Technical Handbook
for
Radio Monitoring
HF

Edition 2013

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Technical Handbook
for
Radio Monitoring
HF

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Description of modulation techniques
and waveforms
with 259 signals, 448 pictures and
134 tables

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Disclaimer:

The information in this book have been collected over years. The main problem is that there are not many open sources to get information about this sensitive field. Although I tried to verify these information from different sources it may be that there are mistakes. Please do not hesitate to contact me if you discover any wrong description.

Content

1 List of Pictures

2 List of Tables

3 Removed Signals

There are some modulations and systeme which ar not used anymore. To keep the number of pages in a useable range, those signals are deleted where the probabilty is very high that they never will be active on shortwave.

At the moment these are the following signals:

- ALF (2013)
- DECCA (2013)
- OMEGA (2013)
- D-OMEGA (2013)

This list will grow with the next editions. In brackets you will find the year of removment.

4 General

For years shortwave radio has been used for communication beyond the line of sight. With the introduction of world wide satellite services in the geostationary or low earth orbits HF radio communication lost more and more in interest.

But with the introduction of new, sophisticated modems and digital broadcast services in high quality HF communication has seen a renewal during the last years.

Shortwave radio, however, has some qualities that will ensure its attractiveness for some time. The most important one for commercial users is that there is no charge for using the ionosphere.
In the military context this translates to low cost, potentially global communication that has the important attributes of national ownership and military control.

And in comparison to satellite services shortwave communication is harder to disrupt.

The good old radio for shortwave has been perfected during the last years in several ways. Information data rates of a few tens of bits per second were increased to more than 19200 bit/s by sophisticated modem techniques and error correction. Algorithms were created to adapt transmission parameters to channel quality or initiate a change to a better channel. Passive and active channel analysis, i.e. sending and measuring test signals on assigned pool frequencies have been developed to solve problems of channel distortions.
For example an automatic link setup (ALE) according to an international standard is performed with a flexible address pattern. Automation guarantees a link setup whenever a useful frequency is found in the pool.

TCP/IP is the most widely used network protocol and supported by the majority of computers and software. This international standard ensures interoperability of very different platforms or operating systems. Most equipment for shortwave like modems and radios are able to interface with local networks by LAN. Even conversions form ISDN networks, GSM, PSTN and others are possible.

New developments are expected which will enhance the capabilities of transmission protocols and modem technology for higher transmission speed. Using wider bandwidths will also achieve higher data rates.

By intensifying the modulation/coding higher data rates and throughputs are possible. With modern processor technology the adaptation of transmission parameters to the channel conditions will give a higher quality for the exchange of information via shortwave.

All these circumstances will present old modes with improvements but mainly new modes with their unique sound to the shortwave listener.

This book has been written to help the listener on shortwave in identifying the different modes or waveforms which are active throughout the shortwave band. It will never be complete. New waveforms are heard nearly every month. Due to the sophisticated possibilities of modern modems the signal analyses becomes more and more very difficult.

But this book will give a good overview which techniques are state of the art today. It has to be mentioned that most of the pictures were produced with the decoder CODE 300-32 by HOKA, but some pictures are made with the PROCEED decoder by PROCITEC GmbH.

This book is divided in four main parts:

- Basic information
- Waveforms used on shortwave
- Tables to help identifying stations or circuits on shortwave
- Abbreviations and Index

The first part basic information is giving an overview about common modulation techniques with a short description and how they look like in the spectrum or phase plane display. This part also describes standard expressions from the field of coding, error correction and so on which are often used in the field of radio communication.

The following section describes most of the waveforms which can be heard on shortwave. Where ever possible the waveform is described with it’s main parameter. If there is any further information available like framing, coding aso. these are also described.

The next part is showing some tables and description which are useful for identifying stations or circuits.

The book finishes with the abbreviation table and the index.

In comparison to the previous version the descriptions of waveforms used on VHF/UHF has been moved to a second book called “Technical Handbook for Radio Monitoring VHF/UHF”. This step was necessary because the number of pages was increasing above 800 which is very difficult to handle.

6 HF Modes

The following part of the “Technical Handbook” describes waveforms in different depths. Wherever possible the different waveforms are described and enriched by spectrum, phase plane or oscilloscope pictures.
On top of the page is written the used name. Below the name is also mentioned other known names for the same waveform.

General Information

In the following descriptions there are different sort of illustrations for the described waveforms. Wherever possible the spectrum is shown. But there are also pictures for phase constellations, correlation functions, sonagram and so on.

These different type of pictures are described in the following part.

Spectrum

The spectrum display is showing the audio frequency range from 0 Hz to 5500 Hz (sometimes a larger bandwidth with 11 kHz or 22 kHz is used). The spectrum is the result of a Fast Fourier Transformation (FFT) calculated on the samples of the used audio card.

Sonagram

The sonagram view displays the relation between frequency, time and amplitude of a signal. One axis shows the frequency similar to the spectrum display, the second axis the time. The amplitude of the signal is displayed in the colour of the signal.

Oscilloscope

The oscilloscope display is showing the amplitude behaviour of a signal either as direct audio signal or the constellation after demodulation of the signal. For FSK or MFSK signals in the vertical domain the audio frequency is shown instead of the amplitude of a signal.

Phase Spectrum

For determination of the speed of a PSK signal the phase spectrum is used. Without any zoom the display is similar to the normal spectrum view. Because PSK signals very often also produce a n amplitude modulation with a peak at the symbol rate. By zooming into the spectrum these peaks can be determined and allow the measurement of the symbol rate.

Phase Plane

This display is also sometimes called a vector scope. It displays any frequency or phase modulation as a rotary vector. The phase plane is used to show the phase constellation of phase modulated signals.

Speed Bit Analyses

This function is similar to a FAX display. The bit information is displayed as a line with black for a 1 and nothing for a 0. With the correct baud rate patterns in the bit stream can be recognized.

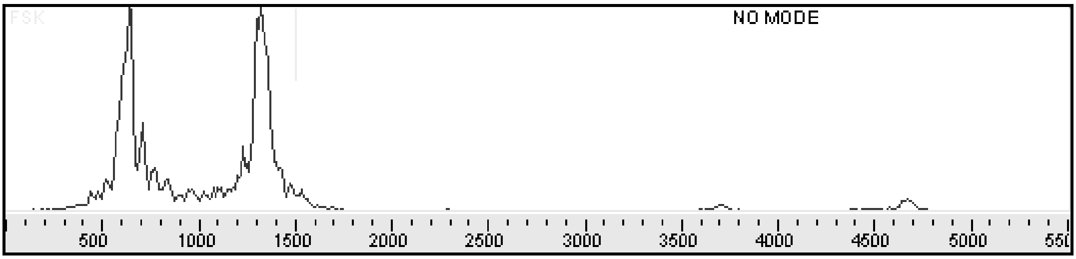
Bit Correlation, Autocorrelation Function (ACF)

The Autocorrelation Function is used to analyse the repetition of bit pattern in a bit stream. If these repetition are constant the ACF will show a peak at a value related to the length of bit pattern with is repeated. These values can range from 2 over 7.5 (like in Baudot with 1.5 stop bit), 11 (like in a ASCII transmission with 1 start, 1 stop and 1 parity bit , up to i.e. 64 for STANAG 4529. The ACF value is very specific for various modes.

1. AFS Navy FSK

This FSK modem is using a baud rate of 130.36 Bd and a shift of 700 Hz. Traffic is always encrypted. The modem is in use of the AFS navy.

The spectrum is shown in the following picture:



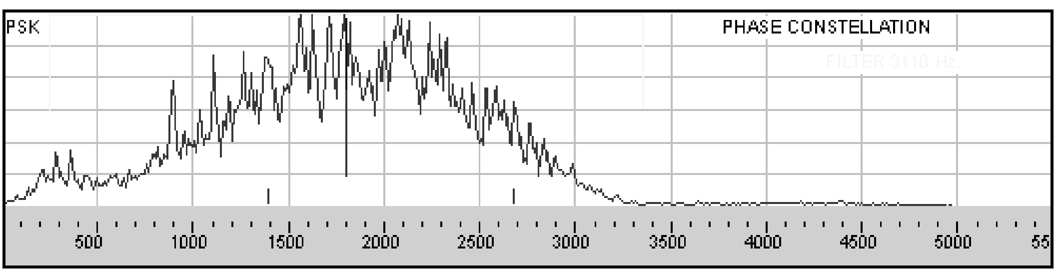
Picture 58: Spectrum of an AFS navy modem

2. ALE 3G

STANAG 4538, MIL STD 188-110A, MIL STD 188-141B App. C

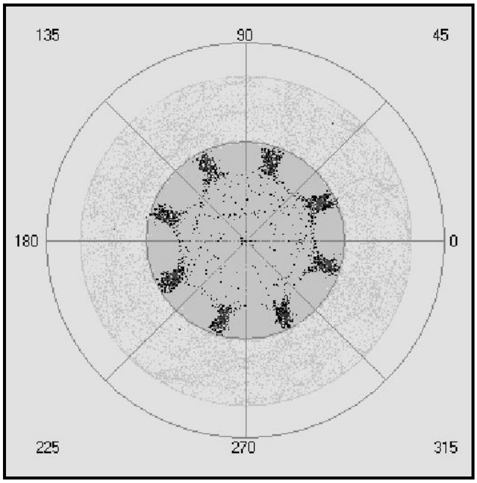
ALE 3G is the third generation of automatic link establishment. It is based on the MIL STD 188-110 with a centre frequency of 1800 Hz and a symbol rate of 2400 Bd. ALE 3G has a burst length of 613.33 ms or 1472 PSK symbols. The payload is always 26 bit. The preamble has a length of 160 ms or 384 PSK symbols. The modulation is 8PSK.

The following spectrum shows an ALE 3G.



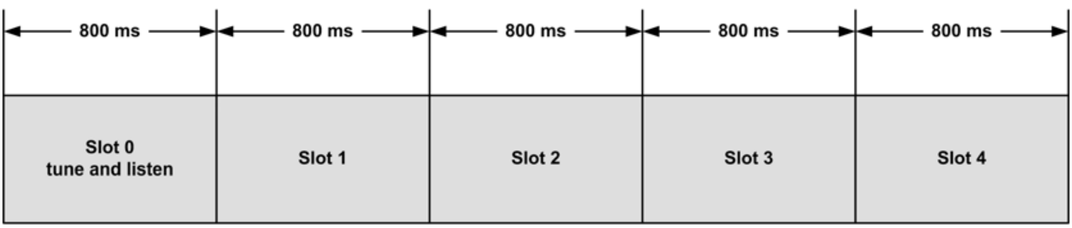
Picture 59: Spectrum of an ALE 3G

The typical phase constellation of a 8PSK is as following:



Picture 60: Phase constellation of an ALE 3G 8PSK signal

ALE 3G has the possibility to work in an asynchronous mode as ALE 2G but achieves the best performance with a synchronous mode. In the synchronous mode a fixed structure for transmissions and listening to a channel is used. Each so called dwell structure has a length of 4 seconds. The timing is divided into 5 different slots with 800ms each. The next figure shows the dwell structure of an ALE 3G.



Picture 61: Dwell structure of an ALE 3G

Each dwell period starts with a listen slot where the modem tries to detect traffic in the specific channel. This listen slot is followed by the calling slots which are used for exchanging protocol data units (PDU). The PDU has a length of 613 ms and allows 70 ms for propagation delay and 100 ms for synchronisation uncertainty.

If a calling station detects a handshake PDU it will stop its own call. If the channels are free it will call in a slot and will listen to a handshake PDU in the next slot.

The following picture shows the different PDU’s which are used in an ALE 3G:

Call Protocol Data Unit

1	0	6 Bit Called Member (not 111xx)	3 Bit Call Type	6 Bit Caller Member	5 Bit Caller Group	4 Bit CRC

Handshake Protocol Data Unit

0	0	6 Bit Link ID	3 Bit Command	7 Bit Argument	8 Bit CRC

Notification Protocol Data Unit

1	0	111111	3 Bit Caller Status	6 Bit Caller Member	5 Bit Caller Group	4 Bit CRC

Broadcast Protocol Data Unit

0	1	110	3 Bit Countdown	3 Bit Call Type	7 Bit Channel	8 Bit CRC

Scanning Call Protocol Data Unit

0	1	111	11	11 Bit Called Station Address	8 Bit CRC

Picture 62: ALE 3G protocol data units

During the call a 3 bit call type is used. These types are listed in the following table.

Call Type	Description
Packet Data	Traffic will use the ALE 3G protocol, negative SNR is ok
HF Modem Circuit	Traffic will use an HF data modem. Needs positive SNR
Voice Circuit	Order wire voice traffic. Needs SNR > 10 to 15 dB
High-Quality Circuit	Traffic needs higher SNR than order wire
Unicast	One-to-one call, caller will designate the traffic channel
Multicast	One-to-many call, caller will designate the traffic channel
Link release	Caller announces release of called station (or stations) and the traffic channel

Table 17: ALE 3G call types

3. ALE400

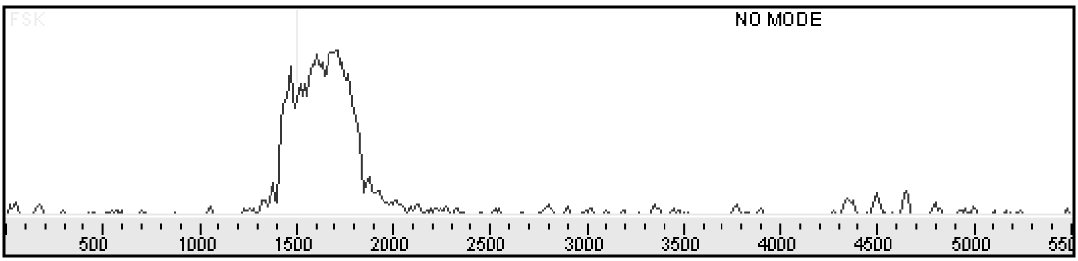
Automatic Link Setup

ALE400 is an 8FSK waveform for automatic link establishment developed by Patrick Lindecker F6CTE derived from the MIL STD 188-141A with a narrow bandwidth of 400 Hz so that this mode can be used in 500 Hz channels. It has exactly the same functions as the standard ALE. The baud rate was reduced to 50 Bd. The tone distance between carriers is 50 Hz.

