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AIRBORNE URBAN/SUBURBAN NOISE MEASUREMENTS AT 121.5/243 MHz

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Summary

An airborne measurement of the terrestrial, radio-frequency (RF) noise environment over U.S. metropolitan urban/suburban areas has been made at the 121.5/243 MHz emergency-distress search and rescue (S&R) communications frequencies.

Flights were at 25,000 feet altitude during the period from December 30, 1976 to January 8, 1977.

Profile contour plots of antenna-noise temperature for U.S.A. East Coast and mid-west urban/suburban areas is presented for daytime/nighttime observations at 121.5/243 MHz. These plots are helpful for compiling radio-noise environment maps; in turn useful for designing satellite-aided, emergency-distress search and rescue communication systems.

Introduction

The primary purpose of the airborne survey was to make in situ measurements of RF noise within the narrow search and rescue (S&R) bands of 121.5 MHz ± 25 kHz and 243.0 MHz ± 25 kHz for compiling RF noise temperature maps. Although other airborne flights over both urban and suburban areas have been reported in the literature, e.g. [1]-[2], these reported measurements are for different frequencies and RF bandwidths other than those associated with the S&R frequency bands.

Aircraft instrumentation included a horizontally-polarized, quarter-wavelength, monopole whip antenna and a narrowband, fixed-tuned, low-noise, radio receiver at each frequency. Receiver IF output power was monitored with an HP435A power meter and Techni-Rite TR-444 stripchart recorder.

RF noise measurements have been expressed in equivalent antenna-noise temperature, in degrees kelvin (K), referenced to the output terminal of the monopole antenna. Observations were made of the steady-background, RF noise environment at 121.5/243 MHz for both daytime and nighttime hours; receiver 6 dB bandwidth was 15 kHz/25 kHz, respectively.

Aircraft Instrumentation

A Cessna 340-II aircraft was selected because of its capability for operation at an altitude of 25,000 feet.

A horizontal-polarization, quarter-wavelength, monopole whip antenna was used for each of the 121.5 and 243 MHz frequency bands. The 121.5 MHz antenna was mounted horizontally on the starboard side of the aircraft fuselage, between the rudder and wing section, with the 243 MHz antenna mounted on the opposite side of the fuselage. No accurate information is available on the antenna radiation patterns.

Electronics instrumentation was mounted in equipment racks housed within the pressurized passenger cabin. Instrumentation for RF noise recording (Figure 1) included low-noise 121.5 and 243 MHz receivers, two HP435A power meters, Techni-Rite TR-444 stripchart recorder and an onboard clock that provided a local Eastern Standard Time (EST) time reference.

The receiver channels were calibrated, in flight, with an onboard, 0 to 20 dB range, reference-noise generator (Figure 1) with zero setting referenced to 290 degrees kelvin (K). A step attenuator with a range of 0 to 12 dB was inserted at the antenna output terminal to extend the temperature measuring range of both 121.5 and 243 MHz channels. The overall calibration accuracy should be 1 dB, or better.

The 121.5 MHz receiver system noise figure was 5.0 dB, referenced to 290K, for zero dB attenuator setting, resulting in a noise-temperature measurement range capability of 290 to 1,400,000K. Similarly, the 243 MHz receiver noise figure was 9.0 dB corresponding to a range of 290 to 3,600,000K.

Aircraft Flight Profile

Flight Path 1 followed a 200-mile, straight-line course over the northeastern U.S.A. from Washington, D. C. to Westchester, New York (Figure 2). Both day and night flights were made. Flights began December 30, 1976 and were completed January 3, 1977

Flight Path 2 over the mid-western U.S.A. began January 6, 1977 and was completed January 8, 1977.

Aircraft Survey Data Measurements

Data presented herein consists of in situ RF noise measurements at 121.5 and 243.0 MHz, expressed in equivalent antenna-noise temperature (degs. K), referenced at the output terminal of a horizonally-polarized, monopole antenna.

RF noise measurements at points 1-2, Figure 1, referenced to the onboard calibrated noise generator, are expressed by an absolute temperature equation from [3] as,

$$T = T_o \left[F \left(\frac{N}{N_o} - 1 \right) + 1 \right] \text{ degs. K.} \qquad (1)$$

where, F = Noise Figure of receiver, expressed as a power ratio

$\frac{N}{N_o}$ = Stripchart deflection, expressed as a power ratio, from reading N_o corresponding to zero setting at 290K from noise generator

T_o = 290K = Ambient temperature.

Using equation (3-70) from [4], the equivalent antenna-noise temperature at the antenna output terminal is

$$T_A = LT \text{ degs. K.} \quad (2)$$

L = Attenuator loss, expressed in power, where $\infty > L \geq 1$.

combining equation (1) and (2).

$$T_A = LT_o \left[F\left(\frac{N}{N_o} - 1\right) + 1 \right] \text{degs. K.} \quad (3)$$

Equation (3) was used for computing the antenna-noise temperature profile graphs shown in Figures 3-6, inclusive.

