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Radiation Laboratory
Electrical and Computer Engineering Department
The University of Michigan
Ann Arbor, Michigan 48104

ELECTRICAL TEST RESULTS ON THREE 10-FOOT PARABOLIC REFLECTOR ANTENNAS

by

Joseph E. Ferris

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Introduction

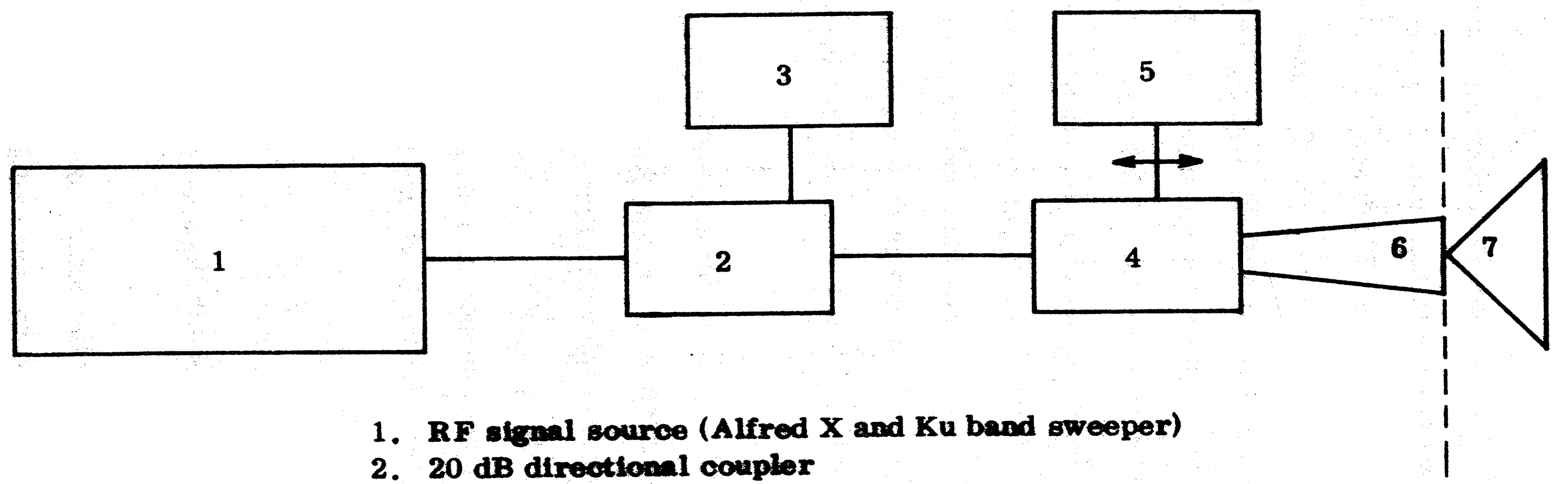
The VSWR, E and H plane patterns, and gain characteristics of three 10-foot parabolic reflector antennas have been measured in accordance with NASA Lewis Research Center Purchase Order 576529 dated 20 January 1975. These antennas were purchased by NASA from Radiation Systems Incorporated (RSI), Andrews, and Westinghouse. One each was supplied to The University of Michigan for tests. The RSI antenna employs a single-port linearly polarized feed operable over the frequency bands of 11.700 - 12.123 GHz and 14.052 - 14.290 GHz, i.e., both bands employ the same sense of linear polarization. The Andrews and Westinghouse antennas employ dual-port, linearly polarized orthogonal feeds with one port operable over the 11.700 - 12.123 GHz band and the other operable over the 14.052 - 14.700 GHz band. Each of the waveguide feeds for the three antennas is fabricated from WR(75) waveguide and fitted with a WR(75) choke flange.

The RSI reflector is the lightest of the three, weighing approximately 150 pounds, and the Westinghouse reflector is the heaviest, at approximately 350 pounds. The three manufacturers employ different reflector fabrication techniques: the RSI reflector is made up of eight "pie-shaped" aluminum sections and thus it can be disassembled for convenience in packaging; the Andrew reflector employs a spun aluminum surface, and the Westinghouse reflector is fiberglass with a metalized reflecting surface.

Test Results

Two test setups were required to obtain the specified VSWR, radiation pattern and antenna gain data.

VSWR data was obtained employing the setup shown in Fig. 1. A Ku band slotted section was connected to the antenna by means of a Hewlett Packard Ku band to WR(75) waveguide transition. Antenna VSWR data was collected at 0.05



1. RF signal source (Alfred X and Ku band sweeper)
2. 20 dB directional coupler
3. Frequency meter (HP Model 5340A)
4. Ku band slotted section (HP Model P810B)
5. Standing wave amplifier (HP Model 415) with bolometer
6. Ku — WR(75) transition (HP Model MP292A)
7. Test antenna

Fig. 1: VSWR test setup.

GHz increments over the frequency bands of 11.60-12.20 GHz and 14.00-14.30 GHz.

The VSWR data for the three antennas was measured over the frequency bands of 11.60-12.20 (receive) and 14.00-14.30 (transmit) GHz and are shown in Table I. Since the RSI antenna has only one port the VSWR for both the receive

TABLE I: VSWR Characteristics of the Three Antennas

	RSI	Westinghouse	Andrews
Frequency (GHz)	VSWR	VSWR	VSWR
11.60	1.22	1.105	1.65
11.65	1.17	1.17	1.60
11.70	1.44	1.05	1.60
11.75	1.45	1.15	1.47
11.80	1.69	1.125	1.35
11.85	1.59	1.09	1.28
11.90	1.45	1.05	1.17
11.95	1.37	1.18	1.07
12.00	1.15	1.05	1.045
12.05	1.19	1.055	1.01
12.10	1.25	1.06	1.06
12.15	1.48	1.07	1.06
12.20	1.52	1.065	1.13
14.00	1.39	1.42	1.21
14.05	1.15	1.26	1.49
14.10	1.17	1.12	1.44
14.15	1.06	1.18	1.12
14.20	1.15	1.065	1.04
14.25	1.29	1.035	1.03
14.30	1.46	1.035	1.025

and transmit frequency bands was measured at this port. The Westinghouse antenna has a dual-port feed; one is designated as the receive port and the other as the transmit port. The VSWR characteristics at each port were measured over the appropriate frequency bands. The Andrews antenna also employs a dual-port feed system, but the function (receive or transmit) of the ports was not indicated. However, the polarization characteristics of each port is identified as shown in Fig. 2. Since the transmit-receive functions were not

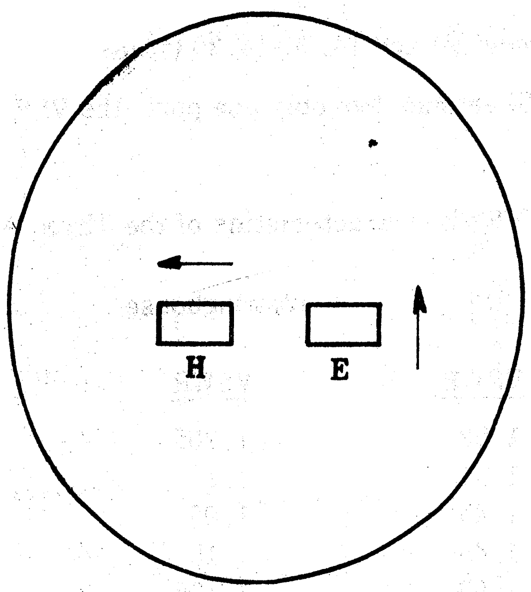


Fig. 2: Andrews feed arrangement, viewed from the back.

obvious, the VSWR characteristics of both ports were measured for both the transmitting and receiving bands. From this data it was concluded that the E and H ports should be designated respectively as the receive and transmit ports. Therefore, only the VSWR data applicable to the receive (E port) and transmit (H port) ports is presented in Table I.

Pattern data for the three antennas was collected employing the equipment setup shown in Fig. 3. The illuminating and test antennas were mounted on towers 70 feet tall and separated by 4000 feet. E plane and H plane patterns were taken for both the transmitting and receiving frequencies for all three antennas. For the Westinghouse and Andrews antennas the appropriate transmitting or receiving feed ports were used. In changing from the E plane to the H plane setup (or vice versa) for the RSI and Andrews antenna, the entire antenna was rotated

1. RF signal source (Varian klystron X13 and X12)
2. 20 dB directional coupler
3. Frequency meter (HP Model 5340A)
4. 20 dB directional coupler
5. Power meter (HP Model 431)
6. 4-foot parabolic reflector.
7. Test antenna
8. Ku — WR(75) transition (HP Model MP292A)
9. Bolometer mount (PRD Model 601)
10. Rectangular pattern recorder (SA Model 1600)

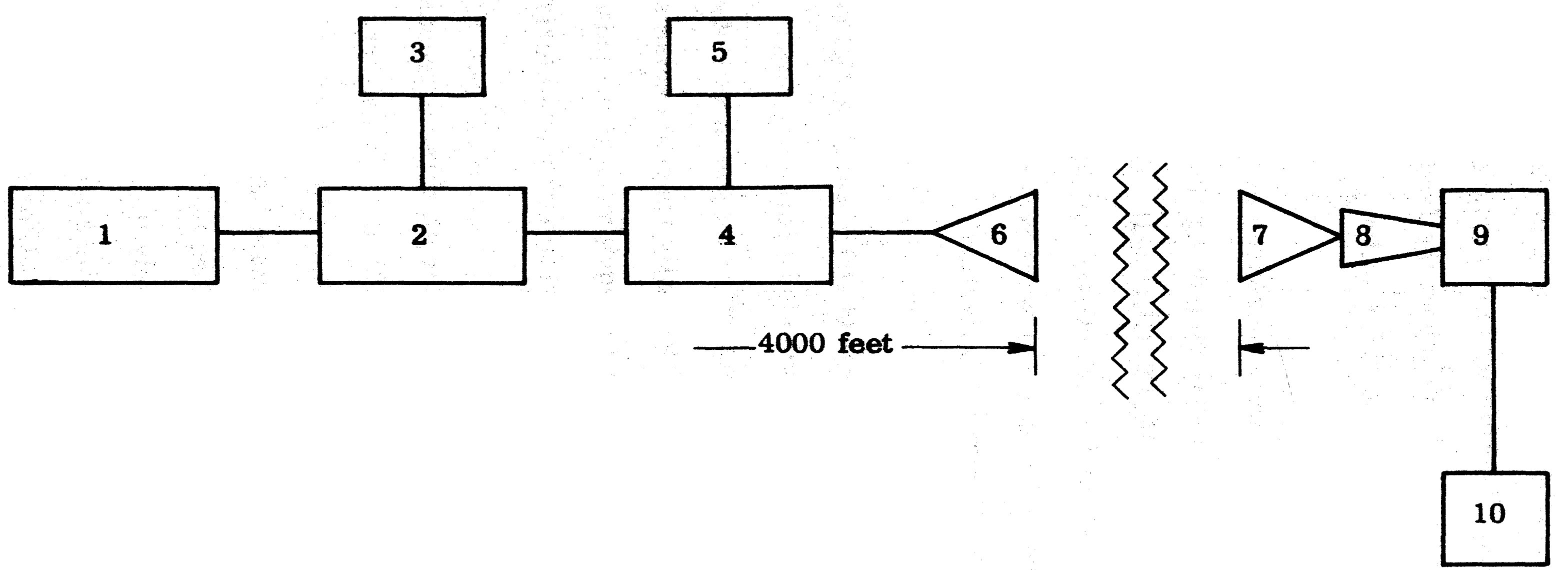


Fig. 3: Antenna pattern and gain measurement setup.

