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</tbody>
</table>
## Summary of Contents

**No. 8 (Part I)**

**Equipment for Short-wave Reception**  page 5  
Survey of the reception problems discussed in Nos. 8 and 9 of this journal

**Multi-Coupler**  page 7  
General requirements to be met by multi-couplers and description of the HF Multi-Coupler Type NV 4

**The Short-Wave Receiver Type EK 07**  page 11  
Frequency pattern, selectivity, sensitivity. Equipment for monitoring the Short-Wave Receiver Type EK 07

**Technical Data of the Short-Wave Receiver Type EK 07**  page 17  
The specifications of the Type EK 07

**A Universal Demodulator for Telegraphy Signals**  page 23  
General requirements to be met by a telegraphy demodulator and description of the Telegraphy Demodulator Type NZ 07

**Diversity Reception in Short-wave Telegraphy**  page 30  
Advantages and disadvantages of the various types of diversity reception

**Modern Measuring Equipment for the Development of Telegraphy Diversity Systems**  page 36  
New measuring instruments and methods

**Addresses of our Branch Offices and Export Distributors**

**No. 9 (Part II)**

**Equipment for Short-wave Reception**  page 5

**A Demodulator Reproducing Single-sideband Transmissions**  page 7

**A Short-wave Receiver of Very High Stability and Setting Accuracy**  page 10

**The HF Monitoring Equipment Type NK 701**  page 12

**The Remote Control Equipment Type NZ 02 Used for Remote Control of the Short-Wave Receiver Type EK 07**  page 14

**Survey of the Conventional Types of Modulation**  page 23

The title page shows how short-waves are propagated up to 1300 km. The reception field strength is plotted for the various frequencies, as a function of the day time and the distance. Field strengths below 1 mv/m have not been considered.

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Equipment for Short-wave Reception

Short-wave transmission and reception has occasionally been called the classic field of radio engineering. In particular, this may be due to the fact that for decades this branch of radio engineering has been helping to establish radio communication with all parts of the world and that the equipment used reached a high degree of development at an early stage. Nevertheless, one would be mistaken to believe that development in this field cannot go much further. Especially in the last few years commercial short-wave equipment has changed considerably and Rohde & Schwarz has found here a vast field of interest.

The numbers 8 and 9 of the R&S Kurzinformation will give an idea of the present state of our production line as far as receiving equipment is concerned. The pages 5 and 6 give a fast survey of the problems and equipment at present being dealt with.

Antennas and Multi-couplers

In connection with the antennas which will be comprehensively discussed in an R&S publication to be issued somewhat later, it shall be mentioned here only that it appeared desirable to realize efficient antenna configurations in spite of smaller dimensions. This does not concern only the dimensions of antennas, but rather it should be possible also to make do with very small antenna sites. In particular, diversity reception presently needed for telegraphy still required a vast area only a few years ago. This was necessary to accomplish the space-diversity effect by separate erection of the antennas. Recent studies showed that the different polarization of the incident radiation is equally well usable for diversity reception and, moreover, offers the advantage that only one antenna system need be erected for a station. Furthermore, it is now possible to build remote-controlled, wide-band directional antennas with variable direction of radiation, in a manner which also means a considerable saving in terrain. These questions are more fully discussed in the section dealing with diversity reception.

Only a few years ago, large receiving stations, which have to pick up signals from all parts of the world and where several receivers are to be operated at the same time, used to erect a large number of antennas and to operate each receiver from a separate antenna. This was due to the fact that it is impossible to connect several receivers to one antenna without a considerable sacrifice in the quality of reception, since receivers which operate on different frequencies might mutually be shorted out.

Today it is possible to build wide-band multi-couplers, which possess several outputs and are sufficiently sensitive, yet so free from distortion that the signals reaching the amplifier input on all frequencies at the same time do not set up new spurious frequencies because of pronounced non-linearities in the amplifier. This method, only one decade ago scorned by the radio operators because of inadequate equipment, has now found general acceptance. Multi-couplers now available feature high freedom from distortion, and there are installations now in operation where fifty receivers are tied to one antenna, two or more multi-couplers being connected in cascade.
**Receivers**

The receivers have undergone a fundamental change. This short-wave band being particularly crowded, fast location of a transmitter is possible only if the frequency setting is sufficiently stable and the frequency scale of the receiver sufficiently accurate to ensure tuning to the frequency with a setting accuracy of a few hundred cycles per second. Reception of single-sideband signals with fully suppressed carrier requires a setting accuracy of a few cycles per second. This requirement has led to a considerable modification of the local oscillator of the receiver. The subject of the frequency synthesis or of the design concept of the receiver is treated in greater detail in this journal.

Today, the requirement is for automated reproduction of telegraphy signals. This holds particularly for radioteletype, where the teleprinter is now expected to function so reliably that the service of a radio operator who still in post-war years picked up the Morse code by ear and scribbled it down is no longer needed. This means considerable savings in personnel, and also the development of additional equipment, such as high-quality telegraphy demodulators, and accessory units for diversity reception. Telegraphy demodulators suitable for driving the teleprinters directly no longer use mechanical telegraph relays, but controlled semiconductors. This simplifies maintenance of the equipment.

Single-sideband reception, which for a long time has been used between large fixed stations, is gaining in importance of late. Its advantages are well known. A few of these advantages will be treated more fully in connection with individual units. The above-mentioned fact that it is now possible to build receivers of very high setting accuracy and stability facilitates single-sideband reception considerably since it is otherwise necessary to operate with residual carrier and AFC circuits in the receiver, rendering the manipulation of the sets more difficult.

Receivers covering the entire short-wave band with extreme stability are now available. Here and there radio networks are being established using single-sideband transmission without carrier.

**Remote Control of Short-wave Receivers**

A technique which is very modern but has to do with old problems is the remote control of short-wave receivers. The aim is to set up receiving stations in a terrain which offers maximum freedom from industrial noise of any kind. The operators generally like to live and work in town and, for organisational reasons also, it is important to have a common centre for associated transmitting and receiving stations which, of necessity, must operate from separate sites.

Receivers of modern design for frequency synthesis offer the possibility to build relatively small units for remote control. It should then be ensured that the control unit is undistinguishable from the receiver in the unattended station. This is particularly true for accurate tuning of the receiver, that is, the setting accuracy of the receiver must be retained.

A survey of a facility for remote control of a short-wave receiver is given in this journal and in an article published in the Rohde & Schwarz Mitteilungen No. 17.

J. Haaks
Multi-Coupler

Probably each modern radio receiving station has provisions for several receivers to be operated from one antenna. This involves the problem of amplifying the available signal power in a multi-coupler and splitting it up between several outputs in a manner simulating for each receiver a direct connection to the antenna. The following requirements must be satisfied to solve this problem:

1. The inherent noise power of the multi-coupler must be such that the total noise power of the antenna, multi-coupler and receiver together is not greater than when the multi-coupler is not used.

2. The linearity of the multi-coupler should ensure that under normal receiving conditions spurious voltages due to harmonics, difference frequencies and cross modulation are much weaker than the signal voltage picked up.

3. Interaction between the multi-coupler outputs should be down so far that the receivers do not affect each other by oscillator reradiation.

4. The multi-coupler should cover the entire range of the connected receivers without band switching.

5. The input impedance should be constant over the entire frequency range to avoid mismatch of the antenna.

6. The power consumption of the multi-couplers from the AC supply should be low to enable many multi-couplers to be housed in a rack without additional ventilation.

7. Defect of an amplifying valve should cause no serious trouble. No more than one of the connected receivers should then be affected.

The section Circuitry and Performance of the R&S Multi-Coupler Type NV 4 shows the extent to which the above requirements are fulfilled by this multi-coupler.

**Measuring the Distortions of a Multi-Coupler**

Generally, the degree to which a multi-coupler is free from distortion is stated by measuring the harmonics and combination frequencies caused by second- and third-order distortions. Higher-order distortions produce more combination frequencies, but their amplitude is so low that they do not disturb the reception more than second- and third-order distortions do.

If only one frequency, \( f_s \), drives the multi-coupler, the second-order distortions produce the harmonic \( 2f_s \) and the third-order distortions produce the harmonic \( 3f_s \). A multi-coupler driven by two frequencies, \( f_1 \) and \( f_2 \), produces not only harmonics but also combination frequencies. The second-order distortions then give rise to the sums \( (f_1 \pm f_2) \) and the third-order distortions cause the image frequencies \( (2f_1 \pm f_2) \) and \( (2f_2 \pm f_1) \). The amplitude of the harmonics is stated by the distortion factors \( K_{2s} \) and \( K_{3s} \) and that of the combination frequencies by the ratios \( r_{2s} \) and \( r_{3s} \). Another quantity making itself felt is the cross modulation \( c_m \) designating the modulating effect which an amplitude-modulated, unwanted transmitter has upon the signal. If the distortions are low compared to the amplitudes of the fundamental waves, the following is true for second-order distortions:

\[
K_{2s} = \frac{\text{amplitude of frequency } 2f_s}{\text{amplitude of fundamental wave}} \quad (1)
\]

and

\[
r_{2s} = \frac{\text{amplitude of frequency } (f_1 \pm f_2)}{\text{amplitude of fundamental wave}} \quad (2)
\]

The two quantities thus defined are mutually proportional.

\[
K_{2s} : r_{2s} = 1 : 2 \quad (3)
\]

Moreover, the third-order distortions give rise to the three quantities:

\[
K_{3s} = \frac{\text{amplitude of frequency } 3f_s}{\text{amplitude of fundamental wave}} \quad (4)
\]

\[
r_{3s} = \frac{\text{amplitude of frequency } (2f_1 \pm f_2) \text{ or } (2f_2 \pm f_1)}{\text{amplitude of fundamental wave}} \quad (5)
\]

and

\[
c_m = \frac{\text{modulation effect on signal}}{\frac{1}{4} \text{ modulation of unwanted transmitter}} \quad (6)
\]

Rohde & Schwarz, Die Kurzinformation No. 8
These three quantities are also mutually proportional, and they are covered by the relation

\[ K_3 : r_{im} : c_m = 1 : 3 : 12 \]  \hspace{1cm} (7)

It is sufficient to determine only one quantity in each of the two groups according to the stated relationship; the others can then be calculated if the amplitudes of the two input frequencies are equal. If both frequencies are jointly changed in their amplitudes, the formulae for converting the three quantities \( K_3, r_{im} \) and \( c_m \) are

\[ K_3 = \frac{G_{m3} E_i^2}{12} \]  \hspace{1cm} (8)

\[ r_{im} = \frac{G_{m3}}{4} E_i^2 \]  \hspace{1cm} (9)

\[ c_m = G_{m3} E_i^2 \]  \hspace{1cm} (10)

where \( G_{m3} \) is a constant which is proportional to the third-order component of the mutual conductance of the multi-coupler amplifier. However, this conversion makes sense only if the amplitudes at the input are small so that combinations due to distortions of higher order need not be taken into account.

