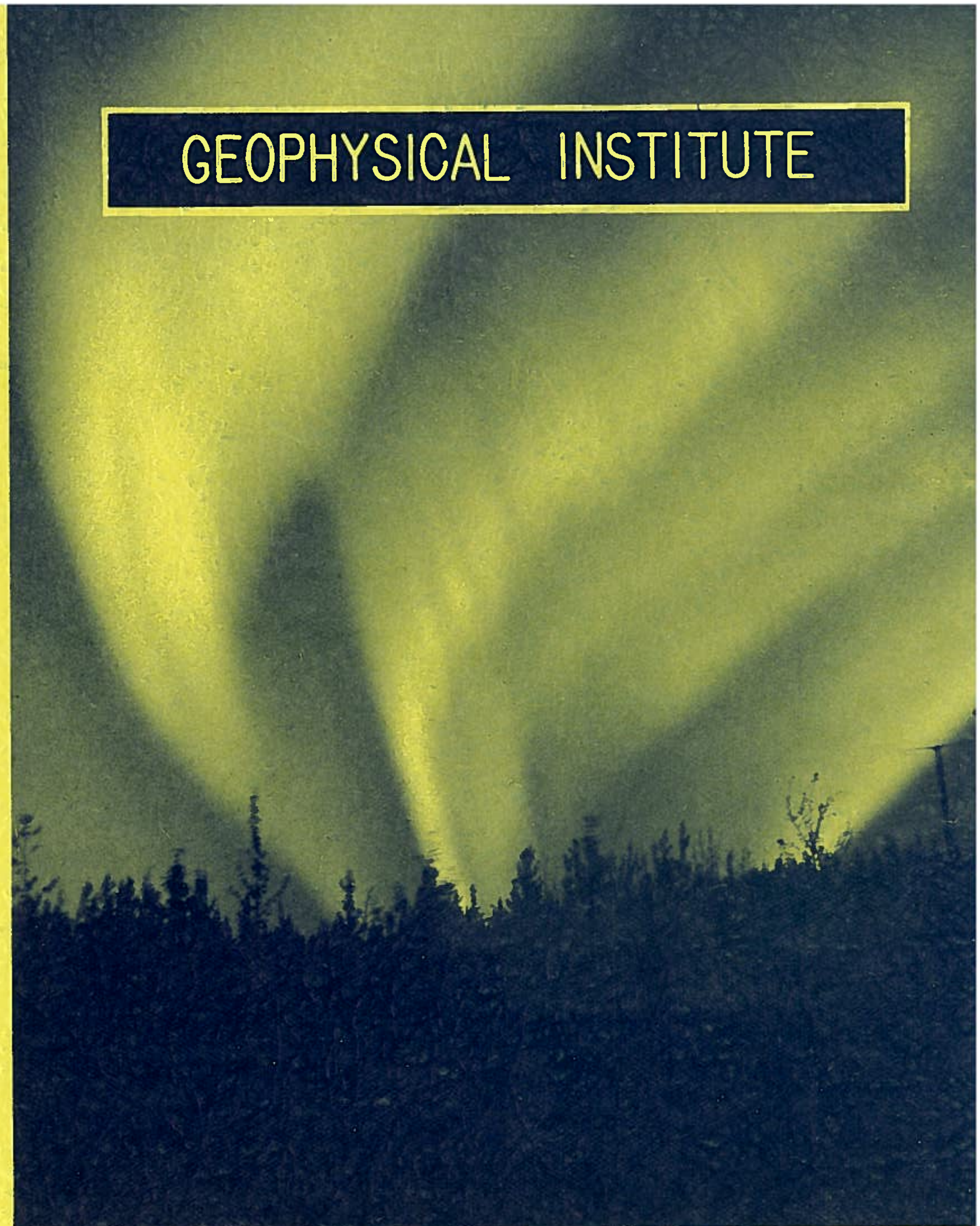

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COLLEGE OBLIQUE IONOGRAMS

by

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and

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COLLEGE OBLIQUE IONOGRAMS

ABSTRACT

This report illustrates some of the typical backscatter echoes observed at College, Alaska. Backscatter soundings are being made in five directions--015, 105, 210, 270, and 325 degrees true bearing.

The majority of the echoes seen were not groundscatter as usually defined. Many echoes from the northern directions were, in fact, direct scatter echoes from the ionosphere. Groundscatter echoes were regularly observed from the south during this past winter, but only rarely from the north.

Sample forward oblique ionograms recorded over the Andöya, Norway, to College, Alaska, path are shown. Preliminary results indicate that the signals were primarily propagated via E or Es layers. Signals with delays of 3 to 10 milliseconds over the great-circle path delay were quite common on all the paths monitored at College. The sample records shown contain signals with delays of 4 to 5 milliseconds.

COLLEGE OBLIQUE IONOGRAMS

This report shows samples of the backscatter records obtained at College, as well as a few transpolar forward oblique ionograms from the records of one day. The records shown are intended to illustrate more or less typical traces obtained at College. In general, although better examples of any specific feature exists in other records, the records shown illustrate most of the types of echoes and traces we see.

The equipment used is a Granger 4 - 64 Mc/s, 30 kw peak pulse power step-sounder. The antennas are Granger vertical, single-bay, log-periodic antennas beamed at 015, 105, 210, 270, and 325 degrees true bearing.

A clipping circuit in the video amplifier section is adjusted to pass only signals above approximately 1 to 2 microvolts at the receiver input. Two sweep modes are used; the first is the short-pulse sequence with 100 (sometimes 200) microsecond pulses and 16 kc/s receiver bandwidth, and the second is the long-pulse sequence of 1000 (sometimes 500) microsecond pulses and 4 kc/s bandwidth. The recording oscilloscope trace is automatically changed between the short-long modes to produce different range displays for each sequence.

The groundscatter trace branches off the second order, vertical incidence trace (Peterson 1951, Silberstein 1954). Its leading edge lies along the line, passing through the origin, which is tangent to the second order vertical incidence trace. Discrete scatterers on the ground can produce echoes whose range is constant as a function of frequency.

Direct scatter from the E and F regions is also possible. Various types of traces observed at high latitudes are described by Bates (1959, 1960, 1961a,b). The slant Es (Smith, 1957) is quite common as is the analogous

F region trace (sometimes called the polar spur). The latter trace is characterized by having a range-frequency dependence that is approximately linear with a slope about one-half that of the groundscatter echo from the same layer. Constant range versus frequency echoes are quite prevalent; their identification as to propagation mode is difficult, and can be accomplished only if some unique characteristic can be recognized.

In the records shown below, the beginning frequency is 4 Mc/s. The frequency steps are linear within each of 4 bands. In each band the distance between the frequency steps is double that of the preceding band. Hence, in band A, from 4 to 8 Mc/s, the frequency marks are 1.0 Mc/s apart, 2.0 in band B from 8 to 16, 4.0 in band C from 16 to 32, and 8.0 in band D from 32 to 64. For this reason abrupt changes in trace slopes should be ignored at the band edges.

The range marks are 1.0 millisecond or 150 km apart on the backscatter traces. The first mark is about 120 km; it was recently discovered that some 30 km delay exists in the receiving system.

In this report the term 'backscatter' is used for any type of echo that is observed. The term 'groundscatter' is used whenever backscatter from the ground is discussed. If the backscattered energy can be identified as coming directly from a particular region of the ionosphere, it will be termed 'direct backscatter'. During the past decade the term 'backscatter' has been used interchangeably with 'groundscatter'. In the mid-latitudes, groundscatter is the predominant echo so the meaning is usually understood. At high latitudes, however, many backscatter echoes other than groundscatter exist so a definite distinction must be made in the interest of clarity.

Backscatter from the north on 6 November 1963 is illustrated in Figures 1 and 2. These records were made with the 200 microsecond, short-pulse sequence. The 0252 UT record is a more or less normal winter record for late afternoon. (All times are UT; local time is 150 WMT or minus 10 hours.) Previous records taken north that day showed very weak groundscatter and good vertical incidence traces from the F region. The critical frequency was approximately 5 Mc/s. The sloping trace is either direct scatter from the F region or E region groundscatter. The echo at 120 km is probably a vertical incidence Es echo.

