RADAR TYPE TESTING
REFLECTIVE INTERFERENCE
RADIO ENGINEERING

CONTENTS PAGE

1. INTRODUCTION

A. General

1.01 This section provides theory and instructions for implementation of a frequency modulated radar technique as a method for locating the source of reflections causing cochannel interference on microwave radio paths. This method, which is suggestive of principles employed in radio altimeters, obviates the need for extensive external equipment by using installed, on site, microwave antennas, receivers, and transmitters to locate geographically and identify reflective objects, thereby indicating whether or not mitigating measures are possible or practical. Although experimental data appearing in this section was obtained in conjunction with TD microwave systems, the procedure is universally applicable, provided appropriate changes are taken into account.

1.02 Whenever this section is reissued, the reason for reissue will be indicated in this paragraph.

B. Scope

1.03 The basic frequency modulated (FM) radar method involves modulating a microwave transmitter with an FM sweep signal developed at intermediate frequency (IF) from a highly linear sawtooth (ramp) waveform. The signal arrives at the receiver via a direct (reference) path and a delayed path or paths produced by any reflecting objects. Application of the combined direct and delayed received signals to an amplitude modulated (AM) detector results in the generation of beat frequencies proportional to the delay difference. A spectrum analyzer then examines the detected signal resolving its various frequency components from which the distance of the offending reflective source or sources can be obtained.

1.04 Following this introduction, Part 2 of this section begins with a definitive description of the three major types of cochannel interference encountered on microwave routes. Figure 1 and Tables A and B, which support this discussion, illustrate the various reflective paths responsible for cochannel interference and summarize FM radar configurations and requirements for path analysis. The two basic equipment configurations as required for detection of the three types of interference are also covered. Part 3 then continues with a theoretical presentation of the general FM radar measurement method, while in Part 4 a step-by-step procedural description for the case of adjacent section interference demonstrates the practical application of FM radar technique. Finally, Part 5 presents data from two typical experimental cases, serving to familiarize the user with the practical results of FM radar testing.

2. REFLECTIVE INTERFERENCE

A. Definitions

2.01 The three major types of cochannel interference with which this section is concerned and which are amenable to FM radar analysis are same section, adjacent section, and junction station interference. These are illustrated and defined in Fig. 1 which locates reflecting objects and traces respective signal paths involved in each case. Table A, which supports Fig. 1, specifies the categories of interference as per Fig. 1 signal path nomenclature—for example, paths designated I_A are same section interference with remaining path nomenclature defining specific transmitters and receivers involved. For example, R_{12} is the receiver at station 1 which links with a transmitter at station 2, while C_{21} is the direct ray carrier between stations 2 and 1.

B. Equipment Configurations

Same Section

2.02 Different types of interference require the FM radar method to be implemented in a slightly different way. As indicated in Fig. 1, for same section interference, two transmitters are utilized which are both modulated by the same test signal. Only one receive antenna and one receiver are used and, as indicated in Table B which again refers to Fig. 1, certain adjacent transmitters might have to be turned off.

Adjacent Section and Junction Station

2.03 For adjacent section and junction station interferences, only one transmitter is modulated with the test signal. Two receive antennas are used and their outputs combined at radio frequency (RF) and then amplified by one receiver. As in same section interference, adjacent transmitters may have to be turned off as indicated in Table B.

3. METHODOLOGY

A. General Method

3.01 The following description of the general FM radar method is based on the case of adjacent section interference, which is illustrated in Fig. 2. As shown in Fig. 2, a single transmitter transmits the test signal to two receiving antennas. One antenna receives the direct, or reference signal (referred from Fig. 1 designation as C_{21}), while the other antenna receives the reflected interfering signal, again referred to in Fig. 1 as $I_{B,\ 21,\ 13}$.

3.02 The transmitted FM signal is modulated by a positive, highly linear ramp (or sawtooth) waveform. The direct signal, after attenuation to provide an optimum C/I (carrier-to-interference) ratio, serves as a reference signal and is combined with the delayed signal in an RF hybrid and fed to a common receiver (R_{12} or R_{13} as they appear in Fig. 1 and 2). The reference signal is typically made to be about 20 dB larger than the interference. The receiver IF output is detected by a linear AM detector, which generates the beat frequency or frequencies in proportion to the delay offset between the two signals.

3.03 In general, a very large number of beat frequencies is present in the demodulated signal because the interference is the result of many reflections and delays (τ). The output of the AM detector is filtered by a low-pass filter which eliminates any possible leakage of the 70-MHz IF signal. The spectrum containing the baseband beat frequencies is then viewed on the spectrum analyzer, which presents an "A-scope" display for the FM radar.

B. Method Analysis

3.04 Figure 3 correlates the frequencies, waveform, and spectrum as produced in a linear AM detector from the comparison of a direct signal with a delayed replica from a reflecting object. The beat frequency (f_d) generated in the linear AM detector is, as shown in Fig. 3a and 3b, equal to:

$$f_d = 2\Delta F \frac{\tau}{\tau_m} = 2\frac{d}{c}\Delta F\, f_m \qquad (1)$$

where d = $c\tau$ = extra path length of interfering ray

c = speed of light

τ = extra path delay time

τ_m = sawtooth period

f_m = repetition rate of sawtooth waveform

ΔF = peak frequency deviation of sawtooth waveform.

(The f_d of interest specified in equation (1) appears as the lower frequency response on Fig. 3d. A second reflection with more delay is also shown on Fig. 3d, indicated f'_d.

3.05 The waveform v_d at the output of the AM detector is shown in Fig. 3c and its spectrum in Fig. 3d. Note that the spectrum consists of discrete lines spaced by f_m and that their amplitudes follow an envelope centered at f_d which is equal to the pulse spectrum of the waveform $v_d(t=t_1 \text{ to } t=t_1+\tau_m)$. This envelope approximates a sin x/x characteristic very closely with $x=\pi f/f_m$. Equation (1) also yields the differential distance

$$d = \frac{c}{2\Delta F}\frac{f_d}{f_m} \qquad (2)$$

The beat frequency can only be determined to the nearest multiple of f_m as seen from the spectrum in Fig. 3d. This leads to what is called the "fixed error" in FM radar (or radio altimeters) and amounts to:

$$d_e = \frac{c}{2\Delta F} \qquad (3)$$

3.06 By studying the detailed amplitude distribution of the discrete spectral lines, the distance of a single reflecting object can be determined more precisely than given by equation 3. A second reflecting object (with $d' = c\tau'$) would generate another signal with another beat frequency f'_d. The spectrum of Fig. 3d shows this as well. A spectrum analyzer will enable the quick measurement of the various frequencies f_d which then will produce the corresponding distances d from equation (2). (Actually, the spectrum analyzer could be easily calibrated in distance and used in the manner of a radar "A-scope".) In order to prevent a reduction in the resolution of the radar, the bandwidth of the spectrum analyzer should be chosen to be equal to or less than f_m. The vertical axis of the spectrum analyzer can be the dB display of the linear AM detector output signal.

3.07 An example illustrates the method described. Practical considerations limit the peak frequency deviation in TD-2 to $\Delta F = 7.5$ MHz. This leads to a fixed error (or resolution) of:

$$d_e = \frac{c}{2\Delta F} = 20 \text{ meters} \qquad (4)$$

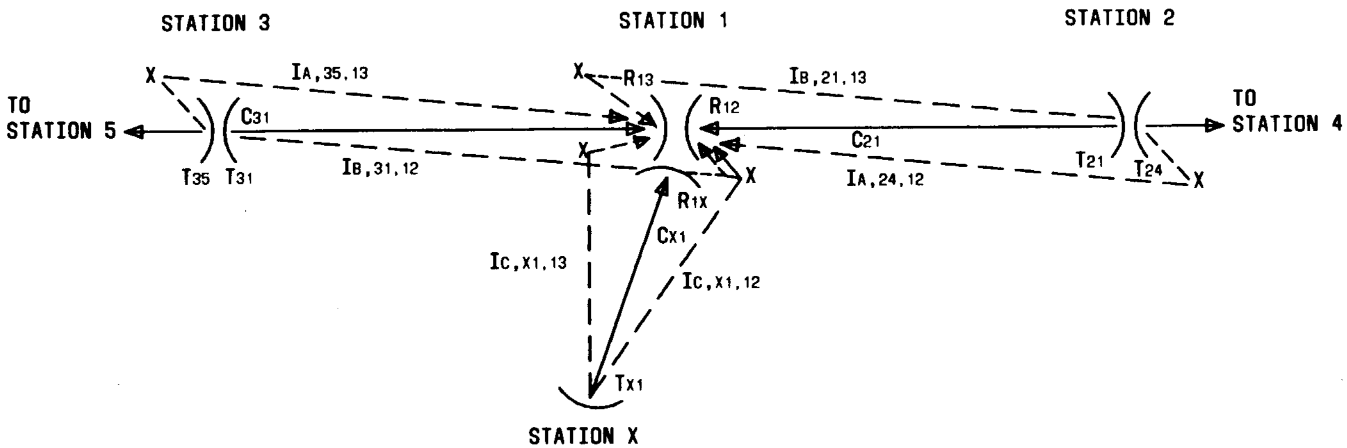
Now we select $f_m = 2000$ Hz which results in the following relation (from equation 2):

$$d = \frac{f_d}{100} \text{ in meters with } f_d \text{ in hertz} \qquad (5)$$

Figure 4 provides a plot of beat tone frequency (f_d) versus distance (d) for pulse repetition rates (f_m) of 500, 2000, and 8000 hertz. Note, for example, that the parameters of equations 4 and 5 above ($f_m = 2000$ Hz, d = 20 meters) would also correspond to a beat frequency of 2 kHz.

