***Not only is the ATRC's Advanced Digital HDTV system the most technologically advanced, its selection would provide for the maximum maintenance of U.S. jobs and would encourage continued U.S. manufacturing investment.***

# DIGITAL VIDEO

Will Change Our Business and Our Lives
in the 1990's

- **HDTV**
- **DBS**
- **Cable**
- **Interactivity**
- **Multimedia**

# NEW SERVICES AND FEATURES

## Permitted by MPEG + + Data Format

- Pix-in-Pix on Single Channel

- Range of Audio Options
  - Including ready access to multiple languages

- Data With Consumer Options
  - Service Identification
  - Program Guides

- Consumer Interactivity
  - Entertainment
  - Education
  - Home Shopping
  - Coupon Service
  - Contests, Games, etc.

- Limited Only by Imagination of Service Providers

# MPEG DIGITAL COMPRESSION STANDARD
## (Motion Picture Expert Group)

- MPEG Standard is a Consensus of the World's Leading Video and Audio Digital Compression Experts

- Our Consortium Extended MPEG to MPEG + + To Achieve Excellent HDTV Performance

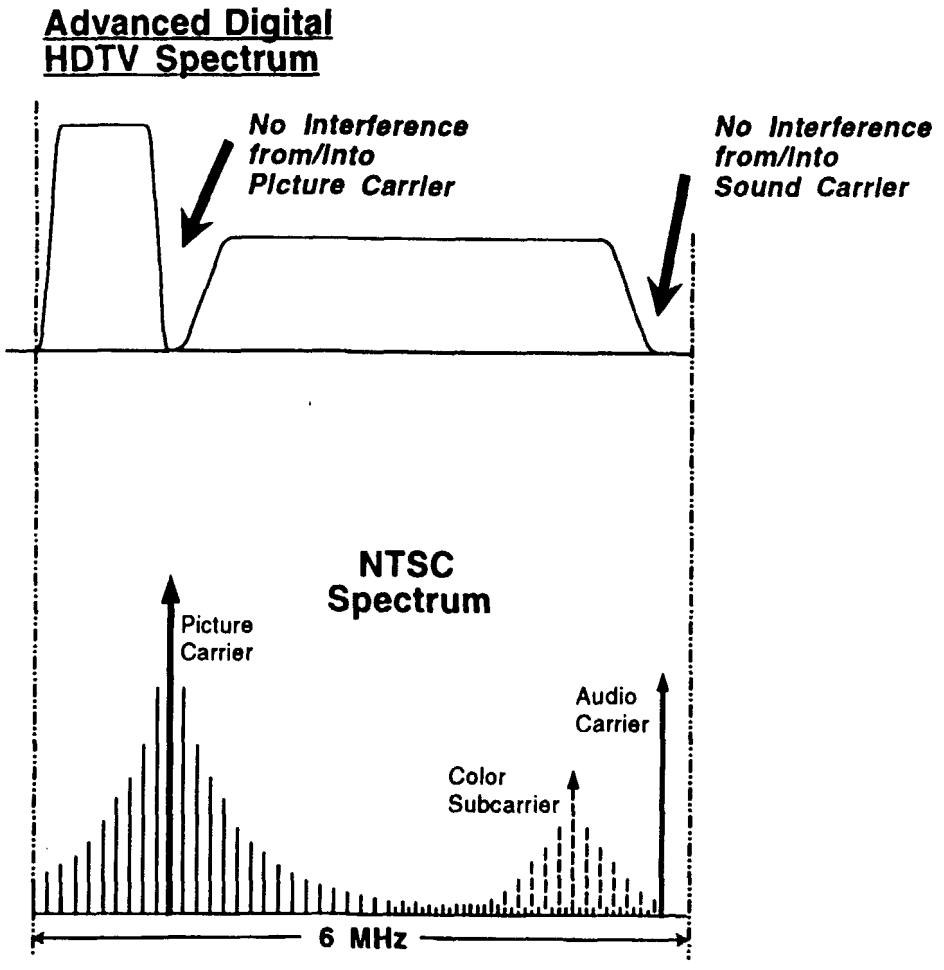
- MPEG and MPEG + + Are Designed for Broad Applications
  - TV and HDTV
  - Recording - VCR, Disc
  - Multimedia
  - Computers

