TACTICAL SPEECH SECURITY TERMINAL

SPENDEX 10

DELTAMODULATED CRYPTOFONIC EQUIPMENT

Philips Usfa N.V.

DESCRIPTION 13916/E EDITION 10-72 RESTRICTED

SHORT DESCRIPTION OF

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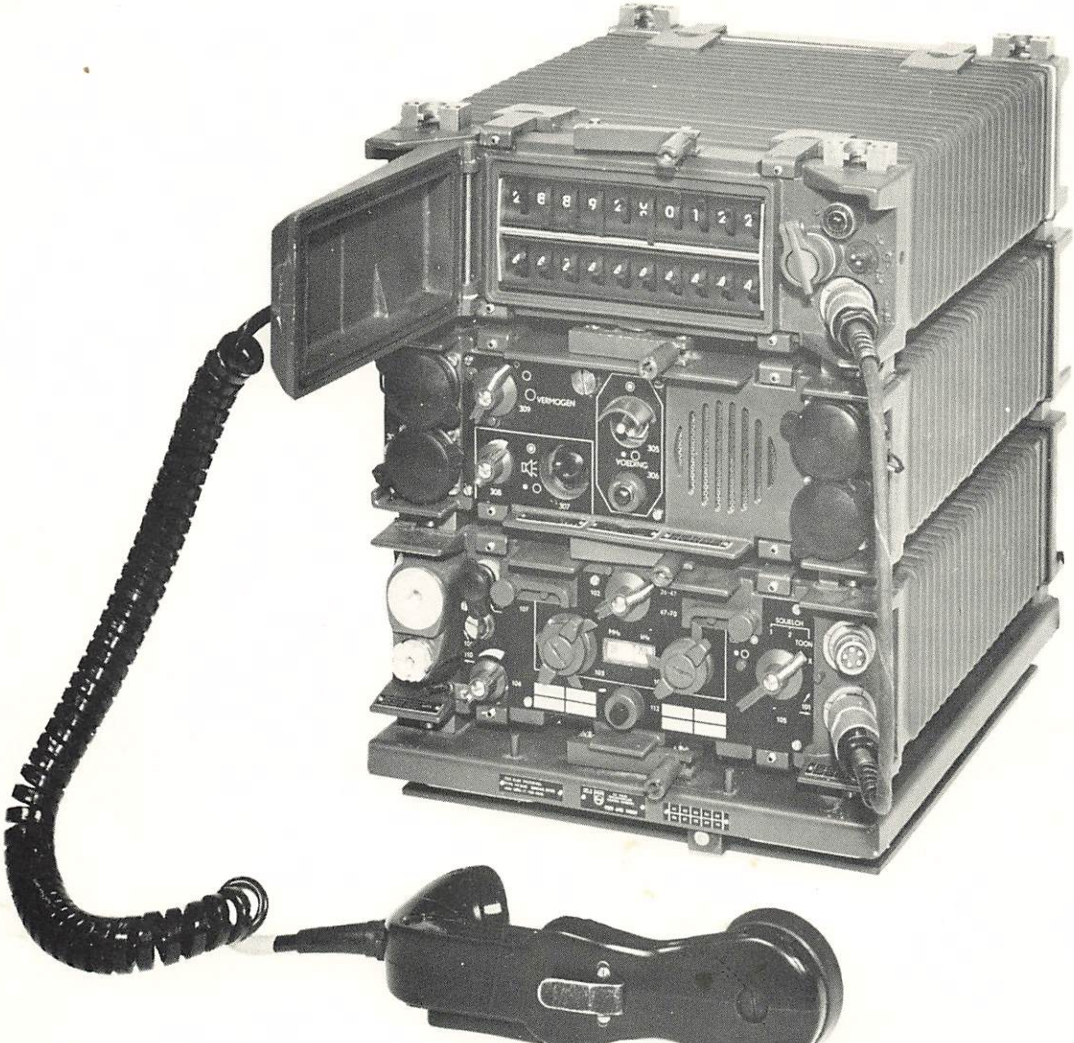

Figure 1. SPENDEX 10, mounted on RT 3600 .

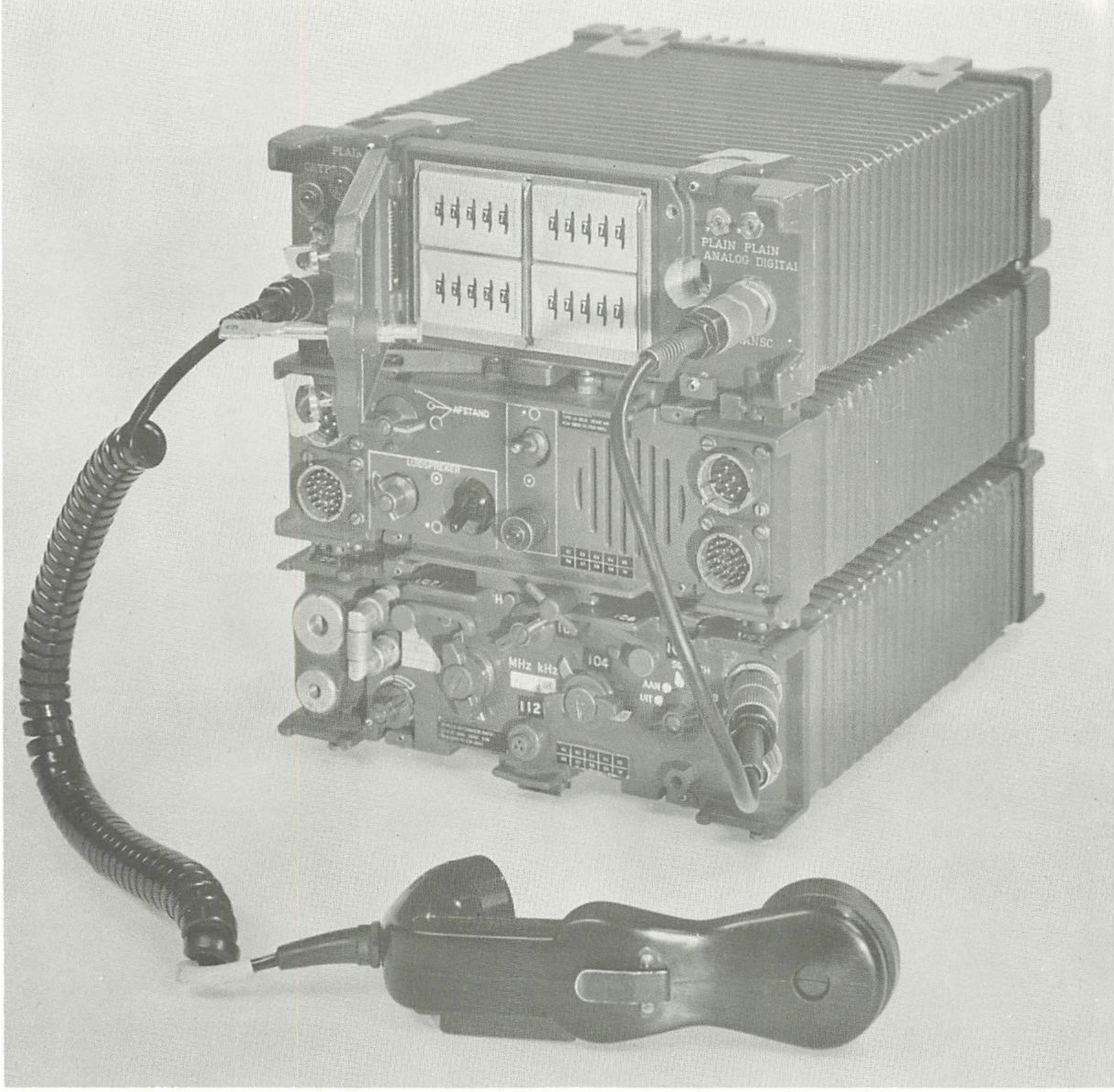

Figure 1. SPENDEX 10, mounted on RT 3600.

