SOME GENERAL DELIBERATIONS AND LESSONS LEARNED

ON STANDARDS CONFORMANCE

AND INTEROPERABILITY

Oddbjørn Strømsnes
Freelance Communication Systems Specialist
Eidsvågveien 130
N-5105 Eidsvåg i Åsane
Norway
o-stroms@online.no

SUMMARY

Please note that this is not a scientific paper, but more an article on observations, deliberations and lessons learned through more than 25 years in design of maritime communication systems. The examples and issues discussed are not limited to HF alone, as that would not provide a sufficient variety of incidents. It starts off with deliberating on some standards conformance and interoperability issues that happened more than 20 years ago. Next follows some more recent experiences. Then testing standard conformance and interoperability is briefly discussed. The general form, as opposed to providing detailed results, is chosen in order to avoid revealing any particular equipment, vendors and even testing institutions. The paper emphasises some lessons learned and concludes with some recommendations.

1 INTRODUCTION

Most of the communication equipment manufacturers refer to some standards when advertising and promoting their equipment. Standards may be FED STDS, MIL STDS and (NATO) STANAGS. During the years these standards have become increasingly more complex, and it is not given that the different manufacturers understand the standards in the same way. Additionally it is not given that they fulfil the standards even if they have interpreted them correctly. This may lead to problems when communicating with equipment from other vendors.

That being said, it is even not always given that an approved standard is the optimum standard for the purpose. Standards are produced in committees constituted of experts, and the product is an agreed draft, which inherently is carrying the features of some compromises. Drafts are distributed to agencies or nations for ratification, and the final result may be an even more "watered down" standard. This is the real world where financial and political interests are the governing factors. However, once a standard is adopted and in force, that should be the yardstick to adhere to- at least. The add-on "at least" is indicating that equipment exhibiting better performance than the said standard will provide better communications results.

Therefore, in order to determine whether the different industrial implementations of new equipment actually is, at least, fulfilling the said standards, and further be confident that this particular equipment will inter-operate properly with somebody else's equipment, testing at government authorised testing institutions may be advisable.

Before this is discussed further some real life experiences on interoperability are provided.

2 TWO EXAMPLES FROM ANCIENT TIMES

More than 20 years ago encrypted voice was introduced at UHF. At the same time tactical data exchange was introduced at HF and UHF. Both introductions entailed some problems.

2.1 INTRODUCTION OF ENCRYPTED VOICE AT UHF

The frequency band in question ranges from some 225 MHz to some 400 MHz. The UHF radio standard in force prescribed channels of 25 KHz bandwidth. This provided 7000 dial-up channels to the users. Until the "secure voice" box came along (in fact a vocoder, a crypto and a radio-modem in one unit) the standard operating procedure at the time was AM DSB modulation with plain analogue voice. This required only a fraction of the channel bandwidth of 25 KHz, and interoperability among the navies was pretty well established at that point in time.

Now comes the splendid new additional equipment, built according to its specific approved standard, and is inserted between the existing microphone and the radio in the present systems. It worked well in most of cases, in fact some times even better intelligibility and longer communication ranges were experienced. But, in some nations this newcomer gave reason to heavy concern. Operating ranges dropped, in some cases drastically, and/or the intelligibility turned out very low. In other words, they were no longer interoperable with the rest of us.

Since there was no other changes performed on the platforms, this incident could not be attributed to EMC problems that could be due to simultaneous introduction of some other new equipment like radar (which tends to disturb UHF), or adding more UHF radios on-to the platform. It turned out after long investigations that in the difficult cases the UHF radios were "to good". The vendors had, in their own opinion, done their utmost to design the radio to suit multi radio installations, may be 10-20 radios, as is common on naval units. In this effort to provide the user with the maximum number of usable channels, the 25 kHz bandwidth filters were extremely sharp and with very high attenuation at the flanks. This was at no harm for the analogue voice operation, but it killed a too large portion of the spectrum of the vocoder signal, which was cvsd modulated at a rate of 16 kbs (kilo bits per second).