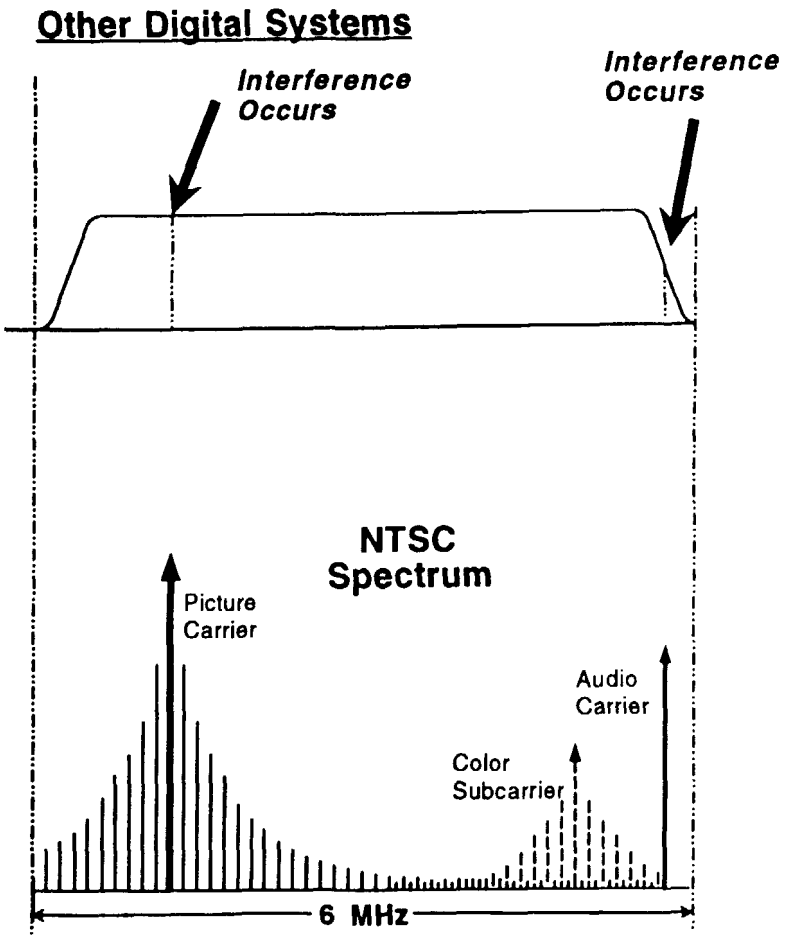
- MPEG Standards Will Become Mainstream Video / Audio Technology
  - Easy Transfer of Video Between Media
  - Broad and Economical Availability of ICs

# DIGITAL VIDEO COMPRESSION STANDARDS

| Service | Data Rate Mbits/Sec | ATRC Strategy | Proposals of Others |
|---|---|---|---|
| **Multimedia** | **1.5** | **MPEG** | **MPEG** |
| **DBS** | **4-7** | **MPEG + +** | **A,B,C, etc.** |
| **Cable** | **4-7** | **MPEG + +** | **M,N,O,P,Q, etc.** |
| **HDTV** | **15-24** | **MPEG + +** | **T,U,V** |

