**national accelerator laboratory**

TM-326
0431.00

# TRAVELING-WAVE BEAM POSITION DETECTOR FOR THE MAIN ACCELERATOR RF SYSTEM

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A beam position detector that permits accurate observation of the individual proton bunches is installed in the RF Straight Section of the Main Ring. It is of the type described in UCID-10116. The RF stripline, shown schematically in Fig. 1, follows the contour of the inner surface of the beam pipe. For further reading on stripline, see references 1 to 198.

RF sum and RF difference signals from the detector are generated by electronics boxes as is customary; the difference signal $\frac{A-B}{A+B}$ controls the horizontal position of the beam during the acceleration cycle and the sum signal A+B provides rf phasing information.

These notes include the test and adjustment results. The detector is constructed according to the drawings #'s 0431.00-ME-21372, 0431.00-MD-21625, 0431.00-MB-21626, 0431.00-MC-21373, 0431.00-MB-21627, 0431.00-MB-21624, and installed according to 0434.00-MD-21576, 0430.00-LD-5024, 0335.03-MB-21438.

A noteworthy mechanical construction feature is that the striplines are pre-bent to a curvature to exert a 1-2 ounce pressure on the 99% alumina support rods. It therefore is practical to electrically "flatten" the line for wideband response from 53 MHz to over 800 MHz.

Fig. 3 (although for coax rather than stripline) illustrates the trend in voltage standing wave ratio (VSWR) with respect to one sort of misalignment. With perfect alignment, there should be no standing waves.

Figure 2 gives test data on the detector, Figure 4 on the the electronics box output voltage.

The detector properties may be summarized as follows:

1. Bunch structure may be observed over the frequency range from the fundamental (53 MHz) to about the 20th harmonic. The frequency response is reasonably flat to 800 MHz and then attenuates with $\sqrt{f}$.

2. Absolute intensity and position calibration has been done by wire and is expected to have no more than ± 5% error.

3. In-situ calibration is an intrinsic feature; coax connections for injecting standardizing test pulses exist naturally.

4. The signal pulses corresponding to individual bunches are quite separate; there is no detectable overlap or storage effect from one bunch to the next.

5. Position calibration is linear.

6. The detector, like a directional coupler, tells which direction the beam is traveling.

7. Ultimate sensitivity is set by the noise level of the input stage of the electronics.

8. Installation of the detector and associated cables includes noise suppression for incidental external RF, SCR spikes and the like, together with accurate phase matching of the A and B signal transmission paths.

9. Because the detector is some distance away in the enclosure, the frequency response of the necessary cables must be considered. Figures 5 and 6, taken from Report CC2-1B of the UCRL Counting Handbook, show the step response of representative cables. Skin-effect losses produce an attenuation whose magnitude in decibels varies as the square-root of frequency. This results in a step function response of:

$$E_{out} = E_{in} \left(1 - \mathrm{erf}\,\frac{b\,\ell}{\sqrt{2\,(t-\tau)}}\right)$$

where

$E_{out}$ = voltage at distance $\ell$ from input end of semi-infinitely long uniform cable, at time t (seconds).

$E_{in}$ = amplitude of step of voltage applied to input of cable at time $t = 0$.

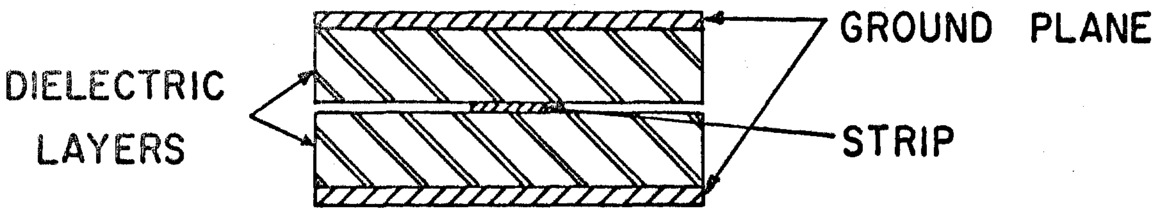
$\ell$ = distance from input end in feet.

