COMPUTER AIDED DESIGN IN A TAPPED TRUNK ENVIRONMENT

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ABSTRACT

Rural areas are becoming the focus of increased attention as the cable industry searches for new areas of growth. In many cases, urban franchisers are being pressured to serve fringe areas and are looking to manufacturers to make the necessary technology available and affordable. While the high tech solutions to expansion continue, there is another avenue of simplicity and tighter economy emerging in system design known as TAPPED TRUNK, which we will explore further.

This presentation documents our experience in gaining an understanding of rural design problems, and addresses methods in which computers can aid in the design process. Software development is discussed in detail with an emphasis on overcoming the constraints imposed by the desire to create a useful software package which will run effectively on a personal computer.

INTRODUCTION

The increasing diversity of CATV plant presents opportunity as well as liability for the system designer. As he explores the frontier for new sources of revenue, he is challenged by a departure from the familiar demographics of the large urban areas where the population density is fairly homogenious. He is faced with lower densities and increasing costs with less revenus potential. There is usually less technical expertise available to cope with system maintenance, but there is certainly no lack of desire for access to the media.

Tapped trunk designs, which unify the previously segrated functions of trunk and distribution, are frequently the best method of serving these needs. However, there are a few special problems involved in extracting the economy and performance potential. The added design complexity of the tapped trunk cascade, together with the iterative nature of the system design process, strongly implies computer analysis so long as there is a high degree of certainty in the methodology of prediction.

THE TAPPED TRUNK ENVIRONMENT

No doubt everyone is familiar with the view from an airplane window. The countryside bears a resemblence to a microscopic view of cellular material with scattered nodes of activity connected by a network of arteries. The density patterns are irregular. Many of the arteries have smaller nodes randomly distributed along their length. This visualization is helpful in establishing a sensitivity to the lack of generality in the design. Rural systems are a string of special cases.

The Rural Electrification Administration has studied rural demographics carefully in an effort to asses the technical and economic considerations of these marginal applications. The basic design philosophy which they have found to be economically appropriate in delivering acceptable quality signals in these areas is to combine the conventional concepts of trunk and feeder plant. Noise and distortion are distributed equally throughout the system by adopting one transmission level which is typically half way between conservative trunk levels and high powered feeder levels. Subscriber taps are also allowed to exist on the primary signal path.

The system design concept which has evolved from studies of this nature has come to be known as TAPPED TRUNK. The benefits of this approach are, first of all, a substantial reduction in the amount of cable necessary, since backfeed situations are virtually eliminated. While backfeed is often a very useful tactic in dense urban areas, it becomes a burden in cable costs when the distance between subscribers increases. Other savings are realized in the inevitable reduction in amplifiers as well. There is less cable loss to overcome, and the amplifier spacing is increased due to the higher transmission levels. For example, in a conservative tapped trunk redesign of a trunk and feeder system built outside of Orillia, Ontario, we uncovered a saving of 16% in cable material costs. We also discovered a cost saving of over 30% in amplifiers, however this effect seems to be a measure of the economy of distributed simplicity as opposed to concentrated complexity in amplifier design rather than simply a reduction in amplifier numbers. It is true too, that maintenance becomes easier with identical amplifiers set at identical levels. Even the cable can be made uniform in the smaller systems. Uniformity is intrinsically cheaper, and can be especially attractive when the access to skilled technical personnel is scarce.

The TAPPED TRUNK concept is not essentially new. Back in the early days of cable technology, when the notions of hardware methodology were similar to plumbing, there was a nasty device called a PRESSURE TAP. Basically, this was a type F connector which actually penetrated the main coax. A simple resistive attenuator inside the connector tapped off a portion of the signal for each subscriber. However, it ignored the perameters of isolation and return loss so the problems encountered with reflections, not to mention the damage to the cable, were discouraging. In retrospect, it seems likely that the tapped trunk concept was abandoned along with the pressure tap, and the two have remained linked in the minds of many of those who have, by now, ascended to positions of authority in the cable industry. Resistance to the belief that tapped trunk is even worth considering seems to be couched in a blanket distrust of the integrity of subscriber taps in general.

