REPORT ITU-R BT.2138

Radiation pattern characteristics of UHF* television receiving antennas

(2008)

1 Introduction

This Report describes measurements of the radiation pattern characteristics of UHF television receiving antennas.

The measurements were made to determine the performance of twelve UHF antennas used for TV reception. Though all antennas tested were designed for multiband operation, the antennas tested covered, *inter alia*, the frequency range of TV channels 40 to 60 for 8 MHz channel plans and TV channels 41 to 65 for 7 MHz plans. These frequency ranges are extensively used for terrestrial television broadcasting services by most ITU administrations.

2 Background

Many administrations currently operate digital and/or analogue broadcasting services in the UHF band.

Recommendation ITU-R BT.419-3 contains a mask for receiving antenna directivity to be used in the planning of terrestrial television services. This does not constitute a design specification for receiving antennas, but is an assumption about their directivity which affects the calculation of potential interference from other services into the broadcasting service.

As part of its work in the study period 2003-2007 in ITU-R, Australia provided representative data for the off-axis performance of UHF receiving antennas (in the elevation plane), noting that the performance may vary with the polarization of the receiving antenna.

The results are in Annex 1. Within this study it is clear that a number of antennas fit well within the Recommendation ITU-R BT.419 mask, while others do not due to their broader patterns and lower gain. This is particularly evident at the lower frequencies.

3 Factors for consideration

3.1 Existing antenna population

Statistics from antenna manufacturers indicate that the antenna types tested in this study represent a high percentage of antenna used in one administration. If these figures were extrapolated for a 10-year period (the estimated notional usable lifetime of a TV antenna) then, given the general commonality of TV antenna designs around the world, the characteristics found in Annex 1 may represent performance characteristics that are also valid for other administrations.

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* The terrestrial television broadcasting service is found in the UHF frequency range of 470 to 890 MHz (refer Article 5 of the Radio Regulations). Performance of the television receiving antennas in upper portion of the UHF band was the subject under study.

3.2 Impulsive noise

This Report states in Annex 1 that "a certain AUT (antenna under test) was susceptible to noise generated by the measurement rotator during a swept frequency measurement using a broadband detector. Turning off the motor eliminated the noise so all further swept frequency measurements were conducted when the measurement rotator was turned off".

Impulse noise immunity is an important consideration for receiver performance and reception signal quality for both analogue and particularly for digital television reception. Interference being received via the antenna may consume level and quality margins. Impulse noise rejection is, amongst other things, dependent upon correct cable terminations and matching cables to the antenna.

Annex 1

1 Antennas measured

The antennas measured are listed in Table 1:

TABLE 1

Antennas measured

Antenna number	Antenna design	Antenna description	Band	Mounting location	Feed connection
1	Yagi	9 elements	IV/V	Centre	Saddle
2	Yagi	12 elements	IV/V	Centre	F connector
3	Phased array	4 elements	IV/V	Rear	Saddle
4	Phased array	4 elements	IV/V	Rear	Saddle
5	Yagi	18 elements	IV/V	Rear	F connector
6	Yagi	20 elements	IV/V	Centre	F connector
7	Combination	UHF – 8 elements VHF – 4 elements	I/II/III/IV/V	Centre	F connector
8	Combination	UHF – 10 elements VHF – 4 elements	IV/V(1)	Centre	F connector
9	Combination	UHF – 18 elements VHF – 8 elements	III/IV/V	Centre	F connector
10	Combination	UHF – 10 elements VHF – 6 elements	III/IV/V	Centre	F connector
11	Cross-polarized	UHF – 10 elements VHF – 6 elements	I/II/III/IV/V(2)	Centre	Saddle
12	Cross-polarized	UHF – 10 elements VHF – 6 elements	I/II/III/IV/V(3)	Centre	F connector

(1) Tuneable UHF frequency range of 526-750 MHz.

(2) Tuneable UHF frequency range of 526-750 MHz.

(3) Tuneable UHF frequency range of 526-750 MHz.

2 Measurements undertaken

For all antennas listed above the following system parameters were measured:

– 360° radiation patterns in the azimuth plane at two frequencies, 620 MHz and 790 MHz within the tunable UHF frequency range. Four radiation pattern cuts at φ = 0°, 45°, 90° and 135° were measured at each frequency.

– Gain-normalized[1] swept-frequency measurements over the range of 620 MHz to 790 MHz within the tunable UHF frequency range.

3 Measurement description

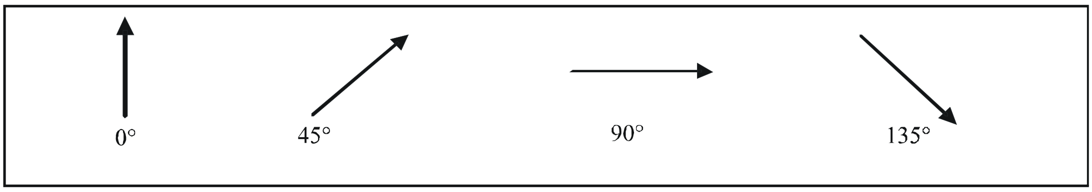
The radiation patterns were measured on the CSIRO 40 metre outdoor antenna test range in Sydney, Australia, using an Agilent E4407B spectrum analyser as the receiver. The measurement system was set up with a standard gain horn (SGH) as the transmit horn allowing the gain of the antenna-under-test (AUT) to be calculated. A linear-polarized WR1150 rectangular pyramidal horn, with a nominal gain of 16.4 dBi, was used for the SGH.

Two 6 m RG6 quad-shield 75 Ω cables were used to connect the AUTs to the measurement system. For the AUTs with an F-type balun input a cable with connectors at both ends was used. For the AUTs with saddle-type balun input a modified cable with one connector removed was used. These cables were then connected to a minimum loss pad used to match impedances between the 75 Ω AUT and the measurement 50 Ω system. The measurement procedure, listed below, was identical for each AUT at both measurement frequencies.

Step 1: The SGH and the AUT were mounted to provide a vertical E-field vector (i.e. an H-plane cut) and the corresponding orientation nominated as 0°. Figure 1 shows the orientation of the E-field vector of the AUT and the SGH at each of the four nominated polarizations.

FIGURE 1

Polarization of E vector when viewed from rear of AUT



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Step 2: With both the SGH and AUT mounted 6 m above ground, a quiet-zone test was performed to establish the range length that introduced the minimum ripple from reflections. A range length of 12 m was the quietest distance that satisfied the far-field distance requirement for both the AUT and SGH. The quiet-zone test was done for E vector vertical only at both the upper and lower frequencies for all AUTs.

Step 3: The AUT was scanned in azimuth through 360° to obtain a co-polar pattern with samples recorded every 1°.

[1] The antenna gain is obtained through a series of measurements and Friis' free-space equation. As such the antenna gain has been normalized to the gain of the SGH and is distinct from a direct gain measurement.

Step 4: Both the AUT and SGH were then rotated to the next orientation angle.

Step 5: The AUT was again scanned in azimuth through 360° to obtain a co-polar pattern with samples recorded every 1°.

Step 6: Steps 4 and 5 were repeated for the remaining orientation angles.

The gain-normalized swept-frequency measurements of the antennas were measured on boresight at 0° orientation for frequencies between 620 MHz and 790 MHz. The measurements were conducted with a HP 8757D scalar network analyser and confirmed by measurements at discreet frequencies with an Agilent E4407B spectrum analyser. Two 1.5 m RG6 quad shield cables were used in the measurements; one with F type connectors for connection to antennas with F type balun inputs, and another with no connector on one end for connection to antennas with saddle type balun inputs. Both cables were measured with a HP 8510C vector network analyser as well as a minimum loss pad that was used to match impedances between the 75 Ω AUT to the 50 Ω system.

The measurement procedure listed below was followed for each antenna tested.

– The SGH was modelled with mode-matching software to accurately predict its gain.

– The range length was set to 12 m and the AUT and the SGH were mounted in the vertical plane (H-plane) nominated as 0° orientation.

– A HP 8757D scalar network analyser was set up to sweep 620-790 MHz with the detector calibrated for absolute power measurement.

– The transmit power into the SGH was measured, via a 20 dB directional coupler, and the data saved to file.

– The received power at the AUT was measured at the output of the 75 to 50 Ω minimum loss pad was measured and the data saved to file.

– Owing to the risk of other signals being picked up by the wide band detector used on the scalar network analyser, an Agilent E4407B spectrum analyser was used to confirm the measured power levels at several discrete frequencies in the swept band.

– At each frequency the corrected gain was calculated from the ratio of transmitted and received powers after taking into account the losses in the measurement system (i.e. coupling factors, path loss, and the minimum loss pad) and the gain of the SGH.

Care is taken with the measurement of each parameter to ensure that errors are minimized, but nevertheless, uncertainties remain. A number of factors contribute to the level of uncertainty in the measurements. These include errors in the measurement accuracy of the spectrum and scalar analysers, and the impact of range reflections on the measured levels. The estimated on-axis gain accuracy for these measurements is < 1 dB. At different azimuth angles the accuracy in the level of the measured pattern may degrade due reflected signals; and will vary differently depending on frequency and polarization of the measured signal.

Finally, the antennas with a centre mounting location required a small offset bracket to facilitate 135° of rotation, this bracket is shown in Fig. 2 along with a general overview of the measurement range shown in Figs. 3 and 4.

FIGURE 2

Offset bracket required for centre mounting antennas

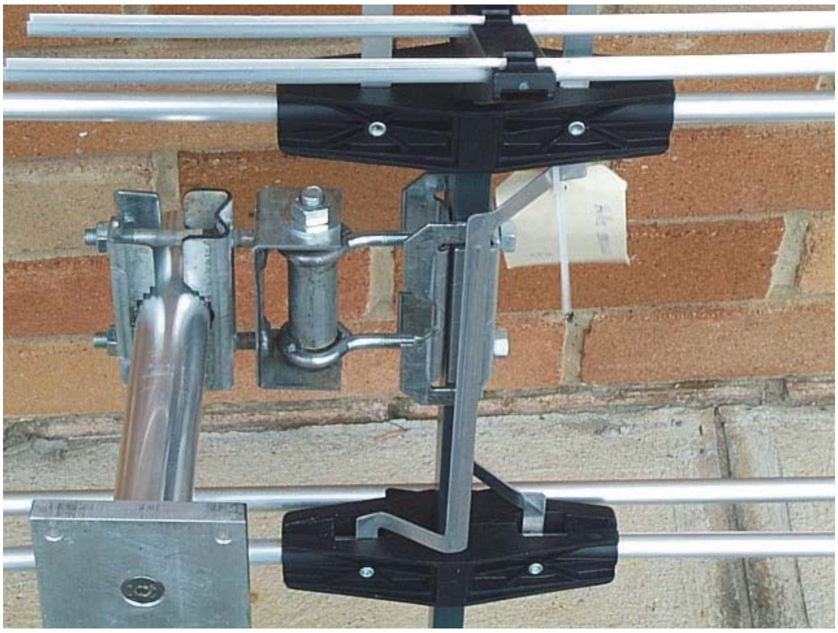

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FIGURE 3

Antenna, located on an azimuth rotator in the foregroung, being tested on CSIRO's outdoor range

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FIGURE 4

Polarization viewed from front of AUT

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4 Results

Table 2 summarizes the gain normalized measurements, and lists the plots for the pattern cuts and swept responses. The discrete points on the swept response plots refer to the narrow-band spectrum analyser measurements used to confirm the gain.

TABLE 2

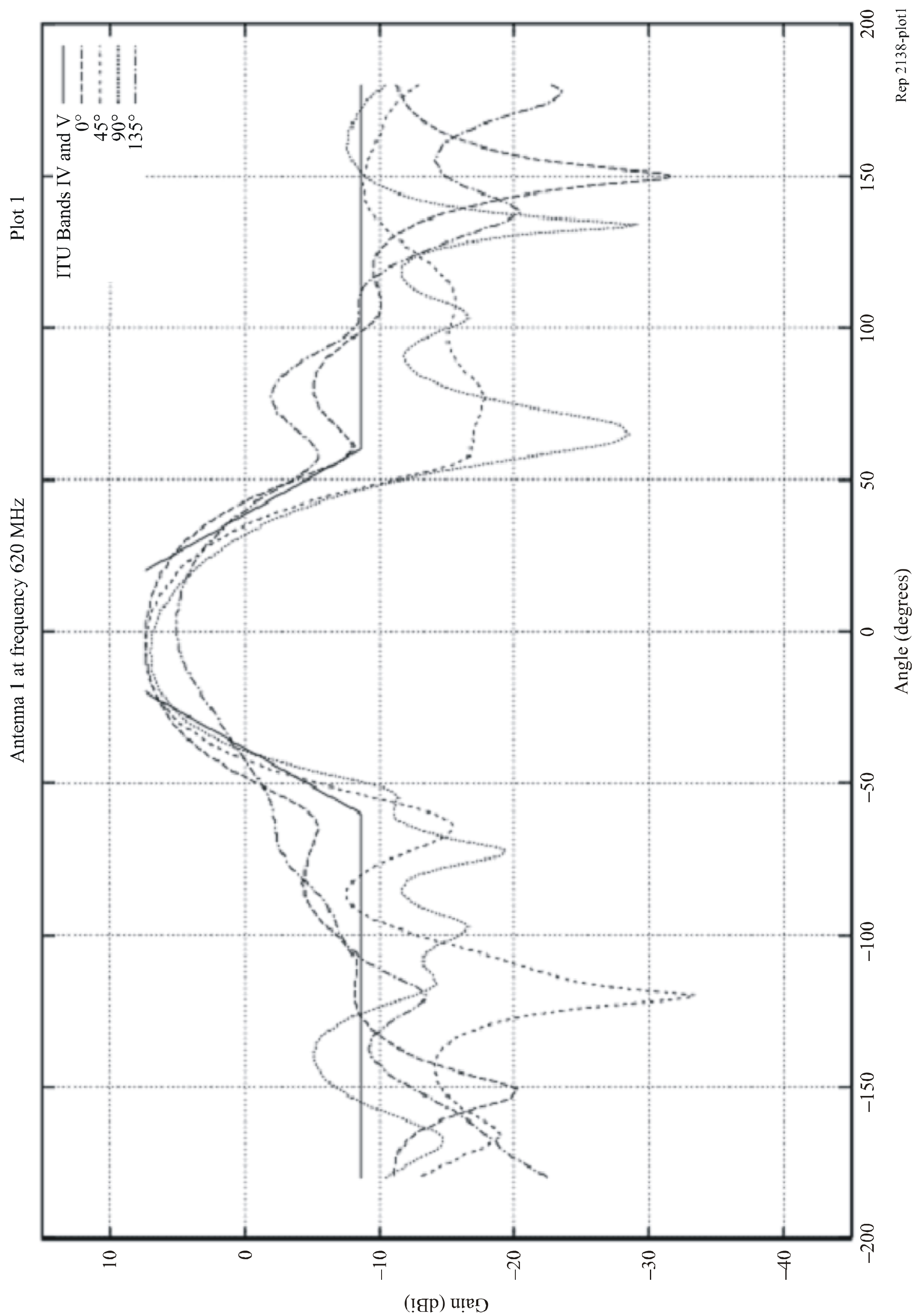
Antenna measurement results

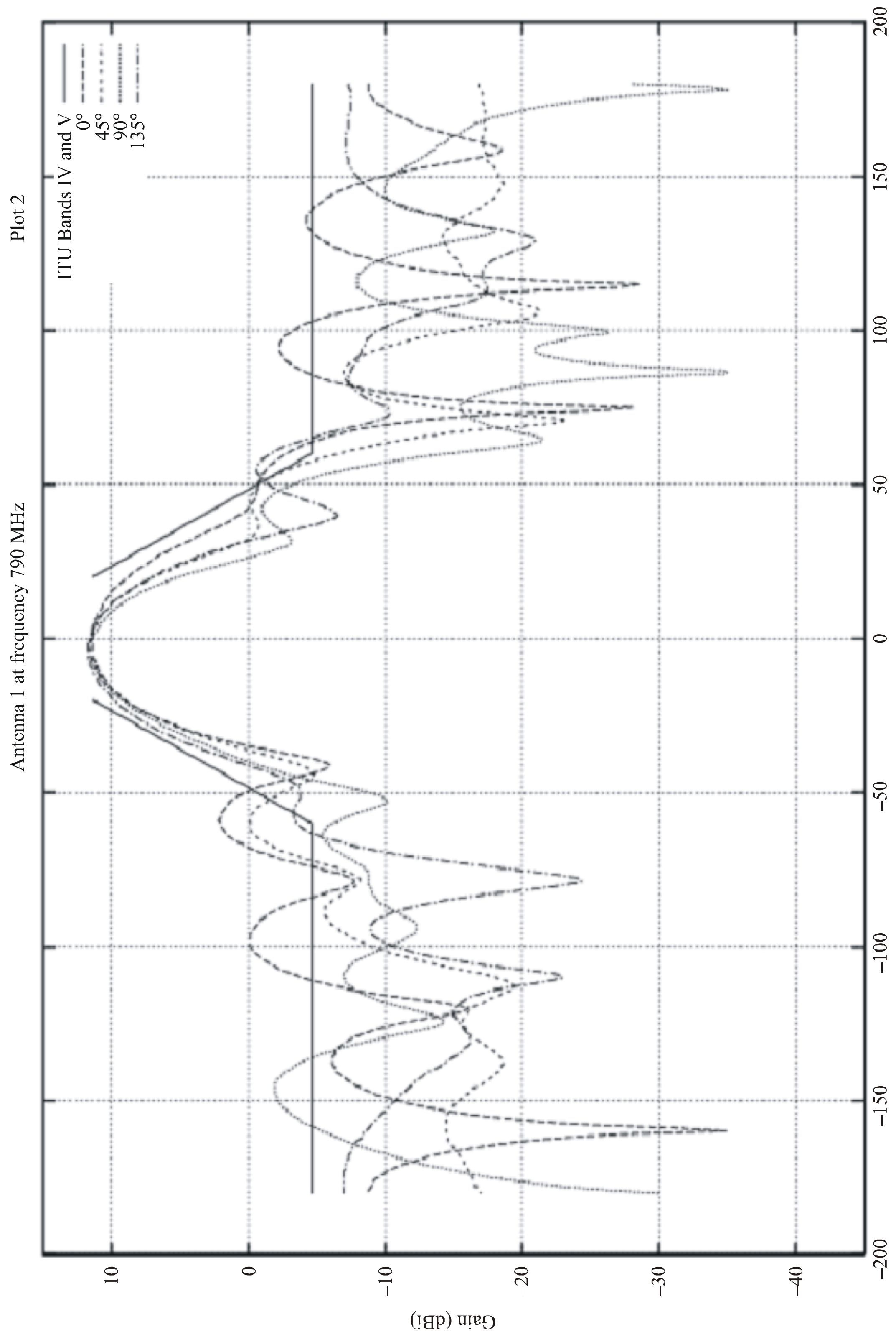
Antenna number	Polarization (degrees)	Frequency (MHz)	Gain (dBi)	Plot number
1	0, 45, 90, 135	620	7.1	1
	0, 45, 90, 135	790	11.4	2
	0	620-790	–	25
2	0, 45, 90, 135	620	9.2	3
	0, 45, 90, 135	790	9.2	4
	0	620-790	–	26
3	0, 45, 90, 135	620	10.2	5
	0, 45, 90, 135	790	13.8	6
	0	620-790	–	27
4	0, 45, 90, 135	620	13.4	7
	0, 45, 90, 135	790	15.0	8
		620-790	–	28
5	0, 45, 90, 135	620	11.1	9
	0, 45, 90, 135	790	12.0	10
		620-790	–	29
6	0, 45, 90, 135	620	11.3	11
	0, 45, 90, 135	790	12.5	12
		620-790	–	30
7	0, 45, 90, 135	620	8.6	13
	0, 45, 90, 135	790	8.6	14
		620-790	–	31
8(1)	0, 45, 90, 135	620	7.9	15
	0, 45, 90, 135	757	0.8	16
	620-790	620-790	–	32
9	0, 45, 90, 135	620	9.7	17
	0, 45, 90, 135	790	5.9	18
	620-790	620-790	–	33
10	0, 45, 90, 135	620	8.4	19
	0, 45, 90, 135	790	8.0	20
	620-790	620-790	–	34
11(2)	0, 45, 90, 135	620	7.1	21
	0, 45, 90, 135	687	7.0	22
	620-790	620-790	–	35
12(3)	0, 45, 90, 135	620	9.5	23
	0, 45, 90, 135	687	5.0	24
	620-790	620-790	–	36

(1) Tuneable UHF frequency range of 526-750 MHz.

