MULTIPLEXING DERIVED VOICE CALLS OVER BASEBAND

RANDY BROWN
PRINCIPAL ENGINEER
AG COMMUNICATION SYSTEMS
2500 WEST UTOPIA RD
PHOENIX, AZ 85027
623-581-4125

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Voice over Digital Subscriber Loop (DSL) solutions promise the ability to multiplex packet or cell based voice calls, using digital subscriber loop transmission technologies, over a single subscriber pair simultaneously supporting baseband voice service. As such, legacy standards for ensuring minimal spectral interference between pairs within a Digital Loop Carrier (DLC) or Fiber In The Loop (FITL) product need to be extended to emerging Voice over DSL products to meet service provider and subscriber expectations. This paper examines the relevant transmission parameters and their potential impact on the design of derived voice systems using a single subscriber pair.

Introduction

Telephone companies distinguish their service offerings from cable companies and other competitive access or wireless providers through reliability and quality. Concepts such as "lifeline" phone service and "carrier class toll-quality" evoke a sense of high reliability and transmission quality.

As switches migrated from analog to digital, the quality of Public Switched Telephone Network voice improved. With the advent of Digital Loop Carrier systems, multiple digital voice lines were multiplexed over existing copper facilities, as shown in Figure 1, and commensurate high quality voice service was maintained. Several standards, such as TR57[1] (Functional Criteria for Digital Loop Carrier Systems) and TA909[2] (Generic Requirements and Objectives for Fiber in the Loop Systems), were developed to ensure TR-008 and GR-303 transmission was robust and users would not detect a noticeable difference in voice quality from direct CO connections.

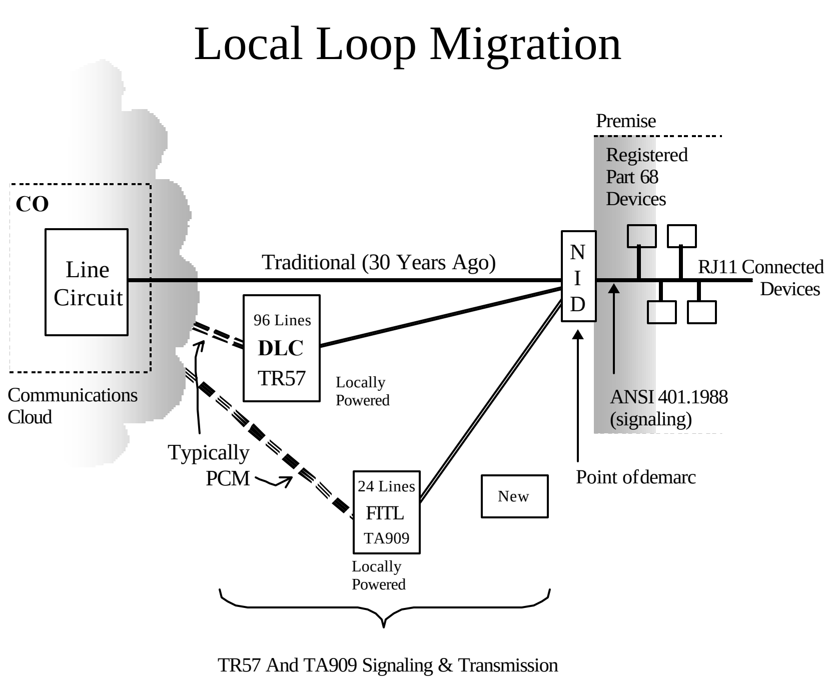

Figure 1

VoDSL & TR57/TA909 Signaling & Transmission Criteria

VoDSL is an extension of the DLC concept. Instead of independent pairs multiplexed onto upstream facilities, VoDSL enables several calls to be multiplexed over the same pair. Then, typically using a GR-303 interface, VoDSL multiplexes individual voice channels (DS0s) with associated out of band call processing and operations messages over facilities to the Class 5 switch.

