HIGH FREQUENCY/HIGH DENSITY DESIGN CRITERIA

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ABSTRACT

United Cable Television won the franchise to build the system in Baltimore, Maryland. This plant will have extremely high density in some sections of the city. In addition, the plant was bid and will be built at 550 MHz. These factors combine to present difficult and unique design challenges.

This paper will address the approach used by United's Engineering Department, in conjunction with Jerrold Electronics, to solve these problems. A detailed set of requirements will be presented and the techniques used to meet these requirements will be given. In addition, some of the more unusual aspects of the design criteria will be discussed.

INTRODUCTION

The Baltimore franchise was one of the last of the major urban areas to be bid by CATV operators. City officials there were familiar with the recent history of extravagant franchising proposals followed by operator failure to follow through completely on the promises made. The request for proposals issued by Baltimore specified that the bidders present a realistic and financially viable plan which would represent the plant as it would actually be built.

This requirement necessitated a good deal of engineering research on which to base the bid. This research was undertaken by United's Engineering Department along with the Franchise Department and utilized the services of several outside consultants. Combined with the information provided by the City in it's RFP, the research revealed some very interesting facts which would have to be considered in both the proposal and the actual build. These included items which we had not encountered before or seen only rarely. For instance, a large portion of plant in the center of the system was termed the 'street crossing area'. This referred to the fact that no aerial cable of any kind was permitted to cross the streets from one block to the next. Naturally this necessitated the use of risers and underground plant to maintain continuity. The additional footage, not to mention the extra costs, had to be considered in the design.

Another item of particular concern was the concentration of row homes in this same general geographic area. Row homes in Baltimore represent a significant portion of the total homes passed so they are an important part of the system. However, at least in this particular city, they tend to be clustered only in certain areas. This leads to small geographic areas which contain a very large number of homes and which are right next to areas with a more normal urban density. Methods for locating and identifying the row home areas, as well as how to properly include them in the design, became a topic of prime interest.

Along this same line we found that Baltimore does not have as high a percentage of apartment houses or condominiums (MDU's) as most of the other urban systems we have built. Those that do exist tend to be very large and many are multiple story buildings as opposed to only two or three stories. Again, this leads into a very high number of residences contained within a relatively small area. Methods for designing and building vertical plant have been refined by the Industry over the years, but this was the first time we had tried this type of plant with 550 MHz technology.

Additional items which were uncovered by the research included an open wire fire alarm circuit, built aerially in some areas of the City, which could affect the routing of large portions of plant. Since the City was desirous of minimum street damage they hoped that underground plant could be built using existing conduit. This approach, while it had some cost benefit, would limit routing flexibility, but had to at least be considered. All in all, we were faced with designing and constructing a major new system with some very unusual features.

SYSTEM DEMOGRAPHICS

The City of Baltimore, as franchised, includes some 302,680 homes and has been described as the City of Neighborhoods. While suffering from of the same troubles experienced by many large cities, Baltimore has a fairly strong economy and many innovative social programs. The weather is mild, as a rule, and should have no impact on the cable design.

The City is shaped roughly like the state of Nevada and fronts on the Patapsco River and Chesapeake Bay. It is divided approximately in half by the Jones Falls

Expressway which provides a natural design boundary. Existing utility poles are placed in streets or alleys, resulting in few backyard easements. Street composition varies but some roads consist of several layers of cobblestone, asphalt and thick (up to 12") concrete. Some streets contain buried trolley tracks.

Baltimore can receive eight local off-air signals plus four from Washington D.C. Hilly terrain causes pockets of poor off-air reception. The residents are active television viewers and have a very high percentage of VCR penetration. There is no history of a previous pay TV sevice in the city, such as MDS, so receptivity to cable services is expected to be good. Due to the density of dwelling units and lack of open areas there are few home TVRO antennas. There is some SMATV activity in the area and most of the surrounding County is served by Cable. The city has virtually no room for outward expansion so future growth will probably consist of high density MDU's.

SYSTEM LAYOUT-GENERAL

Due to the general size and shape of the city, and taking the economics of the build into consideration, a decision was made during the franchise process to serve the system from two headend/hub locations. Each hub would feed about one-half of the system. Hub boundaries were defined by the city limits and the Jones Fall Expessway.

