CESDN 24

MISMATCH LOAD EFFICIENCIES

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Mismatched Generator

The simplest way of transferring power from a high voltage pulse generator to a load at a lower voltage is to mismatch the generator with a load impedance which is less than the characteristic impedance of the generator. When the mismatch is great the efficiency of energy transfer is reduced. The efficiency is calculated assuming a simple charged transmission line generator with a purely resistive load. Let

V_o = generator charging voltage

Z_{oo} = characteristic impedance of generator

V_ℓ = load voltage

Z_ℓ = load impedance.

When the generator is switched into the load the pulse voltage appearing across it is

$$V_\ell = \frac{V_o Z_\ell}{Z_\ell + Z_{oo}} \tag{1.1}$$

This load voltage can be made any predetermined value within the range $0 < V_\ell < V_o$ by adjusting the load impedance to be

$$Z_\ell = \frac{Z_{oo} V_\ell}{V_o - V_\ell} \tag{1.2}$$

The power delivered to the load at this voltage is then

$$P_\ell = \frac{V_\ell^{\,2}}{Z_\ell} = \frac{V_\ell}{Z_{oo}} \,(V_o - V_\ell) \qquad (1.3)$$

Since the maximum power obtainable from the generator is $P_{max} = V_o{}^2/4Z_{oo}$, the efficiency of such a mismatched generator system is

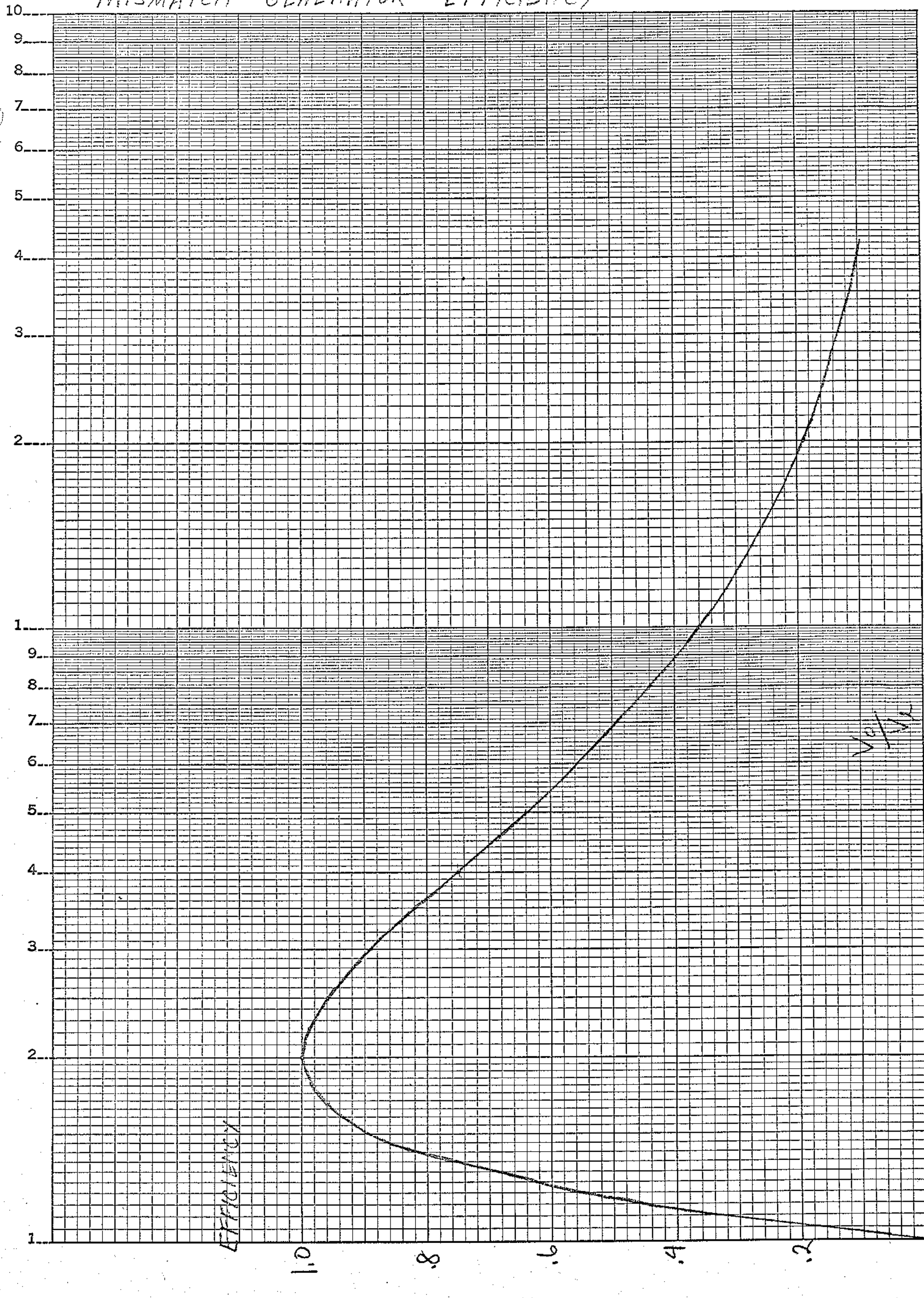
$$\frac{P_\ell}{P_{max}} = 4\,\frac{V_\ell}{V_o}\left(1 - \frac{V_\ell}{V_o}\right) \qquad (1.4)$$

