# Communications Research Centre

# REPORT ON THE GREAT LAKES PROPAGATION MEASUREMENT PROGRAM: COMPARISONS OF THE CANADIAN DATA WITH THE PREDICTIONS OF FCC R-6602


by

F.H. PALMER





CRC REPORT NO. 1332

Department of Communications
Ministère des Communications





OTTAWA, FEBRUARY 1980

COMMUNICATIONS RESEARCH CENTRE

DEPARTMENT OF COMMUNICATIONS
CANADA

# REPORT ON THE GREAT LAKES PROPAGATION MEASUREMENT PROGRAM: COMPARISONS OF THE CANADIAN DATA WITH THE PREDICTIONS OF FCC R-6602

by

F.H. Palmer

*(Radio and Radar Research Branch)*



CRC REPORT NO. 1332

*February 1980*
OTTAWA

## TABLE OF CONTENTS

# EXECUTIVE SUMMARY

DOCUMENT NO: CRC Report No. 1332

TITLE: Report on the Great Lakes Propagation Measurement Program: Comparisons of the Canadian Data with the Predictions of FCC R-6602

AUTHOR(S): F.H. Palmer

DATE: February 1980

In July of 1976 the Canadian Department of Communications (DOC) and the U.S. Federal Communications Commission (FCC) agreed on the establishment of a joint working group to investigate various aspects of bilateral coordination. It was found that there was insufficient propagation data to determine reliably either the interference levels that would be encountered, or the applicability of the existing FCC R-6602 propagation curves, in the region of the Great Lakes. Accordingly, CRC was asked by the working group to conduct a joint study with the FCC to assess, and if possible resolve, the propagation issues involved.

This report details that portion of the joint study for which CRC was responsible, and presents empirical expressions which relate the signal strengths predicted by R-6602 to those actually observed.

The findings presented in this report may be used, in the Great Lakes area, to assist in the regulation and allocation of the VHF and UHF parts of the radio spectrum and in the coordination of such spectrum usage with the United States. The results will also assist users in the private sector in the design of VHF/UHF systems operating in the same area.

Until appropriate measurement programs have been carried out, this report may be used as a qualitative guide to the behaviour of signal strength statistics expected in other parts of the country.

# REPORT ON THE GREAT LAKES PROPAGATION MEASUREMENT PROGRAM: COMPARISONS OF THE CANADIAN DATA WITH THE PREDICTIONS OF FCC R-6602

by

F.H. Palmer

## ABSTRACT

*In July of 1976 the Canadian Department of Communications (DOC) and the U.S. Federal Communications Commission (FCC) agreed on the establishment of a joint working group to investigate various aspects of bilateral coordination. It was found that there was insufficient propagation data to determine reliably either the interference levels that would be encountered, or the applicability of the existing FCC R-6602 propagation curves, in the region of the Great Lakes. Accordingly, it was decided to conduct a joint study to assess, and if possible resolve, the propagation issues. This report details that portion of the joint study for which DOC was responsible. Attention is confined to comparisons of observed field strengths in the Great Lakes area with those predicted by R-6602, and to an interpretation of the differences in terms of various paths and systems parameters. It is shown that, while the R-6602 curves accurately predict the long term (annual average) values of F(50,50) and F(50,10), they do not take into account observed diurnal and seasonal variations of signal strengths of up to about 30 dB. Qualitatively, signal strengths over all paths are found to be higher at night than during the day and higher in summer than in winter. Empirical expressions are presented which relate the signal strengths predicted by R-6602 to those actually observed, and which take into account time of day, day of year, path length, and percentage of propagation path covered by water.*

## 1. INTRODUCTION

### 1.1 BACKGROUND

In July of 1976 the Canadian Department of Communications (DOC) and the U.S. Federal Communications Commission (FCC) agreed on the establishment of a joint working group to investigate various

# SOMMAIRE À L'INTENTION DE LA DIRECTION

N° DU DOCUMENT: Rapport du CRC N° 1332

TITRE: Rapport sur le programme de mesure de la propagation dans la région des grands lacs: Comparaison entre les données canadiennes et les prévisions contenues dans le rapport N° 6602 de la FCC

AUTEUR(S): F.H. Palmer

DATE: Février

En juillet 1976, le ministère des Communications du Canada (MDC) et la Federal Communications Commission des États-Unis (FCC) ont convenue de mettre sur pied un groupe de travail mixte chargé d'examiner diverses questions de coordination bilatérale. Il a été constaté que les données existantes sur la propagation n'étaient pas suffisantes pour déterminer avec certitude les niveaux de brouillage qui se manifesterainet, ni la pertinence des courbes de propagation indiquées dans le rapport n° 6602 de la FCC, en ce qui concerne la région des Grands lacs. En conséquence, ce groupe de travail a demandé au C.R.C. de collaborer avec la FCC à la réalisation d'une étude conjointe visant à évaluer, et dans la mesure du possible à résoudre, les problèmes de propagation qui se posaient.

Le présent rapport expose en détail la partie de l'étude conjointe qui relevait du C.R.C. et présente des modèles empiriques comparant les intensités de signaux prévues dans le rapport no° 6602 à celles qui ont été observées.

Les conclusions de ce rapport pourront servir, dans la région des Grands lacs, d'instrument pour la réglementation et l'assignation des bandes VHF et UHF de spectre radioélectrique et d'outil de coordination de l'utilisation de ces fréquences avec les États-Unis. Les résultats aideront également les usagers du secteur privé à concevoir les systèmes VHF—UHF qui seront exploités dans cette région.

D'ici à ce que des programmes de mesure convenables soient exécutés, le rapport n° 1332 du C.R.C. peut servir de guide qualitatif en ce qui concerne les courbes statistiques sur l'intensité des signaux à prévoir dans d'autres parties du pays.

aspects of bilateral coordination. At the first meeting of the working group in Washington on 8–9 September, 1976, a U.S. proposal for an "Interim Technical Standard for Licencing 900 MHz Private Land Mobile Stations in Border Zones" (1) was considered. The propagation studies on which this proposed Interim Technical Standard was based are described in FCC Report R-6602 (2). Unfortunately, the interference curves contained in this report could not be checked against any comparable Canadian data, since long-term measurements of field-strengths over appropriate paths had not been carried out in Canada. As a result, it was agreed at the September meeting that pending an exchange of pertinent data on various propagation problems, particularly ducting, an additional 10 dB protection above that shown in the proposed technical standard would be afforded to Canadian broadcast services in border areas.

A review of the propagation issues was conducted in preparation for the second meeting of the working group, held in Ottawa on 12–13 October, 1976. It was found that there was not sufficient data pertinent to propagation, particularly in the region of the Great Lakes, to determine reliably the interference levels that would be encountered. Accordingly, it was decided to conduct a joint study, beginning in the spring of 1977, to assess, and if possible resolve, the propagation issues so that the interim working arrangement could be finalized. The terms of reference for this joint study were considered and agreed upon at a further meeting of the working group that took place in Washington on 17–18 November, 1976. These terms of reference are included here as Appendix A.

Subsequently, by an exchange of letters between the Deputy Minister of the Department of Communications and the Chairman of the Federal Communications Commission an interim arrangement came into force in January 1977.

This document details that portion of the joint study for which the Department of Communications was responsible. Attention is confined to comparisons of observed field strengths with those predicted by R-6602, and to an interpretation of the differences in terms of various path and system parameters. Aspects of the data not directly related to the R-6602 intercomparisons will be the subject of a future report.

### 1.2 THE FCC REPORT R-6602

This reports presents a series of nomograms which give received field strength, F, (in dB above one microvolt per metre per kilowatt of radiated power) as a function of transmitting antenna height. Separate curves are given on each nomogram for a variety of path lengths ranging from one mile to 200 miles. The receiving antenna is assumed to be at a height of 30 feet. There are two types of nomograms. One gives received field strengths exceeded at 50 percent of possible receiving locations and also exceeded for 50 percent of the time; the other gives received field strengths exceeded at 50 percent of possible receiving locations and exceeded for 10 percent of the time. These values are denoted by F(50,50) and F(50,10) respectively. Separate pairs of curves are available for TV channels 2–6 FM (low VHF), TV channels 7–13 (high VHF), and TV channels 14–83 (UHF).

These nomograms are empirical and are based on propagation data collected over a period of years at various locations in the continental United States. They are intended to provide estimates of the long-term average values of F(50,50) and F(50,10). No distinction is made between over-land and over-water paths or between different types of climate.

## 2. THE MEASUREMENT PROGRAM

### 2.1 PATH CONFIGURATIONS

The measurement program was designed to provide long-term propagation data, particularly for UHF frequencies, in the region of the Great Lakes. The considerable influence of these large bodies of water on the meteorology of the region and hence on radio wave propagation makes the use of propagation curves based on data from other areas questionable. The main aim of the program was the acquisition of reliable statistics on the enhancement of signals beyond the radio horizon due to superrefraction and ducting. To derive such statistics, signals from existing VHF and UHF television stations were recorded at several sites in the region. The TV channels and receiver sites were chosen so that data for several propagation paths, of which some are over water, would be available. Although the major interest was in the UHF band, some VHF transmitters were included to facilitate the evaluation of frequency dependent phenomena.

The DOC established recording sites at London and at Ottawa, Ontario, while the FCC was to establish sites at Canandaigua and Buffalo, New York, and at Cleveland, Ohio. The FCC also monitored transmissions on the Pacific Coast at Ferndale, Washington, and the DOC established a monitoring site at Vancouver, B.C., to assess propagation conditions in this coastal region. The results of the Pacific Coast measurement program will be the subject of a future report. Figure 2.1 shows the locations of the DOC and FCC receiving sites in the Great Lakes region, together with the transmitter sites, the length of each path, and the channels that are being monitored. Table 2.1 shows the date of which routing monitoring of the different paths was started by DOC. Table 2.2 lists the channels that were monitored, along with data on the transmitters and the associated antennas.

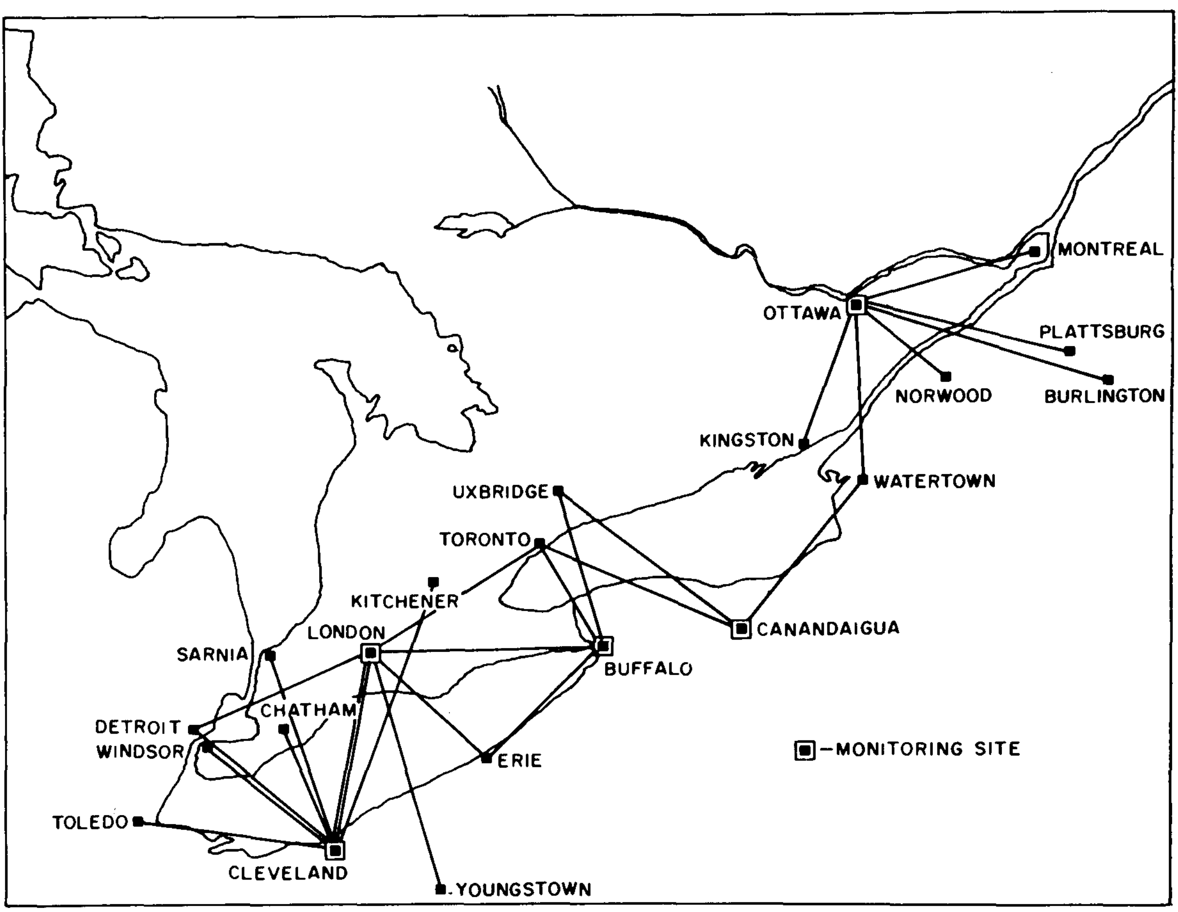


*Figure 2.1. Map showing paths monitored by DOC and by the FCC.*

TABLE 2.1

*Initial Recording Dates for each Channel*

| Path | Chan | Call | Distance (mi) | Date of Start of Recording |
|---|---|---|---|---|
| Detroit – London | 20 | WXON | 108.8 | May 3, 1977 |
| Detroit – London | 50 | WKED | 108.8 | August 15, 1977 |
| Detroit – London | 56 | WTVS | 108.8 | August 15, 1977 |
| Detroit – London | 7 | WXYZ | 106.2 | August 15, 1977 |
| Detroit – London | 62 | WGPR | 102.5 | June 28, 1977 |
| Cleveland – London | 43 | WUAB | 113.9 | June 28, 1977 |
| Cleveland – London | 5 | WEWS | 114.6 | August 15, 1977 |
| Youngstown – London | 21 | WFMJ | 136.3 | May 3, 1977 |
| Youngstown – London | 33 | WYTV | 137.7 | June 28, 1977 |
| Erie – London | 24 | WJET | 90.3 | May 3, 1977 |
| Erie – London | 35 | WSEE | 90.7 | August 15, 1977 |
| Erie – London | 54 | WQLN | 90.3 | August 15, 1977 |
| Erie – London | 12 | WICU | 91.4 | June 28, 1977 |
| Buffalo – London | 17 | WNED | 121.1 | June 28, 1977 |
| Toronto – London | 25 | CBLFT | 104.5 | May 3, 1977 |
| Toronto – London | 79 | CITY | 104.5 | June 28, 1977 |
| Montréal – Ottawa | 17 | CIVM | 111.4 | June 30, 1977 |
| Montréal – Ottawa | 12 | CFCF | 111.4 | June 17, 1977* |
| Kingston – Ottawa | 11 | CKWS | 85.1 | June 17, 1977* |
| Watertown – Ottawa | 16 | WNPE | 102.3 | June 30, 1977 |
| Watertown – Ottawa | 7 | WWNY | 96.1 | July 8, 1977 |
| Norwood – Ottawa | 18 | WNPI | 76.9 | June 30, 1977 |
| Plattsburg – Ottawa | 57 | WCFE | 107.3 | August 23, 1977 |
| Burlington – Ottawa | 22 | WEZF | 159.4 | June 30, 1977 |
| Burlington – Ottawa | 33 | WETK | 159.4 | June 30, 1977 |

** – From November 1976 recordings of these channels were made on chart paper.*

*TABLE 2.2*

*Path and System Parameters*

**Channels Recorded at London (81.28°W, 43.00°N)**

| City | Ch | Freq. (Pict. Carr.) | Call | Lat(N) | Lon(W) | Bearing (Deg) | Distance (Mi) | Eff. Ht (Ft) | Actual (Ft) | ERP |
|---|---|---|---|---|---|---|---|---|---|---|
| Detroit | 20 | 507.25 | WXON | 42.48 | 83.31 | 251.5 | 108.8 | 961 | 1050 | 1.2 MW |
| | 50 | 687.25 | WKBD | 42.48 | 83.31 | 251.5 | 108.8 | 960 | 1053 | 2.34 MW |
| | 56 | 723.25 | WTVS | 42.48 | 83.31 | 251.5 | 108.8 | 960 | 1049 | 0.96 MW |
| | 62 | 759.25 | WGPR | 42.45 | 83.16 | 248.9 | 102.5 | 1070 | 1083 | 1.00 MW |
| | 7 | 175.25 | WXYZ | 42.47 | 83.25 | 250.6 | 106.2 | 1000 | 1073 | 316 KW |
| Cleveland | 43 | 645.25 | WUAB | 41.38 | 81.72 | 191.7 | 113.9 | 1070 | 919 | 1.24 MW |
| | 5 | 77.25 | WEWS | 41.37 | 81.72 | 191.6 | 114.6 | 1020 | 851 | 93.3 KW |
| Youngstown | 21 | 513.25 | WFMJ | 41.08 | 80.64 | 165.8 | 136.3 | 990 | 1085 | 1.00 MW |
| | 33 | 585.25 | WYTV | 41.06 | 80.64 | 165.9 | 137.7 | 557 | 638 | 0.91 MW |
| Erie | 24 | 531.25 | WJET | 42.04 | 80.07 | 136.7 | 90.3 | 740 | 600 | 1.10 MW |
| | 35 | 597.25 | WSEE | 42.04 | 80.06 | 136.4 | 90.7 | 960 | 760 | 2.00 MW |
| | 54 | 711.25 | WQLN | 42.04 | 80.07 | 136.7 | 90.3 | 880 | 714 | 0.96 MW |
| | 12 | 205.25 | WICU | 42.06 | 80.01 | 134.7 | 91.4 | 1000 | 789 | 316 KW |
| Buffalo | 17 | 489.25 | WNED | 42.95 | 78.88 | 90.8 | 121.1 | 720 | 738 | 1.10 MW |
| Toronto | 25 | 537.25 | CBLFT | 43.64 | 79.39 | 64.4 | 104.5 | 1640 | 1721 | 40 KW |
| | 79 | 861.25 | CITY | 43.64 | 79.39 | 64.4 | 104.5 | 1650 | 1731 | 280 KW |

**Channels Recorded at Ottawa (75.88°W, 45.34°N)**

| City | Ch | Freq. (Pict. Carr.) | Call | Lat(N) | Lon(W) | Bearing (Deg) | Distance (Mi) | Eff. Ht (Ft) | Actual (Ft) | ERP |
|---|---|---|---|---|---|---|---|---|---|---|
| Montréal | 17 | 489.25 | CIVM | 45.51 | 73.59 | 83.2 | 111.4 | 983 | 328 | 1.20 MW |
| | 12 | 205.25 | CFCF | 45.51 | 73.59 | 83.2 | 111.4 | 970 | 330 | 325 KW |
| Kingston | 11 | 199.25 | CKWS | 44.17 | 76.43 | 198.8 | 85.1 | 851 | 826 | 250 KW |
| Watertown | 16 | 483.25 | WNPE | 43.86 | 75.73 | 175.1 | 102.3 | 1214 | 939 | 618 KW |
| | 7 | 175.25 | WWNY | 43.95 | 75.73 | 175.2 | 96.1 | 720 | 574 | 316 KW |
| Norwood | 18 | 495.25 | WNPI | 44.49 | 74.86 | 139.2 | 76.9 | 794 | 754 | 667 KW |
| Plattsburg | 57 | 729.25 | WCFE | 44.70 | 73.88 | 114.0 | 107.3 | 2424 | 419 | 562 KW |
| Burlington | 22 | 519.25 | WEZF | 44.53 | 72.82 | 109.4 | 159.4 | 2750 | 324 | 535 KW |
| | 33 | 585.25 | WETK | 44.53 | 72.82 | 109.3 | 159.9 | 2680 | 96 | 631 KW |

## 2.2 THE LONDON, ONTARIO SITE

Six paths were monitored at London, Ontario, and on all but one of these more than one channel was recorded. The channels and paths were carefully chosen to provide a range of azimuths of slightly over 180° and the frequencies ranged from low VHF channels up to almost the top of the UHF band. Three of the paths (eight of the sixteen stations monitored) had significant portions over Lake Erie. The remainder were over land.

The receiving antennas were located on the roof of the University of Western Ontario Physics building, approximately 60 feet above ground level. Although sixteen channels were monitored, only eight antennas were used. Figure 2.2 shows the actual arrangement of antennas, preamplifiers, splitters, and receivers that were employed.

All receivers were constructed at CRC. They were crystal controlled and were tuned to the video carrier frequency of each station. The 6 dB bandwidth was 10 kHz which, with a front-end noise figure of about 6 dB, gave a typical receiver noise floor of about −128 dBm. Since the effective radiated powers of typical television stations were 80–90 dBm, path-losses of up to 218–228 dB could be measured if receiving antenna gains of 10 dB are assumed.

The output of each receiver was sampled ten times per second and, while it was possible for short periods of time to record all of these levels in a time sequence, this was not the normal recording mode adopted for the program. To conserve magnetic tape, and to still allow a high sampling rate for each receiver, a routine was developed that accumulated and recorded signal-strength probability distributions every five minutes for each channel. That was the normal mode of data recording and employed a digital tape recorder controlled by a minicomputer that was also used for data storage and manipulation prior to recording. (See section 3).

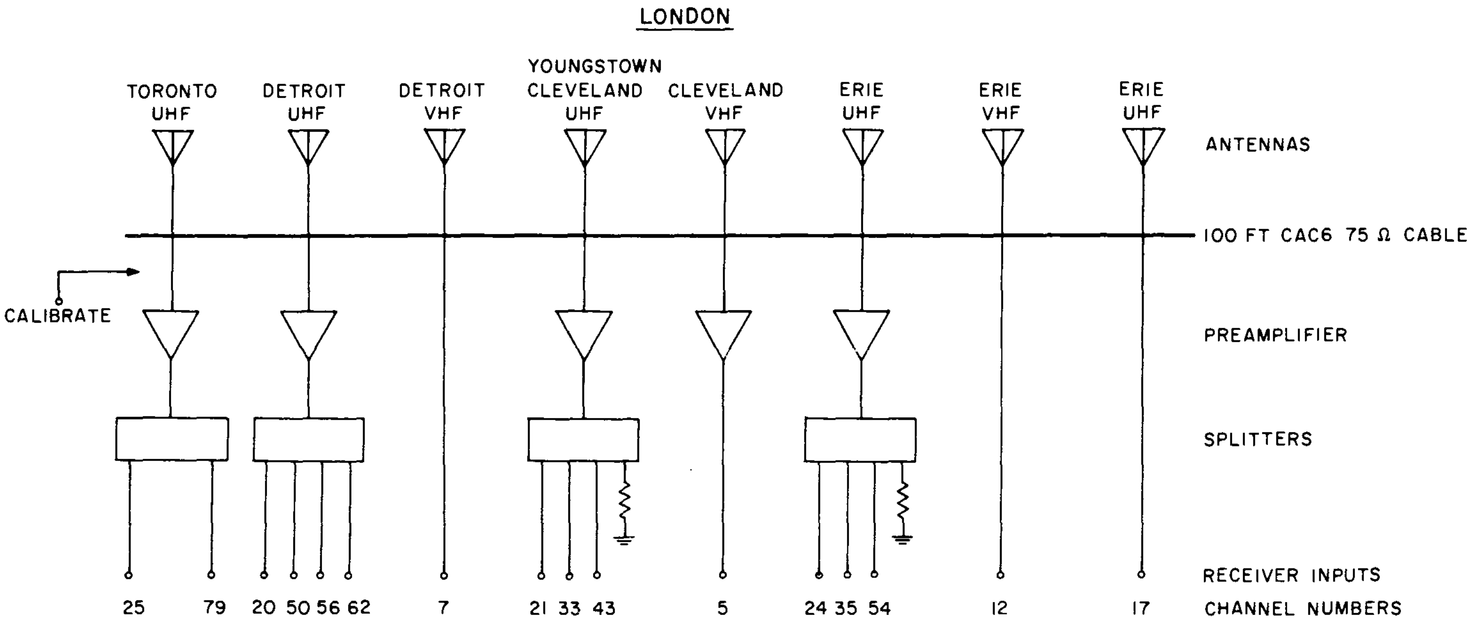


*Figure 2.2. Arrangement of antennas, preamplifiers, splitters, and receivers employed at London.*

### 2.3 THE OTTAWA, ONTARIO SITE

At Ottawa, six paths were also monitored, but only on three of them was more than one channel recorded. The details of these paths are also shown on Figure 2.1. The paths here did not cover as broad a range of azimuths as at London, nor did any of the paths cross a significant body of water. In all, six channels scattered across the UHF band and three in the VHF band were monitored. Table 2.2 lists these channels and gives information on the transmitters and their associated antennas.

The antennas for the monitoring system were located on the roof of a three story laboratory complex at the Communications Research Centre (CRC) site to the west of Ottawa, at an elevation above ground of about 60 feet. The arrangement of antennas, preamplifiers, and splitters is detailed in Figure 2.3. Receiver characteristics were the same as at London.

The recording techniques at Ottawa were also the same as those employed at London. Again, a minicomputer controlled recording system was used, but since only nine channels were recorded the system was also used simultaneously for the collection of other propagation information not related to this project. As a backup, chart paper recordings were also made of all signals monitored at both London and Ottawa.

## 3. THE DATA RECORDING SYSTEM

The CRC data recording system was designed to interrogate one or more experiments at predetermined time intervals, to accept and format the data, and to store it on standard IBM compatible digital magnetic tape. Care was taken to develop the software in modular form so that it was relatively easy to add or delete sections, or to incorporate special routines such as were required by the project described here (e.g., to record signal-strength distributions). This section describes the hardware requirements of the system, the main features of the software, and the format of the data stored on tape.

### 3.1 HARDWARE

The recording system was based on a Hewlett-Packard HP21MX minicomputer which uses 16 bit words. The minimum hardware configuration consisted of 24K 16 bit words of memory, a time-base generator to cause interrupts at 10 msec intervals, a priority interrupt system, floating point hardware, one ASR teletype for paper tape I/O and hard copy, one direct memory access channel, a digital magnetic tape recorder and controller, and serial or parallel I/O interfaces as required. The tape recorder was a Cipher model 100H, and its controller was developed in-house.

