900-mc PTM Over-the-Horizon Radio Link

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Introduction

An EXPERIMENTAL over-the-horizon radio link has been installed and tested for several months by the Federal Telecommunication Laboratories. Its chief purpose has not been to study propagation, although several interesting results may appear, nor to establish a commercially usable communication facility, but rather to study the application of this relatively unexploited type of propagation to multi-channel transmission, particularly that using ptm, pulse-time modulation.

Sites

With this in view, it was decided to install a two-way link with the main terminal located at the Nutley, N. J., Laboratories for convenience in making measurements, and a repeater point at the Mackay Radio receiving station at Southampton, L. I., N. Y. Thus there are, in effect, two links in cascade. It will be seen from Fig. 1

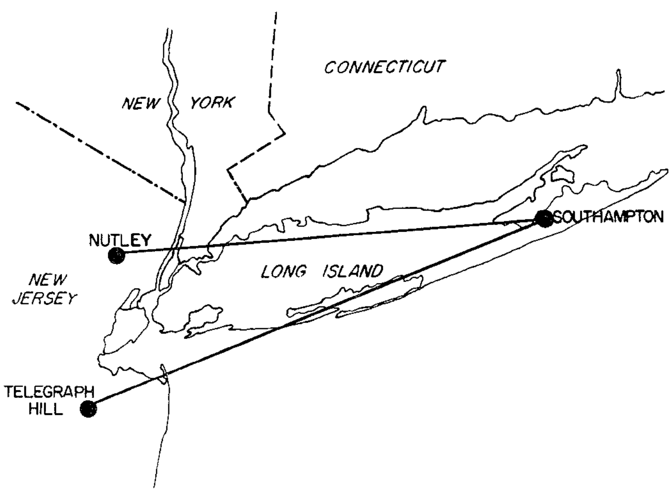

Fig. 1—Map showing test locations.

that this path, approximately 91 miles long, is almost entirely over land, including parts of New York City and some of the most heavily traveled airspace to be found anywhere. The path to Telegraph Hill is shown, as it also is being tested to determine if there is some essential peculiarity on the Nutley path which causes unexpectedly low signals. Fig. 2, a profile of the Nutley path, shows the modest antenna heights and particularly that the Nutley beam must be raised by about one-half degree to clear the Palisades along the Hudson River near the George Washington Bridge. This increases the scatter angle, of course, and thus also the path attenuation, by perhaps six decibels.

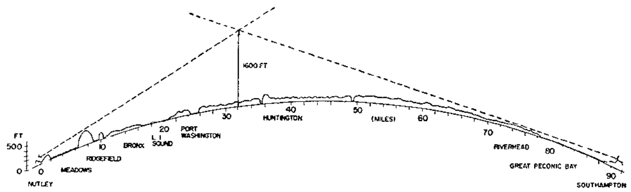

Fig. 2—Profile of Nutley-Southampton path.

Radio-Frequency Equipment

Paraboloidal reflectors twenty-eight feet across have been installed at each terminal. Fig. 3 (next page) shows diplexing antenna feed horn at Nutley. Vertical polarization is used for transmission, and horizontal for reception. The crosstalk is about 50 db and the voltage standing wave ratio is less than 1.3 from 890 to 940 mc. Fig. 4 (p. 24) shows Southampton dish, temporarily located low on the fifty-foot tower, and the equipment trailer. Part of the trailer has been made into a screen room to permit receiver operation a few feet from the one-killowatt transmitter. The transmitter room is also shielded and its power lines filtered to eliminate interference with some very important Mackay receiving circuits.

Fig. 5 (p. 24) is a block diagram of equipment used for most of the tests to date. Frequencies 5 mc inside the borders of the 890 to 940-mc common carrier band were chosen to permit the use of FTL-20B modified uhf-tv transmitters. These provide 1-kw peak power, up to 6 mc bandwidth, frequency drift less than 1 kc, and commercial reliability. They can also be readily adapted to fm transmission.

Each receiver (Fig. 6, p. 25), uses preselector cavity, rf amplifier, and microstrip mixer, to provide a noise figure between 8 and 9 db and about 6-mc bandwidth. The local oscillator power is derived by shifting a cw sample from the associated transmitter by 100 mc in a second microstrip mixer and then filtering with a single cavity. Fig. 6 shows also the 6-pen recorder with associated amplifiers, a rack of test equipment, and the ptm modulator and demodulator bays.

