RADC-TR-76-195
Final Technical Report
June 1976

12

LINE-OF-SIGHT DATA LINK TEST SET

SIGNATRON, Incorporated

Sponsored By
Defense Advanced Research Projects Agency
ARPA Order No. 2973
and
Rome Air Development Center

ROME AIR DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
GRIFFISS AIR FORCE BASE, NEW YORK 13441

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LINE-OF-SIGHT DATA LINK TEST SET

Paul F. Mahoney

Contractor: SIGNATRON, Incorporated
Contract Number: F30602-75-C-0300
Effective Date of Contract: 30 June 1975
Contract Expiration Date: 28 May 1976
Short title of work: RPV Channel Simulator Modification
Program Code Number: 5G10
Period of work covered: Jul 75 - Jan 76

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This research was supported by the Defense Advanced Research Projects Agency and Rome Air Development Center of the Department of Defense and was monitored by Peter K. Leong, RADC (DCLF), Griffiss AFB NY 13441.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: RADC-TR-76-195	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): LINE-OF-SIGHT DATA LINK TEST SET	5. TYPE OF REPORT & PERIOD COVERED: Final Technical Report July 1975 — January 1976
	6. PERFORMING ORG. REPORT NUMBER: N/A
7. AUTHOR(s): Paul F. Mahoney	8. CONTRACT OR GRANT NUMBER(s): F30602-75-C-0300 NEW
9. PERFORMING ORGANIZATION NAME AND ADDRESS: SIGNATRON, Incorporated, 27 Hartwell Avenue, Lexington MA 02173	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62702E, B9730101
11. CONTROLLING OFFICE NAME AND ADDRESS: Defense Advanced Research Projects Agency, 1400 Wilson Blvd, Arlington VA 22209	12. REPORT DATE: June 1976
	13. NUMBER OF PAGES: 29 (12) 46p
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Rome Air Development Center (DCLF), Griffiss AFB NY 13441	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

(15) F30602-75-C-0300, ARPA Order-2973

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

(16) AF-5556

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Peter K. Leong (DCLF)

This effort was funded by ARPA Funds and in part by Project 5556 Funds.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Radio Propagation Simulator
RPV Channel Simulator
Wideband Data Link Test Set
Airborne Data Link Test Set
Line-of-Sight (LOS) Microwave Propagation Simulator
Microwave Line-of-Sight Propagation Simulator

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A versatile laboratory instrument which provides accurate and repeatable simulation of multipath and Doppler propagation effects has been built. Microwave line-of-sight airborne radio links typical of remotely piloted vehicle (RPV) wideband data links can be simulated. The simulator (designated Model S-187) is a test set designed to be used in the development and evaluation of modem equipments operating at intermediate frequencies of 70, 100 and 300 MHz with signal bandwidths up to 100 MHz. The basic channel model consists of an undelayed path having both a constant and a fading component and two delayed paths which

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may be either constant or fading. The delay spacing of the path is 6.6, 16.6, or 50 nanoseconds. The strength of each component may be adjusted over a 60 dB range. The rms bandwidths of the fading components are independently selectable from 1 Hz up to 1,000 Hz. By selection of constant and fading combinations of the undelayed and delayed paths various frequency responses and fading distributions can be simulated.
They are

Frequency Flat, Constant Amplitude
Frequency Selective, Constant Amplitude
Frequency Flat, Rician
Frequency Selective, Rician
Frequency Flat, Rayleigh
Frequency Selective Rayleigh
Frequency Selective, Periodic Fading.

A frequency offset can be introduced between the input and output of the simulator to simulate a fixed carrier Doppler offset up to 30 kHz. A differential Doppler up to 1 kHz between the undelayed path components and the delayed paths is also provided. A separate clock Doppler offset generator is provided which can offset the frequency of sinusoidal clock waveforms from external modems. The simulator also includes a broadband Gaussian noise source added to the output to simulate broadband jamming. A separate input for adding external signals to the output, such as separately simulated jamming signals, is provided.

PREFACE

This Technical Report describes work performed by SIGNATRON, Incorporated, 27 Hartwell Avenue, Lexington, Massachusetts, under Contract F30602-75-C-0300, Job Order 2973, for Rome Air Development Center, Griffiss Air Force Base, New York. The report outlines the modified LOS Data Link Test Set suitable for test and evaluation of wideband modems employed on RPV data links.

Mr. Peter Leong was the RADC Project Engineer. The simulator was developed for DICEF (Digital Communications Experimental Facility) under the direction of Mr. Miles Bickelhaupt.

Mr. Paul F. Mahoney was responsible for the program at SIGNATRON. He was assisted by Mr. Helge Nilssen, and Mr. Roy D. Allen.

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INTRODUCTION AND SUMMARY

1.1 Objectives of the Program

The objective of this program was to modify the existing RPV Channel Simulator built by SIGNATRON under Contract F30602-74-C-0277 so as to provide a more effective replication of radio propagation effects encountered in line-of-sight wideband microwave transmission over airborne data links, such as RPV data links. These effects include multipath, fading, Doppler shift due to motion, receiver noise, and the addition of a jamming signal The resulting, modified instrument, called LOS Data Link Test Set, SIGNATRON Model S-187, provides a versatile and cost effective aid for use in the development and evaluation of modems and spread spectrum communications techniques intended for RPV applications.

1.2 Technical Approach

The simulator operates on the principle that a fading-dispersive transmission link can be modeled as a tapped delay line with fluctuating tap gains. The amount of dispersion on a 5 to 10 GHz is small enough so that just three taps, one undelayed and two delayed, suffice to model the mechanism of frequency selective fading. The time-varying character of the channel is simulated by controlling the tap gain fluctuations from three independent noise sources of a selected bandwidth, thus modifying the amplitude and phase of the signal as if it were propagated over an actual radio link [1].

1.3 Summary

The SIGNATRON Model S-187 LOS Data Link Test Set shown in Fig. 1.1 is a versatile, laboratory-quality instrument which will provide accurate and repeatable simulation of multipath and Doppler effects typical of microwave, airborne line-of-sight radio links encountered in remotely piloted vehicle (RPV) communication links. The S-187 LOS Data Link Test Set is designed to be used between modem equipment operating at 70, 100, and at 300 MHz, and with a signal bandwidth up to 100 MHz.

The S-187 LOS Data Link Test Set channel model consists of a direct path having both a constant and a fading component and two delayed paths which may be either constant or fading. The available delays are 6.6, 16.6 or 50 nanoseconds. The strength of each component may be adjusted over a 60 dB range. The rms bandwidths of the fading components are independently selectable. By selection of constant and fading combinations of the direct and delayed paths the following frequency responses and fading distributions can be simulated:

Frequency Flat, Constant Amplitude
Frequency Selective, Constant Amplitude
Frequency Flat, Rician
Frequency Selective, Rician
Frequency Flat, Rayleigh
Frequency Selective, Rayleigh
Frequency Selective, Periodic Fading

A frequency offset can be introduced between the input and output of the test set to simulate carrier Doppler offset. Differential Doppler between the direct path components and the delayed paths is also provided. A separate clock Doppler offset generator is provided to Doppler offset sinusoidal clock waveforms from external modems.

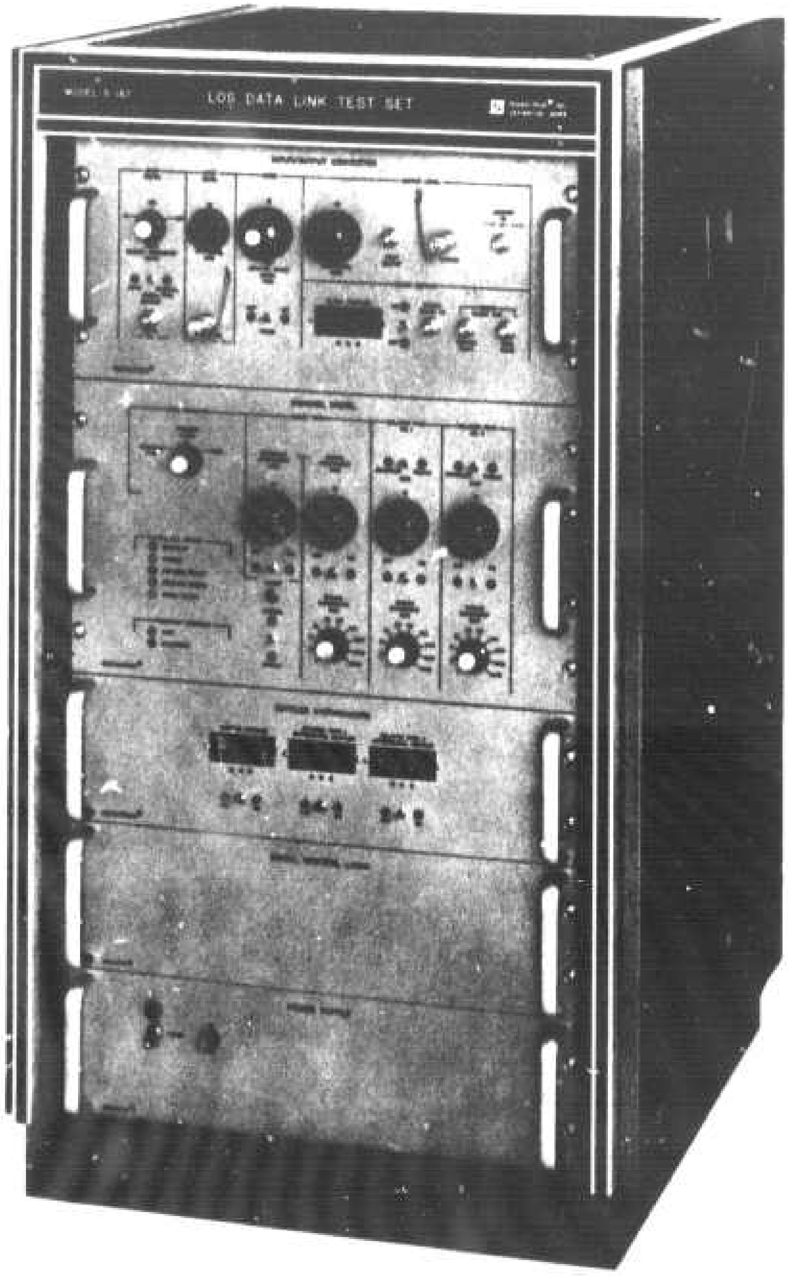

Fig. 1.1 LOS Data Link Test Set

The simulator also includes a broadband Gaussian noise source added to the output and a separate input for adding other external signals to the output.

