GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: April 13, 1977

Project Title: Characterization of Coherent Reflectivity at 35GHz

Project No: A-1981

S

Project Director: Mr. J. A. Scheer

Sponsor: U. S. Army Missile R&D Command; Attn: DRDMI-ICBB/Butler; Redstone Arsenal, AL 35809

Agreement Period: From March 30, 1977 Until ~~Sept. 30, 1978~~ 12/31/78 (Contr. Period)

Type Agreement: Contract No. DAAK40-77-C-0077

Amount: $202,401 (Partially funded at $100,000 est. thru 9/30/77).

Reports Required: Test Plan; Monthly Technical Ltrs.; Interim Tech. Report; Final Technical Report

Sponsor Contact Person (s):

Technical Matters

U. S. Army Missile Research & Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG
Redstone Arsenal, AL 35809

Contractual Matters
(thru OCA)

ONR Resident Representative
325 Hinman Research Building
Campus

Defense Priority Rating: DO-A2 under DMS Reg. 1

Assigned to: Radar Instrumentation Laboratory (School/Laboratory)

COPIES TO:

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Project Code (GTRI)
Other

CA-3 (3/76)

B-440-328

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 6/5/81

Project Title: Characterization of Coherent Reflectivity

Project No: A-1981

Project Director: L. C. Bomar

Sponsor: U. S. Army Missile Command; Redstone Arsenal,AL 35898

Effective Termination Date: 2/28/79

Clearance of Accounting Charges: 2/28/79

Grant/Contract Closeout Actions Remaining:

X Final Invoice and Closing Documents
_ Final Fiscal Report
_ Final Report of Inventions
_ Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other ______

Assigned to: RAIL (~~School~~/Laboratory)

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Other: ______

A-1981

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

12 May 1977

U. S. Army Missile Research and Development Command
Advanced Sensors Directorate
ATTN: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

REFERENCE: Contract DAAK40-77-C-0077

SUBJECT: Monthly Progress Letter Report No. 1
Covering the period 30 March 1977 to 30 April 1977

Dear Hammond:

The expenses on the subject contract totaled $4,925.36 for the month of April 1977, constituting the extent of the expenditures to date.

During the performance period, the formulation of a detailed test plan has begun. We expect that a draft copy will be ready for your review before the end of May.

Additionally, the PENRAD radar system, to be used for the 16 GHz measurements, is being reconfigured to provide the data required.

As you know, we are considering rescheduling of the summer measurements data collection program to accommodate the availability of the test tower and of the 95 GHz radar which may be used for similar measruements. We are preparing the required supporting documents for a suggested modified program.

Respectfully submitted,

James A. Scheer
Project Director

Approved:

J. L. Eaves, Associate Director
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

16 June 1977

U. S. Army Missile Research and
Development Command
Advanced Sensors Directorate
ATTN: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

REFERENCE: Contract DAAK40-77-C-0077 (GIT Project A-1981)

SUBJECT: Monthly Progress Report No. 2 Covering the period 1 May 1977 to 31 May 1977

Dear Hammond:

The draft form of the test plan has been written and is in typing. I will forward a typed copy to you as soon as it is available.

Work has begun on integrating the PENRAD Ku-band antenna system with the appropriate microwave, transmitter, and receiver systems for frequency agile 16 gHz measurements to occur simultaneously with those at Ka-band. The 3 watt amplifier, ordered from Hughes, is not expected for another month. For this reason, along with the preponderance of vacation absences, the summer tests are expected to be performed in the fall, while the leaves are still on the trees. This is consistent with the time schedule planned for the 95 gHz measurements proposed to run concurrently.

Procurement of the lens/horn antennas is underway at this time. We have received a quote from a vendor as well as a cost estimate for internal fabrication. It appears that we will build the antenna at Georgia Tech for cost, delivery, and specification control purposes.

We are obtaining quotes on weather instrumentation gauges, compatible with our recording devices. The purchased gauges will include wind speed and direction, rainfall (accumulated), temperature, barometric pressure, and selective humidity. Marshall Applegate at Eglin AFB (AFATL/DLMT) says we can use his rain drop size distrometer (spectrometer).

The expenses for May 1977 on the subject contract were $11,861.65, bringing the total to $16,787.01 to date, including encumbrances.

Respectfully submitted:

James A. Scheer
Project Director

Approved:

J. L. Eaves, Associate Director
Radar and Instrumentation
Laboratory

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

26 July 1977

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Progress Report No. 3 Covering the Period
1 June 1977 to 30 June 1977

Dear Hammond:

The draft of the test plan has been typed and we are reviewing it for completeness and accuracy.

The GT-2 K_u band radar is being modified to incorporate the Penrad monopulse antenna and the transmitter, local oscillator and afc circuits from the APQ 139 radar. Design of the IF phase processor was completed and the necessary components have been ordered. Four signal mixers were removed from the Penrad radar to be used in the new receiver; however, the pre-amplifiers in the Penrad were not suitable for this measurement program and new pre-amplifiers have been ordered from RHG, Inc. Delivery of the new pre-amplifiers is not expected until late August.

Negotiations have been initiated between GTRI and MIRADCOM concerning the added tasks proposed.

The expenses for June 1977 on the subject contract were $7,245.45 bringing the total to $24,032.46 to date, including encumberances.

Respectfully Submitted,

James A. Scheer
Project Director

JAS/cyk

Approved:

J. L. Eaves, Associate Director
Radar and Instrumentation Laboratory

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A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

29 August 1977

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 4
Covering the Period 1 July 1977 to 31 July 1977

Dear Hammond:

It is anticipated that the 95 GHz measurements will be added to the subject contract. In order to include these measurements with those at 16 and 35 GHz, the first field operation will occur in the winter months of December and January and maybe somewhat into February. The summer measurements will occur sometime between May and September of next year, the exact time depending upon how much modification of the systems is required as determined by the first field operation. As a result of this change in schedule, and of the expected added task, Georgia Tech is requesting the authority to spend the money in the first increment in October and November, rather than by the end of September.

The Ka-band system still needs the Hughes 3 watt solid state amplifier. Hughes representatives assure me that the design problems are essentially solved and they will deliver the amplifier by the end of August. We have experienced some minimum discernable signal problems due to the continuous noise out of the first amplifier stage (during receive time) and the poor isolation (20dB) in the circulators. A solid state switch is being inserted in the system at the output of the first amplifier to turn off the noise during receive time.

A sampler circuit is being bread-boarded for use with the Ku-band system. It is felt that a sampler costing less than the ones being used for the high resolution system (10 nsec) will be adequate for sampling the 200 nsec Ku-band video. Parts are being assembled for fabrication of the Ku-band microwave assembly, joining the AN/APQ-139 radar transmitter, AFC, and local scillator (L.O.) system to the PENRAD antenna system.

The expenses for July 1977 on the subject contract were $10,747.65 bringing the total to $34,780.11 to date, including encumberances. In addition to these expenses, approximately $11,300 has been used for fabrication of the three antennas, although the charges have not yet shown up. Additionally, the $10,000 charge for the Ka-band amplifier does not yet show up on the sheets. With these expenses, the total is approximately $56,000, with $44,000 to be spent in August and September.

Respectfully Submitted,

James A. Scheer
Project Director

JAS/cyk

Approved:

J. L. Eaves, Associate Director
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

20 September 1977

U.S. Army Missile Research
and Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Progress Report No. 5 Covering the Period 1 August 1977 to 31 August 1977

Dear Hammond:

The Ka-band radar system still needs the 3 watt Hughes amplifier, which is now promised in the first week in September. We also have two solid state switches ordered from TRG which will be used to isolate the transmit signal from the receiver, which experiences some overloading at transmit time due to the leakage through the circulators.

Integration of the APQ-139 radar with the PENRAD antenna system, in developing the Ku-band measurements radar is progressing. The PENRAD antenna is being mounted on a metal frame, the microwave assembly needed to develop the polarization agility is being fabricated, and the logic and control circuitry is being built and packaged. The layout for the IF processing circuitry, including preamps, I F amplifiers, phase detectors, phase shifters, and hybrids, is being designed and fabrication is being started. The Ku-band system, consisting of the AN/APQ-139 frequency agile transmitter, the Georgia Tech developed microwave assembly, the PENRAD antenna system, and IF processing circuitry, is being mounted on a tiltable, rotatable frame. Some control and circuitry will be remote from this assembly, along with the data acquisition equipment.

Parts are beginning to arrive for modification of the 95 GHz system for dual polarization. Layout concept and fabrication are progressing. The fabrication of the additional Ka-band antenna and the two additional Ku-band antennas is nearly complete. They are dual polarized horn-lens antennas mounted in a cylindrical enclosure. The 5 inch Ka-band lens should provide about 4.7 degree beam width, and the 5 and 10 inch Ku-band lenses should provide about 10.3 degrees and 5.2 degrees respectively.

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During the period between 1 August 1977 and 31 August 1977, the expenses on the subject contract were $18,762.08. The total spent to date is $53,542.19.

Respectfully submitted,

James A. Scheer
Project Director

JAS/cyk

Approved:

J. L. Eaves, Associate Director
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

10 November 1977

U.S. Army Missile Research
and Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 6 Covering the Period 1 September 1977 to 30 September 1977

Dear Hammond:

Please excuse the tardiness of this report. During the reporting period the integration of the Ku-band system progressed further. The design concept for the frame was sent to the mechanical engineering group for detailing and subsequent model shop fabrication. It is expected that the fabrication will be complete by mid November.

As of yet the Ka-band 3 watt amplifier has not been received. Hughes indicated a couple weeks ago that they were near the shipping date. I will call them and report on their response in the next report, to be written in the next two days.

The new antennas have been fabricated and delivered and a copy of the technical description is included in this report.

During the period between 1 September and 30 September 1977, the expenses on the subject contract were $16,686.54. The total spent to date is $70,228.73.

Respectfully submitted,

James A. Scheer
Project Director

JAS/cyk

Attachment:

Approved:

J. L. Eaves
Associate Director
Radar and Instrumentation Laboratory

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

October 10, 1977

MEMORANDUM

To: J. M. Schuchardt

From: J. M. Newton Jmn

Subject: Lens Antennas for 16 and 35 GHz

Testing of the four lens antennas for 16 and 35 GHz has been completed. The data accumulated during the tests are attached to this memo. Two of the antennas with their associated orthomode transducers are designed to operate between 16.0 and 16.5 GHz (S/N 102 and 104), while the other two systems cover the 35 to 36 GHz range (S/N 101 and 103).

A summary of the measured parameters are given in Table 1. Briefly this table shows that the sidelobes are better than 20 dB below the boresight pattern level and that the E and H plane patterns are matched to within 0.5 dB over 3 dB beamwidths.

JMS/cph

cc: J. A. Scheer (3 copies), J. W. Dees

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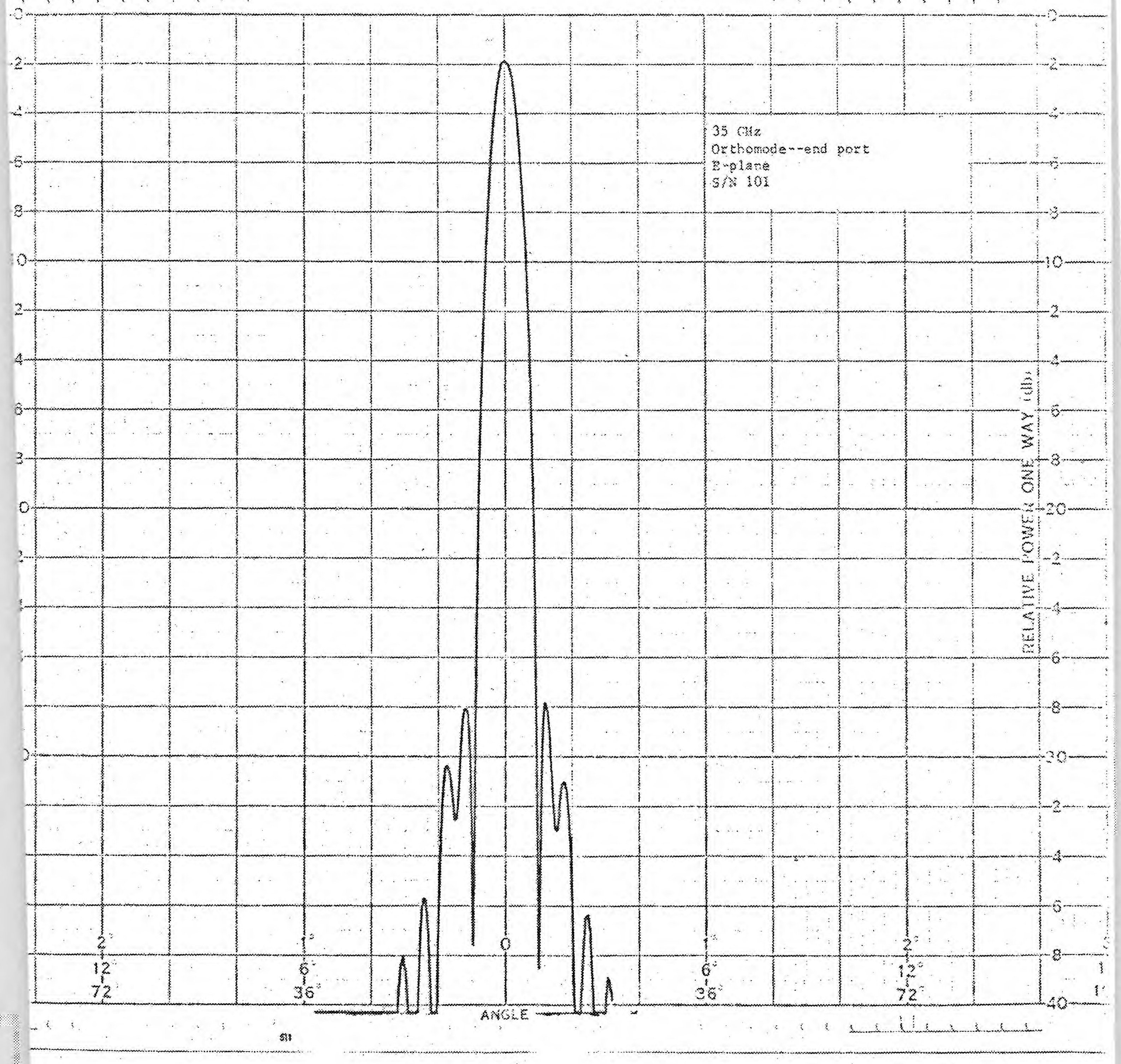
TABLE 1

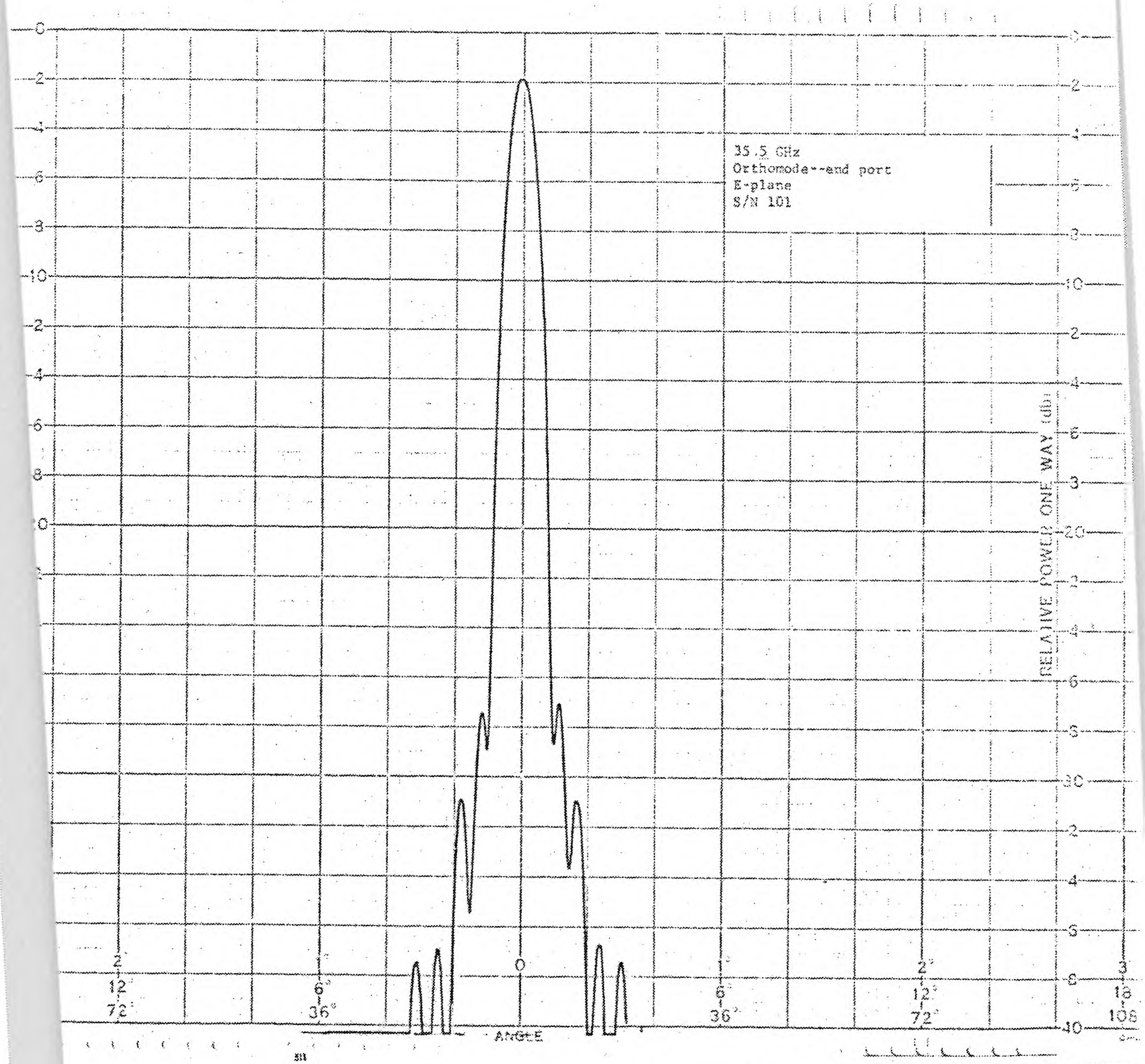
MEASURED ANTENNA PARAMETERS

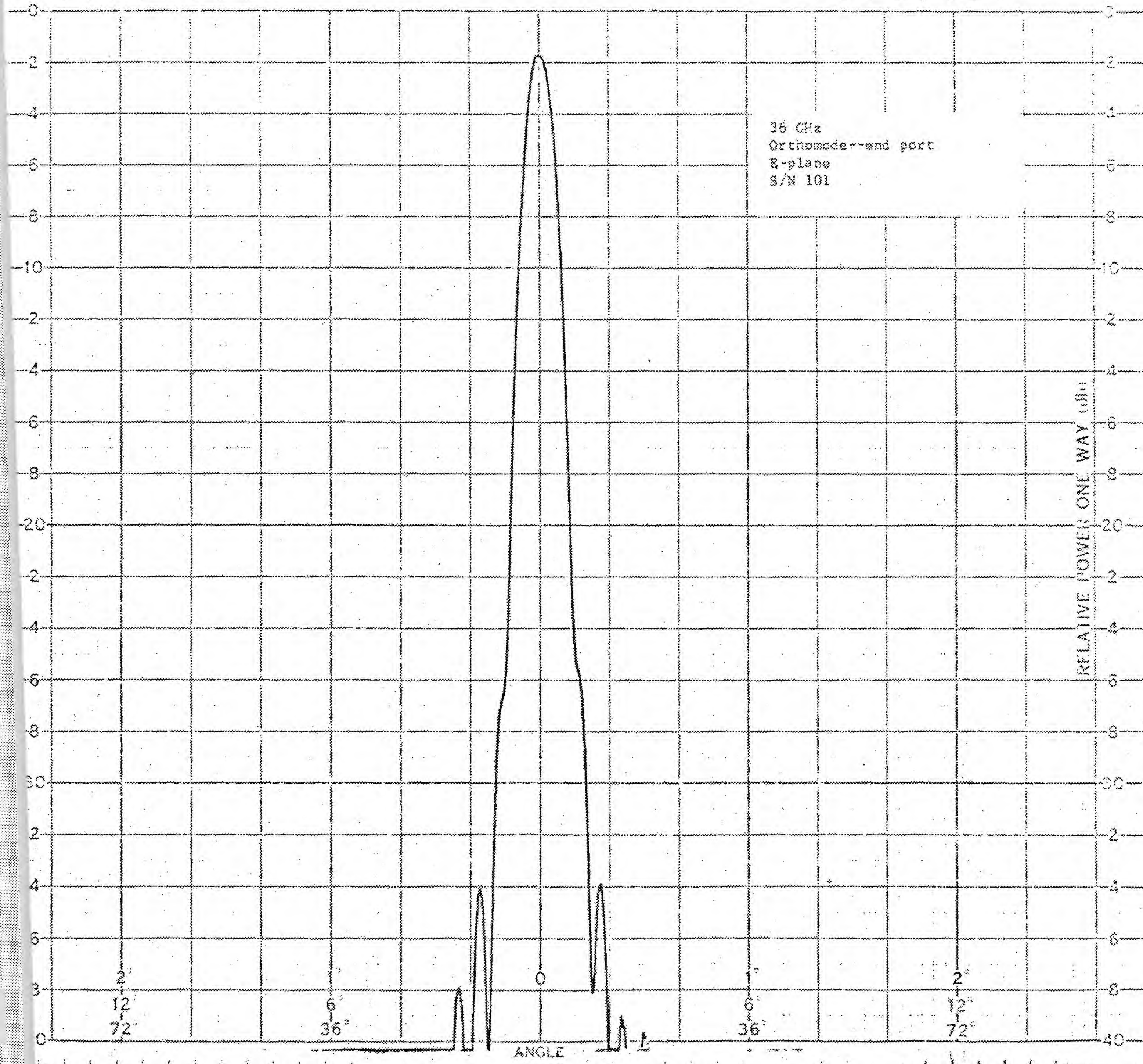
Antenna		f (GHz)	3 dB Beamwidth (Degrees)		First Sidelobes (dB)		On-Axis Cross Polarization Level (dB)	Gain (dB) (Efficiency) at Feed Port
S/N	Diameter (inches)		E	H	E	H		
101	5	35	5.0	4.5	-26	-21	-35	31.5 (65%)
102	5	16	10.0	9.5	-22	-21	-35	24.7 (65%)
103	5	35	5.0	4.5	-28	-22	-35	31.5 (65%)
104	10	16	5.3	5.3	-28	-20	-35	30.7 (65%)

APPENDIX A

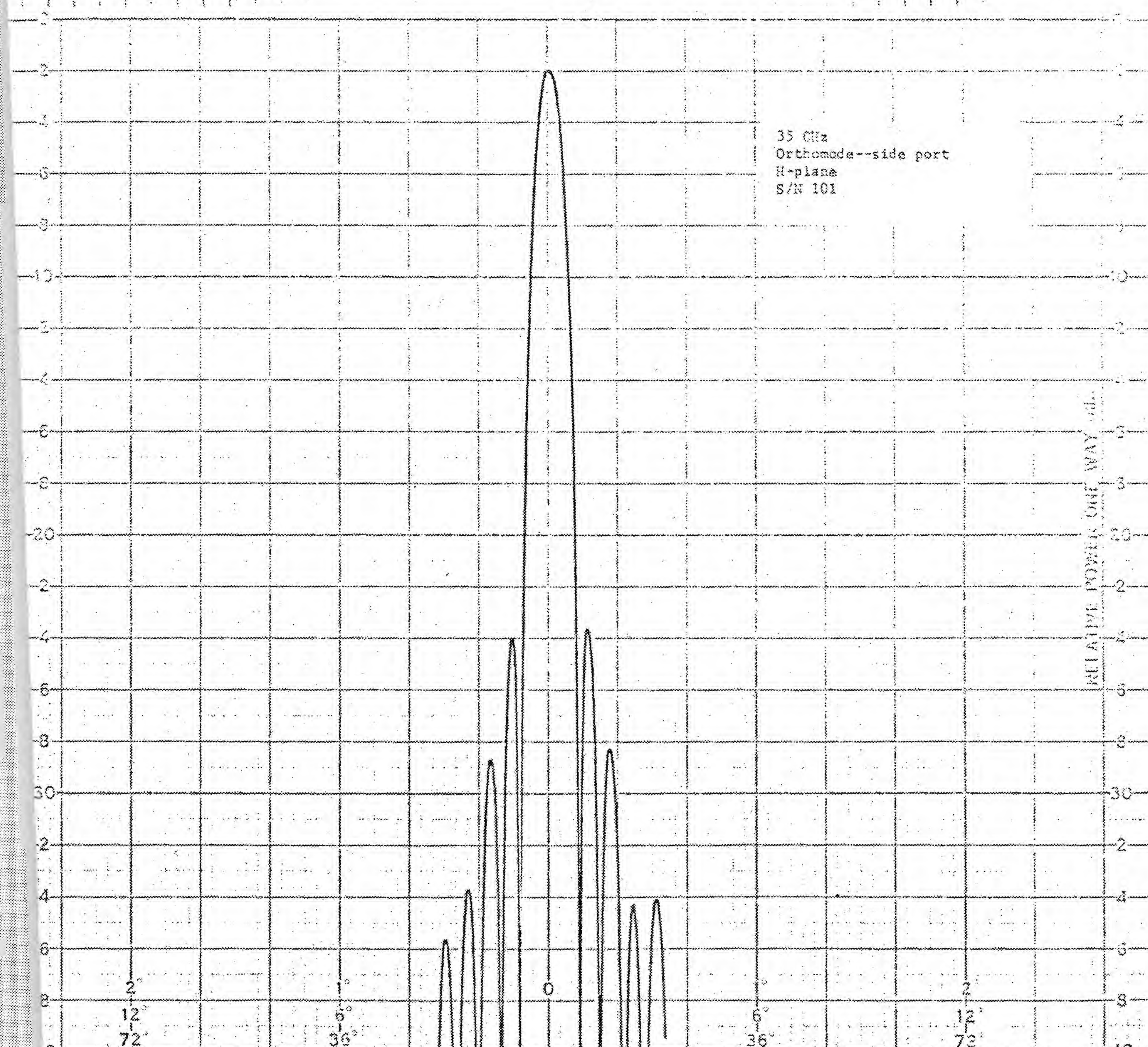
ANTENNA PATTERNS

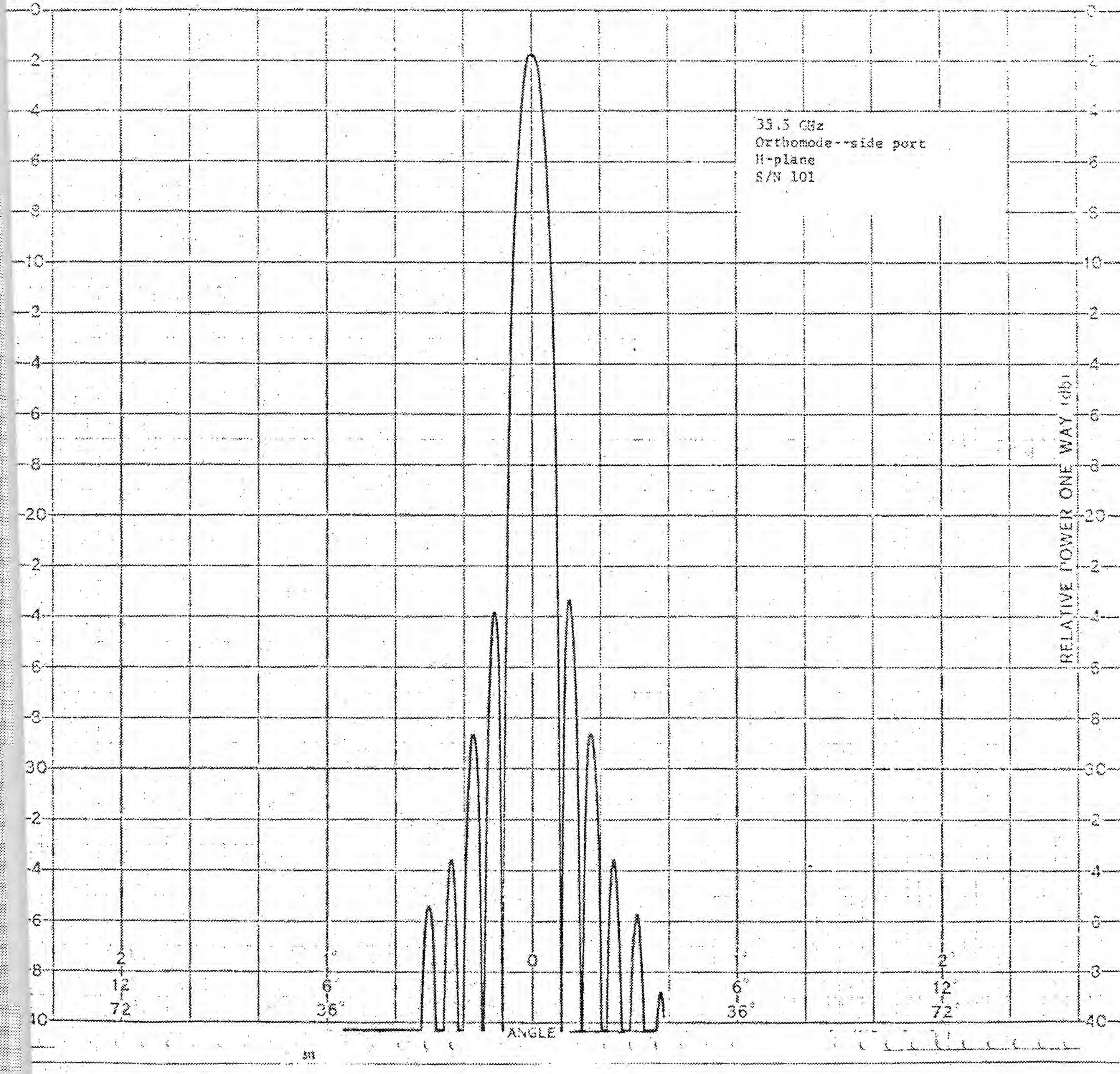

35 GHz
Orthomode--end port
E-plane
S/N 101
RELATIVE POWER ONE WAY (db)
ANGLE
0
2
4
6
8
10
20
40
2°
12°
72°
1°
6°
36°

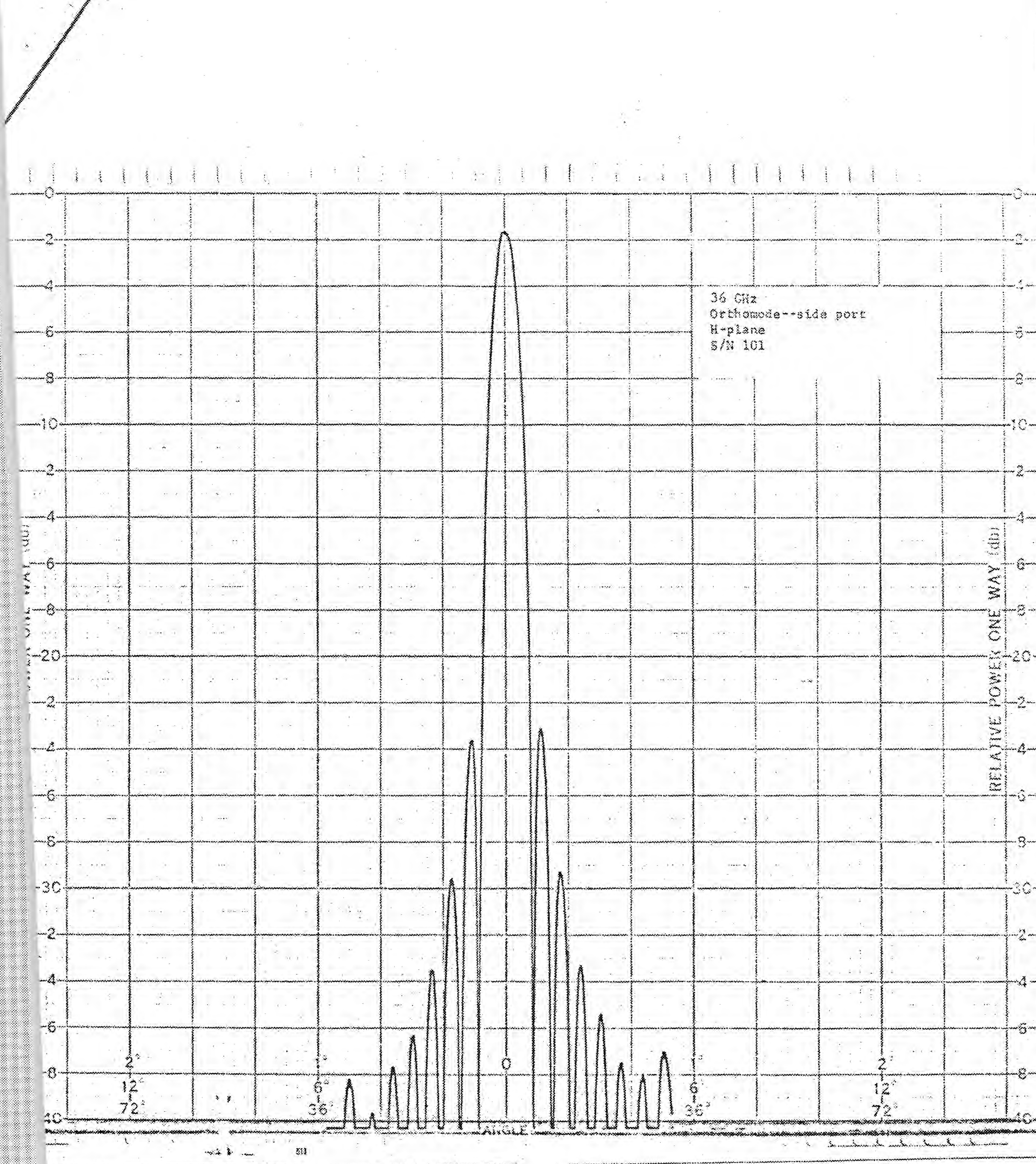

35.5 GHz
Orthomode--end port
E-plane
S/N 101
RELATIVE POWER ONE WAY (db)
ANGLE
0
2°
12°
72°
6°
36°
1°
3°
18°
108°

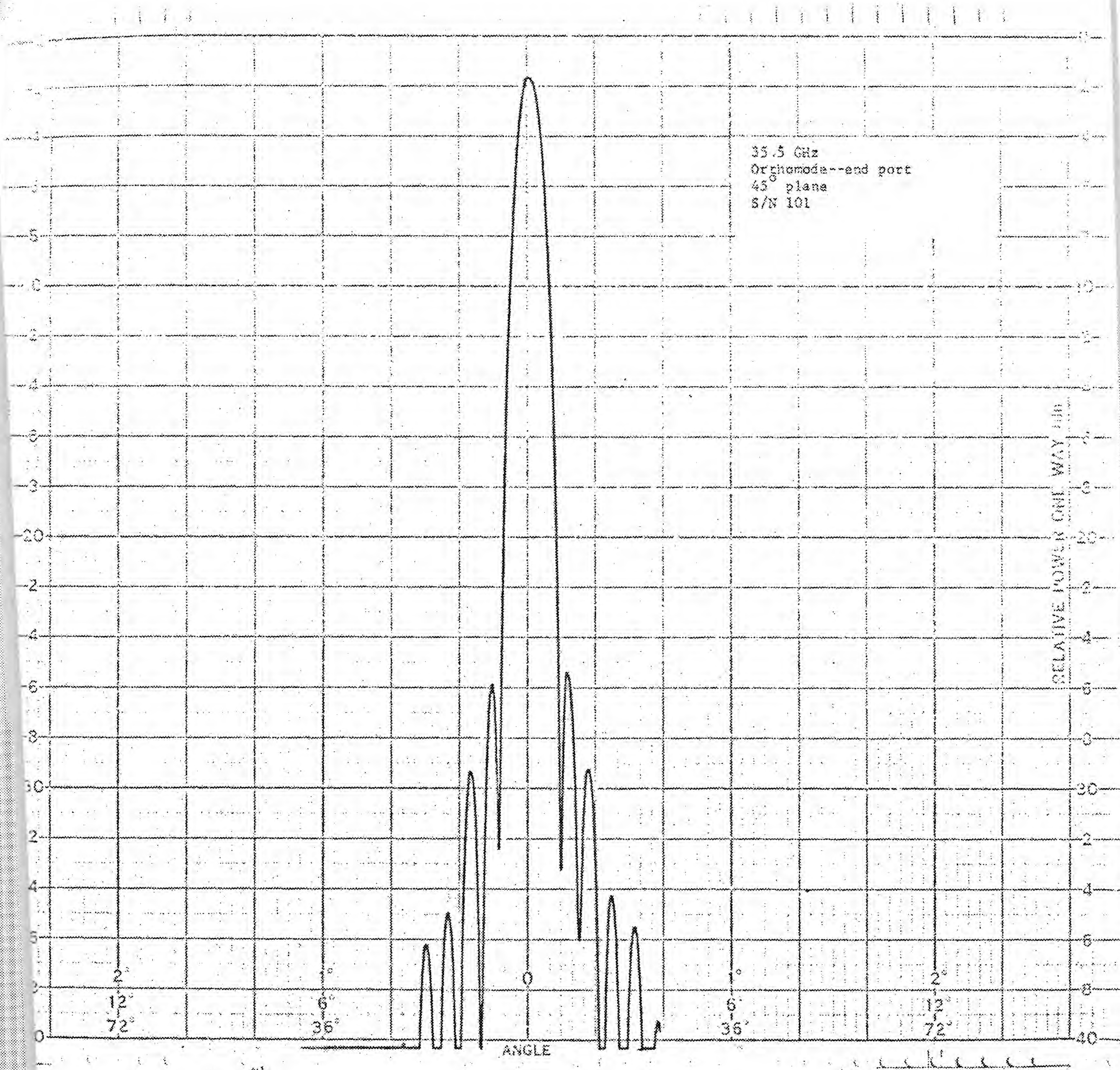


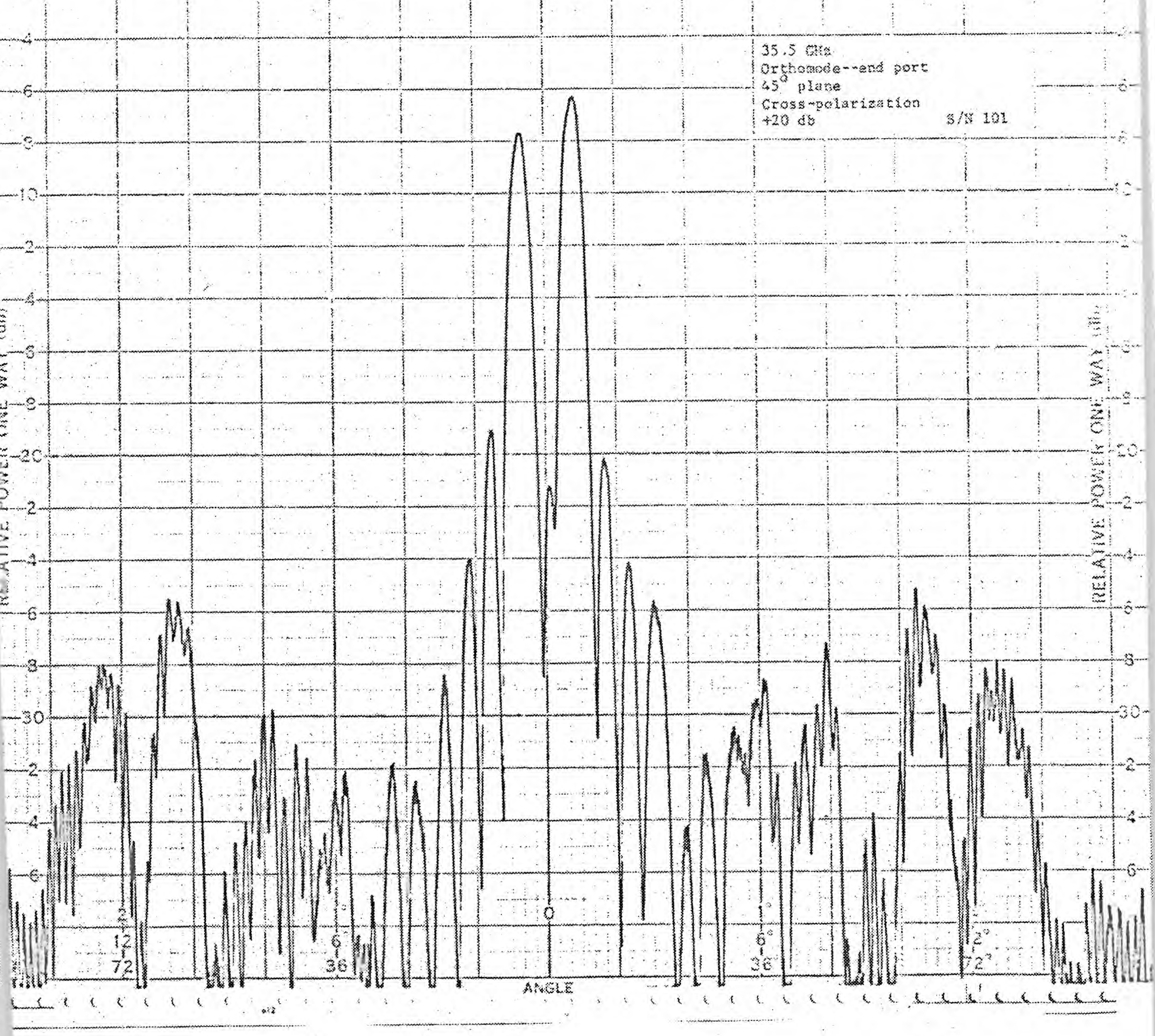
36 GHz
Orthomode--end port
E-plane
S/N 101
RELATIVE POWER ONE WAY (db)
ANGLE
0
2
4
6
8
10
20
30
40
2°
12°
72°
1°
6°
36°


35 GHz
Orthomode--side port
H-plane
S/N 101
RELATIVE POWER ONE WAY dB
ANGLE
0
1°
6°
36°
2°
12°
72°
-10
-20
-30
-40

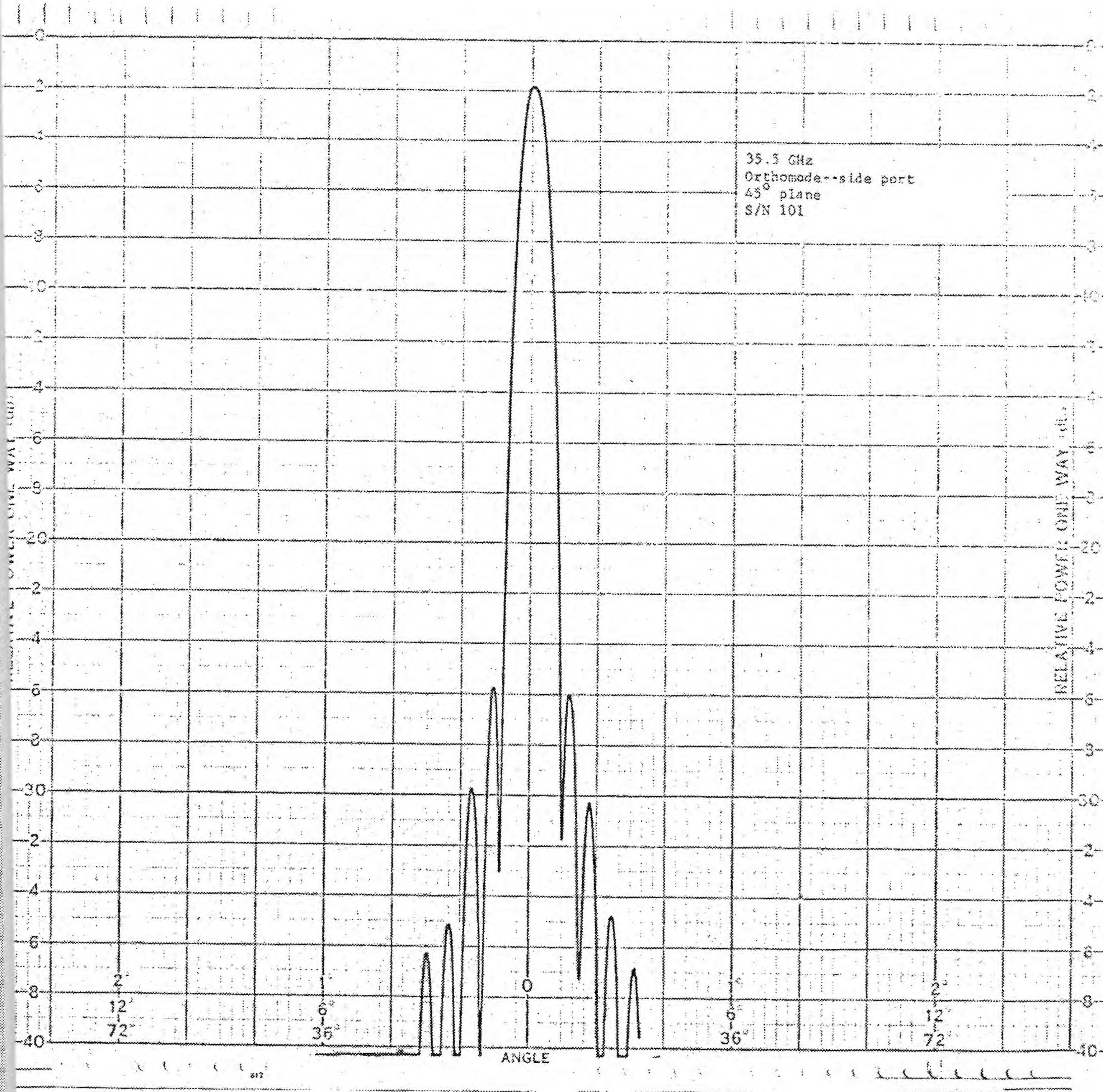

33.5 GHz
Orthomode--side port
H-plane
S/N 101
RELATIVE POWER ONE WAY (db)
ANGLE
0
2
4
6
8
10
20
30
40
2°
12°
72°
1°
6°
36°