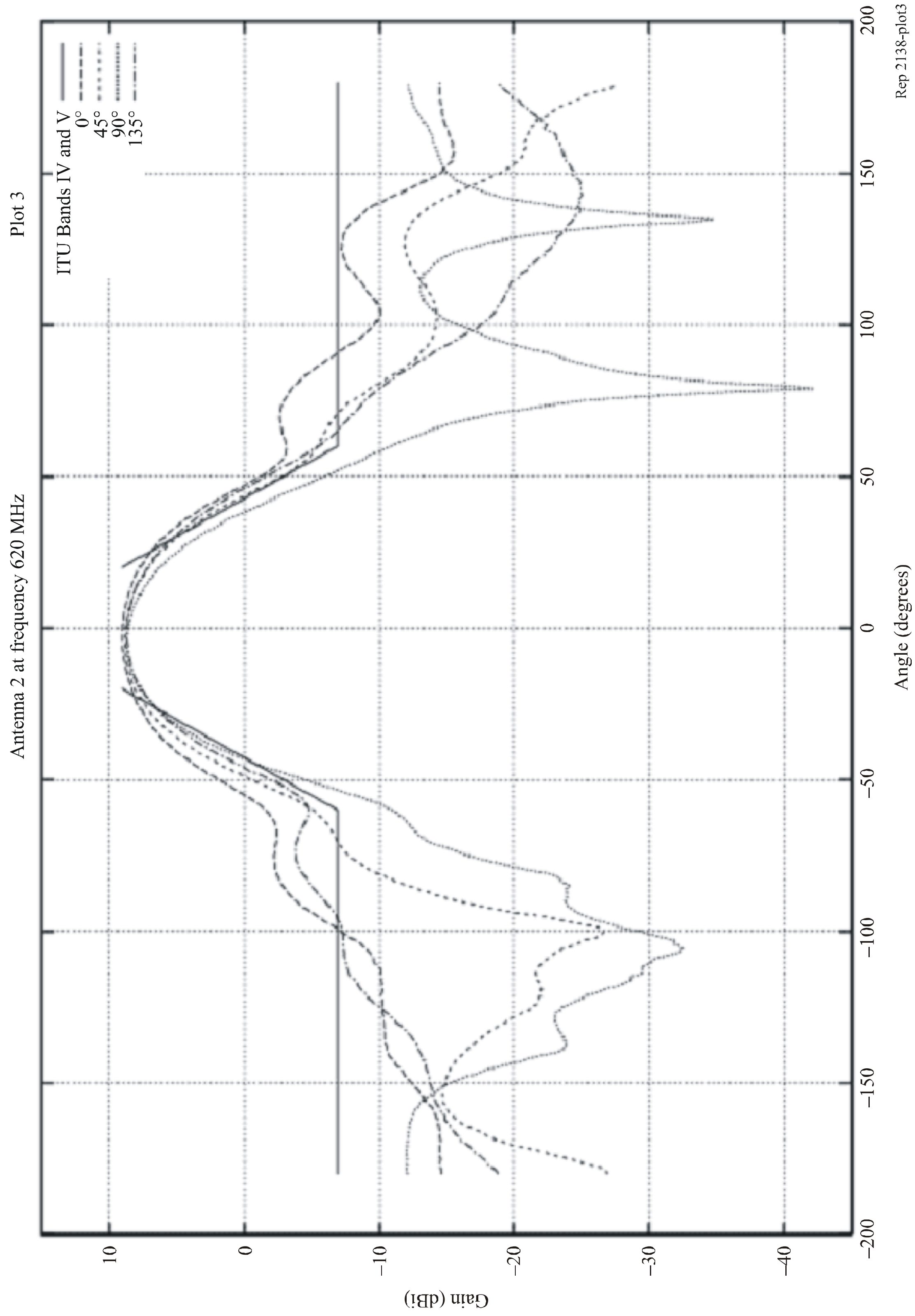
(2) Tuneable UHF frequency range of 526-750 MHz.

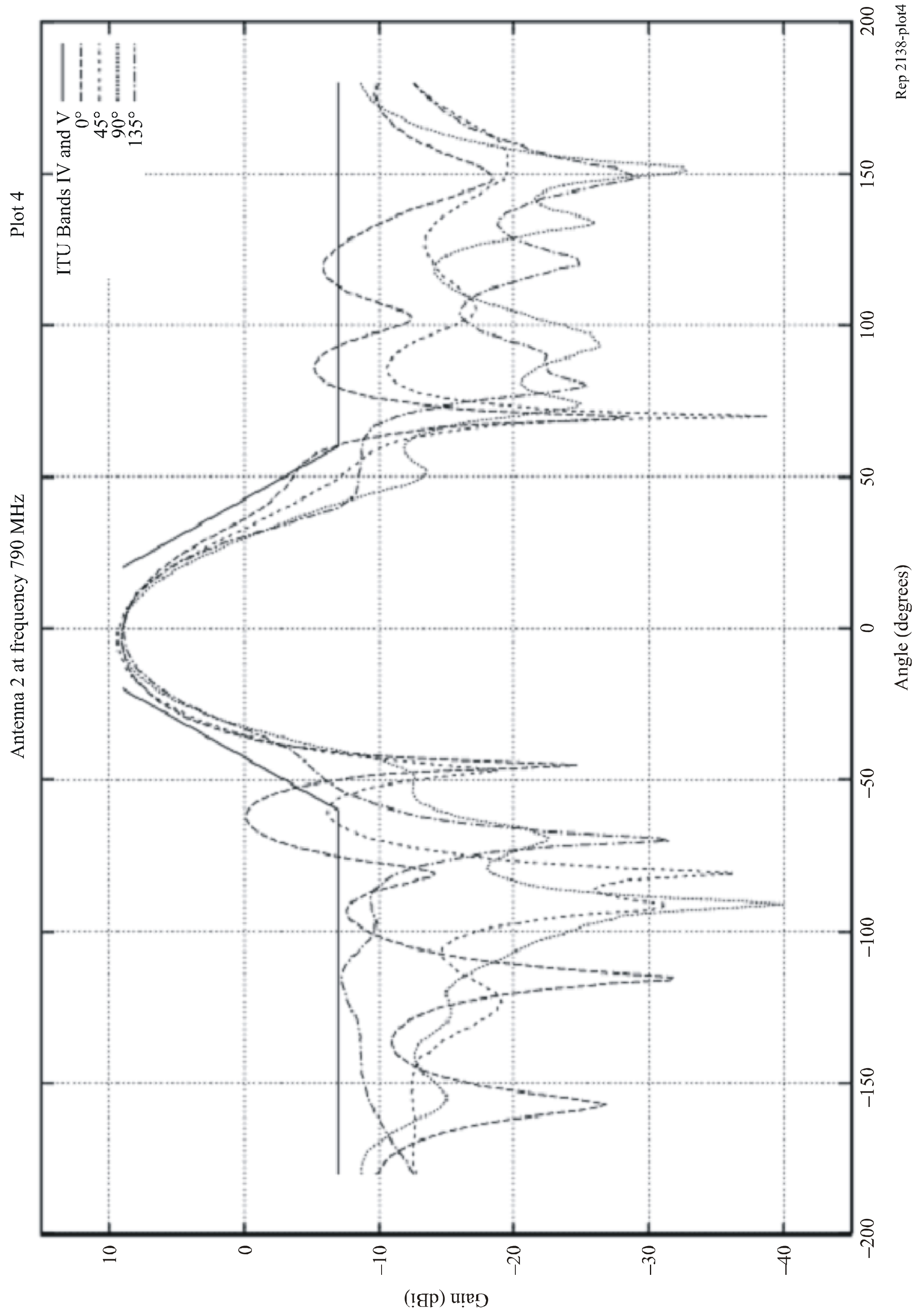
(3) Tuneable UHF frequency range of 526-750 MHz.


Antenna 1 at frequency 620 MHz
Plot 1
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
–10
–20
–30
–40
Angle (degrees)
–200
–150
–100
–50
0
50
100
150
200
Rep 2138-plot1

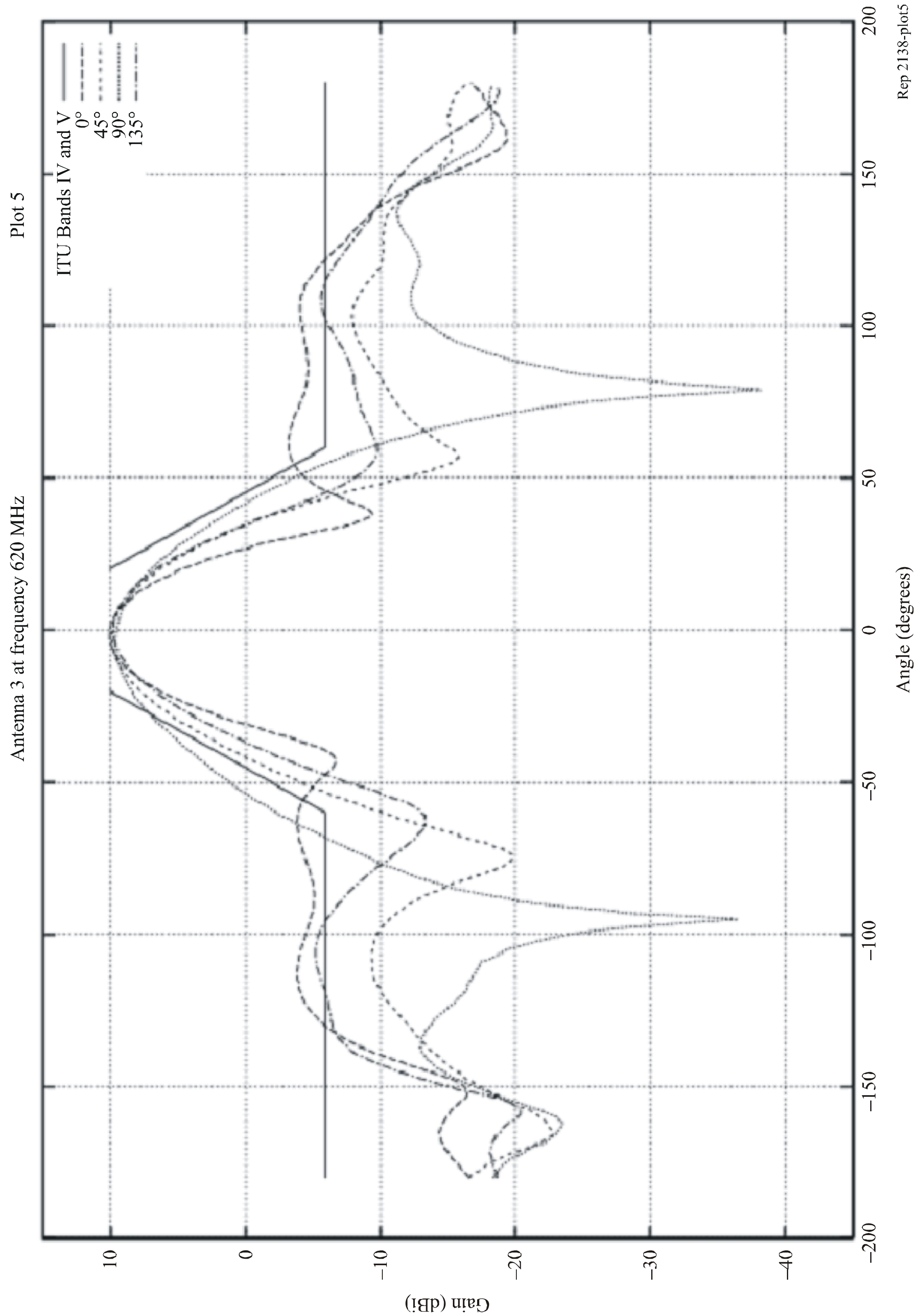


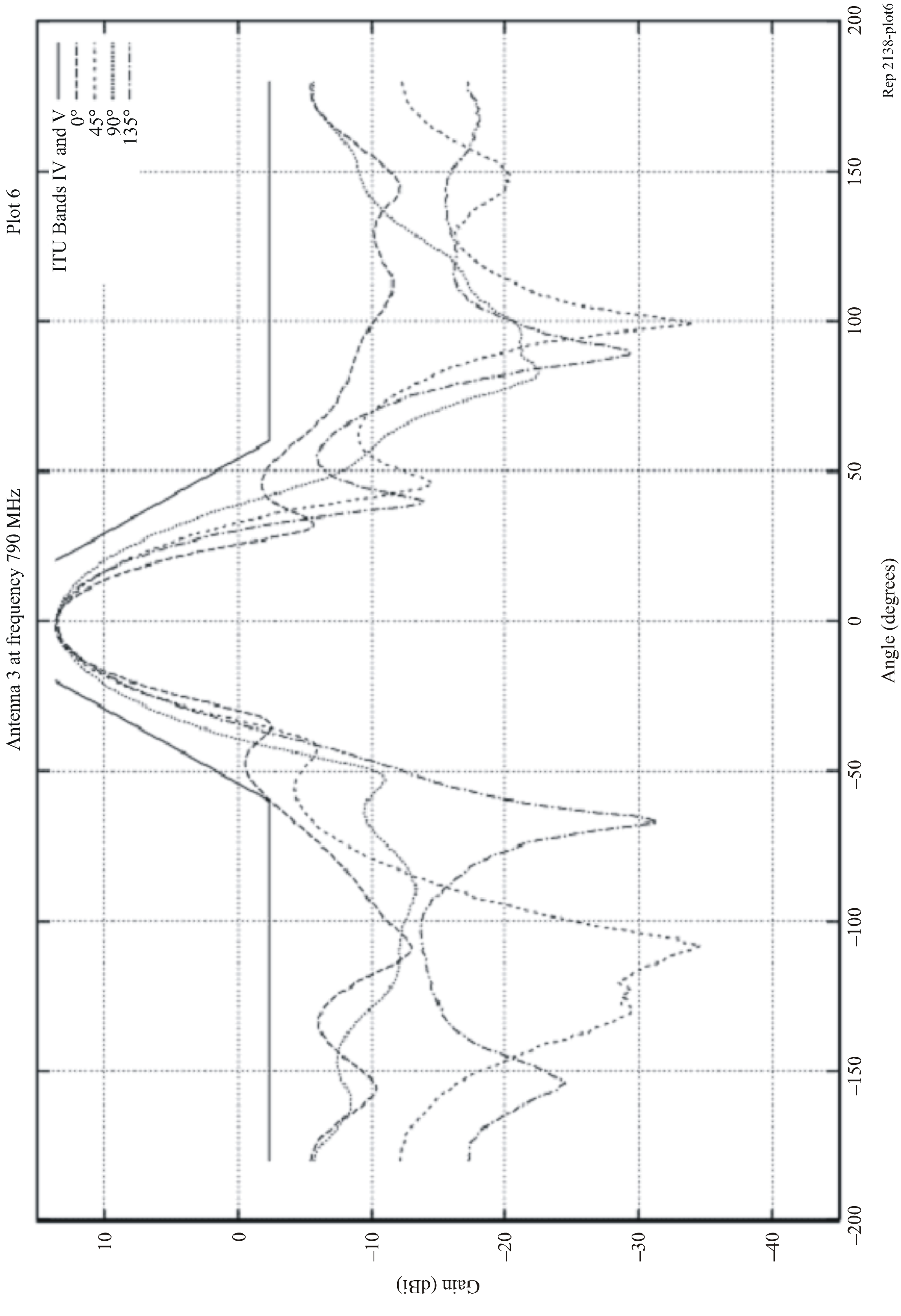
Rep 2138-plot2

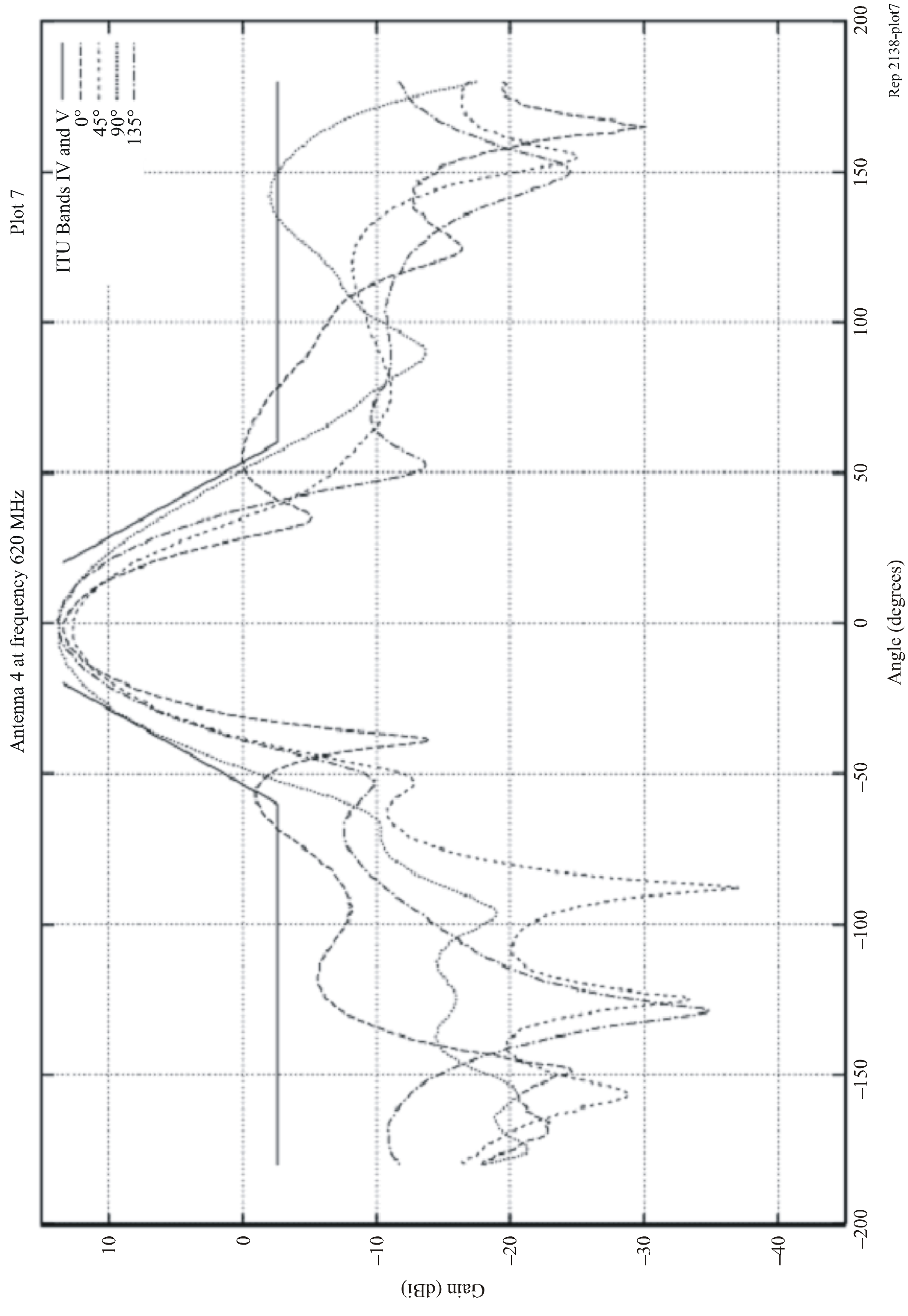

Antenna 2 at frequency 620 MHz
Plot 3
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
Rep 2138-plot3

