EN ROUTE NOISE - NASA PROPFAN TEST AIRCRAFT (CORRECTED DATA - SIMPLIFIED PROCEDURE)

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INTRODUCTION

Surface noise measurements were made by the U.S. Department of Transportation - Transportation Systems Center (DOT/TSC) for the Office of Environment of the FAA during a joint National Aeronautics and Space Administration (NASA) and Federal Aviation Administration (FAA) program to study the high-altitude, low-frequency acoustic noise propagation characteristics of the Advanced Turboprop (propfan) Aircraft. The measurements were made on October 26-31, 1987 in Huntsville, Alabama and on April 3-13, 1989 at the White Sands Missile Range (WSMR), New Mexico.

To effectively compare flight-to-flight data as received on the ground, the procedures and practices of Federal Air Regulation (FAR) Part 36 were used as a guide in adjusting the measured ground data at the time of LA_{max} to a set of reference conditions. After the data for each event were processed using slow detector characteristics, the data record at LA_{max} was then identified and the coordinates of the aircraft at the time of emission were calculated, taking into account atmospheric refraction effects. The effects of atmospheric absorption through the test day and reference day atmosphere were also taken into account and the 1/3-octave data were adjusted accordingly.

1. SLOW SCALE DETECTOR RESPONSE

The corrected raw spectral data (contiguous linear 1/2 second records of data) were processed using a sliding window, or weighted running logarithmic averaging procedure, to achieve an effective "slow" dynamic response characteristic equivalent to the slow response characteristics of sound level meters (2-second exponential averaging) as required under the provisions of FAR 36. The following relationship utilizing four consecutive data records was used:

$$L_i = 10 \times \log \left[0.17\left(10^{0.1LK-3}\right) + 0.21\left(10^{0.1Lk-2}\right) + 0.24\left(10^{0.1Lk-1}\right) + 0.33\left(10^{0.1Lk}\right) \right]$$

where i=1/3-octave band number

k=1/2-second data record

2. TEST DAY METEOROLOGICAL DATA

The sound propagation path, source to receiver, was divided into layers as shown in figure 1 (30 meter layers from ground to 2,100 meters; 150 meter layers to 5,100 meters; and 300 meter layers to 12,000 meters). The average temperature, relative humidity, atmospheric pressure, and wind speed and direction were calculated for each

layer from the measured test day meteorological data profiles for use in the "simplified" layered atmospheric adjustment procedure.

3. REFERENCE PARAMETERS

Reference day temperature and pressure versus altitude were obtained from the 1976 US Standard Atmosphere. The reference day relative humidity used is as shown in the following table:

ALTITUDE	RELATIVE HUMIDITY
0 ft.	70%
7,500	40
18,000	23
35,000	20

In addition the following reference conditions were used:

Reference Altitude = 35,000.0 feet
Reference Speed = Test Speed
Wind Speed = 0.0 mph

4. SIMPLIFIED ADJUSTMENT PROCEDURE: LA_{max}

For each flight, the time of reception (tm) of the maximum A-weighted sound pressure level (LA_{max}) was determined. The curved acoustic path, source to receiver, was traced through the test day layered atmosphere, taking into account the refraction due to temperature and wind effects. The geometric coordinates of the aircraft at the time of emission of LA_{max} were determined, as well as the path length through each individual layer, such that the sum of the emission time (te) and propagation time (tp) equaled the reception time (tm=te+tp).

A reference curved acoustic path was likewise traced from the source at a reference altitude of 35,000 feet through the reference layered atmosphere to the reference receiver under the condition that the reference emission angle equaled the test emission angle.

The following adjustments were calculated and added algebraically to the "as measured" LA_{max} and Sound Exposure Level (SEL).

4.1 DELTA 1 CORRECTIONS:

(SPHERICAL SPREADING AND ATMOSPHERIC ABSORPTION)

With a knowledge of both the reference and test day refracted path length, and the path length through each individual layer for the LA_{max} spectra, spherical spreading and atmospheric absorption adjustments were calculated. The absorption adjustments were calculated using the absorption algorithm of the American National Standard (ANSI S1.26-xx) and the layered reference and test day meteorological conditions.

After applying these adjustments to the as measured one-third octave sound pressure levels (SPL) of the LA_{max} spectra, LA_{adj} was calculated.

