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DIGITAL UNDERWATER SIGNALLING STANDARD FOR NETWORK NODE DISCOVERY & INTEROPERABILITY

Edition A Version 1
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NATO LETTER OF PROMULGATION

24 March 2017

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
DEU	Germany reserves the right: 1. The JANUS frequency range in Ratification Draft 1 of ANEP-87 overlaps with the frequency range given for voice communication in STANAG 1074. The frequency range of JANUS is to be changed in ANEP-87, if submarine safety is affected by interference between JANUS and STANAG 1074 voice communication. According to the attached agreement achieved in a side talk during the UWWCG session on Oct. 15, 2013 in Brussels by JANUS working group leader John Potter of CMRE, Harald Peine of BAAINBw (DEU procurement office) and Tim Hullmann of MarKdo (DEU Navy), the frequency range of JANUS will be changed in the document ANEP-87 as part of STANAG 4748 to a non-interfering frequency, if it turns out that the interference of a JANUS signal according to present ANEP-87 with a voice communication signal according to STANAG 1074 will severely affect - intelligibility of voice communication or - submarine safety as judged by the Submarine Staff Officers Conference (SSOC). 2. Values provided in Table in Annex B are likely not to be implementable in the hardware to be used in the given accuracy. 3. Some of the user classes reserved in Annex A (e. g. Underwater GPS) currently cannot be implemented since their functionality is not specified. The reservation of the class number can be ratified and implemented.
GRC	Greece reserves the right of future implementation which will begin when national industries successfully complete the development and testing of the required firmware updates and/or hardware upgrades of the existing underwater communications devices used in Greece.
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CHAPTER 1 INTRODUCTION

1.1. Background

1. Present NATO Underwater Communication Capabilities are currently standardised as follows:
    - Tactical and safety communication in accordance with STANAG 1074, analogue Voice and Morse
    - Distress in accordance with STANAG 1298.

2. Some NATO nations' maritime assets have underwater (UW) communication capabilities exceeding the above standards based on point-to-point communication links, following either analogue standards or using proprietary digital coding technologies from the communication equipment supplying company. Yet there exists no interoperable capability for digital UW communication between assets, NATO and NON-NATO, military and civilian, using communication systems from different suppliers, as required to support NATO maritime force goals.

3. An interoperability capability is essential as NATO maritime CONUSE seek to integrate an increasingly heterogeneous mix of maritime assets. Submarines, surface craft, fixed- and rotary- wing aircraft, moored ocean sensing systems, gateway buoys and autonomous underwater vehicles (AUVs) depend on underwater acoustic communications for command, control and information sharing. There is currently no existing capability for these to communicate UW with each other unless they carry matching equipment from the same manufacturer.

4. There is also no existing means to discover other communicating assets to permit the formation of ad-hoc networks. Among the several manufacturers of UW digital modems, none are currently able to communicate with systems produced by other manufacturers. The establishment of an UW digital communications standard therefore has wide application in both military and civilian contexts.

1.2. Requirement

The requirement is for communication interoperability between UW NATO and NON-NATO, military and civilian maritime assets to facilitate digital UW communication and, additionally, the ad-hoc networked coordination and sharing of information among underwater sensors, surface ships, submarines, AUVs, gateway buoys and sensor networks, covering the transmission and reception of many types of information and providing a communications service that compliments that offered by existing analogue systems under STANAG 1074.

1.3. Standardisation proposal to meet the requirement

1. The interoperability requirement translates into a standardisation requirement specifying a physical layer coding scheme that allows assets to transmit information in a common format that can be decoded by compliant assets. The proposed physical standard, named JANUS, has been designed to minimise the changes required to bring existing UW communications equipment into compliance, leveraging the inherent flexibility of modern digital communications systems and existing acoustic frequencies and bandwidths.

2. The standard provides for a ‘Baseline JANUS Packet’ to be created, consisting of an acoustic waveform that encodes 64 bits of information (of which 34 bits may be user-defined according to their application) in addition to a facility by which ‘Cargo Data’ may be seamlessly appended to the end of the Baseline JANUS Packet to provide almost unlimited flexibility in the nature and extent of the data to be sent.

3. Including all in-band digital UW telephone systems carried by surface vessels and submarines, together with AUVs operated by NATO forces, it is anticipated that some 800 pieces of equipment will be affected. The changes required to bring existing communications systems into JANUS compliance are expected to be mostly firmware updates from original manufacturers (in the case of digital equipment) with some minor hardware upgrades. It is estimated that up to 24 of the 28 NATO nations may be affected (those with maritime borders).

CHAPTER 2 Technical Specification

2.1 Physical layer coding scheme

1. The JANUS standard deliberately chooses a simple but robust digital coding technology that is well-known and that can easily be adopted by a wide range of existing systems. The physical layer coding scheme is known as Frequency-Hopped (FH) Binary Frequency Shift Keying (BFSK). FH-BFSK has been selected for its known robustness in the harsh UW acoustic propagation environment and simplicity of implementation. FH-BFSK is a common phase-insensitive (incoherent) physical layer encoding technique, used in at least two leading commercially-produced modems, and is known to be robust to a variety of environmental conditions.

2. In the JANUS FH-BFSK scheme, binary data bits are mapped into one of a pair of time-windowed CW tones of unspecified phase, selected from 13 evenly-spaced tone pair choices spanning the frequency band. The initial frequency band allocation is 9440 – 13600 Hz, though it is anticipated that other bands will be proposed and established for different range and application requirements in the future.

