REPORT NO. DOT-TSC-OST-76-44

A SIMULATOR TO PRODUCE NARROWBAND MULTIPATH EFFECTS ON L-BAND AIRCRAFT-TO-SATELLITE SIGNALS

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DECEMBER 1976

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
OFFICE OF THE SECRETARY
Office of the Assistant Secretary for Systems
Development and Technology
Office of Systems Engineering
Washington DC 20590

Technical Report Documentation Page

1. Report No.
DOT-TSC-OST-76-44

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
A SIMULATOR TO PRODUCE NARROWBAND MULTIPATH EFFECTS ON L-BAND AIRCRAFT-TO-SATELLITE SIGNALS

5. Report Date
December 1976

6. Performing Organization Code

7. Author(s)
Edward H. Getchell and Paul F. Mahoney

8. Performing Organization Report No.
DOT-TSC-OST-76-44

9. Performing Organization Name and Address
Signatron, Inc.*
27 Hartwell Avenue
Lexington MA 02173

10. Work Unit No. (TRAIS)
OS219/R7106

11. Contract or Grant No.
DOT-TSC-372

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Office of the Secretary
Off. of the Asst. Sec. for Sys. Dev. & Tech.
Office of Systems Engineering
Washington DC 20590

13. Type of Report and Period Covered
Final Report
March 1972-June 1973

14. Sponsoring Agency Code

15. Supplementary Notes
*Under contract to:
U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

16. Abstract

The purpose of this program was to study the aircraft-to-satellite communications channel and to develop instrumentation to accurately simulate the effects of the multipath, Doppler and additive noise effects of such channels. Such a device which simulates aircraft-to-satellite communication channels has been designed and fabricated. The simulator provides capability for test and evaluation of communications and navigation equipment under controlled and repeatable conditions without the need for extensive, costly, time-consuming and nonrepeatable field experiments.

The basic approach to channel simulation is to split up the signal into several parts, delay each path differently then multiply the delayed signals by a set of complex noise waveforms and sum the results.

Both additive and multiplicative noise signals are exactly reproducible; thus the channel conditions may be reset and repeated.

The channel bandwidth is 10 MHz; the relative delay between direct path and multipath signals may be selected to be 5, 30 or 55 μsec. The multipath delay spread is 8 μsec with a 2 μsec resolution.

17. Key Words
Channel Simulator
Multipath Effects
L-Band Satellite
Communications

18. Distribution Statement
DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
36

22. Price

PREFACE

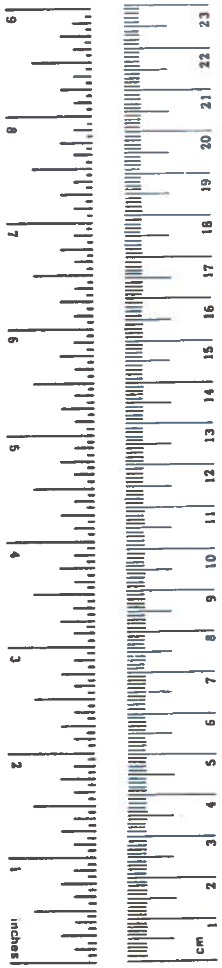
This report describes a new instrument designed to simulate aircraft-satellite communication channels. This work was performed for the DOT/Transportation Systems Center as a part of the overall AEROSAT PROGRAMS.

The main purpose of the facility is to test candidate modems in the laboratory and thus avoid the costly and time-consuming process of field experimentation.

METRIC CONVERSION FACTORS

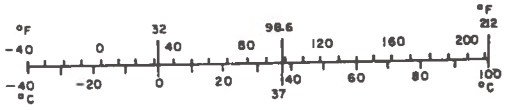
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

The object of this program has been to design and fabricate instrumentation capable of accurately simulating the communications parameters of aircraft-to-satellite channels in a repeatable and controlled manner for the laboratory evaluation of competitive communications and navigational equipment.

The simulated channel parameters had to be variable to simulate varied aircraft-satellite geometries, and the simulated channel had to be exactly reproducible.

The simulator has been designed and built to allow easy modification to accommodate remote controllability of simulator parameters, to allow recorded channels to be played back through the simulator, and to allow operation at either the 1550 to 1650 MHz range or at 70 MHz. The RF path through the simulator is constructed of wideband components so that the bandwidth of the system is in excess of 10 MHz.

Figure 1-1 is a simplified illustration of the geometry of the satellite-to-aircraft communications channel showing the direct and multiple reflected signals, and the additive noise (composed of radiated background noise and receiver front end noise). Appendix A lists the general electrical characteristics of the simulator. The multipath signal consists of reflected signals corresponding to a continuum of delays. The multipath signal has a fixed delay relative to the direct path which is dependent on the aircraft-Earth-satellite geometry. Typical multipath delays are illustrated in Figure 1-2.*

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* J.L. Katz, "Performance of Spread Spectrum Modulation in a Multipath Environment", Lincoln Laboratory Technical Note ESD-TR-72-192, Lexington MA, 21 July 1972.