The Delta 1 correction was derived from the difference between the as measured LA_{max} and the adjusted LA_{adj} levels.

$$\text{Delta 1} = LA_{max} - LA_{adj}$$

4.2 DELTA 2 CORRECTION (DURATION)

To account for the effects of aircraft speed and distance on the duration of the observed noise data at the receiver, a delta 2 correction was calculated following the procedure of FAR-36.

$$\text{Delta 2} = 7.5*\log(CPA_t/CPA_r) + 10*\log(Vg_t/Vg_r)$$

CPA_t and CPA_r are the minimum test and reference path lengths (source to receiver), and Vg_t and Vg_r are the test and reference ground speeds respectively. For this report, Vg_t was set equal to Vg_r. The Delta 2 correction is added algebraically to the SEL.

4.3 DELIMP CORRECTION: CHARACTERISTIC IMPEDANCE (Rho-C)

The characteristic impedance correction is derived from the condition of conservation of acoustic power (source to receiver) within a conical ray tube.

The adjustment applied is the difference in the impedance correction calculated for the test day conditions ($IMPCOR_t$) minus the impedance correction calculated for reference conditions ($IMPCOR_r$).

$$DELIMP = IMPCOR_t - IMPCOR_r$$

where:

$$IMPCOR_t = 10*LOG(P_{h1}*T_{h2}*C_{h1})/P_{h2}*T_{h1}*C_{h2})$$

$IMPCOR_r$ = 5.6 dB @ 35,000 feet

$IMPCOR_r$ = 3.0 dB @ 20,000 feet

and:

h1 = height of observer (0 ft)

h2 = height to surface of cylinder (Alt-SRR*sinB)

P_{hx} = pressure at height hx

T_{hx} = temperature at hx °K

C_{hx} = speed of sound at hx

4.4 TONE CORRECTION

Although the measured signal was highly tonal in nature and a tone correction of 2-3 dB is indicated using the procedures of FAR-36 referenced to the perceived noise level (PNL) metric, no tone correction adjustments were applied to the A-weighted noise metrics calculated in this report.

4.5 POWER CORRECTION

No power adjustments were applied since complete aircraft operational data was not available at the time of preparation of this report.

5.0 SUMMARY DATA ANALYSIS

Adjustments derived as above (for the test flights at 35,000 feet AGL in Alabama and 30,000 feet AGL in New Mexico) were applied to the A-weighted metrics for both the data from the 1.2 meter and 7 mm microphone measuring systems. The corrected data is shown in tables 1-2 (Alabama - 2 test days, 9 runs) and tables 3-4 (New Mexico - 4 test days, 12 runs). Also included are positional data, calculated corrections, and "as measured" data for each run. The average levels, the standard deviation and the 90% confidence interval of all runs are also provided.

The corrected LA_{max} and SEL data are seen to agree between tests to within 2 and 1 dB respectively. An inspection of the Delta 1 correction gives a good indication of the differing meteorological conditions, both day-to-day and test-to-test. With this in mind, the collapsing of the standard deviation in tables 2-3 (New Mexico) indicates the effectiveness of the atmospheric correction process.