3. A core feature of the JANUS specification is that once a frequency band is chosen, the Chip duration (*Cd*), Wake-up tone duration (if present) and Frequency Slot width (*FSw*) are calculated directly from the upper and lower band values, while the Frequency Hopping sequence and reverberation delay time remain constant for any band.

4. Robustness to temporal and frequency fading is provided by convolutional encoding with a 2:1 redundancy, followed by interleaving. Data corruption is detected by an 8-bit Cyclic Redundancy Check (CRC).

5. The coding operation sequence required to generate a Baseline JANUS Packet, without appended Cargo Data, is shown in Fig. I. It begins with the user data (determined by the user content, User Class and application specified by the user). The specification of each of the functional blocks in Fig. I is described in the following sub-sections.

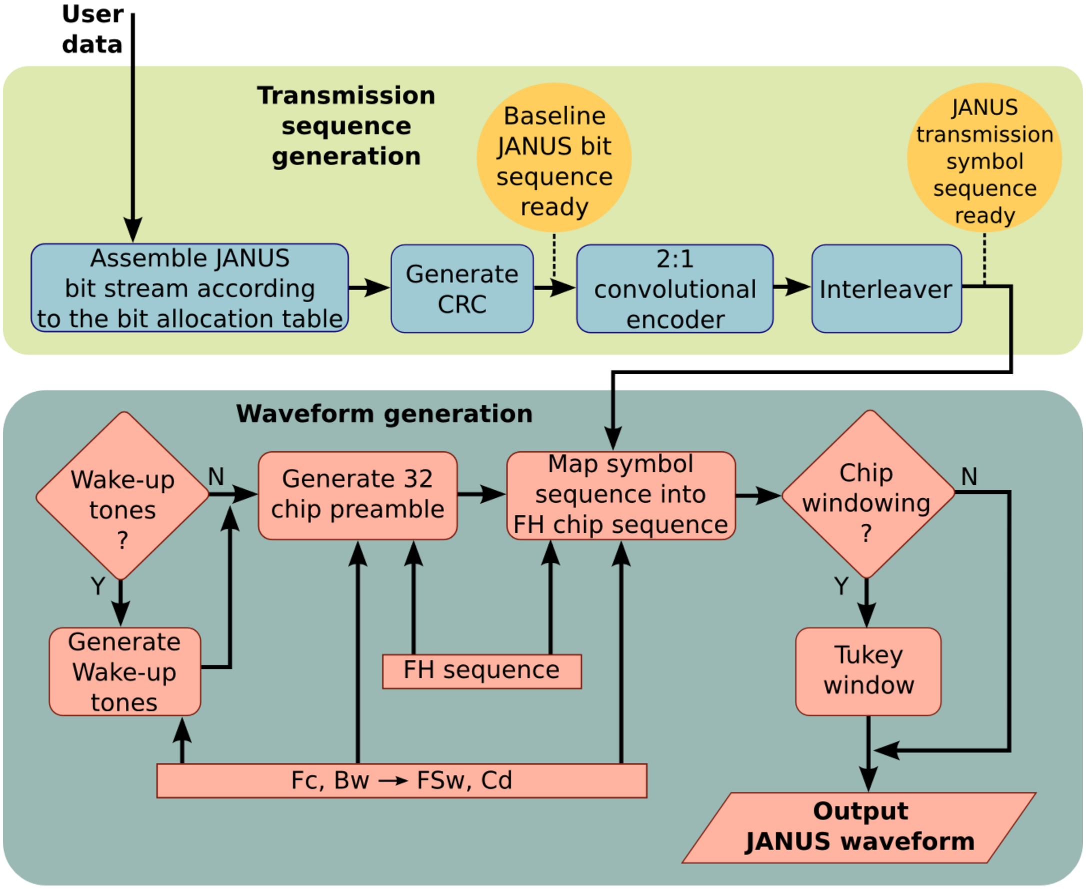

Figure I: Block diagram of the JANUS Baseline Packet encoding process

2.1.1 Baseline JANUS Packet specification

A Baseline JANUS Packet consists of 64 bits of information, constructed according to Table I. This packet includes a 34 bit ‘Application Data Block’ that is defined according to one of 64 possible schemes that may be specified by each User Class. There are 256 User Classes that are allocated to NATO organisations, NATO countries, other countries, specific organisations, submarine rescue, etc. as specified in Annex A.

Bits	Descriptor	0/1 bit set	Comments
1-4	Ver. #	0011	Unsigned 4-bit integer, Version 3
5	Mobility Flag	0=static 1=mobile	Indicates nature of the transmitting platform
6	Schedule Flag	0=off 1=on	If 'On', the first bit in the Application Data Block (ADB) indicates if the interval is to be interpreted as a reservation time (bit set to '0') or a repeat interval (bit set to '1'). The time is specified from (different) look-up tables in bits 2-8 of the ADB, as specified in Annexes B & C
7	Tx/Rx Flag	0=Tx-only 1=Tx/Rx	Tx-only implies at least the ability to detect energy in band to satisfy the MAC requirements. Tx-Rx implies not only detect, but also decode capability.
8	Forwarding capability	0=No 1=Yes	Used for routing and Delay Tolerant Networking
9-16	Class user i.d.	[00000000: 11111111]	Allows 256 classes of users, mostly individual nations (see Annex A)
17-22	Application Type	[000000: 111111]	Allows 64 different types of message per user i.d. class – user specified
23-56	Application Data Block	Determined by user	For scheduled transmissions (bit 6 =1) the first 8 bits are dedicated to defining the nature of the schedule (reserved or repeat interval) with time defined in seconds from a lookup table.
57-64	8-bit Cyclic Redundancy Check (CRC)		8-bit CRC run on the previous 56 bits; polynomial $p(x) = x^8 + x^2 + x^1 + 1$, init=0
64			

