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PHOTOVOLTAIC SYSTEM TEST FACILITY ELECTROMAGNETIC INTERFERENCE MEASUREMENTS

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16. Abstract

Early (spring of 1976) EMI tests were conducted on several solar cell panels of the ERDA Photovoltaic System Test Facility without power conditioning to determine the characteristic radiated interference frequencies. This test was conducted using a manually switched resistive load of approximately 360 W at a 1 Hz rate. Later (early summer) tests were conducted at an array output of approximately 1.5 kW while interfacing with an available line commutated type of inverter. The ERDA Photovoltaic System Test Facility as configured appears to present very few problems associated with common everyday appliances such as radio and television sets with regard to both radiated and conducted interference. Further, field strength measurements on a single row of panels indicates that the operational mode of the array as configured presents no radiated EMI problems. Only one relatively significant frequency band near 200 kHz showed any degree of intensity (9 μV/m including a background level of 5 μV/m). However, the level was measured very near the array (at 20 ft distance) while Federal Communications Commission (FCC) regulations call for these measurements at 1000 ft. FCC regulations limit spurious emissions to 15 μV/m at 1000 ft. No field strength readings could be obtained even at 35 ft distant.

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PHOTOVOLTAIC SYSTEM TEST FACILITY

ELECTROMAGNETIC INTERFERENCE MEASUREMENTS

by J. A. Johnson, F. P. Herke, Jr. and W. D. Knapp

E-9142

INTRODUCTION

During construction of the ERDA Photovoltaic System Test Facility located at the Lewis Research Center, Cleveland, Ohio, electromagnetic interference measurements were made in order to determine or isolate any conducted or radiated interference frequencies peculiar to the photovoltaic array or the associated power conditioning equipment. It was necessary to determine if the system, array or the associated power conditioning equipment could possibly cause interference on assigned frequencies of nearby airport communication and navigation information channels as well as problems with nearby residential radio, stereo and television sets.

Although the operation of a photovoltaic array is not specifically covered by the Federal Communications Commission (FCC) rules and regulations, the following guidelines are being adhered to: first, FCC rules and regulations (Ref. 1) Vol. II, Part 18, Subpart H, regarding miscellaneous equipment, specified requirements under procedures similar to those for diathermy equipment permitting such changes in the procedure as may be required due to the nature of the particular equipment involved. Operation of diathermy equipment (or "miscellaneous equipment") at frequencies other than specifically assigned or reserved is recognized but emission of any radio frequencies generated by such operation, including spurious and harmonic emissions, are not to exceed a field strength of 15 microvolts per meter at a distance of 1000 feet or more. Second, the Lewis Research Center further restricts any potential interference emissions to not more than 10 microvolts per meter at the laboratory boundaries.

DESCRIPTION OF THE FACILITY

The facility is comprised of an array of solar cell modules mounted on 20 - 4' x 8' panels in the arrangement shown in Figure 2. Figure 1 is an overall plan view or plot arrangement of the installation using a simulated aerial photo. The flat panels are oriented directly south and preset at an angle equal to the latitude in degrees for the site location (41^{o}). The modules are connected in 24 series strings and are paralleled at terminal boards in the trailers (reference panel configuration - Figure 3) to establish an open-circuit voltage of approximately 220V DC. The panels extend for approximately 207 ft. in a row. Power conditioning equipment is mounted in two trailers approximately 300 ft. distant and is connected to the array via underground conduit with sufficient copper conductivity to limit transfer losses to 3% from the field to control center power conditioning equipment. A block diagram is shown in Figure 4 showing component arrangement. Positioning a Stoddard field intensity instrument at a distance of 20 ft. from the array utilizing a trial process was necessary to establish a suitable basis for comparison that would yield adequate readings on the intensity indicator (μV/meter scale). Levels decreased as expected the farther the instrument was moved from the array and disappeared completely into the background noise level at a distance of 35 ft.

DESCRIPTION OF TESTS

Solar Array Only

Tests were conducted to search for the dominant characteristic frequencies that could be expected near the array (array acting as an antenna). The first test was conducted without any power conditioning equipment connected in order to establish a baseline for further testing as well as to isolate or identify any dominant characteristic frequencies (see Figure 2 initial array layout).