MODERN DIRECTIONAL TAPS

The state-of-the-art multitap is produced in high volume and is marketed much like a commodity. Its function is virtually taken for granted. Performance specifications tend to be used as marketing tools rather than design criteria. Yet, there seems to be a cloud of uncertainty about their presence in the primary signal path. Since we at Lindsay have had experience in designing and manufacturing taps, we have access to the basic information which may help to dispell some of these doubts.

The design process involved in manufacturing a series of taps is a mixture of science and black art. There are seven perameters to optimize simultaneously and, even though most of them have a common link with the characteristic impedance, the outcome is a matter of destiny. The insertion loss is the most significant consideration with respect to its effect in cascade. It is still referred to as FLAT LOSS which is quite reasonable in a 220 Mhz world. But this assumption is no longer valid as bandwidths increase. While there are slight variations in the signature with each tap value, the overall effect is a build-up in level in the mid band followed by a gradually increasing rolloff in the hyper band. Any effort to design out this effect to preserve the simplifying assumption that the insertion loss should still be flat will inevitably have to sacrifice some other perameter. However, it is unlikely that TAPPED TRUNK systems will be loaded beyond 300 MHz anyway. (The basic premise of the design philosophy is economy in marginal applications, and there are escalating headed and maintenance costs as the channel loading increases.) So, within this perspective, the deviation from the flat loss assumption will be easily manageable with simple mop-up techniques. Idiosyncratic variations from tap to tap will tend to randomly cancel, and cable loss between taps will limit the build-up of reflections.

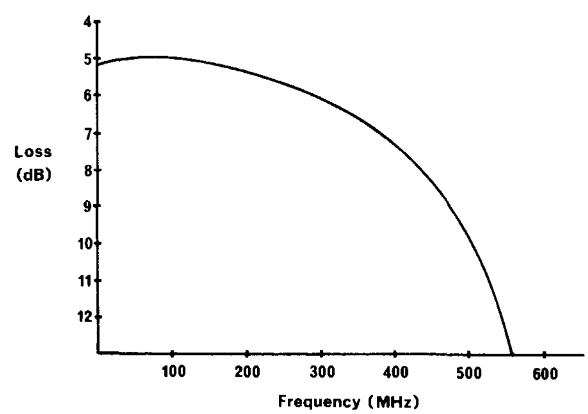

FIG.1

Figure 1. is a wide bandwidth view of a cascade of five multitaps typical of the values found in a tapped trunk cascade. The deviation from ideal flat loss is apparent by drawing a straight line through any two points representing the upper and lower frequencies of a given bandwidth. It is also apparent

that as the bandwidth becomes wider the deviation becomes greater.

Changes in the thermal environment have an impact on everything including taps. The concept of flat loss is further erroded by the findings of a study of insertion loss vs. temperature during a recent multitap design program at Lindsay. It was found that the variation in the insertion loss of a cascade of taps is frequency dependent. Unlike cable, the variation is not a given percentage of the loss. Each tap, regardless of its insertion loss has roughly the same variation which is a function of temperature and frequency only. The effect over wide bandwidths is to accentuate the deviation from the ideal flat loss mentioned earlier. The thermal equation predicting the thermal response of a span of cable containing a given number of taps should be modified to include the equivalent cable contribution due to tap behavior. The contribution appears to be significant enough to be considered in system design calculations especially where open loop thermal compensation methods are being proposed.