A built-in test mode is provided to facilitate rapid equipment setup, calibration, and maintenance.

A detailed Specification of the test set is included in Table 1.

TABLE 1

SPECIFICATION

LOS DATA LINK TEST SET

MODEL S-187

1. <u>Input Signal Characteristics</u>

   a. <u>70 MHz Channel</u>

Center Frequency:	70 MHz
Modulation:	*
Signal Level:	- 15 dBm, min., -10 dBm, max.
Impedance	50 ohms

   b. <u>100 MHz Channel</u>

Center Frequency:	100 MHz
Modulation:	*
Signal Level:	-18 dBm
Impedance	50 ohms

   c. <u>300 MHz Channel</u>

Center Frequency:	300 MHz
Modulation:	*
Signal Level:	0 to +10 dBm
Impedance	50 ohms

2. <u>Output Characteristics</u>

   a. <u>70 MHz Channel</u>

Center Frequency:	70 MHz
Signal Bandwidth (1 dB):	15 MHz min.
Signal Level:	-70 dBm min., -20 dBm max.

*Modulation: FM, PM, FSK, FDM/FM, PSK, TDM-FSK/PSK

Carrier Frequency
Doppler Offset: ± (10 Hz to 30 kHz)

Impedance: 50 ohms

Signal-to-Equipment
Noise Ratio: 30 dB minimum

b. <u>100 MHz Channel</u>

Center Frequency: 100 MHz

Signal Bandwidth
(1 dB): 55 MHz

Signal Level: -40 dBm min., -10 dBm max.

Carrier Frequency
Doppler Offset: ± (10 Hz to 30 kHz)

Impedance: 50 ohms

Signal-to-Equipment
Noise Ratio: 30 dB minimum

c. <u>300 MHz Channel</u>

Center Frequency: 300 MHz

Signal Bandwidth
(3 dB): 100 MHz

Signal Level: -70 to 0 dBm

Carrier Frequency
Doppler Offset: ± (10 Hz to 30 kHz)

Impedance: 50 ohms

Signal-to-Equipment
Noise Ratio: 30 dB minimum

d. <u>Additive Noise</u>

Additive Noise Power
Spectral Density: At least -70 dBm/Hz over a BW from 30 to 500 MHz

Additive Noise Level
Adjustment Range: 60 dB (1 dB steps)

e. <u>Jammer</u>

External Jammer
Input: + 20 dBm max.

3. Tapped Delay Line Channel Model

Direct Paths:	Constant and Fading
Delayed Paths:	Choice of constant or fading
Number of Delayed Paths:	2
Path Levels (adjustable) 1 dB steps):	-60 to 0 dBm, also ON/OFF
Delay between paths (rear patch-panel adjustable):	6.6, 16.6, 50 nanoseconds
Fading Path Modulation Bandwidth (independently selectable for each path):	1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 Hz
Fading Path Modulation:	Complex Gaussion with second-order Butterworth power spectrum
Delayed-Path Differential Doppler:	±(10 millihertz to 999 Hertz) 5 ranges
Frozen Channel	
Repeatable Channel Reset	Reset to the RMS signal level

4. Built-In Test Features

Constant Path:	Constant component of direct path only. Channel model override.
Test Modes:	Rear panel selectable test inputs to tap modulators
Internal 300 MHz Tone:	Crystal controlled

5. Modem Clock Doppler Offset

Clock Input:	Sinusoidal, 0 dBm, 50 Ohms
Clock Output:	Sinusoidal or Square Wave, 0 dBm, 50 Ohms
Doppler Offset:	±(10 millihertz to 999 Hertz)
Input Frequency Range:	55 to 65 MHz

6. AC Power — 250 Watts max., 115 VAC ± 5% at 2A nominal 60 ± 5 Hz, single-phase.

SECTION 2

THEORY OF OPERATION

2.1 RPV Communications

The concept of hardware simulation of transmission media implies the existence of a channel model which can be realized as a laboratory instrument, i.e., a channel simulator. The channel model is a mathematical structure which represents approximately the physical channel. A typical RPV communication system might consist of a number of drones receiving commands from, and transmitting data to, a high altitude relay vehicle over long distances. The drones might also be communicating directly with a ground station. In both situations the communication requires that the terminals be within line-of-sight distance of each other.

In summary the RPV communications channel is a wideband line-of-sight radio channel, probably operating in either or both a TDMA and FDMA mode. The channel may be ground-to-air or air-to-air resulting in non-stationary channel behavior due to terminal movement.

2.2 RPV Channel Characteristics

Consideration of the physical communication environment suggests that the following major channel characteristics should be simulated:

1. Dispersion
2. Fading
3. Doppler shift effects
4. Additive noise
5. Jamming signals.

2.2.1 Dispersion

Channel dispersion is qualitatively defined as the time spread or width of the response of the transmission channel to impulse excitation. When this impulse response width is a significant fraction of the reciprocal of the signal bandwidth, the effects of dispersion must be considered in the system design. Dispersion results from two contributors: the terminal equipment and the transmission medium. The former consists of transmitter and receiver filters.. These dispersive effects (which are time invariant) can be minimized by appropriate design. The transmission medium represents a more serious limitation in that it may support multiple non-stationary paths with sufficient delay differences to produce channel dispersion. For the RPV channel the most probable multipath conditions are due to ground surface reflections. RPV channel potential multipath conditions can exist which produce delay differences over a range from a few nanoseconds to as high as 50 nanoseconds. Moreover, for refractive layer multipath the amplitude of a multipath component can be larger than the direct path component.

Three such paths are illustrated in Fig. 2.1. A physical model for transmission medium multipath is a transversal filter with tap delay spacing equal to the multipath delays and tap gains and phases adjusted to correspond to the individual path components. Such a model is shown in Fig. 2.2. The prediction of the path delays and gains involves the specification of either an atmospheric layer model for layer refraction or a surface reflectivity model for ground reflection paths. Measurement of the channel impulse response with specialized channel sounding equipment is one approach to determining the physical model parameters. However, it must be recognized that due to the wide range of communication terminal geometries, many dispersive channel geometries

