NATIONAL RADIO ASTRONOMY OBSERVATORY
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SOME VEHICLE IGNITION MEASUREMENTS

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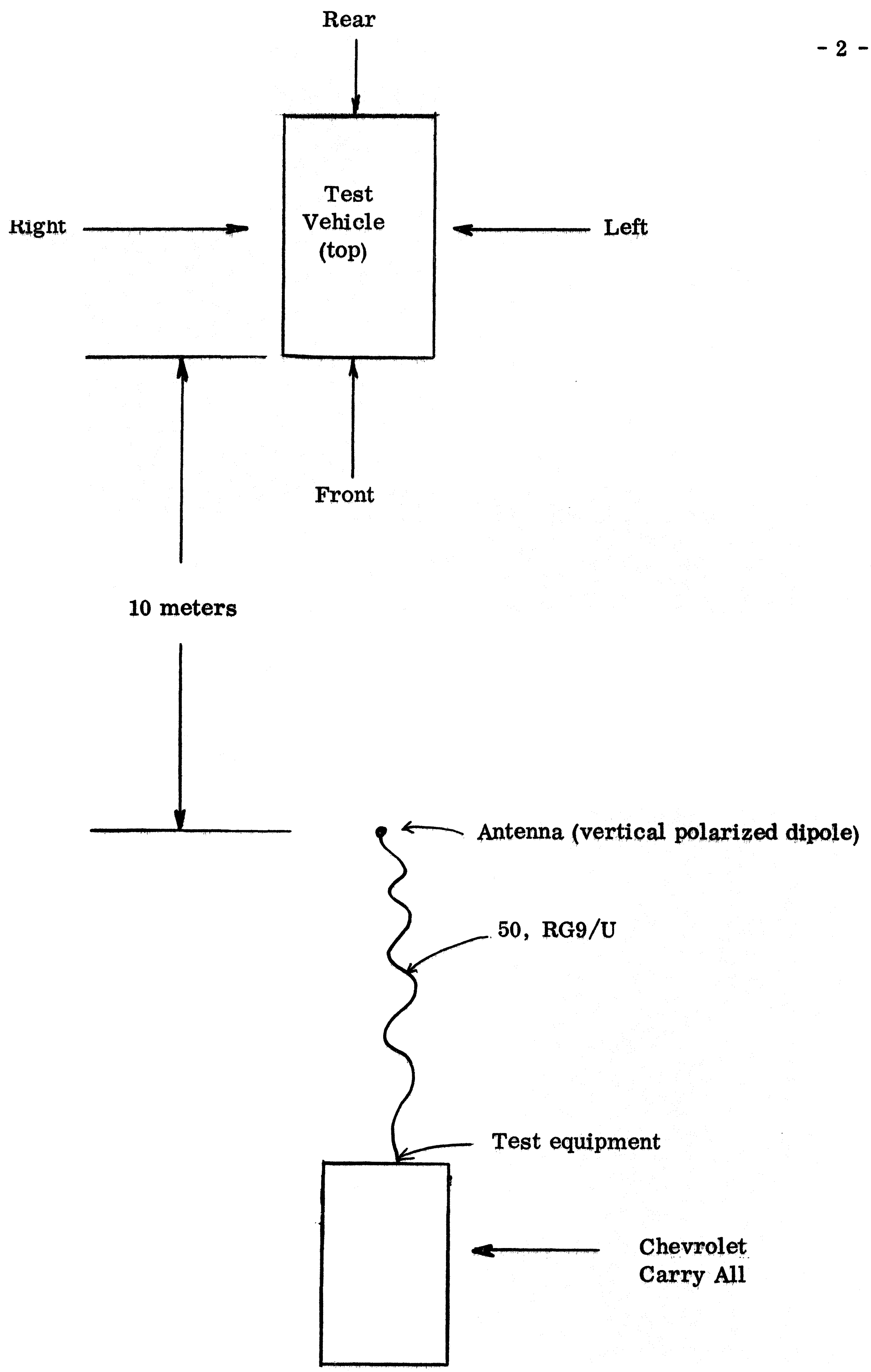
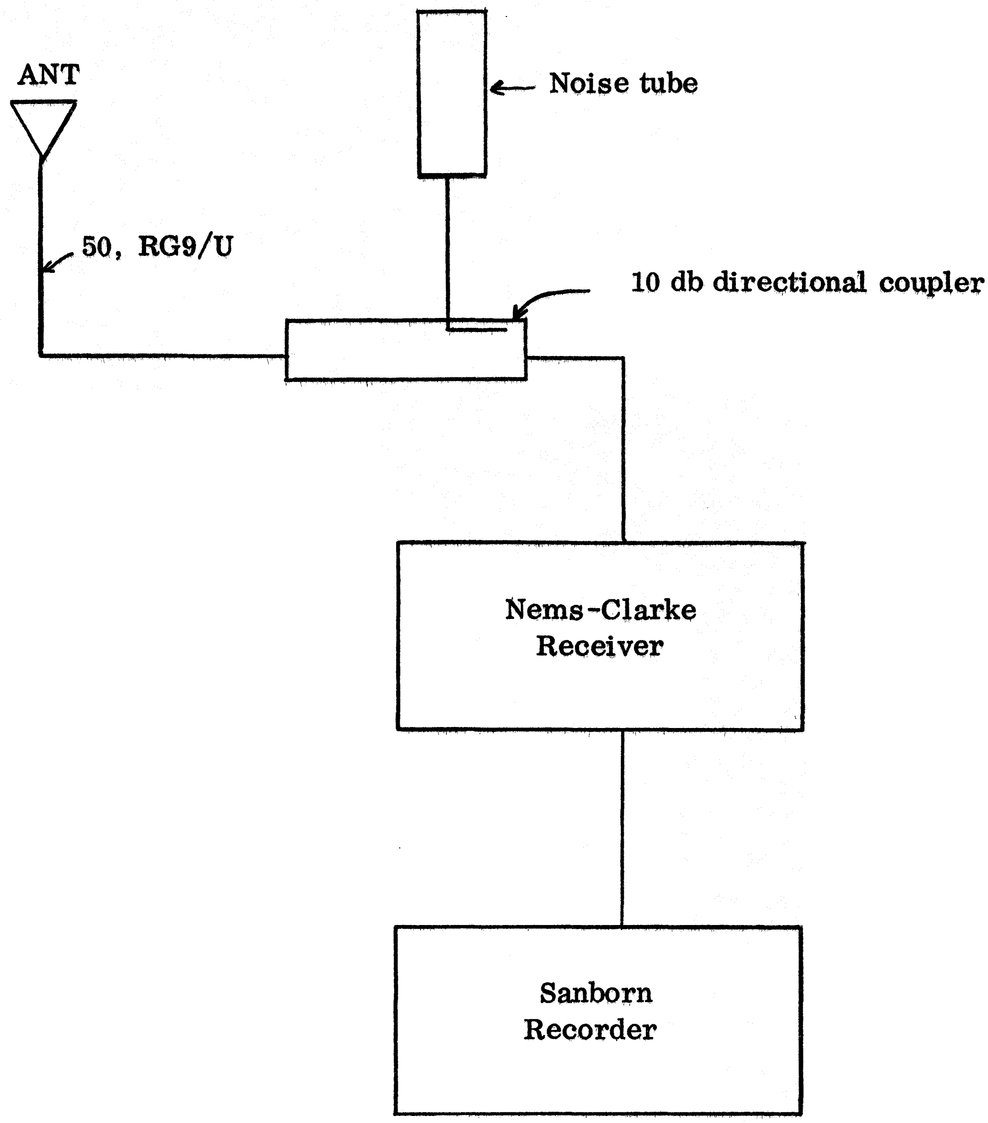
List of Equipment

