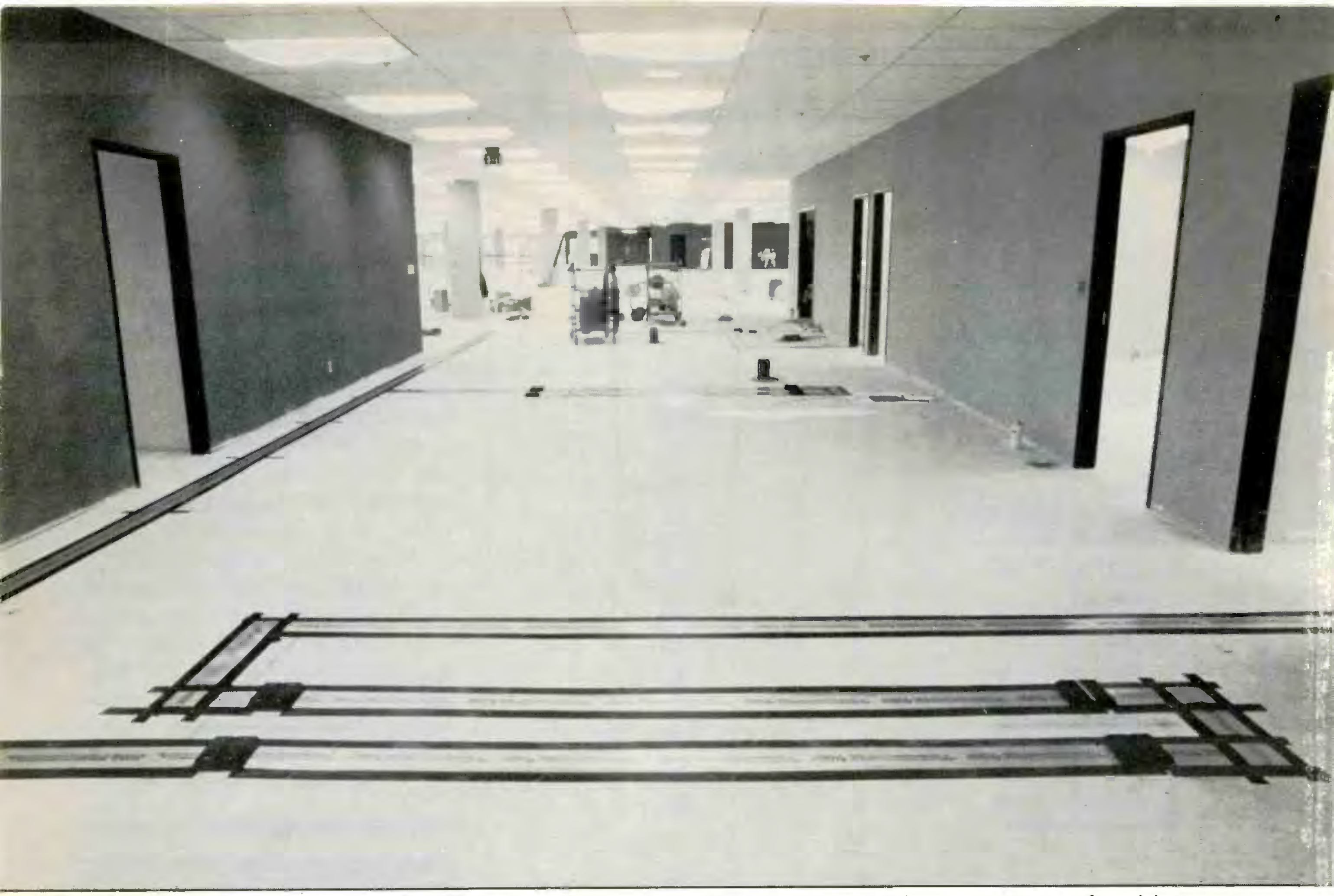

Under-carpet wiring provides uncluttered aesthetics and eases the task of making revisions to the wiring system when required in future.