4. TEST PROCEDURE

4.01 The following step-by-step procedural description exemplifies the practical application of the FM radar measurement method. The case described is that of adjacent section interference as shown in Fig. 2. Three charts providing, as necessary, apparatus lists, setup instructions and test procedural data are respectively presented for the transmitter, receiver (C/I measurement), and FM radar measurements made at the receiver. Although the description is based primarily on TD microwave radio equipment, other systems and frequency bands can be used if appropriate adjustments (eg, in IF frequency) are made.



NOTE:
ALL PATHS SHOWN USE THE SAME FREQUENCY, F_C

LEGEND

T = TRANSMITTER (E.G. T_{21} = TRANSMITTER IN STATION 2 TRANSMITTING CARRIER C_2 TOWARDS STATION 1).

R = RECEIVER (E.G. R_{12} = RECEIVER IN STATION 1 RECEIVING CARRIER C_2 FROM STATION 2).

X = REFLECTING OBJECTS AND/OR ANTENNA SIDELOBES.

C = DIRECT RAY (CARRIER).

Fig. 1—Major Types of Cochannel Interference

TABLE A

TYPES OF COCHANNEL INTERFERENCE (PER FIG. 1)

DESIGNATION	TYPE	EXPLANATION
I_A	Same section	$I_{A,24,12}$ = transmitter T_{24} in station 2 interfering with receiver R_{12} in station 1.
I_B	Adjacent section	$I_{B,21,13}$ = transmitter T_{21} in station 2 interfering with receiver R_{13} in station 1.
I_C	Junction station	$I_{C,X1,12}$ = transmitter T_{X1} in station X interfering with receiver R_{12} in station 1.

TABLE B

TEST CONDITIONS AND EQUIPMENT CONFIGURATIONS (PER FIG. 1)

INTERFERENCE PATH	REFERENCE PATH	TEST TRANSMITTERS	TRANSMITTERS THAT MUST BE TURNED OFF	TRANSMITTERS THAT MIGHT HAVE TO BE TURNED OFF	TEST RECEIVERS
$I_{A,24,12}$	C_{21}	$T_{21} + T_{24}$		T_{31}, T_{X1}	R_{12}
$I_{B,21,13}$	C_{21}	T_{21}	T_{31}	T_{X1}, T_{35}	$R_{12} + R_{13}$
$I_{C,X1,13}$	C_{X1}	T_{X1}	T_{31}	T_{21}, T_{35}	$R_{1X} + R_{13}$