As evening approaches, the identifiable F region echoes disappear. Many echoes appear and disappear, sometimes from frame to frame. Generally, there will be both well defined and quite diffuse echoes as in the 0752 record. By 0902 a good slant Es echo has developed. It definitely originates in the 120 to 130 km region; thus, it cannot be groundscatter via the E region. It shows some horizontal structure, as though it were composed of echoes from spaced, discrete, scattering sources.

The slant Es echo stays until 1322, then it disappears and many echoes appear. The 1412 record shows many echoes beginning at about 900 km. Our present idea is that these echoes are propagated via some combination E and Es, or F and E mode such as Eckersley (1940) proposed to explain what is now known to be mid-latitude groundscatter.

As morning approaches, the echoes increase in strength and frequency range, extending to 40 Mc/s between 1432 and 1522. With the arrival of morning the E region echoes usually disappear, and by 2200 normal vertical incidence F region traces and weak groundscatter appear on the records from

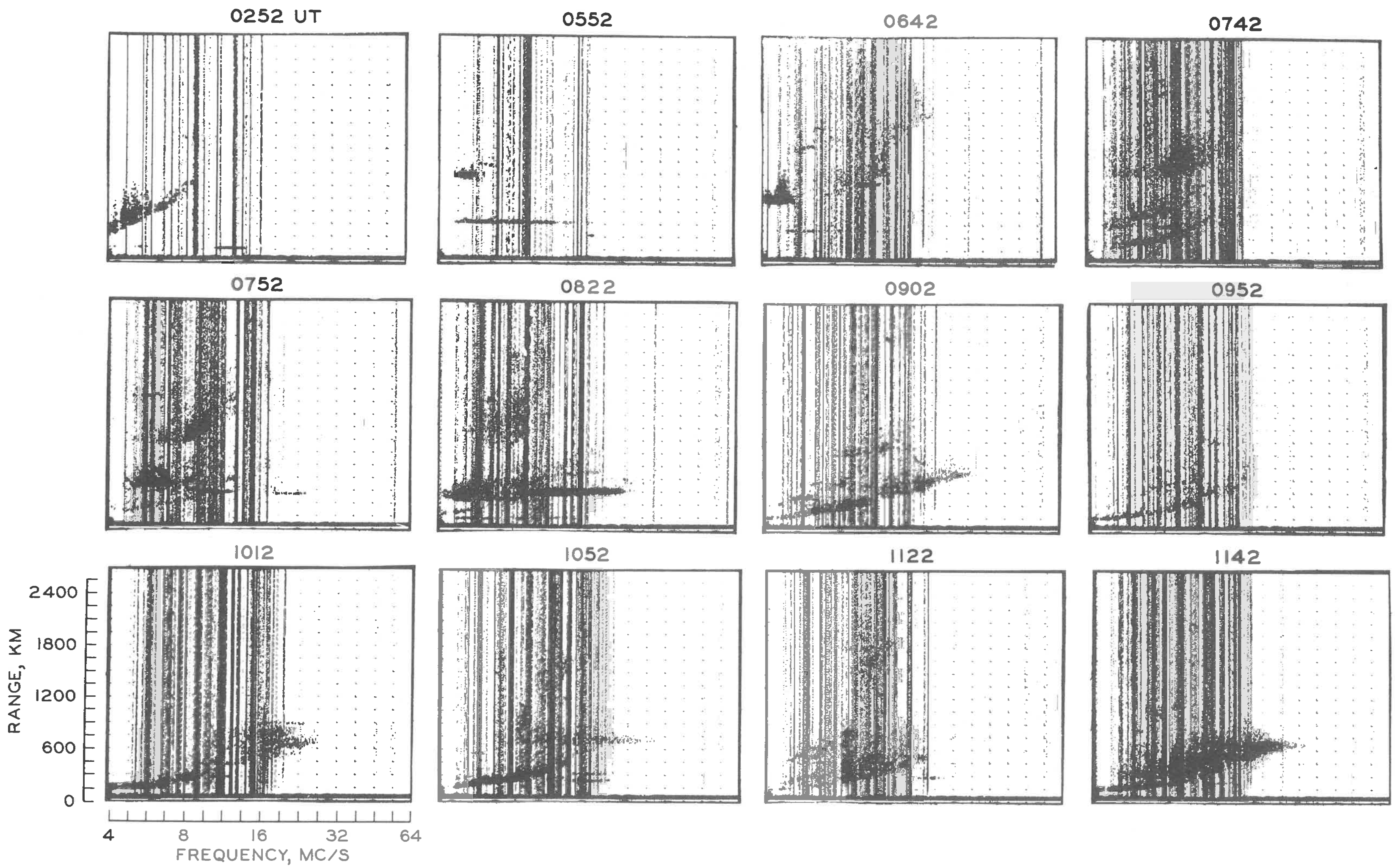

Fig. 1. Short-pulse-sequence backscatter records for 6 November 1963 taken with the 015° antenna.

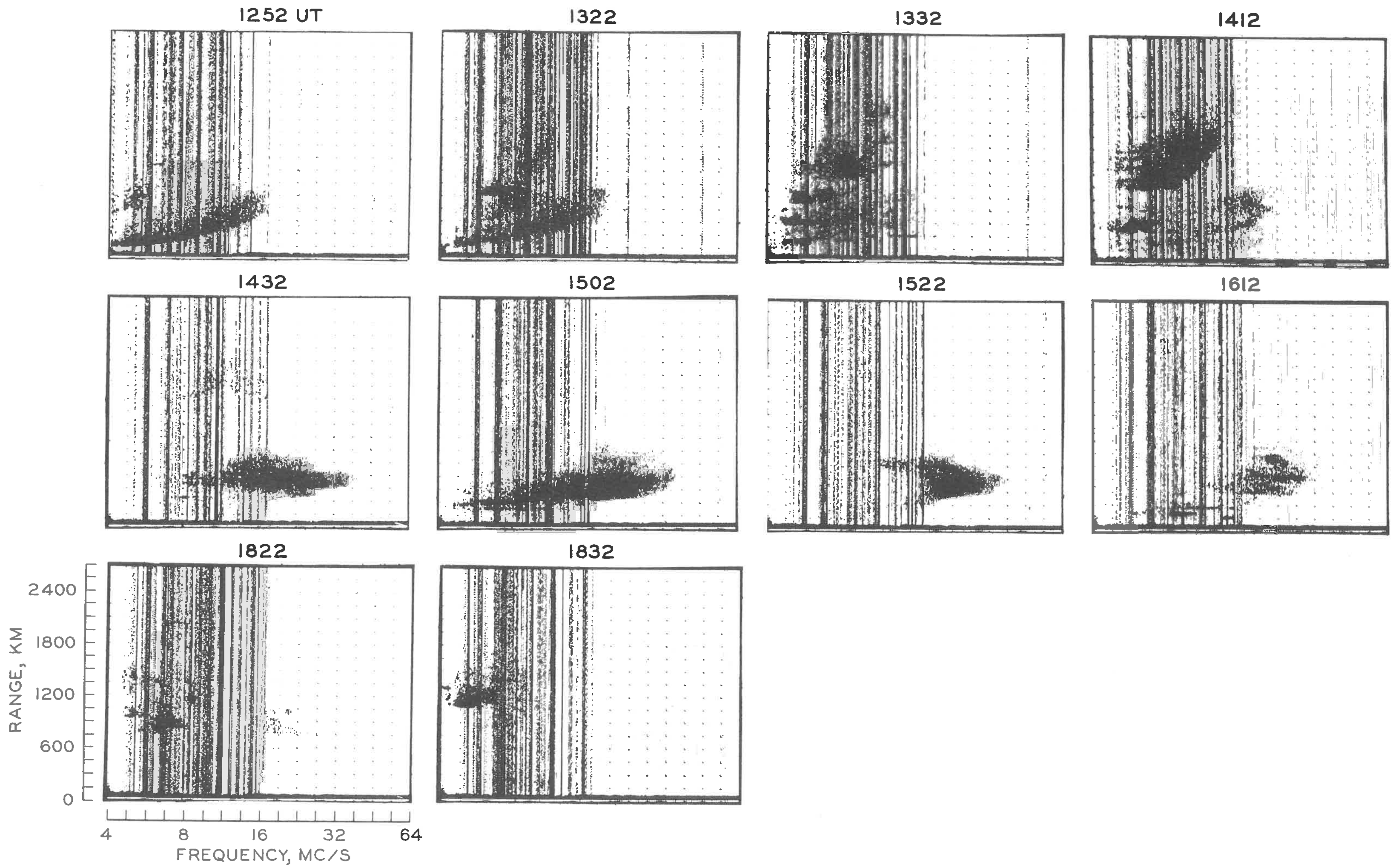

Fig. 2. Short-pulse-sequence backscatter records for 6 November 1963 taken with the 015^{o} antenna.

the north. During large magnetic disturbances, though, the E or Es scatter echoes can persist throughout the day.

