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DEPARTMENT OF COMMUNICATIONS-OTTAWA-CANADA

SPACE PROGRAM

TITLE: A Study to Develop Antennas for the MSAT Transportable Terminals

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TABLE OF CONTENTS

1.0 INTRODUCTION

Along with the advancement in electronic technology, communication system equipment has greatly reduced in size and is becoming more and more portable. Being an integral part of the communication system, the antenna system, if it is to stay compatible with the rest of the system, will also have to be more compact. In this project, different possible antenna configurations with emphasis on portability and ease of erection were investigated for the proposed MSAT 800 MHz communication system.

The object was to come up with two types of antenna associated with the transportable terminals for the MSAT program.

One of them would be a "Rugged" type antenna which, while being easily transportable, would also be suitable for deployment in an unattended location for a period of several months.

The second type would be a "Suitcase" type antenna consisting of a planar array of antenna elements mounted on the side of a box which would contain the associated transceiver. Such a terminal would be designed for rapid deployment in the field; it would be used for relatively short periods of time in an attended situation.

In addition, estimations of the production cost based on sales of each type of 100 units per year for 10 years were to be provided.

The project comprised two main phases. The initial phase consisted of a thorough search to identify and analyse the performances of all possible antenna configurations capable of meeting the required specifications. The two most suitable antennas, one for each type of antenna described previously, were chosen. "Breadboard" antennas were built to demonstrate feasibility and to assist in optimizing the design. In the final phase, improvements were made on the two types of antenna. Measurements were taken. A description of each final design, the rationale for its selection, and the production cost estimates are presented in the sections that follow.

2.0 "RUGGED" TYPE ANTENNA

2.1.0 Antenna Reflector

In accordance with the specifications, this type of antenna would have to be easily transportable and suitable for deployment in an unattended location for a period of several months. Sturdiness of the antenna was of major concern. A horn cavity (Figure 1) made from aluminum was chosen as it would provide the necessary compactness, lightweight, sturdiness and gain value for a reasonably well designed feed system.

2.2.0 Antenna Feed System

2.2.1 Metal Probes

In determining the feed system, the conventional metal probe feed was first studied. Based on theory, a circular polarized field would be generated if two metal probes, placed at 90° to each other, were each fed with signals having a 90° phase shift. Before actually implementing that idea with the horn cavity, the horn would have to be checked for squint while feeding with only one probe; if squint existed, circular polarization with low axial ratio would not be achieved.

Patterns were taken with the horn cavity fed by only one probe. Results showed that there was significant squint between the E and H plane (Figure 2). Different compensating methods were tried; however no significant improvement was observed.

To overcome the squinting problem, the horn cavity was fed with four probes physically located at 90° to each other (Figure 3). The four probes were fed with successive 90° electrical phase difference using the harness as shown in figure 4. The two 6 dB attenuators were inserted to obtain a better match and thus a better distribution of power to each terminal. Using terminal A1 as reference, the amplitude and phase difference of the other terminals were measured at 821 MHz, 831 MHz, 866 MHz and 876 MHz (Table 1).

Test equipment was then set up (see Figure 5) to measure the E and H plane patterns and axial ratios. The axial ratios were measured by rotating the source antenna. Measurements were made at 821 MHz, 831 MHz, 866 MHz and 876 HMz.

The first set of patterns (Figures 6a,6b,6c and 6d) was taken with the connectors connected to the cavity horn in the following manner: A1 and A2 connected to P and P', B1 and B2 connected to Q and Q'. The second set of patterns (Figures 7a,7b,7c and 7d) was taken with A1 and A2 connected to Q and Q', B1 and B2 connected to P and P'.

Test results showed that the system worked reasonably well in the lower frequency range; axial ratios were less than 2dB for the 821 MHz and 831 MHz measurements. At higher frequencies axial ratios were more than 4dB. This was mainly due to the greater difference in amplitude and phase difference between the terminals at higher frequencies (see Table 1).

The E plane measurements in figures 6a, 6b, 6c and 6d were higher than the H plane measurements, while the opposite was observed in figures 7a, 7b, 7c and 7d. This was due to the fact that, in the first set, measurements were taken with connector terminals B1 and B2 connected to Q and Q'. The higher attenuation in these terminals caused the H field to have a lower gain. The opposite was true in the second set since then the connector terminals B1 and B2 were connected to the horizontal probes P and P'.

The low axial ratios obtained in measurements at lower frequencies indicated that this system would work reasonably well as a circular polarized antenna. In order to obtain better results, especially at the higher frequencies, a phase shifter with exact phase shifts of 90°, 180° and 270° and even power distribution would have to be designed. In that case either micro-strip or semi-rigid line techniques could be used. Since the use of four probes and a power divider would lead to a high production cost, other alternative feed structures were considered.

2.2.2 Printed Circuit Feed

The feed system shown in figure 8 was studied. It used a printed-circuit element to excite the horn cavity. As this was done sometime after the study of the "Suitcase" type antenna had started (Section 3.0), the experience gained from the "Suitcase" type antenna study indicated that the best element would be a pair of Archimedean Spirals.

Instead of using ribbon cables to make up the spirals, copper strips were used. The centre equiangular spiral was eliminated (Figure 8). This was done to reduce the production cost as this spiral feed was simpler in structure and could be easily manufactured using printed circuit board techniques. The copper strips were 1/4" wide and they were separated by a distance of 1/4".

A balun was used to feed the spiral through a coaxial transmission line. The quarter wavelength "Bazooka" balun is shown in figure 9. The balun was placed inside a copper tube and the tube was attached to a 9" X 9" polyethylene plate. The spiral was then placed on the surface of the polyethylene plate as shown in figure 9.

The feed structure was then placed inside the horn cavity and measurements (axial ratios) were taken with several different lengths of the tapered copper strip terminals and different separations between the spiral feed and the back of the horn cavity. It was found that the axial ratios were lowest when the lengths of the tapered copper strips were equal to exactly half the outer width of the spiral and the distance between the spiral feed and the horn cavity was about 3.75". Unfortunately axial ratios of 4dB at 821 MHz, 5dB at 831 MHz, 5.2dB at 866 MHz and 5dB at 876 MHz were the best results that could be obtained from this spiral feed.

A second spiral feed (Figure 9) with each arm consisting of 7-1/2 turns of 1/8" wide copper strips separated by 1/8" was constructed. It was fed by using the same balun as before. The feed was placed inside the horn cavity and one set of measurements was taken (Figures 10a, 10b, 10c and 10d). Axial ratios of 2.4dB at 821 MHz, 2.7dB at 831 MHz, 4.0dB at 866 MHz and 4.0dB at 876 MHz were observed.

After some fine adjustment of the distance between the horn and the feed, axial ratios of 1.9dB at 821 MHz, 1.9dB at 831 MHz, 3.7dB at 866 MHz and 2.8dB at 876 MHz were observed (Figure 12). The spacing between the feed and the cavity was found to be 4".

The reduction in the axial ratio prompted the construction of another spiral feed with narrower copper strips and more turns. This third spiral feed consisted of a pair of 11 turns of 0.08" (2mm) wide copper strips separated by 0.118" (3mm). Again, this feed was placed inside the cavity. Axial ratios were measured while the distance between the feed and the cavity was altered. The lowest axial ratios measured were 3.2dB at 821 MHz, 3.0 dB at 831 MHz, 3.2dB at 866 MHz and 3.0dB at 876 MHz.

The increase in axial ratios was probably due to an increase in the induced current on the spirals beyond the radiation region (see Appendix A) by the field reflected from the cavity. This current would flow in an opposite sense to that of the current flowing from the input terminals. The reversed current flow would then generate a field which would radiate in an opposite sense to that of the field generated by the input current. It was the sum of these two fields of opposite sense which resulted in a radiation pattern with increased axial ratio.

Judging from all the patterns, the gains of the three spiral feeds were close to each other. Hence, using the axial ratio as a guide, the second spiral feed (1/8" wide copper strip; 1/8" separation; 7 1/2 turns in each arm) was chosen for further analysis. It was hoped to lower the axial ratios by further fine adjustments on this spiral. However, due to time constraints this was not done.

NOTE: The spirals that were built for this study were left-hand polarized. By reversing the winding sense of these spirals, they would radiate a right-hand circularly polarized beam away from the horn cavity.

2.2.3 Detailed Analysis of the Archimedean Spiral Antenna

A. Short Back Fire Configuration

Metal discs of various diameters were placed at various distances in front of the spirals. The gap between the disc and the spirals was filled with foam. This was done in an attempt to increase the gain of the cavity horn. However, the simultaneous reduction of the axial ratio and increase of the gain seemed impossible.

B. Gain of the "Rugged" Antenna

The chosen Archimedean Spiral feed was placed inside the cavity horn with the distance from the feed to the back of the horn being 4".

In order to compute the gain, several sets of patterns were taken with different combinations of the orientation of the source dipole and the spiral (figure 11). Two major types of spiral orientation were used. In the first type, two edges of the square spiral were horizontal while the other two edges were vertical. It was arbitrarily decided to name this orientation as 0°. In the second type, two edges of the spiral made an angle of 45° with the horizontal while the other two edges made an angle of 315° with the horizontal. This configuration was said to have an orientation of 45°.

For each orientation of the spiral antenna there were four orientations of the source dipole; namely, with the electric field of the dipole making an angle of 0°, 45°, 90° and 315° with the vertical. Patterns were taken at 821 MHz, 831 MHz, 866 MHz and 876 MHz with the spiral antenna being rotated horizontally from -180° to 180°. Axial ratios were also measured (Figures 13, 14, 15 & 16).

The patterns were integrated and the gains of the spiral antenna were computed (Table 2). It was found that the antenna had an average axial ratio of 2dB at 821 MHz, 1.933dB at 831 MHz, 3.47dB at 866 MHz and 3.17dB at 876 MHz. Allowing a 1.5dB system loss, the average gain of the antenna was found to be 10.65dBi at 821 MHz, 10.59dBi at 831 MHz, 11.03dBi at 866 MHz and 11.03dBi at 876 MHz.

During the course of measurement it was suspected that there might be some reflection from the surrounding environment. Due to time limitation this reflection problem was not further investigated. If reflection indeed existed, it would have an impact on the axial ratio. The true axial ratio might be lower than what was measured.

C. VSWR And Impedance

VSWR was measured (Figure 17). The impedance of the spiral (excluding the balun and the coaxial cable) was also measured (Table 3) and plotted on a Smith Chart (Figure 18). The lack of sharp peaks and dips in the VSWR measurement and the closeness of the points on the Smith Chart indicated that the spiral could easily be matched to 50 ohm by the use of a transformer. After the matching, the VSWR would be close to 1.5:1. Since this is a breadboard design used solely to verify the concept of this antenna, the matching transformer was not implemented.

2.3 Conclusion

A medium size horn cavity was chosen as the best suitable reflector system for this type of antenna. The aluminum horn cavity, while being lightweight and sturdy, would provide the necessary gain required. The feed of the antenna could be protected against the environment by covering the aperture with a radome. Under these conditions the antenna could be deployed in an unattended location for a period of several months. In choosing the feed system, emphasis was on low cost and compactness. The Archimedean spirals as shown in figure 9 could easily be printed. Mass production would further cut down the manufacturing cost.

2.4 Cost Estimates

The production costs of the cavity horn antenna using the Archimedean Spirals as the feed (Figure 9) were estimated to be $320 each. These figures were based on sales of 100 units per year for 10 years.

3.0 "SUITCASE" TYPE ANTENNA

3.1 The object of this part of the project was to develop a transportable planar array of antenna elements. The first step was to choose the most suitable type of planar antenna element. The antenna element would then be built and tested. Finally, two of these elements, properly phased, would be put together to form an array.

3.1.1 The Planar Antenna Element

As there were many types of planar antennas that would satisfy the specifications required, consideration was given only to those with low production costs which were easy to build .

Several experimental models of the antenna elements that were considered were built. Axial ratios were measured. Among them, the Archimedean Spiral antenna seemed to be most promising in the sense that it was compact both in width and depth, easy to build and had reasonably good test results. It was decided to choose the Archimedean Spiral as the antenna element for the "Suitcase" type antenna.

3.2 The Archimedean Spiral Antenna

The initial round type Archimedean Spiral antenna was coarsely built and did not meet all the electrical specifications required. Experience gained from the measurements for the round spiral antenna indicated that better performance could be obtained if the number of turns in each arm of the spiral was increased.

A second spiral antenna was made (Figure 19). It consisted of a pair of square Archimedean Spirals made from ribbon cables. A square spiral is better for this application. There were 8 turns of wire in each spiral arm. Each arm of the spiral ended on a radiating tab. The radiating tabs were used to lower the axial ratios. An equiangular spiral was used to feed the square spiral. A quarter wavelength "Bazooka" balun was used to couple the coaxial cable to the equiangular spirals. The spirals were placed inside a 10" square by 2" deep cavity. Tests were conducted on this antenna element. During the course of testing, several changes were made to the spirals. The size and the spacing between the equiangular spirals were reduced. More turns of the Archimedean Spirals were added (Figure 20). It was this final version of the spirals that was given a detailed analysis to obtain the axial ratios, gain, VSWR and impedance.

A Gain and Axial Ratio of the Antenna Element

Patterns were taken (Figures 21, 22, 23 and 24) in a similar way as described in 2.2.3. Axial ratios were also measured.

The patterns were integrated and the gains of the antenna element were computed (Table 4). It was found that the antenna element had an average axial ratio of 1.23dB at 821 MHz, 3.70dB at 831 MHz, 1.40dB at 866 MHz and 2.30dB at 876 MHz. Allowing a 1.5dB system loss, the average gain of the antenna element was 7.23dBi at 821 MHz, 7.18dBi at 831 MHz, 7.15 dBi at 866 MHz and 7.36dBi at 876 MHz.

B VSWR and Impedance

The VSWR of the antenna element was measured (Figure 25). The impedance of the spirals (excluding the balun and coaxial cable) was also measured (Table 5) and plotted on a Smith Chart (Figure 26). Again, the lack of sharp peaks and dips in the VSWR measurement and the relative closeness of the points on the Smith Chart indicated that the spirals could be easily matched by the use of a transformer.

3.3 Antenna Array

Another spiral antenna identical to the one shown in Figure 20 was made. The two spiral antennas were placed side by side and fed via a power splitter. The spiral centres were 10" apart. Two 10dB attenuators, each placed between the spiral antenna and the power splitter, were used to obtain a more even distribution of power to the two spiral antennas. Patterns were taken with the two elements placed side by side horizontally and vertically.

The patterns showed the existence of a phasing problem between the two spiral antennas. Aside from the phasing problem, narrower beamwidths were observed in some patterns (figure 27 and 28). Further experimental work would be required to obtain correct phasing for the two elements of this array. Because of time constraints, no further work could be carried out in this area; however, array theory predicts that two properly phased single elements should have a gain better than the 10 dBiC required for this application.

3.4 Cost Estimates

The production costs of the two element cavity back spiral array antenna were estimated to be $250 each. This figure was based on sales of 100 units per year for 10 years.

3.5 Conclusions

The Cavity Back Archimedean Spiral antenna (Figure 20) was chosen to be the most suitable type of antenna element for the "Suitcase" type two element planar array. When choosing the element, considerations were given to the overall dimensions, production cost and the electrical specifications required.

The chosen antenna element would not occupy a space of more than 10" X 10" X 2". When mass produced, the spirals would be printed to reduce the production cost. Good axial ratios were measured for the single element. It was expected that the gain of the "Suitcase" type planar array antenna when properly phased would be better than 10dBiC. The overall dimensions of the "Suitcase" type antenna would not exceed 10" X 24" X 2".

4.0 SUMMARY

A pair of Archimedean Spirals was chosen to be the feed system for the "Rugged" type antenna as well as the antenna element for the "Suitcase" type planar array antenna.

For the "Rugged" type antenna, the Archimedean Spirals were placed inside an aluminum horn cavity to provide protection against the environment.

For the "Suitcase" type antenna, the Archimedean Spirals were backed by a square cavity to form an antenna element. Two such elements were placed side by side to form an array.

The production costs for these two types of antennas were quite moderate as the spirals could be mass produced using modern printed circuit board techniques.

APPENDIX A

THE ARCHIMEDEAN TWO WIRE SPIRAL ANTENNA

One class of frequency independent circular polarized antenna is the Archimedean Two Wire Spiral Antenna (Figure 29). When properly excited, it radiates a circular polarized beam to each side of the spiral. Each beam is normal to the plane of the spiral. One-sided radiation can be achieved by reflecting the beam on the outer side with a ground plane or cavity.

Details of the radiating mechanism of the spiral have not yet been thoroughly studied. Provided below is a brief explanation of the radiating mechanism which is in accordance with experimental observations.

A simplified sketch of the square spiral is given in figure 30. The spirals are fed at points A and B. Let P be a point on one arm of the spiral whose feed point is A. Let Q be another point on the other spiral such that the distance along the spiral from A to P is exactly equal to the distance from B to Q. Let P' be a point which is adjacent to P on the other spiral. Let D be the perpendicular distance from the center 0 to the side of the square spiral on which P lies. Two parameters are of key interest. The first is the circumference of the turn on which P-P' lies. The second is the length Q P'. Provided that the spacing between the wires is small, i.e. $\Delta d \ll d$, the circumference is approximately 8d and the length of Q P' is approximately 4d.

When d = $\lambda/8$ where λ is the current wavelength on the spiral, the difference in wire length is $\lambda/2$ and the circumference is λ . Under these conditions, phasing of the radiated field from opposite sides of the square is such as to add in a direction normal to the plane containing the spiral. If the spirals are fed with 180° phase difference, the neighbouring parallel wire will also radiate in phase. Moreover, radiation from the two adjacent sides is equal in intensity but with a relative phase difference of 90 electrical degrees, so that the radiation is circularly polarized. Radiation will occur again when the circumference of the spiral is equal to an odd multiple of the current wavelength.

Based on the above explanation, an Archimedean Spiral will radiate a circular polarized field as long as the spiral is large enough to allow its circumference to be equal to the current wavelength of the spiral.

	A2		B1		B2	
FREQ (MHZ)	AMP. (dB)	Ø (DEGREE)	AMP (dB)	Ø (DEGREE)	AMP (dB)	Ø (DEGREE)
841	-0.5	-182.5	-1.6	-107	-1.5	288.2 (-71.8)
821	-0.7	+167.3	-1.5	263(-97)	-1.35	77
831	-0.5	-169.5	-1.65	258.4(-101.6)	-1.45	74
866	-0.2	-185.2	-1.6	-117.1	-1.55	60.5
876	-0.5	-180.8	-2.1	-125.7	-2.15	54.7

NOTE: Terminal A1 was used as reference.

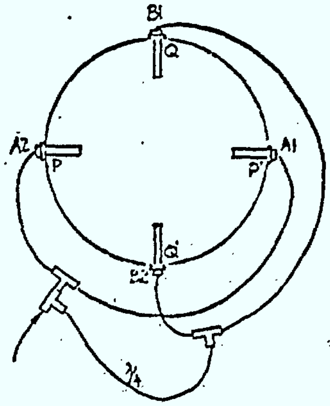


TABLE 1. Difference in amplitude and phase of the four terminals

AXIAL RATIO (dB)

FREQUENCY (MHZ)

Spiral Orientation	821	831	866	876
0°	2.3	1.8	3.2	3.2
45°	1.8	2.1	3.5	3.5
90°	1.9	1.9	3.7	2.8
AVERAGE	2.00	1.93	3.47	3.17

GAIN (dBi)

FREQUENCY (MHZ)

Electric Field of Source Dipole	821				831				866				876			
Spiral Orient.	315°	0°	45°	90°	315°	0°	45°	90°	315°	0°	45°	90°	315°	0°	45°	90°
0°	11.82	11.93	12.79	12.36	11.40	12.02	12.68	12.07	12.05	12.39	13.20	12.38	11.69	12.29	13.24	12.56
45°	11.79	12.00	12.56	12.02	11.68	11.97	12.71	12.22	11.99	12.52	13.19	12.51	12.29	12.60	13.18	12.36
Average	12.15				12.09				12.53				12.53			

TABLE 2

Axial ratio and gain (excluding system loss) of the "Rugged" type Archimedean spiral antenna

FREQUENCY (MHZ)	IMPEDANCE (OHM)
821	70 + 85j
831	74 + 60j
866	82 + 65j
876	75 + 68j

TABLE 3

Impedance of the spirals (at the feed point)

AXIAL RATIO (dB)

FREQUENCY (MHZ)

SPIRAL ORIENTATION	821	831	866	876
0^0	1.1	3.6	1.9	2.2
45^0	0.8	3.3	1.2	2.4
90^0	1.8	4.2	1.1	2.3
AVERAGE	1.23	3.70	1.40	2.30

GAIN (dBi)

FREQUENCY (MHZ)

Electric field of source update	821				831				866				876			
Spiral Orientation	315^0	0^0	45^0	90^0	315^0	0^0	45^0	90^0	315^0	0^0	45^0	90^0	315^0	0^0	45^0	90^0
	8.74	8.50	8.99	9.30	8.59	8.43	8.77	9.32	8.61	8.33	9.04	9.21	8.55	8.50	9.2	9.44
	8.71	7.90	8.42	9.25	9.02	7.76	8.41	9.10	8.85	8.15	8.03	8.96	9.26	8.25	8.48	9.20
AVERAGE	8.73				8.68				8.65				8.86			

TABLE 4

Axial ratio and gain (excluding system loss) of one spiral antenna element for the "Suitcase" type antenna

FREQUENCY (MHZ)	IMPEDANCE (OHM)
821	105 + 38j
831	110 + 27j
866	97 - 32j
876	85 - 40j

TABLE 5

Impedance of the Cavity Back Spirals (at the feed point)

REVISIONS				
SYM	ZONE	DESCRIPTION	...TE	APPROVED

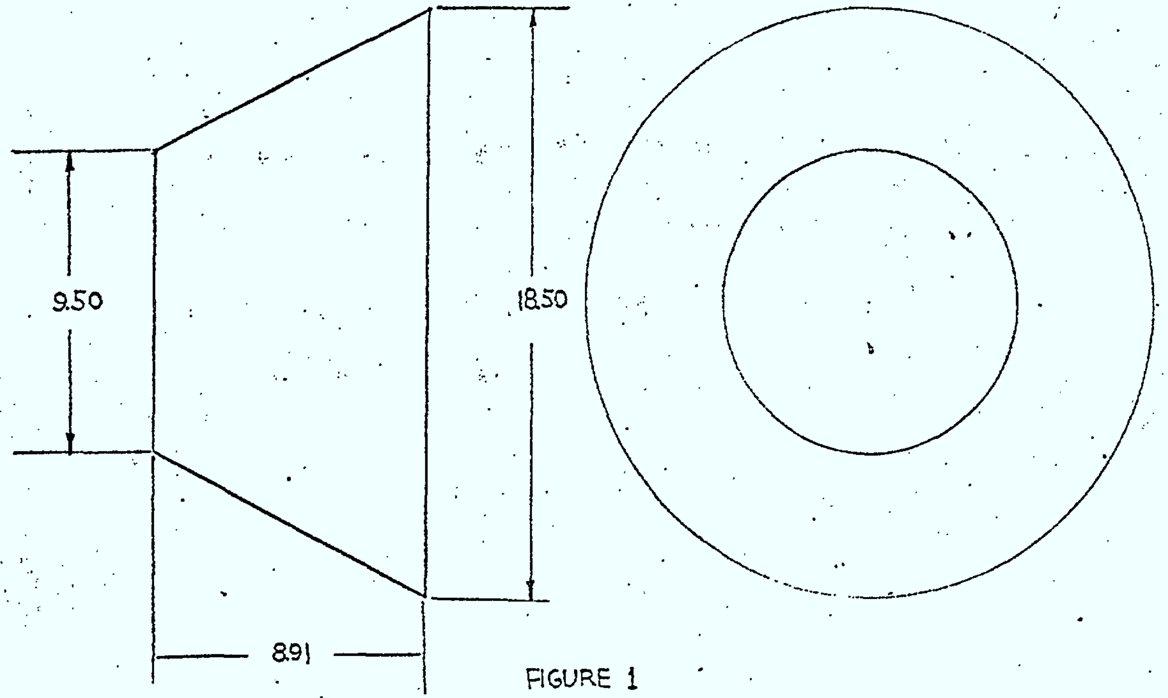


FIGURE 1
HORN CAVITY

FOR LIST OF MATERIAL SEE LM

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON
FRACTIONS ± DECIMALS ± ANGLES ±
ALL SURFACES ✓

SUPERSEDES DWG OF

MATERIAL

FINISH

NEXT ASSY | USED ON

DISTR | APPLICATION

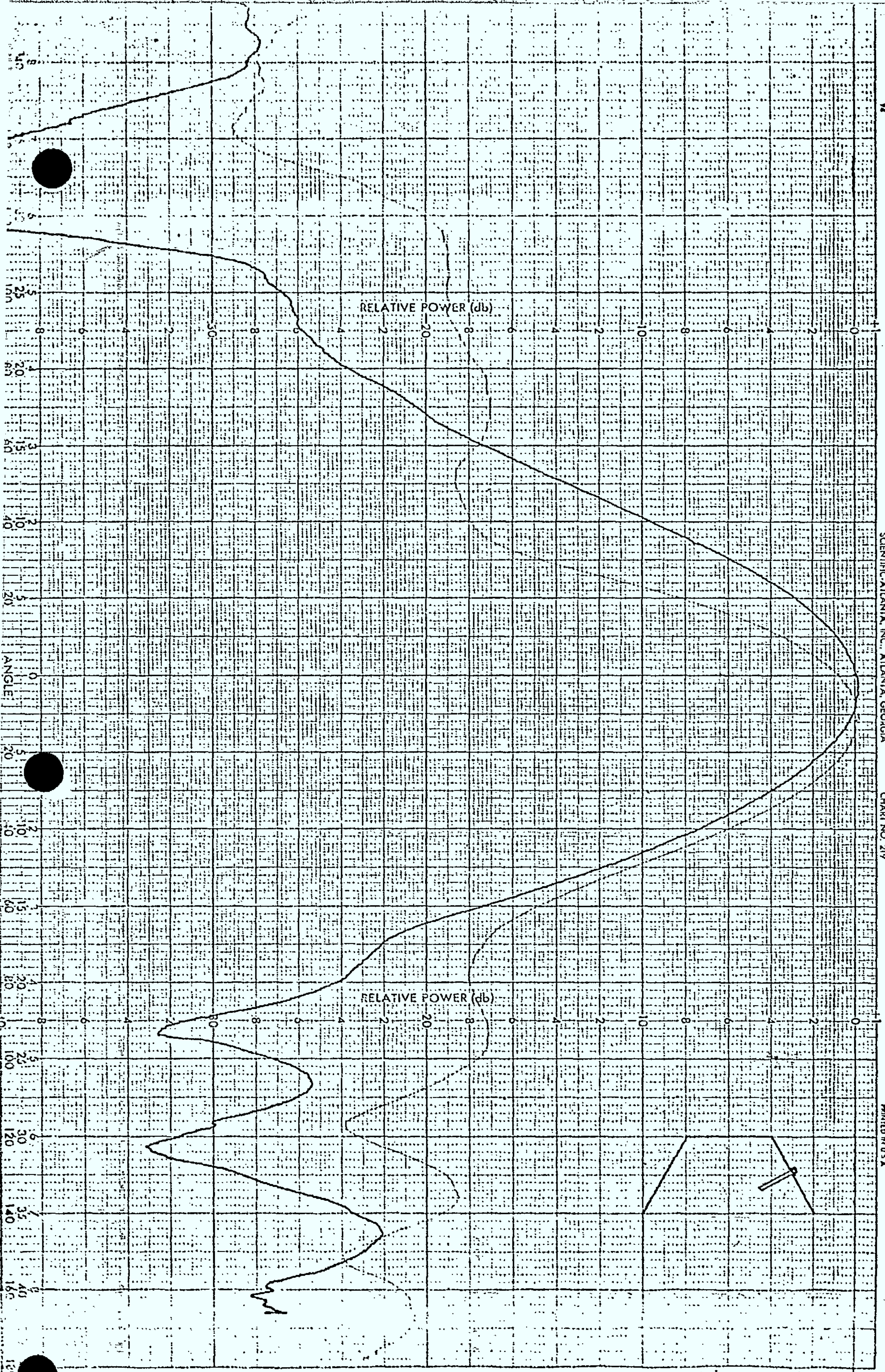
DRAWN
CHECKED
APPROVED
APPROVED
APPROVED
APPROVED

ANDREW ANTENNA
COMPANY LIMITED
606 Beech St., Whitby, Ontario, Canada

HORN CAVITY

CODE IDENT NO. | SIZE B

SCALE | WEIGHT | SHEET



PROJECT: MSAT

REMARKS: 821 MHz

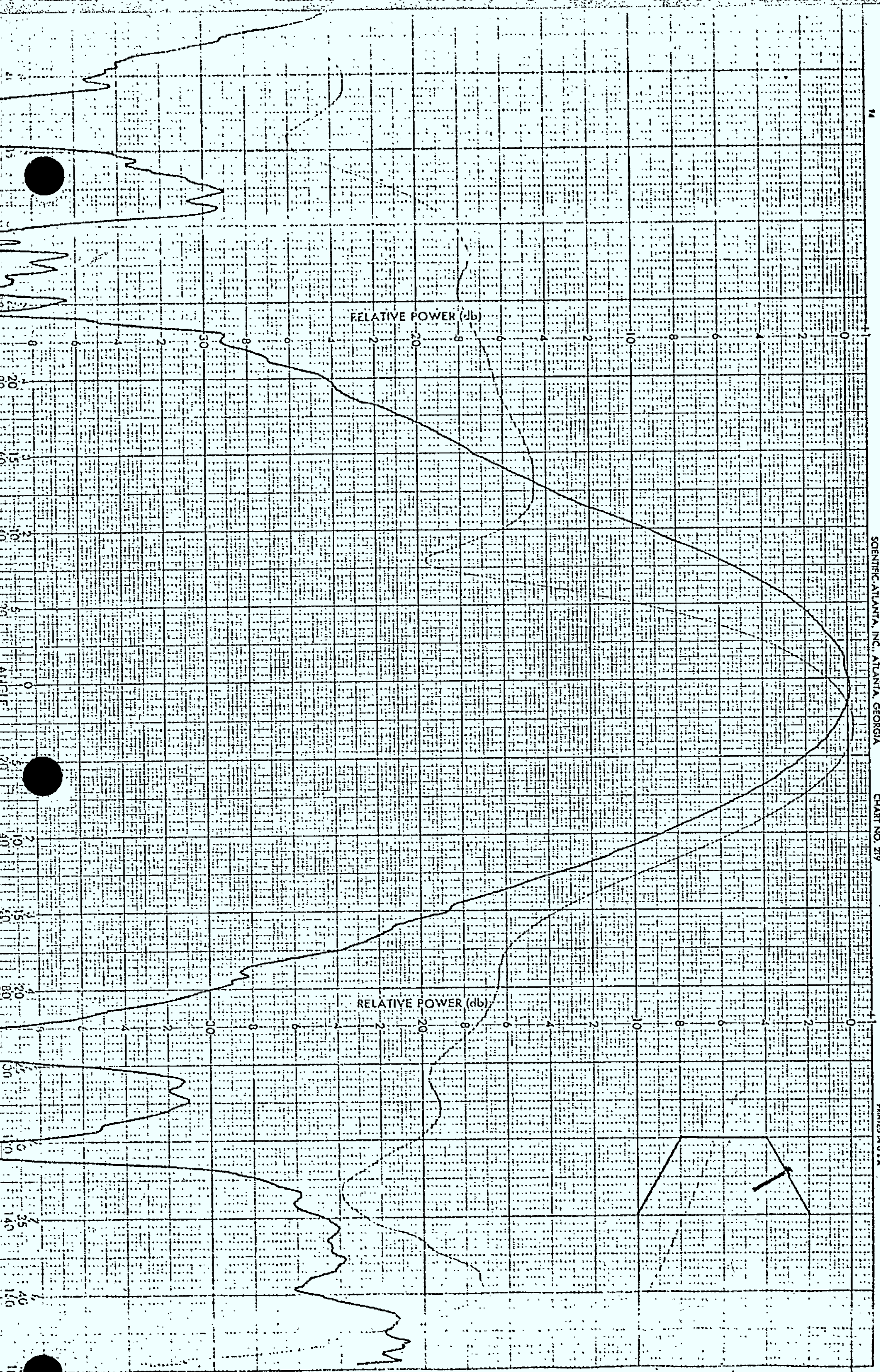
ENGR

DATE 09/09/81

177259

SINGLE PROBE - TOP & LEFT

Figure 2a



ROJECT MSAT

ENGR

DATE 09/09/81

MARKS

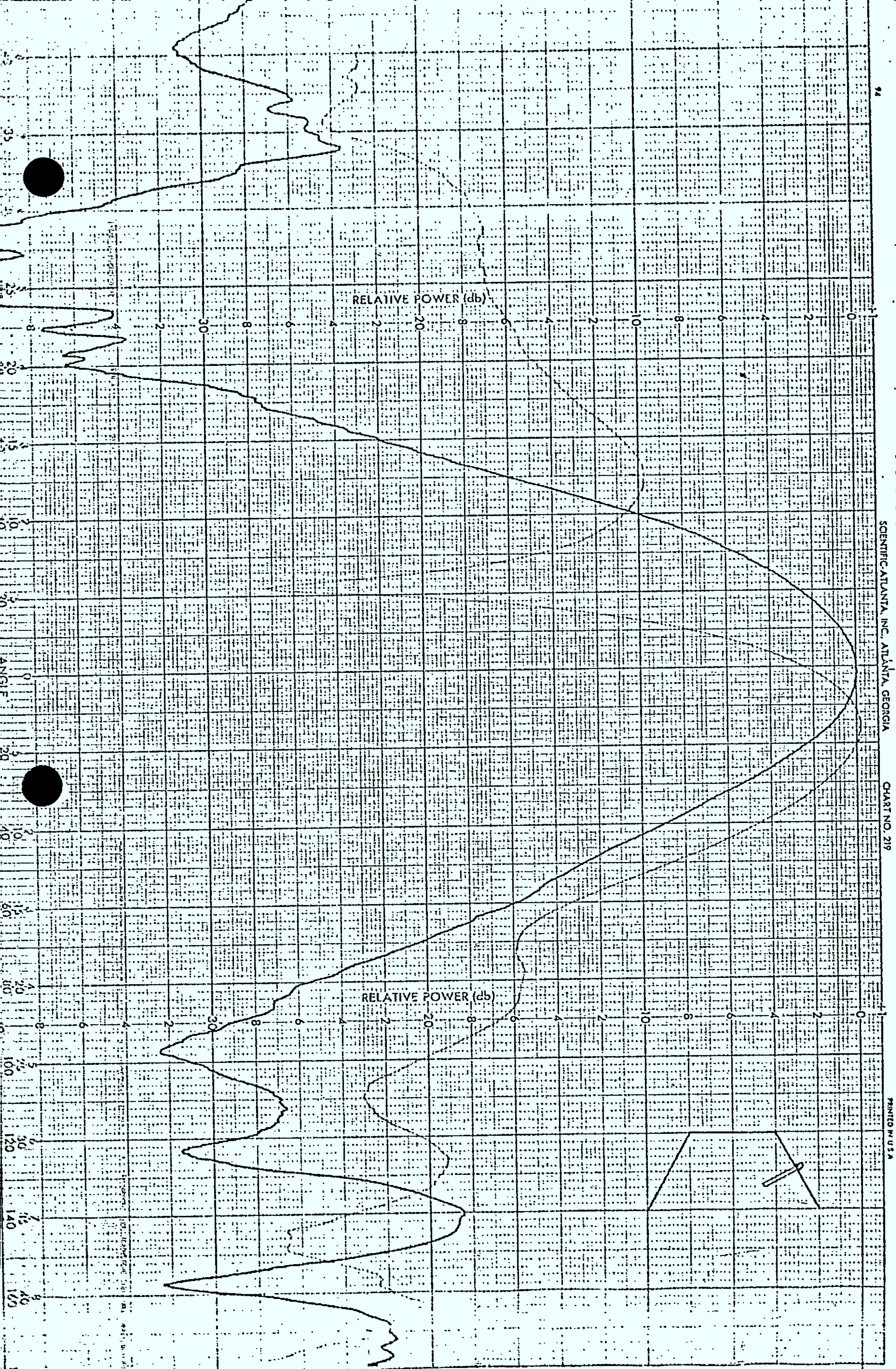
177260

831 MHz

21

SINGLE PROBE - TOP & LEFT

Figure 2b



PROJECT MSAT

ENGR

DATE 09/09/81

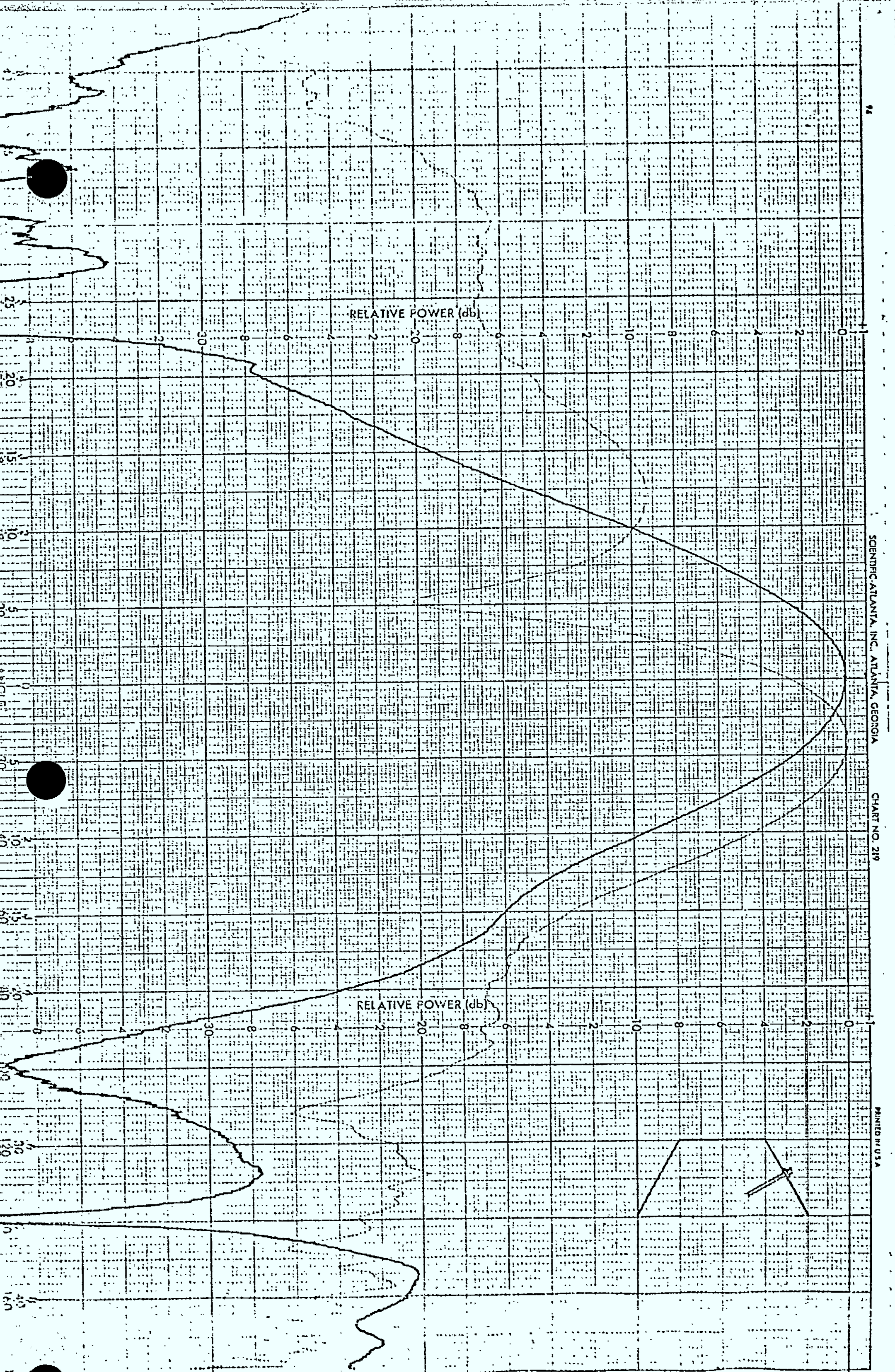
REMARKS 866 MHz

177261

22

SINGLE PROBE - TOP & LEFT

Figure 2c



PROJECT MSAT
REMARKS
876 MHz

ENGR

DATE 09/09/81

177262

SINGLE PROBE - TOP & LEFT

Figure 2d

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED

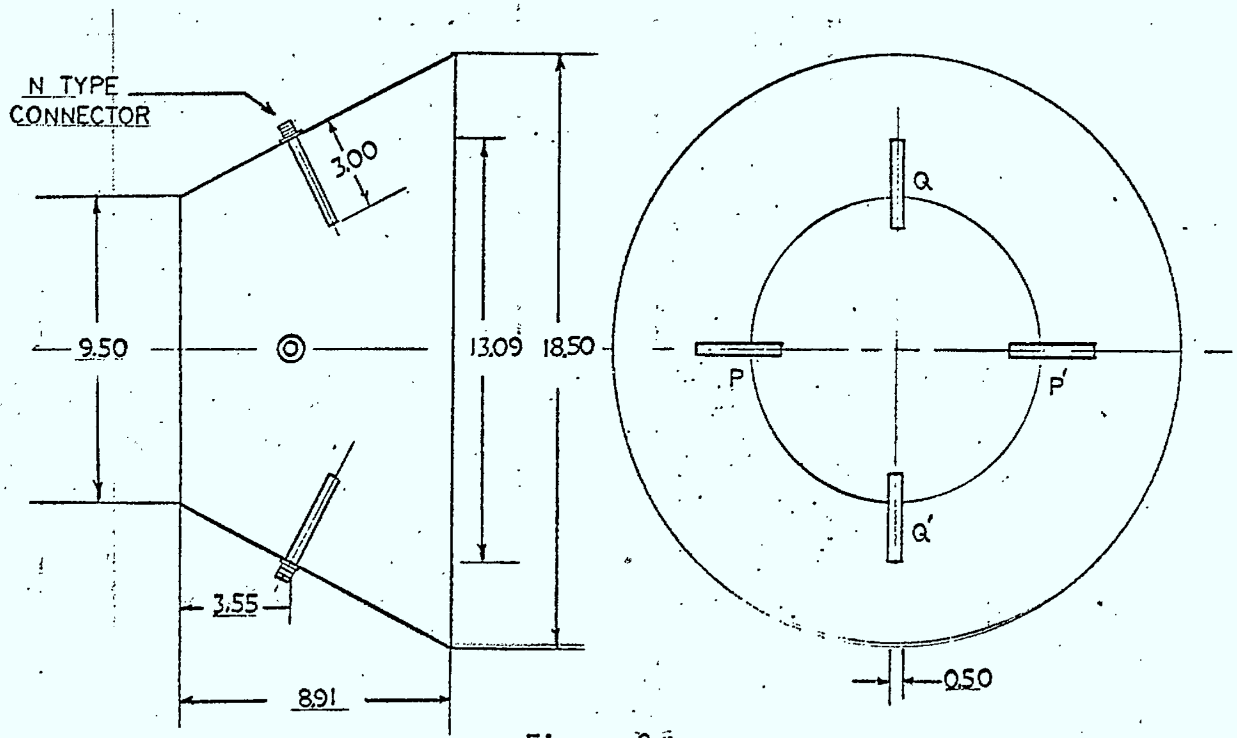


Figure 3

METAL PROBE FED HORN CAVITY

FOR LIST OF MATERIAL SEE LM

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON
FRACTIONS ± DECIMALS ± ANGLES ±
ALL SURFACES

SUPERSEDES DWG OF

MATERIAL

FINISH

NEXT ASSY | USED ON

DISTR | APPLICATION

DRAWN
CHECKED
APPROVED
APPROVED
APPROVED
APPROVED

ANDREW ANTENNA COMPANY LIMITED
604 Beech St., Whitby, Ontario, Canada

CODE IDENT NO. | SIZE B

SCALE | WEIGHT | SHEET

ANDREW

S.O. or E.P. No.	
Type No.	
Desc.	
Name, Date	

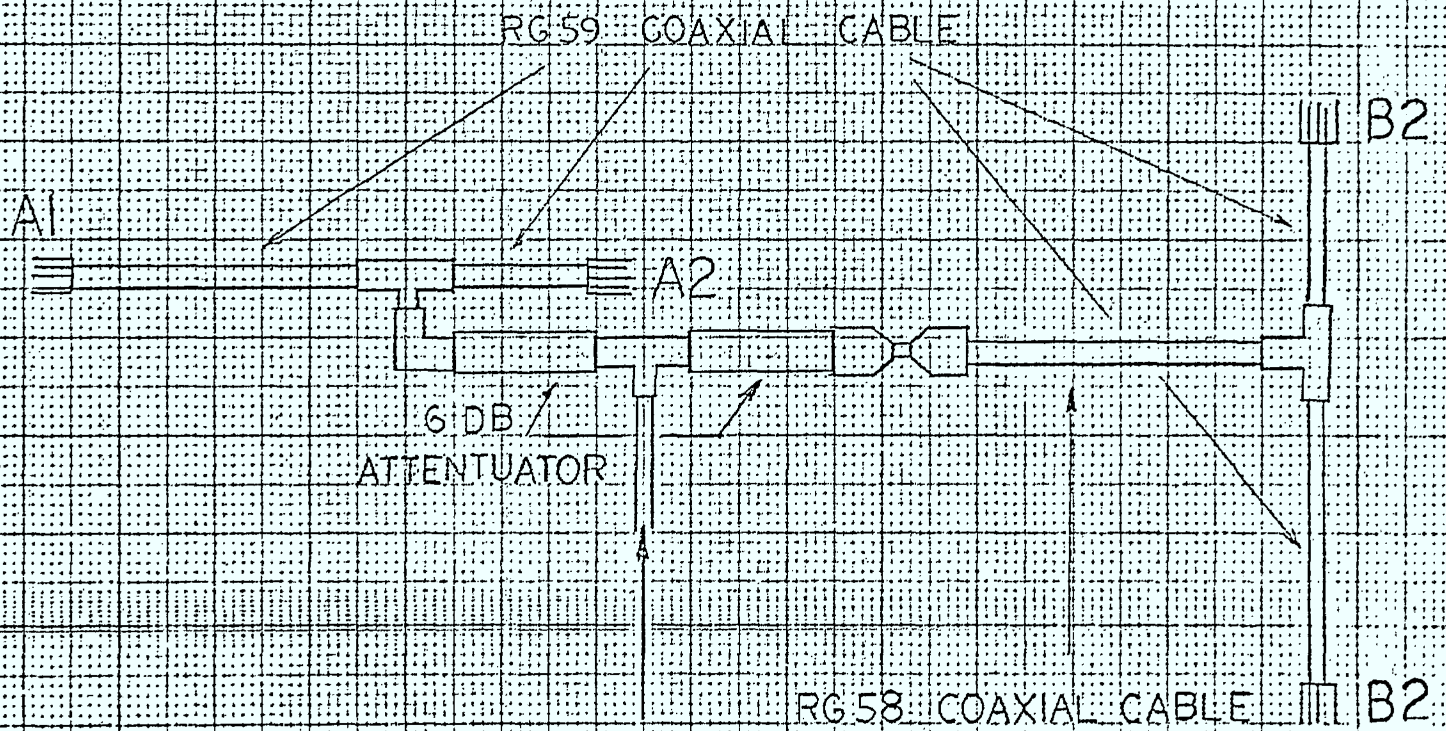


FIGURE 4

Harness for the metal probes

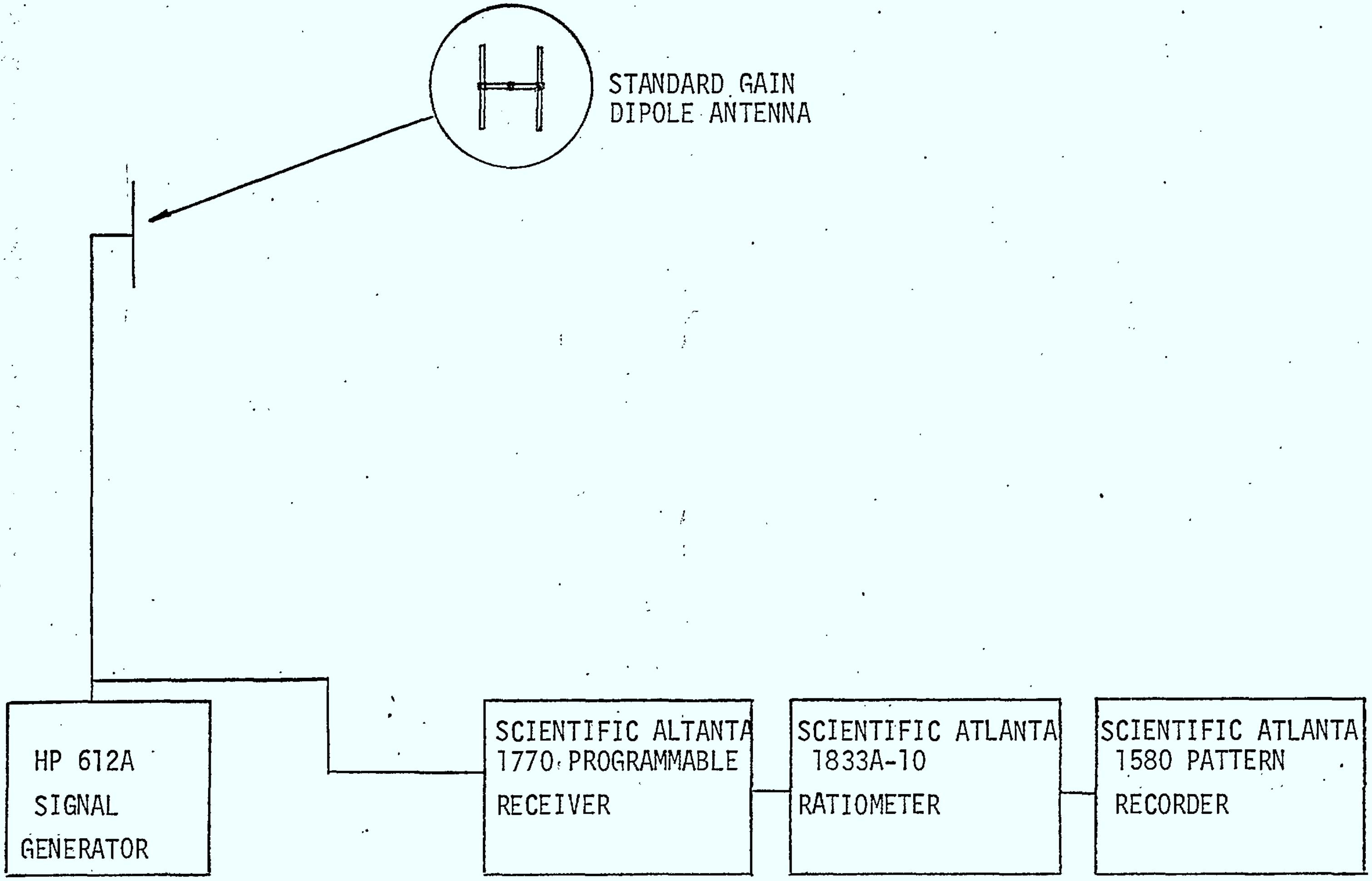
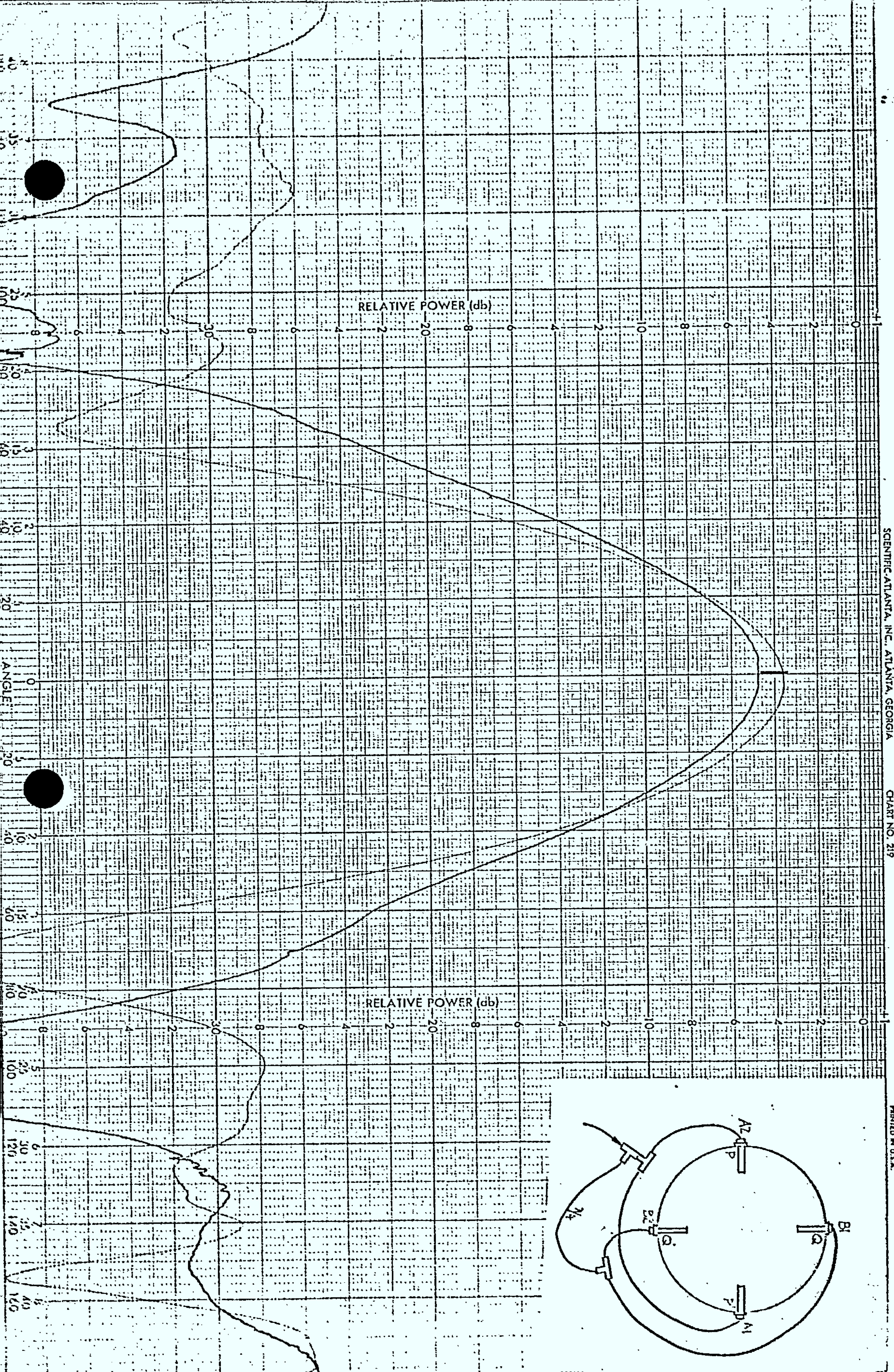


FIGURE 5

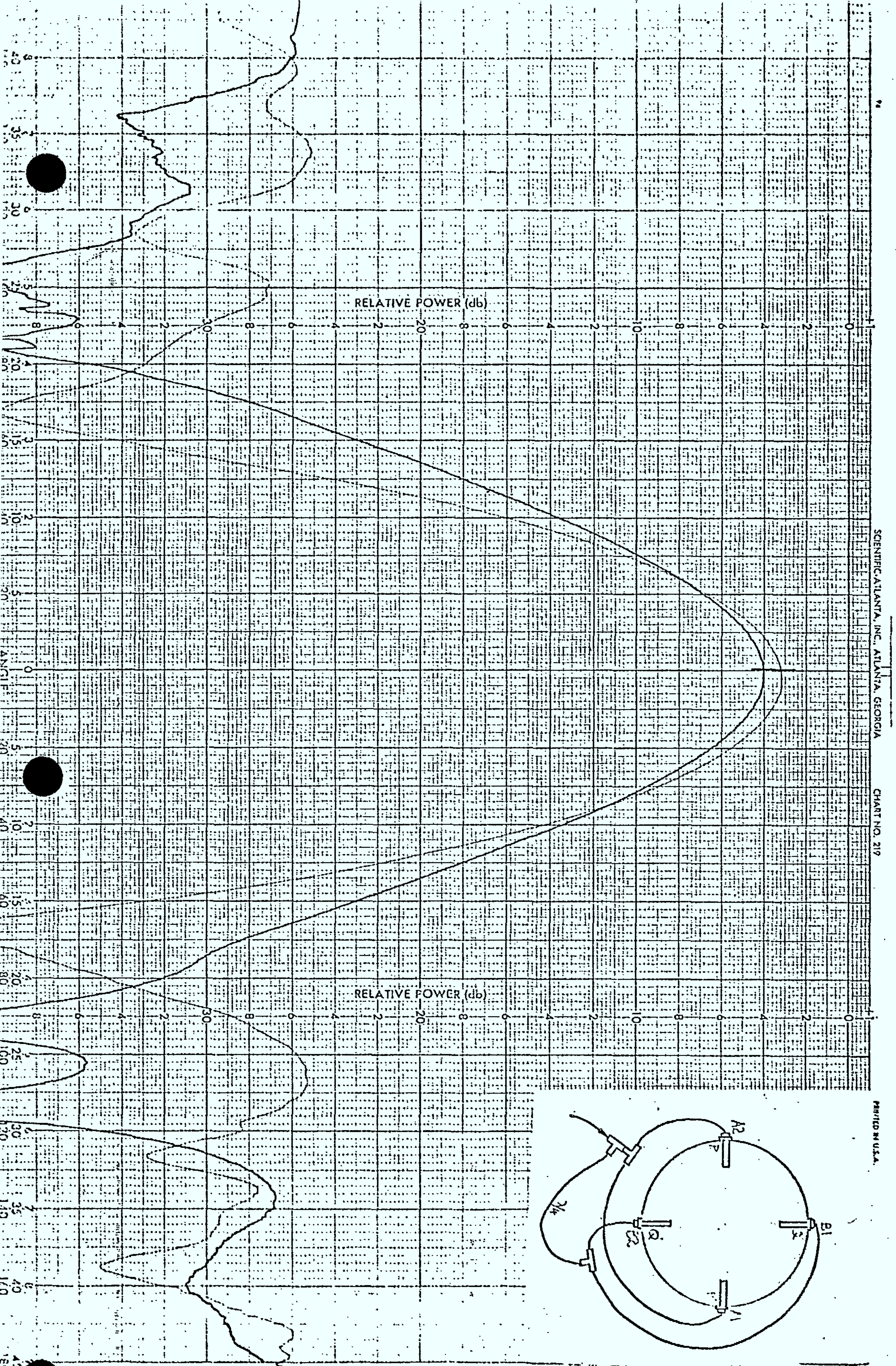
Test equipment for pattern measurement.



