40th ILA(International Loran Association) Annual Convention and Technical Symposium

Proceedings

Haeundae Centum Hotel, Busan, KOREA
November 17-19, 2011

Organized by

International Loran Association

Sponsored by

Maritime Industry Research Institute

BUSAN CONVENTION & VISITORS BUREAU

UrsaNav

KOREA ASSOCIATION OF AIDS TO NAVIGATION

NEWMARINE ENGINEERING

DK

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GMT

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Program of 40th ILA Annual Convention and Technical Symposium

Thursday, November 17, 2011

08:00 am **Registration/Information Desk Open**

09:00 am **Booth Setup / Open (closing time : 17:00 pm, November 18)**

09:20 am **Welcome Remarks**
Mr. Ha Pan-do(Director of Maritime Traffic Facility Department, Ministry of Land, Transport and Maritime Affairs)

09:30 am **Keynote Speech**
Dr. Kenneth C. Crawford(Vice-Administrator, Korea Meteorological Administration)
- The Marine Weather Services of Korea : Improvements Coming, More needed"

10:20 - 10:40 am **Photo time & Morning Break**

10:40 - 12:00 am **Session 1: World Status Updates**
Chairman : Mr. Charles Schue

10:40 am **Status of eLoran in the UK**
Mr. Chris Hargreaves, Mr. George Shaw, Dr. Paul Williams and Prof. David Last, GLAs

International Trend and Status for eLoran and Its Application in Korea
Prof. Dr. Gug Seung-Gi, KMU

Norway - observer's report
Ms. Kirsten Ullbaek Selvig , Norwegian Ministry of Fisheries and Coastal Affairs

Present Status of Chayka in the Russian Federation
Mr. Vadim ZHOLNEROV, The Russian Institute of Radionavigation and Time

Confirmation of the Accuracy Performance of North-West Pacific Loran-C Chain
Mr. Kazuyuki TANAKA, JCG

12:00 - 13:30 pm **Luncheon** - *18F Executive Lounge*

13:30 - 15:00 pm **Session 2: eLoran Technology I**
Chairman : Prof. Dr. Gug Seung-Gi

13:30 pm **Alternative Positioning, Navigation, and Timing (PNT) for Korea and the World**
Mr. Charles Schue, Mr. Chris Stout, Dr. Arthur Helwig, Dr. Gerard Offermans, UrsaNav

14:00 pm **The Operation Status and Expectation of Loran-C in the Republic of Korea**
Mr. Kim Hyun, Mr. Gu Ja-heon MLTM

14:30 am **Deriving Stratum-1 Time-of-day and Frequency using a Pulsed Low-Frequency System: Design and Test Results of an eLoran Timing Receiver**
Dr. Arthur Helwig, UrsaNav

15:00 - 15:30 pm **Afternoon Break**

15:30 - 17:30 pm **Session 3: eLoran Technology II**
Chairman : Mr. Tamotsu Ikeda

15:30 pm **Alternative Configurations for Co-located eLORAN and DGPS Antennas**
Mr. John Pinks, Nautel

16:00 am **Low Frequency Solutions for Alternative Positioning, Navigation, Timing and Data (PNT&D)**
Mr. Chris Stout, Dr. Arthur Helwig, Dr. Gerard Offermans and Mr. Charles Schue, UrsaNav

16:30 pm **GPS Jamming Accidents and its impact in the Korean Peninsula**
Mr. Bae, Yong Chan, MLTM

17:00 am **Differential eLoran Trials in France**
Dr. Gerard Offermans, Dr. Arthur Helwig, UrsaNav
Jean-Francois Grall, and Thierry Denaes, DCNS

17:30 pm - 18:20 pm **ILA Board Meeting**

18:20 - 20:00 pm **Banquet** - *4F Zeus Hall*
Prof. Dr. Kwak Kyu-seok, President, KINPR
Mr. Ryu Young-ha, President, KAAN
Dr. Sally Basker, President, ILA

Friday, November 18, 2011

08:00 am **Registration/Information Desk Open**

09:00 - 12:00 am **Session 4: Tutorial**
Chairman : Prof. Dr. Gug Seung-Gi

09:00 am **Investigating eLoran Integrity**
Mr. Chris Hargreaves & Dr. Paul Williams, GLAs

eLoran Receivers Tutorial
Dr. Arthur Helwig, UrsaNav

Next Generation LF Transmitter Technology for eLORAN Systems Tutorial
Mr. Tim Hardy, Nautel

12:00 - 13:30 pm **Luncheon** - *18F Executive Lounge*

13:30 pm **eLoran Signal Specification Tutorial**
Dr. Gerard Offermans, UrsaNav

14:30 - 15:00 pm **Afternoon Break**

15:00 - 16:00 pm **ILA Annual Convention**

18:00 - 20:00 pm **ILA Convention Dinner** - *4F Zeus Hall*

Saturday, November 19, 2011

Technical Tour - *Korea Maritime University (KMU)*

09:00 am Departure from the *Lobby, Centum Hotel*

10:00 am Simulation Center of KMU

10:45 am Maritime Museum

11:15 am MV HANBADA (Training Ship)

12:00 - 13:30 pm **Luncheon** - Korean BBQ

14:00 pm International & Fish Market (Nampo-dong)

17:00 pm Arrival at Centum Hotel

Contents

SESSION 1

World Status Updates

Status of eLoran in the UK

Chris Hargreaves, George Shaw, Dr. Paul Williams and Prof. David Last
General Lighthouse Authorities of United Kingdom and Ireland (GLAs)

ILA 40 – Busan, Korea

17th November 2011

e-Navigation needs resilient PNT

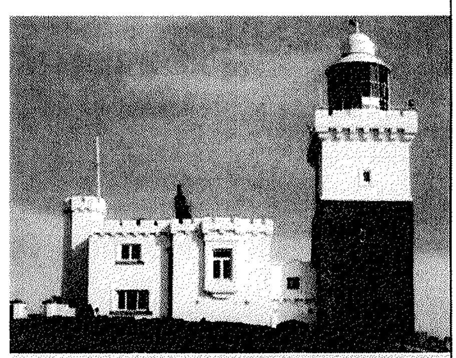
- e-Navigation (2018-2020), IMO says:
  - "e-Navigation systems should be resilient .... robust, reliable and dependable. Requirements for redundancy, particularly in relation to position fixing systems should be considered"
- Resilient Position, Navigation and Timing (PNT)
- Meet Requirements
  - Accuracy
  - Availability
  - Continuity
  - Integrity

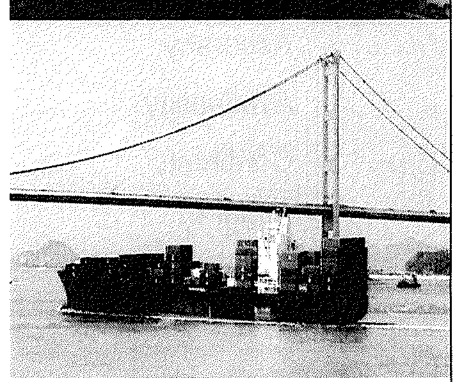
GLA eLoran Business Case

- Business Case to continue eLoran Trials
- Cost / Benefit Analysis
- 4 Options
  1. Keep using Lights, Lighthouses + Physical AtoN
  2. New Technology Radar and RACONS
  3. Hardened GNSS
  4. eLoran
- Rigorous business case provided to the UK Government

Results

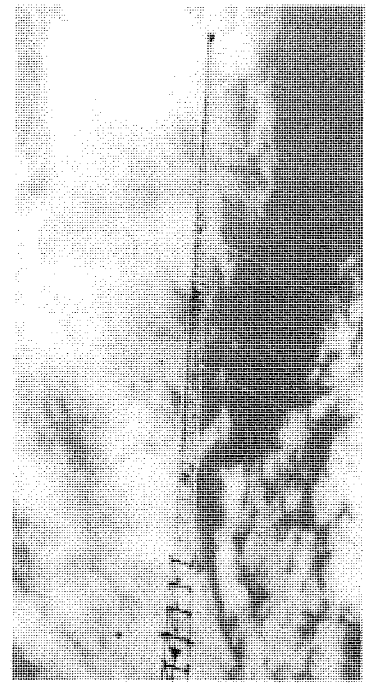
- eLoran shows best economic return
  - Balance cost by reducing Lights
  - Lowest cost to ship-owner
  - Pays for itself in 10 years
- Only eLoran provides Resilient PNT for e-Navigation
- Only eLoran can provide cost savings
- eLoran Trials Continue…





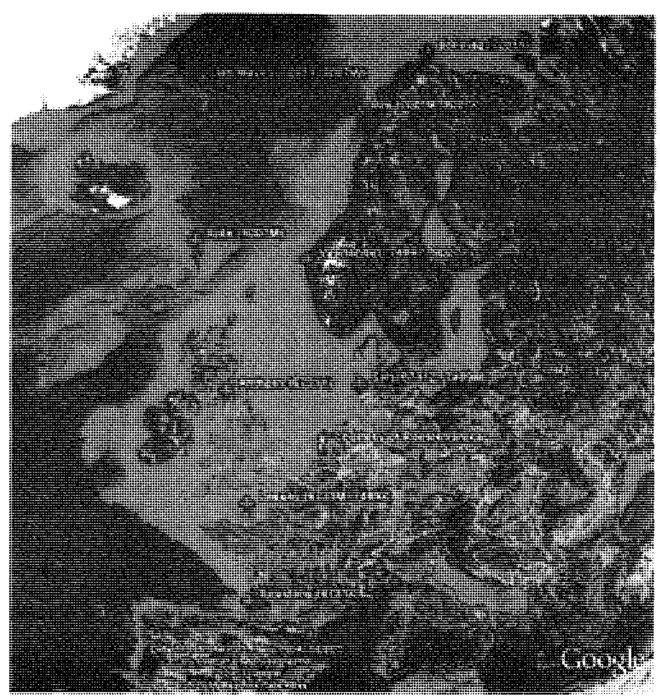
Maritime eLoran – Core Service

- Improve Loran-C to eLoran Spec
  - No Loran-C 'Chains'
  - Upgrade Transmitters
  - Loran Data Channel (Eurofix)
- All-in-View receivers
- Precise Timing and Sync
  - Independent of GPS
  - 2-way Satellite Time Transfer (TWSTT)
  - Control and Monitoring by each nation



European eLoran – Transmitters

- 9 Loran Transmitters
  - Some Upgrades
  - Not yet full eLoran
- Central monitoring and control
- International Cooperation
- UK and France: trials of DLoran and study of TWSTT
- Russian Chayka interoperability by 2013

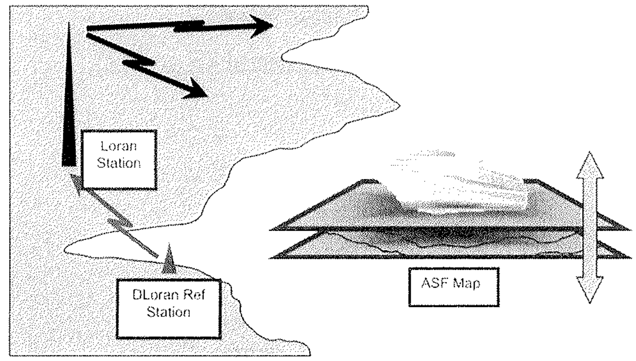


GLA work - Maritime eLoran

- eLoran for Port Approach ~10m (95%) accuracy performance

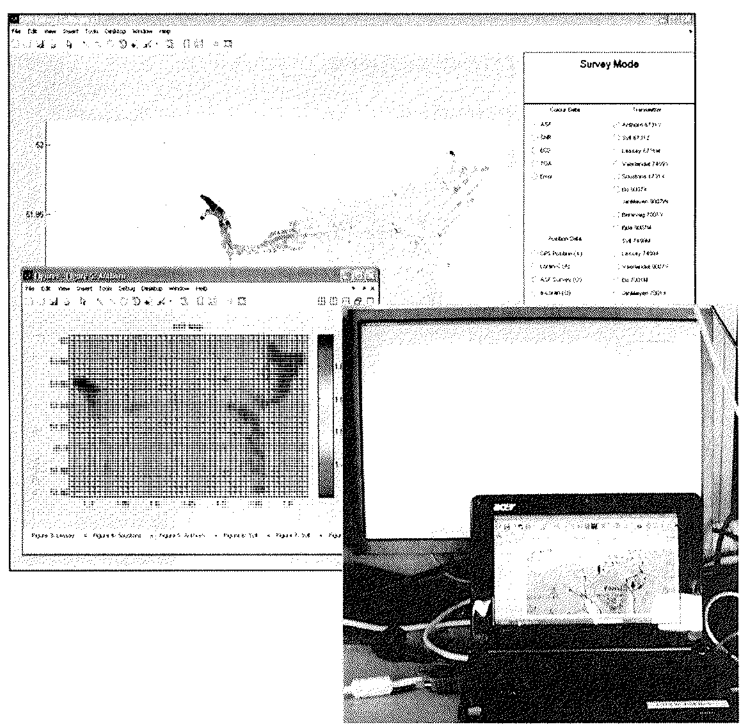
Three vital components:

- Additional Secondary Factors
  - Need to survey ASFs
  - Produce ASF Maps
- Differential Loran (DLoran)
  - Reference stations for harbour approach
- eLoran Data Channel (Eurofix)
  - Used to send DLoran corrections
  - Integrity Alerts



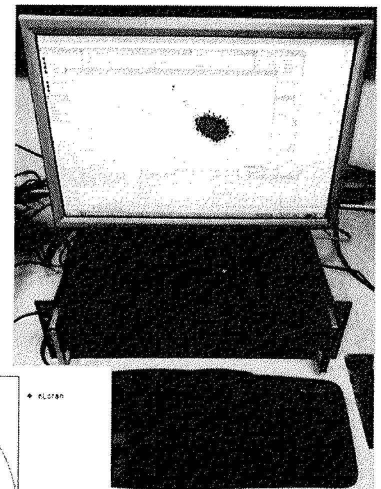
ASF Survey

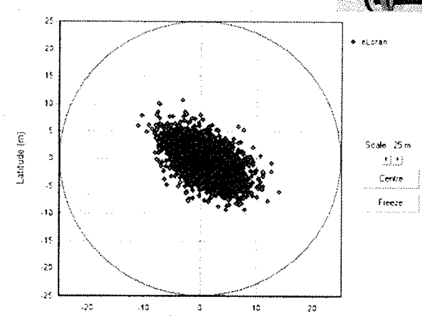
- Our own Software
- 2 Modes:
- Survey Mode
  - Stores ASF
  - Makes ASF Map
- Validation Mode
  - Plots eLoran on Chart
  - Checks Survey Quality
- Survey of Harwich (pictured →)



DLoran – Harwich Reference Station

- Harwich Station running since 2008
- Measures Differantial-Loran Corrections
- Sends Corrections to Anthorn via Internet – VPN
- Broadcast via Eurofix
- < 8m (95%) Accuracy





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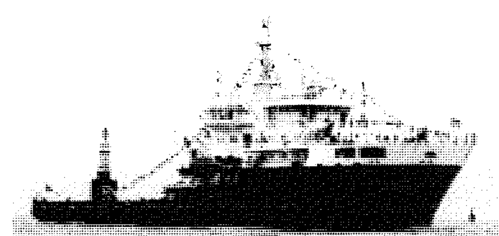
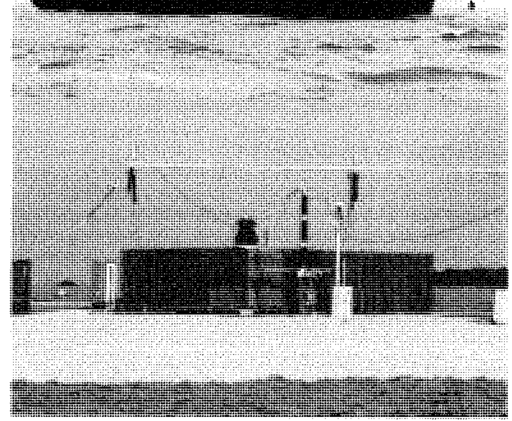
eLoran Highlights so far

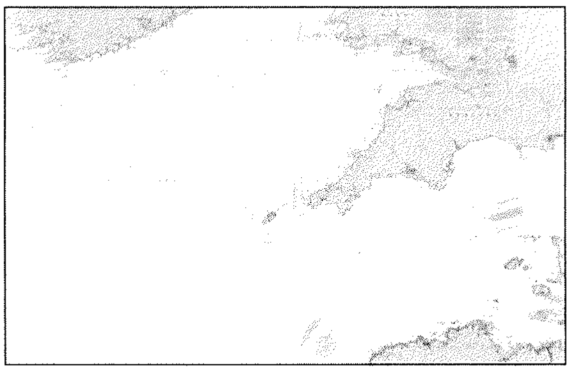
- Prototype eLoran operation continues in UK
- Anthorn transmitter giving 100% monthly signal availability
- Differential-Loran in Harwich since 2008
- eLoran receivers on all 6 GLA vessels
- ASF Survey and Processing Software
- eLoran Trials:
  - Orkneys archipelago
  - Harwich Approach Survey
  - Flamborough Head – GPS Jamming I
  - Newcastle – GPS Jamming II
- R&D continues into Future...



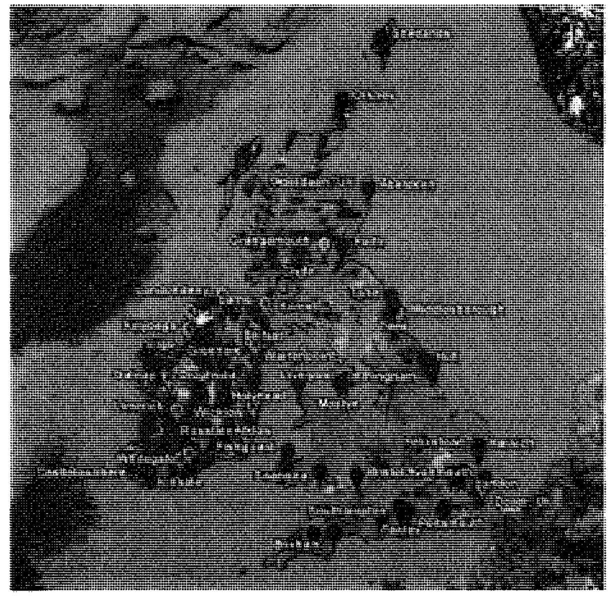


Future Work - eLoran Road Map

- Initial Operational Capability IOC (2013)
  - -7 major ports East of the UK
  - -10m (95%) accuracy eLoran
- Full Operational Capability FOC (2018)
  - -All major ports in UK and Ireland
  - -English Channel
  - -Traffic Separation Schemes (TSS)

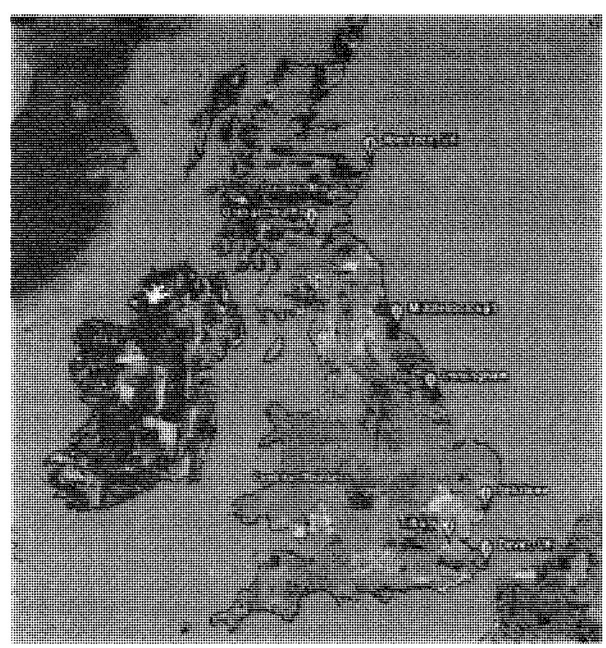


Not to be used for Navigation.



Initial Operational Capability (2013)

- 7 ports on the East Coast of the UK
- Differential-Loran at each port
  - - 1 upgrade at Harwich
  - - 6 new installs
- Corrections broadcast on Anthorn LDC
- Differential-Loran monitoring and control in Harwich
- Perform ASF surveys – ASF Maps
- ~$600k cost for all 7ports
- 10m (95%) Resilient PNT from eLoran
- Tender for work to start in 2012



Beyond IOC and Towards FOC

- Upgrade 24 year old Anthorn Transmitter
  - New Time and Frequency Equipment
  - Two Way Satellite Time Transfer (TWSTT)
  - Full eLoran Spec
- Long term ASF measurements from static monitors
  - Answer Differential-Loran Questions:
- Differential-Loran Research Questions
  - How many reference stations do we need?
  - Where do we put them?
  - What range does a Reference Station have?
  - Can we use Network or Wide-Area Differential-Loran?
- eLoran Integrity Monitoring System

Conclusions

- Resilient PNT is needed for e-Navigation by 2020
- Business Case shows eLoran most cost-effective
- GLA work towards IOC (2013)
  1. ASF Measurement, Processing and Mapping
  2. Differential-Loran for Port Approach
  3. Upgrade from Loran-C to eLoran
- Develop towards FOC (2018)

Thank you!

The General Lighthouse Authorities
Trinity House
The Quay
Harwich
Essex
CO12 3JW
United Kingdom
http://www.gla-rrnav.org

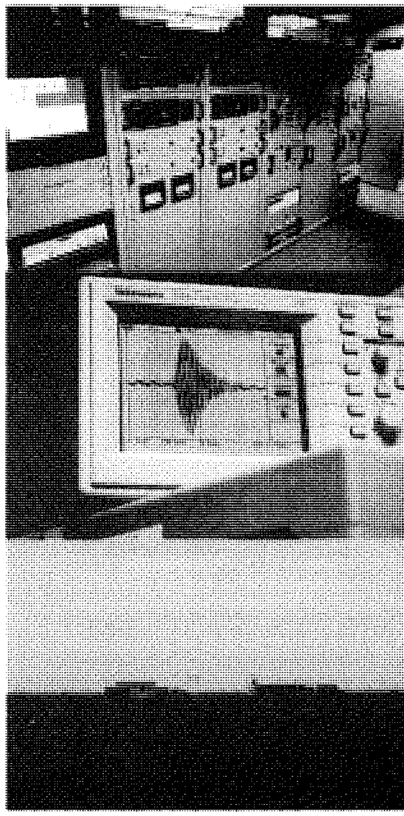
Tel: +44-1255-245000

Chris Hargreaves
chris.hargreaves@gla-rrnav.org

George Shaw
george.shaw@gla-rrnav.org

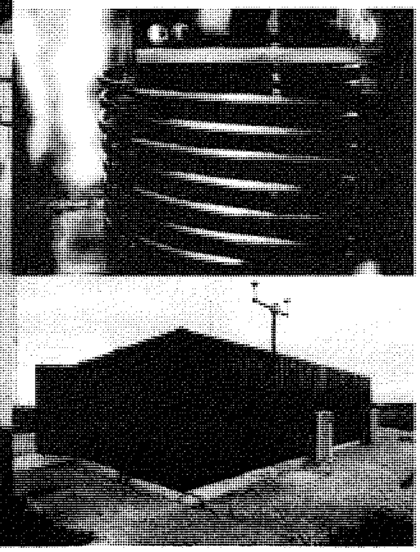
Dr. Paul Williams
paul.williams@gla-rrnav.org

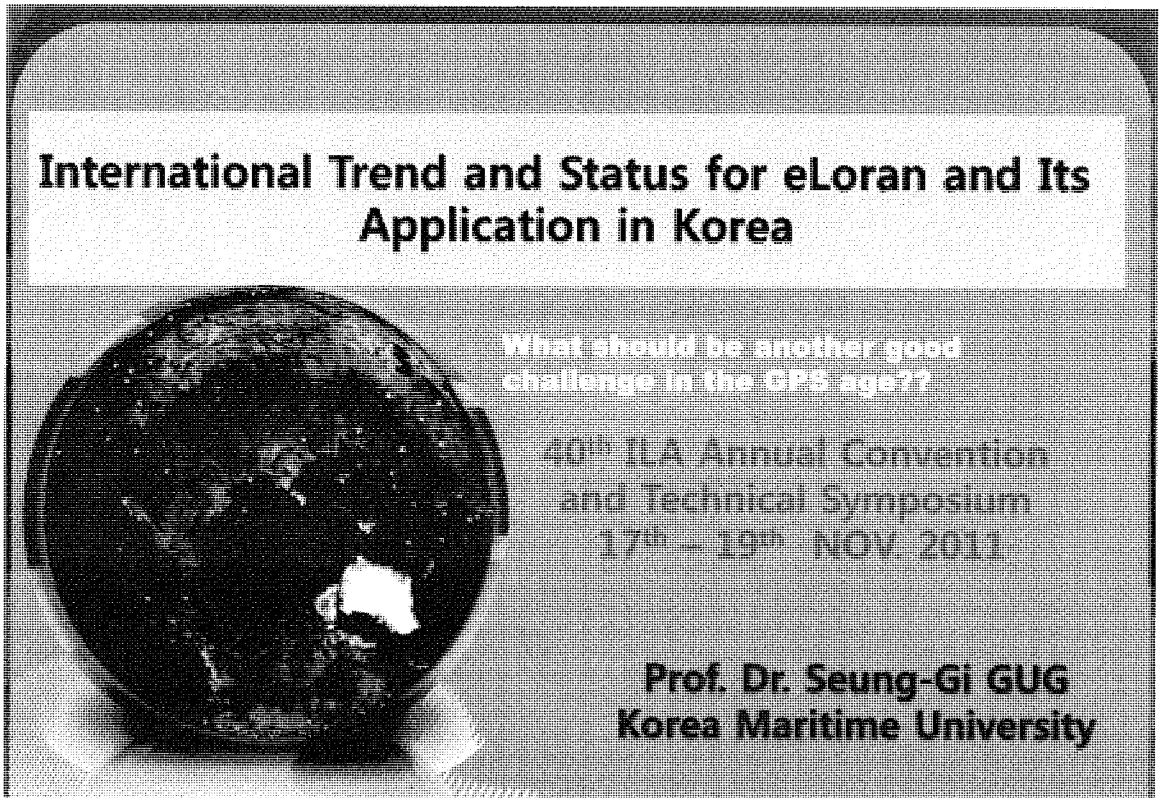
Prof. David Last
jdl@navaid.demon.co.uk



Loran Station Anthorn

54° 54' 40.35"N
003° 17' 14.21"W





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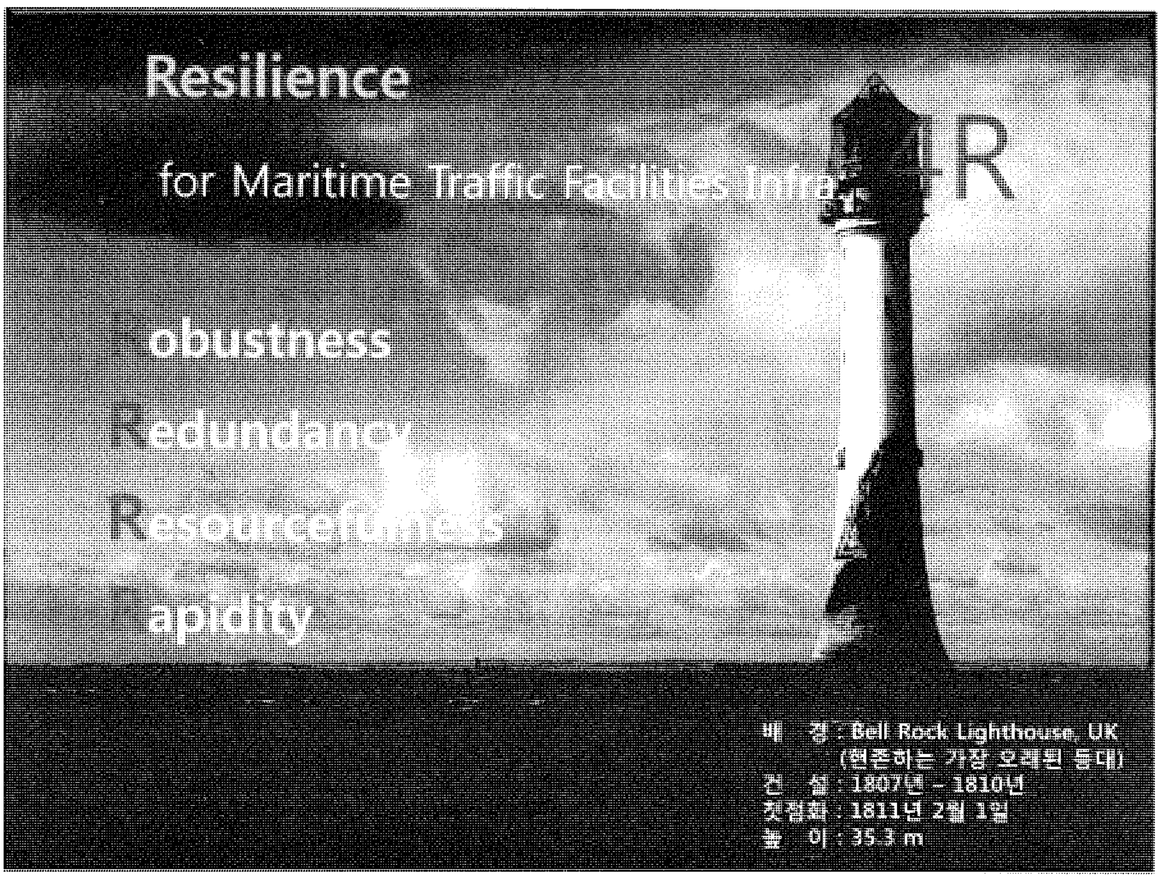
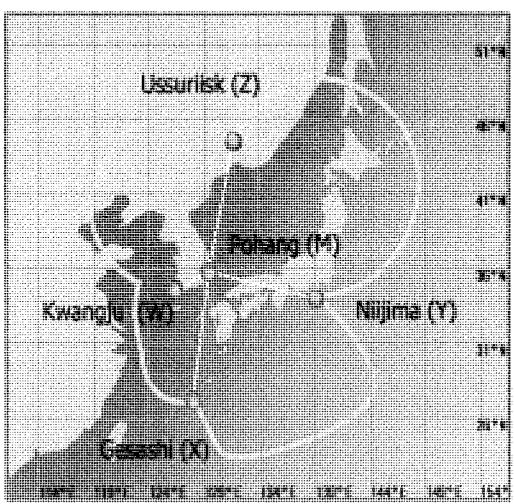


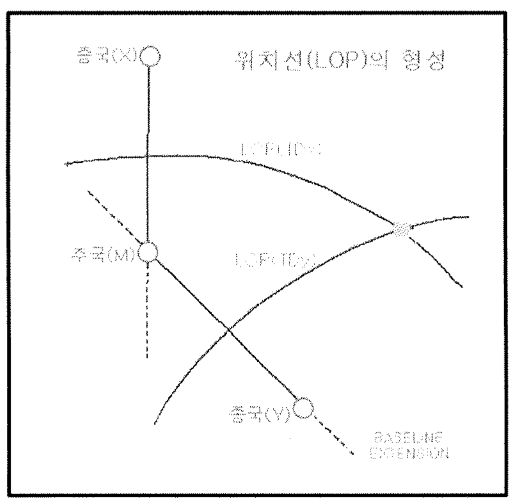
Ch. 1 International Trend of eLoran

1. Overview of Loran-C System

- US & UK Navy started to use the system in 1950s
- LOng RAnge Navigation by using the terrestrial radio wave
- Frequency : 90-110kHz radio , Coverage : 1,000 Km
- Current Loran-C System : Large Position Accuracy Error



< Effective Coverage of Loran-C Korea Chain 9930 >

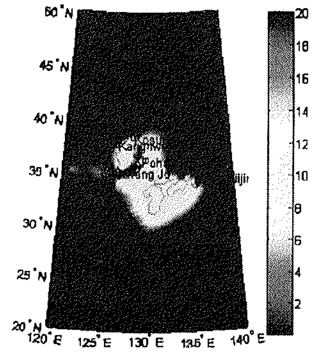


<Principle of Loran-C Position Fix >

2. Goals of eLoran System

Goals of eLoran System

- Better Accuracy
- Improved Availability
- System Integrity
- Continuity



Accuracy within 20m (95%)

Loran-C

- National Policy
- Operational Doctrine
- Transmit / Monitor / Control
- User Equipment / Equipage

eLoran

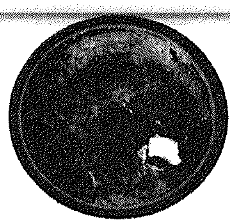
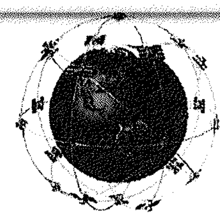
2. eLoran System – Technical Characteristics

eLoran System

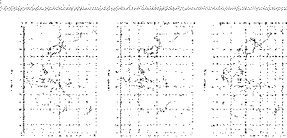
- Loran Data Channel
- Differential Loran
- UTC Synchronized Timing
- Signal Correction Information
- All in view Support
- TOT / SAM Control

Independent Position(P), Navigation(N), Timing(T) Infrastructure
(Non-reliance of GNSS, Overcoming the Vulnerability of GNSS)

3. Comparison between eLoran & GNSS System

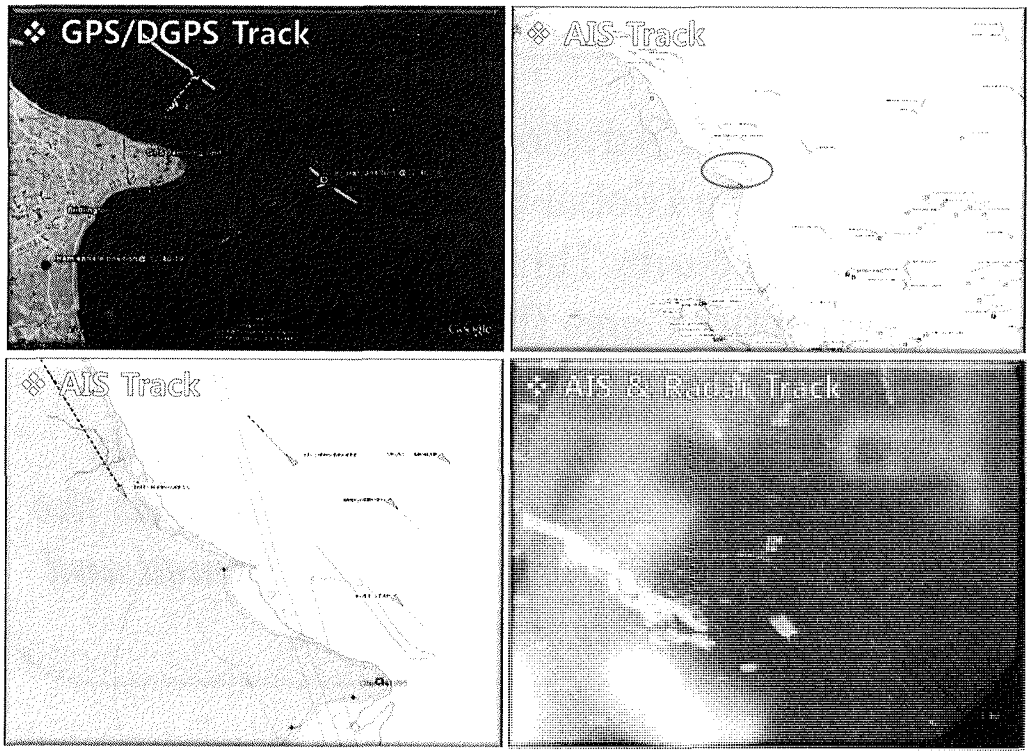
eLoran system	V.S	GNSS system
		
Terrestrial Radio Navigation		Satellite Radio Navigation
$	Cost	$$$$$$$$$$$$
Very Strong (Low Fr, High Power)	Jamming	Very Weak (High Fr, Low Power)
Independence (Independent Infra)	Employment Environment	Reliance (on other Countries)

4. Status GNSS Infra of the World

GNSS		Augmentation (Satellite Based)		Regional Sat. Navigation System
• USA GPS	⇔	• USA WAAS		
• Russia GLONASS		• Japan MSAS	⇔	• Japan JRANS(QZSS)
• EU Galileo	⇔	• EU EGNOS		
• China (Beidou) Compass		• Inida GAGAN	⇔	• India IRNSS

ROK – No Independent Navigation System

5. GNSS Jamming Trial – April 2008, UK



6. International Trend for eLoran

- UK & W. Europe : **UK eLoran Implementation**
  First eLoran **Transmitter (Anthorn)**

- UK, France, Norway, Russia : **Development Work and Further Focus for European Agreement on eLoran Service**

- Chnia & Russia : **Modernization for** Loran/Chayka

- USA : **Modernization for** Loran & eLoran Service **Trials**
  Termination of Loran–C signal from Oct 2010 (Including Canada)
  National Space–Based PNT Advisory Board : White Paper on GPS Jamming (Nov. 2010)

6. International Trend for eLoran

National PNT Advisory Board comments on Jamming the Global Positioning System – A national Security Threat : Recent Events and Potential Cures (November 4, 2010)

We strongly recommend that previously announced decision (to deploy eLoran as the Primary APNT) should be reconfirmed and quickly implemented.

6. International Trend for eLoran

- **Saudi Arabia : Project for Mitigation from Lorna-C to eLoran in 2011**
- **UK : Project for using eLoran Signal in the primary Infrastructures of Airports and Habors when Emergency**
- **Japan : Modernization for Loran by early 2000s**
  2009 – Termination of Minami Tori shima Stn.
  2013 – Announcement for Termination from all Japanese Stns.