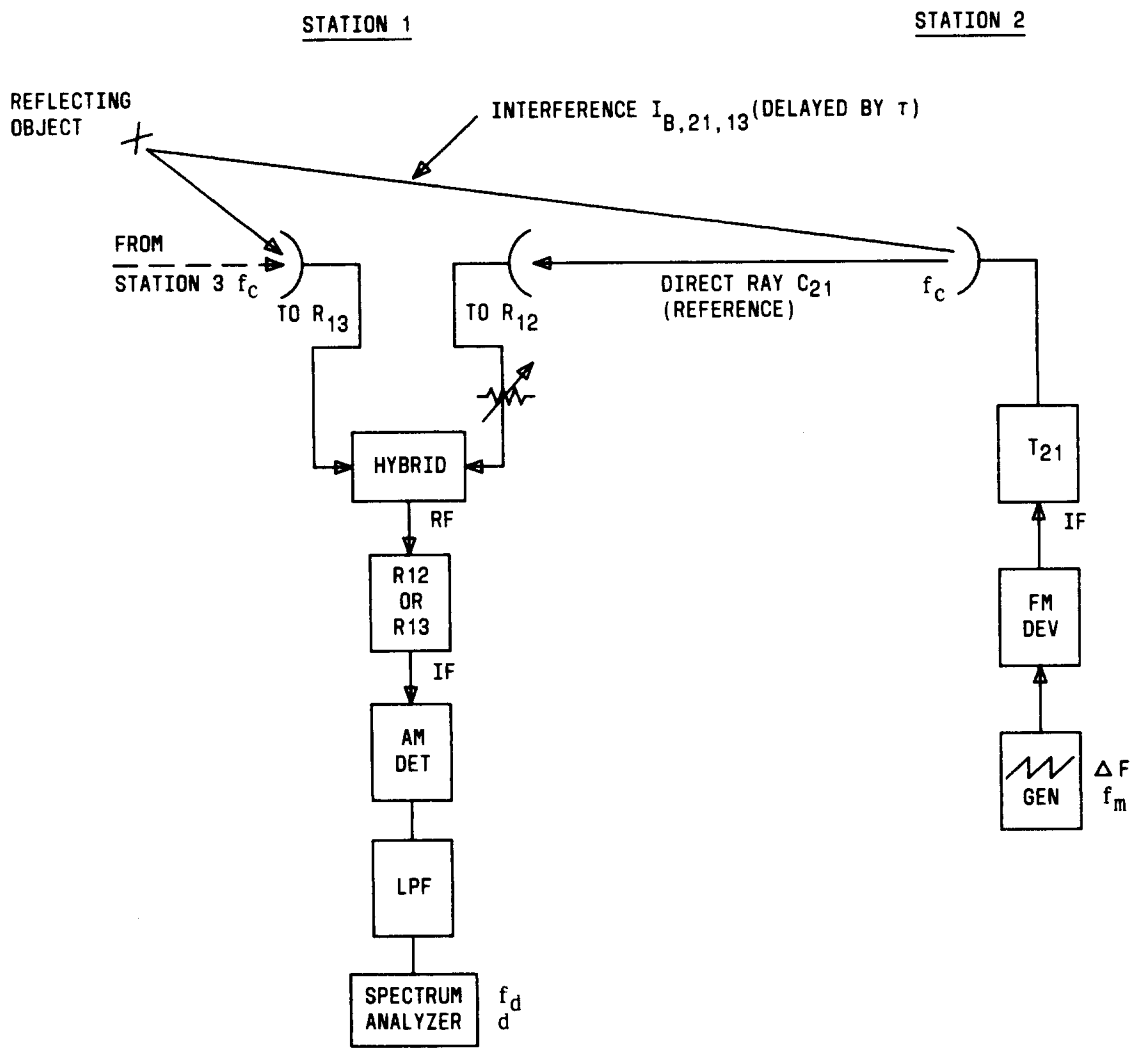


Fig. 2—FM Radar Method for Measuring Distance of Reflecting Objects

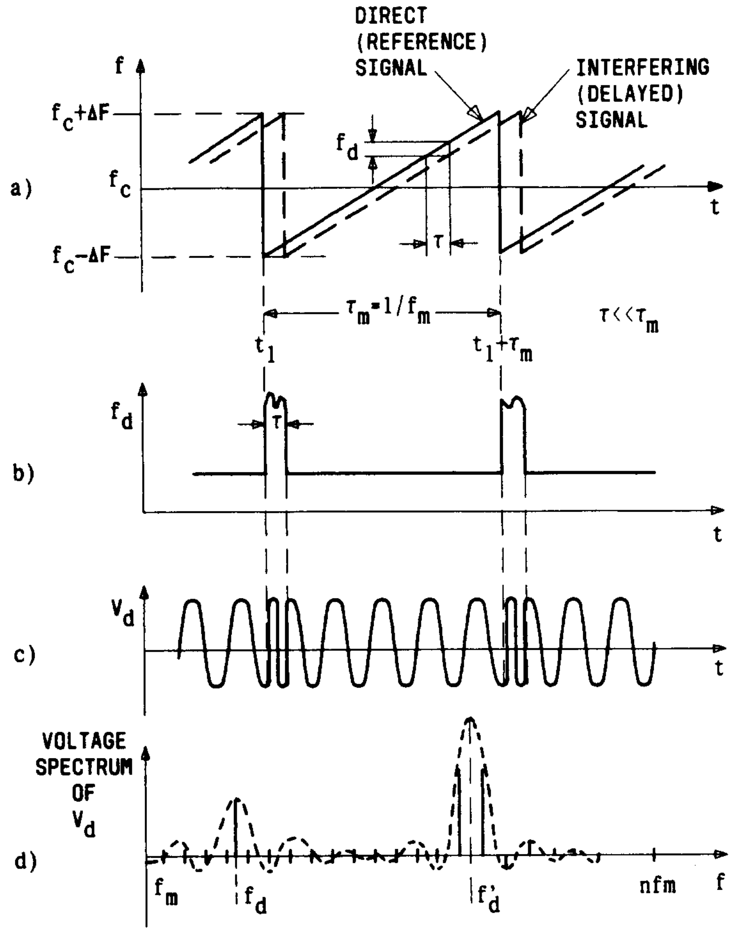


Fig. 3—FM Radar—Frequencies, Waveform and Spectrum

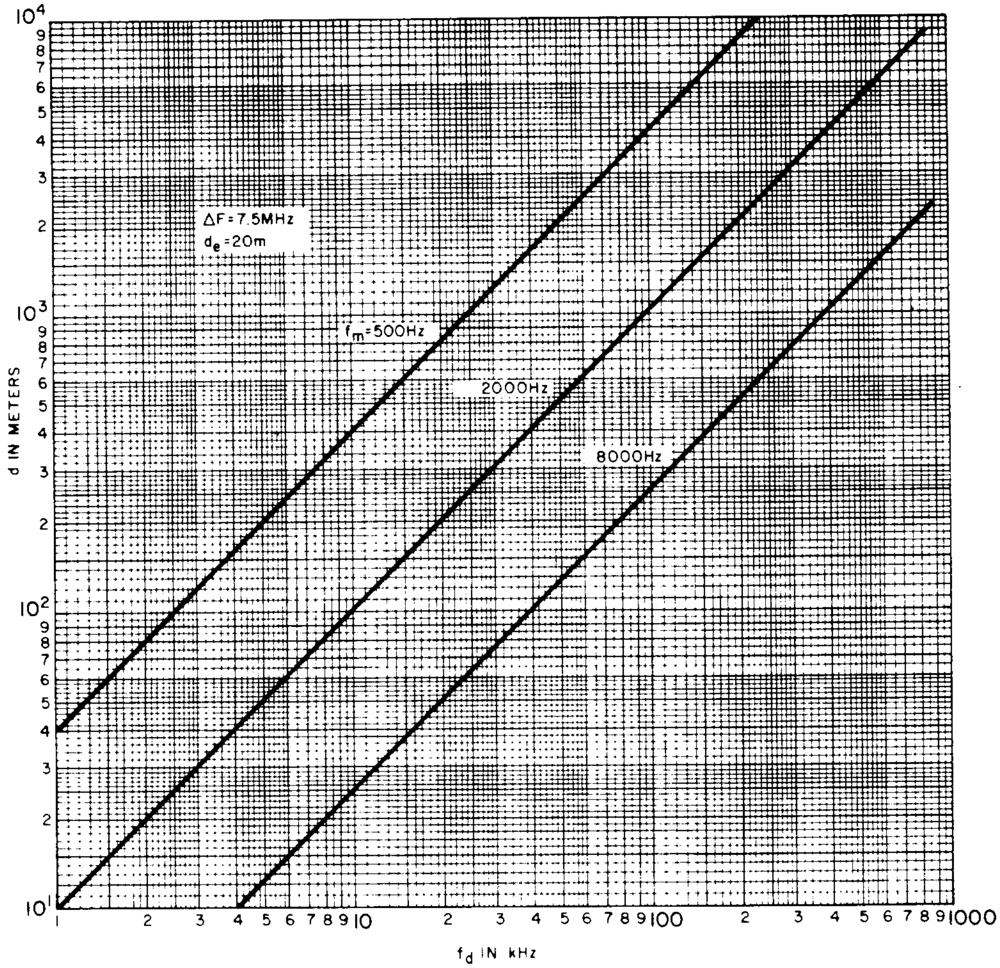


Fig. 4—FM Radar—Distance Versus Beat Tone Frequency

CHART 1

TRANSMITTER SETUP

APPARATUS:

Note: The equipment listed herein refers to Fig. 5.

EQUIPMENT	MANUFACTURER & MODEL NO.	FUNCTION AND REQUIREMENTS
Function Generator	Krohn-Hite 5200A	Provide positive ramp voltage to modulate FM deviator. Ramp rate adjusted for desired f_m (repetition rate). Ramp level adjusted for required ±7.5 MHz deviator out of FM deviator.
Oscilloscope	As appropriate	Provides means of measuring ramp rate.
FM Deviator	Western Electric Co. Model 4AFMT (transmitter)	Provide modulated 70 MHz source to radio transmitter. Ramp voltage input at TRS input. Output taken at IF Out and padded for appropriate input level to driver amplifier input of radio transmitter.
Spectrum Analyzer	As appropriate	Provide means of measuring 70 MHz with ±7.5 MHz deviation. This deviation may also be measured at radio receiver out of IF preamp.

STEP	PROCEDURE
	Note 1: The sawtooth modulated IF to the test transmitter may be supplied over the air from the radio transmitter located at the receiver location. This can be done by looping back into the test transmitter from a receiver at that location. If this is done, the deviation can be measured and adjusted from the receiver location. ***Note 2:*** If near-in distance resolution is not needed, a 200 Hz f_m rate has been found to work well.
1	Connect the equipment at the test transmitter in accordance with Fig. 5. (For convenience, the drive signal to the transmitter may be sent from the receive location as per Note 1 above.)
2	The amplitude of the ramp generator should be adjusted for a transmitter frequency deviation of ±7.5 MHz. (This deviation may be measured at the output of the IF preamplifier on the desired carrier reference receiver.)

CHART 1 (Contd)

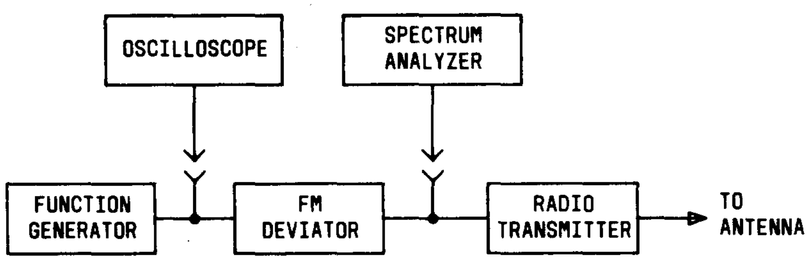


Fig. 5—Source Equipment for FM Radar Measurement

CHART 2

RECEIVER C/I MEASUREMENT

APPARATUS:

Note: The equipment listed herein refers to Fig. 6.

EQUIPMENT	MANUFACTURER & MODEL NO.	FUNCTION AND REQUIREMENTS
CSN & Filter	Western Electric Co. Part of radio receiver encountering interference	Channel separation networks and filters are parts of particular radio system in use.
L_1 Coaxial Cable	RG-214	Coaxial cable as needed to combine signals at hybrid. (Use same overall length in C and I path.)
Attenuator A and B	Weinschel Model 117A-69-34	Attenuator A adjusted for C level at hybrid 20 dB above I. Attenuator B adjusted per description in text.

