FFI RAPPORT

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JODALEN Vivianne, GRØNNERUD Ove, SOLBERG Bjørn

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8) ABSTRACT

This report documents the preliminary testing of the STANAG 4406 (Formal Military Messaging) using IP over the Harris AN/PRC-117F radio. Functional testing and limited performance testing have been conducted in a short time period when the radios were available. Only the IP Line-Of-Sight mode of the radio has been evaluated. Transmitting STANAG 4406 Annex E messages using IP over the AN/PRC-117F is feasible with a maximum data link throughput of 17 kbit/s for a 75 kbyte message over an ideal channel. This was achieved with optimum offered load to the radio. Application throughput is somewhat less. Taking account of non-optimal channel conditions the offered load was reduced, and a maximum application throughput of 6.5 kbit/s was achieved for good channels. This throughput is lower than expected from knowledge of the maximum gross data rate capability of the radio;64 kbit/s. The relatively low application throughput is due to the small buffer size of the radio that sets a limit on the input data rate (offered load).

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CONTENTS

INITIAL LAB TESTING OF IP MESSAGING OVER THE AN/PRC-117F

1 INTRODUCTION

In Project 822 SIGVAT HF at FFI, one activity has focused on the use of Formal Military Messaging, STANAG 4406, in an IP network comprising an HF link. This work is documented in (1). As an extension of this work, we were tasked by the Norwegian Coastal Ranger Command (CRC) to do similar functional testing of the STANAG 4406 using IP over the Harris AN/PRC-117F radio (VHF/UHF). This report documents the results of the AN/PRC-117F tests.

The Military Message Handling System (MMHS) described in STANAG 4406 (2) is currently being widely implemented in NATO, and also the Norwegian Land, Air and Maritime Forces are implementing it in the Norwegian C2IS. The Thales XOmail implementation of S4406 is bought by the Norwegian Defence. S4406 includes both a strategic and a tactical protocol profile, which may be used for exchanging information between the high data rate strategic domains and the low data rate tactical domains. The S4406 may utilize different networking technologies, of which IP seems to be the most important.

The CRC describes an architecture for their future C2IS in (3). They want local area networks (LAN’s) on each of their platforms, and both strategic and tactical bearer systems are connecting the various platforms. Different sub-systems are using the network, amongst them the MMHS. Possible tactical bearer systems are HF, UHF, WLAN and tactical SATCOM. The MMHS may also be used as an integrator between tactical bearer systems such as HF/VHF/UHF/WLAN, and an ultimate goal for the CRC is a network where the optimum bearer system is automatically chosen.

Since our project SIGVAT HF had conducted performance testing of MMHS over IP over HF, we were tasked by the CRC to investigate the performance of MMHS over IP LOS radios represented by the Thales MBITR radio (VHF/UHF) in conjunction with the IDM (Improved Data Modem) technology, and the Harris AN/PRC-117F radio (VHF/UHF). These are candidate tactical radios for the CRC, and they both include NATO approved crypto (Type 1). The MBITR work is documented in (4).

We had a very limited time available for the MMHS over AN/PRC-117F performance tests, so the results reported here are not nearly as thorough as the HF and MBITR work. The results are only indicative of what can be expected from the AN/PRC-117F in an IP network. The High Performance Waveform (HPW) that the AN/PRC-117F makes use of, is also a Harris proprietary waveform that we have no knowledge about. This makes interpretation of the results more difficult than in the HF work where NATO standards were used.

The tests were conducted in the period January to February 2005 with borrowed equipment from the Norwegian Army Special Operation Forces.

2 FACTS ABOUT THE AN/PRC-117F

The AN/PRC-117F is a multi-band tactical military radio that provides NATO approved secure voice and data transmissions over line-of-sight (LOS) and tactical satellite (TACSAT) channels. It provides communications at frequencies ranging from 30 MHz to 512 MHz, offering waveforms such as Sincgars (low VHF), Have Quick I/II (high VHF/low UHF) and UHF Satcom. The latter provides both 5/25 kHz Dedicated Channel or 5/25 kHz Demand Assigned Multiple Access (DAMA). Different modulation techniques are used for the various frequency bands, for instance FM, FSK, AM, ASK, TCM and HPW (High Performance Waveform). The HPW is a Harris proprietary waveform which is always used for IP traffic, both in Satcom mode and in LOS mode. HPW LOS IP nets can be programmed to use a 25 kHz channel within the 30-512 MHz range. HPW Satcom IP nets can be programmed to use a 5 or 25 kHz channel within the 225-320 MHz UHF TACSAT range. The IP capability of the radio is not interoperable with IP capabilities of other radios since the HPW is a Harris proprietary modem waveform, and techniques such as packet conglomeration and compression is used. Depending on modulation technique, data rates over-the-air range from a few hundred bits/s up to 64 kbit/s, the latter being available only for the HPW LOS mode. Data rate adaptivity is possible by setting the data rate to AUTO.

The radio provides several embedded encryption techniques, of which the KG-84C has been used in our tests.

The IP feature of the AN/PRC-117F provides the user with a network transport facility. The interface presented to the user is an RS-232 PPP (point-to-point protocol) connection, over which standard IP packets can be transmitted and received. Multiple radios can be configured to participate in the same radio subnet. There are different network configurations that can be implemented using the AN/PRC-117F, but in all cases, the radios form a separate IP subnet.

A fixed parameter of importance for the transfer efficiency is the *assembly size* which is 16 kbyte for the AN/PRC-117F. This parameter expresses the amount of data that is transferred in one direction before a stop is imposed to allow for IP traffic in the reverse direction. Conglomeration/concatenation of IP datagrams in such an assembly increases the throughput efficiency.

The number of radio parameters to be selected by the operator when using the IP LOS HPW is rather limited. The only parameters to twist, are the selection of an ARQ/non-ARQ protocol, the data rate, and the selection of Cipher Text (CT) or Plain Text (PT) mode. However, a few other parameters could be set in the application, as described in Section 3.

