**AEG-TELEFUNKEN**

#1 | ERQ | =N61.

Hochfrequenztechnik

# Broadcasting Transmitter
# Standard Program
# Long-, Medium- and
# Shortwave Transmitters

# Contents

## Development of AEG-TELEFUNKEN's New Broadcasting Transmitter Standard Program

**Objective**

**High efficiency and high operational reliability**
**Economical operation in the broadest sense**

**Course taken**

**Application of the latest modulation technique**
**Use of the latest tube types**
**Continued application of a proven RF technique**

**Result**

**Maximum efficiency – low operating costs**
**Minimum number of tubes – low tube costs**
**Compact design**
**Very few components subject to wear and tear**
**Low spares requirement**
**Minimum floor space**
**Easy access**

**AEG-TELEFUNKEN's additional services**

**Guaranteed availability and supply of spares for many years**
**Efficient after-sales service**
**Training of transmitter operating staff by AEG-TELEFUNKEN engineers.**

## The New Transmitter Configuration

**RF Technique**

AEG-TELEFUNKEN's RF technique, the result of long years of experience in transmitter construction and observation of transmitters in operation, provides the basis for the high degree of reliability of the new transmitters.

**Latest Modulation Technique**

The carrier modulation is accomplished according to the PANTEL*) method (a PDM method according to the TELEFUNKEN System), where the PD modulator supplies the DC voltage as well as the modulation voltage for the RF output stage without using a modulation transformer.

This PDM method offers the following advantages:

Particularly high efficiency, irrespective of the modulation depth.

Continuous reduction of carrier power is possible down to half of the rated power without interruption of carrier power and practically with remaining high efficiency.

**Maximum Efficiency – Low Operating Costs**

The PANTEL method of PD modulation, in comparison with the hitherto applied, almost classical anode class B modulation offers the advantage of a considerably higher efficiency, which in addition does not depend on the modulation depth.

If, for example, the power consumption of a PD modulated 600-kW mediumwave transmitter is compared with that of an anode class B modulated transmitter of equal power output rating, with a mean modulation depth of $m = 0.4$, as is customary in program operation, a reduction of power consumption from the mains of up to 1,000,000 kWh per year and transmitter will be achieved.

**Low Tube Costs**

The PANTEL method requires only one high-power tube each in the modulation and RF power stages. Both tubes are of the same type. A third tube serves as an RF driver tube.

This limitation to two tube types depending on the class of power – an extremely important aspect for stock-keeping – and the relatively low procurement costs of the tube complement chosen result in lower total costs of tubes.

*) **P**DM–**An**ode Modulation System **TEL**EFUNKEN

## Compact Design

The PANTEL method makes superfluous some of the heavy-weight components usually installed by the side of the transmitter, such as modulation transformer, modulation choke and modulation capacitors.

In the case of the 100-kW transmitter types which are fed from LT supply mains, the voltage distribution and transformer for the HT rectifier are integrated in the transmitter. For all other transmitter types the high-tension distribution, the transformer for the HT rectifier, the step-down transformer for the low voltage needed and the cooling equipment can be installed even outside the transmitter hall.

## Special Features

Tuning and Frequency Change

In longwave- and mediumwave transmitters tuning of the transmitter amplifier possible to any frequency over the longwave and mediumwave broadcast ranges respectively.

For mediumwave transmitters the version with automatic change-over between two (preset-) operating frequencies (e.g. day/night frequencies or frequencies in reserve operation) can be supplied on demand.

In shortwave transmitters fully automatic frequency change and frequency tuning over the broadcast ranges.

Operation possible with reduced power, i.e.

Continuous reduction from rated output to ½ of the rated output and

even reduction from ½ of the rated output to ¼ of the rated output – by change-over in the HT power supply (but this implies placing of a separate order).

Any kind of program modulation (also trapezoidal modulation and/or compressed modulation) possible up to a continuous mean modulation depth of m = 0.75.

Switching on and supervision of the transmitters from the switching and control panel at the transmitter front and, if required, from the extended control console.

All transmitters are suited for remote-controlled and unattended operation.

High-tension rectifiers for the final stages, fitted with avalanche diodes (with the mains ripple being 12 pulses per cycle).
Switching on of the high voltage with automatic switching sequence (in four steps).

HYPER-VAPOTRON cooling of all power tubes.

Basement rooms not required.

Compact design permits short installation time.

## General

The transmitters consist of racks of identical design.

The layout principle may be seen from the dimensional sketches under TECHNICAL DATA.

Easy access has been provided to all mechanical and electrical components and parts; doors and covering plates can be removed.

All meters required for the supervision of operation have been provided in an instrument panel at the front side of the transmitters.

The transmitters meet the requirements of

the CCIR Recommendations (New Delhi 1970)

the Radio Regulations (Geneva 1968)

the General Specification of the German Federal Post (DBP) and the requirements of the Association of Broadcasting Corporations of the Federal Republic of Germany (ARD) of 1970 to the greatest extent

the relevant VDE Regulations and

those of the IEC Publication 215.

# Technical Data of the Longwave Transmitters
# LF Transmitter 600-kW S 4009
# LF Transmitter 350-kW S 4008

## Operational Requirements for the Transmitter Site*)

| | |
|---|---|
| Permissible mains voltage deviation: | ±10%, can be compensated on the transformers of the HT rectifiers and of the low-voltage supply. Short and instantaneous deviations up to ±10% related to nominal voltage will not impair the operation of the transmitter. |
| Permissible mains voltage variations: | In case of max. mains voltage variations of ± 5% the performance data will be met with the exception of power. |
| Permissible mains frequency deviation: | ± 5% |
| Permissible ambient temperature: | +1 to +45° C,<br>for test modulation with m = 1: max. temperature +40° C |
| Permissible relative humidity of the cooling air: | ≦ 80%,<br>short-time maximum 90%, but a temperature tmax = 26° C must not be exceeded. |
| Maximum altitude above sea level: (atmospheric pressure >795 mbar) | 2000 m |

## Drive Unit

A drive unit is not included in the scope of delivery of these long-wave broadcasting transmitter types.
The drive unit can be accommodated in the transmitter or also outside the transmitter, e.g. in a control console.

Available are:

| | |
|---|---|
| S STEU 1441-h | Transistorized Drive Unit |
| Frequency range: | 10 switchable crystals in two crystal ovens (crystal frequency = operating frequency) within the frequency range from 150 kHz to 500 kHz |
| Frequency instability (by ageing): | $1 \times 10^{-6}$ per month |
| S STEU 1370 | Decadally adjustable drive unit, fully transistorized and suitable for remote control |
| Frequency range: | Frequency setting in decade steps from $10^7$ to $10^1$ over the frequency range from 14 kHz to 31.99999 MHz |
| Frequency stability: | $1 \times 10^{-8}$ per day |
| Frequency instability (by ageing): | $\leqq 3 \times 10^{-9}$ per day<br>$\leqq 7 \times 10^{-8}$ per month<br>$\leqq 5 \times 10^{-7}$ per year |
| S STEU 1529 | Transistorized drive unit, plug-in type |
| Frequency range: | 2 switchable crystals (operation/reserve) in a crystal oven, within the longwave range from 150 to 250 kHz (not for remote switching). |

*) Applicable to the standard configuration of the transmitters.
On demand these transmitters can also be supplied for different operating conditions.

## RF Amplifier

| | |
|---|---|
| Rated output: | 600 kW carrier power, modulation capability 100%<br>350 kW carrier power, modulation capability 100% |
| Frequency range: | 150 to 285 kHz tunable without restriction |
| Frequency change: | Any frequency within the range stated can be set according to given data and by making use of the meters incorporated. |
| Type of emission: | A 3 broadcasting (anode voltage modulation) |
| Input: | |
| Input impedance: | $Z = 50\ \Omega$ |
| Standing-wave ratio: | $s \leqq 1.2$ |
| Driving power required: | 20 mW with a permissible tolerance of $\pm 1.5$ dB |
| Output: | |
| Terminating impedance: | $Z = 50\ \Omega$ |
| Permissible SWR: | $s \leqq 1.3$ |
| Connection for a rigid coaxial line according to IEC Publication 339-2: | 600 kW: 66/152 (IEC Publication 50-155)<br>350 kW: 45/103 (IEC Publication 50-105) |
| Unwanted radiations: (measured across a 50 Ω test load or during operation with the antenna): | Harmonics $\leqq 50$ mW, i.e.<br>at 600 kW $\geqq 71$ dB attenuation<br>at 350 kW $\geqq 68$ dB attenuation<br>related to the carrier value |
| | Spurious radiations: attenuation $\geqq 80$ dB (only if the Drive Unit S STEU 1370 is used) |
| | Measurements in accordance with IEC Publication 244-2 Appendix C and with CCIR Recommendation 329-1 |

## PDM Amplifier

| | |
|---|---|
| AF Input: | |
| Frequency range: | 40 to 7500 Hz<br>If the occupied bandwidth shall be reduced, an incorporated low-pass filter ($f_{cut\text{-}off}$ = 4500 Hz) can be connected. |
| Input impedance: | 600 Ω or >2000 Ω balanced and ungrounded |
| Input level: | for m = 1 and $f_{AF}$ = 1000 Hz<br>$N_m$ = −4 dBm to +10 dBm<br>adjustable in steps of 0.5 dB |
| Method of modulation: | Anode voltage modulation of the final stage of the RF amplifier by means of PDM (Pulse Duration Modulation).<br>Co-modulation of the screen grid of the RF output tube via an AF choke |
| Carrier voltage drop: | ≦3% at m = 1 and $f_{AF}$ = 1000 Hz<br>related to carrier voltage at m = 0 and constant mains voltage |
| Modulation capability: | |
| during program operation: | Any kind of program modulation (also with compression) is continuously permissible within the limits shown by Fig. 1 up to a mean modulation depth of m = 0.75 |
| During tests: (Transmitter terminated by a test load, ambient temperature in the transmitter hall ≦40° C): | Once within a period of 6 hours |

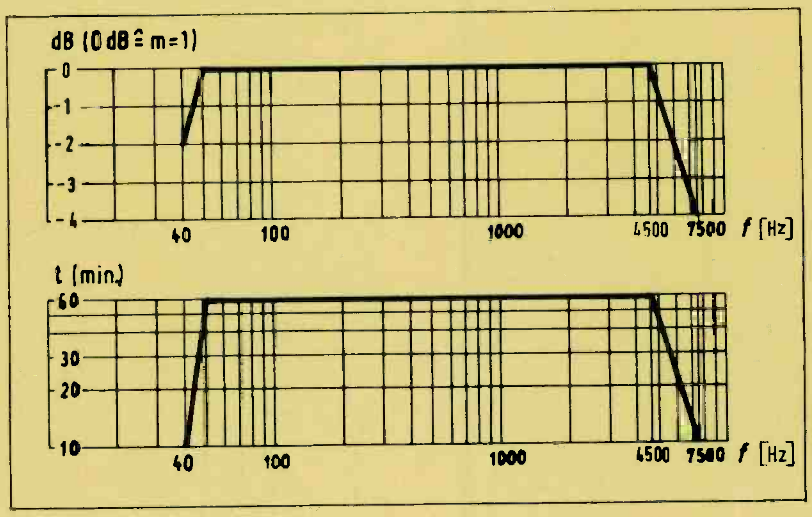



Fig. 1

or once every hour

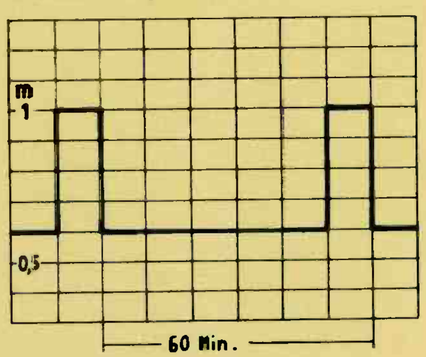



Fig. 2

50 Hz < $f_{AF}$ < 4500 Hz

Overmodulation:

AF input levels exceeding 10 dB for a longer period are regulated downward in the incorporated limiter-amplifier to admissible values.
In the event of overmodulations by more than 10 dB protective elements will intervene.

Linear distortions:
(Frequency response)
Reference frequency
400 Hz or 1000 Hz

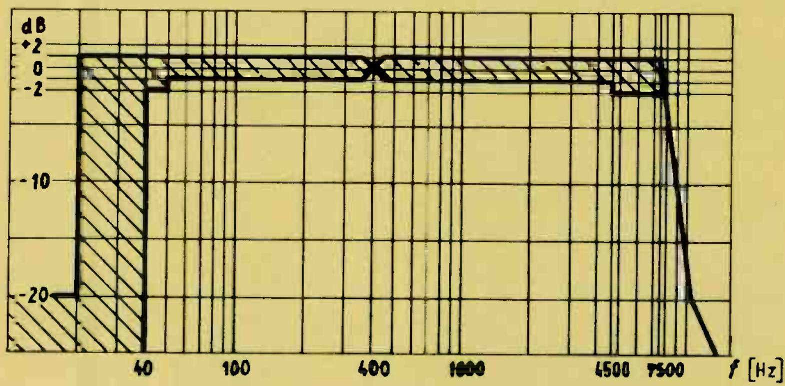



Fig. 3

Out-of-band spectrum according to CCIR Rec. 328-3.
The frequency response measured with any input voltage within the aforementioned modulation capability of the transmitter deviates from that measured at m = 0.5 by not more than ±0.5 dB

Non-linear distortions:
(Distortion factor)

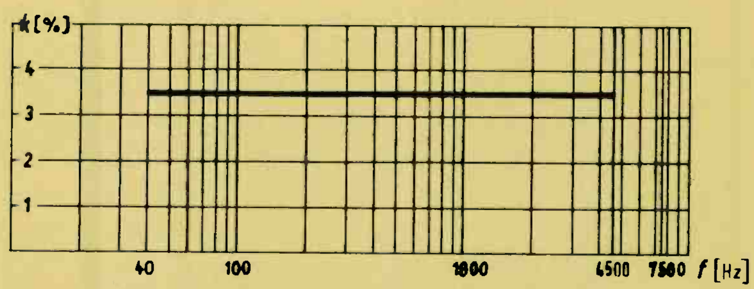



Fig. 4

for $m \leqq 0.9$ within max. permissible modulation depth in accordance with Fig. 1.