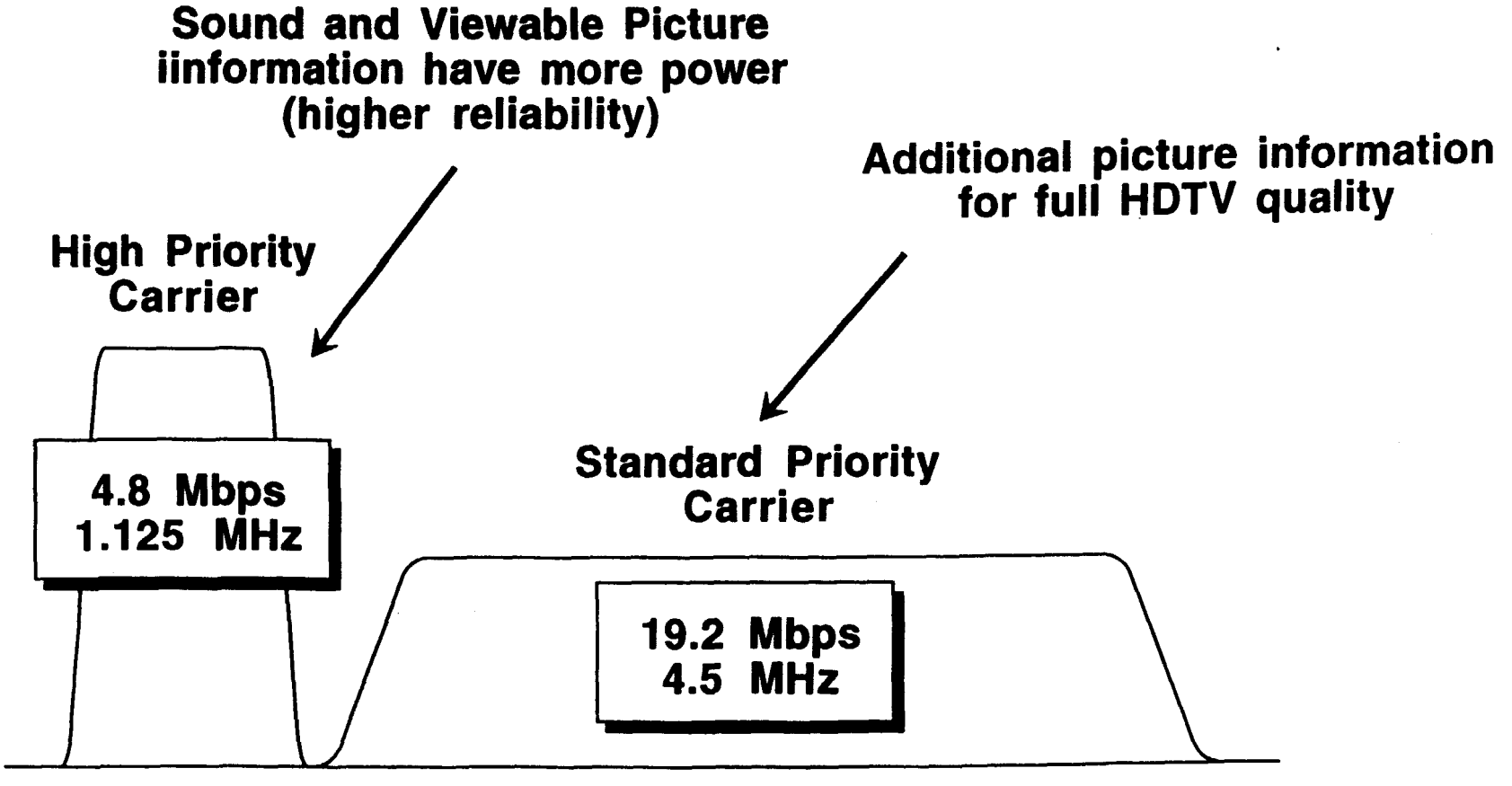
# Advanced Digital HDTV Interference Comparison