Table I. JANUS bit allocation table

2.1.2 The Cyclic Redundancy Check specification

Packet integrity is ensured by a Comité Consultatif International Téléphonique et Télégraphique (CCITT) 8-bit Cyclic Redundancy Check (CRC) which uses the polynomial $p(x) = x^8 + x^2 + x^1 + 1$, initialized to 0. The 8 bits of the CRC are appended to the 56 bits of the main Baseline JANUS Packet as indicated in Table I.

2.1.3 The convolutional encoding specification

1. A ½ rate convolutional encoder is applied to the 64 bits of information with constraint length 9, resulting in 128 symbols of output. The generator sequences used for the encoder are:

$$g_1(x) = x^8 + x^7 + x^5 + x^3 + x^2 + x^1 + 1$$
$$g_2(x) = x^8 + x^4 + x^3 + x^2 + 1$$

2. Prior to encoding, 8 zeros are prepended to the data to flush the encoder, discarded at the receiver. The total number of symbols output by the encoder then becomes 2x(64+8) = 144. The convolution encoder follows the IS-95 CDMA standard (TIA/EIA/IS-95, 1993).

3. Note that if the first two bytes of a test message is, in binary

   {0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0},

   then the corresponding first two bytes out of the encoder are:

   {0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0}

2.1.4 The Interleaving specification

An interleaving process is applied to the 144 symbol message after the convolutional coding. This process separates each consecutive symbol by a constant depth value, k selected as a function of the message size l, such that k is the smallest prime number that satisfies the condition $k^2 > l$ and k is not a factor of l, in other words, l/k is not an integer number.
For a JANUS baseline packet with a length of 144 symbols the above condition will yield a depth value of 13. For an original bit sequence defined by the bits:

$b_1\ b_2\ b_3 \ldots b_{144}$,
the interleaved sequence will look like:
$b_1\ b_{14}\ b_{27}\ b_{40}\ b_{53}\ b_{66}\ b_{79}\ b_{92}\ b_{105}\ b_{118}\ b_{131}\ b_{144}\ b_2\ b_{15}\ b_{28} \ldots$.

For messages with cargo content, the interleaver depth k is determined in the same way, as a function of the number of symbols to transmit.
The baseline packet and the cargo are interleaved separately as the baseline packet needs to be decoded to know how many bytes are in the cargo.

2.1.5 Optional precursor 'wake-up' tones

The JANUS packet may optionally be preceded by three 'wake-up' tones, each of four times that of a single chip duration (defined in subsection 2.1.7.2 below), without pause between the tones, at frequencies:

$$Fc - Bw/2,\ Fc,\ Fc + Bw/2 \text{ [Hz]}$$

in that order. These are intended for use where a modem needs to 'wake-up' from a low power 'sleep' mode. The tones are not expected to be used when the intended receiver is already 'awake'. If used, the tones should finish 0.4 [s] before the main preamble to allow reverberant energy in band to fade and for the intended modem to 'wake up'. All JANUS transmitters should have the capability of sending 'wake-up' tones. Its use is left at the discretion of the user unless the packet includes time reservation, in which case the packet should be sent with 'wake-up' tones to make sure that 'sleeping' devices are aware of the channel reservation.

2.1.6 The Frequency Hopping sequence specification

1. The order in which the 13 pairs of tones are used to encode the binary data is chosen to provide optimal Inter-Symbol Interference (ISI) rejection that could otherwise be caused by multipath or collision with JANUS packets from other users. This pseudo-orthogonal Frequency Hopping (FH) sequence is fixed and therefore known to all potential receivers.

2. The FH indices are derived from Galois Field arithmetic using a primitive prime number to generate 13 frequency slots to provide good orthogonality properties. The FH sequence is defined by an algorithm that, given a prime number Q (Q=13 for JANUS, the number of tone pairs) and a number k (k is set to 3 for the JANUS standard) generates a pseudo-random sequence in the range $\{1,Q\}$ following the procedure developed by T.S. Seay (1982).

3. The heart of the sequence generation algorithm is essentially a matrix multiplication. A generator matrix is multiplied by a user parameterised row vector to create (Q-1) new sequence elements. The first column of the generator matrix is defined as $[\alpha^0,\alpha^1,\alpha^2,\ldots,\ \alpha^{K-1}]^T$ where α is a number selected in conjunction with Q such that α^n modulo Q generates every number between 1 and Q-1. Remaining columns are generated by multiplying the first column of the generator by the previous column. The multiplication is carried out modulo Q and yields the Q-1 columns of the generator matrix.

4. For JANUS, α=2, Q=13, and K=3, creating a generator matrix G as follows (showing a portion):

   $$\begin{vmatrix} 1 & 1 & 1 & 1 & 1 & 1\ldots\ldots \\ 4 & 8 & 3 & 6 & 12 & 11\ldots\ldots \\ 3 & 12 & 9 & 10 & 1 & 4\ldots\ldots \end{vmatrix}$$

   The row vector used to create Q-1 sequence elements is initialised with a number between 1 and 12 as follows:

   $$P = \begin{vmatrix} P_0 & P_1 & P_2 \end{vmatrix}$$

   $|P_0| = |\ 0\ |$ where $i = \{1 : 12\}$
   $|P_1| = |\ i\ |$
   $|P_2| = |\ 1\ |$

5. Therefore 12 new sequence elements are generated by $P*G$. The next 12 elements are obtained by incrementing P_2 modulo Q. P_2 eventually ‘rolls’ from the modulo addition and starts again. P_1 is never incremented.

