NASA TECHNICAL MEMORANDUM

NASA TM X-52751

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AERIAL RF NOISE MEASUREMENT IN URBAN AREAS AT UHF FREQUENCIES

by G. Anzic
Lewis Research Center
Cleveland, Ohio

TECHNICAL PAPER proposed for presentation at
Third Communications Satellite System Conference sponsored
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Los Angeles, California, April 6-8, 1970

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

E-5525

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Abstract

The results of a combined aerial and ground survey of radiofrequency noise in the Phoenix, Arizona area are presented. The measurements were made at 0.3, 1.0, and 3.0 gigahertz. The task objectives were to determine the correlation between air and ground data and to demonstrate the ability to identify high urban noise areas from aerial data. The RMS noise level and average noise envelope voltage were measured. Ten 3 dB step comparators were also used to provide data on noise amplitude distributions, pulse width and frequency of occurrence. The results indicate that an aerial survey can be used to identify high urban noise areas. Ground sites well immersed in noise yielded good correlation with air data and cyclic behavior of noise is easily determined from air data.

Introduction

Many sources contribute to the total radiofrequency noise environment of an urban area. Together with the spurious emissions from radars, broadcast stations and countless other communication and navigation equipment, man-made noise constitutes a major portion of the total problem defined as radiofrequency interference (RFI). In most cases, the major source of man-made radiofrequency noise is an electric arc generated by: flourescent lights, gaseous discharge devices, high voltage transmission lines, switching gear, and ignition systems.

A knowledge of rf noise levels in urban and other inhabited areas is required if a space to earth communication system, serving a large area with many receiving terminals, is to be designed effectively. Very little up-to-date and complete urban rf noise data is available at UHF frequencies where such systems are practicable. Most previous man-made rf noise investigations were limited to narrow (400 KHz or less) voice communication channels in the lower region of the UHF spectrum.[1,2]

An aerial survey is economically more attractive and faster than a ground survey. Large urban areas can be surveyed with one aircraft in a matter of hours, while during the same amount of time the noise characteristics of only one ground location can be determined. The enormity of a ground survey becomes more apparent when many such ground measurements have to be made to yield an area's meaningful noise profile. Although an aerial rf survey yields only data varying in limited time, prudently chosen survey times within one day yield an area's daily noise levels.

To develop the technique of an aerial noise survey, a combined aerial and ground radiofrequency noise survey was conducted in Phoenix, Arizona during the summer of 1968. The objectives of the survey were to determine the correlation between noise measurements taken from the air and from the ground, and to demonstrate the ability to identify high urban noise areas from aerial data. Details of measurements taken during the survey, conducted for NASA-Lewis Research Center by General Dynamics/Convair are given in the contractor's final report.[3]

The contractor performed the aerial and ground surveys; all data tapes were forwarded to NASA-Lewis Research Center for data reduction and correlation calculations. This paper discusses the data reduction techniques employed and the results obtained from survey data.

Ground Survey

The ground measurements were conducted at six city locations as shown in Fig. 1. Radiofrequency noise was measured in clear channels at or near 0.3, 1.0, and 3.0 gigahertz. The receiving system, housed in a generator equipped van, consisted of three low noise (NF < 4 dB) receivers (fig. 2) followed by a data processing and recording system (fig. 3). Ground noise data was measured as a function of antenna azimuth, polarization, elevation above the horizon and time of day. Six antennas, mounted on a 40 ft collapsible tower, were used to receive rf noise. The characteristics of the antennas were as follows:

Frequency, GHz	Type	Gain, dBi	Polarization
0.3	Quad dipole	11	Circular
.3	Corner reflector	10	Vertical or horizontal
1.0	Helical	11	Circular
1.0	Horn	9	Vertical or horizontal
3.0	Helical	13	Circular
3.0	Horn	19	Vertical or horizontal

The noise measurements were made during the morning, noon, and evening hours. No measurements were made on weekends.

To properly characterize the noise and its effect on AM and FM video channels, a noise bandwidth of 2.7 megahertz was used in all three survey channels. The noise parameters measured were:

rms Noise
Average Noise Envelope
60 Hertz Noise Component and
15.75 Kilohertz Noise Component

Ten 3 dB step comparators were also used to provide data on noise amplitude distributions, pulse width and frequency of occurrence. Simultaneous air measurements were made while conducting the ground measurements at three of the ground locations.

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Air Survey

A DC-3 aircraft, equipped with an interference suppressed ignition system and suitable electrical power generators, was used in the aerial survey. An air speed of 100 ±10 knots was used for all survey flights. The altitudes of 1000 feet and 4000 feet were used. The aircraft, frequently used in scientific experiments of similar nature, proved ideal for this task. The experienced pilots, familiar with precise flying requirements were a great asset.

The receiving system used for the airborne survey was essentially the same as the ground system, except that only circularly polarized antennas were used. The antennas were mounted on removable panels on the underside of the aircraft fuselage. The antenna characteristics were identical to the circularly polarized antennas used in the ground system.

Five parallel paths were flown over the city. One path was also flown normal to the above paths passing over the center of the city (fig. 4). Simultaneous ground measurements were made at three ground locations while conducting the air measurements. Like the ground measurements, the air measurements were also made during morning, noon, and evening hours. An automatic sequence camera was used to provide the photographic record of ground area covered by the antenna pattern. The sequence photos were used for noise source identification and air data correction factor calculation.

