

NEW APPROACHES TO CATV SYSTEM POWERING

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ABSTRACT

As CATV grows and becomes more complex, the need to provide additional power for extensions, upgrades and special equipment can pose some interesting challenges, especially if the system wishes to avoid new powering locations or system power sector redesign.

INTRODUCTION

This paper will explore two options: (1) increasing the efficiency of 60 Hz power transmissions, and (2) adding high frequency AC power to the existing 60 Hz power. An overview of research and development is included to demonstrate the feasibility of equipping new amplifiers or off-premise devices with current controllers, and of retrofitting existing AC power supplies with high frequency add-on power sources.

REQUIREMENTS FOR TELACTION PROJECT

In early 1988, Telaction authorized Stern Telecommunications Corporation (STC) to begin a feasibility study to determine if existing CATV powering schemes would accommodate an auxiliary power delivery system to provide power for Telaction Frame Store Units (FSU's). Telaction FSU's are installed at trunk amplifier - bridge stations. The number of FSU's is determined by the number of subscribers connected to the distribution legs of the system as well as the activity of these subscribers. Each FSU requires approximately 50 watts of power and is designed to operate from the standard 60 VAC - 60 Hz CATV system power supplies.

Most CATV systems do not have the excess power capacity available to provide for operation of the FSU's. Any excess capacity that does exist is usually reserved for future expansion of the CATV system. Most system powering designs limit power supply loading to approximately 75% of the output

capacity. Some systems are already using the full capacity of the existing power supplies.

Several FSU powering options have been investigated. These include:

- 1) Direct 120 volt AC powering.
- 2) 60 volt power using new power supplies at each FSU location or by use of an overlashed powering cable.
- 3) Redesign and rebuild of the CATV power system to provide for existing system needs as well as FSU power.
- 4) Alternative power supply designs to provide power in unconventional ways.

120 volt powering requires special construction to comply with local electrical codes. Each installation must be scheduled with the local utility company, and permits must be obtained from the local electrical inspector. This option is considered costly and would require long lead times for implementation.

60 volt powering also requires long lead times for utility installations, plus the additional cost of new AC power supplies and/or the cost of overlashing a new cable to the existing plant. This option may not be acceptable to some of the CATV system operators.

Redesigning and rebuilding the powering system to enhance power availability for the existing plant and to provide for the FSU power requirements would involve considerable expense, long lead times, and would cause disruption to the operation of the CATV system during the rebuild.

Alternate powering systems would require devising an auxiliary power source that could provide useable power to the FSU's using the existing cable as a conductor but with minimal impact upon the existing plant.

APPROACH TO THE POWERING PROBLEM

Modern CATV systems are powered by applying a 60 volt, 60 cycle AC potential between the coaxial cable center conductor and the sheath. The power source is typically a square-wave output ferroresonant transformer, which in reality produces a waveform similar to a trapezoid.

The power supply can be either a pole mounted unit or a pedestal mount for underground systems. Most systems use a standby-type power supply which contains batteries for back-up operation in case of utility power failure. The local utility company provides electrical service to the power supply enclosure. Typically a service disconnect as well as a watt-hour meter is installed at the power supply location.

Most CATV AC power supplies provide up to 16 amps at 60 volts (960 VA). The 60 volt AC power is rectified, filtered, and regulated to provide the one or more DC voltage(s) required to operate the active components within the amplifier. Recent amplifier power supply designs utilize high frequency switchmode technology to provide high conversion efficiency as well as small size and tight voltage regulation. In some cases an isolation transformer will be located at the input of the power supply to step-down the 60 volts AC to a lower voltage prior to rectification. See Fig. 1. These transformers typically have taps for adjusting for different AC input voltages to accommodate IR drop. All amplifier power supplies utilize electrolytic capacitors to filter the rectified (pulsating) DC and to provide energy storage for the switchmode regulator circuit. These capacitors do not draw energy from the AC input for the full duration of the 60 Hz AC cycle. Due to the nature of "peak

charging" of the capacitors, the current input pulse occurs 10 to 20 degrees after the "zero voltage cross," and during the ramp-up of the cycle to the maximum peak voltage. The current pulse usually lasts for less than 60% of the half cycle (100 - 120 degrees). See Fig. 2.