As for the Harris RF-5800H HF radio, the AN/PRC-117F provides the ICMP Source Quench mechanism (5). When the radio buffer overflows, an ICMP Source Quench packet is sent to the source of the data (IP address), causing the application to pause sending data. The radio will then be able to serve the data in the buffer, before the application again starts sending data. The time before packet transmission again starts is configurable in the application. Ideally, a Sourch Quench packet could be sent *before* the overflow situation occurs, but this is not implemented in the AN/PRC-117F. Always when a Source Quench was noted, one or more packets have been discarded due to the overflow.

3 SOME ASPECTS OF THE STANAG 4406 APPLICATION

The protocol stack defined in S4406 Annex C is connection-oriented, defined for strategic, high data rate networks. The protocol stack described in Annex E is connectionless, and developed for tactical, low data rate links. When both protocol stacks are implemented in a message server, they may provide a seamless interconnection between the strategic and the tactical domain. The complete protocol stacks of S4406 Annex C and E when connected to the AN/PRC-117F via IP, are shown in Figure 1.

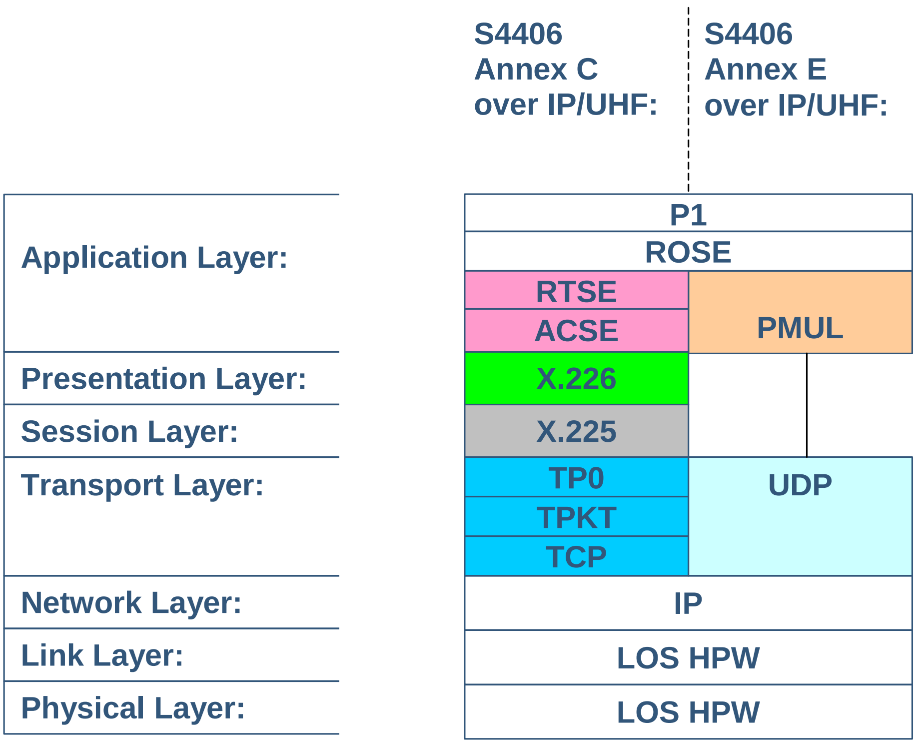


Figure 1 Protocol stack of MMHS (S4406) using IP over the LOS HPW (AN/PRC-117F)

We will not go into details about the protocols at various layers, but just note that TCP is the transport protocol used by the Annex C profile, and that the Annex E profile uses ACP 142 Edition 1 (P-Mul) (6) connected directly to UDP. In the following we focus on the Annex E profile since this is of most importance to narrowband channels such as UHF.

When a message is transmitted from one messaging server to another using the Annex E stack utilizing IP over the LOS HPW, the following occurs:

- The upper application layers add a fixed number of overhead bytes to the message.
- P-Mul divides the message up into packets of a certain *PDU-size* that can be specified by the user. It further adds a fixed number of overhead bytes to each packet (16 bytes).
- The packets are sent from P-Mul at a certain rate specified by the configurable parameter *PDU-delay*.
- UDP adds 20 bytes of overhead to each packet.
- IP adds 8 bytes of overhead to each packet.
- The packets are then sent over the PPP interface to the radio which sends the message over UHF using a data link protocol and waveforms.

S4406 Annex E provides selective acknowledgement at application level. This means that it may use a non-reliable bearer service (such as broadcast) since P-Mul will request retransmissions of packets if they are not received. When a positive ACK is sent from the receiving P-Mul, the sending P-Mul will finally transmit an end-of-message. The current version of the P-Mul protocol is susceptible to the loss of the first and last packet of the complete message. If these packets are lost, no NACK is sent from the receiver, and a retransmission timer in the sending P-Mul will eventually trigger a complete retransmission. This situation is occasionally encountered, and leads to a very long delivery time. The next version of P-Mul (ACP 142 Edition 2) contains better solutions for this situation.

Neither P-Mul, nor UDP contains any flow control mechanisms. If the data rate of the PPP connection to the radio is higher than the data rate over-the-air, and the size of the message to be sent is larger than the size of the radio buffer, the radio buffer will overflow and data packets will be discarded. To handle this situation, the AN/PRC-117F makes use of the ICMP Source Quench mechanism as described in the previous section.

More details about the STANAG 4406 Annex E is given in (7). The implementation of the S4406 that we have been using is the XOmail implementation from Thales, Trondheim.

4 TEST SETUP AND CONFIGURATION

The tests have been conducted only in the laboratory. We were tasked to test the IP LOS mode of the radio, and not the IP satellite capabilities. IP LOS mode of operation is only possible with a radio firmware version higher than 4.0 After loading new radio firmware, our two radios had the following version codes:
System: V4.0.1.8, EP Version V2.5A
SCC Version: V3.38, SPCM Boot Version 1.13A

A special cable (10513-0710-A006-HPW PPP) connected the radios J3 MIL Data connector to a standard RS-232 COM port on the PC. This PPP interface was configured from the PC by first “adding a new modem” from the control panel and selecting a file that could be found on the CD following the AN/PRC-117F. Then the Dial-up connection to the modem had to be installed and configured from the control panel. The maximum speed of the PPP connection was set to 115.2 kbit/s, and the IP address of the PC was defined under the TCP/IP properties. The configuration of the PPP interface is described in (8).

