CTS ATTENUATION AND CROSS POLARIZATION MEASUREMENTS AT 11.7 GHz

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Final Report Covering the Period 18 October 1976 to 31 January 1978
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I. INTRODUCTION

The nominally right hand circularly polarized 11.7 GHz beacon transmitter on the CTS satellite has been monitored at The University of Texas at Austin for the periods of its operation. A two channel receiver, using a turnstile junction as feed and polarization separator was built. Its polarization is adjusted to give better than 45 dB isolation between the channel measuring the co-polarized signal and the one measuring the cross-polarized signal during clear air propagation.

A previous report (Vogel and Straiton, 1977) described the receiver and summarized the data collected from 12 June 1976 to 30 August 1976. The beacon transmitter aboard CTS was deactivated to conserve power during the first eclipse period, starting 31 August 1976 until 17 October 1976. This report presents the data collected from 18 October 1976 to 31 January 1978.

The signal levels in both receiver bands were recorded for 471 days. Thus, the initial 80 days added, data have been obtained for a total of 551 days. The data were used to determine attenuation (to 25 dB) and cross-polarization isolation (below 35 dB).

II. RECEIVER DESCRIPTION

Only the pertinent characteristics of the receiver are given in Table I.

Vogel, W. J. and Straiton, A. W., 1977, "CTS Attenuation and Cross-polarization Measurements at 11.7 GHz," Final Report under Contract NAS5-22576 for 12 June 1976 - 30 August 1976.

TABLE I

Dual Polarization Receiver Characteristics

Antenna:	3m parabola, prime focus feed, f/D = .375, program pointing to .02°, elevation = 49°.
Feed:	turnstile polarizer
Polarization:	RHC, LHC (nominally), matched by adjusting for minimum power in cross-polar channel during clear-air propagation.
Isolation:	better than 45 dB with optimum pointing
Fade Margin:	30 dB for co-polarized channel 45 dB for cross-polarized channel
Calibration:	Precision attenuated 11.7 GHz signal injected into front end.
Output:	logarithmic amplitudes, recorded on strip chart.

III. METEOROLOGY OF AUSTIN

A. Thunderstorm Climatology for Central Texas

Information on thunderstorms in Central Texas is summarized in Table II. The frequency of occurrence is based on a thirty year mean as published by the weather bureau. May and August have the highest observed mean frequencies (though the standard deviation is very large). An average total of 41 thunderstorms occur annually. The height of the tops of the thunderstorm clouds shows a slight bimodal tendency. Also given are the translational speed of the individual rain cells and their

Table II

Mean Values of Thunderstorm Parameters

For Central Texas by Month of Year

Month	Frequency of Occurrence	Height of Cloud Tops km	Cell Speed (km/hr)	Direction of Movement (degrees)
Jan	1	8.5	46	240
Feb	2	9.1	56	250
Mar	3	11.6	65	270
Apr	5	12.2	56	250
May	7	12.8	46	240
Jun	4	10.7	37	180
July	4	9.8	28	170
Aug	5	9.8	28	150
Sept	4	12.2	46	230
Oct	3	11.6	46	230
Nov	2	9.1	46	240
Dec	1	8.5	46	240

direction of movement (clockwise direction from true north from which the cell is moving). It should be pointed out that when the showers are arranged in a line (a squall line) as they frequently are in the spring (March through May) the line usually moves from 300° to 310° (i. e. from the northwest). The individual shower cells within the line, however, move in the direction as indicated in the Table. The direction of movement of individual cells has a strong southwesterly to westerly component most of the year, except in the summer time when cells move from south (June) to southeast (August).

B. Meteorology for 18 October 1976 to 31 January 1978

Precipitation occurred in the form of liquid water only. Table III summarizes the obtained rain data. Given are the 40 year average quantities and the amounts recorded during this period. Under A. are listed the official weather bureau data based on measuring the accumulated liquid captured by a standard 20 cm gage. Column B was obtained by a 7 cm gage with 2.5 mm tip interval, located 70 m from the receiver and the data in column C are from a standard 20 cm tipping bucket gage, derived by counting its tips. (.25 mm liquid per tip). This gage is located at the receiver site.