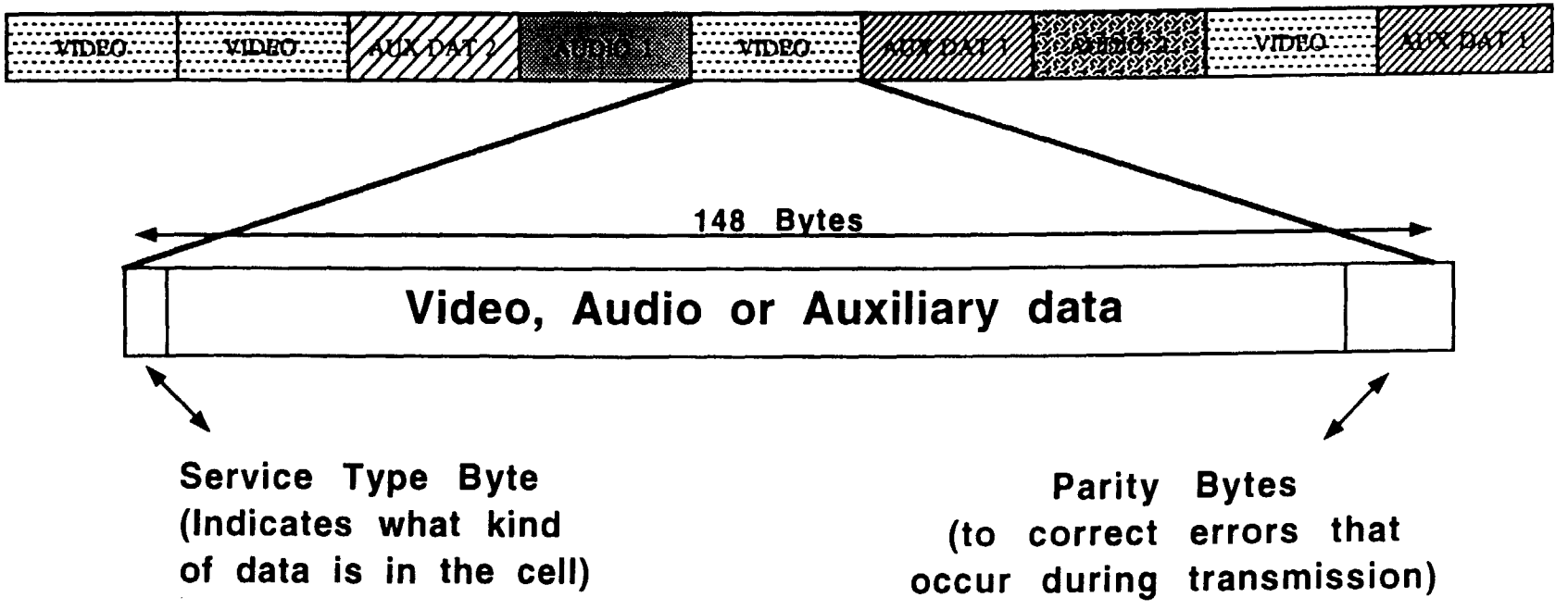

**Advanced Digital HDTV's spectrally-shaped QAM reduces interference and increases coverage area by avoiding the high-power picture and sound carriers of a co-channel NTSC signal.**

# Spectrally-Shaped QAM Concept




Total data rate of 24 Million bits per second delivers outstanding HDTV pictures and CD-quality sound

# Advanced Digital HDTV's Data Format




**Advanced Digital HDTV's data cells provide flexibility and new programming opportunities by delivering a dynamic combination of video, audio, and auxiliary data to receivers**

# ADTV TECHNICAL SUMMARY

ADTV consists of MPEG++ video compression, MUSICAM audio compression, Prioritized Data Transport format and Spectrally-Shaped Quadrature Amplitude Modulation, integrated to operate in unison as an effective simulcast system. This technical summary outlines the fundamental techniques used by ADTV to achieve:

- Outstanding HDTV Picture and Sound Quality
- Reliable and Robust Performance Characteristics for Broadcasting
- Low Interference with Existing NTSC Service
- Coverage Area Greater Than or Equal to NTSC and High Accommodation
- A Flexible Scope of Services
- Interoperability and Extensibility
- Low Cost for Broadcasters, Alternative Media and Consumers