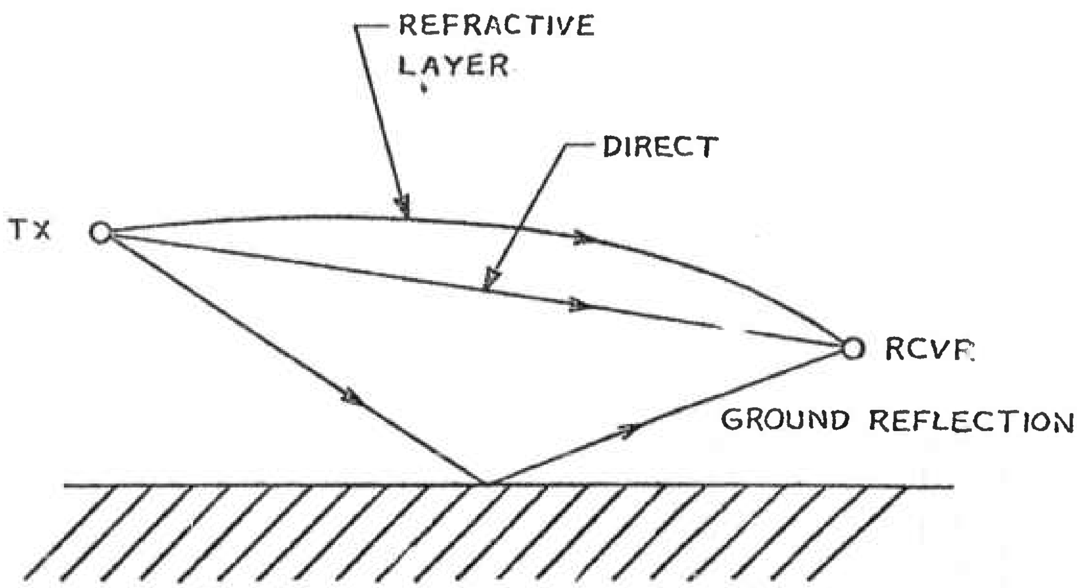

Fig. 2.1 RPV Channel Propagation Path Components

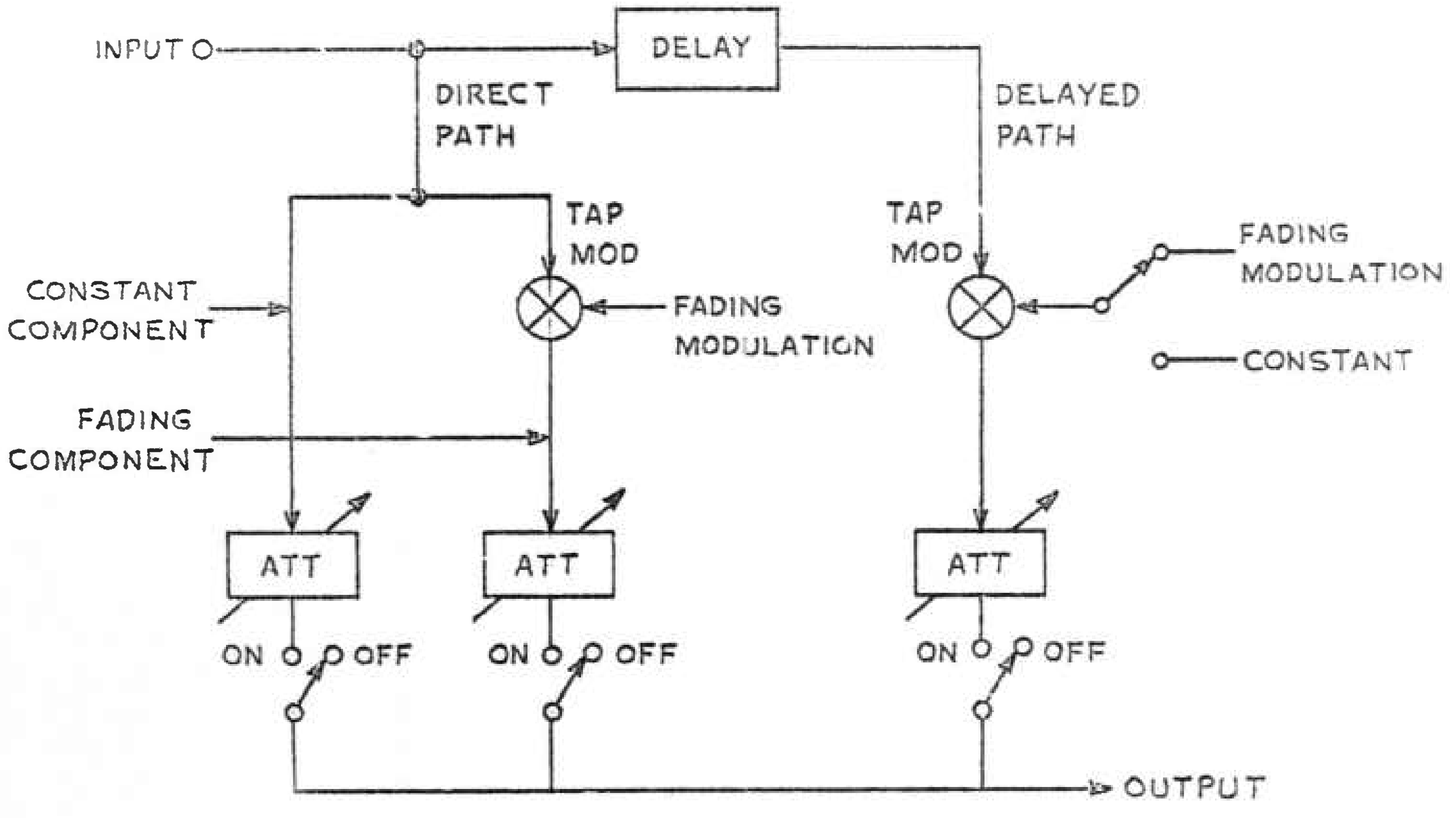

Fig. 2.2 Basic Channel Model Showing Only One Delayed Path

exist. One effective approach is to isolate worst-case multipath conditions which have a sufficiently large probability of occurrence to impact communication effectiveness. The channel model parameters must then be selected with the modulation technique as well as the transmission medium in mind.

2.3 Fading

As a result of terminal motion the refractive index structure in an atmospheric layer multipath environment will change and, similarly, the surface scattering structure will change in a ground reflected multipath environment. Thus, the multipath components, when they exist, arrive at the receiver with time varying fluctuations relative to the direct path. This change results in fading of the received signal as the multipath components combine constructively and destructively with the direct path signal. When the time dispersion is small compared to the reciprocal of the signal bandwidth, the fading is independent of frequency over the frequency band of interest and is referred to as flat-fading. For larger dispersion widths the fading over the signal bandwidth is not constant and frequency-selective fading results.

The fading phenomenon is incorporated into the physical model (Fig. 2.2) by causing the tap strengths of the fading components to vary with time. The bandwidth of the variation determines the fade-rate or Doppler spread of the channel. The modulation sources driving the tap modulators are either low frequency noise sources with Gaussian probability densities for fading components or are deterministic fixed values for constant components.

When the tap modulators are modulated by low-frequency Gaussian noise, the noise power spectral density is shaped by a two-pole Butterworth filter whose 3 dB bandwidth is the rms

Doppler spread of the path. To permit simulation of large Doppler spreads caused by high-speed aircraft motion, the simulator is capable of providing up to 1000 Hertz rms Doppler spread. Spreads are independently selectable for the direct and delayed paths.

When the test set is operating in a flat-fading mode two possible conditions exist. First and most common in RPV applications is the presence of a fixed direct component and a fading component with only negligible delay relative to the direct path. The output signal envelope in this instance has a Rician density function under sinusoidal excitation of the simulator. The second possibility is the presence of only a single flat-fading path which models scatter effects either from layers or the ground surface. Each of these propagation conditions can be modelled by turning on appropriate components of the direct path in the basic channel model shown in Fig. 2.2.

When the fading is frequency-selective there is a significant time delay between the direct and other paths. If one path is fixed while the other fades, frequency-selective Rician fading exists. If all paths fade the simulator mode would be frequency-selective Rayleigh fading. If both paths are constant in signal strength but the terminals are in motion the direct and delayed components will interfere quasi-periodically with each other to produce nearly-periodic fading at a differential Doppler rate determined by the differential path length rate of change between the direct and delayed path. This capability is provided in the basic channel model by modulating the delayed path relative to the direct path as described more fully in the next section.

2.4 Tap Modulators and Modulations

The tap modulators included in the basic channel model modulate both the amplitude and phase of the signal passing through a path by modulating both an in-phase and quadrature-phase component of the input signal as shown in Fig. 2.3. A phasor diagram

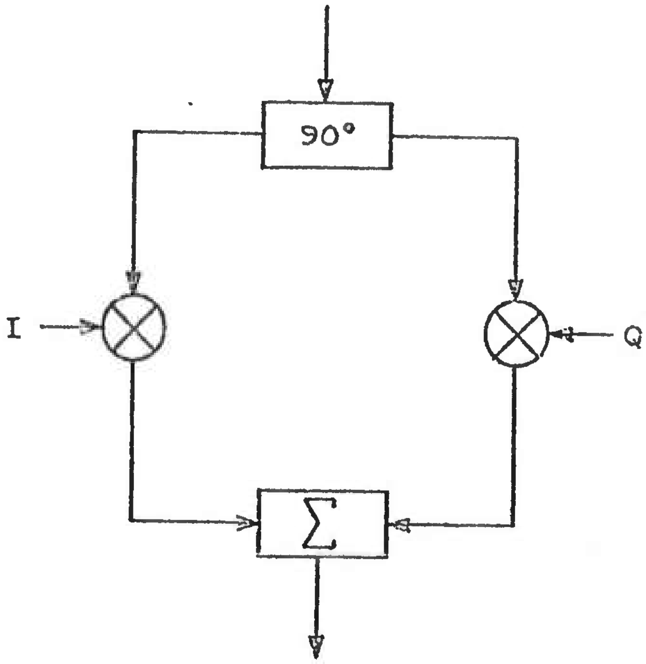

Fig. 2.3 Basic Tap Modulator

illustrating the instantaneous envelope output from the modulator is shown in Fig. 2.4. The instantaneous values of the I and Q modulation voltages to the tap modulator in the fading component of the direct path are independent low-frequency Gaussian noise-like signals with zero mean generated by digitally filtering pseudo-random binary sequences and converting from digital to analog form.

The tap modulator in either of the delayed paths serves a multiple function. The instantaneous values of the I and Q modulation voltages are again independent low-frequency Gaussian signals having zero mean value when the path is fading. If the path is constant, I and Q are set such that the value of $[I^2 + Q^2]^{\frac{1}{2}}$ is constant although the phase of the tap modulator output can be modulated when a differential Doppler is desired between the direct and a delayed path. Rotation of the output phase at a uniform rate introduces a constant differential Doppler frequency relative to the direct path. Phase rotation at a uniform rate is a simple coordinate rotation operation. Figure 2.5 illustrates how this operation is accomplished. Inputs X and Y are independent Gaussian digital signals having zero mean value. Each of the four multiplying digital-to-analog converters (MULT DAC) has either a sine or cosine input at the desired differential Doppler frequency f. The DAC accomplishes the digital-to-analog conversion of the Gaussian digital input and multiplication by the appropriate sine or cosine weight. The frequency of the differential Doppler offset is varied by changing the frequency setting of the source generating the sine and cosine inputs.

2.5 Doppler Shift Effects

2.5.1 Carrier Doppler Offset

In addition to the fading phenomenon caused by relative propagation time variations on the direct and delayed path, both