The technical explanation is trivial. The interesting feature is that this was a matter of lack of interoperability, as some participants could not communicate with the rest of us. It became clear that interoperability is not so much a question of "go" or "no-go", but in general a matter of degraded performance in terms of communication range and/or intelligibility, or in other instances BER (bit error rate) or lost blocks of transmissions. Furthermore it is interesting to note that the radio manufacturers rejected to rectify the situation, as they claimed to be well within the requirements of the standard. This situation prevailed for many years and did cost a lot to rectify.

The following is added for readers having special interest in the system engineering aspect:

With the eyes of a system engineer this expensive effort of making the "best" radio in this case was waste of time and money. This is because one in such multi-installations is forced to use multi couplers with cavity filters. A good multicoupler provides a 3-dB bandwidth of about 1- % of the operating frequency. At frequencies between 225 MHz to 400 MHz such cavity filters thus provide usable minimum channel spacing of 2,25 to 4 MHz. An extreme good multicoupler would provide a 3-dB bandwidth of about 0.5% of the operating frequency corresponding to a channel spacing some 1-2 MHz. Hence, in a multi UHF installation one operating channel will occupy the frequency space of 40-80 25 channels of 25 kHz bandwidth. Only in the case of single equipment installations the 7000 channels could be utilised. In that case however, such sharp filters are not necessary. It gets still stranger if one would take into consideration that out of the 7000 channels that such a radio can be tuned to, only some 429 frequencies are available for maritime use, and they are not co-located in anyway.

2.2 INTRODUCTION OF TACTICAL DATA EXCHANGE AT HF AND UHF

This is a similar case, but not quite equal. For years and years HF communications had been applying AM SSB analogue voice in 3 kHz bandwidth at USB. In addition Teletype traffic was in common use applying FSK modulation at 75 Baud at USB. The existing standard for HF radios was well known and in force. Suddenly a new "tactical data-link modem" appears, today it is called a Data Terminal Set (DTS).

This DTS was built according to its specific and approved standard. At first any attempt to hook the DTS on to a HF radio resulted in shorter ranges, erroneous data messages or lost transmissions. Studying the data exchange standard revealed that it contained a lot of information on protocols and the construction of data messages. Somewhere hidden in the 50-60 pages was only half a page on requirements to the HF and UHF radio. This half page revealed that the "tactical data community" simply required a yet unknown performance of the HF radios.

The technical explanation is trivial. The lesson learned, again, is that interoperability is a matter of being more or less interoperable, in terms of communication range and successful transmissions, and that it took years and years to rectify the situation.

The following is added for readers having special interest in the system engineering aspect:

This hidden page revealed that the response of the 3kHz audio filter had to be extremely good in order to support the transmission of some 16 parallel tones. It also was required that the radios operated in Independent Side Band (ISB) mode as opposed to USB, and in addition the "receive to transmit times" of the radio had to be very short. This is to say that the time from being at zero level transmitting power in the receiving mode to reaching a level of 90% output power in transmitting mode was set very short. This was necessary in order to be able to transmit all the bits of a signal of standardised length within a given time slot. The years to come revealed that any attempts to "fiddle" with these stringent requirements to the radio had painful consequences. In fact special mobile test units were established to certify participating units before exercises took place.

In the case of UHF there is nothing more to report than that suddenly FM was the transmission mode for the tactical data exchange traffic. Another trick played by "tactical data community".