PROJECT MSAT
ENGR
DATE 02/10/81
REMARKS
125543

821 MHz

Figure 6a



PROJECT MSAT

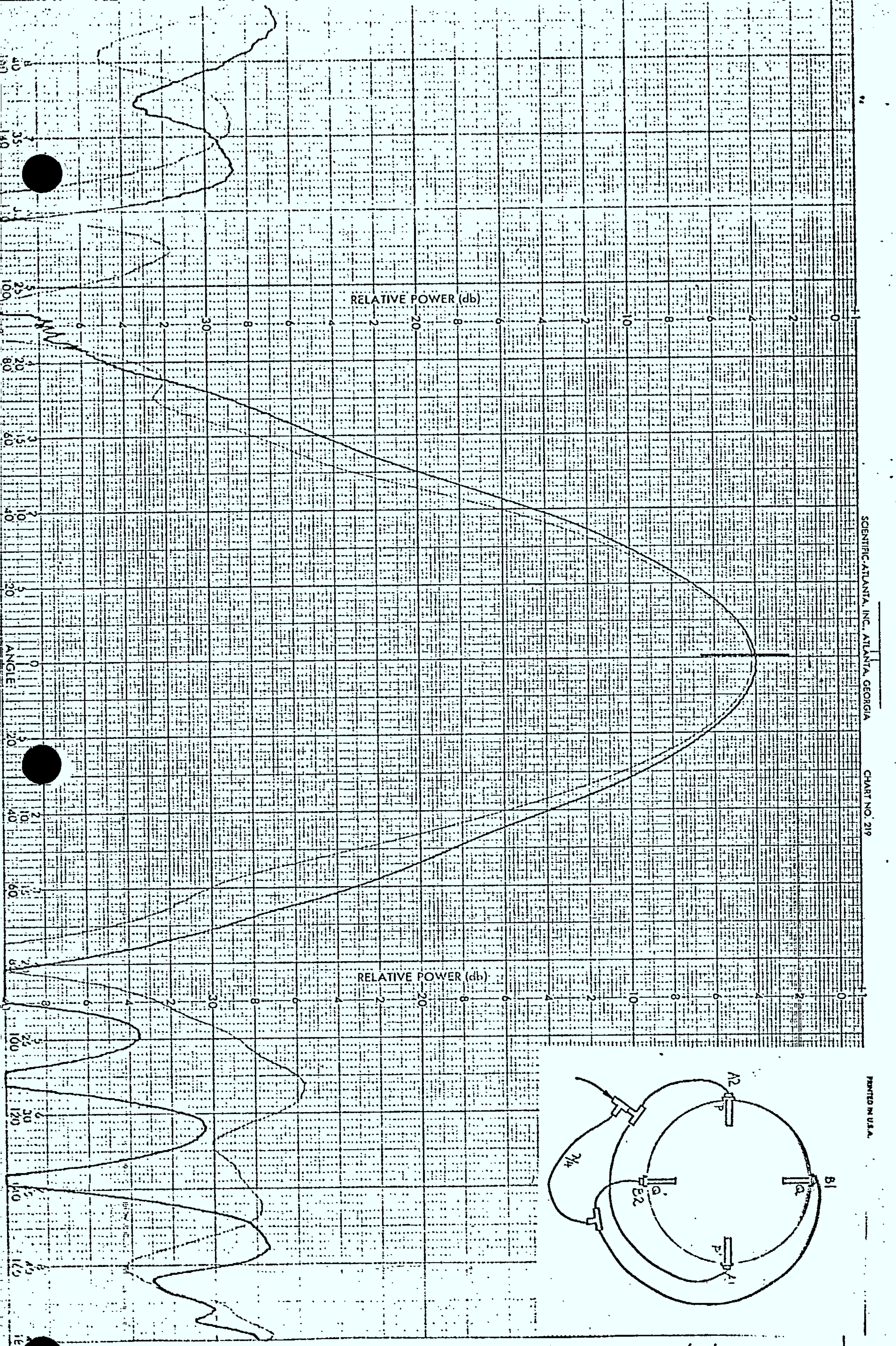
ENGR

DATE 02/10/81

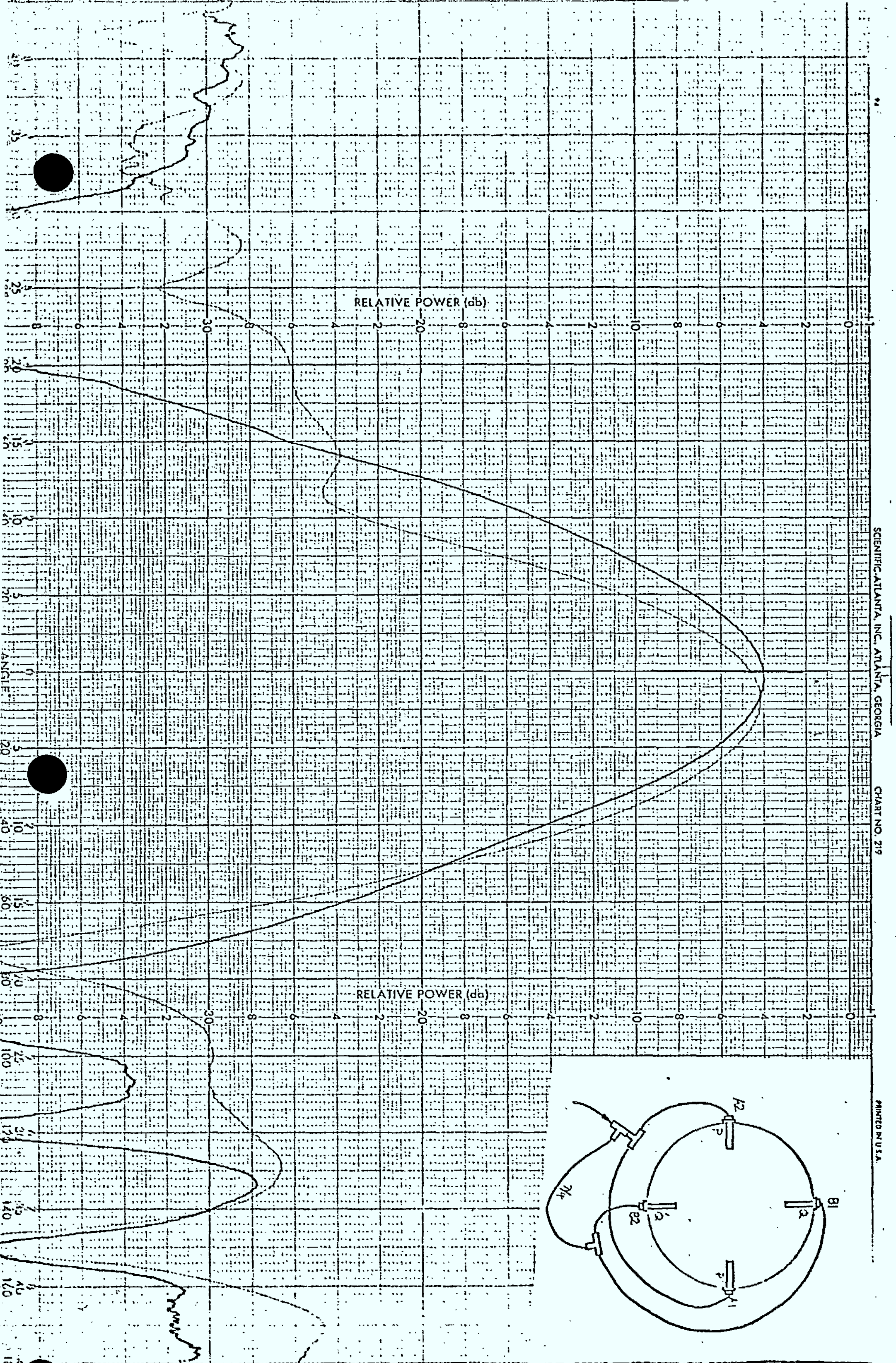
125544

REMARKS 831 MHz

Figure 6b



PROJECT MSAT	ENGR	DATE 02/10/81
REMARKS 866 MHz	Figure 6c	125545



PROJECT MSAT

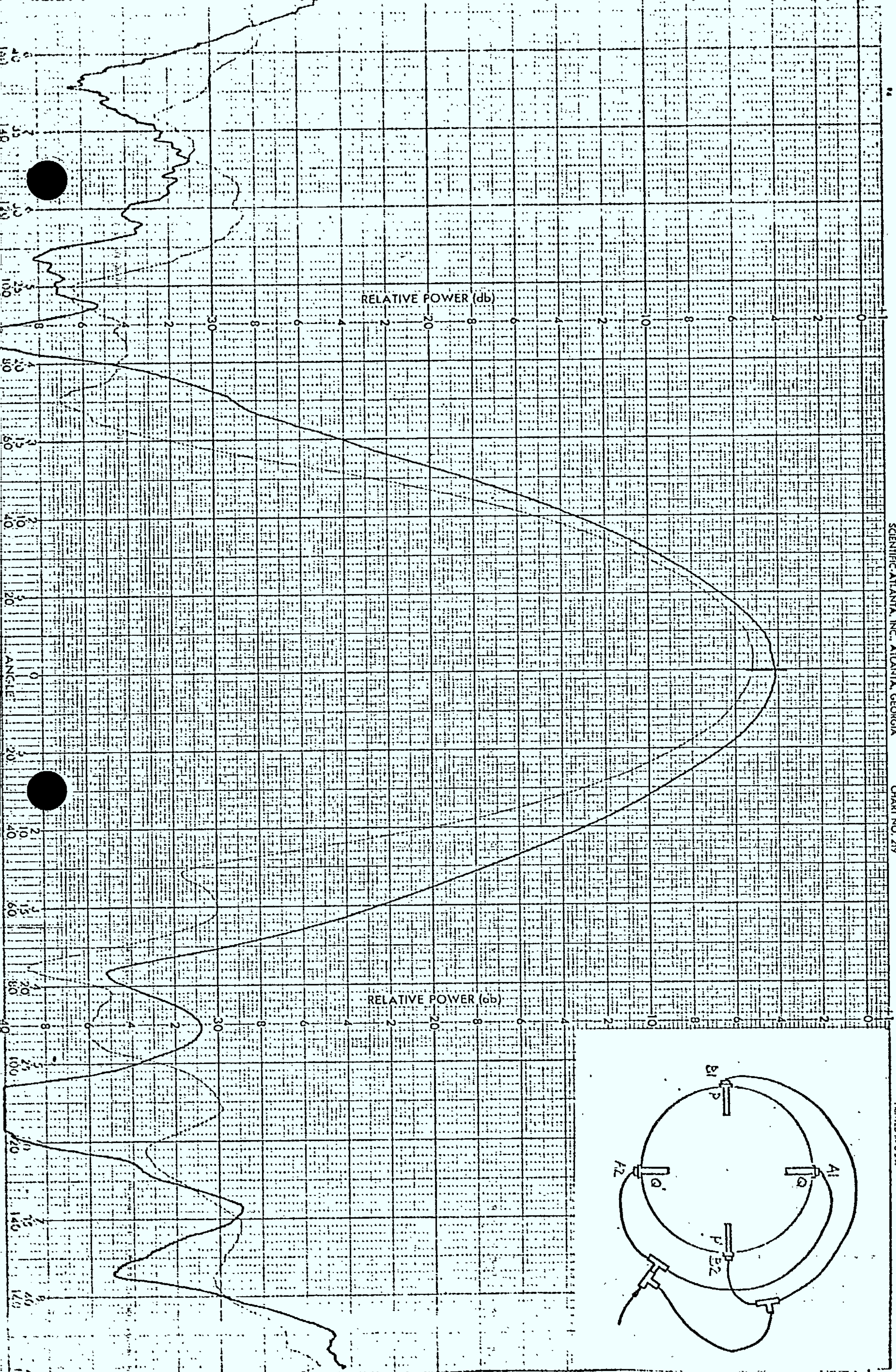
ENGR

DATE 02/10/81

125546

REMARKS 876 MHz

Figure 6d



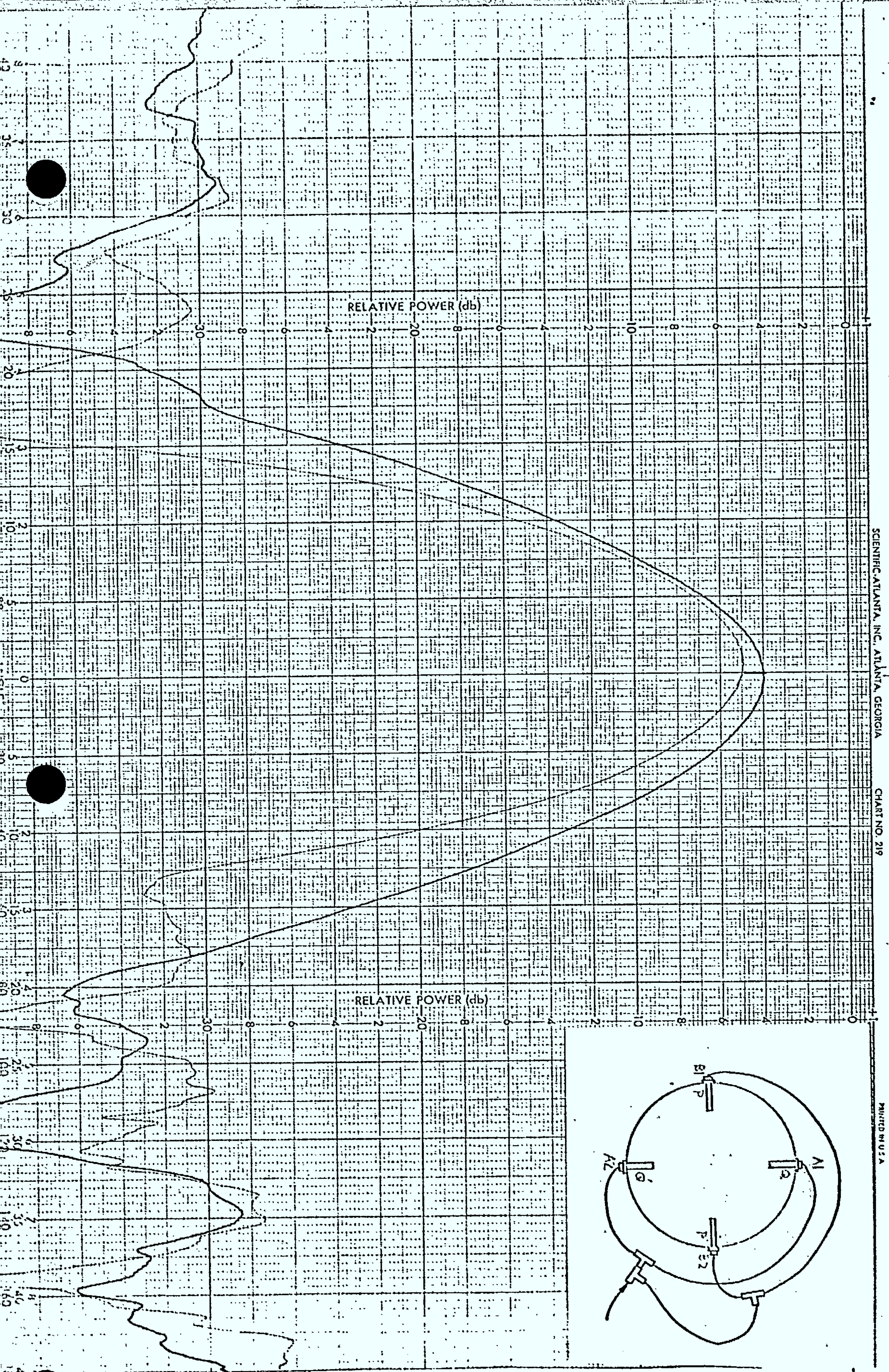
PROJECT
REMARKS: MSAT
821 MHz

ENCR

DATE 02/10/81

125538

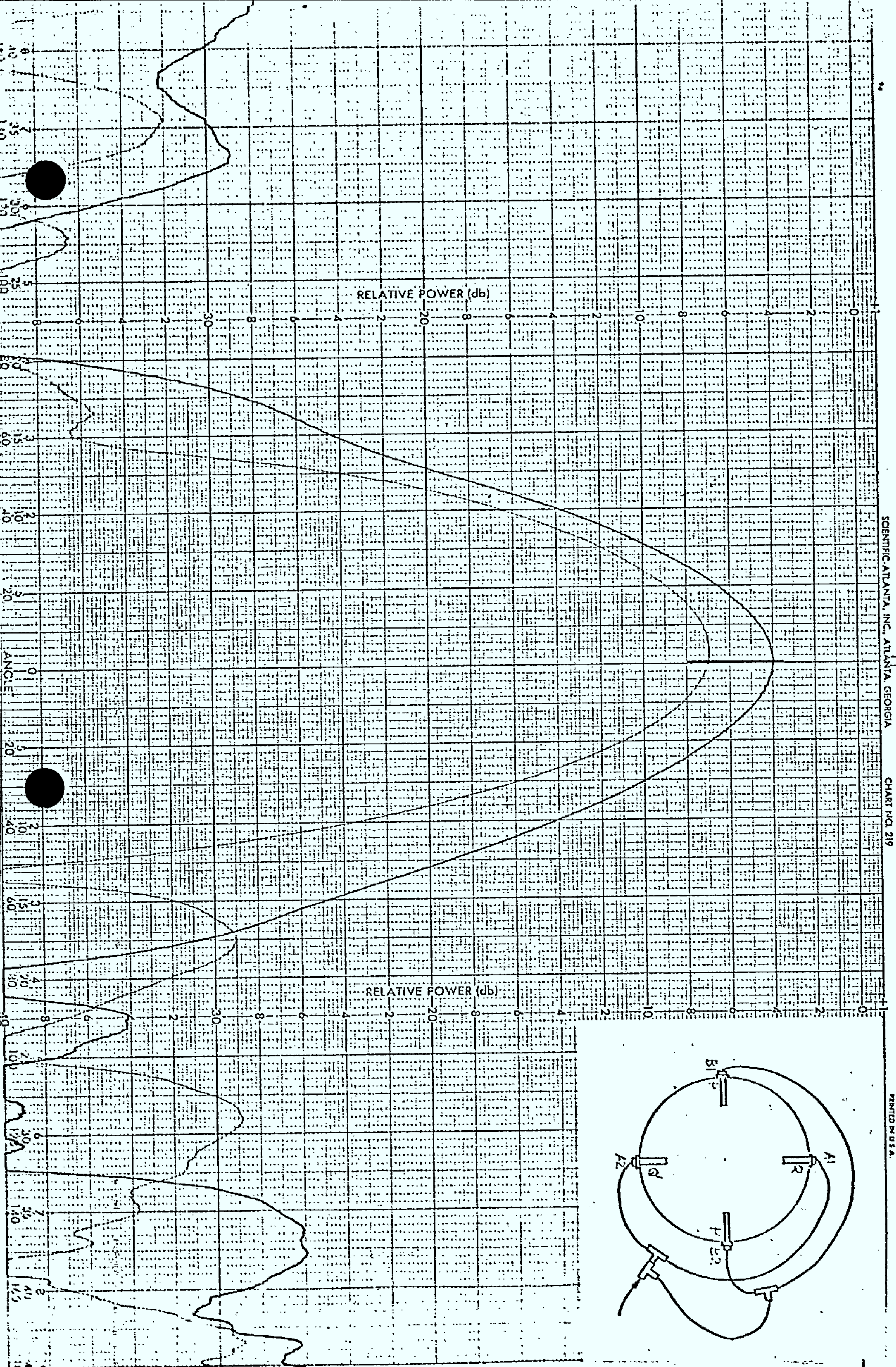
REV Figure 7a



PROJECT MSAT | ENGR | DATE: 02/10/81

REMARKS 831 MHz Rcv Figure 7b

125539



PROJECT MSAT

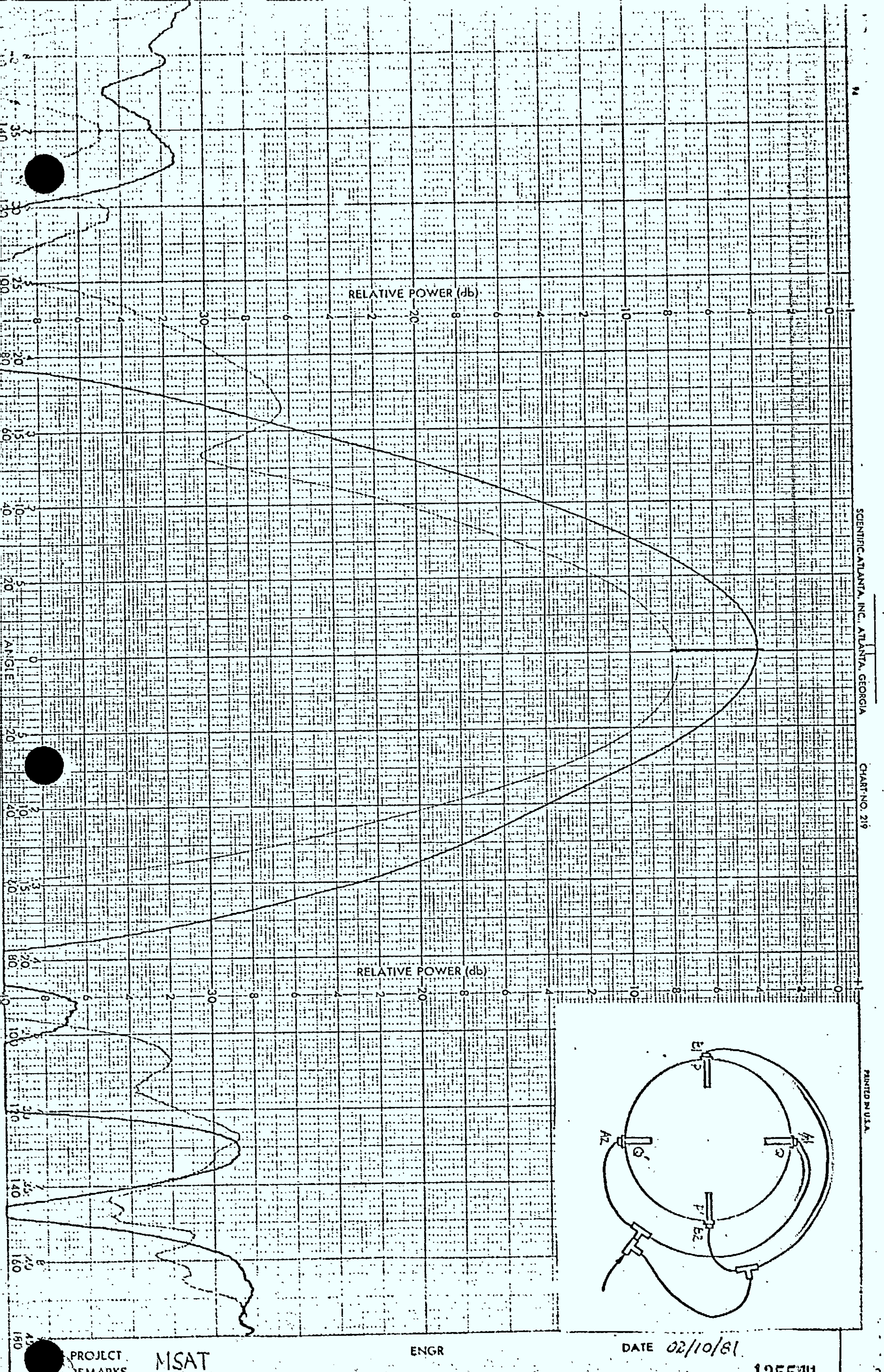
REMARKS

866 MHz Rev Figure 7c

ENGR

DATE 02/10/81

125540



PROJECT REMARKS MSAT

876 MHz Rev

ENGR

DATE 02/10/81

1255[illegible]

Figure 7d

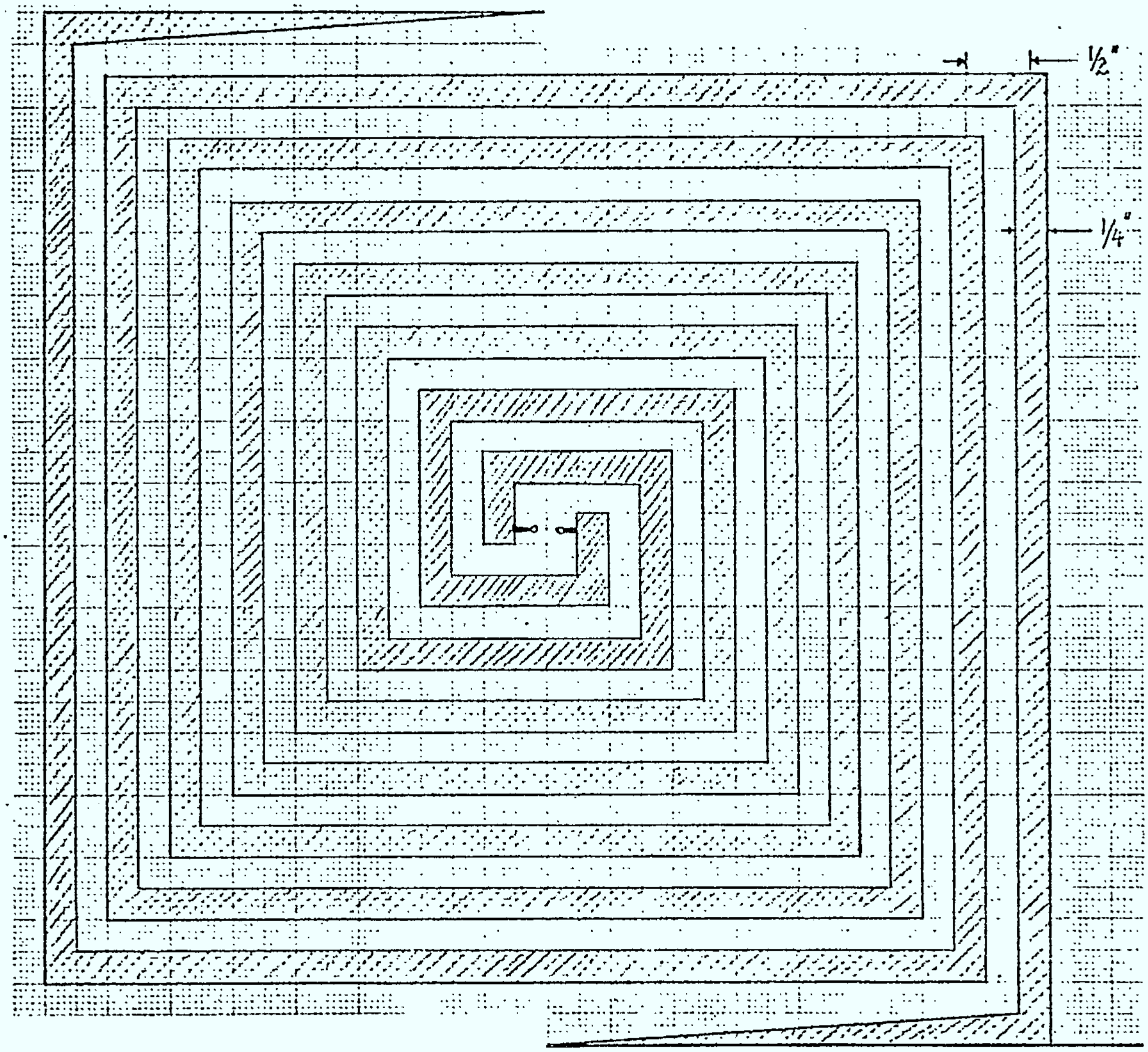
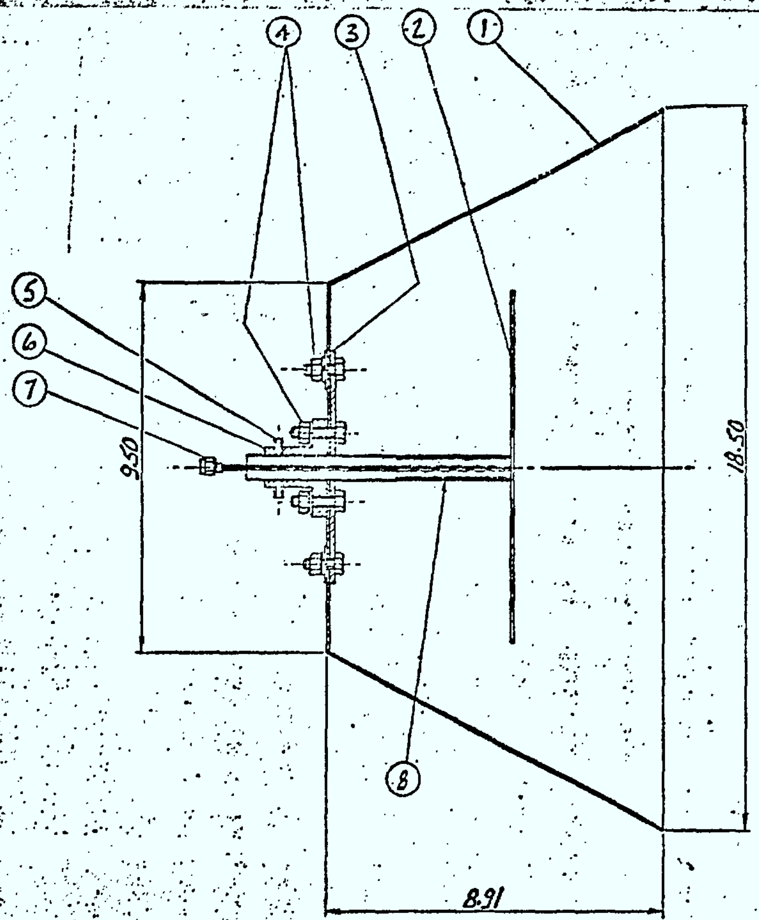


FIGURE 8

The Archimedean Spirals



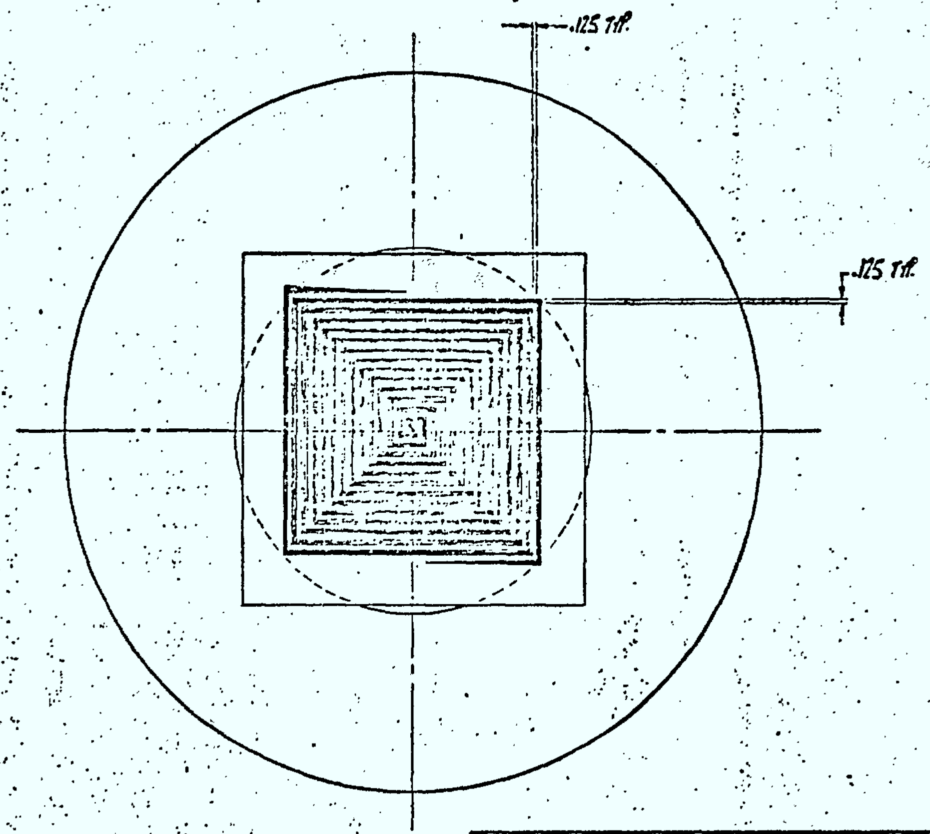


FIGURE 9

"RUGGED" TYPE ANTENNA

NOTE:

THE POLARIZATION OF THE SPIRAL SHOWN IS LEFT-HAND CIRCULAR. RIGHT-HAND CIRCULAR POLARIZATION MAY BE ACHIEVED BY MAKING THE SPIRAL IN A COUNTER CLOCKWISE MANNER.

ITEM	DESCRIPTION
8	BAZOOKA BALUN
7	INNER CONDUCTOR ASSEMBLY
6	MOUNTING FLANGE
5	SET SCREWS
4	1/4 HARDWARE - S.ST.
3	MOUNTING PLATE
2	ARCHIMEDEAN SPIRAL
1	CONICAL HORN

FOR LIST OF MATERIAL ~~SEE~~

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE CHEMICALLY APPLIED OR PLATED FINISHES

TOLERANCES

DRAWN N.M. | CHECKED | APPROVED | APPROVED

MATERIAL SEE L.M.

