ISSN 1392 – 1215 ELECTRONICS AND ELECTRICAL ENGINEERING 2009. No. 4(92)
ELEKTRONIKA IR ELEKTROTECHNIKA

T115 MEDICINE TECHNOLOGY
MEDICINOS TECHNOLOGIJA

Investigation on Noise Characteristic of Cable Channel for Telemedicine

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Introduction

In the new century it's become clear that bandwidth is now the life blood of a community's commerce, lifestyle, education, and growth. For instance this realization has led to the deployment of optical systems Fiber to the Home (FTTH) to over 8M homes and businesses in the United States, and it's likely that number will grow to 50M homes in the next decade. Globally, 25M homes and businesses now have fiber access with 150M likely in 10 years, reaching nearly half of the developed world. As high bandwidth service becomes not only an enhancement to the community but increasingly a necessity, small rural communities desire to participate and grow with the fiber-fueled economy. While many cities are benefiting from FTTH the superior Internet and video services enabled by FTTH, only about 7 percent of homes and businesses have access to FTTH. The super-high-speed Internet and video services that will be provided through its FTTH network will boost the regional economy by attracting and retaining businesses and residents. The benefits of can new system FTTH are connected with many services. FTTH can deliver far more than Internet access and television. New video-rich applications can increase business efficiencies, business development, and quality of life. The systems FTTH can provide many high value applications emerge such as:

- Instant video downloads and uploads,
- Enabling Digital Government,
- Interactive Gaming,
- Video Telephony,
- **Tele-medicine,**
- Virtual Meetings,
- Virtual Shopping,
- Distance Learning.

Full motion video at ever higher definition will be incorporated to many applications, and video eats bandwidth. Fortunately, FTTH can serve up enough bandwidth to satisfy the growing appetites of these applications for many decades, while copper-based systems are severely limited. FTTH systems carry information over optical fibers that possess very high bandwidth, with very low signal loss over long distances. Copper- based systems such as DSL and cable use copper wires that limit both bandwidth and distance. Copper served customers well for many decades but physics are limiting further improvements, while fiber offers nearly unlimited bandwidth potential. The development of services provided by different cable systems in USA for instance can be seen on Fig. 1.

Video mail and downloads will soon provide huge benefits to businesses and residents, if they are fiber-connected. Optical broadband connections make HD and large screen video mail feasible. For instance a business traveler might want to download a movie or a video rich sales presentation before leaving for the airport. With FTTH this would require only minutes while a cable modem or DSL might take hours for the same task. A resident e-mailing a 10 minute DVD quality video clip of a child's birthday (400 MB) to a relative across the country would strangle a DSL or cable modem connected PC for over 1 hour with the typically best available 1 Mbps speeds, while just a first generation 3 Mbps FTTH upload would take only 20 minutes.