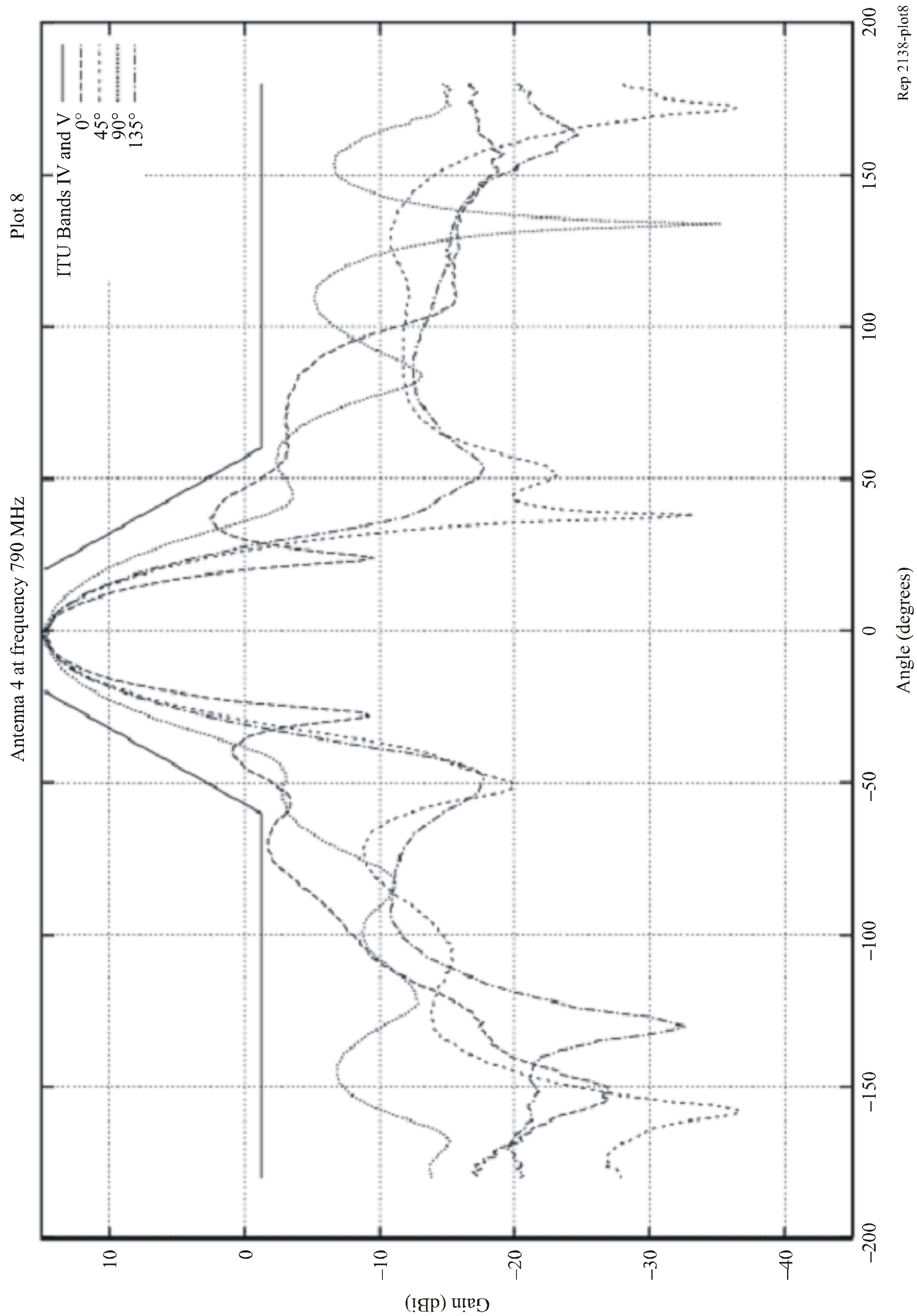


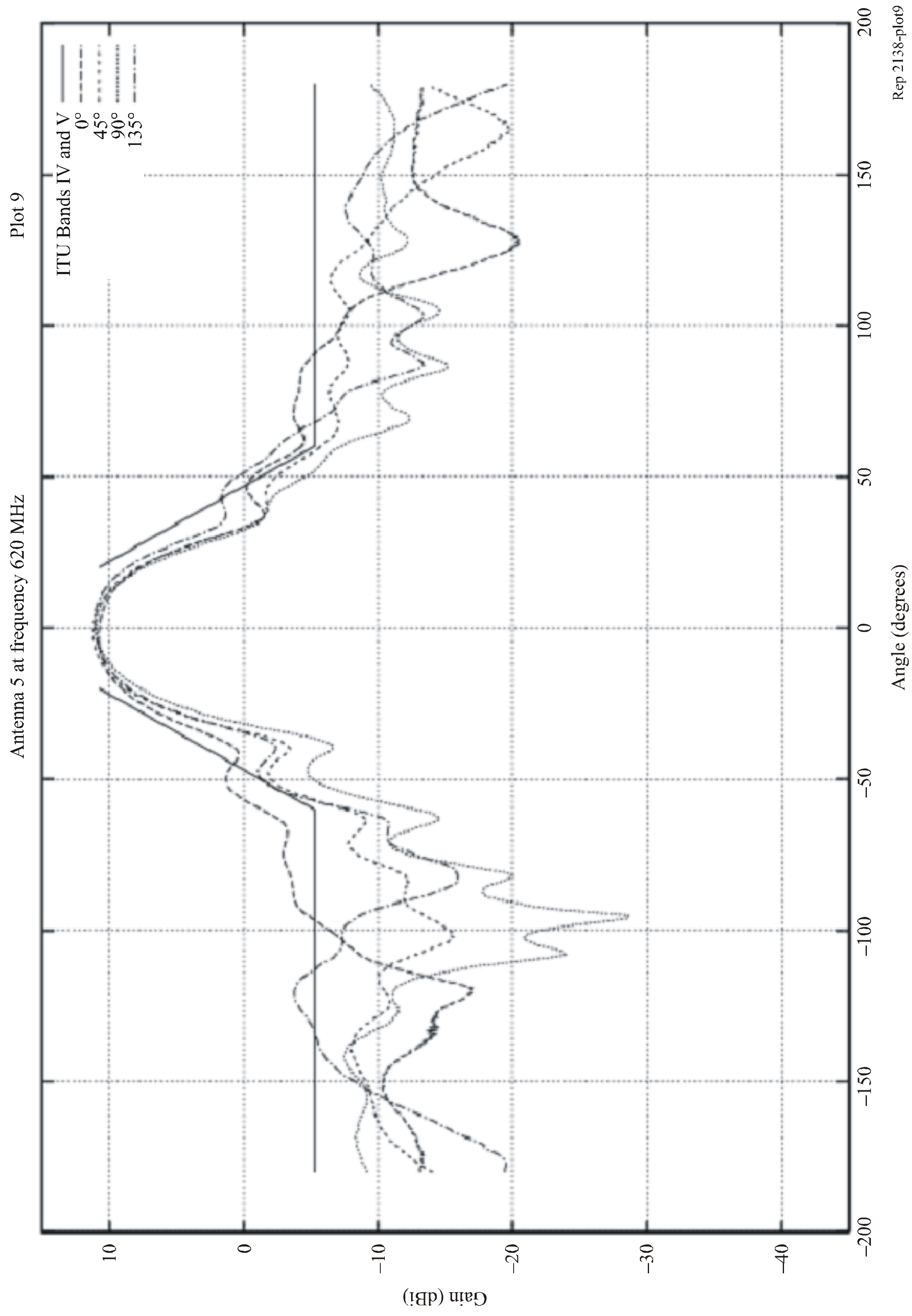
Plot 4
Antenna 2 at frequency 790 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
–10
–20
–30
–40
Angle (degrees)
–200
–150
–100
–50
0
50
100
150
200
Rep 2138-plot4

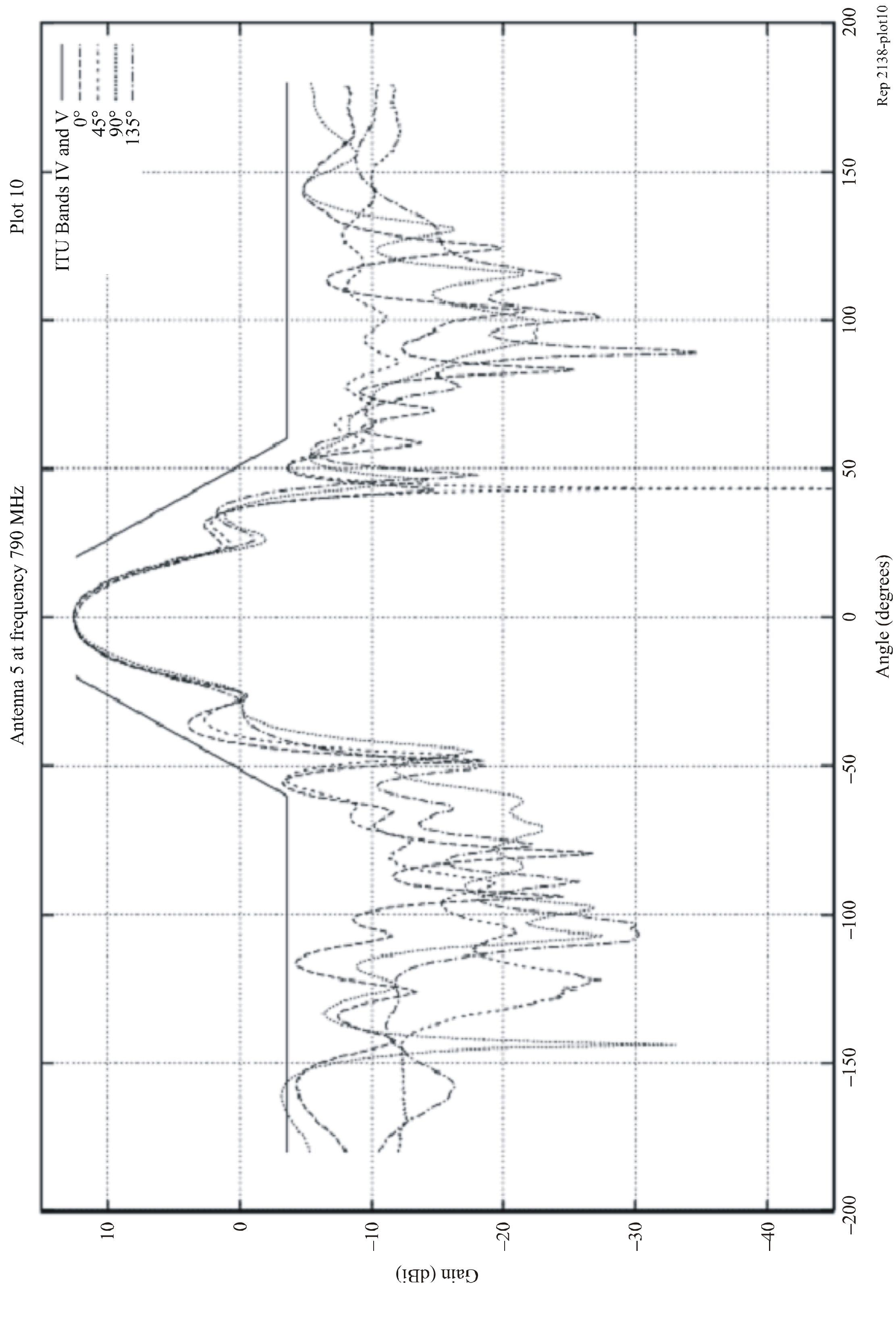

Plot 5
Antenna 3 at frequency 620 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
–10
–20
–30
–40
Angle (degrees)
–200
–150
–100
–50
0
50
100
150
200
Rep 2138-plot5

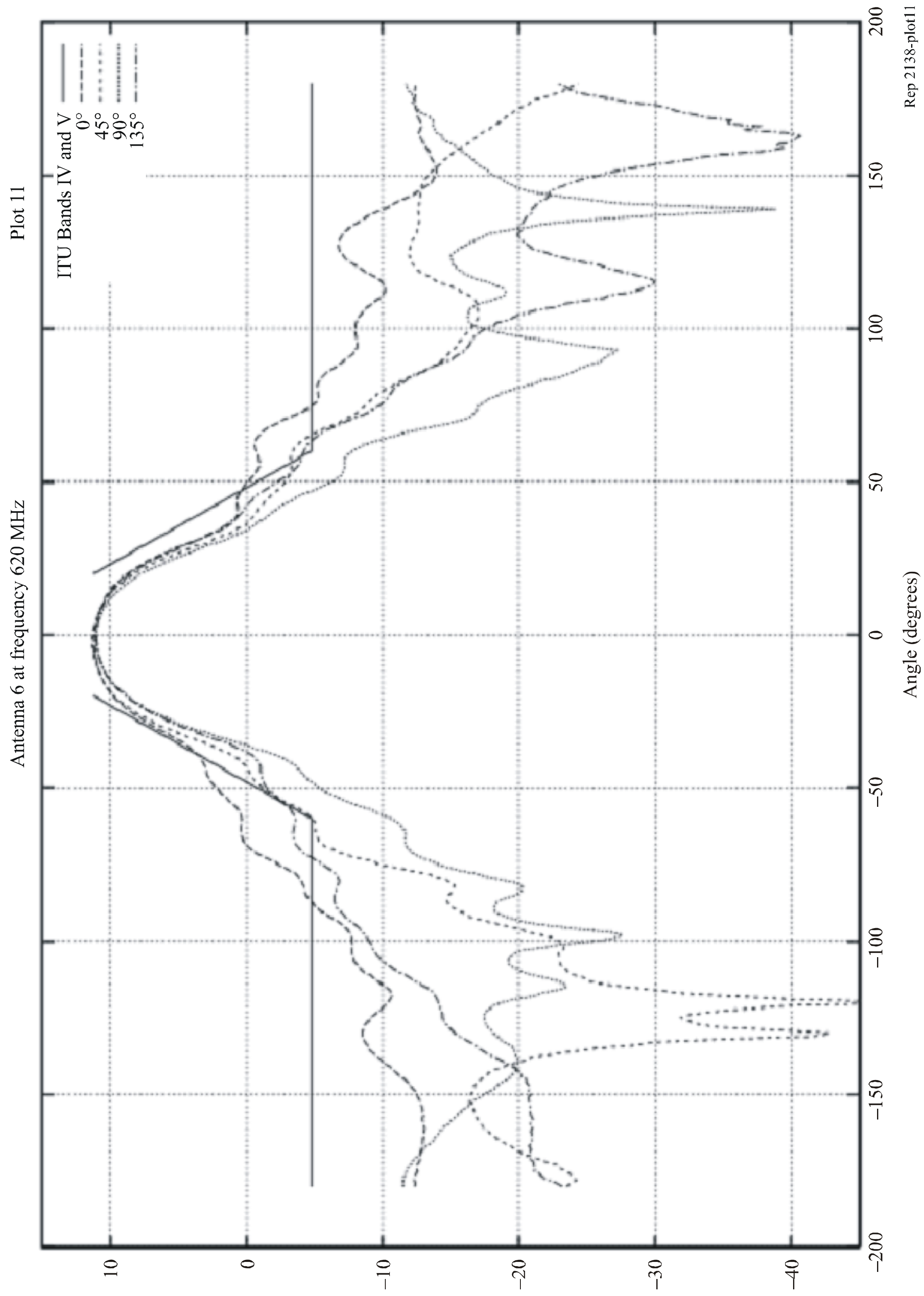

Antenna 3 at frequency 790 MHz
Plot 6
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
10
0
−10
−20
−30
−40
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot6

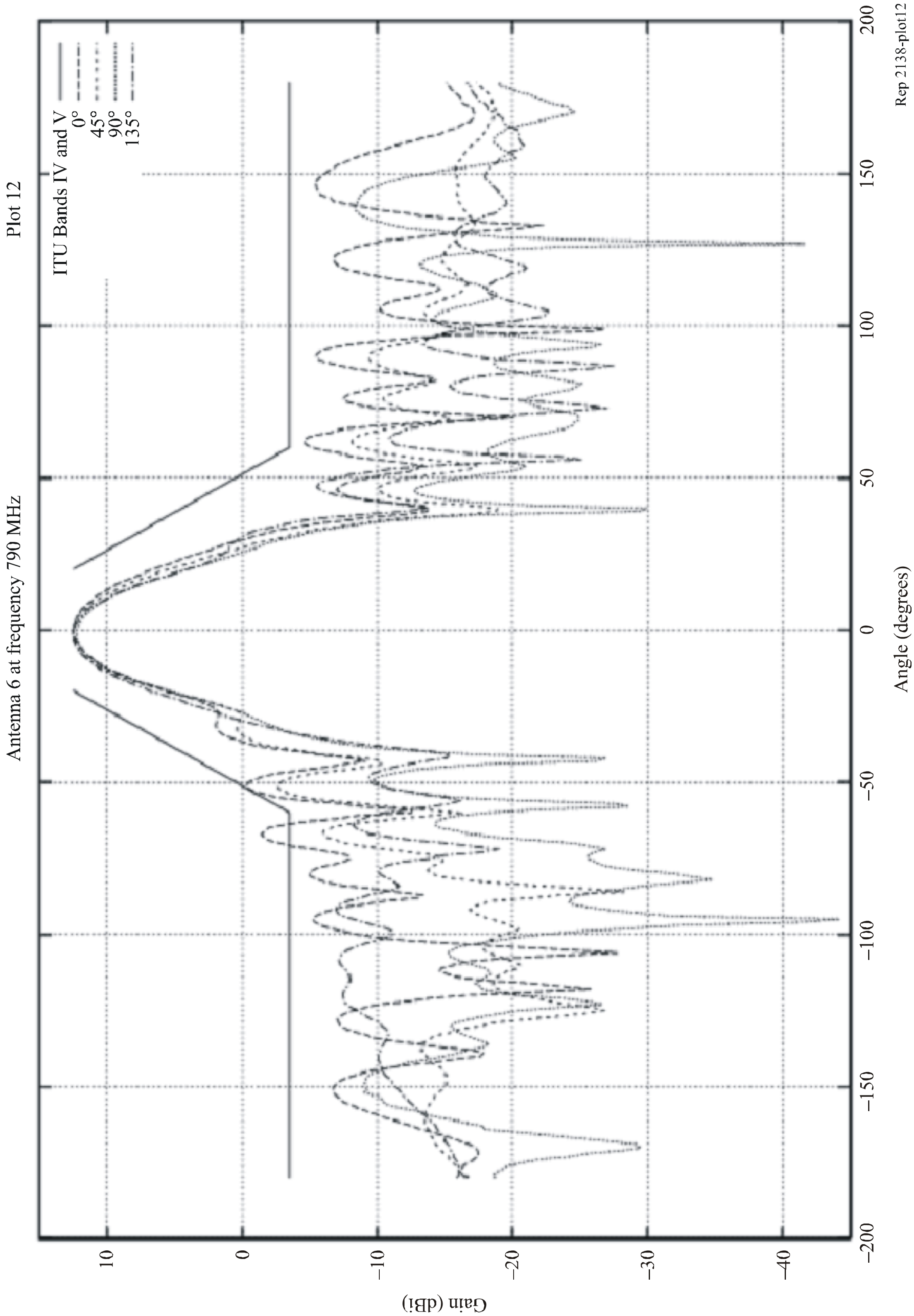

Antenna 4 at frequency 620 MHz
Plot 7
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
Rep 2138-plot7