2.3 CONCLUSIONS FROM THE EXAMPLES

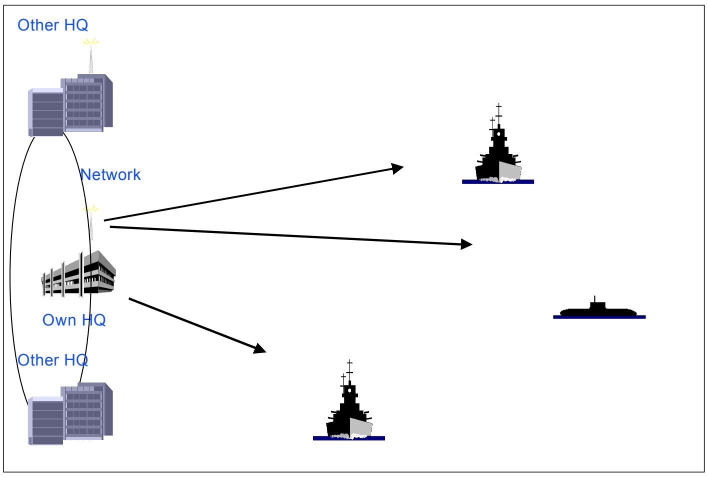
The different equipment in a functional radio circuit is defined by its specific standards. It is not always given that the standards are "matching" and degradation of the radio circuit is the result. If that degradation is severe it becomes a matter of interoperability. In order to produce properly working systems it is important that the requirements and limitations of the applied standards are understood. That being the case it becomes inevitable that the standards conformance of the respective equipment to be procured is known. It is sad to experience that many procurement organisations are dealing with standards as a sort of reference stamp, and do not care for understanding the standards nor do they really check that the equipment supplier is fulfilling the standard. This may cause degraded performance that in severe cases constitutes interoperability problems, additional cost and delay of providing the intended communication service.

3 ONE EXAMPLE FROM RECENT TIMES

Some 3-4 years ago the introduction of serial tone PSK modems started, and quite in line with earlier introductions of new equipment, some problems arose.

3.1 INTRODUCTION OF SERIAL TONE PSK MODEMS

It all started with carefully planned trials in steps and at very low ambition levels. (The author emphasises that one should distinguish between tests and trials. Tests are performed in laboratories under reproducible conditions. Trials are putting the traffic on the air and hope for the best.) In this case ships from different navies were tasked to receive the naval broadcast from different transmitting sites. The units had got new PSK modems that were produced by different manufacturers. The transmitting sites also had got different types of modems. The first step was to read own transmitting sites.

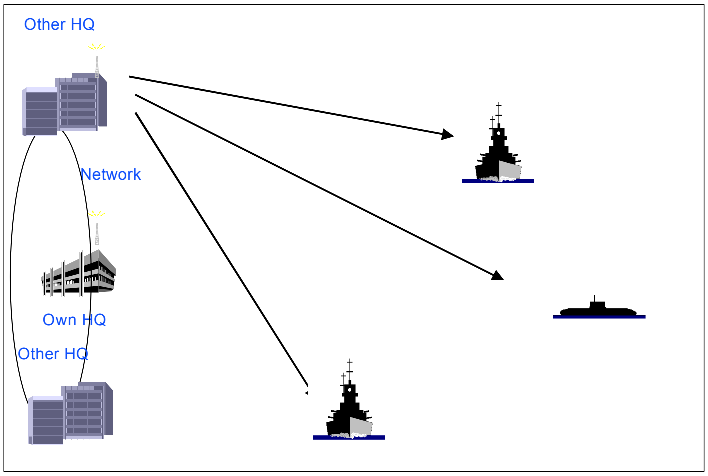


Low ambition levels is to say that:

- only one PSK waveform should be tried out
- the ships were only receiving (not transmitting)
- traffic was only messages traffic (teleprinter traffic)
- only at the low data-rate of 75 bps was applied, which was the current data-rate for the as yet standardised FSK transmissions.