Survey Results

As shown in Fig. 5, the ground system received noise from the following sources: sky (T_s), ground (T_g), the receiver itself (T_r), and the indigenous noise sources (T_i), in the subtended angle θ. Figure 6 presents the weighting factor, G_i, which was calculated from the integration of the antenna gain as a function of angle θ, subtended by the noise source. This angle is estimated from the photographs taken at each ground site. The noise temperature received at a ground site (T_{gr}) can then be expressed as:

$$T_{gr} = 0.5\ (T_s) + 0.5\ (T_g) + T_r + G_i T_i \qquad (1)$$

The noise power received by the airborne system is shown in Fig. 7. The airborne noise temperature (T_{ar}) consists of the ground temperature (T_g), receiver system temperature (T_r) and the indigenous noise temperature (T_i). The weighting factor (A_i), representing the percentage of ground area covered by indigenous noise sources, was selected from the examination of aerial photographs. The noise temperature received by the airborne antenna is:

$$T_{ar} = 1.0\ T_g + A_i T_i + T_r \qquad (2)$$

Assuming that T_g, T_s, and T_r are negligible, above equations yield the following correlation expression:

$$\frac{T_{ar}}{T_{gr}} \cong \frac{A_i}{G_i} \qquad (3)$$

Results of the air and ground data correlation for 0.3 and 1.0 GHz are shown in Figs. 8 and 9, respectively. It is evident that the aircraft altitude and choice of ground site selection greatly affect the degree of correlation. As an example, the correlation data for two ground sites is presented in Table I. Air data collected at a 1000 ft altitude tends to correlate better with the ground data since the aircraft antenna becomes more selective of noise sources in its narrower coverage pattern.

In general, ground sites well immersed in noise yielded better correlation data. On the average, the air-ground correlation data indicates that an estimate of the ground noise levels can be obtained by subtracting 5 to 7 dB from the noise level obtained at a 4000 ft altitude.

Air and Ground Data Reduction

The air and ground data was collected by a periodic sampling of rf noise at each of three frequencies. The large quantity and variety of data recorded made a computer data reduction procedure almost mandatory. All data tapes were first digitized. A computer program was written to accept the digitized data and either plot or print out the desired parameters.

Typical aerial noise data obtained during the survey are presented in Figs. 10 and 11. Radio-frequency noise, seen from the aircraft flying at 4000 feet from west to east over the center of the city is presented in Fig. 10. Figure 11 shows the results from another flight path, crossing the center of town in a north-south direction.

In general, all airborne noise data indicates that the noon and late evening average urban noise levels are respectively 2 dB and 6 dB below the noise during the morning rush hour traffic flow. The average rf noise power levels at 0.3 gigahertz obtained at an altitude of 4000 feet during the morning, noon, and late evening hours were 19 dB, 17 dB and 13 dB above KTB, respectively. Peak rush hour noise levels were near 30 dB above KTB.

Figure 12 shows the 0.3 gigahertz noise probability distribution data of the city of Phoenix as seen from a 4000 ft altitude for all flights. Typical 1.0 gigahertz noise levels during morning rush hour were 5 to 6 dB below the 0.3 gigahertz values. It is interesting to note that a 3 dB difference in the satellite power exists between the systems designed to serve 60 percent of the area (average noise power) and 90 percent of the area.

Figures 13 and 14 show computer presentations of time comparators for 0.3 and 1.0 gigahertz channels, respectively, indicating the percentage of time the noise value exceeded the 3 dB steps ranging from the receiver threshold to 30 dB above the threshold. The rms value of noise, also plotted above the comparator data, illustrates the relatively high peak to rms ratio typically exhibited by all noise data.

The noise data, recorded at each ground site, was reduced as a function of frequency, antenna azimuth, antenna polarization and antenna elevation above the horizon. Typical noise predominating in most cases was the automobile ignition noise. Normally, the highest noise levels recorded at a ground site occurred during the morning rush hour, while the lowest levels were recorded during the late evening hours. Noonday noise levels were somewhat below the rush hour levels. On the average, the ground noise followed the same daily cyclic behavior exhibited by aerial data. This daily cyclic nature of rf noise level is directly dependent on the activity of man.

Noise data was found to be insensitive to polarization during the ground measurements. No 3.0 gigahertz data is presented since most data obtained is questionable because of receiving system limitations. The small quantity of valid data obtained indicates that the rf noise was near the system threshold for the majority of the time (< 4 dB above KTB).

Conclusions

The following conclusions were reached from examination of aerial and ground survey data:

1. An aerial survey of an urban area can be performed in 5 to 10 percent of the time required for the ground survey.[3]
2. An aerial survey can be used to identify high urban noise areas.
3. Cyclic behavior of noise is easily determined from aerial data.
4. Ground noise levels are 5 to 7 dB below the noise levels obtained at a 4000 ft altitude.
5. Ground sites well immersed in noise yielded good correlation with air data.

References

1. Skomal, E. N., Distribution and Frequency Dependence of Unintentionally Generated Man-Made VHF/UHF Noise in Metropolitan Areas. IEEE Trans. on Electromag. Compat., vol. EMC-7, no. 3, Sept. 1965, pp. 263-278.

2. Anon.: Man-Made Noise. Report to Technical Committee of the Advisory Committee for Land Mobile Radio Services from Working Group 3, Federal Communication Commission.

3. Mills, A. H.: Measurement and Analysis of Radio Frequency Noise in Urban, Suburban, and Rural Areas. Rep. GDC-AWV68-001, General Dynamics/Convair (NASA CR-72490), Feb. 1, 1969.

