NASA TECHNICAL MEMORANDUM

NASA TM X-1972

NASA TM X-1972

RADIOFREQUENCY NOISE MEASUREMENTS IN URBAN AREAS AT 480 AND 950 MEGAHERTZ

by Godfrey Anzic

Lewis Research Center

Cleveland, Ohio

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MARCH 1970

1. Report No. NASA TM X-1972	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle RADIOFREQUENCY NOISE MEASUREMENTS IN URBAN AREAS AT 480 AND 950 MEGAHERTZ		5. Report Date March 1970
		6. Performing Organization Code
7. Author(s) Godfrey Anzic		8. Performing Organization Report No. E-5415
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		10. Work Unit No. 160-21
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The results of a limited survey of radiofrequency noise in the Cleveland, Ohio, area are presented. The measurements were made at 480 and 950 megahertz. A portable, self-powered radiofrequency noise measuring system was developed to measure and record the root-mean-square (rms) noise voltage at various urban sites. These sites included residential areas, apartment buildings, heavy and light industry, major street intersections, and low- and high-voltage distribution stations. Forty recordings were made. The noise observed was characteristically impulsive and random in occurrence. The principal source was automobile ignition.

17. Key Words (*Suggested by Author(s)*) UHF noise; man-made radiofrequency (RF) noise; RF noise; RF noise survey; urban RF noise; RF interference; indigenous urban RF noise; RF noise recording system	18. Distribution Statement Unclassified - unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	17	$3.00

*For sale by the Clearinghouse for Federal Scientific and Technical Information Springfield, Virginia 22151

RADIOFREQUENCY NOISE MEASUREMENTS IN URBAN AREAS AT 480 AND 950 MEGAHERTZ

by Godfrey Anzic

Lewis Research Center

SUMMARY

The results of a limited survey of radiofrequency noise in the Cleveland, Ohio, area are presented. The measurements were made at 480 and 950 megahertz.

A portable, self-powered radiofrequency noise measuring system was developed to measure and record the root-mean-square (rms) noise voltage at various urban sites. These sites included residential areas, apartment buildings, heavy and light industry, major street intersections, and low- and high-voltage distribution stations. Forty recordings were made.

The noise observed was characteristically impulsive and random in occurrence. The noise levels obtained during this survey indicate that the extrapolation of noise levels from high-frequency and very-high-frequency data would yield valid ultrahigh frequency noise data. Although many sources contribute to the overall radiofrequency noise environment, the principal source was automobile ignition.

INTRODUCTION

Radiofrequency interference (RFI) in general is the introduction of unwanted signals into the desired signal. One source of these unwanted signals in the near earth environment is man-made noise. Severe cost or power penalties will be incurred in space to earth communication systems if the desired signal has to be recovered without noticeable impairment in a high noise environment.

To determine the required power and system cost for future space to earth communication systems, which will transmit to high noise environment areas, it is necessary to ascertain the noise characteristics of cities and other inhabited areas. It was for this reason that a limited radiofrequency (rf) noise survey was performed in the ultrahigh frequency region.

Previous investigations of man-made noise in the UHF region of the spectrum are quite limited. Most rf noise surveys done to date at all frequencies have dealt with noise measurements in narrow voice communication channels. Almost all data were taken at frequencies below 400 megahertz and receiver bandwidths of 100 kilohertz or less (refs. 1 and 2). Although the present VHF noise data shows that man-made noise decreases rapidly with frequency, very little data exists to confirm this.

This report presents the results of a limited UHF noise survey conducted in and near the city of Cleveland, Ohio, during the summer of 1967. The survey was performed to provide a basis for the technology involved in establishing a video link between a synchronous satellite and terrestrial television receivers. A 4-megahertz channel width was used to simulate the bandwidth of video links.

EQUIPMENT AND PROCEDURE

System Description

Figure 1 is a photograph of the radiofrequency (rf) noise measuring system used in this experiment. To effectively sample the different types of rf noise at a variety of locations, the measuring system had to be portable and self-powered.

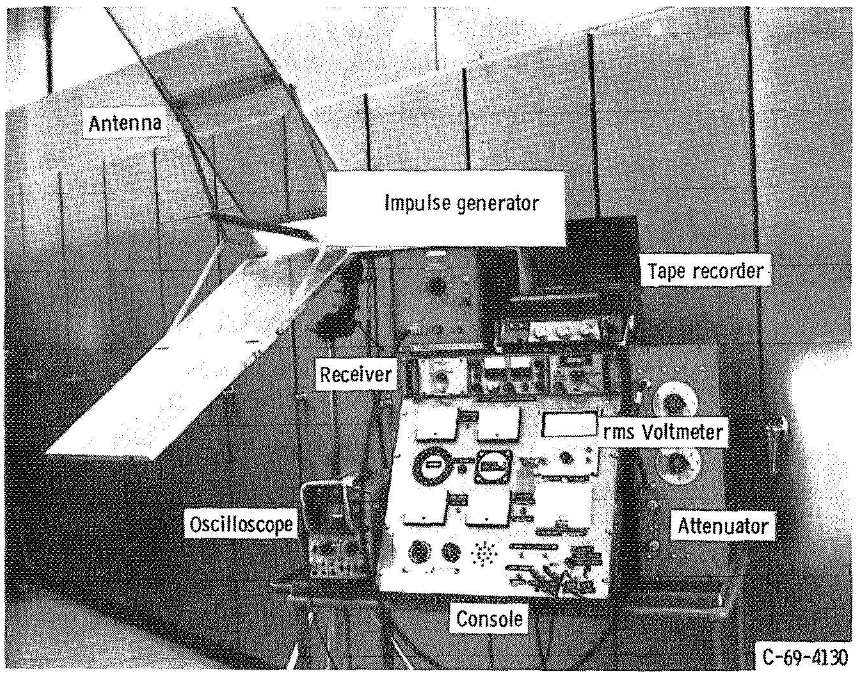


Figure 1. - RF noise measuring system.