Programming the radio for IP LOS mode is well described in (9). We programmed the radio by using the Keypad Display Unit (KDU). However, there exists an 117F Radio Programming Application (RPA) that was released in June 2004 and enables programming the radio from the PC. Figure 2 shows the simple network including IP addresses that we tested. Table 1 is scanned from (9), and it gives details on the necessary radio programming for the IP configuration shown in Figure 2. By using the IP bridging feature, the radios assume the IP identity of the PC’s and are able to form a seamless wireless network. The IP address of the PPP port of the radio is only pingable from the PPP peer direction, not from other radio nodes.

Test crypto keys were loaded into the radio before the radios were delivered to us. The two radios were connected by attenuators. For measuring performance at different SNR levels, the signal level was varied by the attenuators without injecting any external noise. We made an attempt at calibrating the received power, but this turned out to be rather difficult because of a varying signal envelope throughout the transmission. Therefore, attenuation of the signal is used as a parameter in the results, not the received power or SNR, as would have been desired. A frequency of 325 MHz was selected for the tests.

XOmail (server and client) was installed at the PCs and the proper IP addresses and routing defined. A compressed message (to avoid compression at various other layers) was sent from the MMHS client, time stamped at the MMHS server, time stamped again at the receiving server before delivery to the receiving client. Delivery time was calculated, and the *Application throughput* (bits/s) was defined as the compressed file size divided by the delivery time.

Approximately 4-5 measurements were made for each test, and the results are averaged in the figures. If the first or last packet of the transmitted message was lost and the retransmission timer was effectuated as described earlier in this section, we discarded the whole measurement.

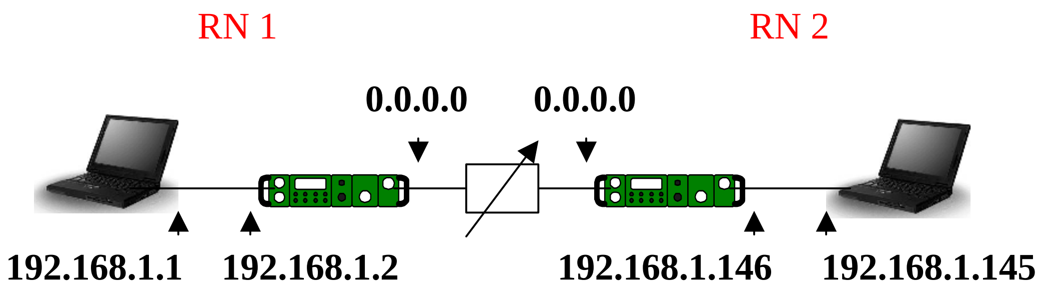


Figure 2 Radios in unconnected subnet using the IP bridging feature

Configuration Item	Item Location	RN 1 Setting	RN 2 Setting	Notes
Items configured on the PRC-117F				
Modulation	PGM/NORM/NET/ DATA_VOC	HPW	HPW	
Enable TCPIP	PGM/NORM/NET/ DATA_VOC	YES	YES	
Radio Wireless IP Address	PGM/NORM/NET/ DATA_VOC	000.000.000.000	000.000.000.000	1
Radio Subnet Mask	PGM/NORM/NET/ DATA_VOC	255.255.255.0	255.255.255.0	
Default Gateway	PGM/NORM/NET/ DATA_VOC	000.000.000.000	000.000.000.000	2
IP Address	PGM/PORTS/PPP	192.168.1.2	192.168.1.146	3
Peer IP Address	PGM/PORTS/PPP	192.168.1.1	192.168.1.145	
Data Rate	PGM/PORTS/PPP	115K	115K	4
Items configured on the Windows computer				
IP Address	Harris Radio Driver/ Properties/Networking Tab/Internet Protocol (TCP/IP)/Properties	192.168.1.1	192.168.1.145	5
Maximum speed (bps)	Harris Radio Driver/ Properties/General Tab/Configure button	115200	115200	4, 5

Table 1 – Sample configurations for standalone subnet

Notes

1 – A setting of 000.000.000.000 for this parameter means "Bridge to the PPP peer". The wireless IP address and the PPP peer address are the same.

2 – A setting of 000.000.000.000 for this parameter means "Do not use a default gateway".

3 – When the radio is configured for "Bridging" (see Note 1), this address is only 'pingable' from the PPP peer direction. Bridging causes this address to be transparent to other radio nodes.

4 – The rate settings are not required to be set to 115,200 bps. They *are* required to match. This speed sets the communication rate between the peer and the radio. It does not necessary reflect the throughput of the radio link/network.

5 – A detailed description of configuring a Windows PC for use with the PRC-117F is available in a separate application note.

Table 1 Radio configuration for the unconnected subnet in Figure 2

5 INITIAL LESSONS LEARNED

We here list some of the experiences that we made during the configuration and initial tests of the simple network. Some of them are answers from Harris to questions that we asked.

It is not possible to establish a Telnet connection from the PC to the radio, as for the RF-5800H HF radio.

No GPS synchronization of the radios is needed, but it is important that the radios are synchronized to within 30 seconds. If they are more than 30 s off from each other, we experienced that Plain Text (PT) would work, but not Cipher Text (CT).

Harris provided us with information of the buffer organization. The buffer size for IP packets is 5 x 1500 bytes for large messages and 15 x 80 bytes for small messages. We do not know the definition of a “small” and a “large” message. In the course of our tests, this buffer size turned out to be rather small.

Our task was to test the XOmail using IP over the LOS HPW. We made an attempt at installing the WMT-HPW (Wireless Messaging Terminal) which is the Harris proprietary e-mail application, but experienced a problem when the WMT was establishing a connection to the radio. This problem remained unresolved, but we believe the problem was entirely due to some mismatched parameters in our set up.