Under-Carpet Fiber Optics

Simplifies routing of lines to carry power, voice signals and data signals throughout an office or building

By Terry Bowen & Jim Kevern*

Under-carpet cable, which carry power, voice and data, are being selected with increasing frequency in today's building designs. For wiring an open office, the most common type of under-carpet cable, coaxial copper, is being challenged now by super-thin fiber-optic cable. An under-carpet version becomes an important ingredient in a total system solution, as the use of optical fibers for premise wiring increases. It offers high performance and durability. For example, optical fibers offer greater bandwidth than copper cables. Moreover, its dielectric properties provide better security of sensitive computer data and immunity to error-causing noise. To properly plan an under-carpet system, one must evaluate cost and performance requirements, comparing copper versus fiber optics.

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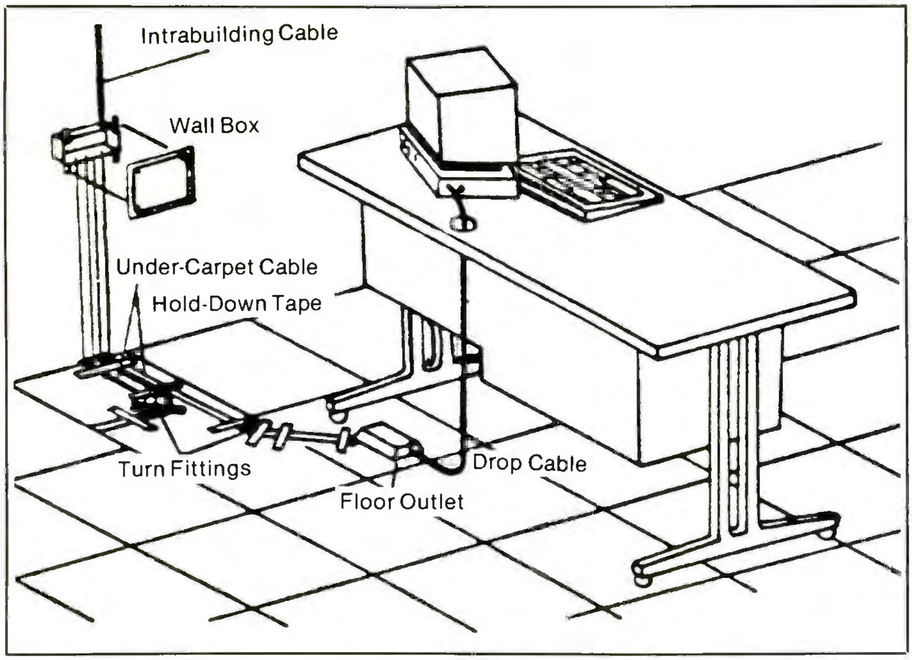
Copper Cable Overview

Copper cable varies according to the application:

- *For Power:* cable is available in 3-, 4- and 5-conductor flat versions in 10 and 12 gauge.
- *For Telephone:* cable is available in 2-, 3-, 4- and 25-pair versions in 26 gauge.
- *For Data Communication:* cable is available in 26- and 28-gauge paired versions, 25-conductor versions, and 50-, 75- and 93-ohm coaxial versions.



A typical optical-fiber cable application.

There are three important issues when considering copper cable versus optical fibers:

- *Signal Radiation & Confinement:* Copper cables radiate and collect electromagnetic energy. To maintain shield effectiveness, cables should use single or double braids, or triaxial construction. Optical fibers, in contrast, convey energy by propagation in a dielectric, rather than a conductor, the latter causing radiation of energy at high frequencies.
- *High Attenuation at HF:* In copper cable, attenuation is related to signal frequency. Transmission distance is primarily limited by frequency-dependent attenuation. Higher frequencies have greater attenuation per unit length and shorter useful transmission distances. In comparison, attenuation in an optical fiber is unrelated to signal frequency (slight receiver sensitivity degradation does occur in high-frequency, long-length links, though).
- *Limited Bandwidth:* Optical fibers have greater bandwidths than most copper cables.