b = constant for the particular cable in question.
$= 1.45 \times 10^{-8}\ A - \mathrm{feet}^{-1}\ \mathrm{sec}^{\frac{1}{2}}$

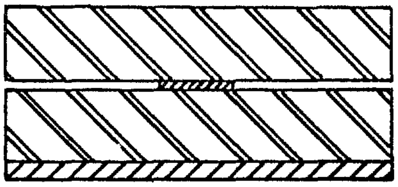
A = attenuation of cable at 1000 mc - db/100 feet (attenuation figures for coaxial cables are commonly quoted in these units).

erf = error function

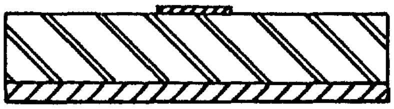
$\tau$ = transit time of cable defined as the value of t at which the voltage at $\ell$ first begins to change (considering only the step function occurring at $t = 0$, of course).



FULL SECTION



3/4 SECTION



1/2 SECTION (Open Line)

FIGURE 1.

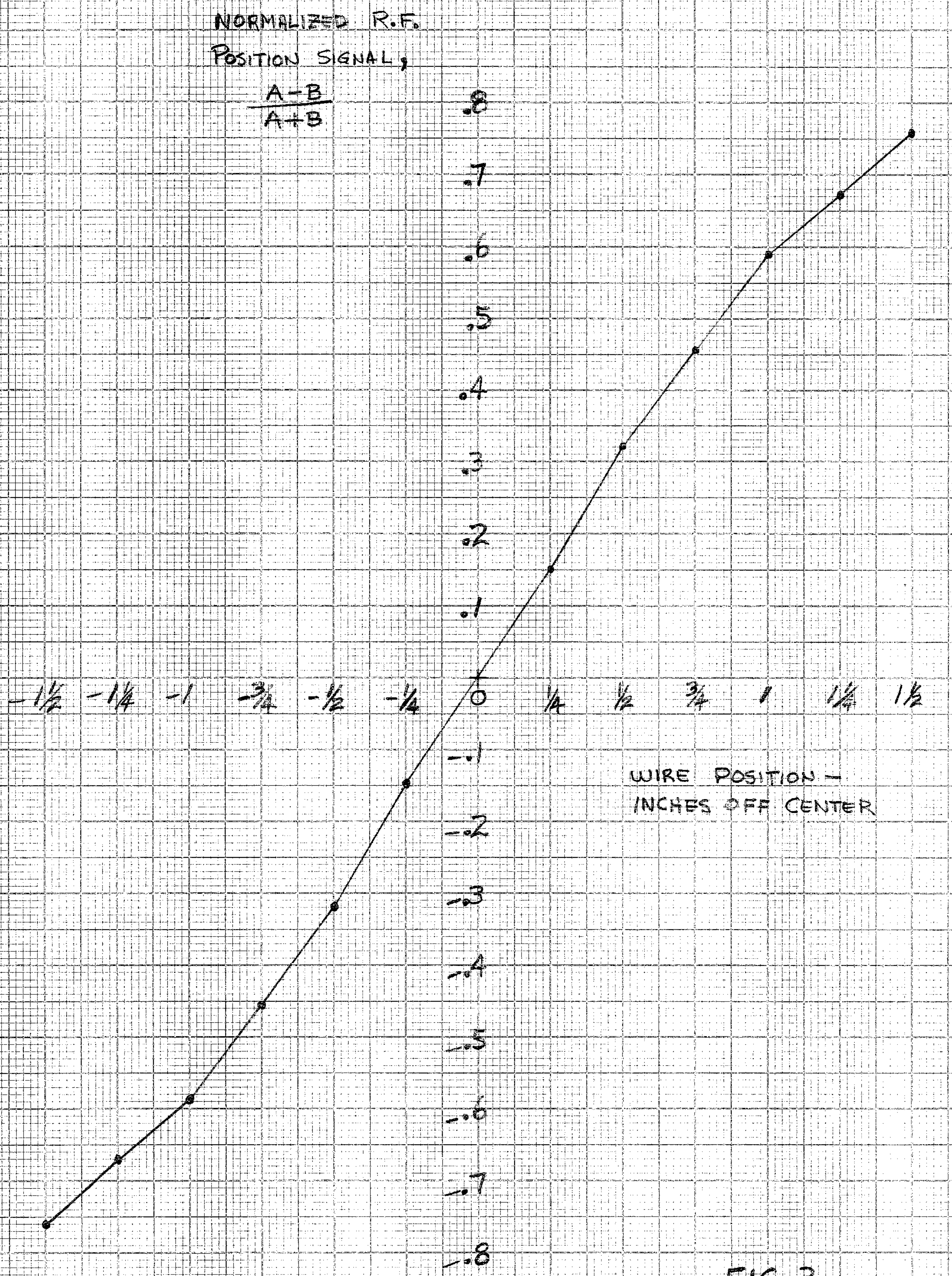


FIG. 2

DETECTOR POSITION INDICATION OBTAINED IN WIRE TEST AT 53 MHZ.

