Upgrade of 450/550 MHz Cable Systems to 600 MHz Using a Phase Area Approach

Robb Balsdon
Vice President, Engineering Services
Rogers Engineering

ABSTRACT

This paper reviews the issues that Rogers considered when it decided to adopt a 600 MHz two-way upgrade strategy for its cable systems that were a combination of 450 MHz and 550 MHz plant (450/550 MHz). The costs of upgrading existing 450 MHz and 550 MHz amplifiers to 600 MHz are summarized. The main advantages and disadvantages of implementing a 600 MHz upgrade are discussed. A cost comparison of upgrading 450/550 MHz plant to 550 MHz, 600 MHz and 750 MHz fiber to the feeder (FTTF) is presented. Lastly, the phase area approach that Rogers is using to manage the 600 MHz upgrade of its plant and deploy new services on the upgraded plant is discussed.

INTRODUCTION

There were five main objectives that contributed to the Rogers' decision in 1994 to utilize a 600 MHz upgrade:

- the Rogers cable systems must support the delivery of 77 analog channels and DVC services with additional spectrum above the last analog channel (550 MHz). .
- where ever possible, capital should be deferred based on a present value (PV) of capital costs including risk factors.
- any upgrade must maximize the reuse of existing assets where possible, in order to reduce total upgrade costs.
- any upgrade must not preclude the addition of fiber nodes to reduce serving areas to 500 homes passed in the future.
- the end of line (EOL) must be of acceptable quality (better than -55dB , -51 dB CTB, 47 dB CNR).

The plans of the Rogers marketing group included a total of 77 channels of: basic service channels, premium tier channels, pay TV channels and expanded PPV channels (20 channels) in 1995/96. The marketing objective was to not remove analog channels below 550 MHz to allow DVC services to be launched. Both analog PPV and DVC services("Digital Tier") would be offered coincidentally. Also, additional spectrum above 550 MHz was required for expanding other non-video services such as PC access (cable modem) services and other future data and voice services.

Similar to most cable operators, Rogers implemented a plant upgrade rather than a full rebuild because of the high cost of placing new cable in system rebuilds. Rogers investigated several plant upgrade alternatives for the upgrade of various Rogers cable systems. There was a wide variation in the existing bandwidth and plant quality across the Rogers owned cable systems.

The upgrade alternatives that were investigated are:

1) 550 MHz upgrade:

- upgrading the 450 MHz sections of plant to a minimum of 550 MHz.
- reducing all trunk cascades to a maximum of 10 amplifiers (plus 3 line extenders) using optical hubs with sufficient fibers installed to allow future segmentation to 500 home nodes.

2) 600 MHz upgrade:

- upgrading all plant to a minimum of 600 MHz, premised on reusing existing amplifiers were possible and purchasing 750 MHz distribution actives and passives to replace units that could not meet 600 MHz as a minimum.
- reducing all trunk cascades to a maximum of 10 amplifiers (plus 3 line extenders) using optical hubs with sufficient fibers installed to allow future segmentation to 500 home nodes.

3) 750 MHz fiber to the feeder upgrade:

- reducing amplifier cascades to 5 actives by installing optical nodes.
- installing 750 MHz actives and passives.

600 MHz Equipment Upgrade

The existing feedforward trunk amplifiers and line extenders resulting from 550 MHz upgrades in the Rogers systems in the early 1990's were analyzed to determine if the bandwidth of the amplifiers could be cost effectively extended to 600 MHz. The performance of the amplifiers were tested with analog channel loading to 550 MHz and DVC loading (8-10 dB below from video) from 550 MHz to 600 MHz. Only certain models and vintages of amplifiers were selected to be upgraded to 600 MHz, with approximately 50% of the 450 MHz equipment and 100% of the 550 MHz equipment being upgradeable. The resulting upgraded equipment met the 600 MHz specifications with DVC loading above 550 MHz. Additional spectrum above 600 MHz is available, however there is a gradual frequency roll-off after 600 MHz where the flatness specification cannot be consistently met. This spectrum is capable of carry more robust modulation formats such as 16 QAM and QPSK. The 600 MHz upgrade makes use of the excess gain available in the amplifier hybrid ICs that is typically reduced by interstage attenuation adjustments by the manufacturer. The 600 MHz amplifiers can be dropped into plant currently spaced at 550 MHz. In most cases a high percentage of the passives and multitaps used in the 550 MHz plant can maintain specification at 600 MHz. All 450 equipment was respaced to 600/750 MHz spacing. The cost savings of upgrading existing amplifiers over purchasing new is shown in Table 1.

