggles between multipath fading active or bypassed

Next Menu: Rician K-factor, Angle of Arrival, correlation between paths, and Log-Normal settings can be adjusted by pressing this key to invoke the Fading submenu.

Paths 1-6 or *Paths 7-12:* Only six paths are displayed at a time. Use this key to view the remaining six paths.

Grid Parameters

Press the appropriate field, type in the desired value, followed by the *Enter* key. Pressing the Type field cycles through the available choices.

Type: displays fading type: Rayleigh, Rician, CW, or Off.
Doppler: 0-10 kHz in 1 Hz steps.
Loss: 0 – 30dB in 0.1 dB steps.

Delay: 0 – 9.996 usec in 1 nsec steps.

Multipath Submenu View

The multipath fading submenu is an extension of the fading main menu to provide the additional controls for Rician K-factor, Angle of Arrival, path correlation and Log Normal controls.

Any path can be correlated to any other path by a percentage ranging from 0%(totally uncorrelated) to 100% (fully correlated).
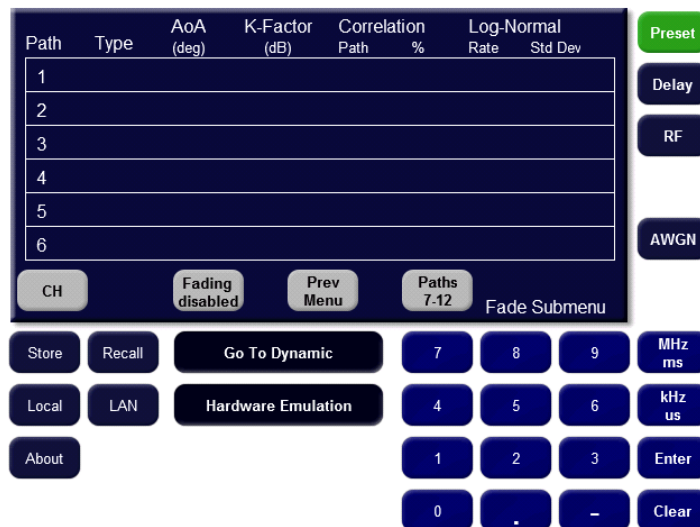
Figure 2-13. Display for the Static Fading Submenu

Soft Keys

CH: To view settings for other channels, press the *CH* key to cycle through all installed channels. The current channel number is displayed at bottom left of the display.

Fading Disabled/Fading Enabled: Toggles between multipath fading active or bypassed

Prev Menu: go to the main Fading view

Paths 1-6 or *Paths 7-12:*Only six paths are displayed at a time. Use this key to view the remaining six paths.

Grid Parameters

Type: displays fading type: Rayleigh, Rician, CW, or Off. The Type cannot be changed from this menu.

K-factor: +20 to -10 dB in 1 dB steps. Only valid for Rician fading.

Angle of Arrival: 0 to 180 degrees. Determines the frequency of the line of sight (LOS) component relative to the path Doppler. The LOS frequency is computed as *cos(AoA)*Doppler*.

Correlation Path: indicates the path to which the selected path is correlated.
Correlation %: 0 – 100% in 1% steps.

Log Normal Rate: 0 – 20 Hz, 1 Hz steps.

Log Normal Std Dev: 0 – 10 dB, 0.1 dB steps

Dynamic States

When in Dynamic Mode, the instrument will be in one of 5 states, which are displayed on the bottom right corner of the front panel display.

Ready

The instrument is initialized, and dynamic execution can begin.

Run

The instrument is currently executing dynamic files. The elapsed time counter will be incrementing.

Armed

The trigger has been set to external and the instrument will begin file execution upon receipt of a hardware trigger signal.

Paused

The instrument is paused during a dynamic run. The currently implemented parameter values are displayed. Pressing the *Step Fwd* key or the *Step Back* key will single step through the files by the defined time step. Pressing *Start* from this point will continue execution. Pressing *Reset* from this point will cause the instrument to initialize the current dynamic files.