Data were acquired from the receivers using a Datel 12 bit, 0–10 volt A/D converter with a 16 channel analogue input multiplexer. This equipment was addressed and commanded by the computer at predetermined time intervals, and presented the resulting binary data to the computer in parallel form.

The system operated using a hardware clock that was updated every 10 msec., and that kept track of the current date and time with a resolution of 10 msec.

### 3.2 THE SOFTWARE

#### 3.2.1 General Considerations

For convenience in processing the recorded data, it was decided that each record on tape would consist of 2048 16 bit computer words. Each 2048 word record was subdivided into 16 data blocks of 128 words each consisting of 120 data words and 8 words of identifying information. This format is explained in detail in

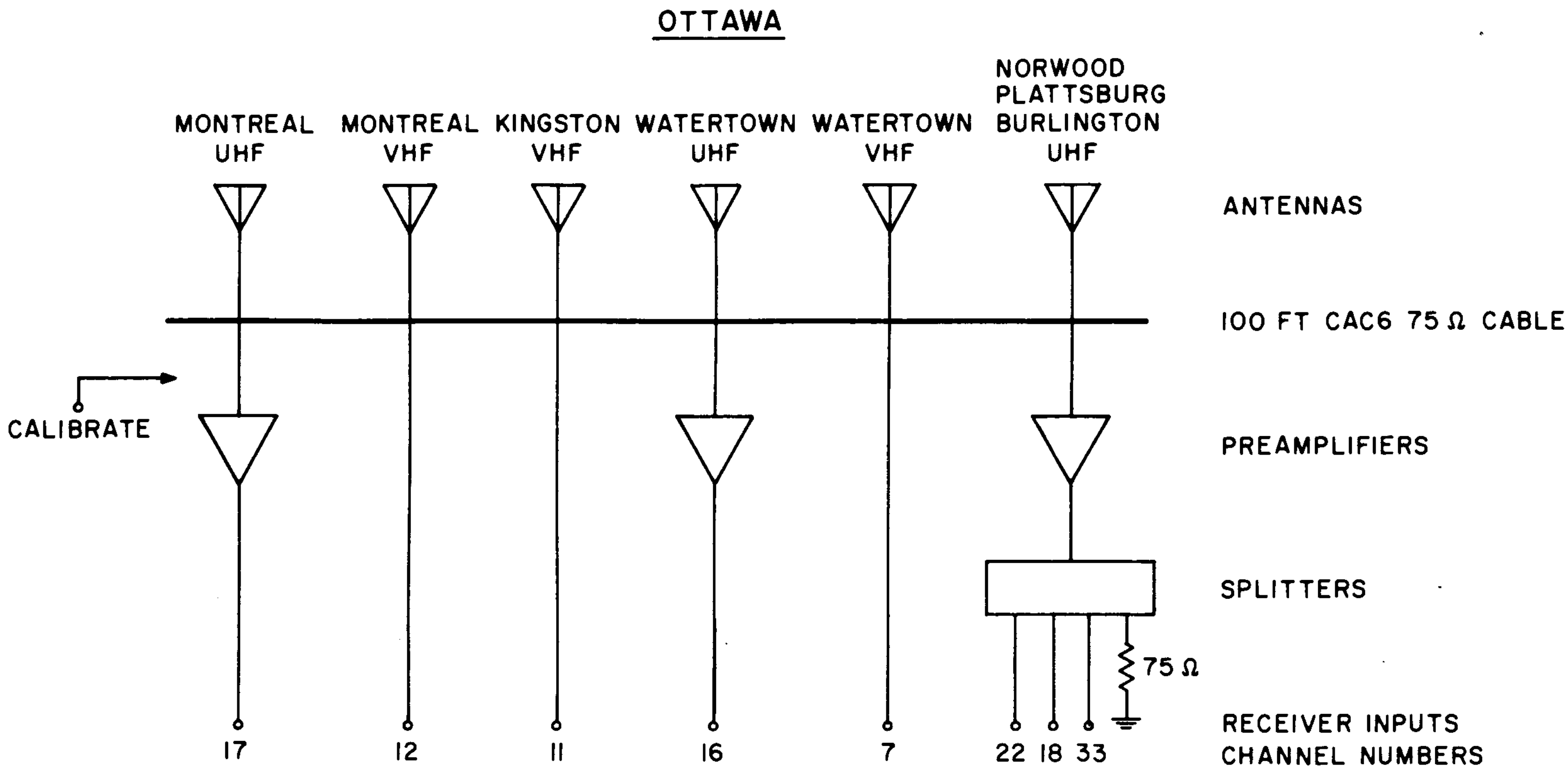


*Figure 2.3. Arrangement of antennas, preamplifiers, splitters, and receivers employed at Ottawa.*

section 3.3. With the available memory (24K), it was possible to accept data from a maximum of 40 separate receivers. Each receiver was assigned a unique 128 word buffer in memory which was filled as the data were acquired. When the buffer became full it was transferred to one of two swinging output buffers where the data from all receivers were assembled prior to being written on tape.

### 3.2.2 Program Operation

When it was not actually servicing a receiver, the program cyclically executed a subroutine which examined a status word associated with each receiver to determine if any action was required. Every 10 msec. the computer was interrupted by the clock routine which determined that it was time to acquire data from one of the receivers. The appropriate I/O channel was turned on, and the receiver commanded. Control was then returned to the main routine until the I/O channel signaled via an interrupt that it has data available. A flag was then set in the status word associated with that particular receiver and control again returned to the main routine. For each flag set in a status word, a branch was taken from the main routine to a routine that serviced and reset that particular flag.

In order to preserve the interrupt structure of the program, and to allow real-time communication with the program via the teletype, routines were included which allowed the teletype to interrupt the processor on a low priority. A number of utility routines were included which allowed the operator to initiate calibration for a particular data channel, to display and set the data/time group, to insert a Hollerith message to be written on tape, to examine and/or change memory locations, and to terminate the program execution in an orderly fashion.

### 3.2.3 Recording Modes

The program was originally conceived to record time-series information — i.e., to record data from experiments at a uniform selectable rate with an accuracy of 12 bits as received from an A/D converter. To conserve magnetic tape and still allow high sampling rates (10/sec) for each receiver in the program, routines were developed which accumulated signal strength distributions over 5 minute periods. The data distributions were formed from the binary data as received from the A/D converter, but with an accuracy of 7 bits (128 separate values). By neglecting the first eight of these values, the distributions fitted into a standard data block of 120 words. Assuming a receiver dynamic range of 60 dB, and a reasonably linear (exponential) characteristic, the resolution then became about 0.5 dB. During final processing, these distributions were converted to dB using the stored calibration tables.

In addition to the signal-level distributions, provisions were made to periodically retain the time-series data for each receiver, using the full twelve bit accuracy of the A/D converter. Throughout most of the project, time-series data for each channel were accumulated for a five-minute period once each hour.

As mentioned previously, provision was made to acquire and store calibration records. In this mode of operation, the normal data acquisition procedures for a given receiver were suspended, and it was assumed that a known power level was being injected into the receiver. The operator was requested to type in this level, the system stored and typed the average of 16 successive samples of the receiver output, and then requested the next calibration level. Up to 60 levels could be used in the calibration process.

## 3.3 DATA FORMAT

The data were stored on magnetic tape in 2048-word blocks, with each record consisting of 16 128-word blocks (Figure 3.1). Each data block was uniquely identified by information in the first eight words according to a bit pattern as follows:

Word 1: 0000XXXYYYYZZZZZ

XXX specified the record type:
- 00 – time series data
- 01 – data distributions
- 10 – calibration
- 11 – message (ASCII)
- 100 – distribution block

YYYYY gives the I/O channel number from which the information was obtained.

ZZZZZ is the subchannel number and will normally be from 0 to 15 corresponding to the address set on the A/D multiplexer

Words 2, 3, and 4 were the data/time group which were in effect at the start of the data record.

Word 2: OOOOOYYYYYYYMMMM (binary year, month)

Word 3: OOODDDDDHHHHHMMM (binary day, hour)

Word 4: MMMSSSSSSMMMMMMM (binary minute, second, 10's of milliseconds)

Words 5 and 6 set the times at which an receiver was to be commanded.

Word 5: XXYYYYYYYYYYYYYY

YY was a BCD number

XX – 00 specified that the remainder of the word referred to tens of msec.
- – 01 specified seconds
- – 10 specified minutes
- – 11 specified days

Word 6: A binary number specifying the intervals, relative to word 5, at which the receiver was to be commanded, e.g., suppose word 5 – 0000000000000101 and word 6 – 0000000000001010 (decimal 10). Then word 5 specified that the experiment was to be commanded whenever the computer clock had a value of 50 msec., and word 6 specified that commands would also be issued at 10 x 10 = 100 msec. intervals after this time. Therefore, data was gathered at times of 50, 150, 250, ..., 950,50 150,... msec. as determined by the computer clock.

Word 7: The total number of values recorded in the data block.

Word 8: Not used.

The remaining 120 words in the data block contained the data in unsigned, 16 bit binary form. In the case of the signal-level distributions, word 9 contained the number of times the A/D output, truncated to 7 bits, was (decimal) 8 or less, word 10 contained the number of times the A/D output was 9, word 11 contains the number of times the output was 10, and so on to word 128 which contained the number of times the output was 127 (i.e., full scale). In the case of time-series recording, the data were in sequence with the timing given by words 5 and 6.

### 3.4 MAGNETIC TAPE USAGE

At a recording density of 800 bpi on 9 track tape, each record (consisting of one data block for each of the 16 receivers at London) required (2048 X 2/800) – 0.75 = 5.87 inches of tape. Thus, one 2400 foot reel of tape could store about 4900 such records. If a record was written every five minutes (288 per day), the tape lasted 17 days. Inclusion of time-series data for 5 minutes of each hour for each channel increased the rate of tape usage. At London, such tapes lasted about 5 days.

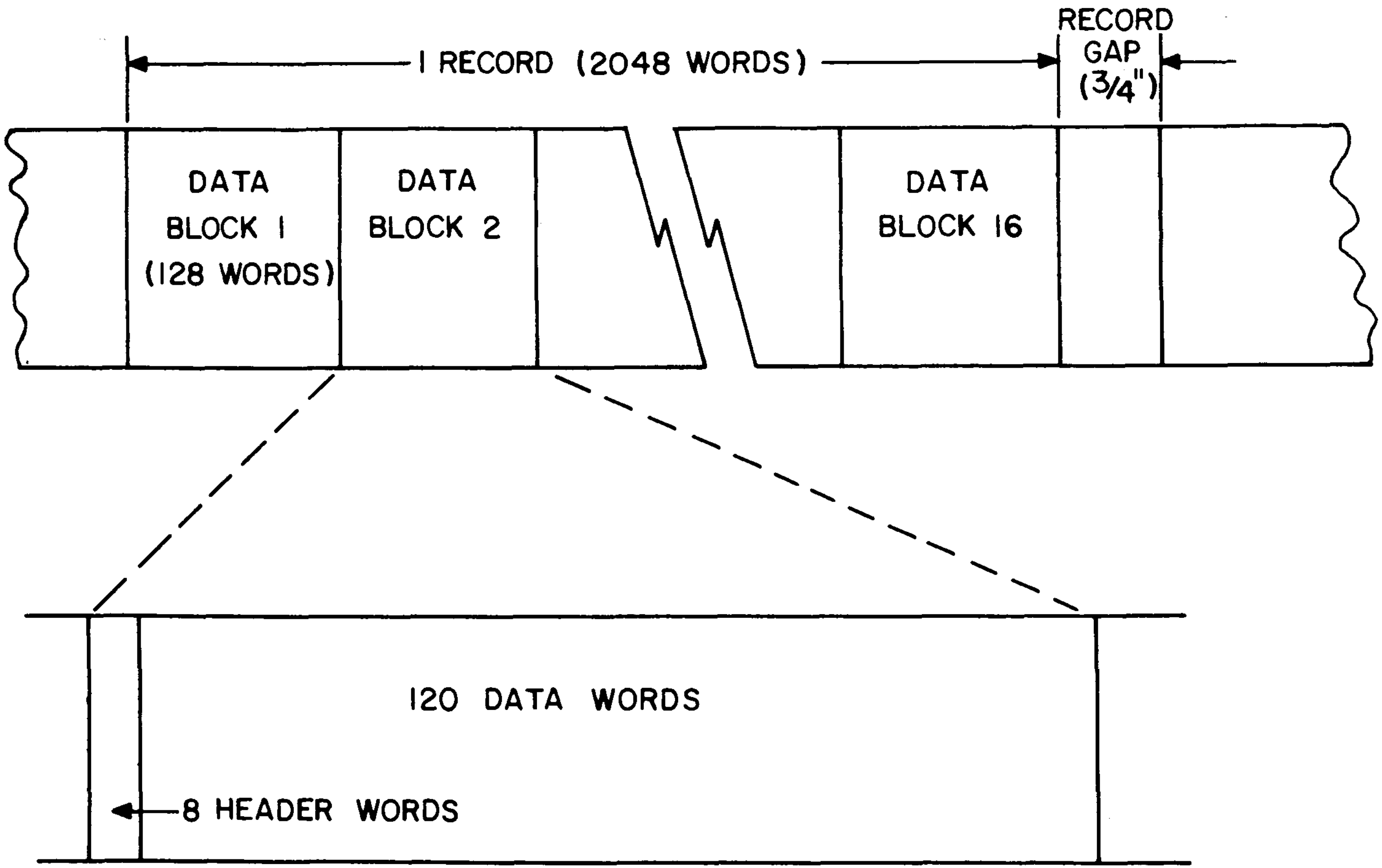


*Figure 3.1. Format of data storage on tape.*

# 4. SUPPORTING MEASUREMENTS

## 4.1 HEIGHT-GAIN AND LOCATION-VARIABILITY

The field strengths predicted by the R-6602 curves refer to those exceeded for either 50 percent or 10 percent of the time at 50 percent of possible receiving locations. The receiving antenna heights are assumed to be 30 feet. The heights of the receiving antennas used in this study were near 60 feet and it was therefore essential to relate the observed field strengths to those observed simultaneously using antennas at a height of 30 feet. In order to relate field-strengths determined by long-term measurements at a single location to the corresponding median field-strengths over a given area it is, in principle, necessary to measure the field-strength of each channel at a large number of secondary sites in the vicinity of the monitoring site. The median value of the difference between the signal-strengths observed at the monitoring site and the signal-strengths simultaneously measured at the secondary sites gives the correction necessary to relate the two types of measurement.

Both the height-gain and location-variability correction factors may be determined from a single series of measurements if the measurements at the secondary sites are done using an antenna at the standard height of 30 feet. Such measurements were carried out at London and at Ottawa.

In order to arrive at a satisfactory estimate of the median value it is necessary to make a relatively large number of measurements. Carrying through this procedure for all 25 channels monitored at London and Ottawa would have resulted in a prohibitively large supporting measurement program. For this reason, on paths where more than one channel was monitored, only one of these channels was chosen for a complete series of supporting measurements. The correction factors were then assumed to be the same for all channels over the same path. A further short series of measurements of nearly all channels monitored supported this assumption.

All measurements were carried out using a mobile laboratory which provided space for the receiving equipment and which carried a pneumatic telescoping mast capable of elevating antennas to a height of 30 feet. The characteristics of the mobile receiver were essentially the same as those used for the routine measurement program. Each secondary measurement of signal-strength consisted of recording the receiver output on strip-chart, and of then determining the median level over a five minute period. The differences between these levels, and those recorded by the routine monitoring strip-chart equipment over the same five minute period, were tabulated. In this way, the effects of the time-varying of the signals were eliminated from the data. The data were corrected for the differing cable-losses and antenna gains of the mobile and fixed installations.

The correction factors to be added to the routinely determined values of field-strength in order to relate them to the field-strengths expected at a height of 30 feet at 50 percent of the possible receiving sites are given in Table 4.1. As expected, the field-strengths at 30 feet were, in most cases, lower than those routinely measured at 60 feet. The Detroit UHF stations are seen to be only exceptions. This was due to the relatively poor placement of the Detroit UHF antenna on the roof of the UWO Physics building roof. It is partially shadowed by other buildings on the UWO campus.

## 4.2 ANTENNA GAIN MEASUREMENTS

It is shown in Appendix B, part B3, that the field strength at any instant is related to received power by the expression $E_O = 137.2 + 20\log f - ERP - G_R + L_R + P_R$ where f is frequency in MHz, ERP is effective radiated power in dBm, $G_R$ is receiving antenna gain in dB, $L_R$ is receiving system line loss in dB, and $P_R$ is measured received power in dBm. All receiving antenna gains must be accurately known in order to compare observed and predicted values of signal-strength, as well as to carry out the supporting measurements as noted above. Early in the program it was noted that the actual gains of the antennas used appeared to be lower than specified by the manufacturer. Gain measurements at the appropriate frequencies were therefore made of all antennas used for both routine and supporting measurements in the project. The measurements were made initially over a 10 mile line-of-sight path from the Gatineau Hills (to the north of Ottawa) to the roof of CRC. Subsequently, the antennas used for the supporting measurements were substituted for the antennas used for the routine measurements and the relative gains were measured. The two types of measurement were consistent within 1 dB (averaged over all antennas used). The values of antenna gains used in the data analysis are given in Table 4.2.

*TABLE 4.1*

*Location-Variability and Height-Gain Corrections*

**London**

| Channel | 20 | 50 | 56 | 62 | 7 | 43 | 5 | 21 | 33 |
|---|---|---|---|---|---|---|---|---|---|
| ΔP (dB) | +3.8 | +3.8 | +3.8 | +3.8 | −3.8 | −7.0 | −3.8 | −7.0 | −7.0 |
| Channel | 24 | 35 | 54 | 12 | 17 | 25 | 79 | | |
| ΔP (dB) | −7.0 | −7.0 | −7.0 | −3.8 | −9.7 | −5.2 | −5.2 | | |

**Ottawa**

| Channel | 17 | 12 | 11 | 16 | 7 | 18 | 57 | 22 | 33 |
|---|---|---|---|---|---|---|---|---|---|
| ΔP (dB) | — | +2.2 | +1.2 | −6.8 | +1.2 | −6.8 | −14.1 | −10.7 | −10.7 |

*TABLE 4.2*

*Antenna Gains*

**London**

| Channel | 20 | 50 | 56 | 62 | 7 | 43 | 5 | 22 |
|---|---|---|---|---|---|---|---|---|
| Gain (dBi) | 13.8 | 14.0 | 16.8 | 11.1 | 12.6 | 5.6 | 10.1 | 10.2 |
| Channel | 33 | 24 | 35 | 54 | 12 | 17 | 25 | 79 |
| Gain (dBi) | 13.1 | 9.9 | 12.6 | 10.2 | 10.6 | 11.6 | 10.8 | 8.1 |

**Ottawa**

| Channel | 17 | 12 | 11 | 16 | 7 | 18 | 57 | 22 | 33 |
|---|---|---|---|---|---|---|---|---|---|
| Gain (dBi) | 14.0 | 11.6 | 11.6 | 13.1 | 12.6 | 10.5 | 12.8 | 8.2 | 14.1 |

## 4.3 CABLE AND MATCHING TRANSFORMER LOSSES

All cables lengths were measured and the losses determined using the manufacturers values for loss as a function of frequency. Matching transmformer losses were measured in the laboratory at each of the experimental frequencies. Total line and matching transformer losses for each channel are shown in Table 4.3.

## 4.4 COMPARISON OF DIGITALLY AND MANUALLY SCALED DATA

The data used in the derivation of the R-6602 curves were derived from manually scaled strip-chart records having a time resolution of at least several minutes. The data used in the present study was digitally

*TABLE 4.3*

*Cable and Matching-Transformer Losses*

**London**

| Channel | 20 | 50 | 56 | 62 | 7 | 43 | 5 | 21 |
|---|---|---|---|---|---|---|---|---|
| Loss (dB) | 7.3 | 9.2 | 9.5 | 9.7 | 4.5 | 8.7 | 2.7 | 7.7 |
| Channel | 33 | 24 | 35 | 54 | 12 | 17 | 25 | 79 |
| Loss (dB) | 8.2 | 4.5 | 4.8 | 5.3 | 2.8 | 6.8 | 7.4 | 9.9 |

**Ottawa**

| Channel | 17 | 12 | 11 | 16 | 7 | 18 | 57 | 22 | 33 |
|---|---|---|---|---|---|---|---|---|---|
| Loss (dB) | 8.6 | 5.3 | 5.3 | 8.6 | 4.9 | 8.6 | 10.7 | 8.8 | 9.4 |

scaled directly from the receiver outputs at the rate of 10 samples per second. It is clear that if the signal-strength had a stable, unvarying value, the two estimates should be identical. In the case of a fading signal the estimates may well differ since low speed strip-chart records show only a wide range of signal levels when the signal fades, and it is up to the scaler to decide what value of signal strength is to be attached to this range of values. The digital sampling rate, on the other hand, was sufficiently high that it followed the details of the fading signal with very little error due to changing signal-level during the sampling interval.

To determine the correction factors necessary to relate the two types of scaled data, manually and digitally derived values of signal-strength were compared for the Montreal-Ottawa channel 12 path, over a period of three months. The form of the diurnal and seasonal variation of the signal-strength statistics as determined by the two methods were found to be in excellent agreement, but with differences in the absolute values of signal-strength corresponding to various values of "percent time signal-strength exceeded". Specifically, the manually derived values of signal-strength exceeded for 50 percent of the time were 4 dB higher, on average, than those derived digitally. The manually derived values of signal-strength exceeded for 10 percent of the time were 2 dB higher than the corresponding digitally derived values. In order to compare the present digitally derived results with the predictions of R-6602, 2 dB and 4 dB were therefore added to the derived values of signal-strength exceeded for 10 percent and 50 percent of the time respectively.

## 5. SUPPLEMENTARY DATA

### 5.1 TRANSMITTING ANTENNA RADIATION PATTERNS

In order to compare measured values of signal-strength with those predicted by R-6602 it is necessary that the effective radiated power (ERP) of each transmitter in the direction of the receiver be known. This requires that both the vertical and horizontal radiation patterns of each transmitter be available. The FCC provided DOC with all necessary information in regard to U.S. stations, while the equivalent data for the Canadian stations monitored was obtained from the Broadcasting Regulation Branch of DOC.

Corrections to the nominal ERP's of most stations were sufficiently small that they could be assumed to be zero. Exceptions are noted in Table 5.1, which shows the amount by which the nominal ERP of each station is reduced by the combination of beam tilt and non-circular horizontal radiation pattern.

*TABLE 5.1*

*Correction for Transmitting Antenna Radiation Pattern*

**London**

| Channel | 7 | 43 | 24 | 35 | 54 |
|---|---|---|---|---|---|
| Correction (dB) | 2.5 | 3.5 | 10.4 | 17.1 | 13.6 |

**Ottawa**

| Channel | 22 | 33 |
|---|---|---|
| Correction (dB) | 7.1 | 7.7 |

## 5.2 STATION OPERATING LOG DATA

Most television stations endeavor to maintain transmitter output power close to the assigned values. Occasionally however, due to equipment malfunction, the ERP of a station may be below nominal. Such times should be noted and appropriate corrections made during data analysis. To this end, the FCC has consistently provided DOC with extracts from the operating logs of all U.S. stations. It has proved difficult to obtain the equivalent data for all Canadian stations. For this, and other reasons, log data have not yet been incorporated into the data analyzed thus far. Examination of the available log data shows, however, that the resulting uncertainties in the comparisons with R-6602, for the methods of analysis used in the present work, are negligible. Since all data analyzed is averaged over one month intervals (Section 6), a station whose ERP is zero for two weeks causes an error in derived field-strengths relative to R-6602 of 3 dB. Averaging data from 13 UHF stations, as done for the London data, reduces the error to less than 0.3 dB. In practice, station ERP's are within 5 percent of nominal for more than 90 percent of the time. Errors in the overall statistics caused by the lack of complete log data are therefore usually less than 0.1 dB.

# 6. DATA ANALYSIS PROCEDURES

## 6.1 FORMAT OF REDUCED DATA

It was pointed out in Section 3.2.3 that cumulative distributions of received signal power were recorded for each five minute period for each station. In order to reduce the quantity of available data to an amount suitable for the present purposes, data from each block of six consecutive (every half hour) intervals were averaged so as to have 48 distributions per station per day. Over 600,000 such distributions are available at the present time. Two steps were taken to further reduce the quantity of data to be analyzed. First, data from each station for each 30 minute block during the day was averaged over one month periods. An example of a distribution of data averaged in this way is shown in Figure 6.1. Second, in this report we are not interested in values of received power for all percent times of occurrence. Values of received power exceeded for 5 percent, 10 percent, 50 percent, 90 percent, and 95 percent of the time were therefore selected from the monthly averaged 30 minutes distributions. These five values of received power, for each of the 48 time blocks throughout the day, were then plotted as a function of time of day, as shown in Figure 6.2. Over 400 such "summary plots" of the experimental data have thus far been generated, and form the basis for intercomparisons with the predictions of R-6602.

