Digital television

Measuring quality of Digital Television

- What is quality??
- Quality aspects
  - Qaualitative measurements
  - Quantitative measurements
- Quality of Serivce (QoS)
- Quality of video coding
- Quality of communcation channel

What is quality

- ”The degree of excellence of a thing....”
- ”Consistent performance of a uniform product meeting the customer’s needs for economy and function”
- Defining measurable boundaries
  - Quality is the ability to verify that products services are inside the boundaries

Quality

- Example: ISO9000 quality system
  - Defines your current process/system using a number of documents
  - Verifying quality is performed by auditing that current process definitions are fulfilled

Quality aspects

- Quantitative measurements
  - Bit Error Ratio (Data stream)
  - Video coding noise
  - Artifacts from noisy communication channel
- Qualitative measurements
  - Viewer ratings
  - Viewing tests
  - Listening tests

Video quality

- Amplitude differences between adjacent pixel pairs
- Spatial activity
  - Average of amplitude differences of all pixels
- Temporal activity
  - Average of amplitude differences of the same pixel in subsequent frames

Quality of digital television

- Analog / pure digital television systems are linear
  - Results are time invariant and signal independent
  - Test signals can be substituted for program material
  - Static tests are enough
- Compression video systems are non-linear
  - Test signal are easily compressed
  - Picture quality is a function of: data rate, picture complexity and encoding algorithm capabilities
  - Tests with complex motion sequences

Factors affecting video quality

- Quality of the input video
  - Amplitude, dc level, bandwith, jitter
  - Noise, composite/component decoding artefacts
- Nature of the video quality
  - Picture spatial and temporal complexity
- Encoding parameters used
  - Profile/level, field/frame, output data rate, GOP
- Encoding algorithm
  - Speed required, hardware vs software
  - Multiple pass (iteration of parameters)
  - Algorithm design
    - Quantization table selection
    - Use of motion vectors, search range

Picture quality measurements

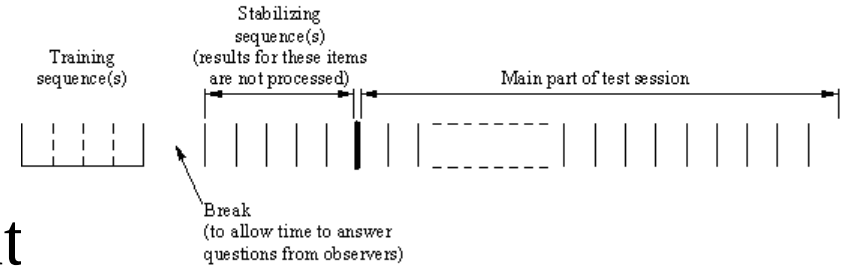
- Difficult to actually measure picture quality
  - Can measure degragation compared to reference
- Subjective measurements
  - ITU-R BT.500
- Objective measurements are most useful if they have good correlation with subjective results

ITU-R BT.500

- Defines
  - Viewing conditions (screen sizes, resolution)
  - Source signals
  - at least 15 test persons
- Test session
- Presentation of the result

FIGURE 1

Presentation structure of test session



Subjective Tests (Human Viewer Trials)

Strengths

- Produces valid results in conventional and digital television system applications
- Provides a scalar result
  - Mean Objective Score
- Works well over a wide range of video (and still image) applications

Weaknesses

- Requires meticulous setup and control
- Needs lots of participants
- Is time-consuming

Subjective tests are only applicable for development purposes. They do not lend themselves to operational monitoring, production line testing or troubleshooting.

Quest for Objective Measurements

- Intuition has led many developers to the same starting point:
  - Picture quality is related to the differences between the original and impaired scenes.
  - A measurement of the magnitude of these differences is somehow related to “picture quality”
  - Therefore, construct a device which indicates the magnitude of these differences.
- There are two approaches to objective measurements
  - Feature Extraction
  - Picture Differencing

Mean Squared Error

- Prediction of quality derived from the result of computing the mean of the squares of the differences
  - As the result approaches zero, the more identical are the original and copy.
  - Conversely, as the result grows, the more different is the copy from the original.
- Peak Signal to Noise Ratio is a variation of MSE:

$$PSNR = 10 \log_{10} \left[\frac{255^2}{MSE^2} \right]$$

But MSE (and PSNR) is Easily Fooled!

