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POLARIZATION OF SYNCHROTRON RADIATION AND THE QUASI-TRANSVERSE PROPAGATION REGION

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Recent observations of synchrotron radiation from trapped electrons injected by the July 9, 1962 nuclear test have shown that the polarization observed after the radiation has propagated through the ionosphere was slightly elliptical. Ochs et al (1963) concluded from the power observed in the two propagation modes that the source was slightly elliptical (Power ratio 1.7 to 1). Westfold (1959) and Le Roux (1961) have shown that synchrotron radiation would be composed of two linearly polarized components, one along the magnetic field and one perpendicular to the field. Both authors have considered an isotropic flux over the effective radiation pattern of the electrons and the results of their work indicates that the total power would be distributed between the two components with 88% of the total power in the component perpendicular to the field. Therefore one should observe a much larger power ratio (7 to 1). If the pitch angle distribution were not isotropic the power ratio would be even higher because there could only be fewer electrons with higher pitch angles.

The apparent discrepancy between the observations and theoretical work (Peterson and Hower, 1963) and can be resolved by consideration of the depolarization which results when the propagation conditions are near the quasi-transverse (QT) region (Ratcliffe, 1959).

Under quasi-longitudinal (QL) propagation conditions a linearly polarized wave, upon entering the ionosphere, splits

into two modes each of which propagates with different phase velocities. The mode polarizations are approximately circular and therefore, as the wave propagates, the differential mode phase velocity results in the well known Faraday rotation of the plane of polarization. (Daniels and Bauer, 1959, Blumle, 1962). However as the QT zone is approached the problem becomes more complex. Ignoring collisions, the QL approximation for the refractive index is considered valid if

$$\frac{Y_T^4}{4Y_L^2} \ll 1 - X \quad (1)$$

For the QT region, the sense of the inequality is reversed.

Figure 1 is a plot of the ratio $\frac{Y_T^4}{4Y_L^2} / (1 - X)$ vs degrees from transverse for $X = .04$ and $Y = .02$ conditions which are typical for 50 Mc/s observations near the magnetic equator. For other conditions, the abscissa is simply proportional to $\frac{Y^2}{1-X}$.

It can be seen from this plot that the QL approximation for the index is valid for propagation at angles greater than about 1.82 degrees, where

$$\frac{Y_T^4}{4Y_L^2(1-X)} = 0.1 \quad (2)$$

However, this conclusion is not entirely correct when one considers the mode polarizations. Figure 2 is a plot of the axial ratio of the polarization ellipse. It can be seen that the QL condition for the refractive index is achieved much closer to transverse than the condition for circular mode polarization (unity axial ratio) associated with the QL approximation.

In fact, at 1.8 degrees from transverse the axial ratio is only 0.72 and approaches 0.9 only for angles greater than 6 degrees from transverse. Since all the Jicamarca measurements (Ochs et al, 1963) of the synchrotron radiation were made three degrees or less from the transverse region it is generally not possible to deduce the polarization of the source because of this propagation phenomenon. This is possible only if the differential phase path is exactly an integral multiple of the wavelength. Since the antenna used for these observations had a 1° by 2° elliptical beam pattern, energy would also be received in adjacent ray paths which would prevent the observation of this special case.

Based upon this discussion, it appears that the observed polarization of the synchrotron radiation is not in disagreement with the work of Westfold and Le Roux. The apparent discrepancy is due to the depolarization of the radiation as it passes through the ionosphere.

The initial polarization cannot be uniquely determined from ground-based observations unless a much narrower beam antenna is used in conjunction with a detailed study of the mode polarizations and differential phase shift. It should be possible to verify this propagation phenomenon by using observations of the ordinary and extraordinary modes from a beacon satellite as the satellite passes through the QT region. To date, no such observations have been made.