The main downtown area, referred to as the Core Area, consists mainly of businesses with a few residences scattered throughout. City governmnent offices are generally located in this area. For this reason subscriber plant will be extended only to those areas with dwelling units. The balance of the Core Area is to be fed with a high-split Institutional Network.

After testing off-air reception and analyzing potential terrestrial interference levels, a site in the East hub was selected for the main headend location. Also considered during the site selection process was the need for a fairly well centralized location within the hub boundary so that trunk cascades could be held to a minimum. Prior to final equipment selection it was felt that maximum trunk cascade would have to be kept within the 20 to 24 amplifier range. A similarly located site for the hub was tentatively identified in the West half of the city. The main headend was designed to be the primary reception facility. It would feed all signals to the hub facility for distibution in that hub area. High levels of microwave interference and poor off-air reception limited the practicality of placing more than one reception facility within the franchise area. The main headend and hub are to be interconnected via a 2-way link. Single mode fiber was eventually selected for this purpose over FM coax or microwave due to its relatively low cost and excellent technical parameters.

Like any large city, Baltimore has areas which are not as wholesome as others. Discussions with the other utilities convinced us that it would be beneficial to exercise caution in the placement of line electronics. To this end, two separate design methods were proposed. The first called for line electronics to be located wherever they actually fell in the design. The second method called for electronics to be placed only on street poles rather than down inside an alley or backyard easement. The second method would have to utilize high gain power-doubling or quadra-powered amplifiers so as not to shorten the overall effective length of the feeder lines. Higher plant and associated powering costs had to be included in considering this approach. The actual design will be a combination of both approaches, rather than exclusively one ot the other, to provide the most efficient system possible for the physical circumstances in each area.

SYSTEM LAYOUT-AERIAL

Initial on-site inspection of the Baltimore area indicated that the vast majority of the plant would be aerial. In fact, about 85% of the plant will be built above ground. As previously noted, most of the existing utility plant is built on poles located on streets or in alleys.

What starts out as a fairly straightforward aerial cable plant is quickly complicated by a number of factors. The first of these, and a major item in the overall design, is a lack of continuity. Many of the alleys are 'L' or 'T' shaped. Feeds into these alleys must come from a lateral street. The lateral runs must be placed at least every other street, and sometimes at every street, in order to pick up all the alleys. The end result is a design which is not as efficient as one with straight alleys.

A second complicating factor is the lack of aerial crossings where the alleys are straight. As previously noted, in one particular part of the city there is a complete restriction against aerial cables connecting the alleys over the street. At the last pole in each alley the cable, if it needs to continue across the street, must be placed in a riser and transverse the road underground. On the other side it is brought up in another riser and continues aerially. This process adds a lot of cable footage to each run for the risers. Each alley will contain only three or four poles. The end poles are anchored, so they must be set in from the street fifteen to twenty feet. Since few of these poles are set on the street there are limited numbers of lateral routes available. Again, design efficiency suffers from a lack of flexibility due to the physical configuration of the existing utility system.

The third complicating factor is the age, condition and size of the existing utility poles and plant. These items directly affect the design and must be included in the overall planning considerations for the system layout. The existing aerial utility plant in Baltimore has been in place for many years. The poles are relatively short and in the kind of shape one would expect for the age of these installations. The designer must keep these factors in mind since there is not a lot of room available on the poles for Cable TV equipment. Rearrangements on this plant are costly and time consuming so great care must be exercised, where possible, in the placement of multiple devices at any one location.

All of these factors occur in the area of the city with the highest percentage of row homes. This means that plant in this area will be passing 600 to 800 homes or more per mile. With a system wide average of

48 poles per mile, each pole location will be feeding 12.5 to 16.6 passings. Some isolated cases exist where 50 or more telephone drops are required at an individual pole. Similar numbers of Cable drops can be anticipated unless techniques besides dedicated taps are used.

SYSTEM LAYOUT-UNDERGROUND

The underground portion of the Baltimore plant is a much smaller part of the overall build but no less complicated than the aerial plant. The City, from the outset of the project, has been concerned about damage to the streets resulting from underground construction. For this reason they originally requested that the winning bidder consider using existing conduit within the franchise area. Attempts were made to determine the exact location and condition of any such conduit systems. Indications were that the City and the Power and Telephone companies all had unused conduit in place. The City's conduit was determined to be unusable for various reasons. The Power company did not have sufficient conduit available and the use of what was there was eliminated by grounding and isolation strictures required by the City and the Phone company. The Telephone company had conduit available but placed so many conditions on installation procedures that this was not a viable alternative. Any of the existing conduit systems, if usable, would have placed severe restrictions on the ability to route the plant efficiently.