RF noise power (watts) is a function of antenna-noise temperature, T_A, in the relationship, $P = kT_AB$ where P equals received RF noise power, k is Boltzmann's constant (1.38×10^{-23} J/K) and B is the receiver noise bandwidth (Hz).

The temperature profile graphs are helpful in computing the estimated signal-to-noise ratio at a satellite in near-earth orbit (e.g., 1000 km altitude) receiving distress signals from a terrestrial Emergency Locator Transmitter (ELT) radiating at 121.5 or 243 MHz.

It is helpful to know both diurnal and nocturnal effects in terms of terrestrially-generated RF noise. The temperature profile graphs (Figures 3-6) reveal a significant difference between the levels of RF noise at 121.5 and 243 MHz that varies both with urban location and time-of-day.

The East Coast, U.S.A. data (Figure 3), including measurements over New York City, at 121.5 MHz, reveals that the nighttime RF noise level is generally lower than daytime by values up to approximately 14 dB, depending upon the urban location. On the other hand, the 243 MHz data shows a much smaller difference between daytime and nighttime measurements for the same urban area (Figure 5).

Furthermore, the mid-west U.S.A. data (Figure 4) generally indicates the opposite in that the nighttime level of RF noise can exceed the daytime level at 121.5 MHZ. In fact, at 243 MHz, the nighttime RF noise level is larger than daytime by values up to 6 dB (Figure 6).

Data reported in Figures 3-6 was measured at approximately the same Eastern Standard Time (EST) corresponding to a 1/2 hour time period from 10:30 AM - 11:00 AM (EST) for daylight measurements and 8:30 PM - 9:00 PM (EST) for nighttime measurements.

A maximum value of 121.5 MHz RF noise, equivalent to an antenna-noise temperature of 410,000K, was observed over New York City (NYC) during daylight hours; nighttime values were reduced approximately 9 dB (Figure 3). On the other hand, data at 121.5 MHz over Chicago, Illinois indicates a value of 135,000K during daylight, with increased value to 225,000K at times during nighttime (Figure 4).

Data at 243 MHz gives maximum values of 260,000K and 430,000K for NJ/NY and Chicago, Illinois, respectively, during daylight hours; however, values increase to 700,000K over Chicago at nighttime (Figures 5 & 6).

Daylight values observed at 121.5 and 243 MHz over New York City, during daylight, agree closely with Skomal's [2] averaged values for "Incidental Man-Made Noise Power for Suburban I (5-15 miles)", a ground-based measurement.

However, values at 121.5 and 243 MHz for Chicago, Illinois, during daylight, were 5 to 6 dB at variance with Skomal's average values.

Included is an antenna pattern analysis (Appendix A) from which the average equivalent temperature of the RF noise environment can be computed.

To obtain the average equivalent temperature of the RF noise environment, antenna-noise temperature values should be increased by a factor of 2.0, at 121.5 MHz, and 2.2 at 243 MHz.

Conclusion

An airborne measurement survey at 25,000 feet altitude monitored RF noise at 121.5 and 243 MHz over East Coast and mid-west cities in the U.S.A.

Profile contour plots of antenna-noise temperature are presented for daytime and nighttime values at 121.5 and 243 MHz. These plots are helpful for compiling radio-noise temperature maps for computing received signal-to-noise ratio at a Search and Rescue communications satellite in near-earth orbit.

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2. Skomal, E. N.: Distribution and Frequency Dependence of Incidential Man-Made HF/VHF Noise in Metropolitan Areas, IEEE Transactions on Electromagnetic Compatability, Vol. EMC-II, No. 2, pp. 66-76, May 1969.

