Cable Channel Modeling Based on Chinese MSO's Network

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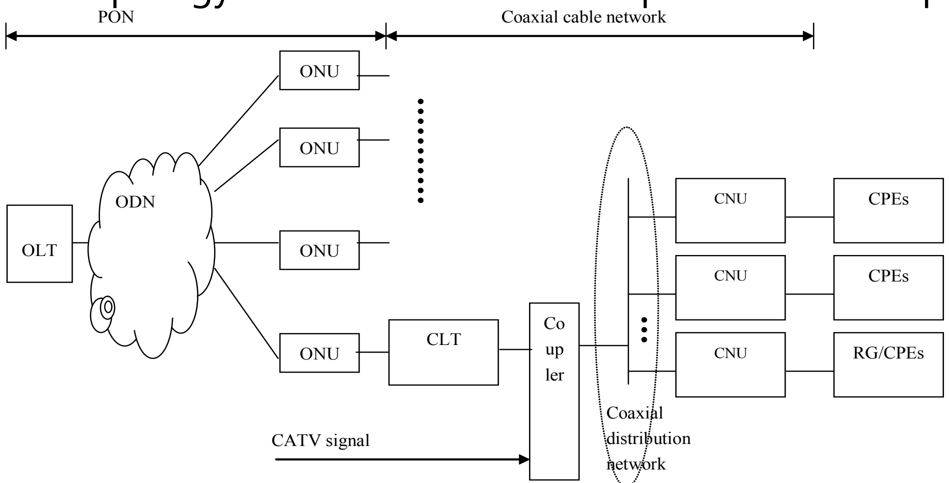
Objectives

- Develop a multi-path (adjacent matrix) modeling method for EPOC cable channel modeling.
- Perform lots of lab tests to verify our modeling algorithm based on Chinese MSO’s network topologies and components.
- Cooperate with Chinese MSOs and Broadcom to test XFBN and ZSCN’s networks and provide simulation results on micro-reflection and SNR estimation to be used in their presentations.

Common Cable Access Network Topologies and Components

Cable Access Network Topology

- The PON+EOC topology defined in the EOC requirement whitepaper of SARFT in 2009.



- With PON as the optical access technology, EOC technology mainly cover the last few hundred meters cable network.
- The maximum subscribers coverage of ONU/CLT should be less than 200 households, and will gradual reduce to 50 households or even 20households.
  - 200 users scenario is usually for fiber-to-the-residential curb. **Node+1**, one amplifier behind the analogue optical receiver
  - 50 users scenario is for fiber-to-the-building-unit (MDU). **Node+0**, without amplifier behind the optical receiver.

Trunk/Drop Cable

Max loss parameter(20° C), dB/100m

Cable type	Frequency					
	5MHz	50MHz	200MHz	550MHz	800MHz	1000MHz
SYWV-75-5-I	2	4.7	9	15.8	19	22
SYWV-75-5 (RG6)	2.2	4.8	9.7	16.8	20.3	24.2
SYWV-75-7-I SYWY-75-7-I	1.3	3	5.8	10.3	12.8	14.4
SYWV-75-7 (RG11) SYWY-75-7	1.5	3.2	6.4	10.7	13.3	15.1
SYWV-75-9-I SYWY-75-9-I	1	2.3	4.5	8	9.9	11.3
SYWV-75-9 (412) SYWY-75-9	1.2	2.4	5	8.5	10.4	11.9
SYWLY-75-9-I	1	2.3	4.5	8	9.9	11.3
SYWLY-75-9	1.2	2.4	5	8.5	10.4	11.9
SYWLY-75-12-I	0.6	1.7	3.5	6	7.4	8.5
SYWLY-75-12	0.7	1.9	3.9	6.7	8.2	9.5
SYWLY-75-13-I	0.5	1.5	3	5.2	6.3	8
SYWLY-75-13	0.6	1.6	3.2	5.4	6.6	8.4

According to: GY/T 135-1998 Cable system physical foam polyethylene dielectric coaxial cable network conditions and test methods

TAP/Splitter

- The splitter and TAP specifications defined by SARFT are consistent with SCTE standards. The TAP/splitter parameters used in Chinese MSO network are similar with that of NA network.
  - --e.g. GY/T 137-1999 Cable system Splitters and Taps (5-1000MHz) network technical conditions and measurement methods
  - --e.g. ANSI/SCTE 153 2008 Drop Passives: Splitters, Couplers and Power Inserters
- Splitters in Chinese MSO network
  - SP2 (Splitter 2), SP3, SP4, SP8, SP10, SP14, SP16, etc.,
  - With metric F female connector, and 75ohm match
- Taps in Chinese MSO network
  - TAP8(1) – one 8dB tap loss branch , TAP10/12/14/16/18/20(1)
  - TAP8(2), TAP10(2), TAP12/14/16/18/20/22(2)
  - TAP10/12/14/16/18/20/22(3), TAP12/16/20/24(4), etc.,
- There are splitters integrated with 5-65MHz upstream diplexers that are used for passive baseband EOC.

Amplifiers

- There are many kinds of CATV amplifiers in Chinese MSO's network.
- We selected one building amplifier in our modeling. The upstream (reverse path) of this kind of amplifier is bypassed with a jumper and usually used in HPAV EOC network.

Items	Downstream	Upstream
Spectrum range	54/87-860MHz	5-42/65MHz
Standard Gain	24dB	-4dB
Standard output level	102dBuV	-
Maximum output level	110 dBuV	-
NF	<8dB	-
CTB	>63dB	-
CSO	>63dB	-
Group delay	<10ns(112.25MHz/116.68MHz)	-
Tilt control	0~20dB adjustable	-

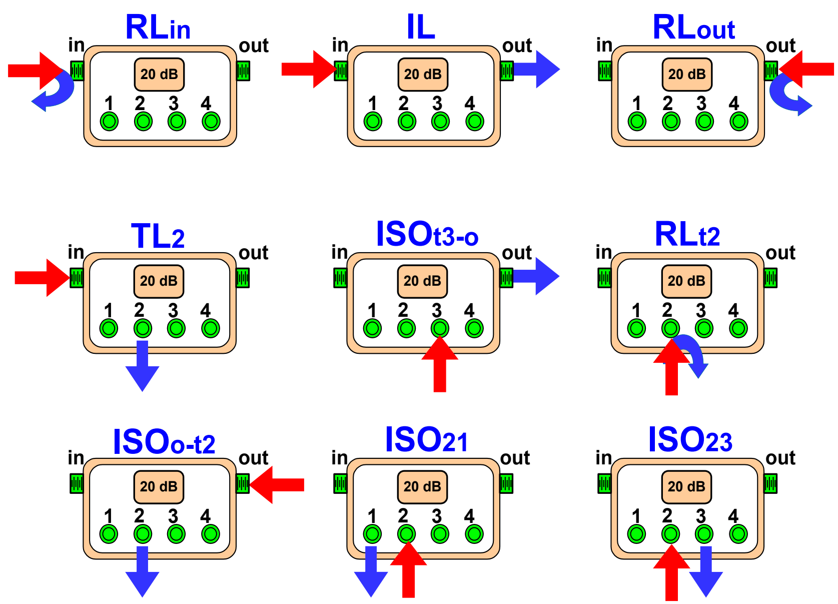
Component Parameters Test/Modeling and Network Modeling Algorithm

Coaxial Cable Test and Modeling

- According SARFT standard, we tested and modeled 3 types of coaxial cables
  - SYWV-75-5, SYWV-75-7, SYWV-75-9
- Coaxial cable propagation function: $H(f) = e^{-\gamma(f)l} = e^{-\alpha(f)l} \cdot e^{-j\beta(f)l}$
  - α(dB/100m) is the insertion loss of coaxial cable; it can be expressed as follow
    $\alpha = \alpha_1 + \alpha_2 = k_1\sqrt{f} + k_2 f$
  - β is the phase constant: $\beta = \frac{2\pi f l}{c\sqrt{\varepsilon_r}}$
- Test/modeling
  - Method1: Given the κ_1、κ_2、ε_r parameters of each type of cables, we can calculate the propagation characteristic of coaxial cables.
  - Method2: With the experimental measuring and curve fitting, we can obtain the parameters.