Figure 3 shows short-pulse-mode records from the 105° direction for November 7, 1963. Although a very weak groundscatter trace can be identified, the primary echo observed at 0203 is direct F scatter, branching off the fundamental vertical incidence trace. At 0323 the echoes are unidentifiable. By 0403 slant Es auroral echoes are present, along with constant range echoes. The 1503 record does not differ significantly from the earlier record. At 0603 strong E region echoes are present to Mc/s. The speed with which changes can occur can be seen on the 3 records 0603, 0623, and 0643. The 0643 record contains a good slant Es trace and probably a direct F trace. The 0923 film shows echoes in the 13 to 15 millisecond range which appear frequently but have not been identified. The slant Es and other auroral E echoes continue throughout the rest of the sequence.

Figures 4 and 5 show records taken in the 325° direction. The sequence of events is roughly as described above for the 105° antenna.

In all of these records groundscatter is weak or non-existent. Good groundscatter echoes are recorded much of the time from the south, are seen frequently on the 105 and 325 degree antennas, and are rare on the north antenna. Figures 6 and 7 show long-pulse-mode records using 500 microseconds taken on the 210° antenna. In the evening hours, local time (morning UT), little or no groundscatter is present. A weak F supported groundscatter trace can be seen at 0904 and 1204, as well as direct F scatter. As local morning comes, the E echoes disappear and the groundscatter echoes get stronger, until in mid-morning, a second order groundscatter trace develops.

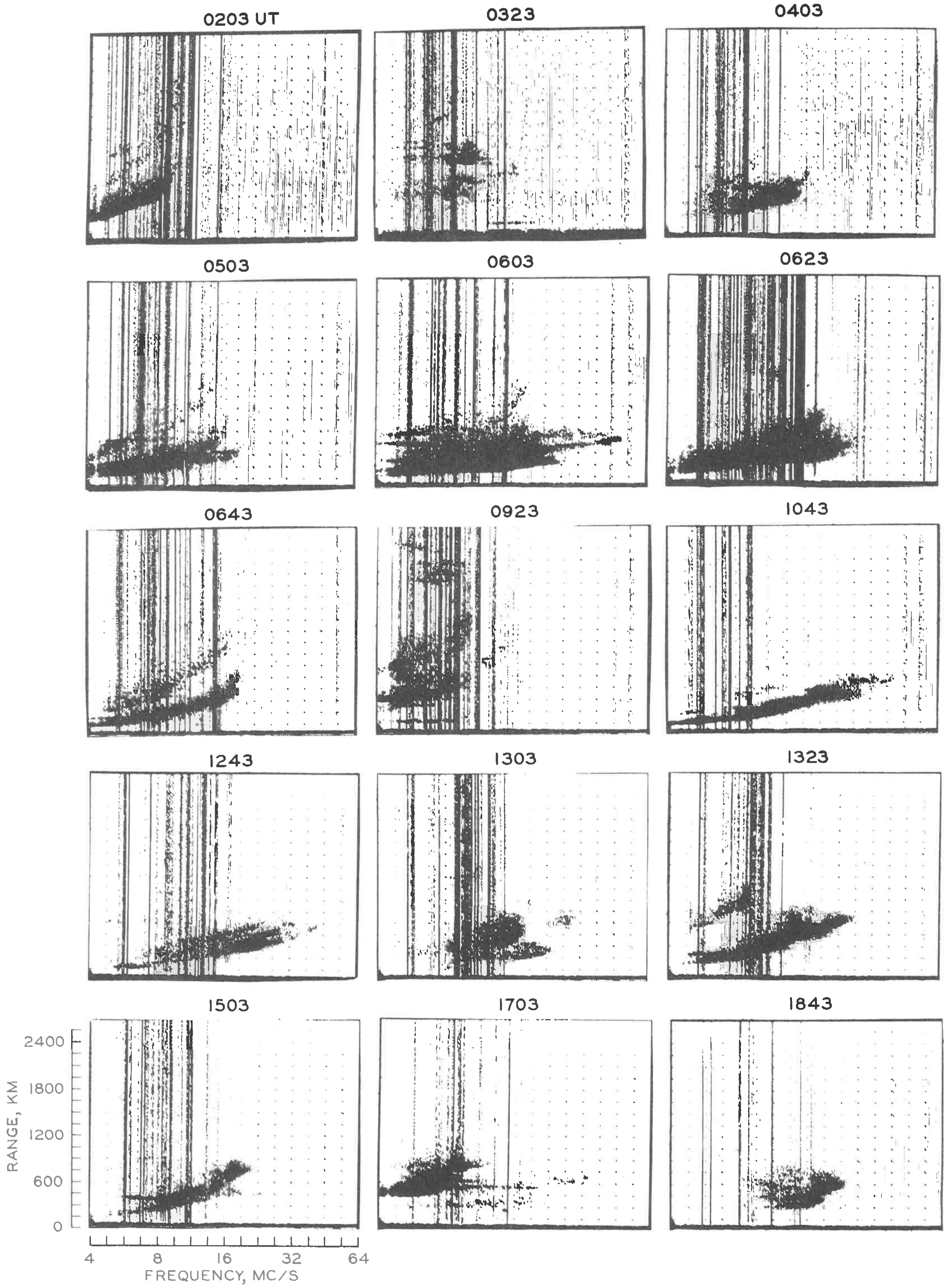

Fig. 3. Short-pulse-sequence backscatter records for 7 November 1963 taken with the 105° antenna.