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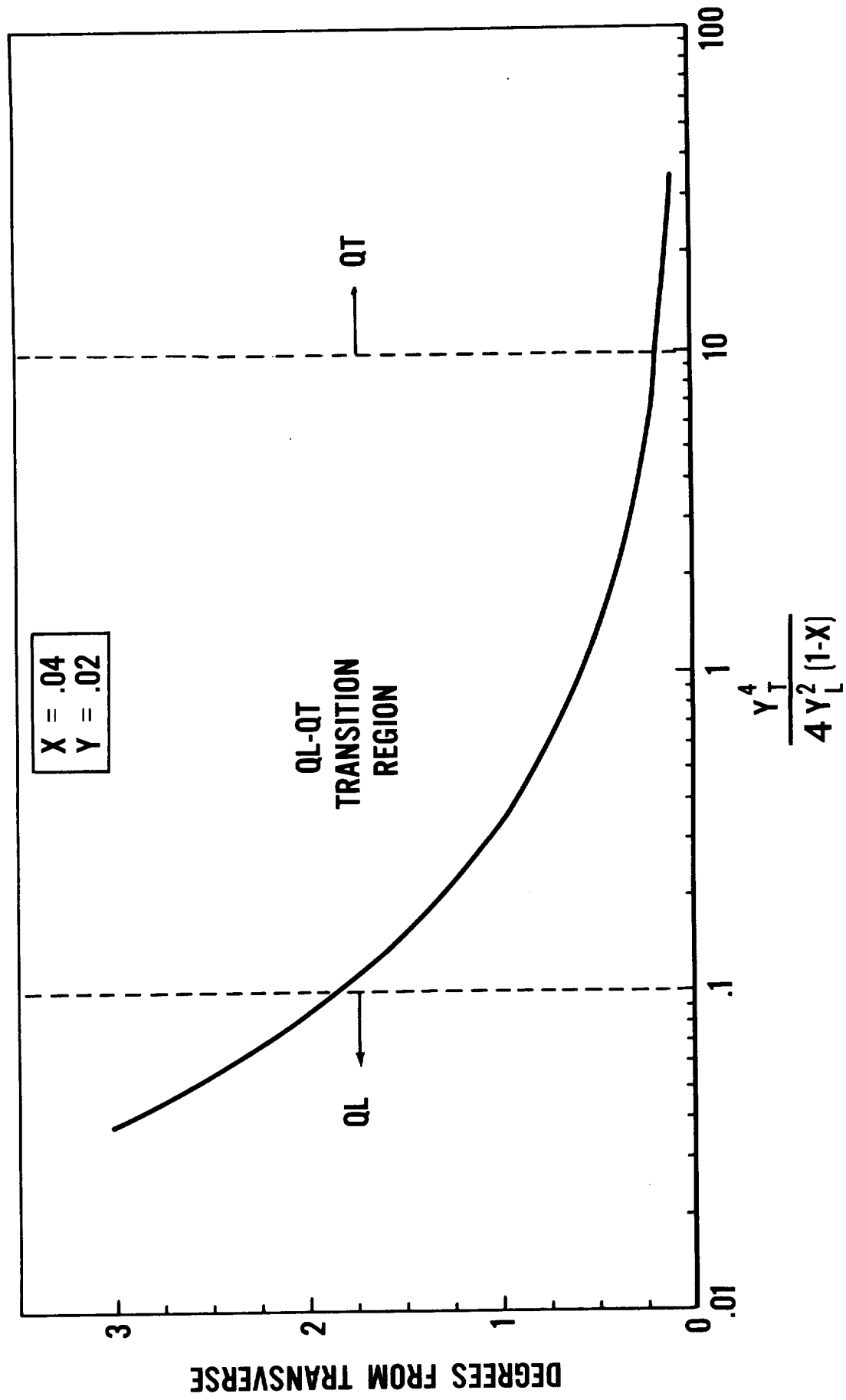