This first test was accomplished by abruptly interrupting the array current of approximately 2 amperes into a resistive load at a power level of 360 watt. The array out put was feeding a resistive load and the load was switched on and off at a 1 Hz rate utilizing a manually operated toggle switch while a Stoddard field intensity instrument model NM 20B was utilized to search for the peak level of any dominant frequencies.

Line commutated inverter connected to the photovoltaic array. - A second test was later conducted with power conditioning equipment connected utilizing a line commutated inverter operating at approximately a 1.5 kW level. The line commutated inverter is one which is synchronized with a utility grid and the 60 Hz line frequency is used to commutate the switches (e.g., silicon controlled rectifiers) on and off at the proper intervals. Figure 4 shows a simplified schematic of the configuration under test. Modules were connected in series strings to supply approximately 170 VDC at the inverter input under load conditions.

Portable commercial AC/DC radio and television sets were utilized to survey the AM/FM and VHF/UHF bands, respectively, in order to qualitatively evaluate their susceptibility to any conducted or radiated interference ferquencies generated in and about the control center as well as the array proper. Operation was compared off an isolated AC utility bus versus operation directly off the inverter AC output. In addition, AC/DC sets were operated on both AC and DC (batteries) to permit distinguishing between conducted and radiated interference.

TEST RESULTS

A plot of the array emission frequencies identified in test No. 1 is shown in Figure 5. Frequencies associated with the line commutated inverter

(test No. 2) are also shown along with the array emission frequencies (test No. 1).

Field strength measurements, for the STF configuration of a single row of 20 solar panels, indicates operation of the array presents no radiated electromagnetic interference problems. All detectable extraneous emission frequencies, while testing in an operational mode (with inverter interface), yielded only one measurable frequency band near 200 kHz at a level of 9 microvolts per meter including a background level of 5 microvolts per meter. This level was measured very near the array (at 20 ft.) while the FCC regulations call for measurements at 1000 feet - at which point spurious emissions must be below 15 microvolts per meter. Field strength readings could not be obtained at a distance greater than 35 ft.

It will be noted that the frequencies as shown in Figure 5 lie at the upper end of the low-frequency (L-F) 30-300 kHz band and the lower end of the medium frequency (M-F) 300-3000 kHz band. These frequencies fall in bands allocated by the FCC to international fixed public, fixed Alaska, aeronautical mobile as well as aeronautical radio-navigation usage.

Some radiated interference in the AM band was noted in the immediate vicinity of the control room which could be eliminated by antenna reorientation or relocation of the receiver to a position approximately 20 ft. away from the inverter. The same condition was noted within 0.5 ft. of each panel junction box where the cable shielding is interrupted at the terminal blocks; however, the interference faded out only 0.5 ft. further away.

CONCLUSIONS AND RECOMMENDATIONS

No electromagnetic interference problems were detected with the photovoltaic array per se in an operational mode while interfaced with a line commutated inverter and as the array field is configured herein.

It is recommended that these tests be repeated periodically as the array size (capacity) is increased and different power conditioning equipment becomes available, e.g., self-commutated inverters, maximum power trackers, batteries, etc.

REFERENCES

1. Miscellaneous Equipment. Federal Communications Commission Rules and Regulations, vol. II, pt. 18, subpt. H, Sept. 1972.

