THEORETICAL NOTES

NOTE 353

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EMP ON HONOLULU FROM THE STARFISH EVENT*

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ABSTRACT

Considerable interest has arisen in assessing what may or may not have happened in Honolulu as a result of the EMP incident on that location from the Starfish event (1962). This note presents an unclassified calculation of that EMP. While the device output parameters used in the calculation have only nominal values, the results should be close enough to the actual EMP for the purposes of that assessment.

*Excerpted from an invited paper given to The American Physical Society on 26 March 1985.

CHART 1

We have performed an unclassified calculation of the early-time part of the EMP from the Starfish event incident on Honolulu. The calculation was carried out using the CHAP computer code, which solves the outgoing wave equation [1]

$$\frac{\partial E}{\partial s} = - Z_0 J - Z_0 \sigma E \ . \qquad (1)$$

Here s is distance along the ray from burst to observer, J is the component of the Compton current transverse to the ray, σ is the induced air conductivity, E is the transverse electric field, and Z_0 = 377 ohms. The derivative is taken at constant retarded time t - s/c. Equation 1 is the planar approximation, which is valid in the thin source region. The spherical 1/r dependence of E is actually included in CHAP, but for simplicity we shall refer to Equation 1.

Chart 1 lists the parameters used in the calculation. Note that the transverse component of the geomagnetic field, to which the EMP amplitude is approximately proportional, was only 0.23 Gauss. Over the northern U.S., for some rays, the transverse geomagnetic field is 2.5 times larger.

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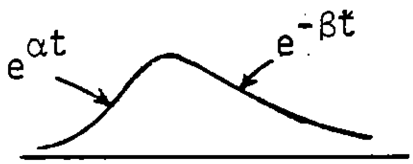
1 Longmire, C. L., <u>IEEE Trans. on Ant. and Prop.</u>, Vol. AP-26, No. 1, p. 3, January 1978.

EMP FROM STARFISH EVENT (JULY 9, 1962) ON HONOLULU

BURST HEIGHT: 400 KM
YIELD: 1.4 MT
} PUBLISHED VALUES

GAMMA EFFICIENCY: ASSUMED = 10^{-3}, ISOTROPIC (NOMINAL)

GAMMA RATE: ASSUMED $\sim e^{\alpha t}/(1+e^{(\alpha+\beta)t})$, $-\infty < t < +\infty$



$\alpha = 1 \times 10^{8}$/SEC
$\beta = 0.5 \times 10^{8}$/SEC
} NOMINAL, NOT ACTUAL VALUES

QUANTUM ENERGY: ASSUMED = 2 MEV (NOMINAL)

AZIMUTH OF HONOLULU: 54.3° EAST MAGNETIC

GEOMAGNETIC FIELD IN SOURCE REGION: 0.35 GAUSS*

DIP ANGLE OF GEOMAGNETIC FIELD: 35°

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* TRANSVERSE COMPONENT = 0.23 GAUSS.

CHART 1

CHART 2

This chart shows the geometry of the event in relation to Honolulu. The EMP source region is largely confined to the space between the dashed curves. Due to fairly oblique entry of the ray into the atmosphere, the center of the source region, where the gammas have passed through one Compton mean free path, is rather high, at about 37 km altitude.

After production in the source region, the EMP amplitude falls proportionally to 1/r where r is the distance from the burst point. This decrease is only about 14 percent in the present case.