PTM Equipment

Most of the tests to date have used FTR-28B 23-channel ptm terminal equipment with the radio bandwidth restricted to 1 mc by video filters in the transmitter input lines. Receiver noise has been accordingly

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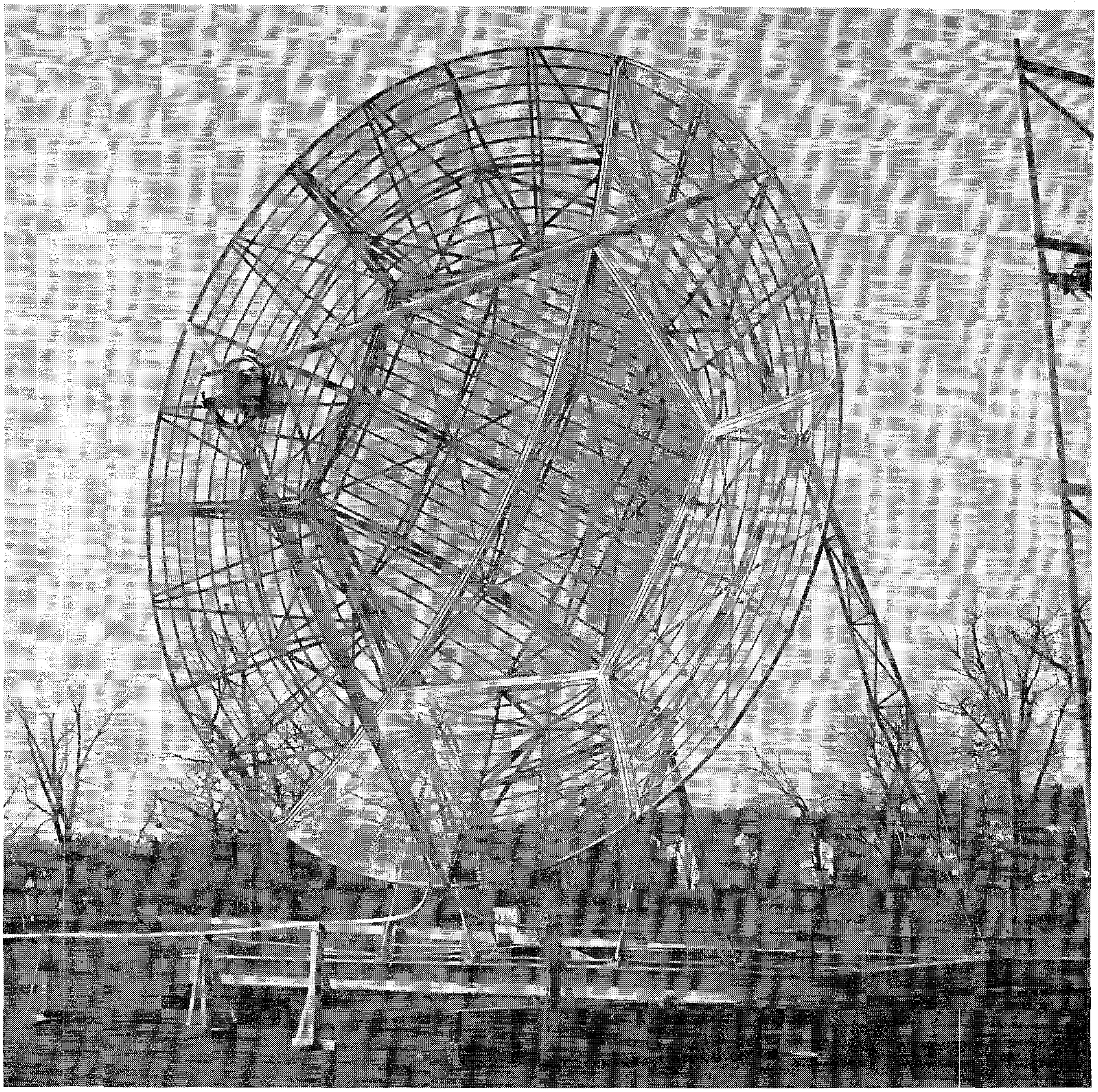

Fig. 3—View of 28-foot dish with dual polarization horn.

reduced by filters at IF frequency. The resulting loss in ptm improvement factor has been made up by use of compandors, demonstrating the feasibility of multi-channel ptm with reduced bandwidth. This is summarized on Fig. 7 (p. 26), which has minimum bandwidth as a function of number of channels. As a check to see if there are any unexpected lower limits to this narrowing, the terminal equipment was modified for an rf bandwidth of 170 kc. Four channel pulses, 6 μsec. wide, deviated plus and minus 6 μsec were used. Appropriate filters are again used to restrict the bandwidth and obtain an improvement in signal-to-noise ratio. Fig. 8 (p. 26) shows system power levels assuming the median path loss given by Bullington. For the wider-band system, a signal-to-noise ratio of 45 db is predicted, and for the narrow-band system, 53 db.