FINISH

NEXT ASSY | USED ON

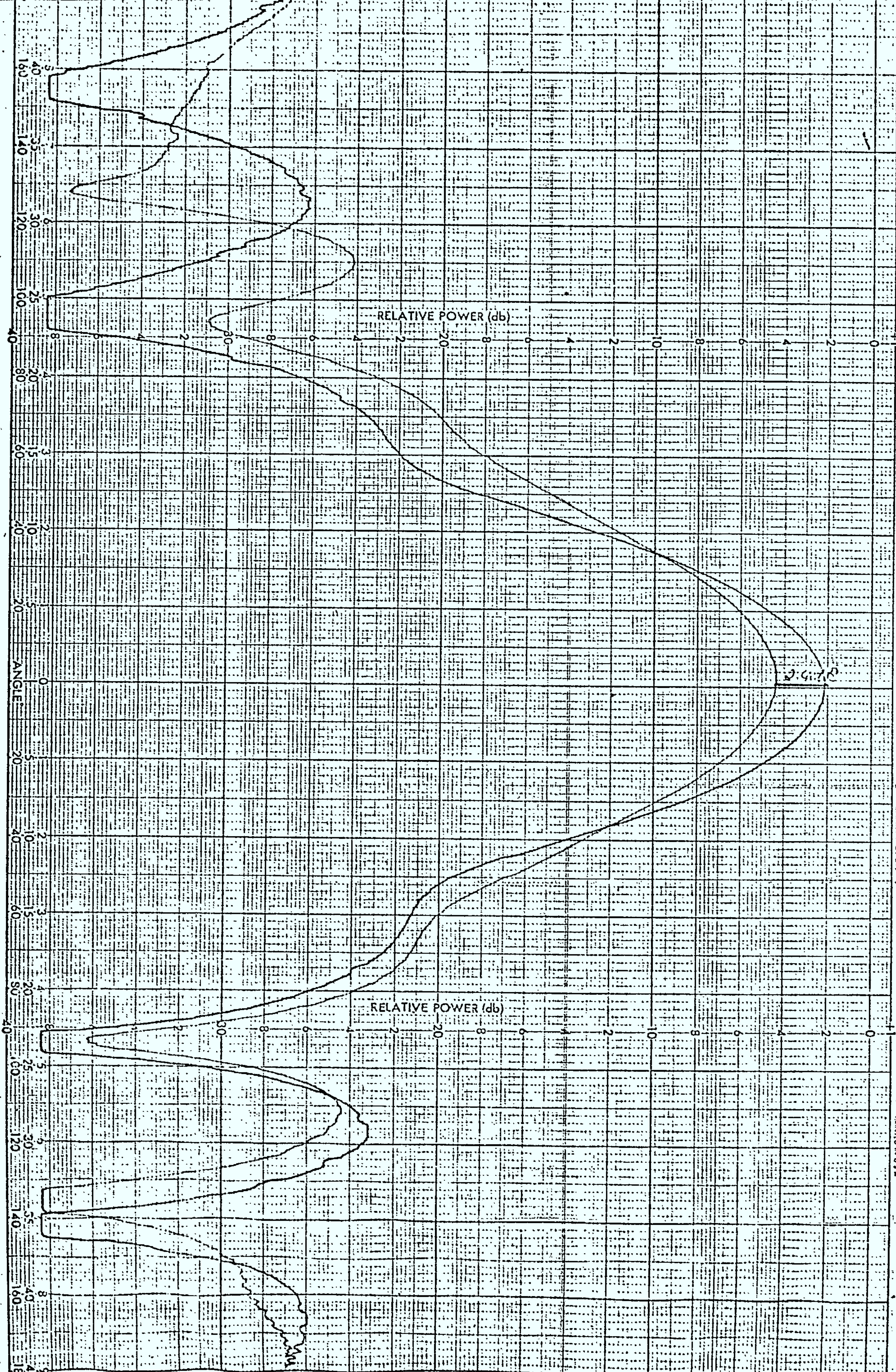
DISTR | APPLICATION

ANDREW

RUGGED TYPE ANTENNA

CODE IDENT NO. | SIZE D | WSK 612

SCALE 1:1 | WEIGHT | SHEET



PROJECT MSAT

REMARKS 821 MHZ

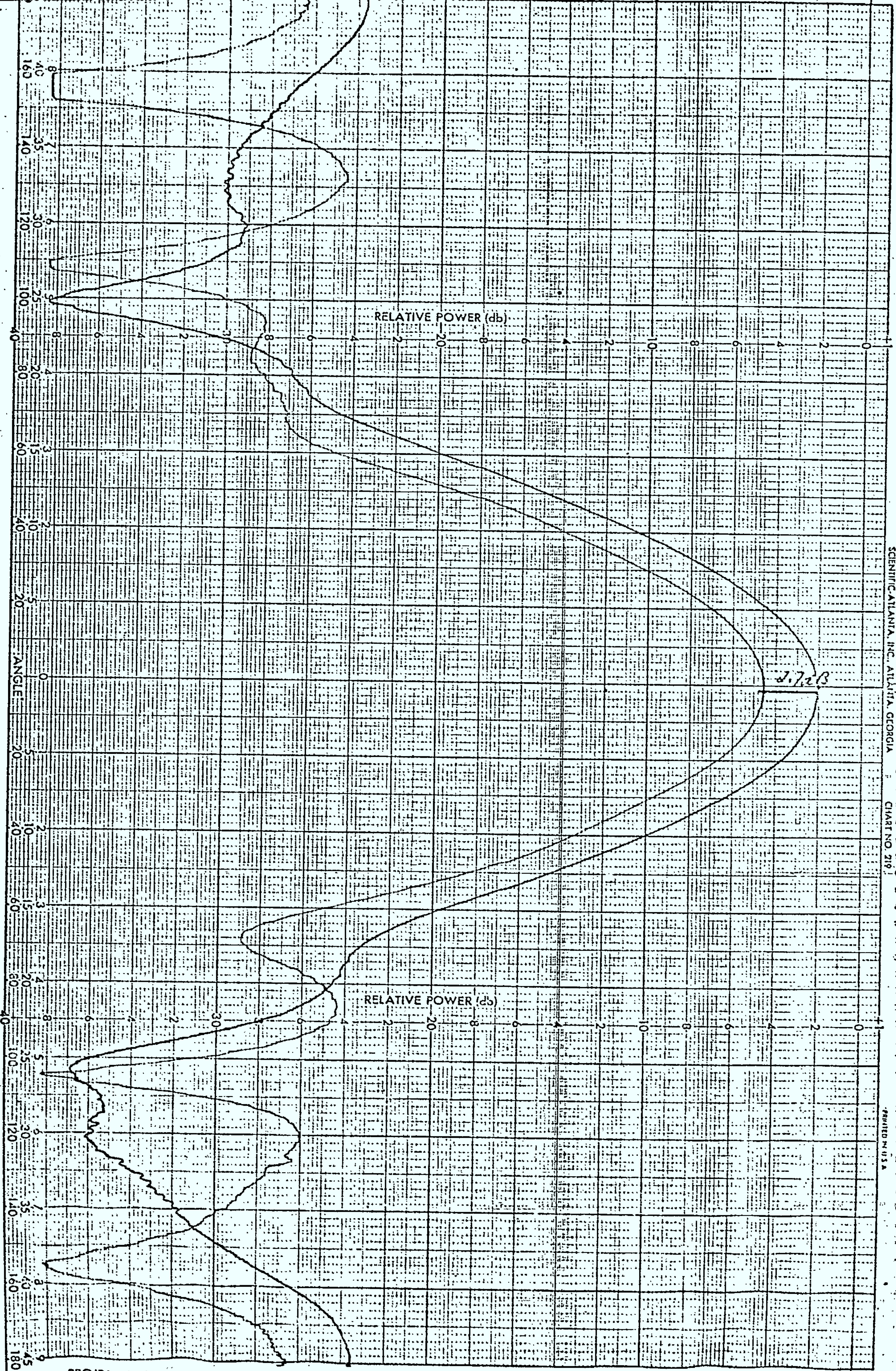
ENGR

FIGURE 10a

DEC 18/81

DATE

169SS9

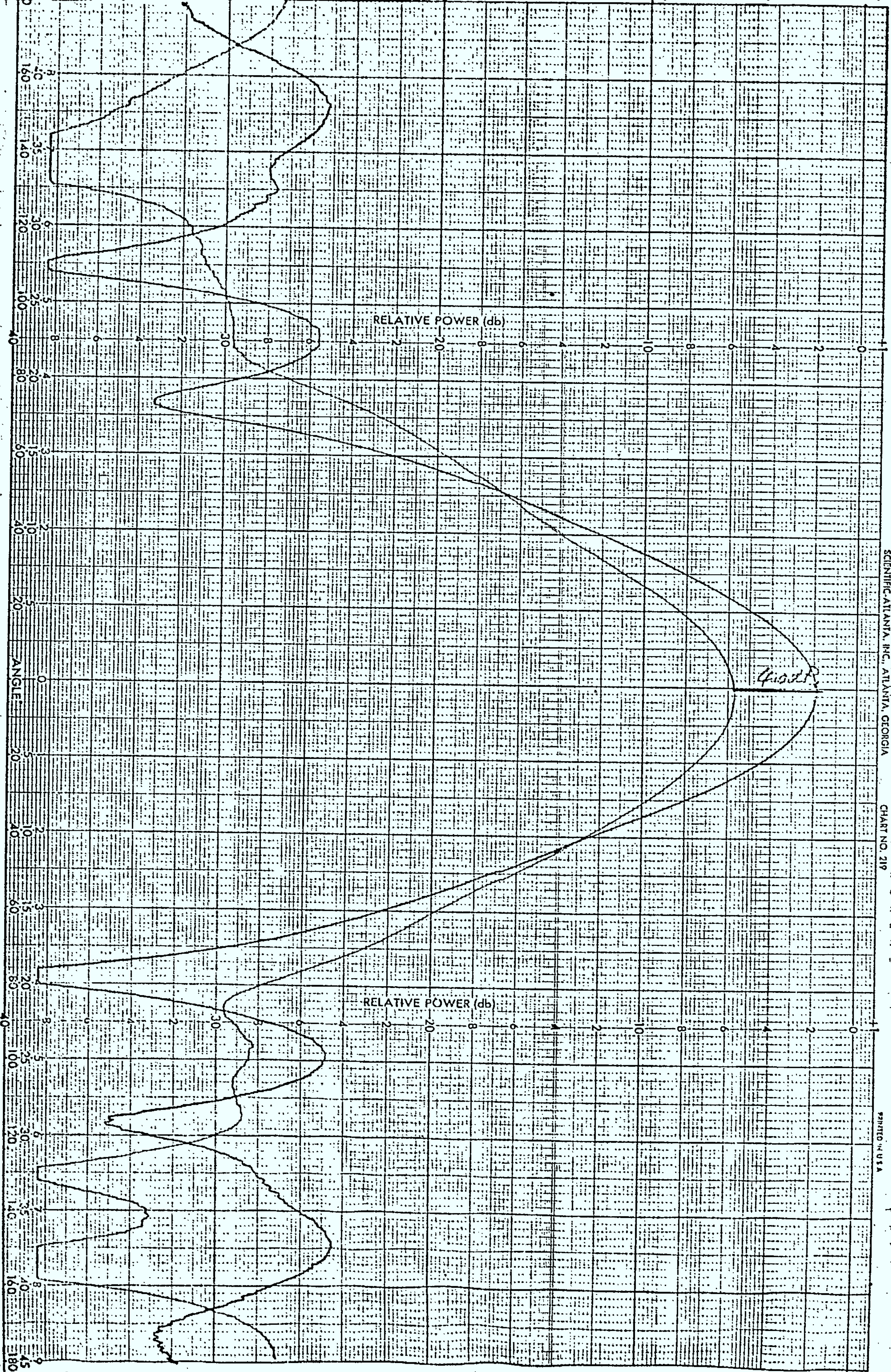


PROJECT MSAT
REMARKS 931 MHZ

ENGR
FIGURE 10b

DATE
DEC 18/81

169SSS

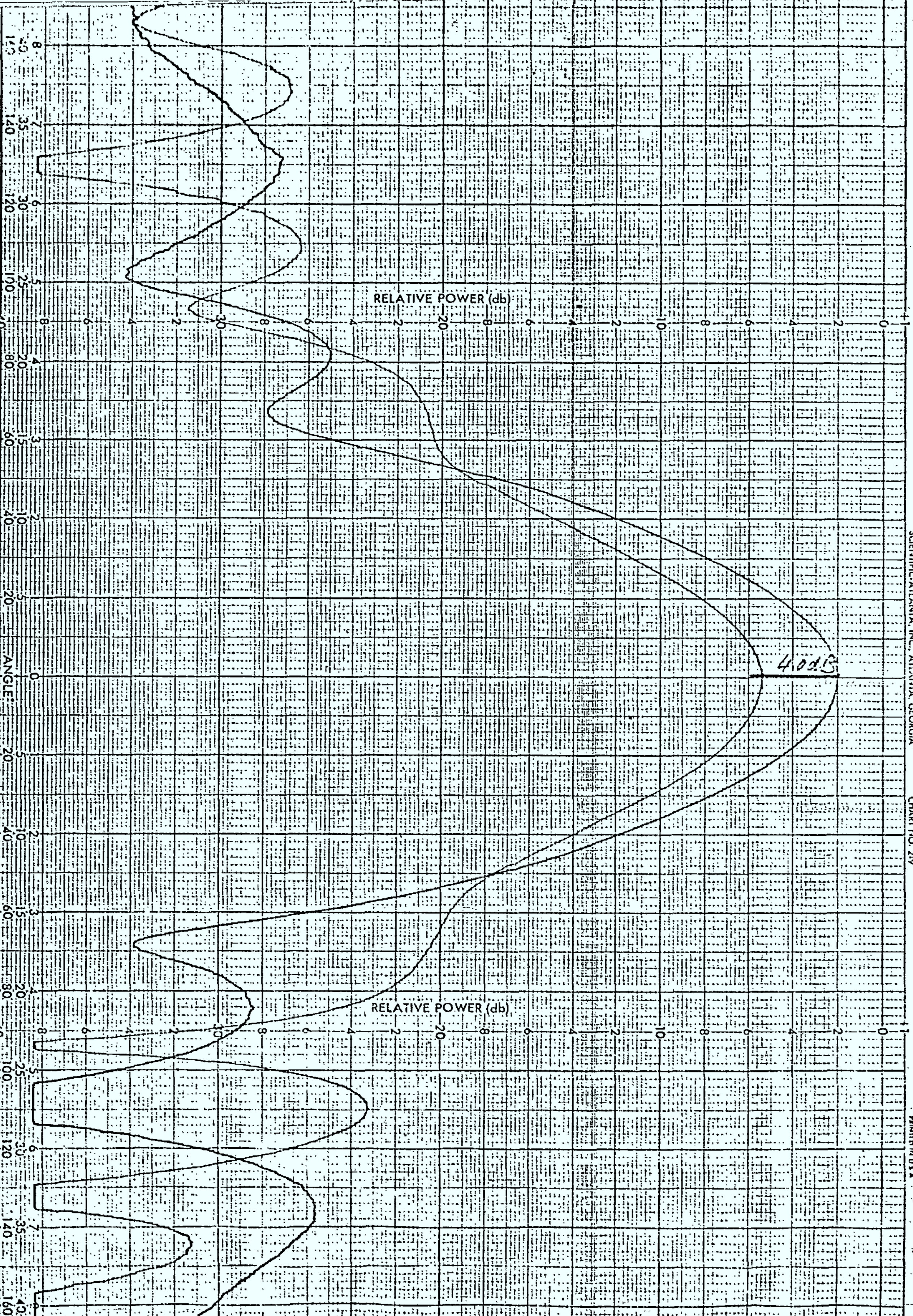


PROJECT MSAT
REMARKS 866 MHZ

ENGR
FIUGRE 10c

DATE
DEC 18/81

169887



PROJECT MSAT
REMARKS 876 MHZ

ENGR
FIGURE 10d

DEC 18/81

DATE

876 MHz

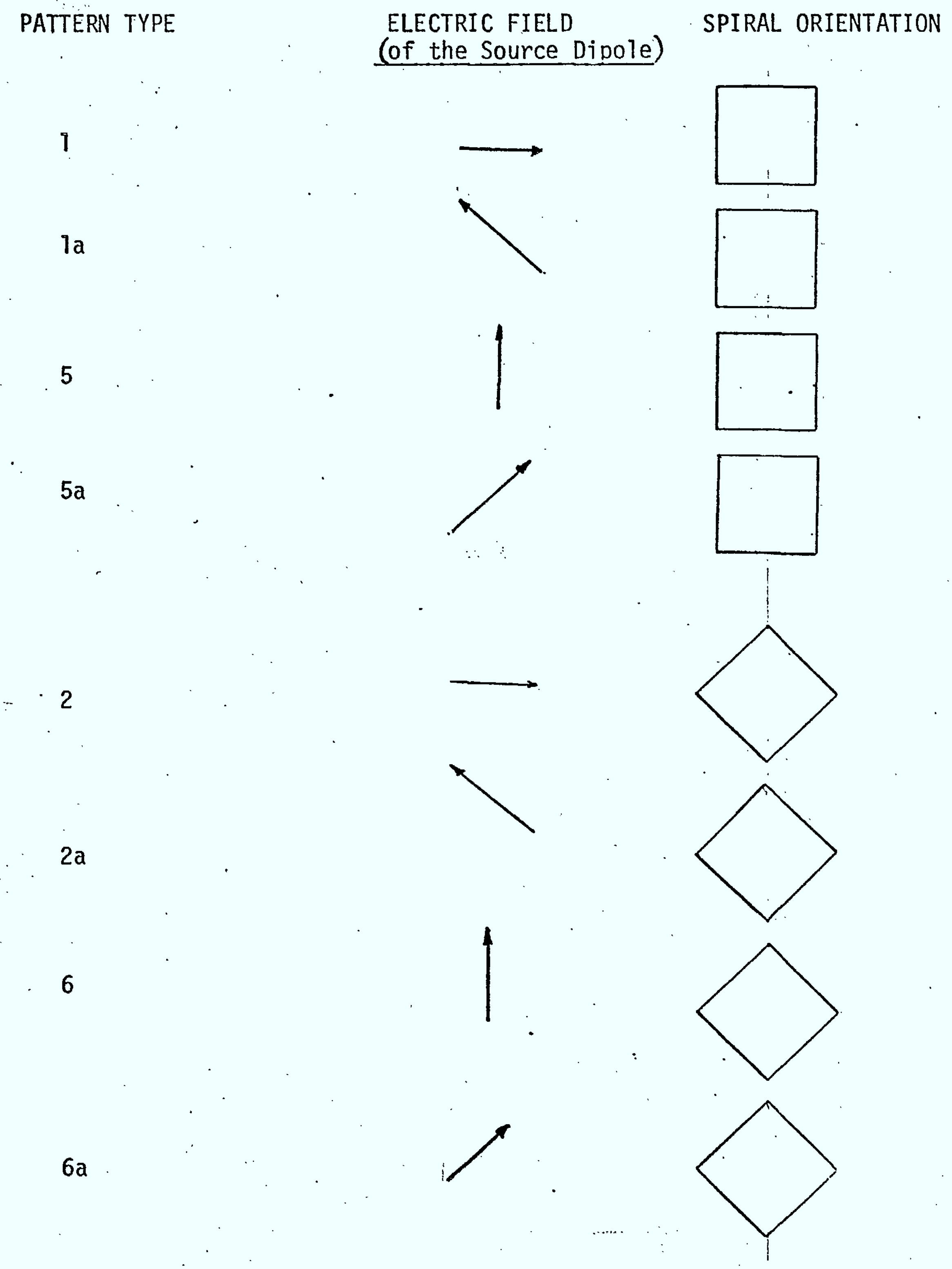
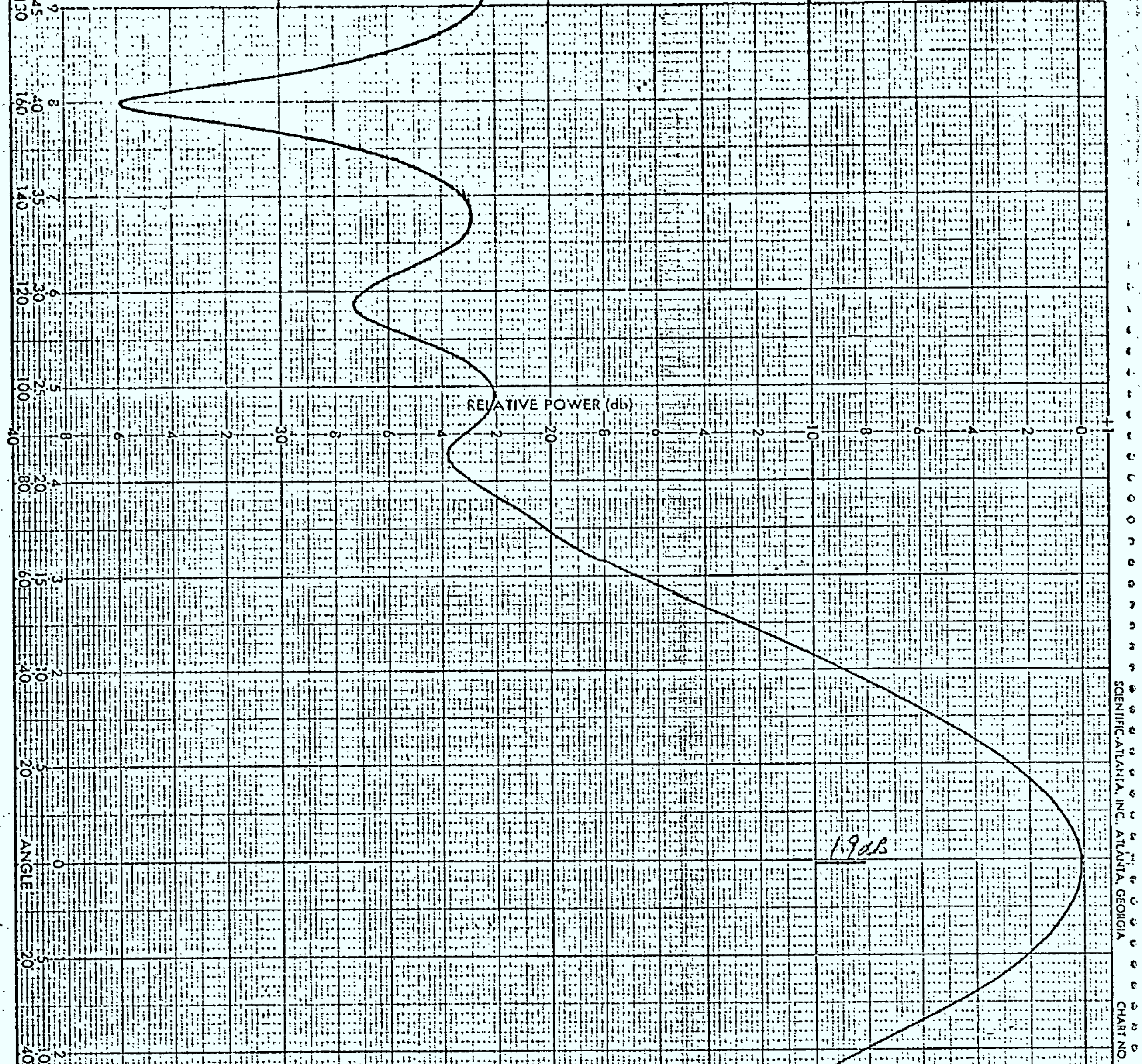


FIGURE 11

Different orientations of the spiral and the source dipole



PROJECT MSAT

ENGR

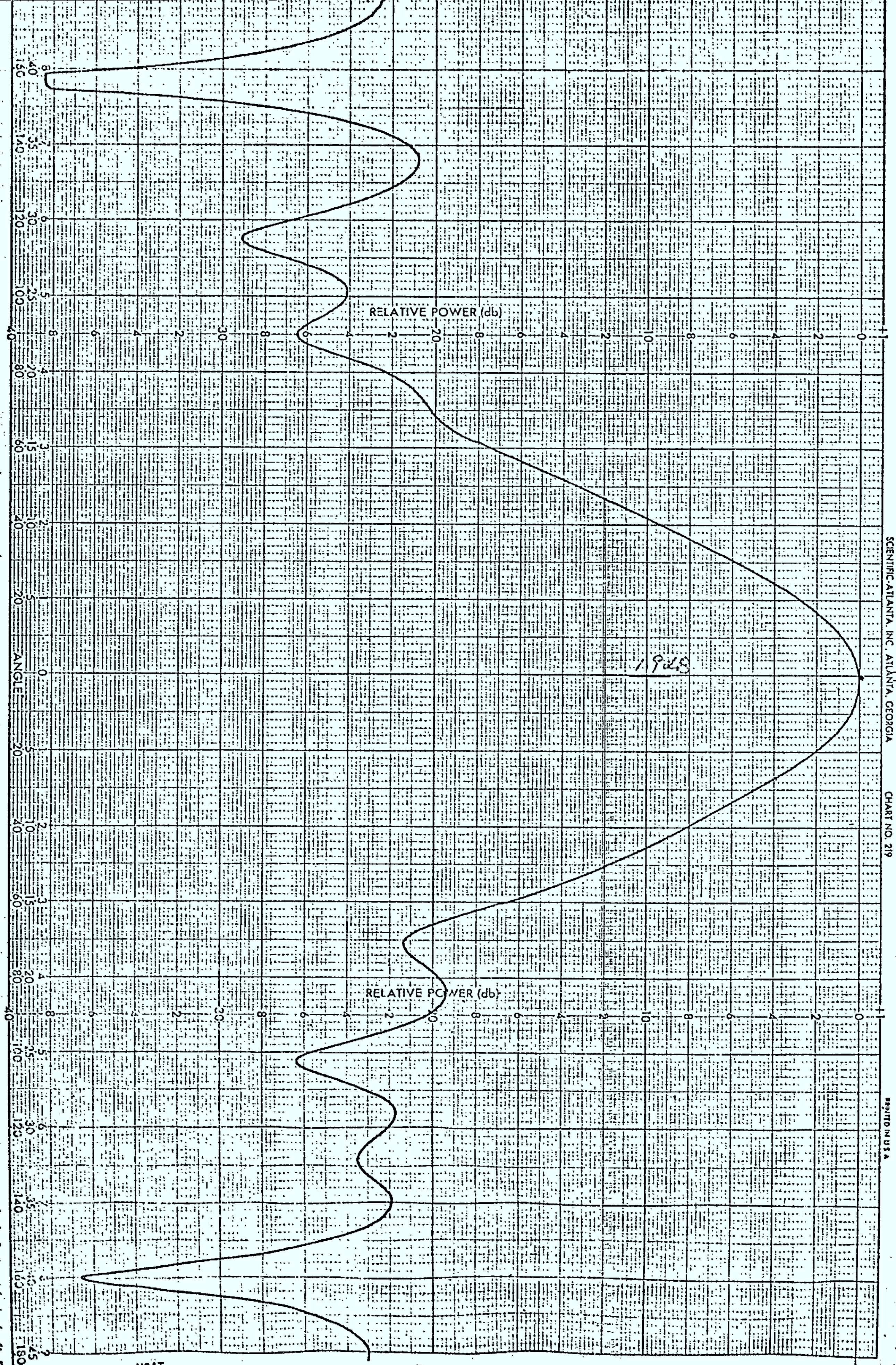
DATE

REMARKS. 821 MHZ PATTERN TYPE: 3
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8"

FIGURE 12a

DEC 29/81

169952



PROJECT MSAT

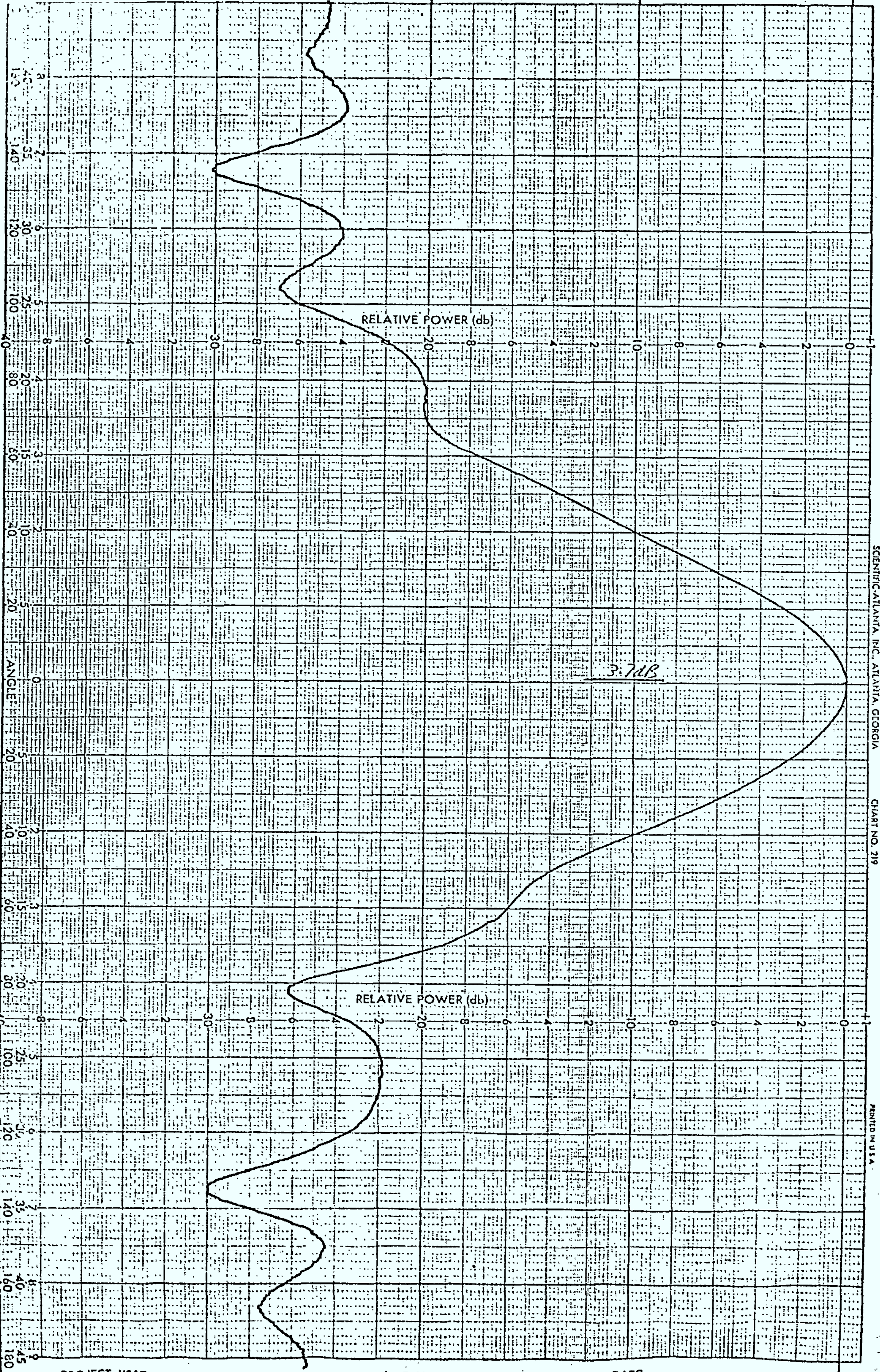
REMARKS 831 MHZ PATTERN TYPE 3
WIDTH OF COPPER STRIP: 1/8
SEPARATION 1/8

ENGR

FIGURE 12b

DATE DEC 29/81

169914



PROJECT MSAT

ENGR

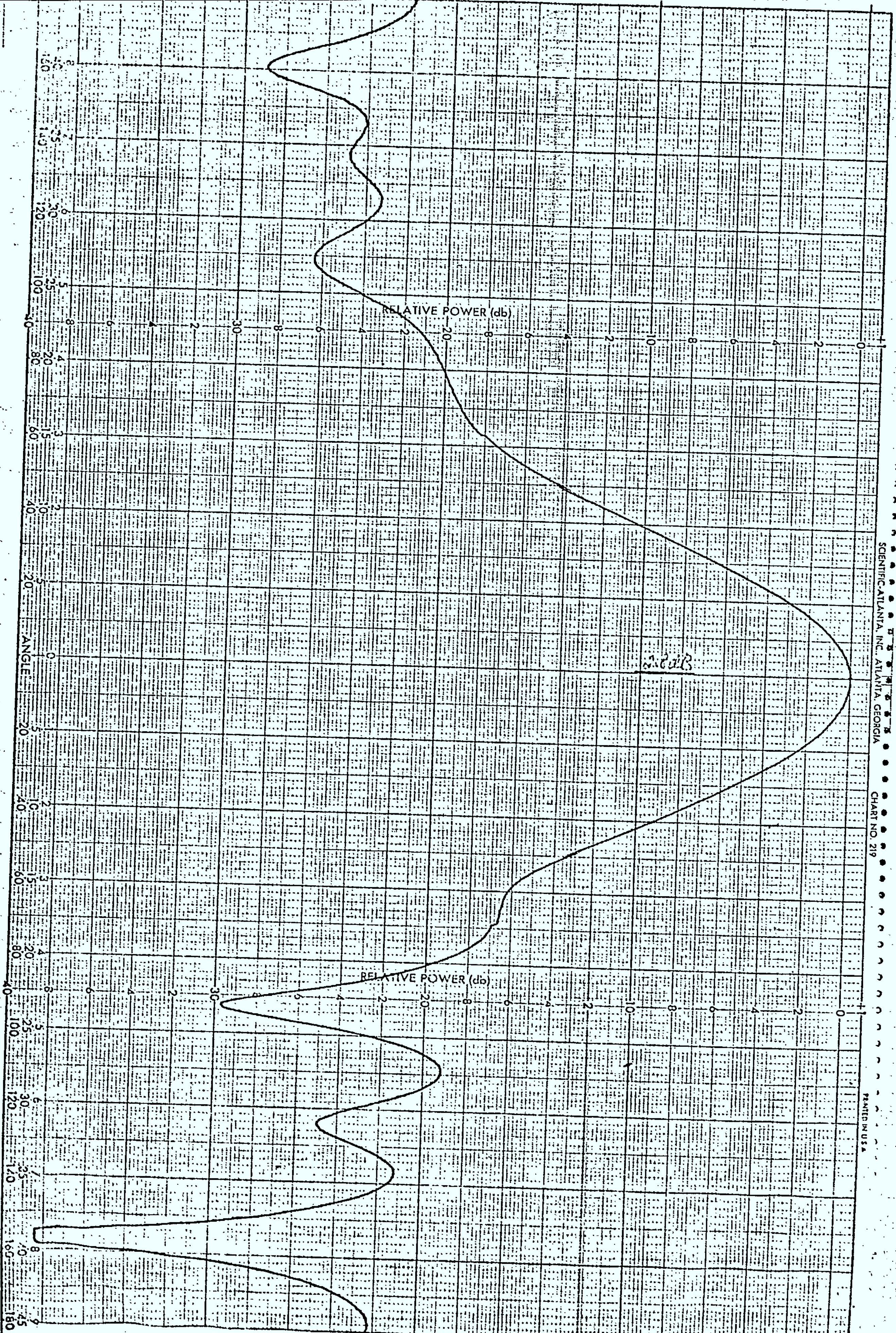
DATE

REMARKS 866 MHZ PATTERN TYPE: 3
WIDTH OF COPPER STRIP 1/8"
SEPARATION 1/8"

FIGURE 12c

DEC 29/81

169940



PROJECT MSAT

REMARKS 876 MHZ PATTERN TYPE: 3

WIDTH OF COPPER STRIP: 1/8"

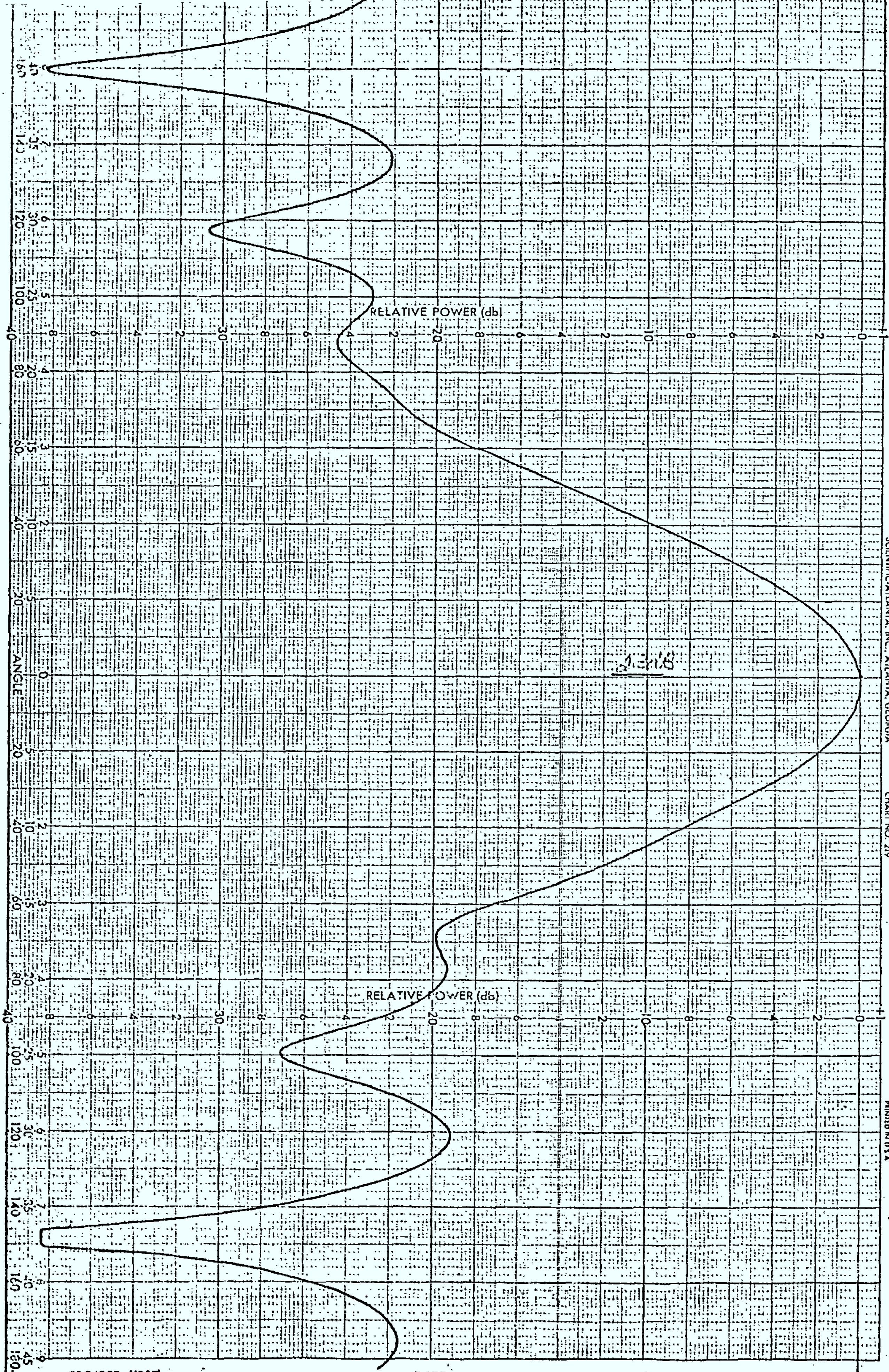
SEPARATION 1/8"

ENGR

FIGURE 12d

DATE DEC 29/81

169935



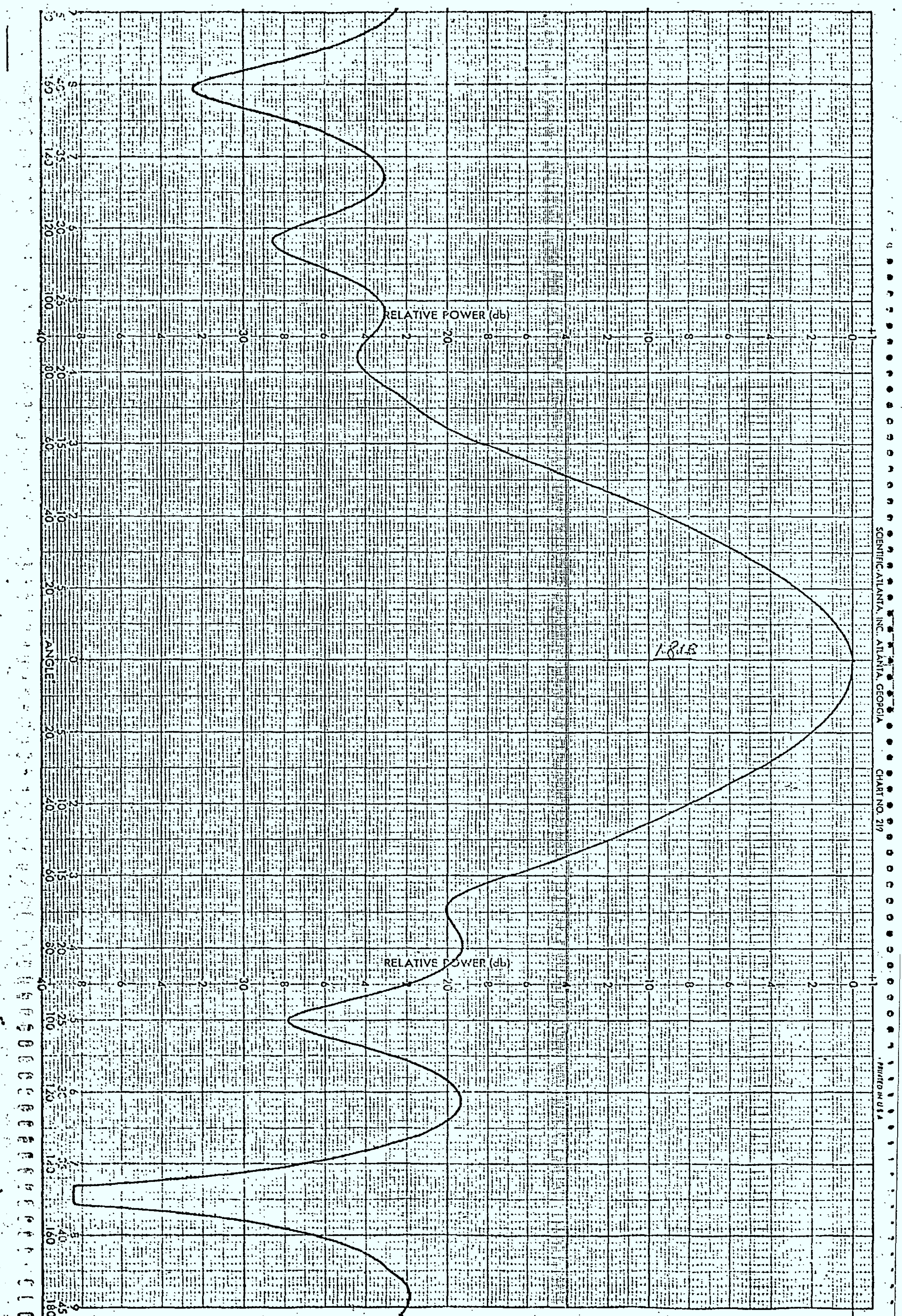
PROJECT MSAT ENGR DATE

REMARKS 821 MHZ PATTERN TYPE: 1
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

FIGURE 13a

DEC 29/81

169971



PROJECT MSAT

REMARKS 821 MHZ PATTERN TYPE: 2

Width Of Copper Strip: 1/8"

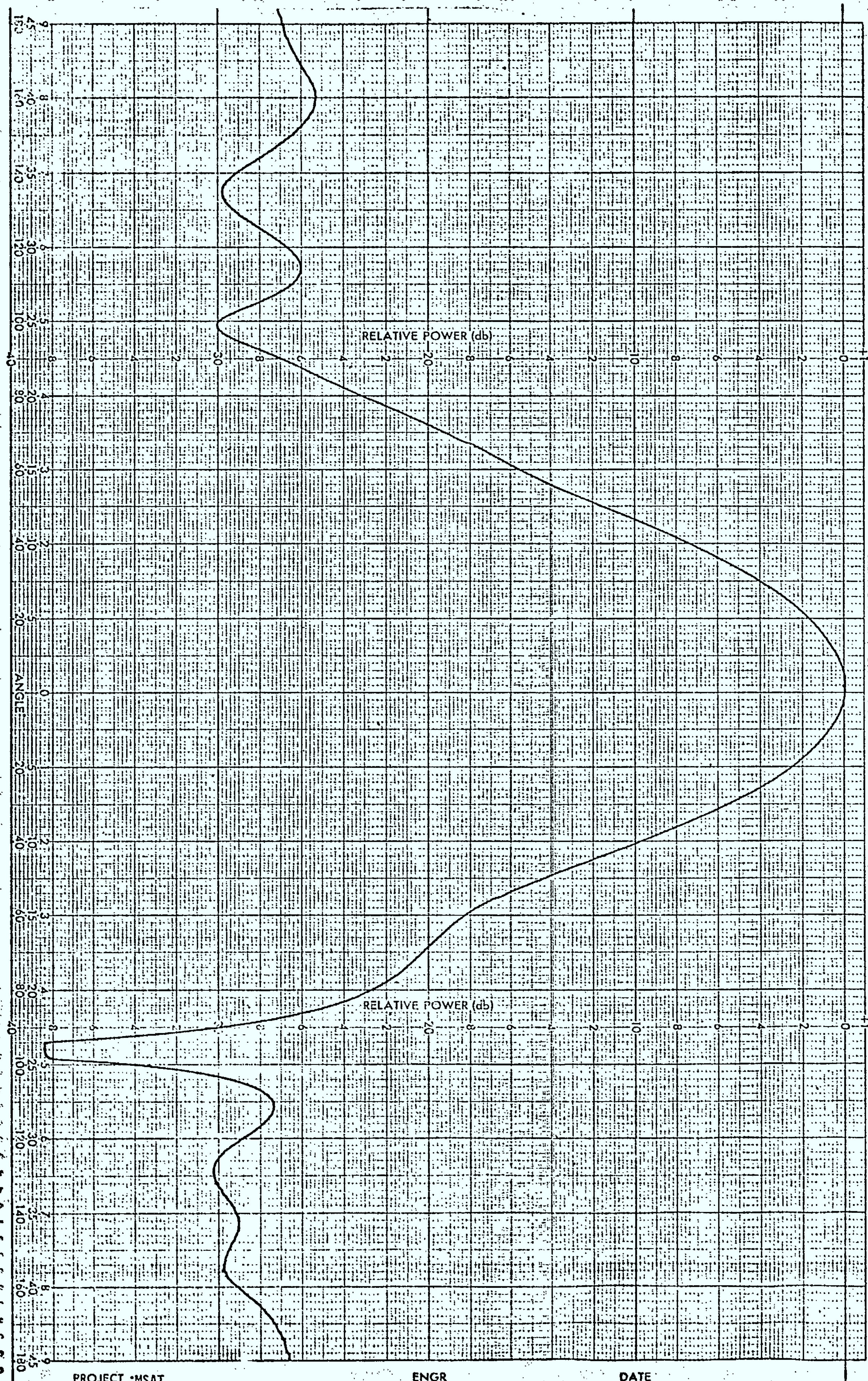
Separation : 1/8"

ENGR

FIGURE 13b

DATE DEC 29/81

160931

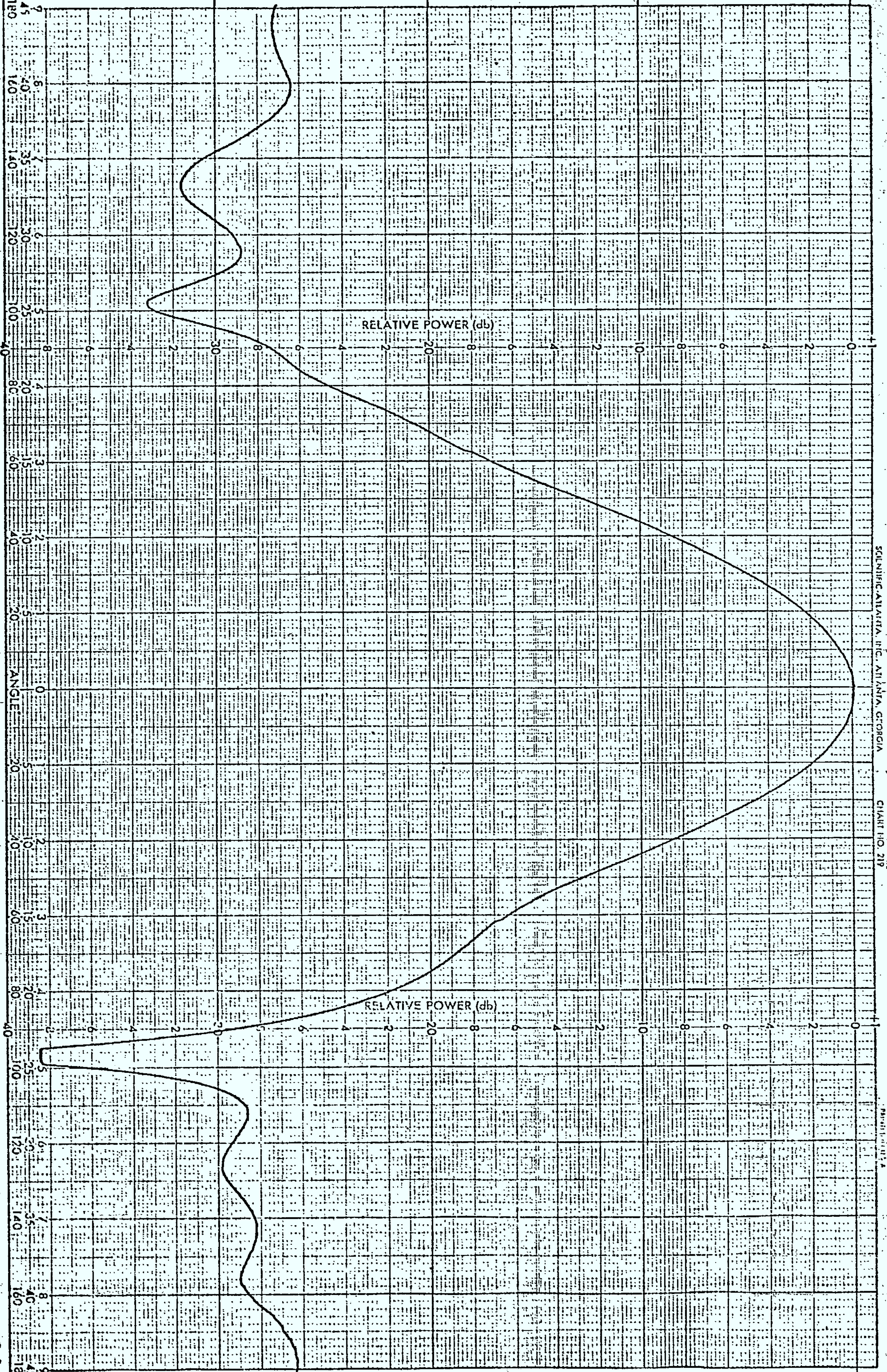


PROJECT MSAT
ENGR
DATE
REMARKS 821 MHZ PATTERN TYPE: 5
WIDTH OF COPPER STRIP : 1/8"

FIGURE 13c

Dec 29/81

169968



PROJECT MSAT

ENGR

DATE

REMARKS 821 MHZ PATTERN TYPE: 6
WIDTH OF COPPER STRIP 1/8"
SEPARATION 1/8

FIGURE 13d

Dec 29/81 169928

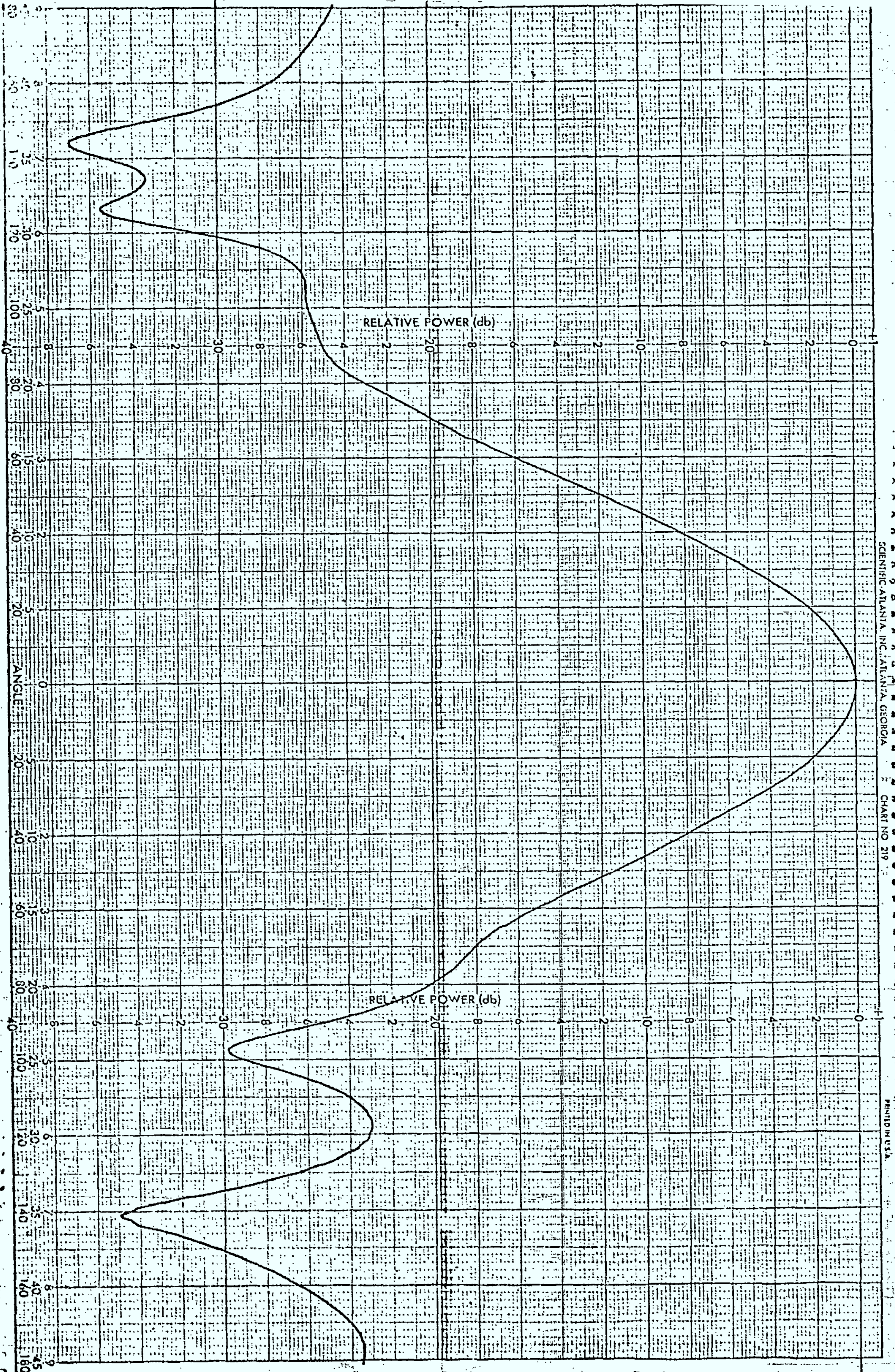
PROJECT MSAT
REMARKS 821 MHZ PATTERN TYPE: 1A
WIDTH OF COPPER STRIP: 1/8"

ENGR

FIGURE 13e

DATE DEC 29/81

169967



PROJECT MSAT

ENGR

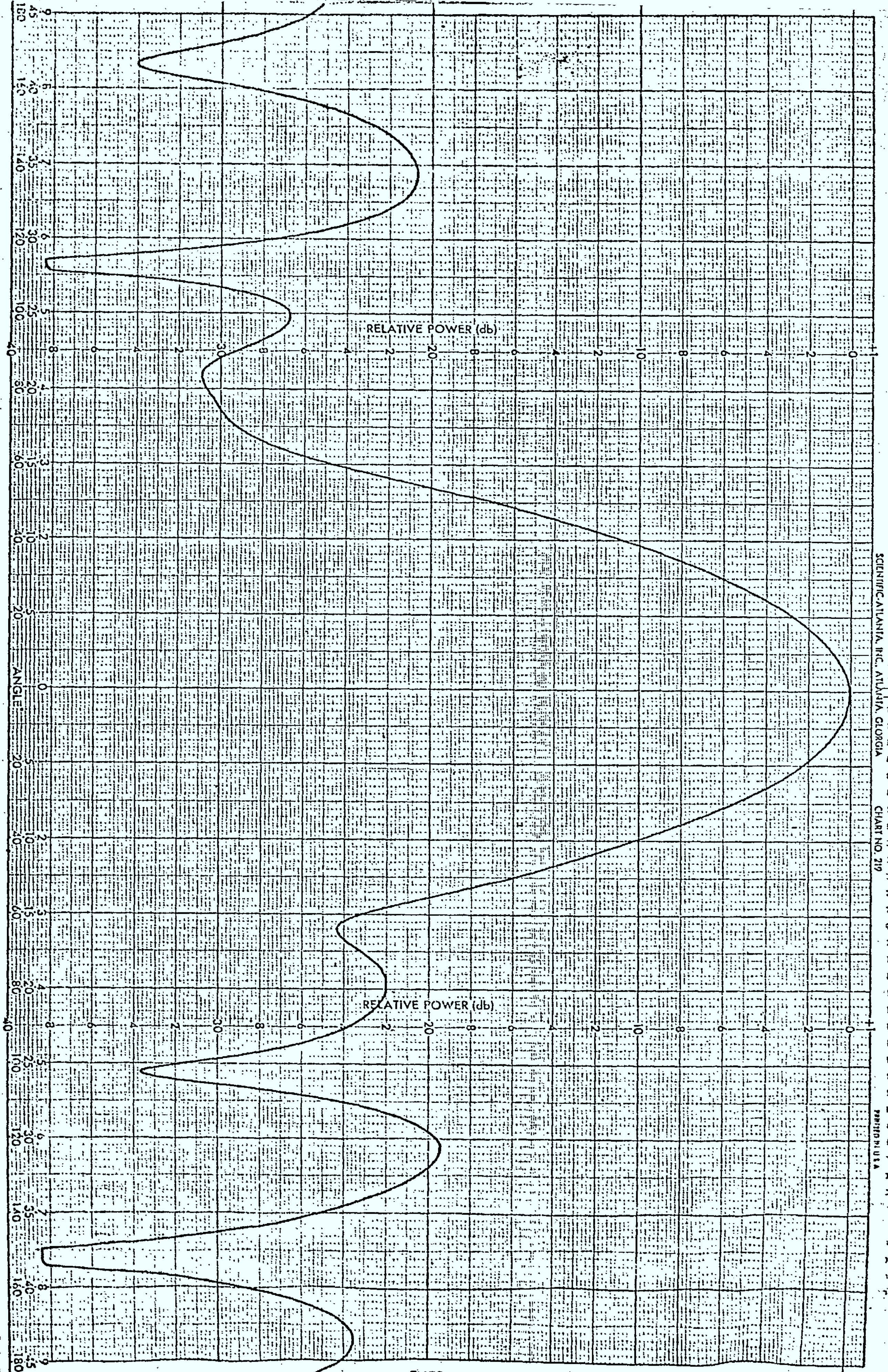
DATE

REMARKS 821 MHZ PATTERN TYPE: 2A
WIDTH OF COPPER STRIP: 1/8"
SEPARATION :1/8"

FIGURE 13f

DEC 29/81

169913



PROJECT MSAT

ENGR

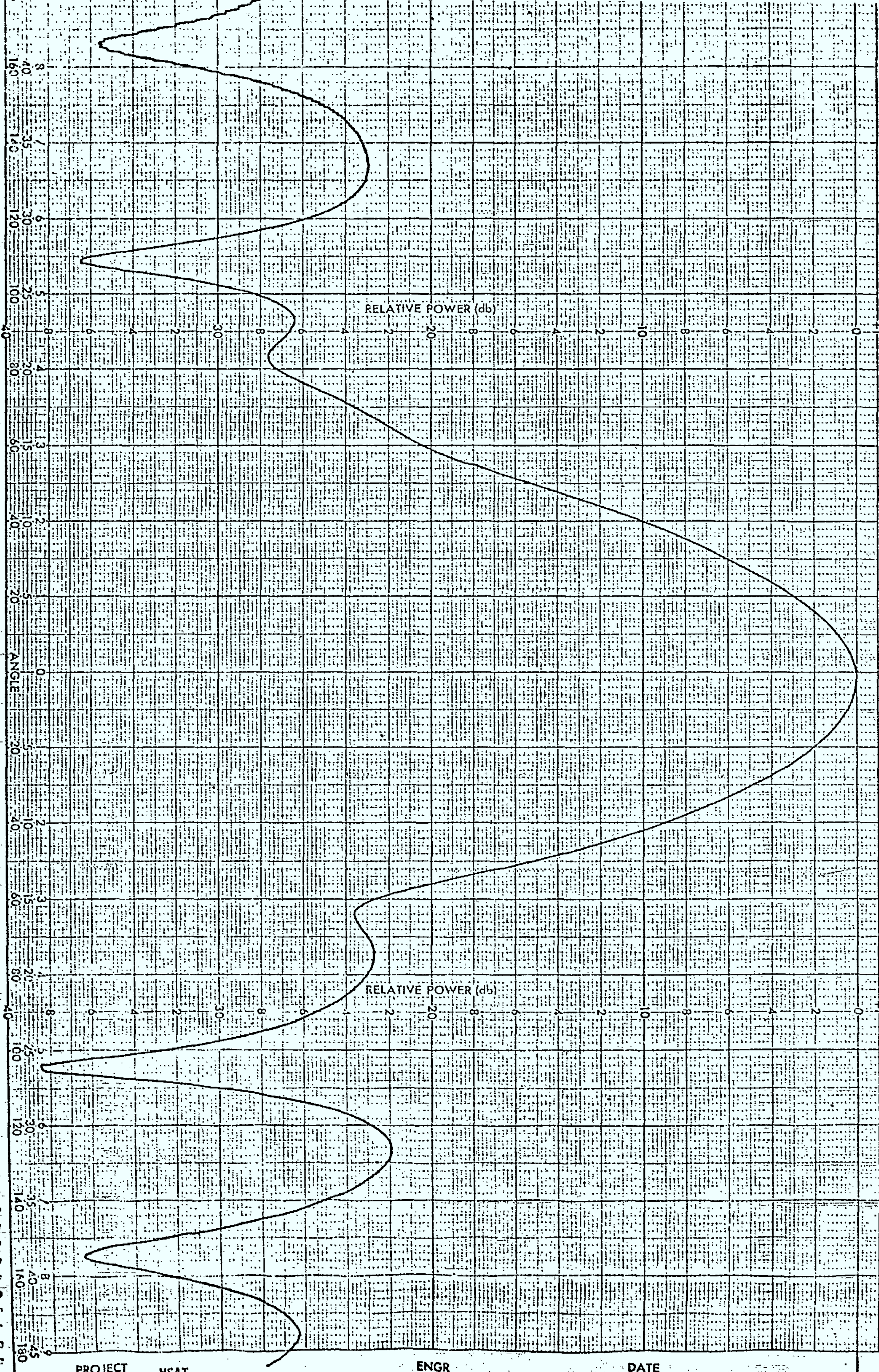
DATE

REMARKS 821 MHZ PATTERN TYPE: 5a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION : 1/8"