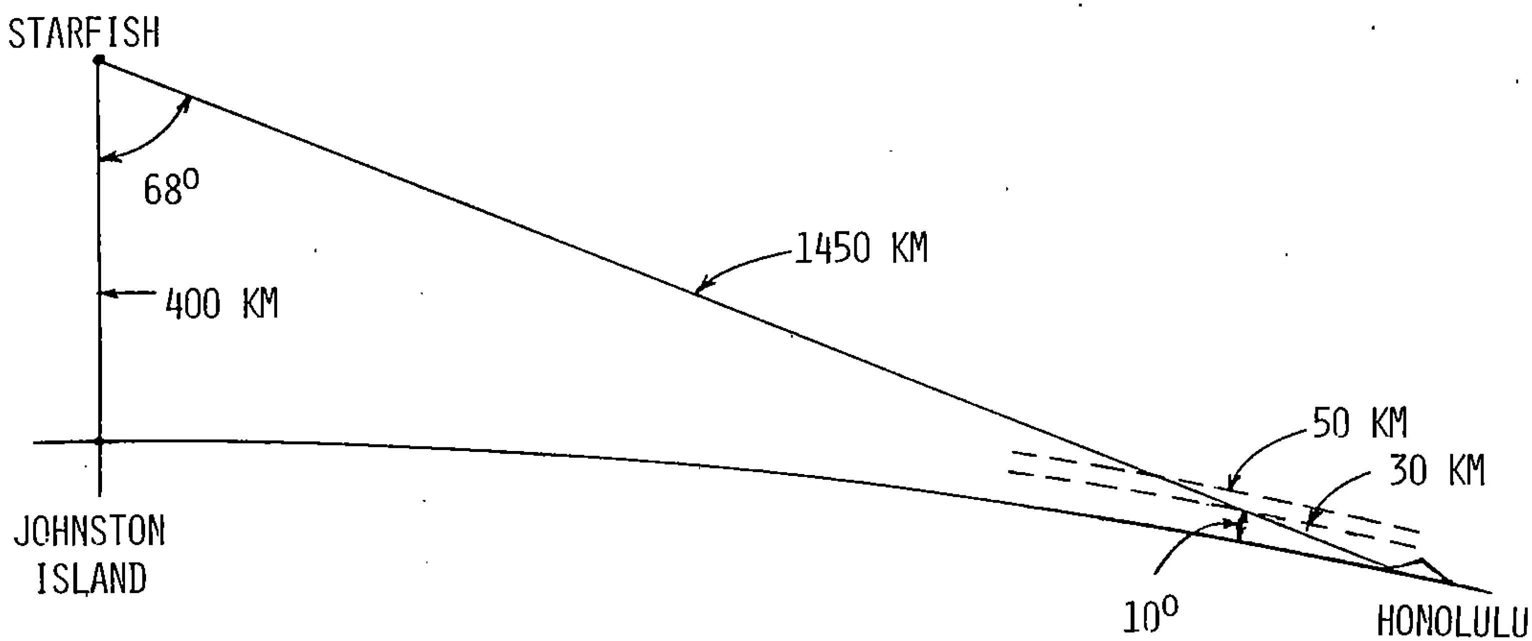
