Don’t Be Passive About Passives

A Technical Paper prepared for SCTE by

Kyle Hohman
Standards Specialist
Shaw Communications
751 Enterprise Crescent, Victoria, BC
403-538-5252
kyle.hohman@sjrb.ca

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1. Introduction

As operators look ahead to expand their speed tiers and offerings, they will also be looking to expand their plant capacity to 1.8 GHz Extended Spectrum DOCSIS (FDD) and DOCSIS 4.0. Passives are the highest quantity device in the outside plant that limits the usable bandwidth and will take the most amount of time and energy to replace.

This paper will discuss the methods that an operator can use to replace passive equipment in their plant and examine the operational and technical benefits of each method. We will explore the considerations for evaluating passives in the plant during field trials from both plant performance and maintenance savings perspectives.

For context, the paper will present some of the advantages of having passive upgrades completed before actives, specifically around the ability for 1.8 GHz signals to pass through the plant to measure for ingress, egress, and other test signals. We will also discuss the benefits of being able to set up plant actives by already having passives upgraded to 1.8 GHz, as opposed to a partial tilt setup, which would require the identification of where rolloff exists in order to do a drop-in style upgrade.

2. Passive Replacement Programs

Before we enter in depth into a discussion around passives and how they can be operationalized in the plant, we need to ensure a consistent language is being used around the devices themselves. Passives devices are a category of devices that includes taps, splitters, couplers and power inserters. A passive is also defined as a device that operates in the plant without consuming power directly. It acts as a gateway for the signals passing through it and is designed with specific RF characteristics in mind. Passives are the most common device in the plant, with an industry average of around six passives per active device. For the purpose of this discussion, we will be using an illustration of a sample plant for the various methods of passive upgrades to outline the benefits of each method, as in the figure below.

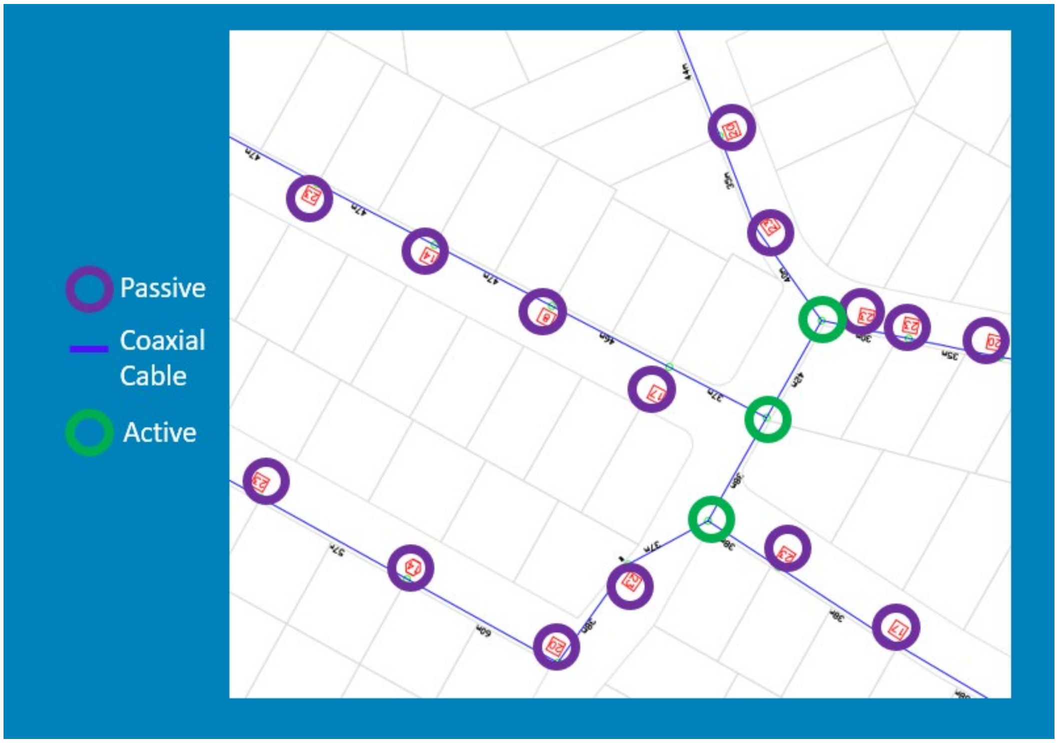


Figure 1 – Sample Plant Illustration

As cable operators begin their planning for DOCSIS 4.0, the work begins on selection of equipment for evaluation. When an operator is looking to bring a new passive into the plant, there are several factors that need to be explored and understood before proceeding with a field trial.