7. eLoran in the IALA & IMO

IMO NAV 56(2010. 7) : considering eLoran in e-Navigation Gap Analysis

IALA 2010 Conference : Recognized the GNSS vulnerability and Need to the Resilient PNT System (Terrestrial Based Radio Navigation) ; Setting up PNT WG in e-Nav Committee of IALA

IALA Submitted the paper on Resilient PNT to IMO NAV 57(June 2011)

. GNSS Vulnerability (including the Jamming events in Korea)
. Do minimum
. Maximise the current infrastructure
. Hardening of GNSS
. eLoran implementation

7. eLoran in the IALA & IMO

Korea gave a proposal " the Needs for eLoran establishment and its own name change" (IALA council MTG in Rio de Janeiro, June 2011)

. eLoran Implementation and Preparation for eLoran Standard Specification in IALA

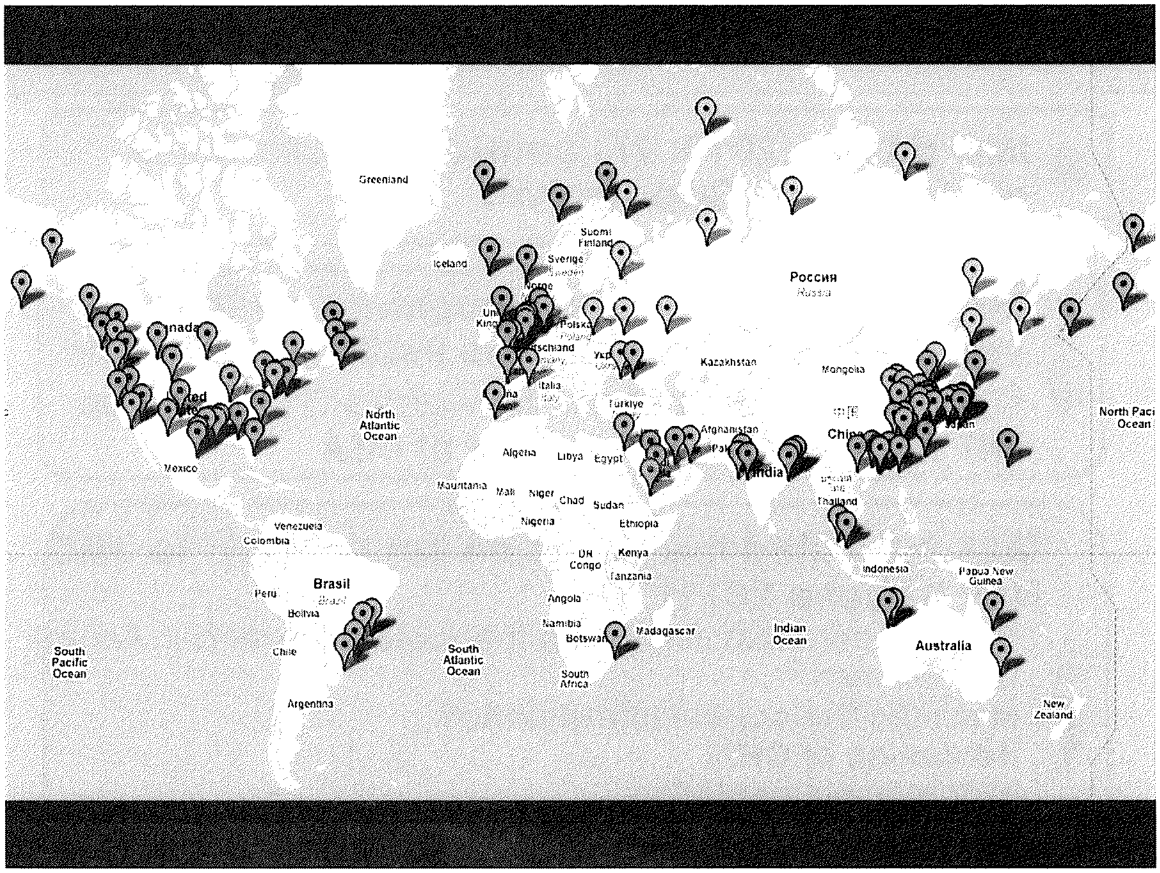
. Change of name "eLoran"

1) TERANAV (TErrestrial RAdio NAVigation)

2) ALPS(Advanced Local Position System)

3) GPNT(Ground Positioning, Navigation, Timing)

* Adopted by the Council (to the e-Nav & ANM Committee)

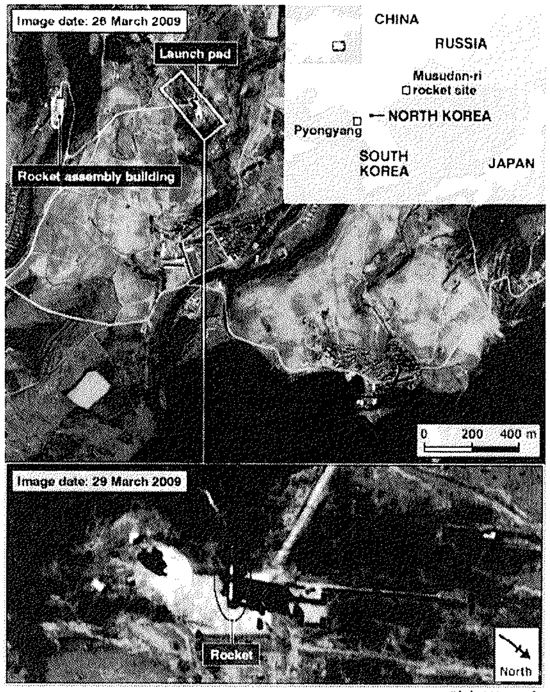


Ch. 2 eLoran Application in Korea

Rocket Launch in North Korea

17

ROCKET LAUNCH SITE IN MUSUDAN-RI, NORTH KOREA



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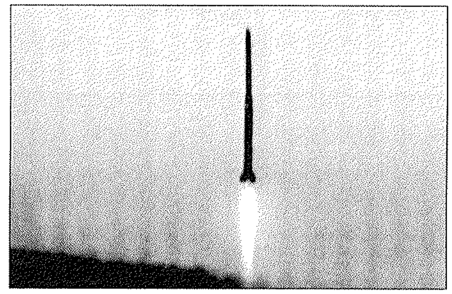

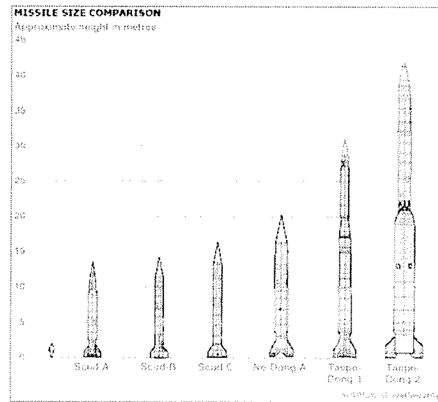

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GPS Jamming Events

GNSS Vulnerability

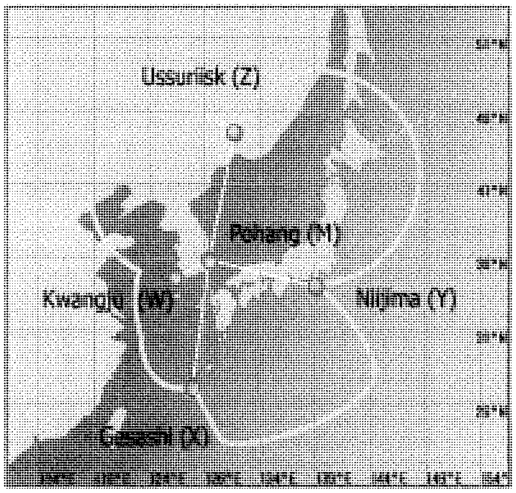
GPS Jamming

In 2010 GPS was lost along 300 km of coastline, in an Asian country, for significant periods over several days, as a result of a jamming signal from an adjacent country.

A similar, smaller event occurred in March 2011, affecting user equipment and telecommunications.

Source : IALA e-Nav 9 outputs

Loran-C coverage



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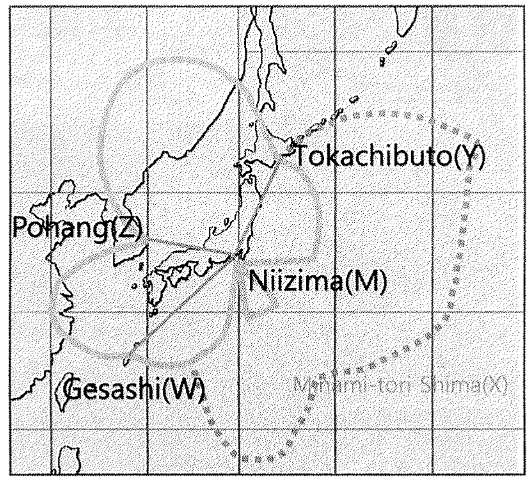
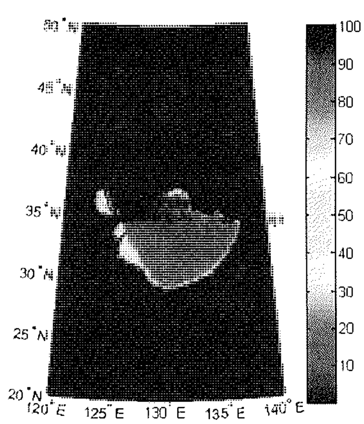
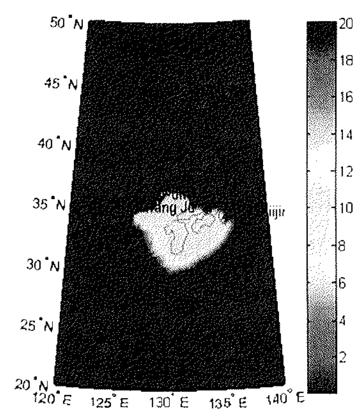


< Loran-C NWP chain 8930>

Current Korea Chain Coverage In case of upgrade to eLoran





Accuracy within 100m (95%)

Accuracy within 20m (95%)

Predicted Accuracy Performance in Korea Chain without Ussuriisk

- By using Pseudo range measurements at Harwich in UK
- Repeatable Accuracy

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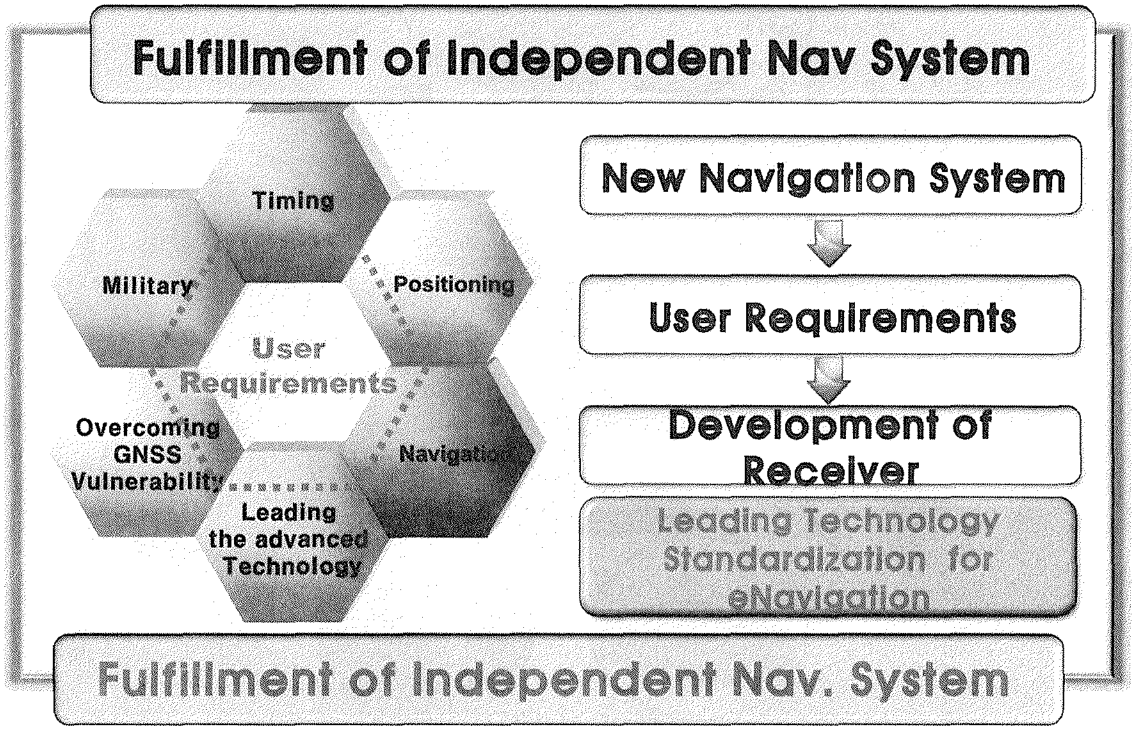
1. Necessity for Implementation of Independent Navigation System in Korea



2. Expected Effectiveness

Making up for GNSS Vulnerability

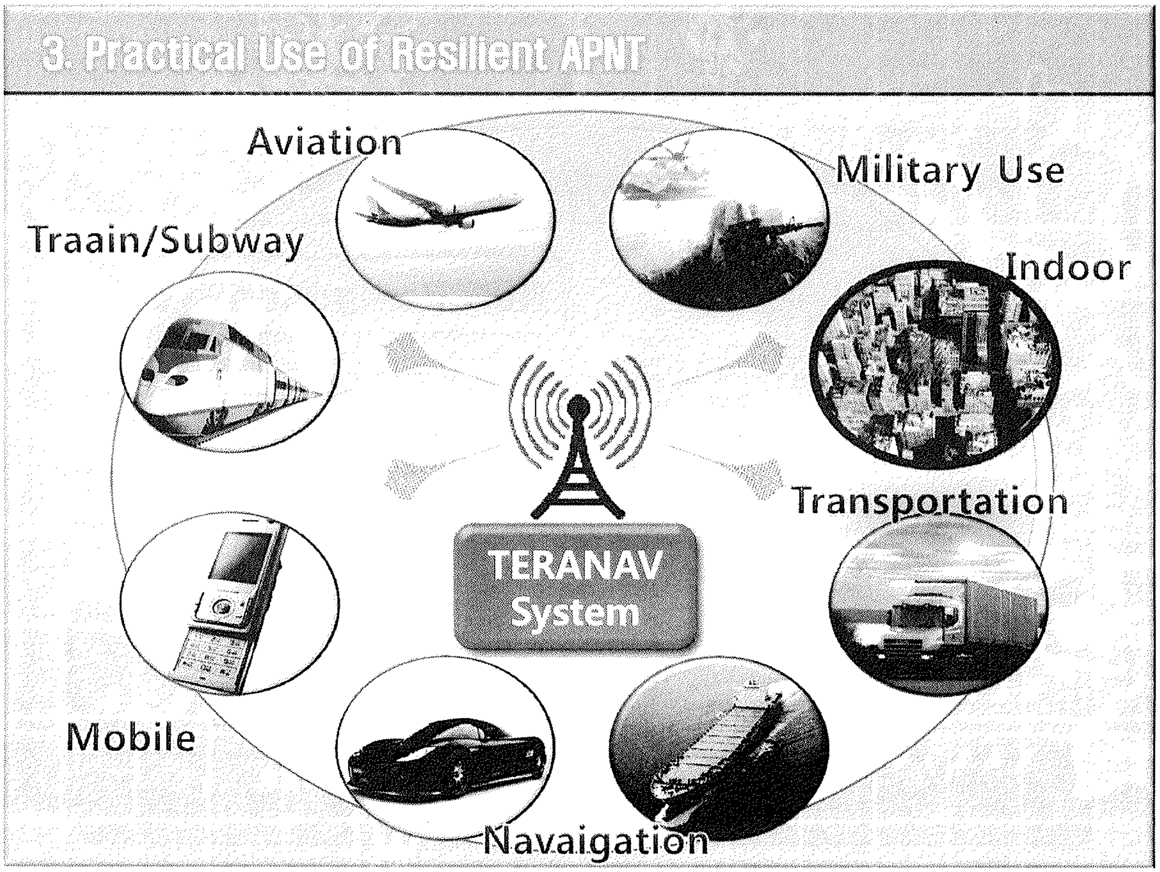
- Solving for GPS Jamming (APNT)
- Indoor Navigation
- Redundancy of PNT

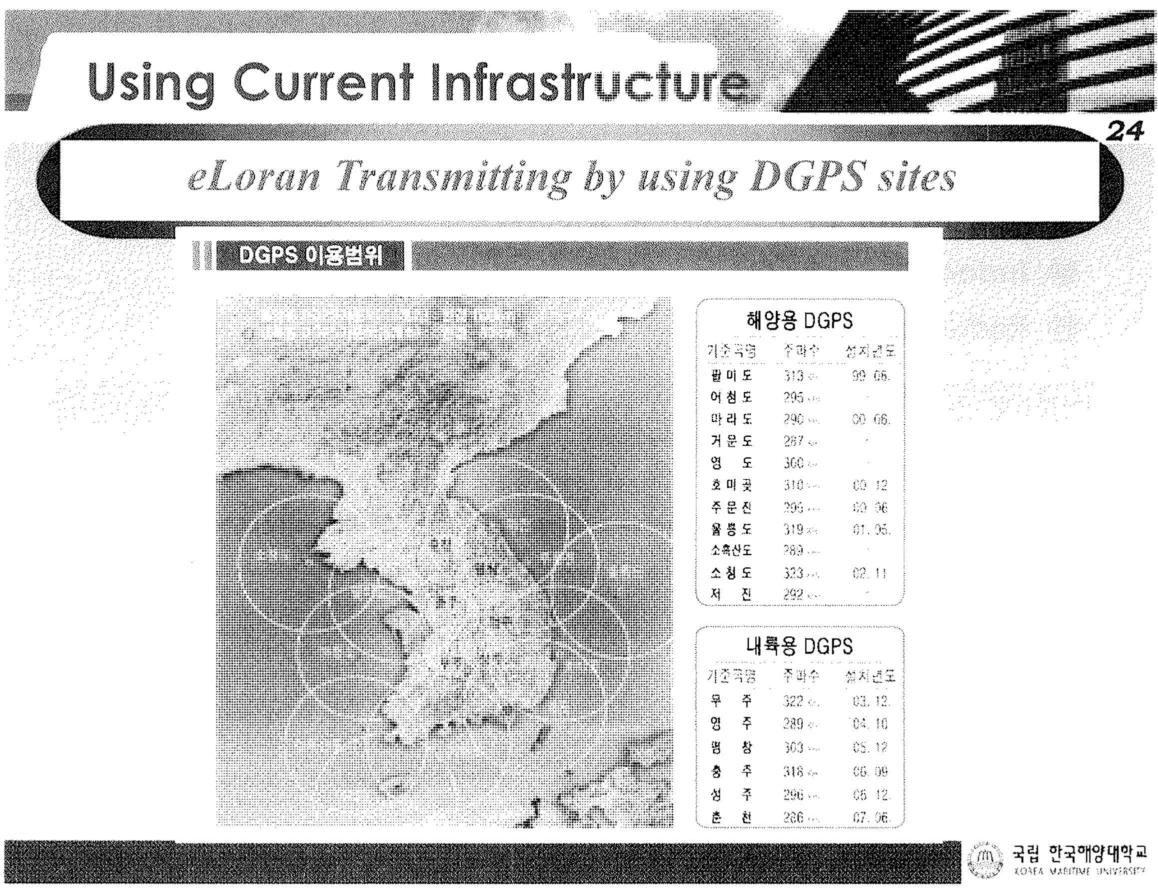
Acquisition of New Technology

- PNT Technology
- Non-Dependency to Other Country for PNT Technology

Leading New Technology of the World

- Using Military Code
- Standardization of Terrestrial Navigation Technology
- Standardization of eNavigation Technology
- Export the technology and receivers

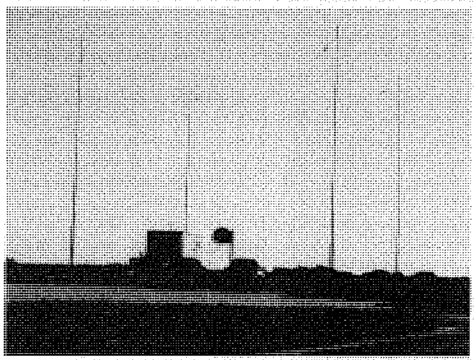

3. Practical Use of Resilient APNT
Aviation
Military Use
Traain/Subway
Indoor
TERANAV System
Transportation
Mobile
Navaigation


Using Current Infrastructure
24
eLoran Transmitting by using DGPS sites
DGPS 이용범위
해양용 DGPS
기준국명 주파수 설치년도
팔미도 313 99.06.
어청도 295 -
마라도 290 00.06.
거문도 287 -
영 도 300 -
호미곶 310 00.12
주문진 295 00.06
울릉도 319 01.06.
소흑산도 289 -
소청도 323 02.11
저 진 292 -
내륙용 DGPS
기준국명 주파수 설치년도
무 주 322 03.12.
영 주 289 04.10
평 창 303 05.12
충 주 318 06.09
성 주 296 06.12.
춘 천 286 07.06.
국립 한국해양대학교
KOREA MARITIME UNIVERSITY

Using Current Infrastructure

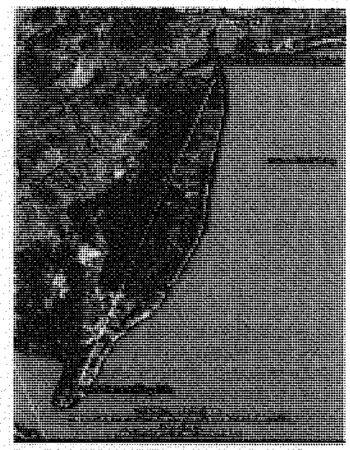
25

eLoran Transmitting by using DGPS sites



System Testing – Looking East

- 115 Miles
- 185 KM
- 99.75 NM



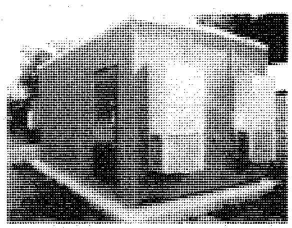
System Testing – New Jersey, USA

Using Current Infrastructure

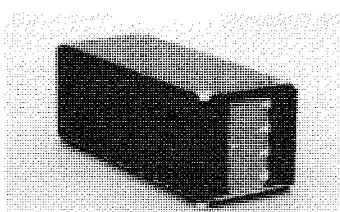
26

eLoran Transmitting by using DGPS sites

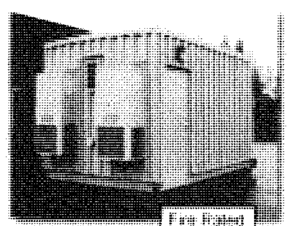
Possible "eLoran in a Box" Boxes



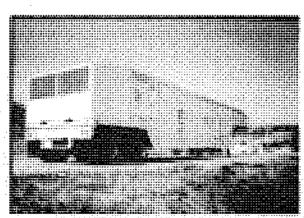
Thermo Bond



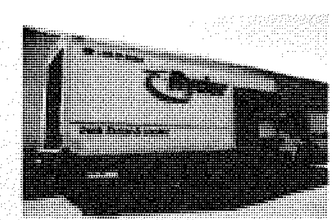
Alkan



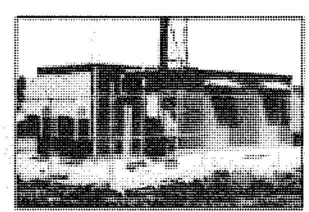
Shelter One



Gichner



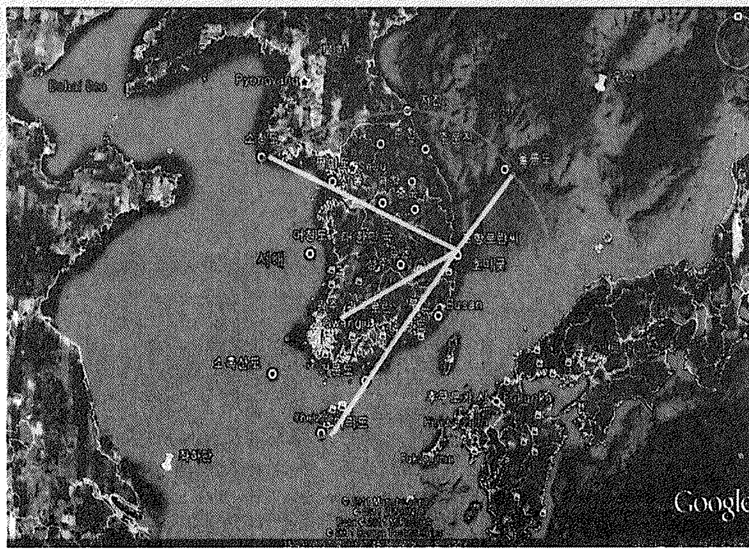
Ryder Rental Truck



Miller Building Systems

Using Current Infrastructure

eLoran Transmitting by using DGPS sites



Independent
Korea New Chain

Pohang (Current)
Gwangju(Current)
Socheong Is (DGPS)
Ulleung Is (DGPS)
Jeju Is

2 Current Stations
+ 3 New Stations

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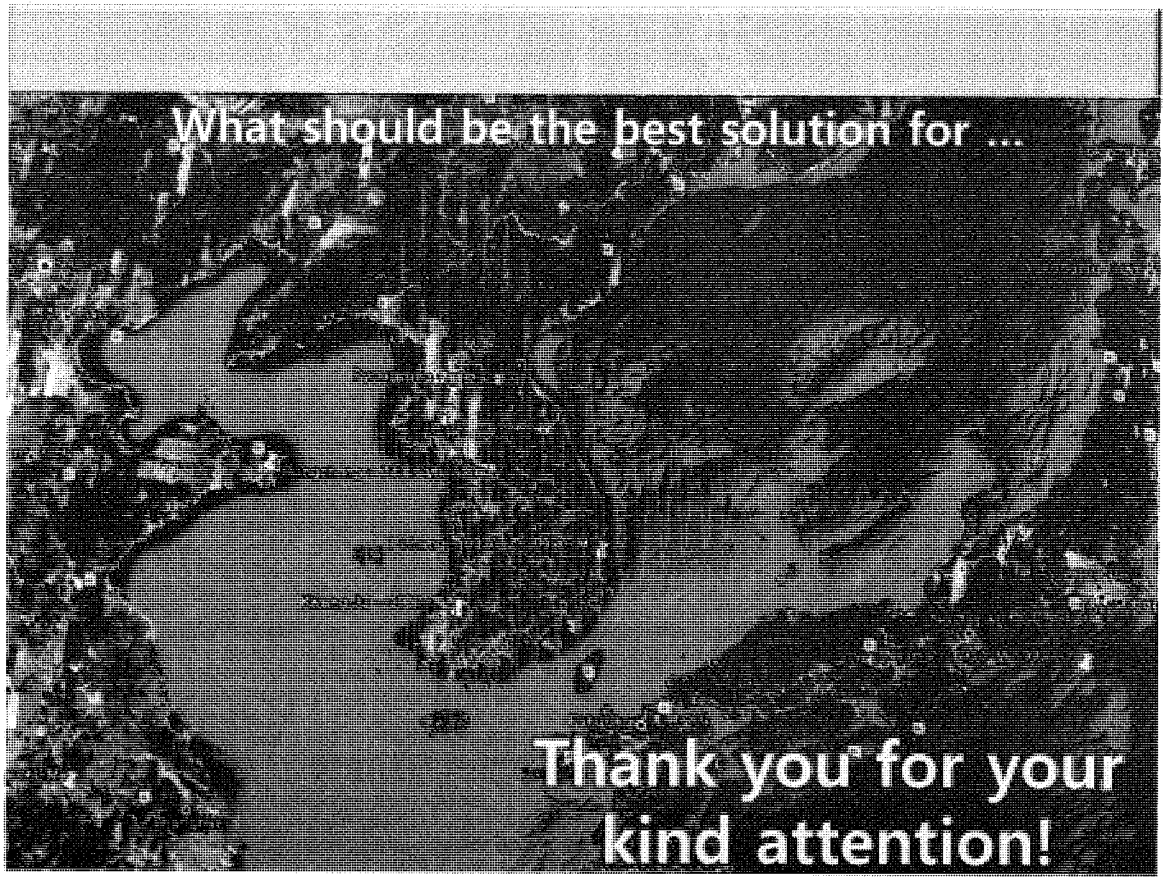
Resilient PNT

P Positioning
N Navigation
T Timing

CPNI: The equipment a[illegible] inherently reliable, secured ag[illegible] threats and capable of withstanding so[illegible] of damage.


What should be the best solution for ...
Thank you for your kind attention!

FISKERI- OG KYSTDEPARTEMENTET

Norwegian Ministry of Fisheries and Coastal Affairs

Norway - observer's report

Ms. Kirsten Ullbaek Selvig
Director General
and
Mr. Odd Tore Jacobsen, Station Manager

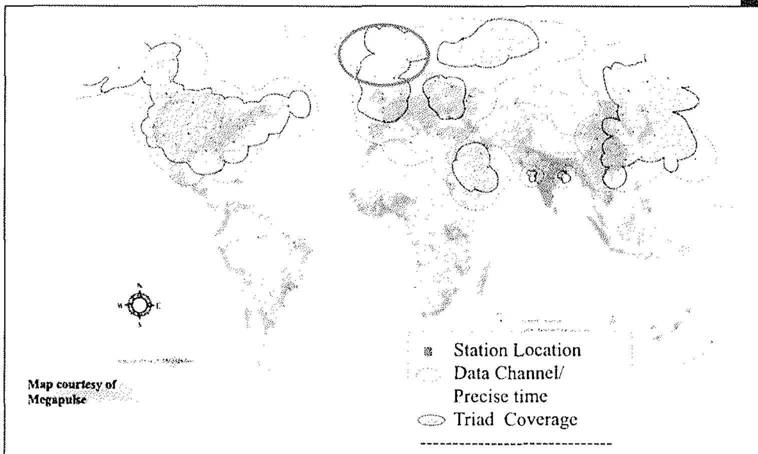
1 - Operation of Norwegian Loran-C stations

The four Norwegian Loran-C stations:

- Vaerlandet Western Norway
- Boe Northern Norway
- Berlevaag Northern Norway
- Jan Mayen Norwegian island 550 km Northeast of Iceland

Norwegian Loran-C stations - Coverage

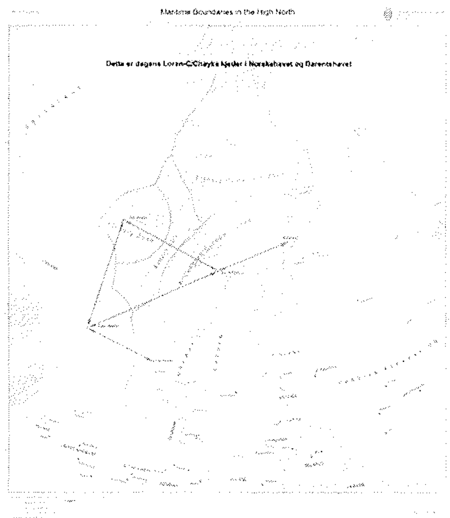
North Sea, Norwegian Sea, Parts of Northern North Atlantic, Western part of the Barents Sea ⇨ the gate from Europe to The Arctic and the western gateway to the Northern Sea Route



Norwegian Loran - C stations cont.

- The four Norwegian stations are transmitting in two chains:
- 7001 Boe chain; Boe (master), Jan Mayen and Berlevaag.
- 9007 Edje chain; Ejde (master), Jan Mayen, Boe and Vaerlandet.

Loran-C and Chayka chains in Norwegian sea and Barents sea



7001 Bo Chain (Loran-C)

9007 Ejde Chain (Loran-C)

Transmitting stations equipment

- All the Norwegian Loran-C stations are equiped with Megapulse Accufix 6500 transmitters and timing/control equipment.
- Loran-C stations Berlevaag and Vaerlandet was new stations in 1994, and they have a 12HCG transmitter with an output on 250kW into a 220 meter antenna.
- Loran-C station Jan Mayen has a 16HCG transmitter with an output on 250kW into a 190 meter (625 feet) antenna.
- Loran-C station Boe has a 24HCG transmitter with an output on 400kW into a 190 meter (625 feet) antenna.

FISKERI- OG KYSTDEPARTEMENTET

The Riches of the Sea
- Norway's Future

Norwegian Loran-C stations Status

- Loran-C stations Berlevaag, Boe and Jan Mayen is working well with no larger problems.
- Loran-C station Vaerlandet was switched off last December due to emergency frequency disturbances on 2182kHz.
- There is work in progress to solve this problem.
- The operational site availability for the norwegian stations (except Vaerlandet) this year is from 99,23% to 100%. The reason for unservicable time is often loss of communication lines, due to no communication redundancy.

Norwegian Ministry of Fisheries and Coastal Affairs

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The Riches of the Sea
- Norway's Future

Norwegian Loran-C stations Baseline control

- Control Center Brest have control with 7001 Boe chain and 9007 Ejde chain.
- The control is TOT/TOE

Norwegian Ministry of Fisheries and Coastal Affairs

2 - Norway's cooperation on Loran

Practical cooperation on the Loran C system in Northwest Europe

- Control center in France
- Norway: 4 stations
- France: 2 stations, and covers operational costs for the Ejde station in Faroe Islands
- UK: 1 station, and covers operational costs for the Sylt station in Germany

Discussions and cooperation on the development of Loran/eLoran

- Discussions with France, UK, Denmark and others
- Discussions with China, Japan, South-Korea and Russia (as observer to FERNS)
- Cooperation with Russia

3 - Russian-Norwegian cooperation on radionavigation and on Loran C/Chayka in the Barents Sea

- **Intergovernmental Agreement of March 1995 on the establishing of a joint radionavigation service in the Barents Sea using Loran-C and Chyka Stations – the Joint Boe Chain**
- **Meetings in Moscow, 2008 and Oslo, 2009**
- **Meeting in Moscow, June 2010:**
  - Agreed on establishing a new Working Agreement on the implementation of the Intergovernmental Agreement of 1995
  - Agreed on establishing a Norwegian-Russian Join Boe Chain Coordinating Council (JBC CC)

Russian-Norwegian cooperation cont.

New Working Agreement signed in Sept. 2010 between The Internavigation Research and Technical Centre and The Norwegian Defence Logistics Orgnaisation – Communication & Information Systems

1st Session of the Norwegian-Russian Joint Boe Chain Coordinating Council (JBC CC) in Oslo, Norway in September 2010:

Agreed on ToR for JBC CC

Agreed on ToR for the JBC CC Technical Working Group (TWG)

Agreed on Action Plan for TWG to provide the JBC Operation

Russian- Norwegian cooperation cont.

The first meeting in the Technical Working Group (TWG) in Norway in June 2011

The Norwegian-Russian Joint Boe Chain Coordinating Council (JBC CC) Council, meeting 2011 – under planning

3 - eLoran/eChayka ?

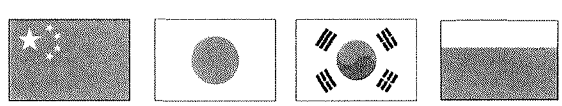
- Satellite-based navigations systems are and will continue to be the main systems for electronic positioning, navigation and timing (PNT).
- The broad use of satellite-based navigation systems rises concern on modern society's dependency on these systems and the question on need for backup system(s) - with signals dissimilar from GNSS.
- The Arctic is an area where this question has a certain importance.

Norwegian Ministry of Fisheries and Coastal Affairs

FISKERI- OG KYSTDEPARTEMENTET
The Riches of the Sea
– Norway's Future

eLoran/eChayka ? cont.

- The outcome of discussions and development on the international arena – regional as well as global - on the need for backup systems to GNSS and the possible role for eLoran in this context, will be among the factors the Norwegian Government will take into consideration on the future operation and development of Loran in Norway
- Has there been changes in the FERNS members' position on eLoran/eChayka ?



Norwegian Ministry of Fisheries and Coastal Affairs

РИРВ

Present Status of Chayka in the Russian Federation

Vadim ZHOLNEROV
The Russian Institute of Radionavigation and Time

1

RIRT

THE RUSSIAN INSTITUTE OF RADIONAVIGATION AND TIME

РИРВ

Chayka composition

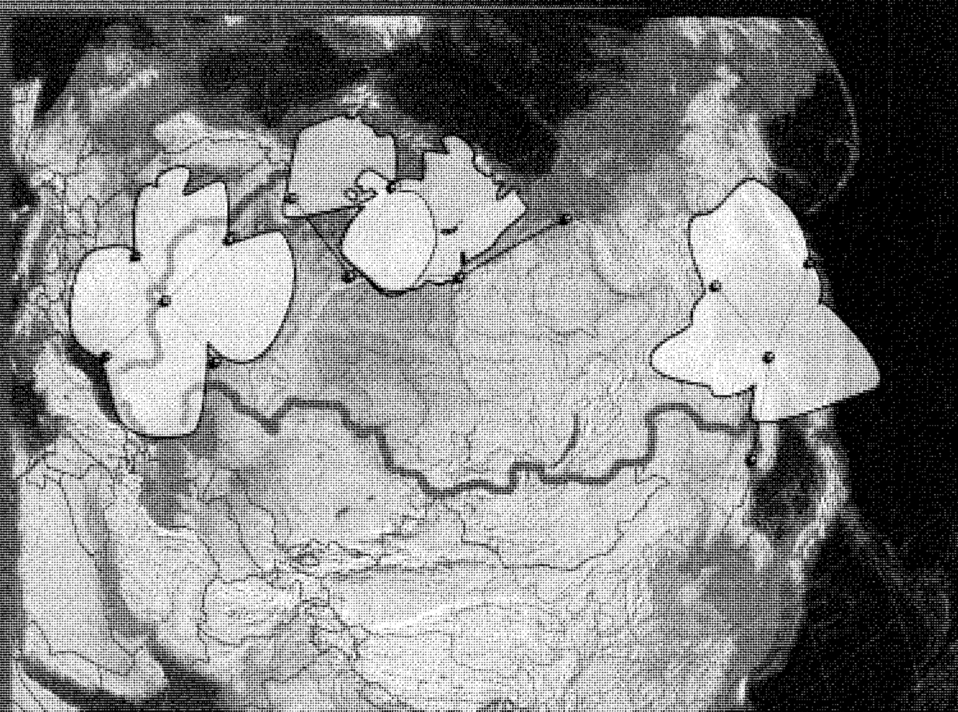
As per November 1st 2011 Chayka includes three independent chains:

- ***Northern*** chain comprising three stations located in Inta, Tumanny and Norilsk;
- ***Eastern*** chain comprising four stations located in Alexandrovsk-Sakhalinsky, Petropavlovsk-Kamchatsky, Ussurijsk and Okhotsk;
- ***European*** chain comprising five stations located in the vicinity of Karachev (Russia), Petrozavodsk (Russia), Syzran (Russia), Slonim (Republic of Belarus), Simferopol (Ukraine).