6. Experiments have shown that initialising P_2 to 1 instead of 0 yields high orthogonality in the initial 32 chips. These first 32 chips comprise the unique synchronisation sequence and need to contain minimal partial pattern overlap to reduce the false alarm probability.

7. For JANUS, we set Q=13, α=2, i=1 which yields P=[0 1 1]. The first 32 generated FH sequence numbers are then:
{2,4,8,3,6,12,11,9,5,10,7,1,6,7,7,12,3,0,2,12,4,6,4,2,10,10,6,8,0,1,6,2}

8. The tone selected is determined by the FH sequence number and whether the symbol is a ‘0’ or ‘1’. The mapping of the FH sequence number and symbol value into a JANUS frequency slot depends on *Fc* and *Bw*.

9. As an example, results for the JANUS initial band are shown in Table II.

Tone lower edge frequency [Hz]	**Symbol to be encoded**	**FH sequence number**
13440	1	12
13280	0	
13120	1	11
12960	0	
12800	1	10
12640	0	
12480	1	9
12320	0	
12160	1	8
12000	0	
11840	1	7
11680	0	
11520	1	6
11360	0	
11200	1	5
11040	0	
10880	1	4
10720	0	
10560	1	3
10400	0	
10240	1	2
10080	0	
9920	1	1
9760	0	
9600	1	0
9440	0	

Table II. Lower tone frequency edges for all possible FH sequence and symbol values for the initial frequency band.

2.1.7 Centre Frequency, Bandwidth, Chip duration and Frequency Slot width

1. The JANUS standard is anticipated to be applied at several acoustic centre frequencies (*Fc*), each with a symmetrical bandwidth (*Bw*) of approximately 1/3 *Fc* (nominally within +/- ~10%) to meet diverse environmental, range and application scenarios.

2. The *Bw* is divided into 13 pairs of Frequency Slots, each of width (*FSw*) = *Bw*/26. The baseline Chip duration (*Cd*) is the inverse of the Frequency Slot width, *Cd*=1/*FSw* [s]. This provides a scalable communication standard for which higher frequencies will be associated with a larger *Bw* and *FSw*, with correspondingly shorter Cd and a higher data transfer rate, at the cost of decreased practical range underwater due to stronger absorption.

3. The transmitted Chip duration and Tukey window size may optionally, at the discretion of the sender, be set to a dyadic multiple of the baseline Chip duration {1, 2, 4, 8...} *Cd* to attempt to achieve greater robustness or detectability. If invoked, this option applies to both the fixed 32-chip preamble and all following data, but does not affect wake-up tones, if used.

2.1.8 The Initial 32-chip Detection and Synchronisation preamble specification

1. The JANUS packet starts with a fixed sequence of 32 symbols, with no temporal gap either between the chips or between the preamble and the main (modulated) part of the JANUS packet. The tones are simply the first 32 FH sequence with symbol value set to the following pseudo-random 31-bit m-sequence (with a final ‘0’ appended):
   {1,0,1,0,1,1,1,0,1,1,0,0,0,1,1,1,1,1,0,0,1,1,0,1,0,0,1,0,0,0,0,0}

2. Once the fixed preamble phase of the waveform is complete, the sequence generator continues smoothly into the message section and the data symbols are then taken from the encoded message to be transmitted.

2.1.9 Tukey Chip Windowing

One of the original requirements for JANUS was that it could be implemented by an analogue class ‘D’ amplifier without amplitude modulation. In principle the chip amplitude window can therefore be square, with successive filters and the transducer response inevitably shaping the envelope to some extent. While the chip amplitude envelope should be nearly square, a Tukey window may optionally be applied to smoothly modulate the initial and final 2.5% of the window to suppress side lobes associated with the step change at the window boundaries. This may serve to protect the analogue amplifiers from potential damage from out-of-band energy.

A $\boldsymbol{N}$ point Tukey window $\boldsymbol{\omega(n)}$ is defined as:

$$\boldsymbol{\omega(n)} = \begin{cases} \frac{1}{2}\left[1+\cos\left(\pi\left(\frac{n}{\frac{\alpha}{2}N}-1\right)\right)\right], & for\ 0 \le n < \frac{\alpha}{2}N \\ 1, & for\ \frac{\alpha}{2}N \le n \le 1-\frac{\alpha}{2}N \\ \frac{1}{2}\left[1+\cos\left(\pi\left(\frac{n}{\frac{\alpha}{2}N}-\frac{2}{\alpha}+1\right)\right)\right], & for\ 1-\frac{\alpha}{2}N < n < N \end{cases}$$

Where α is the total fraction of the shape which is less than 1.

To modulate the initial and final 2.5%, α should be 0.05 in the Tukey window specification

2.1.10 The optional Data Cargo payload

1. The Baseline JANUS Packet may be followed, without a break, by additional data, encoded according to the user-specified application into a continuation of the FH sequence using the same tones specified in Table II. Such ‘cargo’ is to be encoded using a contiguous continuation of the frequency-hopped sequence following directly after the final chip of the Baseline JANUS Packet. Unless the published user application specifies otherwise, the same convolutional encoder and interleaver are to be used as for the main Baseline JANUS Packet. The Baseline packet and the cargo are always separately encoded and interleaved.