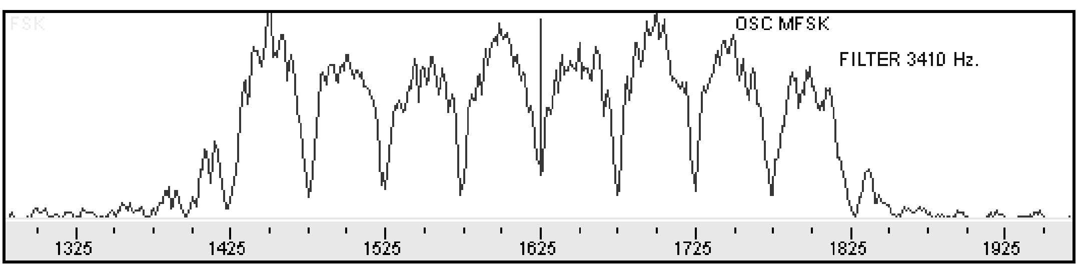
Related to a centre frequency of 1625 Hz this gives the following tone layout:

Tone Number	1	2	3	4	5	6	7	8
Frequency in Hz	1450	1500	1550	1600	1650	1700	1750	1800
Binary Value	000	001	011	010	110	111	101	100

Table 18: Tone layout for ALE400



Picture 63: Spectrum of ALE400

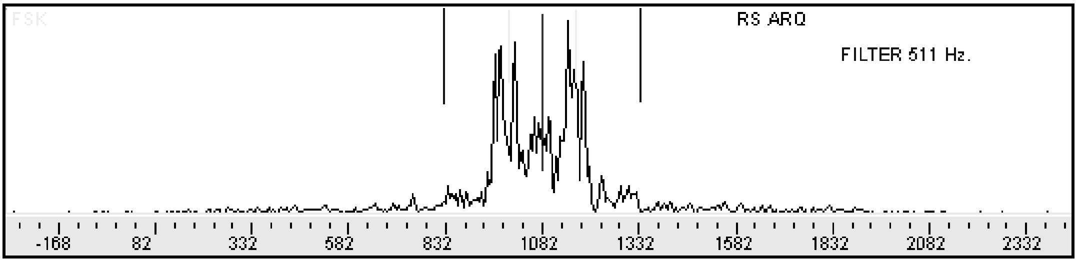


Picture 64: Expanded spectrum of ALE400

4. ALIS

Automatic Link Setup

ALIS is the automatic link processor and frequency management system used by all Rhode & Schwarz modems besides ALE. ALIS is using narrowband FSK with 228.66 Bd and a shift of 170 Hz.



Picture 65: Spectrum of an ALIS signal

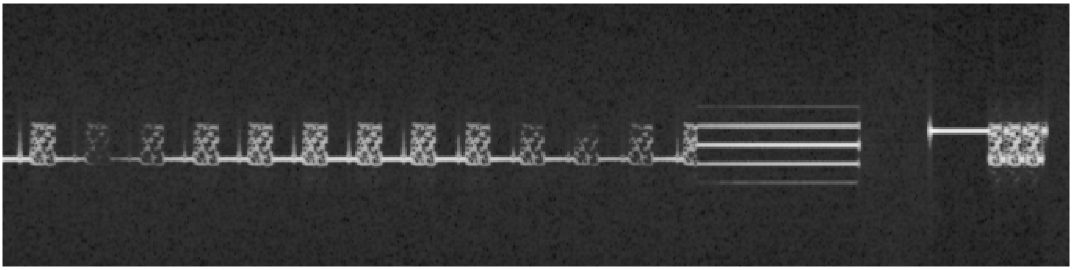
With the ALIS software selected for the Data Link Processor R&S GS2200, the following functions are automatically handled by the processor:

- Continuous passive channel analysis of all pool frequencies during scanning mode
- Channel selection by means of computation of the optimum working frequency from a pool of frequencies
- Reliable and fast link setup at the optimum available frequency
- Selective calling addresses (up to 9999)
- Automatic transmission of status
  - Type of modulation
  - Speed of data transmission
  - Type of data protection (FEC, ARQ, PRP)
- Automatic error correction (ARQ or PRP) and adaptive response during message transmission, either at a data rate of 228.66 Bd (normal FSK modulation, basic feature) or with additional HF data modem up to 5400 bit/s
- Data transmission format
  - 5 bit Baudot (telex)
  - 7 bit ASCII (text files from PCs)
  - 8 bit ASCII (text and binary files etc)
- Message length: unlimited

Depending on the requirements:

- Preferred or existing method
- Link setup with or without adaptive response
- Response to interference on the radio link (ARQ)
- Frequency economy, spectrum pollution and probability of intercept considerations
- Operator convenience, error correction and expandability
- Interoperability with legacy systems and those of other manufacturers

The following sonagram shows the typical link set up procedure of the R & S –ALIS:



Picture 66: Sonagram ALIS link setup procedure

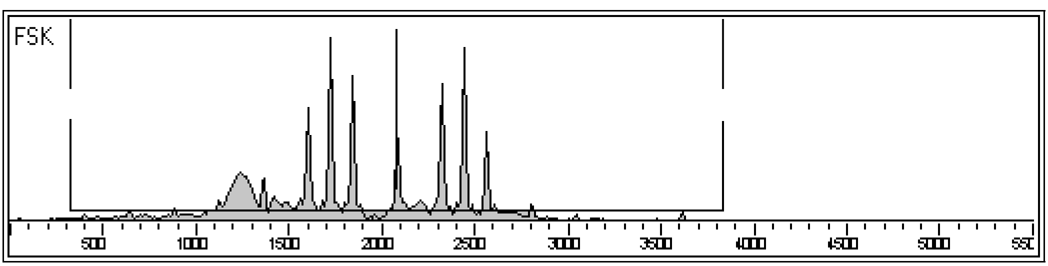
5. ALIS 2

Improved Automatic Link Setup

ALIS 2 is a burst 8 tones MFSK ARQ system made by Rohde & Schwarz with a standard speed of 240 Bd (equivalent to 720 bit/s).
Shift between tones is 240 Hz, and the tone duration is 4.15254 ms.

A preamble which contains an identification code and has a length of 21 bits. The transmission block consists of 55 tri-bits, resulting in 165 bits per frame. A 16 bit CRC checksum is used.

The system can use either 5 bits ITA2 or 8 bits ASCII ITA5 alphabet.



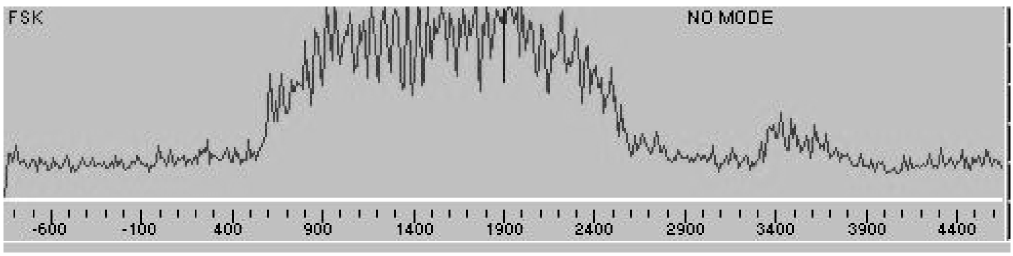
Picture 67: Spectrum of ALIS 2

6. ARD9800 OFDM 36ch Modem

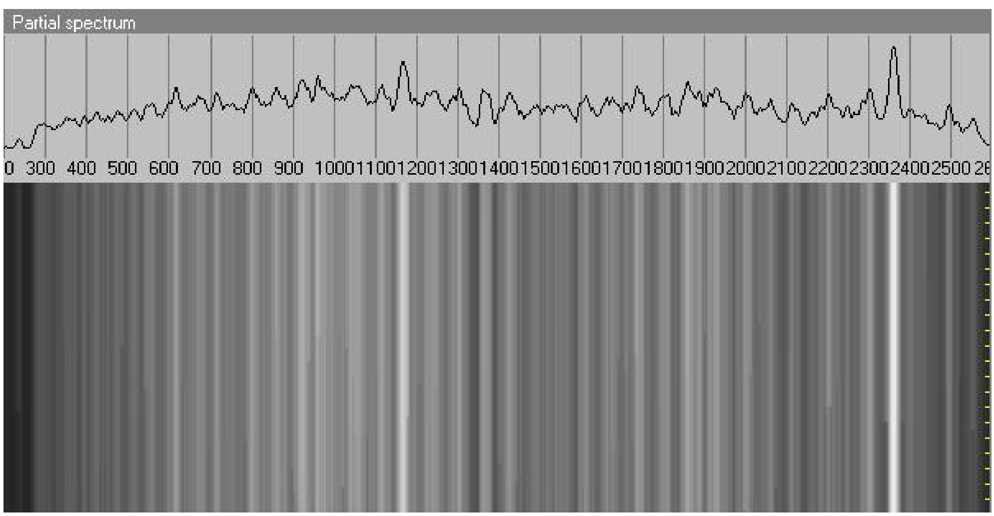
ARD9800

This modem developed by AOR is using OFDM as modulation method. The OFDM is using 36 carriers in the range from 300 Hz - 2500 Hz. The symbol rate of each carrier is 50 Bd with a guard interval of 4 ms. The spacing between the carriers is 62.5 Hz. Each carrier is DQPSK modulated. The error correction for voice is Golay & Hamming, for video/data Convolution & Reed-Solomon.
Each transmission starts with a header of 1 sec and consists of 3 tones and a BPSK training pattern for synchronization.

For digital voice the AMBE2020 coder and decoder are used.



Picture 68: Spectrum of ARD9800-OFDM



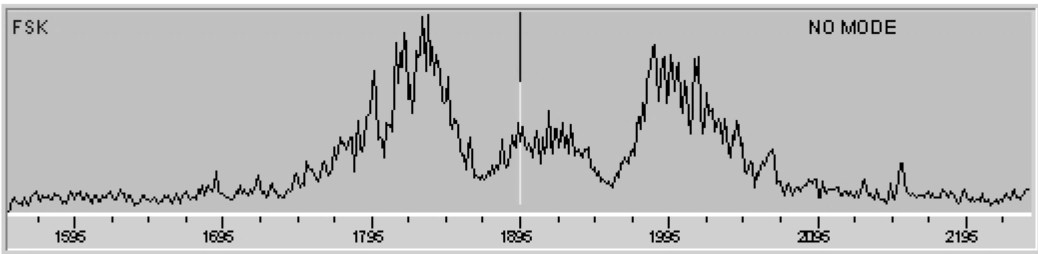
Picture 69: Spectrum and Sonagram of ARD9800-OFDM

7. ARQ-E

ARQ-N, ARQ-1000 duplex

ARQ-E is a synchronous duplex ARQ with the 2 stations on different frequencies. It is using the 7 bit ITA 2-P alphabet with 4, 5 or 8 character repetition cycle, inverting every 4th, 5th or 8th character.

In the ARQ-N system all characters are erect. ARQ-N is mainly heard with 96 Bd.



Picture 70: Spectrum of an ARQ-E signal with 288 Bd

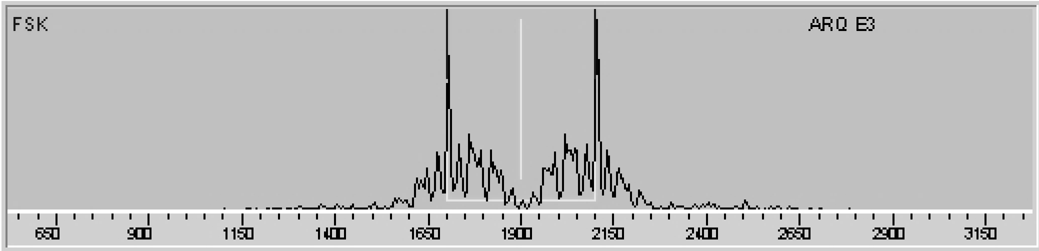
ARQ-E and ARQ-N are operating in duplex mode with baud rates of 48, 50, 64, 72, 96, 144, 184.6, 192 and 288 Bd.

8. ARQ-E3

CCIR 519 Variant, TDM 342 1 Channel

ARQ-E3 is a synchronous duplex ARQ using the 7 bit error correcting ITA 3 alphabet with repetition cycle of 4 or 8 characters.

Two stations are working on different frequencies as Master and Slave stations. If another faulty code than the 35 combinations of the allowed alphabet is received a repetition request is initiated. The RQ signal is initiating the retransmission. All characters are checked within one repetition cycle, an error signal is triggering another repetition process immediately until all signals are received correctly.
In a standard repetition cycle of 4 characters one RQ and three repeated characters and in a repetition cycle of 8 characters one RQ and 7 repeated characters are transmitted.



Picture 71: Spectrum of ARQ-E3 in idle mode

Note: In idle mode ARQ-E3 is often detected as FEC 100!

ARQ-E3 is operating in duplex mode with baud rates of 48, 50, 96, 192 and 288 Bd.

Picture 72: ARQ-E3 – Signal Structure

9. ARQ-M2

TDM 242, TDM 342, CCIR 242, CCIR 342, ARQ-28

ARQ-M2 CCIR 242 is a synchronous duplex ARQ system using the 7 bit error correcting ITA 3 alphabet consisting of two or four channels in time division multiplex in a single radio channel.

The two stations use different frequencies for full duplex operation.

The 2 channel system is simply made from interleaving erect characters for channel A and inverted characters for channel B, i.e. A, -B, A, -B, A, -B, A, -B etc.

ARQ - M2 is used on fixed lines between two stations. Due to their automatic transmission they often have long idling periods in which no information is transmitted. These periods can be recognized by a typical rhythm on the signal. If there is any information transmitted this rhythm is not audible.

The main baud rate is 96 and 200 Bd.

