Worldwide Utility News

Radio Navigation Signals

This series of articles about radio navigation signals appeared in the WUN-newsletters of November and December 1995 and January 1996.

Systems covered in the articles:

Alpha	DECCA	LENA	Ralog-20	SYLEDIS
AN/SSQ-72	Del Norte Trisponder	LORAN-A	RANA	TACAN
AN/TRQ-112	DGPS	LORAN-C	Raydist	Timation
AN/TRQ-114	Diff Omega	LORAN-D	RDF	TORAN P100
AN/TRQ-32	GEE	MARS-75	RS-10	Transit NNSS
Argo DM-54	GeoLoc	Maxiran	RS-WT1	Tsikada
Artemis-3	GLONASS	Mini Ranger	RS-WT1S	Tsyklon
Autotape	GPS	NDB	RSBN	VOR-DME
Bathymetric	Guardrail	Omega	Seafix	WJ-8958
BRAS-3	HI-FIX/6	Parus / Tsikada-M	SECOR	
Chayka	Hydrotrac	Pulse/8	Shoran	
Consol	Hyper-Fix	Quick-Fix	SPRUT	

Radio Direction Finding (RDF)

Radio Direction Finding (RDF) is the most widespread of radio navigation systems. Most pleasure boats, fishing vessels and larger commercial and naval vessels have RDF equipment onboard.

Various countries installed radio direction-finder equipment at points ashore. These stations will take radio bearings on ships when requested, passing that info by radio to the ships. I will explain it in detail using Norddeich Radio as an example. Unfortunately the North Sea DF-net no longer exists, but it gives you a good idea how it works. There are still direction-finder stations in Norway, Pakistan, Bangladesh, Panama and Russia.

The radio direction-finding control station of the North Sea direction finding network was Norddeich Radio. Bearings were taken on the freqs 410 and 500 kHz and on freqs between 1605 and 3800 kHz. The three German North Sea direction-finding stations normally took bearings simultaneously. But they also furnished isolated bearings on request. The direction-finding stations were not equipped with transmitters to communicate with ships. When isolated bearings were to be taken, the ship also communicated with Norddeich Radio. The ship however, had to indicate the call sign of the direction finding station by which she wanted to have her bearings taken: DAE Elbe-Weser Gonio, DAQ Norddeich Gonio or DAG S.Peter-Ording Gonio. Determinations of position were furnished in an area which is defined as to 4.30E and 44.20N degrees.

The ship who wanted her bearings taken, called Norddeich Radio (DAN) on 500 or 2182 kHz by using code 'QTE?'. When a request was made for a determination of position, code 'QTF?' was used. Norddeich Radio informs the other stations and when they were ready, the ship was asked to send its bearing signals.
If the bearing was to be taken on 410 or 500 kHz, the ship then transmitted twice on 410 or 500 kHz two dashes of circa 10 seconds, followed by her call sign.
If the bearing was to be taken on freqs between 1605 and 3800 kHz, the ship then transmitted on 1665, 2153 or 2182 kHz twice two dashes of circa 10 seconds, followed by the name of the ship.

After the bearing was taken, Norddeich Radio transmitted the results to the ship on either 444 or 2614 kHz as follows: QTE + call sign of the direction-finding station + bearing in degrees from 0-360 degrees + accuracy of bearing + time in UTC; or QTF + latitude & longitude + accuracy of bearing.
The result should be repeated by the ship and confirmed by Norddeich Radio.

Other RDF systems for marine navigation use shore-based non-directional beacons (NDB) and direction-sensitive antennas with ship-based receivers. Thus the radio bearing is taken aboard the vessel and plotted directly. Bearings are taken from marine NDBs which are designed and constructed solely for this purpose. Alongside the NDBs there are also Directional Beacons that transmit radio waves in beams along fixed bearings and Rotating Beacons by which a beam of radio waves is revolved in azimuth like the light of a lighthouse. Virtually every country operates NDBs along their coastlines, lots of them are located on lighthouses. Most of them operate in the freq band 250-400 kHz, 24 hours a day but there are also stations who transmit on request only. Most of them are special radio direction-finder calibration stations operated by either coastal stations or the coast guard.

Typical for European aero beacons is that there are no breaks in the transmissions of the ID (call sign) while a typical European maritime beacon transmits its ID several times, followed by either a break or a long dash.
Some dashes last longer than 30 seconds !

For North America, the typical US aero beacon transmits its ID about every 6 to 10 seconds, with silence in-between. Other US beacons transmit their ID several times in a row, followed by a long tone, with the whole thing repeated every 1 minute. The typical Canadian beacon, on the other hand, transmits its ID once every 10 seconds, with a long tone in-between.

Art Ruben, radio officer on mv Sealand Integrity, invited me on board of the container vessel when it called at the port of Rotterdam. Art showed me the extensive radio navigation equipment and the radio room. It was impressive. When GMDSS takes over, lots of the equipment I saw will not be necessary anymore. Too bad.....

Art gave me the following additional info about RDF:
During heavy fog it is difficult for a helicopter to find its way to the ship where it has to deliver a pilot. To help the heli pilot to find the vessel, the ship often transmits long dashes + their callsign on 410 kHz. The helicopter can use this as a homing beacon and can thus find the right vessel without even seeing it.