TABLE NO. 1
NASA PROPFAN TEST AIRCRAFT
EN ROUTE NOISE - HUNTSVILLE, ALABAMA

DOT/TSC
8/25/89

CORRECTED DATA*

SITE 1 — CENTERLINE 4 FOOT MICROPHONE — OCTOBER 26-31, 1987

EV #	CORRECTED AMAX (dB)	CORRECTED SEL (dB)	AS MEASURED** AMAX (dB)	AS MEASURED** SEL (dB)	TRACKING SR (ft)	TRACKING SRR (ft)	TRACKING ALT (ft)	TRACKING EMISANG (deg)	TRACKING LATANG (deg)	CORRECTION FACTORS DEL1 (dB)	DEL2 (dB)	IMPED (dB)	DIST (dB)
10/30/87 FLIGHT 52, 35 kft. AGL, 0.8 Mach, 2963 SHP, Tip Speed: 840 fps													
14-1	59.06	70.18	55.93	67.18	39033.8	38135.9	35759.6	75.0	10.7	2.82	-0.13	+0.31	0.20
15-2	61.24	67.98	57.85	64.66	37861.5	37089.1	35741.2	76.5	-1.7	3.07	-0.07	+0.32	0.18
16-3	55.43	65.31	52.42	62.38	37347.7	36649.3	35640.0	80.4	-5.1	2.69	-0.07	+0.32	0.16
17-4	59.43	68.10	55.76	64.52	38369.6	37605.4	35676.8	75.4	-7.0	3.35	-0.09	+0.32	0.18
18-5	60.21	66.27	56.57	62.70	37536.9	36825.3	35640.0	79.0	-5.0	3.32	-0.07	+0.32	0.17
19-6	60.79	67.46	56.34	63.06	39473.1	38727.9	35667.6	69.7	-1.9	4.14	-0.06	+0.32	0.17
10/31/87 FLIGHT 54, 35 kft. AGL, 0.8 Mach, 2963 SHP, Tip Speed: 840 fps													
14-1	55.52	61.88	52.15	58.17	35232.1	36078.9	34155.4	85.5	-3.1	3.23	-0.04	+0.51	-0.21
16-3	59.42	68.10	54.83	63.17	36253.3	37130.4	34137.3	76.2	-1.0	4.46	-0.04	+0.51	-0.21
17-4	60.42	69.22	55.74	64.20	38083.9	39063.4	34074.1	68.6	-1.7	4.55	-0.04	+0.51	-0.22
AVG	59.05	67.16	55.29	63.34									
STD DEV	2.15	2.50	1.89	2.42									
90% CI	1.33	1.55	1.17	1.50									

* REFERENCE ALTITUDE IS 35000 FEET. ADJUSTMENTS TO REFERENCE CONDITIONS WERE MADE USING THE ABSORPTION ALGORITHM OF THE AMERICAN NATIONAL STANDARD ANS S1.26 WITH A LAYERED U.S. STANDARD ATMOSPHERE, TAKING INTO ACCOUNT SPHERICAL SPREADING, ATMOSPHERIC ABSORPTION AND REFRACTION FOR EACH LAYER.

** NOISE BANDWIDTH 50-1000 Hz ; SLOW-SCALE DETECTOR RESPONSE

TABLE NO. 2

NASA PROPFAN TEST AIRCRAFT

EN ROUTE NOISE - HUNTSVILLE, ALABAMA

DOT/TSC
8/25/89

CORRECTED DATA*

SITE 1 — CENTERLINE 7mm MICROPHONE — OCTOBER 26-31, 1987

	CORRECTED		AS MEASURED**		TRACKING					CORRECTION FACTORS			
EV #	AMAX	SEL	AMAX	SEL	SR	SRR	ALT	EMISANG	LATANG	DEL1	DEL2	IMPED	DIST
	dB	dB	dB	dB	ft	ft	ft	deg	deg	dB	dB	dB	dB
10/30/87 FLIGHT 52, 35 kft. AGL, 0.8 Mach, 2963 SHP, Tip Speed: 840 fps													
14-1	59.68	72.21	56.20	68.85	41148.9	40088.2	35759.6	67.9	10.7	3.18	-0.13	+0.31	0.23
15-2	59.66	66.94	57.29	64.64	37018.0	36266.1	35741.2	82.5	-1.7	2.05	-0.07	+0.32	0.18
16-3	54.56	65.39	52.26	63.16	36747.8	36091.6	35640.0	87.5	-5.1	1.98	-0.07	+0.32	0.16
17-4	58.35	66.63	54.40	62.76	38221.7	37464.7	35676.8	76.2	-7.0	3.63	-0.09	+0.32	0.17
18-5	58.44	67.11	54.79	63.53	37537.0	36825.3	35640.0	79.0	-5.0	3.33	-0.07	+0.32	0.17
19-6	59.60	68.39	55.01	63.86	39473.1	38727.9	35667.6	69.7	-1.9	4.28	-0.06	+0.32	0.17
10/31/87 FLIGHT 54, 35 kft. AGL, 0.8 Mach, 2963 SHP, Tip Speed: 840 fps													
14-1	57.49	65.36	53.30	61.10	35232.1	36078.9	34155.4	85.5	-3.1	3.68	0.08	+0.51	-0.21
16-3	59.56	69.27	54.43	64.06	36188.4	37064.9	34137.3	76.6	-1.0	4.62	0.08	+0.51	-0.21
17-4	61.46	70.41	56.30	65.16	38083.9	39063.4	34074.1	68.6	-1.7	4.65	0.09	+0.51	-0.22
AVG	58.75	67.96	54.89	64.12									
STD DEV	1.89	2.30	1.56	2.12									
90% CI	1.17	1.43	0.96	1.31									

* REFERENCE ALTITUDE IS 35000 FEET. ADJUSTMENTS TO REFERENCE CONDITIONS WERE MADE USING THE ABSORPTION ALGORITHM OF THE AMERICAN NATIONAL STANDARD ANS S1.26 WITH A LAYERED U.S. STANDARD ATMOSPHERE, TAKING INTO ACCOUNT SPHERICAL SPREADING, ATMOSPHERIC ABSORPTION AND REFRACTION FOR EACH LAYER.