[f = 300 MHz, BW = 2.5 MHz]

Ground Site #	#3 Open Field		#10 Near Highway	
Aircraft Altitude (ft)	4000		1000	
T_{ar}	-89 DBM±2		-92 DBM±2	
Ground Antenna Azimuth	North	East	South	East
T_{gr}	-102 DBM±2	-102.5 DBM±2	-97 DBM±2	-98 DBM±2
A_i	-1 DB	-1 DB	0 DB	0 DB
G_i	-8 DB	-10 DB	-3.5 DB	-5 DB
T_{ar}/T_{gr} Calc.	7 DB	9 DB	3.5 DB	5 DB
T_{ar}/T_{gr} Exp.	13 DB	13.5 DB	4.5 DB	5.5 DB
θ	10°	5°	45°	25°

TABLE 1 SAMPLE AIR-GROUND NOISE CORRELATION

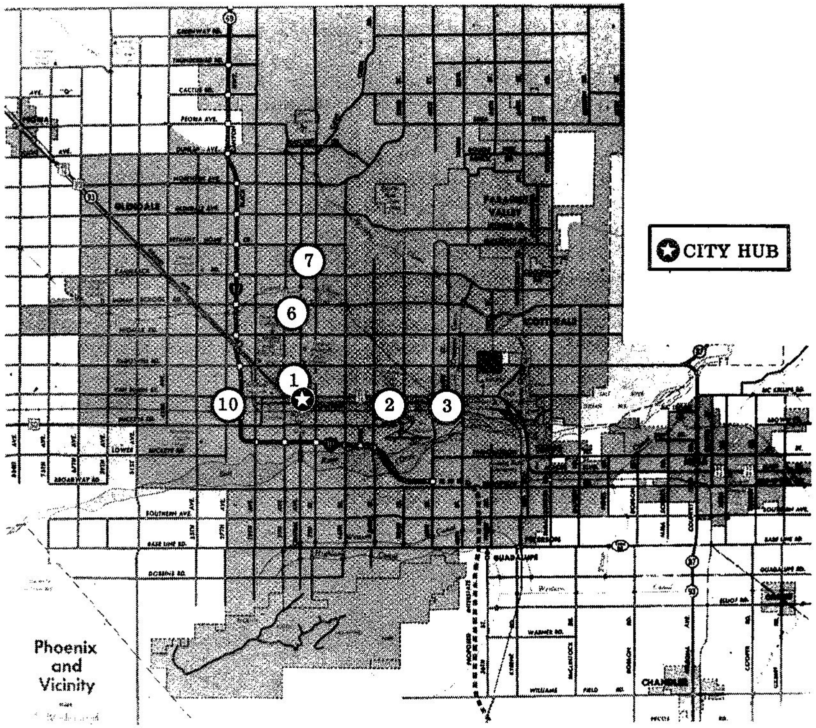


Figure 1. - Map showing ground measuring sites (ref. 3).

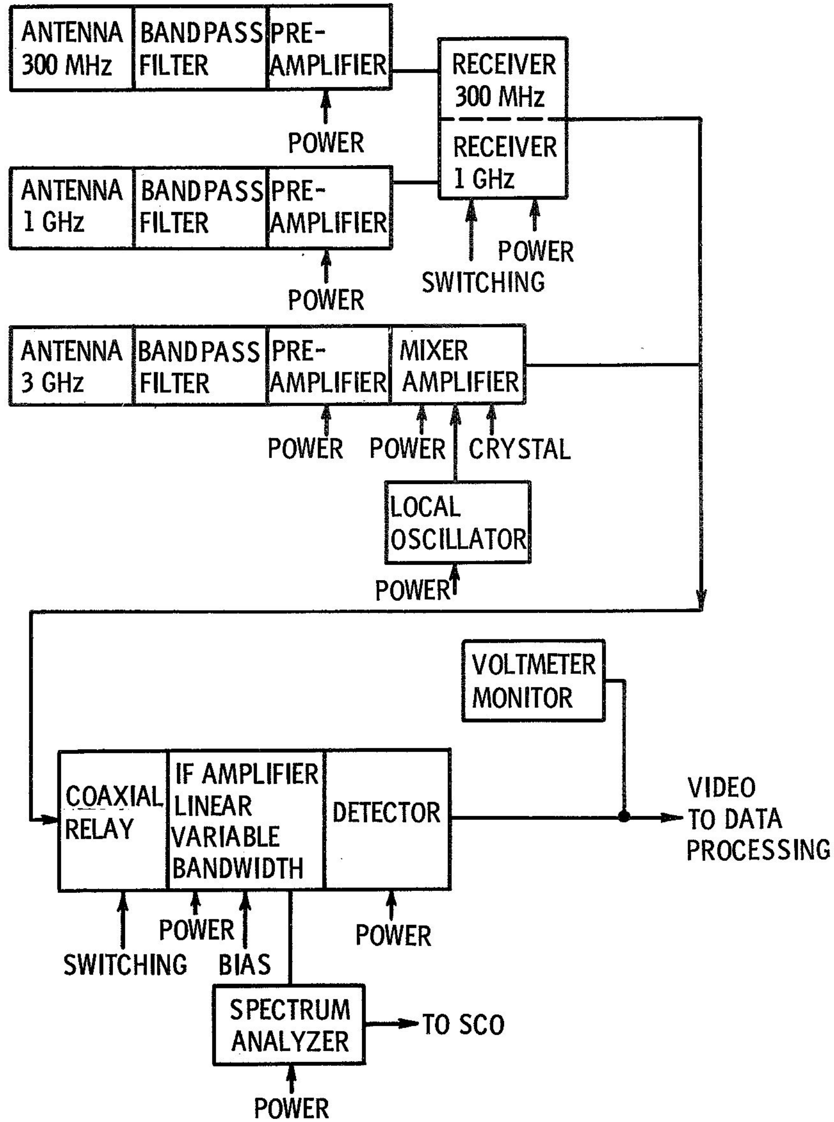


Figure 2. - Receiving system (ref. 3).