36 GHz
Orthomode--side port
H-plane
S/N 101
RELATIVE POWER ONE WAY (db)
ANGLE
0
2
4
6
8
10
20
30
40
2°
12°
72°
1°
6°
36°

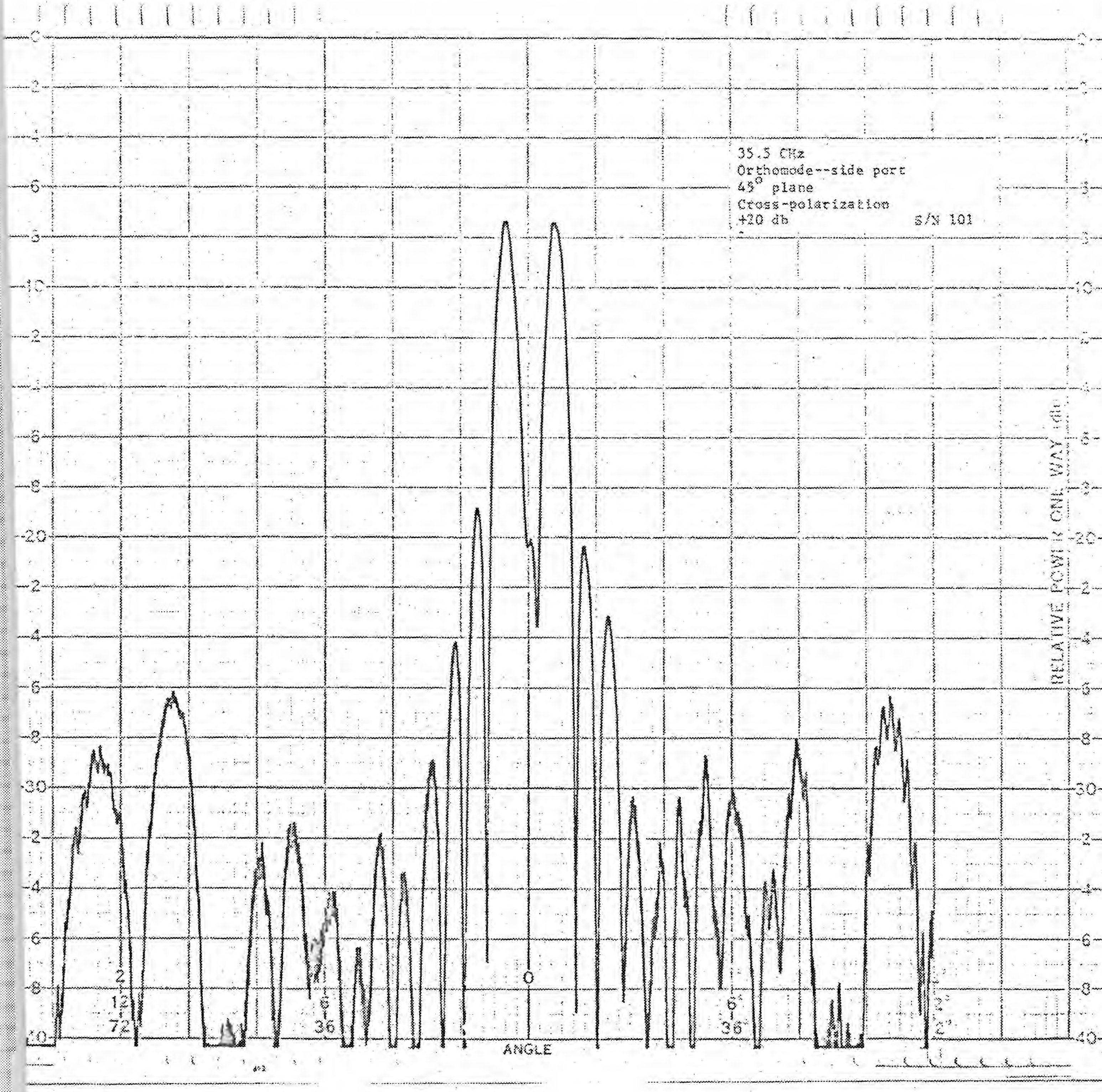

35.5 GHz
Orthomode--end port
45° plane
S/N 101
RELATIVE POWER ONE WAY dB
ANGLE
0
1°
6°
36°
2°
12°
72°
-10
-20
-30
-40

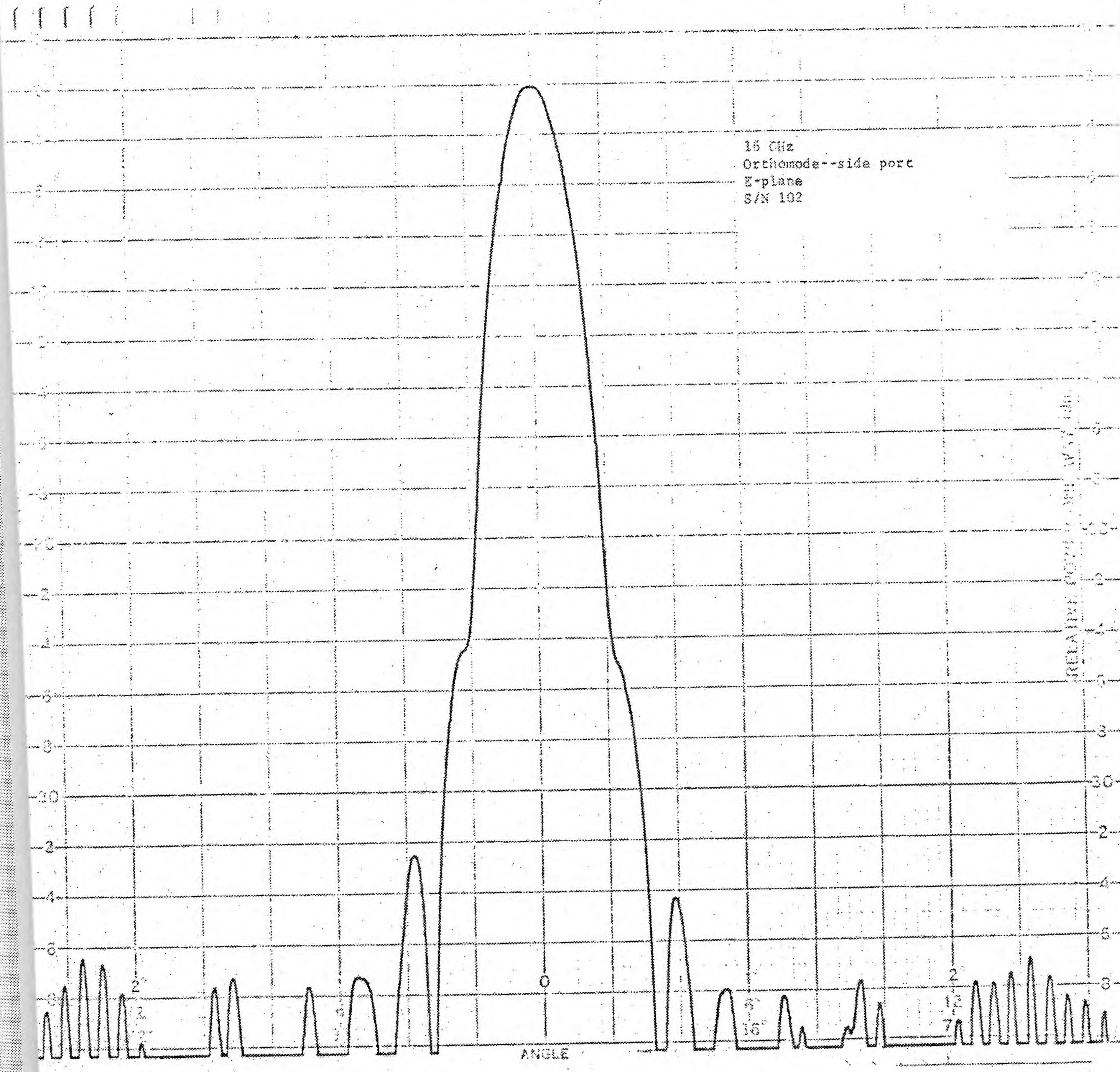


35.5 GHz
Orthomode--end port
45° plane
Cross-polarization
+20 db
S/N 101
RELATIVE POWER ONE WAY (db)
ANGLE

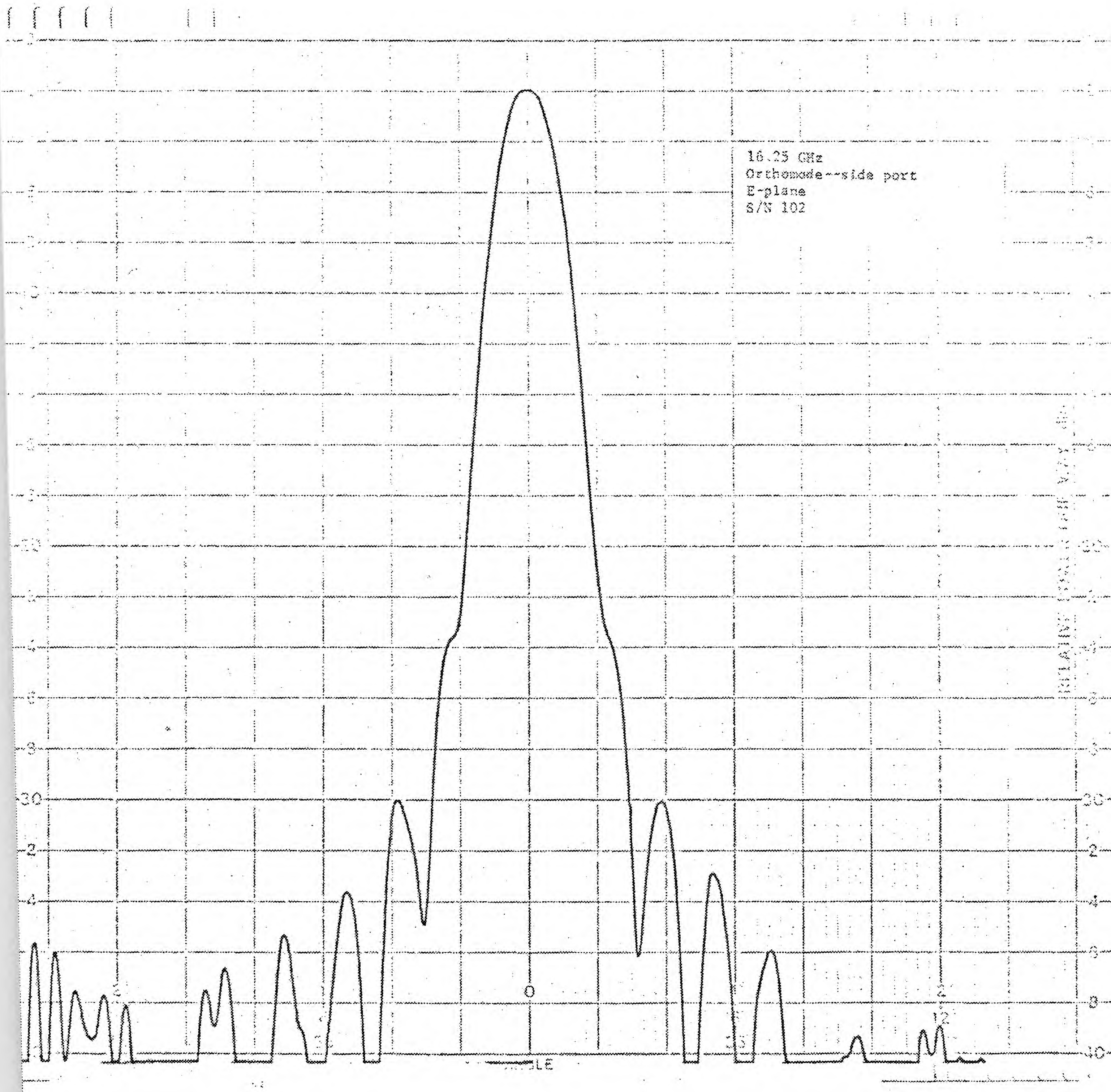


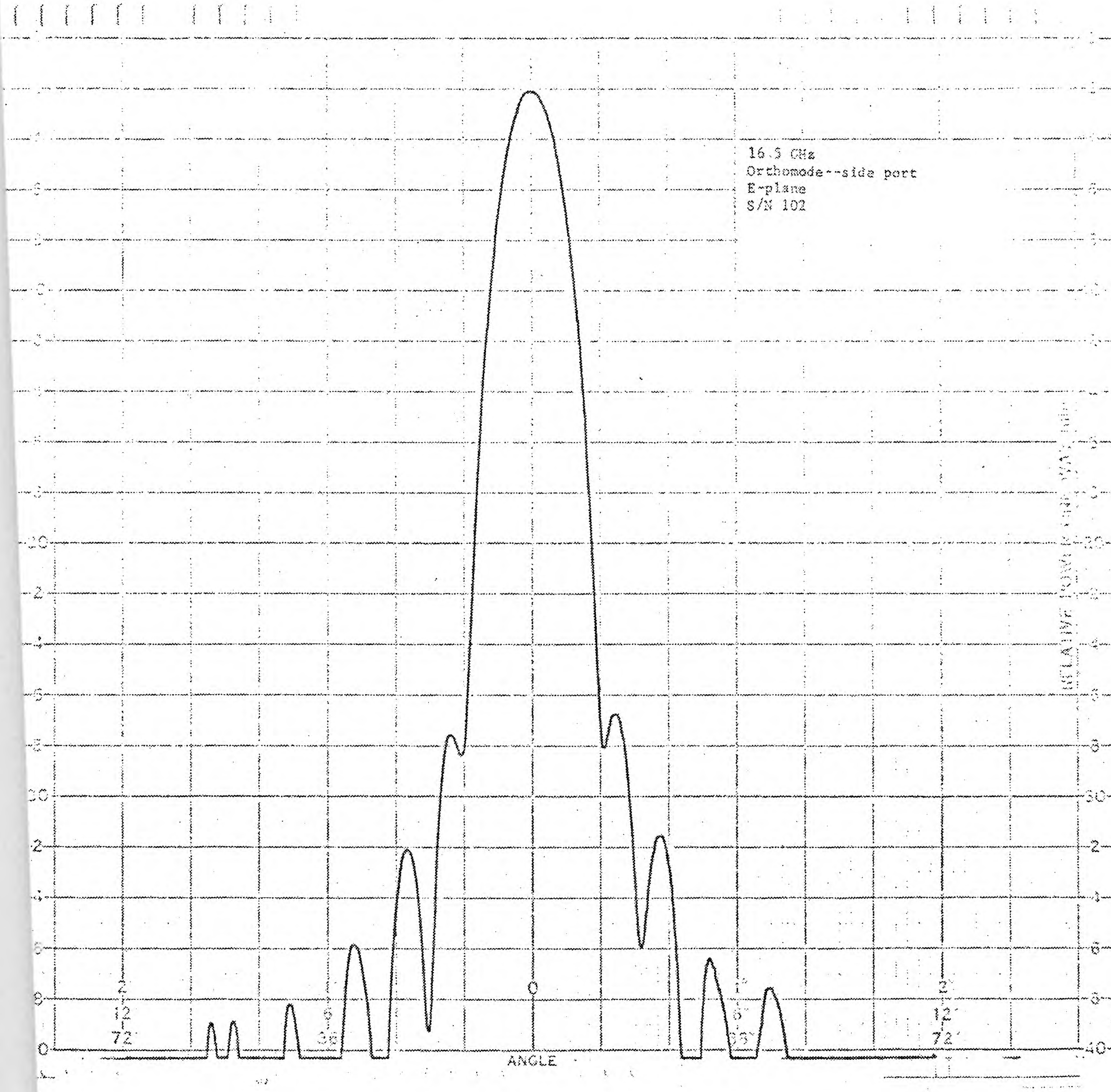
35.5 GHz
Orthomode--side port
45° plane
S/N 101
RELATIVE POWER ONE WAY (dB)
ANGLE
0
2
4
6
8
10
20
30
40
2°
12°
72°
1°
6°
36°


35.5 GHz
Orthomode--side port
45° plane
Cross-polarization
+20 db
S/N 101
ANGLE
RELATIVE POWER ONE WAY (db)

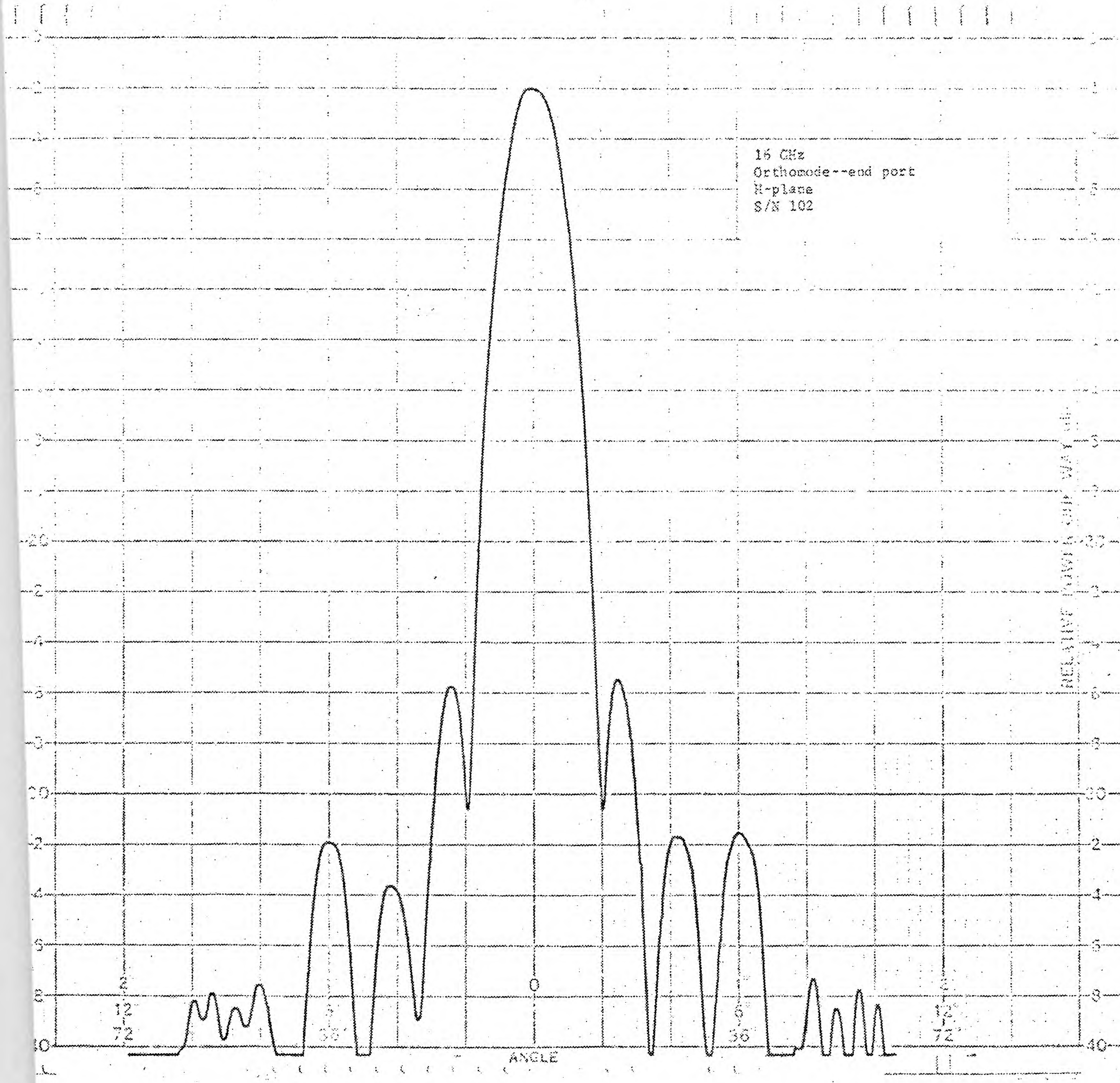


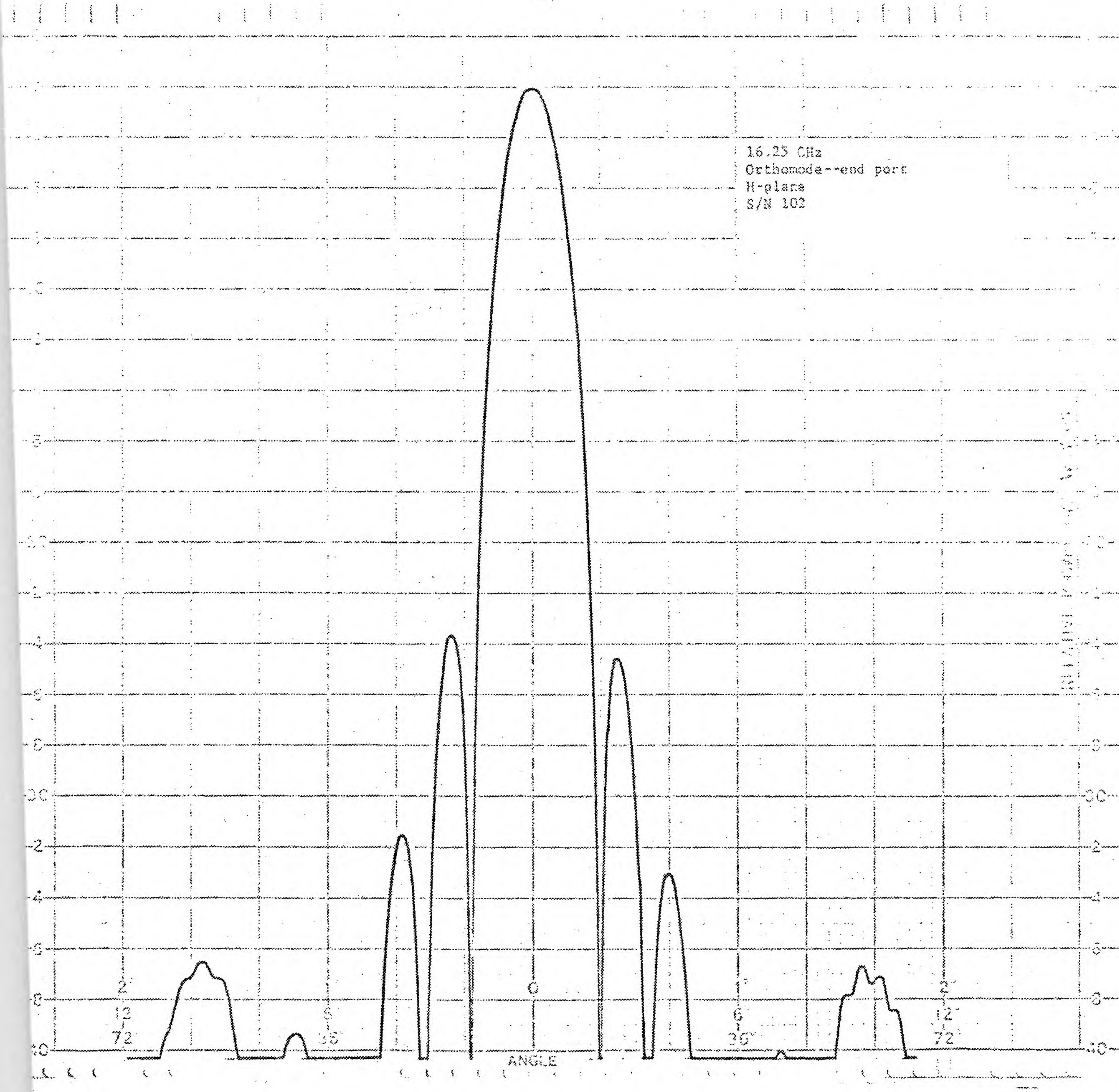
16 GHz
Orthomode--side port
E-plane
S/N 102
ANGLE
0
RELATIVE POWER (dB)

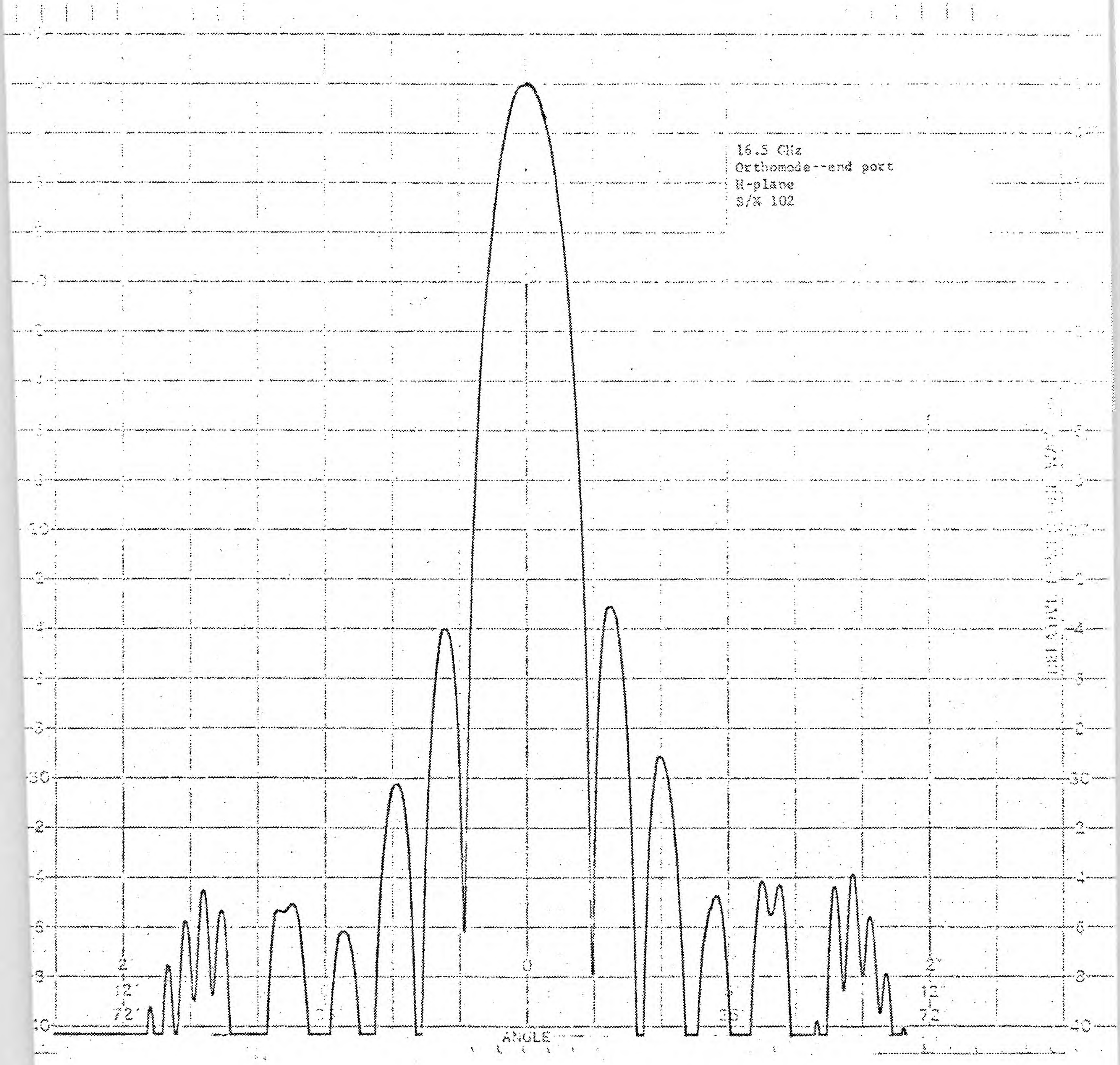

16.25 GHz
Orthomode--side port
E-plane
S/N 102
0
30
40

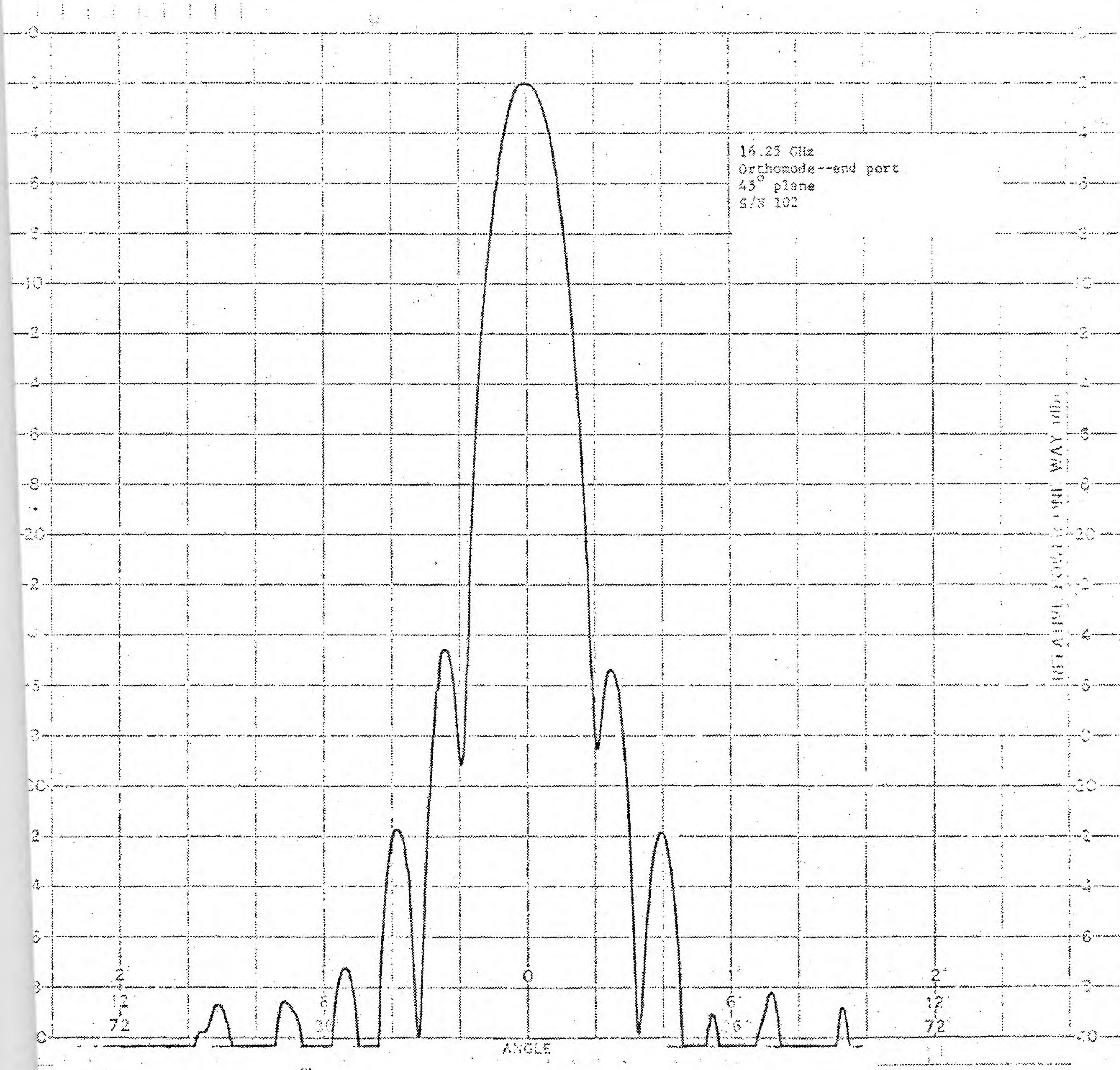


16.5 GHz
Orthomode--side port
E-plane
S/N 102
ANGLE
RELATIVE POWER (dB)

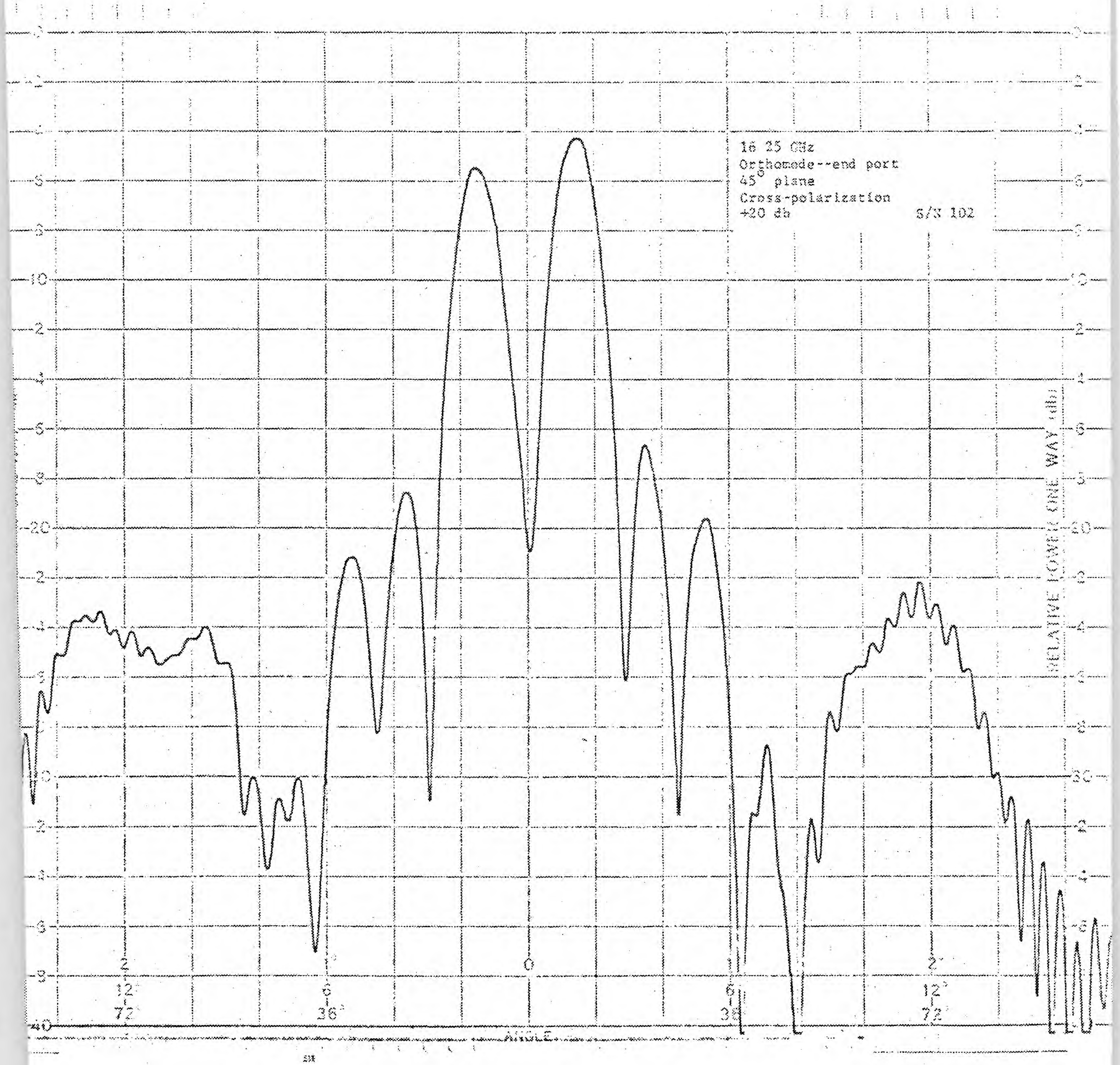

16 GHz
Orthomode--end port
H-plane
S/N 102
ANGLE
0
6°
36'
12°
72'
-20
-30
-40

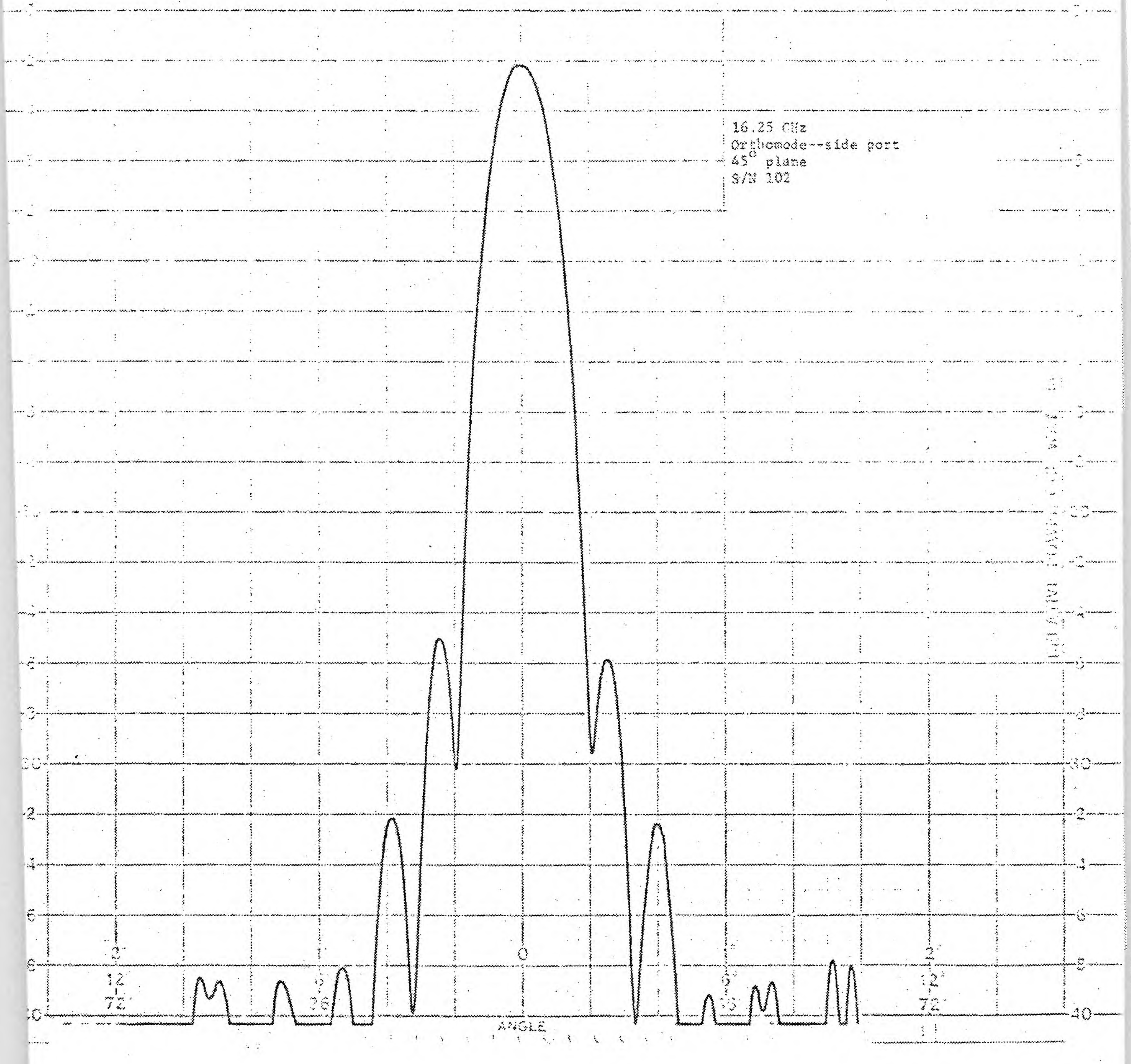

16.25 GHz
Orthomode--end port
H-plane
S/N 102
ANGLE


16.5 GHz
Orthomode--end port
H-plane
S/N 102
ANGLE
0
30
40

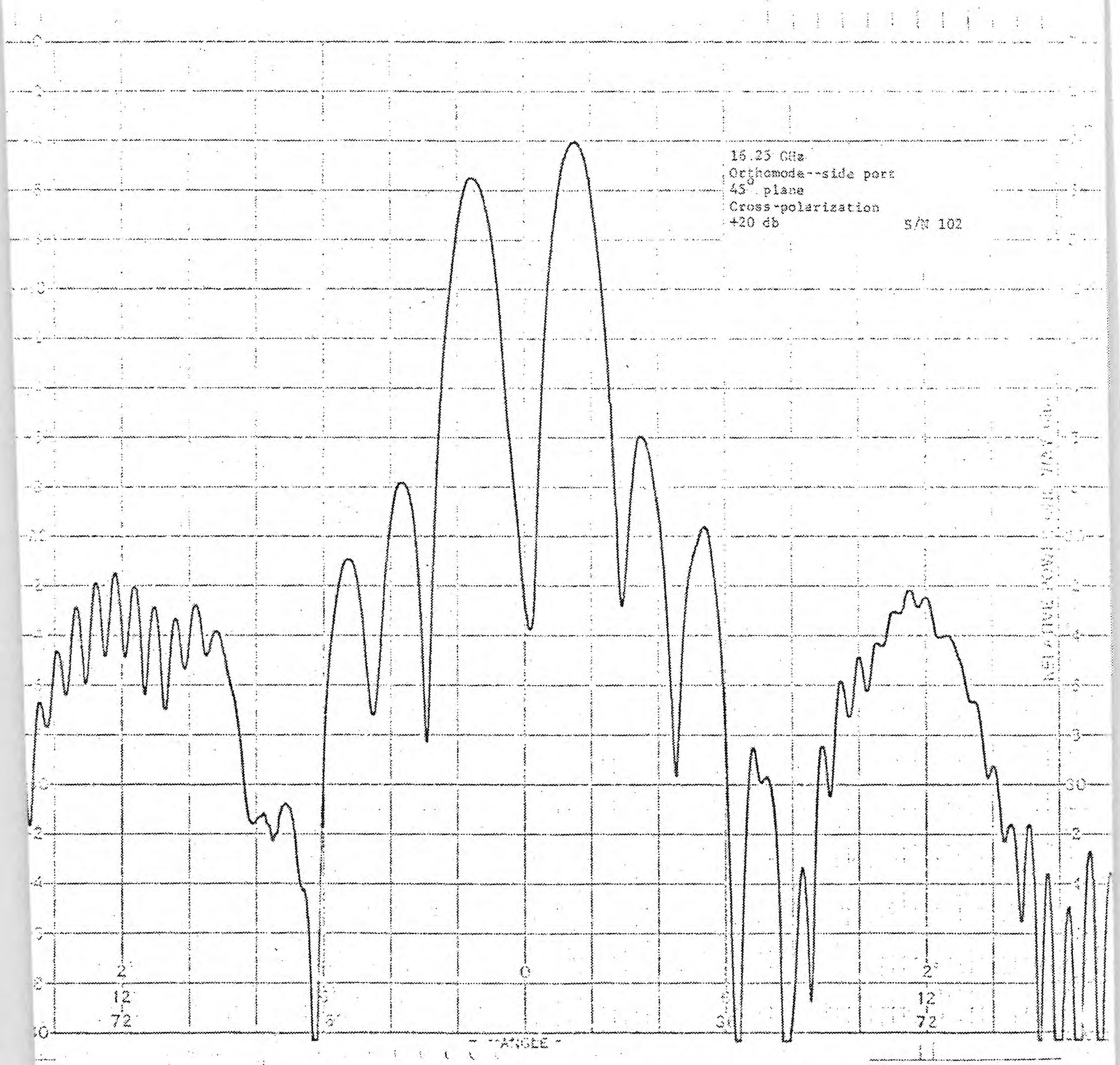


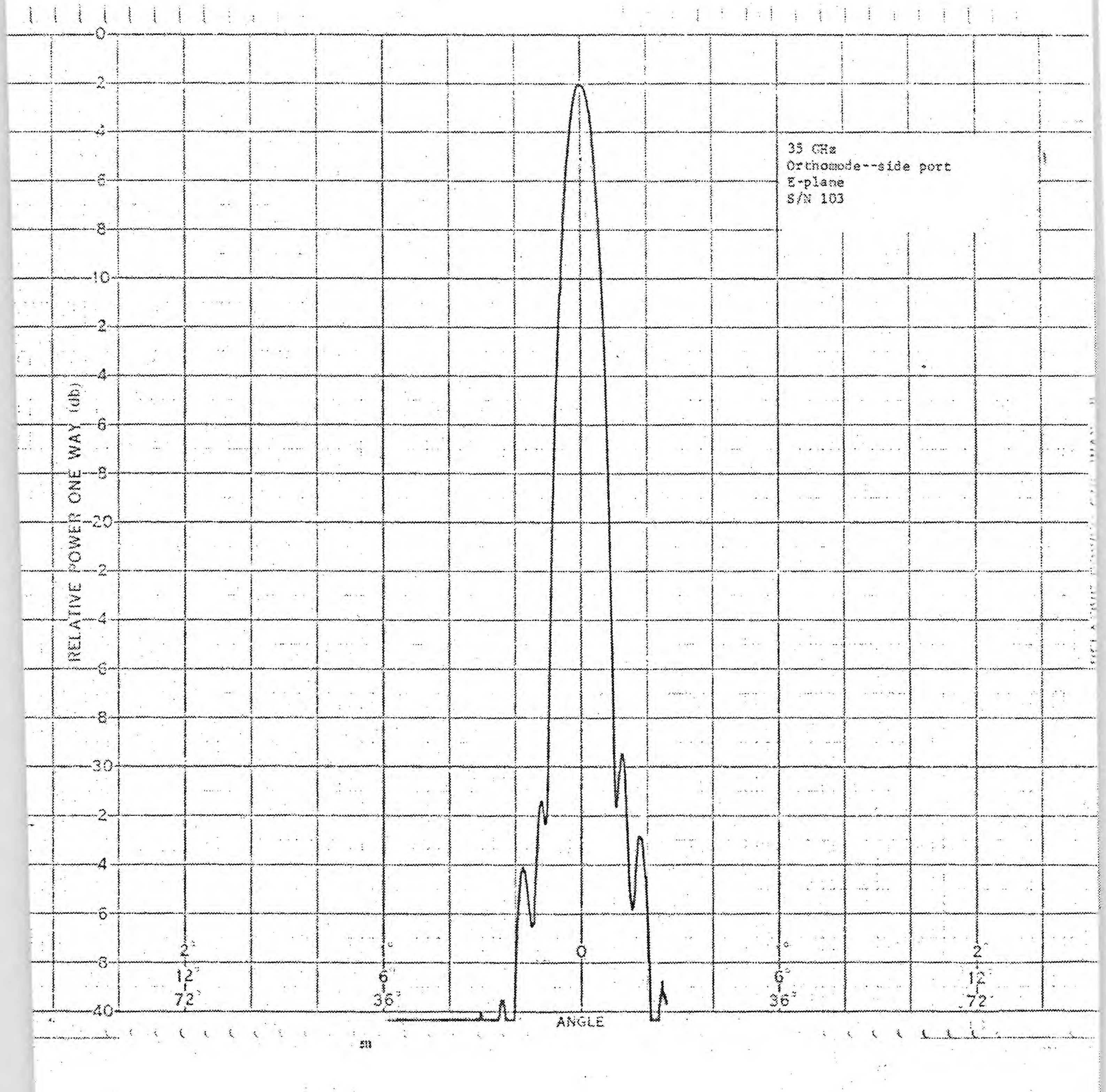
16.25 GHz
Orthomode--end port
45° plane
S/N 102
ANGLE
RELATIVE POWER ONE WAY (dB)