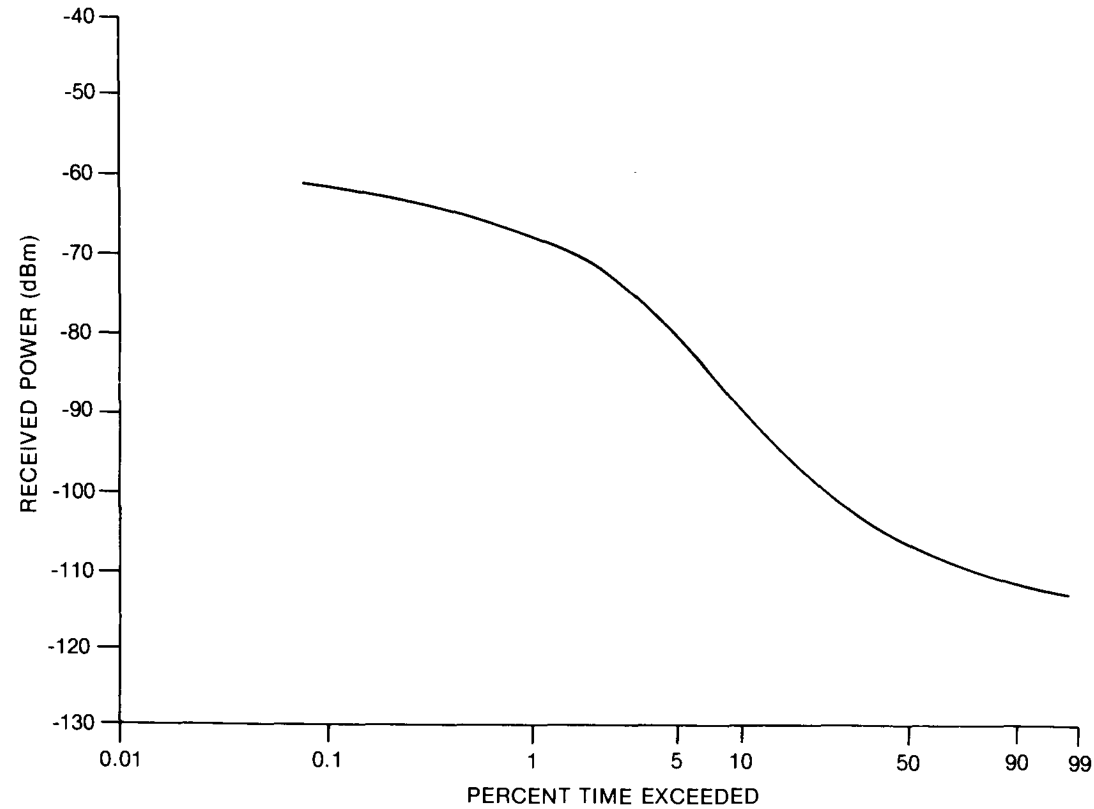


*Figure 6.1. Example of cumulative distribution of received power over a single path. Data from one thirty minute time block during each day have been averaged over one month.*

## 6.2 METHOD OF COMPARING MEASURED DATA WITH R-6602 PREDICTIONS

The data, as illustrated in Figure 6.2, are in terms of power as measured at the receiver input. The predictions of R-6602 are in terms of the expected field-strength, in microvolts per metre, at the receiving antenna location. To facilitate intercomparisons, experimental values of received power were converted to equivalent values of field-strength at the receiving antenna. It is shown in Appendix B that the field-intensity at an antenna is related to the received power at the receiver input terminals by the expression.

$$E \text{ (dB rel. to 1 } \mu\text{V/m per kW radiated power)}$$

$$= (137.2 + 20 \log f - \text{ERP} - G_R + L_R) + P_R$$

where f is station frequency in MHz, ERP is station effective radiated power in dBm, $G_R$ is receiving antenna gain relative to isotropic in dB, $L_R$ is antenna-receiver line loss in dB, and $P_R$ is the measured power at the receiver input terminals, in dBm. Values of $G_R$ and $L_R$ are tabulated in Tables 3.2 and 3.3 respectively. Correction factors, which must be applied to the nominal values of ERP for each station to account for antenna beam tilt and non-circular horizontal patterns, are given in Table 5.1. The frequency and nominal ERP of each station are tabulated in Table 2.2. The correction factors necessary to relate measured values of $P_R$ to those expected at 50 percent of possible receiving locations at a height of 30 feet, are given in Table 3.1. If the sum of these various correction factors is denoted by $\Sigma C$, we may write, for each station:

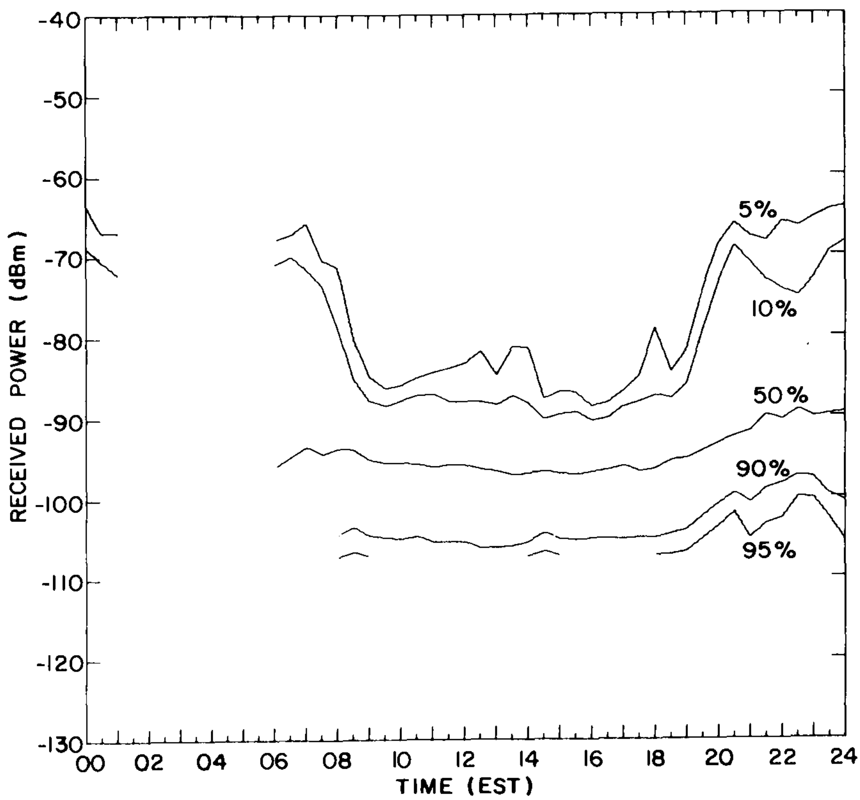


*Figure 6.2. Example of "summary" plot (Erie—London, Ch. 24, July 1977) showing values of received power exceeded for the indicated percentages of time as a function of time of day.*

$$E_o = P_R + k$$

where $k = 137.2 + 20 \log f - ERP - G_R + L_R + \Sigma C$ = constant. Values of k for each station are shown in Table 6.1 for signal strengths exceeded for 50 percent of the time. Values of k for signal strengths exceeded for 10 percent of the time are 2 dB lower than those for signal strengths exceeded 50 percent of the time, for the reasons discussed in section 4.4.

### 6.3 VALIDATION OF THE COMPARISON METHOD

In order to validate the procedures described above, a test comparison of measured and predicted field-strengths was carried out using a local Ottawa televison station. It was assumed that the path-loss could be accurately predicted in this case since the station, Ottawa channel 30, had a line-of-sight path, with ground clearances of more than one Fresnel zone, to the roof of the laboratory complex at CRC. Previous measurements indicated that multipath signals, including ground reflections, could be ignored over this path, and that it could be considered a good approximation to a free-space path.

Measurements of received signal strength were made using a receiving system having similar parameters to those of the actual routine measurement installations. Following the procedures outlined above, the calculated value of field strength at the receiving antenna was found to be within 1 dB of the value expected on the basis of free-space propagation.

*TABLE 6.1*

*Correction factors necessary to relate measured values of $P_R$ to those expected at 50 percent of possible receiving locations at a height of 9.1 metres*

**London**

| Channel | 20 | 50 | 56 | 62 | 7 | 7 | 43 | 5 | 21 |
|---|---|---|---|---|---|---|---|---|---|
| k (50% time) | 101.8 | 103.2 | 105.1 | 111.2 | | 89.2 | 105.1 | 88.0 | 95.9 |
| Channel | 33 | 24 | 35 | 54 | | 12 | 17 | 25 | 79 |
| k (50% time) | 95.0 | 103.3 | 106.6 | 110.5 | | 90.8 | 89.9 | 94.0 | 114.6 |

**Ottawa**

| Channel | 17 | 12 | 11 | 16 | 7 | 18 | 57 | 22 | 33 |
|---|---|---|---|---|---|---|---|---|---|
| k (50% time) | — | 92.0 | 92.9 | 95.7 | 89.4 | 98.2 | 94.8 | 105.2 | 100.8 |

## 7. COMPARISONS OF MEASURED DATA WITH THE PREDICTIONS OF FCC R-6602

Since most television stations that are monitored do not operate on a 24 hours per day basis it is not, in general, possible to carry out meaningful comparisons with the R-6602 predictions throughout a full day. Inspection of the data available reveals, however, that although the magnitude of the observed diurnal variations of signal strength can be quite variable, the qualitative form of the diurnal variation of measured signal strength is always the same. Minimum signal strengths occur between late morning and early afternoon, while maximum signal strengths are observed between late evening and early morning. Signal strengths measured in ±30 minute blocks centred at 1200 EST were thus taken as representative of the minimum signal strengths observed in any 24 hour period.

A significant number of the stations that are monitored sign-off around midnight and sign-on again between 0600 and 0800 the following day. In order to utilize data from the maximum number of stations possible it was decided that signal strengths measured in ±30 minute time blocks centred at 2300 EST would be taken as representative of the maximum signal strengths observed throughout the day. Examination of data from stations that do operate on a 24 hour a day basis showed this to be a reasonable assumption.

Channel 17, Montreal, was found to operate on such a restricted schedule that it was omitted from the data analysis.

## 7.1 SEASONAL DEPENDENCE OF THE UHF DATA

### 7.1.1 Direct Comparison of Measured Data to R-6602

R-6602 presents different prediction curves for the VHF and UHF parts of the radio spectrum, and for signal levels exceeded for 50 percent and 10 percent of the time (F(50,50) and F(50,10) curves). In this section, comparisons will be made between the measured UHF signal strengths and those predicted by the appropriate R-6602 UHF curves.

The comparisons are made by averaging, on a month-by-month basis, the differences between the measured signal strength for each station and that predicted by R-6602. The standard deviation of the differences is also computed on a month-by-month basis to provide an estimate of the station-to-station variability of the differences.

Results are shown, using data recorded between 1 September 1977 and 31 March 1979, in Figures 7.1 to 7.4. Figures 7.1 and 7.2 show comparisons between R-6602 and London F(50,50) and F(50,10) data respectively. Comparisons for both 1200 and 2300 EST are shown on the same plots in order to show the diurnal variability of signal strength. The corresponding plots of Ottawa F(50,50) and F(50,10) data are shown in Figures 7.3 and 7.4.

The standard deviations of the differences are also shown on a month-by-month basis on each plot.

It is clear that the data exhibit significant diurnal and seasonal variations. In general, measured signal levels are higher at night than during the day, and are higher in summer than winter. The diurnal and seasonal variations are larger at London than at Ottawa.

### 7.1.2 Dependence of Results on Path and System Parameters

Inspection of the standard deviations shown on Figures 7.1 to 7.4 shows that the station-to-station variability can often exceed 10 dB. Since the stations that are monitored have a variety of path and system parameters it is of some interest to see if the standard deviations can be reduced by taking such parameters explicitly into account.

The four most important parameters which differ from one station to another are: transmitting antenna height, frequency, path-length, and percentage of path covered by water. To determine the importance of each of these parameters, as far as contributing to the observed standard deviations are concerned, the following procedure was followed:

On a month-by-month basis, least squares techniques were used to derive the best straight line fit to the values of transmitting antenna height and the corresponding differences between measured and predicted values of signal strength. These differences were then normalized to an effective transmitting antenna height of 1000 feet above average terrain (EHAAT) using the equation of the straight line. The standard deviation of the new values of the difference between the measured and predicted signal strengths were then re-derived on a month-by-month basis. If the original differences showed any dependence on transmitting antenna height, the standard deviation of the re-derived values will be less than that of the old. The equation of the straight line may then also be used as a correction factor, to bring the values of signal strength predicted by R-6602 into closer agreement with the observed values.

In a similar fashion, values of the differences between the measured and predicted signal strengths were normalized to a frequency of 600 MHz, to a path-lengths of 100 miles, and to 100 percent land paths.

It was found that little improvement in standard deviation could be gained by normalizing to either a standard transmitting antenna height or to a standard frequency. On the other hand, significant reductions could be brought about by normalizing the data to a standard path-length and to a standard "percentage of path covered by water". These results are illustrated in Figure 7.5. This figure is based on London F(50,50) data for 1200 EST, June 1978. The standard deviation of the differences between the measured and predicted values of signal strength was originally 11.1 dB. After normalizing to a frequency of 600 MHz and to a transmitting antenna height of 1000 feet, the standard deviation was only reduced to 10.5 dB. However, further normalizing the data to a fixed path length (100 miles) reduced the standard deviation to 8.4 dB, and normalizing to a fixed percentage of water (0 percent or 100 percent) finally reduced the standard deviation to 6.0 dB.

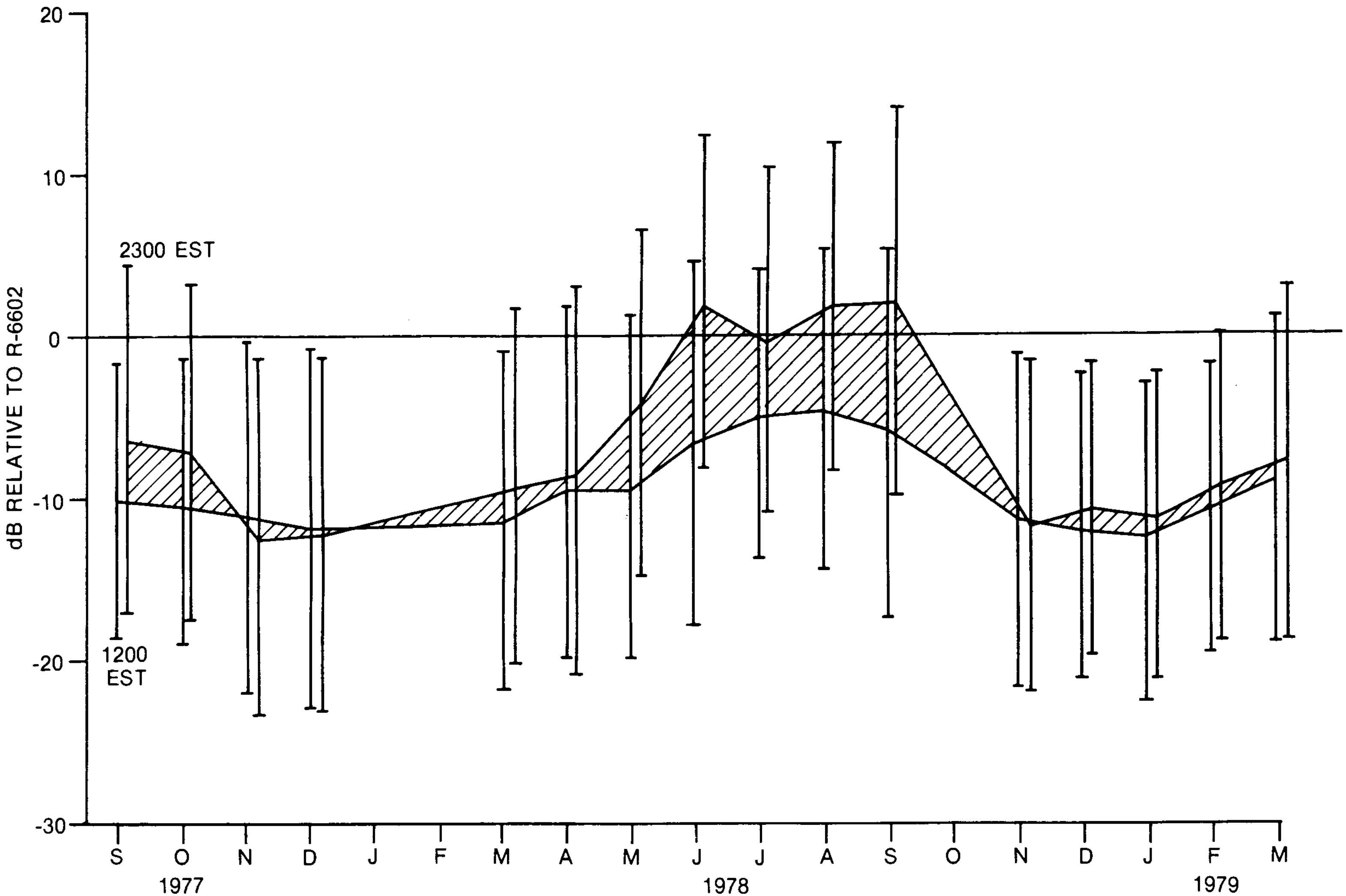


*Figure 7.1. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. F(50,50) data recorded at London.*

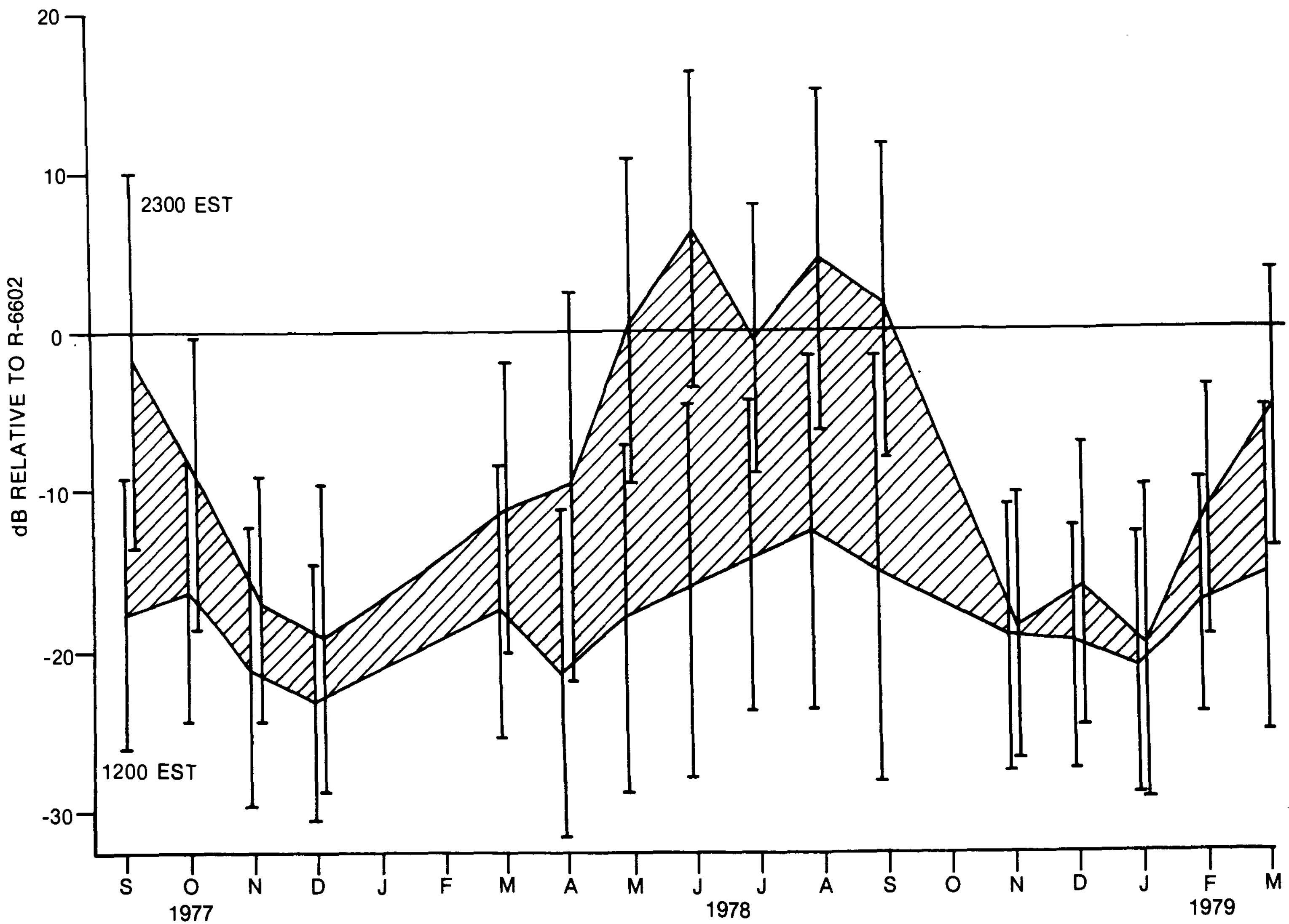


*Figure 7.2. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. F(50,10) data recorded at London.*

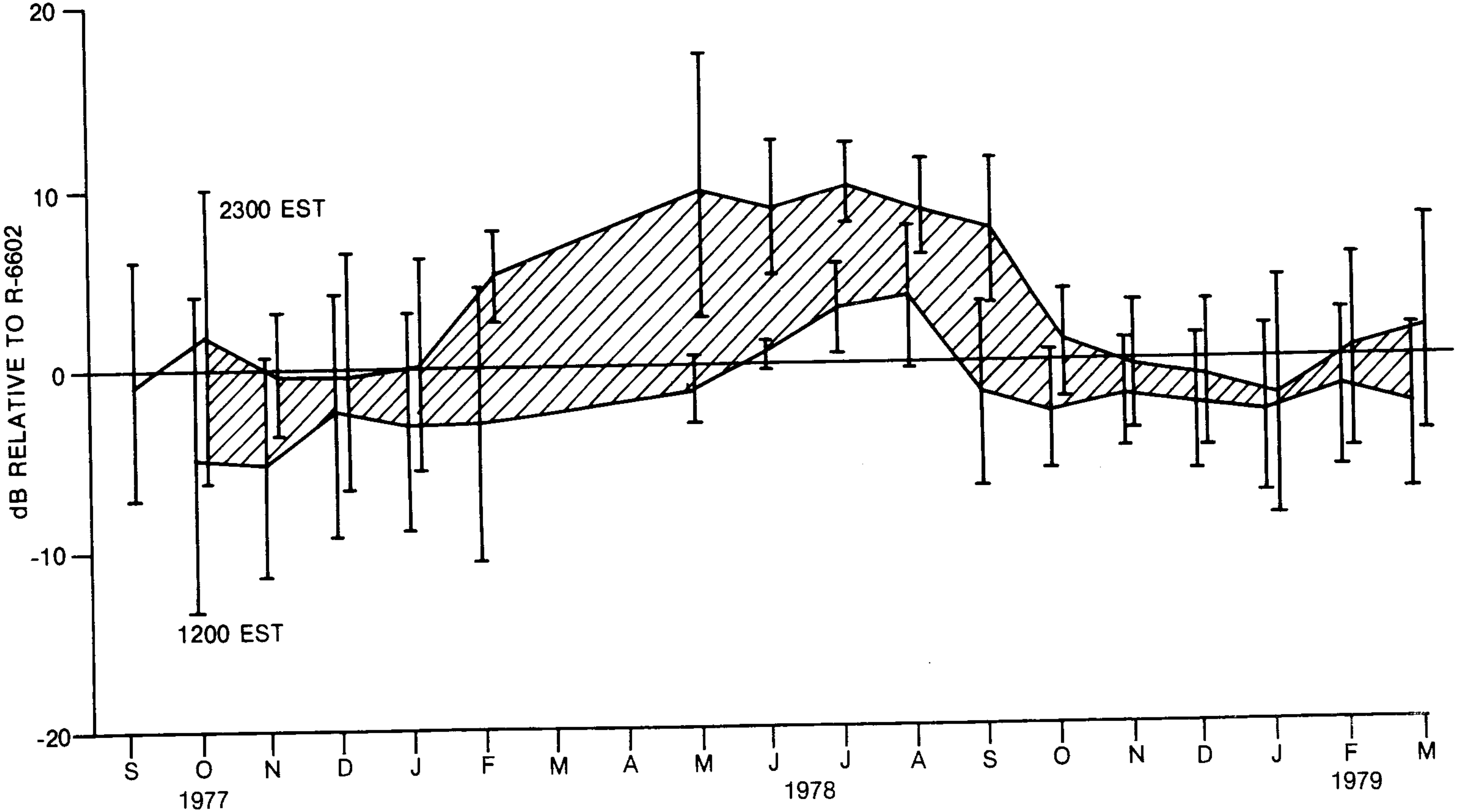


*Figure 7.3. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. F(50,50) data recorded at Ottawa.*

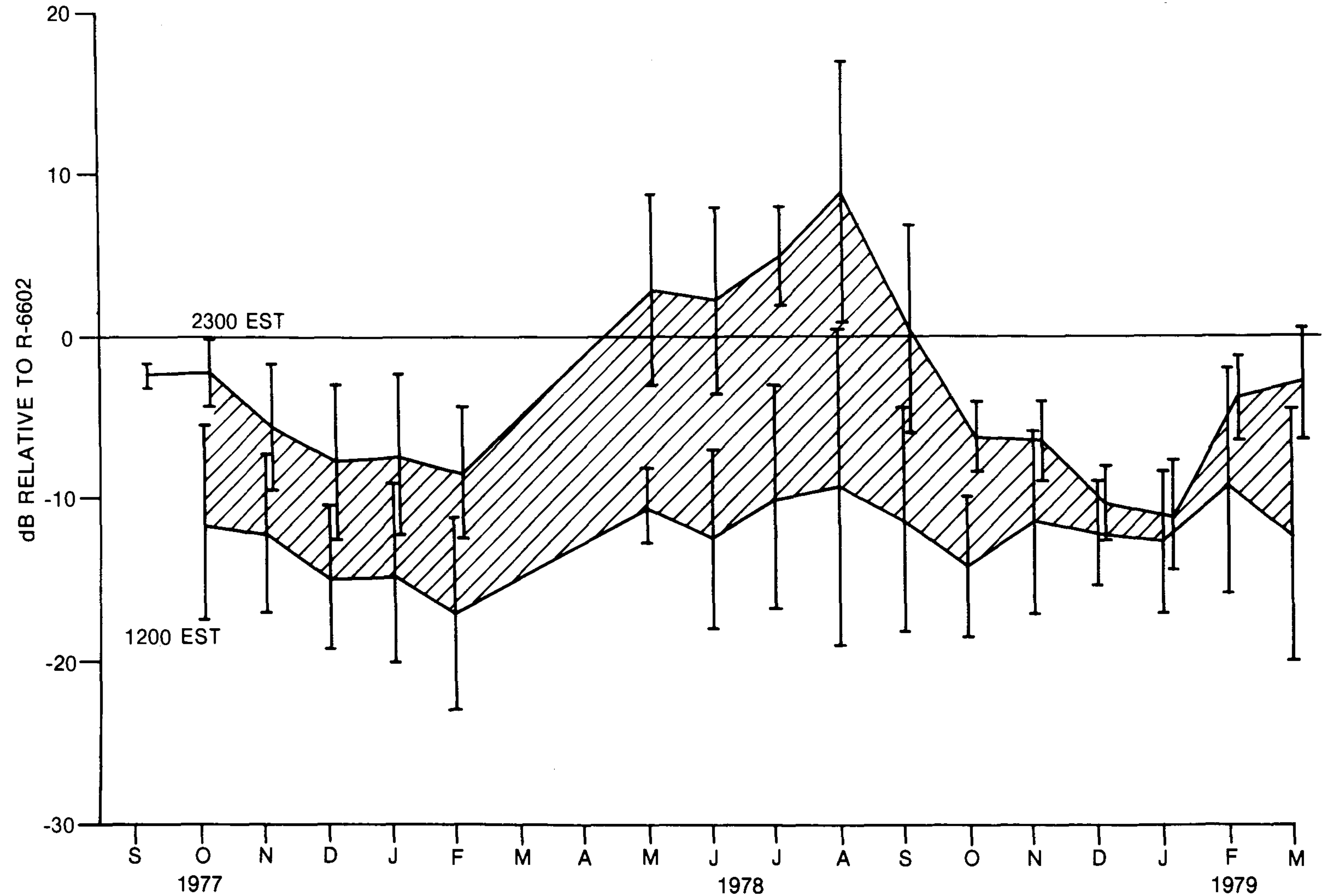


*Figure 7.4. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. F(50,10) data recorded at Ottawa.*