90^{o} about the feed axis. To attach the Westinghouse antenna to the pedestal, it was necessary to have the center of gravity of the reflector several feet in front of the pedestal mounting surface. Because of this it was deemed advisable to have one of the three supporting members of the interface mount at the top of the antenna at all times. Therefore, in changing polarizations, it was necessary to rotate the reflector and feed 120^{o} about the feed axis, and then rotate the feed back 30^{o} to obtain the desired 90^{o} rotation.

E and H plane patterns were measured over a 360^{o} ($\pm 180^{o}$) azimuth angular range for the three antennas employing five receiving frequencies (11.700, 11.885, 12.038, 12.080, and 12.123 GHz) and four transmitting frequencies (14.052, 14.205, 14.247, and 14.290 GHz). In addition to the full 360^{o} patterns, expanded patterns (± 5 degrees) were recorded for all of the above frequencies for either E or H plane polarization.

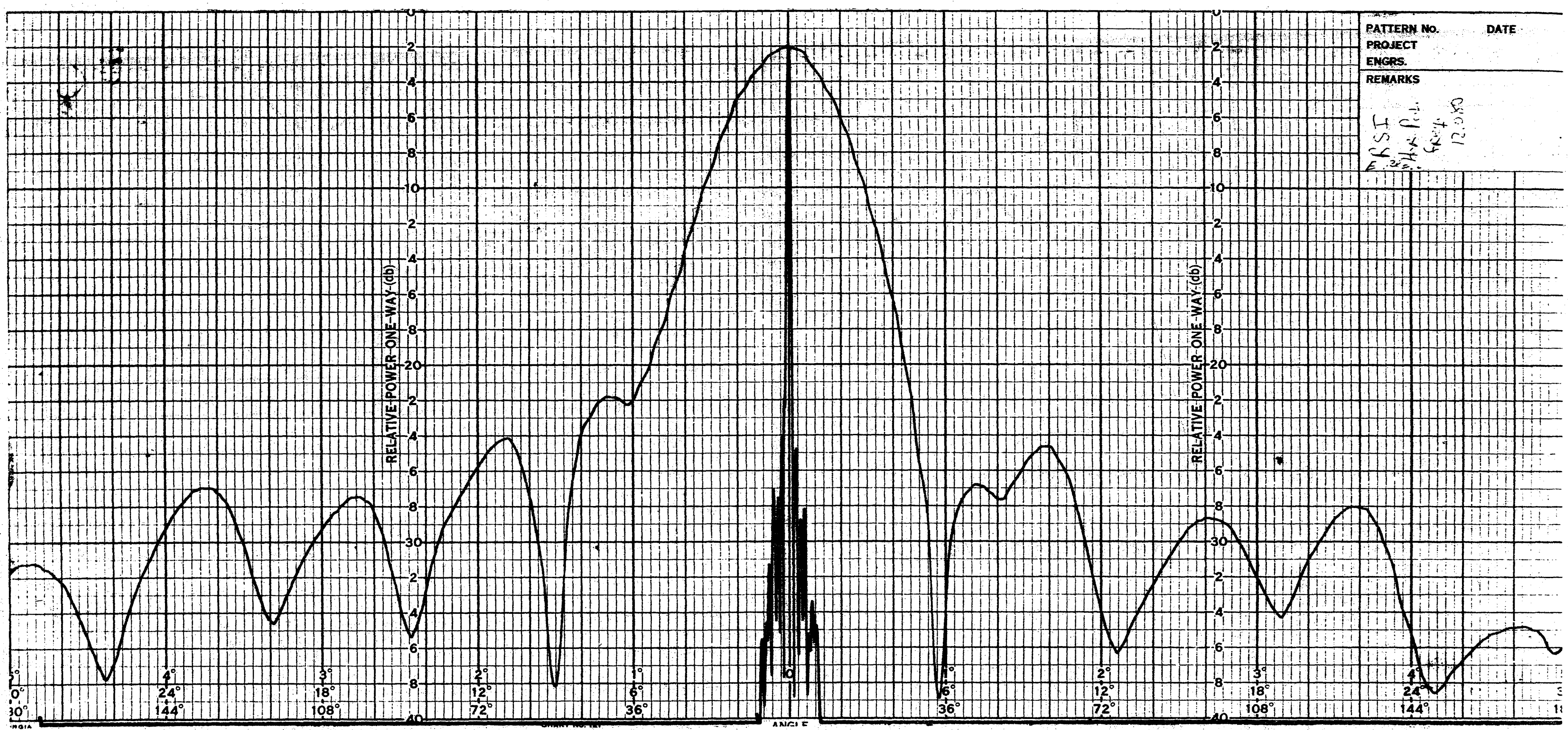
A complete set of full patterns ($\pm 180^{o}$) and a partial set of expanded patterns ($\pm 5^{o}$) were recorded for each of the three antennas. Figures 4-15 are typical E and H plane patterns recorded for the three antennas at frequencies of 12.080 GHz and 14.247 GHz. Periodically spurious noise spikes were recorded because of the operation of other equipment at the pattern recording site. These spurious noise spikes are identified by an asterisk on the appropriate patterns (Figs. 7 and 9).

Typically the first sidelobe level for all three antennas was at least 18 dB down from the main lobe maximum. The H plane patterns generally exhibited sidelobes within ± 4 degrees of the main lobe, while the E plane patterns often had sidelobes out to ± 7 degrees from the main lobe maximum. The average 3 dB beamwidth of the E and H plane patterns for the receiving and transmitting ports of the three antennas were respectively 0.67 and 0.62 degrees.

The gain of the three antennas was obtained using the pattern measurement setup and the method of substitution. After the pattern of the test antenna