(a)	Nems-Clarke receiver -------------------------	NRAO 2786
(b)	Range extension unit ---------------------------	NRAO 2785
(c)	Sanborn portable recorder ----------------------	NRAO 1481
(d)	Noise tube (AIL) ------------------------------	NRAO 687
(e)	Directional coupler, 20 db (Narda) --------------	NRAO 2528
(f)	Noise tube power supply (AIL) ------------------	NRAO 1179
(g)	Frequency meter (Narda) -----------------------	NRAO 2223
(h)	Signal generator (250-920 Mc) (G.R.) -----------	NRAO 473
(i)	Signal generator (40-250 Mc) (G.R.) ------------	NRAO 26
(j)	VHF attenuator (H-P) --------------------------	NRAO 922
(k)	Ant DM-105-T2 (200-400 Mc) Empire Devices	
(l)	Ant DN-105-T3 (400-1000 Mc) Empire Devices	
(m)	Tripod, adjustable height	



PICTORIAL (TOP VIEW) OF TEST SITE



BLOCK DIAGRAM - TEST SET-UP

SOME VEHICLE IGNITION MEASUREMENTS

As directed by Dr. Findlay, a program to measure the impulse noise of a few typical combustion-type engines was started on July 23, 1963.

The site for the measurements was selected near the Hannah house to insure minimum interference to operating telescopes, and also to insure minimum interference with the measurement equipment by unwanted sources. Tuesday's operations were sharply curtailed by the weather; it was raining intermittently.

The test set-up was as shown in the pictorial (Figure 1) and the block diagram (Figure 2). Instead of moving the antenna, all of the test equipment was kept stationary, and the vehicle under test was moved to the positions shown in the pictorial. Since the units desired are watts/meter^2/cycle/sec., the calibration system used is of importance to insure minimum conversions, and decrease the chances of error. The system used is similar to conventional radio astronomy methods. The following steps will illustrate the method used.

1. The AIL noise tube was connected to the receiver input through a 30 db coupler. This proved to be too much attenuation, and the receiver could not detect the 10 °K. The directional coupler was changed to 10 db, and a deflection of 4 millimeters was obtained on the recorder. This was considered ample signal for the calibration. Assuming the receiver bandwidth is correct as stated, 300 Kc, the voltage at the terminals can be calculated as follows:

$$p = KTB$$

$$p = (1.37 \times 10^{-23})\,(1000\ ^\circ K)\,(3 \times 10^{5}\ cps)$$

$$p = \underline{\underline{4.1 \times 10^{-15}\ watts}}$$

p = power in watts

K = Boltzmann's constant, 1.38×10^{-23}

B = bandwidth in cps.

With the antenna input $Z = 50\ \Omega$, it follows that

$$E = \sqrt{Zp} = \sqrt{50\,(4.1 \times 10^{-15})} = \underline{0.42\ micro\ volts}$$

These measurements were made at 750 Mc.

2. The Nems-Clarke receiver was used in the total power mode, with the recorder connected across the detector current meter. A one-second time constant was used on the input of the recorder to filter the incident hum and average the impulse noise power.

3. The test set-up seemed to function properly, and by using the collected data, the following sample calculations can be made:

<u>Tuesday, July 23</u>

<u>Conditions:</u> Vehicle: 1955 Chevrolet panel truck

Frequency: 750 Mc

Antenna dipole: Vertically polarized, approximately 1.5 meters from ground.

R: Distance from antenna to test vehicle, 10 meters.

Antenna gain: 1.64 (Jasik's Handbook)

Also,

$$\text{Gain} = \frac{4\pi A_{eff}}{\lambda^2} \qquad A_{eff} = \text{effective antenna capture area}$$

$$A_{eff} = \frac{G\lambda^2}{4\pi} \qquad \lambda = \text{wavelength, meters}$$

For the half-wave dipole

$$A_{eff} = \frac{1.64\,(\lambda)^2}{4\pi}$$

$$\lambda = \frac{3 \times 10^8 \text{ m/s}}{750 \times 10^6 \text{ c/s}} = \frac{300}{750} = 0.4 \text{ meters}$$

$$A_{eff} = \frac{1.64\,(0.4 \text{ m})^2}{12.56} = \frac{1.64\,(0.16 \text{ m}^2)}{12.56}$$

$$A_{eff} = \frac{0.262 \text{ m}^2}{12.56} = \frac{26.2 \times 10^{-2} \text{ m}^2}{12.56} = 2.09 \times 10^{-2} \text{ m}^2$$

