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**Model 11-P**
**PHASE MODULATORS**
**DATA SHEET 745**

# PHASE MODULATORS: APPLICATION NOTE 1

For electro-optic phase modulators, application of electric field causes a change in the optical index or path length of the material.
The phase modulated signal can be described as:

$$\Theta(t) = w_c t + aKp \cos w_m t + \Theta_o$$

where:
$w_m$ is the modulating signal, $a\cos w_m t$
Kp is the phase modulation constant, mrad/volt
aKp is β, the peak phase deviation
$\Theta_o$ is the DC optical delay
and β is the argument of the Bessel function expansion.

Example:
suppose Kp = 20 mrad/volt
a = 22.4 volts peak (ie. 5 watt into 50 ohms)
then θ = 450 mrad (or .45 rad)

The carrier amplitude of the electric field intensity of the optical wave is $J_o(.45) = .96$
The first side band intensity, $J_1(.45) = .2$
The power in the carrier is $(.96)^2 = .92$
The power in all of the 1st side bands is $(.2)^2 = .04$
The power in the upper <u>or</u> lower 1st side band is then = .02
The impressed phase shift for ADP and $LiTaO_3$ materials at 632.8nm can be described by:

$$\theta = -\pi n_e^3 \frac{r}{\lambda} \frac{L}{b} V$$

Where:
V is the applied peak voltage
r is the E/O material constant
λ is the wave length
L is the total material path length
b is the electrode separation
$n_e$ is the extraordinary index

The following table lists some useful parameters for these materials:

| Parameter | ADP | $LiTaO_3$ | Units |
|---|---|---|---|
| $n_o$ | 1.521 | 2.176 | |
| $n_e$ | 1.476 | 2.180 | |
| $r_{41}$ or $r_{33}$ E/O constant | 24.5 | 30.5 | $\times 10^{-12}$ m/V |
| Phase sensitivity | 0.428 | 1.7 | |

mrad/V x L/b

## TABLE OF THE BESSEL FUNCTIONS OF THE FIRST KIND, $J_n$ (X)

| X | $J_0$ | $J_1$ |
|---|---|---|
| 0.0 | 1.00 | |
| .2 | .99 | .10 |
| .4 | .96 | .20 |
| .6 | .91 | .29 |
| .8 | .85 | .37 |
| 1.0 | .77 | .44 |
| .2 | .67 | .50 |
| .4 | .57 | .54 |
| .6 | .46 | .57 |
| .8 | .34 | .58 |
| 2.0 | .22 | .58 |
| .2 | .11 | .56 |
| .4 | .00 | .52 |
| .6 | -.10 | .47 |
| .8 | -.19 | .41 |
| 3.0 | -.26 | .34 |