# THE EFFECT OF ECCENTRICITY ON THE IMPEDANCE OF 7.000 mm (IDOC) 50 OHM AIR-FILLED COAXIAL LINE

FIG. 3

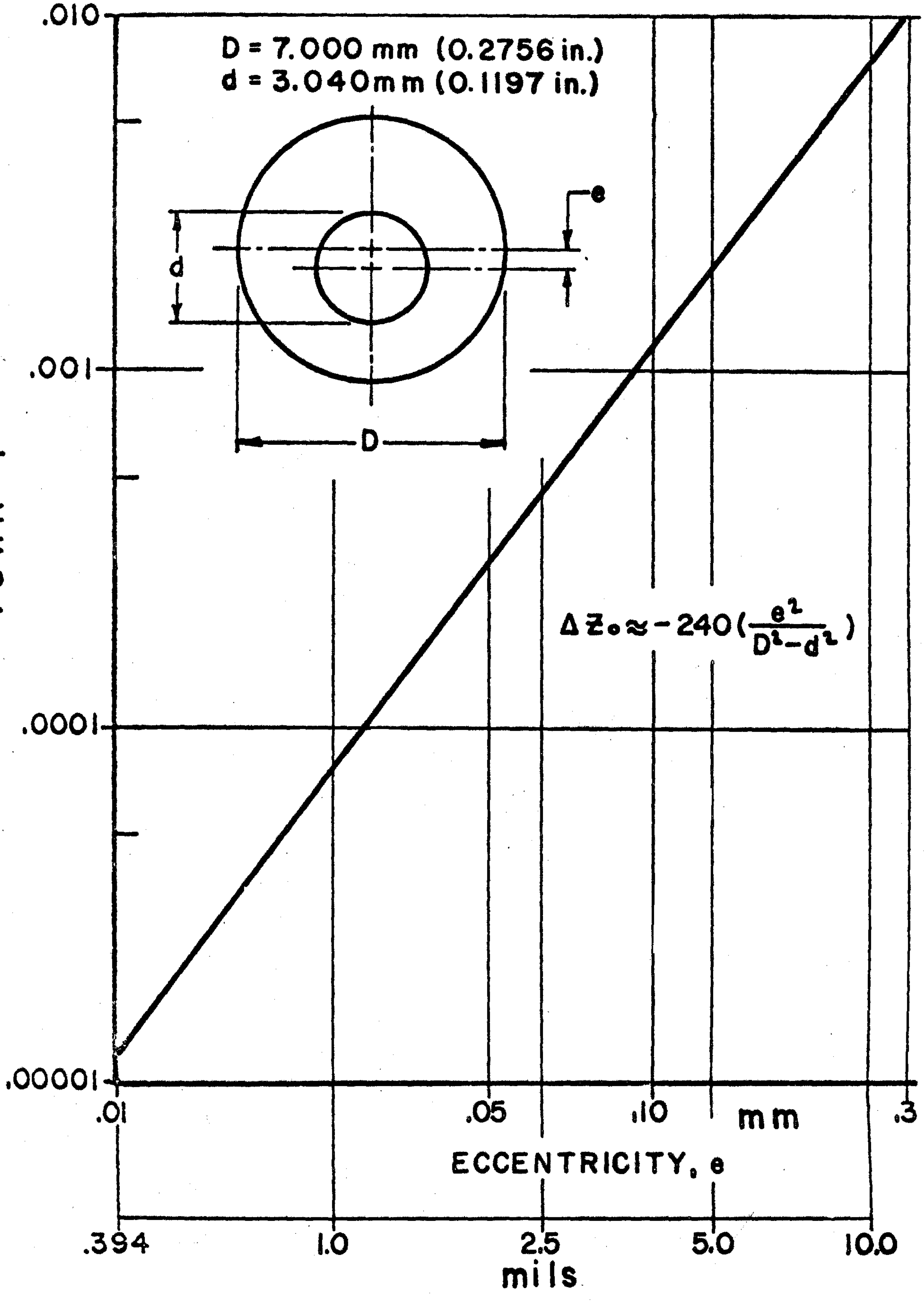
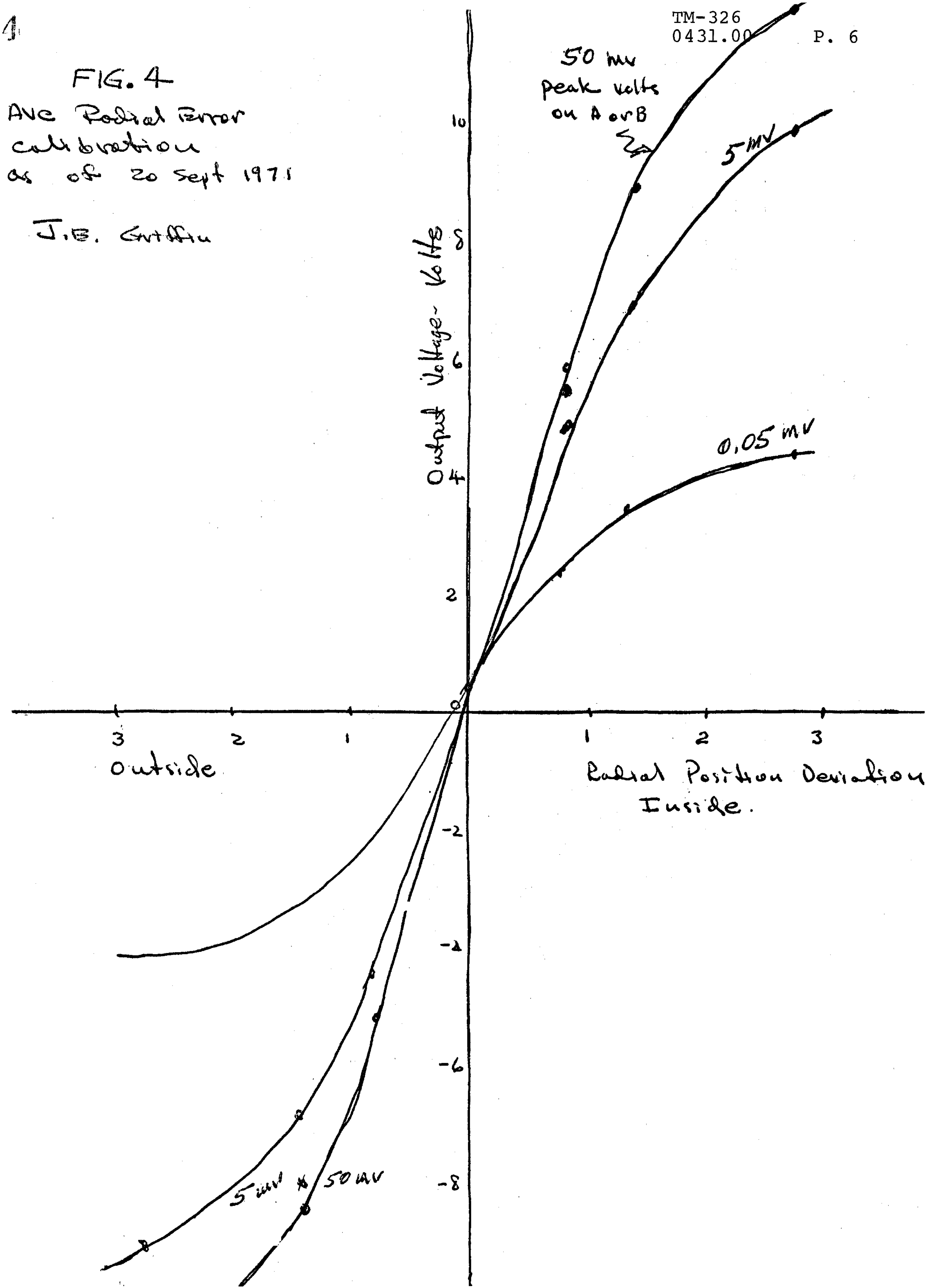