SHORT DESCRIPTION OF THE PHILIPS USFA TACTICAL SPEECH SECURITY TERMINAL TYPE UA 8301.

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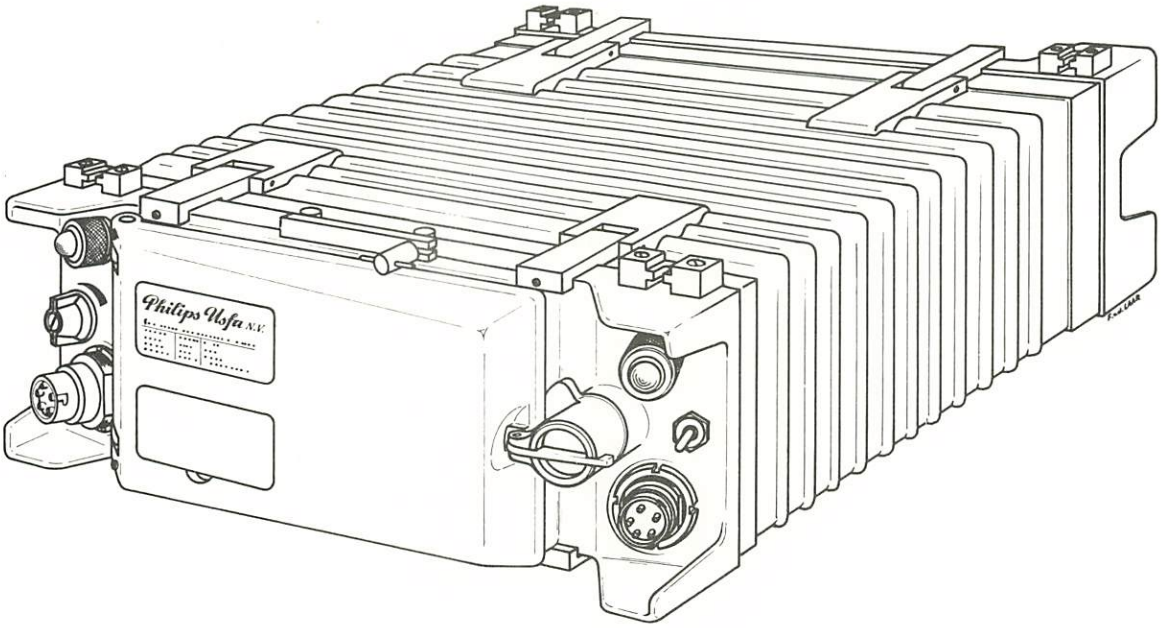

Figure 2. SPENDEX 10, with closed key setting compartment.

1. PURPOSE

SPENDEX 10 provides automatic speech security for simplex one-channel communications such as occur on tactical radio networks. It can be used with all types of transmission media with an audio bandwidth of approximately 10 kHz, such as military FM transceivers, unloaded field cables, grouped carrier telephony channels, service channels on radio relay systems, and leased or fixed lines. With the aid of adaptors SPENDEX 10 can also be used on carrier telephony systems and other transmission media.

SPENDEX 10 is primarily intended for encyphering and decyphering speech on tactical radio sets and is inserted between the handset and the wide-band audio socket of the transceiver. It can also be used for the secure transmission of data of max. 600 baud.

Under normal operating conditions the range and intelligibility of the transceivers will not be decreased noticeably by the use of SPENDEX 10; whereas an analog clear speech link will gradually decrease in quality with increasing range, the intelligibility of a crypto connection over SPENDEX 10 will remain constant until, beyond a certain distance, it drops sharply. A number of field trials in open country showed an average decrease in range of between 5% and 15%, depending on the terrain.

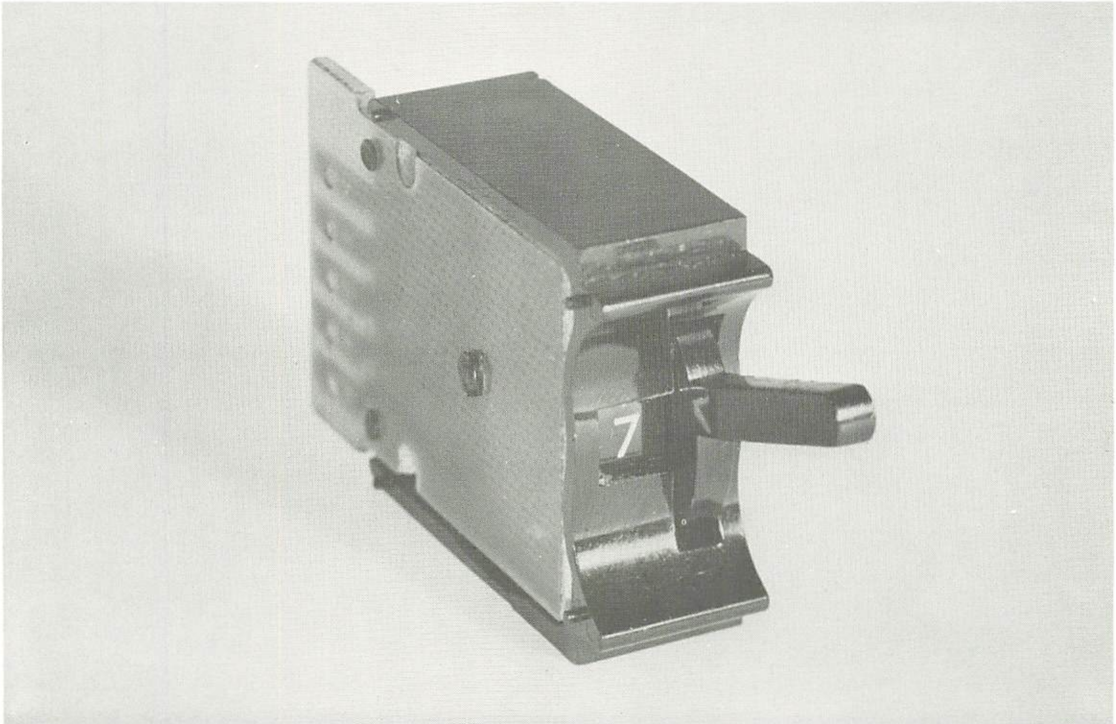

Figure 3. Lever-operated key setting switch.

2. OPERATION

a. Key setting

The classification of SPENDEX 10 itself, when series-produced, is no higher than "restricted". The speech security is determined exclusively by the key setting, which takes the form of twenty lever-operated coding switches, each with 8 positions, which must be set to the appointed position. A total of 8^{20} or 10^{18} different key settings is possible. For correct operation, each of the 20 coding switches must be in the correct position. The key-setting information itself can easily be distributed within the organisation in written form.

The coding switches are grouped on the front panel and hidden from view behind a lockable cover. In case of emergency the coding switches can be reset to zero instanteneously, thanks to the protruding levers of the switches.