2. A sufficient but not excessive time to transmit any such ‘cargo’ must have been reserved in the preceding Baseline JANUS Packet by setting bit 6 to ‘1’, bit 23 to ‘0’ and specifying the reserve time in bits 24-30 according to Annex B.

3. If there is an intention to ‘reserve’ the channel for emergency communications, e.g. using an underwater telephone such as one that implements STANAG 1074, bit 6 may be set to ‘1’, bit 23 to ‘0’ and bits 24-30 to ‘1111111’, thus ‘reserving’ the channel for the maximum period of 10 minutes, without the need to transmit any data cargo.

4. The structure of a JANUS packet is shown in Fig. II, showing the fixed 32-chip preamble, immediately followed by the 144 encoded and

interleaved symbols arising from the 64-bits of input information and an optional ‘Cargo’.

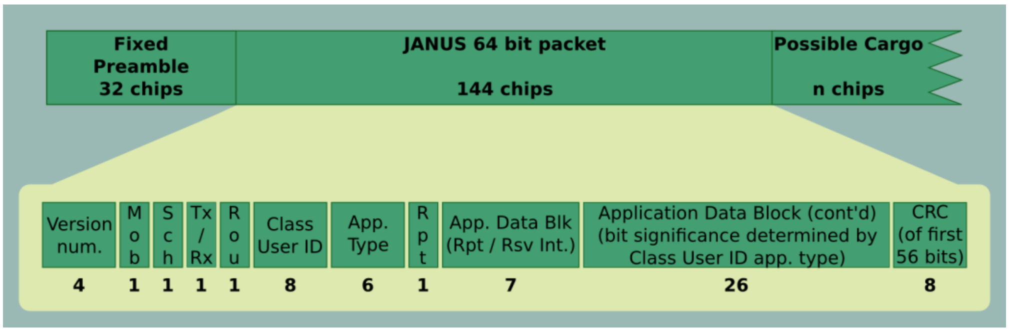

Figure II. The structure of a JANUS packet

5. An illustration (not to scale and not literal) of the time-frequency representation of a JANUS acoustic packet is shown in Fig. III.

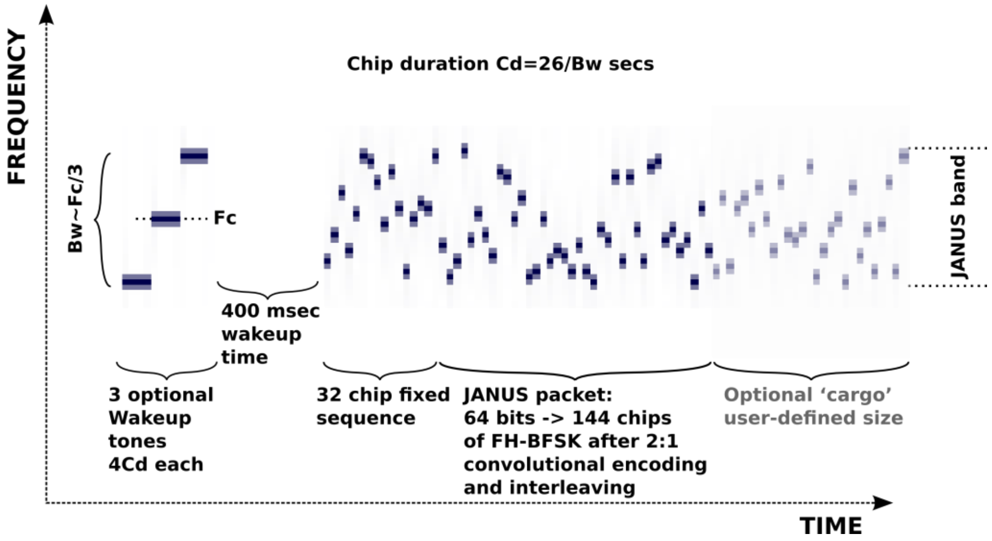

Figure III. Illustration of the Time-Frequency structure of a JANUS packet, showing optional ‘wake-up’ tones preceding the Baseline JANUS Packet and Cargo following

2.1.11 The JANUS initial acoustic frequency band

1. The initial JANUS acoustic frequency band has the following specifications:

$$Fc=11520 \text{ [Hz]}$$
$$Bw=4160 \text{ [Hz]}$$

2. The resulting Frequency Slot width and Chip duration are then:

$$FSw = 160 \text{ [Hz]}$$
$$Cd = 0.00625 \text{ [s]}$$

3. Additional bands may be added to this standard as and when recommended by the NATO sponsoring body and approved by the NATO nations.

2.2 Medium Access Control

1. The default Media Access Control (MAC) mechanism is a species of Carrier Sensing Multiple Access (CSMA) as described in Smith (1997) with Collision Avoidance (CA) via Binary Exponential Backoff (BEB) with Global Awareness (GA) that consists of an in-band energy detector.

2. We take advantage of the frequency-scaling nature of the JANUS protocol to define parameters in chip lengths so that the Backoff and Carrier Sensing window lengths are scaled to the baseline chip length. In addition, if a message from another node has been decoded that included a reservation or scheduled repeat transmission time, the channel is deemed to be busy for that time slot.