Done

The instrument has finished execution of a single dynamic run. The last value of each parameter file is implemented in hardware.

Dynamic Mode Controls
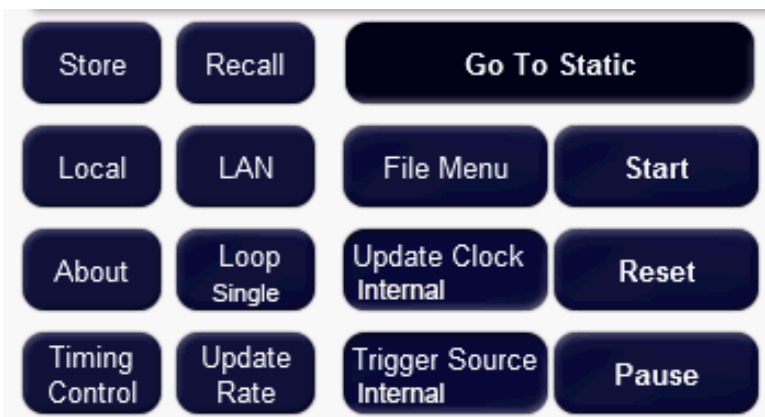
Figure 2-14. Dynamic Mode Control Keys

Loop

Press the *Loop* key to toggle between "Single" and "Continuous". In "Single", parameter files are run from beginning to end, and then execution stops, and the mode changes to DONE. In "Continuous", files are repeatedly run from beginning to end. Mode remains at RUN. Files can only be run in Continuous looping under the following conditions:

1. the first data point and the last data point in the file are identical. If Continuous is selected, and all selected parameter files do not have matching end points, Loop will automatically revert to "Single". All selected files must indicate "Loop: Continuous" in order for "continuous" to be active. If loaded files have unequal run times, the last point of the shorter file(s) is held until the last point of the longest file is executed, and then execution stops
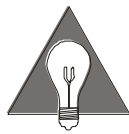
*Continuous looping only functions when all loaded file run times are equal. File run time is the number of file data points times the update rate for that file. Example: 100 data points at a 5 msec update interval is a run time of 500 msec.*

Update Rate Key

Press the *Update Rate* key to select the update rate field. The update rate field is highlighted.

Type a value for update period.

Press *Enter*. The new value is entered and the pointer disappears.

Valid values are 1, 2, 5, 10, 20, 50, 100, 200, 500, and 1000 ms. Invalid entries are rounded to the nearest valid number.

There are three update rates. The first one, controls the rate for all of the parameters that appear on the dynamic delay display, namely, delay, attenuation, frequency offset, phase offset, and AWGN. The second update rate controls the RF Frequency rate, and the third controls the multipath update rate. Each can be set on the respective display, but there is a dependency between them. See the *Dynamic Timing Control"* section for a more detailed description.

Update Clock Source Key

Press the *Update Clock* key to toggle between an internally and externally applied update clock. When set to internal, the update clock is generated internally. The internal clock is derived from an internal timer. The accuracy of the internal timer is based on the accuracy of the 10 MHz reference clock. When set to external, the instrument executes one parameter datum on each external rising clock edge, after a START signal is received. The external clock is a 3.3V logic level signal that is applied at the external timing input connector at the rear of the instrument.

Trigger Source Key

Press the *Trigger Source* key to toggle between "Internal" and "External". When set to "Internal", file execution begins when a Start command is received from the front panel or via an Ethernet command. Latency of the software generated command can cause start time uncertainty when using this type of trigger.

When set to "External", the Start command arms the instrument, and file execution begins on the 2nd update clock after the receipt of the rising edge of a 3.3V logic level trigger signal applied to the trigger

input on the rear panel of the instrument. Once triggered, parameter changes are executed on the rising edge of the update clock. Latency from trigger to actual implementation of the 1st data point is equal to two update clock periods.

File Menu Key

Use the *File_Menu* key to invoke the file display while already in Dynamic mode.