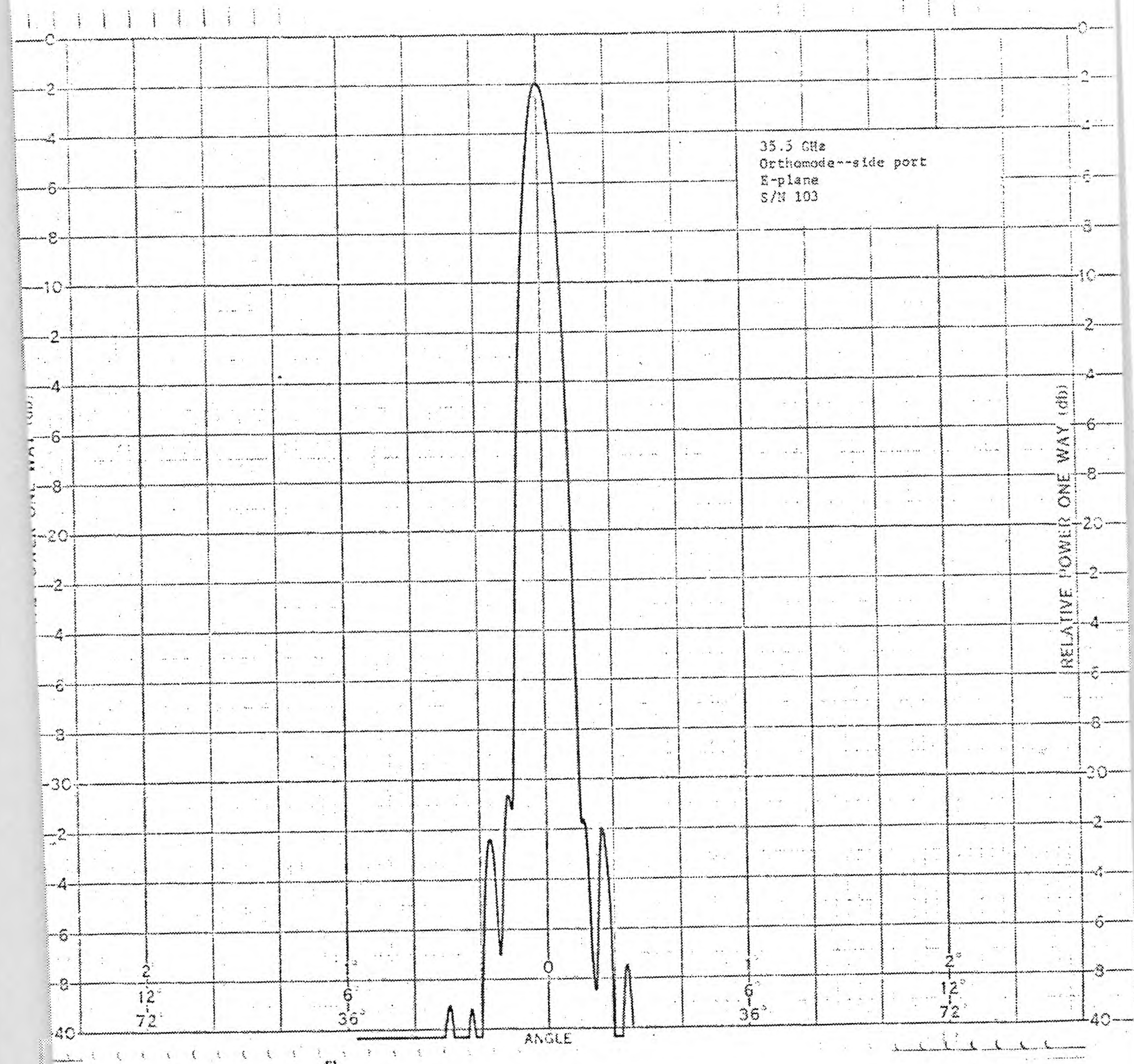

16 25 GHz
Orthomode--end port
45° plane
Cross-polarization
+20 db
S/N 102
RELATIVE POWER ONE WAY (db)
ANGLE
0
10
20
30
40
2
12°
72°
6
36°

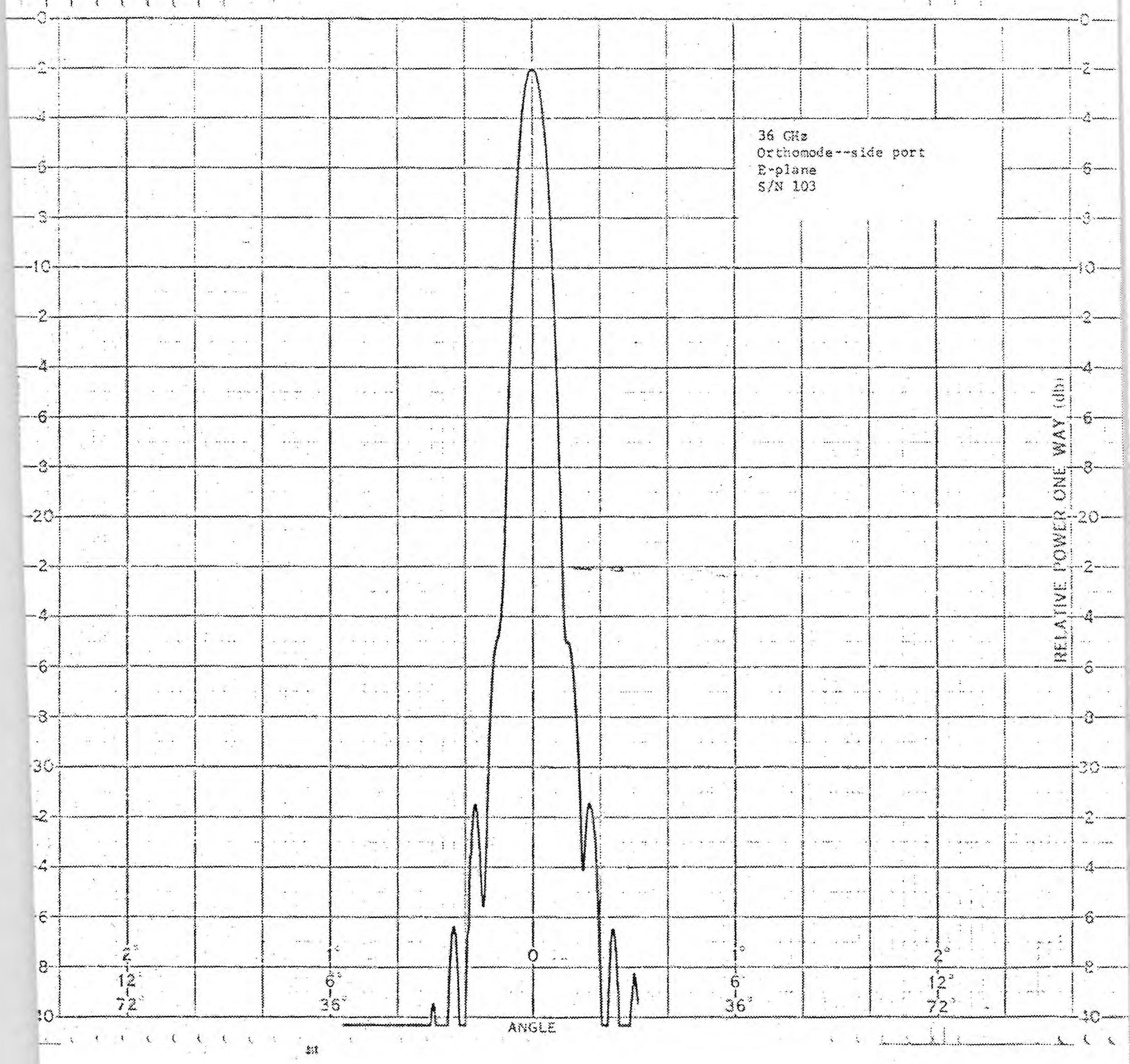


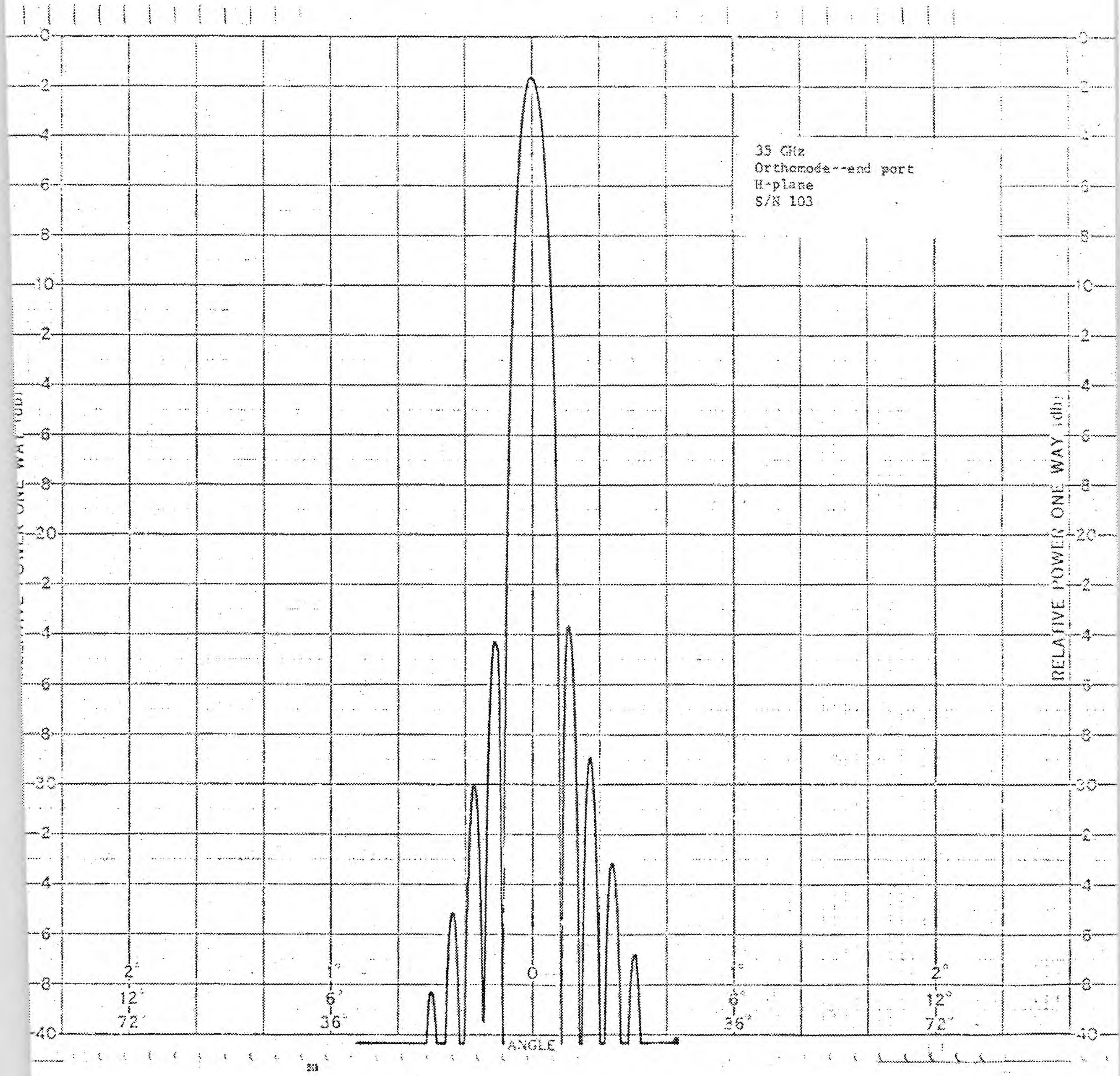
16.25 GHz
Orthomode--side port
45° plane
S/N 102
30
2
4
6
8
40
0
ANGLE


16.25 GHz
Orthomode--side port
45° plane
Cross-polarization
+20 db
S/N 102
2°
12
72
0
2°
12
72
ANGLE
RELATIVE POWER (db)

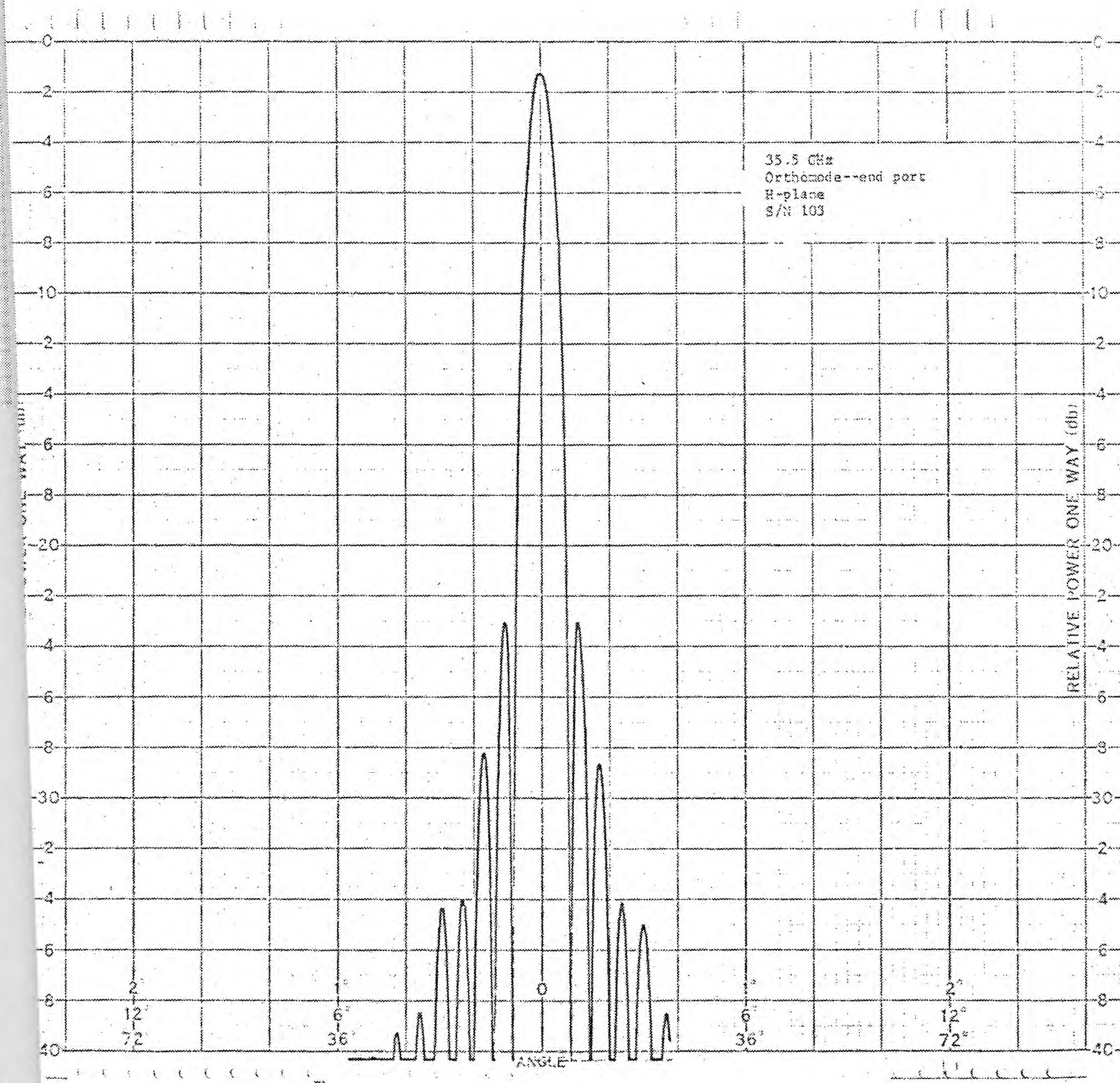

35 GHz
Orthomode--side port
E-plane
S/N 103
RELATIVE POWER ONE WAY (db)
0
2
4
6
8
10
2
4
6
8
20
2
4
6
8
30
2
4
6
8
40
2°
12°
72°
1°
6°
36°
0
1°
6°
36°
2°
12°
72°
ANGLE

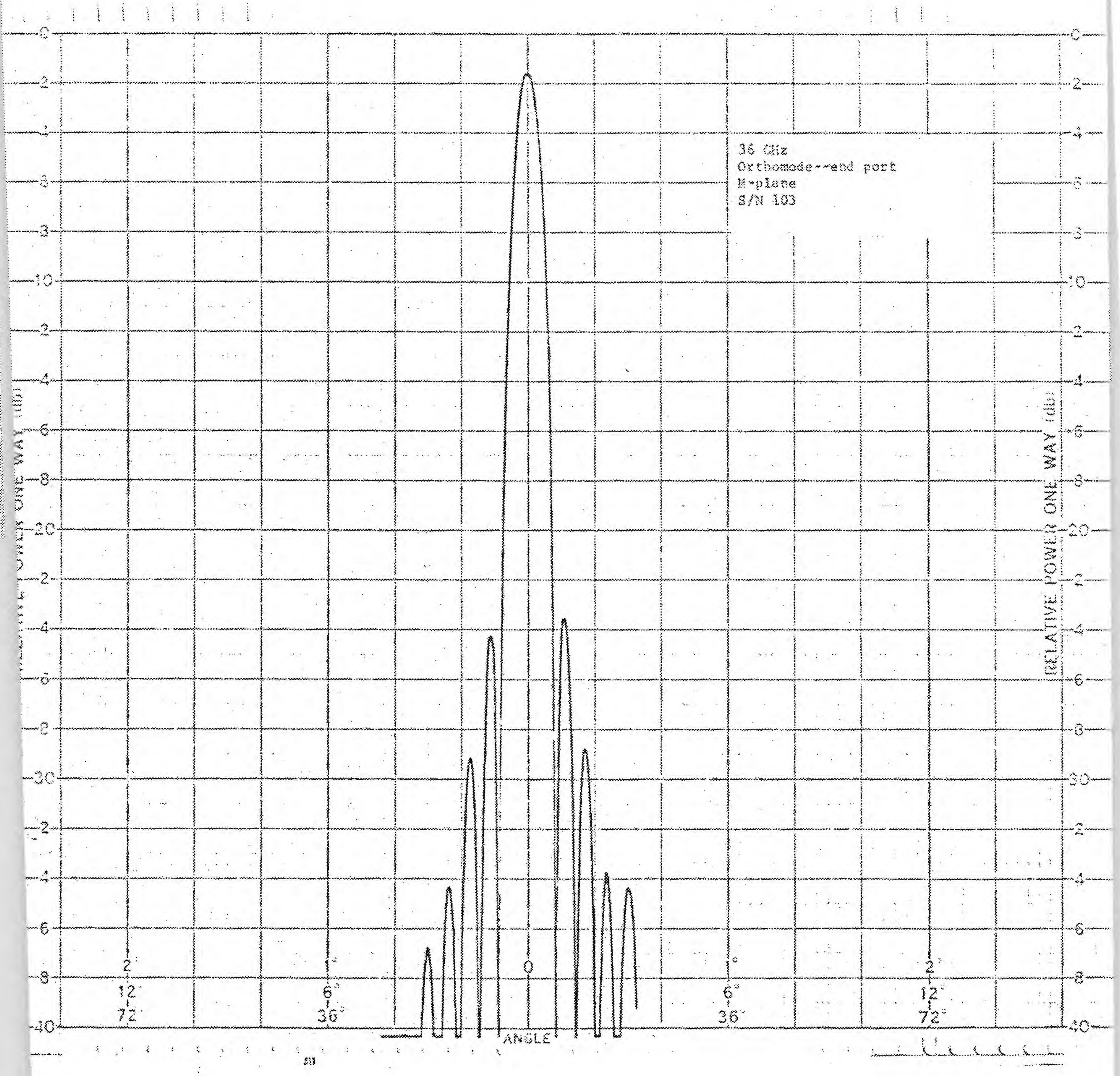

35.5 GHz
Orthomode--side port
E-plane
S/N 103
RELATIVE POWER ONE WAY (db)
ANGLE
0
2
4
6
8
10
20
30
40
2°
12°
72°
1°
6°
36°

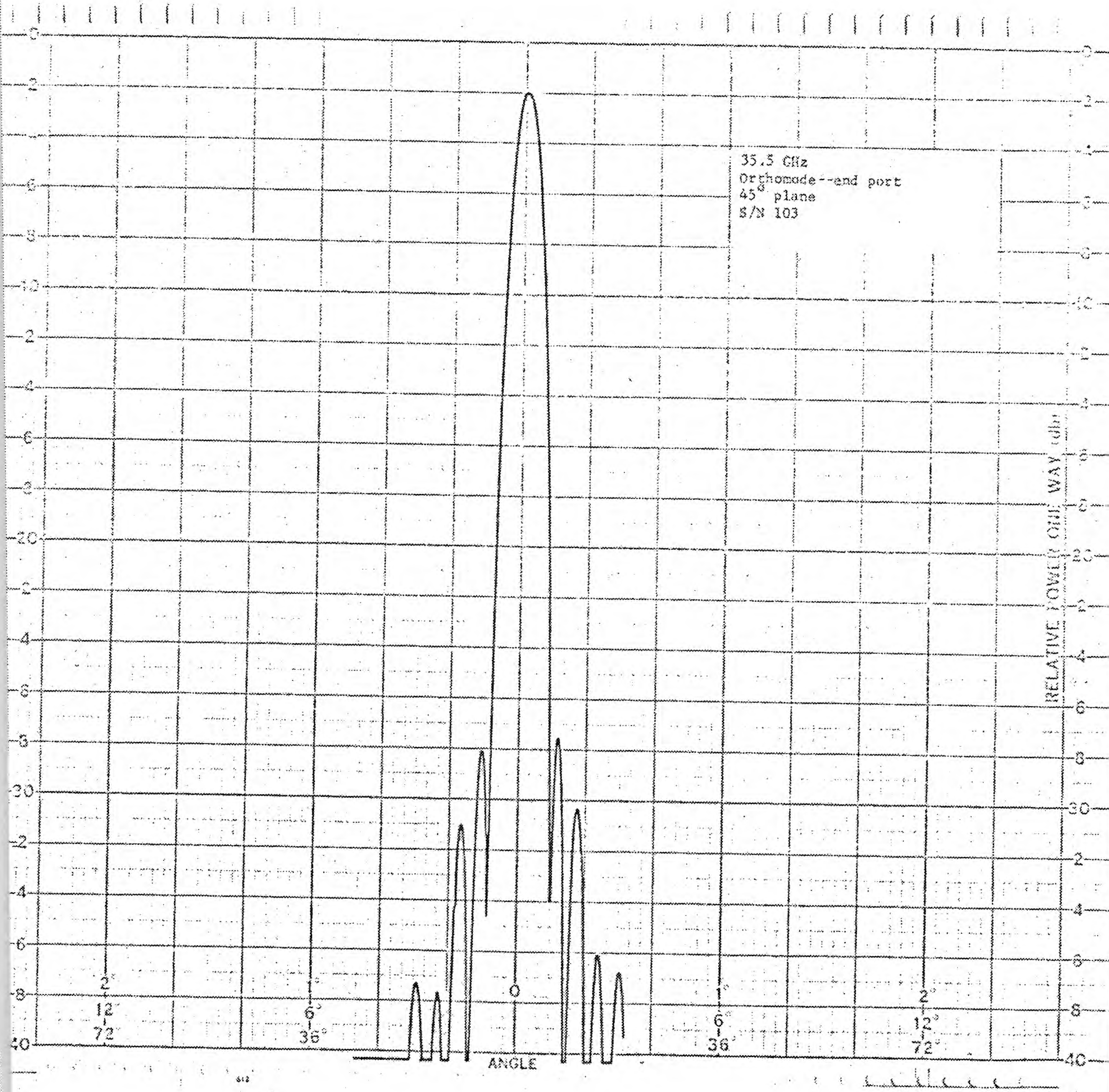

36 GHz
Orthomode--side port
E-plane
S/N 103
RELATIVE POWER ONE WAY (db)
ANGLE
0
2
4
6
8
10
20
30
40
2°
12°
72°
1°
6°
36°



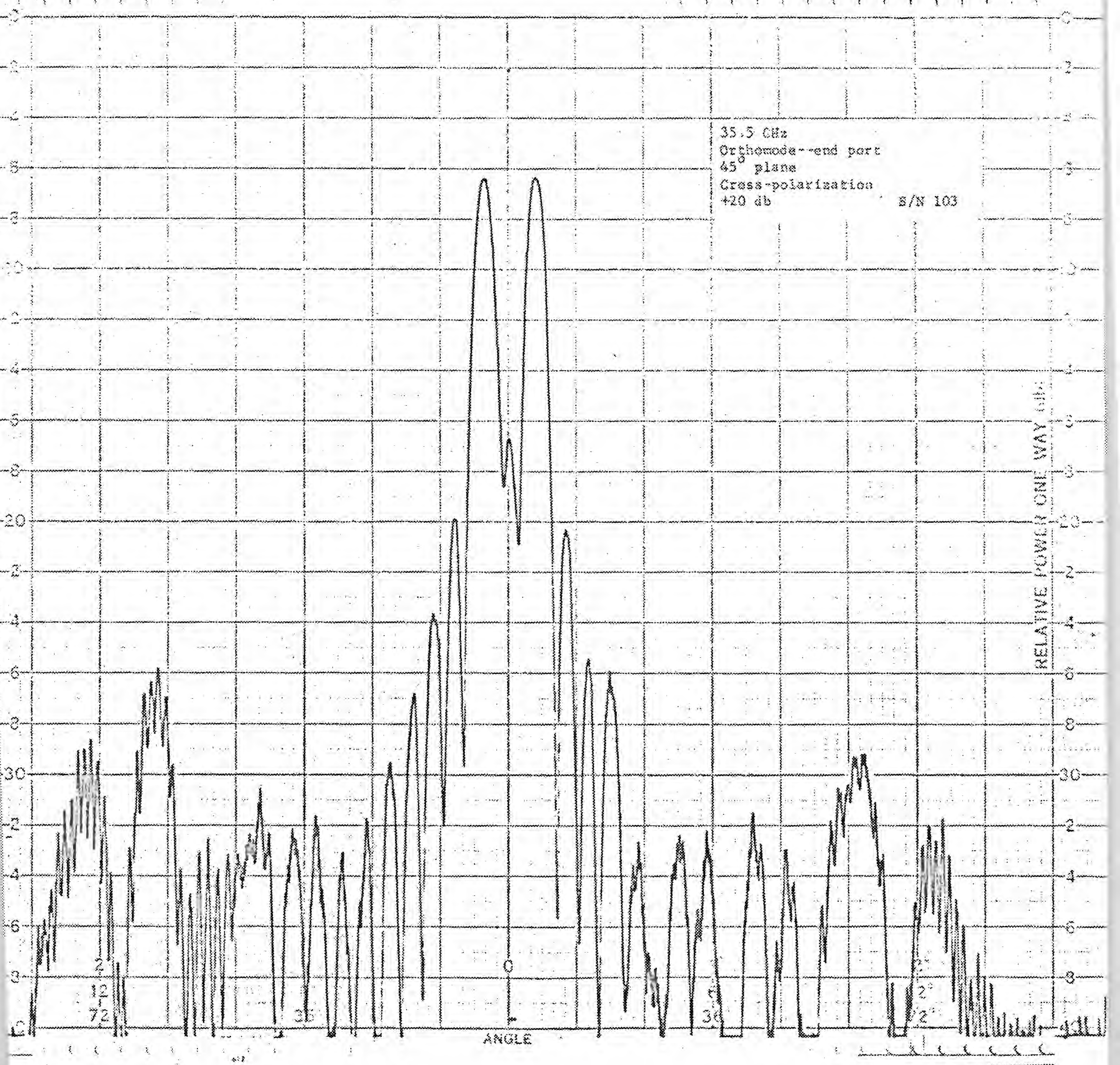
35 GHz
Orthomode--end port
H-plane
S/N 103
RELATIVE POWER ONE WAY (db)
ANGLE