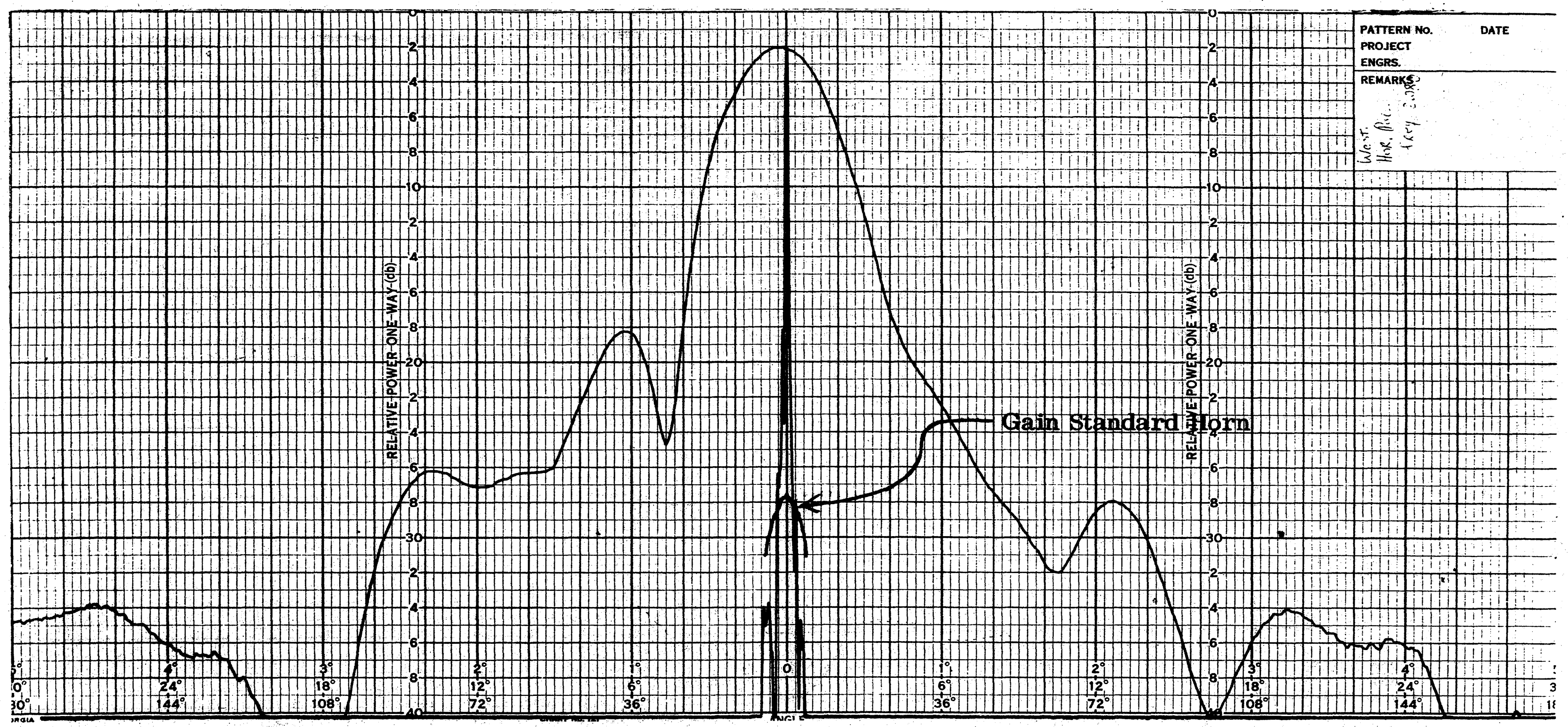
Andrews E-Plane 12.080 GHz

Figure 4



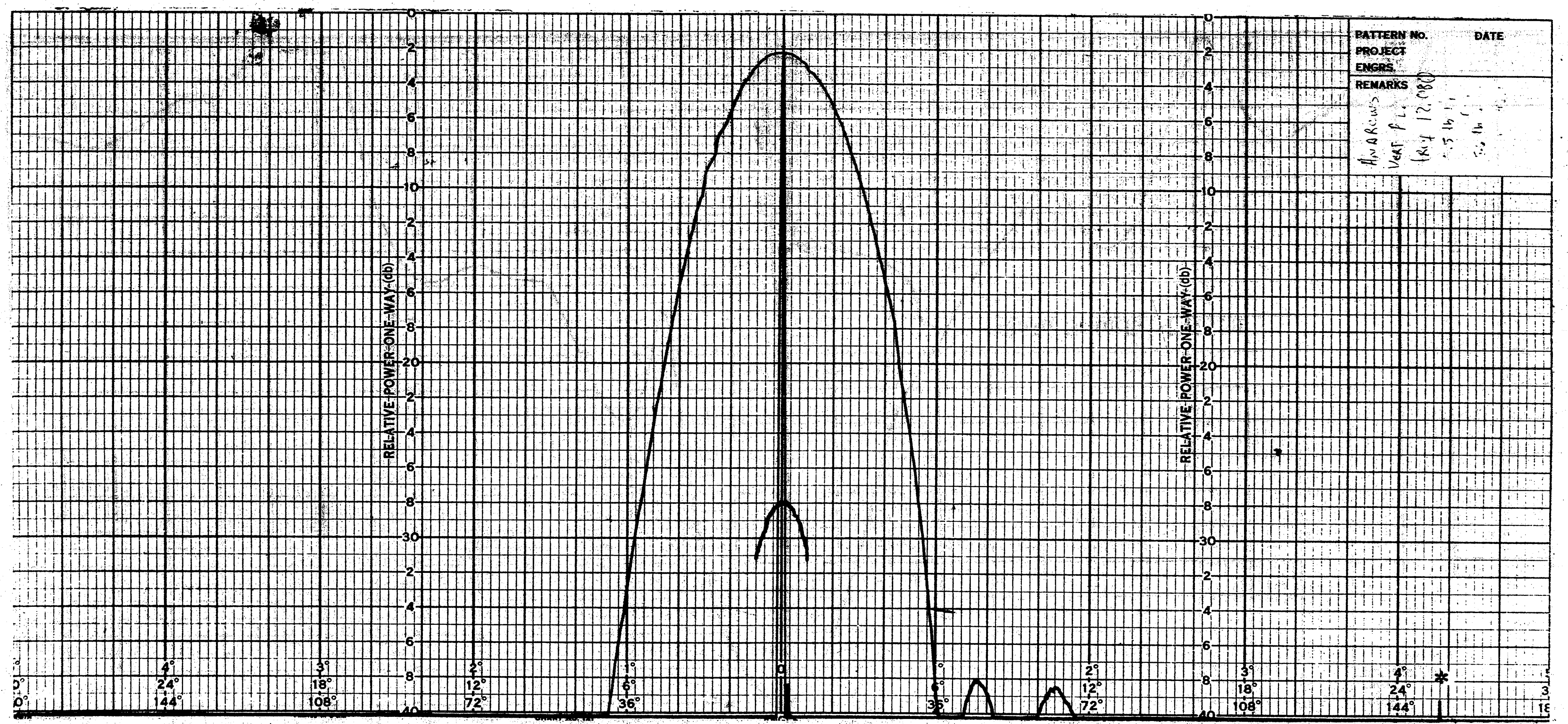
R.S.I. E-Plane 12.080 GHz

Figure 5



Westinghouse E-Plane 12.080 GHz

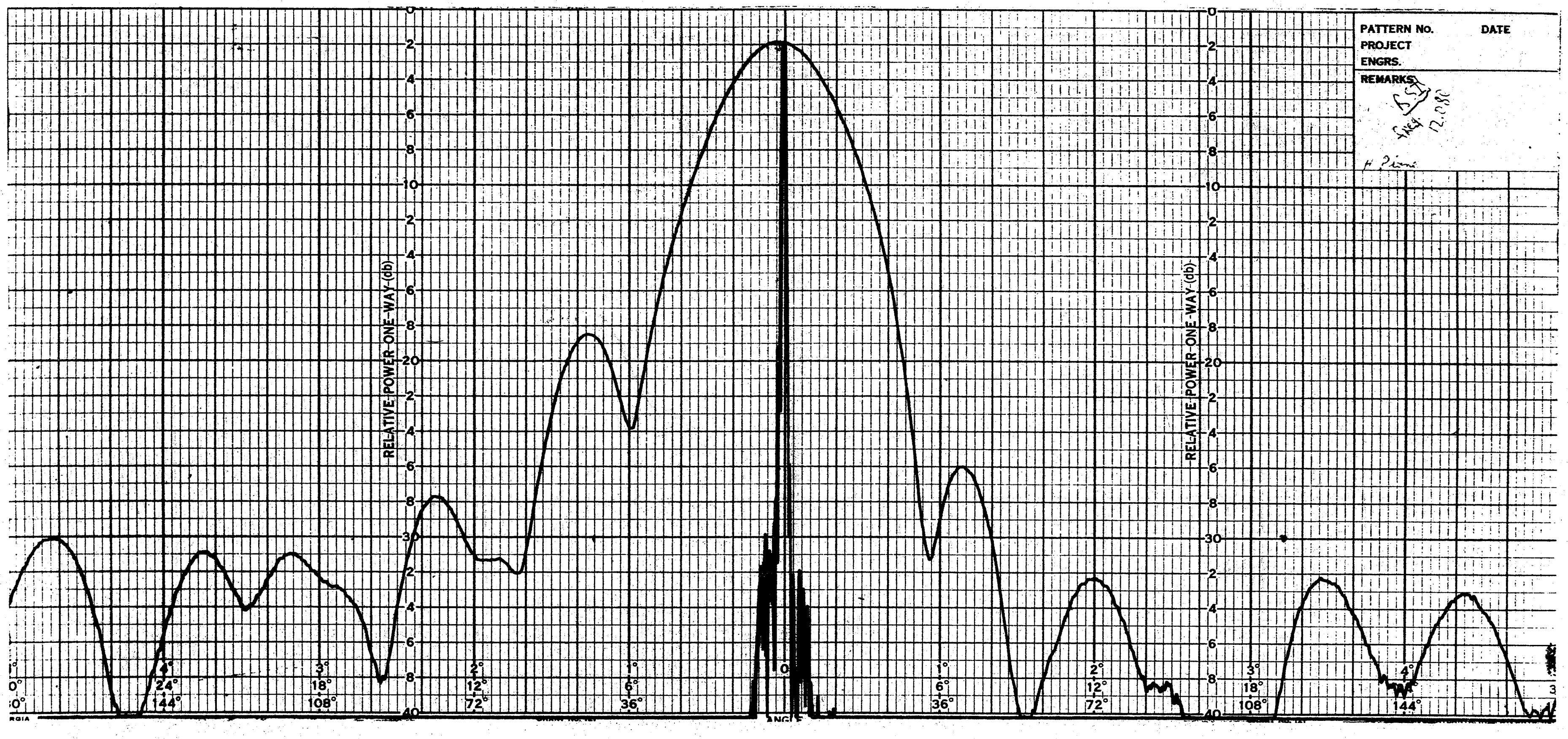
Figure 6



* spurious noise

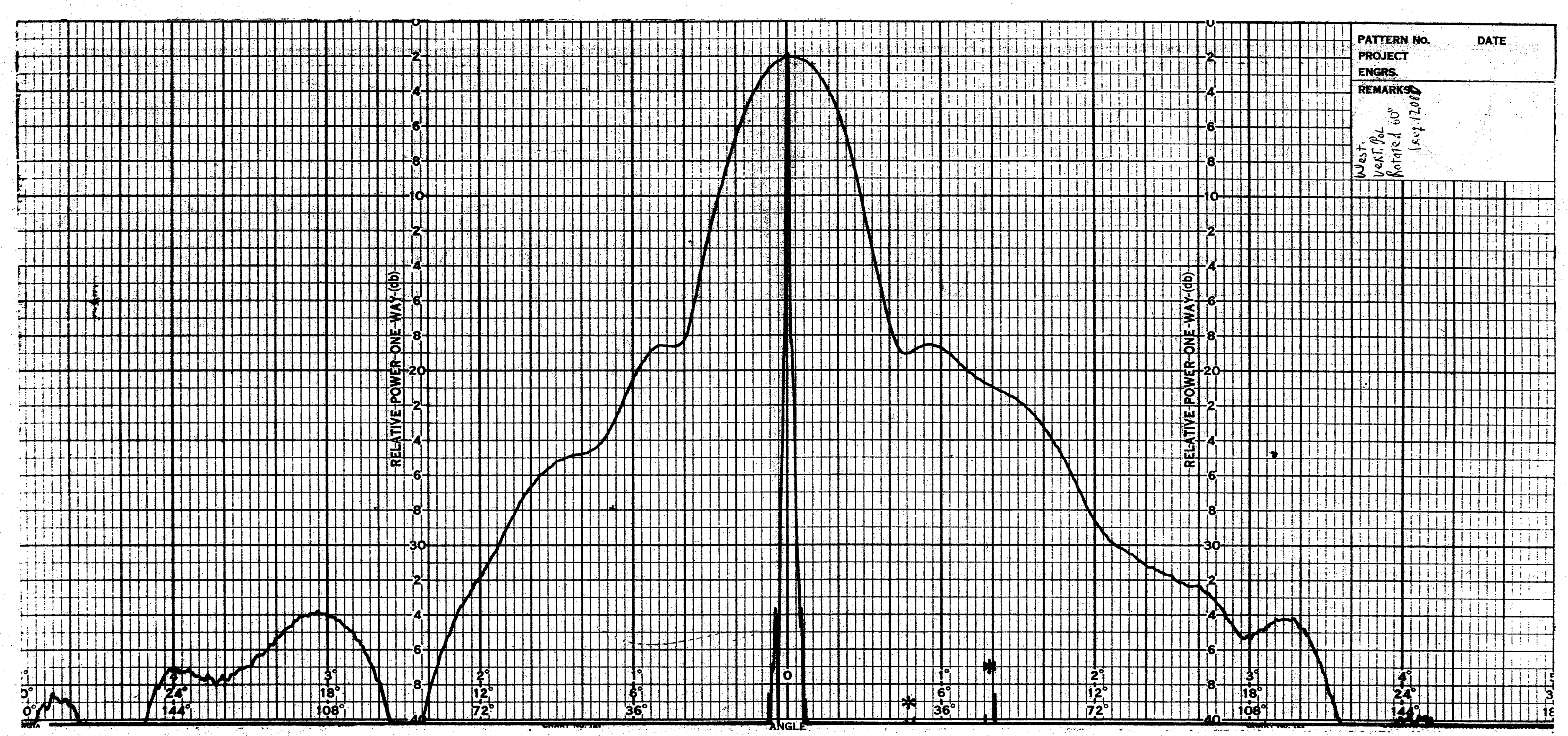
Andrews H-Plane 12.080 GHz

Figure 7



R.S.I.   H-Plane   12.080 GHz

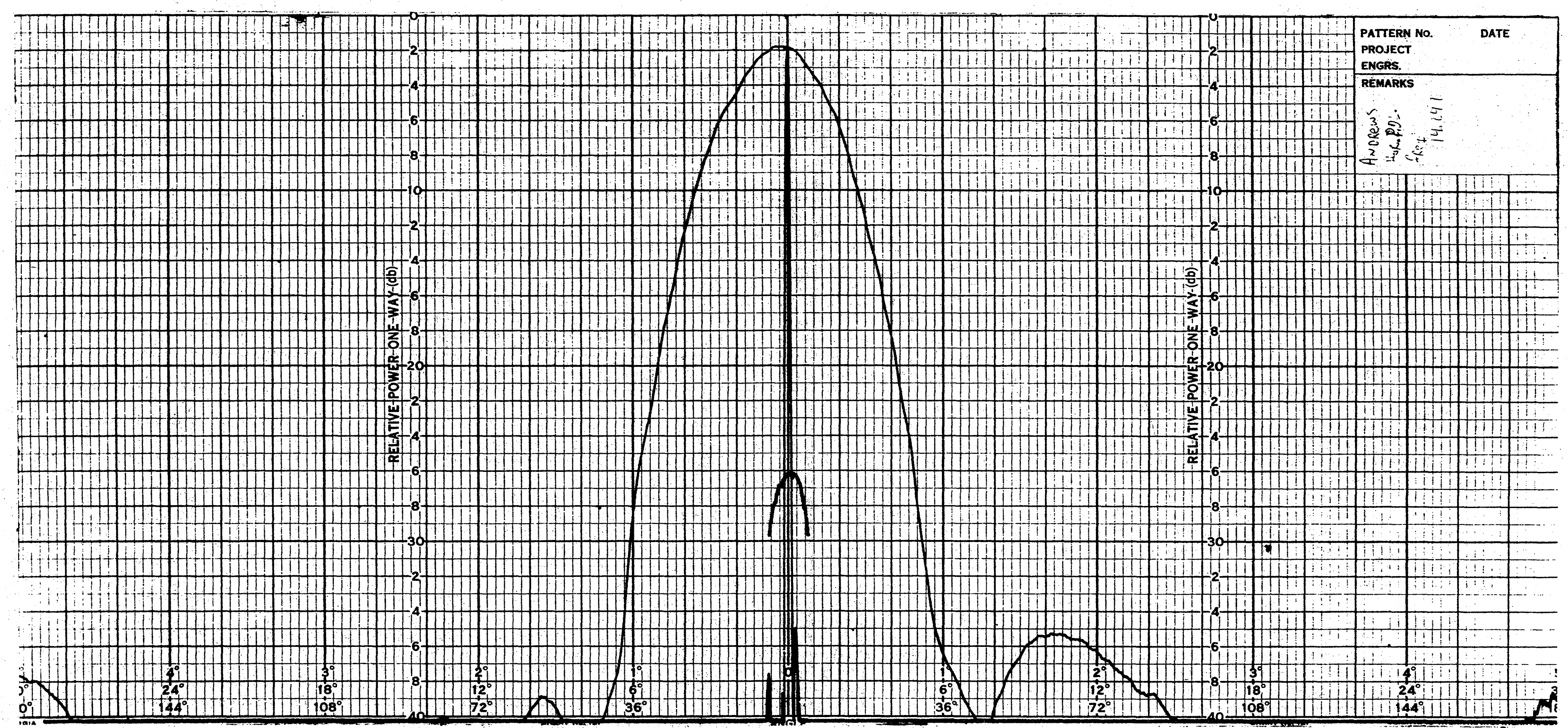
Figure 8



* spurious noise

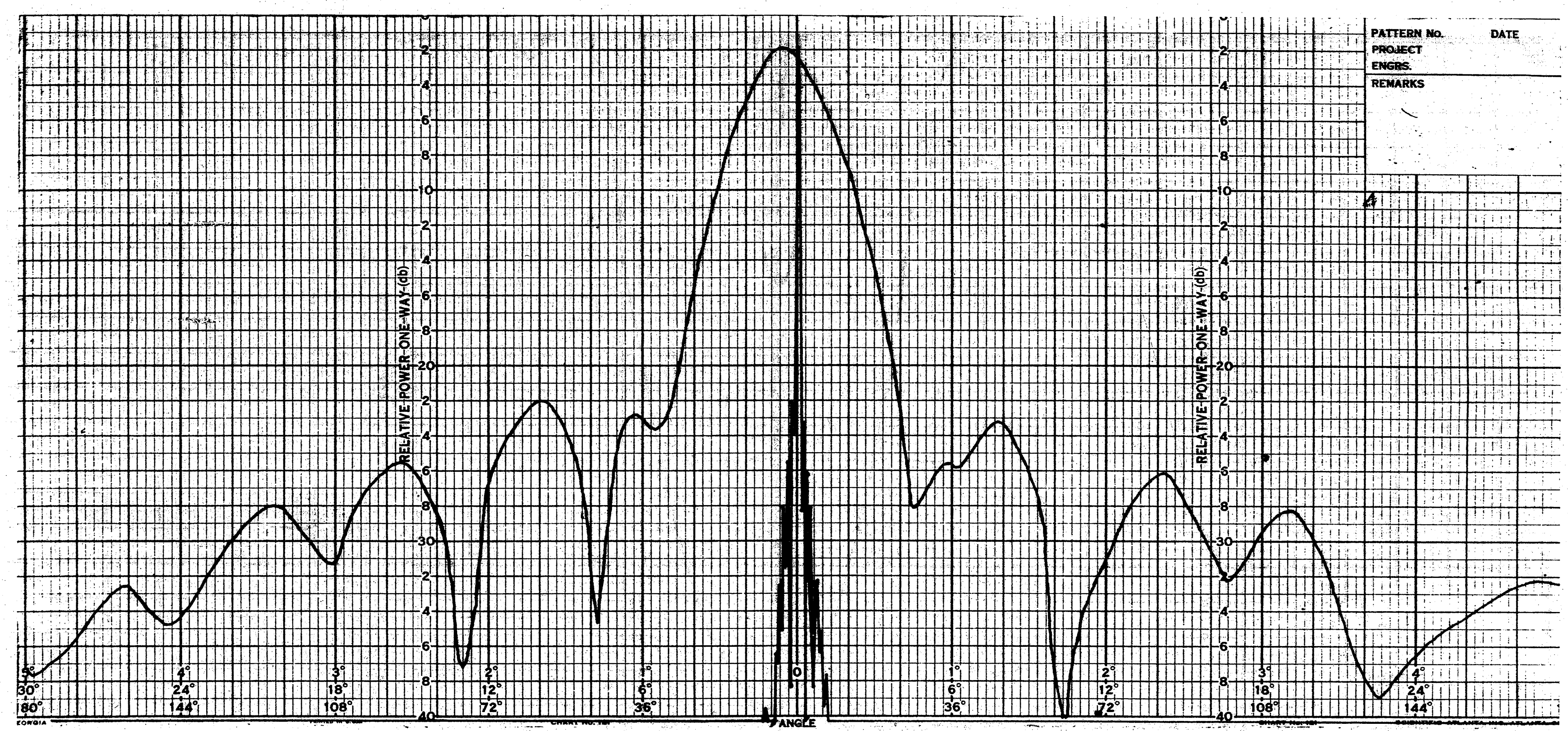
Westinghouse H-Plane 12.080 GHz

Figure 9



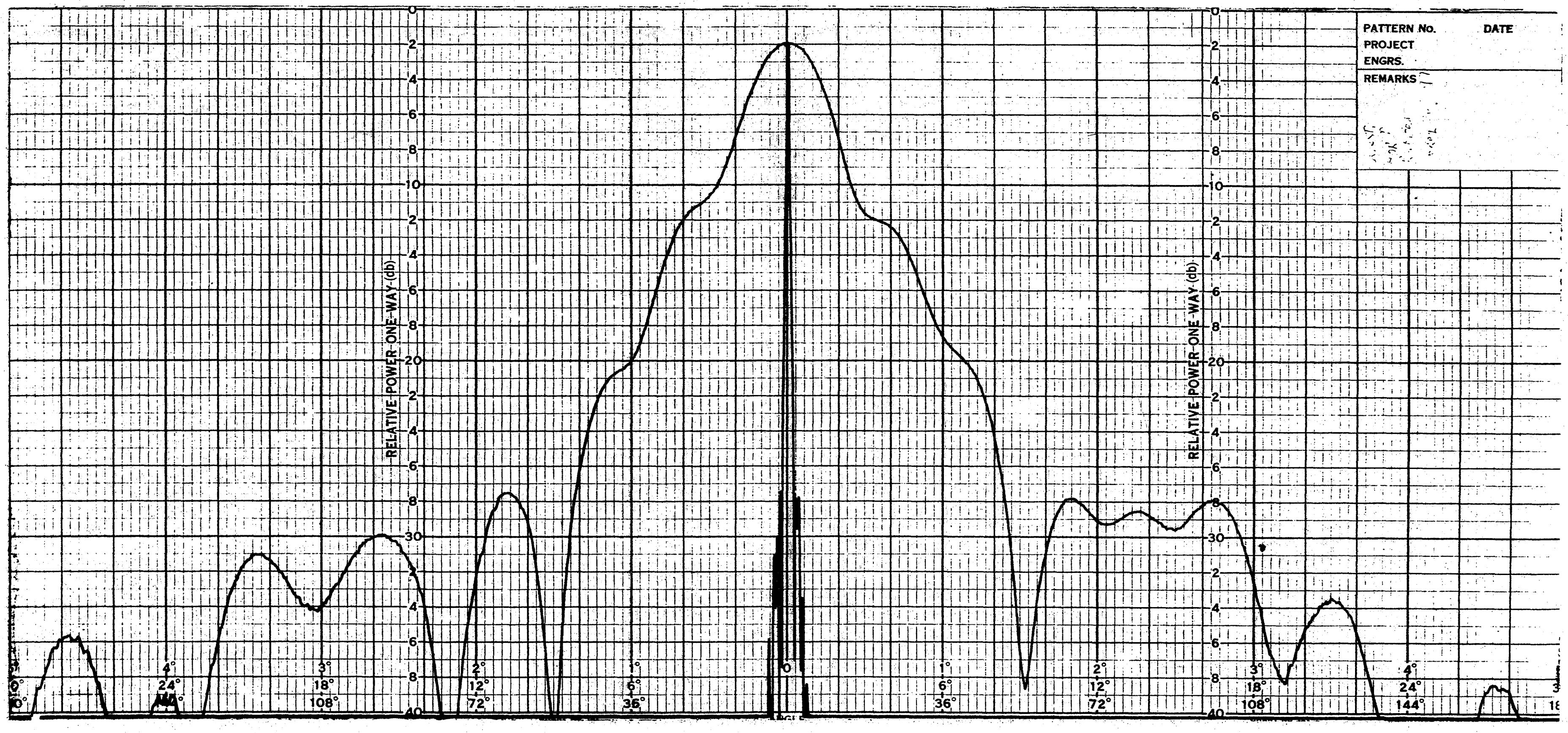
Andrews E-Plane 14.247 GHz

Figure 10



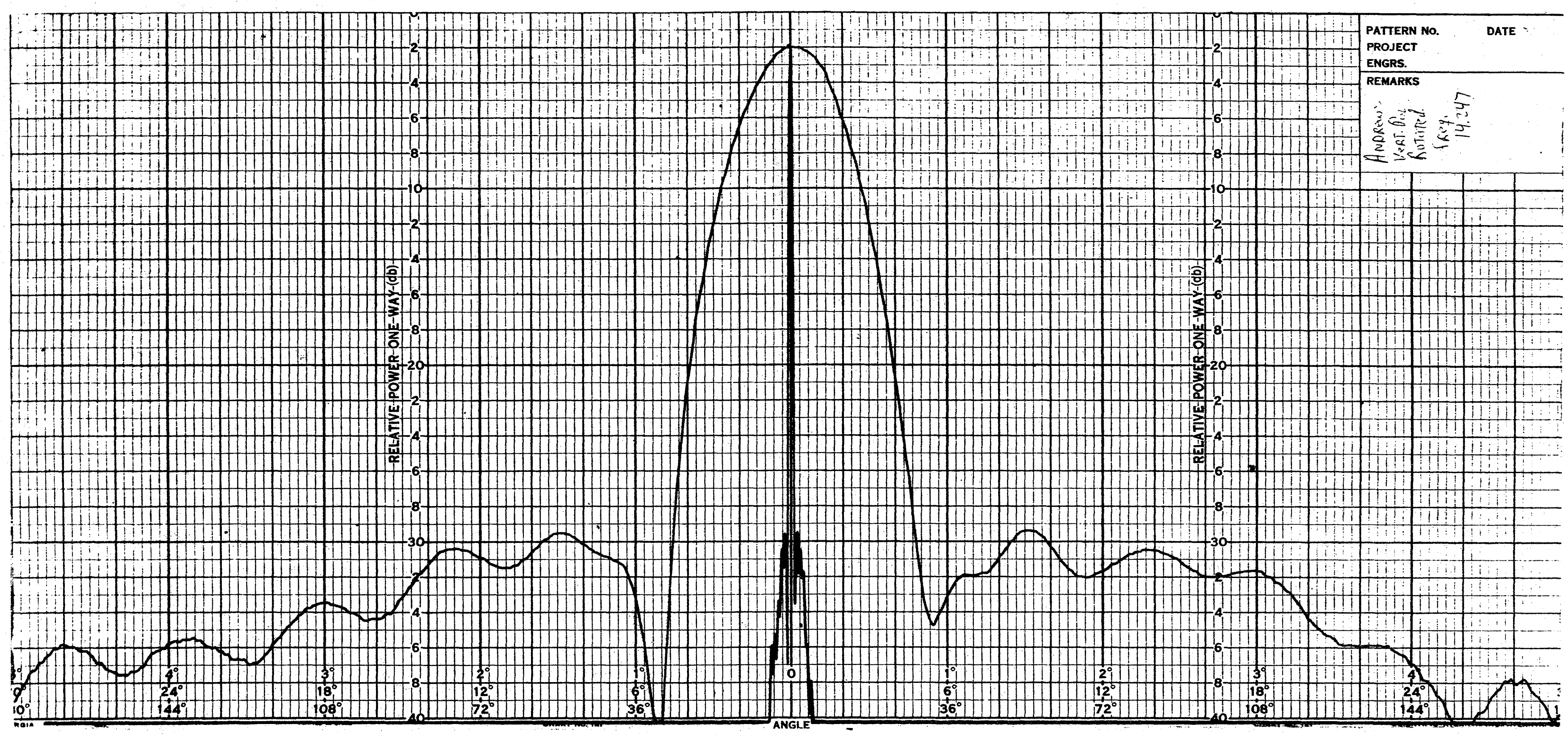
R. S. I.   E-Plane   14.247 GHz

Figure 11



Westinghouse E-Plane 14.247 GHz

Figure 12

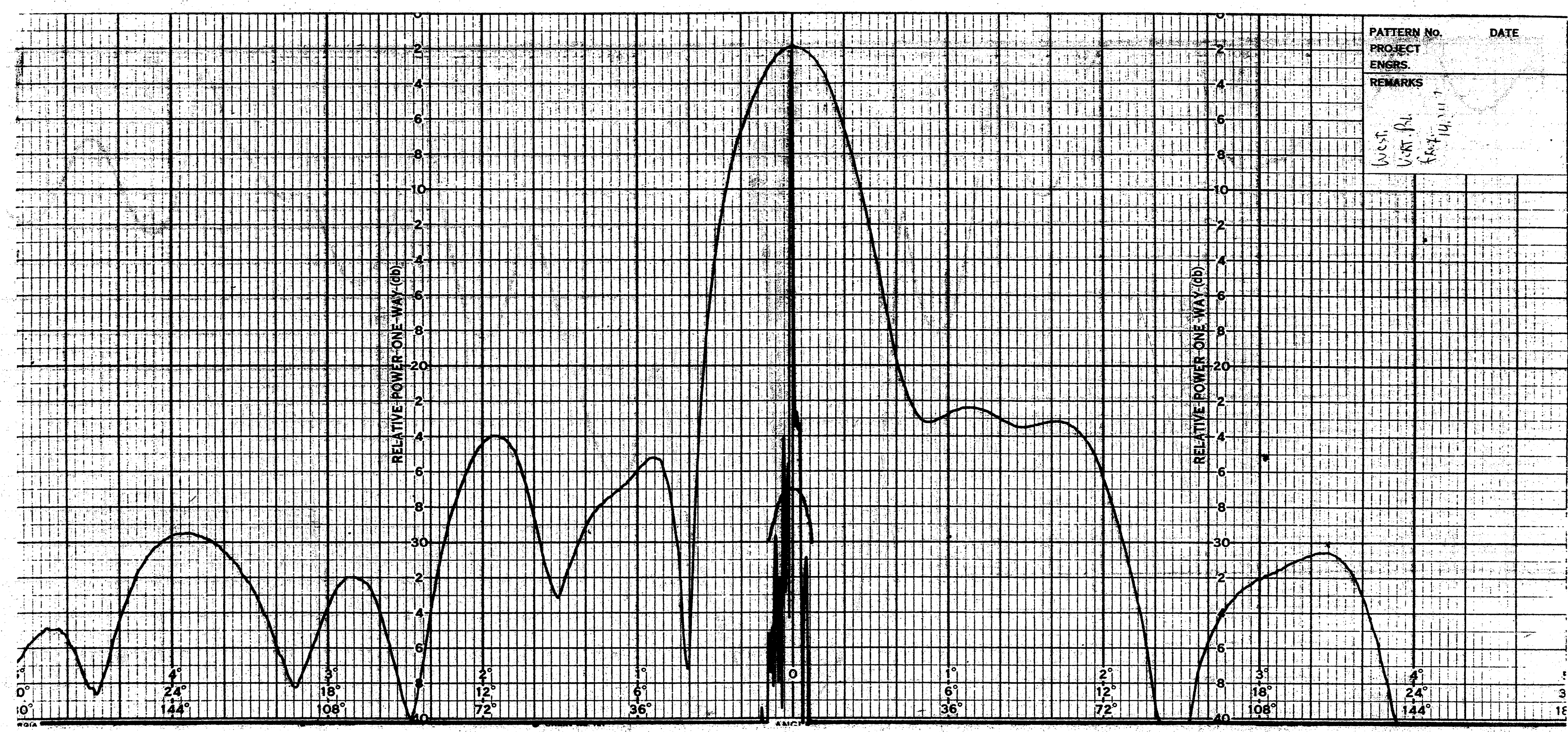


Andrews H-Plane 14.247 GHz

Figure 13

R.S.I. H-Plane 14.247 GHz

Figure 14



Westinghouse H-Plane 14.247 GHz

Figure 15

was recorded, the bolometer detector was attached to a gain standard horn (NRL design from NRL Report 4433) and the pattern peak of the gain standard horn was recorded. Care was taken to ensure that the transmitter power level and the receiver gain settings did not change. The gain of the antennas under test, in dB above isotropic, is obtained from the following expression:

$$G_T = P_t - P_h + G_h$$

where

G_T = gain of the test antennas in dB relative to an isotropic source,

P_t = pattern maximum level in dB of the test antenna,

P_h = pattern maximum level in dB of the gain standard horn,

G_h = gain of the gain standard horn in dB relative to an isotropic source (from NRL Report 4433).

The gain of the three test antennas and the gain standard horn are shown in Table II.

TABLE II: Test Antenna Gain and NRL Gain Standard Horn Gain in dB

Freq. (GHz)	Standard Horn	RSI	Andrews	Westinghouse
11.700	22.8	48.8	47.5	48.8
11.885	22.8	46.9	49.0	46.8
12.038	22.8	47.1	48.3	47.0
12.080	22.8	48.4	48.5	48.7
12.123	22.8	48.3	48.2	48.6
14.052	24.1	48.2	46.3	48.1
14.205	24.2	49.0	49.0	49.2
14.247	24.2	49.2	48.5	49.2
14.290	24.2	49.0	48.7	49.0

System Characteristics