Go To Static Key

Press the *Go To Static* key to transition to Static mode. When exiting the Dynamic mode, parameter values retain the last Dynamic value. The *Go To Static* key is enabled only when the status on the front panel display shows "Ready".

Start Key

Press the *Start* key to begin Dynamic file execution at the current update rate. The displayed status on the front panel display changes to "Running". If Trigger = External, then the status on the front panel display changes to "Armed", and data is implemented only after an external trigger signal has been received. The status on the front panel display will change to "Running" after receipt of the external trigger. The *Start* key is disabled when the status on the front panel display shows "Run" or "Done". The *Start* key is also used to re-start after Pause. Pressing *Start* after Pause causes execution to continue from its current point.

Reset Key

Press the *Reset* key to stop Dynamic file execution and reset each parameter to the 1st point in the current link parameter files. Elapsed time is reset to zero. Reset must also be used to re-initialize the data files after a single run is complete and the status on the front panel display shows "Done".

Pause Key

Press the *Pause* key to stop Dynamic file execution and hold elapsed time at its current value. The displayed parameter values match the actual data implemented in hardware. Parameters are not reset. *Step Fwd* and *Step Back* keys may be used from the Paused state to single step through the dynamic files. Pressing the *Start* key causes execution to continue from its current point.

Timing Control Key

Press the *Timing Control* key to invoke the Timing Control display. Dynamic parameters can be updated in several ways:
1. Continuously at the selected update rate
2. Continuously, but starting at a point in the data files other than the first point
3. Single stepped forward or backward
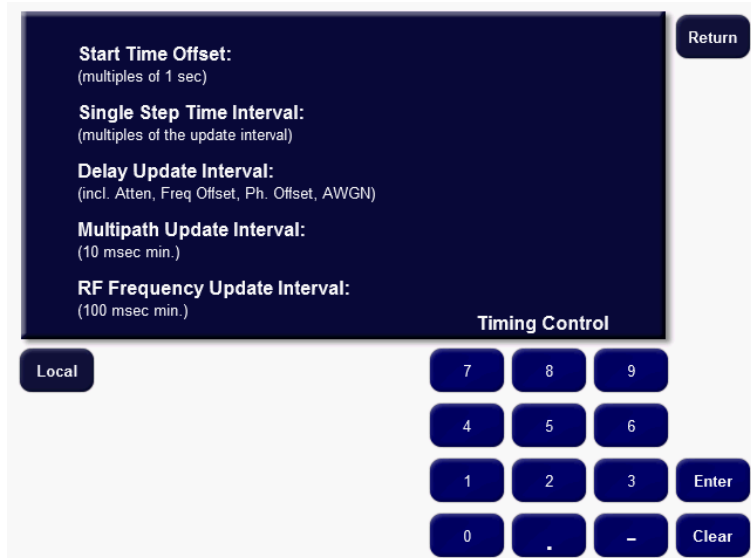
Figure 2-15. Dynamic Timing Controls display

Continuous Dynamic Update

There are three individual update rates. Each can be set on the respective parameter display or all three can be set on the Dynamic Timing Control display. There is a dependency between the update rates as described below. If an invalid combination of update rates is attempted, the instrument will force the update rates to the nearest valid settings.

The Delay update rate controls all of the parameters that appear on the dynamic delay display, namely, Delay, Attenuation, Frequency Offset, Phase Offset, and AWGN. This update rate ranges from 1 msec to 1000 msec in a 1, 2, 5, 10, 20, etc. sequence. This update rate must always be equal to or faster than the RF and multipath update rates.

The second update rate controls multipath fading. It has a range of 100 msec to 1000 msec in a 100, 200, 500, 1000 sequence, and must always be equal to or slower than the delay update rate.

The third update rate controls the RF Frequency. It has a range of 100 msec to 1000 msec in a 100, 200, 500, 1000 sequence, and must always be equal to or slower than the delay update rate.