Consol

Consol is essentially a hyperbolic long-range navigational aid primarily for aircraft, but it can also be of value to ships as an aid to ocean navigation. A consol station consist basically of an MF radio transmitter with a special directional aerial system produced by three aerials in line, evenly spaced at a distance of the order of three times the wavelength of the transmitter. Consols were operating in the range 250-370 kHz. The range of a consol is 1000 to 1200 miles by day and 1200 to 1500 miles by night.
One transmitter transmits a continuous wave, while the other two transmit waves that undergo a 180 degrees phase shift with respect to the continuous wave during so called keying cycles. All signals are modulated by a system of dots and dashes. Preceding each cycle, the call sign of the consol is transmitted. The last consol in the world, LEC in Stavanger Norway, ceased operation only a couple of weeks ago. It is still on the air as a NDB on 319 kHz. It is not clear whether the consol is off the air on a temporary basis for maintenance purposes or that it really ceased operation.

Former European Consol stations:

Location	Callsign	Freq	Position (degrees)
Stavanger	LEC	319	58 37.5N 5 38E
Bushmills	MWN	266	55 12N 6 28W
Ploneis	FRQ	257	48 01N 4 13W
Lugo	LG	285	43 15N 7 29W
Seville	SL	315	37 31N 6 02W

Omega & Differential Omega / Alpha

Omega is a long range radio navigation system which operated on VLF between 10 and 14 kHz. The system comprises eight stations, identified by the letters A to H, which provide continuous world-wide cover. The stations are located in Norway (A), Liberia (B), Hawaii (C), North Dakota USA (D), La Reunion (E), Argetina (F), Australia (G) and Japan (H). The primary signal consists of 10.2 kHz pulses, the duration of which varies from station to station and is 0.9s, 1.0s, 1.1s or 1.2s. The station radiating the signals is identified by the duration of the pulses and by its position in a time-sharing commutation pattern which, with an 0.2s interval between pulses, occupies precisely 10s and is continuously repeated.

The stations transmit on four basic frequencies 10.2, 13.6, 11.33 and 11.05 kHz and each station also transmits on its own unique frequency; station A on 12.1, B on 12.0, C on 11.8, D on 13.1, E on 12.3, F on 12.9, G on 13.0 and H on 12.8 kHz.

Before being plotted on a chart the observed readings must be corrected because of phase variations. The corrections may vary with the time of day, season and geographical location.

Differential Omega is a system that replaces the corrections by current observed corrections to the phase of received Omega signals. The system employs monitoring stations at fixed locations which operate continuously, measuring the phase of the signal of each Omega station and comparing it with the theoretical phase at the same position. The difference is transmitted by beacons and can be used by vessels which have the differential Omega equipment onboard. The differential correction can be applied to the 'normal' Omega readings before plotting.

The following NDBs transmit differential Omega corrections:

c/s	location	frequency
PH	Alprech (F)	294.0 kHz
CA	Pointe de Creac'h (F)	301.0 kHz
YE	Ile d'Yeu (F)	303.0 kHz
FI	Cabo Finisterre (E)	288.5 kHz
LGS	Lagos (POR)	364.0 kHz
PA	Cabo de Palos (E)	313.0 kHz
PQ	Porquerolles (F)	314.0 kHz
HOR	Horta (AZR)	308.0 kHz
PST	Porto Santo (MDR)	338.0 kHz
BN	Cap Bon (TUN)	313.5 kHz
LT	La Isleta (Canarias)	291.9 kHz
PB	Port Bouet (CTI)	294.2 kHz
PPR	Pointe-a-Pitre (GDL)	300.0 kHz
X	Punta Tuna (PTR)	288.0 kHz
Y	Tete de Galantry (SPM)	342.0 kHz
???	Cayenne (GUF)	??? kHz

The Russians have a system similar to Omega called 'Alpha'. The Alpha stations are located in Kamsomolsk, Krasnodar and Novossibirsk. All of them transmit on 11.905, 12.649 and 14.811 kHz. Their pattern occupies precisely 3.6s.

Two new Alpha stations were added to the chain; Murmansk and Ashgabad can now also be heard on 11.905, 12.649 and 14.811 kHz.

LORAN LOng RAnge Navigation systems

LORAN is an acronym for LOng RAnge Navigation, which is one of the oldest and wide spread navigation systems. The system operates by measuring the difference in time of arrival of pulses from the master and the slave station(s). Although each of the three systems operates in the same way, there are several differences.

- **LORAN-A**

LORAN-A is a medium wave navigation system of which each chain consists of a master station and a slave transmitting station spaced up to 600 nautical miles apart. The stations of each chain transmit pulses at a specified interval, the so-called pulse repetition rate. LORAN-A stations use the frequency range 1850-1950 kHz. The only remaining chains are located in China and Japan. The rates are alphanumeric; the Chinese chains begin with a '1' and the Japanese chains with a '2'. The groundwave ranges from 650 to 900 nautical miles and the skywave up to 1250 to 1500 nautical miles.

Rate	LORAN-A Chain
1L1	Chengshan Jiao / Shanggulin chain
1L0	Chengshan Jiao / Zhuanghe chain
1L4	Sheyanghe / Chengshan Jiao chain
1L5	Sheyanghe / Gouqishan chain
1S1	Shitang chain
1S2	Tiandashan chain
1S3	Shibeishan / Sanzao Dao chain
1S4	Sanzao Dao / Shibeishan chain
1S6	Longgun chain
2S3	Niigata / Matsumae chain
2S4	Niigata / Miho Wan chain
2S5	Tsushima / Miho Wan chain
2S6	Noma Ike / Tsushima chain
2S7	Noma Ike / Gesashi chain
2H5	Miyako / Geshasi chain

- **LORAN-C**

A newer LORAN system is the 'C' system which operates at 100 kHz. The system has a greater range than LORAN-A and also provides considerably more accurate fixes. The groundwave ranges from 800 to 1200 nautical miles. Like its predecessor, LORAN-C chains consist of a master (M) and two or more slaves, designated W, X, Y and Z. Each group of stations transmits groups of pulses at a specific interval (GRI), the value of which is unique to each chain. The master pulse proup consist of nine pulses and each slave group of eight pulses. The extra ninth pulse of the master is for identification purposes. The selected GRI is also such as to avoid interference with other chains. Within any chain the transmissions of each slave are retarded with respect to those of the master.