FIG. 1 - THE QL-QT APROXIMATIONS FOR THE PHASE REFRACTION INDEX

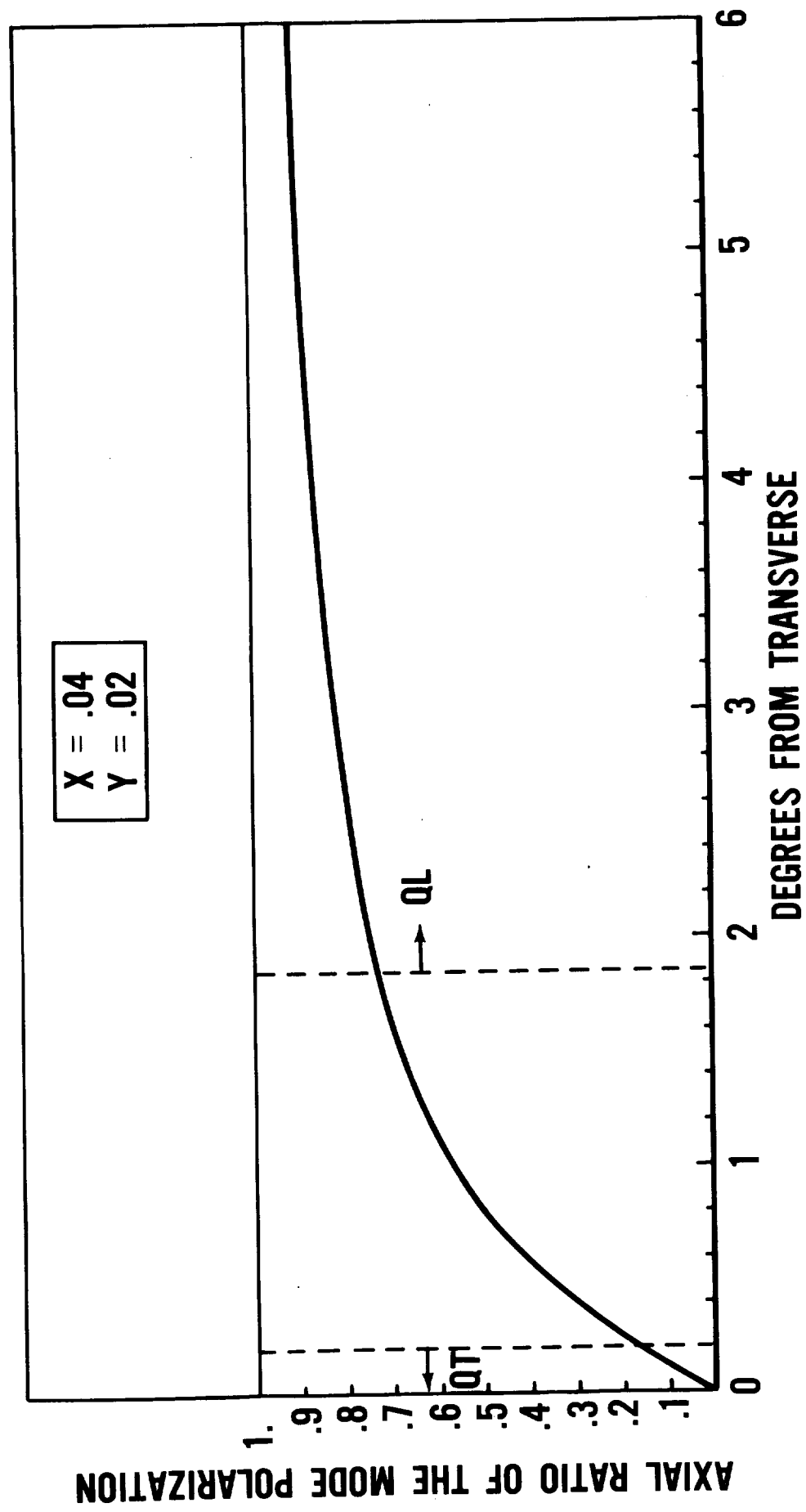


FIG. 2 - MODE POLARIZATIONS NEAR THE QT PROPAGATION REGION