Single Step in Dynamic Mode

Dynamic data parameters can be manually stepped using the *Step Fwd* key and the *Step back* key. Each press of the step keys affects all dynamic parameters. The step keys can be used while the instrument is in the Ready state, or the Paused state. The selected step size must always be a multiple of the least common denominator of all update periods. The instrument will automatically set the minimum possible step size if an invalid combination is entered. For example, if the delay update is 2 msec, RF Frequency is 100 msec, and Multipath Fading is 100 msec, and the step size is 10 msec, each press of the *Step Fwd* key

would move delay forward through the delay file by 5 data points, and 1 point of RF Frequency multipath Fading for every 5 presses of the *Step Fwd* button.

Figure 2-16. Dynamic Time Step Keys

Dynamic File Start Point

Dynamic data files can begin execution at other than the first file point by setting a Start Time Offset. Press the *Start Time Offset* key to modify the value. Start Times must be a multiple of 1 second. The dynamic run will begin at the data point corresponding to the start time offset. For example, if the update rate is 2 msec, and the start offset is 3 seconds, the first data point to be implemented is point number 1500 (3 sec/2msec).

Multi-Chassis Synchronization

The ACE has the capability to synchronously start a dynamic run with up to four instrument chassis' from a single user interface. A single trigger into the Master is distributed to the Slave units, to allow precise timing alignment with up to 16 channels.

Figure 2-17. Multi-Chassis Sync Mode Keys

The default setting is Standalone. The instrument will always power on and Preset to the Standalone mode. When multiple chassis are to be synchronized, one instrument must be set as Master, and the remaining instruments must be set as Slave(s). The external connections required to synchronize multiple chassis' are:

1. Connect the trigger signal to the rear panel of the Master unit.
2. Connect the Master "UART A" port to Slave #1 "UART A".
3. Connect the Master "UART B" port to Slave #2 "UART A".
4. Connect the Master "UART C" port to Slave #3 "UART A"

The UART cables must be male-male, 9 pin Sub-D connectors
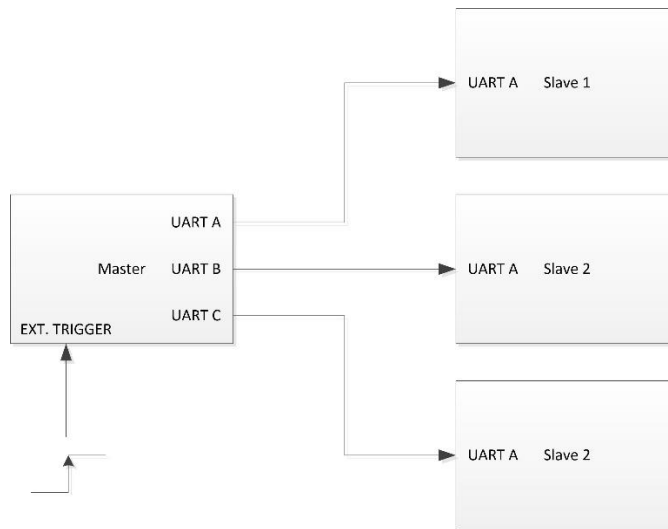
Figure 2-18. Multi-Chassis Sync Mode Keys

Set each instrument chassis to the desired Sync mode, Master or Slave. Then configure the instruments in the following order:
1. Master:
   a. Go to Dynamic mode and load the desired parameter files
   b. Set Trigger = external
   c. Press Start
2. Slaves:
   a. Go to Dynamic mode and load the desired parameter files
   b. Set Trigger = external
   c. Press Start
3. Apply the external trigger and all instruments will start.

Dynamic File Menus

Figure 2-19. File Menu #1

File Menu #1 and File Menu #2 are used to select the desired dynamic data files. File Menu #1 and File Menu #2 are invoked automatically when transitioning from Static mode to Dynamic mode. They can also be invoked using the *File Menu* key while in Dynamic mode and the status is Ready.

File Menu #1 allows the user to select files for 1) Delay 2) Attenuation 3) Frequency Offset and 4) Phase Offset. File Menu #2 allows the user to select files for 1) RF input frequency 2) RF output frequency 3) AWGN and 4) Multipath fading.