The City's concern over street damage arose from the composition of the streets themselves and the methods used to do underground construction up to that time. Many of the streets consist of several layers of various materials including cobblestone, asphalt and concrete. Some streets also contain buried trolley tracks. As information is developed regarding the exact location of the streets with heavy substrata this data will be supplied to the designer so that these roads can be avoided wherever possible. The actual construction will utilize a rocksaw to cut 4" wide slits rather than the 2' foot wide trenches which had always been done before. The City's acceptance of this construction method has freed the designer to route the system as needed for the most efficient design.

EQUIPMENT SELECTION

Cable

The initial decision to build the Baltimore plant at 550 MHz narrowed the equipment considerations to the latest available gear. Cable selection was based on the need for very low attenuation due, to the high design frequency, and the requirement that any cable used be extremely easy to handle because of the physical difficulties expected to be encountered during construction. Other factors taken into account for cable selection included availability and cost. Considerable attention was paid to the cascade lengths which would result given the attenuation of various brands and sizes of cable. Working from scaled maps and using various routing schemes and spacings, the cables were compared to see which would yield the lowest total amplifier usage. The cable which was finally selected combined a low attenuation with good handling characteristics and which was available in sufficient quantities in the time frames needed.

Drop Cable

Drop cable was analyzed in much the same manner as the plant cable. A drop budget was devised which detailed the signal requirements for a typical installation. Each drop had an average length of 150' and had to provide a specified signal level to the converter. Each installation also included the loss for a 2-way splitter. This method of drop budget planning was also used to determine the optimum tap output levels and tilt for feeder design. Drop budget considerations included overall feeder line configuration in the analysis since different tap outputs, as required by the various drop cable attenuations, determined overall line extender requirements and usage levels.

In addition to these considerations, the shielding effectiveness of the different cables was carefully analyzed. This was considered to be an especially important factor in a major urban market such as Baltimore. Naturally, the cost and availability of the cables (and the connectors as well) also entered into the selection decision. The cable type finally chosen was a tri-shield construction RG-6 which used a commonly available connector.

Active Devices

The selection of the system amplifiers was perhaps the most difficult aspect of the entire design criteria. The first step in this area was to decide on an overall design approach. For various reasons, a more or less standard tree and branch approach was selected over switched-star or other configurations. Once this decision was made, several amplifier manufacturers were contacted to obtain detailed specifications of their gear.

As in the case of the cable, a thorough analysis was done on paper of the various brands of equipment. The analysis was done in several stages , the first being to find amplifiers with sufficient gain to make the spacings assumed during the cable selection process.

The second stage consisted of drawing up a list of minimum operating specifications for the system. These included carrier to noise, composite triple beat, cross-modulation, single second order, composite second order and peak to valley response for several different cascades. All of the amplifiers were subjected to a mathematical analysis of various combinations of types (ie. standard, feed-forward, power-doubling, etc), with varying amounts of gain and operating levels to determine performance.

The third step was the preliminary selection of the amplifier supplier. This was followed by physical testing of the amplifiers in environmental chambers to determine actual as opposed to theoretical performance. The results of these tests led to the final refinement of operating levels and system specifications. Included in the final spec callout, in addition to the items noted above, were hum modulation, thermal control limits and powering details.

Coincidental to the development of forward system operating specifications, the return system was also specified. The same steps were used in the analysis and the same specification categories detailed. An operating spec for the Institutional network was also devised based on the subscriber system equipment and cable vendors. In all instances, the derivation of system operating specifications was based on worst case conditions.

Passives

The selection of system passives, including taps, was based primarily on the determination of the amplifier vendor. Taps had already been analyzed in some detail in the drop budgets. The main criteria for passives was insertion loss at the high frequencies and the relative flatness of attenuation over the passband. Again, lab tests were performed on the passives to confirm published specs. The vendor supplying the system actives was also picked to supply the passives.

