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7. This effect has been seen for cytochrome a_3 below 160°K [see (*3*)].
8. We thank Drs. T. L. Brown, D. Hendrickson, and M. Duggan for a generous loan of the Andonian cryostat, and Drs. R. Marcus, P. Debrunner, E. Münck, J. Dow, D. Lazarus, and C. P. Slichter for many useful discussions. Supported in part by NSF grants GP 26282 and GH 36966, HEW grants GM 18051 and AM 00562, and NIH postdoctoral fellowship 5 F02 HD 41376.

2 April 1973

Radio Noise from Towns: Measured from an Airplane

Abstract. *Measurements of broadband radio noise in the range 73 to 440 megahertz were made over several small Illinois cities during August, September, and December 1972. Results for cities with a population larger than 25,000 are presented as brightness temperatures between 2400 and 9600 degrees Kelvin. Even the smallest villages produce significant noise pollution. There is considerable diurnal variation and some evidence for seasonal variation.*

Users of the radio-frequency spectrum have long been aware that the electromagnetic noise environments of cities and towns are not conducive to sensitive measurements of natural electromagnetic phenomena or to communication with minimum power. The problem is perhaps most apparent to radio astronomers, who must seek remote, interference-free sites for their instruments. However, communication transmitters routinely use more power than would be dictated by natural noise alone, in order to overcome incidental man-made noise. Similarly, broadcasting transmitters produce extremely high intensities in urban areas, in part to overcome the ambient man-made noise.

Fig. 1. The 222-Mhz antenna installed on a Cessna 150 airplane.

If lower noise levels prevailed, transmitter powers could be reduced. This, in turn, would reduce pollution of the electromagnetic spectrum by spurious emissions from transmitters.

The increasing pollution of the electromagnetic environment is a largely unappreciated but nonetheless important social problem. The question of incidental man-made noise has received some attention from radio engineers, and some experimental data taken from the air appear in the literature (*1–3*). These data refer mainly to very large cities, and, even for them, present only a tentative sampling of the radio noise environment.

A brief series of measurements was made from the air in the fall and winter of 1972 for a preliminary assessment of the electromagnetic noise generated by small cities and towns in the very-high-frequency and ultrahigh-frequency bands. The noise under consideration is unintentional and might have been generated by electrical appliances, power distribution facilities, automobiles, and other electrical equipment.

The measurements were made from the air, with use of a light airplane, on frequencies of 74, 148, 222, and 440 Mhz. On the 74 Mhz frequency, the receiving antenna was a half-wavelength coaxial dipole towed horizontally behind the airplane; on 148 and 222 Mhz, a three-element Yagi-Uda array (driven dipole and two directors) was mounted vertically beneath the metal wing, which acted as a reflector; and on 440 Mhz, a five-element Yagi-Uda array, including one reflector element, was mounted beneath the wing. The Yagi-Uda antennas were directed vertically downward. Measurements were made one frequency at a time (it was necessary to land while changing antennas). The antenna patterns were not measured; however, their behavior when we were flying over unresolved radio sources indicated they had normal directivity patterns for antennas of their respective types. A typical antenna installation is shown in Fig. 1.

The receiving equipment consisted of a transistor preamplifier and crystal-controlled frequency-converter for each radio frequency, followed by a standard triple-detection superheterodyne communication receiver tuned to the output frequency of the converter. The overall predetection bandwidth was 4.8 khz, and the detector was followed by a resistance-capacitance integrator with a time constant of 1.4 seconds. The output was recorded graphically. The noise figures of the receivers were measured with an Airborne Instrument Laboratories noise generator, type 07005. Noise figures and other parameters used in calculating the characteristics of radiation sources are listed in Table 1.