The rms voltage output of an amplitude modulated receiver was the noise parameter measured. This parameter is the measure of noise power commonly used in noise calculations. The rms noise data were recorded for 900-second periods at each location. Two 4-megahertz channels were used throughout the survey with center frequencies at 480 and 950 megahertz.

The rf noise measuring system (fig. 2) consisted of the following major components:

(1) Receiver
(2) Antenna
(3) Recorder
(4) Calibration system
(5) Power supply

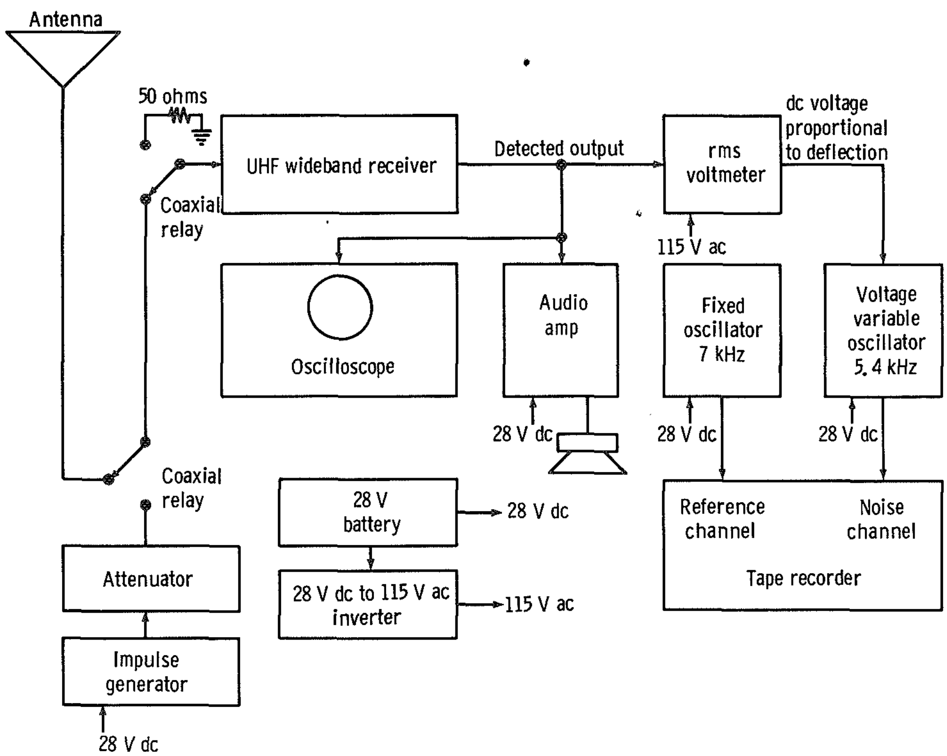


Figure 2. - Ultrahigh frequency noise measuring system.

The receiver used was a solid state, self-powered instrument with a noise figure of 10 dB at 480 megahertz and 12 dB at 950 megahertz. The detected output of the receiver was measured by a calibrated rms voltmeter which also provided a dc output voltage proportional to meter deflection. This voltage was then used as the input to a voltage controlled oscillator which will be referred to as the noise oscillator.

The noise oscillator output was recorded on one channel of a portable, self-powered, good quality, stereo tape recorder. The output of a fixed-frequency oscillator, the reference oscillator, was recorded on the other channel. During playback, this channel then enabled correction for recorder wow and flutter. All recording and playback was done at 7.5 inches per second (19 cm/sec) tape speed.

The receiver detected output was also processed through an audio-amplifier to drive a speaker. Since different types of noise (e.g., ignition, arcing, etc.) are easily distinguishable by ear, noise identification presented no problems.

The antenna used was a frequency and polarization adjustable corner reflector with a 10 dB gain over a dipole. A telescoping mast was used to raise the antenna to a height of 12 feet (3.6 m) above ground. The console consisted of the rms voltmeter and signal and power conditioning with associated monitor meters as shown in figure 1.

The system power supply consisted of a 28-volt battery and a dc to ac inverter to supply the ac power for the rms voltmeter.

