REPORT 1026-1

USE OF NARROW-BAND DIRECT-PRINTING TELEGRAPH EQUIPMENT ON A SINGLE-FREQUENCY RADIO CHANNEL

(Question 5/8)

(1986-1990)

1. Introduction

ARQ narrow-band direct-printing (NBDP) telegraph equipment in accordance with Recommendations 476 and 625, is designed to be operated on the radio path in simplex mode.

The operational maritime systems, however, currently use this type of equipment with duplex two frequency radio channels because of a number of technical problems. This Report highlights these problems and discusses the criteria which would need to be met to enable an operational system to use single frequency channels.

2. Factors affecting the use of single frequency channels

Two main factors affect the reception of an NBDP transmission using a single frequency channel:

2.1 *Reception of very high levels from own transmitter*

This may cause overload of the front end of the receiver and the automatic gain control (AGC) of the receiver to decrease its sensitivity. Then, because of slow recovery, the wanted signal (at a much lower level) may not be received.

2.2 *In-band noise levels from own transmitter*

Modulation of the transmitter is present for at most 210 ms out of 450 ms; however, there will normally still be in-band noise components present for the remaining 240 ms.

The receiver input level due to in-band noise is given by $NC - CL$, where NC = in-band noise levels and CL = coupling loss between transmit and receive antennas.

For a quiet site, combined atmospheric and galactic noise levels at the receiver input for a 300 Hz bandwidth vary from 0 to −11 dB(1μV) over the frequency bands 1.6 to 30 MHz (see Report 322).

To prevent these in-band noise components causing degradation to the received signal, they should be at least 3 dB lower than the normal receive site atmospheric and galactic noise. Therefore, the required minimum reduction to transmitter in-band noise is given by:

$$(NC - CL) - (\text{atmospheric and galactic noise} - 3 \text{ dB}).$$

* The Director, CCIR, is requested to bring this Report to the attention of IMO.

Example of worst case

NC for a maritime mobile transmission can be as much as 200 mW (130 dB(1μV)) (see Appendix 8 of the Radio Regulations).

Therefore, the reduction necessary for a quiet site is:

$$(130 - 26) - (-11 - 3) = 118 \text{ dB}.$$

3. Discussion of problems and possible solutions

The two main factors will be discussed separately and some practical solutions given.

3.1 *Interference from own transmission*

This problem would arise where a mobile or fixed station uses transmit and receive antennas geographically closely sited. The obvious way to overcome this problem which is used by many mobile stations is to mute both the RF input and audio output of the receiver while the transmission is in progress.

A second possibility where receivers with a muting facility are not available is to use some form of antenna switch or switchable attenuator to reduce the level of the unwanted signal from the own transmitter, so that it will not adversely affect the AGC.

For stations without co-located antennas, no modifications are needed as long as the receive signal level meets the above criteria.

3.2 *In-band noise transmissions*

This noise also would cause problems at co-located transmit/receive sites, due to the fact that the noise level can be significantly greater than the wanted received signal.

The use of a transmit antenna switch which is only enabled during the actual transmission period, can, in most cases, eliminate this problem.

An alternative possibility is to use a switch for low power between the drive unit and the power amplifier. The majority of in-band noise is generated in the drive unit and the components from the power amplifier stage can be as much as 140-150 dB down on peak envelope power [Barrs, 1981].

Assuming a 1 kW transmitter (PEP = 167 dB(1μV)) this results in a noise level of:

$$167 \text{ dB} - 26 \text{ dB } (CL) - 150 \text{ dB} = -9 \text{ dB}(1\mu\text{V})$$

This is the same approximate level as the atmospheric and galactic noise (0 to −11 dB(1μV)).

For very closely co-located equipment and antennas, both of the above solutions may be necessary.

For geographically separated transmitters and receivers, no modifications are required as long as the noise levels from the transmitters are below the normal background noise.

4. Experimental results

4.1 *Test configuration*

A test to verify the feasibility of the solutions proposed above was conducted, using an equipment configuration as illustrated in Fig. 1 [CCIR, 1982-86].