The ignition systems of light airplanes, even though shielded, typically produce strong, impulsive noise in the frequency range under investigation. Thus, it was necessary to equip the receiver with a "noise-blanking" system that cancels the receiver output during a strong noise impulse of short duration. This system was highly effective and reduced the influence of the airplane's engine to a negligible level. To test the validity of measurements made

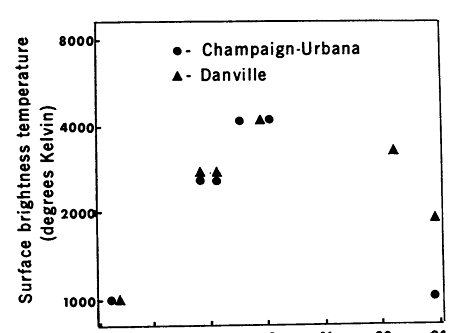

Fig. 2. Diurnal variation of surface brightness temperature of cities in August and September 1972, on a frequency of 222 Mhz. No distinction is made as to day of week.

Table 1. Receiving-system parameters. Bandwidth was 4.8 khz on all frequencies.

Frequency (Mhz)	Measured noise figure (db)	Calculated transmission-line attenuation (db)	Calculated antenna effective area (m^2)
74	1.5	0.4	2.1
148	2.1	0.6	2.7
222	3.0	0.9	1.2
440	7.5	None	0.39

in this way, some of them were compared with measurements made over the same small towns with the noise blanker disabled and the airplane gliding with the engine (ignition) turned off. This test was performed at a frequency of 222 Mhz, and it confirmed that the noise blanker did not bias the measurement.

Calibration marks were placed on the records by disconnecting the antenna and injecting noise from a calibrated semiconductor diode at levels of 0, 3, 6, and 10 db with reference to an ambient-temperature (290°K) resistor.

Approximately 20 towns and villages in central Illinois were surveyed at 222 Mhz, ranging in population from 200 to 90,000. Economic types included small rural market towns, grain-elevator villages, a large university center, a large military-training base, and manufacturing and food-processing cities. With perhaps one exception (a very small crossroads village), every village or town produced sufficient noise to be readily discernible on the graphic record. Flights were also made at various altitudes between 300 and 1200 m over a large coal-fired, electric-generating plant, power-transformer and switching yards, high-voltage transmission lines, and concentrations of motor traffic on an interstate highway. None of these gave detectable deflections of the recorder.

A "standard route" was adopted for subsequent flights, commencing 8 km west of Champaign and passing eastward over Champaign-Urbana, several smaller towns, Danville, and approximately 8 km beyond Danville. This route, approximately 72 km long, was flown several times in each direction on 4 and 5 August, 5 and 9 September, and 6 December 1972, on 222 Mhz (4).

Flights over the same route on frequencies of 74 and 440 Mhz were made on 5 and 9 September and on 148 Mhz on 6 December. All flights along the standard route were made at approximately 700 m above the ground. The audio output of the receiver was monitored by the observer. At no time were transmitter carriers or regular modulation observed; the noise in all cases appeared to be broadband and featureless.

The two larger cities on this route, Champaign-Urbana (population 90,000) and Danville (population 43,000), are extensive enough to be substantially resolved by the beam of the 222-Mhz antenna. Thus their emissions could be treated as surface brightnesses (5). The record for such a source appears as a plateau, above which rise one or more "spikes," caused by intense embedded point sources. The brightness temperatures of Champaign-Urbana and Danville have been plotted as a function of time of day in Fig. 2. A pronounced diurnal effect is noted, probably corresponding with vehicular activity. As the measuring equipment was not completely calibrated and as the routes of successive flights were not exactly similar, these data should be interpreted only qualitatively.

Records of an eastward and a westward flight are shown in Fig. 3, with one record reversed to permit alignment of the communities along the route. It was impossible to navigate the small airplane precisely along the same path on subsequent flights; therefore, it is probable that variations in the strengths of the smaller towns are caused largely by navigational errors. For this reason it is not considered appropriate to list measured strengths for towns that appear as unresolved (point) sources.

Table 2. Surface brightness of cities.

