Tutorial Contents

DBSMATV Business Model

Market Analysis

Apartments and condominiums account for 28% of the entire housing market according to the American Housing Survey of the Census Bureau. Within this market the census breaks down the population based on the size of structures in living units.

- Structures with <10 units
  58% of MDU households
- Structures with 10 to 49 units
  30% of MDU households
- Structures with >50 units
  14% of MDU households

Under-100-unit MDUs are not served by conventional private cable systems. Properties not served by private cable due to "big dish" capital cost are targets for DBS. The July edition of "DBS Investor" places the market at 20 million households.

Cash Flow vs Assets

A Private Cable system owner is the gatekeeper to which programmers can reach their customer base. Paul Kagan Associates, periodically lists the sale price of privately owned SMATV cable systems. Evaluations are listed by either sale price per subscriber or per passing, a potential subscriber. Assume the going rate for a C-band SMATV system is $1,000 per subscriber or $500 per potential subscriber (a door). The goal for the private operator is to get his system installed for under $500 per door while maintaining a positive cash flow. What if the capital cost could be reduce by reducing the number of analog programs by shifting the content to DBS delivery?

Cable television is a scalable product; a private cable system looks like a node of a larger franchised system. People in a 200 unit MDU will pay the same monthly bill for cable services as someone in a 1000 unit complex or a city-wide franchise.

The Sonora Design Associates business model assumes capital costs must be significantly lower than $500 per door for DBSMATV systems. Our goal is to provide systems that minimize the capital cost while offering a full range of programming.

Market Environment

The marketplace for private cable television is undergoing rapid changes initiated by the Telecommunications Reform Act of 1996. The FCC is encouraging competition for television services. On March 13, 1998, the FCC signed into law the "Cable Television Consumer Protection and Competition Act" guaranteeing property owner rights to the inside wiring that enables cable television delivery. The act provides private cable operators significant advantages.

Direct Broadcast Satellites (DBS) has evolved to reach 10% of the 100 million households in the United States. Subscribers want DBS for the quality and program selection it offers. People living in apartments and condominiums also want DBS. In most cases property owners discourage the placement of dozens of dishes on their buildings. DirecTV® with their national marketing campaign has motivated property owners to express their rights to select who will serve their tenants.

A Business Solution

Technology can provide the solution: installation of a cable delivery system with a common antenna and dish to serve the entire building. In addition to the DBS programs, subscribers want basic programming available to all televisions within their living unit. Low cost SMATV headends can be installed to provide local broadcast programs as well as retransmitted DBS programming to ALL of their televisions. Revenues generated by subscription to the analog distribution system greatly enhance the revenue sharing provided by the DBS providers.

Ownership and operation of DBS based cable systems is a viable business for three reasons.

1. DBS broadcasters subsidize the capital cost of installation.
2. System operators receive operating profits on the resale of program content.
3. System owners obtain equity by controlling access to the subscribers.

Scalable Capital Cost

The Sonora business models assumes that capital costs are scalable inversely with programming gross margins. Multiple business models can be profitable. At one extreme is the 1000 door, multiple big dish system. On the other extreme is the small dish system using DBS distribution. Hybrid systems are used in properties in between the extremes. Hardware manufacturers are challenged to reduce the cost of systems so smaller properties can be served profitably.

Capital costs include:

- Headend
- Distribution
- Conditional Access

The cost of the three capital segments need to be scaled for the smaller MDU to be economically served.

Headends for DBSMATV systems are compact and low cost. Modular components like the MICM modulator are recommended.

Distribution systems for DBSMATV or SMATV remain basically the same; cable amplifiers and installation labor. Careful property selection is key to reduce the cost of distribution. Reuse of drop cables is a major cost savings.

The conditional access system for DBSMATV is the DBS distribution system that serves the DBS receivers. Considerable cost can be trimmed from the cable system budget by allowing the DBS provider access to the analog customer. Operators of small systems also cannot afford the $100 to $200 per door cost of restricting access to analog programs.

Operators cannot afford the headend cost of providing 60 to 100 channels of analog programming for small systems. At the same time operators are competing with cable companies with large analog lineups. DBS provides the wide selection of content at minimum cost of installation.

Document Format

The document is written for system operators installing DBS distribution systems. Each subject is written as an individual application note. The document is comprised of illustrations with explanations of the technical aspect of the illustration.

Distributors of Sonora products and systems may use this document to fax or e-mail individual sections for system operators having specific questions or problems. The document is available in a (.pdf) format that can be opened and printed using Acrobat Reader version 4.

Acrobat reader is available free of charge off the Web at **www.adobe.com/supportservice//custsupport/download.html.** Select Acrobat Reader and the type of computer you use to view the file.

Figure 1 Reading Spectrum Analyzer Plots

Spectrum analyzer displays are used throughout the document to illustrate the affects of distribution products on the DBS signal. In the plot to the right, one transponder is centered in the screen.

Horizontally, the analyzer measures frequency. At the bottom of the plot are numbers indicating the frequency of the display. The center frequency is noted to be 1 GHz and the span of the display is 50 MHz. The ten horizontal grid squares are then 5 MHz each.

Vertically the analyzer measures amplitude. On the left of the display you see the words "log 2 dB/". This indicates that each vertical square represents 2 dB.

Diamond shaped markers are placed a strategic locations and the readout of the marker information is provided. In the center left of the screen you see the "Marker" readings of 17.63 MHz and .23 dB. The marker spacing is 17.6 MHz and the difference in amplitude of the markers is 0.2 dB.

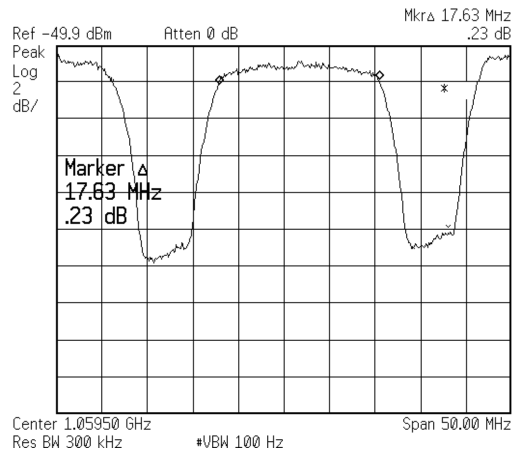


Figure 2 Reading Network Analyzer Plots

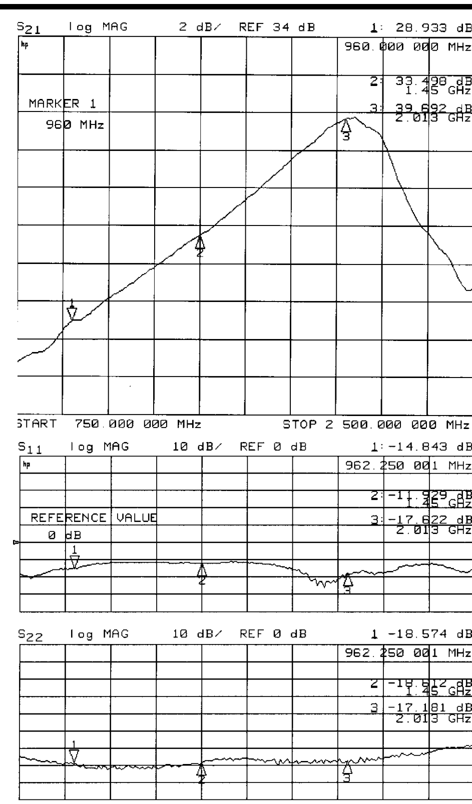
Network analyzer plots are used in the document to illustrate the performance of products used in DBS distribution systems. Network analyzers are very high performance spectrum analyzers. The model used by Sonora costs over $30,000. It allows the engineers to see details on the performance of products over the entire frequency band.

The horizontal scale indicates the frequency of the display. Note the "start" and "stop" frequency annotated at the bottom of the plot.

Two plots are illustrated. The top plot shows amplitude verses frequency. This is a plot of the gain of a Sonora TA2636 amplifier. Note the markers indicated as "1,2,3". These are placed at the key frequencies of 950, 1450 & 2013 MHz. In the upper right hand corner note that the amplitude (gain) is annotated at each of the marker frequencies.

The bottom plot(s) illustrate the "return loss" of the product at the same three frequencies. The first plot labeled "S11" is the input return loss. The lower plot labeled "S22" is the output return loss. Ideally we want the plots to be flat and of high value. Note the return loss marker information indicating the output return loss of

1--16.5 dB, 2--18.8 dB & 3--17.1 dB



DBS Digital Distribution in Multi-Tenant Properties

Distribution of digital direct broadcast signals to multiple tenants in residential and commercial buildings requires an understanding of the technical requirements of DBS satellite receivers. The signal quality at the end of the drop cable must equal or exceed the quality single-family subscribers receive from an 18-inch dish and 175 feet of RG-6 cable. Sonora Design Associates design and sell distribution systems that exceed minimum specifications. Sonora presents a report of our experience in the design, installation and measurement of DBS distribution systems. System specifications are explained, distribution product test results are presented and product minimum specifications are suggested.