Figure 2-20. File Menu #2

Each of the parameter fields indicates the currently selected dynamic data file name for that parameter. A selection of "None" will cause the parameter to remain at its current value.

Characteristics of each file are displayed when the parameter is selected by touching the parameter field (the selected field is highlighted). Scroll through the stored file names using the *Scroll Up* and *Scroll Down* arrow keys. Pressing the *Next* advances from file Menu #1 to File Menu #2. Pressing the *Done* key loads the displayed files and returns to the main dynamic display.

Scroll Down Key
Once the file menu is displayed and a parameter field is selected, the *Scroll Down* key will cause the displayed file name to scroll downward through the list of file names that are valid for that parameter and are currently stored on the internal storage medium.

Scroll Up Key
Once the file menu is displayed and a parameter field is selected, the *Scroll Up* key will cause the displayed file name to scroll upward through the list of file names that are valid for that parameter and are currently stored on the internal storage medium.

Dynamic Delay, Attenuation, Frequency Offset, Phase Offset and AWGN Operation

Figure 2-21. Dynamic Delay display

Once the file loading sequence is complete, the display will continue to the Dynamic Delay display, and the 1st point of each file is pre-loaded

into the hardware. The delay function requires a period of time, typically a few seconds, to initialize. The background color in the delay field will be white during this initialization. Once a dynamic run is started by pressing the *Start* hard key, implementation of subsequent data points in each file begins.

While running, the displayed elapsed time counter (labeled "Time" on the display) increments. Parameter values are changed at the update rate, which is selectable from 1 sample per second, up to 1 sample per millisecond. Parameters that are changing will have a white background. Parameters, for which no dynamic file is loaded, will remain at the pre-existing value and retain the normal background color.

 Each of the parameters, Delay, Attenuation, Frequency Offset, Phase Offset and AWGN are changed synchronously at the selected update rate. When multiple parameters are being controlled by dynamic files, data point #n in each file is updated on the same update clock edge. Delay, Frequency Offset, Phase Offset and Attenuation are not changed instantaneously; rather they slew from the initial point to the final point over one update period. The slew rate can be calculated as (change in value)/(update period). Note that a file can be run at various update rates, which will result in different slew rates. An example is given below:

Delay data value	Rate of change at 1 msec update	Rate of change at 20 msec update
10.200000		
10.200010	10 nsec/msec	10 nsec/20msec
10.200110	100 nsec/msec	100 nsec/20msec
10.200010	100 nsec/msec	100 nsec/20msec

AWGN dynamic files provide direct control of the noise density output power. Note that the ACE9600 does not calculate Eb/No ratio in dynamic mode.

Dynamic RF Operation

Figure 2-22. Dynamic RF display

When the ACE9600 hardware is configured with internal L-band frequency converters, the RF input center frequency and RF output center frequency can be changed dynamically. The RF update rate must be equal or slower than the delay update rate. The maximum RF update rate is 10 msec. The RF dynamic parameter file is assigned in File Menu #2.

Dynamic Multipath Fading Operation

When the ACE9600 hardware is configured with optional multipath fading, a twelve tap fading model can be changed dynamically. The Fade update rate must be equal or slower than the delay update rate. The maximum Fade update rate is 100 msec. The Fade dynamic parameter file is assigned in File Menu #2.
 Only one file is required to control the entire 12 tap model. Parameters that can be dynamically changed are Doppler, path loss, delay, Angle of Arrival, and Log Normal. Each path is independently controllable. Rician k-factor, correlation, and path type cannot be changed dynamically.

Figure 2-23. Dynamic Multipath Fading display

Dynamic Data Files

Dynamic File Names

The ACE distinguishes parameter file types by the first three letters in each file name. File names can be up to 10 alphanumeric characters, as follows:

- DLYxxxxxxx - designates a delay file
- FRQxxxxxxx- designates a frequency offset file
- ATNxxxxxxx - designates an attenuation file
- PHAxxxxxxx – designates a phase offset file
- WGNxxxxxxx - designates an awgn file
- RFFxxxxxxx – designates an RF frequency file
- MPFxxxxxxx – designates a multipath fading file

Dynamic File Formats

Data files are generated in readable ascii characters. The first line in the data file must be the number that represents the exact number of sample points in the file, followed by the resolution of the data. Each subsequent line in the file is the data for one sample.