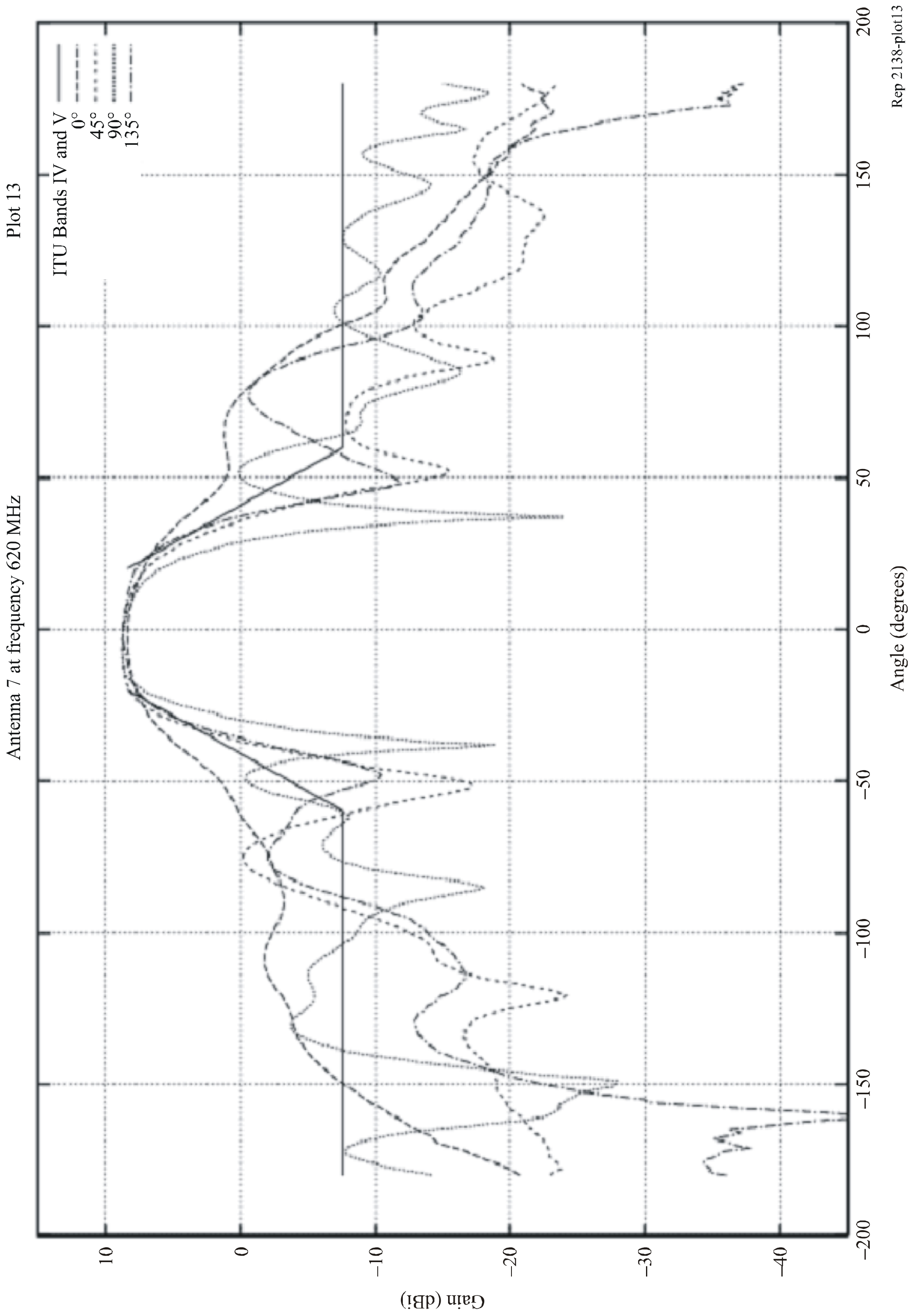

Antenna 4 at frequency 790 MHz
Plot 8
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
−10
−20
−30
−40
Angle (degrees)
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot8

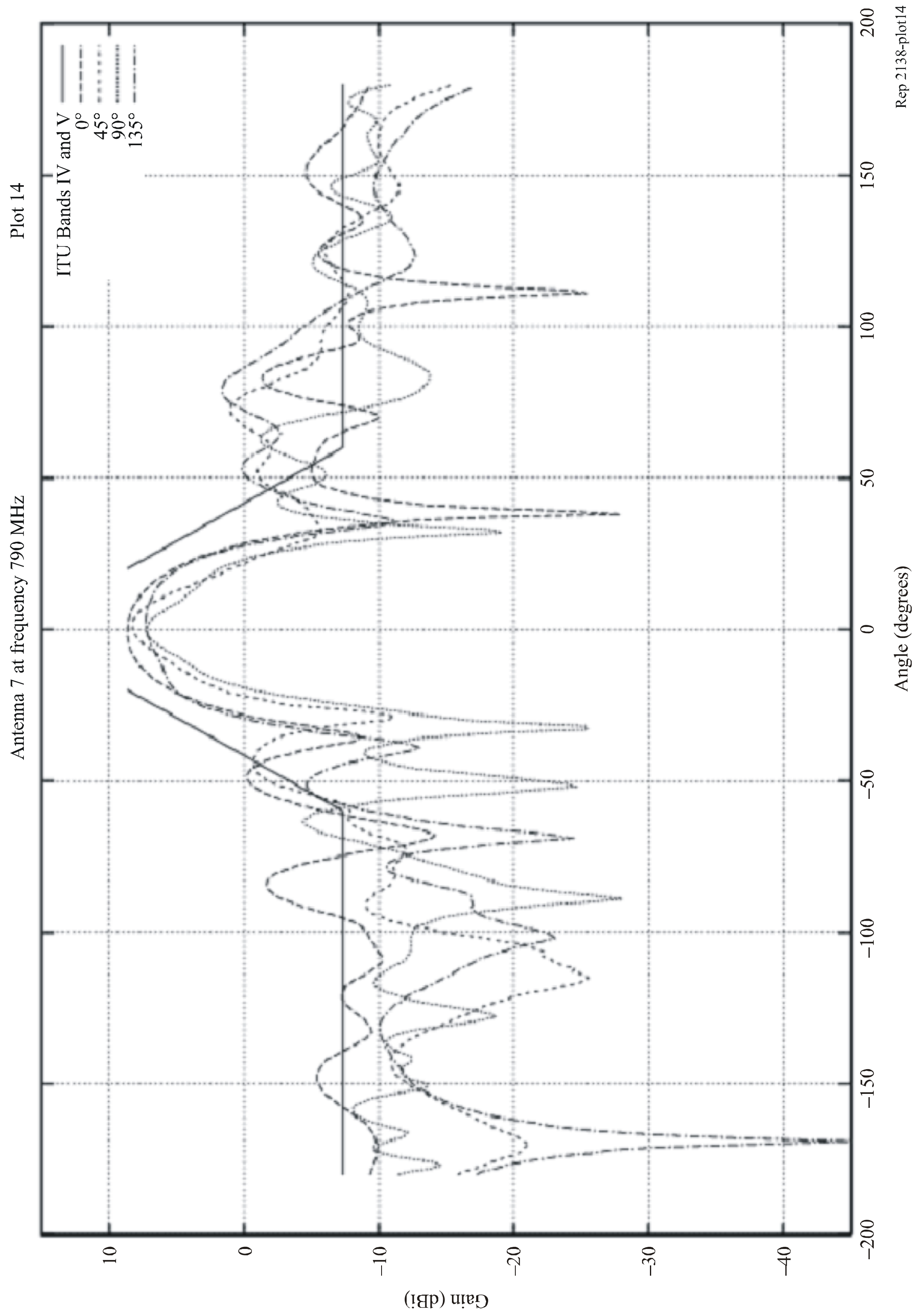

Plot 9
Antenna 5 at frequency 620 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
–10
–20
–30
–40
Angle (degrees)
–200
–150
–100
–50
0
50
100
150
200
Rep 2138-plot9

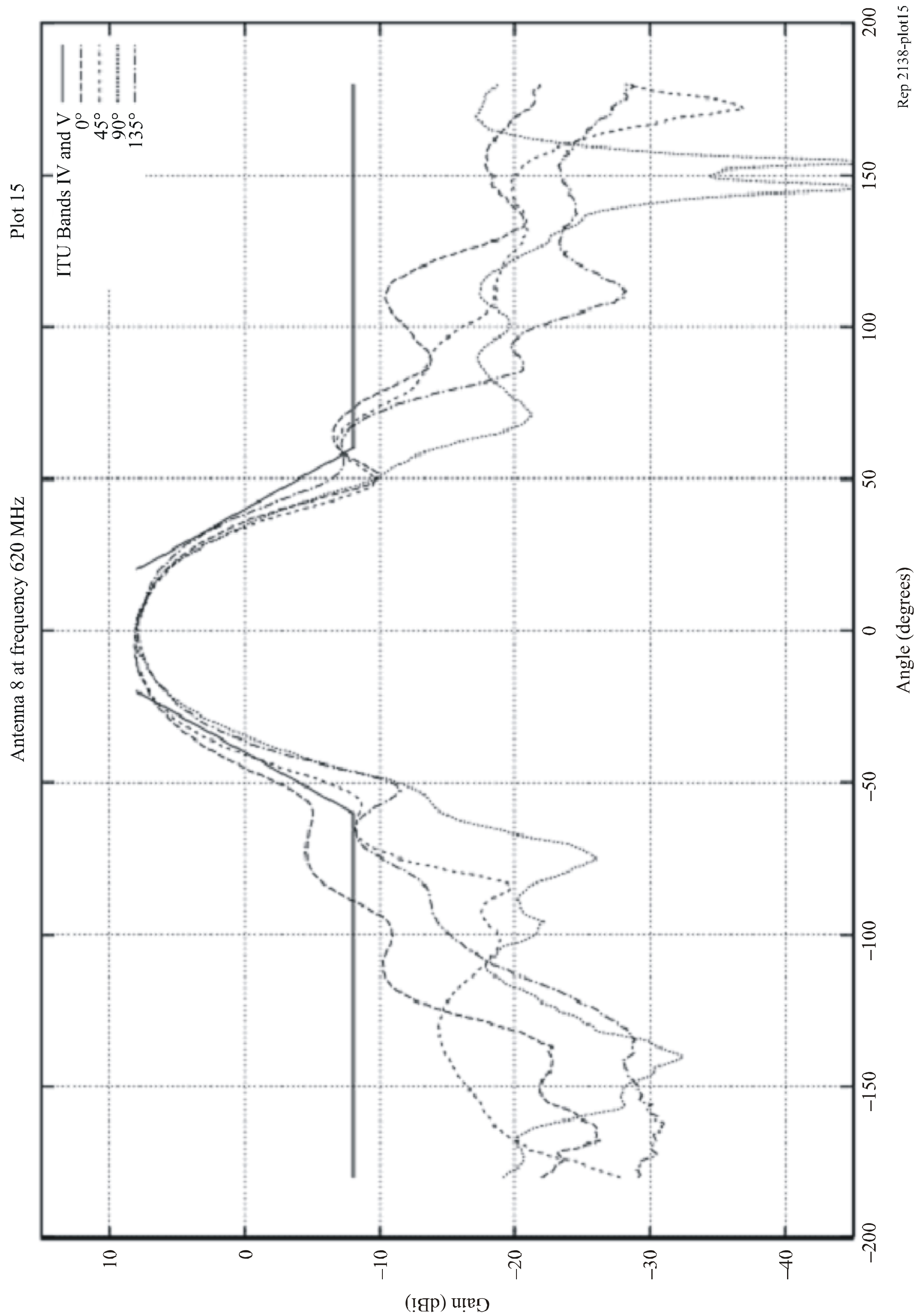

Plot 10
Antenna 5 at frequency 790 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
−10
−20
−30
−40
Angle (degrees)
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot10

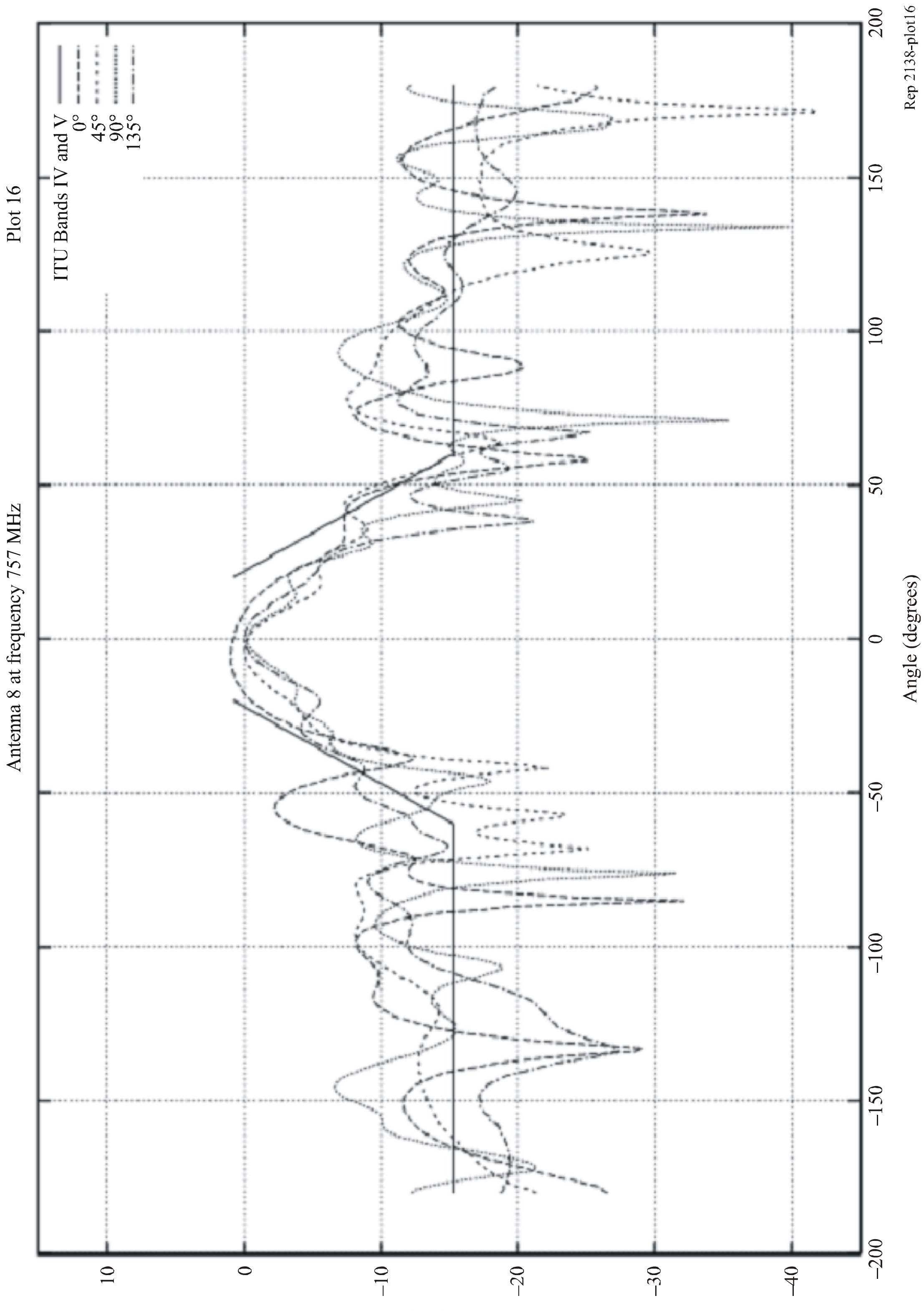

Antenna 6 at frequency 620 MHz
Plot 11
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
10
0
–10
–20
–30
–40
–200
–150
–100
–50
0
50
100
150
200
Rep 2138-plot11

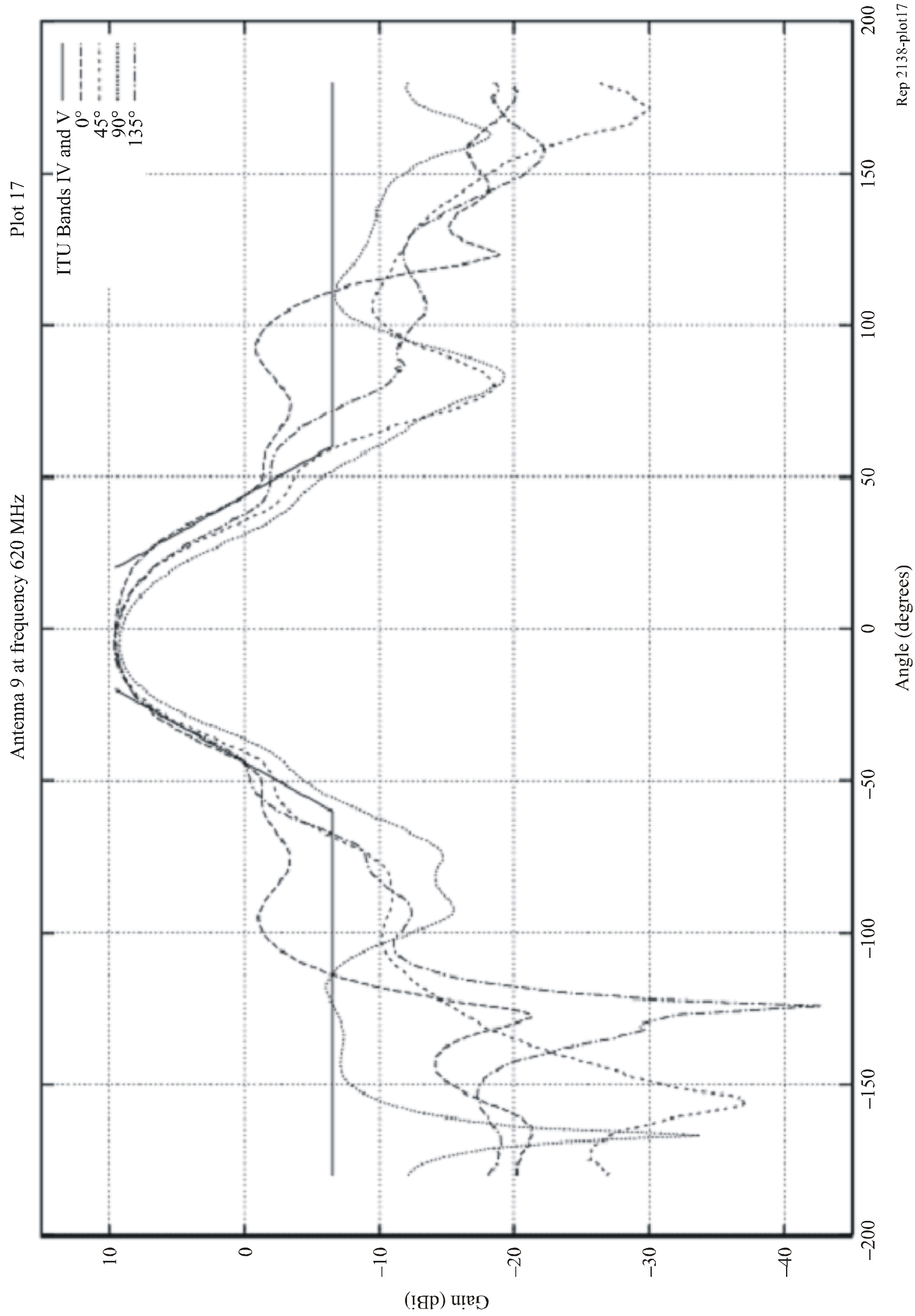

Plot 12
Antenna 6 at frequency 790 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
−10
−20
−30
−40
Angle (degrees)
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot12