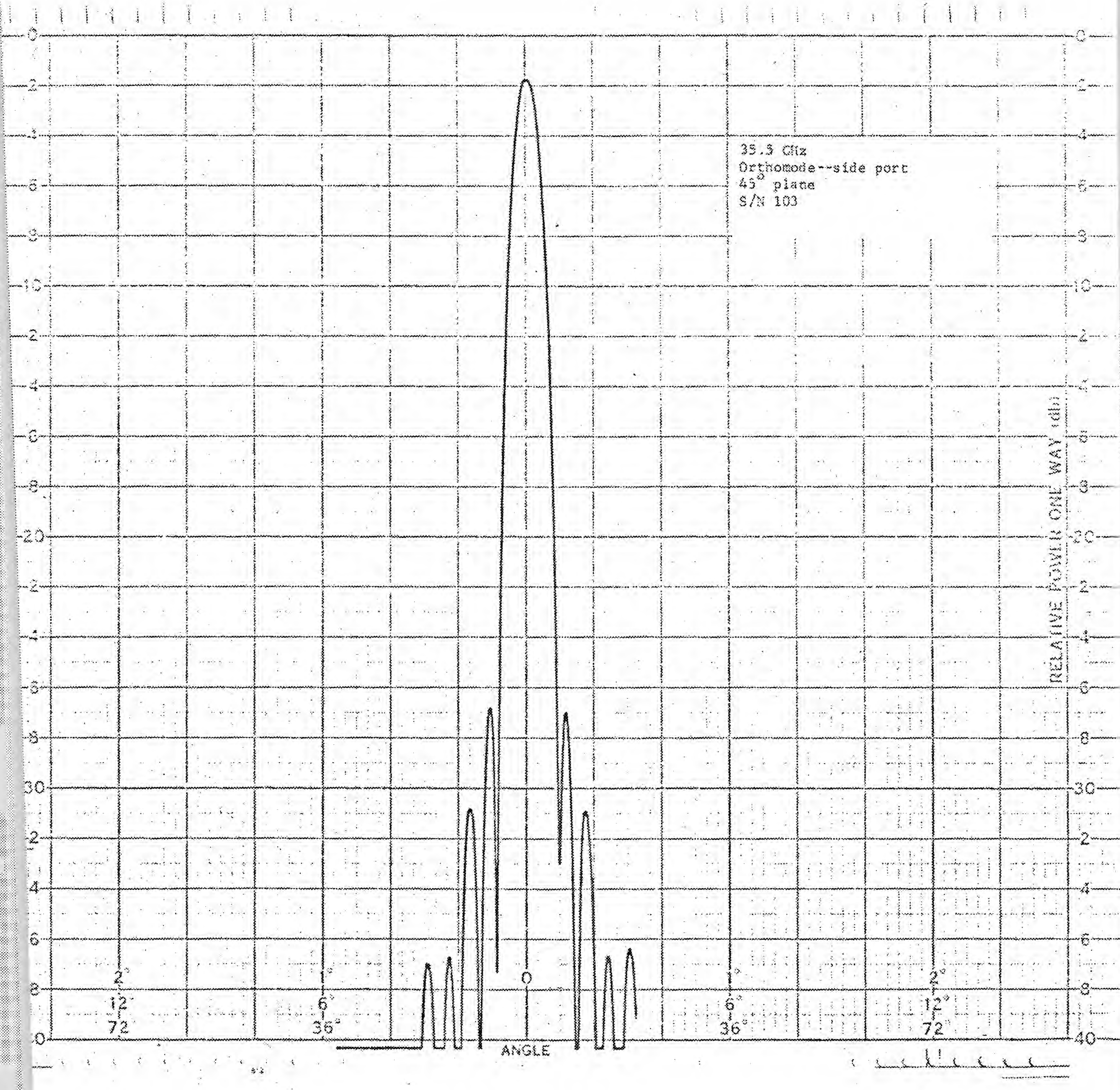

35.5 GHz
Orthomode--end port
H-plane
S/N 103
RELATIVE POWER ONE WAY (db)
ANGLE

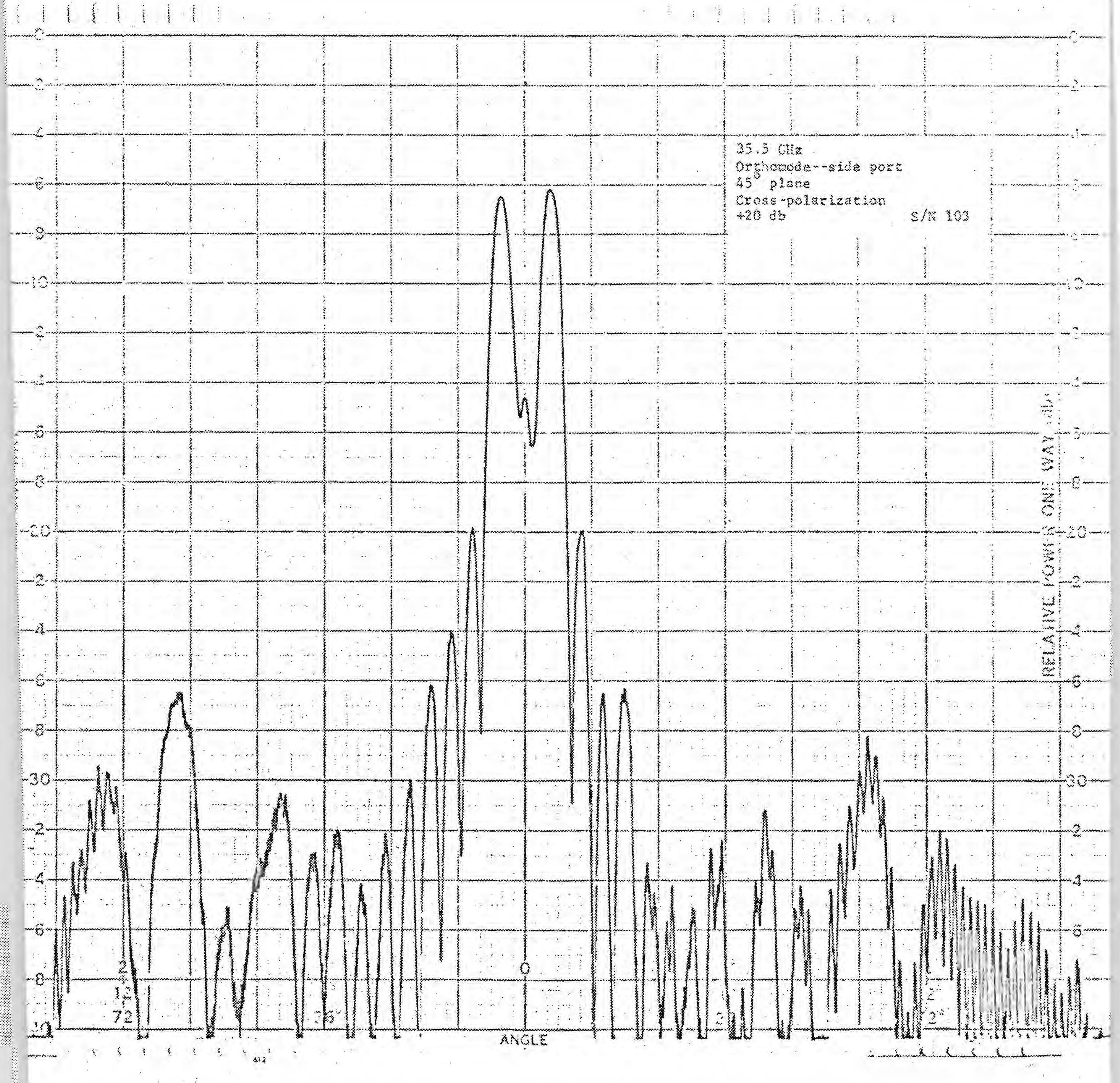

36 GHz
Orthomode--end port
H-plane
S/N 103
RELATIVE POWER ONE WAY (db)
ANGLE

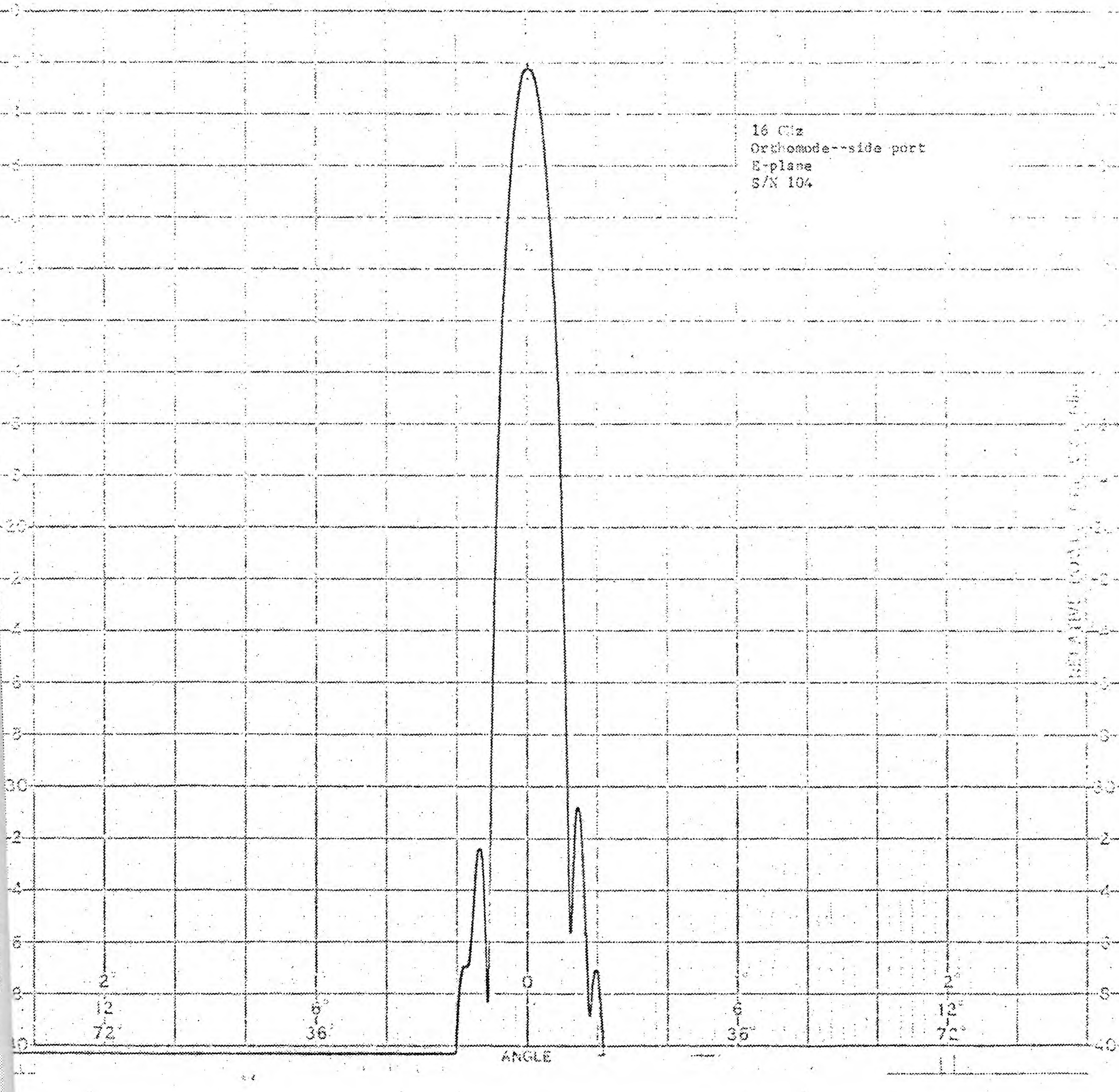


35.5 GHz
Orthomode--end port
45° plane
S/N 103
RELATIVE POWER ONE WAY (db)
ANGLE
0
2°
12°
72°
1°
6°
36°

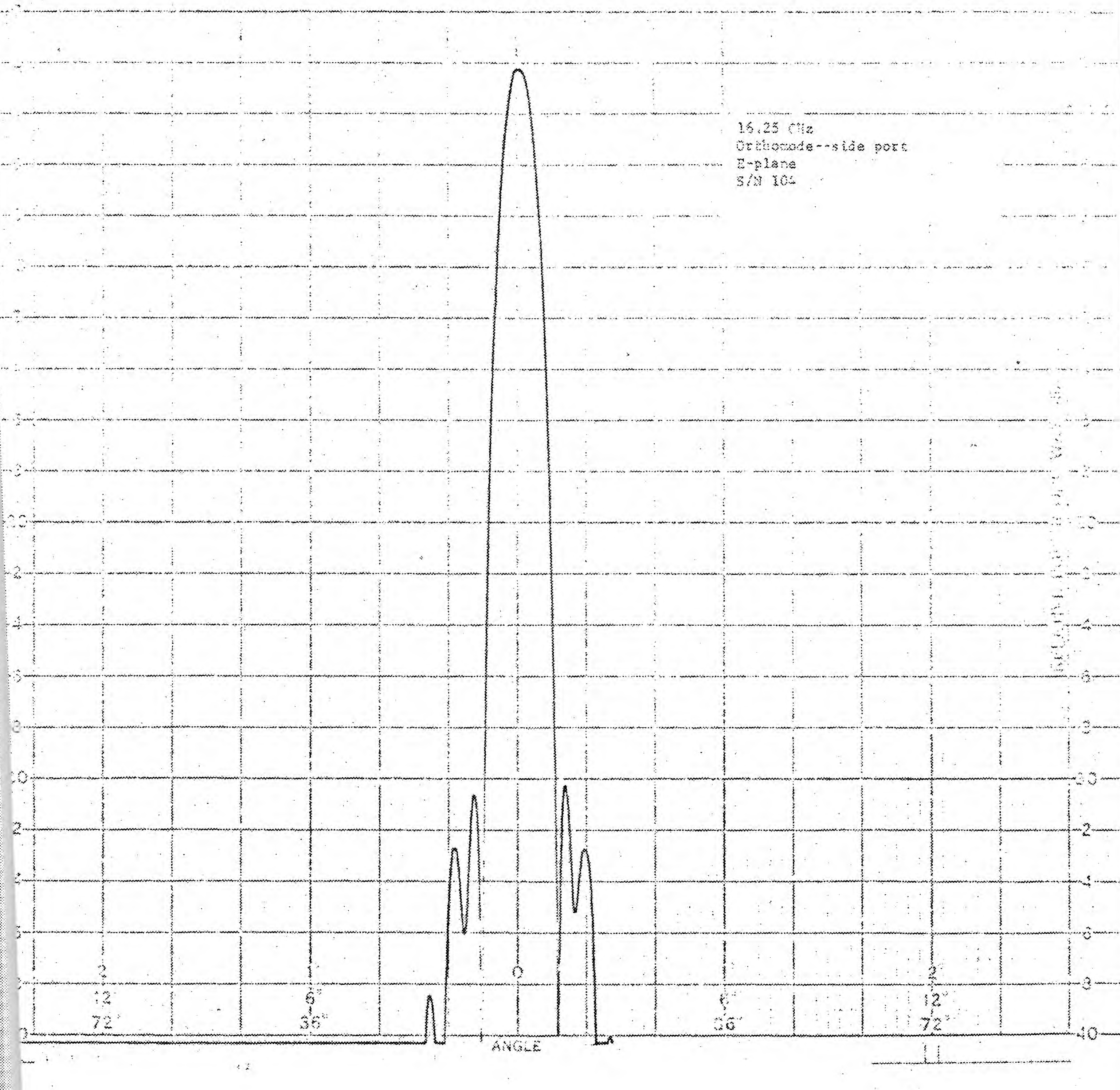

35.5 GHz
Orthomode--end port
45° plane
Cross-polarization
+20 db
S/N 103
RELATIVE POWER ONE WAY (db)
ANGLE
-20
30
0


35.3 GHz
Orthomode--side port
45° plane
S/N 103
RELATIVE POWER ONE WAY (dB)
ANGLE

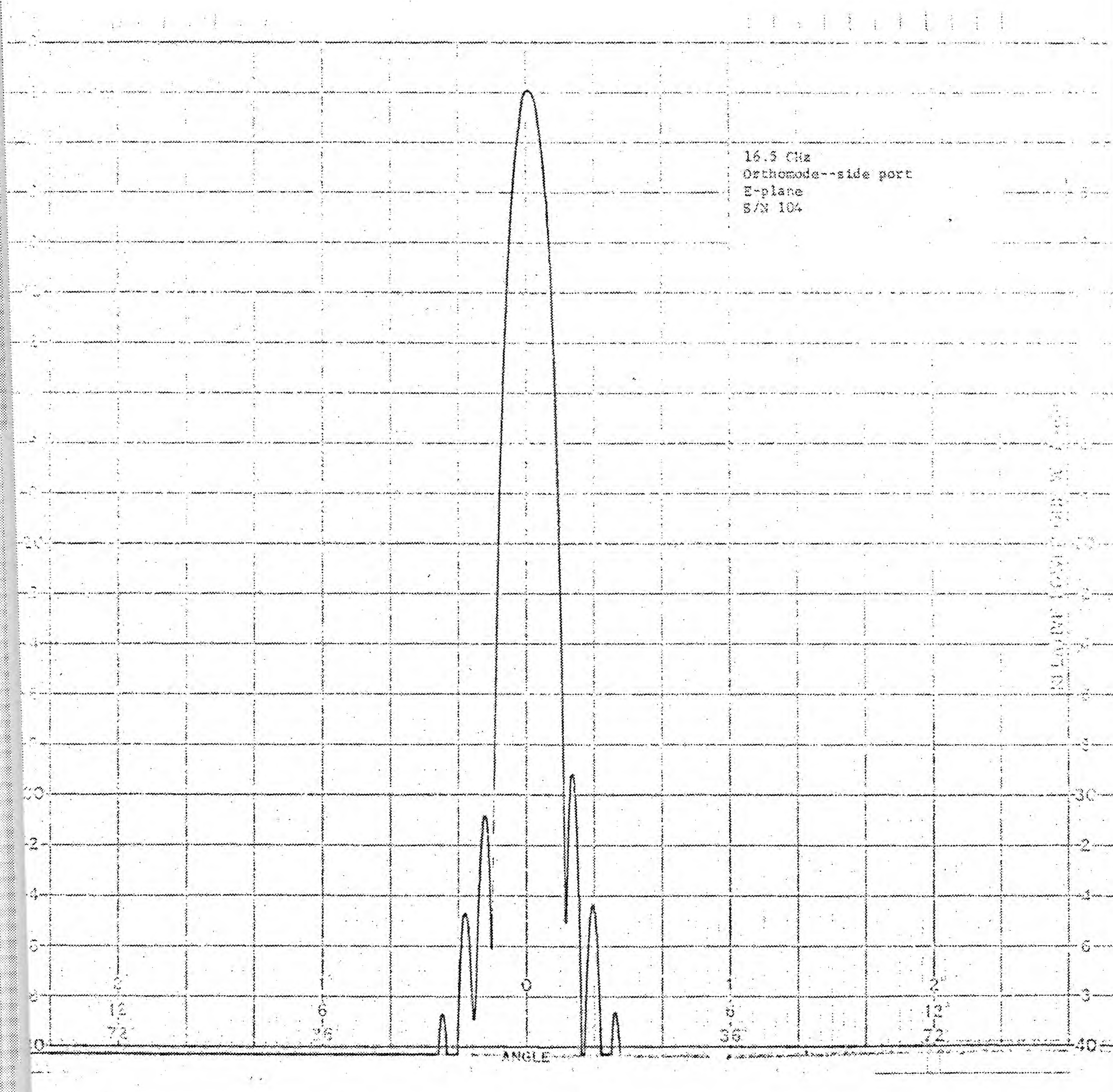

35.5 GHz
Orthomode--side port
45° plane
Cross-polarization
+20 db
S/N 103
RELATIVE POWER ONE WAY (db)
ANGLE
0



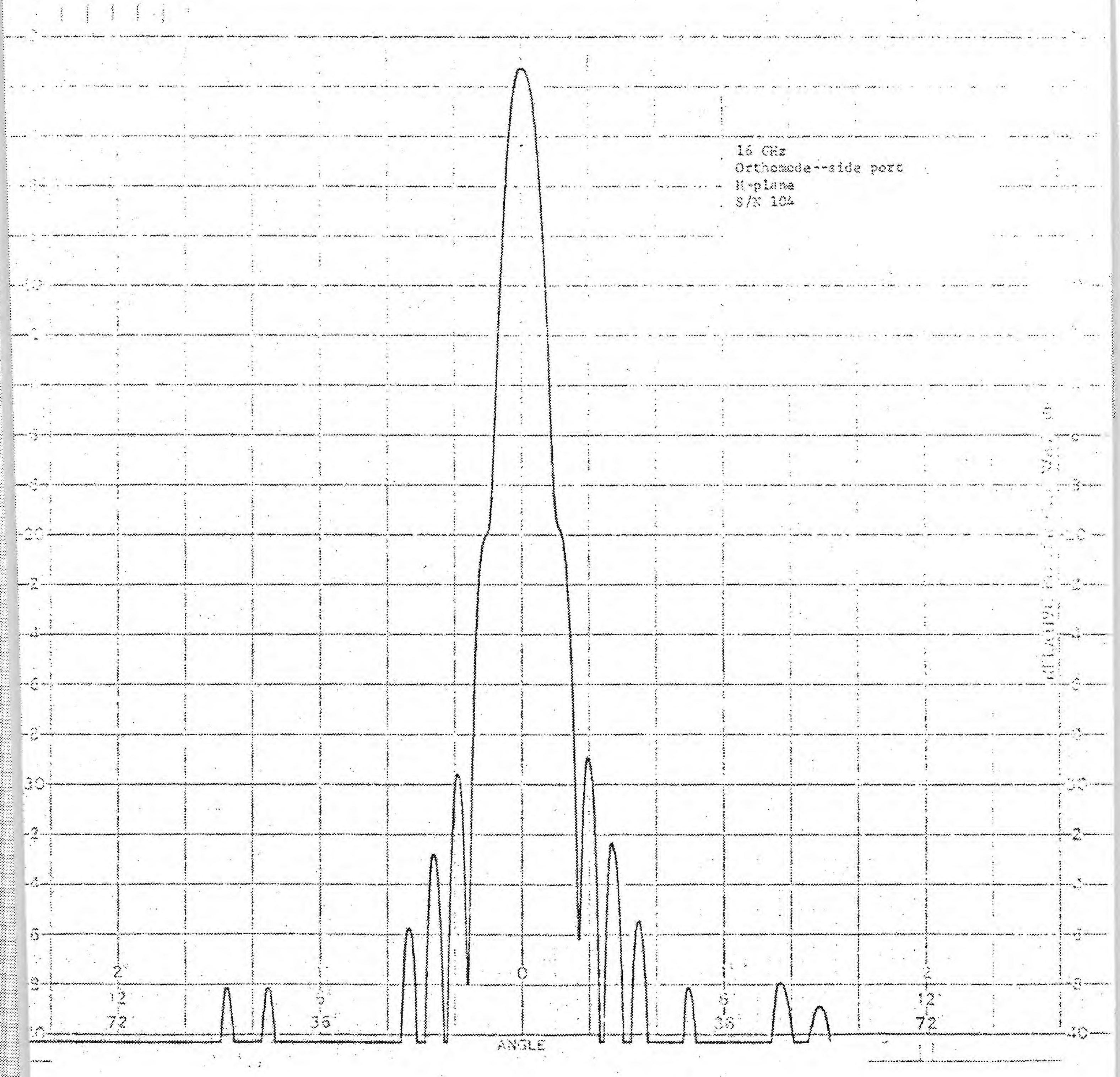
16 GHz
Orthomode--side port
E-plane
S/N 104
ANGLE

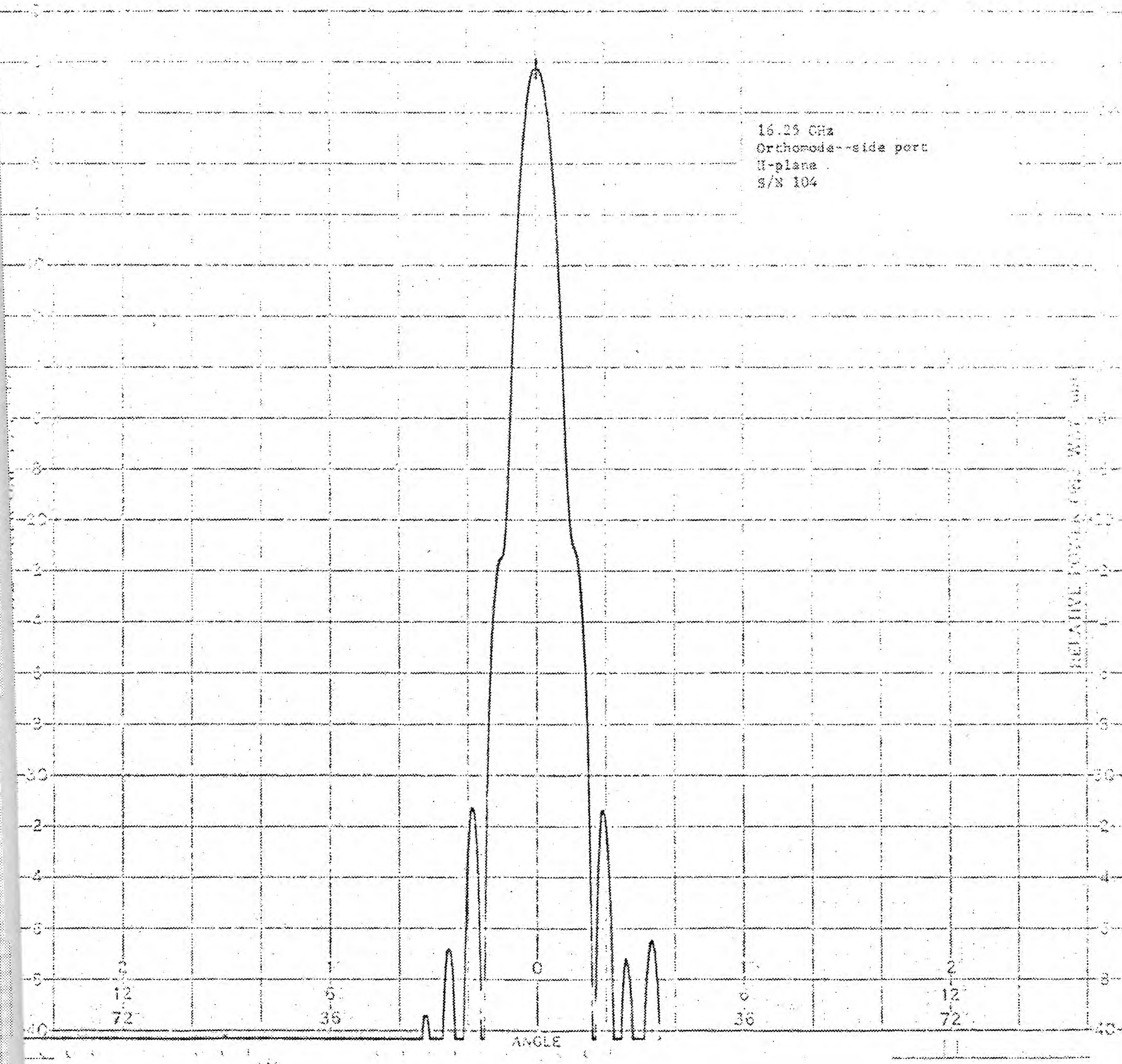


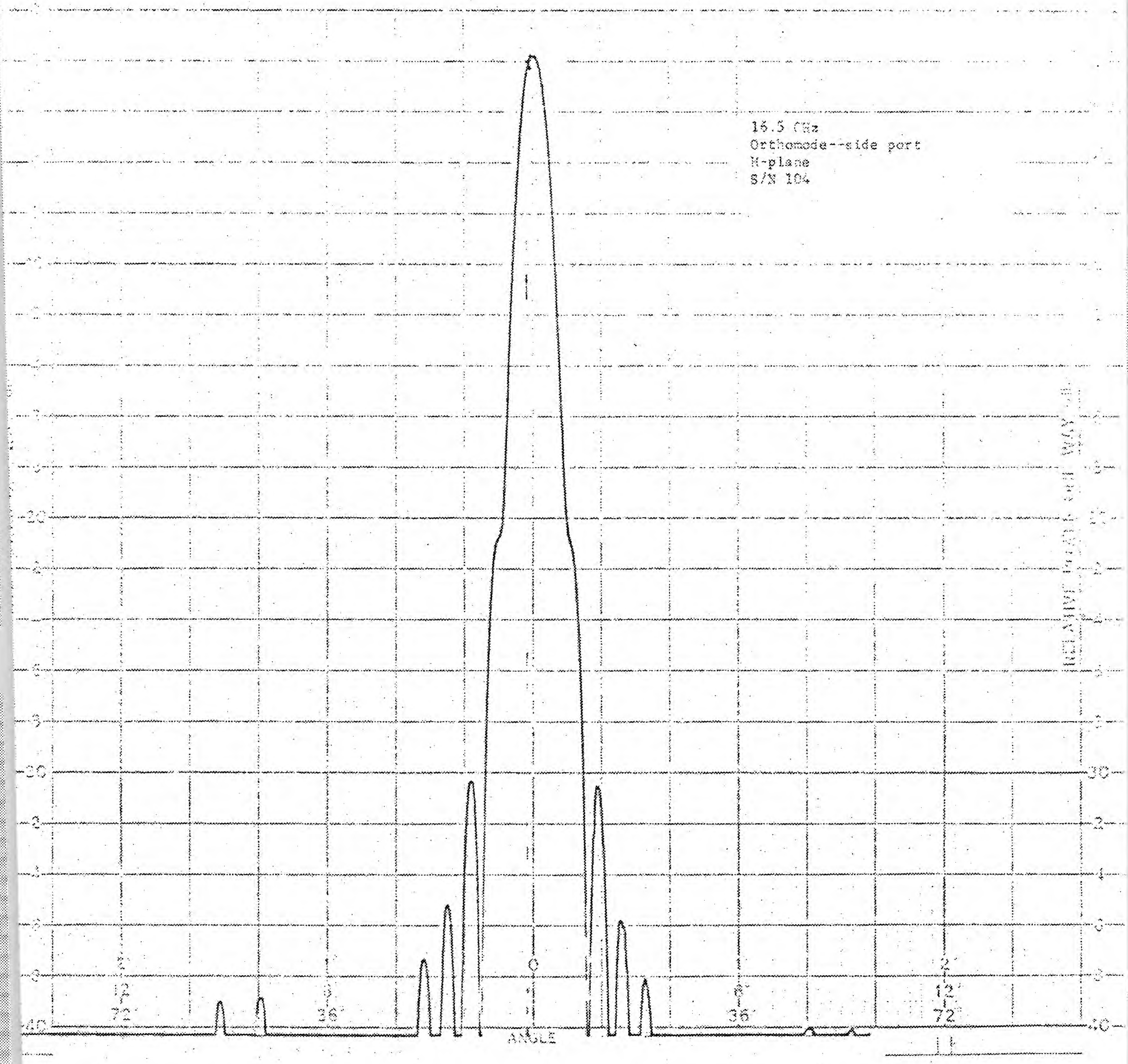
16.25 GHz
Orthomode--side port
E-plane
S/N 104
12°
72°
6°
36°
0
6°
36°
12°
72°
ANGLE
10
20
30
40

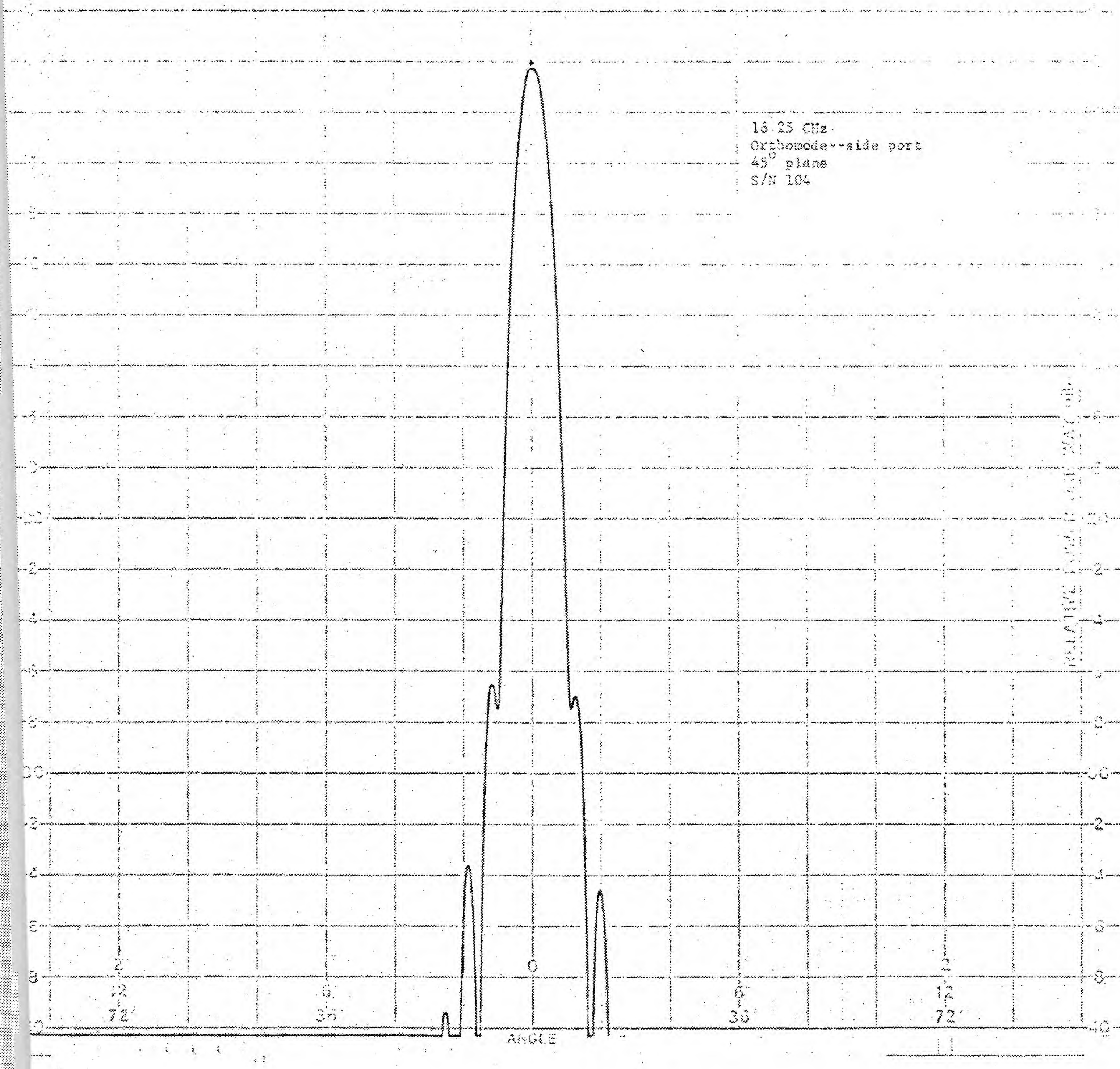


16.5 GHz
Orthomode--side port
E-plane
S/N 104
ANGLE

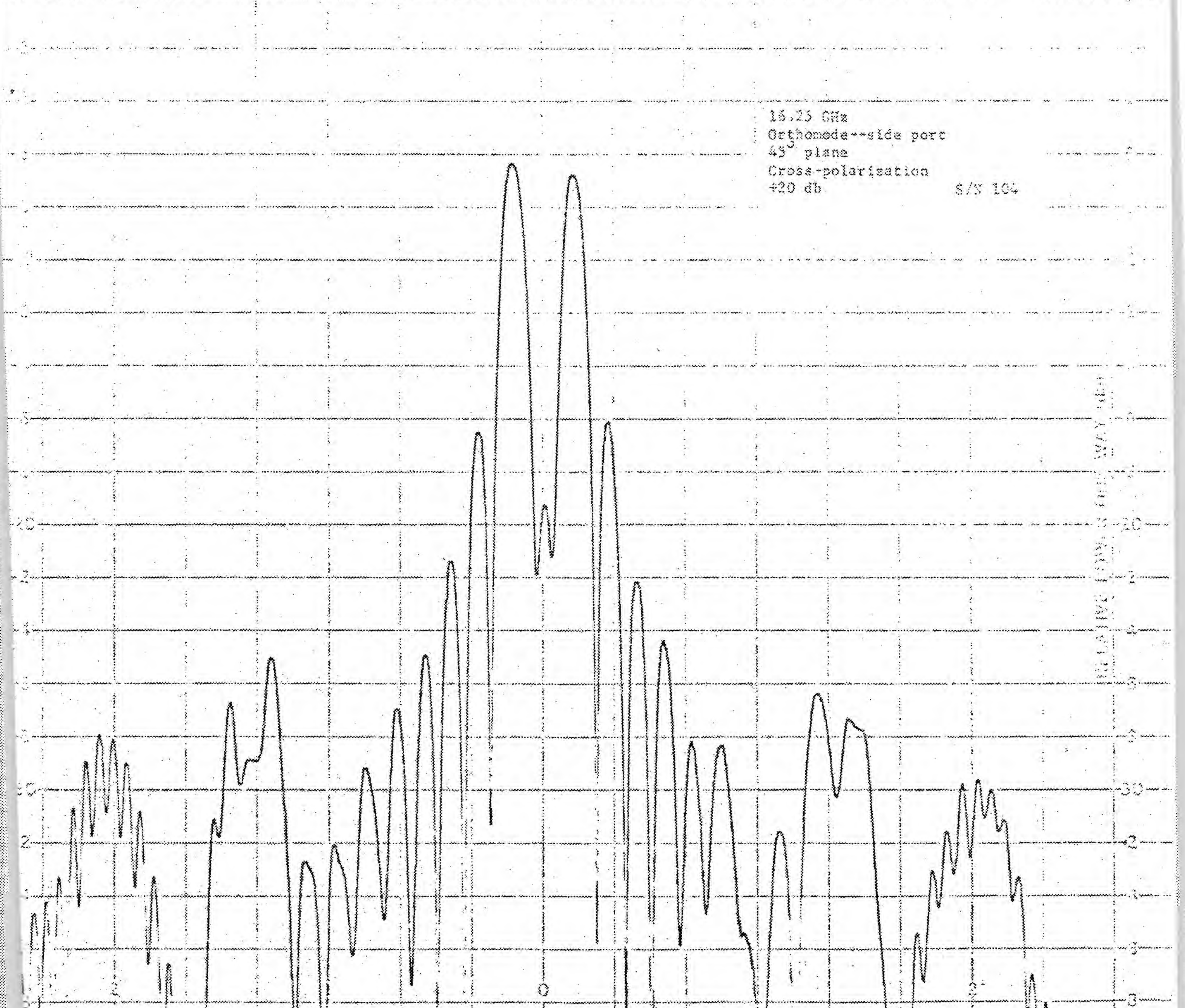

16 GHz
Orthomode--side port
H-plane
S/X 104
ANGLE
0
2
12
72
5
36


16.25 GHz
Orthomode--side port
H-plane
S/N 104
RELATIVE POWER (dB)
ANGLE
0
12
72
6
36
-10
-20
-30
-40


16.5 GHz
Orthomode--side port
H-plane
S/N 104
-20
-30
-40
0
ANGLE
36°
72°
RELATIVE POWER ONE WAY dB

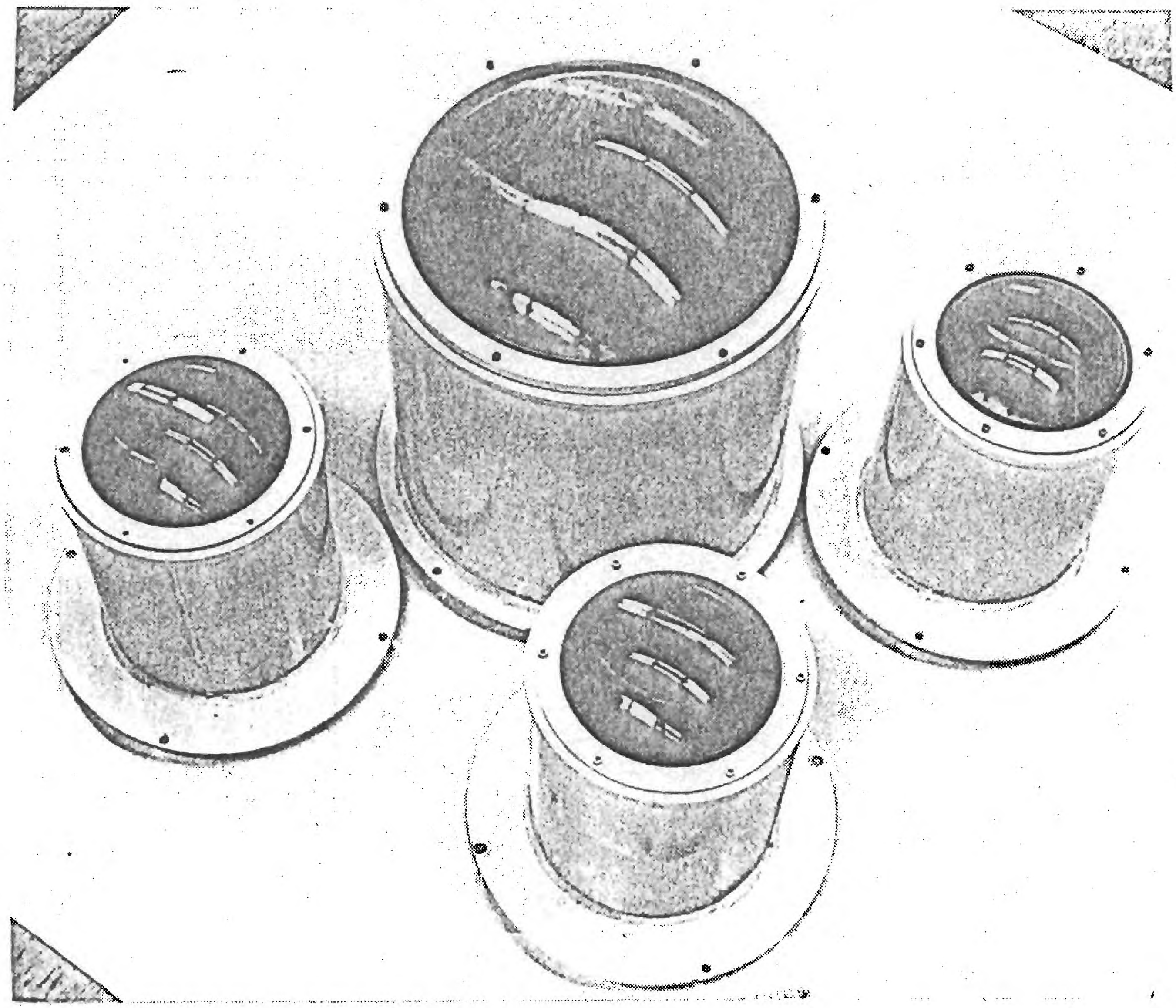


16.25 GHz
Orthomode--side port
45° plane
S/N 104
0
12
72'
6
36'
ANGLE


15.25 GHz
Orthomode--side port
45° plane
Cross-polarization
+20 db
S/N 104
ANGLE
-20
-30
-40

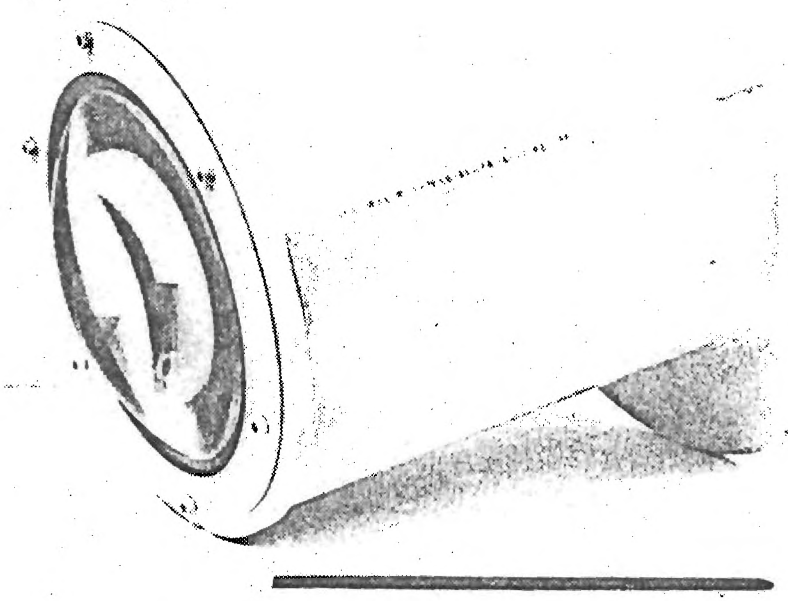
APPENDIX B

ANTENNA PHOTOGRAPHS

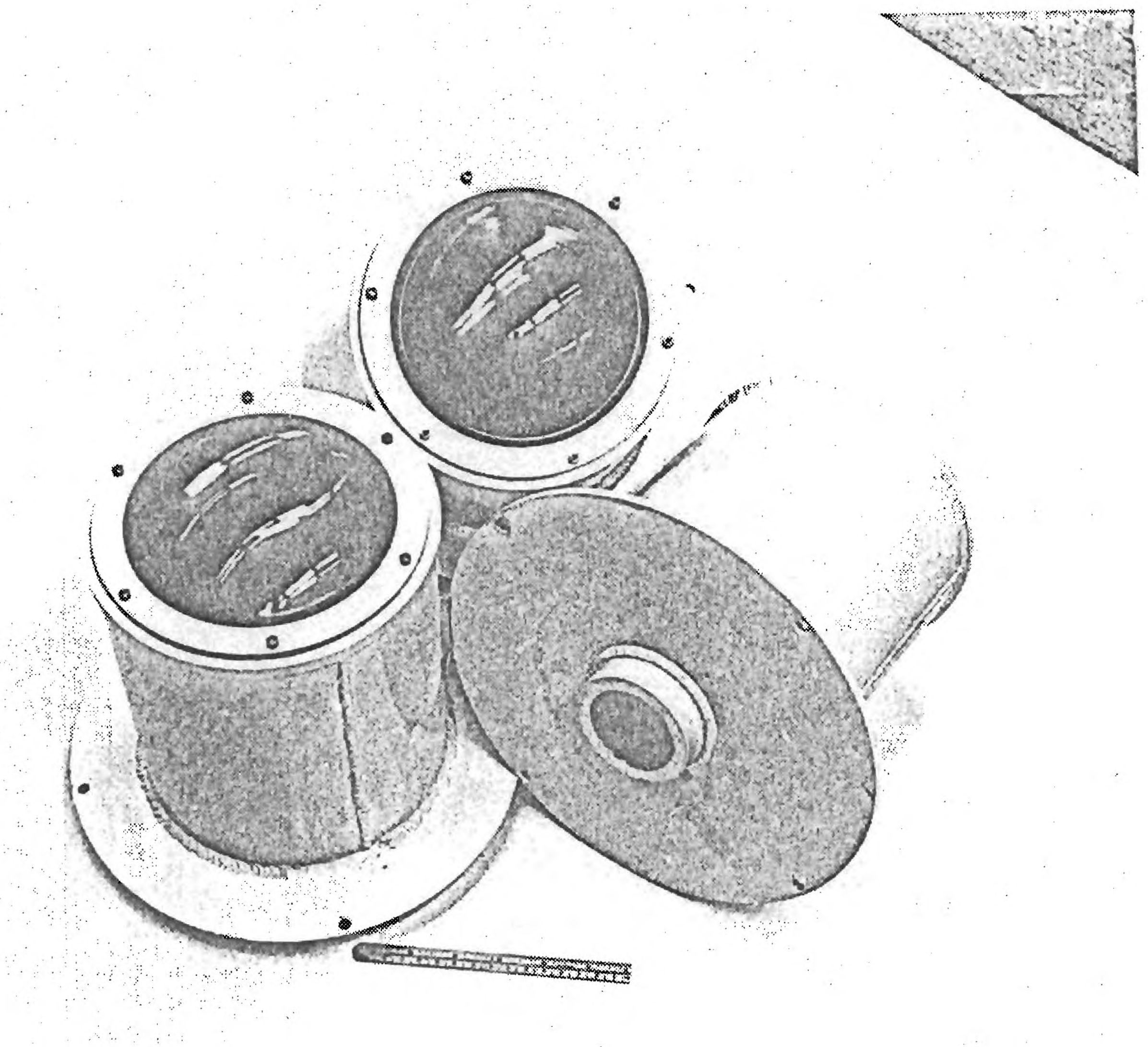


Five and Ten-Inch Diameter (Ku and Ka Band) Antennas - View A

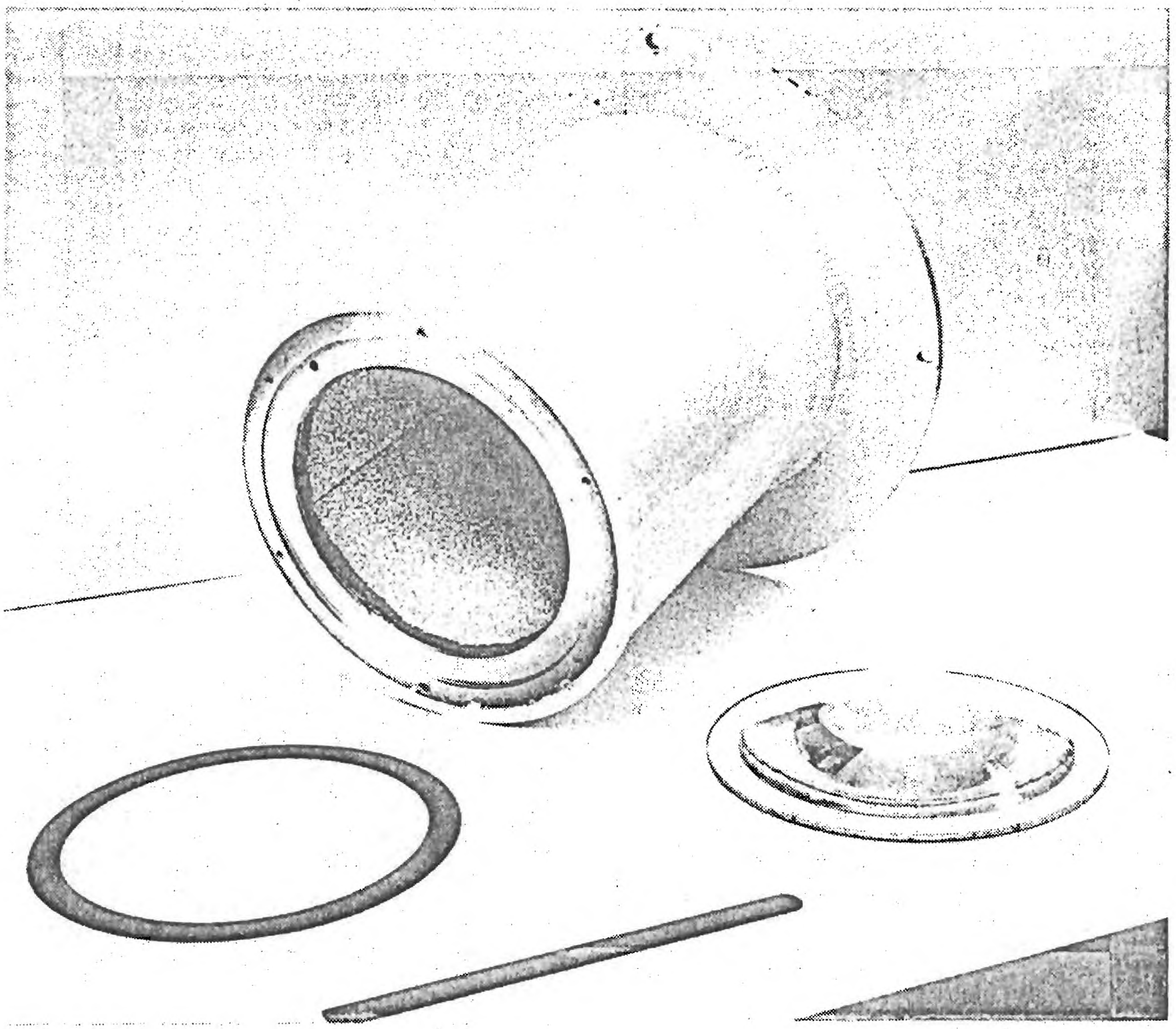
Five and Ten-Inch Diameter (Ku and Ka Band) Antennas - View B



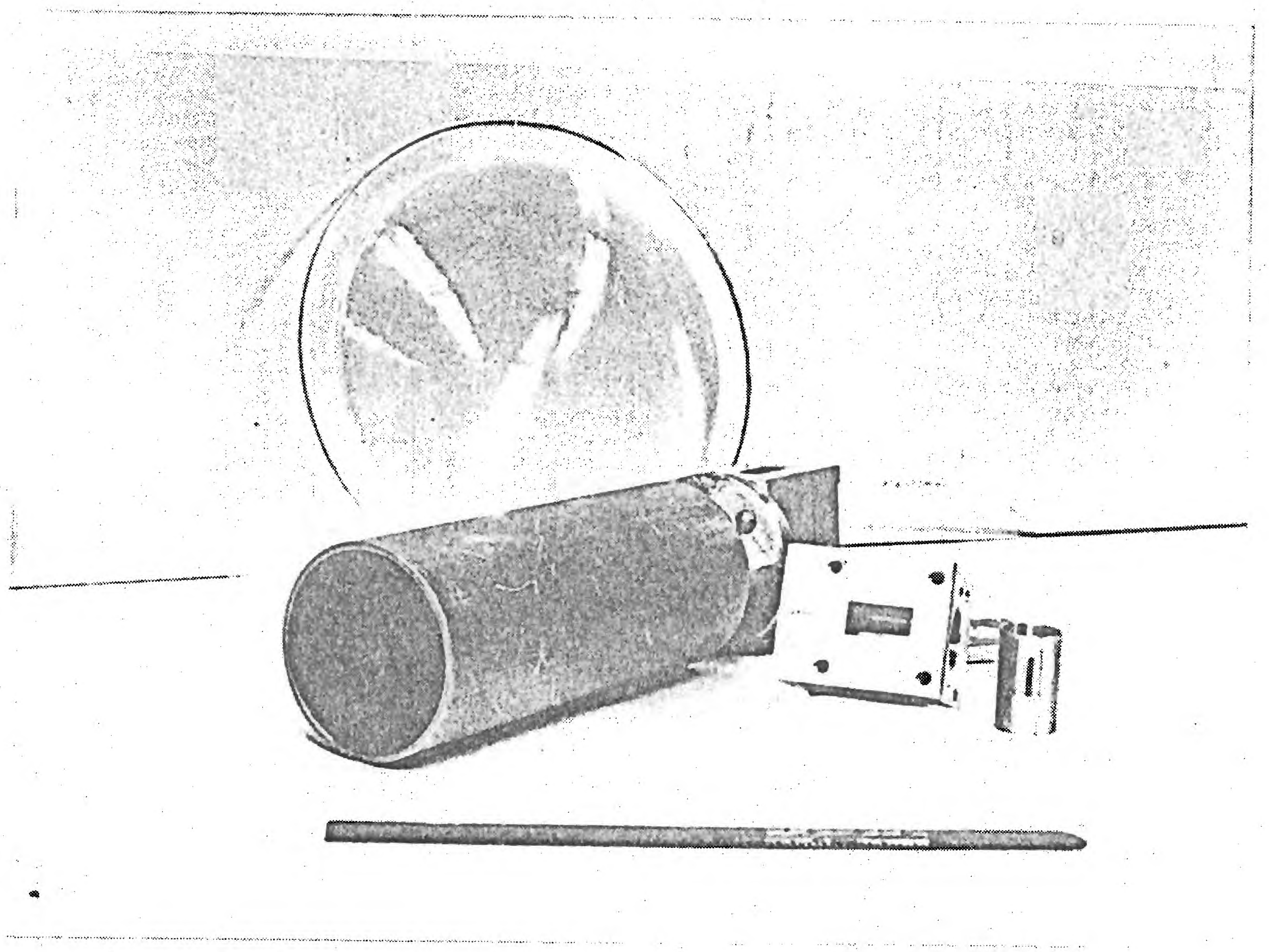
Five-Inch Diameter Lens Fully Assembled



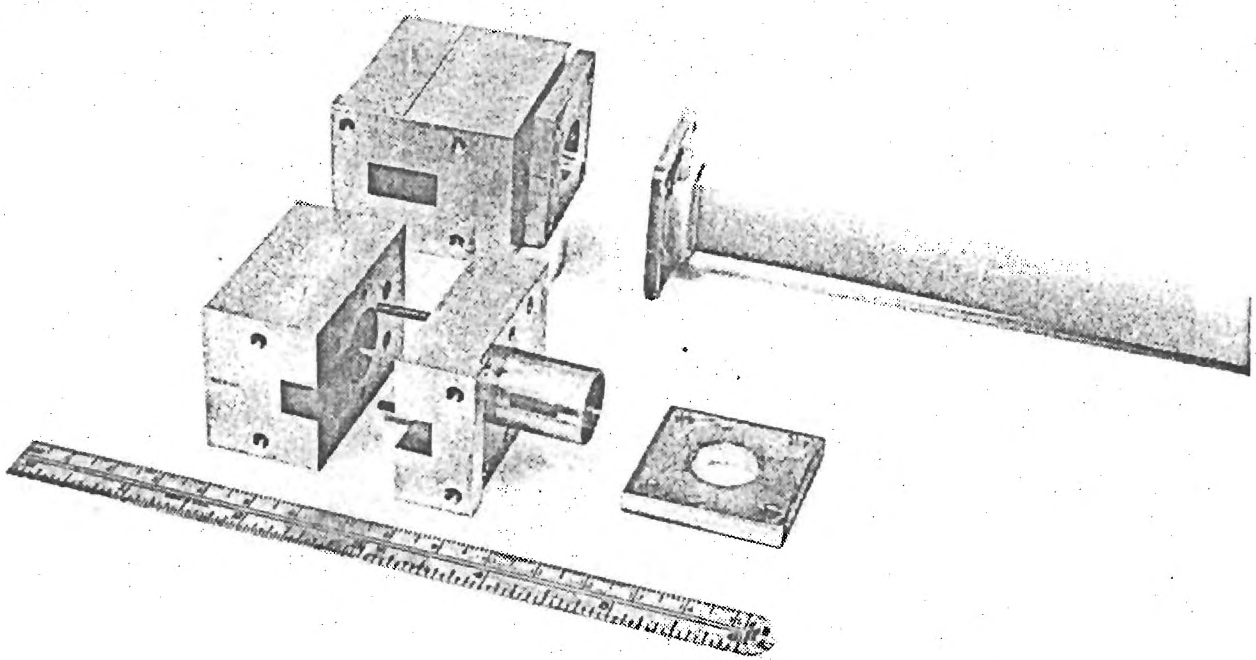
Five-Inch Diameter Lenses - Front, Side and Back Views



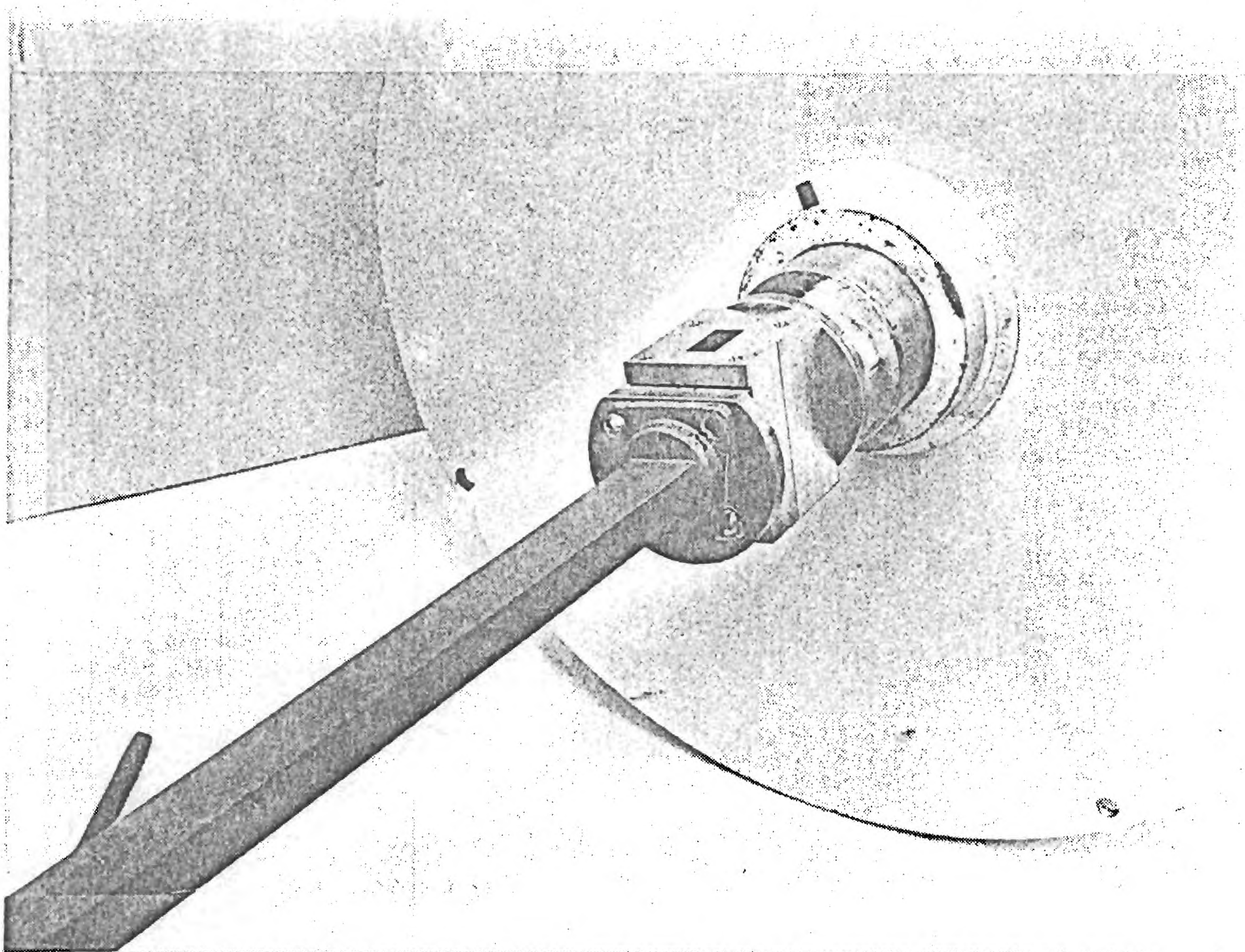
Five-Inch Diameter Lens Assembly Elements