3. Emergency transmissions may be made at any time.

2.2.1 Globally-Aware Carrier-Sensing

1. The goal of the Globally-Aware Carrier Sensing is to avoid collisions with not only other JANUS transmissions, but also other communications that may be in band, including analogue transmissions. Since the nature of the potentially-competing communications and the noise in which they are embedded are both unknown, we choose a simple energy-detection scheme.

2. To test whether the channel is busy, a node wishing to transmit a JANUS packet must have an estimate of the background acoustic power in band. Nodes are required to sense the channel immediately before a planned transmission across the full JANUS band for a minimum of twice the length of an encoded basic JANUS packet (i.e. at least 352 *Cd*) from which an estimate of the background acoustic power in band is to be made. The method by which that estimate is calculated remains open, though if a method consistently produces false alarms and/or missed detection levels that differ greatly from other implementations it may be deemed not to be in compliance.

3. The background estimate may be based on a longer sampling period, indeed this is greatly preferable if the node is able to do so. The estimate may also be a non-linear function of the sensed energy in band.
   In order to avoid excessive “biasing” of the background noise during the ‘busy’ condition, the estimation should have different tracking speeds depending on the state of the channel (*i.e.* faster when in silence, slower when ‘busy’.

4. If the acoustic power in band, estimated over a window of 16 Cd exceeds the estimated background acoustic power by more than 3 dB, the channel is deemed ‘busy’ in that window

5. If a node wishes to make a JANUS transmission, it must first carry out a background acoustic power in band estimation and then determine if the channel is ‘busy’ If not, the node may transmit its JANUS message immediately. If ‘busy’, the node must apply a backoff before retrying, as specified in the following subsection.

2.2.2 Exponential Random Backoff

1. JANUS employs a Binary Exponential Backoff (BEB) to provide Collision Avoidance (CA) properties. This provides a strong protection for other communication systems that may be operating in band and minimizes the hidden-terminal problem within the constraint of no handshaking requirement.

2. If the channel is estimated to be ‘busy’ when a node intended to transmit, the node continues to sample windows of length 16 *Cd* until the channel is deemed no longer ‘busy’. The node then applies a BEB where it transmits in the next slot with probability *P* defined as:

$$P = \begin{cases} \dfrac{1}{1+2^{C-2}} & for\ \ 1 \geq c \geq 4 \\ \dfrac{1}{5} & for\ \ 4 < c \leq 8 \end{cases}$$

   Where *C* is the number of potential transmission slots the device has counted in the backoff process in which there has been at least one ‘busy’ window, initialized with *C*=1. The slot length is defined as the length of a Baseline JANUS Packet (i.e. 176 *Cd*). When the JANUS band overlaps the underwater telephone band (as is the case for the initial JANUS band), as an additional rule, the node should never transmit in the first slot after a slot which has been deemed ‘busy’ (see 2.2.3-2).

3. If the node does not elect to transmit in the first available slot, it continues to sample 16-chip windows to detect if the channel is busy during the next slot, incrementing *C* by one (but only once per slot) if this is the case at any point during the slot, up to a maximum of *C*=8.

4. Once the node elects to transmit its message, *C* is re-initialized to *C*=1. If *C* reaches 8, the attempt to transmit that packet is dropped.

2.2.3 Interaction with STANAG 1074 Underwater Telephone signals

1. The JANUS MAC provides a conservative non-disruptive co-existence with existing UW acoustic systems, including submarine analogue telephones and emergency submarine acoustic communications, through the GA CSMA. The backoff mechanism is deliberately aggressive to give priority to STANAG 1074 communications.

2. In order to prevent occurrences of the specific case where the silence between the words of Underwater Telephone transmissions may be interpreted as an idle channel, a guard time of at least 176 *Cd*. should be guaranteed before a transmit attempt so that no transmission will ever start less than 176 *Cd* [s] after the last busy channel condition.

3. More sophisticated MAC schemes may be defined at a later date for some of the user classes and allocation tables and/or as a result of practical experience with analogue UW telephones conforming to STANAG 1074 if a significant interference issue is found.

4. Additionally, the ability to ‘reserve’ time following a basic JANUS packet allows JANUS-compliant systems to silence neighboring JANUS transmitters for a period of up to 10 minutes with only a short JANUS packet, reserving the channel.

CHAPTER 3 References

1. “TIA/EIA/IS-95”, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, 1993.
2. T. S. Seay, "Hopping Patterns for Bounded Mutual Interference in Frequency Hopping Multiple Access," Proc. IEEE Military Communications Conference, Boston, Massachusetts, October 1982.
3. S. M. Smith, J. C. Park, and A. Neel, "A peer-to-peer communication protocol for underwater acoustic communication," in MTS/IEEE OCEANS '97, 1997, pp. 268-272 vol.1.

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ANNEX A User Class specification table

The following gives the user class number for each type of user, most of which are Nations. The table is intended to be developed as this standard gets developed and the user base grows.