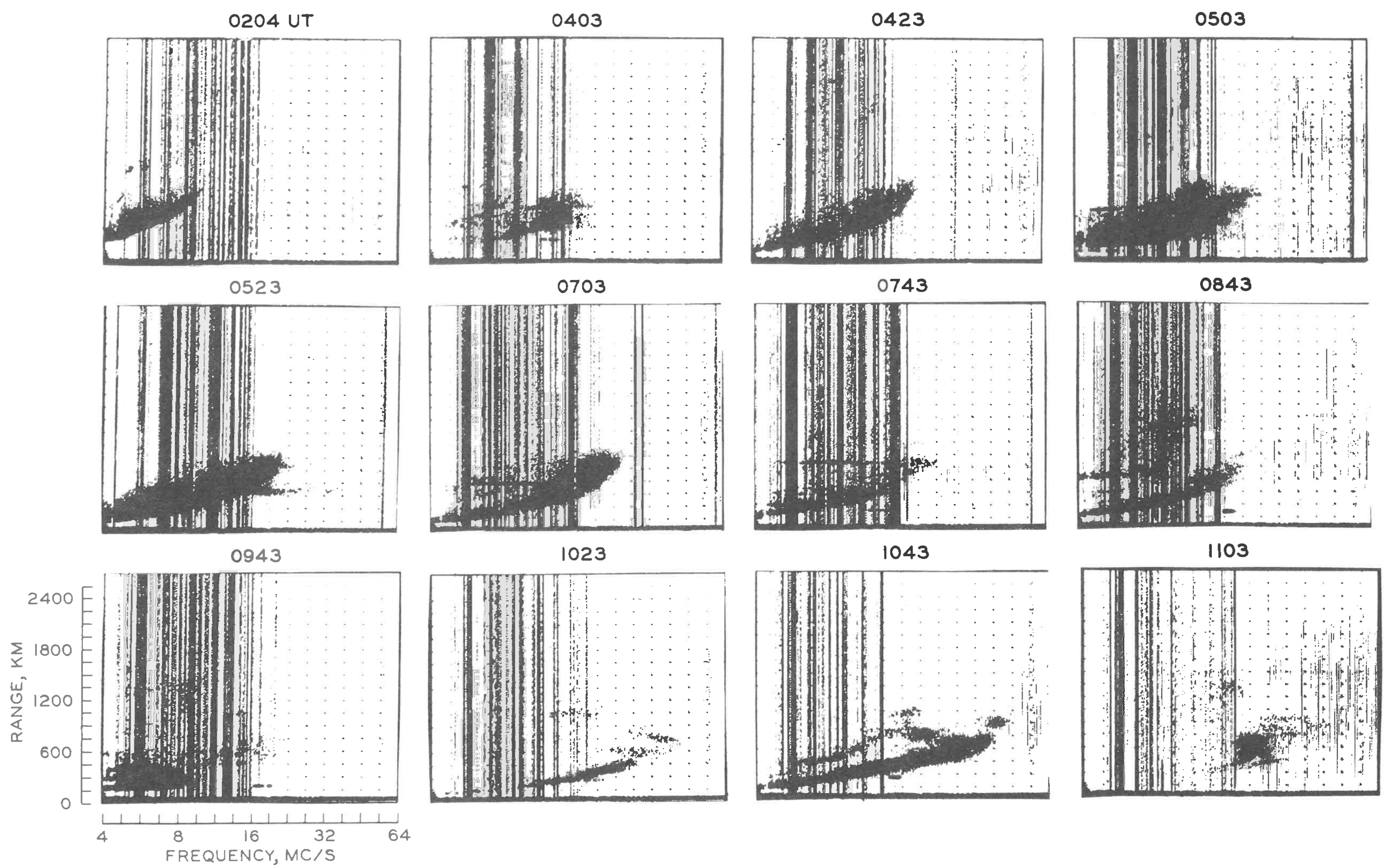

Fig. 4. Short-pulse-sequence backscatter records for 7 November 1963 taken with the 325° antenna.

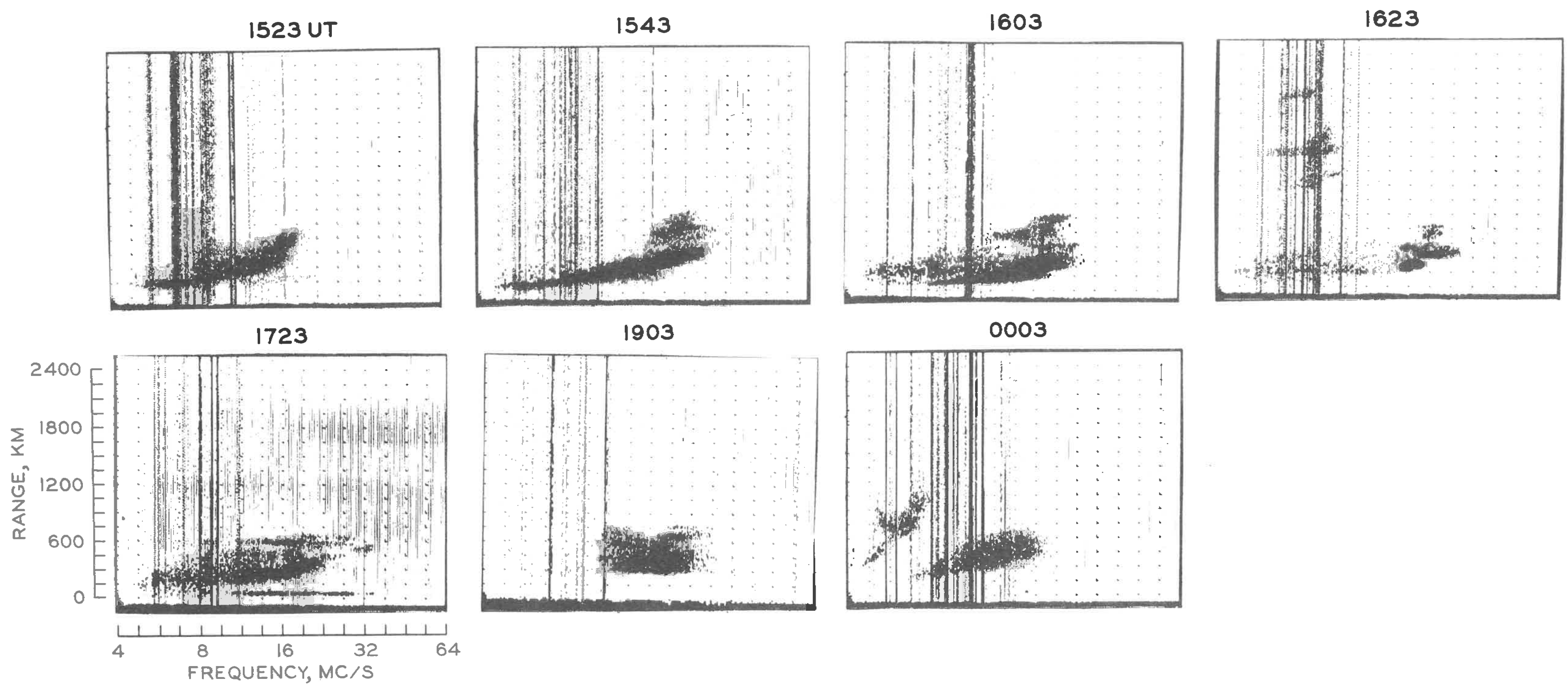

Fig. 5. Short-pulse-sequence backscatter records for 7 November 1963 taken with the 325° antenna.