Spurious modulation:

Signal-to-noise ratio:

$\geqq$60 dB unweighted

$\geqq$70 dB weighted with filter in conformity with DIN 45405 and in accordance with CCITT

Phase modulation:
(synchronous)

$\leqq 6°$ or approx. 1/10 rad.
at $m = 0.5$ and $f_{AF} = 1000$ Hz

## Transmitter Power Supply

| | 600 kW transmitter | 350 kW transmitter |
|---|---|---|
| Mains supply: | Three-phase, four-wire 50 Hz 3.6 kV to 36 kV<br>other data on demand | Three-phase, four-wire 50 Hz 3.6 kV to 36 kV<br>other data on demand |
| Connected load (recommended): | 1700 kVA | 1000 kVA |
| Mains breaking capacity: | 20 MVA | 10 MVA |
| Mains short-circuiting power (recommended): | 200 MVA | 100 MVA |

Power consumption: Below the rated output at a modulation frequency $f_{AF}$ = 1000 Hz (sine wave) The values stated below are average values.

| at a modulation depth of | 600 kW transmitter | | 350 kW transmitter |
|---|---|---|---|
| m = 0 | 875 kW $\eta_{total}$ 69% | 1.4583 | 515 kW $\eta_{total}$ 68% |
| m = 0.3 | 910 kW $\eta_{total}$ 69% | | 530 kW $\eta_{total}$ 68% |
| m = 0.45 | 950 kW $\eta_{total}$ 69% | | 550 kW $\eta_{total}$ 68% |
| m ≈ 1 | 1250 kW $\eta_{total}$ 69% | 2.083 | 720 kW $\eta_{total}$ 68% |

For these values the max. permissible carrier voltage drop has been taken into account.

| | 600 kW transmitter | 350 kW transmitter |
|---|---|---|
| Power factor: | $\cos\varphi > 0.9$ | $\cos\varphi > 0.9$ |
| Phase load max. diff. factor: | 1.05 | 1.05 |

Voltage stabilizer: Only needed for tube filament heating, incorporated in the filament supply.

## Cooling Equipment

Water cooling: Closed water circulation (distillate or softened, fully de-salted water) for the cooling of the tubes as well as for other highly loaded components.

The heat of the power dissipated and eliminated in this cooling circulation can be utilized, for example, for the heating of the building.

Air cooling: Air circulation in a defined manner for incoming and outgoing air for the head cooling of the tubes and for the cooling of components in the transmitter cabinets.

Filtering devices in accordance with the local requirements, closed circuit ventilation, if required.

Heat dissipated in the room:
600 kW transmitter <8 kW
350 kW transmitter <6 kW

## Tube Complement

| | 600 kW transmitter | 350 kW transmitter |
|---|---|---|
| RF and PDM amplifier stages: | 2 x TH 558<br>1 x TH 561 | 2 x TH 573<br>1 x TH 561 |

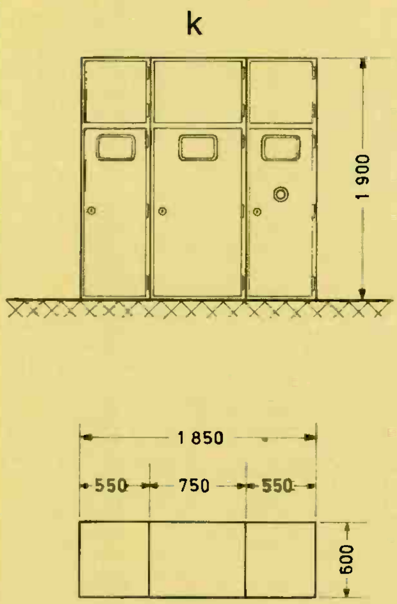
154.92 Amp = 1,200 KW
141.42 Amp = 1,000 KW
109.55 Amp = 600 KW
83.67 Amp = 350 KW
44.73 Amp = 100 KW

100 Amp = 500 KW



1/2 PWR = .7071 OF T AMPERAGE

## Dimensions



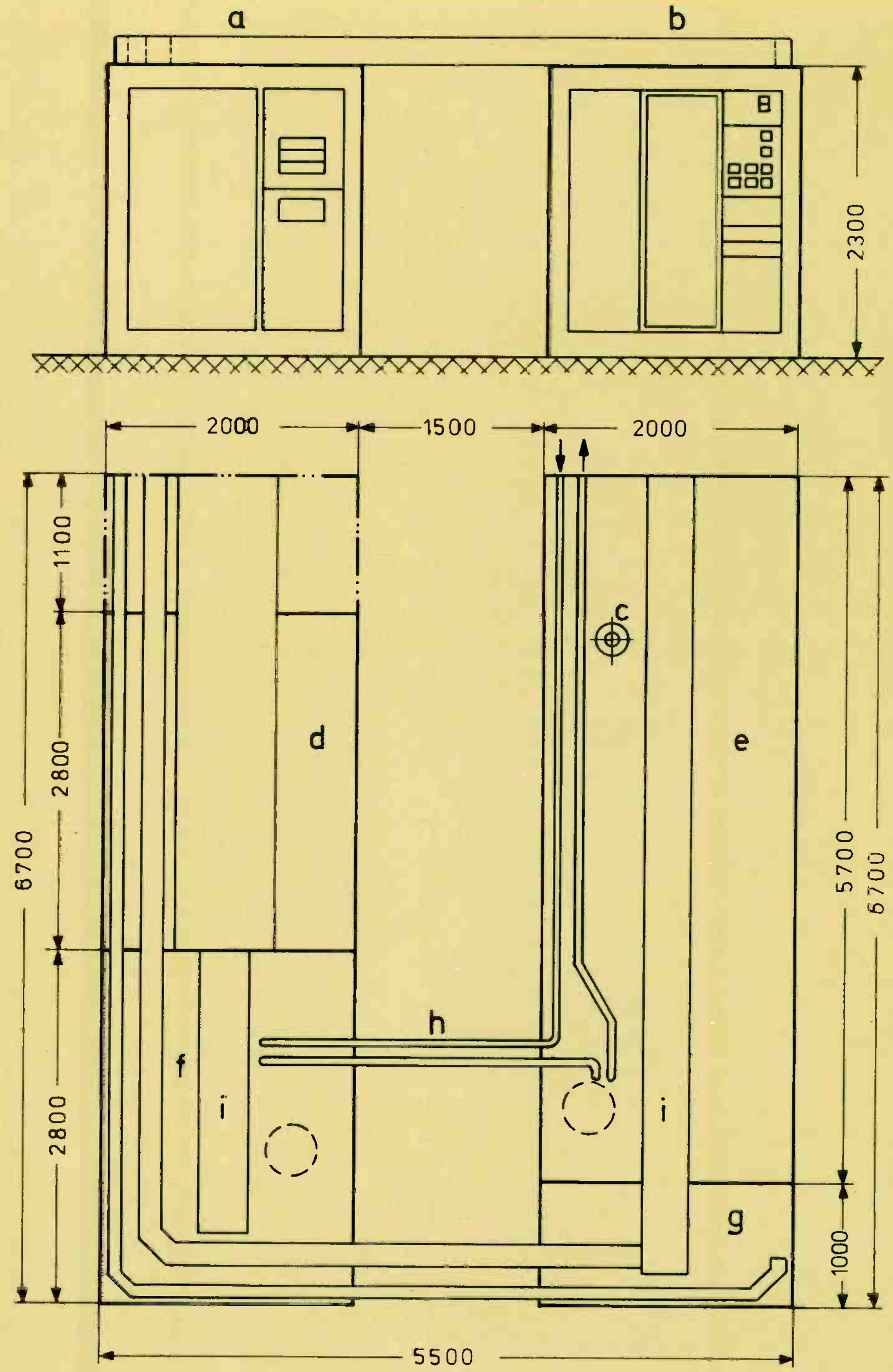




Fig. 5
Dimensional Drawing of the
Longwave Broadcasting Transmitters
LF Transmitter 600-kW S 4009
LF Transmitter 350-kW S 4008

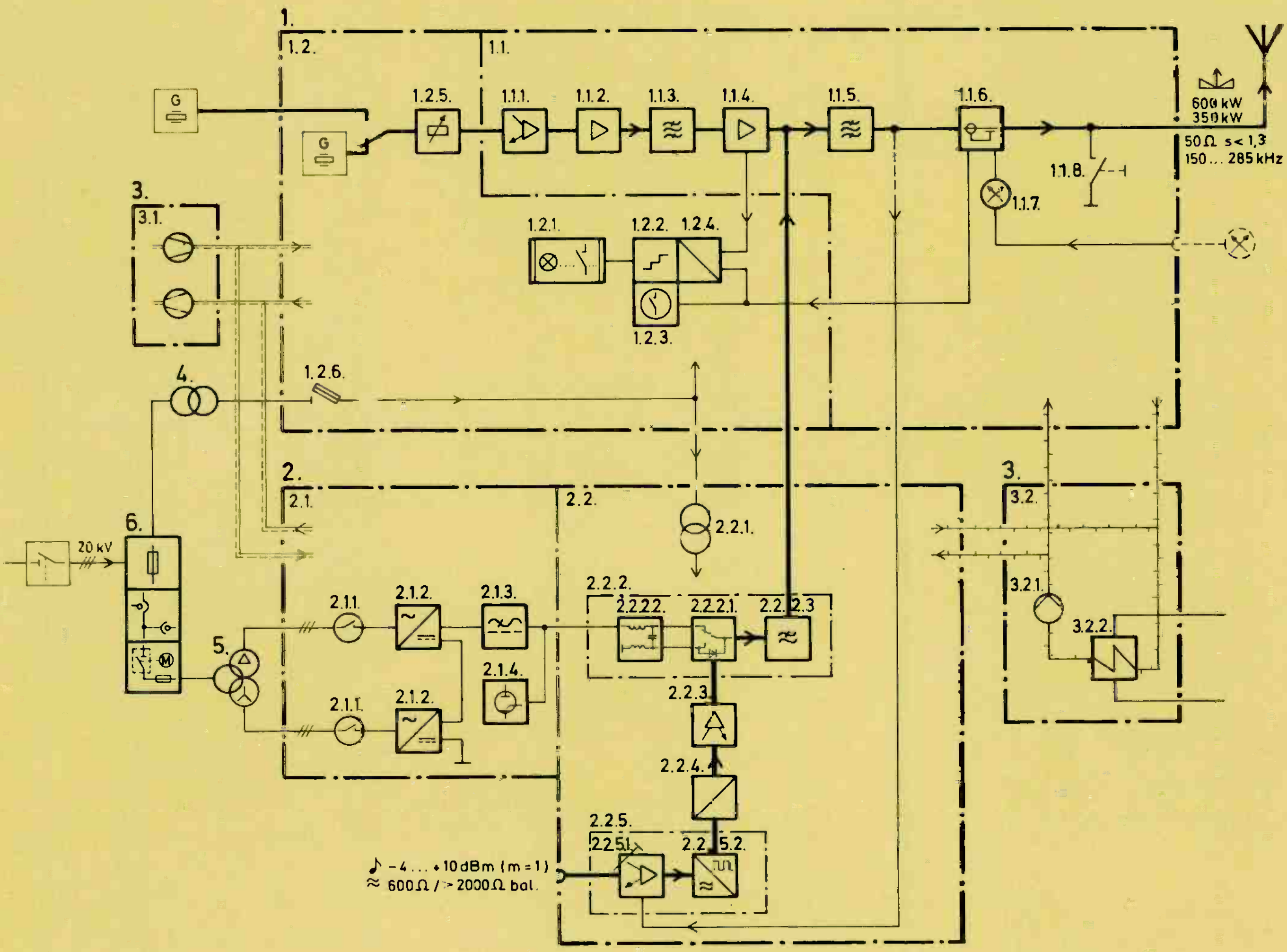
a PDM Section
b RF Section
c to the Antenna
d HT Power Supply
e RF Amplifier with Output Circuits
f Pulse Duration Modulation Amplifier
g Control Rack
h Cooling Water Pipes
i Air Ducts
k Transmitter HT Distribution

In addition to Transmitter HT Distribution:

| | Transmitter | Dimensions mm L | W | H |
|---|---|---|---|---|
| Transformer for HT Rectifier | 350 kW | 2000 | 1100 | 1950 |
| * | 600 kW | 2100 | 1300 | 2450 |
| Step-down Transformer | 350 kW | 1100 | 700 | 1500 |
| * | 600 kW | 1100 | 700 | 1600 |

The dimensions are approximate values, they can be adapted – circumstances permitting – to the given conditions in the building.