3. Hewlett-Packard Company: Noise Figure Primer. Application Note 57, June 22, 1962.

4. Berkowitz, R. S.: Modern Radar Analysis, Evaluation and System Design. John Wiley & Sons, Inc., 1967.

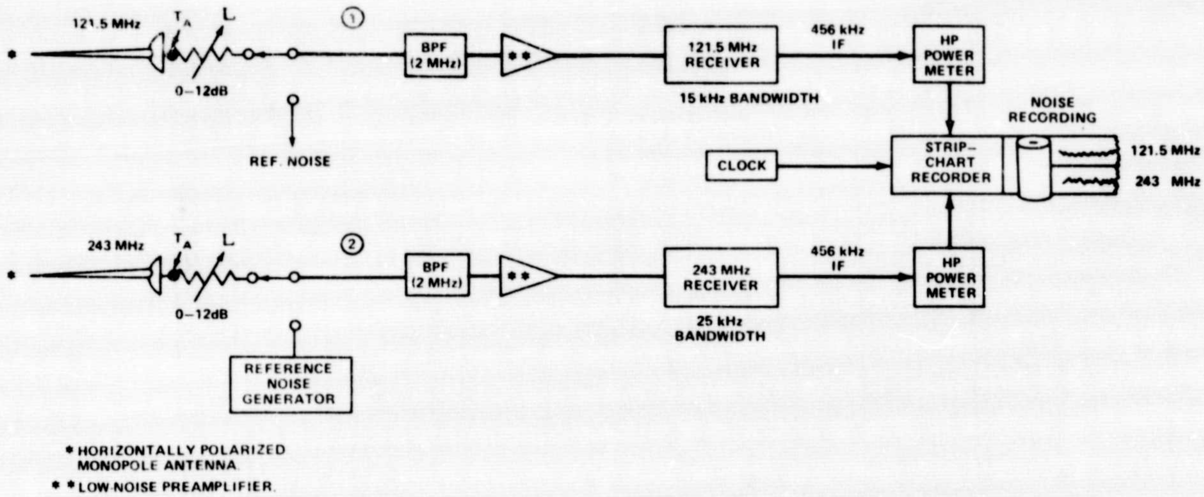

