Signal Conditioning at the Tap

SCTE

Society of Cable Telecommunications Engineers

Golden Gate Chapter

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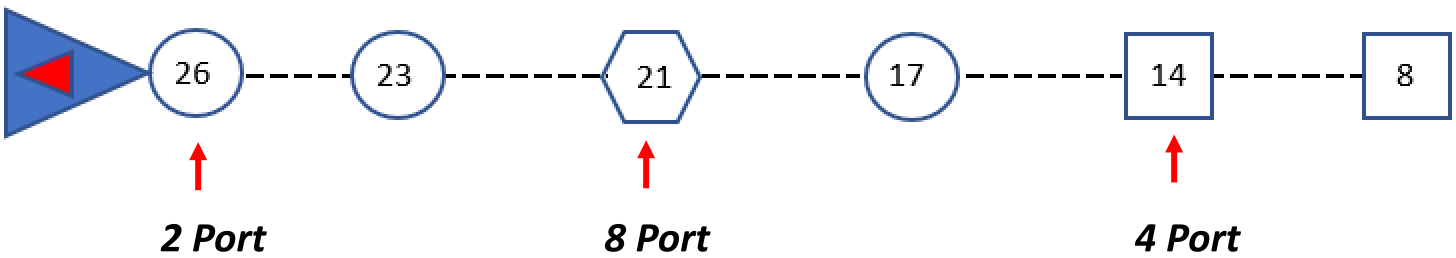
For Today's Review

Signal Conditioning at the Tap

- **Review Sample Tap Designs**
- **Review Conditioning**
- **Discuss benefits of conditioning**
- **Show examples where Conditioning is Required**

Sample Tap Designs & Level Calcs

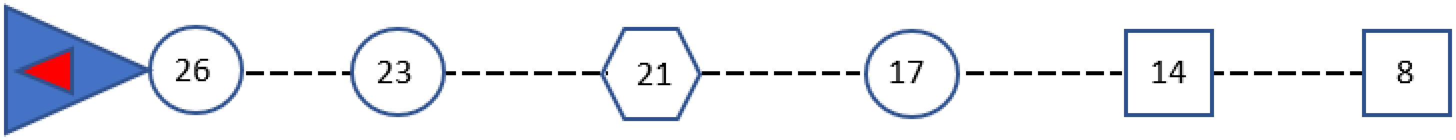
Below is a Tap String noted on a system print and we'd like to know the levels



Organization is Key

- If you wish to repeat this exercise and change levels etc. taken the time to build in Excel is recommended
- Regardless if Excel, pen and paper or in your head, organizing the key 'variables & constants' is key

Sample Tap Designs & Level Calcs



Required

- Amplifier Bandwidth or (High / Low) Forward Freq [MHz]
- Amplifier Forward Level (High / Low) [dBmV]
- Amplifier Return Level Input [dBmV]
- Tap Value Insertion Loss [dB] *(See Mfg. Tap Specifications)*
- Cable Type & Footage tap to tap
- Cable Loss of above [High / Low]
- Regardless if Excel, pen and paper or in your head, organizing the ‘variables & constants’ is key

Filling in some of the above…..

This Calculation is for 860MHz/55MHz –

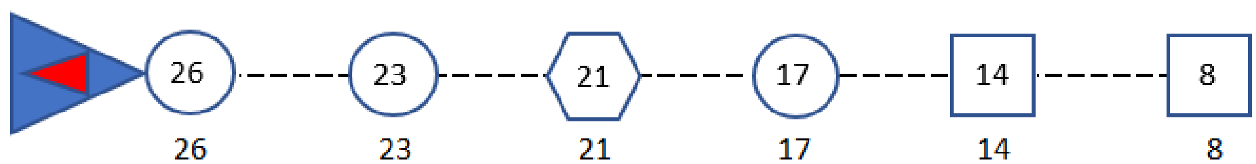
Amplifier Output, Return Input & Losses noted Below

Amplifier Output (dBmV)		
	860	49
	55	37

Cable Loss						
	860	2.3	2.3	2.3	2.3	2.3
	55	0.53	0.53	0.53	0.53	0.53

Tap Insertion Loss						
	860	1.4	1.4	2.1	1.6	3
	55	0.7	0.7	1.2	1.1	1.8

Return (dBmV)	16



All Cable = P3.500	100’	100’	100’	100’	100’

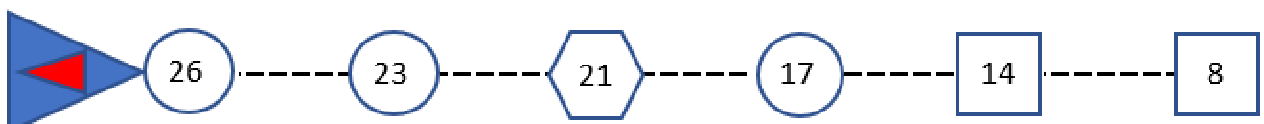
We will keep arithmetic simple and show cable spans as 100 feet….(Use below for real world variances)

Cable Loss	Cross Multiply	Divide
2.3 dB / 100' × x dB / 110	(2.3*110)=100x	(2.3*110)/100=x
		x=2.53dB

Calculating Forward Levels and then Reverse

Amplifier Output (dBmV)	860	49								
	55	37								
Cable Loss	860			2.3		2.3		2.3		2.3		2.3
	55			0.53		0.53		0.53		0.53		0.53
Tap Insertion Loss	860		1.4		1.4		2.1		1.6		3
	55		0.7		0.7		1.2		1.1		1.8

Return (dBmV)	16



26 23 21 17 14 8

(MHz)								
No Conditioner Tap Levels	HI	860	23	22.3	20.6	20.2	19.3	20
	LO	55	11	12.8	13.5	15.8	17.2	20.9

No Conditioner Modem Tx (dBmV)	42	40.2	39.5	37.2	35.8	32.2

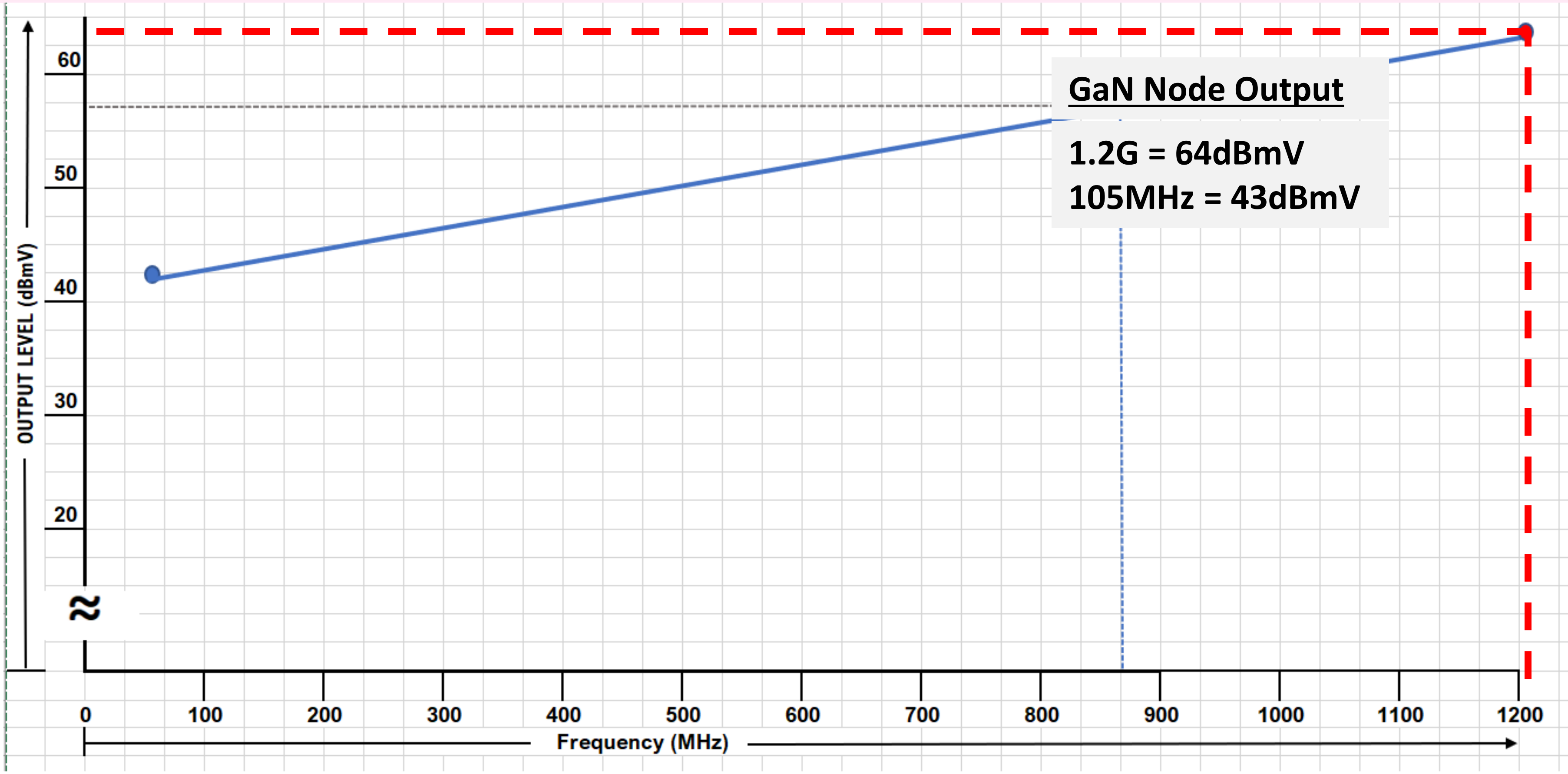
Note – Never Consider Tap Insertion Loss UNLESS you are going through BOTH hardline Input / Output Connectors {True for both Forward & Return Level Calculations}