## OUTSTANDING HDTV PICTURE AND SOUND QUALITY

The combination of MPEG++ compression and SS-QAM's high 24 Mbps data rate achieves outstanding HDTV picture and sound quality. MPEG++ video data compression is based on the ISO-MPEG (International Standards Organization — Moving Picture Experts Group) standard. MPEG was developed by selecting and refining the best approaches for video data compression, based on side-by-side picture quality comparisons by video compression experts around the world. MPEG video compression achieves outstanding picture quality through several approaches:

- MPEG compression uses an adaptive motion-compensated Discrete Cosine Transform (DCT) that perceptually optimizes the picture encoding on a block-by-block basis.
- MPEG motion compensation uses bidirectional prediction (both forward and backward in time) to accurately predict frames. This allows more bits to be used for picture detail (instead of being used to correct motion prediction errors), which results in outstanding picture quality.
- MPEG has periodic frames that are always spatially coded. This preserves the ability to reconstruct pictures in fast-forward and reverse scanning modes from digital storage media.

ADTV's MPEG++ provides additional performance improvements for HDTV:

- ADTV's MPEG++ compression uses frame based coding. This is transparent to interlaced HDTV sources, and provides for *higher quality progressively scanned* film sources, with virtually no additional cost at the receiver.

- ADTV's MPEG++ compression uses a two-pass encoding scheme that allows bit allocation to be performed with perceptual weighting. This significantly reduces compression artifacts and improves picture quality.

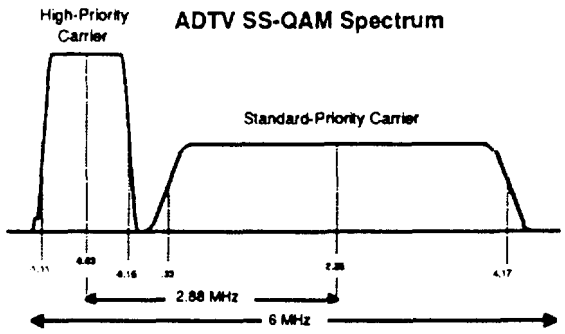
The excellent compression performance of MPEG++ and the high 24 Mbps data rate provided by ADTV's SS-QAM modulation operate in conjunction to produce outstanding picture quality.

ADTV's MUSICAM audio data compression is also based on the ISO-MPEG standard. It was similarly developed by selecting and refining the best approaches for audio data compression, based on side-by-side listening tests by experts.

### RELIABLE AND ROBUST PERFORMANCE CHARACTERISTICS FOR BROADCASTING

ADTV transmits sound and "viewable picture" data with even greater reliability and robustness than the additional data required for full HDTV quality pictures. With this approach, ADTV achieves outstanding *availability*. ADTV will reliably deliver high-quality HDTV service to its entire coverage area under most transmission conditions, and it will deliver viewable pictures and sound to its entire coverage area even under severely impaired transmission conditions. ADTV achieves this reliability and robustness by its unique system design:

- ADTV separately transmits two classes of data — High-Priority data and Standard-Priority data. Its High-Priority data is transmitted with extremely high reliability.
- ADTV's MPEG++ video compression is *prioritized* -- it produces *high-priority data* that provides a viewable picture, and additional *standard-priority data* that provides full HDTV quality. ADTV is designed to deliver viewable pictures with extremely high reliability.
- ADTV's MUSICAM compressed audio is treated entirely as *high-priority data,* so that high-quality sound is delivered with extremely high reliability.
- ADTV's Spectrally Shaped-Quadrature Amplitude Modulation (SS-QAM) signal provides two-tiered transmission. It consists of two *separate* trellis-coded 32-QAM data carriers — a High-Priority carrier and a Standard-Priority carrier. Both carriers can be seen in the SS-QAM frequency spectrum shown below:




- ADTV coverage area is defined based on reliable reception of its Standard-Priority carrier, which provides full-quality HDTV service. The High-Priority carrier (containing viewable picture and sound data) is transmitted at a *higher power level*, providing transmission robustness.