There are LORAN-C chains around the world including Russia. The Russians build their own LORAN system in a way that it fully synchronized with LORAN-C, it also operated at 100 kHz. Now a joined Russian-American chain is operated by the joined US and Russian coastguards.

The Northwest European LORAN-C System (NELS) is due to become fully operational in 1996 after the new station at Loop Head (Ireland) is ready. The Icelandic and Norwegian chains will then be discontinued.

Before I list the LORAN-C chains, I give you examples of two chains.
The first one is the Canadian East Coast chain which is jointly controlled by the US and Canadian Coast Guards and the second one is the Russian-American chain, jointly controlled by US Coast Guard and Russia. The transmission of the master station (M) is followed by those of the slaves (X,Y,Z), listed are the rates, stations and latitude and longitude.

Canadian East Coast chain
5930-M Caribou 46 48' 27.305"N 67 55' 37.159"W
5930-X Nantucket 41 15' 12.046"N 69 58' 38.536"W
5930-Y Cape Race 46 46' 32.286"N 53 10' 27.606"W
5930-Z Fox Harbour 52 22' 35.252"N 55 42' 27.862"W

Russian-American chain
5980-M Petropavlovsk 53 07' 47.584"N 157 41' 42.900"E
5980-X Attu 52 49' 44.134"N 173 10' 49.528"E
5980-Y Alexandrovsk 51 04' 42.80"N 142 42' 04.95"E

I won't list all the stations in the chains because the list would become much too long, so I only list the rates and the names of the chains.

Rate	LORAN-C Chain
5543	India -Calcutta- chain
5930	Canadian East Coast chain
5970	East Asian chain
5980	Russian-American chain
5990	Canadian West Coast chain
6042	India -Bombay- chain
7170	Saudi Arabian South chain
7930	Labrador Sea chain
7960	Gulf of Alaska chain
7970	Norwegian Sea chain
7980	Southeast USA chain
7990	Mediterranean chain
8290	North Central USA chain
8930	Northwest Pacific chain
8970	Great Lakes chain
8990	Saudi Arabian North chain
9610	South Central USA chain
9940	West Coast USA chain
9960	Northeast USA chain
9970	Northwest Pacific chain
9980	Icelandic chain
9990	North Pacific chain
6731	NELS Lessay
7001	NELS Bo
7499	NELS Sylt
9007	NELS Ejde

- **LORAN-D**

LORAN-D is a hyperbolic mobile navigation system similar to LORAN-C. It differs from LORAN-C in its signal (16 pulses, spaced 500 ms apart) and it uses freqs in the range 90-110 kHz. The system is highly resistant to electronic jamming and its mobility make it useful when areas of operation are changing rapidly. It is mainly used by the military.

CHAYKA

Chayka is the Russian equivalent of Loran and is fully compatible. It also operates on 100 kHz. There are 15 stations forming 4 chains:
European chain: Bryansk, Petrozavodsk, Simferopol, Slonim, Syzran
Eastern chain: Petropavlovsk-Kamchatsky, Aleksandrovsk-Sakhakinsky, Ussuriysk, Okhotsk, Kurilsk
Northern chain: Dudinka, Inta, Taimyr, Pankratyev island
N-W chain: Inta, Pankratyev island, Tumanny

PULSE/8

This one is based on LORAN-C and works very similar. It also operates on 100 kHz and seems to be more accurate, especially at night. There is a slight difference in the impulse codes which makes that the system is not compatible with LORAN-C. PULSE/8 is reportedly still in use, but I have no idea where....

HydroTrac

The following part is rather technical. I did my best to keep it as simple as possible. Unfortunately I cannot include illustrations in the newsletter to make it more understandable.

HydroTrac was developed in the USA by ODOM Offshore Surveys of Baton Rouge during the mid 1970's. ODOM operated Hi-Fix in the Gulf of Mexico and wanted a more up-to-date system (Hi-Fix was 1960's system using valve and transistor technology). ODOM designed HydroTrac to be compatible with Hi-Fix and as such the signals on-air were identical, receivers being interchangeable between systems. Most of the Hi-Fix / HydroTrac chains were around 1.7 - 2.3 MHz where Hyper-Fix now operates. There was a North Sea chain around 1795 kHz but as far as I know it doesn't exist anymore.

HydroTrac receivers used CMOS technology which was state of the art at the time and whereas Hi-Fix used mechanical counters to read out the lanes that made up the position fix, HydroTrac used gas-discharge digital displays and highly accurate Hewlett-Packard oscillators as against Hi-Fix's cruder (but reliable) crystal oscillators.

HydroTrac was built under licence by Gardline Surveys in UK and they set up several chains to cover the North Sea areas where there was exploration in progress. Initially, before Gardline had their shore stations in place they used Hi-Fix signals from the extensive network operated by Decca, causing not a little trouble between the companies! HydroTrac was replaced by a later version, HiTrac, which is now also replaced by GPS.

Hyper-Fix. Sea-Fix, Hi-Fix

Hyper-Fix is a medium frequency (1600-2500 kHz) navigation system.