Fig. 6
Block Diagram of the
Longwave Broadcasting Transmitters
LF Transmitter 600 kW S 4009
LF Transmitter 350 kW S 4008




**1. RF Section**

1.1. RF Amplifier
1.1.1. Pre-Driver Stage
1.1.2. Driver Stage
1.1.3. Grid Circuit, 3f-Processing
1.1.4. Output Stage
1.1.5. Output Circuits
1.1.6. Feeder-Line Monitor
1.1.7. Cross-Pointer Instrument
1.1.8. Grounding Switch

1.2. Control rack
1.2.1. Switch Panel
1.2.2. Disconnector Unit
1.2.3. Blocking Unit
1.2.4. Detuning Monitor
1.2.5. Levelling Panel
1.2.6. Fuse Isolating Switch

**2. PDM Section**

2.1. HT Power Supply
2.1.1. Vacuum Switches
2.1.2. HT-Rectifier (12 pulses per cycle)
2.1.3. Filter Elements
2.1.4. Ignitron Protection Unit

2.2. PDM-Amplifier
2.2.1. Isolating Transformer
2.2.2. Output Stage
2.2.2.1. Switching Tube with Commutating Diode
2.2.2.2. Storage Coil
2.2.2.3. Low-Pass Filter
2.2.3. Driver Stage
2.2.4. AF/PDM Isolating Units
2.2.5. AF Stages
2.2.5.1. AF Input Stages/Linear Meas. Detector
2.2.5.2. AF/PDM Converter

**3. Cooling Equipment**

3.1. Air Cooling
3.2. Water Cooling
3.2.1. Pump
3.2.2. Heat Exchanger

**4. Step-Down Transformer**

**5. Transformer for HT Rectifier**

**6. Transmitter HT Distribution**

# Technical Data of the Mediumwave Transmitters
# MF Transmitter 600-kW S 4006
# MF Transmitter 350-kW S 4004
# MF Transmitter 100-kW S 4002

## Operational Requirements for the Transmitter Site *)

| | |
|---|---|
| Permissible mains voltage deviation: | ±10%, can be compensated on the transformers of the HT rectifiers and of the low-voltage supply. Short and instantaneous deviations up to ±10% related to nominal voltage will not impair the operation of the transmitter. |
| Permissible mains voltage variations: | In case of max. mains voltage variations of ±5% the performance data will be met with the exception of power. |
| Permissible mains frequency deviation: | ±5% |
| Permissible ambient temperature: | +1° C to +45° C,<br>for test modulation with m = 1; max. temperature +40° C |
| Permissible relative humidity of the cooling air: | ≦80%,<br>short-time maximum 90%, but a temperature $t_{max}$ = 26° C must not be exceeded. |
| Maximum altitude above sea level:<br>(atmospheric pressure >795 mbar) | 2000 m |

## Drive Unit

A drive unit is not included in the scope of delivery of these mediumwave broadcasting transmitter types.
The drive unit can be accommodated in the transmitter or also outside the transmitter, e.g. in a control console.
Available are:

| | |
|---|---|
| S STEU 1366-h | Transistorized Drive Unit |
| Frequency range: | 10 switchable crystals in two crystal ovens (crystal frequency = operating frequency) within the frequency range from 500 kHz to 1605 kHz |
| Frequency instability (by ageing): | 1 x $10^{-6}$ per month |
| S STEU 1370 | Decadally adjustable drive unit, fully transistorized and suitable for remote control |
| Frequency range: | Frequency setting in decade steps from $10^{7}$ to $10^{1}$ over the frequency range from 14 kHz to 31.99999 MHz |
| Frequency stability: | 1 x $10^{-8}$ per day |
| Frequency instability (by ageing): | ≦ 3 x $10^{-9}$ per day<br>≦ 7 x $10^{-8}$ per month<br>≦ 5 x $10^{-7}$ per year |
| S STEU 1529 | Transistorized drive unit, plug-in type |
| Frequency range: | 2 switchable crystals (operation/reserve) in a crystal oven, within the mediumwave range from 525 to 1605 kHz (not for remote switching) |

*) Applicable to the standard configuration of the transmitters.
On demand these transmitters can also be supplied for different operating conditions.

**RF Amplifier**

| | |
|---|---|
| Rated output: | 600 kW carrier power, modulation capability 100%<br>350 kW carrier power, modulation capability 100%<br>100 kW carrier power, modulation capability 100% |
| Frequency range: | 525 to 1605 kHz tunable without restriction |
| Frequency change: | Within less than 30 minutes any frequency over the range stated can be set according to given data and by making use of the meters incorporated. The transmitters can also be supplied for two operating frequencies, e.g. for day/night frequency change-over; change-over time ≦2 minutes. |
| Type of emission: | A3 broadcasting (anode voltage modulation) |
| Input: | |
| Input impedance: | Z = 50 Ω |
| Standing-wave ratio: | s ≦ 1.2 |
| Driving power required: | 20 mW with a permissible tolerance of ±1.5 dB |
| Output: | |
| Terminating impedance and Permissible SWR: | 600 kW: Z = 50 Ω, s ≦ 1.3<br>350 kW: Z = 50 Ω, s ≦ 1.3<br>100 kW: Z = 50 Ω, s ≦ 1.5 |
| Connection for a rigid coaxial line according to IEC Publication 339-2: | 600 kW: 66/152 (IEC Publication 50–155)<br>350 kW: 45/103 (IEC Publication 50–105)<br>100 kW: 45/103 (IEC Publication 50–105) or 33.4/77 (IEC Publication 50–80) |
| Unwanted radiations: (measured across a 50 Ω test load or during operation with the antenna): | Harmonics ≦50 mW, therefore this means<br>at 600 kW ≦71 dB attenuation<br>at 350 kW ≦68 dB attenuation<br>at 100 kW ≧63 dB attenuation<br>related to the carrier value<br><br>Spurious radiations: attenuation ≧80 dB<br>(only if the Drive Unit S STEU 1370 is used)<br><br>Measurements in accordance with IEC Publication 244-2 Appendix C and with CCIR Recommendation 329-1 |

109.545 AMP
AT 50 Ω = 600KW

## PDM Amplifier

AF Input:

| | |
|---|---|
| Frequency range: | 40 to 7500 Hz<br>If the occupied bandwidth shall be reduced, an incorporated low-pass filter ($f_{cut\text{-}off}$ = 4500 Hz) can be connected. |
| Input impedance: | 600 Ω or > 2000 Ω balanced and ungrounded |
| Input level: | for m = 1 and $f_{AF}$ = 1000 Hz<br>$N_m$ = −4 dBm to + 10 dBm<br>adjustable in steps of 0.5 dB |
| Method of modulation: | Anode voltage modulation of the final stage of the RF amplifier by means of PDM (Pulse Duration Modulation)<br>Co-modulation of the screen grid of the RF output tube via an AF choke |
| Carrier voltage drop: | ≦ 3% at m = 1 and $f_{AF}$ = 1000 Hz<br>related to carrier voltage at m = 0 and constant mains voltage |

Modulation capability:

| | |
|---|---|
| During programm operation: | Any kind of program modulation (with trapezoidal modulation and/or compression) is continuously permissible up to a mean modulation depth of m = 0.75. The possibility of trapezoidal modulation has been provided. |
| Durings tests:<br>(Transmitter terminated by a test load, ambient temperature in the transmitter hall ≦40° C) | Once within a period of 6 hours |

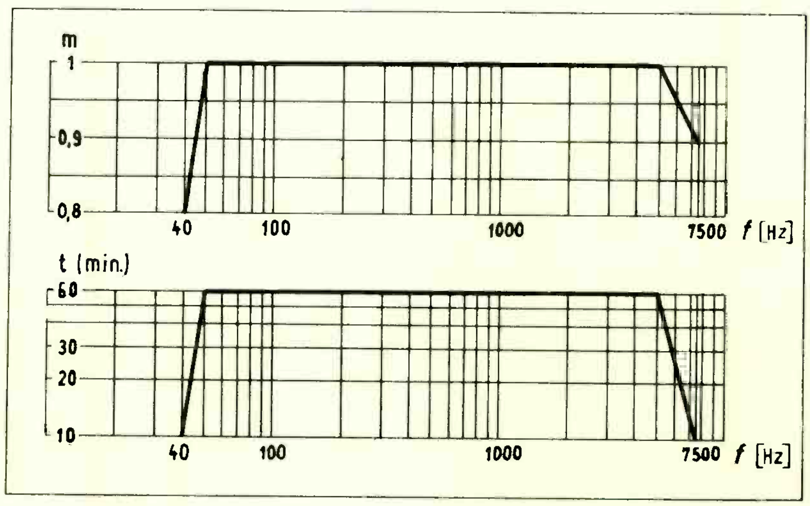



Fig. 7

or once every hour

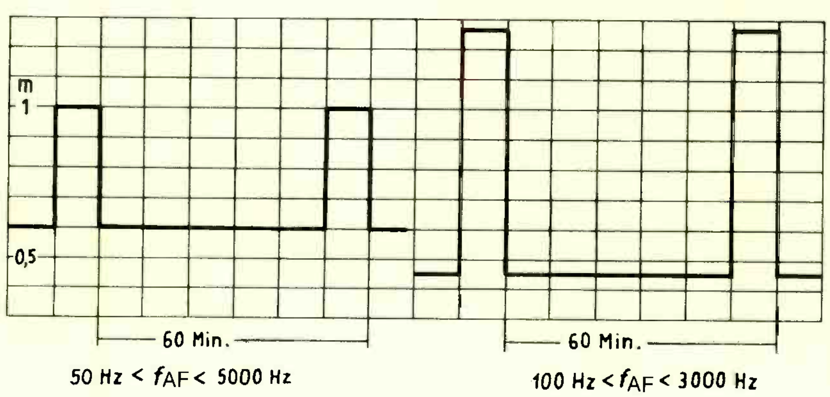



Fig. 8

Overmodulation: AF input levels exceeding 10 dB for a longer period are regulated downward in the incorporated limiter-amplifier to admissible values.
In the event of overmodulations by more than 10 dB protective elements will intervene.

Linear distortions:
(Frequency response)
Reference frequency
400 Hz or 1000 Hz

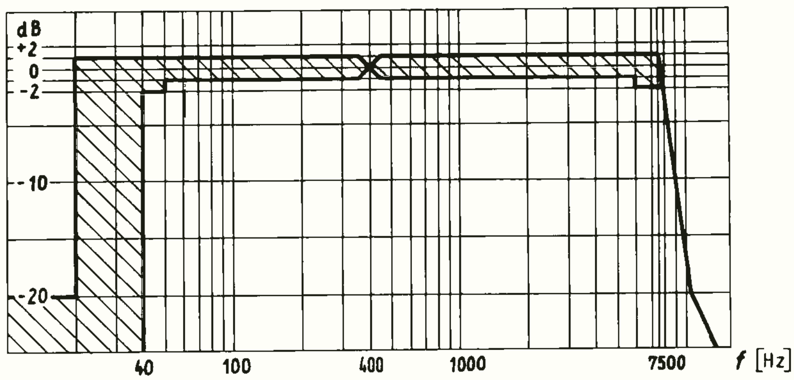



Fig. 9

Out-of-band spectrum according to CCIR Rec. 328-3
The frequency response measured with any input voltage within the aforementioned modulation capability of the transmitter deviates from that measured at m = 0.5 by not more than ±0.5 dB.

Non-linear distortions:
(Distortion factor)

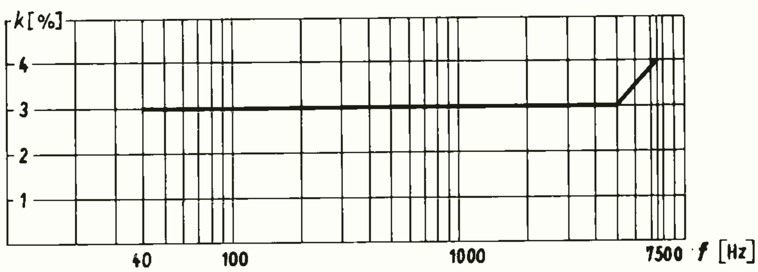



Fig. 10

for m ≦0.9 within max. permissible modulation depth in accordance with Fig. 7.

Spurious Modulation:

Signal-to-Noise Ratio: ≧60 dB unweighted

≧70 dB weighted with filter in conformity with DIN 45405 and in accordance with CCITT.