The criteria in TR57 and TA909 have been proven in technical trials to validate emulated voice services using xDSL technologies in order to ensure commensurate voice quality with the baseband line. In addition, the emerging VoDSL requirements from the DSL Forum refer to these documents in the Broadband Loop Emulation Service (BLES) annex. Timing excerpts from TR57 are listed in the VoDSL recommendation as parameters to which VoDSL equipment should strive to meet, although analog aspects of these legacy standards were not included since some VoDSL equipment may use IP phones as endpoints.

Most customer handsets interface via an analog RJ11 interface and as the telephone network architecture evolves, vendors continue to be obliged to conform to FCC Part 68 rules for preventing harm to the network. The whole notion of Part 68 is that customers should be able to own their own apparatus. The signals on the RJ11 are documented in TR57 and TA909 in that they define signaling and transmission performance for appliances that are closer to a subscriber's home than the typical apparatus. As the wires enter the SOHO or home the intent is that the signals exchanged over the wires will function properly when used with a properly registered communication device.

To realistically address the market VoDSL vendors need to understand and accommodate the significant areas embodied in Part 68 as well as TR57 and TA909. To do otherwise is to invite making a mistake the industry can't live with. Most of the requirements these specifications contain are not new. For example, 20 years ago many in the industry would have supported an end to powered ringing. CO equipment could have alerted the phones without AC energy. Still, it was ultimately upheld and remains the law.

Impact of Impulse Noise & Ringing on Multiplexed VoDSL

DSL connections are subject to interference from various sources of noise in the local loop and may be subject to significant impulse noise from motors, streetlights, dimmers, refrigerators and even the PSTN itself such as is the case for ringing.

Ringing in North America is an AC voltage superimposed on a DC bias. The majority of installations in the US use non-sinusoidal 20 Hz ringing with a nominal rms 90 volts at the ringing source. A significant number of telephone installations in North America use other frequencies that range from 16 2/3 to 66 2/3 with voltages from 85 to 135[3]. One ANSI standard sets the maximum voltage limit to 150V rms[4] and notes cases where it can attain 175V rms.

Ringing is clearly a non-continuous disturber. At the beginning of each ringing burst there is a transition from -48-Volt battery feed to -48-Volt with superimposed AC ringing. Nominal interrupts are 2 seconds on and 4 seconds off. Custom ringing cadences with multiple ringing, such as triple cadences, are common. The ringing waveform is ideally a sine wave with its axis of symmetry shifted -48-Volts from zero. The ringing burst can be characterized in terms of 100's of milliseconds as shown in Figure 2. In this depiction, the sine wave starts and stops in unity with the DC bias and represents the best case relative to instantaneous power changes as a result of ring application and trip.