An example of the conversion may stand in good stead. Assume a multi-coupler with an image-frequency amplitude ratio \( r_{im} \) of 70 db where both frequencies are of an input EMF of \( E_1 = 100 \text{ mv} \). Find the input voltage for which the image-frequency amplitude ratio is 40 db. The conversion is made by using formula (9) twice. Let the source impedance be equal to the input impedance of the multi-coupler so that the input voltage is half the EMF.

\[ r_{im1} = 70 \text{ db} = 3.15 \times 10^{-4} \]
\[ E_1 = \text{EMF/2} = 50 \text{ mv} \]
\[ r_{im2} = 40 \text{ db} = 10^{-4} \]

Find \( E_2 \)

According to (9)

\[ r_{im1} = \frac{G_{m3}}{4} E_i^2 \]  \hspace{1cm} (9a)

and

\[ r_{im2} = \frac{G_{m3}}{4} E_i^2 \]  \hspace{1cm} (9b)

Hence

\[ \frac{r_{im1}}{r_{im2}} = \left( \frac{E_i^2}{E_i^2} \right) \]

\[ E_2 = \sqrt{\frac{10^{-4}}{3.15 \times 10^{-4}}} \times 50 = 282 \text{ mv} \]

An equivalent circuit is shown in Fig. 1. Measuring the distortions of a multi-coupler.

In practice, one mostly measures the quantities \( r_{im1} \), \( r_{im2} \) and \( c_m \), the first two being determined using the arrangement shown in Fig. 1. Here, two signal generators supplying the frequencies \( f_1 \) and \( f_2 \) are connected to the multi-coupler under test via a matching network. The matching network contains three resistors each of Z/3. It ensures that the signal generators and the multi-coupler are match-
terminated provided the source and input impedances are equal. The attenuation of this matching network is 6 dB for each signal generator. The mixture product present at the output of the multi-coupler is measured with a selective valve voltmeter, such as the Type USVH, or with a measuring receiver.

The cross modulation can be determined using a test rig similar to the one set up for measuring the mixture products of the second- and third-order distortions. It is only necessary that the signal generators be capable of being modulated to an accurately-known depth. Moreover, an AF voltmeter should be connected to the output of the selective

Circuitry and Performance of the HF Multi-Coupler Type NV 4

As shown in the block diagram (Fig. 2) the antenna power is fed to the multi-coupler via a high-pass filter. This filter prevents all unwanted frequencies, above all such of powerful medium-frequency broadcast transmitters, from reaching the input of the amplifier stages. The input filter is followed by a wideband transformer matching the generally unbalanced feeders to the balanced reactive network of the multi-coupler. However, this wideband transformer can be laid out also for balanced antenna inputs. Starting from the wideband trans-

![Fig. 2 Simplified diagram of the Multi-Coupler Type NV 4](image)

valve voltmeter or measuring receiver so that it is possible to measure the modulation voltage. First, one of the two signal generators is adjusted to give the modulated signal. The AF developed in the measuring receiver is measured and its value is recorded. Next, the modulation of the signal generator is switched off, care being taken for the RF level to remain unchanged. The other signal generator, representing the unwanted transmitter, is adjusted for a frequency so far off-tune from the signal that the measuring receiver cannot deliver any demodulated information. The signal generator representing the unwanted transmitter is then modulated to the same depth as the first signal generator, the level being increased until the measuring receiver delivers 10% of the AF amplitude measured before. The RF amplitude of the unwanted transmitter thus measured is used to specify the cross modulation.

former the amplifier operates in push-pull, the even distortions thus being considerably reduced. Each output has a separate push-pull amplifier whose input capacitance constitutes the shunt capacitance of the reactive network. Use of the reactive network mutually isolates the paralleled input capacitances of the stages. Every amplifier stage consists of two double triodes of the type E 88 CC. They are arranged in a cascode circuit. This circuitry makes for a low noise figure and the low direct capacitance required for good isolation between the outputs.

Freedom from distortion is accomplished by wide-band feedback. A study [1] showed that in a cascode arrangement using the above-mentioned valves, feedback through an unbypassed cathode resistor of the input valve is sufficient up to the high-frequency limit of the amplifier even without additional equalization.
Freedom from distortion depends largely on the balance condition of the push-pull circuit. Balance is ensured even as the valves age, because a DC feedback with a high-valued cathode resistor is employed in each stage. Moreover, the grid bias of the valves is stabilized. These measures maintain a high degree of balance even if the emission of the valve drops to half the rating.

causing a cross modulation of 10%. Based on the image frequency measurement the calculation would then give an unwanted signal EMF of 4v for the multi-coupler. With voltages that are too high the effect of higher-order distortions is, of course, no longer negligible. A separate cross modulation measurement is therefore recommended. The cross modulation measured at the multi-coupler

Fig. 3 Multi-Coupler Type NV 4

The performance of the Multi-Coupler Type NV 4 satisfies the requirements mentioned in the beginning to a large extent.

The push-pull cascade circuit of the Multi-Coupler Type NV 4 warrants a sensitivity of 5 to 9 db in the operating range. A voltage gain of 1 to 3 db of the entire amplifier reduces the noise power of the connected receiver so that the noise figure of the multi-coupler together with a receiver is hardly greater than that of the receiver alone.

An EMF of 70 mv present at each input results in combination frequencies \(f_1 \pm f_2\) whose level is more than 80 db below the one obtained with an EMF of 70 mv present at the amplifier input on the same frequency. Mixture products due to third-order distortions, viz. \((2f_1 + f_2)\) and \((2f_1 - f_2)\), are at least 100 db below the voltage resulting from an amplifier input EMF of 80 mv on the same frequency if the input EMF on the two frequencies \(f_1\) and \(f_2\) \(<\ 80\ mv\).

The relations stated in the foregoing permit the cross modulation to be calculated from the measured values. An unwanted transmitter coming in with an input EMF of 80 mv would cause a cross modulation of \(-88\ db\). In practice, such a low value of cross modulation is quite negligible. Mostly, one therefore specifies the unwanted-transmitter voltage is less than 10% at an antenna input EMF of 2.6v. The interaction between the outputs is down more than 40 db and down more than 50 and 60 db over the largest portion of the frequency range. Failure of a valve to emit will cause outage of one receiver in the most adverse case. The effect on the other receivers is then hardly noticeable.

The Multi-Coupler Type NV 4 has six outputs enabling six receivers to be connected to one antenna. The low noise power and the very low distortions make it readily possible to connect two multi-couplers in cascade if it is necessary to operate more than 6 receivers from one antenna. Driving six multi-couplers from the first one, up to thirty-six receivers may thus be connected.

The Multi-Coupler NV 4 is very small. It can be delivered to fit into German standard racks (front panel width 520 mm) or into 19" racks. The power input as well as the multi-coupler inputs and outputs are in the rear. The front panel of the multi-coupler contains only the power switch, the fuses and the meter with the check switch. The panel meter permits the anode voltages of the valves and thus the power supply and the operating points of the valves to be checked. The valves are accessible after removal of a perforated cover. Multi-couplers accommodated in a rack are screwed in place through holes in the front panel.
Freedom from distortion depends largely on the balance condition of the push-pull circuit. Balance is ensured even as the valves age, because a DC feedback with a high-valued cathode resistor is employed in each stage. Moreover, the grid bias of the valves is stabilized. These measures maintain a high degree of balance even if the emission of the valve drops to half the rating, causing a cross modulation of 10%. Based on the image frequency measurement the calculation would then give an unwanted signal EMF of 4 V for the multi-coupler. With voltages that are too high the effect of higher-order distortions is, of course, no longer negligible. A separate cross modulation measurement is therefore recommended. The cross modulation measured at the multi-coupler

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Experience gained in the last few years has shown that multi-couplers are now essential for modern radio receiving stations. Freedom from distortion of modern multi-coupler is such that the properties of the receivers are practically not impaired. Even in receiving stations many miles away from inhabited areas and in which man-made noise therefore plays only a minor role the noise level in the short-wave range is such that a slight loss in sensitivity due to the multi-couplers would remain unnoticed. Any scepticism about the usefulness of modern wideband multi-couplers appears therefore unjustified even for receiving stations in areas with an extremely low noise level.

K. Grabe

(In German only.)

The Short-Wave Receiver Type EK07

The heart of the R&S short-wave receiving equipment is the Receiver Type EK07 covering 0.5 to 30.1 Mc. This receiver employs modern frequency synthesis for the local oscillator. It is well known that high stability and setting accuracy of a short-wave receiver is obtainable by various design concepts. Probably the oldest one in practical use features a variable intermediate frequency as shown in the block diagram Fig.1b in contrast to that of the conventional superheterodyne receiver (Fig.1c). Here the first oscillator, which essentially determines the stability of the receiver, is a crystal oscillator, occasionally a separate crystal being available for each frequency range of, say, 1 Mc. Accordingly, the first intermediate frequency is variable in the range of 1 Mc; only an interpolation oscillator used for the second frequency changing causes the development of a stable second intermediate frequency. This circuitry has the disadvantage that it is necessary either to provide the first intermediate-frequency section with variable filters or to give the intermediate frequency a large constant bandwidth. The first alternative leads to an elaborate design — practical receivers of this type contain up to eight selective circuits — the second increases the danger of cross modula-

![Diagram](attachment:image.png)

Fig. 1 Double-superheterodyne receiver with a fixed (a) and a variable (b) intermediate frequency.