System Calibration

An impulse generator was chosen as a portable system calibration source for field use since the excessive power requirement of a laboratory standard made its use in the field impractical. Figure 3 shows the setup used to calibrate the impulse generator

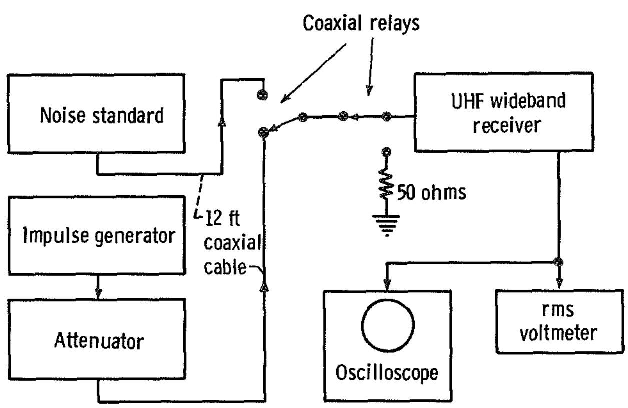


Figure 3. - Impulse generator calibration setup.

against a noise standard. A known value of noise was fed from the standard into the receiver and monitored on the rms voltmeter. The output of the impulse generator was attenuated to match the noise standard by adjusting a calibrated attenuator. The impulse generator was calibrated in dB above KTB (where K is Boltzman's constant, T is 290^{o} K, and B receiver bandwidth). A portable oscilloscope was used to monitor the receiver output and detect signal clipping.

Effects of Crest Factor on Readings

The rms voltmeter has the following reading limitation: a signal crest factor (peak to rms ratio) of 10 results in true rms reading over full scale; a signal crest factor of 20, over first half of full scale, etc. The impulse generator supplied a 0.02-nanosecond wide pulse at a repetition rate of 1 kilohertz to the input of the receiver. The receiver output was a train of pulses with a 1-kilohertz repetition rate and a 1-microsecond width. This calibration signal was fed to the rms voltmeter. The crest factor (CF) is expressed as

$$CF = \sqrt{\frac{1 - D}{D}} \tag{1}$$

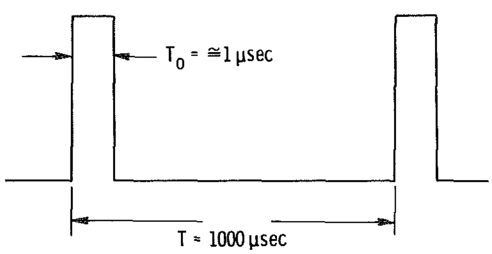
where

$$D = \frac{T_o}{T} \tag{2}$$

In this case

$$CF = \sqrt{\frac{0.999}{0.001}}$$

$$CF = 31.5$$



The resulting calibration signal crest factor of 31.5 restricts the use of the rms voltmeter to only the first third of any scale while calibrating the system.

A typical pulse width for car ignition is about 50 microseconds (T_o). To investigate the crest factors of the ignition noise encountered and the validity of their measurement on the rms voltmeter, two sample calculations were made.

(1) Assume an eight-cylinder engine running at 1600 rpm (driving speed). Since eight spark plugs fire for every two engine revolutions, the engine produces 107 firings/second. This yields the following car ignition crest factor approximation:
Since

$$T_o \cong 50\ \mu\text{sec}$$

$$T = 9345\ \mu\text{sec}$$

using equations (1) and (2),

$$CF = \sqrt{185} \cong 14$$

(2) Assume 10 eight-cylinder engines running at normal driving speed (1600 rpm) with no ignition-pulse overlap yields the following:
Since

$$T_o \cong 50\ \mu\text{sec}$$

$$T = 935\ \mu\text{sec}$$

using equations (1) and (2),

$$CF = \sqrt{18} \cong 4$$

Due to the relatively low ignition noise crest factors and since the average meter deviation throughout the survey was approximately 30 percent or less of full scale (CF = 30) the meter measurement errors due to signal crest factors were considered negligible. To compensate for receiver gain variations, the average value of two calibrations, one before and one after the 900 second run was used.

Data Reduction

Data reduction was accomplished in two parts. These were the laboratory data

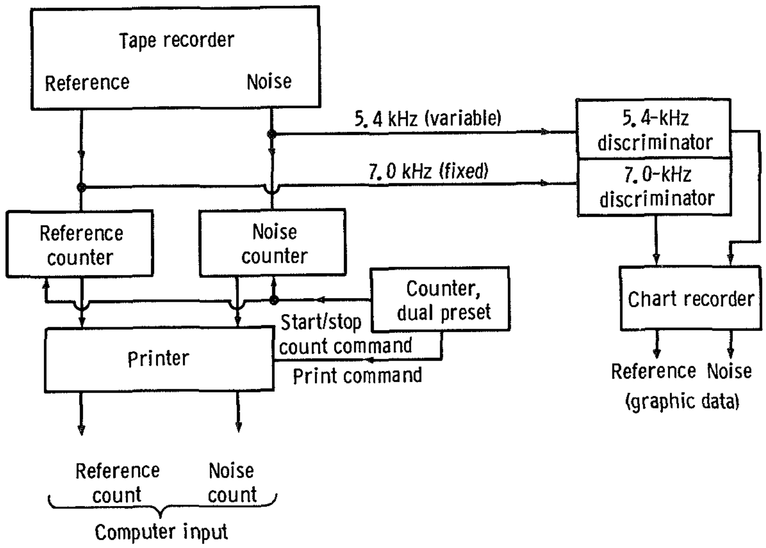


Figure 4. - Radiofrequency noise data reduction system.

processing and the final computer data reduction.

