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AESA and xDSL transmission technology

Introduction

Over the past 20 years, AESA has been very strongly involved in developing test systems to measure telephone cables. During the last decade, computerization of the world's work environment has made computer networking a necessity. This necessity resulted in the development of a new generation of cables, LAN cables. While AESA is still developing and improving its capabilities for testing these cables, the cable factories are now largely equipped and although opportunities for selling LAN cable testers still exist, this market reached its maximum level during the years 2000 and 2001. Currently, the demand for LAN cable testers is stable and AESA is now involved in upgrading existing testers, which requires, for example, the ability to make higher frequency measurements. Within this range, AESA, with its Vega family of LAN cable testers, is probably the world's most advanced supplier and is able to fulfil all current demands with dedicated, customized solutions.

Over the past two years, we have also had to respond to a new demand, which involves provision of test systems able to measure large pair count cables at frequencies up to 40MHz. This new demand arises mainly from a new market, the ADSL market. This new market should become an important part of AESA business in the next few years, and this letter is intended to give you sufficient information to assist you in marketing / selling AESA testers within your respective markets.

What is xDSL? How does it work? What are its limitations? Where is AESA involved?

These are some of the main questions which need specific answers. Please take some time to read this document carefully. It will provide you with much more information than just a leaflet on an AESA tester, which describes functions in great detail but which doesn't help you to conduct a difficult technical meeting with one of your experienced customers.

The aim of this document is to explain, in relatively simple terms, an extremely technical subject in order to allow you to understand what is hidden behind the letters "ADSL".

Enjoy reading it!

History of xDSL

In times past, messengers delivered written or typed letters and messages from one place to another. When Graham Bell presented the phone to an amazed public, the sole reaction in Europe was: "We won't need it, we already have enough messengers". However, the phone imposed itself, at first very slowly, then more and more rapidly, until the telephone had become a standard product which everybody used and needed.

With the breath-taking growth in the number of telephones, the number of cables which needed to be installed grew very quickly as well. This is the reason why thousands and thousands of kilometres of copper cable has been buried in the ground, cable which actually links together almost every point on our planet.

Why so much cable and that many lines?

But why are so many kilometres of cable needed? The reason is that telephone calls are transmitted over physical cables or lines. During a phone conversation, a telephone is connected to another telephone through one or more telephone exchanges. Thus it is not possible to have only one line from your phone to the local telephone exchange and between the telephone exchanges themselves, rather the number of lines between two telephone exchanges needs to correspond to the largest number of possible simultaneous conversations.

However, these telephone lines are not continuously in use. They are actually unused most of the time. Effectively, when somebody has a personal line and makes only a few calls a day, his line is probably unused 95 to 99% of the time. This is also true for the lines between telephone exchanges, which are designed to manage a potential maximum number of simultaneous conversations and not an average number.

Making use of unused line capacity

In the 1960's, the American agency DARPA (Defense Advanced Research Project Agency) started to develop a computer network which was intended to use the unused capacity of telephone lines. The idea was to divide the data into small packages and to use an available line to transmit the packages over unused line capacity. The internet came later but when it did, it developed rapidly based on the same principle but using new transmission protocols such as FTP (File Transfer Protocol) and HTTP (HyperText Transfer Protocol).

The Internet was so successful that there were soon not enough lines available at the telephone exchange level and new lines had to be added. The success was so big that even the added cables could not cope with the demand. So, in the 1990's, optical fibre cables were rapidly installed between the telephone exchanges to overcome the bottlenecks. In the meantime, the trend has inverted: these "backbone" networks are now only partially used - between 2 and 5%, while much heavier demands are made on local subscriber lines. Why?

The technical limits.

Three sorts of lines are used in current telecommunication networks: The oldest lines are twisted pair copper cables, which are mainly found between the subscriber and his local telephone exchange. Then there are also coaxial cables, which were previously only used between telephone exchanges. Now they are also used to connect individual subscribers, typically for cable TV and Internet services. Finally the most modern lines are made of optical fibre. These lines now dominate the long distance communications networks, typically for continental and intercontinental connections.

Today’s bottleneck is the simple copper telephone cables (be careful, it gets technical here), as all switched telephone connections work using a modem (a device which transforms digital signals into sounds, that are then sent over a telephone line). This gives a maximum transmission rate of between 30 and 35 kbit/s due to the 3 kHz bandwidth used, which corresponds to the necessary volume for clear analogue transmission of the voice with a 30 to 35 dB signal. At first, 33.6K modems were supposed to be the highest possible development. Subsequently, with the 56K modem, a new stage was reached by improving the signal/noise ratio. Unfortunately it is not possible to improve on this, because the line’s inherent noise remains constant and it is not possible to increase the signal power.