The first set of considerations are around higher-level plant design requirements for the radio frequency (RF) performance of the devices. The first thing on this list is the insertion loss, or the amount of signal that is lost as the signals pass through the device. As the spectrum is expanded, and to accommodate for higher spectrum transmissions, there is potential for tradeoffs related to the RF design of passive devices. These properties are actively under development by the vendor community and will not be discussed at length in this paper. It is sufficient to understand that the caveat of this performance exists, and how it will impact the operational methodologies examined throughout.

This leads to the signal from the passives to the customer and how it feeds into drop loss. As we look at these higher bandwidths, the total composite power (TCP) of the plant to the modem—and the modem back to the plant—become more of a balancing act than ever before. (Such analysis is outside the scope of this paper but something that will need to be considered as part of the larger design considerations.) After these levels are captured and understood, the secondary RF characteristics of the passive devices must be reviewed.

As spectrum is expanded, some operators are taking a step back to evaluate their network holistically to determine what levels they should be running out of their actives, as well as what levels they would like their modems to be transmitting at. The passive evaluation needs to be included in this discussion as the expanded spectrum greatly impacts the performance achievable through a passive device—along with the design and component usage to build the device—which in turn impacts power passing capability, low-end usable frequency, insertion loss, return loss and isolation between various ports.

Once the high-level design considerations and RF performance characteristics of the passive evaluation are understood, an operator can move to the operational efficiencies and savings that can be realized by selecting the correct passive for their network. The Society of Cable and Telecommunications Engineers (SCTE) has developed a standard for 3 GHz passives (known as SCTE 265 2021) that has completed the foundational work to ensure that the options available to operators have value and longevity in the plant.

At Shaw, we have spent the last few years performing a mid-split upgrade in our plant, coupled with a downstream spectrum expansion. Part of this effort was to replace all passives in the plant from legacy, defined as sub-1 GHz passing, to a minimum of 1 GHz passing. Over the course of this exercise, we learned several operational lessons that will significantly influence our next rounds of passive evaluations and selection.

2.1. Passive Evaluation Criteria

The most immediately impactful piece of selection criteria, aside from questions around advertised spectrum bandwidth, is what the insertion is and through loss of the new device. As touched on above, once the design of the passive is enhanced for almost double the spectrum, there will be tradeoffs with RF performance in other areas of the spectrum. These will vary from vendor to vendor, but they will add up in a cascaded environment. As evidenced in the formulae below, n is the number of passives and x is the loss of the existing passives, which leads you to the legacy loss. The additional loss from the ESD passive, that is the delta from the legacy passive to the new passive, is defined by y. Once a new passive has been added to the plant, every decibel of loss that this expanded spectrum passive could potentially contribute to the overall loss is added for every tap in the run.

$$Legacy\ Loss = nx$$

$$ESD\ Loss = n(x + y)$$

One of the often forgotten but incredibly important considerations is the pin length required for the passive device. As the spectrum that the passive needs to transport expands, the pin length becomes much more important than legacy passives. The accuracy of the pin length creates a much tighter window from a technician craft perspective. Hardline passive connector reusability is a key factor in saving time, and in some cases, there may not be excess cable available to be re-cored and have connectors added.

Another key consideration is the dimensions of the passive devices themselves. Upgrading passives in an existing environment means that the device needs to fit into existing pedestals, into housings and on existing strands. There may not be extra room in pedestals, or enough bend radius or cable length, to implement a large change in passive housing size.

Another often neglected factor in the analysis is the availability of an upgradeable faceplate. Upgradeable faceplates are key features when considering a new passive for the plant. To remove connectors and re-install a device into the plant, rather than unscrewing a faceplate and dropping in a new one, is a massive operational difference.