Cost Saving Of Amplifier Upgrade To 600 MHz
Table 1

Amplifier BW (Type)	Saving Over New 600 MHz Trunk Amp	Saving Over New 750 MHz Line Extender
450 MHz	44%	57%
550 MHz	44%	80%

Note: Includes salvage of existing amplifier when purchasing new amplifier.

Since additional trunk amplifiers are required when respacing trunk from 450 MHz to 550/600 MHz, new 600 MHz trunk amplifiers were purchased to augment the upgraded 600 MHz trunk amplifiers. New 750 MHz line extenders were purchased since only about 70 % of the line extender requirements could be filled with upgraded 600 MHz units. These new 750 MHz line extenders were concentrated (installed) in specific systems (areas) to make any future upgrade to 750 MHz more cost effective in these locations.

Advantages Of An Upgrade To 600 MHz

The main advantage of implementing a 600 MHz upgrade are:

- minimum of 50 MHz of DVC spectrum can be cost effectively added for less than a 10% premium, typically less than $6 U.S. per home passed.
- 600 MHz can be used to offer 77 analog channels plus 72 digital services at 8:1 digital to analog channel (6 MHz) ratio.
- the cable operator can defer or eliminate the high capital cost required to install all the fiber/nodes required for 750 MHz FTTF (especially if a high percentage of the fiber cable installation is buried).
- if necessary, further fiber and nodes need only be installed into areas where additional capacity for new services are demanded.

If the requirement for 750 MHz capacity is uncertain and an upgrade to 600 MHz is adequate based on current analysis then a risk factor must be added to the company's current cost of capital. The cost of capital combined with the risk factor now can be used to compare upgrade alternatives. Table 2, compares the capital for a 750 MHz FTTF upgrade with a 600 MHz upgrade and adds the capital related to a later decision to expand the bandwidth of the system to 750 MHz when additional capacity is needed. The expenditures shown use a 10% cost of capital and the uncertainly about the requirement for 750 MHz was factored into the comparison by using a 10% risk premium. Depending on the risk factor used and the planned expenditure rate (to achieve the desired upgrade completion), it can be economical to upgrade to the capacity that meets expected requirements, but may be interim depending on changes in plans to offer new services and changes in available technologies, such as DVC.

Comparison Of Capital Expenditure Rate For Upgrades
Table 2

Upgrade Alternative	Disc. Rate	Capital Expenditure by Year (millions of $)						Total Capital	PV
		1994	1995	1996	1997	1998	1999		
450 MHz to		7.4	14.8	14.8	0.0	0.0	0.0	$36.9	--
600 MHz	10%	7.4	13.4	12.2	0.0	0.0	0.0	--	$33.0
Total: 450-600 MHz								**$36.9**	**$33.0**
600 MHz to	0.0	0.0	0.0	0.0	2.0	8.0	11.8	$21.8	--
750 MHz	20%	0.0	0.0	0.0	1.5	5.5	7.3	--	$14.3
Total: 600-750 MHz								**$21.8**	**$14.3**
Total: 450-600-750 MHz Upgrade in Two Steps								**$58.7**	**$47.3**
Upgrade Alternative	**Disc. Rate**	**Capital Expenditure by Year (millions of $)**						**Total Capital**	**PV**
		1994	**1995**	**1996**	**1997**	**1998**	**1999**		
450 MHz to		11.0	16.5	16.5	11.0	0.0	0.0	$54.9	--
750 MHz	10%	11.0	15.0	13.6	8.2	0.0	0.0	--	$47.8
Total: Direct Upgrade 450-750 MHz								**$54.9**	**$47.8**

Disadvantages of 600 MHz Upgrade

The main disadvantages of the 600 MHz upgrade are:

- the spectrum available for usage for 256 QAM type signals is limited to 600 MHz.
- non-standard 600 MHz amplifiers are used in the upgrade.
  the cable operator must manage the upgrade of the equipment
- through the OEM vendor or third party contractor.
- the maximum cascade of 10 trunk amplifiers and 3 line extenders provides an availability of approximately 99.95% (259 min. of downtime, at a 4 hr MTTR) in contrast to an availability of 99.98% (128 min. of downtime, at a 4 hr MTTR) for 750 MHz FTTF with 5 actives in cascade