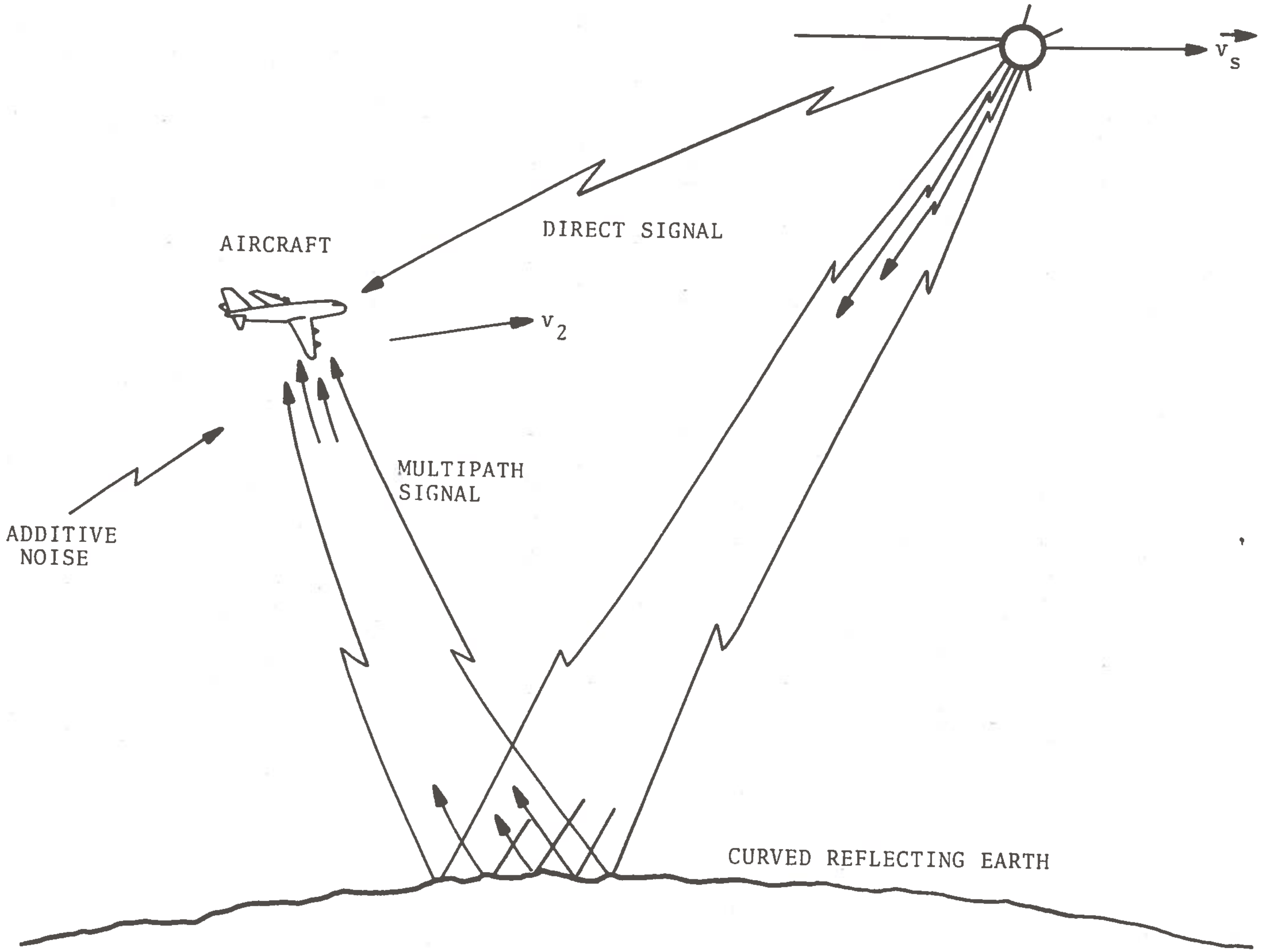

FIGURE 1-1. AEROSAT COMMUNICATION CHANNEL GEOMETRY

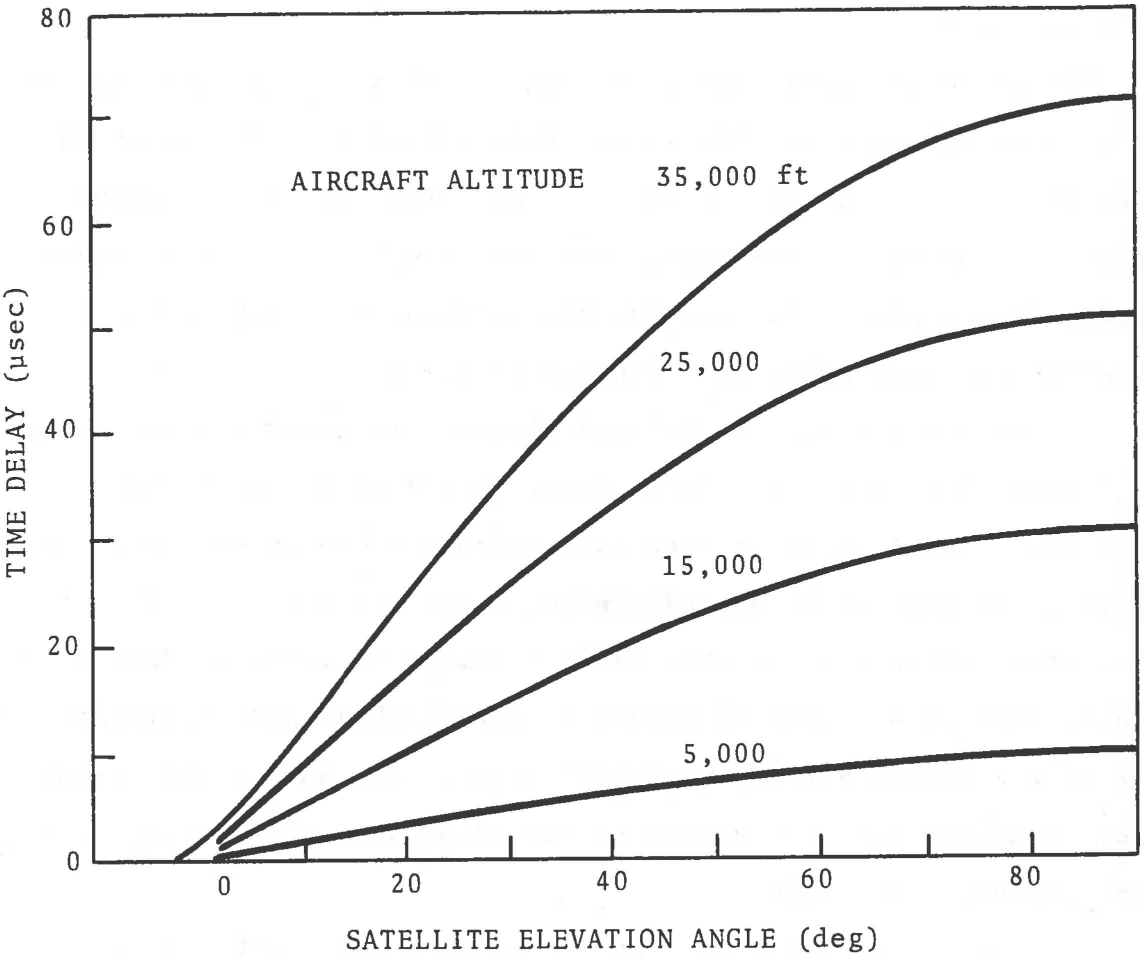

FIGURE 1-2. MULTIPATH TIME DELAY FOR SATELLITE-TO-AIRCRAFT LINK

This continuum of delayed signals may be appropriately modeled using a number of discrete delays.

Figure 1-3 is a simplified block diagram of one method of modeling the aircraft-to-satellite communications channel illustrated in Figure 1-1.

The phase and amplitude of the multipath signal varies randomly in a noise-like manner with an rms fading bandwidth dependent on many factors such as the surface of the Earth, and the relative velocities of the transmitter, receiver, and Earth. These random amplitude and phase fluctuations are modeled by a complex multiplication of each multipath signal with noise.

In the simulator, five delayed signals are generated and spaced at 2 μsec intervals for a total delay spread of 8 μsec.* Each multipath signal is split into two quadrature components, each of which is multiplied by an independent noise voltage. The two modulated components are then added together to again produce a single multipath signal of randomly varying phase and amplitude. The five randomly varying multipath signals are summed and appropriately combined with the direct signal to produce the desired multipath channel simulation.

The average strength of each of the five multipath signals may be set by means of front panel controls so that any desired multipath profile may be constructed.

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*The simulator is not limited to this configuration. Through the use of modular techniques, the basic simulator may be expanded and modified to generate any number of multipath signals and at any desired delay spacings.