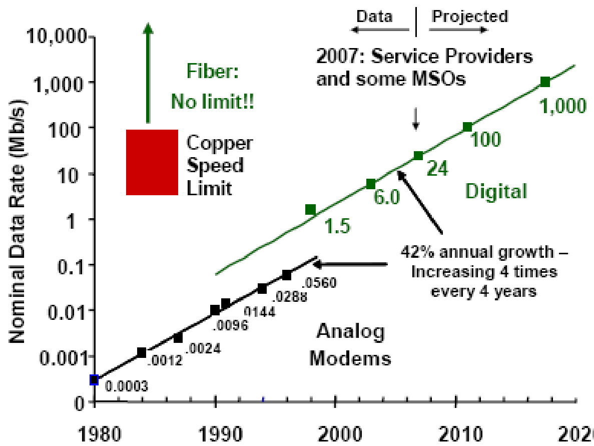

Fig. 1. Development of services provided by different cable systems in USA

The same benefits apply for telemedicine a home based or small business e-mailing video sales presentations to a customer: fiber is feasible while copper would take hours. The next generations of FTTH will be four to 100 times faster to keep pace with video driven bandwidth demands. Fiber-connected telemedicine can more effectively services using video and high definition imagery. This system for telemedicine at home can provide permanent monitoring of physiological parameters. It can reduce medical costs and accelerate innovation by more efficiently collaborating with global suppliers and big hospitals. A fiber connected home sells for 4 percent to 7 percent more than an equivalent copper-connected home (source: RVA analysis) as consumers have come to understand the value of a fiber connected residence. This all adds up to a more vibrant, attractive community with improved quality of life and economic opportunity, enabled by FTTH System. The network operations center (NOC) is the central point from which it's possible to access and manage the video content, connect to the Internet and phone networks, and combine all of those services onto the FTTH network. Usually NOC is situated in Medical University or in big hospital. It's possible to access this equipment from anywhere to manage medical service levels and billing, using an automated billing system. The video acquisition and transmission equipment brings in television video and video on demand from satellites and/or earthbound sources, and then combines those signals into a single stream. An Internet router connects to the Internet backbone. So, it's possible to provide one high-speed Internet connections to FTTH customers. The NOC also utilizes a voice switch that invisibly manages the telephony services. All three of these services are connected into one Optical Line Terminal (OLT), which is the traffic cop managing and combining all the services onto the fiber system. From the OLT, the fiber runs to a cross connect panel and then into the outside cable. Usually the optical fiber system is chosen from OFS since its full spectrum and low-loss capability can cost effectively support many new and higher bandwidth services over the coming decades. Optics includes the OLT and Optical Networking Terminal (ONT) at each home, and can support up to 1 Gbps to and from homes and hospitals. A basic schematic FTTH system can be seen on Fig. 2.

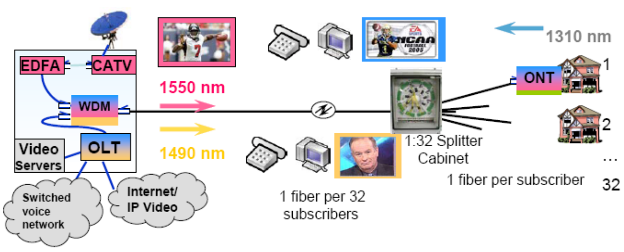

Fig. 2. Basic schematic FTTH system

For instance the outside "feeder" cable can be connected to a small cabinet that serves up to 288 homes in which the optical splitters are housed. From this fiber distribution cabinet a fiber cable is run underground past the homes, and from that cable it's possible to splice in a small single fiber cable to each home when a patient's requests our service. That cable plugs into an Optical Network Unit at the house. From there the optical signals are converted to electrical for supporting the services inside the home. While the current system uses two optical wavelengths downstream and one wavelength upstream, the Full Spectrum fiber can support dozens or even hundreds of wavelengths to enable 10 Gbps or even greater data rates per home, which might be required over the 25 to 50 year typical life of the optical cable. In addition, unlike copper systems the FTTH outdoor network is fully passive – meaning that none of the outdoor components requires electrical power. This not only conserves energy, but also makes the outdoor network nearly immune to service interruptions caused by lightening than can plague a copper network.

Noise sourses in FTTH systems

It's clear that FTTH systems can provide many services at home. The simultaneously propagation of many signals in FTTH systems can be a reason for different kind of noises. Therefore the reduction of noises is very important problem in FTTH systems.

Noise sources in the optical link are connected to its optical devices, as well as the optical fiber itself. In FTTH systems there are the following types of noises:

- relative intensity noise of the laser (RIN);
- shot noise of the photodiode;
- thermal noise of the receiver;
- interferometric intensity noise (IIN) and optical amplifiers' noise.

The laser RIN and the noise, made by the optical amplifiers,are due to a spontaneous emission of photons, raising a generation of incoherent light. Shot noise of the receiver also has a quantum origin, while its thermal noise is raised mostly form the main amplifiers, used for amplifying of detected RF signal to the necessary level. Interferometrical intensity noise in the optical fiber is a result of it's loses.Rayleigh scattering of the light and of the functions of optical wave's length, provoked from laser chirp The level of noise in the link's output depends to different factors. The most important from which are:

- the used optical devices' parameters and their regime of working;also attenuation and reflection in the fiber;
- the temperature;
- the type of transmitter signals (analog or digital).

Usually the expressions, on the base of which are defined the noise's components in an optical link, do not report on one full influence of the different factors and in many cases they are nor useful for an engineer applications. So, the noise's sours for one channel of FTTH system can be not only signals in the rest home channels of FTTH systems (determined noses), but the above mentioned parasitical noises, also. Therefore the noises in one channel of FTTH system usually is a sum of determined noises and parasitical noises. In many cases the frequency band of noises is in the frequency band of information signal. In this case it's very difficult to reduce the level of noise.

Restoration of signals with finite frequency spectrum

Usually the frequency spectrums of information signals in FTTH systems are finite. One method for reducing of noise in the signals with finite spectrum is the Aisenberg's method. The Fourier's transformations (1), (2) are used in this method:

$$F(\omega) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(t) e^{-j\omega t} dt, \qquad (1)$$

$$f(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} F(\omega) e^{j\omega t} d\omega, \qquad (2)$$

where $f(t)$ – the function of signal in the time area; $F(\omega)$ – the function of frequency spectrum of signal; t – the time; ω – the frequency.

