**Application Research of H-field Antenna in Enhanced Loran**

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**Abstract**—Enhanced Loran-C is a Loran system that applies the latest receiver and H-field antennas technology to meet the requirement as backup and complement to GNSS. Loran receiver performance is dependent upon antenna performance, and technology has mainly advanced in H-field antennas. The situation of some research of the H-field antennas overseas is presented in the paper, and as a solution, a design of H-field antenna is presented, and procedure of the intelligent H-field antenna is described. Some experiments and demonstration are made to research the performance of the antenna, the data result of experiments is analyzed and conclusion is made that it’s advantages over the electric antenna by contrast.

**Keywords**—Loran-C; Enhanced Loran, H-field antenna; E-field antenna; SNR;

1. **Introduction**

The antenna is used to provide the signal for receiver by induction, which can be divided into the electric antenna and the magnetic antenna or called E-field and H-field antenna. The electric antenna induce electric field of electromagnetic wave and the magnetic antenna induce the magnetic field. Most of the current loran-c receiver uses the electric antenna to induce the signal, which has some defects. In the paper the H-field antenna technology is introduced to solve some problem in E-field antennas, specially in the background of Enhanced Loran-C, the H-field antennas will be the solution to the aviation application and can be the part of combination of GNSS and e-Loran.

2. **Legacy Loran and Enhanced Loran**

Loran, which means “Long Range Navigation”, is a terrestrial, regional radio navigation system that uses ground-based transmitters¹. Wide usage of Loran started in the 1950s with Loran-C, which was developed by the U.S Navy and U.S. Coast Guard. The system used short phase-coherent pulses with a carrier frequency centred on 100 kHz, and a bandwidth range from 90-110 kHz². Loran-C was also implemented in many areas including North America (USA and Canada), North-West European area (France, Netherlands, Norway, Denmark, Germany and Ireland) and the Far-East area (Russia, China, Korea and Japan).

Today, Loran-C development is in the state of being embarrassed with the introduction of GNSS like GPS GLONASS, GALILEO and COMPASS. Given that Loran-C could not match the performance of GPS, the U.S. Department of Transportation announced its intention to cease Loran-C support by the year 2000. In the late 1990’s it became clear that GNSS, primarily GPS, needed a backup due to its susceptibility to jamming.
(Volpe report, issued in September 2001). The U.S. Congress, which recognized Loran’s value as a GPS backup, provided the Loran-C Recapitalization Project (LRP) with approximately $120m\textsuperscript{3}. LRP work is performed under an interagency agreement between the Federal Aviation Administration (FAA) and the USCG. New enhanced Loran-C, known as eLoran, is a Loran system that incorporates the latest receiver, H-field antennas, and transmission system technology to enable Loran to serve as a backup and complement to global navigation satellite systems. This new technology provides substantially enhanced performance beyond what was possible with Loran-C, eLoran’s predecessor. For example, it is now possible to obtain absolute accuracies of 8-20 meters while the FAA requirement is integrity of 99.99999% using eLoran for harbor entrance and approach\textsuperscript{4}. Similarly, eLoran can function as a highly accurate frequency source and as an independent source of coordinated universal time (UTC). In 2010, the U.S. Coast Guard which is the governor of Loran-C in North America officially announced its ceasing Loran-C support in USA. But some differently, Chinese Loran-C still has potential in some applications specially in timing service, serving as a viable backup to GNSS for precision time and frequency transfer\textsuperscript{3}.

3. **H-field antnna applied in Eloran**

   Loran receiver performance is dependent upon antenna performance, and technology has mainly advanced in magnetic, or H-field, antennas. In the late 1990s, Ohio University performed some tests on receivers\textsuperscript{5}. These tests results improved that H-field antennas were immune to P-static interference (precipitation static) that can occur on an airplane during stormy weather\textsuperscript{6}. Under these conditions, ionized particles accumulate on an airplane’s skin, often generating potentials in the 15,000 – 45,000 volt range. The spontaneous discharge of these high potentials disrupts reception by Loran E-field antennas, thus H-field antennas have a distinct advantage in aviation. In addition, H-field antennas offer several advantages over E-field antennas in virtually all Loran applications (i.e. aviation, marine, terrestrial, and timing). These advantages provided an important impetus to proceed with advancing H-field technology. Several other important advantages of H-field antennas is followed.\textsuperscript{7} Firstly, H-field antennas have an 3 dB SNR advantage over E-field antennas, which can be significant, specially in marginal workaround. Secondly, H-field antennas decrease ECD values, so identification of the correct zero crossing is more rapid and reliable. Thirdly, H-field antennas require no grounding, which means H-field antennas are easier to install and will operate closer to the ground. Finally and important, H-field antennas are small, and can be combined with GPS antennas within a single enclosure or radome. They can be integrated with a GPS antenna into a single unit, described in figure 1, it is shown a mechanical drawing of a combined GPS and Loran H-field antenna, as integrated within a single radome for avionics testing. A GPS microstrip patch antenna is positioned in the center of a Loran H-field antenna. The dimensions of the H-field are 130mm x 130mm x 50mm. Tests on a combined GPS/Loran prototype antenna have demonstrated that neither GPS nor Loran reception is compromised by the presence of the other antenna.

