# NEXT GENERATION SDTV&HDTV DISTRIBUTION SYSTEM

Dr. Peretz Meron

**Scopus Network Technologies,** Israel

## ABSTRACT

This paper describes the next Generation Solution for both SDTV and HDTV distribution system. It is based on the new emerging DVB-$S_2$ Standard, which enables a much more efficient transmission of digital video in current Satellite Transponders.

The new Technology dramatically improves utilization of the available satellite bandwidth which will enable increased programming capacity, increased geographical coverage of the satellite footprint (more customers) and accommodate future requirements for high definition TV (HDTV).

## INTRODUCTION

Digital TV is a reality. The standards that are based on MPEG-2 and DVB-S are implemented world wide, giving services to millions of users. However, as technology progresses the need for more advanced modulation techniques, "compressing" more bits-per-second/Hz, is growing.

The DVB has assigned a special committee (DVB-$S_2$) to define the next generation modulation and FEC technique over satellite based channels. The committee is looking for a scheme that will enable the transmission of more bits-per-second/Hz while maintaining the link budget constrains.

In this paper we will summarize the new trends for new modulation and FEC techniques that are under discussion in DVB. We will describe the commercial forces that influence the process in parallel with the different technical aspects.

The new technique that is under discussion is based mainly on 8 PSK modulation and Turbo code (TC) encoding (decoding) scheme. Since Turbo code encoding is better than the current concatenated Viterbi – Reed-Solomon FEC, the link budget can be maintained despite the fact that we migrate the system to higher modulation scheme.

## DVB-$S_1$ TECHNOLOGY

DVB-$S_1$ uses Quaternary Phase Shift Keying (QPSK) modulation and concatenated error protection strategy based on a convolutional code and a shortened Reed-Solomon (RS) code.

The DVB-$S_1$ standard defines the following Error Correction performance requirements:

| Viterbi Inner code rate | Required Eb/No for BER=2x10-4 after Viterbi QEF after Reed-Solomon | Spectral efficiency (bits/symbol) |
|---|---|---|
| 1/2 | 4.5 | 0.92 |
| 2/3 | 5.0 | 1.23 |
| 3/4 | 5.5 | 1.38 |
| 5/6 | 6.0 | 1.53 |
| 7/8 | 6.4 | 1.61 |

Table 1: DVB-S1 Performance

## DVB-DSNG TECHNOLOGY

Digital Satellite News Gathering (DSNG) and Digital television contribution applications by satellite consist of point-to-point or point-to-multipoint transmissions, connecting fixed or transportable uplink and receiving stations, not intended to be received by the general public.
Maximum commonality with DVB-$S_1$ is maintained, such as concatenated error protection strategy based on Reed-Solomon coding, convolutional interleaving and inner convolutional coding.
The baseline System compatibility includes (as a subset) all the transmission formats specified by DVB-$S_1$ based on Quaternary Phase Shift Keying (QPSK) modulation and is suitable for DSNG services as well as for other contribution applications by satellite.
Nevertheless, other optional transmission modes are added, using Eight Phase Shift Keying (8PSK) Modulation and Sixteen Quadrature Amplitude Modulation (16QAM), in order to fulfill better bandwidth efficiency in certain contribution applications by satellite.
The DVB-DSNG standard defines the following error correction performance requirements:

| Modulation | Inner Code rate | Spectral efficiency (bits/symbol) | Required Eb/No (dB) |
|---|---|---|---|
| QPSK | 1/2 | 0.92 | 4.5 |
| | 2/3 | 1.23 | 5.0 |
| | 3/4 | 1.38 | 5.5 |
| | 5/6 | 1.53 | 6.0 |
| | 7/8 | 1.61 | 6.4 |
| 8PSK (Optional) | 2/3 | 1.84 | 6.9 |
| | 5/6 | 2.30 | 8.9 |
| | 8/9 | 2.46 | 9.4 |
| 16QAM (Optional) | 3/4 | 2.76 | 9.0 |
| | 7/8 | 3.22 | 10.7 |

Table 2: DVB-DSNG Performance

The high spectrum efficiency modes, 8PSK and 16QAM impose the following problems and limitations:

- They require higher transmitted EIRPs and/or receiving antenna diameters, because of their intrinsic sensitivity to noise and interferences;
- They are more sensitive to linear and non-linear distortions; in particular 16QAM cannot be used on transponders driven near saturation;

