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WT-1352(EX)
EXTRACTED VERSION

OPERATION REDWING—PROJECT 6.4 AIRBORNE ANTENNAS AND PHOTOTUBES FOR DETERMINATION OF NUCLEAR-WEAPON YIELD

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NOTICE:
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representation of the wave form from a smaller detonation (8 kt). Curve A of Figure 1.2 is an actual trace, slightly idealized, received at an Air Force Cambridge Research Center (AFCRC) station about 220 nautical miles from the detonation center. The detonation was Shot Bee of Operation Teapot (see Reference 2 and Figure 1 (d) of Reference 1). The ground wave and the first sky wave (the pulse arriving after one reflection from the ionosphere) are shown as received with a vertical antenna responding to the electric component of the electromagnetic signa

Curve B of Figure 1.2 has been constructed from Curve A by differentiation. It simul... the output wave form to be expected from a simple, non-resonant loop antenna. The voltage induced in such an antenna is proportional to the rate of change of the incident magnetic field and is, therefore, proportional also to the rate of change of the incident electric field, since the electric and magnetic fields are directly proportional in a traveling electromagnetic wave.

In Operation Redwing tests the antenna used was not a simple non-resonant antenna and its response was somewhat more complicated. However, for frequencies that were not too high, the general wave form shown in Curve B of Figure 1.2 was found to be a valid representation of the electromagnetic signal as received on the type of fiducial antenna used in Operation Redwing tests. It should be noted that the two lobes in the ground wave of the upper trace, Curve A, have become three lobes in the ground wave of the lower trace, Curve B, while the first sky wave in the upper trace, with its three lobes, has become a four-lobed oscillation in the lower trace, after it has been differentiated to simulate reception by a loop antenna. The fourth lobe, however, is considerably weaker in amplitude than the first three lobes.

Period and Yield. It was found in earlier tests that a correlation existed between the yield of the detonation and the period of the main oscillation in the electromagnetic pulse. The correlation is shown in Figure 1.3, which was drawn from the data in Figure 9 of Reference 1.

The curve of Figure 1.3 shows that a wide range of yields is covered by a relatively narrow range of periods. Furthermore, experimental points from previous test detonations showed considerable scatter about the curve. Consequently a yield determination based on the measurement of the period of the electromagnetic pulse was not expected to be accurate, except perhaps for high yields. The upper part of the curve, above 1 Mt shows a much faster variation of period with yield than does the lower part, near 10 kt.

Field Strength. The field strength of the electromagnetic ground wave was measured extensively in earlier tests. There was a large scatter in the data, but a rough correlation between peak field strength and detonation yield was found. The correlation is shown in Figure 1.4, which is taken from Figure 11 of Reference 1. The field strength has been referred to a range of 100 km or 54 naut mi (62 statute miles).

The electromagnetic ground wave is not significantly attenuated by atmospheric absorption. For ranges which are not great enough for the ground wave to be blocked by the curvature of the earth, it is sufficient to consider the field strength to be inversely proportional to range. The ground wave field strength, $E_{(D)}$, at a particular range, D, in nautical miles, can then be obtained from the field strength at 54 miles, $E_{(54)}$, through the use of Equation 1.1.

$$E_{(D)} = \frac{54}{D} E_{(54)} \tag{1.1}$$

In Figure 1.4 the field strength has been given as E_{max}, in volts per meter, center to peak. The corresponding magnetic field, H_{max}, in ampere-turns per meter, can be obtained from E_{max} through division by 377 ohms, which is the characteristic impedance of a plane wave in free space.