Observations

Return (dBmV)	16		26	23	21	17	14	8
			26	23	21	17	14	8
		(MHz)						
No Conditioner Tap Levels	HI	860	23	22.3	20.6	20.2	19.3	20
	LO	55	11	12.8	13.5	15.8	17.2	20.9
No Conditioner Modem Tx (dBmV)			42	40.2	39.5	37.2	35.8	32.2

- Forward Tilt from +12dB to -1dB
- Ch 2 (55MHz) 11dBmV to 20.9dBmV
- Modem Transmit 42dBmV to 32.2dBmV

What if You had to Design for N + 0 Output Levels?



- *Higher Outputs are possible today due to improvements in the molecular chip sets.*
- *Gallium Nitride (GaN) is 'Silicon of Today' (64dBmV at 1.2G analog)*

Note – If N+1 or N+2 Derate [make lower] 4dBmV

From a Design Levels Point of View, You would Need

- Minimum Tap Levels
- Minimum Tap Tilt (or Max Reverse Tilt if accepted)
- Return Input Level (To Node or First Active in N + x)
- Max Modem Upstream Level at Tap

Design Attempt Info

System Node Example

No Conditioning

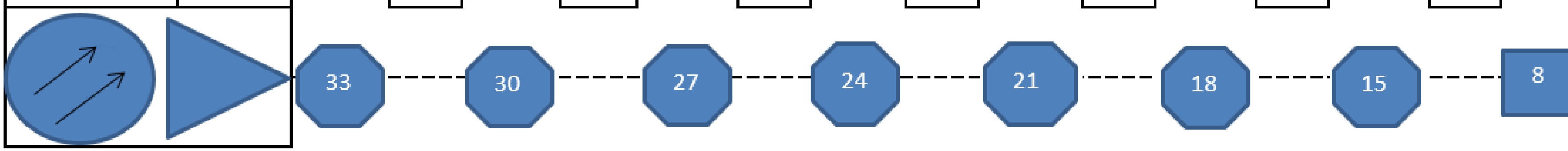
- Levels- (1218M/55M) with 20/11 dBmV min @tap
- 4dB min tilt
- 13dBmV Ret In
- 43dBmV Max Modem Upstream Level at Tap

Design Attempt Below (N + 0) – Full Output

System Node Example - No Conditioning (Return Δ on Plant Side)
Levels- (1218M/55M) with 20/11 dBmV min @tap, 4dB min tilt, 13dBmV Ret In, 43dBmV Max Modem Upstream Level at Tap

All Levels are Analog

		Tap 1		Tap 2		Tap 3		Tap 4		Tap 5		Tap 6		Tap 7		Tap 8
Node Output (dBmV)	1218 M	**64**														
	54 M	**42**														
Tap Insertion Loss (dB)	1218 M	***1.5***		***1.5***		***1.8***		***2.1***		***2.3***		***3.3***		***4.5***		
	54 M	***0.2***		***0.2***		***0.4***		***0.5***		***0.7***		***1.2***		***3.2***		
Cable Loss (dB)	1218 M		**2.78**		**2.78**		**2.78**		**2.78**		**2.78**		**2.78**		**2.78**	
	54 M		**0.54**		**0.54**		**0.54**		**0.54**		**0.54**		**0.54**		**0.54**	



Tap Value		**33**	**30**	**27**	**24**	**21**	**18**	**15**	**8**
Tap Output	1218M	31	29.7	28.4	26.9	25	22.9	19.8	19.54
	54 M	9	11.3	13.5	15.6	17.5	19.3	20.6	24.9
Modem Return		46	44	41.5	39	37.5	35.7	34.4	31

Focusing on Modem Transmit:
Δ Modem Upstream = 15
Δ +/- 2dB Amplifier Levels = 17
Δ +/- 1dB Temperature Change = 18

Design Attempt Below (N + 2) *Same Node, Derate 4dBmV*

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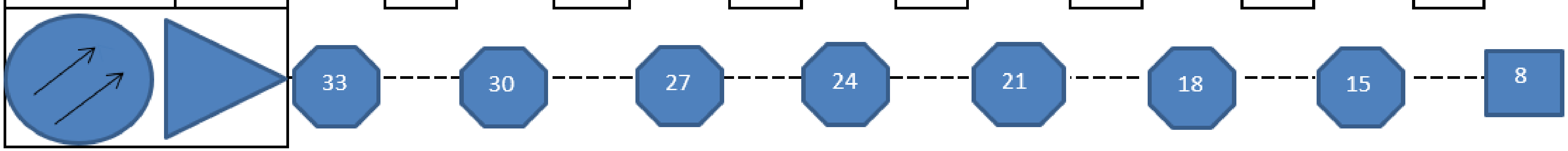
The 4dBmV Derate would probably be across the full spectrum, but just derating High End for illustration – The Point is, Excel is Faster

System Node Example - No Conditioning (Return Δ on Plant Side)
Levels- (1218M/55M) with 20/11 dBmV min @tap, 4dB min tilt, 13dBmV Ret In, 43dBmV Max Modem Upstream Level at Tap

All Levels are Analog

Node Output (dBmV)	1218 M	**60**														
	54 M	**42**														
Tap Insertion Loss (dB)	1218 M	***1.5***		***1.5***		***1.8***		***2.1***		***2.3***		***3.3***		***4.5***		
	54 M	***0.2***		***0.2***		***0.4***		***0.5***		***0.7***		***1.2***		***3.2***		
Cable Loss (dB)	1218 M		**2.78**		**2.78**		**2.78**		**2.78**		**2.78**		**2.78**		**2.78**	
	54 M		**0.54**		**0.54**		**0.54**		**0.54**		**0.54**		**0.54**		**0.54**	



Tap Value		**33**	**30**	**27**	**24**	**21**	**18**	**15**	**8**
Tap Output	1218M	27	25.7	24.4	22.9	21	18.9	15.8	15.54
	54 M	9	11.3	13.5	15.6	17.5	19.3	20.6	24.9
Modem Return		46	44	41.5	39	37.5	35.7	34.4	31

Focusing on Modem Transmit:
Δ Modem Upstream = 15
Δ +/- 2dB Amplifier Levels = 17
Δ +/- 1dB Temperature Change = 18

We Can See that as BW and Levels Increase, Tap Level Variances Grow Beyond Acceptable Limits

In the previous examples the High Outputs of N + 0 and N + 1 0r 2 **demand** some enhancement over legacy design.