FIGURE 13a

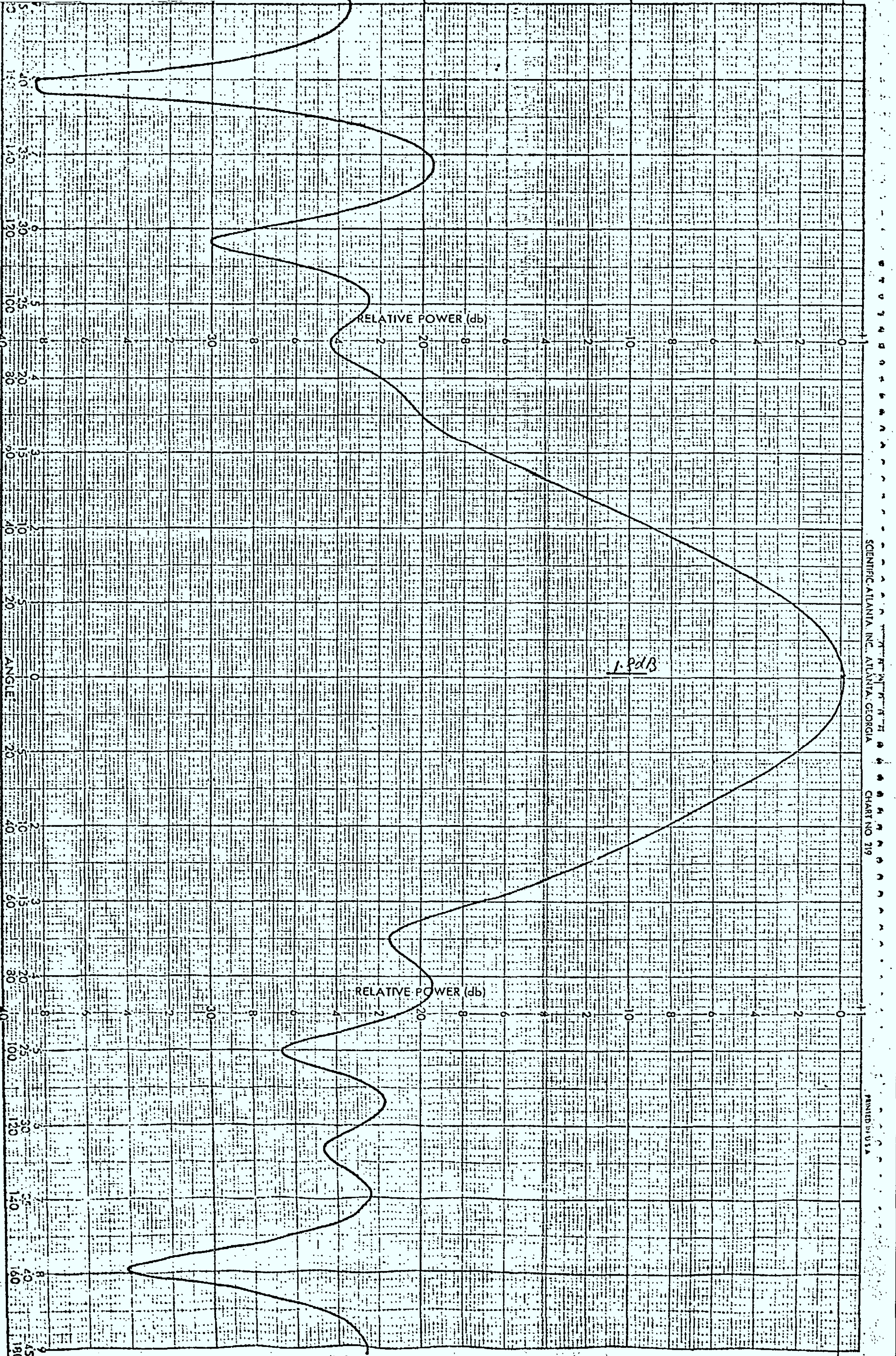
DEC 29/81

169970



PROJECT	MSAT	ENGR	DATE
REMARKS	821 MHZ PATTERN TYPE: 6a WIDTH OF COPPER STRIP: 1/8" SEPARATION: 1/8"	FIGURE 13h	DEC 29/ 81

169930



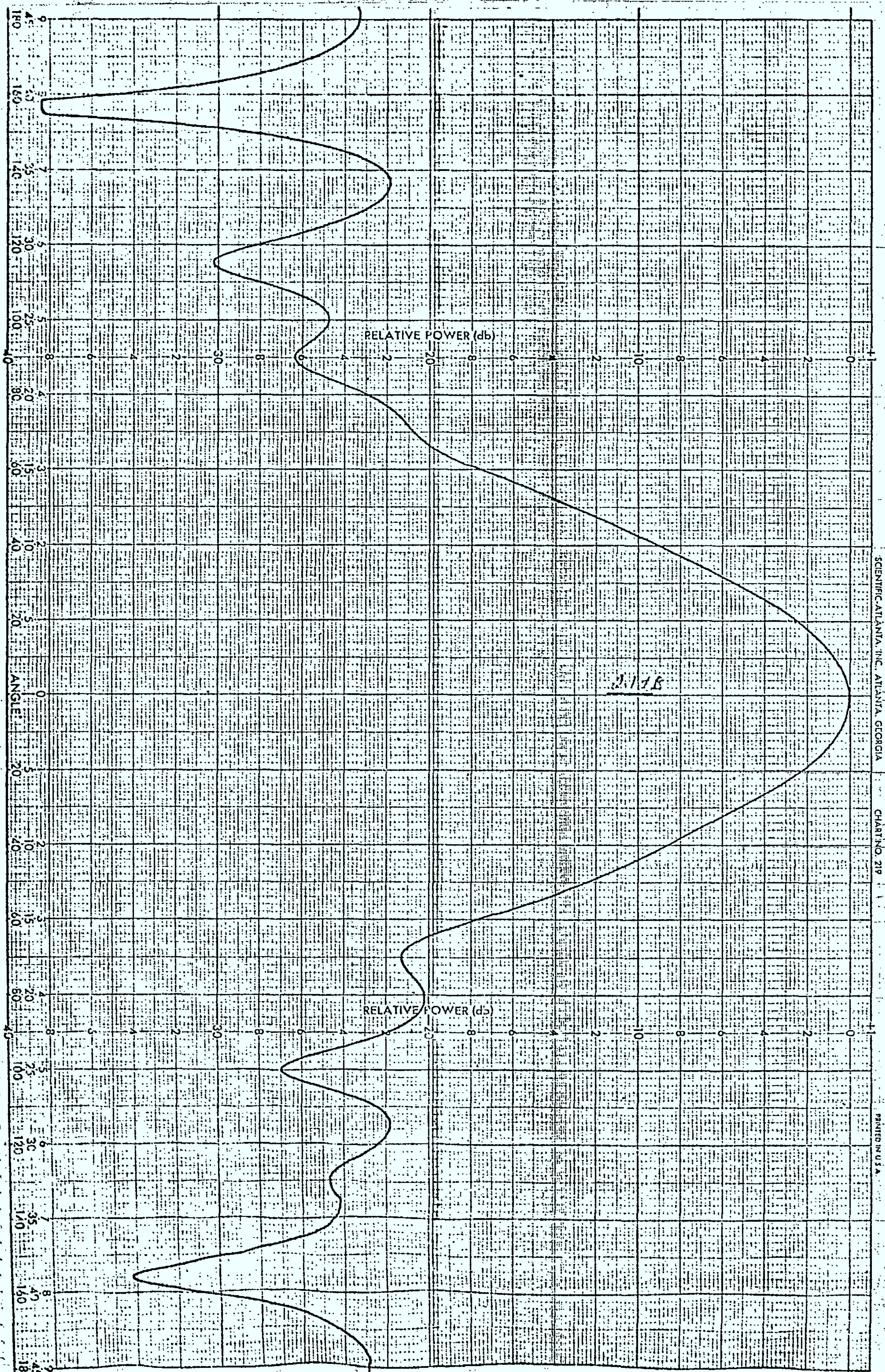
PROJECT MSAT ENGR DATE

REMARKS. 831 MHZ PATTERN TYPE: 1
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8

FIGURE 14a

DEC 29/81

169966

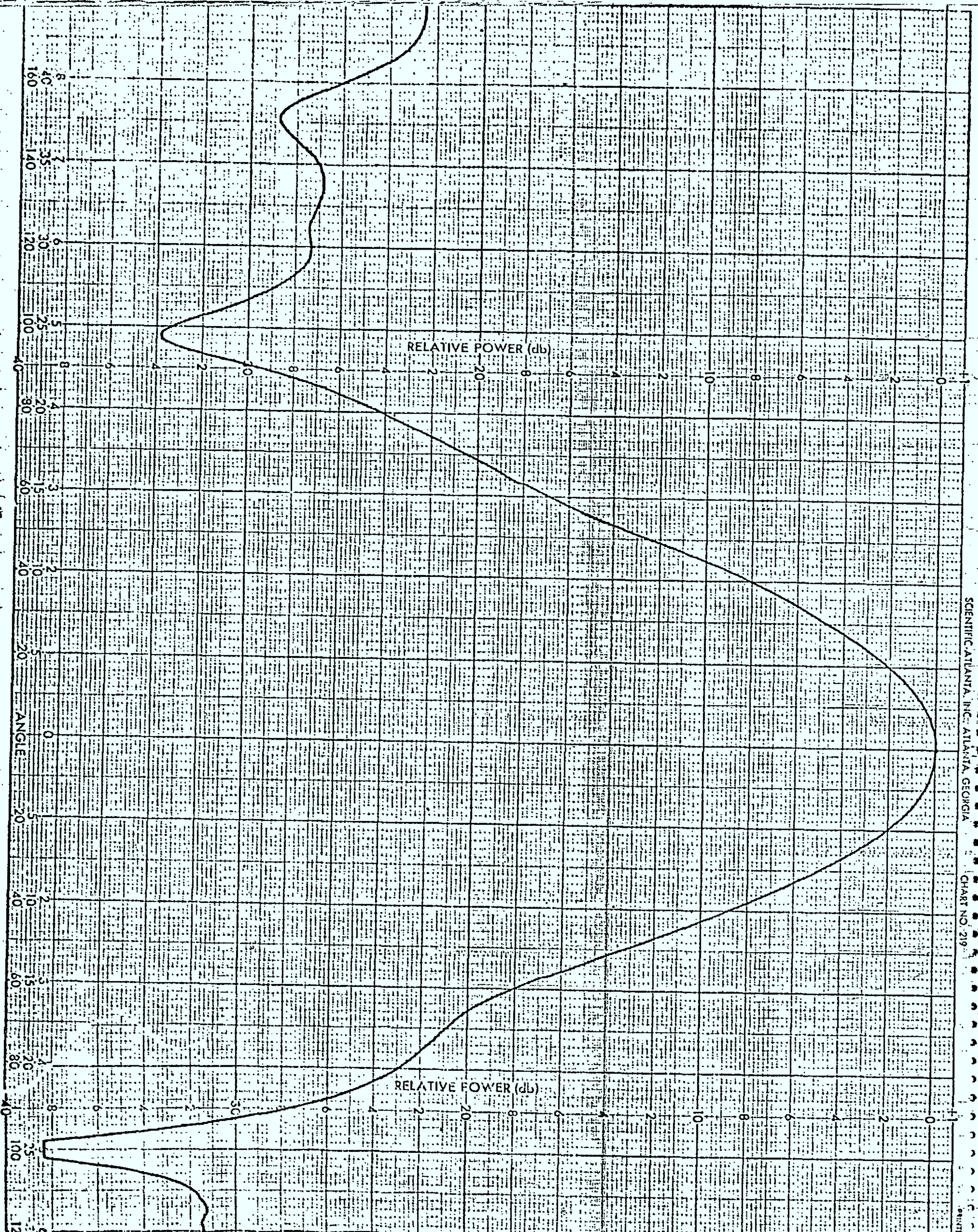


PROJECT MSAT
ENGR
DATE
REMARKS 831 MHZ PATTERN TYPE: 2
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

FIGURE 14b

DEC 29/81

169912



PROJECT MSAT

REMARKS 831 MHZ PATTERN TYPE: 5
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

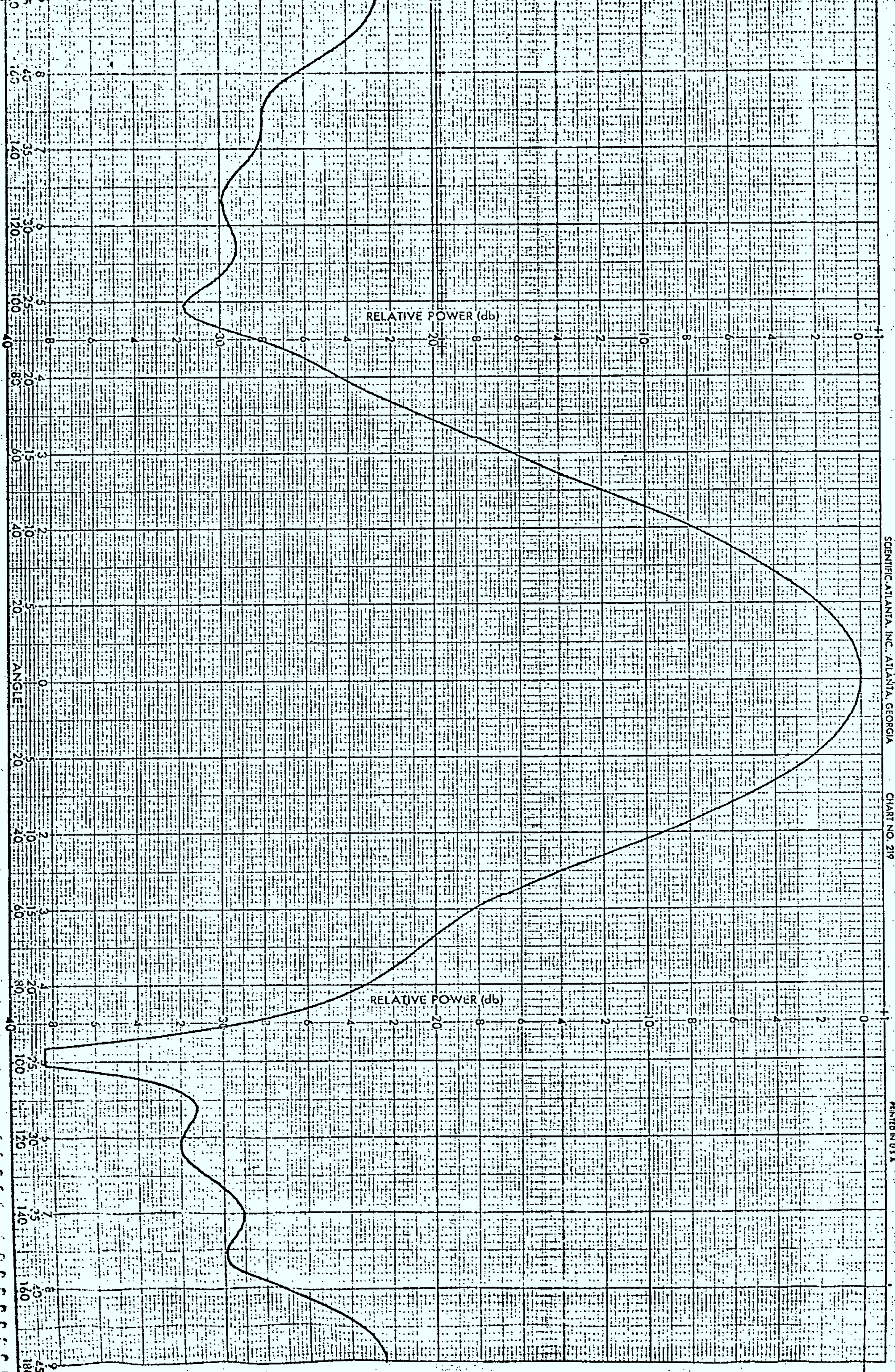
ENGR

DATE

FIGURE 14c

DEC 29/81

169964



PROJECT MSAT

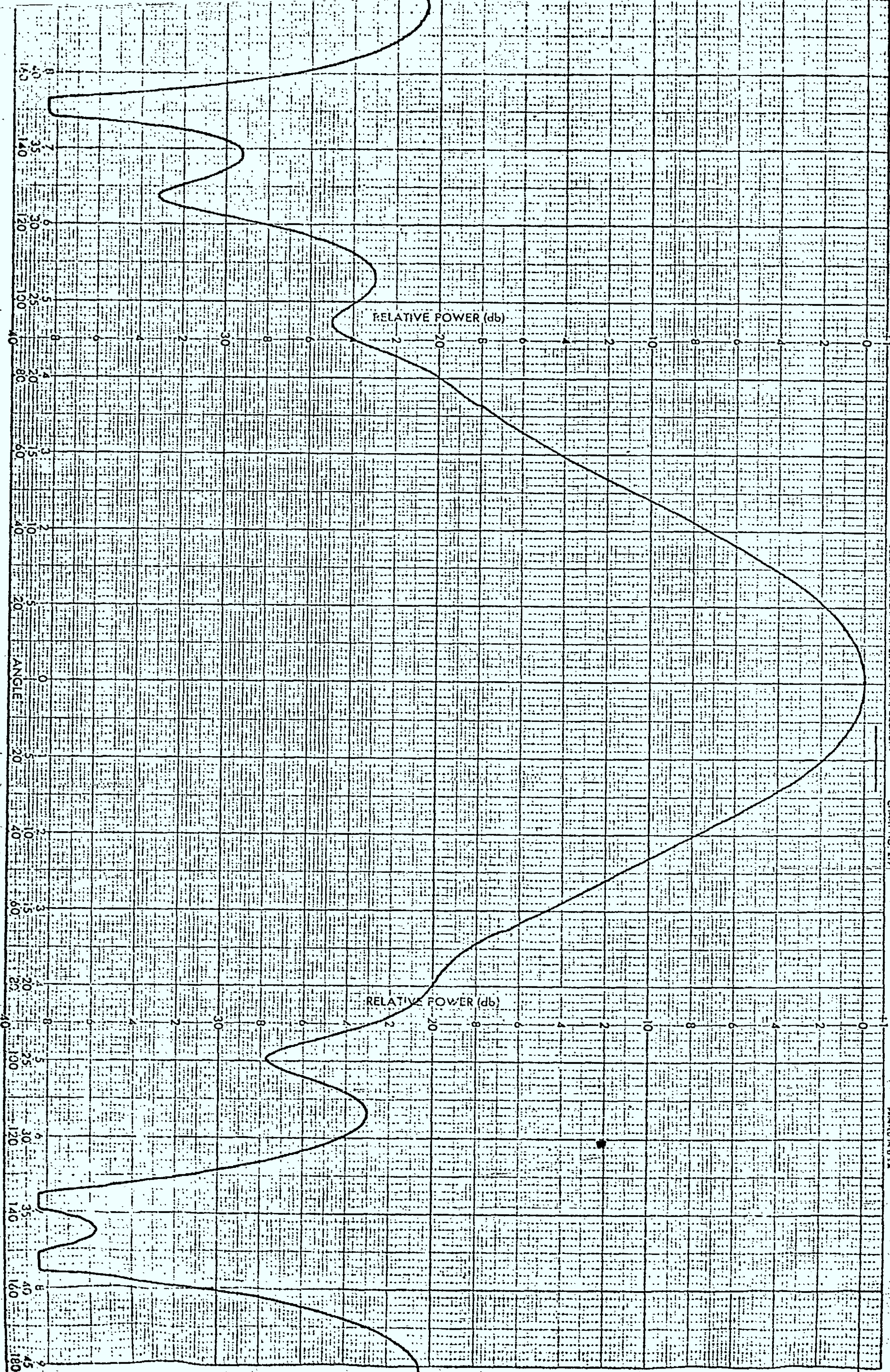
REMARKS 831 MHZ PATTERN TYPE: 6
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

ENGR

FIGURE 14d1

DATE DEC 29/81

169910



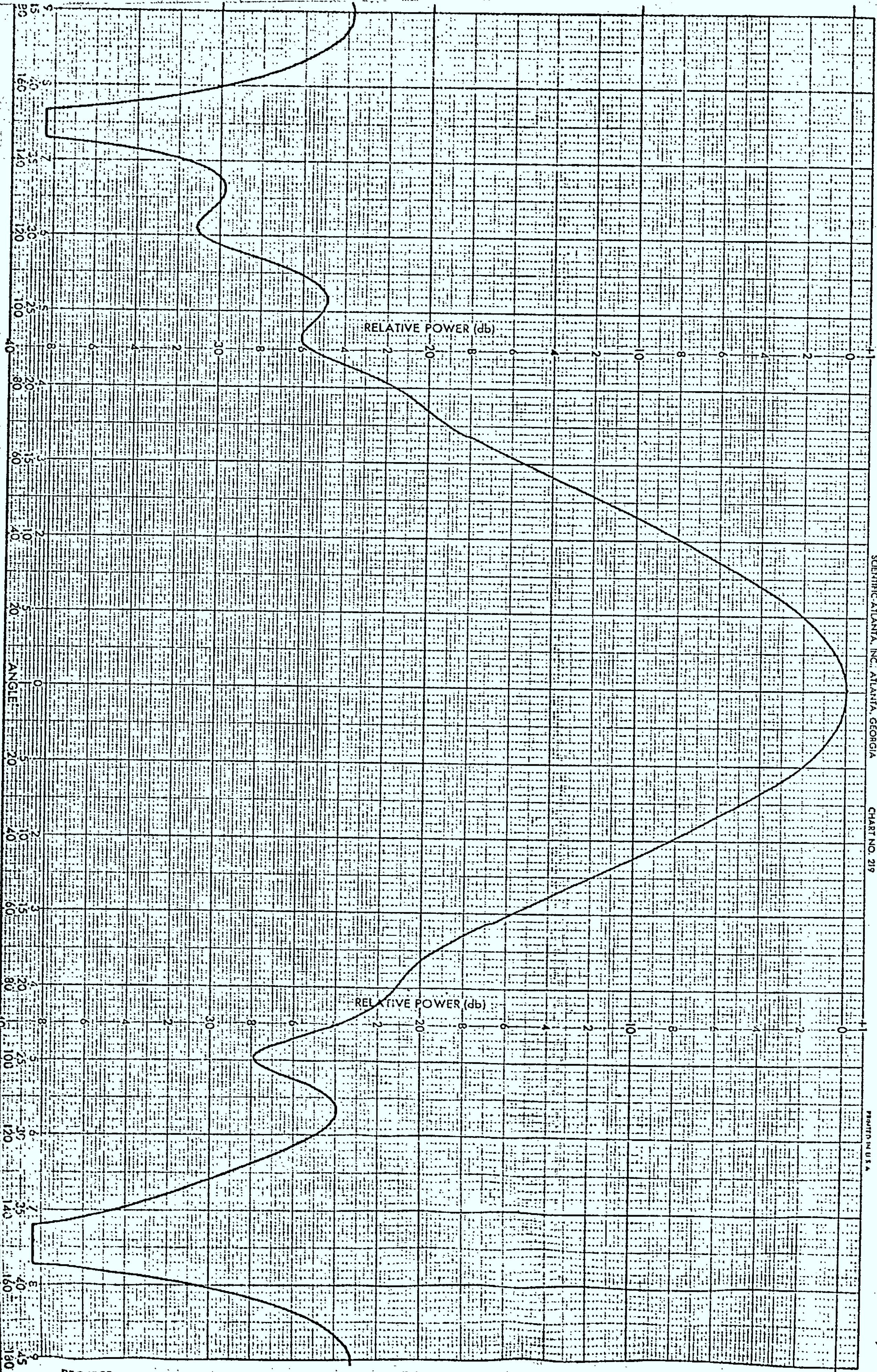
PROJECT MSAT
REMARKS 831 MHZ PATTERN TYPE: 1a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

ENGR

FIGURE 14e

DATE DEC 29/81

169962



PROJECT MSAT

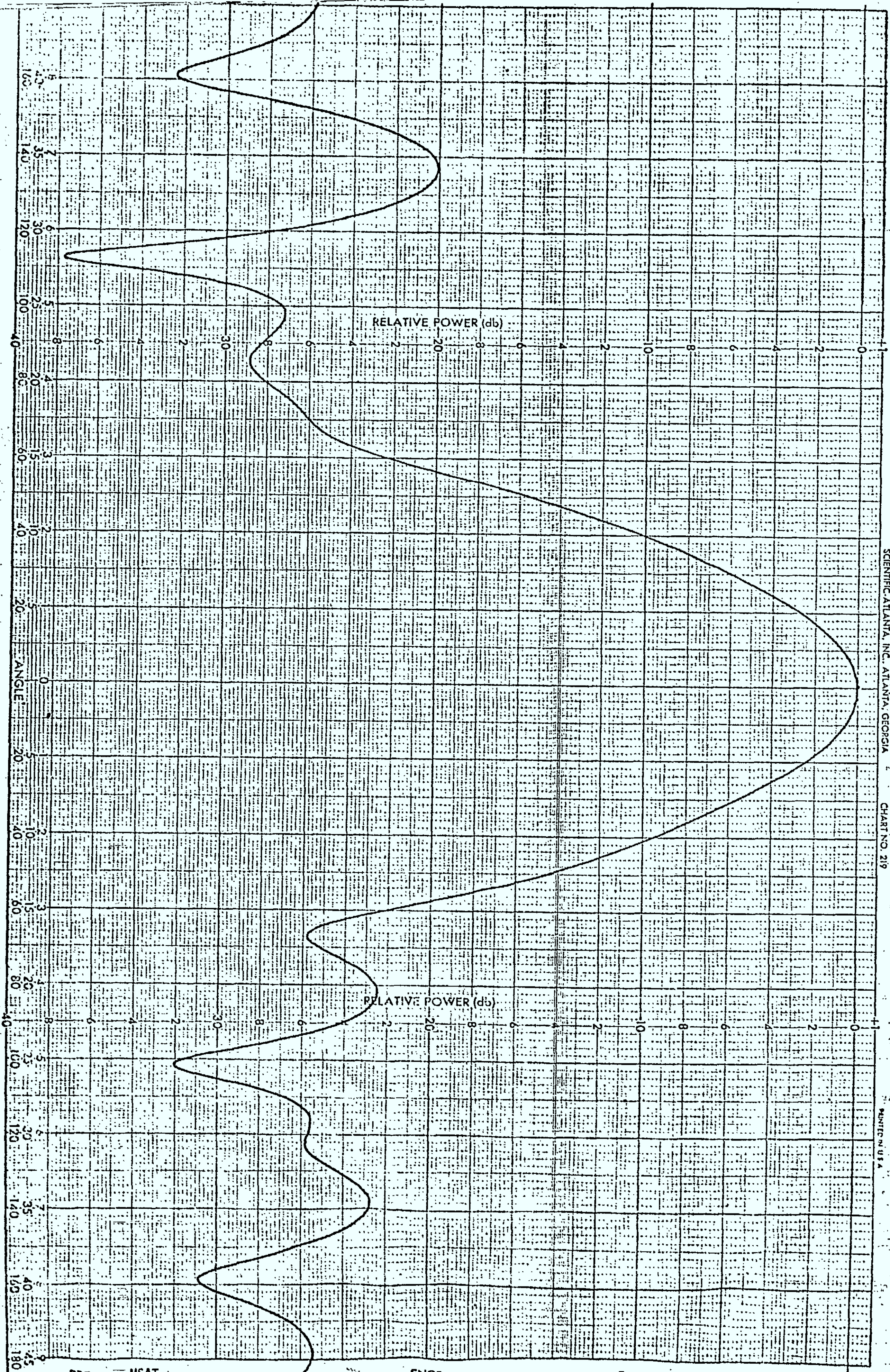
ENGR

DATE DEC 29/81

REMARKS 831 MHZ PATTERN TYPE: 2a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

FIGURE 14f

169909

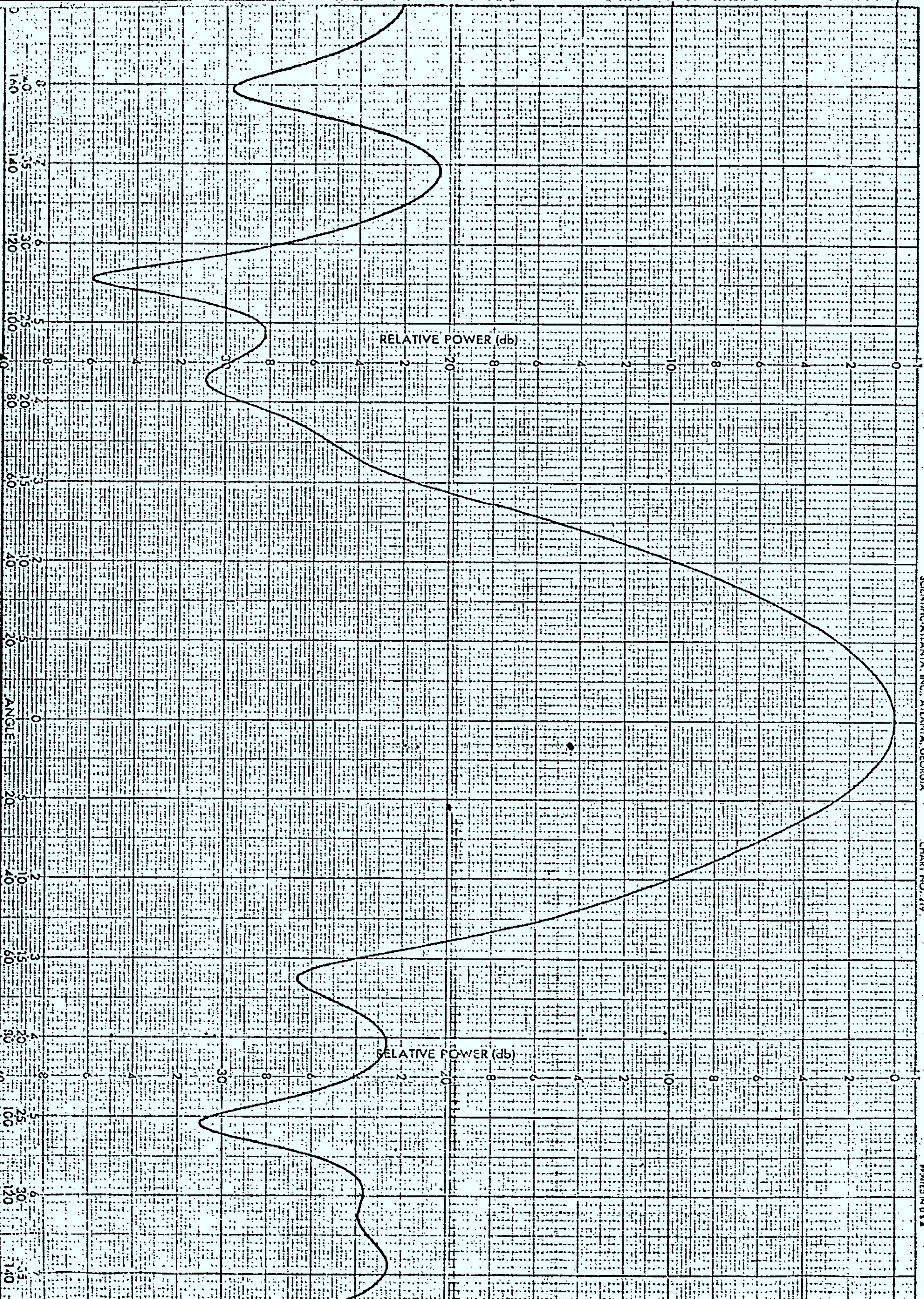


PROJECT MSAT
ENGR
DATE
REMARKS 831 MHZ PATTERN TYPE: 5a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

FIGURE 14a

DEC 29/81

169965



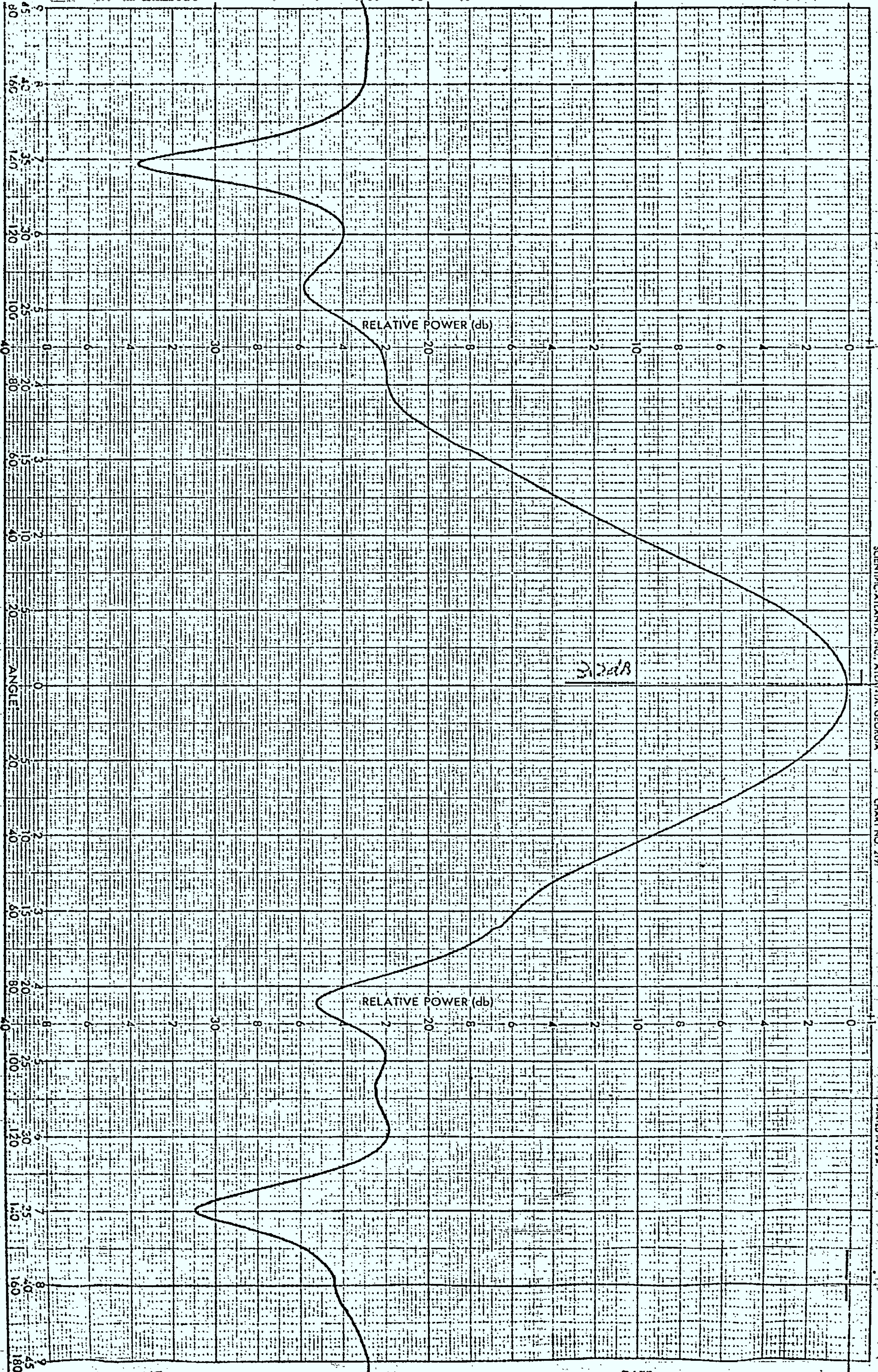
PROJECT MSAT
REMARKS 831 MHZ PATTERN TYPE : 6a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

ENGR

FIGURE 14h

DATE
DEC 29/81

169911

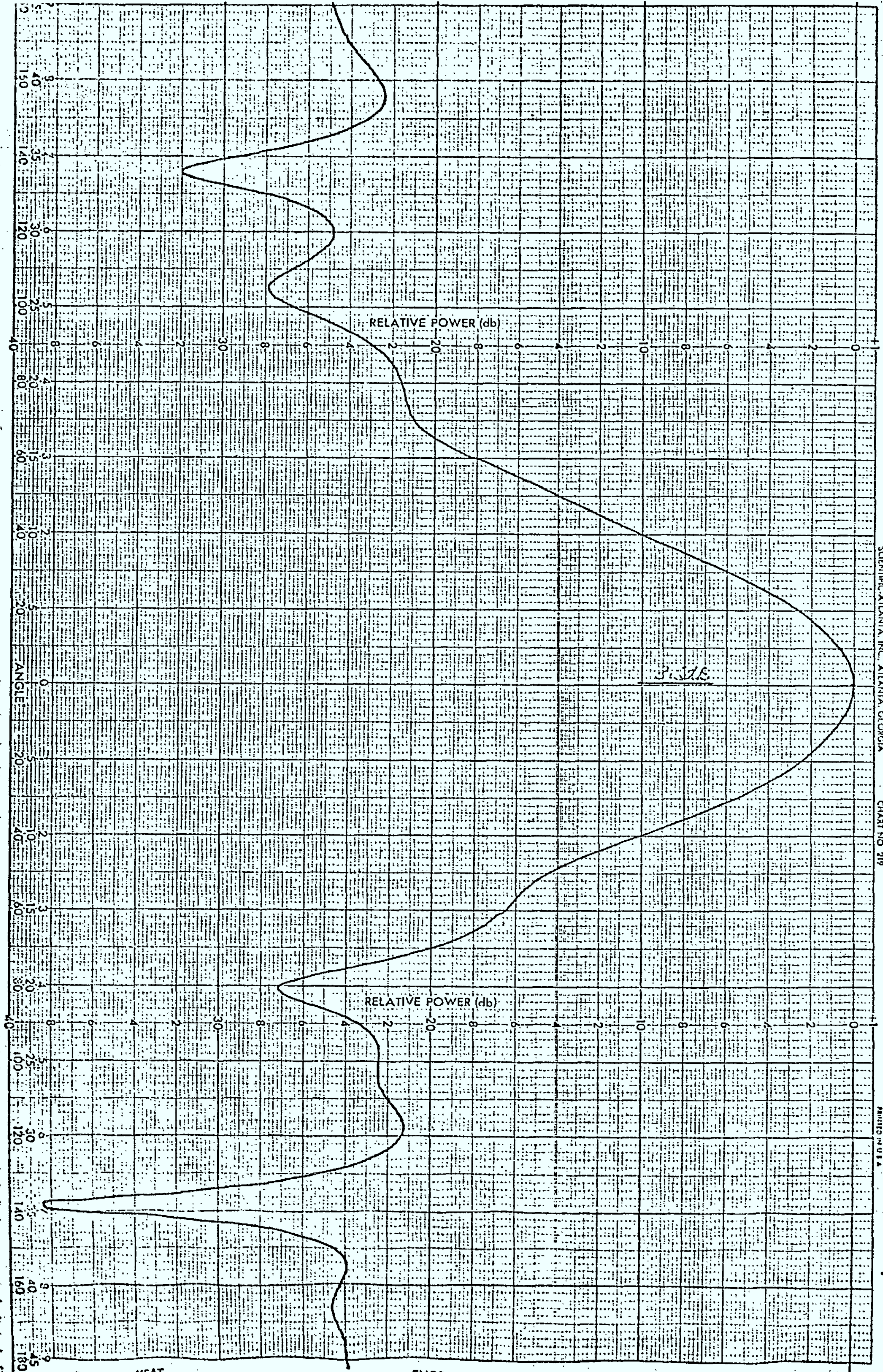


PROJECT MSAT
REMARKS: 866 MHZ PATTERN TYPE: 1
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

ENGR FIGURE 15a

DATE DEC. 29/81

169961



PROJECT MSAT

ENGR

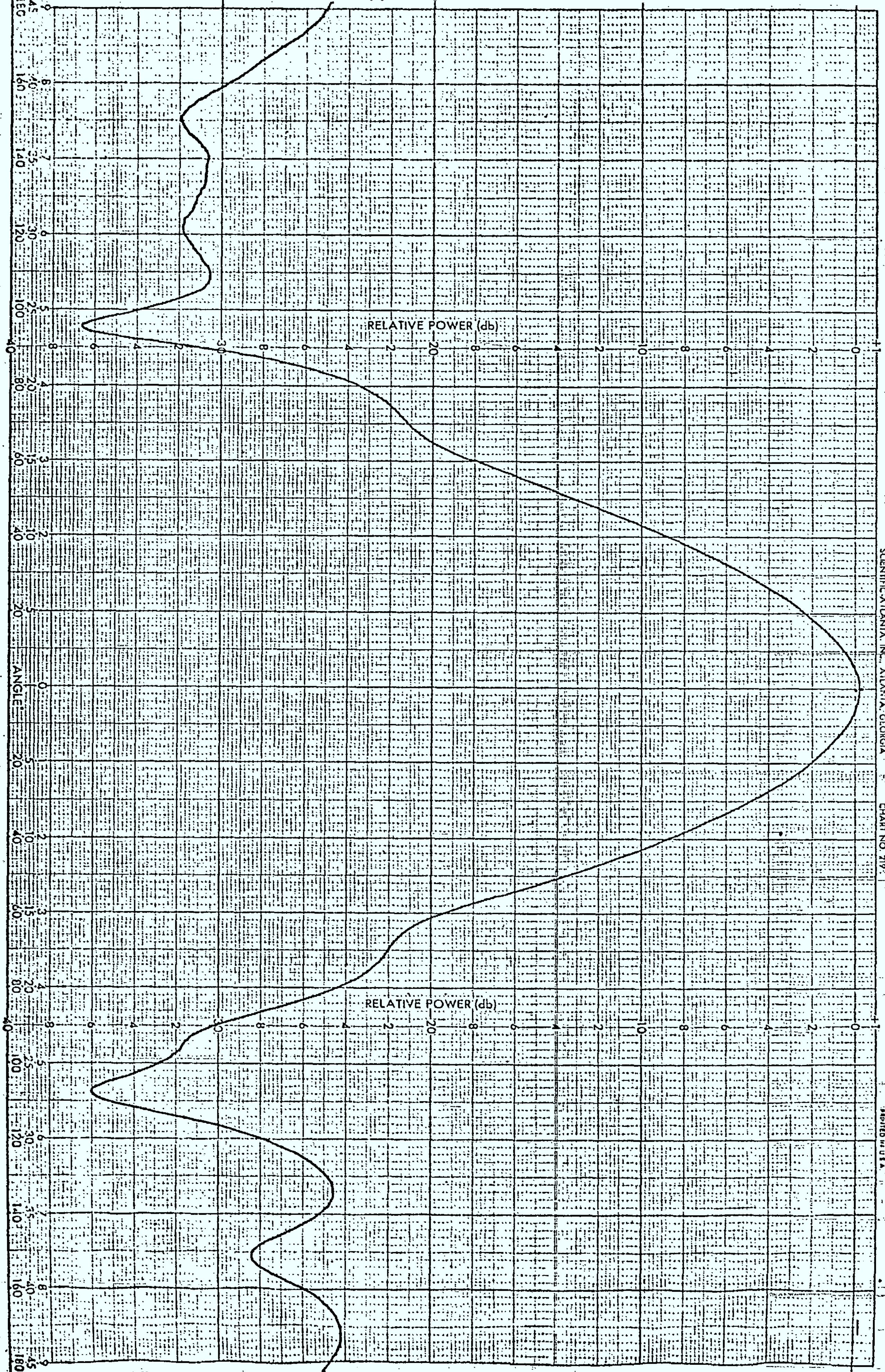
DATE

REMARKS 866 MHZ PATTERN TYPE: 2
WIDTH OF COPPER STRIP: 1/8"
SEPARATION: 1/8"

FIGURE 15b

DEC 29/81

169908

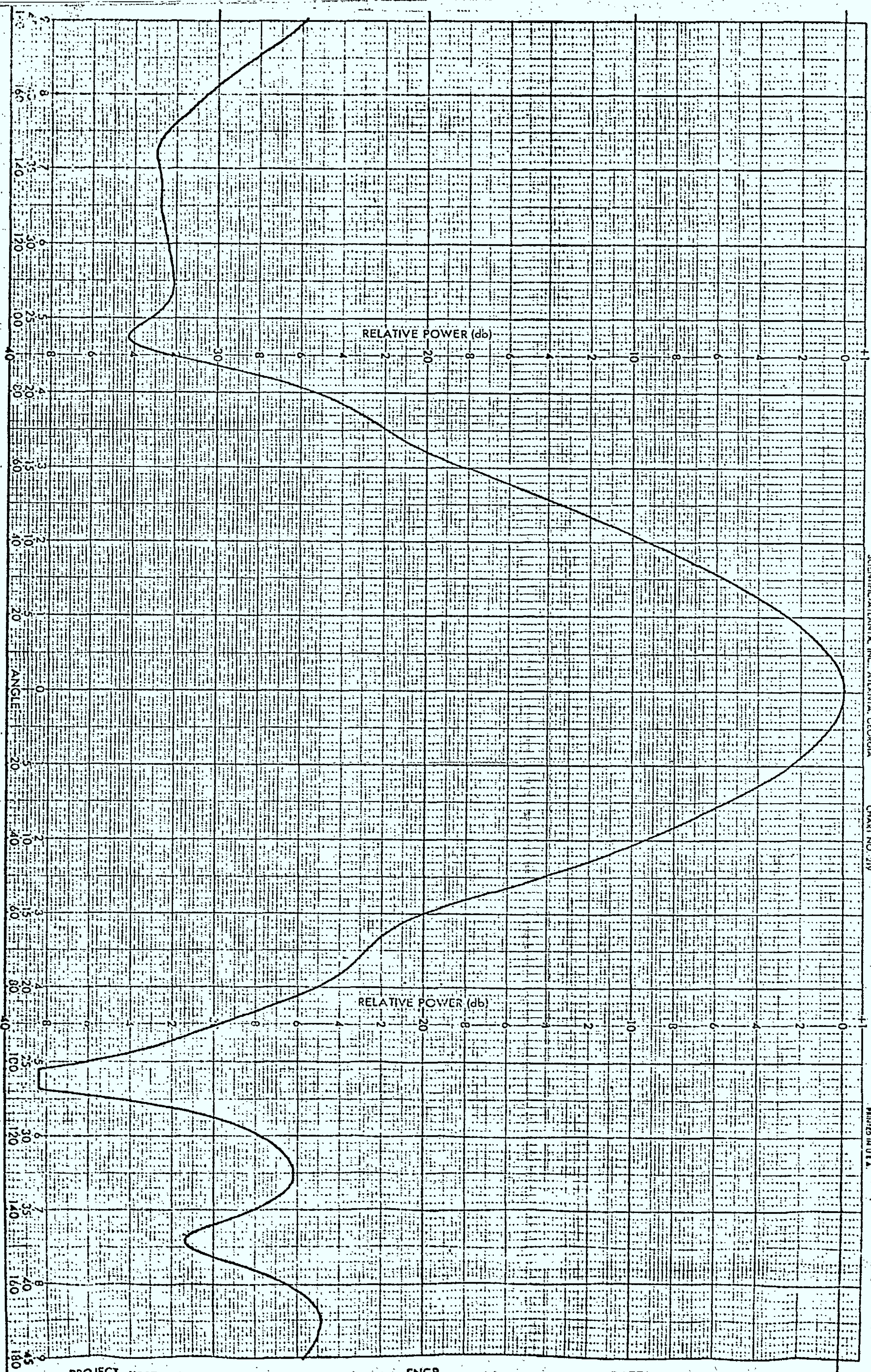


PROJECT MSAT
ENGR
DATE DEC 29/81

REMARKS 866 MHZ PATTERN TYPE: 5
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8

FIGURE 15C

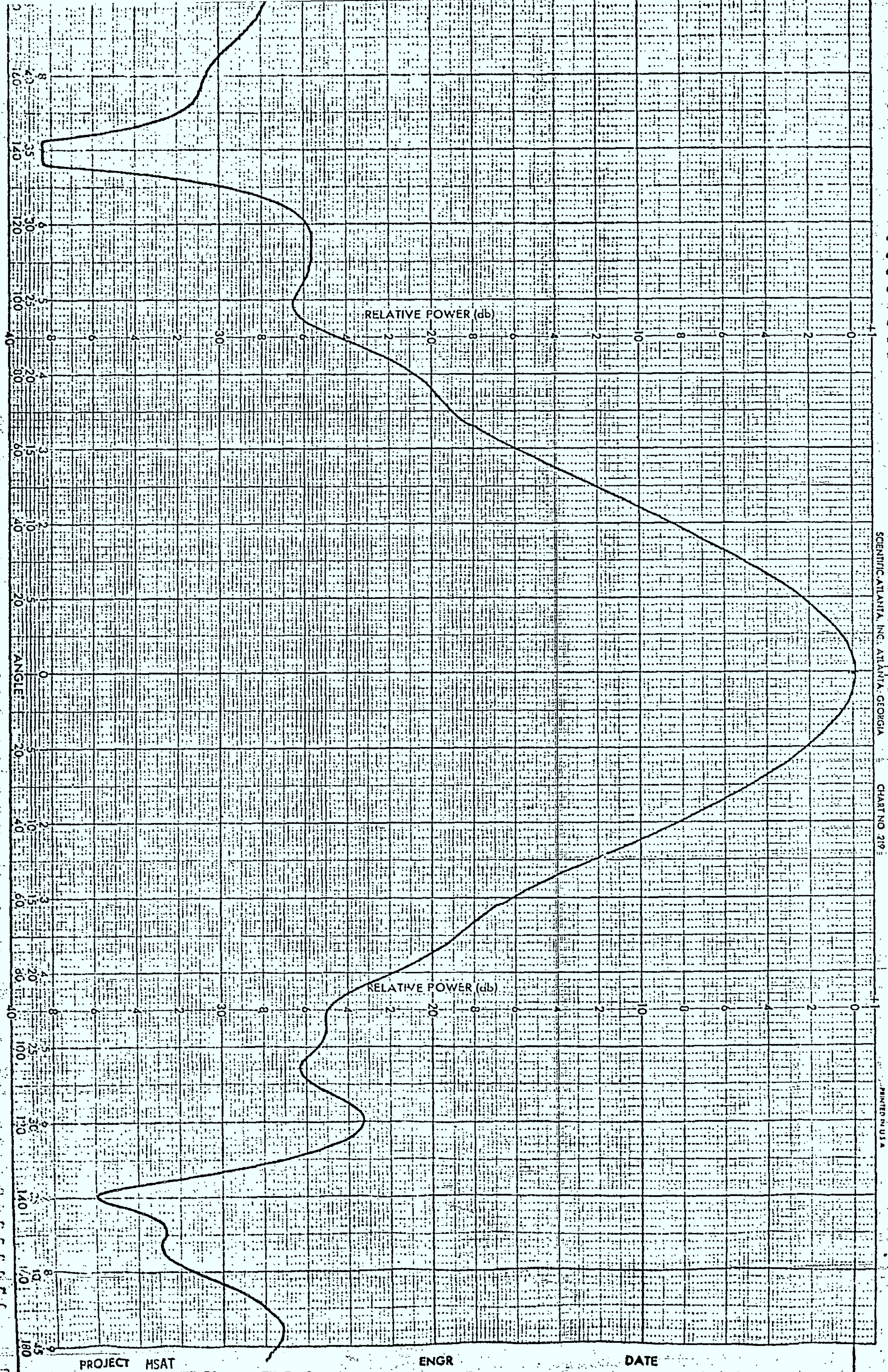
169959



PROJECT MSAT
ENGR
DATE DEC 29/81
REMARKS 866 MHZ PATTERN TYPE: 6
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8

FIGURE 15d

169906



PROJECT MSAT

ENGR

DATE DEC 29/81

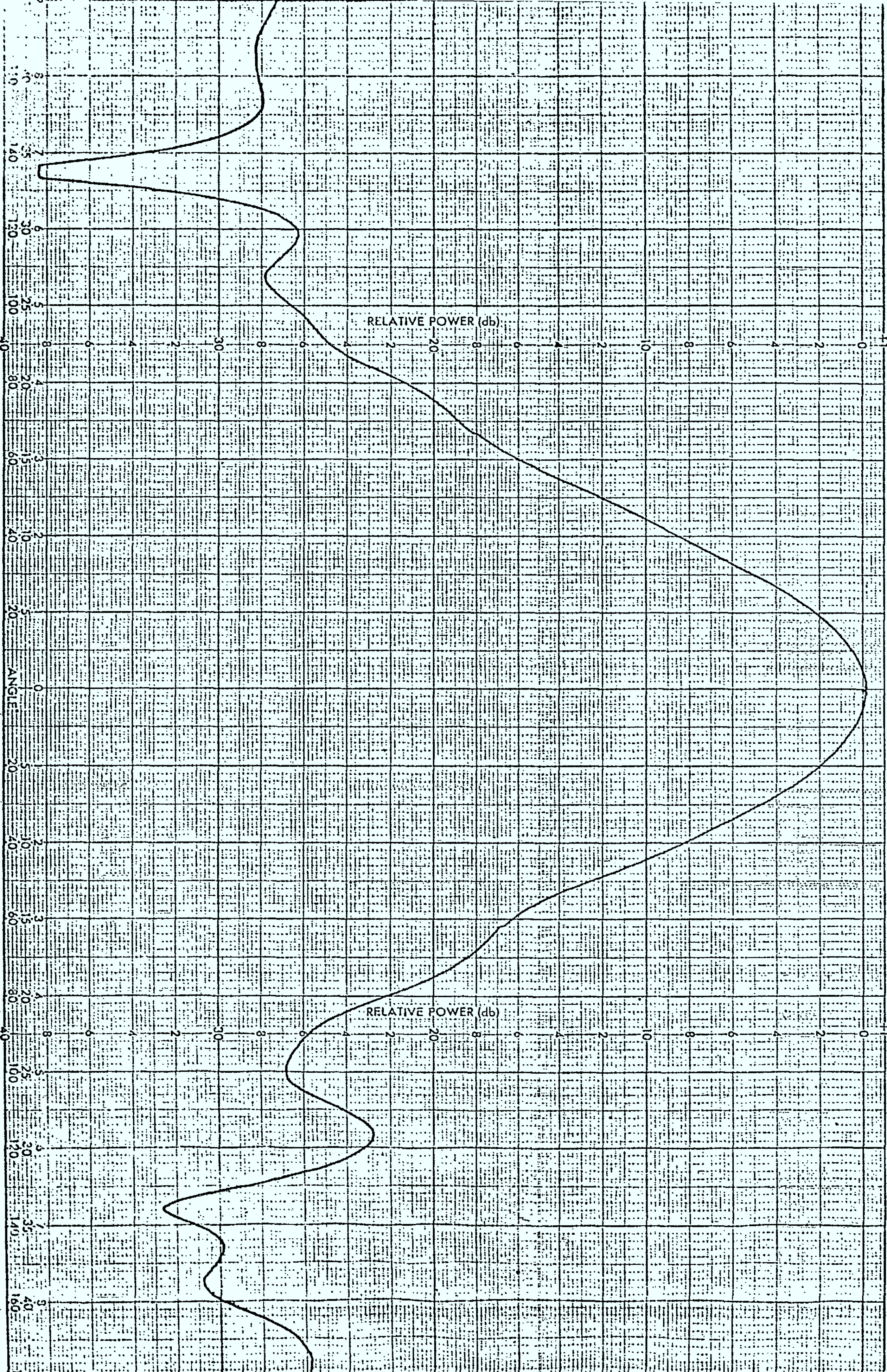
REMARKS 866 MHZ PATTERN TYPE: 1a

WIDTH OF COPPER STRIP: 1/8"