0	Emergency	30	OPEN	60	OPEN	90	OPEN
1	Underwater GPS	31	OPEN	61	OPEN	91	OPEN
2	Underwater AIS	32	OPEN	62	OPEN	92	OPEN
3	Pinger (nav. & ranging)	33	OPEN	63	OPEN	93	OPEN
4	Fixed vertical mooring	34	OPEN	64	OPEN	94	OPEN
5	Rigid vertical structure	35	OPEN	65	OPEN	95	OPEN
6	Hazard marker	36	OPEN	66	OPEN	96	OPEN
7	Channel marker	37	OPEN	67	OPEN	97	OPEN
8	Wind Generator	38	OPEN	68	OPEN	98	OPEN
9	Wave Generator	39	OPEN	69	OPEN	99	OPEN
10	Solar Generator	40	OPEN	70	OPEN	100	OPEN
11	OPEN	41	OPEN	71	OPEN	101	OPEN
12	OPEN	42	OPEN	72	OPEN	102	OPEN
13	OPEN	43	OPEN	73	OPEN	103	OPEN
14	OPEN	44	OPEN	74	OPEN	104	OPEN
15	Capabilities descriptor	45	OPEN	75	OPEN	105	OPEN
16	NATO JANUS reference Implementation	46	OPEN	76	OPEN	106	OPEN
17	OPEN	47	OPEN	77	OPEN	107	OPEN
18	OPEN	48	OPEN	78	OPEN	108	OPEN
19	OPEN	49	OPEN	79	OPEN	109	OPEN
20	OPEN	50	OPEN	80	OPEN	110	OPEN
21	OPEN	51	OPEN	81	OPEN	111	OPEN
22	OPEN	52	OPEN	82	OPEN	112	OPEN
23	OPEN	53	OPEN	83	OPEN	113	OPEN
24	OPEN	54	OPEN	84	OPEN	114	OPEN
25	OPEN	55	OPEN	85	OPEN	115	OPEN
26	OPEN	56	OPEN	86	OPEN	116	OPEN
27	OPEN	57	OPEN	87	OPEN	117	OPEN
28	OPEN	58	OPEN	88	OPEN	118	OPEN
29	OPEN	59	OPEN	89	OPEN	119	OPEN

ANNEX A User Class specification table (contd.)

120	OPEN	150	OPEN	180	OPEN	210	Tajikistan
121	OPEN	151	OPEN	181	OPEN	211	Switzerland
122	OPEN	152	OPEN	182	OPEN	212	Sweden
123	OPEN	153	OPEN	183	OPEN	213	Serbia
124	OPEN	154	OPEN	184	OPEN	214	Montenegro
125	OPEN	155	OPEN	185	OPEN	215	The Republic of Moldova
126	OPEN	156	OPEN	186	OPEN	216	Malta
127	OPEN	157	OPEN	187	Mongolia	217	Kyrgyz Republic
128	OPEN	158	OPEN	188	New Zealand	218	Kazakhstan
129	OPEN	159	OPEN	189	Republic of Korea	219	Ireland
130	OPEN	160	OPEN	190	Pakistan	220	Georgia
131	OPEN	161	OPEN	191	Japan	221	Finland
132	OPEN	162	OPEN	192	Iraq	222	Bosnia and Herzegovina
133	OPEN	163	OPEN	193	Australia	223	Belarus
134	OPEN	164	OPEN	194	Afghanistan	224	Azerbaijan
135	OPEN	165	OPEN	195	United Arab Emirates	225	Austria
136	OPEN	166	OPEN	196	Kuwait	226	Armenia
137	OPEN	167	OPEN	197	Qatar	227	United States
138	OPEN	168	OPEN	198	Bahrain	228	United Kingdom
139	OPEN	169	OPEN	199	Tunisia	229	Turkey
140	OPEN	170	OPEN	200	Morocco	230	Spain
141	OPEN	171	OPEN	201	Mauritania	231	Slovenia
142	OPEN	172	OPEN	202	Jordan	232	Slovakia
143	OPEN	173	OPEN	203	Israel	233	Romania
144	OPEN	174	OPEN	204	Egypt	234	Portugal
145	OPEN	175	OPEN	205	Algeria	235	Poland
146	OPEN	176	OPEN	206	Uzbekistan	236	Norway
147	OPEN	177	OPEN	207	Ukraine	237	Netherlands
148	OPEN	178	OPEN	208	Turkmenistan	238	Luxembourg
149	OPEN	179	OPEN	209	the former Yugoslav Republic of Macedonia [1]	239	Lithuania

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[1] Turkey recognizes the Republic of Macedonia with its constitutional name.

ANNEX A User Class specification table (contd.)

240	Latvia	244	Greece	248	Denmark	252	Bulgaria
241	Italy	245	Germany	249	Czech Republic	253	Belgium
242	Iceland	246	France	250	Croatia	254	Albania
243	Hungary	247	Estonia	251	Canada	255	JANUS special

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ANNEX B Reservation Interval table

The following columns give the decimal bit value and associated reservation period in seconds that may be requested by setting bits 24-30 if bit 6 is set to ‘1’ and bit 23 is set to ‘0’