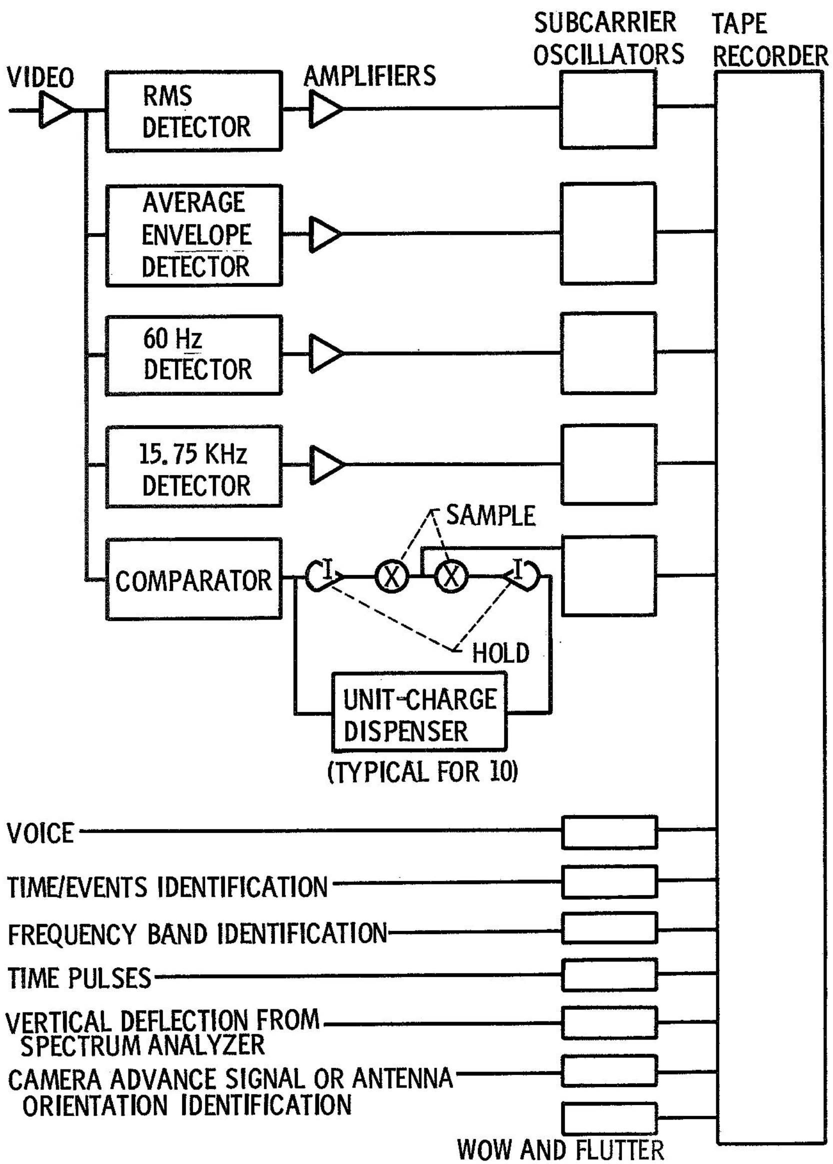


Figure 3. - Data processing and recording subsystem (ref. 3).

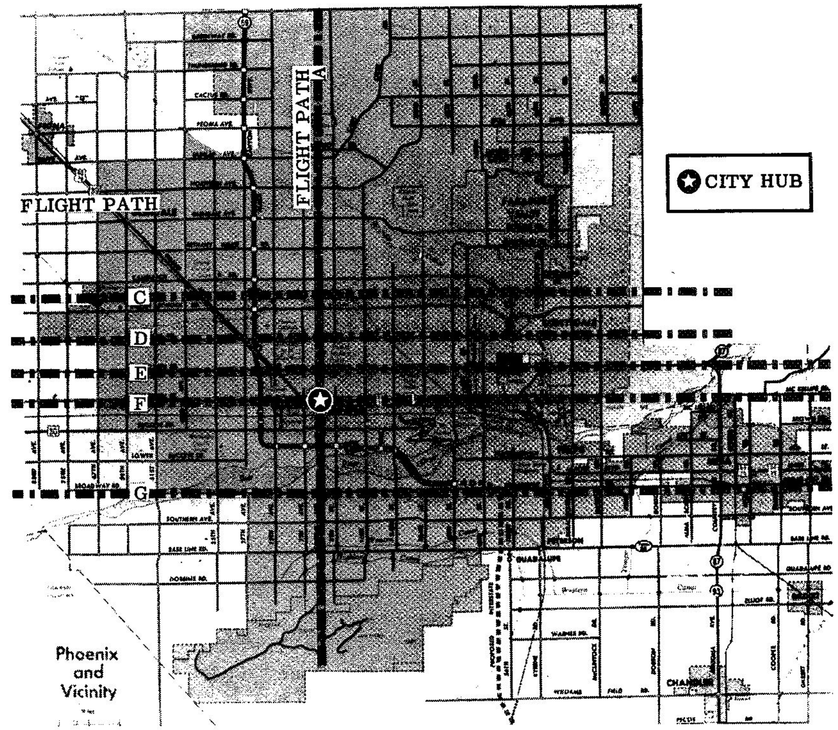
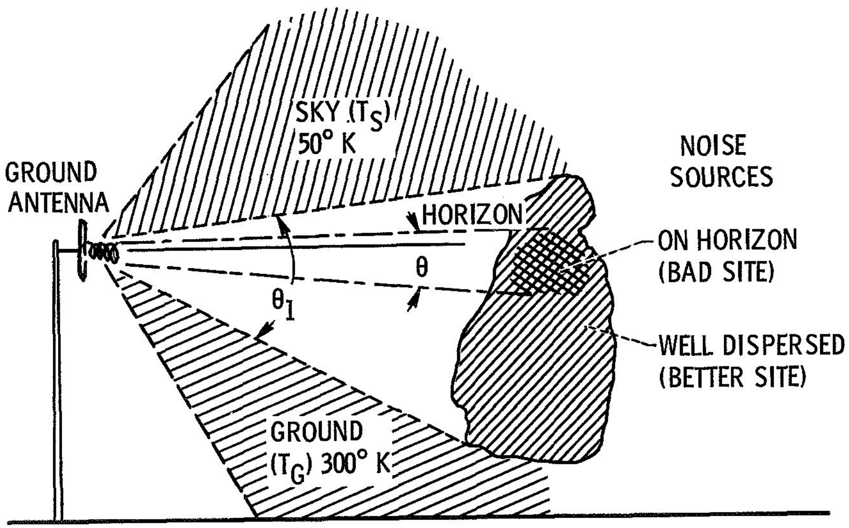
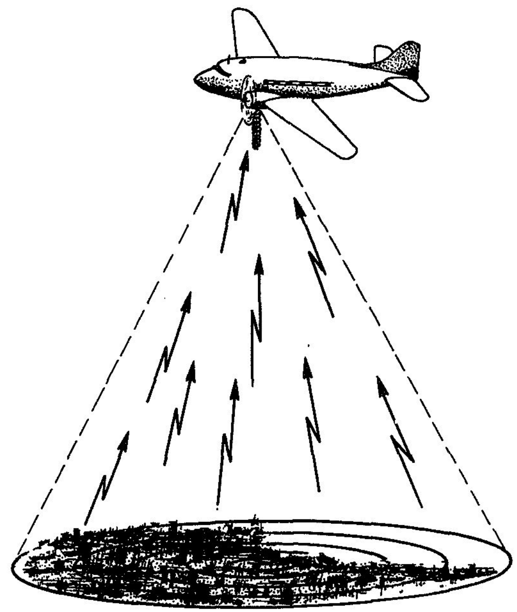