10. ARQ-M4

TDM 242, TDM 342, CCIR 242, CCIR 342-2, ARQ-56

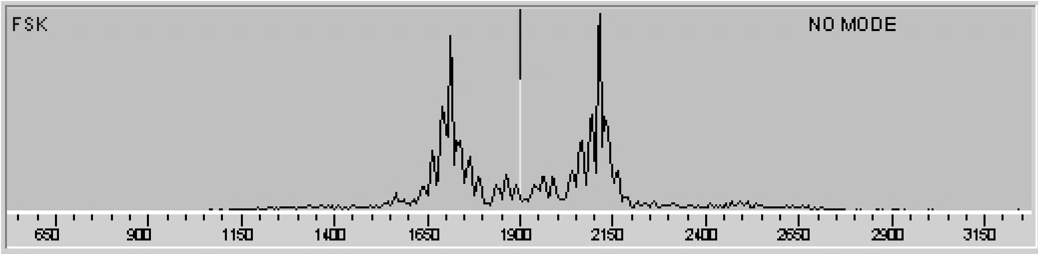
ARQ – M4 CCIR 342 is a synchronous duplex ARQ, which uses the ITA 3 alphabet 7 bit. Two or four channels in TDM (time division multiplex) are possible.

Two stations are working on different frequencies, working as ISS (transmitting) and
IRS (receiving) station.

At start of a cycle the first characters of all channels are inverted;
1 channel: A-channel erect
2 channel: A-channel erect, B-channel inverted, character interleaved.
4 channel: A-channel erect, B-channel inverted, C-channel inverted, D-channel erect
Channels A and B character interleaved, A/B and C/D bit interleaved.

Marked cycles of 4 and 8 characters.

ARQ–M4 is used on fixed lines between two stations. Due to their automatic transmission they often have long idling periods in which no information is transmitted. These periods can be recognized by a typical rhythm on the signal. If there is any information transmitted this rhythm is not audible.



Picture 73: Typical spectrum of an ARQ-M4

This system was mainly heard with 192 Bd.

11. ARQ-S

ARQ 1000-S, Siemens ARQ 1000

ARQ-S is a synchronous simplex ARQ using the 7 bit error correcting ITA 3 alphabet with the addition of 1 bit for parity-check. The receiving station is checking the 3:4 ratio of the ITA 3 code. If the pulse polarity is not corresponding to this ratio, an automatically repetition is initiated. The additional parity of 1 bit is reducing the error rate. The receiving station is transmitting an acknowledgement signal RQ if the character block is received correctly and requests the next block. If the received block contains errors a repetition is requested. If the acknowledgement signal is not received correctly, a special character for retransmission is transmitted.

Two stations use the same frequency, working as ISS (transmitting) and IRS (receiving) stations. For automatic setting - up selective calling is possible also FEC operation with error correction in time diversity mode for broadcast transmissions.

Every odd numbered cycle has all bits inverted. Repetition cycle timings for block lengths of 3, 4, 5, 6 or 7 characters are as follows:

Cycle	Characters	Transmission	Pause
438 ms	3 characters at 7 bits	219 ms	219 ms
583 ms	4 characters at 7 bits	292 ms	292 ms
729 ms	5 characters at 7 bits	365 ms	365 ms
875 ms	6 characters at 7 bits	438 ms	438 ms
1021 ms	7 characters at 7 bits	510 ms	510 ms

Table 19: ARQ-S repetition cycle

For FEC operation every message is transmitted twice in a time diversity procedure. After a space of 15 characters the first transmission is repeated. If a character block is received with errors, the system is waiting for the second transmission to print the correct information. If this is also not possible this character is replaced by a blank space.

12. ARQ-SWE

SWED ARQ, CCIR 518 Variant

ARQ-SWE is a synchronous simplex ARQ using the error correcting 7 bit ITA 3 alphabet with one extra bit for parity checking.

Two stations use the same frequency, working as ISS (transmitting) and IRS (receiving) stations. Every odd cycle has all the bits inverted. According to the quality of the radio link SW ARQ can change the block length between 3, 9 or 22 characters. A block length of 3 characters is identical to SITOR A.

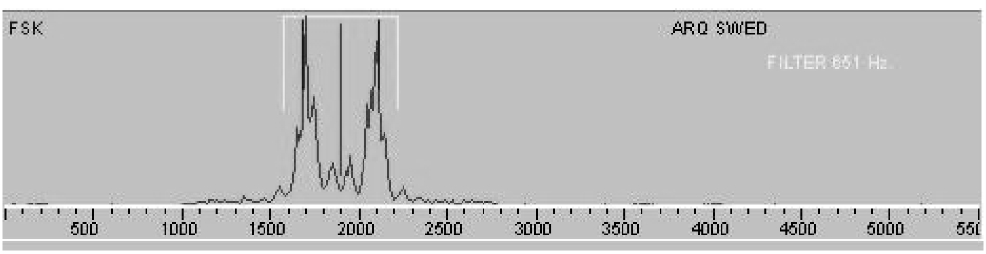
The repetition cycle is as follows:

Cycle	Characters	Transmission	Pause
450 ms	3 characters at 7 bits	210 ms	210 ms
900 ms	9 characters at 7 bits	630 ms	270 ms
1800 ms	22 characters at 7 bits	1540 ms	260 ms

Table 20: ARQ-SWE repetition cycle

SW ARQ is normally using 100 Bd and a shift of typical 400 Hz.

This system, based on normal SITOR, was used by the Ministry of Foreign Affairs (MFA) of Sweden. A similar ARQ was used by the MFA of Norway but without changing the character cycle.



Picture 74: Spectrum of ARQ-SWE

13. ARQ 6-70S

CCIR 518 variant S

ARQ 6-70 is a synchronous simplex ARQ using the 7 bit error correcting ITA3 alphabet with two stations (usually) on the same frequency, one of them called the ISS (transmitting), the other the IRS (receiving) station.

Complete repetition cycle is as follows:

ARQ 6-70: 350 ms: 6 characters at 35 ms = 210 ms with 140 ms pause.

ARQ 6-70 is working with 200 Bd.

14. ARQ 6-90/98

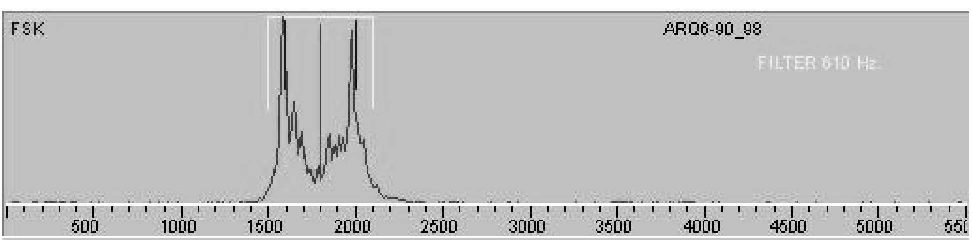
CCIR 518 variant

SITOR ARQ 6-90/98 is a synchronous simplex ARQ using the 7 bit error correcting CCIR 476 alphabet with two stations (usually) on the same frequency, one of them called the ISS (transmitting), the other the IRS (receiving) station. Each transmitted block contains 6 characters or 42 bit.

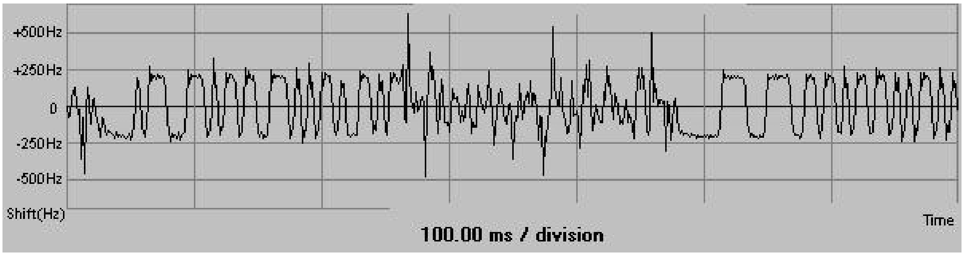
Complete repetition cycle is as follows:

ARQ 6-90: 450 ms: 6 characters at 35 ms = 210 ms with 240 ms pause.
ARQ 6-98: 490 ms: 6 characters at 35 ms = 210 ms with 280 ms pause.

ARQ 6-90/98 is working with 200 Bd.



Picture 75: Spectrum of an ARQ 6-90



Picture 76: Oscilloscope display of ARQ 6-90

15. ASCII

IRA-ARQ ITA No.5

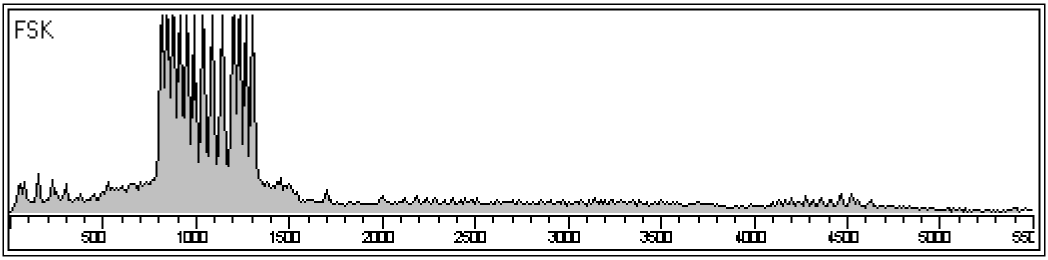
ASCII is a continuous asynchronous signal with 1 start bit, 5, 6, or 7 data bits and optional a parity bit and 1 stop bit. A character can consist of total 8, 9 and 10 bits. Parity can be none odd or even.

This system implements the parity check which means that one bit (parity bit) is added at the end for error detection. The number of *1s* is checked and if an odd number is found and parity has been defined as ODD, then the parity bit should be *1*, otherwise an error has occurred. If parity has been defined as EVEN and an even number of *1s* is found, then the parity bit should also be *1*.

16. AUM-13

AUM-13 is a MFSK which is transmitting numeric codes with a data rate of 8 Bd. This mode uses 10 tones for the transmission of the numbers 0…9 and 3 tones for message handling. On tone is assigned as idle, one for the space and one for repetition.
The transmission starts with a sequence transmitted with 1Bd and is changing to 8 Bd for the data.
The total bandwidth is 480 Hz. The modulation is AM.

This slow speed allows an exchange of information even under poor conditions and multipath propagation with fading.

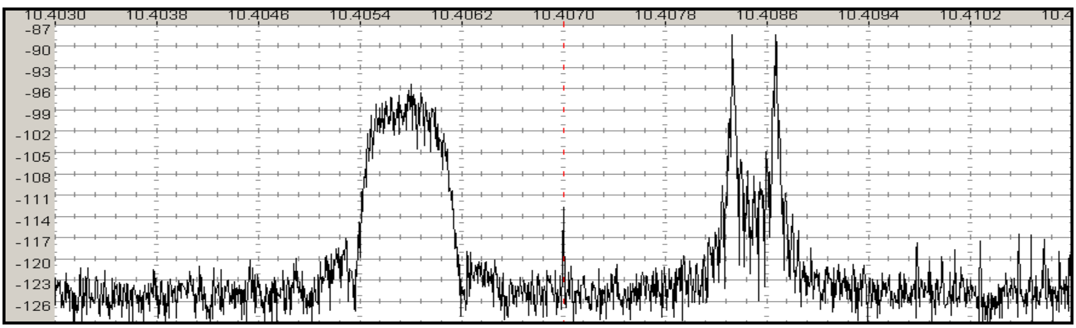


Picture 77: Spectrum of AUM 13 signal

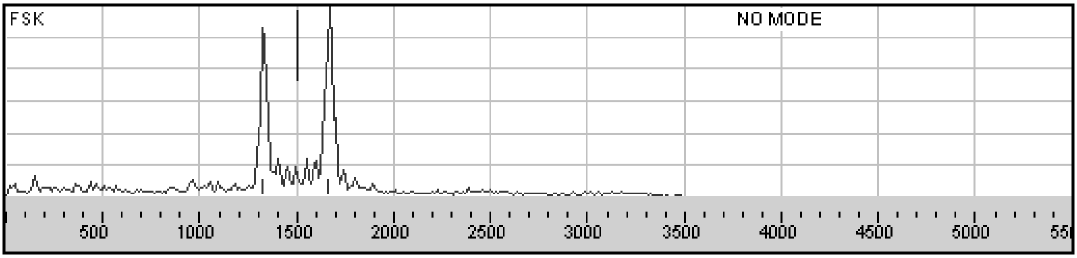
17. AUS MIL ISB Modem

This ISB modem is in used of the Australian forces. It is using the upper and lower sideband with different signals and modulation. In the upper sideband is transmitted a 50 Bd signal with 340 Hz shift and in the lower sideband a 600 Bd signal with 600 Hz shift.

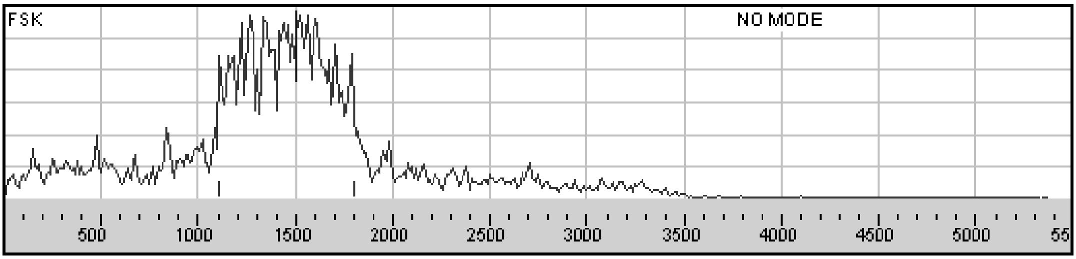
Both modems are encrypted with no apparent ACF.



Picture 78: Spectrum of the AUS MIL ISB modem with both waveforms



Picture 79: Spectrum of the 50 Bd waveform



Picture 80: Spectrum of the 600 Bd waveform

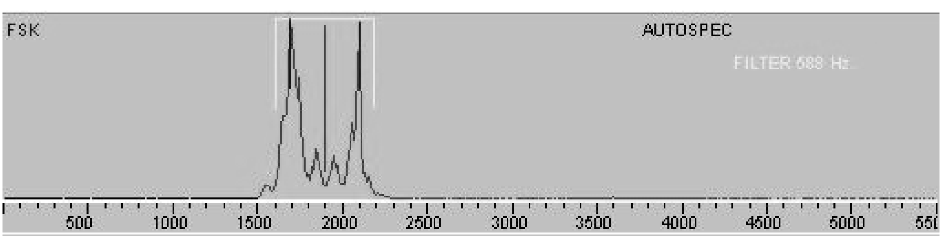
18. AUTOSPEC

AUTOSPEC with Spread 11, Spread 21, Spread 51

AUTOSPEC is a synchronous FEC system that converts the 7 1/2 unit ITA-2 code into 10 element error detectable characters. It is used in one way or two way radio links. Single bit errors are corrected.