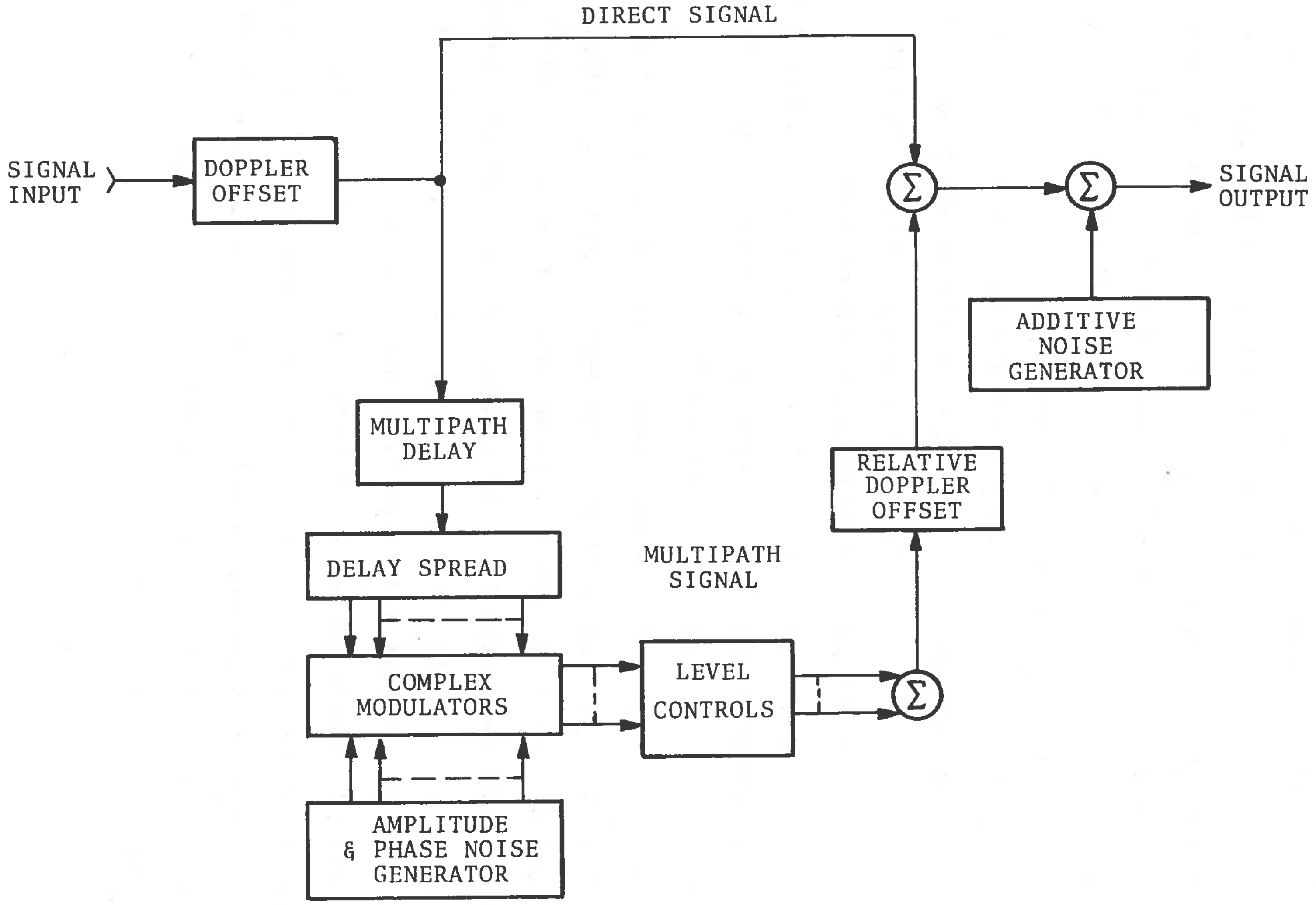

FIGURE 1-3. AEROSAT CHANNEL MODEL

Additive noise is generated in a manner similar to the generation of a multipath signal. A CW signal is split into two quadrature components. Each component is modulated with independent noise signals and combined to produce a noise signal having random amplitude and phase. The additive noise source in the simulator has an rms bandwidth of 50 kHz. Wider bandwidth options up to an rms bandwidth of 10 MHz could be accommodated.

Noise signals used to create the rms fading rate of the multipath signals and the rms noise bandwidth of the additive noise are generated digitally. As a result the simulator may be reset prior to a data run for absolutely reproducible channel simulations. Additionally, the rms bandwidth of each multipath noise source may be set independently, and the instantaneous multipath channel fading profile may be frozen and restarted at will.

Doppler frequency offsets are caused by the velocity of the aircraft relative to the Earth and satellite. Two Doppler effects are observed. One is a frequency offset which is equal on both the direct and multipath signals. The second "relative" Doppler effect appears primarily on the multipath signal and is due to vertical motions of the aircraft and Earth curvature effects.

A DOPPLER control having a ± 1000 Hz range is provided to generate equal Doppler offsets on both the direct and delayed multipath signals from the channel simulator. Additionally a RELATIVE DOPPLER control is provided to produce a ± 100 Hz Doppler offset on the multipath channel only.

2. SIMULATOR DESIGN

The simulator is shown in block diagram form in Figure 2-1. The front of the physical device is shown in Figure 2-2.

The Input/Output interface subsystem accepts the input signal, converts the L-band input to 70 MHz, adds the Doppler and relative Doppler, conditions the signals for the tap modulators, and selects the relative delay between direct and multipath signals. It also combines the output of the tap modulator with the direct signal and adds the additive noise to the signal.

The synthesizer control subsystem produces the Doppler and relative Doppler signals, a 70 MHz tone for use by the test signal generator, and translates the baseband noise from the additive noise generator to 70 MHz.

The tap modulator subsystem splits the signal into five parts, delays each part by a different amount such that the delay separation is 2 μsec, mulitplies the in-phase and quadrature components of each delayed signal by statistically independent noise waveforms, and combines the results.

The digital noise generator subsystem produces the five pairs of noise signals which modulate the in-phase and quadrature multipath signal components in the tap modulators. These noise waveforms are produced by a set of pseudo-random number generators whose outputs are digitally filtered. This makes the noise pattern completely reproducible.

The clock synthesizer subsystem produces a set of clocking signals which drive the noise generator. The bandwidth of the noise waveforms is proportional to the frequency of these clock