TAP/Splitter Test

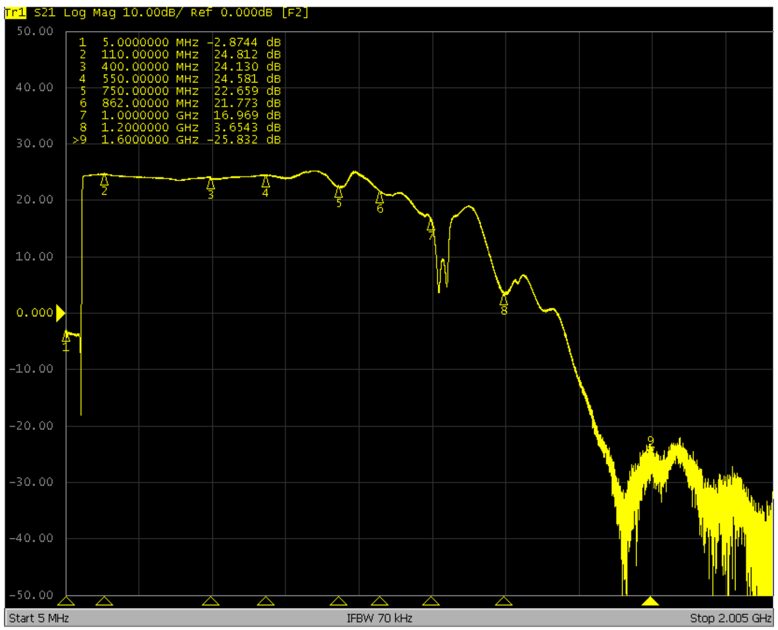
- The main S (amplitude-frequency) parameters of TAP/Splitter are insertion loss/tap loss/input return loss/output return loss/tap return loss/tap-output isolation/tap-tap isolation, etc. The parameters shows in below figure.



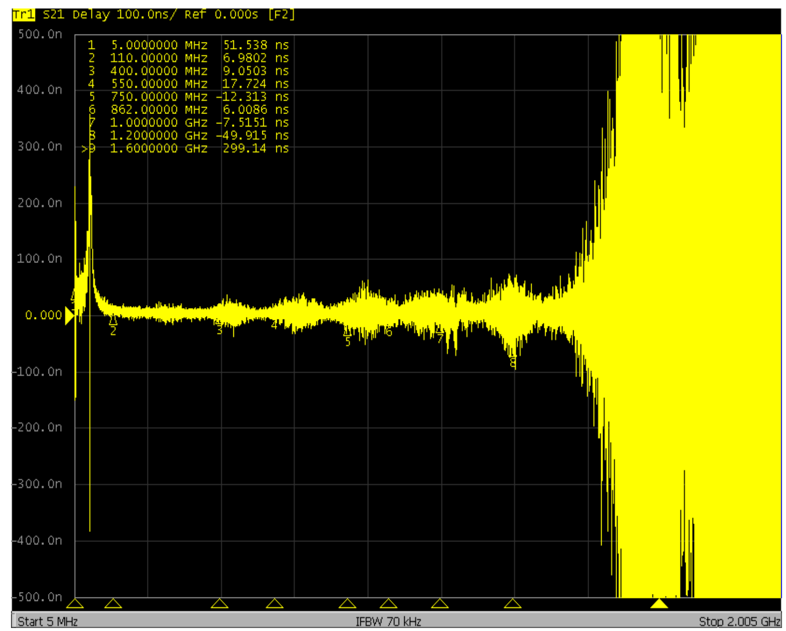
- We can test the S parameters and phase-frequency parameters of all kinds of TAP/splitters with a network analyzer and use these parameters in our channel modeling.

Amplifier Test

- The amplifier is also tested with a Network Analyzer
  - We tested with Agilent network analyzer E5071C at 20,001 points
  - Tested 5M-2005MHz with 0.1MHz resolution S11/S21/S12/S22 parameters and phase parameters, and saved as *.s2p files.
- We tested one building amplifier. Examples are shown in the figures below:



S21 parameter



Group delay (can be converted from phase parameter)

TAP/Splitter/AMP Modeling

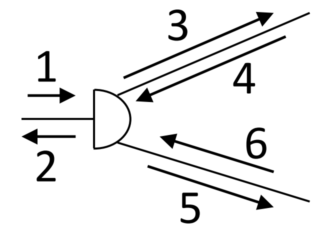
The Reflection /Transmission- coefficient matrix A

- Based on the experimental measurement， we can get the transmission characteristic (loss) between any two ports of the splitter/tap/AMP， and the reflection characteristic at each port, then consists the **reflection /transmission- coefficient matrix A**.
- **In this model, we deal the Splitter/Tap/AMP as a box with some ports, we should know the characteristic of any port.**

$$A(f_x) = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1N} \\ a_{21} & a_{22} & \cdots & a_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ a_{N1} & a_{N2} & \cdots & a_{NN} \end{bmatrix}$$

a_{ji} : the loss of signal from port i to port j.
it is a complex, the real part is converted from S parameter, and its imaginary part is converted from phase response

E.g.

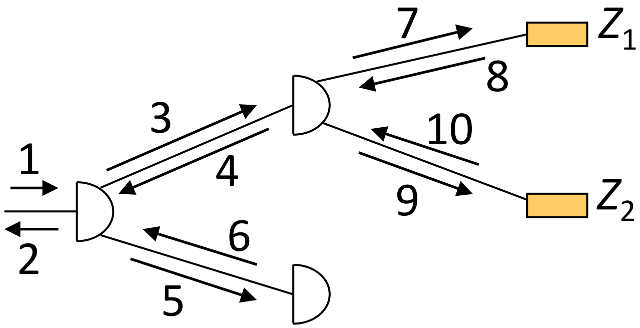


a31:transmission coefficient
a43:reflection coefficient
All coefficient consist of S parameter(real part) and phase response (imaginary part)

Cable Network Modeling Algorithm -1

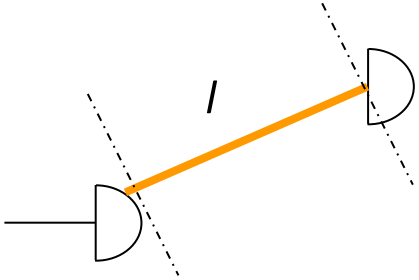
- **Multi-path model (Adjacent matrix) algorithm**
  - Reflection /transmission- coefficient matrix A

$$A(f_x) = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1N} \\ a_{21} & a_{22} & \cdots & a_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ a_{N1} & a_{N2} & \cdots & a_{NN} \end{bmatrix}$$



  - Coaxial cable loss matrix D

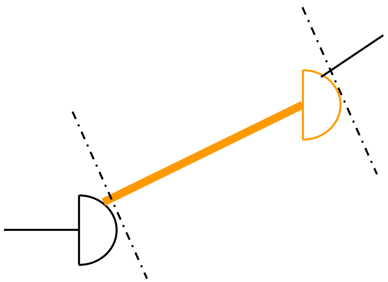
$$D(f_x) = \begin{bmatrix} e^{-\gamma(f_x)l_1} & 0 & \cdots & 0 \\ 0 & e^{-\gamma(f_x)l_2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & e^{-\gamma(f_x)l_N} \end{bmatrix}$$



Cable Network Modeling Algorithm -2

- **Unit loss matrix P**

$$P(f_x) = A(f_x)D(f_x) = \begin{bmatrix} a_{11}e^{-\gamma(f_x)l_1} & a_{12}e^{-\gamma(f_x)l_2} & \cdots & a_{1N}e^{-\gamma(f_x)l_N} \\ a_{21}e^{-\gamma(f_x)l_1} & a_{22}e^{-\gamma(f_x)l_2} & \cdots & a_{2N}e^{-\gamma(f_x)l_N} \\ \vdots & \vdots & \ddots & \vdots \\ a_{N1}e^{-\gamma(f_x)l_1} & a_{N2}e^{-\gamma(f_x)l_2} & \cdots & a_{NN}e^{-\gamma(f_x)l_N} \end{bmatrix}$$



Using the Adjacent matrix P (f_x), all multi-paths from transmitter to receiver can be analyzed.