The solution is to provide the first oscillator with a fixed frequency and the second oscillator with a variable frequency. This combination is shown in Fig. 1a. The advantages of this arrangement are evident: high stability of the receiver without the necessity of elaborate filters or the increased danger of cross modulation by undesired signals within the large IF bandwidth.
The Frequency Pattern of the Receiver Type EK 07

The frequency pattern of the Receiver Type EK 07 is shown in the block diagram of Fig. 2. Here use is made of a conventional superheterodyne receiver with double frequency changing and two fixed intermediate frequencies. The stability and setting accuracy are established by the layout of the first oscillator. The frequency of this oscillator is built up from the harmonics of a 3-Mc crystal oscillator and the frequency of an interpolation oscillator. The second oscillator operates also on the frequency of the crystal. A so-called phase-loop circuit is employed to eliminate spurious mixture products or image frequencies resulting from beating the crystal frequency and interpolation-oscillator frequency. This arrangement includes a free-running first oscillator operating on the final oscillator frequency, which is checked and controlled. To this end, it is translated into the frequency range of the interpolation oscillator by mixing with crystal-oscillator harmonics and then heterodyned with the interpolation-oscillator frequency in a phase-sensitive bridge.

If the frequency of the first oscillator is accurate, the output voltage of the phase comparison circuit is a DC voltage which synchronizes the first oscillator at its nominal frequency, via a frequency-controlling stage. This circuit arrangement has now found general acceptance and offers the advantage of combining simplicity with good rejection of spurious frequencies since there can be eliminated by a low-pass filter in the control loop.

The fact that the Receiver Type EK 07 is successful in practice and popular with radio operators may be mainly due also to its properly arranged scale and range width. This will be discussed later in greater detail.

The short-wave range of the Receiver Type EK 07, 3 Mc to 30 Mc, is subdivided into 9 bands each 3 Mc wide. Consequently, the interpolation oscillator, which in addition to the crystal harmonics governs the frequency stability, has also been given a variation span of 3 Mc.

The interpolation oscillator has a strictly linear frequency response. Accordingly, it is possible to divide the frequency scale of the receiver into a coarse and into a fine scale, the cursor movement over a 100-kc division of the coarse scale corresponding to a complete rotation of the fine scale. Thus the fine scale is rotated thirty times for covering a 3-Mc band. Practically, this means a scale discrimination of 300 cps per one mm and a total scale length of about 100 metres. Reading accuracy, after all a prerequisite of the setting accuracy, is thus ensured. Stability and setting accuracy of the interpolation oscillator, additionally required, are facilitated by the fact that band switching of the interpolation oscillator is unnecessary since always the same band, 3.4 to 6.4 Mc, needs to be covered. The oscillator is housed in a rugged casing. The straight-line-frequency shape of the capacitor plates is maintained correct by a circular plate of the variable capacitor. Thirty fine-adjustment screws in the stator plate opposite the circular plate of the variable capacitor can be approached to the outer rotor plate as near as desired. This permits the frequency response of the variable capacitor to be accurately adjusted for each 100-kc step so that any spread between individual capacitor can be compensated for. (Fig. 3). The oscillator possesses a silver coil embedded in enamel baked on a ceramic coil former. The rotor of the variable capacitor is slightly offset from its middle position between the stator plates. Shifting the spacing between rotor and stator plates due to thermal expansion will then make up for the natural temperature coefficient of the metal.

The interpolation oscillator is hermetically sealed. The cover of the casing surrounding the interpolation oscillator and the feed-throughs of the leads are airtight. A cartridge filled with silicagel keeps the interior of the casing dry. This is necessary since air-humidity variations change the dielectric of the variable capacitor, and a film of moisture in the ceramic shafts and the coil together with particles of dirt cause reactive current changes which, also as a function of the degree of moisture, entail frequency variations.
All these measures ensure a setting accuracy of 500 to 1000 cps for the receiver without recalibration of the scale being necessary. This involves the question of the setting accuracy suitable in the short-wave region. Here, it is firstly necessary to consider the task of the receiver used. If the receiver is essentially used to identify the transmitter clearly and if the operator is then required to tune manually for optimum reception either on the receiver or on an auxiliary demodulator, a setting accuracy between 500 cps and 1000 cps is suitable and sufficient. However, if it is intended to adjust the receiver only by referring to the scale and then to demodulate VF telegraphy signals or single-sideband transmissions with the carrier completely suppressed, a setting accuracy between 10 and 50 cps is needed depending upon the requirements. (See number 9, p. 8). These figures, 10 to 50 cps, do not refer to transmissions of music in single-sideband operation (see number 9, p. 8) which is rare and is mostly affected with residual or full carrier. They refer to voice communication in single-sideband operation or to the adjustment of telegraphy systems and especially of VF telegraphy systems. Here the required setting accuracy and stability are as specified, 10 to 50 cps.

According to what has been said above, it is inadvisable to aim at a setting accuracy of about 100 to 250 cps because it is too good for the first purpose and thus requires an unnecessarily elaborate circuitry, whereas it is insufficient for the other purpose, single-sideband reception without carrier, so that it would take a skilled operator to readjust the receiver. The Receiver Type EK 07 is designed to serve mainly the first purpose which today is still the most frequent one. The Receiver Type EK 11 and the Short-Wave Receiving Equipment Type NK 701 are very suitable for the second purpose. They are respectively discussed on pages 10 and 13 of number 9.

A certain point should not be overlooked. An extremely high setting accuracy calls for an extremely long or greatly subdivided scale. Such receivers are therefore unsuited to search reception, because they can always cover only a very small portion of the frequency range. In the case of the Receiver Type EK 11 with its setting accuracy of 10 cps, this is a band of only 10 kc.

In contrast, the Receiver Type EK 07 is excellent for monitoring because its scale covers the wide frequency range of 3 Mc in spite of a relatively high setting accuracy. Consequently, it lends itself also to automatic frequency monitoring as is possible e.g. in conjunction with a recorder of Messrs. Huber. (Fig. 4). Here it becomes obvious once again that it is disadvantageous to aim at setting accuracies between 100 and 250 cps since these sets also are mostly tunable only over narrow ranges and thus are poorly suited or completely unsuited to monitoring.
Selectivity and Sensitivity

The other features of the Receiver Type EK 07 are simple to outline, resulting as they do from the clear-cut design concept of a double superheterodyne receiver with a stable intermediate frequency. There are three tuned circuits in the RF stages, two of the tuned circuits being arranged immediately at the input. This affords the advantage of undisturbed reception also in the neighbourhood of powerful transmitters. It is thus possible to tolerate an undesired signal of 10 x at the input if the undesired transmitter is off-tune 10% or more from the centre-frequency of the desired signal. The sensitivity of the receiver is only slightly affected by the two tuned circuits at the input; the noise figure is better than 10 db. It is a general rule that increasing the sensitivity of a receiver is reasonable only if the noise inherent in the receiver is weaker than the noise picked up by the antenna. Practically, the HF range differs here quite markedly from the VHF and UHF ranges. Measurements have shown that radio noise in big towns is rarely below a level corresponding to a noise figure of 27 db. Even in excellent receiving stations, that is, far away from large inhabited areas, the effect of atmospherics due to thunderstorms is such that in the short-wave region values lower than 17 db are hardly ever measured. Decreasing the noise figure of an HF receiver far below 10 db therefore makes no sense unless in a few special cases extremely long down-loads from the antenna are used. In these cases, antenna noise and signal would be attenuated until the noise component is eventually of the order of the receiver noise. However, this is in fact an extreme case which happens only in connection with excellent and highly directive antennas.

The image rejection of the set is high owing to the three tuned RF circuits, the respective values being >70 db at the low and >80 db at the high fre-
SHORT-WAVE RECEIVER
Frequency Range 0.5 to 30.1 MC

Uses

The Short-Wave Receiver Type EK 07 is excellent as a communication and monitoring receiver, even under adverse receiving conditions in mobile and fixed radio stations. It is particularly useful also in large stations, in monitoring of assigned frequency bands, and in commercial telegraphy as well as telephony. Not only amplitude-modulated stations radiating A1 to A4 signals will be received, but, with ancillary units, also F1 to F4 and F6 modulated signals as well as single-sideband transmissions of the types A0A and A06.

Outstanding Features

Exceptional setting accuracy of better than 1 kc, scale discrimination of 300 cps per mm throughout the entire short-wave range, extreme stability.

Easy-to-read linear scale, rapid tuning in on a transmitter. Single-knob tuning for all tuned circuits with coarse and vernier drives.

High selectivity and image rejection with three tuned input circuits, high degree of freedom from cross modulation and high discrimination against powerful local transmitters. Bandwidth adjustable in six steps from \( \pm 0.15 \) to \( \pm 6 \) kc. Balanced noise limiter which can be switched in and out of circuit. Very careful automatic volume control with five voltages which differ in amplitude and, in part, in delay; time constants of 0.1, 1, and 10 sec, switch-selected and unaffected when Type EK 07 receivers are combined for diversity reception; "MVC + AVC" operation with adjustable response threshold.

Diversity selection possible by interconnection of AVC outputs. A keying relay can be connected for break-in operation. External oscillator- or crystal-standard frequencies may be applied. Output sockets for first and second intermediate frequencies. Facilities for simple measurement of transmitter frequencies.
Connectors for ancillary units such as single-sideband selector, single-sideband demodulator, and telegraphy demodulator.