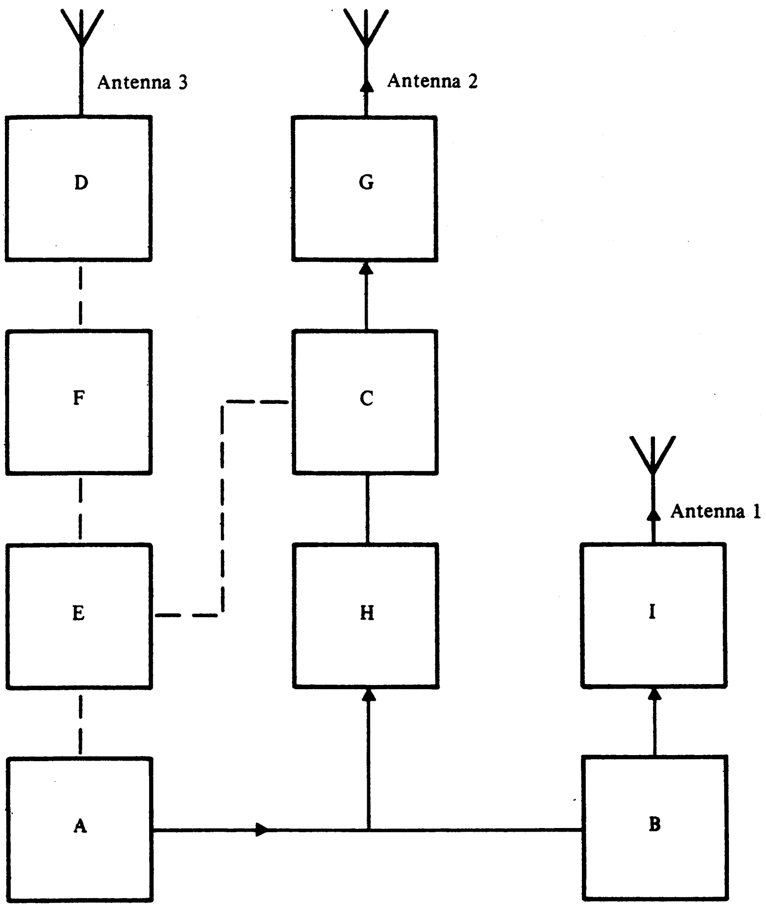

FIGURE 1 – *Equipment configuration for test*

A : ARQ terminal
B : ARQ terminal
C : switched attenuator
D : external RF attenuator
E : external audio mute
F : receiver
G : high power RF amplifier
H : low power drive unit
I : low power drive unit
-------: d.c. control

ARQ "A" was the master equipment transmitting to ARQ "B" via a direct line connection. Return signals from ARQ "B" to ARQ "A" were transmitted via antenna 1 and received via antenna 3. The high level "own transmission" and in-band noise was transmitted from ARQ "A" via antenna 2. Attenuator "C" could be switched in during the silent periods of the ARQ "A" transmit ARQ cycle.

The following characteristics were measured:

- received power of "unwanted" transmission = +137 dB(1μV);
- received power of in-band noise (without attenuator "C" in circuit) = +52 dB(1μV);
- received power of in-band noise (with switched attenuator "C" in circuit) = −12 dB(1μV);

- received power of "wanted" transmission = +20 dB(1µV);
- loop path delay ARQ "A"-ARQ "B"-ARQ "A" = 4 ms;
- receiver AGC decay time (time taken for the audio output to recover to −3 dB for a 40 dB step reduction in input level) = 150 ms.

The "unwanted" and in-band noise powers (without attenuator "C" in circuit) were purely a function of the transmitter used. The in-band noise power when the attenuator "C" was in the circuit was adjusted to be approximately equal to the typical atmospheric and galactic noise minus 3 dB figure quoted in § 2.2. The "wanted" power transmitted from ARQ "B" via antenna 1 was adjusted to be typical of that received by a maritime mobile station.

The receiver incorporated both an RF input mute (> 72 dB attenuation) and an audio output mute, both of which could be disconnected. Three receiver configurations were used in the test:

(a) both RF input and audio output internal mutes in circuit;

(b) both internal mutes disconnected but a separate switchable external RF receive attenuator "D" (80 dB attenuation) controlled by the ARQ equipment in circuit;

(c) as (b) above but with a separate external audio mute "E" in circuit.

4.2 *Test results*

Under configurations (a) and (c) above, the circuit worked satisfactorily with no errors. Under configuration (b) errors were significant.

During this test it was noted that the signal from ARQ "A" received by antenna 3 had undergone a delay. As a result of this delay, high signal levels were applied to receiver "F". This may have degraded the functioning of the receiver. There was also the possibility that ARQ "A" reacted to the end of its own transmitted signal which had been additionally delayed by receiver "F". Since configuration (c) proved to be satisfactory, the primary cause of the poor results in configuration (b) can be attributed to the latter possibility.