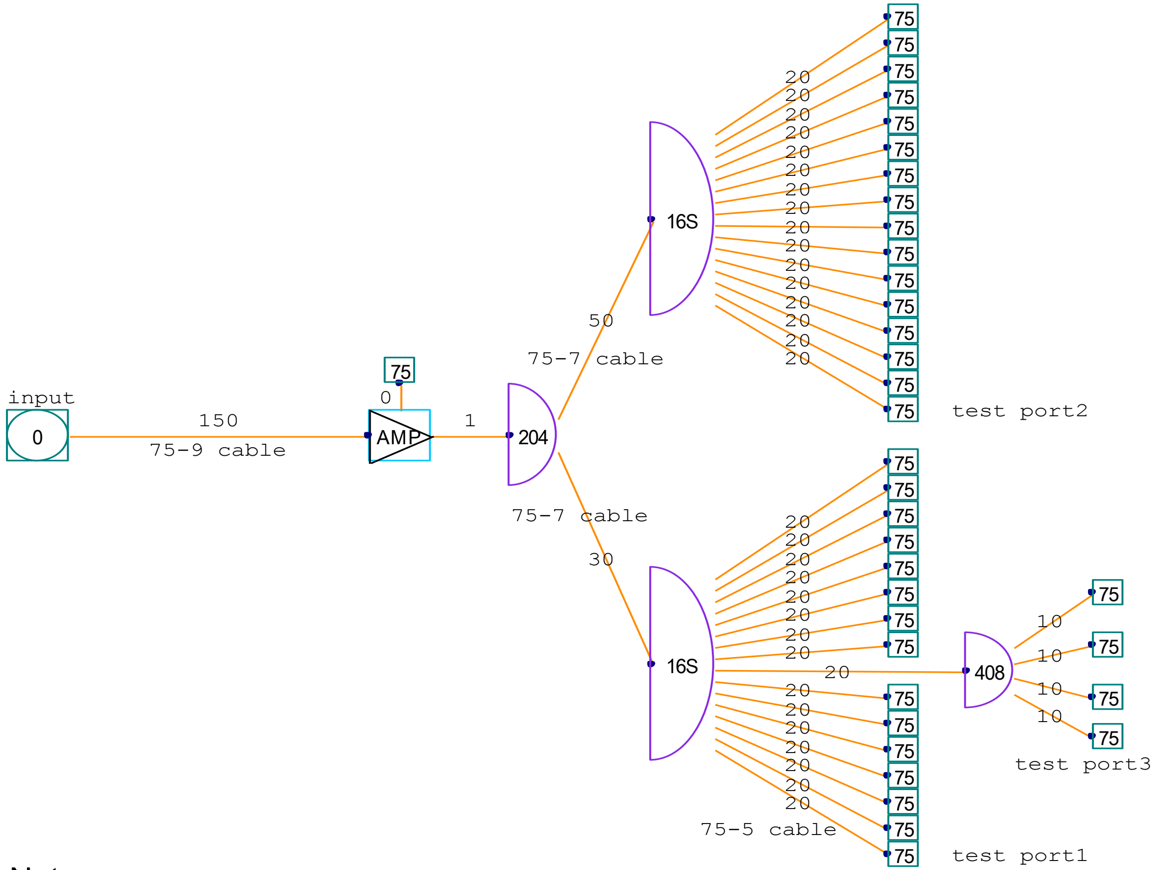
$P(f_x)^k$:all the paths passed k units.

- **Transfer function H (add multi- path signals)**

$$H(f) = \sum_{i=1}^{k} H_k(f) = \sum_{i=1}^{k} P(f_x)^k$$

Insertion Loss/Group Delay/Micro-Reflection Simulation Results under Lab Environment

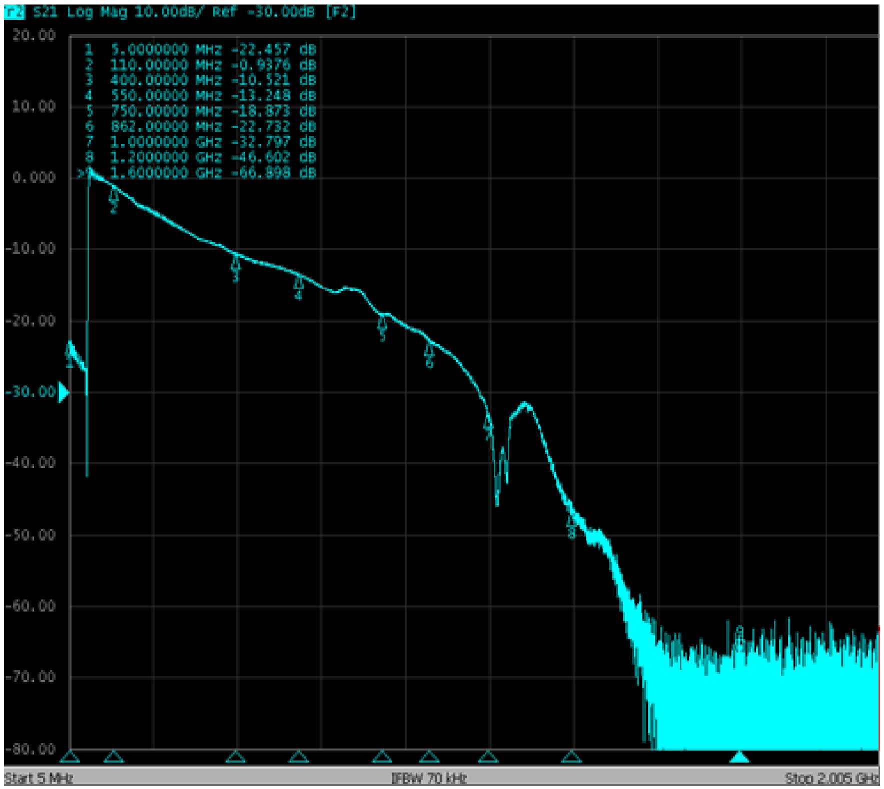
Scenario1: Node+1



Notes:
•75 means 75ohm match
• all lines between TAP/splitters are coaxial cable. SYWV-75-9/SYWV-75-7/SYWV-75-5.
• The number on the line means the length of cable. (e.g. 150 means 150meters length)
• We tested data at ZSCN's lab.

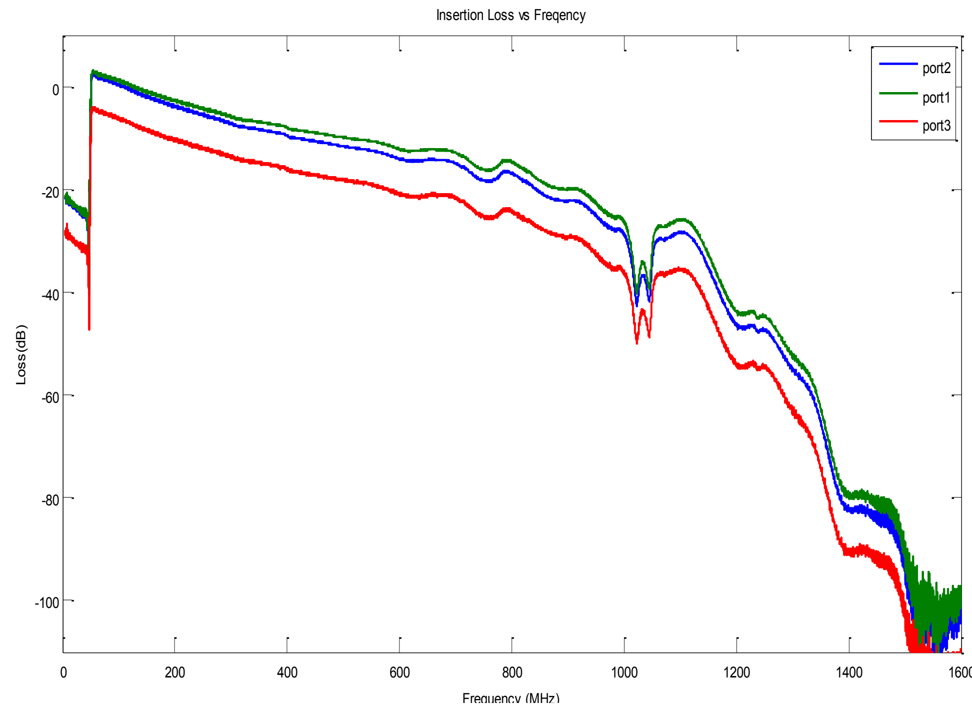
Insertion Loss Test /Simulation Results

Transmission loss (site1- site2)



