CAN NOISE AND INGRESS COEXIST WITH TWO-WAY SERVICES?

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ABSTRACT

As more two-way services are turned on and proliferate on CATV systems, the return path continues to be a limiting factor in the economic viability and reliability of the services.

A practical discussion of the sources and characteristics of noise and ingress in a two-way CATV plant is presented. A number of current practices including bridger switching, filtering, and frequency agility are compared and evaluated.

A technique of using narrowband width transmissions in the return path and other enhancement circuitry at the headend as an alternative to the bridger switching, filtering, and other current methods is described. Test results and comparative data is presented along with a summary of 2 years practical experience using the narrowband techniques.

INTRODUCTION

The dilemma of the cable operators is that they have promised advanced services, but have no cost/benefit justification to do so. Consequently there is no commitment to maintain two-way plant and early experiments are failing, either economically or technically.

We don't know enough about true closed systems in the return direction; in fact, we're just learning about forward "closed systems".

What is presented is a narrowbands technique that lets the CATV operator begin two-way services without having to fight all the traditional problems. Further, the system is compatible with future envisioned services systems by merit of its bandwidth efficiency and may well be just as effective once the return path and its associated problems are understood and solved.

The system presented is formulated around one premise - narrow bandwidth. The baud rate in simply encoded system is roughly:

Baud rate x 2.1 = Bandwidth

For instance 9600 baud will require roughly 25 KHz of bandwidth.

INFORMATION / TIME

is related to

DATA / TIME

is related to

BANDWIDTH

Fig. 1. Relationship between Information, Data Rate, and Bandwidth

To achieve the minimum data rate, each proposed two-way service is analyzed to get to the true information content requirement for a given system. As an observation, I have noticed that the information content is significantly lower than the actual baud rates proposed for use on most systems.

Lets look at some real world examples:

Alarm Systems - the objective is to locate all alarms within 5 seconds. A brute force solution is to poll all customers every 5 seconds for their status.

However, two significant factors are overlooked. The majority of status changes in an alarm system are not alarms; therefore supervision can occur less often - for instance once per minute or (using UL guidelines for alarm operations) once per 90 seconds.

The second factor is that the dispatcher, followed shortly thereafter by the available responsed equipment, i.e. fire trucks and police cars, rapidly becomes the limiting factors. Prioritization is required at the dispatch position to deal with the alarms -

and this prioritization can be established in the system operation by using an interrupt type protocol. This would scan all the accounts slowly (hence in a narrow bandwidth) to supervise or make sure they are on-line, and would be interrupted by alarms at short intervals.

Pay TV Control - the downstream and return (pay-per-view or customer preference) could of course be handled with a rapid, real time data rate. However, in a real world situation, updates can occur slowly, and enabling of special events could be preset on the appropriate terminals, then enabled with a single mass command.

Also, channel authorization decisions can be made within the terminal by comparison to an internal up-dateable ROM.

In the return path, theorists envision overloads could occur in a pay-per-view type event, where within a period of a few minutes, thousands of terminals could request an event. However, again a system of presets that would allow usage for a short period while the system was updated would suffice.

Meter reading - Metering systems generally have 3 requirements - monthly reading, on-line reading (such as when a tenant moves) and demand reading. Demand reading is the most strenuous, although readings per home every 10 to 15 minutes suffices in most instances which can be handled to high capacities with low data rate. Demand reading can be enhanced by only reading the most significant digits which could effectively double the polling rates/hence subscribers served.

Energy management - All proposed systems revolve around customer notification, or system setting in response to factors such as peak demand, or temperature and weather changes. None of the factors requiring control occur instantaneously, nor would a virtually instantaneous (real time) mass command be required. Further, a mass command (such as switching of 10,000 hot water heaters simultaneously) could, in fact, cause significant problems to a utility. Energy management in general can be thought of as a low data-rate type function.

Two-way data systems and Customer Preference Polling - These systems potentially require the highest effective data rates. The downstream requirements are the greatest, with whole pages of data being delivered to each subscriber on the service. Teletext and Video-text systems are already addressing the downstream aspects. Yet the following observations must also be factored:

a. Given the availability of a data system to each home, at any one time, only a small percentage of the population try to use the system. The Bell system has used a factor of 15 to 17% usage for years in planning telephone trunking facilities.

b. A person asking for data is much slower than the data returned. Typically a person will enter a menu select digit or a line of data and receive a page of information back. Rarely can a person deliver data to a system in excess of 110 baud; while, in supplying data back to the subscriber, anything less than 2400 baud "feels" slow.

