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Proposal of super low power consumption detector for emergency communication downstream system in FTTH

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Abstract: This paper discusses an optical access system that enables emergency voice communication when a power failure occurs in a user's house, and we also propose a super low power consumption detector that consists entirely of passive devices. And we present applied techniques that comprise sub-carrier multiplexing for user multiplexing/demultiplexing and a new passive detector for signal regeneration driven solely by the transmitted optical signal power. Then we confirm the feasibility of the system experimentally by using a prototype detector that has 8-channel selectivity. We report the realization of the intended detector functions that we achieved by back-to-back simulated voice signal regeneration.

Keywords: FTTH, PON, emergency voice communication, power failure, no power supply
Classification: Fiber-optic communication

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1 Introduction

Recently the number of Fiber To The Home (FTTH) service users has been increasing rapidly [1]. FTTH services are mainly supplied via a Passive Optical Network (PON, e.g. Gigabit Ethernet-PON, GE-PON [2]), because a PON provides economical triple play services by sharing transmission facilities among several users. And we expect that FTTH services based on PON will continue to expand throughout the world, and will become lifeline services as happened with the Public Switched Telephone Network (PSTN).

However, with FTTH, if there is a power failure in a user's residence, no communication services can be used, whereas the telephone service was guaranteed with PSTN. So, to maintain communication services during power failure, we have already proposed an upstream optical access system and reported related feasibility studies [3].

In this paper, we propose a downstream emergency voice communication optical access system. And we present applied techniques and feasibility studies based on experiments using a prototype detector.

2 Emergency voice communication optical access system driven without domestic power supply

Our aim is to provide basic voice communication services at the level provided by a PSTN over the existing PON architecture when a power failure occurs. We have already studied several possible ways of supplying power if a power failure occurs, and have clarified the primary functions for the system, namely that these are no time restrictions and multiple users. To realize these functions, the system needs signal generation/regeneration and multiplexing/demultiplexing properties for downstream/upstream systems. In addition, we proposed that the system be introduced by installing new units and that transmitted analog voice signals employ different wavelength

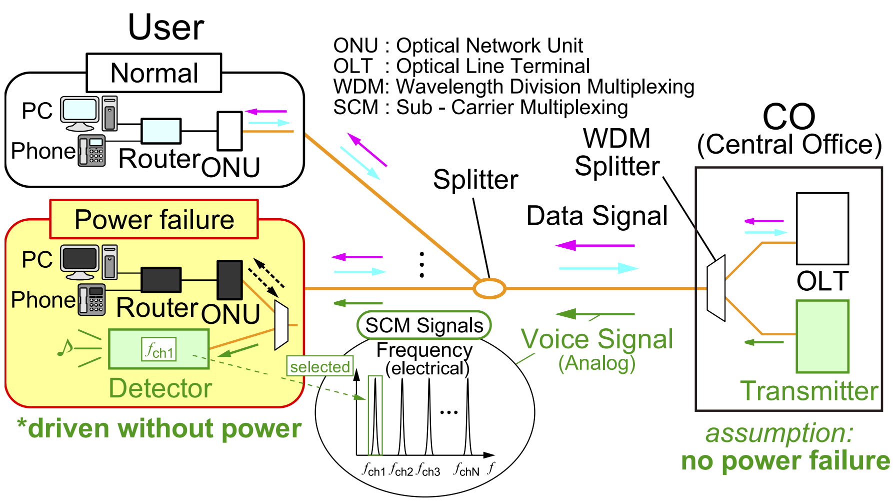

Fig. 1. Proposed downstream optical access system that enables voice communication when a power failure occurs and related techniques

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lights to permit coexistence with the conventional services. We assumed that there are no power failures at Central Offices (COs), and that optical fibers are not disconnected during such emergencies.

Fig. 1 is an overview of the proposed downstream system, which also shows the techniques used to realize primary functions for downstream systems, namely signal regeneration and user demultiplexing at a detector without electrical power. We describe these techniques in the next section.

3 Techniques employed in proposed downstream system

This section shows the techniques employed in the proposed downstream system. First, we describe the applied user multiplexing/demultiplexing technique, namely Sub-Carrier Multiplexing (SCM) [4]. Next, we show the signal regeneration technique, namely the regeneration of a voice signal solely from the transmitted optical signal power using a super low power consumption detector consisting of all-passive devices. This proposed detector is based on the classic crystal radio receiver that operates without an electrical power supply [5]. Then, we clarify the functional requirements and propose a circuit configuration. Finally, we confirm the feasibility of the proposed downstream system experimentally using a prototype detector.

3.1 SCM for user multiplexing and demultiplexing

SCM is a signal multiplexing method and a Frequency Division Multiplexing (FDM) technique. The SCM scheme is described below. First, in the electrical region, each original signal modulated by carrier frequency signals is multiplexed (in general, these carrier frequencies and frequency intervals are much greater than the bandwidth of the original signals). Then, these multiplexed signals are Electrical/Optical (E/O)-converted and transmitted. On the receiving side, multiplexed optical signals are changed back to electrical signals with an Optical/Electrical (O/E) converter. Then, multiplexed electrical signals are isolated and the original signals are regenerated. This technique is extensively used in optical analog signal transmission systems, e.g. video distribution services.