Figure 4 presents the schematic diagram of the system used for laboratory data processing. Each survey run (900 sec) was divided into 30 equal time segments. The total number of cycles from each channel was counted for each time segment. The corresponding noise and reference oscillator frequency counts, which then corresponded to a time average over the segment, were printed out for use in the final computer data reduction. All print and count commands were generated by a dual preset counter. Graphic noise and reference channel data were also obtained for a visual check of the tape recorder operation.

In the computer program, the noise count, corrected by the reference count was converted to the noise power (dB above KTB). The noise power which was already averaged over each 30-second segment of the run was also averaged over the entire 900-second run.

RESULTS AND DISCUSSION

Survey Sites

Forty recordings of rf noise were made at various urban and suburban sites in the greater Cleveland area. To provide a better sample of different types and levels of rf noise, the sites included residential areas, apartment buildings, low- and high-voltage distribution stations, heavy and light industry, and major street intersections.

Out of 13 different sites visited, only two could be identified where, in addition to automobile ignition noise, another type of rf noise was clearly present. These two sites were a heavy industry site and a very congested intersection known for rf noise which causes almost total loss of AM broadcast station reception. Automobile ignition noise was easily identified by ear. The corresponding rise and fall of noise level with the approach and leaving of cars was very evident. Figure 5 shows a typical noise trace

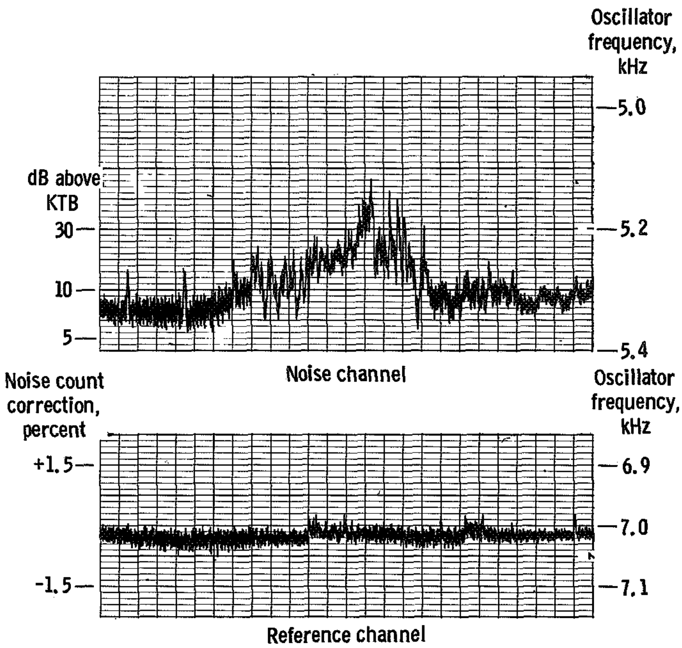
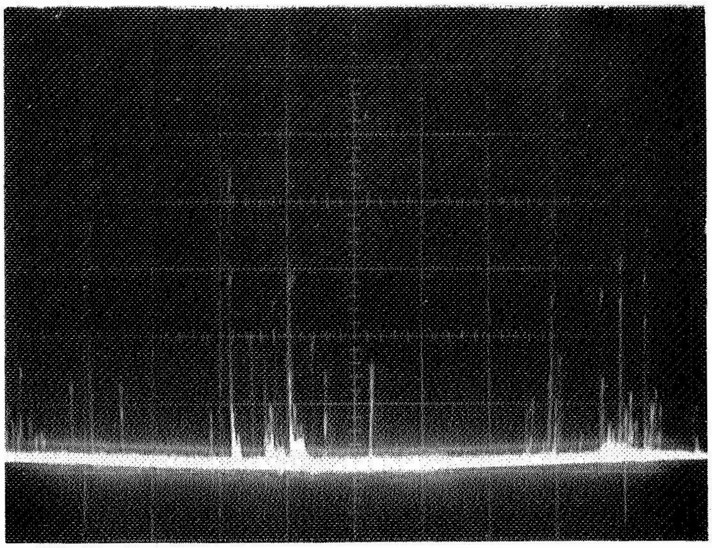


Figure 5. - Typical noise trace; 480 megahertz.

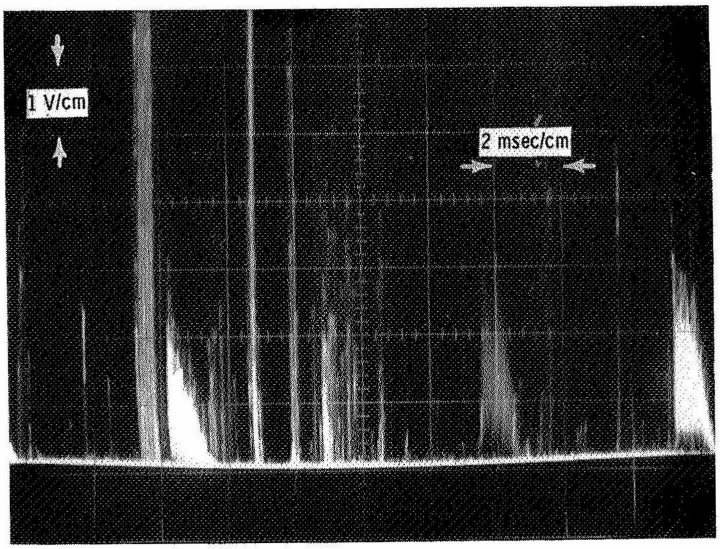
with its reference channel as is recorded on tape and reproduced through discriminators. Figure 6 presents oscilloscope photographs of typical ignition noise observed at all survey sites. All rf noise observed was characteristically impulsive and random in occurrence with very few exceptions. Although many sources contribute to the overall radiofrequency noise environment, the examination of data in this survey indicates that the principal source is the automobile ignition.

