Cablesoft Engineering Inc. Technical Report
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Cablesoft Engineering has spent the past few years involved in research which will assist the cable industry in the sure and eventual move to higher supply (ac powering) voltages. A portion of this research involved an examination of how other communication industries have approached the problem, particularly the telephone industry. This quarter takes a look at telephone coaxial "toll systems" developed and operated in the post WWII era into the 1970's and 1980's.

Telephone Coaxial Toll System Powering

Basic Toll System Design

The telephone industry has used coaxial cable as a transmission medium for long haul transmission (toll repeater systems) since post World War II. Systems have been designed and implemented employing FDM (frequency division multiplexing) in configurations of up to 10,800 voice channels. In long haul application, each "cable tube" generally contained from two to eight coaxial cables or tubes, with .375" the typical diameter for each individual coaxial cable.

Tubes were generally *"paired"* to attain duplex operation with equal bi-directional bandwidth. These long haul systems were generally buried at a depth of 90 to 120 cm, but long aerial runs were sometimes placed as well.

Cable repeaters (amplifiers) were uniformly spaced along the route, with cable lengths factory pre-cut so that repeater locations were at "near identical spacing with little or no splices".

Specific Toll System Design

As an initial example, a typical long haul system design by ITT employed a total bandwidth of 12 Mhz using .375" diameter coaxial cables. Repeaters were uniformly spaced along the route, and powered via coaxial cable by injection points placed every 30 amplifiers (15 in each direction from the injection point). The system was normally buried to realize the following advantages:

- Reduced maintenance requirements
- Minimal network AGC requirements

AGC was typically placed every 4th amplifier in the underground approach via a plug in "level control unit".

The typical 12 Mhz system could carry up to 2,700 voice channels. Besides FDM carriers, several pilots were employed for carrier level control along with supervisory (network monitoring) information.

A high degree of pre-emphasis or forward tilt was employed due to lengthy repeater spacing. In the ITT 12 Mhz system, the spectrum content was therefore:

- Pre-emphasized (forward tilted) FDM (voice circuit) carriers
- Level control pilots
- Network supervisory control
- DC power feed

Toll System Powering
In the ITT system, the DC voltage employed for repeater powering could be as high as 650 volts at the injection point, with a stabilized injection current of 110 ma (.11 A). Power injection points, located at main or terminal repeaters (AGC and accessible), powered up to 15 dependent (typically non-AGC, often buried) repeaters in both directions. Spacing for each dependent repeater was 4.5 km or 2.8 miles in the 12 Mhz system. Amplifiers had gain adjustment of $\pm$ 6 dB, which allowed final repeater location movement of about $\pm$ 570 meters. Power feed points at terminal repeater locations were therefore as great as every 140 km or 87 miles!

Stabilized Current Approach
Toll repeater systems (including trans-oceanic cables) normally employ stabilized current feeds. This methodology says that if (the) system layout employs identical repeater spacing with the same size cables, and amplifiers in the network draw identical DC currents given a particular input voltage, then a given injection voltage and current always powers that portion of the network in a predictable fashion. Therefore, a DC voltage/current injected at every “nth” repeater always yields the same power layout. A further example probably serves as the best explanation.

The CCITT 60 Mhz bandwidth toll repeater system was powered as follows. Up to 64 repeaters were powered from each power injection point, 32 in each direction. Power feeding was accomplished every 100 km or 63 miles. Each dependent repeater tapped off about 15 VDC or 2 watts. The full complement of repeaters to be powered from any given injection point yielded a total injection voltage requirement of 960 VDC. An additional 120 VDC each was required for each AGC unit, along with 50 VDC I^2R loss for the cable, **thus the total injected voltage for each 100 km was a maximum of <u>1226 VDC</u>!** Other transmission systems utilized even higher voltage schemes. For example, the L5 60 Mhz “Bell System” toll configuration utilized a 2,300 VDC potential between center conductor and sheath.