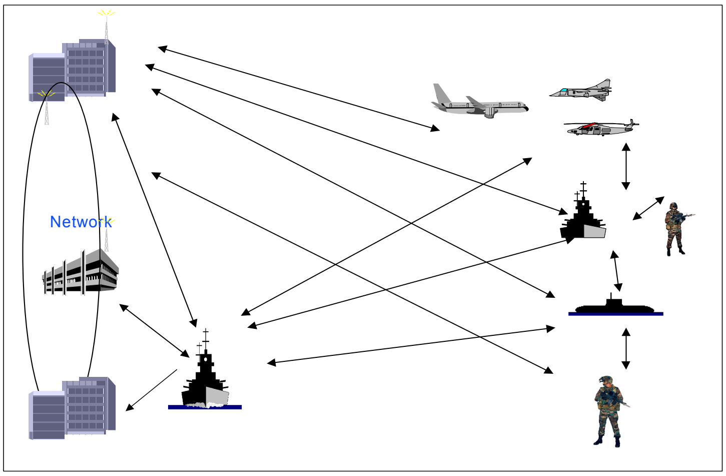
The first results indicated that our units could read our transmitters very good, but the reception degraded after some time in terms of increasing character error rates. (The teleprinter reads characters. Of course this was a sign of increasing bit error rates). This increasing degradation was an unpleasant surprise of course, but we quickly found that the reason was that the modem clock and the crypto clock drifted apart over time. Stunning news, as the established FSK transmissions hitherto did not require any synchronism of the clocks. Modifying the modems such that synchronism was maintained over time rectified the situation. The incident was reported to the other participating nations.

The next step was to receive a number of foreign transmitting stations.



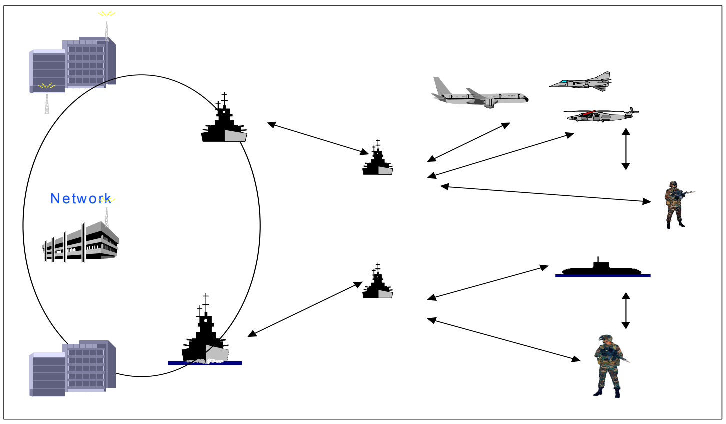
The results were that some stations were received excellently and others not at all. The same was reported from other participants. This first trial was definitely not a success. Some time elapsed until we learned that some other modems were "oppositely wired".

In other words, the lesson learned is that whatever the problems were, the industrial implementations of that very standard were not equal.



This gave reason to concern, because the real scenario in the years to come would be receiving and transmitting from and to all kinds of platforms and stations. These stations and platforms would have a multitude of different makes of equipment.

Moreover the data-rates would over the next few years increase to 300 bps and further on to 9600 bps and above.



And in the not too distant future ALE, ARQ and networking would be introduced. The old warning bell from ancient times was ringing, and it became apparent that it was time to carry out some investigations about modern testing and certification of modems and radio equipment.

The first step was to address this issue to the relevant industry in connection with announcing possible new invitations for bids.

3.2 REACTIONS ON REQUIREMENT FOR CERTIFICATES

An announcement on possible invitations for bids on new radios and modems made it clear that:

- Any offered equipment should hold standards conformance and interoperability certifications issued from a government-authorised institution.

- Or, if that could not be provided because the equipment might be under development, the vendor should agree that any contracted equipment not having the standards conformance and interoperability certification, should be subjected to such testing before delivery.

The responses varied from negative through neutral to positive. On the negative side comments like “Don’t you trust us?” or “ We don’t see any need for this, our equipment is sold all over the world and nothing is wrong with it”. In some cases quite high cost was quoted in association to the certification. On the positive side the comments were more like “We have no objections” or “We are accustomed to such procedures”. It is worth noting that the positive responses came from American (US) industry as opposed to European industry. Later it became known to us that DoD in USA requires such certifications prior to fielding the systems.

Lesson learned is that this was not at all popular in certain industries.