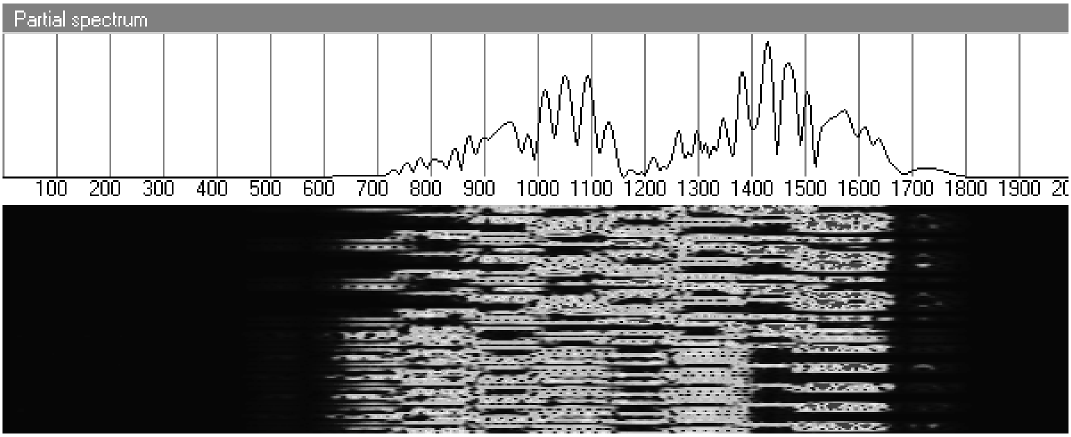
The original Mark I was 0 interleave, MK II introduced 10 (the 'norm'), 20 and 50 character interleave.

The system operates at 68.5 Bps for 50 Bd input and 102.75 Bps for 75 Bd input.



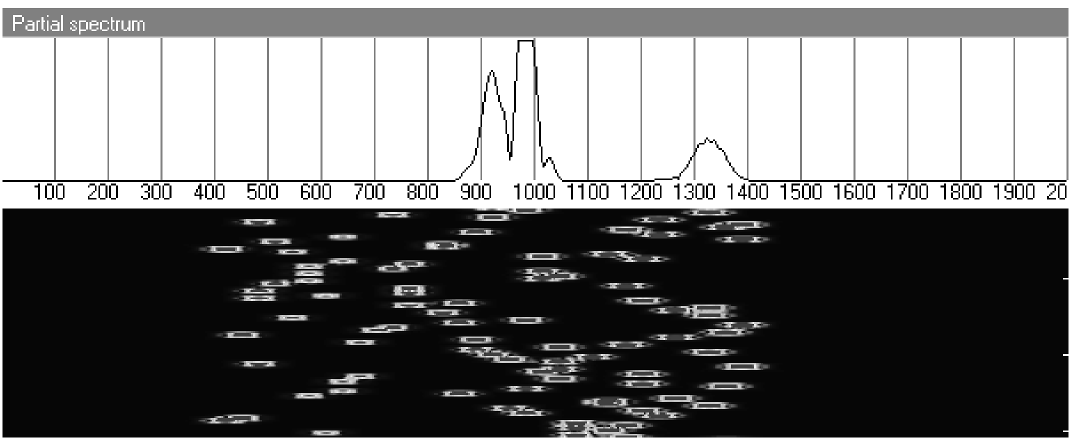
Picture 81: Spectrum of AUTOSPEC with 75 Bd

Contestia 8-1000 mode:



Picture 181:: Spectrum and sonagram of Contestia 8-1000 mode

Contestia 32-1000 mode:

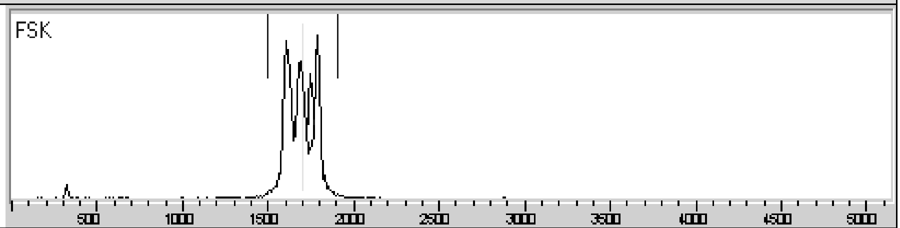
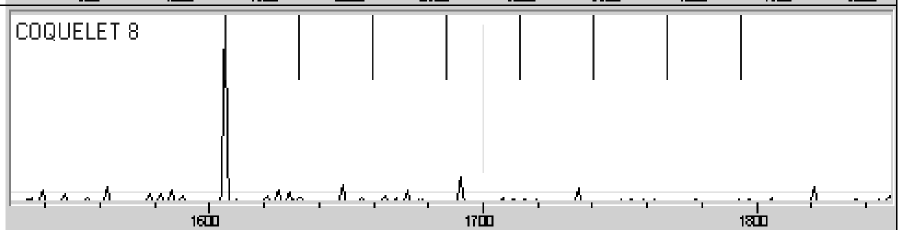
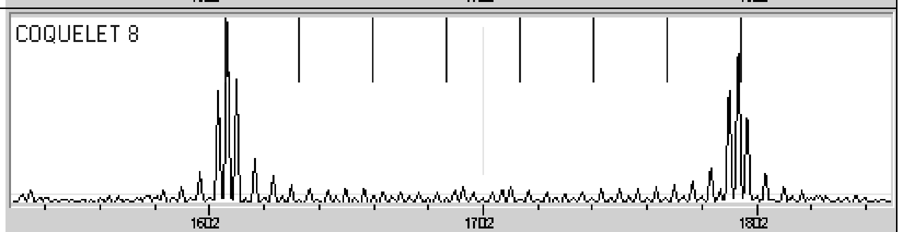
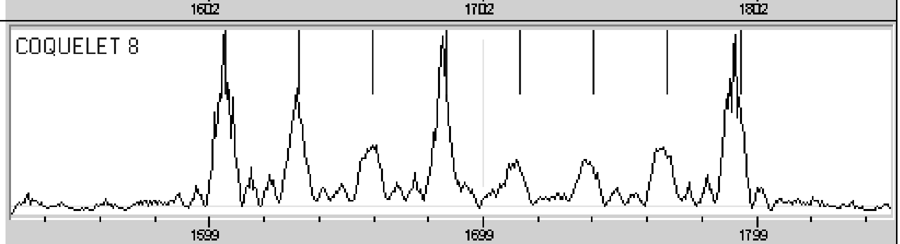


Picture 182:: Spectrum and sonagram of Contestia 32-1000 mode

73. Coquelet 8

Coquelet 8 is a French designed system based on sending 2 audio tones, in sequence from a selection of 8 for each of the different characters to be sent.
Idle /standby condition is between tones 4 and 5.

The tones used have a space of 27 Hz for the 13.3 Bd system and 26.7 Hz for the 26.67 Bd system. Both are grouped in 2 tone groups.

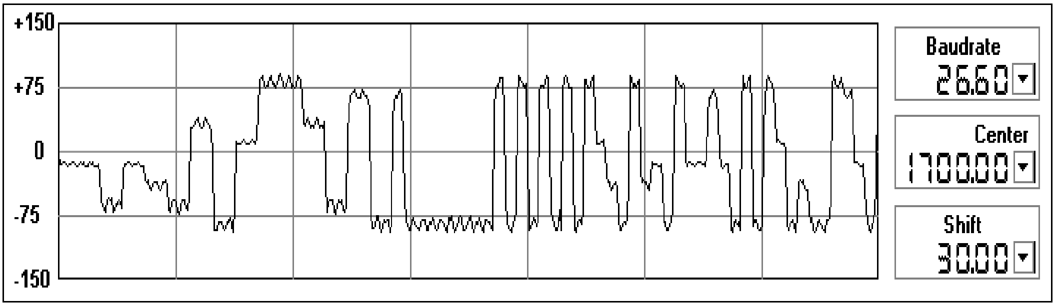
Tuning	
Spectrum Analyzer full scale	
Transmission start Only one tone present	
Idle conditions Only the first and the last tone are present	
Transmission: All eight tones are present	

Picture 183: Example of Coquelet-8 decoding

Tone assignment

Group 1								Group 2			
1	2	3	4	5	6	7	8	9	10	11	12
773	800	826	853	880	907	933	960	880	907	933	960

Table 39: Coquelet tone frequencies



Picture 184: MFSK Coquelet-8 signal

74. Coquelet 8 FEC

Coquelet 80

Coquelet 8 FEC is a synchronous system with error correction. Similar to Coquelet 8 the system is using two tones assigned to two groups but with slightly different frequencies.
The FEC is done by transmitting every character twice with a specific time between both transmissions. The second character has a different format caused by mathematical operations.

Tone assignment:

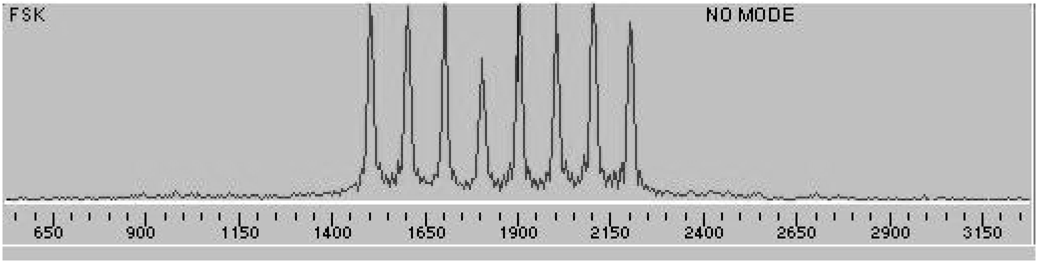
Group 1								Group 2				
1	2	3	4	5	6	7	8	1	5	6	7	8
773	800	827	853	880	907	935	960	773	880	907	935	960

Table 40: Coquelet tone frequencies

75. Coquelet 100

MFSK Modem ALCATEL 810

This robust waveform uses 8 tones which are modulated with different speeds of 16.7 and 100 Bd. The tone spacing is 100 Hz.



Picture 185: Spectrum of Coquelet 100 with 16.7 Bd

76. Coquelet 13

Coquelet MK1, French Multitone

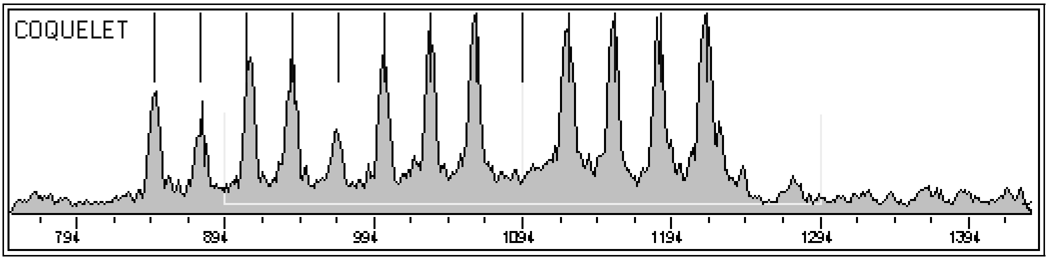
Coquelet 13 is a French designed system based on sending 2 audio tones, each 75 ms, in sequence from a selection of 12 for each of the different characters to be sent. Idle /standby condition is tone 0. This tone 0 is between the two centre tones 8 and 9, thus making tuning easy when the station is in standby/ idling. The baud rate transmitted is 13.33 Bd and 20 Bd.

Tones used are No. 1 to 8 at 30 Hz apart for group I and tones No. 9 to 13 at 30 Hz apart for group II.
Coquelet is using the ITA 2 characters. They are converted into tones by the following table:

Tone number	Frequency in Hz	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5
1	812			1	1	1
2	842				1	1
3	872					1
4	902			1		
5	932			1		1
6	962			1	1	
7	992				1	
8	1022					
0 (idle tone)	1052					
9	1082	1	1			
10	1112	1				
11	1142		1			
12	1172					

Table 41: Frequencies used by Coquelet

The two tones are selected from each frequency group for the transmitted characters.



Picture 186: Spectrum of Coquelet 13

77. CROWD 36

CIS-36, Russian Piccolo, URS Multitone, CIS 10 11 11

It is Soviet MFSK full duplex system on two transmission frequencies that can be also used in simplex mode. It uses 36 tones based on the British Piccolo.

This system runs usually at 40 Bd with a single tone lasting 25ms and hand keyed traffic between operators at 10 Bd with a single tone lasting 100ms.
A spectrum analyzer will show the tones arranged in 3 distinct groups of 10+11+11 tones spaced 40 Hz. Tones 1, 12, 24 and 36 are rarely used so you are likely to see an 80 Hz gap between groups.

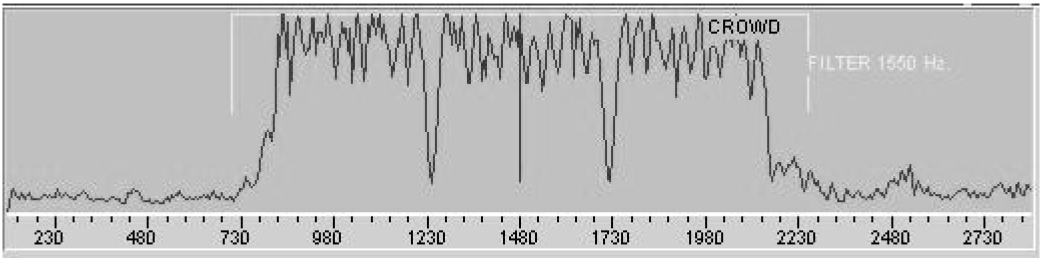
Each of the 32 tones represents one ITA2 character code. CIS diplomatic and Mil service is the main user with suspected use by CIS Intel and Military services.

Idle tone is number 24. For encryption a shift register can be used. CROWD 36 is transmitting blocks of ten data frames and an additional parity frame. Each data frame contains five data characters with one parity character. In case an error is detected the receiving station requests a frame repetition (NAK instead of ACK) from the last complete and correctly received frame.