Sky Waves. The characteristics of sky wave propagation are discussed in considerable mathematical detail in References 3 and 4. Each sky wave has a different total path length and a

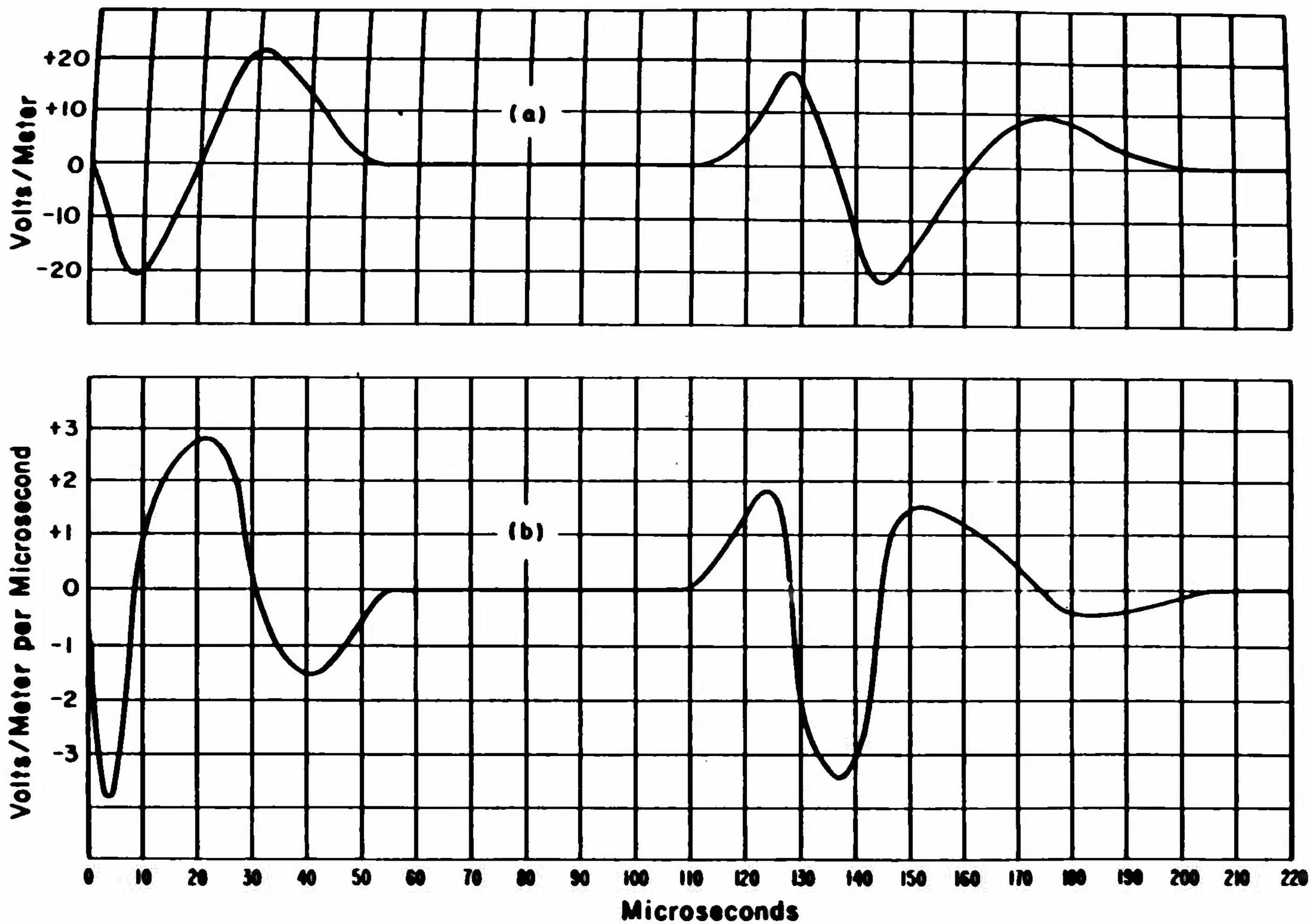

Figure 1.2 Electromagnetic wave form, (A) as received by a vertical whip antenna, and (B) differentiated; to simulate reception by a loop antenna.