This will continue as there is Strong Movement Towards 1.6G and 1.8G Bandwidth

Even on Existing Plant:

-Low Transmit Modems on the End of Line Taps bring Node SNR down

- High Value First Tap can result in Modem Max Transmit Issues *(If too high).* Lowering Return Plant Level to cure **WILL** lower Node SNR 1:1

What Else Can Be Done?……

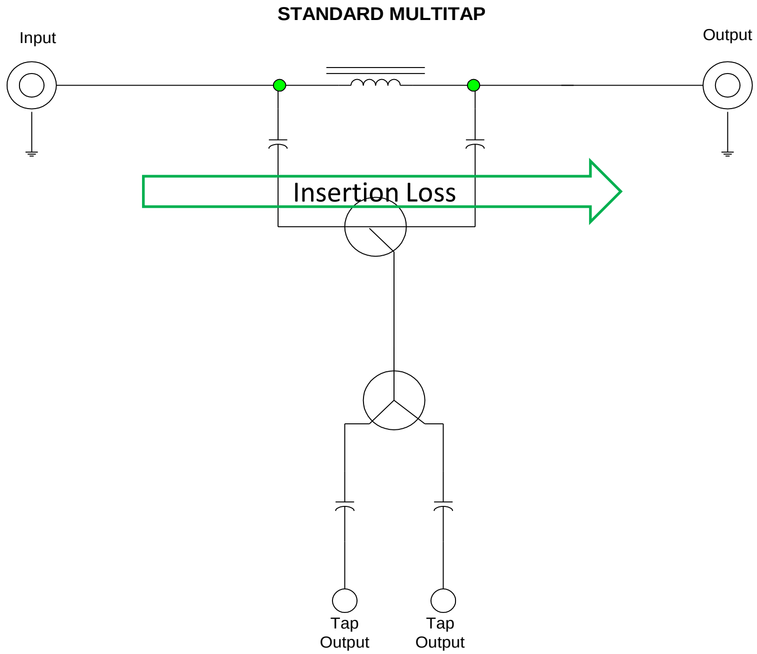
Tap Conditioning

- Methods to Enhance both Existing & Future Designs
- These Methods Produce a Tighter Range for both Forward & Return Levels Tap to Tap
- Designs are more Efficient, Resulting in Improved Performance
- In New Design Cases: Can Produce Longer 'Coherent' Tap Strings thus Requiring Less Nodes / Amplifiers
- Training is Less Difficult
- Setting Meter's Whole House Check in a 'Tighter Range' Will Reduce Repeat Service Calls

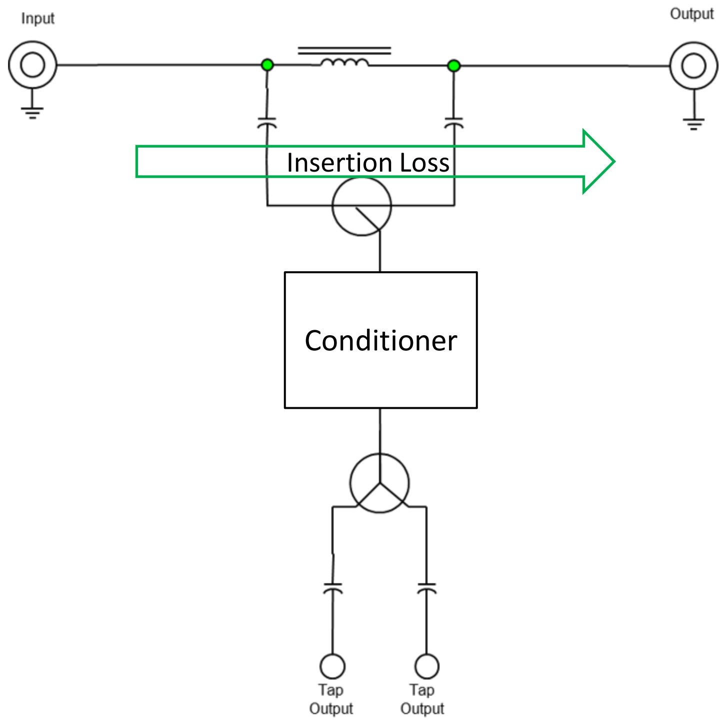
Let's Look at a Tap's Schematic.........................

Comparison of Standard vs. Conditioned Tap

Standard Multitap



Signal Conditioned Multitap



- **Conditioning has no impact on tap insertion loss *(through loss)***
- **Conditioning only impacts tap ports**
- **As depicted, ALL TAP PORTS are conditioned *(cannot condition individual port)***

Types of Conditioners

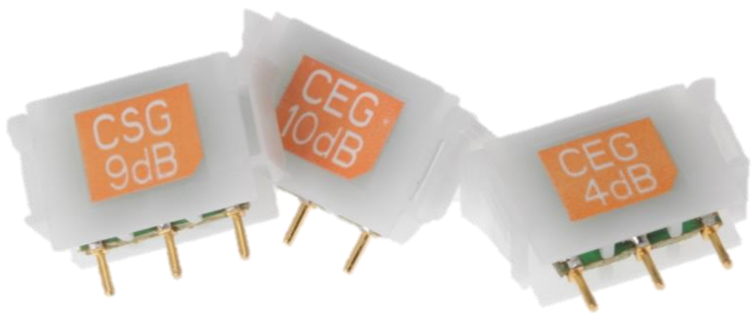
Plug in Conditioner	(XXX)	Filter Shape	
Cable Equalizer	CEG		Lower Value Taps
Cable Simulator	CSG		Higher Value Taps
Return Path Attenuator	RAG		Diplex – Return Only
High Tap Filter	HTG		Diplex – Fwd Only
Jumper**	JP		By-Pass

Types of Conditioners

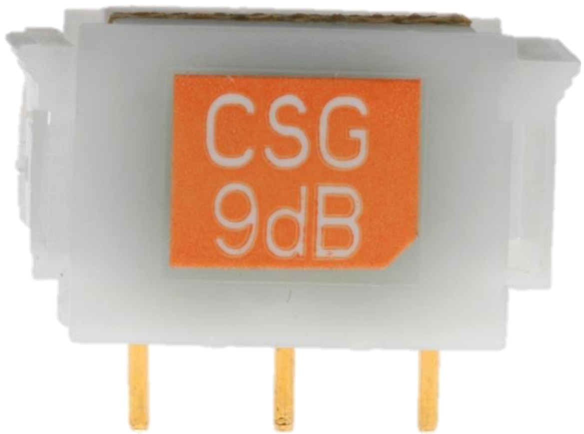
Cable Simulators *and* ***Equalizers:***

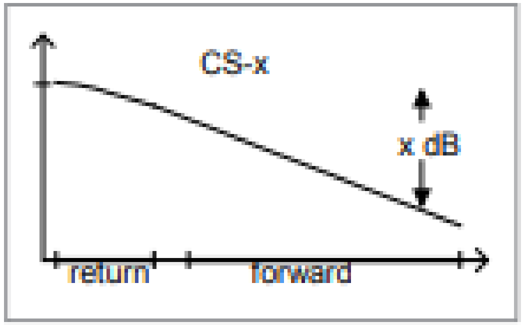
- Most commonly used
- *'NOT DIPLEXED'* which means if an MSO starts at 42M return then goes to 85M, 200M and beyond these plug-ins don't care
- They are 'Full Band' devices

Remember – A Diplex Filter is simply a Frequency Sensitive Splitter that Routes a Certain 'Band of Frequencies' one way & another Band the Other Way



High Tap Value – Cable Simulator



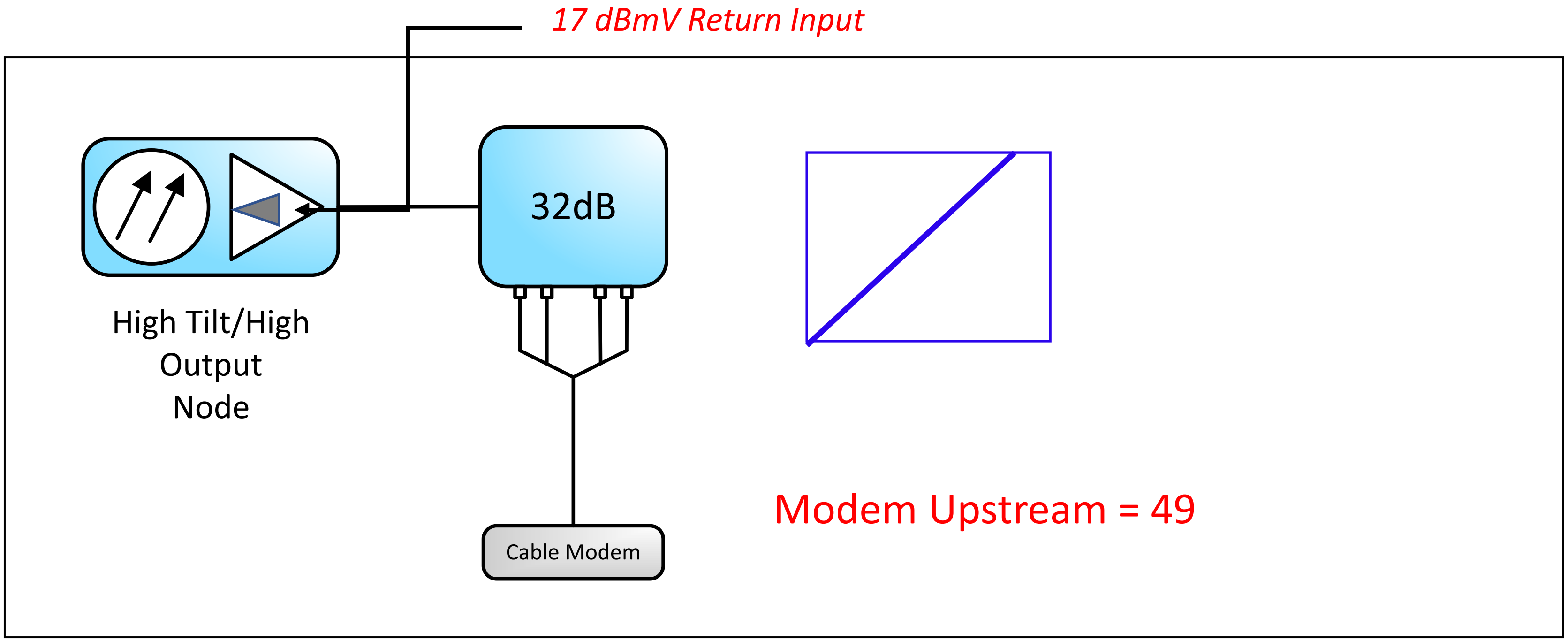


5MHz **1218MHz**

Full Band

Cable Simulator – Used in Beginning Tap(s)

