# The Basics of CABLE LOADING

***Here's how to improve voice frequency transmission in cable by using lumped inductances at uniform spacing.***

WHEN telephone companies used open wire as the transmission path, the heavy gauge of the conductors resulted in a relatively low resistance and the wide spacing produced a good balance between inductance and shunt capacitance. The attenuation of the voice currents was quite low.

The requirements for large numbers of circuits to satisfy service demands made open wire obsolete and brought about the development of cable. The resistance of cable conductors is much higher than that of open wire because the gauges are finer. The attenuation of the voice currents is further increased because the conductors have lower inductance and higher capacitance due to the close spacing of the wires and the use of insulation with a higher dielectric constant than air.

There is no way to eliminate the high resistance but the attenuation can be reduced and made more uniform over the voice frequency band by the insertion of inductance into the circuit, thereby re-establishing the balance between inductance and capacitance that was inherent in open wire. The ideal way to do this would be to spread the inductance uniformly along the cable pair but this would be too expensive. Instead, the inductance is inserted in "lumps" at regular intervals. A pair treated in this manner is said to be "lump loaded."

At very low frequencies, the cable pair acts as though the loading was in fact uniformly distributed along its length but as the frequency goes up, the pair begins to act like a low pass filter. We could represent it by a series of filter sections, each made up of a section of cable and a loading coil.

A low pass filter permits currents below its "cut-off" frequency to pass; it blocks the higher frequencies. This frequency and the characteristic impedance of the pair are both dependent upon the amount of shunt capacitance in the pair and the amount of inductance we add in the loading coil. By selecting the proper size coils and by placing them at the right locations, we can establish the cut-off frequency so that the important voice frequencies get through and we can control the characteristic impedance of the pair so that it will approximately match the impedance of the switching equipment to which it is connected. Such matching gives us the best transmission path possible.

Several loading systems have been devised to produce desired frequency and impedance values. The H88 system places coils with 88 millihenries of inductance every 6000 feet along the pair. These figures were produced from the appropriate formulas by selecting a cut-off frequency of 3500 hertz and a characteristic impedance of 950 ohms to go with the natural shunt capacitance of 0.083 microfarads per mile of cable pair. The D66 system places 66 millihenry coils at intervals of 4500 feet. This produces about the same characteristic impedance but raises the cut-off frequency to 4300 hertz.

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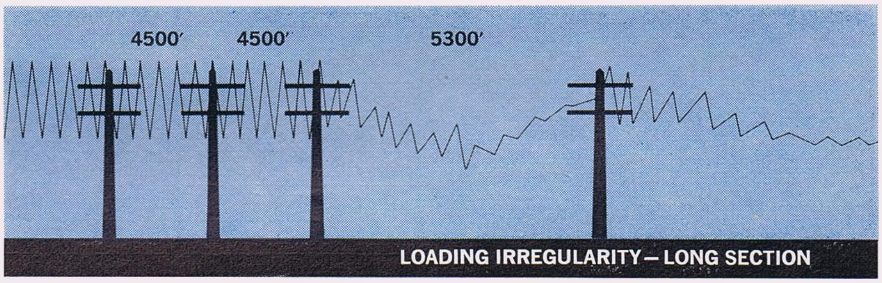
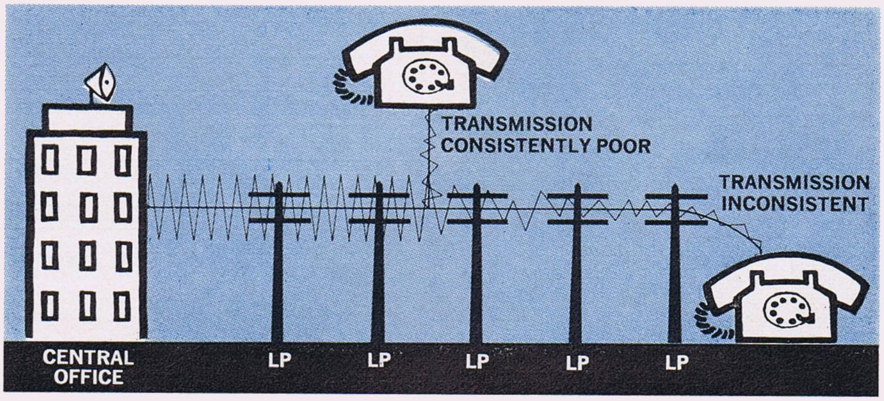
# TEN GUIDELINES FOR CABLE LOADING

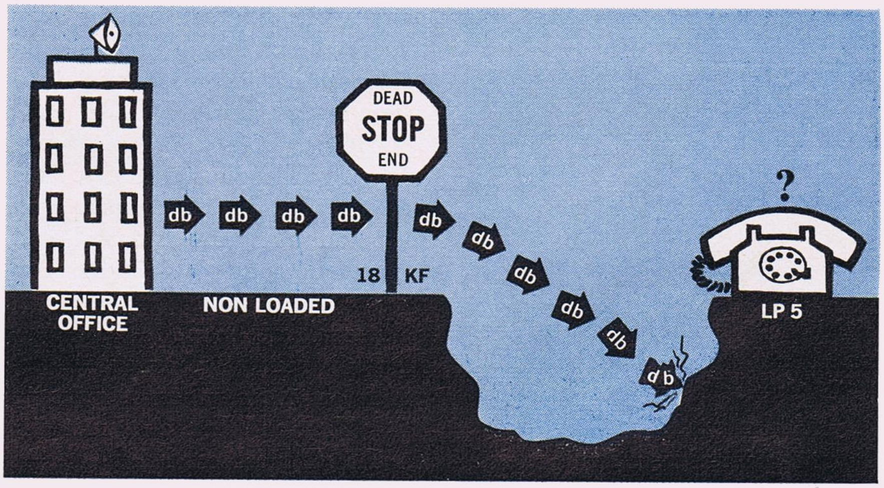
1—Try to keep each full section within 2 percent of the standard lengths shown in Table One. 2—The average full section length should be within 3 percent of the standard spacing. 3—Two adjacent loading sections should not be "averaged out" by making one section short and the other long. 4—The average of the deviations from the average spacing should be within 2 percent of the average spacing. 5—The length of the longest or shortest full section should be within 3 percent of the average spacing.