The maximum efficiency occurs of course when the generator is matched, $Z_\ell = Z_{oo}$ and $V_o = 2V_\ell$. A plot of efficiency as a function of the voltage ratio shows that in the range $1.33 < V_o/V_\ell < 4$ the efficiency is greater than 75% so the simple mismatched generator is an adequate source. For values of V_o/V_ℓ outside of this range some means of voltage transformation is needed for an efficient system.

PARTIAL MATCHING BY TRANSFORMER

If the generator charging voltage is compelled to be much greater than the desired load voltage, consideration should be given to effecting the energy transfer through a transformer to achieve a better impedance match. Transmission lines are suitable

MISMATCH GENERATOR EFFICIENCY



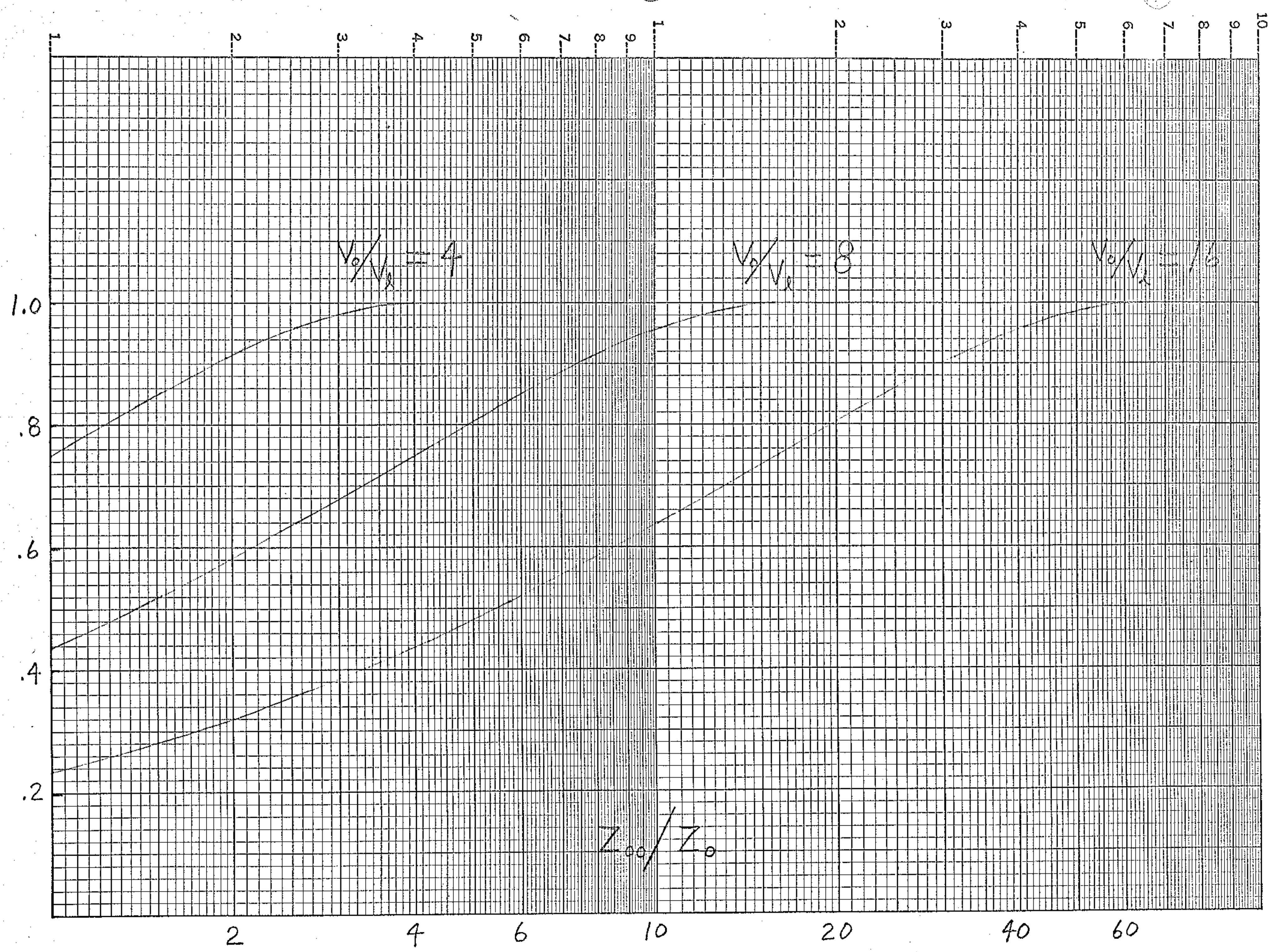
for use as transformers at high voltage. In particular, tapered transmission lines with a gradual change in impedance along the line should effect good impedance matching. Unfortunately a sufficiently gradual impedance transformation may require an extremely long structure; so there are two other possibilities to consider. The impedance change may be rather rapid, in which case pulse distortion and energy loss along the line will occur. The resulting reduction in efficiency must be further analyzed. On the other