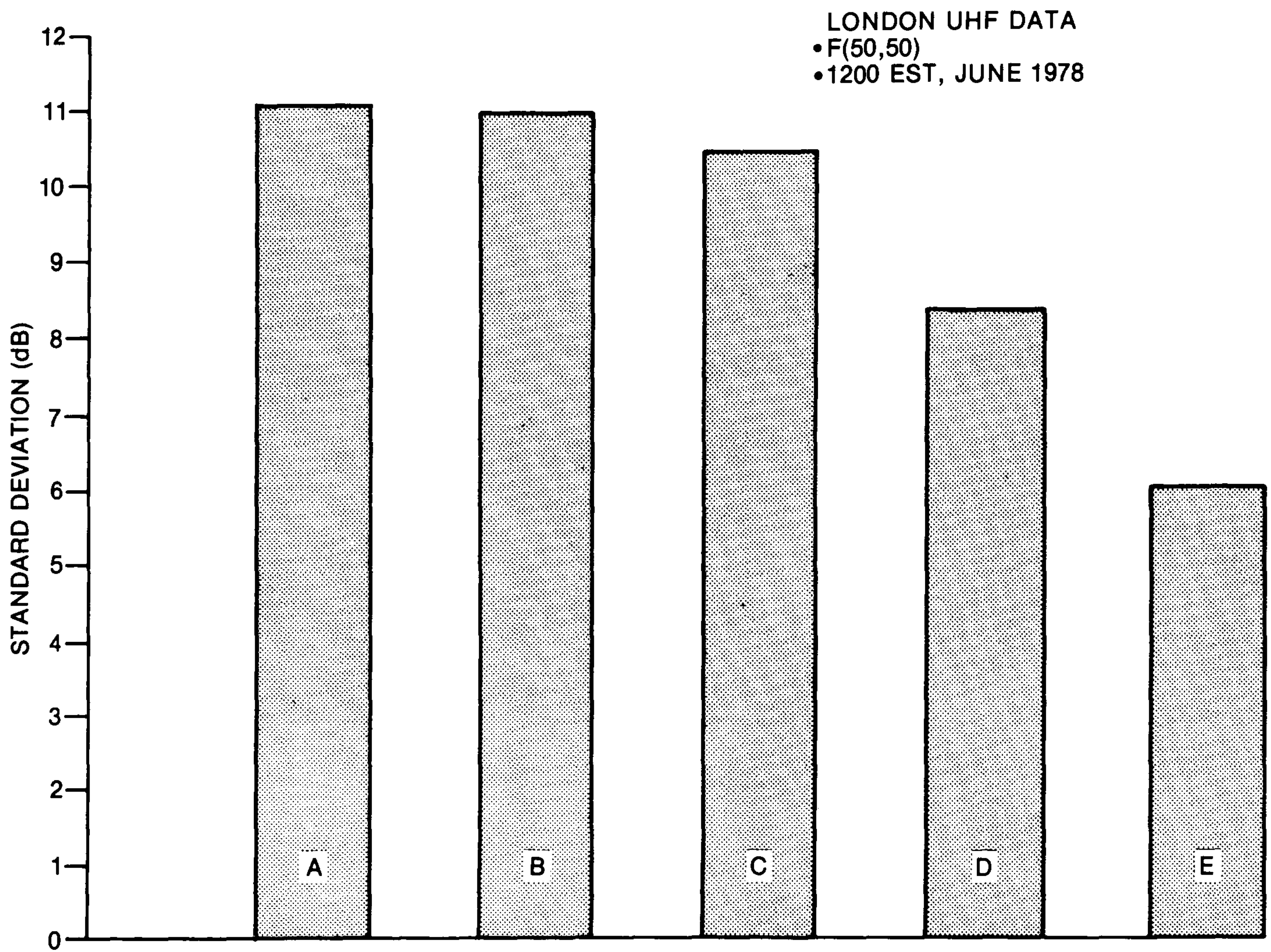


*Figure 7.5. Standard deviation of the differences between measured and calculated received power for all UHF stations recorded at London. A: "raw" measured data, B: Frequencies normalized to 600 MHz, C: Transmitting antenna height also normalized to 1000 feet, D: Path length also normalized to 100 miles, E: Path also normalized to 0 percent water cover.*

### 7.1.3 Comparison of Normalized Data to R-6602

Since the differences between the measured and predicted signal strengths depended only slightly on transmitting antenna height and frequency, these factors were ignored in further analysis. On the other hand, the previously derived relations between the differences and the path length and "percentage of path covered by water" were used to generate plots, similar to those shown in Figures 7.1 and 7.4 but which show the expected differences between the measured and predicted signal strengths on a month-by-month basis for 0 percent and 100 percent water covered paths and for path lengths of 90, 100, 120, and 140 miles as well as for 1200 and 2300 EST and for 10 percent and 50 percent of the time. The results are shown in Figures 7.6 to 7.13. For clarity, the 1200 and 2300 EST data had, in this case, to be shown separately. The station-to-station standard deviations of the data are also shown on the Figures.

## 7.2 DIURNAL DEPENDENCE OF THE UHF DATA

The form of the diurnal variability of the normalized data, as measured by the differences between the signal strengths observed at 2300 EST and at 1200 EST, is implicit in the curves presented in Figures 7.6 to 7.13. In order to bring out the nature of the variability more clearly however, the differences between the signal levels at the two times are plotted on a month-by-month basis in Figures 7.14 to 7.17.

## 7.3 F(50,10) – F(50,50) FADING RATIOS

These fading ratios are also implicit in the data presented in Figures 7.6 to 7.13. For clarity, they also have been replotted in Figures 7.18 to 7.21.

## 7.4 EQUATIONS RELATING THE R-6602 PREDICTIONS TO THE NORMALIZED UHF DATA

The curves presented in Figures 7.6 to 7.13, or the equations used to derive them, could be used as correction factors which, when added to the values of signal strength predicted by R-6602, would allow more accurate estimates of the signal strengths actually observed in the Great Lakes area. These refined estimates take account of time of day, month of the year, path length, and percentage of path covered by water.

In order to simplify the application of the required correction factors, relatively simple equations (Table 7.1) were derived whose form approximates the seasonal variation of the curves presented in Figures 7.6 to 7.13. Diurnal variabilities and fading ratios may easily be derived using these equations.

Curves derived from these equations are shown in Figures 7.22 to 7.27 together with the corresponding data, for 100 mile paths, from Figures 7.6 to 7.13. Curves are shown for 0 percent and 100 percent water covered paths. Results for paths having intermediate amounts of water cover should be linearly interpolated from the 0 percent and 100 percent results.

## 7.5 THE VHF DATA

The primary goal of the Great Lakes Project was to gain a better understanding of UHF propagation characteristics in the Great Lakes area. In order to derive supplementary data three VHF stations were monitored at London and three at Ottawa. This small number does not allow the dependence of the differences between predicted and measured values of signal strength to be adequately related to such parameters as path length and percentage of path covered by water. Checks can be made however, to see if the variability of the VHF data is similar to that of the UHF data. There are several ways in which this might be done. In the present report, the following method was chosen:

*TABLE 7.1*

*Equations Representing the Differences Between Observed Values of Signal Strength and those Predicted by FCC R-6602*

**London Data; 100% land paths:**

$$F(50,50)_{obs} = F(50,50)_{6602} - 13.5 + [3.5 \cos 2\pi (H/24) - (6 + 2 \cos 2\pi(H/24)) \cos 2\pi((D - 15)/365)] + 0.3\,(100 - d)\ (dB)$$

$$F(50,10)_{obs} = F(50,10)_{6602} - 15.5 + [7.5 \cos 2\pi (H/24) - (9.5 + 5.5 \cos 2\pi(H/24)) \cos 2\pi((D - 15)/365)] + 0.2\,(100 - d)\ (dB)$$

**London Data; 100% water paths:**

$$F(50,50)_{obs} = F(50,50)_{6602} + 15.5 + [1.5 \cos 2\pi(H/24) - 4\,(\cos 4\pi((D - 30)/365) + \sin 2\pi((D - 30)/365)] + 0.3\,(100 - d)\ (dB)$$

$$F(50,10)_{obs} = F(50,10)_{6602} + 8.5 + [2.5 \cos 2\pi(H/24) - 6\,(\cos 4\pi((D - 45)/365) + \sin 2\pi((D - 45)/365)] + 0.2\,(100 - d)\ (dB)$$

**Ottawa Data; 100% land paths:**

$$F(50,50)_{obs} = F(50,50)_{6602} + 1.3 + [4.3 \cos 2\pi(H/24) - (3.8 + 2.8 \cos 2\pi(H/24)) \cos 2\pi((D - 15)/365)] + 0.1\,(100 - d)\ (dB)$$

$$F(50,10)_{obs} = F(50,10)_{6602} - 5.0 + [5.0 \cos 2\pi(H/24) - 3\,(1 + \cos 2\pi(H/24)) \cos 2\pi(D/365)]\ (dB)$$

---

*H represents time of day in hours (EST), D represents day of year, and d represents path length in miles.*

The differences between the measured and predicted signal strengths were averaged on a month-by-month basis over all UHF stations having a given path, i.e., the four UHF stations monitored over the Detroit-London path. The difference between the measured signal strength of the Detroit VHF station and the signal strength as predicted by the appropriate R-6602 curve was also determined. The two differences were then compared by subtracting one from the other. In this way, VHF and UHF stations having identical path parameters are compared. Such VHF/UHF comparisons are shown on a month-by-month basis in Figures 7.28 to 7.31. Data for each VHF station are shown separately. The differences between data from different stations are usually near the probable error of the measurements.

## 8. DISCUSSION OF RESULTS

If the observed values of field strength were accurately measured and were accurately predicted at all times by R-6602, the differences between measured and observed field strengths would be zero and month-by-month plots, such as those shown in Figures 7.1 to 7.4, would show only a single horizontal line at 0 dB. Also, apart from errors introduced by the measurement and analysis procedures, the standard deviations of the station-to-station variability of the field strengths would be zero. Inspection of the Figures makes it quite clear that such is not the case. Figures 7.1 to 7.4 show that significant diurnal and seasonal variations of signal strength are observed, neither of which are taken into account by R-6602.

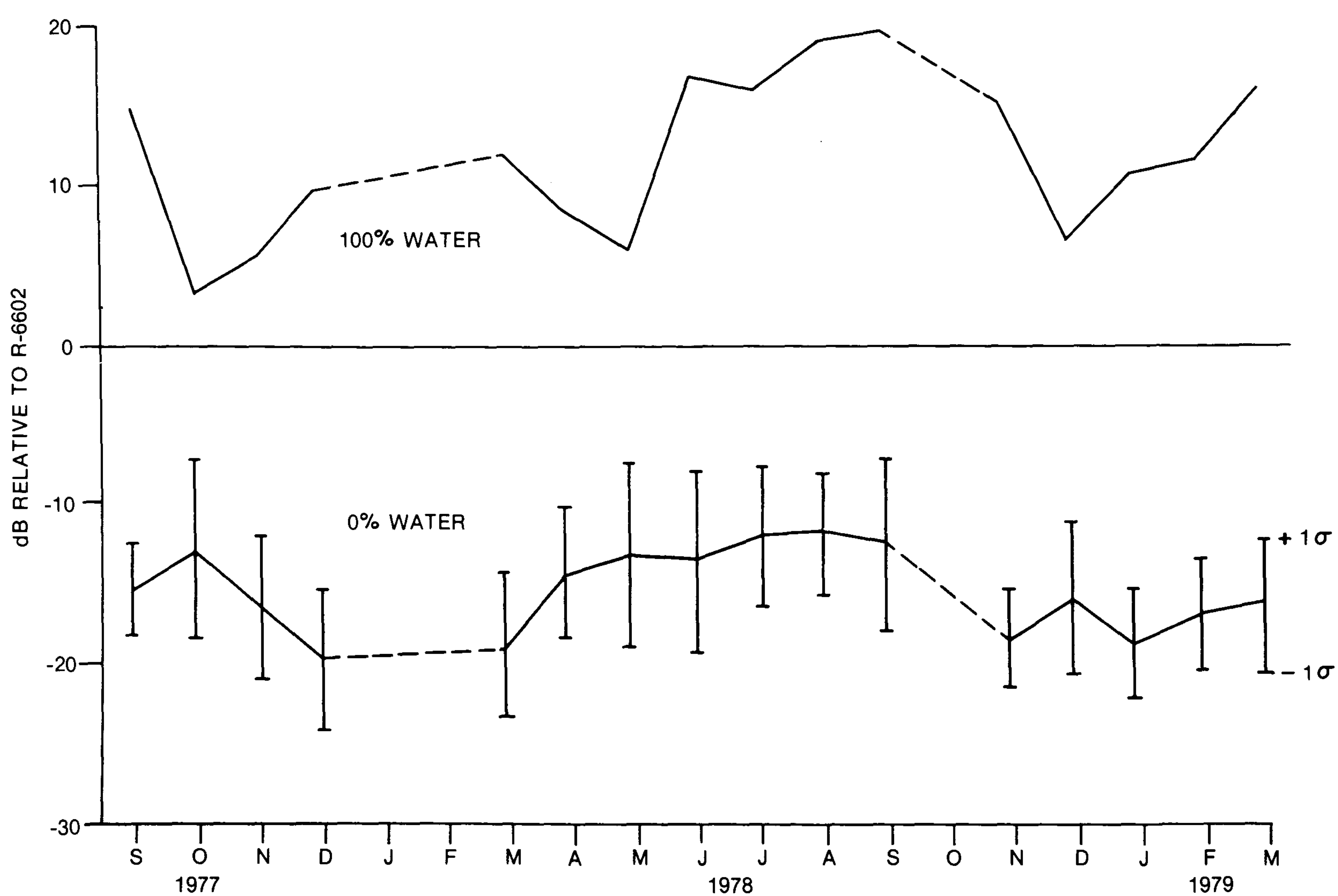


*Figure 7.6. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. In this case data have been normalized to 0 percent and 100 percent water cover and to 100 mile path length. F(50,50) London data recorded at 1200 EST.*

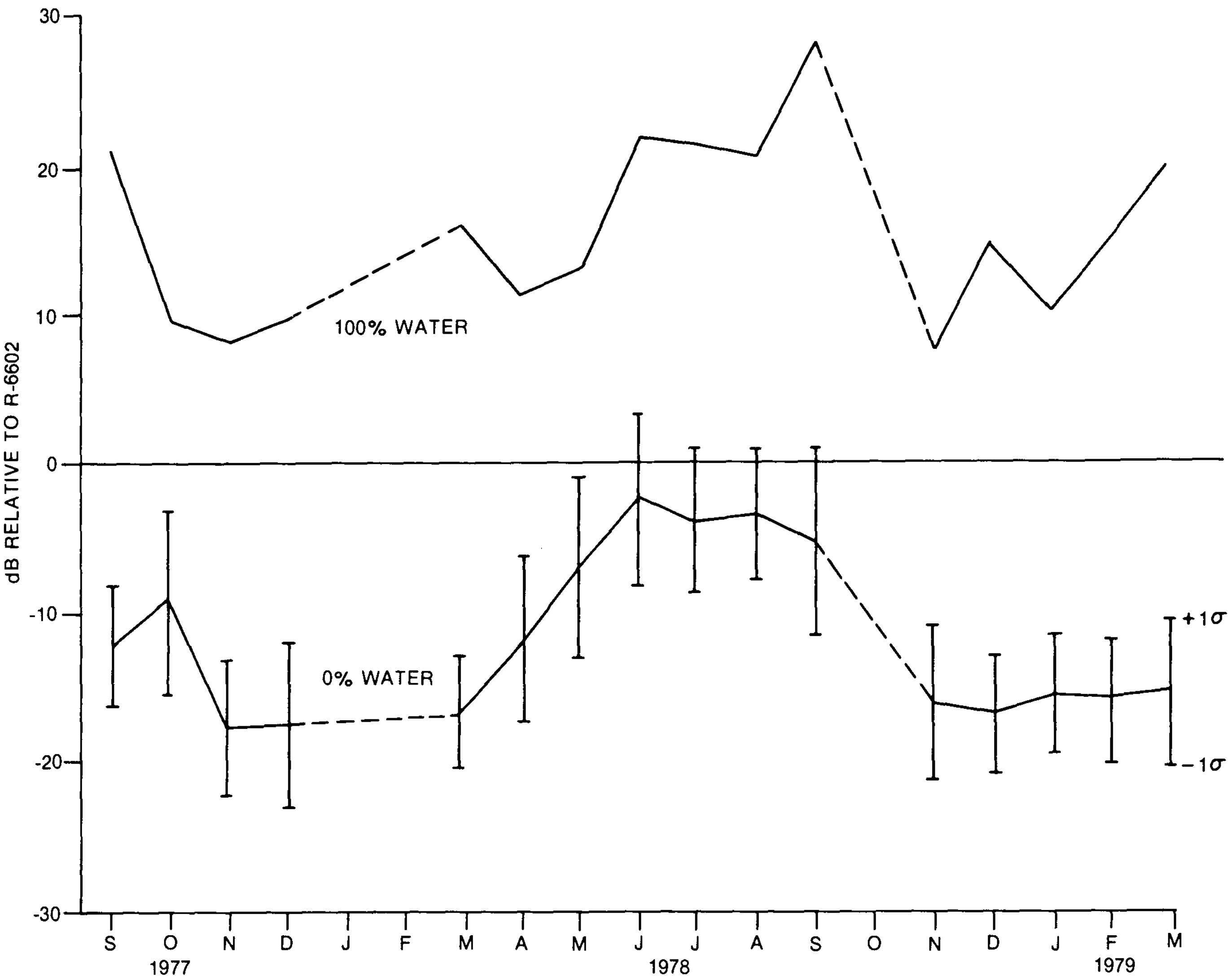


*Figure 7.7. The difference between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. In this case data have been normalized to 0 percent and 100 percent water cover and to 100 mile path length. F(50,50) London data recorded at 2300 EST.*

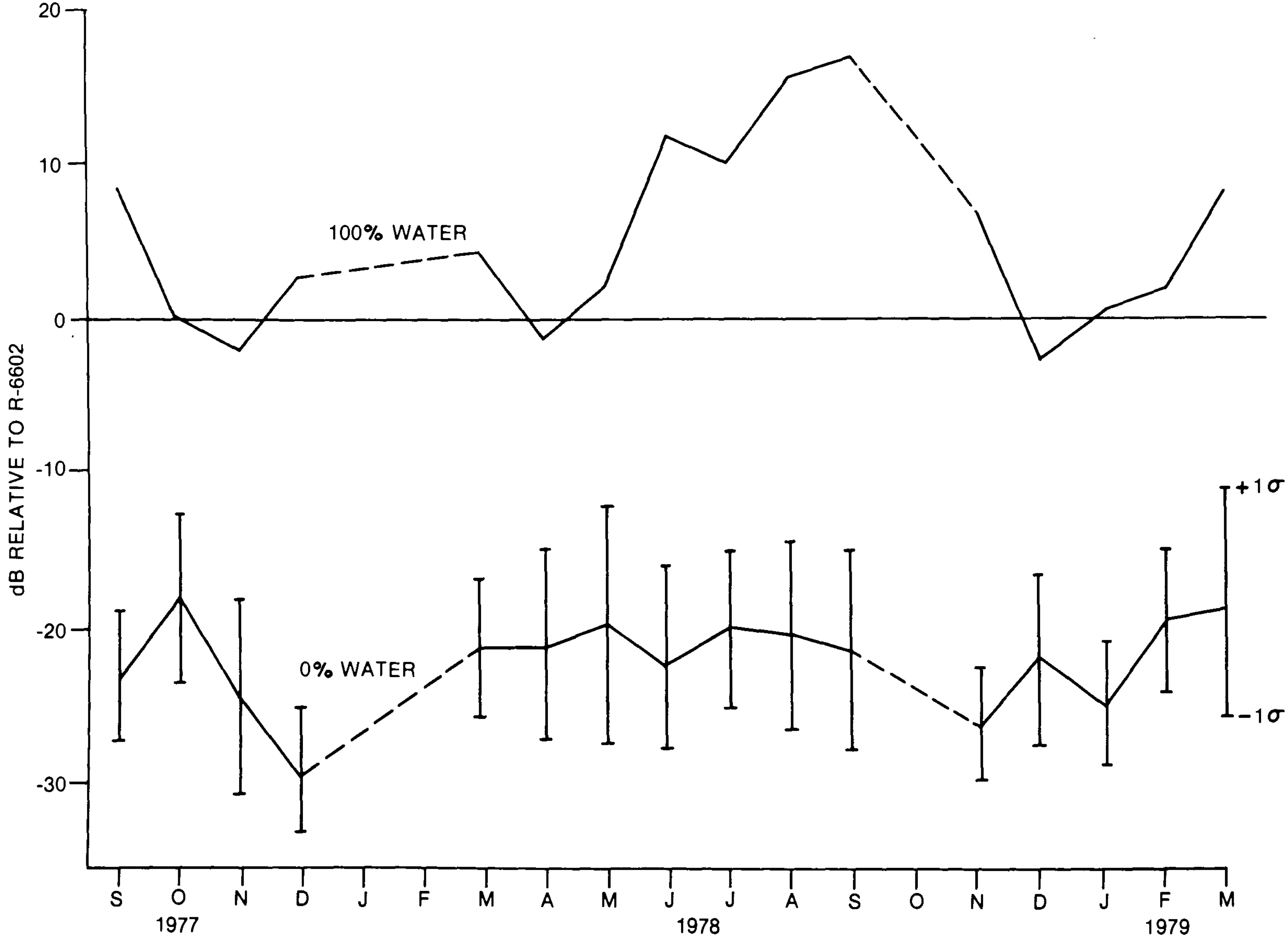


*Figure 7.8. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. In this case data have been normalized to 0 percent and 100 percent water cover and to 100 mile path length. F(50,10) London data recorded at 1200 EST.*

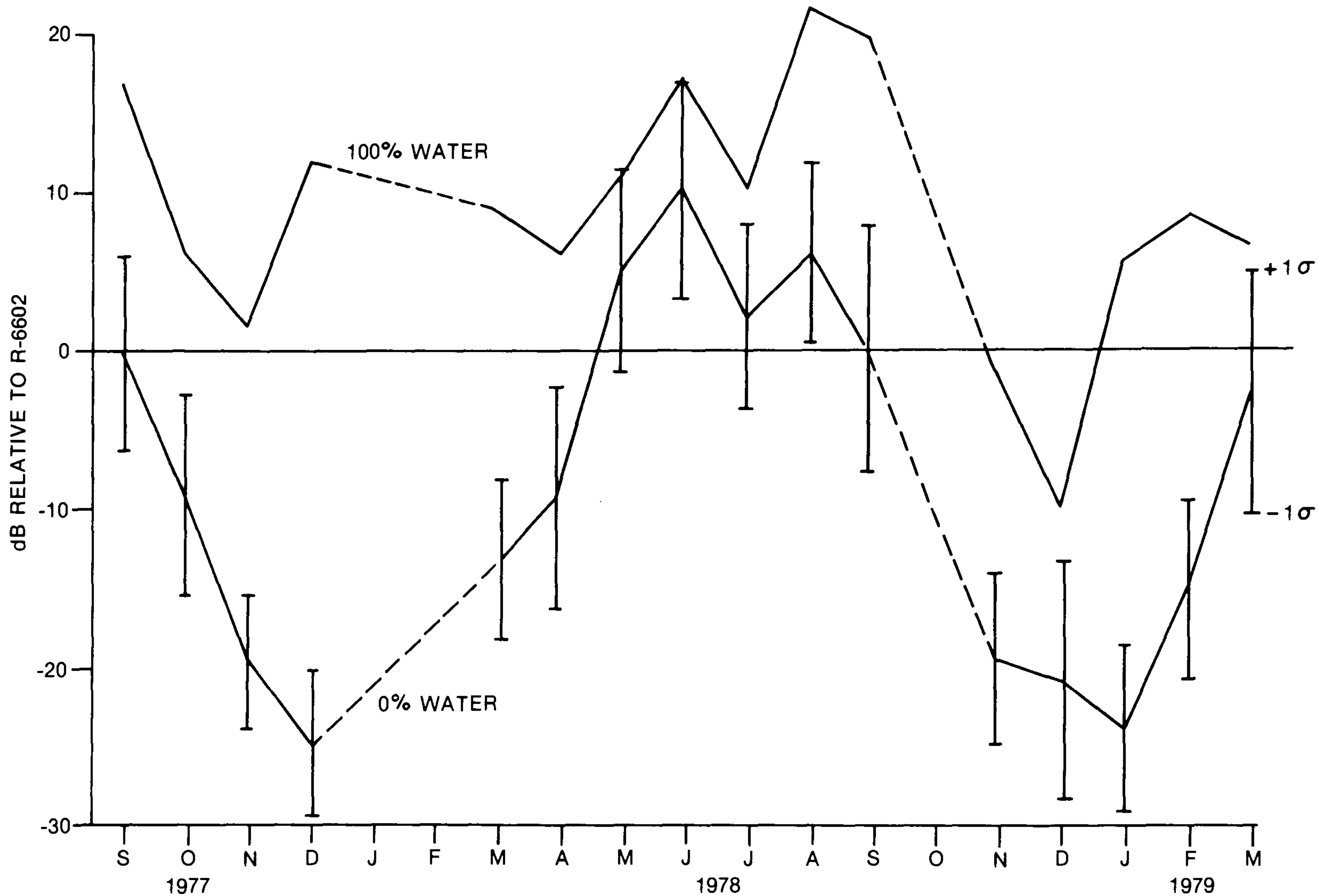


*Figure 7.9. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. In this case data have been normalized to 0 percent and 100 percent water cover and to 100 mile path length. F(50,10) London data recorded at 2300 EST.*