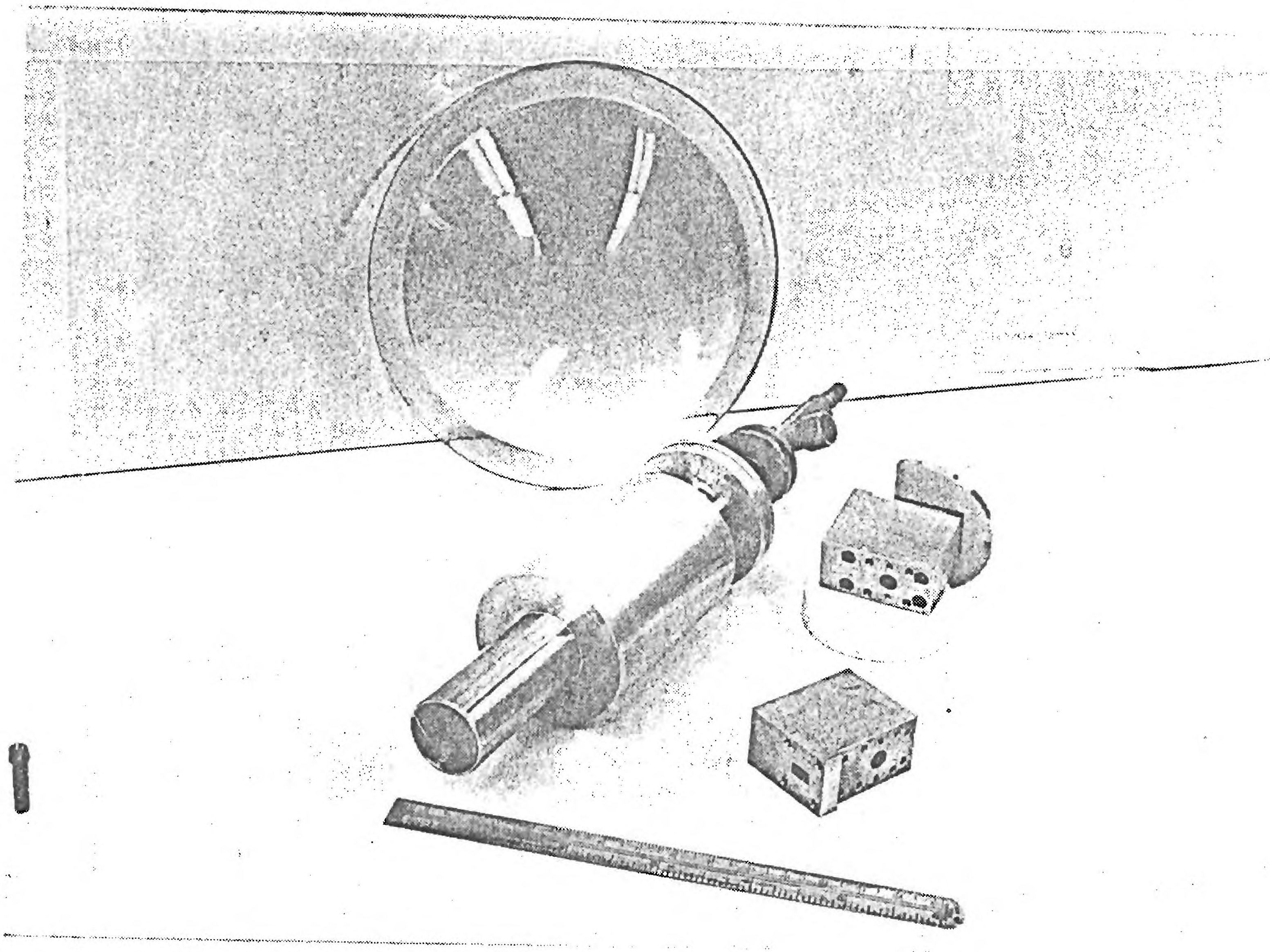
5-Inch Lens and Ku Band Feed Elements - Horn and Orthomode Transducer



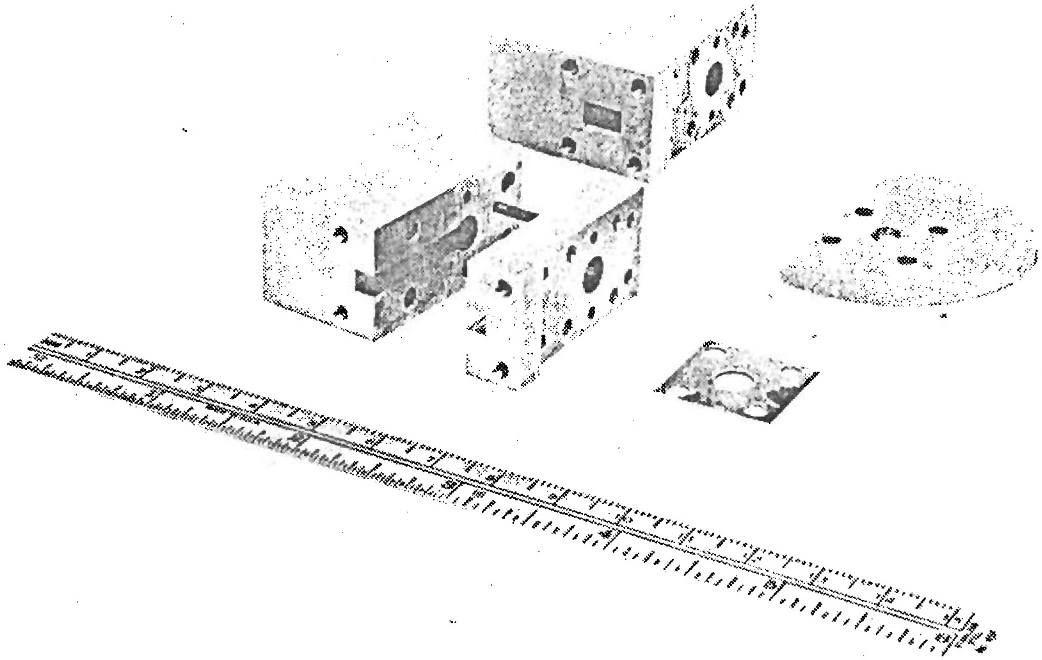
Ku Band Orthomode Transducer Elements



Ku Band Orthomode Transducer Assembled Into Lens Antenna



5-Inch Diameter Lens and Ka Band Feed Elements - Horn and Orthomode Transducer



Ka Band Orthomode Transducer Elements

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GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

16 November 1977

U.S. Army Missile Research
and Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 7
Covering the Period 1 October 1977 to 31 October 1977

Gentlemen:

As of this reporting period the vendor has promised to ship the 3 watt Ka-band solid state amplifier on Wednesday, November 16, 1977. The amplifier design incorporates a Gunn diode instead of the Impatt diode which was the original device being considered. Peak power of the current design is about 2.5 watts. This power level does not reach the design goal of 3 watts, but it does exceed the minimum specification of 2 watts.

As a result of the redesign of the 3 watt amplifier, the mechanical and electrical interface requirements have changed. Georgia Tech personnel have attempted to determine the extent of the changes via telephone contact with the vendor, however, project personnel anticipate that proper mounting and operation of the device will require some time after its arrival.

The detailed design of the frame for carrying the Ku-band system has been sent to the Georgia Tech model shop for fabrication, which should take about two weeks. Electrical integration of the system is nearly complete.

Modification of the 95 GHz system is progressing. With the exception of some specially shaped waveguide pieces for assembly of the microwave section, all major radar components have been received from the various vendors.

It is expected that the earliest date by which Georgia Tech project personnel could depart for field testing the three systems is just prior to the Christmas holiday period in December. Hopefully, set up operations can begin at that time so that the actual testing can be well underway early in January.

The expenses incurred during the reporting period total $18,123.85, bringing the total expenditure to $88,352.58. This total does not include the cost of the Ka-band solid state amplifier; the project will be debited an additional $10,000 upon receipt and acceptance of the amplifier.

Respectfully submitted,

James A. Scheer
Project Director

JAS/cyk

Approved:

J. L. Eaves
Associate Director
Radar and Instrumentation Laboratory

A1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

4 January 1978

U.S. Army Missile Research
and Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 8
Covering the Period 1 November 1977 to 30 November 1977

Gentlemen:

Hughes (Electron Dynamics Division) has shipped the 3 watt amplifier (as they promised) and Georgia Tech is in the process of mounting the device and supplying the appropriate power and control signals.

Most of the effort last month has been directed toward electrical integration of the 16 GHz system components, fabrication of the 95 GHz system, and assembly of the support for the weather and environmental sensors.

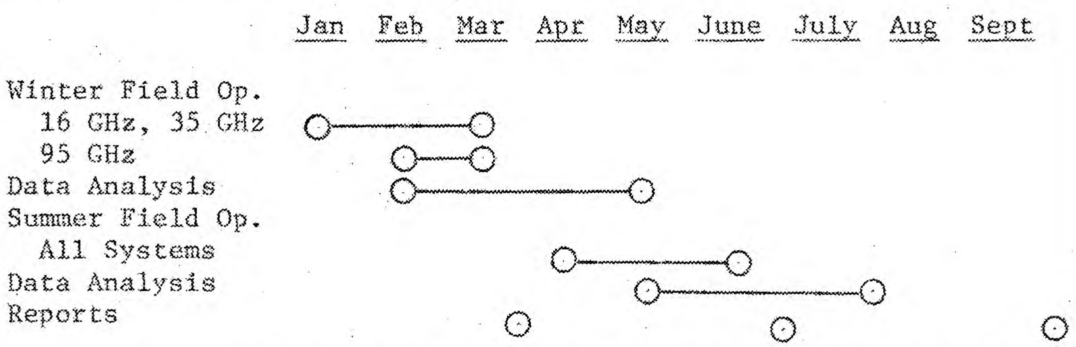
Fabrication of control cables and control panels for use with the 16 GHz system was begun. Until this time, system integration was performed using temporary bread-board type cables and control panels, built quickly in order to expedite trouble shooting of the system. These are now being replaced with longer cables and 19 inch panel mounted controls.

The carriage for the 16 GHz system, as well as the one for the 35 GHz system, are expected from the model shop in the middle of December. The delay is due to a number of problems encountered with materials and supplies and outside services such as plating and finishing. Final mechanical integration of the system will begin upon receipt of the frame.

Fabrication and design of the 95 GHz system modifications are progressing. The special waveguide parts for the 95 GHz system have not yet arrived, and in fact are not expected until sometime in January 1978. It is anticipated that due to the delivery times on the 95 GHz components and the time which will be required to modify the system, Georgia Tech will not be able to operate the 95 GHz system in the field during the first part of the winter tests, but will be able to during the latter portion. The schedule shown in the end of this report shows the expected times.

The environmental sensors (temperature, humidity, pressure, rainfall, wind speed and direction) are mounted on a mast with a tripod which can be placed in the vacinity of the radar field of view. This assembly should not be in the radar beam because of the influence it may have on the reflectivity characteristics of the background. A panel is being designed which will present the information from each sensor, each on its own meter, and a rotary switch which will present the information from the selected sensor on an L.E.D. display.

It is expected that a further slip in the starting time for the field operation will be experienced. The goal for departure is now mid January. The following schedule shows the planned timing of the program from this date onward.



The expenses incurred during the reporting period total $34,938.93, including the $10,000 cost of the 35 GHz amplifier, bringing the total to date to $123,291.51. This total includes the expenses incurred on all tasks including those added in Mod. 1 and Mod. 2.

Respectfully submitted,

James A. Scheer
Project Director

JAS/cyk

Approved:

J. L. Eaves
Associate Director
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

13 January 1978

U.S. Army Missile Research
and Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 9
Covering the Period 1 December 1977 to 31 December 1977

Gentlemen:

During the reporting period, Mr. Lucien C. Bomar was appointed Project Director of the project including Mod 1, but not Mod 2. Mr. James A. Scheer is the Associate Project Director on the contract including Mod 1 and Project Director for the tasks added in Mod 2.

The Hughes 3 watt amplifier was activated and for a while seemed to perform satisfactorily. There was an anomaly in the pulse amplitude coincident in time with an anomaly in the TTL Logic Trigger pulse. It appears from the schematic that the use of the TTL as a driver creates a marginal condition, so a driver circuit was added. Georgia Tech personnel are in communication with Hughes' personnel to try to resolve interface difficulties.

Part of the frame of the 16 GHz system was received from the model shop and the antenna, transmitter, receiver, microwave board and control circuitry were assembled.

The waveguide bends, twists, etc., that are being specially made for the M-band system are due to be delivered in January. The remainder of the 95 GHz waveguide components are not due to be delivered until early February resulting in a late February completion of the 95 GHz radar assembly. Plans are to use the 95 GHz system as soon as fabrication is completed.

The fabrication of environmental instrumentation and interface circuitry is underway. This system will allow the weather data to be transmitted by cable to the top of the F1 tower and be recorded with the radar data.

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The goal for departure is still mid January, but may slip to late January due to completion of the radar systems and interface.

Mod 2 Tasks

Mr. N. C. Currie and J. A. Scheer traveled to Hanscomb AFB, MA and Griffiss AFB, NY to survey possible field sites for snow measurements. The evaluation criteria included: (1) availability of snow on the ground for a good percentage of the winter, (2) availability of a suitable test tower, (3) ability to deploy a tank or other test vehicle in the test area, (4) availability of open fields and tree areas near the tower, (5) assurance of adequate logistic support and (6) nearness of supply vendors for purchase of needed materials. After visiting both sites, the Verona test site in New York was chosen as the recommended site because of a better measurement scenario and apparent better support. A shelter will have to be built on the tower.

Purchase has begun on the required ground truth measuring equipment.

Tasks during the next month will include continuation of planning for the snow measurements, continuation of procurement for the ground truth equipment and planning for the fabrication of the shack. Additionally, materials will be procured for integration of the radiometers with the active measurements system.

Financial Status

Expenses incurred during the reporting period total $30,336.38, of which $4,195.85 are associated with the Mod 2 effort. The total expenses to date are $153,627.89, of which $4,468.01 are associated with Mod 2.

Respectfully submitted,

Lucien C. Bomar, Project Director
James A. Scheer, Assoc. Project Director

LCB/cyk

cc: Boaz Gelernter
Ted Lane

Approval:

J. L. Eaves
Associate Director
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

17 March 1978

U.S. Army Missile Research
and Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 10
Covering the Period 1 January to 31 January 1978

Gentlemen:

The 35 GHz, 3 watt Hughes amplifier was installed in the Georgia Tech K_a-band measurement radar during the past month. The trigger problems encountered earlier were resolved through discussions with Hughes personnel and a minor modification was made by Georgia Tech to the amplifier modulator. Final checkout and tests of the amplifier and K_a-band radar are being completed.

The frame for the K_u-band measurement system was completed during the past month. However, the unit was returned to the model shop for some mechanical modification to the frame supports. The frame modification was completed and returned during the last week of this reporting period. Final assembly and checkout of the K_a-band radar and associated instrumentation were in progress at the end of the reporting period.

The M-band transmitter which is being purchased for the modification of the Georgia Tech M-band measurement radar is not due for delivery until late February. This delivery will result in a completion data that will preclude the use of the M-band radar in the first series of measurements. However, no difficulties are foreseen in completion of the radar for the summer measurement.

All final tests and checkout of the K_u-band and K_a-band radars will be completed in early February. The radars and instrumentation will be transported to Huntsville and field operations will commence during the first week of February.

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Mod 2 Tasks

Planning for the snow measurements continued during the month along with the procurement of the ground truth equipment and procurement and installation of the equipment shelter on the test tower. Fabrication of the framework for holding the radar and radiometers is underway. The units are to be mounted on a common mounting surface which is attached to an elevation over azimuth turntable. The units can then be positioned by use of a TV boresight display and a digital angle readout.

Tasks during the next month will include completion of the radar mounting structure and installation of the equipment shelter.

Financial Status

Expenses incurred during the reporting period total $45,059.35 of which $16,755.63 are associated with the Mod 2 effort. The total expenses to date are $198,687.24 of which $21,223.64 are associated with Mod 2.

Respectfully submitted,

Lucien C. Bomar, Project Director
James A. Scheer, Assoc. Project Director

LCB/cyk

cc: Boaz Gelernter
Ted Lane

Approval:

J. L. Eaves
Associate Director
Radar and Instrumentation Laboratory

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ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

20 March 1978

U.S. Army Missile Research
and Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/Hammond Green
Redstone, Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 11
Covering the Period 1 February to 28 February 1978

Gentlemen:

The K_a-band and K_u-band measurement radar systems were completed during the first week in February. The radar systems and associated instrumentation were transported to Redstone Arsenal, Alabama on 6 February 1978. Equipment installation on the F1 test tower began the next day. The remainder of the month was devoted to equipment installation, checkout, calibration and recording of the test data.

Plans for the next period are to continue data collection through mid March, followed by a return to Georgia Tech and commencement of the reduction and analysis of the recorded data.

Mod 2 Tasks

Fabrication and checkout of the K_a-band radar and turntable assembly were completed during the past month. In addition, Air Force representatives Ted Lane and Ralph Calhoun were present in February to witness final testing of the K_a-band radar system.

The equipment shelter procurement was completed and the shelter installed atop the test tower. The radar and radiometer measurement systems were being prepared for transportation to New York at the end of the reporting period. The equipment will be transported to the New York test during the first week of March with field operations commencing immediately upon installation on the test tower.

Financial Status

Expenses incurred during the reporting period total $62,001.58, of which approximately $16,000 are associated with the Mod 2 effort. The total expenses to date are $260,688.82, of which approximately $37,223 are associated with Mod 2.

Respectfully submitted,

Lucien C. Bomar, Project Director
James A. Scheer, Assoc. Project Director

LCB/cyk

cc: Boaz Gelernter
Ted Lane

Approval:

J. L. Eaves
Associate Director
Radar and Instrumentation Laboratory

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ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

21 April 1978

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 12
Covering the Period 1 March to 30 March 1978

Gentlemen:

Field test measurements were conducted from the F1 test tower in Huntsville, Alabama, using the Ka and Ku-band radar systems during the first two weeks of the reporting period. The desired data set was completed on 4 March and the radar and instrumentation were removed from the tower and transported back to Atlanta on 16 March.

The remainder of the reporting period has been devoted to the cataloging of the recorded data and preparation to run data on the data analysis facility at Georgia Tech. Analog data will be screened by using the spectrum analyzer and correlator to evaluate the statistical properties (probably densities, frequency spectra, correlation functions) of the recorded amplitude and phase data. Selected runs will also be digitized and processed through the Georgia Tech CYBER 70 Model 74 computing facility, to produce some of the same statistical data from the calibrated data files. In addition, the CYBER will be used to exercise signal processing algorithms using the recorded data.

Plans for the next reporting period are to continue the data reduction and analysis currently in progress. Preparation of the interim technical report and an informal preliminary data analysis briefing will begin this month.

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Financial Status

Expenses incurred during the reporting period total $23,640.61 with the total expenses to date being $284,329.43.

Respectfully yours,

Lucien C. Bomar, Project Director
James A. Scheer, Assoc. Project Director

LCB/cyk

cc: Boaz Gelernter

Approved:

J. L. Eaves
Associate Director
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

22 May 1978

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 13
Covering the Period 1 April to 30 April 1978

Gentlemen:

The data reduction and analysis of the Ku- and Ka-band reflectivity data continued during the month. A selected sample of the data was examined on the hardware correlator and spectrum analyser to obtain preliminary results on the amplitude and phase characteristics. Other selected data runs have been digitized on the data facility and are being processed through the Georgia Tech Cyber 70 a computer center to obtain calibrated statistical data. These data are to include probability density functions, frequency spectra, and correlation functions.

Efforts continued in the fabrication of the 95 GHz radar. Fabrication of the modulator for the EIO transmitter as well as the radar electronics were begun during this month. Delivery date of the EIO has been extended and is now set for early May. All other rf components have been recieved and the rf-front end has been assembled.

Plans for the next reporting period are to hold an informal preliminary data analysis briefing to discuss the results to date, and continue the preparation of the interim report. Fabrication of the 95 GHz radar will also continue with consideration being given to obtaining an alternate transmitter.

Financial Status

Expenses concurred during the reporting period total $5,221.43 with the total expenses to date being $289,550.86.

Respectfully submitted,

Lucien C. Bomar
Project Director

LCB/cyk

Approved:

James A. Scheer, Chief
Experimental Division
Radar and Instrumentation Laboratory

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A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

19 June 1978

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 14
Covering the Period 1 May to 31 May 1978

Gentlemen:

The analysis of the K_u-band and K_a-band radar reflectivity data continued during the past month. Emphasis is currently being placed on computer analysis of the statistical properties of the K_a-band amplitude and pseudo coherent phase data. An informal project meeting was held at Georgia Tech on 5 June 1978. The purpose of the meeting was to review data results to date and discuss future analysis and data gathering. In attendance were A. H. Green, USAMIRADCOM and R. D. Hayes, M. W. Long, L. C. Bomar, S. P. Brookshire of Georgia Tech EES.

The fabrication of the 95 GHz radar also continued during the past month. The EIO to be used as the transmitter has been further delayed. However, the vendor has agreed to loan Georgia Tech a lower power tube (500 watts peak) to complete development of the radar and to conduct the summer field test program. This tube is scheduled to be at Georgia Tech by mid June. The modulator for the radar has been breadboarded and tested in conjunction with a 95 GHz magnetron and produces RF pulses of less than 20 nanoseconds. Breadboard testing with the EIO will begin shortly after receipt of the tube.

Plans for the next reporting period are to continue the data analysis, and fabrication of the 95 GHz radar, as well as preparation of the interim report.

Financial Status

Expenses incurred during the reporting period total $13,604.91 with total expenses to date being $303,155.77.

Respectfully submitted,

Lucien C. Bomar
Project Director

LCB/cyk

Approved:

James A. Scheer
Chief, Experimental Division
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

14 July 1978

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/H. Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 15
Covering the Period 1 June to 30 June 1978

Gentlemen:

The analysis of the winter reflectivity data and preparation of the interim report continued during the past month, along with development of the 95 GHz radar and planning for the summer measurement phase.

The EIO to be used as the transmitter for the 95 GHz radar has been delayed as noted last month. However, the vendor has loaned Georgia Tech a lower power tube to test the modulator design. This lower power tube was received during the past month and testing was begun late in the month. In addition Georgia Tech has received a new magnetron oscillator (1 Kw) which has been successfully integrated with a short pulse modulator, producing RF pulses of less than 20 nanoseconds. Work will continue on development of the EIO modulator but in the event that it cannot be completed in the time frame required for the summer measurement phase, the magnetron will be used as the transmitter.

The summer series of measurements are currently being planned for mid August. The test plan for the summer measurements is being completed and the Ku and Ka-band radars are being prepared for return to Huntsville during that period.

Plans for next month are to continue the data analysis, complete the interim report and continue fabrication of the 95 GHz radar.

Financial Status

Expenses incurred during the reporting period total $20,611.14 with total expenses to date being $323,766.91.

Respectfully Submitted,

Lucien C. Bomar
Project Director

LCB/cyk

Approved:

James A. Scheer
Chief, Experimental Division
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

17 August 1978

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Attn: DRDMI-TEG/H. Green
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 16
Covering the Period 1 July to 31 July 1978

Gentlemen:

The reduction and analysis of the winter reflectivity data continued during the month, along with preparation of the interim report, completion of the Phase II Test Plan and continued fabrication of the 95 GHz radar.

The 95 GHz EIO which had been planned as the 95 GHz radar transmitter has been replaced with a magnetron oscillator. This was a result of the late arrival of the EIO and difficulties in obtaining the desired short pulse. The magnetron has the same power output (1 kW), has been tested at a pulse width of 15 nanoseconds, and can be packaged in the radar in time to begin the summer measurements in August.

The test plan for the summer measurements was completed during the month. Plans currently are to begin the summer measurements in late August, although it appears there may be a conflict with NASA testing near the F1 tower. This conflict may result in the summer measurements being delayed until mid September.

Plans for the next month are to complete the current phase of data analysis, complete the interim report and begin the summer measurements, if possible.

An Equal Employment/Education Opportunity Institution

Financial Status

Expenses incurred during the reporting period total $-11,077.26 with total expenditures to date being $312,689.65. The reduction in total expenditures is the result of corrections in charges from previous months.

Respectfully submitted,

Lucien C. Bomar
Project Director

LCB/cyk

Approved:

James A. Scheer
Chief, Experiment Division
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

14 September 1978

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 17
Covering the Period 1 August to 31 August 1978

Gentlemen:

Efforts during the past month have been devoted to preparations for the summer measurements program. The instrumentation along with the 35 GHz and 16 GHz radar were prepared for shipment to Huntsville. The 95 GHz radar fabrication was nearing completion at the end of the month and should be ready at the time the Fl tower becomes available for the summer series of measurements.

Georgia Tech personnel were on site at the Fl tower at the end of the month to prepare the radar and instrumentation shelters for the equipment. Repairs were made to the radar shelter roofing, and an air conditioner installed in the instrumentation shelter. A stand was fabricated in the radar shelter to support the K_a and M-band radars, which will be jointly mounted and boresighted on an antenna positioner. The radars will be boresighted to T.V. camera to facilitate remote aiming of the radar antennas.

Plans for the next month are to ship the radars and instrumentation to Huntsville and begin the summer measurements.

<u>Financial Status</u>

Expenses incurred during the reporting period total $3,064.70 with total expenses to date being $315,754.35.

Respectfully Submitted,

Lucien C. Bomar
Project Director

LCB/cyk

Approved:

James A. Scheer
Chief, Experimental Division
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

13 October 1978

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A1981)

Subject: Monthly Contract Technical Status Report No. 18
Covering the Period 1 September to 31 September 1978

Gentlemen:

Efforts during the past month have been devoted to completion of the 95 GHz radar and preparation of the test site at the F1 tower at Redstone Arsenal.

The 95 GHz radar was completed, and operational tests conducted at Georgia Tech to validate the system sensitivity and performance. The system has a 1 kilowatt, EEV magnetron as its transmitter. It has capabilities of transmitting circular or linear polarizations (RC, LC, H,V) and can be agile between circulars (RC/LC) or linears (H/V) on a pulse-to-pulse basis. The radar currently has two selectable pulse widths of 15 nanoseconds and 50 nanoseconds. The receiver consists of two receiver channels (H and V), balanced mixers and a solid state local oscillator. Both channels have calibrated precision attenuators in the receive lines for calibration, and couplers are included at the input to each receiver channels so that calibration signals may be injected directly into the receiver. The video signals are processed in log amplifier/detectors and converted to box car video (at the prf) for recording. The unit consists of a remote RF/IF section which is connected to a control panel by a 20 foot cable allowing the radar to be used on a remotely controlled positioner. Two antennas are presently available for use in the program and have beamwidths of 3^{o} to 0.7^{o}.

The 35 GHz, 95 GHz and 16 GHz radars as well as the associated instrumentation and support equipments were packed and shipped to the test site at the Redstone Arsenal in Huntsville, Alabama on September 26. At the end of the month, the radars were being installed to begin test measurements during October.

Plans for the next month are to conduct the summer measurement from F1 test tower along with some preliminary on site analysis of the data being recorded.

Financial Status

Expenses incurred during the reporting period total $25,566.00 with total expenses to date being $339,393.00 .

Respectfully submitted.

Lucien C. Bomar
Project Director

LCB/vcy

Approved:

James A. Scheer
Chief, Experimental Division
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

27 November 1978

U. S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A1981)

Subject: Monthly Contract Technical Status Report No. 19
Covering the Period 1 October to 31 October 1978

Gentlemen:

Installation and checkout of the Ku-, Ka- and M-band radars on the F1 test tower was completed during the reporting period along with commencement of data acquisition. The radar systems are being operated simultaneously to obtain comparative data on reflectivity and polarization characteristics of tactical targets and clutter. The remainder of the month was devoted to obtaining the summer measurement data as detailed in the test plan.

Plans for the next reporting period are to continue data collection from the F1 tower along with some preliminary on site data analysis.

Financial Status

Expenses incurred during the reporting period total $15,287.13 with total expenses to date being $352,073.15.

Respectfully submitted,

Lucien C. Bomar
Project Director

LCB/vcy

Approved:

James A. Scheer, Chief
Experimental Division
Radar and Instrumentation Laboratory

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

18 December 1978

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, Alabama 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A-1981)

Subject: Monthly Contract Technical Status Report No. 20
Covering the Period 1 November to 30 November 1978

Gentlemen:

Efforts during the past month have been devoted to completion of the current measurement phase from the F 1 test tower facility at Redstone Arsenal. The Ku, Ka, M-band target and clutter signature data matrix was completed in early November and the MARFS angle error measurements were concluded in the third week of November. The radar systems and associated instrumentation were packed and removed from the F 1 tower on November 22nd and returned to Georgia Tech.

The remainder of the month was devoted to copying of selected data from the original data tapes into a format compatable for playback at Georgia Tech on an intermediate band tape recorder.

Plans for next month are to begin data analysis on the summer measurement data as well as additional analysis of the winter measurement data.

Financial Status

Expenses incurred during the reporting period total $10,510.25 with total expenses to date being $371,098.05.

Respectfully submitted,

Lucien Bomar
Project Director

Approved:

James A. Scheer, Chief
Radar Experimental Division

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A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

19 January 1979

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, Alabama 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A1981)

Subject: Monthly Contract Technical Status Report No. 21
Covering the Period 1 December to 31 December 1978

Gentlemen:

Efforts during the past month have been devoted primarily to the analysis of data recorded during the summer measurement phase. However, only a small data set is currently available at Georgia Tech for analyses. The data obtained during the summer was recorded on a wideband fm recorder, which was not available for the analysis phase. Consequently, a selected portion of the data was copied onto a seven channel wideband recorder, owned by Georgia Tech, to expedite the data analysis. At the same time, a set of new analog tapes have been ordered so that the summer data can be copied onto the intermediate band tape recorder currently available at Georgia Tech.

The work effort during the remainder of the month was abbreviated due to Christmas holidays.

Plans for next month are to obtain a complete set of summer measurement data compatable with the intermediate band recorder available to Georgia Tech and to continue with the data analysis. In addition, a meeting with MIRADCOM personnel is scheduled for January to review efforts on this program.

Financial Status

Expenses incurred during the reporting period total $3,590.22 with total expenses to date being $374,688.27.

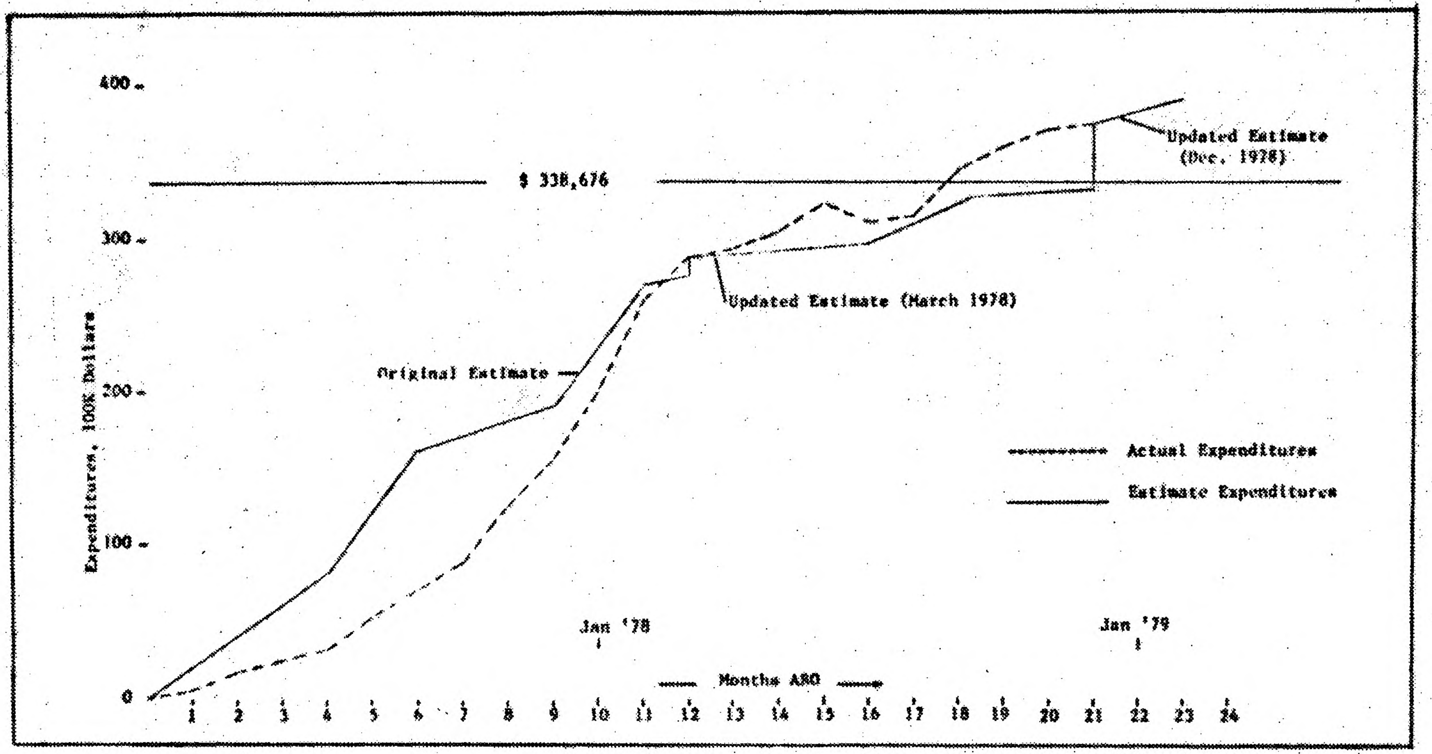
Respectfully submitted,

Lucien C. Bomar
Project Director

LCB/vcy

Approved:

J. L. Eaves
Associate Director
Radar and Instrumentation Laboratory



Financial Status

A-1981

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

15 February 1979

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A1981)

Subject: Monthly Contract Technical Status Report No. 22
Covering the Period 1 January to 31 January 1979

Gentlemen:

Efforts during the past month have been devoted to the data reduction and analysis of the summer measurement data. A complete copy of the summer measurement analog tape data was made during the past month. The data was copied on an intermediate band fm tape recorder which is available to Georgia Tech during the analysis phase. Analysis of this data has begun using the hardware correlator and spectrum analyzer as well as on the Cyber 70 computer facilities.

A program review meeting was held at the MIRADCOM facilities, Redstone Arsenal on 12 January 1979. In attendance were A. H. Green, R. C. Haraway and J. Mullins of MIRADCOM and J. L. Eaves, J. D. Echard, J. A. Scheer and L. C. Bomar of Georgia Tech. The purpose of the meeting was to review technical efforts to date as well as the financial status of the program. In addition, areas of future efforts related to this program were discussed.

Efforts for the next month will be devoted to analysis of the summer measurement data and some performance evaluations of selected signal processing techniques.

Financial Status

Expenses incurred during the reporting period total \$5,438.14 with total expenditures to date being \$380,126.41.

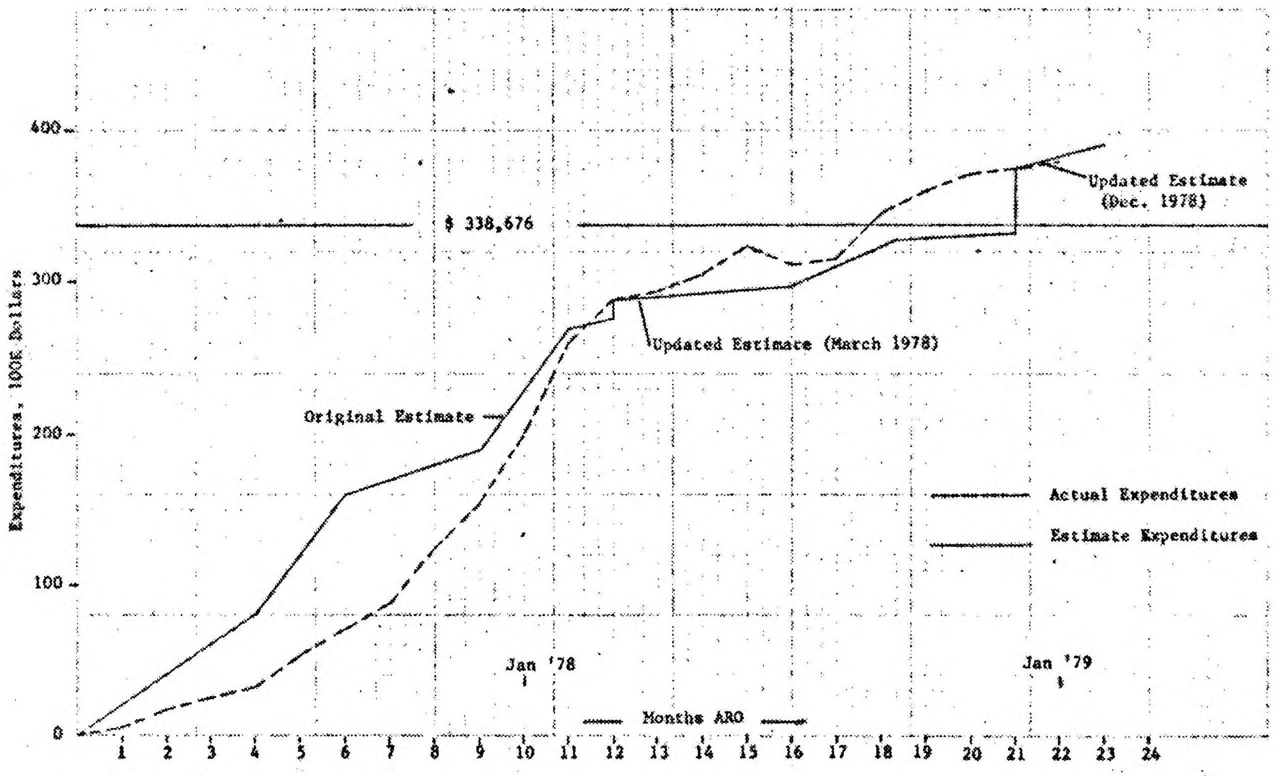
Respectfully submitted,

Lucien C. Bomar
Project Director

LCB/vcy

Approved:

James A. Scheer
Chief, Experimental Division
Radar and Instrumentation Laboratory



Financial Status

A-1981

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

15 March 1979

U.S. Army Missile Research and
Development Command
Advanced Sensors Directorate
Redstone Arsenal, AL 35809

Reference: Contract DAAK40-77-C-0077 (GIT Project A1981)

Subject: Monthly Contract Technical Status Report No. 23
Covering the Period 1 February to 28 February 1979

Gentlemen:

Efforts during the past month have been devoted to the preparation of the final report and data reduction and computer analysis of the summer measurement data. The analysis phase has continued with further statistical characterization of the target and clutter and in addition the PCD and DTG signal processing techniques have been implemented on the Cyber 70 computer. These techniques will be evaluated to determine their performance (PD vs PFA) for the clutter cells available in the recorded summer and winter data.

A program meeting was held at the MIRADCOM facilities, Redstone Arsenal on 12 February 1979. In attendance were A. H. Green and R. C. Haraway of MIRADCOM and J. L. Eaves, J. A. Scheer and L. C. Bomar of Georgia Tech. The purpose of the meeting was to discuss the current program goals and to explore possible additional areas of effort related to the use of the summer and winter data.

Plans for next month are to complete and submit the draft of the final technical report.

Financial Status

Expenses incurred during the reporting period total $-3,992.74 with total expenditures to date being $376,133.67. The reduction in total expenditures is due to the release of encumbered travel funds which were in excess of the anticipated travel expenses.

Sincerely,

L. C. Bomar

LCB/vcy

Approved:

J. A. Scheer
Chief, Experimental Division
Radar and Instrumentation Laboratory

A-1981

MEMORANDUM REPORT NO. 1

TEST PLAN FOR CHARACTERIZATION OF COHERENT REFLECTIVITY FROM TARGETS AND BACKGROUND AT K_u, K_a, AND M-BAND FREQUENCIES – PHASE I

By

J. A. Scheer

L. C. Bomar

Prepared for

ADVANCED SENSORS DIRECTORATE
U. S. ARMY MISSILE RD & E LABORATORY
REDSTONE ARSENAL, ALABAMA

CONTRACT NO. DAAK40–77–C–0077

January 1978

GEORGIA INSTITUTE OF TECHNOLOGY

Engineering Experiment Station
Atlanta, Georgia 30332

1978

Memorandum Report No. 1

TEST PLAN FOR CHARACTERIZATION OF COHERENT REFLECTIVITY FROM TARGETS AND BACKGROUND AT K_u, K_a, AND M-BAND FREQUENCIES PHASE I

J. A. Scheer
L. C. Bomar

Prepared for

Advanced Sensors Directorate
U.S. Army Missile RD&E Laboratory
Redstone Arsenal, Alabama

Contract #DAAK40-77-C-0077

by

Radar Instrumentation Laboratory
Radar Technology Area
Experimental Division
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

January 1978

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MR1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Radar Measurements
Millimeter Waves

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This memorandum report outlines the test organization and procedures for obtaining radar reflectivity data at K_u, K_a, and M-bands for extending the current data base at those frequencies and for evaluation of existing detection techniques.

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1. INTRODUCTION

1.1 Test Objectives

The primary objective of this test is to establish a data base at Ka-band from which target discrimination, recognition, and identification algorithms may be developed for missile radar seeker systems. Such algorithms will seek to improve performance of sensor and seeker acquisition and tracking of tactical targets in realistic ground clutter environments. Data will consist of summer (Phase I) and winter (Phase II) measurements.

A second objective will be to collect M-band (95 GHz) radar reflectivity data which can be used to characterize clutter and target backscatter. These data will also be used in evaluation of noncoherent target discrimination techniques used to lower frequencies.

A third test objective will be to collect appropriate radar data at Ku-band for correlation with data obtained during testing of the MARFS (Multi-environment Active Radar Frequency Seeker) system. These data will be in addition to the limited quantity of conventional Ku-band data required for correlating Ka-band observations with previously reported Ku-band observations.

A fourth test objective is the simultaneous collection of radar backscattering data from clutter and targets at Ku, Ka and M-band frequencies using the same antenna beam widths and pulse widths. These data will be valuable in decoupling the radar frequency dependence of the backscatter from targets and clutter.

1.2 Background

The U.S. Army is tasked with providing helicopter-borne close air support against tactical targets on the ground. In particular the missile-borne seeker system to be utilized will probably be Ka-band frequency, or higher, from consideration of air frame size and antenna beamwidth constraints. Conventional Doppler signal processing techniques can not be used exclusively for target discrimination since the targets in question may be stationary. Thus, an identified technical problem is that of determining an appropriate signal processing technique which improves target discrimination capability at Ka-band.

Previous work at X- and Ku-band in this area, called Stationary Target Indication (STI), indicates transmission of special waveforms such as polarization and/or frequency agility and special signal processing can significantly improve target discrimination capability in realistic clutter background. Similar exploitation of induced radar backscatter characteristics should be possible at Ka-band or M-band. However, there exists no large data base in either band to investigate possible target discrimination techniques. The collection of such a data base and the development of target discrimination processing technique are included in this investigatory program.

The U.S. Army Missile Research and Development Command (MIRADCOM) is currently funding development of the MARFS system, which is a missile-born target tracking concept based on dual polarization and pseudo-coherent detection techniques. An associated helicopter-borne detection, designation, and acquisition system is also being developed which must operate under the same environmental conditions as does the MARFS system. An independent analysis of data pertinent to the MARFS concept is desired in order to increase confidence in the anticipated angle-tracking performance improvement which has been predicted. Data is also required for selection of appropriate radar frequency for the associated helicopter-borne acquisition system.

1.3 General Test Description

This test program addresses the collection of radar backscatter data for targets in a foliated clutter environment. Two distinct measurement tasks are indicated which are to be conducted from the F1 Test Facility at Redstone Arsenal, Alabama. The first task includes simultaneous recording of radar backscatter data from clutter, targets, and reflectors at Ku-, Ka- and M-bands to determine the following:

(a) Spot check of Ku-band backscatter characteristics,

(b) Ka-band backscatter amplitude statistical description as a function of polarization agility, frequency agility, pulse width, antenna beamwidth, target aspect, and weather conditions,

(c) Ka-band coherent backscatter statistical description,

(d) M-band backscatter amplitude statistical description as a function of polarization agility, antenna beamwidth and weather conditions,

(e) Ka-band and M-band pseudo-coherent backscatter statistical description,

(f) Frequency designation for helicopter-borne target acquisition system.

The second task includes measurement of appropriate Ku-band radar data required to evaluate the merit of the MARFS angle-tracking concept. These data include tracking errors and associated signals which are relevant to the MARFS system, plus conventional backscatter signals necessary for concept evaluation.

1.4 Relevency of Measurements

In addressing the need for a data base in the millimeter wave region, it is conceivable that a matrix containing over one million data runs could be generated, representing variations of each of the system parameters for all values of each of the other parameters. In order to develop a managable number of data runs desired, some direction must be given to the selection of the test matrix. Certainly not all parameters can be varied over their full range for full variations of all the other parameters, but each variable can be varied over its range for a limited number of values for the other parameters.