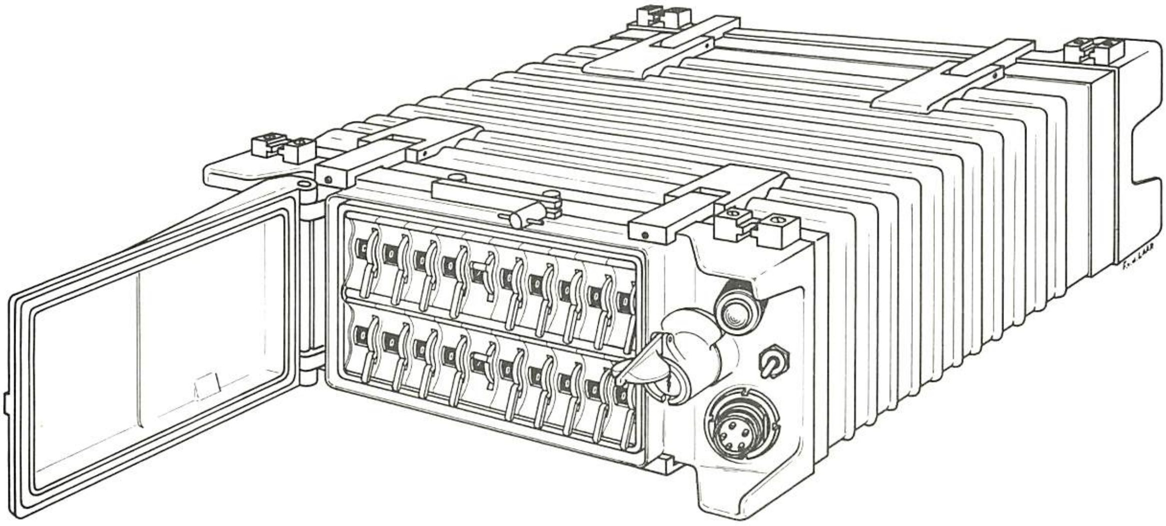

Figure 4. SPENDEX 10, with opened setting compartment.

2 b. Operation

SPENDEX 10 is a simplex device which automatically operates in the receiving mode during standby. When the correct key setting is used, crypto transmission in progress is received immediately as soon as the terminal is switched on. The transmitting mode is achieved only when the press-to-talk switch in the handset is pressed. A station with the correct key setting can enter existing networks immediately.
Synchronization, key starting, and operation are entirely automatic and instantaneous. A receiving SPENDEX 10 automatically differentiates between crypto speech, crypto data, and clear speech. Automatic reception of clear speech,even from sets which are not equipped with SPENDEX 10, is always possible; transmission of clear speech is only possible as long as a spring-loaded "Secure/Clear"-switch on the front panel is kept pressed. Of course clear speech through a SPENDEX 10 equipped transceiver can be received by noncrypto stations. As soon as this switch is released, secure cryptophonic operation ensues automatically.

Normal radio procedure is not affected by the use of SPENDEX 10 and virtually no additional training of operators is required: when the correct key setting is used, only the press-to-talk switch in the handset has to be operated. Instead of a handset with good-quality microphones, a throat microphone with seperate headphones and press-to-talk switch can be employed.

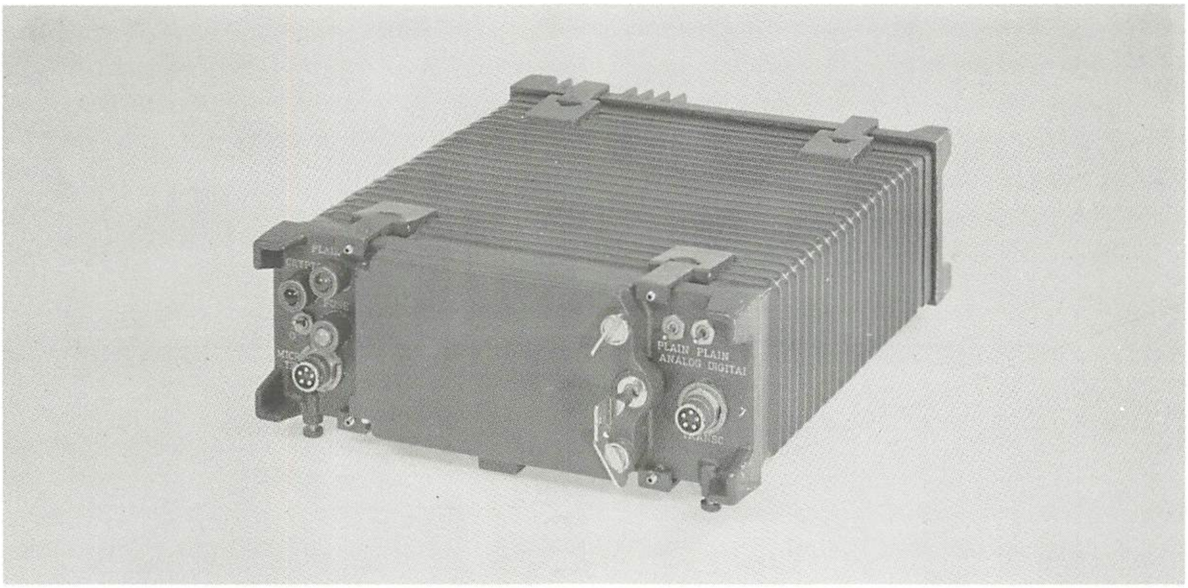

Figure 5. Front view of SPENDEX 10.

3. DELTA MODULATION

Only digital signals can be encyphered with any degree of security; scramblers or other analog cryptophonic devices are either relatively simple to decipher or so complicated and costly that application in tactical radio networks is not feasible. The currently available techniques for digitalizing speech are:

- Vocoders
- Pulse Code Modulation
- Delta Modulation

The channel vocoder analyses the volume of the channels into which the voice frequency spectrum is divided and transmits the amplitude of each channel by means of a digital code. Also information on the pitch is transmitted in digital form.
The information is grouped on a Time Division basis into frames and transmitted in series. The speech quality of such a system is in itself very good indeed, and very narrow bandwidths of some 1800 Hz, suitable for transmission over CCITT "telephone lines", can be achieved with special modems. These systems, however, are too costly and complicated for tactical use; they are available from Philips Usfa under the name SPENDEX 20 for strategic communications. Further nonclassified details on SPENDEX 20 are available on request.

In Pulse Code Modulation the speech signal, also filtered to a bandwidth of 300 - 3400 Hz, is sampled about 8000 times per second. The absolute amplitude of the signal during sampling is translated into a digital codeword, usually consisting of 6 bits. The bandwidth required for one channel in fairly large (48 kHz) and very rigid synchronization procedures are necessary. P.C.M. is usually employed for the transmission of 12 or more channels on Time Division Multiplex systems but it is too complicated and expensive for a single tactical channel.

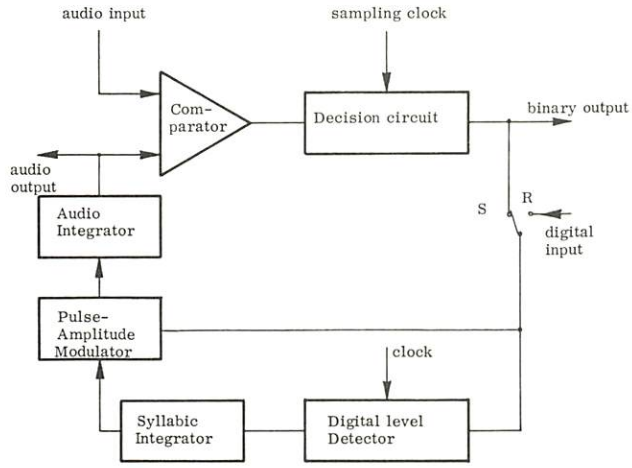

Figure 6.

Block diagram of delta modulator.

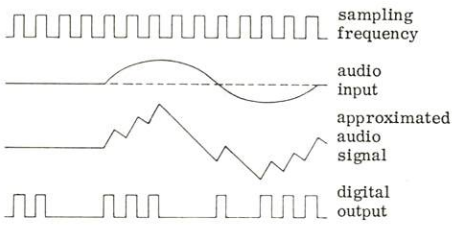

Figure 7.

Sampling by means of deltamodulation.