According to the Aisenberg's method one restoration of part of frequency spectrum is possible on the base of rest part of frequency spectrum of signal. So, as first step the part of frequency spectrum of signal which coincides with the frequency spectrum of noise can be rejected. Then a restoration of the rejected part of spectrum of information signal can be provided using Aisenberg's method. As result after this approximation , the frequency spectrum of output signal will be without noise. It's clear that Fourier's transformation according to the equation (1) should be provided before application of Aisenberg's method. After application of Aisenberg's method the second Fourier's transformation according to equation (2) should be provided. This treatment of signal can be seen on Fig.3.

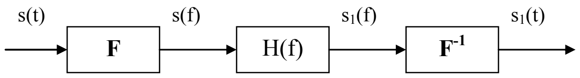

Fig. 3. Treatment of signals using Aisenberg's mathematical method

where $s(t)$ – the input signal with noise; F – device, which provides fast Fourier's transformation according to equation (1); $H(f)$ – device, which provides computer treatment of signal according to mathematical method of Aisenberg; F^{-1} – device, which provides inverse fast Fourier's transformation according to equation (2).

One interpretation of Aisenberg's mathematical method in communication systems

The theorem(sequence) for signal's discretion is well known

$$s(t) = \sum_{n=-\infty}^{\infty} s\left(\frac{n}{2\omega}\right) \frac{\sin[\pi(2\omega t - n)]}{\pi(2\omega t - n)}, \qquad (3)$$

where $s(t)$ – the function of signal in the time area; t – the time; ω – the frequency; n – the number of discreet.

According to this theorem one restoration of signal is possible on the base of discreet's sum. The interval between discreet should be constant. This is very important condition for application of the theorem. It's clear that it's impossible to use this theorem in the case when the part of frequency spectrum of signal coincides with the frequency spectrum of noise. So, according to Aisenberg's mathematical investigations the function of frequency spectrum of signal with finite spectrum can be described with equation (4).

$$\dot{X}(f) = \lim_{m\to\infty} \sum_{k=1}^{m} \dot{X}(f_k) \frac{-2j\sigma}{f - f_k - 2j\sigma}$$

$$\prod_{\substack{\nu=1 \\ \nu\neq k}}^{m} \frac{(f - f_\nu)(f_k - f_\nu - 2j\sigma)}{(f - f_\nu - 2j\sigma)(f_k - f_\nu)}, \qquad (4)$$

where $\dot{X}(f)$ – the complex function of frequency spectrum of signal; $\{f_k\}$ – the limited sequence of different points (frequency) on the real axes; σ – parameter.

If the distance between the frequencies f_k is constant, the time for computer treatment can be reduced. In this case:

$$\dot{X}(l\Delta) = \sum_{k=0}^{m-1} \dot{X}(k\Delta) \frac{\rho}{k - l + \rho}$$

$$\prod_{\substack{\nu=1 \\ \nu\neq k}}^{m} \frac{\nu(\nu - k - l) + kl + \rho(\nu - l)}{\nu[(\nu - k - l) + kl + \rho(\nu - k]} =$$

$$= \sum^{m-1} \dot{X}(k\Delta) C_k^{(l)}, \qquad (5)$$

where $\Delta = const$ – the distance between frequency points; l – the number of frequency point; $l = 0,1,....m-1$; $\rho = \frac{2j\sigma}{\Delta}$.

According to the equations (4) and (5) the frequency spectrum of signal which coincides with the frequency spectrum of noise can be increased if it would be possible to increase the number of determined frequency points m out of the noise spectrum.

The calculations according to the equation (4) and/or (5) should be provided by the device $H(f)$ on fig.3. These calculation can be online if this device is one fast computer. The described method of Aisenberg has been used for restoration of part of ECG signal in FTTH system as practical illustration (Fig. 4). The blue line is the line after computer restoration of signal.The red line is the line before influence of noise.