Much work has already been done in data packeting protocols for networking applications. Systems such as Ethernet, and the Mitre system take advantage of both points "a" and "b" mentioned above to allow efficient packets of data to be sent on a system of much lower baud rate than a cursory glance would suggest.

The author theorizes that other alternatives or adaptations utilizing low baud rate channels and multiple channels could provide efficient solutions.

* * *

The short analysis above was done to bring the reader to a single conclusion: that the actual information content of proposed and envisioned new services on cable is quite low - especially in the return path. Further, if the information content required is low, then the baud rate, and ultimately the bandwidth, is low. This fact can be used to a tremendous advantage by permitting the cable operator to offer advanced service without carrying the overhead in maintenance and associated costs of operating the two-way plant.

A Practical Narrowband Design

The author has designed a narrowband, high-capacity alarm system for cable TV systems that is being used by many cable operators. A detailed analysis is shown to illustrate how the parameters were selected and to show the margins gained over other system approaches.

The system used in this example is the CableBus® Systems Corporation CableAlarm™ system. The design goal was to provide a high-capacity alarm system capable of serving up to 100% of the homes in a cable service area. (Present experience with custom alarms indicates a 5 to 10% penetration; however, significant breakthroughs in price coupled with the increase in crime and decrease in municipal services has the author predicting that we may witness systems with a smoke detector in every home by the mid 1980's.)

The largest block of homes served by a single cable is limited by amplifier spacings to hubs serving 40 to 60 thousand homes. Multiple hubs could utilize the same frequencies to serve different customers. And hubs with exceptions to the maximum proposed capacity could be provided with 2 or more trunk outputs. Therefore, the first premise is that a single trunk area will require a maximum capacity of 40K alarm accounts.

Further dividing, it was felt that a 25KHz bandwidth was the lowest practical value. Factors including the availability of 1F components, frequency stability of the home terminals and cost of obtaining it, and the capability of the resultant data rate (9600 baud) were factored. Two simple modulation options were available: narrow deviation FSK or simple keyed carrier AM. Since narrow deviation FSK has no perceptible C/N advantage over AM, and AM was easy to generate with a minimum number of components, AM was chosen.

Account access times were chosen using UL-611 alarm industry guidelines to arrive at the following:

- Maximum time to check every account for status would not exceed 90 seconds.
- Maximum time between checks for alarms (interrupts) would not exceed 5 seconds (10 seconds required by U.L.) for the first alarm.
- Ability to sort and list multiple alarms would exceed 50 per minute (which would, it should be pointed out, over-run virtually any dispatch center in the U.S.

The limiting factor, therefore, is supervision time (checking to make sure each account is still there). Using a ASCII message format of a header, 4 address characters and 2 command/interrogate characters; a maximum of 77 bits per account would be used. Roughly 11220 accounts could theoretically be covered at 9600 baud using this technique. Allowing for space between transmission, alarms, and other contingencies, a maximum of 5,000 accounts per 25 KHz bandwidth was adopted. To handle 40K accounts, 8 subcarriers of 25 KHz each would be required. The author recommends spacing on 50 KHz intervals, therefore, an entire 100% penetration security operation could be operated in 400 KHz of return bandwidth, with the forward data occupying a similar bandwidth.

Quantifying the Advantages

An analysis of the system advantages over existing schemes is provided. Currently, other manufacturers offer a variety of high baud rate schemes, the narrowest occupying approximately 280 KHz. using an FSK carrier.

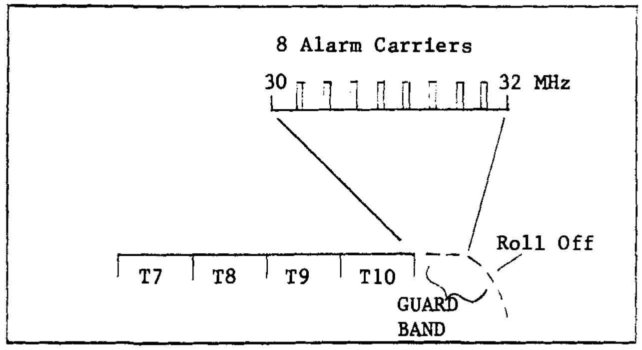

Fig. 2. Typical Return Allocation for 40K Subscriber CATV Alarm System

The CableBus system uses an AM carrier as was described.