Sea-Fix and Hi-Fix were the 60's and 70's predecessors of Hyper-Fix. As far as I know Sea-Fix doesn't exist anymore, while Hi-Fix/6 apparently still is around. The latter is almost completely replaced by Hyper-Fix. This system was introduced in 1982 and established itself as a reliable, accurate, medium range, positioning system. Although GPS has largely taken over now, a few navies maintain Hyper-Fix as a back-up system. The navies of Great Britain, Sweden, the Netherlands, Saudi Arabia, Kuwait, South Africa, Brazil and Japan are still using Hyper-Fix. The US Navy has a large stock of Hyper-Fix equipment which is held in reserve in case it is needed.

The positioning accuracy of Hyper-Fix, within given area depends upon chain geometry but is normally less than 2 meters. The system can be configured in one of several modes.

- Hyperbolic mode. In the hyperbolic mode a minimum of three Hyper-Fix transmitting stations are installed at known locations ashore and hyperbolic patterns are generated between pairs of selected stations. Up to six shore stations per sequence may be deployed in to achieve the desired area of coverage.

- Circular mode. The principle is exactly the same as that for the hyperbolic mode but instead of patterns being generated between pairs of shore stations they are generated between the user's ship and selected shore stations. By siting one of the ship transmitting stations ashore, the circular mode operation can be adapted to combine both hyperbolic and circular operation. This adaption enables one vessel to operate in circular mode and any additional vessels to operate in hyperbolic mode. The principle advantage of circular mode is that it can be used successfully along a flat or convex coastline.

- Multi-sequence operation (mode 3). The Hyper-Fix software enables the user to transmit in a number of different sequences within a single transmission timing cycle. The length of the timing cycle will vary according to the number of sequence used. For single sequence operation the timing cycle is 0.76s and extends to 2.04s for three sequence operation. Each sequence can be configured in either hyperbolic or circular mode.

- Hy-Link. This is a method of transferring DGPS data to a ship's satellite receiver by means of Hyper-Fix transmissions. When Hy-Link is used as part of a Hyper-Fix chain (mode 3 only), one or two sequences may be used for DGPS data and the third may be used for Hyper-Fix positioning.

Transmissions are made from the chain transmitting stations on two freqs (Hi-Fix/6 and Hyper-Fix mode and on five frequencies for Hyper-Fix mode 4). A Hi-Fix/6 chain consists of 3 to 6 transmitting stations, of which one is the master and the others are slave stations. Hyper-Fix chains consist of 3 to 18 transmitting stations in mode 3 or 3 to 6 transmitting stations in mode 4. The pulses are sent in CW mode. A FSK modulation is used when a data slot is included in the timing cycle.

The Swedish navy has at least 3 chains of Hyper-Fix stations. The Military Command East in Musko uses chain 1. Freqs 1809 kHz (master Halshuk), 1630.3, 1809.5, 1808.95 and 1626.3 kHz (used by all stations: Halshuk, Kopparholmarna, Lange Erik, Stora Hastskar and Ostergarnsholm).
The Military Command South in Karlskrona uses chain 3. Freqs 1802.8 kHz (master Horvik), 1630.7, 1802.85, 1802.75 and 1626.7 kHz (used by all stations: Horvik, Simrishamn and Utlangan). All stations have an output of 50 Watt. All Hyper-Fix stations are controlled from the navy's longwave transmitter site in Ruda.

The Royal Navy reportedly uses sites near London (2163.2 kHz), Guernsey (1884 kHz), Glasgow (1991 kHz), Outer Hebrides -Lewis ?- (2154 kHz), Portsmouth (2163.5 kHz) and Land's End (2167.5 kHz).
I heard ''Hyper-Fix sounding stations'' in clusters on the following freqs: 1626-1631, 1802-1810, 1884, 1913-1920, 1929-1939, 1943-1950, 1991-1995, 2154-2156, 2160-2170 kHz and on 144.7 and 132 kHz.

Similar sounding signals were also reported from the Mexican Gulf area and from the East Coast of Canada.

BRAS / RS-10

Although I have hardly any info about the Russian systems, I understand that the BRAS and RS10 systems sound and work very similar as Hyper-Fix. The systems are most likely not compatible.

Dxers from Finland reported signals who most likely originate from BRAS and RS10 systems coming from the Baltic area. On the following frequencies the following tentative clusters were heard:
1664-1674, 1671-1684, 1677-1690, 1688-1697, 1695-1697, 1701-1715, 1758-1770, 1767-1780, 1785-1797, 1799-1812, 1810-1823, 1817-1831, 1895-????, 2079-2088, 2088-2106, 2101-2112 kHz.

Other similar signals from possible navigation systems can be heard on 3666.5-3558 and 3694.8-3696.2 kHz. Users are yet unknown.

RS-10's predecessors were RSWT-1 and RSWT-1S.

Decca Navigator System

The DECCA navigator system is a high accuracy navigational aid intended for coastal navigation. It operates as a continuous wave phase comparison system on LF. Each Decca chain consist of a Master station and two or three slave stations, resp. Red, Green and Purple. The slaves are located between 60 and 120 n.miles from the master. The accuracy of this system depends amongst others on the distance from the transmitters, the time of the day and the season of the year and give the position within 50 meters under favourable conditions up to 100 n.miles from the Master station.

Although GPS is rapidly winning territory, there are still 30 chains left around the world; 2 in Japan, 1 in India, 1 in the Persian Gulf, 5 in South Africa and 21 in Western Europe and Scandinavia. During the last 4 years many chains have disappeared, being replaced by GPS. Just recently the two Spanish chains closed down.

So how does it sound ? It sounds like very slowly transmitted Morse, like a beacon. You can hear patterns of dots and dashes. Combinations of dots and dashes or dashes only. Just tune in on the frequencies and you'll know what I mean :-)

DECCA chains
Country
Name and chain number
Followed by resp. the Master station and the Red, Green and Purple slave stations.