Each of the antennas are to be erected in the field employing a different technique. However, all three require the pouring of cement pads or the use of timbers (railroad ties, etc. and dead man anchors) to support the antenna pedestals. These pedestals are employed to rigidly support the reflector and permit limited electro-mechanical movement of the antenna reflector in both the elevation and azimuth planes.

The Andrews system, pedestal, electronics and reflector could be installed and made operational by a minimum of two men. The RSI system would require the use of a minimum of four men to set up the pedestal because it weighs approximately 250 pounds. However, after the pedestal has been set up, a minimum of two men would be required to complete the installation. The pedestal and electronics for the Westinghouse antenna could be installed by a minimum of two men. However, to attach the antenna reflector to the pedestal, a minimum of six men would be required because of its weight (approximately 300 pounds) and bulkiness. In the event a crane is used for the installation of these systems, a minimum number of two men would be required to install any one of the three systems.

Before installing any one of the three systems it will be necessary to pre-plan the azimuth pointing direction of the antenna reflector. This planning must be done because it is feasible to scan the reflectors only over the limited azimuth angle permitted by the electro-mechanical drive system. However, all three systems can be mechanically adjusted in the elevation plane from 0-60 degrees in addition to being fine adjusted by the electro-mechanical drive system. All three systems are capable of being scanned by their respective electro-mechanical scanning system, over an angular interval of 6 degrees for both azimuth and elevation. Each of the systems has a control box that is used to electro-mechanically position the reflector in azimuth and elevation. The pointing angles associated with the reflector are also indicated on the control box. The power requirement for each system is 110 V, 15 amps at 60 cycles.