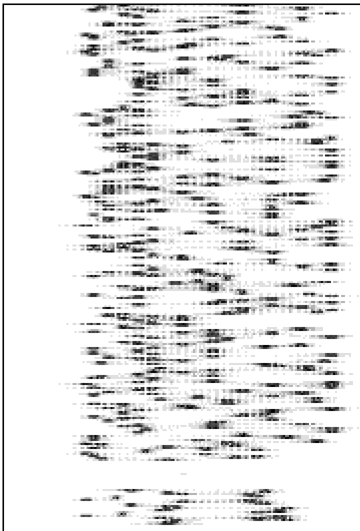
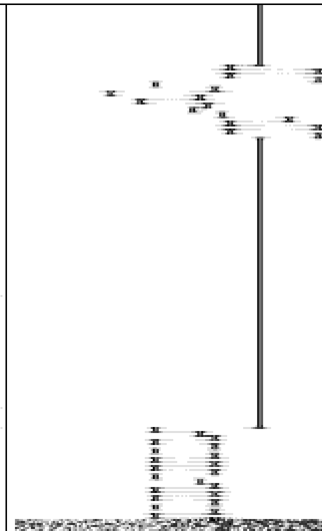
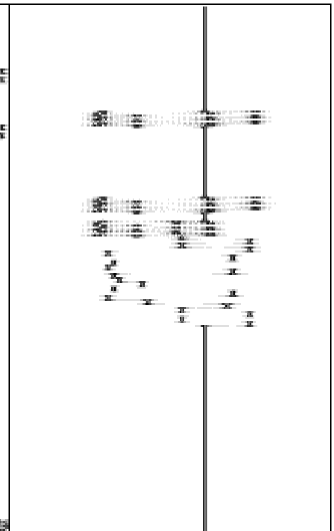
There are several 4 letter groups or control sequences used for different transmission modes.
For example:

VDAE	
VDBA	Change to chat modus
VDBG	
VDGB	
VDCB	
VDCE	resynchronisation?
VDFB	break
VDEA	end of transmission

Table 42: Crowd 36 control sequences



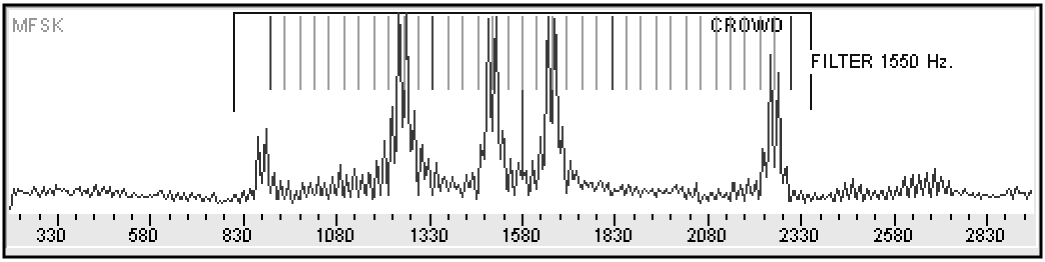
Picture 187: Spectrum of CROWD 36

		
Preamble and 5 letter group transmission	*Op chat : 'RYRYRY' and 'CFM'*	*Op chat: 'QSL' and 'end of transmission'*

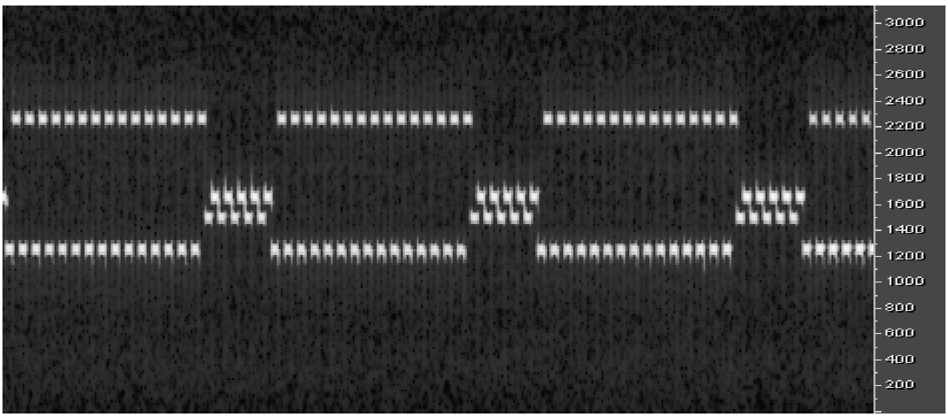
Picture 188: Crowd 36 in sonagram display

78. CROWD 36 Selective Calling

This mode is used for calling a station in the network outside the scheduled times.



Picture 189: Spectrum of CROWD 36 selective calling



Picture 190: Sonagram of CROWD 36 selective calling

79. CW

Morse

The oldest “data” transmission, still in use by the Amateur community, Marine and Military operations.

The standard code is as follows:

A	.-	N	-.	1	.----	.	.-.-.-
B	-…	O	---	2	..---	,	--..--
C	-.-.	P	.--.	3	…--	?	..--..
D	-..	Q	-.--	4	….-	(	-.--.
E	.	R	.-.	5	…..	)	-.--.-
F	..-.	S	…	6	-….	-	-….-
G	--.	T	-	7	--…	“	.-..-.
H	….	U	..-	8	---..	_	..--.-
I	..	V	…-	9	----.	‘	.----.

J	.---	W	.--	0	-----	:	---...
K	-.-	X	-..-	/	-..-.	;	-.-.-.
L	.-..	Y	-.--	+	.-.-.	$	...-..-
M	--	Z	--..	=	-...-		

Table 43: Morse alphabet

80. CW-F1B

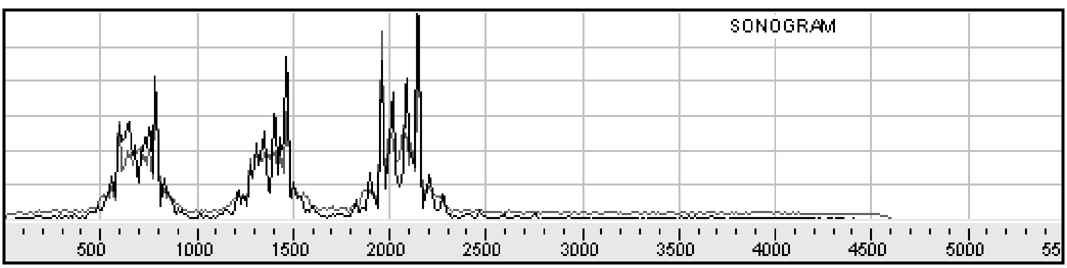
FSK Morse, Morse F1B

In this special mode of a standard FSK the morse character are keyed by using the two frequencies of the FSK**.**

81. D AF VFT

This VFT with 3 channels is in use by the German Airforce. It is transmitting three channels with 144 Bd or 192 Bd and 340 Hz Shift. The shift between channels is 680 Hz.

This system can often be heard for communication training.

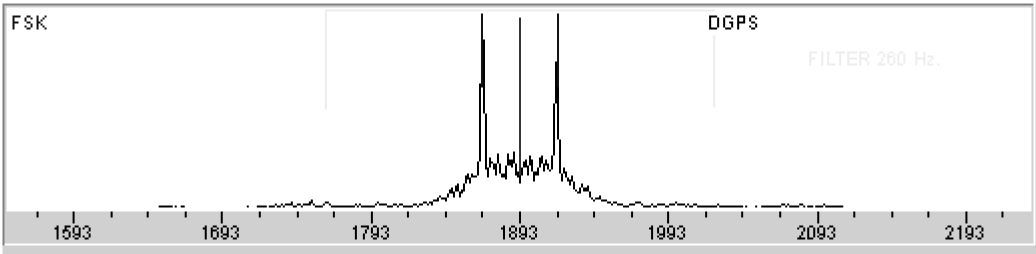


Picture 191: Spectrum of a D AF VFT signal

82. DGPS

Differential Global Positioning System

DGPS transmissions are broadcasted in the 284.5 KHz to 325 KHz band which is allocated for maritime radio navigation (radio beacons). Marine radio beacons are used to broadcast DGPS signals on the main carrier using Minimum Shift Keying (MSK) modulation. DGPS stations have also been monitored in the frequency range up to 7 MHz. The baud rate can be 100 Bd or 200 Bd. There have been stations monitored with 300 Bd and a shift of 200 Hz.



Picture 192: Spectrum of a DGPS signal with 100 Bd

The modulated signal is containing DGPS information and the identification of the transmitting DGPS station according to the RTCM SC104 standard. Broadcasted message types are 3, 5, 6, 7, 9 and 16.
DGPS data are transmitted in frames. The two first words of each frame are containing the reference station ID, the message type, a sequence number and the health of the station. The station health gives the resolution of the user differential range error (UDRE). Each data word has a length of 30 bits with 24 bits data and 6 bits parity.

Parameter	Bits	Description
Preamble	8	Fixed pattern 0110 0110
Message type	6	0 – 63
Station number	10	0 – 1023
Modified z count	13	Counts from 0 to 6000 every 0.6 s
Seq	3	Counts from 0 to 7
N	5	Number of data words following 0 - 31
Station health	3	111 = unhealthy broadcast 110 = unmonitored broadcast 101 = UDRE Scale Factor = 0.10 100 = UDRE Scale Factor = 0.20 011 = UDRE Scale Factor = 0.30 010 = UDRE Scale Factor = 0.50 001 = UDRE Scale Factor = 0.75 000 = UDRE Scale Factor = 1.00
Parity	2 x 6	XOR

Table 44: Data structure of DGPS

TX numbers

The TX number in the first header word identifies the received beacon. Two numbers exits: 1. GPS reference station number and 2. DGPS broadcast station number. Some authorities use the RTCM standard and send the reference station number, others use the TX number.

Message types

Type 3 Message

A Type 3 message contains information on the identity and surveyed position of the active reference station in the DGPS station. Two reference stations are provided in a DGPS station (dual redundancy). At any given time one will be on air and the other will serve as a .hot standby. In the event of a reference station changeover, the position coordinates which are broadcast in the Type 3 Message will change to reflect the other reference station surveyed position and its identity. The Type 3 Message will contain NAD 83 coordinates since this system is the only one in North America that can take advantage of the centimetre resolution provided in this message.

Type 5 Message

The Type 5 message will notify the user equipment suite that a satellite that is deemed unhealthy by its current navigation message is usable for DGPS navigation. This is accomplished by the setting of the “Health Enable Function” in the Type 5 Message by the reference station in order to indicate this condition. An example of this situation is a slowly drifting satellite clock that may render a satellite unhealthy for GPS use, but would be correctable by the reference station for DGPS use. The user equipment suite should not use an unhealthy satellite unless a Type 5 Message allowing the use of an unhealthy satellite was received within the last thirty minutes. If the most recent Type 5 Message received does not indicate that an unhealthy satellite can be utilized, then the use of that satellite should be discontinued if it were being used earlier (i.e. via a previous Type 5 Message).

Type 7 Message

A Type 7 Message provides information of its broadcasting DGPS station and the other two or three adjacent DGPS stations. Where adjacent stations are under US jurisdiction, appropriate arrangements will be made to provide reciprocal information. The user equipment suite should update its internal almanac immediately as new information is received. Non volatile memory should be employed to store the internal almanac. When a broadcast becomes unhealthy or unmonitored in a DGPS coverage area, the Type 7 Message will be set to indicate the subject condition. Upon receiving the next Type 7 message, the user’s equipment suite should immediately update its internal almanac. Additionally, the user equipment suite is immediately notified by means of the station health status indicator contained in the second word of the universal message header. The user should be able to view the contents of the current Type 7 Message in order to obtain information on coverage areas that may soon be entered.

Type 9 Message

Due to the advantages of greater impulse noise immunity, lower latency and a timely alarm capability, the Type 9 Message has been selected for broadcasting pseudo range corrections instead of the Type 1 Message. Two methods of transmitting the Type 9 message are possible.

Type 9-3 Message

The first method of broadcasting PRC’s (Pseudo Range Corrections) is based upon “Three-Satellite “Type 9 Messages. This is denoted as Type 9-3 Message. In this method all satellites for which corrections are broadcast are assigned to either three satellite

Type 9 Messages or to a remainder message of either one or two satellites. The transmission rate could be at either 100 or 200 bps. For example, the pseudo range corrections for eight satellites will consist of three Type 9 Messages, two with 3 satellites and one with two satellites. An equal number of corrections are broadcast for each satellite.
In order to optimize use of the UDRE Scale Factor in the message header, satellites will be grouped in messages by their UDRE values. At a transmission rate of 200 bps this represents a minimum of a forty percent reduction in message loss as compared to a Type 1 Message under high noise conditions broadcast at the same bit rate. The relative latency of the different PRC message types is illustrated in Figure 2 - note that since the corrections can be applied as soon as the parity is verified for the words that contain a given correction, the latencies in Figure 3 are the maximum latencies. PRC accuracy is for the most part a function of the latency of the Range Rate Correction (RRC) since it is the only PRC component in which the error is a function of time. The error of the PRC (t0) term is fixed at the time of measurement and any errors that result from its propagation are a function of RRC accuracy. Figure 3 illustrates an additional advantage of the Type 9 Message - the phasing of the PRCs. When the latency for certain satellites is nearing its maximum the latency for others is very low. This provides a built-in immunity factor to high pseudo range accelerations on one or more satellites. The potential to weight pseudo ranges on the basis of latency is readily apparent and should be beneficial to the user. This method of transmitting a Type 9 message at 100 bps and 200 bps will be used for the standard and enhanced/multiple coverage areas respectively.

Type 9-1 Message

The second method of broadcasting pseudo range corrections is to broadcast individual Type 9 Messages for each satellite at a transmission rate of 50 Bps. This message is referred to as the “Single Satellite” Type 9 Message. and is denoted in this document as the Type 9-1 Message. A high level of impulse noise immunity is achieved by this technique that will extend the effective range of the broadcast. Lower transmission rates such as 50 bps could not be used at this time because of the need to meet the time to alarm requirement due to the length of the PRC Messages. An equal number of corrections are broadcast for all satellites regardless of their pseudo range rates or accelerations The following table summarizes the above mentioned methods of Type 9 message transmission.

