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ADDRESSABLE CABLE TV SYSTEMS : AN AFFORDABLE PAY - TV SOLUTION

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In part II of this three part series, we will break down the main sections of an Addressable Cable TV System, looking in depth at just how control software, encoding equipment and addressable set-top boxes (STBs) perform in a modern Pay TV operation.

In the first article of this series the concept of 'addressibility' was introduced. We stated that 'Addressibility' is the control of the cable subscriber base, such that every user is uniquely identifiable. We also showed a diagram outlining how an addressable system would be implemented.

In Figure 1 we re-draw this diagram in a slightly different form; this time showing how the levels of control exist within an addressable cable TV system.

This diagram is actually the same as before, but with a hierarchical structure. The highest level is the Subscriber Management System (SMS) and Computer Control. This is where the subscriber information is stored and controlled. The data generated by the SMS is then passed to a Conditional Access (CA) module. The CA, which is the second level of hierarchy, takes the data and assigns it in a conditional manner. The access and security are then applied before encrypted data is passed on.

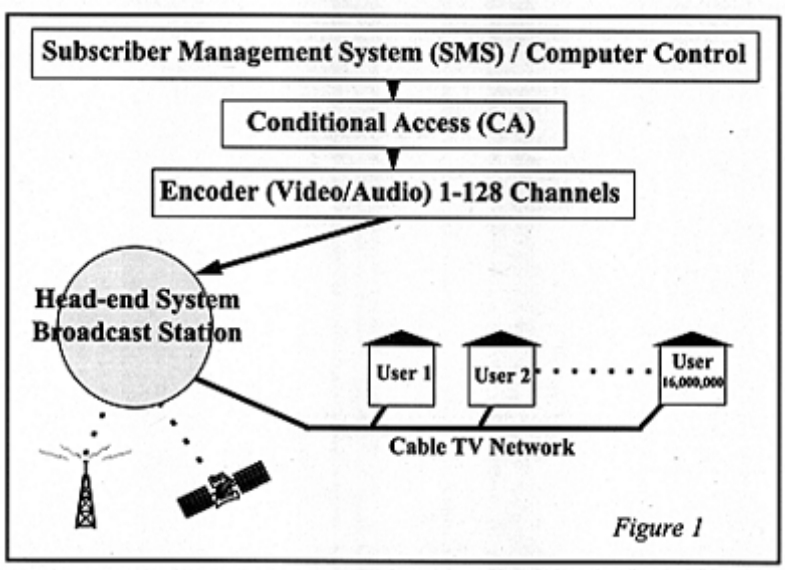

Figure 1

The third level of hierarchy is the Encoding unit, where depending on the exact set-up, up to 128 channels are scrambled. 128 channels are necessary to allow for future developments involving wide bandwidth cable. After the signal encoding, the signals are modulated, combined and distributed in the normal way.
It should be noted that addressable systems do have an upper user limit, but for most systems, this figure is millions and thus unlikely to be a serious drawback. The number shown on the diagram; 16 million, allowing up to 16 million users, is provided by some professional addressable system manufacturers.

ADDRESSABLE SYSTEM BREAKDOWN

In a hierarchical structure the following sections make up the system:

- The Subscriber Management System (SMS) /Computer Control
- Conditional Access (CA)
- The Encoder
- The Signal Distribution / Decoder

THE MANAGEMENT SYSTEM

The computer management of a modern Cable TV network is known as a 'Subscriber Management System' or SMS. It is, for the system operator, the most important component of the Cable TV package. To run a seamless and smooth system, the SMS must be both user friendly and complete with enough functions to make operations easy.

The management software is where the subscriber information is stored and controlled. This statement provides a lot of scope. In fact, the operator has a whole range of options to manipulate addressibility through the management system; Management of the system can be almost fully automated or manually controlled, users can be assigned levels of authorisation, be grouped together or individually addressed (this is just part of the concept of Tiering). It is this flexibility that ensures the ease of operation.

