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ATMOSPHERIC OPTICAL MEASUREMENTS IN WESTERN FLORIDA,  
FLIGHT 112, Part IV, SKY RADIANCES (Red)

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TABLE OF CONTENTS

	Page
INTRODUCTION AND SUMMARY . . . . .	1
PROCEDURE . . . . .	3
Recording Schedule . . . . .	3
Flight Pattern, Figure 1 . . . . .	4
Zenith Angle and Azimuth of Sun, Figure 2 . . . . .	6
INSTRUMENTATION . . . . .	7
Sky Scanning Telephotometer, Figure 3 . . . . .	8
Scanning Pattern . . . . .	9
Filter-Phototube Spectral Responses, Figure 4 . . . . .	10
REDUCTION OF DATA . . . . .	12
PRESENTATION OF DATA . . . . .	13
Notation . . . . .	13
Organization of Data . . . . .	13
Lines used for Sky Radiance Plots, Figure 5 . . . . .	15
INDEX OF GRAPHS . . . . .	16
Sky Radiance (Red) vs Altitude, Figure 6, <u>et seq.</u> . . . . .	17
REFERENCES	
ACKNOWLEDGEMENTS	

Atmospheric Optical Measurements in Western Florida,  
Flight 112, Part IV, Sky Radiances (Red)\*

by

Almerian R. Boileau

INTRODUCTION AND SUMMARY

The Visibility Laboratory of the University of California, La Jolla Campus, is engaged in an on-going research program studying the transmission of optical images through the atmosphere. In connection with this work several data gathering flights were made in Florida, in the vicinity of Eglin Air Force Base, in the spring of 1957. Flight 112, during which data in this report were measured, was one of these flights.

Part I of this report, SIO Reference 60-22 of April 1960, presented data as a catalogue of recorded optical measurements less the sky luminance and radiance distribution.

Part II of the report, SIO Reference 60-32 of June 1960 presented sky luminance data in graph form showing the sky luminance distribution as it varied with altitude, zenith angle, and azimuth with respect to the sun. Similarly, Part III of this report, SIO Reference 60-55 of November 1960, presented sky radiance distribution as measured by a blue light sensitive filter-phototube combination.

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\* This report is a result of research which has been supported by the Geophysics Research Directorate, Air Force Research Division, Bedford, Massachusetts, and the U. S. Navy Bureau of Ships.

This part of the report, Part IV, presents the sky radiance distribution as measured by a red light sensitive filter-phototube combination, and shows how it varied with altitude, zenith angle, and azimuth.

## PROCEDURE

U. S. Air Force XB-29 No. 4224725 took off from Eglin Air Force Base, Florida, at 0917 Eastern Standard Time, 16 May 1957, to begin Flight 112. The airplane carried optical and meteorological instruments from the Visibility Laboratory of the University of California, La Jolla Campus. Two of the optical instruments were sky scanning telephoto-meters by which the sky luminance and radiance distributions were recorded. The airplane arrived at 20 000 feet altitude preparatory to data gathering at 1010.

Recording Schedule. Sky radiance distribution data were recorded as follows:

<u>Eastern Standard Time</u>	<u>Altitude</u>	<u>Headings</u>
1010-1036	20 000 feet	000°
1057-1108	10 000 feet	175°
1119-1127	1 000 feet	180°
1200-1204	Eglin Air Force Base B-29 on runway	185°

Flight Pattern. The flight pattern was north and south between Eglin Air Force and Crestview Florida, as shown in Fig. 1. immediately following this page. However, the sky distribution data were recorded in the northern part of the flight path in the vicinity of Crestview in order that the terrain over which data were recorded would be consistently of the same type.

Weather. The day was clear and warm. During ascent haze layers were observed at 1500, 3000, 7000, 10 000, 12 000, and 14 000 feet altitudes. These layers were observable only when seen edge-on; they could not

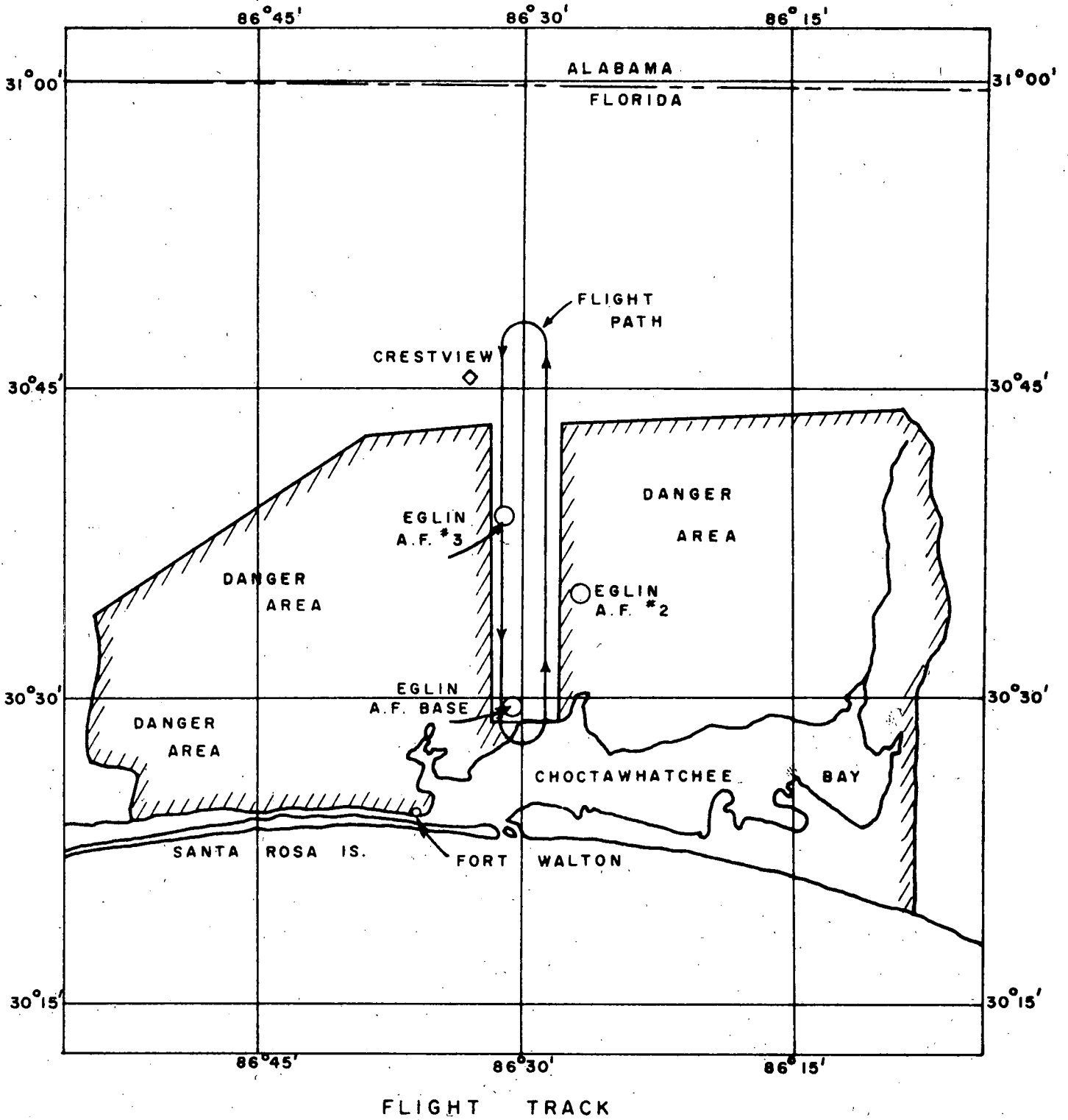


FIGURE 1  
FLIGHT 112  
16 MAY 1957  
CRESTVIEW, FLORIDA

be determined by an observer looking in either an upward or downward direction. At some distance from the flight pattern a few widely scattered altostratus and altocumulus clouds could be seen apparently at the altitude of some of the haze layers. Color prints showing the sky and terrain are included in Part I of this report.<sup>1</sup>

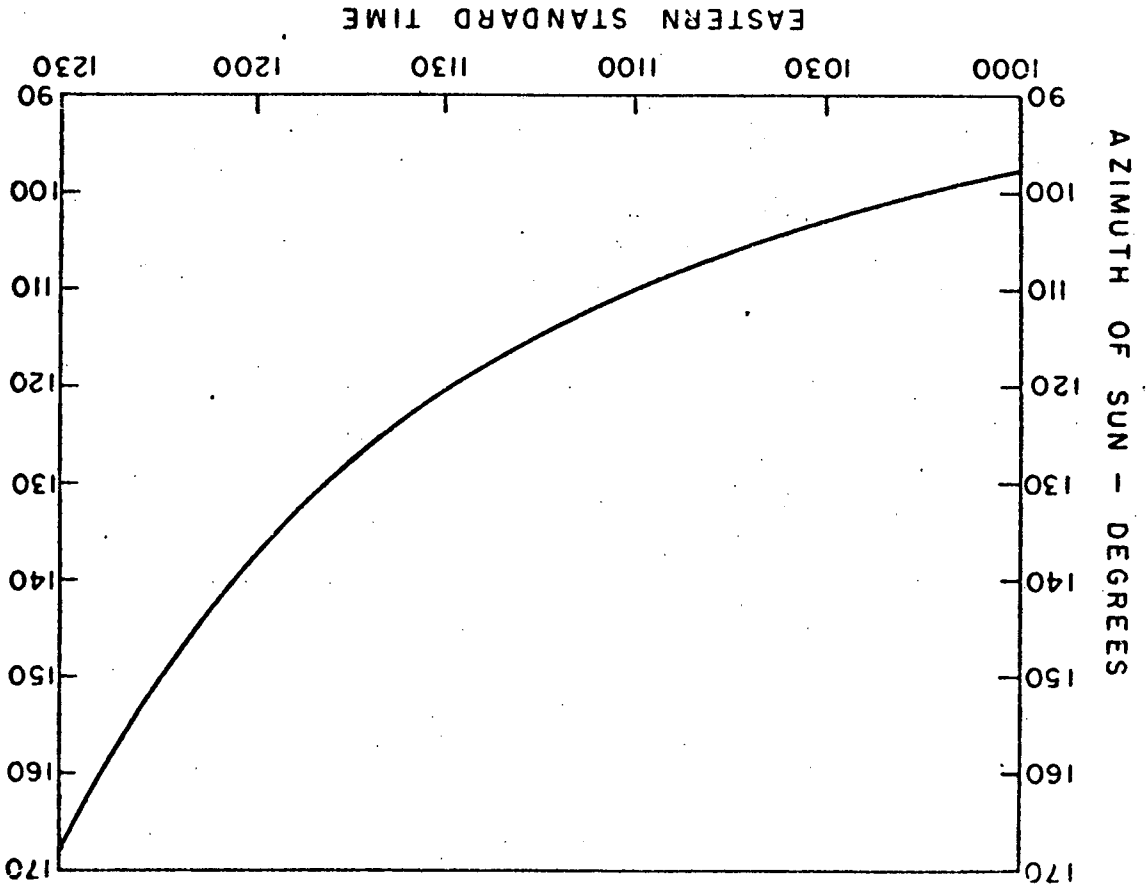
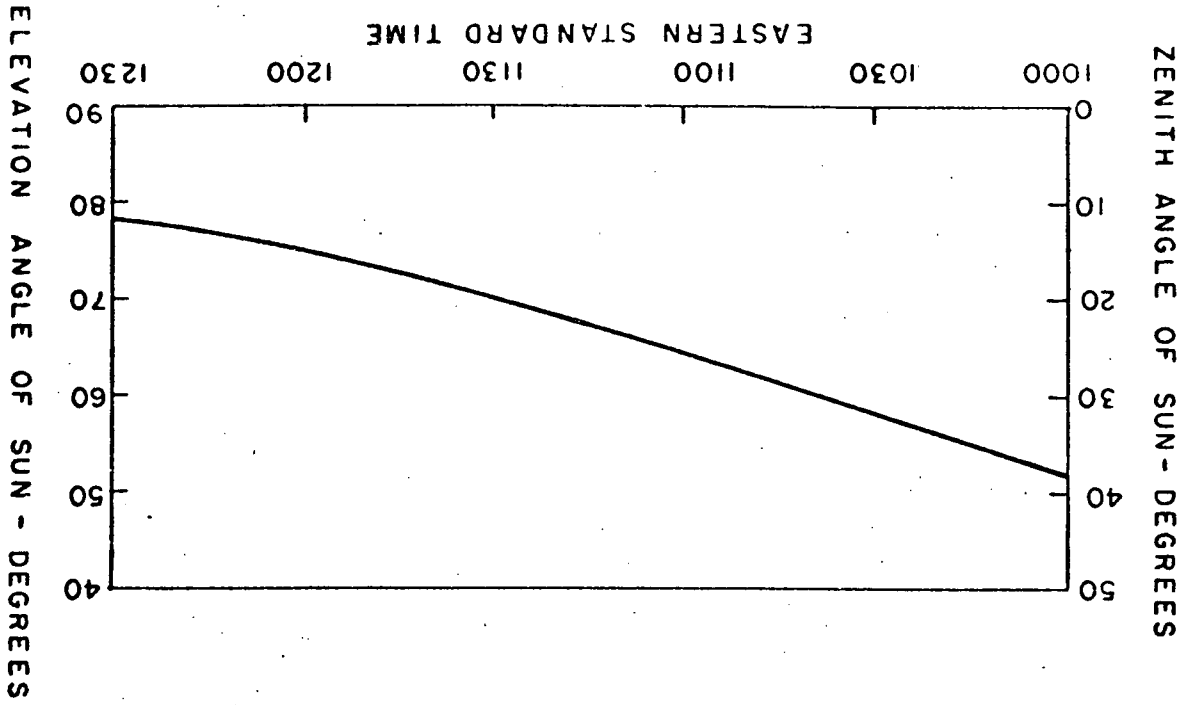
Position of Sun. The azimuth and zenith angle of the sun computed for  $30^{\circ} 40'$  N. Lat. and  $86^{\circ} 30'$  W. Long., the approximate location of Crestview, are shown in Fig. 2, immediately following this page. These angles are plotted for the period 1000 to 1230 Eastern Standard Time. The ordinates on the lower graph are shown as zenith angles on the left and elevation angles on the right, these angles being complementary.

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1. "Atmospheric Optical Measurements in Western Florida, Flight 112, Part I," A. R. Boileau, SIO Reference 60-22, April 1960.

CRESTVIEW, FLORIDA  
 MAY 16, 1957  
 FLIGHT 112  
 FIGURE 2

LONG 86 - 30 W  
 COMPUTED FOR LAT 30-40 N  
 ANGLES OF SUN DURING FLIGHT 112

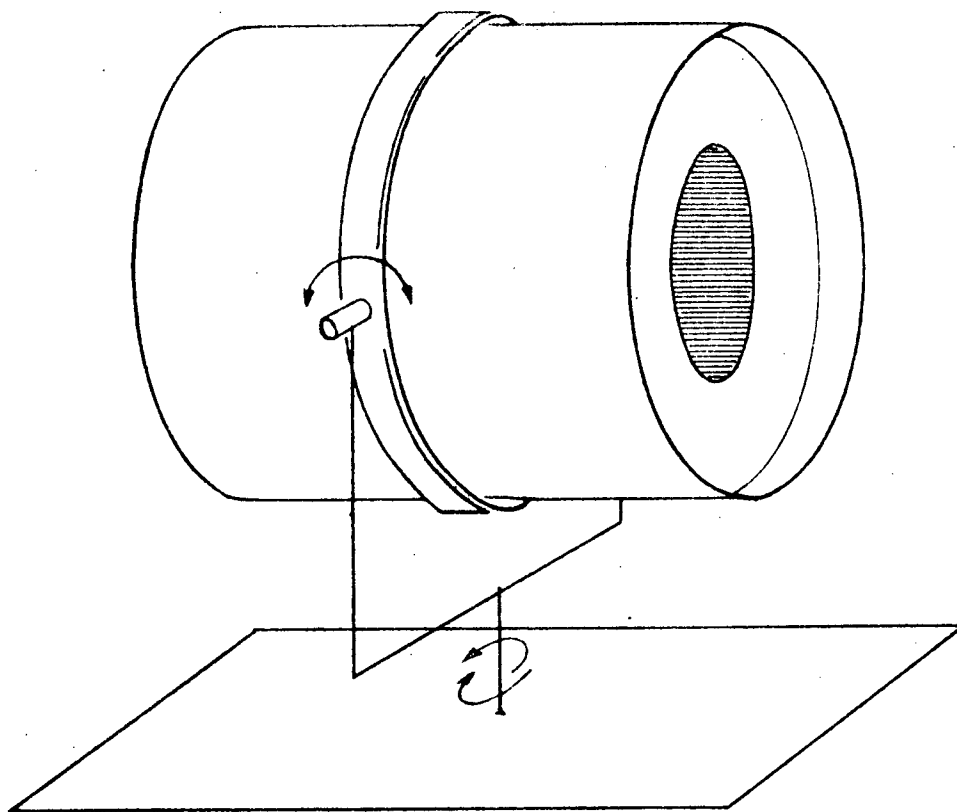
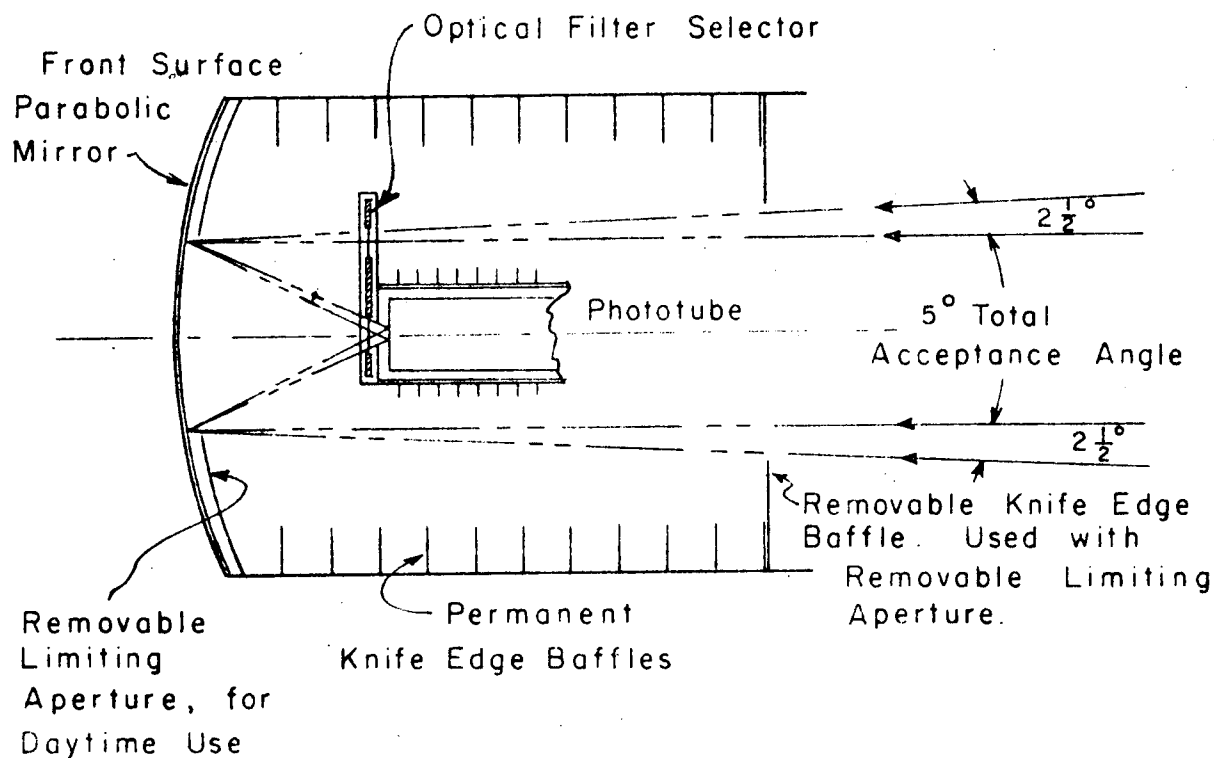


## INSTRUMENTATION

Sky Scanning telephotometers. Two sky scanning telephotometers were carried by the XB-29, one mounted in the forward upper gun turret position and one in a retracting mount in the rearmost lower gun turret position. The telephotometers were operated from the control position in the pressurized after compartment of the XB-29. Once started, both telephotometers continued their scanning operation until completion, at which time they automatically stopped and remained stopped until restarted.

The sky scanning telephotometers are shown schematically in Fig. 3 immediately following this page. The optical unit, shown at the top of the Figure, consists of a cylindrical shell with a 13" parabolic front surface mirror mounted on one end of the shell and an end-on multiplier phototube mounted with its light-sensitive surface at the focus of the mirror. A field stop in front of the light-sensitive surface limits the incoming rays to those contained in a  $5^{\circ}$  circular cone.

The optical units of the sky scanning telephotometers were designed for use in both high and low light levels. For high light level or day time use the sensitivity of the photometer is reduced by the mirror limiting aperture. The flux incident on the phototube is further reduced by the use of neutral density filters. Internal scattering is kept to a minimum by the removable front knife-edge baffle and the permanent knife-edge baffles throughout the inside length of the cylindrical shell and on the outside of the phototube housing.



SKY SCANNING TELEPHOTOMETER

Figure 3

In front of the field stop there is an optical filter selector mechanism which by being operable from the control position permits any one of four optical filters to be interposed in the flux path. The relative spectral sensitivities of the four filter and phototube combinations are shown in Fig. 4 immediately following this page.

The data presented in this part of the report are the data as seen by the "Red" filter - phototube combination.

Scanning Patterns. The scanning patterns of the two sky scanning telephotometers are such that the optical units scan in elevation with a change of azimuth occurring between elevation scans in the case of the upper scanner and simultaneously with elevation scans in the case of the lower scanner.

The upper scanning telephotometer starts from  $2\ 1/2^\circ$  below the horizontal, scans upward through the zenith and continues downward to  $2\ 1/2^\circ$  below the horizontal  $180^\circ$  from the starting azimuth. At the conclusion of an elevation scan the scanner shifts  $10^\circ$  in azimuth and starts a return scan. It makes eighteen elevation scans, thereby completing the upper sky in 90 seconds. At the end of the eighteen elevation scan it reverses its azimuth drive and again scans the upper sky, in reverse, in 90 seconds. A change of optical filters during the time of reversal permits two complete upper sky measurements to be completed in three minutes.

The scanning pattern of the lower sky scanning telephotometer is similar to the scanning pattern of the upper sky scanning telephotometer in that it starts from  $2\ 1/2^\circ$  above the horizontal, scans downward through the nadir and continues upward to  $2\ 1/2^\circ$  above the

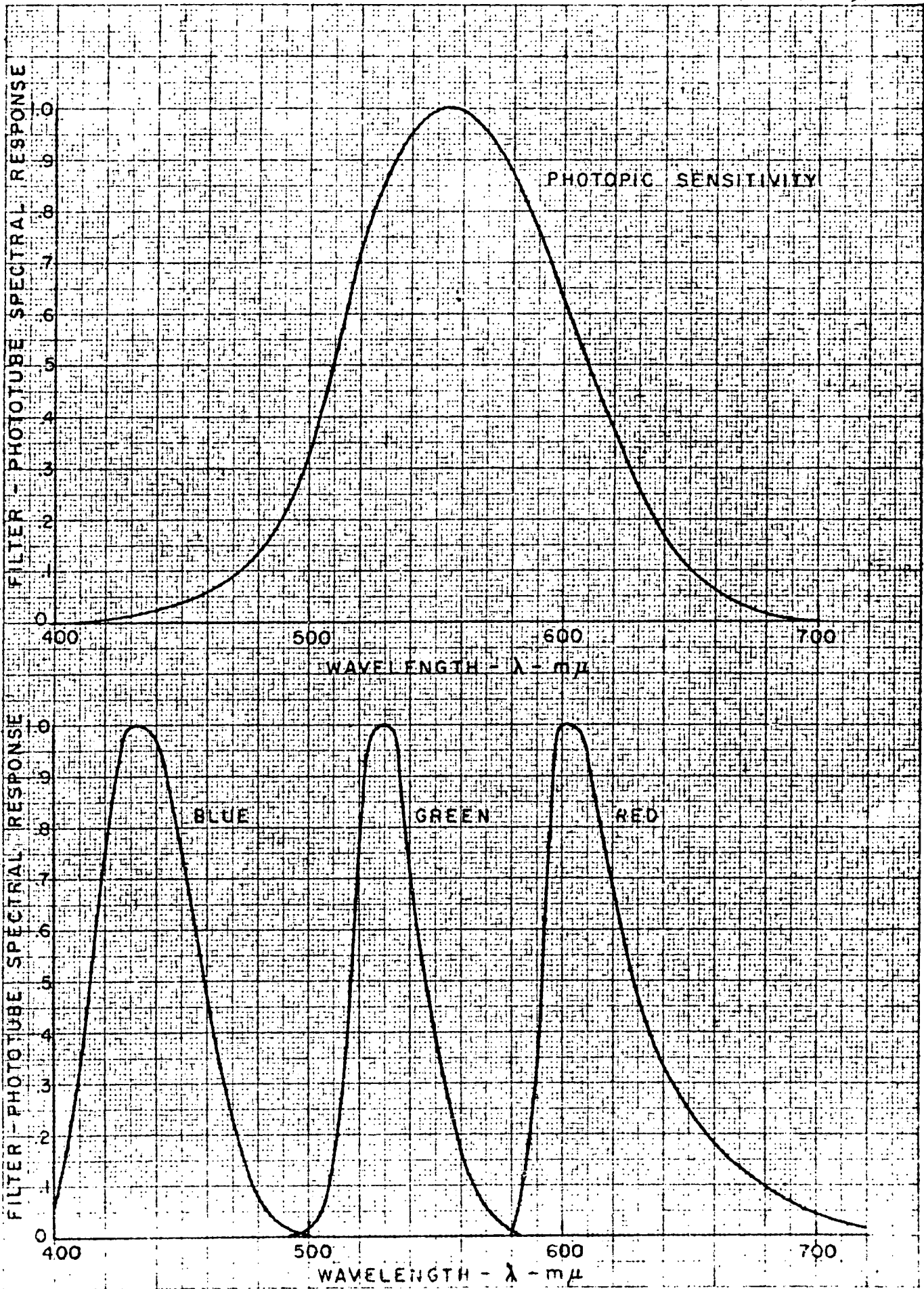


Figure 4

## REDUCTION OF DATA

Method of Recording. Data were recorded during Flight 112 on Sanborn Recorder strip charts. The data were continuous traces representing the value of sky radiance as the scanners operated through their cycles. The angular positions in elevation of the scanners, that is, their zenith angle positions, were indicated by a marking stylus which was activated by a microswitch in contact with a protractor type cam. The data recording stylus and the zenith angle marking stylus recorded continuously and simultaneously so that zenith angle indications and corresponding sky radiance data were synchronized. Because the scanners always started from and stopped in the same azimuthal positions, the azimuth of each elevation scan was easily determined by counting the number of elevation scans.

Handling of Data. The strip chart data were read directly onto IBM cards by the use of computer peripheral equipment. Through the operation of a Burroughs No. 220 computer at the U. S. Navy Electronics Laboratory, San Diego, California, which was programmed to correct for the nonlinearities of the airborne electronic recording equipment, the data points were converted into tables of equivalent radiance values. These radiance values were plotted against azimuth values on semi-logarithmic paper, the azimuth being with reference to geographical north. The azimuthal scale marked off along the linear coordinates of the graph paper was then shifted to cause the azimuthal scale to indicate azimuth with reference to the sun. The last step was to replot radiance values for selected zenith angles against altitude on semi-logarithmic graph paper. Continuous curves were then drawn through these points.

horizontal. It differs from the scanning pattern of the upper sky scanning telephotometer in that it rotates in azimuth at a constant rate, changing  $10^{\circ}$  in azimuth with each elevation scan. At the conclusion of eighteen elevation scans in a little less than 90 seconds it automatically reverses and retraces its pattern. A change of optical filters during the time of reversal permits two lower sky measurements to be completed in the same manner as but in slightly less time than the upper sky measurements.

## PRESENTATION OF DATA

Notation. The notation in this report follows the notation for the various radiometric and photometric optical quantities discussed in detail elsewhere.<sup>2</sup> The general symbol for radiance is  $N$ . The particular symbol for the radiance of a path of sight when neither the path length is specified nor the source of radiance identified is  $N(z, \theta, \phi)$ , the parenthetic symbols indicating that the photometer is at altitude  $z$  and that the path of sight is as specified by the zenith angle  $\theta$  and the azimuth  $\phi$ . The zenith angle varies from  $0^\circ$  for looking vertically upward to  $180^\circ$  for looking vertically downward. The azimuth  $\phi$  in this report is with reference to the sun.

Organization of data. The data are presented as a series of semi logarithmic plots in which the linear ordinate values represent altitudes and the logarithmic abscissa values represent radiances. Each Figure consists of four sheets (with the exception of Fig. 6 which has five sheets) and presents radiance data for one azimuth as a group of curves, each curve representing radiance for one specific zenith angle. The Figures are arranged in order of increasing azimuth in increments of  $20^\circ$  starting with an azimuth of  $0^\circ$  and ending with an azimuth of  $340^\circ$ .

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2. "Image Transmission by the Troposphere I", S. G. Duntley, A. R. Boileau and R. W. Preisendorfer, JOSA 47, 499-506, (1957).

As stated above each Figure, with two exceptions, consists of four sheets. These sheets present data as follows:

Sheet a - zenith angles of  $0^{\circ}$ ,  $15^{\circ}$ ,  $30^{\circ}$ ,  $45^{\circ}$ , and  $60^{\circ}$ .

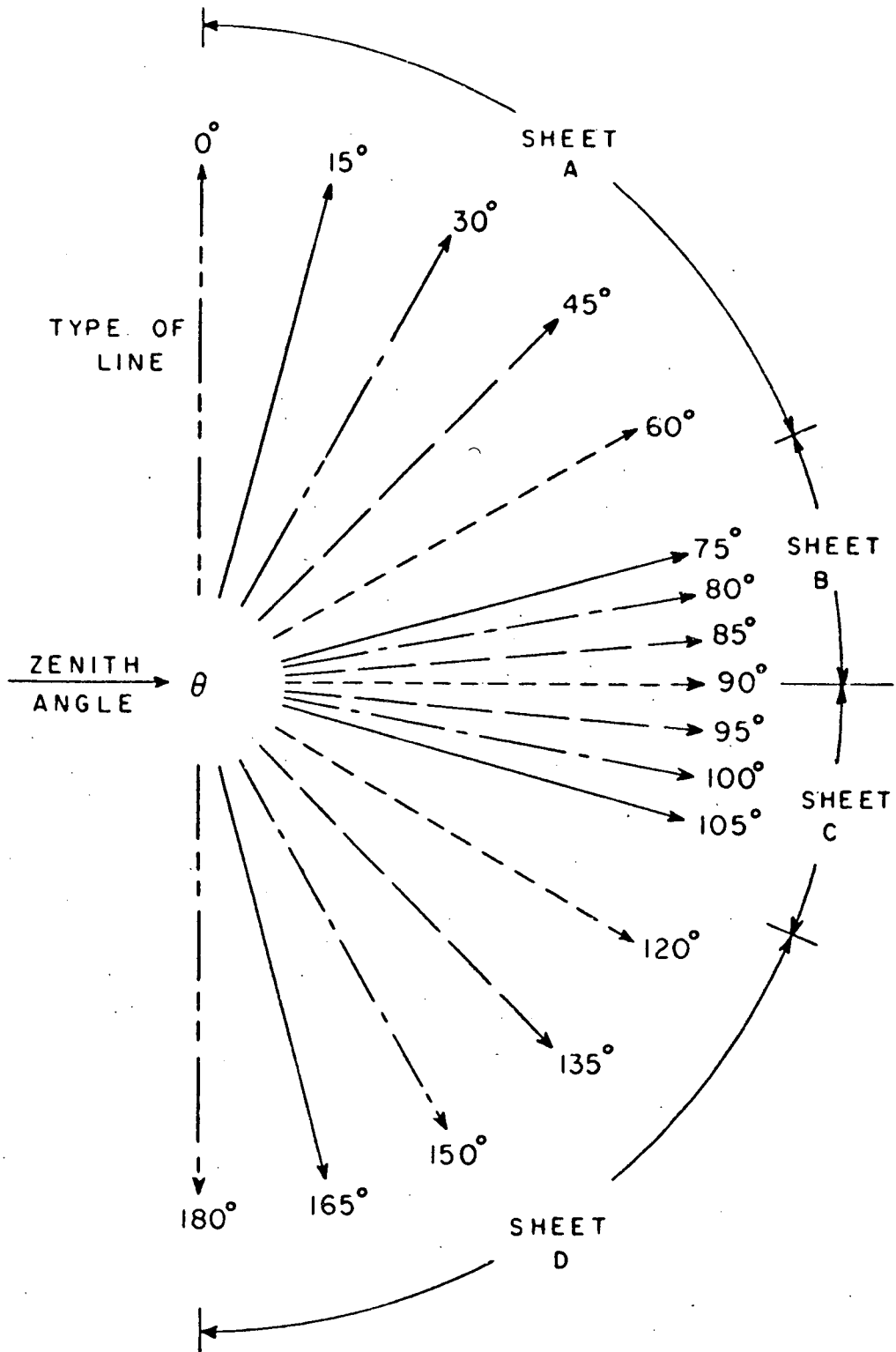
Sheet b - zenith angles of  $75^{\circ}$ ,  $80^{\circ}$ ,  $85^{\circ}$ , and  $90^{\circ}$ .

Sheet c - zenith angles of  $90^{\circ}$ ,  $95^{\circ}$ ,  $100^{\circ}$ , and  $105^{\circ}$ .

Sheet d - zenith angles of  $120^{\circ}$ ,  $135^{\circ}$ ,  $150^{\circ}$ ,  $165^{\circ}$ , and  $180^{\circ}$ .

To differentiate between the data plots for the different zenith angles five distinctive types of lines are used. These lines are illustrated in Fig. 5 immediately following this page.

In the cases of the first and last data Figures, azimuths of  $0^{\circ}$  and  $340^{\circ}$ , respectively, five sheets comprise each Figure. This is because the radiance values for some of the zenith angles at these azimuths exceed the scale of radiance values printed on the master plotting sheet within which almost all of the data fell. The additional sheets are designated as sheet "aa" of the Figure and carry the warning "NOTE CHANGE OF SCALE" near the bottom of the sheet. The scale for these sheets is greater by a factor of 10.

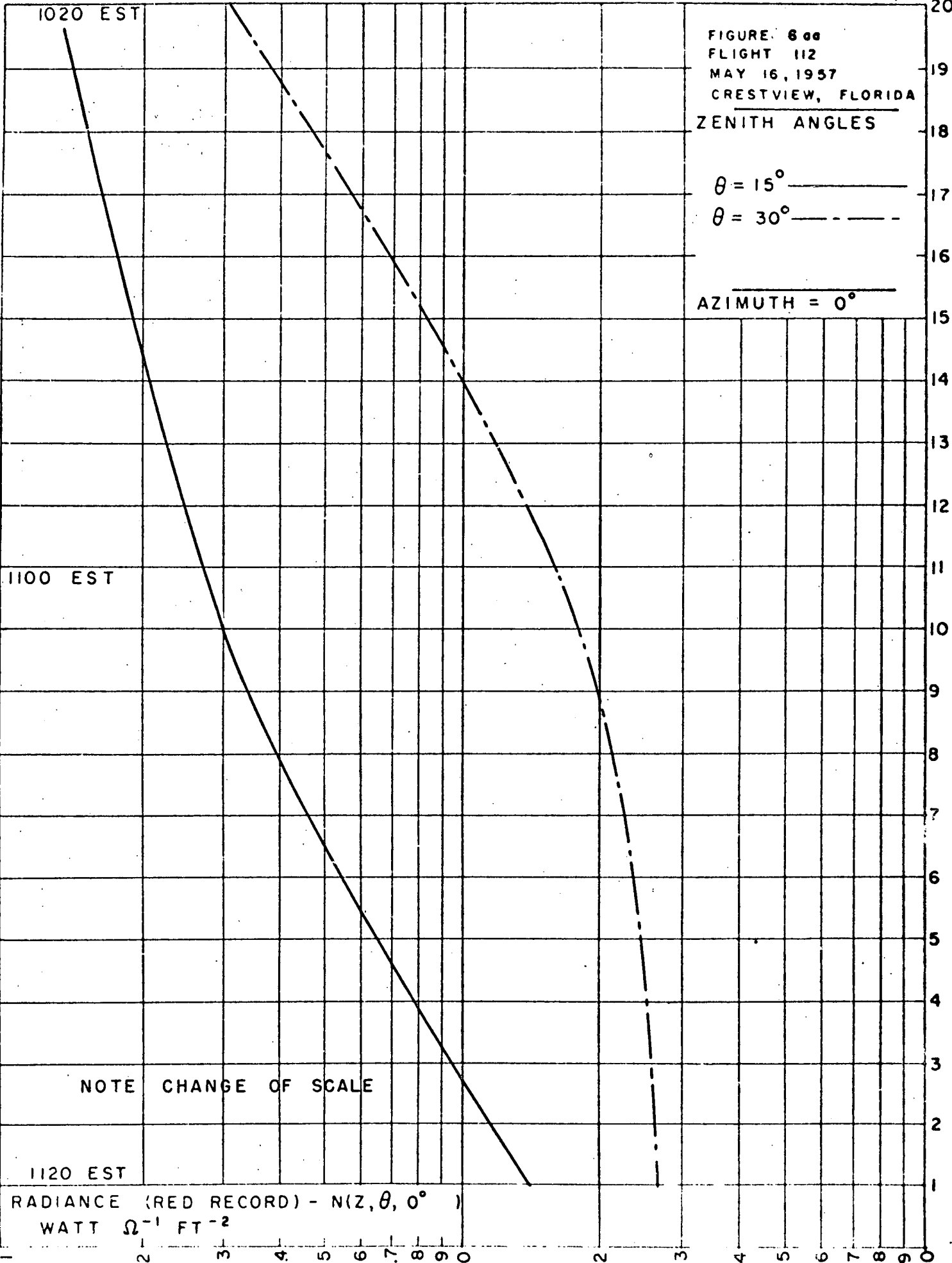


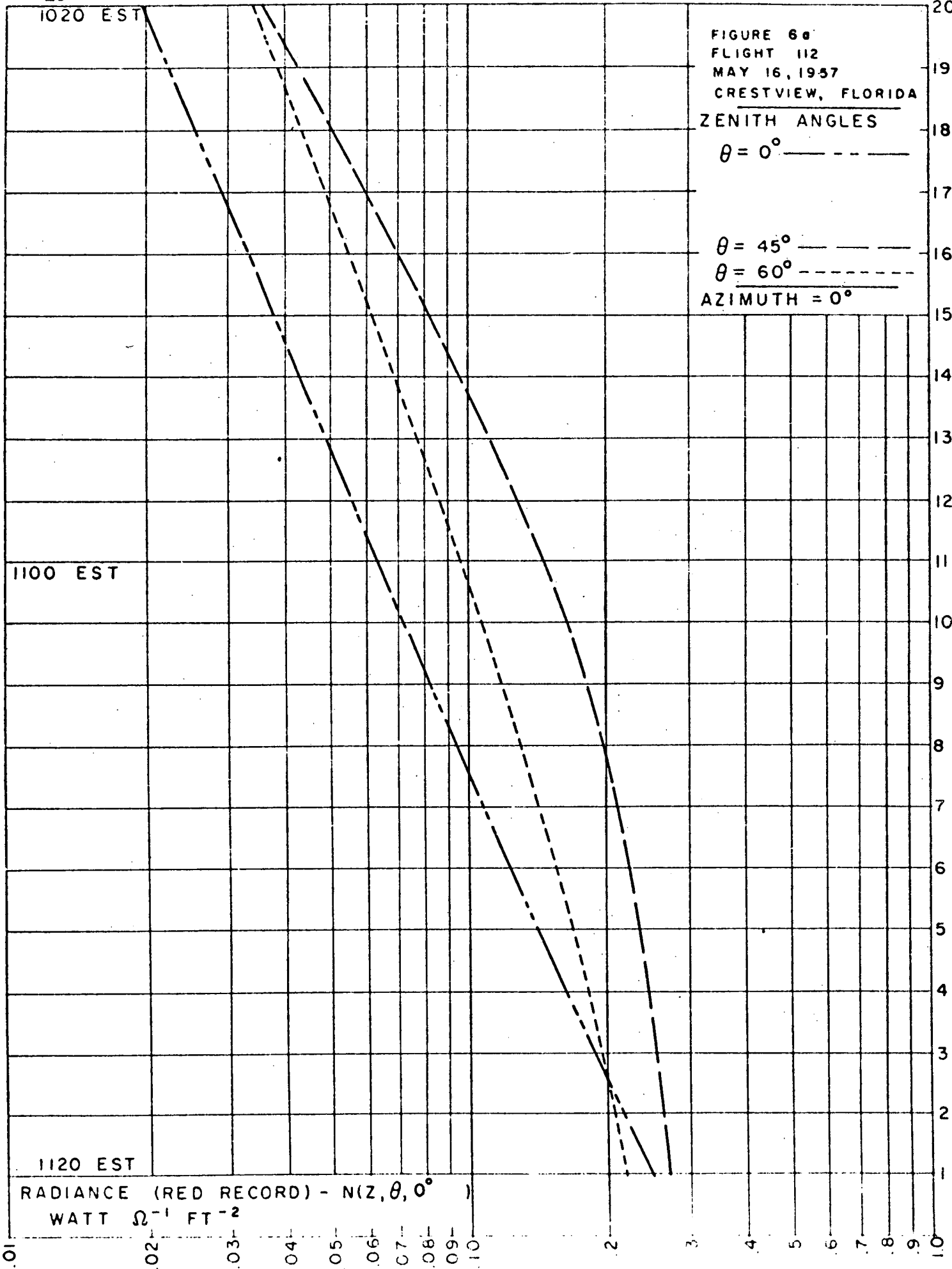
LINES USED FOR SKY RADIANCE PLOTS.