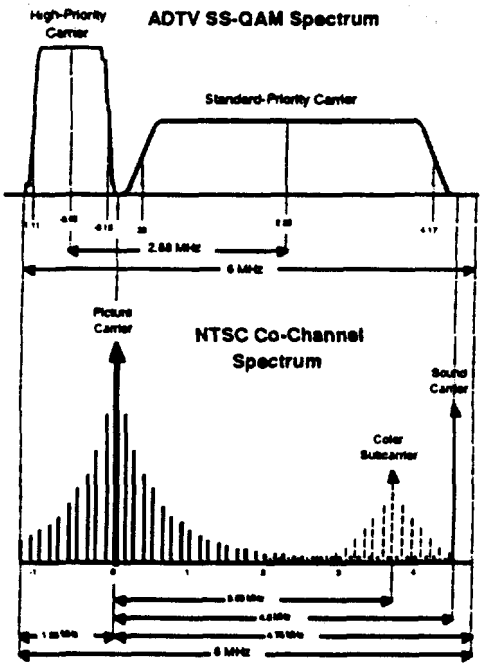
ADTV also has other features that contribute to its robust performance:

- ADTV's Prioritized Data Transport packages and synchronizes both high-priority and standard-priority data for separate transmission. It has several "safety nets" that perform error correction, error detection, and error recovery to protect against transmission errors.
- Both of SS-QAM's data carriers are trellis-coded, and provide additional robustness in the presence of noise and interference.

### LOW INTERFERENCE CHARACTERISTICS REQUIRED FOR SIMULCASTING

Low-interference characteristics are essential in order to perform simulcasting with reduced co-channel separation. ADTV achieves its low-interference characteristics through the virtues of its SS-QAM signal structure:

- ADTV is designed to operate with much lower power than an NTSC station. This substantially eliminates interference with NTSC co-channel stations, even with the reduced co-channel separation needed to accommodate most broadcasters with a simulcast channel.
- SS-QAM provides ADTV with high immunity to interference from higher-power NTSC stations, resulting in a coverage area that is not eroded by NTSC interference. It uses the simple and effective approach of *avoiding* the high-power picture and sound carriers of a co-channel NTSC signal. ADTV's SS-QAM frequency spectrum and an NTSC co-channel frequency spectrum are shown below:




- Although SS-QAM's High-Priority carrier has higher power level, NTSC receivers are relatively immune to it — their Nyquist filter attenuates those frequencies. ADTV interference into NTSC is limited by the power of its Standard-Priority carrier, which results in an effective increase in ADTV coverage area at a given total power.
- SS-QAM's Standard-Priority carrier is friendly to co-channel NTSC receivers because it does not interfere with an NTSC co-channel signal's sound carrier.

### COVERAGE AREA GREATER THAN OR EQUAL TO NTSC AND HIGH ACCOMMODATION

In a simulcast HDTV environment, there are two factors that are of critical interest to broadcasters — how much coverage area a simulcast signal will reach, and how many broadcasters can be accommodated with a simulcast channel. The key approaches that allow ADTV to provide large coverage area and a high accommodation percentage are:

- SS-QAM's High-Priority carrier is attenuated by the Nyquist filter in NTSC receivers. This allows ADTV to have a higher power than signals with uniform spectral density, while causing comparable interference in NTSC receivers. This allows increased transmission power for greater range, and/or reduced co-channel spacing.
- ADTV's noise-limited coverage benefits from trellis coding each of SS-QAM's carriers. The High-Priority carrier has a threshold CNR of 11.1 dB and the Standard-Priority carrier has a threshold CNR of 16.1 dB.



benefits from trellis coding each of SS-QAM's carriers.

- ADTV's interference-limited coverage benefits from SS-QAM's spectral shaping. SS-QAM's NTSC immunity prohibits the erosion of simulcast coverage area by interfering NTSC co-channel stations. For ADTV-NTSC co-channel separation larger than about 112 miles, essentially none of the ADTV coverage area is lost as a result of NTSC interference.
- ADTV's two-tier transmission allows coverage area to be based on approximately 97.5% time availability of its High-Priority carrier and 90% time availability of its Standard-Priority carrier.