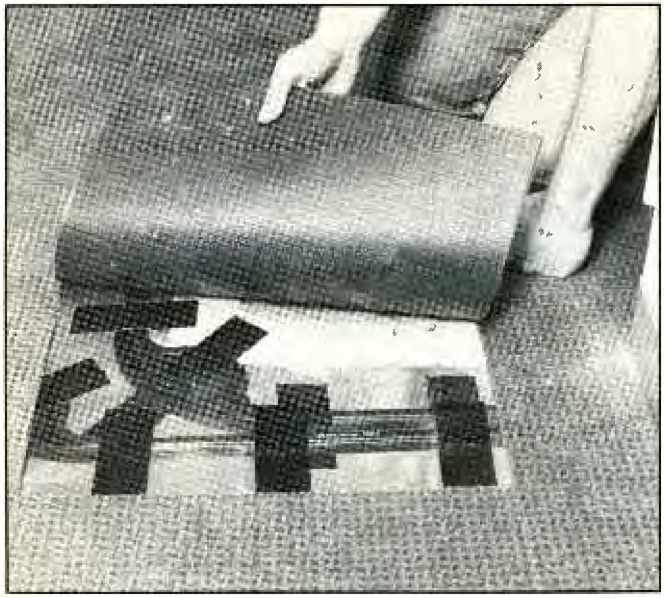
Fiber-Optic Choices

Various cable designs that an engineer has to choose from when routing a fiber cable to a specific building location include plenum and non-plenum multiple-fiber, duplex and single-fiber designs. A given installation may involve several different cable constructions. Since cable runs under carpets, in walls, raceways, conduits and air plenums, each has specific requirements.

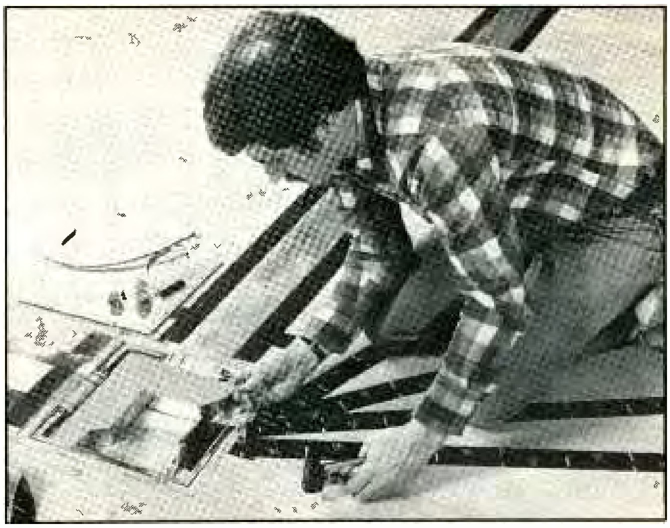
One specific under-carpet fiber-

Special tools help simplify installation of fiber-optic cable. When small slitting block is pulled lengthwise over cable, strength members and ramp material are precisely separated from the jacketed optical fibers. A blanking tool is then used to square off the end of the optical fiber.

Carpet tiles, which completely conceal flat fiber-optic wiring, are usually held down with release-type adhesive to permit easy removal if outlets or wiring require rearranging. Fiber-optic cable does not require any special shielding or other protection.



Turn fittings are positioned for 45- or 90-degree turns in small areas.



Technicians make a transition splice between a flat optical cable and a round optical cable in recessed floor junction box. The blanking tool, shown, provides a clean, precise square-off end of the optical fiber.

optic cable features a two-channel cable that has two optical fibers and three strength members. A polyester elastomer material covers the fibers to protect the glass from abrasion. The strength members are a proprietary fiber-reinforced plastic with good crush and impact resistance.

All the elements are enclosed in a tough flame-retardant polyvinylchloride jacket. The cable has a low profile (0.075 inch high) for installation under carpet or tile without causing a bulge. The fiber-optic cable withstands harsh mechanical and chemical exposures that could destroy flat copper data transmission cable.