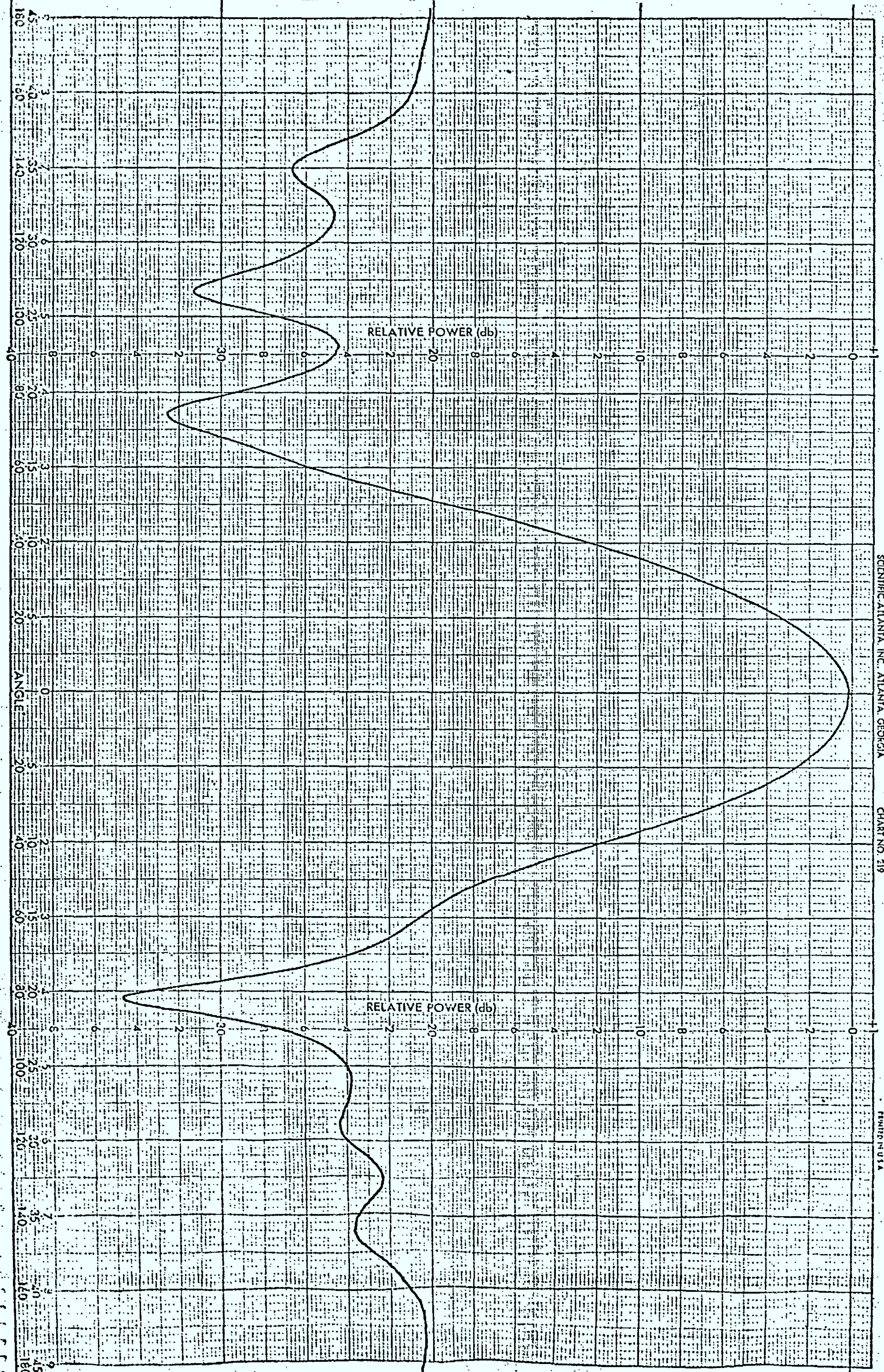
SEPARATION 1/8

FIGURE 15e

169958



PROJECT MSAT
ENGR
DATE
REMARKS 866 MHZ PATTERN TYPE: 2a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8
FIGURE 15f
DEC 29/81
169905

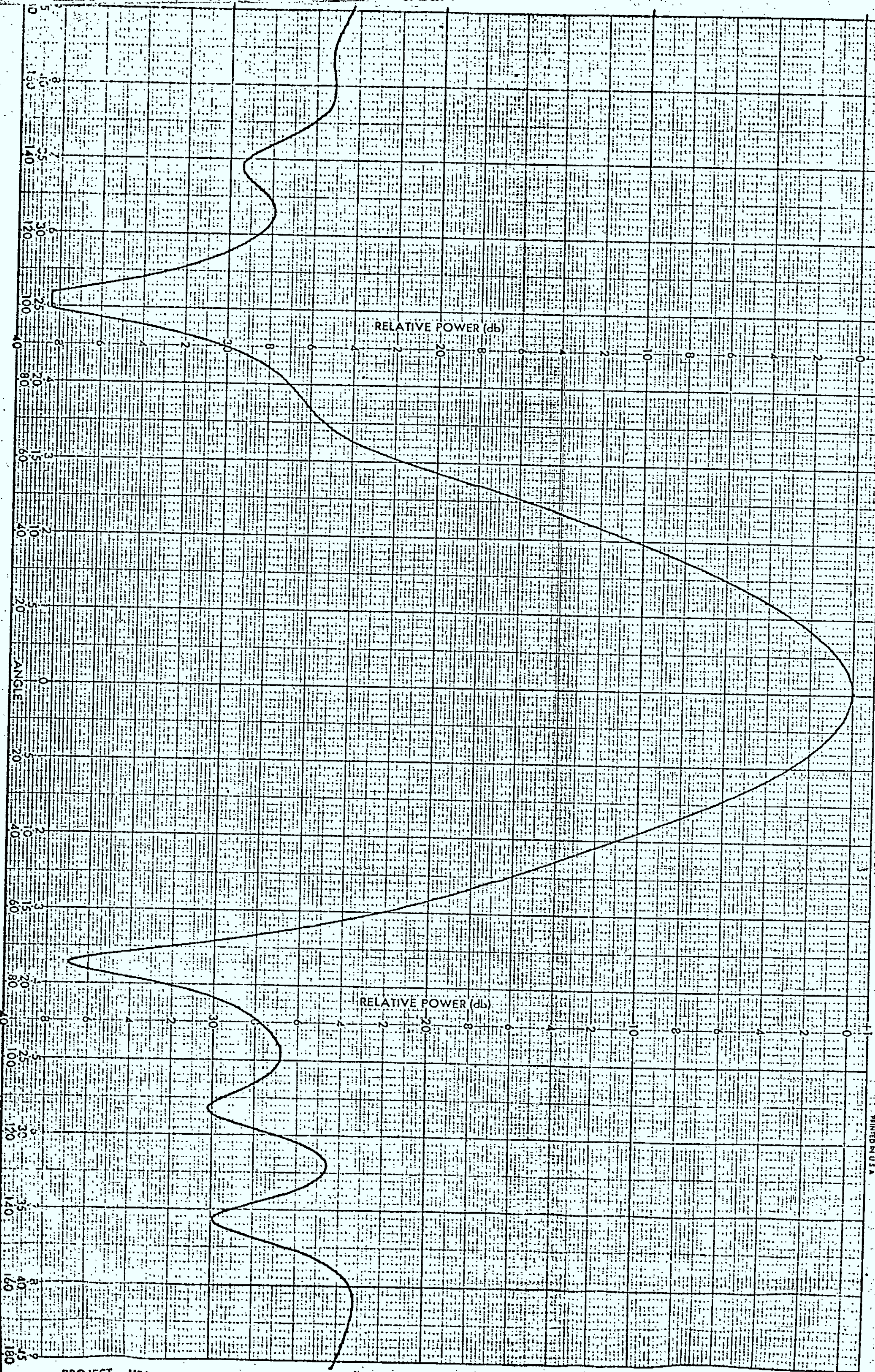


PROJECT MSAT
ENGR
DATE
REMARKS 866 MHZ PATTERN TYPE: 5a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8"

FIGURE 15g

DEC 29/81

169960



PROJECT MSAT

ENGR

DATE

REMARKS 866 MHZ PATTERNTYPE: 6a

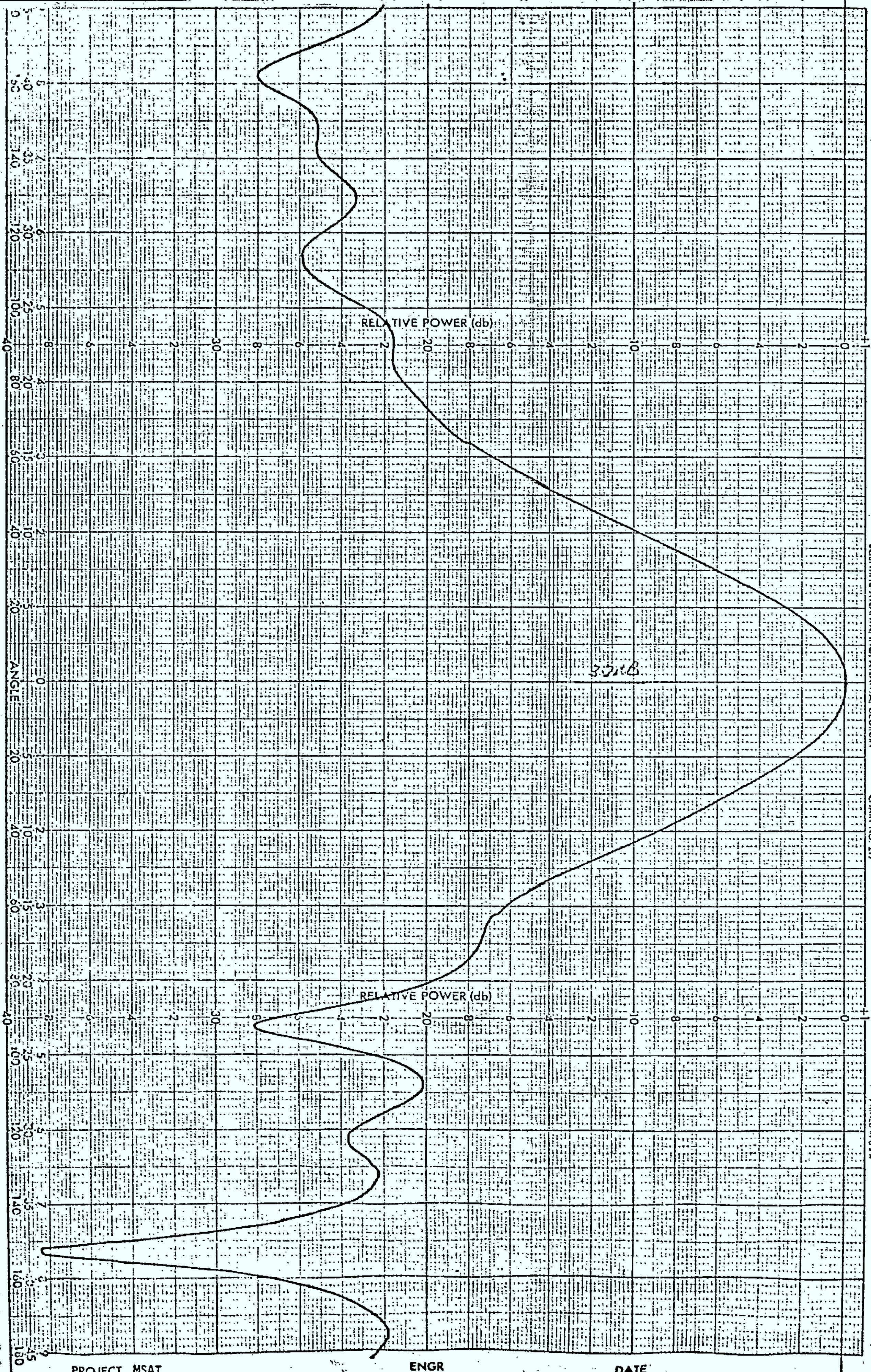
WIDTH OF COPPER STRIP: 1/8"

SEPARATION 1/8

FIGURE 15h

DEC 29/81

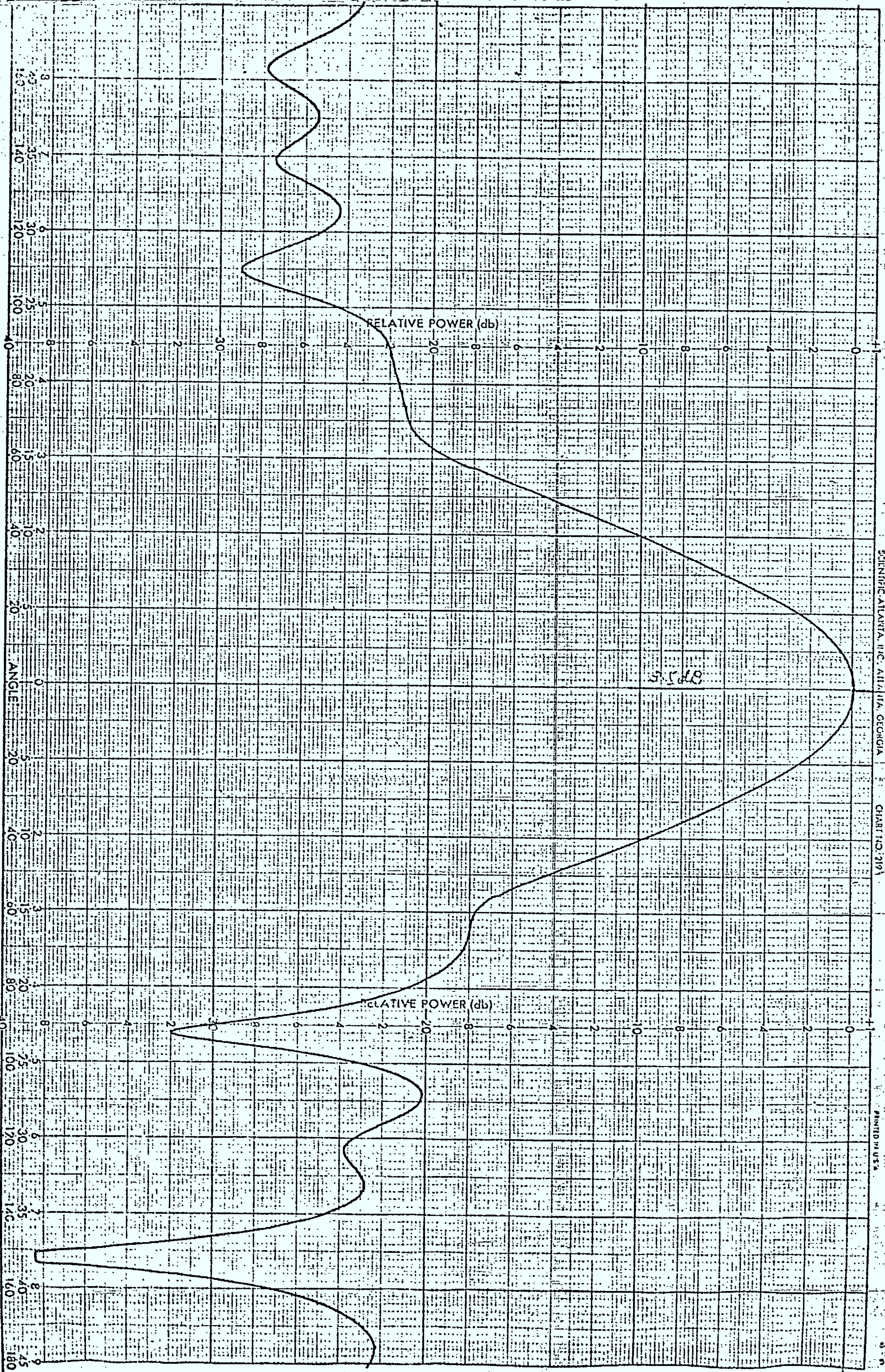
169907



PROJECT MSAT　　ENGR　　DATE

REMARKS- 876 MHZ PATTERN TYPE: 1
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8"

FIGURE 16a　　DEC 29/81　　169957



PROJECT MSAT

ENGR

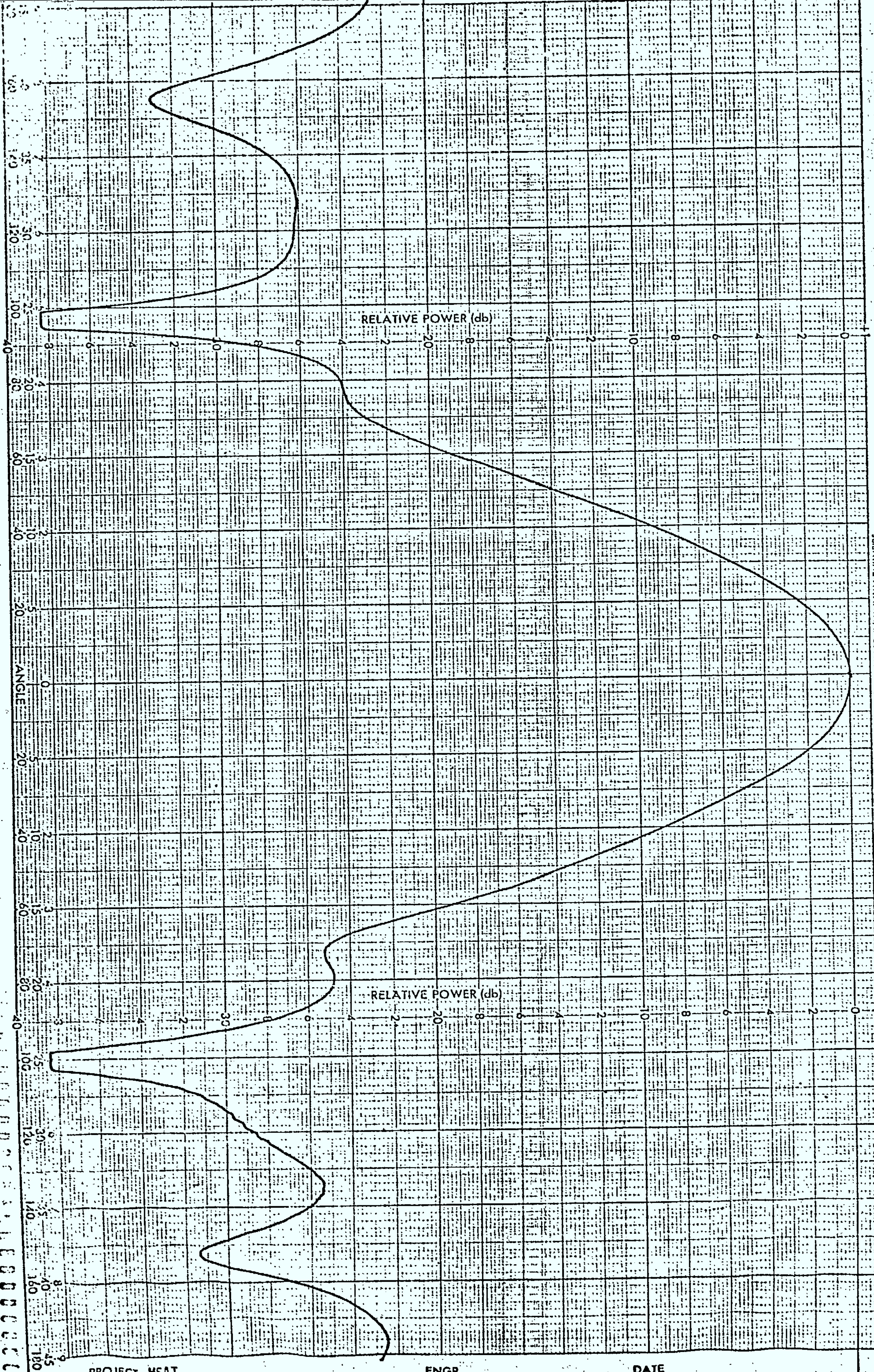
DATE

REMARKS 876 MHZ PATTERN TYP.: 2
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8

FIGURE 16b

DEC 29/81

169004

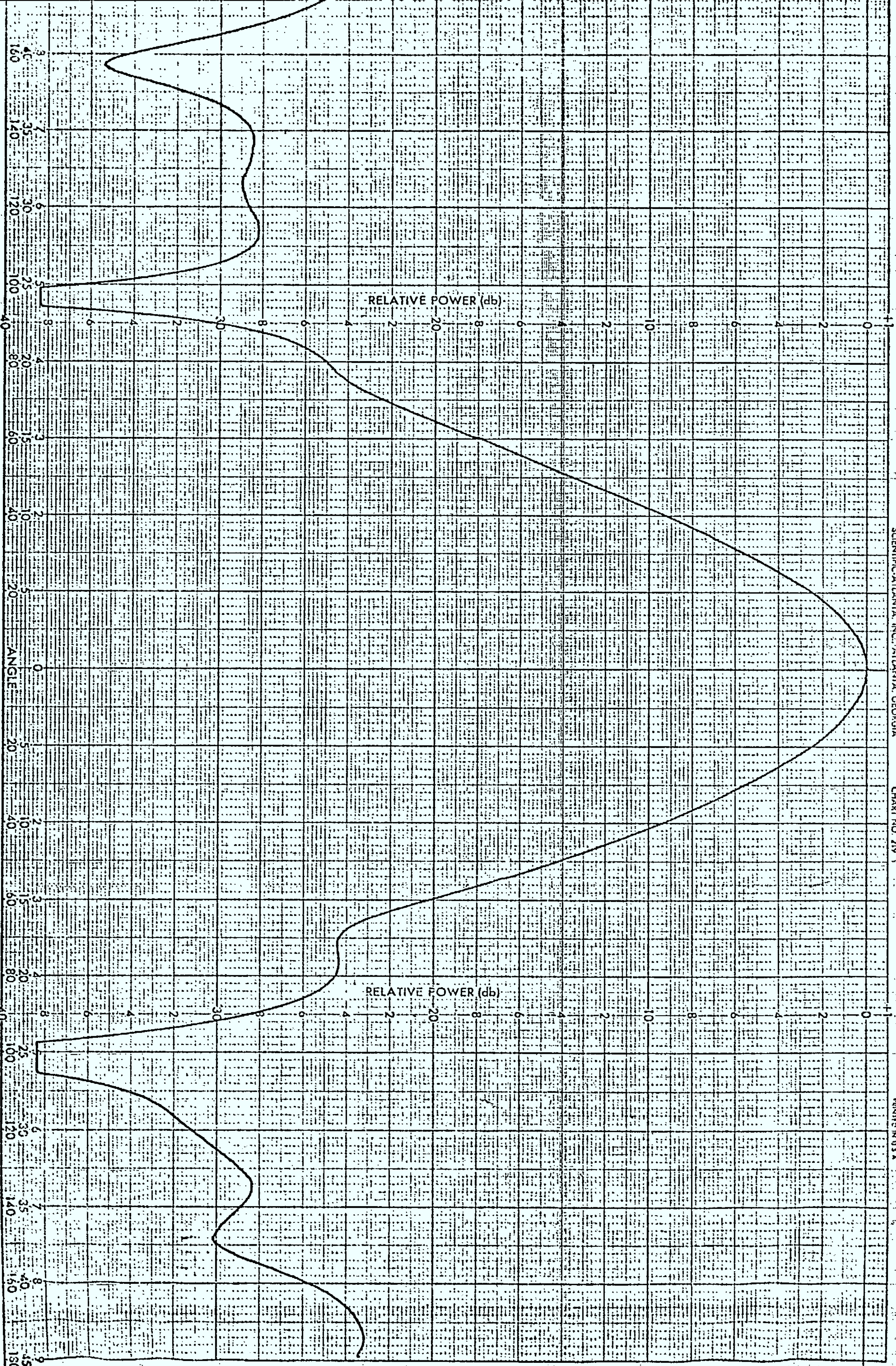


PROJECT MSAT
ENGR
DATE
REMARKS 876 MHZ PATTERN TYPE: 5
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8"

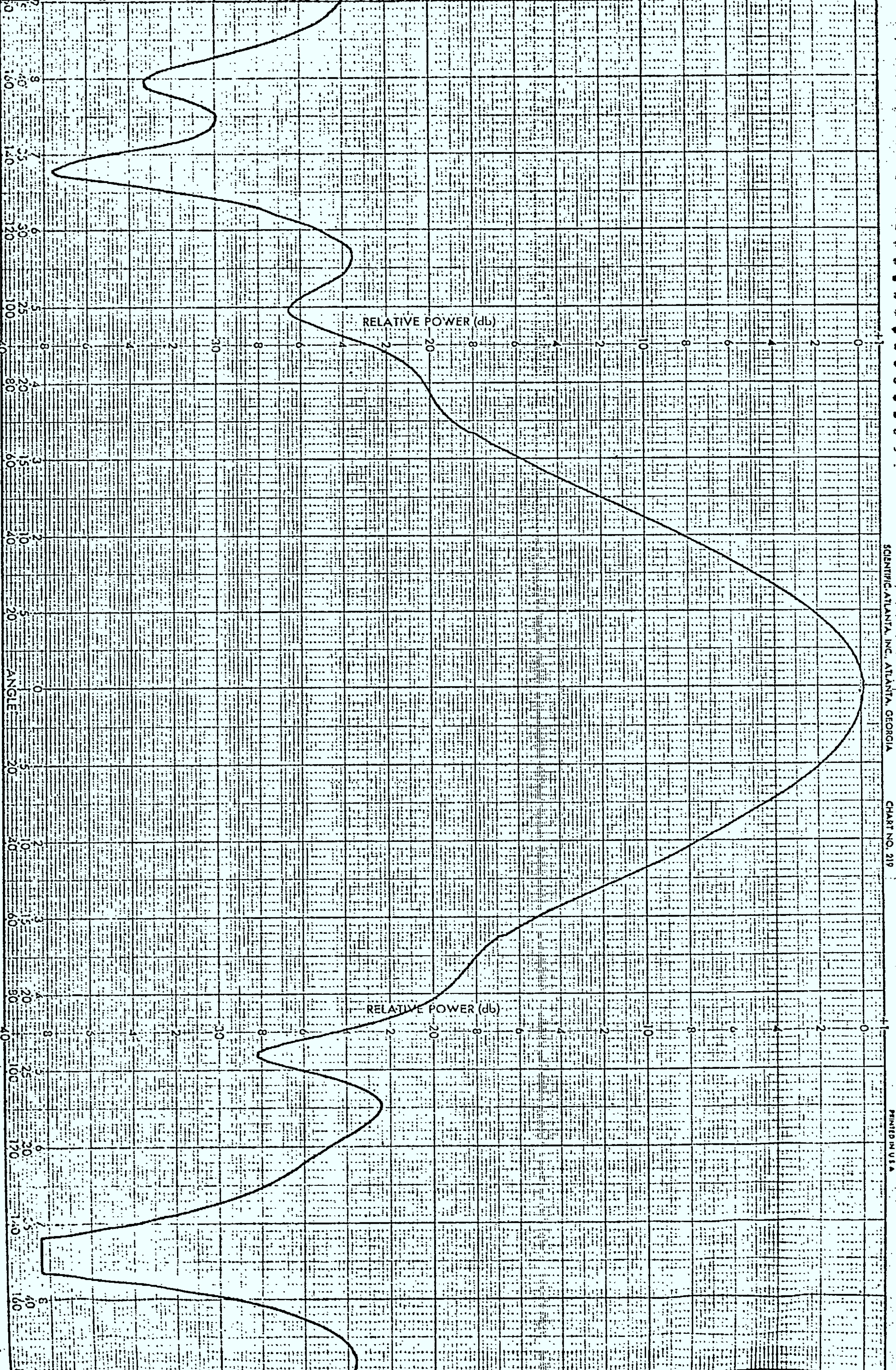
FIGURE 16c

DEC 29/81

169955



PROJECT MSAT
ENGR
DATE
REMARKS 876 MHZ PATTERN TYPE: 6
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8"
FIGURE 16d
DEC 29/81
169902



PROJECT MSAT

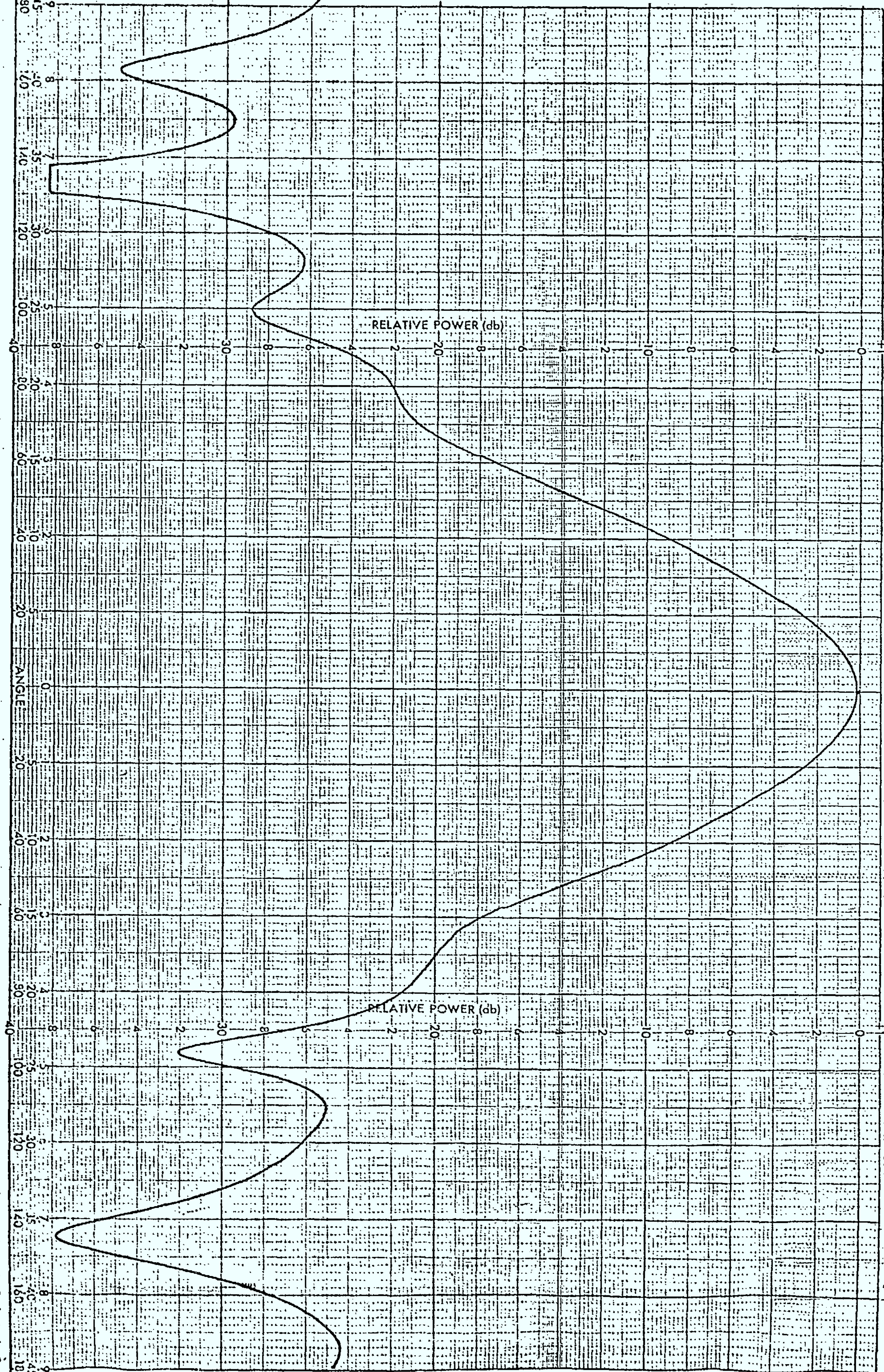
REMARKS 876 MHZ PATTERN TYPE: 1a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8"

ENGR

FIGURE 16e

DATE DEC 29/81

169954



PROJECT MSAT

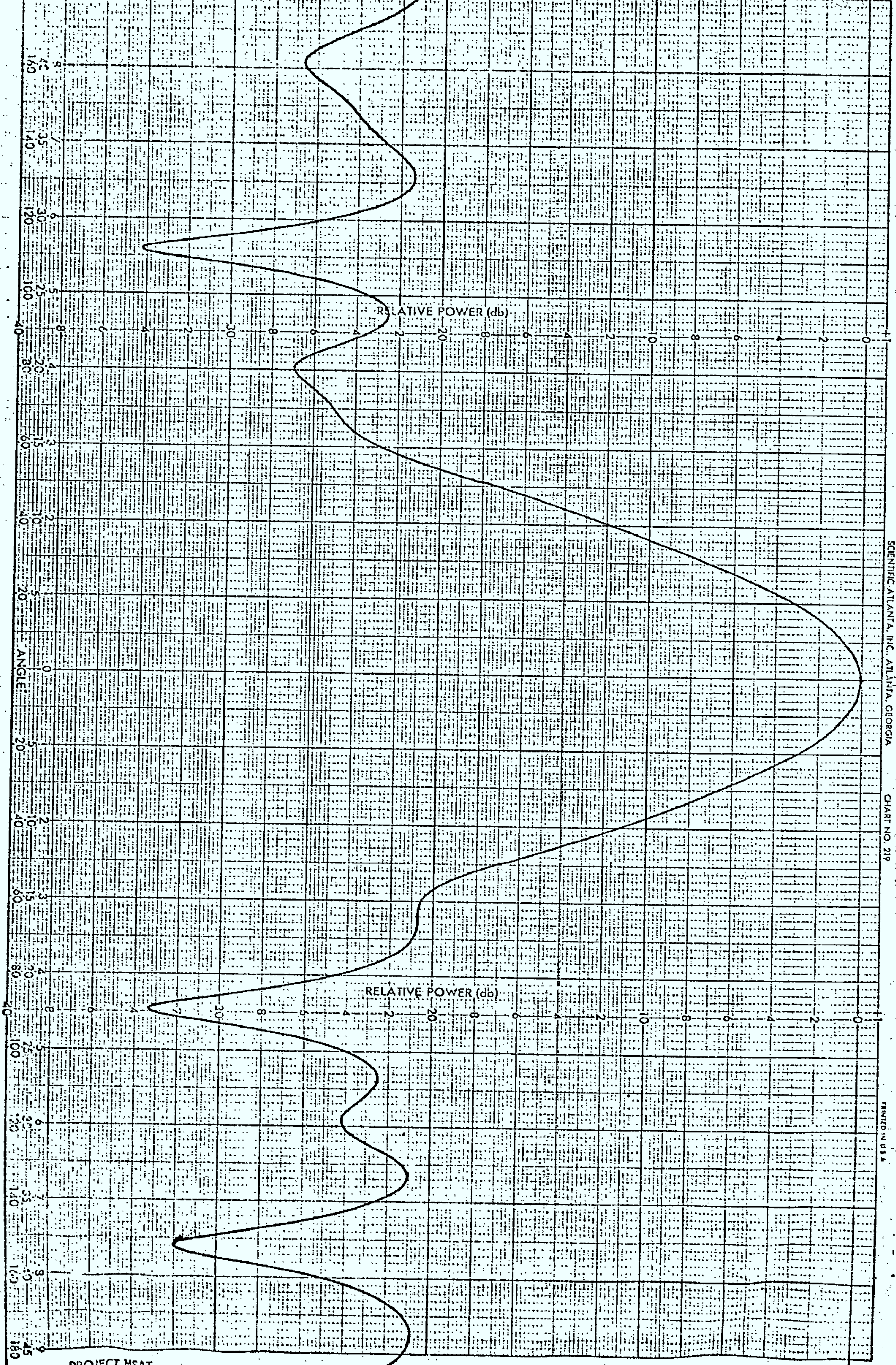
REMARKS 876 MHZ PATTERN TYPE: 2a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8

ENGR

FIGURE 16f

DATE DEC 29/81

169001

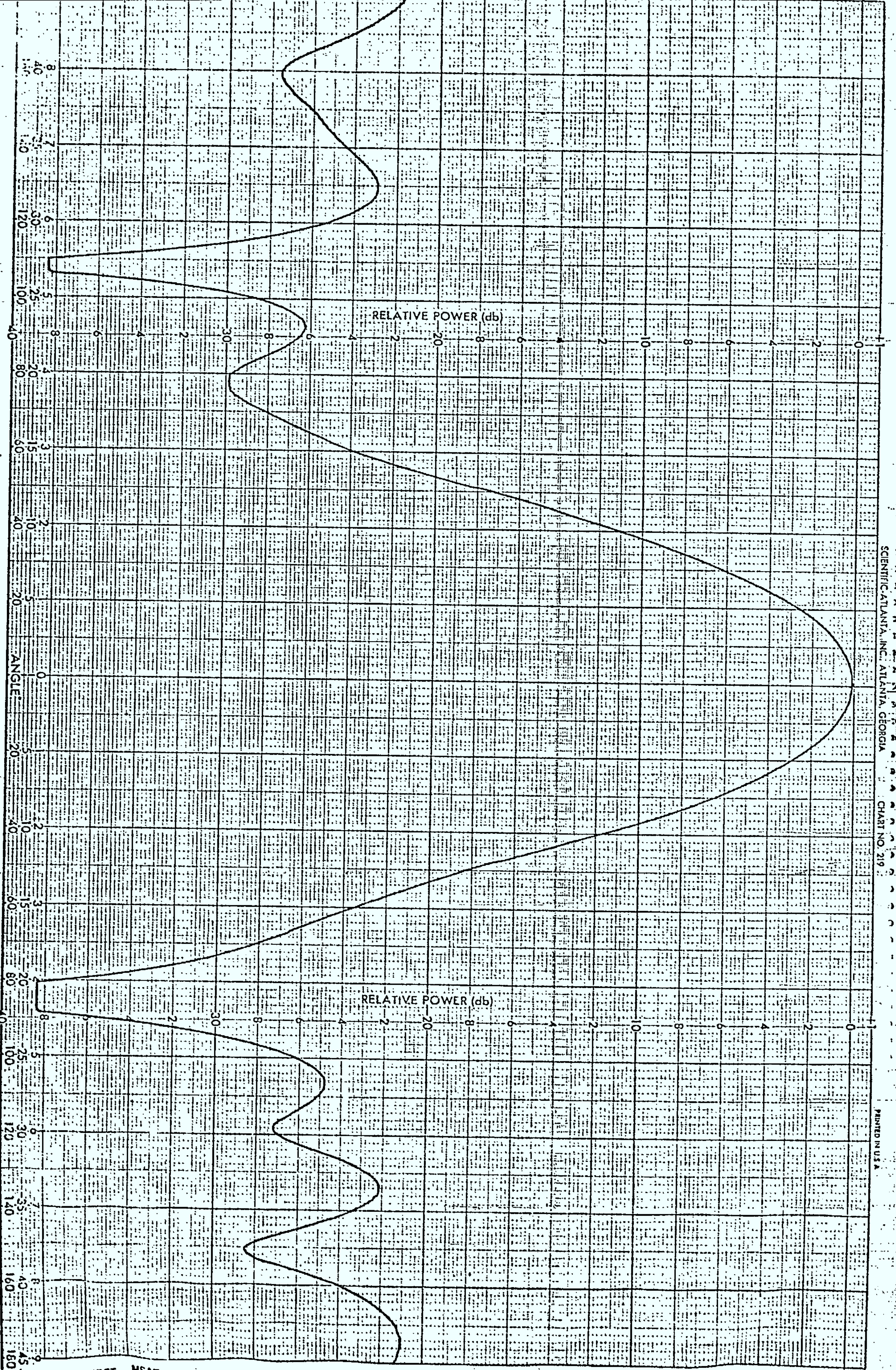


PROJECT MSAT
ENGR
DATE
REMARKS 876 MHZ PATTERN TYPE: 5a
WIDTH OF COPPER STRIP: 1/8"
SEPARATION 1/8"

FIGURE 16g

DEC 29/81

169956



PROJECT MSAT

REMARKS 876 MHZ PATTERN TYPE: 6a

WIDTH OF COPPER STRIP: 1/8"

SEPARATION 1/8"

ENGR

FIGURE 16h

DATE DEC 29/81

169903

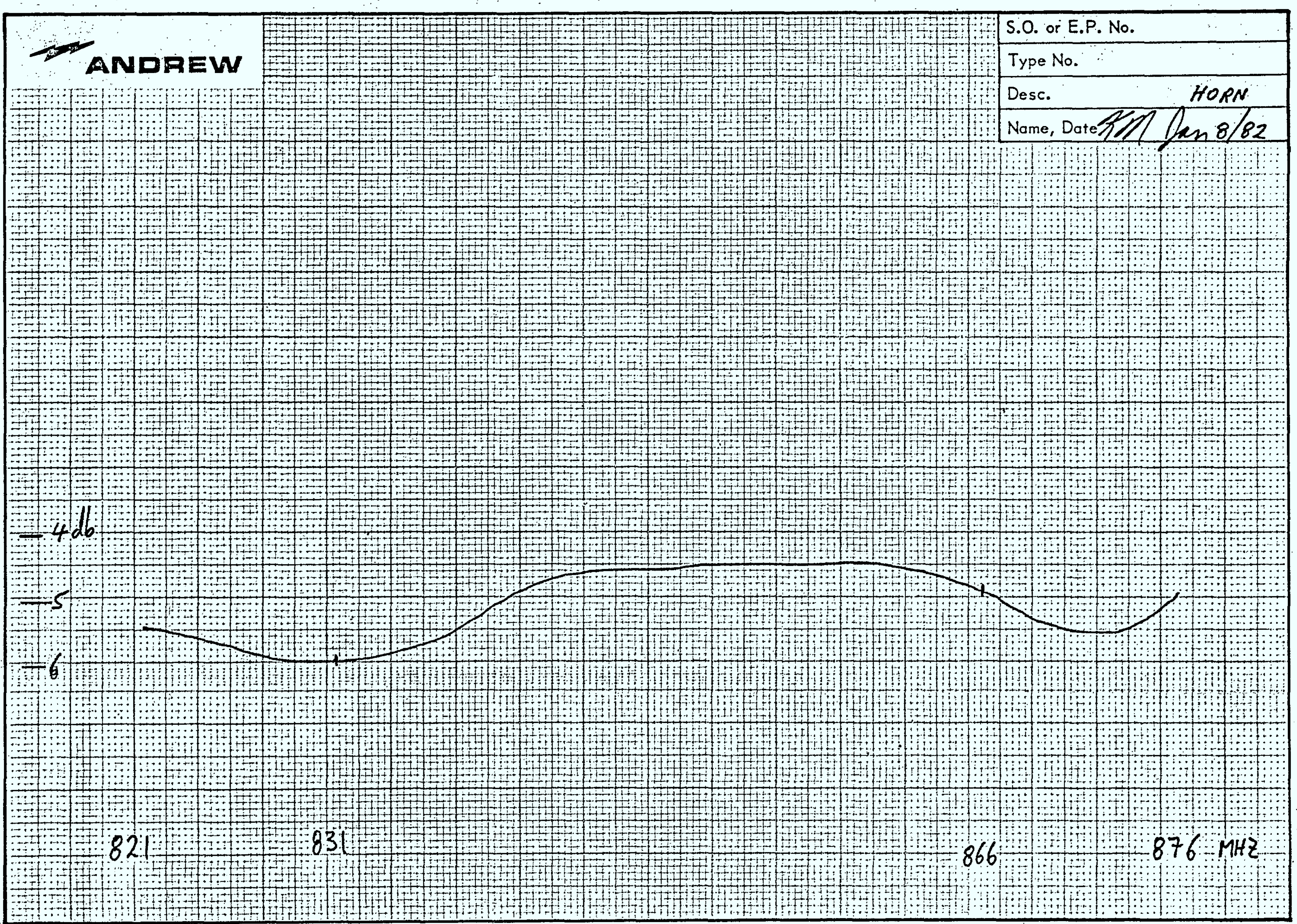


FIGURE 17. VSWR measurement for the "Rugged" type antenna

TITLE DATE

IMPEDANCE COORDINATES—50-OHM CHARACTERISTIC IMPEDANCE

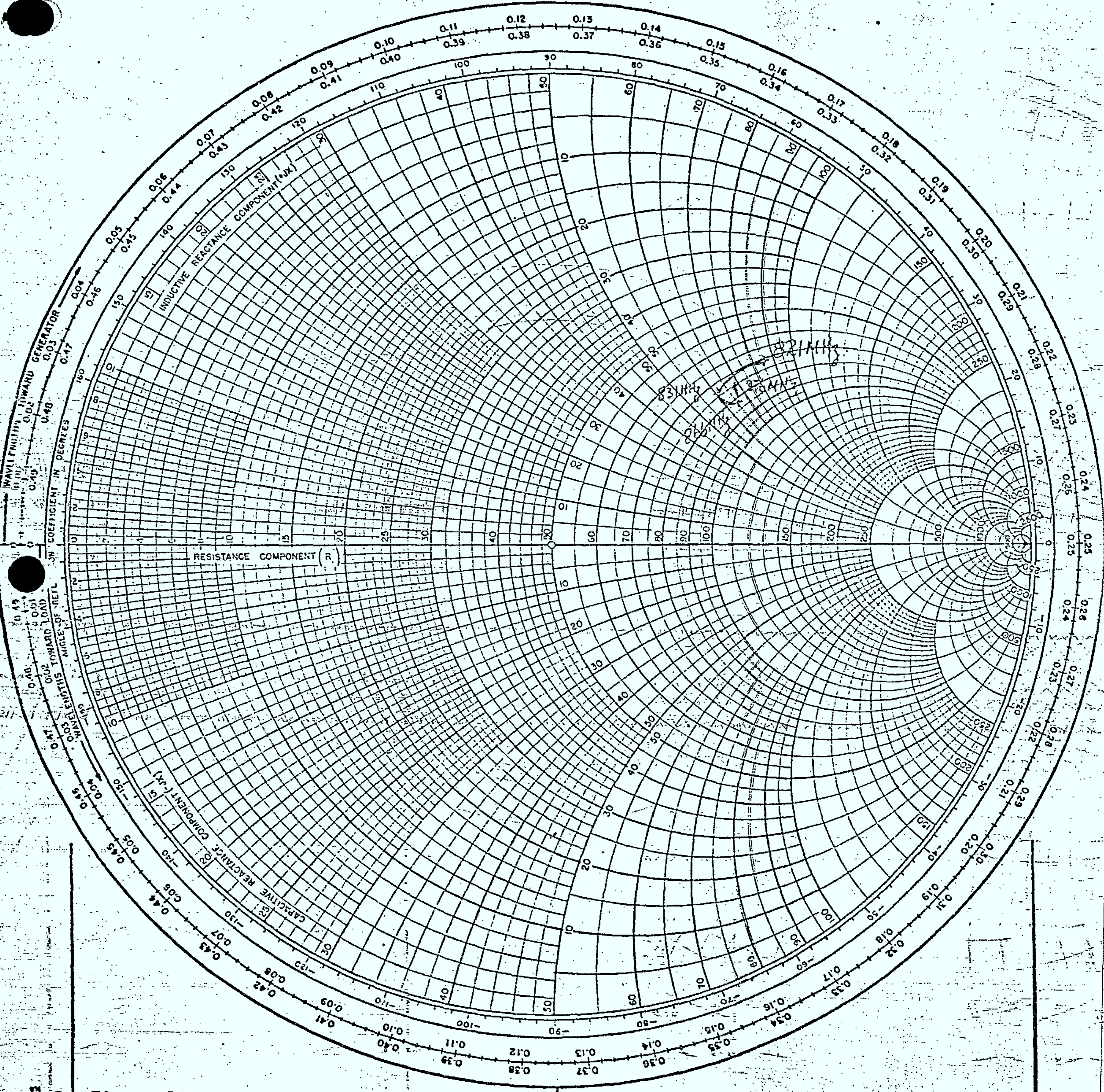
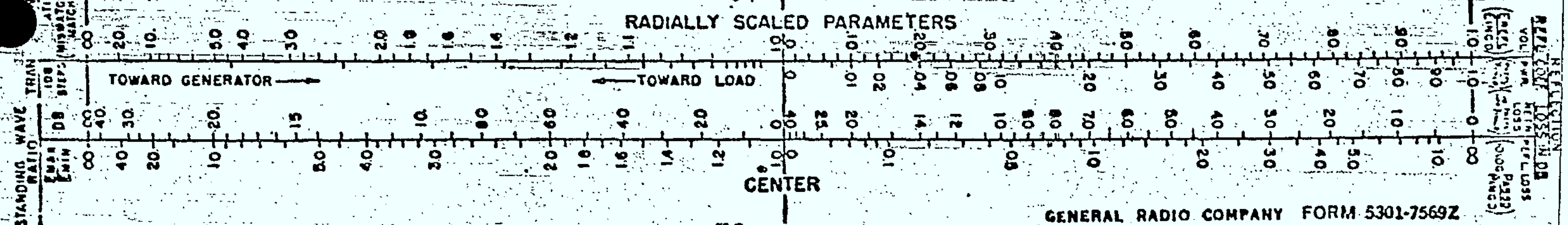


Figure 18 Impedance of the "Rugged " type antenna



GENERAL RADIO COMPANY WEST CONCORD, MASS. FORM 5301-7569Z Printed in USA

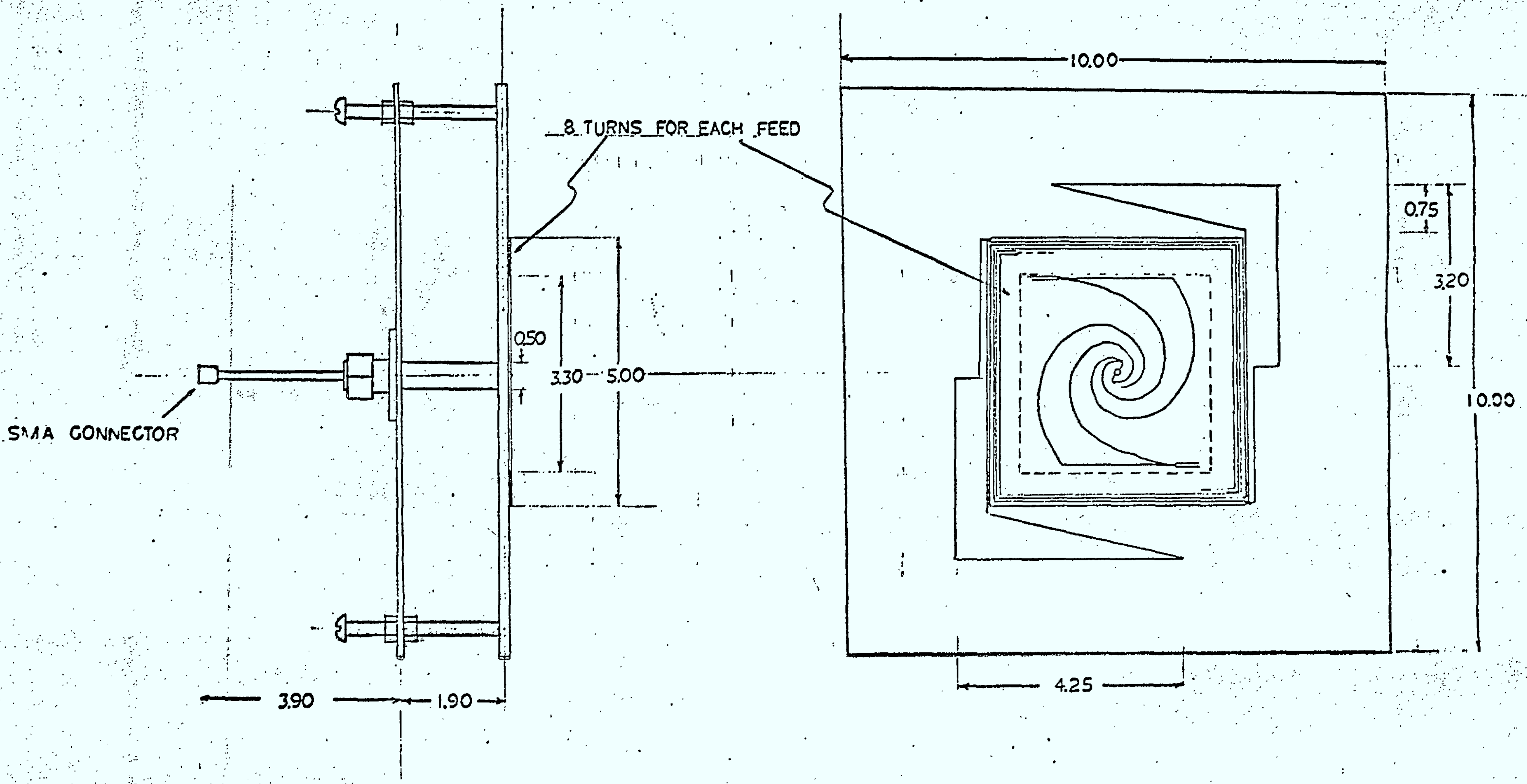


FIGURE 19

INITIAL MODEL OF THE "SUITCASE" TYPE ANTENNA ELEMENT

QTY.	ITEM	PART NO.