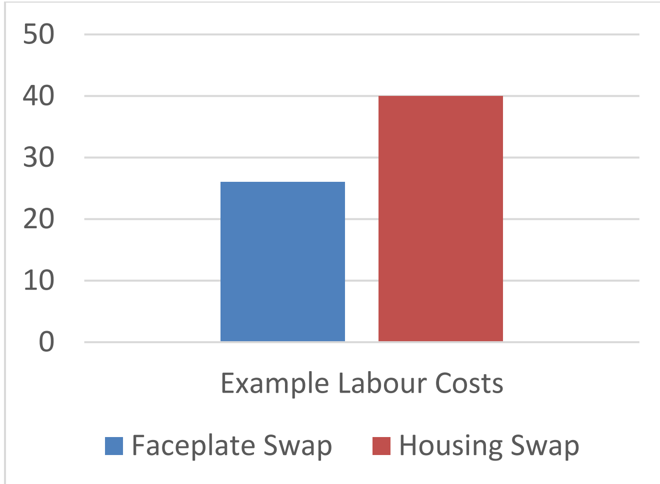


Figure 2 - Faceplate Upgrade Comparison

Something that we have found over years of maintaining cable plant through all imaginable geography is the importance of the seizure mechanism. The seizure mechanism is the way that the mainline connector pin makes contact for RF and power transmission within the passive device. Fundamentally, there are two types of seizer mechanisms: one that is controlled with a technician tightened set screw and one that has an effective and often proprietary mechanism that applies constant pressure to the pin of the connector. After the initial installation, passives tend to be in the plant until they fail, or the network is upgraded. Since the passives are such long-lived devices in the plant, even the smallest design choices can have a great impact on maintenance cost over the lifetime of the device.

One item that has stood out is the seizure screw for the mainline cable entering the passive. Over the life of a passive, our analysis has shown that the seizure screw may have been forgotten and not tightened or working loose over time, which occurs in a surprisingly large number of cases. Each operator will need to apply their own cost structure to how these issues translate into cost, but each one would be a customer impacting truck roll. The self-seizing mechanism has been shown to be a key success factor in our analysis, as it not only saves the costs associated with truck rolls for set screws that have some looseness, but also speeds up installation by removing some labor and tool requirements from plant technicians.

For any operator is looking to expand their plant to enhance capacity and increase service offerings to customers, the category of equipment that will require the most upgrades is the plant passive. The scale of upgrading every passive in the plant is enormous; as previously discussed, the number of passives overshadows the number of actives in the plant. There are two main methods to operationalizing the upgrades to the plant that we will discuss in the next session: the Blanket Method and the BAU Method.

3. Operationalizaton of Passive Upgrades

For any operator is looking to expand their plant to enhance capacity and increase service offerings to customers, the category of equipment that will require the most upgrades is the plant passive. The scale of upgrading every passive in the plant is enormous; as previously discussed, the number of passives overshadows the number of actives in the plant. There are two main methods to operationalizing the upgrades to the plant that we will discuss in the next session: the Blanket Method and the BAU Method.

3.1. Blanket Method

The Blanket Method refers to the complete, targeted upgrade of plant passives in an area or region, as shown in Figure 3.