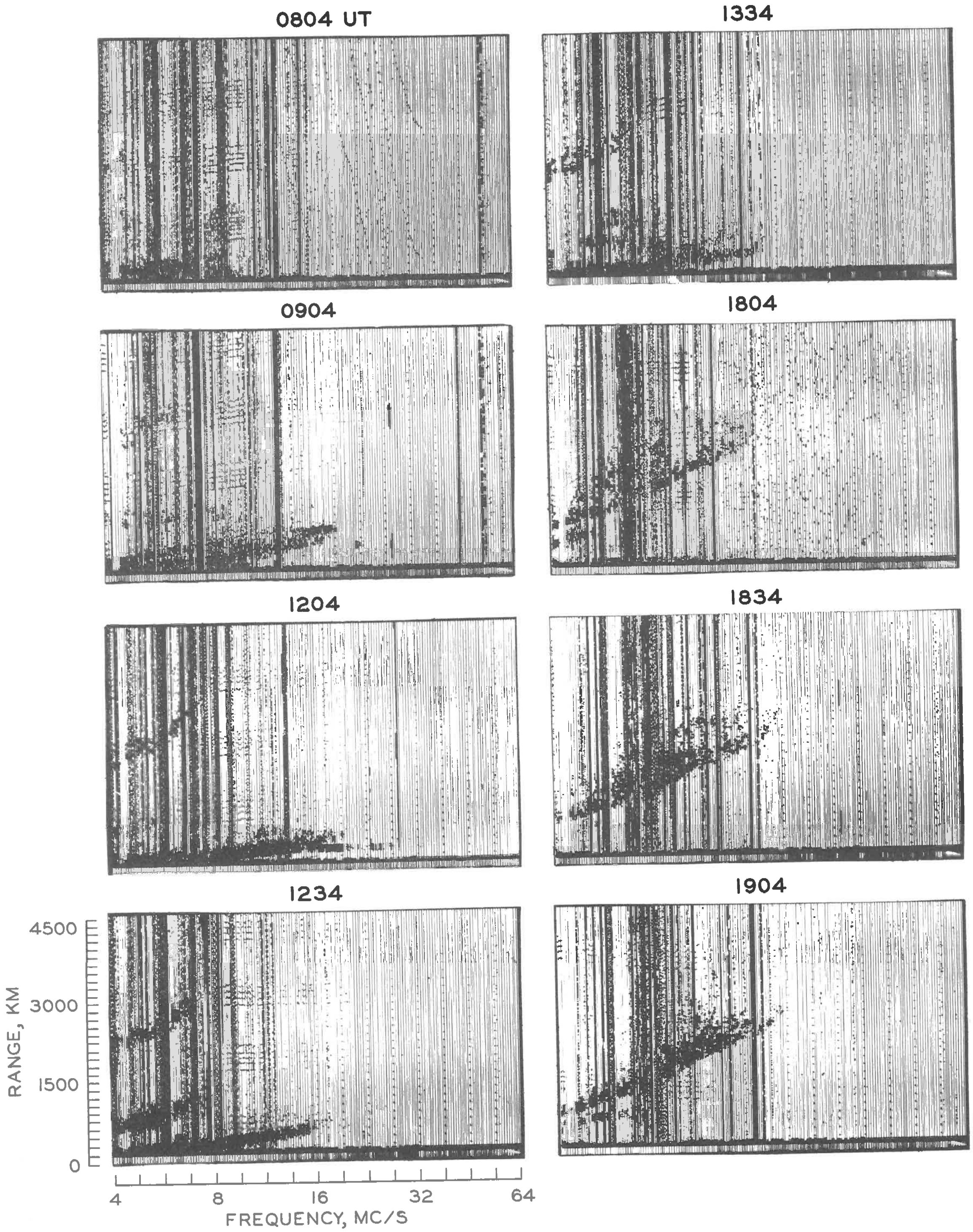

Fig. 6. Long-pulse-sequence backscatter records for 6 November 1963 taken with the 210° antenna.

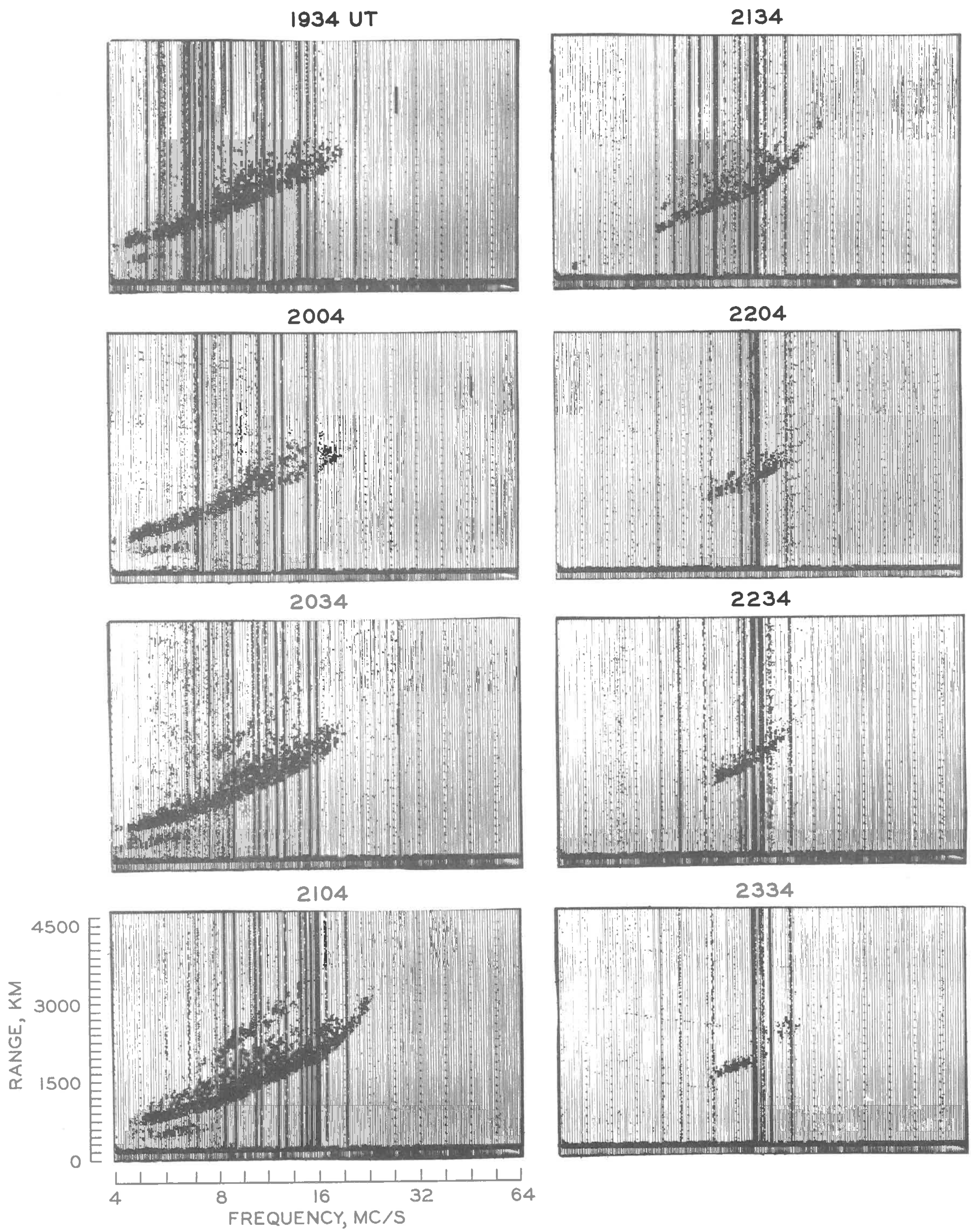

Fig. 7. Long-pulse-sequence backscatter records for 6 November 1963 taken with the 210° antenna.

Figure 8 shows backscatter records taken over one day, 23 November 1963 when echoes were quite good on all antennas. This set illustrates the sometimes marked differences in the backscatter traces from various directions. The 0134 and 0204 210° records show good one- and two-hop groundscatter, as well as some direct F scatter traces. The F layer ordinary critical frequency is between 5 and 6 Mc/s. The 0232 015° record, however, shows no groundscatter, but shows strong direct scatter echoes. The 0608 105° film illustrates an odd echo observed quite frequently from the E region at higher frequencies (this E region echo is shown in Figure 9); it is not known whether the trace shown here is an E or F region trace, though the latter seems most probable. The 0832 015° record shows strong E region backscatter.

Next morning local time, the 1934 record contains a good groundscatter trace from the south. Weak direct E scatter is also present. From the north, though, there is little or no groundscatter; several other echoes are well defined on the 2002 015° record while good groundscatter was recorded from the west at 2004 and from the east at 2008. Similarly, the next two records show strong groundscatter from the south, none from the north.

In previous backscatter work performed at College, groundscatter was frequently not seen from the north during the winter even though strong groundscatter would be seen from other directions (Owren et al. 1957, 1959, 1963). Fixed-frequency PPI records indicated that there was often a hole in the groundscatter ring which was centered on magnetic north. This lack of groundscatter from the north is illustrated in Figure 9. In each pair of records one will note excellent groundscatter echoes from the off-north path,