Some discrepancy exists between the amounts measured with the three gages. The weather bureau station is located several miles from the receiver and one would expect only a rough agreement between the rain measured there and at the receiver. Monthly variations of column A with

Table III

Rain Measured in Austin During the Reporting Period.
All quantities in mm.

Month	40 year Mean	1976			1977			1978		
		A	B	C	A	B	C	A	B	C
Jan	52				57	51	42	22	30	19
Feb	62				66	64	53			
Mar	56				55	51	40			
Apr	90				154	183	144			
May	108				31	41	37			
Jun	72				31	25	25			
Jul	56				5	5	5			
Aug	57				2	0	0			
Sep	92				79	69	61			
Oct	80	94	84	75	30	64	53			
Nov	60	45	28	37	43	64	62			
Dec	63	63	56	49	9	8	6			
Annual	848				562	625	528			

respect to column B are of the order of 10 to 20 percent. The 1977 annual total at B exceeds A by 11%. Gage C, even though located very close to B totalled 6% less rainfall than A in 1977.

By dripping water into gage C it was found that at a rate of 20 mm/hr it underestimates the precipitation by 3% and at a rate of 100 mm/hr by 12%. In addition to this error introduced by the dynamic behavior of the gage, its placement on top of a building near the roof edge may have resulted in a reduced capture efficiency due to air turbulence. (The gage subsequently was moved further away from the roof edge.)

During the reporting period a total of 28 thundershowers were recorded by the Austin Weather Bureau, as compared to a long term average of 46 for the 15.4 months covered. These data are shown in Table IV. The number of thunderstorms and the total rain were reduced by about the same ratio as one can see if the reporting period numbers are compared to their long term averages.

The fraction of time the rainrate exceeded values between 0 and 50 mm/hr is shown in Fig. 1 for this time period.

IV. RESULTS OF THE ATTENUATION AND CROSS-POLARIZATION ISOLATION MEASUREMENTS

The chart records were digitized at one minute intervals for all periods of data events. These are defined by either the attenuation exceeding 1 dB or the cross-polarization isolation being reduced below 35 dB. Since the values recorded are the power levels in the co- and cross-polarized

Table IV

Number of Thunderstorms in Austin During Reporting Period

Month	1976	1977	1978
Jan		1	0
Feb		1	
Mar		3	
Apr		5	
May		3	
Jun		1	
Jul		0	
Aug		1	
Sep		7	
Oct	0	4	
Nov	1	1	
Dec	0	0	