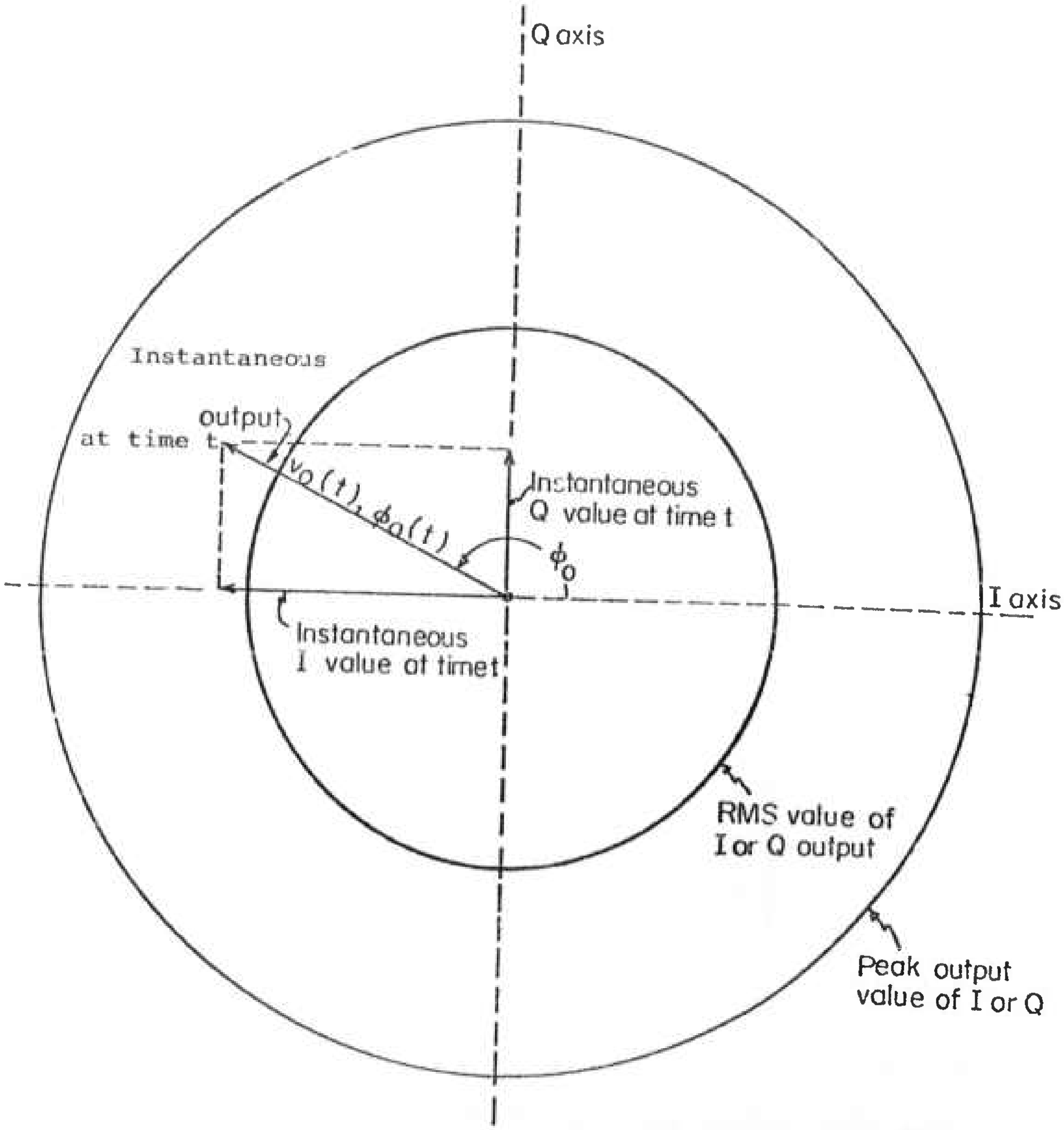

Fig. 2.4 Phasor Relationship for Modulator Outputs

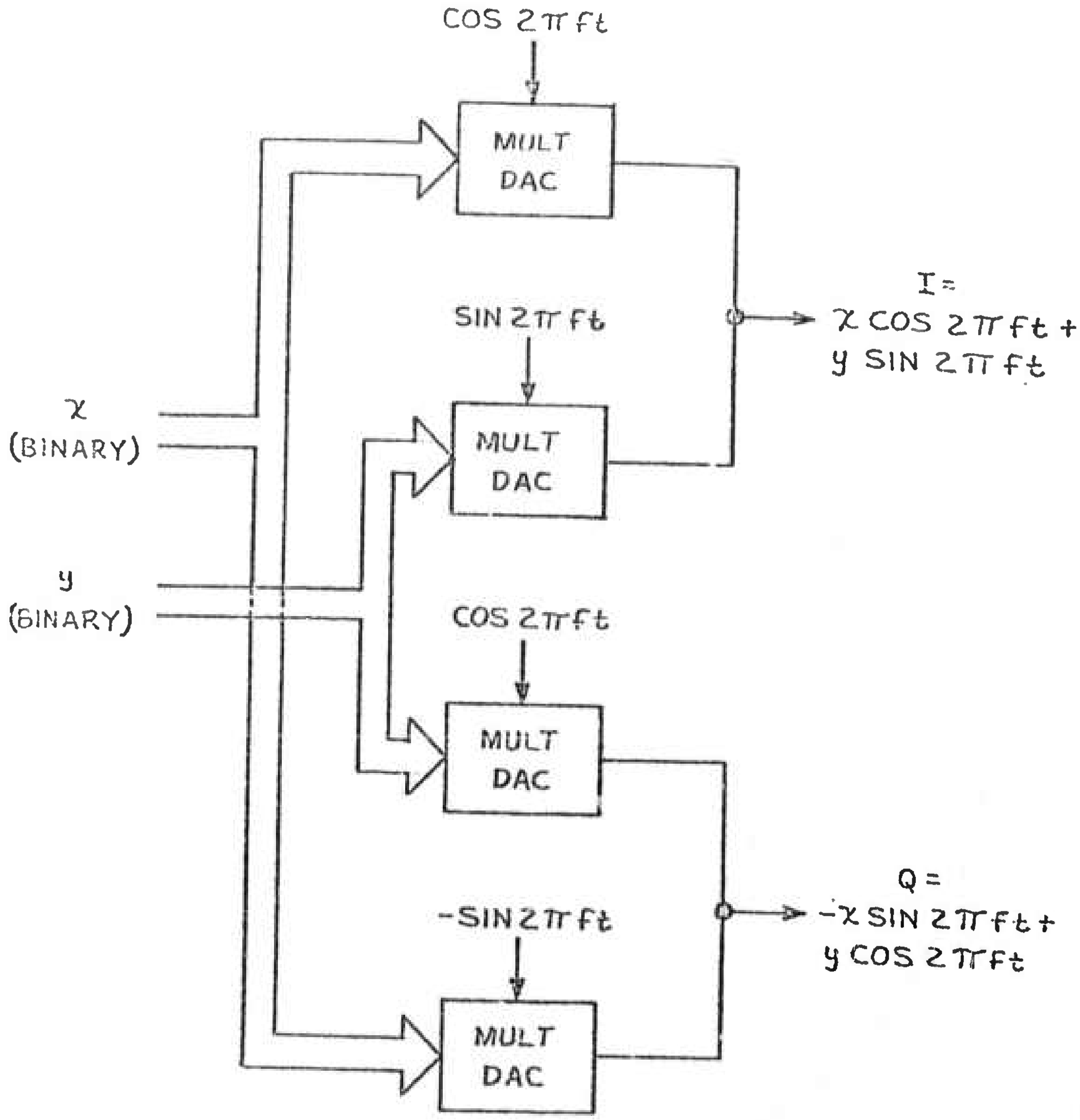

Fig. 2.5 Method for Introducing Differential Doppler to a Delayed Path Tap Modulator Modulation signal.

paths exhibit a common Doppler shift due to the mean relative velocity of the terminals. The Doppler shift is the fraction $(v/c)\ f_o$ where v is the relative terminal velocity, c is the velocity of propagation, and f_o is the radio carrier frequency. Thus, at $f_o = 10$ GHz and aircraft velocities of 1000 feet/second, a Doppler shift of 10 kHz would result. Carrier Doppler frequency shifts for different signal paths in the channel model can be realized by employing frequency conversion with frequency offsets inserted in the conversion operation. A basic block diagram of the conversion system used in the S-187 test set is shown in Fig. 2.6. The input signal centered at 300 MHz is converted to 428 MHz in a mixer utilizing a 728 MHz local oscillator signal derived by frequency multiplying a 182 MHz oscillator output. The 428 MHz signal then passes through the basic channel model which has been implemented at a center frequency of 428 MHz. The output of the channel model is next down-converted to 300 MHz but offset by the required Doppler frequency f_d. The frequency shift is inserted in the down converter local oscillator by performing a single sideband modulation of the 182 MHz signal to produce 182 MHz + f_d. This signal is then mixed with 546 MHz to produce 728 MHz + f_d. The 546 MHz is obtained by multiplying the 182 MHz by three. The carrier Doppler offset frequency is changed by varying the frequency setting of the source generating the sine and cosine inputs to the single-sideband modulator.

2.5.2 Differential Doppler

There also exists a relative Doppler shift between direct and delayed signal paths which results from the difference between the angles-of-arrival in two path propagation. The relative shift is a fraction of the absolute shift roughly equal to one-half the square of the angle-of-arrival difference. For the most extreme case, at long ranges of 200 miles on the ground reflected paths