Phase Modulation: (synchronous): ≦6° or approx. 1/10 rad. at m = 0.5 and $f_{AF}$ = 1000 Hz

## Transmitter Power Supply

| | 600 kW | 350 kW | 100 kW |
|---|---|---|---|
| Mains supply: | Three-phase, four-wire 50 Hz 3.6 kV to 36 kV<br>Other data on demand | | Three-phase, four-wire<br>50 Hz 380 V |
| Connected load (recommended): | 1700 kVA | 1000 kVA | 300 kVA |
| Mains breaking capacity: | 20 MVA | 10 MVA | – |
| Mains breaking current: | – | – | 10 kA |
| Mains short-circuiting power: (recommended) | 200 MVA | 100 MVA | – |

Power consumption: At rated RF output and modulatiion with $f_{AF}$ = 1000 Hz (sine wave)
All values stated below are averages.

| at a modulation depth of | 600 kW | 350 kW | 100 kW |
|---|---|---|---|
| $m = 0$ | 875 kW $\eta_{total}$ 69% | 515 kW $\eta_{total}$ 68% | 155 kW $\eta_{total}$ 65% |
| $m = 0.3$ | 910 kW $\eta_{total}$ 69% | 530 kW $\eta_{total}$ 68% | 160 kW $\eta_{total}$ 65% |
| $m = 0.45$ | 950 kW $\eta_{total}$ 69% | 550 kW $\eta_{total}$ 68% | 165 kW $\eta_{total}$ 65% |
| $m \approx 1$ | 1250 kW $\eta_{total}$ 69% | 720 kW $\eta_{total}$ 68% | 210 kW $\eta_{total}$ 65% |

For these values the max. permissible carrier voltage drop has been taken into account

| | 600 kW | 350 kW | 100 kW |
|---|---|---|---|
| Power factor: | $\cos\varphi > 0.9$ | $\cos\varphi > 0.9$ | $\cos\varphi > 0.9$ |
| Phase load: max. diff. factor | 1.05 | 1.05 | 1.1 |

Voltage stabilizer: Only needed for tube filament heating, incorporated in the filament supply.

## Cooling Equipment

Water cooling: Closed water circulation (distillate or softened, fully de-salted water) for the cooling of the tubes as well as for other highly loaded components.

The heat of the power dissipated and eliminated in this cooling circulation can be utilized, for example, for the heating of the building.

Air cooling: Air circulation in a defined manner for incoming and outgoing air for the head cooling of the tubes and for the cooling of components in the transmitter cabinets.

Filtering devices in accordance with the local requirements, closed circuit ventilation, if required.

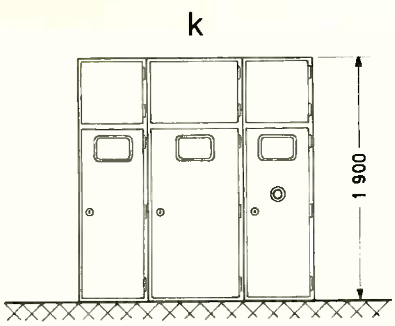
Heat dissipated in the room:
600 kW transmitter <8 kW
350 kW transmitter <6 kW
100 kW transmitter <5 kW

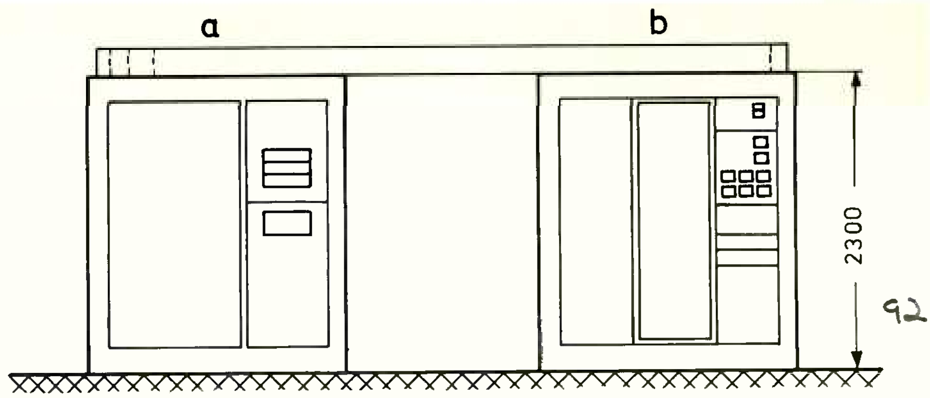
## Tube Complement:

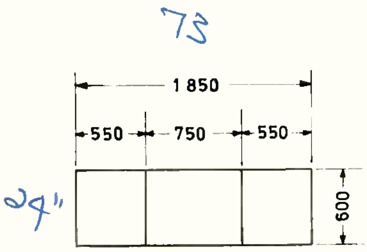
| | 600 kW | 350 kW | 100 kW |
|---|---|---|---|
| RF- and PDM amplifier stages: | 2 x TH 558<br>1 x TH 561 | 2 x TH 573<br>1 x TH 561 | 2 x TH 581<br>1 x 4 CX 1500 A |

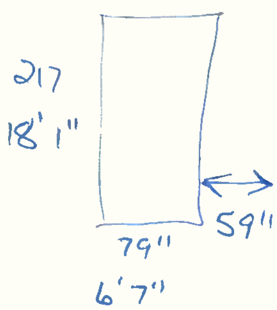
36X VX 24.3 A

**Dimensions**



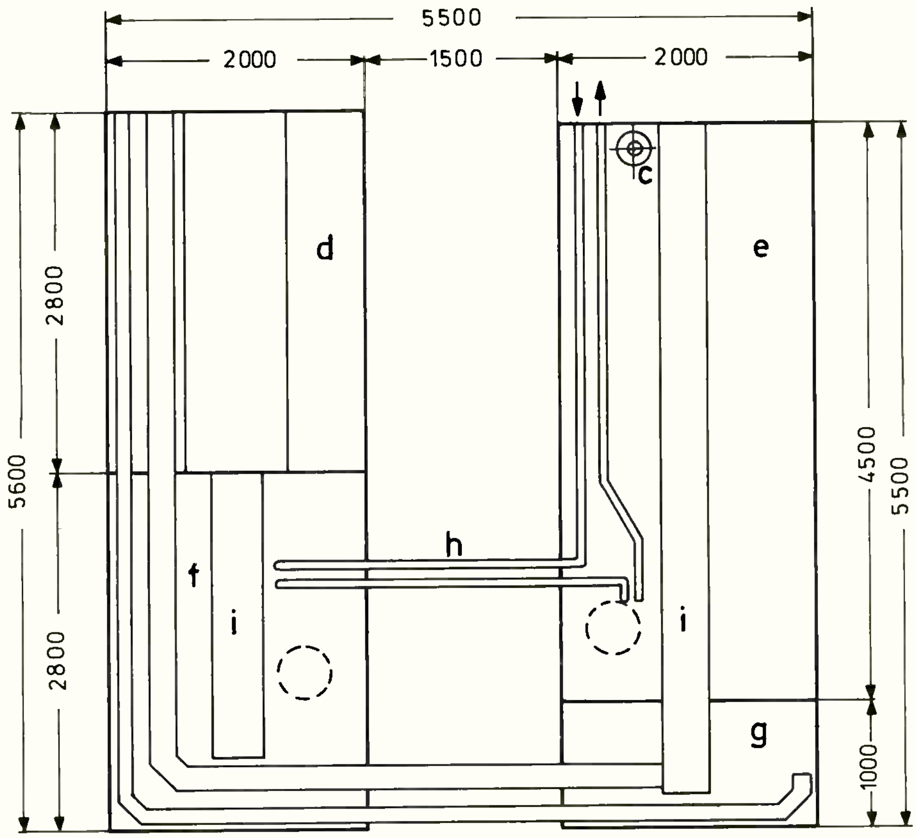




Fig. 11
Dimensional Drawing of the Mediumwave Broadcasting Transmitters
MF Transmitter 600-kW S 4006
MF Transmitter 350-kW S 4004

a PDM Section
b RF Section
c to the Antenna
d HT Power Supply
e RF Amplifier with Output Circuits
f Pulse Duration Modulation Amplifier
g Control Rack
h Cooling Water Pipes
i Air Ducts
k Transmitter HT Distribution

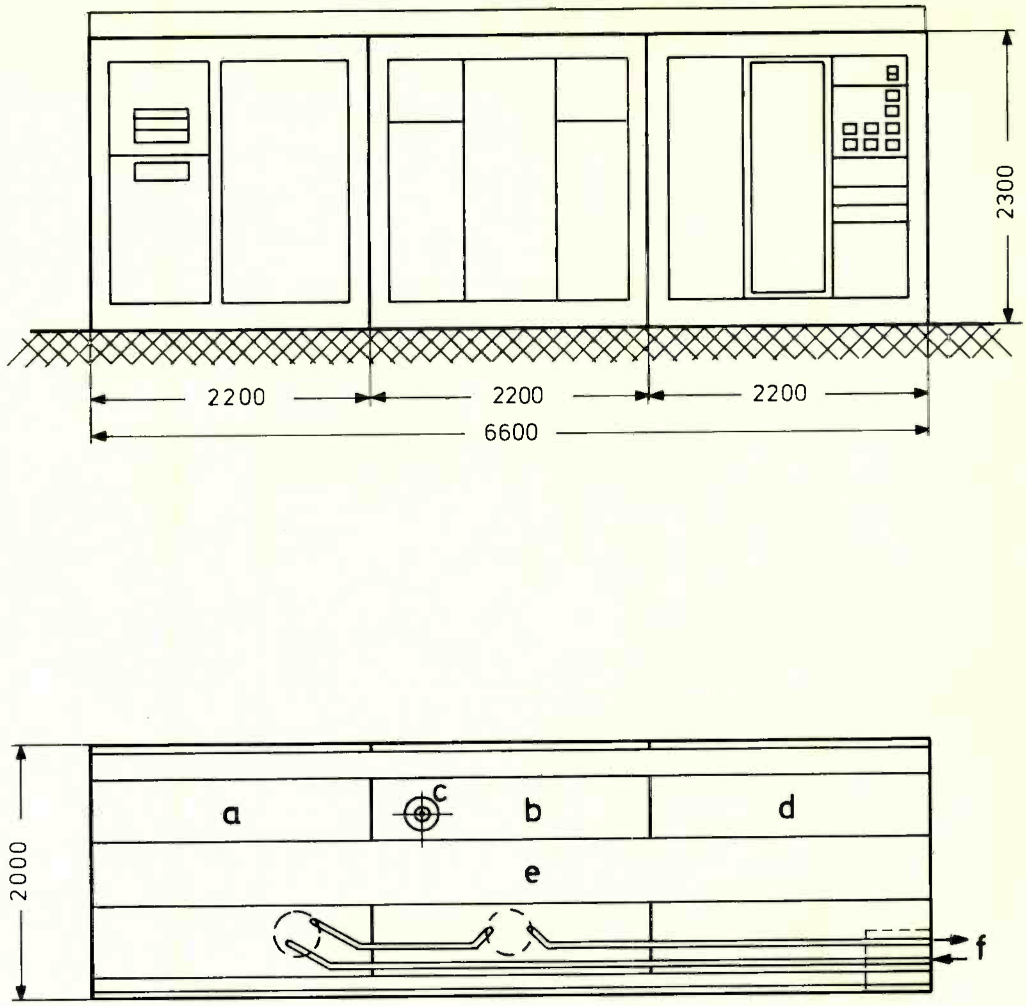
In addition to Transmitter HT Distribution

| | Transmitter | Dimensions mm L | W | H |
|---|---|---|---|---|
| Transformer for HT Rectifier | 350 kW | 2000 | 1100 | 1950 |
| | 600 kW | 2100 | 1300 | 2450 |
| Step-down Transformer | 350 kW | 1100 | 700 | 1500 |
| | 600 kW | 1100 | 700 | 1600 |

18' x 18' BOX
6.56' THICK
83x 51
43x 28
97"

The dimensions are approximate values, they can be adapted – circumstances permitting – to the given conditions in the building.