FIGURE 5  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW FLORIDA

INDEX OF GRAPHS

<u>Figure</u>	<u>Azimuth</u>	<u>Page</u>
6	0°	17
7	20°	22
8	40°	26
9	60°	30
10	80°	34
11	100°	38
12	120°	42
13	140°	46
14	160°	50
15	180°	54
16	200°	58
17	220°	62
18	240°	66
19	260°	70
20	280°	74
21	300°	78
22	320°	82
23	340°	86





SIO Ref. 60-56

1020 EST

FIGURE 6b  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 75^\circ$  —————

$\theta = 80^\circ$  - - - - -

$\theta = 85^\circ$  — — — — —

$\theta = 90^\circ$  - - - - -

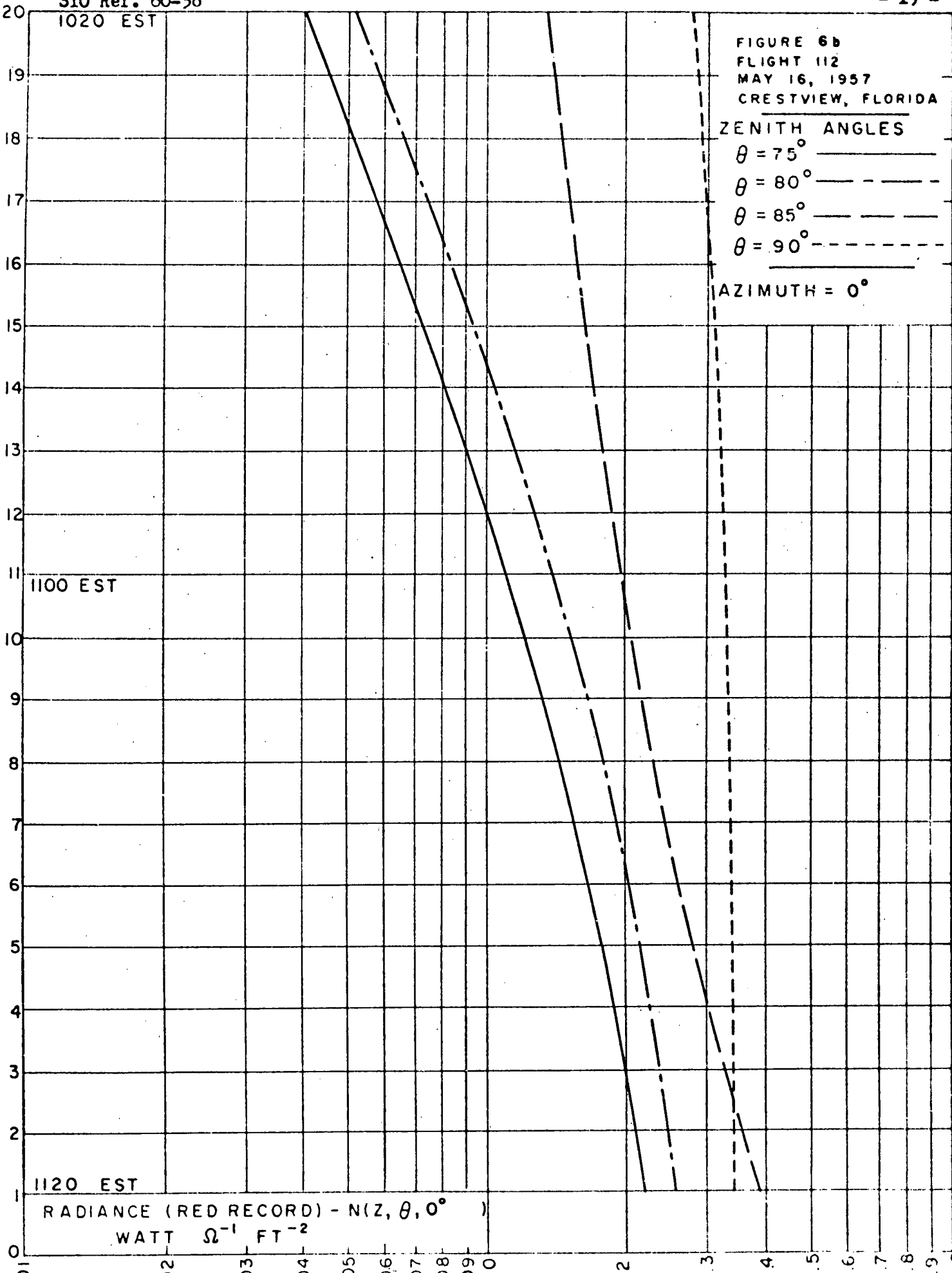
AZIMUTH =  $0^\circ$

ALTITUDE - THOUSANDS OF FEET

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 0^\circ)$   
WATT  $\Omega^{-1}$  FT $^{-2}$



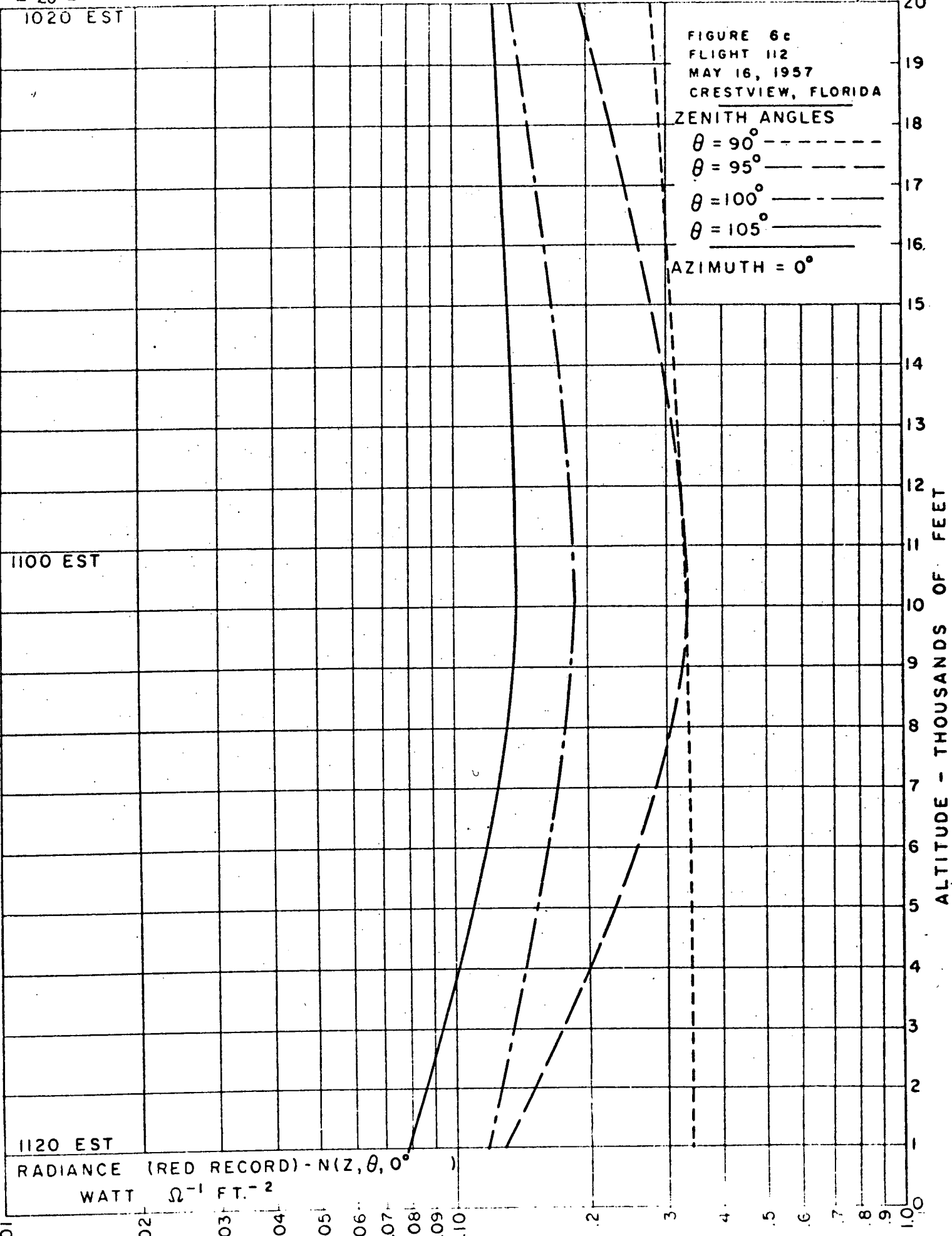
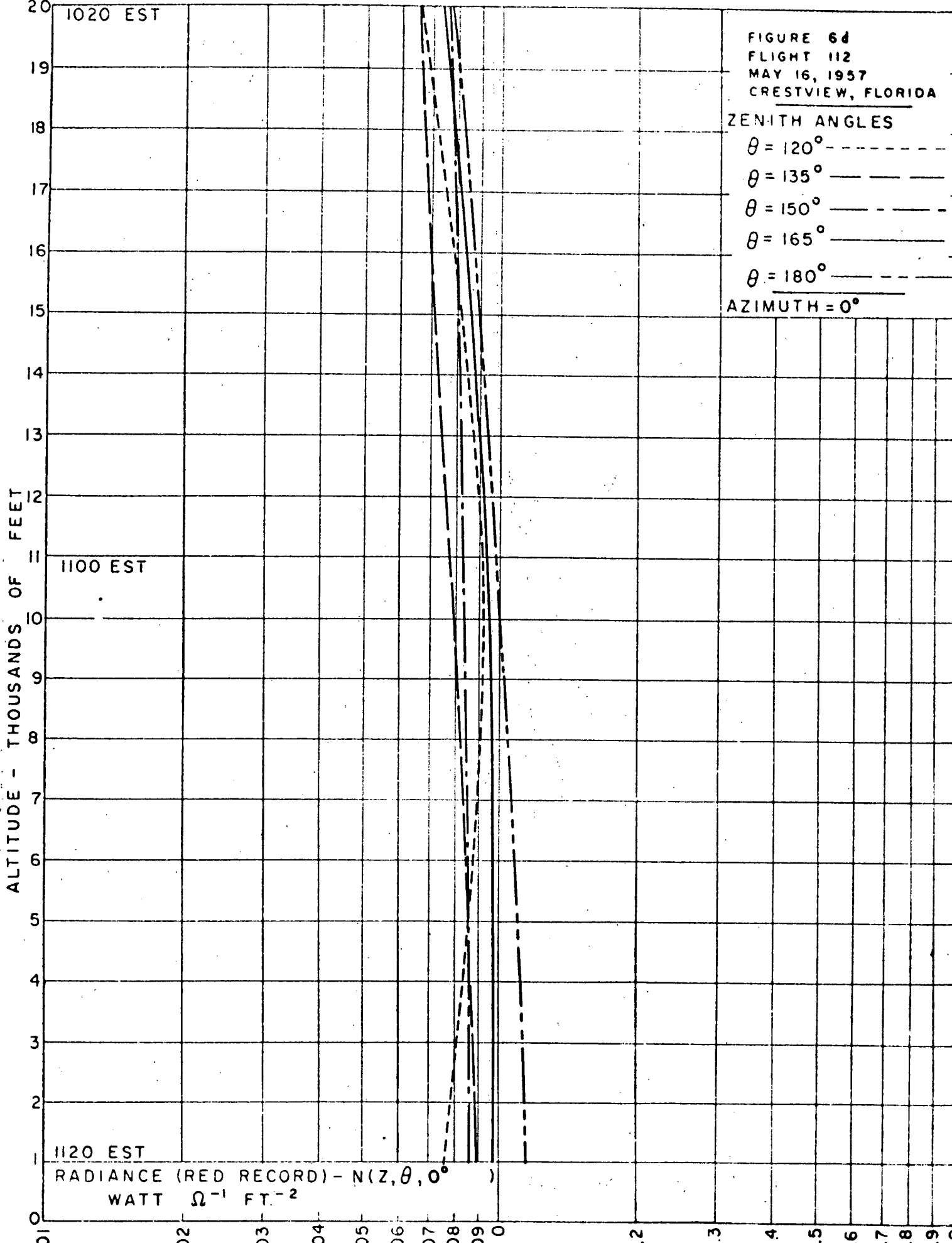


FIGURE 6d  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 120^\circ$  - - - - -  
 $\theta = 135^\circ$  - - - - -  
 $\theta = 150^\circ$  - - - - -  
 $\theta = 165^\circ$  - - - - -  
 $\theta = 180^\circ$  - - - - -  
AZIMUTH =  $0^\circ$



RADIANCE (RED RECORD) -  $N(Z, \theta, 0^\circ)$   
WATT  $\Omega^{-1}$  FT.<sup>-2</sup>

ALTITUDE - THOUSANDS OF FEET

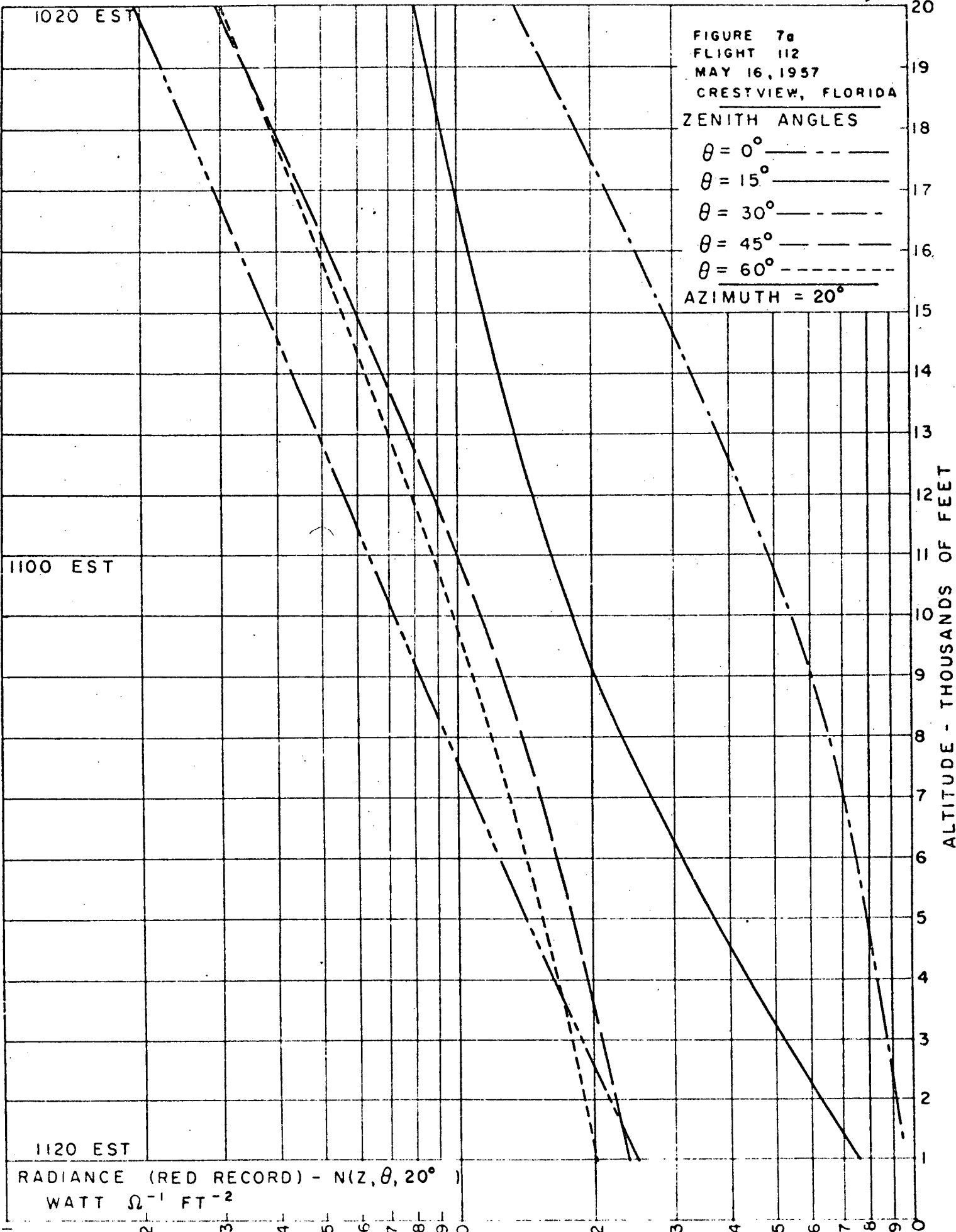
20  
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16  
15  
14  
13  
12  
11  
10  
9  
8  
7  
6  
5  
4  
3  
2  
1  
0

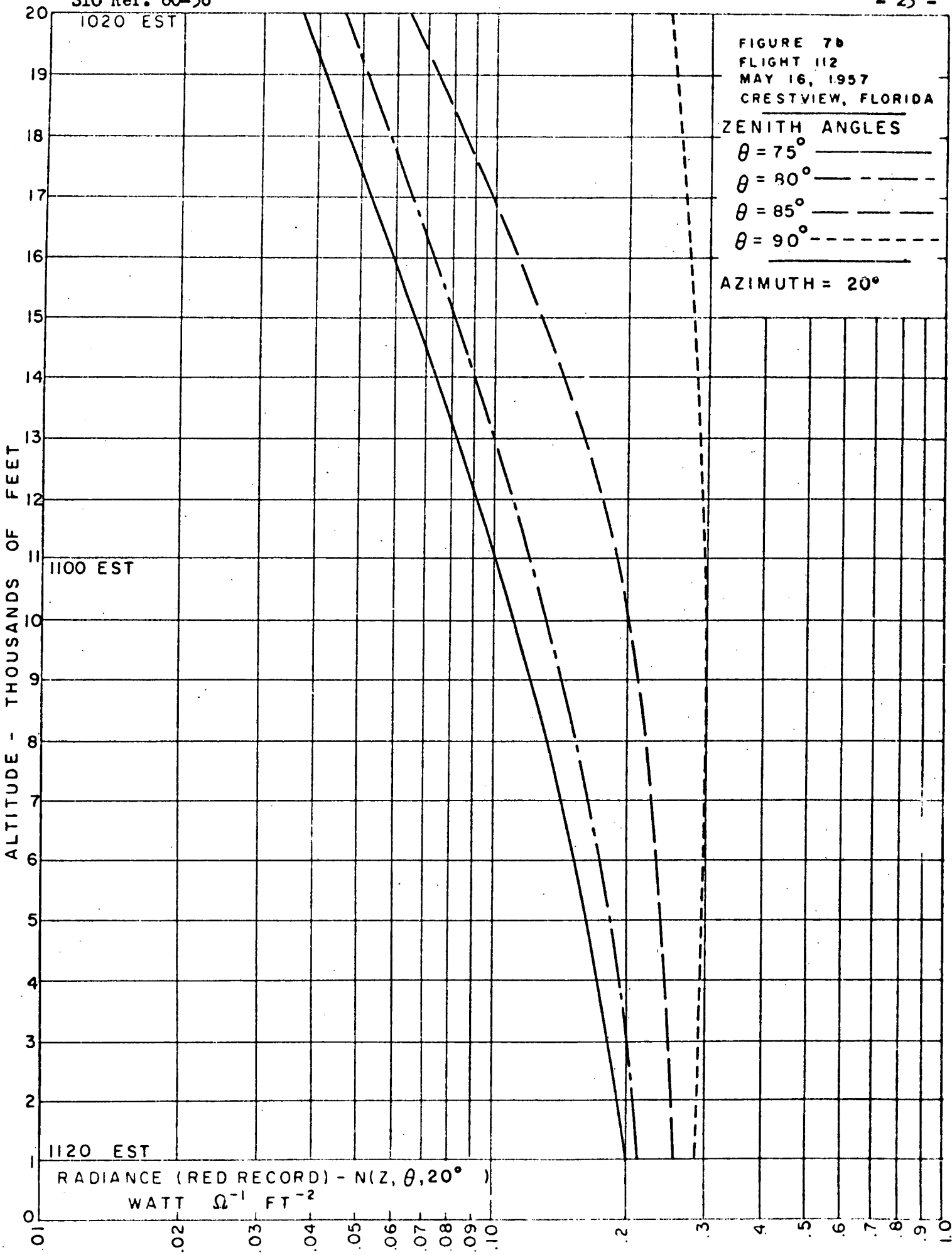
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01 02 03 04 05 06 07 08 09 10 .2 .3 .4 .5 .6 .7 .8 .9





1020 EST

1100 EST

1120 EST

FIGURE 7c  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 90^\circ$  - - - - -  
 $\theta = 95^\circ$  - - - - -  
 $\theta = 100^\circ$  - - - - -  
 $\theta = 105^\circ$  - - - - -

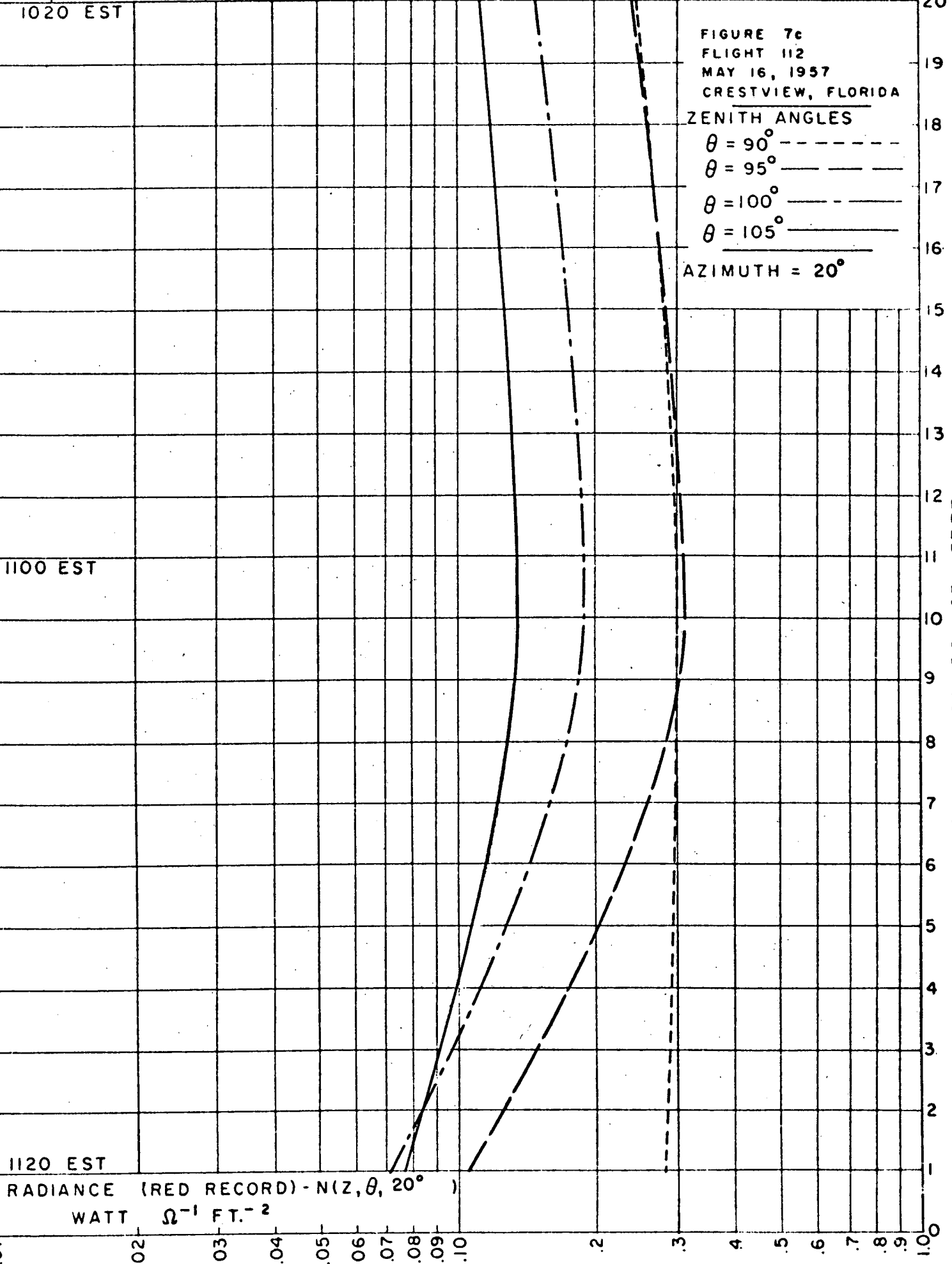
AZIMUTH =  $20^\circ$

RADIANCE (RED RECORD) -  $N(Z, \theta, 20^\circ)$   
 WATT  $\Omega^{-1} \text{ FT.}^{-2}$

20  
19  
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8  
7  
6  
5  
4  
3  
2  
1  
0

ALTITUDE - THOUSANDS OF FEET

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 2 3 4 5 6 7 8 9 10.0



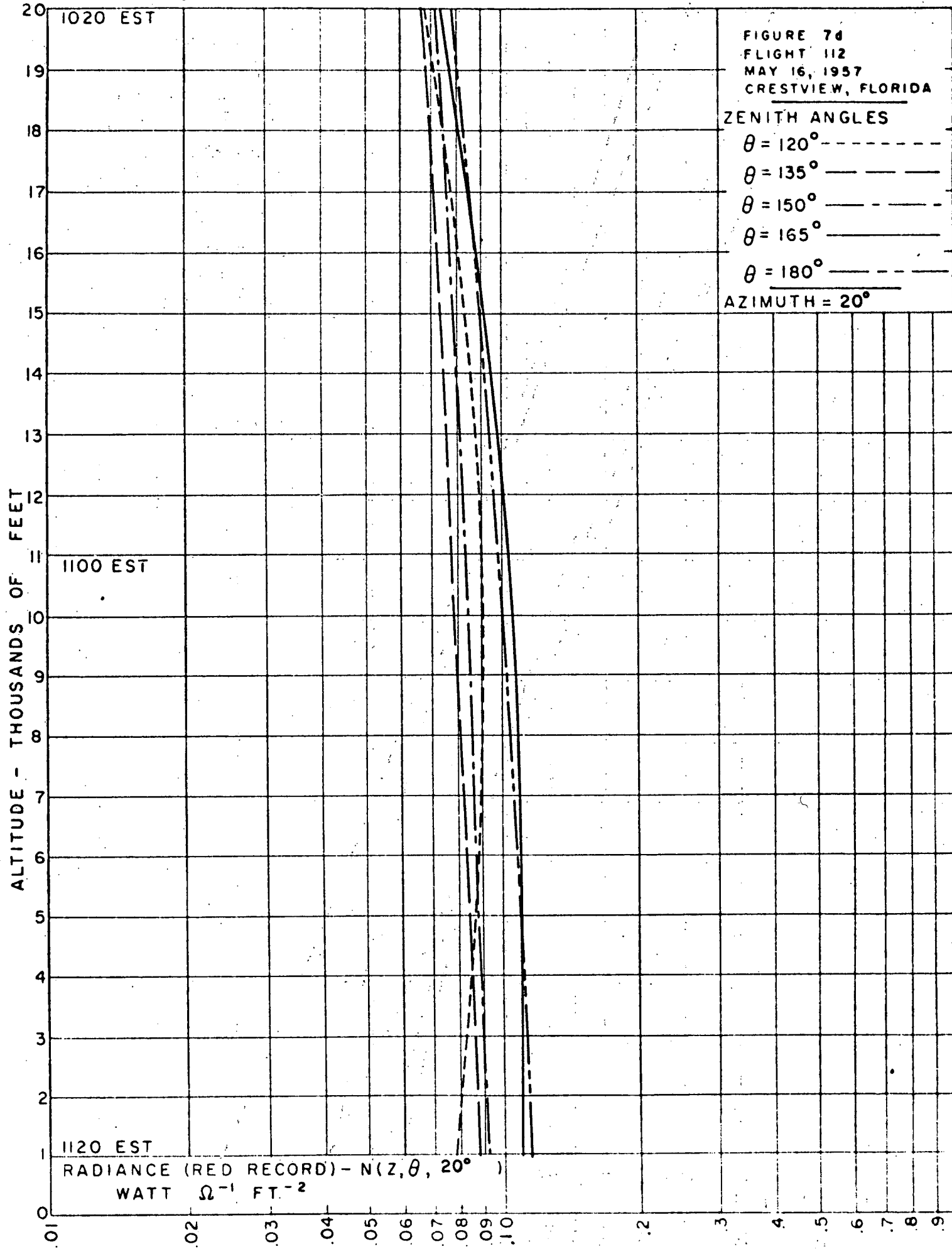


FIGURE 7d  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA  
 ZENITH ANGLES  
 $\theta = 120^\circ$  -----  
 $\theta = 135^\circ$  \_\_\_\_\_  
 $\theta = 150^\circ$  -----  
 $\theta = 165^\circ$  \_\_\_\_\_  
 $\theta = 180^\circ$  -----  
 AZIMUTH =  $20^\circ$

1020 EST

FIGURE 8a  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 0^\circ$  - - - - -

$\theta = 15^\circ$  - - - - -

$\theta = 30^\circ$  - - - - -

$\theta = 45^\circ$  - - - - -

$\theta = 60^\circ$  - - - - -

AZIMUTH =  $40^\circ$

20

19

18

17

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11

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3

2

1

ALTITUDE - THOUSANDS OF FEET

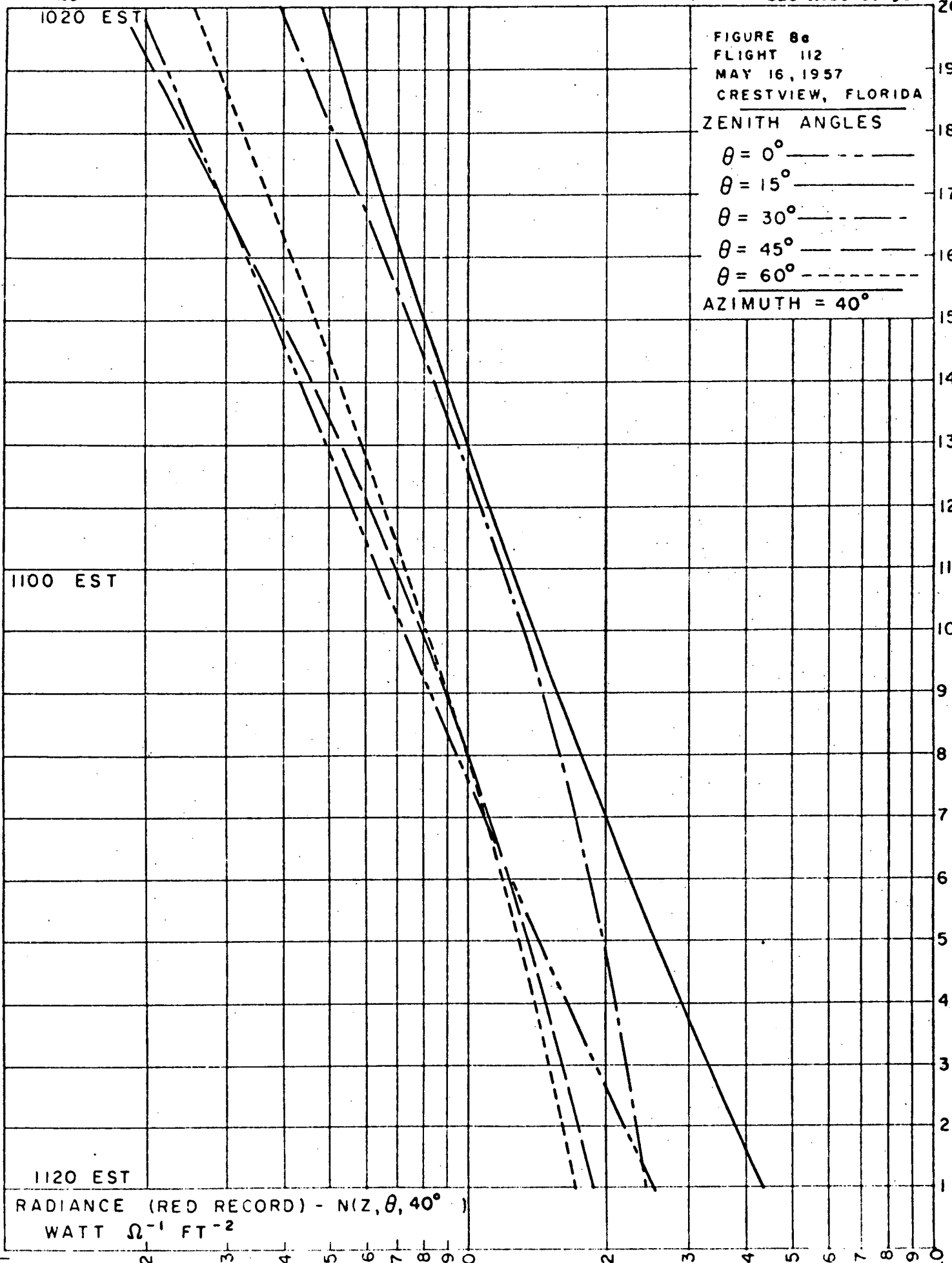
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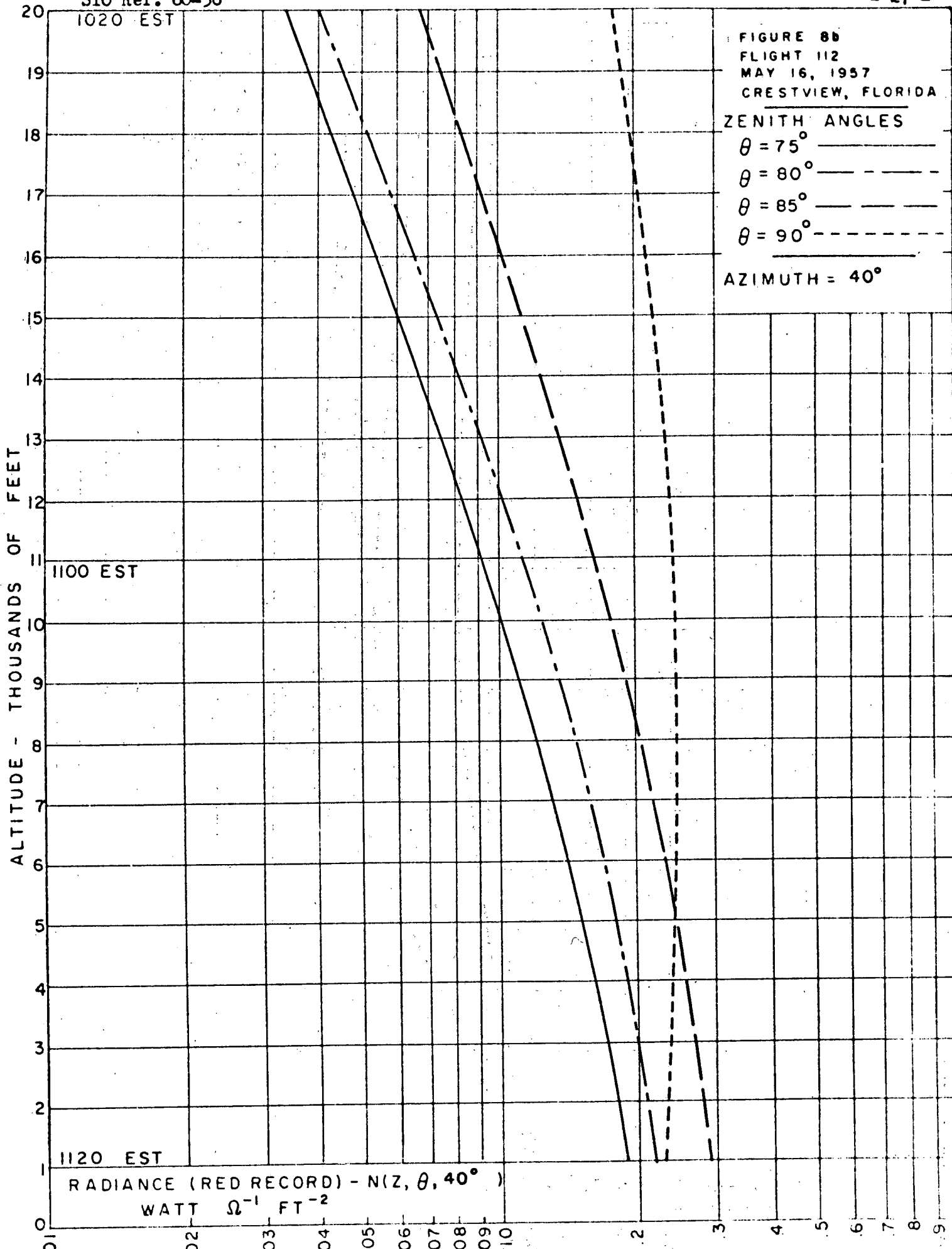
1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 40^\circ)$

WATT  $\Omega^{-1} \text{ FT}^{-2}$

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 2 3 4 5 6 7 8 9 10





20  
19  
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8  
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6  
5  
4  
3  
2  
1  
0

01 02 03 04 05 06 07 08 09 10 2 3 4 5 6 7 8 9

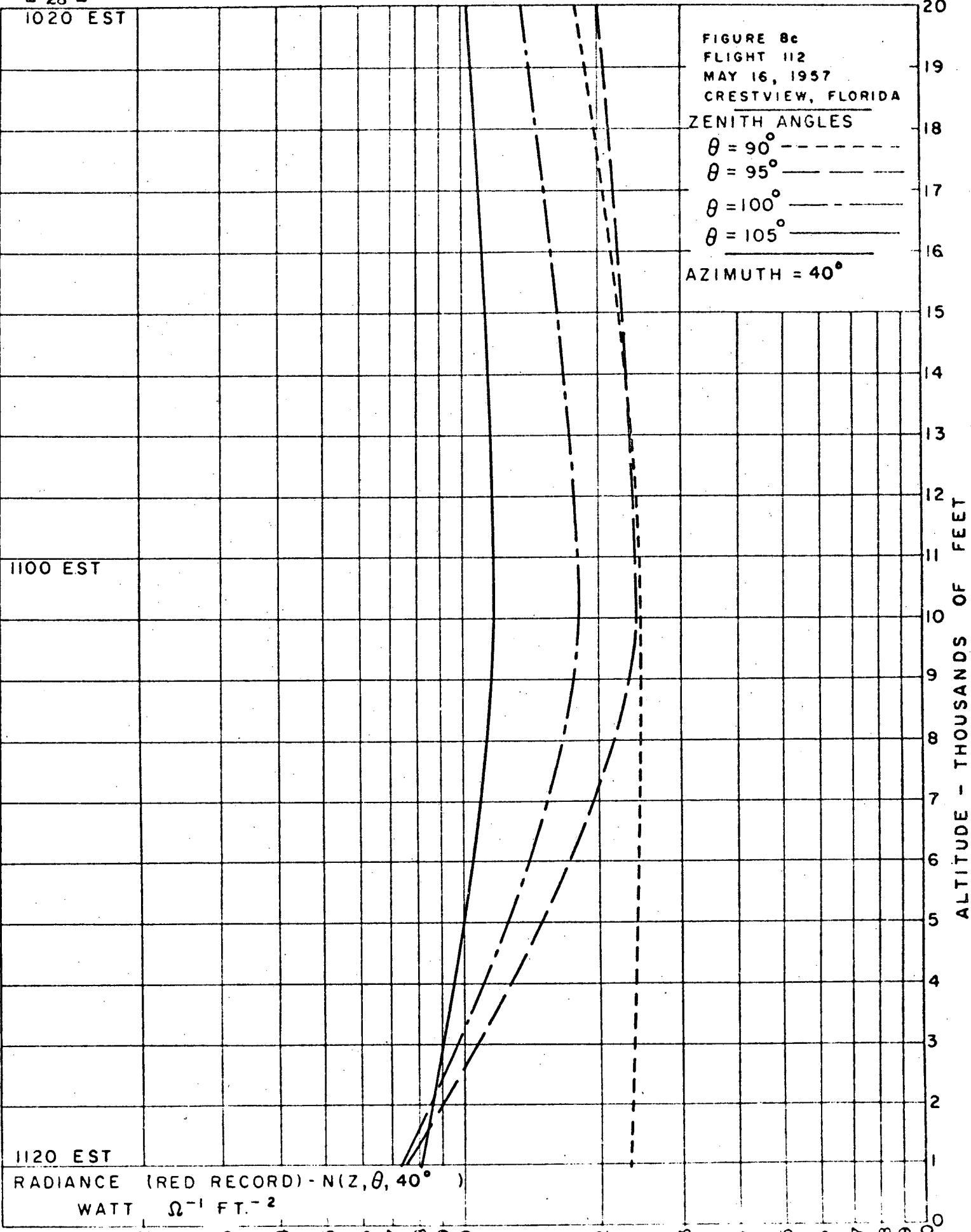


FIGURE 8c  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA  
 ZENITH ANGLES  
 $\theta = 90^\circ$  - - - - -  
 $\theta = 95^\circ$  - · - · -  
 $\theta = 100^\circ$  - - - - -  
 $\theta = 105^\circ$  - - - - -  
 AZIMUTH =  $40^\circ$