CHART 2 (Contd)

APPARATUS (Contd):

EQUIPMENT	MANUFACTURER & MODEL NO.	FUNCTION AND REQUIREMENTS
Hybrid	Narda Model 3033 3 dB coaxial hybrid, 50 ohms	Combines C and I signals.
Termination 50 Ohms	As appropriate	Terminates 4th port of hybrid.
Radio Receiver	Western Electric Co.	Existing receiver with IF preamp and main amplifier. For C/I measurements, output is taken from IF preamp. For FM radar measurements, main amp should be in AGC position.
Added IF Amplifier	Western Electric Co. Model 306A	Portable IF amplifier used as required in accordance with text (operated off separate power supply at 117 Vac).
Crystal Detector	HP-423B	Detection of beat frequency (linear AM detector).
LP Filter	Western Electric Co. 786J	Low-pass filter to remove harmonics of IF signal from the demodulated signal.
Storage Normalizer	HP-8750H	Optional method of improving measurement resolution as described in text.
Spectrum Analyzer	HP-141T with plug-in 8552B and 8553B	For display of beat frequency f_d spectrum. Recommended analyzer settings: f_m selected for spectrum region to be examined, BW 0.3 or 1 kHz, video filter 10 Hz, sweep as needed for display = 0.2 sec/ div, vert. 10 dB/div.

CHART 2 (Contd)

STEP	PROCEDURE
1	With reference to Fig. 6, attach a waveguide-to-coax adapter to the output of the bandpass filter following the channel separation network (CSN) on the carrier antenna.
2	Connect the RF variable attenuator "A" (set initially to 0 dB) via a coaxial cable to the wave-guide-to-coax adapter, of Step 1 above, and through another cable to hybrid "H". *Note:* The cables shall be of sufficient length as to locate the attenuator and hybrid physically close to the receiver.
3	Measure the loss (L_1) in dB of the two coaxial cables connected in Step 2 above.
4	Attach a waveguide-to-coax adapter to the output of the bandpass filter following the channel separation network (CSN) on the interference antenna, and connect a coaxial cable having the same loss (L_1) as measured in Step 3 from the adapter to the other port of the hybrid H. (This assures that the cable loss from the carrier and interference filters will be the same.)
5	Connect the hybrid output by cable to the variable RF attenuator "B", and then by cable to the receiver through a waveguide-to-coax adapter. Measure the loss (L_B) in dB introduced by the two cables and record for future use.

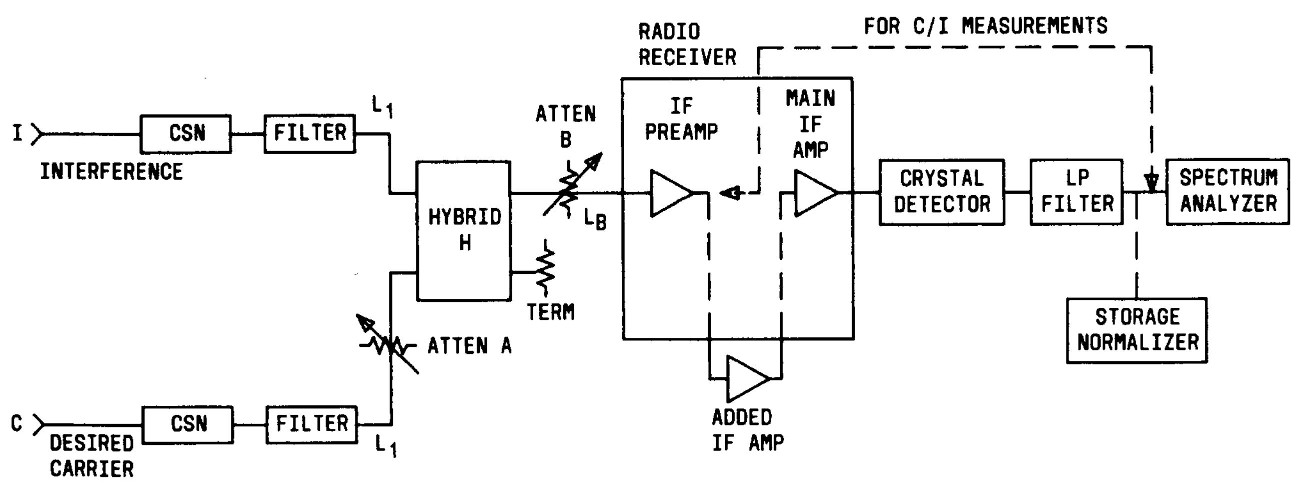


Fig. 6—Receive Equipment for FM Radar Measurement

CHART 2 (Contd)

STEP	PROCEDURE
6	Using the spectrum analyzer, measure and record the C and I levels out of the IF preamplifier, and determine the C/I ratio in dB. Disconnect the I cable to the hybrid when measuring C, and the C cable when measuring I. When disconnecting the cables from the hybrid, terminate the open connector on the hybrid with a 50-ohm termination. Also, assure that the attenuators "A" and "B" are set to 0 dB before making the C/I measurement. ***Note 1:*** If station is equipped with a space diversity antenna, measurements should be performed on each antenna individually. ***Note 2:*** When measuring C and I levels on their respective antennas, or when performing FM radar measurements, potential interference transmitters should be turned off. (See Table B.)

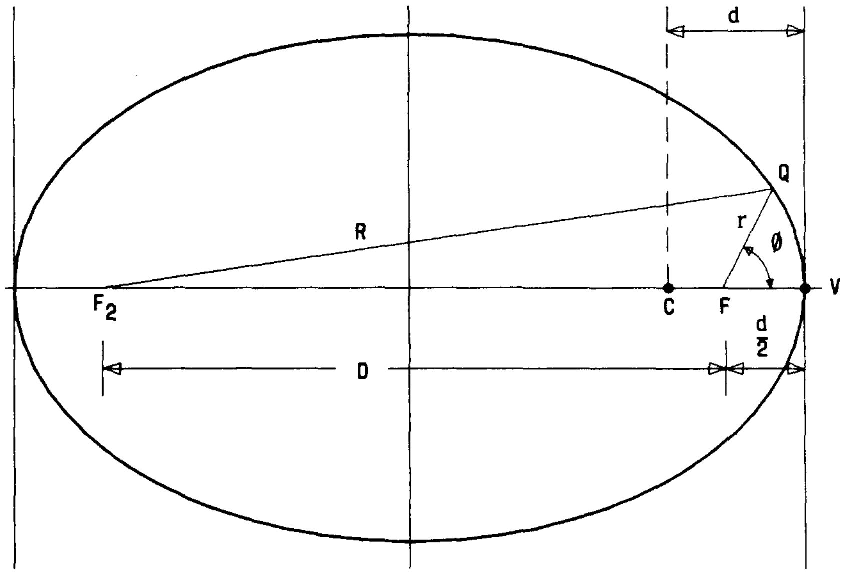
CHART 3

FM RADAR MEASUREMENTS

STEP	PROCEDURE
1	Adjust the variable attenuator A to provide a carrier (C) level 20 dB above the interference (I) level. (This level ratio provides a strong beat frequency component without overdriving the AM detector.) The value of A in dB can be found from the following relation: $A = C/I - 20$, where C/I was determined in Chart 2, Step 6.
2	Adjust the variable RF attenuator B according to the following formula: $B(dB) = 57 - L_1 - L_B - C/I$. ***Note 1:*** This value of B makes the reference carrier at the receiver input 40 dB lower than under normal unfaded conditions. The receiver and the IF main amplifier automatic gain control therefore operate under the conditions of a 40-dB fade. This operating point has been found to minimize incidental amplitude modulation at the ramp-rate (and harmonics) which may be introduced by transmission distortions in the receiver. ***Note 2:*** If B calculates to be less than 0, an additional IF amplifier with gain G_{IF} is required. Attenuator B must then be adjusted according to the following relation: $B(dB) = 57 + G_{IF} - L_1 - L_B - C/I$. If an IF amplifier is required, it should be inserted between the preamplifier and main IF amplifier as shown in Fig. 6.

CHART 3 (Contd)

STEP	PROCEDURE
3	Assure that the main IF amplifier is set to operate in AGC mode, and set the spectrum analyzer controls in accordance with data listed under "Function and Requirements" of Chart 2 apparatus list. (As shown in Fig. 6, the main IF amplifier output is detected by a crystal detector and filtered by a low-pass filter before being displayed on the spectrum analyzer.) *Note:* The following steps discuss interpretation of the spectrum analyzer display and the method of application in the location of sources of reflective, cochannel interference.
4	The frequencies associated with discrete spectral lines displayed on the spectrum analyzer are used to determine the distance of reflecting objects. To calculate that distance, the formula from equation (2) $$d = \frac{c}{2\Delta F}\frac{f_d}{f_m} \qquad (6)$$ can be used, or the graph of Fig. 4 can be applied.
5	The distance determined is the additional length of the interference path over the reference path as shown in Fig. 2. (This assumes that the reference and interference antennas are close together and that the waveguide runs are of equal length.) This added path length forms a constant-delay ellipse with one focus at the source antenna and the other at the reference receive antenna. An example of the ellipse and the formula for drawing it is shown in Fig. 7. Any point on the ellipse is, in theory, a possible source of reflection for a given delay $\tau = d/c$ (c being the speed of light). In practice, the points on the ellipse illuminated by the interfered antenna beam (main lobe and first-side lobes) are much more likely areas from where the interfering reflections come. (The antenna pattern is the weighting function for signals emanating from points on the ellipse.)
6	Improvement in the spectrum analyzer display can be achieved by the use of a storage normalizer connected to the input of the spectrum analyzer. This unit permits storage and subsequent subtraction of the reference display obtained when the output from the interference antenna is temporarily disconnected at the hybrid input. The incidental spectrum of the reference carrier signal is thus stored for subsequent subtraction. Utilization of this normalizer requires its connection to the spectrum analyzer in accordance with the manufacturer's instructions as add-on equipment. (Certain spectrum analyzer models have the storage normalizer built into the unit.)