Standard Ringing Potential with Best Case Start/End

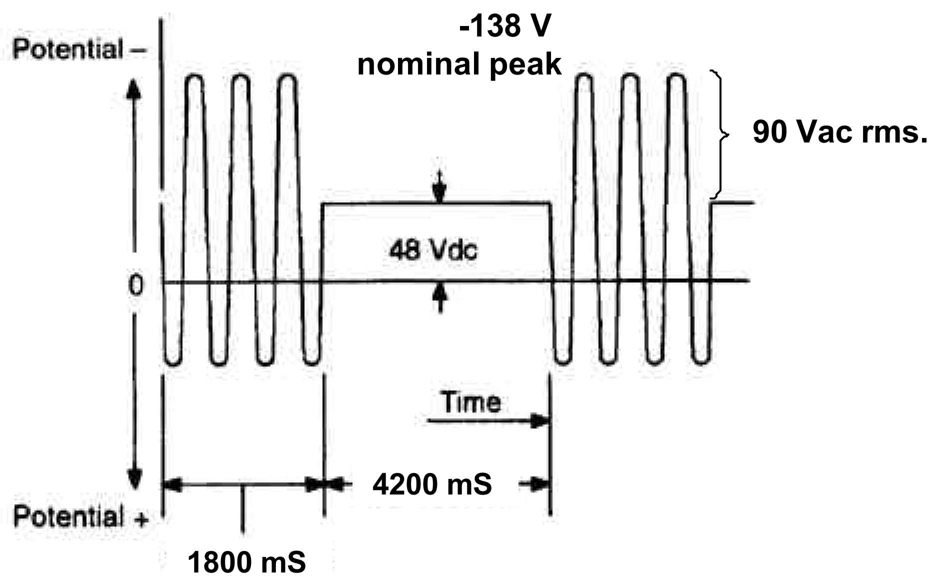

Figure 2.

Elements of synchronization are related to the application of ringing in many applications, such as the use of a common ringing bus serving hundreds of lines. Central office implementations, in many cases, simultaneously ring multiple lines with concurrent cadence. As such, the application and withdrawl of ringing is generally without regard to the phase angle of AC energy. The peak voltage when ringing is tripped can be the sum of the DC and greatest AC or approximately 170 volts as shown in Figure 3.

Standard Ringing Potential Worst Case Start/End

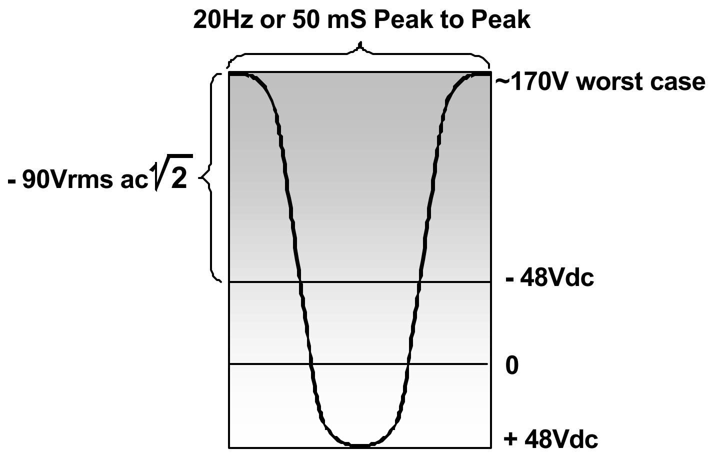

Figure 3.

Ringing is not balanced within the pair as it is ordinarily applied on only the ring conductor of the telephone pair, while the tip conductor is held near earth ground. The unbalanced application of ringing increases the pair-to-pair coupling within the binder group.

In practice, multi-vibrators generate the wave shape of the ringing energy. To smooth the resulting wave edge, post filtering is applied to the generated waveform. The ringing interrupters switch from the AC and DC ringing potentials to a DC-only potential during the silent interval as illustrated in Figure 4. This switching is not synchronized with the ringing waveform.