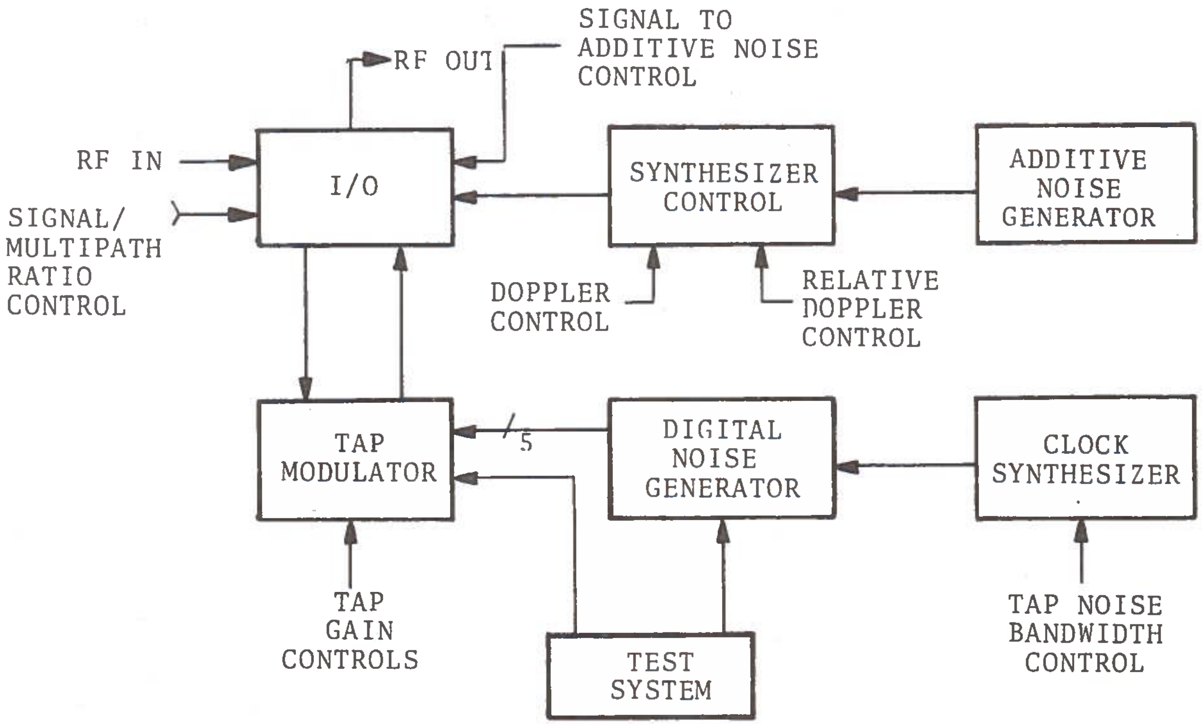

FIGURE 2-1. BLOCK DIAGRAM OF THE SIMULATOR

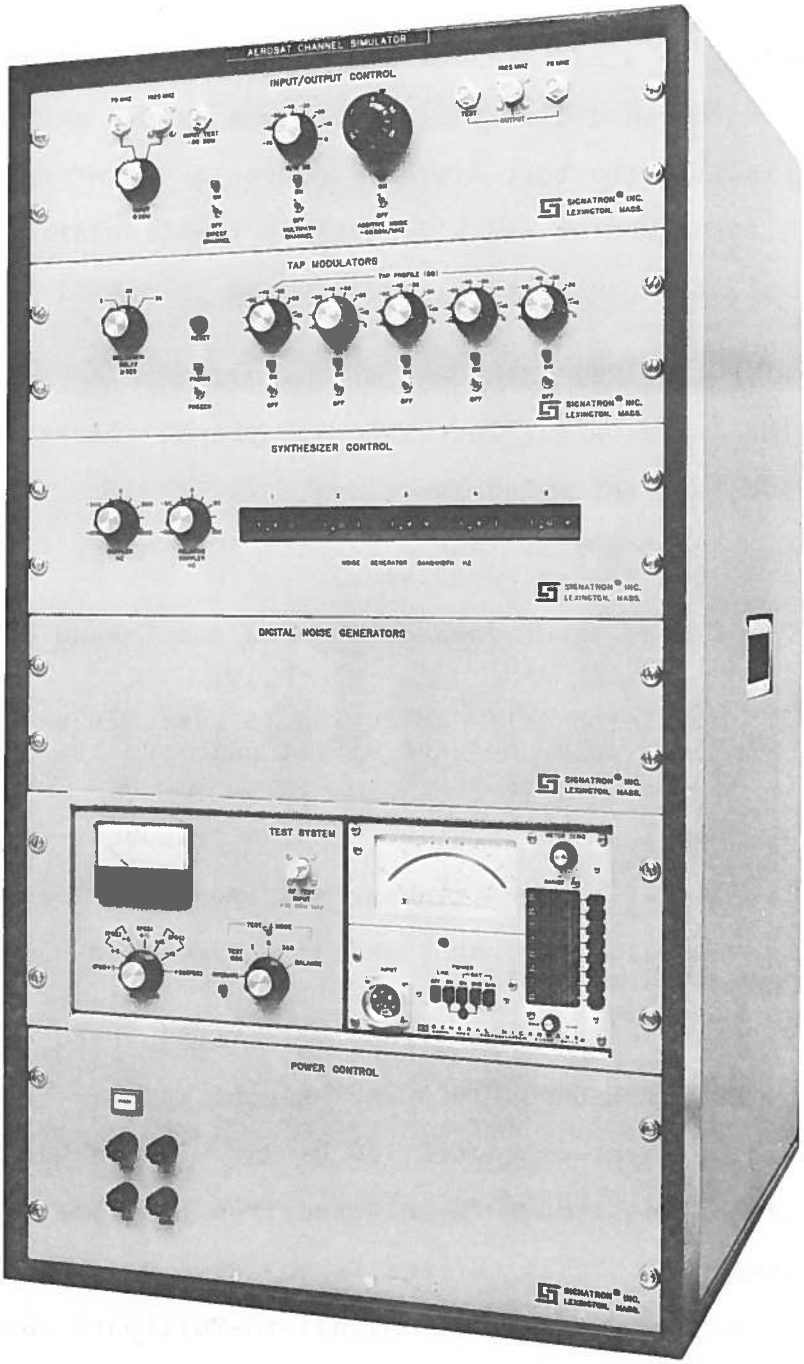

FIGURE 2-2. WIDEBAND AIRCRAFT-TO-SATELLITE COMMUNICATIONS CHANNEL SIMULATOR

signals. To achieve exact reproducibility it is necessary to synthesize these clock signals from a common source.

Finally, the test system produces a set of test signals which facilitate testing and alignment of the simulation. The design of each of these subsystems is discussed in detail below.

2.1 INPUT/OUTPUT INTERFACE

The Input/Output Interface subsystem, illustrated in Figure 2-3, provides the following functions:

1. Input signal source selection (L-band, 70 MHz, 70 MHz test oscillator)
2. L-band input down-conversion and L-band output up-conversion
3. Multipath delay selection (5 μsec, 30 μsec, 55 μsec); i.e., delay between direct path and the beginning of the multipath signal
4. Doppler and Relative Doppler frequency offset generation
5. Signal preconditioning for tap modulators
6. Signal, multipath, and additive noise combining and power ratio control.

A front panel input signal selector is used to select either the 70 MHz or L-band (1625 MHz) signal input. The 70 MHz test oscillator input is controlled by circuits in the input/output interface chassis but is selected from the Test System front panel. The composite Signal (Direct Signal plus Multipath)-to-Noise power ratio (S/N) and the Direct Signal-to-Multipath power ratio (S/M) are front-panel-controlled using attenuators. As illustrated in Figure 2-2, the additive Noise Signal, the Direct Channel, and the Multipath Channel each may be turned off for system calibration and testing. All signal selection, steering, and on/off control are

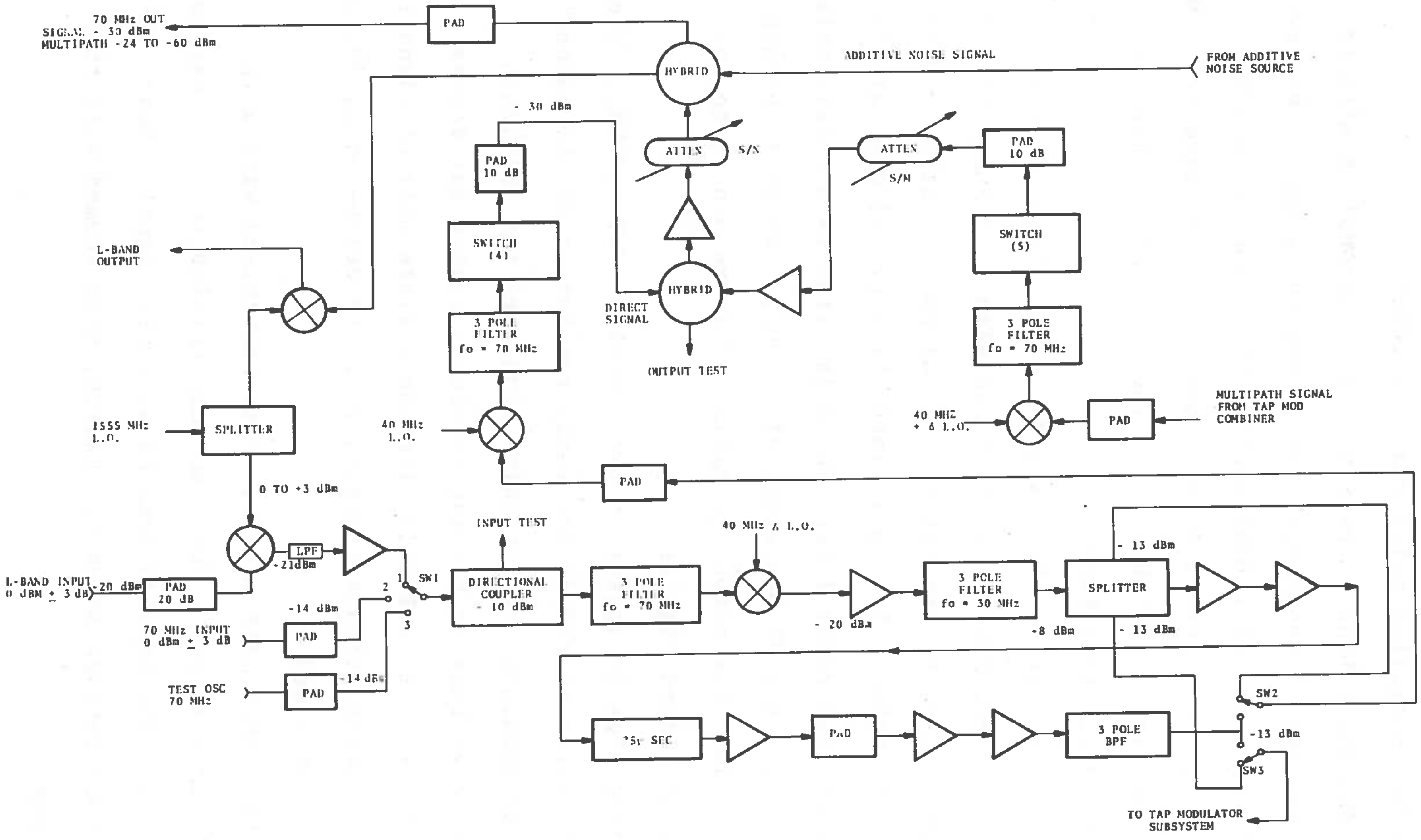

FIGURE 2-3. INPUT/OUTPUT INTERFACE

performed by DC-controlled solid-state switches.