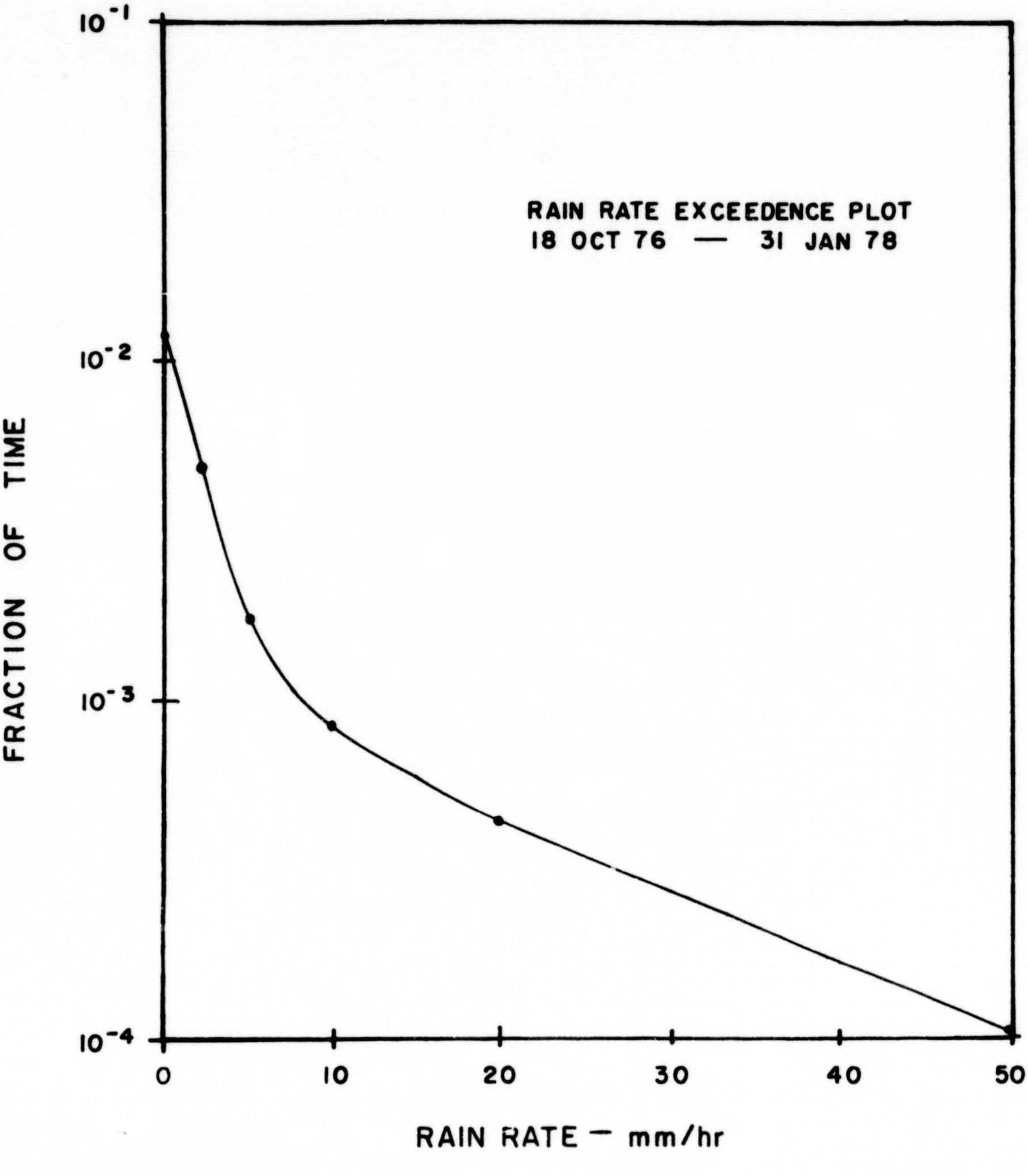

Figure 1 Rain Rate Exceedence Plot for the Period 18 Oct 76 - 31 Jan 78

channels, the desired quantities, attenuation and isolation have to be derived. The relations are

Attenuation (dB) = clear air power (dBm) in co-polarized channel - power (dBm) in co-polarized channel

and

cross-polarized isolation (dB) = power (dBm) in co-polarized channel - power (dBm) in cross-polarized channel.

Logarithmic curve fits were made between the cross-polarization isolation (CPI) in dB and the attenuation (A) in dB. They are of the general form

$$\text{CPI} = a + b \log A$$

The coefficient of determination r^2 expresses the scatter of the points about the curve and has also been calculated. An r^2 of 1 means that all points fall on the curve and an $r^2 = 0$ means that the points were randomly distributed in the CPI - A plane. The fits were made for each month for all periods for which the attenuation was equal to or exceeded 5 dB. This value was chosen to eliminate ice depolarization events. Table V summarizes the results of the fitting.