4.3 Tests at sea

4.3.1 Test conditions

In January and February 1987 field trials were carried out [CCIR, 1986-90] with narrow-band direct-printing (NBDP) telegraph equipment on single frequency radio channels on the motor vessel Komsomolsk on the route between Leningrad and Cuba. The following standard ship's equipment was used for the tests:

- NBDP equipment in line with Recommendation 476;
- 1 kW radio transmitter;
- a radio receiver with facilities for switching off the AGC, blocking the antenna input and protecting the input circuits from HF voltages of up to 100 V;
- separate antennas for transmitting and receiving, separation at least 10 m.

When the NBDP equipment was operating in the ARQ mode, the transmitter drive unit was blocked during the silent period, thus suppressing HF noise at the transmitter output to 140 dB below maximum transmitter output.

A J2B class of emission was used for both transmission and reception.

4.3.2 Test method

Communication was established with the correspondent in the ARQ mode using paired frequencies. An identical special test message was transmitted and received first in paired frequency operation and subsequently on a single frequency. The transmission/reception time of the test message was recorded. The real transmission speed for the same volume of information (of the order of 1000 characters) was determined in two frequency and single frequency operation using the formula:

$$R = \frac{N \times 7.5}{t} \quad \text{(baud)}$$

where N - number of transmitted characters
t - transmission time, in sec.

The efficiency (E) of NBDP equipment operation was evaluated on the basis of the ratio between the real information transmission speed using a single frequency (R_s) and the transmission speed for the same volume of information using two frequency operation (R_d):

$$E = \frac{R_s}{R_d}$$

To allow for variations in propagation conditions in the interval between the beginning of the two frequency transmission and the beginning of the single frequency transmission, the transmission/reception time was averaged out for the communication session.

Test programme evaluations were also made on the effect of interference caused by radio stations operating in adjacent channels, i.e. on frequencies $\pm$500 Hz from the working frequency, on simplex operation with NBDP equipment.

4.3.3 Test results

During the tests 45 communication sessions were carried out, 39 with coast stations and six with ships. The test results are given in Tables I and II.

The relation between R_d and R_s during the same session was significant.

TABLE I

Transmission speed (Bits/sec)	Number of single frequency operation sessions (R_s)	Number of two frequency operation sessions (R_d)
0 - 19.9*	1	1
20 - 29.9	1	2
30 - 34.9	5	2
35 - 39.9	9	8
40 - 44.9	11	17
45 - 49.9	17	12
50	1	3
	45	45

TABLE II

Efficiency $E = \frac{R_s}{R_d}$	Number of sessions
<0.85	1
0.85 - 0.89	4
0.90 - 0.94	1
0.95 - 0.99	14
1.00 - 1.04	15
1.05 - 1.09	4
1.10 - 1.14	4
1.15 - 1.19	1
>1.20	1
	45

* The minimum transmission speeds for single and two frequency operation shown in Table I are 7.40 and 6.35 bits/sec respectively.

The efficiency (E) of NBDP equipment operated on a single frequency channel in comparison with a two frequency channel, shown in Table II, depends on the interference situation in the channel and varies between 0.76 and 1.65. The efficiency E averaged out over all the communication sessions with a mean transmission speed of 41.4 bauds is 1.01. A conclusion can thus be drawn regarding the possibility of making large-scale use of NBDP equipment on a single frequency radio channel in normal operational conditions."

5. Advantages of single frequency NBDP ARQ operation

The use of single frequency operation for NBDP ARQ operation can result in a 50% saving of frequency spectrum. Furthermore, the single frequency NBDP channels proposed for the Global Maritime Distress and Safety System (see Report 747) may allow the use of the ARQ mode of operation which is inherently more reliable than the FEC modes for transmission to single stations. The operation and efficiency of the NBDP equipment in a single frequency channel is practically the same as in a two frequency channel.

6. Conclusion

It has been proved that an NBDP ARQ system using a single frequency can work satisfactorily even where the associated transmitter and receiver are co-located which is the case for mobile stations and for some coast stations. To achieve satisfactory operation, actions are required to reduce the in-band noise components transmitted outside the actual transmission periods, and the receiver employed should be provided with either an internal RF and audio muting device, or with an external switchable receive antenna attenuator and an external audio muting device.