Table 3 and Fig. 1 illustrate examples of the use of the DVB-DSNG system and emphasize its limitations regarding the required power and/or bandwidth. They show the link budget analysis in terms of "Clear Sky Margin" for transmitting a symbol rate of 6.66 Mbaud in 9 MHz (BW/Rs = 1.35) and the following bit rates:

| **BW [MHz]** | **RS [Mbaud]** | **Useful bit rate [Mb/s]** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **QPSK** | | | | | **8PSK** | | | **16QAM** | |
| | | Rate 1/2 | Rate 2/3 | Rate 3/4 | Rate 5/6 | Rate 7/8 | Rate 2/3 | Rate 5/6 | Rate 8/9 | Rate 3/4 | Rate 7/8 |
| 9 | 6.66 | 6.14 | 8.19 | 9.22 | 10.24 | 10.75 | 12.29 | 15.36 | 16.38 | 18.43 | 21.50 |

**Table 3: Useful Bit Rate at various DVB-DSNG schemes at 9 (MHz) BandWidth**

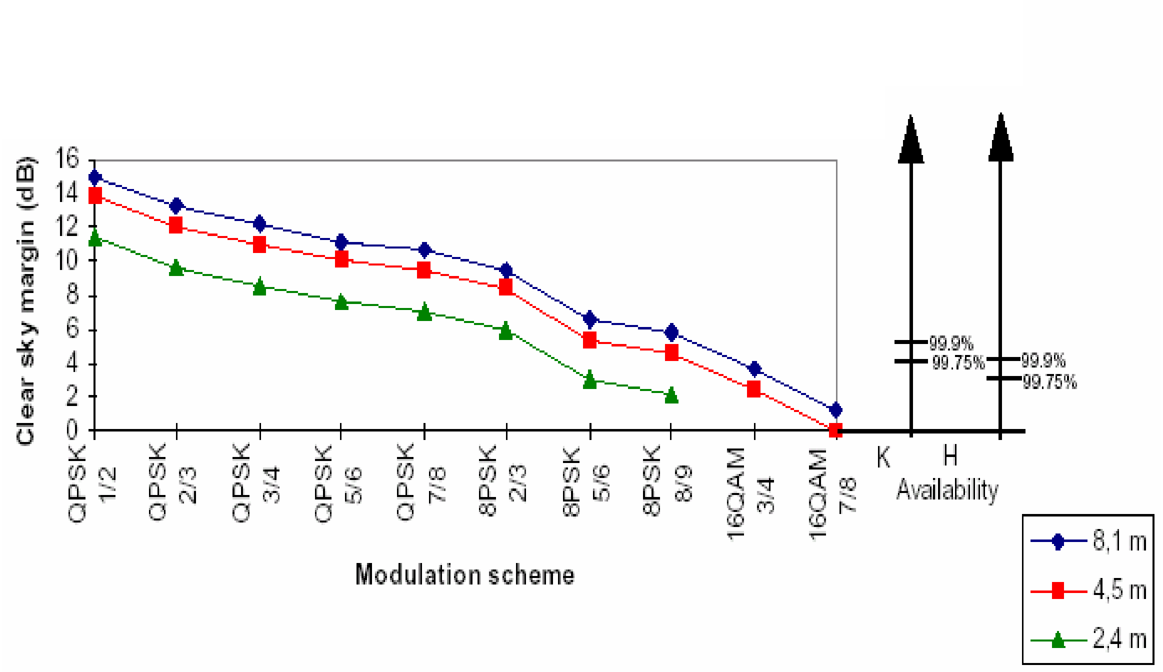

**Fig 1**: Clear sky margin for **fixed contribution links** considering different receiving earth stations (8.1 m, 4.5m and 2.4m) located **at beam centre**. Transponder operated in **"Nominal Gain"**

From the example above we can learn the following: Justification

1. In order to gain 33% increase in useful data bit rate (i.e. by using 8PSK 2/3 instead of QPSK ¾) - additional 2.5dB is required in the link budget.
2. The additional 2.5dB means significantly increasing the receiving site satellite dish diameter by 87% (from 2.4m to 4.5m) or –
3. If using the same satellite dishes at the receiving sites – A significant decrease in the geographical coverage of the satellite transmission (an inferior foot-print).