Figure 4. - Map showing flight paths (ref. 3).



$$T_G = 0.5(T_S + T_G) + G_i(T_i) + T_R$$

Figure 5. - Ground RF noise (T_G).



$$T_{AR} = 1(T_G) + A_i T_i + T_R$$

AERIAL RF NOISE (T_{AR})

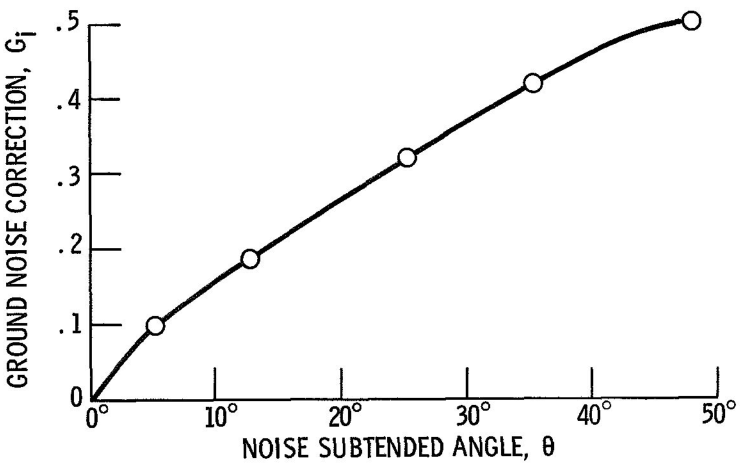
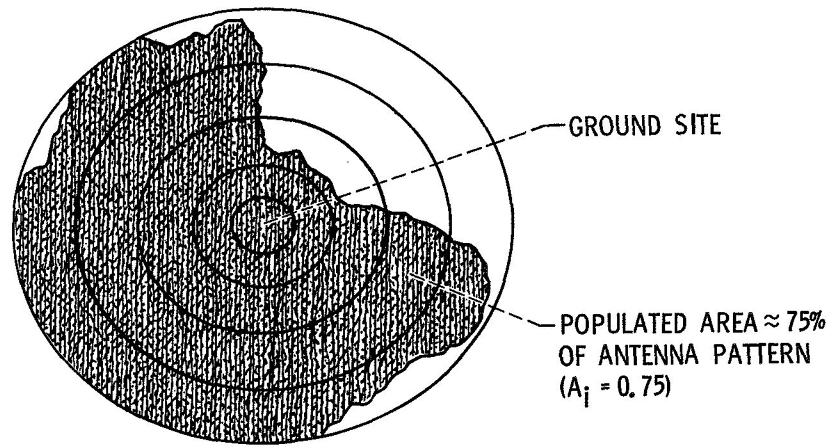


Figure 6. - Ground noise correction factor (G_i); (freq = 300 MHz).



AIR NOISE CORRECTION FACTOR (A_i)

Figure 7

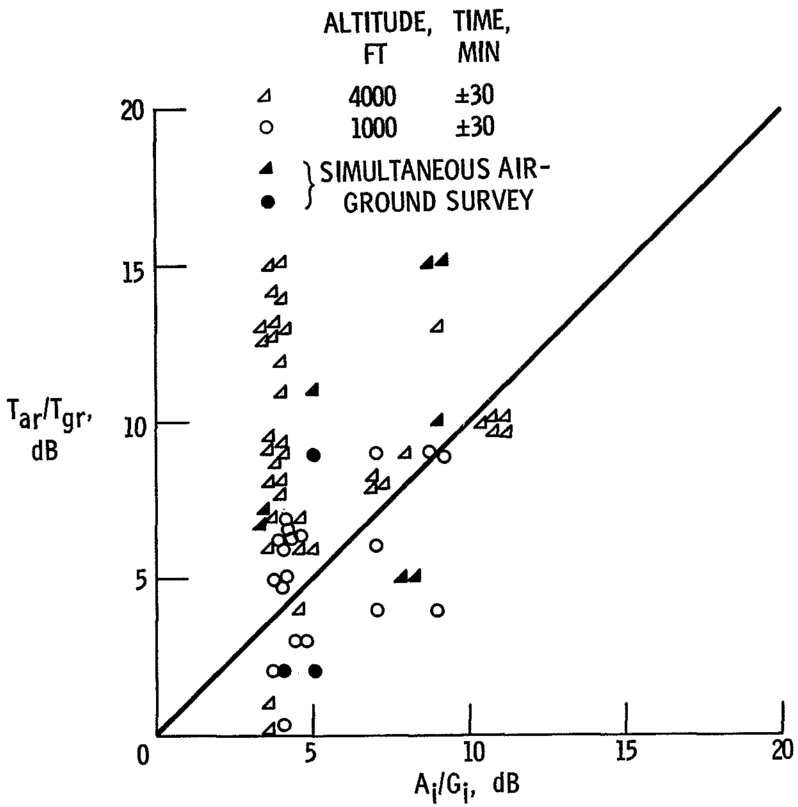


Figure 8. - Air-ground correlation (5 ground sites, 300 MHz).