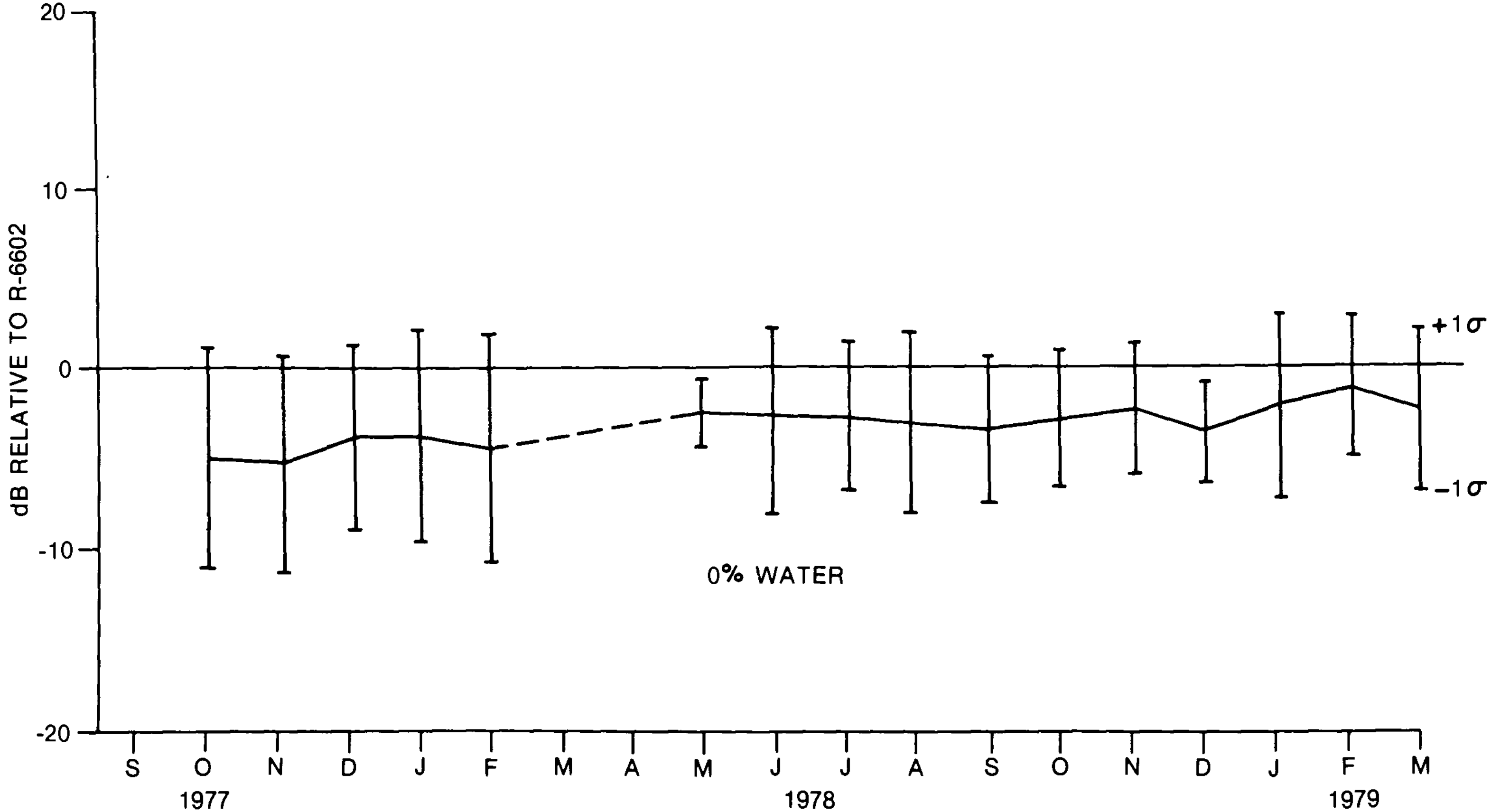


*Figure 7.10. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. In this case data have been normalized to 0 percent and 100 percent water cover and to 100 mile path length. F(50,50) Ottawa data recorded at 1200 EST.*

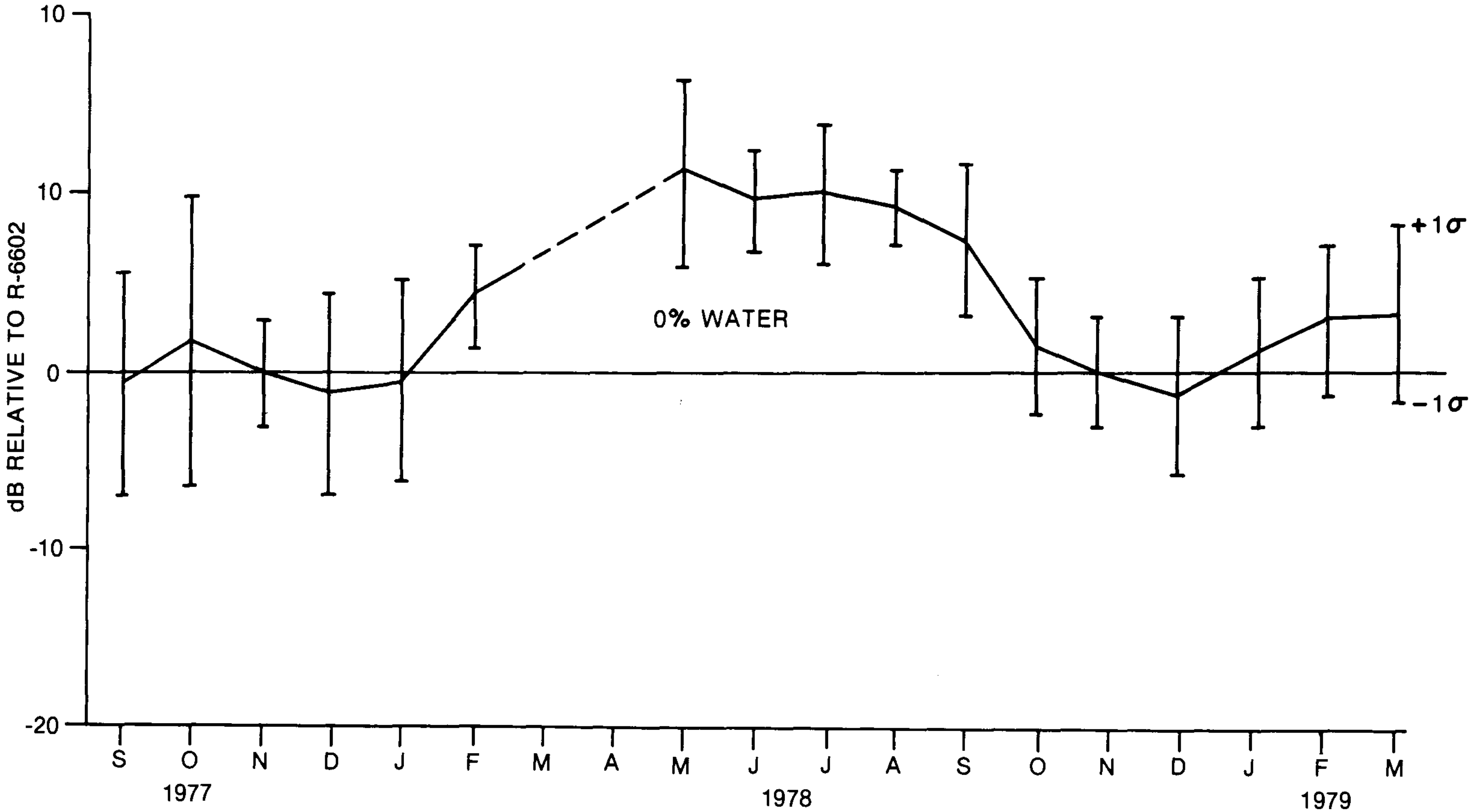


*Figure 7.11. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. In this case data have been normalized to 0 percent and 100 percent water cover and to 100 mile path length. F(50,50) Ottawa data recorded at 2300 EST.*

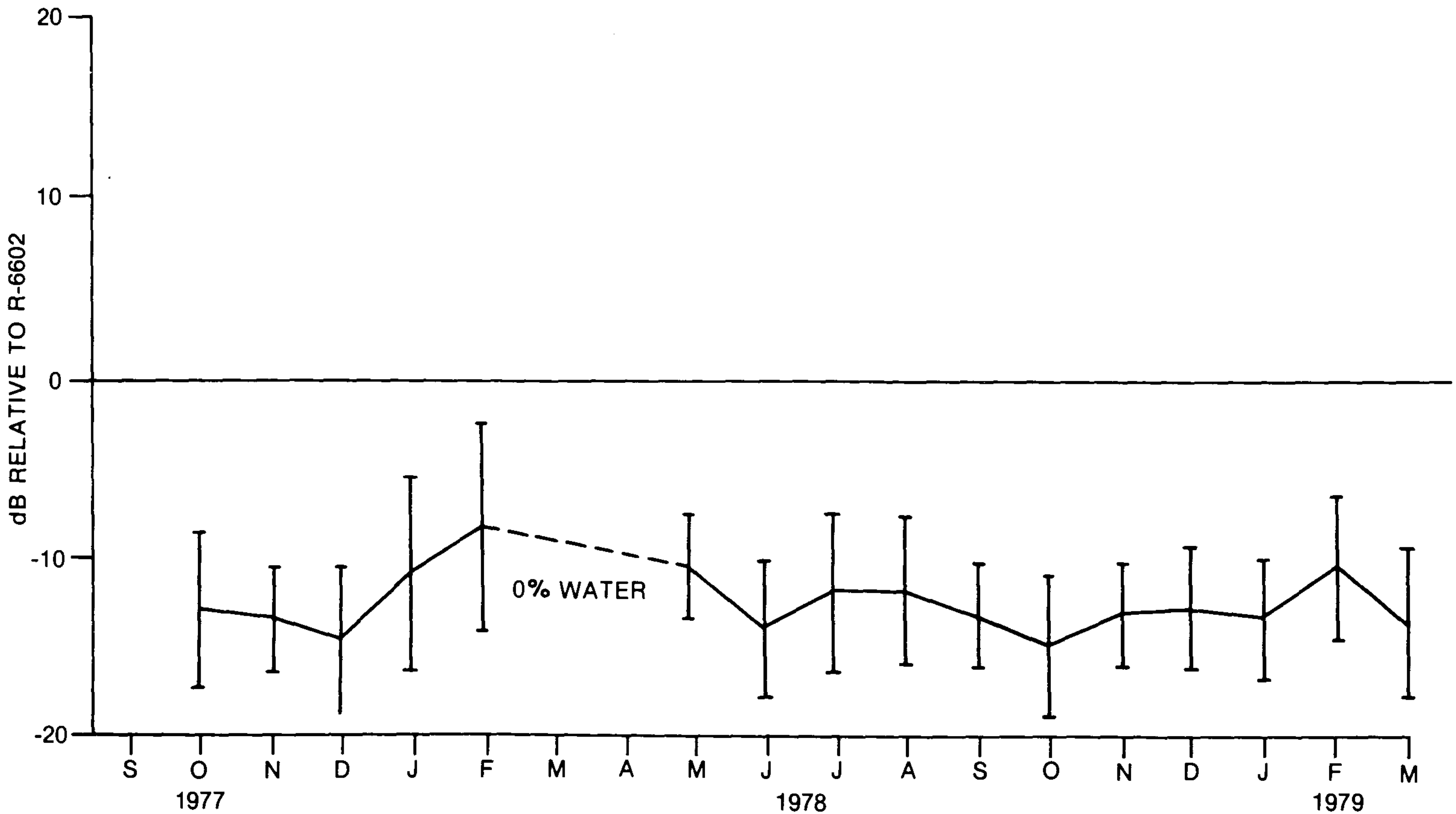


*Figure 7.12. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. In this case data have been normalized to 0 percent and 100 percent water cover and to 100 mile path length. F(50,10) Ottawa data recorded at 1200 EST.*

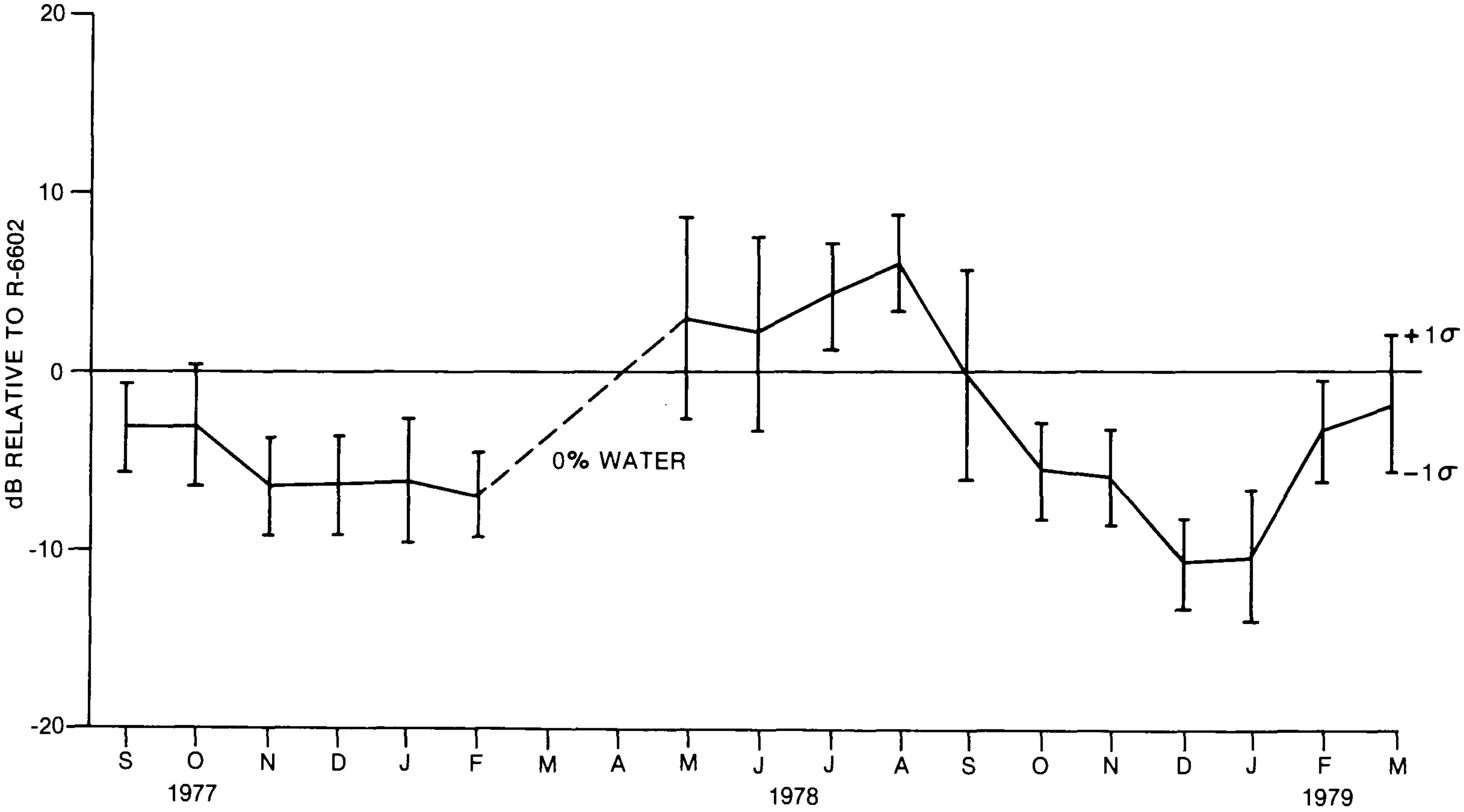


*Figure 7.13. The differences between the measured monthly averaged received powers for each UHF station and the received power levels predicted by R-6602. In this case data have been normalized to 0 percent and 100 percent water cover and to 100 mile path length. F(50,10) Ottawa data recorded at 2300 EST.*

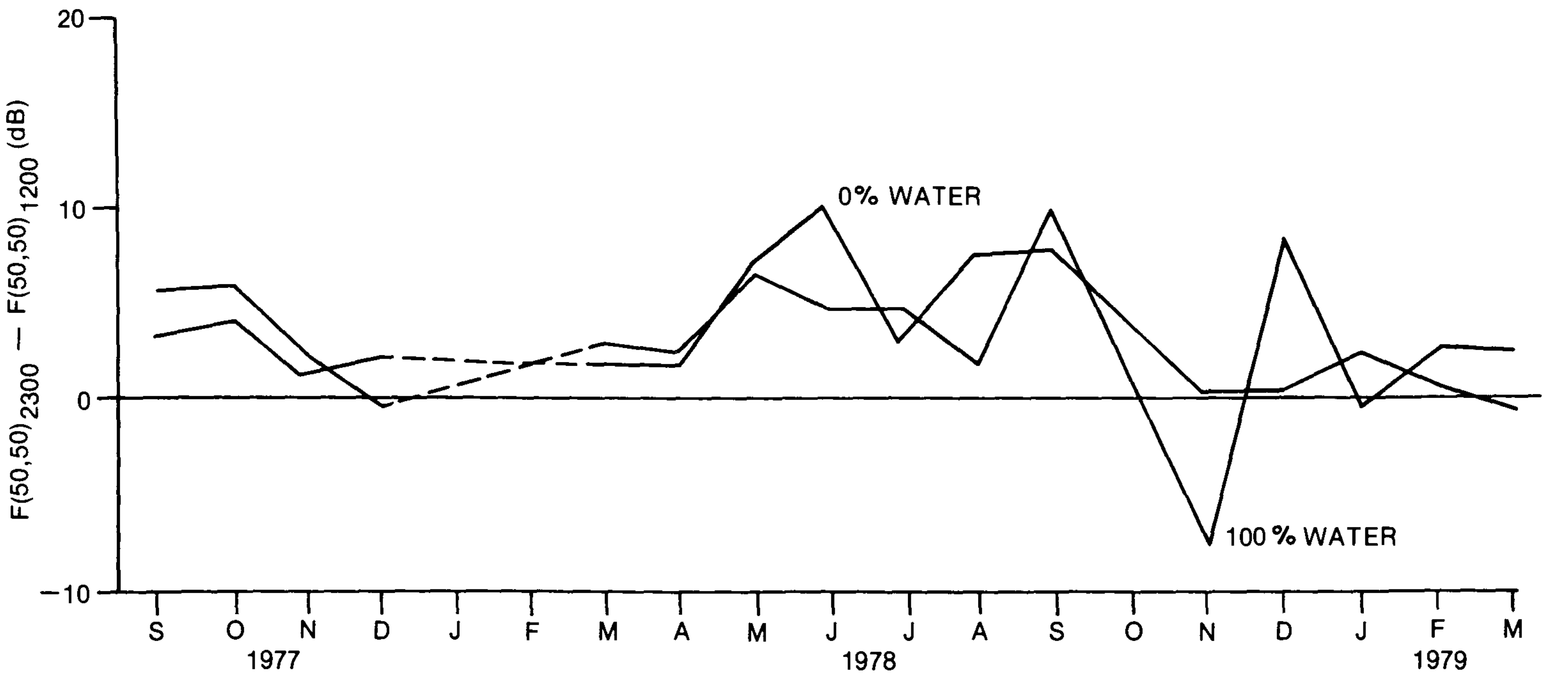


*Figure 7.14. Diurnal variability of the differences between measured and calculated signal levels as a function of time of year. London F(50,50) data.*

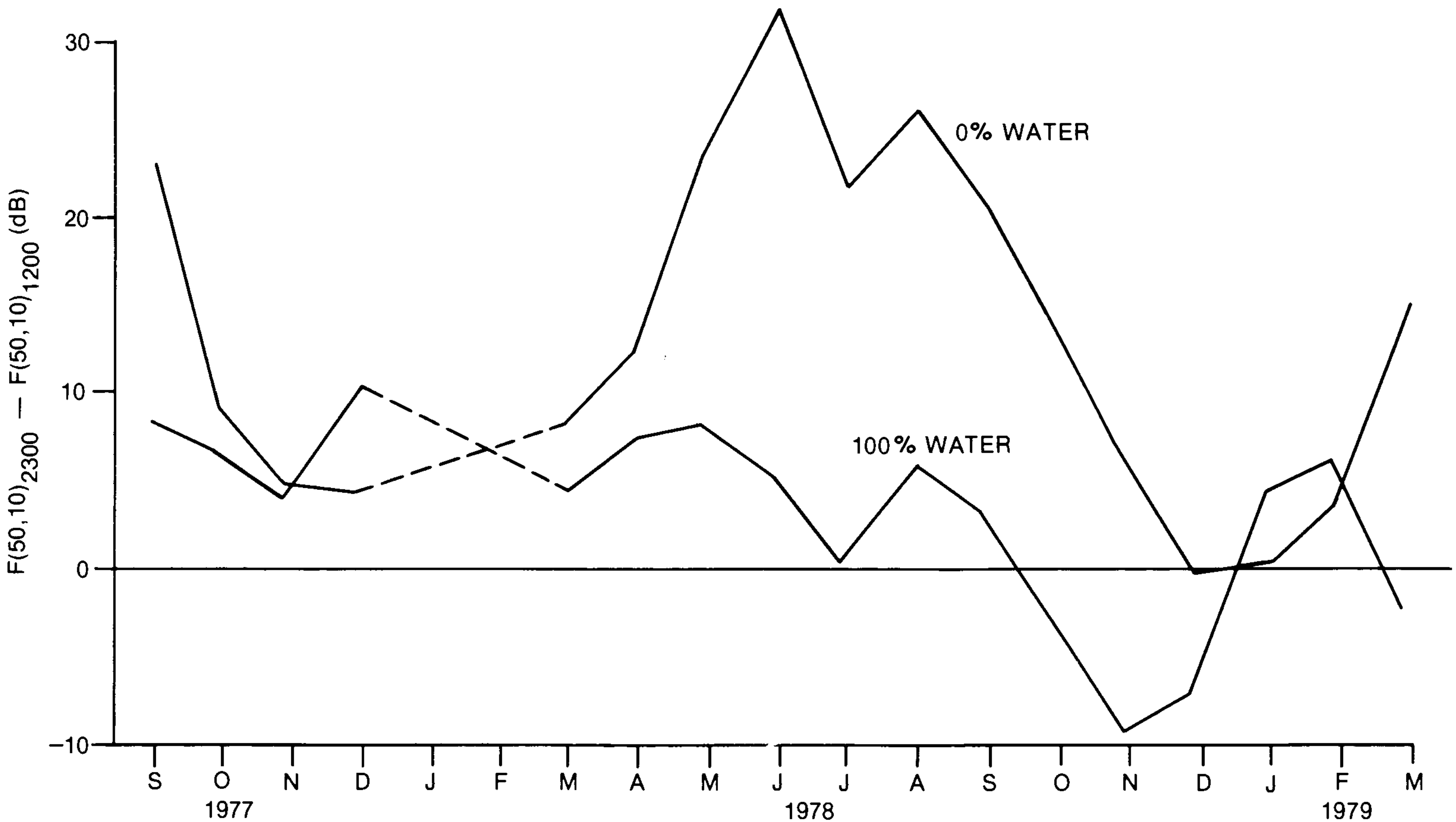


*Figure 7.15. Diurnal variability of the differences between measured and calculated signal levels as a function of time of year. London F(50,10) data.*

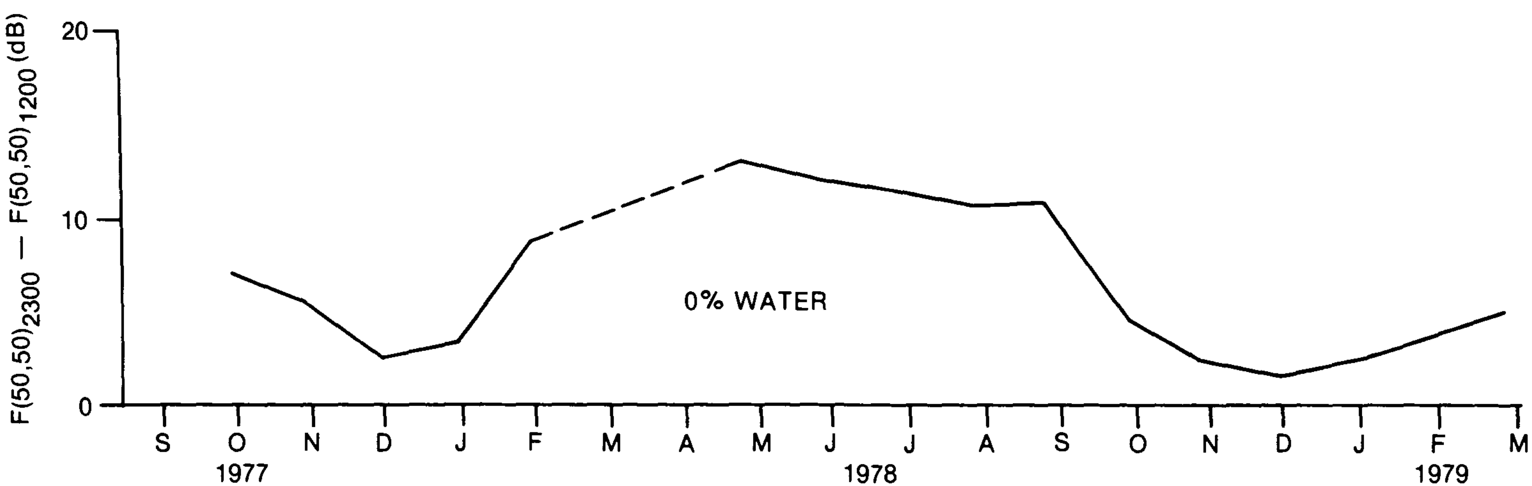


*Figure 7.16. Diurnal variability of the differences between measured and calculated signal levels as a function of time of year. Ottawa F(50,50) data.*