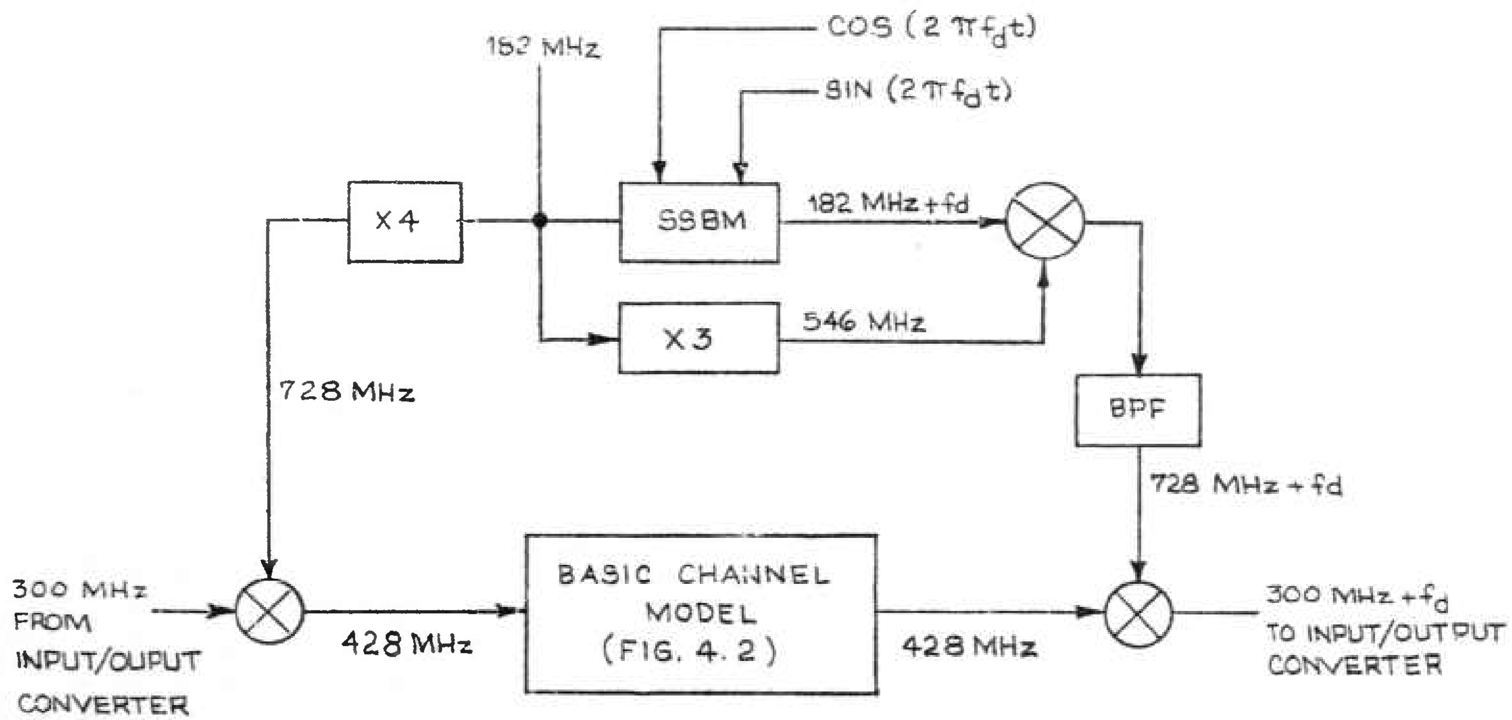

Fig. 2.6 Carrier Doppler Offset

this angle difference is generally less than 0.15 radians. Thus the relative Doppler shift for the 10 GHz example in the case of the largest angle difference above would be about 100 Hz. Implementation of this Doppler effect has been previously described in Section 2.4 in association with Fig. 2.5.

2.5.3 Clock Doppler

The moving terminal also has the effect of imparting a small Doppler shift to the clock of a modem modulator communicating through the channel. For example, a system with a 60 Mbps clock would appear to have its clock shifted by 60 Hz if one terminal were moving at a relative velocity of 1000 feet/second. Thus, this equivalent data rate shift should also be considered in modem evaluation if synchronization is to be maintained. The effective path length change producing the clock Doppler shift can be simulated for waveforms generated by the clock by offsetting the frequency of the clock in the modem modulator relative to the modem demodulator. This is accomplished in the S-187 test set by a separate single-sideband clock waveform modulator accommondating sinusoidal clocks near 60 MHz. The modulator is frequency shifted by sine and cosine inputs generated by a source whose frequency can be offset by appropriate settings of clock Doppler offset.

2.6 Additive Noise

Radio communication channels are characterized by the presence of additive noise at the receiver input. This noise is modeled in the S-187 test set by the addition of flat-spectrum Gaussian noise source having a bandwidth greater than the signal bandwidth. The noise is added to the signal after the transversal filter output to simulate the physical system where the noise and channel are independent.

2.7 Jamming Signals

It is customary in A/J system investigation to assume the jammer presents the worst possible signal type to the receiver. An implicit assumption is that the jammer has knowledge of the RPV channel parameters such as antenna structure, modulation process, and coding techniques. Thus, the choice of jamming signals to be employed in a simulation is dependent on (1) RPV modem to be tested and (2) the communication environment. This flexibility is provided in the S-187 Los Data Link Test Set by providing a combiner at the simulator output for adding external signals directly to the basic channel model output.

SECTION 3

DESCRIPTION OF THE TEST SET

3.1 General

This section provides a description of the SIGNATRON Model S-187 LOS Data Link Test Set. The description is divided into a discussion of the major sub-units of the simulator.

The Test Set consists of the following major sub-units.

1. Input/Output Converter
2. Channel Model
3. Doppler Synthesizers
4. Control Logic
5. Power Supply

The Input/Output Converter accepts the input at 70, 100, or 300 MHz. When this input is 70 or 100 MHz, the frequency is shifted to 300 MHz. Thus, regardless of whether the input frequency is 70, 100, or 300 MHz, the signal enters the Channel Model sub-unit, where it is processed next, at 300 MHz. This is shown in the block diagram of Fig. 3.1. After the signal exits the Channel Model sub-unit, it is then returned to the Input/Output Converter at 300 MHz. This processed signal is returned to its original frequency, then summed with the high power noise source and external jammer signals to form the final output. The clock Doppler circuitry is also located in this sub-unit. The front panel of this sub-unit is shown in Figure 3.2.

The Channel Model contains all RF and IF circuitry required for the channel simulation. A block diagram of this unit is shown in Figure 3.3. Nearly all controls and switches, necessary to

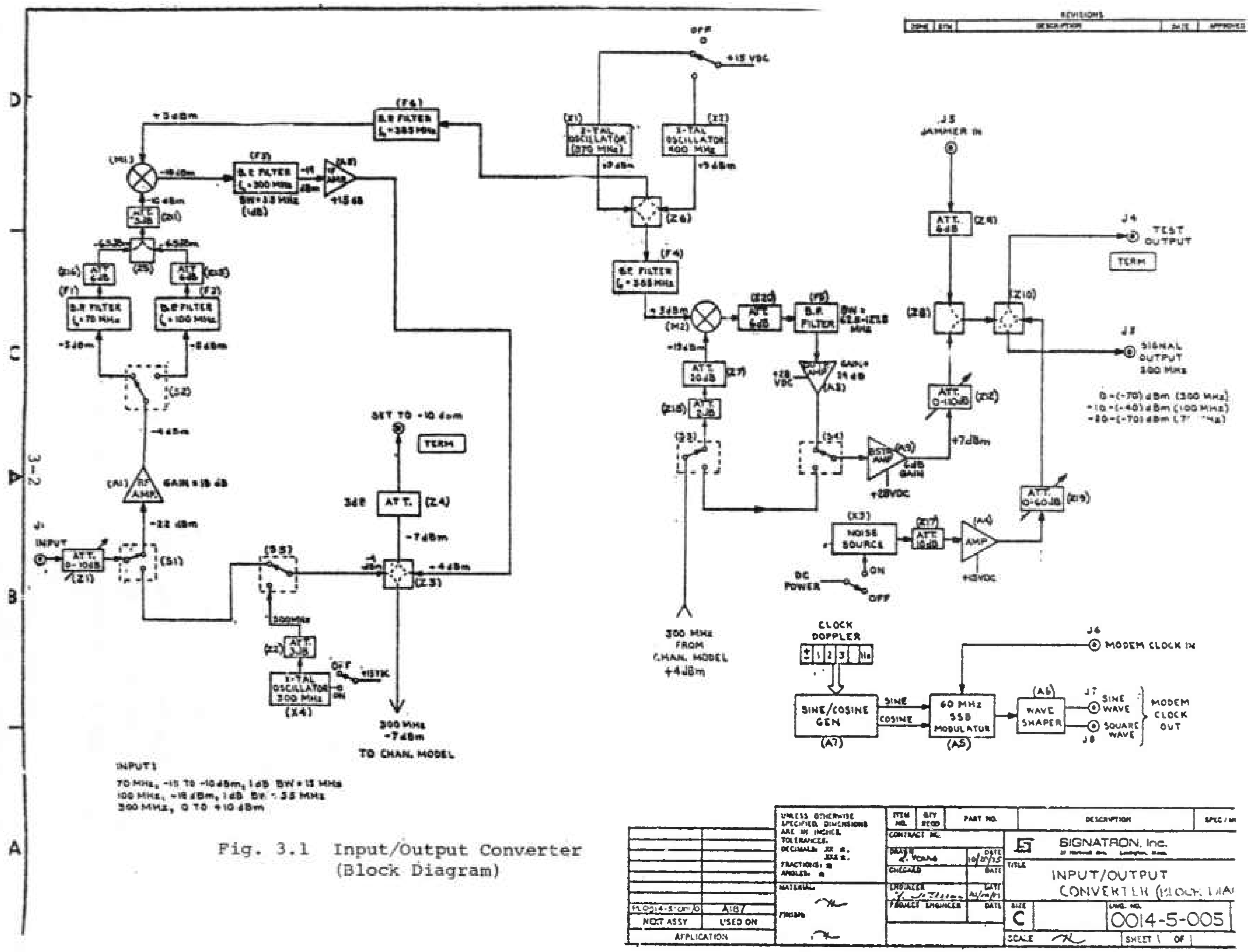

Fig. 3.1 Input/Output Converter
(Block Diagram)