Data Review and Conclusions

Three sets of data (VSWR, pattern and gain) were recorded for three 10-foot parabolic reflector antennas, one each fabricated by Radiation Systems Incorporated (RSI), Andrews and Westinghouse.

The Westinghouse antenna exhibits a VSWR of less than 1.2:1 for the receive band as compared to a VSWR of less than 1.7:1 for the other two antennas. However, all three antennas exhibit approximately equal VSWR's for the transmit band (<1.5:1).

From the pattern data it is seen that the Andrews antenna has fewer sidelobes than either of the other antennas for both senses of linear polarization. Typically the Andrews sidelobes are down 20 dB or more from the main lobe maximum as compared to 16 dB for the other two antennas. Further, the major sidelobes of the Andrews antenna are within ± 2 degrees of the major lobe as compared to ± 6 degrees for the others.

The major lobe 3 dB beamwidth differs for the three antennas in the transmit band as follows: Andrews 0.70 degrees, RSI 0.62 degrees and Westinghouse 0.54 degrees. However, the major lobe 3 dB beamwidth for the receive band of the three antennas is essentially the same, i.e., typically, 0.67 degrees.

From the gain data for the three antennas, it is apparent that all three perform equally well since typically all have a gain of 48.1 ± 0.8 dB for the receive band and 48.6 ± 0.8 dB for the transmit band. The above gain data was measured relative to an isotropic source.

After reviewing the data presented in this report, NASA personnel of the Lewis Research Center have concluded that all three antenna configurations are applicable for CTS receiver ground terminal usage.

Appendix

E and H plane pattern data for the three antennas (RSI, Andrews and Westinghouse) are presented in Figs. A.1-A.9 respectively for frequencies of 11.700, 11.885, 12.038, 12.080, 12.123, 14.052, 14.205, 14.247 and 14.290 GHz. Spurious noise spikes, resulting because of other equipment operating at the recording site, have been noted (*) on several figures.