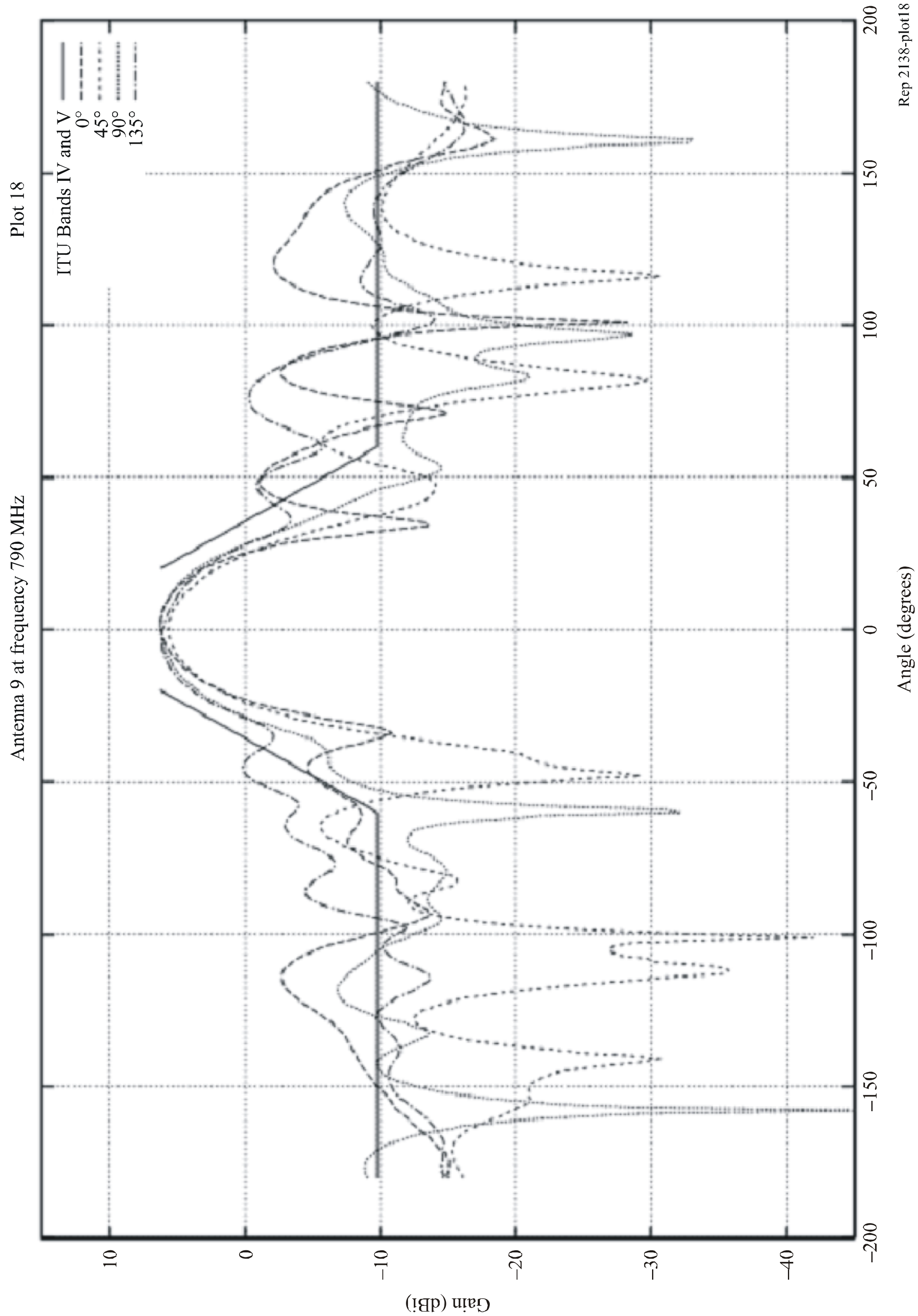

Antenna 7 at frequency 620 MHz
Plot 13
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
10
0
−10
−20
−30
−40
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot13

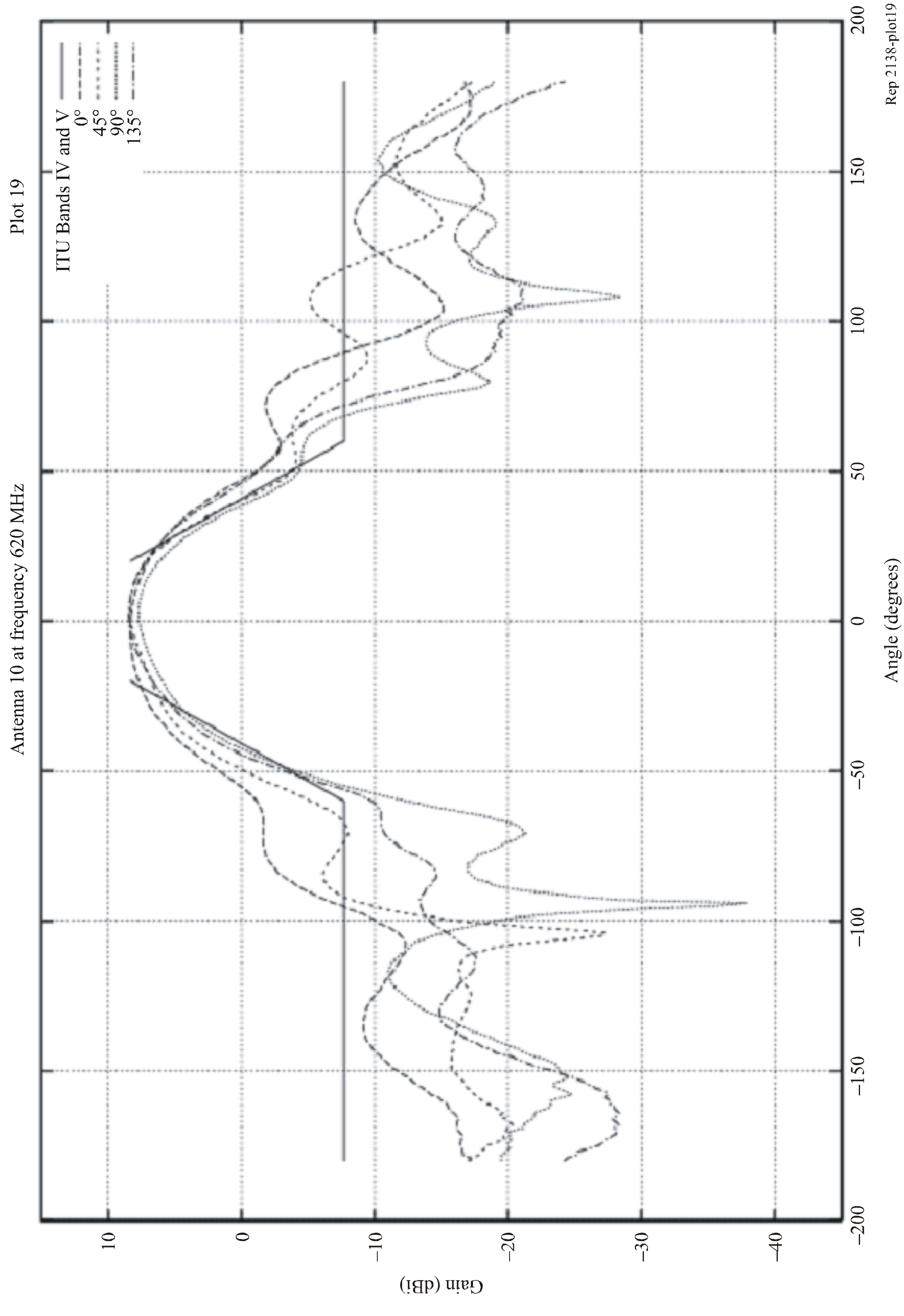

Plot 14
Antenna 7 at frequency 790 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
10
0
−10
−20
−30
−40
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot14

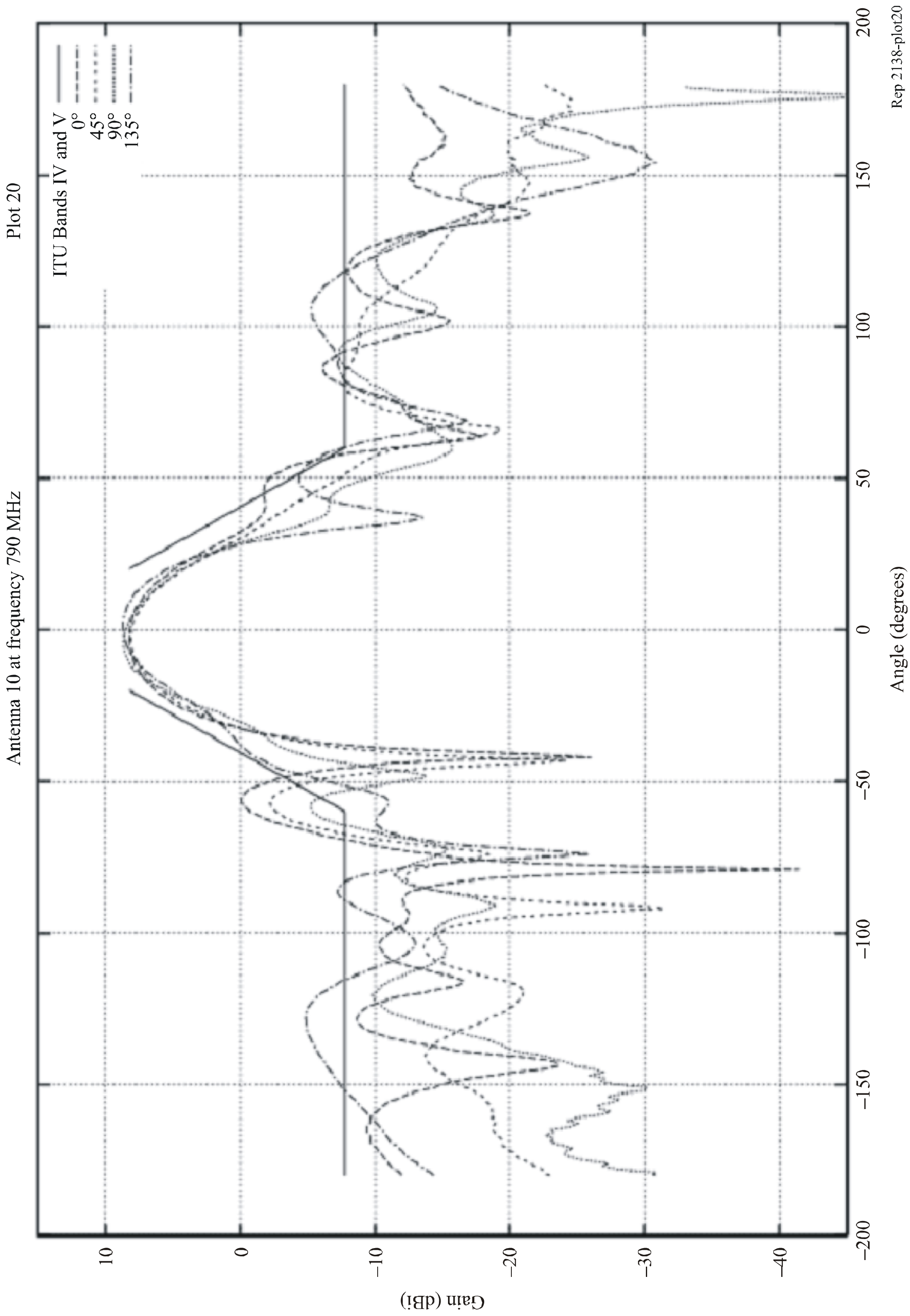

Antenna 8 at frequency 620 MHz
Plot 15
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
−10
−20
−30
−40
Angle (degrees)
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot15

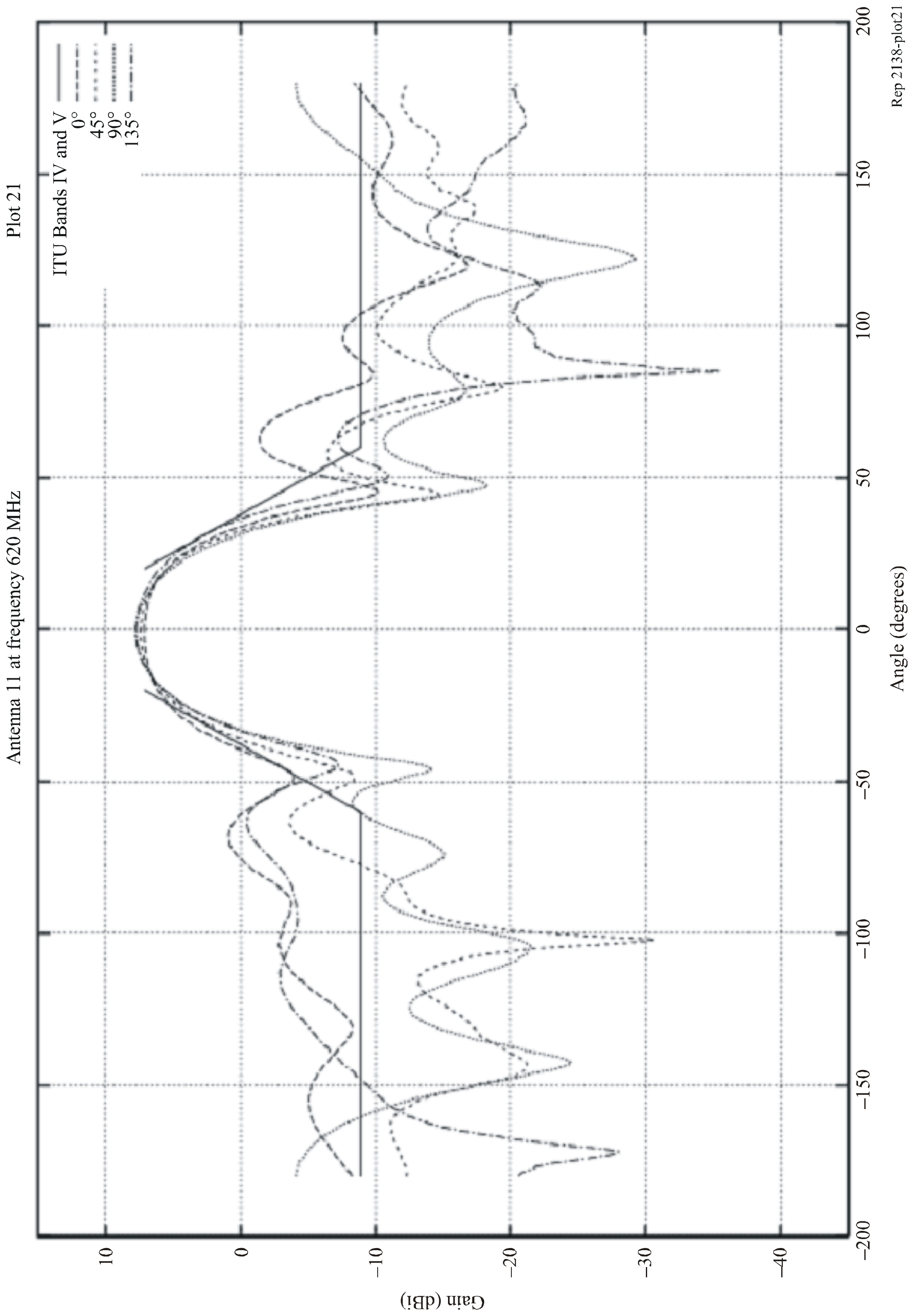

Plot 16
Antenna 8 at frequency 757 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
10
0
−10
−20
−30
−40
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot16

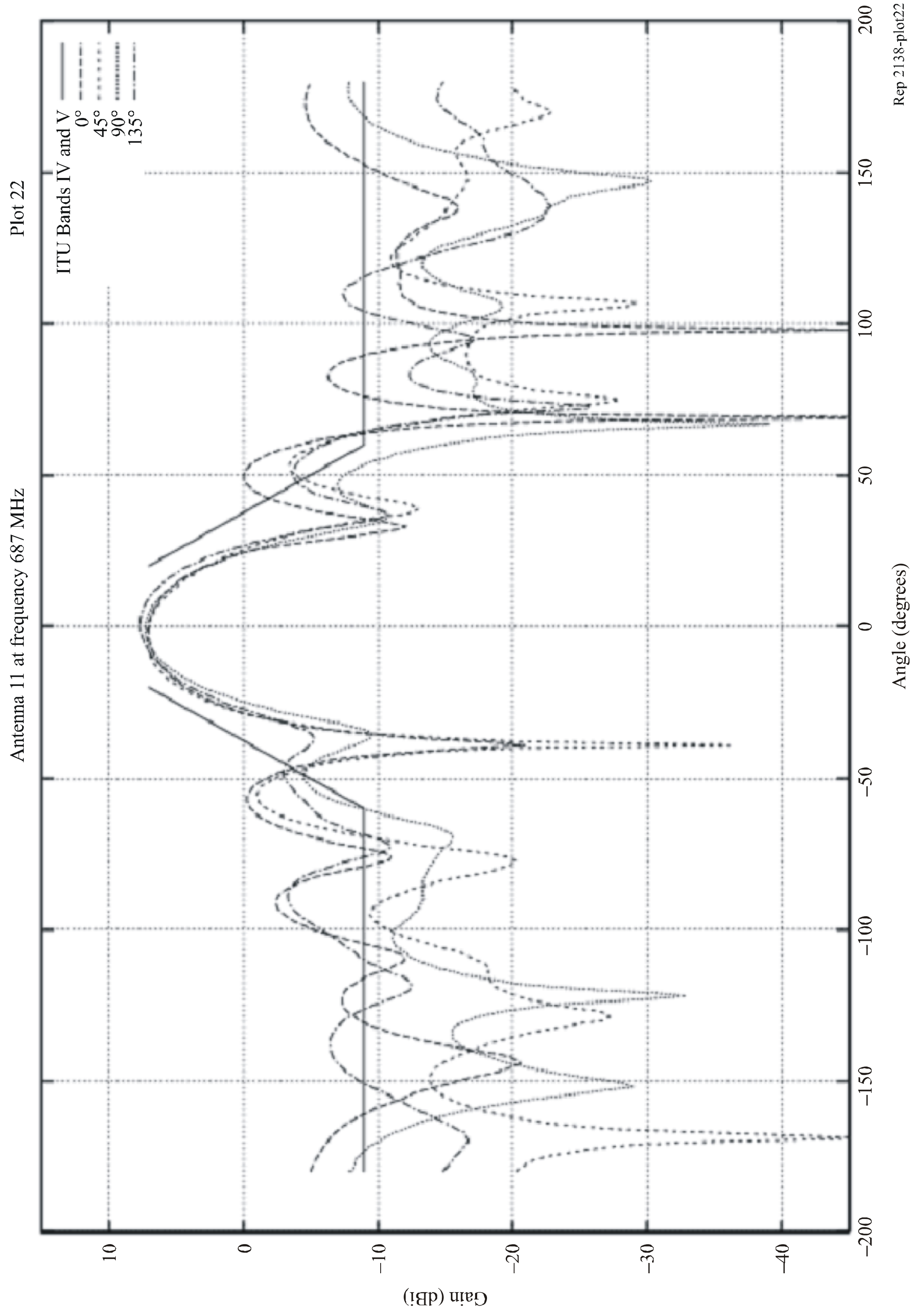

Plot 17
Antenna 9 at frequency 620 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
−10
−20
−30
−40
Angle (degrees)
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot17