0	0.00332110	32	0.07012096	64	1.48051838	96	31.25933450
1	0.00365321	33	0.07713306	65	1.62857022	97	34.38526795
2	0.00401853	34	0.08484637	66	1.79142724	98	37.82379475
3	0.00442038	35	0.09333100	67	1.97056996	99	41.60617422
4	0.00486242	36	0.10266410	68	2.16762696	100	45.76679164
5	0.00534866	37	0.11293051	69	2.38438965	101	50.34347081
6	0.00588353	38	0.12422357	70	2.62282862	102	55.37781789
7	0.00647188	39	0.13664592	71	2.88511148	103	60.00000000
8	0.00711907	40	0.15031051	72	3.17362263	104	67.00715964
9	0.00783098	41	0.16534157	73	3.49098489	105	73.70787561
10	0.00861408	42	0.18187572	74	3.84008338	106	81.07866317
11	0.00947549	43	0.20006329	75	4.22409172	107	89.18652948
12	0.01042303	44	0.22006962	76	4.64650089	108	98.10518243
13	0.01146534	45	0.24207659	77	5.11115098	109	107.91570068
14	0.01261187	46	0.26628424	78	5.62226608	110	118.70727074
15	0.01387306	47	0.29291267	79	6.18449268	111	130.57799782
16	0.01526036	48	0.32220394	80	6.80294195	112	143.63579760
17	0.01678640	49	0.35442433	81	7.48323615	113	157.99937736
18	0.01846504	50	0.38986676	82	8.23155976	114	173.79931510
19	0.02031155	51	0.42885344	83	9.05471574	115	191.17924661
20	0.02234270	52	0.47173878	84	10.00000000	116	210.29717127
21	0.02457697	53	0.51891266	85	10.95620604	117	231.32688839
22	0.02703467	54	0.57080393	86	12.05182665	118	254.45957723
23	0.02973813	55	0.62788432	87	13.25700931	119	279.90553496
24	0.03271195	56	0.69067275	88	14.58271024	120	307.89608845
25	0.03598314	57	0.75974002	89	16.04098127	121	338.68569730
26	0.03958146	58	0.83571403	90	17.64507940	122	372.55426703
27	0.04353960	59	0.91928543	91	19.40958734	123	409.80969373
28	0.04789356	60	1.00000000	92	21.35054607	124	450.79066310
29	0.05268292	61	1.11233537	93	23.48560068	125	495.86972941
30	0.05795121	62	1.22356891	94	25.83416074	126	545.45670235
31	0.06374633	63	1.34592580	95	28.41757682	127	600.00000000

The reservation interval table can also be expressed as:

$$T_{rsv}(i) = \begin{cases} 0.0033211, & i = 0 \\ 1, & i = 60 \\ 10, & i = 84 \\ 60, & i = 103 \\ 600, & i = 127 \\ T_{rsv}(i-1) \times 1.1, & otherwise\ (i < 127) \end{cases}$$

ANNEX C Repeat interval table

The following columns give the decimal bit value and associated repeat interval in seconds that may be requested by setting bits 24-30 if bit 6 is set to ‘1’ and bit 23 is set to ‘1’

0	0.03321100	32	6.07309863	64	1110.55153266	96	203079.97319687
1	0.03908170	33	7.14663902	65	1306.86349766	97	238978.37810416
2	0.04599017	34	8.40994892	66	1537.87748815	98	281222.53663058
3	0.05411984	35	10.00000000	67	1809.72777402	99	330934.18633241
4	0.06368659	36	11.64598917	68	2129.63297875	100	389433.35408199
5	0.07494446	37	13.70464827	69	2506.08776044	101	458273.40762920
6	0.08819237	38	16.12721611	70	2949.08837612	102	539282.30322015
7	0.10378212	39	18.97802077	71	3600.00000000	103	634611.12454890
8	0.12212766	40	22.33276159	72	4083.85967766	104	746791.20192975
9	0.14371615	41	26.28051924	73	4805.76270919	105	878801.32841370
10	0.16912082	42	30.92612119	74	5655.27639046	106	1034146.85768396
11	0.19901627	43	36.39292525	75	6654.95842967	107	1216952.78407016
12	0.23419634	44	42.82609513	76	7831.35405642	108	1432073.27629739
13	0.27559517	45	50.39645511	77	9215.70089508	109	1685220.57349343
14	0.32431208	46	60.00000000	78	10844.75843841	110	1983116.66611658
15	0.38164065	47	69.78836328	79	12761.78414712	111	2333671.78948974
16	0.44910319	48	82.12483784	80	15017.68209432	112	2746194.46959965
17	0.52849107	49	96.64202846	81	17672.35465560	113	3231638.69864865
18	0.62191233	50	113.72541986	82	20796.29313711	114	3802894.80377769
19	0.73184764	51	133.82863883	83	24472.44957860	115	4475131.73259338
20	0.86121620	52	157.48549967	84	28798.43943480	116	5266199.84443698
21	1.00000000	53	185.32417892	85	33889.13362415	117	6197104.90298272
22	1.19260113	54	218.08389574	86	39879.70877367	118	7292565.85640996
23	1.40341698	55	256.63454093	87	46929.23665476	119	8581671.21626093
24	1.65149871	56	301.99977571	88	55224.90812301	120	10098651.46425370
25	1.94343380	57	355.38421367	89	64987.00372288	121	11883787.99728810
26	2.28697419	58	418.20540770	90	76474.74294517	122	13984482.74647170
27	2.69124214	59	492.13149123	91	86400.00000000	123	16456516.87248170
28	3.16697246	60	579.12547326	92	105901.24107592	124	19365531.96024360
29	3.72679753	61	681.49736353	93	124621.38158255	125	22788773.04408960
30	4.38558275	62	801.96551168	94	146650.67745910	126	26817139.74711250
31	5.16082131	63	943.72878951	95	172574.08741667	127	31557600.00000000

The repeat interval table can also be expressed as:

$$T_{rpt}(i) = \begin{cases} 0.0033211, & i = 0 \\ 1, & i = 21 \\ 10, & i = 35 \\ 60, & i = 46 \\ 3600, & i = 71 \\ 86400, & i = 91 \\ 31557600, & i = 127 \\ T_{rpt}(i-1) \times 1.176769793407883, & otherwise\ (i < 127) \end{cases}$$

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