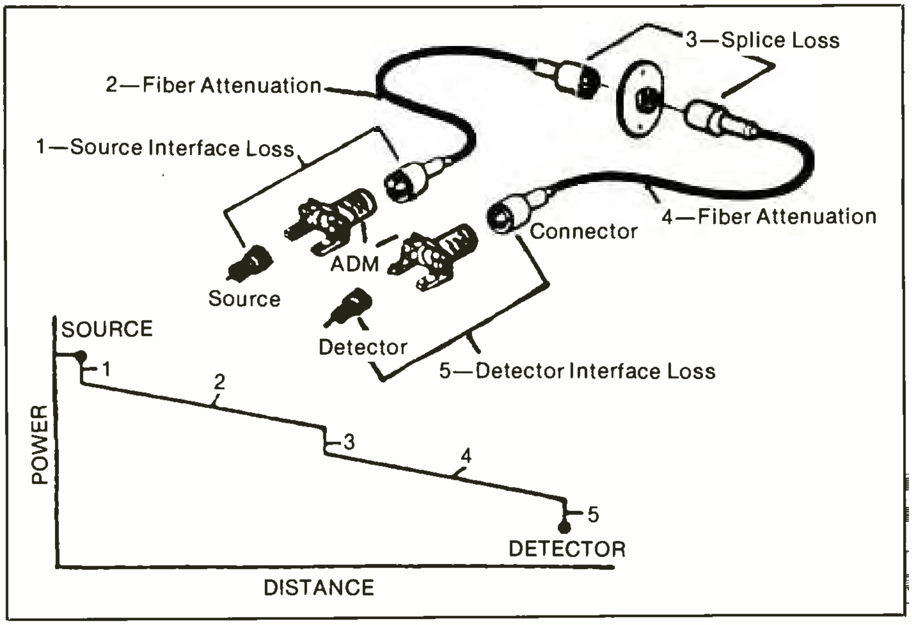
Installation

When routing duplex fiber-optic cable, stress may be induced on fibers if the cable is bent severely. At corners, the inner fiber must, therefore, take a shorter path than the outer fiber.

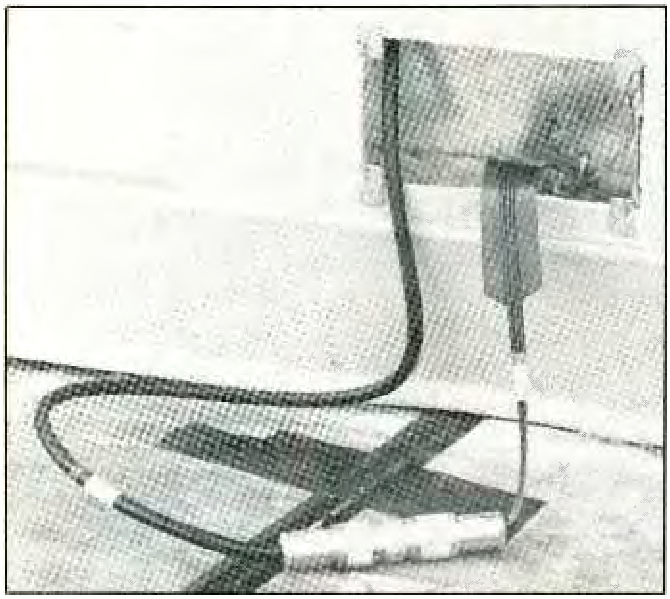
One way to attempt to alleviate stress is to gradually turn the cable, rather than directly bend it. In most office areas, however, gradual turning is impractical because of space limitations. Also, a difference in path length of two fibers still occurs, even if the curve is gradual.

The length of each fiber can be matched if they are first removed from the cable, then laid in different paths, and finally encased in turn fittings. Tracks in 45- and 90-degree turn fittings are designed to provide equal lengths and optimum radii.

