Fast and secure data transmission on shortwave – result of intensive research

FIG 1 HF Transceiver XK2100 with integrated ALIS Processor GP2000 and HF Modem GM2100
Photo 42 878

The sophistication of Rohde & Schwarz's ALIS processor for automatic link setup and shortwave-link adaptability is the result of technical advances and continuous experimentation and trials [1]. By variation of the system parameters frame length, redundancy, type of modulation and frequency, the HF transceivers of the XK2000 family (FIG 1) [2] show high capability in adapting to time-variant channel quality and can achieve data rates up to 3.6 kbit/s using Modem GM2100 (max. 5.4 kbit/s) and the RSX.25 protocol.

Measuring quality of shortwave channels

To obtain typical values for variations of channel quality with time and for the availability of shortwave channels, Rohde & Schwarz carried out trials with prototypes of the ALIS processor on a radio link between Hamburg and Munich at the beginning of 1985 [3]. After link setup, data blocks were sent continuously for periods of one hour at a rate of 100 bit/s, with transmitter output of 100 W, 2FSK modulation deviation of ±42.5 Hz and filter bandwidth of 150 Hz. BER (bit error rate) was continuously determined and recorded. FIG 2 shows typical BER over a period of one hour on a channel of good quality. For the most part it is below 1%. FIG 3 illustrates deterioration of the originally good channel quality after about 20 min and an increase of BER from less then 1% to figures between 10 and 50%.

Relative outages of the tested channels are presented in FIG 4 (mean values over two weeks). BER above 10% was considered a channel failure. Four outage spans were defined: 0 to 12.5 s/12.5 to 30 s/30 to 60 s/60 s to 1 h. The following results were obtained. Failures in the three groups below 60 s occur with approximately the same frequency, but this is considerably less than that for failures between 60 s and 1 h. In other words, if BER exceeds a threshold of 10%, the probability of the failure lasting longer than 1 min is significantly higher than the channel recovering after a short period. This leads to the conclusion that a change of channel is the best reaction for restoring quality once outage has reached 1 min.

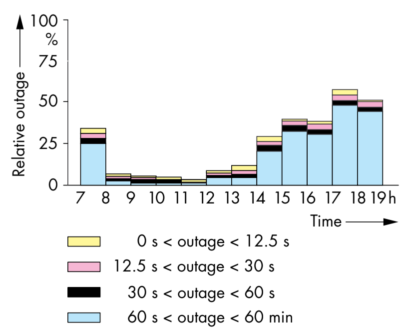

FIG 4 Relative outage of shortwave channels (FSK, 150 Hz bandwidth, 100 bit/s, 100 W)

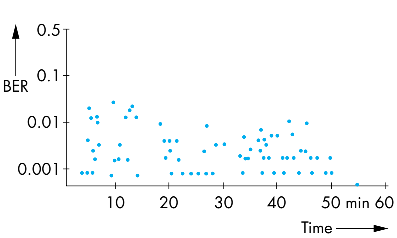

FIG 2 BER for shortwave channel between 9:00 and 10:00 h (7.512 MHz, FSK, 150 Hz bandwidth, 100 bit/s, 100 W)

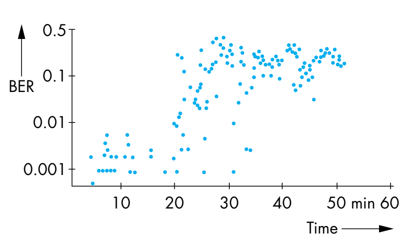

FIG 3 BER for channel between 15:00 and 16:00 h (8.165 MHz, FSK, 150 Hz bandwidth, 100 bit/s, 100 W)

Automatic adaptation of system parameters to channel quality

The above trials showed that channel quality in Europe varies strongly and rapidly. For this reason the ALIS concept attaches great importance to adaptive matching of radio parameters to momentary channel quality. Based on measurements of current channel quality, the system is provided with all the information needed for selecting or changing frequency when a link is set up and during data transmission. When a suitable frequency for link set-up is selected, the levels last measured in the channels (passive channel analysis) plus a forecast analysis are taken as criteria for channel availability. Various parameters can be used to measure channel quality during transmission, ie active channel analysis. The efficiency of the data-transmission method is a highly indicative parameter, easy to obtain and adequate for deciding what measures to take. The following parameters can be varied to maintain an established link: transmitter output power, (frame) length of data packets, redundancy for detecting and correcting transmission errors, bandwidth, type of modulation (parameters directly affecting data rate) and frequency.

