# DIRECT PICKUP INTERFERENCE IN A WORLD WITHOUT CONVERTERS

by

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*Abstract*

*Cable companies introduced converters into the homes of cable subscribers in the mid-sixties to eliminate direct pickup interference (DPU). As cable services expanded, converters were redesigned to increase the tuning range of television receivers from the original twelve channels. Since the converter was effectively a gateway for receiving programs that emanated from the headend into the consumer's television set, the redesign also provided control over conditional access.*

*New conditional access control systems such as interdiction, broadband descrambling, or Multiport, when used with cable-ready TV receivers, do not require the use of converters. At the same time, however, there appeared to be an indication that this combination of new conditional access control systems with an apparent proliferation of cable-ready television sets would substantially eliminate the protection against DPU provided by the converter.*

*This paper reports on a study commissioned by CableLabs to determine the extent of the DPU problem which may result in a cable television environment operating in the spectrum of 50 mHz to 550 mHz, without converters.*

*The study predicts that if the present trend of replacing converters with a different type of conditional access control, and the present design of cable-ready television receivers continues, 26.5% of urban/suburban television households will experience DPU problems from VHF television stations if they are served by cable television. The combined transmissions of VHF and UHF television stations in the 50 mHz to 550 mHz band would cause 47.8% of urban/suburban televisions households to experience DPU problems if they are served by cable television.*

## INTRODUCTION

Direct pickup interference (DPU) is a particular form of ingress wherein off-air broadcast signals interfere with signals delivered on the same channel via the cable system. DPU was recognized as a serious potential problem from the earliest days of cable television. The problem was temporarily solved by the introduction of CATV converters. Those new converters, built with shielded input circuits impervious to DPU, replaced the TV set tuner.

Responding to the growth of CATV channel capacity and the expanding subscriber base, the consumer electronics industry developed "cable-ready" TV receivers and VCR units. These receivers and VCR's were capable of tuning to all the channels in the CATV spectrum without the need for a cable channel converter. This family of cable-ready equipment included new viewing, recording, and remote control features.

In homes where converters were required to descramble programs, the consumer could not use the desirable features built into the new cable-ready receiver. Where it was possible to remove a converter installed to serve a cable-ready set, the consumer's cable-ready TV receiver often began to experience DPU.

Equipment manufacturers, multiple system operators and CableLabs have been searching for conditional access control methods that would allow the consumer to enjoy all the special features of the new cable-ready TV equipment. Traps, interdiction, Multiport decoders, and broadband point-of-entry control devices are being tried, but the DPU problem persists.

## DPU DEFINED

Direct Pickup Interference (DPU) is the name given to a class of co-channel interference caused by the mixing of (1) the desired signal, which enters the TV receiver through the input terminals, and (2) the undesired signal, which enters the TV receiver through one or more other paths. Classically, co-channel interference is caused by the TV receiver antenna's reception of two different signals sharing the same channel.

There are two distinct types of co-channel interference: **coherent** signal interference and **non-coherent** signal interference.

**Coherent** co-channel interference is caused by the mixing of two signals transmitted on the same carrier frequency, but not necessarily in time-phase with one another. Examples of over-the-air coherent interference are (a) reception of two different TV stations operating on the same channel and locked in frequency, and (b) reception of two or more signals from the same TV station by a direct path from the transmitting antenna and from one or more longer reflected signal paths.

Coherent DPU may occur in a TV receiver connected to cable when TV station signals are carried "on-channel" in an area of high ambient signal strength. Coherent interference manifests itself as one or more ghost images superimposed on the primary or desired image. The per-ceptibility of these ghost images is determined by the strength of the interfering signal with respect to the desired signal and the phase difference between the signals. The strength of the interfering signal determines the contrast of the ghost. The phase difference determines the offset or placement of the image on the screen and affects the visibility of the ghost.

**Non-coherent** co-channel interference is caused by the mixing of two signals transmitted within the same TV channel but at a different carrier frequency or frequencies. Over-the-air non-coherent interference is caused by (a) reception of two different TV stations operating on the same channel, (b) reception of a harmonic from a two-way radio system or an FM station while the TV receiver is tuned to a TV channel, or (c) reception of spurious signals from electrical machinery while the TV receiver is tuned to a TV channel.

Cable non-coherent interference occurs when the TV receiver is tuned to a cable channel whose frequency spectrum is used locally for over-the-air TV broadcasting, two-way business radio operations, or FM broadcasting.

Non-coherent interference generally manifests itself as alternating light and dark bands which may move through the picture. The contrast between these bands and the desired picture is determined by the relative strength of the desired and undesired carriers. Non-coherent interference can also cause other presentations, depending on the type of signal.

During the early years of television broadcasting, 1945 through 1965, extensive research was conducted into co-channel interfer-ence to determine the minimum required spacing to avoid interference between stations utilizing the same channel. Studies conducted by Mertz indicated that coherent interference becomes imperceptible at desired-to-undesired signal ratios of 40 dB. The work of Mertz was followed by Lessman who found perceptibility present at desired-to-undesired signal ratios of 36 dB. Other studies and published reports from JTAC, TASO, CTAC, RCA, and CBS generally agree that desired-to-undesired signal ratios of 35 to 40 dB are required to avoid coherent co-channel inter-ference. To avoid non-coherent co-channel interference the desired-to-undesired signal ratios must be even higher than for coherent interference. In 1949, the Joint Technical Advisory Committee (JTAC) to the FCC reported that for non-coherent interference without "offset carriers", interference is noted when the undesired signal is less than 55 dB below the desired signal. This 55 dB ratio was confirmed by studies conducted by members of the Cable Technical Advisory Committee (CTAC) to the FCC, concerned with cable broadcasting, over twenty (20) years ago. More recent literature generally accepts desired-to-undesired signal ratios of 55 to 60 dB in order to avoid non-coherent co-channel interference.