Like most aspects of cable TV, management software has exclusive vendors who offer perhaps the widest range of options for system management. However, a few addressable system manufacturers provide their own software which, since it's been purpose-designed, invariably offers smoother operation.
Collectively, many SMS packages incorporate such features as:

INVENTORY MANAGEMENT

Critical to the success of any modern Pay TV system is professional management of the equipment inventory. With a good SMS, each decoder from the subscriber base and stock-pile is registered; allowing instant information on transactions, store levels, decoder tracking and withdrawals. Reports can be generated, configurable by the operator, to supply concise and useful Management Analysis.

SUBSCRIBER MAINTENANCE

In addition to equipment inventory on each decoder, information on each subscriber is stored. Detailed records list subscriber personal data, with fields ranging from Geographical Address and Social Security Number (SSN) to User Remarks. This searchable subscriber-data is linked directly to corresponding user Account Histories, Billing, Equipment used and other relevant details; It makes subscriber maintenance a simple and intuitive operation which is as fast as a few clicks of the mouse.

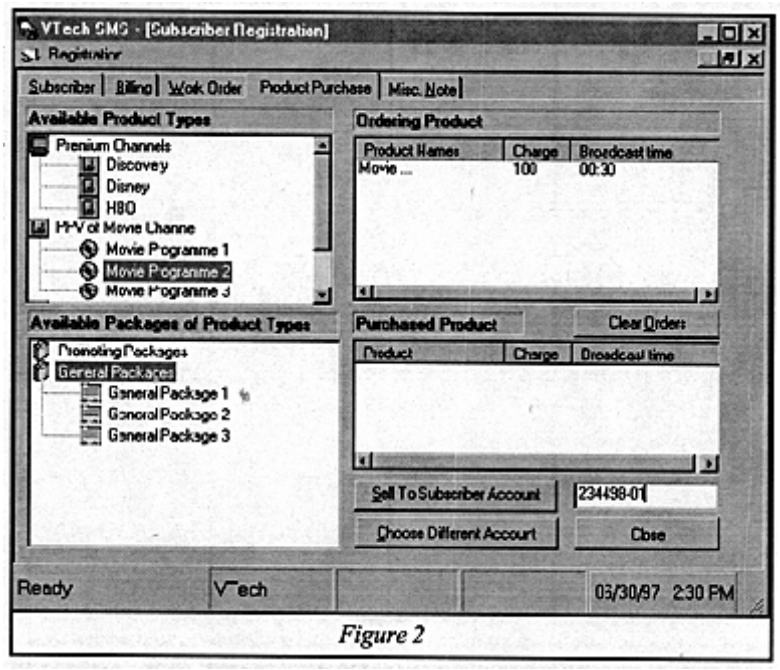

Figure 2

BILLING

Automated account invoice modules, correlating directly to each registered subscriber, allow financial control inclusive of Payment/Adjustment, Collection and Accounting. Modules can support Card, Cheque and Cash transactions with taxation setup for Value Added Tax (VAT), Franchise tax, Copyright fees, etc.

WORK ORDERS

SMS software can make use of Equipment and User inventories to automate the working time of technicans installing and servicing your TV network. Under the heading 'Work Orders', each technicians schedule can be optomised for the most efficient service.

PAY-PER-VIEW MODULES

For the Pay TV operator, the product is the service. It's essential therefore, to provide not just good programming, but smooth, efficient and professional programming. Within some SMS, Product Management Systems allow the use of multiple programming packages to increase viewership. The assignment of packages, from Pay-Per-View to Basic-tier, is scheduled and maintained, with marketing access for support in promotional and advertising stratagies.

HARDWARE SETUP

The flexibility of an addressable Pay TV setup means not just software parameters. Increasingly, operators need to adjust hardware settings such as frequency-channel tables. A good SMS will accomodate this as a hardware setup. Additonally, hardware security can be controlled with options to initiate Electronic Counter Measures (ECMs).

PROGRAMME CATEGORY / SCHEDULING ENQUIRES

Each broadcast event is given time slot information and category ratings to provide accurate and protective transmission.

FULL-FEATURE HELP

Extensive support using notify messages and /or pre-defined keys.