Monitoring possible owing to r-f panel meter and performance-check panel meter with switch selecting the individual valve stages and r-f output voltages. Scale illumination of adjustable intensity.

Remote Control
Remote control of the Receiver Type EK 07 is possible even over a long distance. Apart from the control unit, it is then just necessary to have the usual two-wire circuit over which the modulation picked up in the receiver can be returned at the same time. Remote control does not involve any loss in setting accuracy; the frequency adjustment on the dial is indicated at the control unit.

Description
The receiver can be supplied as a rack-mounting unit for German standard racks 520 DIN 41.490, panel size 520 x 304 mm, for 19-inch standard racks, panel size 482.5 x 311.2 mm, or as a self-contained unit in a steel cabinet 540 x 340 x 535 mm in size, for the 520-mm chassis.

For ease in servicing, the receiver is generally made up of plug-in type assemblies.

The front panel contains the r-f meter and the performance-check meter, the coarse and vernier dials, the headphone sockets, and all controls used in normal operation. A recessed section of the rear wall contains all input and output connectors and a few buttons which must be depressed when connection to certain sockets is made.

Electrical Data

Frequency range . . . . . . . . . . 0.5 to 30.1 mc, total

Range A . . . . . . . . . . . . . . . . 3.1 to 30.1 mc
  divided into the sub-ranges IV to XII each 3 mc wide, coarse and
  vernier dials with linear scales of sufficient overlapping

Calibration . . . . . . . . . . . . . . . . in megacycles and kilocycles

Scale discrimination . . . . . . . . . . 300 cps per mm throughout Range A

Setting accuracy . . . . . . . . . . better than 1000 cps without calibration
  after an operating time of 30 minutes at an ambient temperature
  of 15 to 25°C

Range B . . . . . . . . . . . . . . . . 0.5 to 3.1 mc
  divided into the sub-ranges I to III, viz. 0.5 to 1.1 to 2.1 to 3.1 mc;
  coarse scale calibrated, vernier scale with 100 divisions

Data common to Ranges A and B:

Type of emission . . . . . . . . . . A1, A2, A3, A4

with ancillary units . . . . . . . . . . F1, F2, F3, F4, F5, F6, A20, A21

Intermediate frequency . . . . . . . . ranges I to IV: 300 kc
  ranges V to XII: 1st IF 3.3 mc; 2nd IF: 300 kc

IF bandwidths . . . . . . . . . . . ±0.15, ±0.3, ±0.75, ±1.5, ±3.0, ±6.0 kc
## IF Filter Selectivity

<table>
<thead>
<tr>
<th>Bandwidth setting</th>
<th>20 db</th>
<th>40 db</th>
<th>60 db</th>
</tr>
</thead>
<tbody>
<tr>
<td>±0.15 kc</td>
<td>less than ±0.45 kc</td>
<td>less than ±0.95 kc</td>
<td>less than ±1.35 kc</td>
</tr>
<tr>
<td>±0.3 kc</td>
<td>less than ±0.55 kc</td>
<td>less than ±1.0 kc</td>
<td>less than ±1.5 kc</td>
</tr>
<tr>
<td>±0.75 kc</td>
<td>less than ±0.85 kc</td>
<td>less than ±1.05 kc</td>
<td>less than ±3.25 kc</td>
</tr>
<tr>
<td>±1.5 kc</td>
<td>less than ±1.0 kc</td>
<td>less than ±2.0 kc</td>
<td>less than ±2.9 kc</td>
</tr>
<tr>
<td>±3.0 kc</td>
<td>less than ±1.0 kc</td>
<td>less than ±2.1 kc</td>
<td>less than ±3.5 kc</td>
</tr>
<tr>
<td>±6.0 kc</td>
<td>less than ±1.7 kc</td>
<td>less than ±3.5 kc</td>
<td>less than ±6.0 kc</td>
</tr>
</tbody>
</table>

---

**IF Rejection**

- better than 90 db in Range A.

**Image Rejection**

- range I to IV: better than 70 db
- range V to XII: better than 80 db

**Cross Modulation**

An interfering transmitter modulated 50% and 20 kc off-tune from a station operating on its mid-frequency causes less than 10% cross modulation when the ratio of interfering signal amplitude to desired signal amplitude is smaller than 60 db and the interfering input signal is smaller than 50 mv.

**Noise Figure**

- 10 db, approximately

---

<table>
<thead>
<tr>
<th>Signal-to-noise ratio</th>
<th>for input voltages of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1: Reception</td>
</tr>
<tr>
<td>0.4 μv to 20 db</td>
<td>Bandwidth ± 300 cps</td>
</tr>
<tr>
<td>1.3 μv to 30 db</td>
<td>4 μv to 20 db</td>
</tr>
<tr>
<td>5.5 μv to 40 db</td>
<td>100 μv to 40 db</td>
</tr>
</tbody>
</table>

**Readiuction**

- approx. 5 μv with the aerial input terminated by 60 Ω

**Standardizing Oscillator**

- controlled by 300-kc crystal

**Aerial Connection**

- (a) with coax. connector FD 413/21 for 50- to 75-Ω feeders
- (b) telephone socket for high-impedance feeders (balanced high-impedance feeders with transformer connected ahead)

**IF Output**

- 300 kc; EMF: 100 mv, 250 Ω

**AVC**

- forward and backward control; at an input voltage between 0.7 μv and 100 mv the output voltage varies less than 3 db

**AVC TimeConstants**

- 0.1; 1; 10 sec

**AVC Voltage Output**

- for recording and for direct connection of 2 or 3 receivers for diversity reception

**BFO**

- 0 to ±3000 cps, adjustable; can be switched out of circuit

**Monitoring of Aerial Voltage**

- by meter

**Audio-Frequency Response**

- 40 to 6000 cps: ±3 db

**Noise Limiter**

- adjustable; can be switched out of circuit

**Output for Transmission Line**

- level 0 db into 600 Ω at A and 30% modulation; distortion less than 1.5%

**AF Power Output**

- 2 w into 15 Ω;
- distortion approx. 1.5% at 1 watt

**Headphone Socket I**

- frequency response, 40 to 6000 cps: ±3 db;
- output impedance: 2 kΩ; EMF: 8 v max.

**Headphone Socket II**

- pass-band: 800 to 1100 cps;
- input impedance: 4 kΩ; EMF: 20 v max.
Monitoring of output level ............... by meter

Valve check ..................................... by meter

Positions of mains switch ................. OFF / PREHEATING / ON (ILLUMINATION BRIGHT) / ON (ILLUMINATION DIMMED)

Power supply .................................. 115 v / 125 v / 220 v / 235 v,
                                      47 to 63 cps, approx. 130 va

Dimensions and Weight

Front panel .................................. (a) 520 x 304 mm for 520-mm rack
                                      (b) 482.5 x 311.2 mm for 19"-rack

Steel cabinet .................................. 540 x 325 x 552 mm for 520-mm front panel

Weight (with steel cabinet) ............... 65 kg

Valves, Lamps and Fuses

EAA 901 S ...................................... 6 AL 5 W
E 88 CC ........................................ 6922
ECC 801 S ....................................... 12 AT 7 W A
EF 805 S ........................................ (6 BY 7)
E 180 F .......................................... 6688
EL 84 ........................................... 6 BQ 5
85 A 2 ........................................... Q 6 3
150 C 2 .......................................... Q A 2
RL 290 (R & S) ................................ G1. 5 S (El. Ro. Ges.)
RL 1.65 s (R & S) ............................. No. 6435 / 6 V / 0.5 A (Osram)
1 C DIN 41 571 for 220 / 235 v ............ 2 (fuse)
2 C DIN 41 571 for 115 / 125 v ............ 1 (fuse)
0.4 C DIN 41 571 .............................. 1 (fuse)

Accessories

R & S Stock No. LK 333 ...................... 1 (power cord)
R & S Stock No. FS 413/11 ................. 1 (coaxial connector)
R & S Stock No. FTS 20315 .................. 1 (o-f connector)

Auxiliary Units

Single-Sideband Demodulator Type NZ 10 Rot. 4581
Telegraphy Demodulator Type NZ 07 Rot. 4593

See also:

Telegraphy Short-Wave Receiver Type EK 17 Rot. 4592
Single-Sideband Short-Wave Receiver EK 10 Rot. 4581
High-Stability Single-Sideband Receiver EK 11 Rot. 6285
Theory and Block Diagram

The Short-Wave Receiver Type DK 07 covers the frequency range 0.5 to 30 mc in 12 sub-ranges, the short-wave range of 3 to 30 mc being divided into 9 sub-ranges each 3 mc wide. It is outstanding for extreme setting accuracy and stability.

In the short-wave range, 3 to 30 mc, these features are determined by the local oscillator which after heterodyning with the harmonic of a crystal oscillator is synchronized by a high stability master oscillator. This oscillator is used in every frequency range, without switchover. Its strictly linear frequency response makes it possible to divide the receiver dial into a coarse and a vernier dial. The coarse dial covers bands each 3 mc wide and is calibrated in 100 kc divisions. The vernier dial, which turns once when the coarse dial is moved by 100 kc, has 500 cps divisions. The frequency reading is the sum of the readings from the coarse and vernier dials, a discrimination of 300 cps per mm of scale length being reached in the range 3 to 30 mc. A setting accuracy of 500 to 1000 cps is ensured up to 30 mc. In the frequency range between 500 kc and 3 mc, the receiver operates as a superheterodyne receiver of conventional design. Here, the coarse dial is the only dial from which the direct reading is taken.

The r-f section contains three tunable selective circuits. Two of these are directly at the input so that excellent discrimination against powerful, undesired signals from local transmitters is accomplished. Undesired input voltages up to 30 v are permissible at frequencies 10% off-tune from the reception frequency. The use of three tuned circuits and a high first intermediate frequency of 3.3 mc provides for good image and straight-if rejection, the image rejection being over 80 db over the largest portion of the range of reception. The modern circuit layout with a high-stability local oscillator makes for simplicity of the 1 st-i-f section. It consists only of fixed-tuned multi-section filters. This ensures that cross modulation and spurious response are greatly eliminated.