Tested at ZSCN's Lab

Simulation results

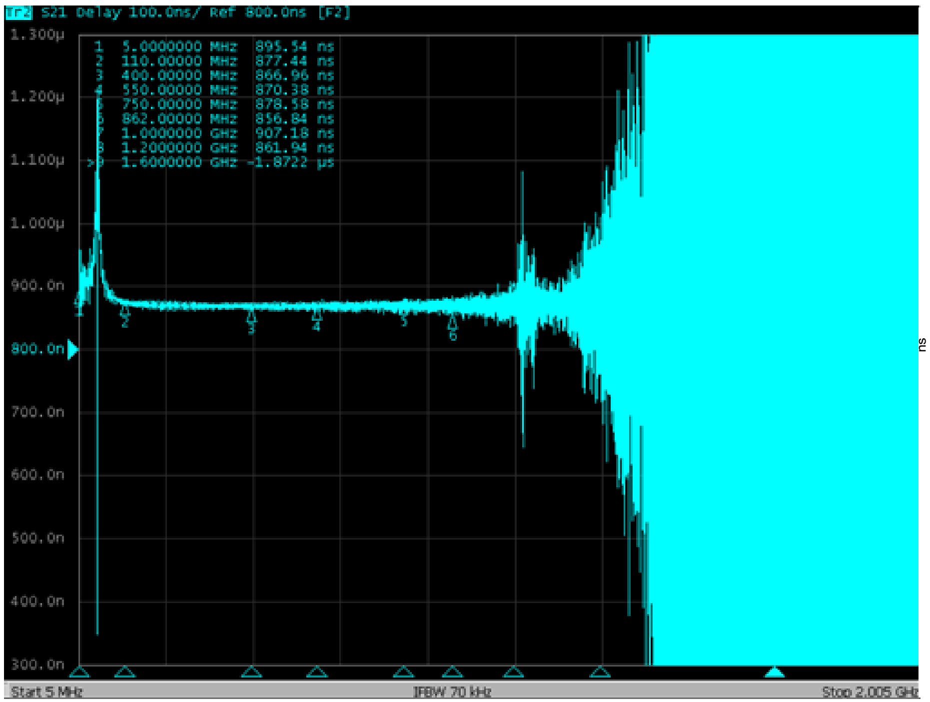


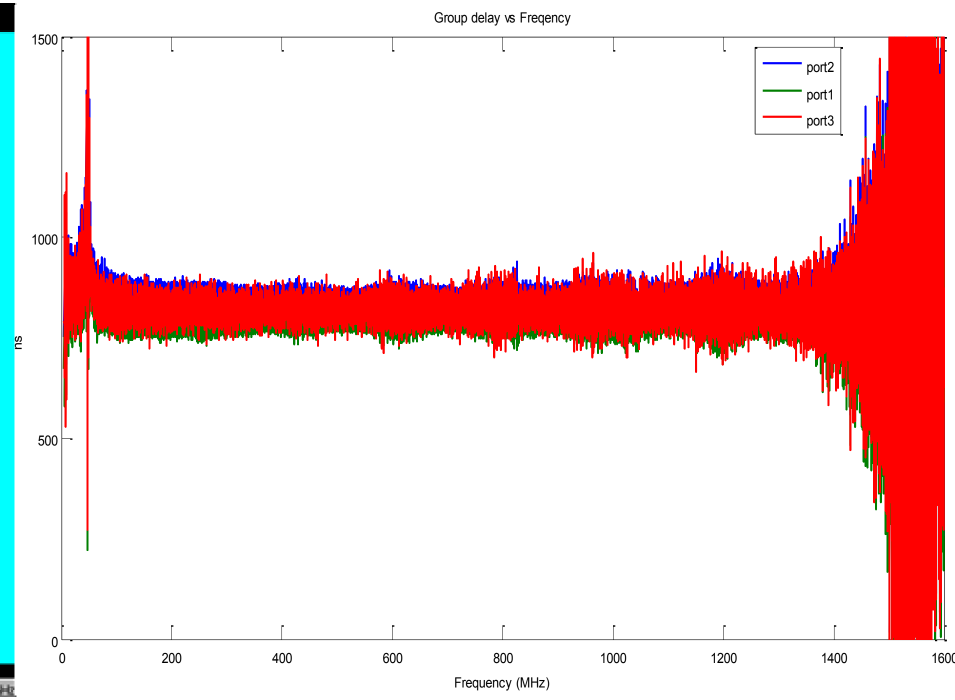
Insertion loss Vs frequency

Group Delay Test/Simulation Results

Group delay (site1- site2)