Personnel and Subscriber Safety Issues
One major concern for the cable industry in the move to higher supply voltages has been subscriber and personnel saftey issues. How the telco industry has faced these same issues in the past is helpful in addressing this viable concern.

<u>Subscriber safety</u> issues strictly don't seen to apply, since the nature of the toll system is that it is a “transport system” i.e., provides multiplexed path(s) between switching points, but no direct path to the subscribers residence. To my knowledge, and since it’s inception, the telco network has only allowed two voltage levels into the subscribers home.

- 48 VDC. The nominal line voltage present from the central office switch (and battery banks) across the “tip” and “ring” terminals of the network interface unit on the outside of a residence.
- 90 VAC. Typical “ringing voltage” present when the subscriber is signaled to an incoming call.

We would anticipate that the cable industry will be forced to a similar line of demarcation, likely at a network interface unit on the side of a residence, as present NEC restrictions will be a formidable hurdle to cross in taking voltages greater than 60 volts <u>*into*</u> the subscriber’s home should the industry wish to do so.

General public safety concerns are also met, since the cable transmission medium is a closed protected one via the use of coaxial cable. Even catastrophic failure of our network plant rarely if ever leads to exposure to the public.

Telephone industry personnel safety concerns were met along several fronts, namely:

- Exposed high voltage points in equipment are covered with "protective panels" to prevent accidental contact and are clearly marked.
- Internal training efforts familiarize applicable personnel in proper safety handling requirements in maintaining these higher voltage systems.

Although we no longer have access to written telephone company records regarding safety histories in the maintenance of toll plant, we know that safety issues due to elevated powering voltages was rarely if ever a concern after toll system operation began. Further, the use of these higher voltages was absolutely paramount to successful deployment of the coaxial toll system for reasons the cable industry is now all too familiar with.

Conclusions As Applicable to The Cable Industry

The purpose of the preceding was to familiarize the reader with past (with many still in operation around the world) telephone industry coaxial toll system configurations, particularly as it relates to how they were powered. Clearly, some precedence has been established in the use of higher voltages in coaxial cable "communication class conductors" as defined by the NESC.

The problem, as we see it, with this established telco toll system precedence in the use of higher voltages, as it applies to the challenges faced by our industry, is two-fold.

- These toll systems were predominantly underground, thus application to NESC code tends to become rather nebulous. The NESC code is meant to apply primarily to the "aerial, utility pole, shared (via common bonding) network".
- Present and past NESC codes have applied a limitation to the "total transferred power" within the network, and these limits seem to have toll systems clearly in mind i.e., toll systems tend to meet code limitations, while most other networks that we am familiar with do not. The definitions section of the NESC states, paraphrasing and in summary "Under 'typical operating conditions', power transferred between any two network locations is limited to 150 watts maximum when the voltage is $\geq$90 volts. At less than 90 volts no power transfer restrictions exist". The typical toll network powering area typically transfers 70 to 100 watts in total, with greater than 150 watts of transferred power very unusual. Present cable system powering areas often transfer typical loads of 600 to 800 watts, with the higher voltages under consideration transferring as much as 2000 to 2500 watts! Either the code was written with the toll system in mind, or toll systems were developed to meet code restrictions that were anticipated in the post-W.W.II era.

Current code wording would certainly seem to allow for a dismissal of this limitation under *"certain conditions"*. Only direct contact with the NESC will clear up this ambiguous area.

This article was first developed for a major MSO as part of their examination of what issues would be encountered in a move to higher supply voltages by the cable television industry. Subsequent quarterly reports will further delineate our research.

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Cablesoft Engineering, Inc.

Cablesoft Engineering Inc. provides engineering and consulting services for the CATV industry. Some of the many services provided are:

- ◊ System RF and AC design/CAD, design analysis, and design verification.
- ◊ System Reliability Analysis with recommendations for improved system performance.
- ◊ Complete System Technical Evaluation Analysis & Reporting including Due Diligence.
- ◊ Full System Proof-of-Performance Testing.

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The CEI Technical Report

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