D = DISTANCE BETWEEN THE TWO RADIO STATIONS (DIRECT RAY)

R+r = DISTANCE TRAVELED BY REFLECTED RAY

R + r - D = d = EXTRA PATH LENGTH OF REFLECTED RAY

IF R + r = D + d = CONSTANT, THEN LOCUS OF Q IS ELLIPSE.
POLAR EQUATION OF ELLIPSE:

$r = \frac{p}{1+e\cos\phi}$ WHERE $e = \frac{1}{1+\frac{d}{D}}$ (EXCENTRICITY)

AND $p = \frac{d}{2}(1+e)$

AT POINT V A CIRCLE WITH CENTER C AND RADIUS p MATCHES THE CURVATURE OF THE ELLIPSE.

<u>METHOD</u>

SOLVE FOR e USING d AND D, THEN DETERMINE p AND USE IN r-EQUATION. WITH r-EQUATION A TABLE OF ϕ AND r CAN BE DEVELOPED TO PLOT ELLIPSE.

Fig. 7—Construction of Constant Delay Ellipse

5. EXEMPLARY RADAR MEASUREMENTS

A. General

5.01 This part presents data and conclusions derived from actual field trials demonstrating the FM radar method in locating the sources of reflective, cochannel interference. Examples of spectrum analyzer displays, with and without reference trace subtraction (as available from use of a storage normalizer), are included. Two experiments are described. The first, based on data obtained in Portland, Maine, reveals that the identified sources of interference are not amenable to remedial action; while the second experiment, performed in Lanark, Pennsylvania, illustrates the case in which the location of the offending reflection permitted corrective measures, providing a C/I improvement of 28 dB.

B. Portland Measurements

5.02 Portland, Maine, has a station flanked by hills with buildings on both sides (see Fig. 8). Incoming signals from Brunswick and Sanford to the Portland station encounter reflecting objects just beyond the station on both sides. As seen in Fig. 8, these reflectors are only a few degrees below the path. The geography of the stations and the various interference paths are shown in Fig. 9.

5.03 A sample of the spectrum analyzer display (without use of a storage normalizer) is shown in Fig. 10. The display is that for Fig. 9 interference path $I_{B,21,13}$ and reference path C_{21}. The C/I ratio is 50 dB, and transmitters T_{31} and T_{35} have been turned off. Note that there are two regions which display higher beat frequency levels—the first is the 210-meter region, and the other is the region from approximately 900 meters to 2000 meters. (Note also that the horizontal scale, in addition to representing f_d in kilohertz, is being visualized as a radar "A-scope" calibration [d/10 in meters], in which case the designation 200 represents 1/10 of 2000 meters.) This distance is the added propagation length to the reflector and from the reflector to the station, as compared to the direct path from the Brunswick station to Portland (27.29 miles). This differential distance forms an ellipse about the station as described in Chart 3, Step 5 and previously shown in Fig. 7.

5.04 Figure 11 depicts a map of the Portland station area showing the radio paths and two sample ellipses corresponding to the two prominent reflections at d = 210 meters and 1850 meters shown in Fig. 10. It can be seen that, in general, the source of the reflections is not just a few but numerous reflectors. Almost all of the buildings in town which are located within or near the main antenna lobe are back-scattering reflectors that contribute to the overall interference power. Reflections are especially