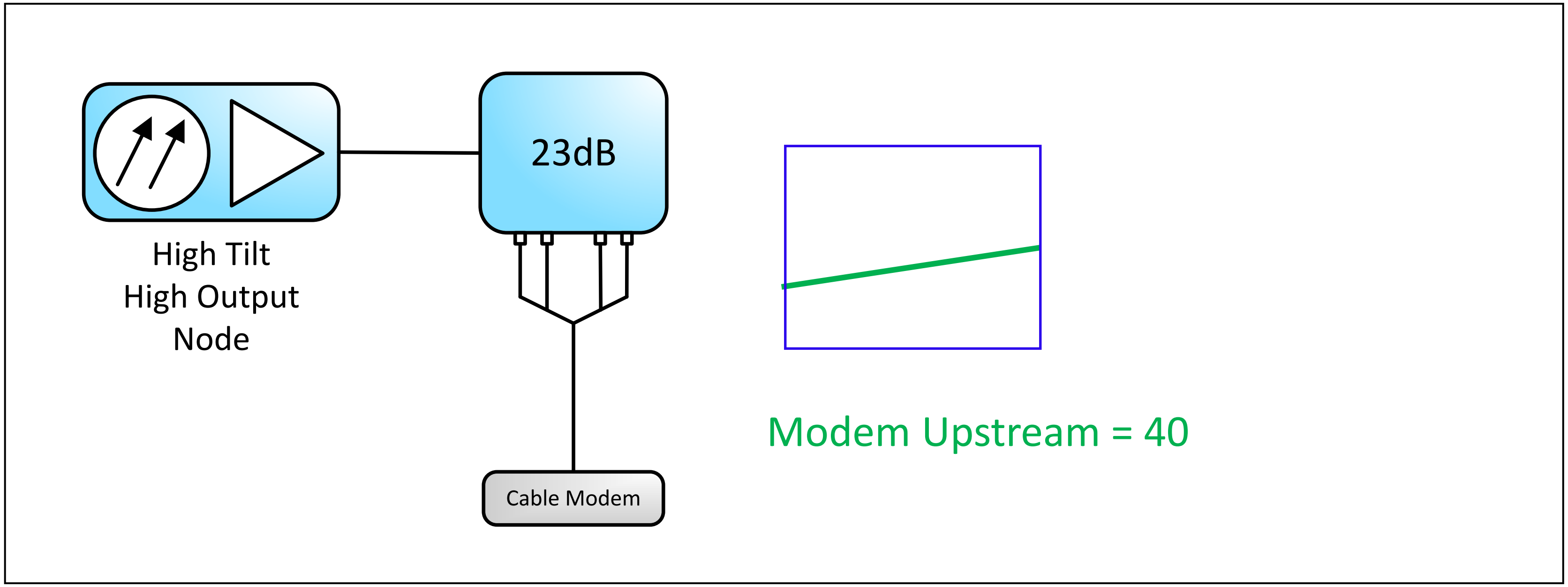
System Example #1 – Before Conditioning



- Excess positive tilt at the tap ports.
- ‘Loud Talker’ modems from these locations.

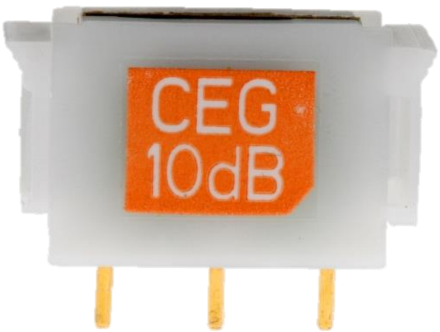
Cable Simulator – Used in Beginning Tap(s)

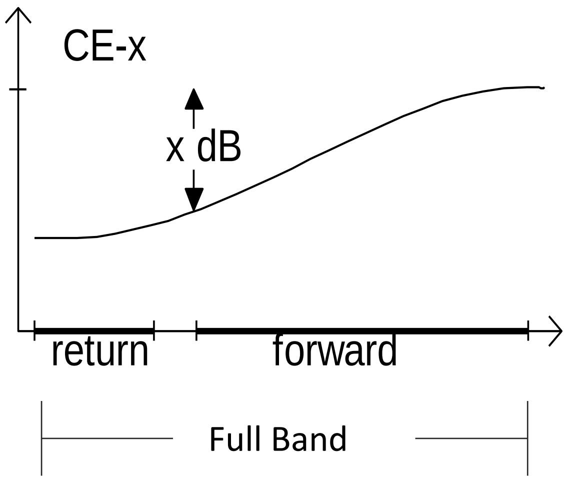
System Example #1 - After Conditioning (CSG-09)



Tap	Forward	Tilt Comp	Return	Final Results
23	23 + CSG-09 = 32dB	9dB	23dB	32dB FWD/23dB RTN

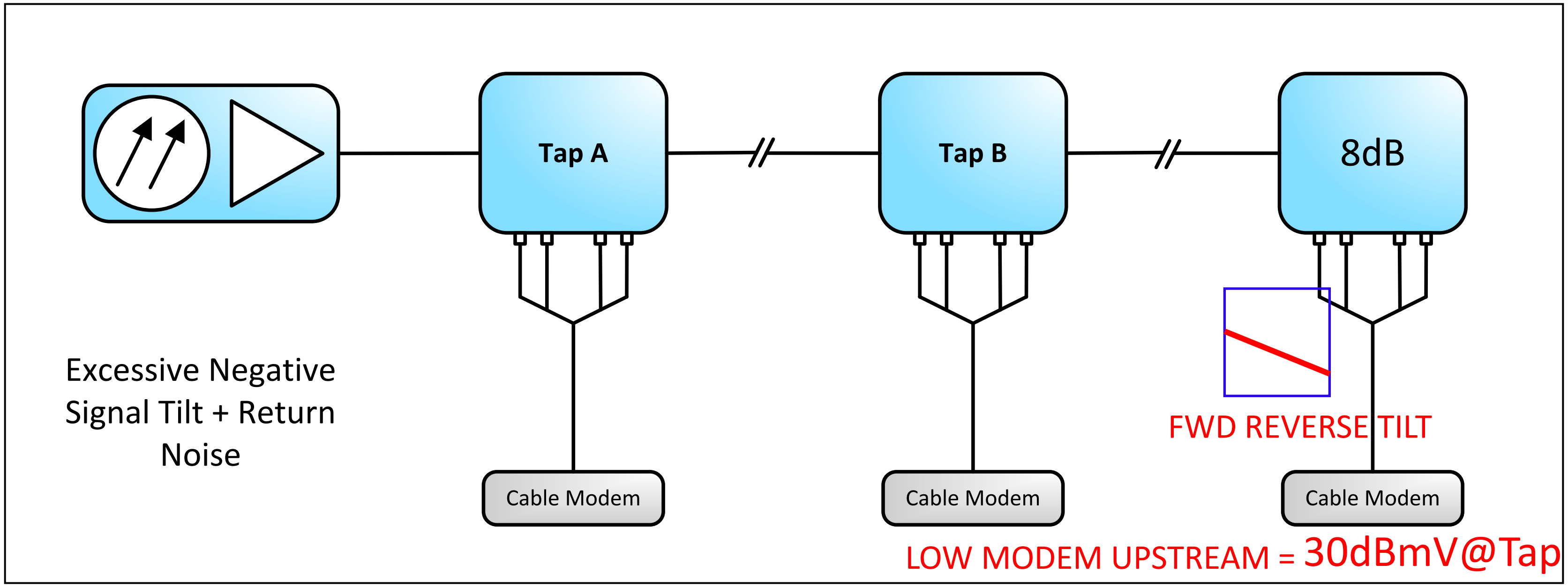
Low Tap Value – Cable Equalizer





Cable Equalizer – Used in the End of Line Tap(s)