The goals of achieving a large coverage area and a high accommodation percentage are inherently at odds with one another. ADTV provides many good options for simultaneously satisfying both of these requirements, such as:

| ADTV-NTSC CO-CHANNEL SPACING | ACCOMMODATION PERCENTAGE | COVERAGE RANGE[1] |
|---|---|---|
| 99 miles (160 km) | 99.7 % | 50.7 miles |
| 112 miles (180 km) | 98.4 % | 54.5 miles |
| 124 miles (200 km) | 95.8 % | 58.6 miles |
| 136 miles (220 km) | 91.3 % | 62.5 miles |

- A noise-limited range of 55.5 miles (the same as NTSC) can be provided with a co-channel spacing of 115 miles[1]. This will accommodate 97.5% of the broadcasters with a simulcast channel. (By comparison, NTSC provides a range of 55.5 miles and a minimum co-channel spacing of 155 miles).

ADTV provides other important capabilities and options for broadcasters (see Chapter 5):

- Broadcasters in especially difficult co-channel situations can reduce their coverage area, or they can slightly reduce their picture quality and select ADTV's 16-QAM option. ADTV (16-QAM) provides a noise-limited range of 55.5 miles with a co-channel spacing of 105.6 miles[1], increasing the accommodation percentage to 98.8%.
- ADTV provides coverage area that is *superior* to NTSC in situations where co-channel interference constraints are not present.

Of course, the final tradeoffs involving the limit of acceptable NTSC interference, simulcast coverage area, and accommodation percentage for minimum-spaced co-channels are best made by the FCC in collaboration with broadcasters.

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1 Assuming that interference affects 15% of an adjacent NTSC co-channel's coverage area. This assumption is similar to the effect of 5 MW UHF NTSC-NTSC co-channel interference at the minimum allowed separation (155 miles).



benefits from trellis coding each of SS-QAM's carriers

### A BROAD SCOPE OF SERVICES

ADTV's Prioritized Data Transport format separately packages video, audio and auxiliary data and allows their mix to vary dynamically, giving video service providers the flexible scope of services needed to innovate new services and new kinds of programming. Some of ADTV's important capabilities are:

- The basic service provided by ADTV is HDTV video, two stereo sound pairs and auxiliary data (256 kbps), which are reliably delivered in its total capacity of 24 Mbps.
- ADTV offers total flexibility in the mix of video, audio and data services that can be provided to appropriately-featured receivers. It separately packages each *type* of data (e.g., video, audio, etc.) in its own set of transmission cells. Each cell has a *service type* byte that identifies its contents, and an ADTV data stream has no constraint on its types or sequence of cells. This capability provides for a scope of services ranging from eight stereo channels of audio, to broadcast distribution of computer software, to the transmission of very high resolution still images to computers.
- ADTV's mix of services can be dynamically allocated. This will enable broadcasters to send multiple "streams" of video, audio and data programming to their audience, all complementing or enhancing the basic program content. This capability can fundamentally change the nature of television programming, since it enables software to be broadcast to "smart receivers" that can operate in conjunction with the HDTV picture and sound. With this capability, ADTV will likely become a more interactive medium than today's television, enabling new forms of educational programming, games and entertainment programming.

### INTEROPERABILITY AND EXTENSIBILITY FOR FUTURE GROWTH

ADTV has been designed with interoperability and extensibility as important considerations. ADTV's features that provide interoperability among different types of media, as well as among a wide variety of consumer electronics, telecommunications, and computing equipment are:

- ADTV has two video formats (1440 x 960 and 1440 x 810) that respectively provide perceptually square pixels on an HDTV display or logically square pixels in the image.
- ADTV provides both interlaced and progressive scan video formats, at related temporal (field/frame) rates (59.94, 29.97 and 24) that are matched to HDTV and film production.
- ADTV's use of MPEG-based video and audio compression provides the possibility of interoperability with MPEG-based computer multimedia applications directly in the compressed bit stream format.