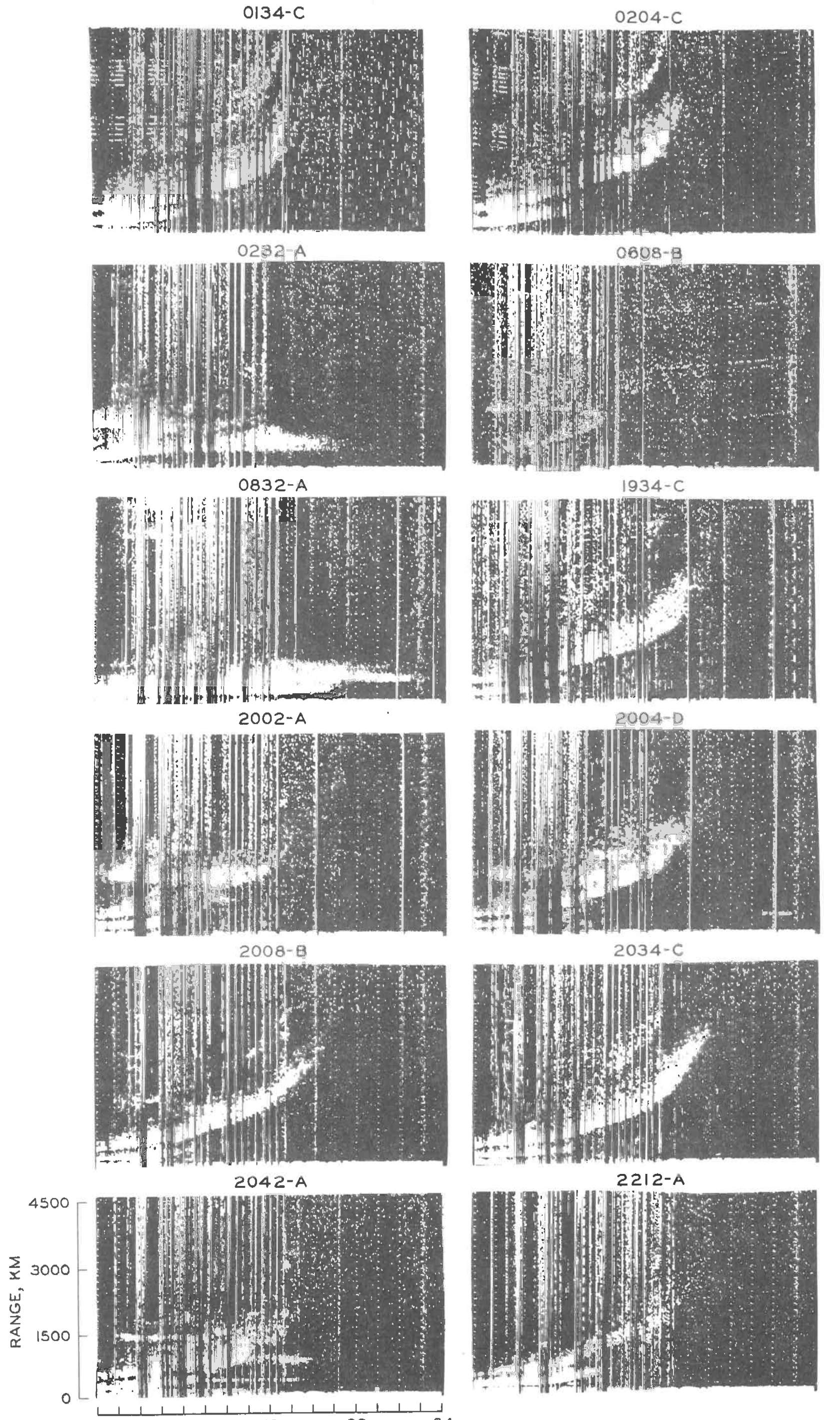

Fig. 8. Long-pulse-sequence backscatter records for 23 November 1963. The directions A through E are 015, 105, 210, 270, and 325^{o}, respectively.

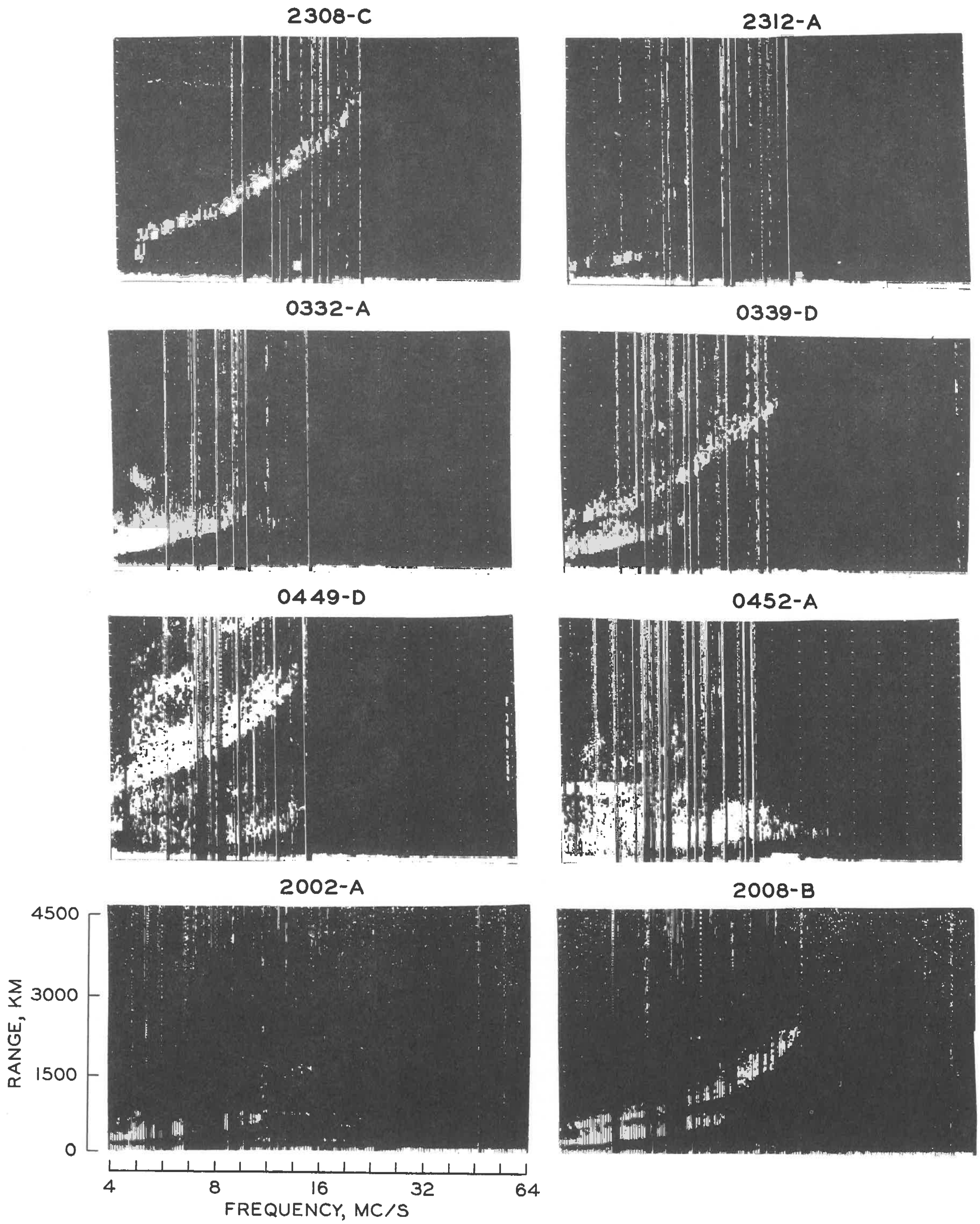

Fig. 9. Backscatter record pairs showing groundscatter from off-north, no groundscatter north. The directions A through E are 015, 105, 210, 270, and 325°, respectively.

and none from the north path. In contrast good direct scatter echoes can be seen on the north records while the direct echoes are weak on the off-north records.

Finally, in Figure 10 are shown some backscatter oddities recorded with the high-resolution, short-pulse (200 microsecond) sequence. These traces are frequent but mostly unexplained.

The five on the left show a regularly observed E region trace. The sloping trace is a slant Es trace. Previous work (Bates 1961 a,b; Cohen et al. 1962) indicates that the slant Es echo is least-time focused energy scattered from a large, random collection of field-aligned, E region scatterers. The constant range trace could be the 'radar' echo from the northern boundary of the scattering; a problem exists with that interpretation, however, in that such a constant range echo should not have a sharp, high-frequency cut-off at the junction with the slant Es trace. This type of record does not appear to be equipmental because the junction cut-off frequency has been noted anywhere between 20 and 40 Mc/s. Occasionally, when the junction of the slant Es trace and the constant range trace exceeds 40 Mc/s, a well-defined constant range echo extends beyond the junction. The echo amplitude of the trace extending beyond the slant Es junction, however, appears to be greatly reduced.

The upper two records on the right in Figure 10 show a commonly occurring set of traces. The upper set of traces appears to be a multiple of the lower set although this is probably coincidental.