Japan

Kyushu chain (7C):	Maebaru, Kamiagata, Nagisima, Seto
Hokkaido chain (9C):	Biei, Akkeshi, Wakkanai, Oshamanbe

Persian Gulf

S. Persian Gulf chain (1C):	Qarnain, Doha, Munayyif, Ras Zubayyah

India

Salaya chain (2F):	Kodal, Kuranga, Dhuvav, Naliya

South Africa

Namaqua chain (4A):	Noordoewer, Chamaites, Gamdep Pofadder, Port Nolloth
Cape chain (6A):	Matroosberg, Piket Berg, Ladismith Cape, Klein Mond
Eastern Province chain (8A):	Addo, Port Alfred, Clarkson, Swaershoek
S.W. Africa chain (9A):	Usakos, Sorris Sorris, Isabis, Swakopmund
Natal chain (10C):	Matatiele, Elliot, Mooirivier, Margate

Europe

South Baltic chain (0A):	Holmsjo, Sandhammaren, Burgsvik
Vestlandet chain (0E):	Sotra, Statt, Shetland Islands, Jaren
S.W. British chain (1B):	Bolberry Down, Jersey, St.Mary's, Llancarfan
Northumbrian chain (2A):	Allerdean Greens, Stirling, Peterhead, Burton Fleming
Holland chain (2E):	Gilze-Rijen, Heiloo, Sas van Gent, Thorpeness
N. British chain (3B):	Kidsdale, Clanrolla, Neston, Stirling
Lofoten chain (3E):	Andoya, Torsvag, Rost, Narvik
N. Baltic chain (4B):	Nynashamn, Aland, Ar, Bjorvik
Trondelag chain (4E):	Skaroy, Rorvik, Statt, Berkak
English chain (5B):	Puckeridge, Shotisham, East Hoathley, Wormleighton
N. Bothnian chain (5F):	Lovanger, Gamla Karleby, Kallax, Jarnas
N. Scottish chain (6C):	Kirkwall, Butt of Lewis, Lerwick, Peterhead
Gulf of Finland chain (6E):	Mantsala, Padva, Sydankyla
Danish chain (7B):	Samso, Moen, Eojer, Hjorring
Irish chain (7D):	Galway, Ballydavid, Dungloe, Youghal
Finnmark chain (7E):	Reksunnjarga, Virgasfjell, Fakken, Nordkap

S. Bothnian chain (8C):	Njurunda, Skutskar, Jarnas
Hebridan chain (8E):	Barra, Kentra Moss, Butt of Lewis, Dungloe
Helgeland chain (9E):	Donna, Rost, Rorvik, Mo I Rana
Frisian Islands chain (9B)	Finsterwolde, Hoyer, Heiloo, Zeven
Skagerak chain (10B)	Fjallbacka, Jomfruland, Valda, Arjang

DECCA frequency list

Purple	Master	Red	Green	Name and chain number
70.979	85.175	113.567	127.763	Cape chain (6A)
71.138	85.365	113.820	128.048	Danish chain (7B)
71.283	85.540	114.053	128.310	Eastern Province chain (8A)
70.833	85.000	113.333	127.500	English chain (5B)
71.213	85.455	113.940	128.183	Finnmark chain (7E)
71.433	85.720	114.293	128.580	Frisian chain (9B)
71.058	85.270	113.693	127.905	Gulf of Finland chain (6E)
71.363	85.635	114.180	128.453	Hebridian chain (8E)
71.508	85.810	114.413	128.715	Helgeland chain (9E)
71.438	85.725	114.300	128.588	Hokkaido chain (9C)
70.458	84.550	112.733	126.825	Holland chain (2E)
71.208	85.450	113.933	128.175	Irish chain (7D)
71.142	85.370	113.827	128.055	Kyoshu chain (7C)
70.613	84.735	112.980	127.103	Lofoten chain (3E)
70.683	84.820	113.093	127.230	Namaqua chain (4A)
71.588	85.905	114.540	128.858	Natal chain (1C)
70.688	84.825	113.100	127.238	North Baltic chain (4B)
70.913	85.095	113.460	127.643	North Bothnian chain (5F)
70.538	84.645	112.860	126.968	North British chain (3B)
70.988	85.185	113.580	127.778	North Scottish chain (6C)
70.379	84.455	112.607	126.683	Northumbrian chain (2A)
70.463	84.555	112.740	126.833	Salaya chain (2F)
71.583	85.900	114.533	128.850	Skagerak chain (10B)
70.083	84.100	112.133	126.150	South Baltic chain (0A)
71.292	85.550	114.067	128.325	South Bothnian chain (8C)
70.238	84.285	112.380	126.428	South Persian Gulf chain (1C)
71.437	85.725	114.300	128.588	SW Africa chain (9C)
70.233	84.280	112.373	126.420	SW British chain (1B)
70.763	84.915	113.220	127.373	Trondelag chain (4E)
70.163	84.195	112.260	126.293	Vestlandet chain (0E)

GPS

As you probably know, GPS is a satellite system and transmits on ca 1.3 GHz and that is way beyond the 0-30 MHz spectrum that we normally handle here. There is however an important link to the radio navigation systems in our frequency range. A rapidly increasing number of stations transmits Differential GPS signals on LF and MF.

What is GPS ?