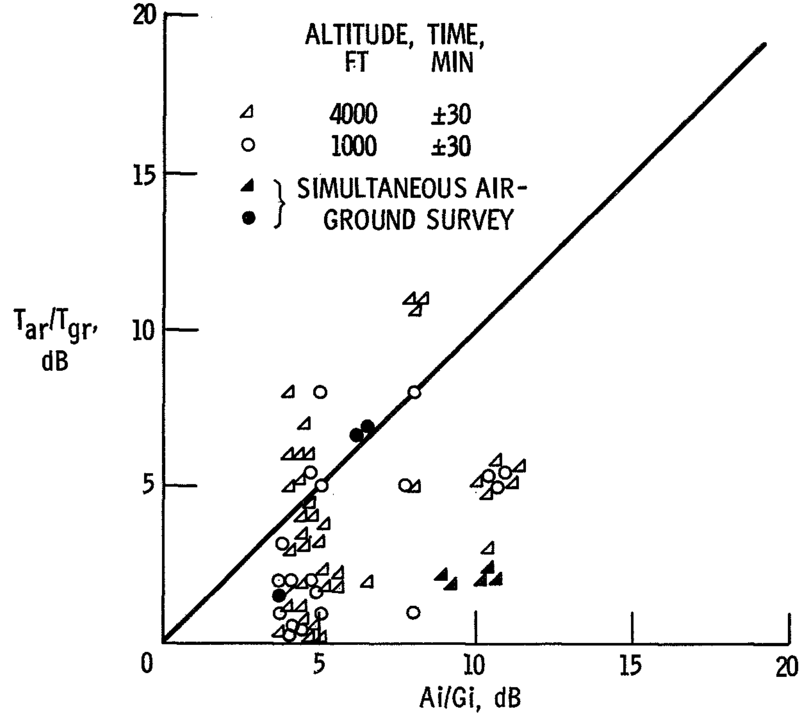


Figure 9. - Air-ground correlation (5 ground sites, 1.0 GHz).

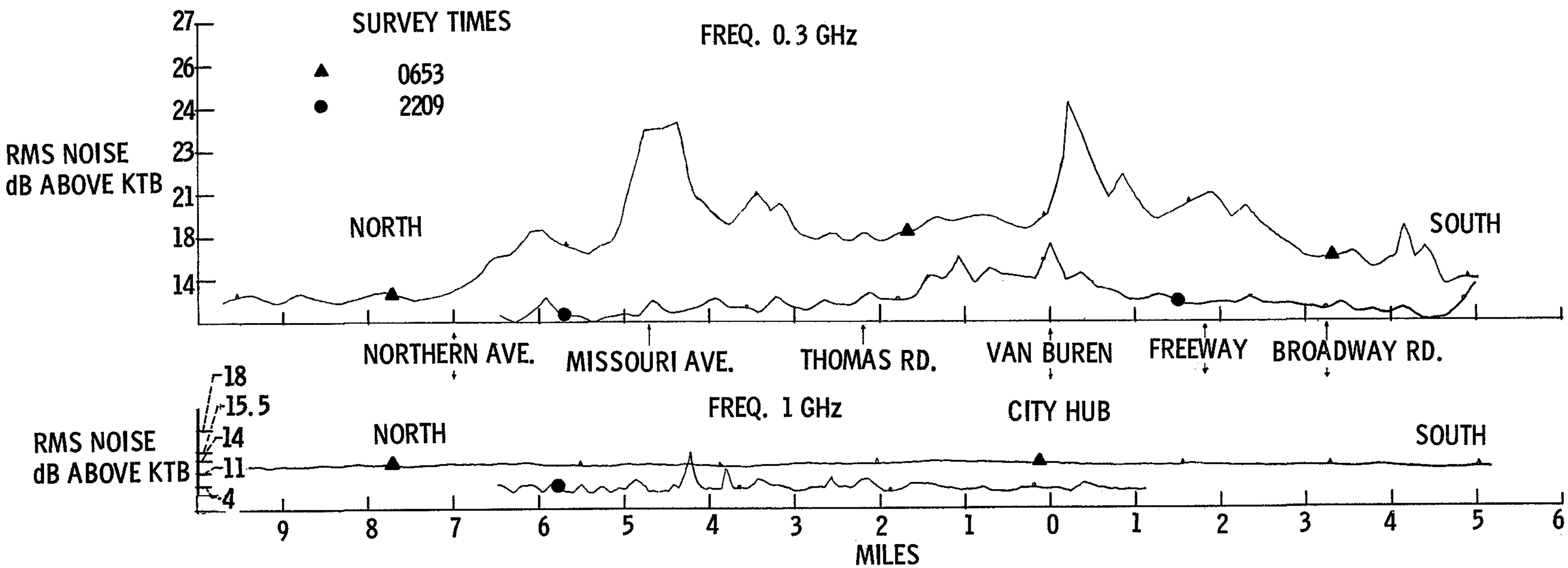


Figure 10. - RMS NOISE. ALTITUDE = 4000 FEET.