The C/N advantage due to bandwidth alone is in the order of a 10 x reduction; approximately 20 dB. A further advantage can be claimed by merit of the simple keyed AM format. A 12 dB C/N is required for reliable performance in a clear (white noise only impaired) noise situation. While it may not be a true advantage in carefully designed equipment, current wideband FSK systems claim to operate only to within an 18 dB C/N.

A third advantage can be obtained by video filtering the data. As shown in the figure, although the bandpass for a given data rate must be 2.1 x the data rate for simple modulation, there are gaps within the bandpass (Figure 3). As shown in the figures, a relatively simple comb filter (Figure 4) can gain an additional 4 to 5 dB of noise reduction.

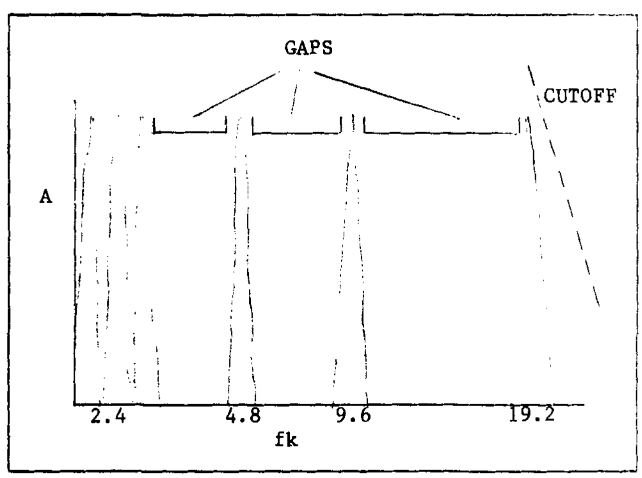

Fig. 3. Fourier Transform Distribution of the Frequency Components in a 9.6 kB Data Transmission

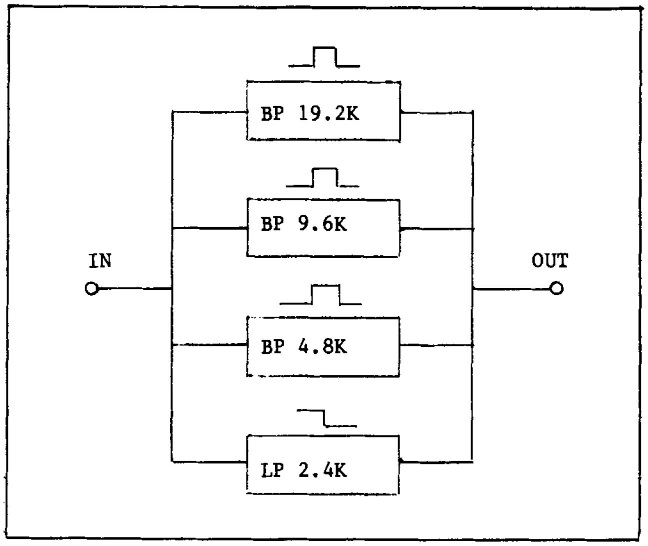

Fig. 4. Comb Filter used to Enhance 9.6 kB Data Reception

A final filtering technique is the "software filter". Random high level system perturbations will always exist on two-way return plants. Lightning strokes and electrical power switching transients are the most violent, although many other sources can "upset" the system. Effective software protection in the form of multiple checks on status and error-correction can enhance a marginal C/N situation. A summary of all these improvements is provided in Figure 5.

Bandwidth reduction to 25KHz	20dB
AM/design improvement	6dB
Video filtering	4-5dB
Software filter	3dB
	33dB

Fig. 5. Summary of Noise Improvements For 25 KHz Alarm System

Alternate Contending Techniques

Other techniques are used to combat return channel ingress and interference buildup. Two of the most popular proposed solutions are bridger switching, and agile frequency control.

Both can provide relief in the areas of operating reliable two-way services, but both add expense and complexity to the system.

Bridger switching is an excellent diagnostics tool for two-way services; however, its use or requirement to make a service functional will ultimately limit the very services we propose to provide. If for instance, it is proposed that the bridger switches be cycled for each security polling cycle (every 5 seconds), we will see about 6 million cycles per year. Other adjacent two-way services must be filtered or time synchronized to the bridger cycles.

Frequency agility, if kept simple, could provide a valuable backup if the primary path is impaired, but in no way should be an excuse for stuck transmitters or as the primary method of handling ingress.

The author submits that cost-effective two-way services must be capable of working independently of each other, and must operate in a "wide open" cable environment (i.e. not sectored or switched).