Digital transmission rather than analogue

If we can not improve the signal/noise ratio, do other solutions exist? Yes! If we stop transforming the data using a modem into analogue oscillations, we can then integrate, within the basic bandwidth, to create a slightly higher data rate. So, the 64kbit/s of ISDN (Integrated Serviced Digital Network) are improved to 160 kbit/s by division into several channels.

From its conception in the 1980's, ISDN was ignored for quite a time, despite the fact that thanks to it, it was possible to simultaneously have a phone conversation and send a fax, or phone and surf on the Internet. This was perhaps because the telephone exchanges were not sufficiently prepared for ISDN or because interest in the Internet was not sufficient. In the meantime, conditions have drastically changed but ISDN is no longer of interest as much faster transmission techniques are available elsewhere.

Cable instead of copper wires

One of these faster techniques was direct connection to a coaxial cable. These cables were installed much earlier for cable TV and could then also be used for Internet access. The promised bandwidths of 2 Mbit/s were enormous compared to anything else at that time, with the exception of internal company networks, based on Ethernet, which were offering 10 to 100 Mbit/s.

One of the disadvantages of a cable connection is the need to install new cables. This is expensive and a cabling company can only justify this price only where the population density is sufficient.

Another disadvantage was recognized once the Internet, via coaxial cable, became popular: the cable is shared with all the people connected to the same selection node, resulting in slower speeds at peak times.

Back to the telephone line

It may not be necessary to dig the roads up to install new cables, because, as mentioned above, cables connecting each home already exist: the telephone line. We just have to find a way to send data faster by using this telephone line twisted-pair. The answer becomes apparent by drawing an analogy to radio transmission technology, because several and not only one frequency range is used. Like radio communication (from long waves to GSM frequencies, via the FM band), where a large number of different frequencies are used, it is also possible to send data over a telephone line twisted-pair, in a frequency range other than 0-3 kHz. Due to the behavioural differences between air and copper, we are obviously limited, but the improvements are still impressive.

The technique used to reach this goal is called DSL (Digital Subscriber Line or Digital Subscriber Loop Technology). By “Subscriber Line”, we mean a telephone line, via which we can send digital data.

In the first stage, in the early 1990's, a 240 kHz bandwidth was used for SDSL (Single Line DSL) and HDSL (High Data Rate DSL). With this, transmission rates between 1.544Mbits/s and 2.048Mbit/s have been reached. The difference between the two technologies is that SDSL only needs two wires (one pair) while HDSL uses 4 to 6 wires and has a longer range of 3000 to 4000 meters instead of only 2000 to 3000 with SDSL

Unfortunately, these first systems had a major disadvantage: standard telephone conversations were no longer possible. This does not however mean that we need to abandon conversation entirely with such a system. Because with VoDSL (Voice over DSL), we can transmit telephone conversations in a data format by using the DSL line. Also because a phone conversation only uses a maximum of 30 kbit/s, we can have at least 50 simultaneous conversations by using a line which was until now only adapted for one single conversation.

Phone and surf simultaneously

Since the middle of the 1990's, another stage has been reached with the development of ADSL (Asymmetric DSL), which has many advantages compared to the systems described above. Firstly, the bandwidth used is above the one used for telephone conversations. This is why usage of ADSL does not affect standard telephone conversations. Secondly, the bandwidth used is larger and employs 1 MHz frequency band rather than the 240kHz mentioned earlier, which obviously considerably increases the achievable data rate.

It must be recognised that for every type of transmission, as the frequency increases, the distance over which we can send the data shrinks. In this case, the distance could be increased by using a more efficient coding principle, which allowed an increase from 2700 to 5500 meters. It could then also be supposed that more than 2 wires would be necessary. This is not the case, since ADSL, like SDSL, needs only 2 wires (one pair).

Moreover, ADSL contains a brand new idea: when we surf the Internet, very little data is sent from the personal computer to the Internet server. However, a lot of data - from Web pages to MP3 or from “Streaming Video” through to images - are transmitted from the Internet to the personal computer. Thus it seems logical not to use 2.048Mbit/s in both directions but rather 16 to 768kbit/s in one direction and 1.544 to 9Mbit/s in the other. If data rates are variable, it is because more bits are required for guidance and control duties, to compensate the perturbations caused by longer distances. This means a maximum receiving (download) speed of 9 Mbit/s can be achieved only over distances shorter than 2700 metres when measured between our personal computer and the nearest selection node.

Finally, at the end of the 1990's, an extension to ADSL, called VDSL (Very high data rate Digital Subscriber Line) was created. VDSL uses a 30MHz bandwidth, which reduces the transmission distance from 3000 to 1500 metres, while increasing the upload rate from 1.5 to 2.3 Mbit/s and the download rate from 13 to 52 Mbit/s. We can call this the "business" version of the ADSL.

Why doesn't it work as fast back home?