General Requirements

Suggested requirements are based on system analysis performed by DirecTV™ and system tests performed by Sonora Design Associates. Contractually, System Operators my not need to meet all of the requirements listed. Sonora Design Associates believes the requirements have sound technical reasons and should be observed whenever possible. The design requirements apply to all DBS services both US and Canada.

Approved Installers

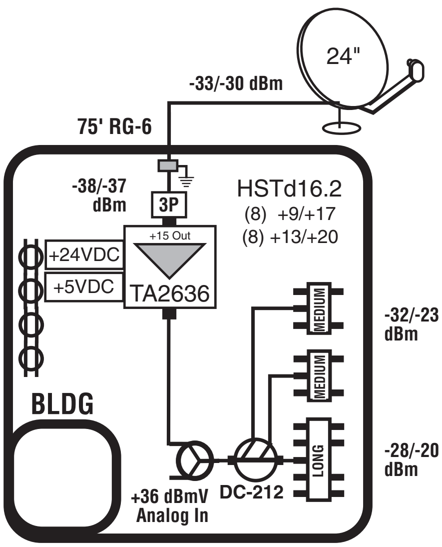
The SO may opt to subcontract the installation. A certified installation company must be used. Sonora identifies the Installation Company on the system drawing. We also can refer clients to installation companies that have successfully installed our systems.

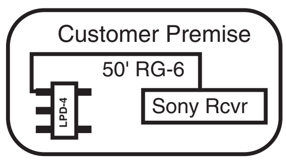
Minimum Installation 100% backbone, 48 hr drop

The entire backbone distribution system must be constructed prior to turning-on the first subscriber. Once the backbone is in place, SO's must install drop hardware within 48 hours of requests by potential subscribers.

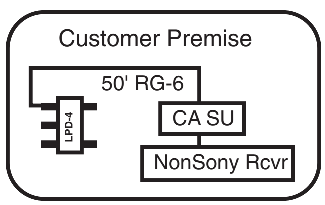
Wind Load 50 m.p.h. operation, 100 m.p.h. survivability

The receivers shall maintain operation under 50 m.p.h. winds. A sturdy mount and solid dish are required to prevent movement off the satellite. At 100 m.p.h., the dish must stay on the roof. Alignment may be required to relocate the satellite.





Minimum drop Input
Assume: 200 ft RG-6 drop
In Premise 4-way & 50' RG-6
Rcvr input - Apt loss - drop loss
-66 dBm -16dB -20dB = -30 dBm



Minimum drop Input
Assume: 200 ft RG-6 drop
In Premise 4-way & 50' RG-6
CASU input - Apt loss - drop loss
-56 dBm -16dB -20dB = -20 dBm

Figure 3 System Documentation

A signed right of entry agreement and a distribution system design is required for the (SO) to obtain a property ID number. System distribution products shall be identified along with calculated signal levels at key points in the distribution system.

Figure 4 is a typical Sonora design using a pre-assembled HSTd16.2 node assembly. Anticipated signal levels are annotated at key points in the distribution system. The two numbers represent levels at 950 MHz and 2025 MHz.

Sonora system packages include our design rules, a listing of approved products with specifications and a computer generated system-drawing. Finally we itemize a bill of materials.

Table 1 Reception Availability by Zone

The signal of all transponders must be available to any passing in the distribution system. In addition, each subscriber requires the signals to be available 99.90% of the time. The maximum outage equates to 44 minutes per month. The availability is a function of dish size and the signal strength.

Availability %	Loss/Month Minutes	Rain attenuation dB by Zone A	B	C	D
99.9	44	3	3	4	9
99.95	22	4	5	6	13
99.99	4	6	7	14	25

Example: In zone "C" you desire a 99.95% signal availability. Chose your dish so you have an extra 6 dB of rain fade margin.

Figure 4 DirecTV® Coverage Regions

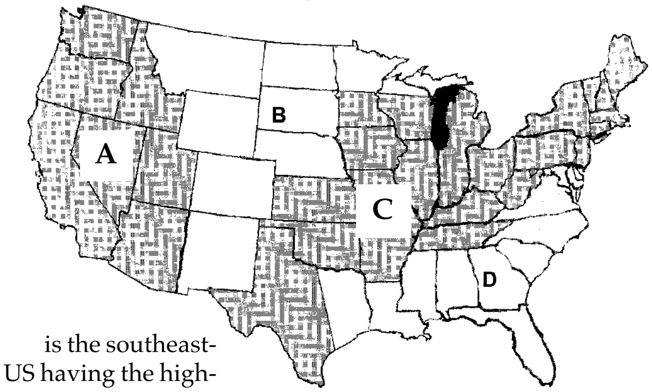
California Amplifier

DirecTV divides the country into four regions that roughly equal the Crane rain model regions.

Region A equates to Crane zone "C & F" covers Washington, Oregon, Idaho, Nevada, Utah, California & Arizona.

Region B equals "Crane B" and covers Montana, North Dakota, Nebraska, Wyoming, Colorado and New Mexico.

Region C equals "Crane D2" includes Texas, Oklahoma, Kansas, Missouri, Illinois, Iowa, Minnesota, Michigan Indiana, Kentucky, Ohio, West Virginia, Pennsylvania, New York and the upper east coast.



Region D is the southeastern part of the US having the highest rain attenuation. Crane calls the region "D3 and E" States include Louisiana, Mississippi, Alabama, Georgia, Florida, South Carolina

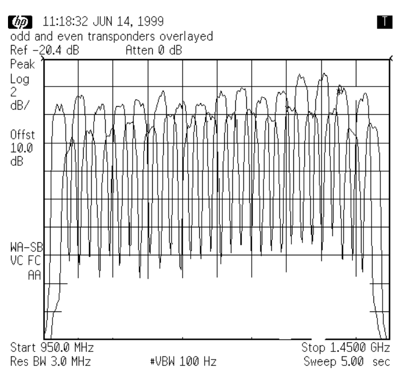
Table 2 Antenna Selection

Antenna Size Inches	Antenna Size Meters	Gain dB	Beam deg	Zone A dBm	Zone A dB	Zone B dBm	Zone B dB	Zone C dBm	Zone C dB	Zone D dBm	Zone D dB
				Output / Rain Fade Margin							
18	.46	34	3.5	**-35**	3	**-36**	2	**-35**	3	**-31**	5
24	0.6	36	2.8	**-32**	5	**-33**	4	**-32**	5	**-29**	7
30	0.75	38	2.2	**-30**	7	**-31**	6	**-30**	7	**-27**	9
36	0.92	40	1.9	**-28**	9	**-29**	8	**-28**	9	**-25**	11
39	1.0	41	1.8	**-27**	10	**-28**	9	**-27**	10	**-24**	12
47	1.2	42	1.5	**-26**	11	**-27**	10	**-26**	11	**-23**	13

A 36-inch maximum dish is shown on system diagrams for both technical and business reasons. On the business side, a 36-inch antenna can be shipped by UPS and is close to the maximum size the FCC supports in local zoning ordinances. A minimum dish size of 24" is recommended.

Satellites that share an orbital position have a control variation of ±0.1 degrees. DirecTV® lists three satellites at the 101°W slot: 100.75°W, 100.85°W and 101.2°W. Hughes suggests that a pointing error of 0.3 degrees is possible for reception dishes. The maximum beam-width is therefore 0.75 degrees. Sonora customers have successfully aligned systems having 1.2 meter dishes, however alignment and mount stability are critical. As the dish size increases, alignment is more difficult due to narrow beam widths. Sturdy mounts and wrench adjustable alignment bolts are critical.

Important Change On December 8, 1999, DirecTV‰ substituted a higher power satellite for the "even" transponders. Each even transponder increased by 6 dB. Even transponders are now 3 dB hotter than odd transponders. **Add 3 dB to the above table.**



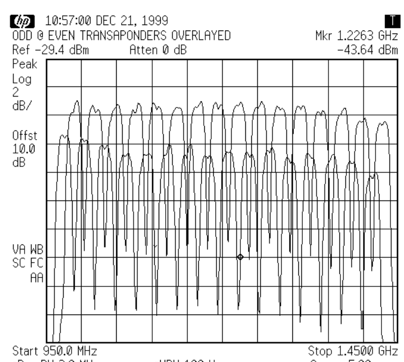


Table 2 lists the expected output levels for various size dishes in each of the four regions. The levels are based on measured performance of installations using a variety of dishes and LNBs'.

To use the table, first choose your antenna size from the first column.

Then select the "zone" of the installation. Two columns of numbers are under each zone. The first is the expected output in dBm. The second column is the rain fade margin in dB.

For example, a 30 inch dish in Florida (zone D) would have an output of -27 dBm with a rain fade margin of 9 dB. Up to 9 dB of atmospheric attenuation (rain, snow, clouds) could be added before receivers would fall below threshold of 8 dB CNR.