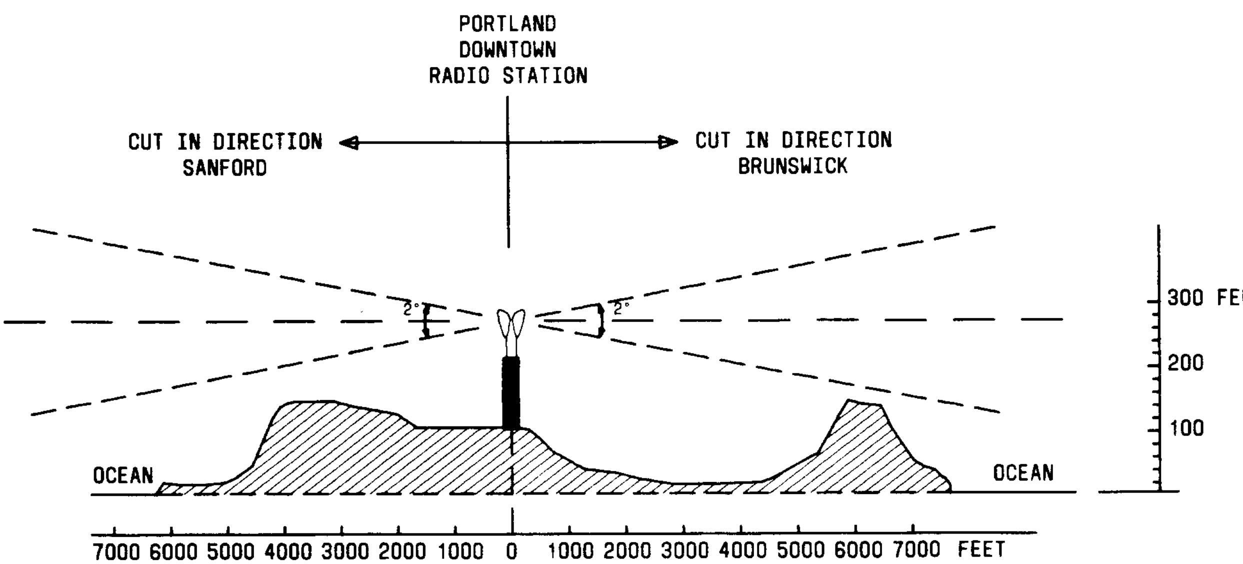


Fig. 8—Path Profiles Near the Portland Station

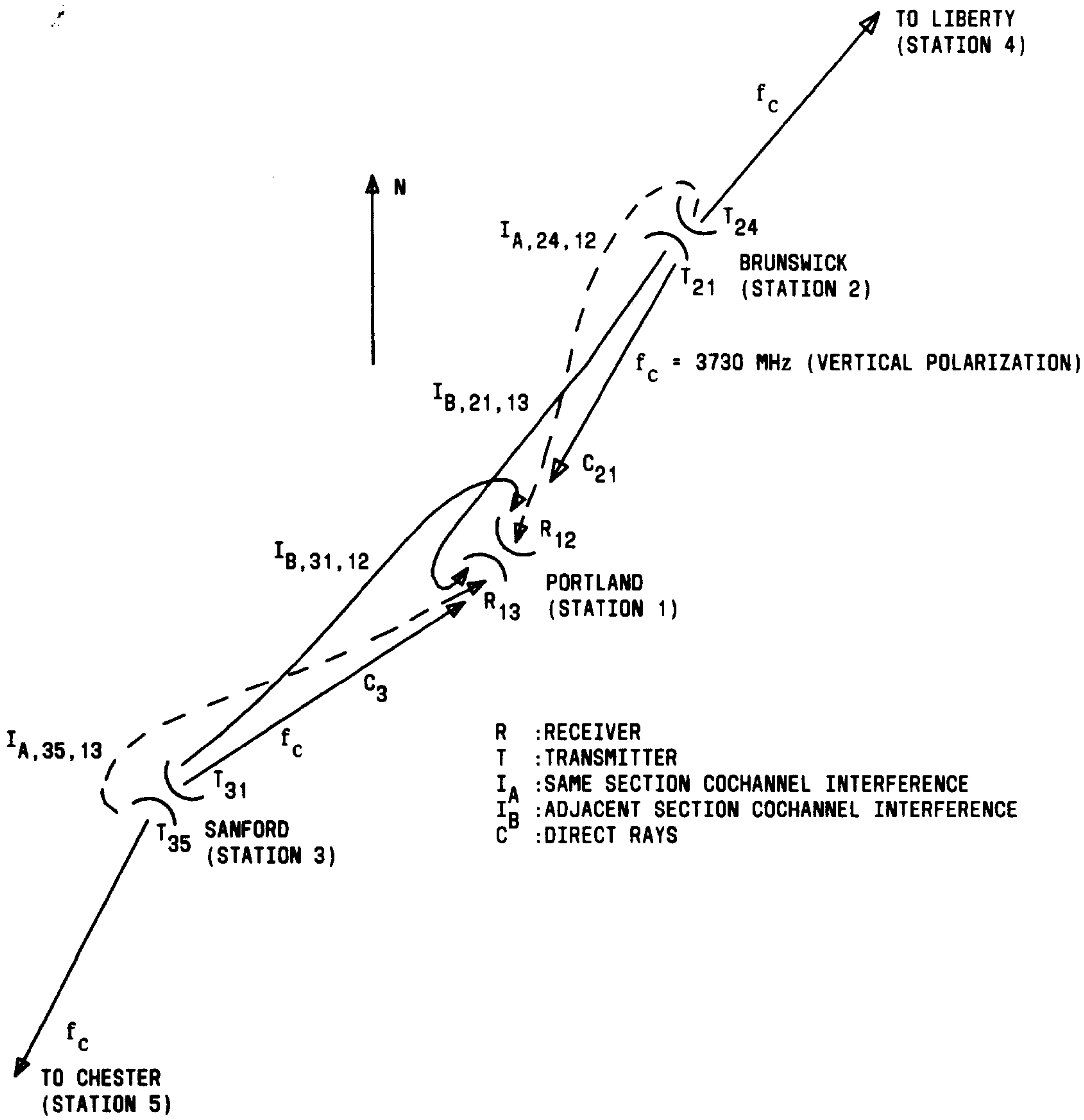


Fig. 9—Cochannel Interference Measurements in Portland, Maine

strong from buildings on the hills that ring the southern and northern sections of town (see Fig. 8) where the antenna beams come closest to the ground.

5.05 Another example is included as shown in Fig. 12. In this case, the interference path $I_{B,31,12}$ (see Fig. 9) is measured (C/I = 58 dB). This data depicts reflections in the near-in region as well as stronger reflections with path delays extending from 3000 to 3700 meters. The reflection at d = 3620 meters comes from the L-shaped apartment building which is directly below and slightly to the right of the antenna beam pointing toward Brunswick (to the right of the word Reservoir in Fig. 11). Beyond that point, the hill abruptly drops toward the Tidal Flats from where no reflections are received as a result of shielding by the hill.

5.06 In the example for Portland, Maine, we see that no practical solutions for interference reduction exist. It is obviously impossible to remove buildings or hills, and a narrowing of the antenna beams (by using larger antennas, for instance) may be impractical as well.

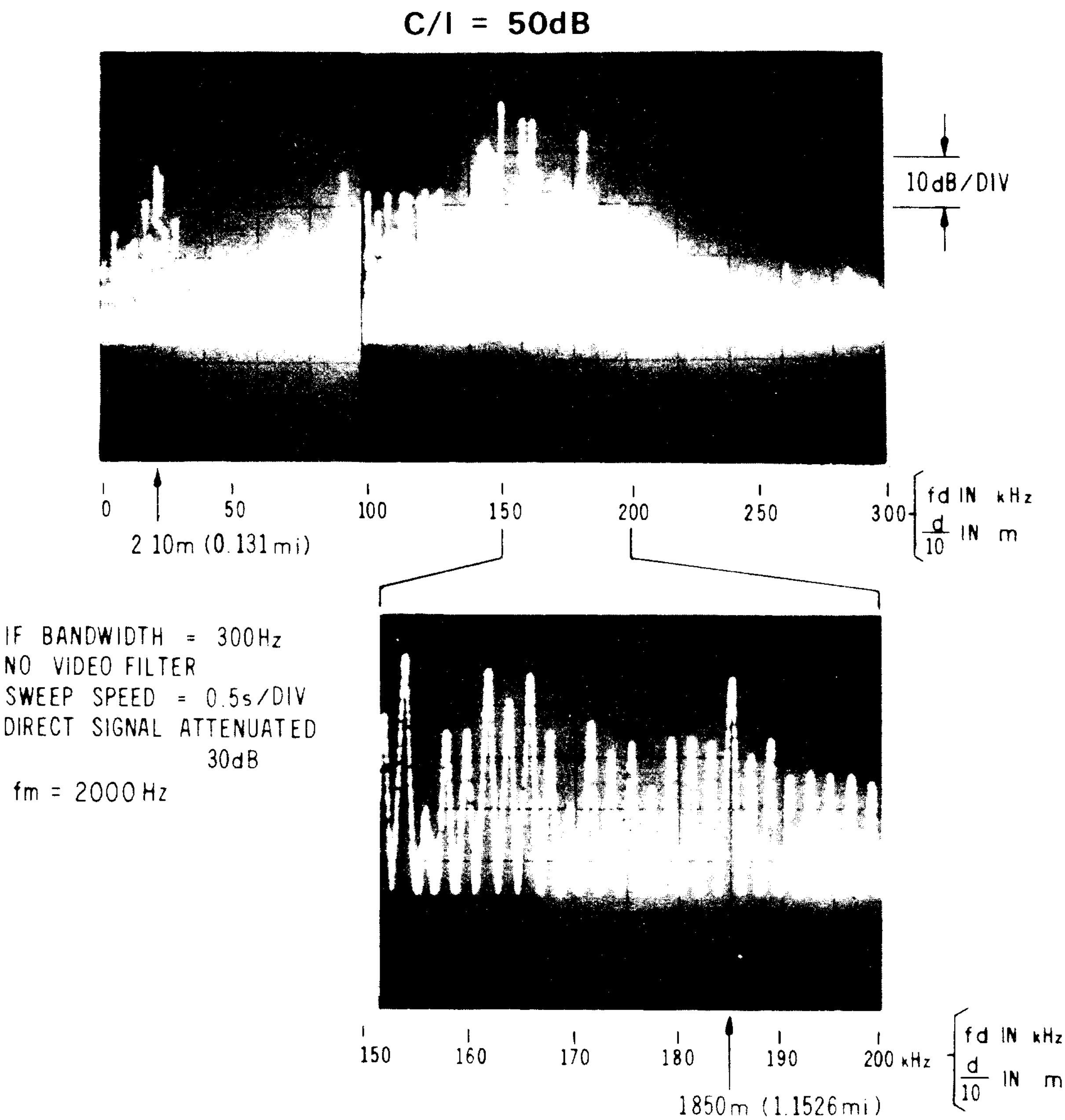


Fig. 10—A-Scope Display for Interference Path $I_{B\ 21\ 13}$ (T_{31} and T_{35} Turned Off)