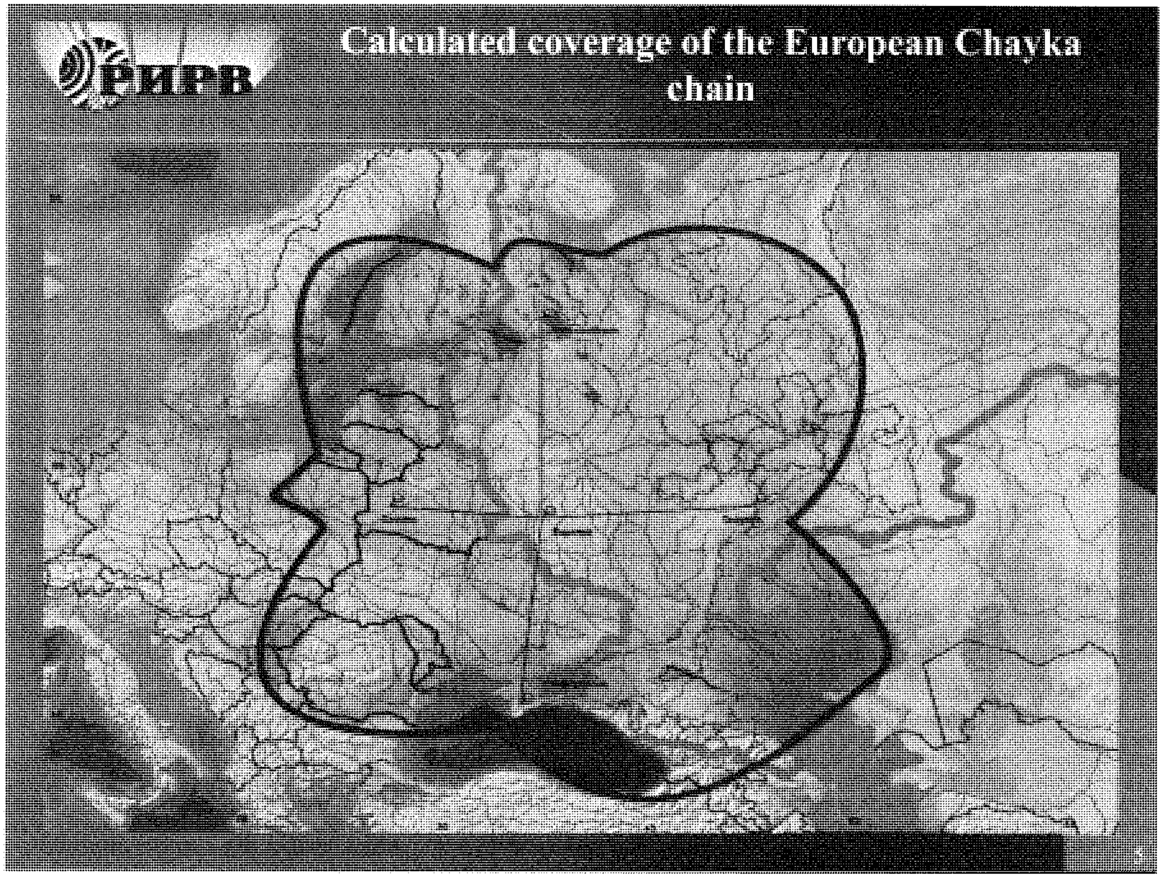
3

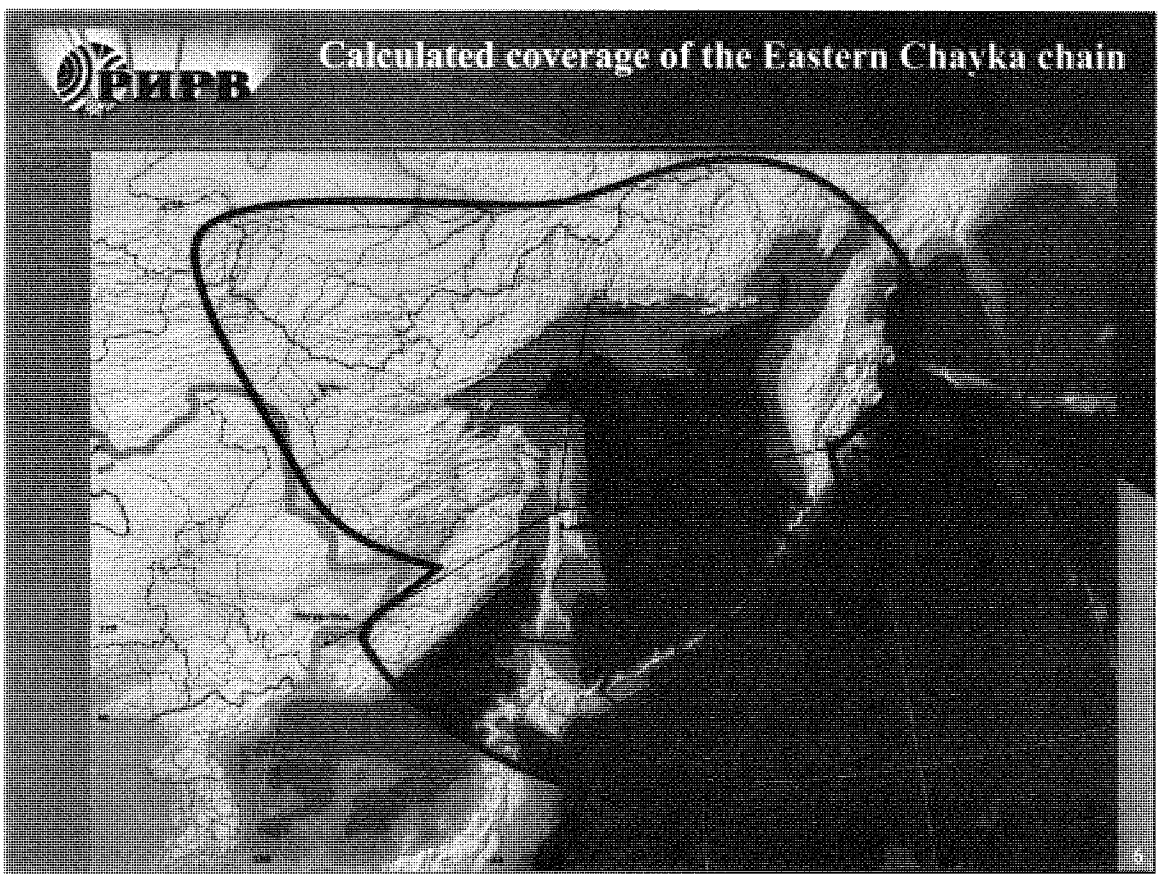
РИРВ

Chayka



4


РИРВ
Calculated coverage of the European Chayka chain


РИРВ
Calculated coverage of the Eastern Chayka chain

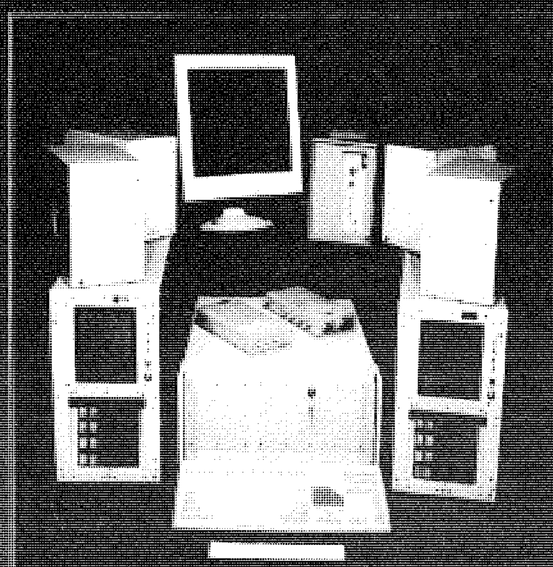
By November 1st, 2011 the following works will have been done at all the Chayka transmitter stations:

- **synchronization equipment upgrade will be complete;**
- **tube control units for high-power thyratrones replaced by solid-state devices;**
- **equipment installed to reference the station time scale to the GLONASS(GPS) time scale.**

7

Control & synchronization equipment complex

It is designed for radiation synchronization and Chayka transmitter control, for broadcasting operating information in the Chayka signal format.



8

РИРВ

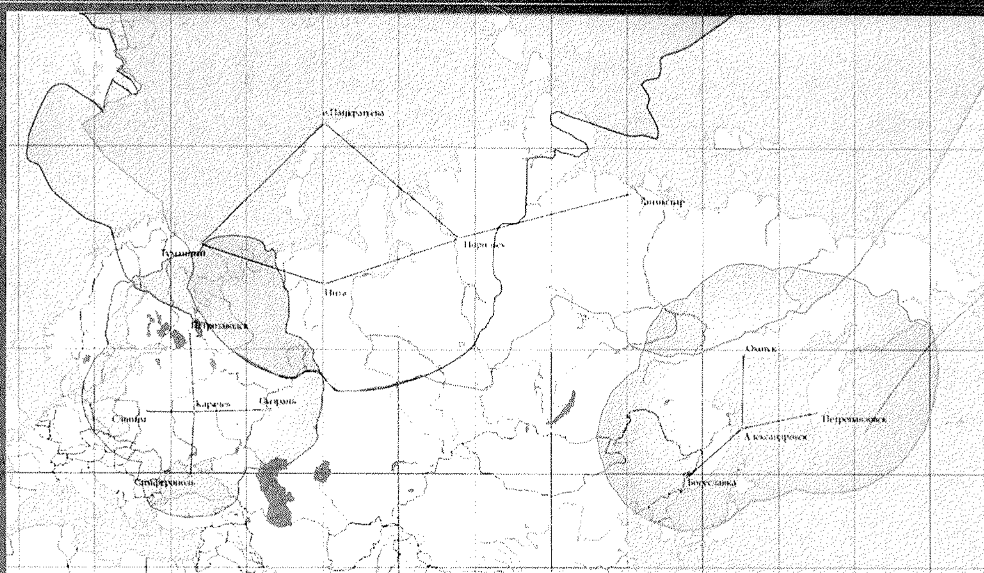
Upgrade of the Chayka stations carried out by the Russian Institute of Radionavigation and Time (St-Petersburg) permits to improve equipment robustness and to achieve the following goals:

- to increase synchronization accuracy of the station time scale to the GLONASS(GPS) time scale to 20 to 30 ns (RMS error);
- to support operating data broadcasting in the signal format at the rate of not more than 80 Bit/s;
- to provide broadcasting of UTC signals.

9

РИРВ

Calculated coverages of differential correction broadcasting to GLONAQSS users via Chayka stations



Расчетные рабочие зоны информационной системы на основе действующих стационарных передающих станций ИФРНС "Чайка". Передача информации осуществляется за счет модуляции временного положения шести последних радиоимпульсов навигационного пакета

10

РИРВ

Tests of the fully upgraded Chayka stations are to complete in 2011.

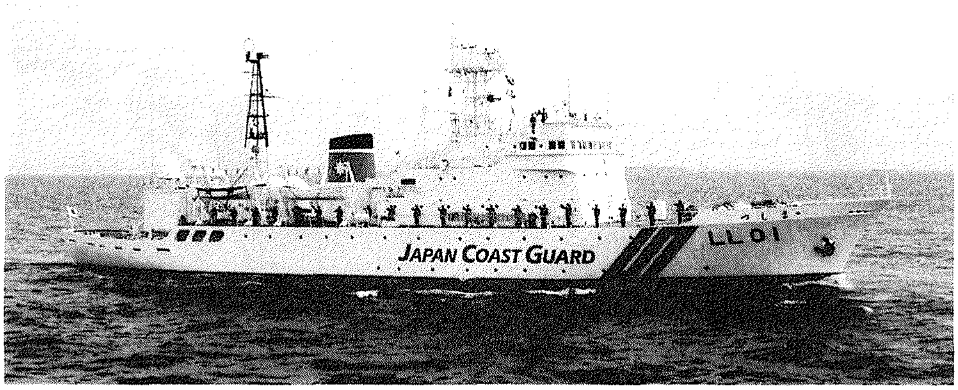
11

РИРВ

Thank you for your attention

12

Confirmation of the Accuracy Performance of North-West Pacific Loran-C Chain

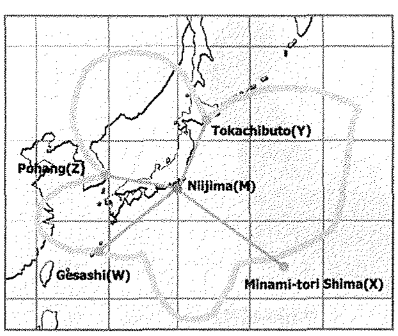


JCG

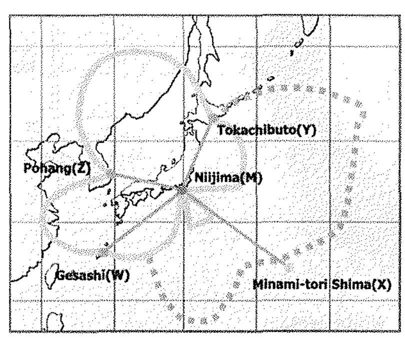
Kazuyuki TANAKA

JAPAN COAST GUARD

- Situation
  Termination of operating LORAN-C broadcasting station in Minamitorishima Island (1st Dec., 2009)
  →Service Area of North-West Pacific LORAN-C Chain (8930) became small
  →We are confirming the actual service area through the measurement by Aids to Navigation Evaluation Vessel "Tsushima" until the end of FY 2011 (March 2012).
- The 5th Session of FERNS Technical Working Group
  We reported the mid-term result.
- The 6th Session of FERNS Technical Working Group (This Session)
  We will report the result until now.

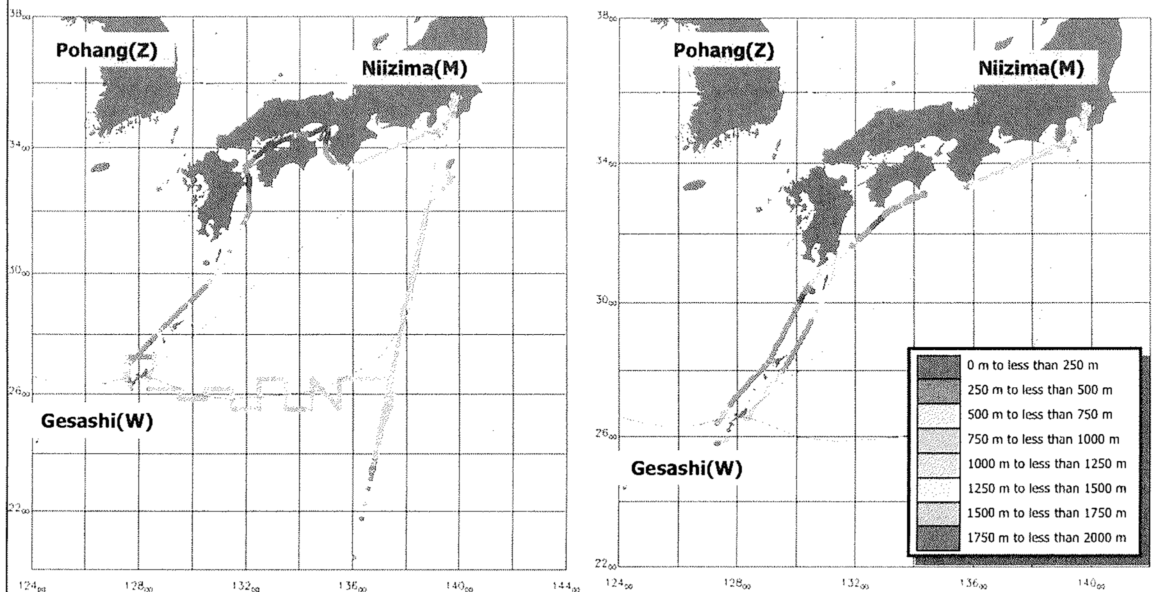


Service Area before Termination



Service Area after termination (predicted)

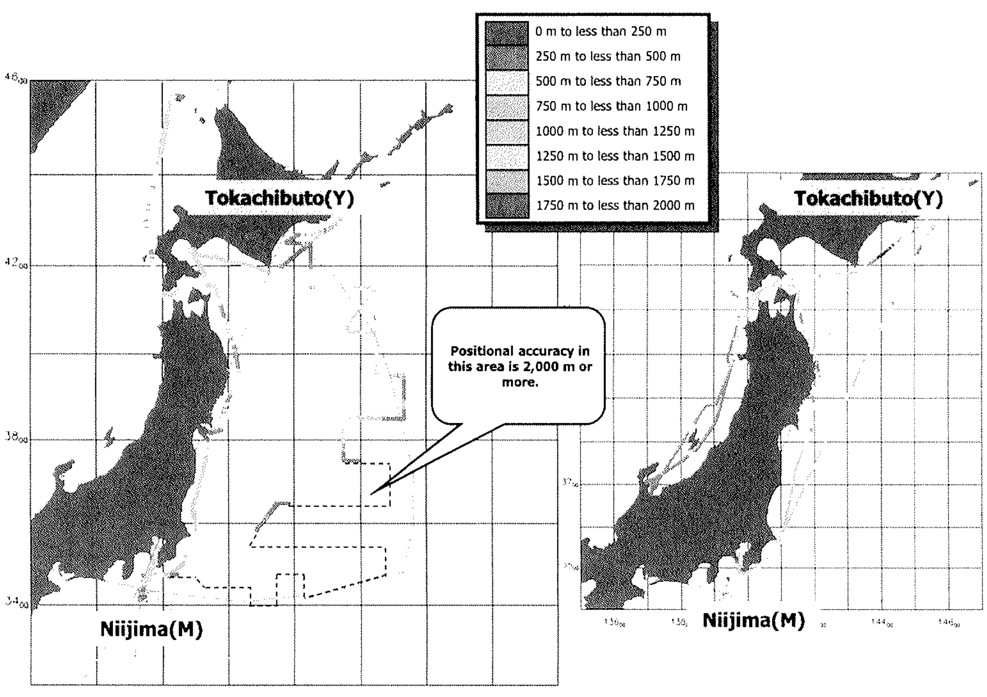
8930 W/Z (Gesashi/Pohang)



Period 27th Nov., 2010 ~ 15th Dec., 2010

Period 7th Jun., 2011 ~ 17th Jun., 2011

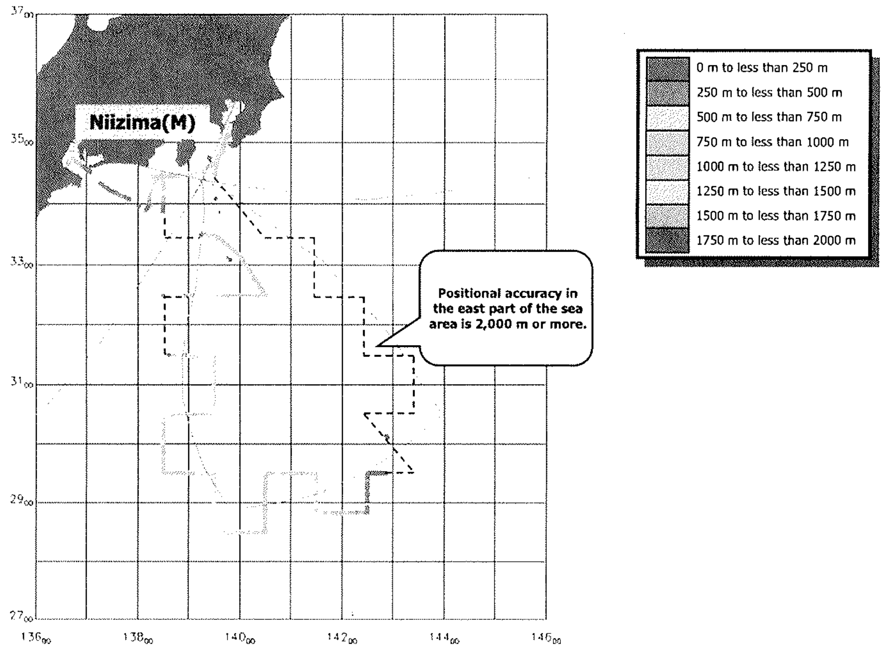
8930 Y/Z (Tokachibuto/Pohang)



Period 16th Apr., 2010 ~ 7th May, 2010

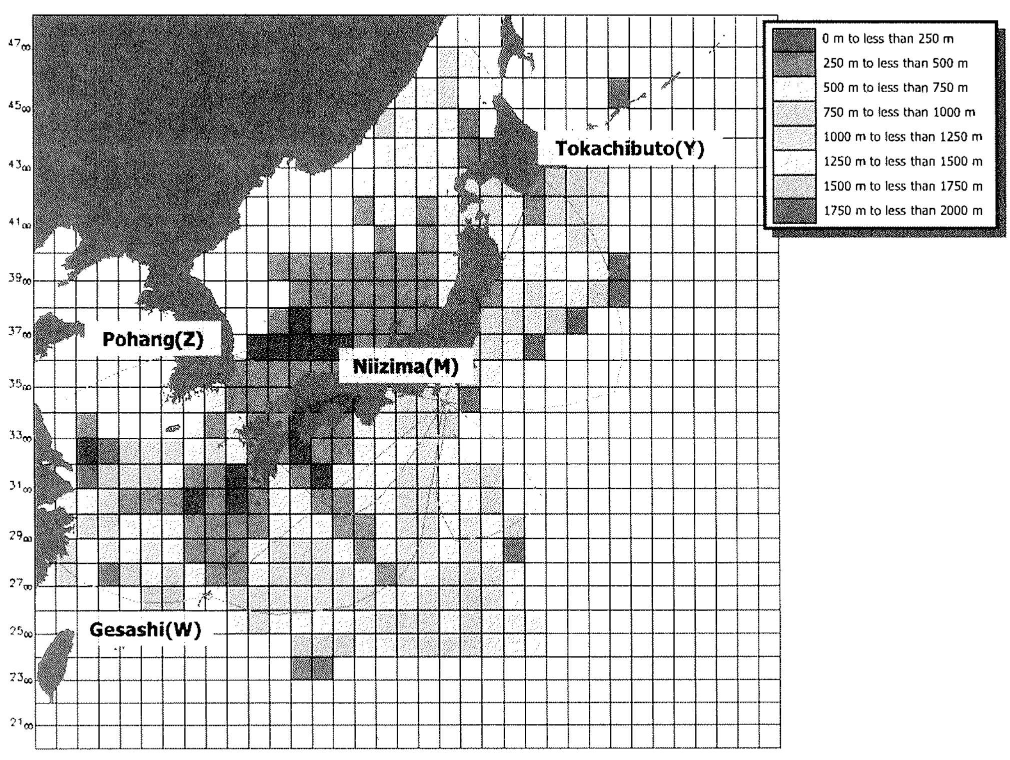
Period 9th Jul., 2011 ~ 2nd Aug., 2011

8930 Y/Z (Tokachibuto/Pohang)

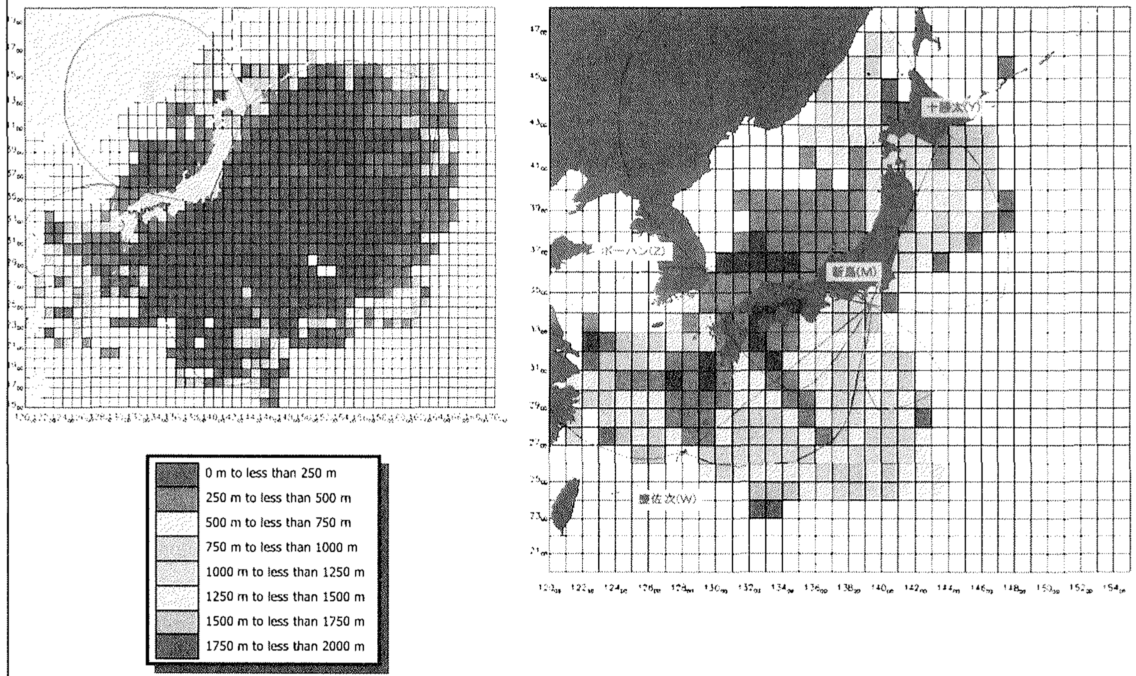


Period 4th Jun., 2010 ~ 16th Jun., 2010

Overall positioning accuracy diagram (Compiled with the past data)



Overall positioning accuracy diagram (Compiled with the past data)



Thank you very much

JCG

Japan Coast Guard

SESSION 2

eLoran Technology I

Shared interest in a more productive tomorrow.

UrsaNav | **OUR capabilities, improve YOUR capabilities.**

Deriving Stratum-1 Time-of-day and Frequency using a Pulsed Low-frequency System: Design and Test Results of an eLoran Timing Receiver

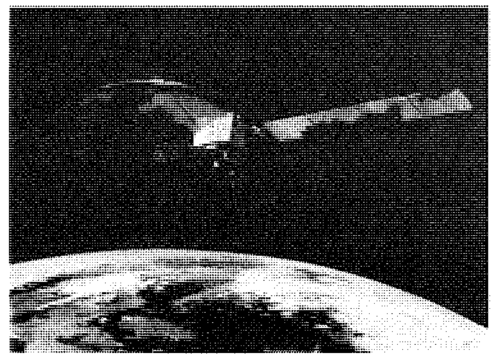
Presented by:
A. Helwig, G. Offermans, C. Stout, C. Schue (UrsaNav)

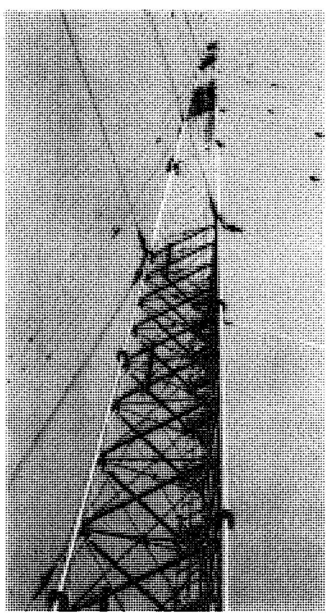
International Loran Association (ILA-40) – November 2011

- GPS is used as the de facto source for positioning and timing
- GPS positioning is critical for many operations, including military, such as:
  - ECDIS
  - Navigation
  - Guidance systems
  - Location of personnel and vehicles
  - ...
- GPS timing is critical for:
  - Self-synchronizing communication networks (AIS and others)
  - IS-95 / TIA-EIA-95
  - Secure communication networks such as TETRA
  - Electric Power network synchronization
  - Banking/trading
  - Telecommunication industry
  - ...
- Loss of GPS can lead to loss of systems and severely reduced operational capability

Known GNSS Vulnerabilities

- Performance degradation - natural phenomenon
  - Ionospheric & solar activities
- Performance degradation - human factors
  - Unintentional & intentional (hostile)
- Signal blockage
- Spectrum competition from non-Rnav systems
- Common signal use across GNSS: L1, L2, L5
- Radio frequency interference
- System anomalies & failures
- Jamming
- Spoofing & Counterfeit Signals



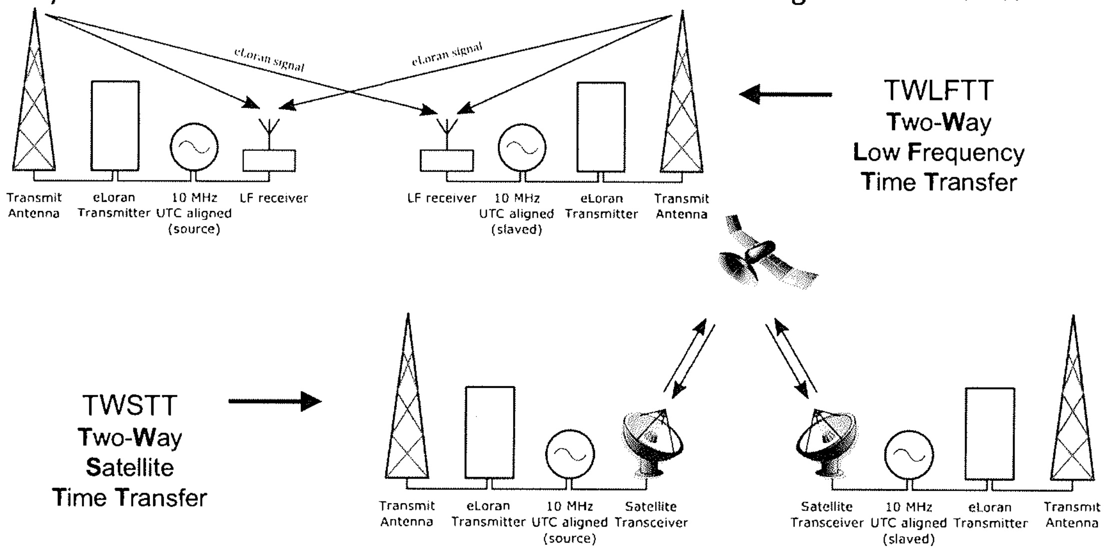


eLoran and other LF APNTD solutions are <u>NOT</u> simply modernized Loran-C!

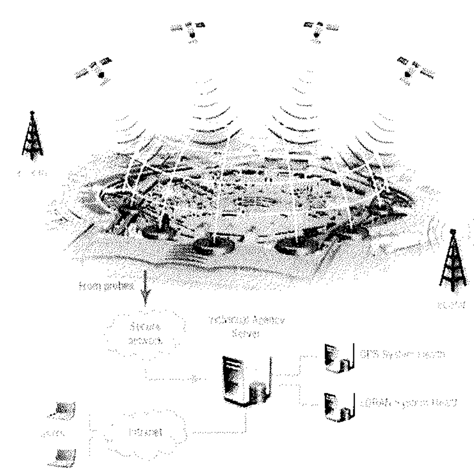
- requires a different timing strategy, control strategy, and new equipment to meet more stringent requirements
- specifies tighter timing tolerances
- transmissions are synchronized with respect to UTC (not SAM)
- employs a data channel for broadcast of application specific data
- includes Differential eLoran monitor stations and ASF maps to provide optimum accuracy in key areas (e.g. marine ports or airports)
- Other LF APNTD solutions, such as LFPhoenix™, add signal and system benefits

eLoran, LFPhoenix™ yield better accuracy and integrity than Loran-C would ever be capable of

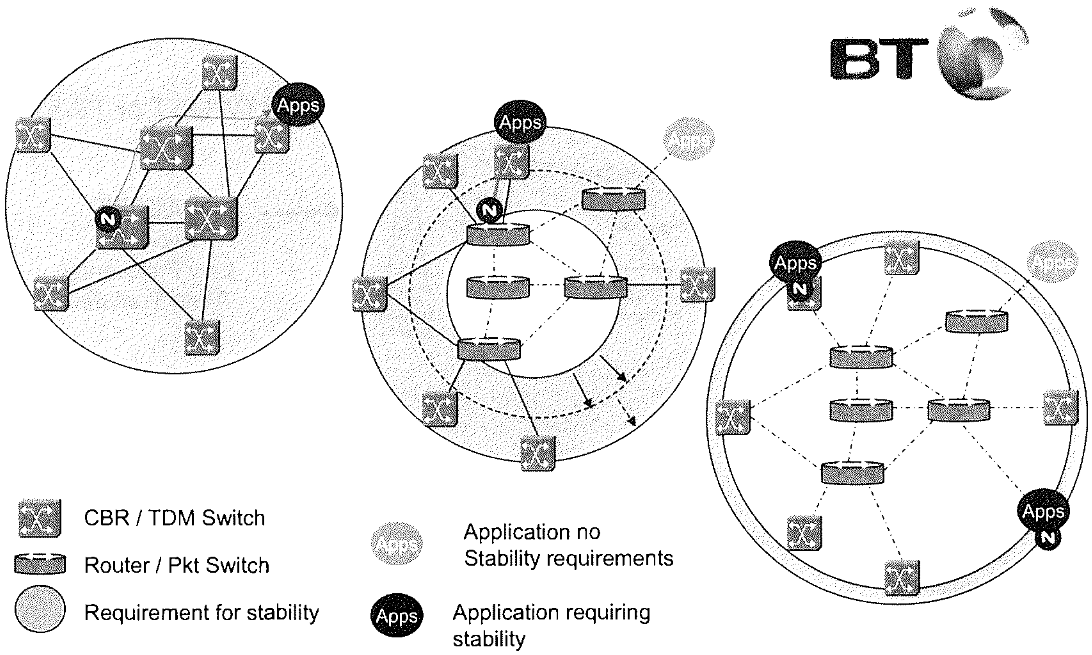
- Every transmitter equipped with 3 Cesium frequency standards
- Provides days of holdover with nanosecond-level accuracy
- Synchronization between transmitters can be done through TWLFTT or TWSTT



- Supply eLoran Timing solution to UK-operated GAARDIAN and SENTINEL programs
  - **G**NSS **A**vailability, **A**ccuracy, **R**eliability an**D** **I**ntegrity **A**ssessment for Timing and **N**avigation (£2m)
  - GNSS **SE**rvices **N**eeding **T**rust **I**n **N**avigation, **E**lectronics, **L**ocation and timing
- Prove suitability of solution to telecoms industry
- Prove suitability to other domains worldwide



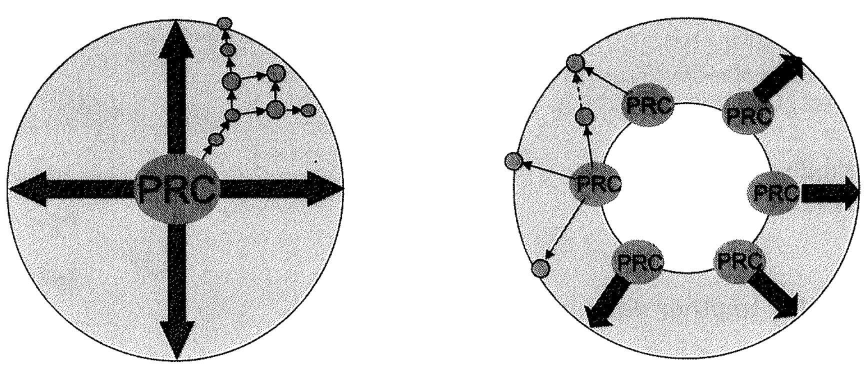
Evolving Telecomms Network Architecture



Need for Accurate Timing at the Edge of telecommunication networks

"Jam in the Doughnut!"

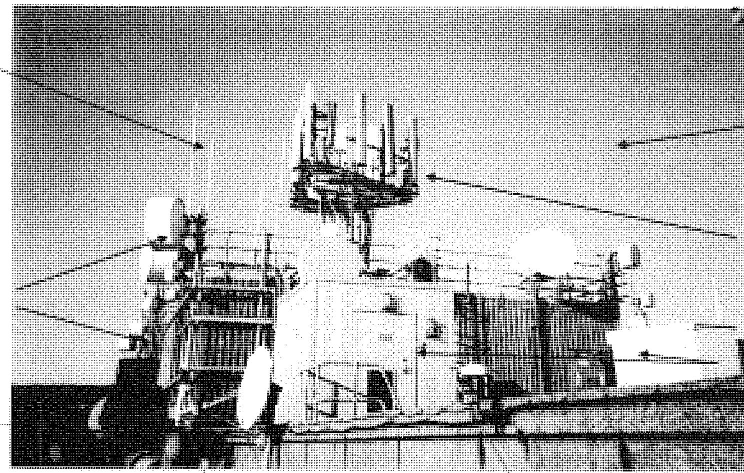
PRC = Primary Reference Clock



Jam in the centre

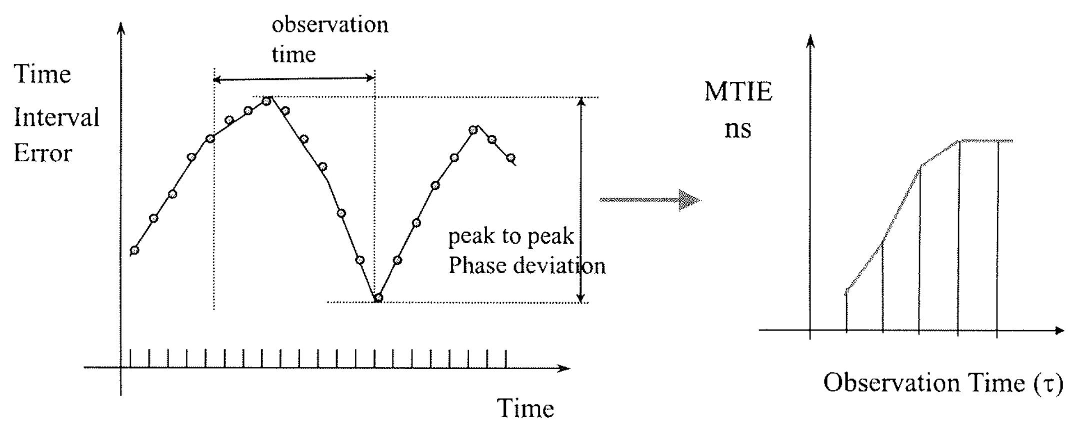
Jam at the edge -
........more jam required!

BT

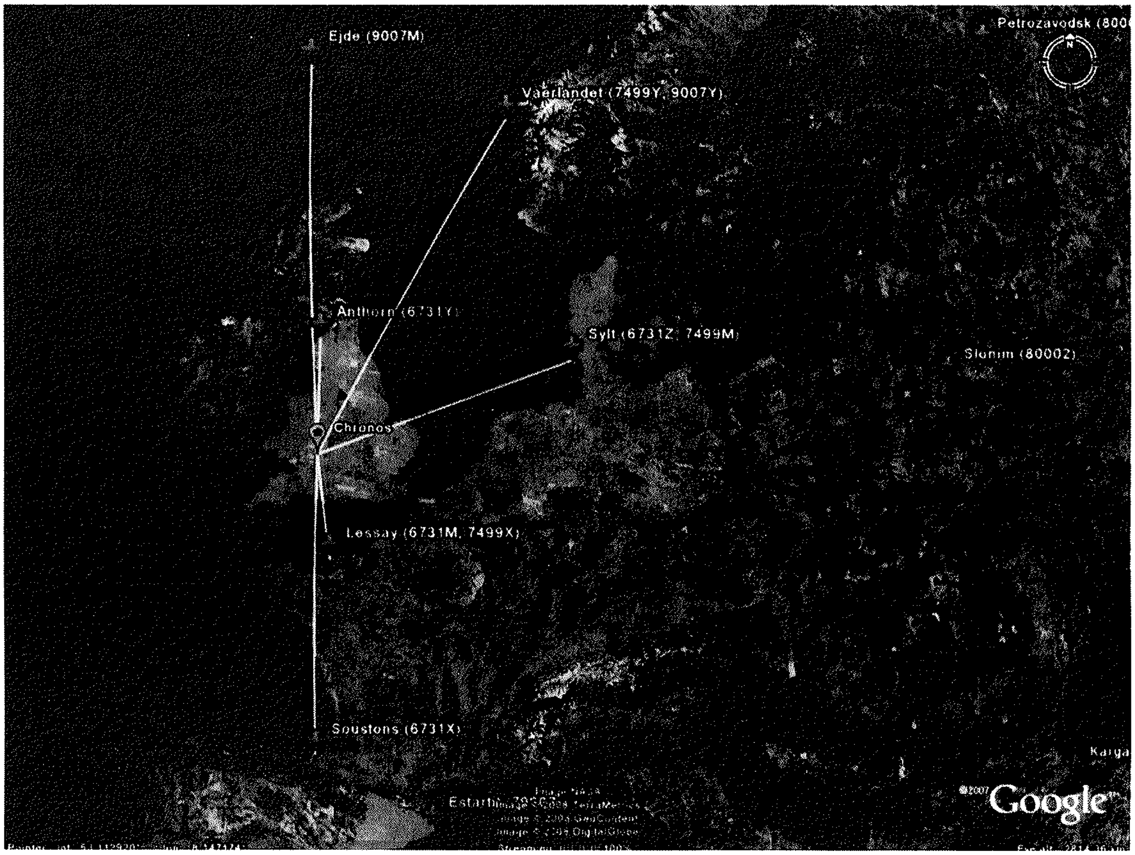


Offsite interference Issues!