GPS stands for Global Positioning System and is a space-based positioning, velocity, and time system that has three major segments: space, control, and user. The GPS Space Segment, when fully operational, will be composed of 24 satellites in six orbital planes. The satellites operate in circular 20,200 km orbits at an inclination angle of 55 degrees and with a 12-hour period. The spacing of satellites in orbit will be arranged so that a minimum of five satellites will be in view to users worldwide, with a position dilution of precision (PDOP) of six or less. Each satellite transmits on two L band frequencies, L1 (1575.42 MHz) and L2 (1227.6 MHz).
L1 carries a precise (P) code and a coarse / acquisition (C/A) code. L2 carries the P code. A navigation data message is superimposed on these codes. The same navigation data message is carried on both frequencies.

The Control Segment has five monitor stations, three of which have uplink capabilities. The monitor stations use a GPS receiver to passively track all satellites in view and thus accumulate ranging data from the satellite signals. The information from the monitor stations is processed at the Master Control Station (MCS) to determine satellite orbits and to update the navigation message of each satellite. This updated information is transmitted to the satellites via the ground antennas, which are also used for transmitting and receiving satellite control information.

The user segment consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user.

Signal Characteristics

The GPS concept is predicated upon accurate and continuous knowledge of the spatial position of each satellite in the system with respect to time and distance from a transmitting satellite to the user. Each satellite transmits its unique ephemeris data. This data is periodically updated by the Master Control Station based upon information obtained from five widely dispersed monitor stations.

Each satellite continuously transmits a composite spread spectrum signal at 1227.6 and 1575.42 MHz. The GPS receiver makes time-of-arrival measurements of the satellite signals to obtain the distance between the user and the satellites. These distance calculations, together with range rate information, are combined to yield system time and the user's three-dimensional position and velocity with respect to the satellite system.
A time coordination factor then relates the satellite system to Earth coordinates.

Differential GPS

Differential GPS (DGPS) is the regular Global Positioning System (GPS) with an additional correction (differential) signal added. This correction signal improves the accuracy of the GPS.

- Accuracy improvement: 10 meters or better for DGPS vs. 100 meters or better for GPS.
- Integrity improvement: provides an independent check of each GPS satellite's signal, and reports whether it's good or bad.

DGPS receivers collect navigational signals from all satellites in view, plus differential corrections from a DGPS station in the area. (Many DGPS receivers consist of two units: a GPS receiver, with a data "port" for DGPS corrections, directly connected to a radio receiver.) DGPS receivers display position, velocity, time, etc., as needed for their marine, terrestrial, or aeronautical applications.

The GPS determined position of a reference station is computed and compared to its surveyed geodetic position. The differential information can be broadcast to the users by radio. Info can be included in other positioning systems like Hyperfix, or on a sub-FM-channel by using RDS. Most of the DGPS stations however transmit 24 hours a day on LF or MF.

In many cases marine radiobeacons that has been modified to accept MSK (Minimum Shift Keying) modulation are being used for DGPS transmissions, some broadcast only on request. Radiobeacons were chosen because of existing infrastructure, compatibility with the useful range of DGPS corrections, international radio conventions, international acceptance, commercial availability of equipment and highly successful field tests.

So far I heard two different sounding types of signals. One has a specific sound, like packet radio but with longer bursts. This system uses 250 bd QPKS (Quarternary Phase Shift Keying) although also 100 and 300 bd broad-casts have been noted. The other sounds like Sitor-B and is in fact MSK transmitted with a speed of 50, 100, 200 or 300 bd.

MSK stations

So, where can you hear those babies ? As I said, many beacons are being used for DGPS nowadays so you have to listen between 285 and 325 kHz. The list is far too long to publish here and new stations are added regularly. The stations in this range are all MSK stations. The coverage is becoming world wide. Stations have been reported from the America's, New Zealand, Australia, Europe and the Mediterranean area.

QPSK stations
A report from New Zealand states that the Radio Frequency Service of the Ministry of Commerce, who are responsible for all NZ frequency allocations, confirms that a QPSK station on 1818.6 kHz is a NZ navigational station. The the station is located in the lower North Island.

The same kind of stations were reported from the Mexican Gulf area, from the Canadian East Coast, from the Mediterranean area and from Western Europe and Scandinavia. Check the frequency range from ca 1700 to 3000 kHz. Most US and Canadian loggings were between 1800 and 2100 kHz.

GLONASS

The Russian counterpart of GPS is GLONASS, an acronym for GLObal NAvigation Satellite System. Full deployment of the system (up to 24 satellites) was completed last year. A modernized version of the satellites is on its way. The Russian Space Forces plan to start flight tests of new GLONASS-M program in 1996. The new GLONASS-M satellite will have higher guaranteed period of service (5 years instead of 3 at the moment) and better characteristics. This enable to increase the reliability and accuracy of the system as a whole. GLONASS operates between 1602.5 and 1615 MHz.

Like GPS, GLONASS also needs a differential system to get better results. The research started way back in the seventies at about the same time that GLONASS itself was developed. However, due to various reasons an implementation of differential GLONASS (DG) in Russia was delayed. So far only one DG station has been reported and that one is in the Ukraine, not in Russia.
A lack of the Selective Availability mode in GLONASS played a not unimportant role in the process. The standard accuracy of GLONASS on the few ten meters level met the requirements of common users in Russia. During the past couple of years however, the interest for DG has increased rapidly. Therefore, the development of differential stations for various applications has been speeded up. At present, there are the plans for the creation of local-area differential systems (LADS) and regional-area differential systems (RADS) for air traffic control and vessels. A third system WADS (wide-area differential system) should cover the whole of Russia.

Here is a short list of stations. It is only the top of an enormous iceberg. I also included a few longwave stations. Both MSK and QPSK stations are included.