Power Supplies and Powering

Power plays a much larger role in expanded bandwidth systems than it ever has before. In order to carry a high number of channels with acceptable distortions an operator must use one of the newer amplifier technologies. Feed-forward, power-doubling and dual power-doubling (quadra-power) amplifiers provide the performance edge needed but all of these devices use high amounts of power compared to standard IC technology. In addition, most current franchises call for the inclusion of standby power capacity. Even without this requirement, most operators will at least consider using standby units to protect potential Pay Per View revenue.

In order to determine powering requirements, sample designs were done for several areas, of various densities, using the cable and amplifiers selected for the system. The test designs showed that, at best, a power supply would be required for each three miles of plant. In the very dense areas, and depending on feeder routing as determined by local physical requirements, a power supply per mile may not be uncommon.

A high output power supply is needed for this type of system, so consideration in this category was limited to those supplies capable of 14 or 15 amperes of power. Due to the pole clutter of existing aerial utiliy plant the physical size of the supply also had some bearing on the final decision. The unit which was selected had a fifteen amp rating and held three batteries in the lower portion of the cabinet. This cabinet design was picked over an upper battery design to minimize potential damage to the power supply electronics by leaky batteries.

In powering a system, United will usually load a power supply to 80% of its rated output. This approach is used because it is felt that the supply is most efficient when loaded in this range and also because it allows a little cushion should the future addition of a line extender or two be needed. Powering and power supply placement are both critical items in this particular design for a number of reasons. First, overall costs, both initial capital and ongoing operating expenses, can be significantly reduced by efficient powering of the system. Second, system passives, especially amplifier chassis, are not capable of passing high amperage so extreme care must be used in selecting power supply locations within the plant. The total load of a fifteen amp supply must be nearly evenly split between the two outputs of the power inserter so that high amperage on the line does not damage passive devices. Power supply placement in Baltimore can be complicated by pole limitations. Consequently, the designer must be provided with exremely accurate strand map data to minimize the cases of power supply relocation due to utility limitations.

STRAND MAPPING CONSIDERATIONS

In a design of the size and complexity of Baltimore, the importance of strand mapping cannot be overemphasized. If the success of the overall design hinged on any one factor it would be this one. It has been previously noted that there are many unusual situations and difficulties facing the design of this plant, from extremely high densities to severe routing limitations to prohibitively expensive underground construction areas. The street crossing area requires very accurate pole placement and footage information to be designed.

The strand mapping specification was designed to take into account all of the special problems of the Baltimore design. All footages had to be wheeled where possible or obtained by optical tape measure. Pole heights, where risers were known to be required, were to be indicated on the maps. Accuracy for all measurements had to be within 2%.

All streets, street names and alleys were required to be shown in their entirety. Street widths, as drafted, were to represent the actual right of way. All bodies of water, parks, cemeteries or any other physical features which could hinder routing were to be indicated. Railroads, highways and existing or potential crossings for both were to be shown.

All homes were designated by address with lot lines indicated. Row homes were to be identified and actual house counts placed near the feeder pole. Businesses, churches, schools and government buildings were all to be shown on the maps as well. The drafting specifications for all items were called out in great detail so that the final maps would be consistent and as readable as circumstances allowed. Accuracy in the drafting process, overlaps and border matching for example, was emphasized in the strand mapping spec. Because of the density and clutter, and because the greatest degree of accuracy possible was desired, a scale of 1"=50' was designated, even though this would mean a very large number of maps. Key maps were specified for a 1"=500' scale.

Routing information was to be provided on blue lines of the strand maps. All possible routes, aerial and underground, were to be indicated to allow the greatest degree of flexibility to the designer.

Additionally, certain pole information, such as existing transformers or heavy drop clutter, was to be shown so that redesign could be minimized. The strand mapping effort was begun well in advance of the design so that a solid base of information could be established.

THE DESIGN CRITERIA

Because of the amount of information required to do the Baltimore design correctly and due to the numerous special considerations involved it was decided that a single document was necessary to provide a comprehensive reference for the designer. It was hoped that this criteria would be thorough enough to give the answers to any question which might arise. Using this resource the designer should not encounter time consuming delays when an unusual situation comes up. Further, the depth of the strand mapping information should minimize field verifications which would also delay the design.

Design delay could not be tolerated in this project. Makeready engineering was to be based on design so that only contacted poles needed to be engineered and rearranged. The smooth flow of makeready depends on the accuracy and consistency of the design. The business plan and projected revenue flows are dependent on the scheduled completion of construction and design becomes the pivot on which all of this turns.