The high-stability local oscillator employs a so-called "analysis" circuit. Heterodyning with the harmonics of a 3 mc crystal brings its frequency into the range of a master oscillator. Both frequencies are compared in a phase-sensitive bridge circuit. Via a reactance stage, its output signal makes the local oscillator lock in on the frequency of the master oscillator. This oscillator, which operates always on the same low range of 3.4 to 6.4 mc, is of particularly careful construction and housed in a hermetically sealed case. Its frequency response is compensated by means of screws.

The second intermediate frequency of 300 kc is brought out, enabling auxiliary units of all kinds to be connected. The selectivity of the set is essentially governed by two four-section filters whose bandwidth is adjustable in six steps.

The automatic volume control is excellent due to additional AVC amplifiers. It is possible to select time constants up to 10 seconds. This permits operation with AVC even in all classes of telegraphy reception. Provision has been made not only for AVC or MVC but also for MVC plus AVC. Here the sensitivity of the receiver can be manually reduced while signals stronger than the response threshold adjusted for are automatically levelled in the conventional manner. This type of operation is of particular usefulness when it is intended to monitor frequency bands where strong atmospherics cause discomfort to the operator while there is no signal. The response threshold can then be set to reduce the discomfort.

The o-f section contains a balanced noise limiter whose response threshold is so adjustable that a reasonable compromise is reached between freedom from noise and from distortion. A standardizing oscillator controlled by a 500-kc crystal permits the calibration of the receiver to be checked against the harmonics of this crystal. Moreover, it is possible to apply its signal to the last i-f amplifier when pressing a button. This is a simple means of checking for accurate tuning of the receiver and a zero beat between the desired carrier and the 300 kc signal can be observed. A switch permits the various currents of the tubes to be applied to a meter which also measures the a-f level.
Fig. 6 Front view.

Fig. 7 Interior view, coil terminal opened.
frequency limit of the overall range. The greater values are due to the fact that in the ranges above 6 Mc the receiver operates with double frequency changing and a first intermediate frequency of 3.3 Mc whereas below 6 Mc only the second intermediate frequency of 300 kc is used. The filters primarily determining the selectivity are arranged at the

input of the second IF section. The bandwidth, switchable in six steps between ±0.15 and ±0.6 kc, is obtained by a total of eight tuned circuits ensuring the high IF filter selectivity.

Very effective automatic volume control prevents signals with an input voltage between 0.7 µv and 100 mv varying more than 3 db at the output.

**Performance Checking**

A feature rarely encountered on other receivers is the possibility of deriving most of the component frequencies from the set or of feeding them in from an external source. This is true, for example, for the frequency of the first oscillator, of the interpolation oscillator and of the 3 Mc crystal. The advantages are evident for measurements and for operational purposes. For example, if it is intended to use two receivers in diversity (see also page 33) it is very convenient to operate both receivers from one oscillator only. The intermediate frequencies obtained in both amplifier channels are then identical so that the combining circuit as well as the tuning indication in telegraphy reception is

simple to make. Diversity reception renders it necessary also to combine the AVC voltages in a manner that either the one or the other takes over. A strong signal in one receiver then suppresses a weak signal in the other, preventing noise in the bad channel from being amplified by automatic gain control. Fig. 5 shows the terminal panel at the rear of the set. The picture reveals that the first mixer is also accessible, permitting measurements to be made without including the RF stages and their RF filters.

Accessibility of the oscillator frequencies facilitates also accurate remote-frequency measurements (see number 9, p. 19) as one can tune to the signal to be monitored and then make a direct measurement of the oscillator frequency, say, using an electronic counter.

The block diagram of the receiver is depicted in Fig. 8. The audio section of the receiver has a 600 Ω AF output whose voltage is fixed and a variable AF output providing a power of 2 watts. Moreover, there are two phone sockets, one covering 800 to 1100 c/s and the other covering the entire frequency range from 40 to 6000 c/s. The first is useful for improving the reception of keyed continuous waves.

The receiver is fitted with industrial valves. Valve checking on a panel meter with a 22-position check switch simplifies trouble shooting.

J. Hacks
A Universal Demodulator for Telegraphy Signals

The first signals to be transmitted by radio were telegraphy signals. The code used until after World War I was the familiar Morse code. The drawback of this code is the relatively low speed of transmission and the necessity of employing skilled personnel for transmission and reception. Only the development of receiving equipment, such as the Hell receiver and the star-stop teleprinter, later ensured largely automatic operation and thus an ever-increasing importance of radiotelegraphy. The first transmissions were made with the aid of keyed continuous waves, well known as Type A1 emissions. The introduction of the start-stop teleprinters stimulated the increasing use of frequency-shift keying, or Type F1 emission, mainly because less elaborate equipment could be used. Another type of emission now being employed is twinplex with frequency-shift keying, known as Type F6. Twinplex is advantageous in that a slight addition to the equipment on the transmitting and receiving ends permits two telegraphy channels to be operated via one RF channel. All the conventional types of emission are mentioned in Number 9, page 23, of this journal.

Fixed telegraphy links continuously handling a large number of messages on several channels employ voice-frequency telegraphy with single-sideband modulation. This type of transmission, which is known by the name of VF telegraphy mainly from transmission over wire, calls for large installations both on the transmitting and the receiving ends and is not dealt with in this paper.

Demands on a Telegraphy Demodulator

In general, short-wave receivers are laid out only for demodulation of amplitude-modulated signals. Moreover, teleprinters or other telegraphy receivers cannot directly be connected to them. A telegraphy
demodulator is therefore meant to meet two requirements: starting from the intermediate frequency of the receiver it should, firstly, demodulate FSK signals and, secondly, convert the demodulated signal in a keying unit so that conventional telegraphy receivers, such as recorders, start-stop teleprinters, Hall receivers and weather-chart recorders, can be directly connected without additional units.

In contrast to the VHF systems, the other telegraphy systems nowadays use almost exclusively Type F1 and F6 transmissions. Nevertheless, a telegraphy demodulator should be very versatile, unless it is built only for communication with a particular station. The frequency shift in F1 emissions is arbitrary in spite of certain recommendations, and also in twinplex there still are four different frequency shifts according to the CCIR recommendations. Greatly differing keying speeds and the requirements encountered in operation with the various telegraphy receivers, Hall printers or weather chart recorders combine into a large number of operating conditions. Another one is diversity operation, dealt with later in this number. Diversity operation and telegraphy reception are closely connected, since diversity here means a marked improvement (see page 30) in contrast to its effect in single-sideband and sound-modulated emissions. It therefore appears reasonable to incorporate all arrangements, which are required for diversity reception, in a telegraphy demodulator. The various types of diversity reception enhance the necessity to make the demodulator versatile.

A telegraphy demodulator should not be built only for operation in conjunction with a given type of receiver, but should be easily adaptable to all conventional receivers by the user himself.

Versatility of the R&S Telegraphy Demodulator Type NZ 07

The R&S Telegraphy Demodulator Type NZ 07 (Fig. 1) complies with all the requirements stated in the foregoing. In spite of its versatility resulting from its circuitry discussed on page 27 its performance is practically as good as that of a receiver designed only for a given frequency shift, a special type of keying and a single type of diversity operation.

Its adaptability to various frequency shifts is accomplished in the following way: the IF signal is applied to a limiter smoothing out amplitude variations up to 50 db and then passed on to a discriminator which covers ±1.5 kc and produces a DC voltage proportional to the instantaneous frequency. This highly efficient limiter/discriminator arrangement provides exclusive weighting of the signal frequency. Frequencies are distinguished by the response threshold of three Schmitt triggers; channel separation in twinplex operation is brought about by a so-called logic circuit connection of these Schmitt triggers. Frequency shift adjustment, in F1 needed only for AFC adjustment and not for demodulation, is relatively simple using resistive voltage dividers.

Connection of various telegraphy units is possible because each channel operates into two keying sections which are paralleled but different. One is for direct current keying, has a floating power supply of its own and can be switched for single and double current keying. The other keying section is for tone keying, and it is possible to switch-select the frequency of 1.5 kc or 3 kc. There is thus a total of four keying sections each of which can be adjusted independently of the others, in the amplitude of the current of the IF voltage and in its polarity. Furthermore, one can interrupt the keying -- also independently of the other keying sections. Accordingly, the message can be transmitted via a telephone circuit, say as tone-keyed signals, and a monitoring machine can be connected at the same time, switching off being possible independently of tone keying.

Adjustment to the various types of diversity operation is rendered possible by plug-in unit type IF sections which also incorporate all facilities needed for diversity switchover and for deriving the switch-over criterion. The various plug-in units can be inserted without modifications on the set. It is just necessary also to change the connection panels in the steel cabinets. These panels contain the sockets for connection to the other sets. In racks, the IF units for antenna and frequency diversity can be exchanged without any modifications in the rack.

Various types of receivers can be connected to the telegraphy demodulator because the latter operates with an intermediate frequency of its own. It is only necessary to change the frequency of the local oscillator of the telegraphy demodulator to ensure proper adjustment to the intermediate frequency of the receiver. The local oscillator design is such that a switch permits selection between two external intermediate frequencies.

Automatic Frequency Control

To keep demodulated telegraphy signals undistorted in telegraphy reception with frequency-shift keying it is very important that the spacing of the keying voltages resulting at the output of the discriminator
from the two frequencies be very accurately maintained with respect to the response thresholds of the Schmitt triggers. For example, consider a frequency shift of ± 200 cps; changes corresponding to 50 cps would then be sufficient to affect the result noticeably. This stability being warranted neither at the transmitting nor at the receiving end, if the transmission continues for a long period, the telegraphy demodulator should have provisions for balancing out the frequency variations. This action should be effective within the demodulator itself since generally it is impossible to influence the local oscillator of a receiver.