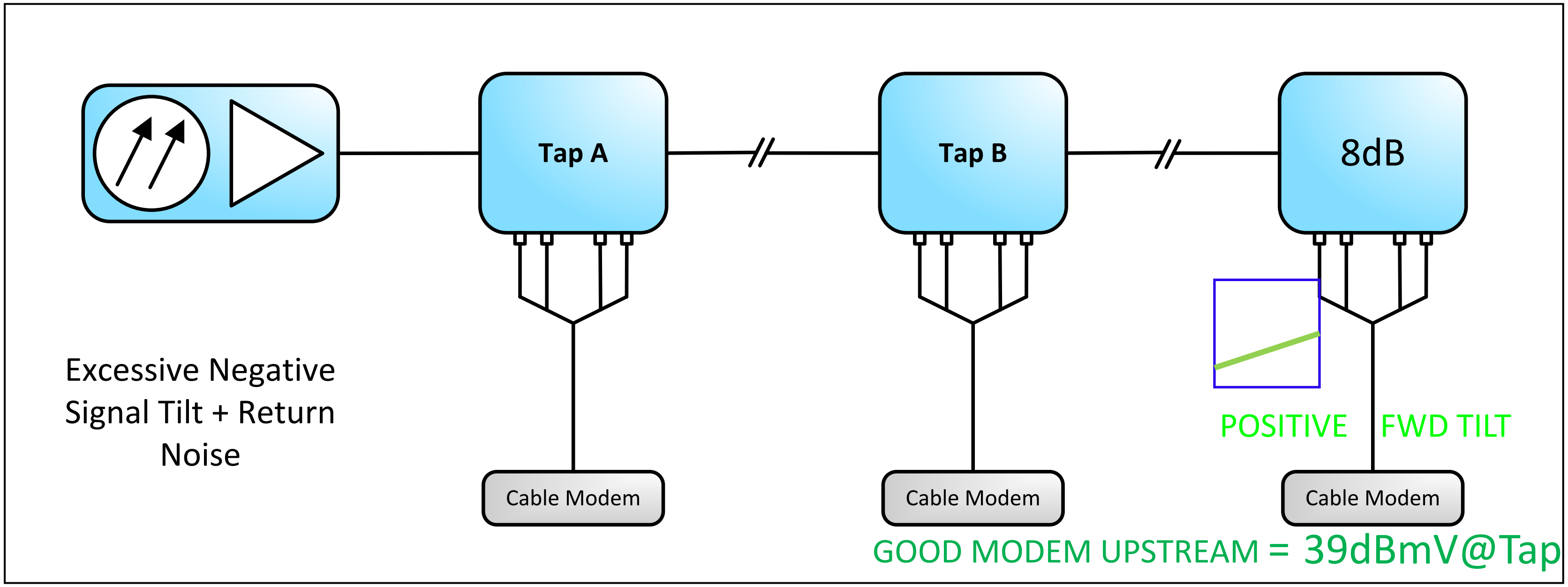
System Example #1 – Before Conditioning



1. High negative tilt at the tap ports.
2. Low Talking Modem.
3. Noise/ingress coming from these tap locations.
4. As noise is “Funnel Effect”, these locations will bring down the SNR levels for the entire node.

Cable Equalizer – Used in the End of Line Tap(s)

System Example #1 – After Conditioning (CEG-10)



Tap	Forward	Tilt Comp	Return	Results
8	8dB	9dB	8dB + CEG-10 = 17dB	8dB FWD/17dB RTN

Simple Tap String Conditioning Example

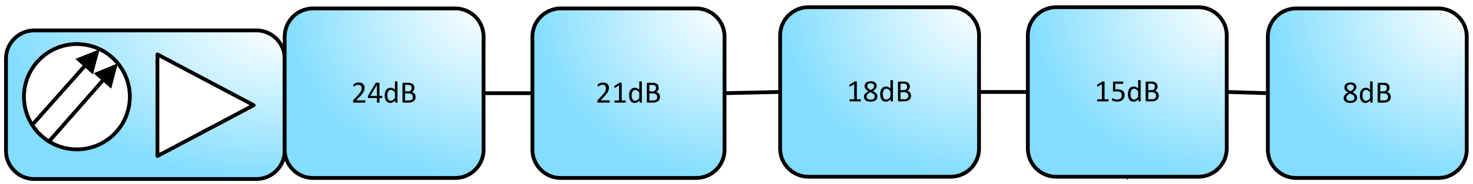
- Now let's look at typical design:
  - What are 'low talkers' and how do we cure them?
  - How do we provide better tilt at the tap?
  - How do we improve SNR performance?

Note – Moving Forward levels will either be at 860MHz/55MHz due to Actual BW and Output or 'Equivalized' to such……

Simple Tap String Conditioning Example- Before

***Levels- (860M/55M) with 18/10 dBmV min @tap, 2dB min tilt, 17dBmV Ret In**

Each span = 100 foot of .500 cable



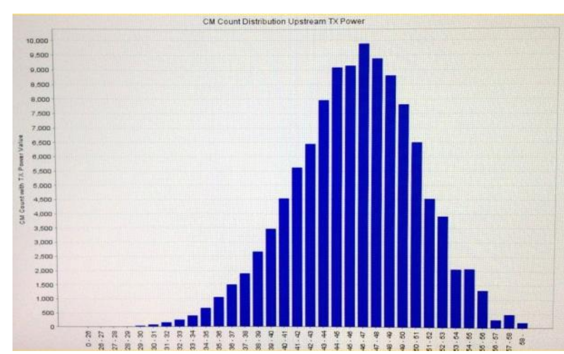
Node Output 47/34	23/10	22/12	22/14	20/15	20/18
Modem Upstream Level	41	39	37	36	30

Ret Cable Loss .50 .50 .50 .50 (2.0dB)

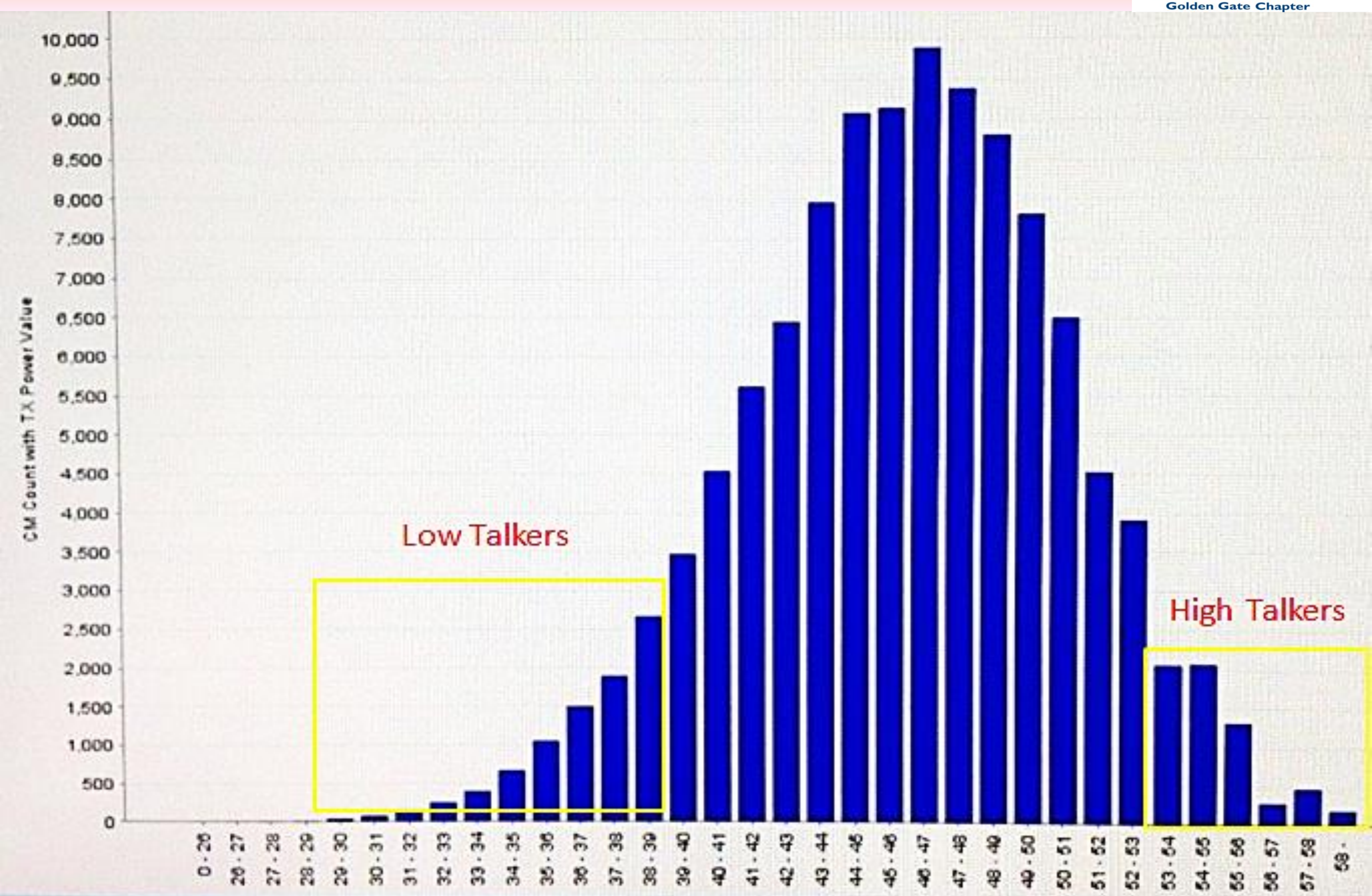
Ret Tap Insert Loss .5 .6 .7 1.3 (3.1dB)