3 REMOVE ALL BURRS AND SHARP EDGES.

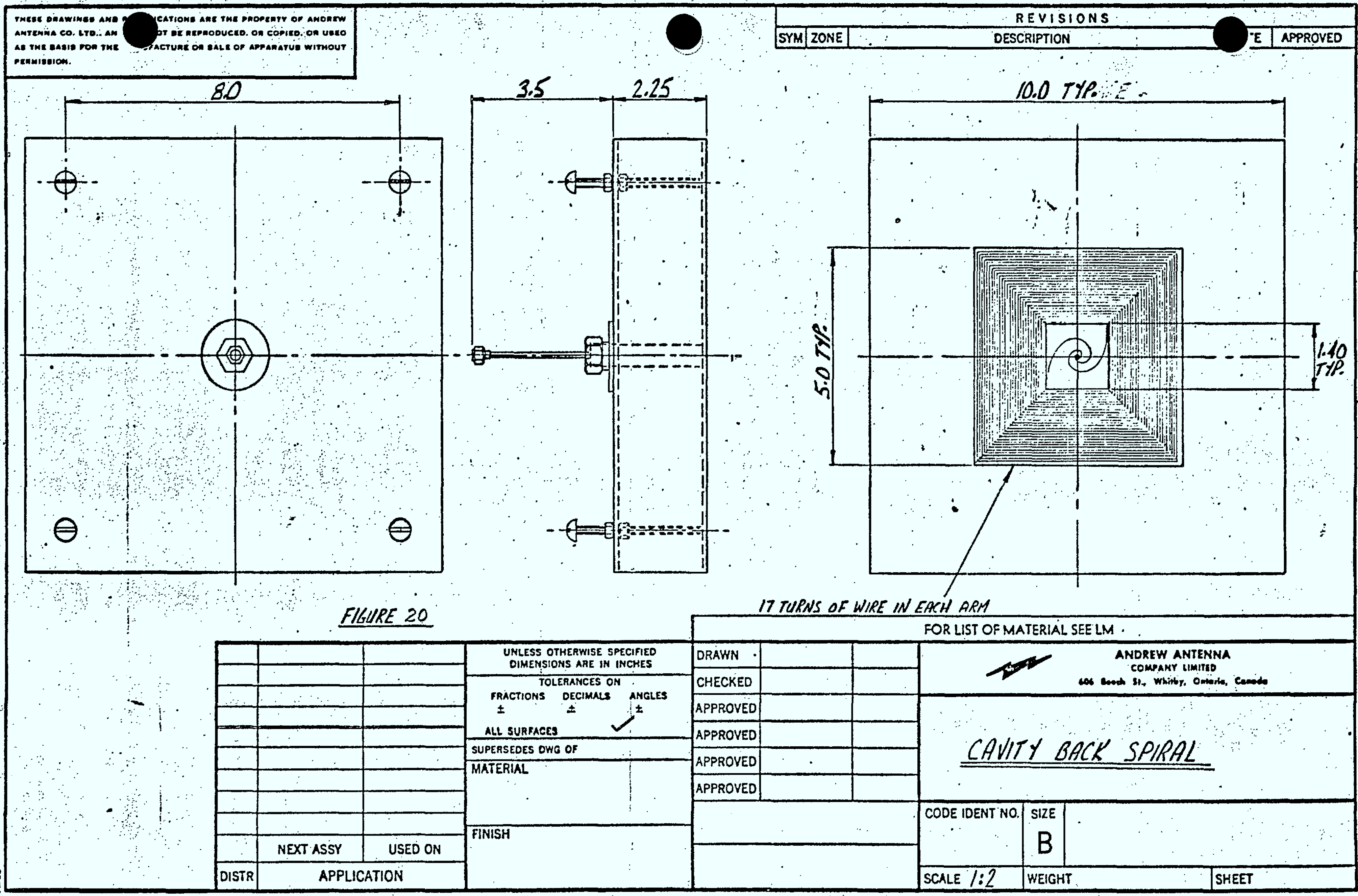
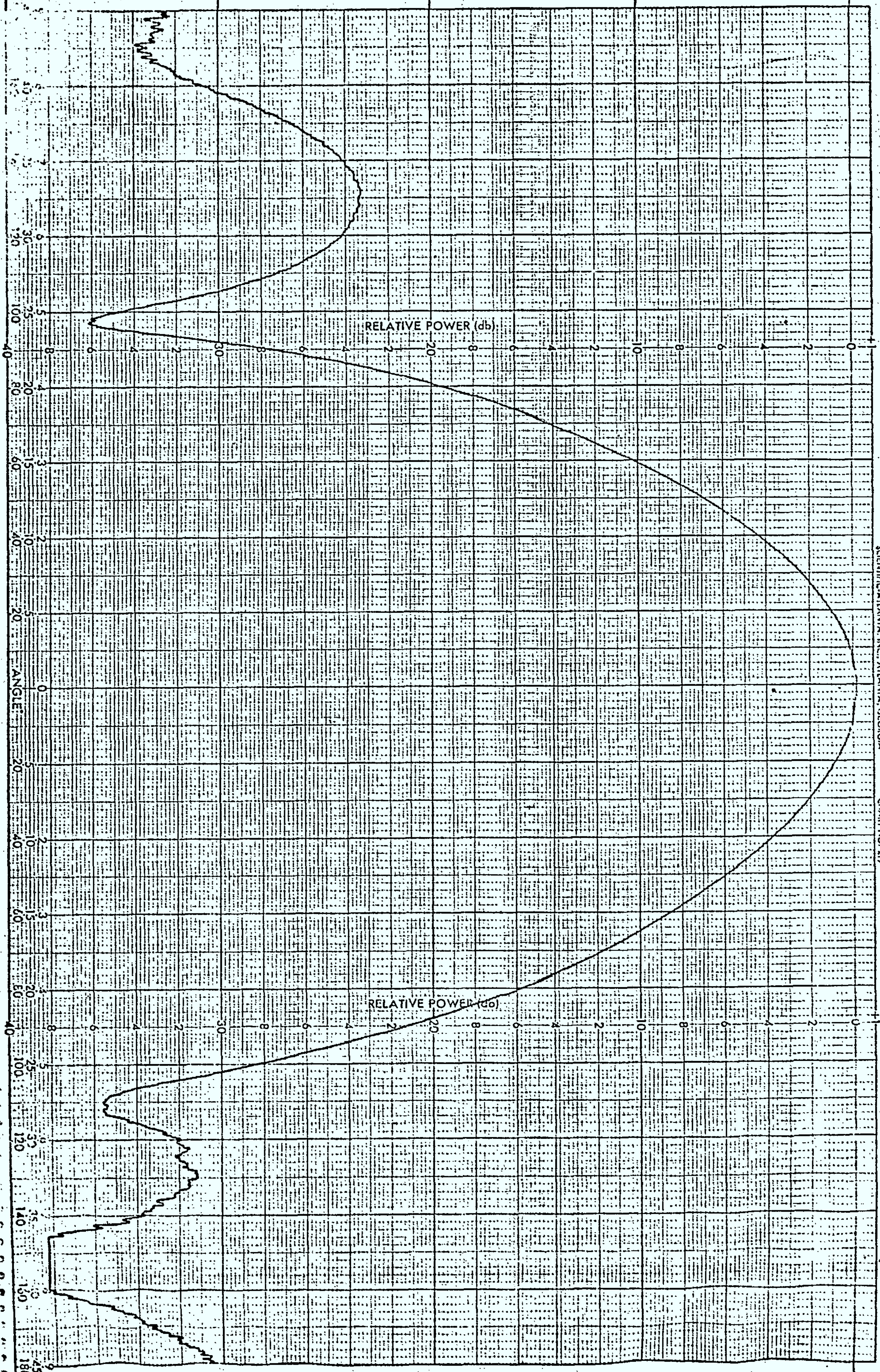


FIGURE 20 Cavity Back Spiral



PROJECT MSAT

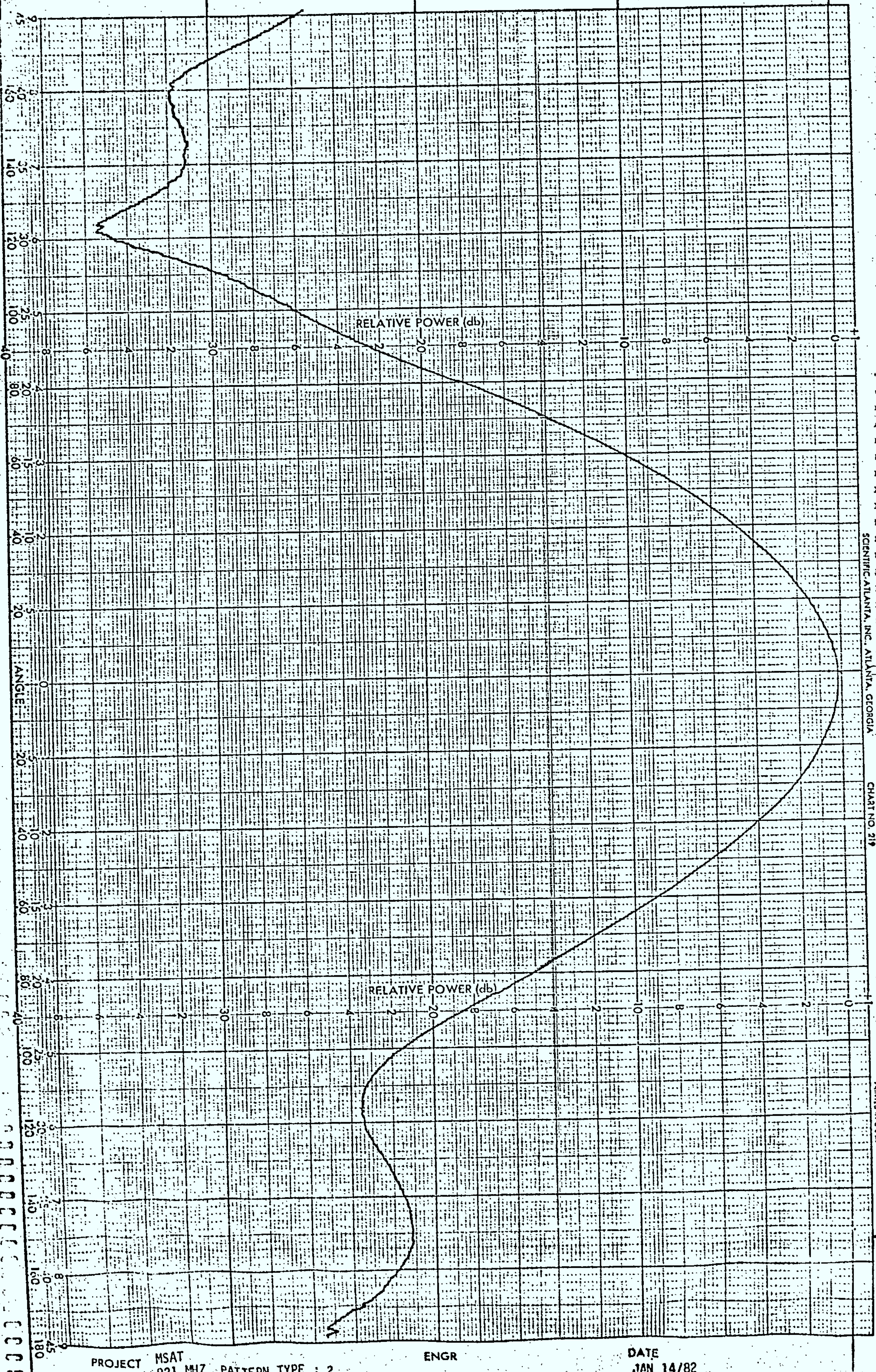
REMARKS 821 MHZ PATTERN TYPE: 1
CAVITY RACK SPIRAL #1

ENGR

FIGURE 21a

DATE JAN 6/82

169793



PROJECT MSAT

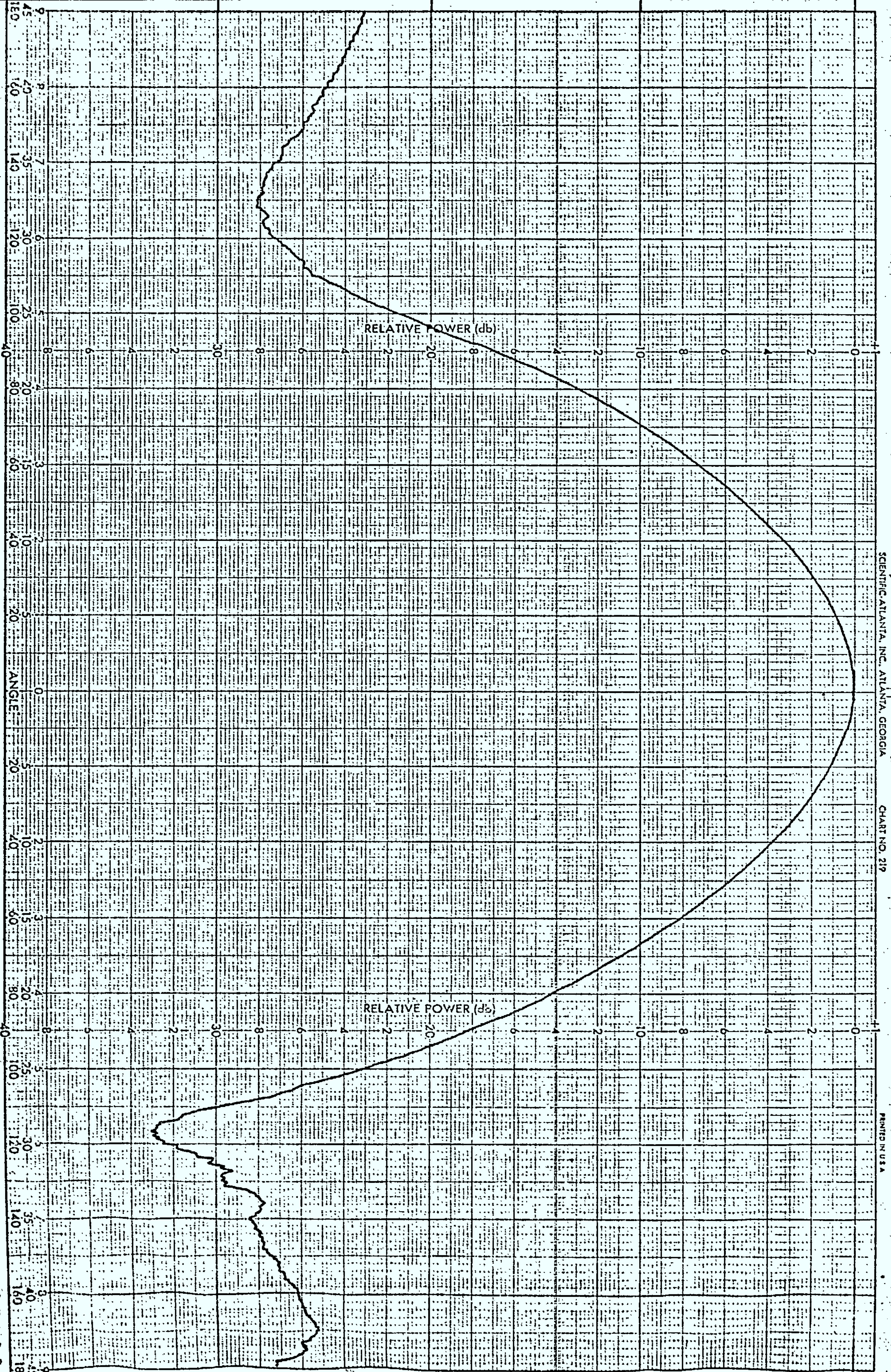
REMARKS 821 MHZ PATTERN TYPE : 2
CAVITY BACK SPIRAL # 1

ENGR

DATE JAN 14/82

FIGURE 21b

169801

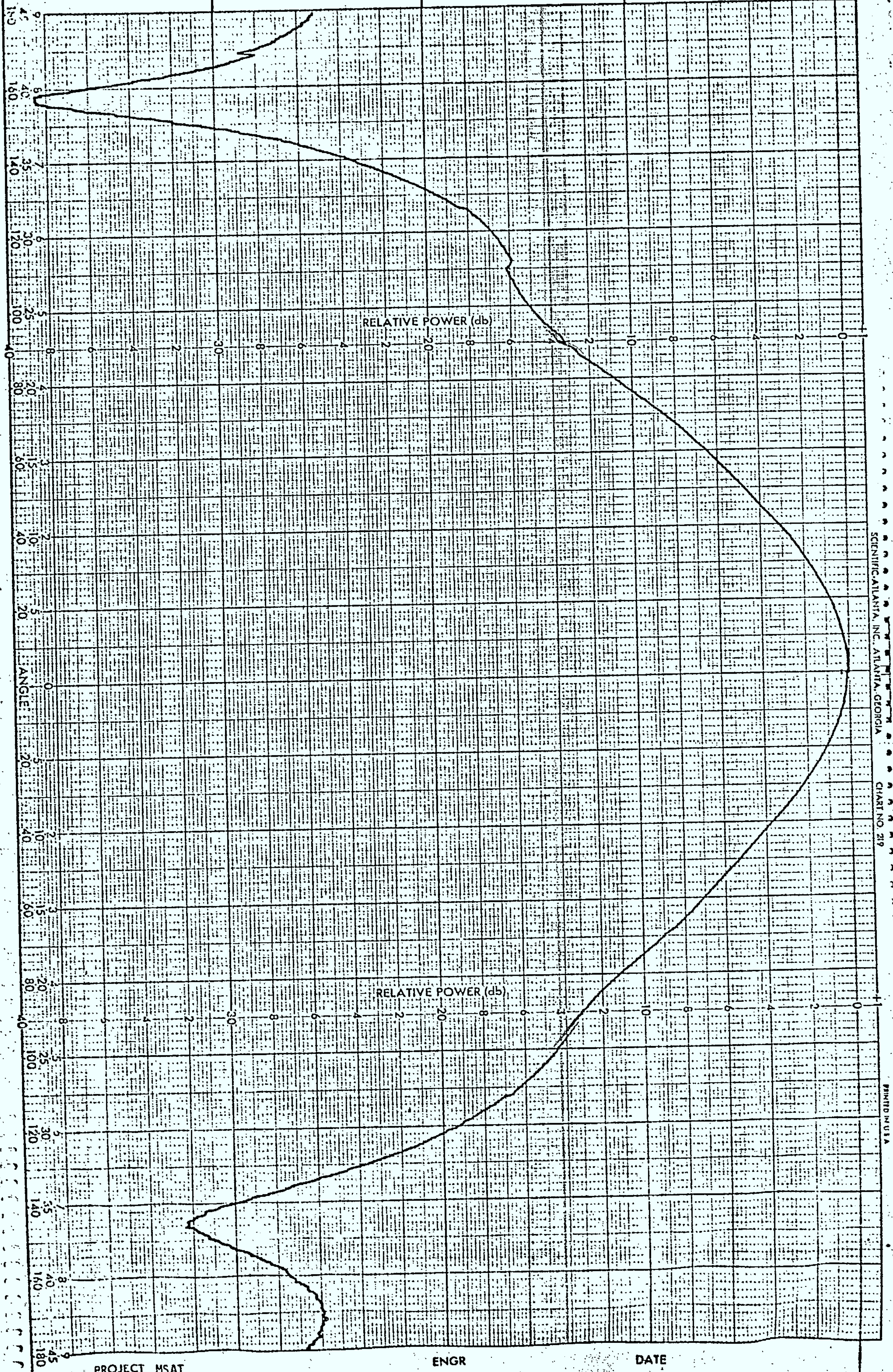


PROJECT MSAT
REMARKS 821 MHZ PATTERN TEST: 5
CAVITY BACK SPIRAL # 1

ENGR
FIGURE 21C

DATE
JAN 6/82

169790

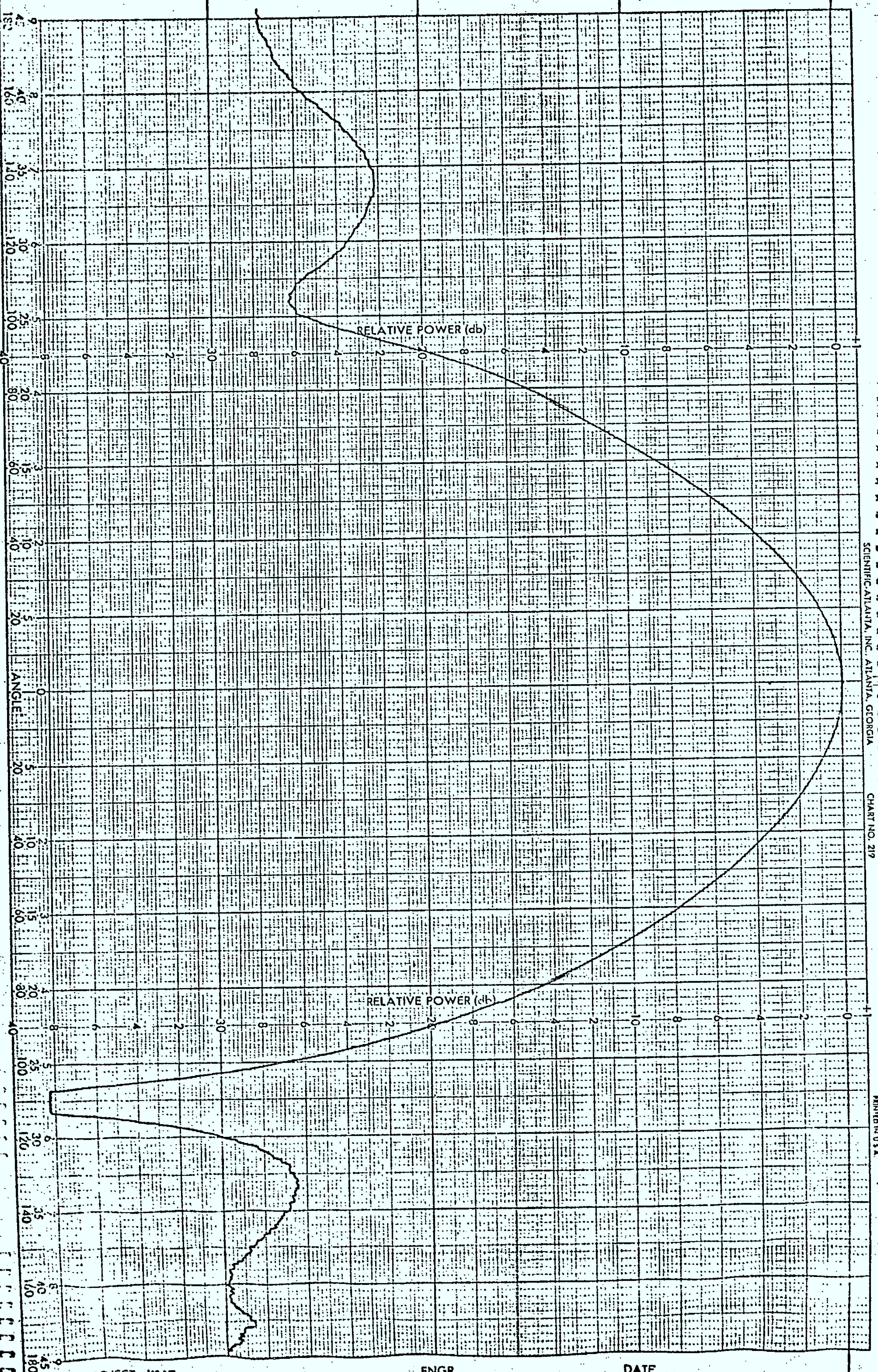


PROJECT MSAT
ENGR
DATE
REMARKS 821 MHZ PATTERN TYPE: 6
CAVITY BACK SPIRAL # 1

FIGURE 21d

JAN 14/82

169S12



PROJECT MSAT

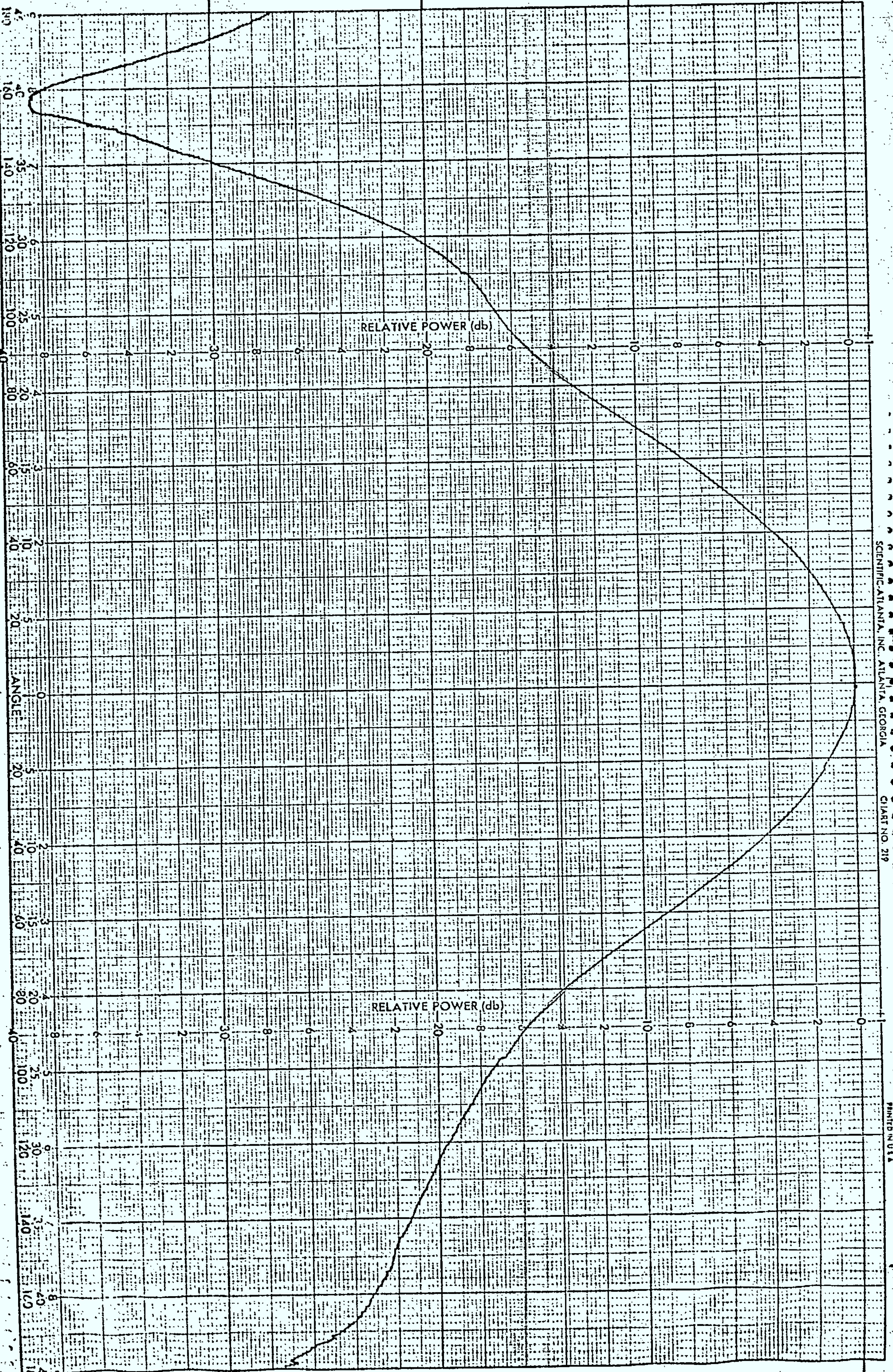
REMARKS 821 PATTERN TYPE 1a
CAVITY BACK SPIRAL #1

ENGR

DATE JAN 6/82

FIGURE 21e

169792



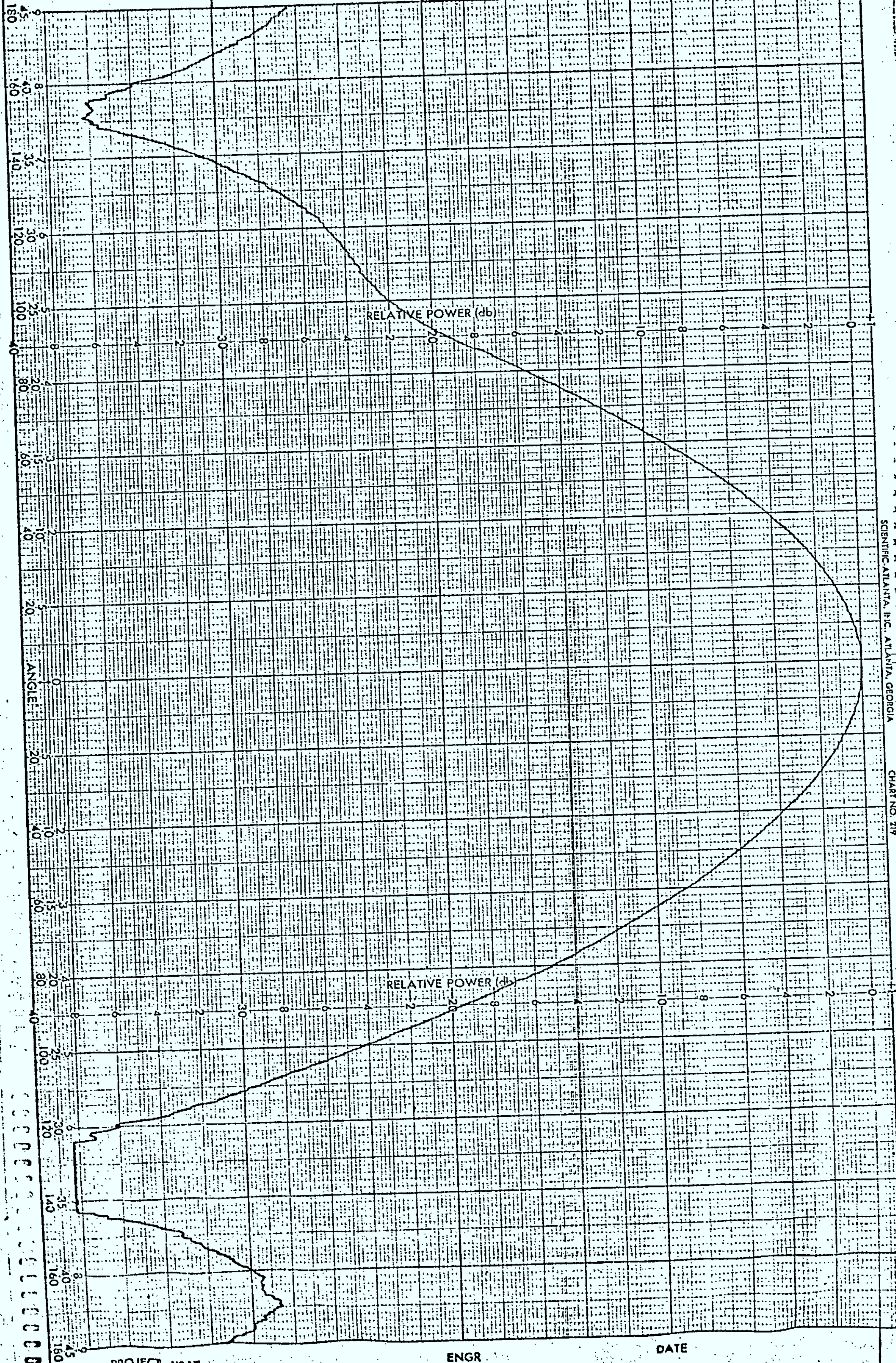
PROJECT MSAT
REMARKS 821 PATTERN TYPE: 2a
CAVITY BACK SPIRAL # 1

ENGR

FIGURE 21f

DATE
JAN 14/82

169502

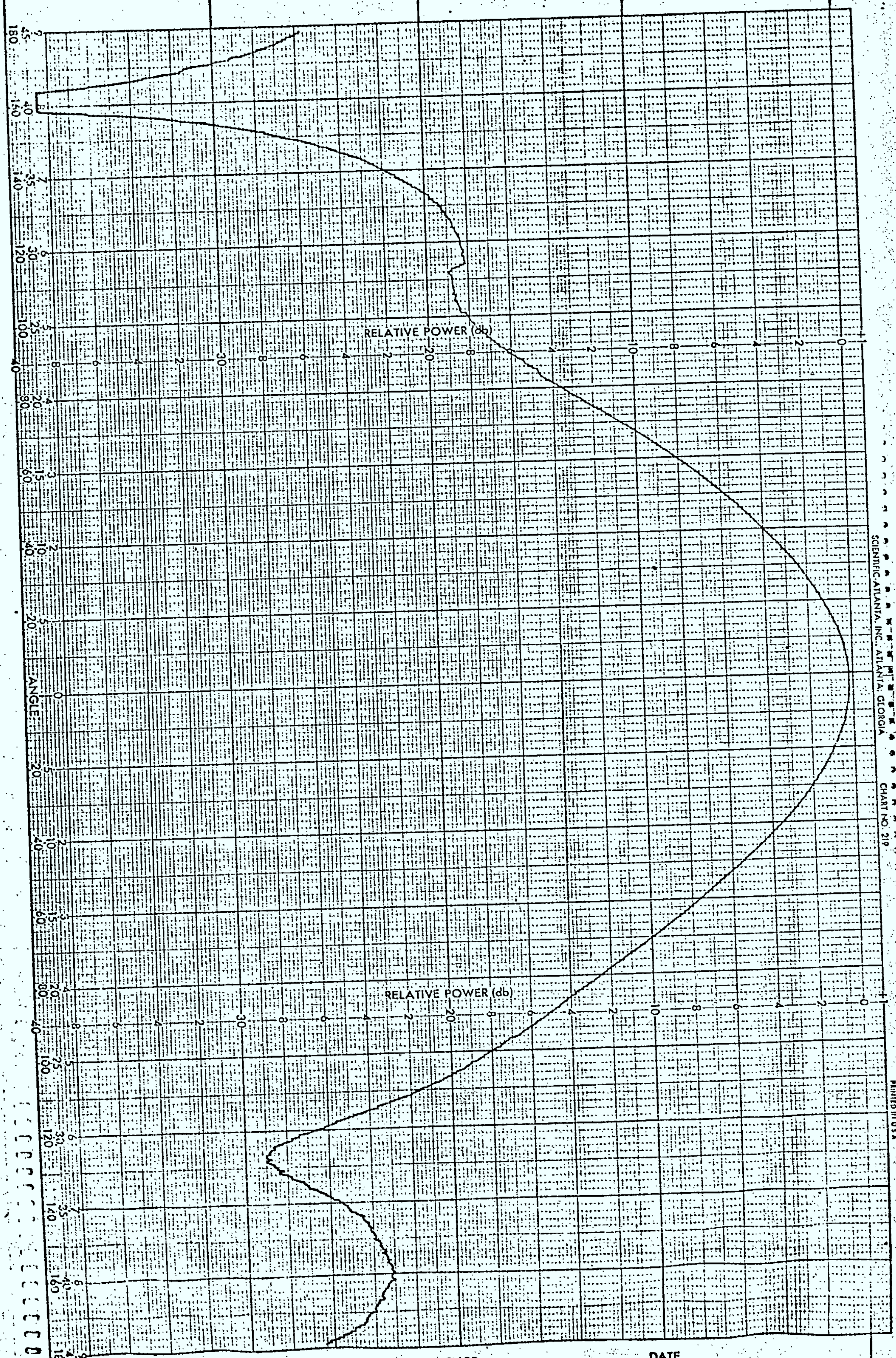


PROJECT MSAT
REMARKS 821 MHZ PATTERN TYPE: 5a
CAVITY BACK SPIRAL #1

ENGR
FIGURE 21g

DATE
JAN 6/82

169789



PROJECT MSAT
REMARKS 821 PATTERN TYPE : 6a
CAVITY BACK SPIRAL # 1

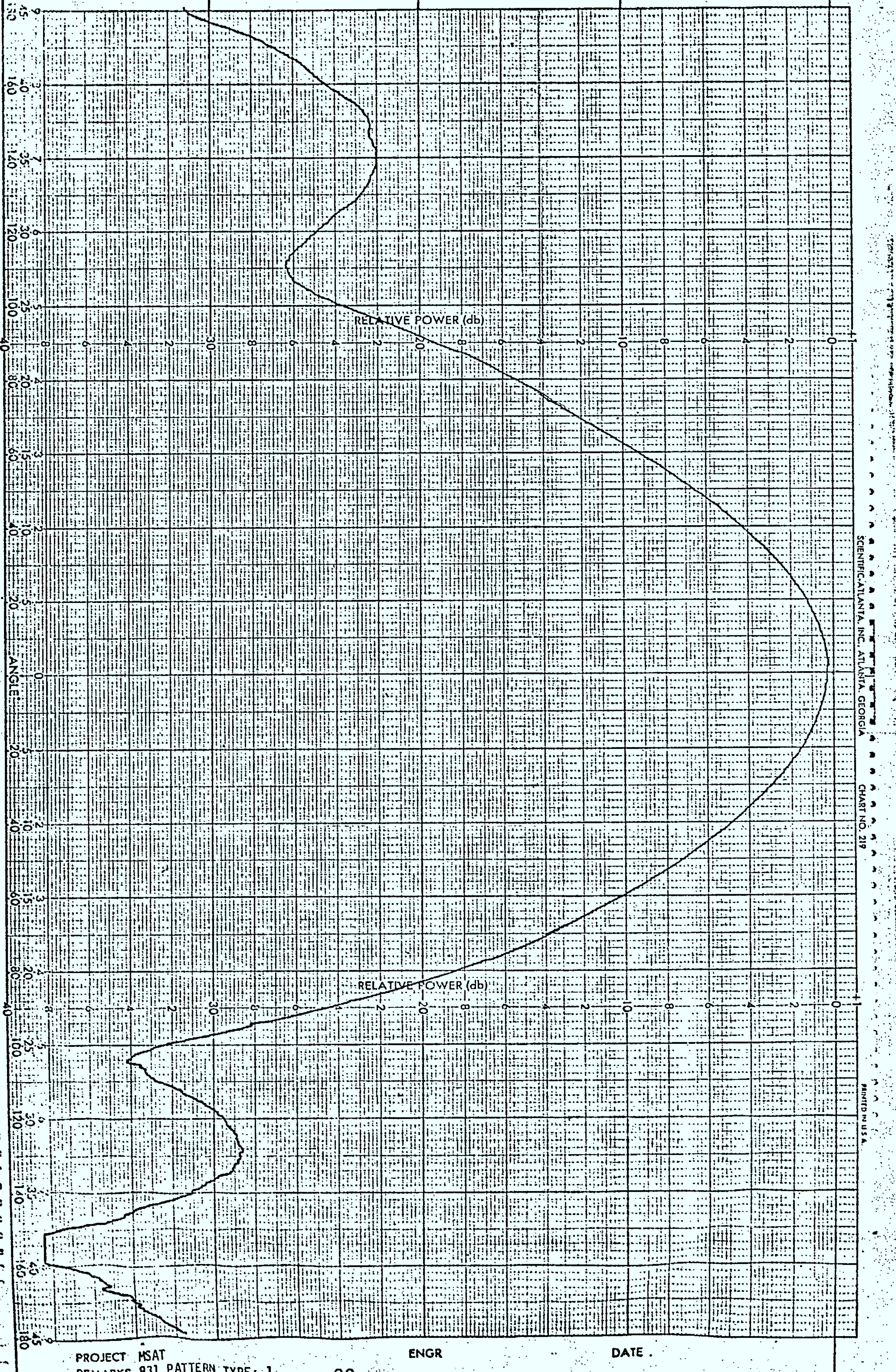
ENGR

FIGURE 21h

DATE

JAN 14/82

169S13



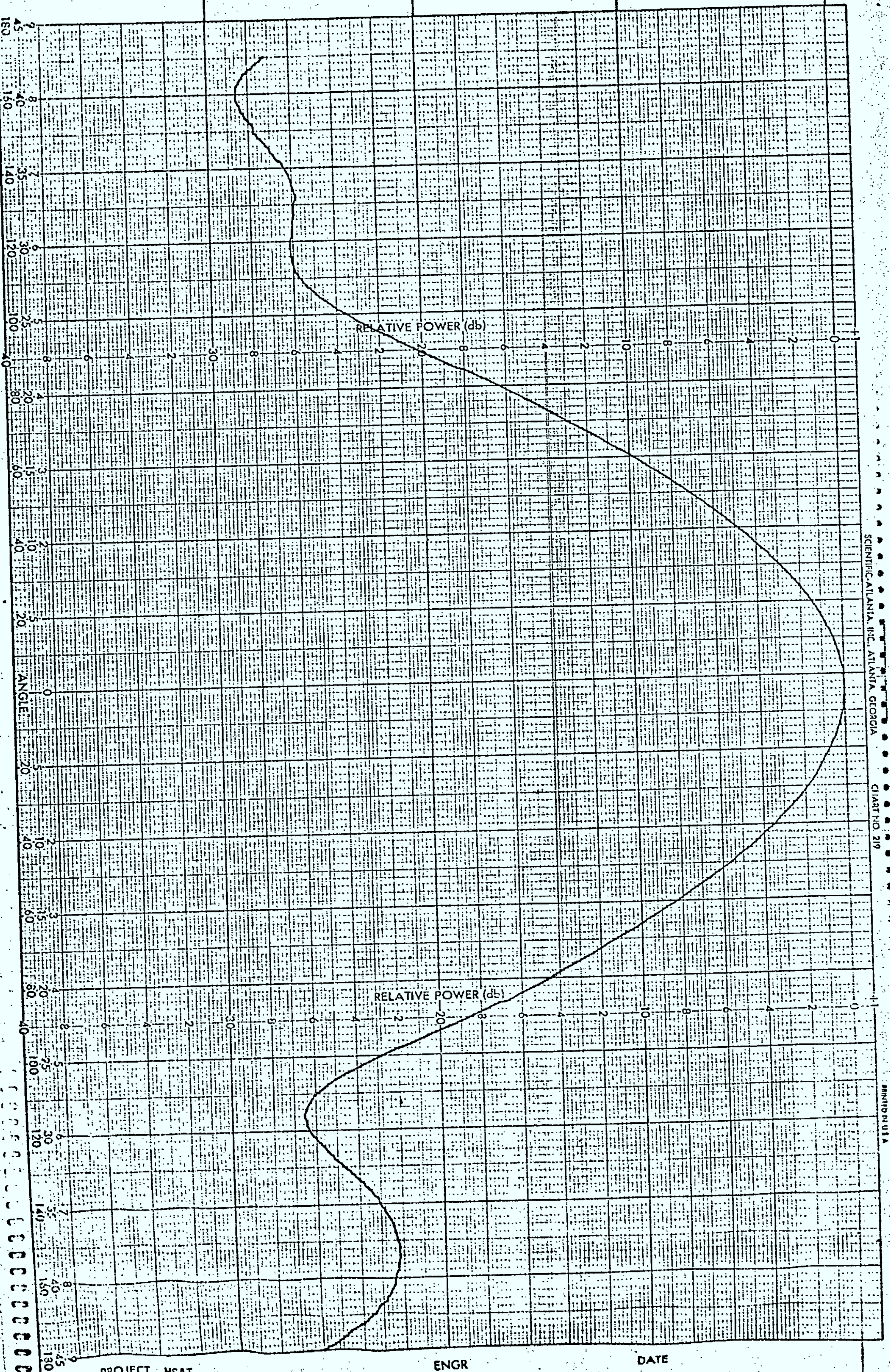
PROJECT MSAT | ENGR | DATE

REMARKS 831 PATTERN TYPE: 1 CAVITY BACK SPIRAL #1

FIGURE 22a

JAN 6/82

169783



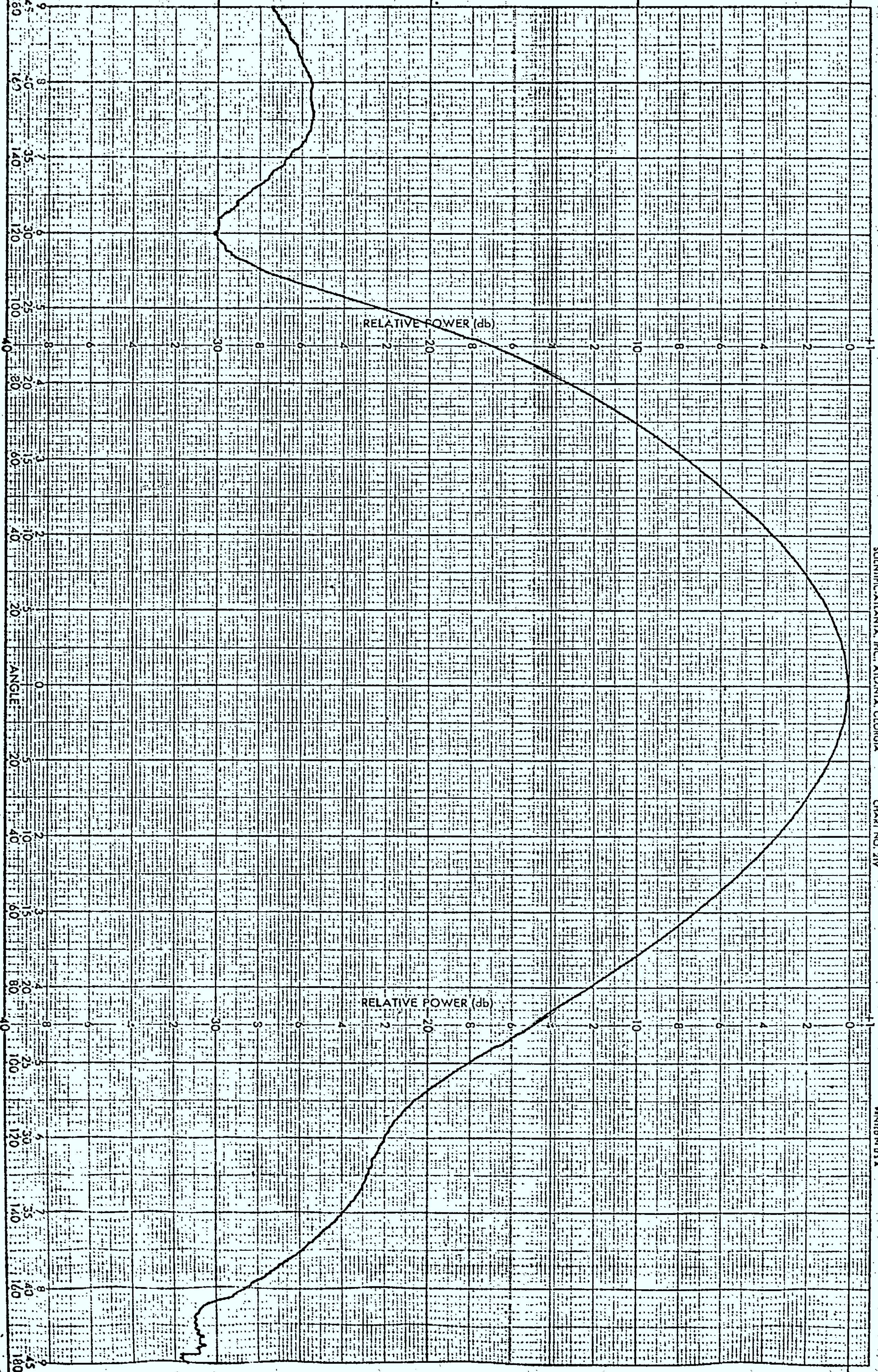
PROJECT MSAT | ENGR | DATE

REMARKS 831 PATTERN TYPE 2

FIGURE 22b

JAN 14/82

169500



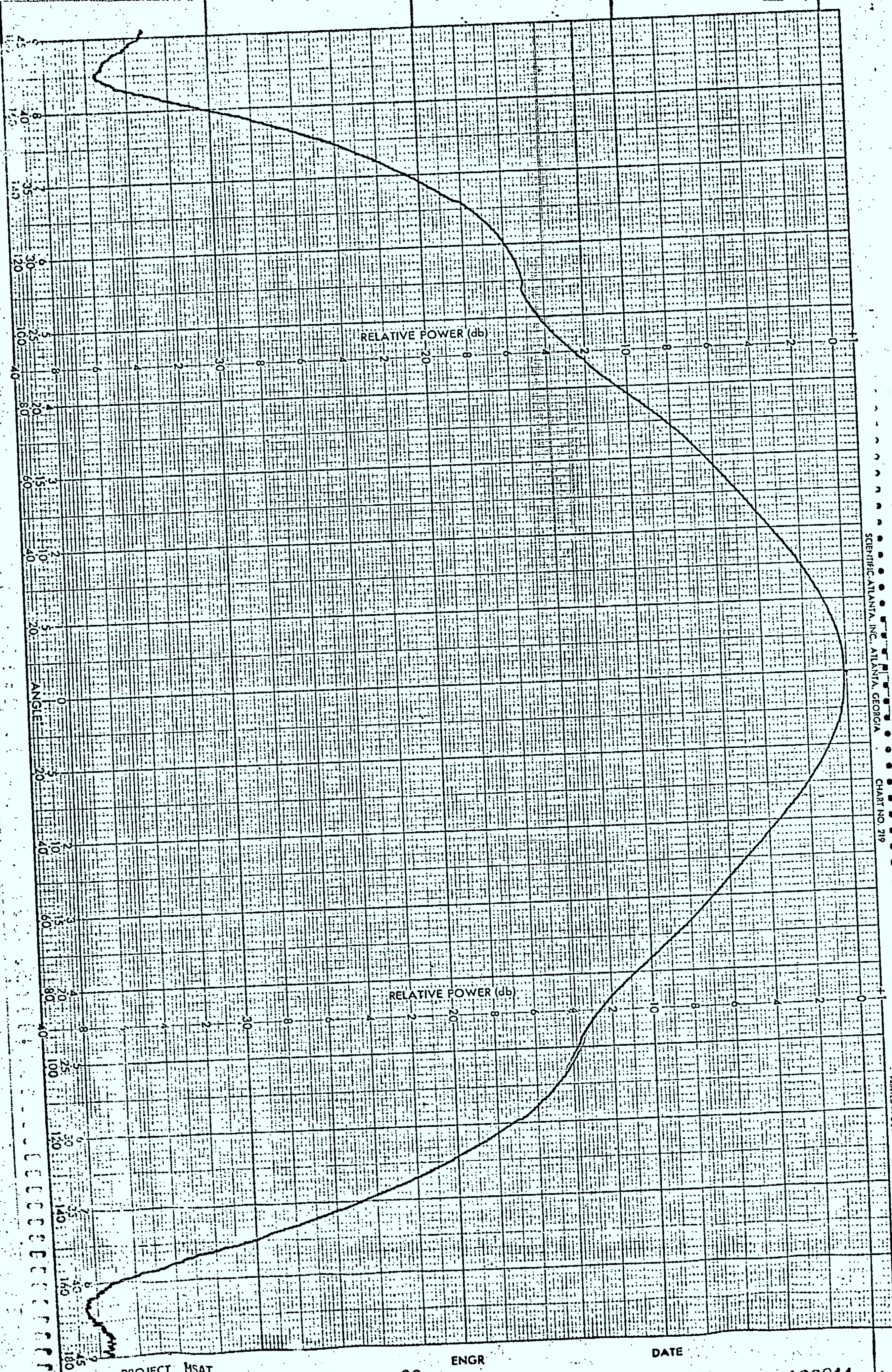
PROJECT MSAT
REMARKS 831 PATTERN TYPE : 5
CAVITY BACK SPIRAL #1

