Transmitter Identification —The Development of a High speed Data Acquisition System with Receiving Functions—

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CRL(Communication Research Laboratory) has developed a system that improves the clarity of trigger settings used in the identification of FM radio transmitters. This method uses a hybrid system that consists of a trigger based high speed data acquisition system with receiving functions. This system enhances the ability to accurately identify FM radio transmitters via a narrow band spectrum trigger system (NSTS) that mediates the variable transient response patterns the at occur when a press-to-talk button is switched on and off. To accomplish this, an NSTS unit was installed into a high-speed data acquisition system to elicit trigger settings that would provide discrete transmitter identification. This hybrid system was used to obtain rise and fall data from FM transmitters, and the transient response patterns were then analyzed. Experimental evaluation demonstrated that this method increases the dynamic range [receiver input level (Pin) = -70 to -110 dBm] and significantly reduces noise interference, making it possible to obtain more accurate transmitters identification

Keywords
Radio transmitter identification, Narrow band spectrum trigger system(NSTS)

1 Introduction

With the rapid development of radio communications, radio stations have increased in number, giving rise to various problems. The radio interference and jamming, by illegal radio stations, of important or general operational radio communications are the most serious of these problems. According to a recent white paper on radio communications, over 45,000 incidents were reported in one year recently, and the number is on the rise. Effective measures to prevent such illegal actions and protect the radio environment are urgently needed. To provide reliable and effective regulations against illegal radio communications, radio monitoring systems are expected to be developed that can identify such radio transmission sources through the application of a direction finder and analysis of the properties of received radio signals.

In 1992, the Communications Research Laboratory (CRL) began a study to identify press-to-talk transmitters by analyzing their transient response characteristics at the time of being switched on and off. In that study, the Wigner-Ville distribution, which is a well-known means of analyzing transient response characteristics in acoustic measurements, was used to identify the transmitters[1].

In 1996, CRL began another study, promoted and subsidized by the Ministry of Posts and Telecommunications, for the creation of a "Next Generation Radio Monitoring System." In the first stage of the three year study (April 1996 to March 1999), we developed a high-speed data acquisition system for the identification of transmitters, along with software for using it. The system was capable of acquiring and displaying RF waveform data or I-Q data, and calculating and displaying spectrograms based on the I-Q data.

In the development of the software, we studied methods of analyzing data by applying an expression for the instantaneous frequency, pseudo-Wigner-Ville distribution, and a spectrogram to a transient response in the form of an unsteady state signal. This application clarified the characteristics and effectiveness of each method. We then proposed a procedure for acquiring spectra using a sequence correlation function, based on the high order exponential function method. This procedure was compared with conventional methods in terms of their time resolution, frequency resolution, and noise robustness[2].

In the second stage (April 1999 to March 2002), we tested 24 transmitters (six types; manufactured by three companies) by conducting an indoor experiment to acquire data. This test was aimed at objectively determining the characteristics and tendencies of each transmitter. In order to process the data, the amplitude envelope at the time of a rise was normalized using the saturation voltage, to allow us to identify transmitters by manufacturer and type. We also hoped that a difference in the amplitude envelope waveform between transmitters of the same type might be found, to allow the identification of transmitters. A receiver function was added to the high speed data acquisition system in order to improve the software. This allowed data to be acquired through an antenna. Finally, we began an experiment to examine the effects of noise and multi-pass functions on the propagation of radio waves[3].

We investigated two methods of analyzing data: the root-MUSIC method and the linear-prediction method[4][5]. They were compared with analyses conducted using an expression for the instantaneous frequency, a spectrogram, and the pseudo-Wigner-Ville distribution. Analyses of the indoor data confirmed that various patterns existed in the time-frequency space for each transmitter model. Unlike in the amplitude waveform, there were many patterns, and we attempted to extract very small differences between patterns in order to identify transmitters. We found, when it was difficult to identify transmitters based on the amplitude waveform, that additional information on the time-frequency space was effective in identification[6]. We also began to examine some adaptive equalization methods for analyzing signals damaged by multi-pass operation or the like. A two dimensional CMA and an eigenvector composition method were other topics for study in the investigation of the applicability of an adaptive array to the radio transmitter identification system. These methods were evaluated from the standpoint of performance by examining spectrograms of their transient responses[7].