Fig. 12
Dimensional Drawing of the
MF Broadcasting Transmitter
100-kW S 4002



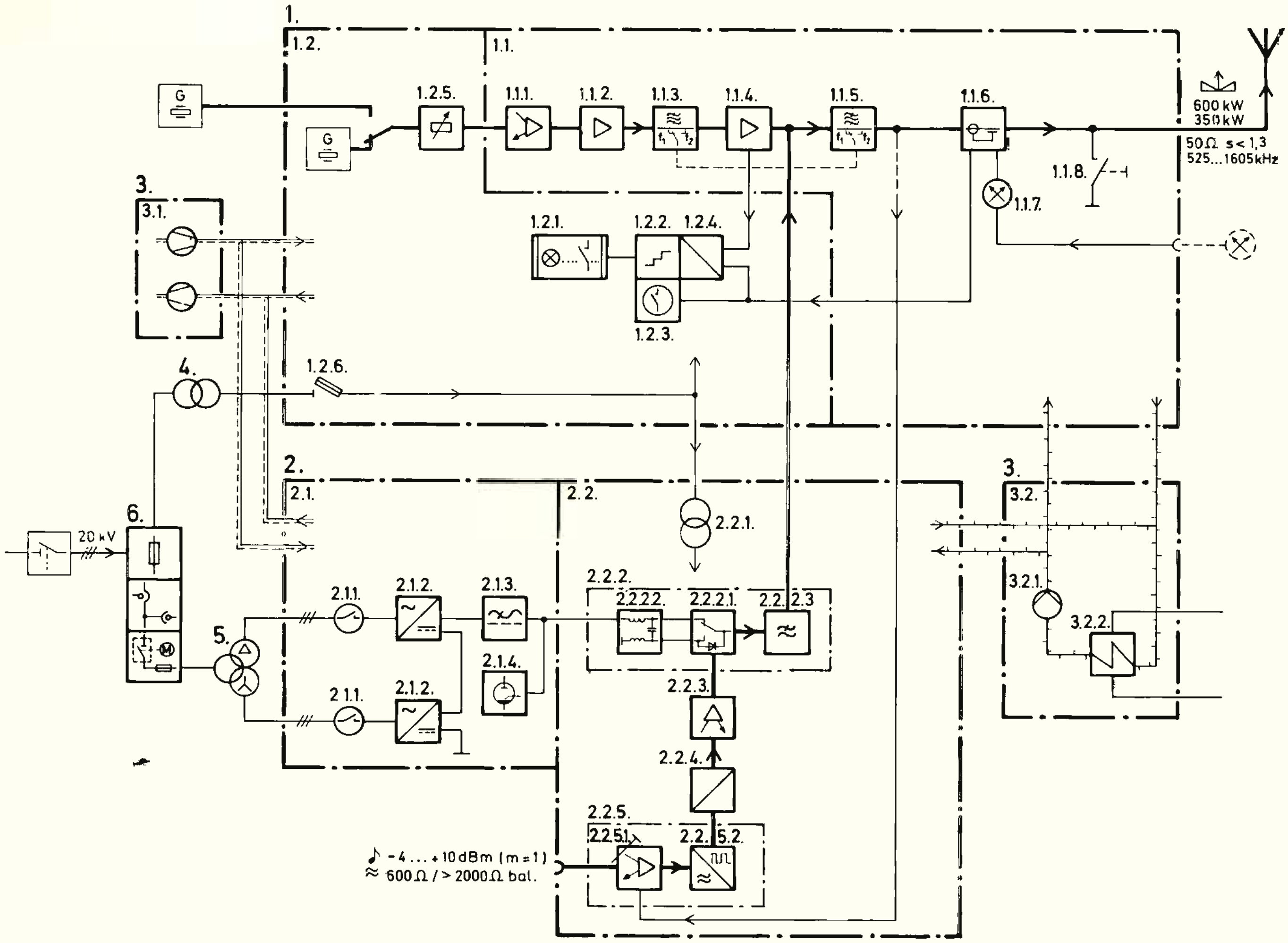

a PDM Rack (PDM Amplifier)
b RF Rack (RF Amplifier)
c to the Antenna

d Rectifier Rack (Control Unit, Power Supply)
e Air Duct
f Cooling Water Pipes

44.72 A 52Ω

260 21'8"
79" 6 7"
91" 7' 7" HIGH TX

Fig. 13
Block Diagram of the
Mediumwave Broadcasting Transmitters
MF Transmitter 600-kW S 4006
MF Transmitter 350-kW S 4004




**1. RF Section**

1.1. RF Amplifier
1.1.1. Pre-Driver Stage
1.1.2. Driver Stage
1.1.3. Grid Circuit, 3f-Processing
1.1.4. Output Stage
1.1.5. Output Circuits
1.1.6. Feeder-Line Monitor
1.1.7. Cross-Pointer Instrument
1.1.8. Grounding Switch

1.2. Control rack
1.2.1. Switch Panel
1.2.2. Disconnector Unit
1.2.3. Blocking Unit
1.2.4. Detuning Monitor
1.2.5. Levelling Panel
1.2.6. Fuse Isolating Switch

**2. PDM Section**

2.1. HT Power Supply
2.1.1. Vacuum Switches
2.1.2. HT Rectifier (12 pulses per cycle)
2.1.3. Filter Elements
2.1.4. Ignitron Protection Unit

2.2. PDM Amplifier
2.2.1. Isolating Transformer
2.2.2. Output Stage
2.2.2.1. Switching Tube with Commutating Diode
2.2.2.2. Storage Coil
2.2.2.3. Low-Pass Filter
2.2.3. Driver Stage
2.2.4. AF/PDM Isolating Units
2.2.5. AF Stages
2.2.5.1. AF Input Stages/Linear Meas. Detector
2.2.5.2. AF/PDM Converter

**3. Cooling Equipment**

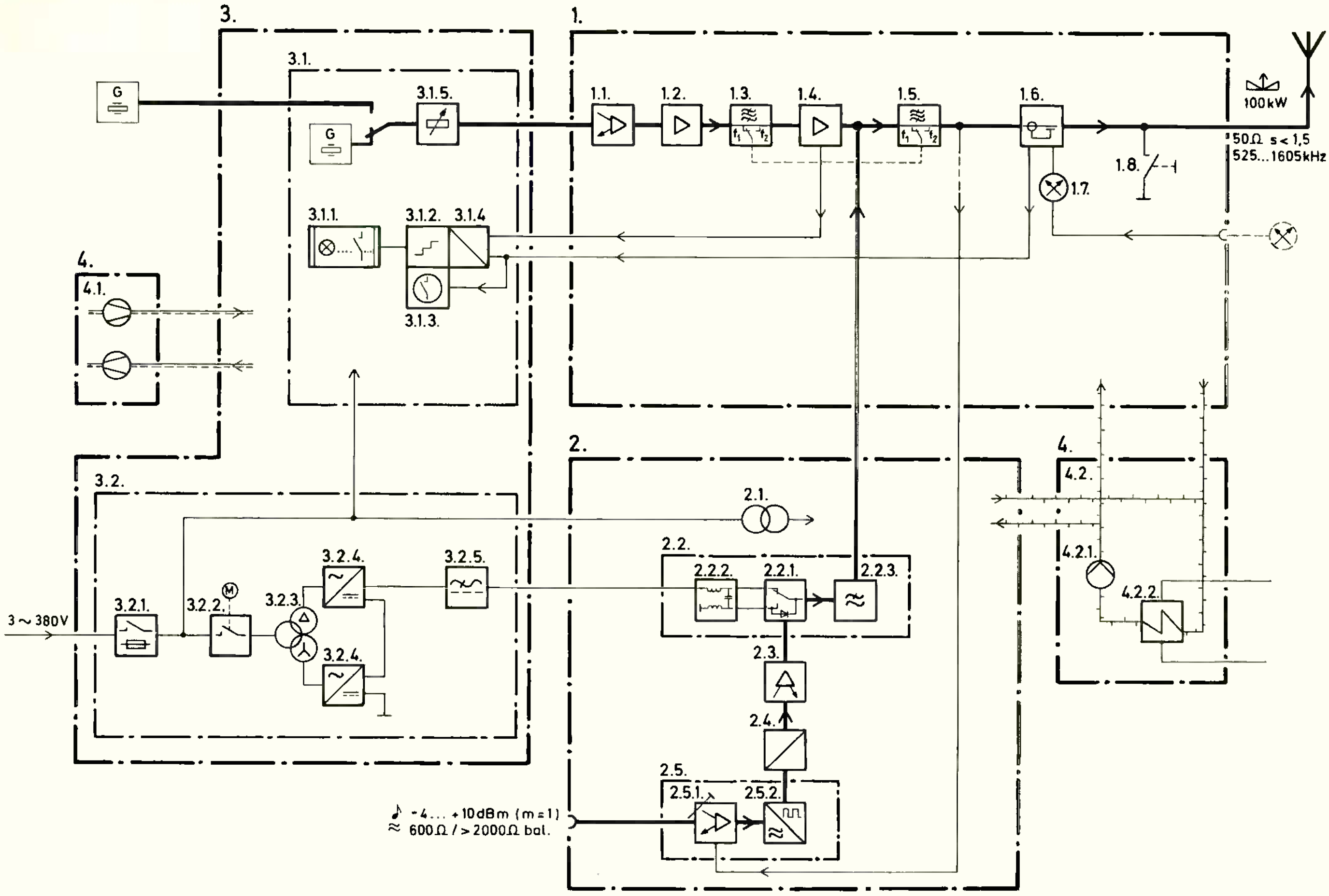
3.1. Air Cooling
3.2. Water Cooling
3.2.1. Pump
3.2.2. Heat Exchanger

**4. Step-Down Transformer**

**5. Transformer for HT Rectifier**

**6. Transmitter HT Distribution**

Fig. 14
Block Diagram of the
Mediumwave Broadcasting Transmitter
100-kW S 4002




**1. RF Amplifier (RF Rack)**

1.1. Pre-Driver Stage
1.2. Driver Stage
1.3. Grid Circuit, 3f-Processing
1.4. Output Stage
1.5. Output Circuits
1.6. Feeder Line Monitor
1.7. Cross-Pointer Instrument
1.8. Grounding Switch

**2. PDM Amplifier (PDM Rack)**

2.1. Isolating Transformer
2.2. Output Stage
2.2.1. Switching Tube with Commutating Diode
2.2.2. Storage Coil
2.2.3. Low-Pass Filter
2.3. Driver Stage
2.4. AF/PDM Isolating Units
2.5. AF Stages
2.5.1. AF Input Stages/ Linear Meas. Detector
2.5.2. AF/PDM Converter

**3. Rectifier Rack**

3.1. Control Unit
3.1.1. Switch Panel
3.1.2. Disconnector Unit
3.1.3. Blocking Unit
3.1.4. Detuning Monitor
3.1.5. Levelling Panel
3.2. Power Supply
3.2.1. Visible Isolating Point
3.2.2. Circuit-Breaker
3.2.3. Transformer
3.2.4. HT Rectifier (12 pulses)
3.2.5. Filter Elements

**4. Cooling Equipment**

4.1. Air Cooling
4.2. Water Cooling
4.2.1. Pump
4.2.2. Heat Exchanger

# Technical Data of the Shortwave Transmitters
# HF Transmitter 500 kW S 4005
# HF Transmitter 300 kW S 4003
# HF Transmitter 100 kW S 4001

## Operational Requirements for the Transmitter Site *)

| | |
|---|---|
| Permissible mains voltage deviation: | ±10%, can be compensated on the transformers of the HT rectifiers and of the low-voltage supply. Short and instantaneous deviations up to ±10% related to nominal voltage will not impair the operation of the transmitter. |
| Permissible mains voltage variations: | In case of max. mains voltage variations of ±5% the performance data will be met with the exception of power. |
| Permissible mains frequency deviation: | ±5% |
| Permissible ambient temperature: | +1° C to +45° C,<br>for test modulation with m = 1: max. temperature +40° C |
| Permissible relative humidity of the cooling air: | ≦80%,<br>short-time maximum 90%, but a temperature $t_{max}$ = 26° C must not be exceeded. |
| Maximum altitude above sea level: (atmospheric pressure >795 mbar) | 2000 m |

| | |
|---|---|
| **Drive Unit** | A drive unit is not included in the scope of delivery of these shortwave-broadcasting transmitter types.<br>The drive unit can be accommodated in the transmitter or also outside the transmitter, e.g. in a control console.<br>Available are: |
| S STEU 2366-h | Transistorized Drive Unit |
| Frequency range: | 10 switchable crystals in two crystal ovens (crystal frequency = operating frequency) within the frequency range from 1.5 MHz to 30 MHz |
| Frequency instability (by ageing): | $1 \times 10^{-6}$ per month |
| S STEU 1370 | Decadally adjustable drive unit, fully transistorized and suitable for remote control |
| Frequency range: | Frequency setting in decade steps from $10^7$ to $10^1$ over the frequency range from 14 kHz to 31.99999 MHz |
| Frequency stability: | $1 \times 10^{-8}$ per day |
| Frequency instability (by ageing): | $\leqq 3 \times 10^{-9}$ per day<br>$\leqq 7 \times 10^{-8}$ per month<br>$\leqq 5 \times 10^{-7}$ per year |

*) Applicable to the standard configuration of the transmitters.
On demand these transmitters can also be supplied for different operating conditions.

