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Comparison between mixed and horizontal polarization for VHF/FM sound broadcasting

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Although it is some forty years since the first VHF/FM sound broadcasting services opened in Europe, no generally-accepted preference has been established for the use of vertical, horizontal or mixed polarization. This is no doubt due in part to the many factors which can affect the conclusions of any field trial: characteristics of the terrain where test measurements are taken, choice of test points, measurement techniques, statistical methods applied to the results, etc.

The present contribution compares mixed and horizontal polarization in various types of terrain, with particular attention to areas where reception is problematic. It is concluded that horizontal polarization is the preferred choice for use in hilly or mountainous terrain.

1. Introduction

Many studies and measurements concerning the optimum polarization of VHF/FM broadcast transmissions have been carried out. Results presented in [1] showed that in hilly or mountainous terrain, horizontal polarization performs better than vertical polarization. Further investigations with high-power transmitters in a hilly service area have been carried out in Slovenia by Radiotelevizija Slovenija (RTVS) in collaboration with the Institut für Rundfunktechnik (IRT) in Munich, to compare the performance of mixed and horizontal polarization.

2. Test transmitters and service area

The tests were carried out using two transmitters at the Krvavec transmitting station (geographical coordinates: 14E32, 46N17) in Slovenia. The station is located on a mountain and the antennas are 1750 m above sea-level, some 1000 m higher than most of the service area. *Fig. 1* shows the azimuthal radiation patterns for horizontal polarization, and for the two orthogonal components of the mixed polarization, measured at an angle of elevation of -1 degree.

The measurements were restricted to two sectorsof the service area, the first between 140 and 210 degrees, the second between 230 and 290 degrees. In these areas, the horizontally-radiated E-field amplitudes of the two antennas were equal within ± 4 dB. For the transmission in mixed polarization, the vertically-radiated E-field amplitude was 3 to 6 dB lower than the horizontally-radiated E-field amplitude.

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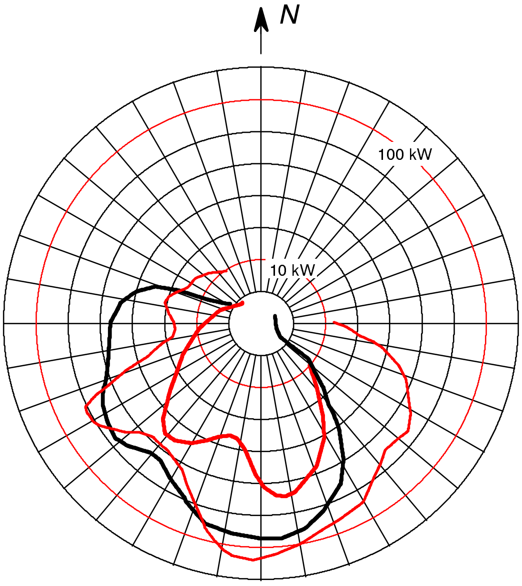


Figure 1
Radiation patterns of the
Krvavec transmissions

—	Horizontal polarization	ERP$_{max}$ = 80 kW, f=98.9 MHz
—	Mixed pol. - vertical component	ERP$_{max}$ = 45 kW, f=102 MHz
—	Mixed pol. - horizontal component	ERP$_{max}$ = 135 kW

The measurement locations for both stationary and mobile reception were situated mainly in problematic shade-reception areas, at distances of 8 to 65 km from the transmitting antennas and at hights in the range 250 to 650 m above sea-level.

Fig. 2 shows three typical sectors of the service area, with some of the measurement points.