Simulation results

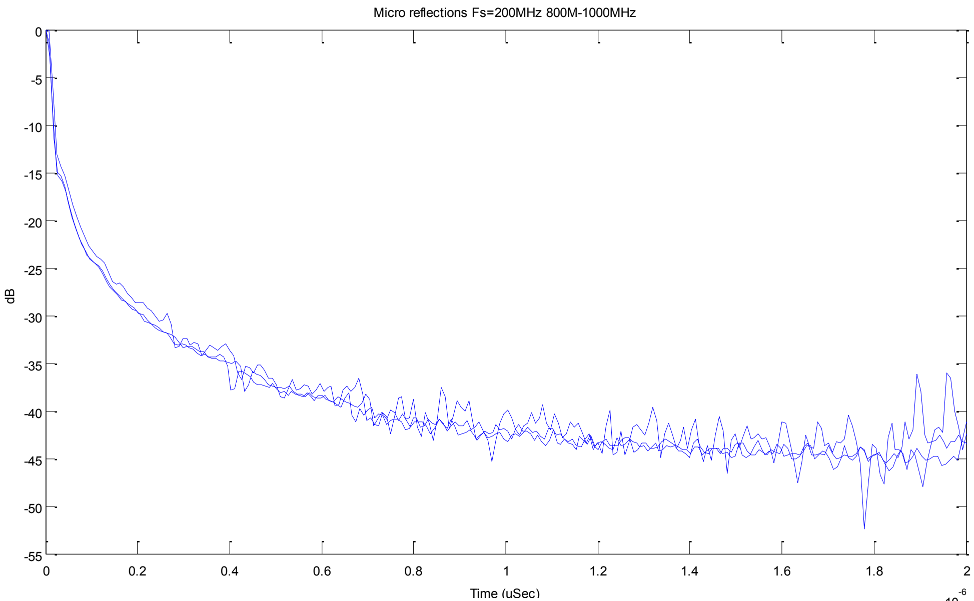


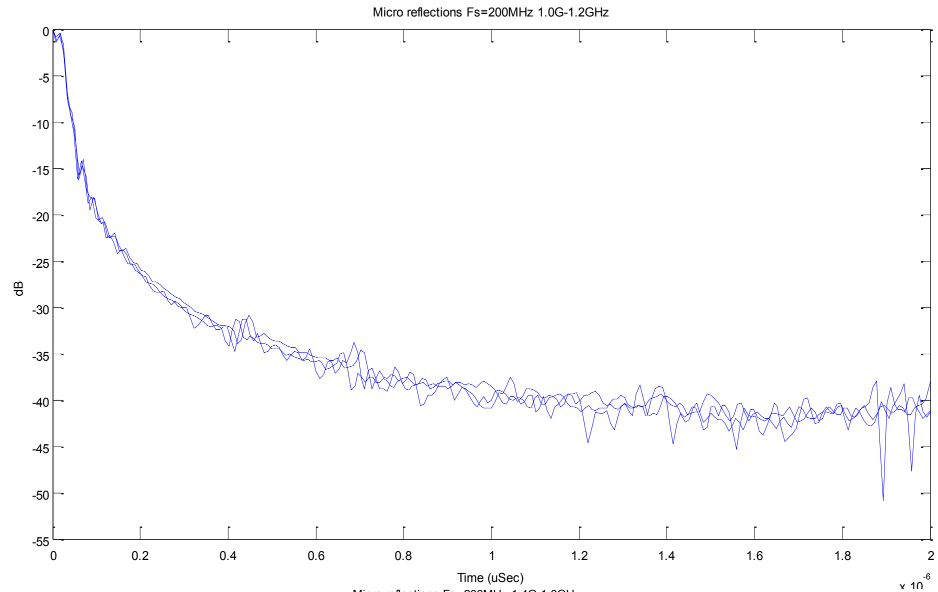


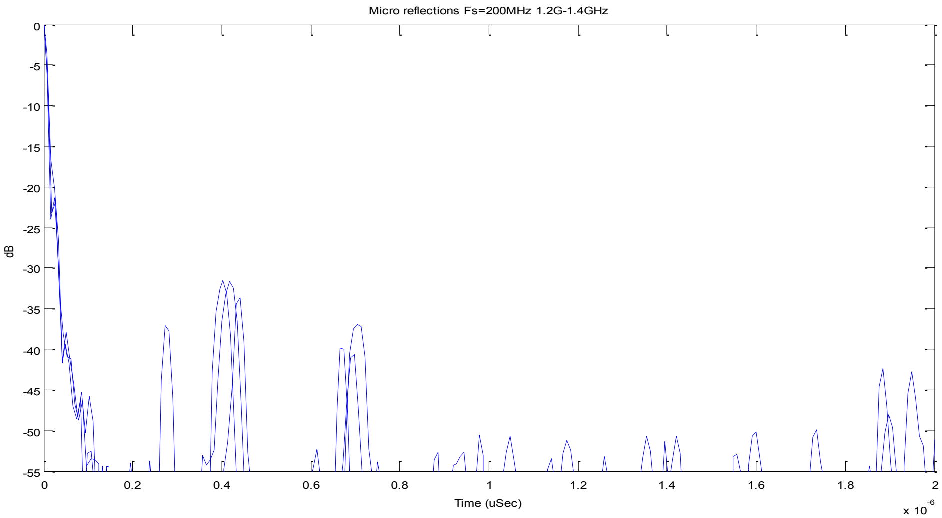
Tested at ZSCN's Lab

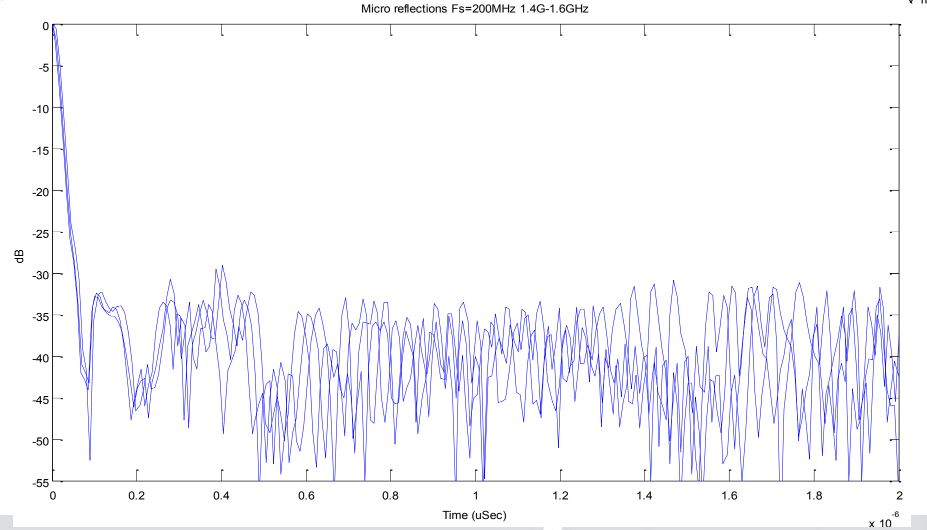
Group delay Vs frequency

Micro-reflection Simulation Results

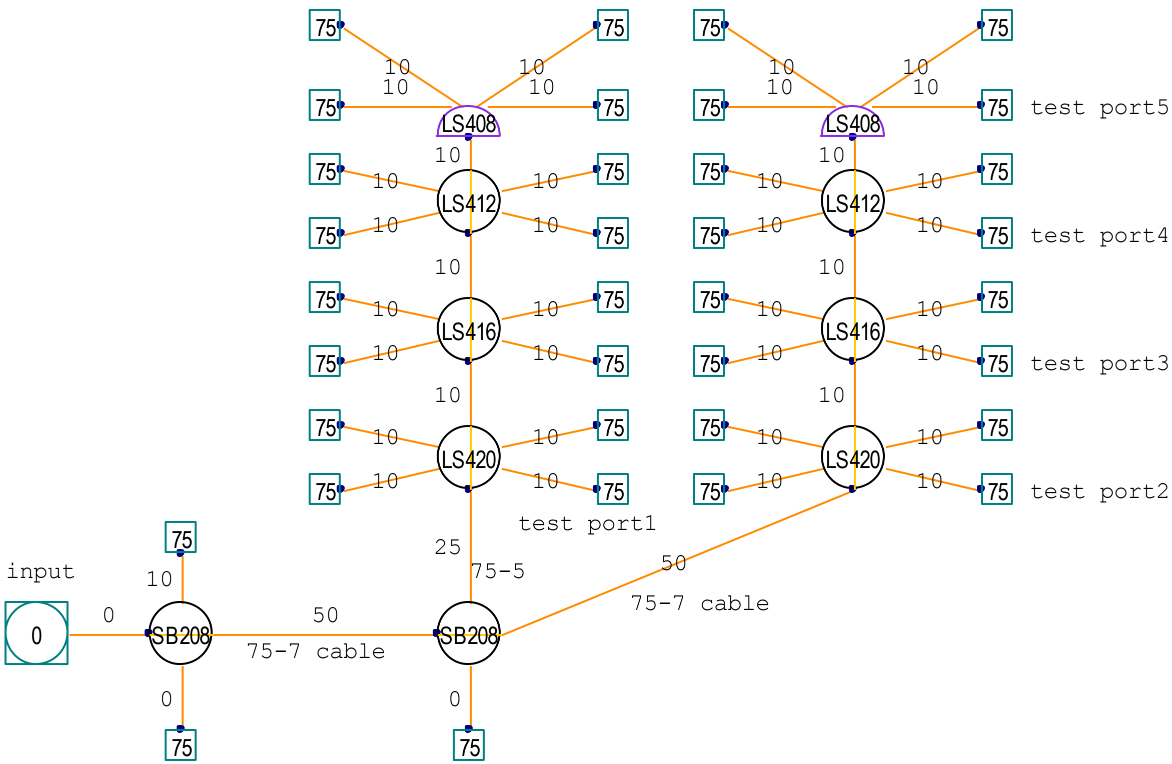








Scenario2: Passive Cable Network with Cascaded TAP Distribution



Notes:

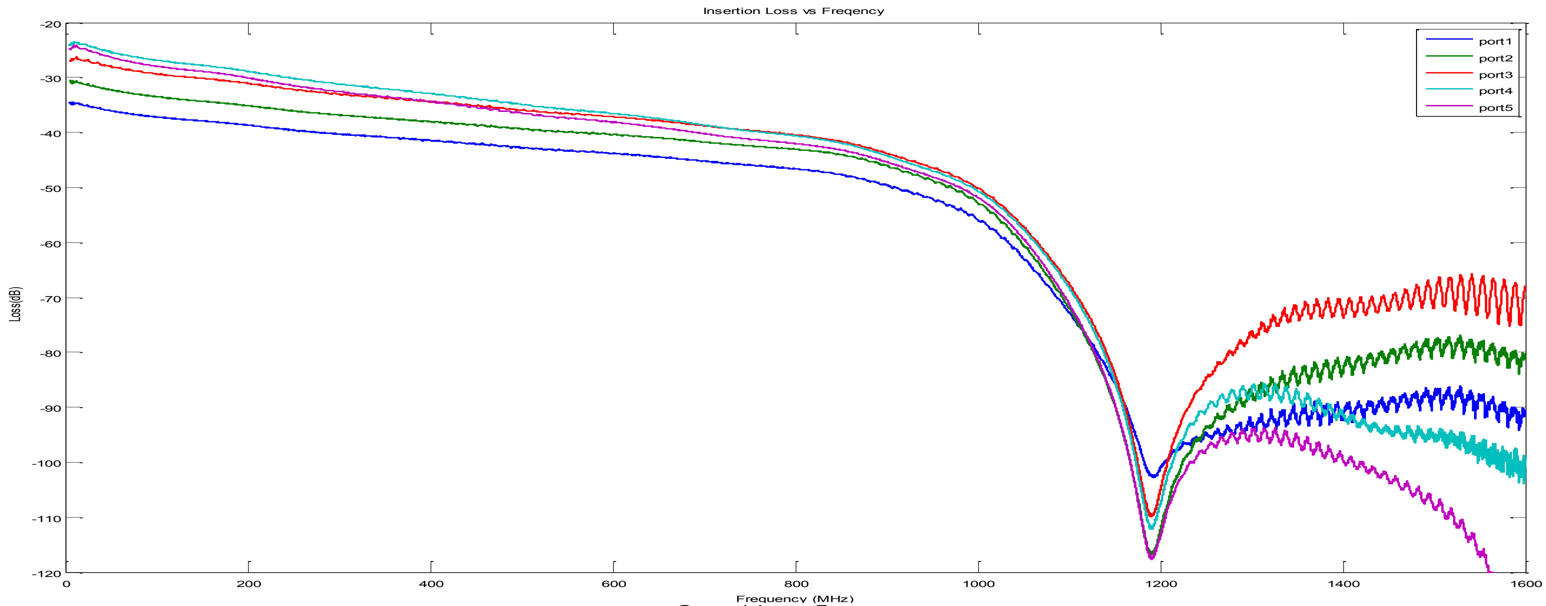
•75 means 75ohm match

• all lines between TAP/splitters are coaxial cable. SYWV-75-7/SYWV-75-5.

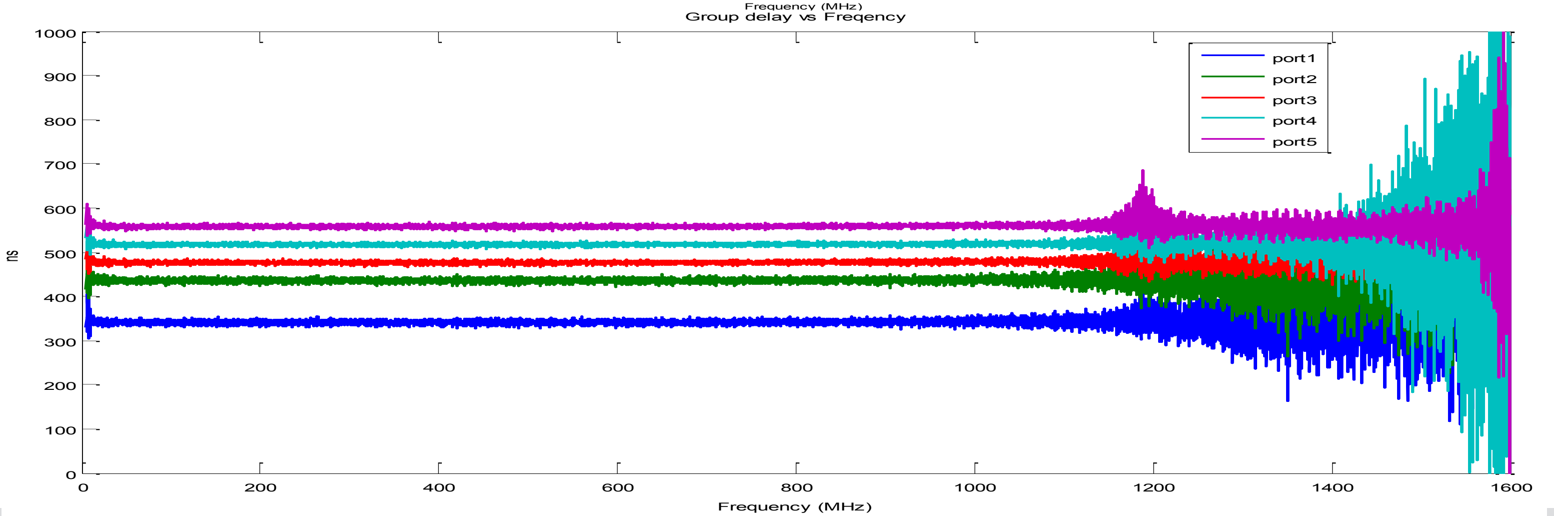
• The number on the line means the length of cable. (e.g. 50 means 50meters length)