We propose using an Amplitude Modulation (AM)-SCM format. This is because if this modulation format is adopted, each user's signal can in principle be demultiplexed using only its own transmitted optical signal power as described in the following sub-section. So, we preliminarily allocate carrier frequencies corresponding to each user when there are no power failures, and the users can only obtain their own signals by using previously selected electrical filters.

3.2 Voice signal regeneration only from transmitted optical signal power with super low power consumption detector

Next, we present a signal regeneration technique that uses only its own transmitted optical signal energy with no electrical power requirement. To realize

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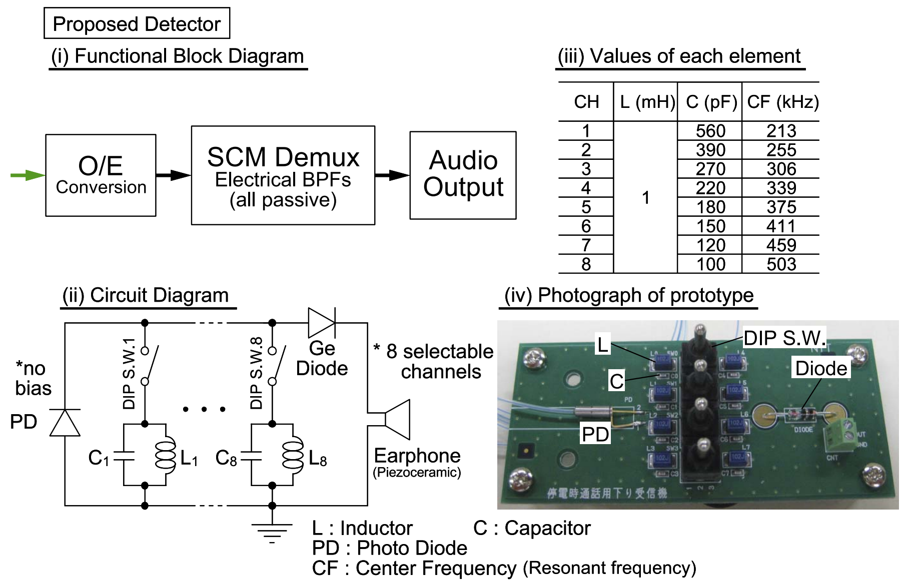
this technique, we propose a super low power consumption detector that consists entirely of passive devices. We decided to employ an AM-SCM format signal, so the detector requires a filtering (demultiplexing) function and an envelope detection function. We developed a new detector to realize these functions, and we shown its configuration in Fig. 2.



CH	L (mH)	C (pF)	CF (kHz)
1	1	560	213
2		390	255
3		270	306
4		220	339
5		180	375
6		150	411
7		120	459
8		100	503

Fig. 2. Schematic views of proposed detector, (i) functional block diagram, (ii) circuit diagram, (iii) values of circuit elements and center frequency of each channel, (iv) photograph of prototype

Fig. 2 (i) and (ii) show the functional block diagram and the circuit diagram, respectively. To realize O/E conversion with no electrical power, we installed a Photo Diode (PD) with no bias voltage. Then the converted multiplexed electrical signal was demultiplexed with passive Band Pass Filters (BPFs) consisting of LC resonant circuits. Next, the separated signals were regenerated and output with an envelope detection circuit consisting of a Ge diode with a low on-voltage and a piezoceramic earphone with high impedance, that is high sensitivity. This detector has 8 channels with different center frequencies to select each of 8 users.

The gain bandwidth of the PD is degraded because there is no bias voltage, however it can achieve O/E conversion. Each channel's center frequency is listed in Fig. 2 (iii), and these values are decided taking the degradation of PD responsivity into consideration. In fact, the PD we used had a gain bandwidth is 600 MHz at a typical reverse voltage, and the center frequency of each BPF was much smaller than this value and lager than the voice signal bandwidth (typically 8 kHz). After the filtering and current-voltage conversion at the BPF, the AM signal is demodulated by employing half-wave rectification with the Ge diode and envelope detection using the RC time constant of an earphone. Finally, Fig. 2 (iv) shows a picture of a test production of a super low power consumption detector.

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3.3 Feasibility studies of using experiments with proposed detector

We confirmed the feasibility of our proposed emergency downstream system by undertaking experiments using our prototype detector. The experimental setups and results are shown in Fig. 3.