A number of signal processing techniques which have been investigated in the past for use with radars operating in the X- and Ku-bands, may have applicability in the Ka- and M-bands. Some of these are Dynamic Threshold Gating (DTG), Correlation Coefficient Discrimination (CCD) and Pseudo Coherent Detection Integration (PDI). These algorithms basically exploit the statistical nature of the returns from targets as they differ from that of clutter, using various operating modes. The autocorrelation properties of the returns depend on such things as the amount of frequency agility employed for various pulse lengths, with and without polarization agility. Varying the amounts of frequency agility and pulse lengths in the data collection will allow evaluation of the effectiveness of frequency agility in employing the processing techniques mentioned above. The use of polarization agility in the data collection will allow determination of the utility of that mode in improving the discrimination potential.

It has been demonstrated that DTG and CCD can achieve intercell subclutter visibility, but not intracell subclutter visibility. For this reason DTG and CCD techniques work best with a maximum target to clutter ratio, the optimum being when the cell size is the same as the target. These modes have application even in an environment in which the clutter exceeds the target in an adjacent cell.

PDI has been shown to possess intracell subclutter visibility capability. This technique relies on the randomness of the clutter statistics, and may demand a larger cell size than the DTG and CCD techniques, to insure this randomness. The variations in antenna beamwidth and pulse length in the data set address the need to vary the cell size in evaluating this effect.

2. DESCRIPTION OF TEST EQUIPMENT

2.1 Ka-band Radar System

A 35 GHz radar system has been fabricated which represents the state-of-the-art for a variable parameter, instrumentation grade radar at this frequency band. The optional operating modes of this system include (1) coherent operation; (2) dual polarization, transmit and receive; (3) pulse-to-pulse polarization agility; (4) pulse-to-pulse frequency agility; (5) and intra-pulse frequency ability. In addition, this portable radar system is self-contained and configured for use with instrumentation and recording equipment. As shown in Figure 1, the radar system involves three units; the radar itself, the power supply, and the control panel. The three are interconnected with appropriate cables.

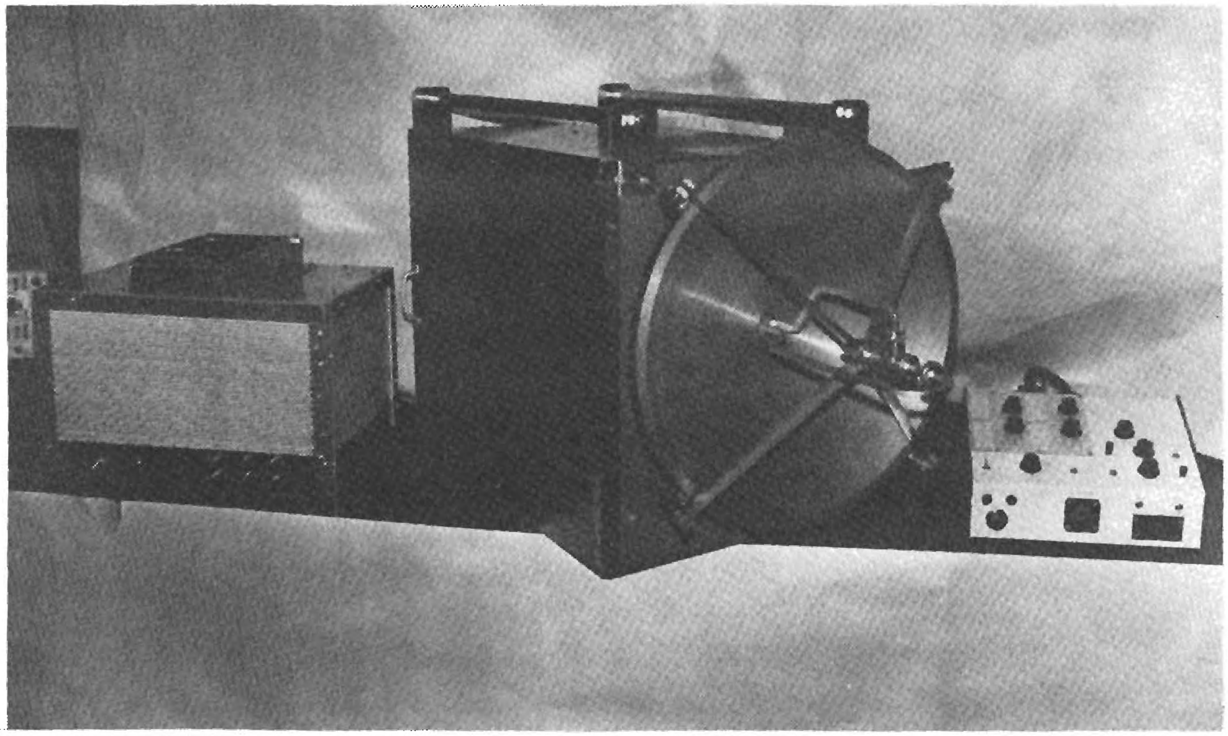
Figure 2 illustrates a block diagram description of the Ka-band radar system, whose parameters are listed in Table 1. Note that this configuration is compatable with both coherent and pseudo-coherent operation. Naturally, not all of the available operational modes are mutually compatable, e.g., frequency agility and coherent operation.

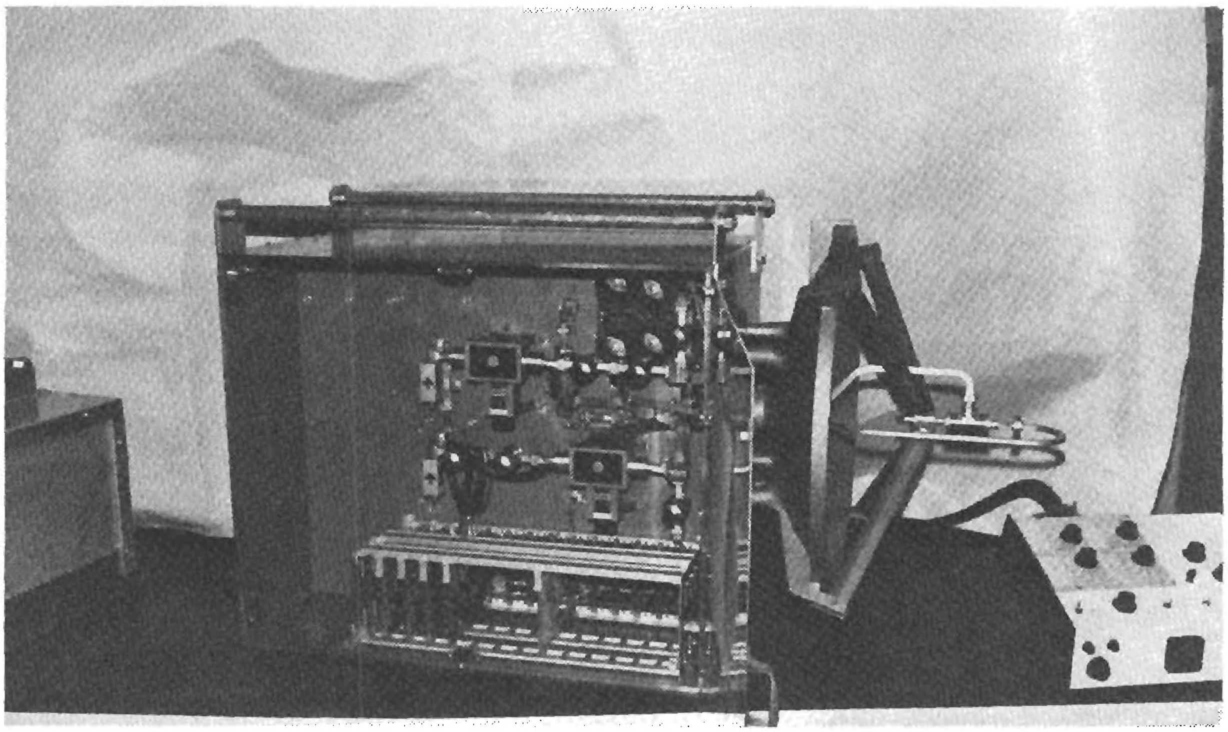
2.2 Ku-band Radar System

A 16 GHz radar system is available to supply the necessary Ku-band data for recording. Table 2 lists the pertinent parameter values for this radar system. Note that it is a noncoherent system, but has both polarization and frequency agility capabilities, and can be configured in a pseudo-coherent mode, as shown in block diagram form in Figure 3. As with the Ka-band system, different antenna beamwidths will be effected by using several antennas of various diameters.

2.3 M-band Radar System

The M-band radar to be used in this measurement program is designated GT-M and is a 95 GHz instrumentation radar. The radar operates in a noncoherent mode with capability for pulse-to-pulse polarization agility and has a dual channel (H and V) receiver. Table 3 is a summary of the





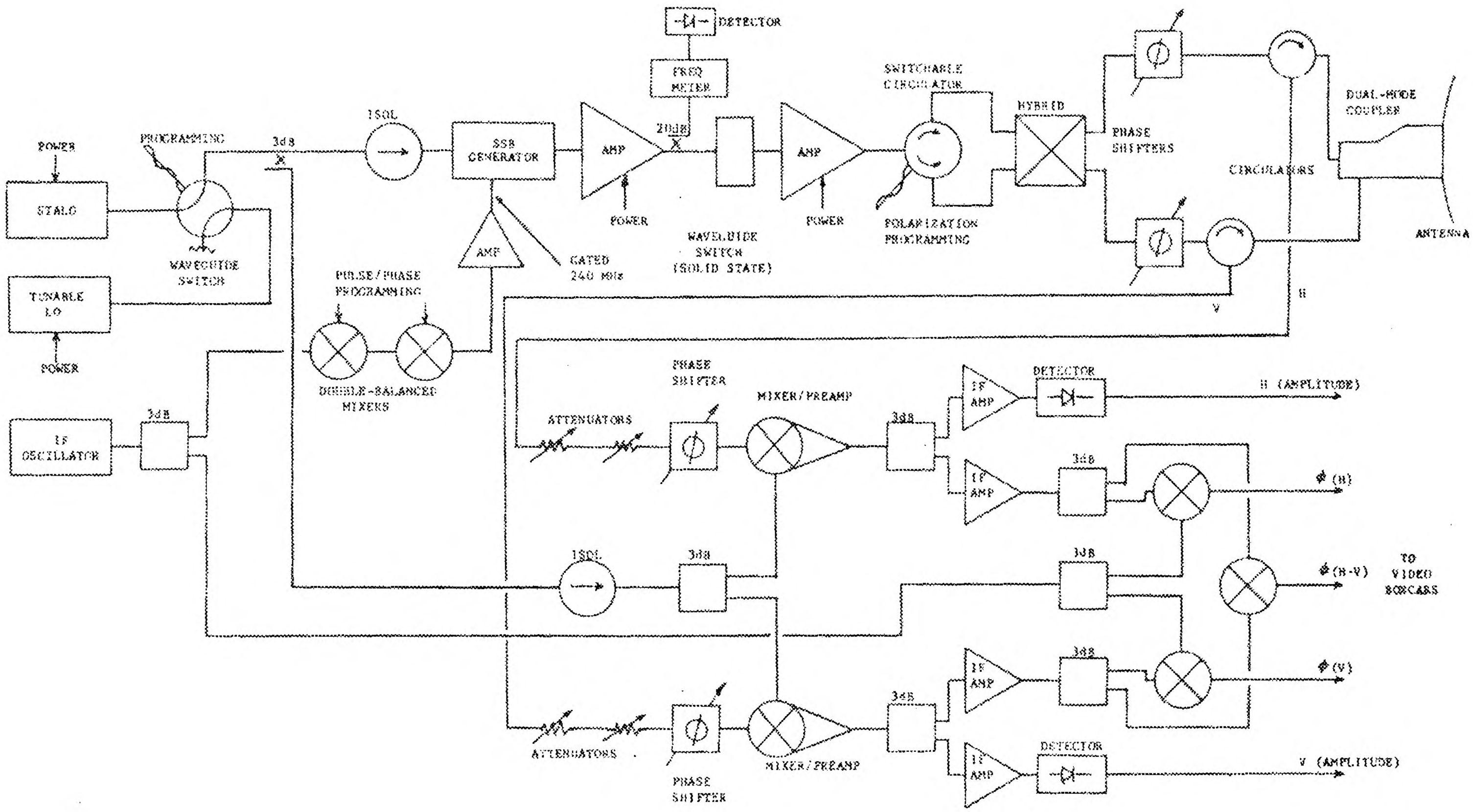
Ka Radar System

Figure 1

TABLE 1

Ka-band Radar Parameters

Transmitter		
RF Frequency:	34.75-35.75 GHz	
Peak Power:	2-3 Watts Pulse 150 mW cw	
Pulse Width:	10 nsec to cw	
PRF:	VARIABLE	
Antenna		
Type:	Machined Aluminum 18" Parabolic Dish	Horn Fed Lens Antenna
Beamwidth: Az El	1^{o} 1^{o}	45^{o} 45^{o}
Gain:	> 40 db	> 30 dB
Polarization: Fixed, or Pulse-to-Pulse Agile	Right Circular Left Circular Horizontal Vertical	
Receiver		
Type:	Linear, Wideband 10 to 500 mHz	
IF:	240 mHz	
Detection:	Amplitude Phase (coherent)	
Sensitivity:	~ 80 dBm	



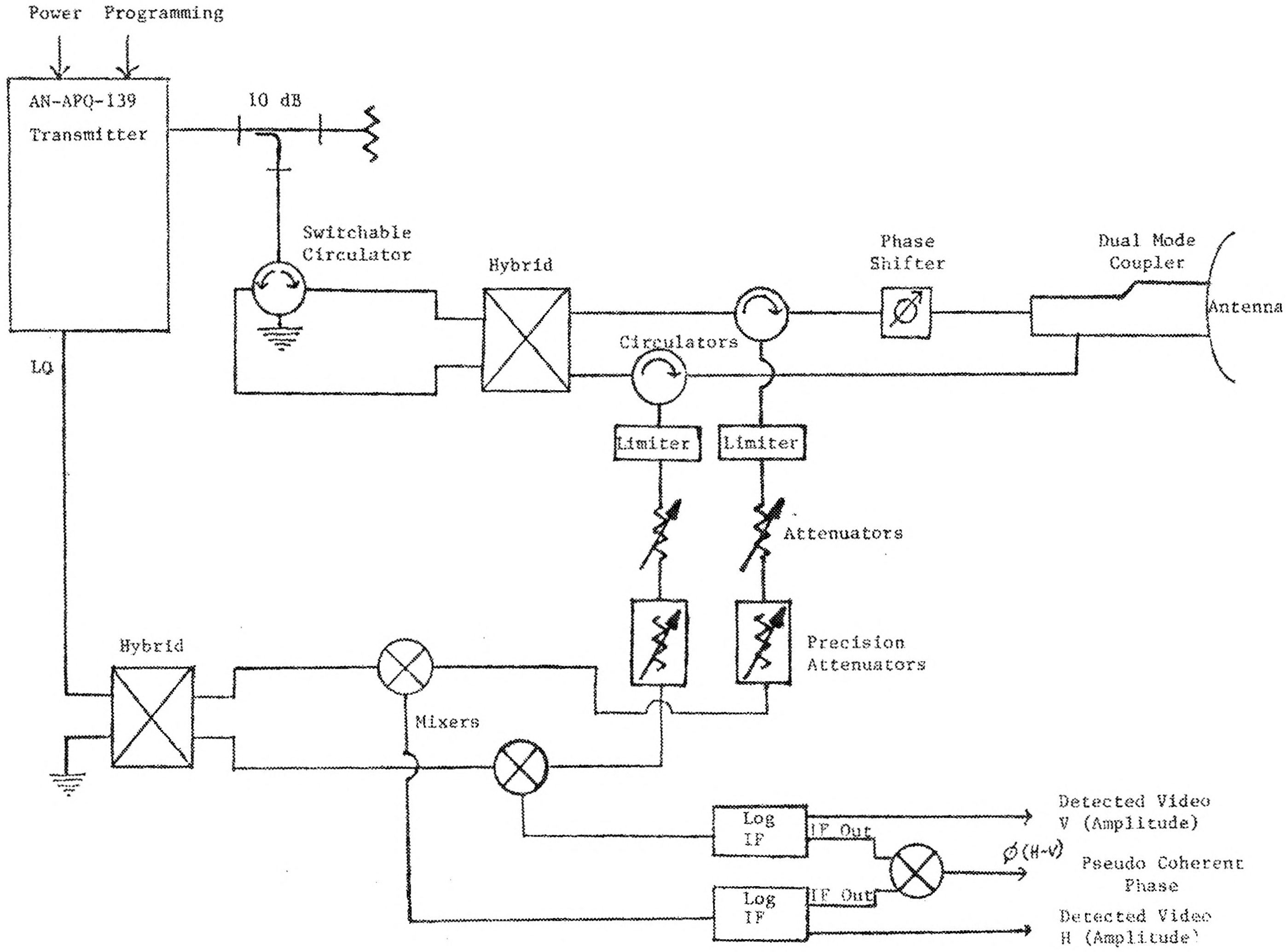
Block Diagram Transmitter-Receiver Portion of Ka-band Radar

Figure 2

TABLE 2

Ku-band System Parameters

Transmitter		
RF Frequency		15.9-16.4 GHz
Peak Power		6 kW
Pulse Width:		200 nanoseconds
PRF		2-8 kHz
Dual Polarized Horn Antennas		9^{o}
		4.5^{o}
Dual Polarized Monopulse Antenna		
Type		Two separate but dependent parabolic reflectors with two full monopulse feeds
Beamwidth:	El Az	6.0 deg (3 dB points) 2.2 deg (3 dB points)
Gain:		30.5 dB (each)
Polarization: Fixed, or pulse-to-pulse agility		Vertical top Horizontal bottom
Receivers, Horizontal and Vertical		
Type		Integrated mixer - IF amplifier
Detection		Pseudo-Coherent
Bandwidth		20 mHz
Dynamic Range		70 dB
Sensitivity		- 90 dBm
Data Recording		
Magnetic Tape		7-channels, FM, 0-20 kHz
Oscillograph		6-channels, 0-5 kHz



Block Diagram Ku-band

Figure 3

TABLE 3

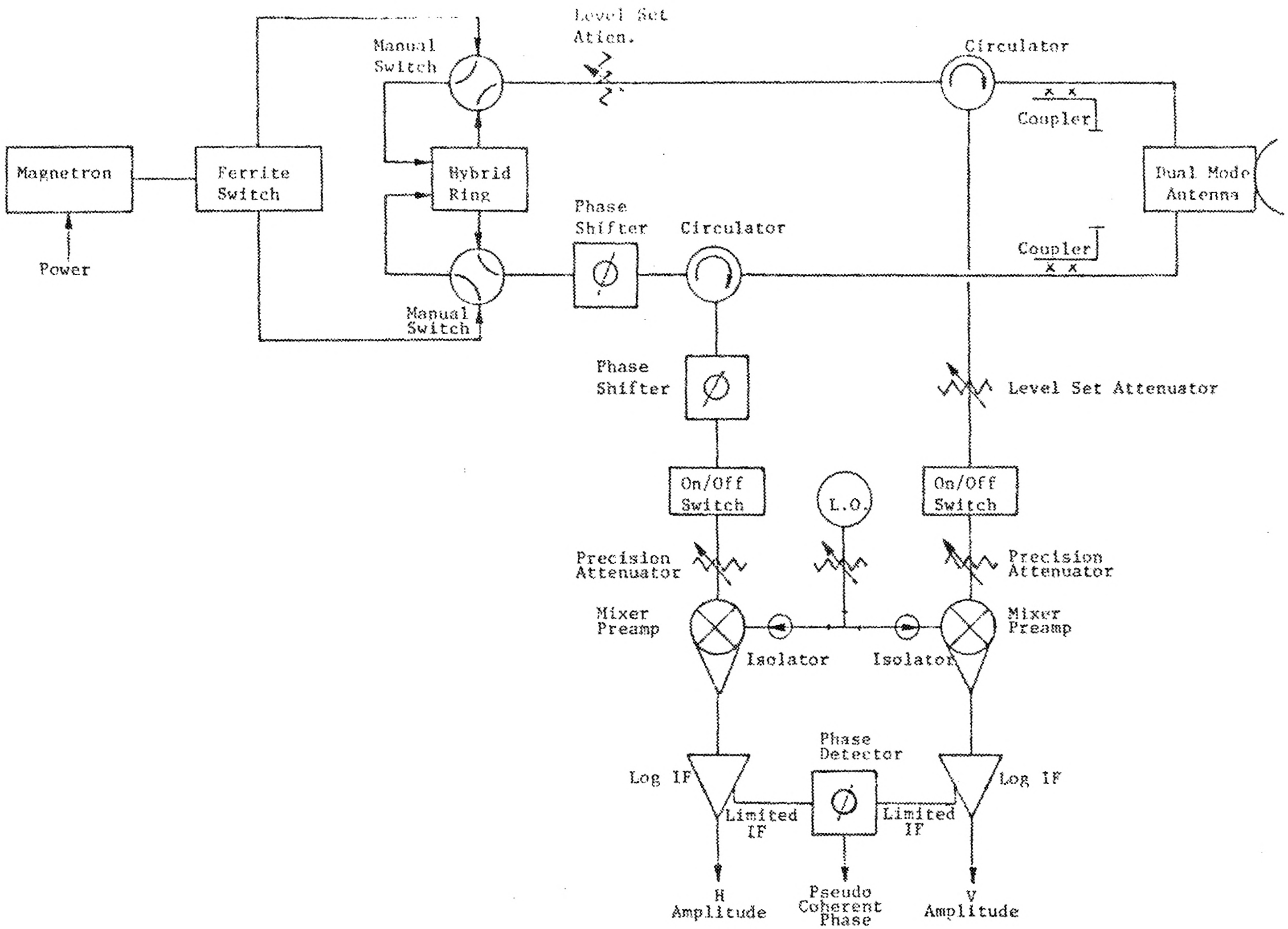
GT-M System Parameters

Transmitter	
RF Frequency	94.5-95.5 GHz
Peak Power:	1 KW
Pulse Width:	200 nsec or 50 nsec
PRF:	Variable
Antenna	
Type:	12" Diameter Cassegrain 3" Diameter Horn Lens
Beamwidth:	0.7 degrees 3.0 degrees
Polarization:	Fixed or Pulse-to-Pulse Agile RC, LC or H,V
Receiver	
Type:	Super hetrodyne, Integrated mixer, preamp, 10-2000 MHz
IF:	300 MHz Logarithmic
Detection:	Amplitude Phase (pseudo-coherent)
Dynamic Range:	60 db
Noise Figure:	12 db

radar parameters and Figure 4 is a block diagram of the receiver-transmitter. Different antenna beamwidths will be accomplished by simple replacement of the antenna.

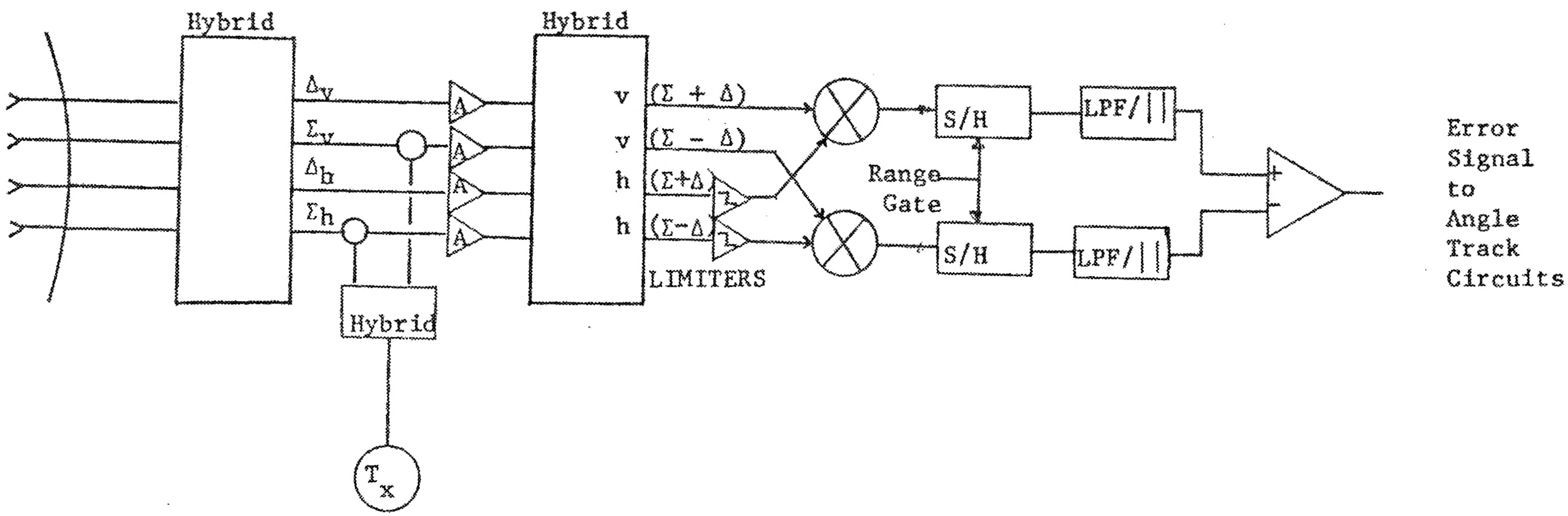
2.4 PENRAD Monopulse Radar System

The PENRAD dual polarized, monopulse antenna assembly will be mated to appropriate RF components in the MARFS configuration, as shown in Figure 5. A calibrated boresight telescope will be attached to the PENRAD antenna assembly to correlate the angle error signal with the true off-boresight angle. The MARFS error signal, conventional monopulse error signal, pseudo-coherent signal, and several intermediate signals will be available for recording and subsequent evaluation.



GT-M Block Diagram

Figure 4



Simplified Block Diagram of MARFS Polarization Diverse Angle Error Detector

Figure 5

3. REQUIREMENTS FOR TEST OPERATION

3.1 Tower Test Facility

The primary site for this data collection program will be the F1 Tower Site at the Redstone Arsenal, Alabama. Figure 6 shows a pictorial sketch of the F1 Tower Site and the associated geometric parameters from the tower to the surrounding field areas. Three platform levels are available on the tower, at heights above the local terrain of 30, 42, and 63 meters.

Fields suitable for target and vehicle placement surround the tower at ground ranges from about 90 to 360 meters. Table 4 summarizes the geometric parameters available from the set of tower platforms and the usable target ranges.

TABLE 4

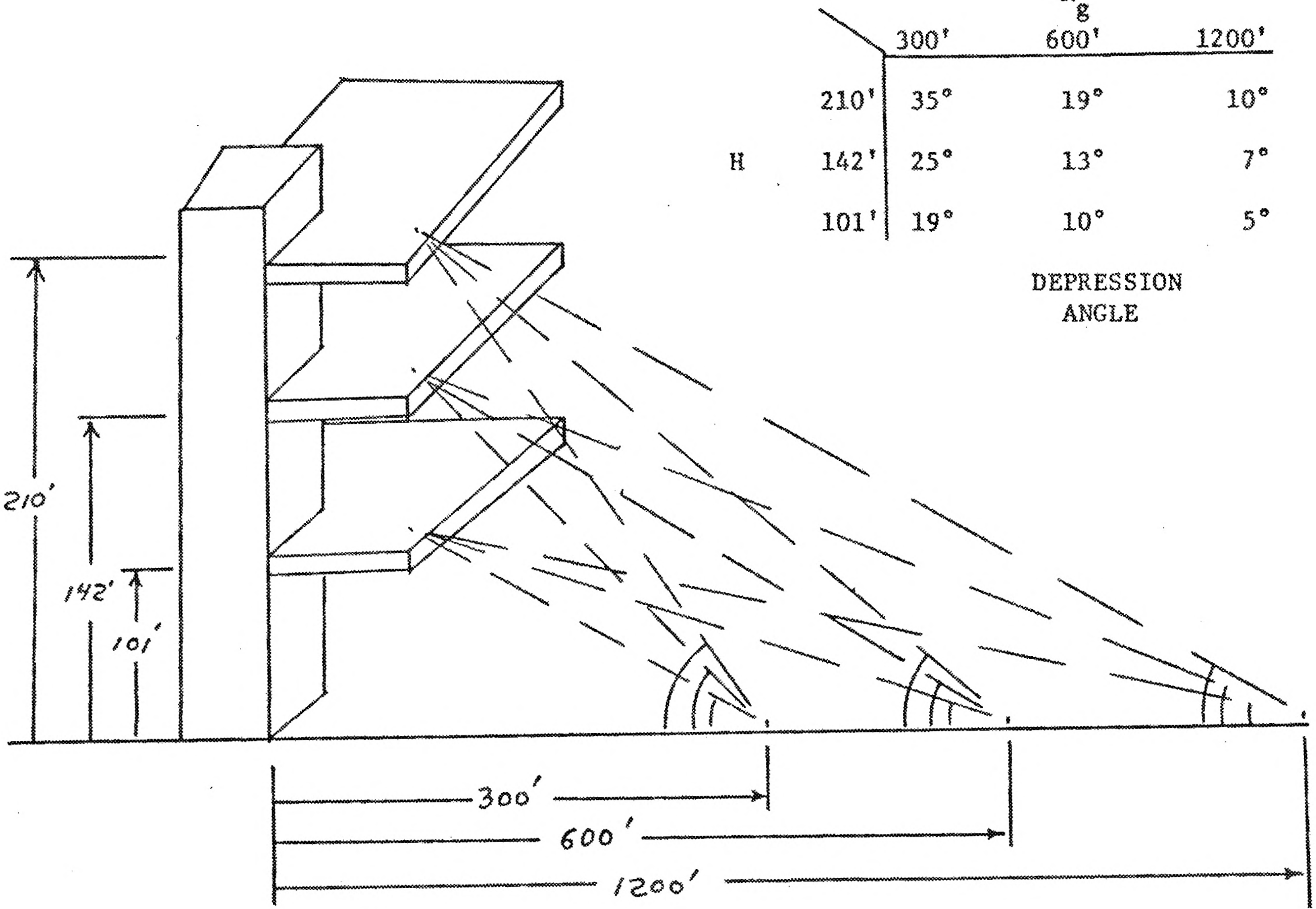
F1 Tower Geometry

Platform Height (m)	Minimum Depression Angle Ground Range = 360 m	Maximum Depression Angle Ground Range = 90 m
30	4.8^{o}	18.4^{o}
42	6.7^{o}	25.0^{o}
63	9.9^{o}	35.0^{o}

It can be seen that a range of depression angles from the tower platform to the target area in the field can be established from less than 5 degrees to as much as 35 degrees.

It is the intent of this measurement program to utilize all three tower platforms in order to fulfill the parameter requirements designated in the test matrix (see section 4.3). The government should, therefore, provide electrical power to operate the radars, recorders, and ancillary equipment at each of the three platform levels. Minimum requirements for power are as follows:

110 V, 60 Hz, 1ϕ 1.5K Watts
110 V, 60 Hz, 1ϕ 1K Watts
110 V, 400 Hz, 3ϕ 1K Watts



H \ R_g	300'	600'	1200'
210'	35°	19°	10°
142'	25°	13°	7°
101'	19°	10°	5°

F-1 Tower Facility

Figure 6

In the event that the government cannot provide the designated power, Georgia Tech will make whatever arrangements are deamed necessary to obtain such power.

The work area will be comprised of the radar systems, support equipment, and recording devices, on each tower platform one at a time. A work bench is desired at the work area which should have the following characteristics:

- o Flat work bench area of at least $4m^2$, with suggested dimensions of 1 x 4 meters at a height of 1 meter.
- o At least 10 115 V, 60 Hz, 1Φ standard power outlets, bussed together to a single male power plug for connection to the main tower power grid, and protected by fuses or circuit breakers with a 20 amp current rating.
- o Capability of supporting at least 200 kilograms, total, and downward surface pressures of 2.1 kg/cm^2.

Additional work ares devices, such as stands, racks, etc., will be provided by Georgia Tech.

Since radar measurements will be made with weather conditions as salient parameters, it will be mandatory that the radar systems operate within a protected enclosure. A waterproof, air-conditioned, enclosure will be required both to protect the electronic equipment from weather-induced damage and to provide an acceptable work environment for attendent personnel. Windows should be so designed that the radar systems may radiate through transparent (at the appropriate frequency) materials or through protected openings in the enclosure walls. If not otherwise provided at the F1 Tower Facility, running water and restroom facilities should be made available either within this enclosure or nearby.

3.2 Personnel Requirements

Radio communication using UHF or VHF transceivers will be required during this test operation. It is suggested that government permission be granted to permit use of Georgia Tech-licensed VHF transceiver base station and remote units operating at frequencies of 151.625 MHz and 151.475 MHz for the duration of this field operation at Redstone Arsenal. The designated call sign for this communication system is KC2XGC. Otherwise the government must furnish a suitable electronic means of communication between the F1 Tower Facility and the target field.

Security clearances and unlimited access to the F1 Tower and target field must be provided for Georgia Tech personnel. If data reduction is undertaken at the Redstone computer facility, proper access must also be provided. Vehicle passes must be provided for both the Georgia Tech owned vehicles and the privately owned vehicles used by Georgia Tech personnel for personal transportation. Additional clearances and/or permit must be provided for that photographic equipment (TV cameras, 16 mm movie cameras, 35 mm still cameras, etc.) needed to document the test activities. Adequate security of both the Tower-based equipment and the Georgia Tech-owned vehicles must be provided by fences, locked gates, etc. and a seemed parking area respectively.

It will be desirable that general office space be made available with desks, chairs, telephones, and storage cabinets for Georgia Tech personnel (up to 6 persons) as near the F1 Tower as possible for the duration of this test program. This requirment may entail additional identification badges, parking permits, etc., as identified.

4. TEST OPERATIONS: FOLIATED BACKGROUND

Radar backscatter data and meteorological data will be recorded to fulfill the two major test objectives of this program. The first data set will adress those data needed to characterize Ka-band reflectivity from ground clutter and targets in clutter, including supportive backscatter at Ka-band. The second data set will address those data required to verify the MARFS tracking concept, at Ku-band alone.

4.1 Ka-band Reflectivity Characterization

4.1.1 Test Matrix

The data collection program designed to characterize Ka-band reflectivity will be based around clutter and an M48 tank, or equivalent, as the tactical target of interest. Trihedral and diplane corner reflectors are required to quantify reflectivity and will also be used to calibrate signal amplitudes, align polarizations, etc. Table 5 lists a matrix of Ka-band radar, target, geometric, and ground clutter parameters which will be varied during this field exercise. It is the intent of listing this matrix that

TABLE 5

Ka-band Measurement Matrix

Test Group	Target Aspect	Antenna Aperture	Depression Angle	Transmit Polarization	Transmit Mode	Pulse Width	Clutter Type	Notes
I	45°	1°	10°	H,V,PAL RC,LC,PAC	Coherent NC(10 MHz)	.2 μsec	Scrub	
II	45°	1°	$5,10,13,19,25^\circ$	*	Coherent NC(10 MHz)	.2 μsec .01	Scrub	*Subject to TGI results
III	$0,45,90,135,180^\circ$	1°	10°	*	Coherent NC(10 MHz)	.2 μsec .01	Scrub	*Subject to TGI results
IV	135°	$1,4.5^\circ$	10°	*	Coherent NC(10 MHz)	.2 μsec .01	Scrub Tree Line	*Subject to TGI results
V	135°	1°	10°	*	Coherent NC(10 MHz)	.01,.03, .05,.2	Scrub Tree Line	*Subject to TGI results
VI	135°	1°	10°	H,V,PAL RC,LC,PAC	Coherent NC(10 MHz)	.2 μsec .01	Scrub Tree Line **	**Includes weather parameters
VII	135°	1°	10°	*	Coherent NC(1,5,10, 20,50 MHz)	.01 μsec .05	Scrub Tree Line	

it serve as a guide for the actual data collection. That is, as the test program progresses, the matrix may be altered to benefit from on-site observations and different priorities and opportunities.

The various tests can be conveniently arranged into seven test groups, as determined by that particular parameter to be varied. The first test group (I) is intended to compare various polarization transmission modes for appropriateness in signal discrimination in both coherent and noncoherent modes of operation. PAL refers to polarization agility with H and V linear polarizations alternately, while PAC refers to polarization agility with circular polarizations alternately. It is anticipated that, at the most, only two of these polarization modes will be used for the remaining tests, except for TG VI.

Test group II varies the depression angle to the target cell, while target aspects are changed in test group III. The effects of beamwidth are investigated in test group IV. While pulse width is the parameter of interest in test group V. Weather effects are contained in test group IV, and all polarization modes will be investigated. It can be assumed that these tests will necessarily be distributed among all the others as weather conditions recur. The last test group, VII, contains pulse-to-pulse frequency change as a parameter (assuming frequency agility has survived as an operational mode of interest). Both scrub and tree line clutter environments are utilized, as shown.

Table 6 and 7 list the analogous matrices for the supportive Ku-bank and M-band measurements. The data collection is also shown arranged into the test groups described previously. Note that all Ku-band data is noncoherent, at .2 or 1 μ second pulsewidth, using primarily a 4.5° beamwidth antenna. These matrices represents only a fraction of the data collection designated for the Ka-band tests. However, it is the intent that common parameter Ku- and M-band data be recorded simultaneously.

4.1.2 Target Description

It is assumed that, for this data collection program, an M48 tank, or equivalent, will be the primary tactical target of interest. If additional tactical targets are needed, it is suggested that they be 2-1/2 ton Army trucks, 3/4-ton trucks, 1/4 tone trucks, or mobile artillery units.

TABLE 6

Ku-band Measurement Matrix

Test Group	Target Aspect	Antenna Aperture	Depression Angle	Transmit Polarization	Transmit Mode	Pulse Width	Clutter Type	Notes
I	45°	4.5°	10°	H,V,PAL RC,LC,PAC	NC(10 MHz)	.2 μsec	Scrub	
II	45°	4.5°	$5,13,25^{\circ}$	*	NC(10 MHz)	.2 μsec	Scrub	*Subject to TGI results
III	$0,45,90^{\circ}$	4.5°	10°	*	NC(10 MHz)	.2 μsec	Scrub	*Subject to TGI results
IV	135°	$4.5,9^{\circ}$	10°	*	NC(10 MHz)	.2 μsec.	Scrub Tree Line	*Subject to TGI results
V	135°	4.5°	10°	*	NC(10 MHz)	.2 μsec 1 μsec	Scrub Tree Line	*Subject to TGI results
VI	135°	4.5°	10°	H,V,PAL RC,LC,PAC	NC(10 MHz)	.2 μsec	Scrub Tree Line **	**Includes weather parameters
VII	135°	4.5°	10°	*	NC(1,5, 10 MHz)	.2 μsec	Scrub Tree Lines	

TABLE 7

M-band Measurement Matrix

Test Group	Target Aspect	Antenna Aperture	Depression Angle	Transmit Polarization	Transmit Mode	Pulse Width	Clutter Type	Notes
I	45°	3.0°	10°	H,V,PAL RC,LC,PAC	NC	.2 μsec	Scrub	
II	45°	3.0°	$5,13,25^{\circ}$	*	NC	.2 μsec	Scrub	*Subject to TGI results
III	$0,45,90^{\circ}$	3.0°	10°	*	NC	.2 μsec	Scrub	*Subject to TGI results
IV	135°	$3.0^{\circ},0.7^{\circ}$	10°	*	NC	.2 μsec.	Scrub Tree Line	*Subject to TGI results
V	135°	3.0°	10°	*	NC	.2 μsec	Scrub Tree Line	*Subject to TGI results
VI	135°	3.0°	10°	H,V,PAL RC,LC,PAC	NC	.2 μsec	Scrub Tree Line **	**Includes weather parameter

Standard corner reflector will be utilized to quantify radar cross sections, locate target positions accurately, and align radar polarization. The following set of calibrated trihedral corner reflectors may be used in this program, as listed in Table 8 below:

TABLE 8

Corner Reflector Radar Cross Sections

Base (cm)	RCS (dbsm, 16 GHz)	RCS (dBsm, 35 GHz)	RCS (dBsm, 95 GHz)
13.9	6.5	13.3	22.0
24.8	16.5	23.3	32.0
30.2	20.0	26.8	35.5
44.1	26.5	33.3	42.0
71.3	34.9	41.7	50.4
94.0	39.7	46.5	55.2
127.6	45.0	51.8	60.5

Table 9 lists the calibrated diplane corner reflectors which may be used. It is anticipated that these selections of corner reflectors will suffice for this field operation.

TABLE 9

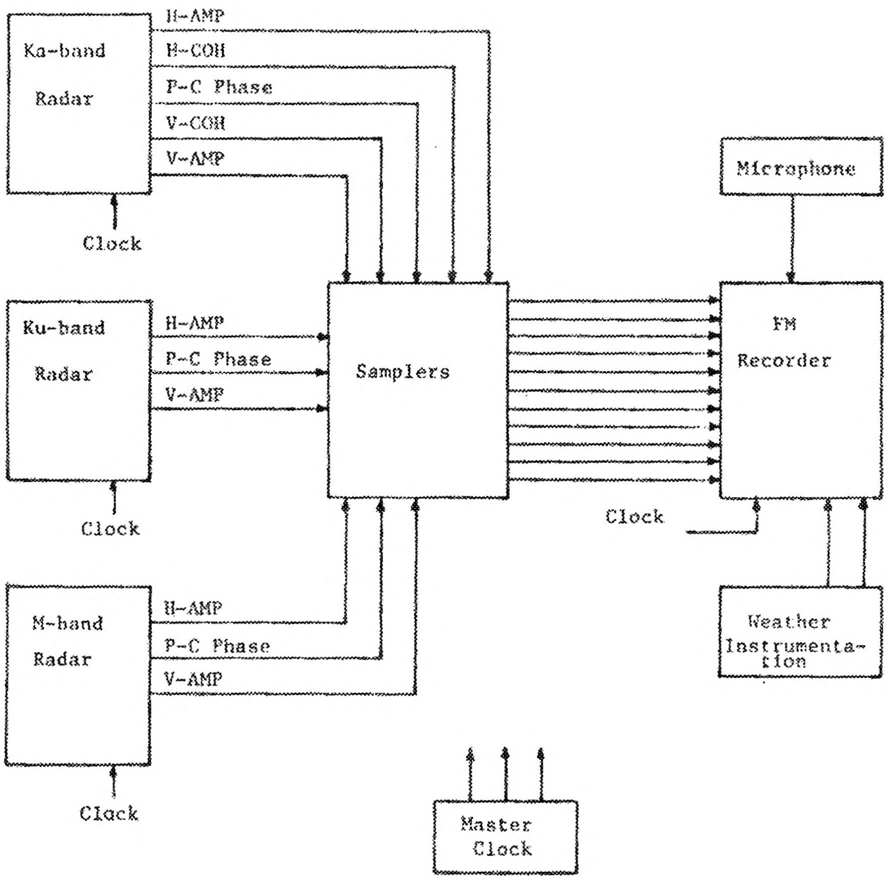
Diplane Radar Cross Sections

Width	Height (cm)	RCS (dBsm, 16 GHz)	RCS (dBsm, 35 GHz)	RCS (dBsm, 95 GHz)
20.4	10.2	14.9	21.7	30.4
30.5	15.2	21.9	28.7	37.4
43.2	21.6	27.9	34.7	43.4
52.4	37.2	34.3	41.1	49.8
46.0	79.0	39.8	46.5	55.2

4.1.3 Data Collection Instrumentation

Various range-gated radar data will be recorded on FM tape, along with supportive weather, clock, and annotation data. In addition real time data analysis and monitoring will be provided to insure validity of the various data. Figure 7 shows a simplified block diagram of the overall equipment interconnection.

The boxcar signals to be recorded are listed in Table 10 below along with assigned FM recorder track designations. Additional signals to be recorded are also identified.



Data Collection Block Diagram

Figure 7

TABLE 10

Data Channel Assignments

Signal	Source	FM Track Number
Hor. Pol. Amplitude	Ka	1
Hor. Pol. Phase	Ka	2
Pseudo-Coherent Phase	Ka	3
Vert. Pol. Amplitude	Ka	4
Vert. Pol. Phase	Ka	5
Hor. Pol. Amplitude	Ku	6
Pseudo-Coherent Phase	Ku	7
Vert. Pol. Amplitude	Ku	8
Hor. Pol. Amplitude	M	9
Vert. Pol. Amplitude	M	10
Pseudo-Coherent Phase	M	11
Range Gate Clock	Master Clock	12
Wind Speed	Weather Inst.	13
Wind Direction	Weather Inst.	14
Audio Annotation	Microphone	Edge Track

Real-time monitoring of each of the eleven radar video signals will be accomplished using an oscilloscope. Analysis of boxcar radar data will be effected through use of a Federal Scientific Correlator, which can provide "real-time" correlation and probability distribution information of selected inputs.

4.1.4 General Measurement Procedure

The intent of this field exercise is to statistically characterize Ku-, Ka- and M-band radar backscatter signals with identified radar target, and environment parameters. This characterization will take the form of autocorrelation functions, mean values, probability density functions, and other conventional statistical descriptions. In order to make these characterizations meaningful, it is essential that target and clutter radar cross sections be determined and that the transmitted polarization be well defined. To these ends two calibration procedures will be described.

4.1.4.1 Signal Amplitude Calibration

Purpose: It is desired to establish radar cross section levels for both clutter cells and for targets in order to determine target-to-clutter cross section ratios relative to various statistical descriptions of the radar backscatter signal. To determine absolute radar cross section levels, it is essential that a relationship be established between the cross section of a target and the radar video signal amplitude levels.

Procedure: To calibrate a radar return signal from a particular resolution cell for absolute radar cross section, a transfer curve is established relating power into the antenna to the numberical output of a dedicated counting circuit. This is effected using a standard microwave signal generator transmitting a signal into the antenna. The counting circuit divides down the digital representation of the detected signal amplitude for a specified number of radar interpulse periods. Thus, the counter contents are related to the power incident at the antenna.