Figure 1. Block Diagram, Noise Recording Instrumentation On Aircraft

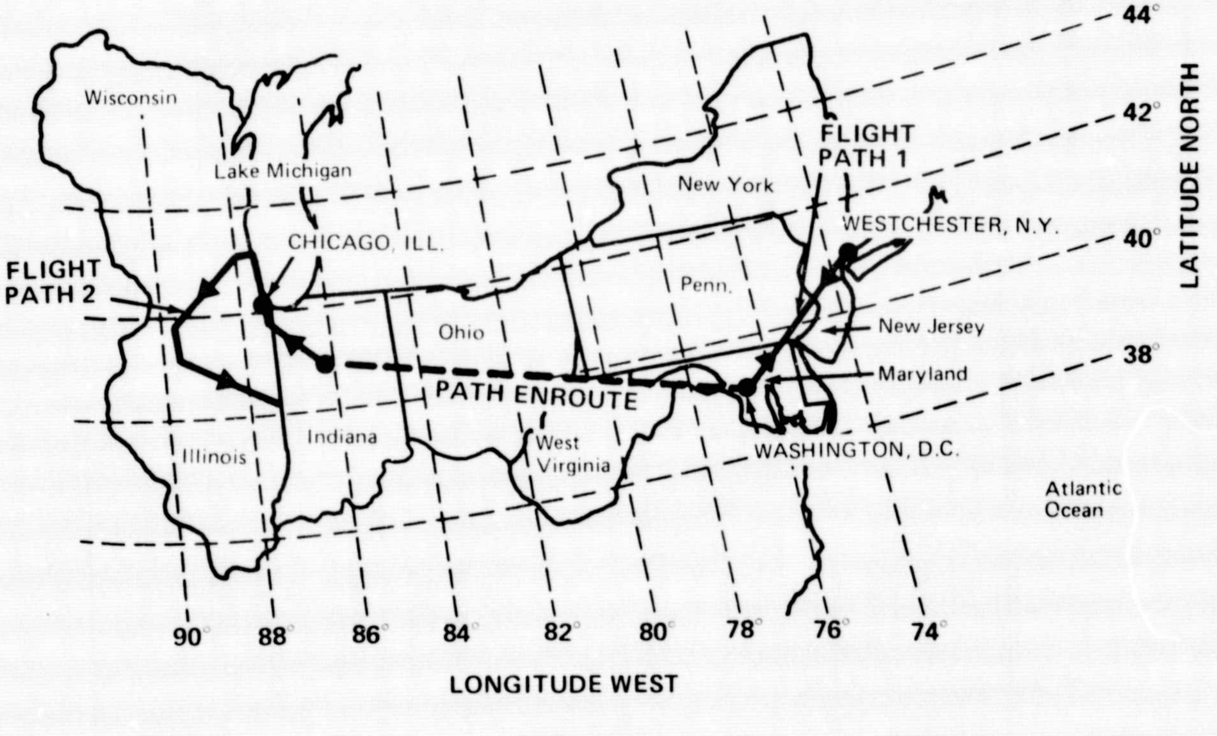

Figure 2. Aircraft Flight Path

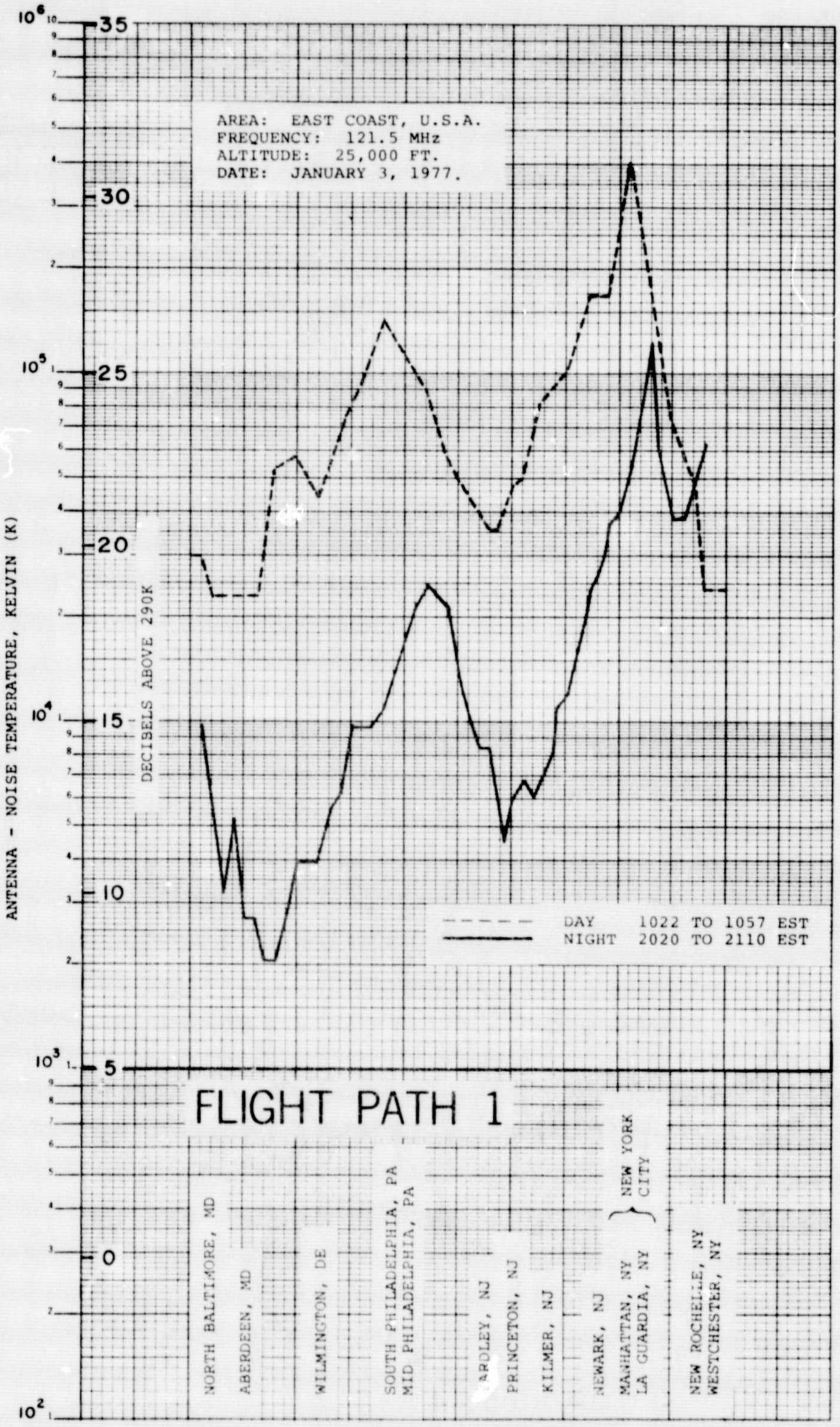

Figure 3. 121.5 MHz ANTENNA - NOISE TEMPERATURE
EAST COAST, U.S.A.

