An Introduction And Overview Of
MATV Design And Application

The art and science of distributing A/V content over coaxial infrastructure in premise installations remains a valuable skill set for the 21st Century!

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Our Agenda

- What is MATV?
- Bandwidth and the RF spectrum
  - What does the MATV installation distribute?
- Understanding coaxial cable
  - The basic MATV “pipe”
- Head-end building blocks
  - Amplification, equalization and notch filters
- Distributing the signal
- Balancing the MATV system
What is MATV?

• **Master antenna television system**
  – System by which a building or zone is fed from a common set of antennas

• **What does MATV distribute?**
  – RF broadcast TV and radio
  – Locally modulated sources
  – Satellite IF
  – Bi-directional broadband data

• **Coax provides from 370 to 1,000 times more capacity than Cat 5E or Cat 6!**
“If it weren't for Philo T. Farnsworth, inventor of television, we'd still be eating frozen radio dinners.”

– Johnny Carson
Broadcast Spectrum

- OTA broadcasts encompass “channels” 2 thru 51
- Digital television stations are placed on high VHF and UHF channels
  - 7 to 13 and 14 to 51, except 37
  - VHF 2 to 6 are rarely used due to impulse noise
  - VHF channels 7 to 13 broadcast from 174 to 216 MHz
  - UHF channels 14 to 36 broadcast from 470 to 608 MHz
  - UHF channels 38 to 51 broadcast from 614 to 698 MHz
  - FM radio broadcasts from 87 to 108 MHz
U.S. Broadcast Spectrum Allocation Over Time
CATV spectrum allocation
Satellite TVRO Spectrum

- C-band occupies 4 to 8 GHz
- Ku-band occupies 12 to 18 GHz
- Satellite signals are “folded” to a lower frequency by the low noise block amplifier (LNB)
  - Superheterodyne a block of high frequencies, amplify and convert them to similar signals at a lower frequency
- Satellite IF frequencies operate from 950 to 1450 MHz
  - Can be piggybacked in the same coaxial cable that carries lower-frequency OTA and CATV signals
“The cable TV sex channels don't expand our horizons, don't make us better people, and don't come in clearly enough.”

– Bill Maher
The Nature Of Coax

• One conductor is formed into a tube and encloses the other conductor
  – This confines the radio waves from the central conductor to the space inside the tube
• Characteristic impedance is important
  – Reduces internal reflections at connections between components
Capacitive losses in coaxial cables reduce the high frequencies more than the low frequencies. This chart shows the loss in dB over a 30 meter length of RG-6 cable. Losses are much higher in RG-59.
## Comparison Of 75Ω Coax Signal Loss

<table>
<thead>
<tr>
<th></th>
<th>RG-59/u</th>
<th>RG-6/u</th>
<th>RG-11/u</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristic Impedance</strong></td>
<td>75Ω</td>
<td>75Ω</td>
<td>75Ω</td>
</tr>
<tr>
<td><strong>Propagation Velocity</strong></td>
<td>0.66</td>
<td>0.75</td>
<td>0.66</td>
</tr>
<tr>
<td><strong>Diameter</strong></td>
<td>0.242 in</td>
<td>0.270 in</td>
<td>0.412 in</td>
</tr>
<tr>
<td><strong>1GHz Loss @ 100 Feet</strong></td>
<td>-8.09dB</td>
<td>-6.54dB</td>
<td>-4.23dB</td>
</tr>
<tr>
<td><strong>1GHz Loss @ 100 Meters</strong></td>
<td>-26.54dB</td>
<td>-21.46dB</td>
<td>-17.22dB</td>
</tr>
<tr>
<td><strong>3GHz Loss @ 100 Feet</strong></td>
<td>-14.29dB</td>
<td>-11.45dB</td>
<td>-7.8dB</td>
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<tr>
<td><strong>3GHz Loss @ 100 Meters</strong></td>
<td>-46.88dB</td>
<td>-37.57dB</td>
<td>-25.29dB</td>
</tr>
</tbody>
</table>

**RG-59/u**
- 20 AWG center conductor
- Used for low-power video and RF signal connections at short distance, high-frequency losses are too high to allow its use over longer runs

**RG-6/u**
- 18 AWG center conductor
- CATV distribution coax typically has a copper-coated steel center conductor and a combination aluminum foil/aluminum braid shield

**RG-11/u**
- 14 AWG center conductor
- Used for longer runs with a transition to RG-6u for drops
MATV Design Parameters

- **Signals are measured in dB relative to 1 mV (millivolt)**
  - At ingress, signals should measure 0 to +10dBmV
  - FCC rule 76.605 requires a minimum signal level of 1 mV across 75 ohms (0 dBmV) at CATV demarcation point

- **MATV systems consist of “unity gain” building blocks**
  - Every run is followed by an amplifier with a compensating amount of RF gain and equalization
  - Proper compensation requires tilt adjustment
  - Pre-amplification should be used to ensure multiple antennae and inputs are matched to .5dB over a single 6MHz channel allocation

$V_{in} = V_{out}$
Measuring MATV Systems

• Measurements Are Done With A Signal Level Meter
• All Programs Should Have The Same Power Level
  – Maximum Differences Between Signal Levels
    – (-3dB) For Neighboring Channels
    – (-6dB) Within Any Band 60 MHz Wide
    – (-10dB) Within The System Spectrum
• All Parameters Of Distributing Installation Should Be Kept At 95% Stability
  – As Ambient Temperatures Increase, So Does System Loss
Elements of an MATV System