![Fig.1. The integrated antenna of Loran-C H-field and GPS](image1)

![Fig.2. Comparison of ECDs (top) and TDs (bottom) from H-field antenna located indoors versus E-field antenna located on Locus’ roof.](image2)
Figure 2 presents some H-field antenna test done 2000\[6\], and illustrates envelope-to-cycle distortions (ECD) and time differences (TD) taken simultaneously from a prototype H-field antenna and an E-field antenna. The H-field antenna was located indoors (by a window) and the E-field was on the roof of Locus’ office building. Data acquired simultaneously using identical SatMate receivers. Note the Cs clock drift and 20 nS timing jumps. Cs clocks and transmitter control electronics are currently being upgraded by the USCG, but still show these jumps. The results show the data from the indoor H-field are noisier but quite similar to the outdoor E-field.

Figure 3\[6\] shows the Simultaneous SNR (top) and ECD (bottom) data from E-field and H-field antennas taken during dynamic field trials in 2001 using identical, all-in-view DSP receivers. Note higher signal levels and SNRs with H-field, as well as lower ECDs\[6\].

4. A Solution of H-field Antenna

4.1. The Unit of the H-field Antenna

The structure of the unit is described as figure 4 followed\[8\]. There are four components which detect the direction of the loran-c wave arriving by the precision of 7°. The signal induced in antenna is flew to the module of Filter and Amplify, which filter and amplify the signal in loran-c band. The output and control module is the interface between the antenna unit and the receiver, which achieve the impedance matching and signal output, synchronously convert the control signal input to the instruction which indicate the antenna to synthesize and switch.

4.2. Experiment about the Performance of the Antenna

1) The brief of the experiment

There are two places for the experiment, one place is around NanHui District, ShangHai and the other point is around Raoqing, GuangDong province. We use the same device of the intelligent magnetic antenna to receive the loran-c signal and record the result, which is compared with the result of the equipment of the electric antenna, and experiment time is chose the sunny day and rainy day respective. It is emphasized that two kind of antenna use the same receiver.

2) Date of the experiment
Fig. 5: The real-time results of electric antenna (upside) and H-field antenna (downside)

Fig 5 is presented the real-time result of the experiments at a point of NanHui district in April 2 and June 19 [9].

The upper map means the result of the receiver by electric antenna and the below map means the result of the magnetic antenna. It present the SNR of signal induced by magnetic is -15db (20:24:26, April 2) and -2db (06:19:46, June 19), and the SNR of electric antenna is -19db (20:24:08, April 2) and -7db (06:19:56, June 19).

<table>
<thead>
<tr>
<th>TABLE I. MEAN DATE FOR HOURS IN NANHUI ON APRIL 2</th>
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<tbody>
<tr>
<td>Time: 5:00-10:00, 11:00-16:00, 17:00-22:00</td>
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<tr>
<td>Mean</td>
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<tr>
<th>TABLE II. MEAN DATE FOR HOURS IN NANHUI ON JUNE 19</th>
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<tr>
<td>Time: 5:00-10:00, 11:00-16:00, 17:00-22:00</td>
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These two tables describe the mean data of the result of 12 hours experiment [9]. Table 1 records the data at some point in NanHui district on April 2 in 2007. The mean data of 12 hours was recorded, including the
SNR, ECD, TD and signal intensity. The other table 2 record data on June 19 in 2007. it is reminded that the weather of two day is sunny and rainy, which is tested the performance in different weather.

4.3. The Analyse of the Date of Experiments

The experiments made to show the continual performance of two kinds of antenna. it can be seen during 12-hours continuous experiment, the mean data of signa intensity and SNR is compared between the two antenna. the result show that the signa intensity of magnetic antenna exceed the signal of electric antenna by 5-8db, and the data of SNR is 3-5db.

The performance affected by the rainy weather is also tested in experiment. The result show that, the rainy weather would depress the performance of the electric antenna by 1-5db of signal intensity, while the magnetic antenna is uninfluenced by weather in the data of signal intensity.

5. Conclusion

The results from these and many other tests strongly suggested that an H-field antenna is one of the key technology for enhanced loran, which could be combined with a modern, DSP-based Loran receiver to provide a higher level than the legacy loran-C system performance. taking advantage of important H-field antenna characteristics, such as immunity to P-static interference and opportunities for significant size reduction, e-Loran can be used in the application of aviation and timing and so on, to be the backup of GNSS.

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7. References

[9] Lin Huizheng. The technology of the receiving and processing of the loran-c signal of low SNR[D]. Wuhan, Naval Engineering University, 2008.