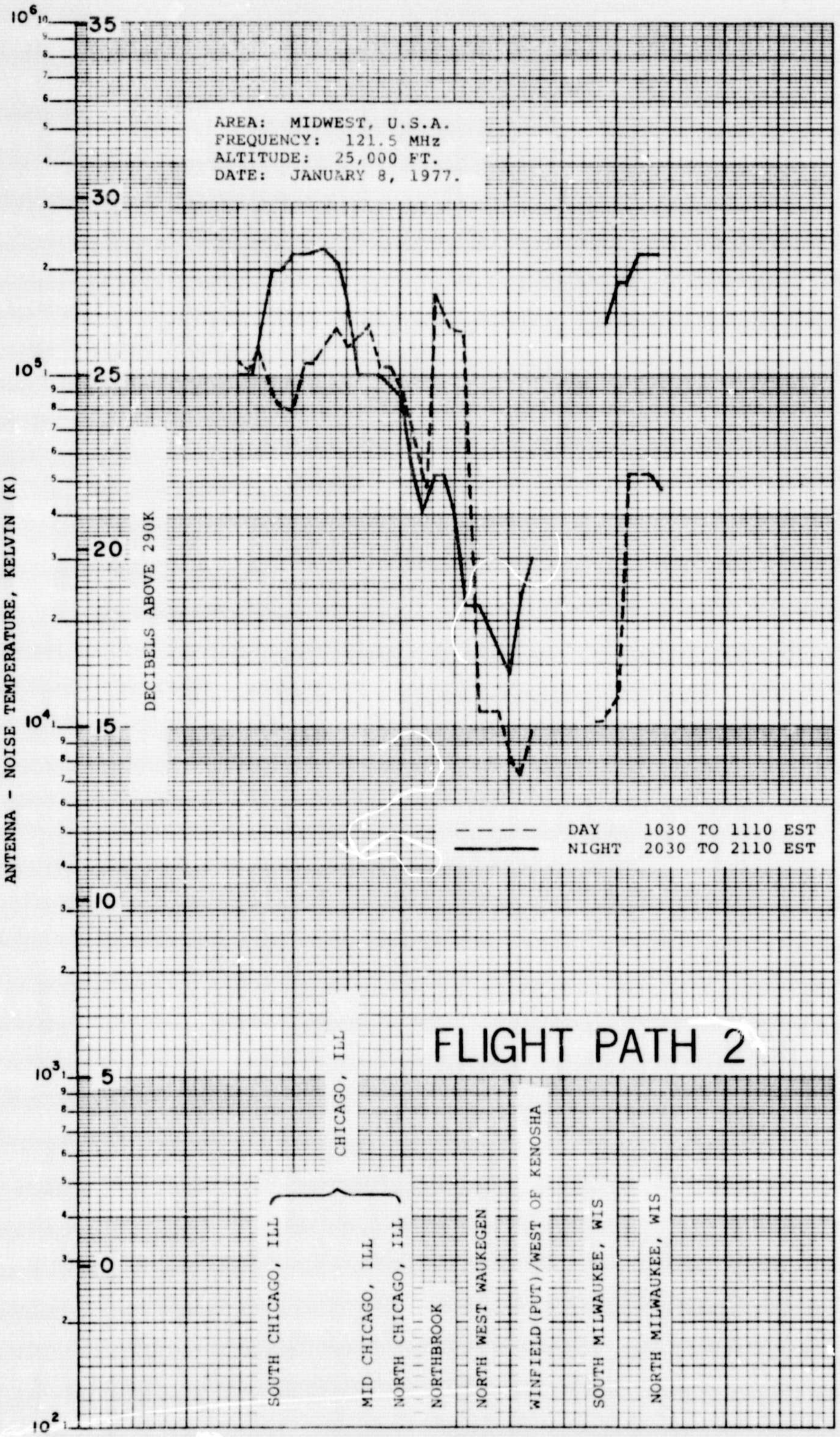

Figure 4. 121.5 MHz ANTENNA - NOISE TEMPERATURE MIDWEST, U.S.A.