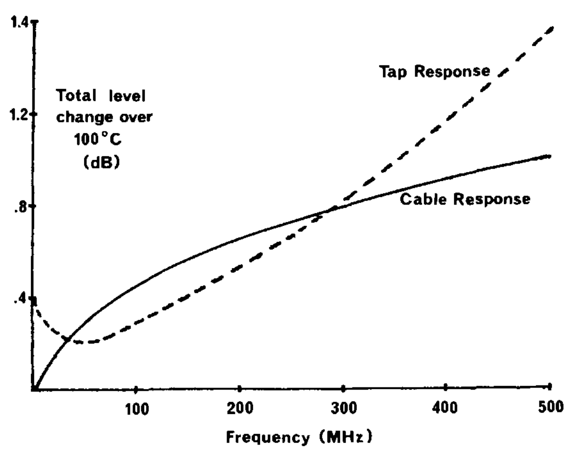

FIG. 2

Figure 2. shows the thermal behaviour of a cascade of five taps compared to the thermal behavior of a length of cable. The length of cable is chosen such that the thermal change over 100 desgrees celsius at 300 Mhz is equal to the thermal change of the taps at 300 Mhz. The length of the cable is actually 4 dB. This means that each tap, regardless of its value, contributes 0.8 dB to the thermal response of the system under these conditions.

Another concern to those uninitiated to the tapped trunk environment seems to be the intrinsic reliability of the tap in the system. There are undoubtedly vast quantities of data available in the maintenance records of cable systems around the world. We examined the maintenance log of Lindsay Cable in Lindsay Ontario to get some idea of the maintenance liability of introducing taps into the main line. Lindsay Cable serves about 5600 subsribers through 64 miles of cable. The evidence we uncovered in the Lindsay Cable log indicated that, over the last five years, 7 of the 1150 taps failed. This represents a 0.12% failure rate per year. Failures in connectors were also of interest since the tapped trunk architecture imposes a greater liability on the main signal line with a greater number of connectors. This accounted for 8 failures out of a total of about 3300 connectors or 0.04% per year. Interviews with service personnel indicated a belief that the reliability of each connection rested heavily on the workmanship involved in the installation. This then seems to be a local variable to be assessed on an individual basis.

REALITY CHECK

The REA has been good enough to provide excellent documentation on the performance of an actual TAPPED TRUNK system showing how well the calculated system perameters correlate with actual measured results. Its studies have identified several of the frontiers of experience with the TAPPED TRUNK concept, and have demonstrated that performance and cost estimates in this domain can be made with a reasonable level of confidence. For example, cascades of 40 amplifiers supporting 150 passives in series are conceivable for bandwidths up to 300 Mhz. The distortions arising from reflections in a system this size are expected to be visually undetectable based on extensive video tests conducted at the tapped trunk system in Edinburg, Virginia. Group delay in a one way system of this size will be on the order of 200 nanoseconds negative on channel 2 and about 120 nanoseconds negative on channel 13.

Unfortunately, the program of rural cable television development at the REA was truncated by a federal policy decision shortly after the Edinburg study so the continuity of development in this field has been somewhat fragmented. Undoubtedly, the frontiers will be pushed back further as greater risks are taken to exploit the potential cost savings of TAPPED TRUNK designs. William O. Grant, who headed the REA development program, estimates savings on the order of 20% over the conventional trunk and feeder approach.

PROSPECTS OF COMPUTER MODELING

When given the opportunity to make several small system design proposals, we were immediatly struck by the diversity of the population density. TAPPED TRUNK design seemed to be appropriate for part of each project, however there were areas of higher density where the technique was clumsy and placed an unnecessary burden on the integrity of the trunk. We felt compelled to develop a computer aided design tool which would be driven not by simplifying assumptions, but by a sensitivity to the demographics, the hardware and the costs.

AN IMPLEMENTATION

The program we designed supports many capibilities meaningful in exploring tapped trunk cable plant. Some of these tasks include:

1) Capture strand and demographic information into an accurate, maintainable DataBase,

2) Allow speculation as to modes of service to that region.

3) Examine this speculation from a number of facets such as costs, RF degradations, temperature, etc.

4) Generate Bills of Material and other documents meaningful to technical and financial professionals.

5) Model sub-optimum device performance to study how this effects cable systems.

The program was authored on an Apple and was written in Basic under the CP/M operating system and MicroSoft Basic. This choice was not optimum but did not function as a constraint.