Simulation Results

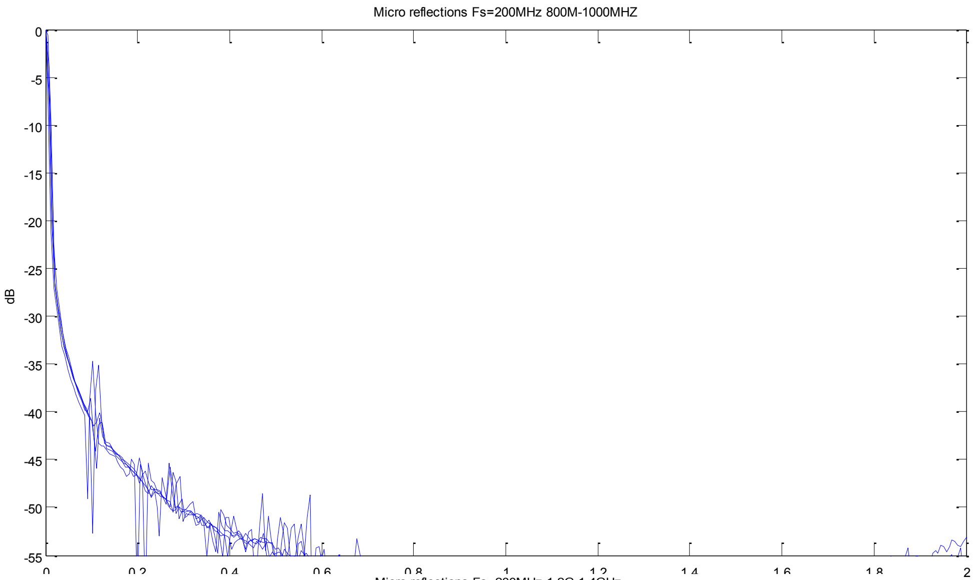
Insertion loss Vs Frequency

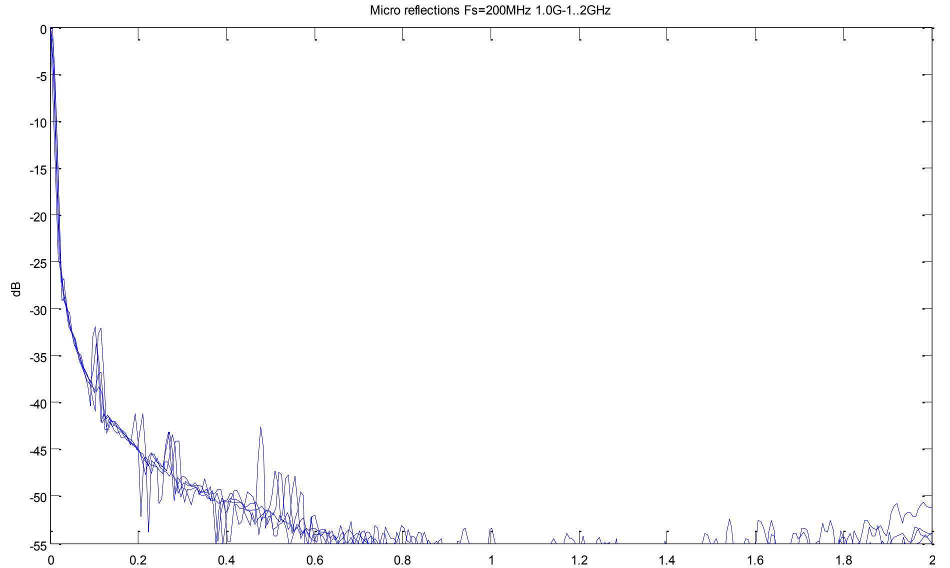


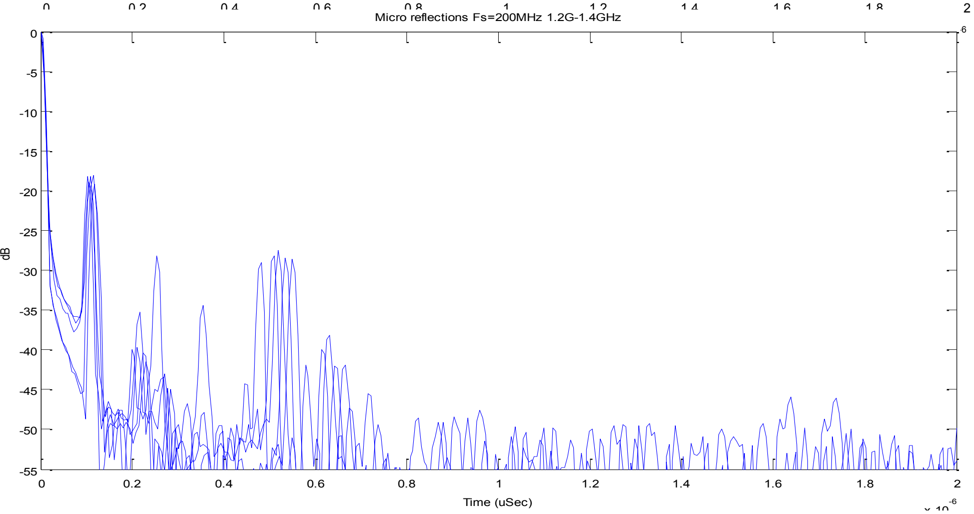
Group delay Vs Frequency

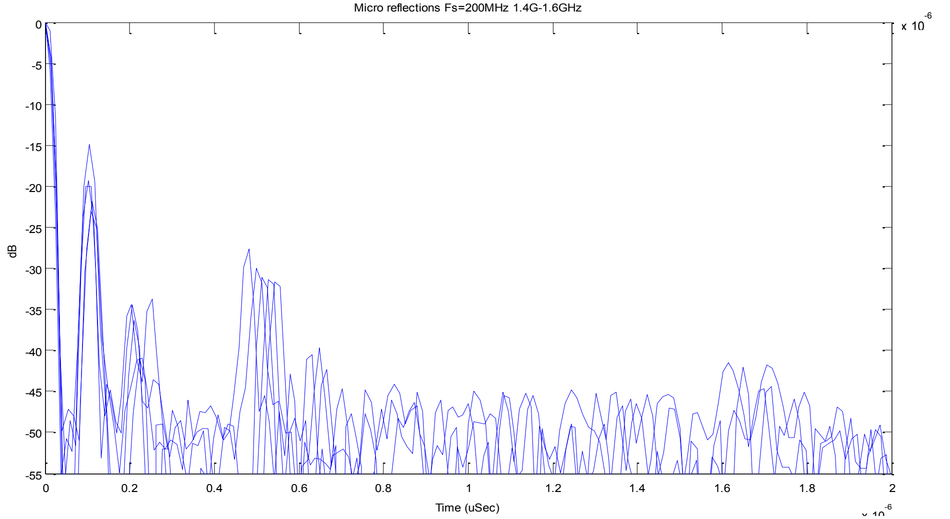


Micro-reflection Simulation Results



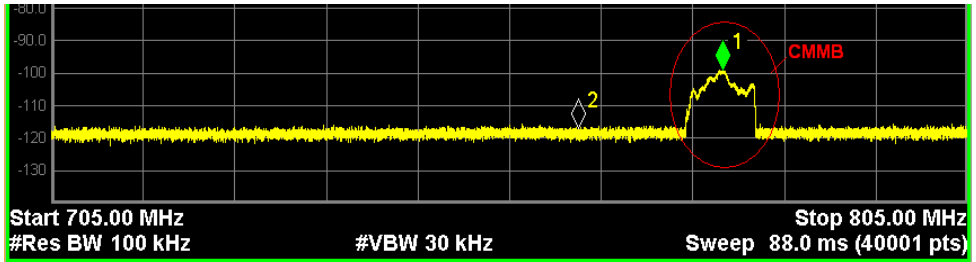




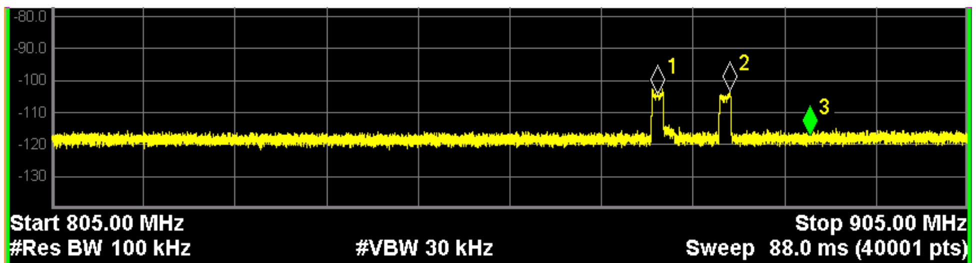


Noise/Interference Test and SNR Estimation

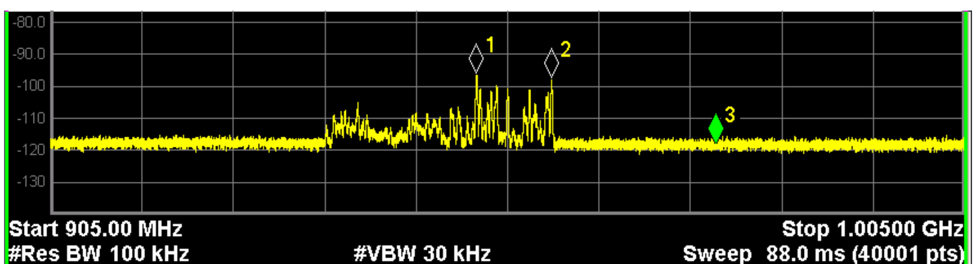
Noise and Interference Test - Downstream



MKR	MODE	TRC	SCL	X	Y	FUNCTION	FUNCTION WIDTH	FUNCTION VALUE
1	N	1	f	778.275 0 MHz	-99.710 dBm			
2	N	1	f	762.510 0 MHz	-117.487 dBm			



MKR	MODE	TRC	SCL	X	Y	FUNCTION	FUNCTION WIDTH	FUNCTION VALUE
1	N	1	f	871.132 5 MHz	-104.775 dBm			
2	N	1	f	878.995 0 MHz	-103.811 dBm			
3	N	1	f	887.757 5 MHz	-117.458 dBm			



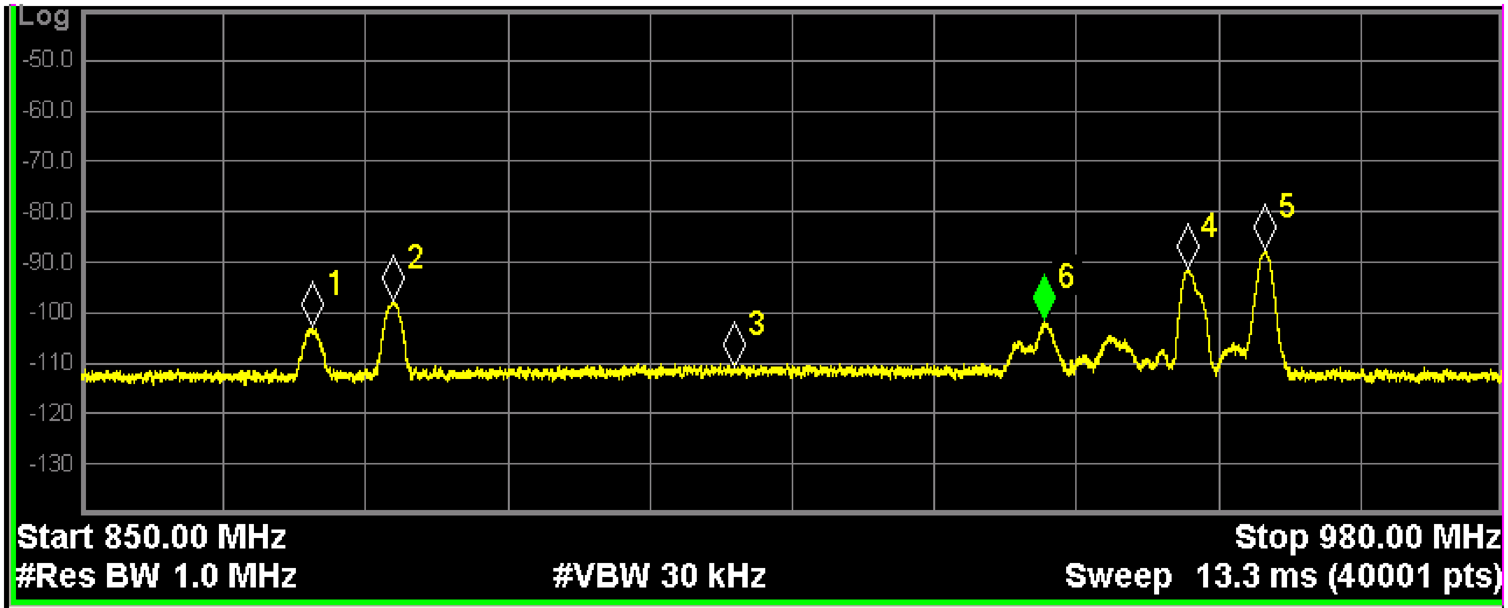
MKR	MODE	TRC	SCL	X	Y	FUNCTION	FUNCTION WIDTH	FUNCTION VALUE
1	N	1	f	951.610 0 MHz	-96.506 dBm			
2	N	1	f	959.802 5 MHz	-97.907 dBm			
3	N	1	f	977.782 5 MHz	-118.432 dBm			