As explained, ADSL promises huge speeds. However, before using DSL, we first need a DSL modem and also a counterpart connected on the same telephone line having a DSL modem. This means that as long as the last wired mile still belongs to a monopolistic telecom company (Swisscom in Switzerland for example), the only possible contractor will be that last mile owner. And even if all this exists, we are still far from being in position to transmit data at the promised speeds.

First, there is a cable attenuation problem: when the frequency rises, the attenuation of the cable rises as well. This means also that the fastest of all xDSL techniques works only over the shortest distances, as it uses the highest frequencies. The knowledge that the attenuation in a cable is an inherent characteristic which governs how electrical signals can be transmitted along a twisted pair, makes us aware that it is a factor that cannot be improved upon.

Another problem is crosstalk. In telephone exchanges, where hundreds or thousands of subscriber lines converge, it is possible that signals are exchanged between cables. During a normal telephone conversation, we can suddenly hear the voice of a third person, who is not a party to the ongoing conversation. This phenomenon has been technically mastered but only where voice traffic is concerned. This means that frequency jumps of 3 kHz are controlled, which is not the case for frequencies of 240 kHz or 1 MHz, which are used in xDSL traffic. All the telephone exchanges or the physical locations where many lines converge to a same geographic point need to be controlled and potentially adapted so that the telephone exchanges are optimally equipped for DSL traffic.

From the efforts made to offer optimal vocal transmission arises another problem: the telephone lines are equipped with “Puppin coils” which cut-off frequencies above 3.4 kHz. By doing so, a voice does not sound exactly like the original speaker’s voice because the harmonics have been cut-off, nevertheless the voice remains understandable over long distances. The disadvantage for the DSL is that we have no possibility, on cables equipped with “Puppin coils”, to generally adopt DSL.

Finally, echo correctors have been installed on telephone lines in order to improve the vocal quality. This installation avoids the production of echoes and thus prevents us from hearing our own voice, slightly shifted. Unfortunately, this system also prevents an integral duplex connection. Fortunately, most of the echo correctors are deactivated with a 2.1 kHz tonality for the duration of the connection. But DSL problems are not necessarily solely a need for additional equipment on the part of the telecom companies.

The telecommunications can also be too modern, because if subscriber lines have been equipped with optical fibres, DSL cannot be used anymore as it is a technology based on copper cables.

Last but not least, we cannot forget that the connection speed from home to the basic international network is not very useful when you have a bottle neck on the other end of the line. In other words, the data we wish to reach can be on a sever connected to the Internet only with an old modem or which has so many accesses that we get only a fraction of the available resources.

The current variants of xDSL.

Three xDSL variants currently exist. The first one is ADSL, which, as an asymmetrical model, seems to be particularly adapted to Internet access. For standard use, we can predict an upload speed of 384 kbit/s to 1.5 Mbit/s and a download speed of 1.5 Mbit/s to 7.1 Mbit/s to or from the nearest selection node. But we always have to bear in mind that the route followed by the data is over one of many possible channels, channels which are not necessarily that fast.

The second possible variant is SDSL, interpreted originally as “Single line DSL”, in contrast to DSL which uses two or three lines, and which is actually called “Symmetric DSL” in contrast to ADSL. In this case, we have the same speed of 2.048 Mbit/s in both directions. With this speed, this system is used everywhere where high data rates are required in both directions, such as video conferencing or data transmission between several operation sites of the same company. SDSL has the disadvantage that the normal voice channel can not be used anymore. This might not be a significant limitation as it is easy to transmit conversations as numerical data by using the data channel, and as such it is possible to have dozens of simultaneous phone conversations on the same telephone line.

It is also necessary to mention the third technique, VDSL. It is a variant of ADSL which operates at much higher frequencies. By doing so, the potential operating distance falls to 300 metres to the nearest selection node. However, data can be transmitted at 52 Mbit/s. VDSL could be an alternative for companies which have an internal telephone installation, but no computer network. The existing telephone lines are used and VDSL modems are added instead of the telephone outlets. This alternative is probably only applicable to large jobs.

Down the line, a wide number of promising operating possibilities exist for xDSL.

Where does AESA fit into this story?

As you can read in the above pages, the actual problems relating to ADSL mainly arise from the limits of the cables which are actually installed. When a telecoms operator offers Internet access using ADSL technology, he will have to check all existing lines to his future potential subscribers and especially those thousands of lines arriving at any telephone exchange. In quite a few cases, it will be necessary for the telecom operator to change some of the cables to reduce the attenuation and/or the crosstalk in order to improve the transmission quality.

For those cases, AESA has already delivered a few testers belonging to the Phoenix family. We are basically talking about test systems able to measure low and high frequency parameters up to a maximum of 40 MHz. The size and the design of the connecting frames vary from one customer to the other, depending on the number of pairs the customer wants to hook up simultaneously on the frame. Typically, these types of frames should not exceed 50 pairs, in order to avoid any problems related to the measurement technology.