Cost Comparison of Alternative Upgrade Strategies

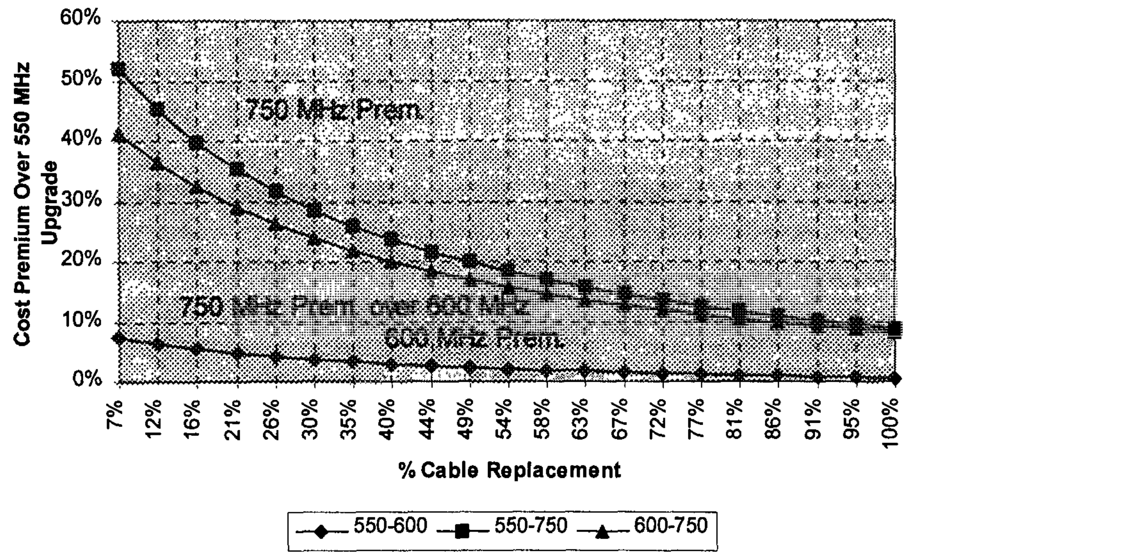
The upgrade costing used for this paper was completed based on a number of Rogers systems that were investigated in 1994 to determine the viability of the 600 MHz upgrade program. The costing was adjusted to provide a sensitivity analysis on the premium to upgrade a typical Rogers system to 550 MHz or 600 MHz or 750 MHz FTTF from an existing 450/550 MHz system. The analysis compares the premium in construction cost for a 600 MHz and a 750 MHz FTTF upgrade to the cost to upgrade a current 450/550 MHz system to full 550 MHz with fiber backbone to fiber hubs that could feed 500 home passed optical nodes in the future. The construction cost of these three alternatives was investigated relative to a number of variables, the main ones discussed here are:

- the percentage of coaxial cable that needs to be replaced as part of the upgrade alternative.
- the percentage of the existing amplifiers that can be upgraded to 600 MHz.
- the percentage of the existing plant (typically a 450/550 MHz mix) that is 550 MHz.

Figure 1, shows that the cost premium required to upgrade 450/550 MHz plant to 600 MHz is less than 10% and this premium falls as the amount of cable that needs to be replaced increases and the total cost of each type of upgrade increases as shown in Figure 2. As more of the existing cable must be replaced in an upgrade and as this percentage of cable increases beyond approximately 50%, the cable operator is effectively in a rebuild mode. While the premium to upgrade the existing 450/550 MHz plant to 600 MHz falls from 7% at 12% cable replacement, to 2% at 50 % cable replacement, the cost to upgrade to 750 MHz FTTF falls below a 20% premium beyond a 50% cable replacement threshold. Figure 1, illustrates why most cable operators consider a 750 MHz FTTF rebuild when most of the cable must be replaced.

As a result of the shorter amplifier cascades at 750 MHz FTTF and the higher gain 750 MHz amplifiers the physical spacing at 600 MHz and 750 MHz can be designed to be the same. Subsequently, a significant amount of feeder plant that was upgraded to 600 MHz is usable at 750 MHz, after exchanging 600 MHz line extenders for 750 MHz units.

