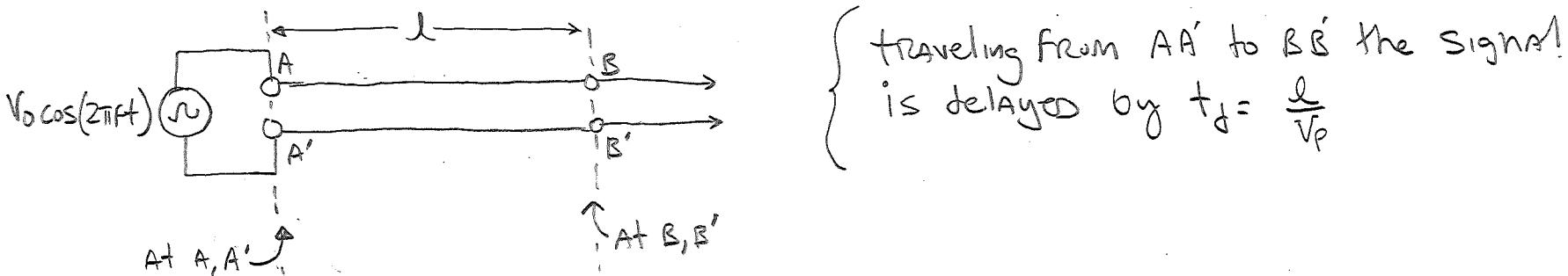


Harmonic Determination of T-line Environments

- Analog Domain
- Period vs Flight Time

In a sinusoidal environment, we can determine if we have a T-line situation or not by comparing the period of the signal with the flight time.

Suppose a signal at frequency F is applied to a line at point A, A'



$$V_{AA'}(t) = V_0 \cos(2\pi ft)$$

$\cos(\omega t)$ rewritten as

$$V_{BB'}(t) = V_0 \cos(2\pi f(t - t_d))$$

remembering that $f = \frac{1}{T}$, where T is the period of the signal F ;

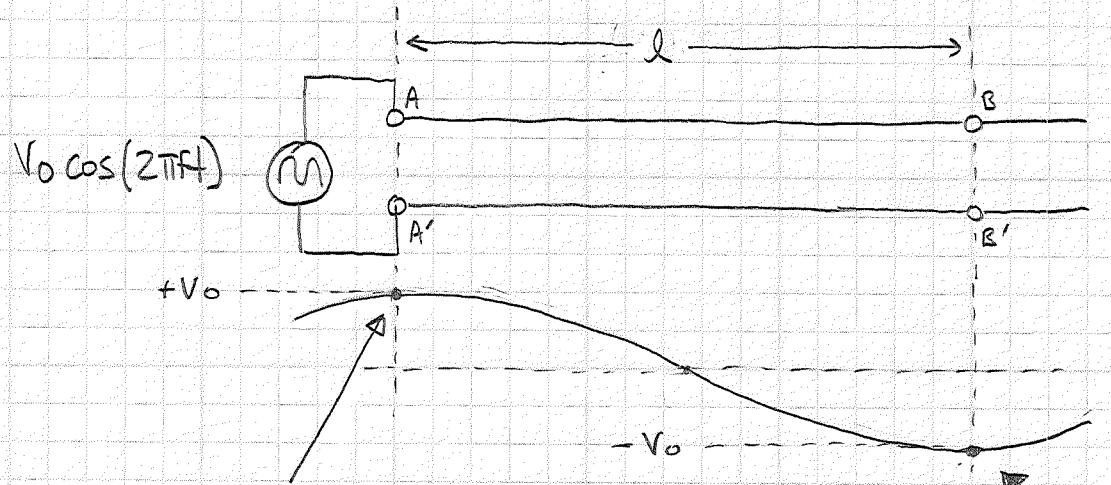
$$V_{BB'}(t) = V_0 \cos\left(2\pi ft - \left[2\pi \frac{t_d}{T}\right]\right)$$

"electrical distance" now expressed in a time dimension instead of a distance z .

flight time as a portion of the period

So, for $t_d \ll T$, $V_{BB'} = V_{AA'}$; thus a lumped circuit condition exists.