For ease of data tabluation the survey sites were grouped into urban noisy and urban quiet areas, the selection criteria being the subjective evaluation of the receiver audio channel. Typical urban noisy (fig. 7) locations were

(1) Congested intersections
(2) Shopping centers
(3) Downtown areas
(4) Heavy industry

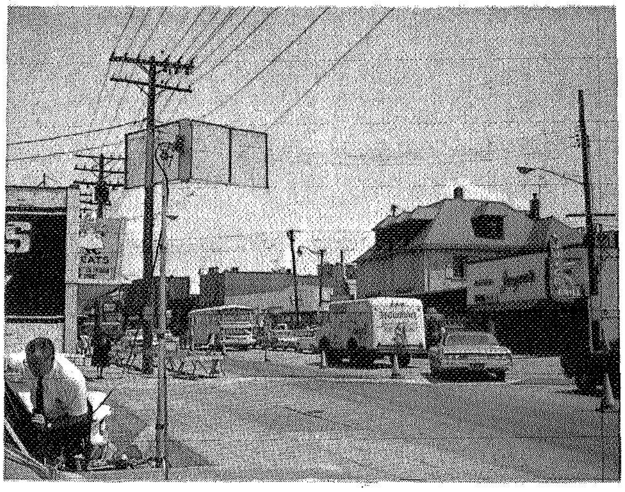


Moderate ingition noise.

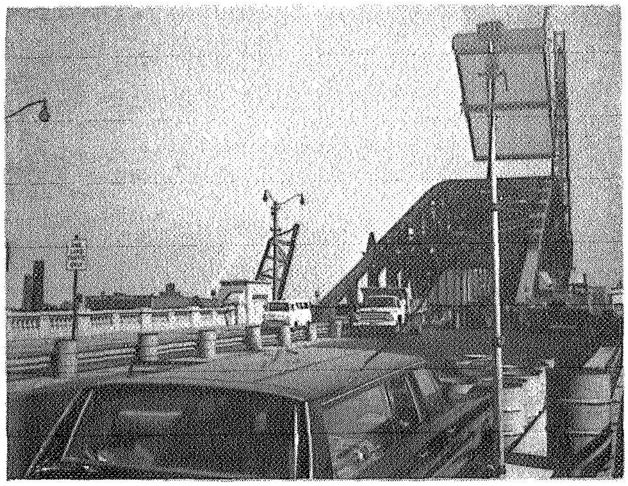


Severe ignition noise; 480 megahertz.

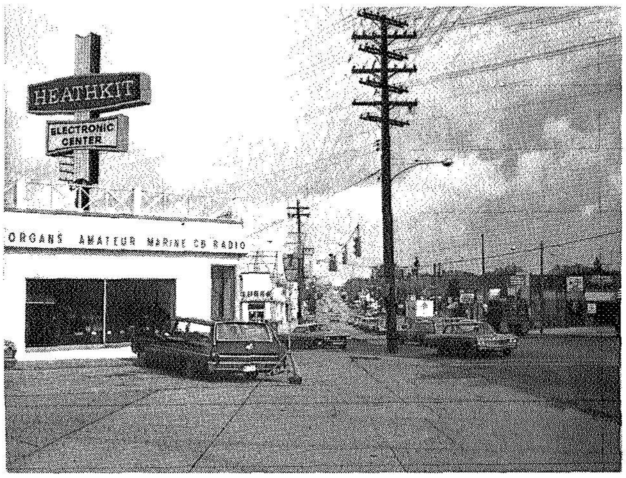
Figure 6. - Ignition noise traces.



Congested intersection

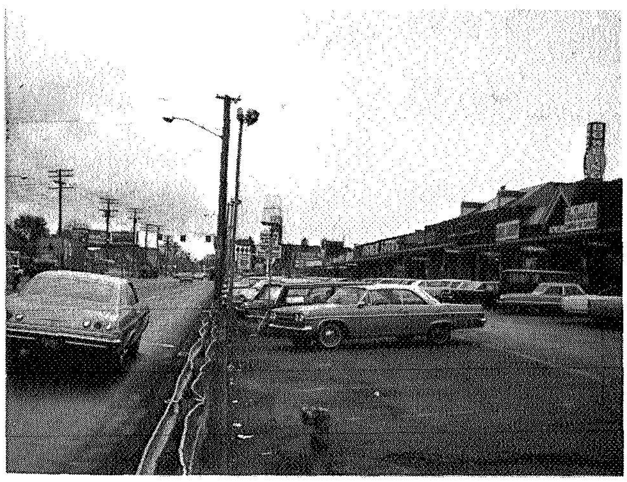


Congested bridge (downtown)



Congested intersection

Public square (downtown)