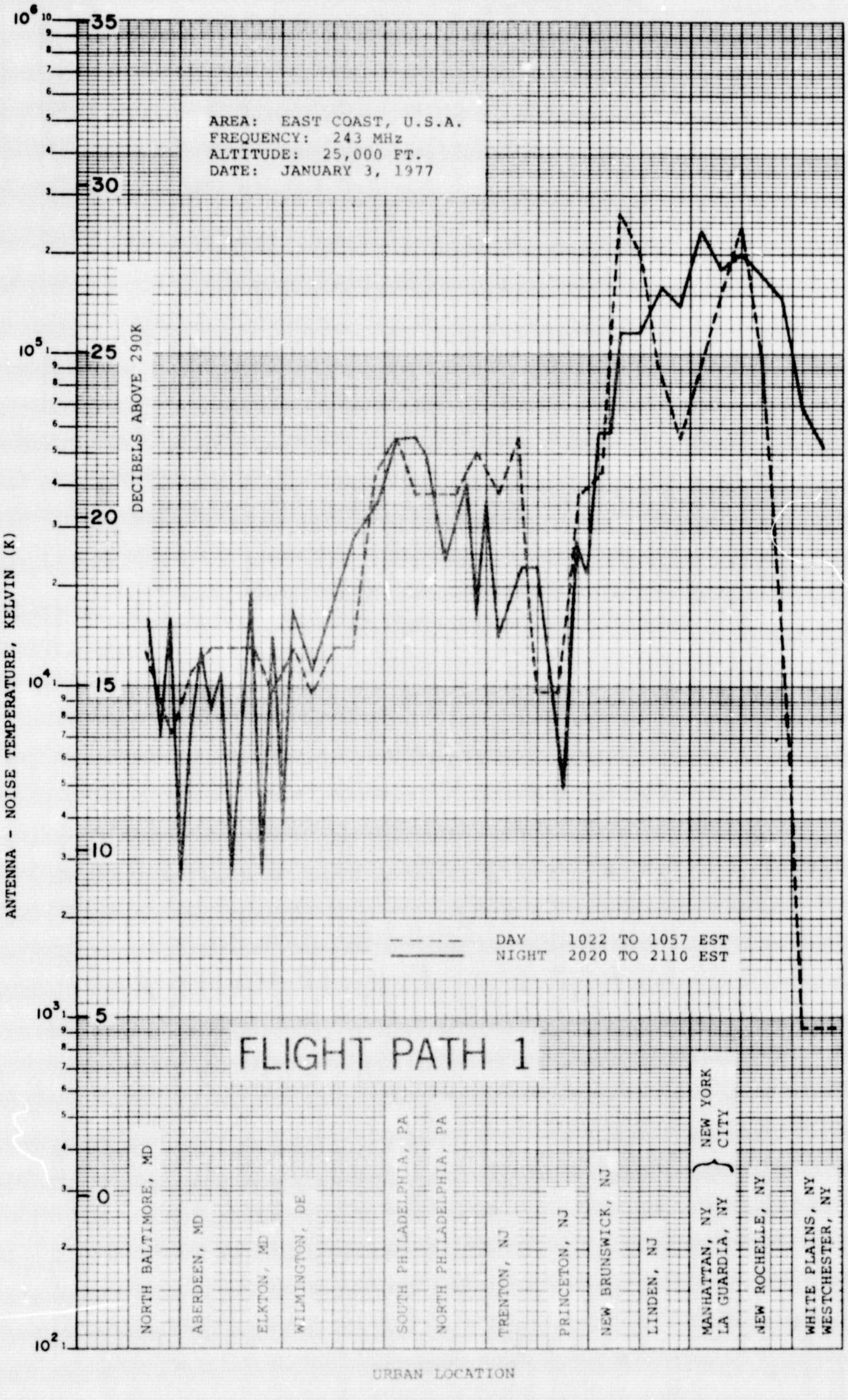

Figure 5. 243 MHz ANTENNA - NOISE TEMPERATURE
EAST COAST, U.S.A.

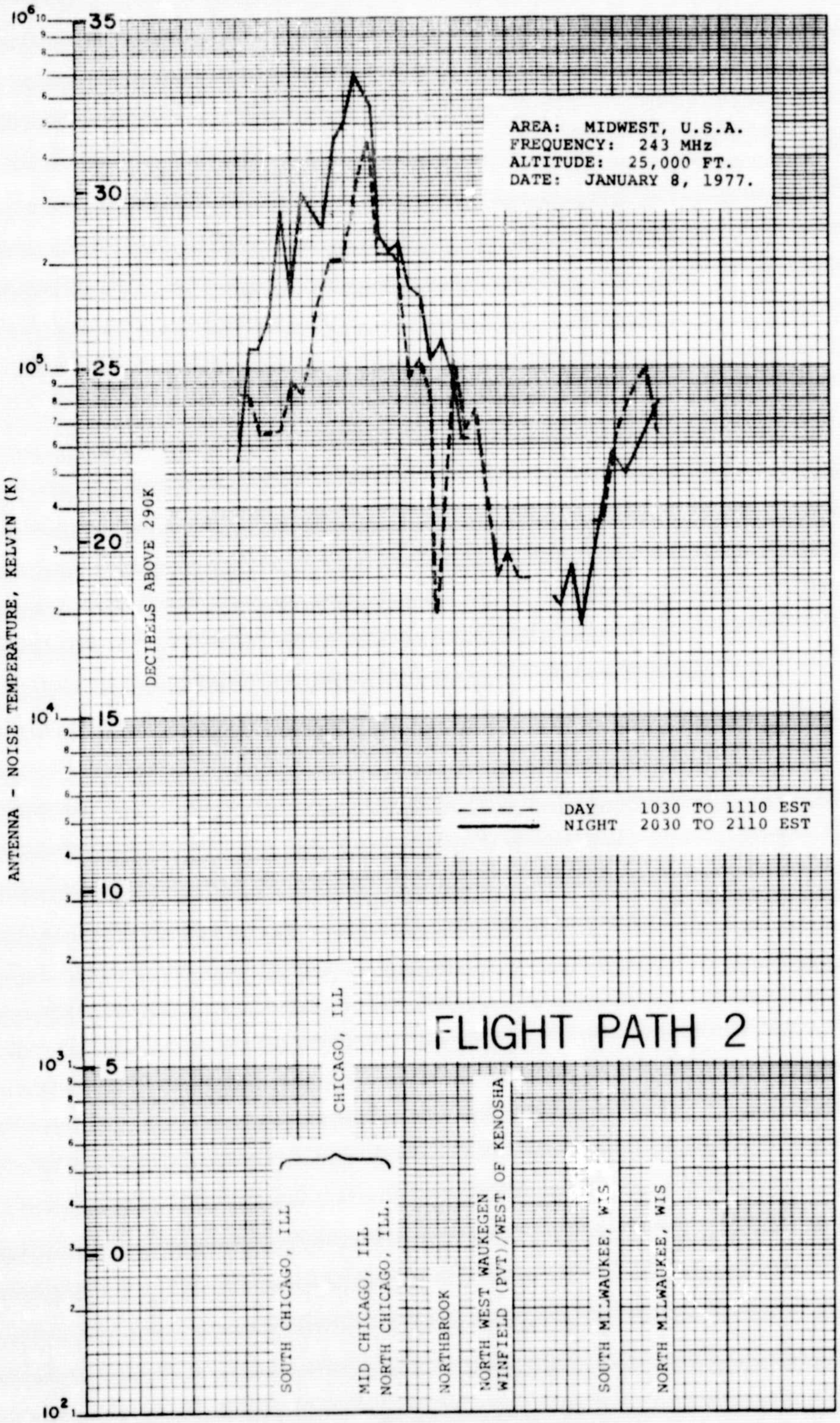

Figure 6. 243 MHz ANTENNA - NOISE TEMPERATURE
MIDWEST, U.S.A.