Δ High Tap to Low Tap =16dB
Δ Modem Upstream High-Low Tap 11dB
Δ +/- 2dB Amplifier Levels = 13dB
Δ +/- 1dB Temperature Change = 14dB

Upstream Bell Graph



Cable Modem Count Distribution Upstream Transmit Power

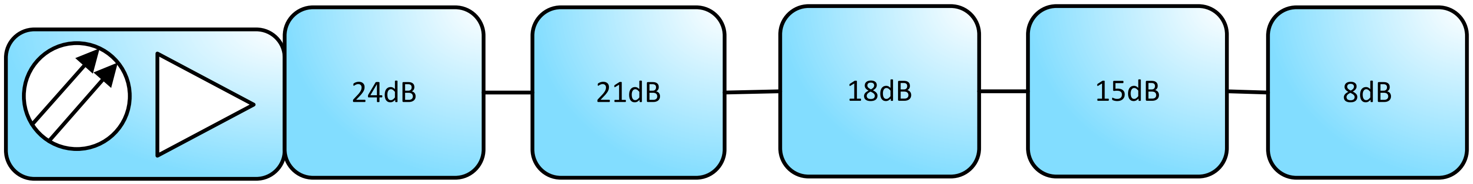


Making Two Adjustments at End of Line

System Node Example (Return Δ on Plant Side)- After Conditioning

***Levels- (860M/55M) with 18/10 dBmV min @tap, 2dB min tilt, 17dBmV Ret In**

Each span = 100 foot of .500 cable



	Node Output 47/34	23/10	22/12	22/14	20/12	19/10
Modem Upstream Level		41	39	37	40	39

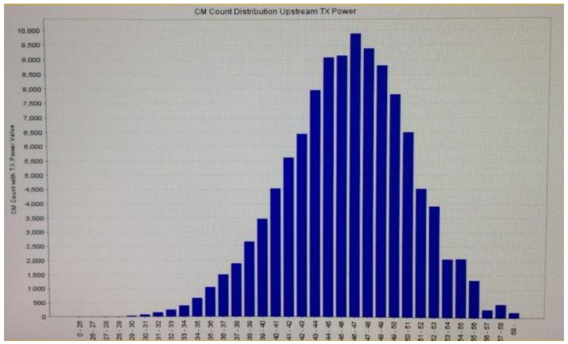
Ret Cable loss .50 .50 .50 .50 (2.0dB)

Ret Tap Insert Loss .5 .6 .7 1.3 (3.1dB)

PLUG IN (4 EQ) (10 EQ)

Δ High Tap to Low Tap =16dB
Δ Modem Upstream High-Low Tap 4dB
Δ +/- 2dB Amplifier Levels = 6dB
Δ +/- 1dB Temperature Change = 7dB

Upstream Bell Graph

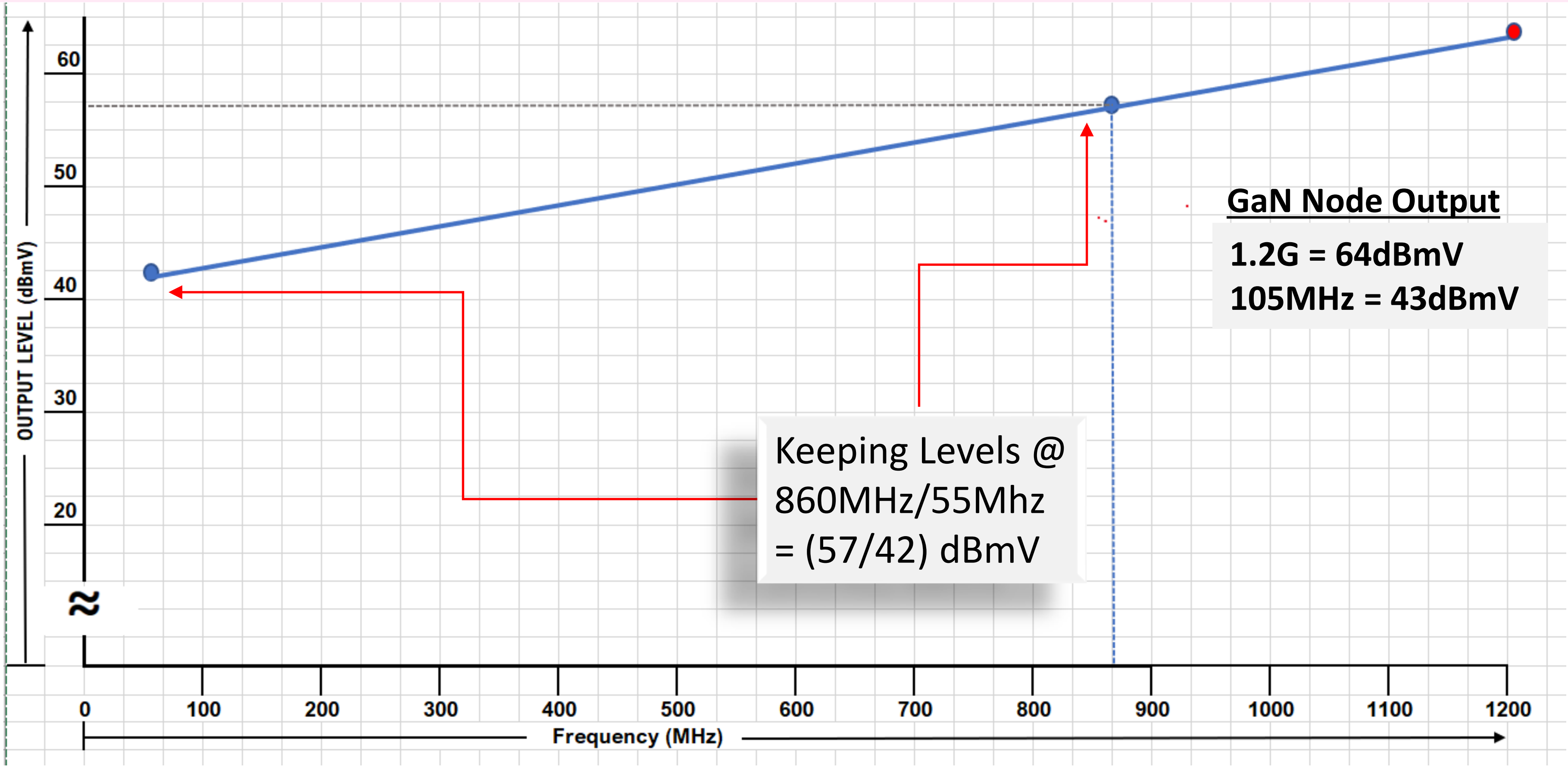


Source-Antronix -Rob Crowe, Rich Gregory

Let's examine a (Node + 0) design again:

- What can we observe about high and low value tap management?
- How can we cure loud AND low talkers?
- How can we maintain tight forward levels?
- What method/s best maintain consistent upstream level?
- Which plug-in will provide positive tilt at every tap?
- How can we maximize tap cascade increasing active efficiency, reducing CAPEX?
- How do we improve SNR by adding return path attenuation at E.O.L. taps?

Remember Our Graph of N + 0 Output….