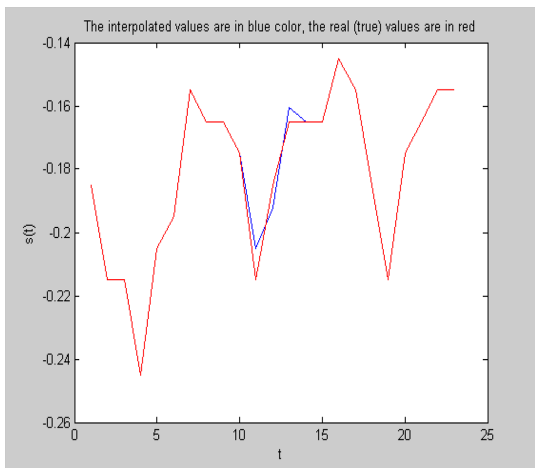

Fig. 4. Restoration of part of ECG signal in FTTH system

In the process of computer restoration the number of input frequency points is 20 and the number of frequency points of restoration is 3: RESULTS for Calculated ERRORS; Absolute Error = 0.0098, Root mean square error= 0.0027.

Conclusion

It's clear that application of Aisenberg's mathematical method for restoration of signals with in-completed frequency spectrum is useful for FTTH systems in the case of transfer of medical diagnostic signals (telemedicine). The application of Aisenberg's method can b illustrated by Fig. 3. The system on Fig.3 can be described as one kind of digital filter. So, the Aisenberg's method is one good base for design of new kind digital filters, which would be very useful in FTTH systems for telemedicine, when requirements fore reducing of noise are very strong.

References

1. **Jordanova L., Topchiev V.** Research of the Characteristics of an Optical Channel of HFC CATV Systems. Electronics Conference Proceedings. – Sozopol, Bulgaria, 2006. – P. 149–154.
2. **Dobrev D., Jordanova L.** Noise and Distortions Limitations in Designing of HFC CATV Systems. Elsevier: Optical Fiber Technology, 2006. – Vol. 12, Issue 2. – P. 196–204.
3. **Добрев Д., Йорданова Л.** Осигуряване на зададено отношение носещо трептение шум в изхода на оптичен канал при пренос на широколентов радиочестотен сигнал, Списание „Е+Е", 2006. Кн. 9–10.
4. **Айзенберг Л. А.** Экстрароляция функций голоморфных в произведение полуплоскостей или полос.Аналитическое продолжение спектра. Докл. АН СССР, 1986. – Т .290. – №2. – С. 265–268.
5. **Лученко Ф. В., Рассомахин С. Г.** Метод экстрароляции сигналов с ограниченным спектром, Радиотехника, Харьков, 1989. – № 91. – С. 10–14..

Received 2009 02 15

L. Jordanova, T. Dimitrova. Investigation on Noise Characteristic of Cable Channel for Telemedicine // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 4(92). – P. 103–106.

An investigation on noise characteristic of optic cable channel for telemedicine is described in the paper. Some application and development of optical systems Fiber to the Home (FTTH) have been done in the paper, also. The different kind of noise sources in FTTH systems are described , also. A computer method for restoration of frequency spectrum medical diagnostic signals is suggested in the paper. The restoration of frequency spectrum is as one development and application of mathematical method of Aizenberg in FTTH systems. Ill. 4, bibl. 5 (in English; summaries in English, Russian and Lithuanian).

Л. Йорданова, Ц. Димитрова. Исследвание характеристик шума канала телемедицинского кабеля // Электроника и электротехника. – Каунас: Технология, 2009. – № 4(92). – С. 103–106.

В статье описываются характеристики шума в оптичеком кабеле для телемедицины. В статье приведены некоторые области применения и развития оптических систем связи домов с больницами "Fiber to the Home" (FTTH). В статье описываются разные источники шумов в оптических системах связи домов с больницами "Fiber to the Home". Предложен компьютерный метод восстановления частотного спектра медицинских диагностичских сигналов. Это восстановление частотного спектра является развитием и применением математического метода Айзенберга в отических системах связи домов с больницами. Ил. 4, библ. 5 (на английском языке; рефераты на английском, русском и литовском яз.).

L. Jordanova, T. Dimitrova. Telemedicinos kabelio kanalo triukšmo charakteristikų tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 4(92). – P. 103–106.

Ištirtos telemedicinos kabelio kanalo triukšmo charakteristikos. Straipsnyje aprašomos kai kurios programos ir optinių sistemų tinklai, jungiantys ligonines ir gyvenamuosius namus, t. y. programa „Optinis tinklas į namus"(FTTH). Aprašomi skirtingi triukšmų šaltiniai optiniuose tinkluose, kuriais namai sujungti su ligoninėmis. Pasiūlytas kompiuterinis metodas medicininių diagnostinių signalų dažnių spektrui atskirti taikant Aizenbergo matematinį modelį FTTH. Il. 4, bibl. 5 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).