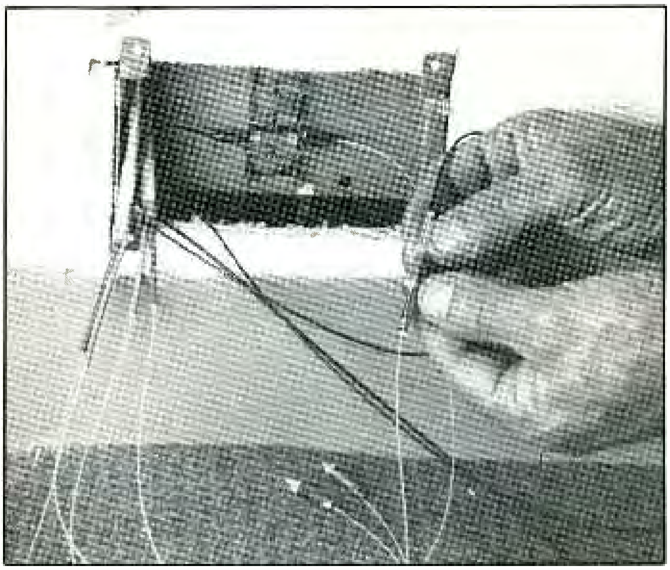
Such turn fittings replace the cable's strength members and side ramps, while providing crush resistance and low profile. By using various combinations of turn fittings, complex cable routes easily can be achieved. It is important to properly prepare the floor before laying the cable under the carpet. Three basic steps should be taken:



Sources of loss in a fiber-optic link.



Transitions between conventional and under-carpet cables are behind cover plates on an interior wall.



Round fiber-optic feed wiring is connected to flat under-carpet cable at wall transition box with disconnectable fiber-optic splices.

(1) All holes or imperfections in the concrete slabs should be filled and all bumps removed;

(2) Porous floors should be sealed and free of grease, oil and moisture;

(3) Floors should be thoroughly cleaned and vacuumed.

System Loss Budgeting

Any fiber-optic cable application requires a loss budget analysis of the system. This analysis quantifies losses throughout the system and power available at the receiver.

To minimize loss, all cables in a building should have the same core and cladding diameter. Total system loss can then be generalized as the sum of the individual losses: SLB (in dB) = L1 + L2 + L3 . . . Ln.

A fiber-optic link must deliver enough of the transmitter power to operate a receiver within system specifications. To provide a wide margin for future re-arrangement and component degradation, losses throughout the system should be minimized.

The main sources of loss in a link are: *Fiber Attenuation; Fiber-to-Fiber Connections*, including numerical aperture (NA) mismatches, core diameter mismatches, connector insertion loss, intrinsic fiber mismatch; and *Loss Margins*, to account for source aging, temperature variations, and loss from bends and mechanical stress.

Loss at connectors is caused by several different factors, including intrinsic fiber mismatch and connector misalignment.

Optical fiber attenuation in an under-carpet system can be viewed as proportional with length. If the cable is specified to have an attenuation of less than 6 decibels per kilometer (dB/km), a 50-meter cable run has only 0.3 dB of loss. For systems with LED (light-emitting diode) sources,

Table 1. Power Budget Analysis

Transmitter Launch Power*	– 15 dBm
Receiver Sensitivity	– 28 dBm
Total Power Budget	13 dB
Power Allocation Example	
System Margin	
(A) LED Aging	1 dB
(B) Temperature Effects	1 dB
(C) Other Factors	1 dB
Total Margin	3 dB
Available Power	10 dB
Cable Loss	
(A) (Attenuation 1 km at 4.5 dB/km)	4.5 dB
(B) Transient Loss:	0.5 dB
Connector Loss (4 connectors at 1.0 dB)	4.0 dB
Installation & Repair Splice Loss (4 splices at 0.25 dB)	1.0 dB
Total Loss	10 dB

*Power specified by equipment manufacturer for size of fiber being used.