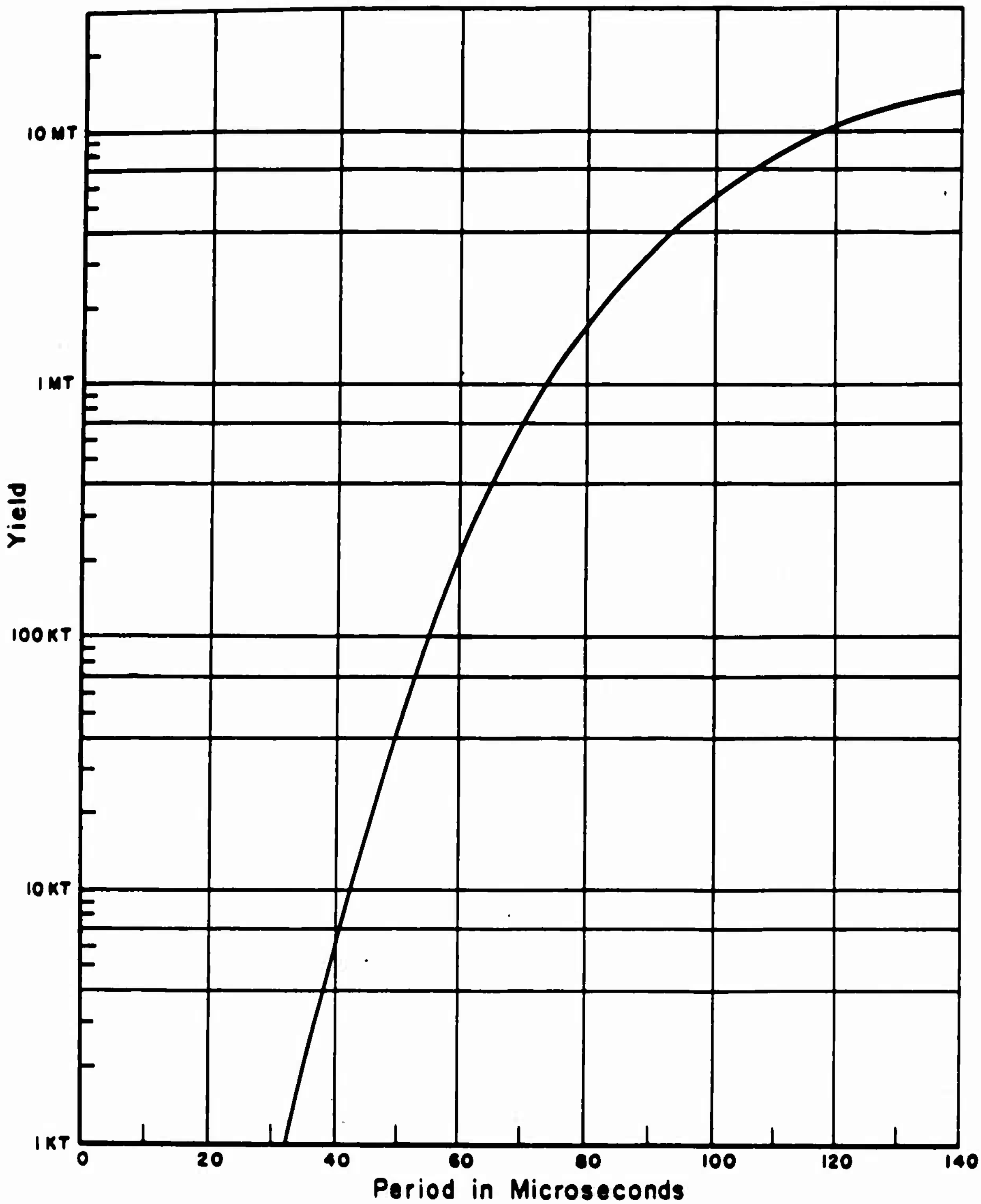

Figure 1.3 Empirical curve relating detonation yield and the period of the electromagnetic pulse.