MESSAGING CONTROL

Traditional Pay TV scrambling systems, with messaging support, require message editing software in the control studio. Modern SMS will incorporate both Message Management and Message Editing under the SMS umbrella. With a range of pre-

set messages and an easy-to-use editor for custom messages, sending instant messages (bill payments, feature promotions, etc.) to your subscribers is simple.

The change in a control studio with a good SMS running is both revolutionary and simple. Current records that you already have on each customer will be accessible in the computer database. Customer service operators can then be employed to work with the management system. Each operator can be given an authority level to further increase your security of the invaluable information.

If Impulse-Pay-Per-View (Impulse PPV) is your requirement, the management system can handle the change in operation. That is to say, if a customer decides on impulse that he/she wants to view the Pay TV movie at nine o'clock, they telephone an operator in the CATV studio 15 minutes before, and they'll be authorised to watch. This system can be automated using touch-tone telephone systems (if they are available), by adding an ARU (automated response unit) or an ANI (automatic number identification) unit.

The software management is the operator's control of the whole addressable network. It controls the management in a way that smoothly and securely runs the system, allowing the Cable TV bosses to worry about other things, like signing more subscribers!

CONDITIONAL ACCESS (CA)

The database information relating to each subscriber in the SMS is constantly changing. With Pay-Per-View events, billing transactions, user messaging and other functions dynamically updating, there is a stage when information must be passed for electronic hardware control. This next stage is handled by a 'Conditional Access' (CA) head-end operation. Conditional Access, as the name implies, deals with conditionally allowing access to broadcast channels and their associated services. It performs the access control by processing a series of decisions for each SMS information exchange.

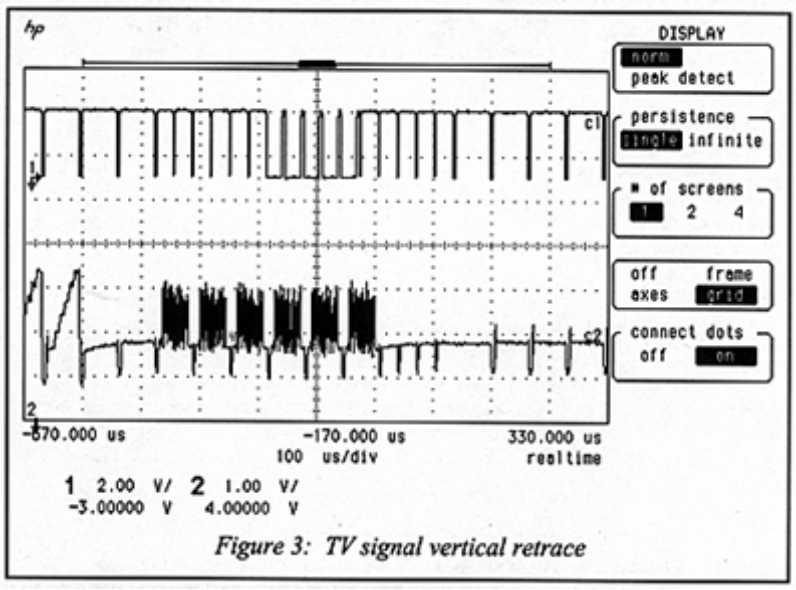

Figure 3: TV signal vertical retrace

The process is sometimes called Subscriber Authorisation Control (SAS) and it provides Entitlement Management Messages (EMMs) and Entitlement Control Messages (ECMs) to the Set-top boxes (STB). Only those entitled viewers can access the content at the STB (Subscriber) end.

Every programming event, for every subscriber, at every level of authorisation, must be handled. And each command coming from the CA system must be encrypted with high security keys to ensure data security. The CA must be fast and efficient but above all else, precise. Errors in access are unacceptable which is exactly the reason that professional CA systems are indispensable for the modern Pay TV network.

ENCODING

When the system control parameters are identified in the SMS and processed with CA, the information is transferred to processing computers. Physically, these may be separate units operationally transparent to the user (operators should never need to work on them).

The processing computers handle the timing of the control signals and convert control information (from the SMS/CA) into control 'data'. This conversion is necessary so that data is suitable for embedding into the vertical blanking interval (VBI) of a TV channel video signal. We will describe the process in detail in a moment.
The actual embedding of data is performed in an encoding unit; the 'Encoder'.