However, if t_d is comparable to T , the circuit is distributed. This will be evident if V or I across the line is not approximately identical.



$$\begin{aligned} V_{AA'}(t) &= V_0 \cos(2\pi f t) \\ &= V_0 \cos(0) \\ &= V_0 \end{aligned}$$

Very different voltages!
 \therefore distributed circuit

traveling from AA' to BB' over distance l
the signal is delayed by

$$t_d = \frac{l}{v_p}$$

but here, we let $t_d = 0.5T$, so

$$\frac{t_d}{T} = \frac{0.5T}{T} = 0.5$$

$$ct = 0$$

$$\begin{aligned} V_{BB'}(t) &= V_0 \cos(2\pi f t - 2\pi(0.5)) \\ &= V_0 \cos(2\pi f t - \pi) \\ &= V_0 \cos(-\pi) \\ &= -V_0 \end{aligned}$$

-180° phase shift

In practice, line is distributed if $t_d > 0.1T$
line is lumped if $t_d < 0.01T$



HERMON LABORATORIES

Period vs Flight - Time

Analog Telephony Compliance Requirements Overview

The standard two-wire telephone-set connection known as analog PSTN (Public Switched Telephone Network) (loop start) or POTS (Plain Old Telephone Service) is the oldest but still most widely used service offered by the telephone companies.

Other types of analog services offered by the telephone companies include:

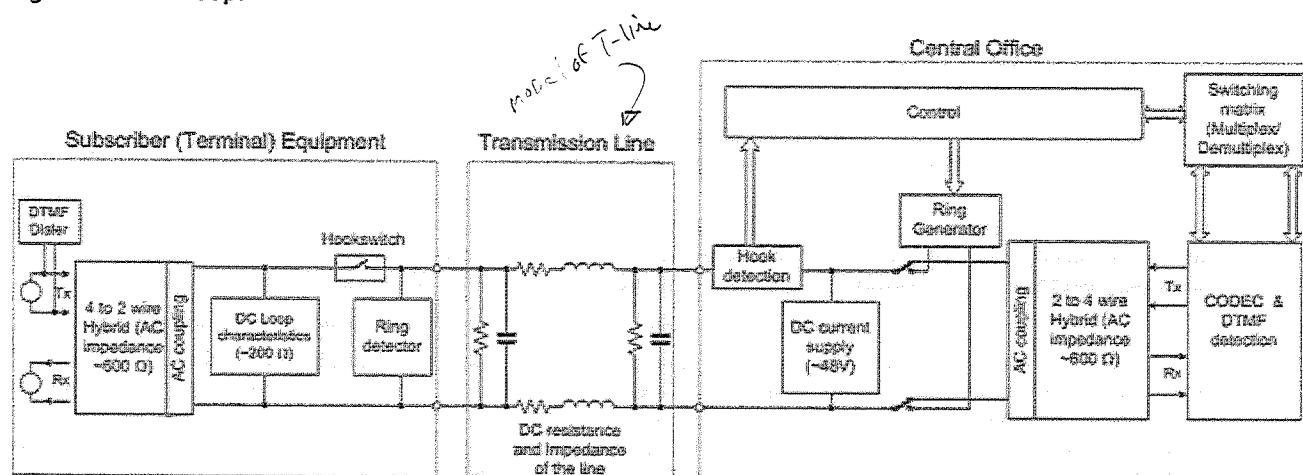
- Four-wire services, using separate pairs of wires for transmitting and receiving provides improved fidelity;
- Reverse battery services allow automated PBXs to act as localized central offices;
- Ground start and E and M tie trunks offer more reliable methods of signaling than the loop start systems.

In addition to the public switched services, where the user can dial different numbers, private point-to-point services are provided in both two-wire and four-wire formats.

Local loop

A customer equipment (also called subscriber or terminal equipment) is usually connected to the telephone company exchange (Central Office) by on average about 5 kilometers (3 miles) of a twisted pair of No. 22 (AWG) or 0.5 mm copper wires, known as the subscriber (local) loop. The resistance of 0.5 mm wire (single lead) is 16.5 ohm per thousand feet (54 ohm per 1 km). The twisted pair is used to provide a balanced line which reduces common mode interference (crosstalk) from adjacent pairs in the cable and RFI (Radio Frequency Interference). Balance is a measure of equality of impedance between each lead in the pair (called Tip and Ring) and the ground. In order to keep the balance of the line, the terminal equipment should be balanced also.

Figure 1. Local Loop.



The telephone company applies loop feed DC voltage between Tip and Ring at the Central Office (CO). This voltage is 50 Vdc on average. Terminal equipment should be able to operate with both positive and negative voltage polarity.

Table 1. DC feed voltages - Test requirements per national standards.

What about telephone lines?