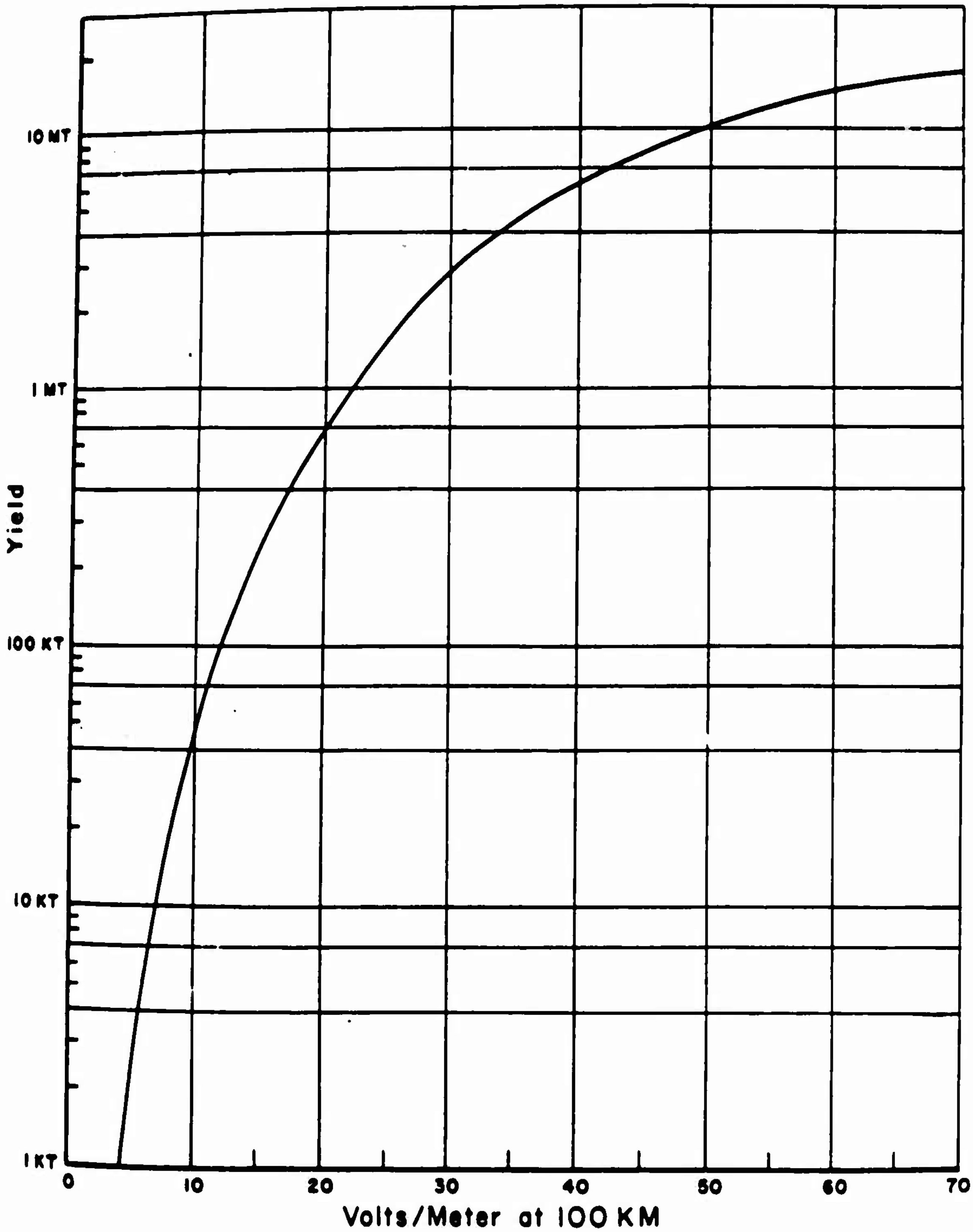

Figure 1.4 Empirical relation between detonation yield and the field strength of the electromagnetic pulse, referred to a range of 100 km (54 naut mi).