## RF Amplifier

| | |
|---|---|
| Rated output: | 500 kW carrier power<br>300 kW carrier power<br>100 kW carrier power<br>±8% for automatic tuning, modulation capability 100% |
| Frequency range: | 500 kW: 3.9 to 26.1 MHz (broadcast ranges)<br>300 kW: 3.9 to 26.1 MHz (broadcast ranges)<br>100 kW: 3.2 to 26.1 MHz (broadcast ranges)<br><br>On demand also without restriction to broadcast ranges. |
| Frequency change: | Automatic tuning over the broadcast ranges to any frequency chosen in the drive unit. Time required for tuning: max. 60 seconds, 30 seconds on the average. |
| Type of emission: | A3 broadcasting (anode voltage modulation) |
| Input: | |
| Input impedance: | $Z = 50\,\Omega$ |
| SWR: | $s \leqq 1.2$ |
| Driving power required: | 20 mW with a permissible tolerance of ±1.5 dB |
| Output: | |
| Terminating impedance and permissible SWR: | 500 kW: $Z = 50\,\Omega$, $s \leqq 2$<br>300 kW: $Z = 50\,\Omega$, $s \leqq 2$<br>100 kW: $Z = 50\,\Omega$, $s \leqq 2$ |
| Connection for a rigid coaxial line according to IEC Publication 339-2: | 500 kW: 100/230<br>300 kW: 100/230 or 86/200<br>100 kW: 66/152 (IEC Publication 50–155) or 45/103 (IEC Publication 50–105) |
| Unwanted radiations (measured across a 50 Ω test load or during operation with the antenna): | Harmonics ≦50 mW, i.e.<br>at 500 kW ≧70 dB attenuation<br>at 300 kW ≧68 dB attenuation<br>at 100 kW ≧63 dB attenuation<br>related to the carrier value<br><br>Spurious radiations: attenuation ≧70 dB (only if the Drive Unit S STEU 1370 is used)<br><br>Measurements in accordance with IEC Publication 244-2 Appendix C and with CCIR Recommendation 329-1 |

## PDM Amplifier

| | |
|---|---|
| AF Input: | |
| Frequency range: | 40 to 7500 Hz<br>If the occupied bandwidth shall be reduced, an incorporated low-pass filter ($f_{cut\text{-}off}$ = 4500 Hz) can be connected. |
| Input impedance: | 600 Ω or > 2000 Ω balanced and ungrounded |
| Input level: | for m = 1 and $f_{AF}$ = 1000 Hz<br>$N_m$ = −4 dBm to + 10 dBm<br>adjustable in steps of 0.5 dB |
| Method of modulation: | Anode voltage modulation of the final stage of the RF amplifier by means of PDM (Pulse Duartion Modulation)<br>Co-modulation of the screen grid of the RF output tube via an AF choke |
| Carrier voltage drop: | ≦ 3% at m = 1 and $f_{AF}$ = 1000 Hz<br>related to carrier voltage at m = 0 and constant mains voltage |
| Modulation capability: | |
| During program operation: | Any kind of program modulation (with trapezoidal modulation and/or compression) is continuously permissible up to a mean modulation depth of m = 0.75.<br>The possibility of trapezoidal modulation has been provided. |
| During tests:<br>(Transmitter terminated by a test load, ambient temperature in the transmitter hall ≦40° C) | Once within a period of 6 hours |

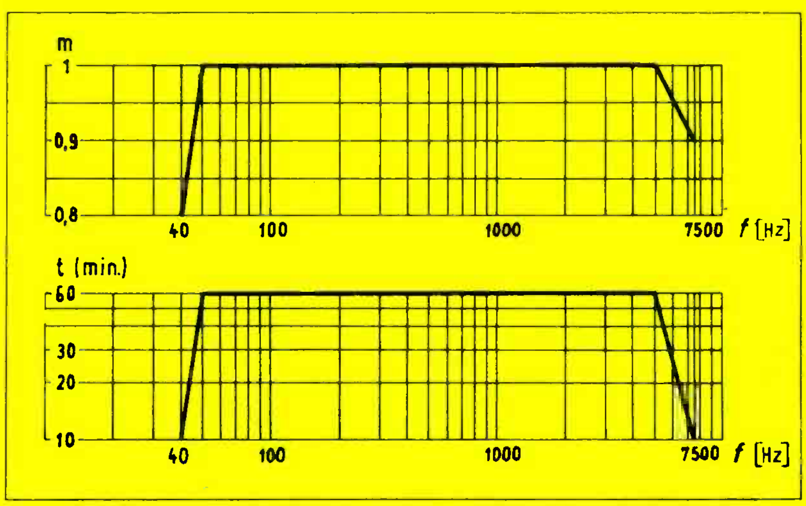



Fig. 15

or once every hour

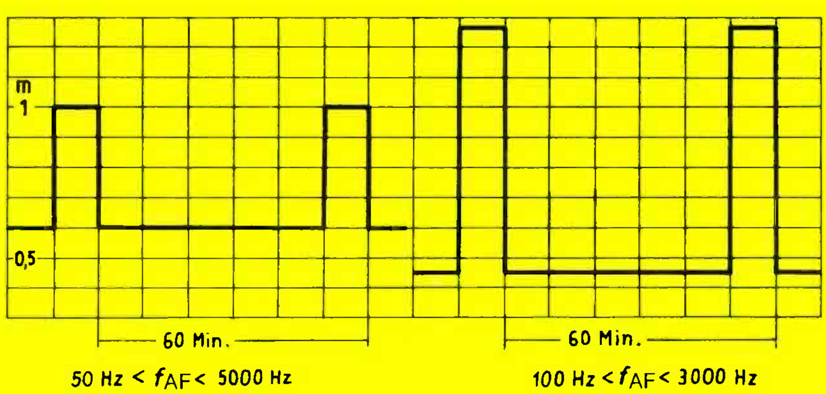


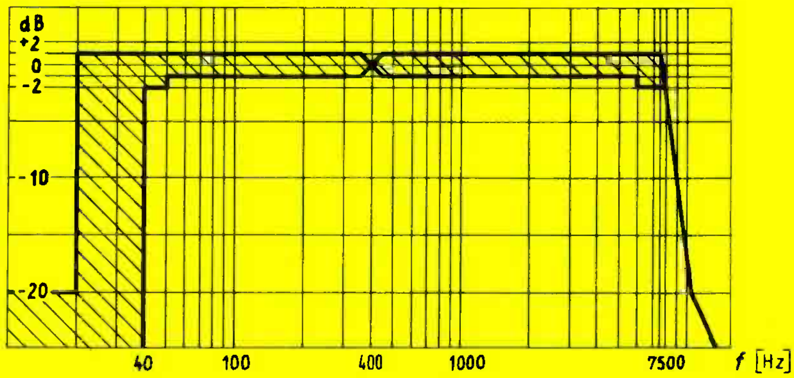

Fig. 16

Overmodulation:

AF input levels exceeding 10 dB for a longer period are regulated downward in the incorporated limiter-amplifier to admissible values.
In the event of overmodulations by more than 10 dB protective elements will intervene.

Linear distortions:
(Frequency response)
Reference frequency
400 Hz or 1000 Hz

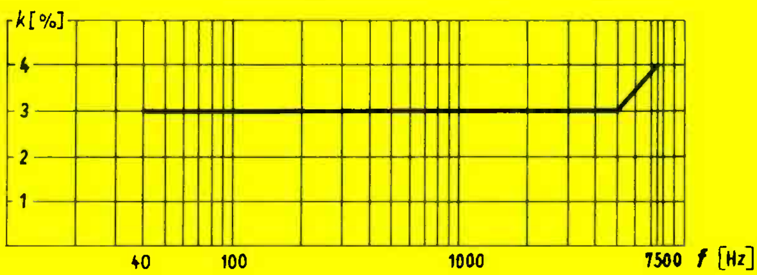
Fig. 17




Out-of-band spectrum according to CCIR Rec. 328-3
The frequency response measured with any input voltage within the aforementioned modulation capability of the transmitter deviates from that measured at $m = 0.5$ by not more than $\pm 0.5$ dB.

Non-linear distortions:
(Distortion factor)

Fig. 18




for $m \leqq 0.9$ within max. permissible modulation depth in accordance with Fig. 15.

Spurious modulation:

Signal-to-noise ratio

$\geqq 60$ dB unweighted

$\geqq 70$ dB weighted with filter in conformity with DIN 45405 and in accordance with CCITT.

Phase modulation:
(synchronous)

$\leqq 6°$ or approx. 1/10 rad.
at $m = 0.5$ and $f_{AF} = 1000$ Hz

## Transmitter Power Supply

| | 500 kW | 300 kW | 100 kW |
|---|---|---|---|
| Mains supply: | Three-phase, four-wire 50 Hz 3.6 kV to 36 kV other data on demand | | Three-phase, four-wire 50 Hz 380 V |
| Connected load (recommended): | 1600 kVA | 1000 kVA | 350 kVA |
| Mains breaking capacity: | 20 MVA | 10 MVA | – |
| Mains breaking current: | – | – | 10 kA |
| Mains short-circuiting power (recommended): | 200 MVA | 100 MVA | – |

Power consumption: Below the rated output at a modulation frequency $f_{AF} = 1000$ Hz (sine wave). The values stated below are average values.

| at a modulation depth of | 500 kW | 300 kW | 100 kW |
|---|---|---|---|
| $m = 0$ | 860 kW $\eta_{total}$ 58% | 525 kW $\eta_{total}$ 57% | 180 kW $\eta_{total}$ 55% |
| $m = 0.3$ | 890 kW $\eta_{total}$ 58% | 545 kW $\eta_{total}$ 57% | 185 kW $\eta_{total}$ 55% |
| $m = 0.45$ | 930 kW $\eta_{total}$ 58% | 570 kW $\eta_{total}$ 57% | 195 kW $\eta_{total}$ 55% |
| $m \approx 1$ | 1210 kW $\eta_{total}$ 58% | 735 kW $\eta_{total}$ 57% | 255 KW $\eta_{total}$ 55% |

For these values the max. permissible carrier shift has been taken into account.

| | 500 kW | 300 kW | 100 kW |
|---|---|---|---|
| Power factor: | $\cos \varphi > 0.9$ | $\cos \varphi > 0.9$ | $\cos \varphi > 0.9$ |
| Phase load: max. diff. factor | 1.05 | 1.05 | 1.1 |

Voltage stabilizer: Only needed for tube filament heating, incorporated in the filament supply.

## Cooling Equipment

Water cooling: Closed water circulation (distillate or softened, fully de-salted water) for the cooling of the tubes as well as for other highly loaded components.

The heat of the power dissipated and eliminated in this cooling circulation can e.g. be utilized for the heating of the building.

Air cooling: Air circulation in a defined manner for incoming and outgoing air for the head cooling of the tubes and for the cooling of components in the transmitter cabinets.

Filtering devices in accordance with the local requirements, closed circuit ventilation, if required.

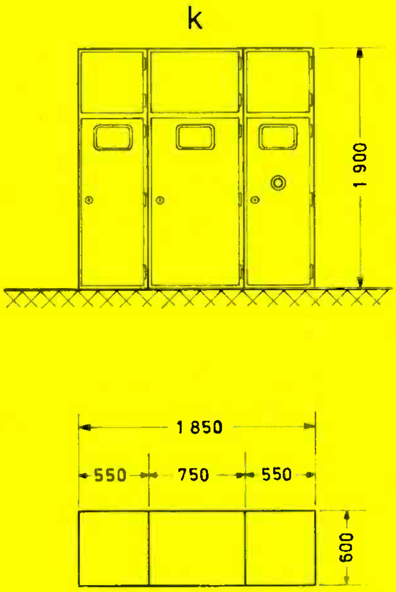
Heat dissipated in the room:

500 kW transmitter $< 10$ kW
300 kW transmitter $< 8$ kW
100 kW transmitter $< 7$ kW

## Tube Complement:

| | 500 kW | 300 kW | 100 kW |
|---|---|---|---|
| RF and PDM amplifier stages: | 2 x TH 558<br>1 x TH 561 | 2 x TH 573<br>1 x TH 561 | 2 x TH 581<br>1 x 4 CX 1500 A |

## Dimensions



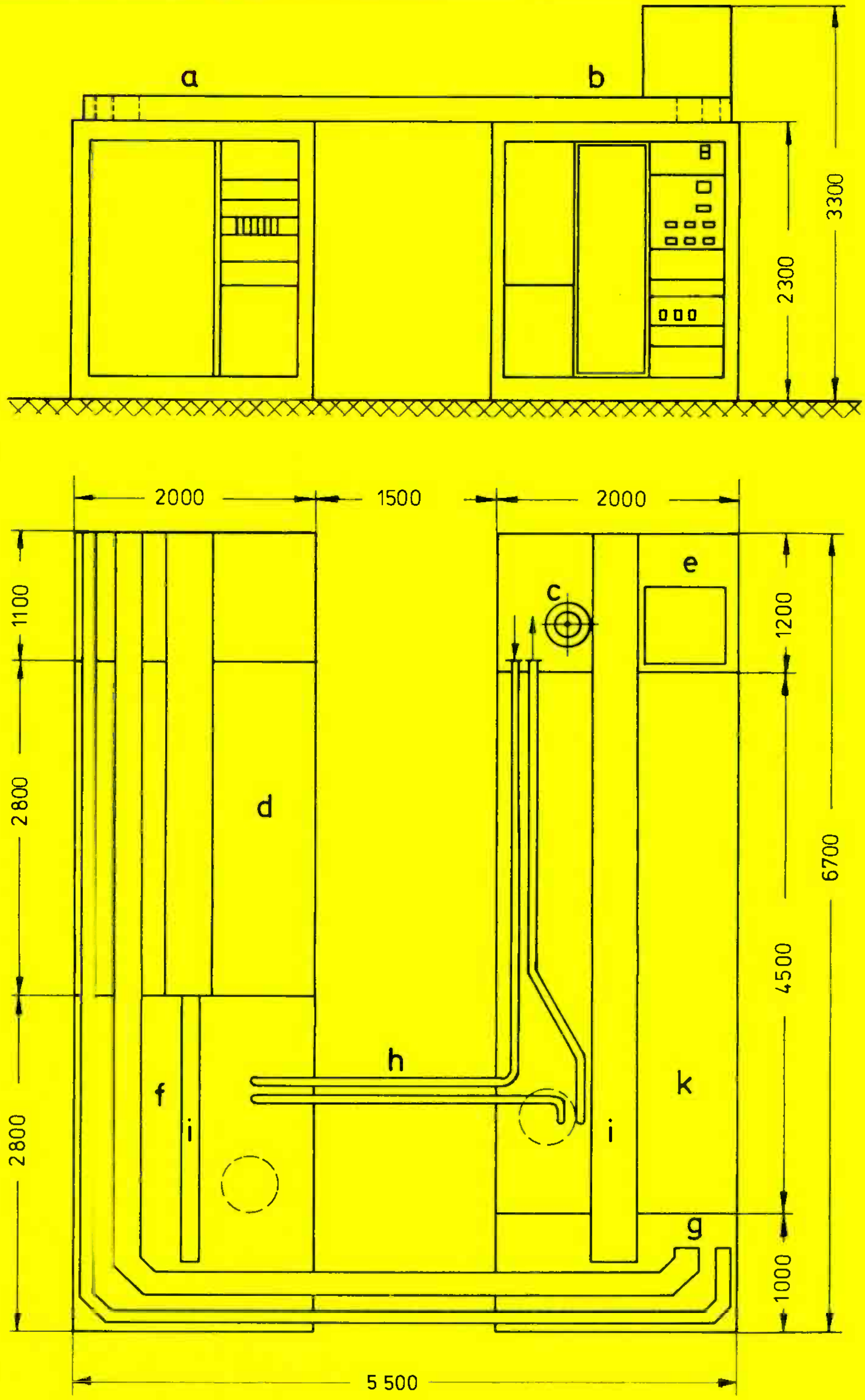




Fig. 19
Dimensional Drawing of the Shortwave Broadcasting Transmitters
HF Transmitter 500-kW S 4005
HF Transmitter 300-kW S 4003
HF Transmitter 100-kW S 4001 *)

a PDM Section
b RF Section
c to the Antenna
d HT Power Supply
e Output Circuits
f Pulse Duration Modulation Amplifier
g Control Rack
h Cooling Water Pipes
i Air Ducts
k Transmitter HT Distribution