ENGR

FIGURE 22c

DATE
JAN. 6/82

169787



PROJECT MSAT

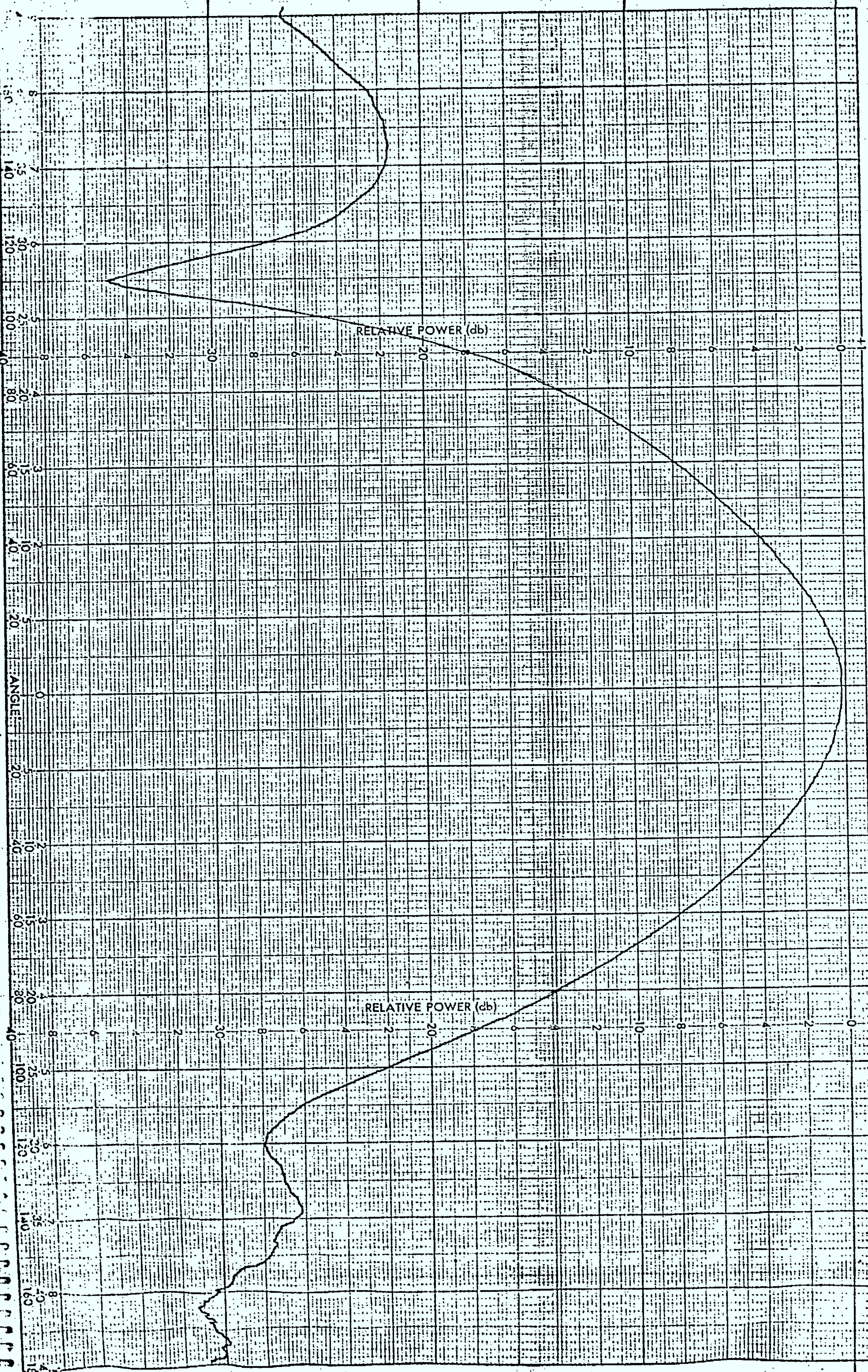
REMARKS 831 PATTERN TYPE : 6
CAVITY BACK SPIRAL # 1

ENGR

FIGURE 22d

DATE JAN 14/82

169S11



PROJECT MSAT

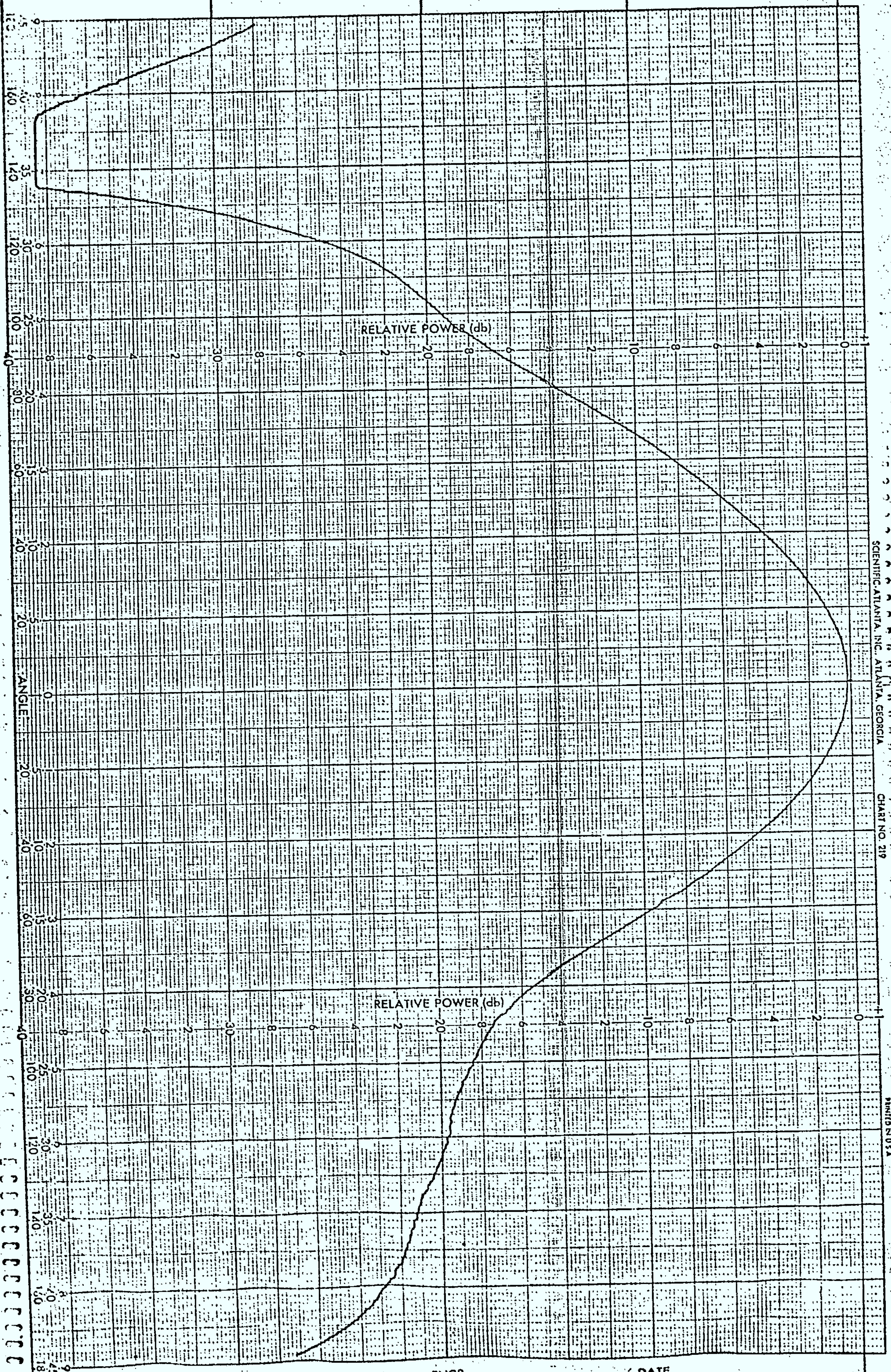
REMARKS 831 PATTERN TYPE : 1a
CAVITY BACK SPIRAL # 1

ENGR

DATE JAN 6/82

FIGURE 22e

169785



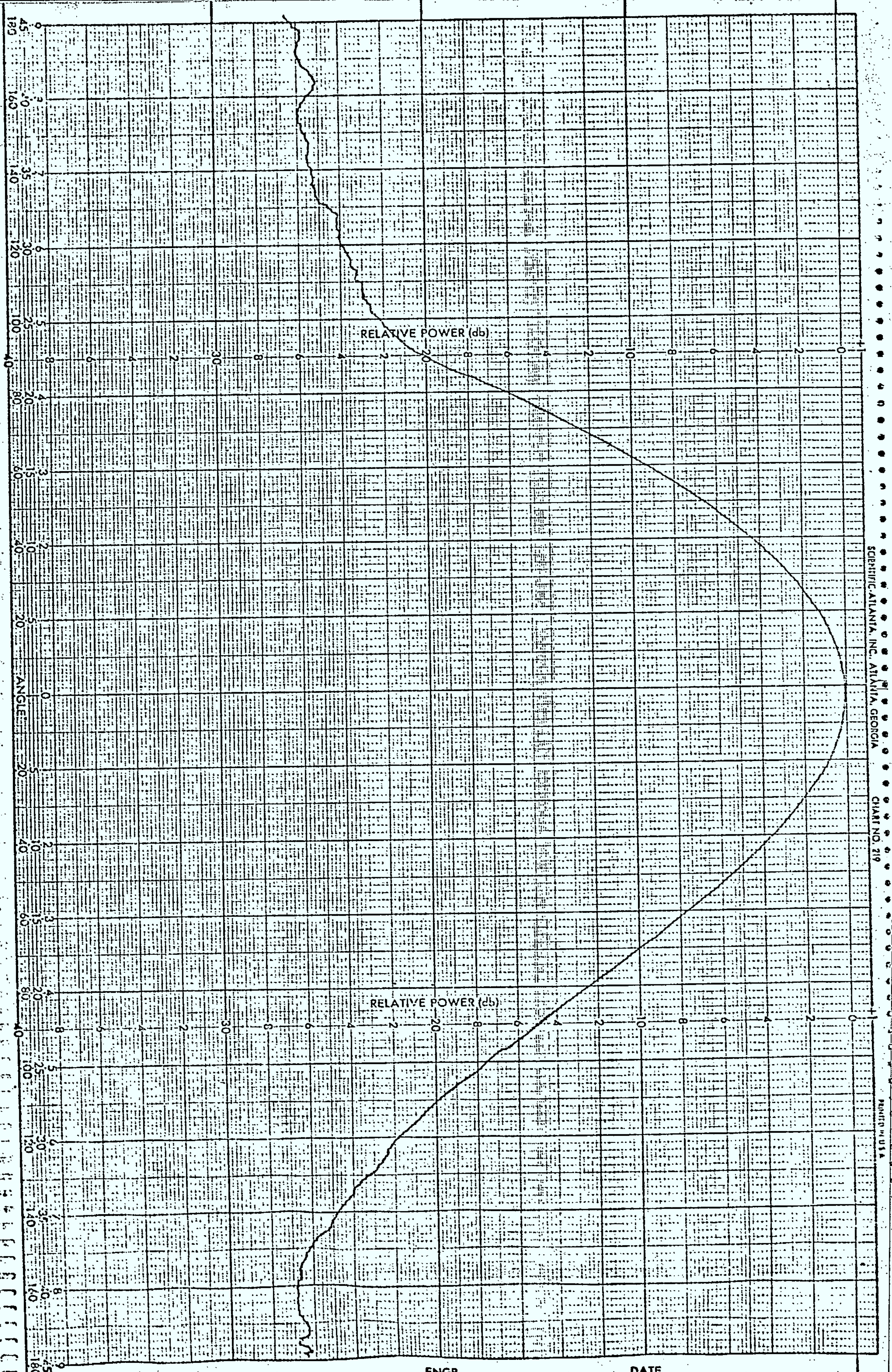
PROJECT MSAT

REMARKS 831 MHZ PATTERN TYPE: 2a

ENGR

FIGURE 22f

DATE JAN 14/82



PROJECT MSAT

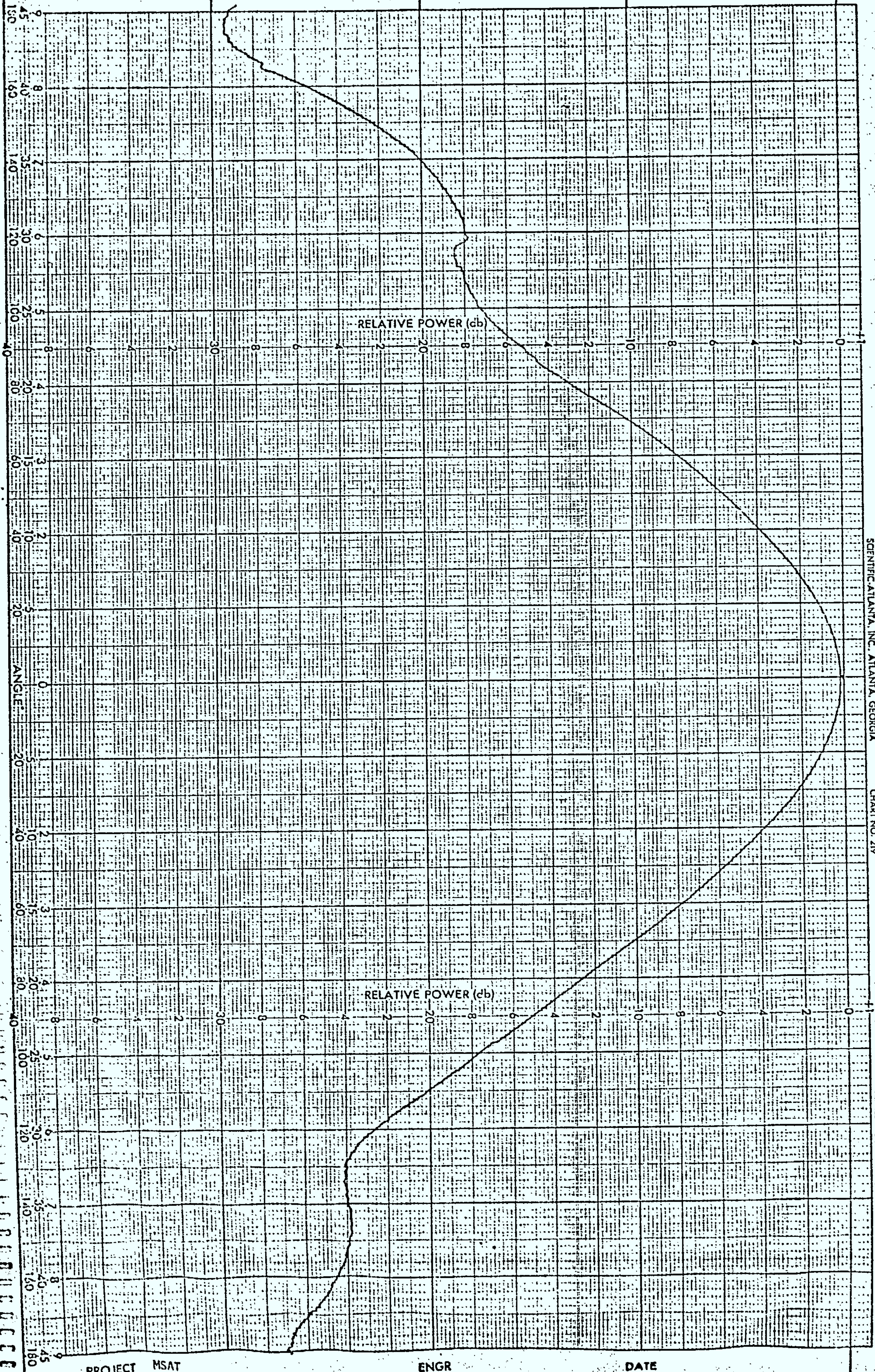
ENGR

DATE JAN 6/82

REMARKS 831 MHZ PATTERN TYPE: 5a
CAVITY BACK SPIRAL #1

FIGURE 22g

169788



PROJECT MSAT

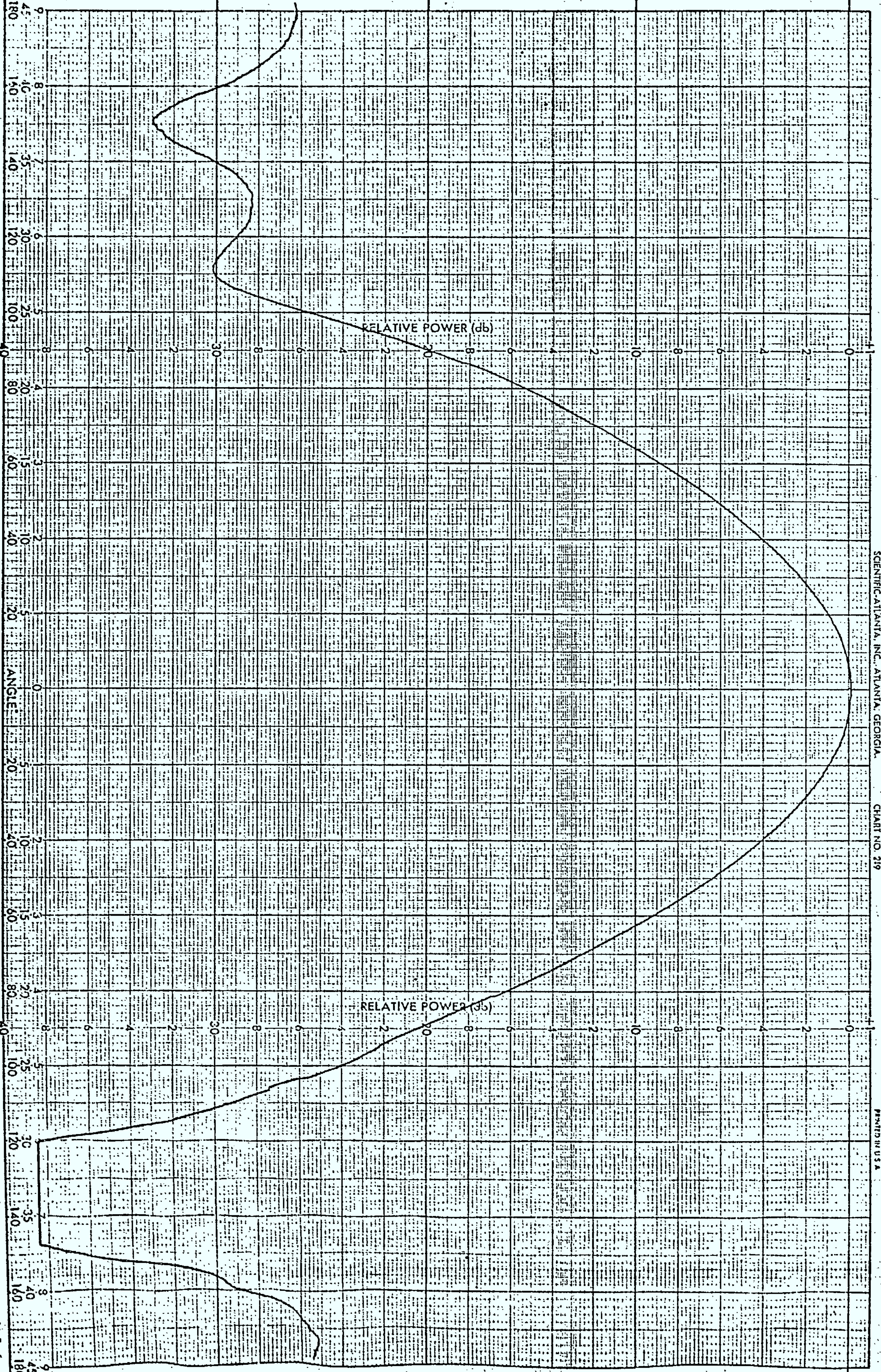
REMARKS 866 MHZ PATTERN TYPE: 6a CAVITY BACK SPIRAL# 1

ENGR

FIGURE 22h

DATE JAN14/82

169S14



PROJECT MSAT

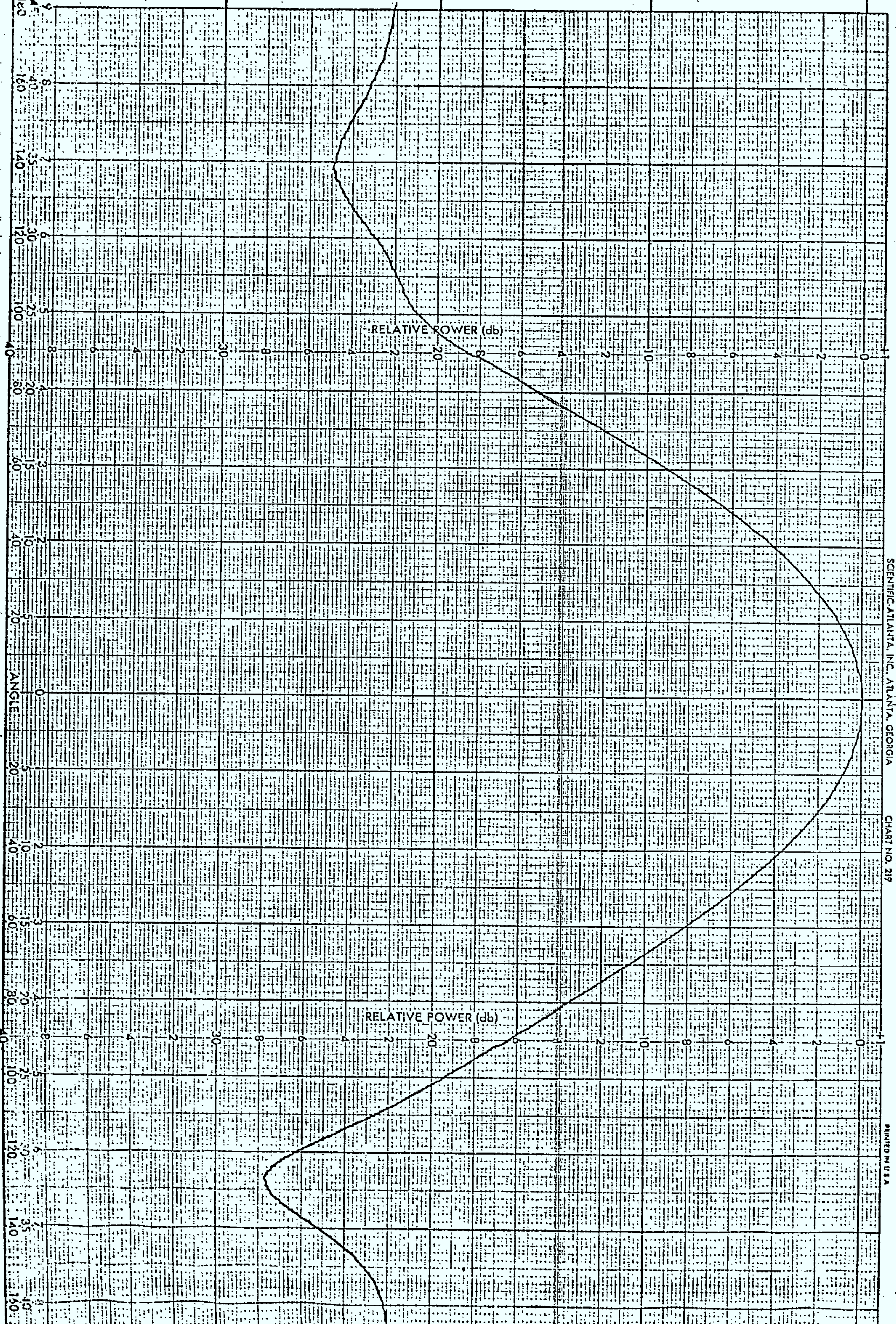
REMARKS 866 MHZ PATTERN TYPE: I
CAVITY BACK SPIRAL #1

ENGR.

FIGURE 23a

DATE JAN. 6/82

169782



PROJECT HSAT

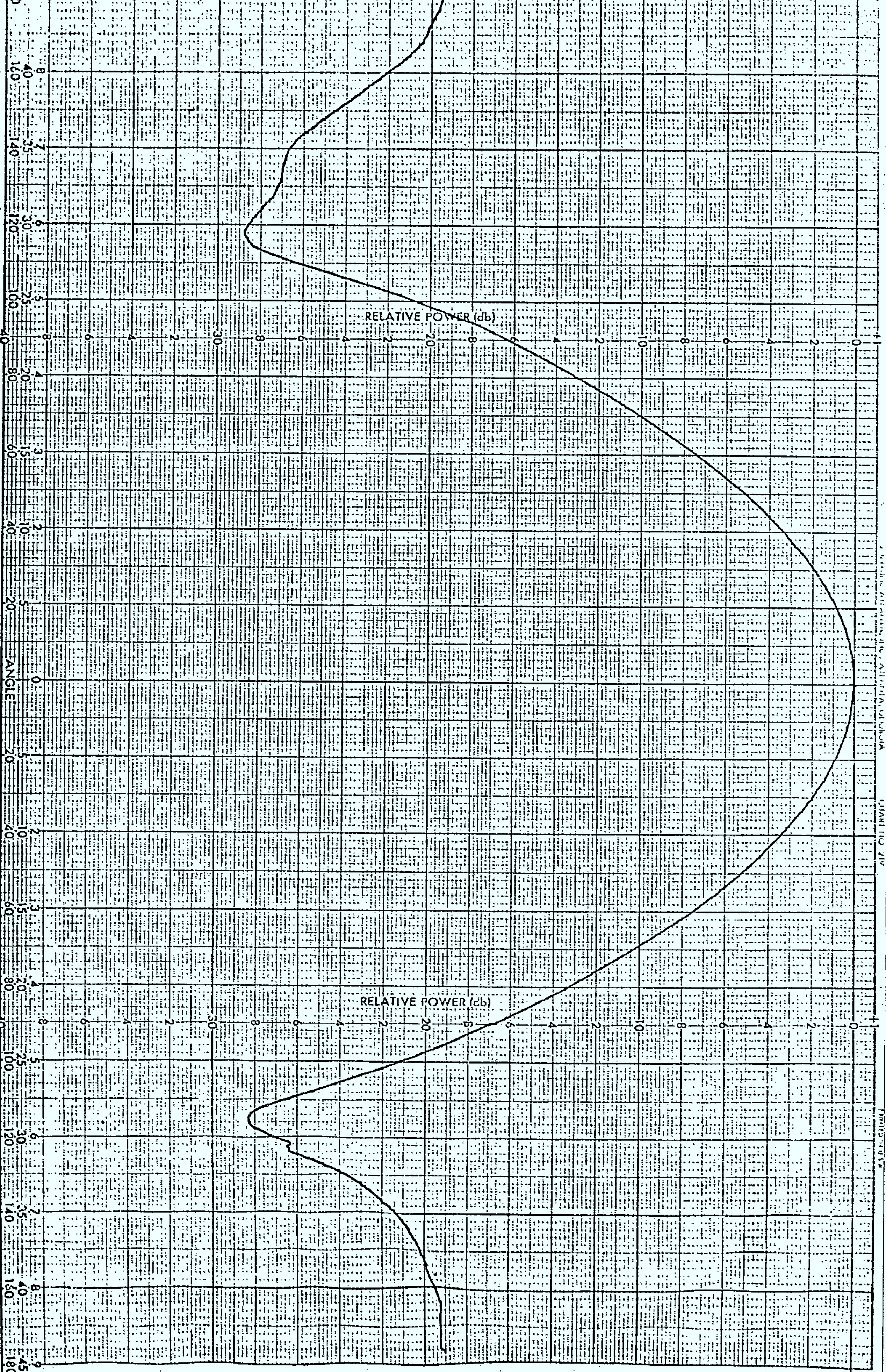
REMARKS 866 MHZ PATTERN TYPE : 2
CAVITY BACK SPIRAL #1

ENGR

DATE JAN 14/82

 FIGURE 23b

160799



PROJECT HSAT

REMARKS 866 MHZ PATTERN TYPE: 5
CAVITY BACK SPIRAL # 1

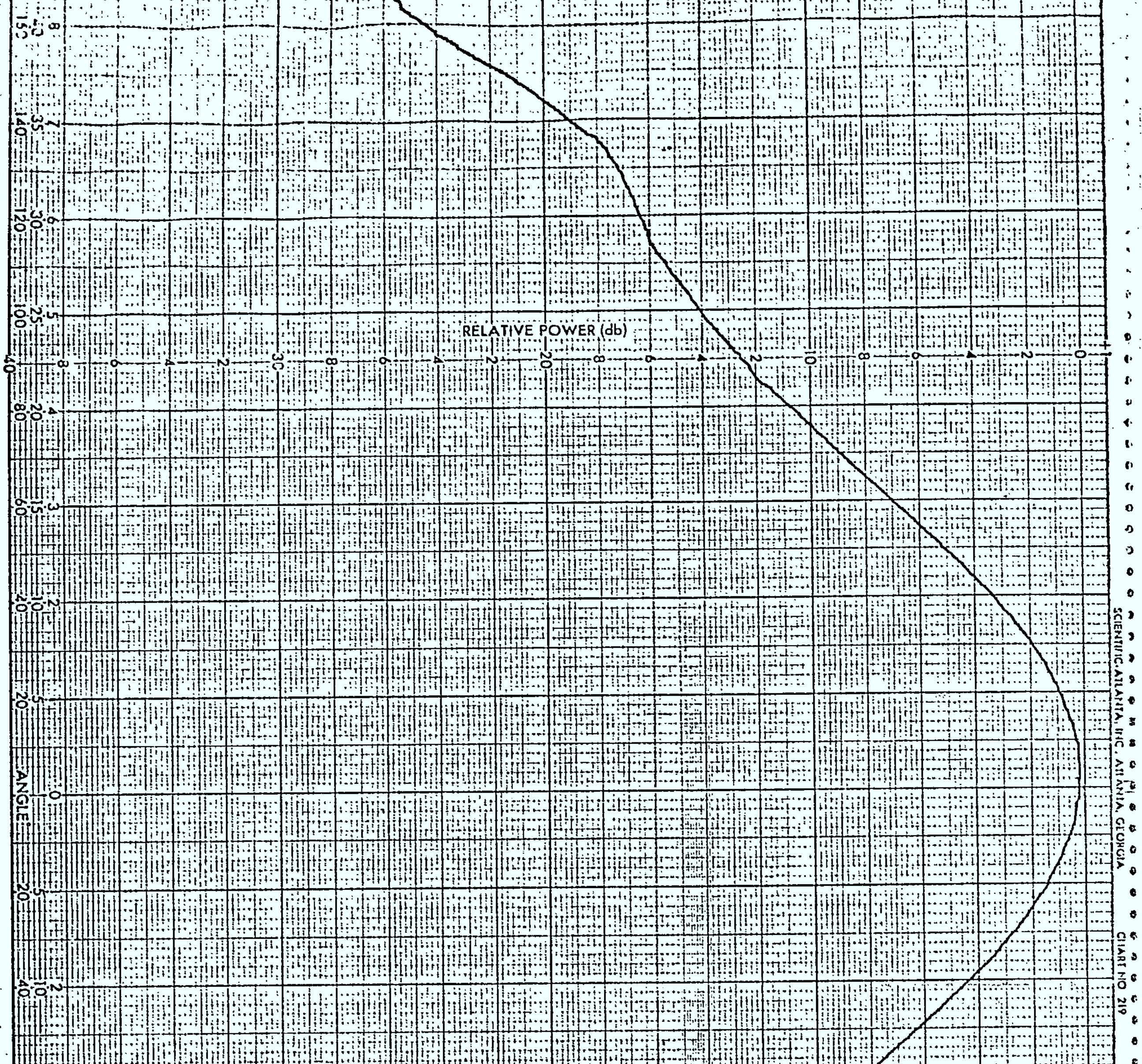
ENGR

FIGURE 23c

DATE

JAN 6/82

169780

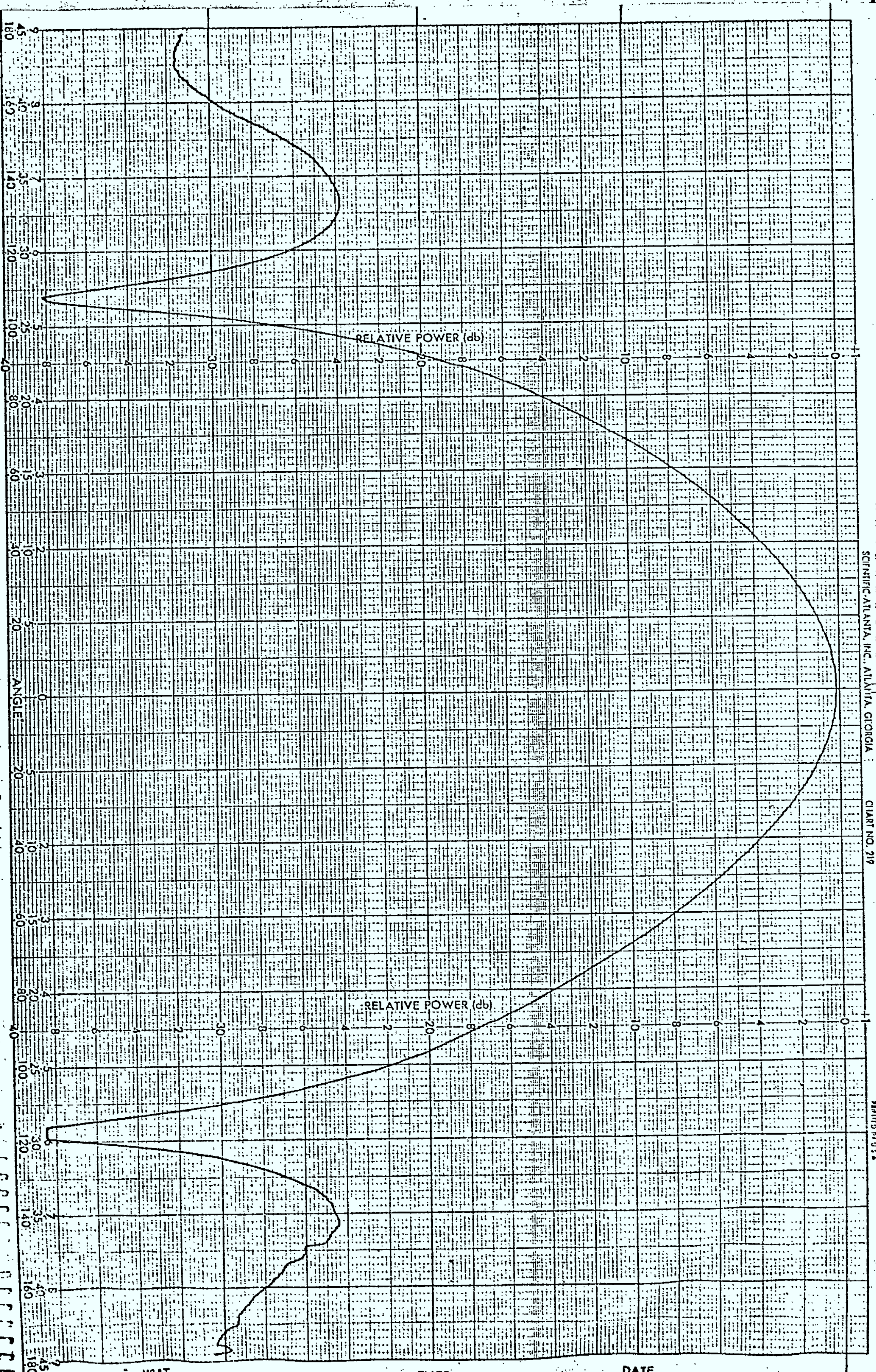


PROJECT MSAT
REMARKS 866 MHZ PATTERN TYPE: 6
CAVITY BACK SPIRAL #1

ENGR
FIGURE 23d

DATE
JAN 14/82

169S10



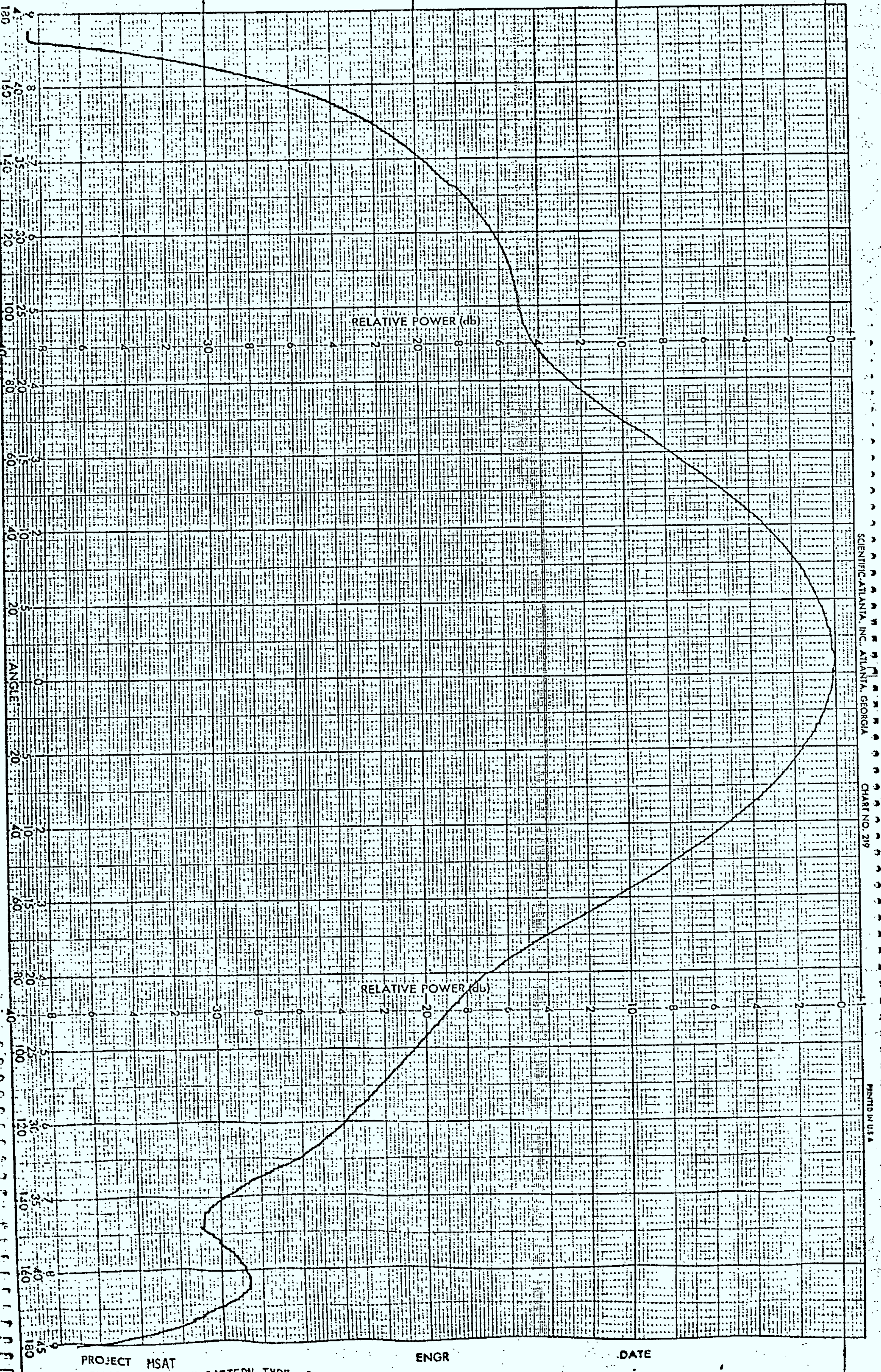
PROJECT MSAT
REMARKS 866 MHZ PATTERN TYPE: 1a
CAVITY BACK SPIRAL #1

ENGR

FIGURE 23e

DATE
JAN 6/82

169781



PROJECT MSAT

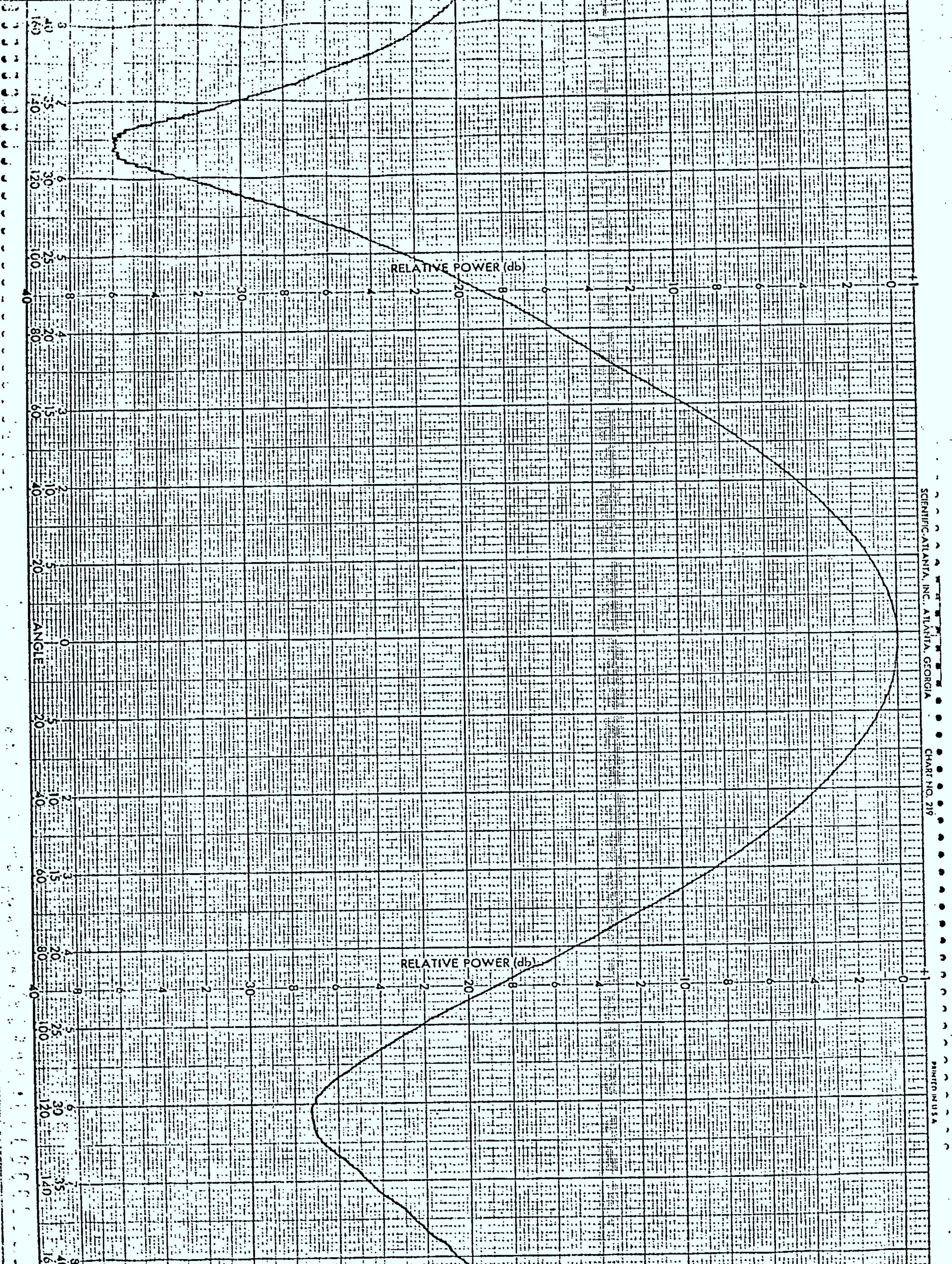
REMARKS 866 MHZ PATTERN TYPE: 2a
CAVITY BACK SPIRAL # 1