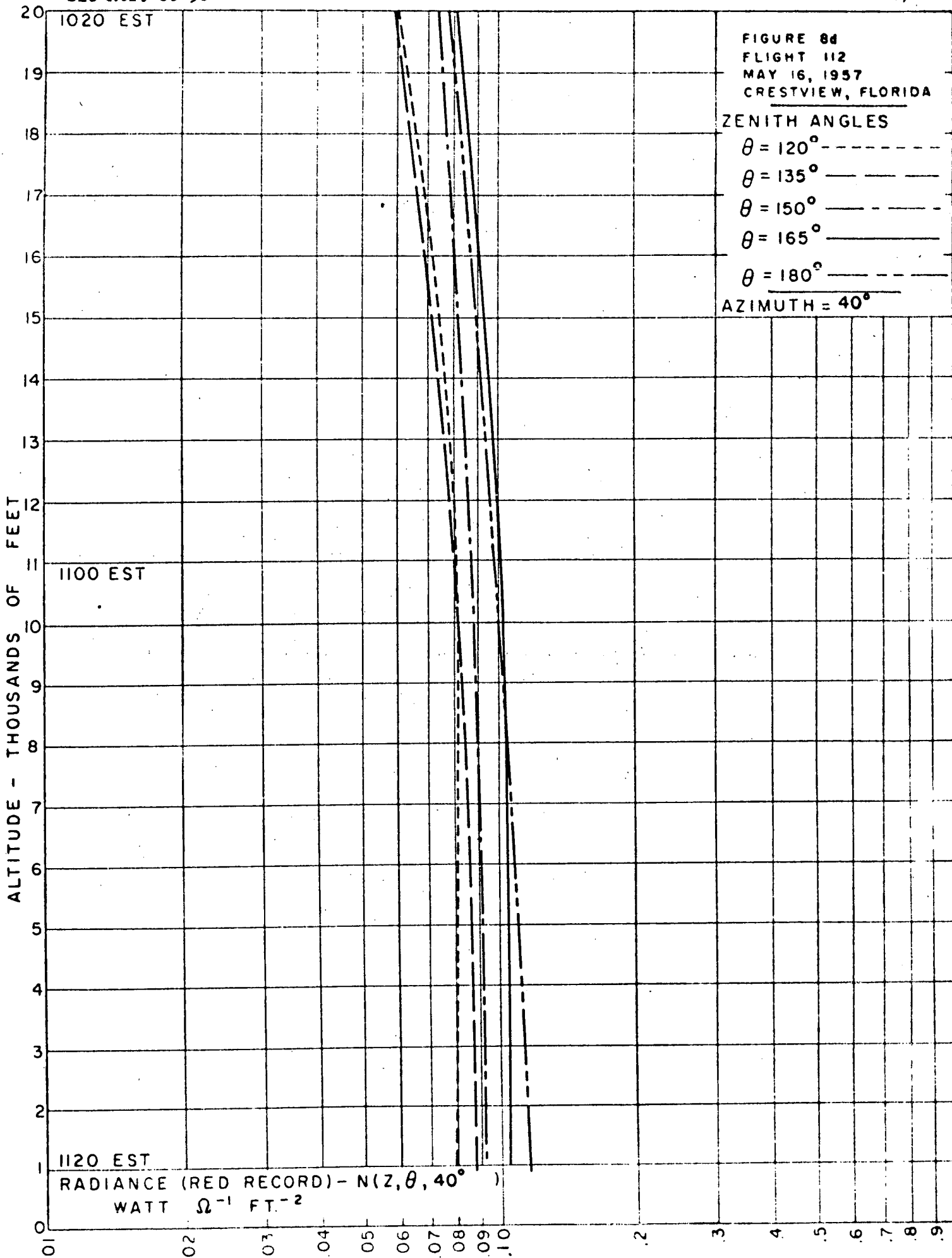
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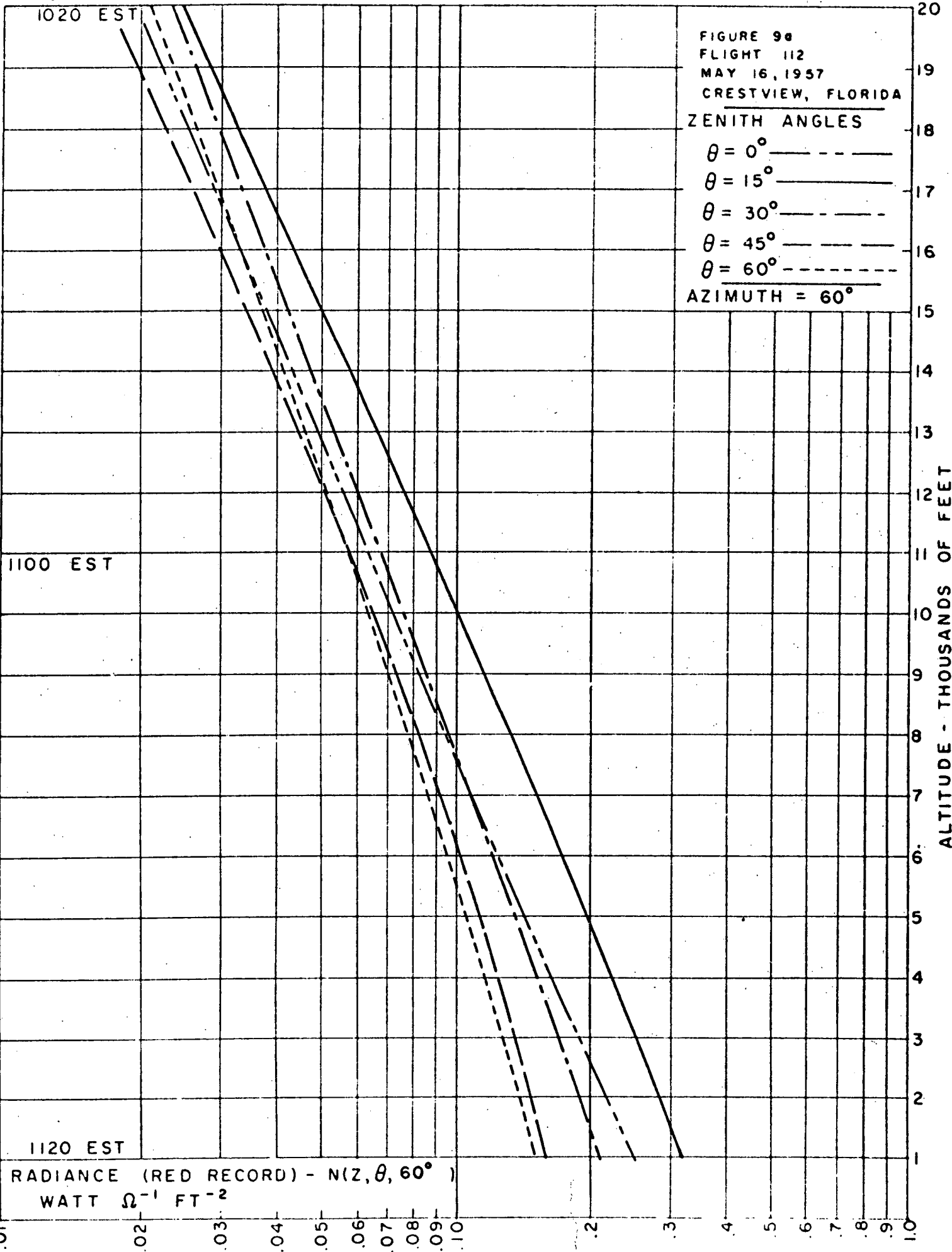
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1120 EST

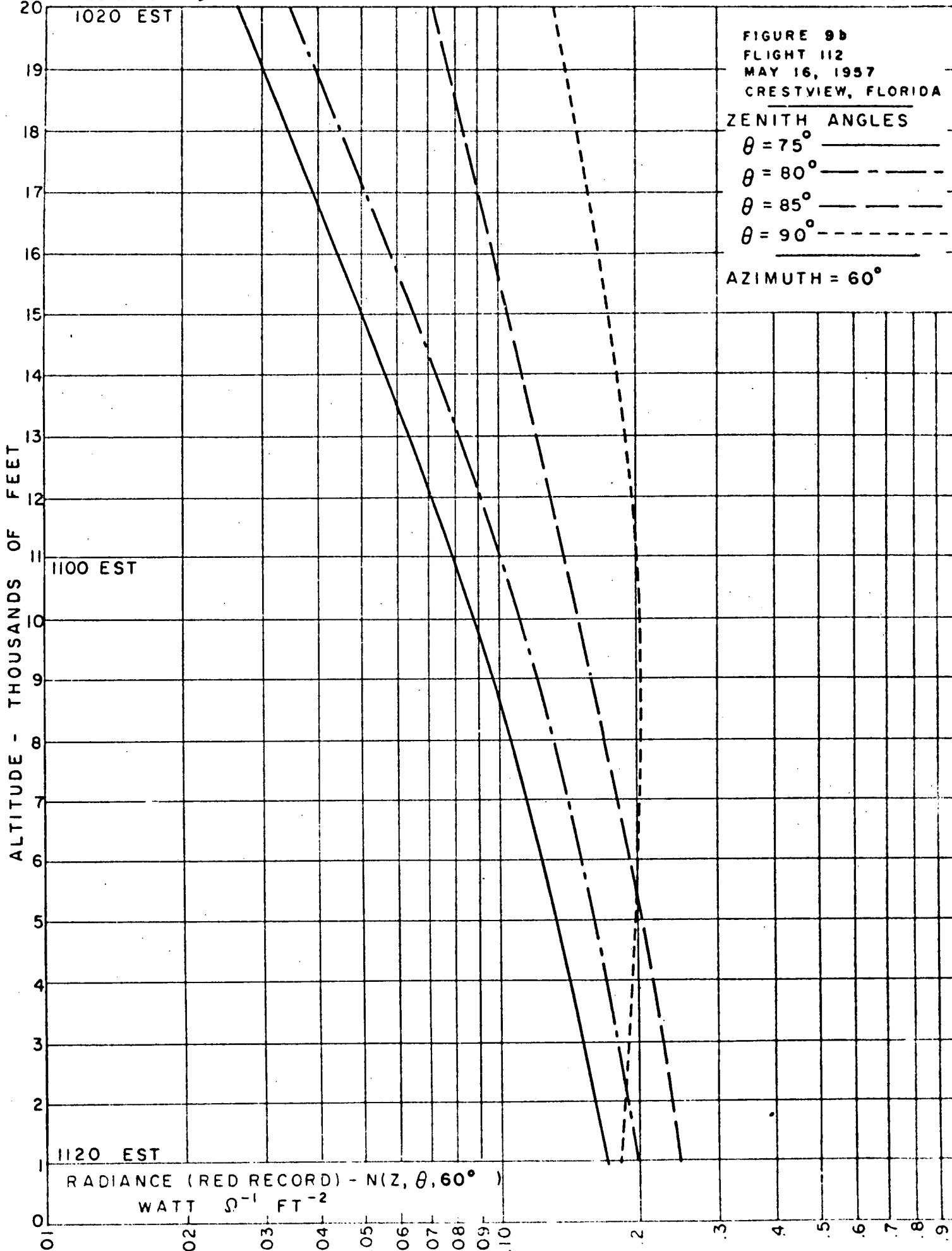
RADIANCE (RED RECORD) -  $N(Z, \theta, 40^\circ)$   
 WATT  $\Omega^{-1} \text{ FT.}^{-2}$

ALTITUDE - THOUSANDS OF FEET





SIO Ref. 60-56



1020 EST

FIGURE 9c  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 90^\circ$  - - - - -

$\theta = 95^\circ$  - - - - -

$\theta = 100^\circ$  - - - - -

$\theta = 105^\circ$  - - - - -

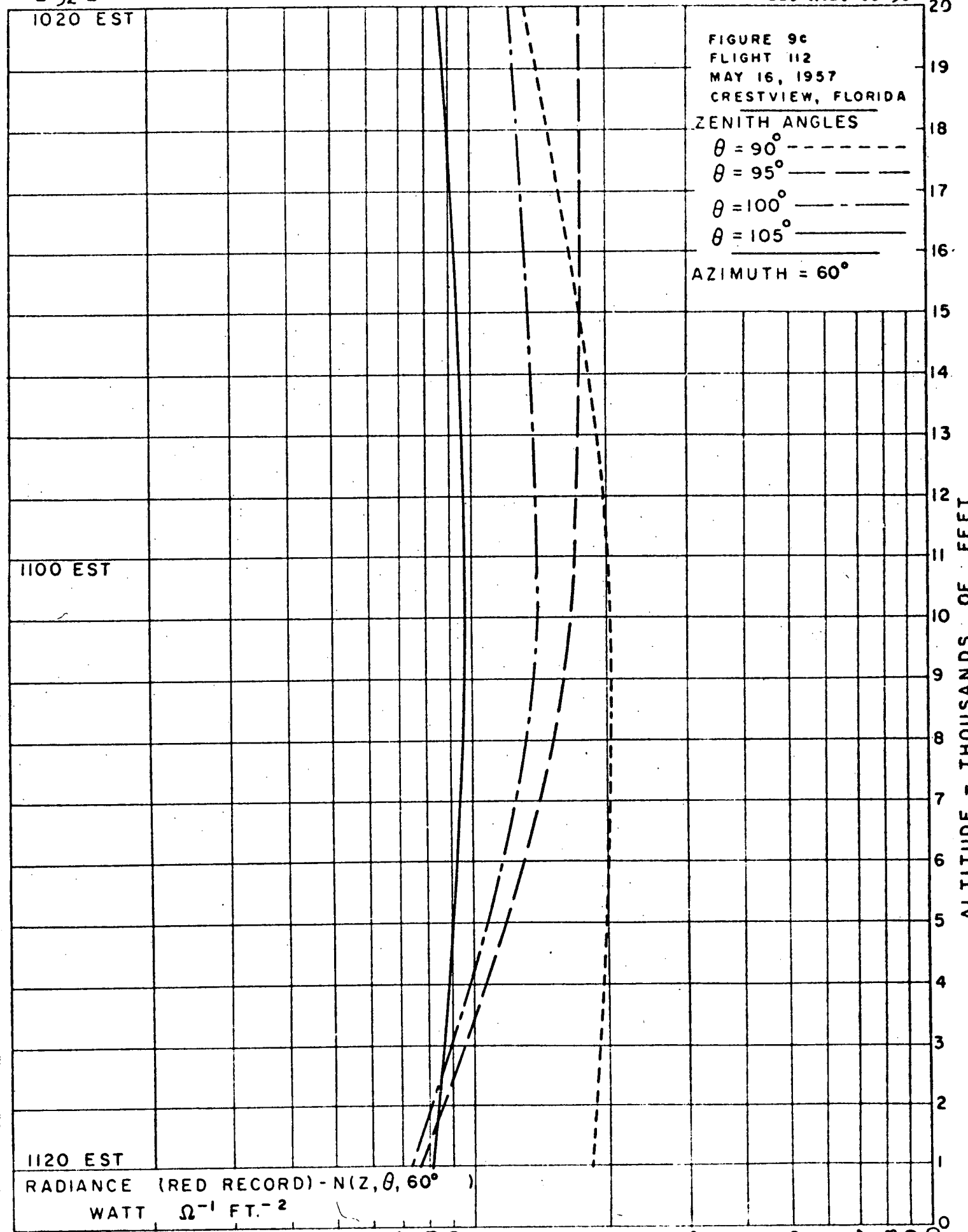
AZIMUTH =  $60^\circ$

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 60^\circ)$   
WATT  $\Omega^{-1} \text{ FT.}^{-2}$

ALTITUDE - THOUSANDS OF FEET



1020 EST

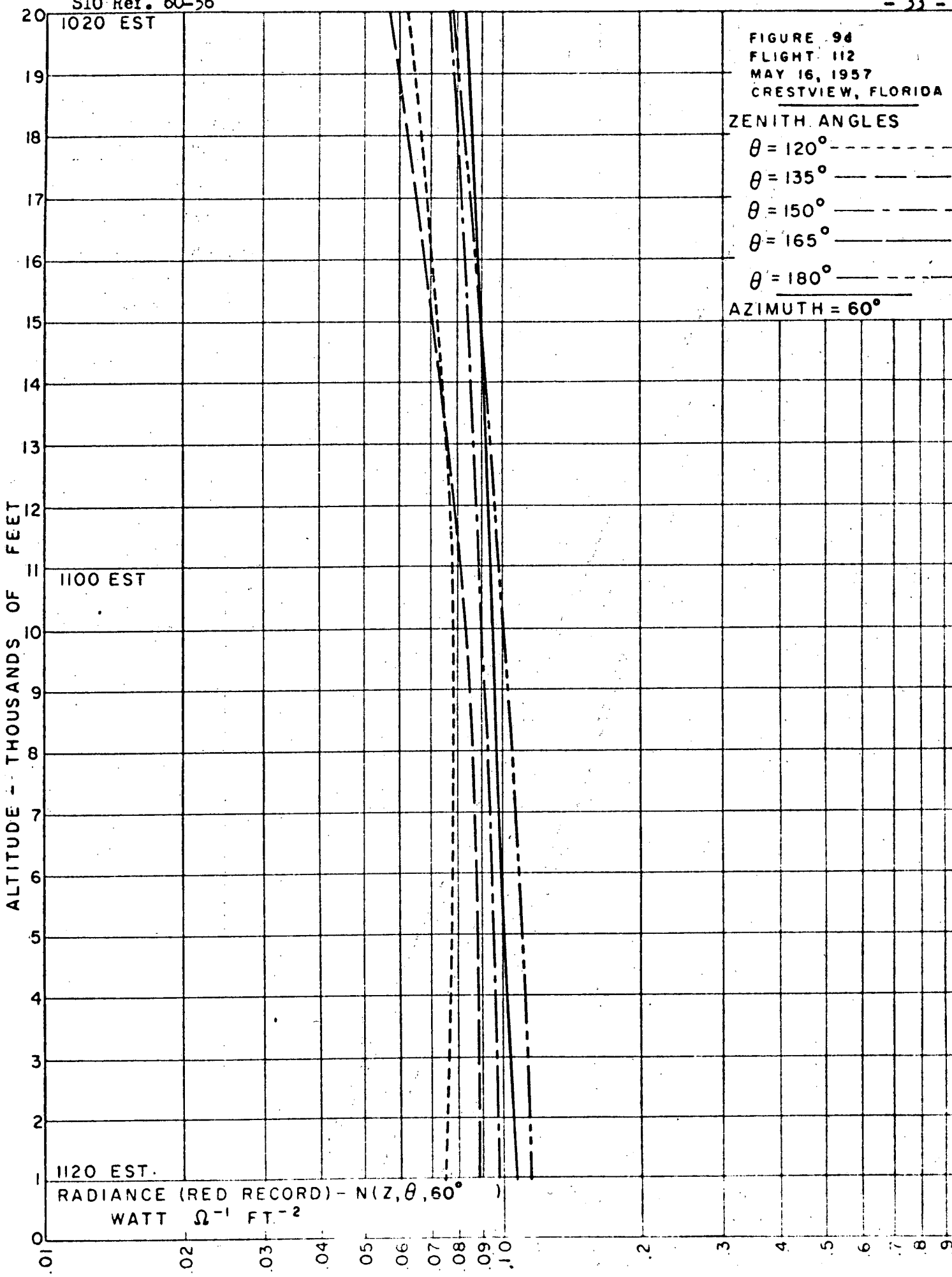
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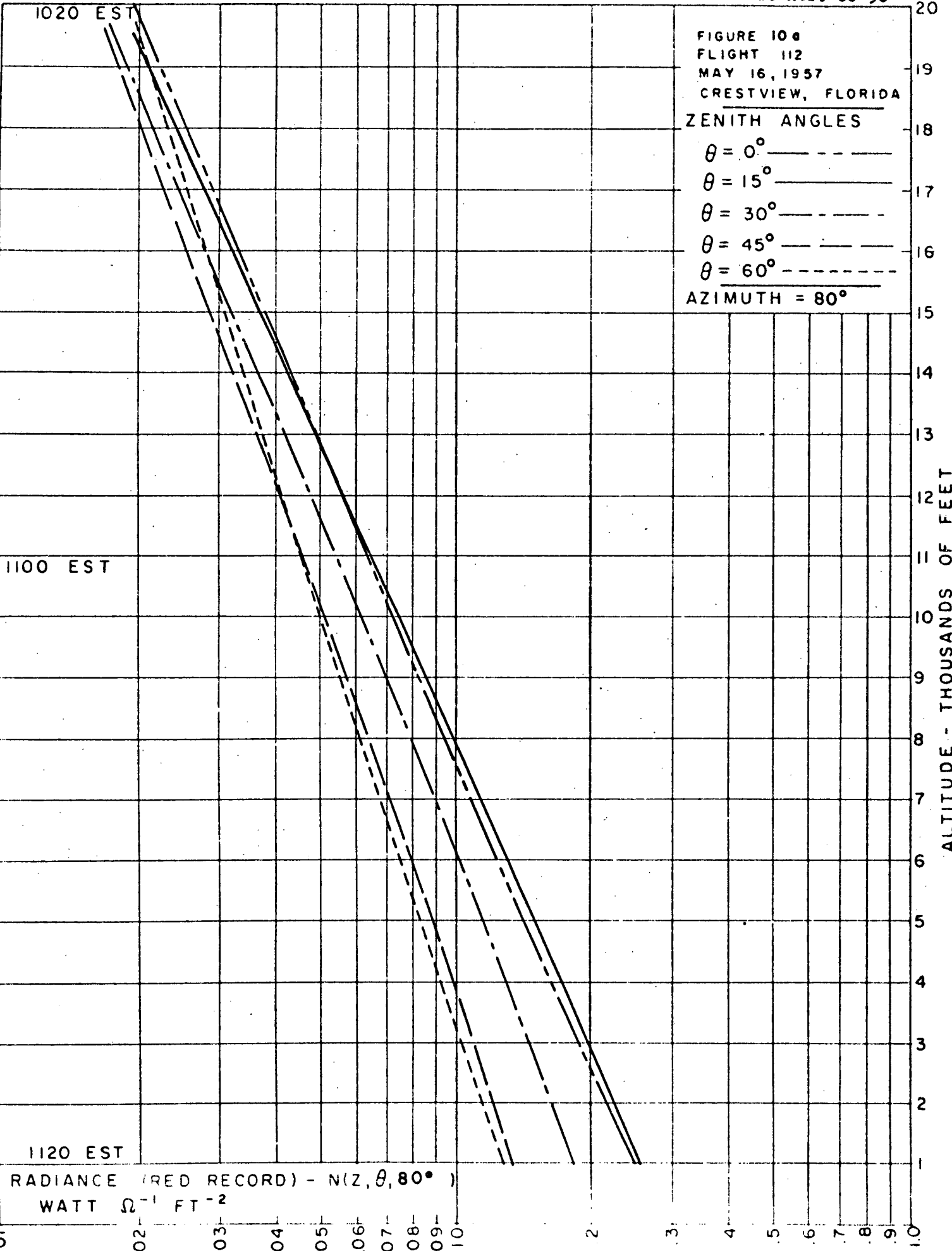
1120 EST.

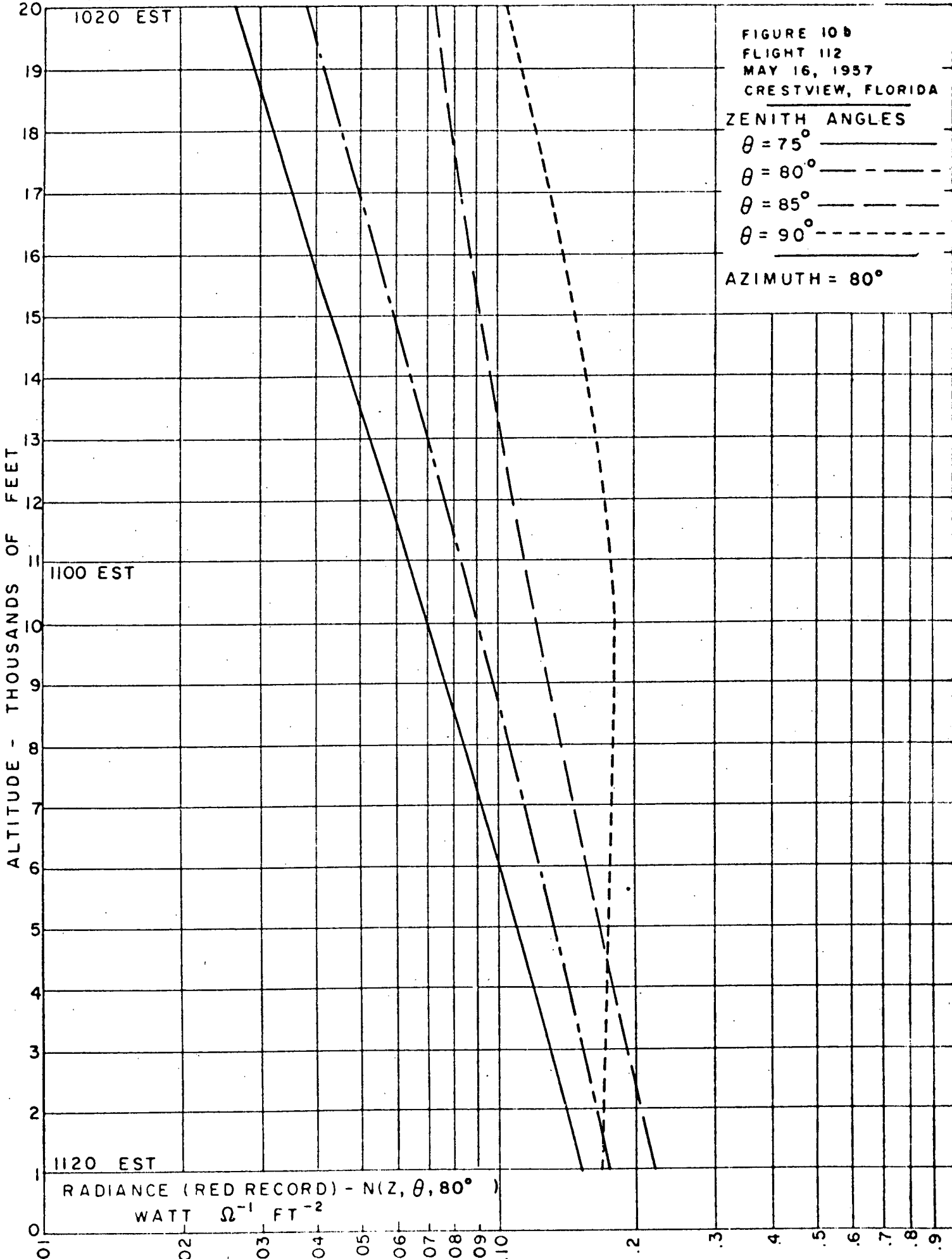
RADIANCE (RED RECORD) -  $N(Z, \theta, 60^\circ)$   
WATT  $\Omega^{-1}$  FT.<sup>-2</sup>

FIGURE 94  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 120^\circ$  - - - - -  
 $\theta = 135^\circ$  - - - - -  
 $\theta = 150^\circ$  - - - - -  
 $\theta = 165^\circ$  - - - - -  
 $\theta = 180^\circ$  - - - - -  
AZIMUTH =  $60^\circ$







1020 EST

FIGURE 10c  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

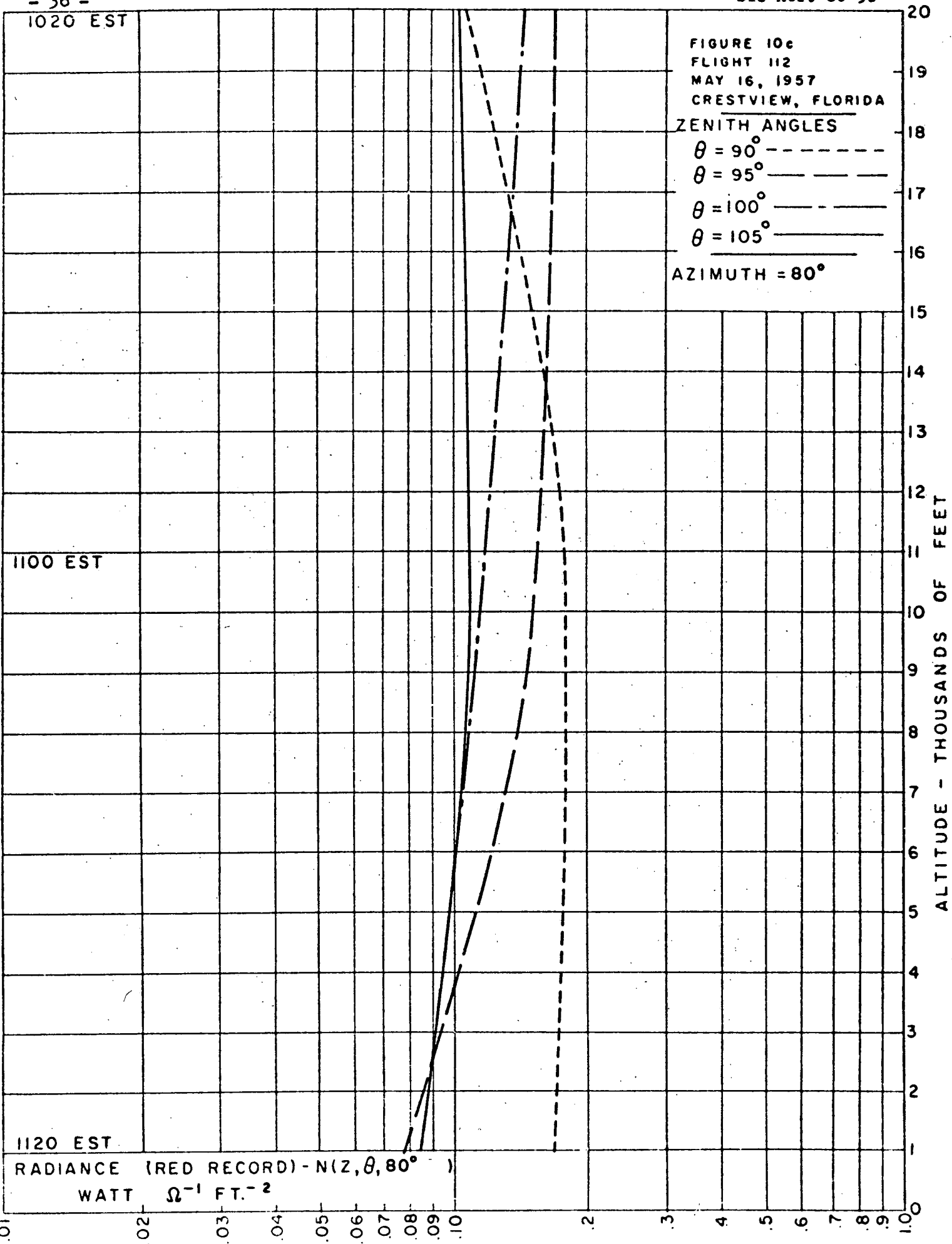
ZENITH ANGLES  
 $\theta = 90^\circ$  - - - - -  
 $\theta = 95^\circ$  - - - - -  
 $\theta = 100^\circ$  - - - - -  
 $\theta = 105^\circ$  - - - - -  
AZIMUTH =  $80^\circ$

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 80^\circ)$   
WATT  $\Omega^{-1} \text{ FT.}^{-2}$

ALTITUDE - THOUSANDS OF FEET



SJO Ref. 60-56

FIGURE 10 d  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 120^\circ$  - - - - -

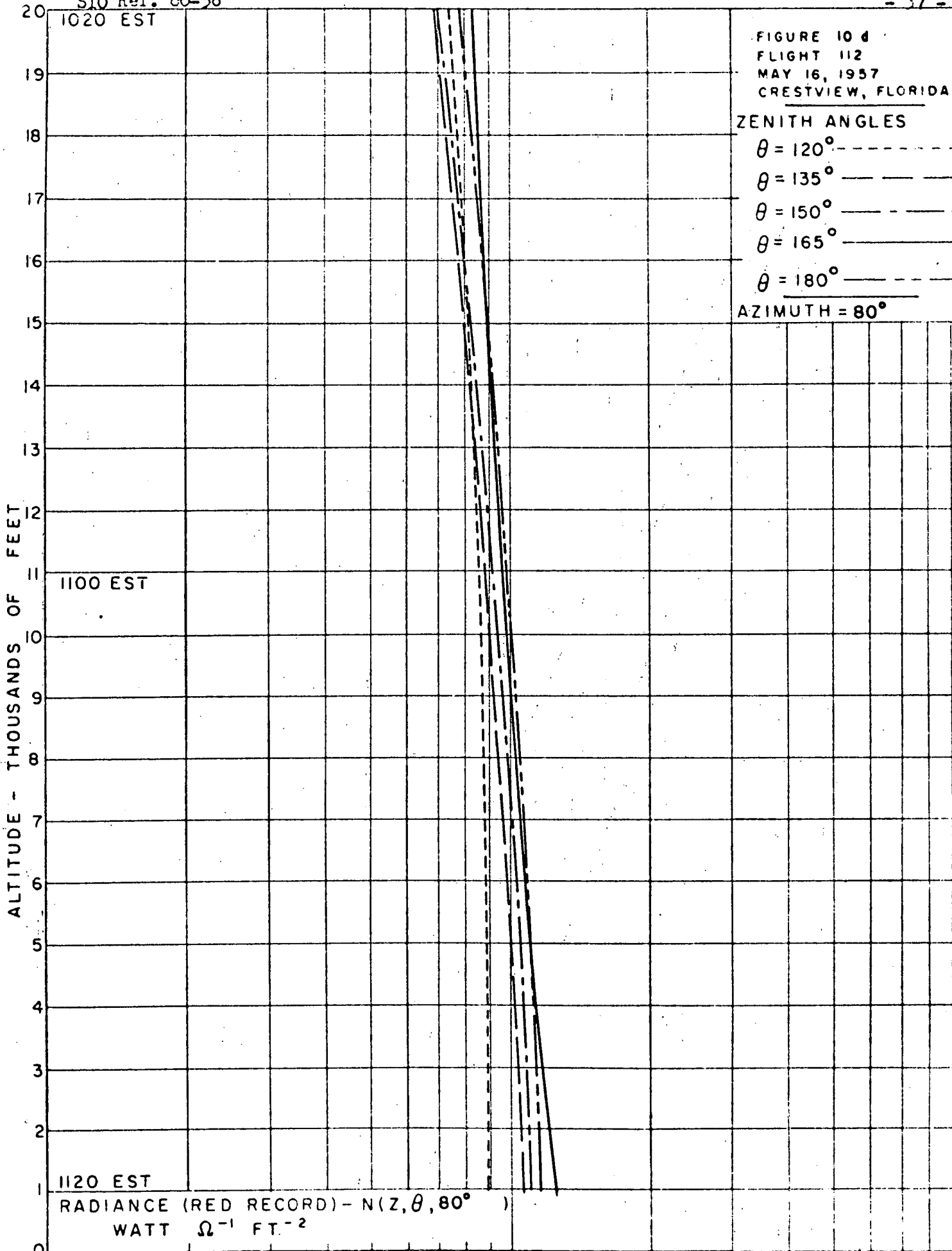
$\theta = 135^\circ$  - - - - -

$\theta = 150^\circ$  - - - - -

$\theta = 165^\circ$  - - - - -

$\theta = 180^\circ$  - - - - -

AZIMUTH =  $80^\circ$



1020 EST

FIGURE 11a  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 0^\circ$  - - - - -

$\theta = 15^\circ$  - - - - -

$\theta = 30^\circ$  - - - - -

$\theta = 45^\circ$  - - - - -

$\theta = 60^\circ$  - - - - -

AZIMUTH =  $100^\circ$

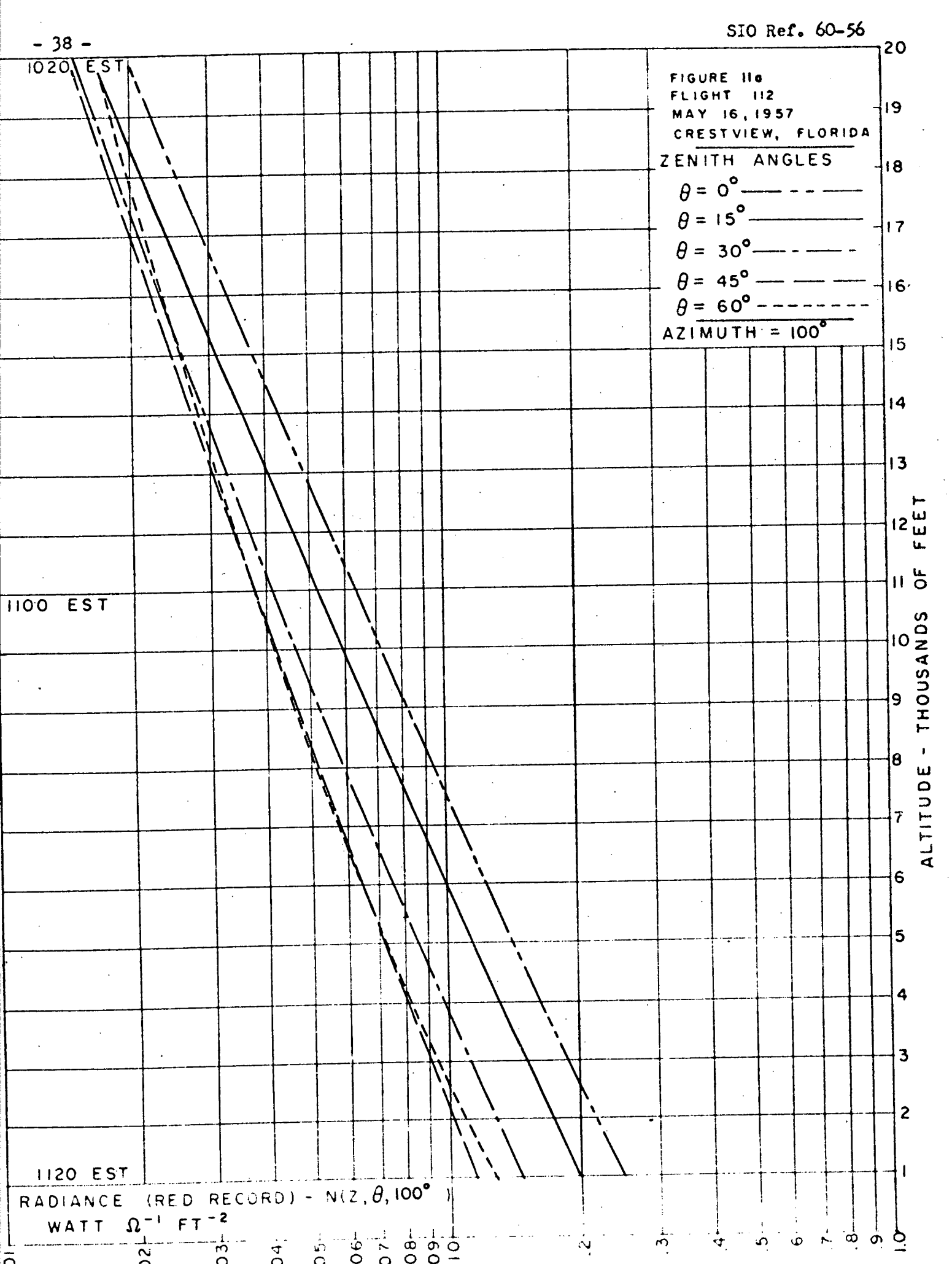
1100 EST

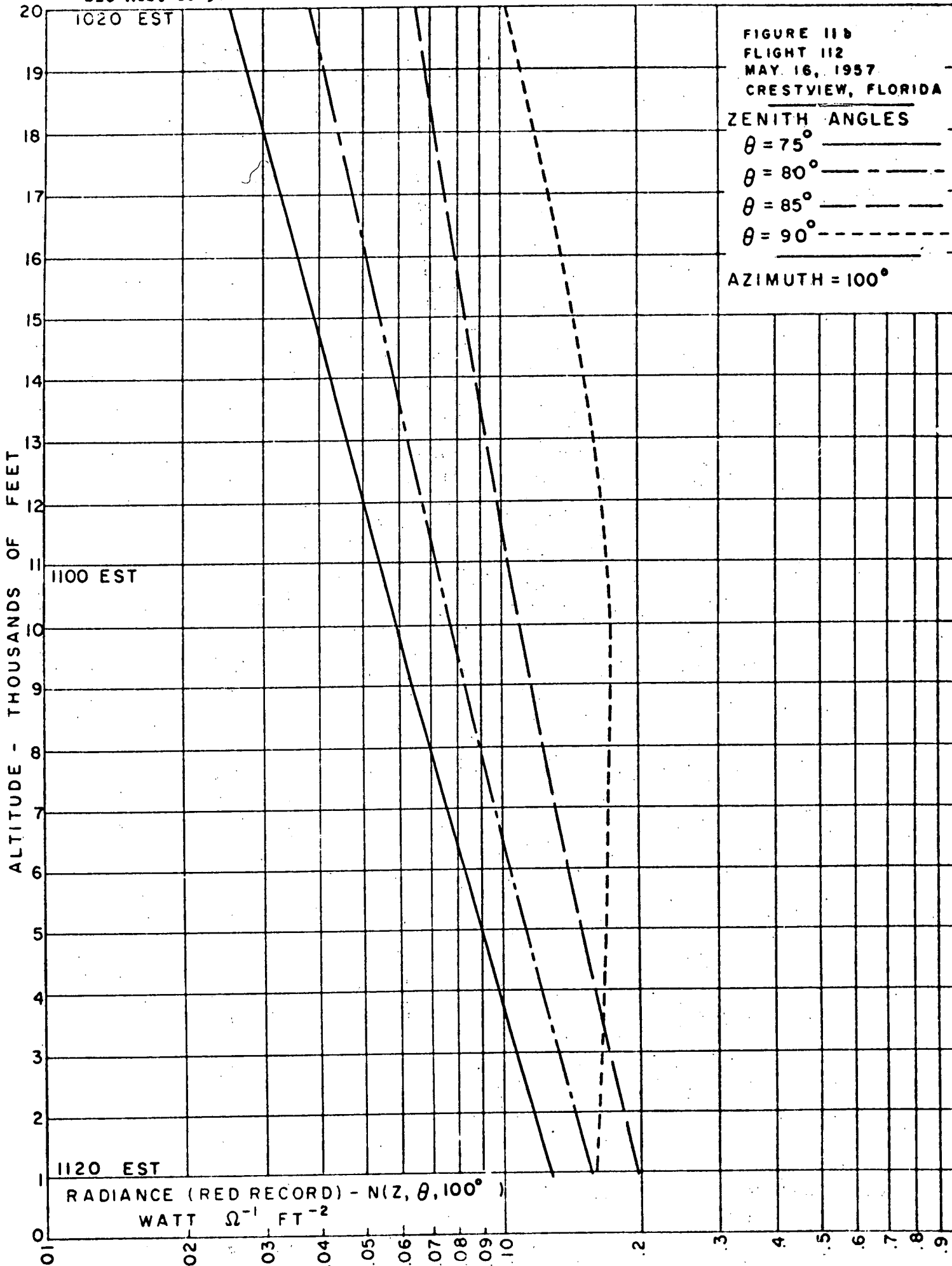
1120 EST

RADIANCE (RED RECORD) -  $N(z, \theta, 100^\circ)$   
WATT  $\Omega^{-1}$  FT $^{-2}$