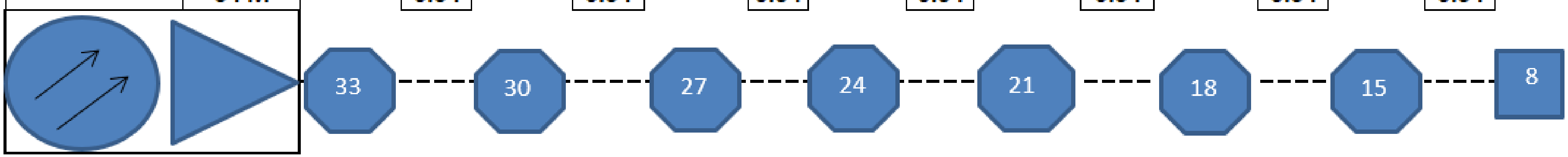


- *There are formulas or a simple Excel Graph can help 'Equivalize' 1218MHz/105MHz Outputs to 860MHz/55MHz (as illustrated above)*

System Node Example - No Conditioning (Return Δ on Plant Side)

***Levels- (860M/55M) with 18/11 dBmV min @tap, 4dB min tilt, 13dBmV Ret In, 43dBmV Max Modem Upstream Level at Tap**

Node Output	860 M	57													
	54 M	42													
Tap Insertion Loss	860 M	0.9		0.9		1.2		1.3		1.5		2.5		4.1	
	54 M	0.2		0.2		0.4		0.5		0.7		1.2		3.2	
Cable Loss	860 M		2.34		2.34		2.34		2.34		2.34		2.34		2.34
	54 M		0.54		0.54		0.54		0.54		0.54		0.54		0.54



Tap Output	860 M	24	23.8	23.5	23	22.3	21.5	19.7	20.0
	54 M	9	11.3	13.5	15.6	17.5	19.3	20.6	24.0
Modem Return		46	43.7	41.5	39	37.5	35.7	34	31

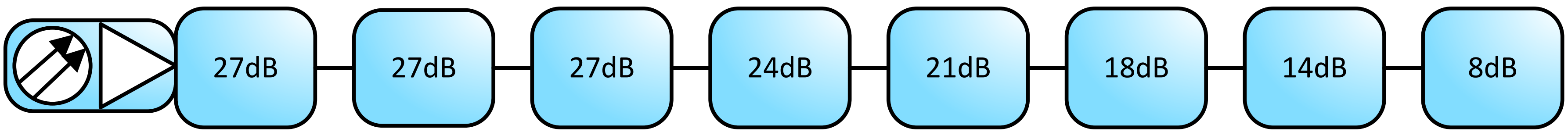
Δ High Tap to Low Tap =25
Δ Modem Upstream = 15
Δ +/- 2dB Amplifier Levels = 17
Δ +/- 1dB Temperature Change = 18

Now an 8 Tap String with Conditioning

System Node Example - With Conditioning (Return Δ on Plant Side)

***Levels- (860M/55M) with 18/11 dBmV min @tap, 4dB min tilt, 13dBmV Ret In, 43dBmV Max at Tap**

Node Output
57/42



Tap Level	20/15	20/14	19.5/12.5	22/14	21/16	19/14	18/13	19/15
E-Option	CS-09	CS-06	CS-03	JMP	JMP	CE-02	CE-06	CE-09
Modem Return	**40**	**41**	**42.5**	**41**	**40**	**40**	**42**	**41**

Previous - No Condition

Δ High Tap to Low Tap =25
Δ Modem Upstream = 15
Δ +/- 2dB Amplifier Levels = 17
Δ +/- 1dB Temperature Change = 18

This Example with Conditioning

Δ High Tap to Low Tap =19dB
Δ Modem Upstream = 2.5dB
Δ +/- 2dB Amplifier Levels = 4.5dB
Δ +/- 1dB Temperature Change = 5.5dB

Reviewing the First Tap String we Started with – No Conditioning

Amplifier Output (dBmV)	860	49
	55	37

Cable Loss		860		2.3		2.3		2.3		2.3		2.3	
		55		0.53		0.53		0.53		0.53		0.53	
Tap Insertion Loss		860	1.4		1.4		2.1		1.6		3		
		55	0.7		0.7		1.2		1.1		1.8		
Return (dBmV)	16		26		23		21		17		14		8
			26		23		21		17		14		8
		(MHz)											
No Conditioner Tap Levels	HI	860	23		22.3		20.6		20.2		19.3		20
	LO	55	11		12.8		13.5		15.8		17.2		20.9
No Conditioner Modem Tx (dBmV)			42		40.2		39.5		37.2		35.8		32.2

Reviewing the First Tap String we Started with - Conditioned

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Amplifier Output (dBmV)		860	49					
		55	37					
Cable Loss		860		2.3	2.3	2.3	2.3	2.3
		55		0.53	0.53	0.53	0.53	0.53
Tap Insertion Loss		860	1.4	1.4	2.1	1.6	3	
		55	0.7	0.7	1.2	1.1	1.8	
Return (dBmV)	16		26	23	21	17	14	8
			26	23	21	17	14	8
		(MHz)						
No Conditioner Tap Levels	HI	860	23	22.3	20.6	20.2	19.3	20
	LO	55	11	12.8	13.5	15.8	17.2	20.9
No Conditioner Modem Tx (dBmV)			42	40.2	39.5	37.2	35.8	32.2
Conditioner Insertion Loss	HI	860	2.7	2.7			0.9	1.2
	LO	55	0.1	0.1			3.9	7.3
			(3 csg)	***(3csg)***	***(jmp)***	***(jmp)***	***(4ceg)***	***(8ceg)***
Conditioner Tap Levels	HI	860	20.3	19.6	20.6	20.2	18.4	18.8
	LO	55	10.9	12.7	13.5	15.8	13.3	13.6
Conditioner Modem Tx (dBmV)			42.1	40.3	39.5	37.2	39.7	39.5

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Removing some Clutter

Amplifier Output (dBmV)		
	860	49
	55	37

Cable Loss		860		2.3	2.3	2.3	2.3	2.3
		55		0.53	0.53	0.53	0.53	0.53
Tap Insertion Loss		860	1.4	1.4	2.1	1.6	3	
		55	0.7	0.7	1.2	1.1	1.8	
Return (dBmV)	16		26	23	21	17	14	8
			26	23	21	17	14	8
Conditioner Insertion Loss	HI	860	2.7	2.7			0.9	1.2
	LO	55	0.1	0.1			3.9	7.3
			(3 csg)	***(3csg)***	***(jmp)***	***(jmp)***	***(4ceg)***	***(8ceg)***
Conditioner Tap Levels	HI	860	20.3	19.6	20.6	20.2	18.4	18.8
	LO	55	10.9	12.7	13.5	15.8	13.3	13.6
Conditioner Modem Tx (dBmV)			42.1	40.3	39.5	37.2	39.7	39.5

Δ High Tap to Low Tap =18dB
Δ Modem Upstream = 4.9dB
Δ +/- 2dB Amplifier Levels = 6.9dB
Δ +/- 1dB Temperature Change = 7.9dB

Want this tighter? Next slide....

Can add CEG-2 on 17 two way to reduce delta

Amplifier Output (dBmV)		860	49					
		55	37					
Cable Loss		860		2.3	2.3	2.3	2.3	2.3
		55		0.53	0.53	0.53	0.53	0.53
Tap Insertion Loss		860	1.4	1.4	2.1	1.6	3	
		55	0.7	0.7	1.2	1.1	1.8	
Return (dBmV)		16	26	23	21	17	14	8
			26	23	21	17	14	8
Conditioner Insertion Loss	HI	860	2.7	2.7		0.9	0.9	1.2
	LO	55	0.1	0.1		2.7	3.9	7.3
			(3 csg)	***(3csg)***	***(jmp)***	***(2ceg)***	***(4ceg)***	***(8ceg)***
Conditioner Tap Levels	HI	860	20.3	19.6	20.6	19.3	18.4	18.8
	LO	55	10.9	12.7	13.5	13.1	13.3	13.6
Conditioner Modem Tx (dBmV)			42.1	40.3	39.5	39.9	39.7	39.5

<u>Previous Example</u>

Δ High Tap to Low Tap =18dB
Δ Modem Upstream = 4.9dB
Δ +/- 2dB Amplifier Levels = 6.9dB
Δ +/- 1dB Temperature Change = 7.9dB

<u>This Example (2 ceg add)</u>

Δ High Tap to Low Tap =18dB
Δ Modem Upstream = 2.6dB
Δ +/- 2dB Amplifier Levels = 4.6dB
Δ +/- 1dB Temperature Change = 5.6dB

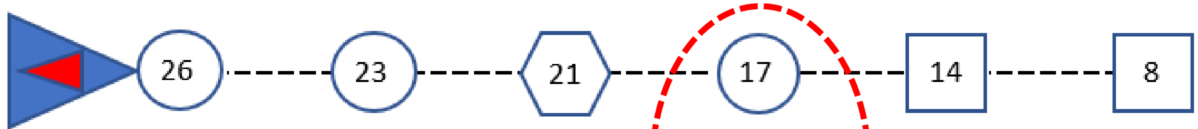
What if Later a New Directive Comes In?

