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**Adaptability of real zero single sideband technology
to HF data communications**

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1 Introduction

Automated HF communications brought a number of innovative solutions to long standing problems in HF radio links, such as channel selection, unattended operation, and interoperability. These systems rapidly and automatically scanned a set of assigned frequencies, listening for modem tones that carried their call signs. The resulting automatic link establishment (ALE) systems were developed after several industry solutions, and later tried and confirmed in the marketplace [Johnson *et al.*, 1997]. The ALE technology standardized in MIL-STD-188-141A and FED-STD-1045 is under consideration within ITU-R. An ALE-capable radio station consists of an ALE controller, a controllable single sideband (SSB) radio, and transmission equipment such as antennas, etc. More advanced automated stations also include high-speed HF data modems, networking controllers, and so on.

The SSB system, originally developed in the 1910s, is still widely used for HF radiocommunications [Maslin, 1987]. SSB has the distinct advantage of narrow bandwidth, but it is difficult to maintain transparency of received signals through fading environments. In order to cope with fading, the Lincompex system was developed by the British Post Office in the 1960s. In the demodulation process, conventional SSB, including the Lincompex, requires an automatic gain control (AGC) circuit to restore amplitude degradation, and a clarifier to fine tune the frequency. Without employing these two circuits, the detected signal is greatly impaired.

In order to overcome the drawbacks of conventional SSB, the real zero concept was successfully introduced for establishing real zero SSB (RZ SSB) technology for V/UHF bands in Japan [Daikoku and Suwa, 1988]. This is because the SSB is one of the most promising modulation methods for utilizing the limited radio spectrum as effectively as possible.

Anticipating that the RZ SSB technology is effective for data communications over HF radio link, in this Report, the RZ SSB technology is introduced in detail.

2 RZ SSB technology

RZ SSB technology is a combination of two technologies employing digital signal processing techniques; SSB modulation and phase modulation (PM) reception.

2.1 Design of transmitter

Since a carrier plays major roles in the detection process of RZ SSB, SSB with a reduced carrier signal is adapted into transmitting signals.

2.1.1 Generation of SSB signal

For generating SSB signals, there are three methods, the filter method, the phasing (phase-shift) method, and the Weaver method [Sabin and Schoenike, 1987]. Among them, the phasing method is selected. This is because SSB signal can be generated without using a band pass filter (BPF) with sharp attenuation characteristics which induces severe impairment on the information signal. The phasing method however requires a Hilbert transformer for an information signal with reasonable accuracy, which is somewhat difficult to actually fabricate. To avoid this, it is desirable to fabricate a Hilbert large scale integration (LSI) transformer using digital signal processing technology.

2.1.2 Linear power amplifier

The simplest means of increasing the received signal strength is to increase the transmitter power. The result may introduce spurious effects at the transmit terminal, and will cause further pollution of the radio spectrum. RF feedback can be effective for reducing both amplitude and phase distortion. However, there are some limitations in conventional RF feedback techniques where some amount of RF output signal expressed as a scalar quantity is merely returned to the input port.

Recently, a Cartesian feedback loop technique, in which the amount of feedback is treated in the Cartesian (orthogonal) coordinate just as with a vector quantity, has been successfully developed to fabricate a linear amplifier for narrow-band radio in the V/UHF bands [Nagata, 1989]. As the Hilbert pair inherently is orthogonal to each other [Hahn, 1996], the Cartesian feedback loop technique is easily introduced for fabrication of the linear amplifier for SSB systems.

2.1.3 Information signal bandwidth

The information bandwidth for conventional SSB ranges from 350 Hz to 2.7 kHz within a 3.0 kHz channel spacing. In contrast with SSB, the information bandwidth for RZ SSB can be extended up to 3.4 kHz.

2.2 Design of receiver for no degradation from mistuned carrier and immunity from fading

Since SSB is susceptible to carrier synchronization and to severe fading encountered in mobile environments, two breakthrough technologies are introduced into the RZ SSB demodulation process to cope with these issues.

2.2.1 New demodulation method

The first breakthrough is a new demodulation method that makes use of the zero crossings of the received signals. The conventional SSB receiver employs both an AGC circuit and a clarifier (or a high stability oscillator). As these circuits limit performance of conventional SSB, RZ SSB takes a completely different approach in order to achieve superior transmission quality without employing these performance limiting circuits in a receiver.

In 1977, Dr. Benjamin F. Logan of Bell Labs. showed using the entire function theory that the information can be recovered, without any loss, from the zero crossings of band-pass signals such as RZ SSB [Logan, 1977]. This means that it is unnecessary, as it is in the conventional SSB