“Everything you can imagine is real.”
— Pablo Picasso
Amplification

- **Strip amplifiers** are single channel amplifiers designed to receive a single television signal
  - Strip amplifiers don’t alter the frequency of the signal
- **Broadband amplifiers** boost gain for all channels in the system
  - Most feature tilt compensation
  - Broadband amplifiers also boost system noise!
Isolation Amplifiers

- Used on the antenna or incoming cable feed to process, amplify and isolate its signal
  - Relatively low gain designed into system only to compensate for near 0 dBmV sources
  - Prevents the antenna from becoming a sink for system power
- Not all systems need a system isolation transformer
  - Simple 2 to 4 input head-end designs with a single OTA antenna typically don’t siphon power from the system
Modulators and Notch Filters

• Modulators take video and audio signals from satellite receivers, video servers or cameras and produce a standard modulated television channel
  - The signal output level from a modulator is constant and can be as much as +60dBmV (1000x too much)

• Notch filters pass most frequencies but attenuate those in a specific range to very low levels
  - Typically used to remove a channel from an system to replace content or improve performance
Splitters and Taps

• **Splitters**
  — Transformers that split the power in the input signal to multiple outputs, while maintaining the 75Ω impedance

• **Directional couplers**
  — Typically called a “tap”
  — Asymmetrical splitter where “through” ports exhibit minimal loss and each “drop” exhibits multi dB loss
  — Used to balance near and far sinks
Combiners

• In MATV, addition is the same as subtraction
  — An RF splitter is composed of two transformers that approximately split signal power while maintaining 75Ω characteristic impedance
  — A splitter used “backwards” is a combiner

• Signals being combined must be of similar power levels as measured in dBmV
  — And they must not have the same embedded channels
Designing an MATV System

“Luck is the residue of design.”
— Branch Rickey
Calculate System Gain

- The goal is to end up with the same power level in each band, and that power level should match the incoming broadcast feed.
- Two sections of gain must be considered:
  - Locally modulated sources must be gain-matched to the broadcast feed.
  - Ensures constant power level across all bands.
  - The trunk/zone/room delivery devices must have all insertion losses compensated.
Example Project Parameters

- The project requires the modulation and input of two unique sources housed in the facility
  - For this exercise, let’s assume these are the output of a computer and a media server with no HDCP compliance necessary
- The project demands that we insert the signals from these two devices into a system that is carrying traditional OTA television content as sourced from a local antenna
  - This could be a CATV input instead of an antenna, but more care will be needed to parse and control the wider bandwidth and plethora of channels found on a typical cable feed
  - CMTS and network carriage is not part of the design parameters for this exercise
- The signal will be routed to 4 separate zones in the building
  - Each zone will have 8 displays (for a total of 32 displays)
  - Assume all displays are grouped equidistant from the head-end and from each other
Feed Side

Antenna

Source 1

Mod 1

100'

100'

Mod 2

Source 2

RF Amp

Combiner

Output to Head End
Feed Side Calculations

- Incoming feed measures +5dBmV
- Locally modulated sources rated +25dBmV
- Located in a rack 100-feet from RF head end
- Modulators flow through a 3-port combiner with -4dB signal loss per port on ports 2 & 3 (insertion loss only on port 1).
- +25db -6.5dB cable loss -4dB combiner loss = +14.5dB at head end
- +15dB modulated signal – (+5dB) broadcast feed = +10dB difference
- Use a 10dB broadband isolation amplifier with tilt compensation to achieve balanced RF sources at head-end input
Drop Side

Output of Combiner

Distribution Amp

4-port Trunk Splitter

4-Port Tap

50'

4-Port Tap

50'

4-Port Tap

50'

4-Port Tap

50'

4-Port Tap

50'

4-Port Tap

50'

4-Port Tap

50'

4-Port Tap

50'
Drop Side Calculations

- Input feed to distribution amplifier is +10dBmV (calculated on feed side)
- 4-port trunk splitter loss is -8dB on each trunk
- 50-foot cable loss is -3dB
- Unidirectional coupler (tap) insertion loss is -2dB
- Second 50-foot cable run loss is -3dB
- Furthermost tap-to-port loss is -12dB
- +10dB - 8dB - 3dB - 2dB - 12dB = 18dB Max Signal Loss
- Select a 20dB broadband distribution amplifier for this project
- (-12dB) + (-3dB) + (-2dB) = -17dB. Select -18dB taps to balance near displays with distant displays

Note: Drop lines must be terminated with a 75Ω load for best performance
In Conclusion…

“Knowledge is a process of piling up facts; wisdom lies in their simplification.”

– Martin H. Fischer
What We’ve Learned…

- MATV installations offer significant value in distribution of cable and broadcast video sources across multiple displays and devices in any project from small to large scale.
- Coaxial cable offers significantly more bandwidth than unshielded twisted pair making MATV installations a cost-effective and high performance alternative to distributing content over a LAN.
- The Quality Of An MATV Installation Depends On The Quality And Condition Of The Coaxial Cable Used In The Project.
- MATV systems are designed for unity gain.
- Success In MATV Installation Is Only Ensured When You Know The Quality Of The Starting Signal And Accurately Account For All Insertion Loss, Slope Loss And Drop Loss Across The Distribution Network.
Questions?