Method	Message Type	Data Rate	Trans. Rate
1a	Type 9-3	200 Bps	200 Bps
1b	Type 9-3	100 Bps	100 Bps
21	Type 9-1	50 Bps	50 Bps

Table 45: PRC Message Broadcast Parameters

Since each Type 9 Message contains the freshest possible corrections, the corrections contained in each and every Type 9 Message are computed at different times (i.e. computed at the latest possible time before broadcast). The user equipment suite can mix corrections that may have been computed up to 30 seconds apart, thus the reference station should utilize a highly stable frequency source, within one part in 10-11 (30 second Allan Variance). The use of a highly stable frequency reference and a tightly controlled clock provides the additional benefit of allowing corrections for each satellite to be applied as they are received, as long as the parity for both of the words which contain a given correction is verified. This capability should be implemented for the Type 9 Message in all user equipment suites. Generally, the Reference Station clock will be within 100 ns of GPS time. Clock stability is of far greater priority then absolute time accuracy since PRC's are generated relative to each other for a given Reference Station. The shorter message length and greater frequency of preambles provided by the Type 9 Message result in a substantially improved impulse noise performance as compared with the Type 1 Message. The higher rate of preambles allows a

much faster re-synchronization, especially during high noise periods. As previously discussed, even in low noise conditions the Type 9-3 Message provides a lower latency than the Type 1 Message, making it advantageous when operating with a low data rate as well as in high noise environments. This is especially useful since the position error growth due to latency is non-linear.
If a satellite suddenly becomes unhealthy when in use by a given reference station the PRC (to) and the RRC are set to predefined values as delineated in RTCM SC104 (Version 2.1) that designate this condition.

Type 16 Message

The Type 16 message will be utilized as a timely supplement to the notice to mariners or shipping, regarding information on the status of the local DGPS service that is not provided in other message types. Additionally, the Type 16 Message may provide limited information on service outages in adjacent coverage areas or planned outages for scheduled maintenance at any broadcast site. In order to keep data link loading to a minimum, Type 16 Messages will contain only system information that is crucial to the safety of navigation. Any broadcast of the Type 16 Message will not exceed 4.8 seconds. At 200 bps this translates into 32 words that allow a maximum 90 characters after accounting for the message header. The Type 16 Message is not intended to act as a substitute for the notice to mariners, even though it pertains to DGPS information. Type 16 Messages will be utilized to alert the user of an outage condition for which a broadcast in an adjacent coverage area may be unhealthy, unmonitored, or unavailable. This information would be useful to the mariner who is planning a transit through an affected area or whose equipment suite is presently incapable of automatic selection from the beacon almanac. Further details of an outage condition can be derived from the Type 7 Message for route planning purposes.

DGPS Message Scheduling

The routine data stream will consist mainly of message types 3, 7, & 9 and broadcast of message types 5,6 and 16 will be on an exceptional basis. Due to the advent of continuous tracking receivers the Type 2 Message is no longer required and its use would only serve to increase the latency of the broadcast. For each new Issue of Data (IOD) there will be a 90 second delay before the broadcast pseudo range corrections are computed with the new IOD. Ninety seconds should be more than adequate for a continuously tracking DGPS receiver, as it will be able to instantaneously read the navigation messages as they are broadcast from each satellite. Any short term blockage of a satellite at IOD, such as passing under a bridge, are compensated for by the ninety second delay. This method of handling a new IOD requires the user equipment suite to store both the new and the old IOD for the subject period. Message Types 3, 5, 7, 15 and 16 will not be broadcast within 90 seconds of each other under any circumstances.

Type 3 Message

Type 3 Messages will be broadcast at fifteen and forty-five minutes past the hour.

Type 5 Message

If an unhealthy satellite is deemed usable for DGPS, a Type 5 Message will be broadcast at fifteen minute intervals beginning at five minutes past the hour. If an unhealthy satellite that was deemed usable is later deemed unusable the reference station will no longer broadcast corrections for the subject satellite.

Type 7 Message

A routine Type 7 Message will be broadcast at ten minute intervals beginning at seven minutes past the hour. Special Type 7 Messages will be broadcast as soon as possible, subject to the other scheduling constraints, when the status of a beacon in the almanac changes. This will aid the user equipment suite in its choice of the proper beacon.

Type 9 Message

Pseudo range corrections will be broadcast only for satellites at an elevation angle of 7.5 degrees or higher through use of the Type 9 Message. The official GPS coverage is based on elevation angles of ten degrees or higher. Satellites at elevation angles lower than 7.5 degrees are adversely affected by spatial decorrelation, multipath, and minimal processing time between acquisition and actual use. The level of 7.5 degrees is identical to that recommended by RTCA Special Committee 159. Corrections for all satellites in view above the mask angle will be broadcast. Positioning users of the system who are interested in achieving the highest accuracy level possible should use a higher mask angle in order to avoid the more pronounced atmospheric effects associated with satellites at low elevation angles. When a reference station drops a satellite it will broadcast an indication to the user equipment suite to stop applying corrections for that satellite to its navigation solution

Type 16 Message

This message type will be broadcast as deemed necessary but within strict limits. The interval between successive Type 16 Messages will be no less than three minutes.

83. DominoF

DominoF is an experimental amateur mode with dual interleaved tone sets, each of 16 tones. DominoF uses a tone spacing of 10.766 Hz. The total bandwidth is 213 Hz.
In fact, 18 tones (2 x 9) are used to limit the rotations. A character is composed of 2 symbols of 3 bits each, each symbol being sent on a tone set (first symbol on J1 then second symbol on J2).
The character set has 62 characters (lower case, numbers and some punctuation) & an error reset character (6 bits long characters) & a synchronization character.

DOMINO is the name given by the developers to a family of IFK coded coherent phase single tone MFSK keyed modes, using sequential tones in spectrum-managed orthogonal tone sets

The tone sets are arranged so that ionospheric modulation products cannot easily spill from one possible tone position to another or from one symbol to the next. In DominoF, this was done by double-spacing the tones and interleaving the tone sets. DominoF had two independent tone sets, used alternately, to ensure that tones could not overlap. Another advantage was that the alternation is very quickly detected as an odd-even component in the receiver FFT, and this was used to provide sync. Sync lock-up time was well under one second. Interleaving the tone sets does reduce the necessary bandwidth.

84. DominoEX

DominoEX is an experimental amateur mode using a MFSK with 18 tones which are separated by a shift which is related to the transmission speed. The main data of this waveform are collected in the following table:

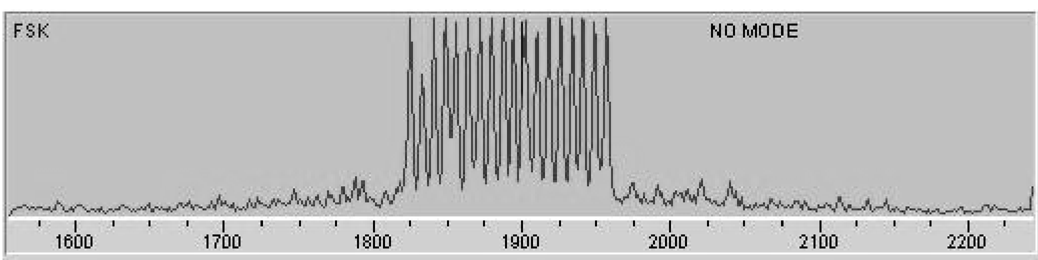
Mode	Baud rate	WPM	Tone Shift	Total Bandwidth
DominoEX 4	3.90625 Bd	27	7.8125 Hz	140 Hz
DominoEX 7	5.3833 Bd	38	10.766 Hz	194 Hz
DominoEX 8	7.8125 Bd	55	15.625 Hz	281 Hz
DominoEX 11	10.766 Bd	77	10.766 Hz	194 Hz
DominoEX 16	15.625 Bd	110	15.625 Hz	281 Hz
DominoEX 22	21.533 Bd	154	21.533 Hz	388 Hz

Table 46: DominoEX waveforms

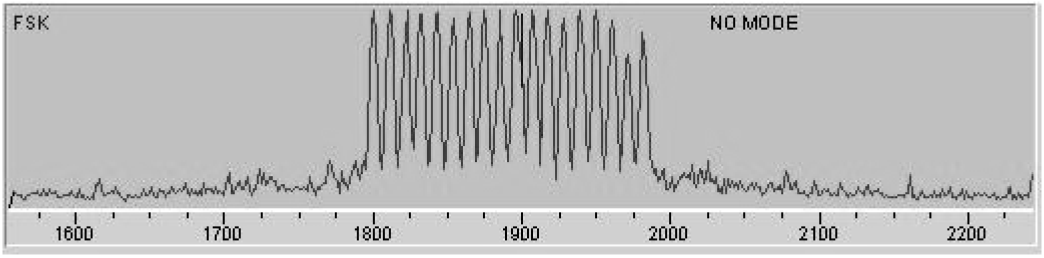
DominoEX is using the incremental frequency keying (IFK).

Each transmitted character is composed of 1 to 3 "nibbles" (group of 4 bits). The first one is called "Initial nibble" and has a value between 0 and 7, the 2 others are called "Continuation nibbles" and have a value between 0 and 15. The "initial nibble" is compulsory and, from its value, permits to know that it is the first 4 bits start of the character. The "continuation nibbles" exist only depending of the transmitted character. Only one tone is used for a given "nibble". For determination of the tone number, it is used the following formula:

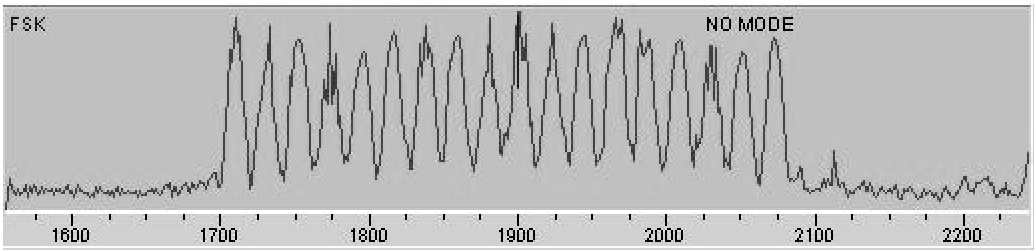
* Tone number (between 0 and 17) = Previous tone number + data nibble (0 to 15) +2
* If the tone number>=18 then Tone number = Tone number -18



Picture 193: Spectrum of DominoEX with 4 Bd



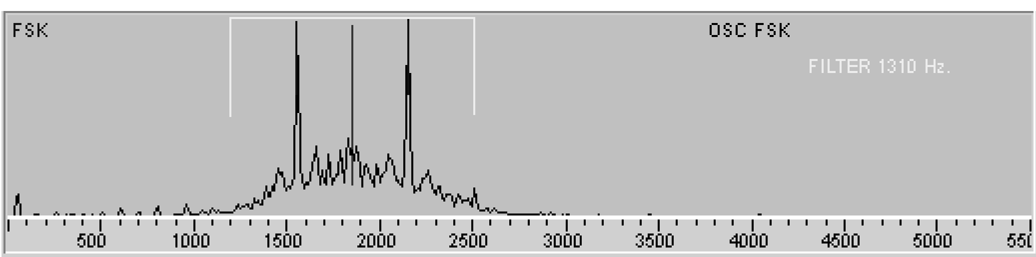
Picture 194: Spectrum of DominoEX with 11 Bd



Picture 195: Spectrum of DominoEX with 22 Bd

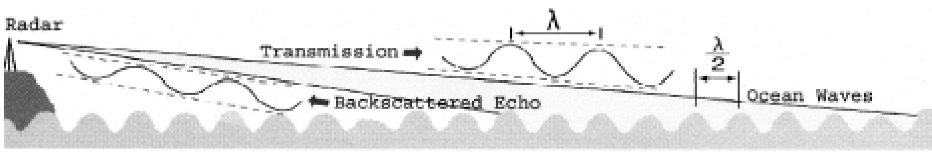
85. DPRK ARQ 600 Bd

This teletyper is used by the Democratic People Republic of Korea (DPRK) with 600 Bd and 600 Hz shift for diplomatic traffic in ARQ mode. The block length is 217 ms, the pause 323 ms so that the total packet has a length of 540 ms. Each bit has a length of 1.67 ms so that one packet has 130 bit



Picture 196: Spectrum of DPRK FSK in ARQ mode

possible by transmitting radio waves at frequency of 9.2 MHz with maximum transmission power of 1 kW. In Japan, it is almost impossible to secure a sufficiently wide and continuous frequency bandwidth in the HF band, so the LROR adopts a frequency modulated interrupted continuous wave (FMICW) type radar that is able to use frequencies resources more efficiently than the short-pulse type radar. The sweep bandwidth is 22 kHz, which corresponds to the range resolution of about 7 km. The current velocity resolution, which is determined by the incoherent integration time of received signal, is 2.5 cm/s.

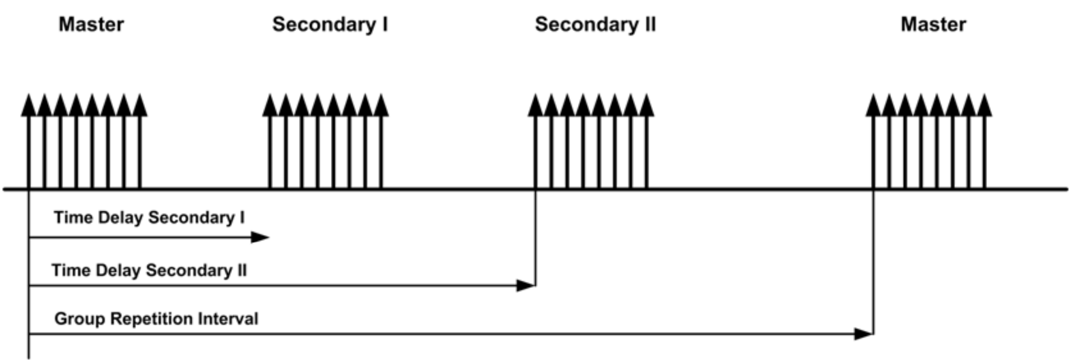


Picture 412: Function of an Ocean Radar

245. LORAN-C

Long range Navigation

LORAN is a navigation system used by ships and planes to accurately determine their position. It is hyperbolic navigation system which uses three to five transmitters. These transmitters are located several 100 miles on land.
LORAN transmits on a centre frequency of 100 kHz. The net has one master station and several secondary stations which are called W, X, Y and Z. The transmission signal of the secondary stations are synchronised to the signal of the master station.
For navigation is measured the time difference between the master station and a minimum of two secondary stations. This measurement gives to every station a line of position. The cross point of several lines of position gives the location of the user.
Every LORAN - C net is transmitting group repetition intervals which is unique for this net. Every master has 10 ms and the secondary station 8 ms for his group transmission.
The minimum length of group of intervals is determined by the number of stations.
The master station is transmitting 8 pulses with a space of 1000us, additional a ninth pulse which follows after 2000 us behind the 8. pulse.