"A mix of interference & environmental issues"

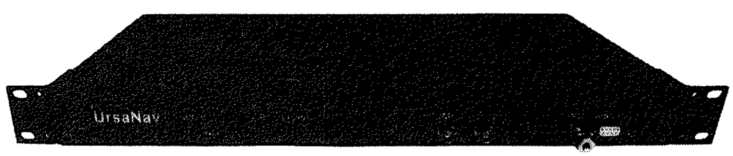


$$MTIE(\tau) = \max_{-\infty > \tau_0 > \infty} \left(\max_{-\tau_0 > \tau > \tau_0 + \tau} ([x(t)] - \min_{-\tau_0 > \tau < \tau_0 + \tau} [x(t)]) \right)$$



UrsaNav

UN150 eLoran Timing rece

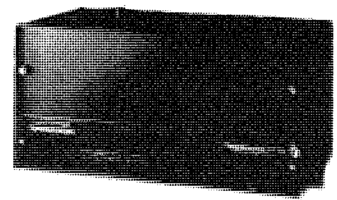


- eLoran/Loran-C timing receiver
- 10 MHz and 1PPS output aligned to UTC
- All-in-view receiver with monitoring capabilities
- Meets Stratum-I frequency stability, ETSI EN 300 462-3-1 requirements for Primary Reference Clocks
- 1 PPS < 50 ns from UTC
- Independently tested and approved by renowned UK based timing company

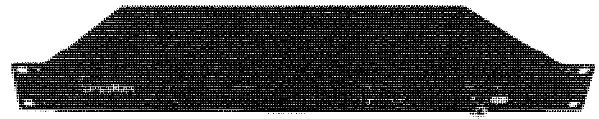
UrsaNav

Test set

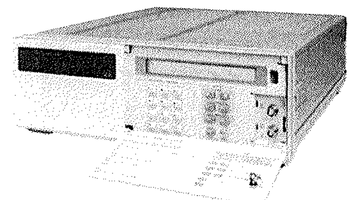
- Device 1: *"TimeSource™ 3100 is a stand alone office Primary Reference Source (PRS) with integrated GPS receiver which meets ITU-T G.811 network performance requirements.*
  The TimeSource 3100 provides undisturbed frequency and time Stratum 1 synchronization when locked to GPS. Upon loss of GPS, continued Stratum 1 performance can be maintained for up to 72 hours with optional inputs."



- Device 2: UN-150 Timing receiver

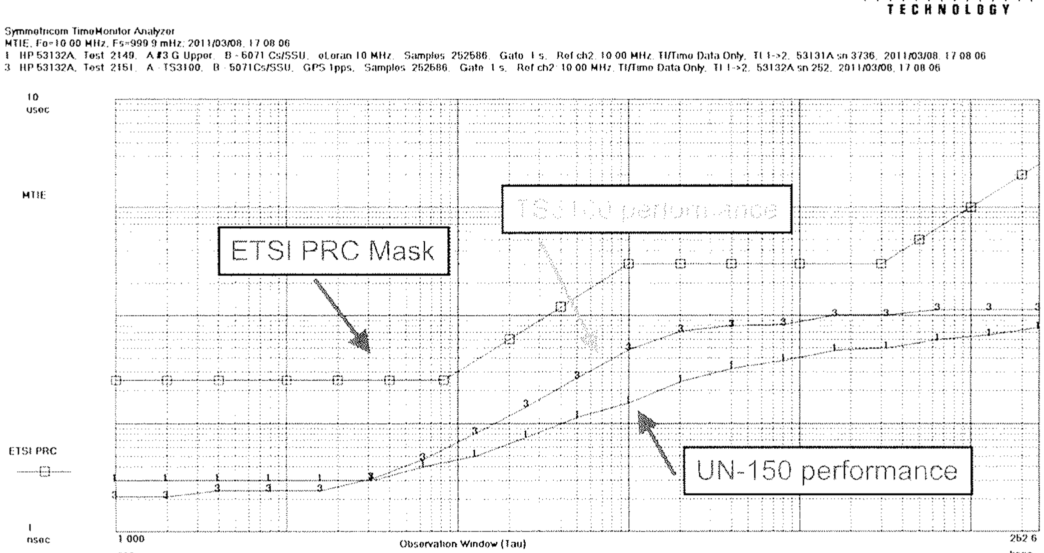


- Both devices referenced against Cesium atomic frequency standard

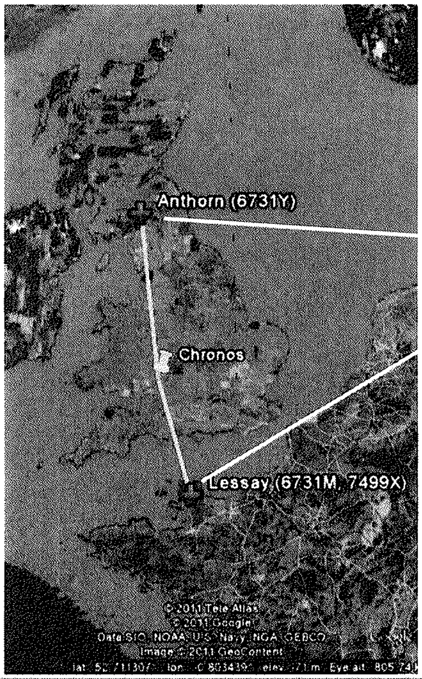


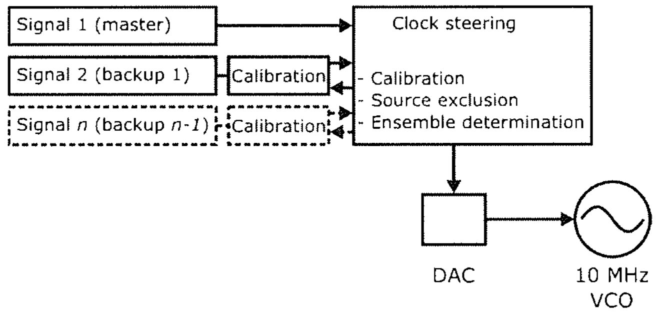
UrsaNav

UN-150 performance vs TS3



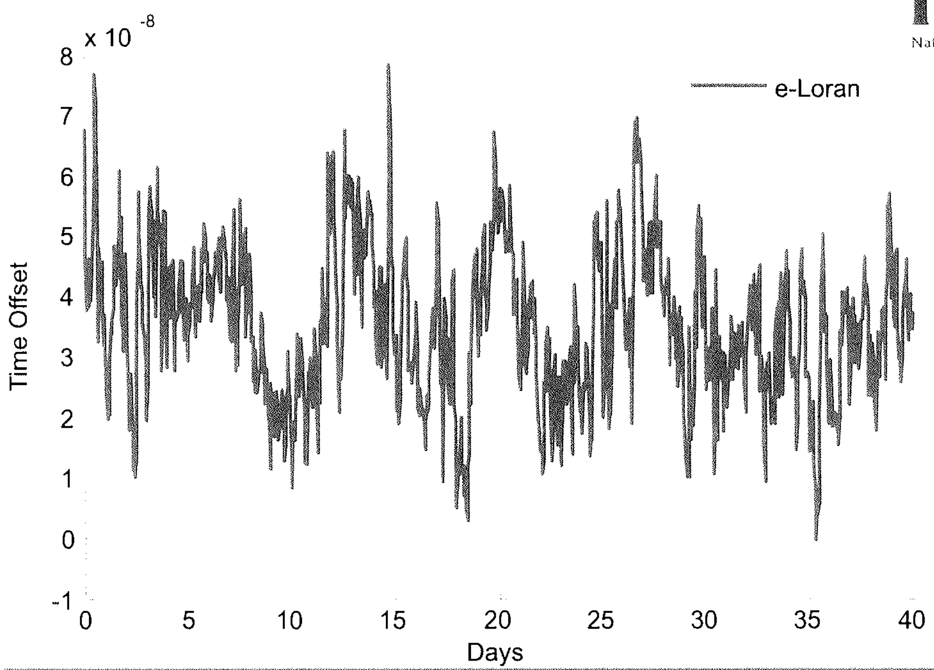
UN-150 hitless handover algorithm





UTC(NPL) – e-Loran

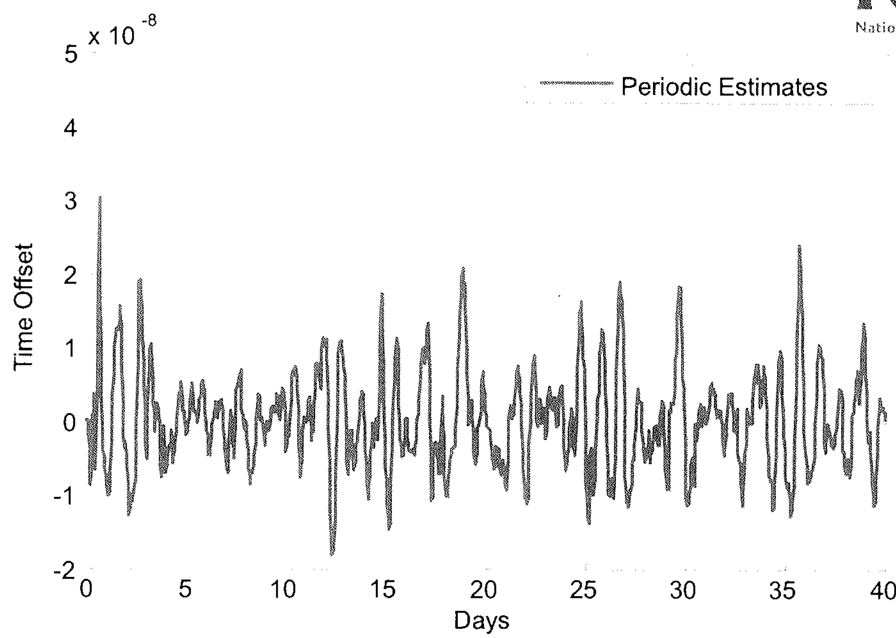
NPL
National Physical Laboratory



UrsaNav

Periodic Instabilities

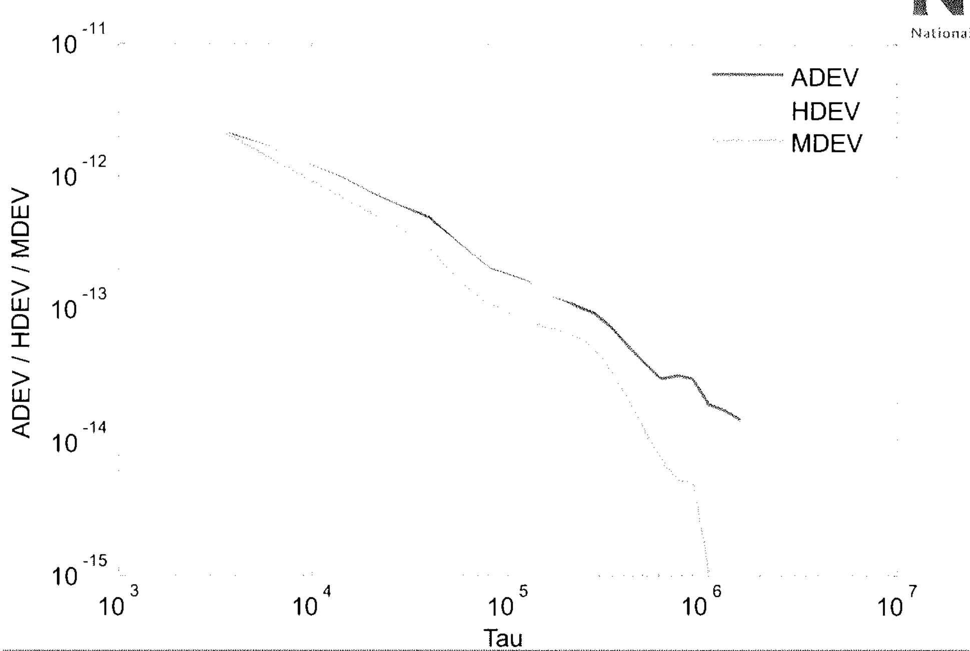
NPL
National Physical Laboratory



UrsaNav

ADEV, HDEV, MDEV Stability (UTC(NPL) – e-Loran)

NPL
National Physical Laboratory



UrsaNav

Scheduled Anthorn unavailability

chronos TECHNOLOGY

08(En) - AUTM & UTM check

European LORAN-C unavailability

Unavailability types:

AUTM: (Autorized Unusable Time): These are scheduled transmitter off-air or blink periods for maintenance or system modification.

UTM: These are unscheduled off-air or blink periods (Failures, out of tolerance conditions...)

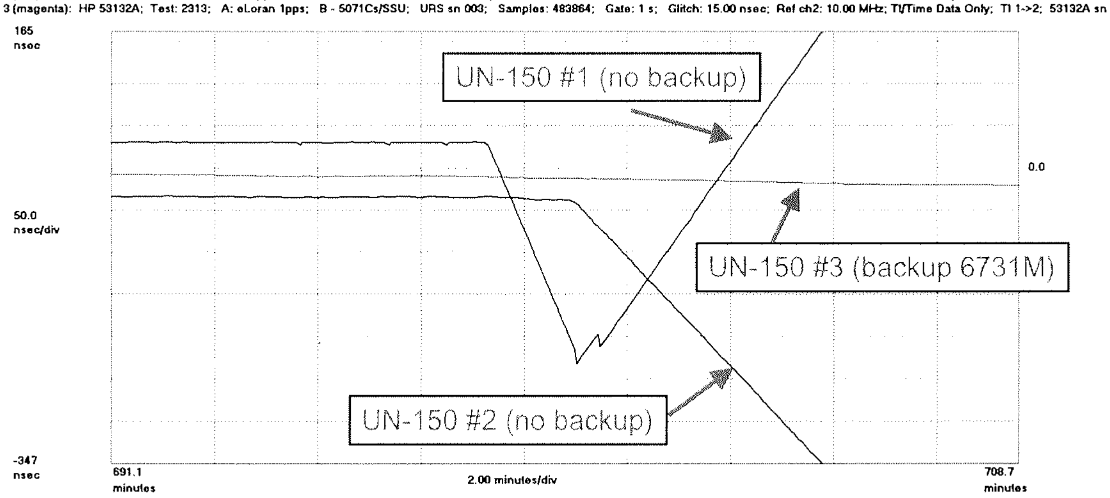
				Scheduled Time (UTC) Format: yyyy-mm-dd hh:mm	
Reference	**Type**	**GRI**	**SITE**	**Start**	**End**
2011/051	AUTM	9007	Ejde	2011-05-12 08:00	2011-05-12 16:00
2011/050	AUTM	9007	Ejde	2011-05-11 08:00	2011-05-11 16:00
2011/049	AUTM	9007	Ejde	2011-05-10 08:00	2011-05-10 16:00
2011/048	UTM	6731	Sylt		
2011/048	UTM	7499	Sylt		
2011/047	UTM	9007	Jan-Mayen		
2011/047	UTM	7001	Jan-Mayen		
2011/046	UTM	7001	Berlevag		
2011/045	UTM	6731	Soustons		
2011/044	AUTM	6731	Anthorn	2011-05-05 08:00	2011-05-06 18:00
2011/043	AUTM	6731	Anthorn	2011-04-14 09:00	2011-04-14 16:00
2011/042	AUTM	6731	Anthorn	2011-04-13 09:00	2011-04-13 16:00
2011/041	AUTM	6731	Anthorn	2011-04-12 09:00	2011-04-12 16:00
2011/040	UTM	9007	Boe		

UrsaNav

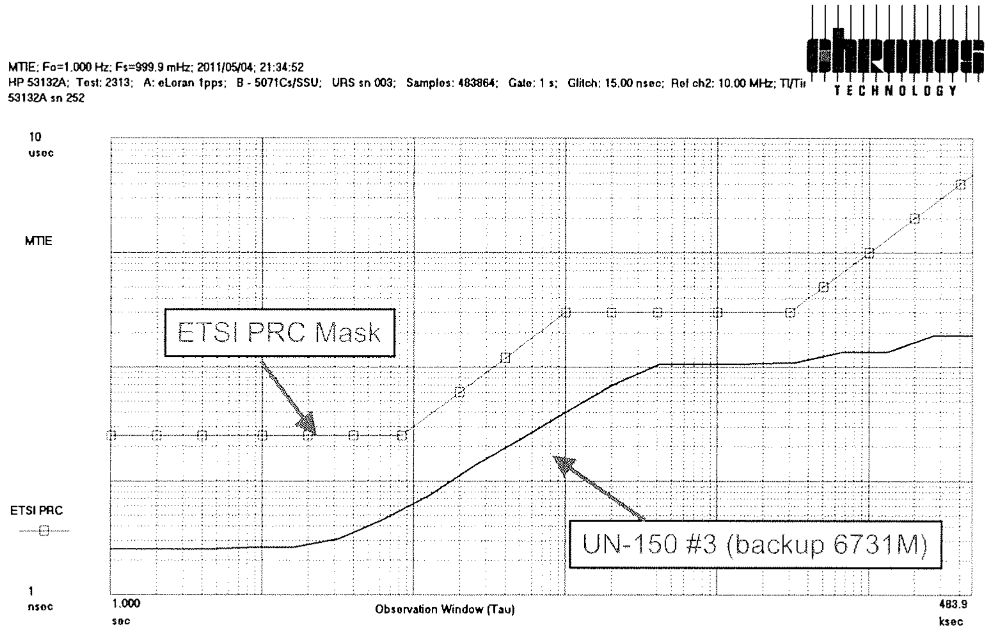
3 UN-150 receiver configurations

chronos TECHNOLOGY

Phase deviation in units of time; Fs=999.9 mHz; Fo=1.0000000 Hz; 2011/05/04; 21:34:52
1 (blue): HP 53132A; Test: 2311; A: eLoran 1pps; B: 5071Cs/SSU; URS sn 007; Samples: 483864; Gate: 1 s; Glitch: 15.00 nsec; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; 53131A sn 3736
2 (red): HP 53132A; Test: 2312; A: eLoran 1pps; B: 5071Cs/SSU; URS sn 004; Samples: 483864; Gate: 1 s; Glitch: 15.00 nsec; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; 53131A sn 6250;
3 (magenta): HP 53132A; Test: 2313; A: eLoran 1pps; B - 5071Cs/SSU; URS sn 003; Samples: 483864; Gate: 1 s; Glitch: 15.00 nsec; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; 53132A sn



MTIE performance during Anthorn unavailability



UN150 usage

- 16 UN150 receivers delivered for GAARDIAN project
- UN150 provides stable timing for GPS interference/outage monitoring and prediction
- 20-30 UN150 receivers anticipated for follow on project in the UK
- UN150 receiver basis for UrsaNav's monitoring/survey grade eLoran/LF Phoenix receivers

- UN-150 eLoran timing receiver provides stratum-1 level time and frequency
  - Capable of seamless handover between stations for increased operational continuity
  - Independently tested and verified
- Results are also applicable to future LF APNTD systems
- LF APNTD is a robust, reliable alternative to satellite technology
  - eLoran is already proven
  - New transmitter technology available for further system refinement
  - System can be deployed cost-effectively
  - Tactical installation possible
- LF APNTD can be used side-by-side with GPS
  - Two fully independent systems
  - The two systems can be tightly integrated or loosely coupled
  - The combination enhances operational capability in case one system is unavailable

SESSION 3

eLoran Technology II

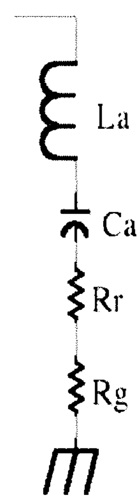
Alternative Configurations for Co-located eLORAN and DGPS Antennas.
Author: John Pinks, Chief Engineer Emeritus, Nautel

Abstract:

In recent years, many nations have expressed concern about the fragility of the signals from GPS satellites and their susceptibility to disruption by accidental or deliberate means. The use of more robust, terrestrial based, low frequency backup positioning systems is being considered. Hyperbolic systems similar to LORAN-C but with significantly improved accuracy and integrity have been proposed. Public opposition to the erection of the very tall antenna structures traditionally used for LORAN is evident in many countries. This paper describes a theoretical study that explores opportunities to reduce the antenna height. In addition, the possibility to co-locate eLORAN and DGPS installations is investigated.

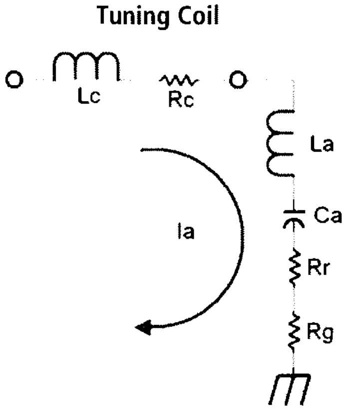
Existing LORAN antennas were designed at a time when physical scale models were used to evaluate their performance. This new investigation uses advanced computer models to measure detailed antenna characteristics, drastically reducing experimental times. The commonly used top loaded monopole (TLM) is compared to alternative lower structures utilizing multiple support towers. Characteristics such as input impedance, reactance slope, efficiency, peak input voltage and current, radiation pattern, bandwidth and intensity of near electromagnetic fields are readily available using the powerful NEC-4 computer program. With each antenna, the potential to co-locate a DGPS system is studied. This includes a measurement of the magnitude of the cross coupled signals, the effect on radiation patterns and a means of acquiring sufficient filtering to facilitate co-location.

Optimizing the LORAN Antenna
LORAN antennas are typically much larger than those used at DGPS stations. Selecting an optimum configuration for the LORAN antenna must therefore be the primary factor when considering their co-location. The equivalent circuit of a low frequency antenna is shown in Figure 1.



Where La = Antenna Inductance
Ca = Antenna Capacitance
Rr = Antenna Radiation Resistance
Rg = Ground Plane Loss Resistance

The reactance (Xc) of the capacitor Ca is much larger than that of the reactance (Xl) of inductance La. A loading coil is therefore commonly used to resonate with the net input capacitance in order to maximize the antenna current as shown in Figure 2.



Where
Lc = TUNING COIL INDUCTANCE
Rc = TUNING COIL LOSS RESISTANCE
La = ANTENNA INDUCTANCE
Ca = ANTENNA CAPACITANCE
Rr = RADIATION RESISTANCE
Rg = GROUND LOSS RESISTANCE
Ia = PEAK ANTENNA CURRENT

The effective radiated power (ERP) is given by:

$$ERP = Ia^2 \times Rr$$

Where Ia = RMS value of the highest peak of the pulse current waveform.

The Radiation Resistance (Rr) is given by:

$$Rr = 160\,\pi^2\,(He/\lambda)^2$$

Where He = Effective Height of the antenna

Effective Height is a term used to compare the efficiency of different types of antennas. It recognizes the fact that the input current tapers to zero at the other end of the antenna. For a short vertical radiator, the current tapers linearly to zero at the top and has an average value equal to one half of the input current. This antenna is said to have an He value equal to one half of the actual height. The effective height of a vertical radiator can be improved by adding capacitance at the top. If for example, a horizontal wire is added to the top of a vertical radiator, the current then tapers to zero at the ends of the horizontal section. This significantly increases the average current in the vertical section. The current in the horizontal section does not radiate however, because it is cancelled by the return current flowing in the antenna's ground plane.

The peak voltage (Vp) at the input to the antenna is given by:

$$Vp = Ia \times \sqrt{2} \times Za$$

Where Antenna Input Impedance $(Za) = Rr - j\,(Xc - Xl)$.

As Rr and Xl are normally very small compared to Xc, the peak voltage is largely determined as;

$$Vp = Ia \times \sqrt{2} \times Xc$$

In summary, Ia and Rr must be high enough to achieve the required ERP and the resulting peak voltage must not exceed the rating of the antenna insulators. Antenna designers strive to maximize the antenna's effective height (and consequently the value of Rr) and to minimize the capacitive reactance by maximizing the total capacitance at the top of the structure. Increasing the capacitance near the base of the vertical section would be counter-productive as it would decrease the He value.

Antenna Structure Design

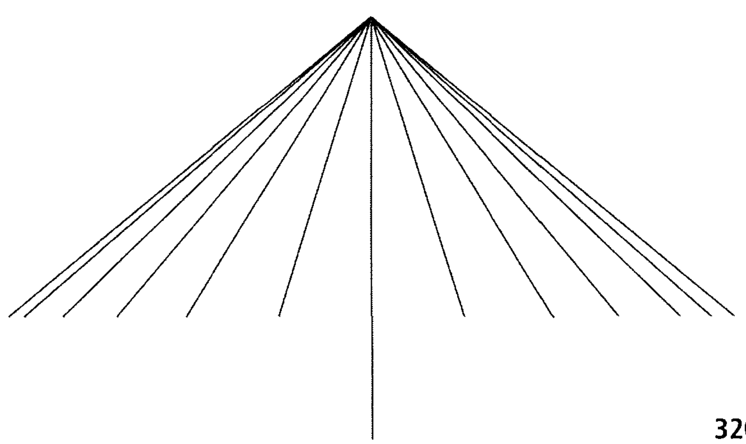
The design of low frequency antennas that are very short compared to their operating wavelength primarily involves the task of obtaining as much capacitance to space, as high as possible above the antenna ground plane.

A single wire with a diameter of 0.73cm, positioned above ground, contributes a capacitance of approximately 8 pico-farads for each meter of its length. By comparison a lattice tower with a 0.5m face dimension contributes only twice this capacitance at 16 pico-farads for each meter of its length. These contributions diminish however when other conductors are placed in close proximity, competing for the capacity to space. Top loading wires are more effective when they are placed well apart. Clearly the wire is a cost effective way of maximizing antenna capacitance. This explains why a top loaded monopole (TLM) with a large number of top loading radials is a popular choice as a LORAN radiator. It should be understood however that these radials would provide a greater advantage if they were horizontally oriented. This is because one component of their current is in a downward direction, partially cancelling some of the current flowing vertically in the support mast. T antennas contribute top loading capacitance horizontally hence have a good effective height but are limited by the total top loading capacitance that they are able to supply. This significantly limits the maximum ERP that they can handle.

This theoretical study compares the performance of a top loaded monopole with various arrangements of horizontal wires supported by four shorter towers. Detailed results are given for a 137m TLM compared to an arrangement of horizontal and slant loading wires supported by four 92m grounded masts. The ability to co-locate a DGPS antenna system with both approaches is investigated in detail. In order to minimize computer run times, the NEC models were tested above a perfect ground.

137m Top Loaded Monopole

Figure 3 illustrates the NEC model of the 137m TLM showing only the radiating elements. The guying radius of the 24 x 148m top loading radials is 160m such that the guy insulators are 41m above the ground plane.



320m Diameter

Measured from the LORAN antenna model

Input Impedance Za = 0.953 – j95.55 ohms
Reactance Slope = 2.87 Ω / kHz

As the model uses a perfect ground, the radiation resistance Rr =0.953 ohms

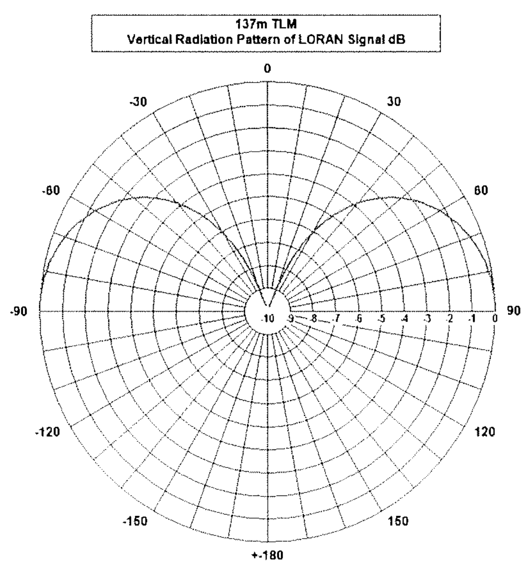
This value of reactance slope enables the antennas Ca and La to be calculated (Reference 1)

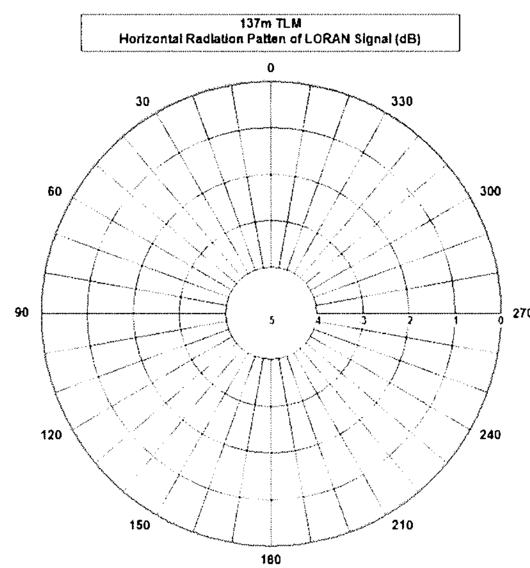
Where Ca = 8311.9 pico-farads
La = 152 micro-henries

The antenna current required to radiate an ERP of 150KW = 396.73 Amps

The Peak Antenna Voltage = 53.6 KV
The Antenna Gain = 1.953 dB
The Effective Height $=\lambda\sqrt{Rr/160\pi^2}= 73.69\text{m}$ (53.8% of actual height)

Figure 4 shows the vertical and horizontal radiation patterns of the LORAN signal.





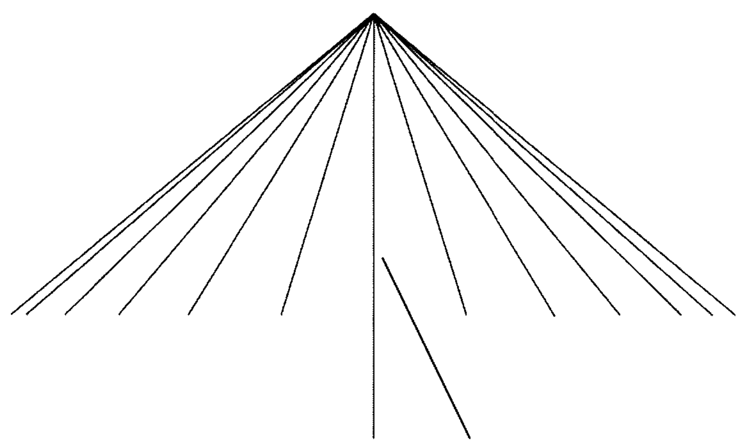
The antenna was tuned to 100kHz with a 152.7μH loading coil with a loss resistance of 0.095Ω and a series resistor added to simulate a 1Ω ground loss. The antenna was energized to produce an antenna current of 396.8 Amps. The field strength at ground level at a range of 46km measured 78.91mV/m.

The radiated power can be calculated by $Pr = (e^2 \times d^2) / 90$

Where e = field strength V/m
d = distance in meters
Hence Pr = 146,390 KW

Adding a DGPS Antenna

A DGPS slant wire antenna was connected from a point at ground level 30m from the TLM mast to a point 3m from the mast 200m above ground as shown in Figure 5.



Measured from DGPS Antenna Model

Input Impedance Za = 1.598 – j1113.4 ohms at a frequency of 300kHz
As model uses a perfect ground, the Radiation Resistance Rr = 1.598 ohms

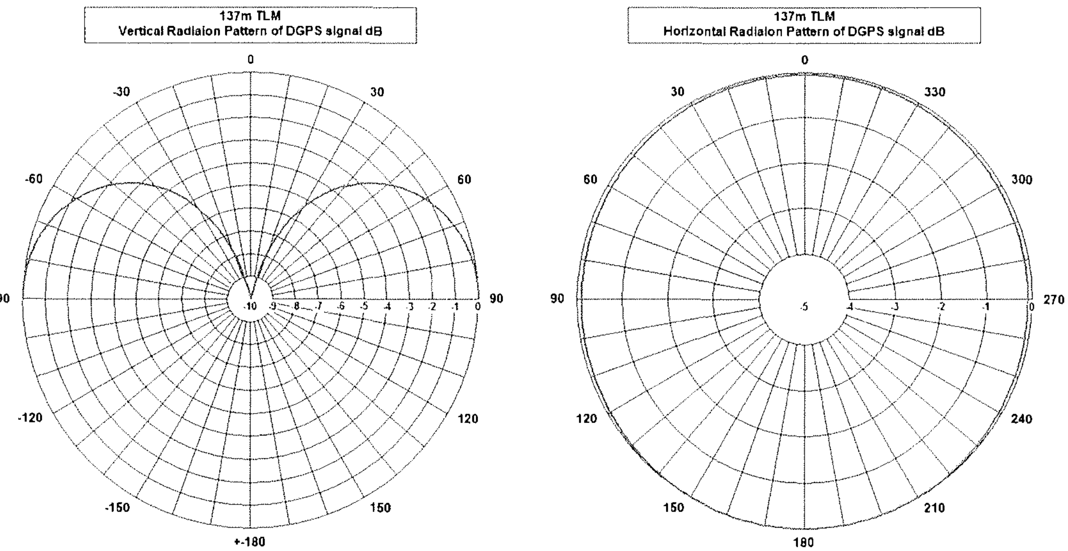
The DGPS antenna was tuned to 300 kHz using a 590.687μH loading coil with a coil loss resistance of 1.1 ohms.

A ground loss resistor of one ohm was also added in series giving a total input resistance of 3.698 ohms.
Efficiency of DGPS Antenna = Rr / Rt = 43.21%

An input power of 2000W was applied producing an antenna current of 23.26 Amps.
The DGPS field strength at a distance of 46km was measured as e = 6.054 mv/m

Radiated Power $Pr = (e^2 \times d^2) / 90 = 861.7$ Watts

Figure 6 Shows the vertical and horizontal radiation patterns of the DGPS signal



Cross Coupling Between Antennas

Energized Antenna	TLM	Slant Wire	Cross Coupling
LORAN Signal	396.73A	6.43A	-35.8dB
DGPS Signal	1.953A	23.258A	-21.5dB

Signal Interference
LORAN to DGPS -11.16dB
DGPS to LORAN -46.15dB

These interference levels ignore any filtering that occurs in either transmitter apart from that of the series loading coils.

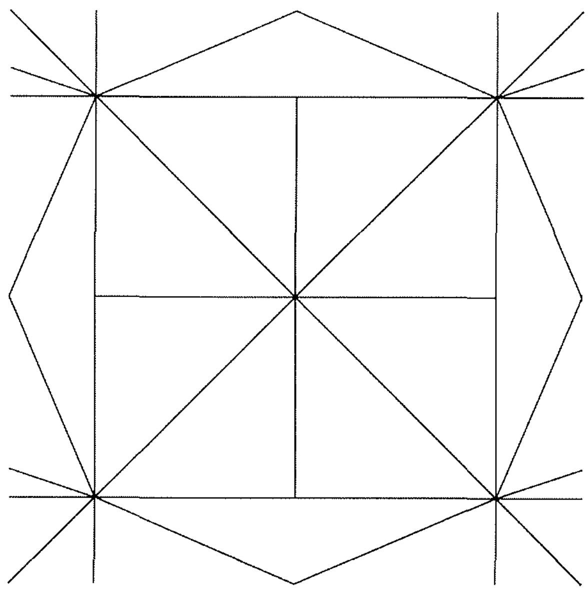
Comparison with Isolated Slant Wire Antenna

Model Measurements

Z= 1.498 – j1152.55 ohms
Tune with 611.44 μH and add 2.15 Ω for coil and ground loss resistance
Efficiency 1.498 / 3.64 = 41.15%
Ia = 23.62 A
Field strength at 46km = 5.966 mv/m
Radiated Power = 836.8 Watts.

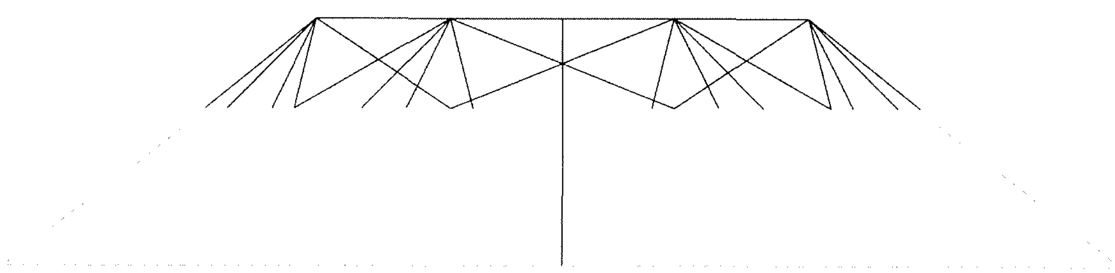
Flat Top Antenna 4 x 92m Masts 150m Apart with Five TLE's at Each Mast

Figure 7 Shows the Plan View



220m Square

Figure 8 Shows the Side Elevation



306m Square

Model Measurements

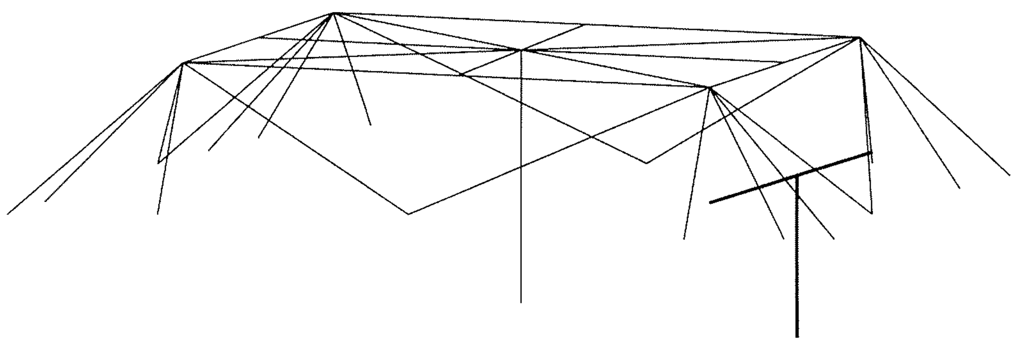
Input Impedance z = 0.983 –j51.686
Reactance Slope = 3.1 Ω / kHz

As the model uses a perfect ground the radiation Resistance Rr = 0.983 ohms
Hence Ca = 8889 pico-farads
La = 205 micro-henries
The antenna current required for an ERP of 150KW = 390.6Amps
The Peak Antenna Voltage = 28.55KV
The Effective Height $=\lambda\sqrt{Rr/160\pi^2}$ = 74.84m (81% of actual height)

The antenna was tuned with 82.26µH with a loss resistance of 0.05Ω and a ground loss of one ohm such that Z= 2.033 + j0. The antenna was energized to produce an antenna current of 390.6A. Field Strength at ground level at a range of 46km measured 79.75 mV/m,
Hence Radiated Power = 149.532 KW

Adding a DGPS Antenna

A horizontal wire was suspended between two of the support masts, 61m above the ground plane fed by a vertical wire at its center as shown in Figure 9.

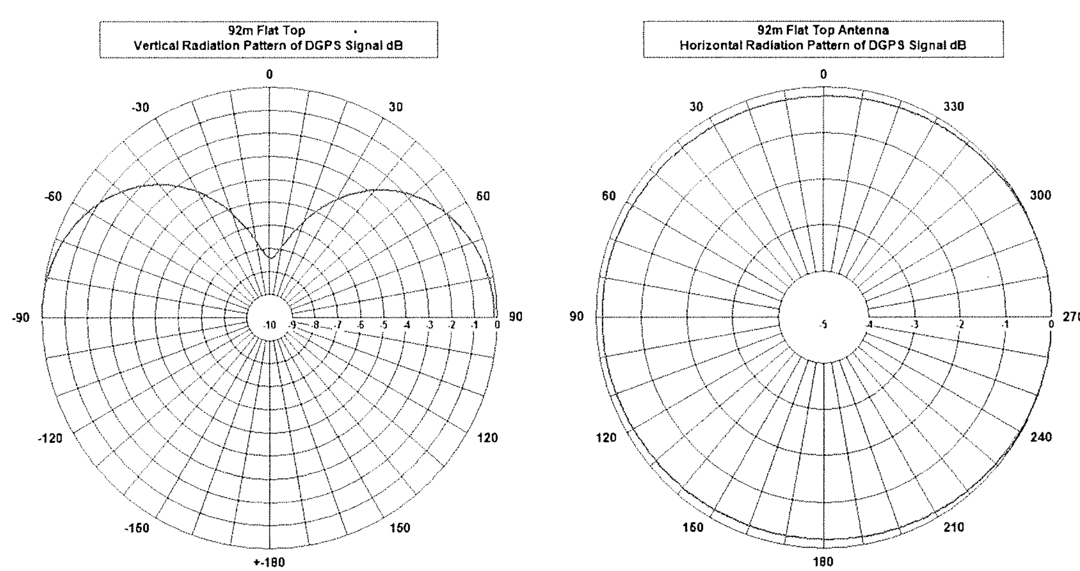


Measured from DGPS Antenna Model

Input Impedance z = 5.543 –j259.893 ohms at 300kHz. System was tuned with 137.878µH in series with a coil resistance of 0.259 ad a ground loss resistance of one ohm giving an input impedance of
Za = 6.802 +j0
Efficiency = 5.543/6.802 = 81.5%

An input power of 2000W was applied producing an antenna current of 17.146A
The DGPS field strength at a distance of 46km was measured as e = 7.845 mV/m
Radiated Power Pr $= (e^2 \times d^2) / 90 = 1439W$

Figure 9 shows the vertical and horizontal radiation patterns of the DGPS signal from the Flat Top antenna.