In delta modulation, a Philips speciality, the total audio signal is sampled about 10.000 times per second and each sampling produces a bit of value "1" or "0". A "1"-bit indicates that the sampled amplitude is higher than that of the previously sampled bit.
A "0"-bit indicates a relative amplitude decrease.
The bit rate is equal to the sampling rate and may in principle be set at any value between say 7000 and 30.000 bits per second. Delta modulation requires no synchronization bits at all and is far less sensitive to errors in the transmission: error rates of up to 1% are already prohibitive in Pulse Code Modulation, but with delta modulation there is still a fair degree of intelligibility at error rates of up to 5%.

A higher bit rate gives a better quality but requires also more bandwidth. The sampling frequency for SPENDEX 10 is derived from easily exchangeable crystals and is the result of a compromise between "bandwidth" and "quality" or "intelligibility". The user can in principle chose his own bit rate but for SPENDEX 10 a sampling frequency of 9.6 kilobits (half the sampling frequency used in the "DELTAMUX" Time Division Multiplex by Philips Telecommunication Industries) is the most commonly used.

Quality, intelligibility, voice recognition, and other parameters of human speech can be measured and tested in many ways. Commonly used in laboratories and comparative tests is the "logatom" intelligibility test. A 50% positive logatom test is usually taken to stand for a "sentence-intelligibility" of more than 95%, as shown in the graphs below.

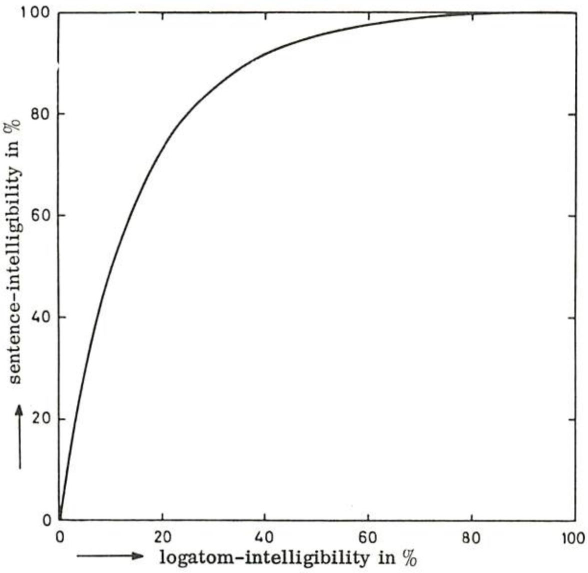

Figure 8.

Relation logatom- and sentence-intelligibility.

In practical application, however, the signal-to noise ratio also affects the communication ; the combined result of the various sampling frequencies and the increasing signal-to-noise ratios are shown in the graphs below. These graphs are based on a study by the Governmental Institute for Perceptual Physiology (known as I. Z. F. - R. V. O. /T. N. O.) under laboratory conditions.

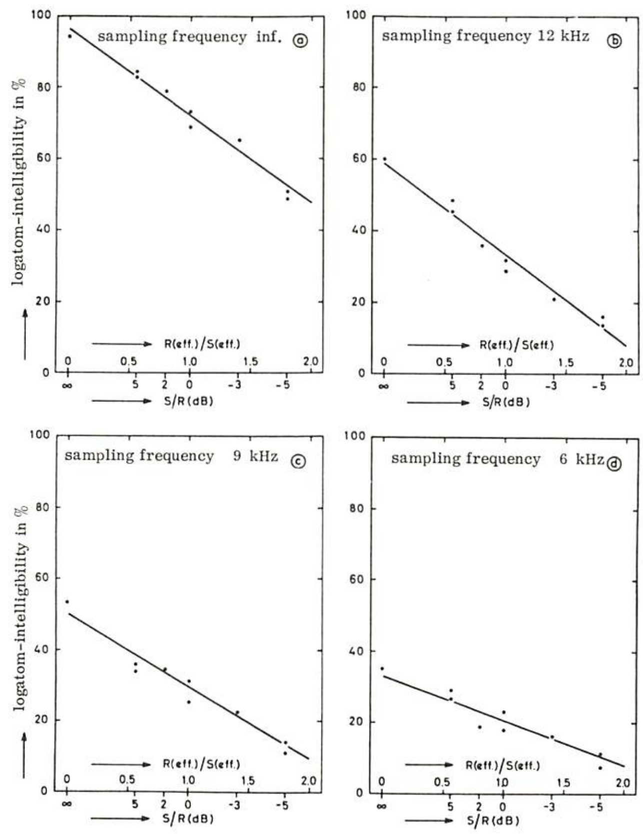

Figure 9 : Logatom-intelligibility at various sampling frequencies.

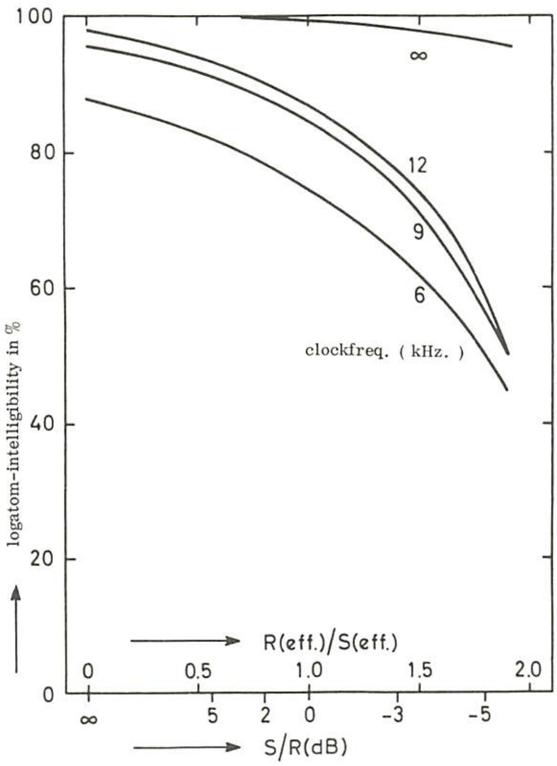

Figure 10. Sentence-intelligibility versus S/N ratio.

But tactical communication networks within for instance an Army Corps or a Division are as a rule used for the transmission of tactical messages in a prescribed format. The messages will by their very nature contain a large number of spelled words and single figures with a very limited vocabulary, whilst it is common practice to repeat difficult or unexpected words. Under tactical circumstances a message such as, for example:"Artillery support required for position Alpha at 19.45 hours" will have a greater chance of being understood than text spoken by a newsreader and dealing with sundry subjects.

The design of the delta modulator and demodulator has a great influence on the quality: research into possible improvements in the design and the development of more sophisticated circuitry are still progressing. A recent example is the development of new integrated circuits, making for improved dynamic characteristics of the delta modulator and hence for better intelligibility at lower bit rates.

Effective companding for Delta Modulation can be effected with a simple system which extracts the compression information from the digital bit stream. At the receiving end the exact reverse of the process can be performed, without any additional information having to be sent along the transmission path. This system, used in SPENDEX 10, is known as Digitally Controlled Delta Modulation.

4. CIRCUIT DESCRIPTION

4 a. Transmission

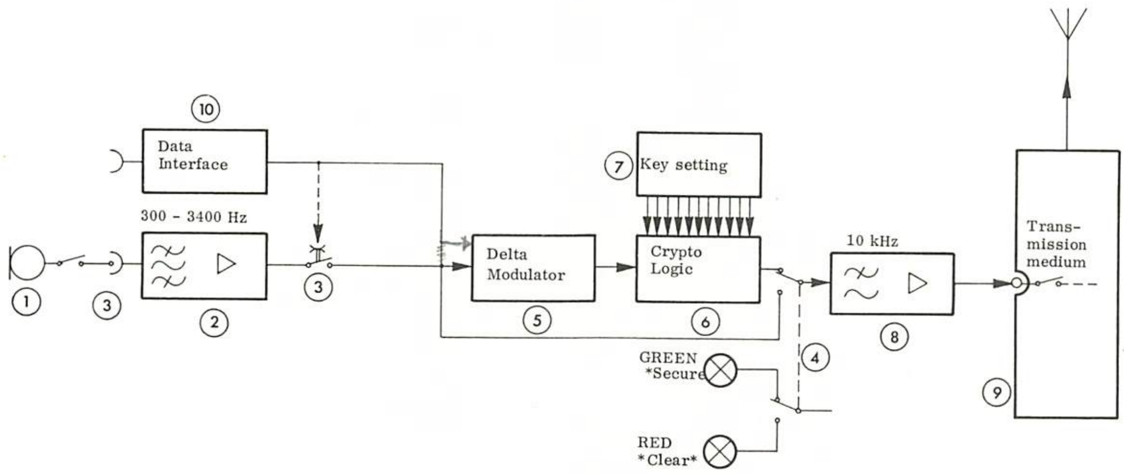

Figure 11. Block diagram of SPENDEX 10 in the transmitting mode.