The eventual bounds of a programs capability are determined by initial premises which later become limitations. In exploring other computer aided methods in use in the cable industry we became aware of approaches which are intrinsically suboptimum. The most common (and painful) tactic we found was a preoccupation with the visual representation of the cable plant. Conspicuous by its absence in the foregoing list of objectives is rendering of the final design as a drawing. A bent to automating the drafting side of the design process is a problem which may have begun as an ill-directed cost control measure. Casual analysis of the costs-to-design a plant may show drafting as a significant, if not outstanding cost. This is true only if the instantainious costs are evaluated. Costs occuring "downstream" in unnecessary cable, line extenders and labour during construction as well as the long term burden of unneccessary actives must be fully comprehended. In order to insure that our software effort would not encounter a limitation before it reached its goals was difficult. We utilized a combination of techniques to maintain generality in the core of the program early in the authoring process. It is sometimes said "Every complex system that works began as a simple system that works", this is certainly true in software development in general and this program in particular.

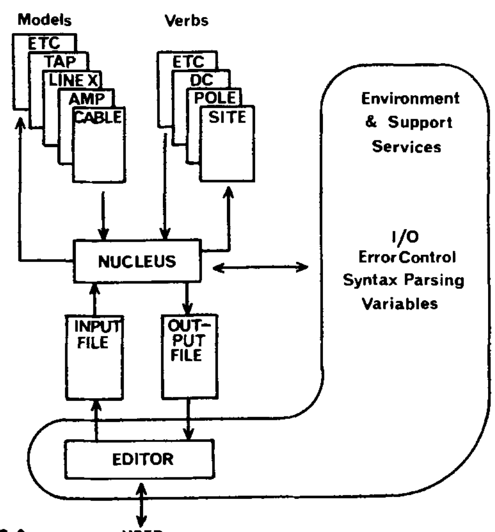

FIG. 3

Figure 3. will help the reader visualize how this program is constructed. The program is composed of a small nucleus of code which refers to a library of models of the devices under study. The emphasis here is on "small" and "devices under study"; we were careful to leave these pieces of the program totally free of non-essential complexity. The support services, such as text control and syntax parsing (turning the program into a custom programming language of sorts) are very large in comparision. This partioning of the program to isolate the model is very important. It allows the researcher to consider a particular model in isolation, change it, and see how this effects the cable design.

Another important black box inside the program is the verb dictionary; in the context of computer languages this precise kind of dictionary is called a lexicon. The function of the lexicon is to specify what must be done upon encountering each word in the directions. What "must be done" is specified as a series of transformations which are specified as models. The "things they are done to" are the elements of the environment, which are any entities that have both names and values. Of course, what knits these black boxes together, is the nucleus. The nucleus is simple, but calls up black boxes of significant complexity. The overriding concern of the nucleus is as simple as its structure; from its perspective the conclusions are byproducts of reading through the directions looking for the special verb called "END".

The content of the lexicon and transformations in the models characterize precisely what the output file will contain. No other portion of the program will effect the environmental values. Thus improvements in input/output, editing or other subsystems will not affect the calculations and/or results.

The first pass of the program had a repetoire of seven verbs. This was barely adequate to perform a tapped trunk design requested for a small site in Hawaii. By the time we were ready to attempt a system of non-trivial size, the lexicon contained more than twenty verbs. Table 1 contains the verbs and how they are evoked in the current implemention. Many of the additions do not direct the cable plant design, but produce condensed reports of one kind or another. Examples of this are the pseudo-family of "REPORT" commands, which show how loss was accumulated,(useful in deciding on the relative merit of AGC vs thermals), and "BUMPS" from non flat loss devices. Procedurally it appears that the commands and/or verbs do fall into catagories, such as "REPORTS", "RESETS", "ASSIGNMENTS", "DEVICES", etc. This adds a linguistic uniformity useful as a memory aid for the researcher but has no impact on the machines implementation. All VERBS point to the LEXICON which directs the MODELS to change the ENVIRONMENT. There are no exceptions and the VERBS do not directly modify or reference each other in any way.