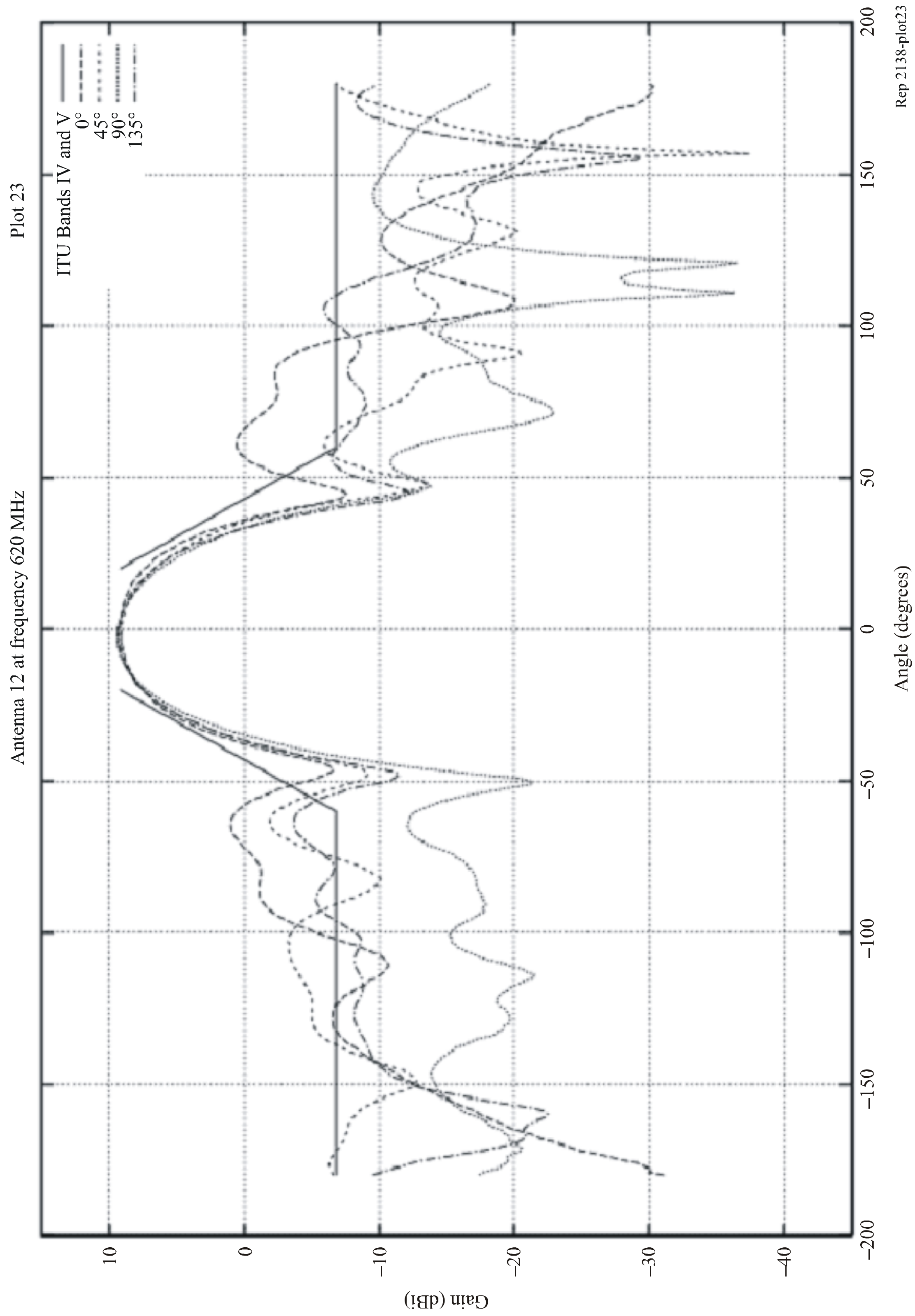

Plot 18
Antenna 9 at frequency 790 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
10
0
−10
−20
−30
−40
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot18

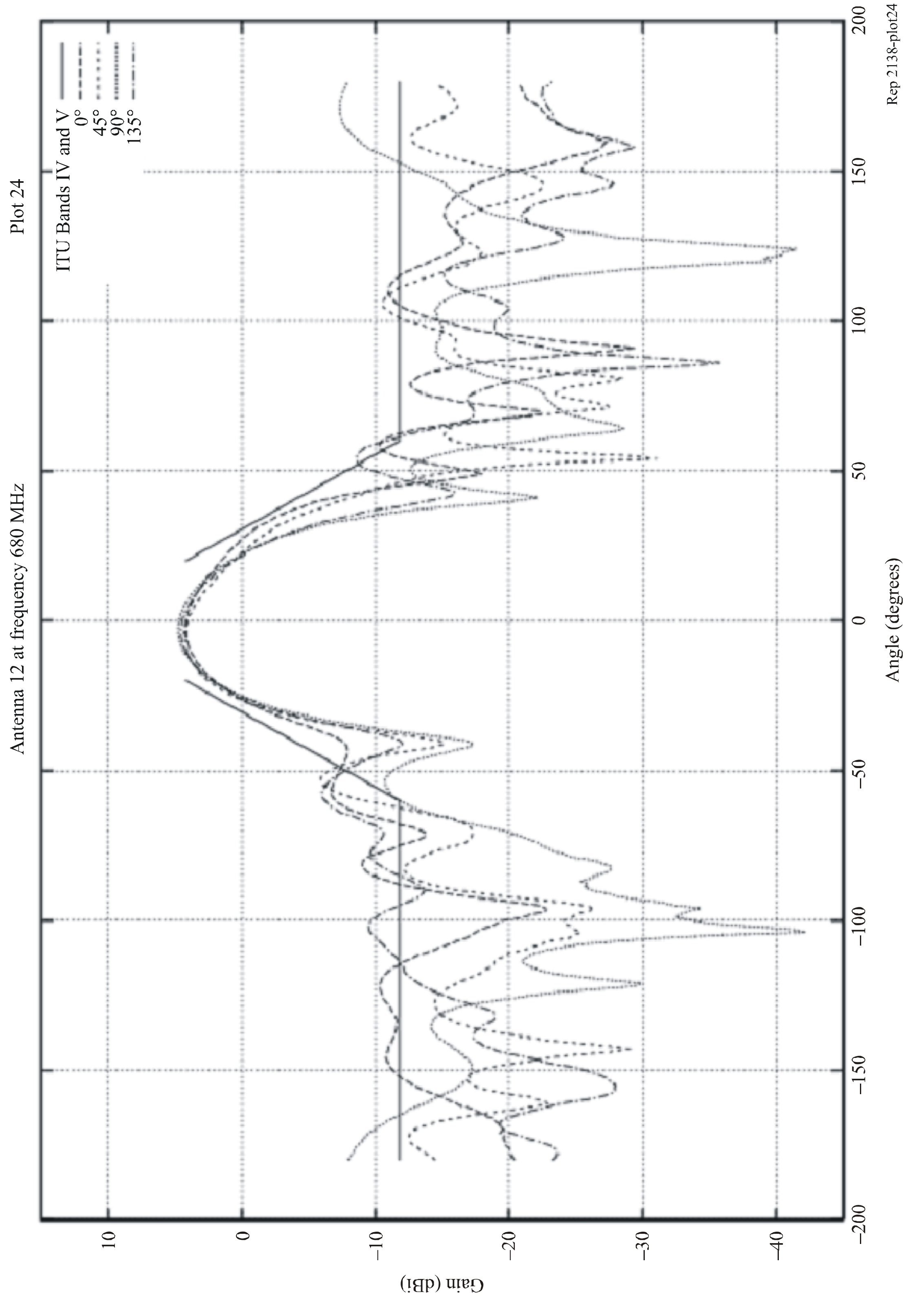

Plot 19
Antenna 10 at frequency 620 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
Rep 2138-plot19

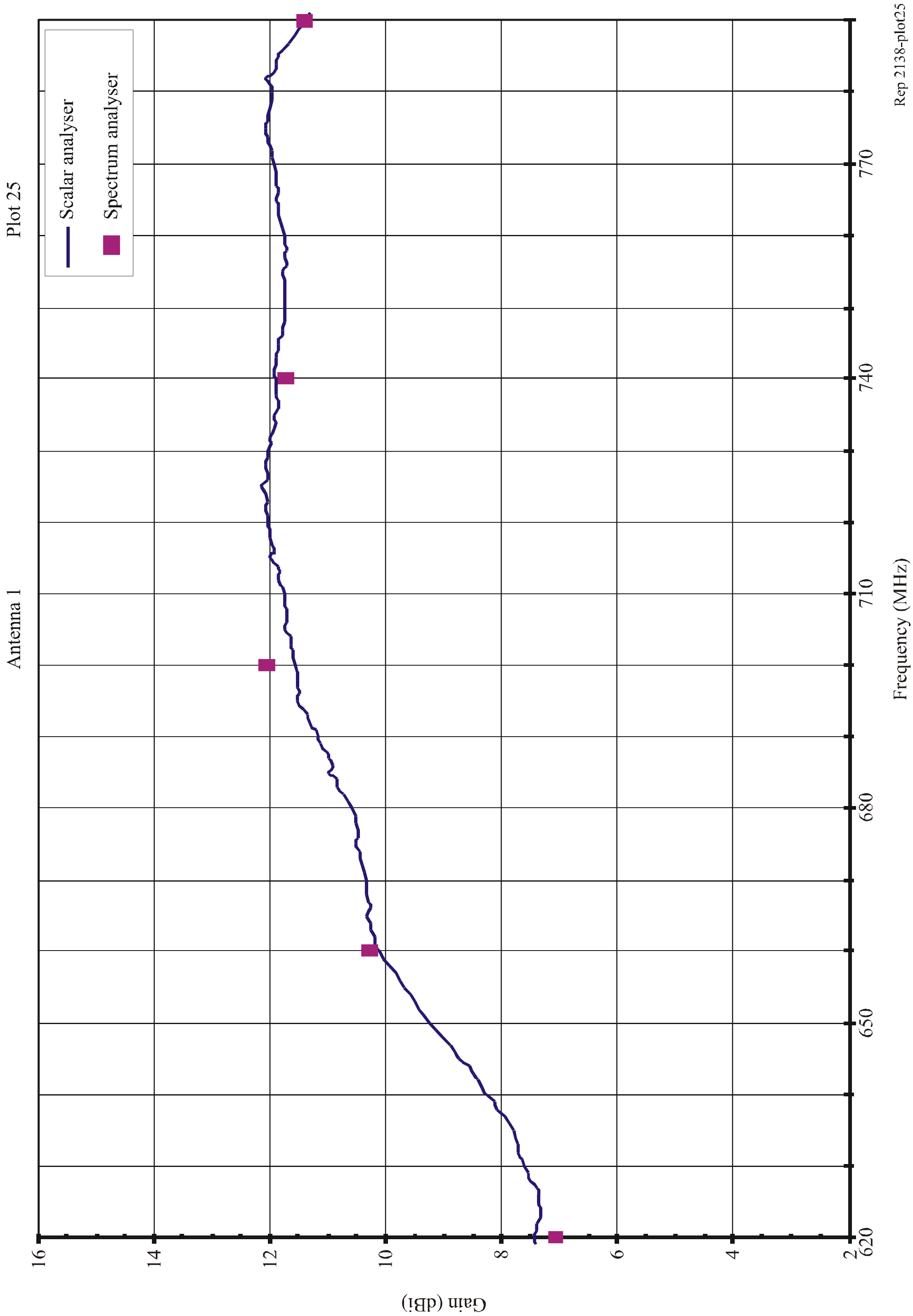

Plot 20
Antenna 10 at frequency 790 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
10
0
–10
–20
–30
–40
–200
–150
–100
–50
0
50
100
150
200
Rep 2138-plot20

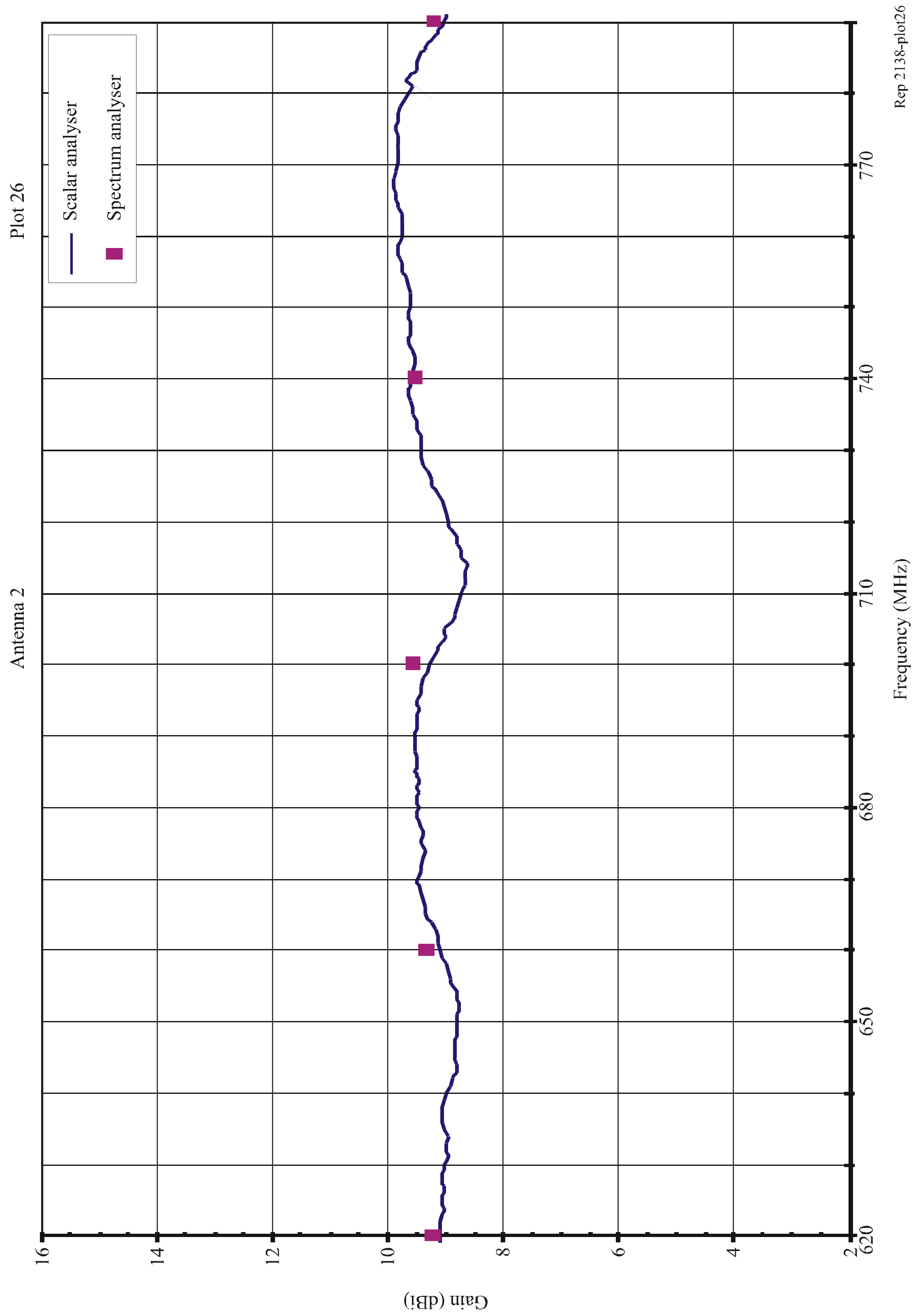

Antenna 11 at frequency 620 MHz
Plot 21
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
Rep 2138-plot21

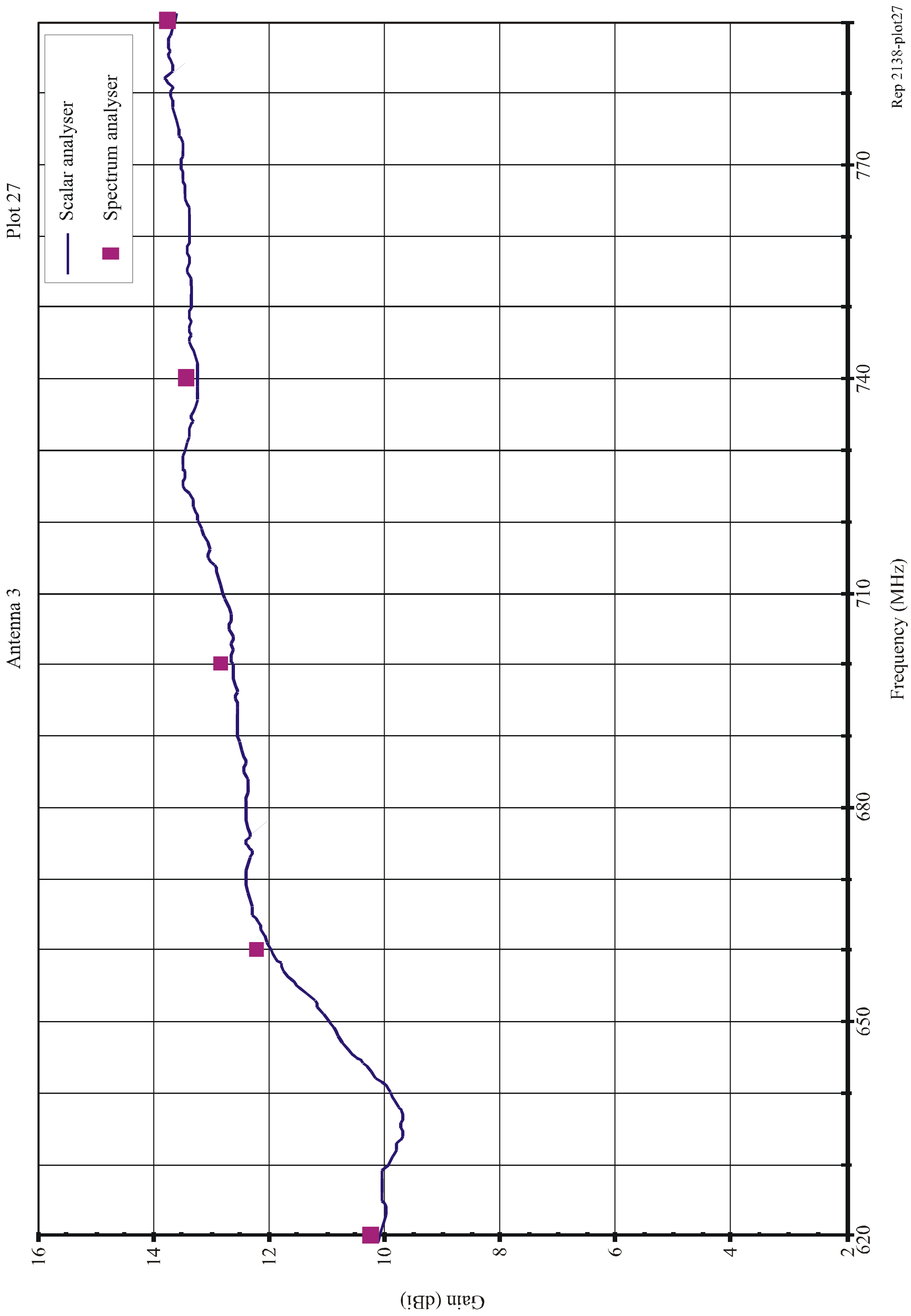

Plot 22
Antenna 11 at frequency 687 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
−10
−20
−30
−40
Angle (degrees)
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot22