Analog clear speech is spoken into the microphone (1) of the standard handset (a throat microphone may also be used) and amplified in the band-pass amplifier (2) which filters the signal to one between 300 and 3400 Hz. The press-to-talk switch (3), usually incorporated in the hand-set, must be kept pressed during transmission to exercise the send/receive control over both SPENDEX 10 and the transceiver. The signal passes via the springloaded "Secure/Clear"-switch (4) either to the delta modulator (5) for secure transmission or directly to the final amplifier/low-pass filter (8) for transmission in the clear. The "Secure/Clear"-switch also controls the burning of the green (=secure) or red (=clear) pilot lamps on the front panel.

In the delta modulator, the analog clear speech signal is translated into a digital bit stream of 9.6 kilobits/second and passed to the crypto logic (6). Here, the digital signals are processed in a way which is exclusively determined by the key-setting code switches (7), so that to each bit of the clear text a key bit is added to form the crypto bit for transmission. The output of the crypto logic is fed to the final amplifier/low-pass filter (8) and thence to the transmission medium (9), which may be a tactical trans-ceiver, an unloaded field cable, or such.

SPENDEX 10 is equipped with a special data interface (10) through which data at up to 600 baud can be transmitted. The press-to-talk switch need not be kept pressed for the transmission of digital data, as a voltage originated in the data interface will take care of that function. Data transmission has priority over all other operating modes. except "clear-speech"

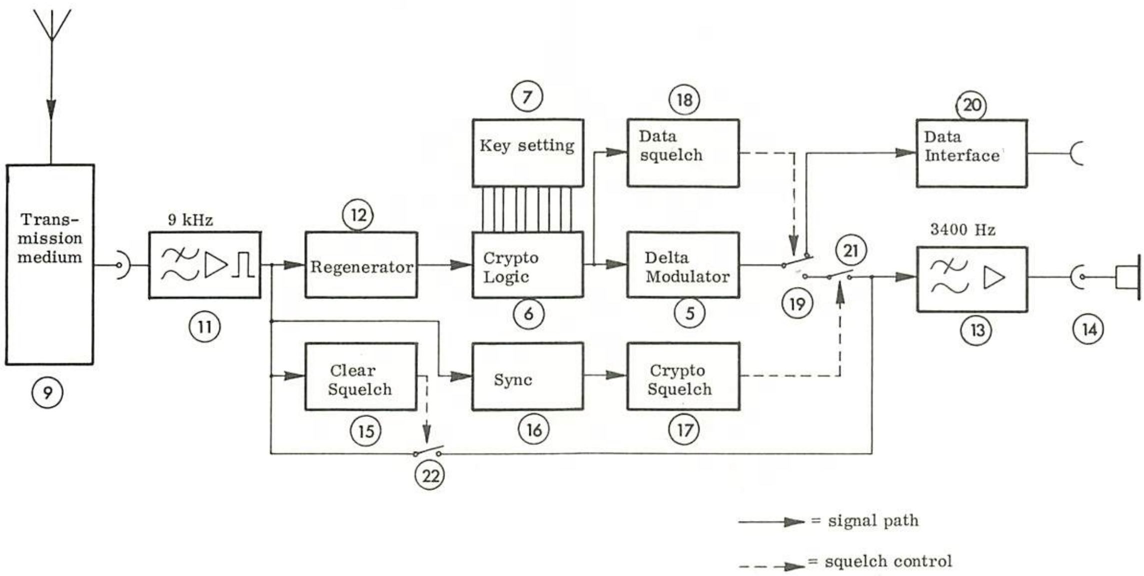

Figure 12. Block diagram of SPENDEX 10 in the receiving mode.

4 b. Reception

The signal which comes from the transmission medium (9) is filtered, amplified, and shaped in a receiving amplifier (11). A regenerator (12) eliminates the effect of disturbances and supplies a "clean" signal to the crypto logic (6) which processes the signal in a way which is determined by the key-setting code switches (7). As the key setting at either end are identical, identical series of key bits will be generated, so that the original digital clear text, as it came out of the delta modulator at the transmitter, is now available again. The delta demodulator converts the digital clear text, now decyphered, into an approximation of the original clear speech which is passed to the final audio amplifier (13) and made audible in the telephone element (14).

If the original clear text was "data", the output pattern of the delta modulator at the transmitter shows characteristics which can be recognized by the data squelch (18) at the receiving end. When the data squelch becomes operative, the bit stream through the two-way switch (19) is diverted from the audio amplifier (13) and instead directed to the data interface (20).

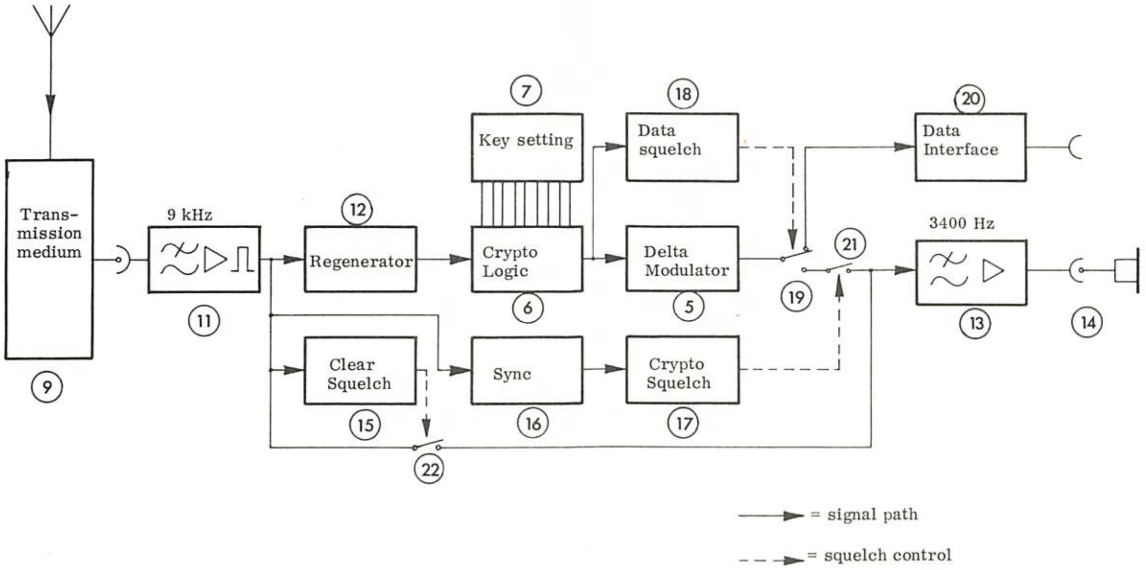

Figure 13. Block diagram of SPENDEX 10 in the receiving mode.