Harris recommended to use the AUTO data rate. However, if the channel conditions are known to be poor, choosing a low data rate could be more productive, according to Harris. Our experience is that the AUTO data rate quickly adapts to the prevailing channel conditions, but we have made no direct comparison with selecting a fixed low data rate.

6 RESULTS

In the following we have investigated a few aspects of the messaging application over the IP LOS mode of the AN/PRC-117F.

6.1 Pinging

We first tested the IP connectivity of the radio by pinging peer-to-peer. We compared the performance of the two data rate settings AUTO and 64 kbit/s when changing the channel conditions from high to medium signal-to-noise ratio.

Figure 3 shows the ping traffic over-the-air for the 64 kbit/s data rate. For the good channel conditions (left) both the ping and ping return is transferred and acknowledged correctly at first attempt, whereas for the medium channel conditions (right) a retransmission of both the ping and ping return using another waveform is necessary.

Figure 4 shows the ping traffic over-the-air for the AUTO data rate. For the good channel conditions (left) the sequence of events are exactly the same as for the 64 kbit/s case, but for the medium channel conditions a lower rate waveform is immediately tried and no retransmission is needed. The throughput performance is thus better for the AUTO data rate.

In fixed data rate mode, only the retransmissions occur at a lower data rate, not the first attempt transmissions. True data rate adaptivity (radio is learning) is only achieved by setting the data rate to AUTO.

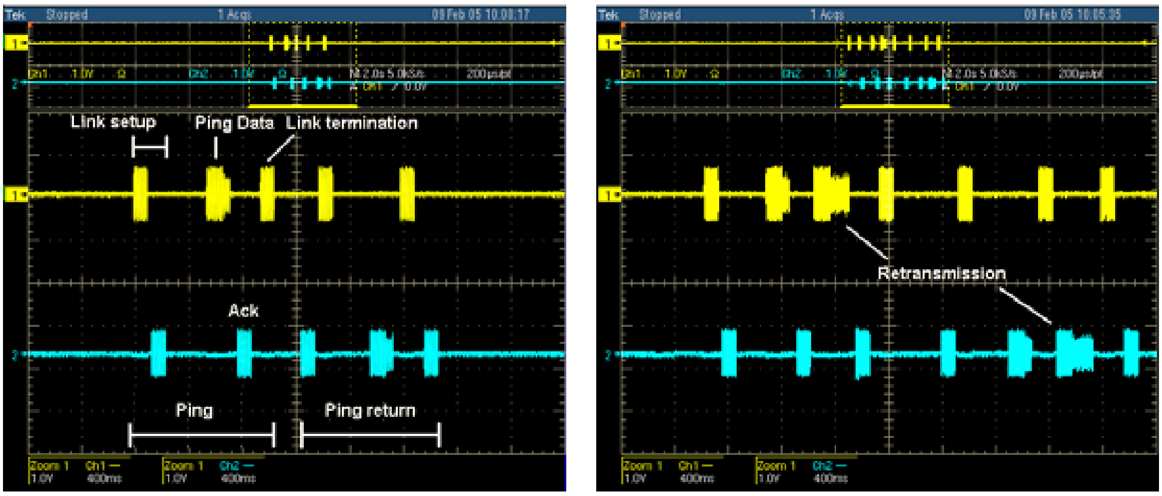


Figure 3 Traffic over-the-air when transmitting a single Ping with the data rate of the radio set to 64 kbit/s. Good channel conditions (left), medium channel conditions (right)

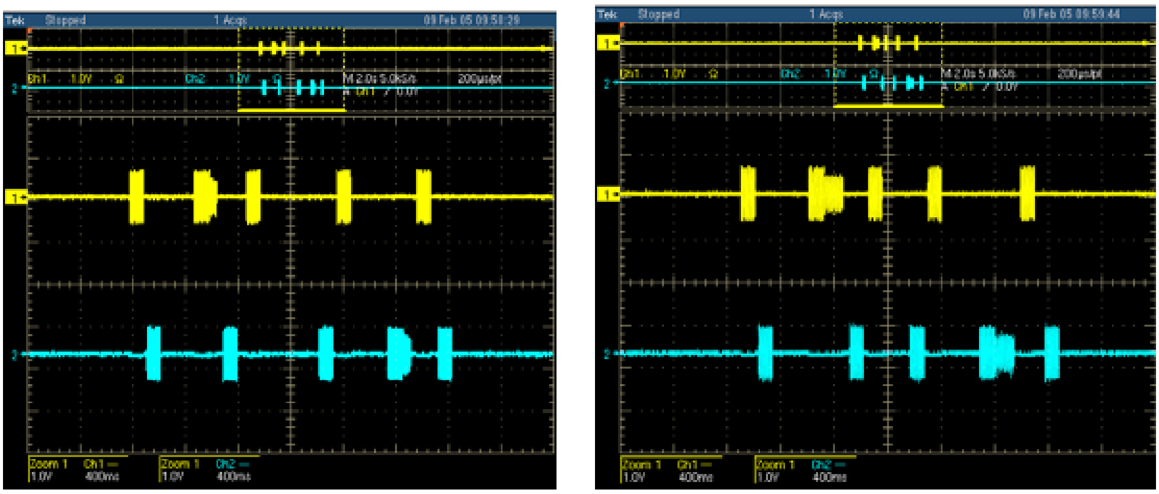


Figure 4 Traffic over-the-air when transmitting a single Ping with the data rate of the radio set to AUTO. Good channel conditions (left), medium channel conditions (right)

6.2 Offered load and maximum throughput

Our initial idea was that under ideal channel conditions, and a radio giving a maximum data rate of 64 kbit/s, the offered load (input data rate) to the radio should be of the same magnitude. The formula for calculating the input data rate is as follows:

$$Input\,data\,rate[bit/s] = \frac{(PDUsize + UDP/IP\,overhead)[bytes] \cdot 8\ [bits]}{PDUdelay[s]}$$