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ALTIITUDE - THOUSANDS OF FEET

01 02 03 04 05 06 07 08 09 10 2 3 4 5 6 7 8 9 10





1020 EST

FIGURE 11c  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 90^\circ$  - - - - -

$\theta = 95^\circ$  - - - - -

$\theta = 100^\circ$  - - - - -

$\theta = 105^\circ$  - - - - -

AZIMUTH =  $100^\circ$

20

19

18

17

16

15

14

13

12

11

10

9

8

7

6

5

4

3

2

1

0

ALTITUDE - THOUSANDS OF FEET

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 100^\circ)$

WATT  $\Omega^{-1} \text{ FT.}^{-2}$

0.02

0.03

0.04

0.05

0.06

0.07

0.08

0.09

0.10

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6

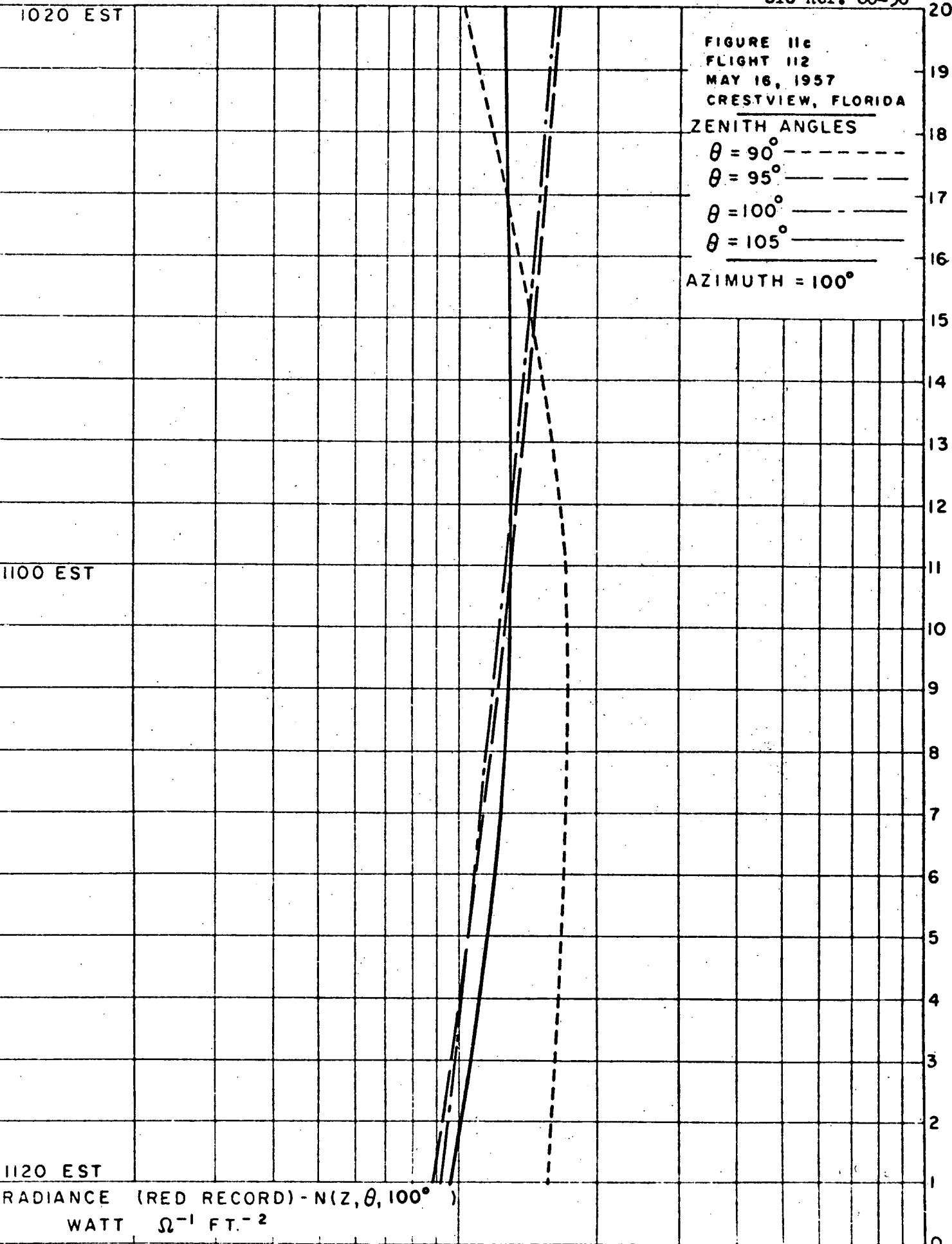
7

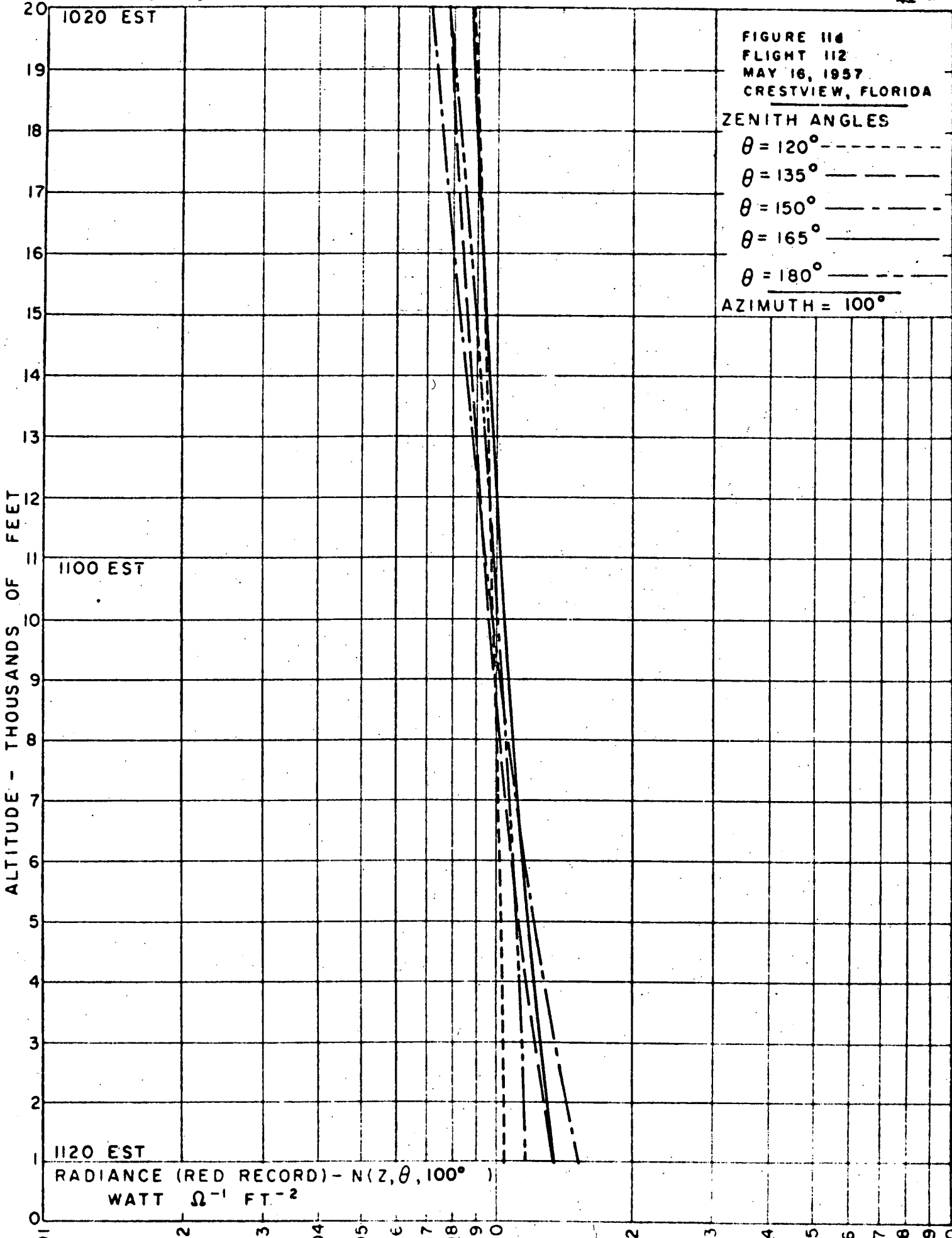
8

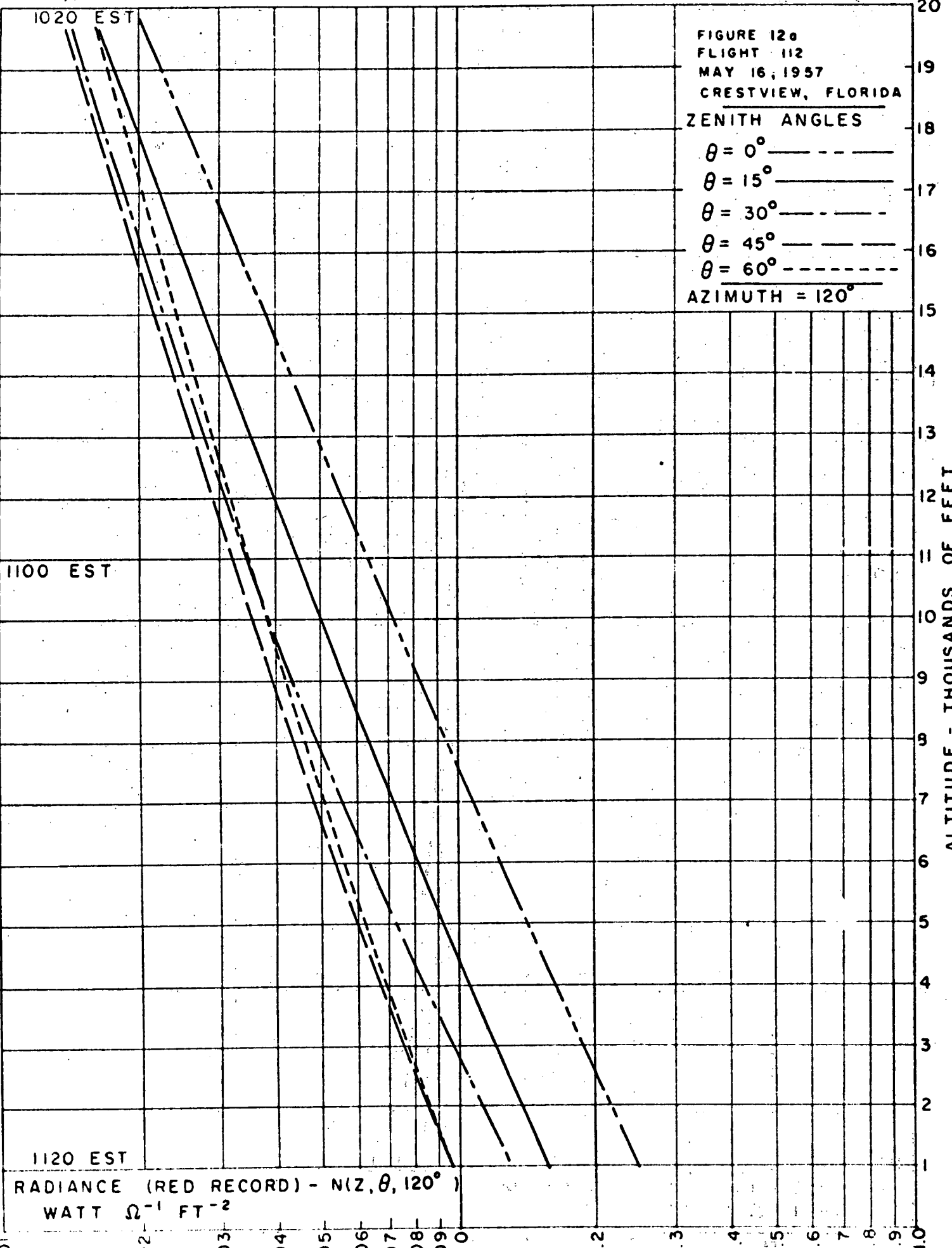
9

10

0





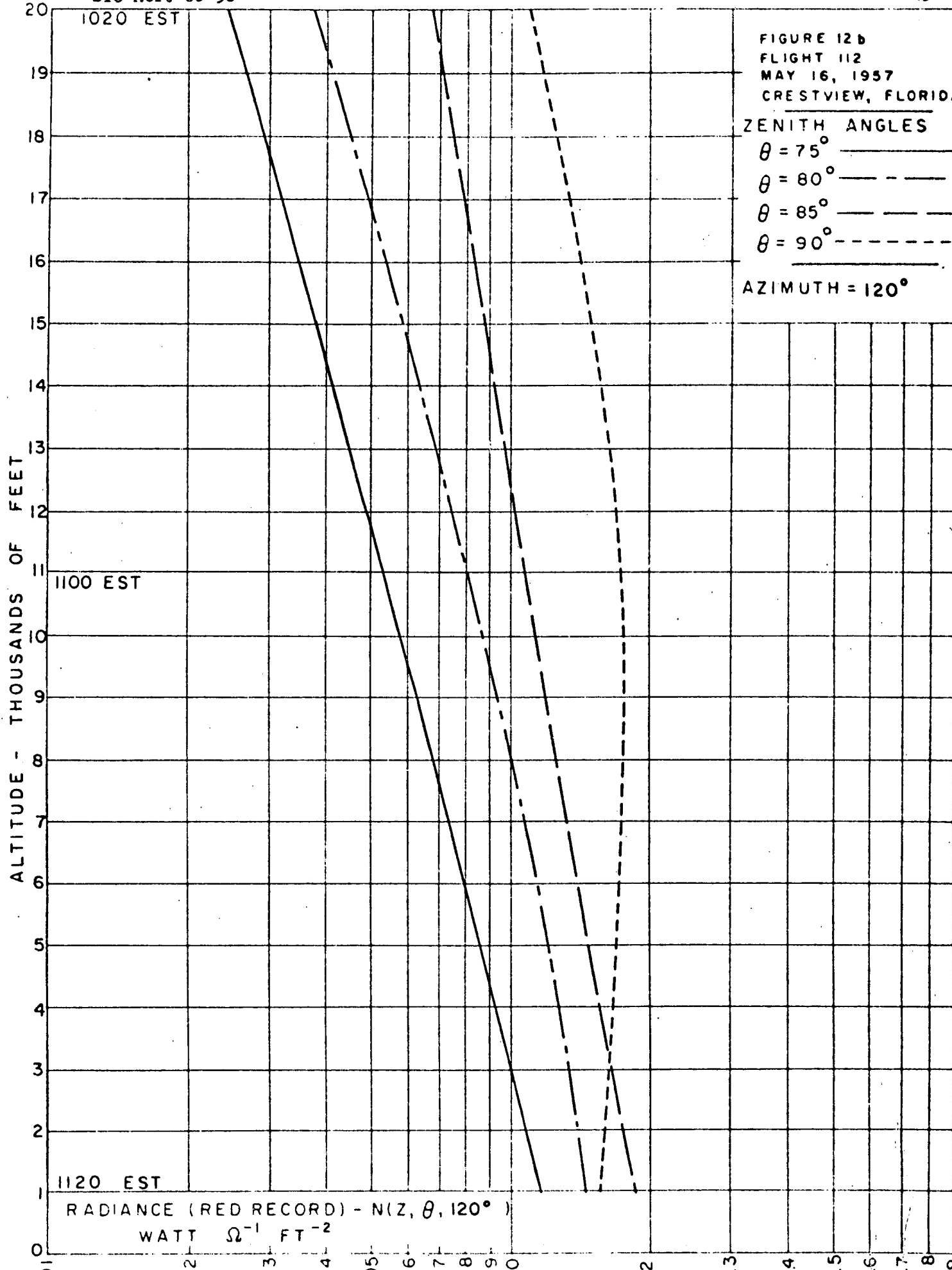


SIO Ref. 60-56

FIGURE 12b  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 75^\circ$  —————  
 $\theta = 80^\circ$  - - - - -  
 $\theta = 85^\circ$  - - - - -  
 $\theta = 90^\circ$  - - - - -

AZIMUTH =  $120^\circ$



RADIANCE (RED RECORD) -  $N(Z, \theta, 120^\circ)$   
WATT  $\Omega^{-1}$  FT<sup>-2</sup>

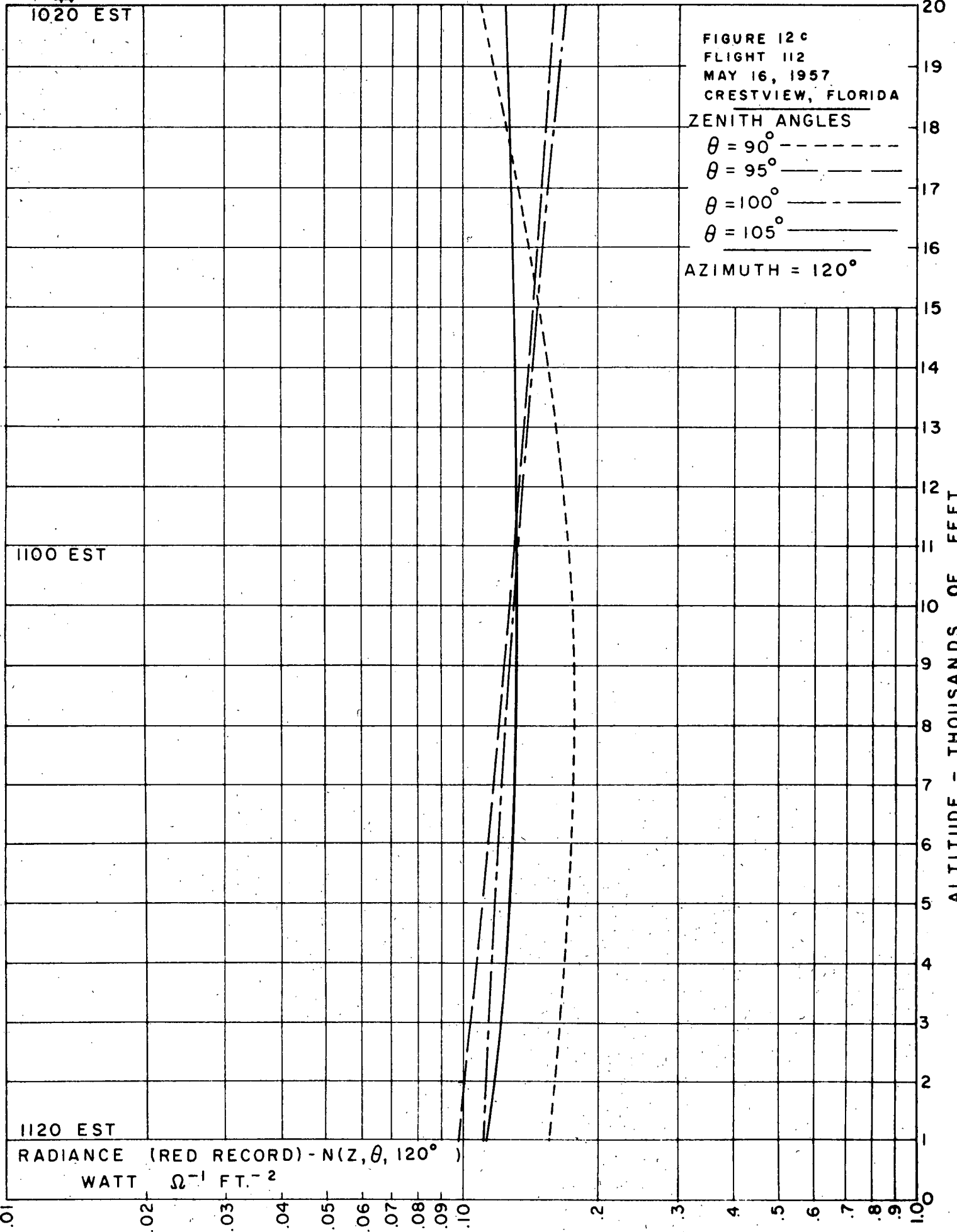


FIGURE 12d  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 120^\circ$  - - - - -

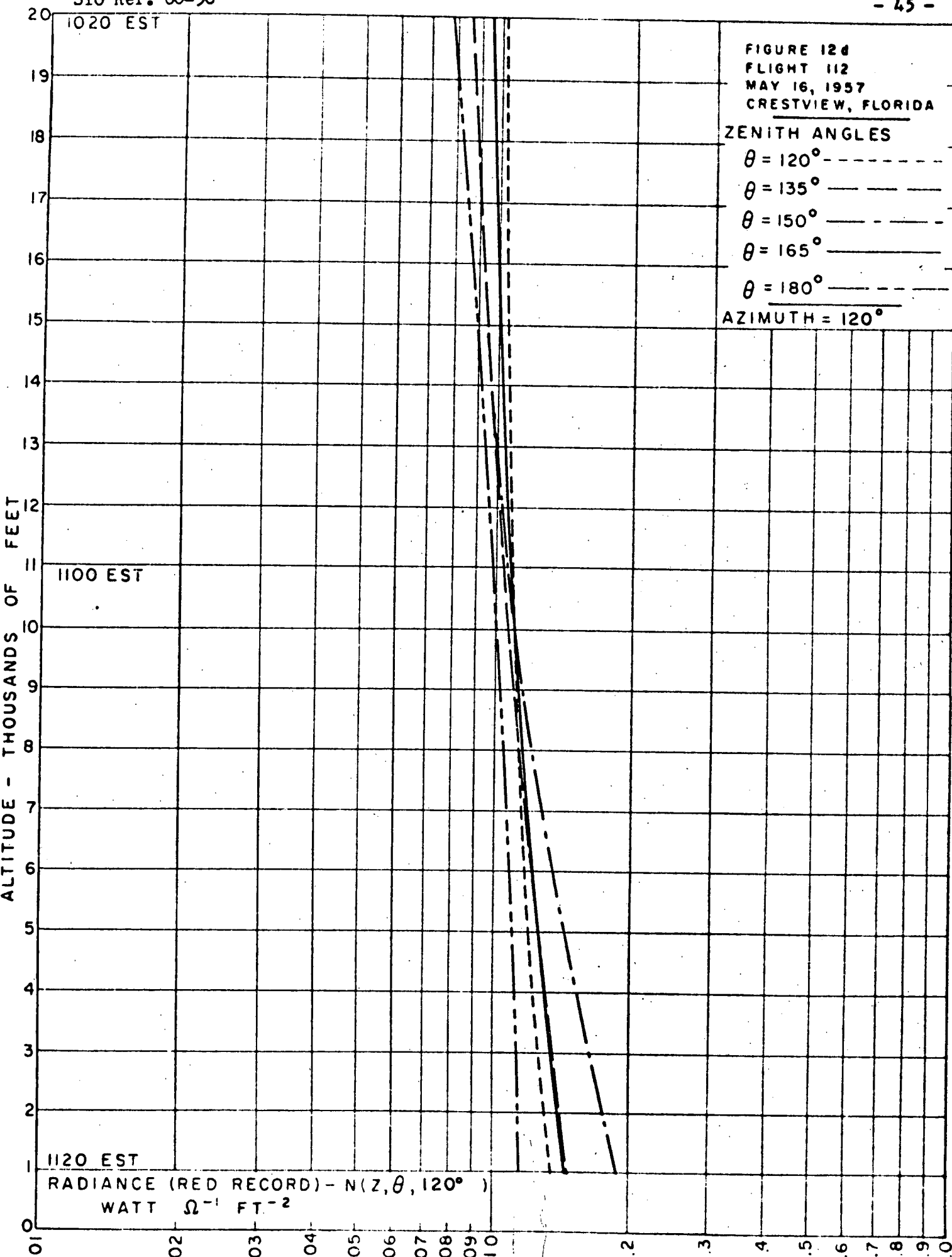
$\theta = 135^\circ$  - - - - -

$\theta = 150^\circ$  - - - - -

$\theta = 165^\circ$  - - - - -

$\theta = 180^\circ$  - - - - -

AZIMUTH =  $120^\circ$



RADIANCE (RED RECORD) -  $N(z, \theta, 120^\circ)$   
WATT  $\Omega^{-1}$  FT.<sup>-2</sup>

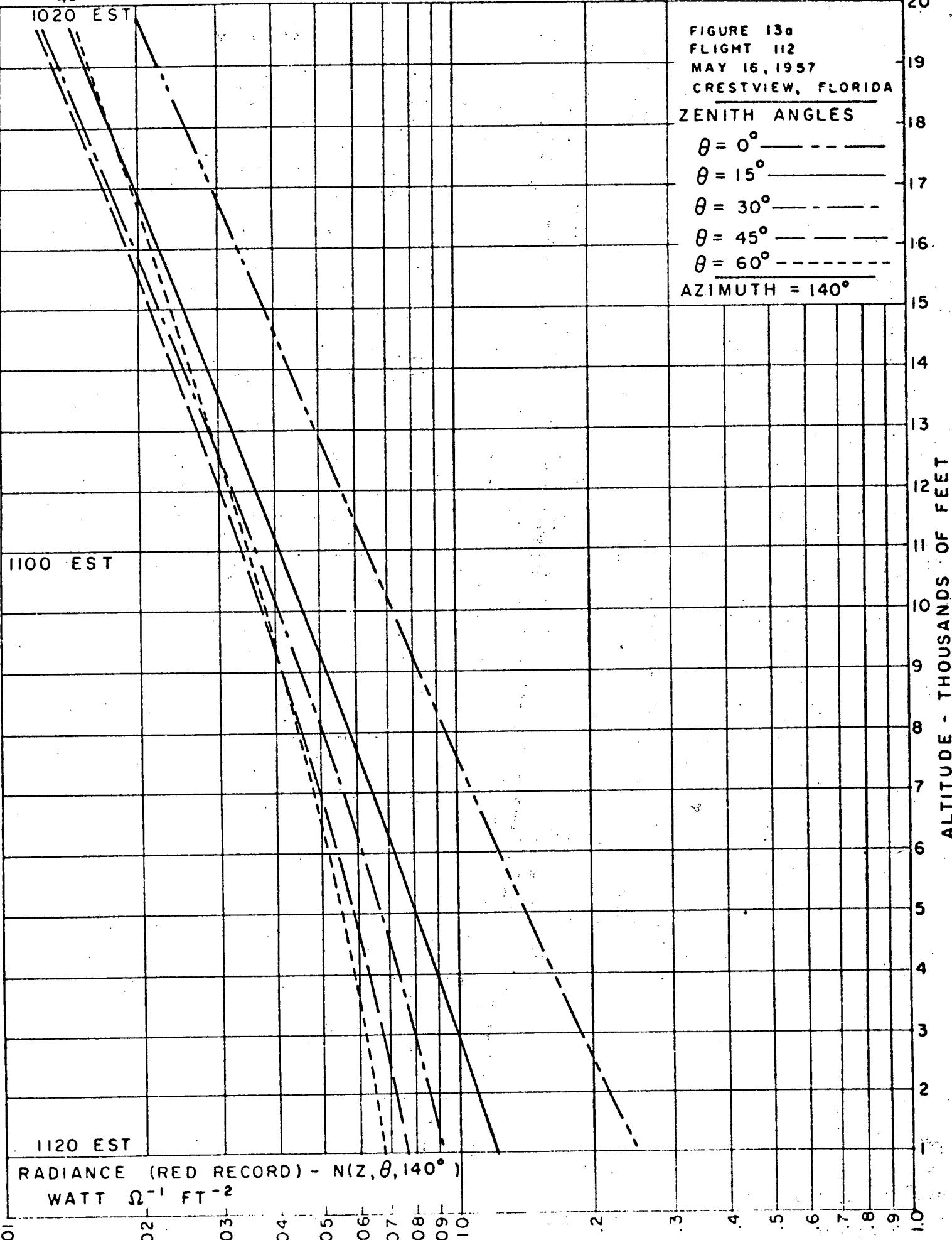
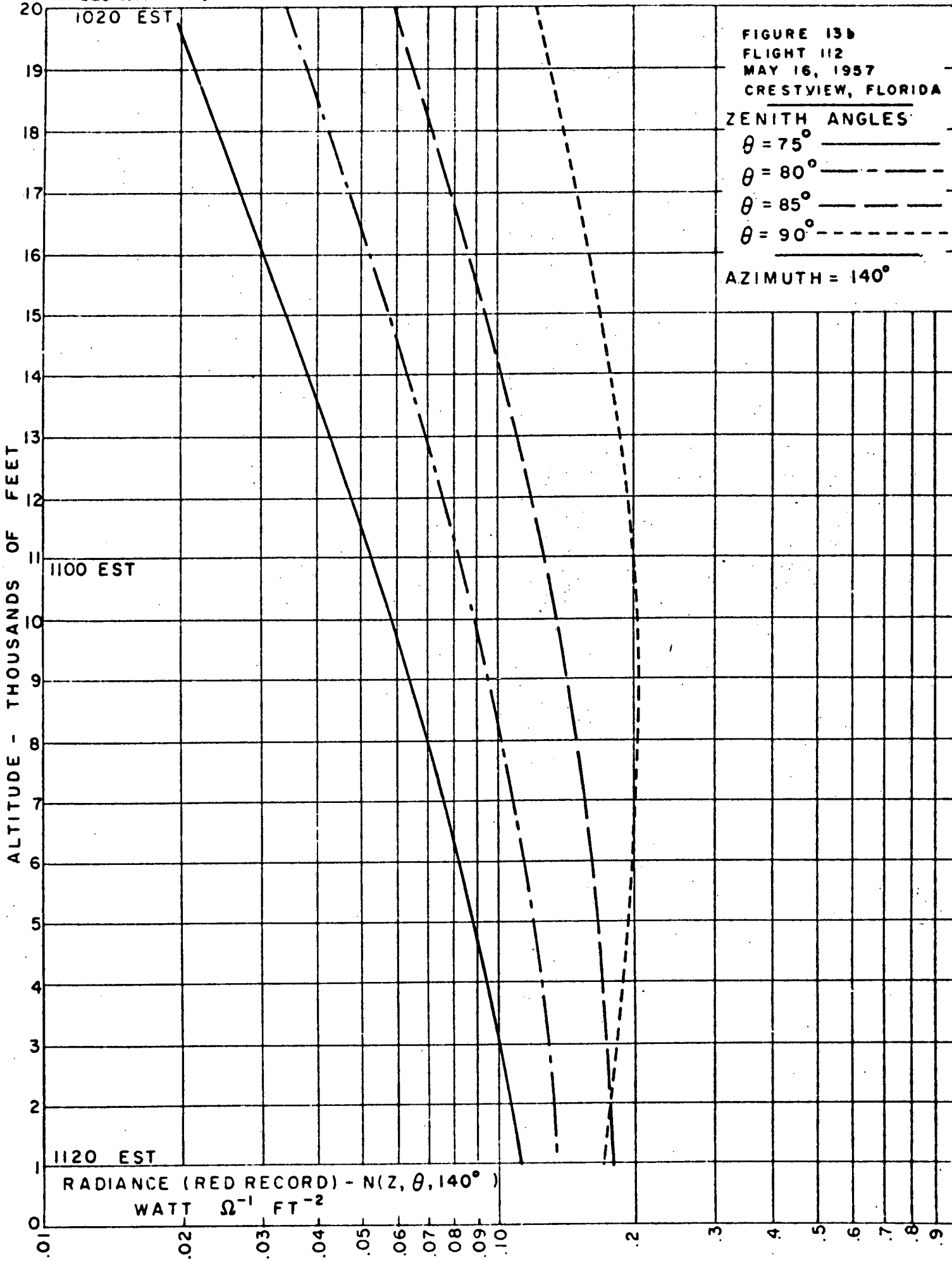


FIGURE 13a  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 0^\circ$  -----  
 $\theta = 15^\circ$  \_\_\_\_\_  
 $\theta = 30^\circ$  -----  
 $\theta = 45^\circ$  \_\_\_\_\_  
 $\theta = 60^\circ$  -----  
 AZIMUTH =  $140^\circ$

RADIANCE (RED RECORD) -  $N(Z, \theta, 140^\circ)$   
 WATT  $\Omega^{-1}$  FT $^{-2}$



1020 EST

1100 EST

1120 EST

FIGURE 13c  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 90^\circ$  - - - - -  
 $\theta = 95^\circ$  - - - - -  
 $\theta = 100^\circ$  - - - - -  
 $\theta = 105^\circ$  - - - - -

AZIMUTH =  $140^\circ$

RADIANCE (RED RECORD) -  $N(Z, \theta, 140^\circ)$   
 WATT  $\Omega^{-1} \text{ FT.}^{-2}$

ALTITUDE - THOUSANDS OF FEET

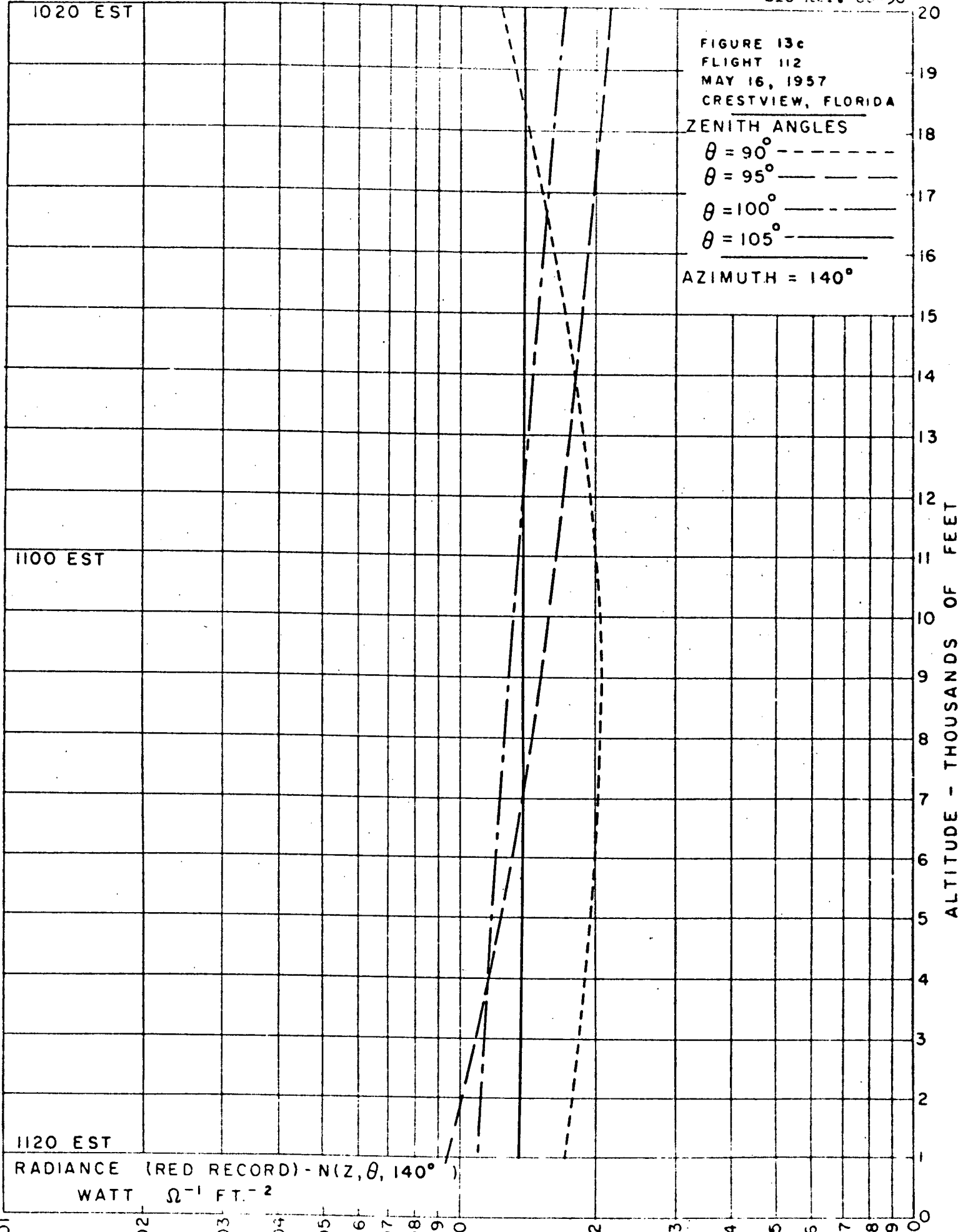


FIGURE 134  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 120^\circ$  - - - - -