Chapter 3

RESULTS and DISCUSSION

The results obtained during Operation Redwing have been grouped under three headings: electromagnetic results, photohead results, and sequence camera results. For convenience, the discussion of these results has been included with their presentation. As preface, an operational synopsis has been prepared in tabular form.

3.1 OPERATIONAL SYNOPSIS

The operational procedure used in Operation Redwing was discussed at the beginning of Chapter 2. A description was given there of the changes which were made in the method of operation as experience was gained on the first few test shots.

Table 3.1 summarizes the tests in which Project 6.4 participated and shows that increasingly valuable data was obtained on the later tests as the equipment and the operating procedures were improved.

3.2 ELECTROMAGNETIC RESULTS

Because of the amplifier saturation discussed in "Fiducial Amplifiers", Chapter 2, many of the recorded electromagnetic pulses were badly distorted in wave shape, making it difficult to draw quantitative conclusions from them. However, during Shot Tewa a very slow sweep was used on the oscilloscope, and a number of sky waves appeared, most of which had amplitudes small enough to avoid saturation in the fiducial amplifier. From the detailed analysis of these sky waves, a considerable amount of information was obtained, making it easier to understand and interpret the electromagnetic signals from the other shots.

3.2.1 Shot Tewa. During Shot Tewa, the sixteenth of the seventeen Redwing test shots, the aircraft was 96 naut mi (178 km) south of the detonation, at the 18,000-foot altitude which was usual for the flights. The signals received on the two fiducial antennas were both shown in the dual-beam oscilloscope, Type 333. The amplified signal from the smaller fiducial antenna, mounted inside the aircraft on the window rack, was displayed on Channel A, while Channel B displayed the signal from the larger antenna, mounted outside the aircraft skin.

Figure 3.1 (left portion) is a photograph showing the signals received on the two fiducial antennas and displayed on the dual-beam oscilloscope; Figure 3.1 (right portion) is a tracing made from the photograph. Before the shot, Channel A was positioned about two small divisions above the center line, and Channel B was positioned below the center. The sweep was so slow that about six sky waves, in addition to the ground wave, can be identified on the sweep. The first part of the sweep, containing ground wave and first sky wave, shows very strongly the effects of amplifier saturation. The saturation is gone by the second sky wave, whose pulse shape can therefore be studied in detail and compared directly with the form of pulse expected from a loop antenna. The periods, the separations, and the amplitudes of the sky waves and ground wave can all be used as sources of information, as will be demonstrated in the following sections.

Oscilloscope Calibration. The oscilloscope was adjusted to a nominal vertical sensitivity of 100 volts full scale, or 25 volts per large division, on both channels. However, cali-

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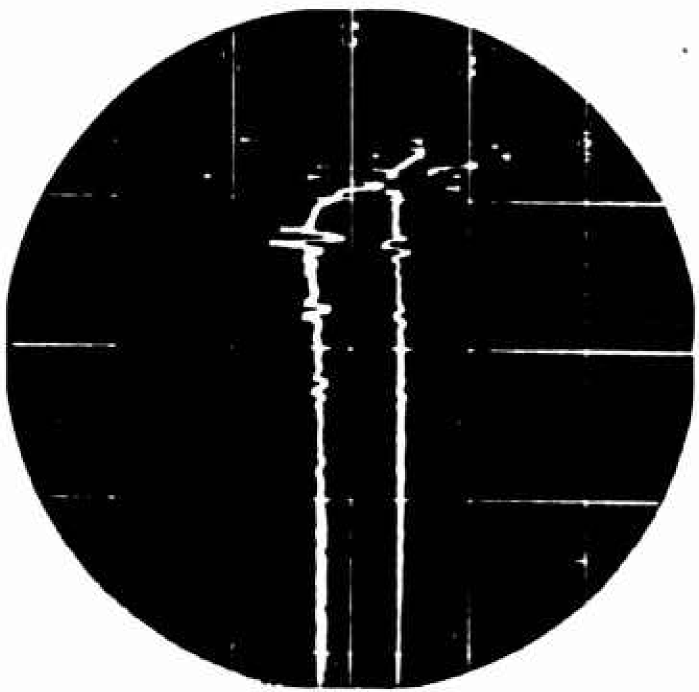