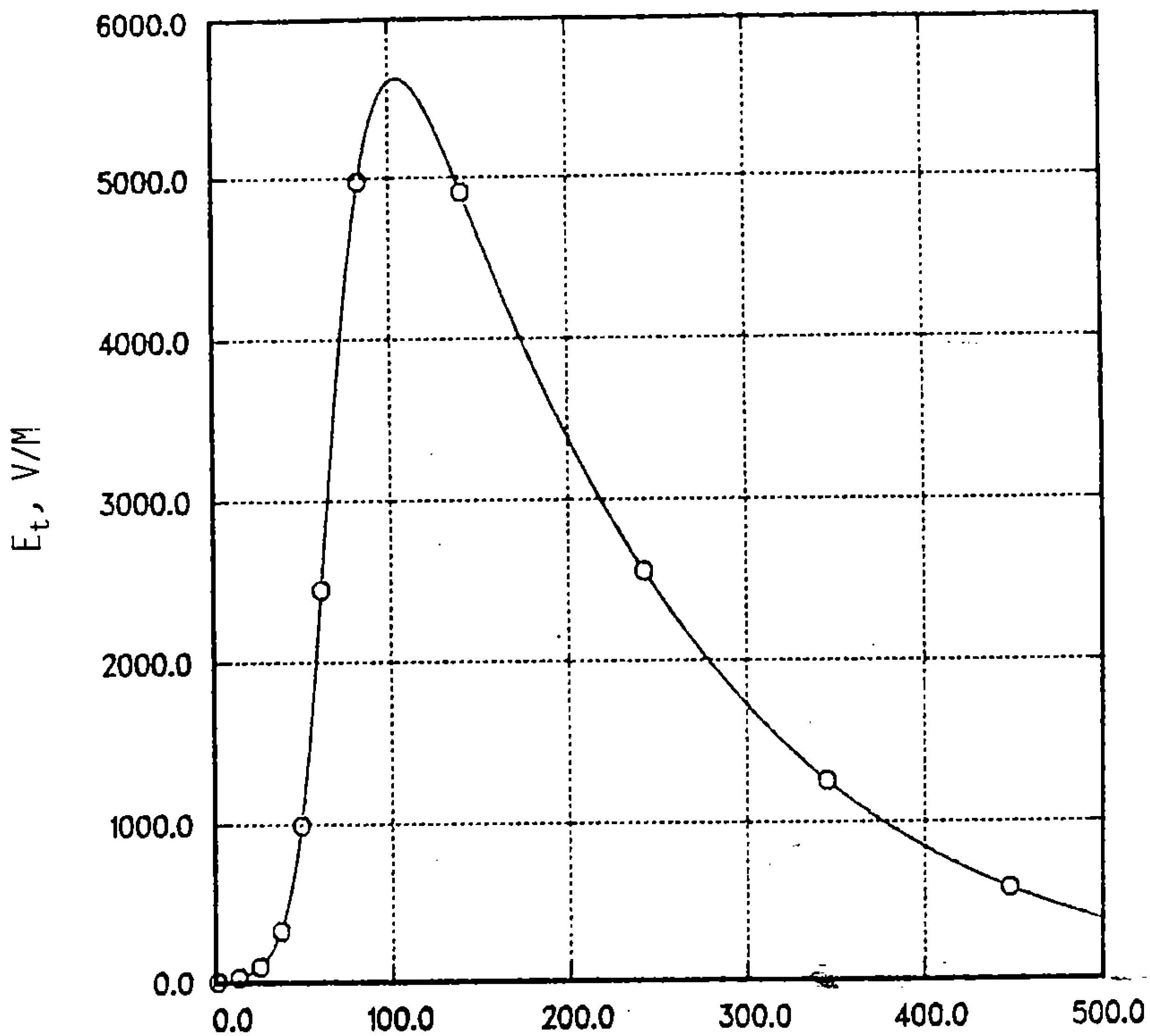