Both 70 MHz and L-band outputs are simultaneously available. Also, input and output test points are provided to facilitate system setup, alignment, and continuous monitoring during operation.

Referring to the Figure 2-3 the L-band input is mixed to 70 MHz by combining it with a 1550 MHz L.O. The same L.O. is used to reconvert the output to L-band.

The switch SW1 selects the desired input (L-band, 70 MHz or TEST OSC). From here the signal is mixed with a 40 MHz ± Δf L.O. The Δf is the Doppler offset set by a front panel control. Next the signal is filtered, then split into three parts; one part is delayed by a 25 μsec delay line. The delay line is a quartz bulk effect device with a 1 dB bandwidth of 10 MHZ. The loss through the line is 53 dB. The output is amplified to return it to the level of the undelayed signals.

These three signals appear at two switches, SW2 and SW3. The output of the first is the direct path; the output of the second drives the tap modulator system which simulates the multipath signal. The delay bank in the tap modulator system has delays from 30 to 38 μsec. By selecting the appropriate pair of signals for the direct and multipath signals, relative delays of 5, 30, and 55 μsec may be obtained.

As for the direct path signal, it is next mixed with a 40 MHz L.O. to return it to 70 MHz. Because this 40 MHz L.O. has no frequency offset, the Doppler remains with the signal. Next, the signal is passed through an on/off switch, then summed with the multipath signal.

The multipath signal from the Tap Modulator Subsystem is mixed with a 40 MHz ± δf L.O. and then summed with the direct path signal. The relative Doppler shift is δf. The output of the summer is combined with the additive nosie signal. The 70 MHz output is taken at this point. The L-band output is produced by mixing this signal to 1625 MHz using the 1555 L.O. source.

2.2 TAP MODULATOR SUBSYSTEM

The tap modulator subsystem block diagram is illustrated in Figure 2-4. The purpose of the tap modulator subsystem is to produce five simulated multipath signals having a gross signal path delay of 30 μsec and a delay spread of 8 μsec, in 2 μsec intervals. This is accomplished in the following manner (referring to the figure):

A sample of the direct path signal is amplified to + 25 dBm by the high level buffer amplifier. The ouput of the buffer amplifier is split five ways using an eight-way splitter with three output ports terminated. The five outputs from the signal splitter are each passed through a delay line. The delay lines are quartz bulk effect devices with a 1 dB bandwidth of 10 MHz. The delays through the five delay lines are 30, 32, 34, 36, and 38 μsec to develop the required 2 μsec separation, 8 μsec delay spread, and 30 μsec gross delay. The delay lines have an insertion loss on the order of 45 to 50 dB. Buffer-Amplifiers follow each delay line in order to compensate for the loss of the delay line. The gain of each amplifier is internally adjusted to compensate for the loss of the preceding delay line so that the output of all the buffer-amplifiers is at a level of +3 dBm ± 1 dB. This is the required drive level

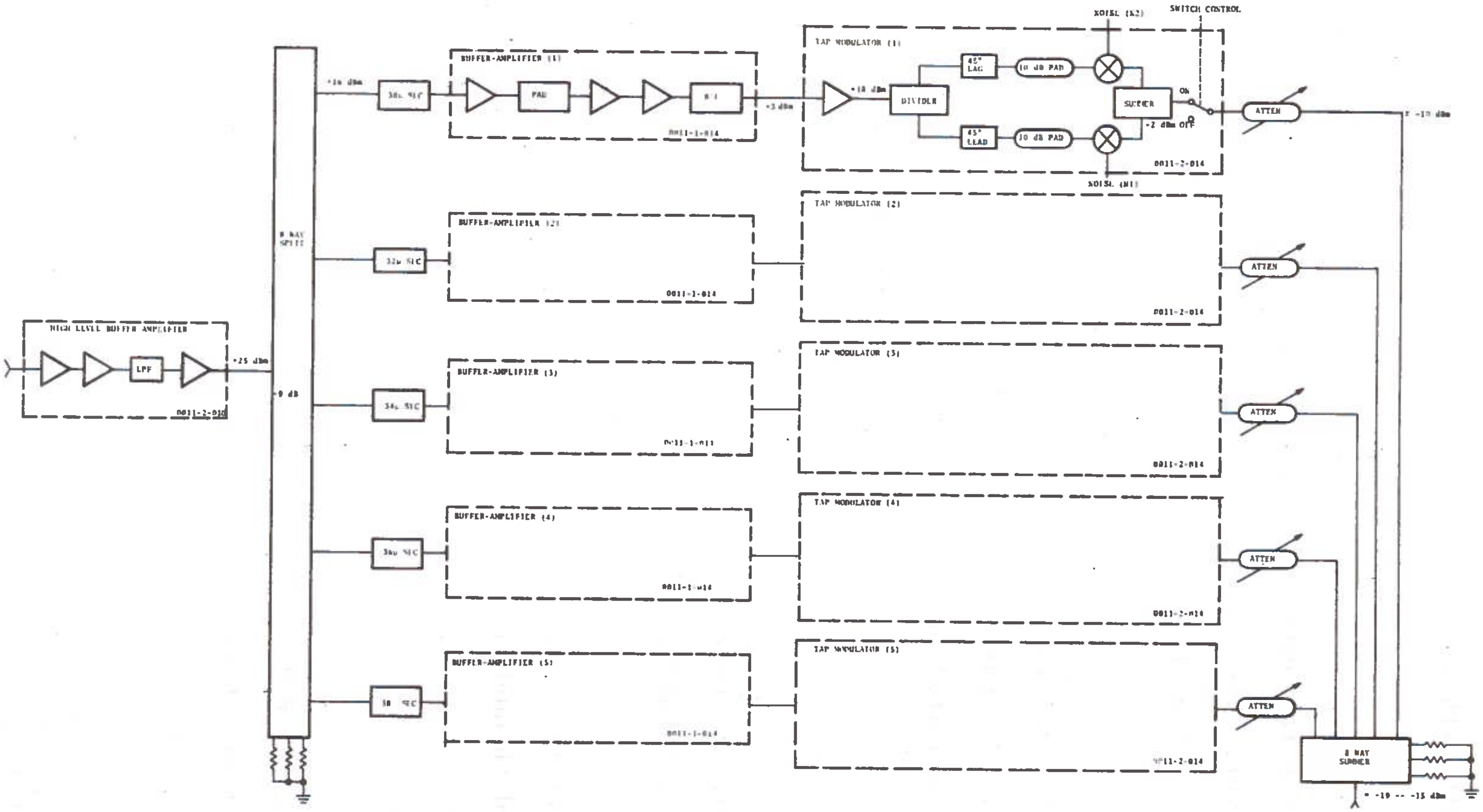

FIGURE 2-4. TAP MODULATOR SUBSYSTEM

at the input to the five tap modulators. The tap modulators are used to multiply the delayed signals with noise so as to simulate the random amplitude and phase characteristics of multipath signals.

The output of each tap modulator represents a multipath signal. Each of the five output multipath signals passes through a front-panel-mounted continuously variable attenuator to allow manual level setting of each of the multipath signals. The five signals are then summed in the eight-way summer with three ports terminated and returned to the Input/Output interface subsystem.