The result is quite ambiguous. There are months when the logarithmic relationship holds reasonably true, but not with the same coefficients from month to month. There are also months for which the fit is not good at all. No clear seasonal dependence is indicated. The reason for this seems to be the variability of the parameters of rain which produce polarization effects, i.e. drop shape and canting angle distributions. Their statistics

Table V

Logarithmic Fit for CPI vs. A: $CPI = a + b \log A$ while $A \geq 5$ dB

Month	# of points (minutes)	a	b	r^2
Oct 76	3	53.6	-31.6	.89
Nov	0			
Dec	4	20.5	18.2	.42
Jan 77	40	42.4	-18.5	.67
Feb	0			
Mar	7	21	7.5	.05
Apr	37	44.6	-22.7	.89
May	21	45.8	-22.0	.75
Jun	9	50.1	-29.3	.66
Jul	0			
Aug	12	41.6	-20.0	.89
Sep	71	*		
Oct	48	42.1	-20.0	.62
Nov	12	61.9	-50.6	.75
Dec	0			
Jan 78	11	50.6	-28.5	.80

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*The cross polarization receiver failed during the two storms that produced essentially all of the rainfall of September 1977, consequently no isolation data were obtained for that month.

are different for different rain events, making it impossible to formulate a universal deterministic relationship between CPI and A. Fortunately such a relationship is not really required by designers of satellite communication systems. For their purpose a furmula which relates CPI and A on a statistical basis is much more useful. That type of relationship can be derived from the "exceedence plots" for attenuation and isolation.

Figure 2 gives the fraction of time for the reporting period (18 Oct 76 - 31 Jan 78) and Fig. 3 for the 551 observation days following 12 June 1976 until 31 January 1978 during which the attenuation exceeded and the isolation was reduced below the abscissa. Since the cross polarization receiver had a failure during the storms that produced esentially the entire September 1977 data, a second curve for the attenuation exceedence, with the month of September 1977 deleted, has been drawn in Fig. 3. This curve and the one labelled CPI are used to derive the equal probability relationship between CPE and A. They represent all simultaneous attenuation and isolation data gathered. The equal probability CPI-A pairs have been drawn up in Fig. 4. They lie very closely to the line

$$\text{CPI} = 41 - 20.6 \log A$$

with a coefficient of determination of .99. The relationship between CPI and A recommended by the CCIR is

$$\text{CPI} = 30 - 20 \log A$$

and has been added to Fig. 4. The slope is in very close agreement but the CCIR curve is more conservative from a design viewpoint. It overestimates