** NOISE BANDWIDTH 50-1000 Hz ; SLOW-SCALE DETECTOR RESPONSE

TABLE NO. 3

NASA PROPFAN TEST AIRCRAFT

EN ROUTE NOISE - WHITE SANDS, NEW MEXICO

DOT/TSC
8/25/89

CORRECTED DATA*

SITE 1 — CENTERLINE 4 FOOT MICROPHONE — APRIL 4-13, 1989

	CORRECTED		AS- MEASURED**		TRACKING					CORRECTION FACTORS			
EV #	AMAX	SEL	AMAX	SEL	SR	SRR	ALT	EMISANG	LATANG	DEL1	DEL2	IMPED	DIST
	dB	dB	dB	dB	ft	ft	ft	deg	deg	dB	dB	dB	dB
04/04/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
103	57.75	66.80	58.28	66.94	33630.5	37955.6	30949.7	72.7	-0.1	-1.58	0.40	+1.05	-1.05
104	57.48	67.22	58.15	67.50	34659.1	38808.4	30998.9	69.4	0.0	-1.54	0.39	+0.87	-0.98
105	59.79	67.55	60.55	67.91	35436.3	40076.0	31034.3	65.6	-0.1	-1.81	0.40	+1.05	-1.07
106	55.59	66.51	56.25	66.77	33384.2	37473.0	30975.9	74.6	0.0	-1.53	0.39	+0.87	-1.00
04/05/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
107	51.97	61.76	48.94	58.36	35141.3	39798.4	30878.9	67.7	-0.1	2.13	0.37	+0.90	-1.08
108	53.39	63.11	50.30	59.62	34446.7	38751.0	30938.6	69.5	-0.1	2.18	0.40	+0.90	-1.02
109	53.56	62.72	50.78	59.54	33761.1	38121.7	30928.7	71.8	-0.1	1.87	0.40	+0.91	-1.06
110	51.35	62.34	49.41	60.00	32528.3	36654.6	30920.1	79.1	-0.1	1.03	0.40	+0.91	-1.04
04/06/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
111	59.50	68.50	56.44	65.07	34461.1	38597.9	31215.3	70.3	-0.1	2.31	0.37	+0.75	-0.99
112	59.87	67.51	56.60	63.87	34747.0	38784.2	31154.6	69.4	0.0	2.51	0.38	+0.76	-0.96
113	57.40	67.30	54.31	63.81	34481.8	38550.8	31196.7	70.2	0.0	2.33	0.37	+0.77	-0.97
114	56.90	66.93	53.66	63.32	34667.6	38654.1	31205.5	69.9	-0.1	2.47	0.37	+0.77	-0.95
04/13/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
117	58.72	68.02	63.01	71.84	33327.2	38440.0	30283.6	70.6	0.0	-5.12	0.47	+0.83	-1.24
119	61.05	69.13	65.50	73.12	33928.1	39098.1	30306.8	68.5	0.0	-5.29	0.47	+0.83	-1.23
120	59.89	69.37	64.09	73.10	33213.4	38204.7	30297.3	71.6	0.0	-5.03	0.47	+0.83	-1.22
122	57.34	66.36	61.39	69.94	33851.0	38909.6	30289.0	69.0	0.0	-4.88	0.47	+0.84	-1.21
AVG	56.97	66.32	56.73	65.67									
STD DEV	3.00	2.45	5.27	4.83									
90% CI	1.31	1.07	2.31	2.11									

* REFERENCE ALTITUDE IS 35000 FEET. ADJUSTMENTS TO REFERENCE CONDITIONS WERE MADE USING THE ABSORPTION ALGORITHM OF THE AMERICAN NATIONAL STANDARD ANS S1.26 WITH A LAYERED U.S. STANDARD ATMOSPHERE, TAKING INTO ACCOUNT SPHERICAL SPREADING, ATMOSPHERIC ABSORPTION AND REFRACTION FOR EACH LAYER.