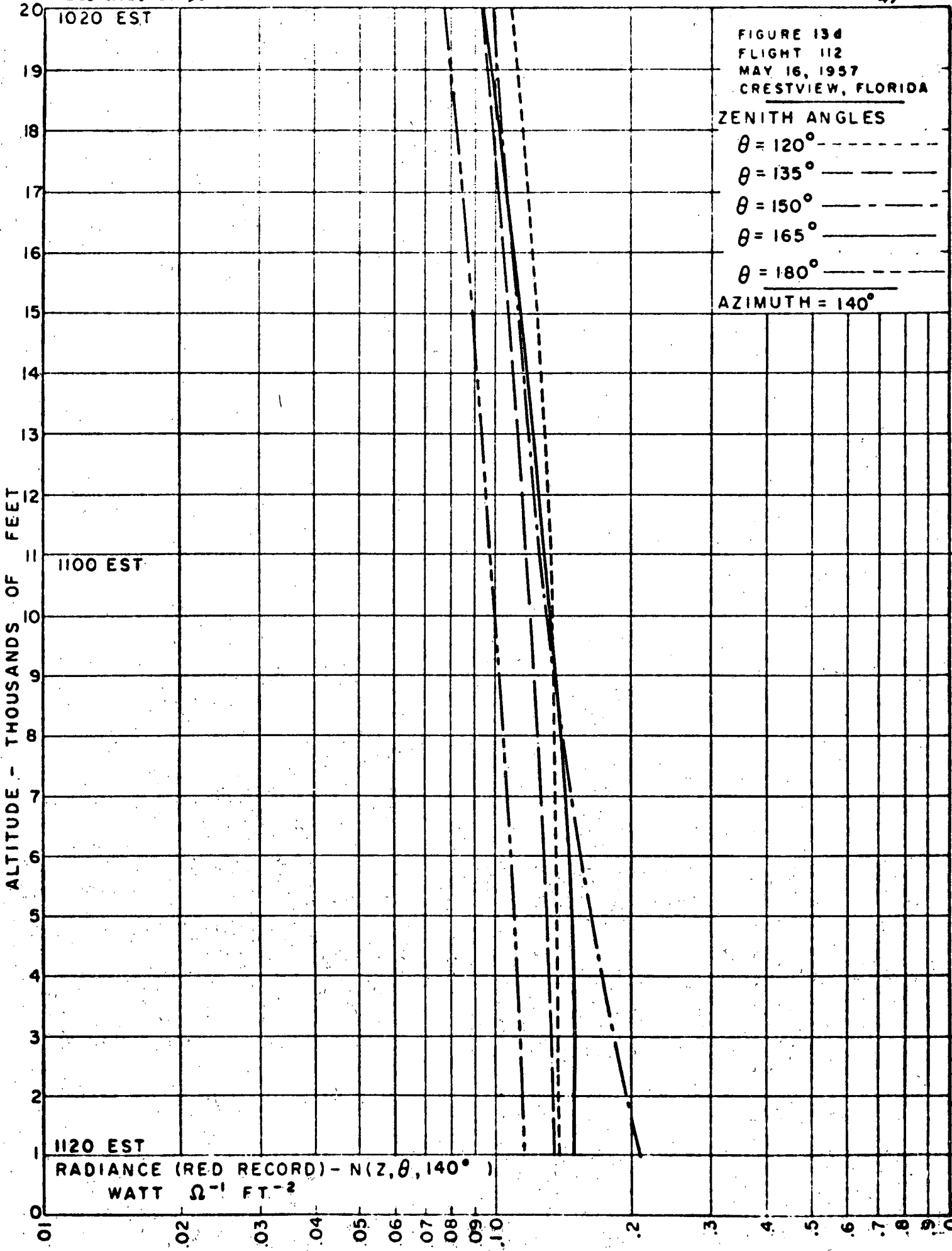
$\theta = 135^\circ$  - - - - -

$\theta = 150^\circ$  - - - - -

$\theta = 165^\circ$  - - - - -

$\theta = 180^\circ$  - - - - -

AZIMUTH =  $140^\circ$



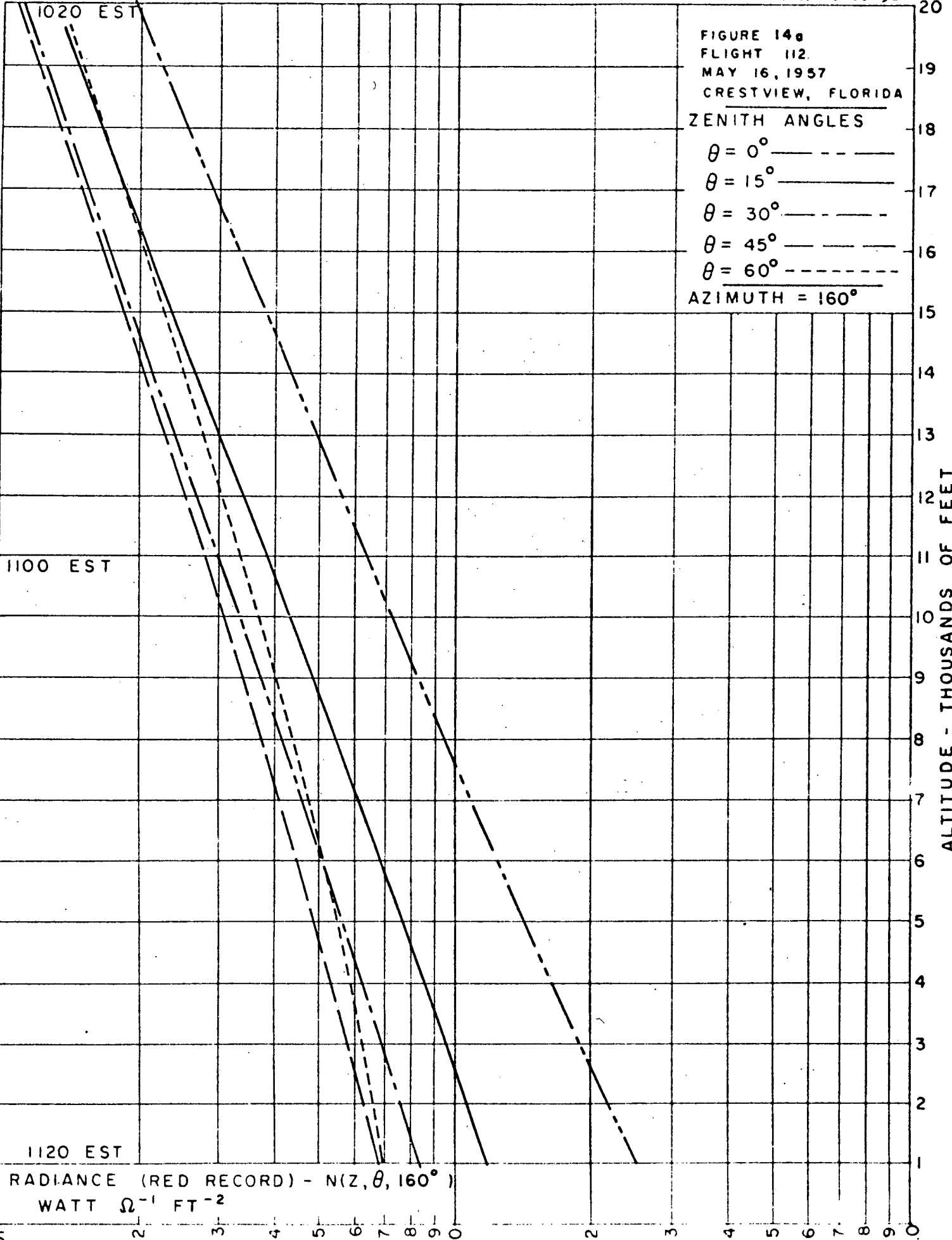


FIGURE 14a  
 FLIGHT 112.  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA

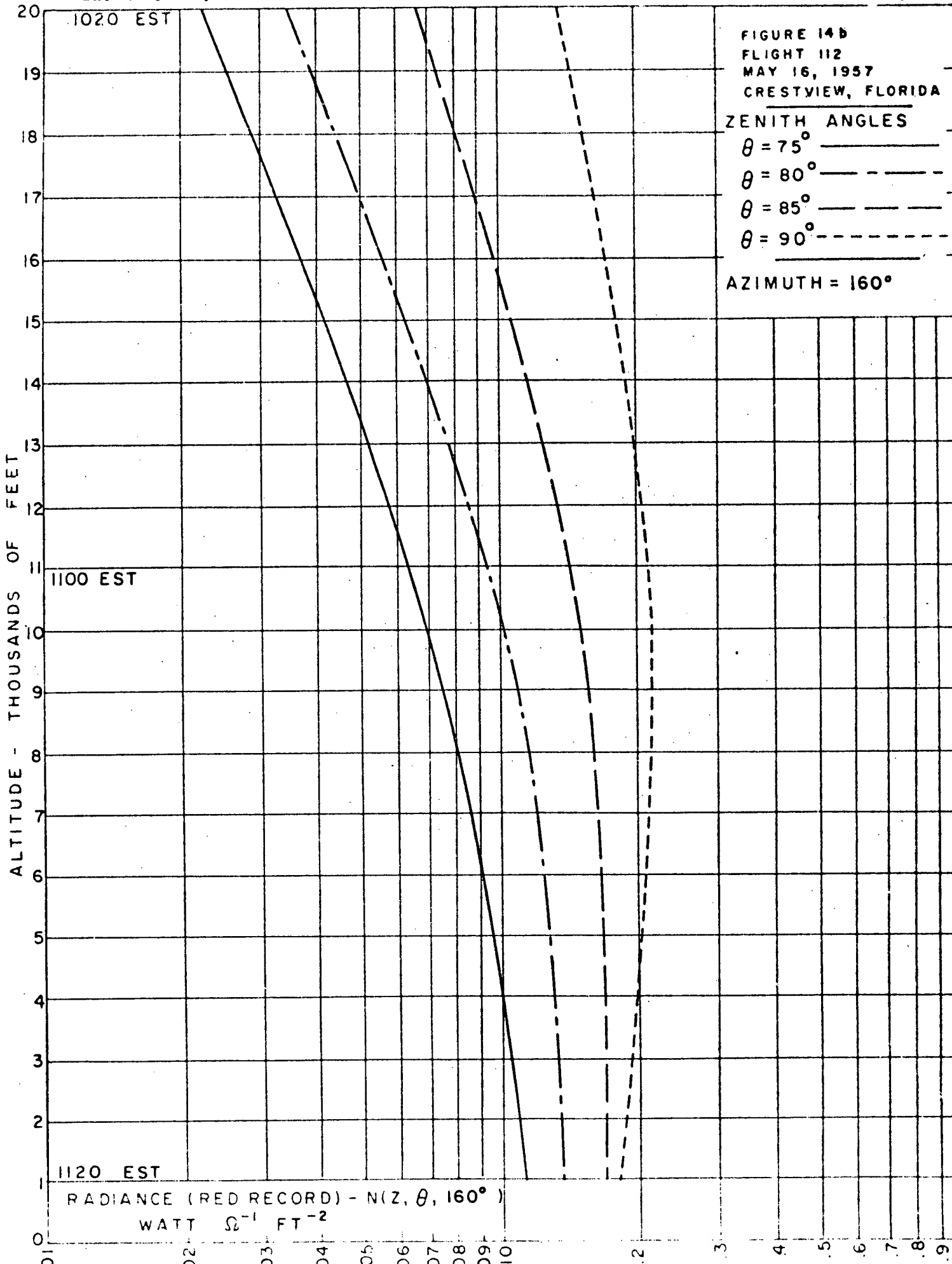
ZENITH ANGLES  
 $\theta = 0^\circ$  -----  
 $\theta = 15^\circ$  \_\_\_\_\_  
 $\theta = 30^\circ$  - . - . - .  
 $\theta = 45^\circ$  - - - - -  
 $\theta = 60^\circ$  - - - - -  
 AZIMUTH =  $160^\circ$

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 160^\circ)$   
 WATT  $\Omega^{-1}$  FT $^{-2}$

ALTITUDE - THOUSANDS OF FEET



1020 EST

FIGURE 14c  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 90^\circ$  - - - - -

$\theta = 95^\circ$  - - - - -

$\theta = 100^\circ$  - - - - -

$\theta = 105^\circ$  - - - - -

AZIMUTH =  $160^\circ$

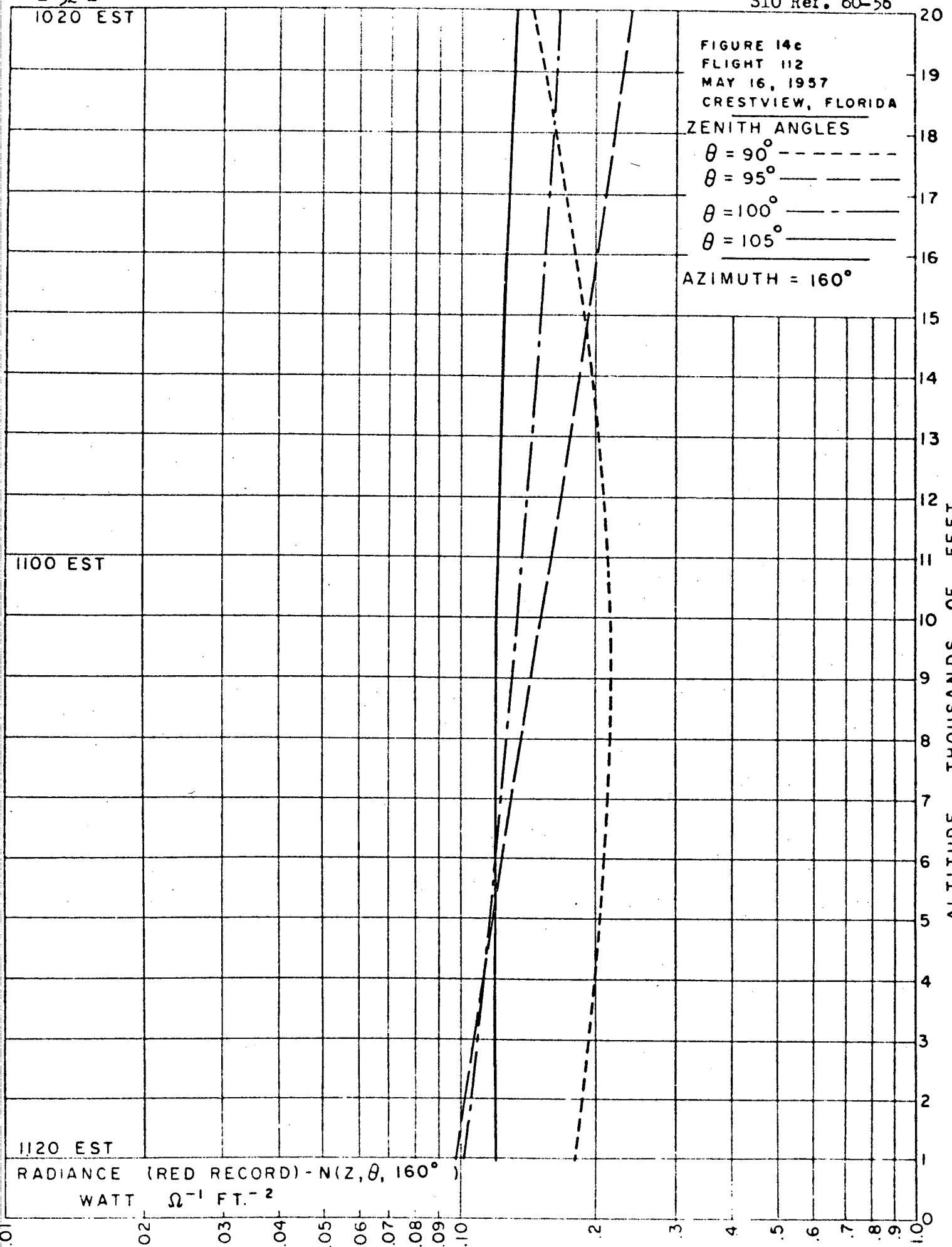
1100 EST

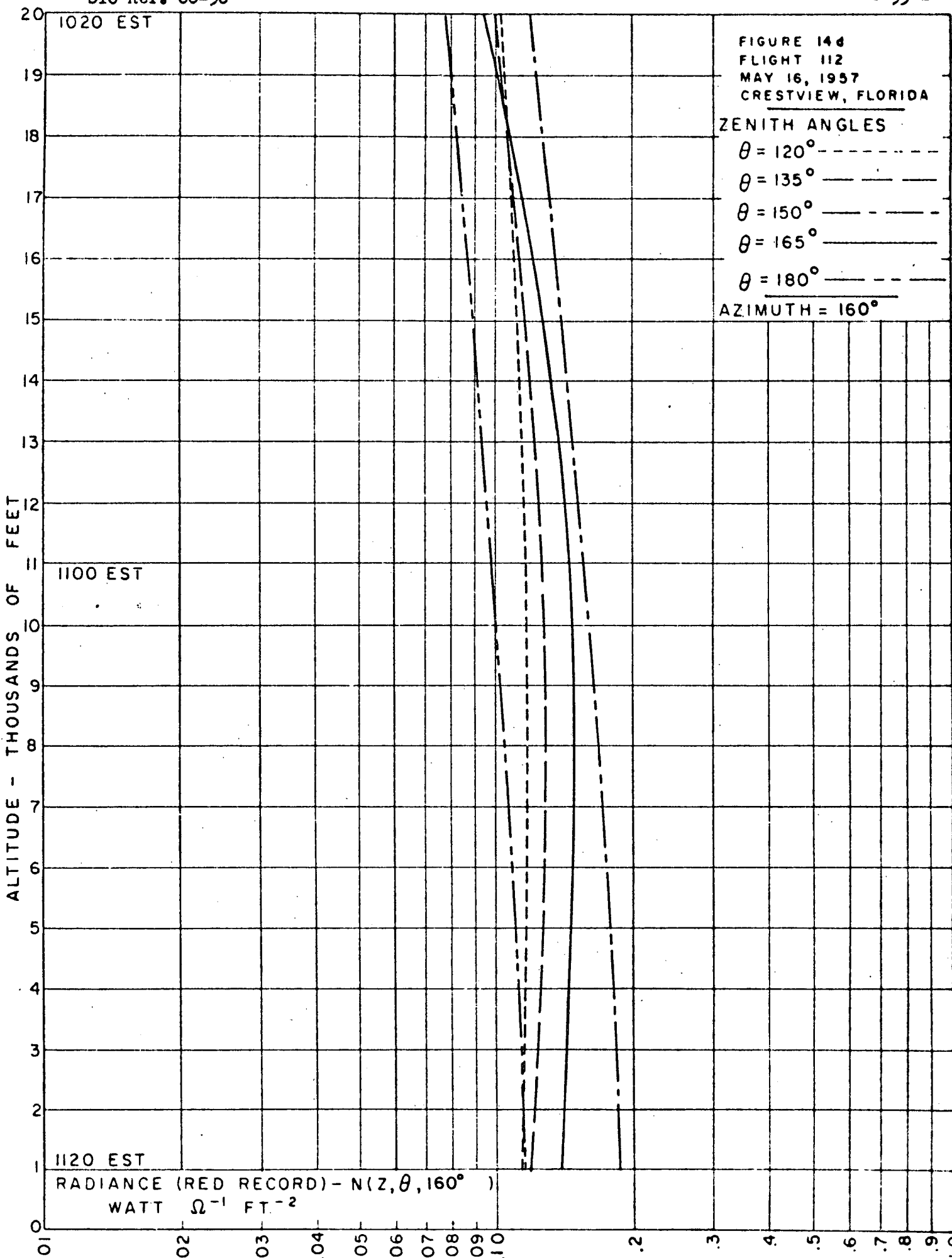
1120 EST

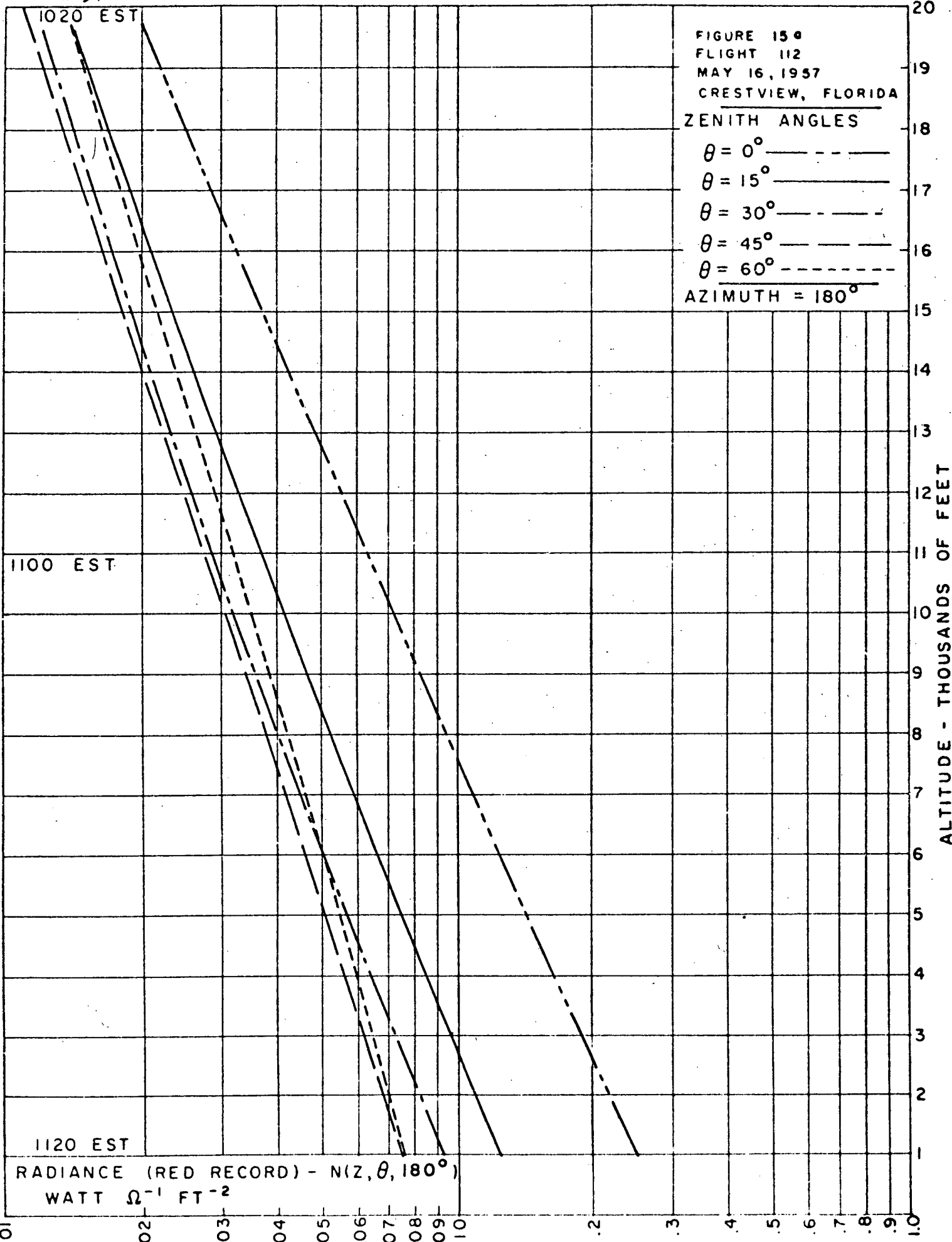
RADIANCE (RED RECORD) -  $N(Z, \theta, 160^\circ)$

WATT  $\Omega^{-1} \text{ FT.}^{-2}$

ALTITUDE - THOUSANDS OF FEET

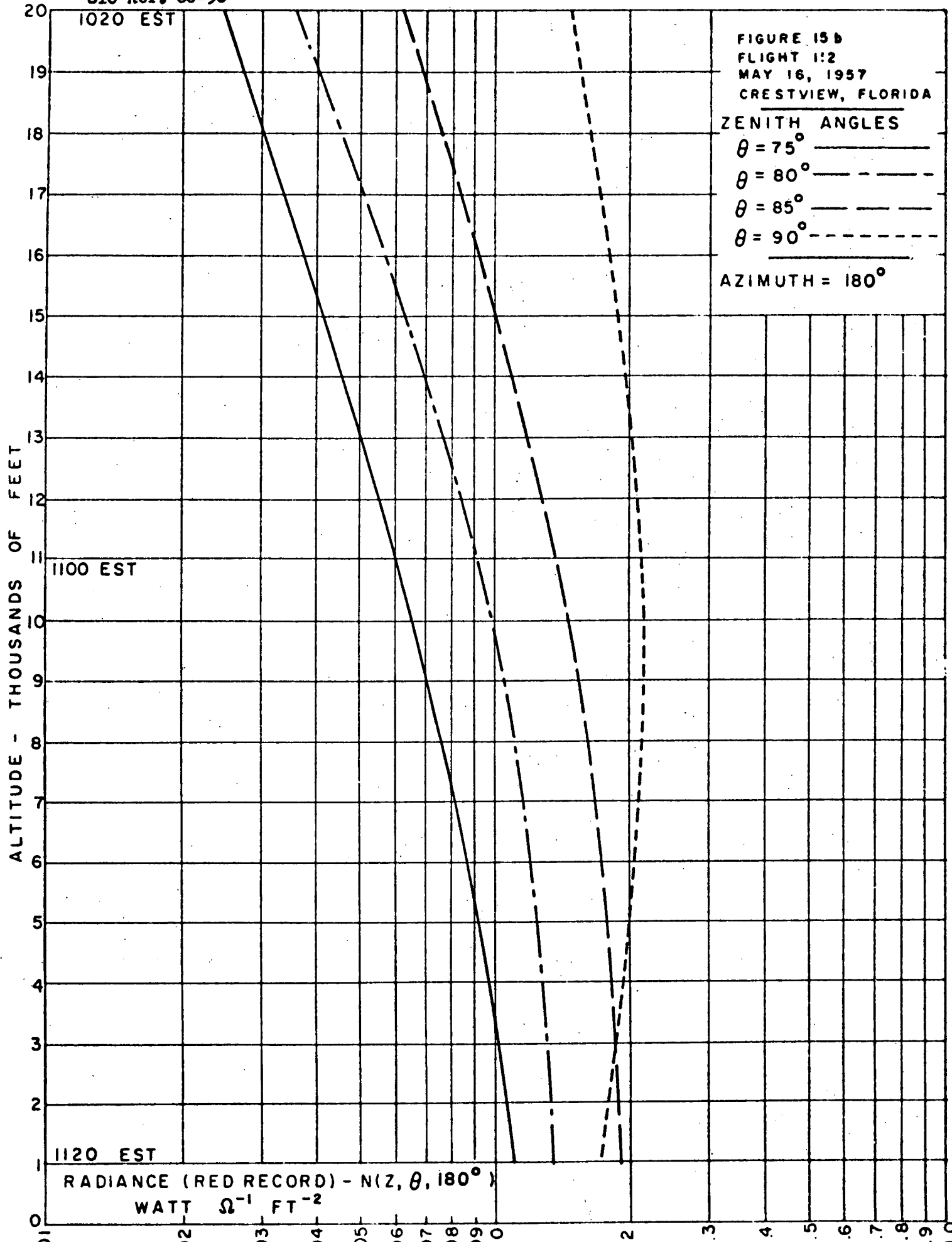






SIO Ref. 60-56

FIGURE 15b  
FLIGHT 1:2  
MAY 16, 1957  
CRESTVIEW, FLORIDA  
ZENITH ANGLES  
 $\theta = 75^\circ$  \_\_\_\_\_  
 $\theta = 80^\circ$  - - - - -  
 $\theta = 85^\circ$  - - - - -  
 $\theta = 90^\circ$  - - - - -  
AZIMUTH =  $180^\circ$



1020 EST

1100 EST

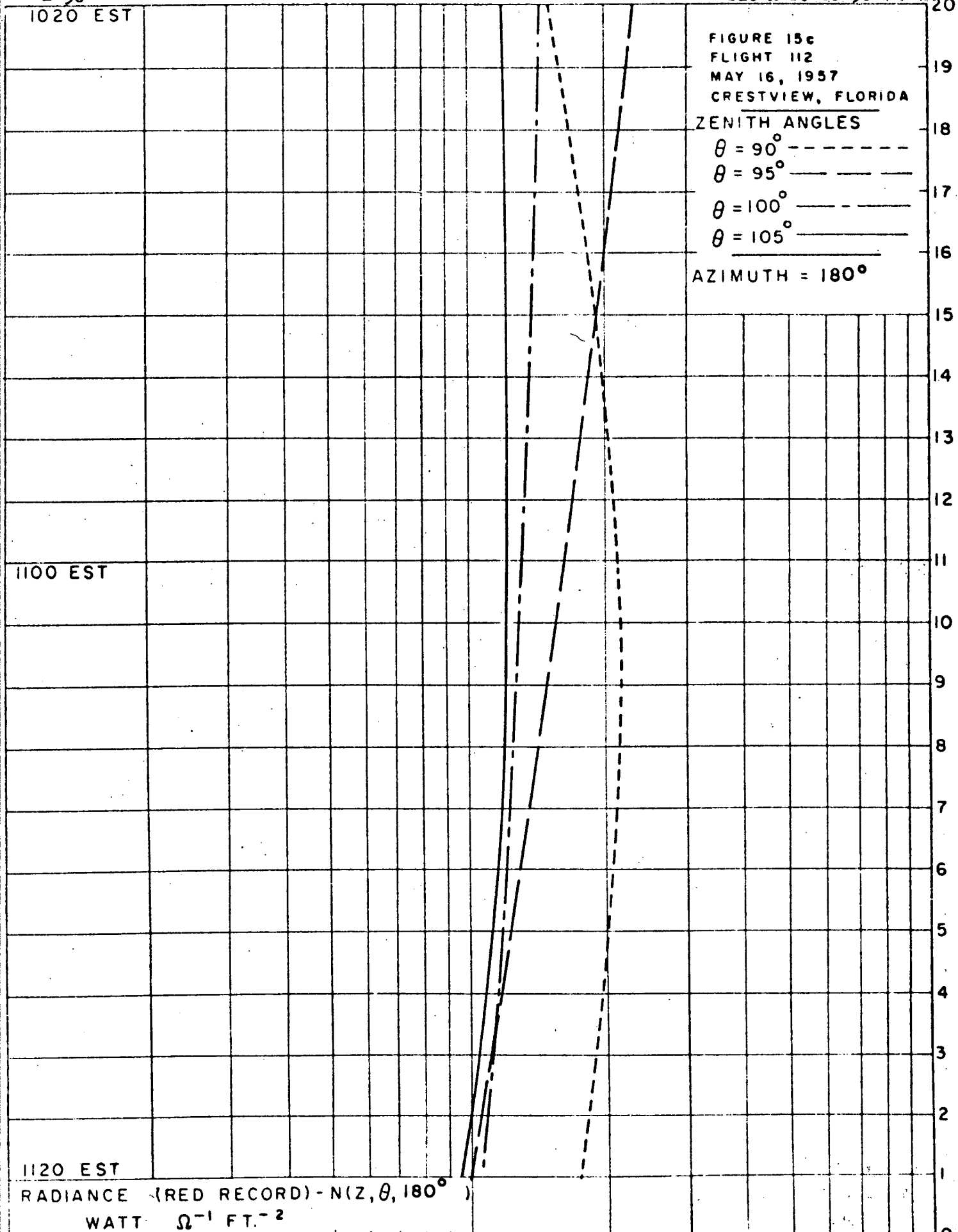
1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 180^\circ)$   
WATT  $\Omega^{-1}$  FT.<sup>-2</sup>

FIGURE 15c  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA  
 ZENITH ANGLES  
 $\theta = 90^\circ$  - - - - -  
 $\theta = 95^\circ$  - - - - -  
 $\theta = 100^\circ$  - - - - -  
 $\theta = 105^\circ$  - - - - -  
 AZIMUTH =  $180^\circ$

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ALTITUDE - THOUSANDS OF FEET

01 02 03 04 05 06 07 08 09 10 2 3 4 5 6 7 8 9 10



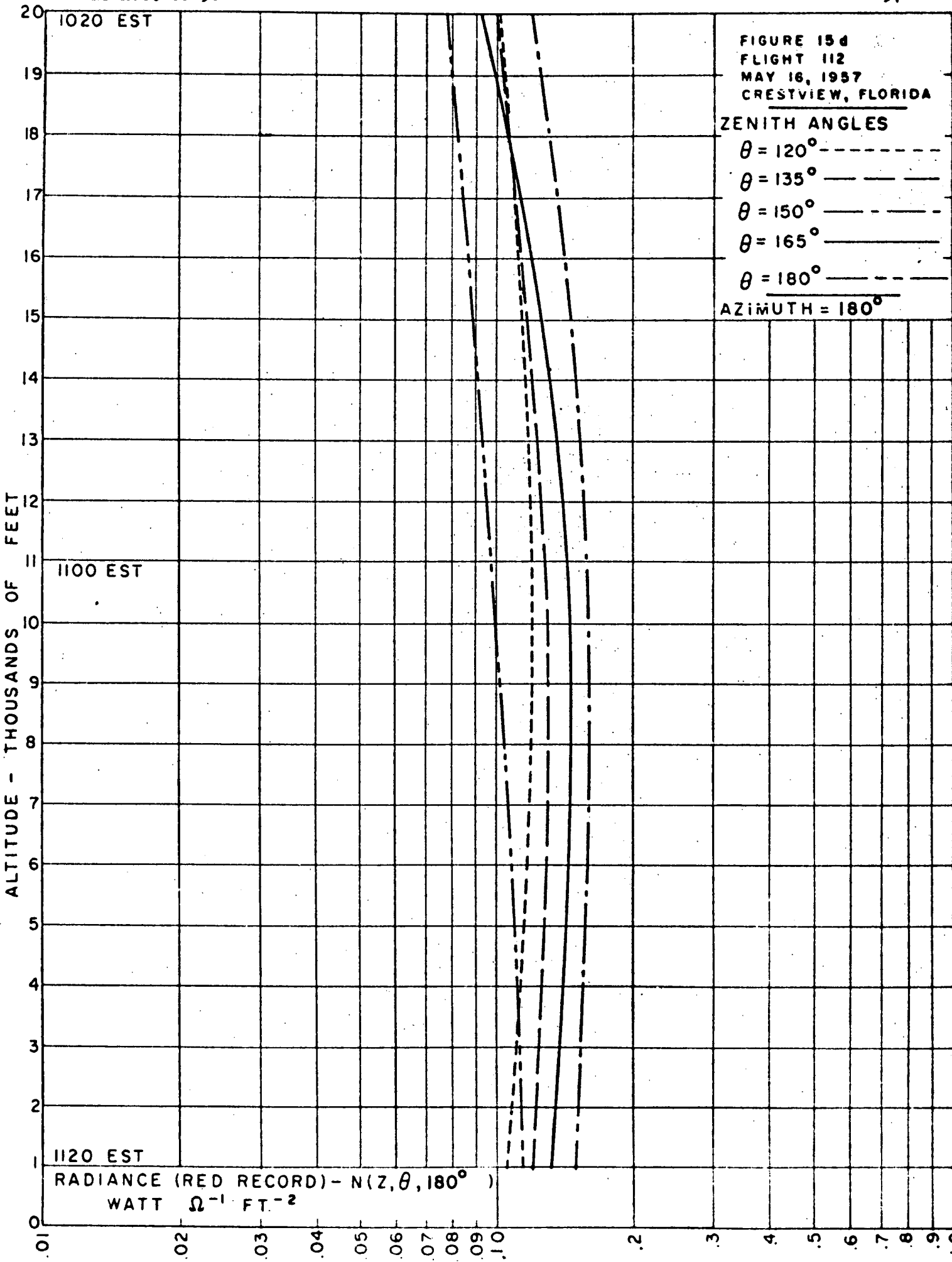


FIGURE 16 a  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 0^\circ$  - - - - -

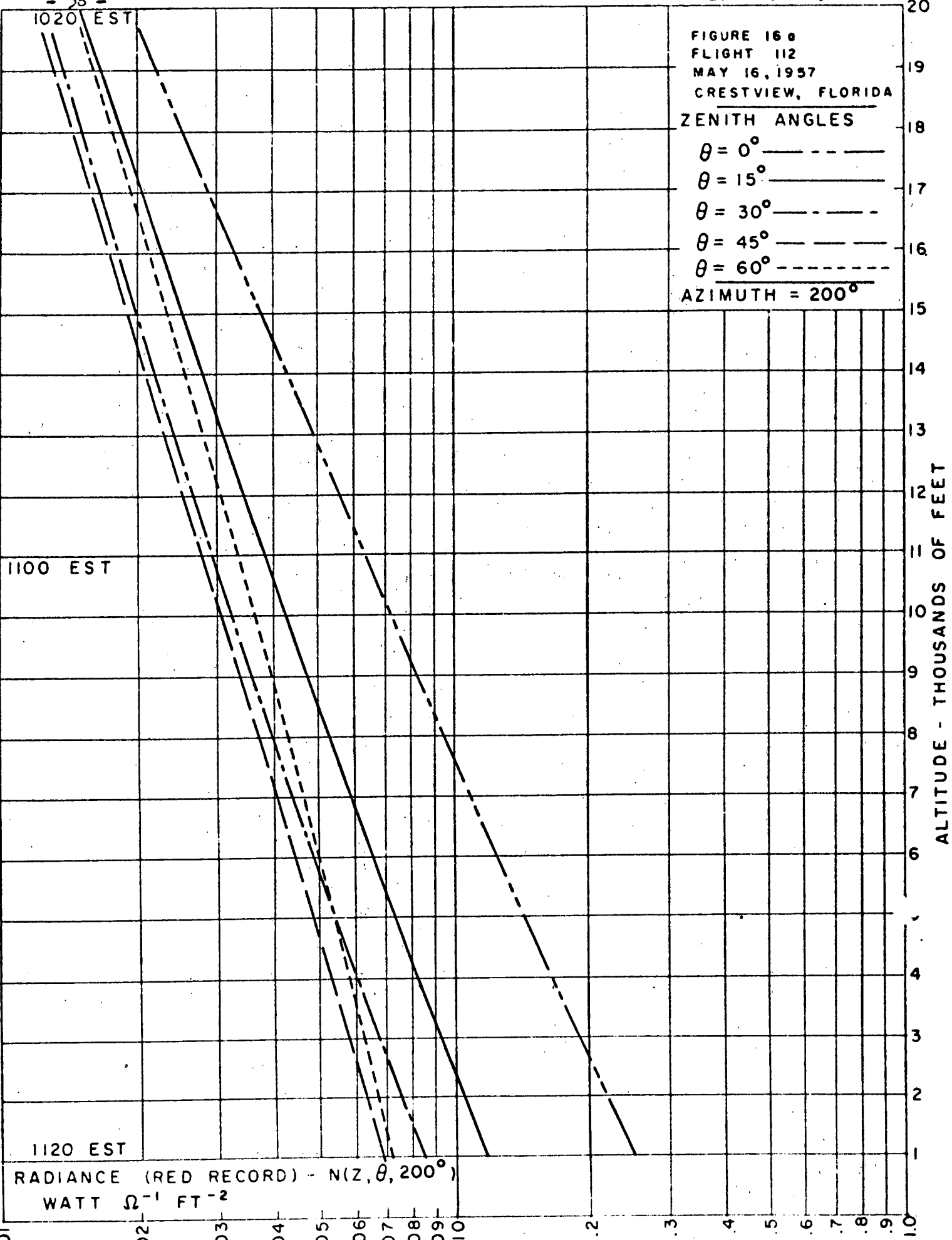
$\theta = 15^\circ$  - - - - -

$\theta = 30^\circ$  - - - - -

$\theta = 45^\circ$  - - - - -

$\theta = 60^\circ$  - - - - -

AZIMUTH =  $200^\circ$



RADIANCE (RED RECORD) -  $N(Z, \theta, 200^\circ)$   
WATT  $\Omega^{-1} \text{ FT}^{-2}$