Cross Coupling between Antennas

Energized Antenna	TLM	Slant Wire	Cross Coupling
LORAN Signal	390.6A	19.42A	-26.0dB
DGPS Signal	0.45A	17.146A	-31.6dB

Signal Interference
LORAN to DGPS +1.08-dB
DGPS to LORAN -58.77dB

These interference levels ignore any filtering that occurs in either transmitter apart from that of the series connected loading coils.

Conclusion

The primary object of the study was to seek a new antenna shape with a higher value of effective to actual height (He/H) compared to that of the standard TLM design. A 92m flat top design is compared in detail to that of a 137m TLM in terms of its ability to radiate an ERP of 150KW. The flat top has an effective height equal to 81% of the actual height compared to 53.8% for the TLM and sits on the same ground footprint. The results show performance characteristics that are quite similar, except that the flat top has a peak input voltage of 28.5KV compared to 53.6KV on the TLM.

The capability of both configurations to be co-located with a DGPS antenna was investigated.
The use of a diplexer feeding a single radiator was considered but rejected due to the very high voltages resulting from the high peak currents of the LORAN signal flowing in diplexer components.

The use of separate radiators using common mechanical support components was thought to be a more practical approach. No effect on the LORAN radiation characteristics was discovered for either configuration. Cross coupled interference of levels -46dB (TLM) to -59dB (Flat Top) without contribution from filters in the LORAN transmitter would appear to be quite acceptable. The effect of the LORAN tower indicated a slight effect on the DGPS horizontal pattern, but to a negligible degree. The cross coupled signal interference from LORAN to DGPS of -11dB for the TLM and + 1dB for the flat top was more significant due to the much higher amplitude of the LORAN signal. Interference was more severe with the flat top because the sample DGPS antenna was much more efficient than that used with the TLM. In either case, filtering of the LORAN signal in the DGPS antenna connection is a relatively simple task due to the relatively small current levels of the DGPS signal. It was noted that the cross coupling was reduced when the LORAN and DGPS antennas were further separated but that the omnidirectional horizontal pattern of the DGPS signal became more affected.

The overall conclusion is that other antenna configurations can equal or exceed the TLM on the same ground footprint. The required isolation of co-located LORAN and DGPS radiators has not been determined by actual field experiments. Co-location experiments in U.S.A. with DGPS and high accuracy DGPS signals have proved to be successful with cross coupled isolation levels of 40-50 dB.

References
1. Hardy, T "Next Generation LF Transmitter Technology for (e)LORAN Systems.

Alternate Configurations for Co-Located eLoran and DGPS Antennas

Authored By: John Pinks
Chief Engineer Emeritus, Nautel

Overview

Signals from GPS satellites are susceptible to disruption by accidental or deliberate means

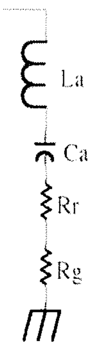
Enhanced eLoran stations can provide a more robust positioning system.

Due to the 3000m wavelength of Loran signals, the transmitting antenna must be extremely large.

It therefore constitutes a significant portion of the overall cost of a Loran installation.

Optimizing the LORAN Antenna

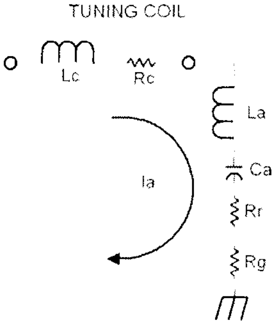
The antenna's equivalent circuit comprises a series connection of inductance La – Capacitance, Ca – Radiation Resistance, Rr – Ground Loss Res Rg



Optimizing the LORAN Antenna

The capacitive reactance Xca is much larger than the inductive reactance Xla

Standard coupling arrangements resonate the net capacitive reactance with a loading coil to maximize the antenna current



Optimizing the LORAN Antenna

The effective radiated Power

$ERP = Ia^2 \times Rr$

Where Ia = RMS value of the highest peak of the pulse current waveform

The Radiation Resistance

$Rr = 160 \pi^2 (He / \lambda)^2$

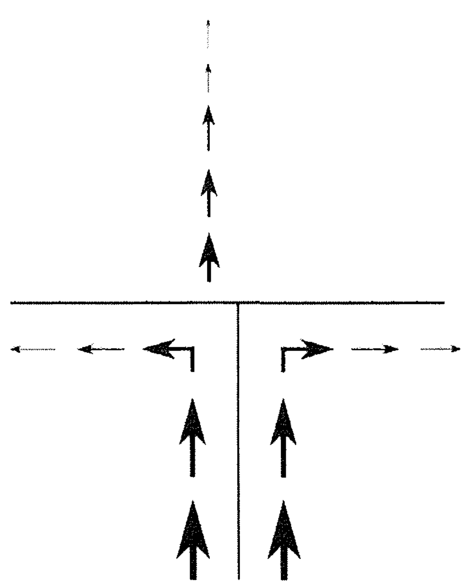
Where λ is the signal wavelength

The peak antenna voltage $Vp = Ia \times \sqrt{2} \times Xc$

Radiated power is proportional to Ia x vertical distance in which it flows

Optimizing the LORAN Antenna

Effective height He is less than the actual physical height of the antenna. It represents the degree to which the input current diminishes as it flows in the vertical section of the antenna



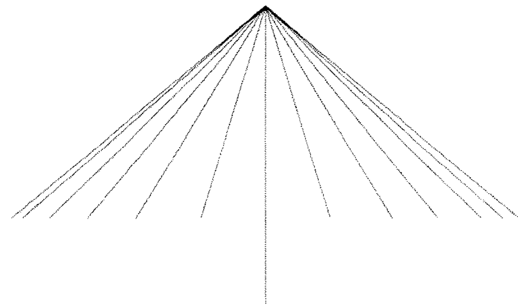
The current in a vertical radiator tapers linearly to zero at the top. The average value = 0.5Ia. Hence antenna is said to have an He value of 0.5H

Top loading increases the current in the vertical section He > 0.5H

Optimizing the LORAN Antenna

A top loaded monopole (TLM) is commonly used to transmit Loran signals

24 TLE's maximize the capacitance at the top to maximize He



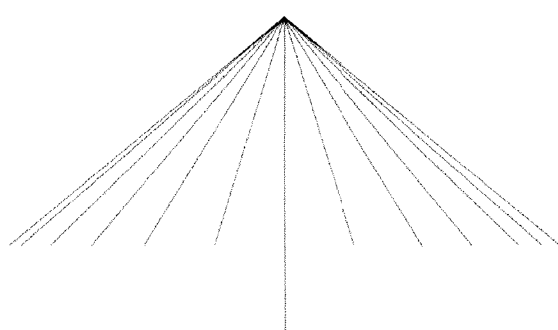
Is this the best configuration?

Can it be co-located with a DGPS antenna?

This theoretical study uses computer modeling to answer these questions

Antenna Structure Design

A 137m TLM above a perfect ground is analyzed



Footprint is a 320m diameter circle

Input Impedance Za = 0.953 – j95.55 Ω

Reactance Slope = 2.87 Ω / kHz

Antenna Structure Design

Ca = 8311.9 pico-farads

La = 152 micro-henries

The antenna current required to radiate an ERP of 150KW = 396.73 Amps

The Peak Antenna Voltage = 53.6 KV

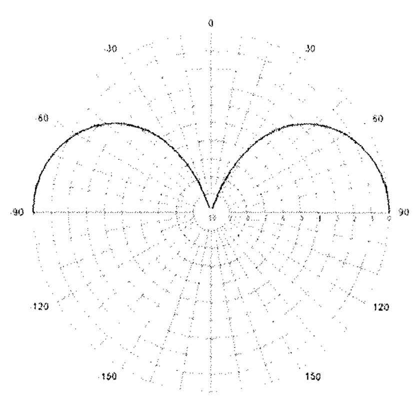
The Antenna Gain = 1.953 dB

The Effective Height =73.69m (53.8% of actual height)

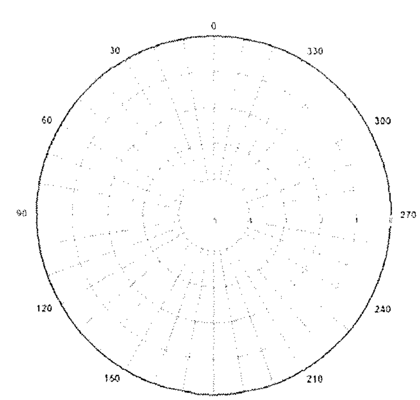
Antenna Structure Design

Loran Radiation Patterns

137m TLM
Vertical Radiation Pattern of LORAN Signal dB

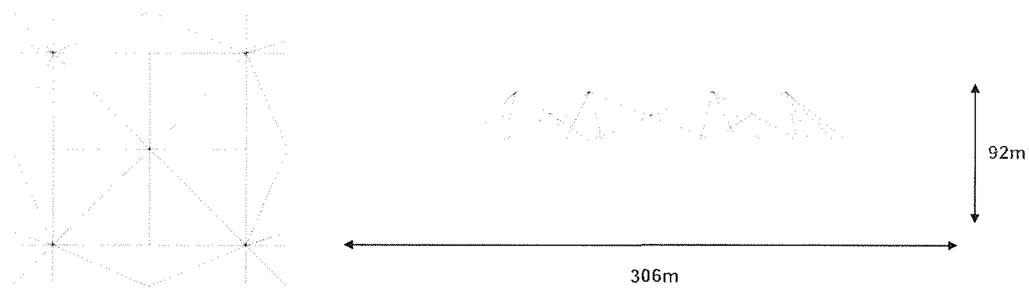


137m TLM
Horizontal Radiation Pattern of LORAN Signal dB



Antenna Structure Design

Flat top antenna supported by 4x 92M grounded masts 150m apart

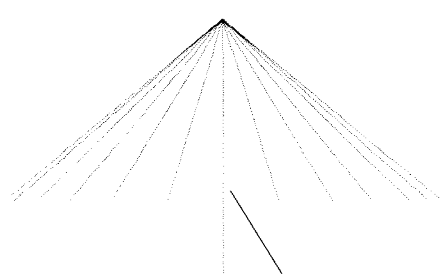


Input Impedance z = 0.983 –j51.686
Reactance Slope = 3.1 Ω / kHz
Ca = 8889 pico-farads
La = 205 micro-henries

Antenna current required for 150KW ERP
Ia = 390.6 Amps
The Peak Antenna Voltage = 28.55KV
Effective Height = 74.84m (81% of actual height)

Antenna Structure Design

Co-Locating a 200m Slant wire DGPS antenna

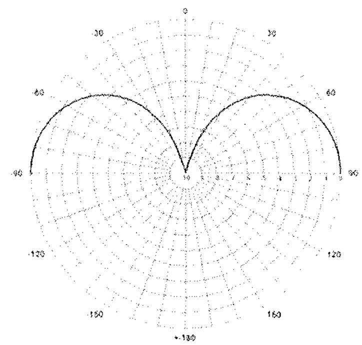


Input Impedance Za = 1.598 – j1113.4 ohms
Transmitter power = 2000w
Efficiency = 43.21%
Ia = 23.26A

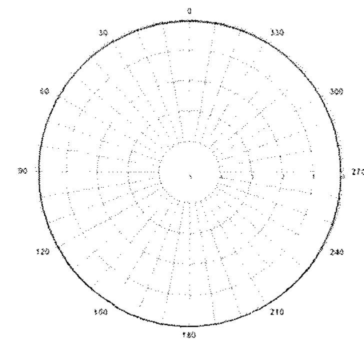
Antenna Structure Design

DGPS Radiation Patterns

137m TLM
Vertical Radiation Pattern of DGPS Signal dB



137m TLM
Vertical Radiation Pattern of DGPS Signal dB

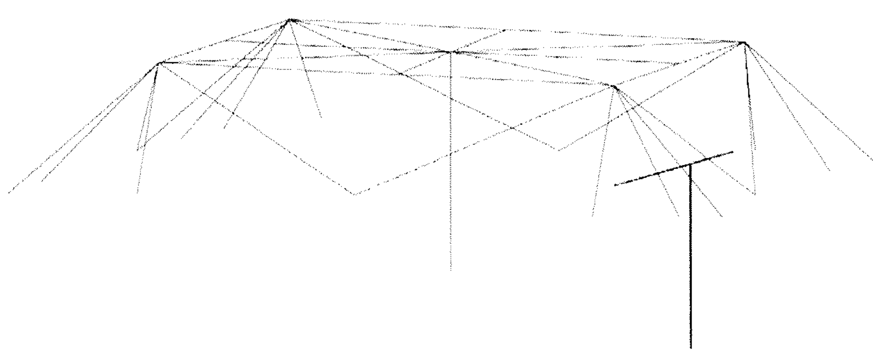


Signal Interference without filtering

- Loran to DGPS – 11.6 dB
- DGPS to Loran – 46.15 dB

Antenna Structure Design

Co-locating a 61m x 150m T DGPS antenna



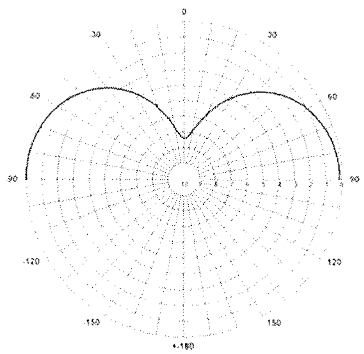
Input Impedance Za = 5.543 – j259.89 ohms

Transmitter Power 2000w

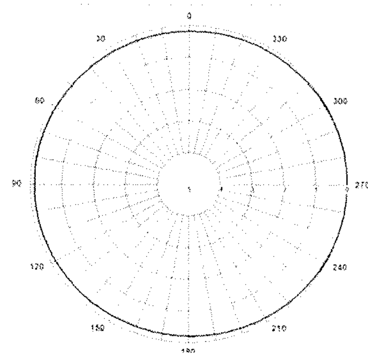
- Efficiency 81.5%
- Ia = 17.146A

Antenna Structure Design

92m Flat Top
Vertical Radiation Pattern of DGPS Signal dB



92m Flat Top
Vertical Radiation Pattern of DGPS Signal dB



Signal Interference without filtering

Loran to DGPS +1 dB

DGPS to Loran -58.77 dB

Conclusion

1. Both Loran antennas required the same footprint
2. Flat top reduced height from 137m to 92m
3. Flat top reduced peak voltage from 53.6kV to 28.5kV
4. Co-location seems possible with either alternative
5. Interference is greater with flat top because the DGPS antenna is more efficient
6. DGPS to Loran interface is more critical because additional filtering in Loran coupler has to carry large Loran peak currents
7. Filters in DGPS coupler are easier to implement

Thank You

42

years of NAUTEL 1969 2011

Shared interest in a more productive tomorrow.

UrsaNav | OUR capabilities, improve YOUR capabilities.

Low Frequency (LF) Solutions for Alternative Positioning, Navigation, Timing, and Data (APNT&D)

Presented by:
C. Stout, A. Helwig, G. Offermans, C. Schue (UrsaNav)
B. Walker, T. Hardy, K. Zwicker (Nautel)

International Loran Association (ILA-40) – November 2011

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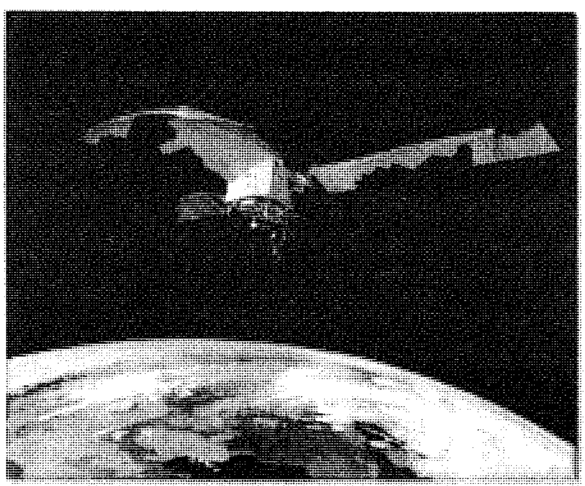
Satellite technology alone is not sufficient nor prudent

- Worldwide awareness is rising that reliance on satellites alone for PNT is unwise



- Intentional jamming increasing
- IMO e-Navigation concept states the need for resilient navigation
- IALA council recommends that a global system, dissimilar to GNSS should be encouraged
- ICAO looking for alternatives
- Timing community aware of issues – loss of sync means loss of revenue
- Loss of GPS may reduce operational capability

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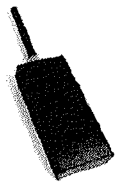
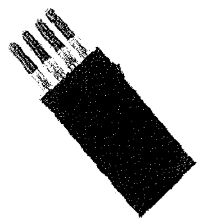
GPS Jammers – "Personal Privacy Devices"

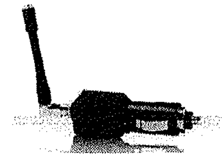
- Jamming & spoofing devices are becoming more sophisticated.



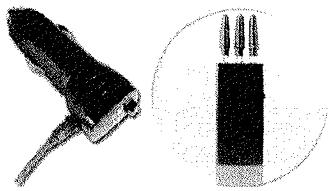
$110 Ebay



$335 Ebay

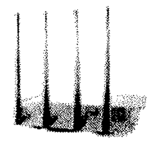


$92 Ebay

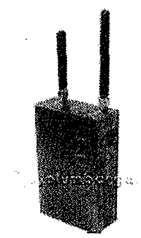


$40 GPS&GSM
www.chinavasion.com

$55 Ebay



$83 GPS&GSM
www.Tayx.co.uk



$152 Ebay

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Why does a Terrestrial LF solution make sense?

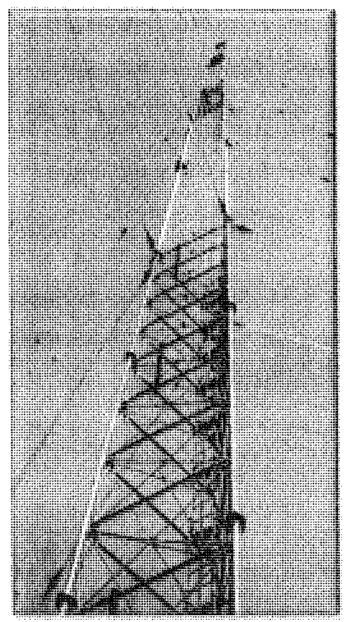
- It is a terrestrial system
  - Higher power than satellites
  - Dissimilar failure modes to GNSS
- Useable range of an LF signal for timing/navigation is significantly greater than using higher frequencies
  - Groundwave can be used – ranges up to 1,000 NM
  - Fewer transmitters needed
  - Lower cost
- Protected spectrum worldwide
- Terrestrial LF systems such as Loran-C / eLoran have already been proven to meet IMO HEA / FAA RNP 0.3 requirements
- Terrestrial LF technology is proven and is being further developed

LF Alternative PNT&D (Loran, eLoran, NextGen LF) Uses

- Robust, multi-modal alternative PNT&D (APNT) solution reducing reliance on GNSS
- Nation-state controlled system
- Critical infrastructure protection (ports, harbors, airports, key assets)
- Interference-enabled crime fighting (car theft, border crossings, tracking felons)
- Wide-area or localized timing source (+/- 50 ns of UTC)
- Law enforcement & military operations (tree/foliage cover, jamming situations, mountainous regions, counterinsurgency)
- High-profile events (Olympics)
- GNSS interference detection & mitigation
- Military operations (triple canopy, jamming situations, mountainous regions)
- Automatic Vehicle Location (AVL) services
- Submarine communications and navigation
- Heading / Pointing (Compass)

What are the Solutions?

- Loran
  - PNT service in use in many parts of the northern hemisphere
- eLoran
  - PNT & Data service
- Tactical (e)Loran
  - Deployable (e)Loran PNT&D service
- Next Generation LF (LFPhoenix™, TerraNav)
  - Alternative Waveforms
  - Alternative Modulation Schemes
- All these systems can co-exist worldwide
  - "Do no harm" policy
  - Receivers can handle all systems



- Independent from GNSS but can coexist with GNSS
- Sovereign control of APNT assets
- Loran/eLoran remains as a "mode" of operation
- Use existing "protected" spectrum i.e. 90 -110 kHz
- UTC timing to an accuracy of at least 50 ns
- Data Channel Capable of 1,500 bps
- System must have integrity and security
- Safety of Life System
- Navigation Accuracy, Availability, Integrity and Continuity are paramount and provision of data should not compromise the reliable delivery of navigation information

Loran-C:

- Radio navigation system
- 90 – 110 kHz
- Ground wave signal
- Typically high power
- Provides lateral position
- Stratum 1 frequency standard
- Timing within +/- 50 nS of UTC
  - Currently operated by 13 nations
- Autonomous
- Interoperable
- Diverse

Enhanced **Loran:**

All the good stuff from Loran, plus:

- Tighter tolerances
- Data broadcast
- UTC controlled (TWSTT, TWLFTT, GNSS)
- All-in-view signals
- New infrastructure & technology
  - State-of-the-Art RF transmitters
  - Three cesium primary reference standards per station
  - Precision time & frequency equipment
  - Whole-station Uninterruptible Power Supply (UPS)
  - Robust telecommunications
  - GNSS monitoring
    - NOT directly coupled or controlled

Our LF APNTD solutions include Loran-C, eLoran, LFPhoenix™ and beyond

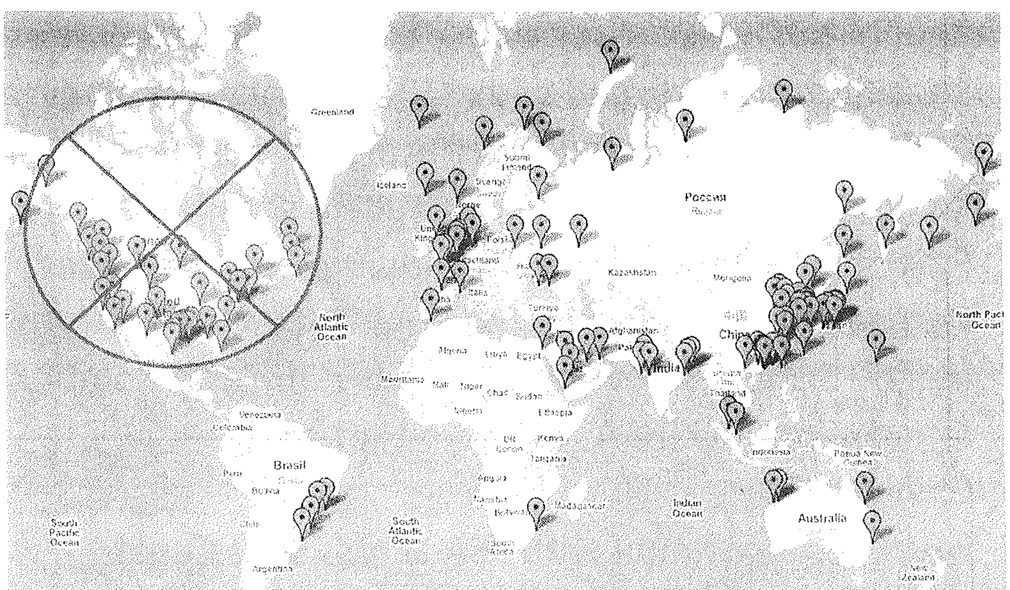
Why eLoran?

- eLoran is more than just a modernized Loran-C system
- Different timing strategy, control strategy, & new equipment to meet more stringent requirements
- Improved positioning & timing performance

Application	Accuracy	Availability	Integrity	Continuity
Maritime Harbor Entrance and Approach (HEA)	20 meters (95%)	0.998 over 2 years	10 seconds Time to Alarm	0.9997 over 3 hours
Aviation Non-Precision Approach (RNP 0.3)	0.3 Nautical Mile (556 meters)	0.999 – 0.9999	1 x 10^{-7} per hour	0.999 – 0.9999 over 150 seconds
Timing	Stratum-I frequency stability; timing to +/- 50 ns from UTC			

- Transmissions synchronized to UTC allowing transmitter independence
- Available data channel for broadcasting application specific information

Historical Loran & Chayka Stations



Loran (Red), Chayka (Green), World's 50 Busiest Cargo Ports (Blue)

Courtesy of the General Lighthouse Authorities of the UK & Ireland

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Loran / eLoran Worldwide Implementation

Current Installations

- Republic of Korea
- Russia (Chayka)
- Norway
- England
- Kingdom of Saudi Arabia
- France
- Denmark
- India
- Japan
- China
- Germany
- USA (dormant)
- Canada (dormant)

Near-Term Movement

- Republic of Korea
- England
- Republic of Ireland
- Kingdom of Saudi Arabia
- Russia (Chayka)
- Norway
- France / Denmark
- India
- Japan
- China
- Egypt
- Germany
- USA / Canada

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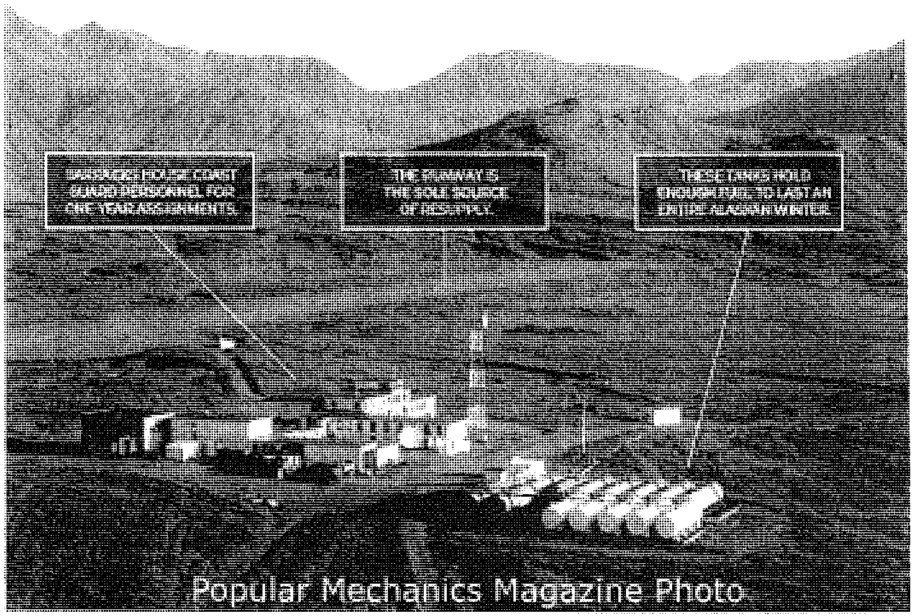
eLoran Interest and Exploration

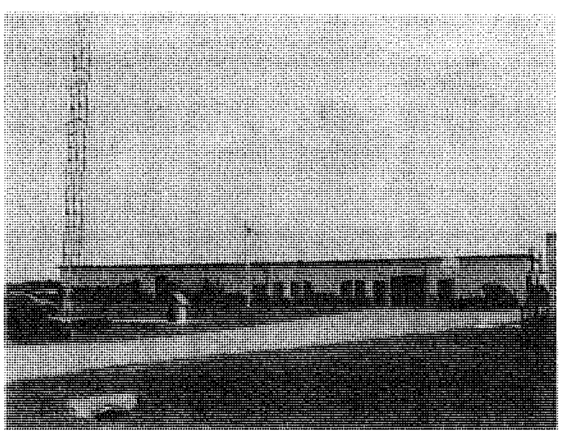
- Republic of Korea – upgrading and installing new sites
- England – upgrade site with 21st century technology
- GLA – improve coverage in critical port areas
- Kingdom of Saudi Arabia – upgrade 4 sites
- France – upgrade 2 sites; considering 3 - 4 new sites
- Denmark – upgrade site
- India – install 26 new sites (60-day non-GNSS solution)
- Japan – improve HEA for Tokyo Harbor
- China – TBD
- Egypt – cooperation with KSA across Suez Canal
- Germany – renewed interest
- USA – Exploring backup timing implications

Goal: Destination / Build: Station



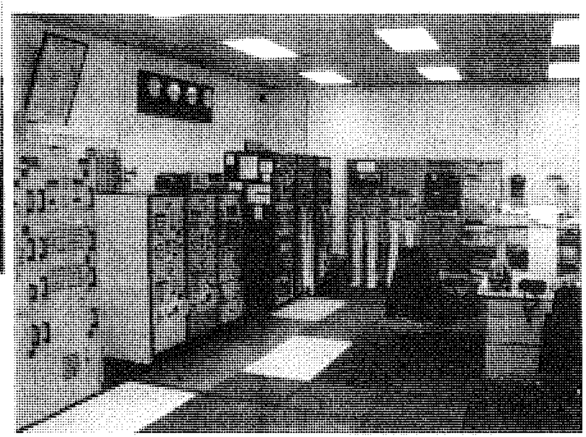
Popular Mechanics Magazine Photo

Yesterday's Systems: 1970's Vintage



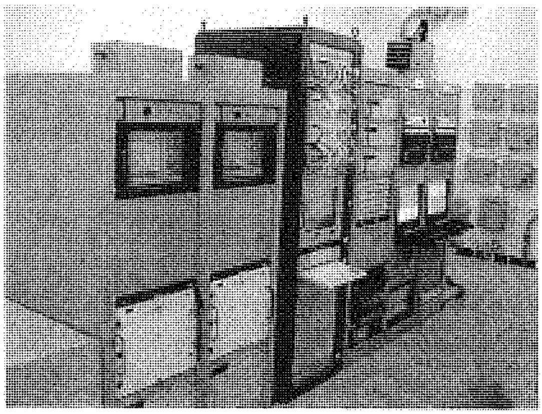
USCG Photos

- Large SWAIP
- Expensive
- Manpower intensive

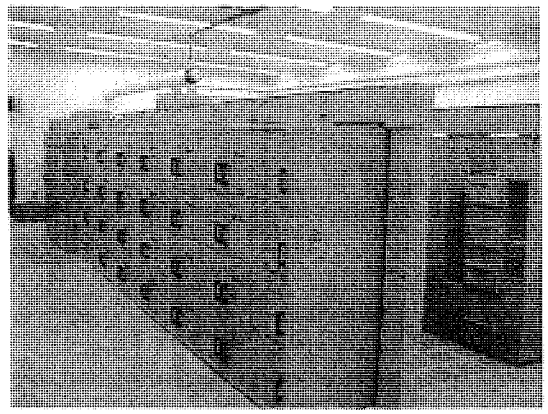


Today's Systems: 1980's, 1990's, early 2000's
USA, Europe, Asia, Middle East

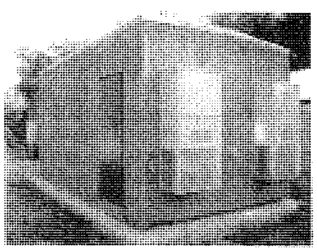
- Large SWAIP
- Expensive
- Less manpower intensive



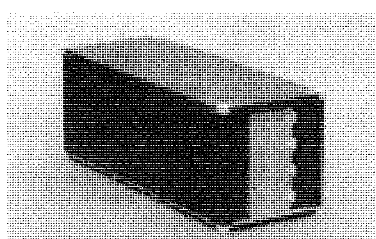
USCG Photos



Goal: Provide a service / Build: Site

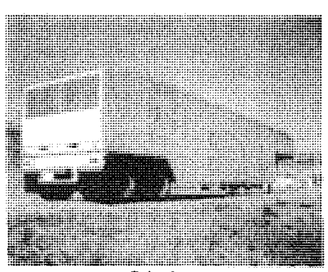


Thermo Bond

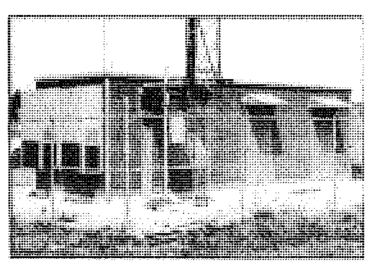


Alkan

Shelter One



Gichner



Miller Building Systems

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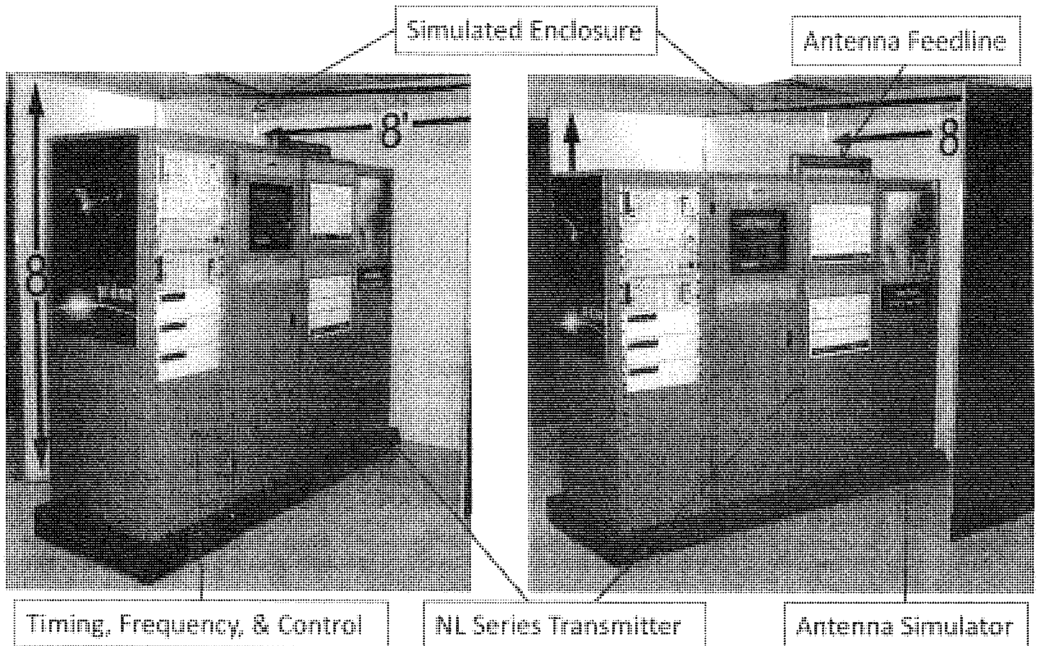
"eLoran-in-a-Box" Solution



Washington DC Metropolitan Area
Leesburg, Virginia

Corporate Headquarters
Chesapeake, Virginia

EMEA Operations
Bertem, Belgium

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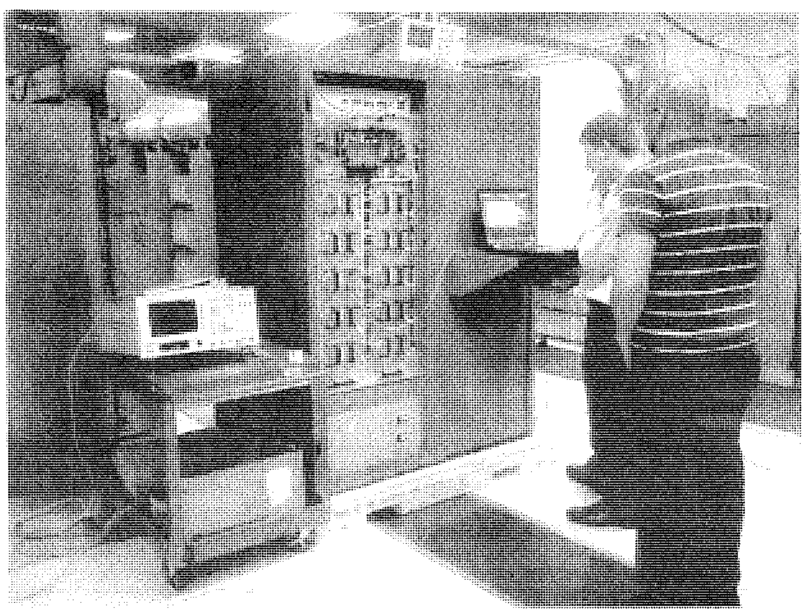
The Transmitter



First pulses into 625-foot TLM: 1100, May 12, 2008

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Leesburg, Virginia

Corporate Headquarters
Chesapeake, Virginia

EMEA Operations
Bertem, Belgium

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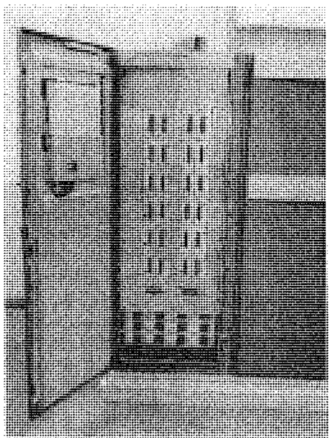
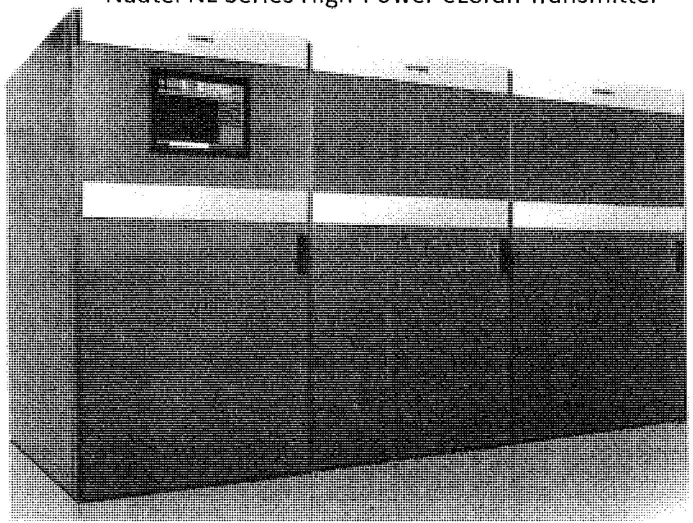
The Transmitter (cont.)

- 21st century robust LF transmitter
- Powerful hot-swappable power amplifiers
- Very high efficiency
- Very small footprint
- Very flexible



Nautel NL Series High-Power eLoran Transmitter



(1.84 m H x 5.58 m W x 1.12 m D)

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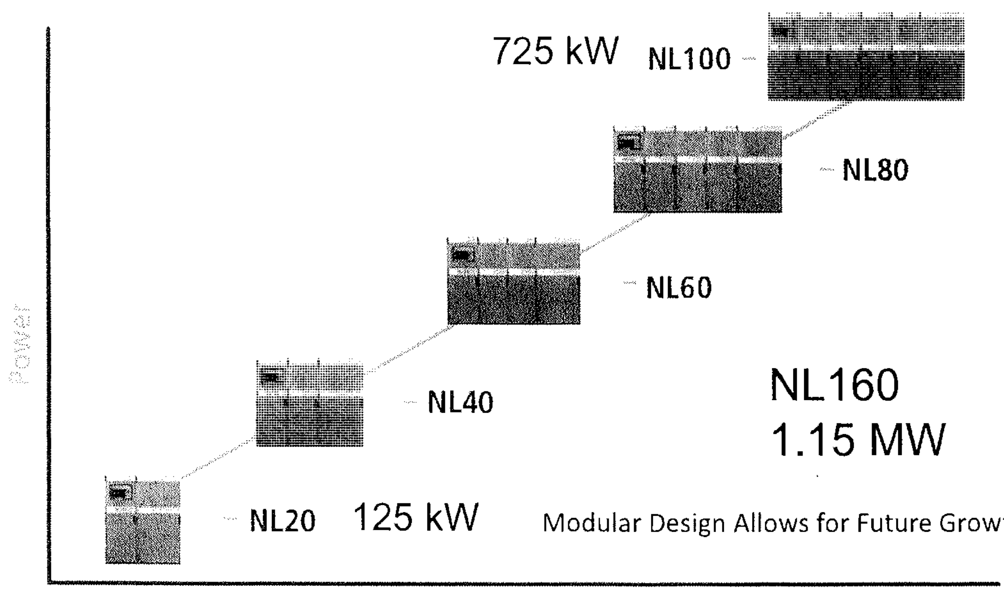
The Transmitter (cont.)