## DVB-$S_2$ AND TURBO CODING (TC) TECHNOLOGY

The new DVB-$S_2$ standard will include the combination of both high order modulation schemes (8PSK & 16-QAM) and Turbo Codes for channel error correction. Turbo Codes Technology includes Multi-dimensional coding; Iterative decoding using Soft In Soft Out (SISO) Algorithm; Near-Shannon performance and no error floor.

TC technology will allow achieving additional 2.5 dB gain compared to the Reed-Solomon & Viterbi technology in accordance with DVB-S and DVB-DSNG standards, thus, providing a solution for the problems and limitations related with the use of 8PSK and 16QAM modulation modes for transmitting high channel bit rates.

This gain can be transformed into higher bandwidth efficiency (more TV channels/services) or into higher power efficiency (better coverage or smaller receiver dishes).

## TURBO CODES

Today, Turbo Codes are considered as the most efficient coding schemes for FEC (Forward Error Correction). The turbo code concept was first introduced at the ICC'93 conference in Geneva by Prof. Berrou.

The Block Turbo Codes method is based on the concatenation of two block codes, as a Concatenation of two block codes.

Let us consider two systematic linear block codes C1 with parameters (n1,k1,d1) and C2 with parameters (n2,k2,d2) where ni, ki and di (i=1,2) stand for codeword length, number of information bits and minimum Hamming distance, respectively. The concatenation of two block codes (or product code) P = C1 * C2 is obtained (see Figure 2) by :

1. Placing (k1*k2) information bits in an array of k1 rows and k2 columns.
2. Coding the k1 rows using code C2.
3. Coding the n2 columns using code C1.

This is schematically shown in Figure 2:

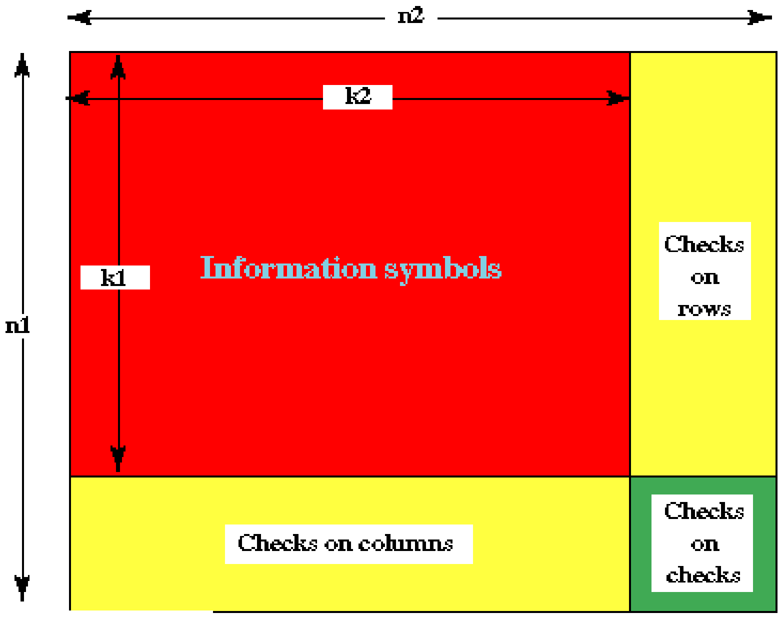

Figure 2 : Example of a product code P = C1 * C2

The parameters of the turbo product code are: n = n1 * n2, k = k1 * k2 , d = d1 * d2 and the code rate R is given by R1 * R2 where Ri is the code rate of code Ci.

## SHANNON LAW

For analyzing the performances of Turbo Codes, and comparing them to other coding methods, we give here a short review on Shannon Law, and channel capacity.
Shannon law defines the capacity of a communication channel (C) as the maximum bitrate (R) that we can communicate through this channel without distorting the information.
The Shannon result for the channel capacity C is:

(1) $C = W \log_2 (1 + S/N)$

Where W is the bandwidth of the communication channel, S is the power of the transmitted signal and N is the power of the noise.
To understand intuitively the above formula, let us suppose S>>N and say we quantize the signal S by n bits, i.e. we divide it into $2^n$ levels. Let us suppose N is of order of magnitude of 1 quantization level of S, hence $S/N= 2^n$. In this case, we obtain for C approximately:

(2) $C = nW$

Which means that the capacity is the number of bits per symbol multiplied by the bandwidth. As the noise N gets bigger, we must restrict ourselves to a more coarse quantization so that 1 level equals roughly to the noise level, which means decreasing n, i.e. decreasing the number of bits per symbol.