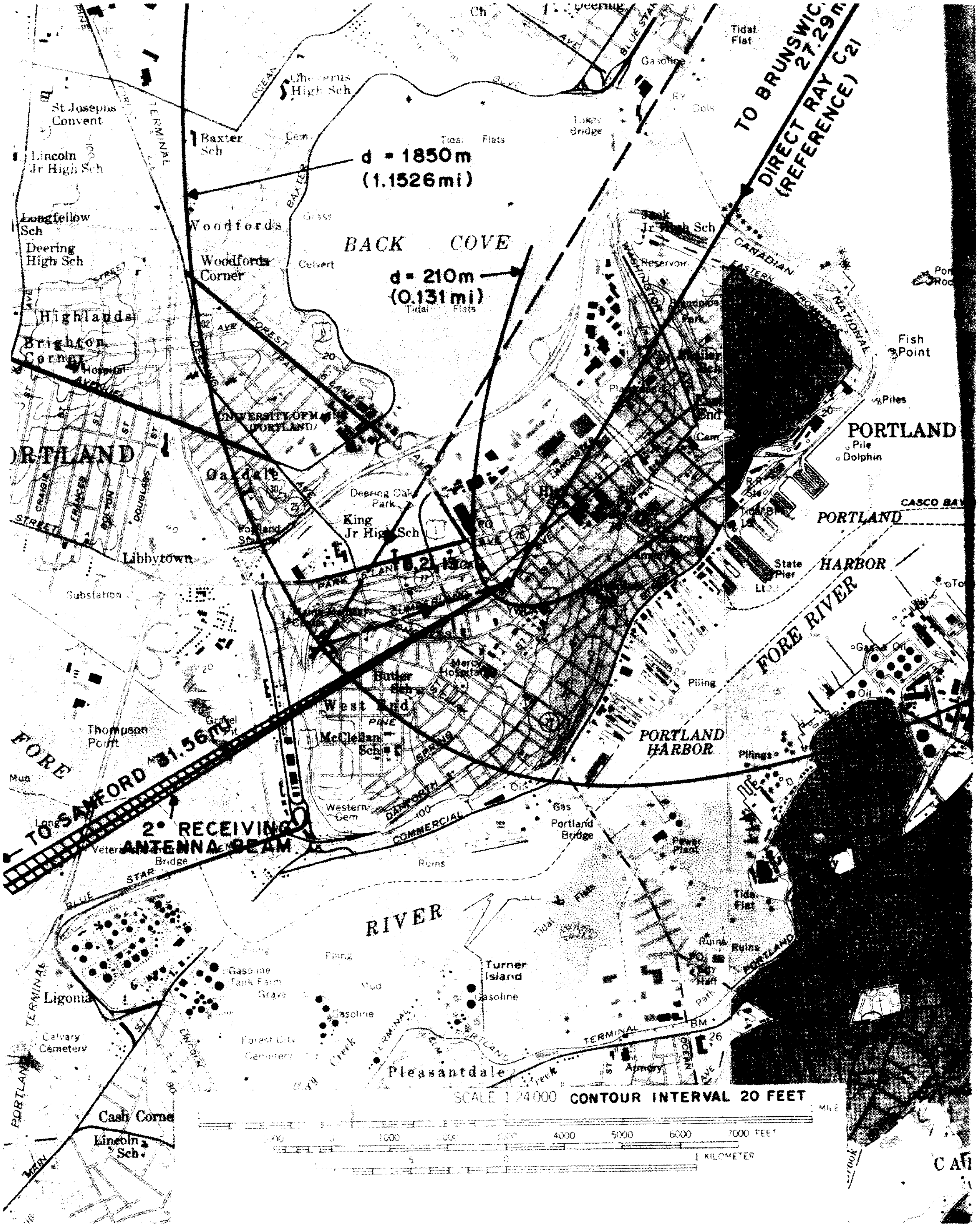


Fig. 11—Interference Path $I_{B.21.13}$

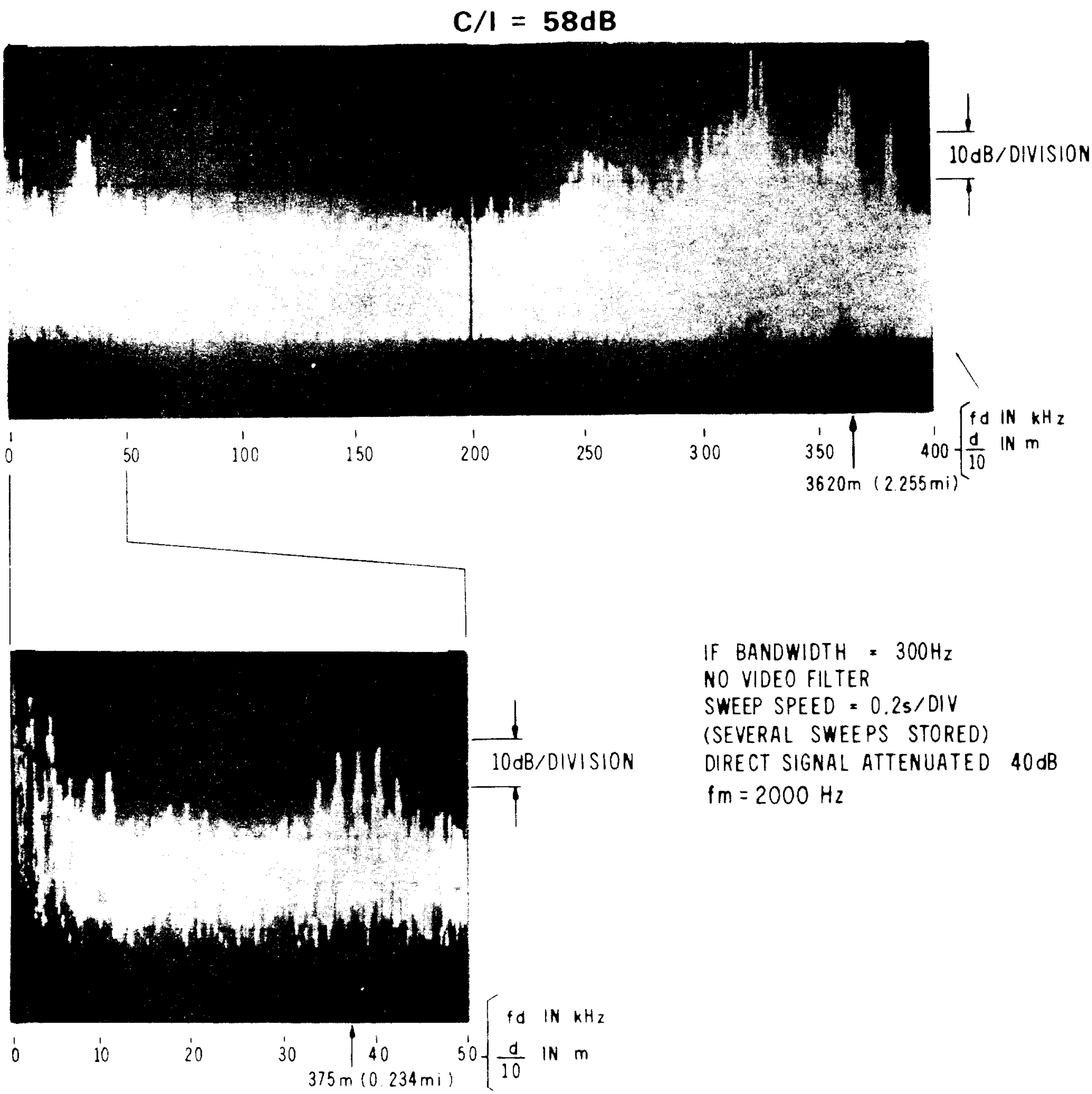


Fig. 12—A-Scope Display for Interference Path $I_{B\ 31,\ 12}$ (T_{21} and T_{24} Turned Off)

C. Lanark Measurements

5.07 The adjacent section interference measurements made in Lanark, Pennsylvania, serve to provide an example of a near-in reflector together with displays which have been storage-normalized. In this case, the interfering signal had a C/I ratio of 40 dB and resulted from reflections from an ice shield of a lower antenna mounted on the same tower (see Fig. 13). These reflections are thrown upwards into the reduced discrimination region of the antenna, called the "window" lobe. The reflecting ice shield is slightly forward and approximately 100 feet below the antenna subject to interference.

5.08 Spectrum analyzer display examples of the Lanark measurements are shown in Fig. 14. Figure 14A depicts the reference trace (only C present, I disconnected) with the actual radar trace (both C and I present) superimposed over it. The reference trace is identifiable by low-amplitude peaks under the peaks located at 6 and 8 kHz. This reference trace is an example of the incidental spectrum of signal C when the interference signal I is removed. The nonflat reference trace can be subtracted by using the storage normalizer, thus producing an improved A-scope radar display. Figure 14B is an example of this technique. Figure 14C is included to depict an extended search range. The range is extended by setting the spectrum analyzer to 10 kHz/Div. instead of the 2-kHz/Div. used in Fig. 14A and 14B. Further range extension is achievable by increasing the frequency per division and/or tuning the spectrum analyzer to begin its sweep at a higher frequency.

5.09 An interpretation of the normalized displays, Fig. 14B and 14C, discloses that no reflections with detours greater than about d = 125 meters are present. This can be explained by the fact that the Lanark station is located on top of a mountain which effectively shields objects in the antenna beam of the interfered-with antenna from being illuminated by microwave energy. The most pronounced reflections are at approximately 6 and 8 kHz, corresponding to 60 and 80 meters of added propagation distance. It should be recognized that the resolution of the FM radar is 20 meters (60 feet) as explained in paragraph 3.07 and equation (4). Because of this limitation, we cannot say with any certainty that two discrete reflections exist at 60 and 80 meters. More likely, there is a strong reflection at about 65 meters which generates responses at 60 and 80 meters, with an additional side lobe at 100 meters. This has been shown in Fig. 3d. The distance of 65 meters corresponds closely to the delayed reflection from the ice shield of the antenna 100 feet below and on the opposite side of the tower with respect to the signal received by the reference antenna. Reflections with d = 100 to 120 meters appear to be due to a small astronomical observatory located adjacent to the tower.