The Encoder has two primary functions;
1) To Add (embed) the controlling data into the unseen region of the video (VBI).
2) To collect all incoming Video and Audio signals and scramble them as directed.
When the Encoder completes these two tasks, the signals can be output and modulated, ready for transmission. All this happens in real-time, so data is added and signals are scrambled ready for transmission every second.

An Encoder looks very similar to a modulator; It fits in the studio rack in the same way. The front panel is typically simple, with just power and indicator lights. This simplicity is deliberate, for like the processing computers, the operation of Encoders is largely transparent.
The Encoder rear panel is also simple, with standard connections for Video, Audio, Data and Power.

DATA EMBEDDING

To fully understand the workings of a scrambling Encoder, we must consider how information (data) is transferred. Basically, this means considering the electronic communication between the head-end studio and each decoder. The significant operation to understand is the form of communication; digitally embedded 'data'.
To understand the process we can consider the standard form of a video signal. Figure 3 depicts the vertical blanking interval (VBI) of a normal TV signal (above) and a scrambled TV signal (below). The image was captured using a digital oscilloscope.

Most readers will probably be familiar with the format, but what may be new is the addition of digital 'data' on the lower, scrambled signal. Early systems used 32 bits on each video line, but now systems use 64 bits or 128 data bits per video line (The lower trace of Figure 3 shows 128 bits per video line).

The actual process of data embedding is performed using a technique of signal multiplexing (a selective adding procedure) to attach the data onto the video signal. With data attached, the video signal can be sent to all decoders, where 'reading' of the information takes place. The whole process can be thought of as something like a carrier pigeon message. The sender attaches his message to the bird, and the bird flies to the receiver(s). For TV transmission, the data (message) is attached to video (the bird) and sent to the decoders (receiver).
Further interesting points can be seen when looking at the traces of Figure 3. Some slight changes to the standard video format may be noticeable, depending on the scrambling method used. For example, a Sync Suppression scrambling method would remove selected synchronisation pulses (the downward pointing signal spikes in the diagram). Remember that the video scrambling method is the key to a successful Pay TV application. Of all the areas of interest in Pay TV, in the end, the video scrambling effect is the first line of defence.

VIDEO SCRAMBLING

The visual effect that 'scrambling' the video signal provides is often different for each Pay TV system manufacturer. This is one area where the security of a scrambling system can really be examined. Of course, scrambling system manufacturers will always tell you that their particular scrambling method is the most secure. But what is the reality? To answer the question let's consider the most common scrambling methods used in the industry today;

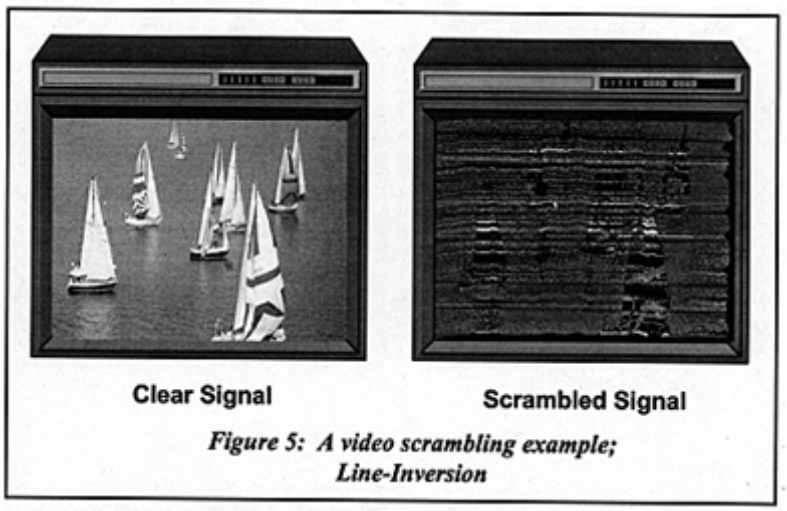

Figure 5: A video scrambling example; Line-Inversion

FIELD INVERSION

This is one of the simplest forms of video scrambling, where the video information is sent with reversed polarity. The TV set may or may not sync to it (depending whether the sync pulses are also inverted) If synchronisation is possible, the visual image will be a negative picture - light areas are dark, and dark areas are light. Pictures are watchable, but only if you don't mind seeing blue faces, brown skies and red trees.
A more sophisticated approach inverts only selected lines within the video frame. This would cause flicker or a superimposed pattern. Such an improvement would be less watchable since it soon causes eye-strain and headache.