City	Month of 1972	Midday surface brightness temperature (°K) 74 Mhz	148 Mhz	222 Mhz	440 Mhz
Champaign-Urbana (population 90,000)	Sept.	4700		4100	2400
	Dec.		9600	6700	
Danville (population 43,000)	Sept.	2500		4100	3000
	Dec.		9600	6900	
Rantoul (population 26,000)	Sept.			3800	2400

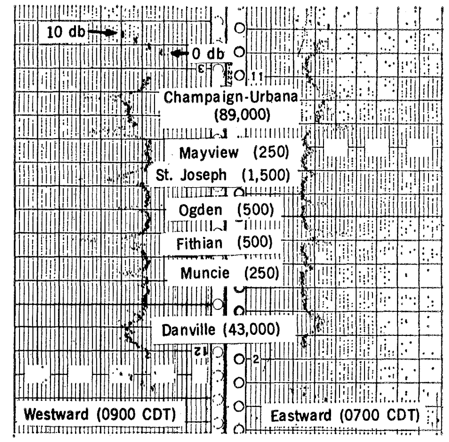

Fig. 3. Typical flight records for "standard route" on a frequency of 222 Mhz, made in August.

An interesting feature in Fig. 3 is the anomalously high emission from Fithian (population 523). This feature was present on each flight, prompting an investigation on the ground. The source was found to be the superregenerative radio receiver of an automatic garage-door opener, radiating continuously over a wide band of frequencies. Such receivers are widely used, evidently, and produce considerable spectrum pollution. Probably some of the "spikes" superimposed upon the background emission at other cities are also caused by these receivers. The spectral power density of this particular receiver is of the order of 10^{-11} watt/hertz.

Flights over the study area were also made on frequencies of 74, 148, and 440 Mhz, but insufficient data are available to yield the diurnal variation, if any. The sharp spikes believed to be garage-door openers on 222 Mhz are absent on 74, 148, and 440 Mhz and the smaller towns are less prominent. Surface brightnesses (5) for three cities on four frequencies, measured around midday, are given in Table 2. These temperatures were calculated from the background values and do not include the "spikes" associated with strong point sources. The noise was higher in December than in September, possibly as a result of a seasonal increase in the use of certain types of electrical equipment.

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4. A heavy rain occurred on 7 September after a dry period of some weeks. The rain had no discernible effect on subsequent records. The midday temperature on 6 December was around 10°F.
5. Surface brightness temperature is defined by the relation $P = KTB$, in which P is the power radiated in frequency band B by a unit area of surface at absolute temperature T, and K is Boltzmann's constant. If the radiating source is much larger than the antenna beam, the antenna can be thought of as being enclosed in a "black cavity" at temperature T.

29 January 1973; revised 13 March 1973

Aftershocks and Intensity of the Managua Earthquake of 23 December 1972

Abstract. *Two portable seismic stations and a fixed array of five seismometers were used to record aftershocks in the vicinity of Managua, Nicaragua, after the earthquake of 23 December 1972. Approximately 3000 aftershocks were recorded during a 20-day period in January 1973. Left lateral motion along at least two faults, both trending N40°E, is inferred from the seismic data. This is in good agreement with dislocations mapped at the surface in Managua. The data suggest that the shallow earthquakes of the Managua region are a consequence of north-south compressional stresses and east-west tensional stresses. This is consistent with regional plate movements deduced in other investigations.*

In the aftermath of the earthquake that struck Managua on 23 December 1972 at 06h:31m:36s G.M.T., the government of Nicaragua is faced with an extremely difficult question: Should they rebuild the capital city where it stands or establish a new city?

At the invitation of General Anastasio Somoza, head of the National Emergency Committee of Nicaragua, we went to Managua to make seismic measurements, survey the pattern of the destruction caused by the earthquake, and supply as much information as possible on the distribution of earthquake activity within Nicaragua. To appreciate the magnitude of the problem, it must be remembered that 400,000 people lived in Managua—20 percent of the total population of Nicaragua. It was the seat of government and the major industrial center of the country. Today, central Managua lies in nearly complete ruin. Between 4,000 and 6,000 people died, and 20,000 were injured. Fifty-seven thousand structures were lost or severely damaged, leaving between 200,000 and 250,000 people homeless.