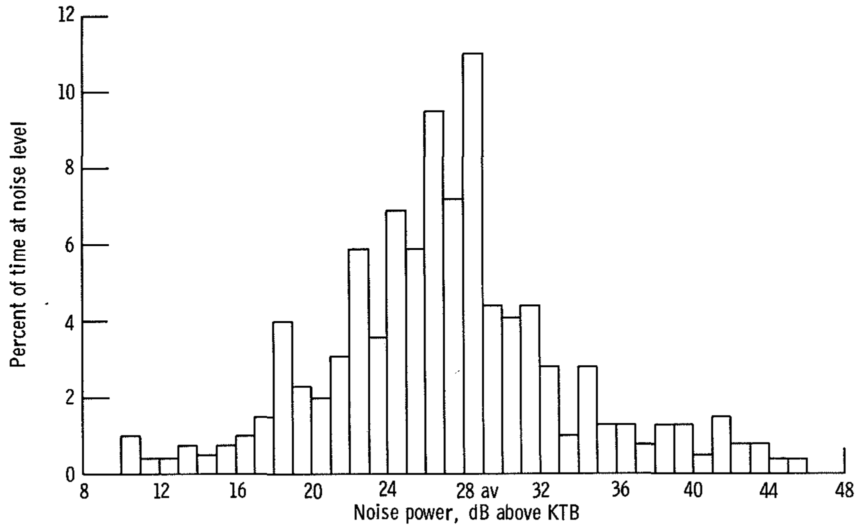


Shopping center

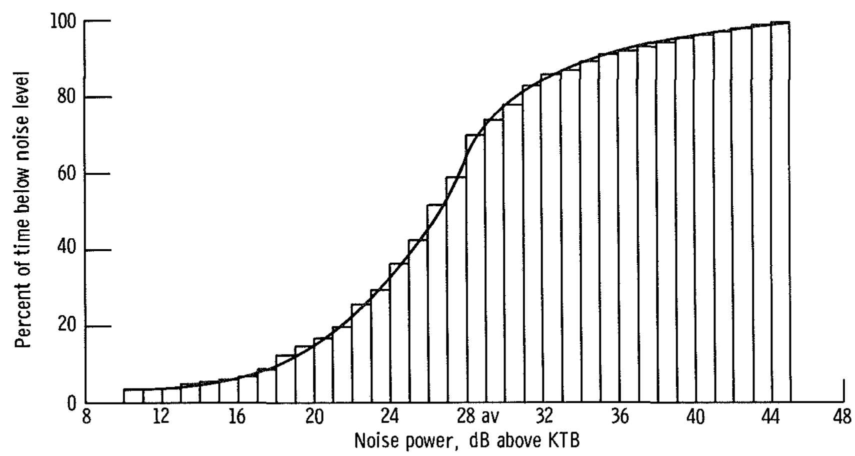
Heavy industry

Figure 7. - Noisy locations.

where at 480 megahertz the 900-second average noise power was approximately 28 dB above KTB, and the noise level remained below 38 dB above KTB for 90 percent of the time. At 950 megahertz the average noise power was approximately 11 dB above KTB, and the noise remained below 14 dB above KTB for 90 percent of the time. Figures 8 and 9 show the noise deviation about average power levels and noise level percentiles for the two channels monitored at all noisy locations. The noisiest location encountered was a congested intersection where ignition noise predominated. The average noise levels recorded were 33 and 12 dB above KTB for 480 and 950 megahertz, respectively.

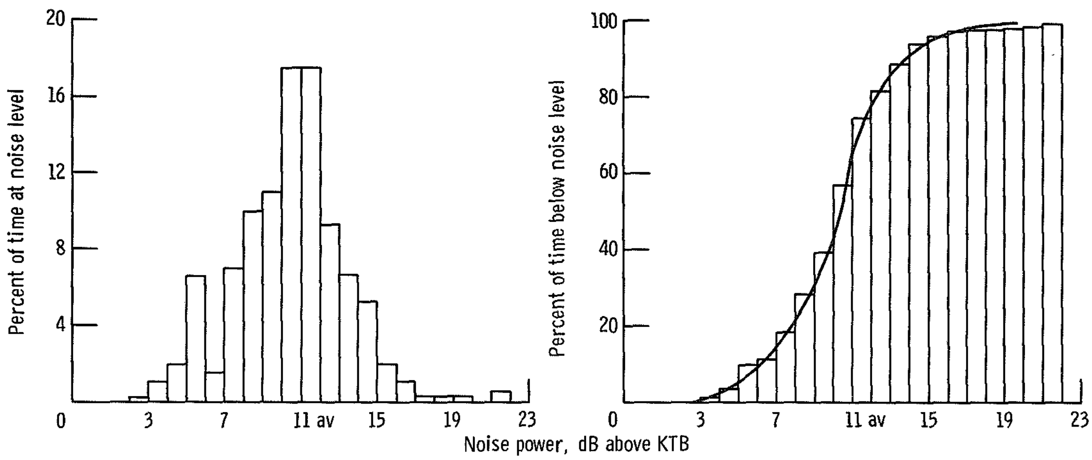


(a) Noise distribution about average level.



(b) Noise probability distribution.

Figure 8. - Radiofrequency noise at 480 megahertz (13 recordings at urban noisy areas).



(a) Noise distribution about average level. (b) Noise probability distribution.

Figure 9. - Radiofrequency noise at 950 megahertz (12 recordings at urban noisy areas).