Completely unexplained echoes are shown in the last three prints on the right in Figure 10. On the 0822 015° record the seven constant range traces starting at 750 km are almost exactly 110 km apart from trailing

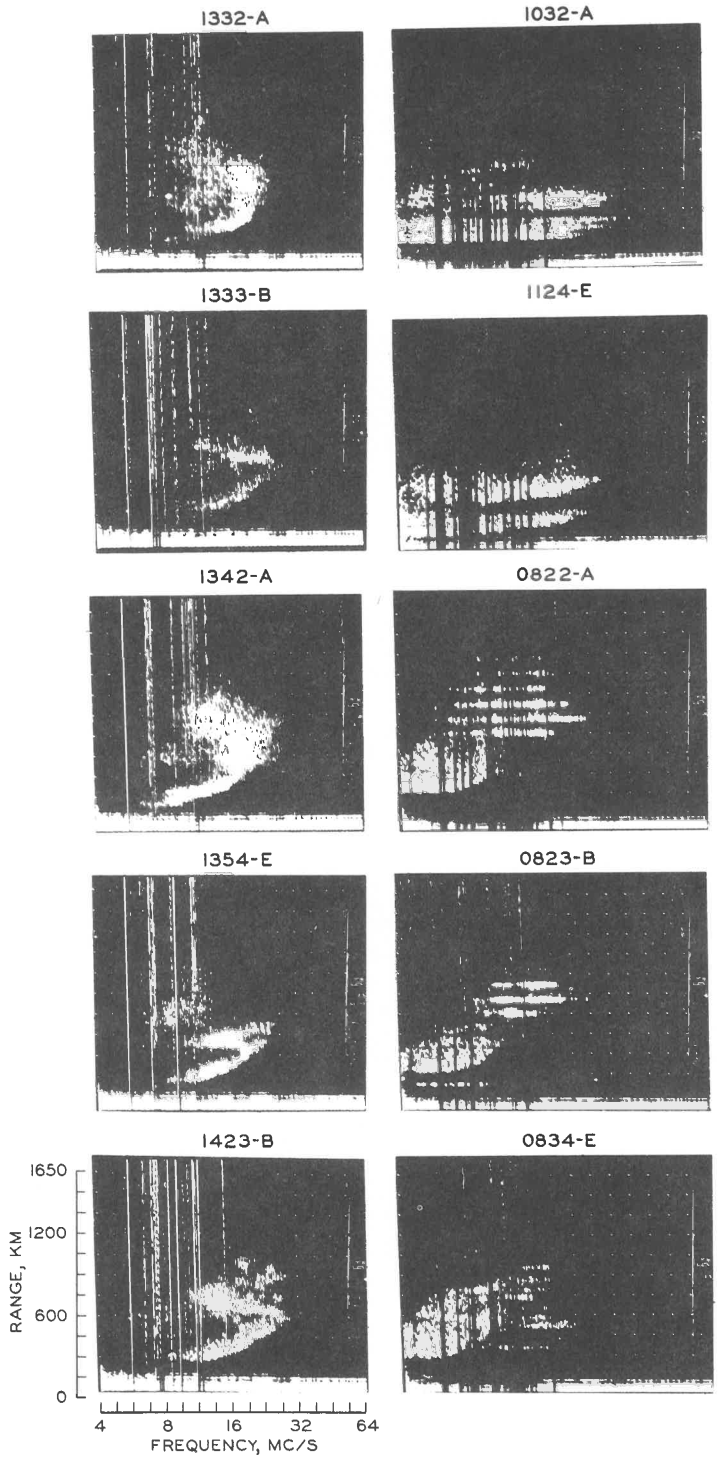

Fig. 10. Short-pulse-sequence backscatter records. Letter denotes direction as in Figures 8 and 9.

edge to trailing edge. From leading edge to leading edge the first three are 110 km apart, the third and fourth, 125, and the last four, 110. Two or three hard echoes are quite common. Here, the regularity of spacing is the oddity; it may be coincidental although this seems unlikely.

Figures 11, 12, and 13 contain forward, oblique, pulse transmission traces from Andöya, Norway. The short-long sequence pairs are shown, having 100 and 1000 microsecond transmitted pulses, respectively. Because Norway is almost directly across the geographic pole from Alaska, the winter-time path is always partially night and day. Arctic propagation at night appears to be primarily by E region modes as the F region critical frequency usually goes below 2 Mc/s. Thus, E or Es propagation across the pole should be important much of the time, and this indeed seems to be borne out by the records. The E modes are characterized by being well-defined and showing no retardation at either end. F region propagated signals all show retardation at the high frequency end, and will show retardation at the low frequency end if an appreciable E region exists.

Previous transpolar research reported by Owren and Ortner (1961) indicated that transpolar signals were sometimes highly deviated. The 0726 and 2206 records show normal great-circle signals and signals delayed by 3 to 5 milliseconds. Delays as much as 9 milliseconds have been observed from the Norwegian step-sounder, one located in Greenland, and one in the Pacific Basin.

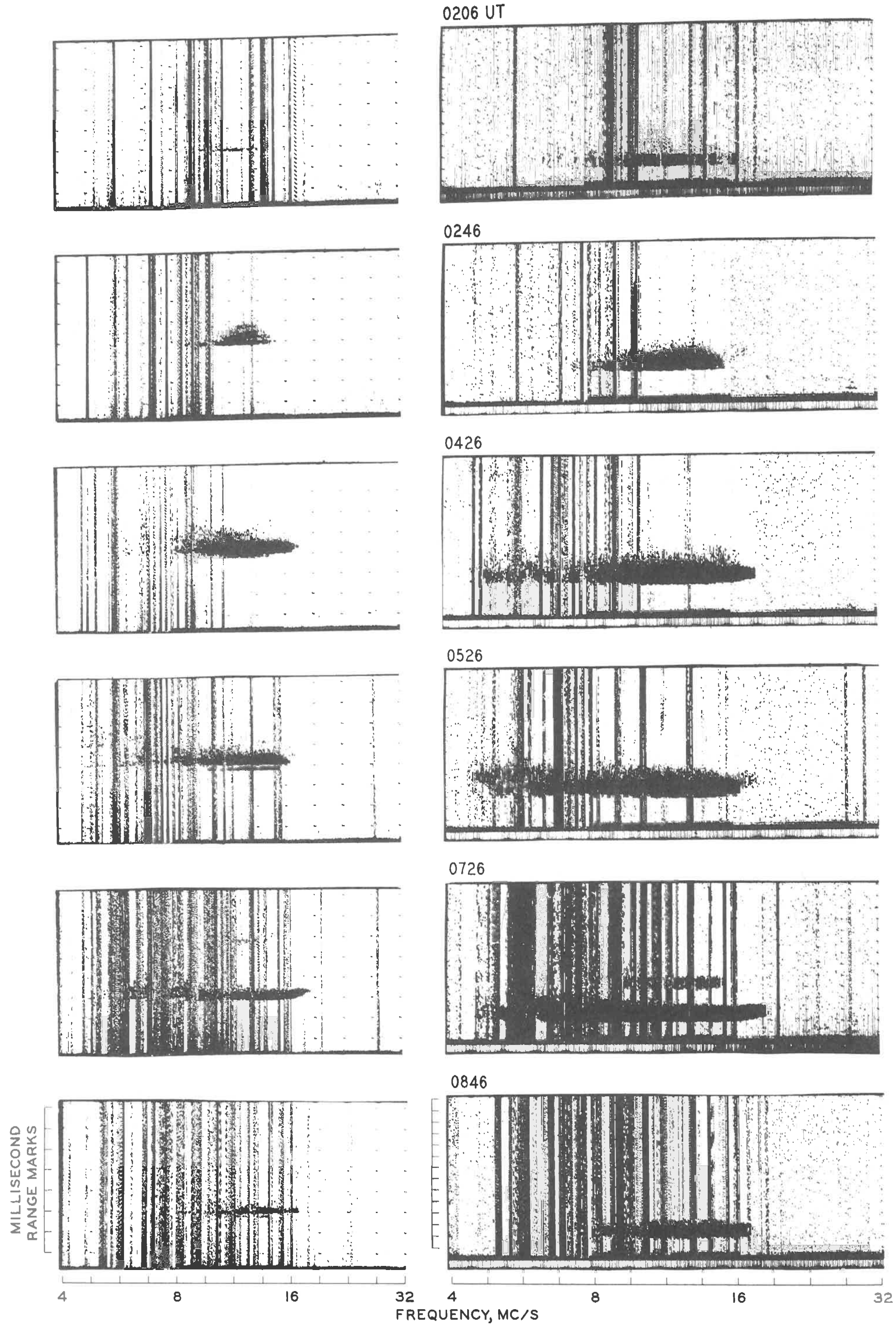

Fig. 11. Forward oblique ionograms from Andöya, Norway.