When analog clear text is being transmitted in the clear text mode through the transmission path, this is filtered to 300 - 3400 Hz and will consequently contain no signals of the order of 5000 Hz. If, therefore, 5000-Hz signals are detected by the clear speech squelch (15), these are either enciphered digital text between 10 and 10.000 Hz or just the normal FM noise during pauses in transmission. The clear speech squelch (15) therefore opens switch (22) when 5000 Hz is present in the received signal, thus interrupting the clear speech path to the final amplifier (13). When clear speech is received, the clear speech squelch closes switch (22) so that the signal can be amplified in amplifier (13), bypassing the crypto logic and the delta modulator. Reception of clear speech is thus entirely automatic.

Directly after the receiving amplifier (11) the synchronisation circuit (16) tries to find the approximate sampling frequency in the received signal in order to synchronize the local oscillator at the receiving end with the transmitting oscillator. As soon as the synchronisation circuit has succeeded in detecting the approximate sampling frequency, the crypto squelch (17) closes switch (21), so that the decyphered speech signal reaches the final amplifier (13). If, however, the amount of interference rises above a certain threshold, the crypto squelch will open switch (21) again and silence the final amplifier. This is the reason why the effect of increasing distance between transmitter and receiver will make itself felt abruptly instead of gradually.

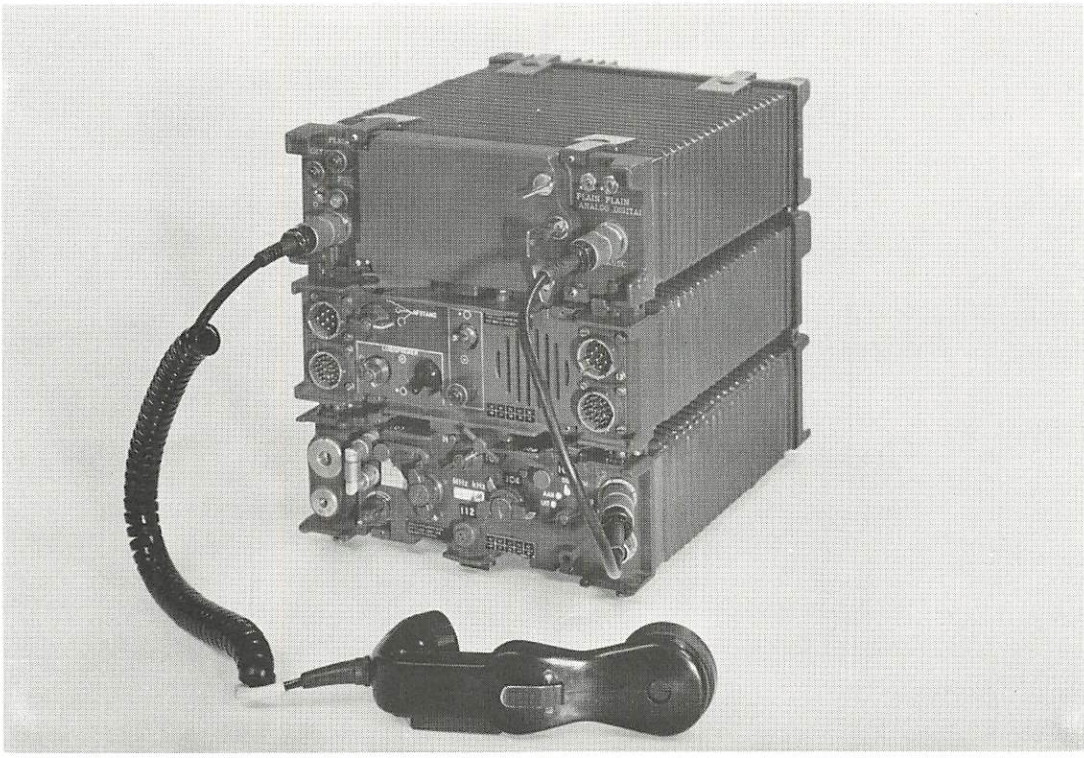

Figure 14. SPENDEX 10 on transceiver.

5. MECHANICAL DESIGN

The construction of SPENDEX 10 is based on the construction of the family of tactical transceivers RT 3600 made by Philips Telecommunication Industries of Hilversum, Netherlands. SPENDEX 10 has been designed as an integral part of this family and can be connected to these transceivers without any modification or preparation whatever. The units can be stacked on top of each other and clipped together for mounting in command vehicles or such. Of course, the mechanical design of SPENDEX 10 is not limited just to a fitting of the RT 3600 alone; it can be made to match the casings of other types of transceivers, provided enough room is made available for the circuitry and key-setting code switches.

SPENDEX 10 has length of 315 mm, a height of 80 mm, a width of 255 mm, a weight of only 5 kg, and a volume of some 7 litres. SPENDEX 10 is of modular construction, with interchangeable plug-in units on two frames which are strapped together inside a watertight casing. The modules, mounted in protective cans, are fastened to the large printed wiring board which also contains the instrument wiring. The front part contains the crypto part, the key setting arrangement, the delta modulator, the squelches, and the amplifiers, whereas the stabilized power supply and the filters are lodged in the rear part. The 20 key-setting switches, grouped on the front panel, are hidden from view behind a lockable door. Next to this door the MIL-C-55116 sockets for connection of SPENDEX 10 to the handset and to the transceiver, as well as the "On/Off"-switch, the "Clear/Secure"-switch, and the red and green pilot lamps, are located. The rear panel accomodates the socket for the power supply, for the input and output of data and for the adaptors.

The integrated circuits which form the digital electronics are of the TTL-type in a ceramic dual-in-line package with extended temperature range.

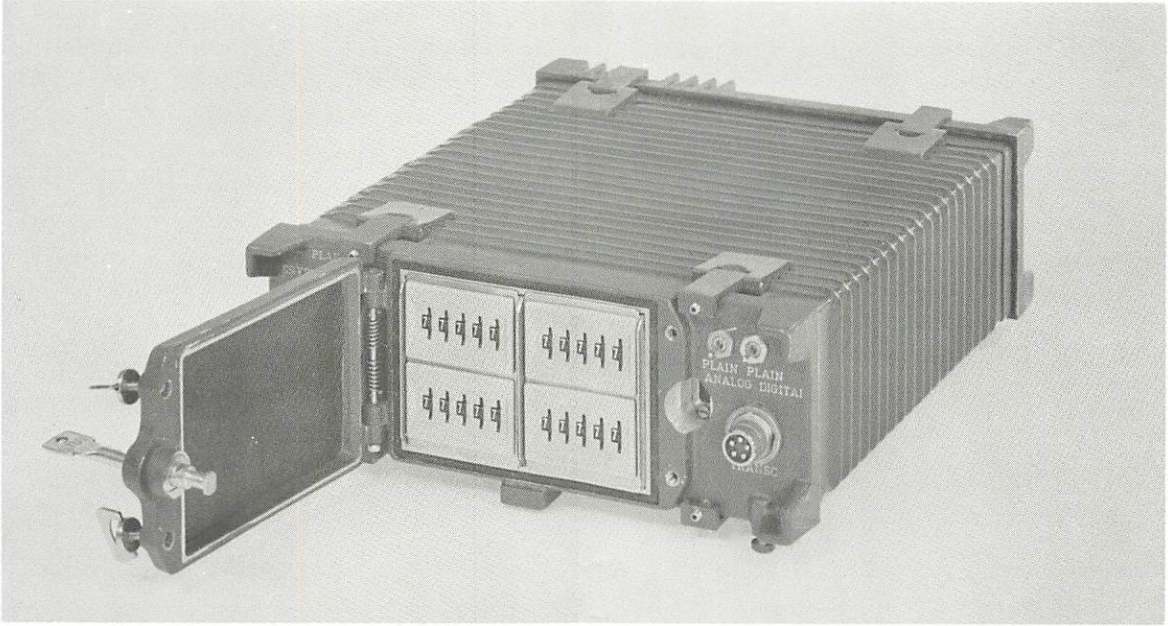

Figure 15. Front view of trial model of SPENDEX 10.