The counting circuit then records the power from a trihedral corner reflector placed at the range of interest for the same number of radar transmissions. If the radar cross section of the corner reflector is much larger than that of the clutter around it, the counter content will then represent radar cross section of the reflector. Radar cross sections of other targets in the same resolution cell may then be obtained via the transfer curve with this reflector point as a reference. Calibration of the FM tape tracks containing amplitude information is obtained similarly, substituting the FM recorder for the counting circuit. The amplitude calibration procedure which should be undertaken daily and for each different range of interest need only consist of establishing a reference point against the transfer curve.

4.1.4.2 Transmit Polarization Calibration

Purpose: To accurately characterize the radar video signal resulting from pseudo-coherent detection as implemented, it is essential that the circular polarization used on transmission be accurately established and maintained.

Procedure: Calibration of electrical path lengths required to generate circular polarizations (see Figures 2 and 3) is effected using a diplane corner reflector mounted with its crease 22.5° from vertical. The phase shifters in the transmit legs are adjusted until one of the linearly polarized received signals is nulled. At this point the transmitted polarization will be linear 45° from the vertical. The same phase shifter in one leg is then adjusted an additional 90° to create the quadrature relationship between H and V legs required to generate circular polarization.

4.1.4.3 Data Collection

Purpose: Radar video signals will be recorded on FM tape simultaneously from a Ku-, Ka- and M-band radar. A data base at 35, and 95 GHz will be established which will characterize the radar backscatter for target discrimination potential. Sufficient 16 GHz data will be recorded to provide adequate confidence in the Ka-, M-band data base.

Procedure: The tank target will be placed at a specified resolution cell at an aspect angle determined by using a standard protractor. This procedure is adequate to providing target aspects to within $\pm 5^{\circ}$ accuracy.

Slant range to the target cell can be determined from the time delay between transmission of a radar pulse and reception of the radar return from a corner reflector at the target location. Displaying radar signal amplituder versus slant range on an oscilloscope so that the maximum slant range (366 m) represents full scale (10 cm), each millimeter on the screen will represent about 3.7 meters, which will also be the accuracy to which slant range will be determined.

Each radar antenna will be boresighted onto the target cell using an optical telescopic sight mounted rigidly onto the antenna assembly. (This sight will have been calibrated prior to the field operation).

Data collection will then commence using the multi-channel FM tape recorder for storage of sampled radar video signals. The target radar cross section will be determined from signal amplitudes referenced to the calibrated system transfer function previously determined. The radar cross section of the resolution cell, without the target, will then be determined in order to calculate the target-to-clutter radar cross section ratio for a particular target aspect in that clutter cell.

The data will be collected according to a reasonable schedule, with Tables 5, 6, and 7 outlining the test parameter matrix. Test group I will be undertaken first, and test group VI will be undertaken as weather conditions dictate. A log will be maintained of date, run number, and listing of significant parameters. Equivalent annotations will be made on the voice track of the FM tape recorder for later run identification.

4.2 MARFS Data Characterization

4.2.1 Test Matrix

The data collection program designed to characterize the MARFS radar tracking concept will be based around clutter and an M48 tank, or equivalent, as the tactical target of interest. Trihedral and diplane corner reflectors will be used as targets of known reflectivity characteristics for later evaluation of the MARFS data. Table 11 lists a matrix of target, geometry, and ground clutter parameters which will be varied during the MARFS investigation. As before, the intent of this matrix is to serve as a guide for the actual data collection, which will be adaptive to conditions identified.

Four separate test groups are identified in Table 11. The first group investigates the effects of depression angle primarily on the MARFS data, while the second group is based on various target aspects to the radar. A third group is shown to identify weather effects on the radar signals. Group four addresses the fixed and agile circular polarization effects on the MARFS concept.

4.2.2 Target Description

An M48 tank, or equivalent, will serve as the primary tactical target for the MARFS data collection. Additional targets, such as those listed in section 4.1.2, are also appropriate. The set of trihedral and diplane corner reflectors will also be utilized when calibrated radar cross section targets of known reflectivity characteristics are required.

4.2.3 Data Collection Instrumentation

The range-gated radar data of the MARFS investigation will be recorded on FM tape, along with supportive weather, clock, and annotative data. Some real time data analysis will be provided to insure validity of the data.

TABLE 11

MARFS Measurement Matrix

Test Group	Target Aspect	Off Boresight Angle	Depression Angle	Clutter Type	Notes
I	45°	$\pm$ one beamwidth az and el *	$5,10,13,19,25^\circ$	Scrub Tree Line	*az: $-6,-3,0,+3,+6^\circ$
II	$0,45,90,135,180^\circ$	$\pm$ one beamwidth az and el *	10°	Scrub	
III	45°	$\pm$ one beamwidth az and el *	10°	Scrub	Includes weather parameters
IV	45°	$\pm$ one beamwidth az and el *	10°	Scrub	Polarization: RC, LC, agile

The boxcar signals which will be recorded are listed below in Table 12 along with tentative FM recorder track designations.

TABLE 12

MARFS Data Channel Assignments

Signal	FM Track No.
MARFS Error Signal	1
Pseudo-coherent (Σ+Δ) Signal	2
Pseudo-coherent (Σ-Δ) Signal	3
Conventional monopulse (Δ) Signal	4
Pseudo-coherent (Σ) Signal	5
Range Gate Clock Signal	6
	7
Audio Annotation	Edge Track

A block diagram of the sources of these MARFS signals and related radar signals is shown in Figure 8.

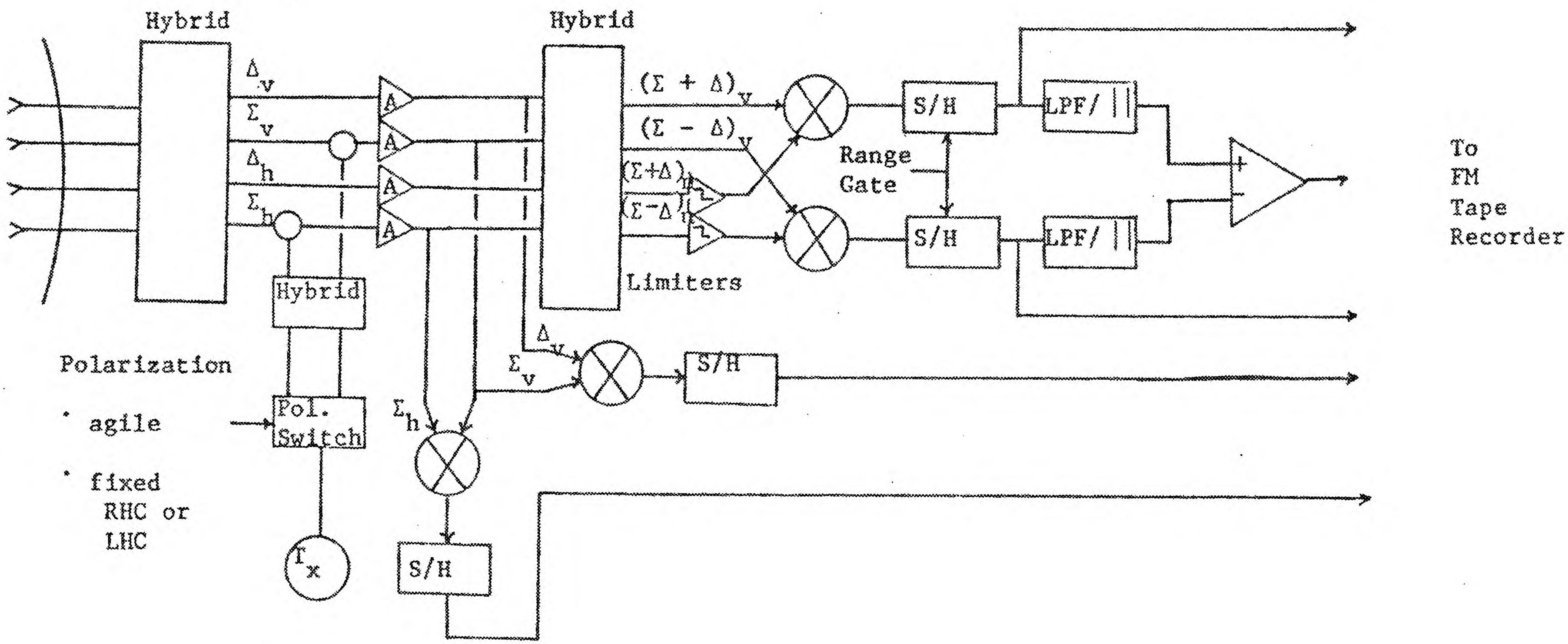
4.2.4 General Measurement Procedure

Purpose: Radar video signals will be recorded on FM tape, along with supportive data, which will characterize the MARFS tracking concept. Various parameters will be varied during the data collection, including the off-boresight angle, the target aspect angle, the depression angle to the target, the clutter enviornment, and the polarization mode on transmission.

Procedure: The MARFS measurements will be interleaved with those of the Ka/Ku/M investigation so that radar cross section determinations will not have to be undertaken twice. The polarization integrity of the MARFS implementation will be established in the manner described in section 4.1.4.

The reference point on the tank target, for off-boresight designation, will be its apparent optical centroid and will be so designated by a marker. Azimuth and elevation boresight positions will be referenced to this spot, and will be determined by measurement of pertinent geometry or by reference to fiducial marks on the sightglass.

In the data collection itself, test group III will be accomplished as weather conditions permit. The other three test groups will be undertaken in a manner compatible with the Ka/Ku/M measurements.



Simplified Block Diagram of Ku-band Data Collection System

Figure 8

4.3 Detailed Measurement Procedure

4.3.1 Radar System Calibration

The purpose of the calibration procedure is to record on each reel of FM Tape, a calibration curve giving the value of voltage versus the parameter the voltage represents; i.e.: amplitude versus voltage, phase versus voltage, and angle error versus voltage. This is accomplished by either injecting a known signal into the radar receiver or boresiting on a corner reflector or target of known characteristics. For convenience in the field operation environment a corner reflector of known characteristics is used.

The radar operator boresites the antenna to the reference corner reflector, first by viewing through the boresite telescope and subsequently by fine tuning the pointing angle by peaking the amplitude response on the "A"-scope. The range to the target will be noted in the log and the FM recorder will record the amplitude of the H and V channels, the phase between the two channels, and in the case of the Ku-band system the amplitude monopulse error signal and the pseudo-coherent detector derived error signal. These two error signals will be nulled to zero using appropriate offset controls. The amplitude calibration signal is developed by the increasing the precision RF attenuator from 0 dB to 50 dB in 5 dB increments, as the operator notes the size of the reference corner reflector and the position of the attenuator on the voice recording track. This recorded signal provides the calibration curve of voltage versus target cross-section for the amplitude channels.

The pseudo-coherent phase signal is calibrated by varying the calibrated phase shifter through its 360° range by increments of $22\frac{1}{2}^{\circ}$, while recording the phase signal and indicating the phase shifter position in the voice track.

The Ku-band error signal channels are calibrated by recording both error signals while turning the antenna system in azimuth over a range of angles from -3° to $+3^{\circ}$, in $\frac{1}{2}^{\circ}$ increments, as estimated from the cross hair on the boresite telescope and from the azimuth angular scale on the radar frame.

4.3.2 Ku-band Measurements (MARFS)

The specific objective of this set of measurements is to correlate the results obtained by using the Ku-, Ka-, and M-band systems with measurements made simultaneously with the actual MARFS system. At Ku-band, the effect of using polarization agility and varying amounts of frequency agility on the angle tracking error signal can be determined. A comparison can be made of the relative merit of using pseudo-coherent detection (phase processing) compared to the conventional amplitude tracking technique. At Ka- and M-band, due to the fact that monopulse antennas are not being used, angle tracking error signals cannot be investigated. The decorrelation properties of the amplitude and pseudo-coherent phase signal of the clutter and of the target in the clutter will be investigated using polarization agility in the case of the M-band data and using polarization and frequency agility in the case of the Ka-band data.

Key elements of the data recording procedure include the need to operate simultaneously with the MARFS system, use the same calibration reference as the MARFS system, and use the same target and clutter cells as the MARFS system. In the case of the Ku-band data recording, the conventional amplitude monopulse error voltage will be recorded, as well as the error voltage derived from the pseudo-coherent detection circuitry. The data analysis will involve comparing the performance of the two types of error signal generation; and cross correlating the error signals with those developed in the MARFS system. Varying amounts of pulse-to-pulse frequency agility will be employed to determine the sensitivity of tracking performance to that parameter. Also, the polarization agility will be turned on and off while operating with varying amounts of frequency agility to determine the advantage, if any, in using polarization agility.

After the radar amplitude phase and angle error calibration signlas are recorded, clutter and target signatures can be recorded. The data required is recorded while the instrumentation system is boresited to the same target as the MARFS system. The instrumentation system is then operated through a variety of modes as listed below. The operator must record the operating mode for any given data run on the recorder voice track, while at the same time noting the mode in the log. Data is recorded for each run for a period of approximately 30 seconds.

Operating Modes

F/A	P/A
Off	Off
Off	On
1 mHz	Off
1 mHz	On
2 mHz	Off
2 mHz	On
3 mHz	Off
3 mHz	On
5 mHz	Off
5 mHz	On
7 mHz	Off
7 mHz	On

This procedure is performed for a variety of targets at a variety of ranges and depression angles. The target positions will be determined in coordination with the MARFS system program personnel on site. The log will include the following information: time, run number, target scenario, range, depression angle, aspect angle, azimuth position, F/A mode, P/A mode, recorder channel listing. Figure 9 is an example of the data log.

4.3.3 Ka-band Measurements

The specific objectives of this set of measurements are: 1) to develope a basic data base at Ka-band, from which any user can draw to satisfy his needs; 2) to provide data for analysis by Georgia Tech to determine statistical correlation, and spectral properties of the clutter and target reflectivity; and 3) to determine whether processing techniques such as Dynamic Threshold Gating (DTG), Correlation Coefficient

DATE
SYSTEM
TAPE NO.

WEATHER CONDITIONS:

TEST DESCRIPTION	TIME start stop	RANGE	TARGET	ASPECT	CLUTTER	DEP∠	AZ∠	P.W.	POL	FREQ.	LOCATION	REMARKS

Data Collection Log

Figure 9

Discrimination (CCD) and Pseudo-coherent Detection Integration (PDI) and the like can be used to improve target-to-clutter ratios for target discrimination in a severe clutter environment. The objectives are met by collection of a comprehensive set of data, varying target and radar parameters, such as range aspect angle, depression angle, antenna beamwidth, pulse width, frequency agility, and polarization agility. Table 13 shows a sequence of data runs which when implemented will result in a recorded collection of data consistent with the needs.

The first set of runs, lines 1-9, provide coherent data with varying pulse width and polarization modes.

The second set, lines 10-14, provide data to determine the reflectivity characteristics of weeds and a tank in the weeds using frequency agility and fixed and agile circular polarization.

The third set, lines 15-18, is the same as the second set, except that linear polarization is used.

The fourth and fifth sets, lines 19-27 are the same as the second and third sets, except that a tree line replaces the weeks as the type of clutter.

4.3.4 Ku-band Measurements

The objective of this set of data is to determine the correspondence in the data at Ka- and Ku-band for similar operating modes. A secondary objective is to relate the Ku-band data to some of that which has been analyzed in the past, to determine the consistency of the new Ku-band data.

The objectives are met by performing a sampling of tests using the Ku-band system, similar to those being performed at Ka-band.

Selected sets of runs from the Ka-test catalog, Table 13, will be performed at Ku-band. Specifically this includes all of the runs which use the 4.5 degree beamwidth and the 200 nanosecond pulsewidth--lines 10, 13, 19, and 22. These runs will also be done using the 9° antenna at Ku-band.

TABLE 13

Ka-band Test Catalog

	Target	Clutter	Height	Ground Range	Frequency	Pulse Width	Polarization	Record	Beam-width	Number of Runs
1.	None, 1	1	1	1	1	1-5	1-3	1,2,3,4,5	1	30
2.	None, 1	1	1	2,3	1	1,3,5	1,3	1,2,3,4,5	1	24
3.	None, 1	1	1	1	1	1-5	4-6	1,2,3,4,5	1	30
4.	None, 1	1	1	2	1	1,3,5	4-6	1,2,3,4,5	1	18
5.	None, 1	1	1	3	1	1,3,5	4-6	1,2,3,4,5	1	18
6.	None, 1	2	1	1	1	1-5	1-3	1,2,3,4,5	1	15
7.	None, 1	2	1	2	1	1,3,5	1,3	1,2,3,4,5	1	6
8.	None, 1	2	1	1	1	1-5	4-6	1,2,3,4,5	1	15
9.	None, 1	2	1	2	1	1,3,5	4-6	1,2,3,4,5	1	9
										165
10.	None, 1	1	1	1	2-6	1,2	1	1,2,5	1,2	40
11.	None, 1	1	1	1	3-7	3,4	1	1,2,5	1,2	40
12.	None, 1	1	1	2	3-7	3,4	1	1,2,5	1,2	40
13.	None, 1	1	1	2	2-6	1,2	3	1,2,5	1,2	40
14.	None, 1	1	1	2	3-7	3,4	3	1,2,5	1,2	40
										200
15.	None	1	1	1	2-6	1,2	4-6	1,2,5,	1	30
16.	None	1	1	1	3-7	3,4	4-6	1,2,5	1	30
17.	None	1	1	2	2-6	1,2	4-6	1,2,5	1	30
18.	None	1	1	2	3-7	3,4	4-6	1,2,5	1	30
										120
19.	None, 1	2	1	1	2-6	1,2	1	1,2,5,	1,2	40
20.	None, 1	2	1	1	3-7	3,4	1	1,2,5	1,2	40
21.	None, 1	2	1	2	3-7	3,4	1	1,2,5	1,2	40
22.	None, 1	2	1	2	2-6	1,2	3	1,2,5	1,2	40
23.	None, 1	2	1	2	3-7	3,4	3	1,2,5	1,2	40
										200
24.	None	2	1	1	2-6	1,2	4-6	1,2,5	1	30
25.	None	2	1	1	3-7	3,4	4-6	1,2,5	1	30
26.	None	2	1	2	2-6	1,2	4-6	1,2,5	1	30
27.	None	2	1	2	3-7	3,4	4-6	1,2,5	1	30
										120

TABLE 14

Key to Table 13

Target	Clutter	Height	Ground Range
1 = Tank	1 = Weeds	1 = 3rd Floor (210')	1 = 1200'
2 = Howitzer	2 = Treeline	2 = 2nd Floor	2 = 600'
		3 = 1st Floor	3 = 300'

Frequency	Beamwidth	Polarization	Receiver
1 = Coherent	1 = 1.25°	1 = RHC	1 = H
2 = 1 MHz	2 = 4.5°	2 = LHC	2 = V
3 = 2 MHz		3 = AC	3 = ϕ_H
4 = 4 MHz		4 = H	4 = ϕ_V
5 = 8 MHz		5 = V	5 = ϕ_{H-V}
6 = 16 MHz		6 = AL	
7 = 32 MHz			

MEMORANDUM REPORT NO. 2

A-1981

TEST PLAN FOR CHARACTERIZATION OF COHERENT REFLECTIVITY FROM TARGETS AND BACKGROUND AT K_u, K_a, AND M-BAND FREQUENCIES-PHASE 2

By

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REDSTONE ARSENAL, ALABAMA

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This memorandum report outlines the test organization and procedures for obtaining radar reflectivity data at K_u, K_a, and M-bands for extending the current data base at those frequencies and for evaluation of existing detection techniques.

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Memorandum Report No. 2

TEST PLAN FOR CHARACTERIZATION OF COHERENT REFLECTIVITY FROM TARGETS AND BACKGROUND AT K_u, K_a, AND M-BAND FREQUENCIES PHASE II

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1. INTRODUCTION

1.1 Test Objectives

The primary objective of this test is to establish a data base at Ka-band from which target discrimination, recognition, and identification algorithms may be developed for missile radar seeker systems. Such algorithms will seek to improve performance of sensor and seeker acquisition and tracking of tactical targets in realistic ground clutter environments. Data will consist of winter (Phase I) and summer (Phase II) measurements.

A second objective will be to collect M-band (95 GHz) radar reflectivity data which can be used to characterize clutter and target backscatter. These data will also be used in evaluation of noncoherent target discrimination techniques used at lower frequencies.

A third test objective will be to collect appropriate radar data at Ku-band for correlation with data obtained during testing of the MARFS (Multi-environment Active Radar Frequency Seeker) system. These data will be in addition to the limited quantity of conventional Ku-band data required for correlating Ka-band observations with previously reported Ku-band observations.

A fourth test objective is the simultaneous collection of radar backscattering data from clutter and targets at Ku, Ka and M-band frequencies using the same antenna beam widths and pulse widths. These data will be valuable in decoupling the radar frequency dependence of the backscatter from targets and clutter.

1.2 Background

The U.S. Army is tasked with providing helicopter-borne close air support against tactical targets on the ground. In particular the missile-borne seeker system to be utilized will probably be Ka-band frequency, or higher, from consideration of air frame size and antenna beamwidth constraints. Conventional Doppler signal processing techniques can not be used exclusively for target discrimination since the targets in question may be stationary. Thus, an identified technical problem is that of determining an appropriate signal processing technique which improves target discrimination capability at Ka-band.

Previous work at X- and Ku-band in this area, called Stationary Target Indication (STI), indicates transmission of special waveforms such as polarization and/or frequency agility and special signal processing can significantly improve target discrimination capability in realistic clutter background. Similar exploitation of induced radar backscatter characteristics should be possible at Ka-band or M-band. However, there exists no large data base in either band to investigate possible target discrimination techniques. The collection of such a data base and the development of target discrimination processing technique are included in this investigatory program.

The U.S. Army Missile Research and Development Command (MIRADCOM) is currently funding development of the MARFS system, which is a missile-born target tracking concept based on dual polarization and pseudo-coherent detection techniques. An associated helicopter-borne detection, designation, and acquisition system is also being developed which must operate under the same environmental conditions as does the MARFS system. An independent analysis of data pertinent to the MARFS concept is desired in order to increase confidence in the anticipated angle-tracking performance improvement which has been predicted. Data is also required for selection of appropriate radar frequency for the associated helicopter-borne acquisition system.

1.3 General Test Description

This test program addresses the collection of radar backscatter data for targets in a foliated clutter environment. Two distinct measurement tasks are indicated which are to be conducted from the F1 Test Facility at Redstone Arsenal, Alabama. The first task includes simultaneous recording of radar backscatter data from clutter, targets, and reflectors at Ku-, Ka- and M-bands to determine the following:

(a) Spot check of Ku-band backscatter characteristics,

(b) Ka-band backscatter amplitude statistical description as a function of polarization agility, frequency agility, pulse width, antenna beamwidth, target aspect, and weather conditions,

(c) Ka-band coherent backscatter statistical description,

(d) M-band backscatter amplitude statistical description as a function of polarization agility, antenna beamwidth and weather conditions,

(e) Ka-band and M-band pseudo-coherent backscatter statistical description,

(f) Frequency designation for helicopter-borne target acquisition system.

The second task includes measurement of appropriate Ku-band radar data required to evaluate the merit of the MARFS angle-tracking concept. These data include tracking errors and associated signals which are relevant to the MARFS system, plus conventional backscatter signals necessary for concept evaluation.

1.4 Relevency of Measurements

In addressing the need for a data base in the millimeter wave region, it is conceivable that a matrix containing over one million data runs could be generated, representing variations of each of the system parameters for all values of each of the other parameters. In order to develop a managable number of data runs desired, some direction must be given to the selection of the test matrix. Certainly not all parameters can be varied over their full range for full variations of all the other parameters, but each variable can be varied over its range for a limited number of values for the other parameters.

A number of signal processing techniques which have been investigated in the past for use with radars operating in the X- and Ku-bands, may have applicability in the Ka- and M-bands. Some of these are Dynamic Threshold Gating (DTG), Correlation Coefficient Discrimination (CCD) and Pseudo Coherent Detection Integration (PDI). These algorithms basically exploit the statistical nature of the returns from targets as they differ from that of clutter, using various operating modes. The autocorrelation properties of the returns depend on such things as the amount of frequency agility employed for various pulse lengths, with and without polarization agility. Varying the amounts of frequency agility and pulse lengths in the data collection will allow evaluation of the effectiveness of frequency agility in employing the processing techniques mentioned above. The use of polarization agility in the data collection will allow determination of the utility of that mode in improving the discrimination potential.

It has been demonstrated that DTG and CCD can achieve intercell subclutter visibility, but not intracell subclutter visibility. For this reason DTG and CCD techniques work best with a maximum target to clutter ratio, the optimum being when the cell size is the same as the target. These modes have application even in an environment in which the clutter exceeds the target in an adjacent cell.

PDI has been shown to possess intracell subclutter visibility capability. This technique relies on the randomness of the clutter statistics, and may demand a larger cell size than the DTG and CCD techniques, to insure this randomness. The variations in antenna beamwidth and pulse length in the data set address the need to vary the cell size in evaluating this effect.

2. DESCRIPTION OF TEST EQUIPMENT

2.1 Ka-band Radar System

A 35 GHz radar system has been fabricated which represents the state-of-the-art for a variable parameter, instrumentation grade radar at this frequency band. The optional operating modes of this system include (1) coherent operation; (2) dual polarization, transmit and receive; (3) pulse-to-pulse polarization agility; (4) pulse-to-pulse frequency agility; (5) and intra-pulse frequency ability. In addition, this portable radar system is self-contained and configured for use with instrumentation and recording equipment. As shown in Figure 1, the radar system involves three units; the radar itself, the power supply, and the control panel. The three are interconnected with appropriate cables.

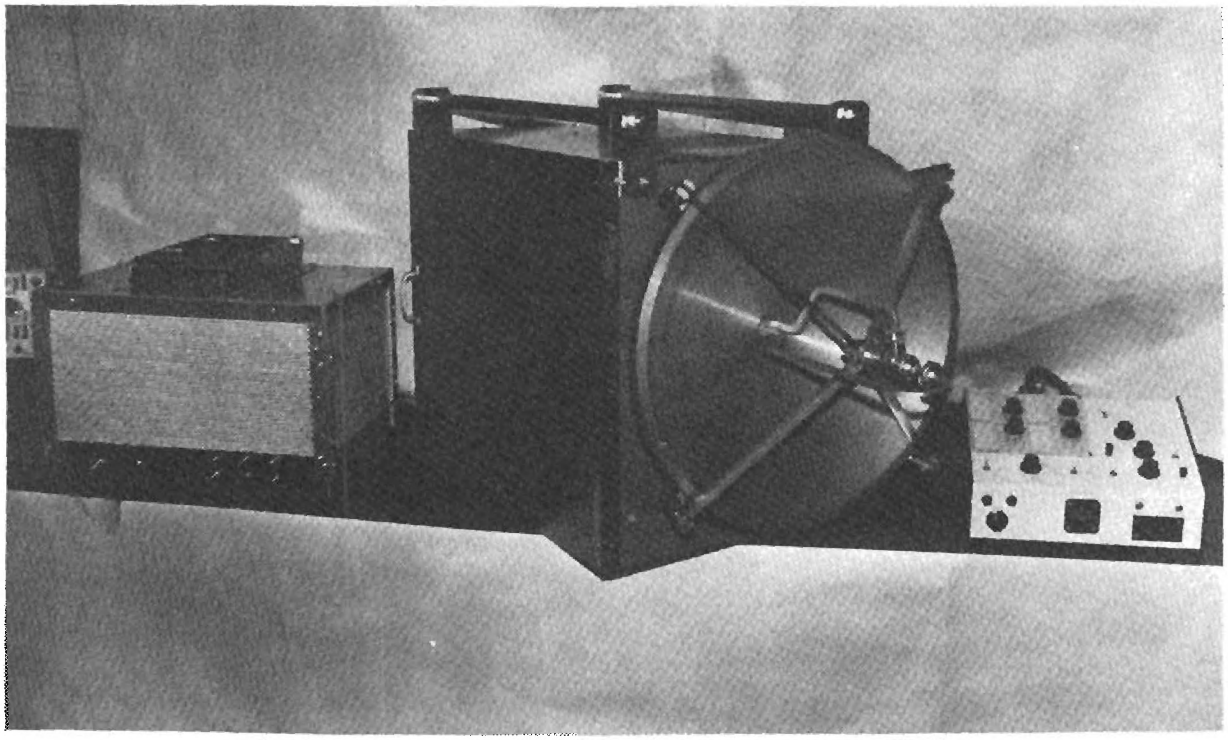
Figure 2 illustrates a block diagram description of the Ka-band radar system, whose parameters are listed in Table 1. Note that this configuration is compatable with both coherent and pseudo-coherent operation. Naturally, not all of the available operational modes are mutually compatable, e.g., frequency agility and coherent operation.

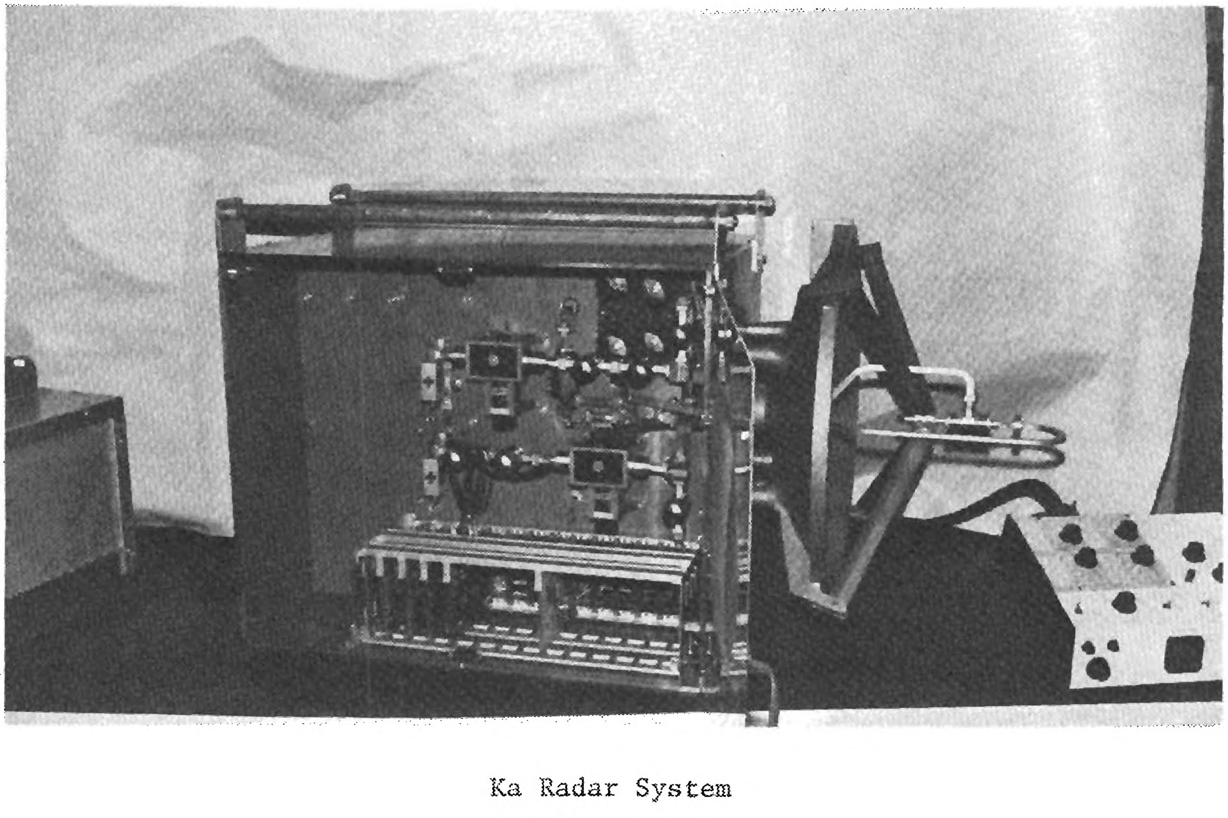
2.2 Ku-band Radar System

A 16 GHz radar system is available to supply the necessary Ku-band data for recording. Table 2 lists the pertinent parameter values for this radar system. Note that it is a noncoherent system, but has both polarization and frequency agility capabilities, and can be configured in a pseudo-coherent mode, as shown in block diagram form in Figure 3. As with the Ka-band system, different antenna beamwidths will be effected by using several antennas of various diameters.

2.3 M-band Radar System

The M-band radar to be used in this measurement program is designated GT-M and is a 95 GHz instrumentation radar. The radar operates in a noncoherent mode with capability for pulse-to-pulse polarization agility and has a dual channel (H and V) receiver. Table 3 is a summary of the





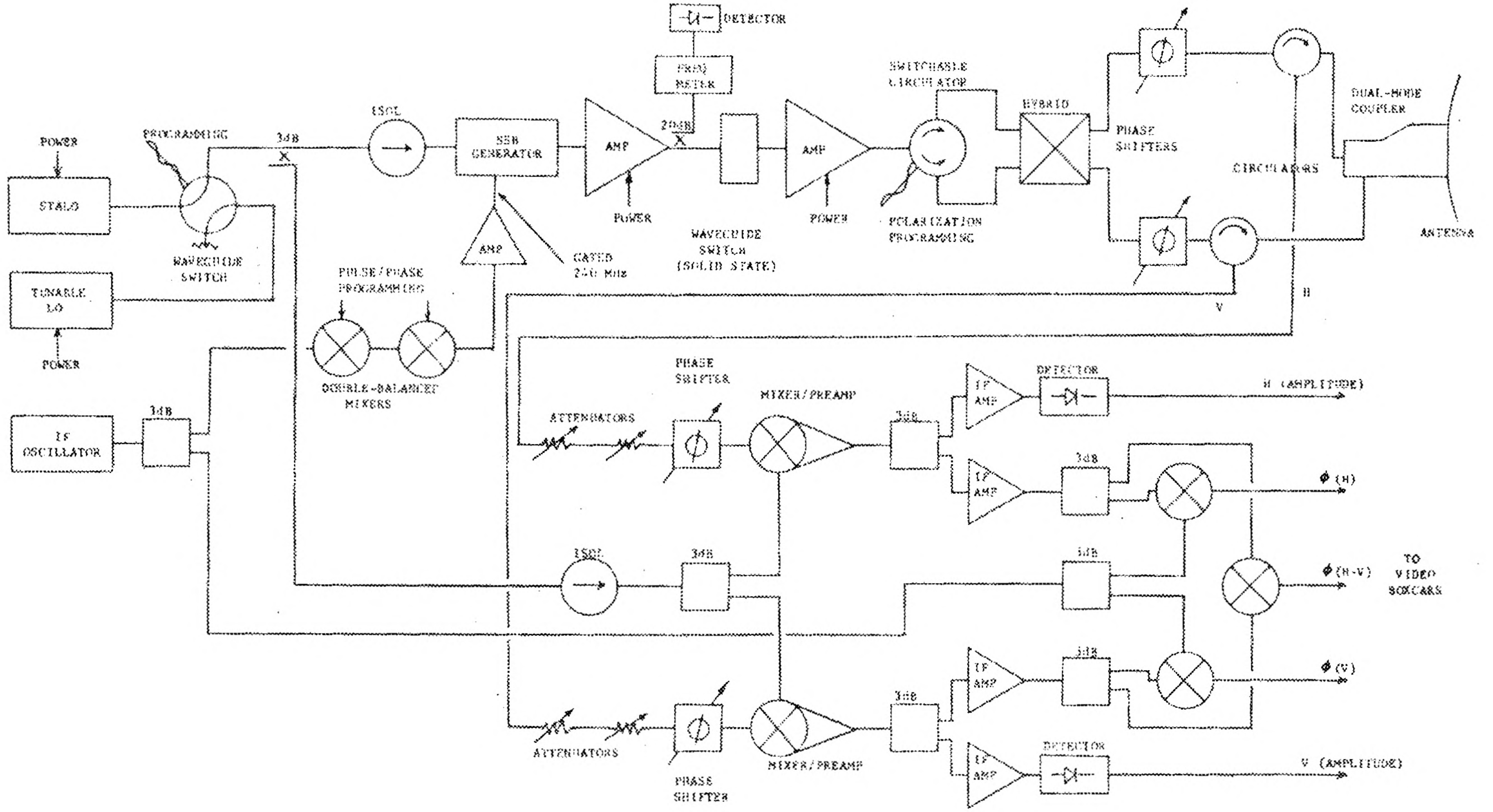
Ka Radar System

Figure 1

TABLE 1

Ka-band Radar Parameters

Transmitter		
RF Frequency:	34.75-35.75 GHz	
Peak Power:	2-3 Watts Pulse 150 mW cw	
Pulse Width:	10 nsec to cw	
PRF:	VARIABLE	
Antenna		
Type:	Machined Aluminum 18" Parabolic Dish	Horn Fed Lens Antenna
Beamwidth: Az El	1^{o} 1^{o}	45^{o} 45^{o}
Gain:	> 40 db	> 30 dB
Polarization: Fixed, or Pulse-to-Pulse Agile	Right Circular Left Circular Horizontal Vertical	
Receiver		
Type:	Log, 140 MHz Bandwidth Linear, Wideband 10 to 500 MHz	
IF:	240 mHz	
Detection:	Amplitude Phase (coherent)	
Sensitivity:	- 80 dBm	



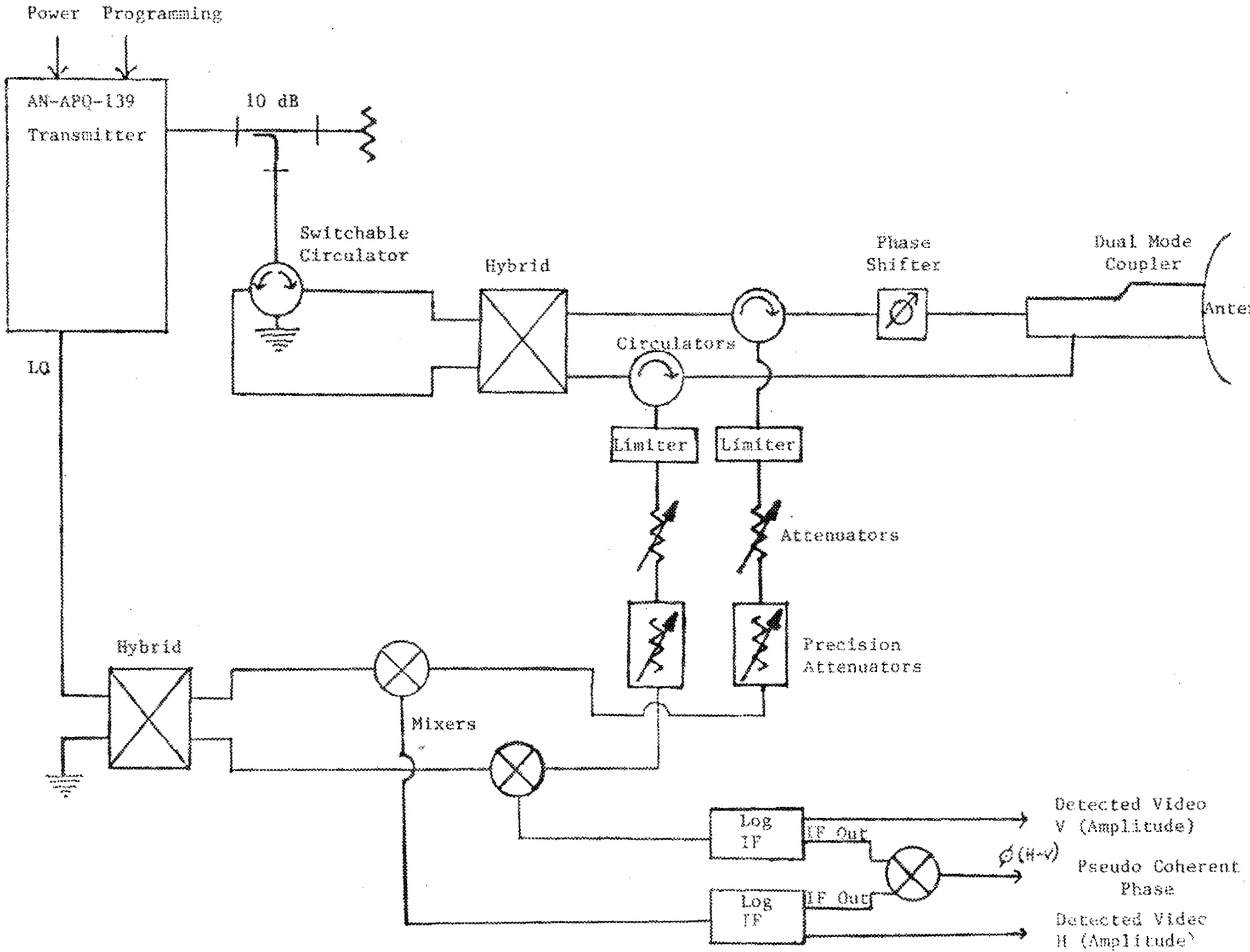
Block Diagram Transmitter-Receiver Portion of Ka-band Radar

Figure 2

TABLE 2

Ku-band System Parameters

Transmitter		
RF Frequency		15.9-16.4 GHz
Peak Power		6 kW
Pulse Width:		200 nanoseconds
PRF		2-8 kHz
Dual Polarized Horn Antennas		9°
		4.5°
Dual Polarized Monopulse Antenna		
Type		Two separate but dependent parabolic reflectors with two full monopulse feeds
Beamwidth:	El	6.0 deg (3 dB points)
	Az	2.2 deg (3 dB points)
Gain:		30.5 dB (each)
Polarization:	Fixed, or pulse-to-pulse agility	Vertical top Horizontal bottom
Receivers, Horizontal and Vertical		
Type		Super heterodyne, log IF and linear IF amplifiers
Detection		Pseudo-Coherent, Amplitude
Bandwidth		20 MHz, Lob IF 20 MHz, Linear IF
Dynamic Range		70 dB, Log IF
Sensitivity		- 90 dBm
Data Recording		
Magnetic Tape		7-channels, FM, 0-20 kHz
Oscillograph		6-channels, 0-5 kHz



Block Diagram Ku-band

Figure 3

TABLE 3

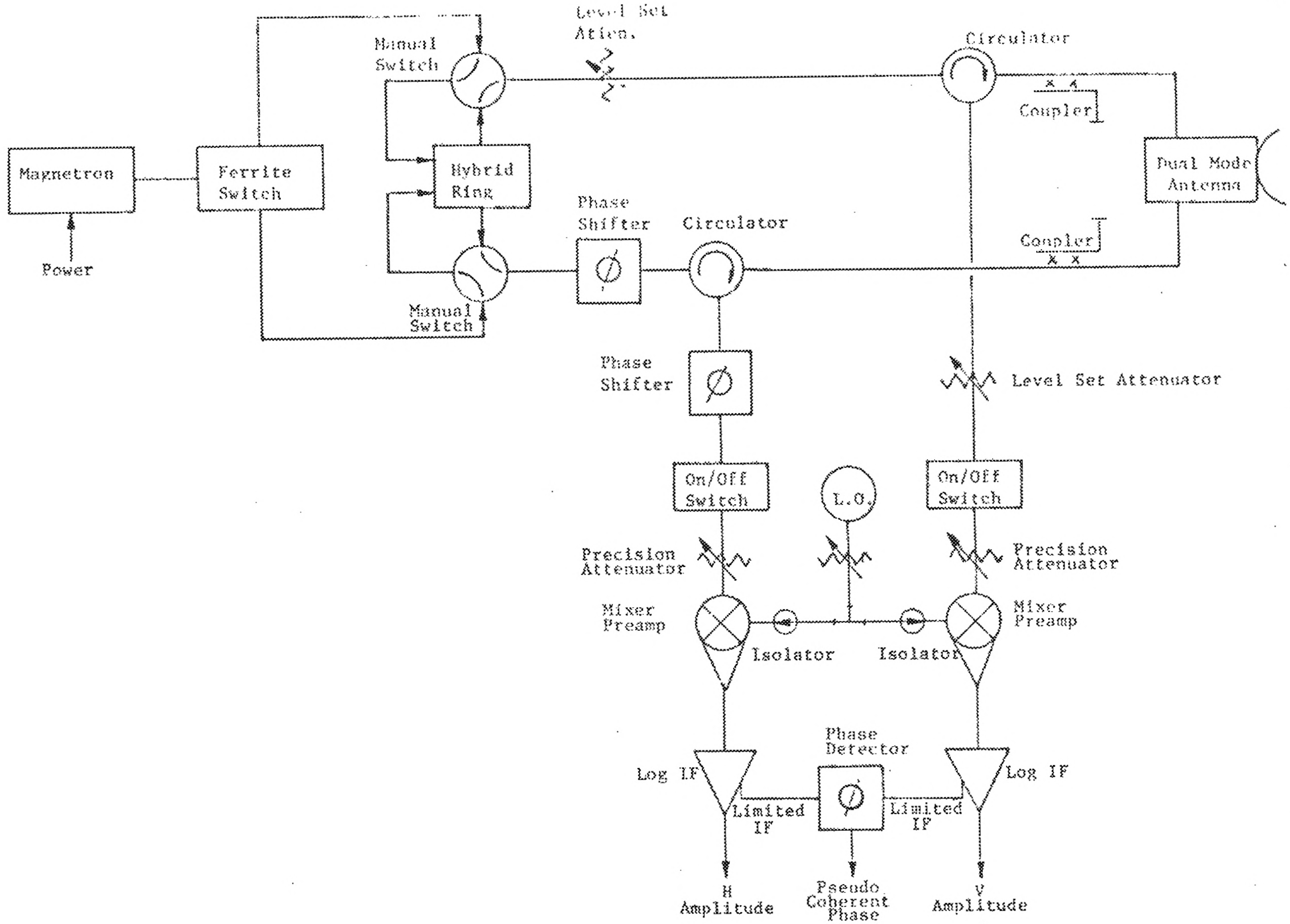
GT-M System Parameters

Transmitter	
RF Frequency	94.5-95.5 GHz
Peak Power:	1 KW
Pulse Width:	15 nsec or 70 nsec
PRF:	Variable
Antenna	
Type:	12" Diameter Cassegrain 3" Diameter Horn Lens
Beamwidth:	0.7 degrees 3.0 degrees
Polarization:	Fixed or Pulse-to-Pulse Agile RC, LC or H,V
Receiver	
Type:	Super hetrodyne, Integrated mixer, preamp, 10-2000 MHz
IF:	300 MHz Logarithmic
Detection:	Amplitude Phase (pseudo-coherent)
Dynamic Range:	60 db
Noise Figure:	12 db

radar parameters and Figure 4 is a block diagram of the receiver-transmitter. Different antenna beamwidths will be accomplished by simple replacement of the antenna.