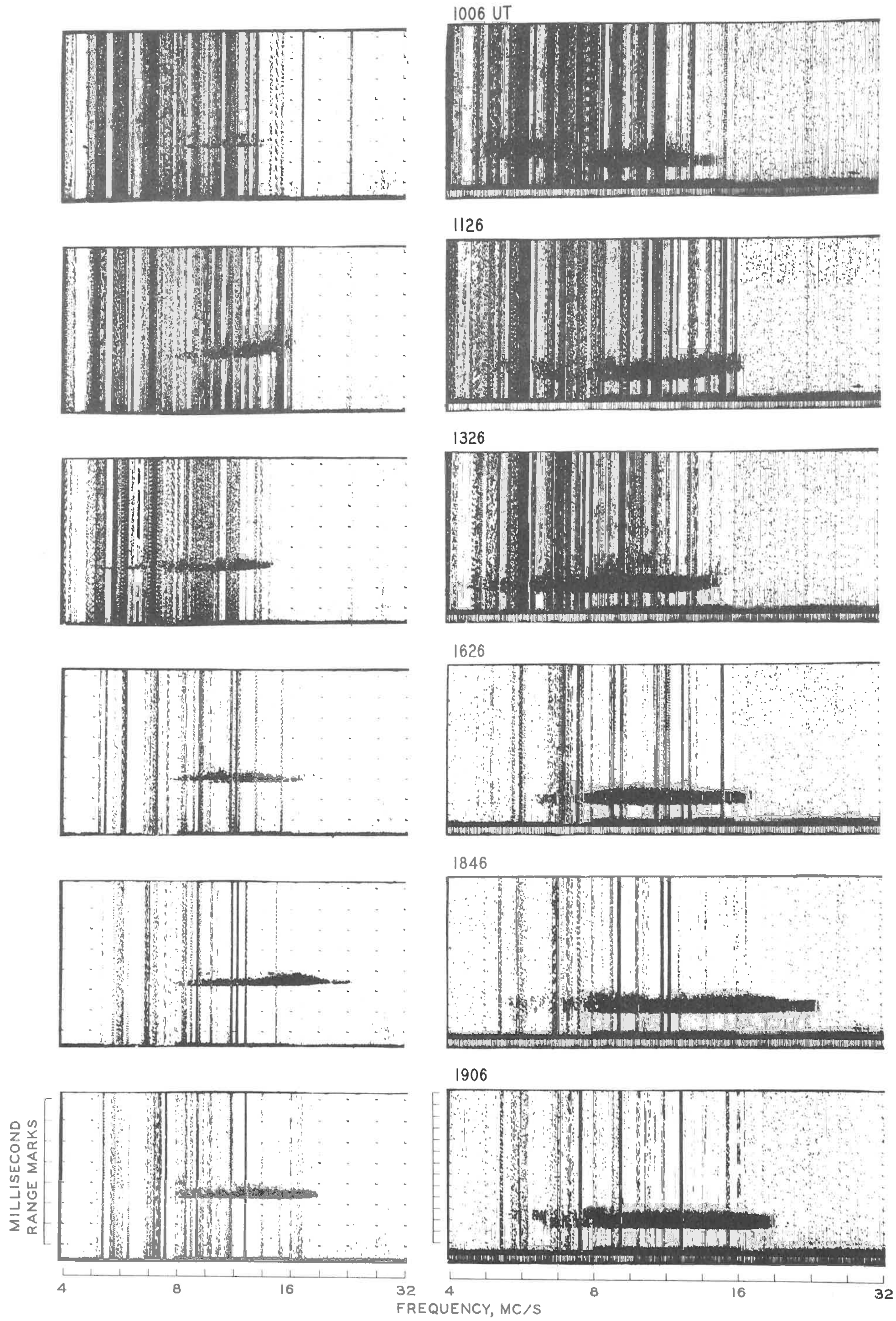

Fig. 12. Forward oblique ionograms from Andöya, Norway.

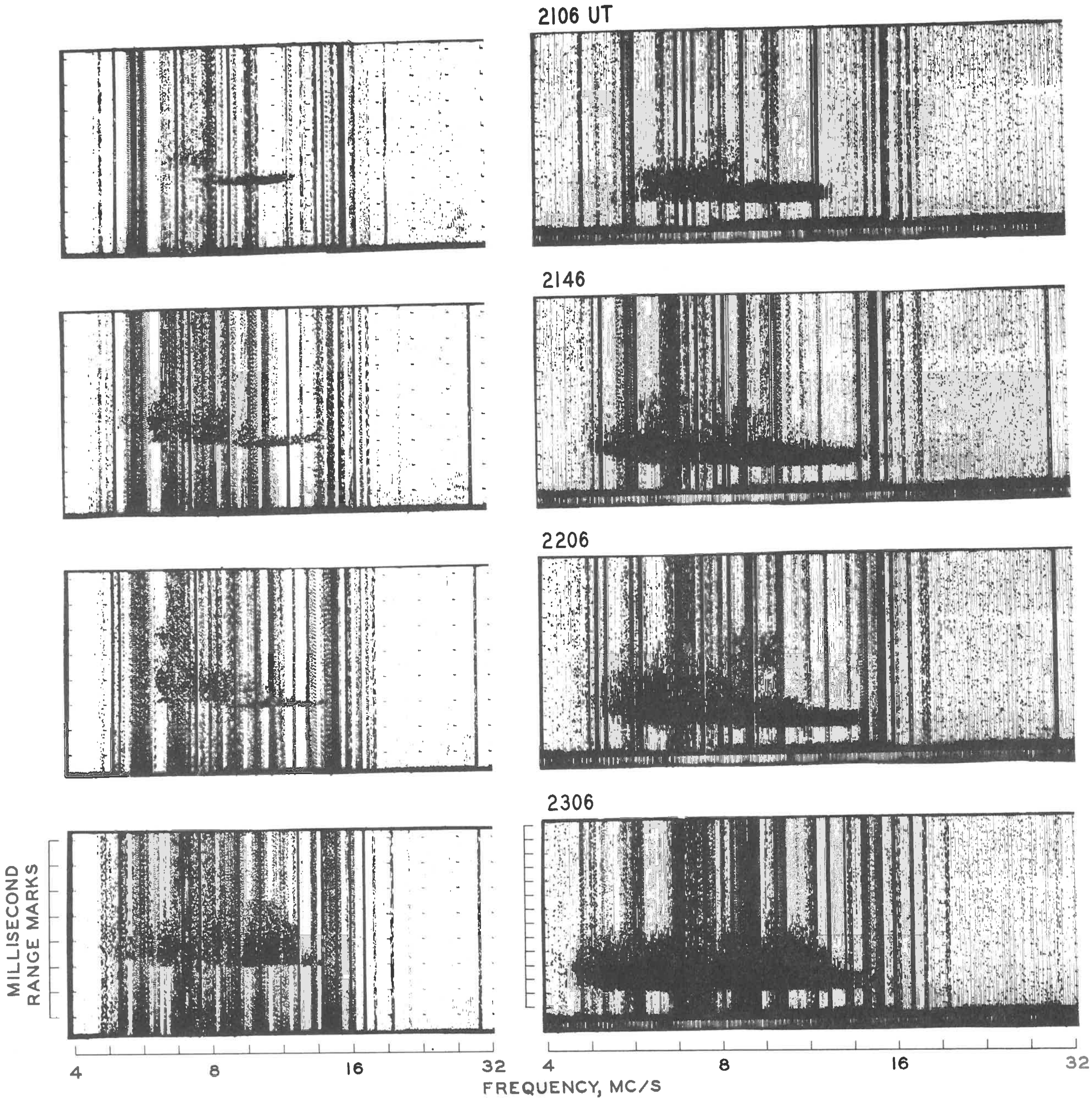

Fig. 13. Forward oblique ionograms from Andöya, Norway.

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