5.10 Unlike the Portland tests, the Lanark measurements were able to identify a specific interference for which there are mitigation capabilities. The application of a bottom-edge blinder (see Fig. 13) to the antenna subject to interference resulted in a C/I of 68 dB, for an overall improvement of 28 dB.

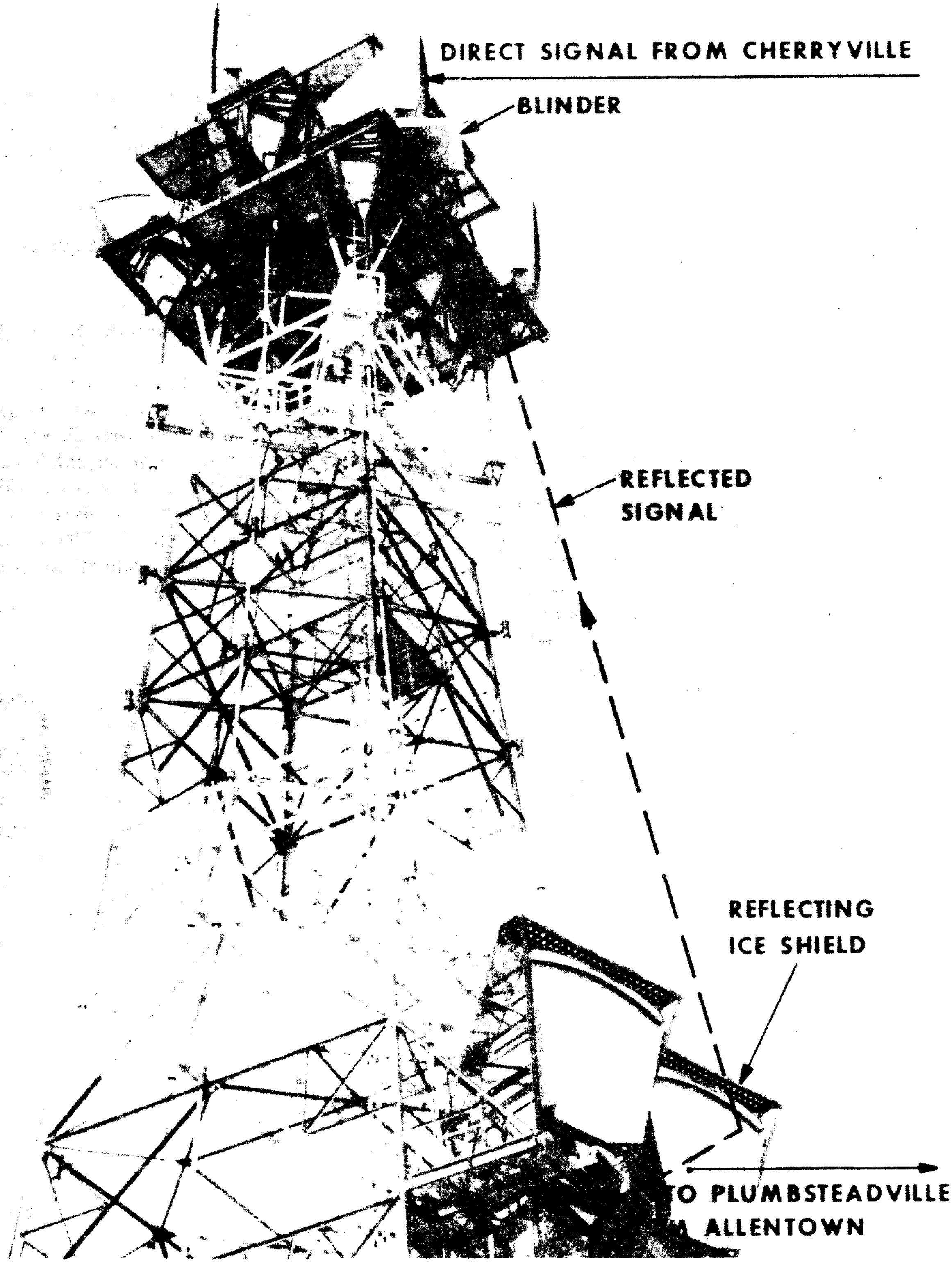


Fig. 13—Installed 64-Inch Blinder and Interference Causing Reflector Surface in Lanark, Pennsylvania

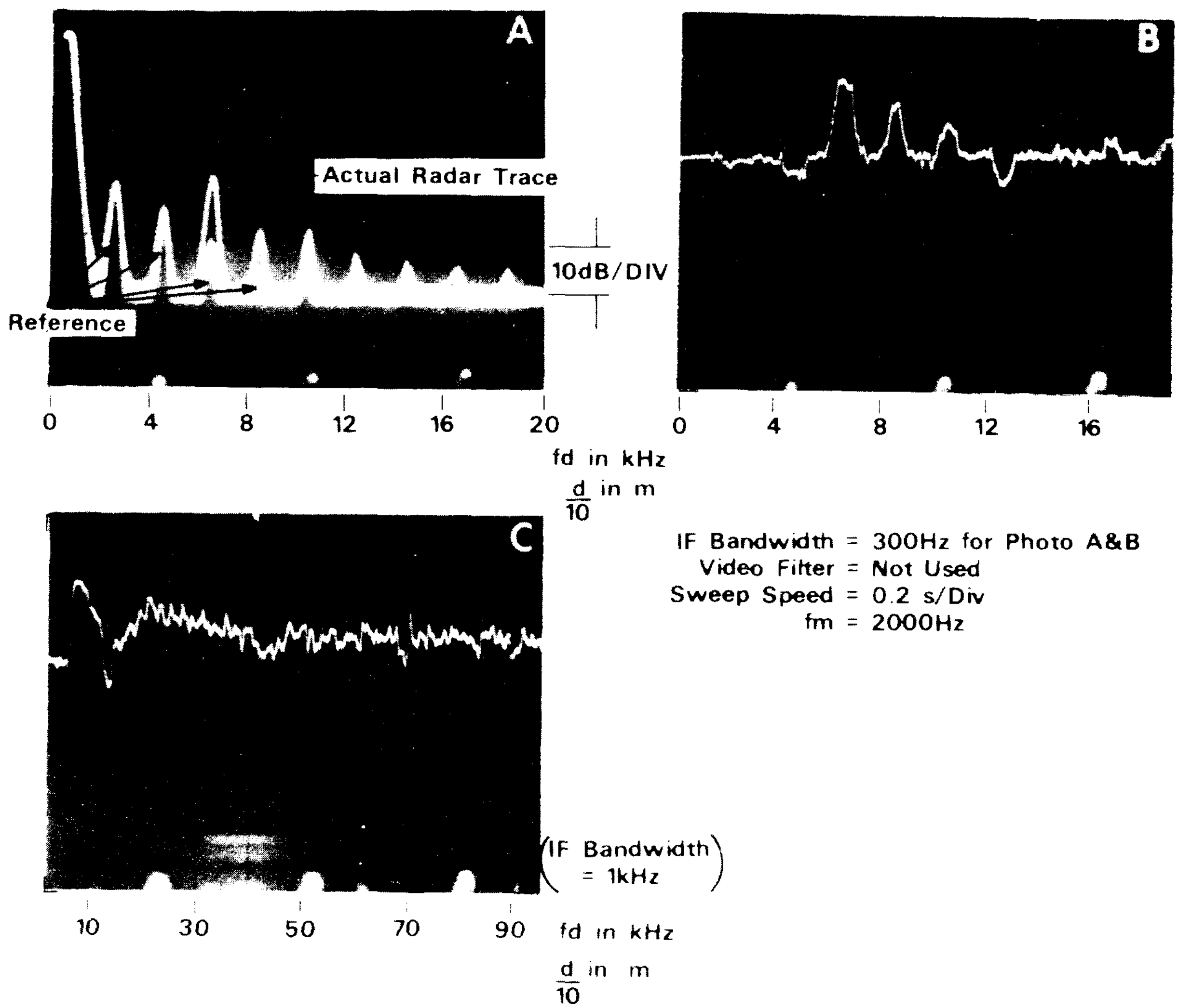


Fig. 14—Spectrum Analyzer Display for Lanark Tests