The NL Series naming convention is based on the total number of active modules in a given transmitter (ex. NL40 – 40 power modules)

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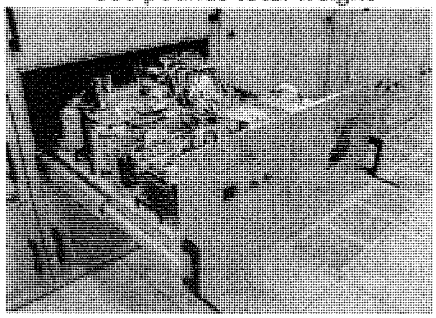
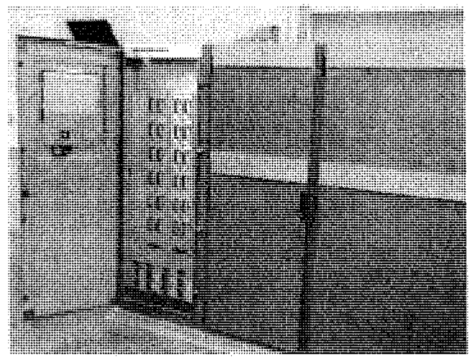
The Transmitter (cont.)

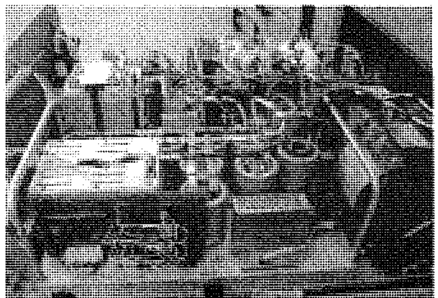
~ 300 pounds total weight



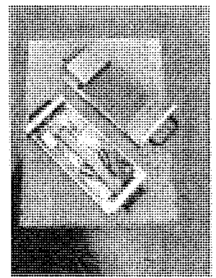
Accufix 6500/7500 Transmitter RF Amplifier (HCG)

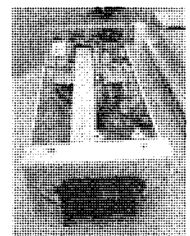


Nautel NL Series Transmitter RF Amplifier



50-75 pound individual module weights





~ 4 pounds

No heavy lifting required!

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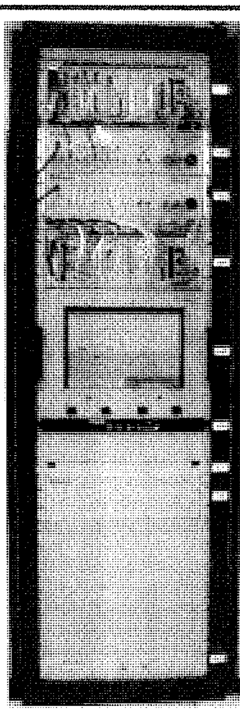
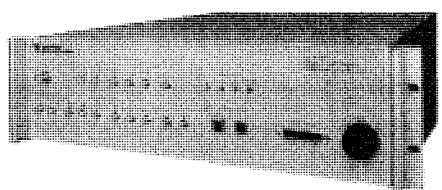
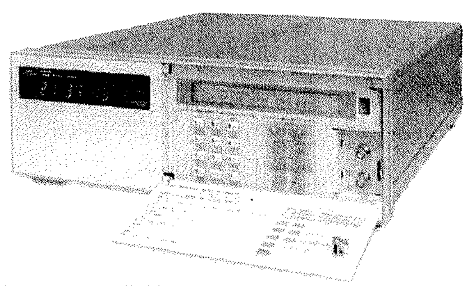
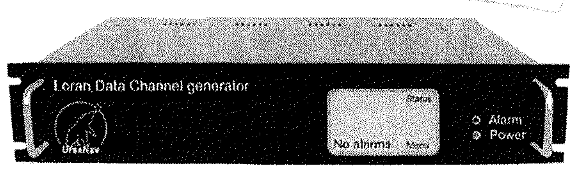
Timing and Frequency Equipment

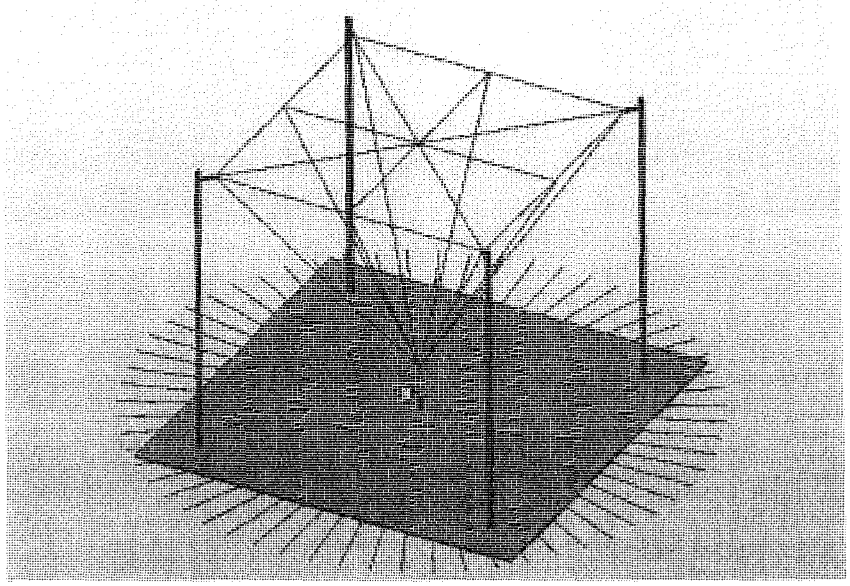




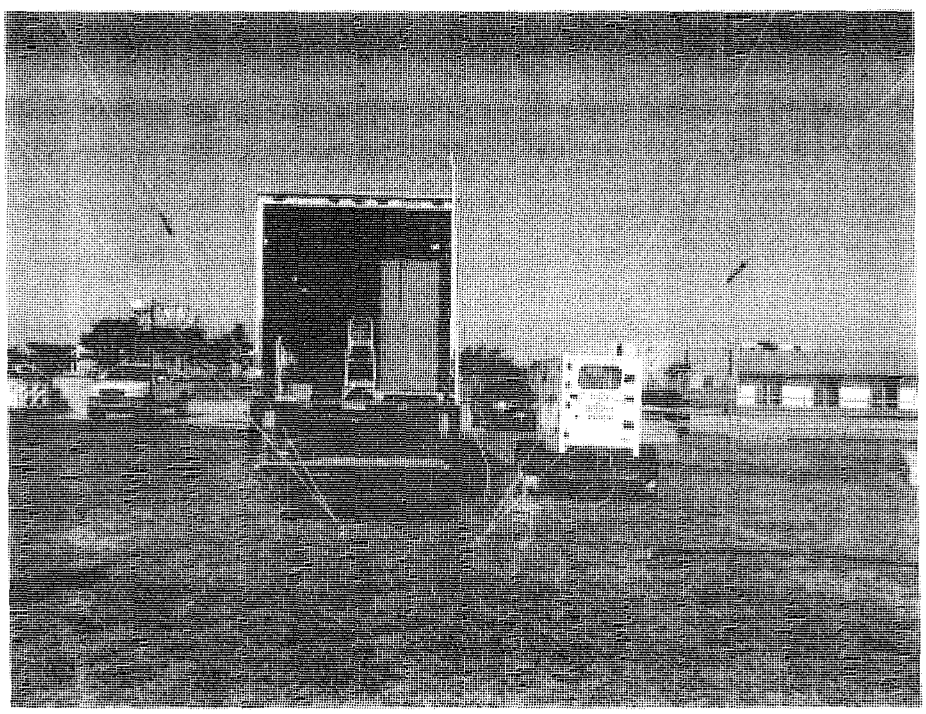




Small Footprint Inverted Cone
70- x 70- x 70-feet



Tactical eLoran System Field Testing



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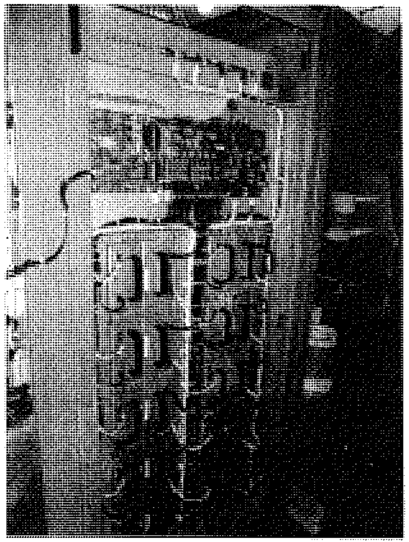
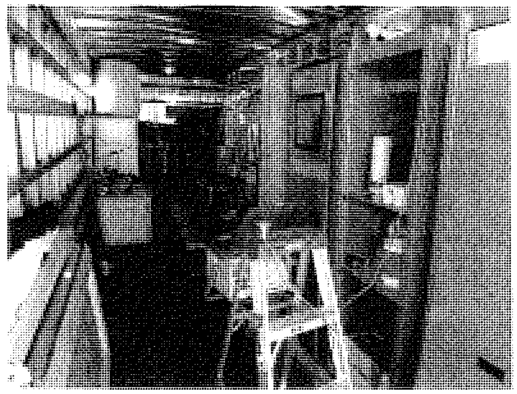
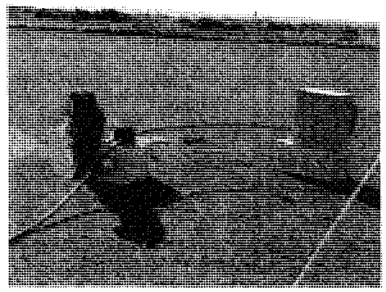
Tactical eLoran System Field Testing (cont.)

Prototype Transmitter





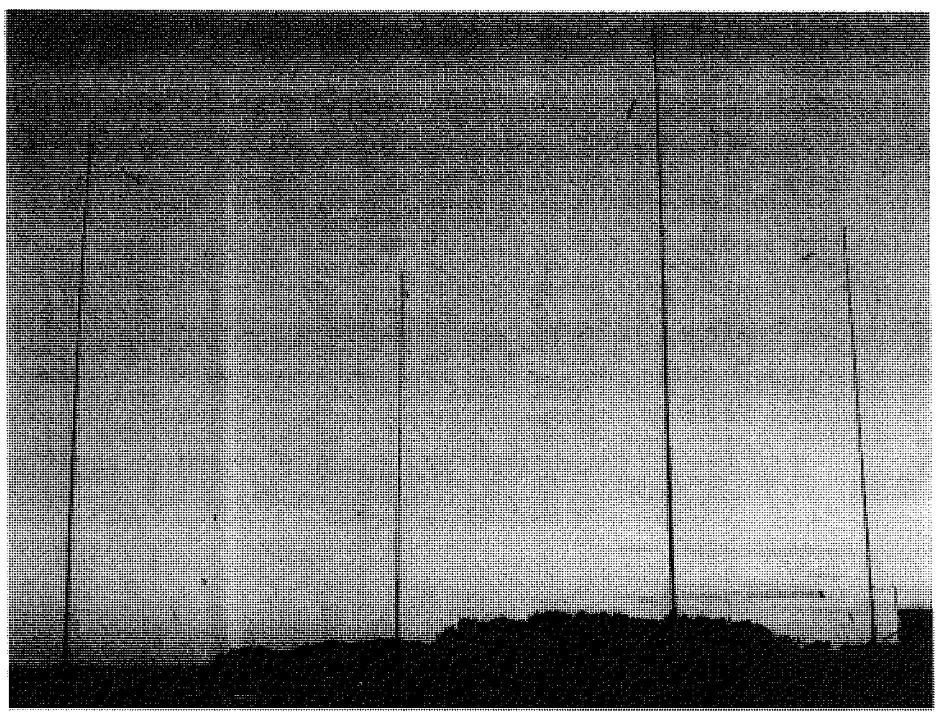
View Inside Truck



Antenna Feed Point

UrsaNav

Tactical eLoran System Field Testing (cont.)



Washington DC Metropolitan Area Leesburg, Virginia | **Corporate Headquarters** Chesapeake, Virginia | **EMEA Operations** Bertem, Belgium

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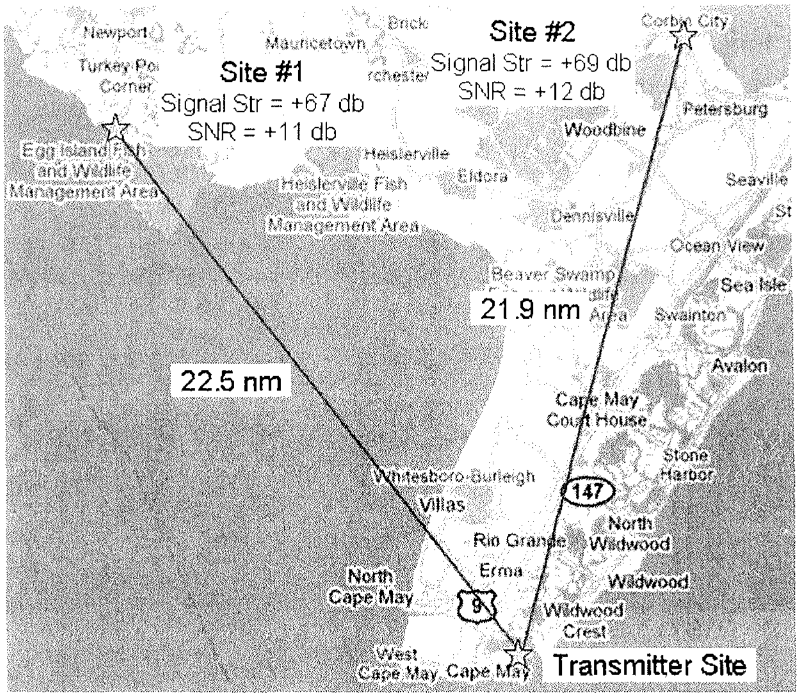
Tactical eLoran System Field Testing (cont.)



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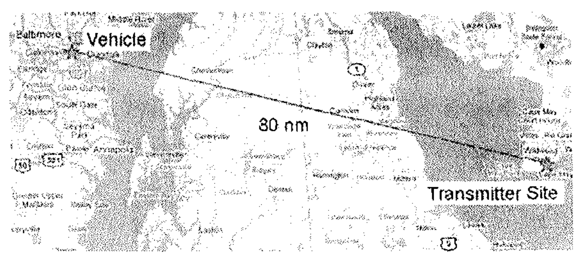
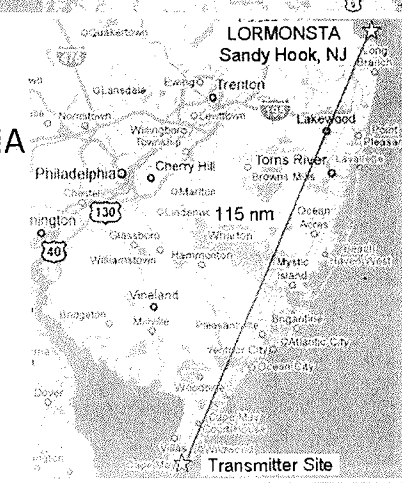
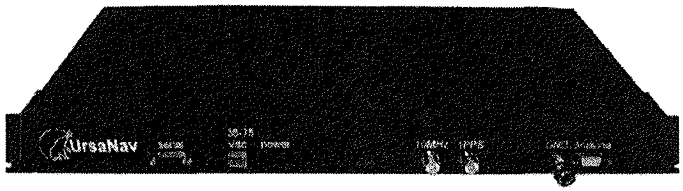
Tactical eLoran System Field Testing (cont.)

- 80 nm: Baltimore, MD
- 115 nm: Monitor Site
  Sandy Hook, NJ
  (+6 db SNR)
- 243 nm: Loran Station Seneca, NY
  (+1 db SNR)
- 263 nm: Loran Station Nantucket, MA
  (-2 db SNR)
- 328 nm: Loran Station
  Carolina Beach, NC
  (+1 db SNR)



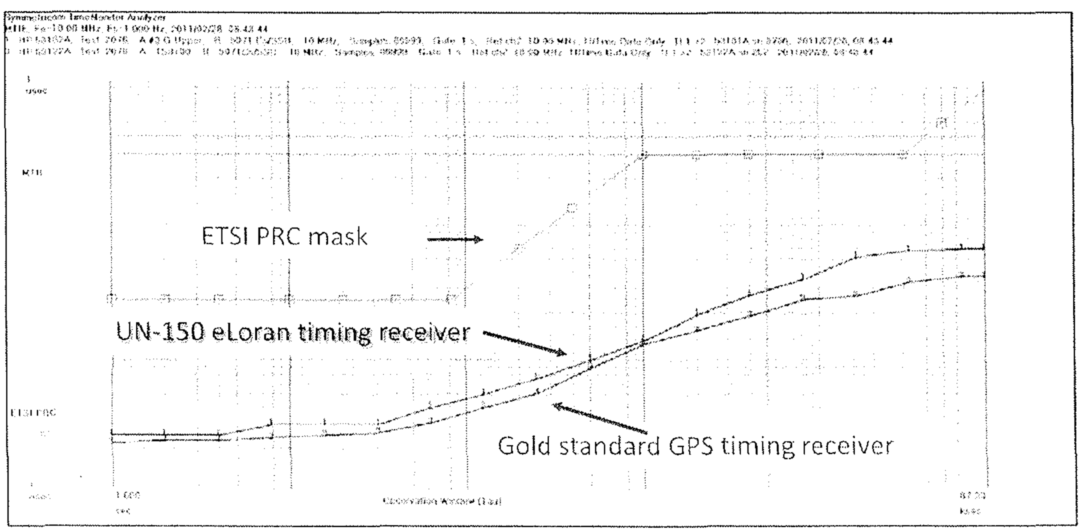


- UrsaNav acquired all Intellectual Property rights of **Locus** Inc., **Crossrate** LLC, and **Plutargus** – Combining IP to provide the best solutions for our customers



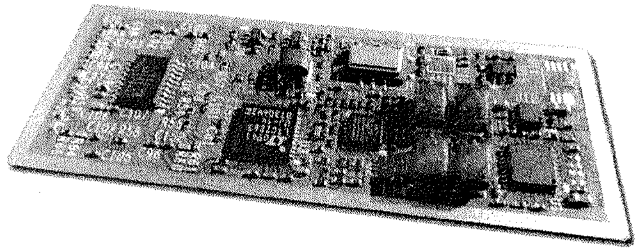
UrsaNav UN-150 eLoran Timing Receiver

- UN-150 eLoran timing receiver is the **first** to meet the stringent ETSI requirements for telecommunications Primary Reference Clocks
- **First and only** receiver to maintain smooth timing through failures of individual LORSTAs



- eLoran and GPS timing receivers both meet the ETSI Primary Reference Clock mask
- Both receivers show equivalent performance

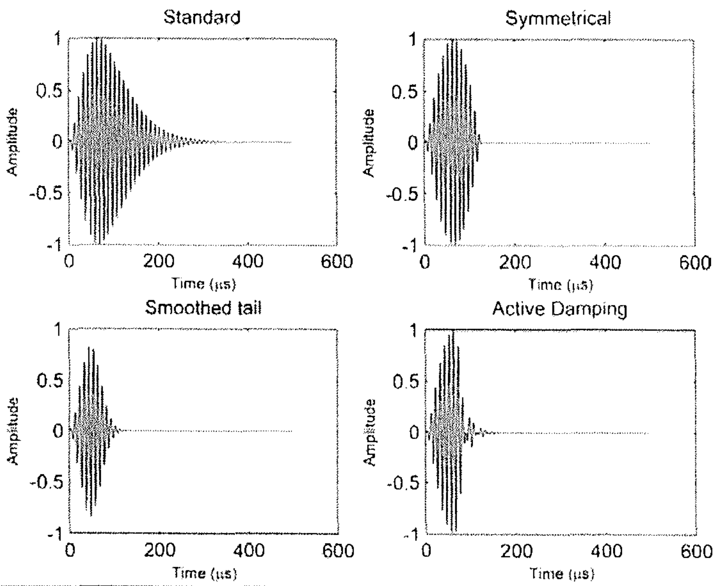
- Introducing the *Ursa Mitigator*^{TM} UN-151 LF PNT&D OEM Module



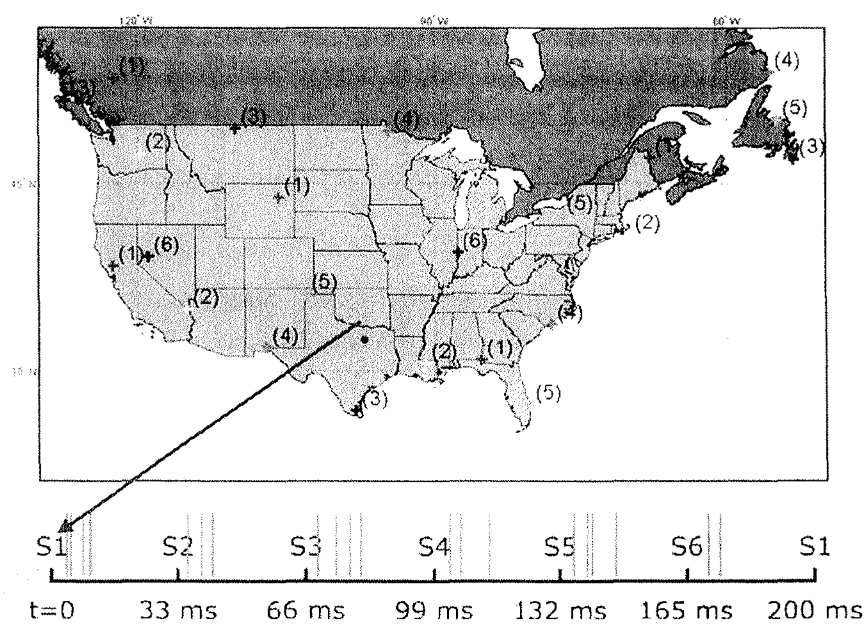
  - Robust, flexible, and affordable solution to meet the range of PNT&D receiver needs
  - Fully capable of receiving Loran-C, eLoran, and Chayka signals with built in future-proofing for next generation LF signals.
  - Small form factor.
  - Software configurable.
  - Complete range of integration capabilities.
  - Capable of processing multiple signals in the LF and MF bands.

- LF Phoenix™ is the newest generation in LF APNTD
- LF Phoenix™ combines its strong foundations with new insights in system design, making optimal use of today's improved technology for both provider and user equipment
- LF Phoenix™ will surpass the performance already demonstrated by the systems it is founded on
- Improved phase codes
  - Phase codes should average to zero
  - Pseudo-Random Noise (PRN) based phase codes will allow unique identification of a station in a group and will reduce cross-correlation of signals from other stations
- Remove Master 9th pulse
  - reduce cross-rate and free up time for data
- Improve pulse shape
- Reduce cross-rate effects
  - more stations with the same GRI
  - all stations single rated

- Waveforms can be optimized and specified more tightly
- Examples of experimental transmitted waveforms:



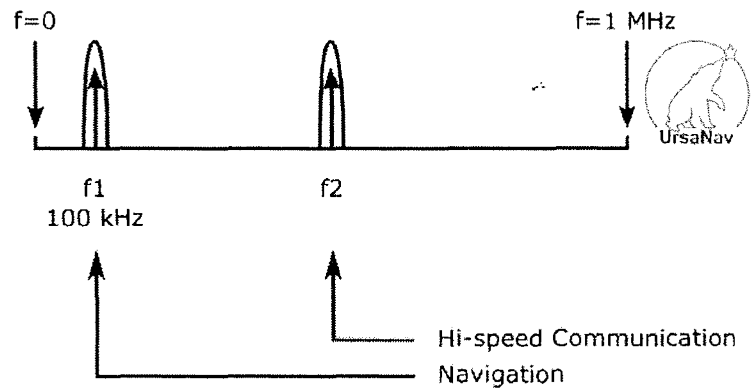
Transmitter equipment



UrsaNav

"Alternative to the Sky" LF APNT Mode 1

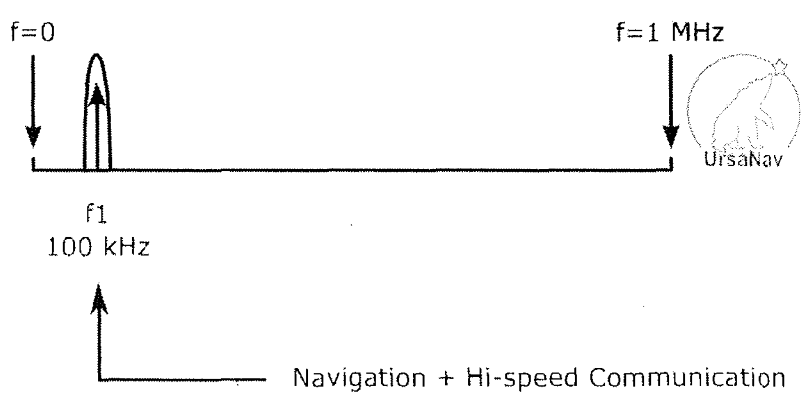
- Navigation with low-bitrate comms. eLoran has proven performance.
- Separate high-bitrate comms channel (1500 bps or more)
- Nav and comms possibly transmitted from single antenna
- Receiver: single box, single antenna



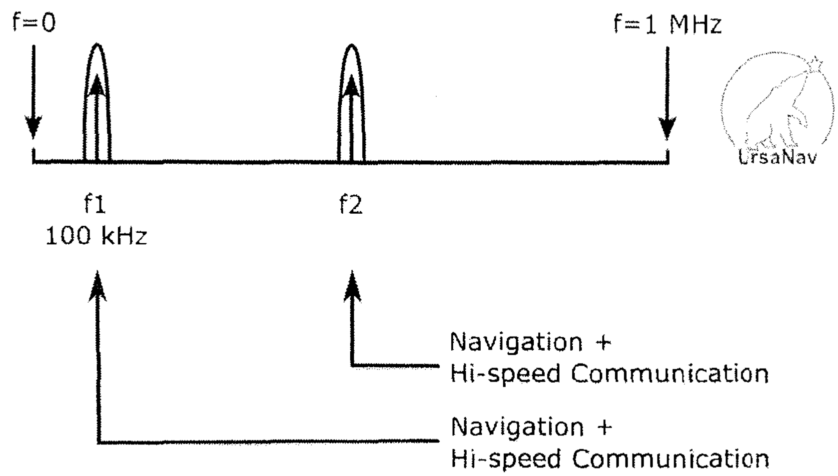
UrsaNav

"Alternative to the Sky" LF APNT Mode 2

- Navigation with high-speed comms (1500 bps or more)
- Uses same spectrum as Loran-C / eLoran
- LFPhoenix™



"Alternative to the Sky" LF APNT Mode 3



- f1: Long-range navigation with comms (1500 bps)
- f2: Short-range navigation with comms (>1500 bps)
- Nav and comms possibly transmitted from single antenna
- Receiver: single box, single antenna

OFDM(A) for LF APNT Mode 2/3

- Current LF communications are typically below 100 bps
- Dedicating a time slice to communications allows advanced techniques
- Orthogonal Frequency Division Multiple Access (OFDMA)
  - Allows very efficient time/bandwidth use
  - High data throughput (>1500 bps usable)
  - Robust against impulsive noise
  - Multiple transmitters operating at the same time with no interference
  - Little to no increase in power outside of the 90-110 kHz band, depending on transmitter linearity
- While OFDMA is the most promising new modulation technique, we are studying others

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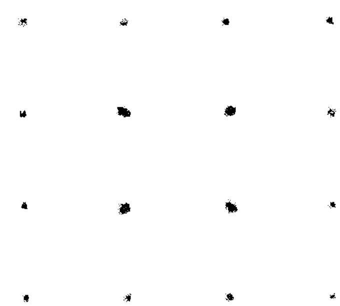
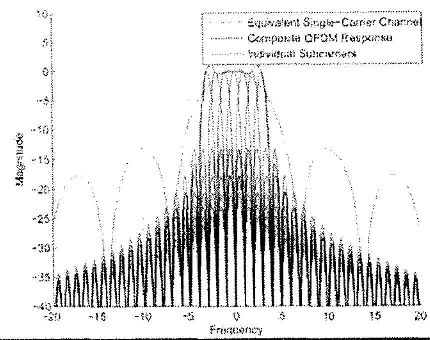
OFDM(A) Overview

- Large number of orthogonal carriers
- Typically uses amplitude and phase modulation on each carrier (QAM)
- Used in modern communications systems due to bandwidth efficiency
- Longer symbol times decrease bandwidth requirements and increase robustness
- Use of pilot carriers enhances synchronization and allows the channel to be equalized





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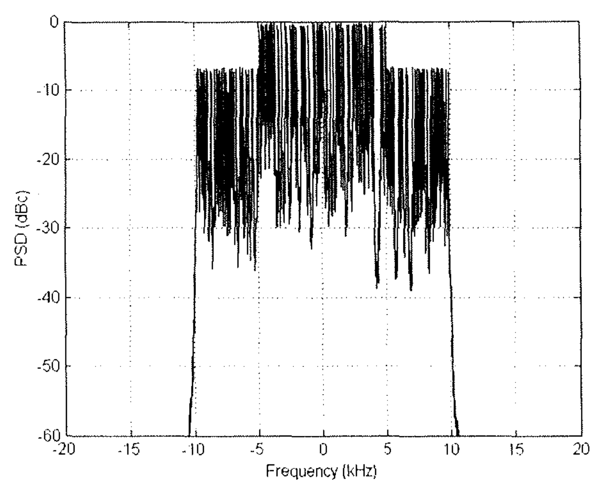
OFDMA LF Signal

- 805 carriers total
- 161 carriers per site
- 78 16 QAM carrier
- 78 QPSK carriers
- 5 BPSK pilot carriers
- 473 bits/symbol
- 2838 bps (uncoded)



- Coding rate of 2/3 could achieve **1892** bps per transmitter
- Resultant signal has similar bandwidth requirements to the navigation pulse, allowing **one transmitter** for both signals

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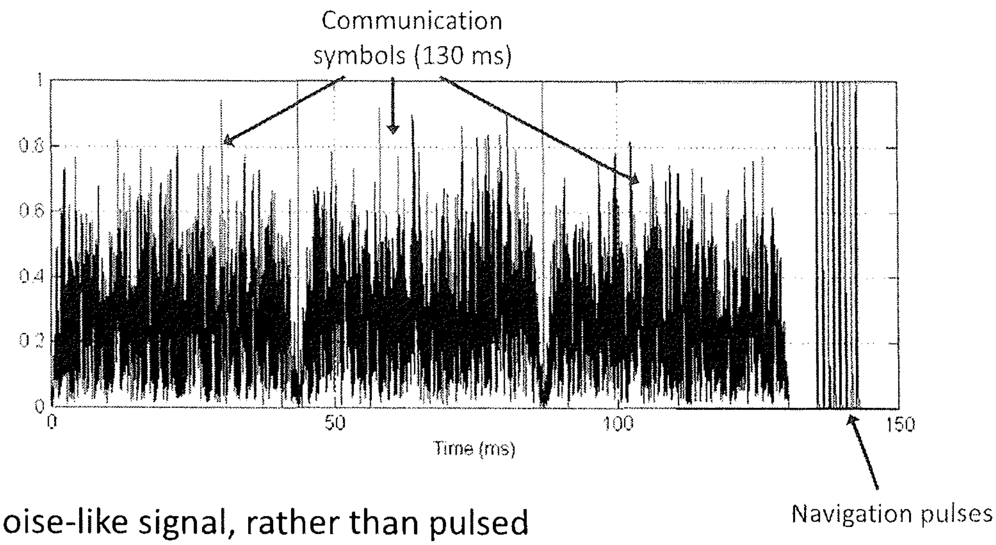
OFDMA Signal Envelope



- Noise-like signal, rather than pulsed
- Signal peaks similar to navigation pulses
- Long symbol time allows noise to be averaged

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Signal Receivability

- Time and frequency synchronization from the navigation pulses
- Skywave component signal strength boosts receivability with proper signal equalization
- Navigation pulses can help determine the equalization coefficients for the receiver
  - Navigation signal is known
  - Several pulses per second
- Signal from one transmitter provides reliable communication, although multiple sites could be received simultaneously without degradation

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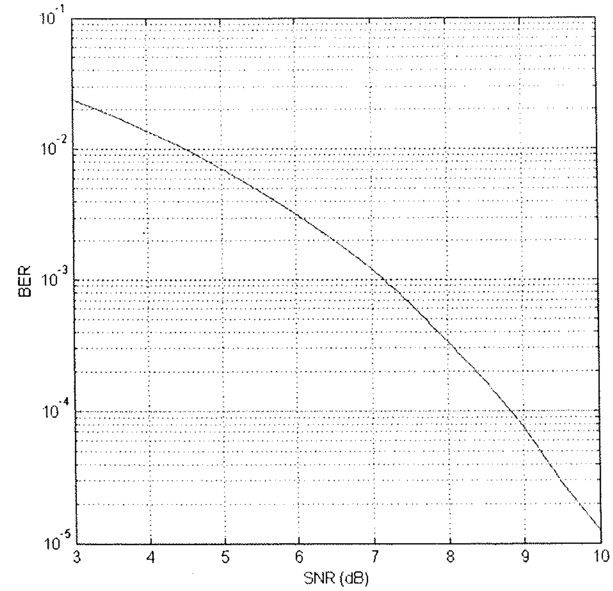
Bit Error Rate Performance

- SNR of 7 dB required for BER of 0.1%
- At possible transmitted power, should be feasible
- Forward error correction can be used to lower BER
- Cyclic redundancy check would ensure reliable reception



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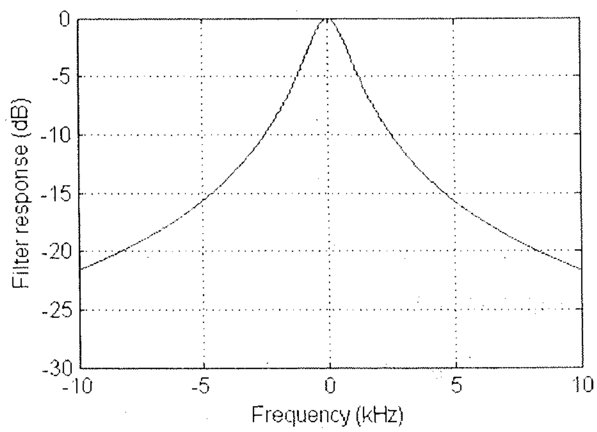
Achievable Output with Q=55

- With an antenna Q of 55, a system Q of 60 would be a reasonable expectation
- Scaling the signal for the transmitter peak voltage, it is possible to get -9.7 dB continuous power relative to the navigation pulse peak



- For a 400 kW LORAN transmitter, 42.8 kW RMS would be achievable
- More aggressive peak limiting could be used to get additional power if required

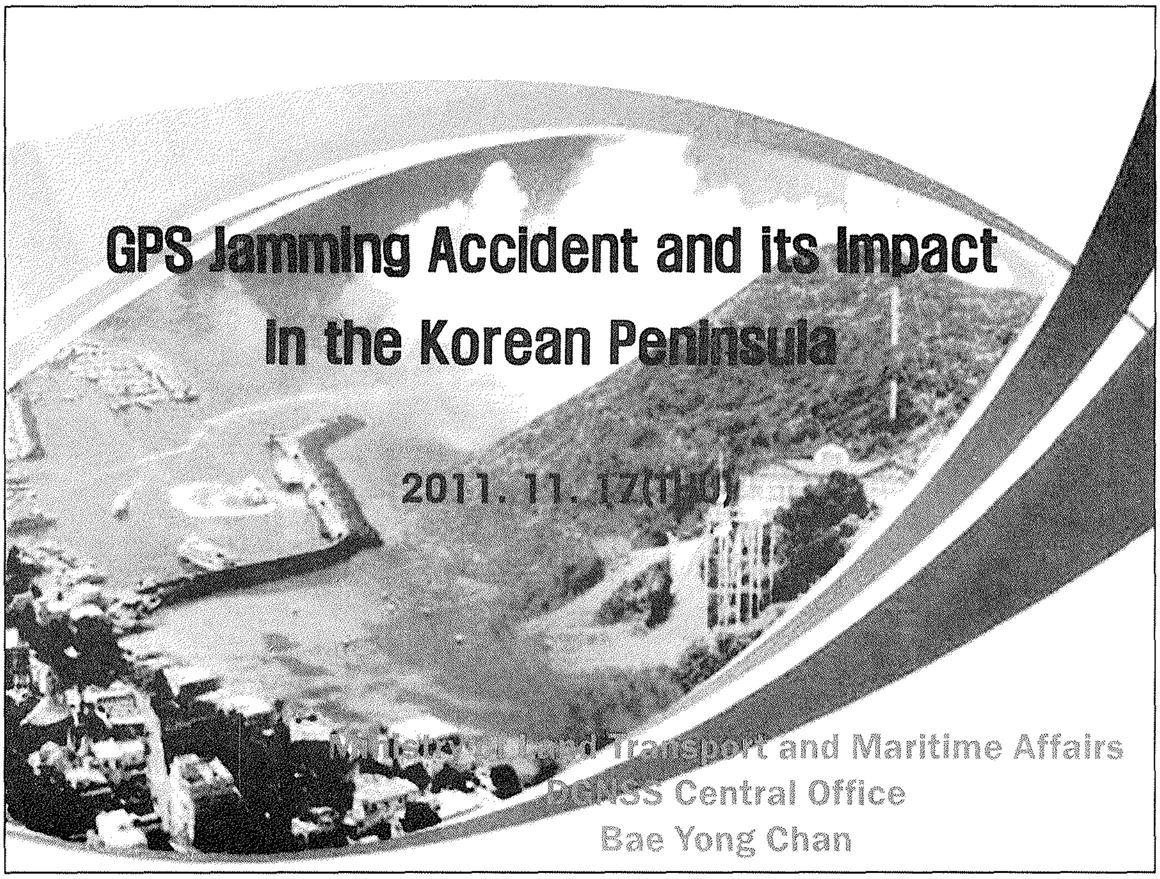
Advances in Technology

- High efficiency, low cost, multi-mode transmitters
- Advanced transmit antenna designs (including diplexing)
- Precision time and frequency foundation
- ns UTC synchronization capability
- State-of-the-art multi-mode receivers
- Advanced H-Field and E-Field antenna designs
- Advanced signal waveforms
- Advanced modulation techniques
- Loran data channel equipment
- TWSTT / TWLFTT equipment
- Autonomous control capability
- Small size, weight, input power, and cooling

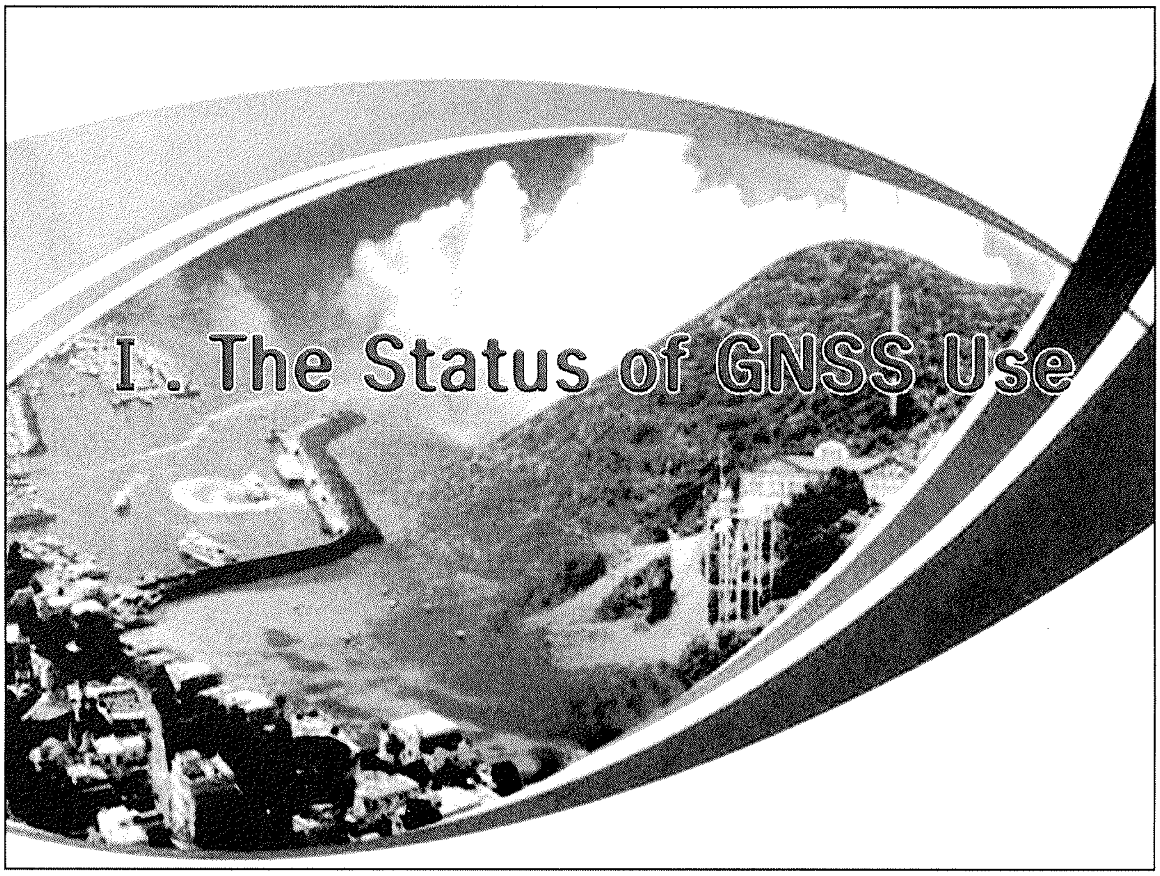
UrsaNav / Nautel / Symmetricom

- Our LF options:
  - Provide independent UTC timing to an accuracy of at least 50 ns;
  - Provide an independent positioning service that meets HEA, FAA RNP 0.3 and PBN RNAV + RNP for aviation enroute requirements
  - Include data channel capabilities of at least 1,500 BPS;
  - Can meet world-wide APNT requirements
- We have already developed and tested a high-efficiency, small footprint, LF system
- Our LF solutions include a combination of fully developed and proof-of-concept technology
- We are building upon proven receiver technology to develop the next generation of Loran-C, eLoran, LFPhoenix™, and future LF PNT&D receivers
- We recommend that LF options receive the highest consideration as alternative solutions for the international PNT community.