It was imperative to characterize existing CATV systems to understand operation of the power supplies interacting with the coax. cable, the parasitic inductive, capacitive, and resistive elements, and the amplifier loads. Current and voltage waveforms were measured on a number of CATV systems and on laboratory test cascades. The systems tested include: B-Q Cable (Warner) in Queens; Post Newsweek in Deerfield and Highland Park; Alpha Technologies Research and Development Labs in Bellingham, WA, and Burnaby, B.C.; the test laboratory at Cablesare in London; and the burn-in room system at Telaction, Schaumburg.

The measurements show that there is a "time window" during which there is very little or no current flowing to the load. It is the existence of this window that provides the opportunity to deliver power to the FSU's without disrupting the existing power supplies or amplifiers.

Fig. 2 shows the typical 60 volt - 60 Hz voltage waveform as well as the current pulse waveform drawn by several amplifiers in a cascade. It is evident that there is a portion of the half cycle where very little energy is delivered to the amplifiers. Fig. 3 is the product of the voltage and the current (Volts x Amps = VA). This is a waveform of the actual power delivered to the load during the half cycle. Fig. 4 defines the "time window" available where additional power could be inserted and delivered via the coax. cable to the FSU's.

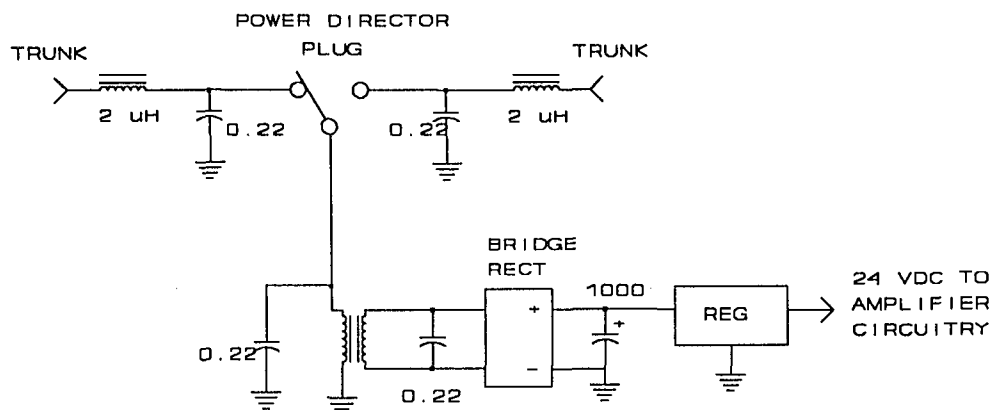


FIG. 1
TYPICAL INTERNAL AC/DC
POWER PATH, TRUNK AMP

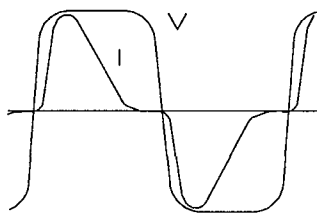


FIG. 2

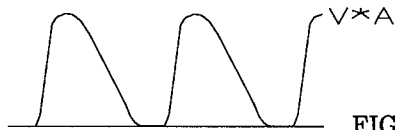
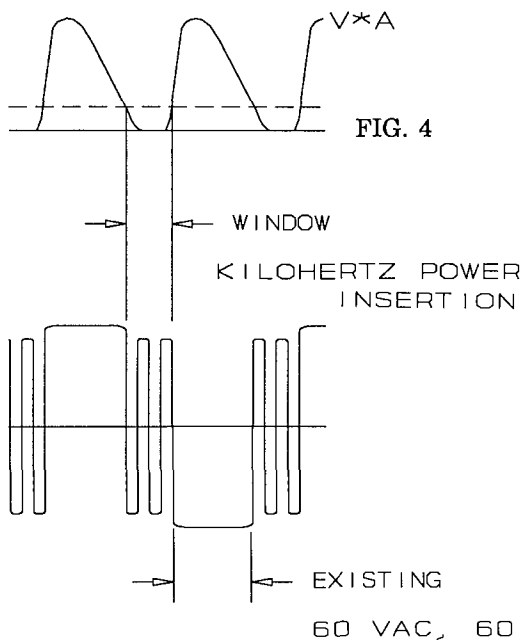