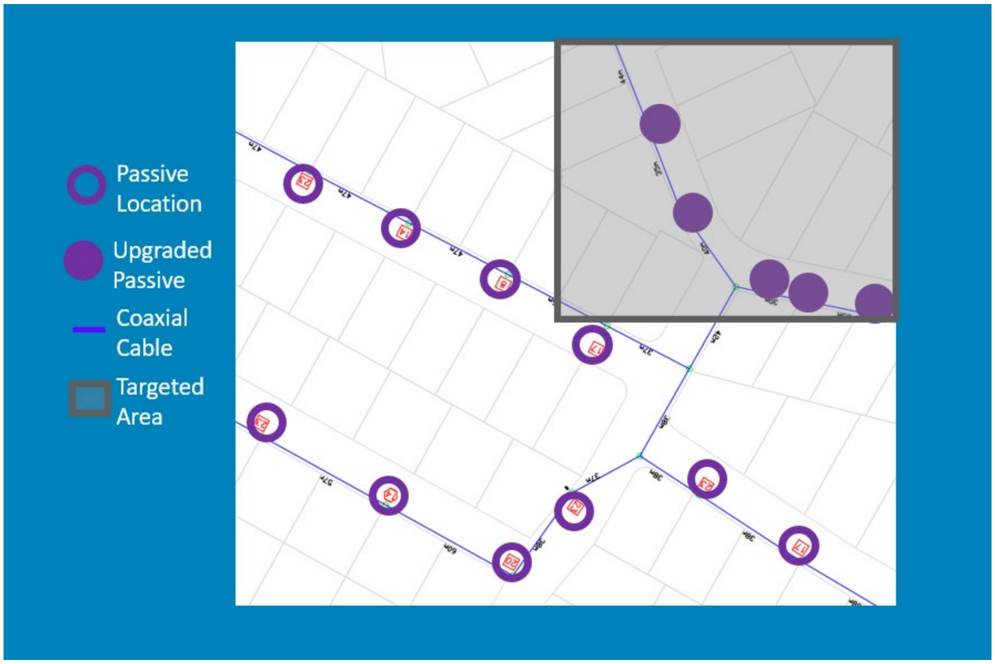
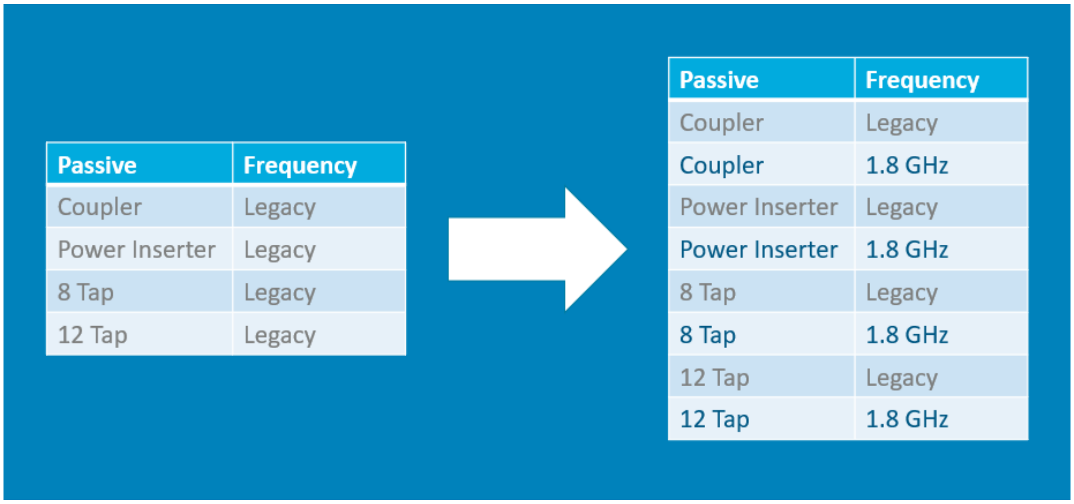


Figure 3 – Blanket Method Illustration

This method is advantageous if the upgrade is complex and requires more than a simple drop-in upgrade. As we will explore further in the paper, upgraded passives may introduce different loss characteristics that will require subsequent changes in the actives portion of the plant.

When using the blanket method, the number of SKUs (Stock Keeping Units) required to maintain the plant doubles. There will be two types of passive devices contained within a system, the existing 1.2 GHz and new 1.8 GHz. Operational teams will be required to stock and maintain equipment for both types of passives. This not only strains local technician resources in terms of truck stock and ensuring the swapping on passives, but it can also exacerbate existing supply chain issues, causing the like-for-like strategy to become unmanageable.



Passive	Frequency
Coupler	Legacy
Power Inserter	Legacy
8 Tap	Legacy
12 Tap	Legacy

Passive	Frequency
Coupler	Legacy
Coupler	1.8 GHz
Power Inserter	Legacy
Power Inserter	1.8 GHz
8 Tap	Legacy
8 Tap	1.8 GHz
12 Tap	Legacy
12 Tap	1.8 GHz

Figure 4 – Blanket Method Truck Stock / SKU

3.2. BAU Method

The second method to consider is the BAU (Business As Usual) Method that we leveraged at Shaw during our mid-split upgrade program. This method is based around making a wholesale switch for the business to a new passive device at a single point in time, across the entire network.

