Implementation of maintenance system based on Bluetooth Low Energy for hermetic inline amplifiers in CATV networks

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Abstract*— Cable television (CATV) systems generally consist of a headend, trunk cables, distribution cables in the neighborhood, drop cables to a home and in-house wiring, and terminal equipment. Coaxial cables bring a CATV signal to customer premises through a service drop, an overhead or underground cable. Hermetic inline amplifiers are used to amplify the attenuated CATV signal due to propagation loss or splitting the coaxial cable. They are usually installed on utility poles. Therefore, maintenance methods for inline amplifiers on utility poles are important issues in CATV operations. This paper proposes a new maintenance system for inline amplifiers in CATV systems, and develops a prototype implementation. The proposed system consists of an amplifier gain analyser to measure amplification performance of inline amplifiers, a special smartphone application, and a cloud server. The proposed amplifier gain analyser is composed of three functions: a generation of high frequency signals for testing, measurement of the test signal gain, and wireless communication based on Bluetooth Low Energy (BLE). We develop a signal generation circuit for a test signal and a smoothing circuit for converting the high frequency test signals into DC signals. The amplifier gain analyser can evaluate an amplifier gain by comparing an input test signal from the signal generation circuit and an output test signal from an inline amplifier. The measurement function uses Nordic nRF51822, which is a System on Chip (SoC) for BLE because Nordic nRF51822 has some AD converter ports for evaluating the DC signals. The smartphone application employs BLE communication function to collect the measured amplifier gain from the amplifier gain analyser. Therefore, we developed a special data collection application for iOS. The data collection application has a central function of BLE, and can find a target peripheral device that is the amplifier gain analyser in this paper. Therefore, technicians of CATV systems can easily check the operational status of inline amplifiers on utility poles. Additionally, the smartphone application can upload the measured information to a cloud storage server. We employ Google App Engine and use Cloud Datastore to implement the cloud storage service. Therefore, our storage service has flexibility for various kinds of information.

***Keywords*— Inline amplifiers maintenance, CATV, Sensor networks, Bluetooth Low Energy, Smartphone application**

I. Introduction

Cable television (CATV) systems were introduced in the United States in 1948[1]. Recently, more than half of all American homes subscribe to basic cable television services. The standard for CATV systems has been developed by CableLabs and contributing companies. Data Over Cable Service Interface Specification (DOCSIS)[2] is an international telecommunications standard that permits the addition of high-bandwidth data transfer to a CATV system. DOCSIS provides variety in options available at Open Systems Interconnection (OSI) layers 1 and 2, the physical and data link layers.

DOCSIS architecture includes two primary components: a cable modem (CM) located at customer premises, and a cable modem termination system (CMTS) located at a CATV office. CMTS is a device which hosts downstream and upstream ports for CMs. These ports are typically separated to some connectors for downstream and for upstream communication due to the noise in the upstream path. Therefore, a typical CMTS has 4 or 6 upstream ports per a downstream port. Recent CATV systems use a hybrid fiber-coaxial system to extend the service area and to reduce the effect of the noise in the upstream path[3]. Fiber optic lines bring digital signals to