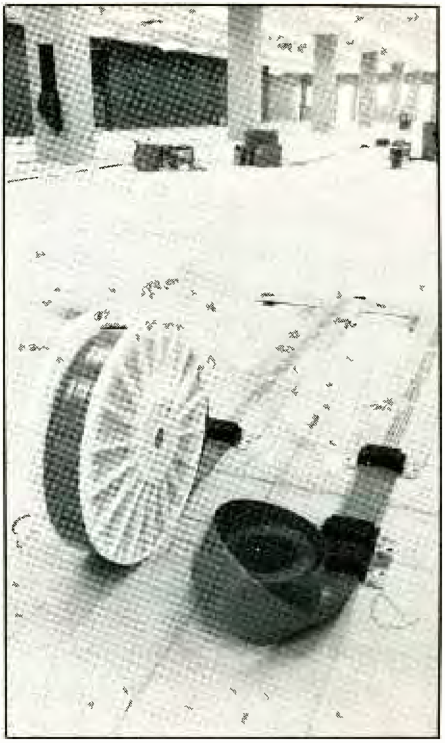
Table 2. Under-Carpet Cable Specifications

Fiber (μm)	Attenuation (dB/km) 850 nm	1,300 nm	Optical Characteristics Bandwidth (MHz-km) 850 nm	1,300 nm	NA
50/125	< 5	< 3.5	> 400	> 400	0.215/0.185
63/125	< 6	< 4.5	> 100	> 200	0.305/0.275
85/125	< 6	< 4.5	> 100	> 200	0.275/0.245
100/140	< 7	< 6.0	> 100	> 100	0.305/0.275
485/500	< 300 at 650 nm		> 0.5 at 450 nm		0.50/0.44

Mechanical Characteristics

Operating Temperature Range	0° to 50° C
Storage Temperature Range	−120° to +60° C
Minimum Bend Radius	1.5 inch
Maximum Tensile Loading	22.5 pounds
Flammability	Passes UL B3

*Plastic fiber



A newly completed tilt-up building requires an under-slab membrane to prevent methane gas seepage from entering the building. Opting for under-carpet wiring systems avoids the possibility of disturbing the building's protective barrier.

an additional one-time penalty of 0.5 to 1.0 dB is allowed for transient loss. This loss is due to high-order modes launched by LEDs, which are not efficiently carried by the fibers.

The obvious best approach is to use the same fiber diameter throughout an installation. However, this is not always possible. Telephone fibers entering a building may be 50/125 μm, while equipment such as computers and terminals may be designed for 100/140 μm cable.

Also, the direction of light transmission may not be known by the cable installer, and losses may not be the same in both directions. Signals moving in one direction may go from smaller to larger fibers, meaning no diameter or NA mismatch loss. Signals moving in the opposite direction *are* affected by these losses.

A loss margin must be allowed for performance change over time and temperature extremes, as well as for loss due to mechanical stress and bends. An allowance of 1 to 3 dB for LED aging and 2 dB for temperature variations and allowance for stress and bends is common.

Also, analysis must consider source type (laser diode or LED), emission characteristics like diameter and NA, output power, and operating wavelength (fiber attenuation is lower at 1,300 nm than at 850 nm, for example). The source manufacturer will usually provide information on the power coupled into the fiber.

Given the amount of power coupled into the fiber, the system loss budget analysis shows how much power remains to operate the receiver. Sufficient power must reach the detector to maintain the desired bit error rate (BER).

On the other hand, too much power will saturate the receiver. Therefore, received power must lie within the dynamic range of the receiver. Saturation can be prevented by introducing additional attenuation into the system, of course.

Conclusion

A power budget analysis can be performed by developing a worksheet. The example provided in Table 1 is for electric power.

The worksheet includes information on the sensitivity of the receiver and the power launched by the transmitter. Next, system power is allocated to the various components that make up the system.

The number of ways one might configure a system is countless. Each configuration will be determined by the particular building layout. The use of the Power Budget Analysis Worksheet will ensure that power allocated falls within the total power budget available.

In sum, then, under-carpet fiber-optic cable provides a convenient and flexible way to obtain the benefits of optical communications in an office environment, where it is desirable to install hidden wiring that can better withstand mechanical stress and chemical exposure to assure the integrity of data communication.