For geographically separated transmitters and receivers, no modifications are required providing the levels of the received signals from the own transmitter meet the requirements discussed in § 2 and 3.

In the case of transmitters and receivers located relatively close to one another (e.g. on the same ship), the suppression of the noise emission of a ship transmitter during a 240 ms silent period to a level of -140 dB relative to maximum output-power is sufficient for ensuring NBDP equipment operation on a single frequency radio channel.

Blocking the receiver input during the emission of its associated transmitter for a period of 210 ms using the usual relays and switching off the AGC has no appreciable effect on the effectiveness of NBDP equipment operation on a single frequency radio channel.

A report on practical experience with NBDP-ARQ using a single frequency is given in Annex I.

Several immediate applications for single frequency operation using NBDP systems in the ARQ mode, which is inherently more reliable than the FEC mode, can now be indicated:

- for distress and safety purposes in the GMDSS on single frequency channels available in the MF and HF bands,
- for NBDP telegraphy on single frequency channels thereby reducing the need for two frequency channels provided by Article 60 of the Radio Regulations, and thus doubling channel availability.

REFERENCES

BARRS, R. A. [1981] A reappraisal of HF receiver selectivity, *Proc. IERE*, Vol. 50.

CCIR Documents:

[1982-1986]: 8/25 (United Kingdom) .

[1986-1990]: 8/84 (USSR)

ANNEX I

PRACTICAL EXPERIENCE FROM SINGLE FREQUENCY USAGE OF NBDP RADIOTELEGRAPHY CHANNELS IN THE MARITEX SYSTEM

1. Introduction

The data link and physical layer protocols used in NBDP systems (CCIR Recommendations 476-4 and 625) are inherently simplex, and the Amateur Service implementation (AMTOR) always works in the single frequency mode with good results. Interest has been focused on the system consequences of single frequency usage in automatic and semi-automatic radiotelex systems.

Reasons for this are both the possibility of better spectrum utilization, by using the same frequency for both the forward and return channels and the opportunity of using radio terminals of the transceiver type primarily designed for single frequency usage now appearing in the market, thus enabling lower terminal costs.

This annex is intended to give some information about the practical implementation and system consequences of trial single frequency working in the automatic NBDP system MARITEX operated by the Nordic Administrations [CCIR, 1986-90].

2. Mobile terminal implementation

The mobile terminal used for the trials was a 150 watt output MF/HF transceiver of Japanese manufacture equipped with an ARQ conforming to the CCIR Recommendation 476-3. The transceiver was placed onboard the motor freight ship M/S Boxy and was used during a six-month voyage across the North Atlantic in mid 1987. The antenna arrangement used was a 7 m glass-fibre whip antenna tuned by the companion automatic antenna matching unit.

No special precautions were observed with regard to the equipment which was used as delivered from the manufacturers.

3. Coast station implementation

The radio channel for the trial was in the 12 MHz band, and used the standard components in the MARITEX system.

The receiver used had an IF bandwidth of 350 Hz and was connected to the log-periodic antenna complex at the MARITEX receiving site at Onsala, 30 km south-south-west from Gothenburg.

Transmitting equipment was situated in an auxilary transmitter site at Grimeton, 60 km south of the receiving site.

The transmitter had a power of 5 kW to a dipole antenna, and operated in the J2B mode.

A standard ARQ was connected to the radio equipment and to the MARITEX message-handling computer system.

Some adjustments to Recommendation 492 free-channel signal format were made.

In order to make calls from the ship possible, a silence period of three seconds was inserted after eight free-signal blocks. Otherwise the coast station emission would render the ship's call transmissions undecodable.

4. Observations

No difficulties or abnormal message delays attributed to the radio link were detected throughout the voyage. Traffic offered to the system either from shore telex subscribers or from the ship was forwarded well within the delay limits of the system.

5. Conclusions

The single frequency usage of NBDP channels is a practicable way of reducing the spectrum congestion in the NBDP HF bands, and lends itself well to use even in fully automatic systems.

However, some difficulties can be foreseen with older mobile equipment, which may have less than optimum switching times, muting and noise behaviour.

Coast station radio equipment may also have to be slightly modified in order to meet the requirements with respect to muting and transmitter noise performance.

The format of the free-channel signal for optimum performance is also an area of further study, when a mobile terminal in an automatic system must scan a number of radio channels.

REFERENCES

CCIR Documents

[1986-1990]: 8/118 (Sweden)