- Location: one user room site at XFBN
- Node+0, Downstream signals power off (disconnect with optical receiver)
- Tested with Agilent N9030A spectrum analyzer.

- The main downstream interferences at 750M~1000MHz are from CMMB/Mobile

- The thermal noise floor tested is about -168dBm/Hz .

Noise and Interference Test - Upstream



MKR	MODE	TRC	SCL	X	Y	FUNCTION	FUNCTION WIDTH	FUNCTION VALUE
1	N	1	f	871.080 MHz	-103.321 dBm			
2	N	1	f	878.463 50 MHz	-98.303 dBm			
3	N	1	f	909.675 MHz	-111.383 dBm			
4	N	1	f	951.205 00 MHz	-91.833 dBm			
5	N	1	f	958.199 00 MHz	-87.989 dBm			
6	N	1	f	938.052 25 MHz	-101.778 dBm			

- Location: one cable access point under the optical receiver at XFBN.
- Node+0, without upstream signals. (all users power off.)
- Tested with Agilent N9030A spectrum analyzer.
- The main interferences at 850M~1000MHz are also from Mobile signals.

EPOC DRFI parameter assumption

For EPOC downstream with a 192MHz continuous spectrum bandwidth of a RF port, it can be equal to N= 32 combined 6MHz channels.

Refer to "***Table 6–6 - EQAM or CMTS Output Out-of-Band Noise and Spurious Emissions Requirements N>=9 and N'>=N/4" in "DOCSIS3.0 DRFI spec.", we calculate EPOC DRFI parameter as below:***

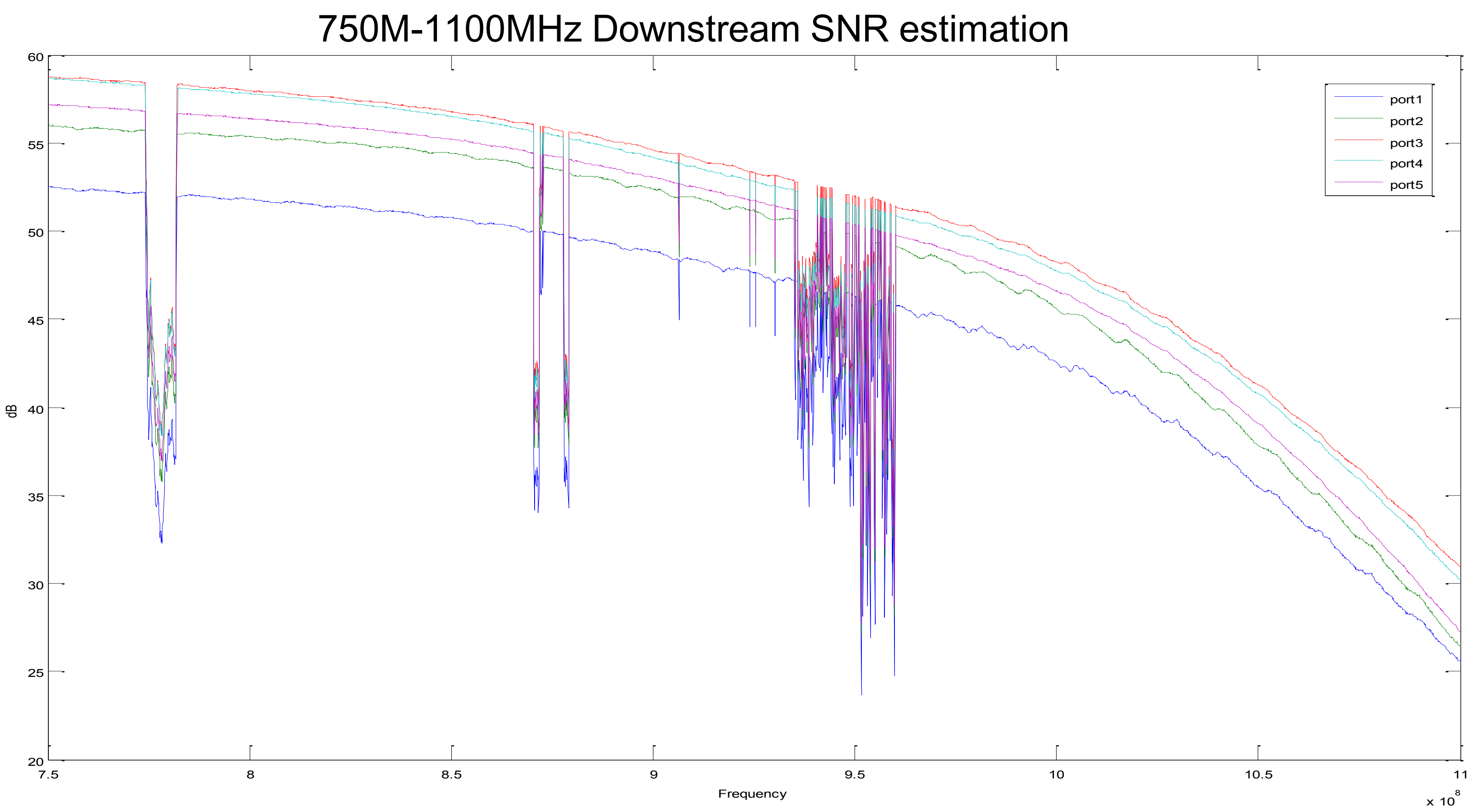
Item	Band	*N'* >4 (>24MHz)
1	Adjacent channel up to 750 kHz from channel block edge	<-56dBc
2	Adjacent channel (750 kHz from channel block edge to 6MHz from channel block edge)	<-57dBc
3	Next-adjacent channel (6 MHz from channel block edge to 12MHz from channel block edge)	<-59dBc
4	Third-adjacent channel (12 MHz from channel block edge to 18MHz from channel block edge).	<-60dBc
5	Noise in other channels (47MHz~1002MHz) in each 6MHz bandwidth	<-60dBc

Note: Where N is the Maximum Number of Combined Channels per RF Port, and N' is the Number of Active Channels Combined per RF Port.

- To coexist with DOCSIS legacy service, EPoC signal PSD can not be higher than the legacy service.
- We will use the DFRI parameters in below table for the following SNR estimation.

Transmitter power over 192M bandwidth	**60dBmV**
Converter to dBm/Hz	**-71.6dBm/Hz**
DRFI SNR	**56dB**
EPOC inband Noise floor	**-127.6dBm/Hz**
Thermal noise floor (with 5dB receiver noise)	**-169dBm/hz**

Downstream SNR Estimation – Under Node+0



Summary

- Under Node+0/+1 scenarios, the micro-reflection is not significant under 1.2GHz, but echo power grows seriously at 1.2G-1.6GHz
- Through SNR estimation results, we think that adaptive modulation is very important for downstream.
- We can make contribution on EPOC channel modeling.

THANK YOU