** NOISE BANDWIDTH 50-1000 Hz ; SLOW-SCALE DETECTOR RESPONSE

TABLE NO. 4
NASA PROPFAN TEST AIRCRAFT
EN ROUTE NOISE - WHITE SANDS, NEW MEXICO

DOT/TSC
8/25/89

CORRECTED DATA*

SITE 1 — CENTERLINE 7mm MICROPHONE — APRIL 4-13, 1989

	CORRECTED		AS- MEASURED**		TRACKING					CORRECTION FACTORS			
EV #	AMAX	SEL	AMAX	SEL	SR	SRR	ALT	EMISANG	LATANG	DEL1	DEL2	IMPED	DIST
	dB	dB	dB	dB	ft	ft	ft	deg	deg	dB	dB	dB	dB
04/04/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
103	58.08	68.56	58.67	68.75	33630.6	37955.3	30953.7	72.7	-0.1	-1.64	0.40	+1.05	-1.05
104	56.96	69.49	57.39	69.52	31975.1	35975.3	31025.2	87.1	-0.1	-1.30	0.39	+0.87	-1.02
105	61.58	68.96	62.31	69.29	35436.4	40076.0	31034.3	65.6	-0.1	-1.78	0.40	+1.05	-1.07
106	57.34	69.07	58.06	69.39	33488.3	37583.2	30978.9	74.1	0.0	-1.59	0.39	+0.87	-1.00
04/05/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
107	51.51	62.58	49.53	60.22	32464.2	36661.1	30908.4	82.6	-0.1	1.09	0.37	+0.90	-1.06
108	52.79	65.37	49.57	61.74	34446.7	38751.0	30938.6	69.5	-0.1	2.32	0.40	+0.90	-1.02
109	52.61	63.91	49.81	60.70	33761.1	38121.7	30928.7	71.8	-0.1	1.90	0.40	+0.91	-1.06
110	51.60	64.34	49.83	62.17	31842.0	35906.4	30933.2	88.3	-0.1	0.86	0.40	+0.91	-1.04
04/06/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
111	58.07	69.35	54.96	65.87	34460.9	38597.9	31215.3	70.3	-0.1	2.36	0.37	+0.75	-0.99
112	57.87	68.76	54.56	65.07	34747.0	38784.2	31154.6	69.4	0.0	2.55	0.38	+0.76	-0.95
113	55.80	68.18	52.64	64.64	34481.8	38550.8	31196.7	70.2	0.0	2.40	0.37	+0.77	-0.97
114	55.93	67.16	53.85	64.71	32796.9	36626.5	31221.0	79.4	-0.1	1.31	0.37	+0.77	-0.96
04/11/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
115	54.95	66.19	59.58	70.39	33510.4	38356.7	30581.4	71.0	-0.1	-5.64	0.44	+1.00	-1.17
116	56.30	65.86	60.29	69.42	33007.2	37524.6	30557.0	74.3	0.0	-5.00	0.44	+1.00	-1.11
118	52.77	66.10	56.29	69.18	33932.6	38577.3	30540.4	70.1	0.0	-4.53	0.45	+1.00	-1.11
04/13/89 30 kft. AGL, 0.7 Mach, 90% SHP, Tip Speed: 800 fps													
117	57.47	68.17	61.93	72.16	33744.7	38936.0	30295.8	68.9	0.0	-5.29	0.47	+0.83	-1.24
119	59.70	69.56	64.38	73.78	33765.4	38905.2	30306.5	69.1	0.0	-5.51	0.47	+0.83	-1.23
120	58.84	69.72	63.09	73.50	33852.0	38934.5	30292.2	69.0	0.0	-5.08	0.48	+0.83	-1.22
122	57.25	67.20	61.52	70.99	34359.4	39491.2	30291.4	67.2	0.0	-5.01	0.47	+0.84	-1.21
AVG	56.18	67.29	56.75	67.44									
STD DEV	2.82	2.13	4.93	4.22									
90% CI	1.10	0.83	1.93	1.65									

* REFERENCE ALTITUDE IS 35000 FEET. ADJUSTMENTS TO REFERENCE CONDITIONS WERE MADE USING THE ABSORPTION ALGORITHM OF THE AMERICAN NATIONAL STANDARD ANS S1.26 WITH A LAYERED U.S. STANDARD ATMOSPHERE, TAKING INTO ACCOUNT SPHERICAL SPREADING, ATMOSPHERIC ABSORPTION AND REFRACTION FOR EACH LAYER.