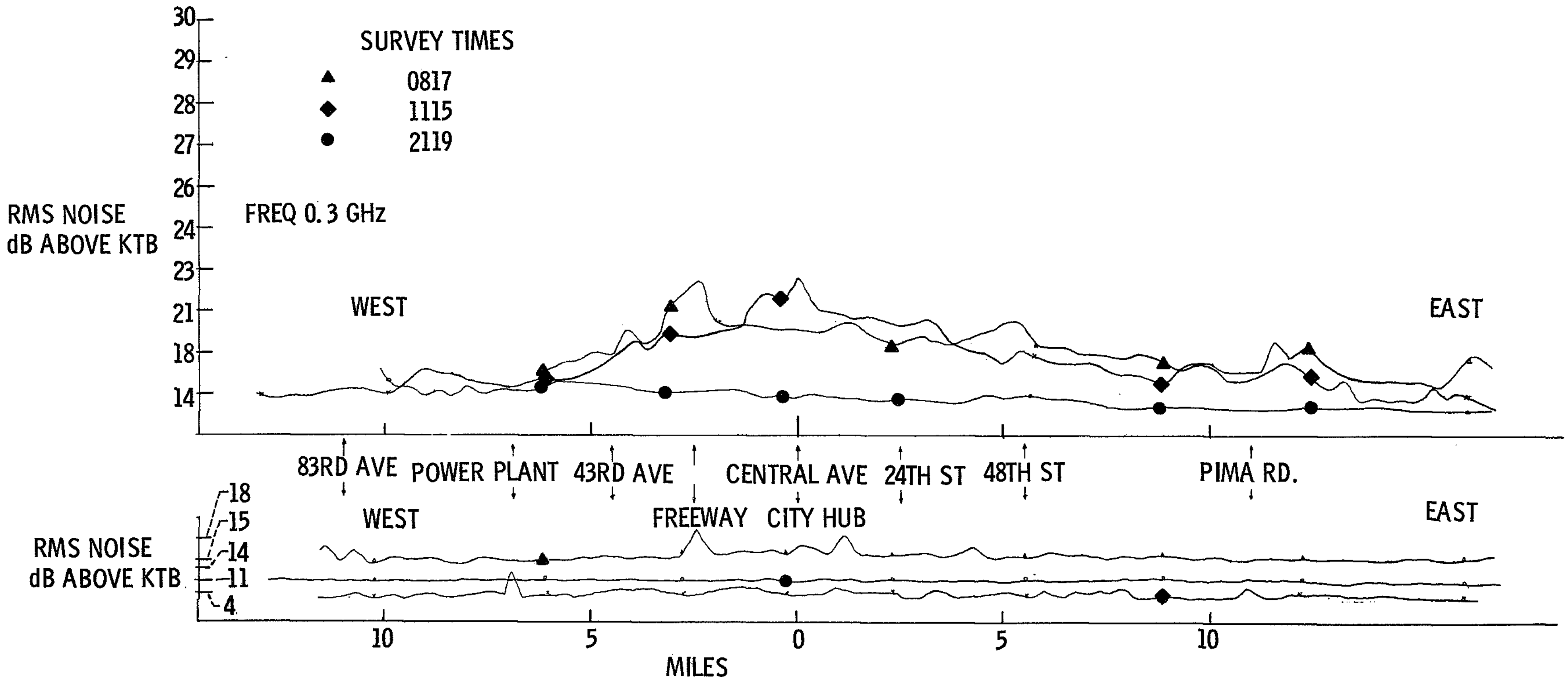


Figure 11. - RMS NOISE. ALTITUDE = 4000 FEET.

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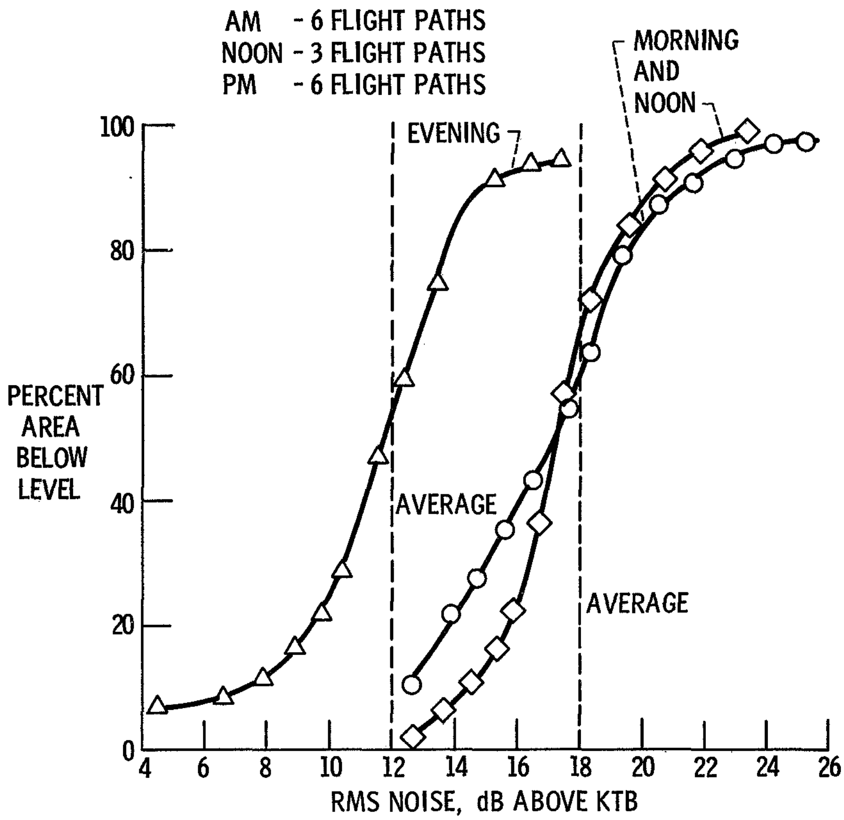

Figure 12. - Noise probability distribution (frequency = 300 MHz, altitude = 4000 feet).