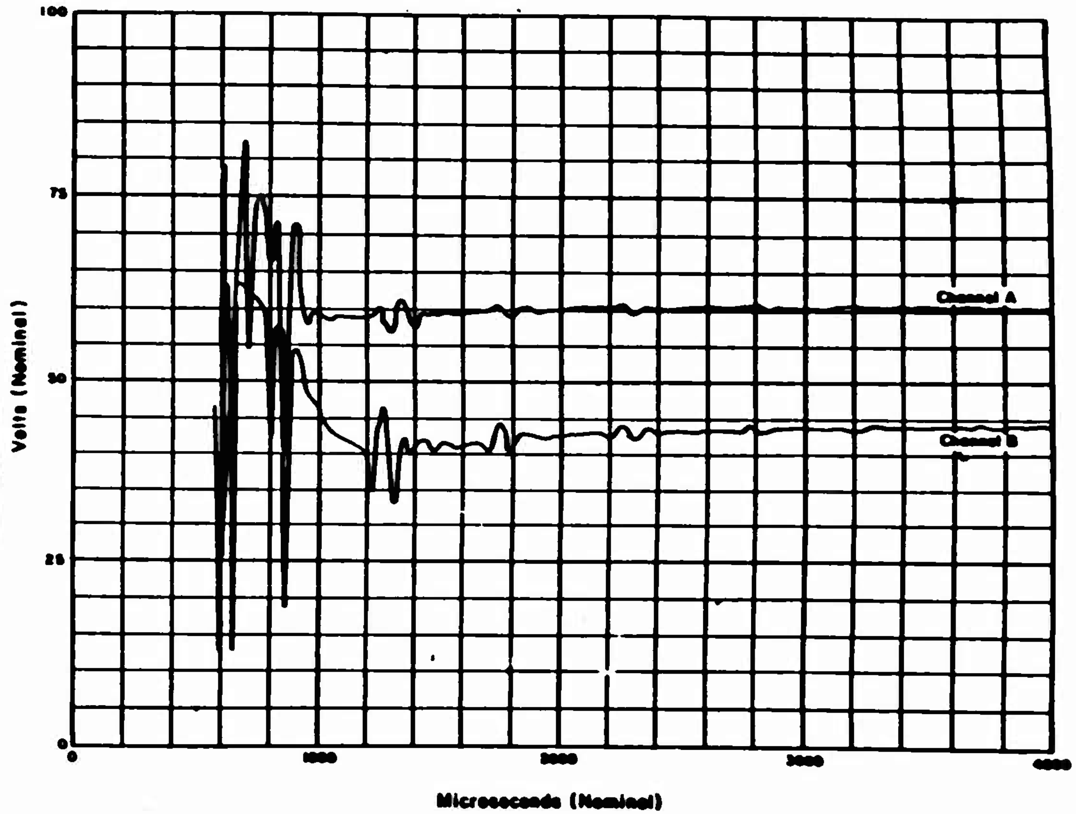

Figure 3.1 Electromagnetic signal from Shot Tewa. Photograph of oscilloscope display shown at left. Tracing from photograph shown at right.