Knowing the buffer size of the radio, we assumed that a large, but smaller than 1500 bytes PDU-size, would give the most efficient transmissions. We also assumed based on our knowledge of the Harris HF radio, that a nearly full buffer also gives the most efficient data link transmission. Setting the PDU-size to 1024 bytes and the PDU-delay to 0.15 s, the input data rate would be 56 kbit/s (UDP/IP overhead is 28 bytes). Initial tests using this input data rate revealed that for message sizes exceeding the size of the radio buffer, Source Quench was rapidly sent from the radio, pausing the input traffic and reducing the measured throughput. So an optimisation task was to find the input data rate that gave the highest throughput of the data link protocol. For this purpose, we transmitted a 75 kbyte message from the MMHS server over an ideal channel using a PDU-size of 1024 bytes and varying the PDU-delay. *Data link* throughput was measured by reading off from an oscilloscope the time used for transferring a number of assemblies containing a number of PDU's. The maximum data link throughput was achieved at a PDU-delay of 0.5 s and measured to be 17.6 kbit/s. The maximum data link throughput for IP traffic is thus far below the maximum gross data rate that the AN/PRC-117F is able to support.

Assuming that sub-optimal channel conditions will be more realistic, the data packets waiting in the radio buffer will be served at a slower rate. We therefore increased the PDU-delay to 1 s for the rest of the tests (except the results given in section 6.3). The input data rate is then 8.5 kbit/s, far below the value that we initially tried.

We were surprised by the small radio buffer capacity of the AN/PRC-117F. With a larger buffer, the Source Quench problems would have been smaller.

6.3 Effects of the use of cipher text versus plain text

We examined the added overhead when cipher text mode (CT) was used in the radio instead of plain text (PT). When pinging and when transmitting a S4406 Annex E message with data rate AUTO set in the radio, the measured transfer time increased by approximately 20% when CT mode was used and the channel conditions were poor. The sequence of PDU's over the air when a 403 byte S4406 Annex E zipped file is transmitted, is shown in Figure 5 for PT and in Figure 6 for CT. The channel conditions were poor for these tests. The decrease in throughput for CT is evident also in Figure 7 for the message sizes 403 byte and 9300 byte, respectively. The other two message sizes were not compared. However, the measurements in Figure 7 were conducted under favourable channel conditions, and the decrease in throughput by using CT is less than for the poor channel conditions in Figure 5/6.

Figure 7 also shows the advantages in throughput when using the Annex E tactical protocol profile instead of the Annex-C strategic protocol profile. The throughput is increased by a factor of three for the two smallest file sizes, and by a factor of two for the largest file sizes. The advantage of the Annex E protocol over the Annex C protocol is considerable, although not as large as for HF. Note that the data points in Figure 7 shows application throughput when the PDU-delay is 0.5 s. This gives maximum throughput for ideal channel conditions as noted in the previous section, but the values shown in this figure cannot be directly compared with other figures of this report where we have used a PDU-delay of 1 s.

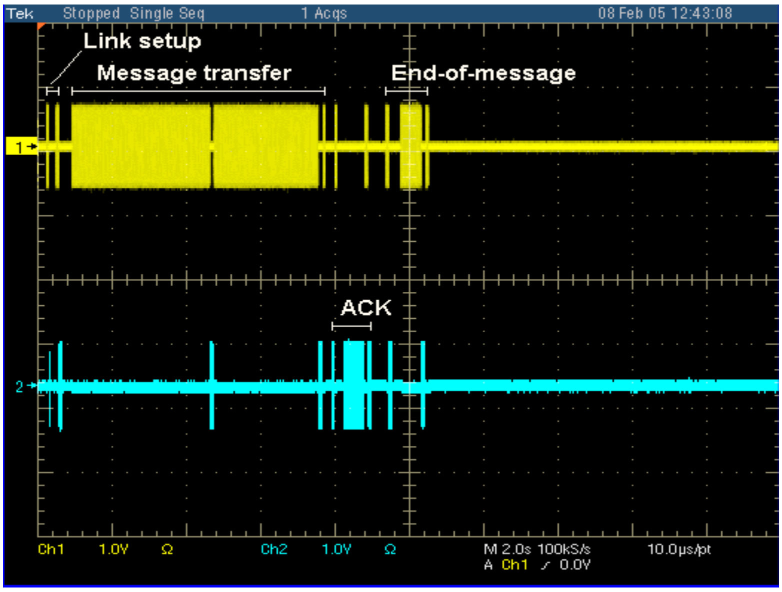


Figure 5 *Signalling over-the-air when transmitting a 403 byte MMHS message using the IP LOS mode of the AN/PRC-117F. PDU-delay 150 ms, Plain text, AUTO data rate, poor channel conditions*

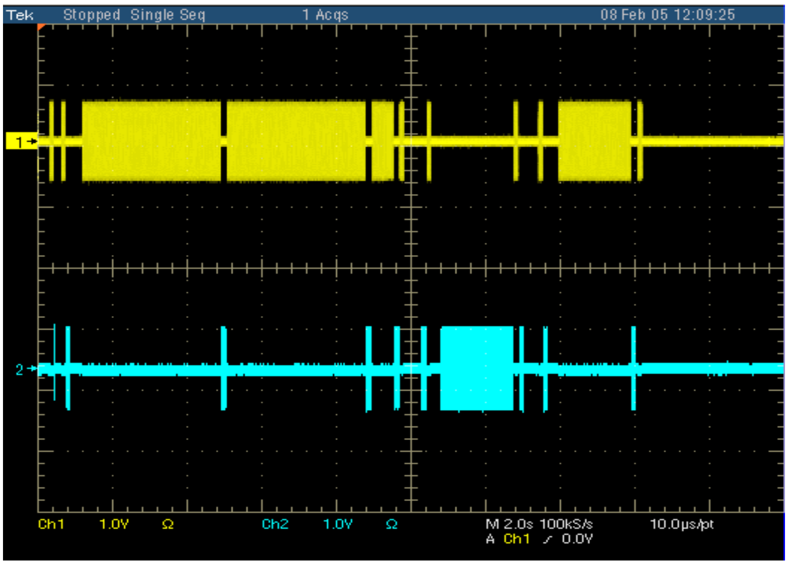


Figure 6 *Signalling over-the-air when transmitting a 403 byte MMHS message using the IP LOS mode of the AN/PRC-117F. PDU-delay 150 ms, Cipher text, AUTO data rate, poor channel conditions*