Typical Urban Quiet (fig. 10) locations were

(1) Light industry

(2) High voltage distribution stations

(3) Apartment houses

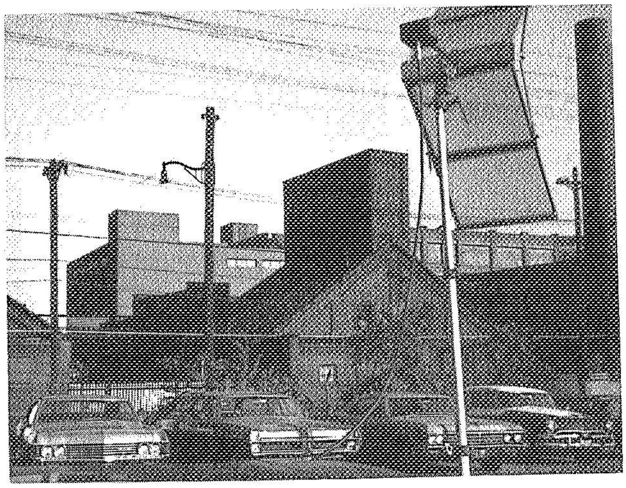
(4) Suburban residential area

where the average noise level at 480 megahertz was 11 dB above KTB and remained below 13 dB above KTB for 90 percent of the time. At 950 megahertz the noise level was too low to be measured with the equipment. Figure 11 shows the noise deviation about the average and noise level percentiles for 480 megahertz. The quietest area visited was a typical suburban residential street located about 3 miles from the nearest major traffic route, where no noise could be measured at either frequency.

Correlation with Other Surveys

Radiofrequency noise data obtained during this survey is compared in figure 12 to the recent data obtained by three other rf noise surveys in the high frequency (HF) and very high frequency (VHF) regions of the spectrum for urban, suburban, and rural areas. Narrow bandwidth receivers (BW < 400 kHz) were used for all three surveys. The urban quiet noise level at 480 megahertz of the Cleveland survey agrees with the

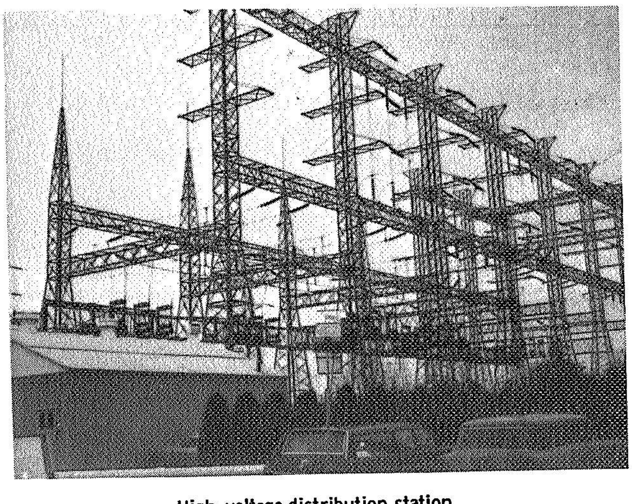
Light industry



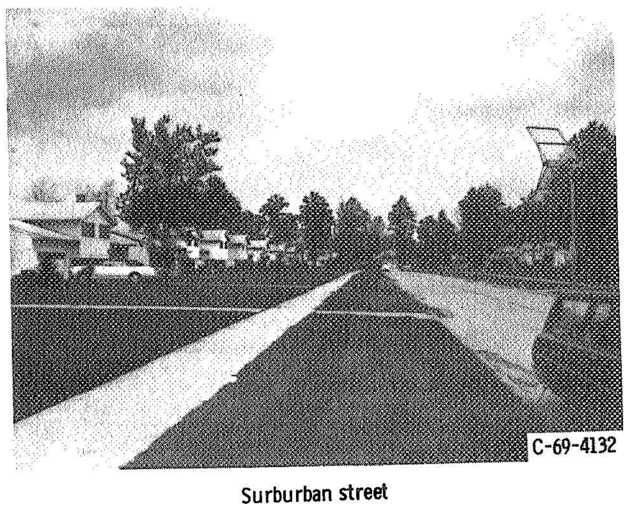
Light industry

High-voltage distribution station

Apartments

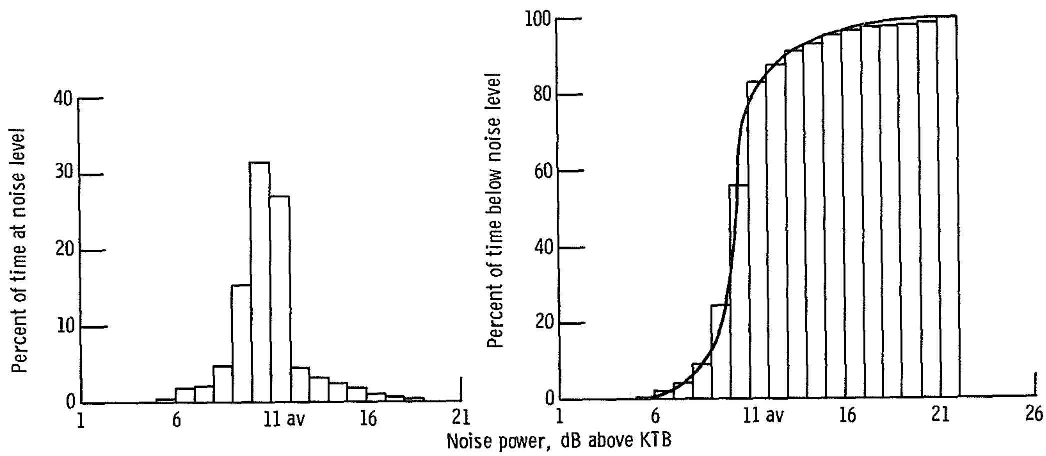


High-voltage distribution station



Surburban street

Figure 10. - Quiet locations.