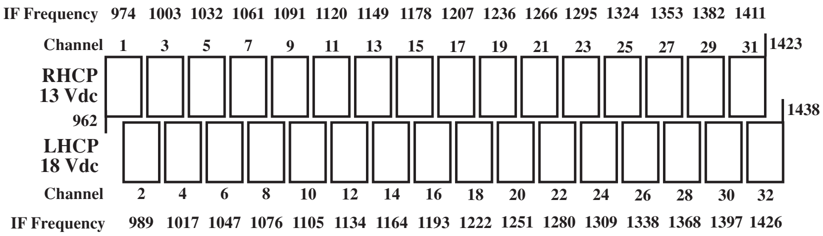
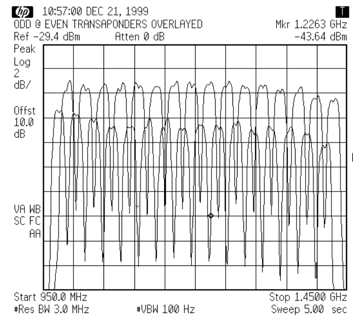


Figure 5 Dual 500 Frequency Plan



Dual 500 Polarities Overlayed DirecTV® even transponders have 3 dB more power

1.5 div = 3 dB

Original DBS receivers were designed to accept transponders downconverted to the frequency plan illustrated above. Receivers selected one of the two 950 - 1450 MHz satellite polarities by sending a control voltage to the LNB.

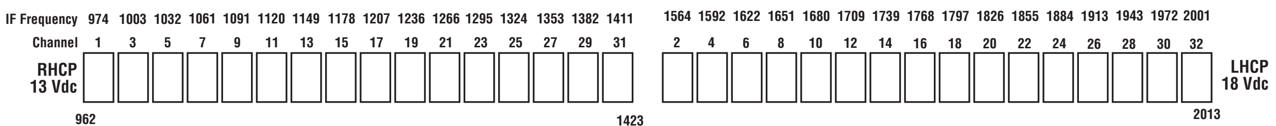
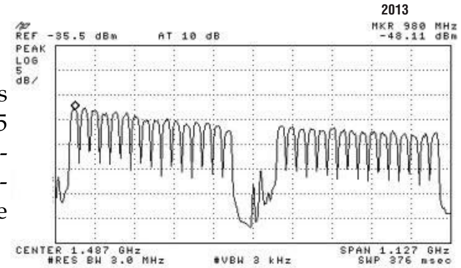


Figure 6 Wideband Frequency Plan



Single 1000 LNB Output

California Amplifier manufacturers an LNB that converts both polarities in a continuous band of frequencies from 950 MHz to 2013 MHz. Figure 5 shows the frequency assignment established for the "stacked" LNB distribution. A "subscriber unit" downconverts the upper (LHCP, 18 Vdc) polarity back to 950-1450 MHz when it detects the 18 Vdc control voltage from a DBS receiver.

In May 1999, SONY released the first US DBS receiver designed with a "wideband" tuner capable of selecting transponders without the use of the subscriber units. The GI StarChoice receiver also operates "wideband".

DBS & FSS "Single 1000" Hi-side Upconverter Frequency Plan

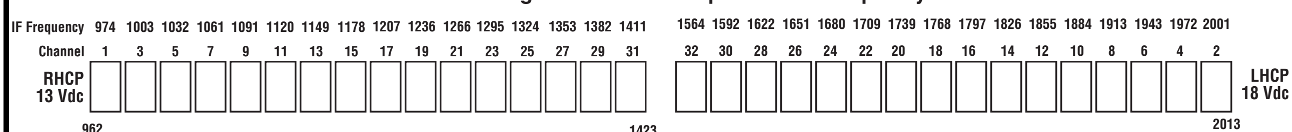
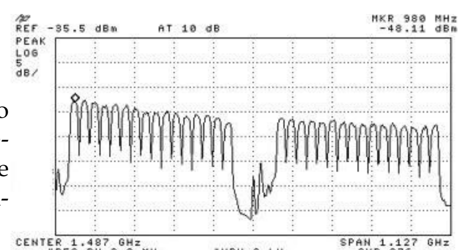


Figure 7 Hi-side Upconverter Wideband Frequency Plan



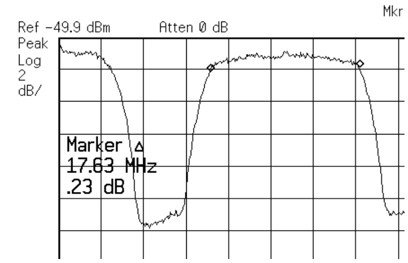
Hi-Side Upconverter Output

Bell ExpresVu required high-side upconversion for their initial FSS (11.7 to 12.2 GHz) satellite service. Low-side conversion in this frequency band creates a spurious image of the oscillator that falls within band of one of the transponders. (For DSS 12.2 to 12.7 GHz, the spur fall between transponders and is manageable.)

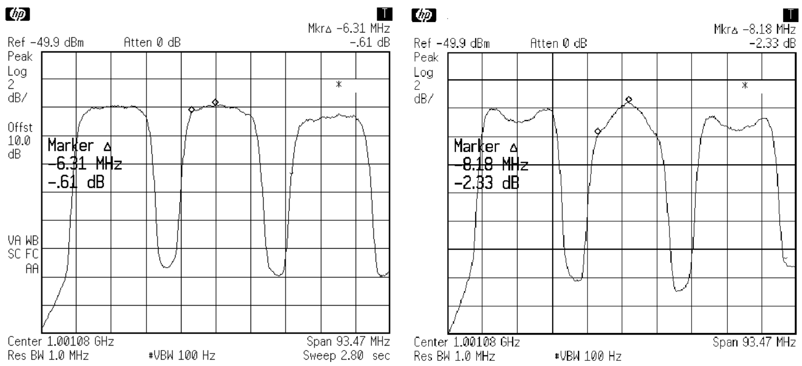
NAS and Sonora Design manufacture upconverters and downconverters using the high-side conversion oscillator. The converters are operable with either FSS or DSS dual LNBs. Figure 6 shows the frequency assignment established for the "high-side stacked" distribution. A "high-side subscriber unit" downconverts the upper (LHCP, 18 Vdc) polarity back to 950-1450 MHz when it detects the 18 Vdc control voltage from a DBS receiver. Note that high-side upconversion inverters the order of the upper frequency band. The high-side downconversion re-inverts the band back to the original transponder order.

Figure 7 Transponder Flatness (dB per 24 MHz)

Transponder flatness is the most critical specification. Show me a transponder with a notch in the passband and I will show you five freeze-framed programs. The displayed transponder to the right is direct from the LNB. Note flatness from marker to marker is 0.2 dB.



DirecTV specifies a flatness of plus or minus 0.5 dB. The 1 dB flatness specification is difficult to meet. Our experience is that 2 dB flatness is acceptable and pictures do not begin to tile until the flatness exceeds 3 dB. A steady slope of 2 dB has less affect on signal counts than a 2 dB notch.



The figures to the left show the affect of passing 3 transponders through two splitters connected by 20 feet of RG-6.

First, 15 dB return loss splitters are used. Then, two 6 dB return loss splitters are substituted.

Note the standing waves cause a 2.3 dB peak in the middle transponder and valleys in the first and third transponders.

Figure 8 Adjacent Transponder (dB per 24 MHz)

The signal amplitude of any two adjacent 16 transponders in each 500 MHz band must not vary by more than 1 dB. Signal reflections due poor return loss products can cause peaks and valleys. Amplifiers with nonlinear gain can also introduce variations. Figure 9 illustrates how reflections can violate this specification.

The figure show two traces. The top trace is a sweep response of two 6 dB return loss devices connected by 2 feet of coax. The bottom trace illustrates how transponder are affected by the ripple induced by reflections.

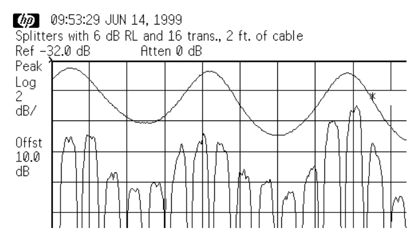


Figure 9 Polarity Flatness (dB variation per 500 MHz)

The signal amplitude of each the 16 transponders in each 500 MHz band must not vary by more than 5 dB. The specification targets the increased insertion loss products have at higher frequencies. 200 feet of RG-6 cable has 2 dB more loss at 1450 MHz than at 950 MHz. Split the signal with a 2-way splitter and the variation increases to 3 dB. Slope compensation is required in distribution systems.