## THE STUDY

In January 1992, CableLabs asked Stern Telecommunications Corporation (STC) to undertake a study to answer the following question:

**What is the extent of the DPU problem that may result from the use of cable-ready TV equipment in a 550 mHz environment without converters?**

STC undertook to answer this question by a combination of research -- both a literature search and laboratory experimentation. The literature search included reports of investigations into the cause and effects of co-channel interference, as well as documentation and analysis of DPU complaints from cable subscribers.

For laboratory experimentation, measurements were made of the shielding efficiency versus frequency of a representative sample of recently manufactured cable-ready TV receivers.

In addition, a computer model, designed for this project, was developed. The model analyzed variables of field intensity contours from multiple sources and related the resultant product with census data to develop household counts subject to a specific field intensity value.

## METHODOLOGY

Evaluating the potential extent of DPU interference required first that a geographic area for measuring these phenomena be defined. STC chose to use the television industry's designated market areas (ADIs), generally agreed to as the basis for reporting and evaluating program viewership. Using ADIs gave us access to the on-line or published databases that report on television household distribution. For our sample we chose the top ten television ADI's, representing approximately 30% of US households. Furthermore, these ADI's represent a number of different population distributions in relationship to the site of broadcast transmitters. This varied population distribution made possible the extrapolation of results for urban and suburban America.

Having defined the geographic area for assessing the extent of DPU, we established the criteria for determining the number of households that might be subject to this interference. Whether or not a given household experiences perceptible DPU, and the severity of this interference, is determined by many factors.

1. The ambient field strength of the interfering signal with respect to the desired signal;
2. The TV receiver's ability to shield against the undesired signal;
3. The location of the TV set in the dwelling;
4. The channel or channels being viewed;
5. The number of TV sets in a dwelling.

The model considering all of these variables would not only have been unwieldy, but would have required information on the distribution and DPU immunity of all television equipment -- data that is not available. The model chosen defined a DPU "trigger point" of a field strength of 100 mV/meter, making the assumption that all households located in an area with this predicted field strength or greater were assumed to have the potential for DPU. Consideration of variations in the shielding efficiency of different television receivers was not included in the model.

The 100 mV/meter (100 dBu) level was selected after two research efforts were completed. The first was an examination of field service records from several cable television system operators. Their records show a dramatic change in the number of complaints related to DPU as the ambient field strength approaches 100 mV/meter. The second effort was the review of results obtained from our laboratory tests of shielding efficiency on several current model television receivers. The tests showed that each set exhibited visible DPU interference on at least one channel when immersed in a 100 mV/meter

Note

The chart that follows, "DPU Potential in Top 10 ADIs" shows the results of the computer model analysis. The variations in the percentage columns reflect the siting of and the number of television transmitting stations in each ADI.

For example, Detroit has no UHF-TV transmitting service operating at frequencies below 550 MHz, and ADIs 8, 9, and 10 have significant UHF-TV operation below 550 MHz.

## SUMMARY OF FINDINGS

- Over twenty years ago engineers in CATV and the consumer electronics industry stressed that DPU posed a serious threat to the growth of the cable TV industry.
- Records compiled by a number of CATV system operators showed DPU complaints from subscribers located in VHF television station ambient fields of 80 to 100 dBu.
- Twenty-five years of laboratory testing shows that DPU problems may occur with desired-to-undesired coherent signal ratios of 35 to 40 dB and with desired-to-undesired non-coherent signal ratios of 55 to 60 dB.
- STC's laboratory tests on a sample quantity of TV receivers in current production demonstrated that all receivers may suffer from DPU from 100 dBu ambient non-coherent sources on all channels.
- Laboratory tests by STC on a sample quantity of TV receivers in current production demonstrated that all receivers may suffer DPU from 100 dBu ambient coherent sources on at least one channel.
- STC's computer modeling predicts that 26.5% of all urban/suburban house holds in the USA, or 18,438,000 households, may be subject to DPU from VHF television stations.
- The same computer modeling predicts that 47.8% of all urban/suburban house holds in the USA, or 35,671,000 households, may be subject to DPU from the combined transmissions of VHF and UHF television stations oper ating at 550 mHz or below.

## DPU POTENTIAL IN TOP 10 ADIs
## (50 to 550 MHZ)

| Area | Total Number of TV Households | Percentage Subject to 100 dBu or Higher | |
|---|---|---|---|
| | | VHF | UHF+VHF |
| New York | 6,944,400 | 26.0% | 38.2% |
| Los Angeles | 4,807,700 | 15.1% | 45.4% |
| Chicago | 2,860,600 | 28.5% | 51.8% |
| Philadelphia | 2,642,500 | 32.4% | 58.2% |
| San Francisco | 2,164,100 | 37.3% | 42.3% |
| Boston | 2,045,100 | 14.0% | 40.1% |
| Detroit | 1,712,600 | 42.1% | 42.1% |
| Dallas/Ft.Worth | 1,676,700 | 15.9% | 66.6% |
| Washington | 1,638,900 | 38.5% | 62.6% |
| Houston | 1,447,800 | 33.5% | 62.7% |
| TOTAL | 27,940,400 | | |

| | VHF | UHF+VHF |
|---|---|---|
| **Average percentage:** | **28.3%** | **51.0%** |
| **Average Percentage Weighted by Number of TV Households:** | **26.5%** | **47.8%** |