Equating the Improvement to Dollars and Cents

Up to this point we have been talking about only numbers. The real advantages of a narrowband technique are cost benefits to the operator and the numbers must be translated accordingly. The author feels that the single largest advantage today is gained through a reduction in manpower for trouble calls and maintenance. The two-way plant for a system such as the one described would not be running anywhere close to its maximum potential; therefore, alignment, and ingress problems would be substantially reduced.

The terminal and the central computer equipment benefit from the data rate reduction. In the home terminal, lower baud rates can be very effectively handled with 'bit-crunching' in a single microprocessor, rather than requiring a separate UART or other converter. Further, the home terminal processor can be multi-tasked to handle the other local intelligence required both for a "software filter" and to operate the home alarm system. A single chip home terminal design means lower cost and/or greater performance.

The central computer can also operate using one or more RS-232 ports rather than having to provide a more expensive high speed port.
Another significant advantage is that the narrow carriers can be placed on the cable in places not normally considered by other systems. For instance, most of the CableBus systems so far have operated in the 30 to 32 MHz guard-band. (See Figure 2) While most systems do begin to roll off in this area, the C/N advantage is so great that losses of up to 10dB in the guardband are not a significant factor. Another related advantage is that the narrow carriers can be placed to avoid known

ingress carrier sources. In a marginal or older CATV plant, it is simplest to chose a quiet slot on the cable, a task that is easy if the bandwidth is narrow. (Figure 6)

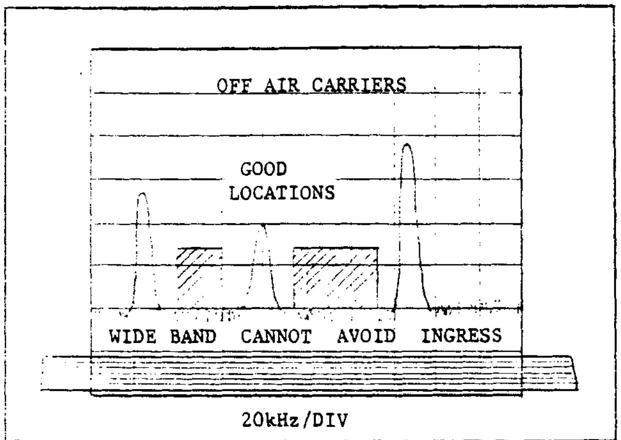

Fig. 6. Choosing a Quiet Return Frequency for a Narrowband Service

A final advantage is that of using a lower return transmitter level from the home. Industry standard is to use +50 up to +60 dBmV for the home terminal return transmitter. The author questions the impact upon factors such as leakage from the cable which is governed by FCC part 15 and part 76.613. Most home drops are marginally effective with downstream signals in the 0 to +10dBmV level range. A return signal of +50dBmV, even of short duration, could be wildly out of spec. on a standard RG-59 drop, especially after the foil deteriorates. Without final supporting data, CableBus has limited its maximum output level to +41 dBmV at the home. A typical worse case flat loss of 47 dB will be encountered between the home and the headend on a well designed two-way plant, resulting in a return level at the headend of -6dBmV. The practical worse case white noise floor (coherent carriers excluded) that we have ever encountered in a two-way plant, across 25 KHz has never been greater than -30dBmV. An additional minor advantage of lower terminal transmit levels is that less filtering is required on the TV leg to the home.

Conclusion

To answer the question posed by this paper - by utilizing narrowband techniques, new services can be accommodated on CATV plants, and need not become a tremendous maintenance and repair burden to the operator. The use of alternate noise reduction techniques such as bridger switching or trunk sectoring should be used only for maintenance or emergency procedures. Frequency agility can provide an enhanced reliability for systems, but should not be the primary method used to make two-way operate.

Narrowbanding, on the other hand, is a method of combating and/or dodging noise and ingress problems. Significant advantages can be gained over wideband systems.

Narrowbanding also forces the user to efficiently utilize the CATV spectrum. To most operators today, bandwidth is not a problem; however, within a few years, after a few successes, the author feels that bandwidth will be at a premium. It is analogous to the pre-1973 gasoline situation. Nobody believed in conservation of gas till they ran out!

Experience gained using the CableBus Alarm System over the past 2 years has proven that less is required of the return path to operate successfully on two-way and marginal plants.

Narrowbanding has significant advantage whether applied as a single carrier or as hundreds of narrow carriers. Someday there may be so many services and revenue sources using two-way that they can easily justify the manpower and equipment necessary to support a very tight high-quality return plant and allow wideband return schemes. Until then, the alternative presented may be the answer.