Basic Ringing Generator

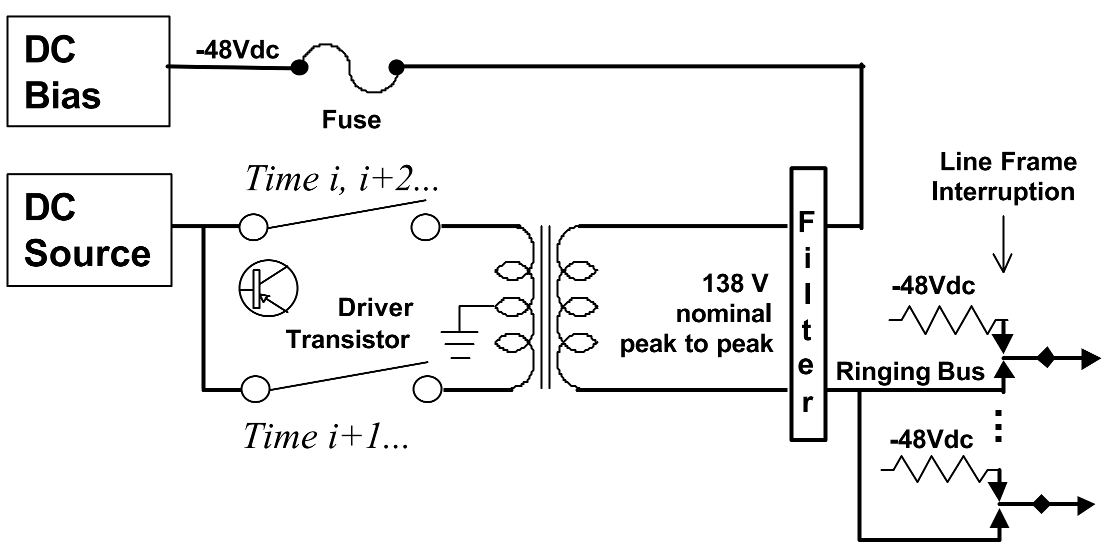

Figure 4.

In its worst case, a generated ringing waveform is a trapezoidal shape, which means it has higher frequency components occurring at 25 mS intervals. Transient energies often result from gap switching in the ringing generator as shown in Figure 5.

Ringing Waveforms (Worst Case Generalization)

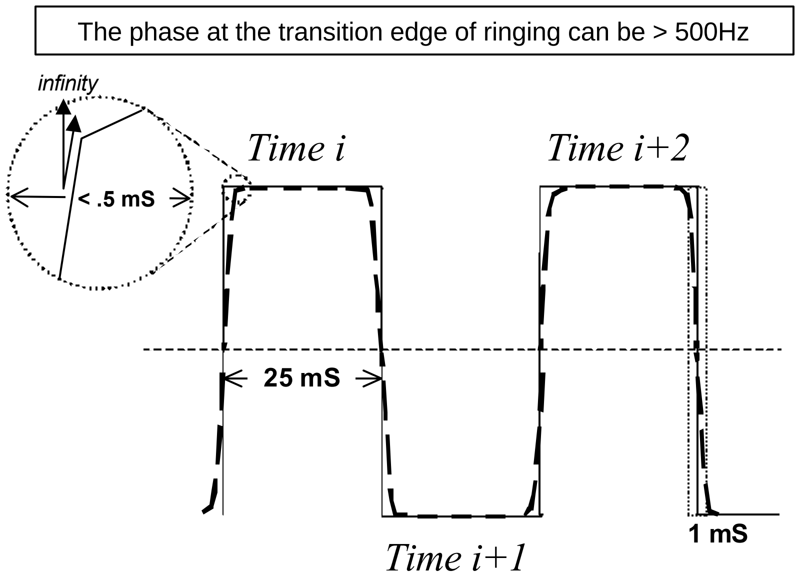

Figure 5.

A square waveform is made of a fundamental frequency *f* and all the odd harmonics rising to infinity, that is, 3*f*, 5*f*, 7*f* and so on. As a ringing waveform nears a square or trapezoidal shape together with its instantaneous application on a line, it can be expected to produce fundamental harmonics across a wide array of frequencies. This was observed using a spectrum analyzer sampling distinctive ringing frequencies at 3kHz for approximately 10 minutes, on a copper pair with 135 Ohms termination impedance adjacent to a continually ringing line, within a binder of 10Kft 24AWG, for the upstream ADSL bandpass as shown in Figure 6:

Ringing Impulse Noise within the ADSL Upstream Bandpass

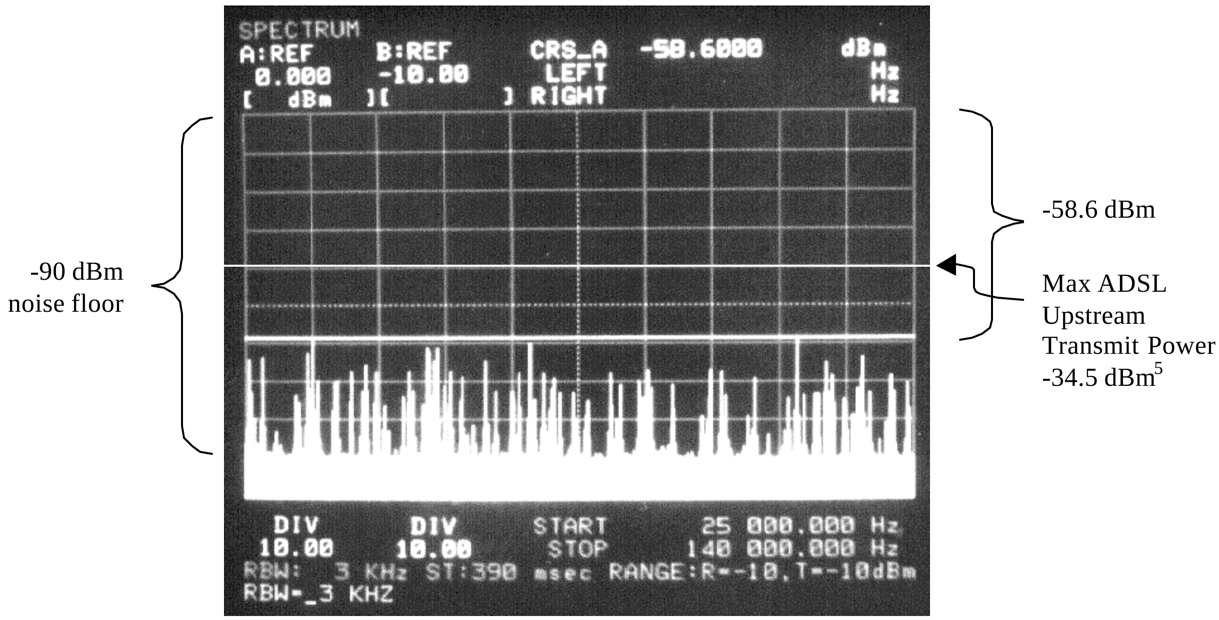

Figure 6.

With the noise floor shown of approximately -90dBm along with a peak ringing amplitude of about -58dBm, it's clear that over 30dBm of ringing impulse noise within the frequencies of interest to xDSL is not uncommon. This effect of ringing was also observed on various lengths of copper, with randomly selected pairs across a wide array of frequencies using ringing generators, line circuits and ringing cards in current commercial service.

As an illustration of the effects of legacy ringing, an ADSL DMT based modem was set up to produce 640 kbs segmented into 1000 byte IP packets in its upstream bandpass exchanged across an Ethernet link connected to a premise modem. A corresponding average reduction in throughput of 300 - 600 bits/second on the ADSL modem was observed with errored seconds corresponding to the application and removal of ringing as illustrated in Figure 7.