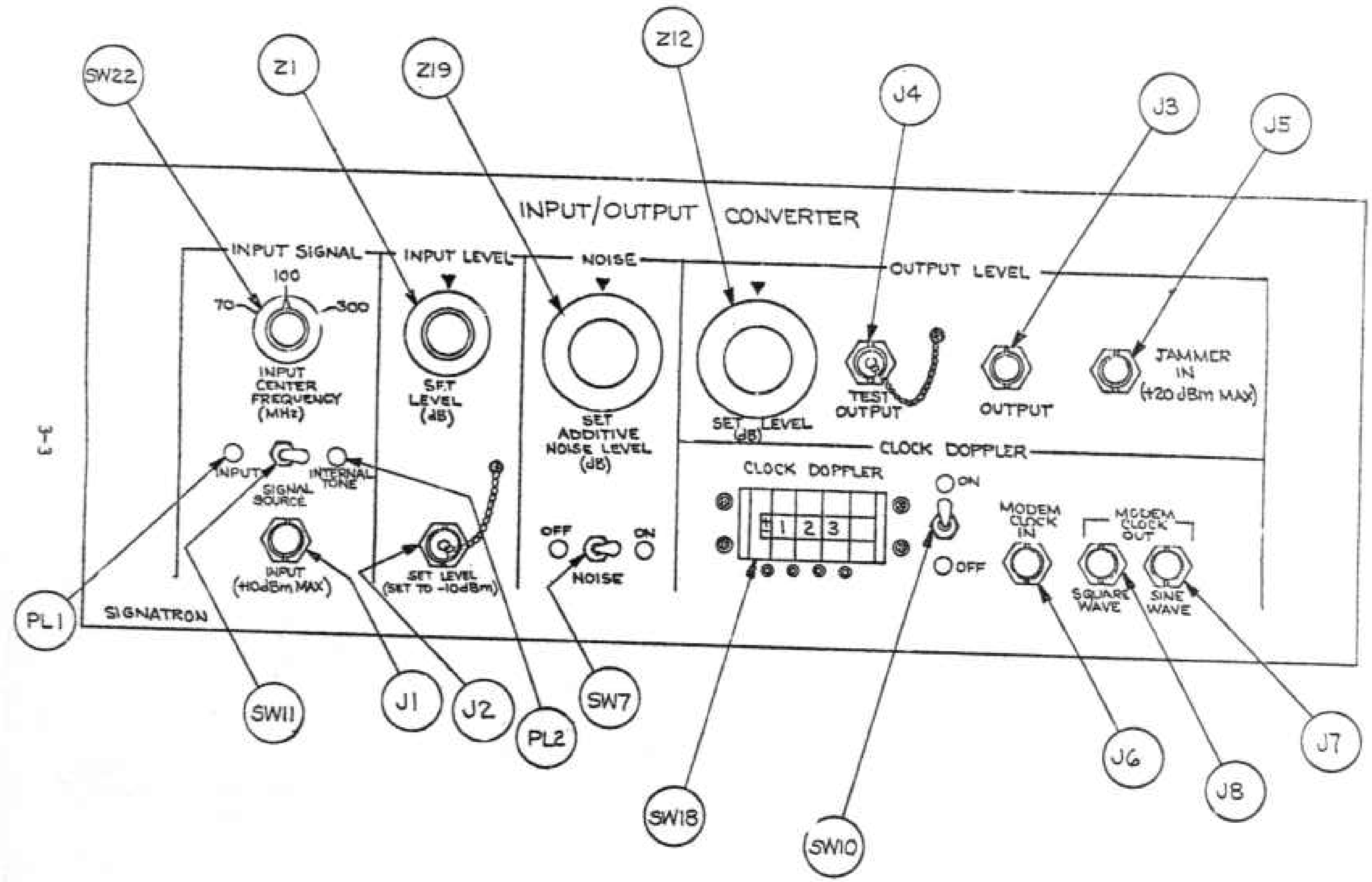

Fig. 3.2 Input/Output Converter, Front Panel Features

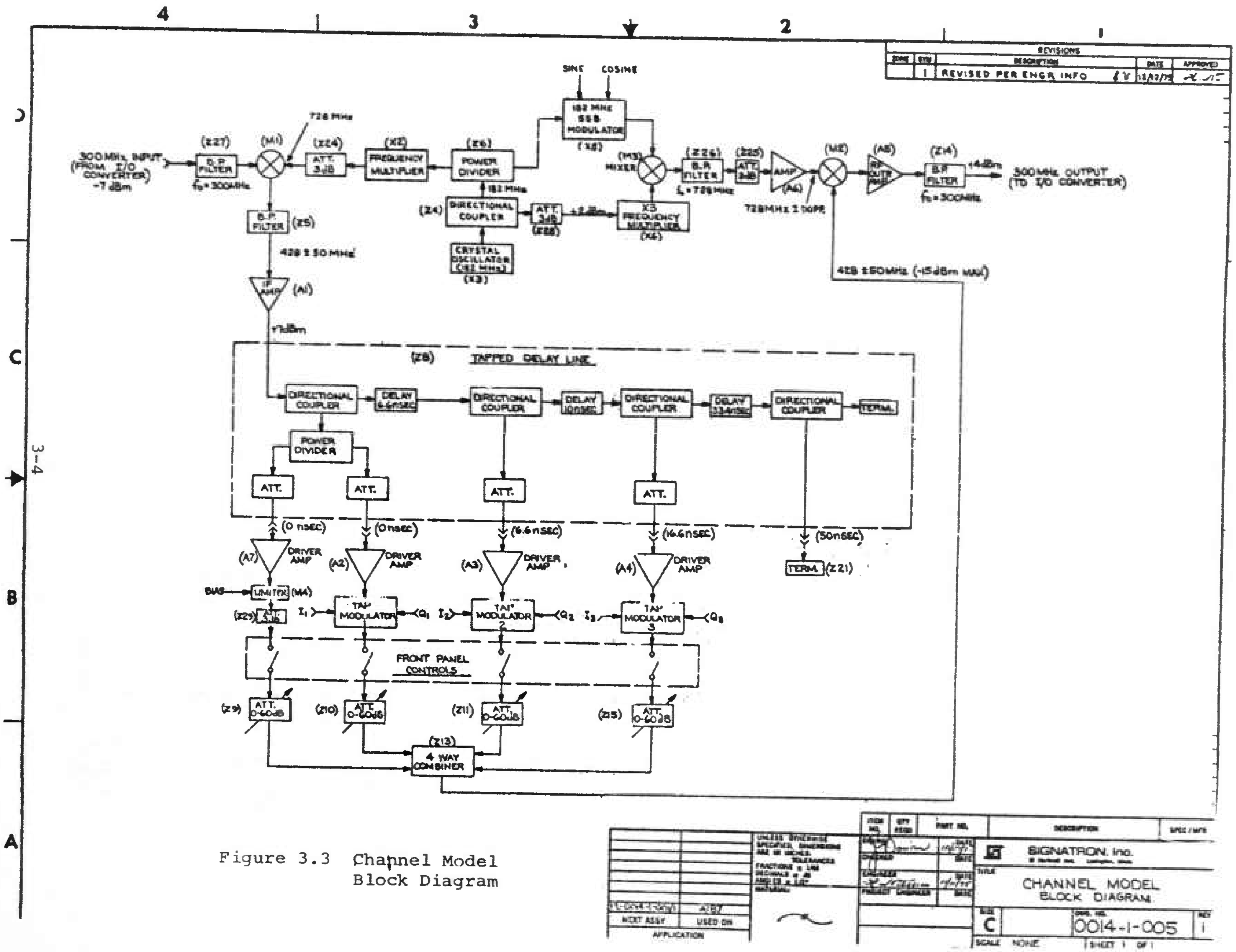

Figure 3.3 Channel Model Block Diagram

operate the instrument, are found on the control panel of this unit (Fig. 3.4). A patch panel located the the rear of the Channel Model Drawer provides a means for selecting different time delays between the direct and delayed paths (Fig. 4.2).

The Doppler Synthesizer unit contains three (3) independent frequency synthesizers designed to generate the so-called sine/cosine outputs. The frequency of each synthesizer is controlled from the panel by a thumbwheel switch which furnishes 3-digit frequency display. The synthesizers serve to supply the Channel Simulator with Carrier Doppler and Delayed Path Differential Doppler. Fig. 3.5 shows the front panel features of this unit. The circuits in this unit are unchanged from the previous design except for minor component changes to improve the reliability. The performed modification was to add another synthesizer associated with the additional delayed path.

The Control Logic sub-unit contains the Digital Noise Generator system consisting of PRN Generation and Timing Logic, Digital Filters, Multiplying DAC's and Switching Logic required to control the panel status lights and coaxial switches.

The Power Supply sub-unit simply furnishes the DC power required to operate the system. The rear panel of this unit contains power distribution wiring and Test Points to monitor DC voltages.