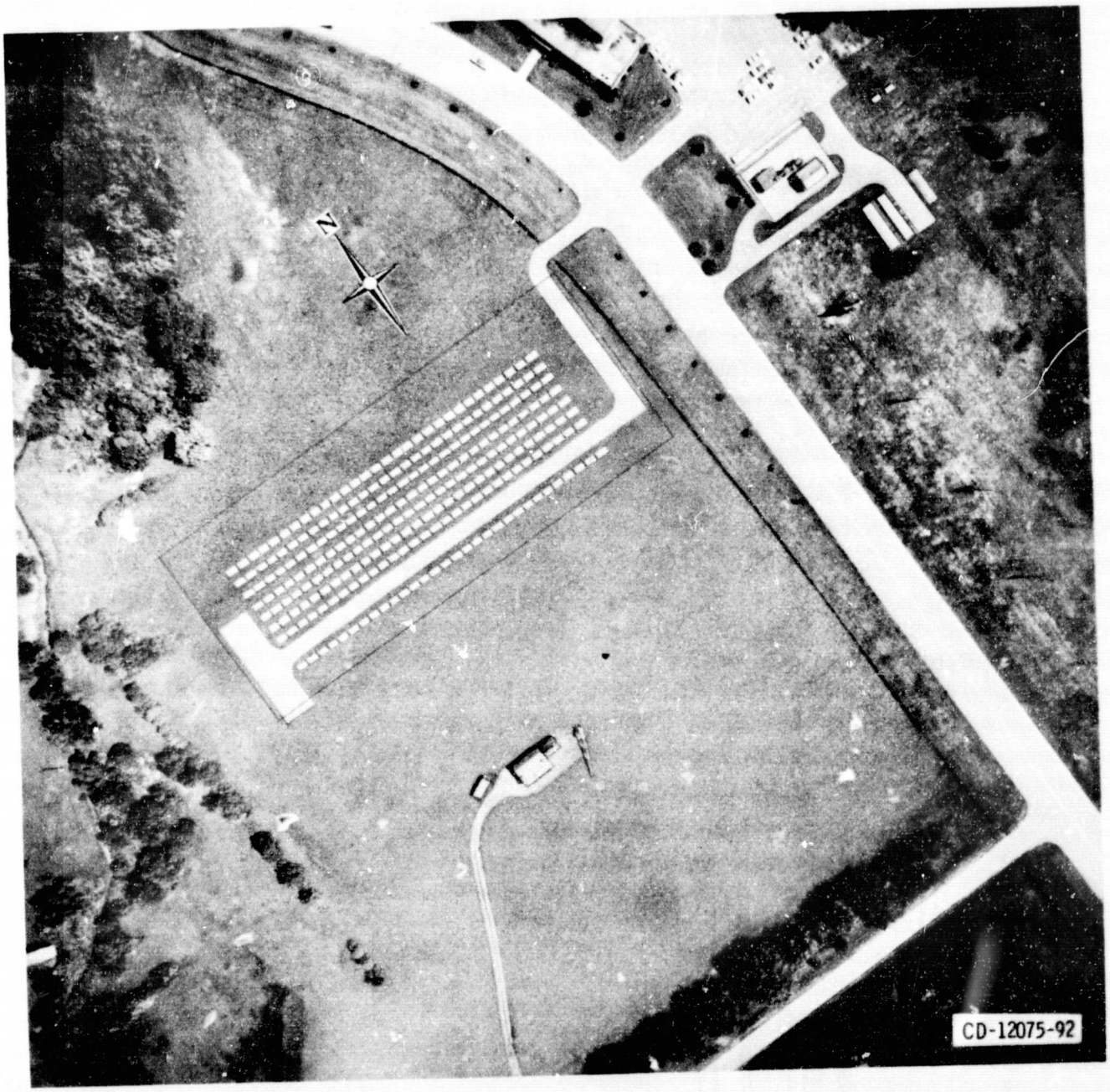


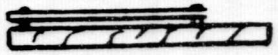
Figure 1. - System Test Facility layout

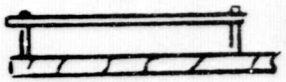
FIGURE 2 PHOTOVOLTAIC SYSTEMS TEST FACILITY

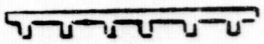
INITIAL 20 FRAME ROW I LAYOUT

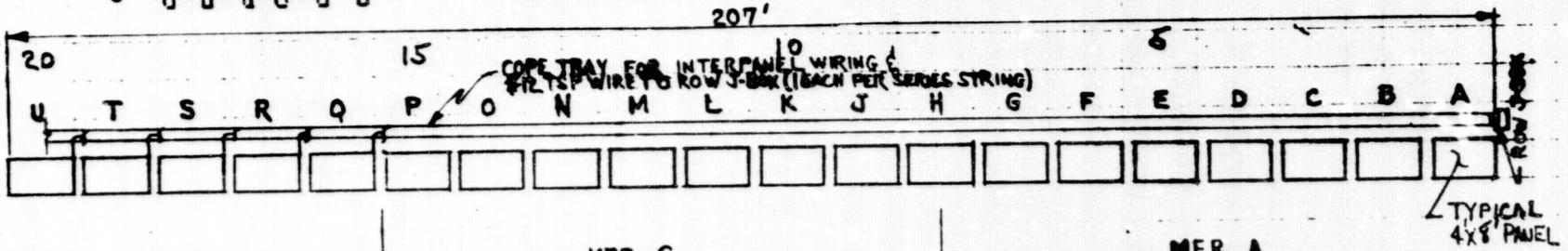
SILICON SOLAR ARRAY

MOUNTING METHODS

MFR A  1/8" STANDOFF/PLYWOOD BACK

" B  1 1/4" STANDOFF/PLYWOOD BACK

" C  ALL ALUMINUM



MFR B
60 MODULES
5 PNLS X 162 W/PNL
0.81 KW
(3 SERIES STRINGS)