CABLE? = N	: ft. of special cable
CABLE5 = N	: ft. of .500 cable
CABLE7 = N	: ft. of .750 cable
TAP	: calc. tap value
DC? = N	: specify coupler
AMP = N	: specify amplifier
NOTE = T	: remark
GAINON	: normal amp placement
GAINOFF	: no amp placement
FL = N	: specify flat loss
REPORTLOSS	: loss summation
REPORTBUMPS	: bumps summation
RESETLOSS	: loss reference pt.
RESETBUMPS	: bumps reference pt.
A.T = N	: assignment
SETCABLE? = N	: specify cable

TABLE 1. N is a Number - T is Text

INADEQUACIES AND EXTENSIONS

A significant flaw in our first implementation was its inability to elegantly handle how branches of the system interrelate. This was the primary drawback of authoring this program in a non-recursive language such as Basic. The only approach to elegantly handle this important aspect is to model the system as a large linked list which should be memory resident. This implies an implementation in PASCAL, LISP, C, SNOBOL, or even ADA. It implies a fairly large memory as well.

It is probably possible to do such wholistic analysis on the most powerful of personal computers with the addition of lots of extra memory. Another inadequacy of our implementation, also stemming from the language, was how slowly the most complete version ran. Waiting for end to end analysis for the Orillia plant was an ordeal. However the exhaustive nature of the analysis generates a pleasant certainty that the design is valid.

As is always the case with technology, our effort supplied us with a few answers and generated a multitude of questions; most importantly, what would the general shape be for an optimum program? We have pondered this thought and would like to present the reader with some further directions. In some ways it is similar to what we have written but is substantially more open-ended. Figure 4 may be helpful in visualizing these principle points:

1) The central nucleus should be highly interactive. Primarily this means clarity and speed are of the highest priority.

2) The source files should be amenable by software entities just as if these changes were done by the researcher/ designer. The concept of In and Out should be softened to meld both into one entity with two "flavors". When decisions on what to do are made, the entity which made them should "initial" the entry. The concept here is that input files transform into conclusions in a stepwise fashion.

3) The environment variables should be more contained and multiple values for a given variable should be allowed to exist depending on context. An example of how to utilize this function is that a branch, when explored would seem a self-supporting system independant of the whole. Also, variations of the entire design could exist for comparative purposes.

4) Entities called advisors could inspect in real time any value or event occuring. These entities could be activated or deactivated with ease. Expansion of the programs power would be done by adding advisors. Some might be large. Examples of potential advisors specialties are represented by their names; Tap-placer, Amp-placer, Drop-placer, Constructor, Maintainer, De-bumper, Reliability-watcher, Reverse-watcher, etc.

5) Considering all the variations of reports which may be required is a mind numbing task. What all "pure" reports have in common is that they are passive. That is, they look at but do not change the design. An advisor could be charged with interfacing with external spread-sheet programs. An example of an appropriate use for such a function would be to move bills of materials and labour estimates directly from the program into accounting tuned spreadsheets such as LOTUS 1-2-3. This would allow economic planning vs time estimates to transpire without reprocessing this information. Also summaries of all different systems could be merged into regional type reports for comparative analysis and/or presentation. Using intermediary languages such as DBase 11 for this would allow merging with addresses, pay TV records, outage history make ready directives and a mass of other knowledge useful in other aspects of the cable operation.