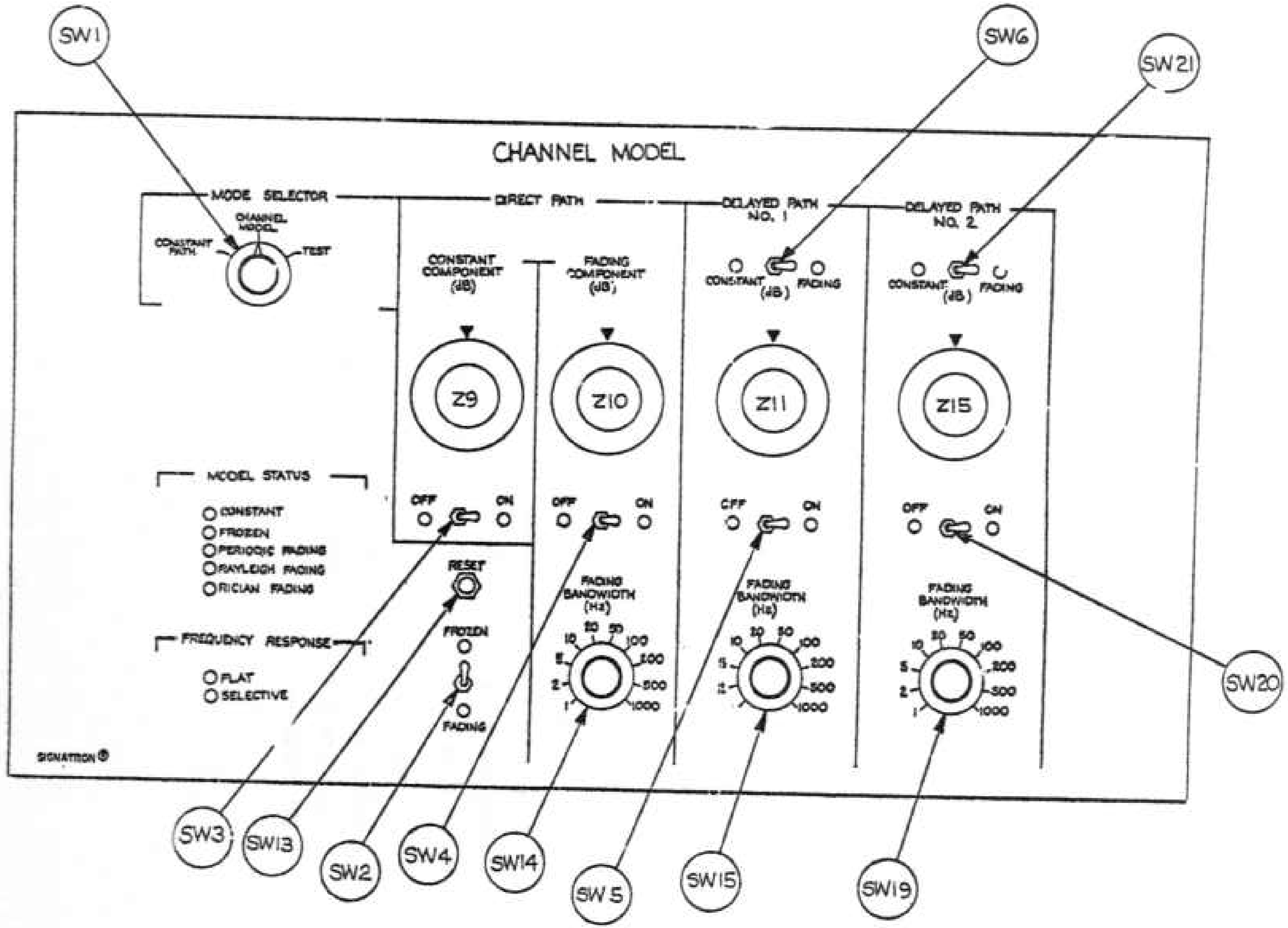

Fig. 3.4 Channel Model, Front Panel Features

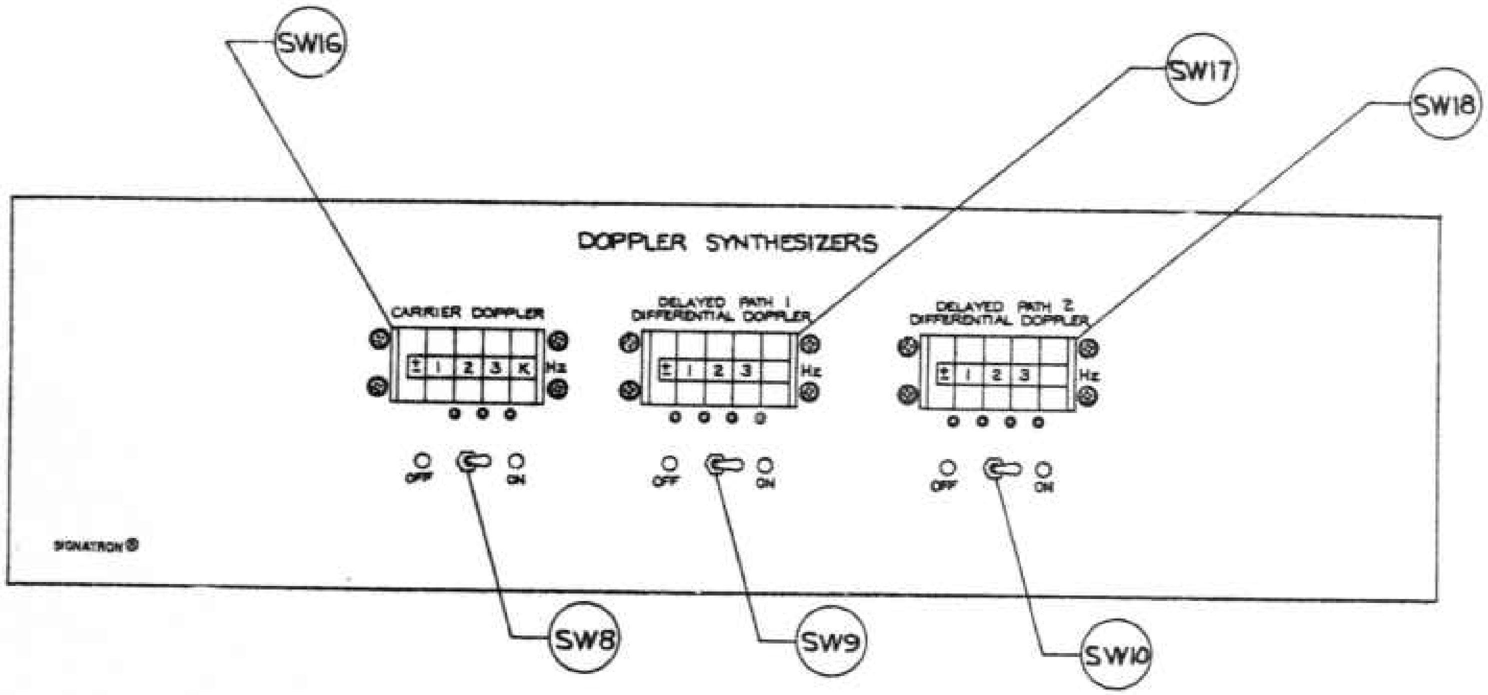

Fig. 3.5 Doppler Synthesizer Front Panel Features

SECTION 4

TYPICAL MODEM TESTS

4.1 Test Configuration

A block diagram for a typical RPV Modem test using the S-187 Los Data Link Test Set is shown in Figure 4.1. The cascade of the data pattern generator and the RPV Modem modulator provide modulated 300 MHz inputs to the test set. A separate clock interface unit, customer provided, is necessary to exercise the modem clock Doppler feature of the test set. The output of the test set provides an input to the RPV Modem demodulator. Data errors present at the demodulator data output are detected and counted in the error detector and counter. All units with the exception of the S-187 Los Data Link Test Set are customer supplied equipments necessary to perform the modem test.

Typical settings for three different channel models are illustrated in the following examples.

4.2 Nonfading Channel (Constant Amplitude; Flat Frequency Response)

For a nonfading channel test the model is exercised over a path consisting of only a constant direct component. The test would consist of measuring the modem demodulator bit error rate as a function of signal power, carrier Doppler, and clock Doppler.

The error rate of a modem operating over a nonfading channel is typically given by a complementary error-function or an exponential function of the signal-to-noise ratio. Such functions range from approximately 0.5 error rate to nearly zero error rate

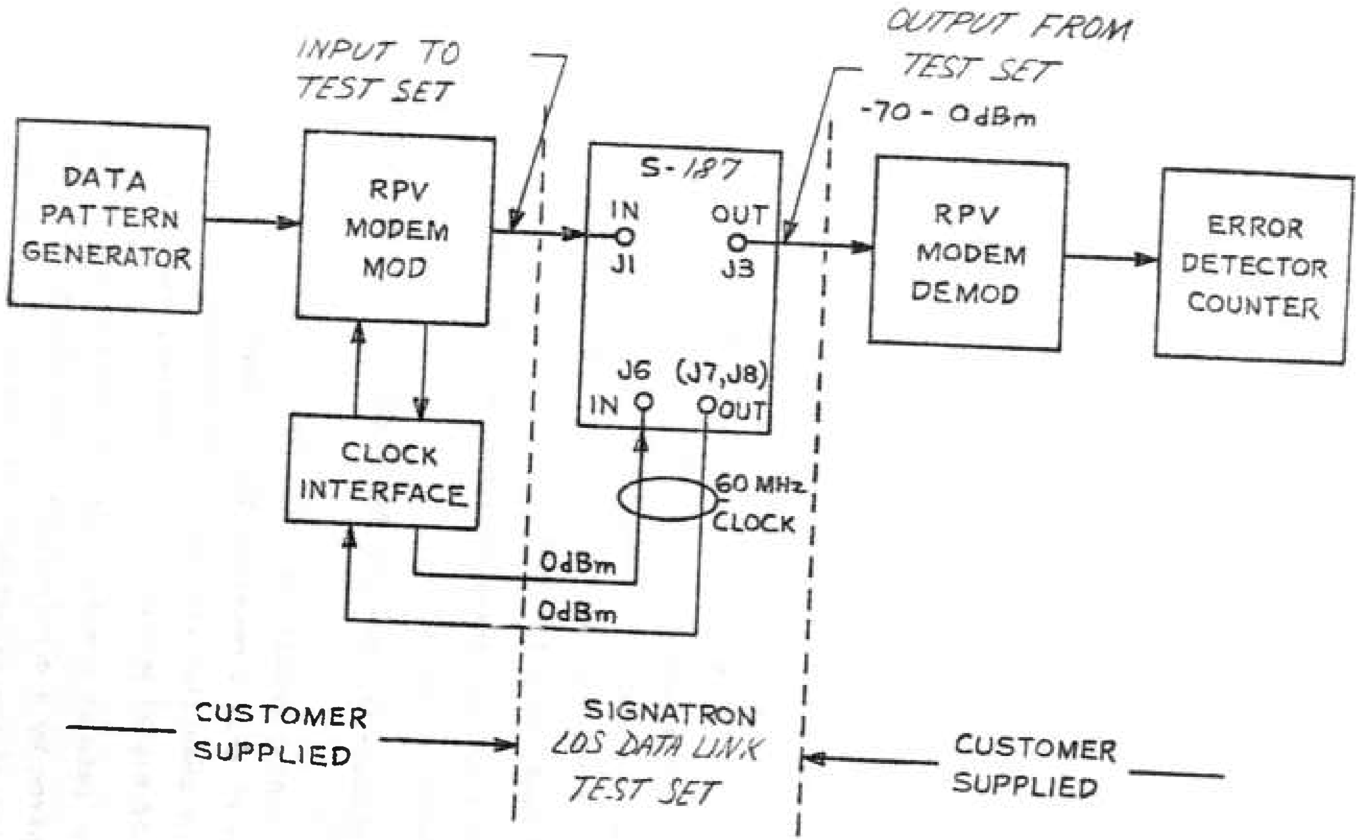

Fig. 4.1 Block Diagram of RPV Modem Demonstration Test.

in a 10 dB range. This range should be located experimentally if it is not otherwise known.

Typical control settings for this test are outlined in Table 4.1.