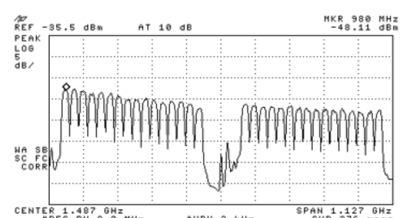


Figure 10 Alternate Transponder Power (Dual 500 system)

The signal amplitude of two adjacent transponders of opposite polarity cannot vary by more than 10 dB. Transponder 3 must be within 10 dB of transponder 2 and 4. Each side of the dual 500 distribution system should be balanced. DirecTV® even transponders have 3 dB less power than the odd transponders (at the 110° W orbital slot).

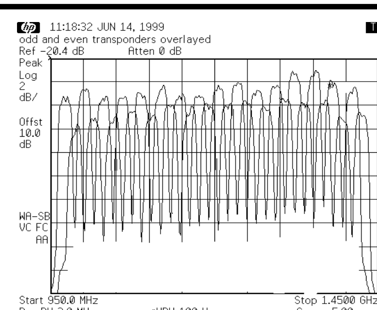


Table 3 Signal Amplitude (dBm vs dBmV)

DBS signals are measured in average power using the units of dBm. Test equipment designed to measure analog signals require a correction factor to compensate for the full bandwidth of the digital signal. Applied Instruments manufactures a hand held meter that includes a built in correction factor.

Conversion from dBm to dBmV is helpful to understand the operating levels involved in DBS L-band distribution.

LNB Output	+16 dBmV =	-33 dBm
Amplifier Output	+49 dBmV =	0 dBm
Receiver Input	--11 dBmV =	-60 dBm

Table 4 Spectrum Analyzer Correction Factor

If you are measuring the levels of transponders with a spectrum analyzer that has a Marker noise function (1Hz BW), follow the procedure below.

Set the spectrum analyzer Resolution Bandwidth to 300 kHz.

Position the marker in the center of the transponder and turn on the MKR noise function.

The correction factor is 10*log (20MHz / 1Hz) = 73. Add 73 dB to the marker noise value.

A close approximation can be made on analyzers that do not have the MKR noise function.

Set the spectrum analyzer resolution BW to 3 MHz and the video bandwidth to 100 Hz, or maximum video filtering.

Position the marker in the center of the transponder to measure the amplitude. The true amplitude is the measured reading plus 10 dB. The above procedure works well with HP analyzers. Other brands may require a different log detection and bandwidth correction factor.

In general, analyzer with 3 MHz resolution bandwidths require that you add 10 dB to the measured reading to get true average power. The correction is calculated by CF= 10*log(20MHz/3MHz) + 2 dB (Analyzer filter and log detection correction).

RBW	Correction
1 MHz	15 dB
3 MHz	10 dB
8 MHz	6 dB
18 MHz	2.5 dB

Add the correction factor to the measured reading to get true power.

Figure 11 Peak verses Average Amplitude

Digital signals appear as blocks of random noise as seen on a spectrum analyzer. Care must be taken in amplifying digital signals so as to not limit any instantaneous peak. Peak limiting results in increased bit error rates and decreased receiver counts. Figure 10 illustrates the near 10 dB difference between average amplitude and peak amplitude of QPSK transponders. Sonora de-rates amplifier operating levels in system designs to prevent limiting the peaks.

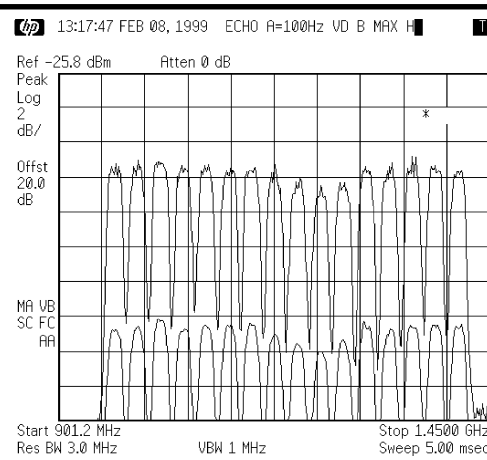


Figure 12 Carrier to Noise

Measuring carrier to noise requires the test operator to determine the noise floor as well as the transponder peaks. The AI MDU meter has a built in CNR test that can be used under controlled conditions. Figure 21 illustrates the first transponder in the lower block of transponders. Note the spectrum analyzer markers are set to the noise floor below the transponder and the transponder peak. (The signal is from a 1 meter commercial dish so the CNR is 16 dB)

Note further that the noise floor below the transponder is lower than the noise floor between transponders. Applied Instruments has the noise floor frequency preset to below transponder one. Measurements of CNR on transponder one are accurate.

Tilt due to amplifier gain or cable loss can cause the upper transponder to vary by up to 10 dB from the lower transponder. Since noise is calculated at transponder one, CNR measured at transponder 32 can be in error by 10 dB.

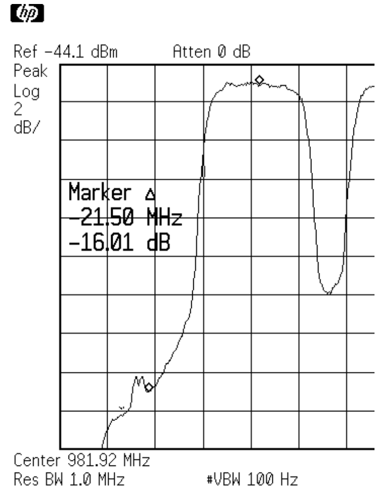


Figure 13 QPSK Receiver Threshold

The digital DBS system designs of DirecTV®, and EchoStar were based on link margins calculated to include satellite power, space loss, atmospheric loss, antenna gain and LNB temperature. DirecTV® operates 32 transponders on three satellites from the 110° West orbital slot. Two satellites each have 8 transponders at 240 watts while one satellite has 16 transponders at 120 watts. On December 8, 1999 a new satellite replaced the 120 watt bird. The EIRP increased by 6 dB.

The Effective Isotropic Radiated Power (EIRP) for DirecTV® and EchoStar range from 48 dBw to 56 dBw. DVB compliant digital QPSK receivers operating at a Reed-Solomon error-correcting rate of 3/4 have an Eb/N0 threshold of 5.5 dB. The calculated minimum carrier to noise is 7.7 dB.

EchoStar operates 21 transponders on two satellites from the 119°.

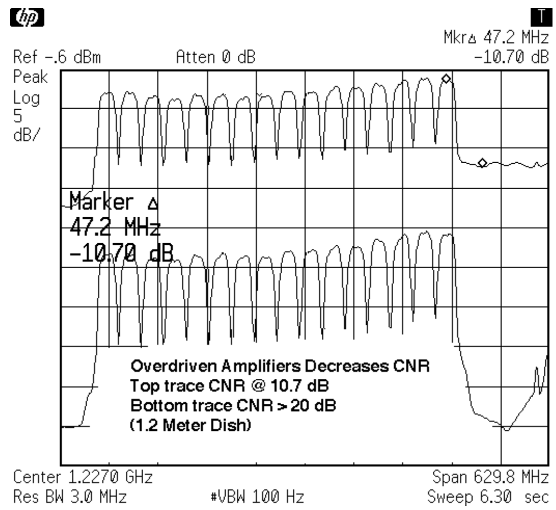
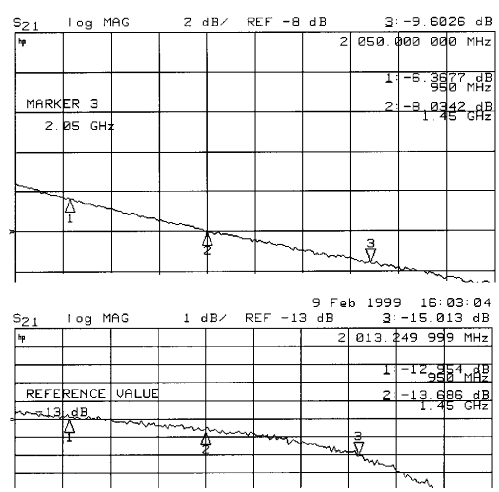


Figure 14 Distribution Loss

Cable loss is higher at 2025 MHz than 950 MHz. The network analyzer plot of insertion loss of 100 feet of RG-6 appears to the right. Markers indicate the losses at 950, 1450, and 2025 MHz. Note the linear slope of the cable.

Splitter and taps add loss to the distribution system. Their loss is not so linear. Note the loss of a typical 8-way splitter shown to the right. The loss increases faster at the higher frequencies. Higher grade splitters show less roll-off at higher frequencies and appear more like cable in loss characteristics.



Return Loss

After two years of design and measurement of digital distribution systems and distribution products, I now know the technical justification for the "sacred trunk" architecture

RETURN LOSS! RETURN LOSS! RETURN LOSS!

Return Loss is the most misunderstood yet most critical specification for a system component. Ideally the next device will absorb all the energy transmitted by a device; none of the signal will be reflected. In reality, a reflection travels back the coaxial cable until it hits the source device. If the source has a high return loss, most of the signal is absorbed.

A low return loss source will reflect the signal creating "standing waves" that have a frequency relative to the cable length connecting the two devices. Ripple results from the connection of two components having poor return loss.