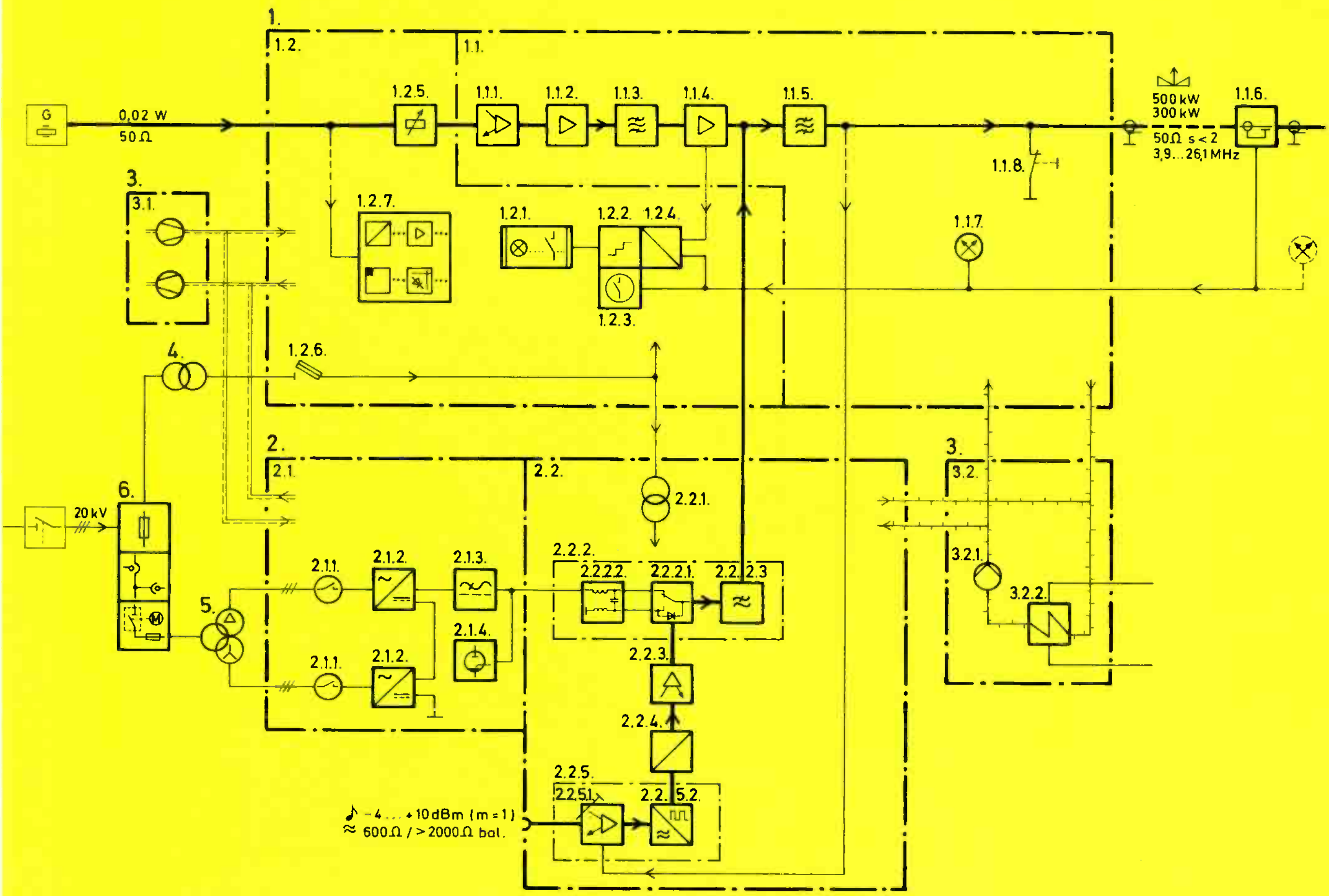
In addition to Transmitter HT Distribution

| | | Dimensions mm | | |
|---|---|---|---|---|
| | Transmitter | L | W | H |
| Transformer for HT Rectifier | 300 kW | 2000 | 1100 | 1950 |
| | 500 kW | 2100 | 1300 | 2450 |
| Step-down Transformer | 300 kW | 1100 | 700 | 1500 |
| | 500 kW | 1100 | 700 | 1600 |

*) under preparation

The dimensions are approximate values, they can be adapted – circumstances permitting – to the given conditions in the building.

Fig. 20
Block Diagram of the
Shortwave Broadcasting Transmitters
HF Transmitter 500-kW S 4005
HF Transmitter 300-kW S 4003
HF Transmitter 100-kW S 4001 *)




**1. RF Section**

1.1. RF Amplifier
1.1.1. Pre-Driver Stage
1.1.2. Driver Stage
1.1.3. Grid Circuit
1.1.4. Output Stage
1.1.5. Output Circuits
1.1.6. Feeder Line Monitor
1.1.7. Cross-Pointer Meter
1.1.8. Grounding Switch

1.2. Control Rack
1.2.1. Switch Panel
1.2.2. Disconnector Unit
1.2.3. Blocking Unit
1.2.4. Detuning Monitor
1.2.5. Level Control
1.2.6. Fuse Isolating Switch
1.2.7. Control Unit for Automatic Tuning

**2. PDM Section**

2.1. HT Power Supply
2.1.1. Vacuum Switches
2.1.2. HT-Rectifier (12 pulses per cycle)
2.1.3. Filter Elements
2.1.4. Ignitron Protection Unit

2.2. PDM Amplifier
2.2.1. Isolating Transformer
2.2.2. Output Stage
2.2.2.1. Switching Tube with Commutating Diode
2.2.2.2. Storage Coil
2.2.2.3. Low-Pass Filter
2.2.3. Driver Stage
2.2.4. AF/PDM Isolating Units
2.2.5. AF Stages
2.2.5.1. AF Input Stages/Linear Meas. Detector
2.2.5.2. AF/PDM Converter

**3. Cooling Equipment**

3.1. Air Cooling
3.2. Water Cooling
3.2.1. Pump
3.2.2. Heat Exchanger

**4. Step-Down Transformer**

**5. Transformer for HT Rectifier**

**6. Transmitter HT Distribution**

*) under preparation

# Pulse-duration Modulation for High-Power Broadcasting Transmitters

## Introduction

The main demands put on high-power broadcasting transmitters are low distortion, easy RF carrier frequency change and high efficiency. Sufficiently low distortion is nowadays attained by all conventional methods of modulation. Apart from Doherty modulation and ampliphase modulation the RF carrier frequency change does not offer any problems. All three technical requirements, however, are met in an optimal manner by the PANTEL method (**P**DM-**AN**odenmodulation System **TEL**EFUNKEN), of which the high efficiency in particular of high-power transmitters, deserves special attention.

In case of anode modulation of the RF output stage, this stage itself has an excellent efficiency, because it operates saturated during the entire modulation cycle. With anode class B modulation, nowadays employed in most cases, the overall efficiency of the transmitter is however considerably reduced by the conventional modulation amplifier.

A decisive improvement of the efficiency can be achieved only by using a modulation amplifier of very high efficiency, while the anode modulation of the RF output stage is retained. For this purpose a PD modulated switching amplifier is used, the efficiency of which is practically independent of the modulation depth and higher than 90%.

## Functioning of the PDM Method

During pulse-duration modulation the duration of pulses of a rectangular waveform is varied as a function of the AF voltage. The frequency of the rectangular waveform (50 kHz to 80 kHz) shall be sufficiently high above the max. audiofrequency (5 kHz to 8 kHz). The relationship between AF voltage and pulse duration is linear. The AF oscillation corresponding to the arithmetic mean value of this PDM oscillation can be obtained from the PDM oscillation by simple filtering via a low-pass filter.

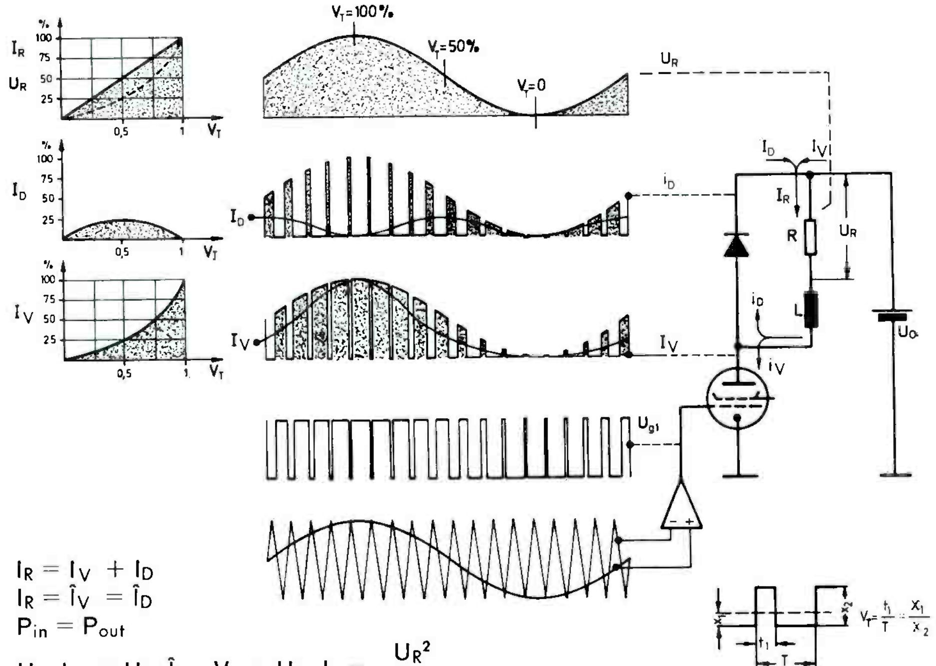
The detour of AF amplification via a pulse-duration modulation serves to improve the efficiency. Theoretically, a rectangular oscillation can be generated with 100% efficiency, provided that an "ideal switch" is used for the purpose. In the open state of this "ideal switch" a voltage is present, while the current is zero. In the closed state a current is flowing through this switch, while the voltage is zero. The product of current multiplied by voltage, – the dissipated power – is in all cases zero and the efficiency is 100%.

## Basic PDM Circuit

The functioning principle of the basic PDM circuit will now be explained under the following idealized conditions:

1. The tube is an ideal switch
2. The inductance of the storage coil is virtually infinite for the switching frequency, i.e. only direct current and AF current can flow.
3. The inductance of the storage coil is sufficiently low for the audio-frequency, and the coil has no ohmic restistance.
4. The diode is an ideal rectifier.

Fig. 21
PDM Generation
$V_T$ = Duty ratio of pulses, in general




$I_R = I_V + I_D$

$I_R = \hat{I}_V = \hat{I}_D$

$P_{in} = P_{out}$

$$U_0 \cdot I_V = U_0 \cdot \hat{I}_V \cdot V_T = U_R \cdot I_R = \frac{U_R^2}{R}$$

$$U_0 \cdot I_R \cdot V_T = U_R \cdot I_R$$

$$\underline{\underline{U_0 \cdot V_T = U_R}}$$

$$I_{Ro} = \frac{U_R^2}{U_0 R} = \frac{U_0}{R} V_T^2$$

$$I_D = \frac{U_0}{R} V_T - V_T^2$$

The functioning of the basic PDM circuit is shown in Fig. 21. The resistance R represents the load by the RF section of the transmitter. The PDM circuitry supplies the required direct current and AF current. The limit values of the drive can be clearly perceived:

In case of zero level the tube is blocked (duty ratio of pulses $V_T = 0$), no current flows, no voltage is present at R.

In case of peak level the tube is conducting continuously (duty ratio of pulses $V_T = 1$) and full operating voltage is present at resistance R.