Path Loss

Although the signal loop is 182 miles long, signal strength recordings represent one-way loss because the agc circuit maintains a constant peak output from the repeater transmitter. Signals received have not been as high as expected, as may be seen from Fig. 9 (p. 26) a distribution plot covering a typical period. The fact that

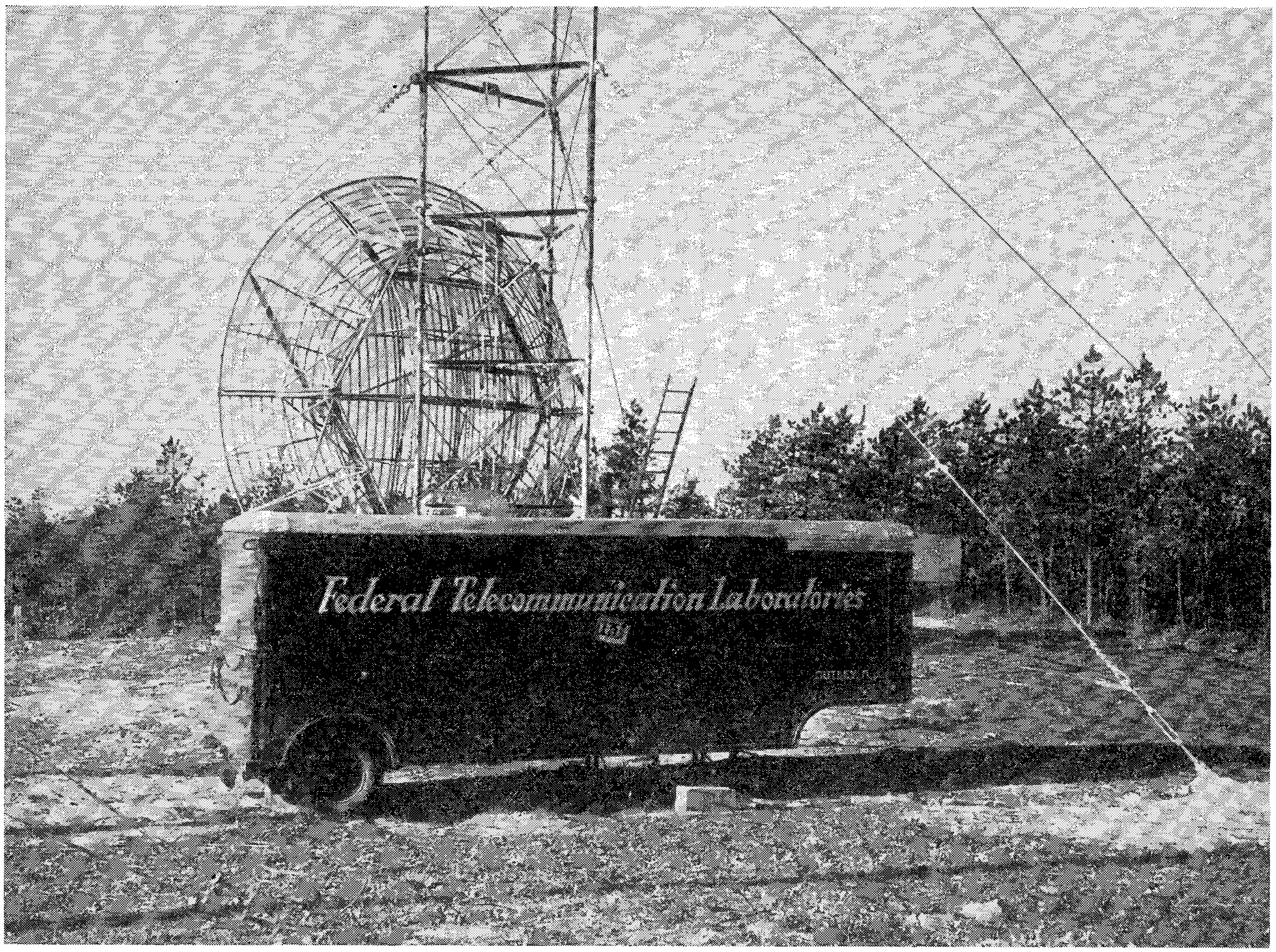

Fig. 4—View of Southampton antenna and equipment trailer.