hand, the impedance transformation may be gradual enough to avoid distortion but the structure can be truncated before a complete match is achieved. The load impedance is then mismatched to produce the desired lower load voltage. The improvement in efficiency by this scheme will be determined.

If a short risetime is desired, the impedance at the generator switch should be kept as high as possible. So no mismatch at the generator is considered. The input impedance of the line transformer is taken to be equal to the generator impedance, Z_{oo}. Z_o denotes the characteristic impedance at the transformer output. The effect of this transformer is to make the generator appear to the load as if its voltage were $V_o \sqrt{Z_o/Z_{oo}}$ and its impedance Z_o. The load voltage can be adjusted to a predetermined value, V_ℓ, by setting

$$Z_\ell = \frac{Z_o}{\frac{V_o}{V_\ell}\sqrt{\frac{Z_o}{Z_{oo}}} - 1} \qquad (2.1)$$

The efficiency is then

$$\frac{P_\ell}{P_{max}} = 4 \sqrt{\frac{Z_{oo}}{Z_o}} \frac{V_\ell}{V_o} \left(1 - \sqrt{\frac{Z_{oo}}{Z_o}} \frac{V_\ell}{V_o}\right) \qquad (2.2)$$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KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS
$V_o/V_L = 4$
$V_o/V_L = 8$
$V_o/V_L = 16$
1.0
.8
.6
.4
.2
2
4
6
10
20
40
60
Z_{oo}/Z_o