3. Measurement method

3.1. Stationary reception

At each test point, the horizontally-polarized E-field of both waves, and the vertically-polarized E-field of the mixed polarization wave were measured. The reception quality was estimated and the distortion due to multipath propagation was measured using a four-element Yagi receiving antenna at a height of 10 m above ground, directed towards the transmitter and in the direction

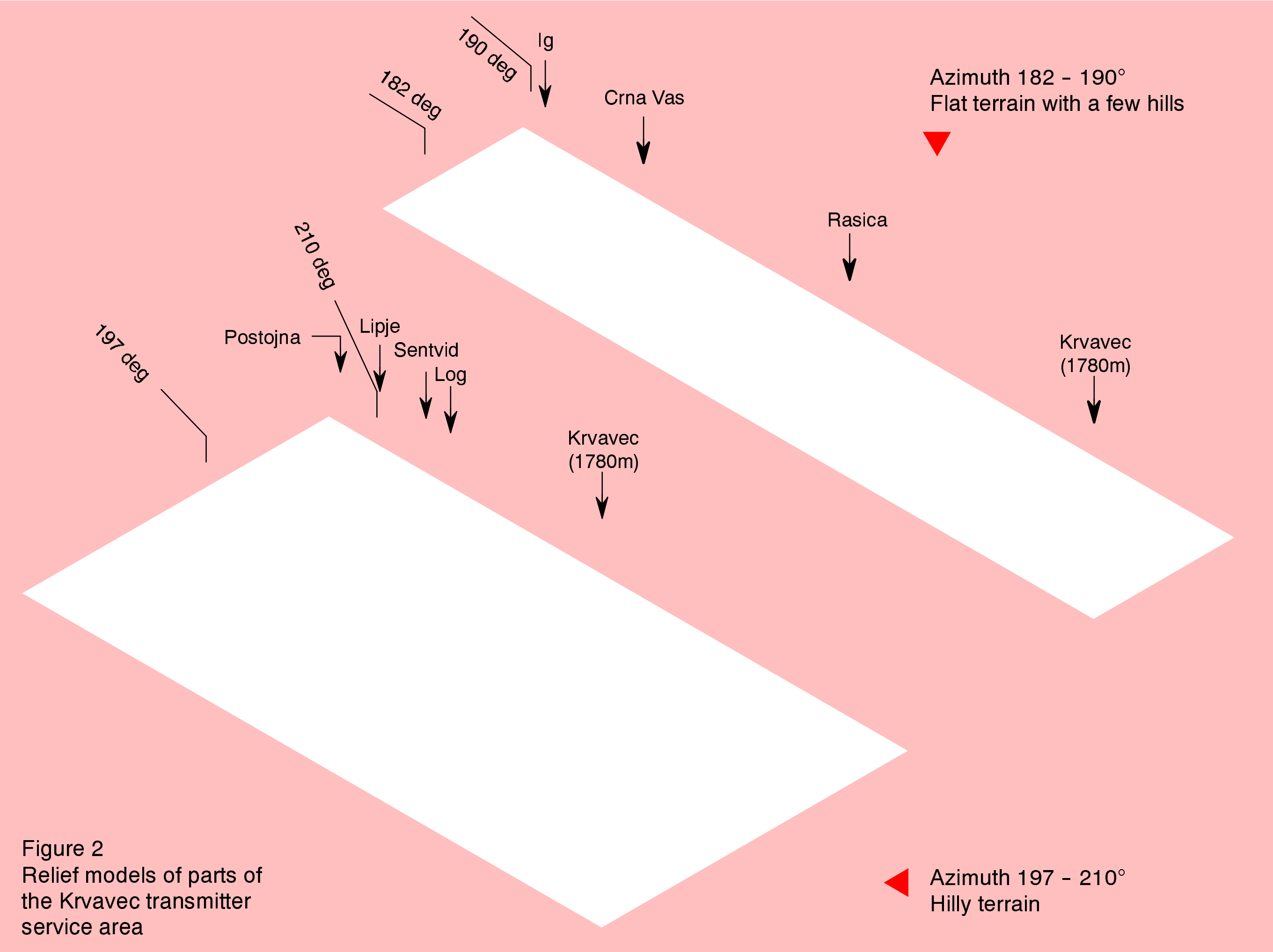


Figure 2
Relief models of parts of
the Krvavec transmitter
service area

of maximum received signal strength. The relevant techniques are described in more detail in [1].