In this report, we will describe an improved radio transmitter identification system. Prior to the improvement, the lower limit of the receiver input level was -70 dBm when the trigger of the transmitter identification system with an added receiver operated normally. Following the improvement, in which a narrow band spectrum trigger system was added to the receiver, the lower limit of the smallest receiver input level was greatly improved, to -120 dBm.

2 High-speed data-acquisition system

In the course of development, the high-speed data acquisition system was improved to the capacity of existing systems for indoor experimental use and outdoor use with an antenna. The indoor experimental structure served to determine the environmental characteristics and power supply dependence of the transient response under noise free conditions.

The outdoor structure was used to examine the effectiveness of identifying transmitters by analyzing acquired data.

Fig.1 is a photograph showing the transmitter identification system. Fig.2 shows a block diagram of the system with an added receiver function. Signals from a transmitter enter an input connector of the 0 to 30 dB attenuator positioned between a receiver RR502A and a down converter E6500A, as shown in Fig.2. The signals must be kept at -10 dBm for input into a mixer, while E6500A is expected to have a gain of approximately 10 dB. Thus, E6500A's attenuator should be set in accordance with the following inequalities:

$$Att \geq -10\ dBm - 10\ dB - Pin\ (dBm)$$

where $Att \geq 0$ dB and Pin is the receiver input level.

The range of frequencies is adjustable to any value between 30 MHz and 3000 MHz. The trigger input can be selected from between an external trigger and an internal trigger. When the trigger mode is free run, data is acquired continuously without a trigger. In an indoor experiment, an internal trigger is normally selected. In this case, the trigger level of signals to enter into the down converter is set on the control screen. A common level is approximately one-tenth of that of the input signals. The functions of this down converter and related functions will be described in detail in the next section.

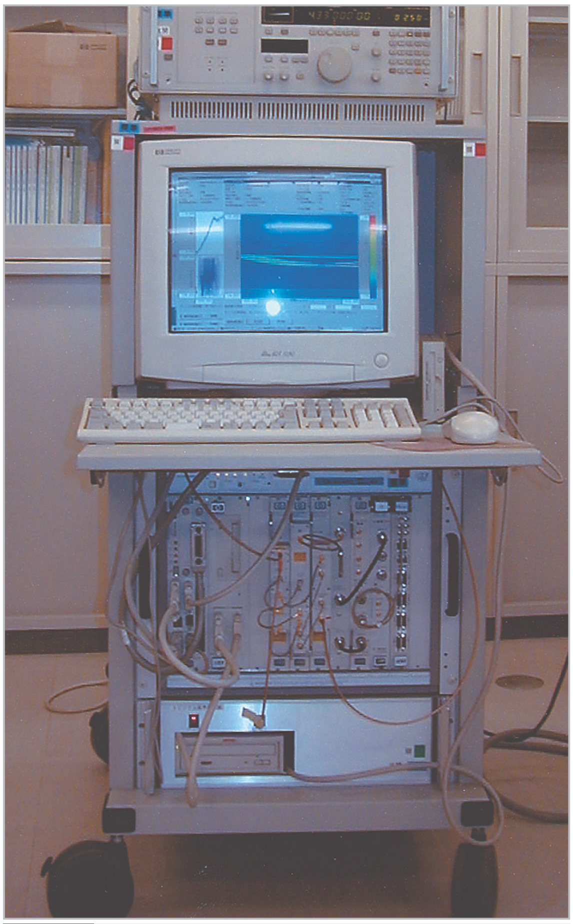

Fig.1 Radio transmitter identification system

The intermediate frequency (IF) of a signal from the receiver RR502A (21.4 MHz) was frequency converted to 2.7 MHz by the down converter E6500A. Following A/D conversion, the IF was separated into a real component (I) and an imaginary component (Q) by digital orthogonal detect. A decimation filter was then used to curtail and band-limit data, and the data was finally stored as a 64 MB data file. The length of time for data acquisition could be set between 0 ms and 200 ms. The optimal conditions of E6500A in terms of the S/N ratio of skewness were set so that the IF input level would be between -20 dBm and -10 dBm. For values above this range, the skewness increased, and for lower values, the S/N ratio worsened due to the noise characteristics of E6500A. Therefore, if the signal level to be acquired is known, to set the IF output between -20 dBm and -10 dBm, the values of attenuation and gain should be determined in accordance with the following relation:

$$-20 < Pin - Att + Gain - Loss < -10 \quad (1)$$

where Pin is the input level of the receiver in dBm, and Att is the value of attenuation of the receiver in dB (0, 6, 10, or 20). If it is impossible to predict or desirable to accurately determine the input signal level, Pin, the measurement mode should be selected on the screen for setting the conditions, thereby giving the signal level for a free run, as shown in Fig.3.