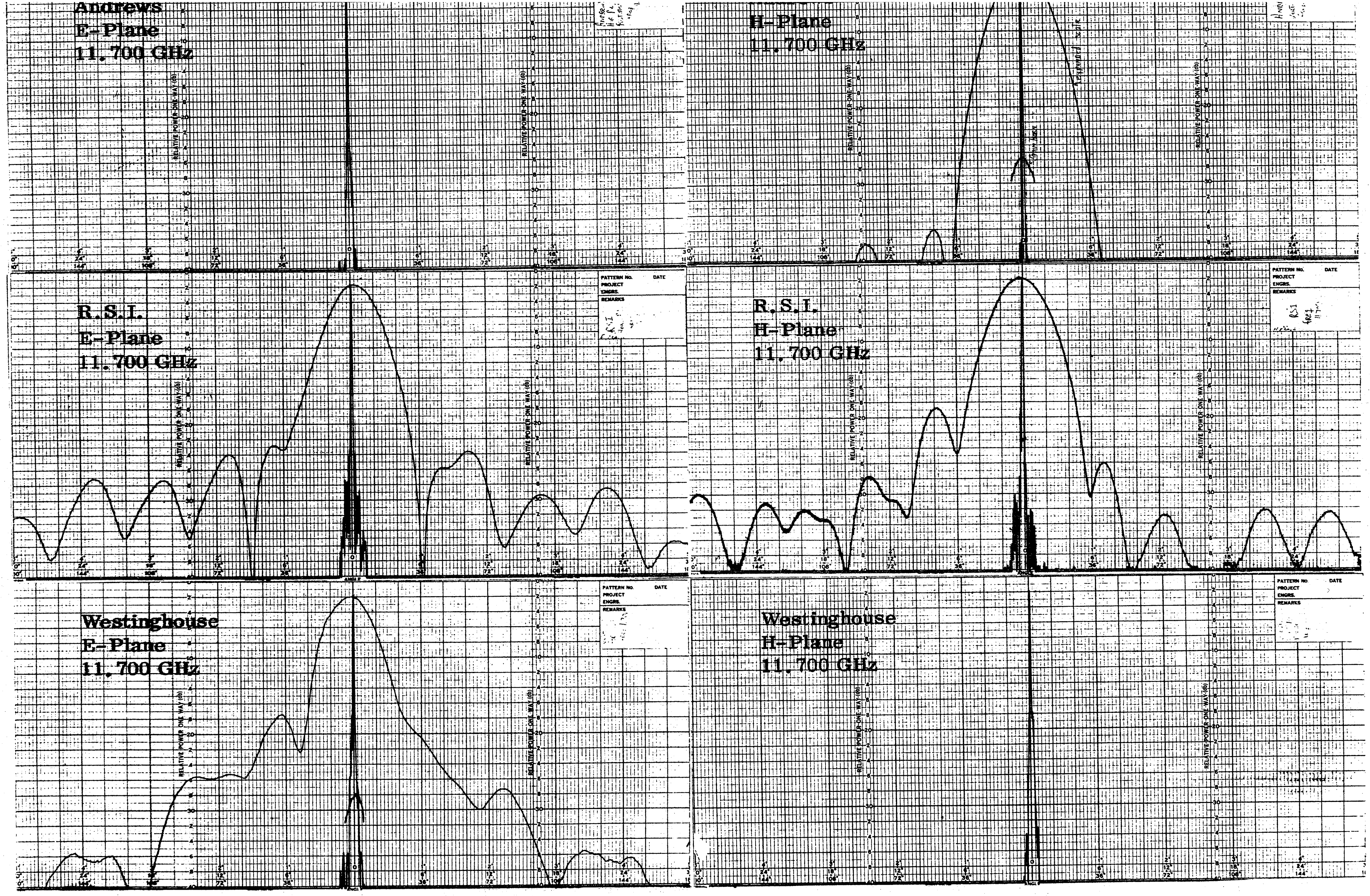
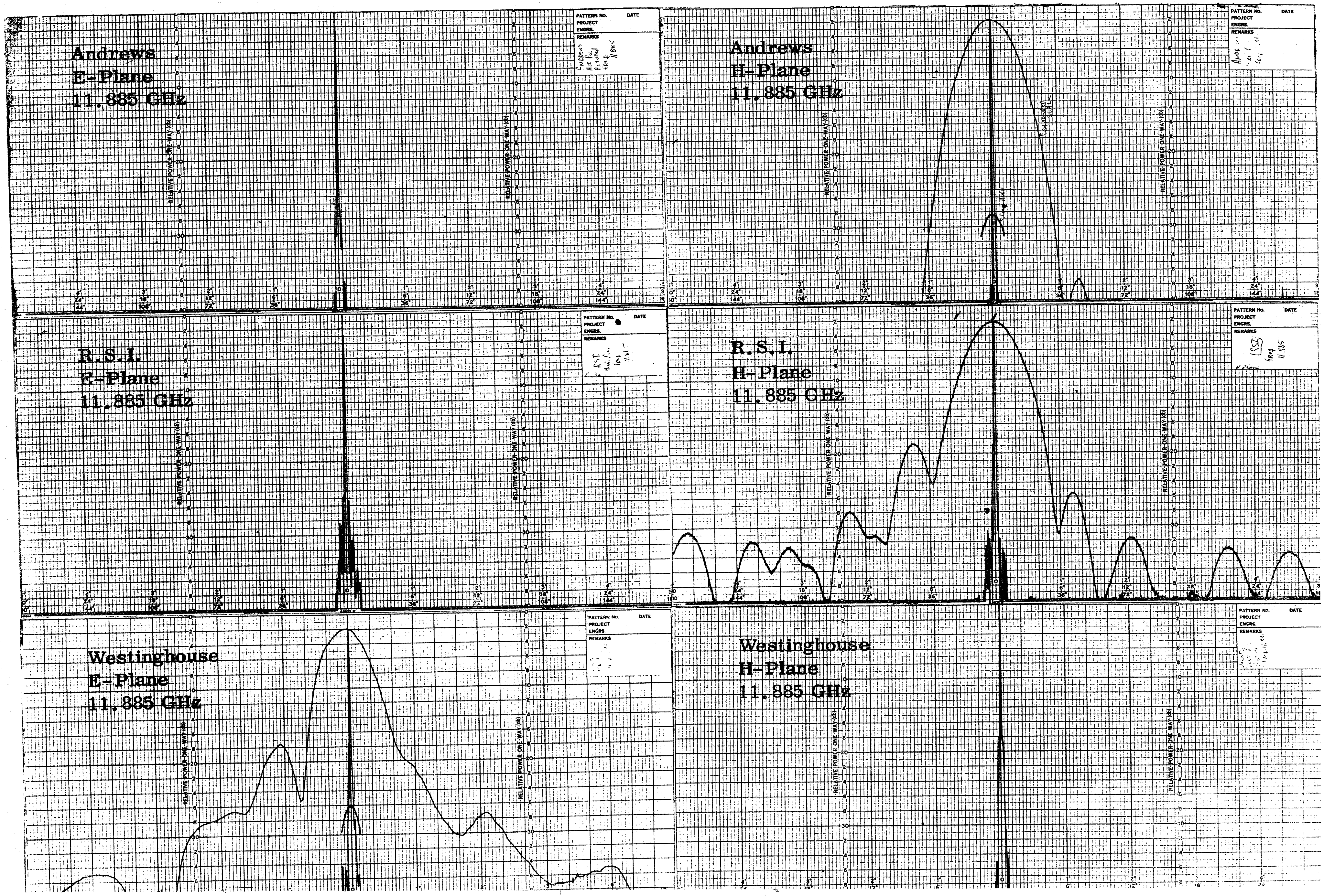
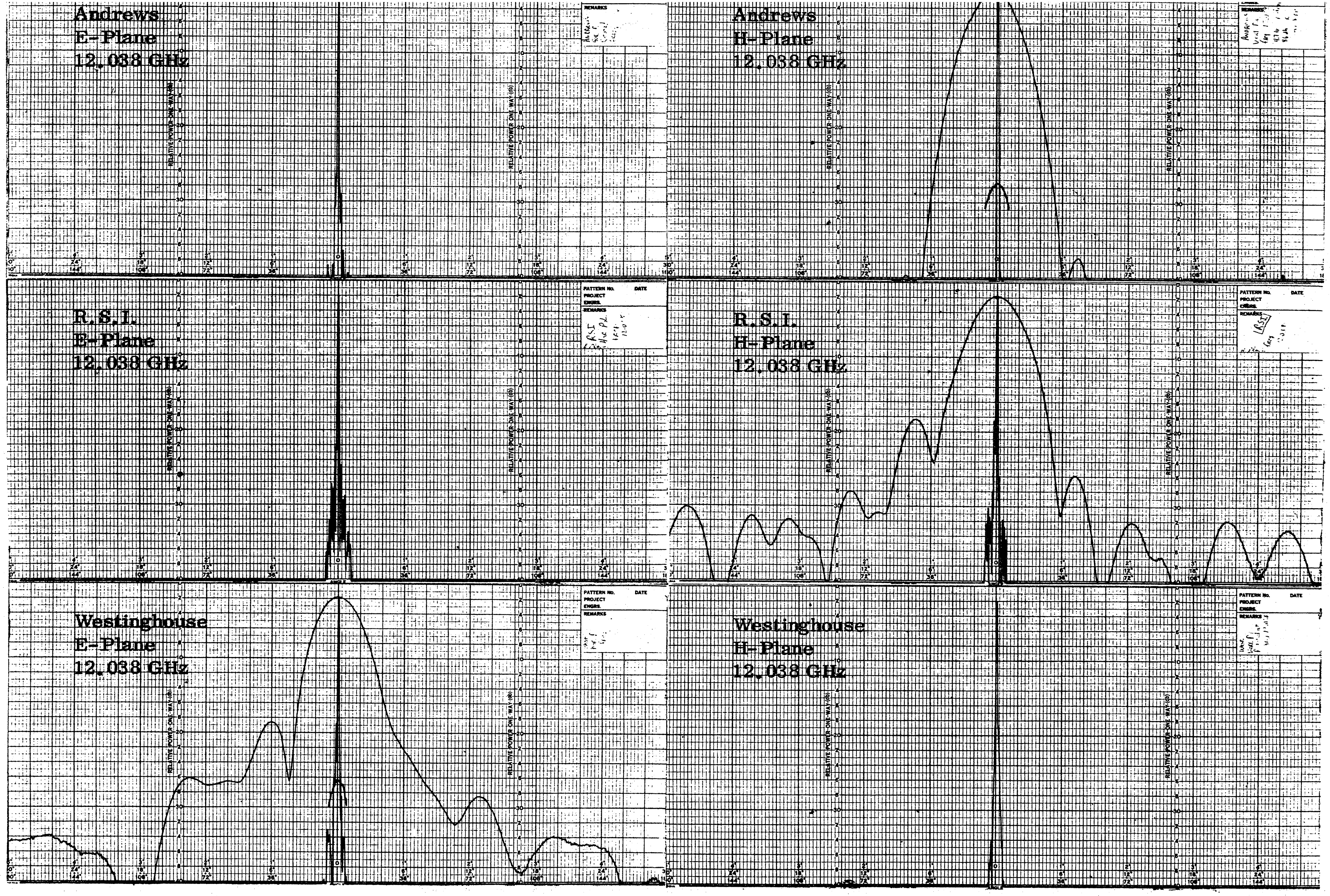

Andrews
E-Plane
11.700 GHz
H-Plane
11.700 GHz
R.S.I.
E-Plane
11.700 GHz
R.S.I.
H-Plane
11.700 GHz
Westinghouse
E-Plane
11.700 GHz
Westinghouse
H-Plane
11.700 GHz

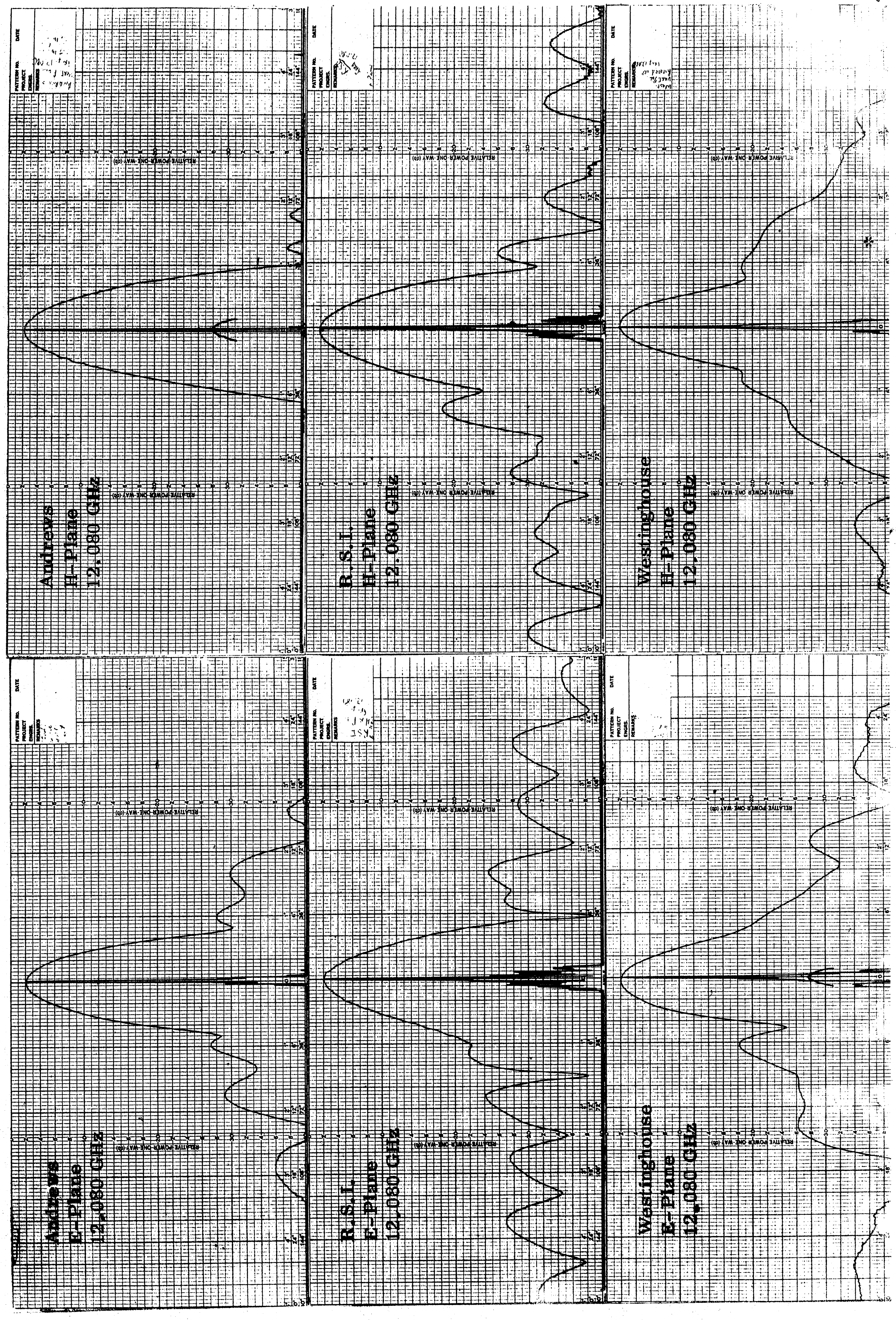
Figure A.1


Andrews
E-Plane
11.885 GHz
Andrews
H-Plane
11.885 GHz
R.S.I.
E-Plane
11.885 GHz
R.S.I.
H-Plane
11.885 GHz
Westinghouse
E-Plane
11.885 GHz
Westinghouse
H-Plane
11.885 GHz