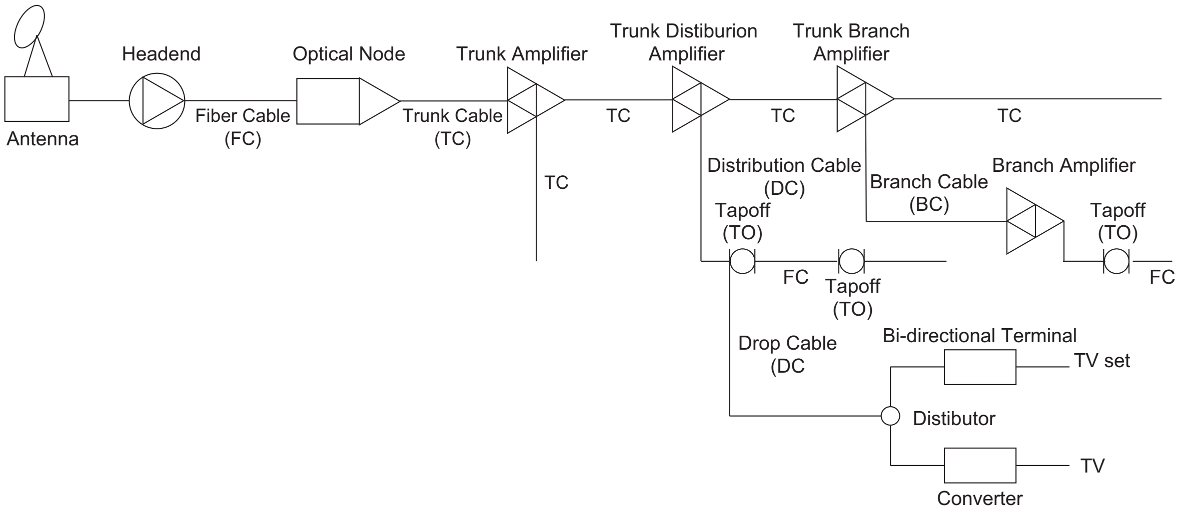

Fig. 1. Overview of CATV system.

fiber optical nodes where they are converted into RF channels and modem signals on coaxial trunk lines. The latest CATV systems still use coaxial trunk lines due to the limitation of the installation at customer premises.

CATV operators generally require maintenance systems for CATV networks[4]. Some schemes have been proposed for a failure analysis of fiber optical cables because fiber optical cables are easily damaged[5], [6], [7], [8], [9], [10]. Coaxial cables are comparatively undamageable than fiber optical cables. However, coaxial networks usually employ hermetic inline amplifiers to amplify the attenuated CATV signal because the CATV signal generally attenuates due to signal decay depending on the increase of the coaxial cable length. They are typically installed on utility poles, and are easily damaged due to severe outdoor condition such as high temperature and humidity. Therefore, maintenance methods for inline amplifiers on utility poles are important issues in CATV operations.

This paper proposes a new maintenance system for inline amplifiers in CATV systems, and develops a prototype implementation. The proposed system consists of an amplifier gain analyser to measure amplification performance of inline amplifiers, a special smartphone application for collection the measured amplification performance of the amplifier gain analyser, and a cloud server for storing the measured data. The proposed amplifier gain analyser consists of three functions: a generation of high frequency signals for testing, measurement of the test signal gain, and wireless communication based on Bluetooth Low Energy (BLE)[11]. We develop a signal generation circuit for a test signal and a smoothing circuit for converting the high frequency test signals into DC signals. The amplifier gain analyser can evaluate an amplifier gain by comparing an input test signal and an output test signal from an inline amplifier. The measurement function uses Nordic Semiconductor nRF51822[12], which is a System on Chip (SoC) for BLE because Nordic Semiconductor nRF51822 has some AD converter ports for evaluating the DC signals. The smartphone application employs BLE communication function to collect the measured amplifier gain from the amplifier gain analyser. Therefore, we developed a special data collection application for iOS. The data collection application has a central function of BLE, and can find a target peripheral device that is the amplifier gain analyser in this paper. Therefore, technicians of CATV systems can easily check the operational status of inline amplifiers on utility poles. Additionally, the smartphone application can upload the measured information to a cloud storage server. We employ Google App Engine and use Cloud Datastore to implement the cloud storage service. Therefore, our storage service has flexibility for various kinds of information.

II. CATV SYSTEM

Recent cable systems are large, with a single network and headend often serving an entire large area. Most systems use hybrid fiber-coaxial (HFC) distribution where the trunklines

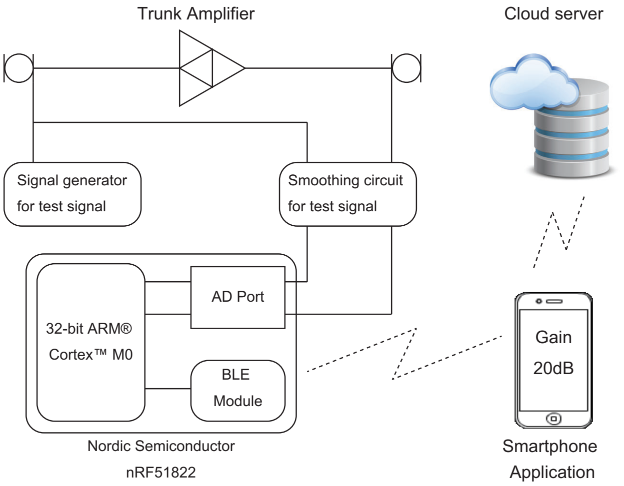

Fig. 2. System model of proposed maintenance system.