4 SOME EXPERIENCES WITH TESTING INSTITUTIONS

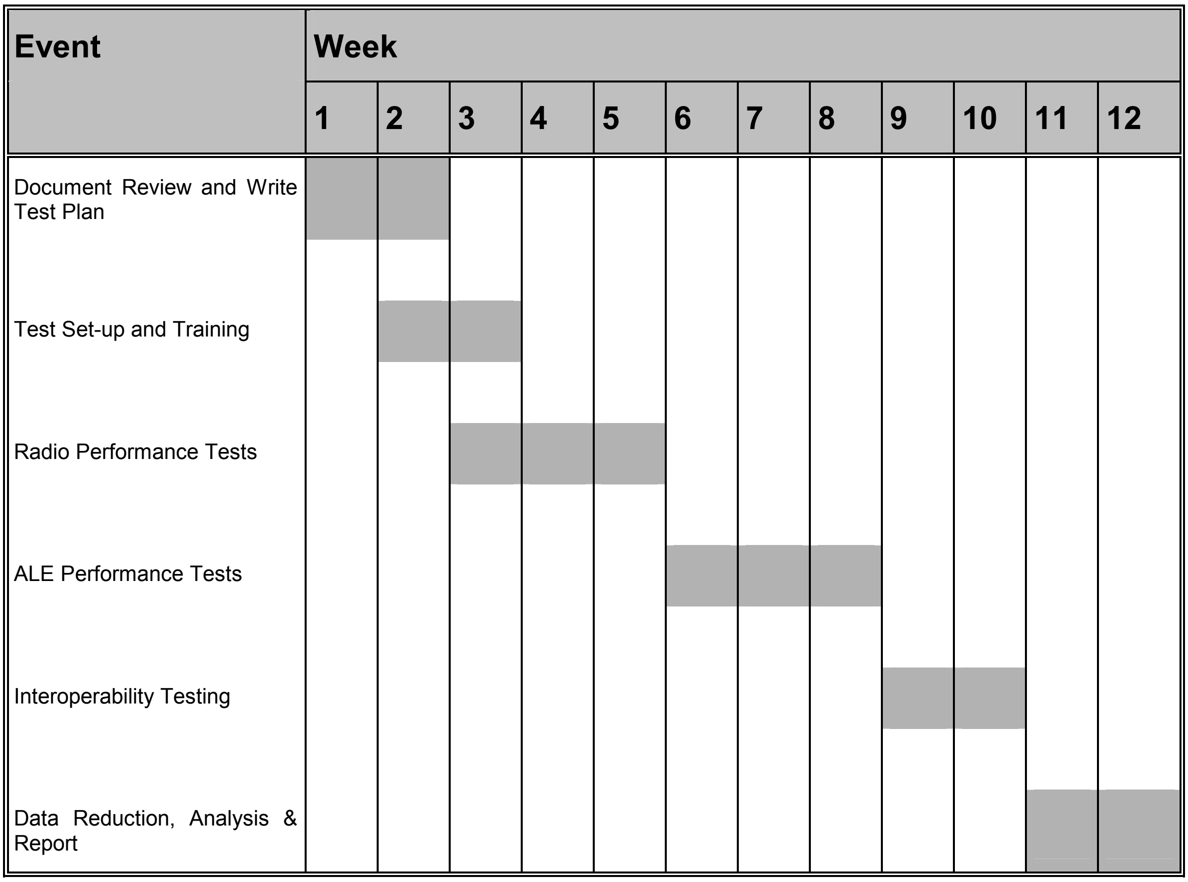
The first question when visiting an institution might be. “Whom do you want to inter-operate with?” If you had the intention of saying “everybody”, they would probable smile discretely and explain that this can not be guaranteed.

In the following typical testing schedules, payment conditions, documentation obtained after testing, standards conformance testing procedures and interoperability testing procedures will be discussed briefly.

4.1 TESTING SCHEDULE AND PAYMENT CONDITIONS.

Testing a radio or a modem might as an example have duration of some 12 weeks. This is meant to be effective weeks i.e. if there are any stops underway due to malfunctioning of the equipment under test it can be agreed that the testing institution diverts to some other activities. So the “money clock “is not running for that interval. If the tests are to be paid by some customer/agency/institution that may be wanting to test some equipment under procurement before accepting it, arrangements should be made with the equipment vendor that any costs occurring after, say 12 effective weeks are elapsed, should be borne by the vendor.