From the equation, $p = KTB$, the following information can be derived:

$$\text{Power per unit bandwidth} = p/B = KT$$

To compute watts/unit area/cycle/sec., divide by the effective capture area

$$p/B/A = \frac{KT}{A}$$

A = area in square meters

K = Boltzmann's constant 1.38×10^{-23} joules/°K

T = temperature, °K

Neglecting some unknown effects, such as inadequate data on ground constants, weather conditions, etc., the calculations based on our measured data should be correct to an order of magnitude. From the basic information, which is $\frac{KT}{A}$, frequency, and the distance from antenna to source, it is possible to interpolate and arrive at some significant conclusions. Of course, our data would be more representative if we collected data from many vehicles, but time limits us to a relatively small sample.

The following lists the measured data in order as it was taken:

Vehicle: 1955 Chevrolet panel truck, NRAO

Frequency: 750 Mc

	Front	Right	Rear	Left
T_e:	750 °K	750 °K	125 °K	600 °K

Frequency: 850 Mc

	Front	Right	Rear	Left
T_e:	500 °K	500 °K	140 °K	250 °K

Rain forestalled any further measurement on this vehicle. A check on 300 Mc was desired.

Wednesday, July 24, 1963

Receiver controls (same as previous measurement)

Audio gain	:	As desired
Squelch	:	Open
IF gain	:	28 μA
Pitch control	:	Not used
IF bandwidth	:	300 Kc
BFO	:	Off
Video bandwidth	:	Not applicable
Man-Agc	:	Man.
Dial	:	60 Mc = converted frequency

Calibration: 1000° = 7 mm on recorder

Vehicle: 1955 Chevrolet sedan (John Sapp's)

Frequency: 750 Mc

	Front	Right	Rear	Left
T_e =	500 °K	570 °K	700 °K	850 °K

Frequency: 200 Mc

	Front	Right	Rear	Left
T_e =	3500°	3500°	4000°	4500°

Attenuation versus distance, same vehicle, frequency = 750 Mc

R	T_e
10 meters	640°
20 meters	570°
30 meters	215°
40 meters	Barely perceptible, approximately 50-75 °K

There was a difficulty in maintaining constant motor speed in these tests and power output is proportional to the motor speed. Also, the above figures do not include the loss of 50 feet of RG9/U cable. This is about 3 db at 750 Mc and about 2 db at 300 Mc.

Thursday, July 25, 1963

Tests on 1961 Jeep -- Bob Elliott's. This jeep was not very noisy. It seemed to have one large pulse with a relatively long time interval between pulses. The average power output was small.

With R = 10 meters, f = 750 Mc

$$T_e \cong 50\ °K$$

With f = 300 Mc

$$T_e \cong 50\text{-}75\ °K$$

About 50 °K is the maximum sensitivity for our test set-up.

Tests were also made on other vehicles (1961 Plymouth, 1958 Plymouth, and 1962 Ford). None of these vehicles were detectable at 10 meters. At point blank distance, $T_e \cong$ 10-20° (unmeasurable with our test set-up).

From the figure it can be seen that the average equivalent measured temperature at 750 Mc is about 615 °K. With cable loss approximately 3 db, the actual temperature is approximately 1200 °K. From the equation, power (watts/meter^2/cycle/sec.) $\frac{KT}{A}$, the average can be computed.

With

$$K = 1.38 \times 10^{-23} \text{ joules/°K}$$

$$T_A = 1200\ °K$$

$$A = .02\ m^2$$

$$\frac{KT_A}{A} = \frac{1.38 \times 10^{-23}\ (1.2 \times 10^3)}{2 \times 10^{-2}}$$

$$\frac{KT_A}{A} = \underline{\underline{8.3 \times 10^{-19}}} \text{ watts/meter}^2\text{/cycle/sec.}$$