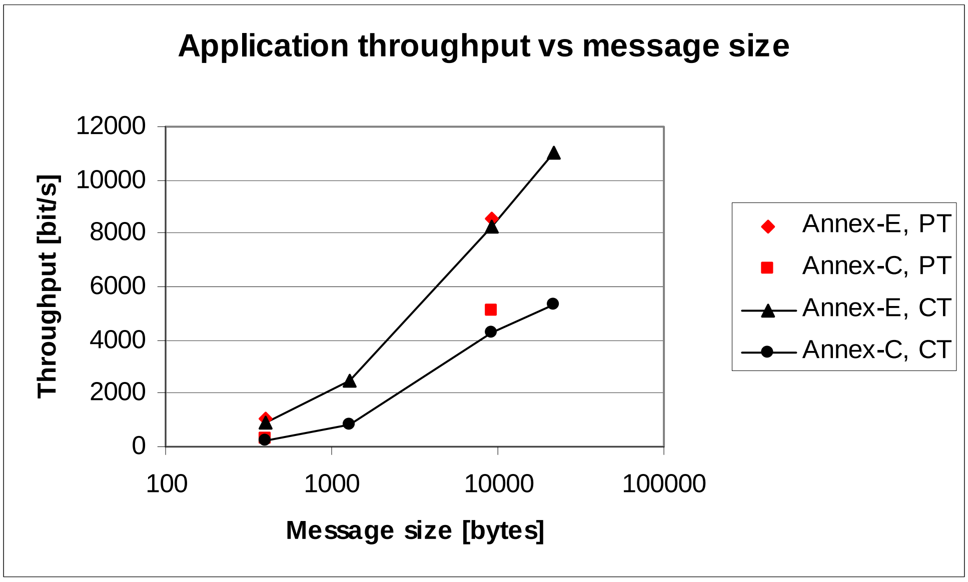


Figure 7 *Application throughput (unidirectional) versus message size for S4406 Annex C and E in plain and cipher text mode, respectively. Radio parameters: data rate AUTO, ARQ enabled. MMHS parameters: PDU-size 1024 byte, PDU- delay 0.5 s. Ideal channel.*

When setting the data rate to fixed 64 kbit/s, we encountered some difficulties using the PT mode. With high attenuation of the signal corresponding to bad channel conditions, the PT mode retransmits lost packets at the same data rate, refusing to decrease the data rate. This may be infinitely repeated. The CT mode however, retransmits lost packets at a lower data rate, increasing the probability of successful packet delivery. The CT mode is thus more robust than the PT mode to changing channel conditions when they are both operated at fixed 64 kbit/s. This results in higher throughput for the CT mode when channel conditions are poor.

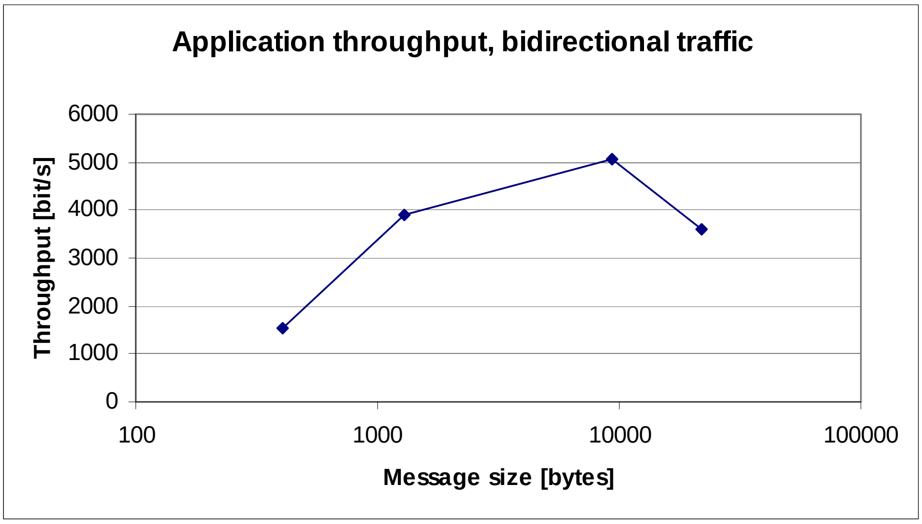
As the NATO approved crypto mode of the AN/PRC-117F is the most interesting mode for use by the Coastal Ranger Command, the following tests have been conducted only in the CT mode. Also, only the tactical profile of S4406 Annex E has been tested in the following.

6.4 Bidirectional throughput

Normally, applying traffic simultaneously in both directions of a link is a way to find out how well the data link protocol (including MAC) of the radio is able to share the channel resource between two competing traffic sources. Collisions will occur, but the data link protocol should be able to sort out the congestion by backoff mechanisms and retransmissions. This was assessed for the IDM/MBITR technology in (4). However, the MAC protocol of the AN/PRC-117F turned out to start with a link set up between the two nodes in our network, similar to the Fast Link Set Up protocol of the RF-5800H. The following data link protocol seems to be deterministic, even when traffic is applied in both directions, and collisions on the data link do not occur. With these types of protocols, testing a two-node network with bi-directional traffic is *not* representative of traffic from two nodes in a multi-node network. However, since we only had two radios, we nevertheless tested our two-node network by sending messages simultaneously in the two directions.

Four message sizes were tested under ideal channel conditions; 403 bytes, 1.3 kbyte, 9.3 kbyte and 22 kbyte. For the two smallest message sizes, all transmitted messages came through, and the throughput is larger than for the unidirectional case. The data link protocol thus provides efficient piggybacking of data PDU's and ACK PDU's. For the two largest message sizes, we experienced a mal-function of XOmail that has not been observed in our testing of the RF-5800H or the IDM/MBITR: Even if both the first and the last "critical" PDU of the message were received by the receiving P-Mul, an ACK/NACK was in some cases not released, and the message was not delivered. Thales Trondheim found the mal-function to occur in XOmail when the receiving P-Mul, that simultaneously was transmitting in this bi-directional traffic test, was in a Source Quench state. Bi-directional traffic was not tested in our HF-work, therefore this mal-function had not been discovered before. In XOmail version 11.3, this problem shall have been fixed.