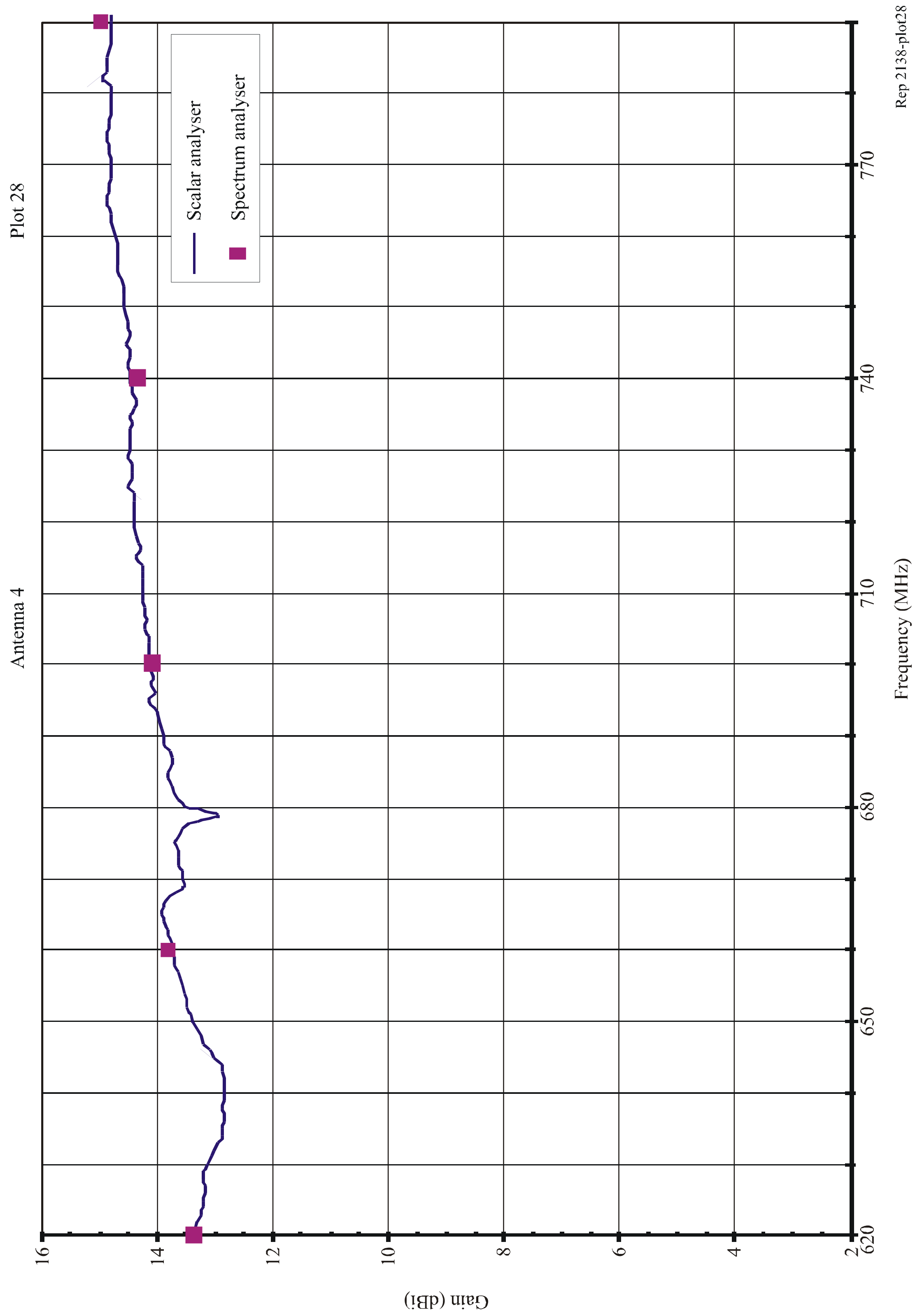

Plot 23
Antenna 12 at frequency 620 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
10
0
−10
−20
−30
−40
Angle (degrees)
−200
−150
−100
−50
0
50
100
150
200
Rep 2138-plot23

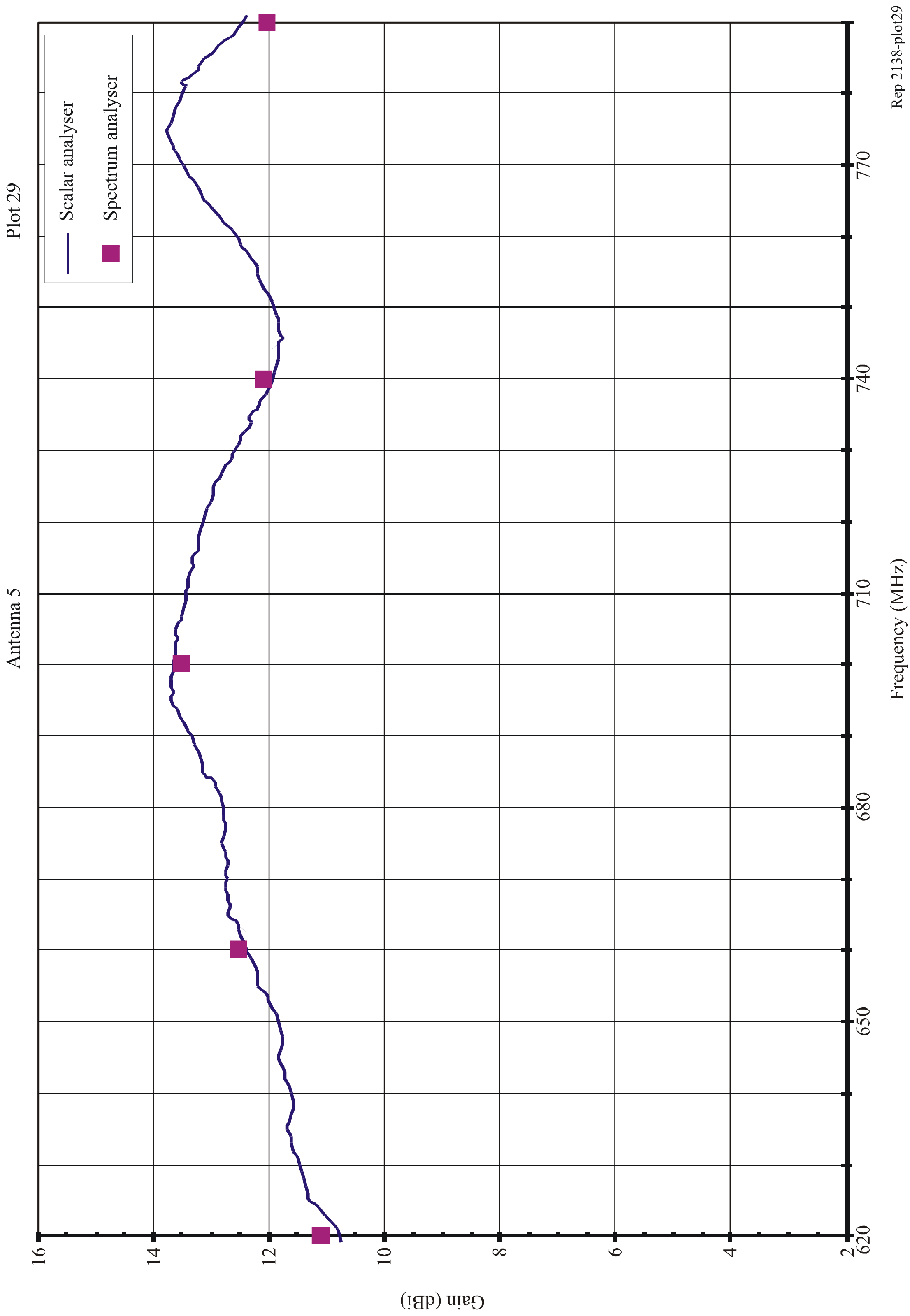

Plot 24
Antenna 12 at frequency 680 MHz
ITU Bands IV and V
0°
45°
90°
135°
Gain (dBi)
Angle (degrees)
Rep 2138-plot24

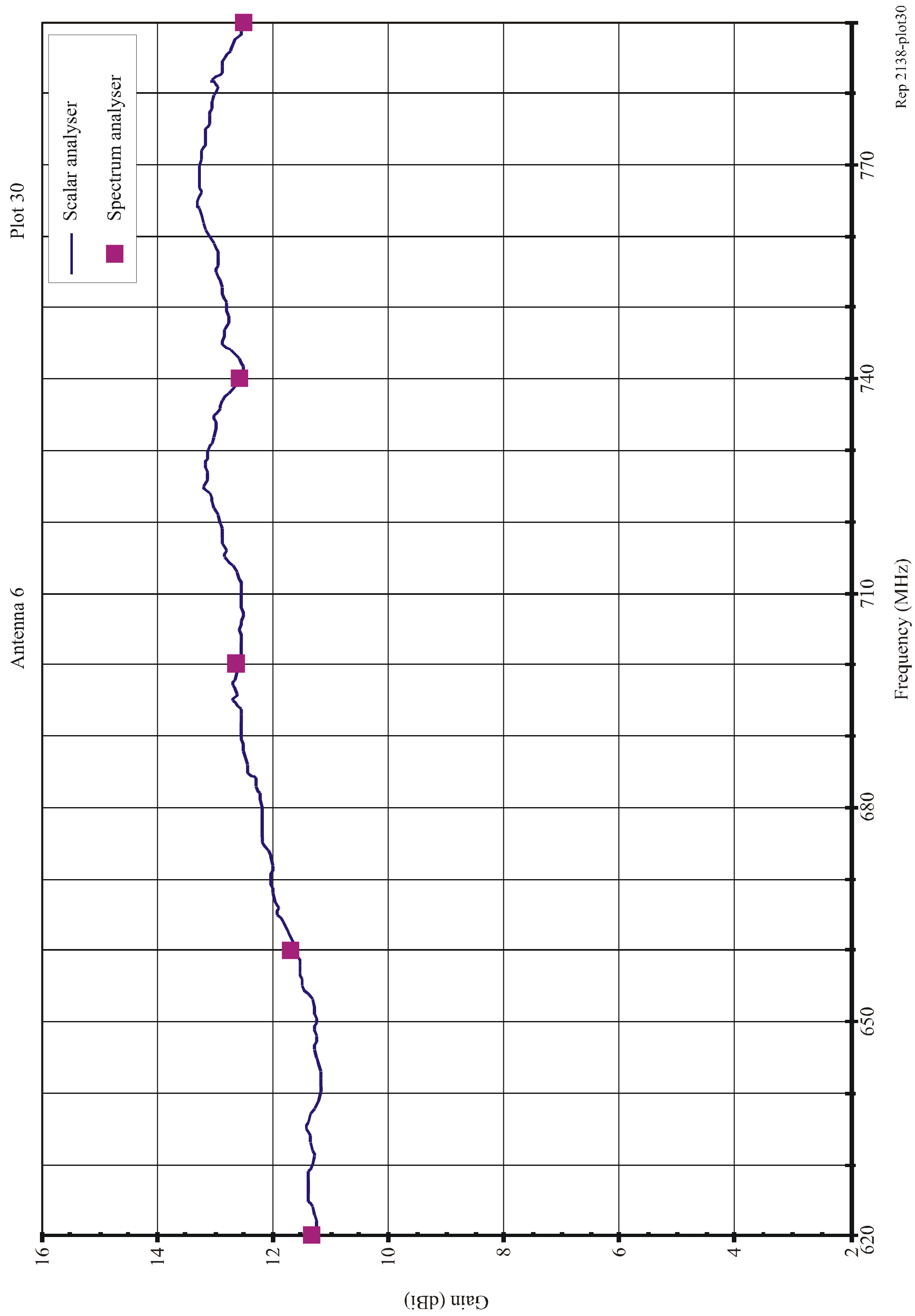

Plot 25
Antenna 1
Scalar analyser
Spectrum analyser
Gain (dBi)
16
14
12
10
8
6
4
2
Frequency (MHz)
620
650
680
710
740
770
Rep 2138-plot25

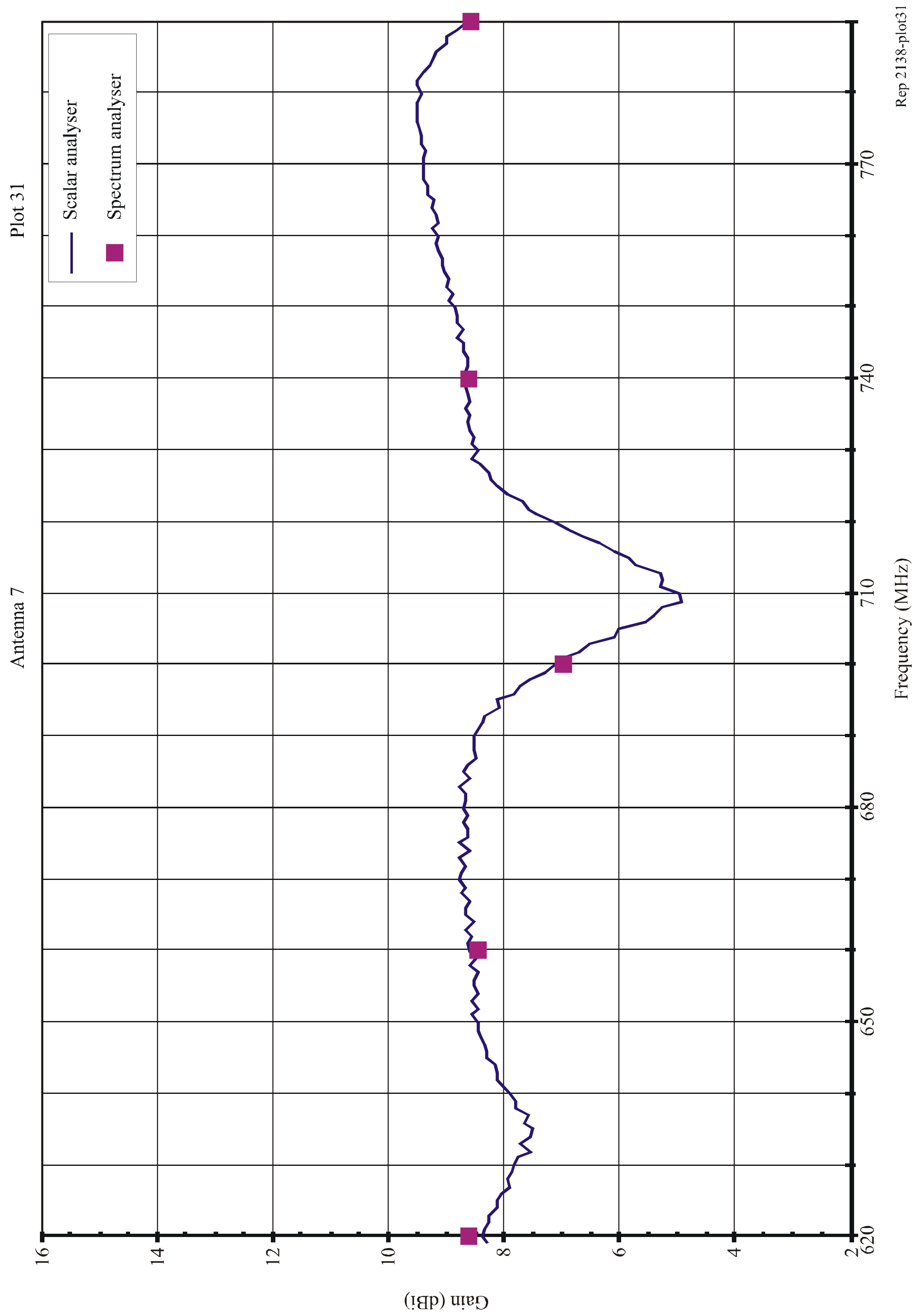

Plot 26
Antenna 2
Scalar analyser
Spectrum analyser
Gain (dBi)
16
14
12
10
8
6
4
2
Frequency (MHz)
620
650
680
710
740
770
Rep 2138-plot26

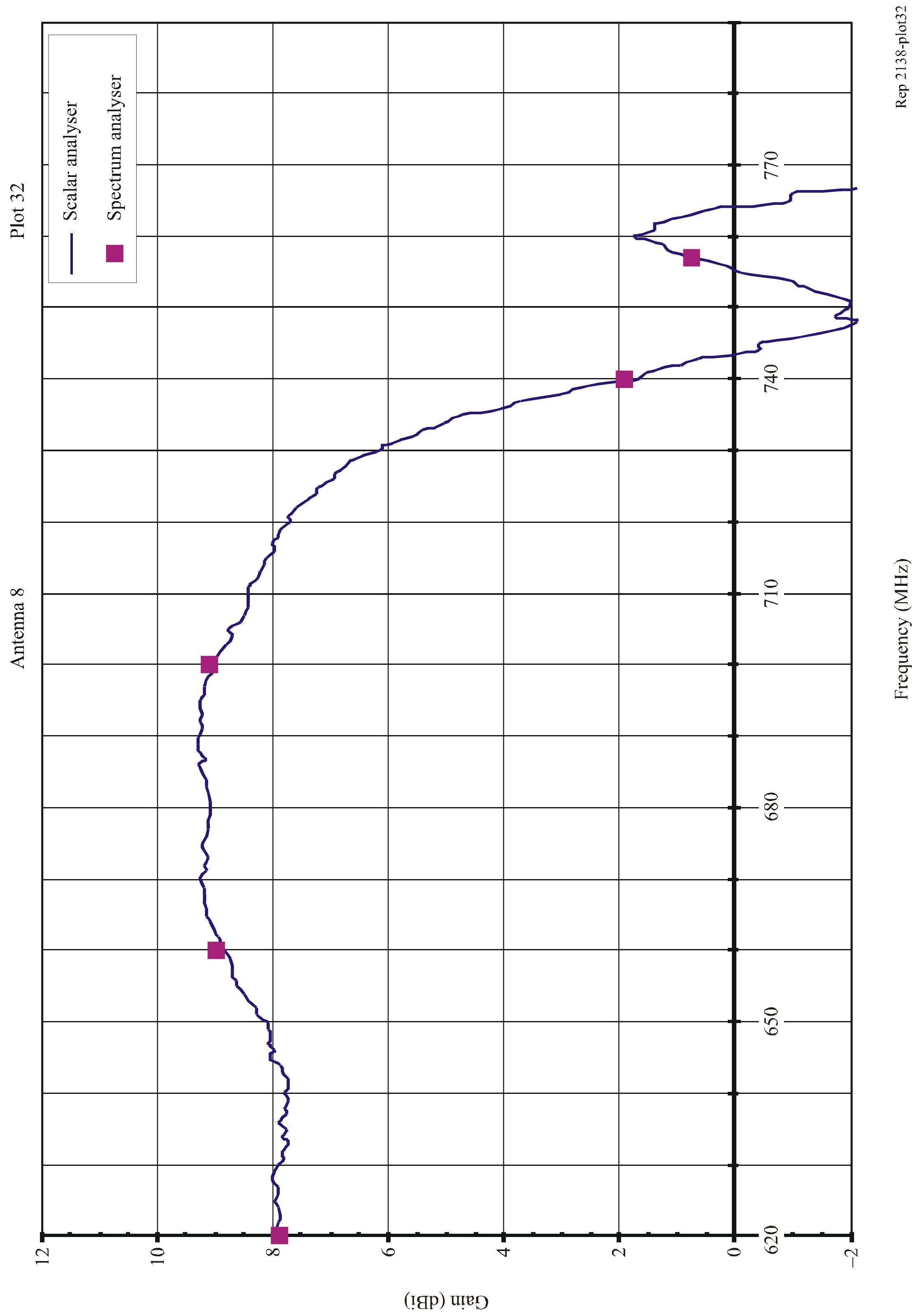

Antenna 3
Plot 27
Scalar analyser
Spectrum analyser
Gain (dBi)
16
14
12
10
8
6
4
2
Frequency (MHz)
620
650
680
710
740
770
Rep 2138-plot27