STARFISH
68°
400 KM
1450 KM
JOHNSTON ISLAND
50 KM
30 KM
10°
HONOLULU

CHART 2

CHART 3

This chart shows the transverse electric field incident on Honolulu, as calculated by CHAP. The peak amplitude is 5.6 kV/m. The total energy density in the EMP at Honolulu is about 0.01 J/m^2. The efficiency of conversion of gamma energy to EMP in this direction is about 4.5 percent. The direction of the electric field is that of $\vec{r} \times \vec{B}_0$, where $\vec{r}$ is the vector distance from the burst point and $\vec{B}_0$ is the ambient geomagnetic field in the source region.

The peak field would have been larger for larger gamma flux on the source region, since the pulse is not saturated at the peak. The increase of peak field with gamma flux is estimated in the following charts.



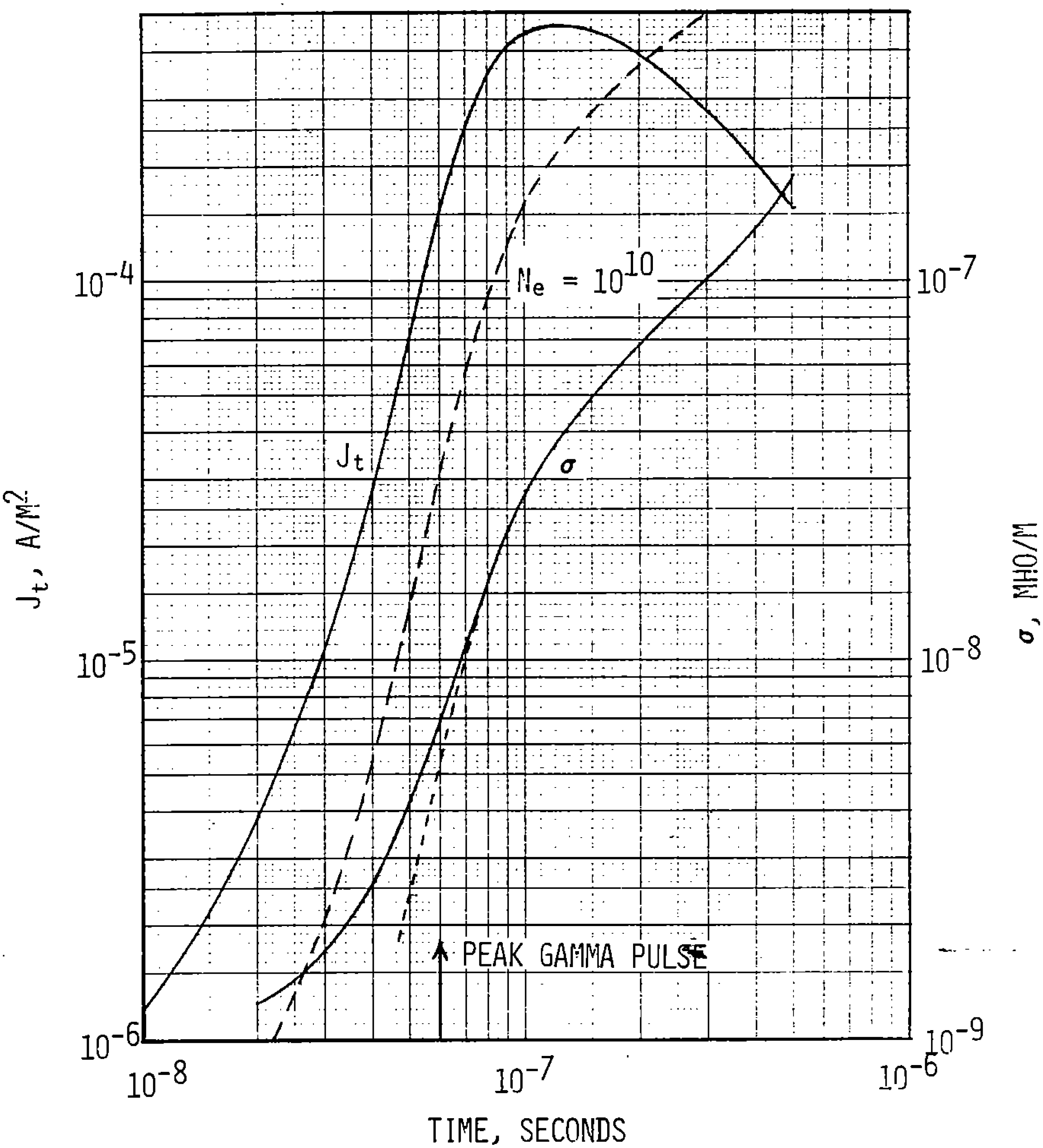
TIME, NS

TRANSVERSE ELECTRIC FIELD AT HONOLULU

CHART 3

CHART 4

This chart shows several quantities at the center of the source region, at altitude 37 km, about 200 km from Honolulu. The quantity J_t is the transverse Compton current density, and σ is the air conductivity. The long-dashed curve N_e is the secondary electron density. The fact that σ is not proportional to N_e at times before 70 ns is due to the fact that E is small at earlier times and that the secondary electron mobility decreases with increasing E. If E had been equal to its peak value at earlier times, the conductivity curve would have followed the short-dashed extension shown.



