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L5 Coaxial-Carrier Transmission System

Foreword

Coaxial-carrier transmission systems constitute a significant portion of the Bell System long-haul transmission facilities. These systems have been developed over several decades to provide the basis of a high-quality, high-capacity, long-distance communications network.

After extensive exploratory work on wideband amplifiers and coaxial cable, the feasibility of a coaxial-carrier system was demonstrated in 1936 between New York and Philadelphia. The success of this trial was followed by development of the first Bell System coaxial-carrier transmission system, the L1. Placed in service in 1941, the L1 system was initially capable of carrying 480 four-kHz two-way message channels per pair of 0.270-inch-diameter coaxial cables, with a repeater spacing of 5.5 miles. Soon, 0.375-inch-diameter cable became standard and, with system improvements, the vacuum-tube-operated L1 system was capable of carrying 600 circuits per coaxial pair with 8-mile repeater spacing. Its capacity was later increased to 720 circuits.

The major expense of the coaxial system has been in the outside plant area: cable, cable placement, right-of-way, and buildings, including aboveground or underground structures for housing repeaters. Once this portion of the system is established, development of electronic equipment to provide maximum utilization of the cable becomes economically attractive. Each successive generation of repeaters achieved wider transmission bandwidth and, hence, larger channel capacity through use of shorter repeater spacing, new technology, and more advanced system concepts. Use of cables with more

Table I — Evolution of coaxial-carrier transmission systems

System	First Service	Capacity in Telephone Circuits		Typical Coax Units Per Sheath	Approximate Repeater Spacing (Miles)	Repeater Technology	Repeater Types	Equalization	Other Key System Features
		Per Coax Pair	Per Cable*						
L1	1941	720†	720 2,160	4 8	8	Vacuum tube	Manually and automatically adjusted regulating repeaters; equalizing repeaters	Adjustable static and dynamic "bump" shapes	
L3	1953	1,860	5,580 9,300	8 12	4	Vacuum tube, statistically controlled key components	Buried-thermistor and line-pilot-controlled regulating repeaters; equalizing repeaters	Manual "cosine" shapes; dynamic broad shapes	Hardened configuration
L4	1967	3,600	32,400	20	2	Discrete transistor, printed wiring board	Fixed basic repeaters; regulating repeaters controlled by both a buried thermistor and line pilot; equalizing repeaters	Static "bump" shapes	Noise objective more stringent by 4 dB
L5	1974	10,800‡	108,000‡	22	1	Discrete transistor, hybrid integrated circuit	Same repeater hierarchy as L4	Static "bump" plus dynamic cause-related shapes	Phase-shaping networks to control third-order modulation addition; same noise objectives as in L4

* One coaxial pair reserved for protection of failed regular lines.
† Originally 480 circuits per coaxial pair, but widely used at 600-circuit capacity.
‡ Extensions to L5 are being developed to provide 13,200 telephone circuits per coaxial pair, or 132,000 circuits per 22-tube cable.

coaxial units per sheath increased route capacity and further reduced per-channel-mile costs.

From the outline of the evolution of coaxial-carrier systems in Table I, we can see that, in 33 years, the channel capacity of repeatered coaxial line has increased by a factor of 22.5—from 480 to 10,800 channels, and further increases are anticipated. In the same period, improvements in cable technology allowed the manufacture of cable with 5.5 times more coaxial units in the cable sheath—from 4 tubes to 22 tubes—resulting in a 10-fold increase in signal-carrying capacity, not including the two units reserved for service protection. The total impact, then, was a 225-fold increase in route capacity. During the same 33 years, Bell System circuit miles increased 485-fold.

This issue of *The Bell System Technical Journal* describes in detail the latest in the line of coaxial systems—the L5 Coaxial-Carrier Transmission System. The articles include descriptions of an advanced systems approach and sophisticated repeatered-line and equalization designs. Also included are the novel concepts in repeatered-line powering, line-protection switching, equipment-performance surveillance, centralized maintenance, and carrier reference-frequency generation. Other articles describe the new multiplex and signal-administration equipment and the important role in the success of L5 played by innovations in physical design and thin-film techniques and by the use of ultralinear semiconductor devices. The many computational aids and measurement facilities that were effectively used in the development of the system are also discussed.

The initial L5 system—815 miles of cable, 14 stations, 850 manholes, 3400 manhole repeaters, and over 250 bays of transmission equipment—went into service on January 3, 1974, fulfilling a schedule developed six years earlier. This on-time completion of such a massive system required the dedicated effort of many individuals in the Bell System companies. Bell Laboratories people conceived and developed the system and its components; Western Electric people were responsible for manufacture of cable and electronic equipment and for installation of main-station equipment; and AT&T and Long Lines people were actively involved in system planning, coordination, route selection, cable placement, installation of line equipment, and operational testing. It is to this skilled Bell System team that this issue is dedicated.