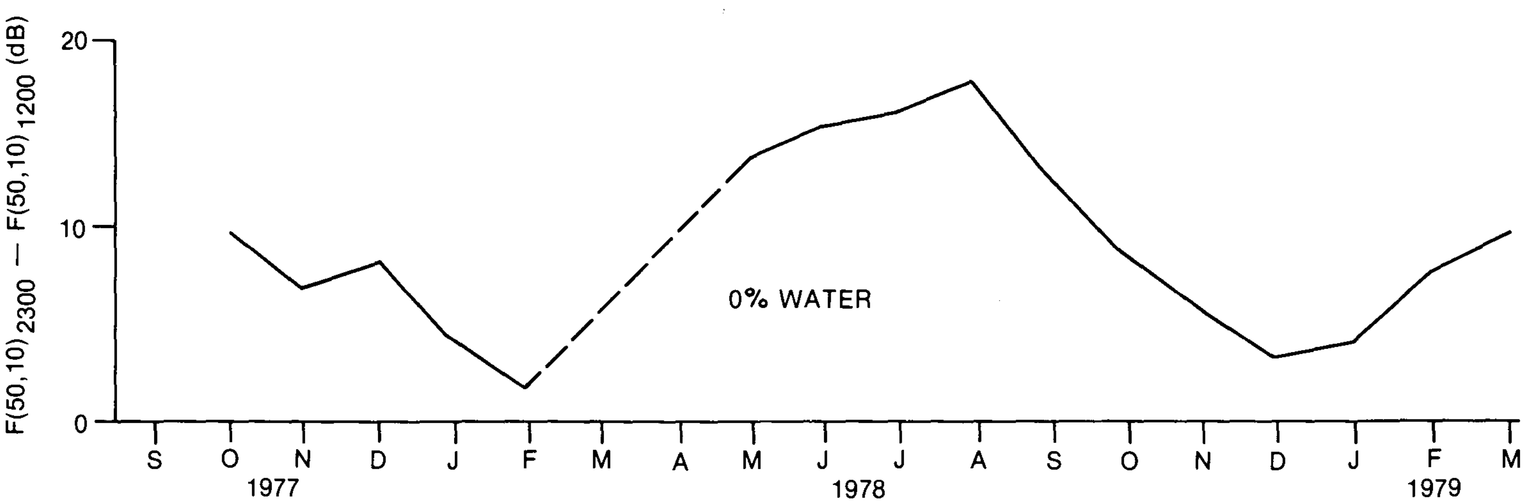


*Figure 7.17. Diurnal variability of the differences between measured and calculated signal levels as a function of time of year. Ottawa F(50,10) data.*

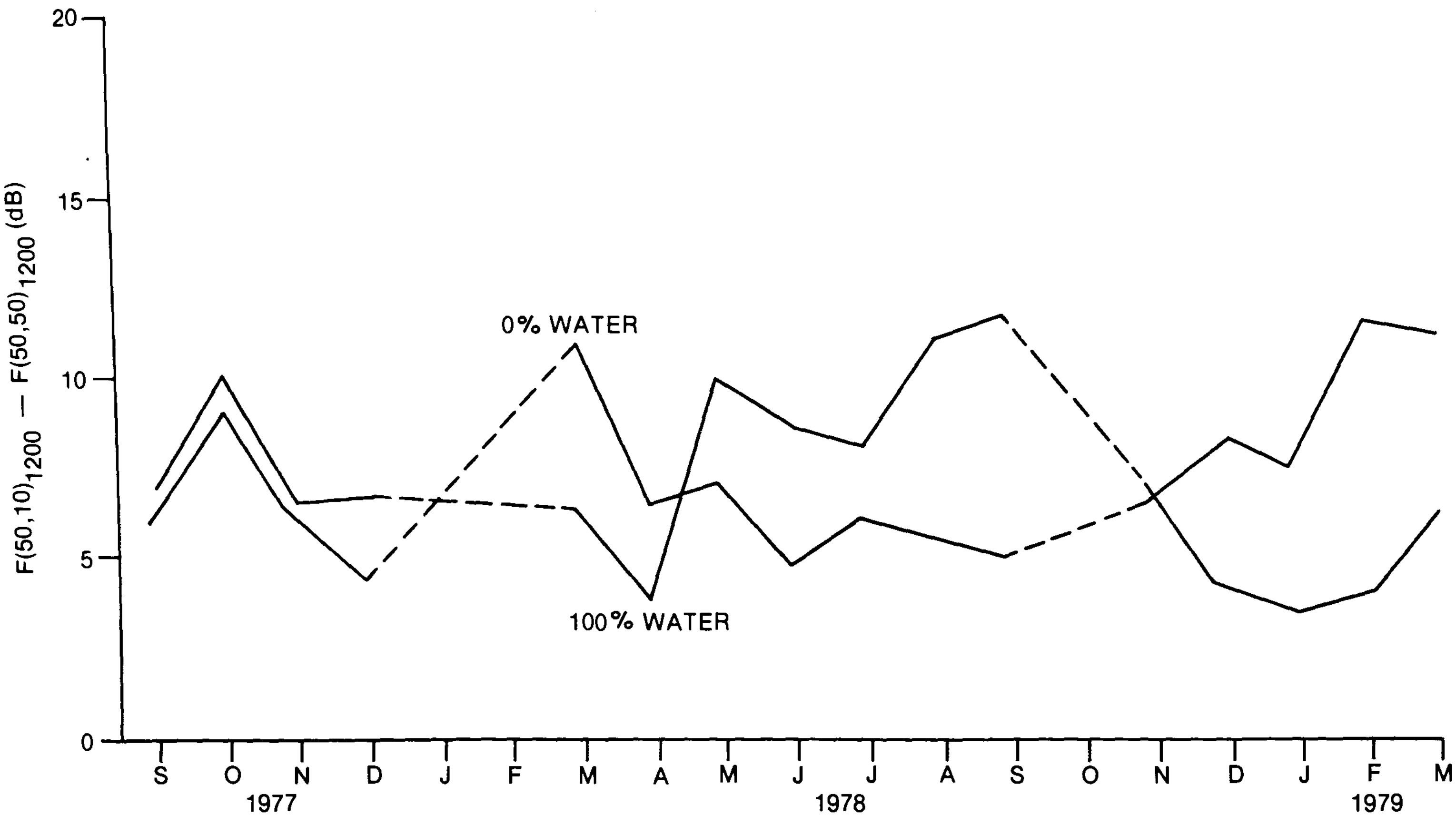


*Figure 7.18. F(50,50) – F(50,10) fading ratios as a function of time of year: London data recorded at 1200 EST.*

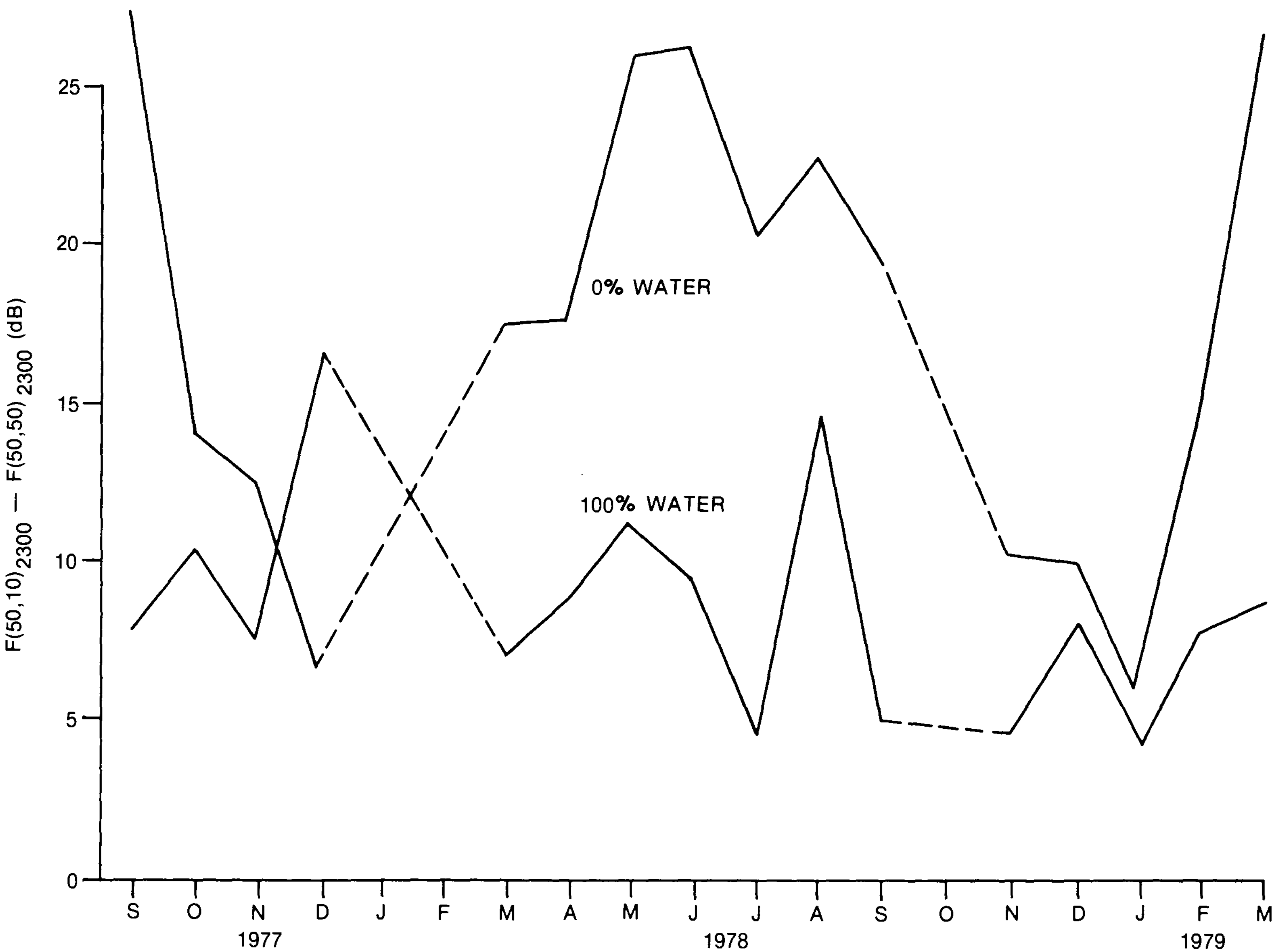


*Figure 7.19. F(50,50) – F(50,10) fading ratios as a function of time of year: London data recorded at 2300 EST.*

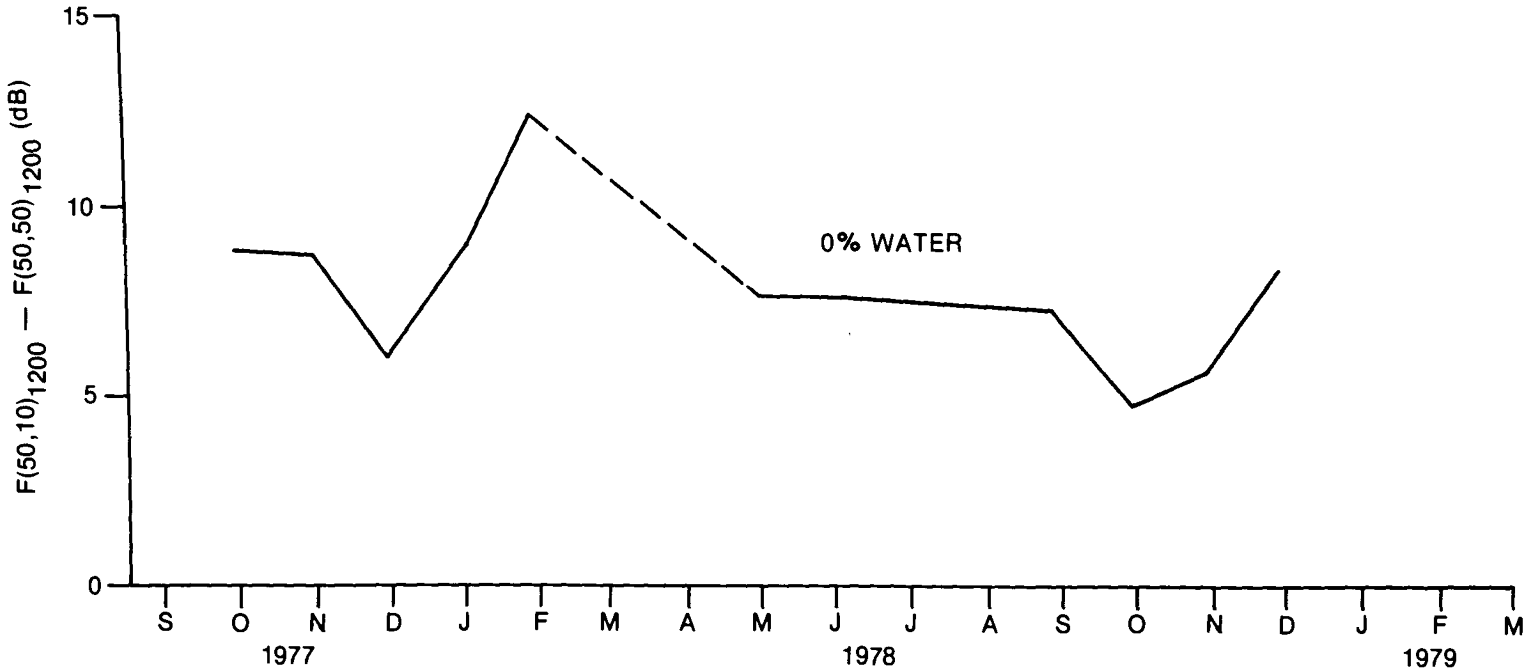


*Figure 7.20. F(50,50) – F(50,10) fading ratios as a function of time of year: Ottawa data recorded at 1200 EST.*

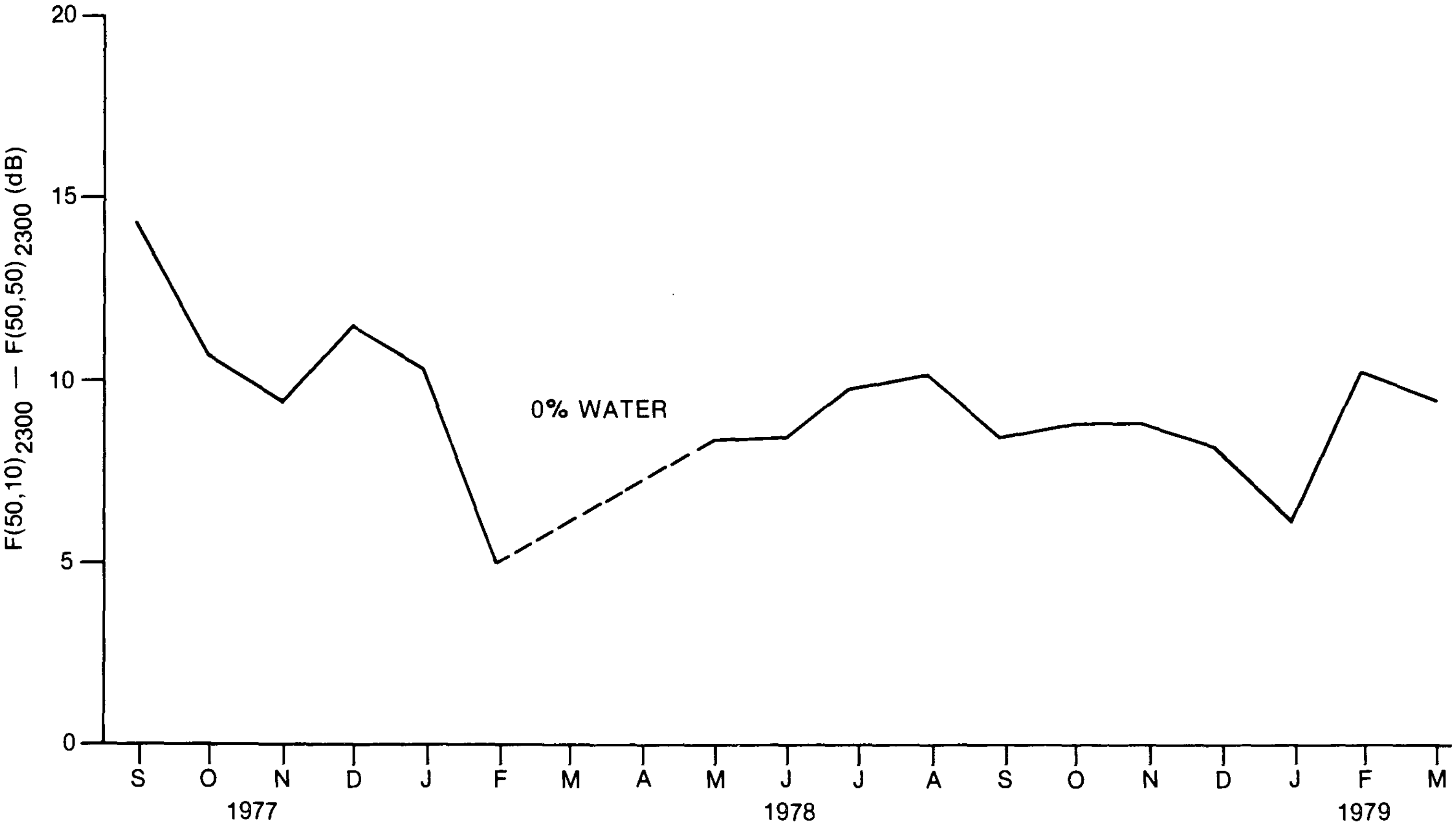


*Figure 7.21. F(50,50) – F(50,10) fading ratios as a function of time of year: Ottawa data recorded at 2300 EST.*

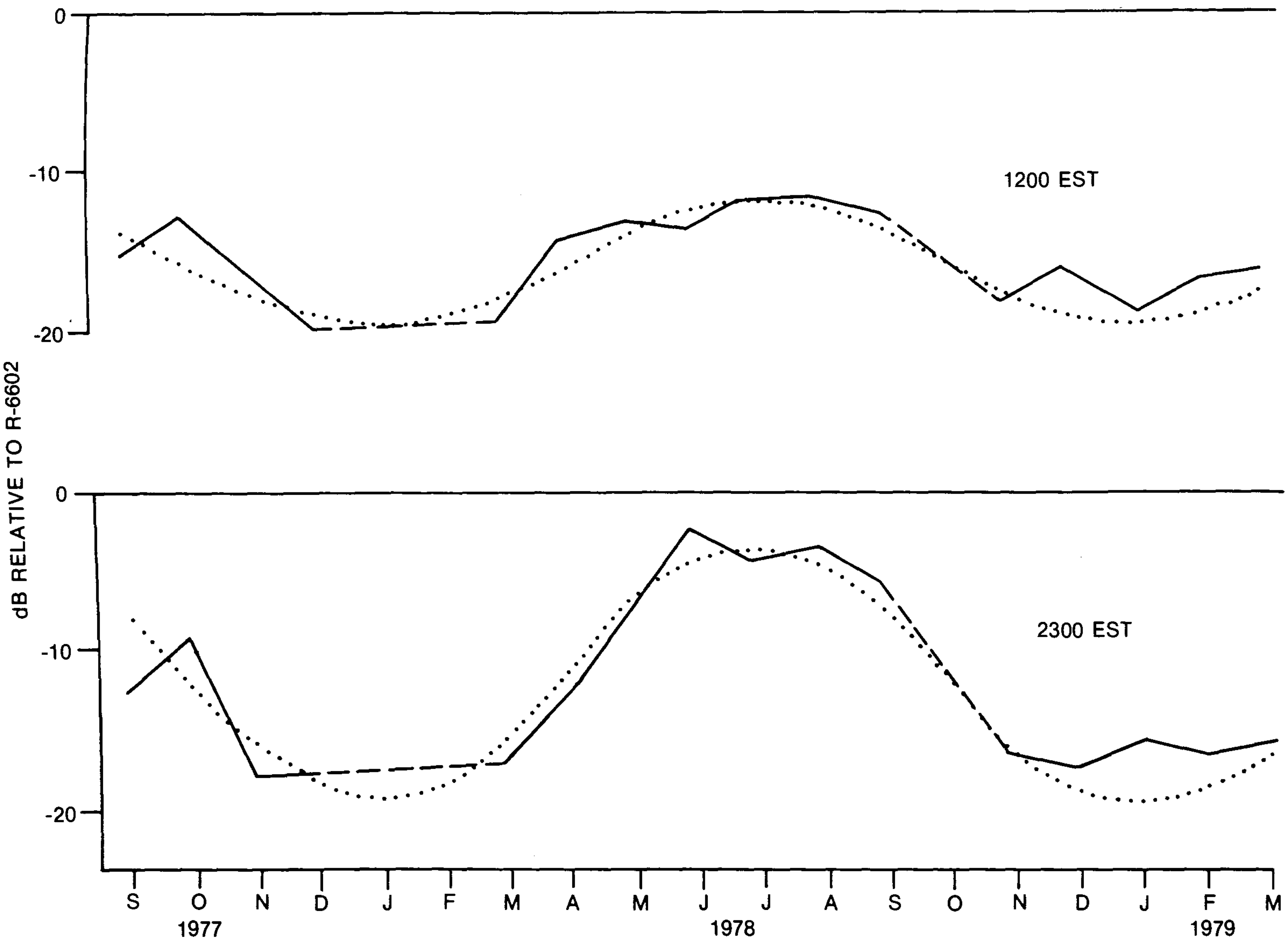


*Figure 7.22. Empirical curves fitted to the data presented in Figures 7.6 and 7.7 for 100 mile paths. London F(50,50) land (0 percent water) paths.*

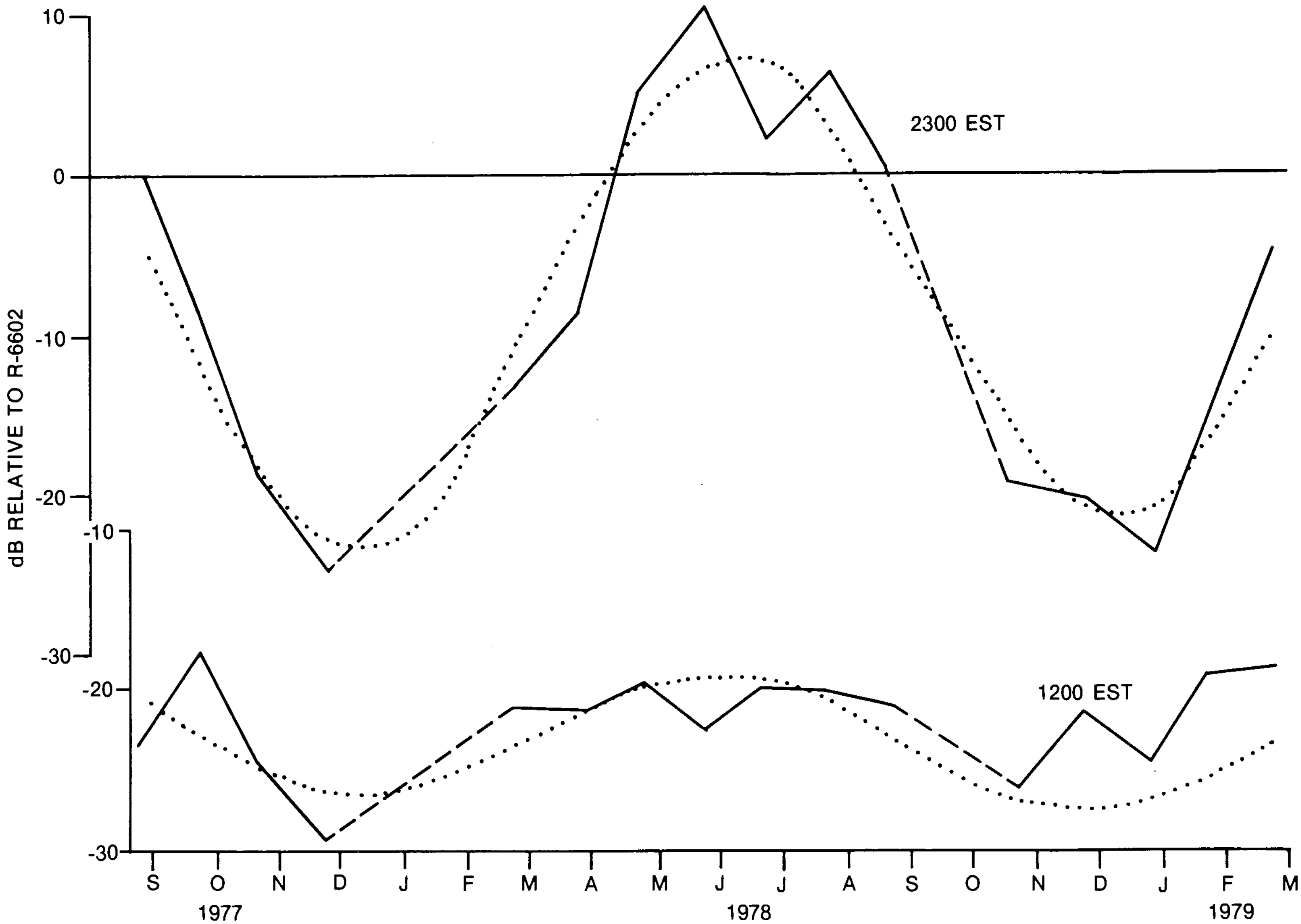


*Figure 7.23. Empirical curves fitted to the data presented in Figures 7.6 and 7.7 for 100 mile paths. London F(50,10) land (0 percent water) paths.*