The controlling action in the Type NZ 07 is a two-step type which in F1 responds to the frequency assigned to the spacing interval. In F6 operation, the frequency used for regulation means spacing interval on both channels. A seeming disadvantage of this technique which utilizes only one frequency for deriving the regulation criterion is the fact that the regulation fails if the transmitter remains at the frequency assigned to the marking signal — in F6 operation at one of the frequencies f2 to f6. The regulation effect would disappear and return only with proper keying. However, this trouble is definitely due to the transmitter, and it would also cause the other telegraphy receivers to fail; a teletypewriter would run continuously, a TDM system would fall out of step, a weather chart recorder would trace a black area. Experience shows that the above-mentioned failure need not be taken into account and that measures against such failures would only make the receiving equipment more intricate.

Use of the principle of two-step action control made it possible to find a procedure which is simply adjusted to the different frequency shifts and, above all, permits the regulation criterion to be derived from the discriminator which also delivers the signal voltages for the demodulation. Differences in temperature response and aging, liable to occur where regulation criterion and demodulation are obtained in two separate, frequency-dependent arrangements and apt to impair the regulation which should be very accurate, are thus without importance.

**Tuning Indication and Performance Checking**

As stated before, the spacing of the keying frequencies to the response threshold of the demodulation facilities requires accurate adjustment to minimize telegraphy distortions. This calls for a tuning indication which is easy to survey. The tuning indicator which has found general acceptance for telegraphy demodulators is a CRT where the two, or in F6 four, keying frequencies are displayed as vertical bars. These bars form a group travelling across the screen while the receiver or the demodulator is tuned. Proper tuning is obtained when this group is symmetrically arranged about a centre line which is mostly fixed to the screen and is to mark the response threshold in F1 distinguishing between spacing and marking signals. However, a fixed centre line is disadvantageous in that changes occurring in the oscillograph section with its amplifiers also affect the tuning indication.

Fig. 2 shows that in the case of the Telegraphy Demodulator Type NZ 07 this centre line is superposed electronically, its value being derived from the
response threshold. The accuracy of the tuning indication is thus completely independent of the operating conditions in the oscillograph.

The CRT of the tuning indication and its amplifier are supplemented by a simple sweep circuit. Thus, one has a complete small oscilloscope which permits several check points of the entire demodulator, such as the IF amplifier and the keying sections, to be monitored.

**Modes of Operation**

The modes of operation of the Telegraphy Demodulator Type NZ 07 are outlined below.

A1 Telegraphy on pure continuous waves is possible at all conventional keying speeds. Use of the Telegraphy Demodulator Type NZ 07 suggests itself for A1 operation because of the additional selective circuits specially tailored for telegraphy reception and because of the incorporated DC and tone keying sections.

F1 FSK telegraphy with a frequency shift continuously variable between ±50 cps and ±1,5 kc. Variation of the frequency shift requires only readjustment of the automatic frequency control. No readjustment is necessary for monitoring if the transmitters are changed frequently, since use of automatic frequency control would then become meaningless. The maximum keying speed is 4000 bauds. The demodulator is followed by a low pass filter which is adjustable in 9 steps and thus can be well adjusted to the keying speed.

F6 Twinplex (Duoplex). Demodulation is made according to the international Code 2 which today is used exclusively and is made up as follows:

Frequency \( f_1, f_2, f_3, f_4 \)
Channel A: S S M M
Channel B: S M S M

[\( S = \text{sparking} \quad M = \text{marking} \)]

The shift is adjustable to:
- 3 x 200 cps
- 3 x 400 cps (most frequently used)
- 3 x 500 cps
- 3 x 1000 cps

The frequency shift is selected with the function selector, no readjustment or other switching being necessary. The keying speed obtainable in phase-arranged transmissions is up to 4000 bauds. In practice, however, a maximum keying speed of only 2 x 200 bauds is used and thus easily handled.

The keying speed is governed not only by the performance of the demodulation circuit and of the keying sections, but also by the IF bandwidth of the receivers and of the IF section in the telegraphy demodulator itself. The minimum bandwidth \( B \) needed for an FSK signal can be stated as

\[
B = \frac{S_h}{K}
\]

with an accuracy sufficient for practical purposes. Here, \( S_h \) is the total frequency shift and \( K \) the keying speed in bauds - bit/sec. At the IF bandwidth of \( \pm 2Kc = 4Kc \) of the Telegraphy Demodulator Type NZ 07 the specified maximum keying speed is achievable only with a very small frequency shift,

![Diagram of Direct-current and Tone keying](image)

*Fig. 3 Direct-current and tone keying. These types of keying can be selected with the Telegraphy Demodulator Type NZ 07 independently of each other.*
Types of Keying

Fig. 3 gives a survey of the types of keying for the direct connection of the telegraphy receivers or of a line. The following types of keying can be selected:

1. Tone keying with 1.5 kc or 5 kc; open or closed circuit tone keying with a variable output voltage of maximum 3 volts rms into 600Ω can be switch-selected.

2. Direct current keying is possible in single current or double current operation at a variable output current of maximum 60 ma or ± 30 ma, open or closed circuit keying being switch-selected for single current keying, whereas the direction of the current flow can be selected in double current keying.

All the keying sections are off earth and mutually independent in their adjustment, as set forth previously.

Fig. 4  Block diagram of the Telegraphy Demodulator Type NZ 07.

Theory

The circuitry of the set shall be described here with reference to the block diagram in Fig. 4. More particulars are given in [1], whereas the automatic frequency control is exhaustively treated in [2].

The first section of the IF amplifier is built into the diversity IF units. The mixer changing the receiver IF into the IF of the Type NZ 07 is followed by an IF amplifier from which the switch-over criterion for diversity operation is derived by inductive or capacitative coupling. The signal is then applied to an amplifier functioning as grid-current limiter which in the unit for receiver diversity is also employed for switchover of the intermediate frequency in diversity.

For A1 reception, the basic unit next contains the A1 demodulator, for frequency-shift keying it contains a double-ended limiter followed by the driver for the discriminator and the discriminator itself. A special control circuit in the driver stabilizes the AC anode current also in the case of AC supply fluctuations and, particularly, in the case of valve aging. The load resistor of the discriminator is a switch-operated voltage divider enabling in F6 the demodulation facility to be adapted to the different frequency shifts. The DC amplifier following next is connected to the A1 demodulator in A1 operation and to the discriminator in F1 and F6 operation. The signal is then applied to the first AF filter, a low-pass type adjustable in 9 steps, and passed on to the pulse shaping circuits.

The signal separation for F6 operation is achieved using three Schmitt triggers whose response thresholds S1, S2 and S3 are assigned to the discriminator voltages for the four keying frequencies as is shown in Fig. 5. At the frequency f1 assigned to the spacing interval in both channels, the three Schmitt triggers are in their state of rest. Upon changeover to f3 the first flips into its conductive state, the second following suit upon changeover to f5, f4 eventually finding all the three Schmitt triggers in the conductive state. The output voltages of the three Schmitt triggers are combined in an impedance matrix so proportioned that the sum voltage fires the fourth Schmitt trigger in accordance with the Code 2.

Fig. 5  Assignment of the response thresholds, S1, S2 and S3 of the Schmitt triggers No. 1 to 3 provided for signal separation at F6.
The table on page 96 shows that for channel A only the change from $f_2$ to $f_1$, i.e., the crossing of the response threshold $S_2$, is related with a change between spacing and masking intervals. It is therefore sufficient to utilize the state of this Schmitt trigger for controlling the keying sections of channel A. The fourth Schmitt trigger operates the keying sections for channel B. In FK operation the cutoff frequency of the first low-pass filter ahead of the signal-separating Schmitt triggers cannot be made less than about 250 cps even at a keying speed of $2 \times 50$ bauds, the reason being the lack of symmetry of the discriminator voltage with respect to the response thresholds of the Schmitt triggers. Consequently, the main AF filtering is provided after signal separation. Channel A contains a low-pass filter following the second Schmitt trigger, channel B another following the fourth Schmitt trigger. Both filters can be jointly adjusted to the keying speed. The second low-pass filter is followed, in each channel, by another Schmitt trigger which restores the rectangular shape of the pulses greatly distorted by the second filter. This Schmitt trigger operates into the frame. The front panel forms also a separate subassembly. The large number of terminals, mainly on the front panel, provides readily accessible check points. All the subassemblies can be withdrawn after removal of a few screws. Fig. 7 shows that this is easily done also with the front panel.

Fig. 6. Constructional make-up of the Telegraphy Demodulator Type NZ/60. Bottom: The front panel seen from behind. 12094

Fig. 7. The removable front panel. 12099

The frequency keyed in the tone-keying section is either 1.5 kc or 5 kc. No balancing transformers are employed, but the section is nevertheless completely direct-current free. Transient responses due to transformers are thus prevented particularly at high keying speeds, such as occurring in weather-chart transmissions.

The direct-current keying sections use power transistors instead of the customary telegraphy relays. Telegraphy relays are not very reliable, no matter how carefully they are built, and they require maintenance after relatively short intervals. The power transistors make any maintenance unnecessary.

Constructional Features

The versatility of the set called for a large number of components. The design problem therefore was to provide a neat arrangement and ease of access. Fig. 6 gives an idea of how this problem was solved. The total circuitry is made up of seven plug-in subassemblies separately wired and easily inserted.
Performance

The performance of the set is illustrated in Fig. 8 by a graph already published in an earlier paper [1]. Here the number of errors are plotted as a function of the S/N ratio, for channel A and for channel B in twinplex operation.

An F6 emission with a frequency shift of $3 \times 400$ cps was picked up during this measurement. The probability for the occurrence of signal distortions greater than 20$\%$ was $10^{-4}$ at the above signal voltages. The inherent distortion of the set is less than 1$\%$ at a teleprinter keying speed of 50 bauds or less than 1.5$\%$ at 200 bauds.