(a) Noise distribution about average level. (b) Noise probability distribution.

Figure 11. - Radiofrequency noise at 480 megahertz (nine recordings at urban quiet areas).

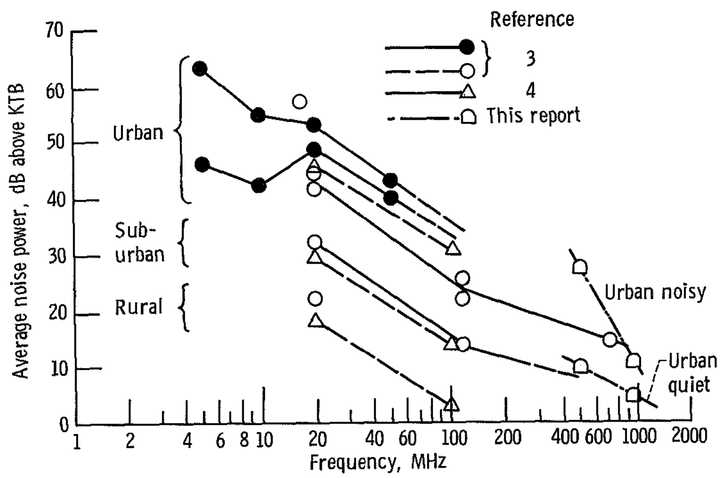


Figure 12. - Comparison of radiofrequency noise data.

extrapolated value of noise obtained from the suburban data of references 3 and 4. The validity of the urban quiet noise level at 950 megahertz is questionable because of measuring equipment limitations.

The urban noisy noise levels of the Cleveland survey at the two monitor frequencies exhibit a somewhat steeper slope than the values extrapolated from the HF and VHF data would indicate. Such variations may be due to measurement techniques and survey site selection. In general, the noise levels obtained in this survey indicate that extrapolation of noise levels from HF and VHF data would yield acceptable UHF noise data.

Noise Discrimination Due to Antenna Elevation and Polarization

Most noise data recorded was done with the antenna at horizontal polarization and 0^{o} elevation. A few noise recordings were made with the antenna at vertical polarization and 45^{o} elevation above the horizon. Due to the relatively low antenna height (12 ft or 3.6 m) and insufficient number of data points, no conclusion could be drawn as to the noise discrimination due to antenna polarization or elevation. In most cases the antenna, which was immersed in heavy ignition noise, was not polarization sensitive. Some noise discrimination due to antenna elevation was observed, although the quantity of data obtained is not sufficient to yield a valid conclusion.

SUMMARY OF RESULTS

A limited UHF radiofrequency noise survey was conducted in the Cleveland, Ohio, area during the summer of 1967. Noise data were collected at various residential, industrial, and commercial sites throughout the city. The following results were obtained:

The average noise power at 480-megahertz in the urban noisy location was approximately 28 dB above KTB. The rms noise level was below 38 dB above KTB for 90 percent of the time. In the urban quiet locations at 480 megahertz, the average rms noise power was 11 dB above KTB. Here the noise power was below 13 dB above KTB for 90 percent of the time.

At 950 megahertz, the urban noisy location exhibited an average noise power of 11 dB above KTB. A noise value below 14 dB above KTB was measured 90 percent of the time. The urban quiet noise values were below the receiver noise figure and, therefore, are questionable.

The major source of man-made radio interference was automobile ignition noise.

The urban quiet noise values obtained in the survey extrapolate well from the high-frequency and very-high-frequency noise data obtained in references 3 and 4. The urban noisy data exhibited a steeper slope than other investigators indicating a difference in site selection as the probable cause.

Antenna polarization did not noticeably affect the noise data obtained. Noise discrimination due to antenna elevation above the horizon yielded no conclusive results due to the insufficient quantity of data obtained.

The difference in noise levels obtained by other investigators during various surveys was attributed primarily to the selection of city locations.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, December 11, 1969,
160-21.

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 Tech. Comm. of the Advisory Committee for Land Mobile Radio Services from Working Group 3, Federal Communication Commission.
3. Anon.: Voice Broadcast Mission Study. Rep. AED-R-3187, Radio Corp. of America (NASA CR-95491), May 1967.
4. Anon.: Voice Broadcast Mission Study. Rep. GE-67SD4330- Vol. 2, General Electric Co. (NASA CR-98711), July 14, 1967.

NASA-Langley, 1970 —— 7 E-5415

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS

FIRST CLASS MAIL

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS A
SPACE ADMINISTRATION

POSTMASTER: If Undeliverable (Section 158
Postal Manual) Do Not Retur

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Notes, and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C. 20546