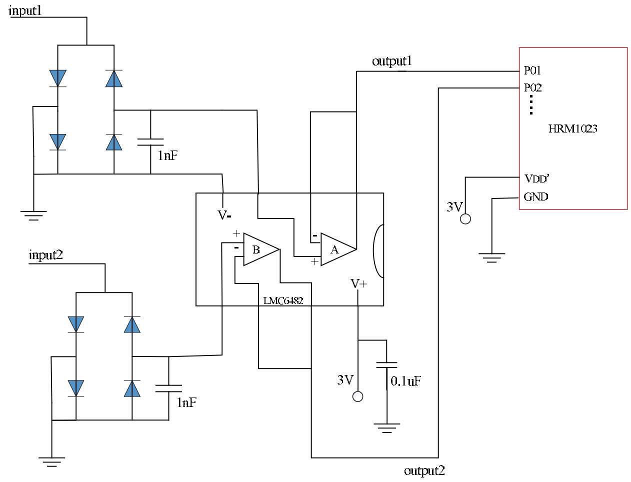

Fig. 4. Smoothing circuit for test signals.

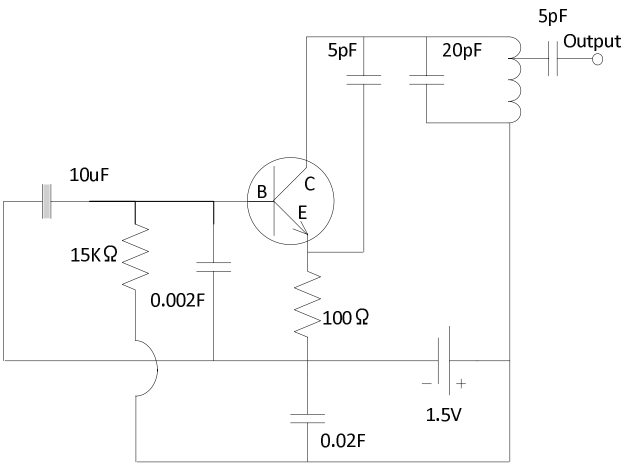

Fig. 3. Signal generation circuit.

that carry the signal from the headend to local neighborhoods are optical fiber to provide greater bandwidth and also extra capacity for future expansion. The headend modulates the radio frequency electrical signal carrying all the channels on a light beam and sent it through the fiber. The fiber trunkline goes to boxes called optical nodes in local communities. At the optical node, the light beam from the fiber is translated back to an electrical signal and carried by coaxial cable distribution lines on utility poles, from which cables branch out to customer premises.

Fig. 1 is the overview of coaxial cable distribution lines in CATV system. A fiber optical node has a broadband optical receiver, which converts the downstream optically modulated signal coming from the headend to an electrical signal going to the homes. It also contains a reverse/return path transmitter that sends communication from the home back to the headend. The optical portion of the network provides a large amount of flexibility. The coaxial portion of the network connects typically 500 homes in a tree-and-branch configuration off of the node. Hermetic inline amplifiers are used to overcome cable attenuation and passive losses of the electrical signals caused by splitting the coaxial cable.

Trunk coaxial cables are connected to the optical node and form a coaxial backbone. Trunk cables also carry AC power which is added to the cable line by a power supply and a power inserter. The power is added to the cable line so that optical nodes, trunk and distribution amplifiers do not need an individual, external power source. Smaller distribution cables are connected from the trunk cables to a port of the trunk amplifier to carry the RF signal to individual streets. The distribution line is used to connect the individual drops to customer premises.

III. Proposed Maintenance System

Fig. 2 shows the system model of the proposed maintenance system. The system consists of three functions: the amplifier gain analyser, the smartphone application and the cloud server.