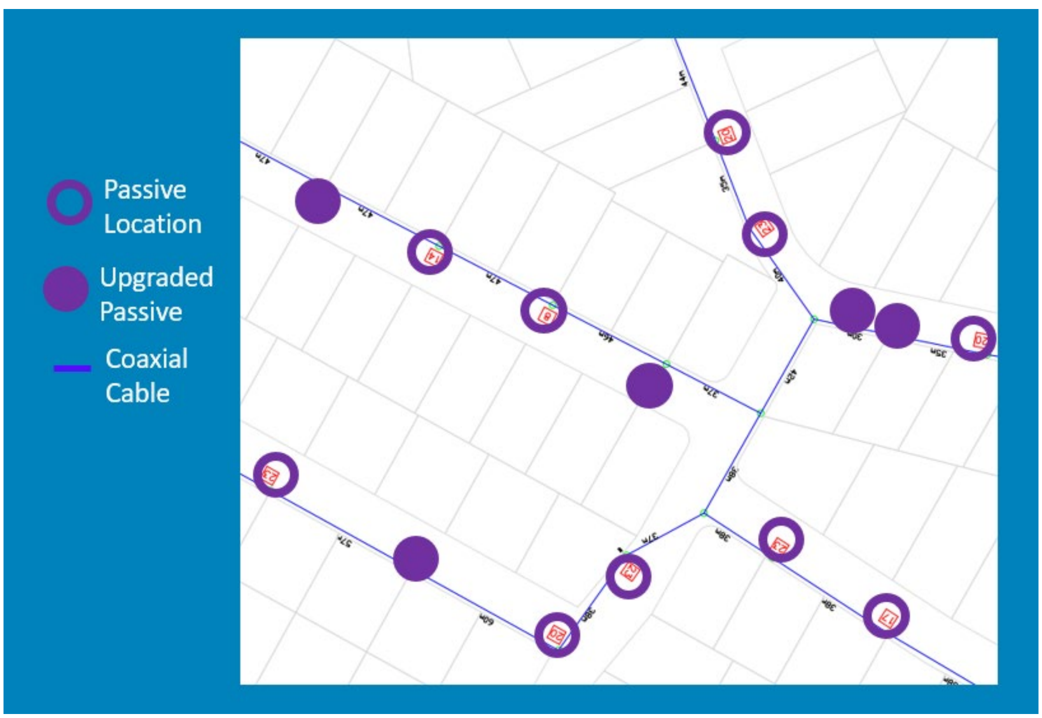


Figure 5 – BAU Method Sample Illustration

This mitigates one of the key operational issues that is seen with the Blanket Method, which is the doubling of the relevant SKUs. This is avoided by doing a straight part-for-part replacement within the inventory system.

Passive	Frequency
Coupler	Legacy
Power Inserter	Legacy
8 Tap	Legacy
12 Tap	Legacy

Passive	Frequency
Coupler	1.8 GHz
Power Inserter	1.8 GHz
8 Tap	1.8 GHz
12 Tap	1.8 GHz

Figure 6 – BAU Method Truck Stock / SKU

The other key operational benefit of this method is that it does not preclude using the Blanket Method when targeting an area ready to offer enhanced service tiers or for an upgrade of actives to complete spectrum expansion.