ALTITUDE - THOUSANDS OF FEET

1100 EST

1120 EST

1020 EST

FIGURE 16b  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

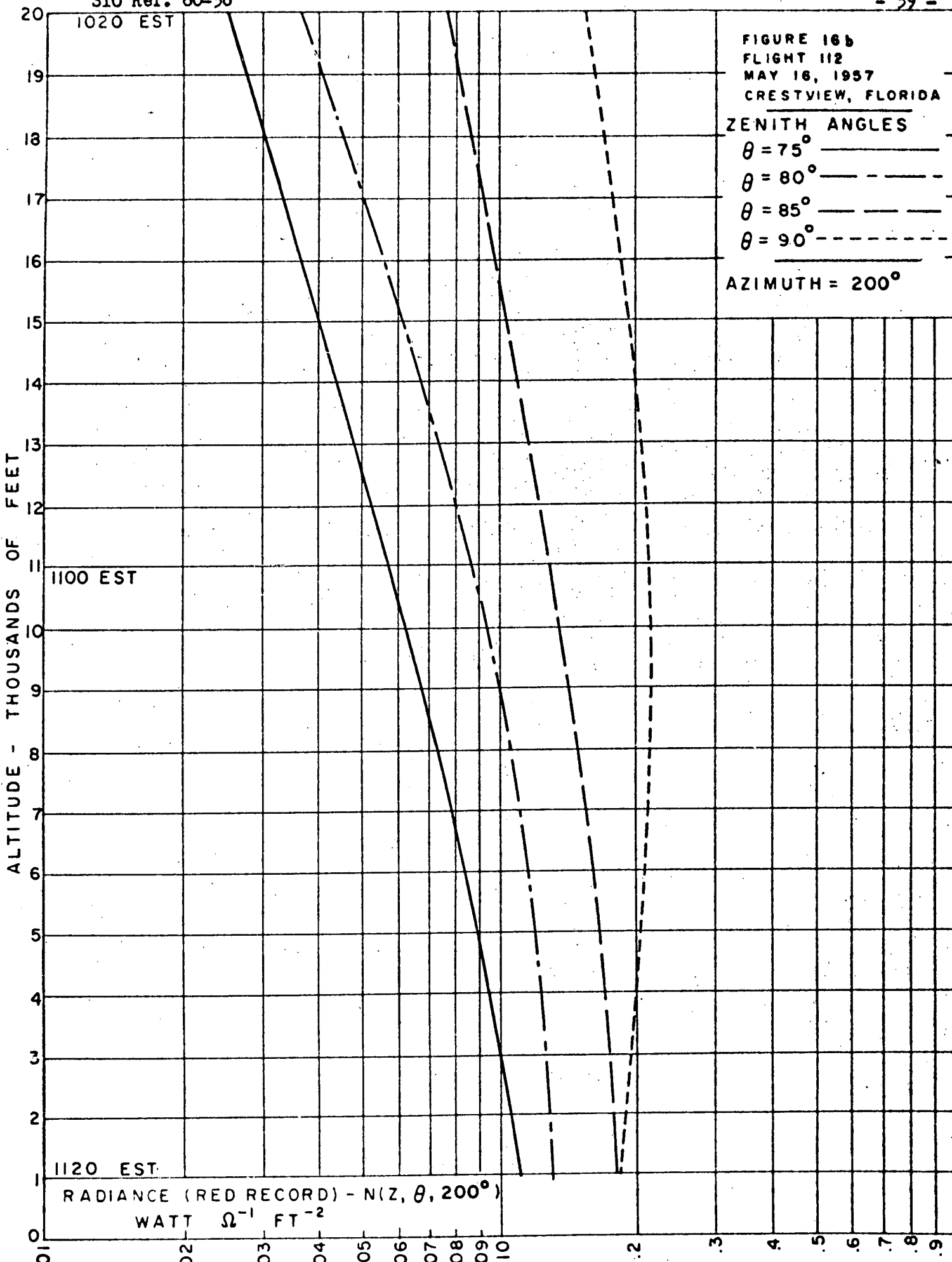
$\theta = 75^\circ$  —————

$\theta = 80^\circ$  - - - - -

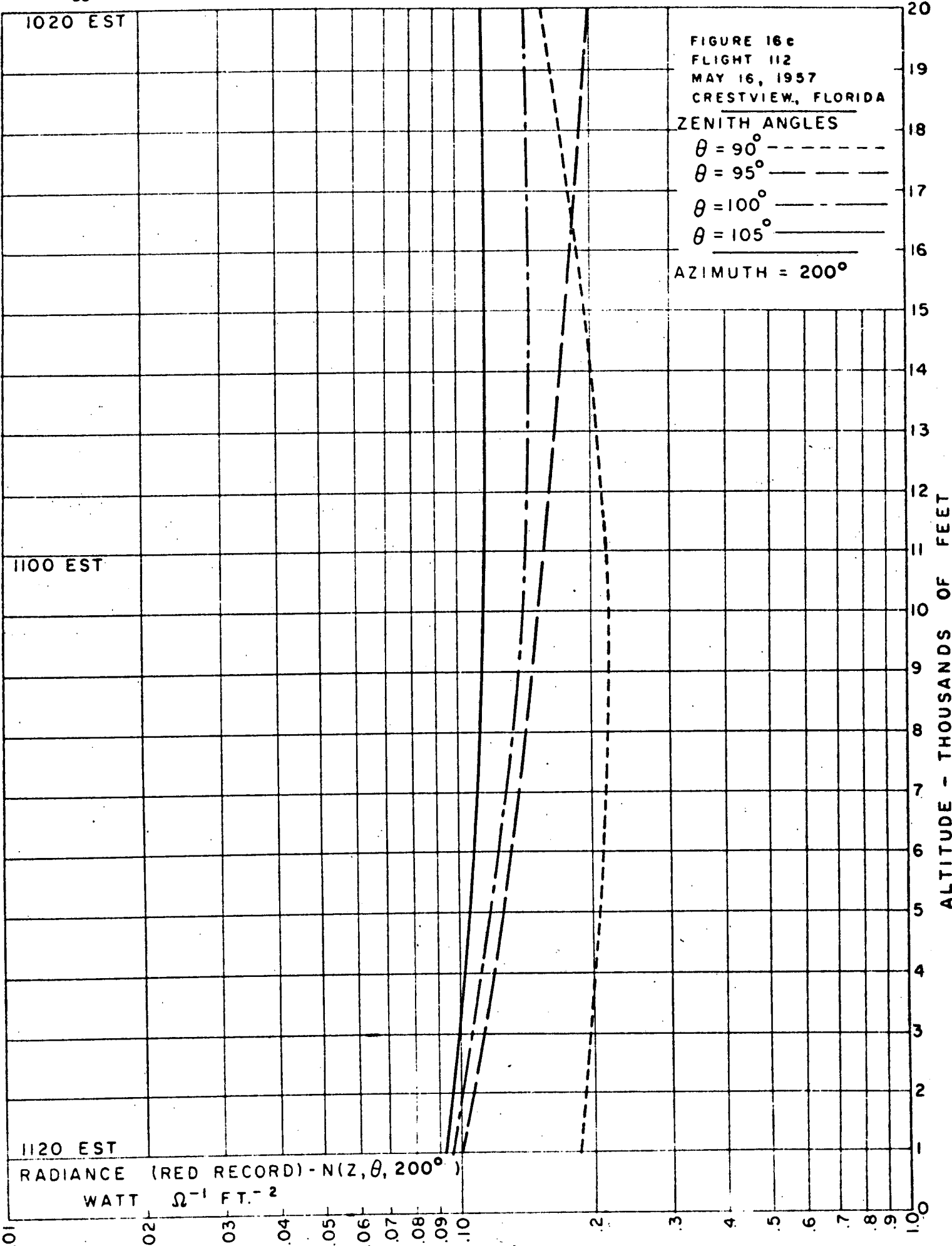
$\theta = 85^\circ$  - - - - -

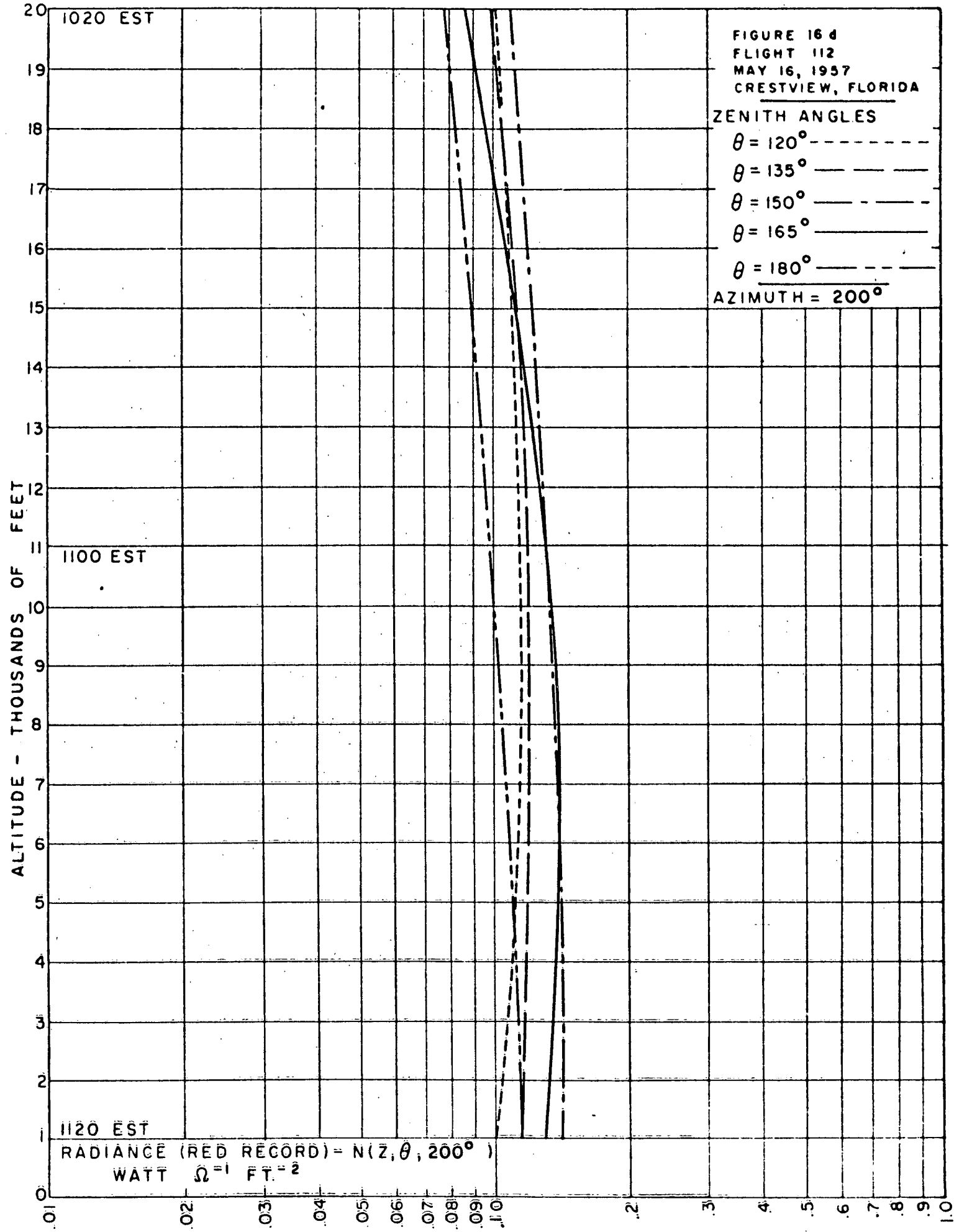
$\theta = 90^\circ$  - - - - -

AZIMUTH =  $200^\circ$



RADIANCE (RED RECORD) -  $N(Z, \theta, 200^\circ)$   
WATT  $\Omega^{-1}$  FT<sup>-2</sup>





1020 EST

FIGURE 17e  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 0^\circ$  - - - - -

$\theta = 15^\circ$  - - - - -

$\theta = 30^\circ$  - - - - -

$\theta = 45^\circ$  - - - - -

$\theta = 60^\circ$  - - - - -

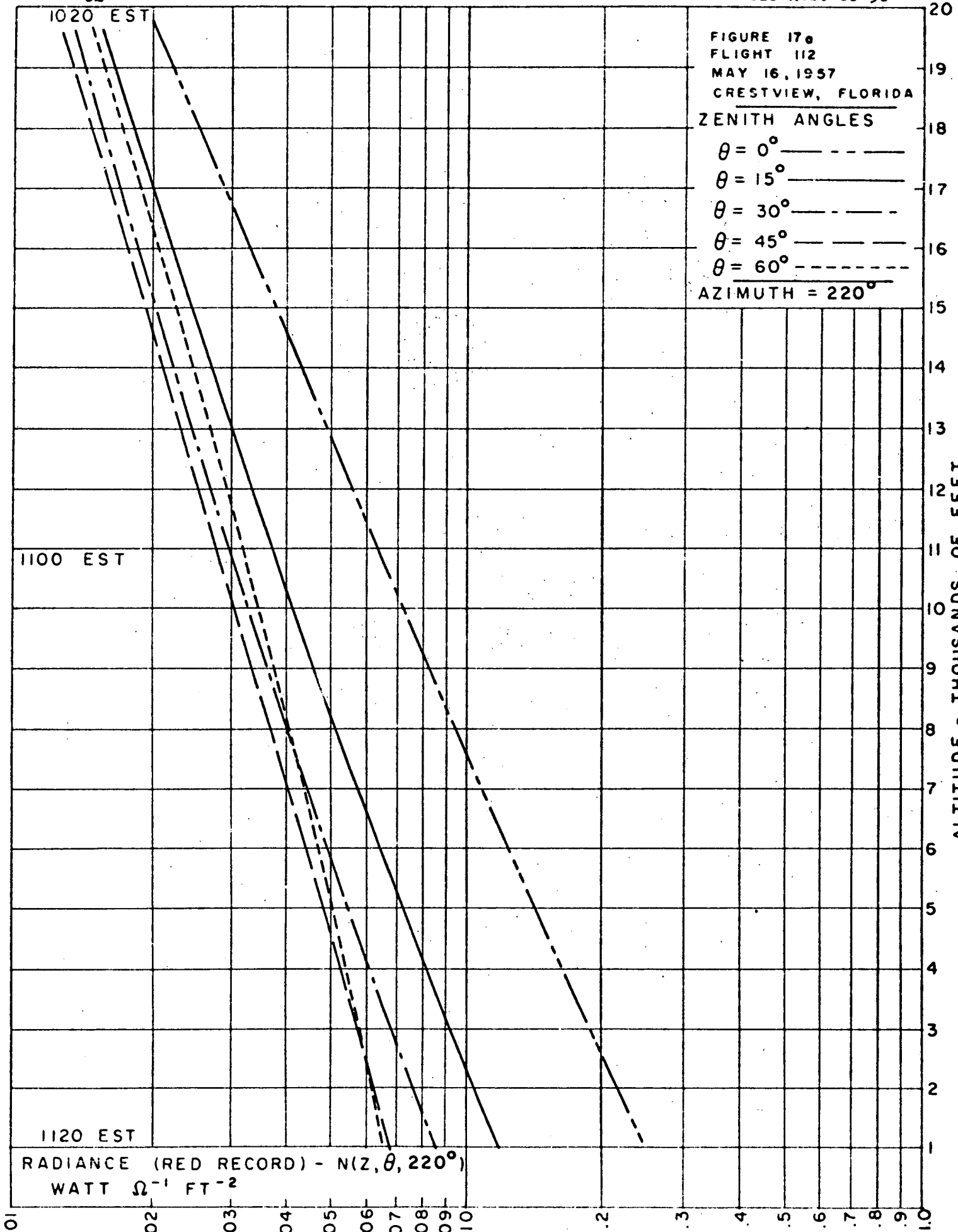
AZIMUTH =  $220^\circ$

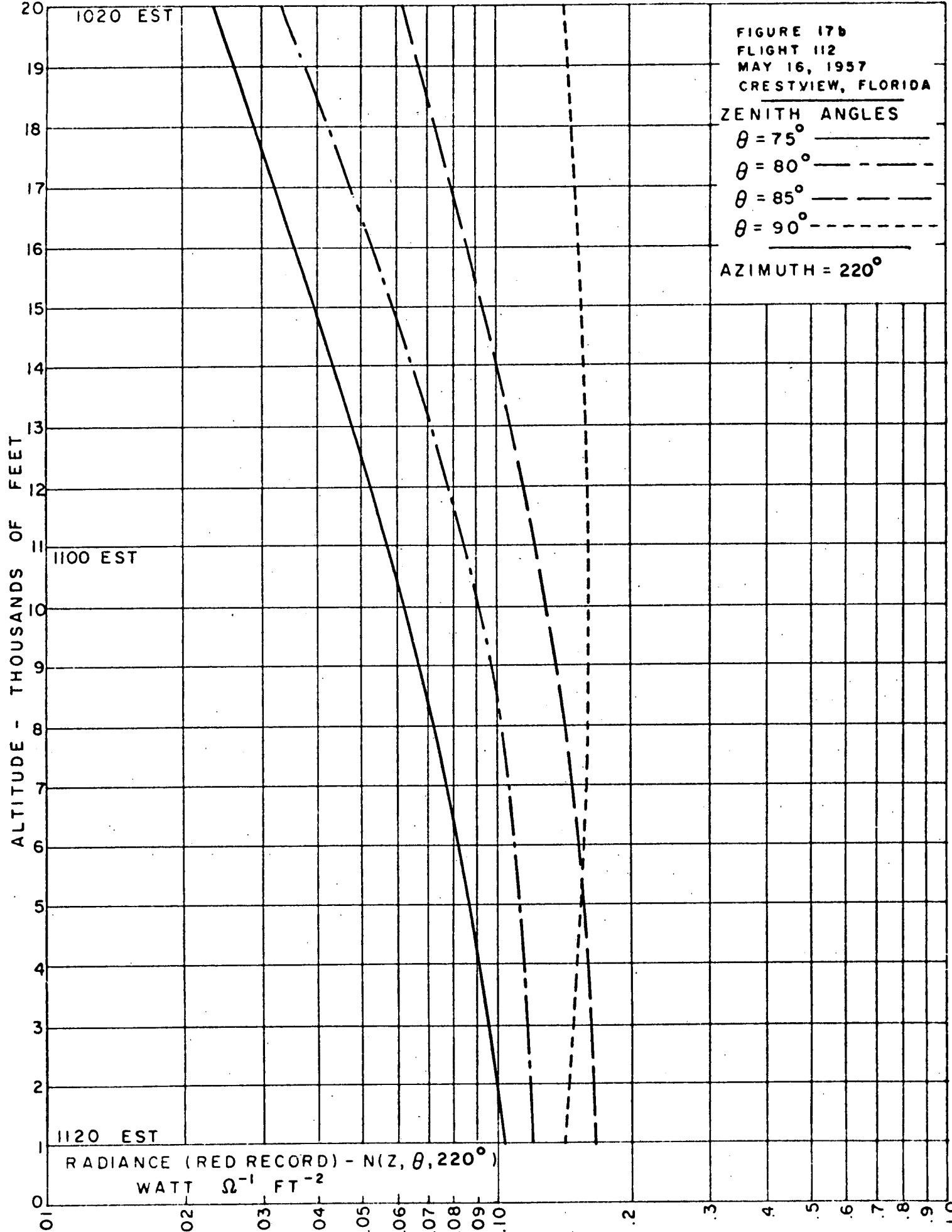
1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 220^\circ)$   
WATT  $\Omega^{-1} \text{ FT}^{-2}$

ALTITUDE - THOUSANDS OF FEET





1020 EST

FIGURE 17c  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 90^\circ$  - - - - -  
 $\theta = 95^\circ$  - - - - -  
 $\theta = 100^\circ$  - - - - -  
 $\theta = 105^\circ$  - - - - -  
AZIMUTH =  $220^\circ$

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 220^\circ)$

WATT  $\Omega^{-1} \text{ FT.}^{-2}$

ALTITUDE - THOUSANDS OF FEET

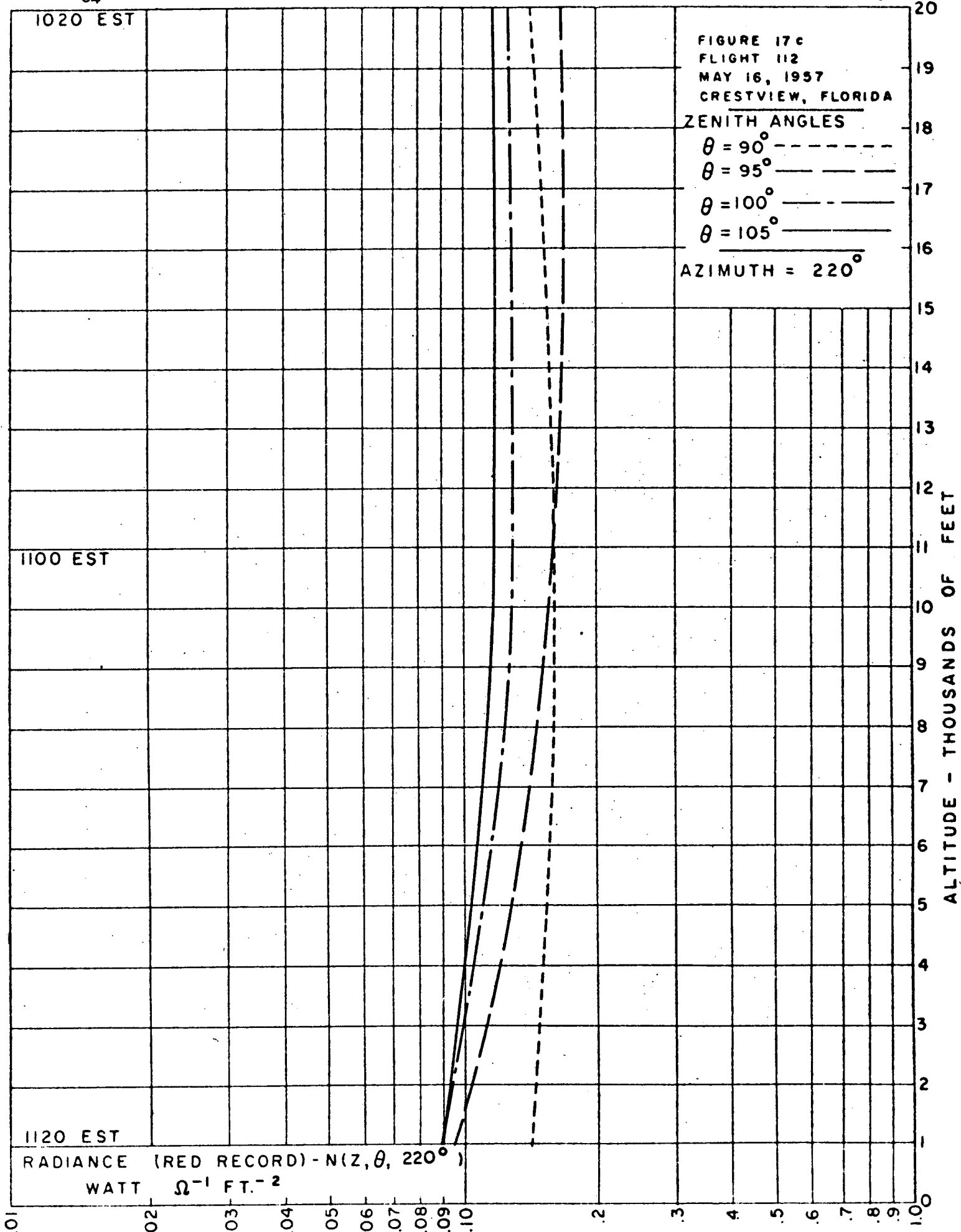


FIGURE 17d  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 120^\circ$  - - - - -

$\theta = 135^\circ$  - - - - -

$\theta = 150^\circ$  - - - - -

$\theta = 165^\circ$  - - - - -

$\theta = 180^\circ$  - - - - -

AZIMUTH =  $220^\circ$

ALTITUDE - THOUSANDS OF FEET

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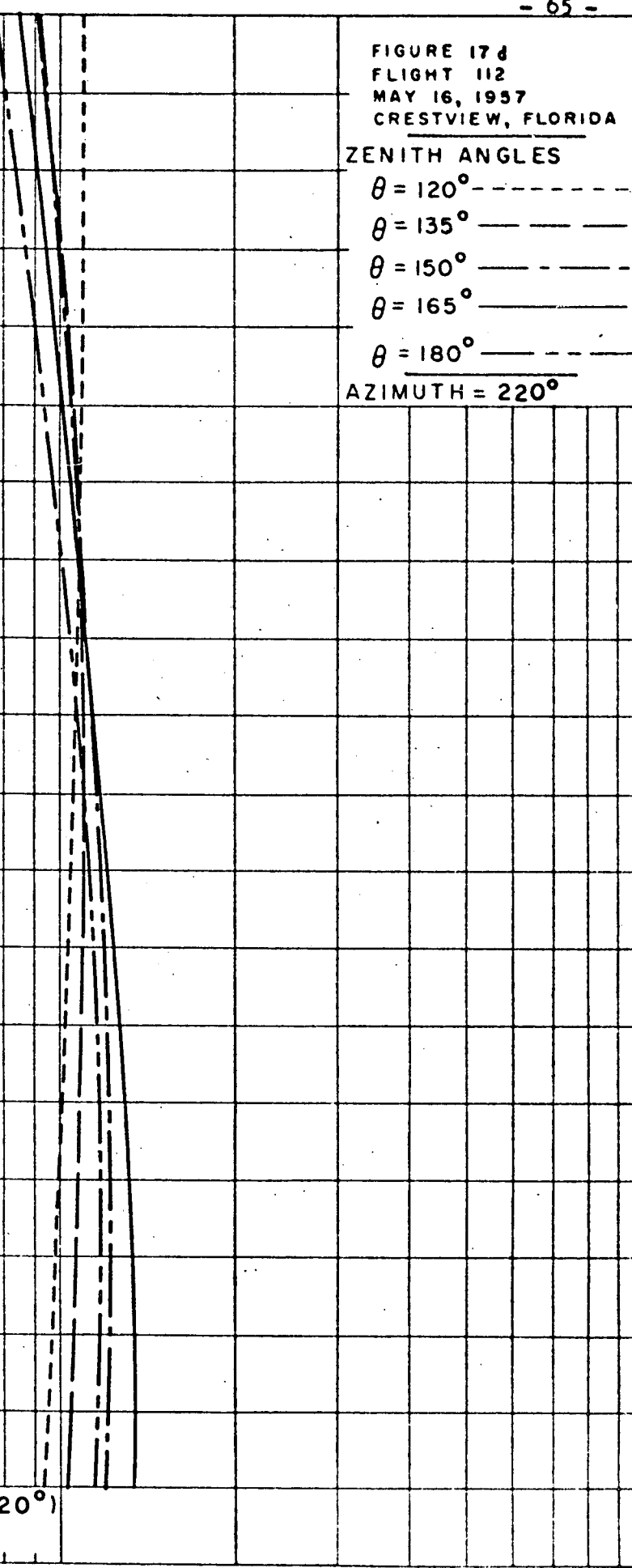
1020 EST

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 220^\circ)$   
WATT  $\Omega^{-1}$  FT.<sup>-2</sup>

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 .2 .3 .4 .5 .6 .7 .8 .9 1.0



- 66 -

1020 EST

FIGURE 18 a  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 0^\circ$  — — — — —

$\theta = 15^\circ$  — — — — —

$\theta = 30^\circ$  - - - - -

$\theta = 45^\circ$  — — — — —

$\theta = 60^\circ$  - - - - -

AZIMUTH =  $240^\circ$

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 240^\circ)$   
WATT  $\Omega^{-1}$  FT $^{-2}$

ALTITUDE - THOUSANDS OF FEET

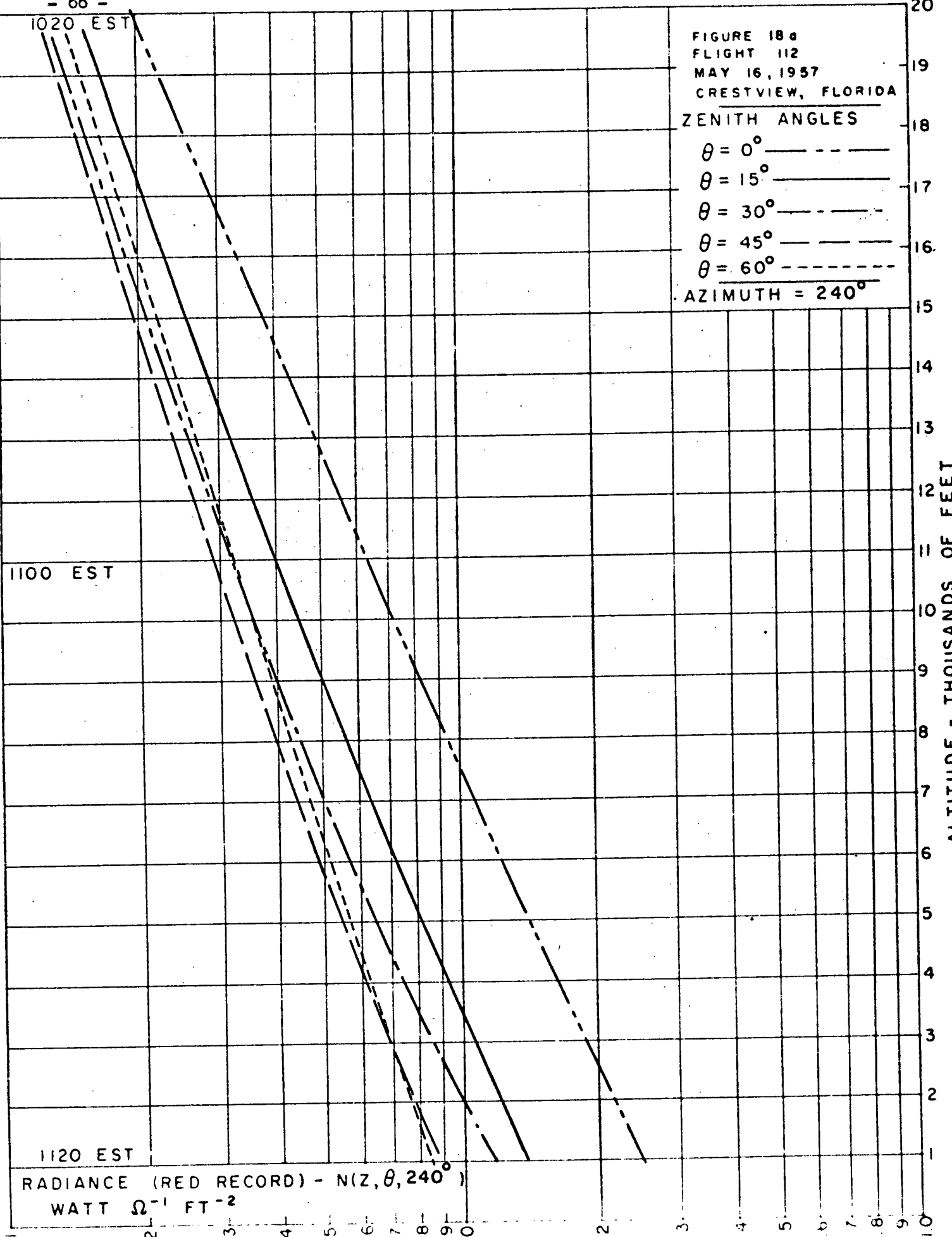


FIGURE 18b  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 75^\circ$  —————

$\theta = 80^\circ$  - - - - -

$\theta = 85^\circ$  — — — — —

$\theta = 90^\circ$  - - - - -

AZIMUTH =  $240^\circ$

ALTITUDE - THOUSANDS OF FEET

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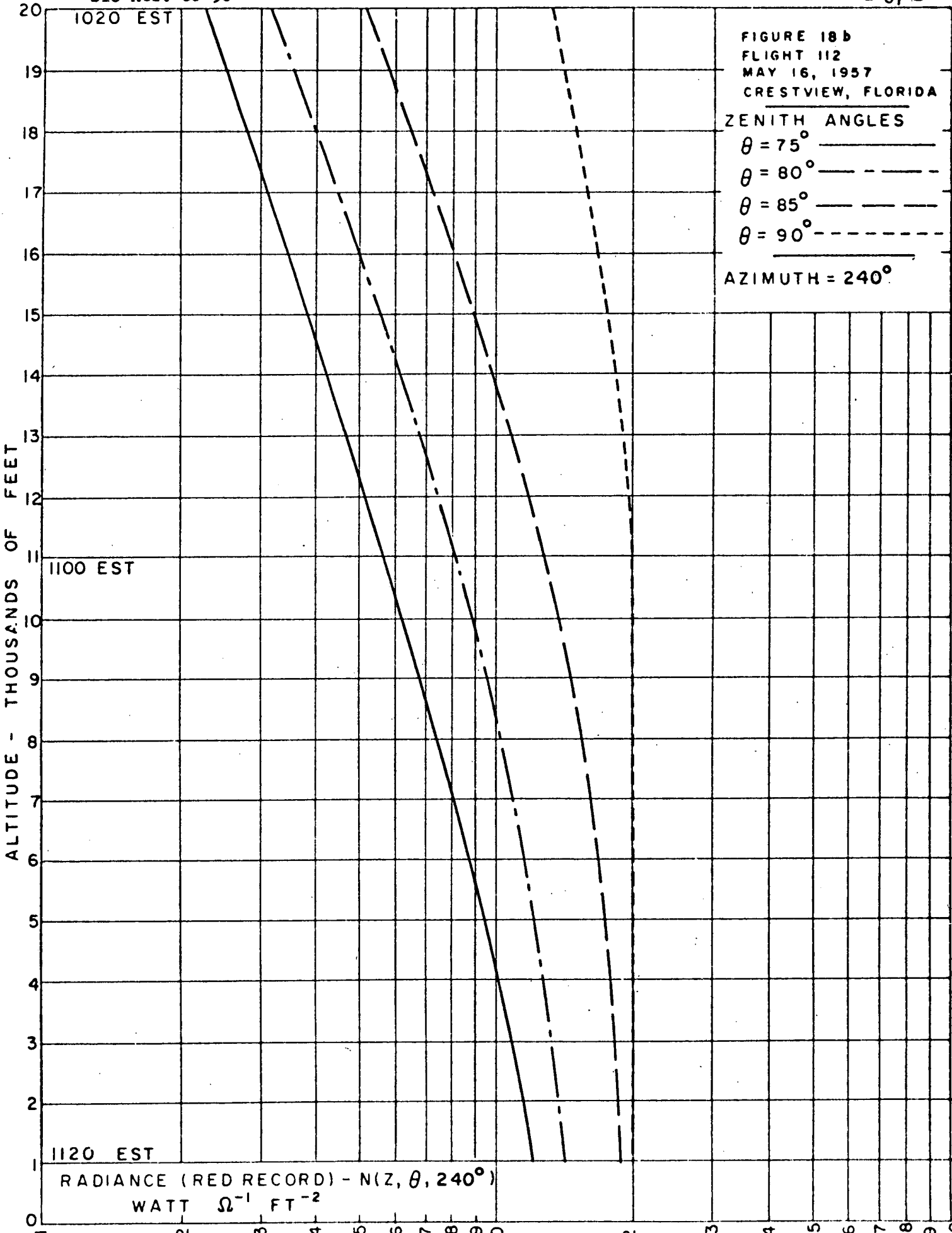
1020 EST

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(z, \theta, 240^\circ)$   
WATT  $\Omega^{-1} FT^{-2}$

01 02 03 04 05 06 07 08 09 10 2 3 4 5 6 7 8 9 0



1020 EST

FIGURE 18c  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA  
 ZENITH ANGLES  
 $\theta = 90^\circ$  - - - - -  
 $\theta = 95^\circ$  - - - - -  
 $\theta = 100^\circ$  - - - - -  
 $\theta = 105^\circ$  - - - - -  
 AZIMUTH =  $240^\circ$

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(z, \theta, 240^\circ)$   
 WATT  $\Omega^{-1} \text{ FT.}^{-2}$

ALTITUDE - THOUSANDS OF FEET

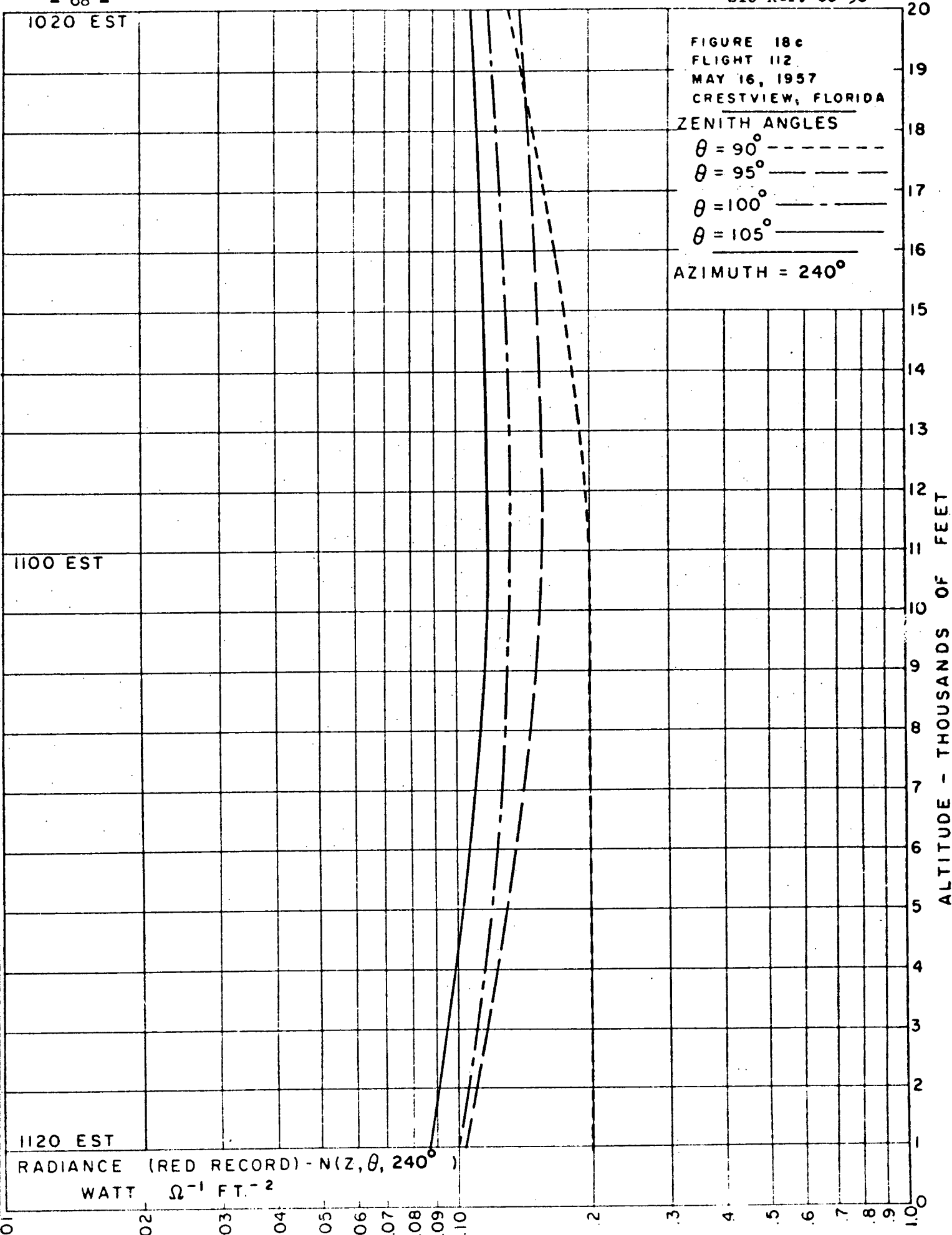


FIGURE 18 d  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 120^\circ$  - - - - -

$\theta = 135^\circ$  - - - - -

$\theta = 150^\circ$  - - - - -

$\theta = 165^\circ$  - - - - -

$\theta = 180^\circ$  - - - - -

AZIMUTH =  $240^\circ$

ALTITUDE - THOUSANDS OF FEET

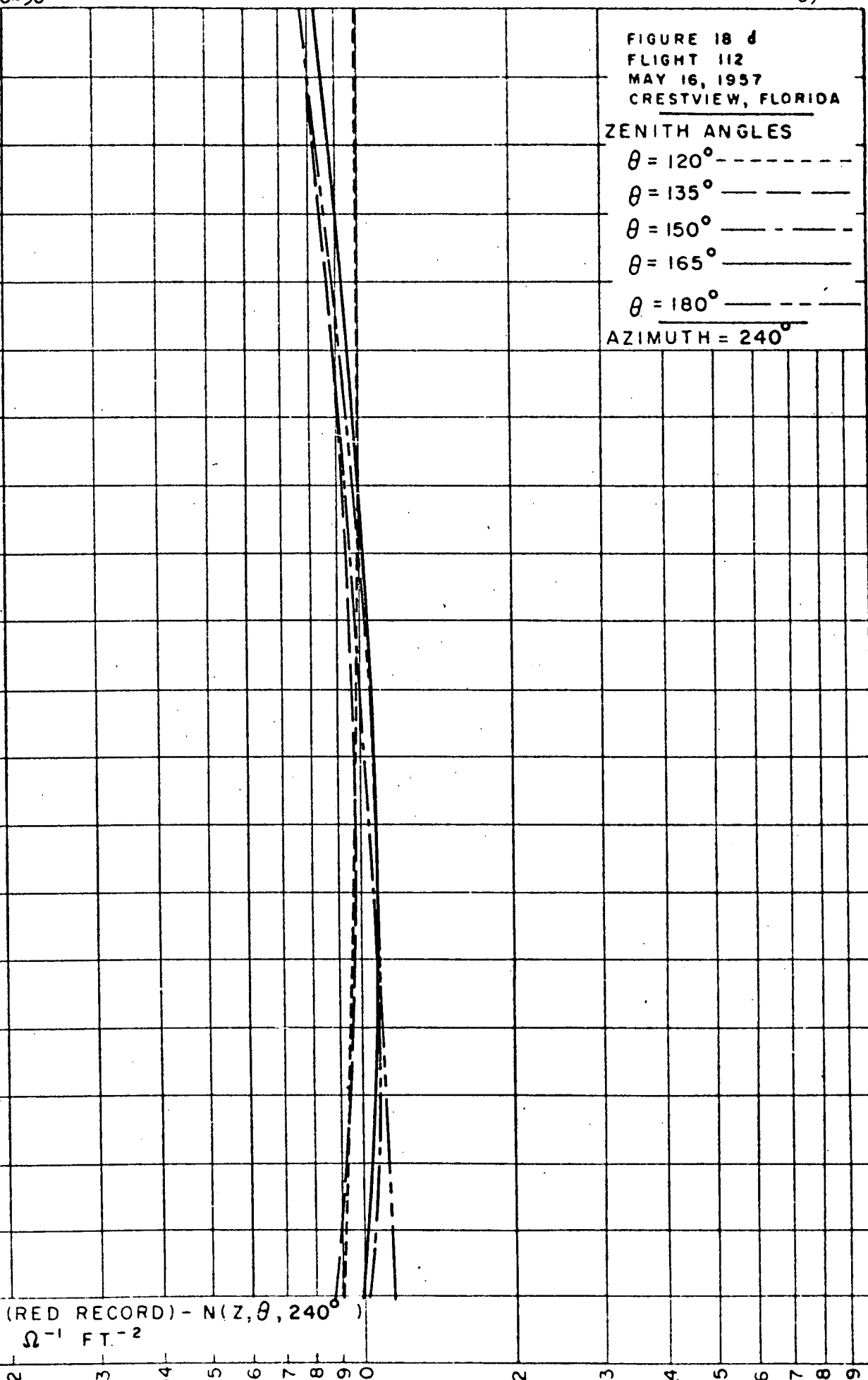
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1020 EST