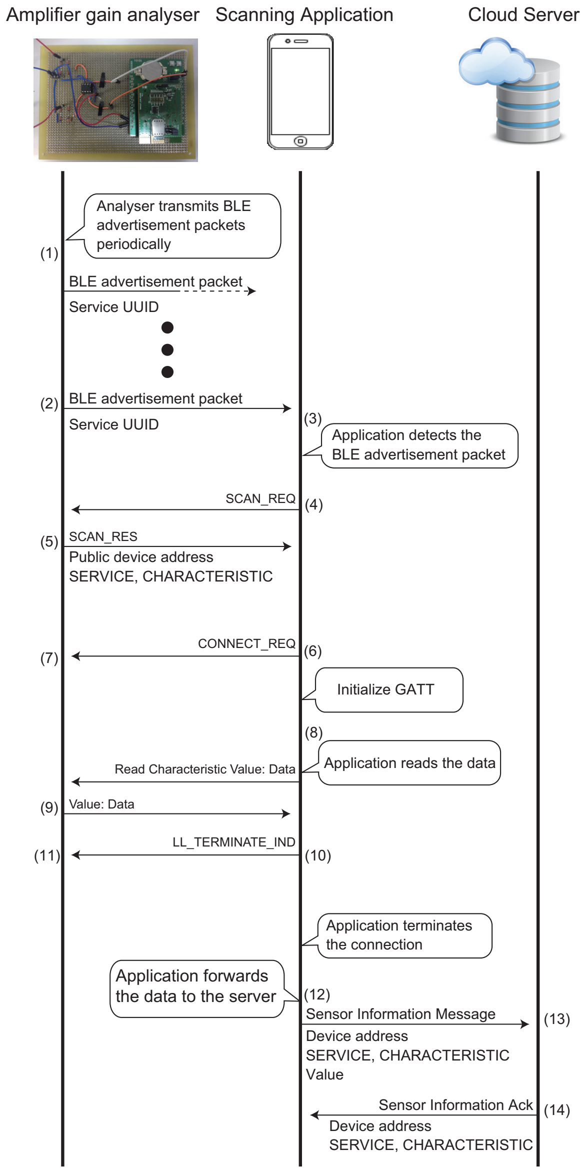

Fig. 5. Signaling.

A. Amplifier gain analyser

The amplifier gain analyser has three modules: a generation module for high frequency signals for testing, a measurement module for the test signal gain, and a wireless communication module based on Bluetooth Low Energy (BLE) technology.

Fig. 3 shows the circuit design for the high frequency signal generation for testing. The circuit generates 260 MHz signals as the test signal. Fig. 4 shows the circuit design for the smoothing for test signals because an AD converter cannot measure the test signal directly due to the high frequency.

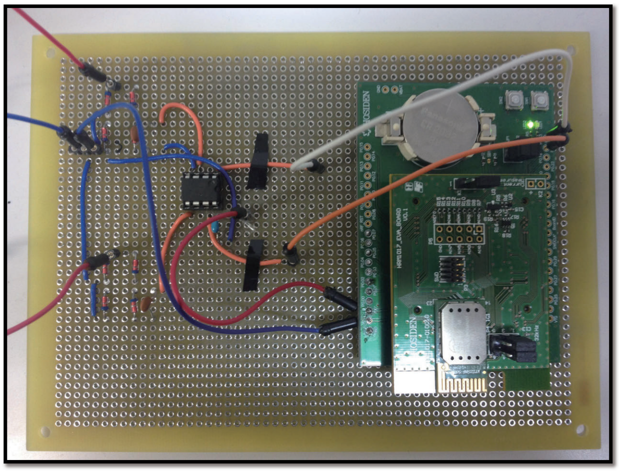

Fig. 6. Overview of amplifier gain analyser

The circuit smooths both the original test signal as the reference signal and the output signal of the amplifier as the measured signal. The output signals are inputed into the AD converter of nRF51822. nRF51822 has a 32-bit ARM Cortex M0 core. Therefore, it can calculate the amplifier gain from the smoothed signals.

B. Signaling

We employ nRF51822 for calculating the amplifier gain and the communication module for a smartphone application. Fig. 5 shows the signaling process between the amplifier gain analyser and the smartphone application, and between the smartphone application and the cloud server. The following is the maintenance procedures.

1) The amplifier gain analyser starts transmission of BLE advertisement packets. It operates by the power from a coaxial cable because a headend or a power inserter generally provides the power to a coaxial cable.
2) The amplifier gain analyser transmits the advertisement packets periodically to broadcast the service to neighbor smartphone application.
3) The smartphone application starts receiving of BLE packets when technicians launch the smartphone application. The smartphone application continues to receive BLE packets until it receives the BLE advertisement packet for the target amplifier gain analyser.
4) The smartphone application transmits the SCAN_REQ packet to the amplifier gain analyser to request the

Fig. 7. Overview of inline amplifier.

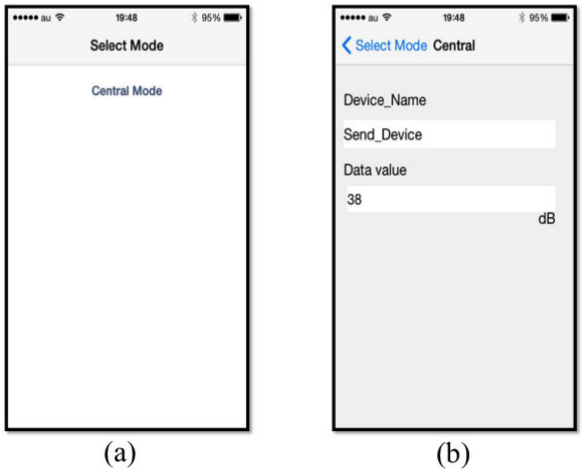

Fig. 9. Captured images of iOS application.