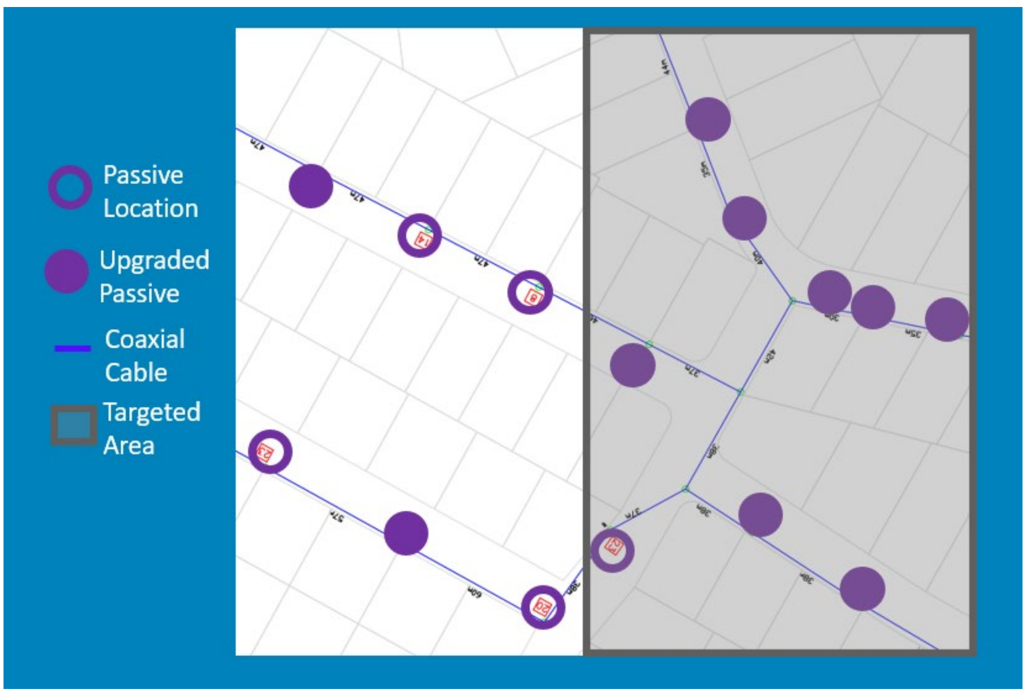


Figure 7 – BAU Method with Overlay

However, it is important to consider that this method is built upon a drop-in style upgrade, where existing loss characteristics are matched by newly deployed passive devices. Since passives are being replaced on an as-needed basis, they can be dropped into any point in the plant and in any concentration. This creates a scenario in which there is a mix of 1.2 GHz and 1.8 GHz passives in the plant through maintenance and failure replacements. Care and attention will be required to ensure that these are properly documented in the network documentation, or at the very least, that they are easy to physically identify. Additionally, issues may occur if the loss characteristics change because of expanding the spectrum, which would require levels of actives to be reset.

4. Passive-Enabled Spectrum Expansion

When an operator has made the decision to expand their spectrum, there would inevitably be discussions around which equipment to upgrade first—actives or passives. When considering the options in this decision, it becomes clear that the answer is not straightforward—what are the benefits to upgrading the passives when there are no actives to generate the signal, and why upgrade actives without having any passives to pass the signal through?