Objective Picture Measurements

- ANSI T1.801.03
  - Peak Sig/noise Average gain Offset level
  - Spatial shift Spatial info Temporal info
  - Added/lost; spatial frequencies, motion/edge energy
  - Radial average of spatial frequencies
- Insufficient for comparison of systems
- Useful for yesterday/today comparisons
  - Unfortunately most systems are not constant
    - Bit rate changes
    - Concatenation of different coding systems

Checking MPEG-2 transport stream

- TS Protocol testing
  - Defined by DVB-MG (measurement group)
  - DVB-PI (physical interface)
    - 8-bit synchronous interface (+clock, sync, data-valid)
    - SSI (Syncronous serial interface)
    - ASI (Asyncronous serial interface)
      - 270 Mbit/s
  - High-priority tests
    - TS_sync_loss (5 consecutive sync bytes -> sync, 2 or more consecutive sync errors -> syn loss)
    - PAT_error
      - PID0000 does not contain PAT data
      - time between two PID0 packets > 0,5 s
      - PAT packet is scrambled (not allowed)

Checking MPEG-2 transport stream

- High priority tests
  - Continuity_count_error
    - order of packet incorrect, packet is multiply transmitted, missing
  - PMT_error
    - time between PMT PID packets > 0,5s
    - if packet is scrambled
  - PID_error
    - if no packet is transmitted with the corresponding PID

Checking MPEG-2 transport stream

- Low priority tests
  - Transport_error
  - CRC_error
  - PCR_error
  - PCR_accuracy_error
  - PTS_error
  - CAT_error

Measurements for Digital Transmission Technology

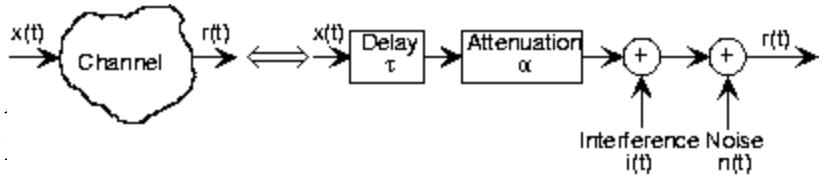
- Direct measurements of error rates
  - TS Packet error Rate (TS PER)
  - TS Bit error rate (TS BER)
    - Normally TS PER = TS BER
  - Graph
    - BER / C/N
    - BER / Eb/N
    - BER / Signal level
  - Effects of
    - Signal level
    - Channel
    - Doppler

Types of measurements performed

- Lab tests
  - Testing equipment in laboratory environment
    - Repeatable, well known environment
    - Typically generating results for
      - A channel model, at a certain signal strength (measurable)
- Field tests
  - Testing equipment in real environment
    - used for verifyinglab results
    - varying conditions, hard to repeat
    - Signal strengths hard to give correctly

Channel models

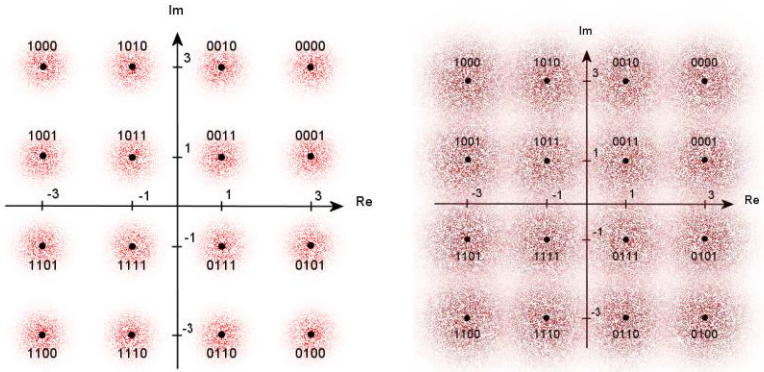
- A channel model ”simulates” the real communication channel
- Some ”standardized” model



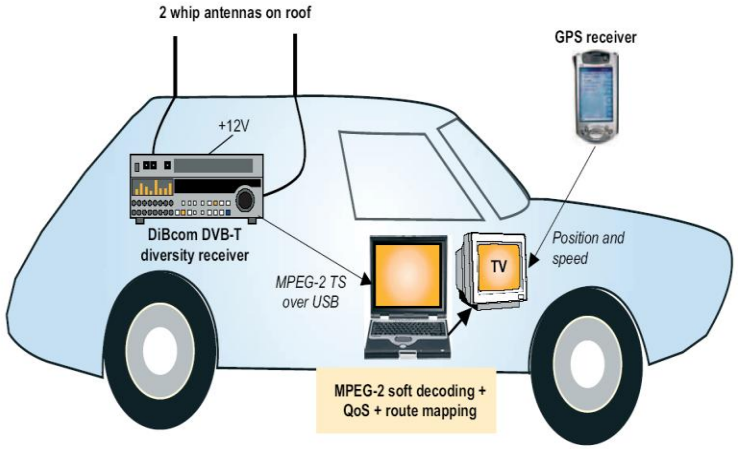
  - Gaussian
    - Additive noise
  - Rayleigh
    - Multipath reception: Antenna receives a large number of reflections
  - Rice
    - Reflections + direct path