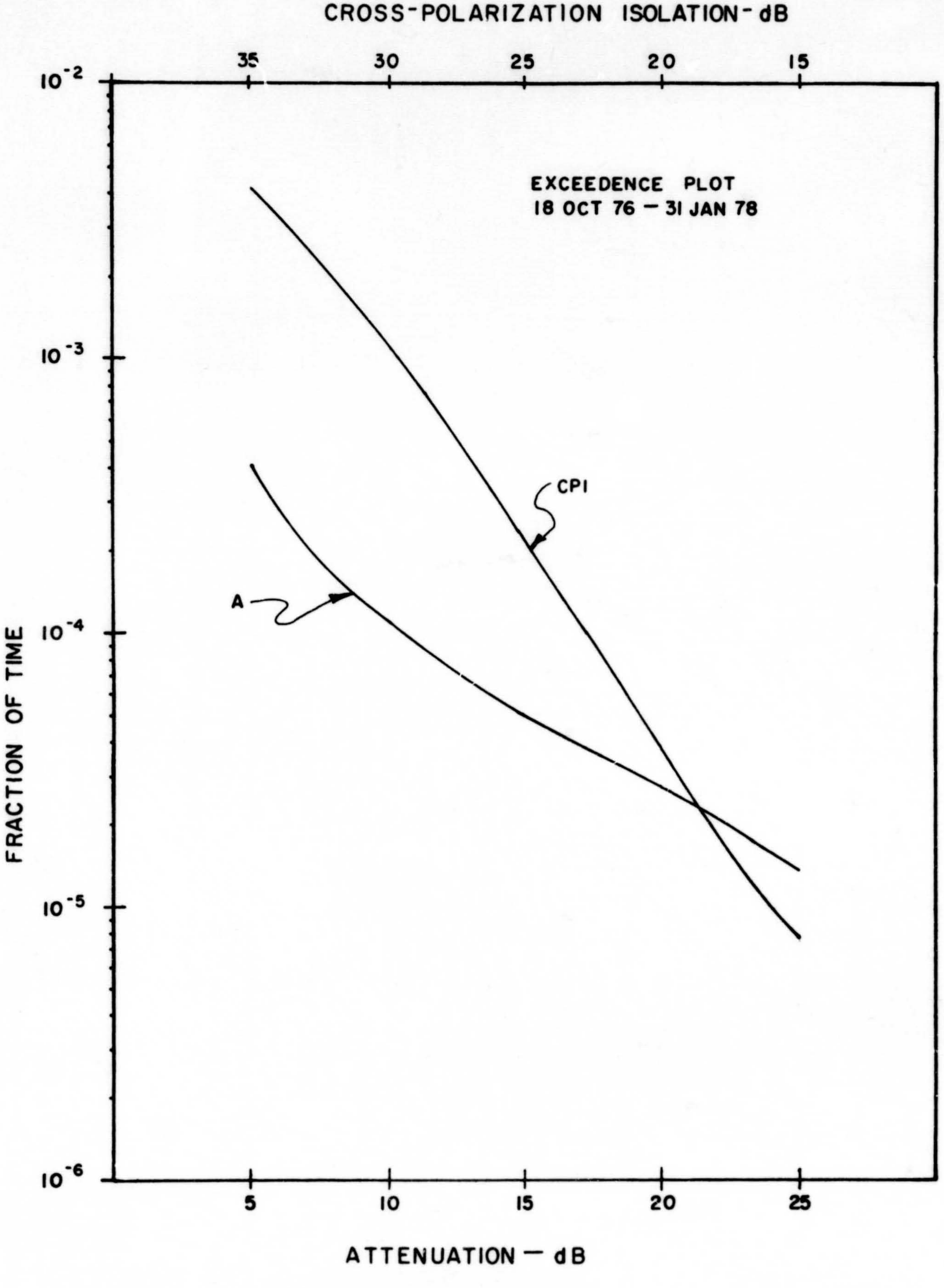

Figure 2 Attenuation and Cross-polarization Exceedence Plot for the Period 18 Oct 76 - 31 Jan 78