The above system was operated on Microsoft Windows NT 4.0J. The development language was Visual Basic 5.0. Visual C++ 5.0 was used to improve the functions for

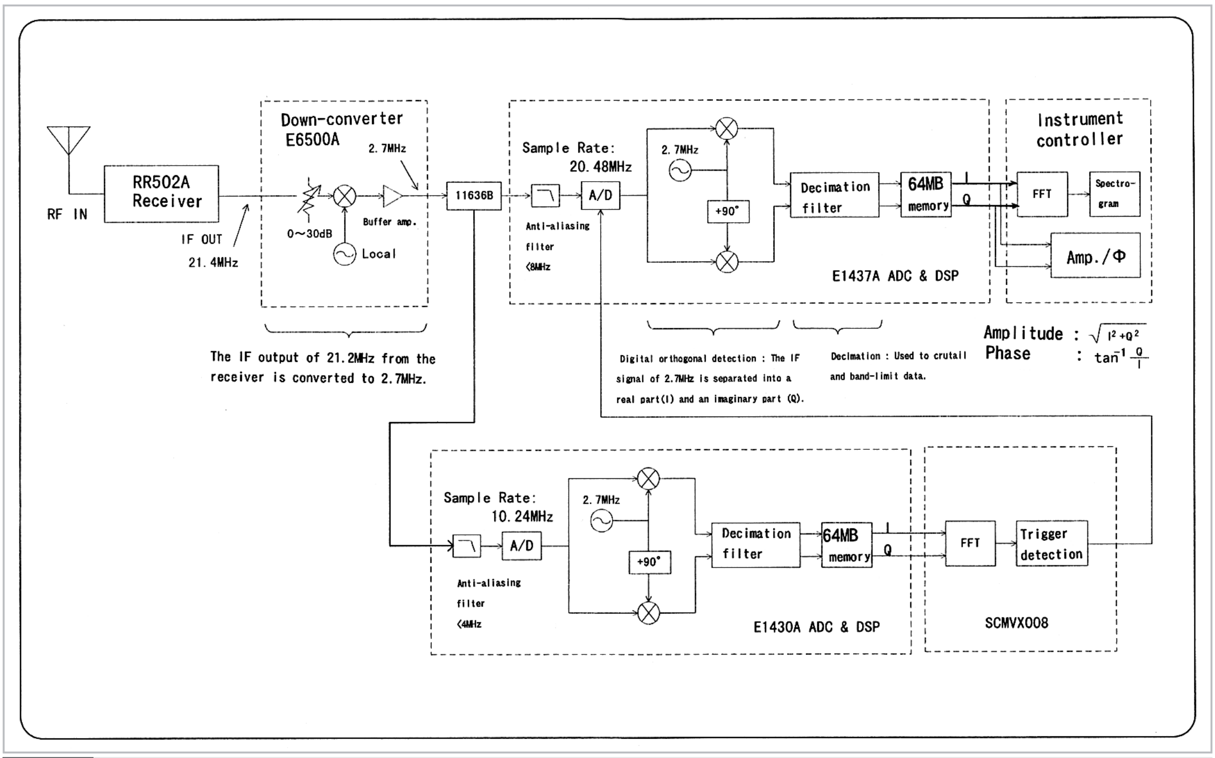

Fig.2 Block diagram of the radio transmitter identification system having a receiver function