Only accept products that have input and output return loss specifications.

A Hewlett Packard explanation of return loss yields a set of equations that predict the worst case ripple when two devices of known return loss are connected. Note that two devices of 12 dB return loss cause 1.1 dB of ripple. Some low cost products tested by Sonora have had return losses of 6 dB or less. An amplifier with 6 dB output return loss will create 4.5 dB of ripple when it sees a 6 dB return loss splitter.

Device 1 Rtn Loss	Device2 Rtn Loss	Ripple	Device 1 Rtn Loss	Device 2 Rtn Loss	Ripple
15	6	1.6 dB	12	6	2.2 dB
15	8	1.2 dB	12	8	1.7 dB
15	10	1.0 dB	12	10	1.4 dB
15	12	0.8 dB	12	12	1.1 dB
10	6	2.8 dB	6	6	4.5 dB
10	8	2.2 dB	6	8	3.5 dB
10	10	1.7 dB	6	10	2.8 dB
10	12	1.4 dB	6	12	2.2 dB

Table 5 Ripple Created by Reflections

Each QPSK transponder starts as a flat block of noise with some minimum carrier to noise ratio. Figure 15 illustrates a single transponder of 18 MHz in width and having a carrier to noise of better than 10 dB. Transponder flatness in a broadband digital QPSK distribution system is the limiting factor in system design.

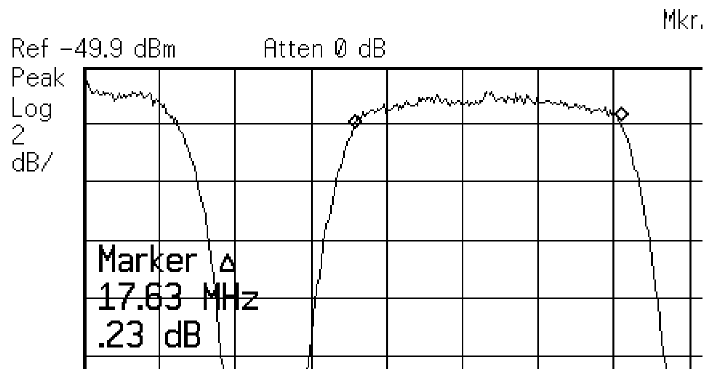


Figure 15 Transponder Flatness

Signal reflections caused by poor return loss devices can cause the affects seen in the figure to the right. The reflection between the two splitters spaced at 24 inches causes peaks and valleys to appear in what started as a flat group of equal level transponders. The top trace is the sweep response of connected splitters. The bottom trace shows how the standing waves affect transponder amplitude.

This a very simple test that can be performed with two splitters, two high return loss pads and a piece of cable. Connect the output of one splitter to the input of the other splitter through a 24 inch jumper. Terminate the unused ports. Place a high return loss pad on the input of the first splitter. Connect a signal source, padded with the other high return loss pad to the input of the first splitter.

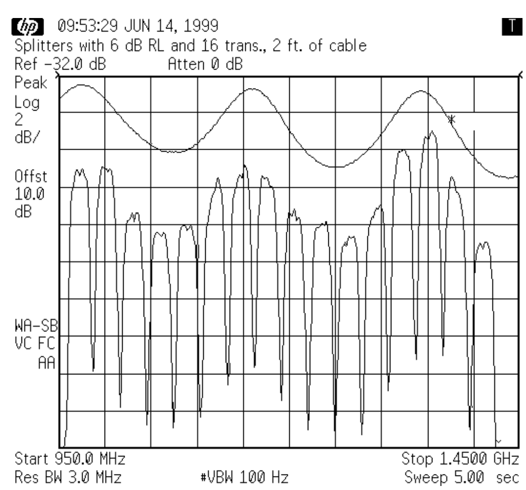


Figure 16 Standing Waves

The spectrum analyzer plot to the right illustrates the difference between 15 dB return loss splitters and 6 dB return loss splitters. Using the same configuration as Figure 17, we substituted two 15 dB return loss splitters and overlaid the response. Note the peak to valley of the high return loss devises is less than 0.2 dB,

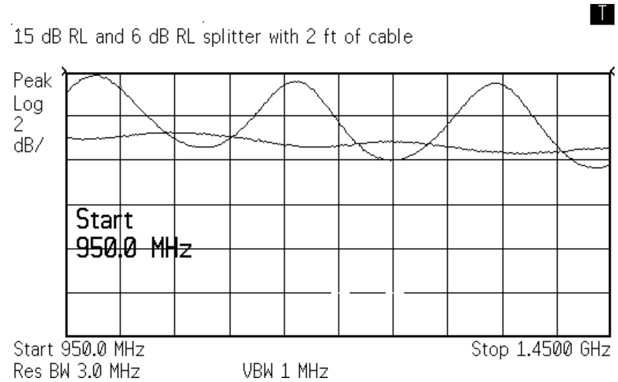


Figure 17 Return Loss 15 dB vs 6 dB

Figures 18 and 19 show the affect of passing 3 transponders through two splitters connected by 20 feet of RG-6.

In Figure 18, 15 dB return loss splitters are used. In Figure 19, two 6 dB return loss splitters are substituted.

Note the standing waves cause a 2.3 dB peak in the middle transponder and valleys in the first and third transponders.

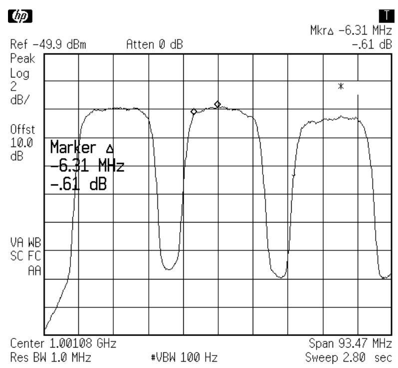


Figure 18 15 dB RL Transponders

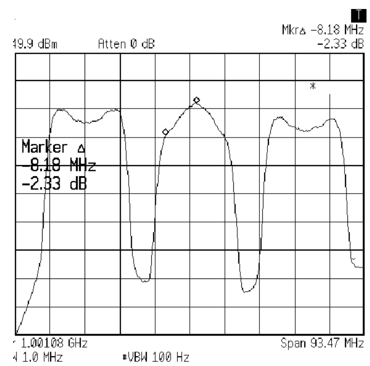


Figure 19 6 dB RL Transponders

Devices that do not equal 75 ohms reflect a percentage of the signal back to the source. Sources that are not exactly 75 ohms reflect the reflected signals. Standing waves are created.

The frequency is proportional to the spacing of the devices. The swept response of the 6 dB devices of Figure 19 is displayed with both a 1 foot spacing and a 20 foot spacing of RG-6.

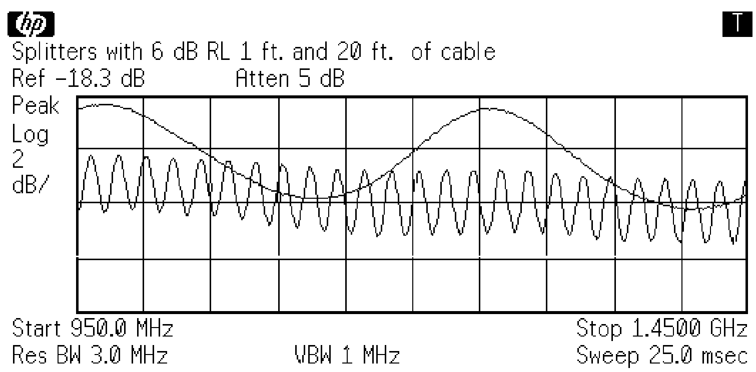


Figure 20 Ripple Frequency: 1 ft vs 20 ft

Hex crimping is final illustration of the effects of poor return loss. Figure 21 is what you will see if you do not use compression type fittings. This is a photograph of an actual installation problem we encountered in a high rise building. The frequency of the notches indicates a spacing of 20 feet to 25 feet. (The distance between floors and repetitive bad connectors)

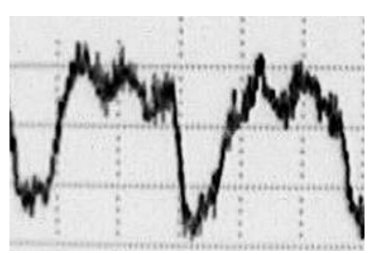


Figure 21 RG-11 Hex- Crimp

The three figures to the right display superimposed plots of both the swept response of the two splitters and the resulting distortion imposed on a flat group of 16 transponders. You can match the wave pattern of the swept response on the distorted transponder band.

Figure 22 is typical of jumpers used to connect amplifiers to splitters to multiswitches. Note that no single transponder is severely distorted yet there are 5 dB differences in transponder peak levels.