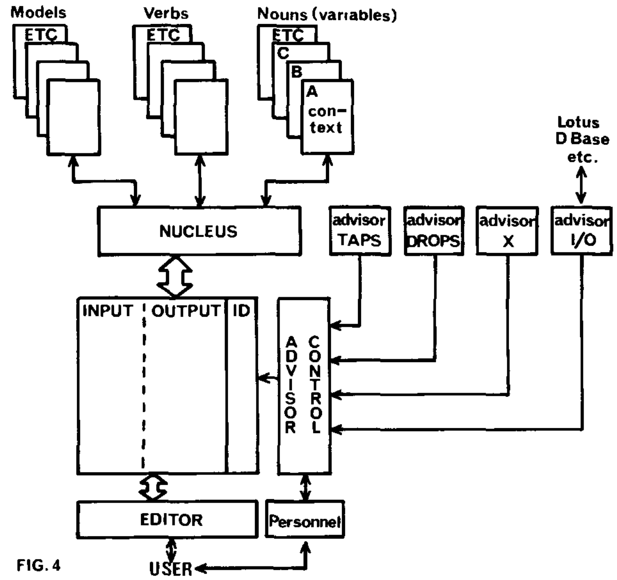

FIG. 4

6) An intrinsic method of marking boundaries into the source file should exist. In text for example, paragraphs, sentences and punctuations put words into context. The analogues in a cable system are street names and regional demarcations such as "North Ward". These should be elegantly supported.

There is no doubt that the above agenda is extensive. It is fortunate that writing the initial portions, such as the nucleus, is not significantly constrained by future inclusion of more complex functions. Any effort to write code of this sort is a major project and the architecture of the program should be documented and understood in significant detail before any work begins.

The existence of a truly superb cable design program for general use would benefit the cable operators to a significant degree. It would be of particular value in tapped trunk, where the interconnectivity of the plant is a particular opportunity for clever methods and careful clear logic to yield savings. How likely is such a program to exist in the near future? This is a difficult question that we cannot answer. However, there are some encouraging trends. First there is an increasing awareness that designs in circulation can and should be improved; this is clear from our external communication with our customers as well as recent articles about suboptimum designs. Second the general trend of literacy is benefiting the cable industry. A recent program which may be available commercially has been written based on a linked list model. It is written in Pascal. It is fast and clear. Hopefully those responsible for design in the cable industry can encourage more programs of this calibre to be authored and made available. Those interested in this particular effort should speak with Mr. Frank Himsl of CableNet in Oakville, Ontario.

CONCLUSIONS

Both Tapped Trunk and extended accuracy of computer modeling in cable environments are at an embryonic level of development. This leaves the system operator/designer in a difficult position; in order to achieve savings some exposure to risk must be tolerated. We had hoped to define where and when Tapped Trunk was appropriate and be able to state this with relative certainty.

We believe our effort yielded results between certain success and total failure. On one hand we can state with certainty that the reliability of taps and connectors has reached a satisfactory level to consider tapped trunk systems and that effects of temperature and signature in concert generate tolerable distortions of the passbands at frequencies up to 300 Mhz. The commonly held belief that the normal distribution of tap values have signatures which do not generate summed massive distortions is borne to be true using computer, manual, and experimental analysis. We can also state that in the isolated cases of two particular cities Tapped Trunk resulted in a 20% saving in material costs alone.

The existence of a successful system built by the REA proves a system with 18 amplifiers and 74 passives in line can work. Extrapolating the REA experience and combining that with our studies it would not be difficult to support the claim that a system of twice that size is viable. No intrinsic barrier to construction of the 400 tap system (Orillia) seems apparent, especially considering the slight branchedness imparted there to be conservative. The actual length of this tapped trunk cascade was only 17 amplifiers deep. The REA projected the upper limit of tapped trunk technology to be about 40 amplifiers with between 100 and 200 passives.

It is our hope that the contours between pure Tapped Trunk, moderation of Trunk and Feeder with Tapped Trunk and classical design will become clearer as systems in the safe regions of design philosophy are constructed. Experimental knowledge of this type can then be used to tune the computer model(s), which, in turn decrease the likelyhood of experimental systems becoming liabilities.

We are indeed fortunate have an opportunity to work with an informed and well managed system operator and may soon embark on such a multi-faceted, multi-site project. It is encouraging to be part of an exploration linking the efforts of the design, manufacturing, operations and finance phases of the cable industry into a cooperative unit. Perhaps the experiment in corporate communication is as meaningful to the cable industry as the technological and economic advances under study!

ACKNOWLEDGEMENTS

Special thanks to Barry Harper and Lynn Taylor of Lindsay Cable for their assistance in providing data relative to their system.

Thanks also to Don Sterling and Ken Lynes of Lindsay Specialty Products Limited for their advice and cooperation in making this study possible.

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