ENGR

FIGURE 23f

DATE JAN 14/82

169S04



PROJECT MSAT

REMARKS 866 MHZ PATTERN TYPE: 5a

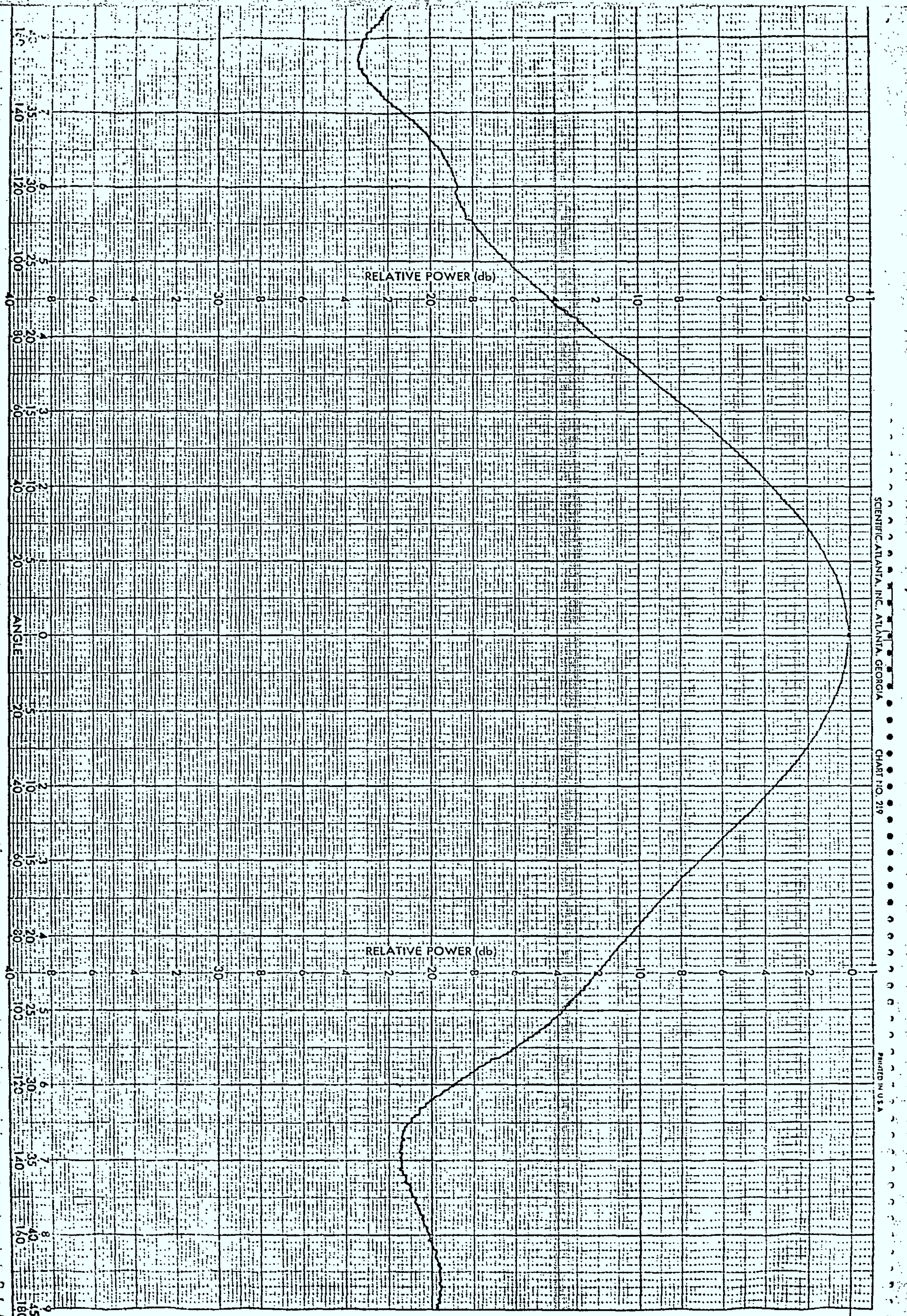
CAVITY BACK SPIRAL #1

ENGR

FIGURE 239

DATE JAN 6/82

169779

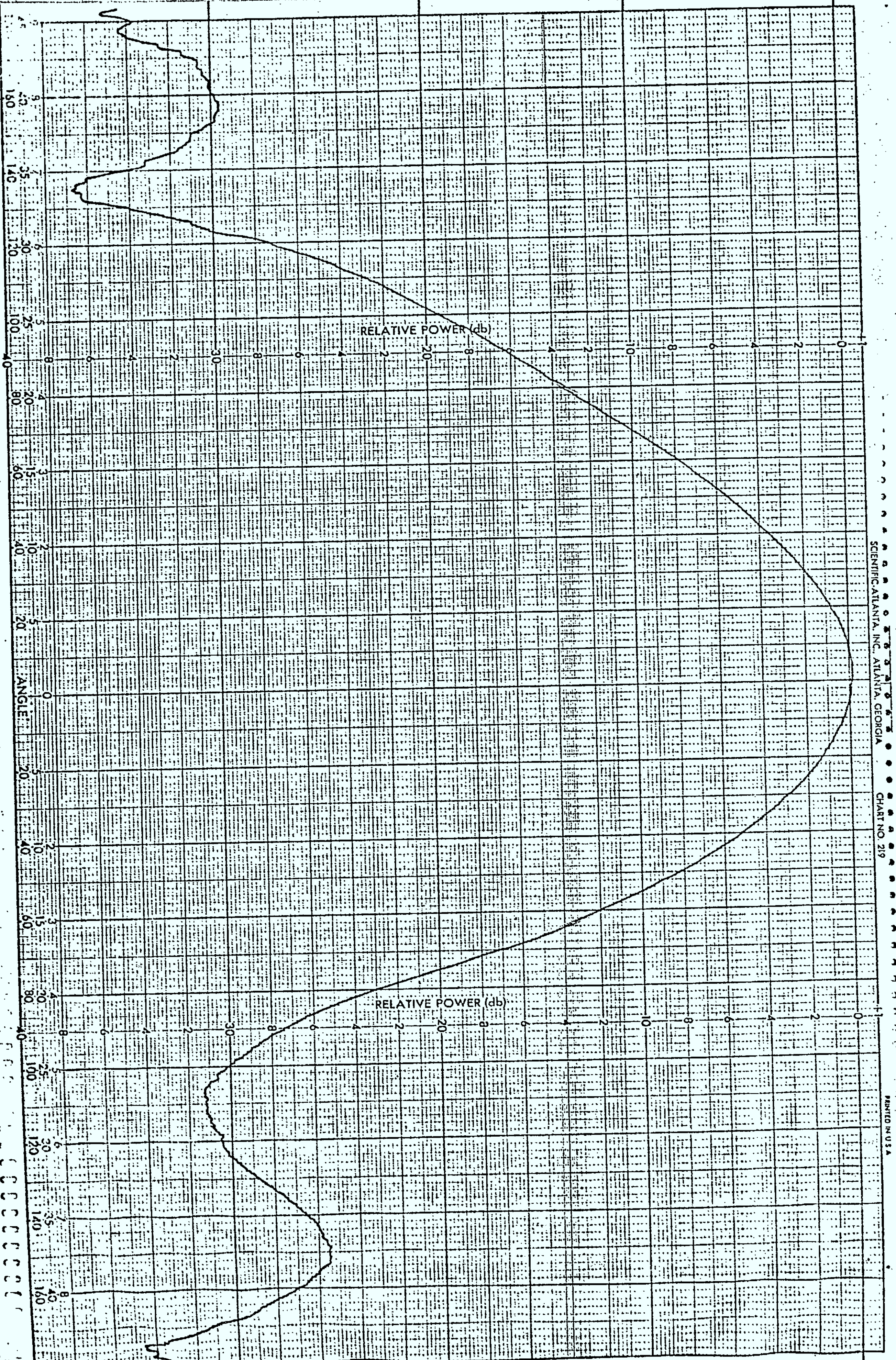


PROJECT MSAT
REMARKS 866 MHZ PATTERN TYPE: 6a
CAVITY BACK SPIRAL# 1

ENGR
FIGURE 23h

DATE
JAN 14/82

169815



PROJECT MSAT
REMARKS 876 MHZ PATTERN TYPE: 1
CAVITY BACK SPIRAL # 1

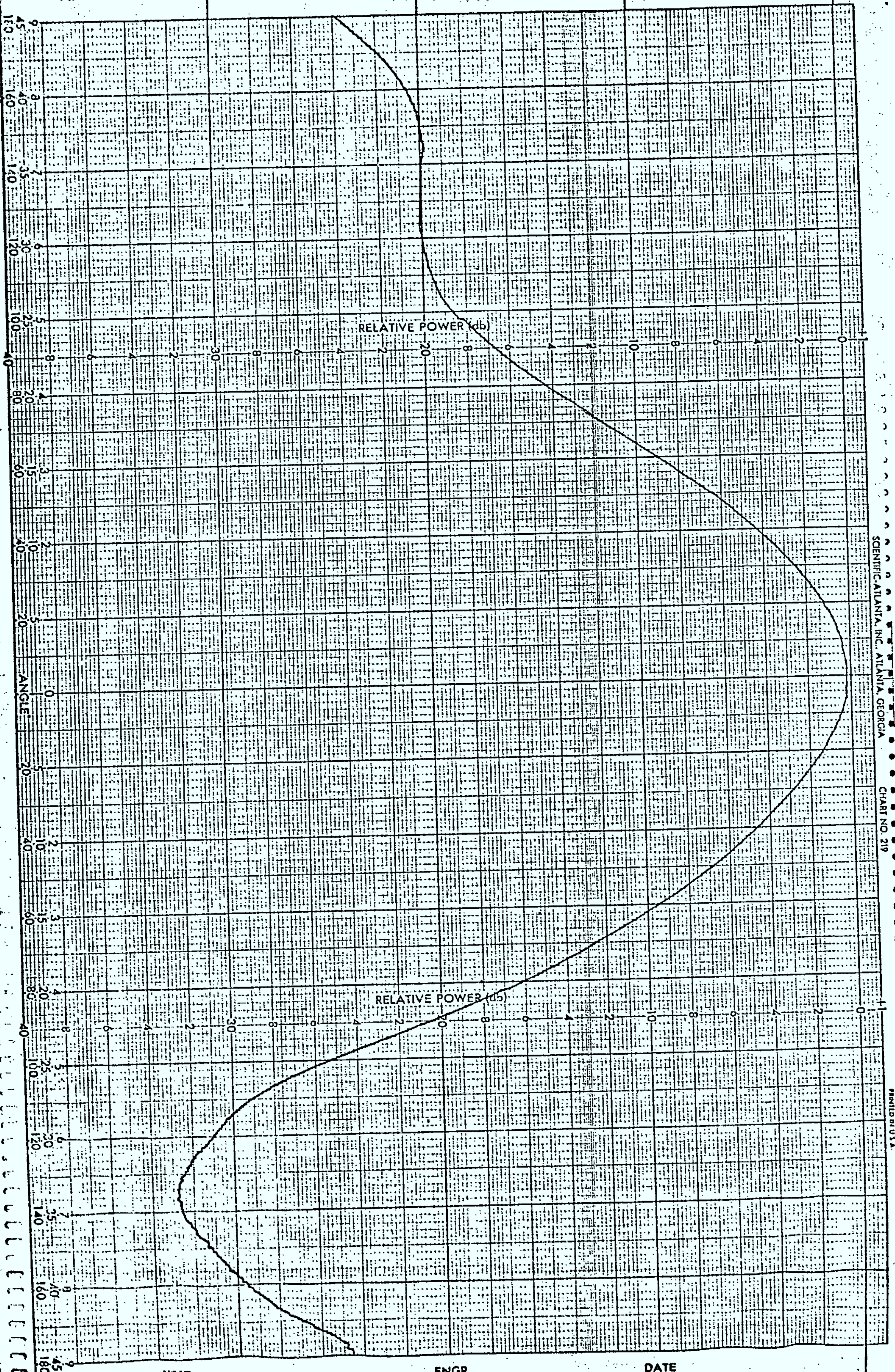
ENGR

DATE

FIGURE 24a

JAN 6/82

169987



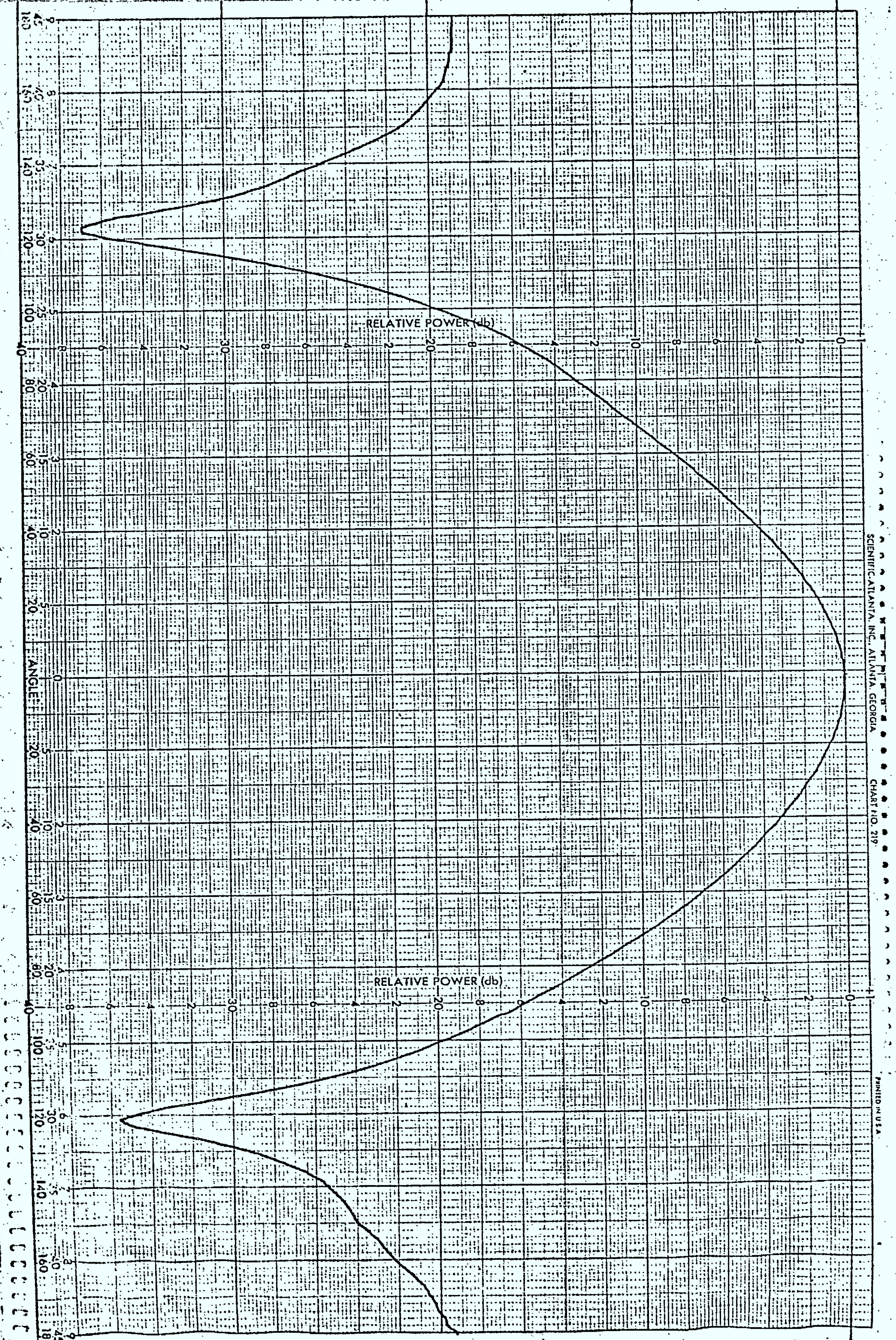
PROJECT MSAT
REMARKS 876 MHz PATTERN TYPE: 2
CAVITY BACK SPIRAL # 1

ENGR

FIGURE 24b

DATE
JAN 14/82

169798

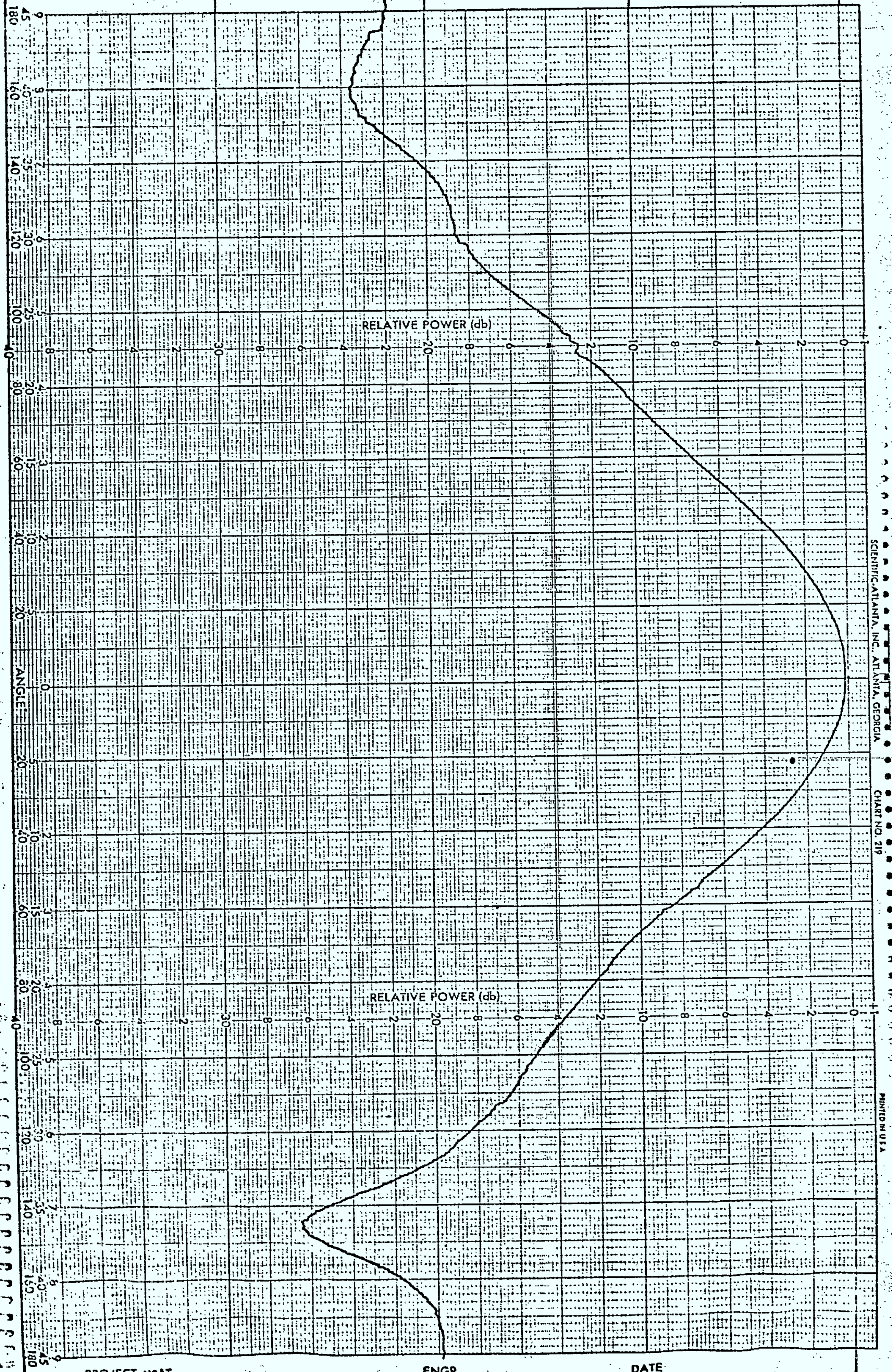


PROJECT MSAT
ENGR
DATE
REMARKS 876 MHZ PATTERN TYPE 5
CAVITY BACK SPIRAL #1

FIGURE 24c

JAN 6/82

169777



PROJECT MSAT

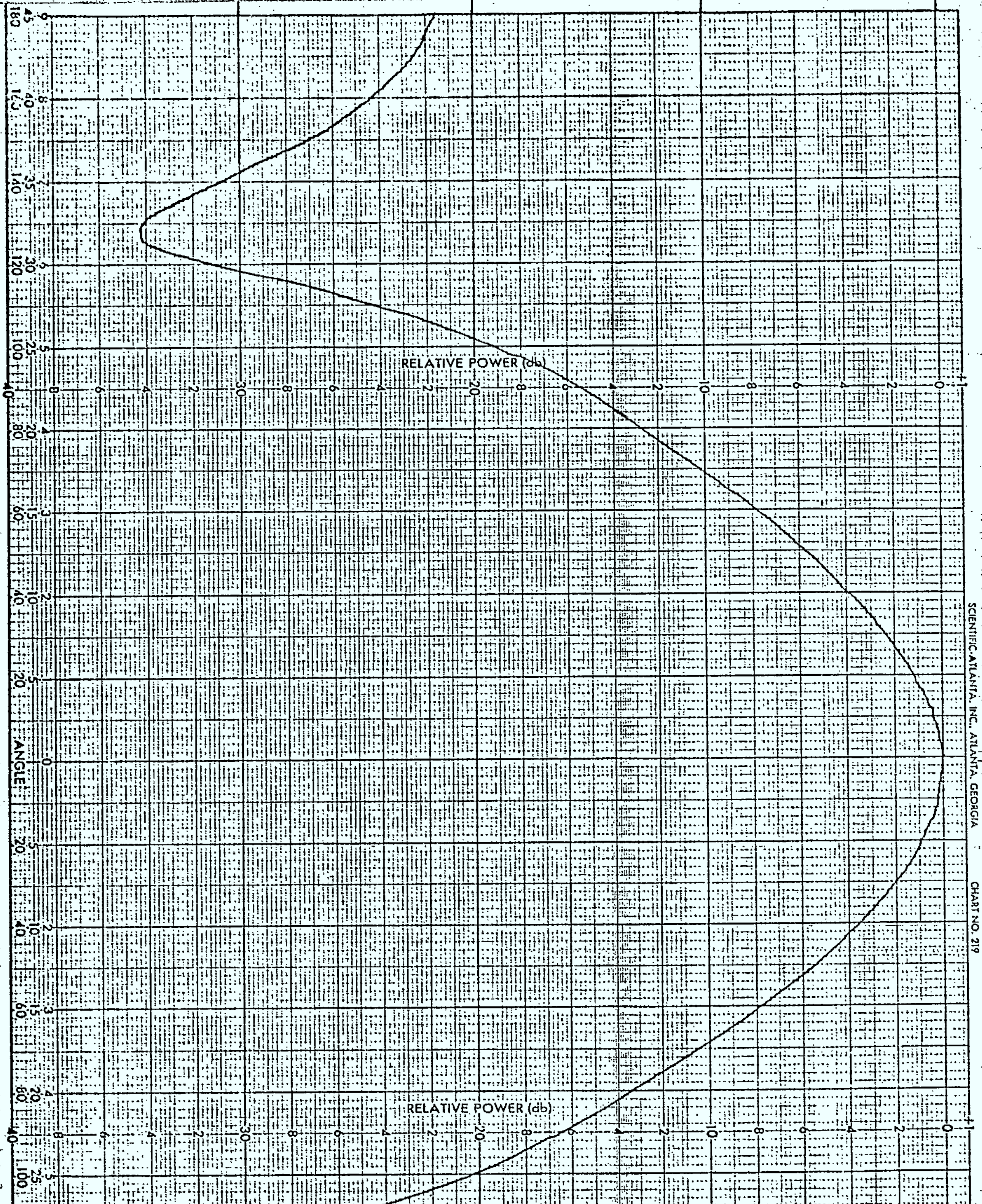
ENGR

DATE JAN 14/82

REMARKS 876 MHZ PATTERN TYPE : 6
CAVITY BACK SPIRAL # 1

FIGURE 24d

169S09



PROJECT MSAT

ENGR

DATE

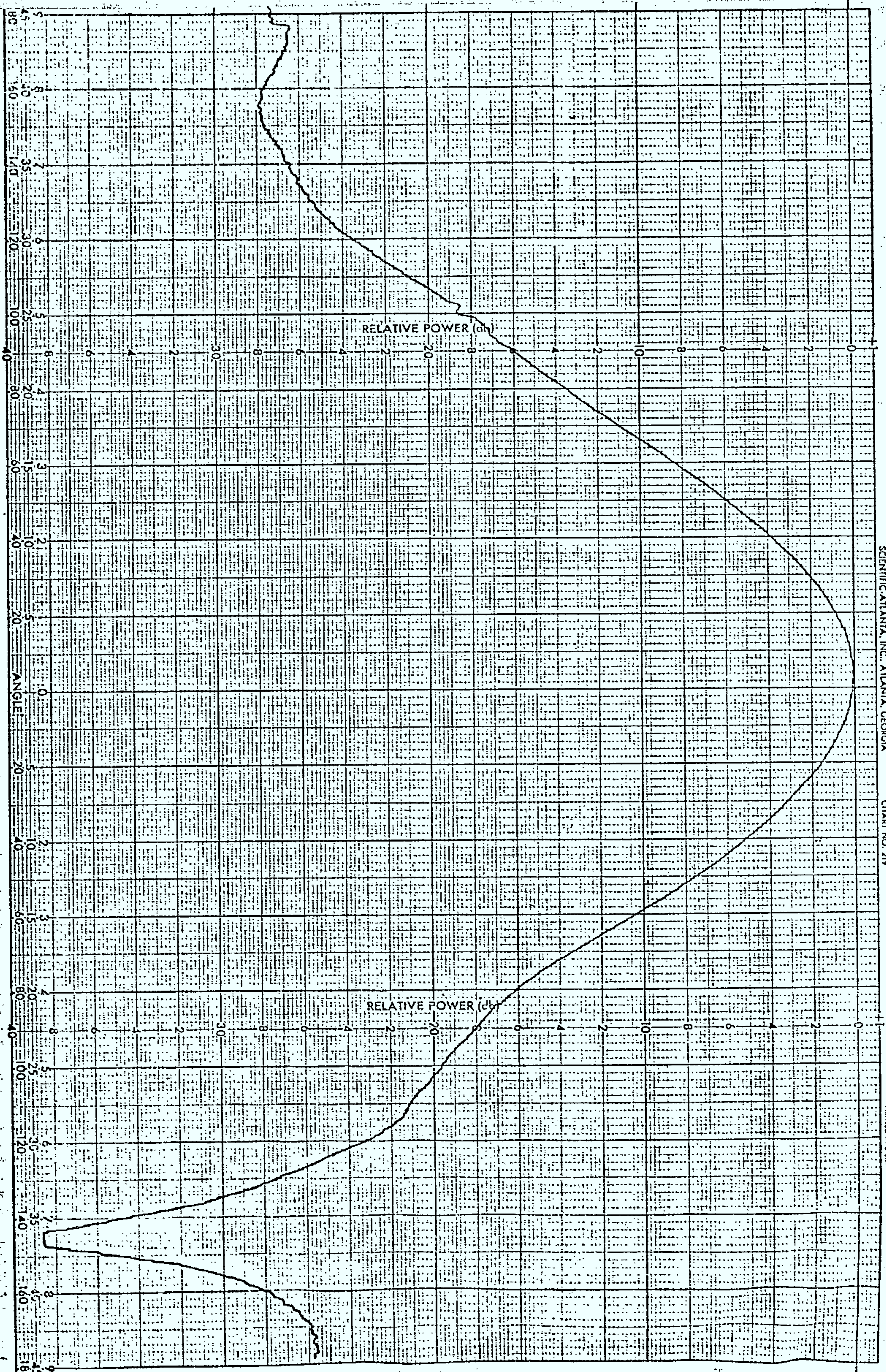
REMARKS 876 MHZ PATTERN TYPE: 1a

CAVITY BACK SPIRAL # 1

FIGURE 24e

JAN 6/82

169988



PROJECT MSAT

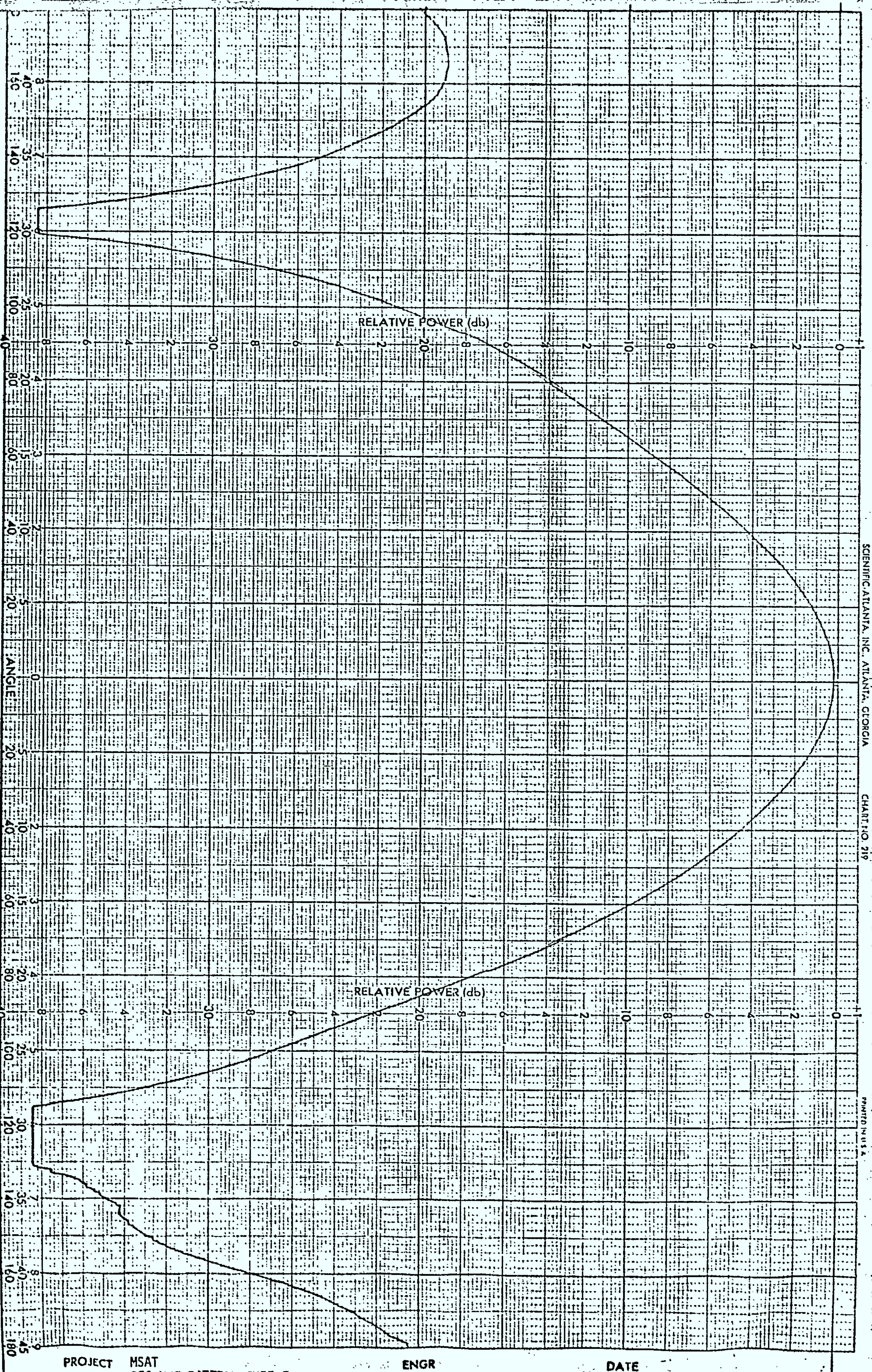
ENGR

DATE JAN 14/82

REMARKS 876 MHZ PATTERN TYPE 2a
CAVITY BACK SPIRAL # 1

FIGURE 24f

169SOS



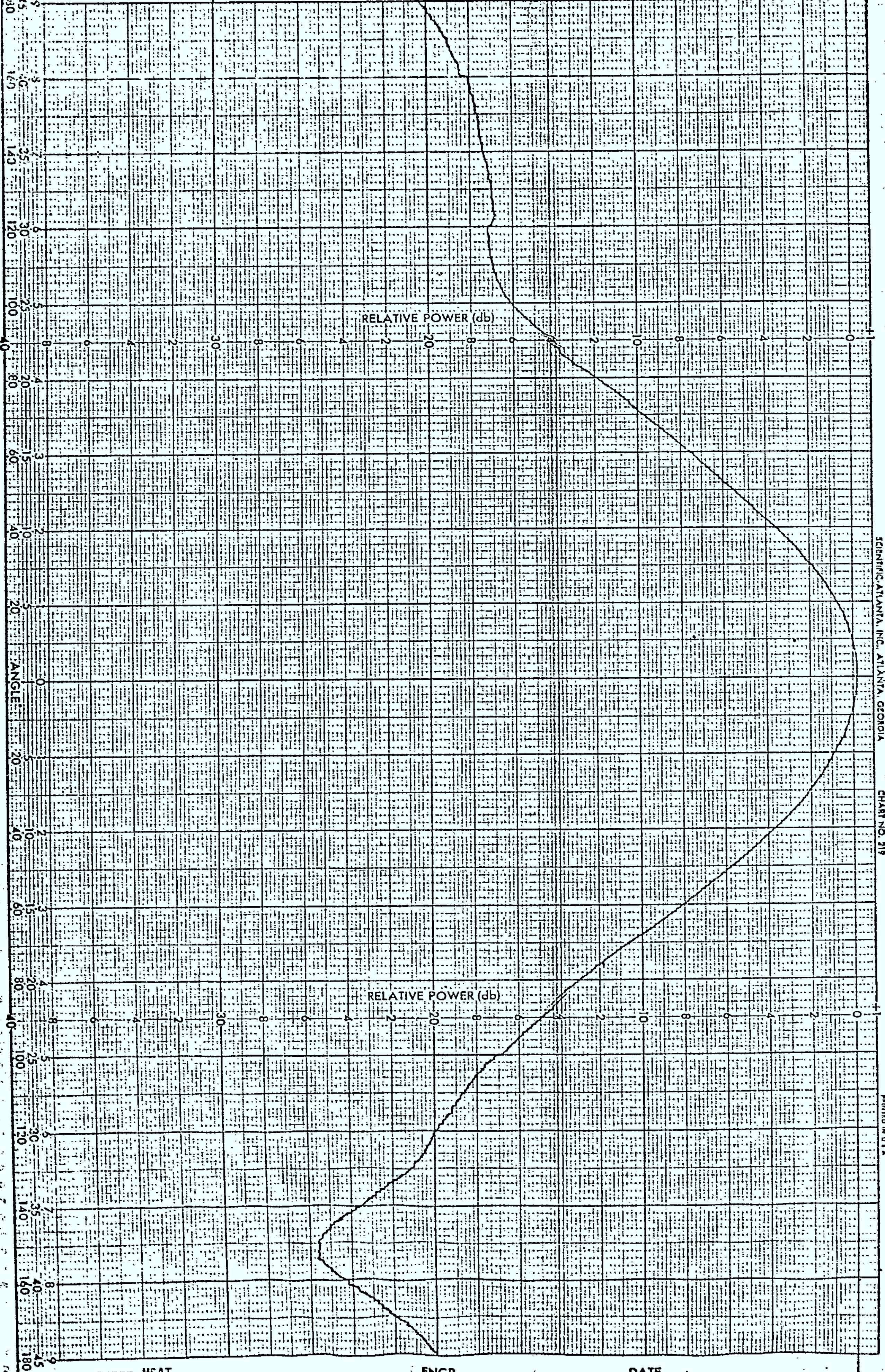
PROJECT MSAT
REMARKS 876 MHZ PATTERN TYPE 5a
CAVITY BACK SPIRAL # 1

ENGR

FIGURE 24g

DATE JAN. 6/82

169778



PROJECT HSAT

REMARKS 876 MHZ PATTERN TYPE: 6a
CAVITY BACK SPIRAL # 1

ENGR

FIGURE 24h

DATE JAN 14/82

169817

Form C1074

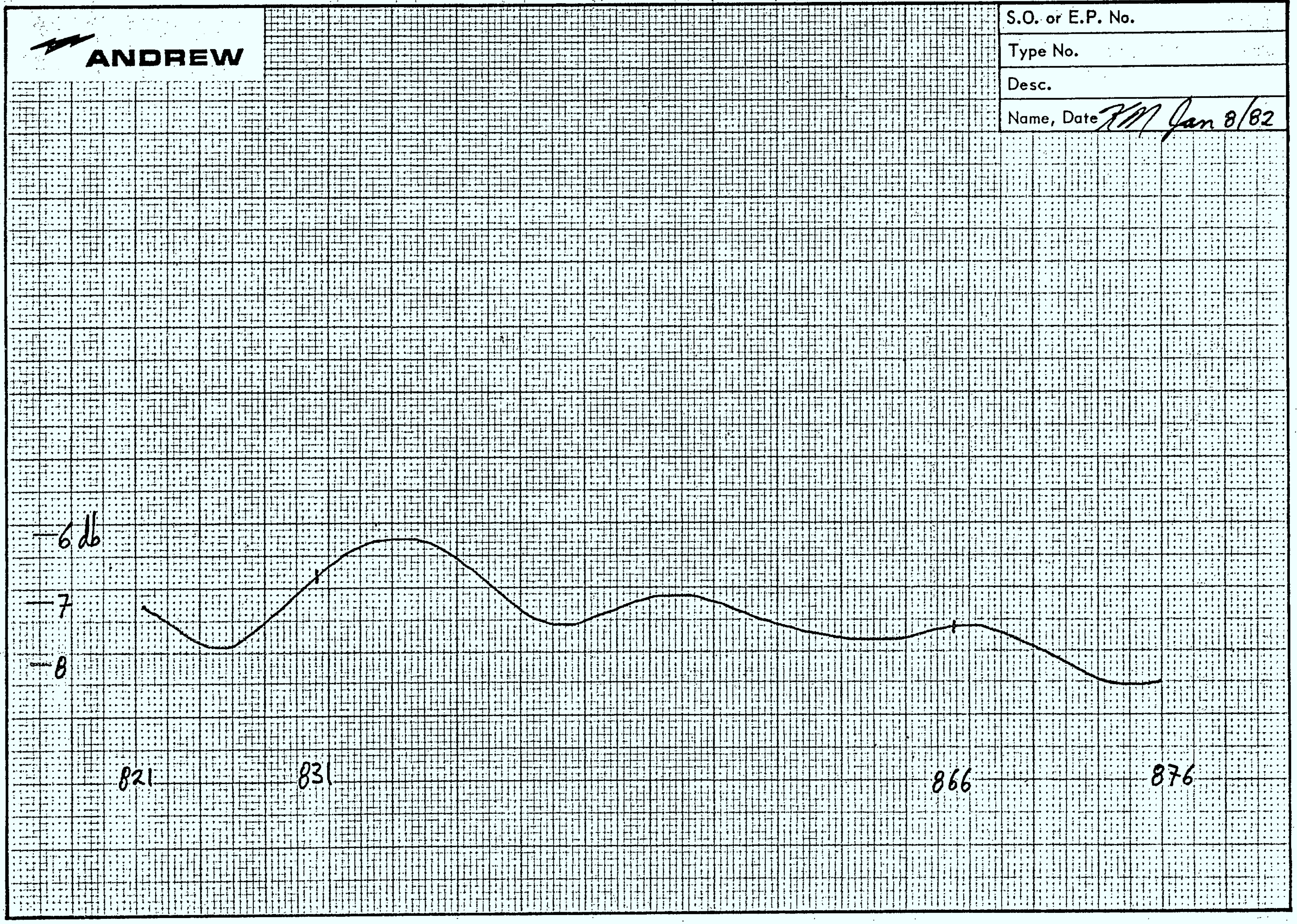


Figure 25. VSWR measurement for the antenna element of the "Suitcase" type antenna

TITLE DATE

IMPEDANCE COORDINATES—50-OHM CHARACTERISTIC IMPEDANCE

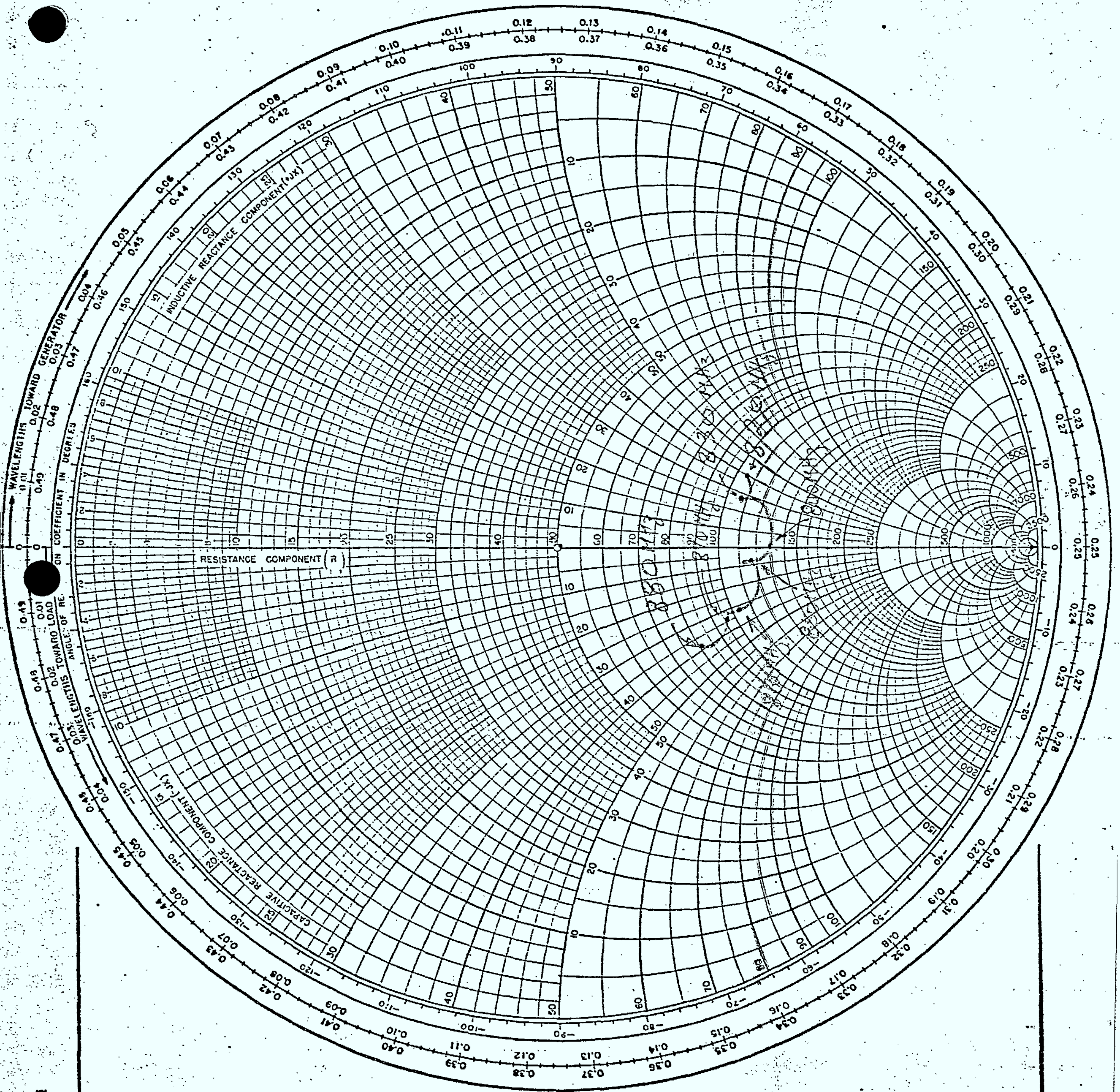
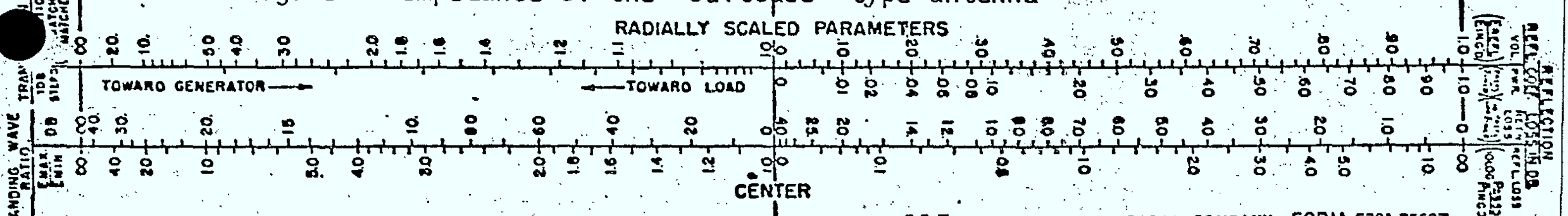
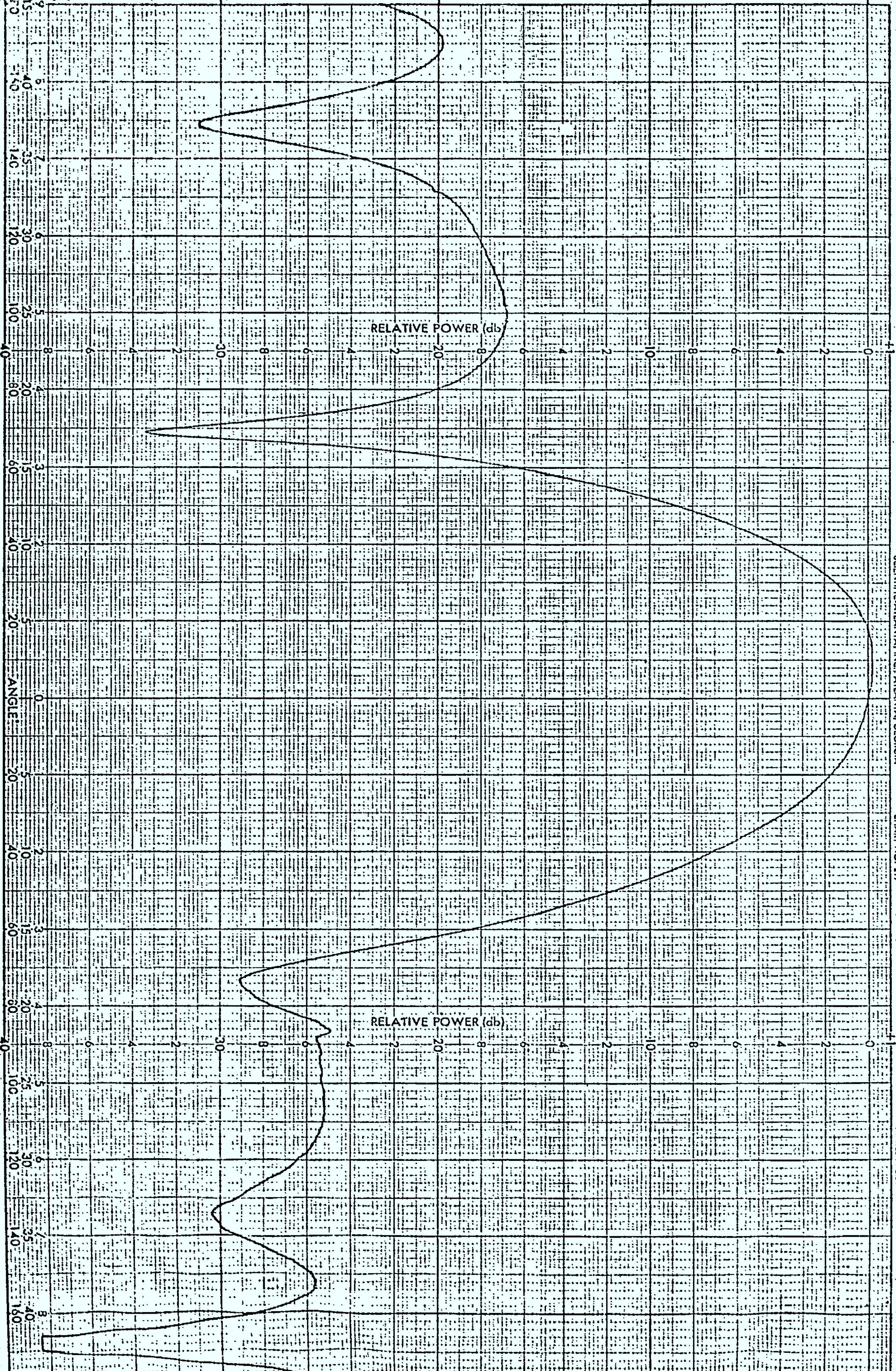


Figure 26 Impedance of the "Suitcase" type antenna



Electronics - VOL. 17, NO. 1, PP.-130-133, 318-325, JAN. 1944



PROJECT MSAT

REMARKS 876 MHZ PLANAR ARRAY

Spirals placed side-by-side Horizontally

Source Dipole 45° with vertical

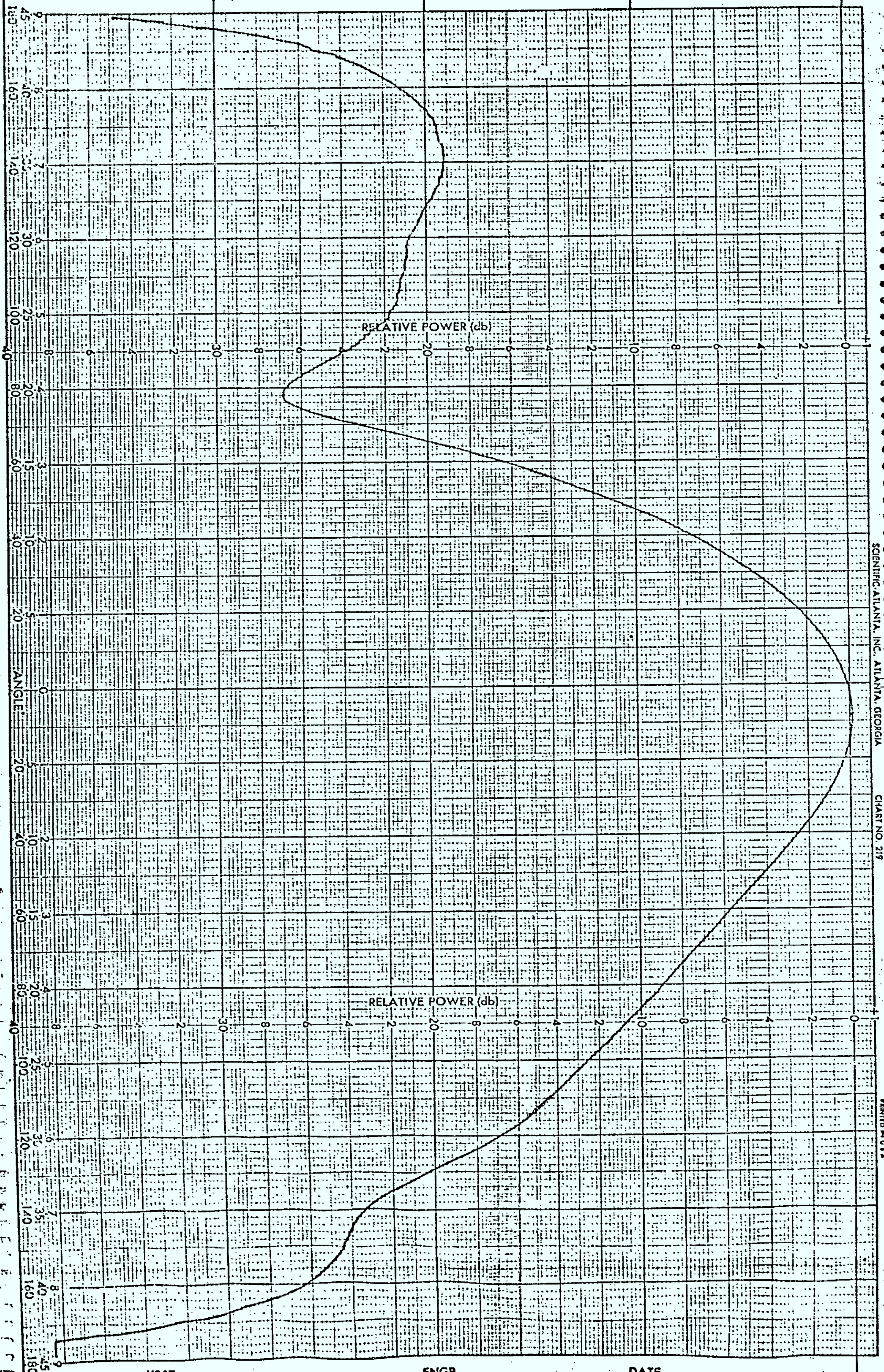
ENGR

FIGURE 27

DATE

Jan 15/82

160014



PROJECT MSAT

REMARKS 876 MHZ PLANAR ARRAY

Spirals placed side-by-side Vertically

Source dipole 45° with vertical

ENGR

FIGURE 28

DATE Jan 15/82

160031

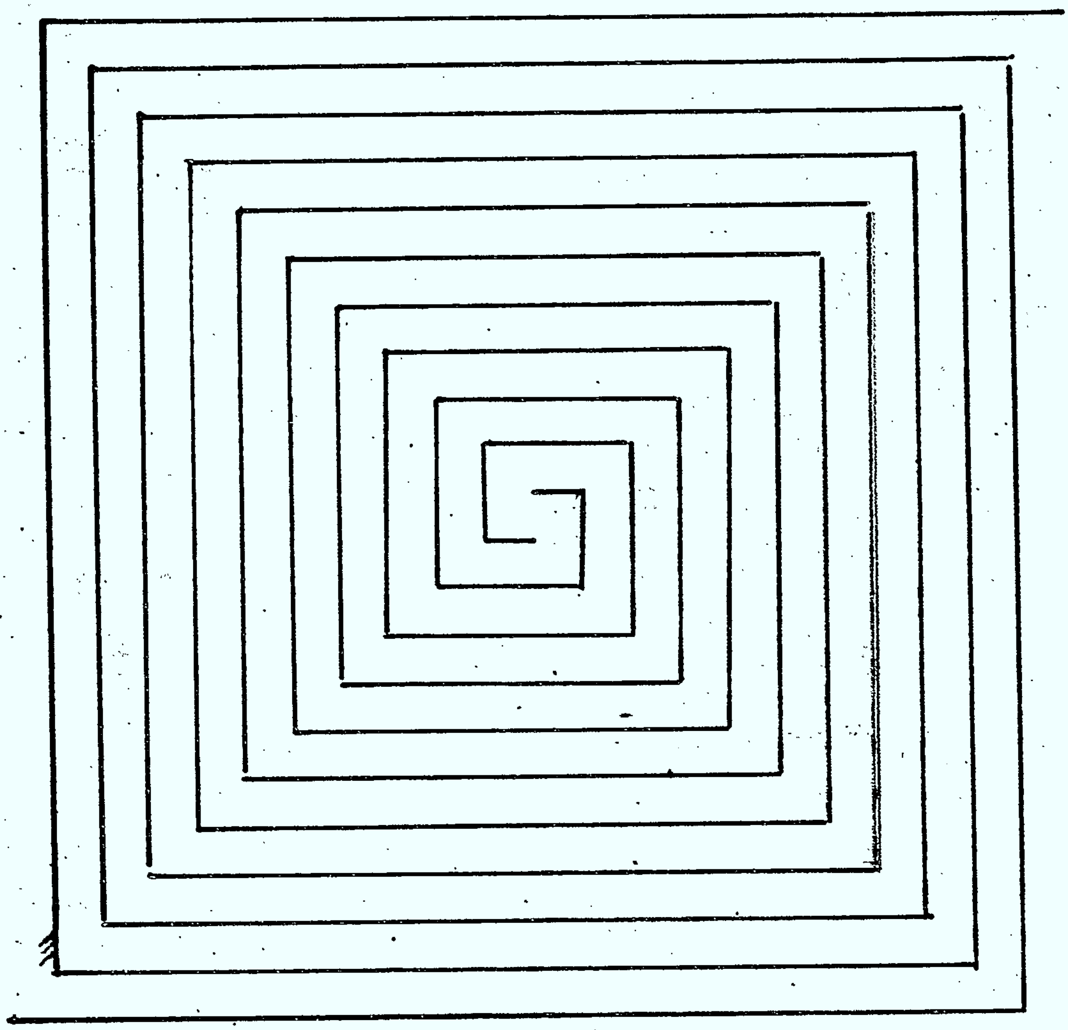


FIGURE 29 The Archimedean spiral

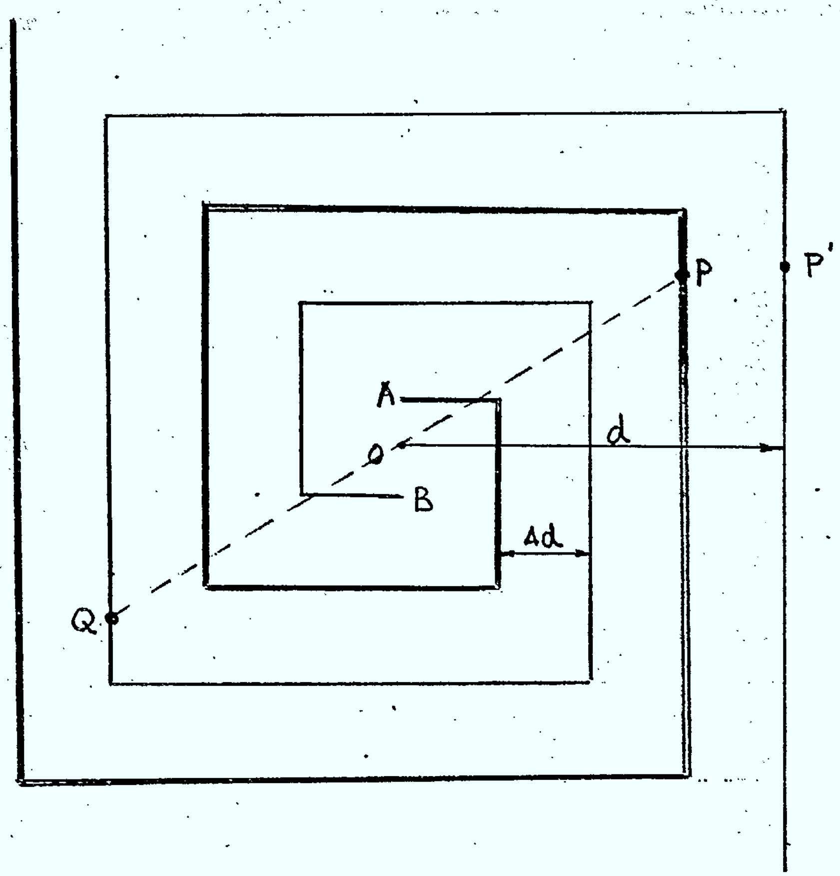


FIGURE 30 Simplified sketch of the Archimedean spiral