NOTE: 1/2 PNL U NOT CONNECTED

MFR C
210 MODULES
7.5 PNLS X 140 W/PNL
1.05 KW
(15 SERIES STRINGS)

MFR A
120 MODULES
7.5 PNLS X 127 W/PNL
0.95 KW
(6 SERIES STRINGS)

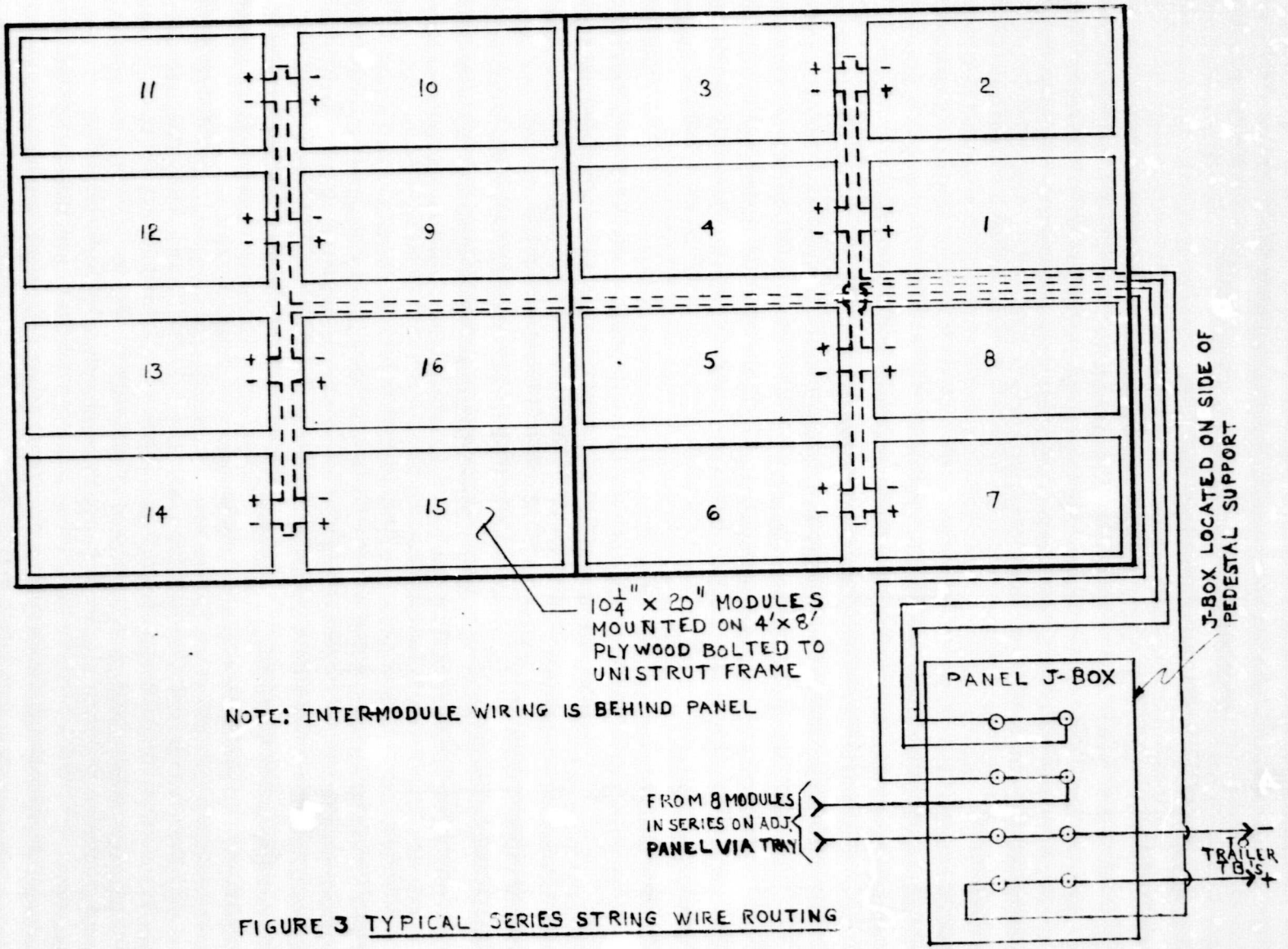