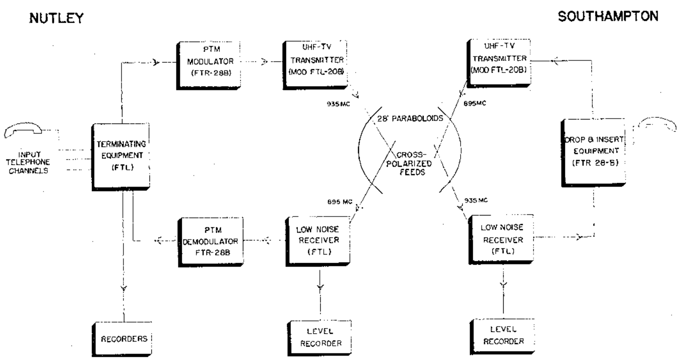

Fig. 5—Ptm equipment; block diagram.

the signal exceeded about 92 db below 1 mw fifty per cent of the time, and is some 30 db below that predicted, may be partly accounted for by seasonal loss, usually not considered to be more than 10 db, and partly by the loss due to the ridge mentioned above. There seems to remain, however, an additional loss factor which is suspected to arise from the overland nature of the path, possibly the over-city portion. To check this, an alternate path, to Telegraph Hill, is being tested with a 10-foot dish and receiver which were first used for measurements at Nutley. In this way, equipment factors are being held constant to bring out the effects of medium and path configuration. Loss in antenna gain is being made up by use of a narrow-band receiver and simple tone modulation of the transmitter. Preliminary figures indicate that the median path loss is close to that predicted by Bullington.

Signal Recordings

Numerous recordings have been made and some of the more interesting are reproduced here. Fig. 10 (p. 26) shows the use of that extra-terrestrial noise generator, the sun, for determining antenna beamwidth and receiver performance. Here, as predicted, the quiet sun is 5 db above receiver noise. If it had been equal, that is, 9 db above theoretical noise, the trace would have risen to just under the 10-db point shown. The beamwidth checks at about three degrees, as expected.

Fig. 11 (p. 26) shows at the top a fast recording of variation of signal strength when an airplane crosses the beam. This effect is, of course, familiar to tv viewers in poor service areas, but at times may be forgotten by researchers using recorders with long time constants. The typical fast-slow-fast doppler frequency variation is