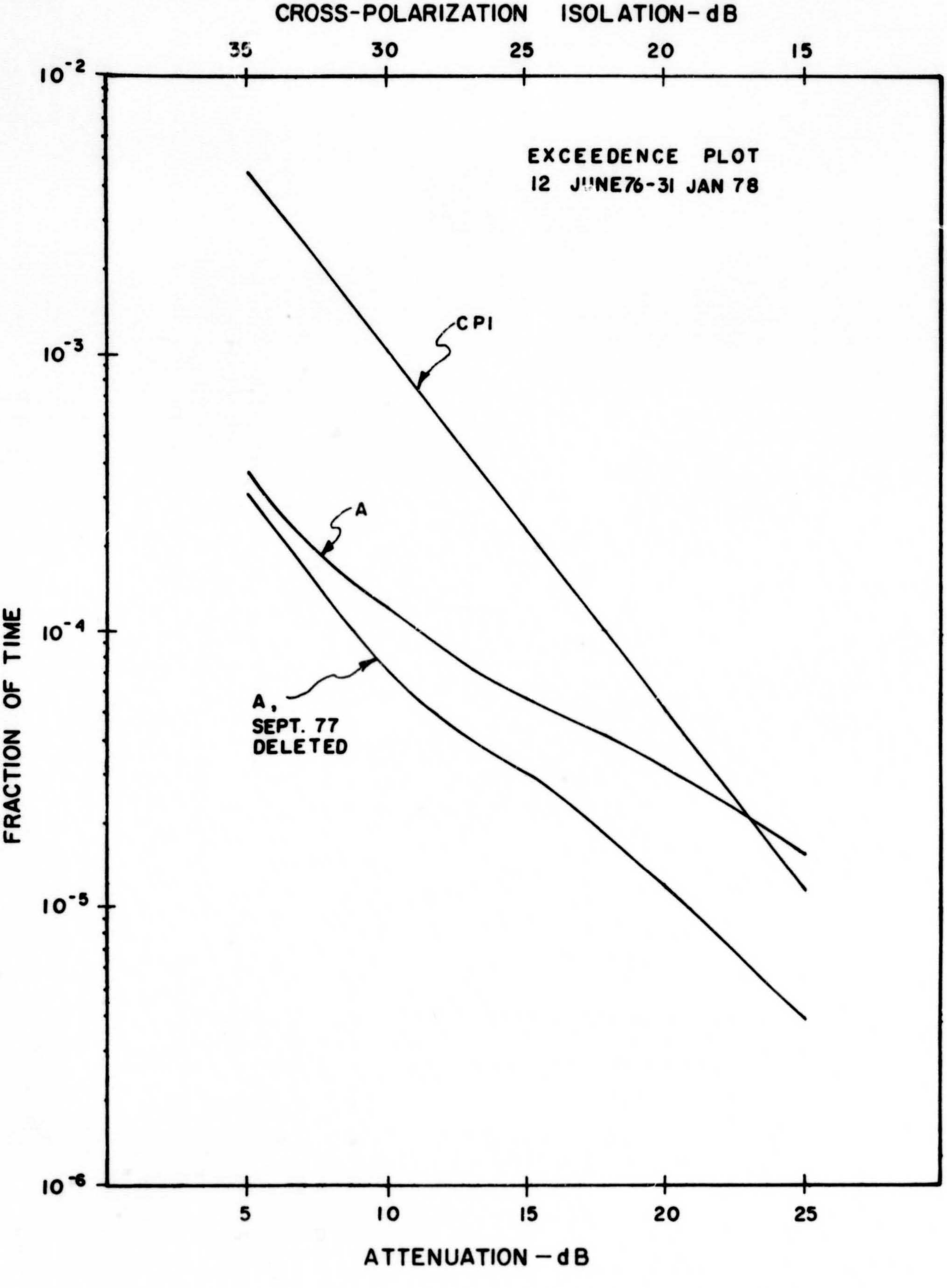

Figure 3 Attenuation and Cross-polarization Exceedence Plot for the Period 12 June 76 - 31 Jan 78