Picture 413: Transmission of LORAN-C

The secondary station is transmitting 8 pulses with a space of 1000 us. The ninth pulse gives the information, that the pulse group is transmitted by a master station. The pulse is also coded for internal information.
The identification of the group repetition interval is a fixed length divided by ten. The following table gives the LORAN-C nets working in different areas:

GRI number	Location of LORAN - C net
9990	North Pacific
9970	North West Pacific
9960	USA North East Coast
9940	USA West Coast
8970	Great Lakes
7990	Mediterranean Sea
7980	USA South East Coast
7970	Norway Sea
7960	Gulf of Alaska
7930	North Atlantic
5990	Canadian Pacific Coast
5930	Canadian Atlantic Coast
4990	Central Pacific
9980	Iceland
8000	Russia West
8990	Saudi Arabia North
7170	Saudi Arabia South
8290	USA North
9610	USA South
7950	Russia East
5970	Asia East
6930	China
	India Bombay
	India Calcutta

Table 106: LORAN chains and their identification numbers

LORAN data channel communication (LDC)

During the operation of the LORAN system it was desired to add a communication functionality to the current LORAN-C signal. The capabilities should include:

- the transmission of absolute time,
- Differential LORAN corrections for maritime and timing users,
- anomalous propagation (early sky wave) warnings and
- LDC system information for high-integrity applications.

Ninth-Pulse Modulation

This modulation scheme was chosen for its negligible impact on the current operational LORAN-C signal, and its facility for cancellation of cross-rate interference. Here, an additional pulse is inserted in time following the eighth pulse of the LORAN pulse group. Thirty-two state Pulse-position modulation is used to change the time delay of this pulse from the zero-symbol offset. In this manner, the data transfer rate is five bits per group repetition interval (GRI).
The phase code of the 9th pulse is the same as the phase code of the last navigation pulse.
The zero-symbol offset is 1000 microseconds after the 8th navigation pulse. The remaining 31 symbols are positioned in time a specific number of microseconds later in relationship to the zero symbol.

Messages

All messages are 120 bits in length and consist of 3 components: a 4-bit type, a 41-bit payload, and a 75-bit parity component as shown in Table 2. The messages are transmitted 5bits/GRI. The time length of the messages is 24 GRI (maximum of approximately 2.4 seconds).

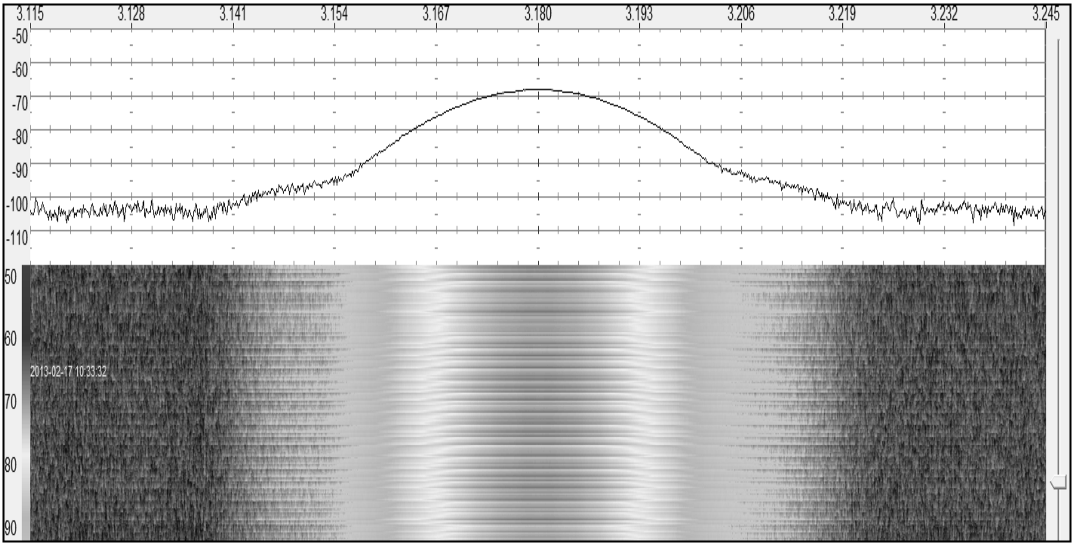
Section	Type	Payload	Parity
Length (bits)	4	41	75
Bit assignment	0…3	4…44	45…119

Table 107: LORAN Data Channel message components

246. MF RADAR

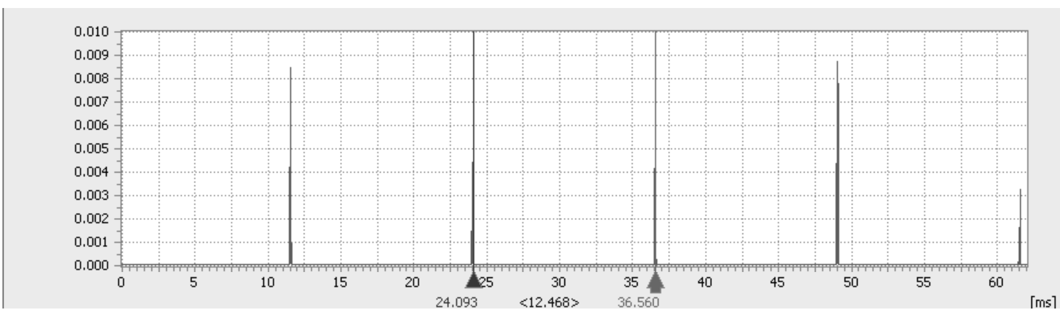
MF radars are used for measurments on freuencies between 2 and 3 MHz and allow the cointinuous observation of the mesosphere in heights of 50 km to 95 km during the entire year. The radar are used for studies of the dynamic of the mesosphere, turbulences, internal gravity waves, tides and planetary waves.
In Juliusruh a MF radar on the frequency 3,18 MHz is operated. It is a puls radar, which is equipped with a modular transmit and receive system with distributed power and a so-called Mills-Cross antenna. This antenna radiates a beam of a width of 18° which can be directed from the vertical elevation to any direction in the sky. It works in defined time angles and also allows DBS (Doppler-Beam-Swinging-Mode) measurements. The puls power is 128 kW with a puls width of 27 us. The hight resolution is 4 km and the sample resolution 1 km.

The spektrum of this radar is shwon in the next picture:



Picture 414: Spectrum of the MF radar at Juliusruh

The time distance between pulses is 12,5 ms and shown in the following picture.



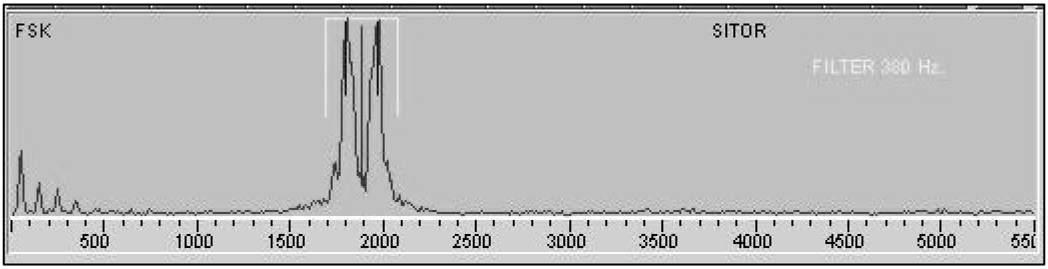
Picture 415: Puls repetition time of the MF radar at Juliusruh

247. NAVTEX

The stations in the NAVTEX system are transmitting navigational and meteorological warnings and other important information.
It is a part of the Maritime Safety Information (MSI) net which is part of the Global Maritime Distress and Safety System (GMDSS).

The information is transmitted on 518 kHz by selected coast stations in SITOR B. The baud rate is 100 Bd with a shift of 170 Hz.

This time shared service is designed for a distance of 400 nautical miles around the coast station.



Picture 416: Spectrum of a NAVTEX signal

For differentiation the following identifications are used:

A	: navigational warnings
B	: meteorological warnings
C	: ice messages
D	: search and rescue information
E	: meteorological forecast
F	: pilot message
G	: information about DECCA
H	: information about LORAN - C
I	: information about OMEGA
J	: information about SATNAV
K	: information about other navigational systems
L	: navigational warnings
Z	: QRU

Table 108: NAVTEX identification letters

NAVTEX messages are started with an identification group which has the following meaning:

1. ZCZC followed by the identification letter of radio station with message number
2. Identification for message type
3. Date/Time group
4. Message
5. Ending with NNNN

Table 109: Structure of a NAVTEX message

248. NBTV

Narrow Band Television

The following information about all NBTV modes are taken from the webpage www.qsl.net/Zl1bpu/NBTV with permission by Murray Greenman

NBTV (Narrow Band Television) is a technique with some similarity to SSTV, and some to conventional FSTV (Fast Scan TV). Like SSTV, it operates in a narrow bandwidth, suited to an HF SSB transceiver, but rather than send individual image frames, NBTV is designed to send multiple frames one after the other, in much the same way as FSTV, but with considerably slower frame rate. This idea allows frame-averaging to be used on noisy channels, and enables the transmission of moving images.

For the technique to be practical, the frame rate must of course be much slower, the image resolution is much reduced, and various compression techniques must be used, along with a range of strategies designed to reduce or eliminate the effects of propagation, especially noise and multi-path fading and timing errors.

The image resolution is generally lower than it is for SSTV, but this is made up for by the motion effects, and also by the faster frame rate, typically 1 - 10 seconds per frame, rather than 30 seconds or more for SSTV.

Three systems are described here. They are broadly, analogue, digital, and hybrid designs, and all were developed by Con Wassilieff ZL2AFP, the acknowledged world expert on NBTV, and to date the only developer of modes that are successful on HF (there have been modes which work on VHF or on telephone lines). These new systems use sophisticated techniques, including digital signal processing, forward error correction, image compression and even path equalization. The three modes are:

- Orthogonal Frequency Division Multiplex Analogue OFDM NBTV
- Single-tone 2000 baud PSK modem Digital NBTV
- Hybrid FM NBTV with PN-sequence synchronization

With all three of these systems you can transmit live pictures from a web camera, TV capture card or TV camera, send still frames in any image format and any size, and transmit movie clips in several formats. Because the frame rate is low, the receiving programs allow transmissions to be recorded, and played back later at movie speed.

Compared with SSTV, which sends even more slowly (and still has trouble with multi-path propagation tearing the images) NBTV must send faster, and is therefore even more prone to ionospheric effects. Thus the unconventional nature of these designs is explained by the emphasis on managing or countering these effects.

These different NBTV programs enable low and modest resolution B&W and colour TV images to be transmitted at modest power, and received via a limited performance HF radio channel. The systems has been optimized for specific radio conditions; most are designed for NVIS conditions (such as the

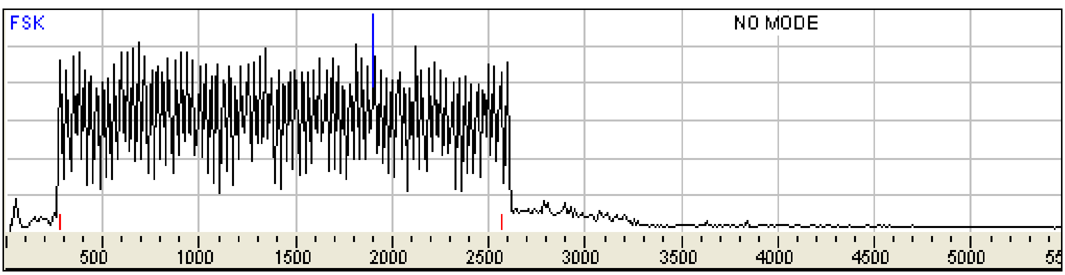
Amateur 80m band at night); but there are other versions with better resolution, more suited to higher bands; and at least one faster version for VHF. In most cases the pictures are easily tuned with practice, as the software provides special tuning aids.

All three systems operate using a conventional digital modes setup: PC, sound card, radio interface with audio and PTT functions, and an SSB or (on VHF) FM transceiver. Use the links below to explore these modes further.

249. OFDM NBTV

OFDM NBTV is an analogue technique, in fact it is a true Fuzzy design as well. The transmission technique used is quite different from conventional TV - each line is transmitted separately, but all lines are sent at the same time, on a slightly different frequency. Because the transmitter and receiver operate at precisely the same speed, controlled by the computer sound card, there is no need for any sync pulses to align the picture; in fact there is no automatic synchronizing mechanism at all - it simply isn't necessary.

The following picture is showing the typical spectrum of the OFDM signal:



Picture 417: Spectrum of an OFDM

Modulation on each of the many carriers is very narrow FM (a few Hz), for best noise rejection, and the overall transmission bandwidth is only 2 kHz, so an SSB transmitter and receiver can be used. These modes are Fuzzy Modes, which means that although the computer samples the images for transmission and display, the signals are essentially analogue in nature, and at the receiver the images are presented without decoding decision or interpretation by the computer - they are interpreted by eye and brain at the receiver. This means that the signals are inherently very noise immune and continue to be useable despite interference and propagation effects until they fade into the noise.

The design is very versatile, and you can use still photographs (like a slide show), moving GIF images, AVI movies and many different types of live video, including 'web cams', video capture cards, digital cameras, screen shots from other software, and even live (fast scan) TV, although only one frame in many is transmitted in this case. A 'drag-and-drop' technique makes all this very easy.