FIG. 4
AVC Radial Error
calibration
as of 20 Sept 1971

J.B. Griffin



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CC 2-1B (8)

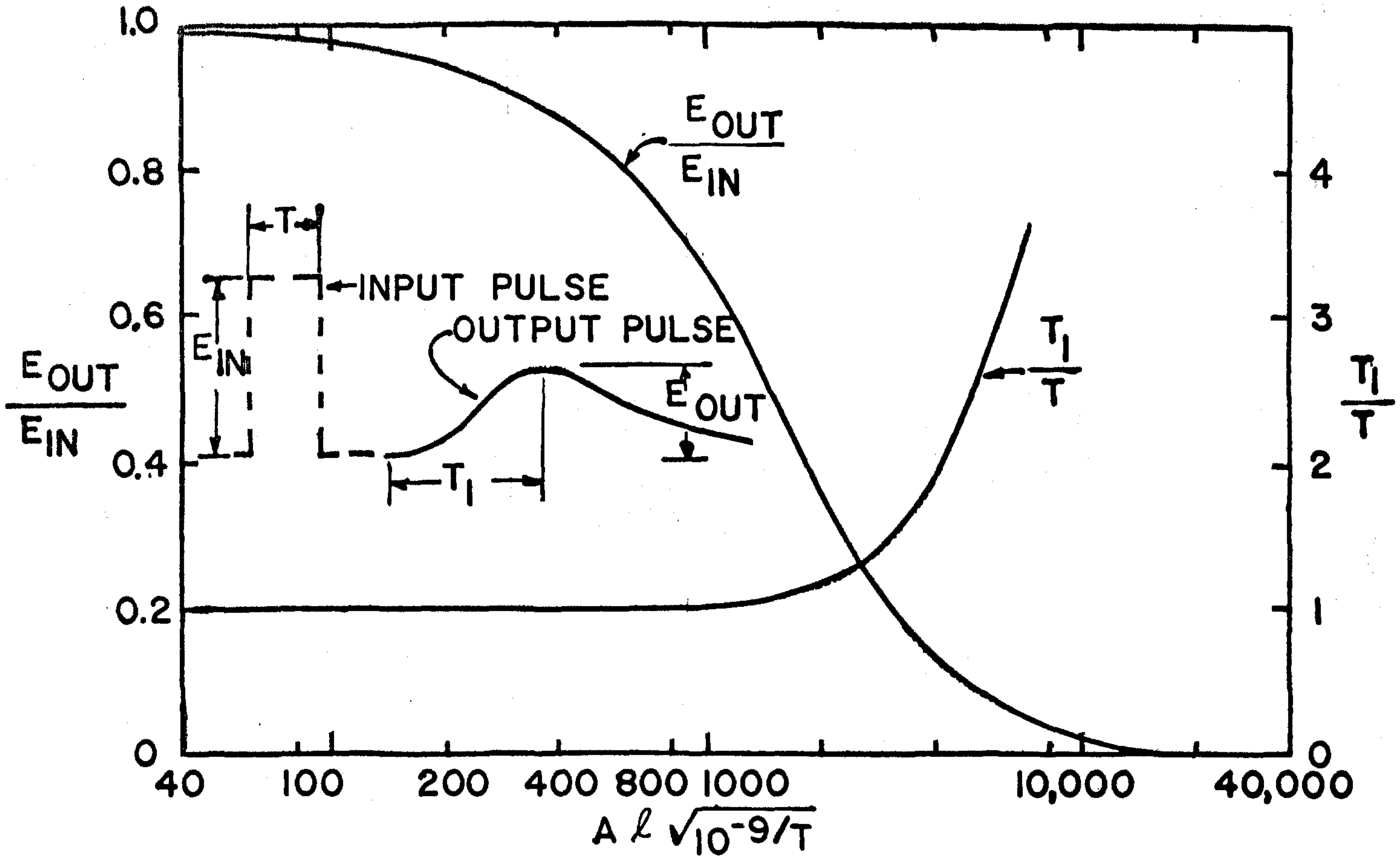
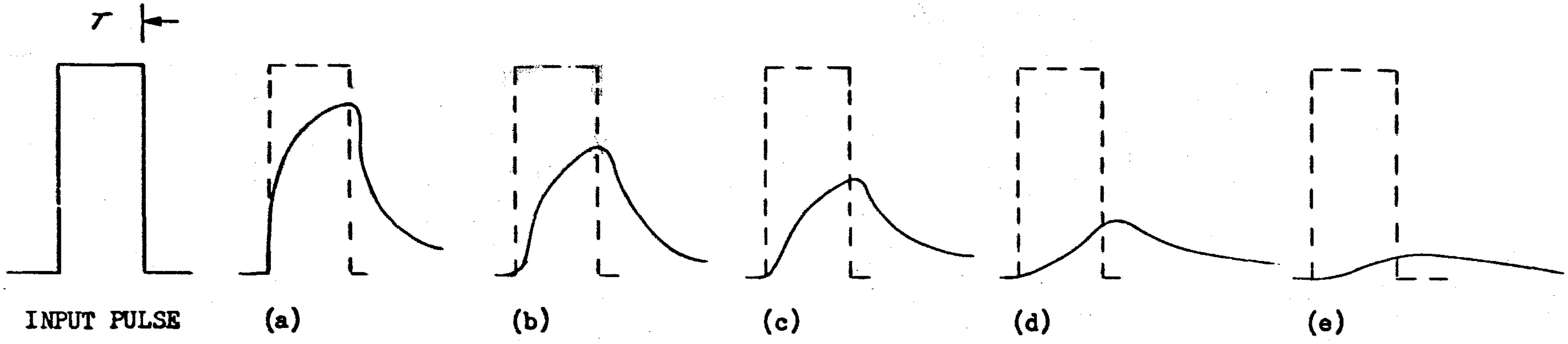