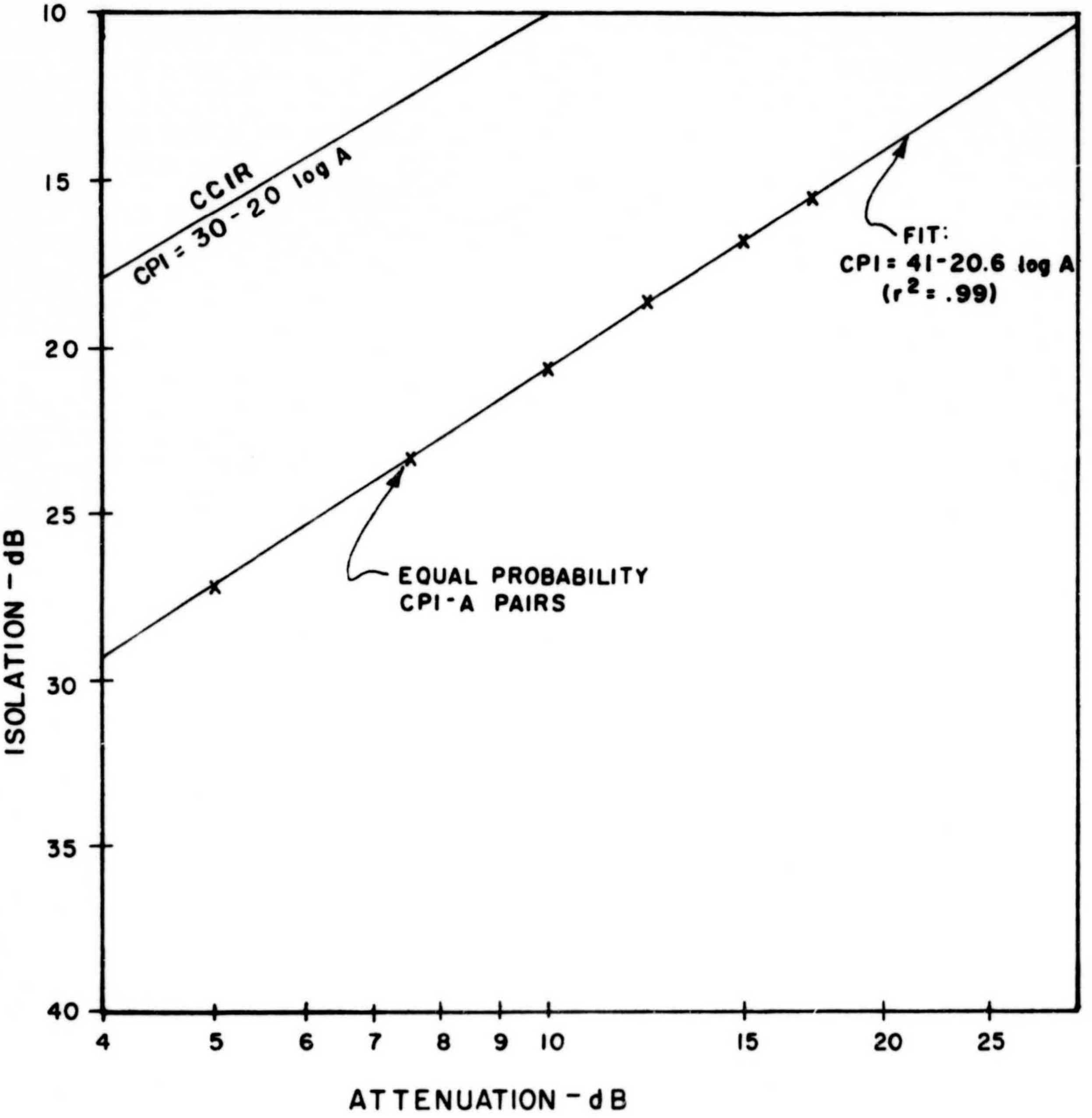

Figure 4 Equal Probability Fit for all CPI-A Pairs

the isolation degradation by 11 dB.

A portion of all depolarization events was distinguished by the absence of simultaneous fading. This type of depolarization has been linked to the presence of ice crystals in the propagation path. While such ice crystals absorb very little electromagnetic energy, they do scatter it (mostly in the forward direction) and because of their asymetrical shapes introduce a phase shift which depends on the polarization of the wave. In general, the output polarization of such a medium will be different from the transmitted input polarization, i.e. cross polarization isolation between orthogonally polarized transmitted waves will have been reduced.

To assess the importance of phase events from a system design viewpoint, the percentage of time during which the isolation was reduced below these values was determined. These results are given in Table V. Ice depolarization events observed in Austin were associated either with thunderstorms during the summer months or with clouds in the presence of polar airmasses during the winter. The averages given in Table V have also been plotted in Fig. 5.

V. CONCLUSIONS

Attenuation and cross polarization isolation have been measured for circular polarization at 11.7 GHz. While a one to one relationship between the two quantities cannot be supported by the data, their cumulative probability equates lead to a dependence of

$$\mathrm{CPI} = 41 - 20.6 \log A.$$

Table V

Percentage of Time the Loss of Isolation was not Coincident with Fades greater than 1 dB.

	Isolation (dB) below)		
Month	35	30	25
Nov 76	78	56	62
Dec	51	0	0
Jan 77	60	3	0
Feb	84	100	0
Mar	63	11	0
Apr	59	43	10
May	6	0	0
June	31	0	0
Jul	0	0	0
Aug	0	0	0
Oct	11	21	8
Nov	41	35	22
Dec	0	0	0
Jan 78	37	29	0
Average (Nov 76 - Jan 78)	51	27	15
Average (12 June 76- 31 Jan 78)	47	24	11