3.2. *Mobile reception*

The mobile tests were carried out with a saloon car equipped with a conventional whip antenna. As its receiving characteristic is distorted by the presence of the car body, two series of measurements were taken on each test route, travelling in opposite directions. For the evaluation, the series which gave the worst reception was selected.

The test routes were 1 km in length. Every one metre, a burst of 100 measurements of the received signal strength, within a period of 1 ms, was taken. The minimum, maximum and average values during the burst were determined and stored. These values were later used to evaluate the cumulative frequency distributions of the minimum, maximum and average signal strength (*Fig. 3*), as well as the difference between the minimum and maximum signal-strengths; this last value served as a measure of the un-wanted amplitude variation for each test route (*Fig. 4*). The minimum signal-strength shows where drop-outs occur, and the amplitude variation is useful for estimating the received audio quality. The threshold values for stereophonic and monophonic transmissions are taken from the study presented in [1], and are shown by the broken lines in *Fig. 4*.

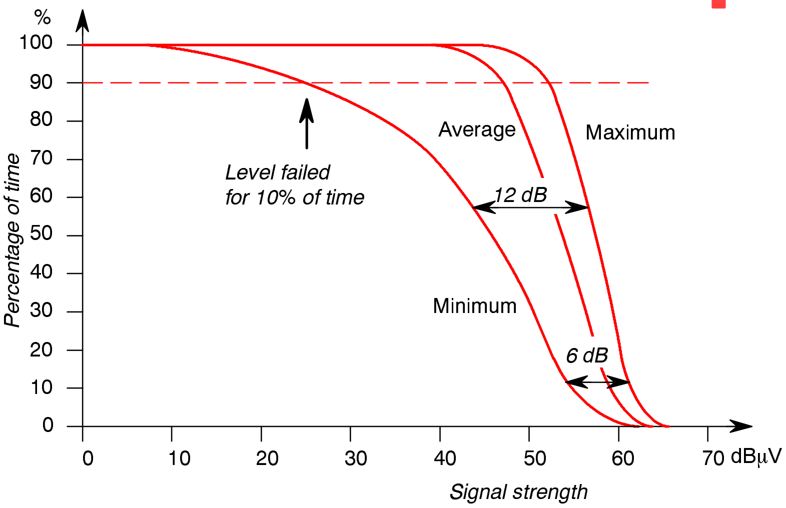


Figure 3
Cumulative frequency distributions of the minimum, maximum and average signal strength for a 1-km test route