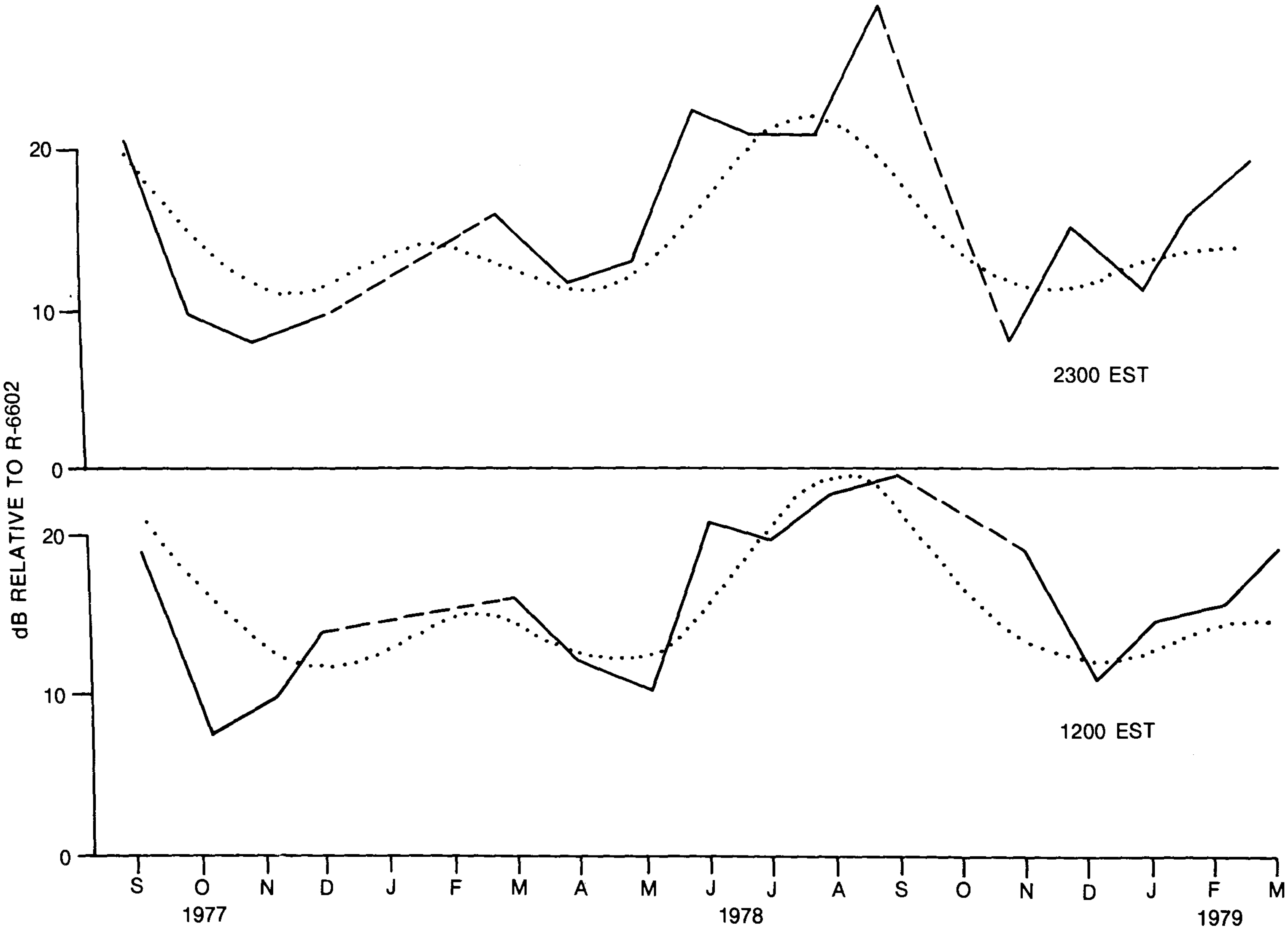


*Figure 7.24. Empirical curves fitted to the data presented in Figures 7.6 and 7.7 for 100 mile paths. London F(50,50) 100 percent water paths.*

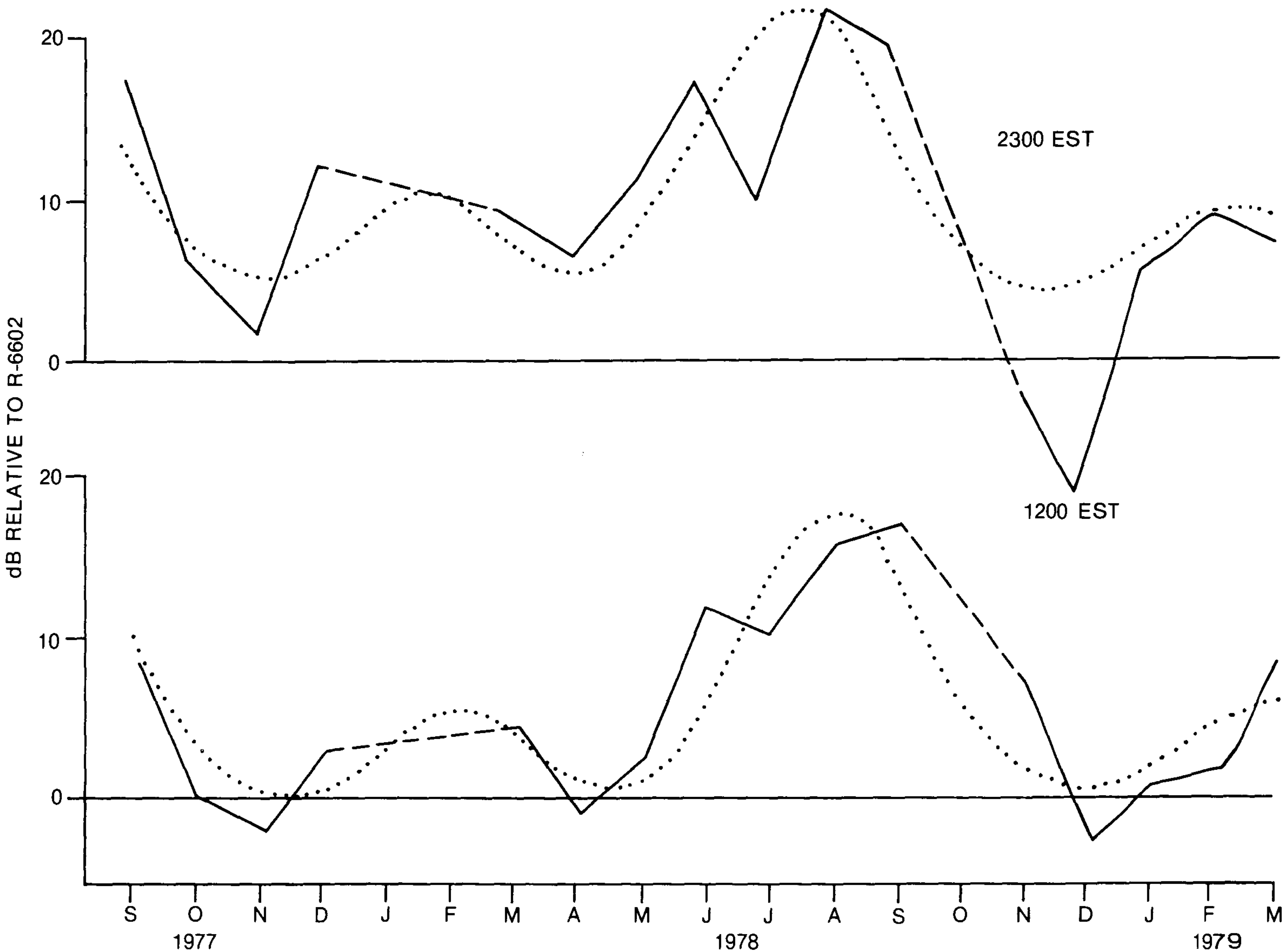


*Figure 7.25. Empirical curves fitted to the data presented in Figures 7.6 and 7.7 for 100 mile paths. London F(50,10) 100 percent water paths.*

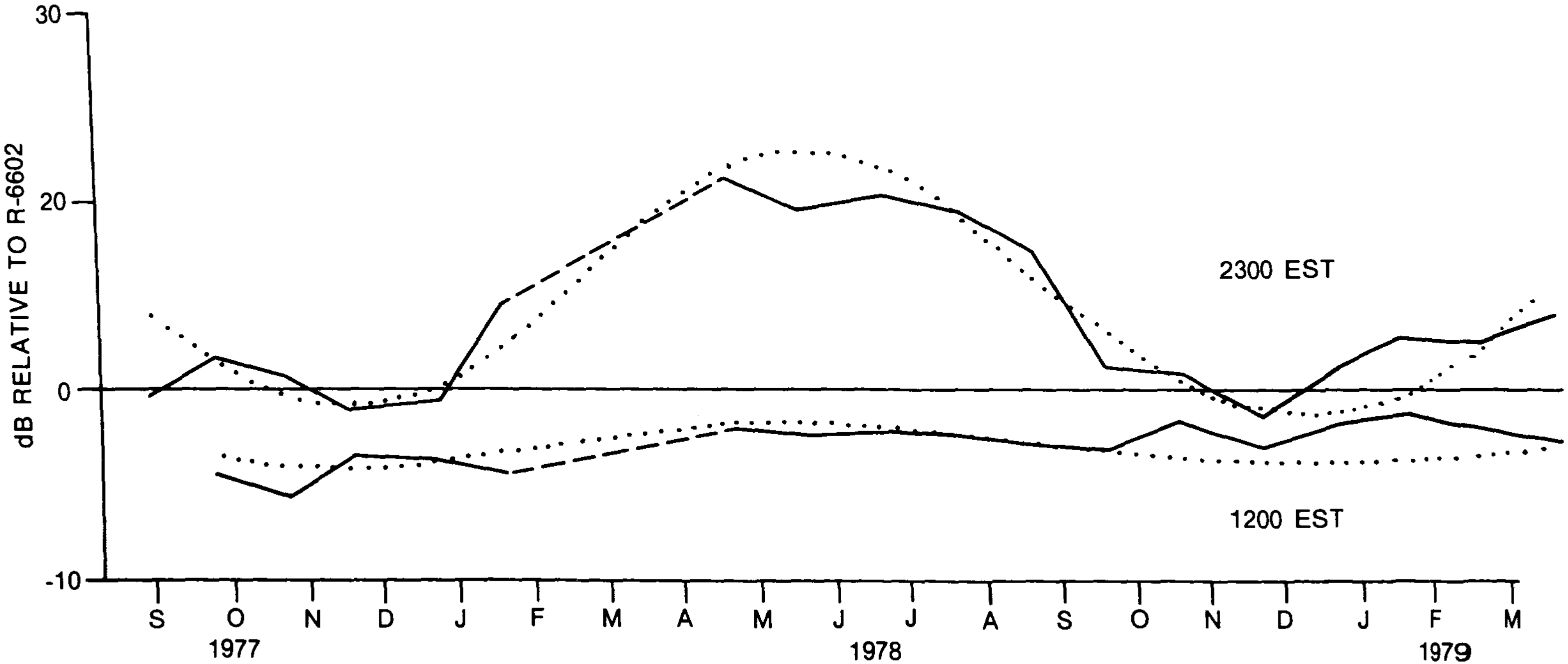


*Figure 7.26. Empirical curves fitted to the data presented in Figures 7.6 and 7.7 for 100 mile paths. Ottawa F(50,50) land (0 percent water) paths.*

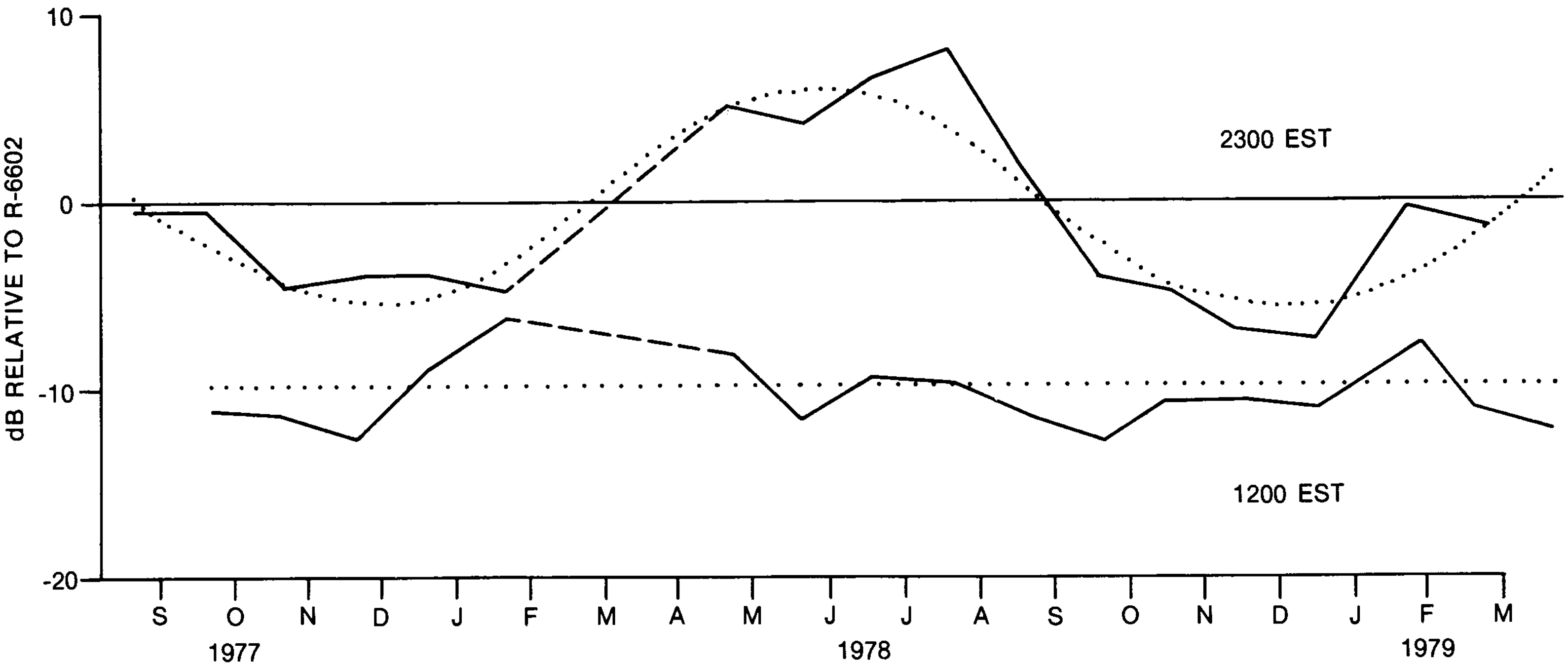


*Figure 7.27. Empirical curves fitted to the data presented in Figures 7.6 and 7.7 for 100 mile paths. Ottawa F(50,10) land (0 percent water) paths.*

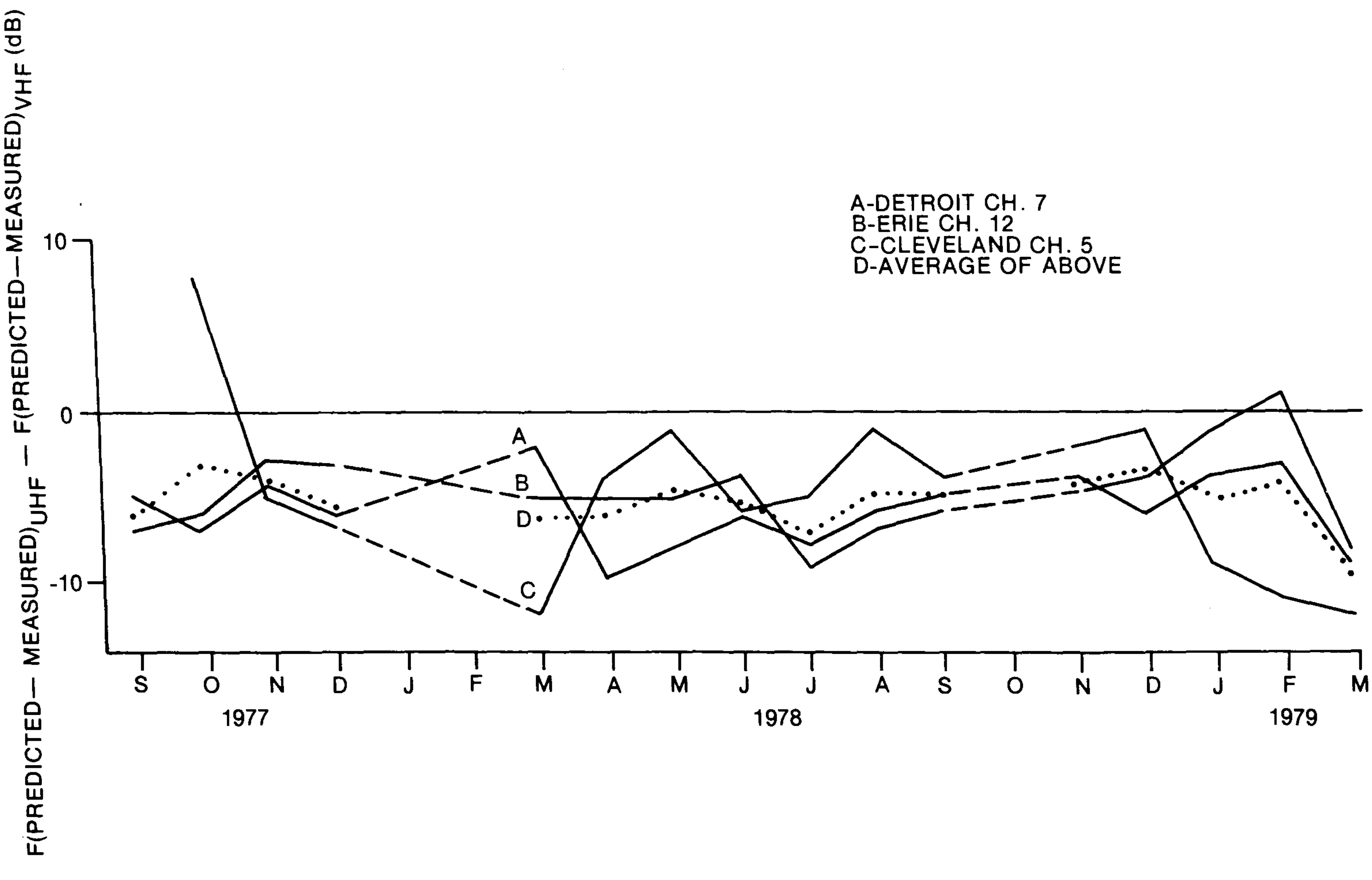


*Figure 7.28. Comparison of observed VHF and UHF signal strengths relative to those predicted by R-6602. F(50,50) 1200 EST.*

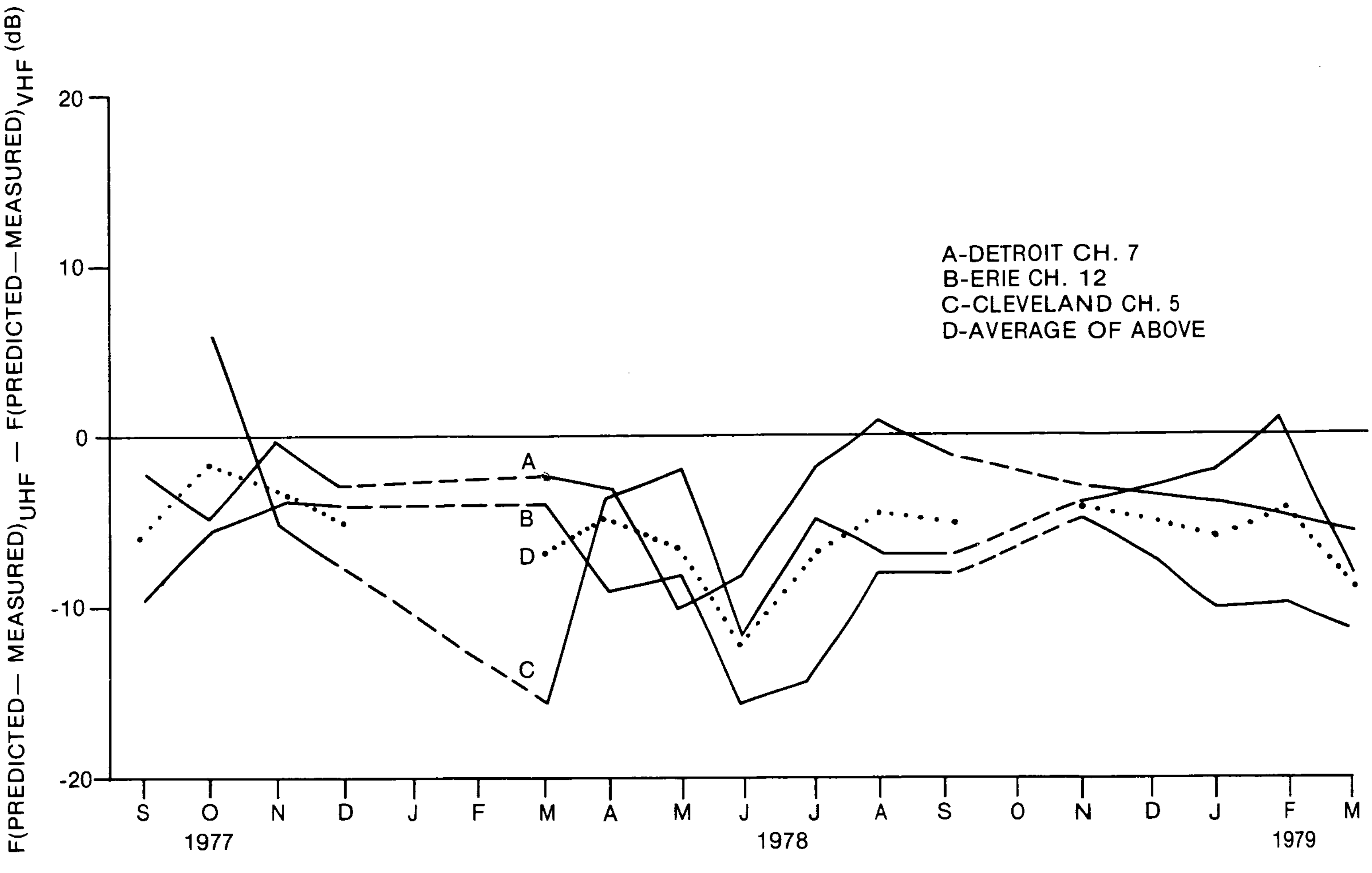


*Figure 7.29. Comparison of observed VHF and UHF signal strengths relative to those predicted by R-6602. F(50,50) 2300 EST.*

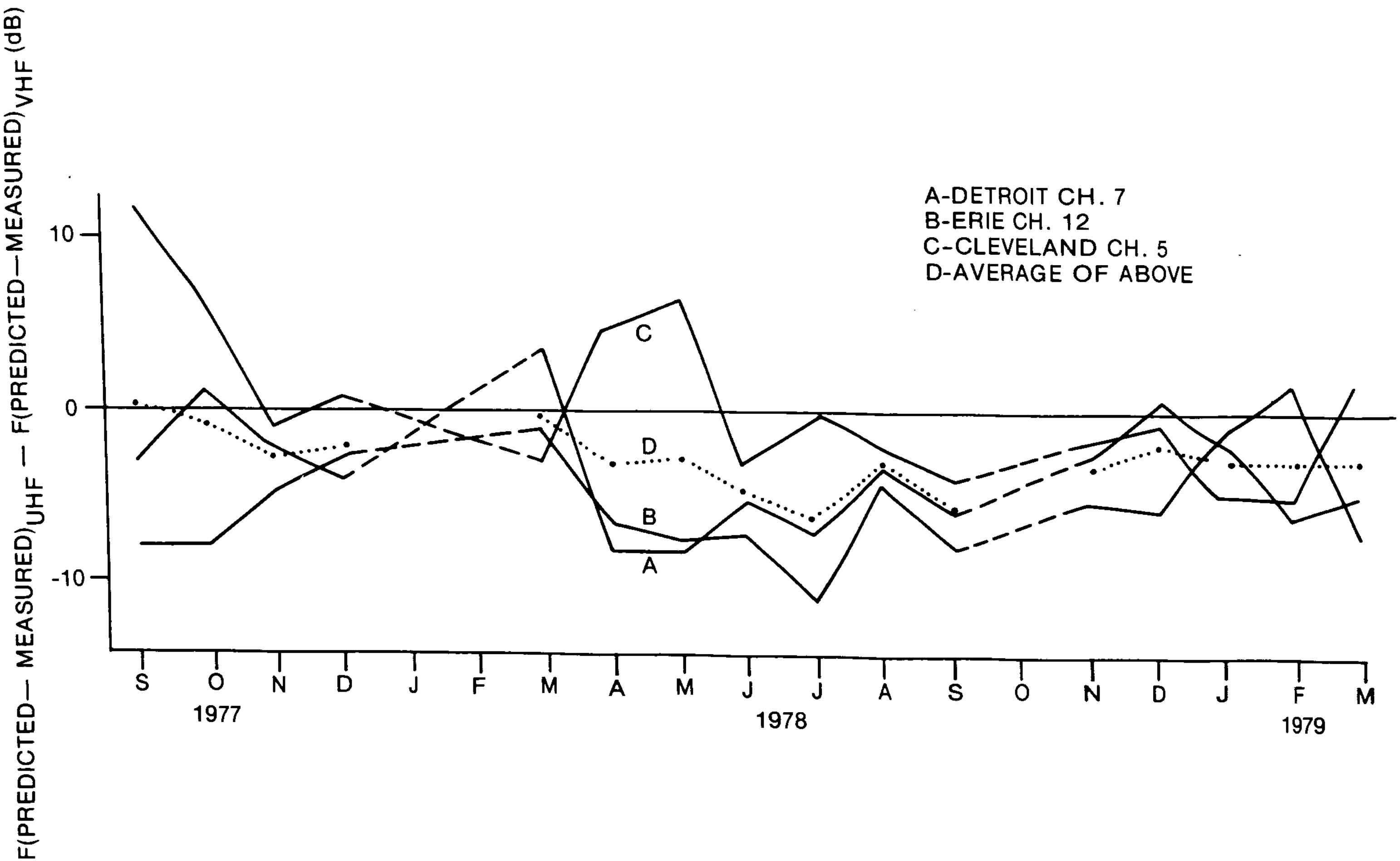


*Figure 7.30. Comparison of observed VHF and UHF signal strengths relative to those predicted by R-6602. F(50,10) 1200 EST.*

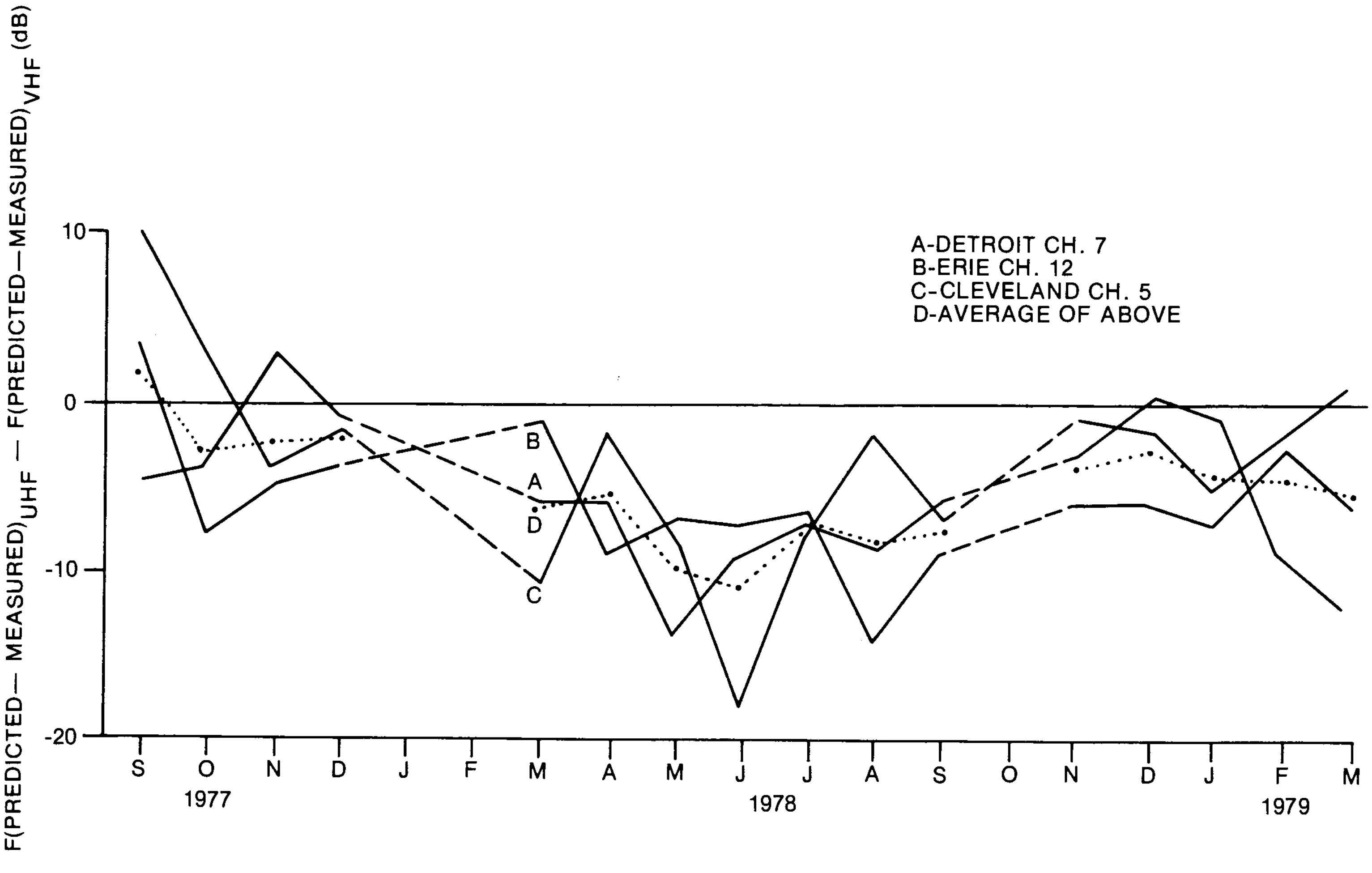


*Figure 7.31. Comparison of observed VHF and UHF signal strengths relative to those predicted by R-6602. F(50,10) 2300 EST.*

The standard deviations have been shown to be significantly reduced if the data are normalized with respect to path length and percentage of path covered by water. Taking transmitting antenna height and frequency into account in a similar way does not result in a significant reduction in the standard deviation. This indicates that transmitting antenna height and frequency are already adequately accounted for by the R-6602 curves but that path length and percentage of path covered by water are not. In fact, percentage of path covered by water is not accounted for at all by R-6602.