- ADTV is a "layered" system that provides interoperability at any of its layers. This allows interoperability among various transmission media, data formats, compressed video and audio bit streams, and the uncompressed pictures and sound.

Future growth will also require extensibility, to ensure that new products and services can be provided within the framework of an established standard. ADTV provides *open-ended extensibility* through its Prioritized Data Transport format:

- An ADTV receiver will *disregard* any cell with a service type that it does not recognize or cannot process. This will eliminate future "backward-compatibility" problems in the installed base of receivers, removing a crucial constraint from the introduction of new services.

These capabilities pave the way for delivering many new features or services using the ADTV standard, ranging from compatible HDTV stereo (3-D) television, to new interactive entertainment forms, to compatible ultra-high definition television. With future improvements to its compression, ADTV's higher-power, narrow bandwidth High-Priority carrier even provides the opportunity to provide service to "personal video" receivers that are small, economical and mobile.

### LOW COST FOR BROADCASTERS, ALTERNATE MEDIA AND CONSUMERS

ADTV leverages the ISO-MPEG standard to achieve the most powerful economy of all — a single video compression standard for all consumer and computer delivery media, which will eliminate the need for multiple decoder types and create important synergies and economies of scale. ADTV provides this opportunity:

- ADTV's MPEG video and MUSICAM audio are based on the International Standards Organization MPEG compression standards. MPEG has achieved a great degree of worldwide consensus, and it will be used in many new computer and consumer electronics applications.
- ADTV's transmission is based on QAM transmission, a standard technique that is used in microwave communications as well as at lower speeds in computer modems.

Leveraging standards also creates important cost-reducing economies of scale. The largest factor in reducing cost is high production volume and associated commodity pricing of essential integrated circuits. ADTV's standards-based approach is advantageous in two ways:

- At the time of its introduction, ADTV will benefit from the established momentum of the MPEG video and audio standards. High-volume production of MPEG video and audio

decoder ICs will help to cost-reduce the most complex electronic portions of an ADTV receiver, resulting in accelerated receiver penetration.

- Over the long term, a standards-based approach will result in the use of common (or at least similar) devices in both the consumer and computer industries. The resulting high-volume production and commonality will benefit both industries, as well as the consumer.

ADTV also has attributes that contribute to low cost for program producers, broadcasters, and alternative delivery media:

- ADTV's 59.94 field rate is identical to NTSC — this eliminates temporal artifacts and the need for frame synchronization in mixed ADTV-NTSC production environments.
- ADTV's 1440 x 960, 1050-line scanning format is cost effective in the production studio. Its 2:1 vertical ratio with 525-line (NTSC) video and 2:1 horizontal ratio with the CCIR Rec. 601 sampling standard used in 525-line D1 tape recorders offers economical transcoding in mixed ADTV-NTSC production environments.

Other aspects of ADTV that contribute to low cost for consumers are:

- ADTV's 1050-line scan format is cost-effective in the receiver. The 2:1 vertical ratio with 525-line NTSC allows economical combination (ADTV-NTSC) receivers. In addition, the required 2H deflection system is practical and economical.
- ADTV's 1440 x 960 format is well-matched to low-cost memory devices. The 16 Mbit DRAM frame memories in an ADTV receiver are predicted to cost about $13 each in 1996.
- ADTV's data format is similar to broadband data network formats. This creates potential economy of scale for interface ICs that are common to HDTV and telecommunications.
- MPEG compression was designed for digital storage media and provides important capabilities for a viewable picture in fast-forward and reverse in VCRs, as well as random access capabilities for disks.

## CONCLUSIONS

ADTV has the outstanding HDTV picture and sound quality, transmission reliability and robustness, low-interference characteristics, and large coverage area required to be an effective HDTV simulcast system. ADTV also has flexible operating characteristics that allow it to provide a broad scope of services, as well as the interoperability and extensibility needed to form the basis for new and innovative applications of HDTV in many industries. And ADTV ensures low cost by its approach of leveraging other widely accepted standards.