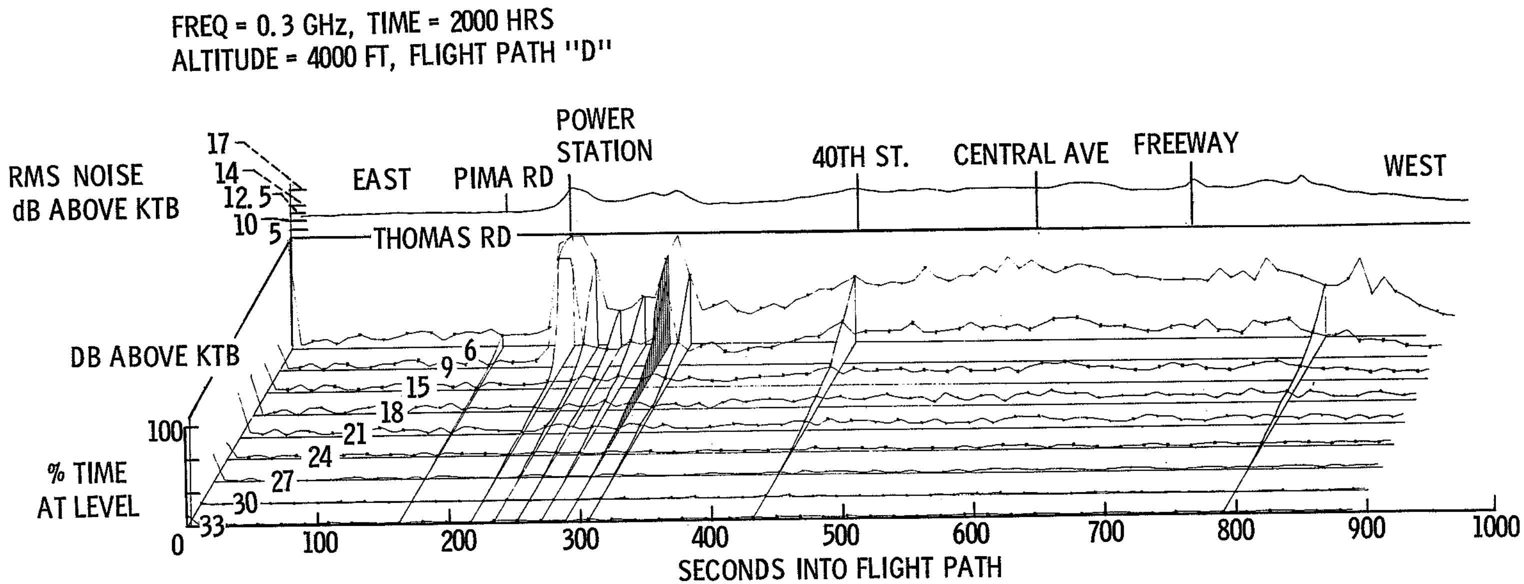

Figure 13. - RMS noise and time comparator data.

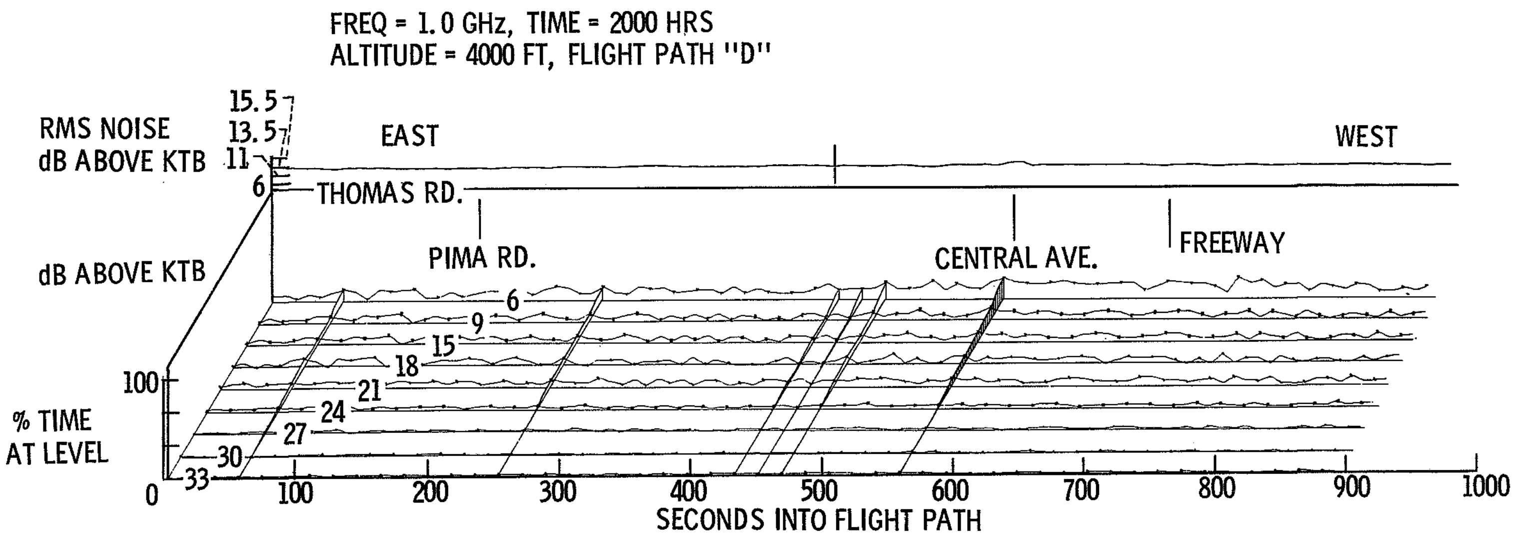

Figure 14. - RMS noise and time comparator data.