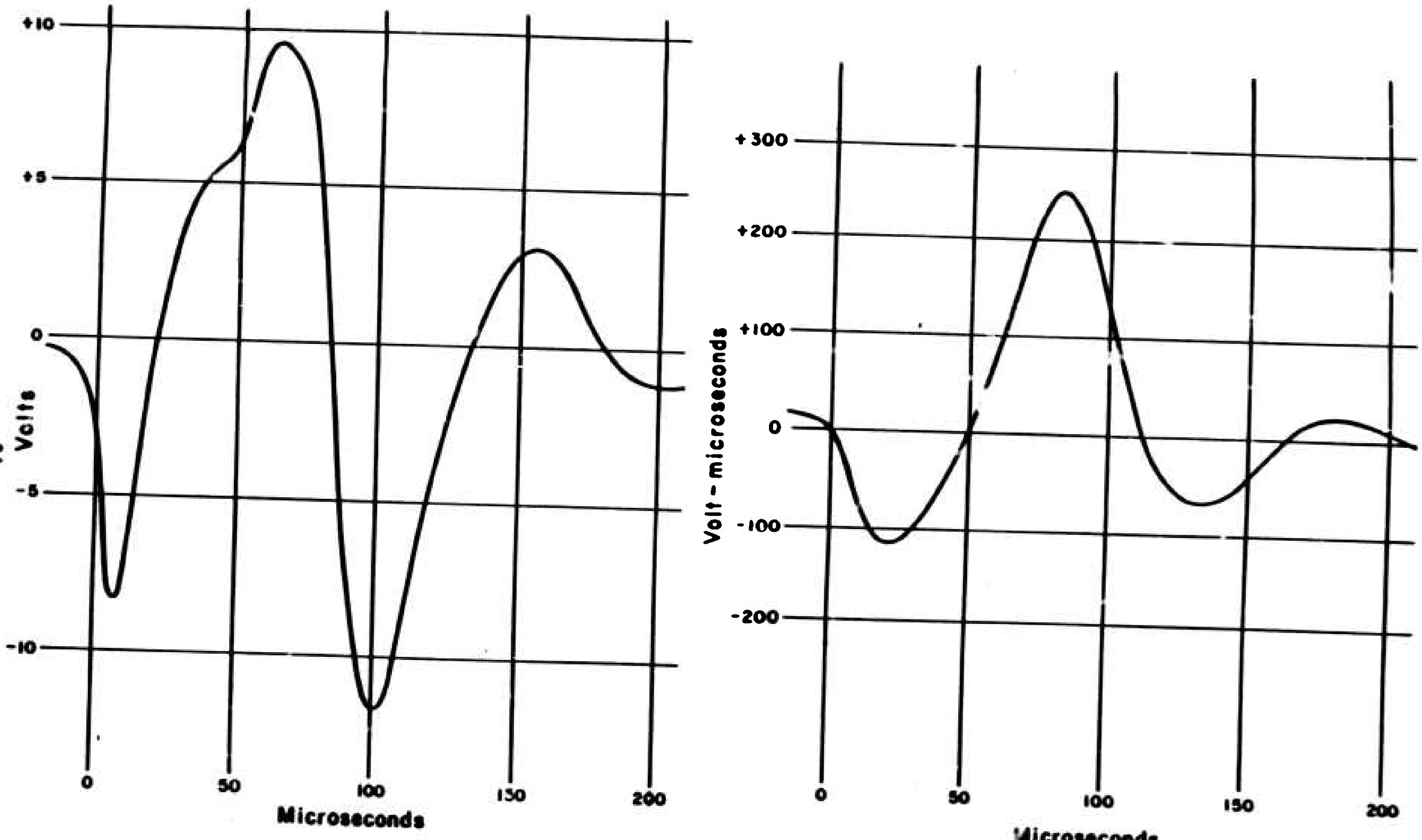

Figure 3.2 Shot Tewa: second sky wave on Channel B. Tracing from photograph of oscilloscope display shown at left. Numerical integration of tracing shown at right.