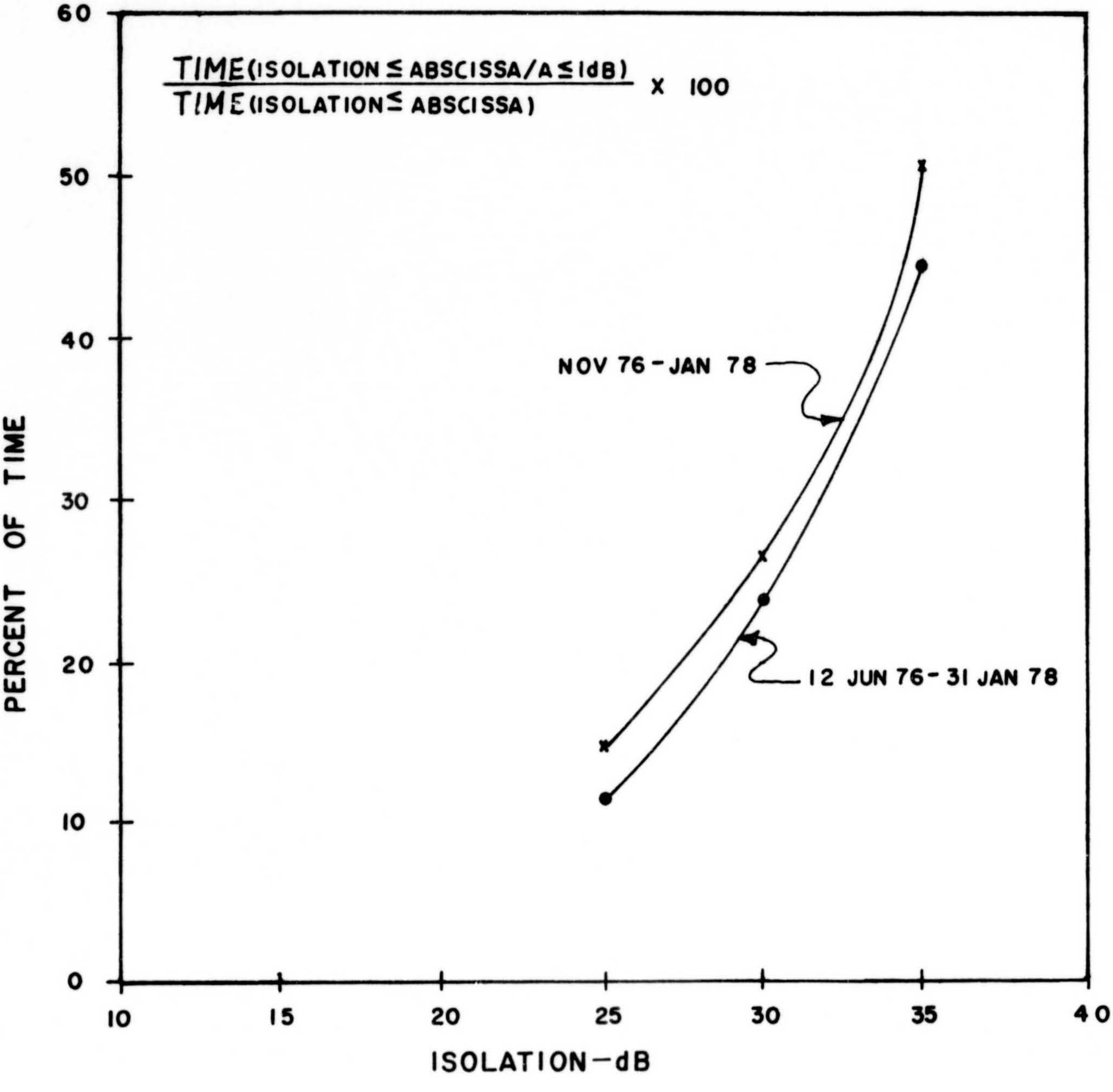

Figure 5 The Percentage with which Ice Depolarization Contributed to the Total Depolarization Events

Whether ice depolarization is of a major system design important depends very much on the level of isolation required. At 35 dB isolation 50% and at 25 dB isolation 15% of the depolarization events were due to this effect.