6. INTERFACE OF RADIO TRANSCEIVERS

The interface to the radio transceivers with which SPENDEX 10 is intended to work must have the following characteristics:

Output of SPENDEX 10:

Required input impedance of transceivers: more than 1 kilo-ohm.
Voltage of basic binary signal: maximum 6 volts peak-to-peak, adjustable to other levels according to the type of transceiver.
Frequency spectrum: 0 - 10 kHz.
Impedance formed by SPENDEX 10 in transmitting mode: about 200 ohms.

Input for SPENDEX 10:

Admissible level of input signal: between 20 mV and 10 volts peak-to-peak.
Output impedance of receiver: less than 390 ohms between 10 and 10.000 Hz.
Impedance formed by SPENDEX 10 in receiving mode: more than 3,9 kilo-ohms.

Overall transmission characteristics:

Bandwidth: flat to within 1.5 dB between 10 and 6000 Hz, gently sloping with less than 6 dB/octave between 0 - 10 Hz and 6000 - 10.000 Hz.
Delay distortion: less than 25 μs between 10 and 6000 Hz.

7. MAINTENANCE AND REPAIR

SPENDEX 10 requires the same level of preventive maintenance as the radio transceivers; calibrations or special adjustments are not necessary. The apparatus is of modular construction, with interchangeable plug-in units. Fault finding on third echelon level is quickly accomplished, without special tools or test equipment, by replacement of the modules one by one and noticing when the fault disappears. The faulty module itself must be repaired at the highest echelon. The manufacturer can keep service facilities at the client's disposal and perform highest echelon repairs.

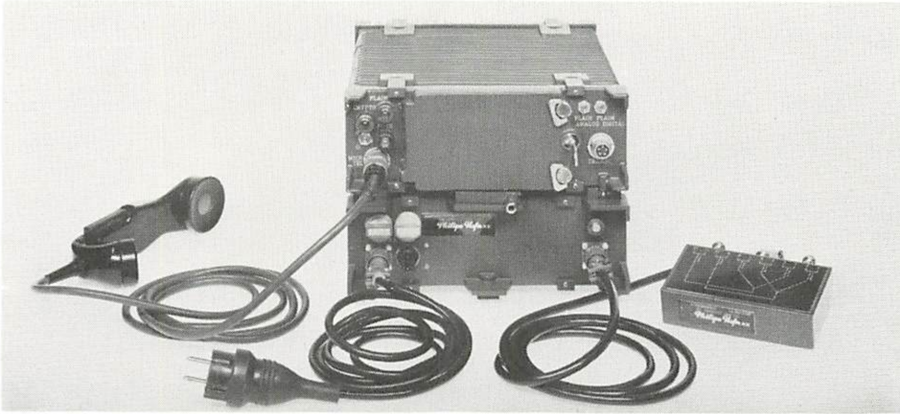

Figure 16. SPENDEX 10 with frequency-compressing Modem UA 8401.

8. ADAPTATION TO VARIOUS TRANSMISSION MEDIA

The output of SPENDEX 10 is available in two forms for further processing: filtered to 10 kHz on the front panel socket for injection into the radio transceiver, and unfiltered on the rear panel for use with other transmission media. With the aid of suitable adaptors, SPENDEX 10 can in principle be made to operate over any transmission medium which offers a bandwidth of between 10 and 10.000 Hz, flat within 1.5 dB. In the course of trials and suitability tests during development, various adaptors have been designed which might be useful for special applications.

8a. Unloaded field cables are sometimes used as means of communication for personnel guarding the perimeter of airfields and large staging areas where radio silence is necessary. SPENDEX 10, together with a special adaptor to offset the capacitance of the field cable and to attenuate the level of the received signal, has been used with excellent results over cables of some 15 kilometres in length.

8b. Carrier telephony systems usually have a free space between the service channel (0 - 3 kHz) and the lowest carrier channel, which begins at 12 kHz. A special modem (type UA 8401) is available which compresses the digital SPENDEX 10 output of 0 - 10 kHz into an analog 4 - 10 KHz signal (with a 10 kHz pilot), which just fits into the free space in the system. This provides a secure point-to-point connection parallel to the carrier link. Further details are given in section 11.

8c. Multiplex systems are equipped with amplifiers and modems for single channels of between 300 and 3400 Hz. Combination of the equipment for two adjacent channels into a wide-band "music" channel of some 8 kHz yields a secure point-to-point connection on fixed lines.

8d. Leased wide-band or music channels can also be made to accept SPENDEX 10 traffic when use is made of high-speed modems.

8e. Single Side Band systems with suppressed carrier are at the moment being investigated for their suitability of accepting SPENDEX 10 traffic. Further details available on request.

9. TECHNICAL DATA

Operational data

3 operating modes, viz crypto speech (digital)
clear speech (analog)
crypto data up to 600 baud (digital).

Entirely passive reception, automatically differentiating between the 3 operating modes.
Intentional transmission of clear speech only as long as the "Clear/Secure"-switch is kept pressed.
Simplex device with a press-to-talk switch, hence normal radio procedure not affected.
Only 2 operating controls, viz "On/Off"-switch and "Clear/Secure"-switch, hence no additional training for operators.

Cryptophonic data

Cryptophonic principle approved for tactical use and transmission of all classifications.
Reconstruction of key setting by means of intercepted crypto signals impossible.
More than 50% logatom-intelligibility, equivalent to better than 95% sentence intelligibility, at 9,6 kbits sampling frequency.
Entirely automatic and instantaneous synchronization, key starting and operation.
Capable of joining networks communications at any moment without delay.
Key setting by means of twenty lever-operated coding switches, hidden from view behind a lockable cover.

Transmission data

Decrease in range, caused by use of SPENDEX 10: 15% average.
Average error extension: approximately 50 bits.
Signal-to-noise ratio of received signal: minimum 10 dB.
Dynamic range of audio input levels: 30 dB.
Maximum permissible delay distortion of transmission medium: 25 micro-seconds between 10 and 6000 Hz.
Speech digitalization by means of digitally controlled delta modulation, requiring neither rigid frame nor bit synchronization.
Sampling frequency: 9,6 kbits/second; other frequencies applicable.
Frequency spectrum of digital signal: 0 to 10 kHz.
Digital output: 6 volts peak-to-peak or less, as required.
Required level of received signal: between 20 mV and 10 volts.
Data input: logical levels maximum 600 baud, minimum 1 baud.
Required bandwidth: flat to within 1.5 dB between 10 and 6000 Hz, gently sloping with max. 6 dB/octave between 6000 and 10.000 Hz.

Technical data

Physical data (pertaining to the RT 3600 design); length 315 mm, height 80 mm, width 255 mm, weight 5 kg, volume 7 litres.
Power requirements: 12 W between 20 and 31 volts d-c, protected against voltage peaks and reversal of polarity.
Operating temperature range between minus 30 and plus 55 degrees centigrade, storage temperature range between minus 50 and plus 70 degrees centigrade.
Immersible to 1 metre below surface, equipped with checking facilities for hermetic sealing.
Mean Time Between Failures, calculated according to MIL-Std-756-A and MIL-Hdbk--217-A, estimated to be well in excess of 2000 hours.
Suppression of radio interference according to MIL-Std-461-A, class 1c.
Meets relevant DEF 133 tests, category L2, and/or equivalent FINABEL 17-E-1 tests for panclimatic serviceability.
Constructed in accordance with the military specifications MMR 27 (construction), MMR 100 (preferred MIL SPEC components), and meets MIL-Std-275 (printed wiring).