Figure 23 is typical of a high rise trunk where the cable has taps every floor. Note that the distortion now creates some serious “suck-outs” in most of the transponders

Figure 24 illustrates the loss within the drop cable can reduce the amplitude of the ripples. The frequency of the ripples is higher than at 20 feet spacing while the amplitude is reduced to less than 2 dB. Note that the amplitude increases with frequency. This indicates that the return loss is less at the higher frequency.

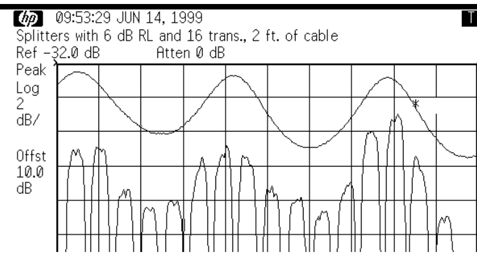


Figure 22
Ripple @ 2 Ft

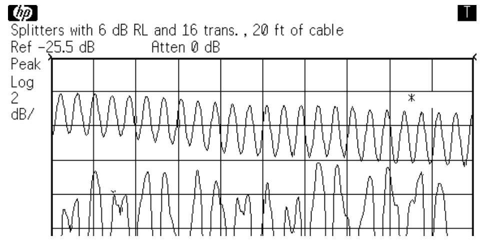


Figure 23
Ripple @ 20 Ft

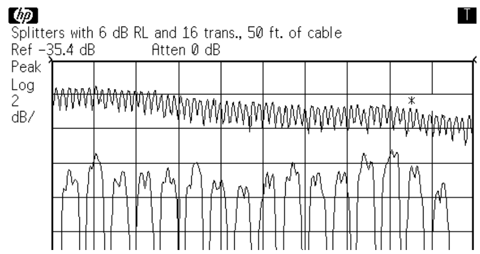


Figure 24
Ripple @ 50 Ft

Table 8 Noise Figure

The beauty of digital signal distribution is the ability to run amplifiers well below their maximum operating level without the penalty of carrier to noise degradation. DBS QPSK signals start from a 36” dish with 20 dB of carrier to noise while analog TV signals from the headend start at 60 dB CNR. The inset analysis indicates that 10 amps in cascade result in a reduction of CNR for the QPSK signal from 20 dB to 19.8 dB. In the analog system, a ten-amp cascade results in a CNR reduction from 60 dB to 51 dB.

QPSK CNR after a 10 Amp Cascade

NF = 8 dB, Gain = 30 dB, Input = 0 dBmV (-49 dBm)

Thermal noise in 24 MHz = -51 dBmV (-100 dBm)

C/N_0 = Input Level + 51dB - NF

C/N_0 = 43 dB

The amplifier cascade CNR is calculated below.

C/Nc = C/N0 - 10 log N, where N = 10= # of amps in cascade

C/Nc = 33 dB

The summation of a 20 dB CNR and the amplifier cascade CNR is:

C/Ns = $-10 \log (10^{-33/10} + 10^{-20/10})$

C/Ns = 19.8 dB

Analog CNR after a 10 Amp Cascade

In the analog world, the stating CNR is 60 dB

The individual amplifier CNR is calculated below:

NF = 8 dB, Input = 10 dBmV

Thermal noise in a 4 MHz bandwidth = -59 dBmV

C/N0 = Input Level + 59.4 - NF

C/N0 = 61 dB

A 10-amplifier cascade CNR is calculated.

C/Nc = C/No - 10 log N, where N = # of amps in cascade

C/Nc = 51 dB

The summation of the Headend output CNR and the amplifier cascade CNR is calculated.

C/Ns = -10 log (10 -51/10 + 10 -60/10)

C/Ns = 51 dB

QPSK Amplifiers

Digital QPSK amplification differs from analog amplification in terms of the effects of return loss, noise figure and intermodulation distortion.

We will describe the importance of each specification and illustrate typical problems using the captured data from spectrum and network analyzers.

Figure 25 Slope Compensated Gain

Distribution losses from 950 MHz to 2025 MHz increase with frequency. Amplifier gain should therefor increase with frequency to offset the losses. The figure to the right illustrates the net output (dotted line) for input signals to an amplifier with built-in slope compensation. Amplifier specifications should list the gains at three frequencies; 950 MHz, 1450 MHz and 2025 MHz. (2013 MHz is technically the end of the last transponder) Slope of 10 dB compensates 300 feet of RG-6 or 200 feet of RG-11 and three 8-dB taps.

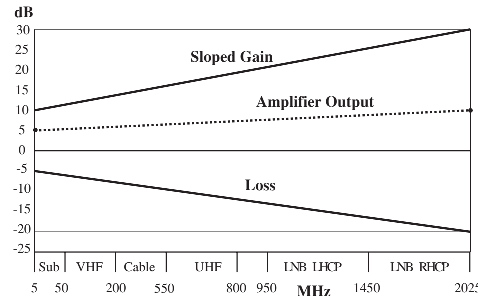


Figure 26 Gain Linearity

One should be able to draw a straight line between the gain at the lowest desired frequency and the highest desired frequency. The plot to the right shows two amplifier responses. The vertical scale is 2 dB per division.

The upper trace is the 6-Sigma model PA2530. Markers are located at 950 MHz, 1450 MHz and 2050 MHz. The lower trace is a major band amplifier used in multiswitch systems. While the competitor is linear between 950 and 1450 MHz, the gain drops off sharply after 1700 MHz.

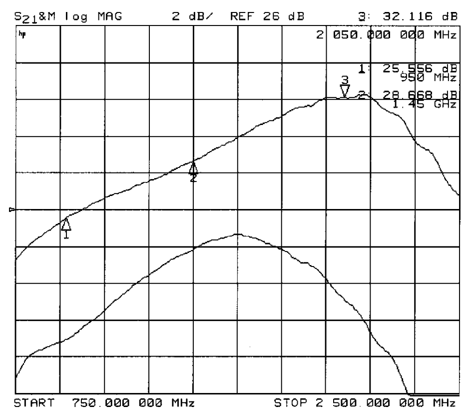
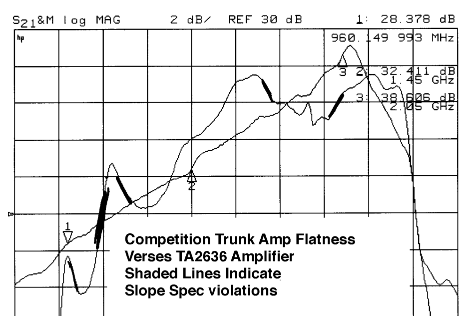


Figure 27 Gain Flatness over 24 MHz

Any transponder must remain flat within 2 dB peak to valley. Exceeding this flatness will result in lower receiver counts and can cause programs to freeze frame. The figure on the right has two traces overlaid. Each vertical division represents 2 dB of gain. The trace that has markers is the gain of the TA2636 amplifier. The other trace is a competing model having similar gain. Rapid changes in gain cause transponder flatness variations exceeding the transponder flatness specification. The highlighted areas are violations of the specification.



One of the highlighted regions is expanded in the plot to the right. Markers are placed on the gain slope spaced 24 MHz apart. Note the marker delta readout indicates the marker amplitude difference is 2.2 dB.

The middle trace of the plot is the TA2636 amplifier. Sonora specifies a gain flatness across any 24 MHz band of less than 0.2 dB.

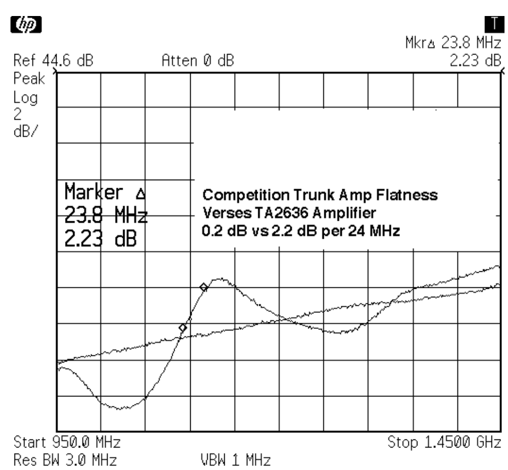


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Figure 28 Output Capability

Gain and output capability are often believed to be the same. A consumer grade 20 dB gain drop amplifier will work for low level inputs but will distort the signal when too much signal is present at it's input. The illustration to the right plots gain verses output. The vertical axis is output and the horizontal axis is input.

Go to the -40 dBm input vertical line. Follow it up to where it intersects the drop amp curve. The resulting output to the left is -20 dBm. Continuing up the vertical line to the node amp you see the node amp output would be -10 dBm. The trunk amp for the same input would have an output of 0 dBm. Note the gain slope is linear until amplifier compression begins.

Now go to the -30 dBm input vertical line. Going up to the intersection of the drop amp you see that the drop amp output is only slightly higher than when the input was -40 dBm. The amplifier is overdriven and is creating distortion. The Node amp is near its maximum output at this input level.