The people of Managua had a warning. On the evening of 22 December two small earthquakes were felt at about 9:30 p.m. and 10:15 p.m. local time (6 hours behind G.M.T.). But small earthquakes are frequent occurrences in the vicinity of Managua, and no one could foresee the disastrous earthquake that was to occur at about 31 minutes after midnight.

Managua is situated near the western edge of a long, narrow depression—the Nicaragua Trough—that runs through much of Central America (Fig. 1). A belt of youthful volcanoes runs along the depression. This feature is interpreted as a graben in which the block that forms the floor of the trough has moved downward relative to the blocks on either side (*1*). There is some evidence that the bounding block to the west has tilted downward toward the Pacific, raising the western wall of the trough (*1*). The volcanoes of Nicaragua are noted for the explosive character of their eruptions. It is estimated that outpourings of ash from these volcanoes over the past 200 years have been sufficient to cover the entire region of the seismic belt to an average depth of 1 m (*2*). In fact, most of the ash falls to the west of the volcanic belt owing to the prevailing easterly winds. Thus, over long periods of time, the danger of widespread destruction in western Nicaragua may be as great from volcanism as it is from earthquakes.

Sixty-eight earthquakes, large enough to be located by the World-Wide Standard Seismograph Network (WWSSN) (generally magnitude 4 and larger), have occurred in Nicaragua in the past 11½ years, as shown in Fig. 1. This number includes the coastal zone arbitrarily taken as extending 15 km from shore along the western border of Nicaragua. Many earthquakes, too small to be located by the WWSSN, have undoubtedly occurred in this region during the interval plotted. Many others occurred seaward of the 15-km limit. But neither the small earthquakes, nor those that occur farther seaward, are likely to be hazardous to land areas in Nicaragua.

As shown in Fig. 1, the earthquakes of Nicaragua are confined almost entirely to a belt lying along the western border of the country. Ninety percent

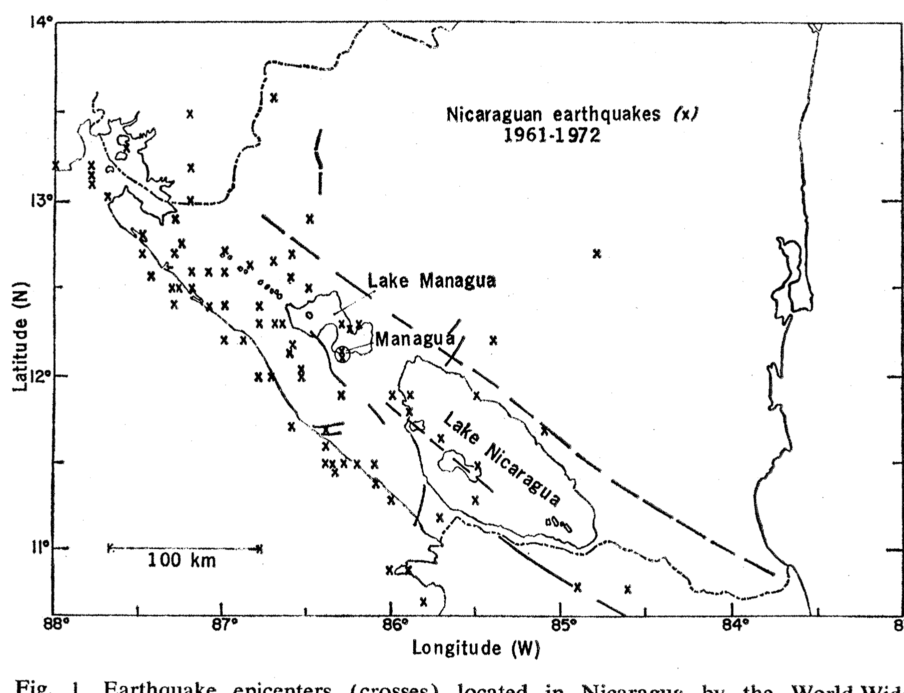

Fig. 1. Earthquake epicenters (crosses) located in Nicaragua by the World-Wide Standard Seismograph Network between 1 January 1961 and 31 August 1972. The edges of the Nicaragua Trough (dashed lines) are as given by McBirney and Williams (*1*).