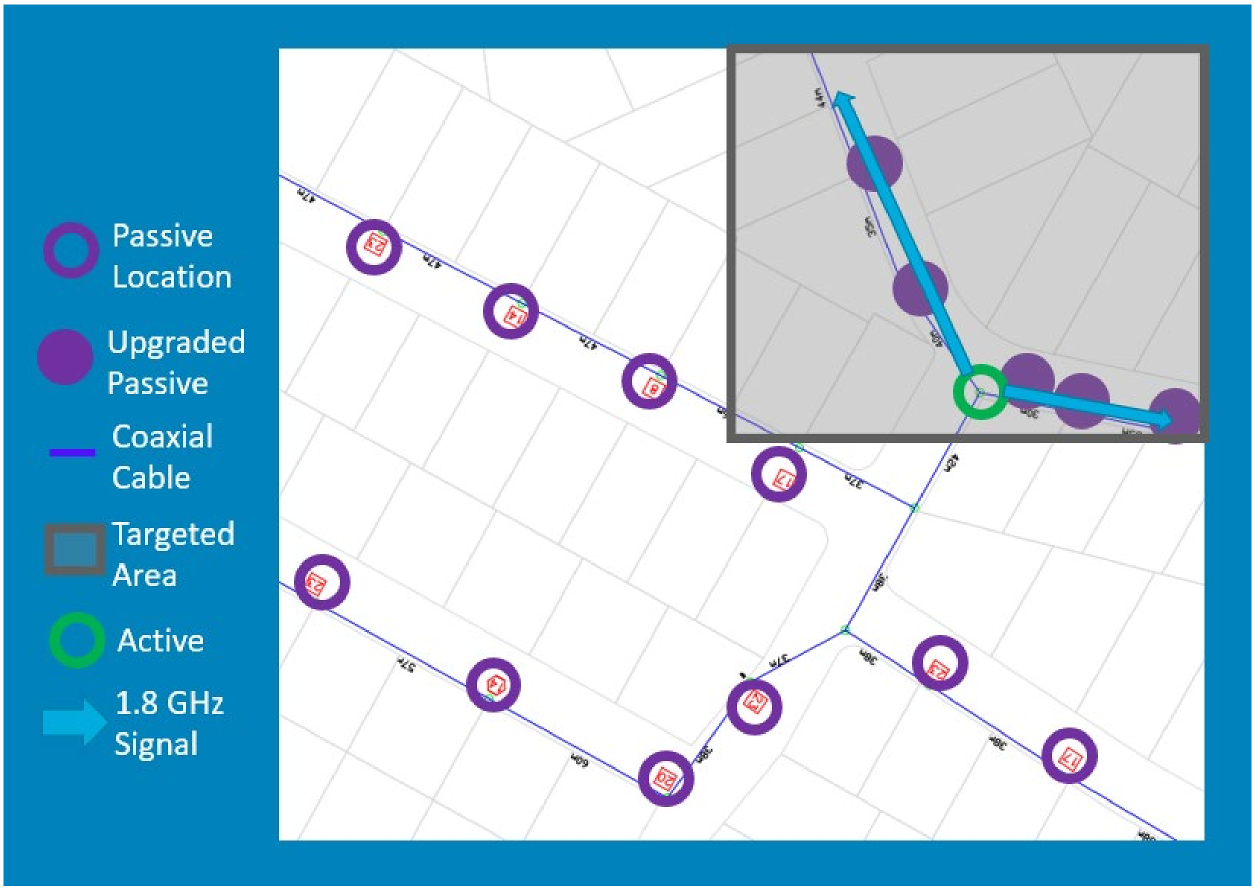


Figure 8 – Passive Enabled 1.8 GHz Testing

To support the decision-making process, we will argue that there are considerable operational advantages to upgrading passives first that have been, thus far, under explored given that operators have not had a way to characterize or utilize the expanded spectrum.

When we expand spectrum through the use and upgrade of passives, we are able to capture both incoming ingress into the plant, as well as the signals that are already entering the plant on the higher frequencies. This has been noted as we move into the more heavily used LTE frequencies and will only become more notable as the spectrum expands. As operators are becoming increasingly aware, the higher spectral transmissions on the plant can cause egress and be impacted by ingress from smaller physical faults in the cable. It is seemingly no longer the pedestal that has turned into a squirrel nest causing the issue, but an improperly tightened back nut now acting as a slot radiator.

Another often-overlooked benefit is that having a head-start on the passives will minimize downtime and outages as the actives are upgraded in the area due to the larger number of devices in the plant already having been upgraded. This is becoming more and more of a customer experience piece in the work from home era, and with the rollout of more intelligent and power-hungry nodes and amplifiers that may have longer boot times, ensuring that customers' uptime is maximized is becoming increasingly important when making upgrades to the plant.

At the time of this writing, there are massive supply chain issues worldwide that show no sign of relenting. This also feeds into an operator's strategy and is worth including in any evaluation of timing. There has been a shift from an on-demand availability to an as-available environment for network equipment. The impact this has on the strategy for upgrading passives can be felt immediately in lead times for ordering equipment, but also in trying to create and upgrade new plant.

Having a flexible strategy and understanding for implementation of the equipment is a key component of any strategy, especially in the competitive landscape of telecommunications. As operators look to expand their downstream spectrum to reap the benefits of the spectrum available in coaxial cables, there are many options on the path forward, and multiple factors that can impact the decision for which avenue to proceed down first when updating the equipment in the plant to expand services.

5. Conclusion

Every cable operator must continue to upgrade their plant in order to remain competitive in the telecommunications landscape and be able to offer their customers best-in-class services. To do this, a well-considered and evaluated strategy for plant upgrades, and especially for passive upgrades, is vital. There is no longer a single path, or even one simple strategy, when it comes to opportunities to innovate within the telecommunications space, but with that freedom of choice there are often pitfalls, especially as the demands for speed and reliability grow and evolve exponentially. Passives are the foundation on which the rest of the plant is built and allow for our products and services to reach millions of customers around the world every day, and as such, a well-devised strategy can ultimately be the differentiator between competitors.

Abbreviations

BAU	Business As Usual
DOCSIS	Data Over Cable Service Interface Specification
FDD	Fixed Duplex DOCSIS / Extended Spectrum DOCSIS
GHz	Gigahertz
RF	Radio Frequency
TCP	Total Composite Power
SCTE	Society of Cable Telecommunications Engineers

Bibliography & References

ANSI/SCTE 265 2021: *Broadband Radio Frequency Hardline Passives for Cable Systems;* Society of Cable and Telecom Engineering