The main advantage of Video Inversion is cost; it's generally a cheap method. But this is countered by low security levels.

HORIZONTAL / VERTICAL JITTER

Changing the horizontal and/or vertical sync pulses in the video signal, such that the TV synchronises onto a time-varying position. Changing the horizontal pulses results in a TV image which shuffles right-to-left. Similarly, changing the vertical pulses results in an up-to-down shuffle.

Jitter methods are rarely used alone because they leave the main TV content untouched. They are most likely coupled with another, more content-disrupting approach. The combined total then produces a visually annoying and unwatchable TV image.

SYNC SUPPRESSION

The technique of Sync Suppression is widely used as a cable scrambling technique. It involves removal of the horizontal or vertical synchronisation pulses, such that the TV set cannot lock onto the picture. This is an effective, but rather insecure method, which gives a rolling effect on the TV. It adds significant cost at the head-end since modulators and other head-end equipment must be compatible.

SINEWAVE SYNC SHIFTING

The imposing of a sine-wave onto the signal, after which the product is shifted (sometimes randomly) is a popular scrambling method. The approach works by careful addition of the sinewave (typically 15.75kHz) such that the TV set is

"confused" to the point where they cease to function correctly. The result is a rolling image with dark vertical bands in the middle of the picture.

A weakness exists in this method when very light images are scrambled; the TV will often synchronise for a while, but generally the picture is unstable and cannot be watched. The method can be considered as a medium security approach, with costs reflecting this.

POSITIONAL SCRAMBLING

The re-positioning of the video content, with respect to time, is known as positional or delay scrambling. It has been a common scrambling method because it offers a good compromise between complexity and security. However, it's popularity has made it well documented and this ultimately decreases it's anti-piracy potential.
The method works by shifting the active video in time, either by fixed amounts (about 900nS and 1800nS) or by variable amounts. The variable method is much more secure, giving a scrambled TV image which distorts severely in the horizontal plane.

LINE INVERSION

Instead of inverting the entire field of video, Line Inversion reverses the polarity of selected groups of lines. Usually, choosing which lines are to be inverted, and which lines are to be left alone, is carried out in a pseudo-random fashion. The code to determine the sequence can then be encrypted allowing only authorised set-tops to descramble.

Looking at a Line Inverted image is something like watching TV through a Venetian blind. Slats of dark and light regions flicker with time to severely strain the eyes. The security level of this method can be considered medium to high. The costs are typically medium.

CUT & ROTATE

A Cut and Rotate scrambling method is an example of digital video scrambling. Though the transmission system need not be digital, the actual scrambling / descrambling is performed by storing the video form in memory and manipulating digitized lines. For Cut and Rotate, the digitized line is cut at a particular point and the two sections are rotated so that the last section becomes the first and visa versa. It is a very secure method which gives a recognizably digital scrambling effect, with short horizontal lines randomly crossing the TV screen. The resulting image is not so much annoying but completely unrecognisable.

The price to pay for such security is cost. Generally, digital scrambling techniques, because of the necessary digital components, are more expensive than their analog counterparts.

As an example into what a scrambled video image really looks like, Figure 5 shows a Line Inversion before-after comparison. On the left is the original and on the right is the same image after passing through the Encoder (i.e. scrambled). We can see the described scrambling phenomenon, where light areas are often dark and visa-versa; thus the white sails of the yachts appear black when scrambled. Notice also the horizontal lines seen in the scrambled image; this shows us the scrambling is not Field Inversion, but a form of Line Inversion.
Typically a Random Line Inversion scrambling method is not used alone. For example, if the additional effects of Sync Suppression and Horizontal Jitter were provided, and viewed over time, the effect would be a scrambled image that has shuffling lines, while rolling and shaking from side to side.