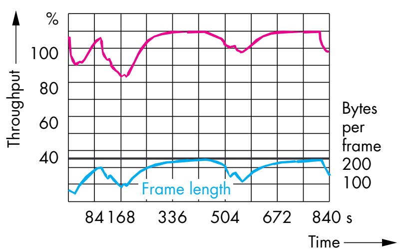

FIG 5 Throughput and frame length on good shortwave channels; low variation of channel quality and thus frame length

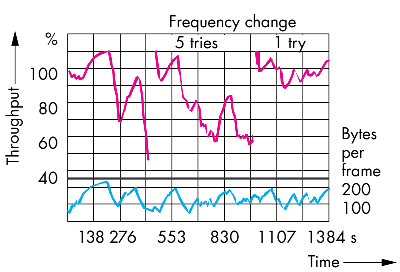

FIG 6 Throughput and frame length on medium-quality shortwave channels. Two adaptive frequency changes can be seen in center. In first case suitable frequency was found after five tries, in second case one try was sufficient.

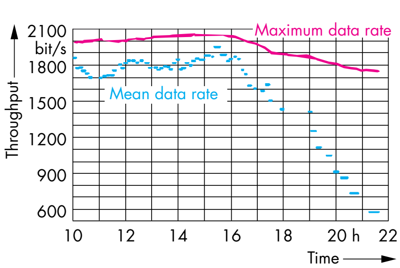

FIG 7 Mean throughput on channel during daytime (RSX.25, 8PSK); at about 16:00 h throughput starts to fall off.

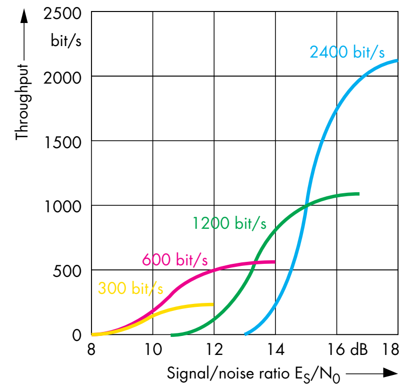

FIG 8 Adaptability of modem speed, throughput in bit/s versus S/N ratio E_S/N_0

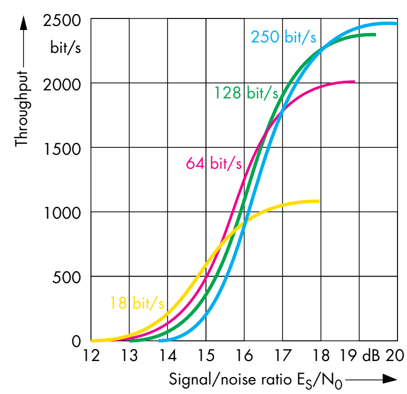

FIG 9 Adaptability of frame length (bytes/frame), throughput versus S/N ratio

When the ALIS system was first implemented with a conventional FSK modem, the transmission channel was changed in the presence of persistent interference. With HF Modems GM857C4 and GM2000 [4] and the RSX.25 protocol, specially created for this purpose, it became possible to adapt several parameters – frame length, number of frames per packet and frequency – to channel quality. Plus there was the use of narrowband 2FSK modulation. RF power is not adapted because transmission is usually at full level and this would produce no improvement. The RSX.25 protocol used with the new modem generation is a modified AX.25 packet radio protocol. The advantages compared to earlier shortwave communication protocols are: use of a common channel in a network, routing and relay function, bidirectional communication and greater flexibility of frame structure due to asynchronous transmission. With 8PSK the net data rate of the serial modem with adaptive echo cancellation is 5400 bit/s. Errors are at first corrected by FEC (forward error correction, convolutional code, 1/2 code rate, Viterbi decoding), which reduces net data rate to 2700 bit/s. Errors escaping FEC are eliminated by the ARQ (automatic repeat request) procedure of the RSX.25 protocol.

FIGs 5 and 6 show the results from field trials with HF Transceivers XK2000 on channels of good and medium quality. These trials were carried out in early 1993 on a link between Bonn and Munich. The upper trace represents the efficiency of the RSX.25 transmission protocol, while the lower one shows how frame length varies between 16 and 250 bytes. FIG 7 illustrates average throughput between 10:00 and 21:00 h on a particular day.