The tap Modulator subsystem front panel controls consist of the following:

1. Tap modulator Gain control on each tap used to set the multipath delay power profile
2. Tap modulator ON/OFF switch on each tap used to eliminate the signal from any or all taps (these facilitates tap profile setup and system alignment)
3. MULTIPATH DELAY Selector used to select the multipath delay: 5 μsec, 30 μsec, 55 μsec
4. Noise source control RESET, used to reset all digital noise sources (for both tap modulators and the additive noise source) to a fixed starting point
5. Noise source control FADING/FROZEN switch which allows all noise sources to be manually stopped to produce a "frozen" channel. The noise system can be re-started to FADING from FROZEN without the noise generator being reset.

2.3 SIGNAL SYNTHESIZER SUBSYSTEM

The Signal Synthesizer Subsystem of the RF signal processing portion of the Aerosat simulator is illustrated in Figure 2-5. This chassis contains the three 40 MHz precision oven-controlled quartz oscillators used for local oscillators in the Input/Output

Interface subsystem. One of the three 40 MHz oscillators (f_3) is fixed; the other two are voltage-controllable using front panel potentiometers. One 40 MHz oscillator (f_1) generates the ± 1000 Hz Doppler offset on all signals; another (f_2) generates the ± 100 Hz Relative Doppler offset on the multipath signal only.

A 70 MHz crystal oscillator used as a built-in test signal source is also a part of the signal synthesizer subsystem.

Finally, as shown in Figure 2-5, the Additive Noise Modulator and the Additive Noise Low Pass Filter used to generate 50 kHz bandwidth Additive Noise are also located in the signal synthesizer subsystem.

It will be noted from observations of Figure 2-2 that the digital noise generator bandwidth controls are located on the front panel of the Synthesizer Control subsystem. This is a mechanical and operational convenience only. Mounting of the digital system control switches on the panel above the digital system permits easy access to the digital cards for servicing and alignment. All electronics of the digital noise generator except the bandwidth control switches are located in the digital noise generator drawer.

2.4 DIGITAL NOISE GENERATOR SUBSYSTEM

The noise waveforms which modulate the outputs of the five delay line taps are produced by the digital noise generators.

Since the waveforms must be exactly reproducible both in shape and in time scale, and also relative to one another, the noise is derived from a set of digital pseudo-random number generators. Since the bandwidth of each tap must be independently variable while maintaining reproducible sets of noise waveforms the clock

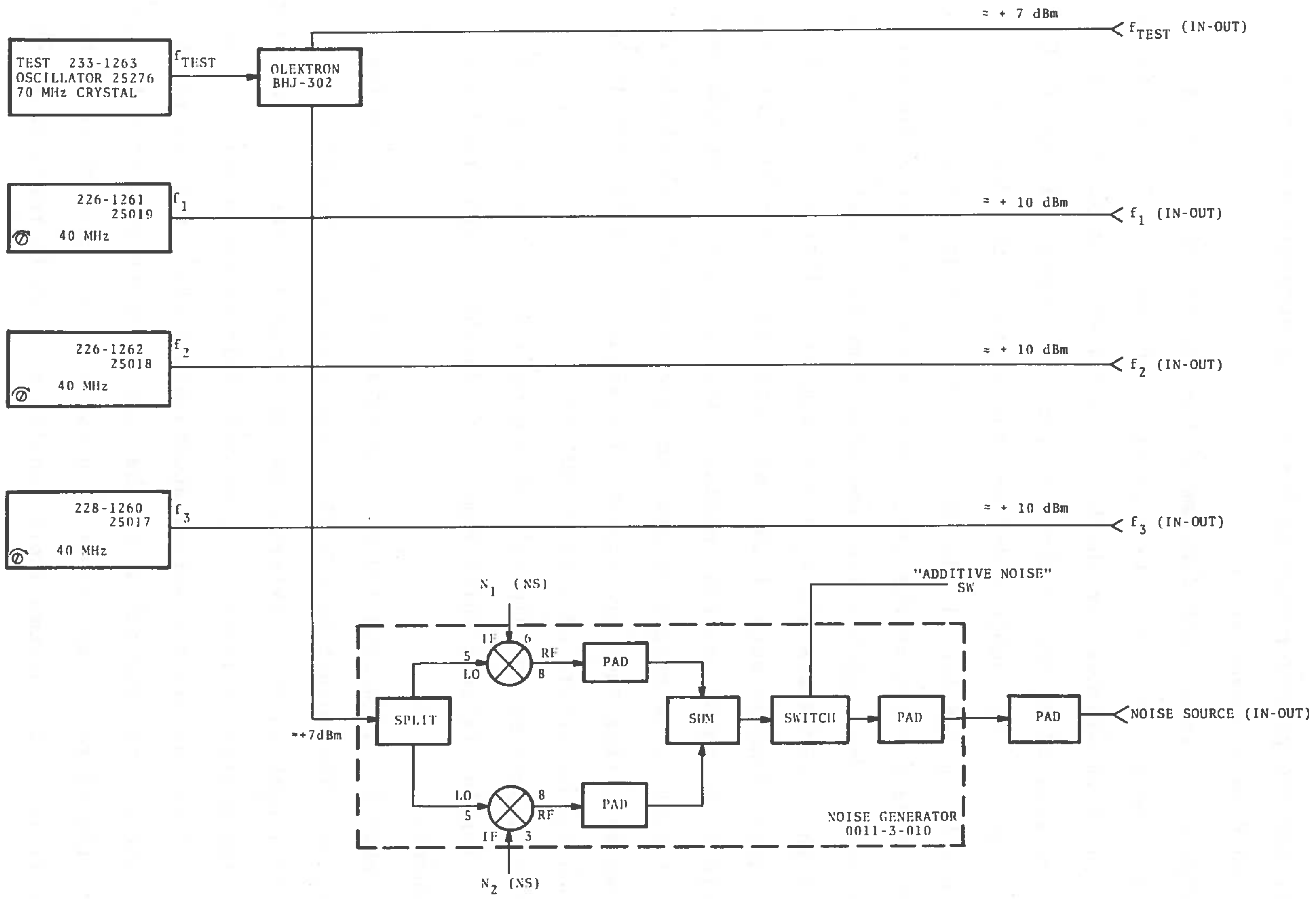

FIGURE 2-5. BLOCK DIAGRAM OF SIGNAL SYNTHESIZER

pulses for the pseudo-random number (PRN) generators must be synthesized from a common source.

Figure 2-6 is a block diagram of the digital noise generator system. The timing source is a crystal oscillator. The oscillator drives a clock synthesizer which is controlled by a bank of digiswitches located on the "Sythesizer Control" panel. By means of these switches the double sided rms bandwidth of the noise waveform may be varied from 10 Hz to 1.99 kHz in 10 Hz steps.

The five outputs of the clock synthesizer drive five digital noise generators. Each noise generator contains a pair of maximal-length shift registers and a pair of digital filters. The feedback connections in each of the shift registers are different, and therefore the noise patterns produced are different. The two outputs of each noise generator are the same bandwidth but statistically independent; thus they are appropriate signals to drive the inphase and quadrature inputs of a tap modulator.

The outputs of the digital noise generators are filtered by a set of alias filters which remove the unwanted high frequency components.