The parameter data files should be generated in ASCII format as a sequential data list with a carriage return <CR> separating the parameter fields. File names must begin with "DLY", "FRQ", "ATN", "WGN", "RFF", or "MPF" and have an extension of ".DAT" When the files are converted to a compressed format for the ACE9600, the

generated files have the same prefix, but the extension becomes ".ACE". The converted files are then transferred over the LAN interface, and stored in flash memory in the ACE. The converted files are in binary format.

The first line includes two values: the number of sample points, followed by a space, followed by the resolution of the data values. Each subsequent line will contain one data value (Multipath files have a different format. See the Multipath file section). Lines are separated by a carriage return. An example of a delay file with 3 points is:

3.000001
12.456789
12.456788
12.456787

The ASCII parameter files must have a file extension of ".dat" in order to be recognized by the conversion program. The SATGEN II satellite data generation program automatically generates the correct file extension. User generated files should be created with the .dat extension also. The first three letters of the file name should be one of DLY, FRQ, ATN, PHA, WGN, RFF, or MPF to represent delay, frequency offset, attenuation, phase offset, AWGN, RF frequency, and multipath fading files. Up to 7 alphanumeric characters, including the underscore character "_" can follow the first three letters in the file name.

Data File Description

Delay Files

The ACE9600 changes delay linearly over the update period. The delay change does not cause phase discontinuities. The change in delay between two adjacent data points must not require the delay to slew at a rate greater than 2 msec/sec, nor less than a rate of 0.5 psec/sec. The delay slew rate is dependent on both the change in delay and the update period. And the available delay resolution is also dependent on both parameters. The ACE9600 computes the required delay slew rate from point to point such that there is constant linear change that occupies the entire update period. For example, if the update rate is 10 msec, and the change in delay values is 10 nsec, then the resulting delay slew rate will be {10 nsec/10msec} or 1 usec/sec. If the same data file is operated at a 100 msec update rate, the resulting slew rate will be 100 nsec/sec.

In all cases,

- Each data line consists of 10 to 14 characters, depending on resolution, including a decimal point
- Units are ms

Achievable resolution is based on the selected update rate. The range of delay step size as a function of update rate is given in the table below.

Update Rate		Range of Achievable Slew Rates			
1000ms	Min	0.1ns/sec	0.01ns/sec	1ps/sec	0.1ps/sec
1000ms	Max	3.2767us/sec	0.32767us/sec	32.767ns/sec	3.2767ns/sec
500ms	Min	0.2ns/sec	0.02ns/sec	2ps/sec	0.2ps/sec
500ms	Max	6.5535us/sec	0.65535us/sec	65.535ns/sec	6.5535ns/sec
200ms	Min	0.5ns/sec	0.05ns/sec	5ps/sec	0.5ps/sec
200ms	Max	16.384us/sec	1.6384us/sec	163.84ns/sec	16.384ns/sec
100ms	Min	1.0ns/sec	0.1ns/sec	10ps/sec	1ps/sec
100ms	Max	32.767us/sec	3.2767us/sec	327.67ns/sec	32.767ns/sec
50ms	Min	2.0ns/sec	0.20ns/sec	20ps/sec	2ps/sec
50ms	Max	65.535us/sec	6.5535us/sec	655.35ns/sec	65.535ns/sec
20ms	Min	5.0ns/sec	0.5ns/sec	50ps/sec	5ps/sec
20ms	Max	163.84us/sec	16.384us/sec	1638.4ns/sec	163.84ns/sec
10ms	Min	10ns/sec	1.0ns/sec	100ps/sec	10ps/sec
10ms	Max	327.67us/sec	32.767us/sec	3276.7ns/sec	327.67ns/sec
5ms	Min	20ns/sec	2.0ns/sec	200ps/sec	20ps/sec
5ms	Max	655.35us/sec	65.535us/sec	6553.5ns/sec	655.35ns/sec
2ms	Min	50ns/sec	5.0ns/sec	500ps/sec	50ps/sec
2ms	Max	1638.4us/sec	163.84us/sec	16384ns/sec	1638.4ns/sec
1ms	Min	100ns/sec	10.0ns/sec	1000ps/sec	100ps/sec
1ms	Max	2000.0us/sec	200.00us/sec	20000ns/sec	2000.0ns/sec
1st data point in .dat file		ms.1234567	ms.12345678	ms.123456789	ms.1234567890