APPENDIX A

ANTENNA PATTERN ANALYSIS

The antenna-noise temperature, T_A, expressed by eq. (3) and referenced to the antenna output terminal, can be expressed in terms of the average equivalent temperature, T, of the terrestrial RF noise environment. However, a knowledge of the antenna radiation pattern is required.

Since no accurate information is available on the antenna radiation pattern for the quarter-wavelength, monopole whip antenna mounted horizontally on the aircraft's fuselage, the following analysis is made to obtain an estimate of the average equivalent temperature, T, of the terrestrial RF noise environment.

The radiation pattern assumed is that of an ideal, half-wavelength, dipole antenna shown in Figures A-1 and A-2. Furthermore, the following additional assumptions are made:

1. Contributions from galactic sky noise are negligible (100-200 degs. K) when the RF noise environment is removed.
2. Average equivalent temperature of RF noise environment is constant and completely fills the antenna radiation pattern beamwidth.

   This appears a valid assumption since the antenna footprint diameters defined by d = 4.7 S. Mi. and D = 8.2 S. Mi. (Figs. A-1 and A-2) are small compared to distances between cyclic changes in antenna-noise temperature along the 200- mile flight path (Figs. 3-6).

Kraus (Kraus, John D., "Radio Astronomy", pp. 100-101, 1966 McGraw-Hill, Inc.) has shown that the average equivalent temperature, T, of a source can be determined from

$$T = T_A \frac{\Omega_A}{\Omega_S} \text{ degs. K} \qquad \text{(A-1)}$$

where,

T_A = antenna temperature due to source, degs. K

Ω_A = beam solid angle, degs^2.

Ω_S = source solid angle, degs^2.

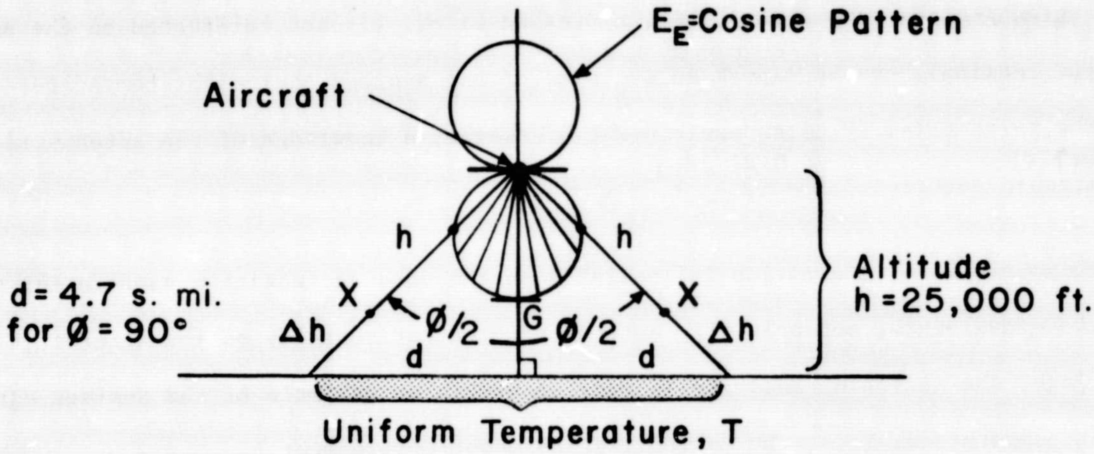

Figure A-1. IDEAL CROSS-TRACK RADIATION PATTERN.