The figure below depicts the activities of a general test schedule for a radio.



A test schedule

However, the normal procedure should be that the vendor subjects the new equipment for testing prior to advertising and promoting sales. That is to say that the vendor has covered all the testing expenses. It is somewhat annoying to experience that those vendors not subjecting their equipment for testing sometimes are the winners of the game. This is because they can sell at lower prices not having the expenses of the testing effort including the expenses of shaping up their equipment in order to conform to the standards.

Lesson learned is that many companies have spent months (not weeks) to get things straightened out in order to comply with the standards and achieve demonstrated interoperability. These companies deserve admiration as opposed to those trying to avoid testing. However procurement organisations tend to buy the cheapest equipment.

4.2 TESTING DOCUMENTATION TO BE OBTAINED

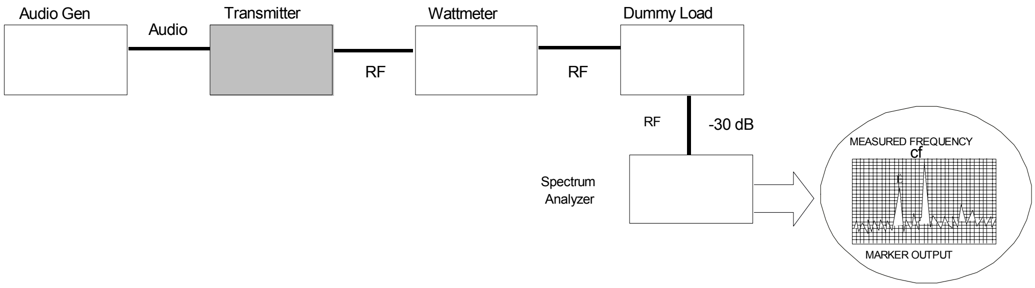
The institution may provide some kind of a Conformance Certification Document. This might be a document that is stating conformance to the specified standard or standards. In an appendix (Conformance Certification Testing Summary) any details and impacts on possible "not met" sub-tests are discussed. If there is an interest in learning how well all the sub-tests were met a complete Interoperability and Performance Test Report is required.

In general these documents are provided to the vendor only if he is undertaking the testing effort on his own expenses. On the other hand, if any customer/agency/institution is paying the effort these documents they will get the documents. Experience has shown that in general the vendors do not like to provide any customer of the full report. This can be a drawback for system design where any parameter may be of interest. It should be noted that the brochures and sales promoting documentation in general refers to the vendors own testing results.

4.3 STANDARDS CONFORMANCE TESTING

Standards conformance testing firstly takes care of all the "trivial aspects" like human safety, grounding, connectors and pins, polarities and interfaces in general. This concerns radios as well as modems.

The figure below depicts the test set-up for testing a transmitter.



In this context however the more "elevated aspects" are of interest. That is to say that with respect to radios: ALE performance is checked against spec, ECCM performance against spec, and the "legacy aspects" such as filter response, intermodulation and so on against spec.

It is interesting to note that some of the testing institutions in different countries are working according to the same agreed procedures. These are called ITOP (International Test Operations Procedures) and signed by France, Germany and USA. For radio testing two ITOP procedures are available:

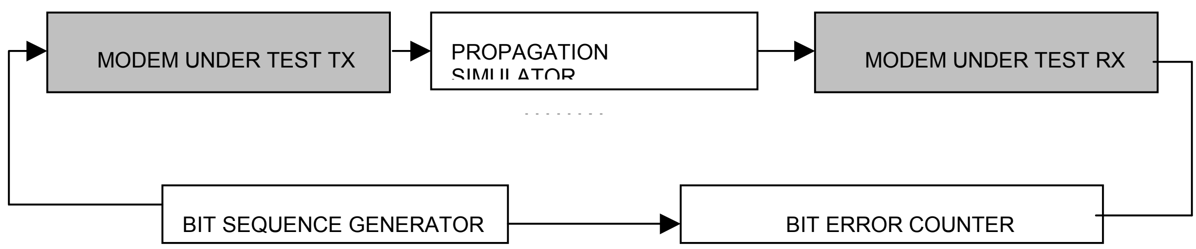
- Analogue Communication Transmitter and Receiver Test Procedures (ITOP) 2 July 1993.
- Digital Communication Transmitter and Receiver Test Procedures (ITOP) 12 October 1995.