Cable Placement vs Cost Premium Over 550 MHz Upgrade
FIGURE 1



Cable Placement vs Total Upgrade Costs
FIGURE 2

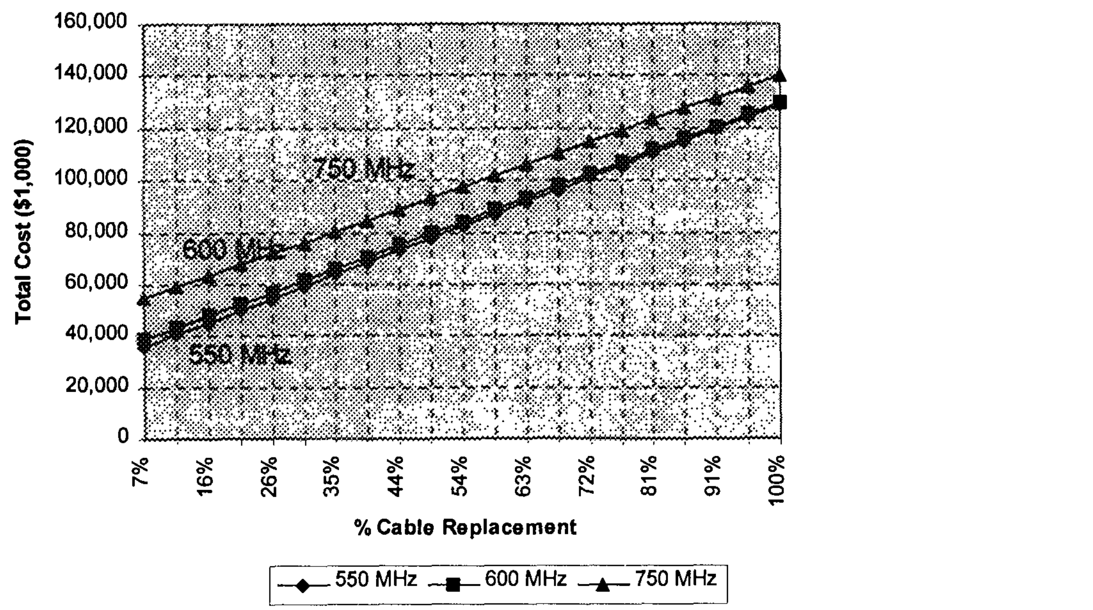
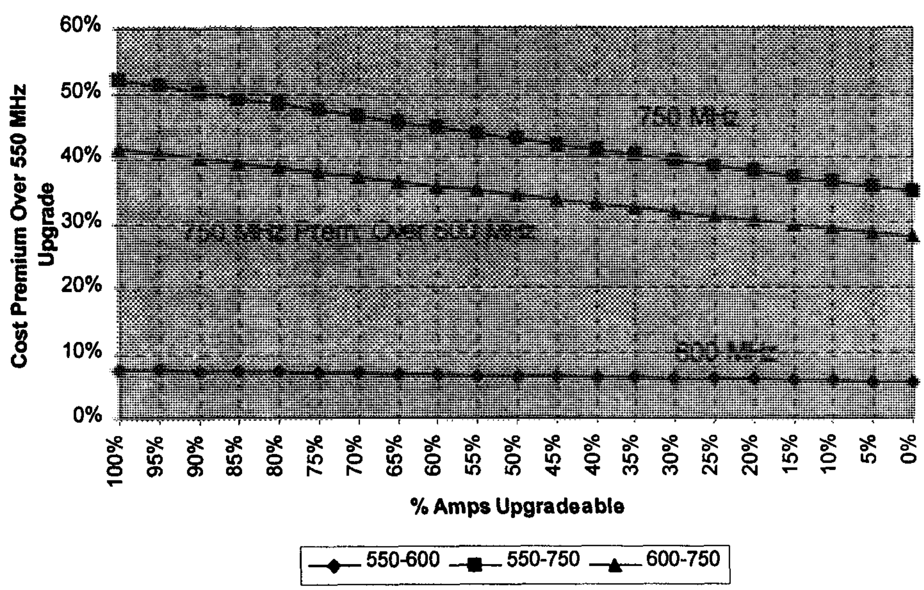
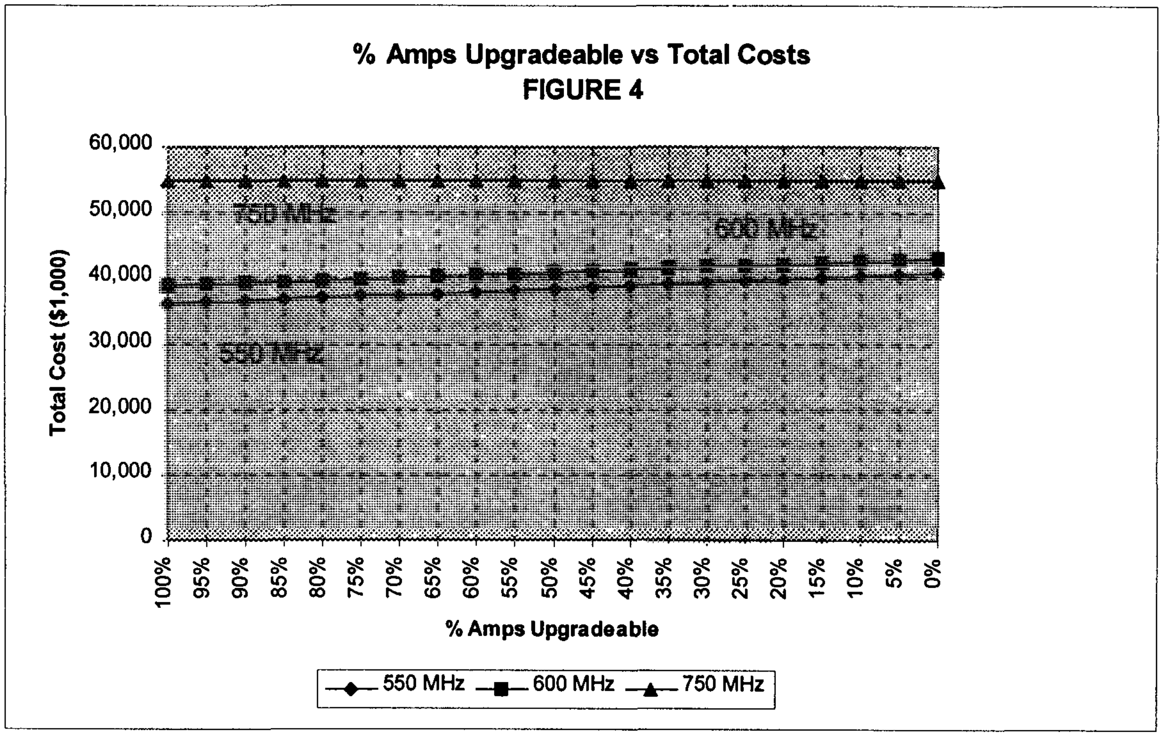