Experience gained hitherto has shown that the design concept of a very versatile telegraphy demodulator is good. The Type NZ 07 admittedly contains provisions not used in certain special services. For example, the two keying sections for channel B are unnecessary if F1 is received exclusively. Accordingly, there may seem to be a few knobs and switches too many on the front panel. On the other hand, a versatile telegraphy demodulator like the Type NZ 07 will prove its value in any unforeseen change of the type of emission.

K. Grobe

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Diversity Reception in Short-wave Telegraphy

The importance of diversity reception in telegraphy stations is steadily increasing. Diversity operation can reduce the effect of selective fading so much that an uninterrupted succession of several words, that would be completely mutilated by fading, may remain clearly readable.

Diversity reception is the reception of one and the same information over two or more transmission channels which differ in their characteristics. The signals arriving via these different paths are then selected or combined in a manner which makes the mean signal-to-noise ratio better than that of only one path.

Several conditions must be satisfied if diversity operation is to give a noticeable improvement. Diversity reception makes sense only where one path varies so much in its characteristics that the received signals will cause errors. This requirement is a matter of course; no improvement can be expected by combination of signals from several paths if reception via one path is always fully satisfactory. Furthermore, the mean signal-to-noise ratio of all transmission channels should be nearly equal. For example, the result of combining two signals, of which one is mostly good whereas the other nearly always leads to errors, is worse than the signal of the good channel. Moreover, the mean signal-to-noise ratio of each single channel should be sufficiently large to ensure undisturbed reception over this channel during most of the time. Combining signals disturbed at any time cannot give any improvement of value for practical purposes.

The main requirement, which the paths should fulfill, is mutually independent fading. The situation would be ideal if the minimum of the transmission characteristics of one channel coincided with the maximum of another. In other words, there should be minimum correlation between the situations on the different channels. Here also the reasons are easily understandable. If all transmission channels become equally bad at the same time, combining the signals from several paths would remain without avail because no single channel enables a satisfactory result to be obtained.

All short-wave circuits not established by the short-range ground wave suffer from narrow-band selective fading, which may even entail complete cancelling of a frequency. Unlike radiotelephony transmissions with their relatively wide bands, telegraphy messages are practically carried by one frequency. This is the reason why selective fading in telegraphy reception may cause a total loss of information. However, since in selective fading the requirement most important for diversity operation — little correlation between the conditions in a channel — is easily fulfilled, diversity reception affords a very good possibility to reduce trouble due to selective fading. Today, for example, transatlantic telegraphy service without diversity is unthinkable.

One distinguishes between space, polarization and frequency diversity, dependent upon the transmission channel selected.

**Space-diversity** receiving antennas, generally two or three, are mutually separated for the phase difference to be large enough to have the fades occur at different times. In the short-wave range, a separation not greater than about 100 m may be sufficient to obtain the desired diversity effect. As a rule, the separation is the tenfold to twentyfold value of the wave length.

In **polarization diversity** one profits from the different transmission characteristics of the components at a right angle to each other. This offers the advantage that the separation between the antennas can be reduced to zero. The simplest case is that of two antennas disposed at a right angle to each other. Thus two whip antennas arranged in a V configuration may give a satisfactory result.

**Frequency diversity** is carried out using two different frequencies for reception. This technique offers the great advantage that only one antenna is needed. The drawback lies in the fact that it is often hard to find two suitable frequencies because of the scarcity of such frequencies in the short-wave region. There is also another disadvantage: Much
more frequently than in space or polarization diversity one of the two frequencies will come in with a voltage lower than the other, due to long-duration fading. During this period, the system will function only with the same efficiency as does a non-diversity system. Two relatively close frequencies are therefore the most suitable solution to this problem. Frequency diversity is recommended where it is impossible to set up two or three antennas delivering sufficiently uncorrelated voltages to the receiver. For example, it is well suited to diversity operation on ships.

The terms antenna selection diversity and receiver selection diversity refer to the receiving and combining system.

In antenna selection diversity systems the antennas are directly selected, that is, a combining circuit arranged between the antennas and the receiver delivers a switchover command from the output of the receiver. Space or polarization diversity reception is then possible, dependent upon the arrangement of the antennas. The receiver remains connected to one antenna until the antenna signal drops below a certain threshold. At this instant, the diversity combining circuit switches to the next antenna and checks that the input voltage of this antenna arrives with the required amplitude. If this is true, the receiver remains connected to this antenna until the voltage drops below the threshold. However, if the input signal of the second antenna is insufficient from the beginning, the circuit switches to the third antenna and, possibly, back to the first. The probability that two antennas have too low an input voltage is not very great if the antennas are set up in such a way that their feedings are sufficiently uncorrelated. Use of three antennas reduces this probability even further so that usually at least one of the three antennas delivers a high enough voltage. This method has the advantage that operation from one antenna is carried on until the level of the incoming signal is below a certain minimum. The minimum level should be such as to ensure a large enough signal-to-noise ratio, but should not lie so high that switchover occurs at every slight variation. Switchover itself takes only 50 μsec, but the transient response of the IF filters in the receiver may last up to 1 msec dependent upon the bandwidth. During this period, the reception is additionally affected.

The antenna selection diversity method is unsuited to amplitude-modulated transmissions, particularly to A1. In A1 transmissions, switchover between the antennas would occur at every break during keying and the antenna in circuit when the RF signal appeared would then remain in circuit. Selection of the best signal is thus impossible. Antenna selection diversity calls for a continuously transmitted frequency as is the case in the frequency-shifted types of telegraphy.

Moreover, restrictions must be made for the use of the above method. These refer to frequency-shifted emissions, in which the keying frequency in comparison to the frequency shift is such that the receiver bandwidth used is determined by the keying rate and not by the frequency shift. For example, this is the case with black-white facsimile (Class F4 emission). Here the response of the receiver filters upon switchover takes roughly the same time as the shortest signals to be transmitted. Consequently, the switchover will mutilate the signals. Antenna selection diversity therefore finds its main use in radioteletype, which is carried out with F1 and F6 emissions. Here, frequency diversity cannot be used, since there is only one receiver.

The great advantage of antenna selection diversity is the fact that only one receiver is used. Accordingly, it is possible to build the complete telegraphy diversity receiver including the combining circuit and the connection possibility for three antennas in the form of a table model. Using the modern wideband antennas, which unlike the cage and rhombic antennas often found in short-wave services require only little space, it is possible to install a complete antenna selection diversity system on roofs or on any other narrow site within a city. This may be of great importance for government and press agencies. Mobile service, such as the police, will find this method very convenient, because the shock-mounted receiver can be easily accommodated in every radio van and because using polarized antennas both antennas can be mounted on the same vehicle. The efficiency of a triple diversity antenna selection system is better than that of a dual-diversity receiving system.

Receiver selection diversity is carried out with a receiver for each antenna. Dependent upon the arrangement of the antennas it is possible to operate with space or polarization diversity. If both receivers are connected to one antenna, frequency diversity reception can be accomplished. All incoming signals are then compared at any instant and the best is utilized for demodulation. Unlike the antenna selection diversity the comparison can here be made continuously, that is, it is not necessary to wait for a drop below a minimum level. This fact makes the dual-diversity receiving system superior to a dual-diversity antenna selection system. However, the main advantage lies in the greater reliability, as there is a second receiver. In contrast to antenna selection diversity it is, in addition, possible to receive A1 signals because the comparison is made continuously and there are no transient responses during switchover. Whereas the improvement between non-diversity and dual-diversity reception is quite obvious a further improvement brought about by a third antenna and a third receiver is less noticeable. Today, dual-diversity receiving systems are therefore most frequently encountered.
Combining the Information

Three methods are commonly employed in receiver diversity to combine the information received over the different channels: switchover, equal-gain diversity and square-law diversity, also called ratio squarer diversity. Switchover means that only the signal in the channel with the highest field strength is selected, whereas the others is fully suppressed. Equal-gain diversity means linear addition of the demodulated signals, square-law diversity first squaring and then adding the demodulated signals.

The three methods mentioned in the foregoing paragraph have a common prerequisite: Common may even be a drawback, since squaring puts more emphasis on the disturbance than on the desired signal, the signal-to-noise ratio after addition possibly being worse than that of the channel with the weak signal.

The R&S Diversity System

The R&S Diversity System is constituted by four diversity units designated A, E, F and S, which can be inserted into the Telegraphy Demodulator Type NZ.07. It is thus possible to obtain three different diversity systems, as is shown by the Figs. 1, 2 and 3.

![Fig.1 Block diagram of the R&S antenna selection diversity system.](image)

control of the receivers or additional control of the audio frequency of each receiver by the internal AVC voltage must ensure that the signal-to-noise ratio of the antennas is correctly repeated at the point where the signals are combined. Theoretically the best procedure is the square-law one, provided white noise is the only unwanted signal. The improvement then obtained in dual-diversity reception as compared to the switchover method corresponds to a signal-to-noise ratio greater by 0.6 db. The improvement brought about by equal-gain diversity is even less. However, disturbances occurring in the short-wave region are not so much caused by white noise of the antennas and receivers as by unwanted transmitters and pulse sources, and appear on the antenna with full correlation. Only the fading of the desired transmitter is nearly uncorrelated. Square-law diversity in the presence of noise pulses

Because of the reasons outlined in the foregoing paragraph, only switchover is employed for combining the information.

The dual-diversity or triple-diversity antenna selection system consists of a receiver and a Telegraphy Demodulator Type NZ.07 fitted with the IF diversity unit A. Switchover between the antennas is made with diodes acting as switches. The attenuation is 2 db, maximum, for the selected channel and at least 40 db for the other. The switchover time is approximately 50 usec, no additional signal distortions thus being likely.