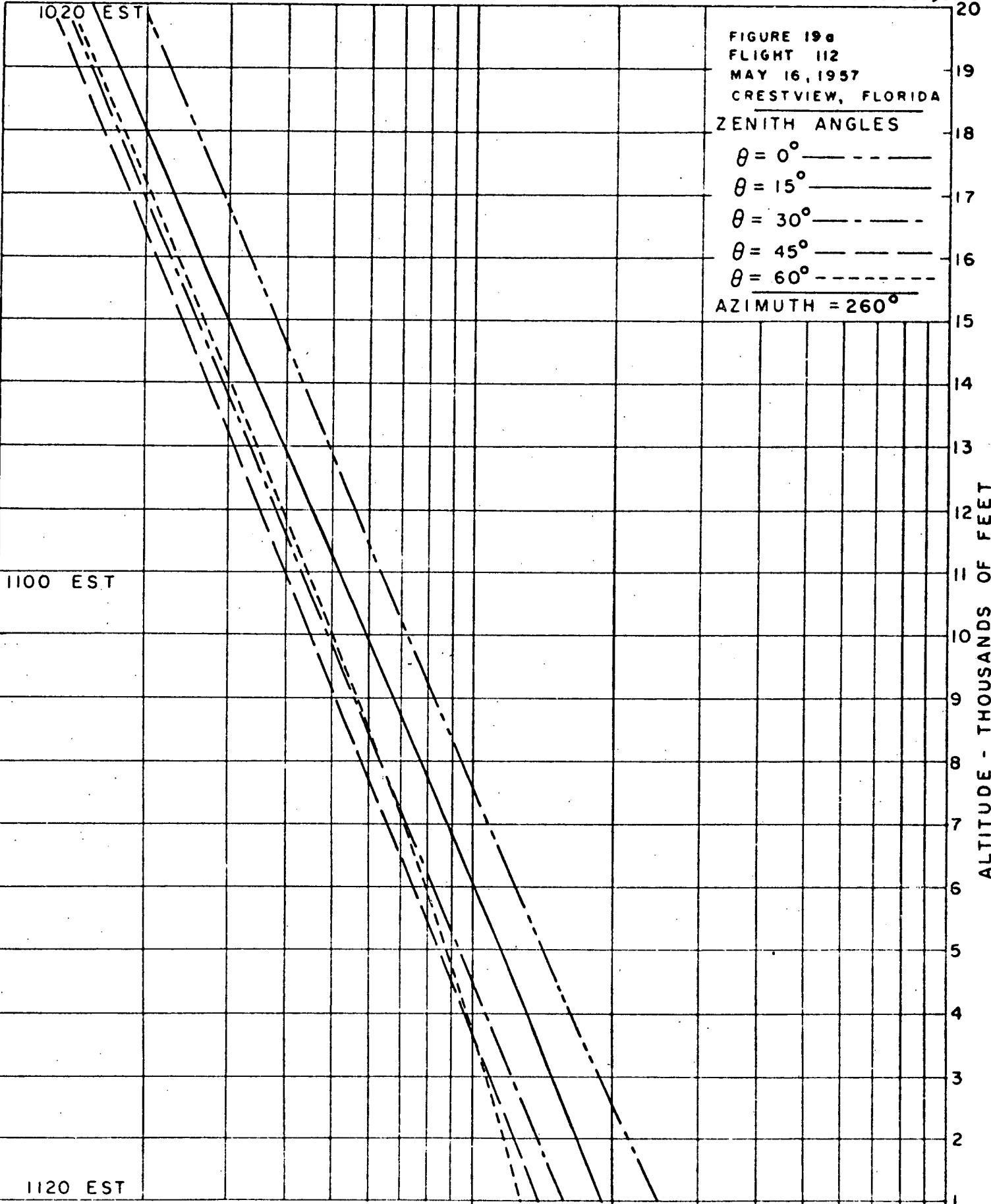
1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 240^\circ)$   
WATT  $\Omega^{-1}$  FT.<sup>-2</sup>



01 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0



0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

SIO Ref. 60-56

1020 EST

FIGURE 19b  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 75^\circ$  ————

$\theta = 80^\circ$  - - - - -

$\theta = 85^\circ$  — · — · —

$\theta = 90^\circ$  - - - - -

AZIMUTH =  $260^\circ$

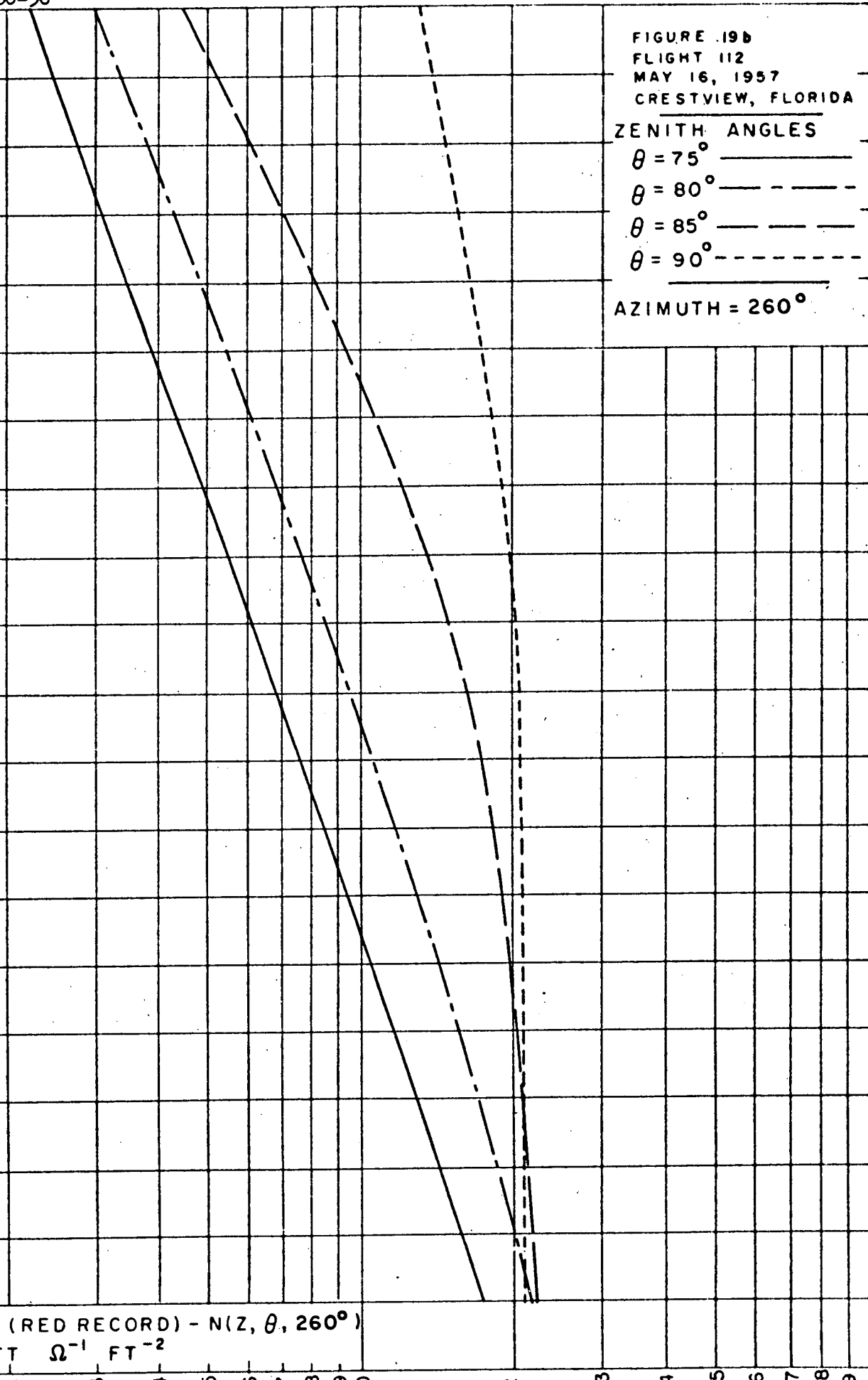
ALTITUDE - THOUSANDS OF FEET

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(z, \theta, 260^\circ)$   
WATT  $\Omega^{-1}$  FT $^{-2}$

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0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 2 3 4 5 6 7 8 9 10

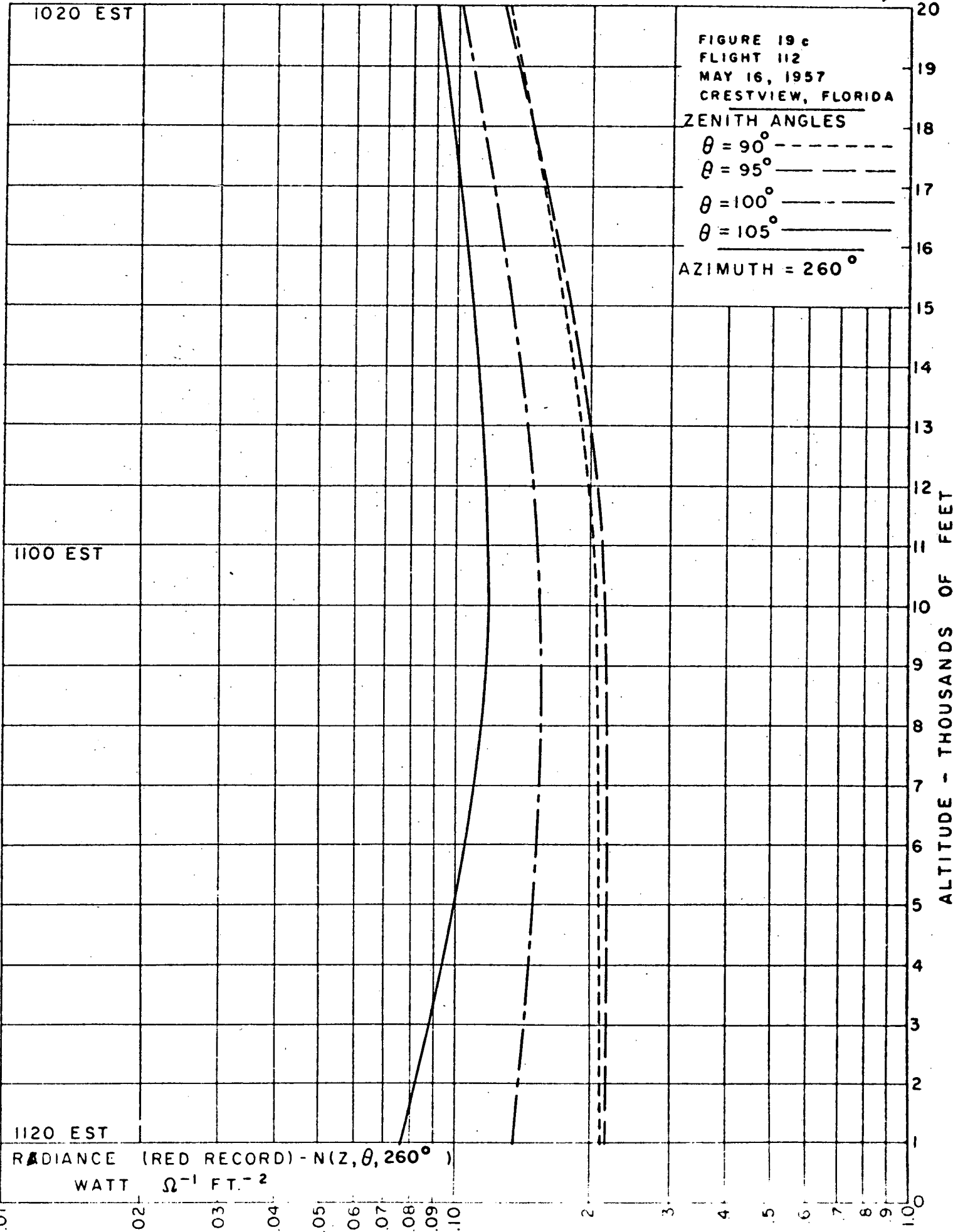


FIGURE 19d  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 120^\circ$  - - - - -

$\theta = 135^\circ$  - - - - -

$\theta = 150^\circ$  - - - - -

$\theta = 165^\circ$  - - - - -

$\theta = 180^\circ$  - - - - -

AZIMUTH =  $260^\circ$

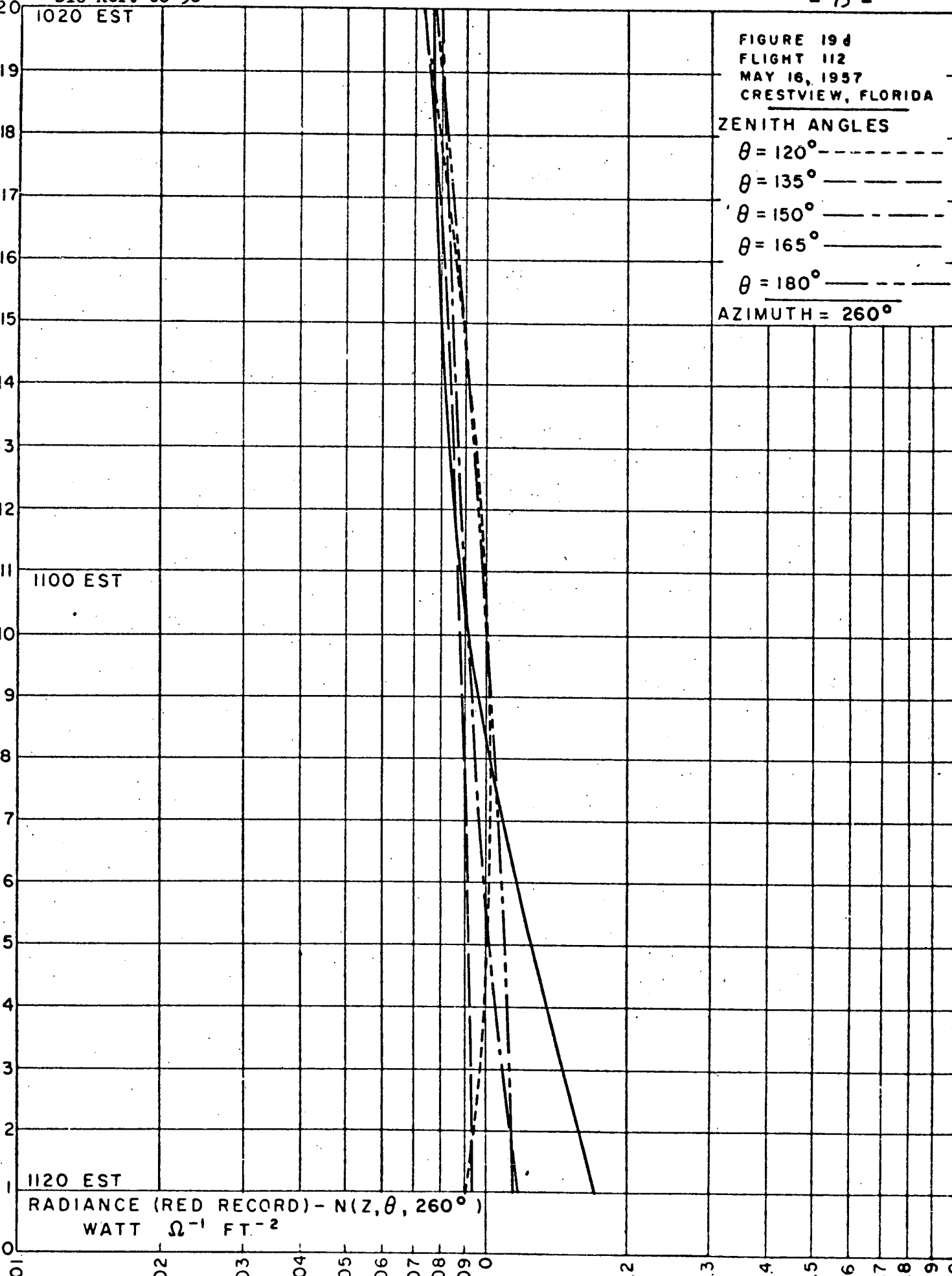
ALTITUDE - THOUSANDS OF FEET

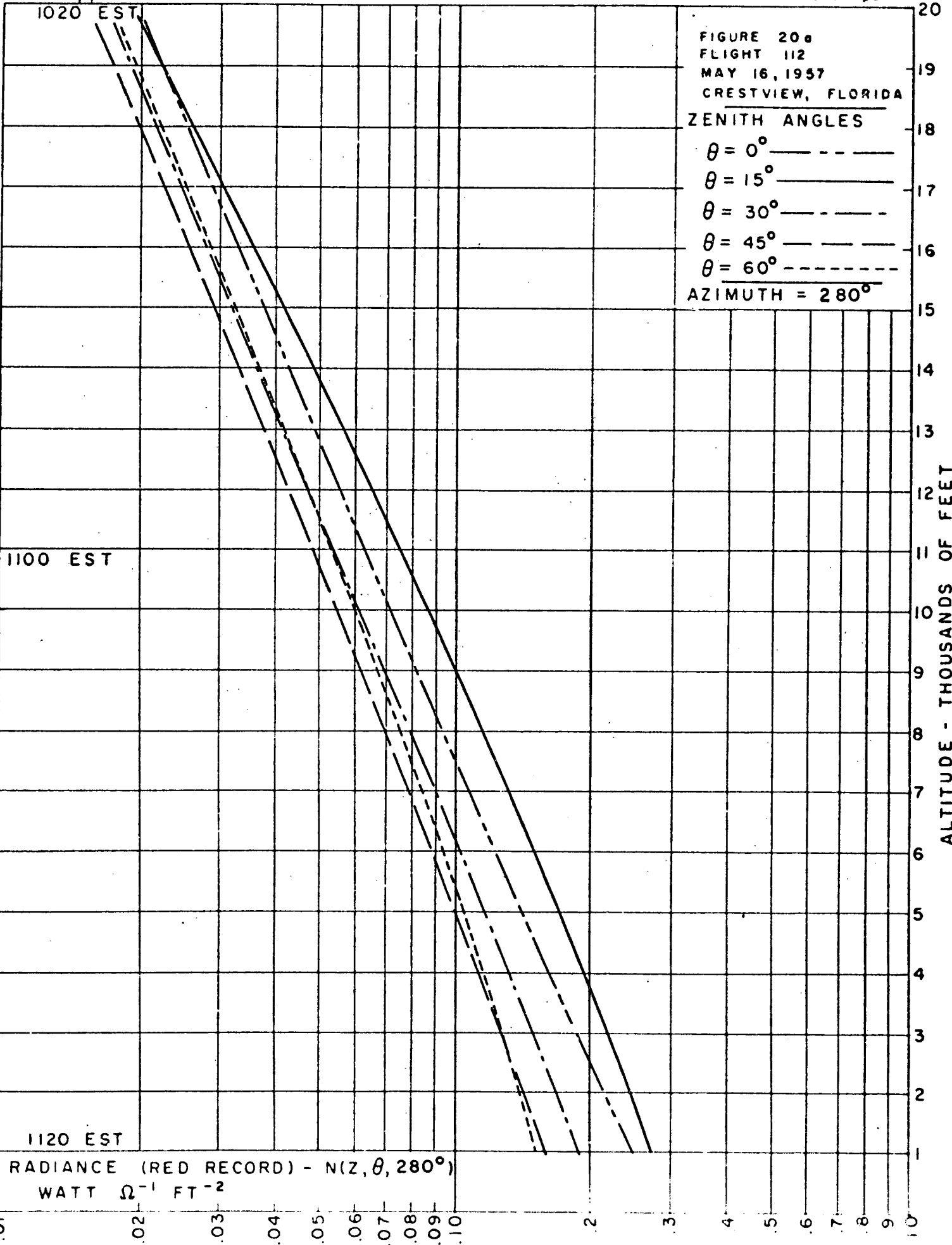
1020 EST

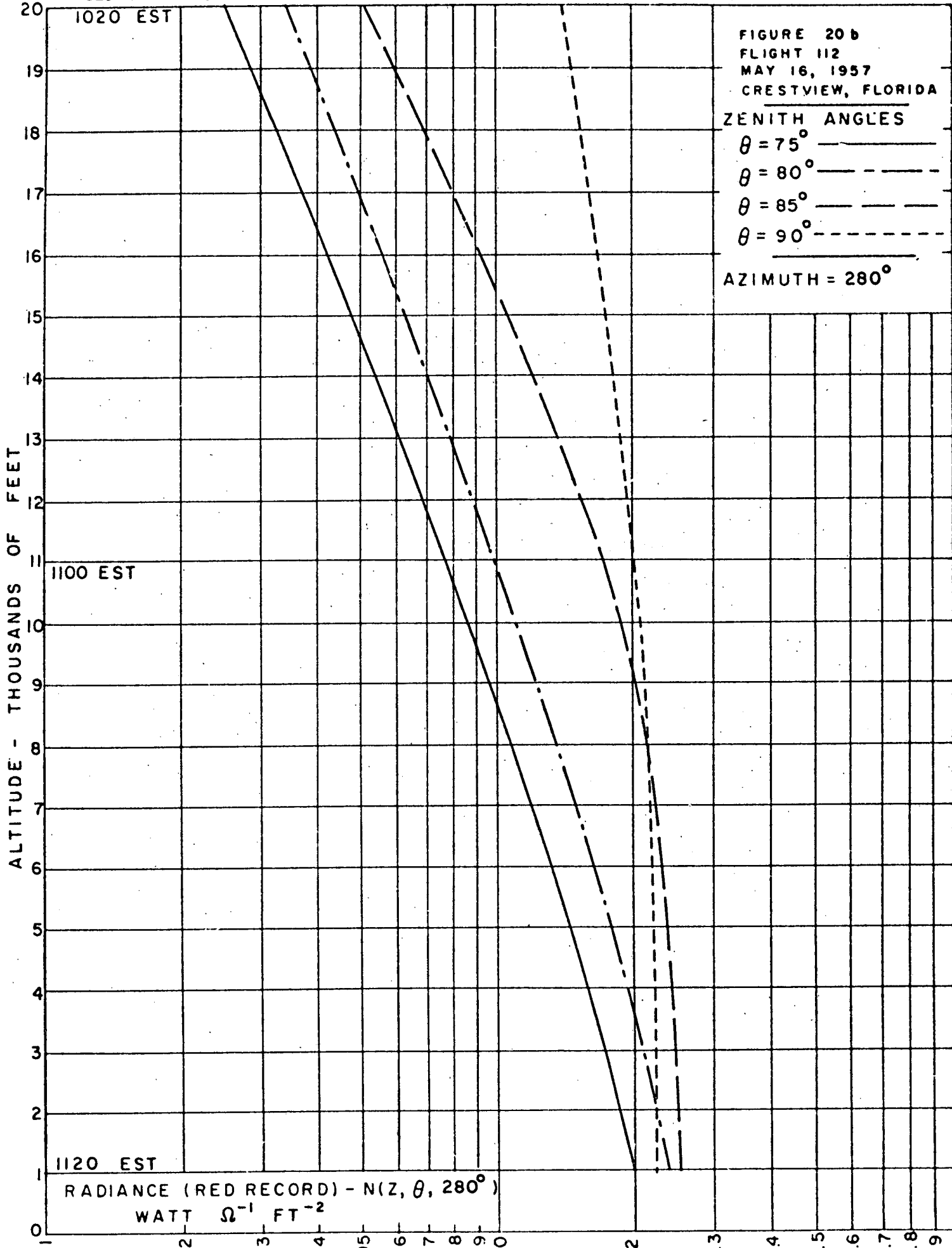
1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 260^\circ)$   
WATT  $\Omega^{-1}$  FT $^{-2}$







1020 EST

FIGURE 20c  
FLIGHT 112  
MAY 18, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 90^\circ$  - - - - -

$\theta = 95^\circ$  - - - - -

$\theta = 100^\circ$  - - - - -

$\theta = 105^\circ$  - - - - -

AZIMUTH =  $280^\circ$

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 280^\circ)$   
WATT  $\Omega^{-1} \text{ FT.}^{-2}$

ALTITUDE - THOUSANDS OF FEET

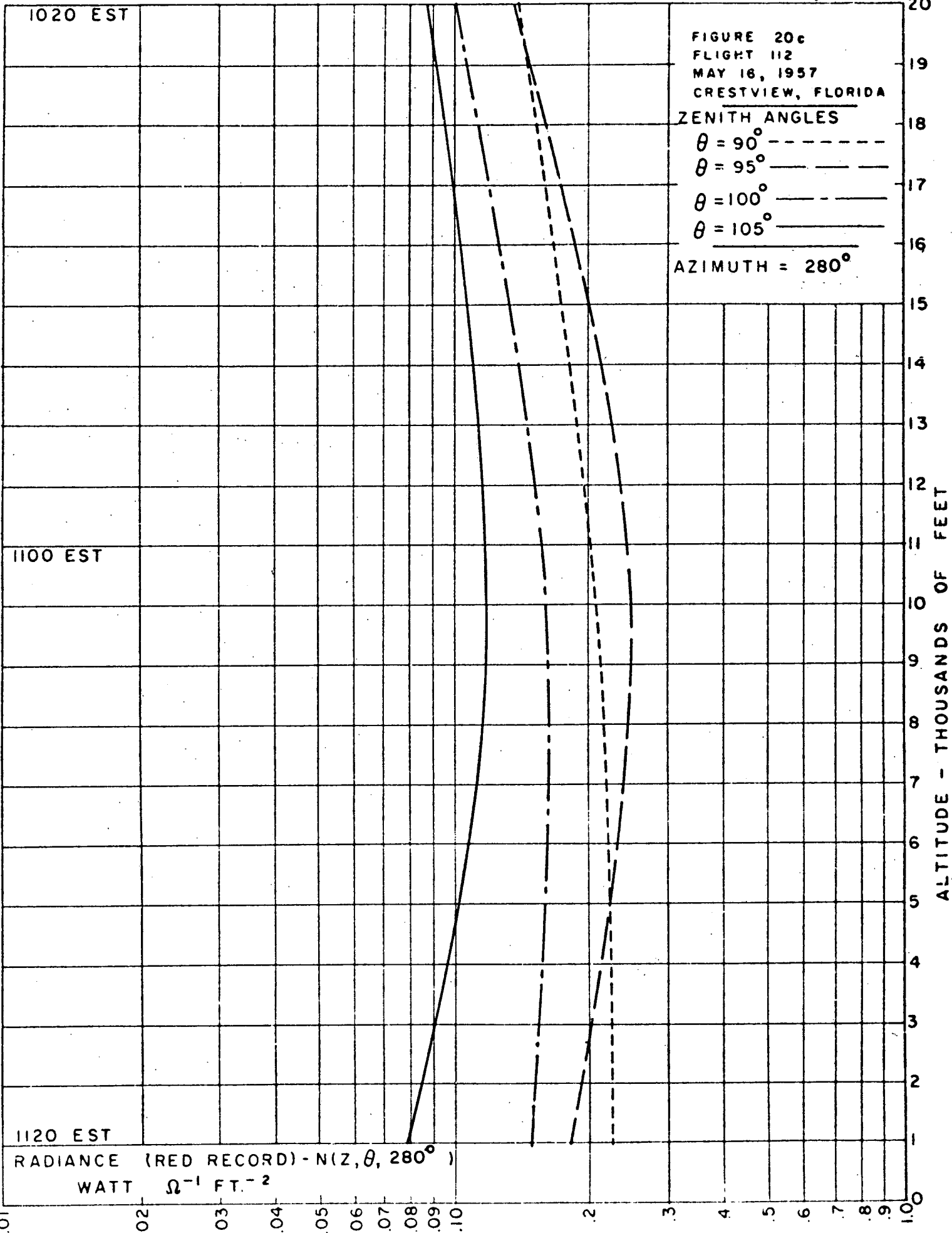


FIGURE 20 d  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 120^\circ$  - - - - -

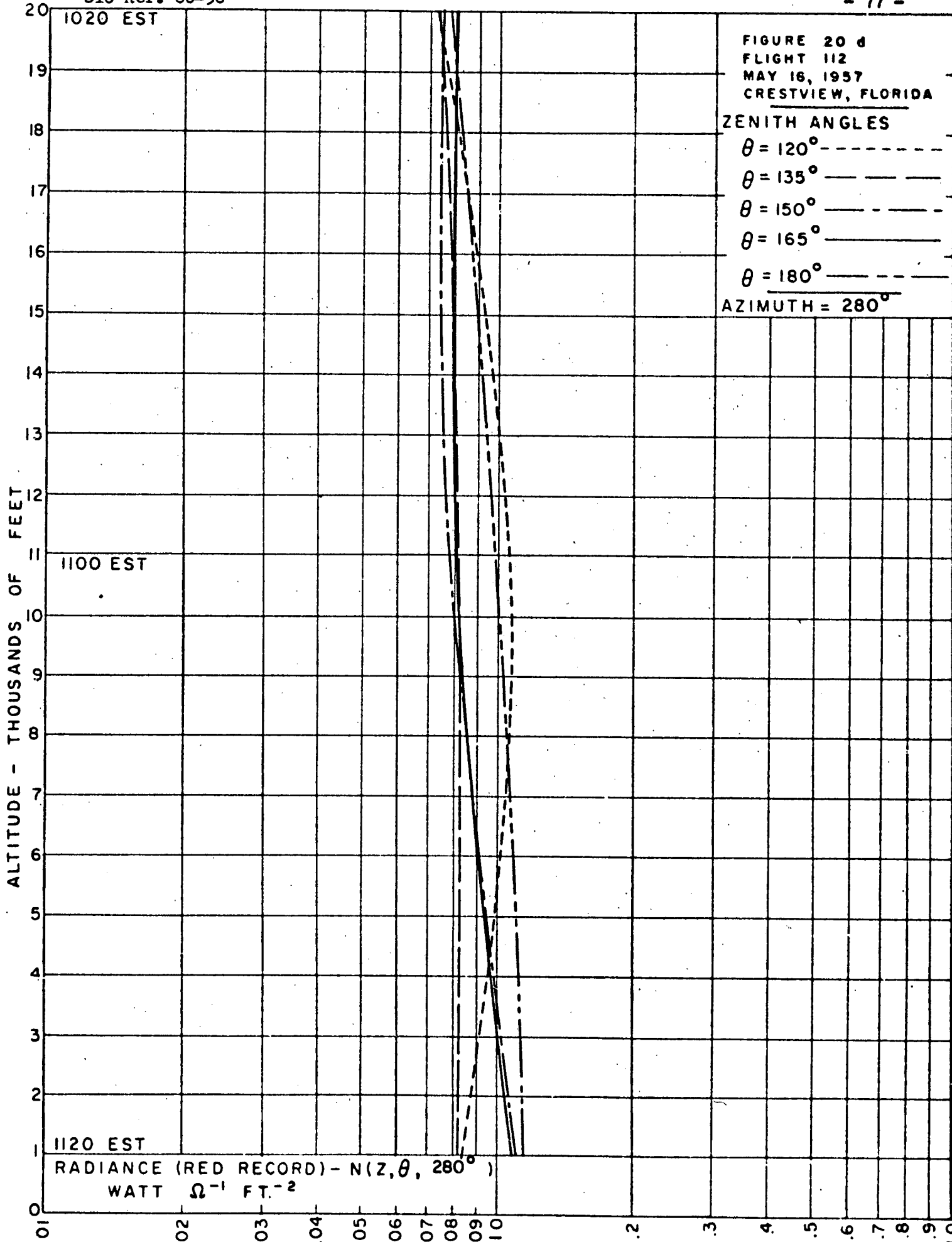
$\theta = 135^\circ$  - - - - -

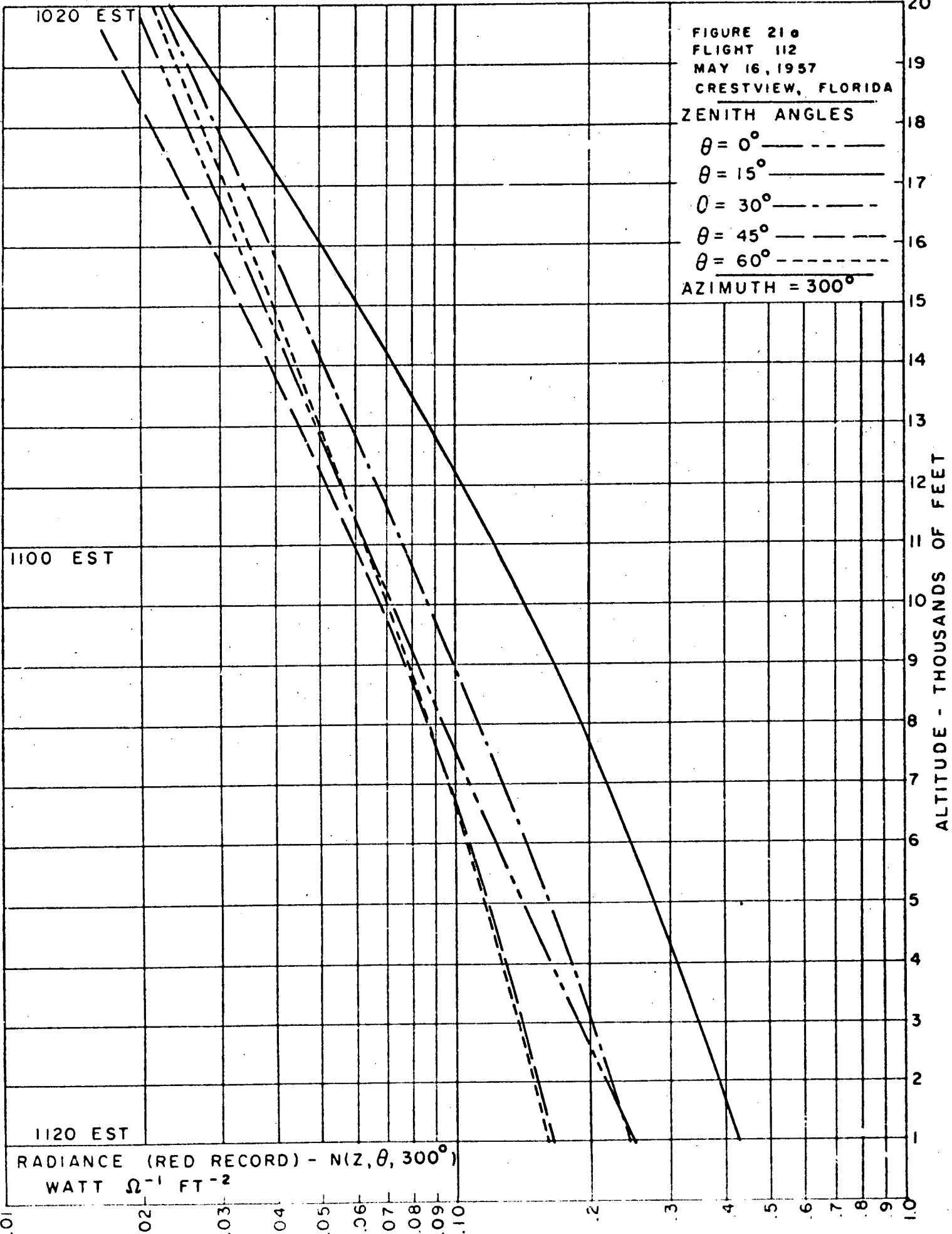
$\theta = 150^\circ$  - - - - -

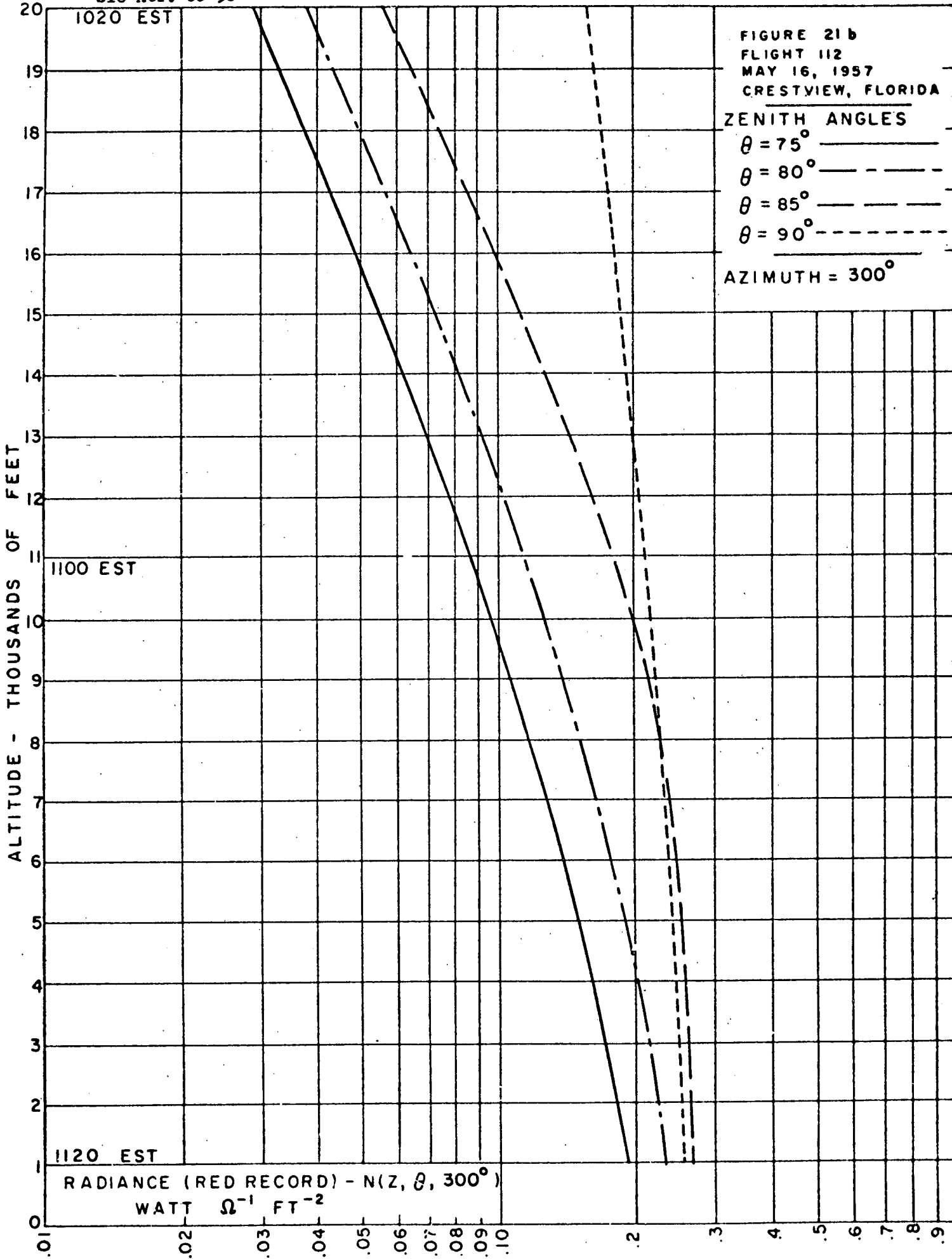
$\theta = 165^\circ$  - - - - -

$\theta = 180^\circ$  - - - - -

AZIMUTH =  $280^\circ$







1020 EST

1100 EST

1120 EST

FIGURE 21c  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 90^\circ$  - - - - -