Ringing Application & Removal Effects on DMT

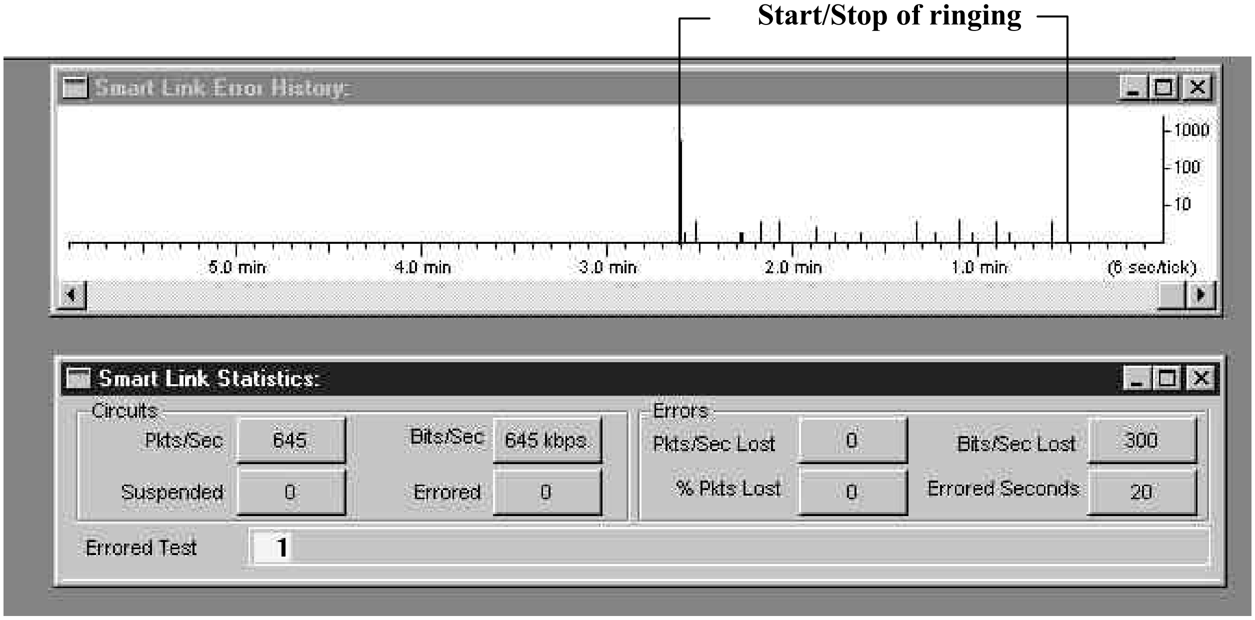

Figure 7

Most DSL implementations are targeted initially for data and they assume that upper layer protocols such as TCP are used to retransmit data and therefore interleaving is not used. It's clear from this one example of noise in the legacy PSTN that significant crosstalk events exist, which may affect the ability to deliver multiplexed packet or cell voice over xDSL that is commensurate with baseband voice service quality.

An important question arises from this insight: can we really expect to do voice without interruptions and in particular the pair-to-pair coupling that increases along with the frequency in use (15dB per decade)? Impulse noise tests from TR57 seek to ferret out poor DLC backplane designs through an impulse-ringing test. Essentially the test is to ring the line continually for 15 minutes and check adjacent circuitry. The point is to verify that each path is isolated from the others, which stems from a fundamental requirement that all calls are independent. In effect there should be no ability to cause a disruption of another call through software manipulation of call paths or ordinary events such as simple ringing.

If one call interferes with another call nobody will buy the system. However, it's also an important multiplexing issue for VoDSL that is often overlooked but becomes apparent when considering the application of legacy standards accepted for decades to this new application. In effect, the pairs of a cable are now the backplane of a DLC. As new line codes and splitterless technologies intended for consumer installation are adopted in standards, it's important to stop to consider if these technologies are robust enough to accommodate simple non-zero crossing ringing much less the extensive criteria set forth in TR57 and TA909.

Conclusion

In telephony, there are "penny services" and "nickel services." TR57 single party service is a penny service. It's fundamental to providing commensurate baseband voice service. Even cellular companies recognize the need to provide RJ-11 interoperability for a fax interface. The research justifying TR57 single party transmission services have been settled for years and there is no smaller denomination that ensures compliance to federal and industry standards. Most all of the criteria in TR57 as it relates to single party service are applicable to VoDSL and other forms of derived voice service designed to use xDSL bandwidth. A particular challenge for vendors is to ensure compliance to those criteria that relate to ringing and interference tests between calls.

References

[1] TR-NWT-000057 Functional Criteria for Digital Loop Carrier Systems

[2] TA-NWT-000909 Generic Requirements and Objectives for Fiber in the Loop Systems

Appendix A - TR57 Single Party Service Parameters

4.1 Single-Party Message Telephone Service (MTS)
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4.1.2 Signaling & Supervision
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