The percentage of successful message transfers in the two directions is shown in the lower part of Figure 8. We have calculated the bi-directional application throughput by calculating the average throughput in each direction and adding the two numbers. Included in the average throughput numbers is the effect of lost messages, which means that the anticipated time of delivery of a lost message is included in the calculation, but not any bytes delivered during that time. This may lead to a slightly pessimistic estimate of throughput, since parts of the lost message may have been delivered during that time. The upper panel of Figur 8 shows the bi-directional throughput for the four message sizes. *Note that the low throughput for the two largest message sizes is not due to the performance of the link protocol, but to a mal-function of the XOmail application.*



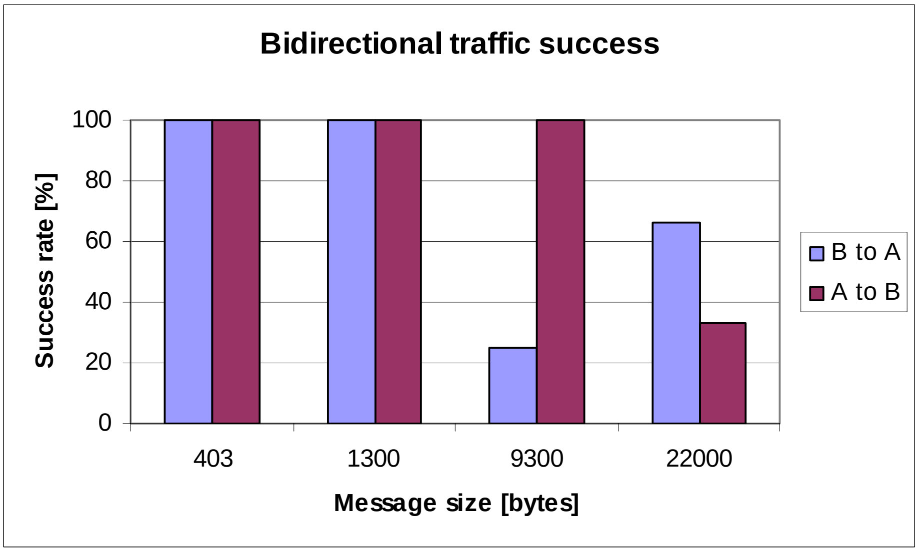


Figure 8 *Bidirectional total throughput including the effect of lost messages (upper panel). Success rate of transferred messages (lower panel). Radio parameters: data rate AUTO, ARQ enabled. MMHS parameters: PDU-size 1024 byte, PDU-delay 1 s.*

6.5 Throughput versus attenuation

The S4406 Annex E application using the AN/PRC-117F was also tested under non-optimal channel conditions. The received signal level was reduced by increasing the attenuation on the channel. Unfortunately, as explained in an earlier section, we were not able to calibrate the test setup, so the received signal levels cannot be given in dBm. Two P-Mul PDU-sizes were tested; 1024 bytes and 256 bytes. The offered load to the radio from the application was approximately the same for the two packet sizes since the PDU-delays were adjusted accordingly.

In Figure 9 we see that by using a PDU-size of 1024 bytes, the 22 kbyte message is transferred most efficiently as long as the channel is good enough. The application throughput for the 256 byte PDU-size is rather drastically reduced, and this can not be explained only by added overhead for an increased number of packets, but also to lower efficiency of the data link protocol for smaller data packets.

However, the smaller PDU-size is able to cope better with lower signal levels. Without knowing the characteristics of the HPW waveform, it is difficult to explain this phenomenon. Since the AUTO data rate is enabled in the radio, we see that the data rate is adjusted down when the attenuation reach 67 dB for both PDU sizes. It is not adjusted further down for the PDU-size 1024 test, but reduced another time for the PDU-size 256, at an attenuation of 70 dB. So the AUTO data rate mechanism in the AN/PRC-117F does not go through the whole range of available data rates, only a small subset of them. It was particularly amazing that the data rate was only adjusted once for the messages of PDU-size 1024 bytes, before the radio is giving up.

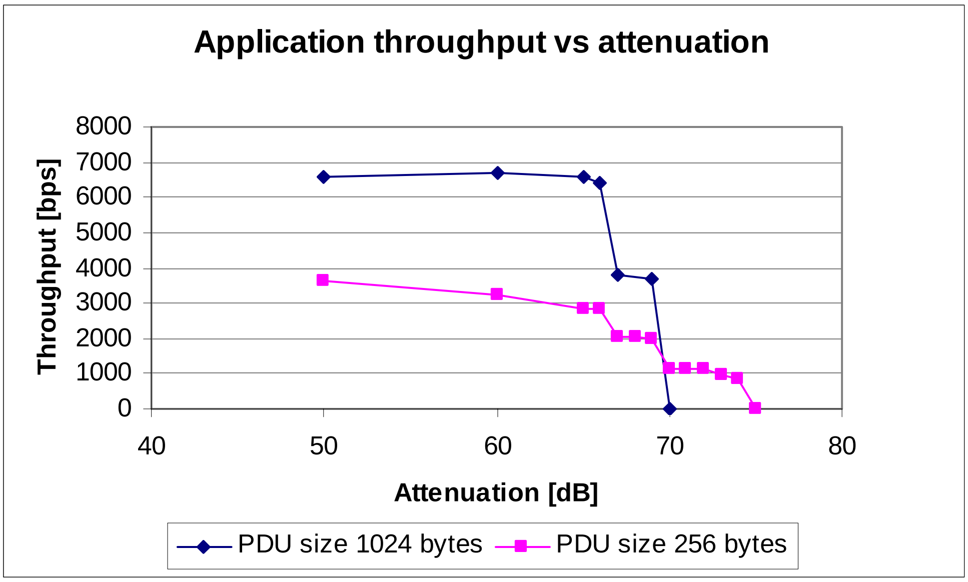


Figure 9 *Application throughput versus attenuation for different PDU-sizes. Message transmitted: 22 kbyte. Radio parameters: data rate AUTO, ARQ enabled. MMHS parameters: For PDU-size 1024 byte, the PDU-delay is 1 s. For PDU-size 256 byte, the PDU-delay is 0.25 s*