Demodulation of signal

- Constellation point mismatch



Typical measurement setup



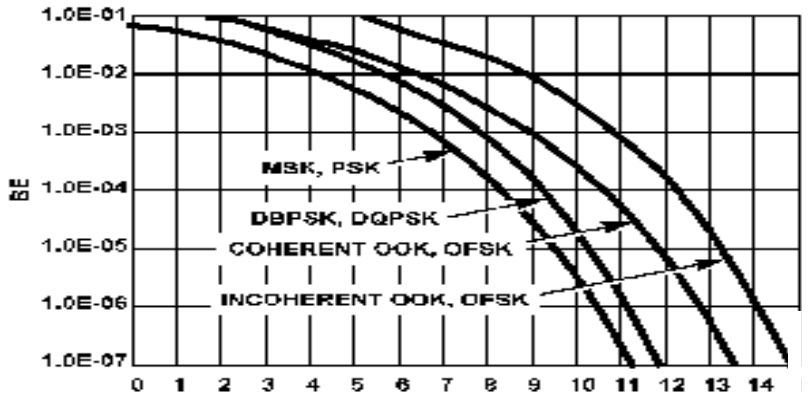
Typical results

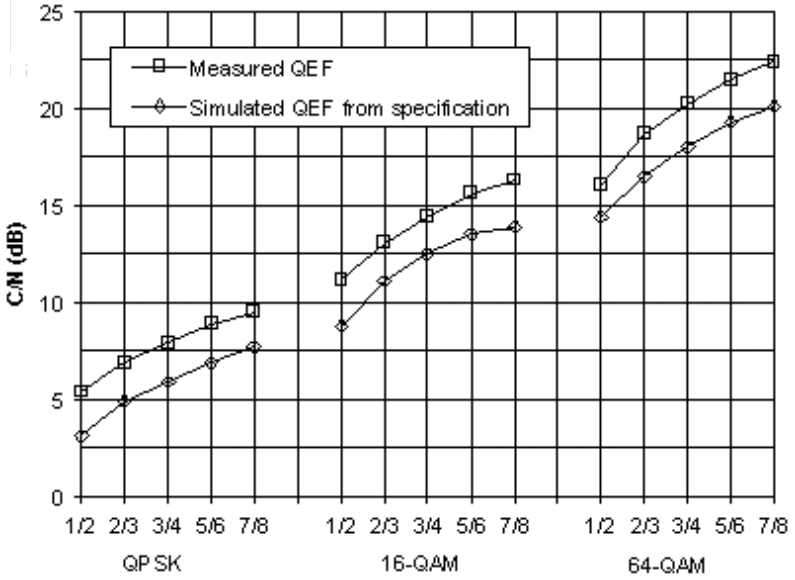
PER = 0 (no packet errors) during the last 3 seconds
Perfect video

PER < 10% during the last 3 seconds
Acceptable quality: very short picture freezes

PER > 10% during the last 3 seconds
Poor video reception: blocking, or frequent picture freezes

Typical graphs





From DVB-T standard....

		Required C/N for BER= $2 \cdot 10^{-4}$ after Viterbi QEF after Reed-Solomon			Bitrate (Mbit/s)			
Modu-lation	Code rate	Gaussian channel	Ricean channel (F_1)	Rayleigh channel (P_1)	Δ/T_U = 1/4	Δ/T_U = 1/8	Δ/T_U = 1/16	Δ/T_U = 1/32
QPSK	1/2	3,1	3,6	5,4	4,98	5,53	5,85	6,03
QPSK	2/3	4,9	5,7	8,4	6,64	7,37	7,81	8,04
QPSK	3/4	5,9	6,8	10,7	7,46	8,29	8,78	9,05
QPSK	5/6	6,9	8,0	13,1	8,29	9,22	9,76	10,05
QPSK	7/8	7,7	8,7	16,3	8,71	9,68	10,25	10,56
16-QAM	1/2	8,8	9,6	11,2	9,95	11,06	11,71	12,06
16-QAM	2/3	11,1	11,6	14,2	13,27	14,75	15,61	16,09
16-QAM	3/4	12,5	13,0	16,7	14,93	16,59	17,56	18,10
16-QAM	5/6	13,5	14,4	19,3	16,59	18,43	19,52	20,11
16-QAM	7/8	13,9	15,0	22,8	17,42	19,35	20,49	21,11
64-QAM	1/2	14,4	14,7	16,0	14,93	16,59	17,56	18,10
64-QAM	2/3	16,5	17,1	19,3	19,91	22,12	23,42	24,13
64-QAM	3/4	18,0	18,6	21,7	22,39	24,88	26,35	27,14
64-QAM	5/6	19,3	20,0	25,3	24,88	27,65	29,27	30,16
64-QAM	7/8	20,1	21,0	27,9	26,13	29,03	30,74	31,67

NOTE: Quasi-error-free (QEF) means less than one uncorrected error event per hour, corresponding to BER = 10^{-11} at the input of the MPEG-2 demultiplexer.