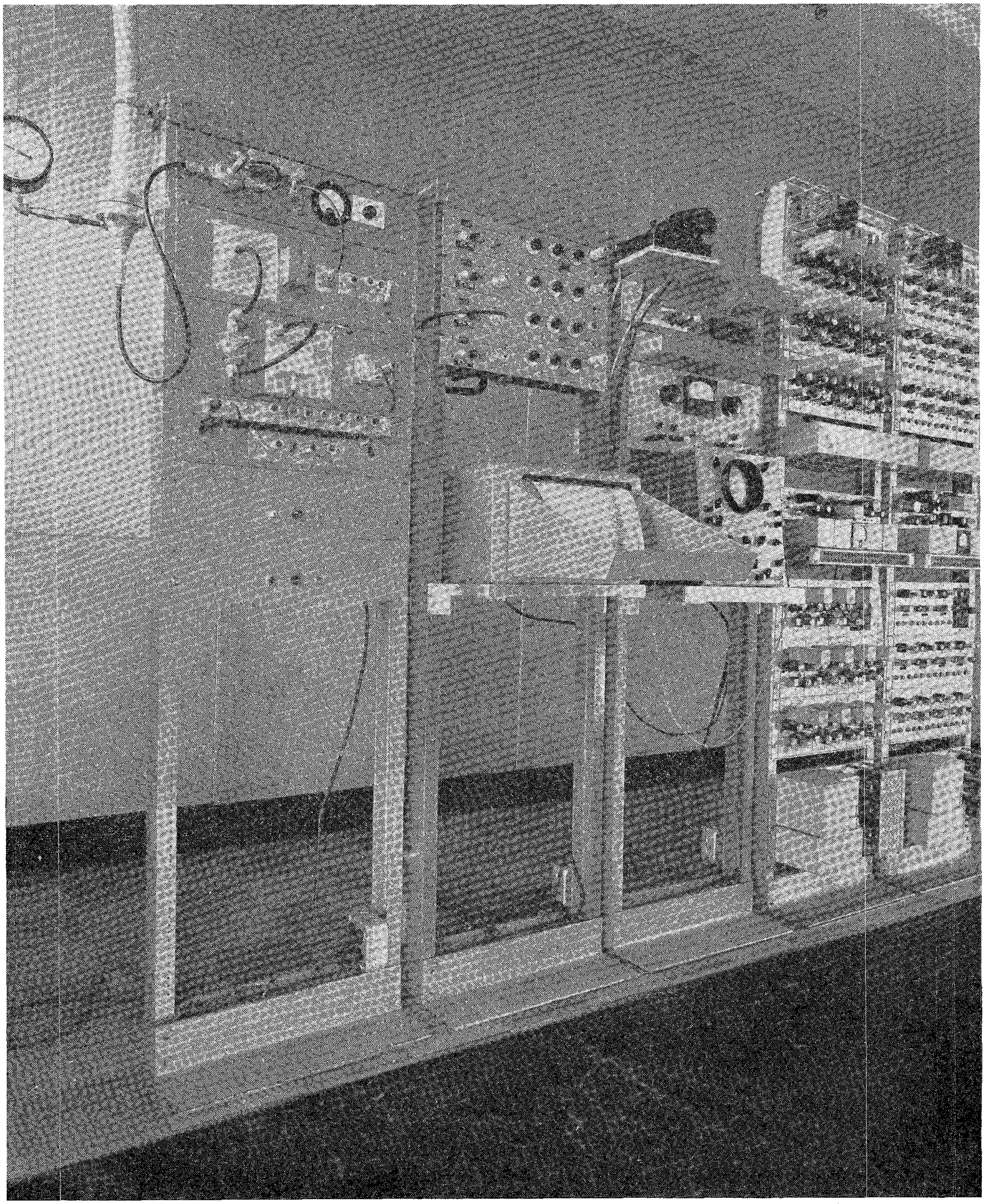

Fig. 6—View of receiver, recording, and multiplex equipment.

clearly evident. During this, an effect on pulse shape and position may also be noted by oscilloscopic observation. No photographs of this were taken, but it was realized that the ptm demodulator makes an ideal instrument for studying the time shift of the effective leading edge of the pulse. Accordingly, the normal synchronizing circuits were modified to provide an absolute time reference and the recordings in the lower part of the slide

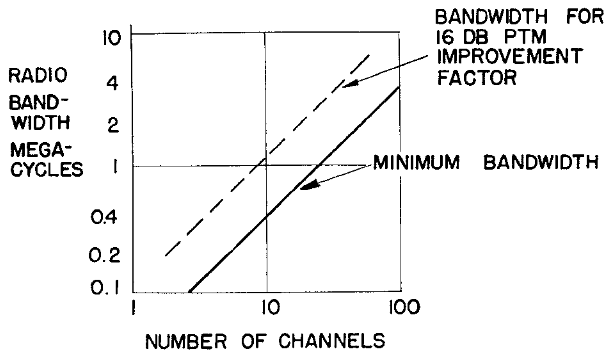

Fig. 7—Bandwidth versus number of channels for ptm.

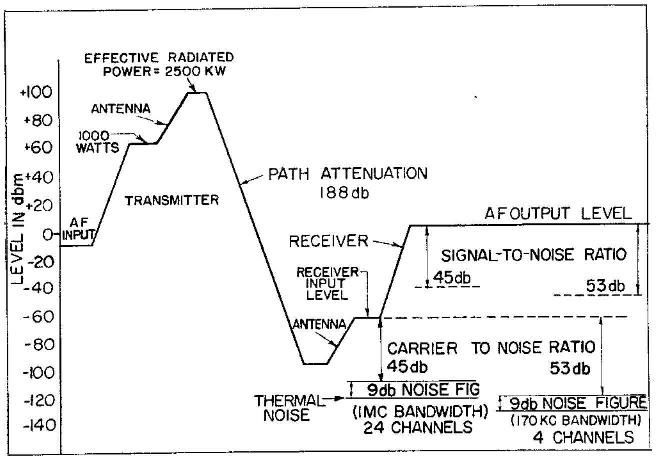

Fig. 8—Power level diagram.