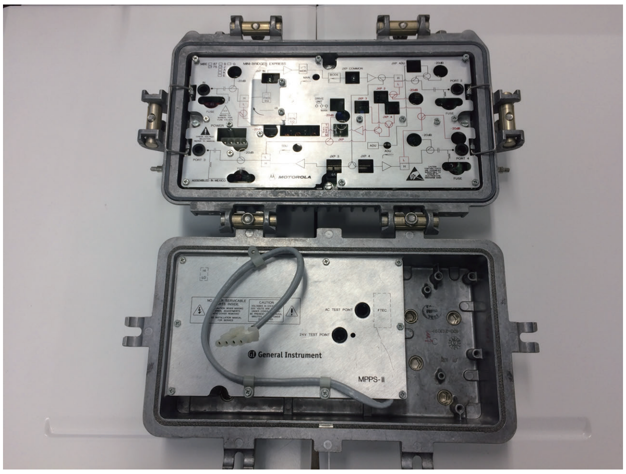

Fig. 8. Internal view of inline amplifier.

communication when it detects the BLE advertisement packet.

5) The amplifier gain analyser replies the SCAN_RES packet to the smartphone application. The application can recognize the specific information about the amplifier gain analyser.
6) The smartphone application transmits the CONNECT_REQ packet to initialize GATT communication to the amplifier gain analyser.
7) The amplifier gain analyser starts GATT communication when it receives the CONNECT_REQ packet from the smartphone application.
8) The smartphone application requests specific characteristic values by transmitting the READ_REQ packet to the amplifier gain analyser.
9) The amplifier gain analyser replies the requested characteristic values by replying the READ_RES packet. It continues the data transfer process with READ_REQ and READ_RES packets until the data transmission is completed.
10) The smartphone application terminates the connection by transmitting the LL_TERMINATE_IND packet.
11) The amplifier gain analyser disconnects the connection when it receives the LL_TERMINATE_IND packet.
12) The smartphone application uploads the measured information to the cloud server by HTTP.
13) The cloud server stores the measured information in the database.
14) The cloud server replies the acknowledgement to the smartphone application when it receives the measured information successfully.

IV. Experience

Fig. 6 shows the overview of the amplifier gain analyser. Figs. 7 and 8 show the overview and the internal view of the inline amplifier which is STARLINE series of MiniBridger amplifiers produced by General Instrument (Motorola). We

TABLE I

EXPERIMENTAL RESULTS.

	By oscilloscope	By developed circuits
Input signal [mV]	90	38
Output signal [V]	7	3
Gain [dB]	38	38

employ the development board of nRF51822 because the original nRF51822 chip is a product for the surface mounting and is difficult to solder. The developed circuit for the signal generation is connected to the inline amplifiers and the smoothing circuit. The smoothing circuit is connected to the development board for the nRF51822. As a result, the developer board of nRF51822 can measure the smoothed signals from the signal generation module and the output port of the amplifier.

Fig. 9 shows the captured images of the developed iOS application. The application can connect to nRF51822, and can obtain the amplifier gain by BLE communication. In the experimental trials, we measured the amplifier gain with an oscilloscope or the developed circuits to evaluate the accuracy of the amplifier gain value. As the input signal, we configure that the signal generator circuit outputs 90 [mV] signal at 260 [MHz]. Tab. I shows the experimental results. We have confirmed that the developed circuits can obtain the accurate amplifier gain comparing to the measured value with an oscilloscope.

We employ Google apps as a cloud server service. Therefore, iOS application can post the measured amplifier gain to the cloud server by HTTP. We confirm that the developed application on the google apps can receive the measured amplifier gain from the iOS application and can store the data.

V. CONCLUSION

This paper has proposed the new maintenance system for inline amplifiers in CATV systems, and has developed the prototype implementation. The proposed system consists of an amplifier gain analyser to measure amplification performance of inline amplifiers, a special smartphone application for data collection, and a cloud server for the data store. We have confirmed that the proposed amplifier gain analyser can measure the amplifier gain by the generated test signal, and iOS application can receive the measured amplifier gain from the amplifier gain analyser by BLE technology and can post the gain to the cloud server on Google Apps.

ACKNOWLEDGMENT

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