UrsaNav
Your Alternatives to the Sky™
Safeguarding your mobile communications, banking, and utilities.


GPS Jamming Accident and its Impact
in the Korean Peninsula
2011. 11. 17(THU)
Ministry of Land Transport and Maritime Affairs
DGNSS Central Office
Bae Yong Chan

CONTENTS



I. The Status of GNSS Use

1. GNSS Market

- The development of a new huge market by GNSS technology

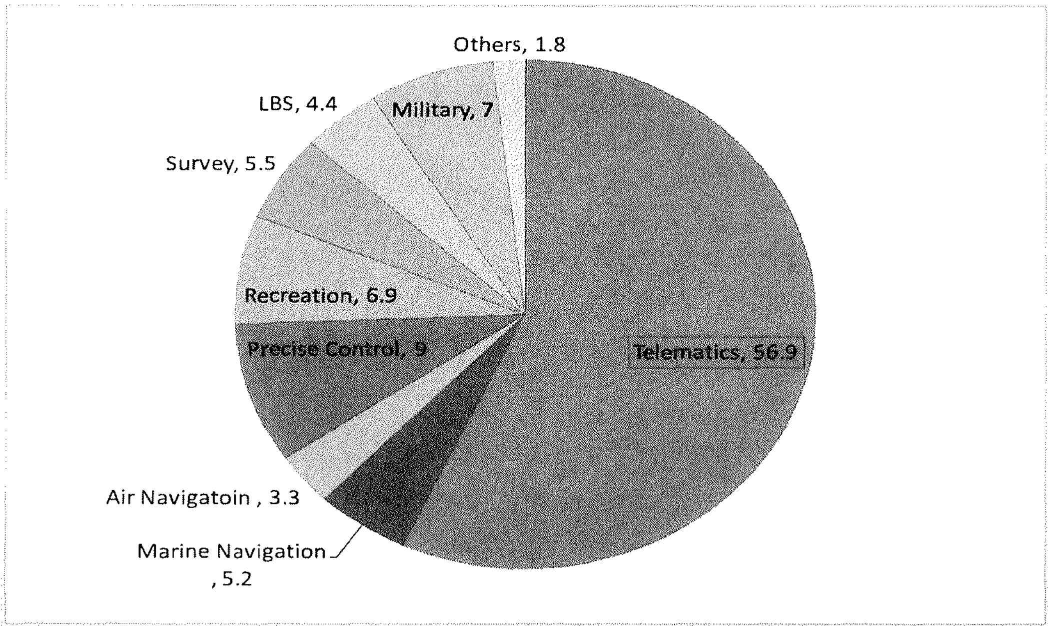
<GNSS World Market Expectation> (ABI Research , million $)

Year	2005	2006	2007	2008	2009	2010	Annual Growth Rate
Scale	21,787	25,197	28,025	31,283	34,961	37,931	11.8%

- The Scale of Korean GNSS Market is expected to be $1.66 billion
  - The main social Infrastructures (Defense, Administration and Communication)
  - The Personal positioning information utilities (Navigation, Smartphone and Security)

Ⅰ. The Status of GNSS Use

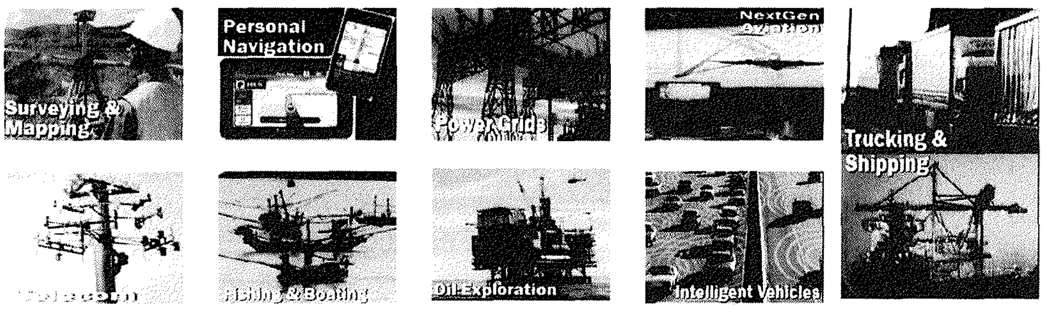
2. Application Market (%)



Ⅰ. The Status of GNSS Use

3. Dependence on GPS

○ GNSS is Essential to Our Economies



○ GPS Dependence in Europe (from 9th March 2011, BBC)

- GDP 6~7% from Positioning Information (Commission of the European Communities)
- The Lack of Countermeasures Against the Jamming
- The Necessity of eLoran to cope with the GPS failure due to Jamming

○ **Korea Expects roughly $ 7 billion worth of GPS annually**

Ⅱ. IMO & IALA

1. IMO - 57th NAV (London, 6~10 JUNE 2011)

- Need for high Accuracy Position information system
  - The GNSS jamming or interference would damage or threaten the safe navigation of vessel
  - Recommended to use GNSS for positioning system (Res A.915(22))
  - Recognized the essential factor e-Navigation strategy
  - The 14th COMSAR committee proposed terrestrial GNSS back up
  - The 56th NAV recommended to consider the use of terrestrial navigation system like eLoran for GNSS back up

- Although GNSS including DGNSS have integrity monitoring function, all of them are not resilient against jamming

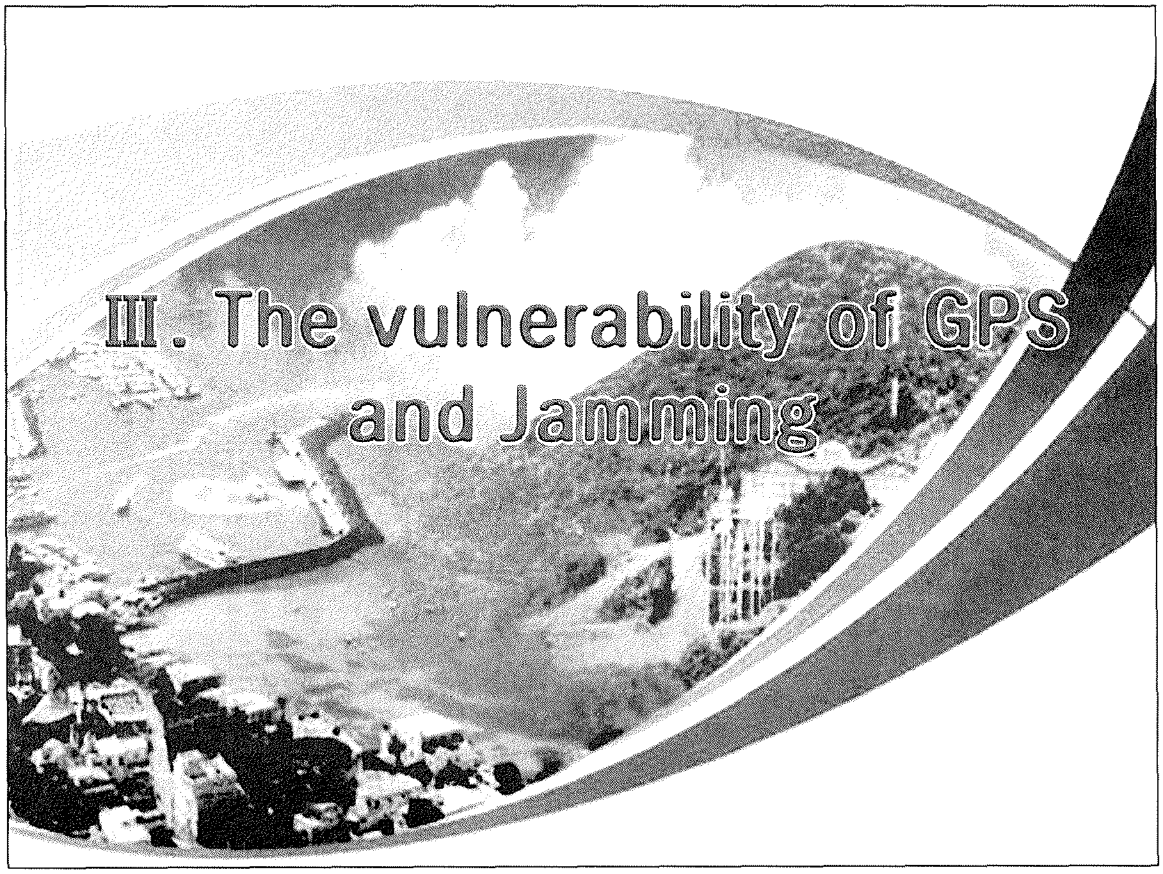
Ⅱ. IMO & IALA

2. IALA - 51th Council (Brazil, 20~24 June 2011)

- Korea suggested another name of eLoran as TERANAV (Terrestrial RAdio Navigation)
  - The eLoran Guideline will be developed

- The seminar or workshop for reviewing the ground-based alternative navigation system (eLoran) against the GPS jamming or vulnerability
  - This will be the Formal agenda for the next meeting

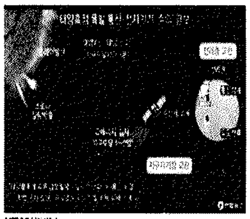
- U.K and Ireland run 3 eLoran monitoring stations, India advances to develop eLoran



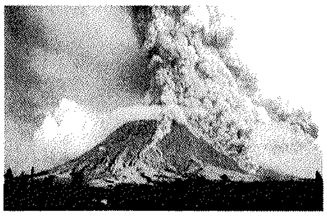
Ⅲ. The vulnerability of GPS and Jamming

1. GPS vulnerability

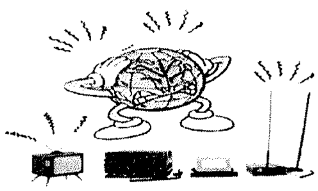
- Unintentional Jamming
- Intentional Jamming



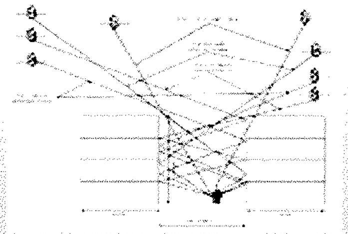
(Solar Flare)



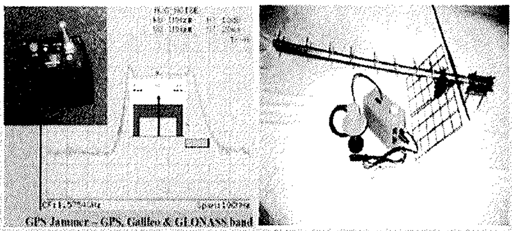
(Earthquake or Volcano)



(Radio Frequency Interference, RFI)



(Multipath)

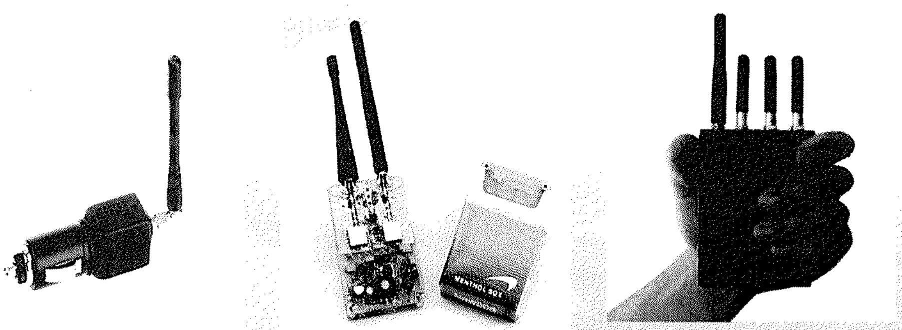


(Jamming / Spoofing)

Ⅲ. The vulnerability of GPS and Jamming

2. GPS Jamming Feature

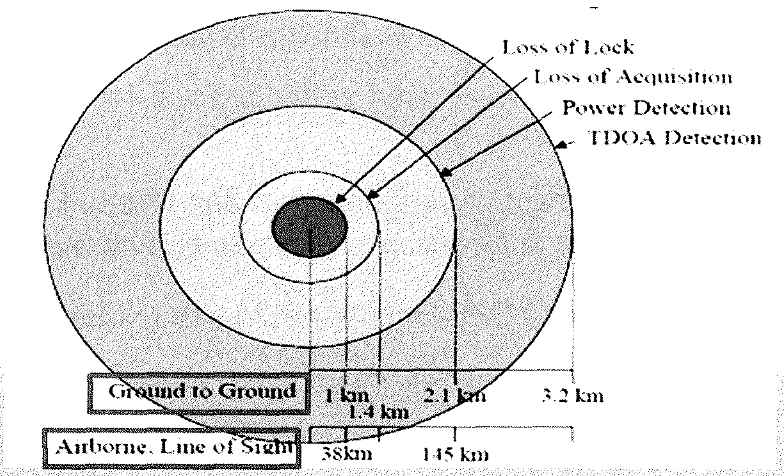
- Jamming : "Interfering with communications or surveillance"
- Provoking GPS signal interruption or Position error
  ※ much less level than mobile phone (under 0.01uW)
- Easy to produce and buy various type of Jammer

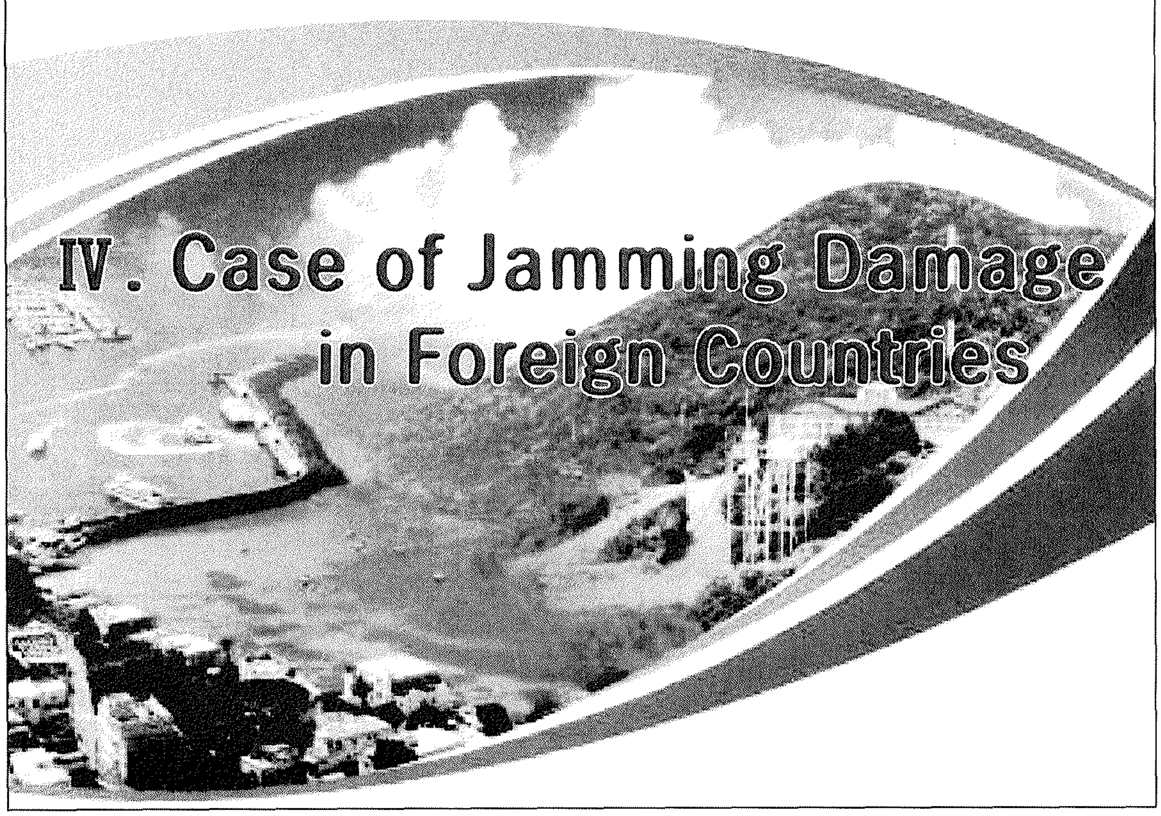


Ⅲ. The vulnerability of GPS and Jamming

3. GPS Jamming Coverage

- Only 10W Jammer, it impacts to hundreds km distance in the air
  ※ The effect distance is Land < Coast < Air by UHF feature





Ⅳ. Case of Jamming Damage in Foreign Countries

1. GPS Jamming Example

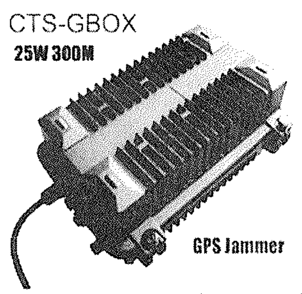
- 2001, USA used L1 C/A interference equipment in the Afghanistan war
- April 2001, The unintentional malfunction of TV antenna amplifier occurred in Moss Landing, CA for 37 days
- Dec. 2001, The Jammer impact to the air-navigation in Mesa ,AZ
- 2003, Russian Jammers were used in the Iraq war for incapacitating USA guided missile
- April 2007, Naval Jamming train(2 hours) in San Diego, CA
  ※ mobile phone was out of service, aircraft & ship guiding system stopped
- 2009, A truck driver used GPS jammer not to pay toll fee in NJ
- 2010, A truck robber activated GPS jammer to interrupt tracking
- OCT 2011, GPS Jamming during Europe's largest military exercise has been suspended, following complaints from fishermen.

Ⅳ. Case of Jamming Damage in Foreign Countries

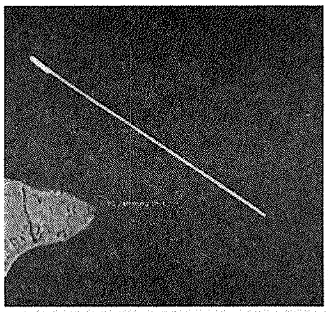
2. GPS Jamming Test

- GLA and DSTL jointly tested the Jamming in April 2008

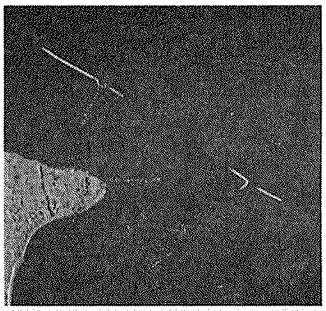
  -Test Item : DGPS based Navigation, Ship AIS, Synchronized Lights, and etc.
  - Conclusion : GPS is easy to be attacked by low power jammer and the effect can take serious impact to the maritime navigation safety



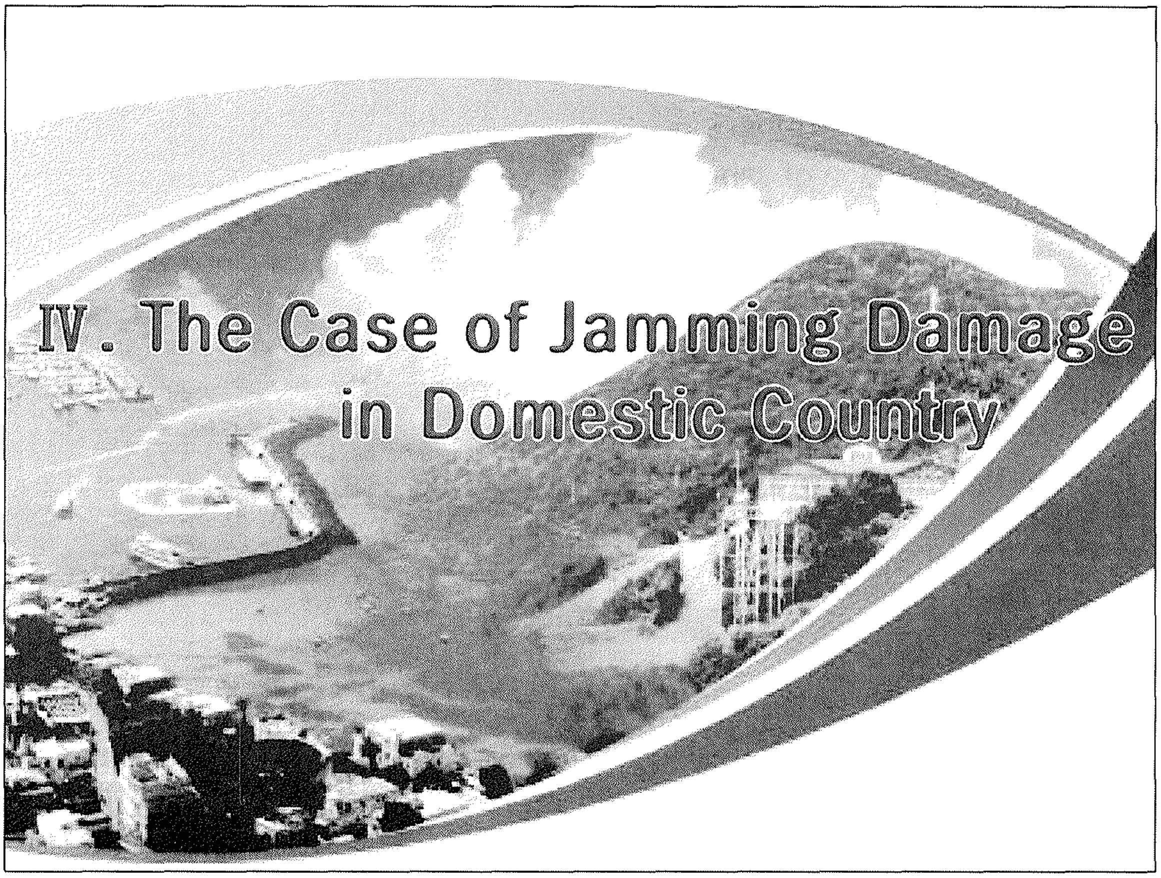
(Used Jammer)



(Before Jamming)
※ Green shows ship movement



(After Jamming)
※ False navigation information

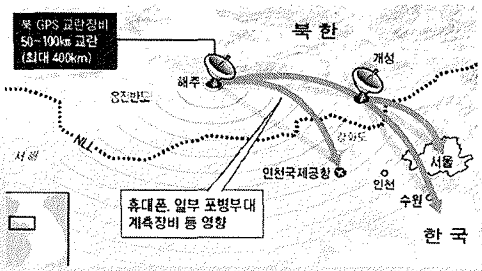


Ⅳ. The Case of Jamming Damage in Domestic Country

Ⅳ. The Case of Jamming Damage in Domestic Country

1. GPS Jamming Case

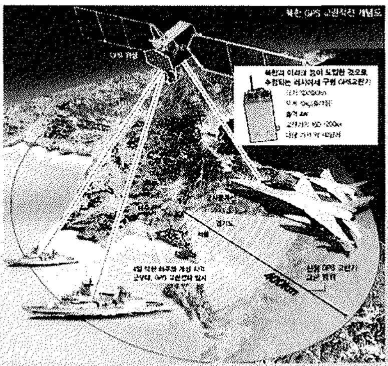
- Period and its impact
  - '10. 08. 23 ~ 25 – Ships and Aircraft experienced GPS malfunction (180)
  - '10. 12. 19 ~ 20 – GPS failure affected mobile communication station in
  - '11. 02. 25 ~ 26   the metropolitan area
  - '11. 03. 04 ~ 09 – DGPS in Western Sea experienced the GPS error
- Character
  - A number of Intentional Jamming attacks occurred by NK after Aug 2008
  - During Korean Military training period, it occurred intesively
  - KCC assumed Hae-ju and Gae-sung by the signal tracking
  - Assuming Jammer was improved after importing from Russia in the late 90s

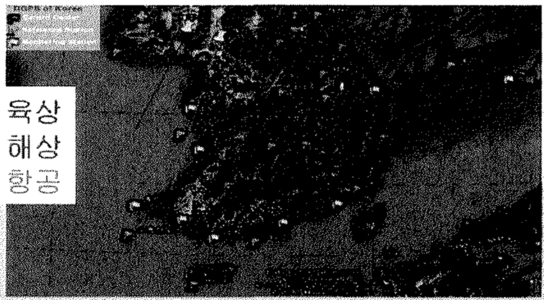


Ⅳ. The Case of Jamming Damage in Domestic Country

2. GPS Jamming Impacts

- The propagation of Jamming signal new thoughts
  - GPS L1(1.5GHZ, UHF) transmits Visibility Range Wave
  - The Jamming signal was transmitted form 2 locations in the mountains (alt. 400~600m)
  - Jamming effect covers 100km in the maritime and 400km in the air (alt. 8km) from calculation of radio wave visibility range principle
  - But it can affect to Seoul neighbor area due to reduction of power



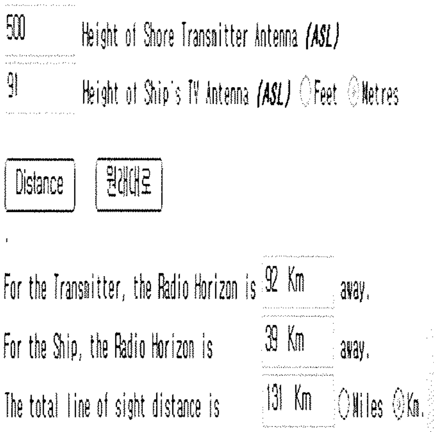


(국민일보 기사 참조)

Ⅳ. The Case of Jamming Damage in Domestic Country

3. DGPS detects Jamming

- DGPS RS/IM detected Jamming
  - 23~25 Aug 2010 (3 days) Some DGPS detected GPS failure
  - It reached farther 60km than the theoretical distance in Eochungdo (Assuming, the high power jammers were used in high altitude with the high acquisition terrestrial antenna)

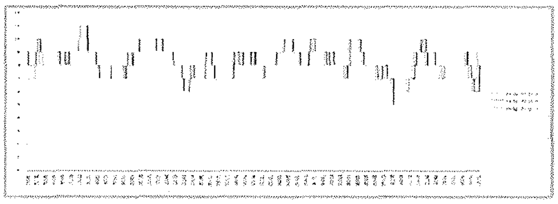


(Theoretical distance/Eocheongdo RS Alt =91m)

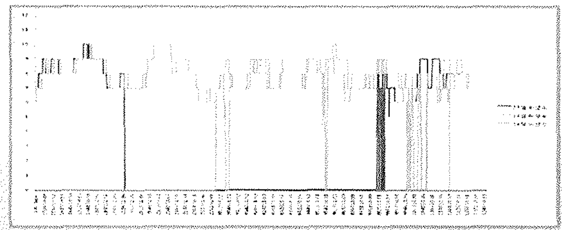
Ⅳ. The Case of Jamming Damage in Domestic Country

4. DGPS Jamming Impacts

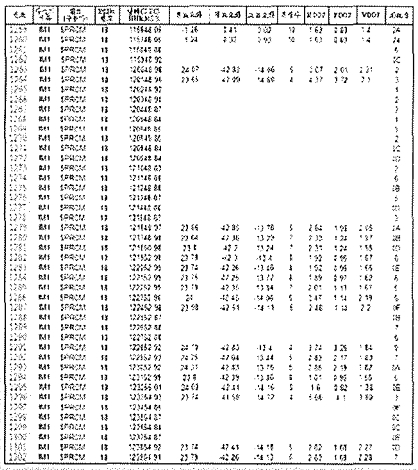
- DGPS system Jamming Impact
  - GPS failure occurred in short 1~2 min. and in long over 10min intermittently
  - It took SVN down, and protected GPS signal traking



(Un-affected RS / 3 days)



(Affected RS (Eocheongdo)/ 3 days)

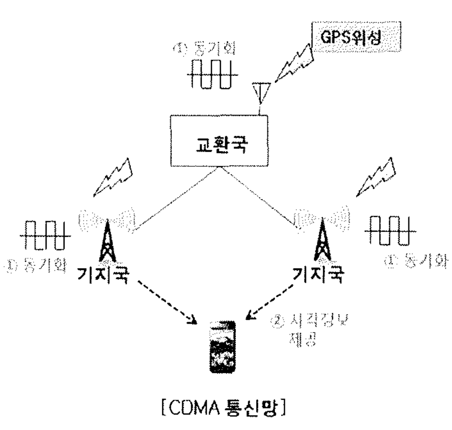


(When Jamming occurred, RSIM #18 Msg)

Ⅳ. The Case of Jamming Damage in Domestic Country

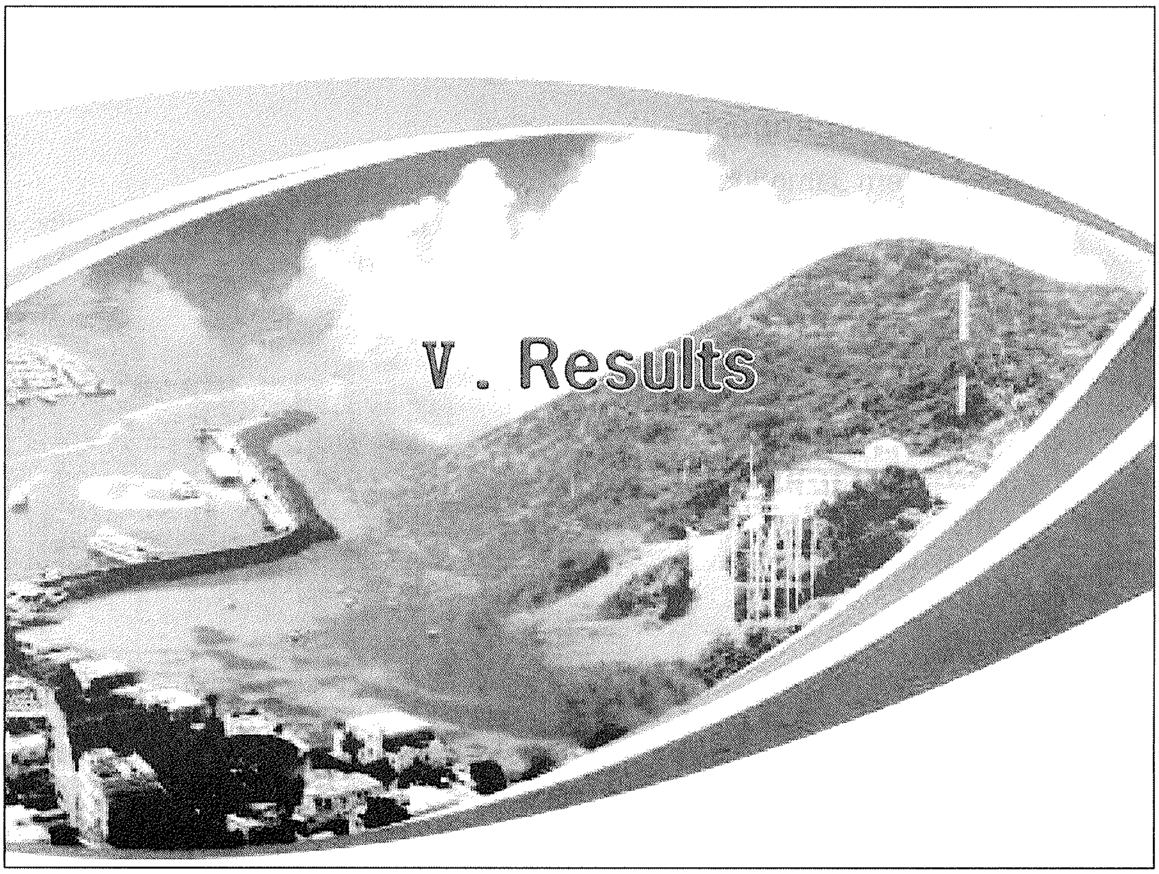
5. Mobile Communication Jamming Impact

- Mobile Communication service(CDMA) impact by GPS jamming
  - Receiver timing error, Hand-off error and Trans/Rec failure
  - 23~25.AUG. 2010 : 13 CDMA stations (metropolitan area)
  - 4~14.March. 2011 : 39 CDMA stations (metropolitan area))
  - Impact CDMA stations, 60km from Jamming transmission point



(How CDMA works and Sync)

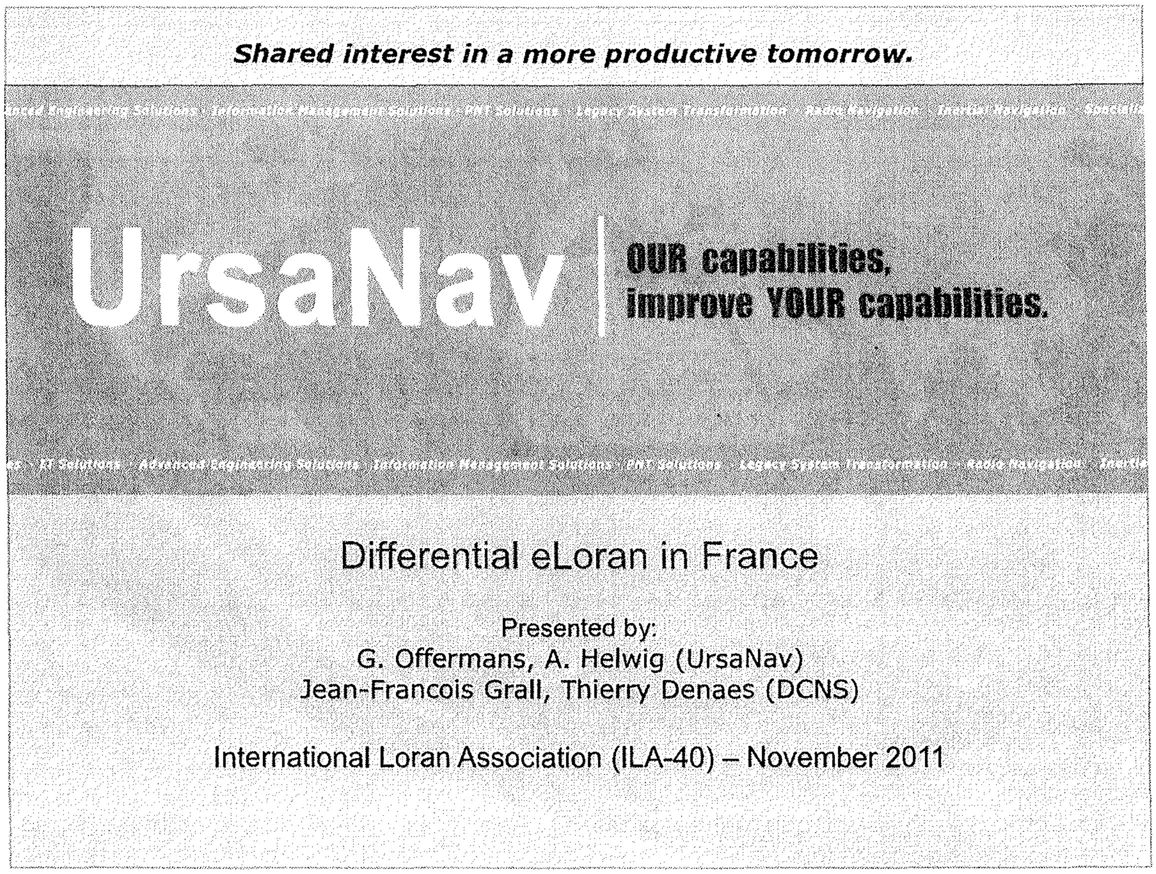
(Mobile communication station in damage area)

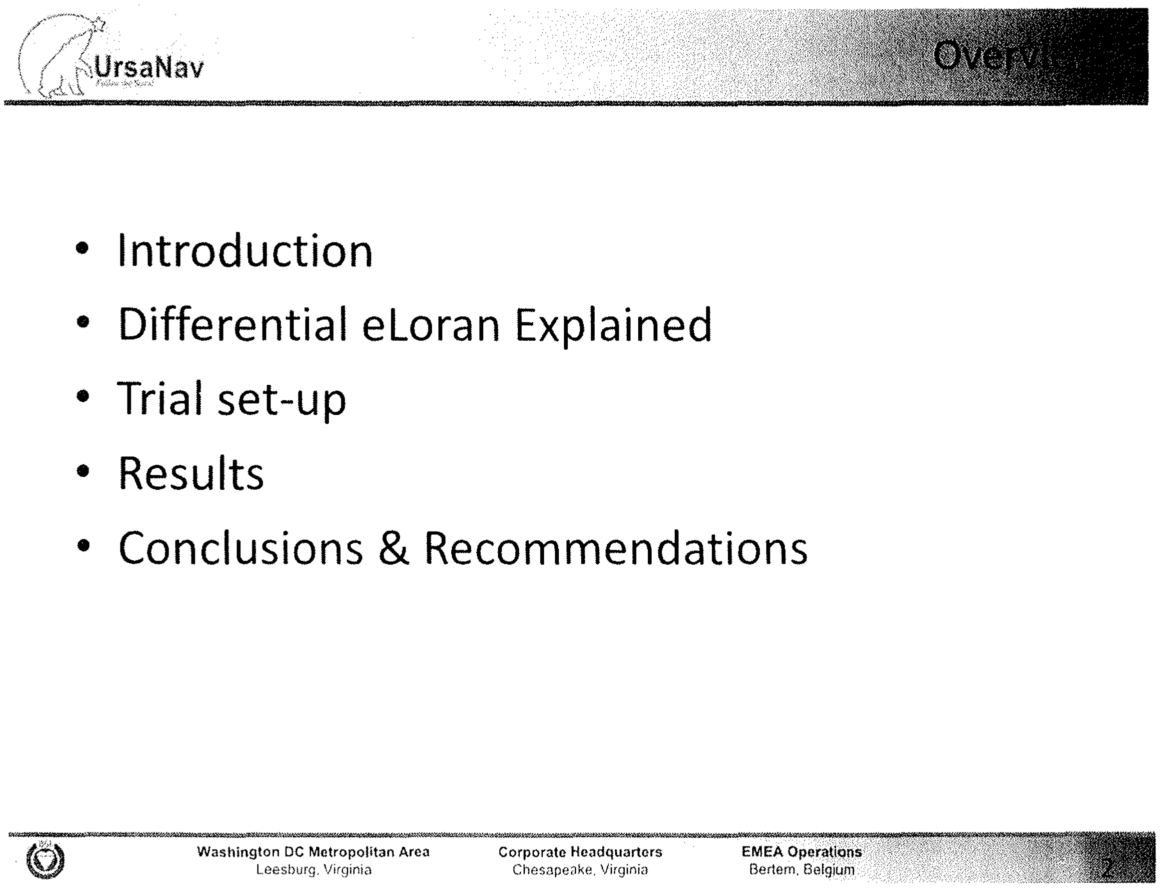


Ⅴ. Results

- As Korean PNT depends on GPS heavily, the Intentional jamming by North Korea can provoke serious impact to many applications
- Integrity Monitoring system adoption for detection of GNSS vulnerability including jamming, and the close relation among the Authorities
- Land based Timing synchronizing system for complementary cooperation between Broadcast and Communication
- Early establishment of eLoran, using Loran-C with low cost, for GNSS failure


Thank You


Shared interest in a more productive tomorrow.
UrsaNav
OUR capabilities,
improve YOUR capabilities.
Differential eLoran in France
Presented by:
G. Offermans, A. Helwig (UrsaNav)
Jean-Francois Grall, Thierry Denaes (DCNS)
International Loran Association (ILA-40) – November 2011


UrsaNav
Overvi
• Introduction
• Differential eLoran Explained
• Trial set-up
• Results
• Conclusions & Recommendations
Washington DC Metropolitan Area
Leesburg, Virginia
Corporate Headquarters
Chesapeake, Virginia
EMEA Operations
Bertem, Belgium
2

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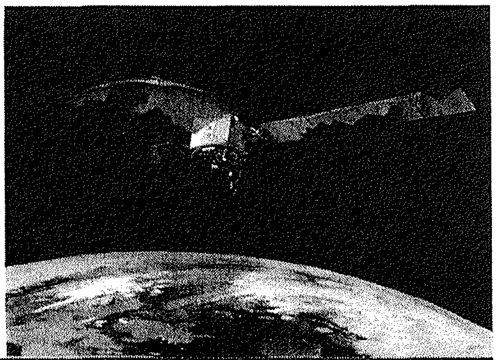
Why do we need an alternative PNT solution?