6.6 Effects of the use of a non-ARQ data link protocol

As the use of the ARQ protocol is optional in the IP LOS mode of the AN/PRC-117F, we investigated the effect of not using it. A non-ARQ data link protocol provides no feedback to the transmitter for adjusting the data rate, so that a fixed data rate has to be selected. For real channels, a wise choice would be a medium data rate, for instance 16 kbit/s as tested here. 64 kbit/s would have a high probability of failing if the channel deteriorates. We used only the 22 kbyte message for these tests.

First, we selected the following parameters: ARQ disabled, 64 kbit/s, ideal channel conditions, PDU-size 1024 byte, PDU-delay 1 s. The resulting throughput of 6500 bit/s is marked in

Figure 10 as a single point. Comparing it with the blue curve in Figure 9 for the same attenuation, we see that the throughput using the non-ARQ protocol is approximately the same as when the ARQ protocol is used.

Another test was made keeping the same parameters as above, except for the PDU-size that was changed to 256 byte and the PDU-delay to 0.25 s (same offered load to the radio). The throughput for this test was a little more than half that of the test above. Comparing it with the PDU-size 256 byte curve for small attenuation values in Figure 9, the throughput of 3800 bit/s is approximately the same. So for good channel conditions, the non-ARQ protocol seems to be just as efficient as the ARQ protocol.

With a lower data rate of the radio; 16 kbit/s versus 64 kbit/s or AUTO used in earlier tests, and a limited buffer capacity, Source Quenching will occur earlier. Source Quench explains the lower throughput for the attenuations of 55 dB and 67 dB in Figure 10. We do not know why Source Quench does not occur for the neighbouring values.

Transfer of messages with the selected PDU-size (1024 bytes) and 16 kbit/s data rate using the non-ARQ link protocol is possible up to an attenuation of 74 dB. This value of attenuation is the same as the largest attenuation still providing message transfer in Figure 9, indicating that 16 kbit/s is the lowest data rate that the AUTO mechanism will adapt to.

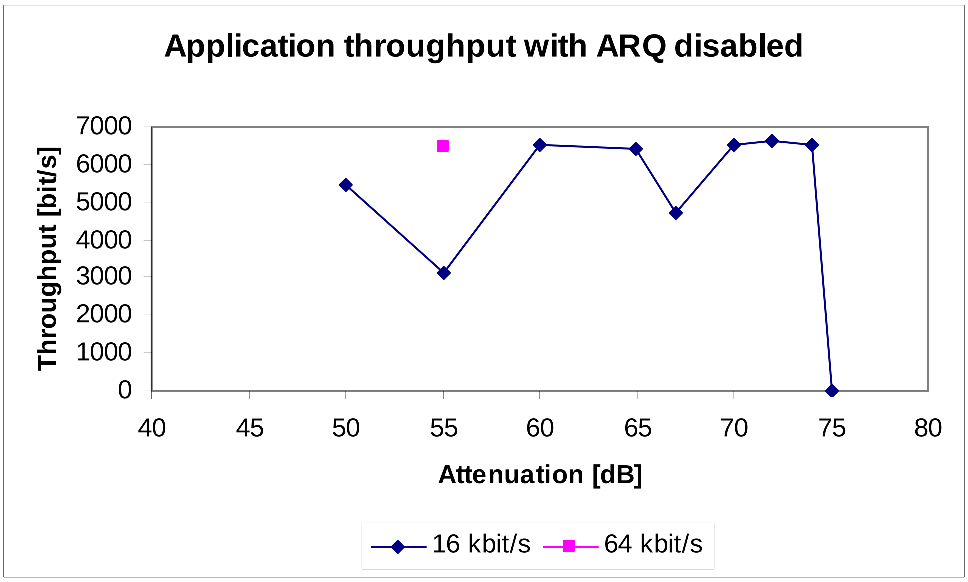


Figure 10 *Application throughput for a 22 kbyte message using the non-ARQ data link protocol. MMHS parameters: PDU-size 1024 bytes, PDU-delay 1 s.*

7 CONCLUSIONS

We have made some initial lab testing of the Thales XOmail implementation of STANAG 4406 using the IP LOS mode of the AN/PRC 117F from Harris as the bearer service.

Transmitting STANAG 4406 Annex E messages using IP over the AN/PRC 117F is feasible with a maximum *data link* throughput of 17 kbit/s for a 75 kbyte message over an ideal channel. This was achieved with optimum offered load to the radio. Application throughput is somewhat less. Taking account of non-optimal channel conditions the offered load was reduced, and a maximum application throughput of 6.5 kbit/s was then achieved for good channels.

This throughput is higher than that achieved with the Harris RF-5800H HF radio (1) and the Thales MBITR radio (4). However, the throughput is lower than expected from knowledge of the maximum gross data rate capability of the radio; 64 kbit/s. The relatively low application throughput achievable is due to the small buffer size of the radio. If the message to be transmitted is larger than the size of the buffer, we experience frequent Source Quenching with a corresponding retransmission, which reduces the throughput efficiency. To achieve the maximum application throughput we tuned the PDU-delay parameter of XOmail to obtain a small probability of Source Quenching, whilst still keeping the radio buffer relatively full. Varying channel conditions will disturb the optimum value of the PDU-delay parameter.

The AUTO data rate of the radio is most efficient over variable channels, but is not adaptive over the whole range of available data rates.

Time and equipment did not permit testing more than two nodes in a network. This type of testing would have explored the MAC and data link capabilities of the radio further. Also, the data analysis was conducted after the radios had been delivered back to the owners, this was not an ideal situation since the analysis revealed things that should have been done differently.

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