Freq.	Location	Baud
123.7	Mainflingen, Germany	300
140.3	Mainflingen, Germany	300
162.5	Ras Caxine, Algeria	100
285.0	Porkkala, Finland	100
285.0	Upolo Point, Hawaii	100
287.5	Hoek van Holland, Neth.	100
288.0	Cape Race, Canada	100 (Atlantic coast)
289.0	Cabo Finisterre, Spain	100
289.0	Cape Henry, USA	100 (Atlantic coast)
289.5	Butt of Lewis, UK	100 *)
292.5	Kapp Martin, Svallbard	50
292.5	Reykjanes, Iceland	100
293.0	New Orleans, USA	200 (Gulf coast)
293.0	Montauk Point, USA	100 (Atlantic coast)
296.0	Galveston, USA	100 (Gulf coast)
296.5	Blavandshuk, Denmark	100
300.0	Utvaer, Norway	100
300.0	Kokole Point, Hawaii	200
300.5	Mizen Head, Ireland	100
300.5	Pt da Sao Marcos, Brazil	300
305.0	Alexandria, USA	100 (Atlantic coast)
306.5	Skagsudde, Sweden	100

307.0	Ristna, Estonia	100
308.0	Triple Islands, Canada	100 (Pacific coast)
310.5	North Foreland, UK	100 *)
311.0	Partridge Island, Canada	100 (Atlantic coast)
314.0	Cape Schanck, Australia	100
314.0	Lauzon, Canada	100 (Atlantic coast)
323.0	St Davids Head, Bermudas	100
323.0	Robinson Point, USA	200 (Pacific coast)
1655.0	Pt de la Coubre, France	50
1719.6	Venezia, Italy	100
1801.0	Amsterdam, Netherlands	100
1804.8	Isle of Wight, UK	250
1806.5	Kiel, Germany	250
1851.0	London, UK	300
1894.0	N-Scotland, UK	100
1942.0	Copenhagen, Denmark	100
1975.0	Aberdeen, UK	300
1997.0	Copenhagen, Denmark	100
2021.0	Mid-east coast, UK	300
2128.0	Cabo Finistere, Spain	300
2163.7	Portsmouth, UK	250
2165.9	Lands-End, UK	250
2657.1	Tripoli, Lybia	300
2805.0	N.O.Polder, Netherlands	250
2834.0	N.E. England	250
2885.0	Krasnodar, Ukraine	250
3226.0	Denmark	250
3328.8	Pt de la Coubre, France	50

*) the British stations provide this service for a subscription fee, whereas most countries provide this service for free. The British DGPS data is coded.

Bathymetric Navigation

Bathymetric navigation is the art of establishing a geographic position on the open sea by use of geological features of the ocean floor. The transmissions can most probably not be heard on land, therefore only a short note about this system.

The ocean bottom features are like mountains and canyons on dry-land. By measuring the depth of the sea and thus visualising the seamounts, trenches, etc. you can plot an echo sounder trace. There are bathymetric charts available for many seas and there are special coastal charts. By comparing the trace and the bathymetric chart you can discover your position. All you need is an echo sounder (also 'fathometer'). The echo sounder consist of two basic components, the transducer and the recorder.

The transducer is located at the keel and transmits the signals into the sea and picks up the returning echoes. The recorder records the echoes for chart plotting purposes. The US Navy uses the AN/UQN4 sounder, which is transmitting on 12 kHz. CW electromagnetic signals are translated in pulses by the transducer. Pulse duration and repetition cycle are variable.

MARS-75, LENA

MARS-75 is the Russian answer to DECCA. This Soviet made system is also a hyperbolic LF system, but more advanced. MARS-75 was first used in the early seventies and is still in use. The former Baltic chain was closed down after the fall of the USSR. The transmitters in Wismar (E. Germany) and Tallinn were dismantled. There are still chains along the western and northern coasts of Russian like the Gulf of Finland and the Barentsz Sea. MARS-75 operates in the 64-92 kHz range. The transmitters are arranged in groups of three or four. Spread-spectrum signals are used and there are nine clusters. At the moment some 47 transmitters are still running.

LENA

A modernized MARS-75 version, LENA, will probably never come in operation because satellite systems are taking over most of the terrestrial systems at the moment.

RANA

Another system, somewhat similar to MARS-75, is the French RANA system which operates along the French coast in the frequency range 285-415 kHz. It is a complicated, time-sharing system.

DECCA look-alikes

The following systems are most probably no longer in use:
Del Norte Transponder
Mini-Ranger
Autotape DM-40A
RALOG-20
Artemis III DART

They were all based on the DECCA system and operated on LF.

Raydist

This is also a 2 MHz system similar to Hyperfix. The latest version of this system was the 'DRS-H /T' who needed four land-stations. There are no current European users but there may be some chains in the USA.

Toran P100

Another 2 MHz system is TORAN, a French made system somewhat similar to differential Omega. It is hardly used anymore.

ARGO

The U.S. DM-54 ARGO (Automatic Ranging Grid Overlay) system was originally designed for the positioning of underwater pipelines. This is also a 2 MHz system and was last heard in the USA in 1993. It is possible that there still is a chain for the Mexican Gulf.

SPRUT

SPRUT is a fairly new system, designed in 1992 and is based on spread spectrum techniques. It is a Russian system similar to BRAS-3 and RS-10. SPRUT operates in the range 1550-2050 kHz.

GEOLOC

GEOLOC is a radio positioning system with land based transmitting stations. The transmitting stations radiate spread spectrum signals in the 2 MHz band. The system has a range of 1000 km and an accuracy of about 2 meters.