Attenuation Files

- Each data line consists of five characters in a "xx.xx format.
- Range is 0 to 70 dB in 0.10dB steps
- Step size between any two adjacent points can be up to 70
- Units are dB

Frequency Offset Files

Frequency offset is typically used to impose the carrier Doppler shift that occurs as a result of time varying path length change. Note that dynamically changing delay in the ACE9600 causes a frequency shift proportional to the frequency offset from the instrument's nominal center frequency. For example, if the instrument is tuned to 1000 MHz, an incoming frequency component at 1000 MHz will experience no shift with changing delay, whereas frequency content above and below 1000 MHz will shift away from the 1000 MHz when delay is decreasing. Therefore chip period variations as a function of Doppler are emulated correctly, irrespective of the actual signal carrier frequency. Carrier Doppler shift however must be computed based on the actual carrier frequency, and applied using a Frequency Offset file.

- Each data line consists of eight or 10 characters, depending on resolution, including a decimal point
- Range is 0 to ± 6000KHz in 1 Hz or 0.01Hz resolution
- Step size between any two adjacent points can be up to ± 32,767 times the resolution.
- Units are kHz

In Dynamic mode, Frequency offset resolution is 0.01 Hz if there are 5 decimal places in the first data point in a frequency offset file, eg. x.12345 will invoke 0.01 Hz resolution. Otherwise, resolution will be 1 Hz.

Phase Offset Files

Dynamic phase offset is driven by data files containing the value of absolute phase shift. The phase offset update rate is the same as that selected for delay, frequency offset, attenuation and AWGN.

- Each data line consists of five characters in a "xxx.x" format
- Range is 359.9 degrees in 0.1 degree steps.
- Step size between any two adjacent points is unlimited
- Units are degrees

AWGN Files

When noise density is enabled in static mode (either by direct entry or via Eb/No calculation), the noise will remain enabled at that level when the ACE9600 mode is changed to dynamic. If awgn is not desired in dynamic mode, it must be set to off in static mode. When a dynamic awgn file is loaded, awgn is automatically enabled, irrespective of whether it was on or off in static mode. Once enabled in dynamic mode, awgn cannot be disabled without returning to static mode. Dynamic awgn is driven by data files containing the value of absolute noise density (for example, -95.23 dBm/Hz). The AWGN update rate is the same as that selected for delay, frequency offset, and attenuation.

- Each data line consists of seven characters in a "-xxx.xx" format
- Range is 60 dB in 0.01 dB steps. The largest absolute noise density value is instrument dependent.
- Step size between any two adjacent points is unlimited
- Units are dBm/Hz

The range of control for the noise density is 60 dB. However, the usable range may be less, as it is limited by the maximum density the instrument can produce and the intrinsic noise floor of the instrument. Additionally, when AWGN is active, the channel attenuation should be limited to less than 32 dB.

RF Frequency Files (With L-band Converter Option)

When L-band frequency converters are installed in the ACE9600, the tuned center frequency can be varied dynamically. Depending on the

hardware configuration, the input and output frequency are either independently tunable, or are slaved together.