Figure 2-7 is a detailed block diagram of one digital noise generator. The output of the clock synthesizer increments two maximal-length shift registers (PRN generators). The PRN generators drive two digital filters. The digital filters use a serial arithmetic. They contain two serial accumulators which are tapped at strategic points; the output of the taps is subtracted from the input to the filter. The resulting network is a second-order Butterworth filter. The accumulators consist of a shift register whose

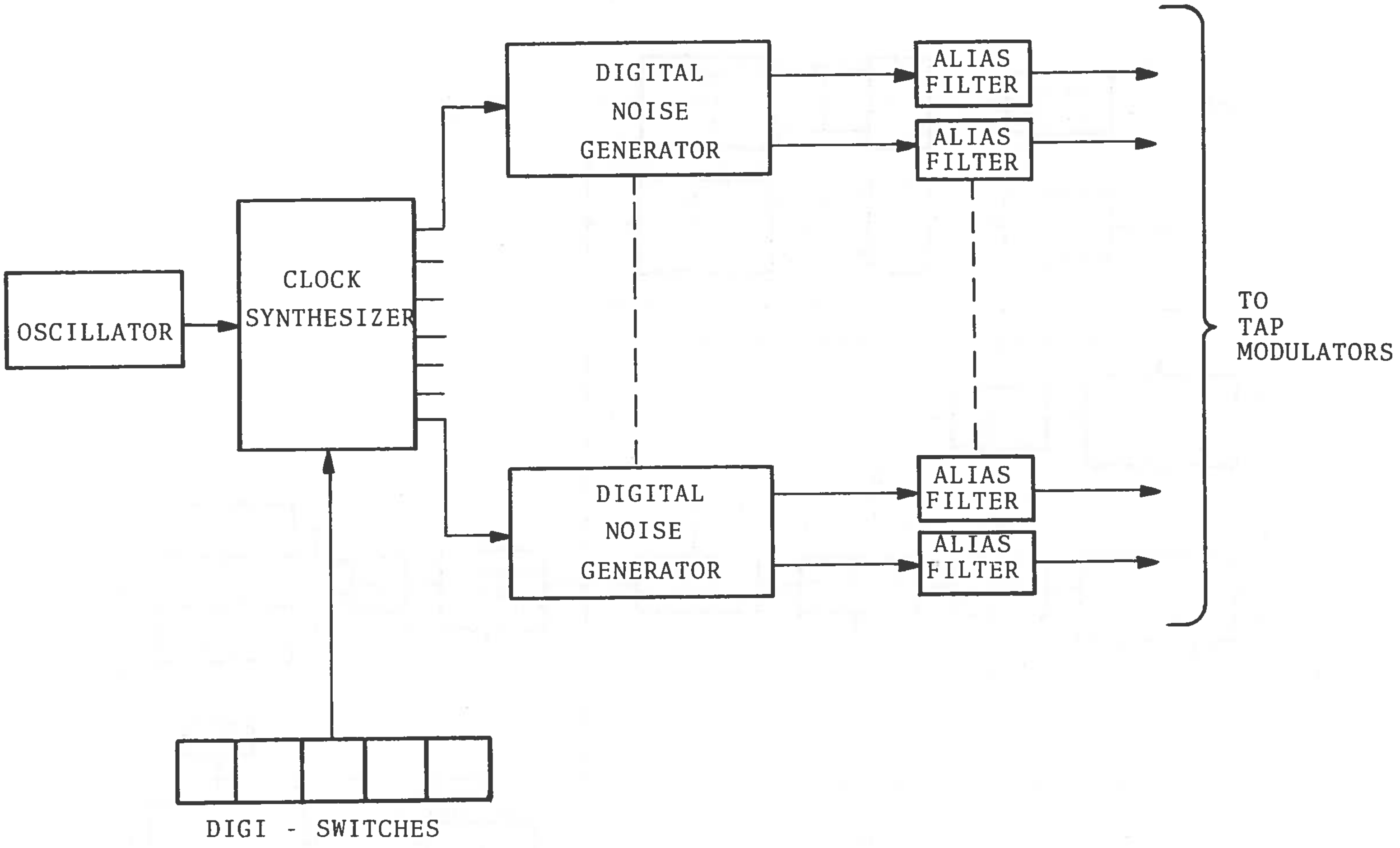

FIGURE 2-6. BLOCK DIAGRAM OF DIGITAL NOISE GENERATOR SYSTEM

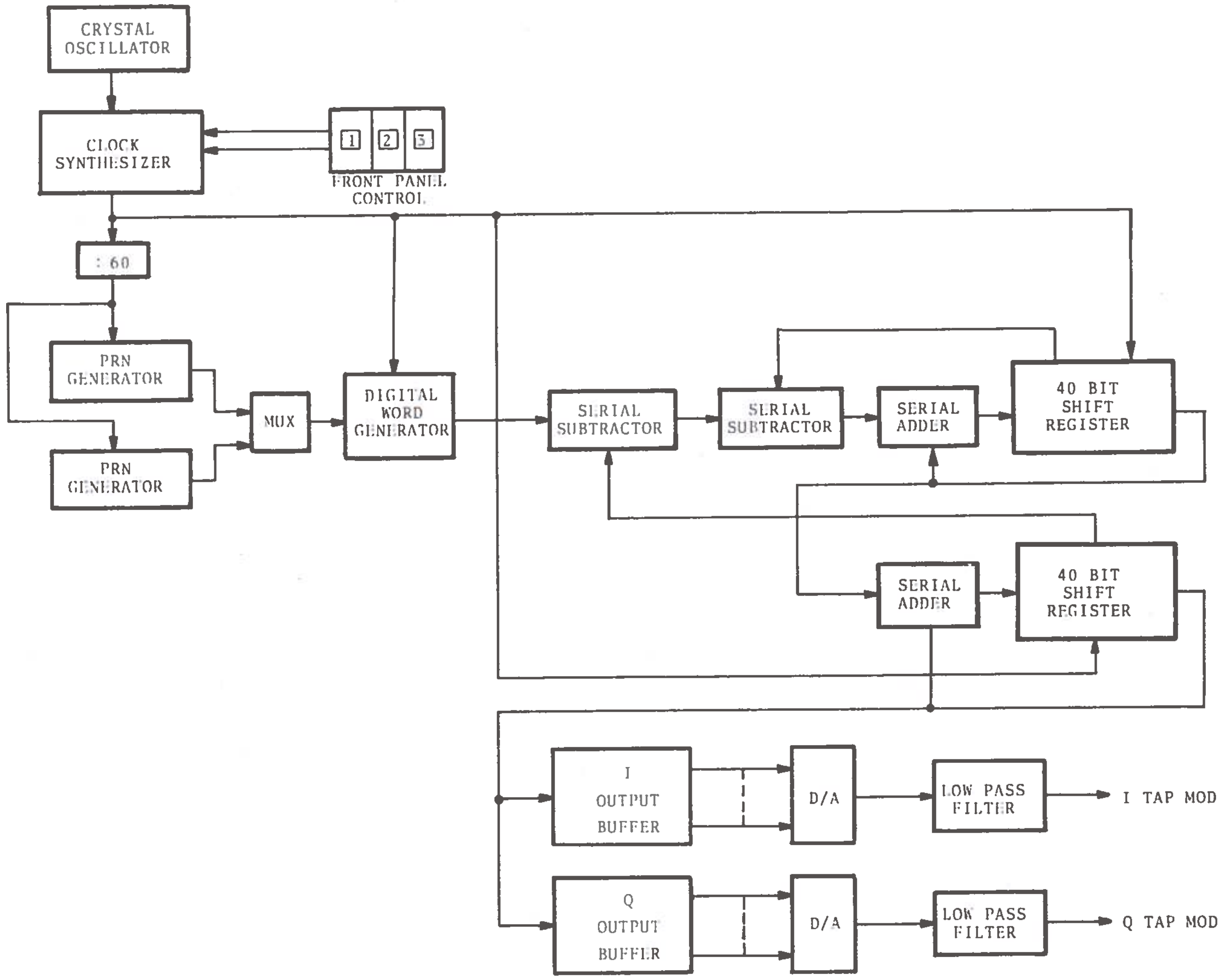

FIGURE 2-7. DIGITAL NOISE GENERATOR BLOCK DIAGRAM

output is fed back and added to its input. By making the length of these shift registers twice as long as one word length, it is possible to time-multiplex the filter between the two sets of pseudo-random data so that the two filters share a common set of adders and subtractors. The output of this network is alternately read into one output buffer register and then the other.