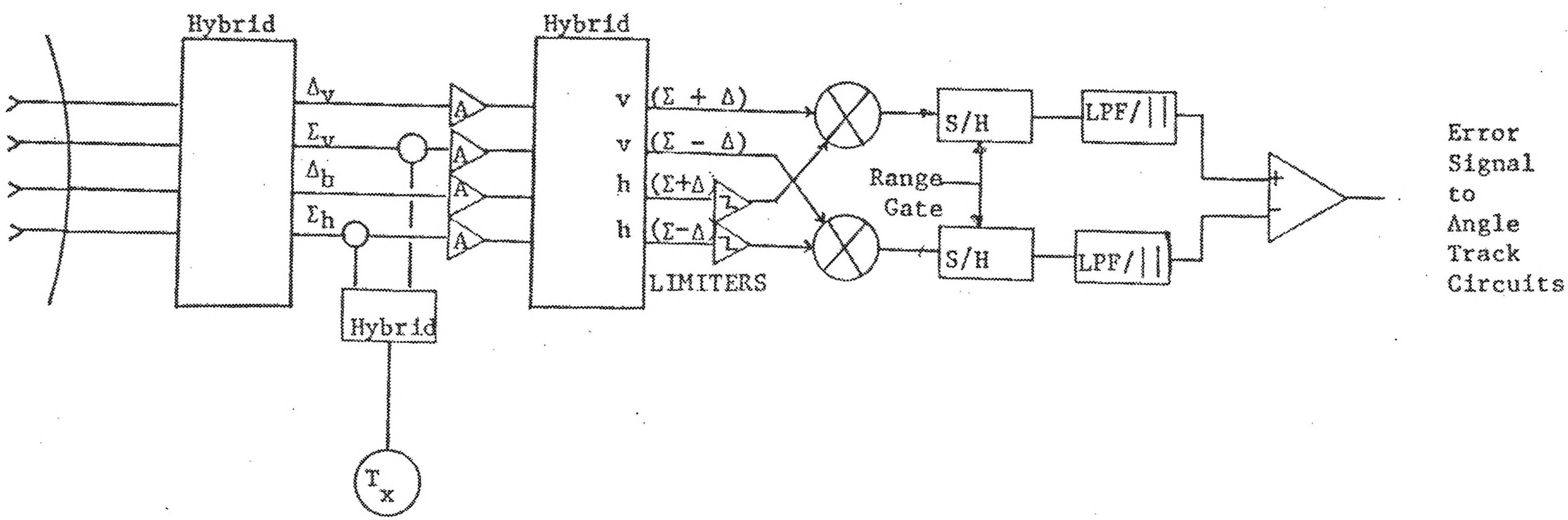
2.4 PENRAD Monopulse Radar System

The PENRAD dual polarized, monopulse antenna assembly will be mated to appropriate RF components in the MARFS configuration, as shown in Figure 5. A calibrated boresight telescope will be attached to the PENRAD antenna assembly to correlate the angle error signal with the true off-boresight angle. The MARFS error signal, conventional monopulse error signal, pseudo-coherent signal, and several intermediate signals will be available for recording and subsequent evaluation.



GT-M Block Diagram

Figure 4



Simplified Block Diagram of MARFS Polarization Diverse Angle Error Detector

Figure 5

3. REQUIREMENTS FOR TEST OPERATION

3.1 Tower Test Facility

The primary site for this data collection program will be the F1 Tower Site at the Redstone Arsenal, Alabama. Figure 6 shows a pictorial sketch of the F1 Tower Site and the associated geometric parameters from the tower to the surrounding field areas. Three platform levels are available on the tower, at heights above the local terrain of 30, 42, and 63 meters.

Fields suitable for target and vehicle placement surround the tower at ground ranges from about 90 to 360 meters. Table 4 summarizes the geometric parameters available from the set of tower platforms and the usable target ranges.

TABLE 4

F1 Tower Geometry

Platform Height (m)	Minimum Depression Angle Ground Range = 360 m	Maximum Depression Angle Ground Range = 90 m
30	4.8°	18.4°
42	6.7°	25.0°
63	9.9°	35.0°

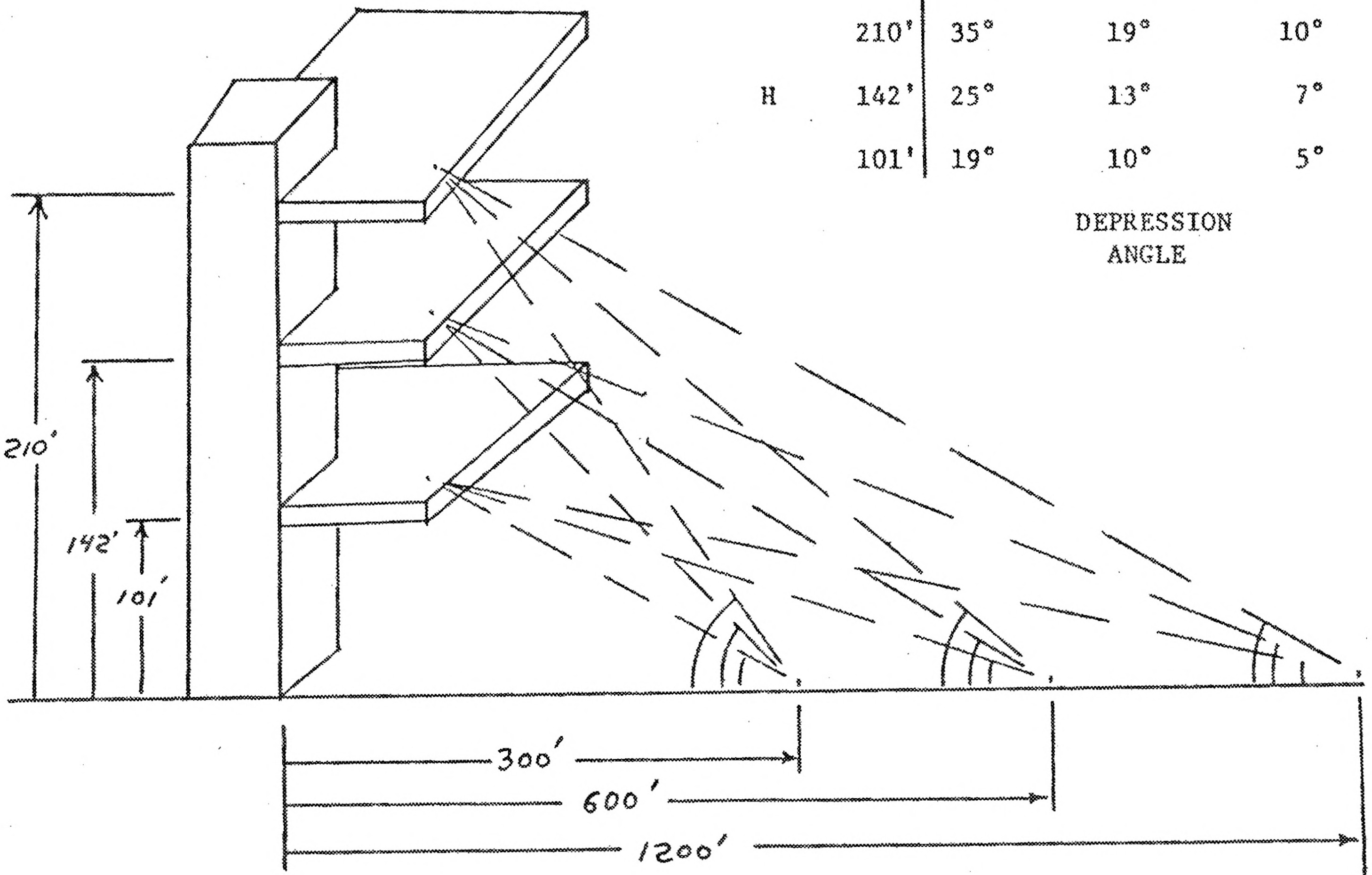
It can be seen that a range of depression angles from the tower platform to the target area in the field can be established from less than 5 degrees to as much as 35 degrees.

It is the intent of this measurement program to utilize all three tower platforms in order to fulfill the parameter requirements designated in the test matrix (see section 4.3). The government should, therefore, provide electrical power to operate the radars, recorders, and ancillary equipment at each of the three platform levels. Minimum requirements for power are as follows:

110 V, 60 Hz, 1Φ 1.5K Watts
110 V, 60 Hz, 1Φ 1K Watts
110 V, 400 Hz, 3Φ 1K Watts

		R_g	
H	300'	600'	1200'
210'	35°	19°	10°
142'	25°	13°	7°
101'	19°	10°	5°

DEPRESSION ANGLE



F-1 Tower Facility

Figure 6

In the event that the government cannot provide the designated power, Georgia Tech will make whatever arrangements are deamed necessary to obtain such power.

The work area will be comprised of the radar systems, support equipment, and recording devices, on each tower platform one at a time. A work bench is desired at the work area which should have the following characteristics:

- Flat work bench area of at least $4m^2$, with suggested dimensions of 1 x 4 meters at a height of 1 meter.
- At least 10 115 V, 60 Hz, 1Φ standard power outlets, bussed together to a single male power plug for connection to the main tower power grid, and protected by fuses or circuit breakers with a 20 amp current rating.
- Capability of supporting at least 200 kilograms, total, and downward surface pressures of 2.1 kg/cm^2.

Additional work area devices, such as stands, racks, etc., will be provided by Georgia Tech.

Since radar measurements will be made with weather conditions as salient parameters, it will be mandatory that the radar systems operate within a protected enclosure. A waterproof, air-conditioned, enclosure will be required both to protect the electronic equipment from weather-induced damage and to provide an acceptable work environment for attendent personnel. Windows should be so designed that the radar systems may radiate through transparent (at the appropriate frequency) materials or through protected openings in the enclosure walls. If not otherwise provided at the F1 Tower Facility, running water and restroom facilities should be made available either within this enclosure or nearby.

3.2 Personnel Requirements

Radio communication using UHF or VHF transceivers will be required during this test operation. It is suggested that government permission be granted to permit use of Georgia Tech-licensed VHF transceiver base station and remote units operating at frequencies of 151.625 MHz and 151.475 MHz for the duration of this field operation at Redstone Arsenal. The designated call sign for this communication system is KC2XGC. Otherwise the government must furnish a suitable electronic means of communication between the F1 Tower Facility and the target field.

Security clearances and unlimited access to the F1 Tower and target field must be provided for Georgia Tech personnel. If data reduction is undertaken at the Redstone computer facility, proper access must also be provided. Vehicle passes must be provided for both the Georgia Tech owned vehicles and the privately owned vehicles used by Georgia Tech personnel for personal transportation. Additional clearances and/or permit must be provided for that photographic equipment (TV cameras, 16 mm movie cameras, 35 mm still cameras, etc.) needed to document the test activities. Adequate security of both the Tower-based equipment and the Georgia Tech-owned vehicles must be provided by fences, locked gates, etc. and a seemed parking area respectively.

It will be desirable that general office space be made available with desks, chairs, telephones, and storage cabinets for Georgia Tech personnel (up to 6 persons) as near the F1 Tower as possible for the duration of this test program. This requirment may entail additional identification badges, parking permits, etc., as identified.

4. TEST OPERATIONS: FOLIATED BACKGROUND

Radar backscatter data and meteorological data will be recorded to fulfill the two major test objectives of this program. The first data set will address those data needed to characterize Ka-band reflectivity from ground clutter and targets in clutter, including supportive backscatter at Ka-band. The second data set will address those data required to verify the MARFS tracking concept, at Ku-band alone.

4.1 Ka-band Reflectivity Characterization

4.1.1 Test Matrix

The data collection program designed to characterize Ka-band reflectivity will be based around clutter and an M48 tank, or equivalent, as the tactical target of interest. Trihedral and diplane corner reflectors are required to quantify reflectivity and will also be used to calibrate signal amplitudes, align polarizations, etc. Table 5 lists a matrix of Ka-band radar, target, geometric, and ground clutter parameters which will be varied during this field exercise. It is the intent of listing this matrix that

TABLE 5

Ka-band Measurement Matrix

Test Group	Target Aspect	Antenna Aperture	Depression Angle	Transmit Polarization	Transmit Mode	Pulse Width	Clutter Type	Notes
I	45°	1°	10°	H,V,PAL RC,LC,PAC	Coherent NC(10 MHz)	.2 μsec	Scrub	
II	45°	1°	$5,10,13,19,25^{\circ}$	*	Coherent NC(10 MHz)	.2 μsec .01	Scrub	*Subject to TGI results
III	$0,45,90,135,180^{\circ}$	1°	10°	*	Coherent NC(10 MHz)	.2 μsec .01	Scrub	*Subject to TGI results
IV	135°	$1,4.5^{\circ}$	10°	*	Coherent NC(10 MHz)	.2 μsec .01	Scrub Tree Line	*Subject to TGI results
V	135°	1°	10°	*	Coherent NC(10 MHz)	.01,.03, .05,.2	Scrub Tree Line	*Subject to TGI results
VI	135°	1°	10°	H,V,PAL RC,LC,PAC	Coherent NC(10 MHz)	.2 μsec .01	Scrub Tree Line **	**Includes weather parameters
VII	135°	1°	10°	*	Coherent NC(1,5,10, 20,50 MHz)	.01 μsec .05	Scrub Tree Line	

it serve as a guide for the actual data collection. That is, as the test program progresses, the matrix may be altered to benefit from on-site observations and different priorities and opportunities.

The various tests can be conveniently arranged into seven test groups, as determined by that particular parameter to be varied. The first test group (I) is intended to compare various polarization transmission modes for appropriateness in signal discrimination in both coherent and noncoherent modes of operation. PAL refers to polarization agility with H and V linear polarizations alternately, while PAC refers to polarization agility with circular polarizations alternately. It is anticipated that, at the most, only two of these polarization modes will be used for the remaining tests, except for TG VI.

Test group II varies the depression angle to the target cell, while target aspects are changed in test group III. The effects of beamwidth are investigated in test group IV. While pulse width is the parameter of interest in test group V. Weather effects are contained in test group IV, and all polarization modes will be investigated. It can be assumed that these tests will necessarily be distributed among all the others as weather conditions recur. The last test group, VII, contains pulse-to-pulse frequency change as a parameter (assuming frequency agility has survived as an operational mode of interest). Both scrub and tree line clutter environments are utilized as shown.

Table 6 and 7 list the analogous matrices for the supportive Ku-bank and M-band measurements. The data collection is also shown arranged into the test groups described previously. Note that all Ku-band data is noncoherent, at .2 or 1 μ second pulsewidth, using primarily a 4.5^{o} beamwidth antenna. These matrices represents only a fraction of the data collection designated for the Ka-band tests. However, it is the intent that common parameter Ku- and M-band data be recorded simultaneously.

4.1.2 Target Description

It is assumed that, for this data collection program, an M48 tank, or equivalent, will be the primary tactical target of interest. If additional tactical targets are needed, it is suggested that they be 2-1/2 ton Army trucks, 3/4-ton trucks, 1/4 tone trucks, or mobile artillery units.

TABLE 6

Ku-band Measurement Matrix

Test Group	Target Aspect	Antenna Aperture	Depression Angle	Transmit Polarization	Transmit Mode	Pulse Width	Clutter Type	Notes
I	45°	4.5°	10°	H,V,PAL RC,LC,PAC	NC(10 MHz)	.2 µsec	Scrub	
II	45°	4.5°	$5,13,25^\circ$	*	NC(10 MHz)	.2 µsec	Scrub	*Subject to TGI results
III	$0,45,90^\circ$	4.5°	10°	*	NC(10 MHz)	.2 µsec	Scrub	*Subject to TGI results
IV	135°	$4.5,9^\circ$	10°	*	NC(10 MHz)	.2 µsec.	Scrub Tree Line	*Subject to TGI results
V	135°	4.5°	10°	*	NC(10 MHz)	.2 µsec 1 µsec	Scrub Tree Line	*Subject to TGI results
VI	135°	4.5°	10°	H,V,PAL RC,LC,PAC	NC(10 MHz)	.2 µsec	Scrub Tree Line **	**Includes weather parameters
VII	135°	4.5°	10°	*	NC(1,5, 10 MHz)	.2 µsec	Scrub Tree Lines	

TABLE 7

M-band Measurement Matrix

Test Group	Target Aspect	Antenna Aperture	Depression Angle	Transmit Polarization	Transmit Mode	Pulse Width	Clutter Type	Notes
I	45°	3.0°	10°	H,V,PAL RC,LC,PAC	NC	.2 μsec	Scrub	
II	45°	3.0°	$5,13,25^{\circ}$	*	NC	.2 μsec	Scrub	*Subject to TGI results
III	$0,45,90^{\circ}$	3.0°	10°	*	NC	.2 μsec	Scrub	*Subject to TGI results
IV	135°	$3.0^{\circ},0.7^{\circ}$	10°	*	NC	.2 μsec.	Scrub Tree Line	*Subject to TGI results
V	135°	3.0°	10°	*	NC	.2 μsec	Scrub Tree Line	*Subject to TGI results
VI	135°	3.0°	10°	H,V,PAL RC,LC,PAC	NC	.2 μsec	Scrub Tree Line **	**Includes weather parameters

Standard corner reflector will be utilized to quantify radar cross sections, locate target positions accurately, and align radar polarization. The following set of calibrated trihedral corner reflectors may be used in this program, as listed in Table 8 below:

TABLE 8

Corner Reflector Radar Cross Sections

Base (cm)	RCS (dbsm, 16 GHz)	RCS (dBsm, 35 GHz)	RCS (dBsm, 95 GHz)
13.9	6.5	13.3	22.0
24.8	16.5	23.3	32.0
30.2	20.0	26.8	35.5
44.1	26.5	33.3	42.0
71.3	34.9	41.7	50.4
94.0	39.7	46.5	55.2
127.6	45.0	51.8	60.5

Table 9 lists the calibrated diplane corner reflectors which may be used. It is anticipated that these selections of corner reflectors will suffice for this field operation.

TABLE 9

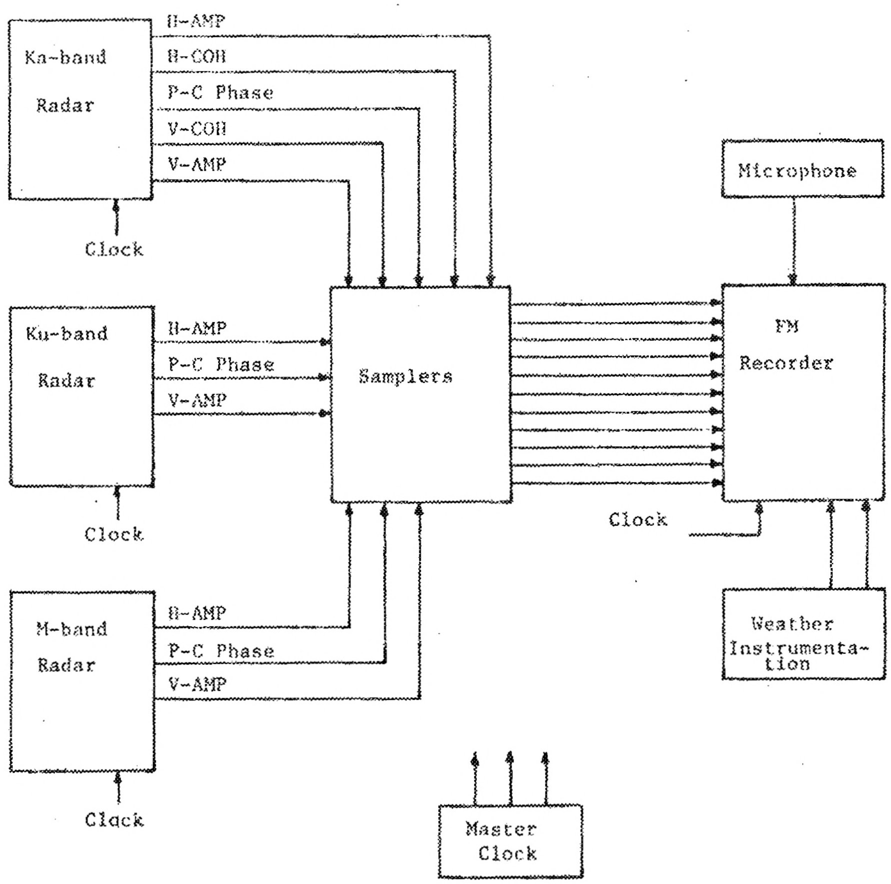
Diplane Radar Cross Sections

Width	Height (cm)	RCS (dBsm, 16 GHz)	RCS (dBsm, 35 GHz)	RCS (dBsm, 95 GHz)
20.4	10.2	14.9	21.7	30.4
30.5	15.2	21.9	28.7	37.4
43.2	21.6	27.9	34.7	43.4
52.4	37.2	34.3	41.1	49.8
46.0	79.0	39.8	46.5	55.2

4.1.3 Data Collection Instrumentation

Various range-gated radar data will be recorded on FM tape, along with supportive weather, clock, and annotation data. In addition real time data analysis and monitoring will be provided to insure validity of the various data. Figure 7 shows a simplified block diagram of the overall equipment interconnection.

The boxcar signals to be recorded are listed in Table 10 below along with assigned FM recorder track designations. Additional signals to be recorded are also identified.



Data Collection Block Diagram

Figure 7

TABLE 10

Data Channel Assignments

Signal	Source	FM Track Number
Audio Annotation	Microphone	1
Vert. Pol. Amplitude	Ka	2
Hor. Pol. Amplitude	Ka	3
Pseudo-Coherent Phase	Ka	4
Vert. Pol. Amplitude	Ku	5
Hor. Pol. Amplitude	Ku	6
Pseudo-Coherent Phase	Ku	7
Vert. Pol. Amplitude	M	8
Hor. Pol. Amplitude	M	9
Pseudo-Coherent Phase	M	10
Ka, M PRF Reference	Ka, M Clock	11
Ku PRF Reference	Ku Clock	12
Wind Speed	Weather Inst.	13
Wind Direction	Weather Inst.	14

Real-time monitoring of each of the nine radar video signals will be accomplished using an oscilloscope. Analysis of boxcar radar data will be effected through use of a Federal Scientific Correlator, which can provide "real-time" correlation and probability distribution information of selected inputs.

4.1.4 General Measurement Procedure

The intent of this field exercise is to statistically characterize Ku-, Ka- and M-band radar backscatter signals with identified radar target, and environment parameters. This characterization will take the form of autocorrelation functions, mean values, probability density functions, and other conventional statistical descriptions. In order to make these characterizations meaningful, it is essential that target and clutter radar cross sections be determined and that the transmitted polarization be well defined. To these ends two calibration procedures will be described.

4.1.4.1 Signal Amplitude Calibration

Purpose: It is desired to establish radar cross section levels for both clutter cells and for targets in order to determine target-to-clutter cross section ratios relative to various statistical descriptions of the radar backscatter signal. To determine absolute radar cross section levels, it is necessary that a relationship be established between the cross section of a target and the radar video signal amplitude level.

Procedure: To calibrate a radar return signal from a particular resolution cell for absolute radar cross section, a transfer curve is established relating the received video output (voltage) to a known radar cross section at a known range. This is accomplished by measuring the signal return from a trihedral reflector with known characteristics, at a precisely measured range. The radar cross-section of the reflector is chosen so as to be much greater than the clutter in the measurement cell. The transfer characteristics of the receiver are then defined by stepping the calibrated attenuator in each receiver line in 5 dB increments from 0 dB to -50 dB. Radar cross sections of other targets in this resolution cell may then be determined via the transfer curve.

4.1.4.2 Transmit Polarization Calibration

Purpose: To accurately characterize the radar video backscatter, especially for phase or polarization processing techniques, it is essential that the circular polarization used in transmission be accurately established and maintained.

Procedure: Calibration of the circular polarization is effected by using a diplane corner reflector. The diplane is erected with its seam at a $22\frac{1}{2}^{\circ}$ angle from vertical. The horizontal and vertical amplitude of the backscatter are displayed simultaneously on an oscilloscope. The phase shifters in the horizontal and vertical transmit legs are adjusted to produce a maximum return in the vertical receive channel, and a null in the horizontal receive channel. This produces a 45° linear transmitted wave. The circular transmitted wave is then produced by observing the output of the horizontal phase detector and advancing the horizontal transmit phase shifter 90°.

4.1.4.3 Data Collection

Purpose: Radar video signals will be recorded on FM tape simultaneously from a Ku-, Ka- and M-band radar. A data base at 35, and 95 GHz will be established which will characterize the radar backscatter for target discrimination potential. Sufficient 16 GHz data will be recorded to provide adequate confidence in the Ka-, M-band data base.

Procedure: The tank target will be placed at a specified resolution cell at an aspect angle determined by using a standard protractor. This procedure is adequate to providing target aspects to within $+5^{o}$ accuracy.

Slant range to the target cell can be determined from the time delay between transmission of a radar pulse and reception of the radar return from a corner reflector at the target location. Displaying radar signal amplitude versus slant range on an oscilloscope so that the maximum slant range (366 m) represents full scale (10 cm), each millimeter on the screen will represent about 3.7 meters, which will also be the accuracy to which slant range will be determined.

Each radar antenna will be boresighted onto the target cell using an optical telescopic sight mounted rigidly onto the antenna assembly. (This sight will have been calibrated prior to the field operation).

Data collection will then commence using the multi-channel FM tape recorder for storage of sampled radar video signals. The target radar cross section will be determined from signal amplitudes referenced to the calibrated system transfer function previously determined. The radar cross section of the resolution cell, without the target, will then be determined in order to calculate the target-to-clutter radar cross section ratio for a particular target aspect in that clutter cell.

The data will be collected according to a reasonable schedule, with Tables 5, 6, and 7 outlining the test parameter matrix. Test group I will be undertaken first, and test group VI will be undertaken as weather conditions dictate. A log will be maintained of date, run number, and listing of significant parameters. Equivalent annotations will be made on the voice track of the FM tape recorder for later run identification.

4.2 MARFS Data Characterization

4.2.1 Test Matrix

The data collection program designed to characterize the MARFS radar tracking concept will be based around clutter and an M48 tank, or equivalent, as the tactical target of interest. Trihedral and diplane corner reflectors will be used as targets of known reflectivity characteristics for later evaluation of the MARFS data. Table 11 lists a matrix of target, geometry, and ground clutter parameters which will be varied during the MARFS investigation. As before, the intent of this matrix is to serve as a guide for the actual data collection, which will be adaptive to conditions identified.

Four separate test groups are identified in Table 11. The first group investigates the effects of depression angle primarily on the MARFS data, while the second group is based on various target aspects to the radar. A third group is shown to identify weather effects on the radar signals. Group four addresses the fixed and agile circular polarization effects on the MARFS concept.

4.2.2 Target Description

An M48 tank, or equivalent, will serve as the primary tactical target for the MARFS data collection. Additional targets, such as those listed in section 4.1.2, are also appropriate. The set of trihedral and diplane corner reflectors will also be utilized when calibrated radar cross section targets of known reflectivity characteristics are required.

4.2.3 Data Collection Instrumentation

The range-gated radar data of the MARFS investigation will be recorded on FM tape, along with supportive weather, clock, and annotative data. Some real time data analysis will be provided to insure validity of the data.

TABLE 11

MARFS Measurement Matrix

Test Group	Target Aspect	Off Boresight Angle	Depression Angle	Clutter Type	Notes
I	45°	$\pm$ one beamwidth az and el *	$5,10,13,19,25^{\circ}$	Scrub Tree Line	*az: $-6,-3,0,+3,+6^{\circ}$
II	$0,45,90,135,180^{\circ}$	$\pm$ one beamwidth az and el *	10°	Scrub	
III	45°	$\pm$ one beamwidth az and el *	10°	Scrub	Includes weather parameters
IV	45°	$\pm$ one beamwidth az and el *	10°	Scrub	Polarization: RC, LC, agile

The boxcar signals which will be recorded are listed below in Table 12 along with tentative FM recorder track designations.

TABLE 12

MARFS Data Channel Assignments

Signal	FM Track No.
MARFS Error Signal	1
Pseudo-coherent (Σ+Δ) Signal	2
Pseudo-coherent (Σ-Δ) Signal	3
Conventional monopulse (Δ) Signal	4
Pseudo-coherent (Σ) Signal	5
Range Gate Clock Signal	6
	7
Audio Annotation	Edge Track

A block diagram of the sources of these MARFS signals and related radar signals is shown in Figure 8.

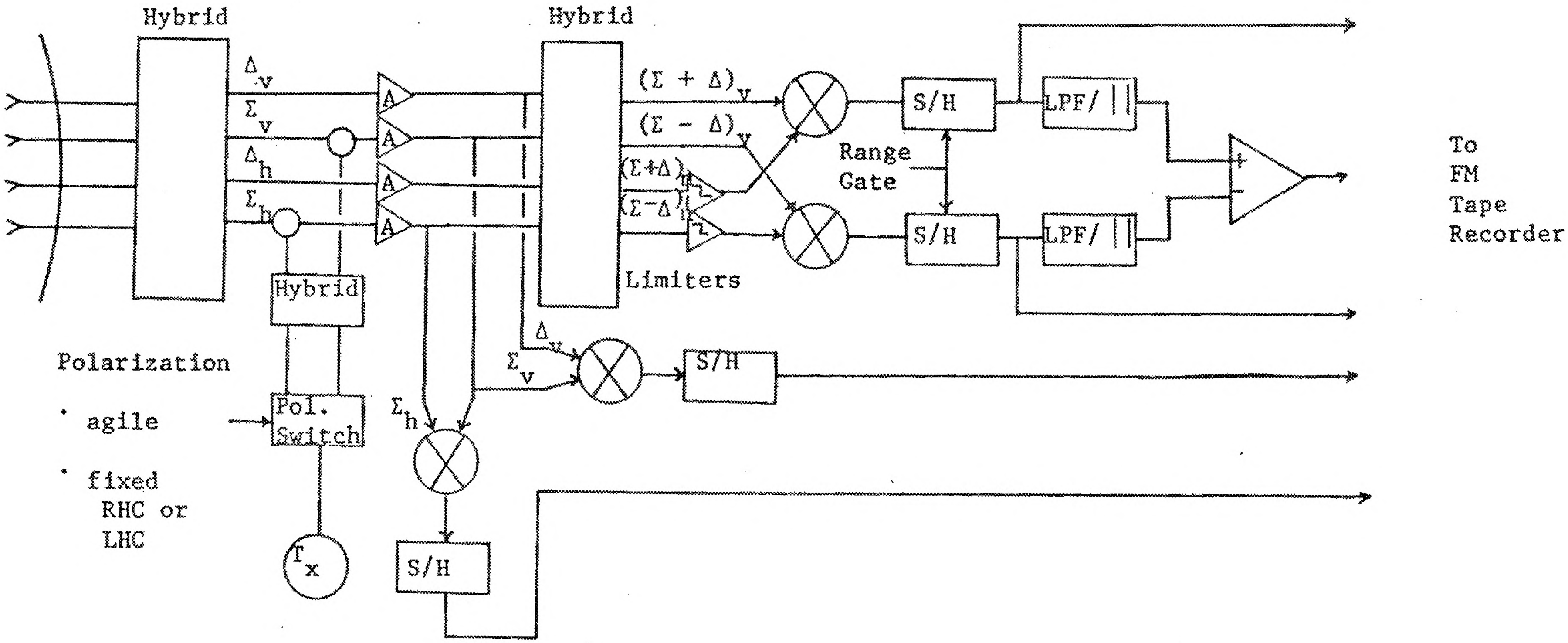
4.2.4 General Measurement Procedure

Purpose: Radar video signals will be recorded on FM tape, along with supportive data, which will characterize the MARFS tracking concept. Various parameters will be varied during the data collection, including the off-boresight angle, the target aspect angle, the depression angle to the target, the clutter enviornment, and the polarization mode on transmission.

Procedure: The MARFS measurements will be interleaved with those of the Ka/Ku/M investigation so that radar cross section determinations will not have to be undertaken twice. The polarization integrity of the MARFS implementation will be established in the manner described in section 4.1.4.

The reference point on the tank target, for off-boresight designation, will be its apparent optical centroid and will be so designated by a marker. Azimuth and elevation boresight positions will be referenced to this spot, and will be determined by measurement of pertinent geometry or by reference to fiducial marks on the sightglass.

In the data collection itself, test group III will be accomplished as weather conditions permit. The other three test groups will be undertaken in a manner compatible with the Ka/Ku/M measurements.



Simplified Block Diagram of Ku-band Data Collection System

Figure 8

4.3 Detailed Measurement Procedure

4.3.1 Radar System Calibration

The purpose of the calibration procedure is to record on each reel of FM Tape, a calibration curve giving the value of voltage versus the parameter the voltage represents; i.e.: amplitude versus voltage, phase versus voltage, and angle error versus voltage. This is accomplished by either injecting a known signal into the radar receiver or boresiting on a corner reflector or target of known characteristics. For convenience in the field operation environment a corner reflector of known characteristics is used.

The radar operator boresites the antenna to the reference corner reflector, first by viewing through the boresite telescope and subsequently by fine tuning the pointing angle by peaking the amplitude response on the "A"-scope. The range to the target will be noted in the log and the FM recorder will record the amplitude of the H and V channels, the phase between the two channels, and in the case of the Ku-band system the amplitude monopulse error signal and the pseudo-coherent detector derived error signal. These two error signals will be nulled to zero using appropriate offset controls. The amplitude calibration signal is developed by the increasing the precision RF attenuator from 0 dB to 50 dB in 5 dB increments, as the operator notes the size of the reference corner reflector and the position of the attenuator on the voice recording track. This recorded signal provides the calibration curve of voltage versus target cross-section for the amplitude channels.

The pseudo-coherent phase signal is calibrated by varying the calibrated phase shifter through its 360° range by increments of $22\frac{1}{2}^{\circ}$, while recording the phase signal and indicating the phase shifter position in the voice track.

The Ku-band error signal channels are calibrated by recording both error signals while turning the antenna system in azimuth over a range of angles from -3° to $+3^{\circ}$, in $\frac{1}{2}^{\circ}$ increments, as estimated from the cross hair on the boresite telescope and from the azimuth angular scale on the radar frame.

4.3.2 Ku-band Measurements (MARFS)

The specific objective of this set of measurements is to correlate the results obtained by using the Ku-, Ka-, and M-band systems with measurements made simultaneously with the actual MARFS system. At Ku-band, the effect of using polarization agility and varying amounts of frequency agility on the angle tracking error signal can be determined. A comparison can be made of the relative merit of using pseudo-coherent detection (phase processing) compared to the conventional amplitude tracking technique. At Ka- and M-band, due to the fact that monopulse antennas are not being used, angle tracking error signals cannot be investigated. The decorrelation properties of the amplitude and pseudo-coherent phase signal of the clutter and of the target in the clutter will be investigated using polarization agility in the case of the M-band data and using polarization and frequency agility in the case of the Ka-band data.

Key elements of the data recording procedure include the need to operate simultaneously with the MARFS system, use the same calibration reference as the MARFS system, and use the same target and clutter cells as the MARFS system. In the case of the Ku-band data recording, the conventional amplitude monopulse error voltage will be recorded, as well as the error voltage derived from the pseudo-coherent detection circuitry. The data analysis will involve comparing the performance of the two types of error signal generation; and cross correlating the error signals with those developed in the MARFS system. Varying amounts of pulse-to-pulse frequency agility will be employed to determine the sensitivity of tracking performance to that parameter. Also, the polarization agility will be turned on and off while operating with varying amounts of frequency agility to determine the advantage, if any, in using polarization agility.

After the radar amplitude phase and angle error calibration signals are recorded, clutter and target signatures can be recorded. The data required is recorded while the instrumentation system is boresited to the same target as the MARFS system. The instrumentation system is then operated through a variety of modes as listed below. The operator must record the operating mode for any given data run on the recorder voice track, while at the same time noting the mode in the log. Data is recorded for each run for a period of approximately 30 seconds.

Operating Modes

F/A	P/A
Off	Off
Off	On
1 mHz	Off
1 mHz	On
2 mHz	Off
2 mHz	On
3 mHz	Off
3 mHz	On
5 mHz	Off
5 mHz	On
7 mHz	Off
7 mHz	On

This procedure is performed for a variety of targets at a variety of ranges and depression angles. The target positions will be determined in coordination with the MARFS system program personnel on site. The log will include the following information: time, run number, target scenario, range, depression angle, aspect angle, azimuth position, F/A mode, P/A mode, recorder channel listing. Figure 9 is an example of the data log.

4.3.3 Ka-band Measurements

The specific objectives of this set of measurements are: 1) to develope a basic data base at Ka-band, from which any user can draw to satisfy his needs; 2) to provide data for analysis by Georgia Tech to determine statistical correlation, and spectral properties of the clutter and target reflectivity; and 3) to determine whether processing techniques such as Dynamic Threshold Gating (DTG), Correlation Coefficient

DATE: TAPE NO:	WEATHER CONDITIONS TEMP: WIND SPEED: HUM: PRESS: WIND DIR: RAIN: GROUND:	CONSTANT PARAMETERS Ku BEAM Ka BEAM M BEAM

RUN NO.	TEST DESCRIPTION	TIME START STOP	RANGE	TARGET	ASPECT	CLUTTER	DEP ∠	AZ ∠	P.W. Ku Ka M	POL Ku Ka M	FREQ Ku Ka	REMARKS

Data Collection Log

Figure 9

Discrimination (CCD) and Pseudo-Coherent Detection Integration (PDI) and the like can be used to improve target-to-clutter ratios for target discrimination in a severe clutter environment. The objectives are met by collection of a comprehensive set of data, varying target and radar parameters, such as range aspect angle, depression angle, antenna beamwidth, pulse width, frequency agility, and polarization agility. Table 13 shows a sequence of data runs which when implemented will result in a recorded collection of data consistent with the needs. This data set provides for data using antenna beamwidths of 4.5^{o} and 1.25^{o}, using circular and linear transmit polarizations, fixed on frequency agility operation, for a variety of pulse lengths from 25 nanoseconds to 230 nanoseconds.

4.3.4 Ku-band Measurements

The objective of this set of data is to determine the correspondence in the data at Ka- and Ku-band for similar operating modes. A secondary objective is to relate the Ku-band data to some of that which has been analyzed in the past, to determine the consistency of the new Ku-band data.

The objectives are met by performing a sampling of tests using the Ku-band system, similar to those being performed at Ka-band. Table 14 is a basic set of measurements that will comprise the Ku-band data set. The index to the measurement catalog can be found in Table 16. The data set includes data with beamwidths of 4.5^{o} and 9^{o}, using circular and linear transmit polarizations, fixed and frequency agility operation, for a fixed pulse width of 200 nanoseconds.

4.3.5 M-band Measurements

The objective of this set of data is to extend the current data base of 95 GHz reflectivity data and to provide specific data for evaluation of the target detection algorithms used at the lower frequencies. The data set will be composed of data using a 0.7^{o} and 3^{o} beamwidth antennas, circular and linear transmit polarizations for a fixed frequency of 95.5 GHz and pulse widths of 15 nanoseconds and 70 nanoseconds. Table 15 is the test catalog which lists the basic test data to be obtained in the M-band radar.

TABLE 13. Ka-band Test Measurement Catalog

	Target	Clutter Cell	Target Aspect	Frequency Agility	Pulse Width	Polarization	Beam Width	Number of Runs
1.	None,1	1,2	0	0	1-5	1-3	1	60
2.	None,1	1,2	0	2-6	1-4	1,3	1	160
3.	None,1	3	0	0	1,3,5	1-3	1	18
4.	None,1	3	0	2,4,6	1,3	1,3	1	24
5.	1	1	1-4	1	1,3	1,3	1	16
6.	None,1	1,3	0	0	1,3,5	4,6	1	24
7.	None,1	2	0	0	1,5	4-6	1	30
8.	None	1,3	0	2-6	1,3,5	4,6	1	60
9.	None	2	0	2-6	1-5	4,6	1	50
								442
10.	None,1	1,2	0	0	1-5	1-3	2	60
11.	None,1	1	0	2-6	1,3,5	1,3	2	60
12.	None,1	2	0	2-6	1-5	1,3	2	100
13.	None,1	3	0	1-6	1,3,5	1,3	2	72
								292
14.	None,1	1,2,3	0	1,2,4,6	1,3,5	1,3	2	144
15.	None	1	0	2-6	1,3,5	4,6	2	30
16.	None	2	0	2-6	1-5	4,6	2	50
17.	None	3	0	1-6	1,3,5	5,6	2	36
18.	None,1	1	0	1	1,3,5	4,6	2	12
19.	None, 1	2	0	1	1-5	4-6	2	30
20.	1	3	0	1	1,3,5	4,6	2	6
								164
21.	None	4	0	1,2,4,6	1,3,5	1,3	2	24
22.	1	4	0	1	1,3,5	1,3	2	6
23.	1	4	0	2-6	3	1,3	2	10
								40
							Total	1082

TABLE 14. Ku-band Test Measurement Catalog

	Target	Clutter Cell	Target Aspect	Frequency Agility	Pulse Width	Polarization	Beam Width	Number of Runs
1.	None,1	1,2	0	0	0	1-3	2	12
2.	None,1	1,2	0	1-5	0	1,3	2	20
3.	None,1	3	0	0	0	1-3	2	6
4.	None,1	3	0	1,2,4	0	1,3	2	12
5.	1	1	1-4	0	0	1,3	2	8
6.	None,1	1,2,3	0	0	0	4,5	2	12
7.	None	1,2,3	0	1-5	0	4,5	2	30
								100
8.	None,1	1,2	0	0	0	1-3	3	12
9.	None,1	1,2	0	1-5	0	1,3	3	40
10.	None,1	3	0	0-5	0	1,3	3	24
								76
11.	None,1	1,2,3	0	0,1,3,5	0	1,3	2	48
12.	None,1	1,2,3	0	0	0	4,5	2	12
13.	None	1,2,3	0	1-5	0	4,5	2	60
14.	None	4	0	0,1,3,5	0	1,3	2	8
15.	1	4	0	0-5	0	1,3	2	12
								92
							Total	316

TABLE 15. M-band Test Measurement Catalog

	Target	Clutter Cell	Target Aspect	Pulse Width	Polarization	Beam Width	Number of Runs
1.	None, 1	1,2,3,4	0,2	6,7	1,2,3	4	72
2.	1	1,3	0-4	6,7	1,2,3	4	60
3.	None	5,6,7	0	6,7	1,2,3	4	18
4.	None, 1	1,2,3,4	0,2	6,7	1,2,3	5	72
5.	1	1,3	0-4	6,7	1,2,3	5	60
6.	None	5,6,7	0	6,7	1,2,3	5	18
7.	2	1,3	0-4	6,7	1,2,3	4	60
8.	2	1,3	0-4	6,7	1,2,3	5	60
9.	None, 1	1,2,3	0	6,7	4,5,6	4	36
10.	1	1,3	0-4	6,7	4,5,6	4	60
11.	None, 1	1,2,3	0	6,7	4,5,6	5	36
12.	1	1,3	0-4	6,7	4,5,6	5	60
						Total	612

TABLE 16. Key to Table 13, 14 and 15

Target

None = Clutter
1 = M48 Tank
2 = TBD

Location

1 = 1200'
2 = 1563'
3 = 697'(Open)
4 = 656'(Tree Line)

Clutter

1 = Short Grass
Tank Tracks
2 = Tall Trees < 25'
Brush
Tank Tracks
3 = Tall Grass < 1'
Brush < 2.5'
Tank Tracks
4 = Tall Grass < 1'
Brush < 2.5'
Tree Line < 15'
Small Creek
5 = Areas TBD
6 = Areas TBD
7 = Areas TBD

Polarization

1 = RC
2 = LC
3 = Agile Circular
4 = H
5 = V
6 = Agile Linear
(Ka, M only)

Pulse Width (10^{-9}s)

0 = 200 (Ku only)
1 = 25 (Ka only)
2 = 50 (Ka only)
3 = 100 (Ka only)
4 = 180 (Ka only)
5 = 230 (Ka only)
6 = 10 (M only)
7 = 70 (M only)

Aspect Angle

0 = 0°
1 = 45°
2 = 90°
3 = 135°
4 = 180°

Depression Angle

1 = $10^\circ 20'$
2 = $7^\circ 56'$
3 = $17^\circ 22'$
4 = $18^\circ 23'$
5 = TBD
6 = TBD
7 = TBD

System

1 = Ka
2 = Ku
3 = M

Frequency Agility (Pulse-to-Pulse)

Ka	Ku	M
0 = None (Coherent Source)	0 = None Standard	0 = None
1 = None (Agile Source)	1 = None	
2 = 1 MHz	2 = 1 MHz	
3 = 2 MHz	3 = 2 MHz	
4 = 4 MHz	4 = 3.15 MHz	
5 = 8 MHz	5 = 4.75 MHz	
6 = 16 MHz		

Beamwidth

1 = 1.25°
2 = 4.5°
3 = 9.0°
4 = 0.7°
5 = 3.0°