Limitations

Because of the low bandwidth, it is not possible to send moving pictures in real time. Each image frame takes from one second to nine seconds to transmit, depending on the mode used. However, the received signal can be recorded and later played back faster for a very realistic effect. Standard .AVI format files are used, and the transmitters can also retransmit previous recordings. The images can also be post-processed for noise reduction and smooth motion effect. The quality of moving images is such that you'd never believe that the pictures contain only 48 or 72 lines!

On lower HF bands, especially with NVIS conditions (strong fading and multi-path reception), performance suffers as noise and colour stripes invade the picture. The 96 x 72 pixel colour mode is most affected. However, on the higher bands and VHF, the pictures are superb.

Another limitation is that tuning requirements are fairly stiff - a VFO rig CANNOT be used - it simply isn't stable enough. Most modern synthesized transceivers are OK if used with care. Tuning needs to be within 1Hz of the transmission. On VHF the secret is to use FM transceivers, and thus avoid the problem completely.

The OFDM NBTV Modes

There are in total five modes, two black and white, and three colour. There is some compatibility between the B&W and Colour modes, so you can soon work out which is being transmitted. There are two different image resolutions, 48 x 48 pixel low resolution (which is faster and more robust), and 96 x 72 pixel modest resolution, which of course is slower, but gives more picture detail. A special compressed 96 x 72 pixel colour-only version is provided - this provides a frame rate twice as fast as the standard 96 x 72 colour mode, but is suited only to higher bands and VHF. The picture on the right below shows typical 48 x 48 colour reception.

- 48 x 48 Low resolution B&W and RGB colour for NVIS conditions
- 96 x 72 Modest resolution B&W and RGB colour for HF use
- 96 x 72 Modest resolution compressed RGGB colour for VHF

The following table shows an overview of the technical parameter of these modes:

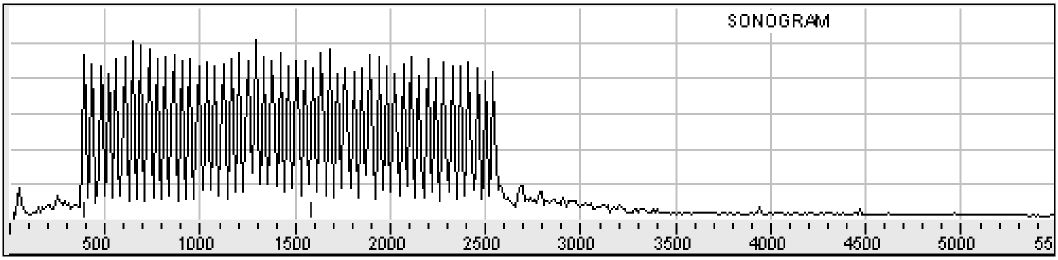
Mode	Image Properties	Pixel Rate	Frame Period	Bandwidth
BW 48	48 x 48 Black & White	50 Hz	1.0 s	2100 Hz
CO 48	48 x 48 RGB	50 Hz	3.0 s	2100 Hz
BW 96	96 x 72 Black & White	33 Hz	3.0 s	2100 Hz
CO 96	96 x 72 RGB	33 Hz	9.0 s	2100 Hz
RGGB	96 x 72 RGGB	33 Hz	6.0 s	2100 Hz

Table 110: OFDM NBTV modes

48 x 48 Mode

In this mode, there are 48 carriers, spaced 42Hz apart, one carrier for each picture line. The total signal is therefore about 2 kHz wide. This includes a 'pilot carrier', transmitted in the middle of the image carriers (see picture above). This is slowly sine-wave modulated, and used for fine tuning.

In the B&W option, just one field is transmitted per frame. With 48 pixels per line, each pixel takes 20ms to transmit, and the carrier modulation bandwidth is about 40Hz. At the end of each line a vertical dotted line is transmitted, so the end of frame can be identified. In colour mode, three separate fields, much the same as described, are transmitted for Red, Green and Blue image data. At the end of the third (blue) field of, a vertical dotted line is transmitted, so again the end of frame can be identified. In this case it also identifies the correct colour order (you can see this line at the left of the picture). The picture has a square (1:1) aspect ratio.



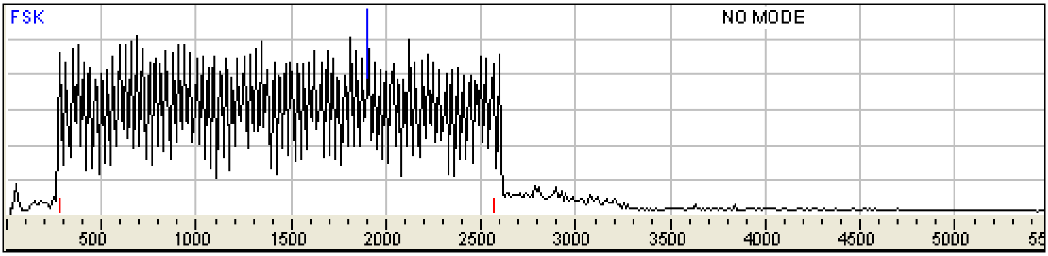
Picture 418: Spectrum of 48 x 48 OFDM NBTV

96 x 72 Mode

This mode uses 72 carriers, spaced 32Hz apart, again one carrier for each picture line. There is one 'pilot carrier', right in the middle of the picture carriers. The pixel modulation rate is lower, and so the carriers can be closer together. The total signal bandwidth is also about 2kHz.
In the B&W mode, just one field is transmitted per frame. There are 96 pixels per line, and each pixel takes 30ms to transmit. As in the 48 x 48 modes, the end of each frame is identified by a vertical dotted line. In colour mode, three separate fields are transmitted for Red, Green and Blue image data. At the end of the third (blue) frame, a vertical dotted line is transmitted, so again the end of frame and correct colour order can be identified. The picture has a standard TV (4:3) aspect ratio.

96 x 72 Mode

This mode uses 72 carriers, spaced 32Hz apart, again one carrier for each picture line. There is one 'pilot carrier', right in the middle of the picture carriers. The pixel modulation rate is lower, and so the carriers can be closer together. The total signal bandwidth is also about 2kHz.
In the B&W mode, just one field is transmitted per frame. There are 96 pixels per line, and each pixel takes 30ms to transmit. As in the 48 x 48 modes, the end of each frame is identified by a vertical dotted line. In colour mode, three separate fields are transmitted for Red, Green and Blue image data. At the end of the third (blue) frame, a vertical dotted line is transmitted, so again the end of frame and correct colour order can be identified. The picture has a standard TV (4:3) aspect ratio.

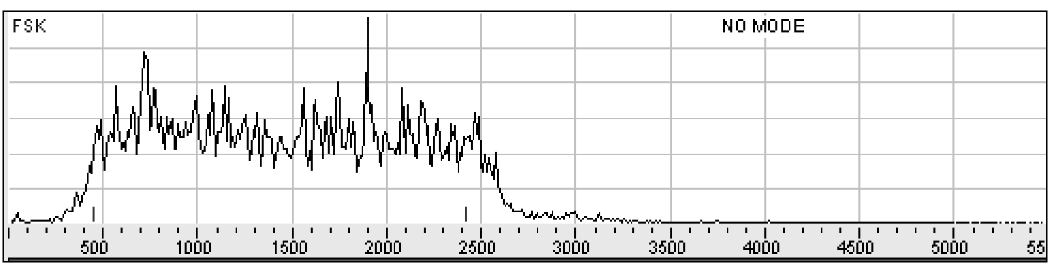


Picture 419: Spectrum of 96 x 72 OFDM NBTV

250. Digital NBTV

A number of problems experienced with the OFDM NBTV system led to the development of this Digital NBTV mode. First, the OFDM signal is very difficult to tune, especially for beginners, and requires extreme transceiver accuracy and stability. Then in addition, the pictures tend to be noisy and individual frames can be marred by multi-path effects, especially when used on the lower bands.
The approach taken for the Digital NBTV mode is completely different, in many senses:
It uses separate programs for modem and codec in the transmitter and receiver
TCP/IP communications is used between program modules The modem is high speed single-tone PSK, similar to NATO's STANAG 4285. An equalizer system is included to compensate for ionospheric path variation
Wavelet image compression and forward error correction are used. It provides completely noise-free and error-free image reception, even on 80m. So nothing could be more different! The transmission consists of a stream of packets, each containing data for a small number of image lines. The amount of data in the packet varies according to the image complexity, the compression level and the level of forward error correction included, but the packet size is constant at 256 symbols plus an 80 symbol header.
Modulation

Digital NBTV uses a modulation technique which is widely used by high speed HF radio modems. A single 1500Hz phase modulated carrier is used to send both packet sync and payload. Using BPSK modulation, a pseudo-random binary (PN) sequence starts each packet, and is used to identify an exact point in the transmission from which the data can be synchronized.
The audio spectrum is shown in the following picture:

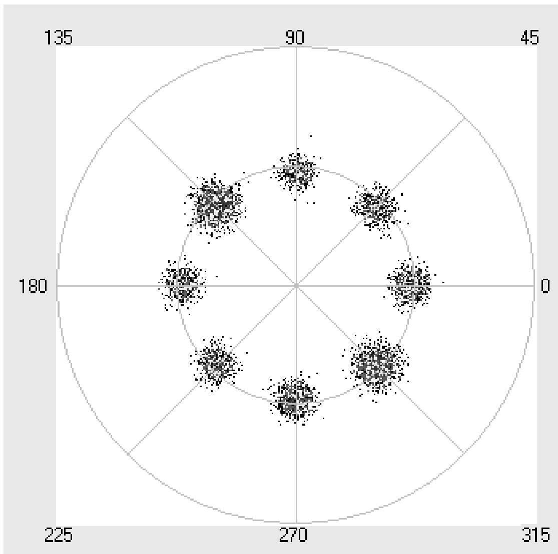


Picture 420: Spectrum of digital NBTV

A cross-correlator is used in the receiver to locate the one point in the whole message where the sequence matches up with the local copy of the sequence. The cross-correlator works with a known pattern to look for, and is a very powerful and sensitive tool.

These radio modems use the PN sequence technique to enable complex high speed data to be decoded accurately - the ranging information determined from the cross-correlator is used to correct the received data timing to reduce errors induced by the ionosphere, using a signal processing device called an 'equalizer'. The equalizer also corrects for Doppler errors which affect carrier phase, making the use of 8-PSK practical.

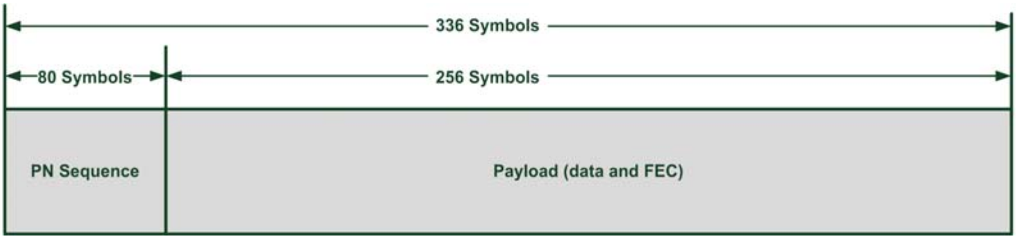
The phase constellation is shown in the next picture:



Picture 421: Phase plane of digital NBTV

The two dots on 135° and 315° are bigger in size and density. This is caused by the BPSK which is used for synchronisation.

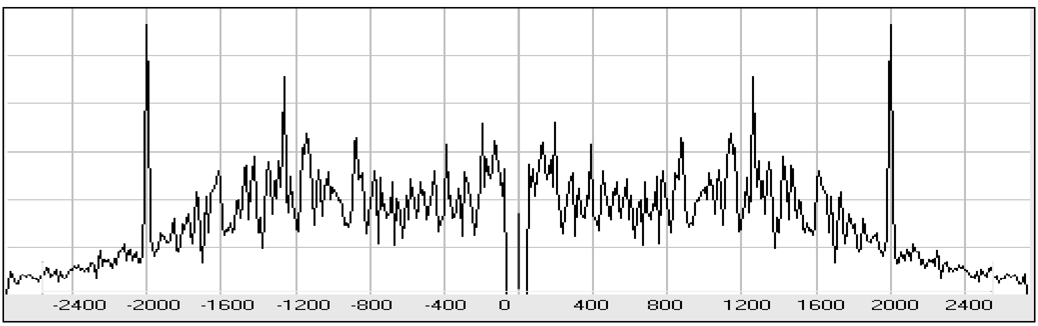
Digital NBTV uses a 31-bit PN sequence borrowed from STANAG 4285, with one chance in two billion of a perfect score being caused by noise. It uses 80 symbols (modulation time slots) to send this sequence about 2.5 times. Each packet is contained in a 336 symbol frame. 256 symbols are used for image data and FEC information. Since 4-PSK is used for the data, each packet could contain 512 bits of image data, or 3047 bps raw data rate. The data symbols are scrambled in an 8-PSK pattern to improve resistance to selective fades.



Picture 422: Framing of digital NBTV

Like the STANAG 4285 system, single-tone PSK Digital NBTV can also operate at 2400 baud, using a sub-carrier frequency of 1800Hz. The corresponding bandwidth (just under 3kHz) is too much for most HF transceivers, but quite suitable for VHF, and gives a worthwhile speed improvement. However, to fit the signal into a normal amateur transceiver IF, it is usually operated at 2000 baud using a 1500Hz sub-carrier.

The following picture shows the measurement of the baudrate of 2000 Bd with the help of a phase spectrum:



Picture 423: Baudrate measurement of digital NBTV

Modem

The modem section of the transmitter or receiver converts digital data into PSK audio for the transmitter, or received audio into digital data, respectively. The receiver modem also has to manage sync and equalization.
Each transmitted packet commences with a BPSK pseudo-random (PN) sequence (same sequence as STANAG 4285), which is used to synchronize the receiver timing with the start of the packet, and also serves as a measuring point for the receiver equalizer software which measures and compensates for frequency offset and drift, and other code which compensates for timing errors. Detection of the PN sequence is achieved using a cross-correlator. This technique is extremely sensitive, so no matter how weak the signal is, packet synchronization is secure.
The packet data payload is transmitted as 4-PSK, to ensure a high data rate. There are nearly six packets per second, using a 2000 baud modem.