Shannon law tells us that the best we can do is to use the rate $R=C$, provided we have a "smart enough code". Practical systems always achieve $R<C$.

To show the parameters by which systems are analyzed, we show here the performance of an "ideal" system, which achieved Shannon performance.

For such a system:

(3) $R=C$

Using (1), this can by written in the following way:

(4) $(W/R) \log_2 [1 + (Eb/No)(R/W) ] = 1$

Where Eb is the energy of one bit [joule/bit], and No is the power of noise per unit of frequency [watt/Hz].

Therefore Eb*R is in units of [joule/bit]*[bits/sec]=watt and represents the power of the signal, noted above by S, and No*W is the power of the noise included in the bandwidth W of the channel, noted above by N.

So $(Eb/No)(R/W)$ in (4) is exactly S/N.

The performance may be measured as the possible rate with respect to the bandwidth (R/W), versus the ratio between the energy of 1 bit and the noise power per frequency (Eb/No).

We may therefore normalize (4) by defining the spectral efficiency $y=R/W$ in [bits/sec/Hz] and $x=Eb/No$, and obtain:

(5) $(1/y) \log_2 (1 + xy) = 1$

or

(6) $(1 + xy)^{1/y} = 2$

For $y>0$, we use the mathematical limit:

$(1 + xy)^{1/y} \rightarrow e^x$ , where $e=2.718$ and hence $x=\ln(2)=0.693$, or -1.6dB.

This means that even if we have an "infinite" bandwidth, the signal's power must be higher than 69% of the noise power (or higher than the noise minus 1.6dB).

The graph describing (6) can be numerically plotted and it looks like in Figure 3.

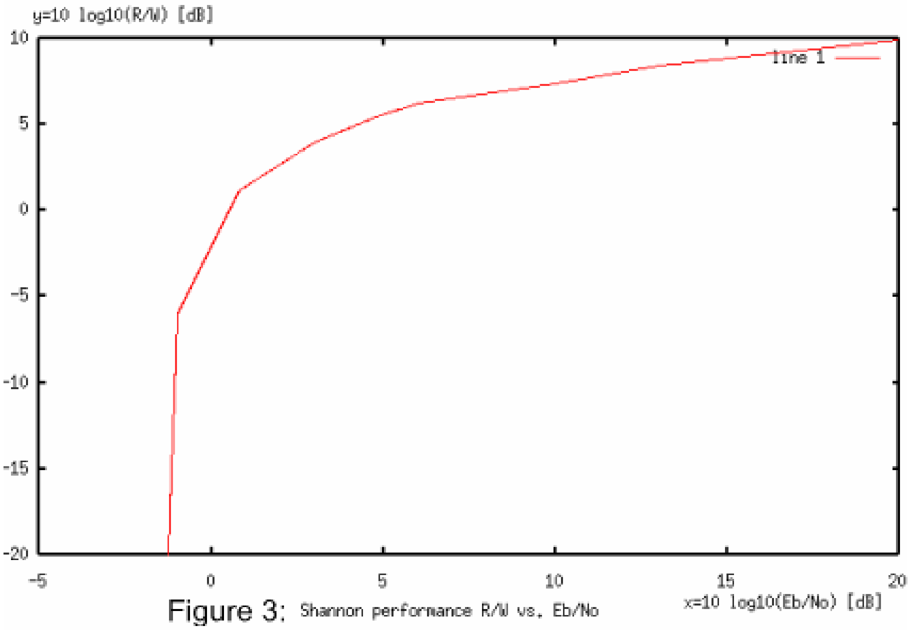

Figure 3: Shannon performance R/W vs. Eb/No

An alternative way of describing the performance of a "Shannon" system is by R/W versus S/N, which means y versus z=xy in (5).
This may be written as follows:

(7) $\log_2 (1 + z) = y$.

The graph describing (7) is given in Figure 4.