Andrews
E-Plane
12.038 GHz
Andrews
H-Plane
12.038 GHz
R.S.I.
E-Plane
12.038 GHz
R.S.I.
H-Plane
12.038 GHz
Westinghouse
E-Plane
12.038 GHz
Westinghouse
H-Plane
12.038 GHz
RELATIVE POWER ONE-WAY (db)
PATTERN No.
DATE
PROJECT
ENGRS.
REMARKS
ANGLE

Figure A.3


Andrews
H-Plane
12.080 GHz
R.S.I.
H-Plane
12.080 GHz
Westinghouse
H-Plane
12.080 GHz
Andrews
E-Plane
12.080 GHz
R.S.I.
E-Plane
12.080 GHz
Westinghouse
E-Plane
12.080 GHz
RELATIVE POWER ONE-WAY (db)

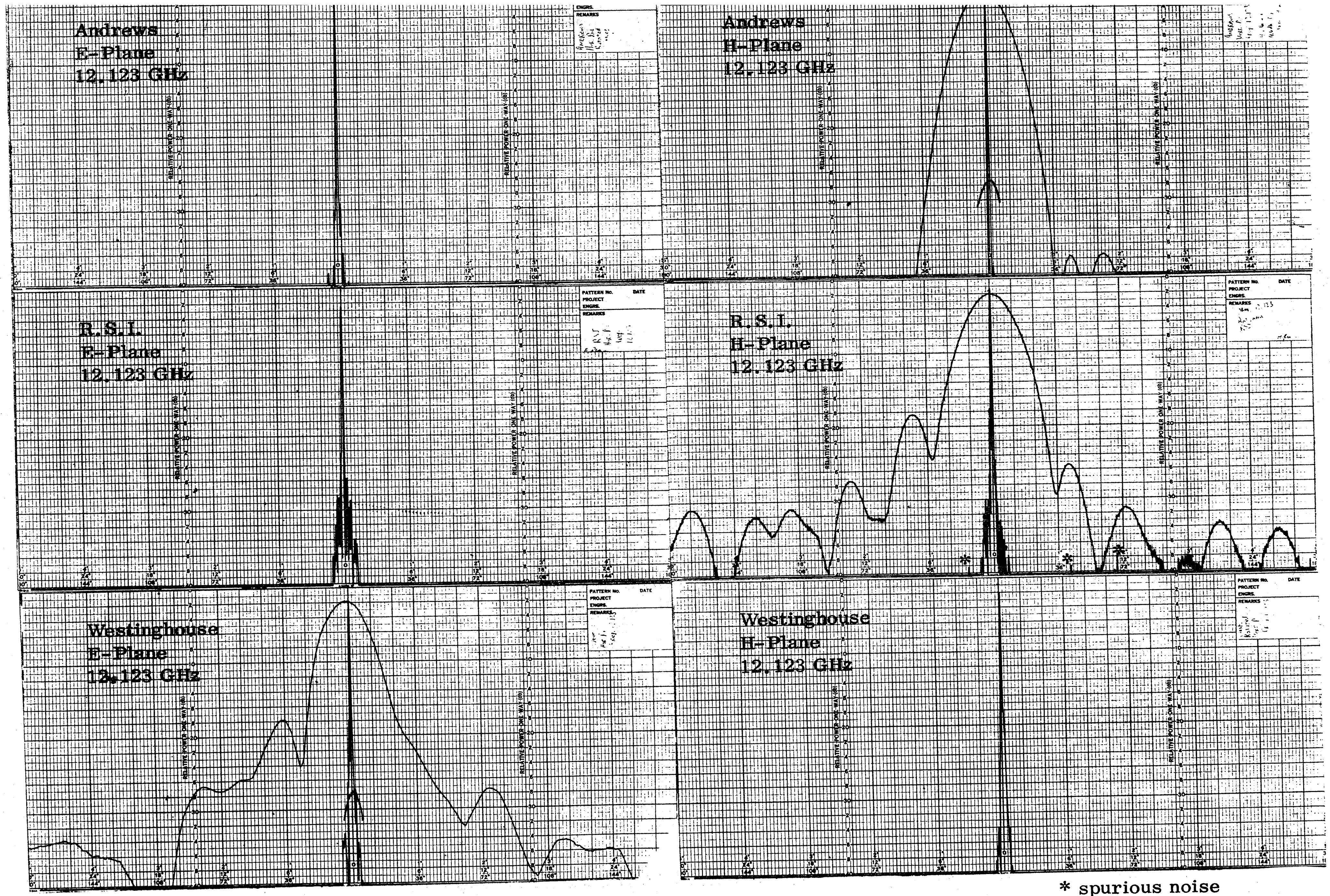
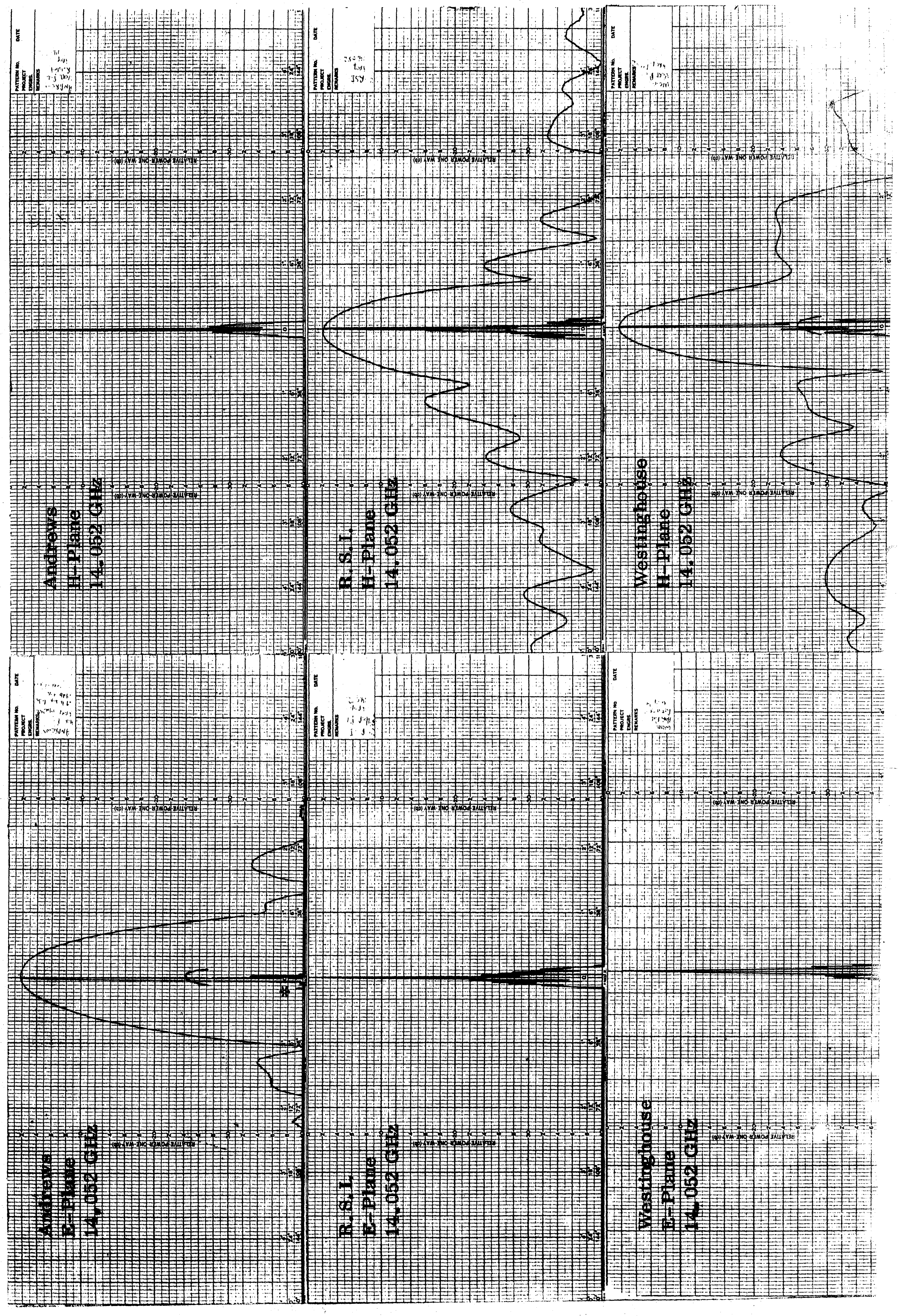

Andrews
E-Plane
12.123 GHz
Andrews
H-Plane
12.123 GHz
R.S.I.
E-Plane
12.123 GHz
R.S.I.
H-Plane
12.123 GHz
Westinghouse
E-Plane
12.123 GHz
Westinghouse
H-Plane
12.123 GHz
RELATIVE POWER ONE-WAY (db)
PATTERN No.
DATE
PROJECT
ENGRS.
REMARKS
* spurious noise

Figure A.5


Andrews
H-Plane
14.052 GHz
R.S.I.
H-Plane
14.052 GHz
Westinghouse
H-Plane
14.052 GHz
Andrews
E-Plane
14.052 GHz
R.S.I.
E-Plane
14.052 GHz
Westinghouse
E-Plane
14.052 GHz