By using least squares fitting techniques the month-by-month variability expected between signal strengths predicted by R-6602 and those observed overpaths of different lengths and covered by varying amounts of water can be determined. A number of interesting features are seen in the results which are shown in Figures 7.6 to 7.13, and which are discussed below.

## 8.1 STATION-TO-STATION STANDARD DEVIATION OF DATA

After taking into account path-length and percentage of path covered by water, the station-to-station standard deviation of the data is 4 to 6 dB. Part of this spread, perhaps 2 to 3 dB, is due to measurement and calibration error. The rest is probably due to variations from one station to the next of path and system parameters that have not been taken into account. Terrain roughness is one such parameter that has not been included in the present study. Previous studies carried out at CRC have indicated that the terrain roughness corrections given in R-6602 do not significantly improve the agreement between measured and predicted values of signal strength, particularly when the terrain is relatively smooth as in the present set of measurements.

## 8.2 SEASONAL VARIABILITY

Results presented in Figures 7.6 to 7.13 and summarized in Figures 7.22 to 7.27 show that in all cases signal strengths observed in summer are higher than those observed in winter. Interestingly, 100 percent land paths show only a single annual peak in signal strength while 100 percent water paths show peaks in both winter and summer. The winter peak is about 10 dB lower than that observed in summer. Signal strengths observed on land paths at London are typically 20 dB below those predicted by R-6602 during the winter. During summer, the F(50,10) signal strengths observed at London at 2300 EST rise to 5 to 10 dB above the levels predicted by R-6602, while the corresponding F(50,50) levels rise to about the level predicted by R-6602. Even in summer, the F(50,50) and F(50,10) levels observed at 1200 EST remain 10 to 20 dB below predicted. Similar, though less extreme, behaviour is observed at Ottawa. Here, the F(50,50) and F(50,10) levels observed at 1200 EST remain 5 to 10 dB below predicted throughout the year, with only a slight increase observed during the summer. Signal strengths observed at 2300 EST are 0 to 5 dB below predicted in winter, but rise to about 10 dB above predicted in summer.

## 8.3 DIURNAL VARIABILITY

Diurnal variability of signal strength is shown in Figures 7.14 to 7.17. Statistically, signal levels are invariably higher at 2300 EST than at 1200 EST. In winter, this difference ranges from 2 to 5 dB at both London and Ottawa for land or water paths, and for signal strengths exceeded for both 50 percent and 10 percent of the time. In summer, the diurnal variability is greater at London than at Ottawa, and is greater for land paths than for water paths. Specifically, at London in summer, the 2300/1200 EST difference is about 5 dB for both F(50,50) and F(50,10) data recorded on 100 percent water paths, 5 dB for F(50,50) land paths, but 25 dB for F(50,10) land paths. At Ottawa in summer, the difference is about 10 dB for F(50,50) data and about 15 dB for F(50,10) data. In general, shorter paths (90 miles) show greater diurnal variability than do longer paths (140 miles). These results are summarized in Table 8.1.

## 8.4 F(50,10) – F(50,50) FADING RATIOS

The R-6602 curves predict fading ratios of from 11 to 14 dB for the UHF stations used in the present study. The experimentally determined fading ratios, as a function of path length and percentage water cover, are shown in Figures 7.18 to 7.21. These fading ratios, when averaged over all types of paths and over all times of day and year, are about 12 dB at London and 10 dB at Ottawa. The average experimental values are thus slightly lower than predicted. As in the case of signal strength itself however, significant diurnal and seasonal variations are usually observed. At London, such variations are minimal at 1200 EST (the average fading ratio at that time being about 9 dB), but are considerable at 2300 EST. For 100 percent land paths, fading ratios range, at 2300 EST, from about 10 dB in winter to about 25 dB in summer. For 100 percent water paths, the fading ratios range from about 17 dB in winter to about 7 dB in summer.

Fading ratios measured at Ottawa also show significant seasonal variations. At 1200 EST, fading ratios average about 15 dB in winter and about 7 dB in summer. At 2300 EST on the other hand, the lowest fading ratios are observed in winter, about 5 dB, while the highest, averaging about 12 dB, are found in summer. Overall, there seems to be little consistency between fading ratios observed at different times or over different types of path (land or water). These results are summarized in Table 8.2.

Estimates of signal strengths exceeded for 90 percent of the time, F(50,90), are usually made by assuming that F(50,50)–F(50,90) differences are equal to F(50,10)–F(50,50) differences. The observed behaviour of F(50,90) levels has not been included in the present report. However, superficial examination of the data reveals that diurnal and seasonal variations of the F(50,90) levels are small, and that the F(50,50)–F(50,90) differences are almost always nearly equal to the 1200 EST values of F(50,10)–F(50,50). At 2300 EST, the F(50,50)–F(50,90) differences are usually, especially in the summer months, much less than the corresponding F(50,10)–F(50,50) differences.

*TABLE 8.1*

*Observed Diurnal Variability of Signal Strength*

| | London | | Ottawa |
|---|---|---|---|
| | **100% Water Paths** | **100% Land Paths** | **100% Land Paths** |
| Winter, F(50,50) | 2 – 5 dB | 2 – 5 dB | 2 – 5 dB |
| Winter, F(50,10) | 2 – 5 dB | 2 – 5 dB | 2 – 5 dB |
| Summer, F(50,50) | 5 dB | 5 dB | 10 dB |
| Summer, F(50,10) | 5 dB | 25 dB | 15 dB |

*TABLE 8.2*

*Observed F(50,10) – F(50,50) Fading Ratios*

| | London | | Ottawa |
|---|---|---|---|
| | **100% Water Paths** | **100% Land Paths** | **100% Land Paths** |
| Winter, 1200 EST | 9 dB | 9 dB | 15 dB |
| Winter, 2300 EST | 17 dB | 10 dB | 5 dB |
| Summer, 1200 EST | 9 dB | 9 dB | 7 dB |
| Summer, 2300 EST | 7 dB | 25 dB | 12 dB |

## 8.5 PATH LENGTH

Although path length is one of the input parameters for the R-6602 curves, the observed dependence on path length of the difference between the measured and predicted signal strengths shows that the R-6602 curves do not adequately (in the Great Lakes area at least) model the observed dependence of signal strength on path length. The results summarized in Table 7.1 show that, under all circumstances, the signal strengths expected on shorter paths (90 miles) are higher, relative to the predictions of R-6602, than are those expected on longer paths (140 miles). The (relative) decrease in signal strength with distance is about 0.5 dB/mile for the London F(50,50) data, 0.3 dB/mile for the London F(50,10) data, 0.15 dB/mile for the Ottawa F(50,50) data, and near zero for the Ottawa F(50,10) data. It is seen that the R-6602 predictions represent the Ottawa data better than the London data.

The dependence of the differences between observed and predicted signal strengths was derived from data recorded over paths of differing lengths, the majority of which lay between about 90 and 140 miles. Results were normalized, using linear fits, to paths lengths within this range. Signal strengths expected for paths less than 90 miles, or greater than 140 miles, in length should be extrapolated with great caution from the results presented here.

## 8.6 MIXED PATHS

Expected signal strengths relative to the predictions of R-6602 were extrapolated to paths having 0 percent and 100 percent water cover, as described in Section 7.1.2. The paths actually used in the present study had from 0 percent to 72 percent water cover. Figures 7.6 to 7.13 show that signal strengths expected over completely water covered paths are always higher than those expected over land paths. The differences are, typically, 25 dB. The seasonal variations of signal strength over 0 percent and 100 percent water covered paths are similar except, as noted in Section 8.2, that a secondary seasonal maximum of signal strength is observed in the data from 100 percent water covered paths. At London, signal strengths observed over 100 percent land paths are generally lower than those predicted by R-6602. Conversely, the signal strengths observed over 100 percent water covered paths are generally higher than predicted.

The diurnal variability of signal strengths observed over 0 percent and 100 percent water covered paths is quite similar in the case of F(50,50) data in both summer and winter (Figure 7.14), and in the case of F(50,10) data in the winter (Figure 7.15). The diurnal variability of the F(50,10) data for land paths is, on the other hand, much greater than for water paths during the summer months. In these cases, the diurnal variability can be as high as 30 to 35 dB.

The dependence of fading ratios on percentage water cover was discussed in Section 8.4.

## 8.7 THE VHF DATA

Comparisons of the London VHF and UHF results are shown in Figures 7.28 to 7.31. Results are shown for the Detroit, Erie, and Cleveland VHF stations individually. In all cases, the observed VHF signal strengths are about 5 dB lower, with respect to the appropriate R-6602 prediction curve, than are the corresponding UHF signal strengths observed over the same path. It is suggested therefore, as a first approximation, that VHF signal strengths be determined by applying the UHF correction factors derived in this report (Figures 7.6 to 7.13 or Figures 7.22 to 7.27) to the appropriate R-6602 VHF prediction curves, and then subtracting 5 dB.

## 8.8 COMPARISON OF LONDON AND OTTAWA RESULTS

The two most obvious results of such a comparison are that the seasonal variability of signal strength tends to be much higher at London than at Ottawa and that, while the observed signal strengths at Ottawa are, on average, in reasonable accord with the predictions of R-6602, those observed at London are often, except in summer evenings, considerably below predicted. These points will be further discussed in Section 8.9.

The reasons for the differences between the London and Ottawa data are not clear. A possible explanation is related to the expected higher incidence of ducting at London than at Ottawa. The effective transmitting antenna heights used in this study lie between about 500 and 2800 feet while the receiving antenna heights are about 60 feet above ground level. Since surface ducts are usually a few hundred metres in thickness, the transmitting antenna can, under suitable conditions, lie above a duct while the receiving antenna is within the duct. This situation can lead to a decrease in received signal strength rather than to the expected increase. This explanation requires that stable, well defined surface ducts of less than a few hundred metres in thickness exist at London, particularly over land, during a large fraction of the year. Enhanced evening and summer signal levels would result from increases in duct thickness to include the transmitting antenna, or to changes in duct characteristics so that signals incident upon the duct from above would be easily trapped.

Any such explanation in terms of duct thickness has important consequences if the results contained in this report are to be extrapolated to lower transmitting antenna heights. If stable, well defined surface ducts do exist at London for a significant fraction of the time, then transmitting antennas of less than, say, 300 feet in height would lie within the duct at all times. In this case, the diurnal and seasonal statistics of signal strength, and of the differences between measured and predicted signal strengths, could be quite different from those presented here. If such extrapolations are required, it would be worthwhile to carry out a relatively small measurement program at London in which the signal strengths from two transmitters are monitored. The path and system parameters of the two transmitters would be identical, except for the transmitting antenna heights. One antenna should have an effective height of at least 2000 feet while the other should have an effective height of less than 300 feet. The behaviour of the relative signal strengths would place limits on possible ducting models such as described above, and would enable the results of this report to be more confidently extrapolated to lower transmitting antenna heights.

### 8.9 ANALYTIC APPROXIMATIONS TO THE RESULTS

These approximations are illustrated in Figures 7.22 to 7.27. They are intended to give a first estimate of the actual observed signal strengths in the Great Lakes area, and are suitable for use with portable programmable calculators. The expressions were derived using the results for 100 mile paths, and simple correction factors were added to enable extrapolations to other path lengths. The long term averages (over one year) of the differences between observed and predicted signal strengths are, for 100 mile paths, given by the second term (a constant) on the right side of each equation. These values (measured – predicted) are:

| | | | | |
|---|---|---|---|---|
| London | F(50,50) | Land | −13.5 dB | average = +1.0 dB |
| | | Water | +15.5 dB | |
| | F(50,10) | Land | −15.5 dB | average = −3.5 dB |
| | | Water | + 8.5 dB | |
| Ottawa | F(50,50) | Land | + 1.3 dB | |
| | F(50,10) | Land | − 5.0 dB | |

The observed long term average F(50,50) signal strengths, averaged over *both land and water paths*, are seen to be quite close to the values predicted by R-6602. The long term average F(50,10) signal strengths are, on the other hand, somewhat below those predicted by R-6602, i.e., −3.5 dB at London and −5.0 dB at Ottawa.

## 9. SUMMARY

R-6602 predicts single values of received signal strength, exceeded for 50 percent and 10 percent of the time, for given system parameters. These two values may be taken to represent the long term average signal strengths expected at a given receiving site. It is clear from the results presented here that while long term average signal levels are relatively close to those predicted by R-6602, diurnal and seasonal variations of signal strength of up to about 30 dB can occur for paths in the immediate Great Lakes area. Signal strengths were found to be higher at night than during the day and higher in summer than in winter. Diurnal and seasonal variability of signal strength is higher at London than at Ottawa. A difference was expected in view of the different climates at the two locations. An interpretation in terms of duct characteristics was presented and an experiment was suggested that would allow more confident extrapolation of the present results to transmitting antenna heights below 500 feet.

It was found that R-6602 takes adequate account of transmitting antenna height (between 550 and 2800 feet, at least) and frequency, but not of path length and percentage of path covered by water. Empirical equations were presented which relate the signal strengths predicted by R-6602 to those actually observed, and which take into account time of day, day of the year, path length, and percentage of the path covered by water.

## 10. REFERENCES

1. *Interim Technical Standard for Licencing 900 MHz Private Land Mobile Stations in Border Zones*, FCC submission to DOC, June 1976.

2. Damelin, J., et al, *Development of VHF and UHF Propagation Curves for TV and FM Broadcasting*, FCC Report R-6602, September 1966.

# APPENDIX A

## Terms of Reference of Propagation Study

### A1. PROPOSED PROPAGATION MEASUREMENT PROGRAM IN THE GREAT LAKES AND PUGET SOUND REGIONS

At the request of the FCC/DOC liaison working group, on November 16, 1976, FCC staff members from the Office of Chief Engineer, Safety and Special Radio Services Bureau, and Field Operations Bureau met with Dr. R.E. Barrington of the Canadian Department of Communications to discuss the feasibility of conducting a coordinated propagation measurement program in the Great Lakes and Puget Sound Areas.

There was general agreement on the need to collect long-term propagation data in view of the anticipated heavy use of the UHF frequencies in these regions in the TV broadcasting and mobile services on both sides of the border, and the present paucity of long-term data for these regions. The considerable influence of large bodies of water on the meteorology of these regions makes extrapolation of propagation predictions based on data from other areas uncertain. A major concern is the need for reliable statistics of the enhancement of signals beyond the radio horizon due to superrefraction and ducting.

It was agreed that it would be desirable to obtain data from several paths spread throughout the regions, including a number of over-water paths. Although the major interest is in the UHF band, some VHF measurements should be included to facilitate the evaluation of frequency dependent phenomena.

As now visualized, DOC will record the signals of four TV stations at a site in Ottawa and up to 16 stations at London, Ontario. A list of probable stations to be recorded is attached hereto.

The FCC will record at its field facilities in Canandagua, New York; Buffalo, New York; Allegan, Michigan; Seattle, Washington; and possibly Cleveland, Ohio. A list of possible stations to be recorded is attached hereto. The final selection will depend on the availability of recording equipment and the ability to receive a usable signal at the recording site.

Supplemental measurements on some of these stations will be carried out with the use of mobile measurement vans operating out of Canandagua and Chicago.

To the extent feasible all paths will be recorded for one full year commencing May 1977. The data will be analyzed as it becomes available. Since it is expected that maximum signal enhancements due to superrefraction and ducting will occur during the summer, it is expected to have statistics available for the "worst" month by the end of October 1977.

An attempt will be made to correlate signal variations with available meteorology data. The meteorological conditions in 1977 will be compared with long-term averages to determine if 1977 approximates an average year.

Daily logs of the pertinent TV stations will be obtained to ensure adjustments for variations in radiated power.

Every effort will be made to ensure that the DOC and FCC data are analyzed and presented in a similar manner and that the conclusions of the study be based on the consolidated FCC/DOC study data with the objective of issuing a common report available to the public.

## A2. DATA EXCHANGE

Under the terms of reference for this project it was agreed that the data collected in each of the countries involved would be exchanged. To facilitate this a common format for the exchange tapes was developed. This task requires some processing of the data since the receiving and recording systems used in each country are different. It has been agreed that the exchange tapes will be in terms of path-loss rather than field-strength and that only the average path-loss over 5-minute periods will be recorded.

The DOC receivers are sampled many times per second and have a single time constant in the integration system that averages the signal strength between sampling times. The receivers used by the FCC record the quasi-peak level of the signal during a 30 second sampling interval. These differences in integration procedure have been considered at CRC, and it was shown that the two data sets could be made compatible by a simple correction procedure.

Exchange tapes containing dummy sets of data have been produced and the computers that have been used for the routine data analysis have each successfully read them. The actual exchange tapes will not be produced until after the end of the monitoring program when all of the data is available. Since the exchange tapes will only contain 5 minute averages of the measured quantities, all of the data resulting from this program will be contained in a very small number of tapes, i.e., 2–5.

*List of Candidate Paths to be Recorded by the U.S. Federal Communications Commission*

| Channel | Call | Transmitter | Recorder |
|---|---|---|---|
| 8 | CHAN | Vancouver, B.C. | Seattle |
| 62 | KTPS | Tacoma, Washington | Ferndale |
| 78 | Translator | Sheboygan | Chicago/Allegan |
| 11 | CHCH | Hamilton | Canadaigua |
| 16 | WNPE | Watertown | Canadaigua |
| 9 | CFTO | Toronto | Canadaigua |
| 19 | CICA | Toronto | Canadaigua |
| 25 | CBLF | Toronto | Canadaigua |
| 79 | CITY | Toronto | Canadaigua |
| 12 | WICU | Erie | Buffalo |
| 24 | WJET | Erie | Buffalo |
| 54 | WQLN | Erie | Buffalo |
| 50 | WKBD | Detroit | Cleveland |
| 62 | WGPR | Detroit | Cleveland |
| 78 | | Windsor | Cleveland |

*List of Candidate Paths to be Recorded by the Canadian Department of Communications*

| Channel | Call | Transmitter | Recorder |
|---|---|---|---|
| 16 | WNPE | Watertown | Ottawa |
| 57 | WCFE | Plattsburg | Ottawa |
| 17 | CIVM | Montreal | Ottawa |
| 12 | CFCF | Montreal | Ottawa |
| 50 | WKBD | Detroit | London |
| 7 | WXYZ | Detroit | London |
| 22 | CKGN-1 | Windsor | London |
| 43 | WUAB | Cleveland | London |
| 5 | WEWS | Cleveland | London |
| 24 | WJET | Erie | London |
| 54 | WQLN | Erie | London |
| 12 | WICU | Erie | London |
| 9 | CFTO | Toronto | London |
| 25 | CBLFT | Toronto | London |
| 79 | CITY | Toronto | London |
| 29 | WUTV | Buffalo | London |
| 7 | WKBW | Buffalo | London |

# APPENDIX B

## Relation Between Received Power, Field-Intensity, and Path Loss

### B1. PATH-LOSS IN TERMS OF RECEIVED POWER

Path-loss is defined as $L_P = P_T - P_R$ (dB) where $P_T$ and $P_R$ are the powers transmitted and received by omnidirectional antennas at the same location as the actual system antennas. From the above, $P_R = P_T - L_P$.

If gain antennas are installed at each end of the link, the received power is increased:

$$P_R = P_T + G_T + G_R - L_P$$

where $G_T$ and $G_R$ are the transmitting and receiving antenna gains relative to an isotropic radiator. If the antenna feeder lines are of any length, the received power is decreased:

$$P_R = P_T + G_T - L_T + G_R - L_R - L_P$$

where $L_T$ and $L_R$ are the transmitter and receiver line-losses. The effective radiated power (ERP) of a station is defined as

$$ERP = P_T + G_T - L_T$$

so that one can write, with a slight re-arranging of terms:

$$L_P = ERP + (G_R - L_R) - P_R \qquad \text{(dB)}$$

### B2. PATH-LOSS IN TERMS OF FIELD-INTENSITY AT THE RECEIVER SITE

In terms of the field-intensity $E_o$ at the location of the receiving antenna, the power flux P′ is given by

$$P' = E_o^2/Z_o \qquad \text{Watts/metre}^2$$

where $E_o$ is measured in volts per metre, and $Z_o$ is the characteristic impedance of free-space (120 $\pi$ ohms).

The power intercepted by an omnidirectional receiving antenna is then

$$P_R = P' A = (E_o^2/Z_o) \quad (\lambda^2/4\pi) \qquad \text{Watts}$$

where A is the effective area of the receiving antenna and $\lambda$ is the operating wavelength. This may be written as

$$P_R = 19.0\ E_o^2/f^2 \qquad \text{Watts}$$

where $E_o$ is in volts per metre and f is in megahertz.

Path-loss is defined as $L_P = P_T - P_R$ where $P_T$ and $P_R$ are measured in dBm. In R-6602, it is assumed that the transmitter ERP is 1 kW. We therefore write

$$L = 10 \log (P_T/P_R)$$

$$= 10 \log (1000/(19.0\ E_o^2/f^2))$$

$$= 137.2 + 20 \log f - 20 \log E_o$$

where E is now measured in microvolts per metre. The last line is equivalent to

$$L = 137.2 + 20 \log f - E_o \quad (\text{dB rel. to } 1\ \mu\ \text{V/m})$$

where $E_o$ (dB rel. to 1 $\mu$ V/m) may be read directly off the R-6602 curves.

## B3. FIELD-INTENSITY IN TERMS OF RECEIVED POWER

Equating in expressions derived for path-loss in (B1) and (B2) above, and rearranging terms gives

$$E_o \ (\text{dB rel. to } 1\ \mu\ \text{V/m from R-6602 curves})$$

$$= (137.2 + 20 \log f - ERP - G_R + L_R) + P_R$$

where f is in MHz, ERP in dBm, $G_R$ and $L_R$ in dB, and $P_R$ in dBm.

# CRC DOCUMENT CONTROL DATA

1. **ORIGINATOR:** Department of Communications/Communications Research Centre

2. **DOCUMENT NO:** CRC Report No. 1332

3. **DOCUMENT DATE:** February 1980

4. **DOCUMENT TITLE:** Report on the Great Lakes Propagation Measurement Program: Comparisons of the Canadian Data with the Predictions of FCC R-6602

5. **AUTHOR(s):** F.H. Palmer

6. **KEYWORDS:**
   (1) Propagation
   (2) Great Lakes
   (3) Measurements

7. **SUBJECT CATEGORY (FIELD & GROUP: COSATI)**

   20 Physics
   20 14 Wave Propagation

8. **ABSTRACT:**

In July of 1976 the Canadian Department of Communications (DOC) and the U.S. Federal Communications Commission (FCC) agreed on the establishment of a joint working group to investigate various aspects of bilateral coordination. It was found that there was insufficient propagation data to determine reliably either the interference levels that would be encountered, or the applicability of the existing FCC R-6602 propagation curves, in the region of the Great Lakes. Accordingly, it was decided to conduct a joint study to assess, and if possible resolve, the propagation issues. This report details that portion of the joint study for which DOC was responsible. Attention is confined to comparisons of observed field strengths in the Great Lakes area with those predicted by R-6602, and to an interpretation of the differences in terms of various paths and systems parameters. It is shown that, while the R-6602 curves accurately predict the long term (annual average) values of F(50,50) and F(50,10), they do not take into account observed diurnal and seasonal variations of signal strengths of up to about 30 dB. Qualitatively, signal strengths over all paths are found to be higher at night than during the day and higher in summer than in winter. Empirical expressions are presented which relate the signal strengths predicted by R-6602 to those actually observed, and which take into account time of day, day of year, path length, and percentage of propagation path covered by water.

9. **CITATION:**

Government of Canada Gouvernement du Canada