The measured distances are made available for external processing whenever desired and are converted by the central processor connected to the receiver into a fix which is corrected in real time for propagation speed variations. Geoloc can be linked to Transit and Navstar satellite systems when set in 'H' mode. The satellite info improves the result of Geoloc's fix. When used in AS mode, all transmitters are synchronized through a monitoring station and two-way HF links.

In GEOSYL mode all transmitters are synchronized through a two-way time transfer SYLEDIS chain. The last known chain was in France with stations in Plouray, Aizenay and Hasparren. It closed down a few years ago. The system reportedly has no current users.

VHF/UHF systems

- **GEE**

GEE is a British system, similar to LORAN but using VHF frequencies. This limits the system to line-of-sight.

- **MAXITRAN, SHORAN**

MAXITRAN operates between 420 and 450 MHz and need two land stations.
Maxitran's predecessor SHORAN is still in use and operates between 220 and 300 MHz.

- **NDB / Locator**

Non Directional Beacons are being used by aircraft for en-route navigation, while Locators are used for navigation during approach and landing.
The beacon that is used for

- **NNSS**

NNSS (Navy Navigation Satellite System) operates in the range 399-988 MHz and is rumoured to be phased out in 1996.

- **PARUS (TSIKADA-M)**

Russian six-satellite military navigation system.

- **RSBN**

RSBN, a Russian satellite system, is slipping away after the introduction of GLONASS. Frequency range: 873.6-935.2 MHz and 939.6-1000.5 MHz.

- **SECOR**

SECOR (Sequential Collation of Range) was a US Army satellite navigation and positioning system. Thirteen satellites were launched between 1964 and 1969. Most of the satellites were small (17 kg - 20 kg) and boxy.

- **SYLEDIS**

SYLEDIS operates between 420 and 450 MHz and need two land stations.

- **TACAN**

The aero navigation systems TACAN (960-1215 MHz) is widely used. It basically has the same function as VOR-DME.

- **TIMATION**

Developed in 1972 by the Naval Research Laboratory (NRL), Timation satellites were intended to provide time and frequency transfer. The original satellite flew with stable quartz crystal oscillators. Later models flew with the first space-borne atomic clocks. The third satellite acted as a GPS technology demonstrator.

- **TRANSIT**

TRANSIT was the first operational satellite navigation system. Developed by the Johns Hopkins Applied Physics Laboratory, the system was intended as an aid to submarine navigation. The Transit system allowed the user to determine position by measuring the doppler shift of a radio signal transmitted by the satellite. The user was able to calculate position to within a few hundred meters as long as the user knew his altitude and the satellite ephemeris.

The system has several drawbacks. First, the system is inherently two dimensional. Second, the velocity of the user must be taken into account. Third, mutual interference between the satellites restricted the total number of satellites to five. Thus, satellites would only be visible for limited periods of time. These drawbacks pretty much eliminated aviation applications and severely limited land-based applications.

- **TSIKADA**

Russian is a passive Doppler, four-satellite, civil navigation system similar to the US Transit system.

- **TSYKLON**

First navigation satellite launched by the Soviet Union in late 1967. The satellite is based on Doppler techniques demonstrated by US Transit system.

- **VOR-DME**

VOR-DME (108-118 and 960-1213.5 MHz) are widely used. VHF omnidirectional range (VOR) and distance measuring equipment (DME) are used by aircraft.

Military equipment

Although primary designed for COMINT purposes and to DF enemy positions, these systems can also be used for determining your own position.

- WJ8958 is an US naval DF system which covers the 1 MHz-2 GHz bands.
- AN/SLQ-30, AN/SLQ-32 and AN/SLQ-72 are also US naval systems with HF DF capabilities.
- AN/TRQ-32 Teammate, a Comint/DF system which covers the HF/VHF/UHF frequency bands. Teammate is mounted on a US Army truck and has a telescoping antenna mast. When several units are used, one can act as the master and the others as slaves, which makes it a perfect DF system.
- AN/TSQ-112 TACELIS is the system that will replace the Teammate.
- TACELIS is an acronym for Tactical Automated Communications Emitter Location and Indentification System. It is a Comint/DF system that covers the range 500 kHz-500 MHz. The system is also mobile and works about the same as the Teammate.
- AN/TSQ-114 Trailblazer, ground mobile Comint/DF system that operates in the 500 kHz-150 MHz frequency range an accomplishes DF between 20 and 80 MHz. A Trailblazer system consists of two master stations and three remote slave stations. Each of them is mounted on a M113 vehicle and has telescoping antenna masts.
- Guardtrail is an airborne Comint/DF system that has DF capabilities in the ranges 20-70 MHz and 100-150 MHz. The system needs several aircraft, operating in pairs, to obtain the DF info which is relayed to a processing station.
- AN/ALQ-151 Quick Fix II is also an airborne system with DF and early warning capabilities. It covers the 2-76 MHz bands and is mainly used in helicopters. It's twin brother, the AN/TLQ-17, is used for intercepting communications and has also a jamming device called Traffic Jam.

Credits

Special thanks to the following WUN-members for their loggings, suggestions and information. I am very proud that so many of you participated in this project.

Andrew Brill, Bob Margolis, Craig MacKinnon, Dave Gentile, David Crawford, Day Watson, George Karayannopoulos, Klaus Betke, Lennart Deimert, Lyn Kennedy, Martin Barry, Michiel Schaay, Mike Chace, Mike Jacons, Robert Moore, Roger Basford, Roger Craig, Roland, Stan Scalsky, and everyone I have forgotten.

Other sources / further information:
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Professor B. Forsell
Racal Positioning Systems
Telia Company AB
US Coast Guard
Vaino Lehtroranta