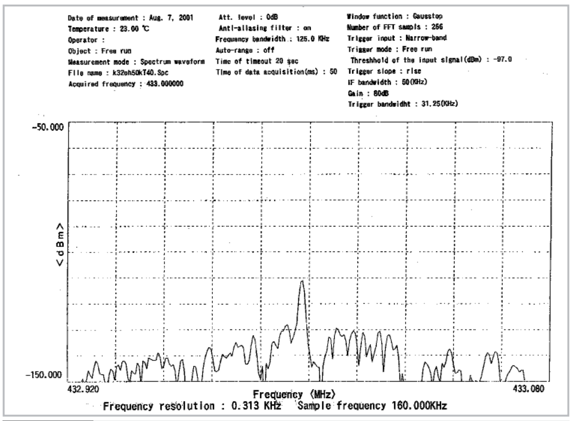

Fig.3 Spectra for a free run

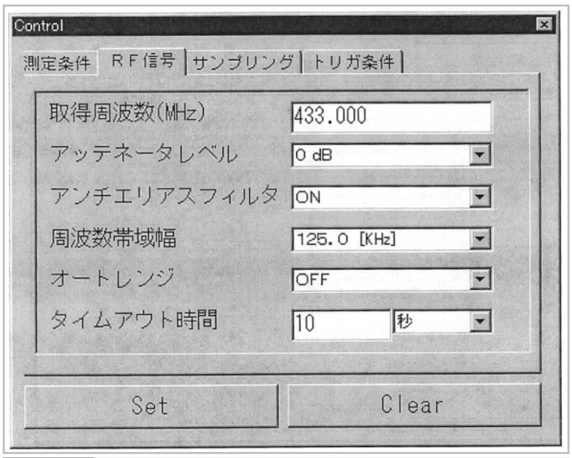

Fig.4 Control panel

graphic drawing and data acquisition. Fig.4 shows an example of the RF signal conditions on the control panel. This panel had five tabs to set conditions for the measurement, RF signals, sampling, trigger, and receiver. The receiver tab included an item for IF bandwidth that allowed selection from among 12 kHz, 50 kHz, and 250 kHz. This system applied the rubidium frequency standard as an external reference signal (10 MHz) for the receiver and down converter, establishing the accuracy and stability of the frequency. The standard software for the system included that which allows the acquisition and display of I-Q data; the display of spectrum waveforms, RF waveforms, and spectrograms; data processing; and printing. Fig.5 shows some results obtained by the system.

A block diagram of the portion that contained the prior to improvement internal trigger is shown in the upper part of Fig. 2. This trigger contained a pre trigger function that was capable of acquiring data dating back up to 3 ms. A signal generator was used to evaluate the functions of each part of the data-