Amplifier Output (dBmV)		
	860	49
	55	37

Cable Loss					
860	2.3	2.3	2.3	2.3	2.3
55	0.53	0.53	0.53	0.53	0.53

Tap Insertion Loss					
860	1.4	1.4	2.1	1.6	3
55	0.7	0.7	1.2	1.1	1.8

Return (dBmV)	16



			26	23	21	17	14	8
Conditioner Insertion Loss	HI	860	2.7	2.7		0.9	0.9	1.2
	LO	55	0.1	(		2.7	3.9	7.3
			(3 csg)	(3		2ceg)	(4ceg)	(8ceg)
Conditioner Tap Levels	HI	860	20.3	19.6	20.6	19.3	18.4	18.8
	LO	55	10.9	12.7	13.5	13.1	13.3	13.6
Conditioner Modem Tx (dBmV)			42.1	40.3	39.5	39.9	39.7	39.5

New Directive – Max Modem Tx @ Tap = 40.5dBmV

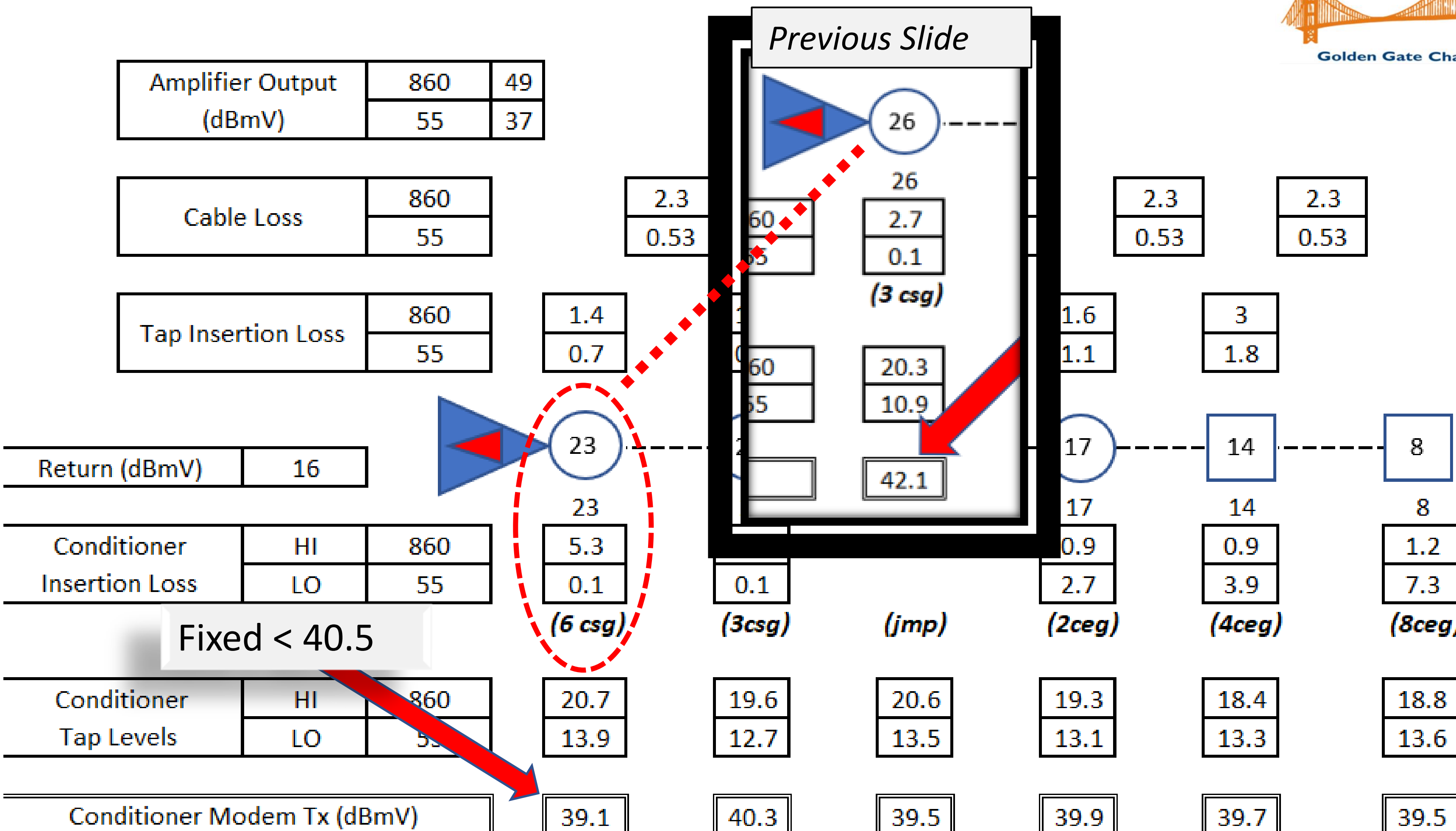
Previous Example

Δ High Tap to Low Tap =18dB
Δ Modem Upstream = 4.9dB
Δ +/- 2dB Amplifier Levels = 6.9dB
Δ +/- 1dB Temperature Change = 7.9dB

This Example (2 ceg add)

Δ High Tap to Low Tap =18dB
Δ Modem Upstream = 2.6dB
Δ +/- 2dB Amplifier Levels = 4.6dB
Δ +/- 1dB Temperature Change = 5.6dB

Drop 1st Plate and increase Cable Sim- 40.5 max Tx



Previous Example
Δ High Tap to Low Tap =18dB
Δ Modem Upstream = 2.6dB
Δ +/- 2dB Amplifier Levels = 4.6dB
Δ +/- 1dB Temperature Change = 5.6dB

This Example (Delta Drops = Tighter Design)
Δ High Tap to Low Tap =15dB
Δ Modem Upstream =1.2dB
Δ +/- 2dB Amplifier Levels = 3.2dB
Δ +/- 1dB Temperature Change = 4.2dB

Can Take 2 CEG Back Out if Desired – Slight Increase to Delta

Amplifier Output (dBmV)		
	860	49
	55	37

			Tap 1 (23)		Tap 2 (23)		Tap 3 (21)		Tap 4 (17)		Tap 5 (14)		Tap 6 (8)
Cable Loss		860		2.3		2.3		2.3		2.3		2.3	
		55		0.53		0.53		0.53		0.53		0.53	
Tap Insertion Loss		860	1.4		1.4		2.1		1.6		3		
		55	0.7		0.7		1.2		1.1		1.8		
Return (dBmV)	16		23		23		21		17		14		8
			23		23		21		17		14		8
Conditioner Insertion Loss	HI	860	5.3		2.7						0.9		1.2
	LO	55	0.1		0.1						3.9		7.3
			(6 csg)		*(3csg)*		*(jmp)*		*(jmp)*		*(4ceg)*		*(8ceg)*
Conditioner Tap Levels	HI	860	20.7		19.6		20.6		20.2		18.4		18.8
	LO	55	13.9		12.7		13.5		15.8		[illegible]		13.6
Conditioner Modem Tx (dBmV)			39.1		40.3		39.5		37.2		39.7		39.5

Δ High Tap to Low Tap =15dB
Δ Modem Upstream =3.1dB
Δ +/- 2dB Amplifier Levels = 5.1dB
Δ +/- 1dB Temperature Change = 6.1dB

Save Jumpers for these Cases

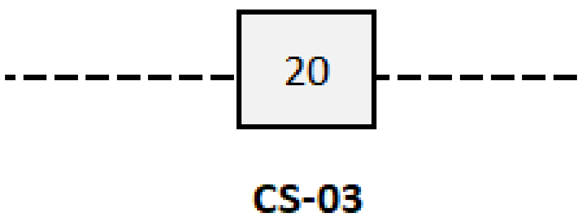
So, We Can See the Design Flexibility, but What about Auto-Cad?

Can this be Designed in Auto-Cad ?

- Yes, All the Major Design Platforms are Capable of Loading Conditioner Types
    - The Design Software states which Conditioner to use in the same way it determines Tap Value
    - Conditioners are small ‘plug ins’ – like a small eq
    - Note – Same is true for ‘Window Taps’ which is really ‘Fixed Conditioned’ Taps
    - Window Taps create a much larger inventory of taps, vs. Standard Tap values and conditioner

Identification Example

- **Typical Print Notation**



- **Typical Tap Notation**

- Typical reference on network design print will denote ***conditioned tap value*** below conditioner type and value

- Affix label to tap plate as shown
- Tap will denote ***original value*** alongside value and type of installed conditioner

Conclusion

- *Conditioning offers greater design flexibility, yielding consistency in both forward and return levels*
- *This in turn nets superior performance and reduces Capex by allowing the longest tap strings possible (Buy less Nodes & Amps)*
- *Greater Symmetry tap to tap affords tightening of whole house check windows, which in turn; reduce Opex & raise NPS*
- *Training Technicians is made easier by not having to explain a myriad of levels and tilts*

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Thanks for Your Time


Wake up
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