** NOISE BANDWIDTH 50-1000 Hz ; SLOW-SCALE DETECTOR RESPONSE

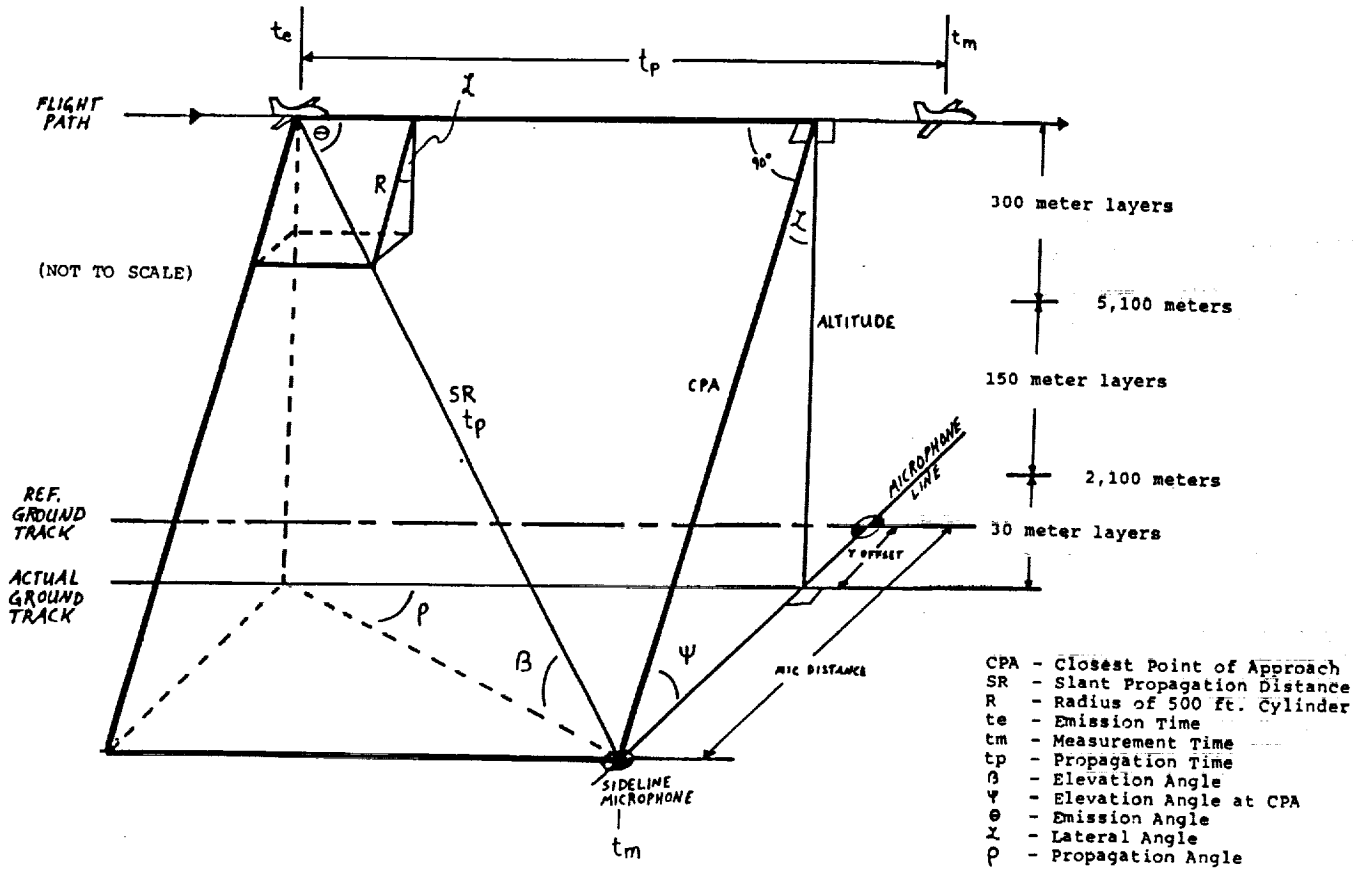

FIG. 1 FLIGHT GEOMETRY