Albeit these convincing agreed test procedures it may happen that a vendor questions the measured results, and provides more favourable readings from own testing. In such an event the explanation might be that the vendor is applying an automatic communications tester device. If that device is set up and works as a ordinary receiver, i.e as an example is carefully mixing down, and demodulating the output of a transmitter under test, it is no wonder that the readings of transmitter inband intermodulation are very good. However this is not measuring the transmitted signal on the air.

Lesson learned is that measurements performed by the vendors own test lab may not always be trusted i.e. the performance that is advertised is questionable.

Now turning to modems testing.

The figure depicts a test set up for some of the tests listed below.



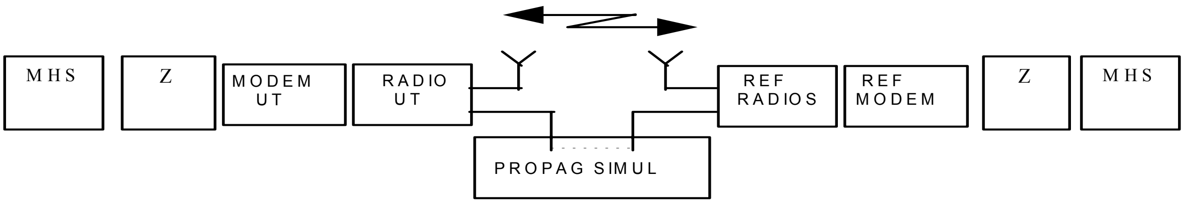
Aside from testing that the modem and the associated cipher equipment are running in synchronism, the following parameters are of relevance.

- The waveform(s): Checking the source codes.
- Demodulator receiving performance- signal sensitivity: Testing the signal sensitivity for a given BER under specified propagation conditions. (Some standards do not specify any signal sensitivity requirement. This is very unfortunate).
- Demodulator receiving performance- synchronisation on data. Testing the maximum time to acquire modem synchronisation on received data.
- Demodulator receiving performance- interference rejection. Testing the SIR (Signal to Interference Ratio) performance vs BER.
- Demodulator receiving performance- frequency offset tolerance. Testing the modem's tolerance to frequency errors due to the combined effects of the tolerances of the frequency standards in the transmitter and the receiver and any Doppler shifts caused by ionospheric and/or platform movements.
- Modulator transmitting performance (transmitted BER). Testing the "purity" in terms of BER of the signal produced by the modulator.

4.4 INTEROPERABILITY TESTING

Interoperability testing is concerned with testing the performance of complete radio circuits or links. This paper is only concerned with the testing of radios and modems. But it is emphasised that in order to obtain proper performance and interoperability of a total communication circuit; all the individual equipment should be tested for standards conformance and interoperability.

The figure below depicts the total set-up for a message communication circuit.



MHS= Message Handling System.

Z= Cipher Unit.

MODEM UT= Modem under test.

