The Interworking of Voiceband Fax and Data Modems with Network Echo Cancellers

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1. Introduction

The Public Switched Telephone Network (PSTN) uses both 4-wire circuits and 2-wire circuits to carry full duplex voice circuits. The 2-wire circuits tend to be used in the local loop portion of the network, which is the connection between the end user (home or business) and the telephone central office.

Hybrid circuits are used to convert between 2-wire and 4-wire circuits. Since the hybrid circuits are not perfect, they reflect a portion of the signal received on the 4-wire circuit back to the transmitted signal. This causes an echo to be heard at the far end of the network.

In order to combat this problem, the PSTN employs echo cancellers and echo suppressors. Echo cancellers are designed to remove echo from a signal, while echo suppressors suppress one direction of the full duplex link at a time so that echo will not be heard. Echo suppressors were commonly used for satellite based overseas connections before echo cancellers became available.

The introduction of voiceband fax and data modems brought a new set of requirements to the PSTN. The echo suppressors and cancellers can interfere with the transmission of modem signals. Many modem standards have been adopted over the years and they are not all affected in the same way by echo cancellers and suppressors.

2. A Brief History of Voiceband Modems

The early voiceband modems were designed to be impervious to echo. These modems were split-band modems. In general, the answering modem would transmit in the upper portion of the frequency band, and the originating modem would transmit in the lower frequency band. That way, the echo of a modem's signal would not appear in its transmit band, not its receive band. The echo would therefore be blocked by the receiver's bandpass filter.

The Bell standard modems such as Bell 103 (300 bps) and Bell 212 (1200 bps) were unable to work in the presence of echo suppressors. Although these modems were split-band modems, they were still full duplex modems. In other words, both modems transmitted at the same time. Echo suppressors are designed to suppress one direction of transmission.

In order to circumvent this problem, the ITU standardized on a modem answer tone that could be used to disable echo suppressors in the network. The ITU V.22 bis (2400 bps, split band) modem transmits a 2100 Hz tone for 3 seconds when it first answers. When an ITU G.164 compliant echo suppressor detects this tone, it disables itself.

This 2100 Hz tone is referred to by the ITU as a "tone disabler". This terminology probably lost something in translation. It is a tone that is used to disable the echo suppressor.

As modem technology improved, it became possible to design modems that were no longer split-band. The newer modems could transmit in both directions using the same frequency band. This increased the modulation bandwidth, enabling higher data rates. These newer modems (ITU V.32 bis, for example) include internal self-training echo cancellers. The presence of network echo cancellers interferes with the proper operation of these higher speed modems.

The ITU therefore built in a newer tone disabler into its G.165 (and subsequently G.168) echo canceller recommendations. When a V.32 bis (and other) modems first answers, it transmits a

2100 Hz tone with 180 degree phase reversals every 450 milliseconds for a duration of 4 seconds. This is the G.165/G.168 tone disabler.

When a G.165 or G.168 echo canceller detects this signal, it disables itself. If the older answer tone (G.164, 2100 Hz without phase reversals) is detected, the echo canceller does not disable itself. This is particularly important for fax modems which use the G.164 tone. Fax machines are half duplex in nature. Only one machine transmits at a time. They take turns transmitting. If an echo is present, a fax machine can interpret the tail end of the echo of its transmission with the start of a new transmit burst from the other end. The network echo canceller removes such echoes and is therefore intended to be enabled for fax transmissions.

As more and more modem standards were adopted, it became difficult for an originating modem to determine what standard was supported by the answering modem. The ITU adopted a new standard, V.8, which is used, among other things, to simplify modem classification. The V.8 standard has yet another variation of the answer tone. It uses the G.165 tone (2100 Hz with phase reversals), but it amplitude modulates it with a low frequency tone. This answer tone therefore is intended to disable network echo cancellers, but it is possible to distinguish this tone from the G.165 answer tone which does not include the amplitude modulation.

3. Summary

The G.164 answer tone consists of a 2100 Hz signal lasting 3 seconds. It is used to disable network echo suppressors.

The G.165/G.168 answer tone consists of a 2100 Hz tone with periodic phase reversals for a duration of 4 seconds. This tone is used to disable network echo cancellers.

The V.8 answer tone is a G.165/G.168 answer tone that is amplitude modulated by a low frequency tone. It is used to disable network echo cancellers and to assist in identifying the far end modem.