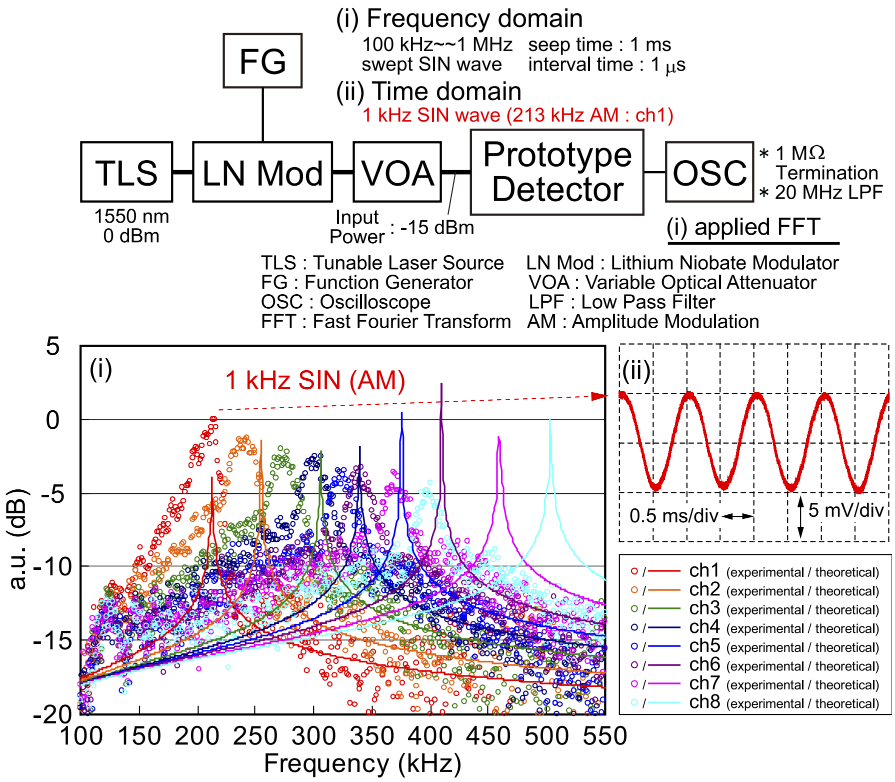

Fig. 3. Experimental setups and outputs, (i) frequency domain characteristic, that is, power spectral density (include theoretical impedance of each channel), and (ii) time domain characteristic, that is, back-to-back simulated voice signal outputs

First, we investigated the frequency characteristic of the prototype detector. We input an FM signal into the prototype, and signals separated by each channel were obtained with a storage oscilloscope. We applied a Fast Fourier Transform (FFT) to the obtained signals to confirm the power spectrum density of each channel. And the input port of this oscilloscope was equipped with a 1 MΩ termination because prototype output port was not terminated. These settings were for the convenience of our experimental setups, thus the measured signal values are not strictly accurate.

Second, we specified the time domain characteristic, namely output signal distortion through the prototype detector. Here we input a single AM signal rather than an AM-SCM signal to simulate the simplest situation, and we selected a carrier of 213 kHz. This value is the same as the theoretical center frequency of ch 1. And, we adopted a 1 kHz sinusoidal wave for the simulated voice signal. This experiment was run under back-to-back signal transmission

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conditions.

Additionally, we set the input optical power at −15 dBm. This is because we considered the case of the most distant user within this system based on the maximum transmitted optical power at a CO [6] and the allowed loss budget of an optical access system. As regards the time domain experiment, it had been previously confirmed by a subjective assessment that the required audible input signal voltage for an earphone (equal to the minimum prototype output signal voltage) is no lower than 5 mVp-p at 1 kHz.

Fig. 3 (i) shows the obtained frequency characteristics. None of the BPF characteristics is sufficient, namely, each BPF center frequency value is different from its theoretical values, and the isolation of each filter seems insufficiently sharp. However, the prototype detector certainly has frequency selectivity, and we confirmed its user demultiplexing capability. We consider the difference between the measured and theoretical value of the center frequency to result from the impact of the floating capacitance of the circuit board, because the difference increases as the channel number (center frequency) increases, and the capacitance value decreases as shown in Fig. 2 (iii). Improving this performance by redesigning the prototype circuit is our future work.

Fig. 3 (ii) shows the output of the regenerated signal. From the waveforms, we verified the capability for signal regeneration solely using the transmitted optical power. The output signal voltage magnitude of 10 mVp-p enabled us to achieve the same coverage as existing optical access systems, namely a maximum distance of 20 km. However, this output level is insufficiently large to guarantee voice signal audibility. We expect that the proposed detector needs further improvement. So, after a more detailed theoretical study, we will investigate the optimization of the detector design. In addition, the nonlinear optical effect cannot be ignored because the transmitted optical power may become much larger than that of existing systems. Therefore, we should perform signal transmission experiments and confirm the feasibility of our system in more detail.

4 Conclusion

We described the needs to realize an emergency communication function for FTTH, and proposed a downstream analog optical access system that makes it possible to maintain voice communication services during a power failure. And we proposed employing SCM and a detector driven with only the transmitted optical signal power. We confirmed the feasibility of the proposed system experimentally using a novel super low power consumption detector, and briefly mentioned the future direction of our work.

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