Known GNSS Vulnerabilities

- Performance degradation - natural phenomenon
  - Ionospheric & solar activities
- Performance degradation - human factors
  - Unintentional & intentional (hostile)
- Signal blockage
- Spectrum competition from non-Rnav systems
- Common signal use across GNSS: L1, L2, L5
- Radio frequency interference
- System anomalies & failures
- Jamming
- Spoofing & Counterfeit Signals



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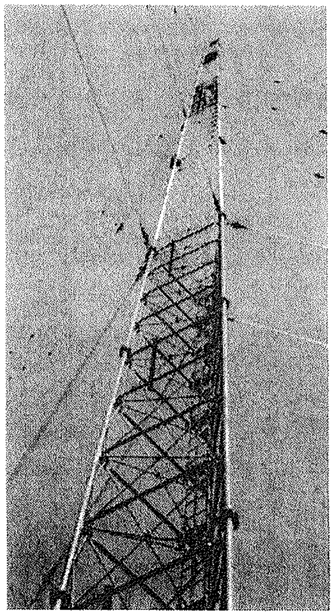
What is eLoran?

- eLoran is a Low Frequency PNT system that can meet the requirements for Maritime Harbor Entrance and Approach, Aviation Non-Precision Approach, Stratum-I frequency stability and UTC recovery to 50 ns.
- Developed over the past decade as a response to the recognized vulnerability of GNSS, by international government agencies, industry and academia
- eLoran technology is built upon the foundations of Loran-C
- eLoran transmitter and receiving equipment makes full use of 21st century technology
- eLoran can provide a second source of Positioning and Time for IMO's e-Navigation concept
- Recognized and recommended by the International Association of Lighthouse Authorities (IALA)
- eLoran receiver Minimum Performance Standards are being developed by the Radio Technical Commission of Maritime services (RTCM) Special Committee 127

What is eLoran?



eLoran is <u>NOT</u> simply modernized Loran-C!

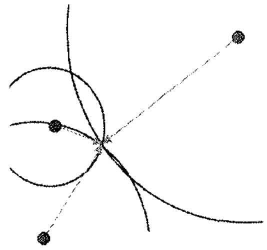
- requires a different timing strategy, control strategy, and new equipment to meet more stringent requirements
- specifies tighter timing and signal shape tolerances
- transmissions are synchronized with respect to UTC (not SAM)
- employs a data channel for broadcast of application specific data
- includes Differential eLoran monitor stations and ASF maps to provide optimum accuracy in key areas (e.g. marine ports or airports)
- Existing Loran-C installations in Europe act as an eLoran test-bed

eLoran yield better accuracy and integrity than Loran-C would ever be capable of

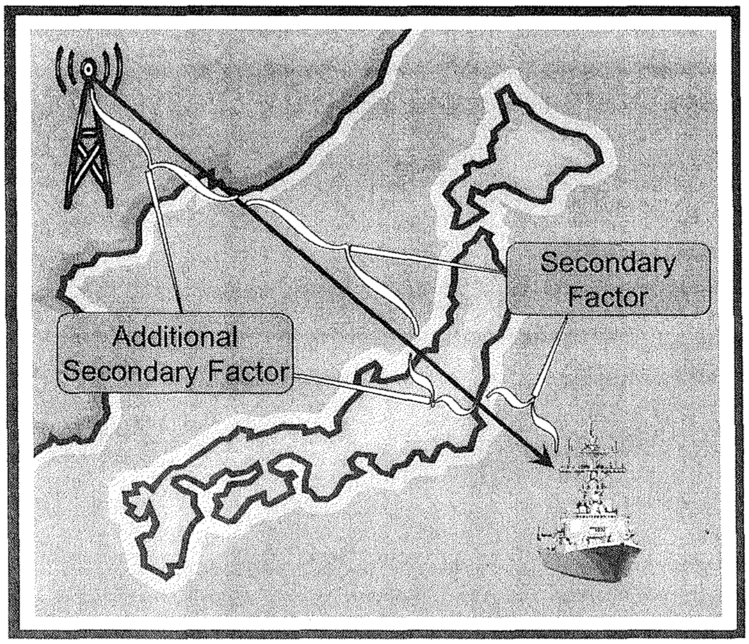
eLoran System Requirements

Application	Accuracy	Availability	Integrity	Continuity
Maritime Harbor Entrance and Approach (HEA)	**20 meters (95%)**	**0.998 over 2 years**	**10 seconds Time to Alarm**	**0.9997 over 3 hours**
Aviation Non-Precision Approach (RNP 0.3)	**0.3 Nautical Mile (556 meters)**	**0.999 – 0.9999**	**1 x 10^{-7} per hour**	**0.999 – 0.9999 over 150 seconds**
Timing	**Stratum-I frequency stability; timing to +/- 50 ns from UTC**			

- A properly configured and installed eLoran system can meet the above requirements



- eLoran positioning is based on range measurements to three or more stations
- Three (or more) range measurements allow the calculation of a 2D position and time
- Receiver measures propagation time of the signal, which is converted to a range by multiplication with the signal's propagation speed
- LF signal propagation speed varies with the terrain the signal travels over
  - Propagation speed over seawater is known
  - Propagation speed over land is slower



- Signals travel slower over land, causing a delay in the measured time of arrival (TOA)
- These delays are called Additional Secondary Factors (ASF)
- ASF Delays are nearly constant and can be mapped by survey
- Corrections on the nominal ASF values are broadcast

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Maritime Differential eLoran

In order to provide a Maritime Differential eLoran service, we need to:

- Install a Differential eLoran Reference Station in the harbor of interest, differential corrections are broadcast to the users using the Loran Data Channel
- Perform a survey of the harbor and approach area to measure nominal ASFs
- Publish the ASF map and distribute to the users

The Differential eLoran user:

- Takes measurements for all eLoran stations in view
- Corrects the measurements using the published ASF map
- Corrects the measurements using the broadcast differential corrections
- Calculate a differential eLoran position fix

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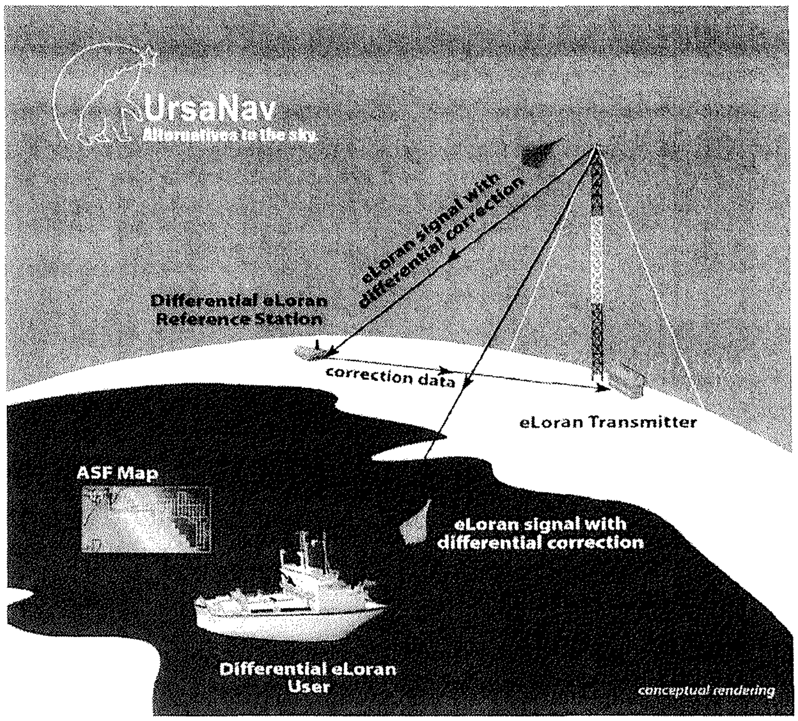
Maritime Differential eLoran



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Trial logic and objectives

- DNCS is the operator of Loran-C services in France and the Control Center in Brest providing time and control for the European Loran system
- Based on the results of other trials (UK and US), DCNS decided to conduct Differential eLoran trials in Brest
- Objectives are to show Differential eLoran capabilities using the existing Loran-C infrastructure, with minor modifications
- UrsaNav provided and installed the necessary equipment on a temporary
- Equipment is based on existing Loran Data Channel and Loran Navigation-grade receivers (no monitor equipment available at the time)
- ASFs and Differential corrections are relative and referenced to the measurements of the strongest station (Lessay)
- No capability to provide absolute ASFs or absolute Differential corrections in this trial

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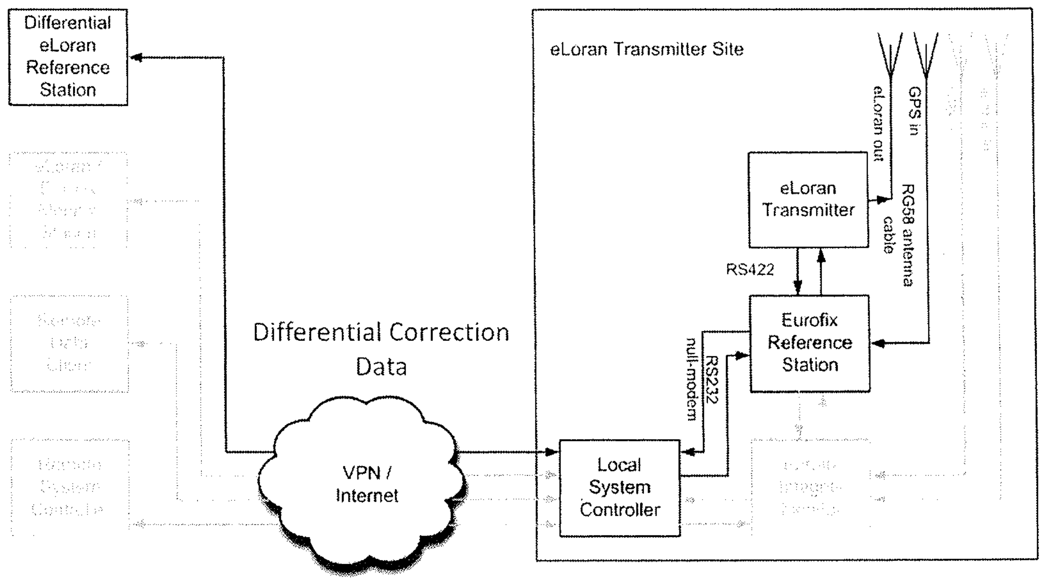
Trial set-up

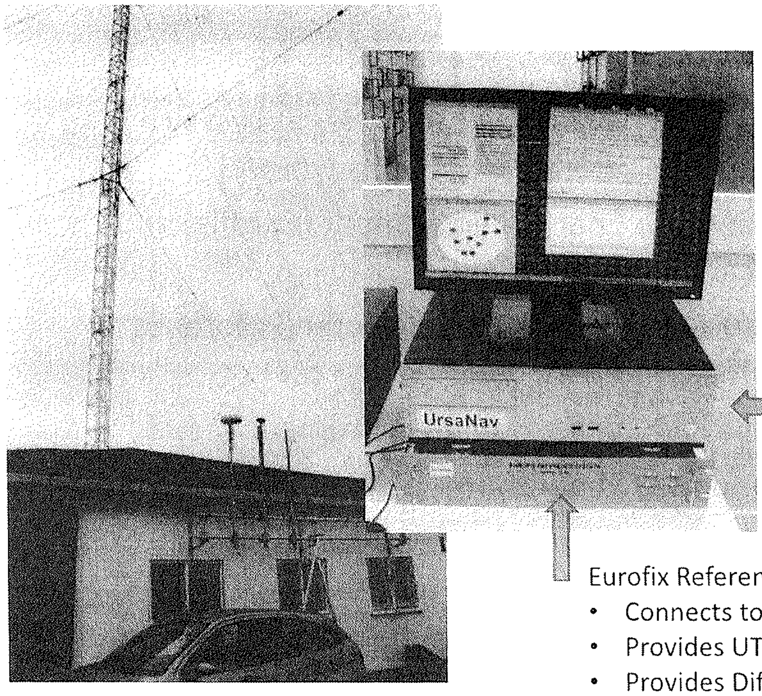
- Restoration of Loran Data Channel capabilities at Lessay (Eurofix, installed in 2000, not operational anymore)
- Installation of Loran Data Channel equipment (Eurofix) and remote communication interface
- Installation/configuration of Differential eLoran Reference Station at DCNS offices in Brest
- Installation of survey equipment on measurement vessel
- ASF map survey and map generation
- Differential eLoran verification run and post-processing

Trial set-up

Brest *Lessay*



Installation at Loran station Lessay



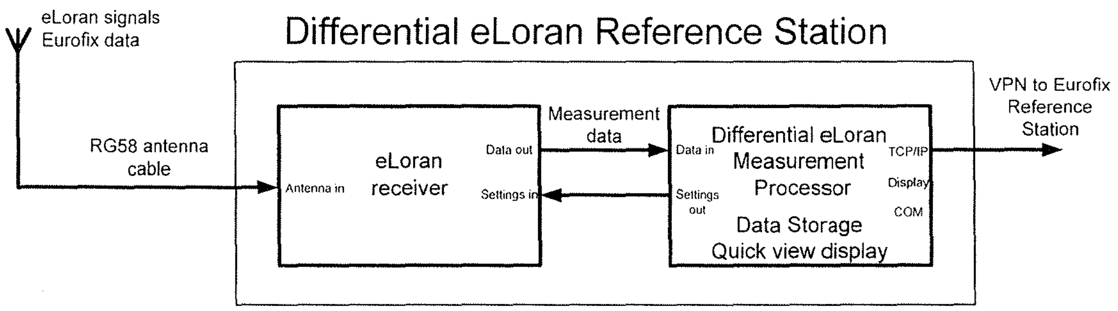
LDC Control and Remote Data input

- Differential Correction data from Brest

Eurofix Reference Station

- Connects to Loran transmitter
- Provides UTC message service
- Provides Differential eLoran service

Differential eLoran Refernce Station block diagram

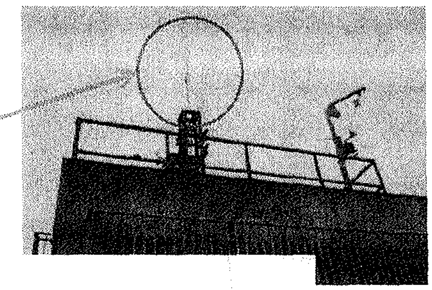


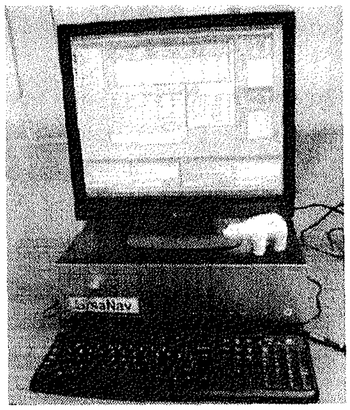
Measurement data consists of:
- eLoran TOA measurements
- Differential eLoran corrections
- Eurofix data reception including received Differential eLoran corrections
- Calculated user position including differential corrections
- Feedback on used settings

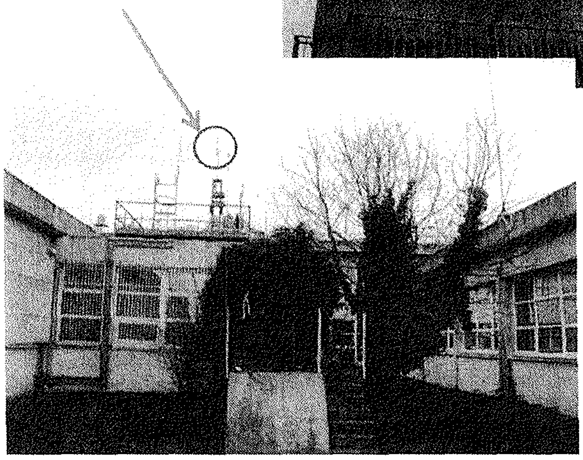
- Differential corrections are relative and referenced to the measurements of the strongest station (Lessay)
- No capability to provide absolute ASFs or Differential corrections in this trial

Differential eLoran Reference Station

E-field eLoran Reference Antenna

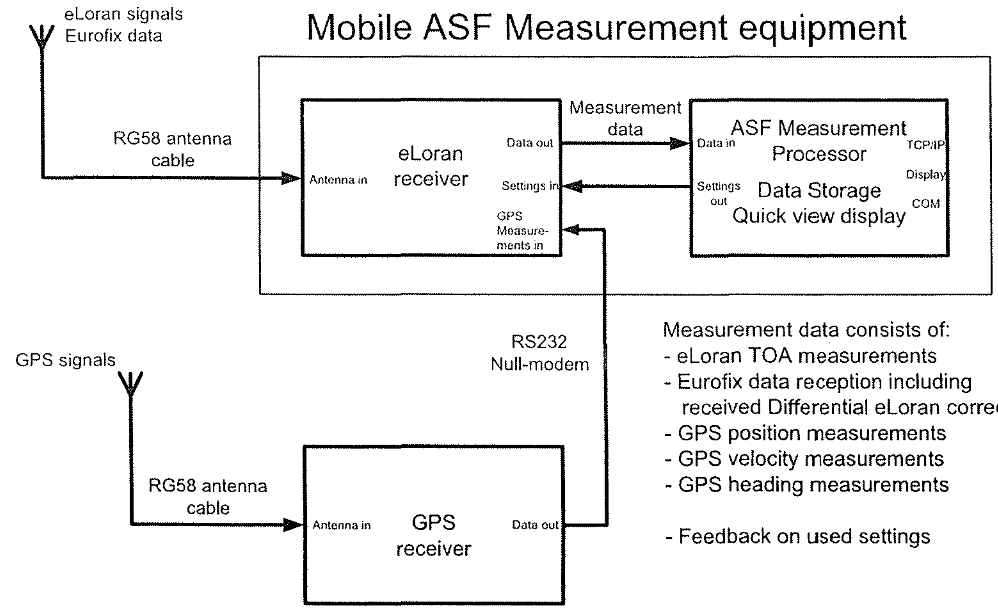






- Reference Station based on standard Navigation-grade Loran receiver
- Not ideally located in office space/ industrial area

Mobile ASF Measurement installation

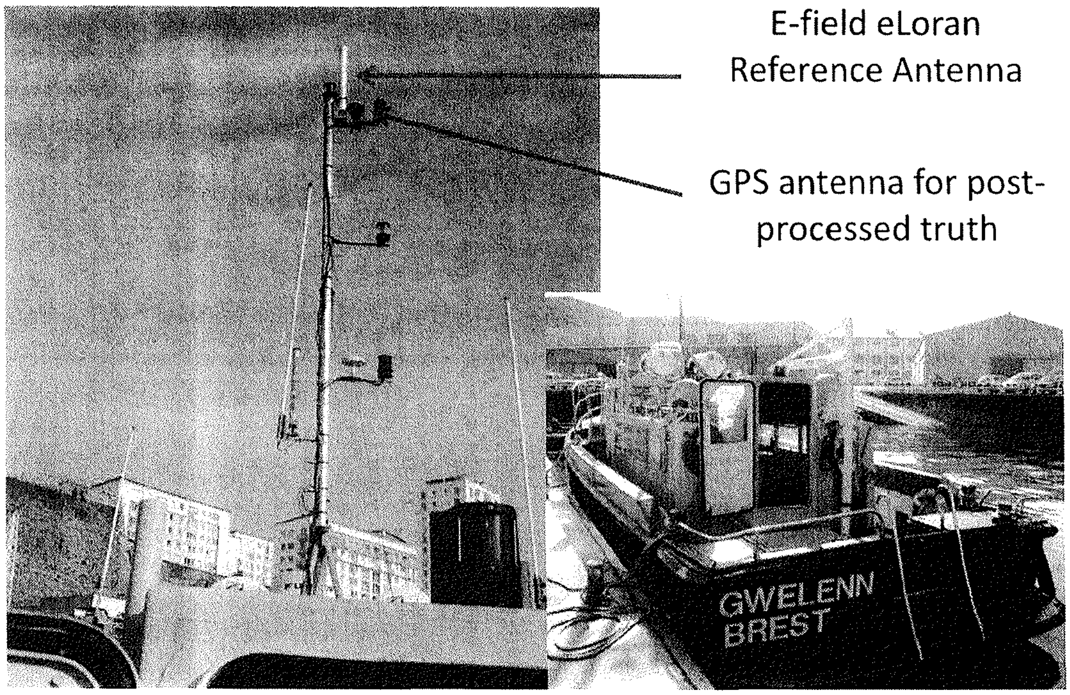


Measurement data consists of:
- eLoran TOA measurements
- Eurofix data reception including received Differential eLoran corrections
- GPS position measurements
- GPS velocity measurements
- GPS heading measurements

- Feedback on used settings

- GPS receiver provides post-processed position truth reference (provided by DCNS)

Mobile Measurement set-up



E-field eLoran Reference Antenna

GPS antenna for post-processed truth

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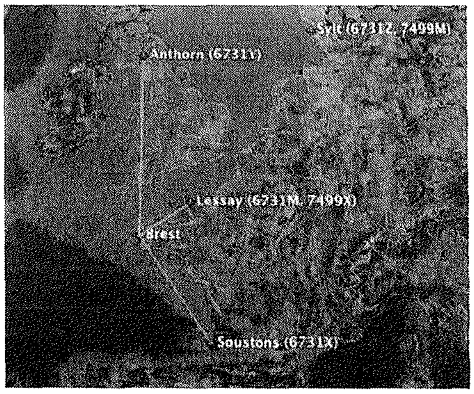
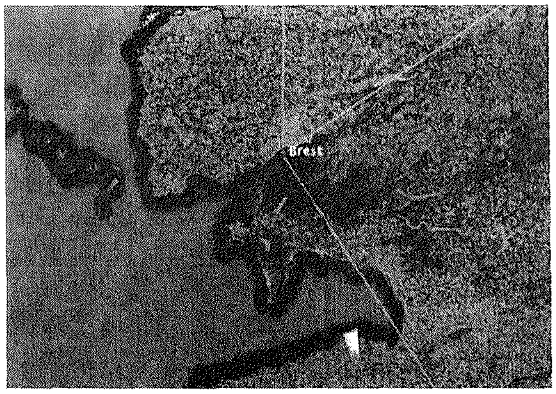
Area of operation and eLoran geometry





Name	eLoran	Distance	SNR	Nominal ASF
Lessay	6731M	240 km	30-40 dB	0.600 µs
Soustons	6731X	550 km	20-30 dB	0.086 µs
Anthorn	6731Y	730 km	10-20 dB	1.664 µs
Sylt	6731Z	1140 km	5-15 dB	0.097 µs

HDOP=1.60 using Lessay, Soustons and Anthorn; Sylt not included due to lower SNR

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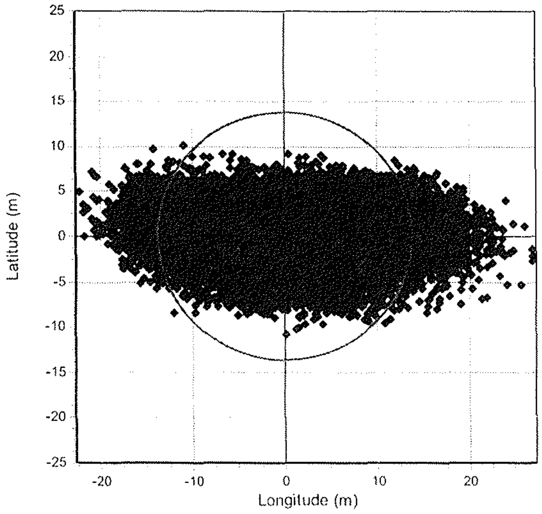
Zero-baseline Differential eLoran performance

- Differential eLoran Integrity Monitoring:
  - Differential eLoran Corrections received through the LDC and nominal ASFs applied to real-time measurements
  - Position performance is compared against known surveyed position



Zero-baseline performance	
Accuracy (50%)	5.8 m
Accuracy (95%)	13.8 m

- Performance not ideal:
  - Cigar shaped scatter due to geometry and signal strength
  - 5 m (95%) zero-baseline accuracy target for 10 m accuracy system not met

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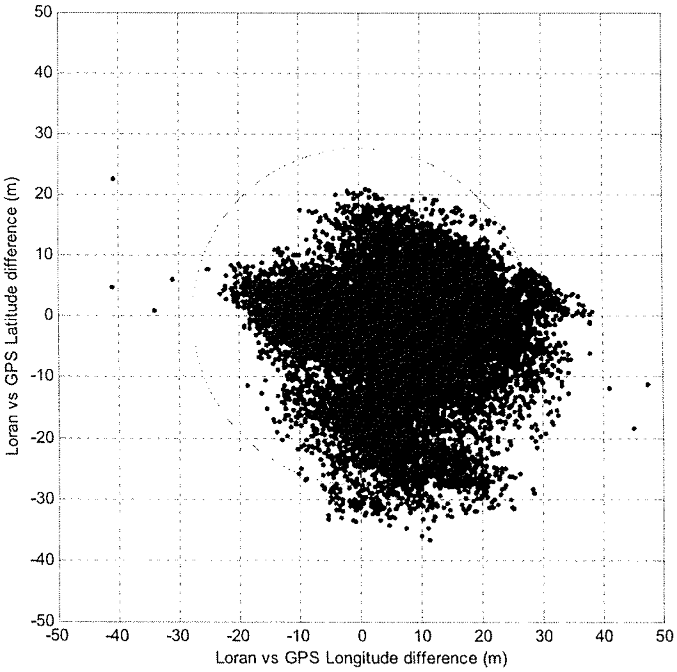
Mobile measurement performance



- ASF map and Differential correction data applied to mobile measurements
- Resulting eLoran position compared against post-processed DGPS truth

eLoran vs GPS truth performance	
Accuracy (50%)	11.6 m
Accuracy (95%)	27.8 m

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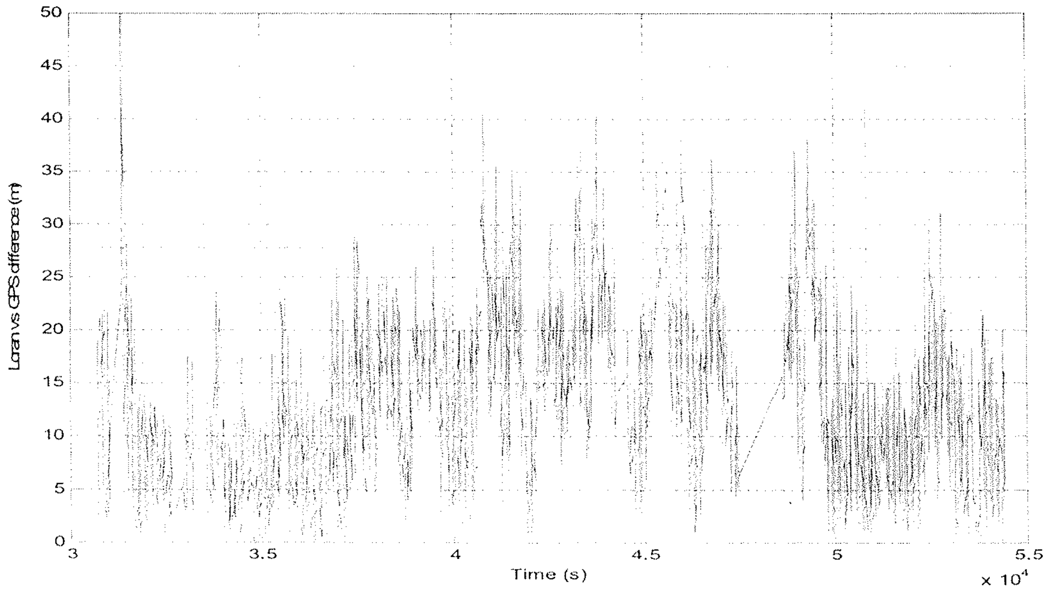
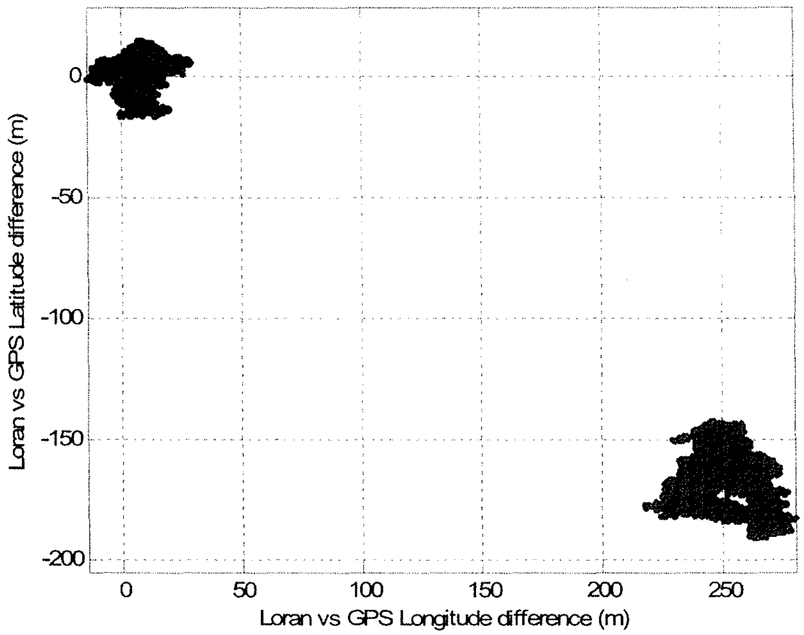
Mobile measurement performance over time



- Areas with better and worse performance correlate with higher and lower SNRs

Differential eLoran vs. Unaided Lor...



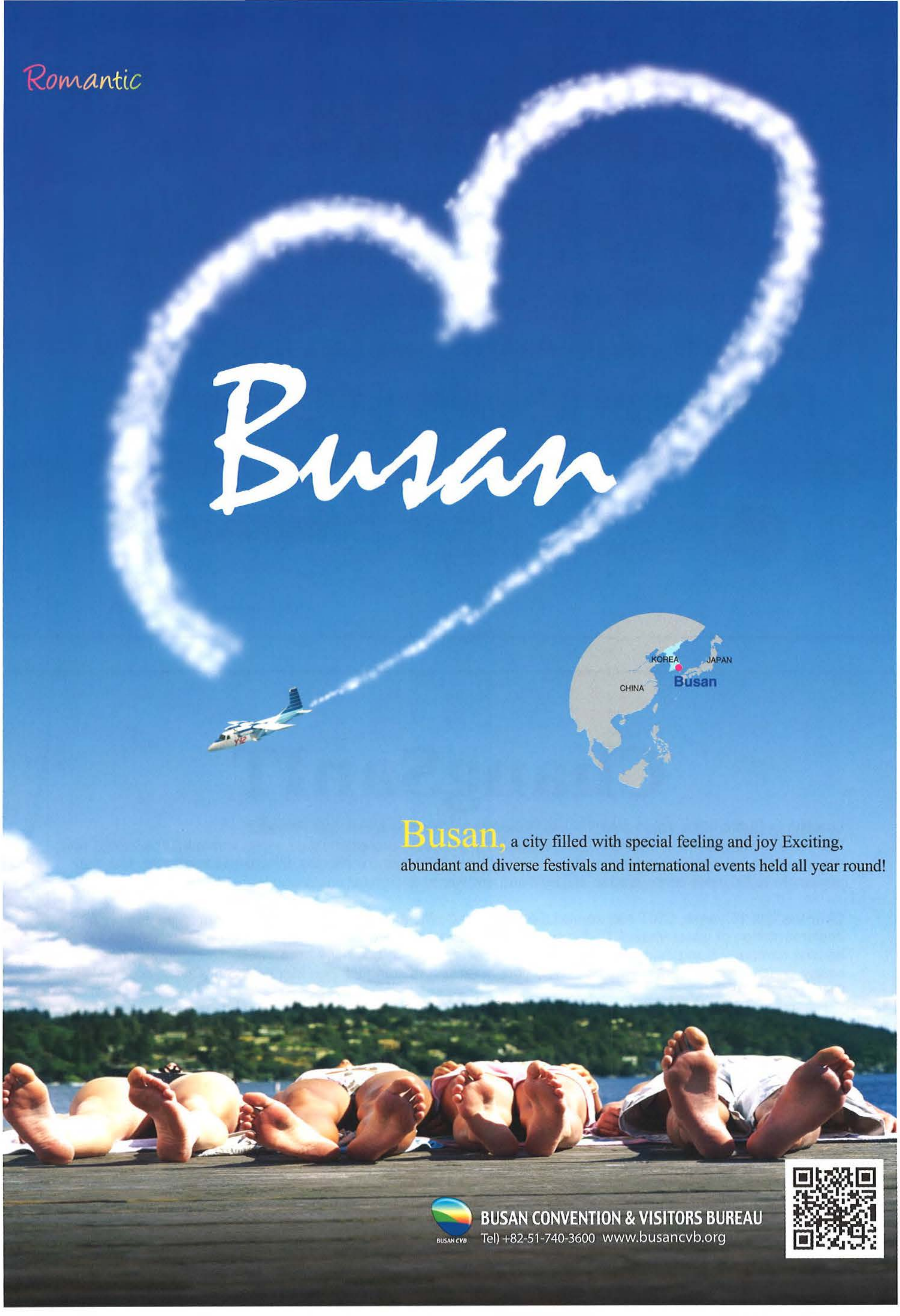
- Uncorrected Loran shows offset of 302 m due to uncompensated ASFs

Conclusions and Recommendatio...

- Trial results are satisfying considering the limited time, resources and temporary nature of the installation
- Trial results are in line with earlier trials conducted in the UK and the US
- Differences in performance with earlier trials due to:
  - Increased noise and interference levels on the vessel at certain times
  - Location of the Differential eLoran Reference Station and resulting zero-baseline performance
  - Slightly less favorable geometry of transmitters
  - Use of navigation-grade eLoran measurement equipment (no monitor-grade equipment available at the time)
- Differential eLoran capable to provide positioning and timing service for e-Navigation
- Modest upgrade cost of existing Loran network for a significant performance boost

Conclusions and Recommendations

- Use monitor-grade eLoran equipment for ASF survey and Differential eLoran Reference Station, especially with better grade local oscillator for more stable measurement results
- Careful installation of receiving antennas on survey vessel and reference station
- Careful planning of the location of the Differential eLoran Reference Station
- Upgrade system with true eLoran provider equipment will show significant improvement over current trial results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• Berth Planning System
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2009 AtoN AIS Management System for Gunsan District by MLTM
2010 The Maritime Transportation Facilities Integration of Management System for Yeosu District by MLTM

Product Area:




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Company Location and Contacts:

Headquarter:C-1104 Woorim Lions Valley, 425 Cheongcheon-dong, Bupyeong-gu, Incheon, Korea.

Tel:+82-32-623-6690~7,Fax:+82-32-623-6698,Email:woori@woorimarine.com, www.woorimarine.com

Factory: 363-155 Gyeongseo-dong, Seo-gu, Incheon,Korea Tel: +82-32-467-3295
Research Center: 506 Centlex, 440-4 Cheongcheon 2-dong, Bupyeong-gu, Incheon, Korea
Tel: +82-32-363-3684
Yeo-Su Branch: 682-1 Ferry Terminal 2nd Floor, Gyo-dong, Yeosu-si, Jeollanam-do, Korea
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Je-Ju Island Branch: 659-2 Geonip-dong, Jeju-si, Jeju-do, Korea Tel: +82-64-702-6690