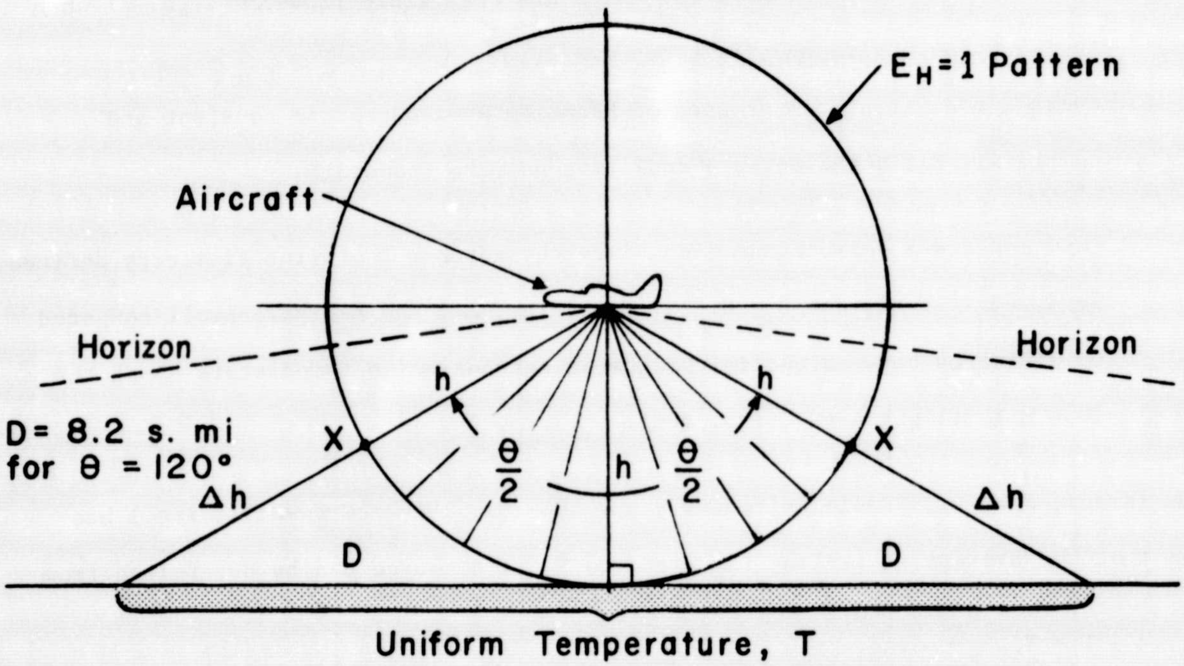

Figure A-2. IDEAL ALONG-TRACK RADIATION PATTERN.

The beam solid angle for a dipole is determined from

$$\Omega_A = \frac{4\Pi}{G} \quad \text{(A-2)}$$

where,

$G = 1.64$ = power gain above isotropic.

From (A-2),

$$\Omega_A = \frac{4\Pi}{1.64} = 7.662 \text{ steradians}$$
$$= 7.662\ (57.29)^2$$
$$= 25{,}150 \text{ degs}^2.$$

Since the source completely fills the effective beamwidth of the downward-looking lobe, the source solid angle can be determined from Kraus (pp. 65) as

$$\Omega_S \simeq \frac{4}{3}\,\phi\,\Theta \quad \text{degs}^2 \quad \text{(A-3)}$$

where,

ϕ = Effective beamwidth across-track, degs.

θ = Effective beamwidth along-track, degs.

Since the cross-track pattern is a cosine function, the 3 dB (HPBW) points occur at 45° off nadir. However, the path length increases by an amount, Δh, beyond point X (Fig. A-1), where $\Delta h = 0.41\,h$ at angles $\pm$ 45° off nadir. This results in an effective beamwidth that is 6 dB down.

A word of explanation is in order about θ, the effective beamwidth along track. Whereas the cross-track pattern is assumed a cosine function, the along-track pattern (Fig. A-2) has unity gain. However, an increase in path length Δh, also occurs for angles off nadir. The equivalent beamwidth point along track, comparable to cross track, occurs for a value of $\Delta h = h$ corresponding to angles $\pm$ 60° off nadir, at point X (Fig. A-2). The value for Ω_S can now be computed from eq. (A-3) as

$$\Omega_S \simeq \frac{4}{3}\,\phi\,\theta$$

where, ϕ = 90° beamwidth, across-track

θ = 120° beamwidth, along-track

$$\Omega_S = \frac{4}{3}\,(90°)\,(120°) = 14{,}400 \text{ degs}^2.$$

Substitution of numerical values from eqs. (A-2) and (A-3) in eq. (A-1) gives

$$T = T_A \frac{25,150}{14,400}$$

$$T = 1.75\ T_A \text{ degs. K.} \qquad \text{(A-4)}$$

Eq. (A-4) states that the average equivalent temperature of the RF noise environment for an ideal (loss-free) dipole antenna is approximately 2.4 dB (1.75 power ratio) greater that the observed antenna-noise temperature, T_A, computed from eq. (3).

Since the measurement antenna was not loss-free, a correction must be made for the antenna terminal- to-attenuator transmission line loss of 0.65 dB, (1.16 power ratio) at 121.5 MHz and 0.93 dB (1.24 power ratio) at 243 MHz. Therefore,

$$T = 2.0\ T_A \text{ at 121.5 MHz} \qquad \text{(A-5)}$$

and,

$$T = 2.2\ T_A \text{ at 243 MHz.} \qquad \text{(A-6)}$$

In conclusion, to obtain the average equivalent temperature of the RF noise environment, the antenna-noise temperature values plotted in Figures 3 and 4 at 121.5 MHz should be increased by a factor of 2.0, and consequently Figures 5 and 6 by a factor of 2.2 at 243 MHz.