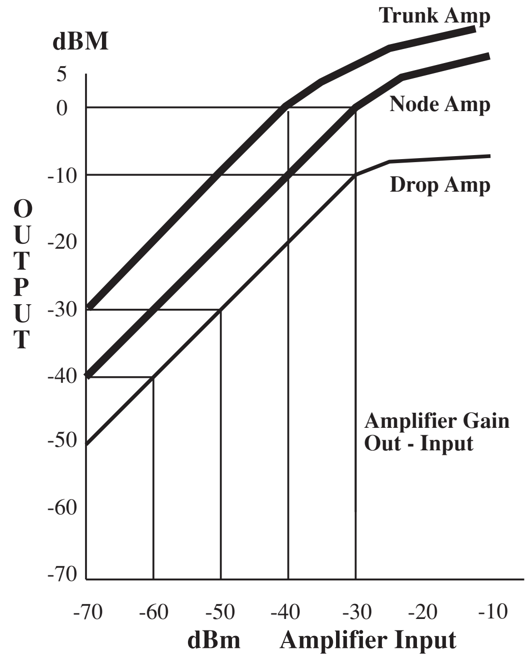
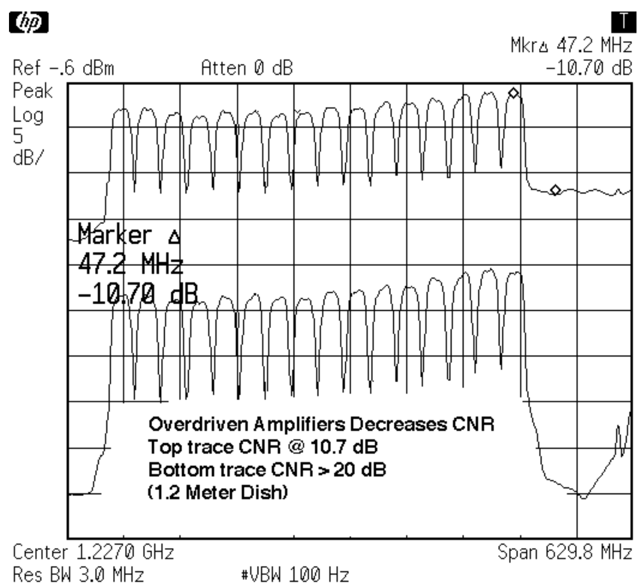


Figure 29 Amplifier Overdrive

A common design problem of system operators is overdriving amplifiers. An overdriven amp creates distortion products that fall on top of the desired signals. In the analog world, the indication on the TV is a herringbone pattern in the picture. In a spectrum analyzer, the overdriven analog appears as spikes or "spurs" within the 6 MHz channel window.

Overdriving a digital signal results in a decrease in the carrier to noise ratio. On receivers, the indication is a lowering of the receiver counts. The figure to the right show the effect of an overdriven amplifier. Note the bottom trace has a full 16 dB of carrier to noise. The upper trace has good flatness but the noise level has increased and the resulting CNR has decreased to 10 dB



Another way to compare amplifier output performance is to adjust the input to two amplifiers such that each has the same output level. The resulting carrier to noise performance can then be measured. The figure to the right compares the TA2636 to another band of DBS amplifier. The test was done for a single polarity sine the competitor amp was designed for only 950 to 1450 MHz performance.

Note at both the high and low frequency noise floor has increased on the upper trace. The scale is 5 dB per division indicates the TA2636 has 2.5 dB better output capability. (Distortion increases 2:1 with output level)

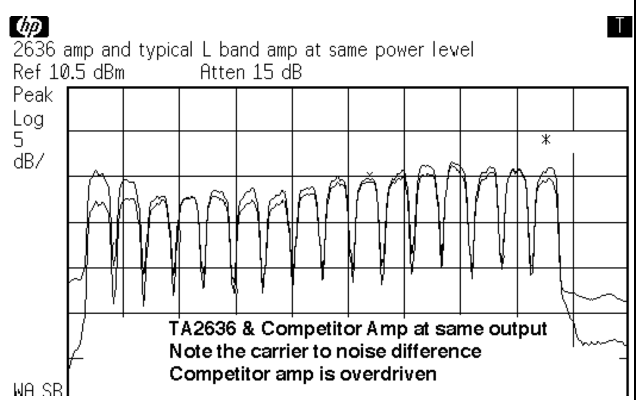


Figure 30 TA2636 Return Loss

Network analyzer plots are used in the document to illustrate the performance of products used in DBS distribution systems. Network analyzers are very high performance spectrum analyzers. The HP model 8753D used by Sonora cost over $30,000. It allows the engineers to see details on the performance of products over the entire frequency band.

The horizontal scale indicates the frequency of the display. Note the "start" and "stop" frequency annotated at the bottom of the plot.

It was shown earlier the frequency ripple affects of low return loss in passive devices. Amplifiers also must have high return loss to maintain flatness across the transponders. The frequency response of a TA2636 amplifier is shown to the right. The flatness could not be achieved without good return loss on both the input and the output.

The bottom plot(s) illustrate the "return loss" of the product at the same three frequencies. The first plot labeled "S21" is the input return loss. The lower plot labeled "S22" is the output return loss. Ideally we want the plots to be flat and of high value. Note the return loss marker information indicating the output return loss of

1--16.5 dB, 2--18.8 dB & 3--17.1 dB

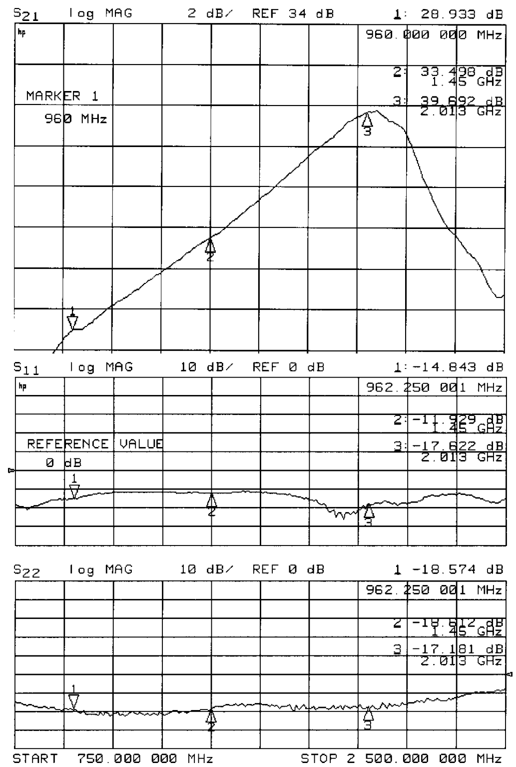


Figure 31 AMP#2 Return Loss

The frequency response of amplifier #2 was previously shown in Figure 27 to exceed the per transponder flatness requirements. One possible explanation for the gain fluctuations is poor return loss.

The S11 trace to the right is the input return loss. Markers indicate the return loss varies from 4.9 dB to 10.6 dB.

The S22 trace to the right is the output return loss. Markers at the same key frequencies indicate the return loss varies from 5 dB to 16 dB.

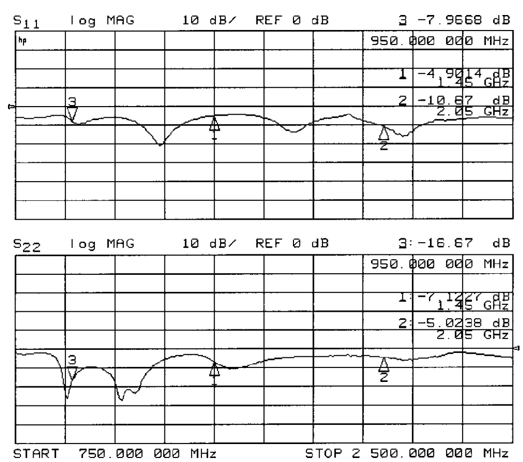
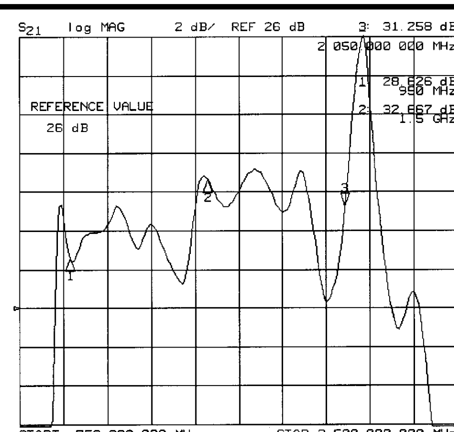


Figure 32 Amplifier Gain Instability

When return loss falls below a minimum oscillation can occur within the amplifier. The figure to the right shows the reaction of a low return loss amplifier to seeing a low return loss splitter 10 feet from its output. The oscillation is indicated by the extreme spike in gain located near 2 GHZ.



Necessity Products

Sonora imports high return loss accessory products we call necessities. Small items like connectors, terminators, pads and barrels can kill system performance if they do not have high return loss.