RADIO UT= Radio under test

PROPAG SIMULATOR= Propagation simulator

REF RADIOS= Reference radios

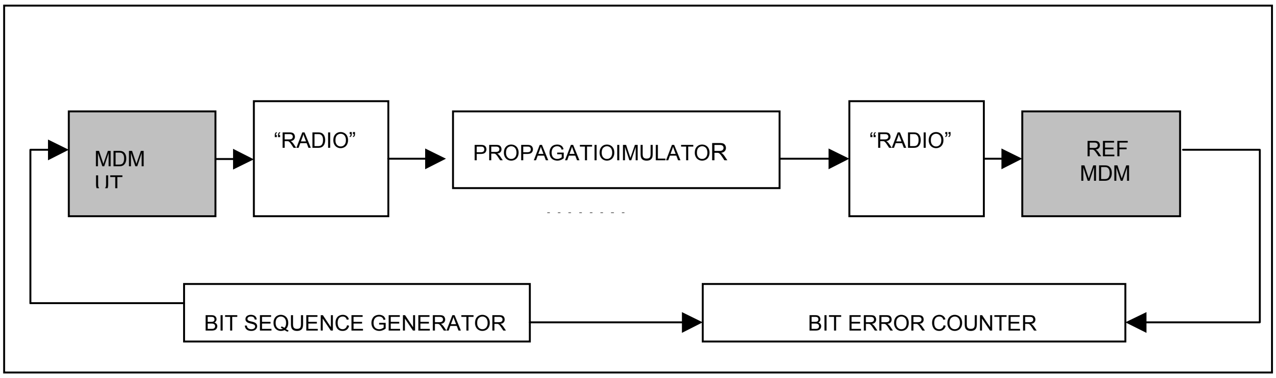
REF MODEM= Reference modems

This would be the final set-up after individual testing of the following parts in the chain:

- Interoperability testing of the Message Handling System (MHS) on its own. Such a test would require in some specific test set-up where Message Handling System Under Test (MHS UT) is tested against a number of Reference Message Handling Systems.

- Interoperability testing of the Cipher unit on its own. Such a test would require some specific test set-up where Cipher unit Under Test (Z UT) is tested against a number of Reference Cipher Units.

This article is only concerned with interoperability of modem and radios. The figure below depicts the test set up for interoperability testing of modems.



The modem under test (MDM UT) is tested against a number of reference modems (REF MDM) at different data rates and interleaver settings. The propagation simulator is set to various standardised propagation conditions. Any increase in measured BER would indicate "lower interoperability" between the two modems, or it might be that the radios are not "matching" the modems. The experience from ancient times is showing up again.

The interoperability testing of radios is done in a similar manner. Finally, over-the air testing to other networks in operation is carried out. Radios are operated in ALE and ECCM modes, and the modems are switched to various waveforms and datarates. It may take some years until real life networks are fitted with high datarate waveforms and high datarate compatible radios, and interoperability at high rates can be tested.

Lesson learned is that presently there are not sufficient numbers of reference modems available that have incorporated all the new waveforms. Also high datarate compatible reference radios are not at hand.

Therefore interoperability at high datarates is an issue. This concerns the modems as well as the radios.

Similar test set up is required for testing tactical a data exchange circuit. The difference being that Data Terminal Set (DTS) and a REF DTS are replacing the MHS and the REF MHS. In this case number of lost data messages are counted.

In the case of testing a digital voice circuit a Voice Digitizer Unit and a REF Voice Digitizer Unit have to be inserted.

4.5 CONCLUSIONS ON CONFORMANCE AND INTEROPERABILITY TESTING

Standards conformance and interoperability testing is a large effort. It is tedious and time and cost consuming. Despite these negative aspects such testing may be a considerable time and money saver and a safeguard to prevent degraded performance and even lack of interoperability.

5 CREDIBILITY ISSUES

It is important that testing institutions are acting in such a way that they obtain high credibility. This encompasses issues like the validity of the testing results, not "leaking" information between vendors, and not providing any preferences to industry of the own country versus foreign industry.

Lesson learned is that some companies are reluctant to having their equipment examined by testing experts, especially if the testing is conducted in a foreign country.

7 RECOMMENDATIONS

Procuring agencies, system engineering houses and users are, in light of the increasing complexity of communication equipment, recommended to:

- Consider to only acquiring equipment that is standards conformance and interoperability tested and certified by a government authorised organisation.
- Consider demanding the whole range of test reports that are issued by the testing organisation.
- In case of acquiring equipment still under development, consider stating that the equipment will not be accepted until it is standards conformance and interoperability tested and certified by a by a government authorised organisation.

The "communication community" is recommended to:

- Consider making standards conformance and interoperability testing an important subject at their meetings.
- Consider encouraging the testing institutions to participate in the meetings.
- Consider encouraging the testing institutions to provide papers on testing issues at the meetings.
- Consider encouraging the testing institutions to develop and align their testing procedures.