The list of video scrambling methods we have discussed is not exhaustive. There are many sub-categories and approaches not mentioned. The point is to examine the most common methods, since, for one reason or another, these methods have proved themselves in international markets.
So we know a rough list of video scrambling methods... but which is the best? Some methods, such as Video Inversion, are recognised as a low security option, but are often cheaper because of it. A high security system, like Cut & Rotate, you'd expect to pay more for; is it worth it? We've indicated that some manufacturers offer a combination of approaches, which, because of the uniqueness, can be an attractive and reasonably priced option. To answer these questions, and for a general comparison of common methods, examine Fig. 4. This is a head-to-head comparison of methods, with three important considerations; Cost, Quality and Security. Consider this table if you are considering a potential Pay TV system. Of course it's only a guide, but it will help to get the right price-performance ratios.

OTHER ENCODING ISSUES

There are cases where an operator actually wants his customers to be able to view some of the screen, while still in a scrambled state. This might seem a strange idea at first, especially when we've discussed the importance of video transmission security in such depth, but can be a very good marketing idea.
The practice is known as a 'teaser' and is used to show a potential viewer of a scrambled channel 'what he could be seeing'. In such cases the customer views the scrambled image and because they can see roughly what's broadcast, their interest is captured and they telephone the operator to subscribe. This kind of marketing tactic can be accommodated with advanced Pay TV systems. Particularly with a digital scrambling approach (such as Cut & Rotate), levels of scrambling effect can be defined by the operator. Typically, 3 or more levels are given allowing high, medium and low concealment choices.

Moving on from video scrambling, the option of audio scrambling can also be considered as a way to ensure

SYSTEM SECURITY

Audio scrambling is normally simpler in approach, with just a few recognised scrambling methods. Generally, most of the video security principles apply (For example, operators might transmit a scramble-free audio as a form of teaser). Examples of audio scrambling methods are Spectrum Upshift, Spectrum Inversion, Digital Encryption and Sub-carrier Jamming. All these methods work on the principle that typical audio signals will sound unintelligible after encoding. As such, for testing audio scrambling, human words usually give the best guide to the concealment level.

SIGNAL DISTRIBUTION & DECODERS

With the data embedded by the encoder, and the video and audio signals scrambled (if deemed necessary), the signals can be treated as any normal channel. Thus, modulating and combining at the head-end before system transmission. If the addressable system runs one-way operation, then the signal distribution itself is unaltered. Due to the technology of the decoding equipment, the signal data on each channel can suffer quite serious degradation before it becomes unreliable, so no additional amplifiers (besides those already in normal operation) should be necessary. It is generally true that the visual quality of the video signal will become unwatchable before signal data fails.

The completion of the distribution stage is the tapping of signals to the subscriber home and then on to the decoder. The decoder is the final stage of a standard addressable system, it is here that all signals are decoded (descrambled) and authorisation is verified. All that remains after the decoder is the TV set.
The addressable decoder is basically an intelligent set-top converter. For the user it performs all the functions of the set-top converter and gives the advantages of extra features using modern interface practices (typically the On-Screen-Display). For the operator it gives high quality signal reception and full descrambling capabilities, controllable entirely from the TV studio.Some common features included in good quality analog decoders include;

On-Screen Display (OSD)

Easy manipulation through available features listed on your TV screen. Typically displayed in menu form with color backgrounds or text-overlay options.

Automatic tuning

No more manually tuning channels; Simple auto-scans and downloadable channel mapping are complimented with automatic tuning. Gives the best quality pictures, without hours spent tuning.
RCA / Modulator outputs
Gives interface options for both older and new TVs, providing both, video and audio outputs or an RF output.
Messaging

Reception of messages sent from the head-end, and displayed on the TV screen using an On-Screen Display (OSD). The messages might contain billing information, news reports, financial data programming guides, etc. Good decoders will support Individual, Group and Global messaging.

Smart Card Upgrade
To ensure the decoder is secure now and into the future, the provision of a SMART CARD
Upgrade is an important consideration. The SMART CARD provides a ‘digital key’ to unlock the scrambling capabilities of the decoder in a changeable form.