Screw a 6 dB return loss pad on a 15 dB return loss amp and you now have a 6 dB return loss amp. Alternately, screw a 18 dB return loss pad on a 6 dB return loss splitter and you have an 18 dB return loss splitter.

Figure 33 Terminator Return Loss

The network analyzer plot to the right is the return loss measurement of two terminator. The top trace is a standard terminator. The bottom trace is a HR-FT high return loss terminator. Note the scale is 10 dB per division. The HR-FT has greater than 10 dB more return loss than a standard terminator.

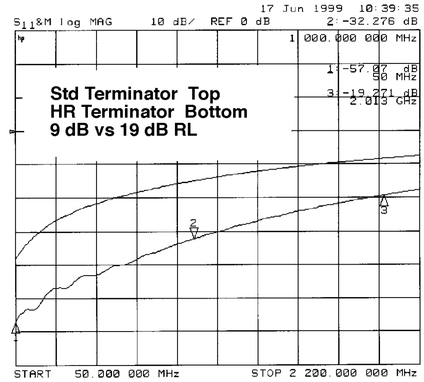


Figure 34 Pad Return Loss

The network analyzer plot to the right is the return loss measurement of a high return loss pad. While the high return loss version may look similar to the low cost version, the performance improvement is significant. Use the model HR-FAMP* on signals where DC is present.

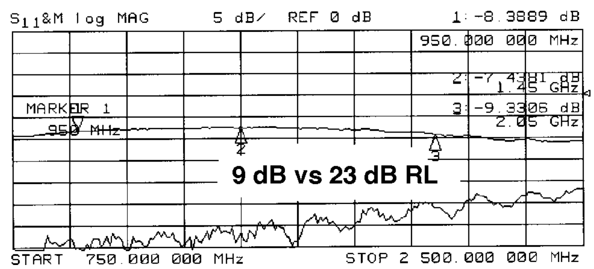


Figure 35 Barrel Return Loss

The network analyzer plot to the right is a return loss comparison of a HR F81 high return loss barrel connector verses a standard wall plate barrel. The upper trace is the standard barrel having 7 dB return loss at 2025 MHz. Note the scale of 10 dB per division meas the lower trace HR F81 has 15 dB better return loss! Pushing the 2 GHz signal through a barrel in a ground block is even more critical than the barrel used at wallplates. A reflection caused by a poor return loss ground block will affect the entire system.

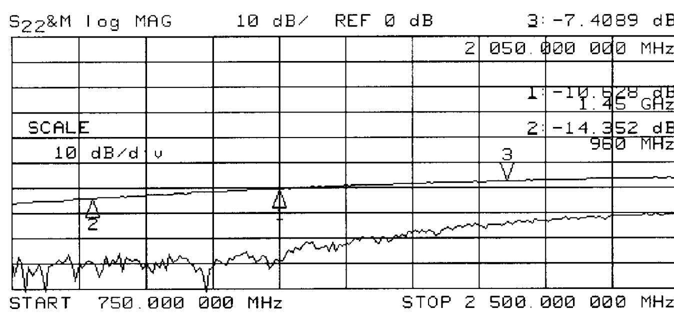
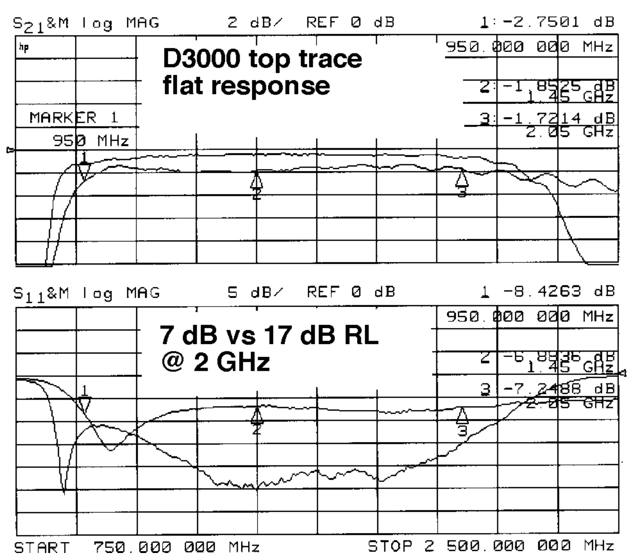


Figure 36 Trunk vs drop grade diplexer

Most diplexers commonly used at the end of drops lack the performance required for use in trunk applications. The frequency response plot to the right illustrates two models of diplexers. The top trace is the D3000 diplexer specified by Sonora. Note the response is flatter and has a lower insertion loss than the standard diplexer.

The critical specification of diplexers for trunk use is return loss. The top trace with markers is the standard grade diplexer. Note the lower trace of the D3000 has 10 dB better return loss.



Distribution Architectures

When building a house you hire an architect before you begin construction. As a system operator, you are required to submit a plan for your distribution system prior to obtaining the property identification number.

Many small multi-switch systems have been installed without regard to signal levels or architectures. Most work because the of the small scale of the distribution system

Single wire distribution systems operate at higher frequencies and are used in larger installations. Planning is required to provide highly reliable systems. When beginning a design, step back and first look at the overall layout before beginning detailed signal calculations.

Two design parameters are the basis for all designs, antenna output and receiver minimum input.

Figure 37 Sacred Trunk

The first systems I designed and installed were based upon design recommendations of two industry pioneers. Frank Accardo coined the phrase "sacred trunk" to relate his experiences in installing DirecTV® systems in MDUs. Martin Turner who installs MDU systems in Europe, uses the term "virgin trunk" to describe his method of distribution.

The "sacred trunk" method of high frequency distribution is illustrated to the right. The concept is similar to "node" architecture employed by cable and telephone companies. While the MDU model is smaller in scale, the goal is to maintain the integrity of the trunk signals.

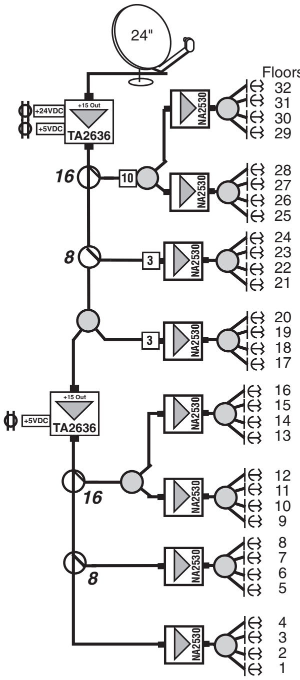


Figure 38 1 Dish, 1 Receiver

DBSMATV distribution system design is based on duplicating the signal a single family receiver would see when connected to it's own 18 inch dish. The single family model above indicates a typical output from the dish of -35 dBm. After 200 feet of RG-6 cable the receiver sees an input of -51 dBm or the equivalent of -2 dBmV.

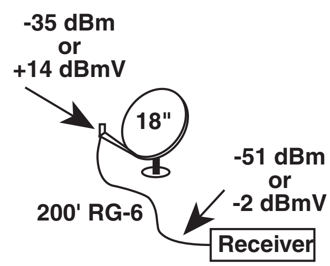
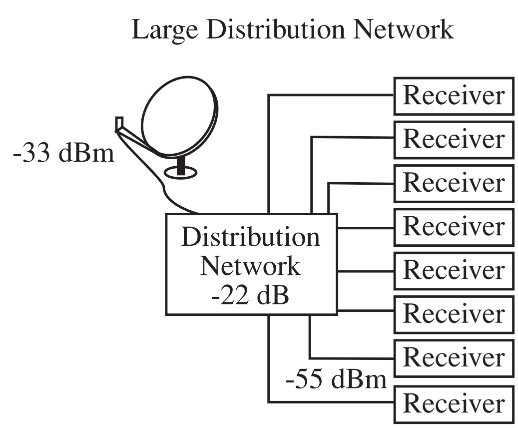


Figure 39 1 Dish, 8 Receivers

Distribution system design involves working from both ends of the system. The dish has a maximum output level and the receivers have a minimum input level. Assume we upgrade the dish from 18 inches to 24 inches. We now have -33 dBm to start our distribution.

We still need -55 dBm minimum to each of the receivers. Assume the receivers are connected to the distribution system by 100 feet of RG-6. The drop cable eats 8 dB of our distribution loss budget. We add 8 dB to the -55 dB receiver input to determine the signal level required into each drop cable. (-55 dBm + 8 dB = -47 dBm)

Further assume for this example that all receivers are connected to a common distribution "node". Now we work our way down from the dish and LNB to the distribution node. If the dish is 100 feet from the node and we use RG-6 cable, the input to the node is (-33 dBm - 8 dB = -41 dBm)



We now have the signal requirements for both ends of the distribution node. The input is -41 dBm. The required output to each drop cable is -47 dBm. We have a 6 dB budget to get the single signal split to feed the 8 receivers. An 8-way splitter has 14 dB of loss at the DBS frequencies. If we just use an 8-way we would be 8 dB low in signal level to each receiver.

Amplification is required.