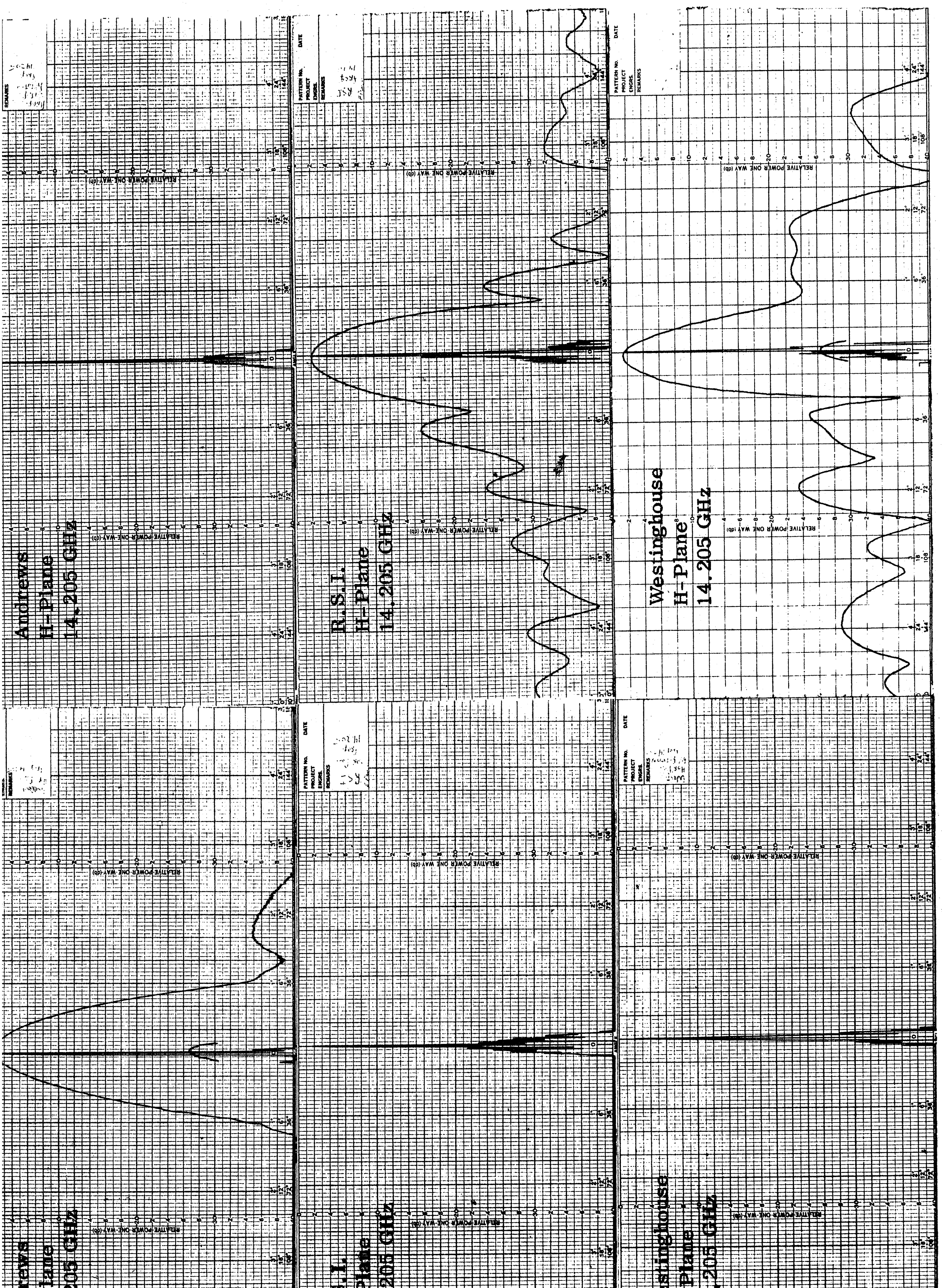
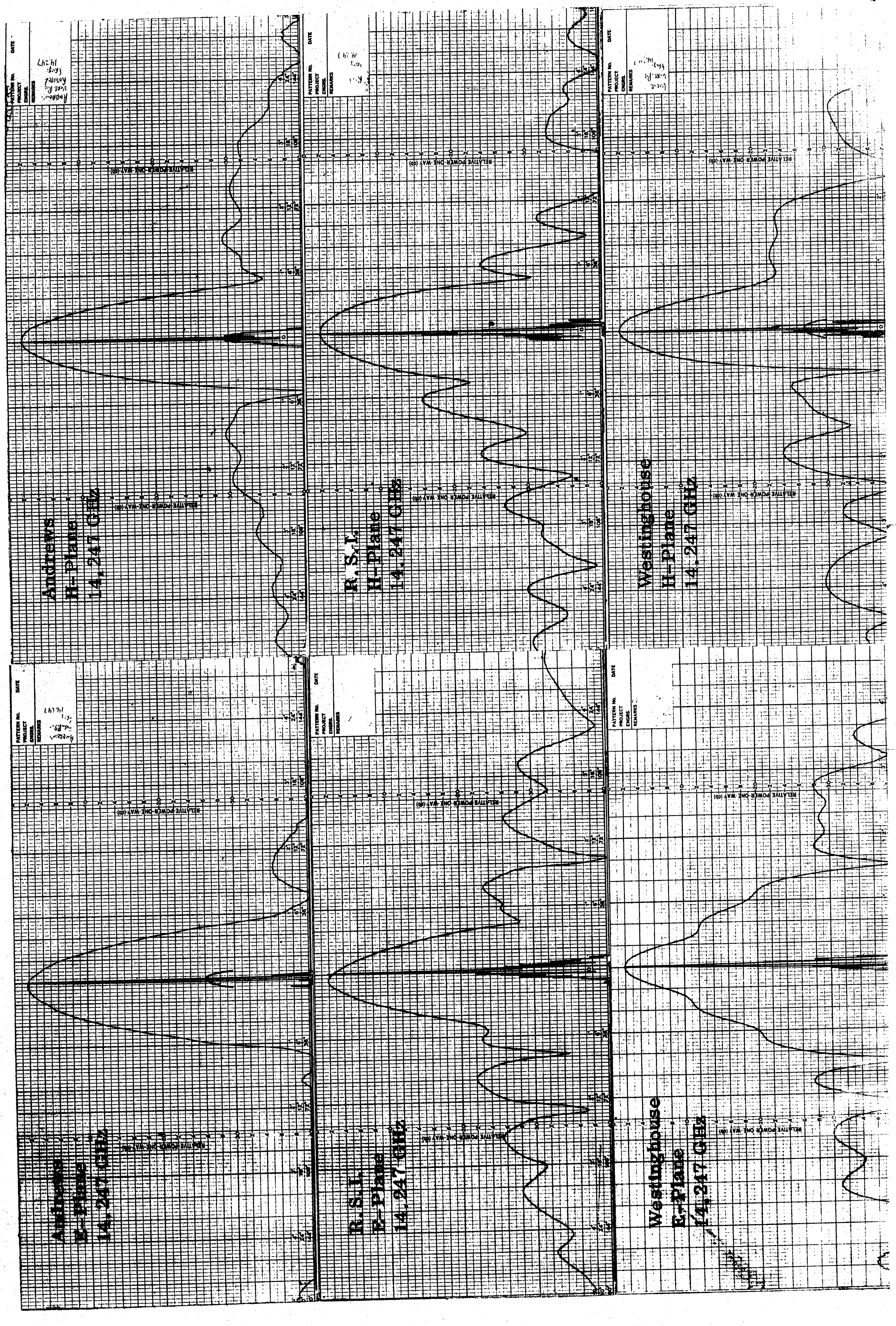
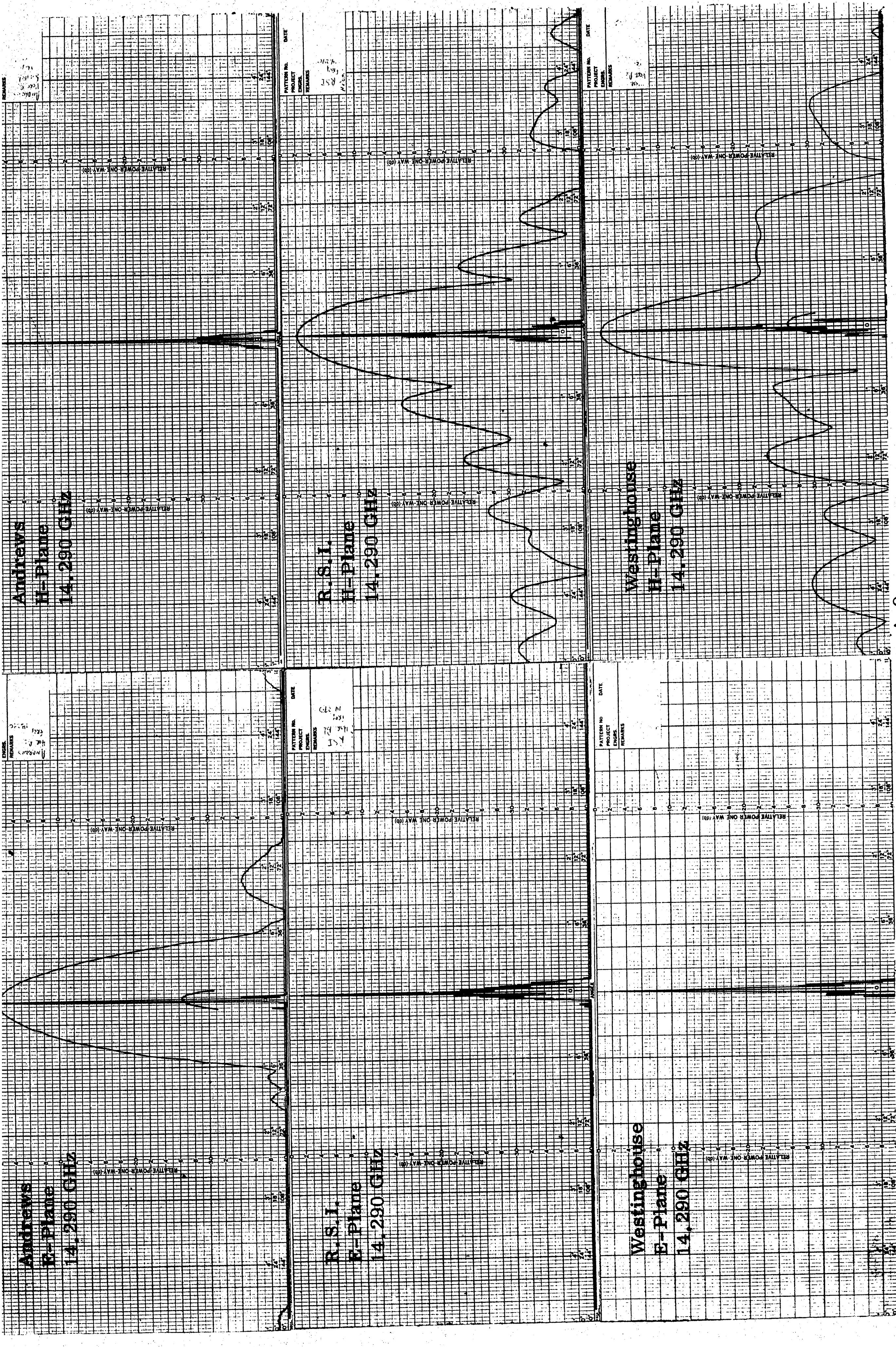

Andrews
H-Plane
14.205 GHz
R.S.I.
H-Plane
14.205 GHz
Westinghouse
H-Plane
14.205 GHz
Andrews
E-Plane
14.205 GHz
R.S.I.
E-Plane
14.205 GHz
Westinghouse
E-Plane
14.205 GHz
RELATIVE POWER ONE WAY (db)

Figure A.7


Andrews
H-Plane
14.247 GHz
R.S.I.
H-Plane
14.247 GHz
Westinghouse
H-Plane
14.247 GHz
Andrews
E-Plane
14.247 GHz
R.S.I.
E-Plane
14.247 GHz
Westinghouse
E-Plane
14.247 GHz
RELATIVE POWER-ONE WAY-(db)
PATTERN NO.
PROJECT
ENGRS.
REMARKS
DATE



Andrews
H-Plane
14.290 GHz
R.S.I.
H-Plane
14.290 GHz
Westinghouse
H-Plane
14.290 GHz
Andrews
E-Plane
14.290 GHz
R.S.I.
E-Plane
14.290 GHz
Westinghouse
E-Plane
14.290 GHz

Figure A.9