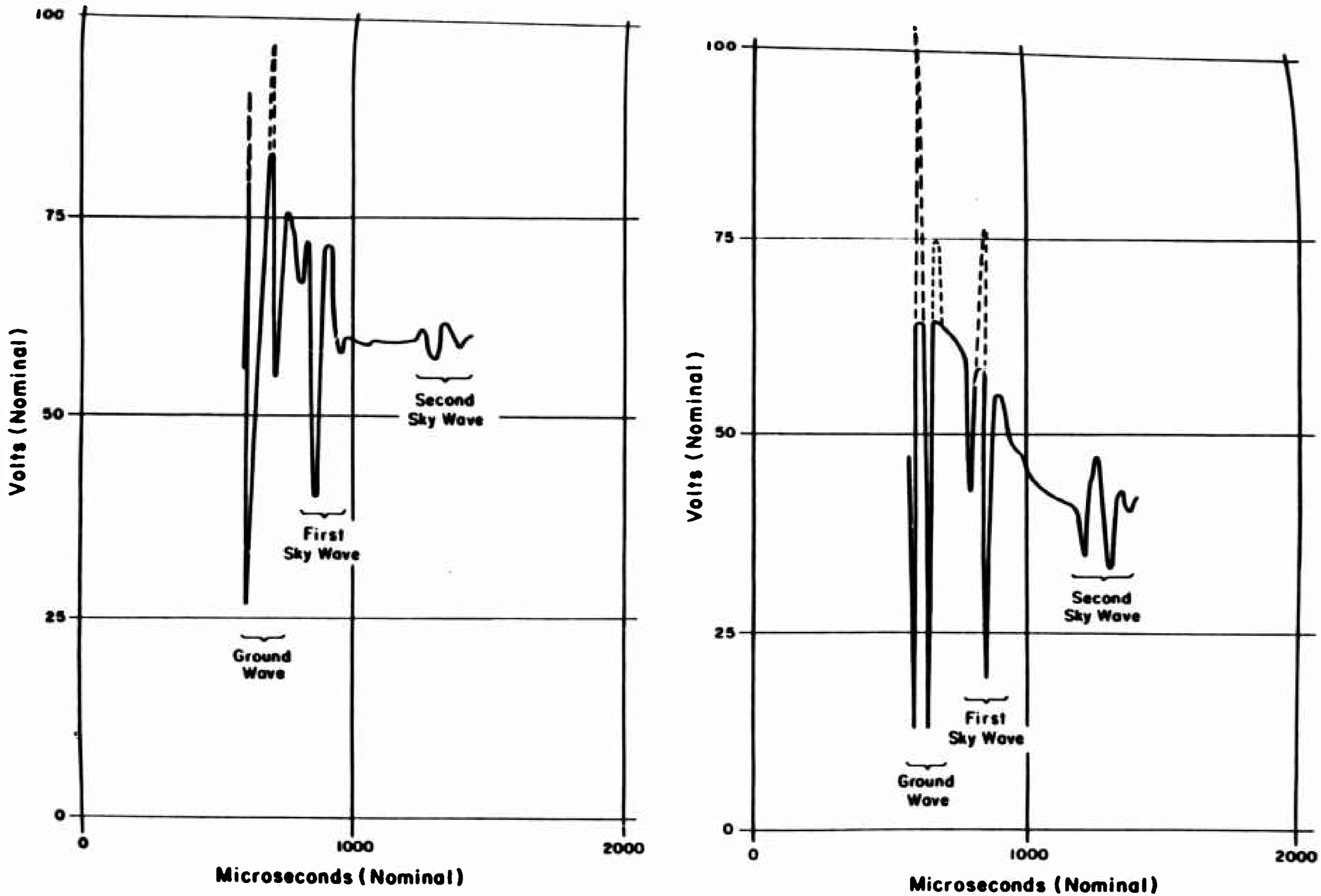

Figure 3.3 Shot Tewa: partial reconstruction of first part of trace on Channel A shown at left. Partial reconstruction of first part of trace on Channel B shown at right.

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