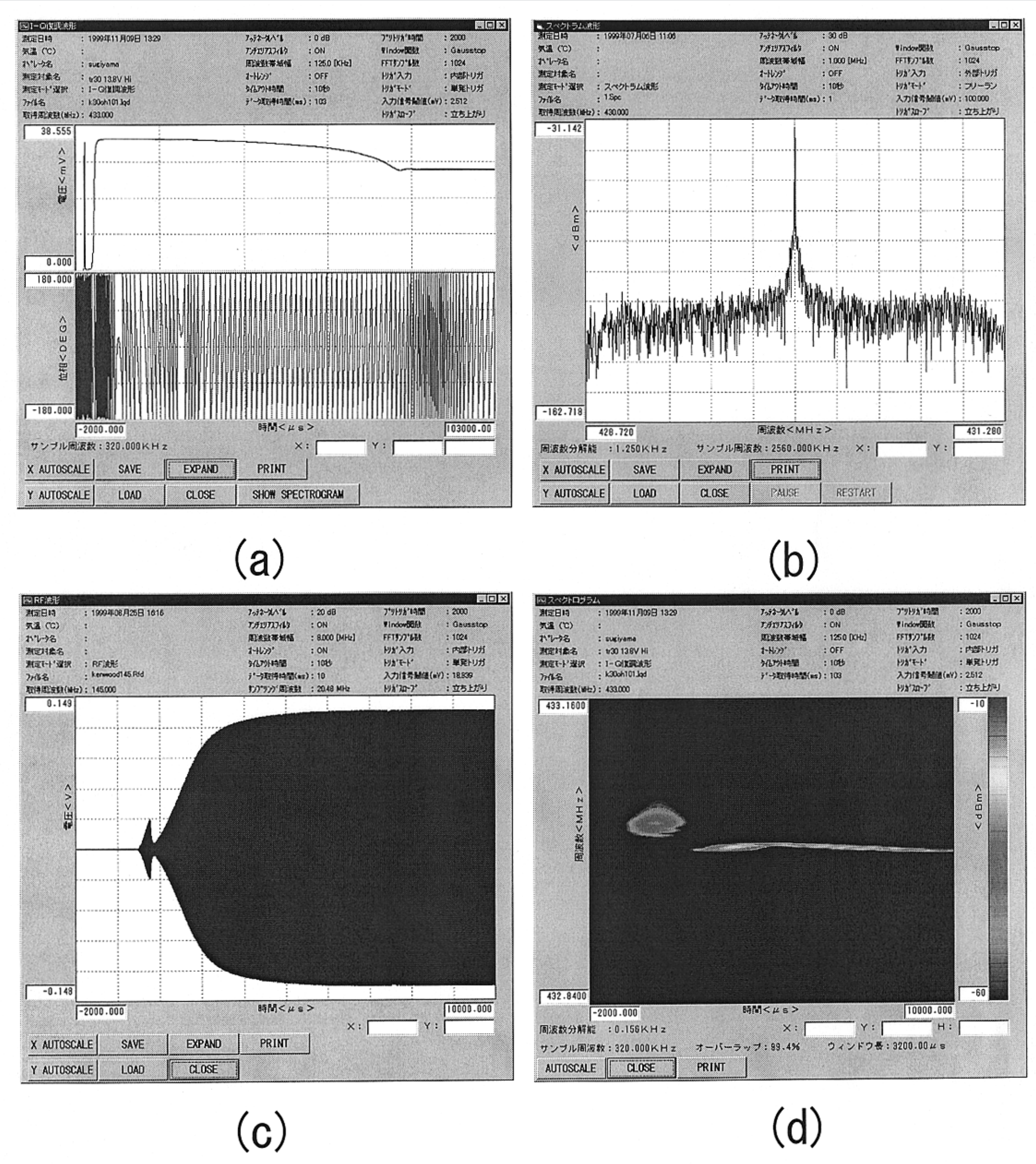

Fig.5 *Results obtained by the data-acquisition system*

acquisition system. No problem was found in any part. After confirming that all of the evaluation items were complete and acceptable, a data-acquisition test was conducted using an antenna. During this test, the system became unstable when the RF input signal level was approximately -70 dBm, and data acquisition was not completed normally. The trigger level of the system was set in the following way:

$$Tl\ (dBm) > Pin\ (dBm) - 10\ (dB) \quad (2)$$

It was found that this system triggered an input signal into the A/D converter when the waveform of the signal reached a set value of the trigger level. Within the IF band, the noise is generally white, with a peak value over ten times the effective value. Thus, when the IF band is enlarged, an adequate trigger level may be difficult to set. This proved to be a major reason for the above mentioned instability.

To solve this problem of instability, we designed a portion of the acquisition system as shown in the lower half of Fig.2. This portion was used to detect the trigger timing for signals containing random noise, and is referred to as a “narrow band trigger system.” The portion comprised both an A/D converter for detecting the trigger timing, and a digitizers/signal processor module, and successfully eliminated random noise to pick up a rise in a required signal. It allowed selection of the bandwidth from among three values: 31.25 kHz, 15.63 kHz, and 7.81 kHz. As a result of the incorporation of such a trigger system, in an experiment using an antenna, data acquisition was successfully completed even when Tl = -110 dBm and the IF bandwidth = 250 kHz for Pin = -120 dBm.

Indoor and outdoor experiments were conducted following the above preliminary test. Their results will be described in a separate report.

3 Conclusions

A narrow band spectrum trigger system (NSTS) was incorporated into a receiver that was added to a high speed data acquisition system for the identification of transmitters. This trigger system improved the dynamic rage for setting the trigger of the data acquisition system, allowing the system to operate with good stability in a range of antenna input-converted values of Pin = -70 dBm to -120 dBm.

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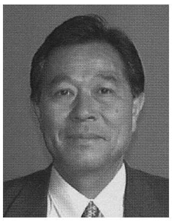

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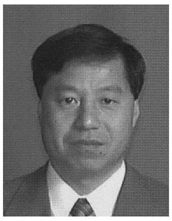

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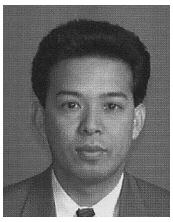

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