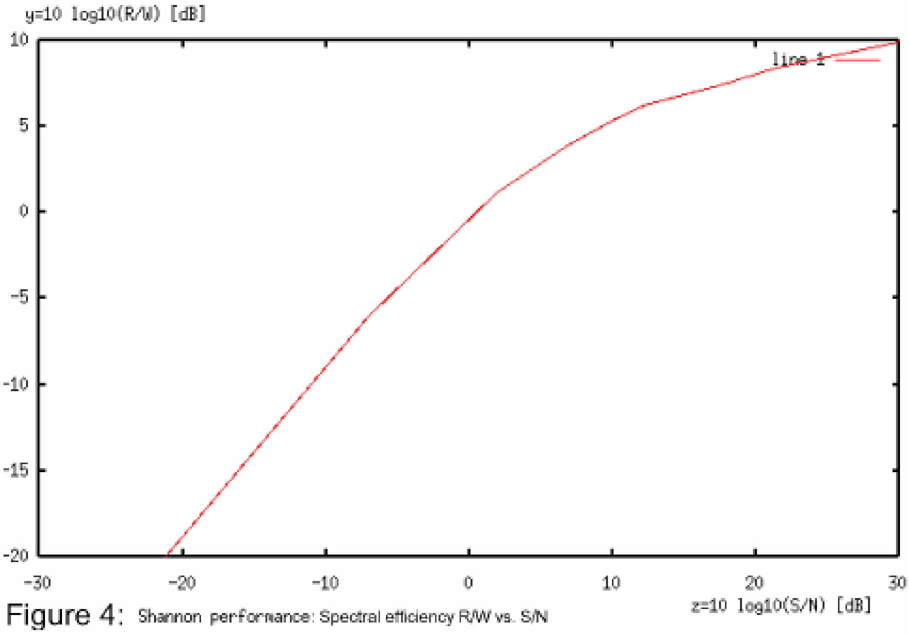

Figure 4: Shannon performance: Spectral efficiency R/W vs. S/N

## TC TECHNOLOGY PRINCIPLES

- Multi-dimensional (usually 2 or 3) codes;
- Very simple to encode/decode as long blocks are constructed based on short component codes;
- Iterative decoding using Soft In Soft Out (SISO) Algorithm;
- Near-Shannon performance;
- No error floor or error flair;

## PERFORMANCE OF TURBO CODES

Knowing Shannon limit, research institutions and industry are looking for better encoding methods, to approach as much as possible this limit.

The performance of any practical communication system is described by a graph similar to Figures 3 and 4 and stays always at the right side of those graphs, i.e. for a given signal to noise ratio (S/N) in Figure 4, or a given energy of bit -energy of noise ratio (Eb/No) in Figure 3, the spectral efficiency (R/W) is less than in those graphs. The closer to these graphs, the better the performance is.

## SUMMARY OF THE FIRST PHASE OF THE DVB-$S_2$ COMMITTEE

The "First DVB-$S_2$ call for proposals" is focused on the Forward Error Correction (FEC) and modulation scheme for the following spectrum efficiencies: 1; 1.5; 2; 2.5 bit/s/Hz (+-10%).

Replies were received from Hughes, Philips, ESA, Spacebridge & STMicroelectronics, Conexant, Turbo concept and Comtech/EFData.

Four basic coding approaches were proposed: Parallel Turbo codes, Serial Turbo codes, Turbo Product codes and LDPC. Simulation results show around 1 [dB] loss from Shannon limit in the above-mentioned operating points.

## SUMMARY

Current DVB-$S_1$ and DVB-DSNG standards, which make use of the concatenated Reed-Solomon & Viterbi Forward Error Correction technologies, do not exploit the full potential of the available bandwidth and are about 4 dB away from the theoretical Shannon limit.

TC technology will enable an additional 2.5 dB gain to be achieved. This gain can be transformed into higher bandwidth efficiency (more TV channels/services) or into higher power efficiency (better coverage or smaller receiver dishes), and overcome problems and limitations imposed by 8PSK and 16QAM modulation modes specified in the current
DVB-DSNG standard.

The DVB-$S_2$ solution enables broadcasters to transmit content and data at high speeds, reaching up to 100 Megabits per second in a single satellite transponder. It will enable professional broadcasters to leverage their current satellite transponders by adding both significant capacity and increased geographic coverage. This will facilitate the transmission of far more content at higher quality and with better compression quality.

Professional broadcasters will move to deploy DVB-$S_2$ platforms covering both master Head-Ends and local sub-Head Ends. The estimated size of this market is around 50,000 sites world wide, with an average annual growth / replacement rate of 15%.