The criteria had to incorporate a section which dealt with MDU's and row homes. Initially, row homes were to be treated as individual dwelling units and tapped accordingly but this soon proved to be impractical in some areas. In the high density sections of Baltimore, dedicated tapping would have required upwards of 48 tap ports on each of a high percentage of the poles. The row home design method was changed to treat them similarly to apartment building, which is in essence what they were. Based on the strand map information, each row home was to fed with a single 'hot drop' which would supply enough signal to a splitter box to meet the minimum level requirements for the number of units involved. Maximum level on any one drop was limited to 24 dBmV to help minimize future leakage problems on the high level drops. MDU's were handled in a similar manner. A chart was devised which called out the tap and splitter configurations required for any given number of units. Depending on size, MDU's were fed with either high level drops, feeder line extensions or trunk extensions. With all of this information available, the designer should be able to move through the dense population areas and MDU's with an absolute minimum of delay.

The design criteria also called for specific treatment of the underground design. The designer was directed to add specified amounts of footage to the design to account for the numerous risers in the street crossing area. Additionally, vault, manhole or pedestal locations were detailed as to cable looping requirements so that this extra footage could also be added to the design. Wherever such information was available the strand maps were to indicate which streets contained heavy subsurface materials so that these streets could be avoided if possible. Again, the idea behind this requirement was to minimize design and subsequent construction delays due to uncuttable streets.

The aerial portion of the criteria dealt specifically with the two design approaches. In areas where the second approach was to be used, as designated by the construction manager, all actives were to be located so as to be accessable from a bucket truck. Specific items included in this section, to allow for the second approach, included backfeed limits, the use of and levels for high gain bridgers and line extenders, the use of trunk sized cables in feeder lines to make reaches and power supply placement.

The entire design criteria document, when completed, consisted of some 35 pages divided into 3 sections plus a 16 page Bill of Materials which detailed the allowable equipment for each design approach.

The first section of the criteria dealt with general information and was prepared in the format of a summary of operating levels, performance specifications, cable types and attenuations and some powering data. This section also contained a question and answer portion which supplied the designer with specific answers to certain situations which could arise.

The second section was a detailed listing of all operating levels. These were given for the input and output of each type of amplifier in both the forward and reverse directions. Feedermaker levels, tilts, tap levels and feeder line equalizer specifications were given in this section. Also detailed are the amp equalizer specs. Equalizer values are called out for each type of amplifier and a footage window is provided for each trunk equalizer value. Similarly, a table giving total passive losses for each value of line extender equalizer is given. Through losses for taps and other passives is detailed for both forward and reverse design.

Section two also provides detailed powering assumptions for each station configuration. Cable attenuations are called out for forward and return frequencies. All attenuations used in the criteria are maximum values rather than nominal values. Trunk cable attenuations are increased by a factor of 5% to allow for future aging of the plant. The use of trunk sized cables in approach two feeder design is covered in detail in this section and appropriate losses, without the 5% aging factor added, are given.

The second section then provides the MDU chart for reference. Thermal equalizer usage and relevant technical data is detailed. The second section is completed by inclusion of the published specs for all passive devices.

The third section of the criteria begins with a narrative system description. This details exactly what the system is and the overall configuration to be used. Amplifier types are called out and specified for location within the cascade or design approach. System performance specifications are given for the forward and reverse of both subscriber and institiutional networks. Finally, performance testing and recording requirements are called out for the system. Procedures for the review and approval of strand and design maps are given. A problem resolution procedure, specifying contacts and lines of authority, is the final step in the criteria.

The appendix contains two 8 page BOM's which provide the designer with an exact list of eqipment which is to be used in both design approaches. Pricing is given so that accurate BOM's can be drawn from finished design.

SUMMARY

Faced with a complex and technically advanced system in the city of Baltimore, a design specification which provides the designer with as much information as possible is an absolute necessity. The design criteria which developed as a result and described in this paper meets that requirement. The Baltimore system can be designed in a timely and consistent manner using the methods specified in the criteria. Accurate design of this system will result in a smoother and more cost efficient construction effort. The ultimate result will be a cable system which will function correctly and provide the highest quality signals possible for the life of the plant.

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