FIG. 3



It is important to note that the "window" will vary in duration depending upon the actual voltage at each amplifier location and the current draw, i.e. the AC voltage at the end of a powering sector is usually lower due to the draw of current through the resistance of the coax. cable and the resultant voltage drop. An amplifier at this location will draw current for a longer period of the cycle in order to supply constant power to its circuitry. The window of minimal power consumption can also be altered due to power factor of a particular location. A load with a capacitive component (such as CATV amplifier power supplies and high frequency bypass capacitors in the amplifier AC power bus) will exhibit a phase shift of the current and voltage. The current waveform will tend to "lead" the voltage by a few degrees (see Fig. 2). The same is true if there is an inductive component in the load. The current waveform will tend to "lag" the voltage waveform by a few degrees. In the majority of the systems tested, the waveforms indicated either a slight "leading" power factor or the voltage and current were in phase (unity power factor).

UNIQUE APPROACHES

Based on the understanding of the CATV current and voltage relationships, two possible approaches to supplemental powering became evident:

- 1) "Shared time control"
- 2) "Kilohertz power"

"Shared time control" of existing 60 volt loads to optimize power draw over the voltage cycle. Theoretically, existing power transfer would be more efficient, thus making extra power available for powering FSU's.

A prototype "shared time controller" (STC) was tested. This approach used solid state switches to intelligently control the AC input to the FSU's. A simple synchronization circuit detected the zero cross of the AC waveform and waited for a preset time delay before allowing the FSU to draw power. Controlling the FSU current draw in relation to the existing CATV current draw provided an improvement in power delivery by spreading the total CATV and FSU current draw over the entire voltage cycle. The major effect was a reduction in IR drop in the cable. This approach also supports the use of existing power supplies (if there is enough excess capacity) or the addition of a supplementary 60 Hz power supply. Although promising for some applications, it was determined that this approach could not provide the extra power required.

"Kilohertz power" inserted during the previously described "window." A high frequency energy burst with an amplitude less than the 60 volt waveform would be coupled onto the coax. cable via an impedance matching network. See Fig. 4. This "Kilohertz power" would be recovered by a special "power receiver" in the front end of the FSU power supply. The FSU would ignore 60 VAC - 60 Hz power and only accept the "Kilohertz power" bursts. This energy would be converted to the appropriate DC voltages required by internal circuitry of the FSU.

IMPLEMENTATION OF THE CHOSEN APPROACH

In mid-1988, Alpha Technologies began a cooperative effort with Stern Telecommunications to research and develop a "Kilohertz Power Unit" (KPU). The preliminary design specifications included an "intelligent" controller to measure the existing 60 Hz voltage and current. This would allow determination of the "window" in which to insert a high frequency power burst with a power amplifier and coupling network. The most efficient frequency of this power burst had to be determined. A "Kilohertz Power Receiver" (KPR) was required to

mount in the FSU. This unit would ignore 60 volt - 60 Hz power and only receive the Kilohertz power. The power would be regulated to provide the appropriate DC voltages for FSU operation.

Other important requirements included:

- 1) Small physical size in order to allow retrofit in existing AC power supply enclosures. This would provide the advantage of deriving input power from the existing AC receptacle, thus eliminating additional utility installations.
- 2) Minimum impact on the existing CATV plant. The KPU must not introduce interference with the existing AC power supplies or with the video signals.
- 3) High reliability.
- 4) Provisions for status monitoring.