Fig. 5

The time-stretching and amplitude-reduction of an originally rectangular pulse plotted as a function of A, the attenuation of the cable at 1000 mc in db/100 ft.; $\ell$, the length in feet; and T, the duration of the input pulse in seconds. Attenuation figures may be obtained from CC 2-2B. As an example, for RG63, A is 7 db/100 ft. Thus if T were $10^{-9}$ sec, and $\ell$ were 100 feet, the chart should be entered at an abcissa of 700.



For T = $10^{-9}$ sec., the output pulse will have the shape and amplitude shown for the following cable lengths.

| CABLE TYPE | (a) | (b) | (c) | (d) | (e) |
|---|---|---|---|---|---|
| RG174 | 23 | 41 | 67 | 90 | 110 |
| RG58 | 30 | 56 | 93 | 136 | 156 |
| RG8 | 77 | 145 | 240 | 350 | 400 |
| RG63 | 95 | 180 | 290 | 430 | 500 |
| 2"Styrofoam | 1200 | 2300 | 3700 | 5500 | 6400 |
| C3T | 90 | 170 | 280 | 400 | 470 |
| RG114 | 37 | 70 | 110 | 170 | 200 |
| RGUCL 55B/U | 39 | 73 | 118 | 174 | 203 |
| YK198 | 46 | 88 | 142 | 211 | 245 |

Fig. 6

The above waveforms show the deterioration of an originally rectangular pulse as it travels along a transmission line for which the decibel attenuation varies as the square root of frequency. For comparison purposes, the input pulse is also shown with each output waveform. The figures listed above give the cable lengths that will cause the distortion shown when T= $10^{-9}$ second. To find the cable lengths for which the output pulse will have the same form relative to the input pulse for other input pulse durations, multiply the above lengths by T, where T is the input pulse duration in millimicroseconds.