However, it should not be overlooked that each switchover means a short interruption of the reception, because of the transient responses and delays
in the filters. With conventional filters the interruption lasts longer than 1 msec if the bandwidth is

Furthermore, the frequency with which all antennas are sampled when the input voltage is insufficient

±300 cps. If the length of the marking signal is, say, 20 usec per bit, such a relatively short interruption does not cause any harm since it will be eliminated by the AF filter in the telegraphy demodulator. On the other hand, it is necessary to avoid too many switching operations as may be due to noise pulses. The diversity unit A has therefore provisions making sure that the switchover on any of the antennas is soon reduced from about 500 cps to less than 20 cps. Thus the reception, which is then heavily affected anyway, is not disturbed even more.

The receiver diversity system comprises two receivers, but only one Telegraphy Demodulator Type NZ 07, which is fitted with the IF unit E. A system

command is not passed on to the antenna selector if the IF falls too often below the response threshold because of noise pulses or random noise.

of this make-up operates under the condition that it is possible to tune the two receivers with a common local oscillator, in consequence of which
the intermediate frequencies of both receivers are identical. At this condition is fulfilled, the switch-over can already be made in the IF section so that the entire demodulation arrangement including the automatic frequency control and the tuning indication is required only once. Of course, there is thus no possibility of frequency diversity operation. As in the frequency diversity system described below the switch-over criterion is derived by rectifying the IF of both receivers, subtracting these two voltages from each other and applying the difference voltage to a Schmitt trigger, which controls the switch-over stages.

Frequency diversity does not require common tuning of both receivers with one local oscillator. All the demodulation facilities, the automatic frequency control and the tuning indication must therefore be separately provided for each receiving channel. Thus the receivers are fully independent with respect to the RF and IF sections; switch-over to the best signal is made in the AF section. Frequency diversity calls for two receivers and two telegraphy demodulators, of which one is fitted with the plug-in unit F and the other with the plug-in unit S.

The system described in the previous paragraph comprises two receivers and two complete telegraphy demodulators and thus more units than all the other systems discussed before. A simple switch-over permits each channel consisting of a receiver and a demodulator to be separately operated as non-diversity telegraphy receiving equipment, a possibility non-existent in the other systems. Moreover, a frequency change can be made at the receiving end without interruption of the reception, if the transmitting station temporarily radiates the same information on two different frequencies. Of course, it is also possible to operate with space or polarization diversity if two antennas are employed.

The unit S is so simple in its design that it essentially contains the first IF amplifier section for the Telegraphy Demodulator Type NZ.07, a section needed in any case. This unit can be inserted for non-diversity reception also or when there are no plans for extension of the system at a later time.

**Constructional Features**

As stated before in the paper on the Telegraphy Demodulator Type NZ.07, the diversity IF units include all the provisions needed for deriving the switch-over criterion and the switch-over itself. No modifications or adjustments need be made in the basic unit of the demodulator. However, since the various types of diversity require different connection possibilities the cabinet model is not provided with a terminal panel containing all the sockets necessary for the various types of diversity. Instead, there is a replaceable frame which provides the connection between the unit and the sockets for the external connections. The side facing the char-
Diversity units come with a suitable frame of its own, for insertion in the steel cabinet. The frame can be withdrawn after removal of four screws. The two pictures 4 and 5 depict the frame A in the steel cabinet as seen from the interior and from the outside. Fig. 6 shows the frame F provided for the frequency diversity system.

As a rule, it is unnecessary to change from one type of diversity to the other. It is therefore sufficient to supply the basic unit together with the desired slide-in unit and the steel cabinet together with the associated frame. From time to time it may, however, be important to be able to change the equipment rapidly from operation in one to operation in the other type of diversity. There is the possibility of arranging the frame as a perfect counterpart to the telegraphy demodulator. In this case it would be provided with the connectors for the unit A (antenna selection diversity) as well as for the units F and S (frequency diversity). Because of the many sockets needed for the other sets, such a frame can, however, be made only for cabinet racks or for our HF Monitoring Equipment Type NK 701. Not all of the plugs on the units A, F and S profit from the sockets in this special frame. For example, the unit F does not utilize the plugs which are necessary for the unit A as they connect to the antennas.

A rack accommodating two receivers and two Teleg-raphy Demodulators Type NZ 07 as well as this special frame, two antenna selection diversity units A, a unit F and a unit S permits either two separate antenna selection diversity systems or a frequency diversity system to be set up. The necessary connections require only a few manipulations.

Summarizing it can be said that all types of diversity of interest can be carried out with the R&S diversity system. Because of the relative simplicity of antenna selection diversity, this type of diversity is doubtless the most important one, particularly for mobile services. Agencies planning a non-diversity telegraphy receiving station should nevertheless order the telegraphy demodulator to be equipped with the diversity unit A. This adds only little to the initial cost and permits diversity operation, if the need arises.

K. Grabe
Modern Measuring Equipment for the Development of Telegraphy Diversity Systems

The development and checking of modern short-wave receivers and of the necessary auxiliary equipment raises many problems of instrumentation. Most measurements, e.g., determination of the frequency response of oscillators or of the gain characteristic of RF and AF amplifiers, can be made with conventional measuring equipment; obviously, the increasing requirements for the performance of communications equipment makes improved measuring instruments necessary. Indispensable for development work in the short-wave range is a signal generator of adequate frequency stability offering an output voltage accurately adjustable down to the limit of sensitivity of the receiver and permitting defined percentage modulation with an adjustable frequency.

The Power and Standard Signal Generator Type SMAR fulfills these requirements. Its output voltage shift keying is possible up to 300 bauds and ±1 kc. deviation. Also, the signal generator frequency can be synchronized with an internal 500-kc spectrum or any external frequency, all modulation characteristics being maintained. In conjunction with a frequency synthesizer, e.g., the Type XII, the Type SMAR forms a high-grade signal generator exhibiting crystal accuracy.

As automatic telegraphy transmissions in the short-wave range become more and more important new types of measurements are needed for which suitable instruments have not been available up to now. An example is the universal measurement of telegraphy signal distortion in a demodulator, in particular, of keying speeds up to 3600 bauds, as used nowadays in the short-wave range. The Telegraphy Test Set developed for this purpose permits telegraphy distortions to be measured in the

![Fig. 1 Telegraphy Test Set. The division into distortion meter and generator section is clearly visible. The generator section "Information II" permits squarer-wave modulation of the second channel in FSK operation; both channels may also operate synchronously.](image)

into 40 can be adjusted down to 0.1 μV full-scale deflection. A built-in modulation oscillator permits modulation up to 15 kc, the modulation depth being indicated on a meter. Harmonic distortion is less than 1% with modulation up to 90%. Frequency

[labatory with an accuracy of 0.5% between 10 and 5000 bauds and of 1% at 10,000 bauds.]

The generator section of this set (Fig. 1) permits modulation of an FSK transmitter with a periodically...
repeated signal of 10 bits. Any combinations of marks and spaces can be selected within the 10 bits. The signal delivered by the demodulator under test is ordinarily delayed by the filters. For this reason, the same signal is produced with delay in the generator section of the Telegraphy Test Set, the delay being adjustable in units of 0.5% (or 1% or 10,000 bauds) up to the tenfold width of a bit. The comparison between each bit of the received signal and the delayed signal is carried out in a receiver section of the Telegraphy Test Set to determine the percentage by which the received mark falls to agree with the signal delivered directly by the generator section.

This test set also permits the number of marks going beyond a given limit of distortion to be measured. The limit of distortion is adjustable in units of 1% between 0 and 99% of the width of a bit. This measurement is very instructive for judging disturbed telegraphy channels. In conjunction with an automatic classifier it is possible to measure the statistical distribution of all distortions occurring in a disturbed telegraphy channel.

In both cases, the telegraphy signal to be measured must again be generated in the Telegraphy Test Set and applied to the telegraphy channel under test. This is, however, impossible whenever the input of a telegraphy channel is at a distant location.

In this case, a measurement with the Telegraphy Test Set is possible only if the channel remains unkeyed, i.e., if the signal remains at mark or space. The Telegraphy Test Set then acts as the output of the channel under test as though mark or space were sent continuously. For the measurement, the time is divided into units corresponding to the width of a bit, within these intervals, the portion of time during which the signal differs from the expected mark or space position is determined.

In a laboratory it is extremely difficult to determine numerically the improvement achieved against previous methods used in short-wave reception. Since the conditions of transmission heavily influence it would be necessary to extend the measurements over long periods of time and to find the average of all measurement results. Above all, this method...
would require a suitable opposite station providing a receiving level which at any time has the exact value desired for the measurement. Much more favourable is a test rig where all values, e.g. the signal-to-noise ratio or frequency spacing of an interfering transmitter, can be adjusted and kept constant. Obviously, the test rig has to take account of the fading also. A fading simulator, replacing the fluctuating antenna voltages independently of each other, has been developed for laboratory tests. At the outputs of this set the individual keying frequencies may occur with mutually independent fluctuations. In this connection it is important that the fading is simulated by noise generators producing statistical instead of periodic variations of the signal voltages.

A test assembly for measuring, say, the improvement accomplished by antenna selection diversity is shown in Fig. 2. In addition to the test item, in the present case the Short-Wave Receiver Type EK 07 with the Telegraphy Demodulator Type NZ 07, the following measuring instruments are used:

1. Signal Generator Type SMAR, simulating the transmitter.

2. Telegraphy Test Set, for modulation of the signal generator and measurement of the telegraphy distortions.

3. Electronic Counter, for counting the signals going beyond a given limit of distortion.

4. Fading Simulator, for simulating the selective fading of three antennas.

5. Noise Generator Type SUF, for accurate adjustment of the signal-to-noise ratio.

6. Signal Generator Type SMLR, for simulating interfering transmitters of defined amplitude and selectable frequency spacing.

This list shows that simulating the actual receiving conditions in the laboratory is not simple. It is still occasionally necessary to compare the results obtained by means of this test assembly with those from a test of the actual reception, and thus to make a kind of calibration. Once the comparison has been made for a series of tests the differences between various reception methods are numerically determined much more quickly and accurately by means of the laboratory test assembly.

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