Work began at Alpha Technologies to construct and test a prototype KPU system. The first requirement was to determine the appropriate frequency for the Kilohertz power. A test cascade was constructed with Alpha AC power supplies and Jerrold trunk stations and passives to provide a convenient system simulator for testing. A variable frequency / variable amplitude power amplifier was

constructed to "sweep" the cascade to determine the losses at various frequencies. A simple controller was added to couple the power bursts during an adjustable window time in the 60 Hz voltage cycle. Frequencies from 400 Hz to 25 kHz were tried and the losses through various components in the cascade were recorded (see Fig. 5). At low frequencies (less than 700 Hz), the amplifier power supplies loaded down the Kilohertz power, which was unacceptable. At higher frequencies, the AC bypass capacitors in the passives and in the trunk amplifiers also loaded down the Kilohertz power. It was determined that 1200 Hz was the optimum frequency for power transmission with relatively low losses.

After testing and analysis, it was determined that it would be necessary to actually disconnect the existing 60 Hz AC power supply from the load during the "window" when Kilohertz power was coupled onto the coax. By doing this, the window became much more defined and consistent in width. A rugged diode-switching circuit was designed to accomplish this function. A "fail-safe" relay was included to bypass the existing AC power around the KPU in the event of a malfunction (see Fig. 6). A 400 watt power amplifier stage was designed to provide the Kilohertz power. The amplifier was designed to drive a low impedance load without damage. A current limit circuit was included to protect the amplifier from short circuit faults.

The main control and coordination of the system was provided by the microprocessor control

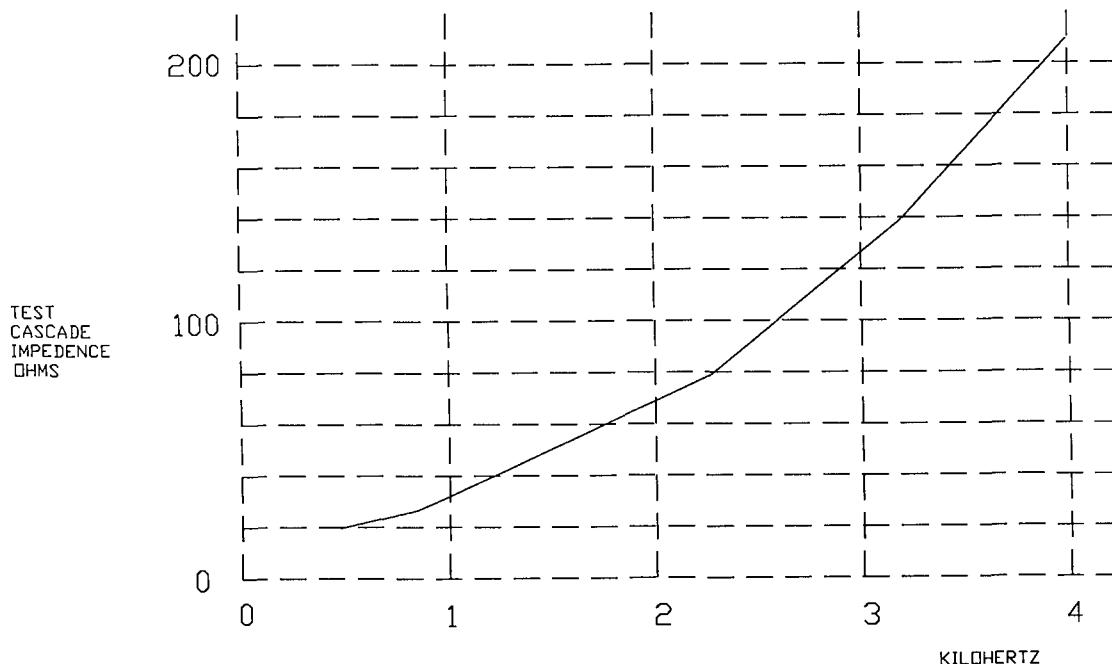


FIG. 5
TEST CASCADE
IMPEDENCE VS. FREQUENCY

unit (MCU). The MCU uses a high speed analog to digital converter to measure currents and voltages in real time. This enables the MCU to determine the 60 Hz AC and Kilohertz power being delivered to the loads in order to adjust the duration of the Kilohertz insertion window. The MCU decided when to drive the diode switches to disconnect 60 Hz power and connect the Kilohertz power to the system. It also determined the duration of the Kilohertz insertion, then re-connected the 60 Hz power for the next half cycle. The MCU continuously adjusted its operation to accommodate voltage or load fluctuations.