FIGURE 3 TYPICAL SERIES STRING WIRE ROUTING

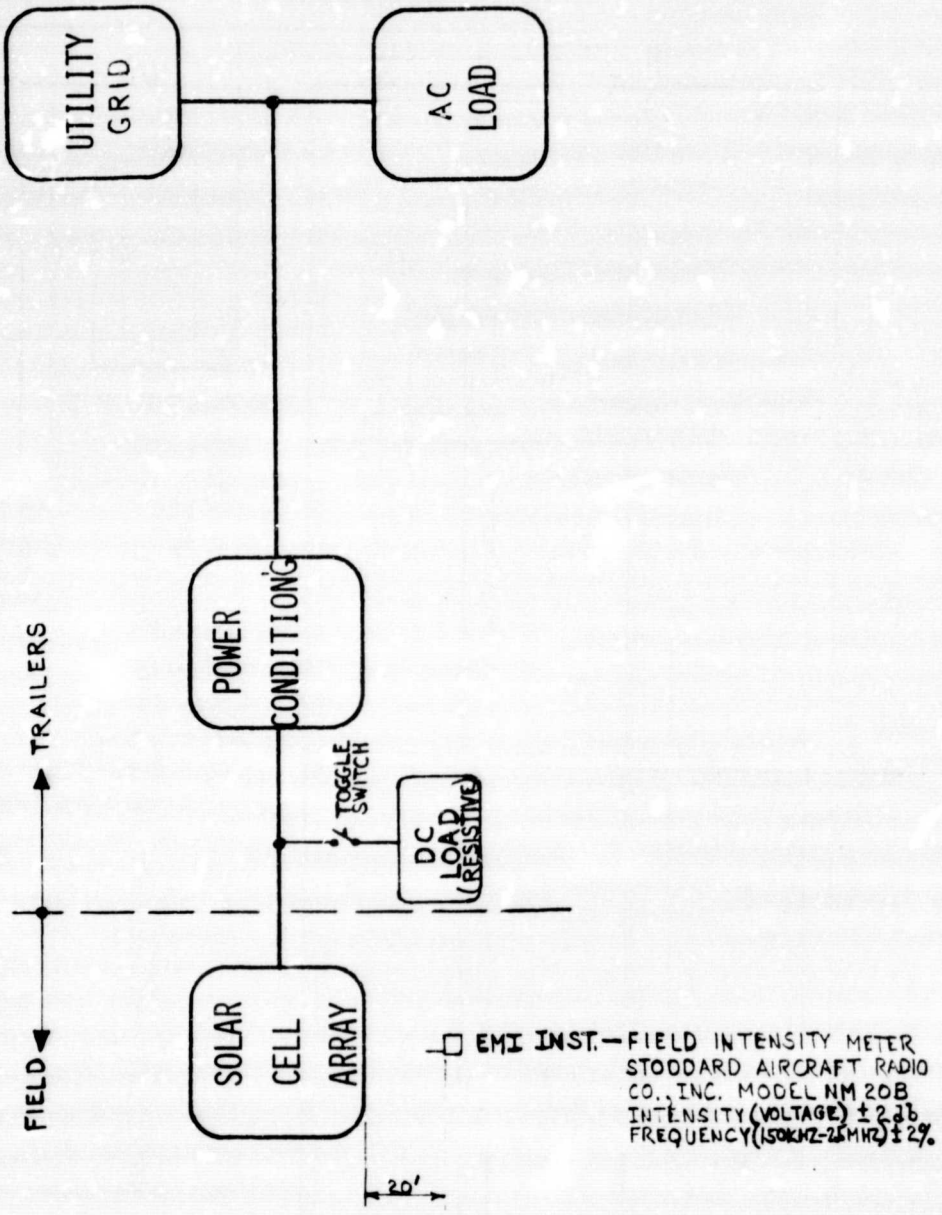


FIGURE 4 SIMPLIFIED BLOCK DIAGRAM FOR EMI TEST SET-UP

FIGURE 5 EMI - FIELD INTENSITY MEASUREMENTS - RADIATED