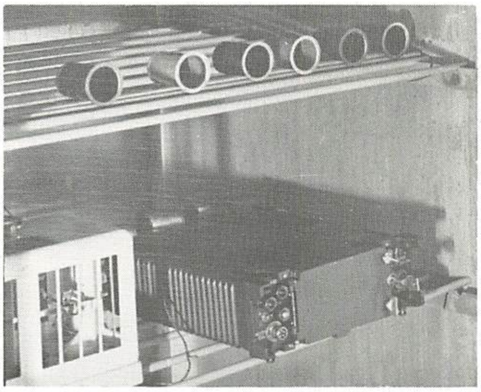

Figure 17. Tropical life testing.

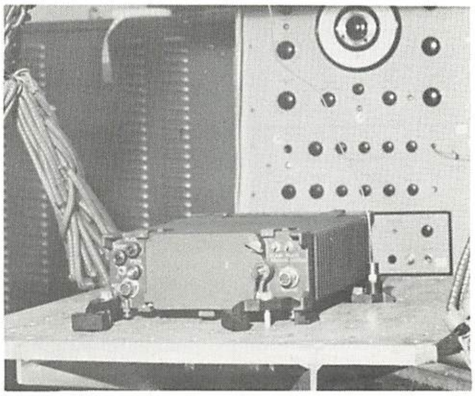

Figure 18. Vibration testing.

10. OUTLINE OF ENVIRONMENTAL AND CLIMATIC TESTING

For type approval, SPENDEX 10 can be subjected to the following sequence of tests, based on DEF 133 Specification, category L2:

DEF clause	Test	Remarks
6,1	Visual examination and functioning test	20 hours
7.0	Bump test	200 shocks, horizontally mounted
-	Reversal of power supply polarity, surges in power supply	65 volts max., 1 ms max.
15.3	Immersion test	1 m below surface
6.1	Visual examination and functioning test	20 hours
8.1	Resonance search test	5 - 1000 Hz, 1 g, 1 oct/2 min
8.2	Vibration functional test	5 - 1000 Hz, 2 g, together with tranceiver
8.3	Vibration endurance test	5 - 1000 Hz, 2 g
11.0	Dry heat test	test A with functional test test B 72 hours, switched off test A with functional test
11.1	Damp heat test	48 hours
12.1	Extra-low temperature exposure test	test A switched off, operating test at -30^{o}C
11.1	Damp heat test	48 hours
11.0	Dry heat test	test A with functional test
13.1	Rapid temperature cycling test, damp	13 cycles, functional test after each cycle
11.2	Tropical life test	twice 14 days, functional test during every 7 th period of 35^{o}C
7.1	Drop test	once on every corner, edge and plane, 5 cm drop height
7.4	Toppling test	5 times around each edge, 45^{o} angle
7.0	Bump test	during 5 minutes
15.3	Immersion test	1 m below surface
6.1	Visual examination and functioning test	20 hours

Note
Tests 14.0 (Corrosion, salt), 14.1 (Corrosion, acid), 14.2 (Corrosion, alkaline) and 14.3 (Contamination) to be carried out on samples of lacquered external parts, one cycle of 7 days per test.

11. FREQUENCY-COMPRESSING MODEM, TYPE UA 8401

The SPENDEX 10 output is a digital signal of approximately 10 kilobits/ second, which is not suitable for direct injection into a multiplex or radio relay system. The UA 8401 Modem compresses the digital signal into an amplitude-modulated analog signal of 4 to 10 kHz, with a 10 kHz pilot. The output of the modem thus neatly flits into the free space between the service channel (0 - 3 kHz) and the lowest carrier channel (12 kHz upwards) of most 12-channel carrier systems.

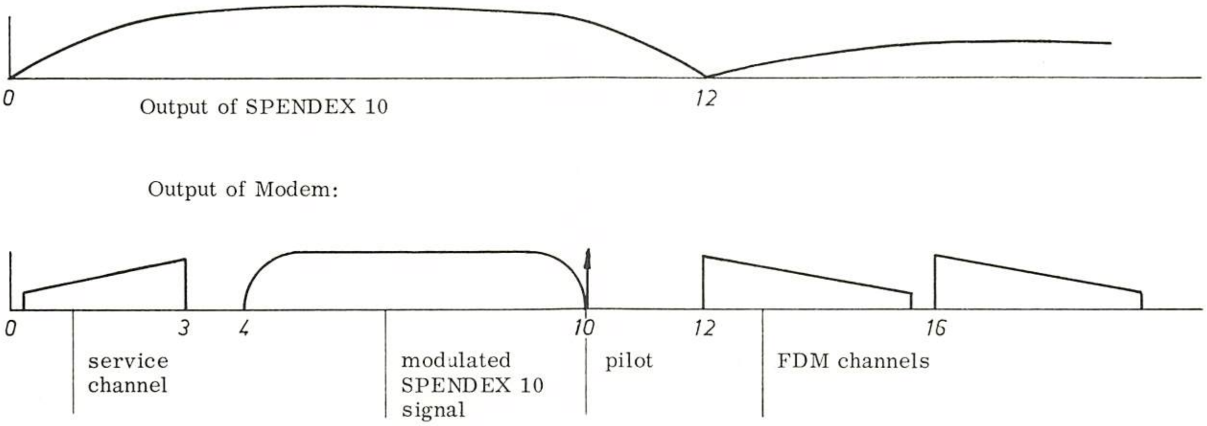

Figure 19. Frequency diagram of Modem UA 8401.

The output of the modem is combined with the output of the carrier system in a hybrid transformer for injection into, for instance, a radio relay transmitter. At the receiving end, the hybrid transformer separates the SPENDEX 10 channel again from the other signal on the link. The receiving part of the modem automatically demodulates the 4 - 10 kHz analog signal into a digital 10 kHz bit stream which is decyphered by the receiving SPENDEX 10. The modem is a full duplex device without operating controls. It is connected to the mains and supplies the 0.5 A, 24V d-c power for SPENDEX 10. In turn, SPENDEX 10 supplies the modem with the secondary voltages of 5 and 18 volts d-c. The combination of SPENDEX 10 and the modem can also be powered by a 24 volt accumulator. As depicted in figure 14, the construction of the modem is similar to that of the family of RT 3600 transceivers; it can be clipped on top of SPENDEX 10. The transmitting level of the modem is -15 dBm into 150 ohms, the receiving level must be between 0 and -30 dBm into 150 ohms.

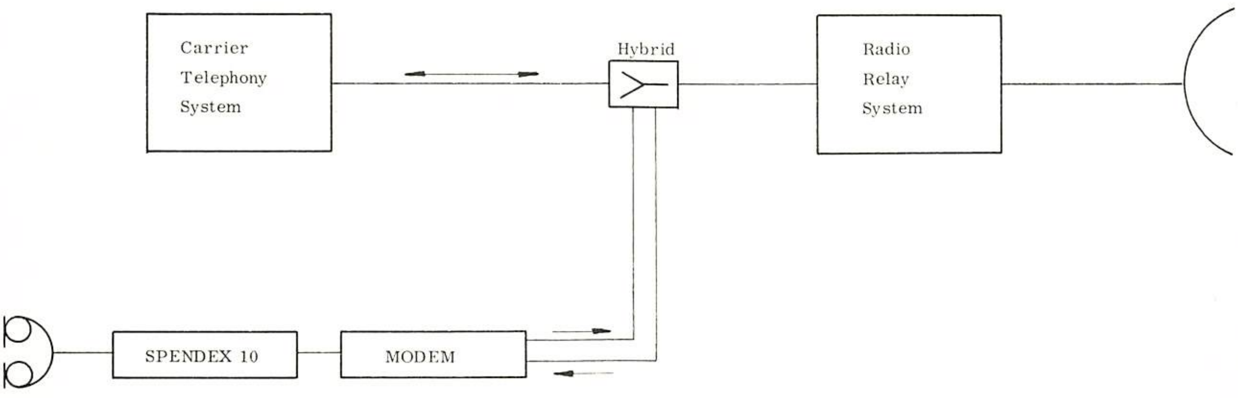

Figure 20. Block diagram of SPENDEX 10 + Modem on carrier system.