Figure 3, shows that the premium for 600 MHz doesn't change significantly if fewer amplifiers in the cable system are upgradeable. If fewer of the existing 450/550 MHz amplifiers are upgradeable to 550 MHz or 600 MHz, the cost of both the 550 MHz and 600 MHz upgrades increase at approximately the same rate, refer to Figure 4. The premium for 750 MHz FTTF falls faster than the premium for a 600 MHz upgrade since fewer 450/550 MHz line extenders are upgradeable and more new 750 MHz line extenders must be purchased. As a result, the total cost of the 550 MHz and 600 MHz upgrades increase faster than the total cost for 750 MHz FTTF upgrade. If very few of the amplifiers are upgradeable, it can still make sense to buy 600 MHz feedforward trunk stations, install 750 MHz line extenders and defer the placement of fiber and FTTF nodes. If significant (>30%) of the cable must be replaced the case for a 600 MHz trunk upgrade becomes weaker.

% Amps Upgradeable vs Cost Premium Over 550 MHz Upgrade
FIGURE 3



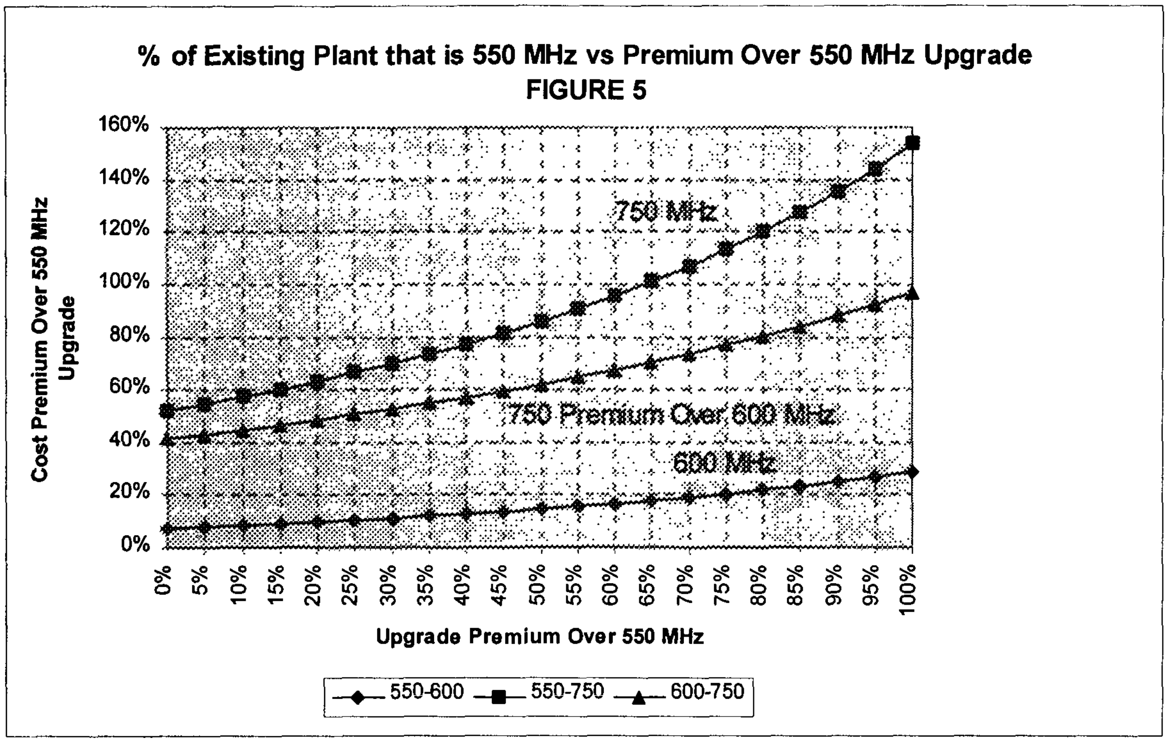


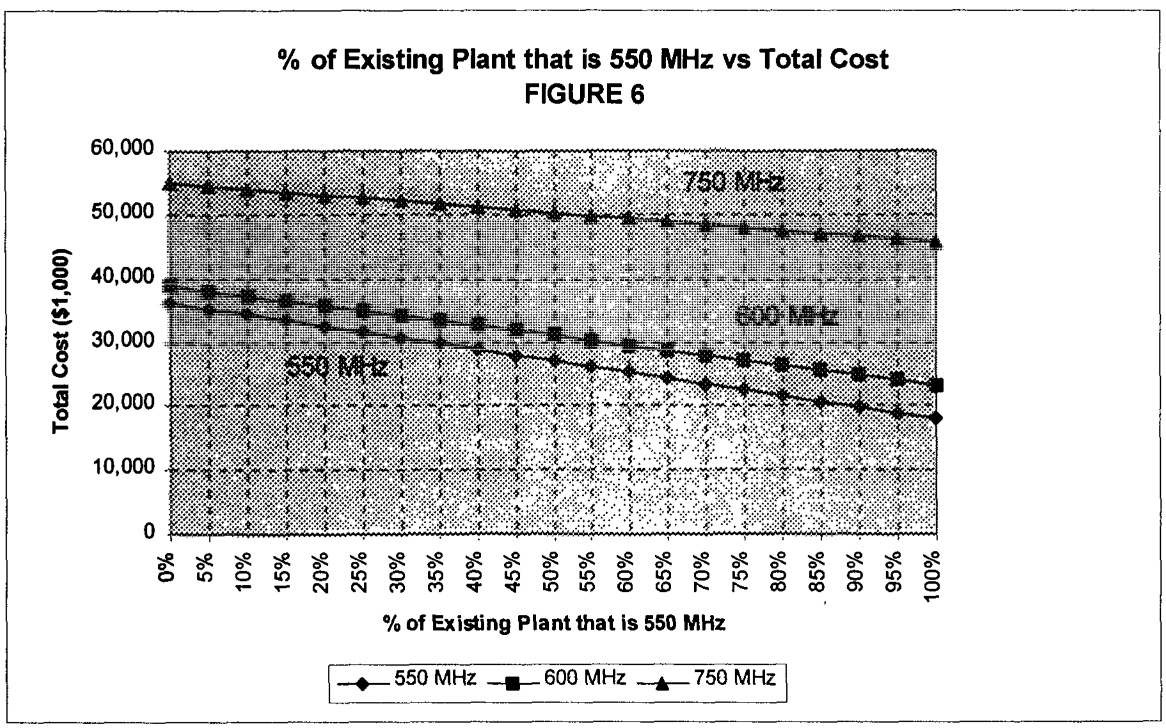
If a large percentage of the existing plant is 550 MHz (450 with 550 MHz areas), the total cost to upgrade to 550 MHz, 660 MHz or 750 MHz falls, refer to Figure 5. The total cost for 550 MHz plant falls faster than the cost for 600 MHz or 750 MHz FTTF plant as shown in Figure 6. As the percentage of 550 MHz plant in a system increases the cost shown for a 550 MHz upgrade is effectively the cost to install the fiber backbone, fiber hubs and nodes to reduce all trunk cascades to a maximum of ten. The premium to upgrade existing 550 MHz plant to 600 MHz is 20% to 30% higher than the cost to simply install fiber hubs and nodes in the existing 550 MHz plant.

