Annex G: Use of Waveforms at Data Rates Above 2400 bps (information only)

G.1.0 Introduction

This Annex presents guidelines and requirements for the use of the STANAG 5066 protocol profile with modems and waveforms at rates above 2400, when these waveforms become standardized and available in future.

G.2.0 Background

Currently, NATO standards for HF waveforms such as STANAG 4285 and 4529 are limited to data rates of 2400 bps and below. These standards form the basis for support for the STANAG 5066 HF protocol profile in its current form. However, on-going research, development, and standardization attempts for high-speed HF waveforms show promise of increasing the usable data rate on HF long-haul channels to 9600 bps and higher. Early draft versions of STANAG 5066 Annex G included a detailed specification for high-speed single-tone waveform and convolutional forward-error-correction coding with data rates up to 9600 bps, and this formed the basis for more than one vendor implementation of a commercial product. Subsequent waveform designs also have been submitted and considered for inclusion in this STANAG. A design for a second single-tone waveform with multi-level Reed-Solomon-coding was submitted for consideration, also with rates to 9600 bps. Finally, a third waveform design based on Orthogonal Frequency Division Multiplexing and turbo-coding was submitted, with projected data rates to over 10 kb/s. No timely agreement has been reached on which, if any, of these waveforms should form the basis for a NATO standardization agreement or be included in STANAG 5066.

G.3.0 Implementation Guidance for STANAG 5066 Operation at Higher Rates

It is clear that higher throughput will be available for the HF long-haul channel in near future (i.e, post 2000). What is not clear is the final form of the waveform standard or standards that will provide these data rates. Accordingly, this Annex focuses only on the generic requirements and guidance implementers of the STANAG 5066 Profile for HF Data Communications must follow when using waveforms at speeds higher than 2400 bps. Guidance is of the form of the maximum data rates for which an implementation must be sized, and on the identification of system configuration parameters and requirements that are dependent on data rates and will likely change as the result of implementing the protocol profile with higher-rate modems as support.

G.3.1 Maximum Data Rate

Implementations of STANAG 5066 should be designed to operate at maximum data rates on the rough order of 20 kilobits per second. As a ‘rough-order’ estimate, this recommended maximum data rate could be expected to vary by a factor of 2, larger or smaller, as the discussions presented here demonstrate.

Given foreseeable technology, dense signaling constellations operating within a 3kHz bandwidth at rates as high as 7 bits or 8 bits per hertz might be achievable in future, giving satisfactory performance, even for long-haul fading channels, for FEC codes at ½-rate, ¾-rate, or even $^{7}/_{8}$-rate.

For example, current standardization proposals for high-speed HF waveforms include a proven implementation based on 64-QAM at 2400 baud operating in a nominal 3 kHz channel, with a ¾-rate FEC code. This design yields a signaling rate of 10,800 bps. The inclusion of known data sequences in the waveform to support adaptive equalization algorithms for long-haul fading channels yields a final data rate of 9600 bps. Extension of such a design to 128-QAM might be achievable in future, and this would yield a user data rate on the order of 19.2 kbps.

Note that with more optimistic assumptions on the capabilities of future signal processing technology for HF transmission, the recommended maximum speed could have been established at an even higher value on the order of 38.4 kbps. This higher maximum data rate could also be achievable if wider bandwidths are assumed for the HF channel, or if channels are assumed with less stressing fading conditions than those that exist on the long-haul skywave channel. For example, wider bandwidth to 6 kHz can be achievable with independent side-band operation, though given the congestion in the HF band, this is not considered a likely prospect from a frequency-management perspective. Alternatively, channel coherence is known to be more stable for surface wave operation at HF where one signal path is non-fading. Signal design for surface channels can yield reliable and satisfactory performance in a waveform design where the number of known data symbols required for equalization in severe channels is reduced from that required for long-haul operation, allowing an increase in the available user data rate.

As a further note, the STANAG 5066 protocols could be used on 25-kHz (or other) LOS or SATCOM channels at UHF as a means of combating bursty interference rather than the channel fades characteristic of HF. ARQ protocols have been used on UHF-SATCOM channels to successfully combat unintentional burst interference from uncontrolled LOS terrestrial sites within the satellite coverage area. The STANAG 5066 protocols could be used in similar fashion but with LOS/SATCOM modems that offer higher data rates because of their greater bandwidth.

The recommended maximum data of 20 kilobits per second is therefore considered a reasonable design margin for implementation of STANAG 5066 for the foreseeable future.

G.3.2 Buffer Sizes

The required sizes for data stores and buffers within an STANAG 5066 HF subnetwork implementation depend on the expected arrival rate for traffic from both the local client, via the Subnetwork Interface, and remote clients, via the interface to the communications equipment. Subnetwork implementers will be aware that the buffer sizes they allocate will likely need to change when implementing to support the higher maximum data rate.

G.3.3 Data Rate Control Protocol

The Data Rate Control (DRC) Protocol in STANAG 5066 uses the Type 1 Engineering Orderwire (EOW) messages embeddable in D_PDUs to specify the desired or actual data rates of the sender and receiver on a link, as specified in Annex C.5.1.

Mandatory requirements currently specify field values that allow the DRC protocol to control data rates up to 9600 b/s. Unused field values will be assigned for data rates above 9600 should these become necessary. Proposed values are given in the following table, but may be changed in future to support the final waveform(s) ratified for high-speed HF transmission:

Table G-1. Proposed Extensions to Data Rate Parameter Message Type 1 EOW Message

MSB - LSB	Interpretation
0 0 0 0	*As in Annex C*
through	. . . . . .
1 0 1 1	*As in Annex C*
1 1 0 0	14400 bps
1 1 0 1	16000 bps
1 1 1 0	19200 bps
1 1 1 1	reserved

Implementers of STANAG 5066 may wish to adopt the use of the proposed values for higher data rates for the Data-Rate-Parameter field of the Type 1 EOW message. If so, they are advised that the specific values may change in future editions of 5066, and their software should be based on site- and modem- configuration parameters that allow change in these values without recompilation of their software.

Likewise, the addition of new waveform STANAGs to support higher data rates may entail changes to the allowable choices for modem interleaver. This may also effect the interpretation of values for the Interleaver-Parameter field of the Type 1 EOW message. At present, however, there are no proposed changes to the Interleaver Parameter planned for future editions.

G.3.4 EOT Calculation

Support for higher data rates must be accounted for in calculation of the End-of-Transmission field required in each Data Transfer Sublayer PDU (D_PDU).

Calculation of the End-of-Transmission field required in each Data Transfer Sublayer PDU (D_PDU) depends on a number of factors:

- the size of the D_PDU,
- the sizes of D_PDUs that follow it in the transmission,
- the interleaver settings for the modem (because of fill-bits inserted by the modem when data does not completely fill an interleaver or coding block),
- and the data rate of the transmission.

Since compliant implementations of the STANAG 5066 protocols that also implement the Data Rate Change capability must factor the variable data rate into calculations of the EOT, support for a higher maximum data rate is not considered a major impact.

G.3.5 Waiting and Response Times

Waiting and response times for STANAG 5066 protocols that depend on the data rate of the supporting link will need to be determined with allowance for the greater range in data rates. As in the case of EOT calculations, waiting and response times may be modified during execution of the DRC protocol and resultant changes in the link data rate, and therefore support for higher data rate is not considered a major impact on the implementation in this area.