Table 4.1

Typical Settings for a Nonfading Channel Test

SW1	MODE SELECTOR	CHANNEL MODEL
SW11	SIGNAL SOURCE	INPUT
Z1	SET LEVEL	-10 dBm at J2
SW3	DIRECT PATH	CONSTANT ON
SW4		FADING OFF
Z9	CONSTANT COMPONENT	0 dB
SW5, SW20	DELAYED PATHS	OFF
Z12	OUTPUT SIGNAL LEVEL	As required by test
Z19	ADDITIVE NOISE LEVEL	As required by test
SW7	NOISE ON/OFF	ON
SW8, SW16	CARRIER DOPPLER	As required by test
SW9, SW24	DIFFERENTIAL DOPPLER	Both paths OFF
SW10,SW18	CLOCK DOPPLER	As required by test.

The remaining Test Set settings can be in any position.

4.3 Flat-Fading Channel Test

For a flat-fading channel test, the modem is exercised over a Rician path made up of a constant direct and a fading direct component. The test typically would consist of measuring the bit error-rate over a range of average signal-to-noise ratios.

Typical settings for this test are listed in Table 4.2.

Table 4.2

Typical Settings for a Flat-Fading Channel Test

SW1	MODE SELECTOR	CHANNEL MODEL
SW11	SIGNAL SOURCE	INPUT
Z1	SET LEVEL	-10 dBm at J2
SW3	DIRECT PATH	CONSTANT ON
SW4		FADING ON
Z9	CONSTANT COMPONENT	0 dB
Z10	FADING COMPONENT	10 dB
SW14	FADING BANDWIDTH	100 Hz
SW5, SW20	DELAYED PATHS	OFF
Z12	OUTPUT SIGNAL LEVEL	As required by test
Z19	ADDITIVE NOISE LEVEL	As required by test
SW7	NOISE ON/OFF	ON
SW8, SW16	CARRIER DOPPLER	As required
SW9, SW24	DIFFERENTIAL DOPPLER	Both paths OFF
SW10, SW18	CLOCK DOPPLER	Consistent with Carrier Doppler

Remaining settings can be in any position.

The path model attenuators are set at 3 dB, so that the total output power is the same as for one 0 dB tap, thus approximating the power output of the nonfading and flat-fading tests.

4.4 Periodically Selective-Fading Channel Test

The selective-fading channel test will illustrate the use of the tapped-delay line and the interference (due to differential Doppler) between two constant path signals. The test is run with two equal strength paths, a 16.6 ns delay, and a 100 Hz differential Doppler. This produces a periodic (100 Hz rate) selectively-fading channel. Typical settings for such a test are listed in Table 4.3.

Table 4.3

Typical Settings for a Periodically Selective-Fading Channel Test

SW1	MODEL SELECTOR	CHANNEL MODEL
SW11	SIGNAL SOURCE	INPUT
Z1	SET LEVEL	-10 dBm at J2
SW3	DIRECT PATH	CONSTANT ON
SW4		FADING OFF
Z9	CONSTANT COMPONENT	3 dB
SW5	DELAYED PATH No. 1	ON
SW6	CONSTANT/FADING	CONSTANT
SW20	DELAYED PATH No. 2	OFF
Z11	ATTENUATOR	3 dB
PATCH CABLE (REAR)	DELAY (DELAYED PATH No. 1)	16.6 ns (see Figure 3.5)
Z12	OUTPUT SIGNAL LEVEL	As required by test
Z19	ADDITIVE NOISE LEVEL	As required by test
SW7	NOISE ON/OFF	ON
SW8, SW16	CARRIER DOPPLER	As required
SW9, SW17	DIFF. DOPPLER, PATH No. 1	On at 100 Hz
SW10, SW18	CLOCK DOPPLER	Consistent with Carrier Doppler

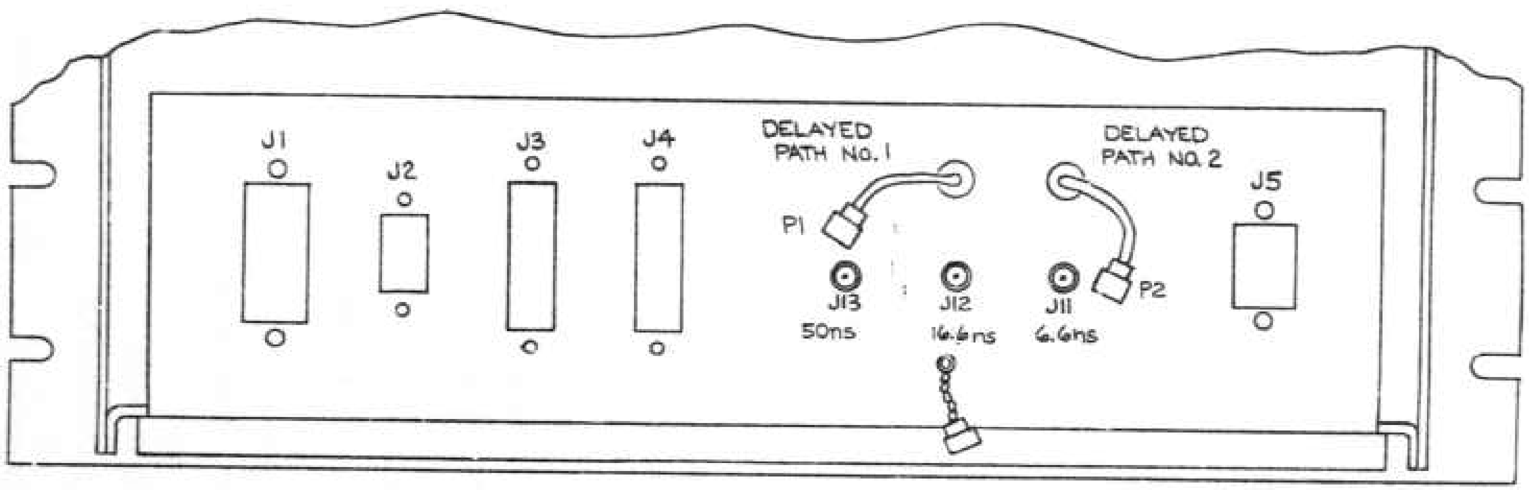

Fig. 4.2 Rear Panel, Channel Model Drawer

4.5 Selecting a Channel Model and Model Status Indicator

The model status indicator LED lights provide a visual indication of the simulated channel model state. For example:

a. A CONSTANT channel model is defined as a fixed gain path model without frequency selectivity. This situation exists when the Mode Selector switch SW1 is in the CONSTANT position or when only the constant component of the direct path is present [SW3 = ON] or when only one of the delayed paths is present and is constant [(SW5 = ON)° and °(SW6 = CONSTANT)].

b. A FROZEN channel exists whenever the FROZEN switch SW2 is in the FROZEN POSITION

c. The Rayleigh Fading light lights whenever the amplitude distribution of the signal at the test set output has a Rayleigh probability distribution if the input to the test set is an unmodulated tone. This distribution will occur if there are no constant components and at least one fading component.

d. Rician Fading exists when either the direct or delayed path having a constant component and a fading component, delayed or undelayed, is present.

e. Flat frequency response exists when one of the direct or delayed components is present but not more than one.

f. Selective frequency response exists when both the direct and a delayed component are present, or when two delayed components are present.

These Channel Model characteristics as well as others are summarized in Table 4.4. Entries left blank have no effect upon the Channel Model.

Table 4.4

Simplified Table of Channel Model Characteristics

CHANNEL MODEL		DIRECT PATH		DELAYED PATH NO. 1			DELAYED PATH NO. 2			FROZEN/ FADING
Distribution	Freq. Response	Constant	Fading	Constant	Fading	Diff. Doppler	Constant	Fading	Diff. Doppler	
Constant	Flat	On	Off	Off	Off		Off	Off		
		Off	Off	On	Off		Off	Off		
		Off	Off	Off	Off		On	Off		
Constant	Selective	On	Off	On	Off	Off	Off	Off		
			On		On		Off			Frozen
		On	Off	Off	Off	Off	On	Off	Off	
			On	Off	Off			On		Frozen
Periodic	Flat	Off	Off	On	Off	On	Off	Off		Fading
		Off	Off	Off	Off		On	Off	On	Fading
Periodic	Selective	On	Off	On	Off	On		Off		Fading
		On	Off		Off		On	Off	On	Fading
		Off	Off	On	Off	On	On	Off		Fading
		Off	Off	On	Off		On	Off	On	Fading
Rayleigh	Flat	Off	On	Off	Off		Off	Off		Fading
		Off	Off	Off	On		Off	Off		Fading
		Off	Off	Off	Off		Off	On		Fading
Rayleigh	Selective	Off	On	Off			Off			Fading
		Off		Off	On		Off			Fading
		Off		Off			Off	On		Fading
Rician	Flat	On	On	Off	Off		Off	Off		Fading
		Off	Off	On	On		Off	Off		Fading
		Off	Off	Off	Off		On	On		Fading
Rician	Selective	On								Fading
		On						On		Fading
			On	On						Fading
				On				On		Fading
					On		On			Fading
			On				On			Fading

SECTION 5
CONCLUSIONS

The modifications of the original Signatron Model S-170 RPV Channel Simulator [1] have resulted in a successful completion of an improved test instrument with enhanced capabilities. The instrument has been renamed LOS Data Link Test to reflect its broader applicability to simulate a variety of other non-RPV, airborne microwave data links. The new designation is Model S-187.

The principal modifications consist of:

1) The capability to accept signals from modems with IF at 70 and 100 MHz, in addition to the previous 300 MHz capability.

2) The augmentation of the channel model to provide a third fading path with its associated Differential Doppler.

3) An increased level of the Gaussian noise source from -100 dBm/Hz to -70 dBm/Hz so as to provide a realistic test of spread spectrum modems having a large signal processing gain.

REFERENCES

[1] J. J. Bussgang, E. H. Getchell, B. Goldberg and P. F. Mahoney, "Stored Channel Simulation of Tactical VHF Radio Links," IEEE Trans., COM-24, February 1976, pp. 154-163.

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