Phased Approach

The phased approach to plant upgrades used by Rogers involves dividing a system into phase areas that typically have a similar: number of amplifiers, amount of coax/fiber cable and are served by a similar number of fiber hubs or nodes fed from the headend or regional hub. The use of fiber hubs or nodes allows a particular phase area to be treated independently from the other phase areas. Each phase area has its own database detailing:

- the existing equipment.
- the bill of materials requirements for upgrade.
- all other resources for the construction and testing of the phase area.
- costs per home passed, costs per subscriber and associated upgrade efficiency measures.
- characteristics of the plant or subscribers in a phase area, such as: line extenders per trunk station, home passed per active


% of Existing Plant that is 550 MHz vs Premium Over 550 MHz Upgrade
FIGURE 5
Cost Premium Over 550 MHz Upgrade
160%
140%
120%
100%
80%
60%
40%
20%
0%
750 MHz
750 Premium Over 600 MHz
600 MHz
0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%
Upgrade Premium Over 550 MHz
550-600
550-750
600-750


% of Existing Plant that is 550 MHz vs Total Cost
FIGURE 6
Total Cost ($1,000)
60,000
50,000
40,000
30,000
20,000
10,000
0
750 MHz
600 MHz
550 MHz
0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%
% of Existing Plant that is 550 MHz
550 MHz
600 MHz
750 MHz

- and subscriber demographics within a phase area.

The ability to treat the phase areas independently provides several benefits:

- each phase can be tested and certified for: construction quality, end of line performance, operation of plant status monitoring and system control completely independent of the other phase areas.
- variations in construction cost and upgrade progress for phase areas can be identified early in the upgrade and factored into the completion schedule and cost estimates of the other phase areas and the entire upgrade plan.
- trouble shooting and clean up of two-way return plant can be implemented based on the planned launch of two-way services for each phase area.
- new services or products can be launched phase area by phase area depending on plant characteristics or subscriber demographics.

SUMMARY

Three main factors determine the viability of a strategy to upgrade existing 450/550 MHz plant to 600 MHz plant with a fiber backbone and fiber hub architecture. These factors are:

- quality of the existing plant (percentage of cable that must be replaced).
- the channel capacity required for expected new services.
- the cost of capital and the risk of stranding capital by building 750 MHz FTTF plant substantially before it is a proven requirement.

If in fact more capacity is required in the future, the 600 MHz plant can be upgraded to 750 MHz FTTF on an phase area by phase area and a system by system basis.

The phase area approach to upgrades is a way to dimension upgrade areas, collect important information on the plant and subscribers in that phase area to assist in a phase area by phase area project management of the upgrade and launch of new services to the subscriber.