*ASSUME target of $t_d = 0.05T$

*ASSUME voice 300-3000hz

(midole is 1650hz, $T = 600\mu s$)

* ASSUME polyethylene insulator

$$v_p = \frac{C}{T \epsilon_r} = \frac{300 \times 10^6}{72.4}$$

$$= 1.94 \times 10^8 \text{ m/s}$$

$$t_d = \frac{l}{v_p}$$

$$0.05(600 \times 10^{-6}) \text{ s} = \frac{l}{1.94 \times 10^8 \text{ m/s}}$$

$$\underline{l = 5.82 \text{ km}}$$

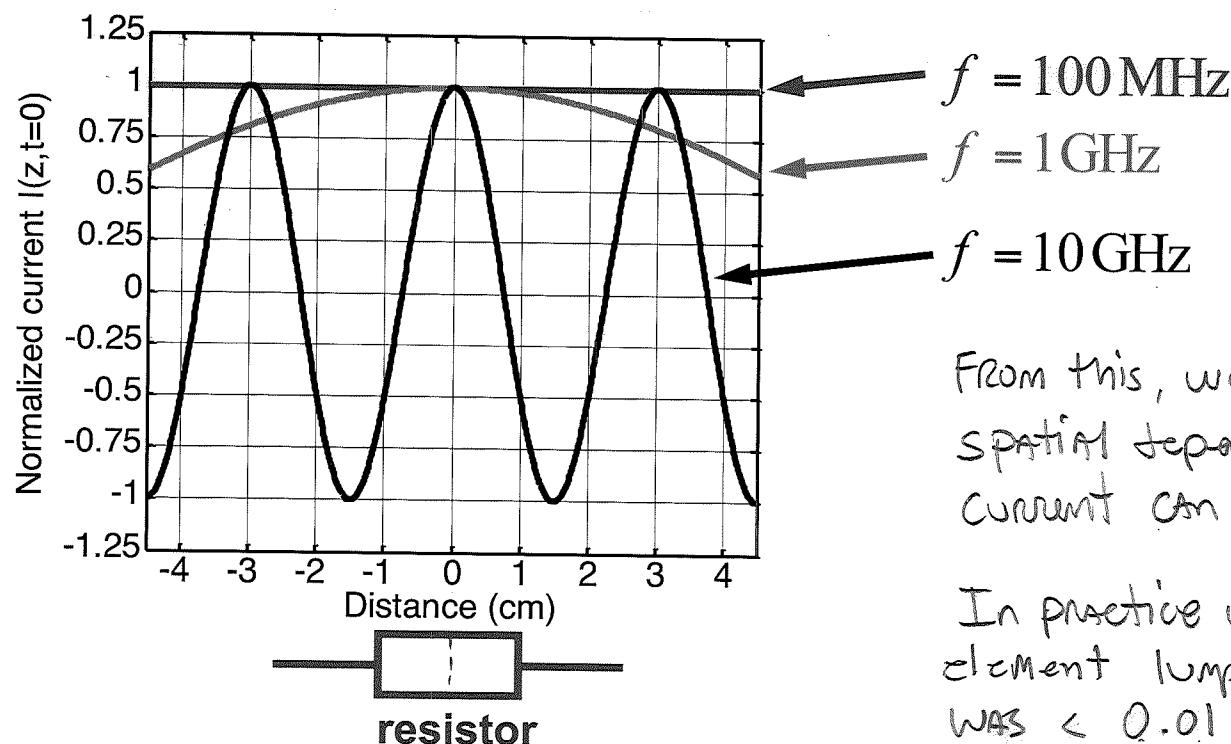
Heuristic Determination of T-line Environments

- Analog Domain
- Component size vs wavelength

For periodic waveforms λ is the physical length of one cycle. The physical length can vary however even at a fixed frequency depending on the propagation medium. $\lambda = \frac{c}{f}$ in free air, but we are often not in air.

In our applications we find: $I(z,t) = A \cos \left[2\pi f t - 2\pi \frac{z}{\lambda} \right]$

Consider the current through a resistor 2cm long at a fixed time.



From this, we can see that the spatial dependence, z , of the current can be ignored for $\frac{z}{\lambda} \ll 1$

In practice we would consider the element lumped if its length was $< 0.01\lambda$.

In terms of fractions of λ , components should have a length of less than about 0.01λ to not be considered distributed elements.

At 100 MHz, $\lambda = \frac{c}{100 \times 10^6} = 3 \text{ m}$; non-distributed resistor $< 30 \text{ mm (1.2")}$.
but...

@ 2.4 GHz $\lambda = \frac{c}{2.4 \times 10^9} = 0.125 \text{ m}$; non-distributed resistor $< 1.25 \text{ mm!}$

@ 802.11 frequencies, small (SMT) components must be used.

0805 $\Rightarrow 2.0 \times 1.25 \text{ mm}$ — no way!

0603 $\Rightarrow 1.6 \times 0.8 \text{ mm}$ — no, still too big!

0402 $\Rightarrow 1 \times 0.5 \text{ mm}$ — ah, just right
 $(.039" \times .020")$

Reference: A dime is about 1mm thick (Actually 1.35mm)