- Each data line consists of four characters, in a "xxxx" format
- Range is 800 to 2600 MHz in 1 MHz steps.
- Step size between any two adjacent points is limited only by the total frequency range.
- Units are MHz

Multipath Fading Files

All of the twelve paths in a multipath channel can be driven dynamically by a unique data file. During a dynamic run, the path values for path Doppler, Delay, Loss, and AoA are modified sequentially according to the fading file values.

Multipath type filenames must begin with "MPF" and end with ".DAT". The first line in the file is a value that represents the number of sample points in the file.

The second through thirteenth line in the file represents the path Type, CorrPath, CorrVal, Rate, StdDev, and Kfactor settings, which remain fixed during a dynamic run.

Each subsequent line contains Doppler, Loss, Delay and AoA values for each of the 12 paths. Each of these path settings must begin with a semi-colon delimiter ";" and use an ASCII space character to separate the four values. If a path is off, the values between semi-colons are ignored.

The assumed resolution, range and units for each value is as follows:

Type	Units		Resolution	Range
CorrVal %		1%		0 to 100%
Rate	Hz	1 Hz		0 to 100 Hz
StdDev dB		1 dB		0 to 12 dB
Kfactor dB		1 dB		-10 to 20 dB
Doppler Hz		1 Hz		0 to 10,000Hz
Loss	dBm	0.1 dBm	0.0 to 30.0 dBm	
Delay	usec	0.001 usec	0.000 to 9.996 usec	
Aoa	degrees	1 degree	0 to 180 degrees	

```
 3
 RICE 1 20 0 0 10
 OFF
 OFF
 OFF
 OFF
 OFF
 OFF
 OFF
 OFF
 OFF
 OFF
 RICE 12 30 10 10 20
 ;0 0.000 0.0 0;;;;;;;;;;;11 0.011 1.1 11;
;12 0.012 1.2 12;;;;;;;;;;;23 0.023 2.3 23;
```

Figure 2- 13. An example of a Dynamic Multipath file. Two out of 1000 data lines are illustrated.

Line 1: designates the total number of time increments included in the file. This number must exactly match the number of data lines.

Lines 2 -13: Represents paths 1 through 12 respectively. The format for these lines is:

Type   Correlation Path   Correlation %   K-factor

In each line, the path type is followed by the correlation path and then the correlation percentage. k-factor is required for Rician paths, and can optionally appear for other path types. Path type is one of

      CW
      RAY
      RICE
      OFF

Each subsequent data line contains the dynamic path parameter values. The format for the path data is:

;Doppler (Hz) Delay (usec) Loss(dB) AoA(degrees)

Path data is delimited by a semicolon. Each data line must contain six semicolons. The first semicolon is followed by path #1 data, the second semicolon is followed by path #2 data, etc. AoA can optionally appear for Rayleigh paths, but is required for Rician and CW paths. When no path data is required, the semicolon must still be present. A path that is OFF can have path data in the file, and the data will be ignored.

Each line in the file is ended with a carriage return. Spaces are allowable.

Dynamic File sizes

Parameter data file sizes are unlimited, however the total of all downloaded files is limited by the ACE9600 SD card memory capacity.

3

Remote Operation Section

Remote Operation Overview

The ACE9600 can be controlled remotely using its LAN interface. The instrument can be connected to any IEEE-802 network. It uses TCP/IP, and achieves transfer rates up to 100 MSPS. The ACE is configured as a network server, and can communicate with a network client. The client can also add and delete dynamic parameter files on the mass storage device in the ACE.

All front panel Static and Dynamic commands can be initiated with the LAN interface. While in remote all front panel controls except the *Local* key are disabled.

ACEControl provides a graphical user interface to manipulate parameter files, and to control and monitor the ACE, both in Static and Dynamic mode. *ACEControl* is a Windows® PC based application that is included with the ACE instrument.

Programming control of the ACE9600 can be implemented by two means: 1) Using *ACEControl* or 2) by creating a test script, which sends and receives text commands with the instrument.

A complete description of *ACEControl* is given in the ACE Programmer's Manual.

For creating test scripts, refer to the ACE Programmer's Manual for syntax and code examples.