The KPR (Kilohertz Power Receiver) was installed in the FSU's and included a coupling circuit to acquire the Kilohertz power and convert it to DC. The KPR was synchronized to the zero cross of the 60 Hz power. It featured an adjustable window duration to enable input of the Kilohertz power (as well as some of the 60 Hz power, if de-

sired). This is advantageous if a particular CATV system has some excess 60 volt capacity.

In lab testing at Alpha, the system was able to provide power to 4 KPR's (50 watts each) in the cascade. No degradation of the cable signals was observed, and no adverse effects on the existing 60 volt - 60 Hz power supplies or amplifiers were noted.

CONCLUSION

It has been demonstrated that there are viable alternatives to standard 60 volt - 60 Hz power for specific applications with limited performance criteria. Assembly of several pre-production Kilohertz power units will be completed by Alpha Technologies and installed for actual system tests. Although experimental in nature, this approach shows promise for implementation by Telaction in systems where other options for powering are not available.

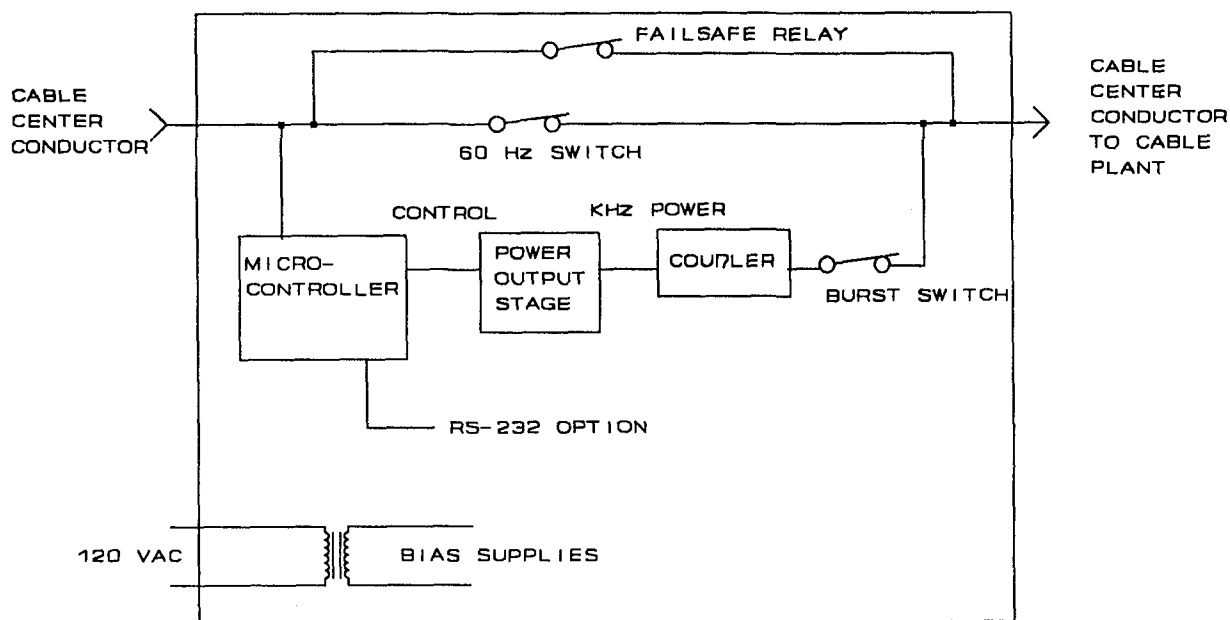


FIG. 6
KPU FUNCTIONAL BLOCK DIAGRAM