Provision is made at the output buffer to insert a digital number which equals the rms value of the noise voltage. This number is switched in when the rms channel gain is set during calibration.

2.5 CLOCK SYNTHESIZER

The clock synthesizer produces a coherent set of clocks to drive the noise generator. The relationship between the sample rate and the three-dB cutoff frequency of the digital filter is:

$$S = \frac{64\pi}{\sqrt{2}} f_{3dB} = 137 \; f_{3dB} \; .$$

The design of the filter is such that 40 clock pulses are required for each output sample. Thus the maximum clock rate (for a double sided B.W. = 1.99 kHz) equals

$$C\ell_{max} = 142 \text{ x } 40 \text{ x } 995 = 5.68 \text{ MHz}.$$

The minimum clock rate is

$$C\ell_{min} = 142 \text{ z } 40 \text{ x } 5 = 28.4 \text{ kHz}.$$

A mod-200 counter is driven by a 28.4 MHz crystal oscillator. At the time when the counter reads zero a flip-flop is cleared. The flip-flop controls a gate which allows the 28.4 MHz to pass while the flip-flop is cleared. When the count in the counter reaches the number which matches the number set on the digi-switches the flip-flop is set, gating off the 28.4 MHz pulses.

Thus the number of pulses out of the gate during each cycle of the mod-200 counter is between one and 199 according to the setting of the digi-switches.

The pulse trains produced in this manner are uneven; however, if the pulses are divided by a modulo-200 divider a set of evenly spaced pulses will result. The clock pulse into the digital filters need not be evenly spaced as long as the samples which appear at the output are evenly spaced. Since the output samples occur once every 40 input clock pulses, the digital filter acts like a modulo-forty divider. Therefore, if the gated 28.4 MHz pulses are divided by five before being applied to the digital filters the overall divide ratio will be 200. Since the maximum clock rate required is 5.68 MHz and it must be pre-divided by five, the counter must operate at 5 x 5.68 = 28.4 MHz.

2.6 ADDITIVE NOISE GENERATOR

The Additive noise pseudo-random number (PRN) generator is part of the additive noise system. A pair of binary pseudo-random sequences are generated and drive the Additive Noise low-pass filters. The low-pass filtering converts the wideband binary sequence to continuous Gaussian noise waveforms which may be exactly reproduced by resetting the PRN generator.

The two noise waveforms modulate the in-phase and quadrature components of a 70 MHz carrier in the additive noise modulator to produce a 50 kHz wide noise centered at 70 MHz.

The PRN-generator board contains a 1 MHz crystal oscillator which clocks a 39-bit maximal length sequence generator; at this rate the period of the sequence is about 6 days. Alternate bits of the sequence are read into a pair of flip-flops to produce two sequences each going at a bit rate of 500 kc.

The sequences of bits which occur at the output of these two flip-flops are identical; however, they are shifted with respect to one another by a number of bits equal to one-half the sequence length. Therefore, there is a delay of 6 days between the two sequences.

The PRN generator is set to a particular state each time the reset button is pushed.

2.7 TEST SYSTEM

The test system portion of the Aerosat simulator provides sufficient built-in test equipment and system control functions to perform two essential tasks. First, pre-operational system alignments such as setting tap gain profiles and signal levels, relative signal, multipath, and additive noise levels, and routine go/no-go subsystem checks are easily performed using the test subsystem. Second, a majority of system maintenance, calibration, and trouble-shooting tasks can be performed by using the built-in test functions and measurement gear.

All RF power levels are measured using the built-in General Microwave 460 B power meter and N421D sensing head. A BNC input connector is provided to allow patching the power meter to front panel test points for system setup and to internal signal access points for trouble-shooting and maintenance.

All supply voltages are selectably monitored by the switched panel mounted voltmeter.

By setting the noise sources driving the tap modulators to predetermined DC voltages the quadrature phase and "carrier leakthrough" (balance) behavior of each top modulator may be tested. These functions are controllable using the Test Mode selector switch. The following modes are available:

1. Operate - Not test functions implemented - system is in operational status.
2. Test Osc. - System operating but signal source is 70 MHz from the internal test oscillator (the internal 70 MHz test oscillator is also used for all the following test functions).
3. I - In-phase channel tap modulator noise source set to a fixed DC level, quadrature (Q) channel noise source set to zero.
4. Q - Quadrature channel tap modulator noise source set to a fixed DC level, in-phase (I) channel noise source set to zero.
5. I&Q - Both in-phase and quadrature channel tap modulator noise sources set to equal fixed DC voltages.
6. Balance - Both in-phase and quadrature channel tap modulator noise sources set to zero.

Note that the fixed DC voltages selected in 3, 4, and 5 above equal to rms value of the noise sources when operational.

3. CONCLUSIONS AND RECOMMENDATIONS

From this program we can conclude that aircraft-to-satellite communication links may be modeled and simulated by means of the tap delay line channel model. By using digital noise generation and stable, well balanced RF components a stable reproducible channel simulator has been fabricated which allows accurate, repeatable, and controlled laboratory evaluation of aircraft-satellite communications equipment without recourse to expensive and non-repeatable field testing.

Although the simulator in its present form is adequate for studying many channel properties it does provide only a limited range of multipath spreads. If extensive channel simulation is to be performed or if the study of devices sensitive to the larger multipath spreads which occur in real channels is undertaken, then it would be recommended that the number of taps be increased. Also, the additive noise source provided has a bandwidth of only 50 kHz, which is much less than the 10-MHz bandwidth of the simulator. If the study of wideband transmission were to be undertaken a simple modification to a wideband noise source would extend the capabilities of this simulator.

APPENDIX A

SIMULATOR SPECIFICATIONS

Input

Center Frequency	70 MHz or 1625 MHz
Signal Bandwidth	10 MHz
Signal Levels (min.)	-3 dBm
Impedance	50 Ω
Modulation	constant amplitude, FM or PM

Output

Center Frequency	70 MHz and 1625 MHz
Signal Bandwidth (3dB)	10 MHz
Signal Level (max.)	-30 dBm
Impedance	50 Ω
Signal-to-Instrumentation Noise	40 dB
Additive Noise Source (50 kHz bandwidth)	-60 dBm/1 MHz
S/N ratio	40 dB max.,-10 db min (continuously adjustable)
Overall Doppler shift	0 ± 1000 Hz (continuously adjustable)

Multipath Characteristics

Relative Delay*	5,30,55 μsec switch selected
Delay Spread	8 μsec
Relative Doppler Shift*	0 ± 100 Hz (continuously adjustable)
RMS Fading Rate	10 - 1990 Hz (adjustable in 10-Hz steps)

Relative Multipath Power*	-40 dB to + 60 dB (continuously adjustable)

Operational and Test Features

Unit creates a tapped delay line realization of channel impulse response

Unit can be reset to a unique start point for repeatable data runs

Multipath fading can be stopped at any point to create a "frozen channel"

Built-in test signal source

Built-in power meter

Built-in system status monitor

Electronically switched test modes

Power

Line input	115V ± 5% 60 cycle 200 Watt

Dimensions

Size	H-40 in., W-21-1/2 in. D-24 in.

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[*] The relative specifications are relative to the direct path quantities.

APPENDIX B

REPORT OF INVENTIONS

The work performed under this contract resulted in the fabrication of a simulator which can reproduce a satellite-to-aircraft communication link. The effects of multipath, Doppler and thermal noise were included. The basic approach was to split the signal so that one porion of it represents the direct path return and the other the earth-reflected multipath.

Although this contract has yielded a significant extension to existing technology, a diligent review of the work performed under this contract has revealed no new discovery or invention.