6—The first, or central office, end section should be one-half of a full section. When not practical, this may vary between 0.4 and 0.6 of a full section. A short CO end section is preferred to a long one. 7—The subscriber loop end section is the length of cable beyond the last load point, including all unisolated bridged cable taps. 8—Never—for any reason—connect a subscriber to a pair between load points. This will destroy all the improvement gained from loading and may even make transmission worse than it would be with no loading at all.




9—Subscriber loops made up entirely of 26 gauge cable do not need loading if they are less than 15,000 feet long. They should have two or more load points if they are 15,000 feet or more in length. 10—Subscriber loops made up of 19, 22 or 24 gauge cable, or a combination of these, do not need loading if they are less than 18,000 feet long. They should have three or more load points if they are 18,000 feet or more in length. Quality of service drops off rapidly as these non-loaded limits are exceeded.



# Cable Loading

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All loading systems call for the installation of fixed amounts of inductance at regular specified intervals. The manufacturer of the loading coils guarantees inductances very close to the required amounts; it is up to the plant engineer to place them as near as he can to the proper locations. Since physical conditions often prevent the placement of the coils at the ideal locations, some practical rules have been developed to tell the engineer about how much deviation he can allow.

The first general rule is to try to keep each full section within 2 per cent of the standard section length. For H88 loading, this means between 5880 feet and 6120 feet. For D66 loading, it means between 4410 feet and 4590 feet.

The second rule is applied if some of the sections fail to meet the first one. It is: The average full section length should be within 3 per cent of the standard. For H88, the average of all sections should be between 5820 and 6180 feet. For D66, the average should be between 4365 and 4635 feet.

The third rule should also be applied to sections that fail to meet the first rule. It is: The length of the longest and the shortest sections should be within 3 per cent of the average spacing.

Transmission will definitely suffer if an actual installation fails to meet this last rule. Adjustments should be made in the physical plant to reduce the deviations unless the cost is too great to justify the improvement. Judgment will have to be applied; more money can and should be spent on correcting deviations in trunk plant than is justified on subscriber plant.

The length of cable between the central office and the first loading coil is called the central office end section. The length of this end section should be one-half of a full section less an allowance of up to 300 feet for central office wiring. The mid-point of a section is one of two places where the characteristic impedance of the loaded cable pair appears to be the same in both directions; the other is at the mid-point of a coil. By placing the central office switch at the mid-point of a section, we can connect two pairs with different loading systems and not impair transmission or we can connect a loaded pair to a non-loaded pair.

Loading coils are physically mounted in loading coil cases. This protects them from damage and they can be easily installed and connected to the cable pairs. The cases contain varying numbers of coils and are made of different kinds of material; the number depends on the number of pairs to be loaded and the case material on the physical conditions at the loading point. Single coils and combinations up to 25 are available encapsulated in plastic for mounting in splice cases, closures and buried terminal housings. Cases of lead or steel are made for strand mounting; larger ones mount on poles or manhole walls. Some steel cases are wrapped and treated so that they may be buried directly in the earth. Some companies specify cases made of fiberglass and use the same ones in the air or in the ground. Finally, super-sized steel cases are available holding several thousand coils with separate in and out cable stubs for use on maximum size cables in the larger communities. ■

| Load Point | Distance From Central Office D-66 | Distance From Central Office H-88 |
|---|---|---|
| 1 | 2,250 Feet | 3,000 Feet |
| 2 | 6,750 Feet | 9,000 Feet |
| 3 | 11,250 Feet | 15,000 Feet |
| 4 | 15,750 Feet | 21,000 Feet |
| 5 | 20,250 Feet | 27,000 Feet |
| 6 | 24,750 Feet | 33,000 Feet |
| 7 | 29,250 Feet | 39,000 Feet |
| 8 | 33,750 Feet | 45,000 Feet |
| 9 | 38,250 Feet | 51,000 Feet |
| 10 | 42,750 Feet | 57,000 Feet |
| 11 | 47,250 Feet | 63,000 Feet |
| 12 | 51,750 Feet | 69,000 Feet |
| 13 | 56,250 Feet | 75,000 Feet |
| 14 | 60,750 Feet | 81,000 Feet |
| 15 | 65,250 Feet | 87,000 Feet |
| 16 | 69,750 Feet | 93,000 Feet |
| 17 | 74,250 Feet | 99,000 Feet |
| 18 | 78,750 Feet | 105,000 Feet |
| 19 | 83,250 Feet | 111,000 Feet |
| 20 | 87,750 Feet | 117,000 Feet |
| 21 | 92,250 Feet | 123,000 Feet |
| 22 | 96,750 Feet | 129,000 Feet |
| 23 | 101,250 Feet | 135,000 Feet |
| 24 | 105,750 Feet | 141,000 Feet |
| 25 | 110,250 Feet | 147,000 Feet |
| 26 | 114,750 Feet | 153,000 Feet |

**Table 1. Nominal load point spacing.**

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