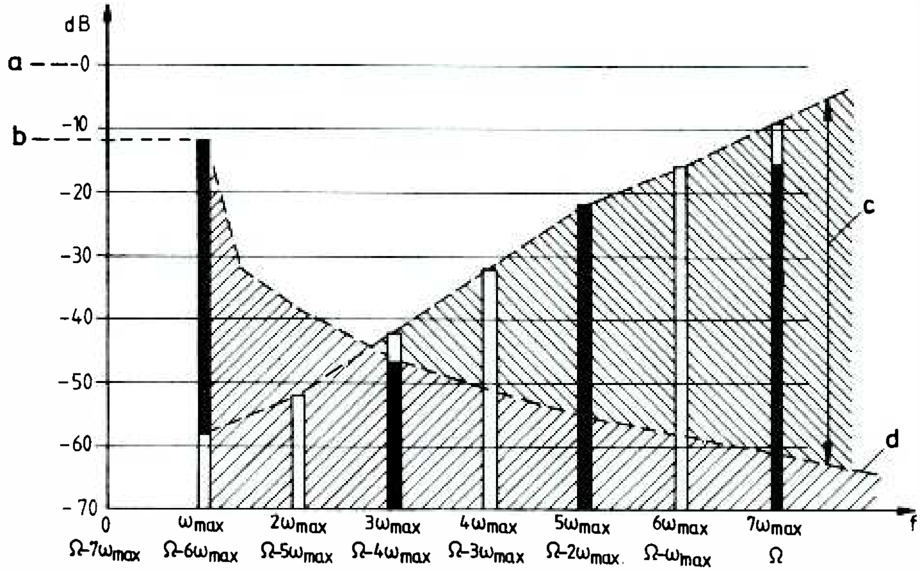
A study of the current and power relationships gives a clear idea of the intermediate values during operation with a modulation oscillation. Because of the "ideal elements" the input power $P_{in}$ delivered by the source can be consumed only in resistance R. Only the tube current $I_V$ flows through the source. The peak value of the tube current $\hat{I}_V$ is equal to the peak value of the diode current $\hat{I}_D$. These two currents flow alternately and mutually complement in a resulting direct current and audio frequency current $I_R$ which is equivalent to the sum of the mean values of $I_V$ and $I_D$.
The relationships for the modulation depth m = 1, based on a duty ratio $V_T = 0.5$ during carrier operation are shown in Fig. 21. The power delivered by the source is $P_{in} = U_0 \cdot \hat{I}_V \cdot V_T$, the consumed is $P_{out} = U_R \cdot I_R = U^2/R$. Since the powers and currents are equal, the output voltage $U_R = U_0 \cdot V_T$ is in the desired linear relationship with $V_T$. The current $I_R$ flowing through the load resistance and the mean values of diode current $I_D$ and tube current $I_V$ with their dependance on the duty ratio $V_T$ are shown by the diagrams. The tube current is proportional to the square of the duty ratio and attains at $V_T = 1$ the value of 100%. The diode current attains its maximum value at 25% at a duty ratio $V_T = 0.5$. It is remarkable that the AF fundamental wave is not present in the diode current, the 2nd harmonic, however, is very strong.

## Choice of the Switching Frequency

The switching frequency $\Omega$ is chosen under the following points of view: According to the scanning theorem the switching frequency must be higher than the twofold of the highest modulation frequency $\omega_{max}$. In the present case it ought to be higher than $2 \cdot 7.5$ kHz $= 15$ kHz.

The generation of the PDM causes the occurrence of additional spectral components which had not been present in case of the hitherto used anode class B modulation. These are multiples of the switching frequency with their side bands. As the lower side bands of the switching frequency fall into the AF range and cause hereby an increase of non-linear distortions and in addition unwanted contributions to out-of-band radiations, it is desirable to put the switching frequency as high as possible. With rising switching frequency, however, the unwanted capacitances cause trouble in an increasing extent. The losses and the non-linear distortions are rising. For these reasons it is necessary to choose an as low as possible switching frequency.

Fig. 22
Spectral components of a PDM oscillation




a RF peak power
b Level of a single tone
c Minimum attenuation of the AF filter
d Admissible out-of-band radiations acc. to CCIR 328-1
□ determined limit values
■ theoretical values for $V_{TC} = 0.5$

$$
\begin{aligned}
a(\omega t) = {} & V_{TC}(1 + m \cdot \sin\omega t) + \\
& + \sum_{\nu=1}^{\infty} \frac{2}{\nu\pi} \sin(\nu\pi V_{TC})\ J_0(m\nu\pi V_{TC})\ \cos\nu\Omega t \\
& + \frac{2}{\nu\pi} \cos(\nu\pi V_{TC})\ J_1(m\nu\pi V_{TC})\ [\sin(\nu\Omega + \omega)t + \sin(\nu\Omega - \omega)t] \\
& + \frac{2}{\nu\pi} \sin(\nu\pi V_{TC})\ J_2(m\nu\pi V_{TC})\ [\cos(\nu\Omega + 2\omega)t + \cos(\nu\Omega - 2\omega)t] \\
& + \frac{2}{\nu\pi} \cos(\nu\pi V_{TC})\ J_3(m\nu\pi V_{TC})\ [\sin(\nu\Omega + 3\omega)t + \sin(\nu\Omega - 3\omega)t] \\
& + \frac{2}{\nu\pi} \sin(\nu\pi V_{TC})\ J_4(m\nu\pi V_{TC})\ [\cos(\nu\Omega + 4\omega)t + \cos(\nu\Omega - 4\omega)t] + \ldots
\end{aligned}
$$

for $V_{TC} = 0.5$ and odd $\nu$ is

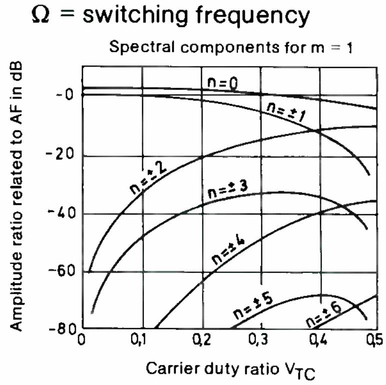
$$\cos\left(\nu\frac{\pi}{2}\right) = 0$$

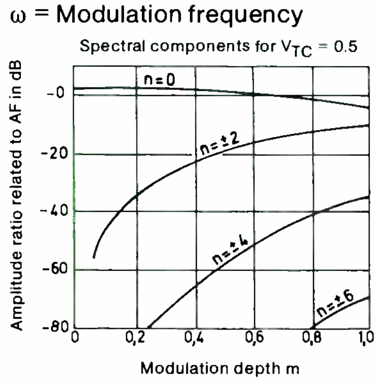
Amplitude

$V_{TC}$ = carrier duty ratio
$\nu$ = multiple of the switching frequency $\Omega$ (ordinal number of the harmonic)
$\Omega$ = switching frequency

Frequency

n = ordinal number of the side frequencies of $\nu = 1$ (n = 0 : switching frequency $\Omega$)
J = Bessel functions
$\omega$ = Modulation frequency



For the optimization of the switching frequency it is necessary to know the PDM spectrum. The limit values are shown in Fig. 22 for the PDM spectrum below the switching frequency. For a PDM oscillation related to a carrier value $V_T$ = 0.5 the spectrum contains only the even-number side band components. The duty ratio deviates already from the carrier value because of the switching tolerances of $V_T$ = 0.5. Such deviations may even be usefully employed for regulating purposes or power reduction. Under these circumstances a spectral distribution will result with all side band components. The idealized assumptions for the Fourier analysis are not sufficient for determining the spectrum. Distortions of the scanning oscillation and the finite ratio of the switching frequency to the highest modulation frequency considerably affect the magnitude of the spectral components. The spectrum shown by Fig. 22 was determined as a result of the theoretical reflections and experience with interfering influences. From there and from CCIR Rec. 328-1 on out-of-band radiations e.g. data may be derived for the necessary attenuation of the AF output filter. The admissible out-of-band radiation according to CCIR Rec. 328-3 has a somewhat different characteristic, because weighted noise is employed as modulation oscillation. The requirement for the AF filter selectivity has not been made more stringent hereby.

Oscillations immediately near the useful band and caused by the modulation process are called "out-of-band radiations". These include the harmonics of the AF and the lower side band components of the switching frequency. The components of the switching frequency and its harmonics depend in their values only slightly on the modulation oscillation. At the output of the transmitter these oscillations must therefore be considered as unwanted oscillations for which the necessary attenuation has to be provided.

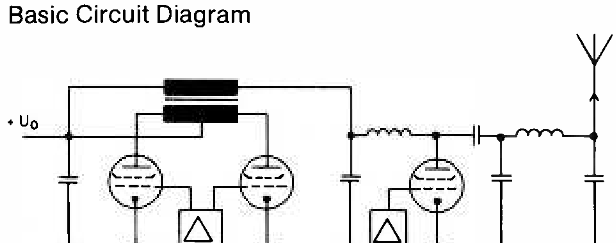
The upper side band of the switching frequency as well as the side bands of their harmonics indeed depend on the modulation oscillation but are not immediately adjacent to the useful band and must consequently also be regarded as unwanted oscillations at the transmitter output.

## PANTEL Method

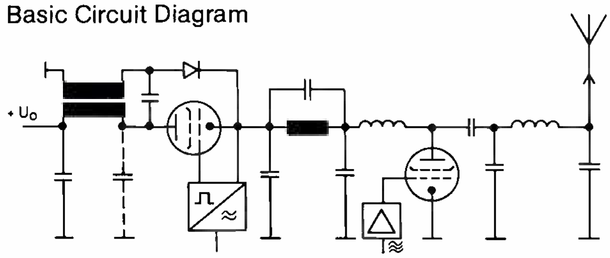
The basic circuit is shown in Fig. 23 of an RF output stage modulated according to the conventional anode class B method and of an RF output stage modulated according to the PANTEL-method.

Fig. 23
Comparison of Anode Class B Modulation with TELEFUNKEN's PANTEL Method

**Anode Class B Modulation**
Basic Circuit Diagram




**PANTEL Method**
Basic Circuit Diagram




Common to both basic circuit diagrams is that the respective RF amplifier is related to the RF potential zero = ground.

This is the main reason for developing and adopting the PANTEL-method (**P**DM **AN**ode Modulation System **TEL**EFUNKEN).

In the basic PDM circuit, as already employed elsewhere in transmitters up to medium power, the RF potential is related to a point corresponding to the anode of the PDM tube. This reference point consequently varies in the rhythm of the audio frequency. (Cf. illustration in Fig. 21, where load resistance R is shown acting as a substitute for the RF output tube). By-passing elements for this reference level by which the cathode of the RF output tube as well as the elements of the RF output network for the operating frequency and for its harmonics shall be forced down to an RF potential zero, cause difficulties and mean a considerable technical expenditure. In transmitters with a high carrier power and a large RF range many unwanted resonance points must be expected.

For transmitters which shall be operated over the entire shortwave range, and also with fully automatic tuning, we deem it impossible that the basic PDM circuit can be materialized at all.

In principle, indeed, a direct connection between the cathode of the RF output tube and ground is possible also in conjunction with the basic PDM circuit, but detrimental effects, such as stray capacitances and effects of the audio frequency on the high-tension rectifier, would render it almost impossible to meet the established performance requirements.

A method for avoiding these detrimental effects was described in a Patent Specification filed by TELFUNKEN in 1963. The described PDM system provides for the use of a storage coil with two windings.

The study of the idealized basic PDM circuit showed that the same amount of current continues to flow through the storage coil with the field remaining unchanged, when the current commutates between tube and diode ($I_R = I_V + I_D$).

Also in the storage coil with two windings the field remains constant provided that switching operations cause the current to change-over from one winding to the other.

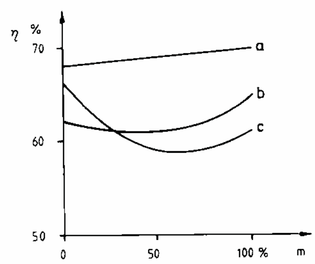
Except for these processes in combination with the above-mentioned storage coil the principle of functioning of the basic PDM circuit described above can be transferred to the PANTEL-method.

## Comparison of the conventional Modulation Methods

The diagram of Fig. 24 shows that at present no similar high degree of efficiency is atteined by any other method than that of the PDM System. The total efficiency of 69% during a mean program operation deserves special attention. During the operation of one 600 kW broadcasting transmitter with a customary operating time of 6000 hours 3600000 kWh are radiated within one year.
A transmitter with anode class B modulation and an efficiency of 59% in case of program operation consumes a power of 6100000 kWh under such circumstances.

A corresponding transmitter working according to the PDM Method of the TELEFUNKEN System requires only 5200000 kWh with an efficiency of 69%. This means 900000 kWh less for each year. At present-day costs of energy this corresponds to a yearly saving of DM 100,000.–

Fig. 24
Efficiency of different Amplitude Modulation Modes




a PDM
b Doherty-Modulation
c Anode Class B Modulation

Summing up one can say that AEG-TELEFUNKEN's PDM Method "PANTEL" offers the possibility of increasing the total efficiency of the transmitter by 10 per cent, which means a significant economic advantage. In addition, the possibility is implied of varying the anode voltage of the RF output stage during the operation without much additional outlay. This permits e.g. to reduce the output power during favourable propagation conditions. It can also be thought of reducing the transmitter power, if the admissible antenna mismatch is exceeded, and of avoiding thereby disconnections of the transmitter.

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