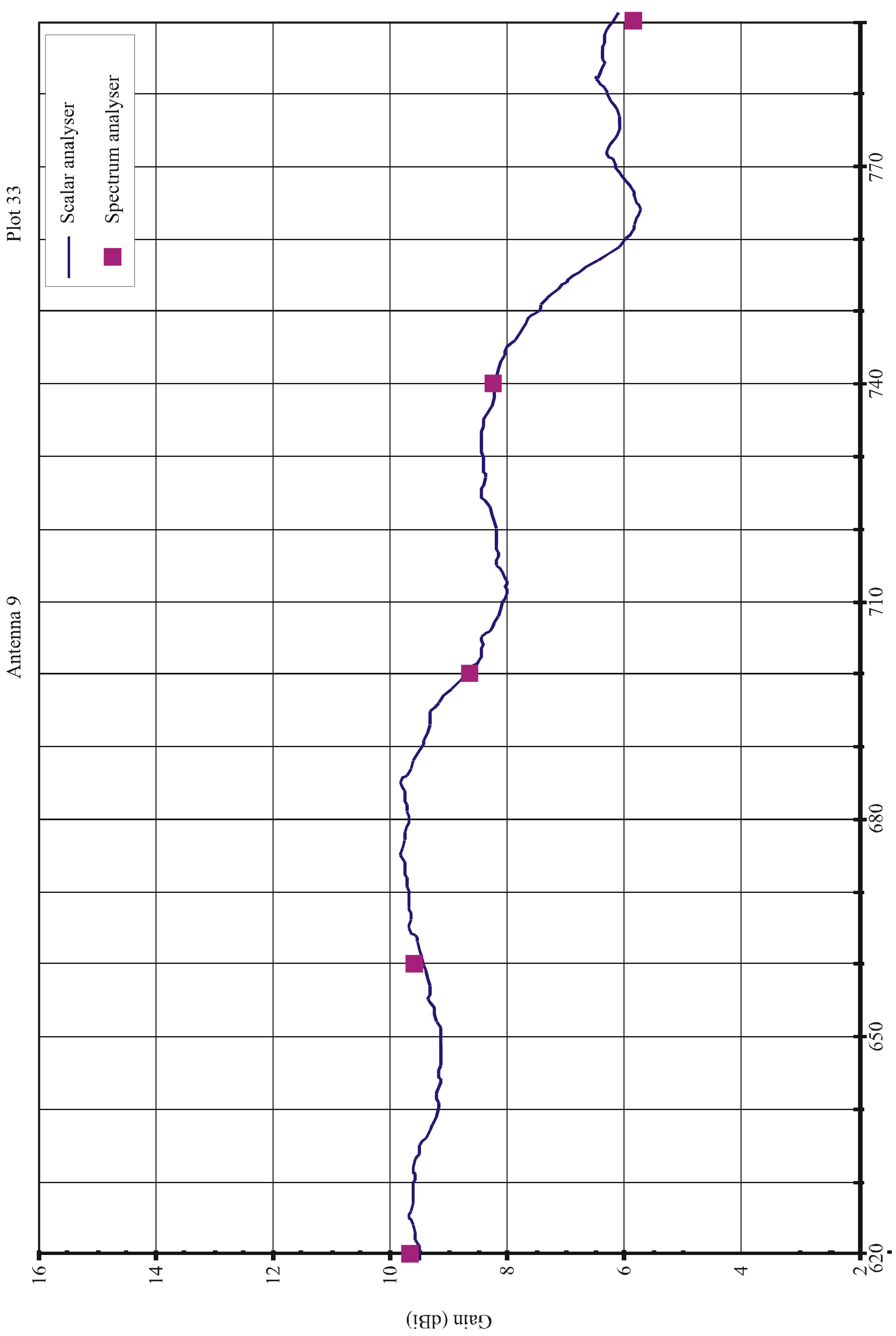

Antenna 4
Plot 28
Scalar analyser
Spectrum analyser
Gain (dBi)
16
14
12
10
8
6
4
2
Frequency (MHz)
620
650
680
710
740
770
Rep 2138-plot28


Antenna 5
Plot 29
Scalar analyser
Spectrum analyser
Gain (dBi)
16
14
12
10
8
6
4
2
Frequency (MHz)
620
650
680
710
740
770
Rep 2138-plot29

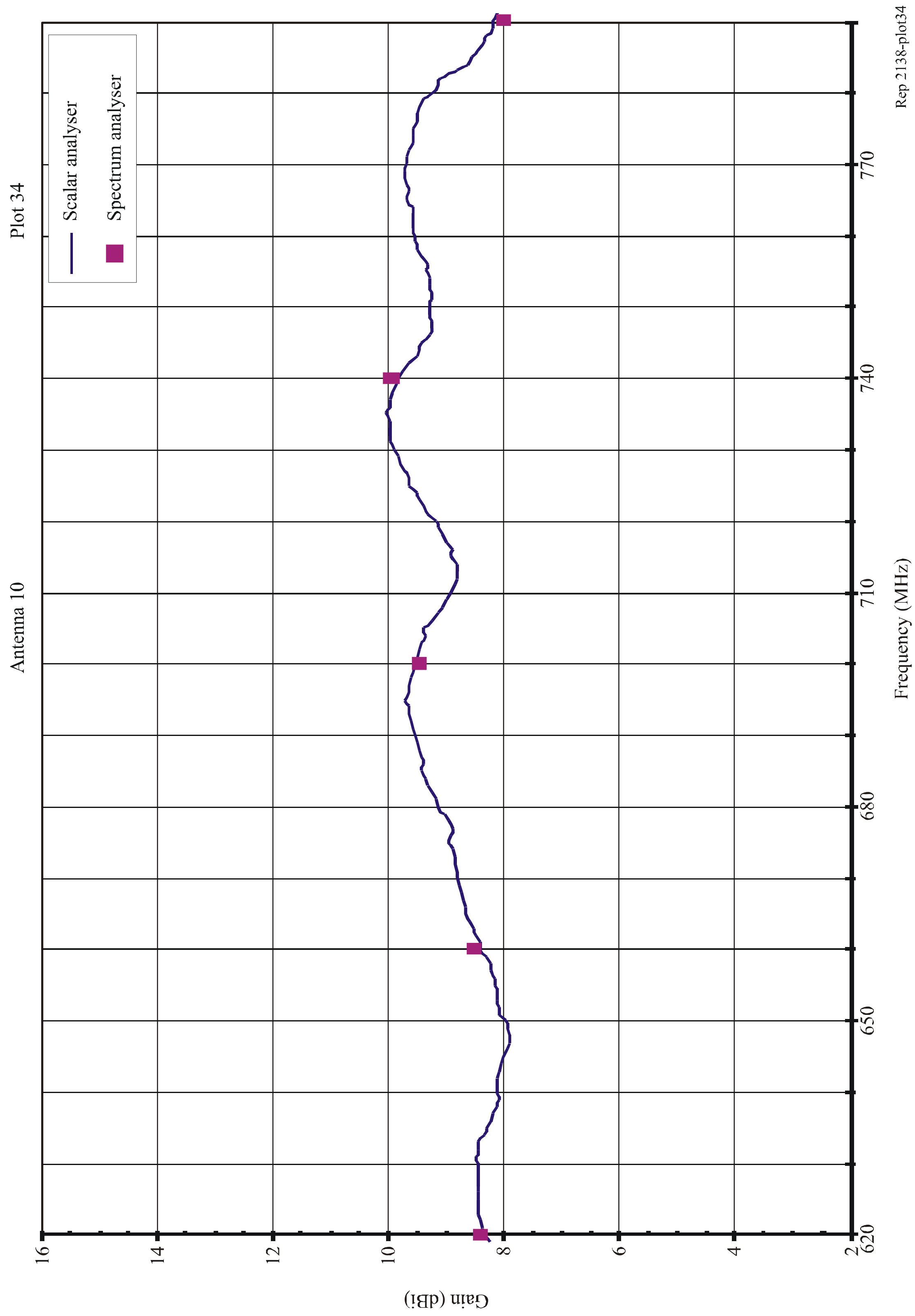

Antenna 6
Plot 30
Scalar analyser
Spectrum analyser
Gain (dBi)
16
14
12
10
8
6
4
2
620
650
680
710
740
770
Frequency (MHz)
Rep 2138-plot30

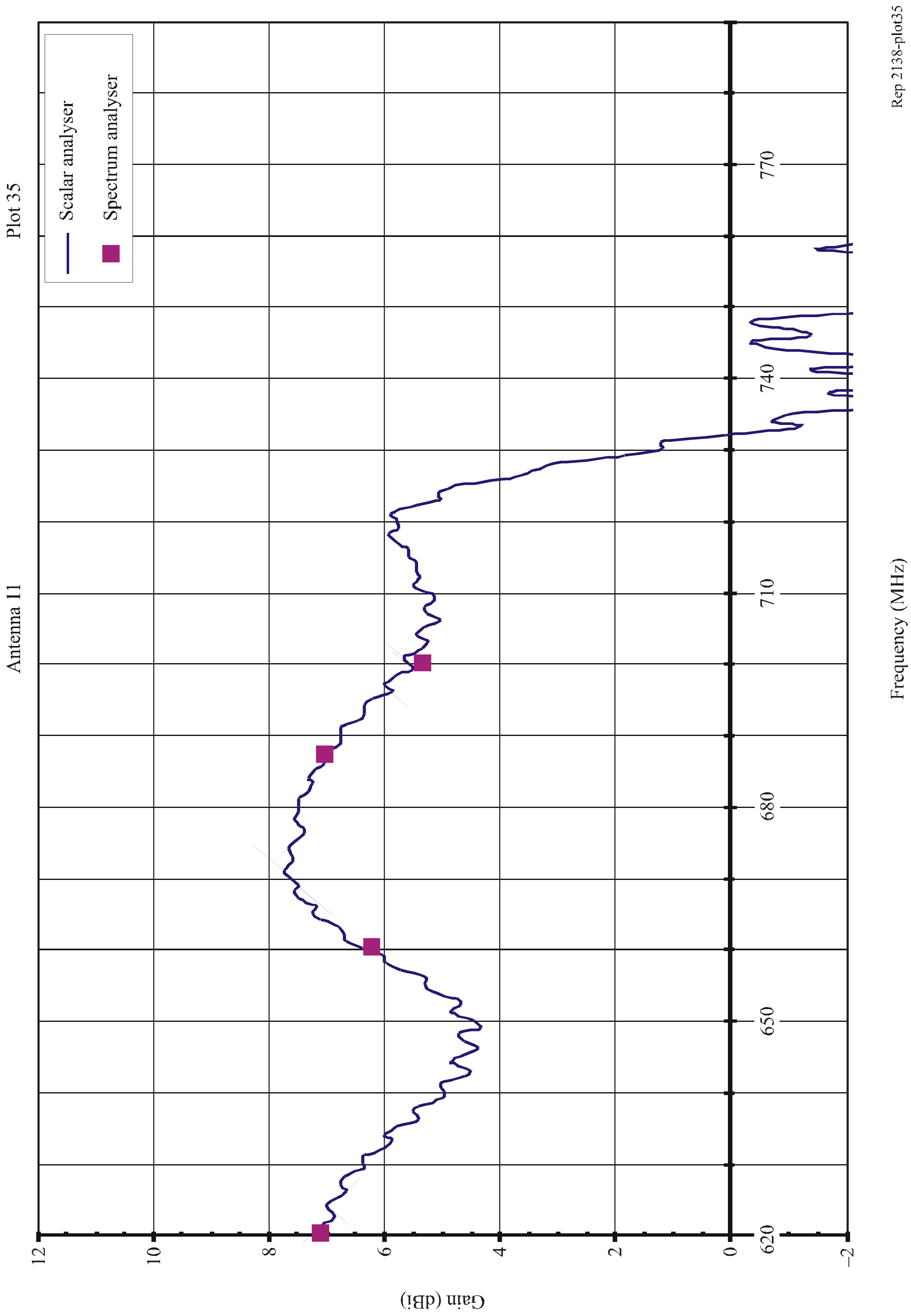

Plot 31
Antenna 7
Scalar analyser
Spectrum analyser
Gain (dBi)
16
14
12
10
8
6
4
2
Frequency (MHz)
620
650
680
710
740
770
Rep 2138-plot31

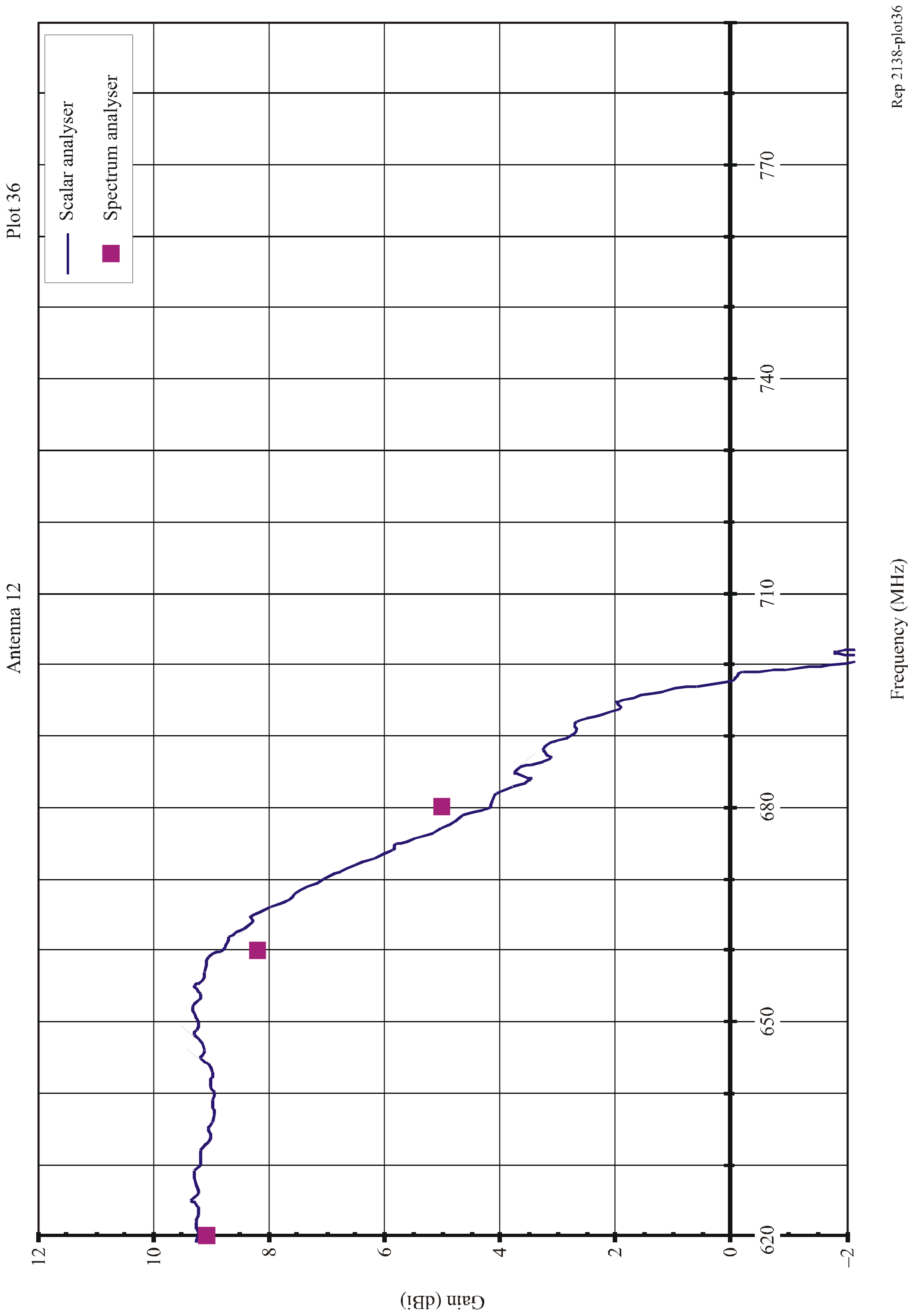

Antenna 8
Plot 32
Scalar analyser
Spectrum analyser
Gain (dBi)
12
10
8
6
4
2
0
–2
Frequency (MHz)
620
650
680
710
740
770
Rep 2138-plot32



Rep 2138-plot33


Antenna 10
Plot 34
Scalar analyser
Spectrum analyser
Gain (dBi)
16
14
12
10
8
6
4
2
620
650
680
710
740
770
Frequency (MHz)
Rep 2138-plot34


Plot 35
Antenna 11
Scalar analyser
Spectrum analyser
Gain (dBi)
12
10
8
6
4
2
0
–2
620
650
680
710
740
770
Frequency (MHz)
Rep 2138-plot35


Plot 36
Antenna 12
Scalar analyser
Spectrum analyser
Gain (dBi)
12
10
8
6
4
2
0
–2
Frequency (MHz)
620
650
680
710
740
770
Rep 2138-plot36

5 Comments

A number of aspects of the physical testing environment can have an effect on the measured radiation patterns. These include but are not limited to:

– range reflections differing with different polarization of the AUT;

– the proximity of the mounting and or offset bracket to the driven element; and

– the orientation of the AUT with respect to the mast on which it is supported, particularly when the E-field vector of the AUT is co-aligned with the metal mast such that the mast effectively becomes part of the antenna.

Part way through the measurement program it was observed that a certain AUT was susceptible to noise generated by the measurement rotator during a swept frequency measurement using a broadband detector. Turning off the motor eliminated the noise, so all further swept frequency measurements were conducted when the measurement rotator was turned off. No further investigation was conducted into why this antenna was affected by noise, as it was outside the scope of the measurement program. It does however raise the issue of noise and the potential need to investigate, and perhaps improve, the noise immunity of the antennas.

The measurement of low-frequency antennas with broad radiation patterns is a difficult problem. To minimize reflections into the test zone the research organization, CSIRO Australia, has tried to keep the distance between the range antenna and AUT to a minimum by measuring the on-axis ripple, keep the antennas as high as possible above the ground, and use as large a range antenna as practicable, i.e. a directive antenna. Nevertheless residual reflections can affect the measured patterns, where for example a −45 dB reflection can produce a 1 dB measurement error for a signal −20 dB down from the peak. This is not thought to be a problem at the near in azimuth angles as the range length is short and precludes reflections from surrounding buildings, but at broader azimuth angles it is possible that residual reflections from buildings may influence the far-out side lobes.

6 Conclusions

Recommendation ITU-R BT.419-3 (1992) contains a mask for receiving antenna directivity that is to be used in the planning of terrestrial television services. This does not constitute a design specification for receiving antennas, but is an assumption about their directivity which affects the calculation of potential interference from other services into the broadcasting service.

The mask from Recommendation ITU-R BT.419 for Bands IV and V is shown overlaid on the measured patterns in Plots 1 to 24. Clearly a number of antennas fit well with the mask, where others do not due to their broader patterns and lower gain, particularly at the lower measurement frequency. As only one antenna of each model was measured, it is unknown whether the measurement results reflect a broad cross-sectional sample of each antenna model.

If, however, these measured results are taken to be indicative of antennas already in service, then it should be considered whether the mask of Recommendation ITU-R BT.419 continues to be appropriate for terrestrial television planning, or whether a relaxed mask to accommodate broader, lower-gain antennas, should be proposed. A relaxation of Recommendation ITU-R BT.419 may impact on other services in the UHF bands, and this effect should be carefully considered.