$\theta = 95^\circ$  - - - - -

$\theta = 100^\circ$  - - - - -

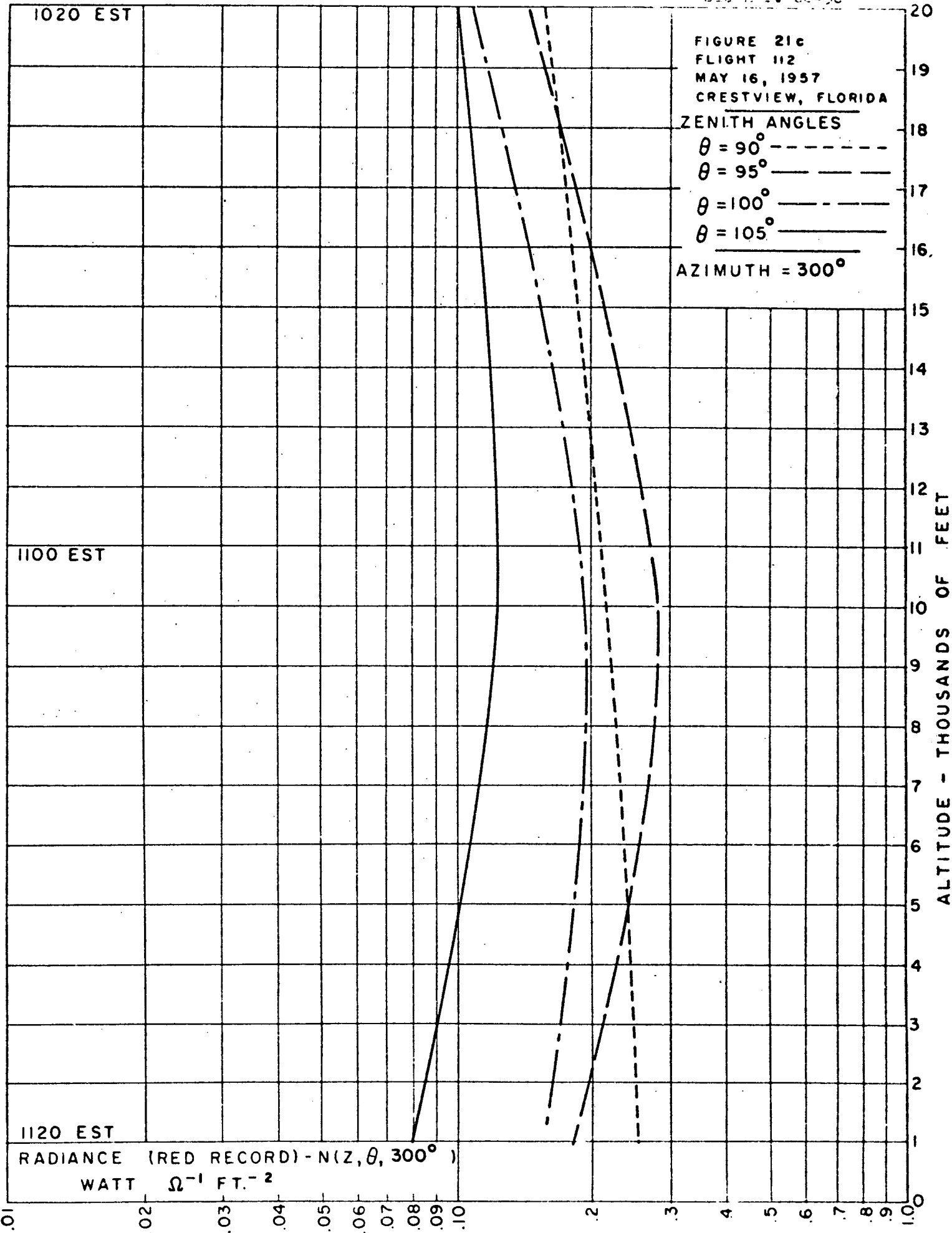
$\theta = 105^\circ$  - - - - -

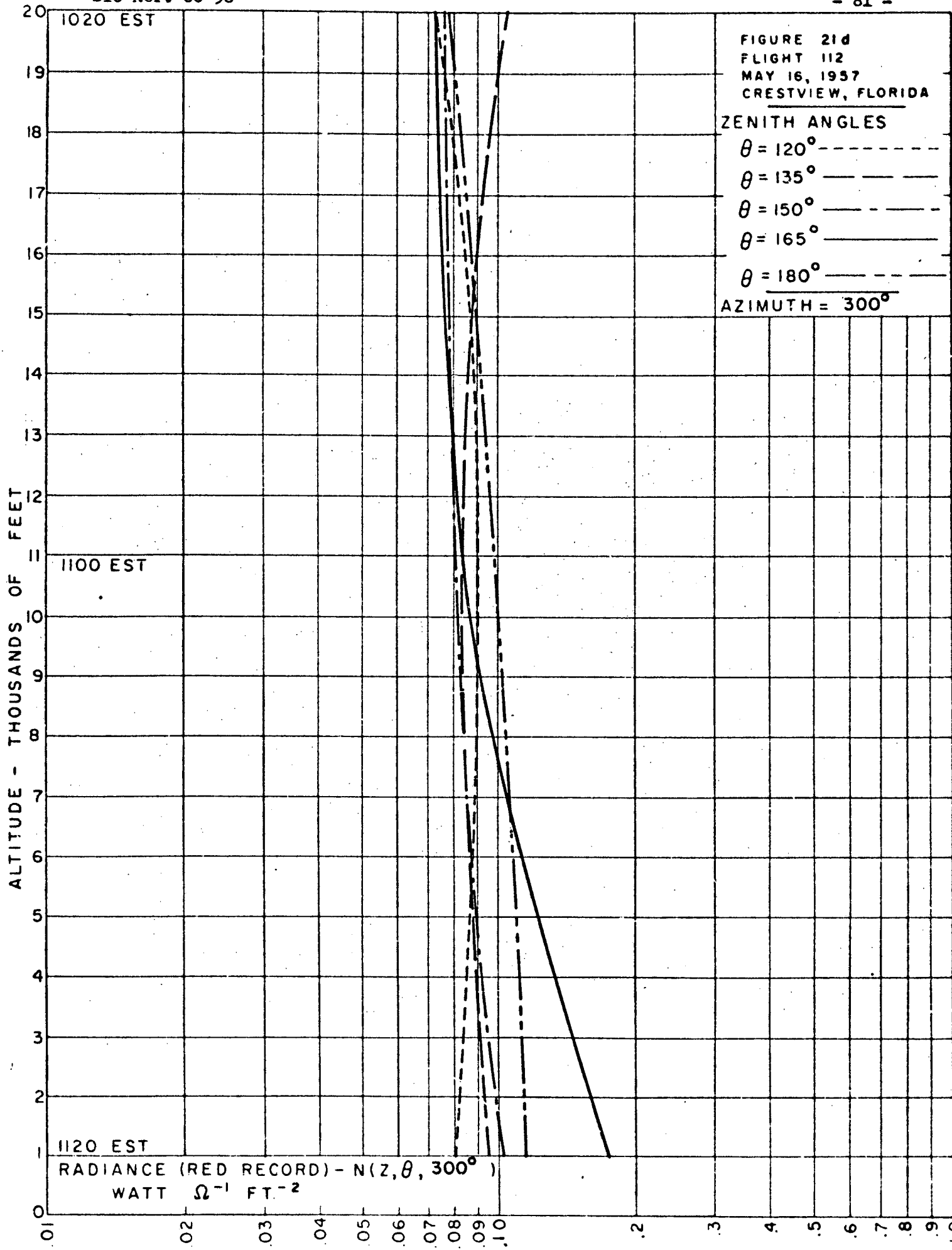
AZIMUTH =  $300^\circ$

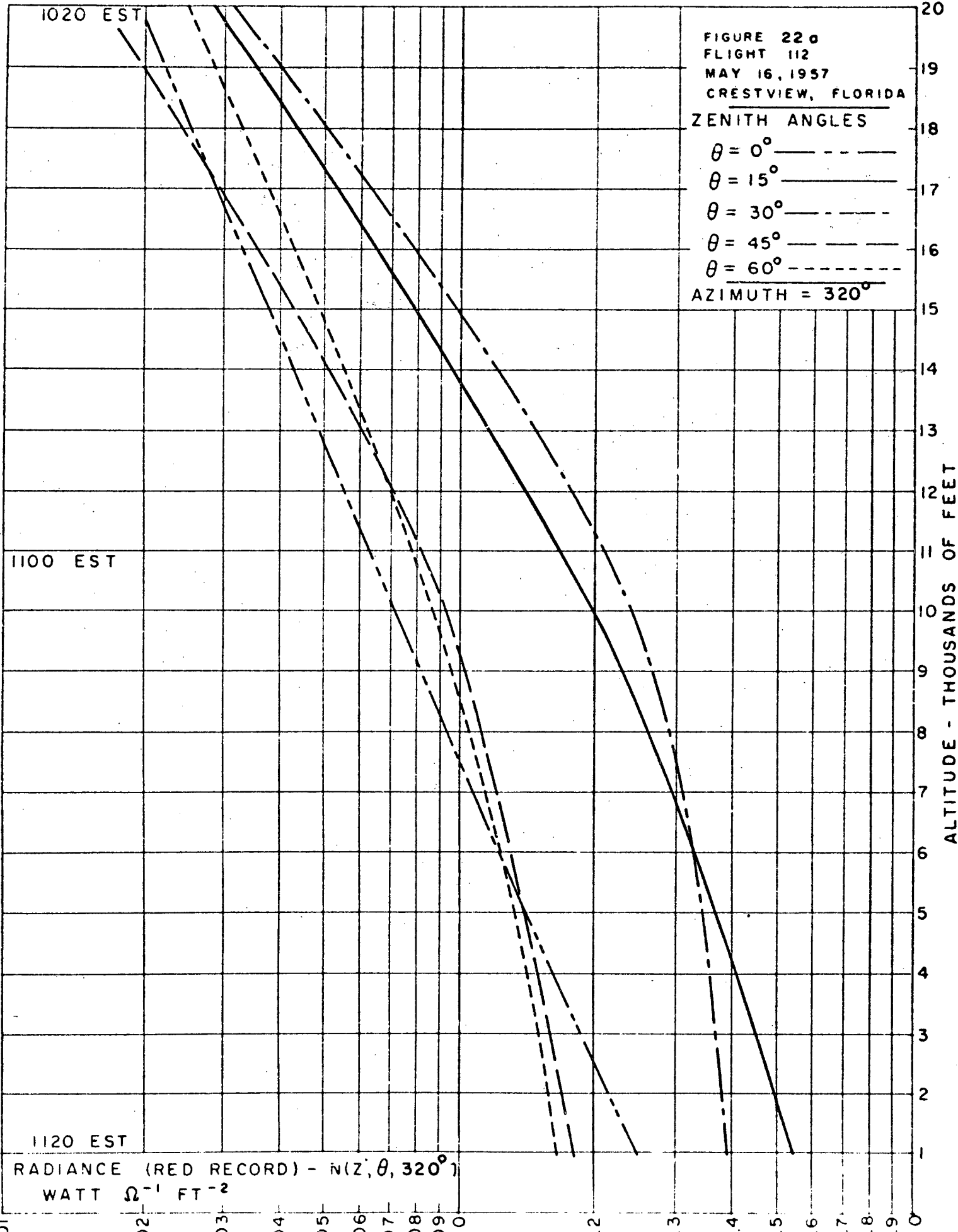
ALTITUDE - THOUSANDS OF FEET

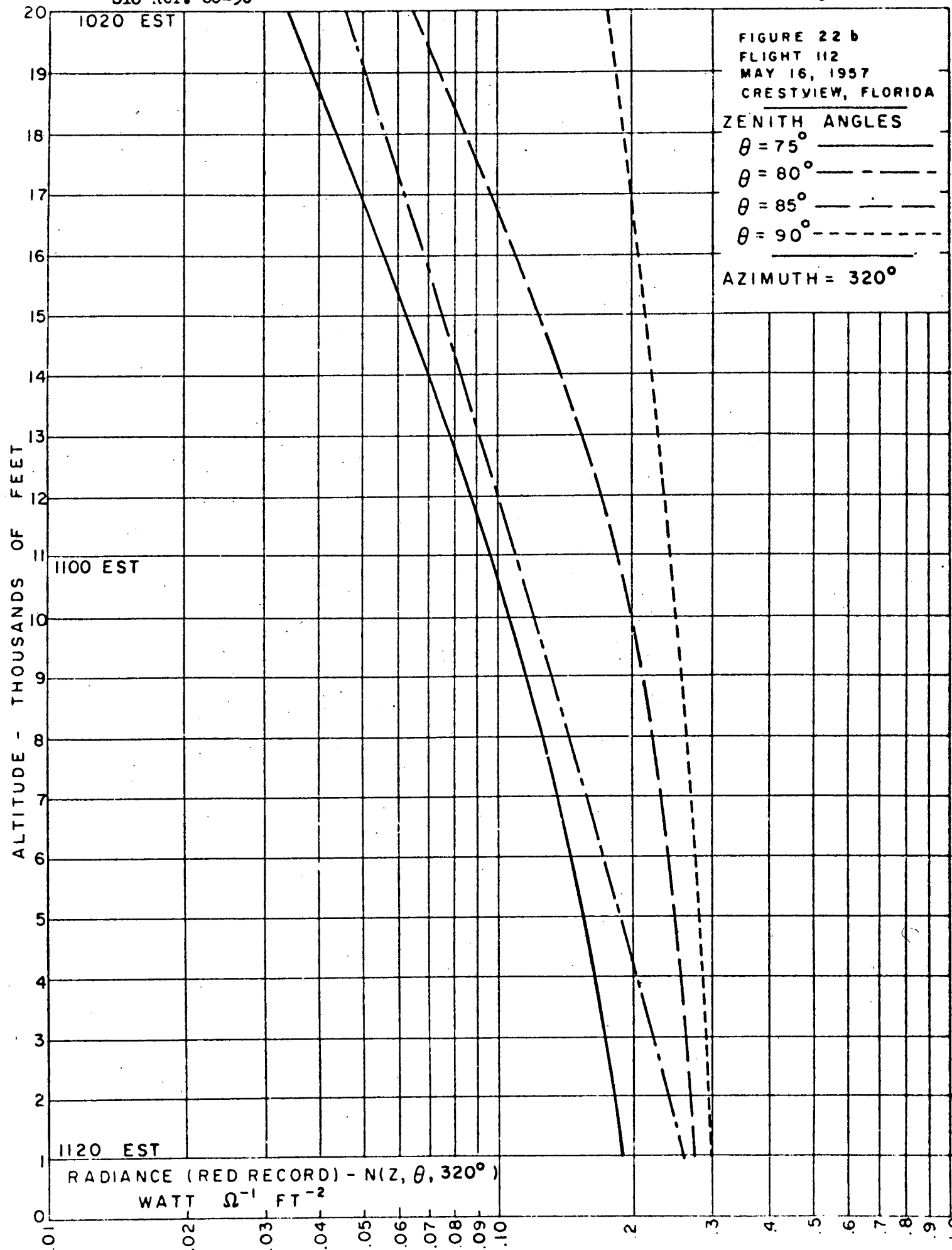
RADIANCE (RED RECORD) -  $N(Z, \theta, 300^\circ)$

WATT  $\Omega^{-1}$  FT.<sup>-2</sup>









1020 EST

1100 EST

1120 EST

FIGURE 22 c  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 90^\circ$  - - - - -

$\theta = 95^\circ$  - - - - -

$\theta = 100^\circ$  - - - - -

$\theta = 105^\circ$  - - - - -

AZIMUTH =  $320^\circ$

20  
19  
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12  
11  
10  
9  
8  
7  
6  
5  
4  
3  
2  
1  
0  
ALTITUDE - THOUSANDS OF FEET

RADIANCE (RED RECORD) -  $N(Z, \theta, 320^\circ)$   
WATT  $\Omega^{-1}$  FT.<sup>-2</sup>

01 02 03 04 05 06 07 08 09 10 2 3 4 5 6 7 8 9 10

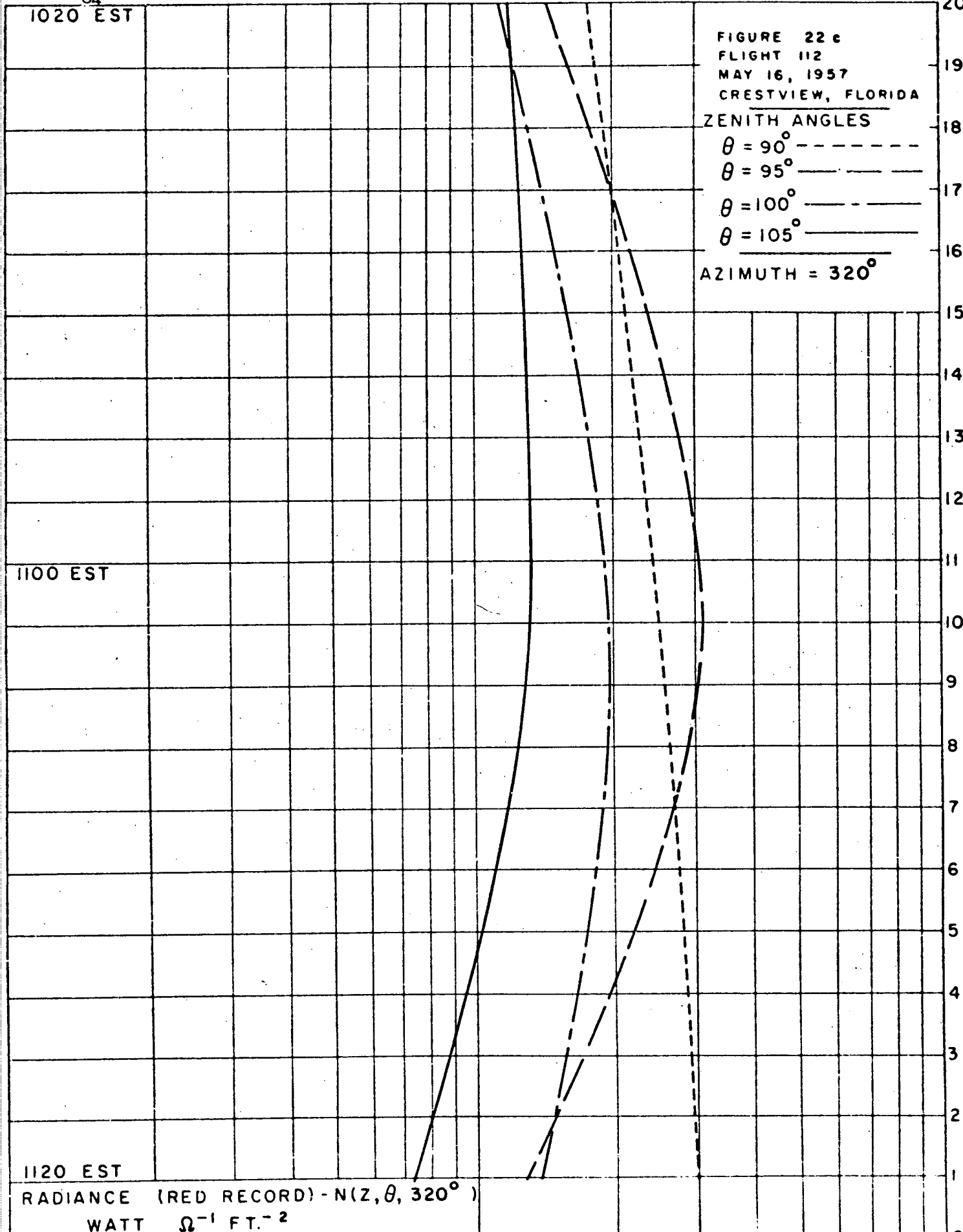


FIGURE 22 d  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 120^\circ$  - - - - -

$\theta = 135^\circ$  - - - - -

$\theta = 150^\circ$  - - - - -

$\theta = 165^\circ$  - - - - -

$\theta = 180^\circ$  - - - - -

AZIMUTH =  $320^\circ$

ALTITUDE - THOUSANDS OF FEET

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2  
1  
0

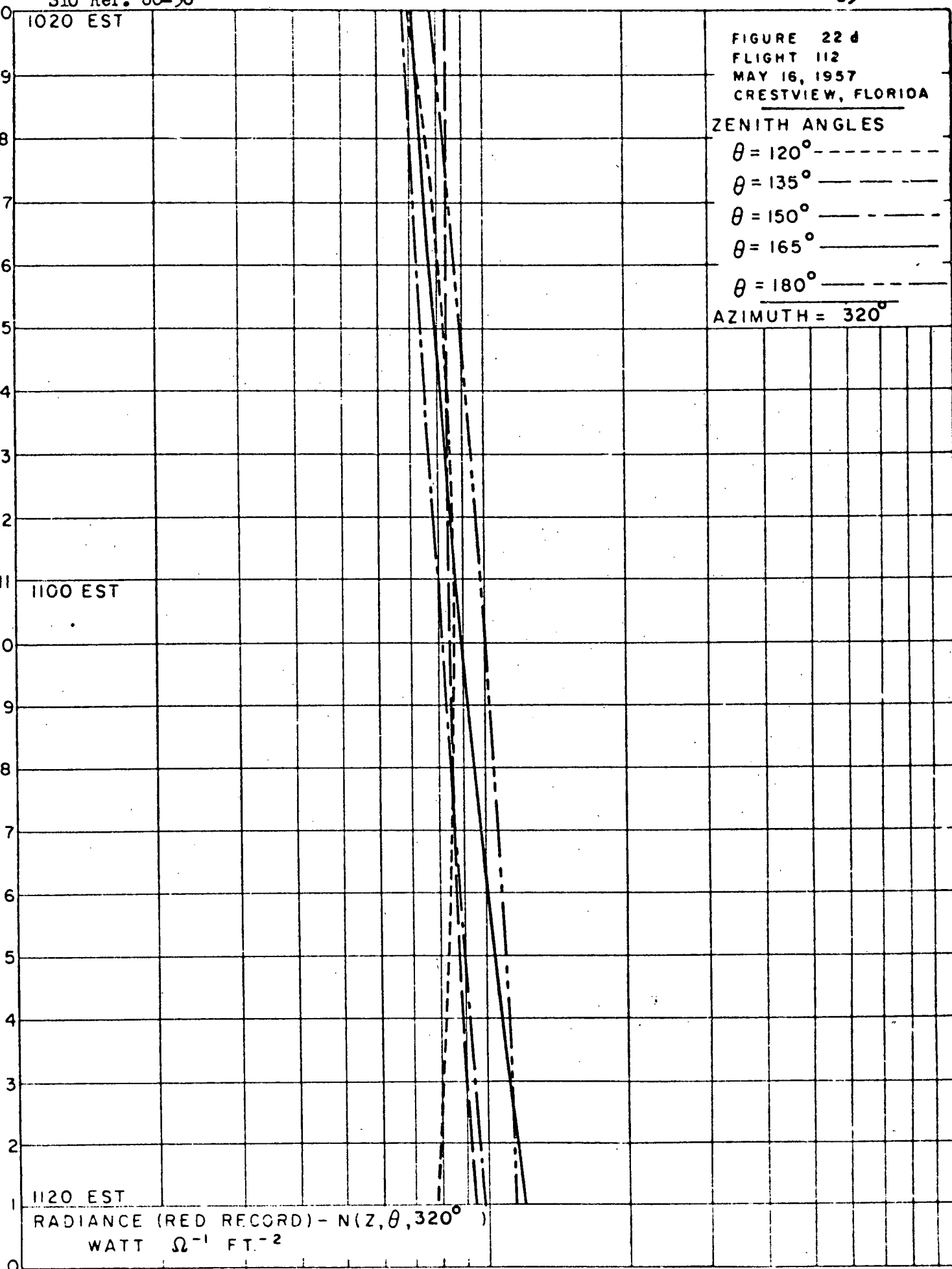
1020 EST

1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(z, \theta, 320^\circ)$   
WATT  $\Omega^{-1}$  FT.<sup>-2</sup>

01 2 3 04 05 06 07 08 09 0 2 3 4 5 6 7 8 9



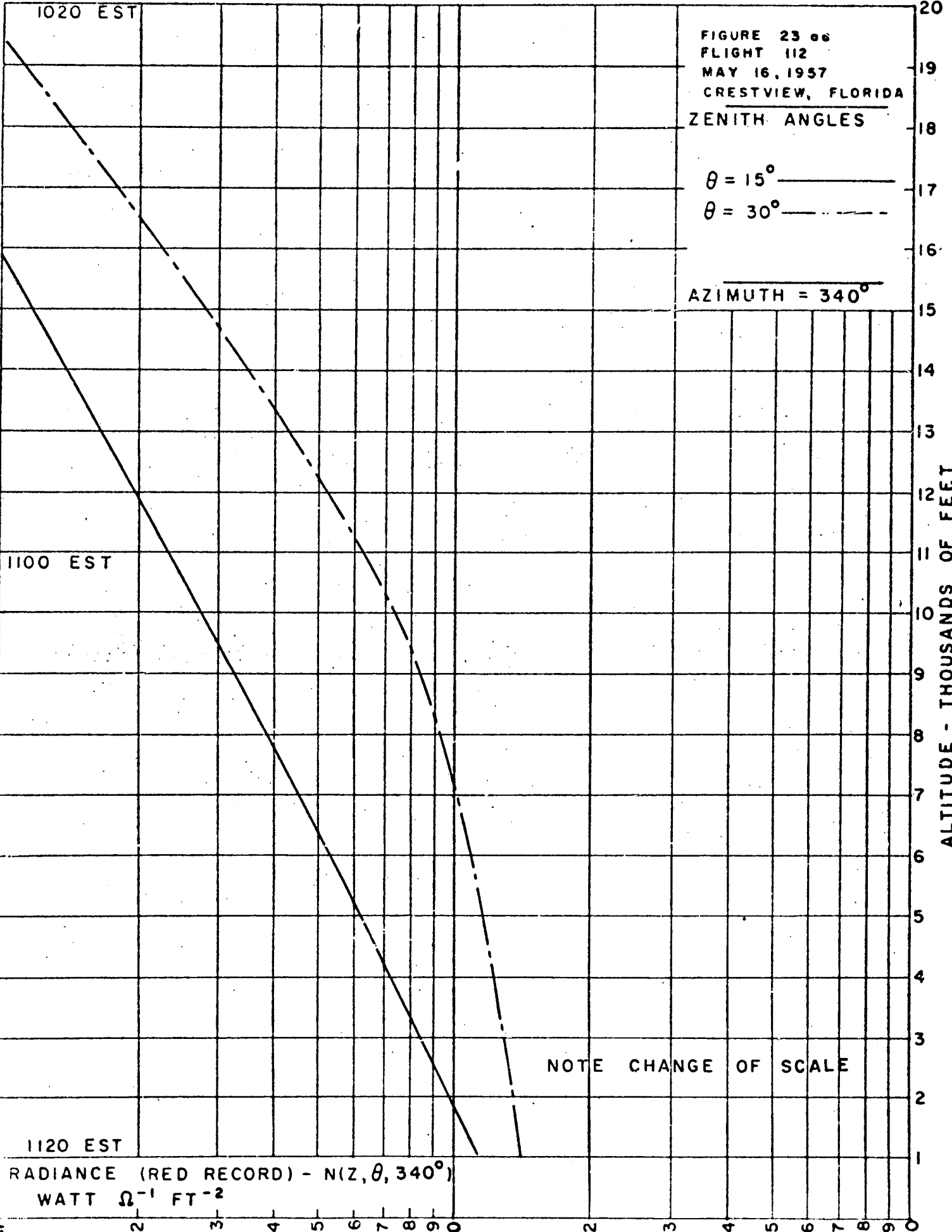


FIGURE 23 00  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA  
 ZENITH ANGLES

$\theta = 15^\circ$  ———  
 $\theta = 30^\circ$  - - - - -

AZIMUTH =  $340^\circ$

1020 EST

1100 EST

1120 EST

NOTE CHANGE OF SCALE

RADIANCE (RED RECORD) -  $N(Z, \theta, 340^\circ)$   
 WATT  $\Omega^{-1}$  FT<sup>-2</sup>



1020 EST

FIGURE 23a  
FLIGHT 112  
MAY 16, 1957  
CRESTVIEW, FLORIDA

ZENITH ANGLES

$\theta = 0^\circ$  -----

$\theta = 15^\circ$  \_\_\_\_\_

$\theta = 30^\circ$  - - - - -

$\theta = 45^\circ$  - - - - -

$\theta = 60^\circ$  - - - - -

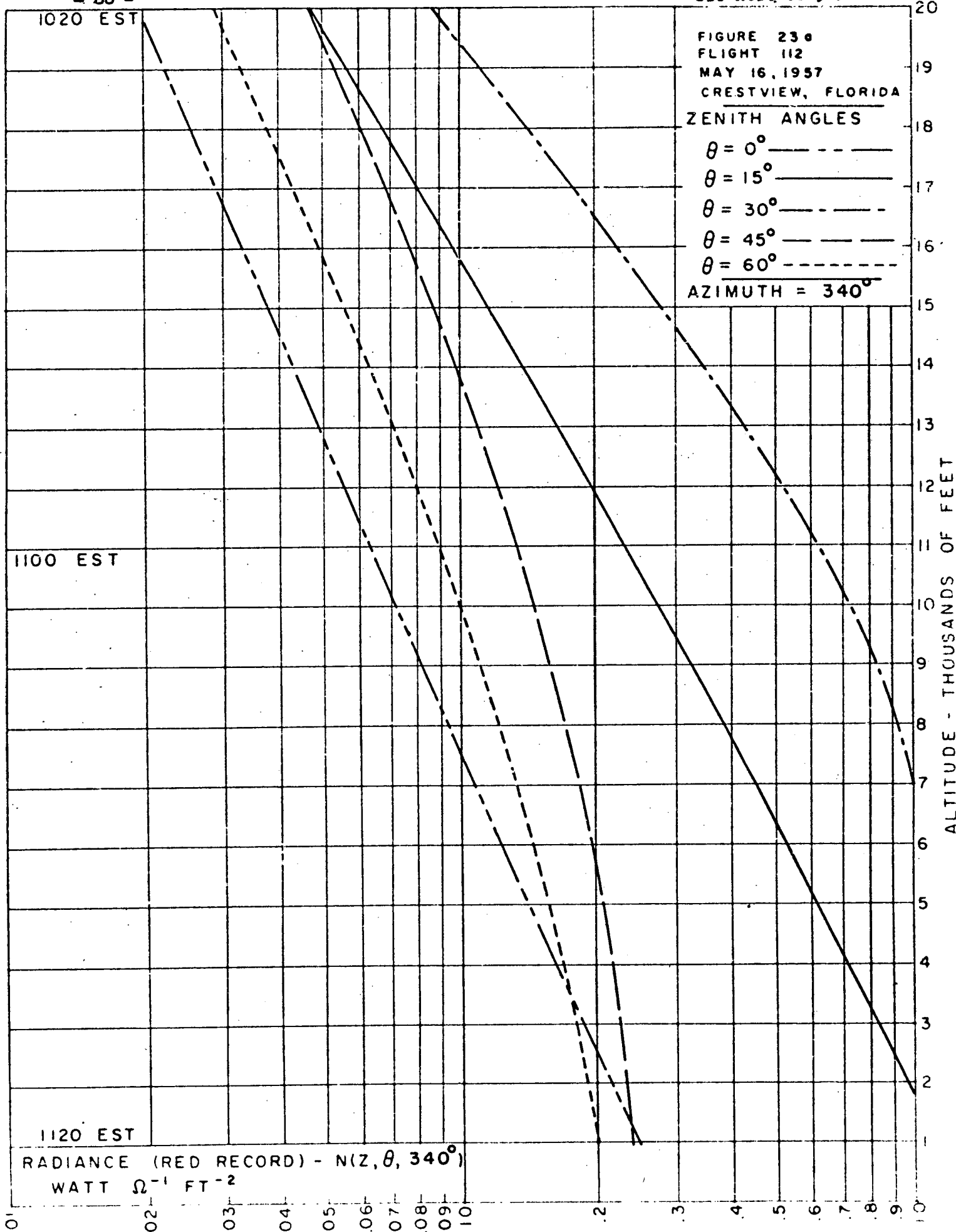
AZIMUTH =  $340^\circ$

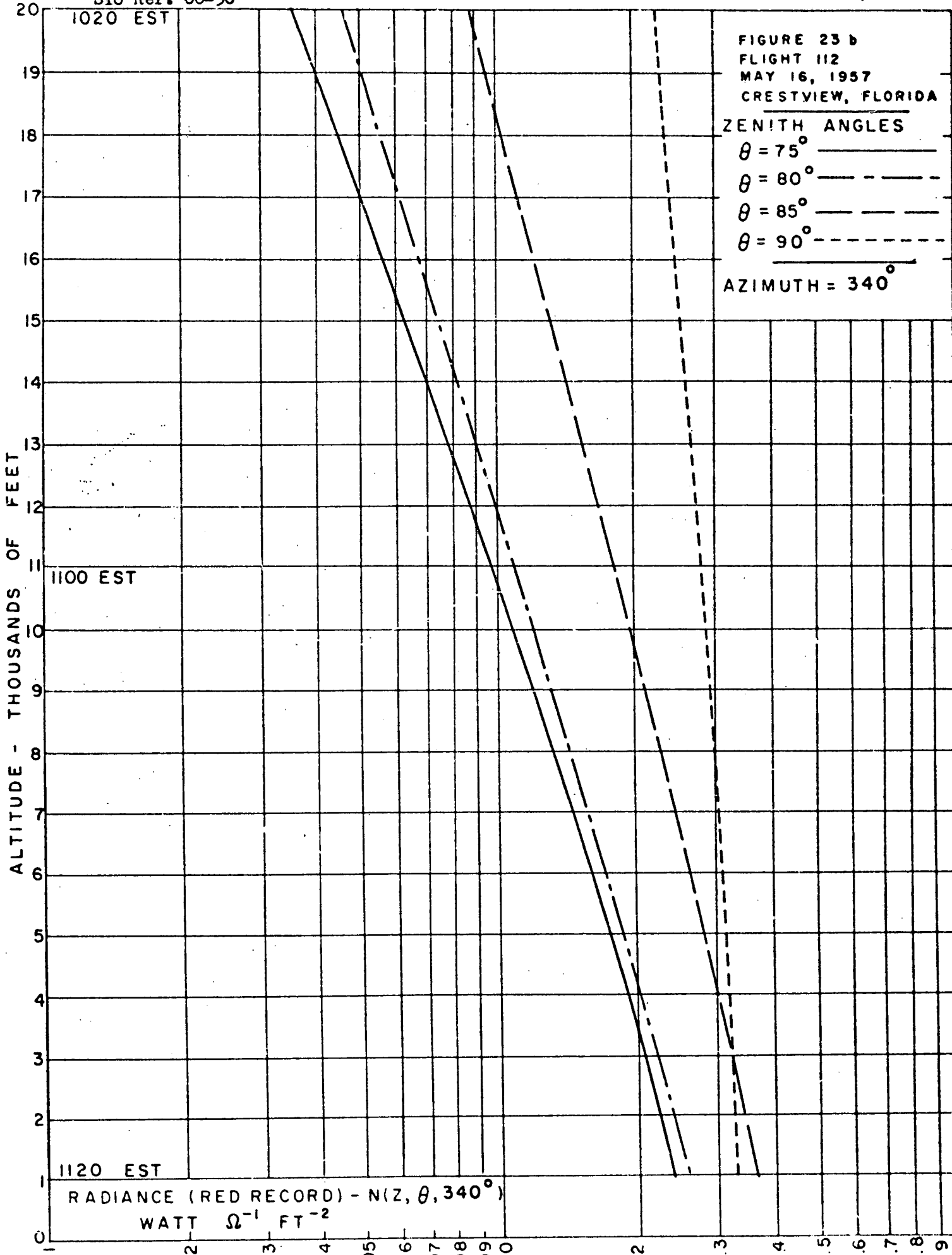
1100 EST

1120 EST

RADIANCE (RED RECORD) -  $N(Z, \theta, 340^\circ)$   
WATT  $\Omega^{-1} \text{ FT}^{-2}$

ALTITUDE - THOUSANDS OF FEET





1020 EST

1100 EST

1120 EST

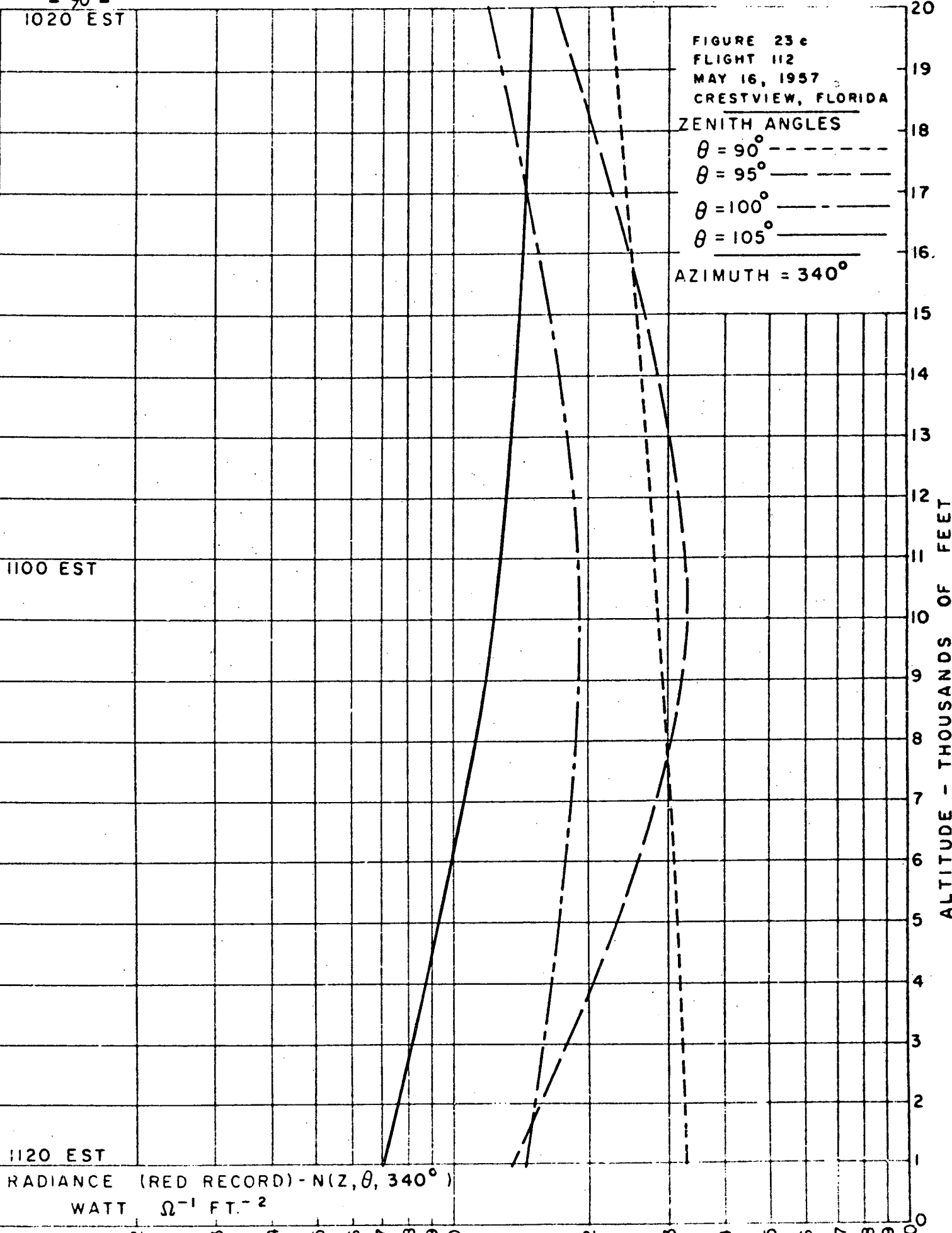
RADIANCE (RED RECORD) -  $N(Z, \theta, 340^\circ)$   
WATT  $\Omega^{-1} \text{ FT.}^{-2}$

FIGURE 23c  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 90^\circ$  - - - - -  
 $\theta = 95^\circ$  - - - - -  
 $\theta = 100^\circ$  - - - - -  
 $\theta = 105^\circ$  - - - - -

AZIMUTH =  $340^\circ$

ALTITUDE - THOUSANDS OF FEET

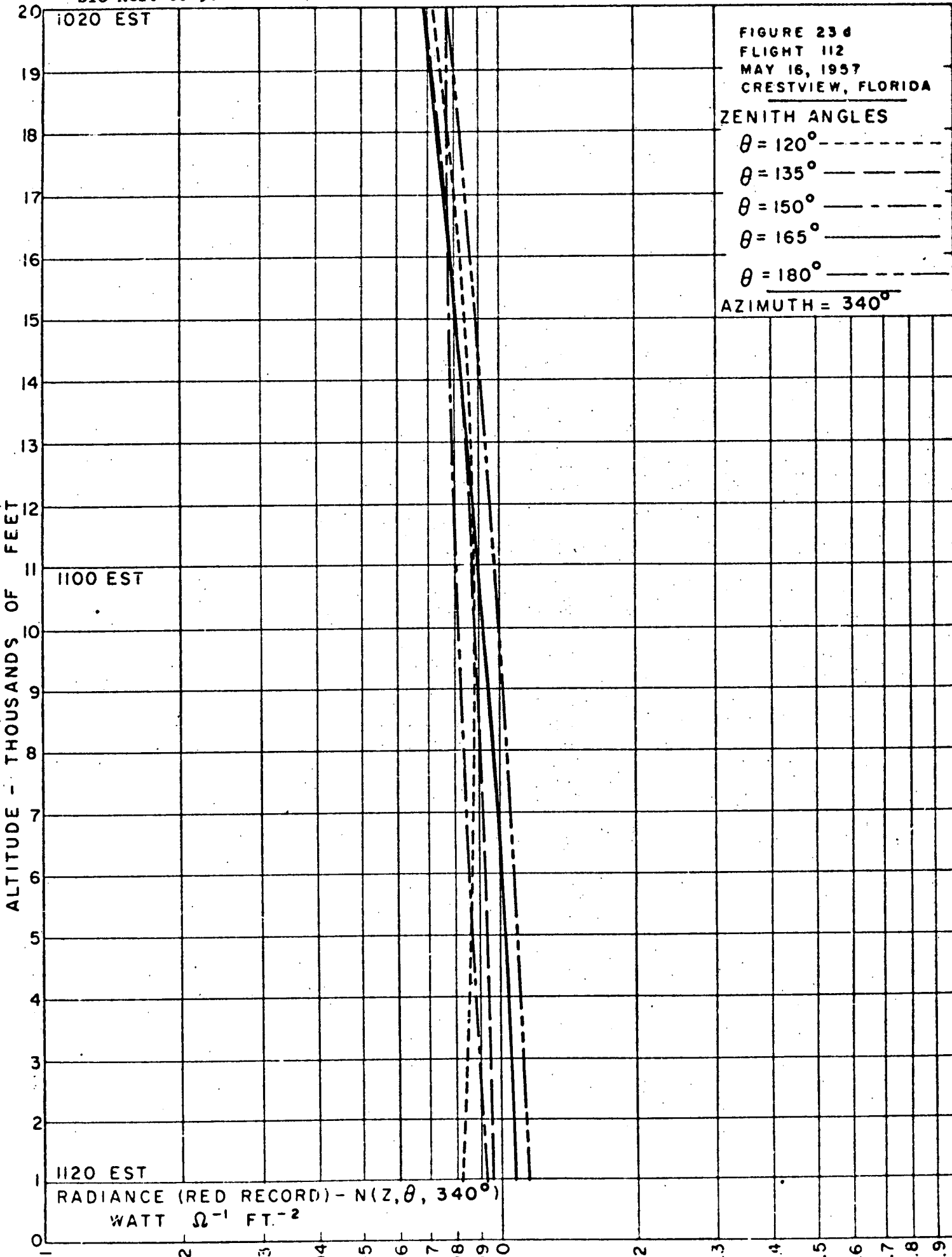


SIO Ref. 60-56

FIGURE 23 d  
 FLIGHT 112  
 MAY 16, 1957  
 CRESTVIEW, FLORIDA

ZENITH ANGLES  
 $\theta = 120^\circ$  - - - - -  
 $\theta = 135^\circ$  - - - - -  
 $\theta = 150^\circ$  - - - - -  
 $\theta = 165^\circ$  - - - - -  
 $\theta = 180^\circ$  - - - - -

AZIMUTH =  $340^\circ$



## REFERENCES

1. Boileau, A. R., "Atmospheric Optical Measurements in Western Florida, Flight 112, Part I," SIO Ref. 60-22, Scripps Institution of Oceanography, University of California, La Jolla Campus, April 1960.
2. Duntley, S. Q., A. R. Boileau, and R. W. Preisendorfer, "Image Transmission by the Troposphere I," Journal of the Optical Society of America, 47, pp 499-506, (1957).

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