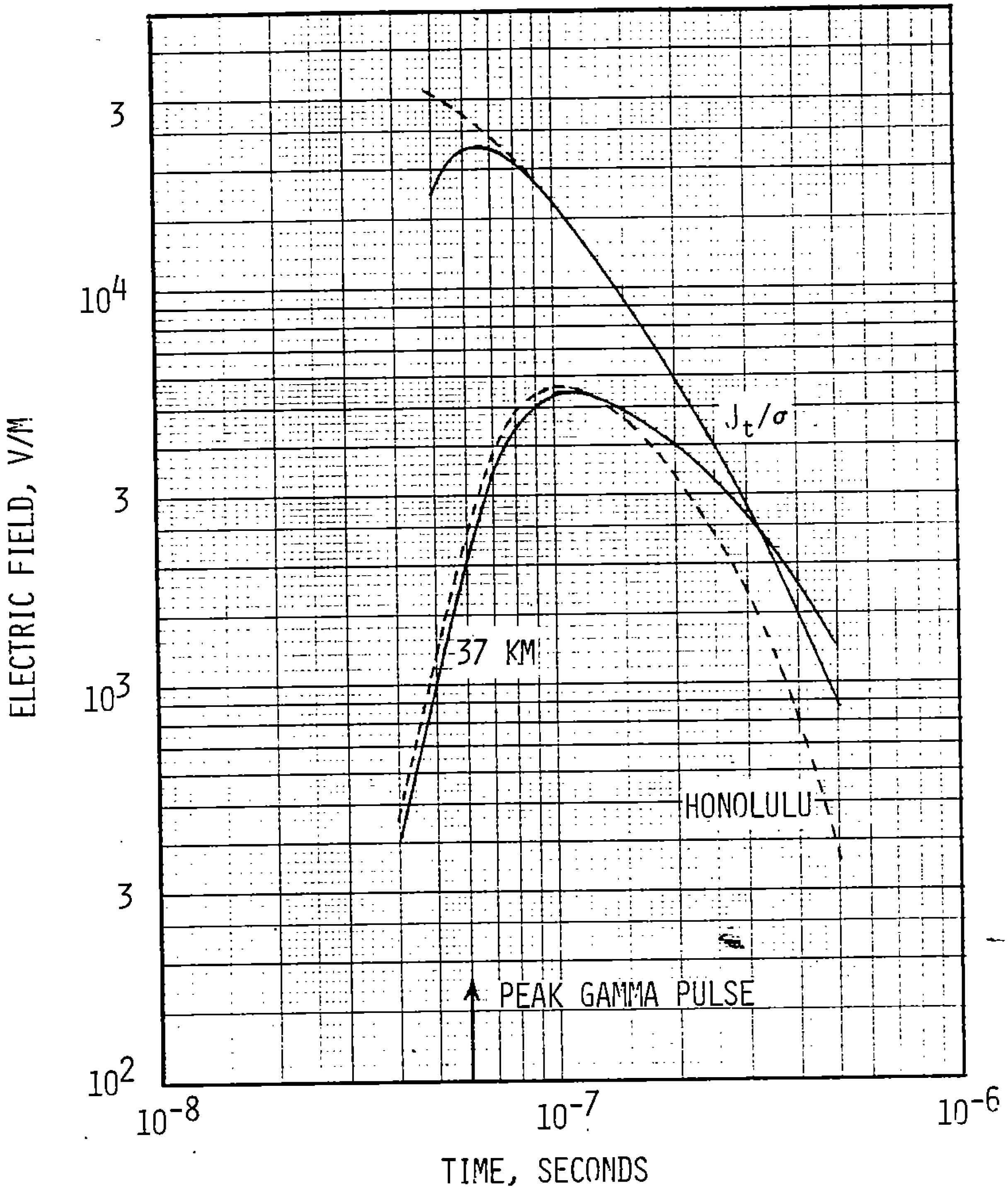
TRANSVERSE CURRENT DENSITY, SECONDARY ELECTRON DENSITY, AND CONDUCTIVITY AT ALTITUDE = 37 KM, 200 KM FROM HONOLULU.

CHART 4

CHART 5

This chart shows the saturated field J_t/σ at the center of the source region as a function of retarded time. As may be deduced from Equation 1, the saturated field is about the maximum field that could be produced with larger gamma flux. With J_t and σ from Chart 4, the peak saturated field is about 22 kV/m. However, using the corrected air conductivity gives a peak saturated field of at least 30 kV/m. Increasing the transverse geomagnetic field (to northern U.S. values) would increase the peak saturated field even further.

The other solid curve is the actual transverse E at the center of the source region. This curve shows that E has not reached saturation at its peak, but does reach saturation at about 300 ns. The other dashed curve is the transverse E at Honolulu. At early times this E is larger than that at the center of the source region, where not all of the gammas have yet produced their Compton electrons. At later times the Honolulu E is smaller than that at the center of the source region. This occurs because the saturated field (at a fixed retarded time) decreases with decreasing altitude, and because the later parts of the pulse desaturate at lower altitude. Desaturation occurs where too few unscattered gammas remain to produce a σ large enough to significantly attenuate the EMP, which then propagates as a free wave.



TRANSVERSE ELECTRIC FIELDS

CHART 5

CONCLUSION

We see that the amplitude of the EMP incident on Honolulu from the Starfish event was considerably smaller than what could be produced over the northern U.S. by more intense gamma fluxes. Therefore one cannot conclude from what electrical and electronic damage did not occur in Honolulu that high-altitude EMP is not a serious threat.

In addition, modern electronics is much more sensitive than that in common use in 1962.

Strings of series-connected street lights did go out in Honolulu approximately coincident with the time of the event. The bulbs did not burn out. It is known that the spark-gap device across each of the bulbs did fire, presumably initiated by the EMP-induced voltage. The resulting large current driven in the loop by the power source for the lights then (presumably) blew the fuse for the loop. This is typical of EMP-caused damage, in that the EMP is often only the trigger which puts the system into a state in which the system's own power does it in.

On the other hand, sensitive semiconductor components can easily be burned out by the EMP itself, 10^{-7} Joules being reportedly sufficient.