Further improvement of RSX.25 transmission protocol

To investigate possibilities for improving the RSX.25 protocol, Rohde & Schwarz compared it by computer simulation with the STC protocol developed by and named after the Shape Technical Centre [5]. Major features of this STC protocol are the adaptive data rate of the modem, which matches type of modulation (8-, 4-, 2PSK) and redundancy, and selective repeat ARQ. The maximum data rate of the modem is 2.4 kbit/s, yielding a maximum data rate of the ARQ protocol of around 2 kbit/s. The RSX.25 protocol adapts frame length in the memory-go-back N-ARQ. The modem, otherwise identical, achieves a data rate of 2.7 kbit/s because of a different ratio of test to data bits. Thus a maximum data rate of 2.5 kbit/s is obtained for the RSX.25 protocol. However, even in the diagram normalized to the same modem rate and at higher S/N ratios, the transmission rate of the RSX.25 protocol is somewhat higher than that of the STC protocol because of the slightly lower overhead.

The advantages of an adaptive modem rate can be seen from FIG 8, those of the adaptive frame length from FIG 9, where the data-rate improvement is shown as a function of S/N ratio (E_S/N_0). The greater robustness of the modulation at lower modem rates is attained by increasing the phase angle of the mPSK modulation and the redundancy in the coder of the modem, while shortening frame length reduces the probability of bit errors in the frame and thus the need for data repetition.

The two protocols are compared in FIG 10. At low S/N ratios the adaptation of modulation method and redundancy has a greater effect, and here the STC protocol produces higher throughput. Above an S/N ratio of 17 dB, the throughput of the RSX.25 protocol is higher even in the normalized display because of the lower overhead, particularly when long frames are transmitted. FIG 11 compares the RSX.25 protocol and an optimized form of it called RSop2. The latter uses an adaptive modem data rate, adaptive frame length and selective repeat ARQ. Throughput improves in the whole S/N range.

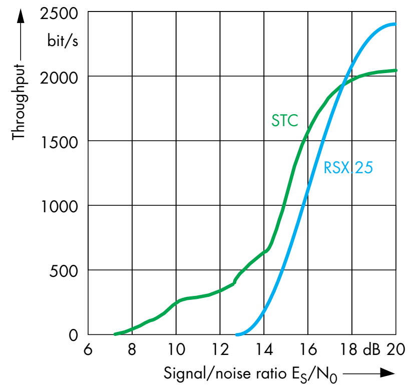

FIG 10 Comparison of STC and RSX.25 protocols, throughput versus S/N ratio

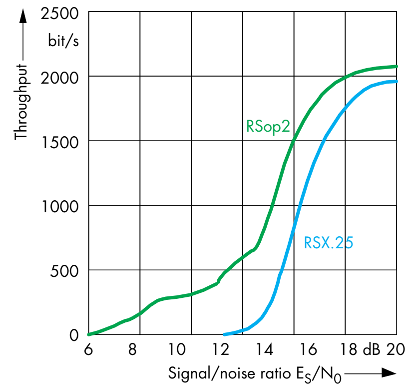

FIG 11 Comparison of RSop2 (RSX.25 + selective repeat ARQ + adaptive modem speed) and RSX.25 protocols

As a result of what was learnt from the comparative simulation, Rohde & Schwarz developed HF Modem GM2100 [6] for HF Transceivers XK2000. This offers different types of modulation (2-, 4-, 8PSK) and redundancy (1/2, 1/3, 5/6, 1/1 code rates) and features maximum data rate of 5400 bit/s. The modem was integrated in an optimized RSX.25 protocol that controls modulation and redundancy adaptation. With the aid of this protocol, data rates of 3600 bit/s can be achieved on undisturbed links, ie considerably more than the 2 to 3 kbit/s of conventional shortwave links.

Dr Günter Greiner

REFERENCES

[1] Greiner, G.: Reliable shortwave with ALIS. News from Rohde & Schwarz (1987) No. 116, pp 47–50

[2] Helmke, B.; Wachter, G.: HF Transceiver XK2100 – Digital shortwave for future-proof, long-haul communication. News from Rohde & Schwarz (1994) No. 144, pp 4–7

[3] Greiner, G.: Kurzwellenkommunikation: Historischer Überblick über die Entwicklung und Diskussion moderner Verfahren. telekom praxis, Schiele & Schön GmbH, Berlin, 23–24 (1989), 1–2 (1990)

[4] Hackl, H.: Secure data transmission with 2700 bit/s on shortwave links. News from Rohde & Schwarz (1994) No. 146, pp 29–31

[5] Eken, F.; Clark, D.; Voordouw, H.: High-Frequency Open Systems Interconnection Data Link Protocol, Technical Memorandum Shape Technical Centre TM-930 (1993)

[6] Wicker, G.; Greubel, G.: Fast adaptive data transmission on shortwave at up to 5400 bit/s with HF Modem GM2100. News from Rohde & Schwarz (1996) No. 152, pp 42–43

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