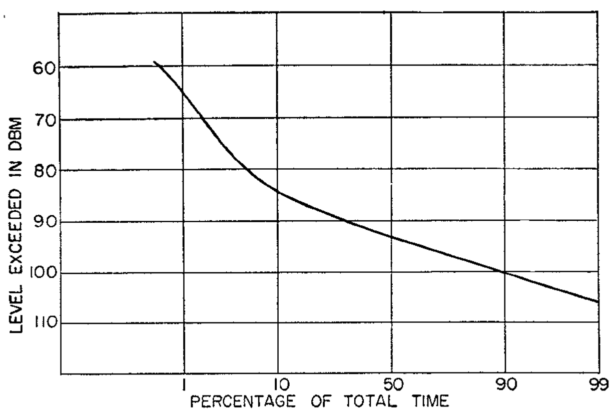

Fig. 9—Summary of measured median levels.

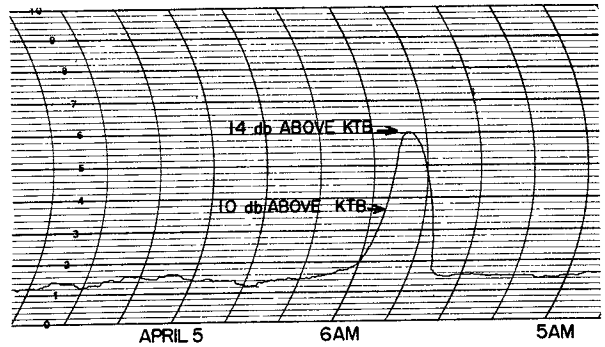

Fig. 10—Recording of noise at 900 mc received from the sun.

(a)

()b

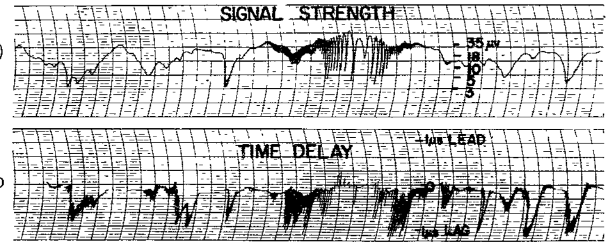

Fig. 11—Recordings showing effect of airplane reflection on (a) received signal, (b) time delay.

(a)

(b)

(c)

(d)

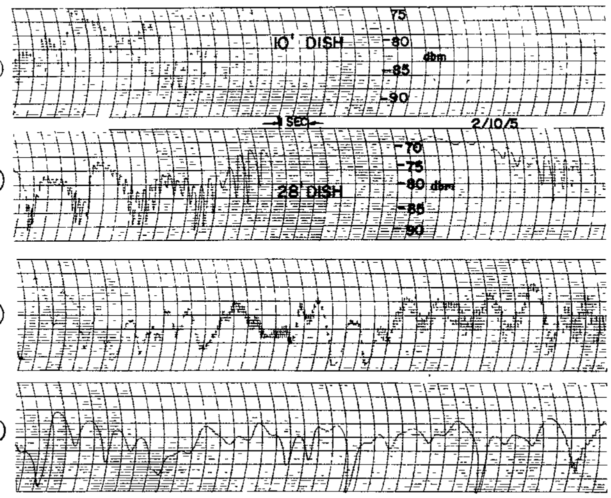

Fig. 12—Recordings showing effect of airplane reflection when using (a) and (c) wide-beam antenna, (b) and (d) narrow-beam antenna.

made. Lags of 1 μsec are shown. The time shifts may be seen to correlate with the signal changes at some points, but not at all. In a typical airplane passage, the time shifts are largest at the beam edges, because then the path differences are greatest.

Fig. 12 displays simultaneous recordings made with two receivers and two sizes of receiving antenna. The upper track from the smaller, 10-foot dish shows the airplane doppler signal for a longer time than does that for the 28-foot dish. Again, the rapid signal changes are clearly shown by the high-speed recorder. Each strip is about 20 seconds long, presenting detail which is completely suppressed on normal long-term recordings made with a time constant of twenty seconds. Even with no airplanes in the beam, fades of 15 db in one-half second have been noted. The correlation between the signals from antennas about 40 feet apart is of interest. It is evident at some times and absent at others.

It should be mentioned in passing that ignition noise has been noticed occasionally. This is not usually a problem at uhf, but the high gain of the antennas used here makes it of some importance when there are roads in front of the receiving antenna.

Conclusion

In conclusion, it has been found that pulse-time modulation retains its known properties when applied to over-the-horizon propagation. Certain details appear to require further study, but these are functions of the medium and not of the modulation method.