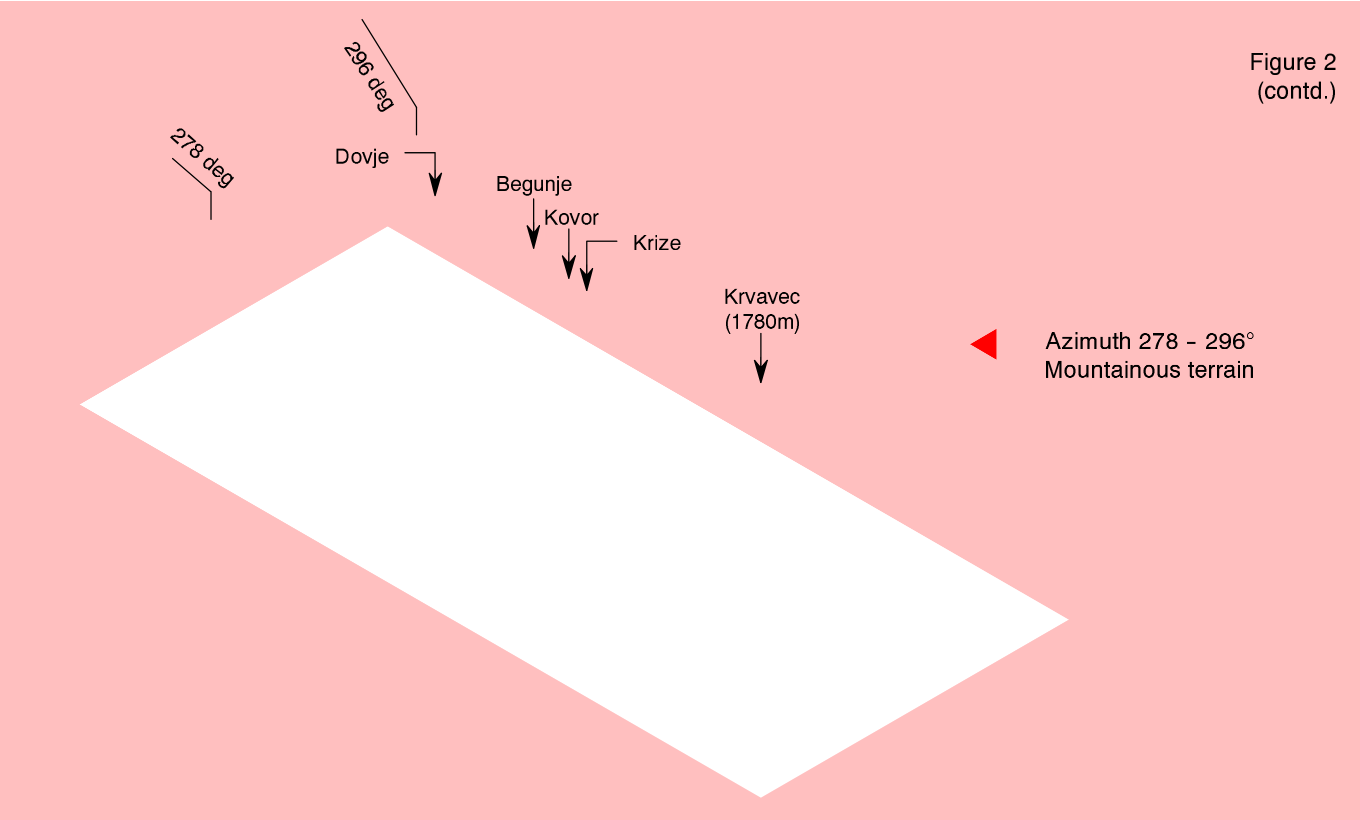


Figure 2 (contd.)

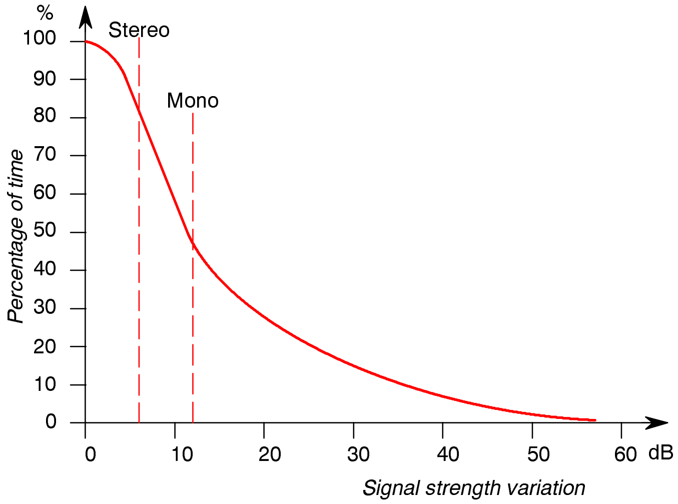


Figure 4
Cumulative frequency distribution of the signal strength variation for a 1-km test route

4. Results

4.1. Stationary reception

The 31 measuring points were situated as follows: four in locations with line-of-sight to the transmitter, 16 behind one obstacle and 11 behind two obstacles, with diffraction angles up to 20 degrees.

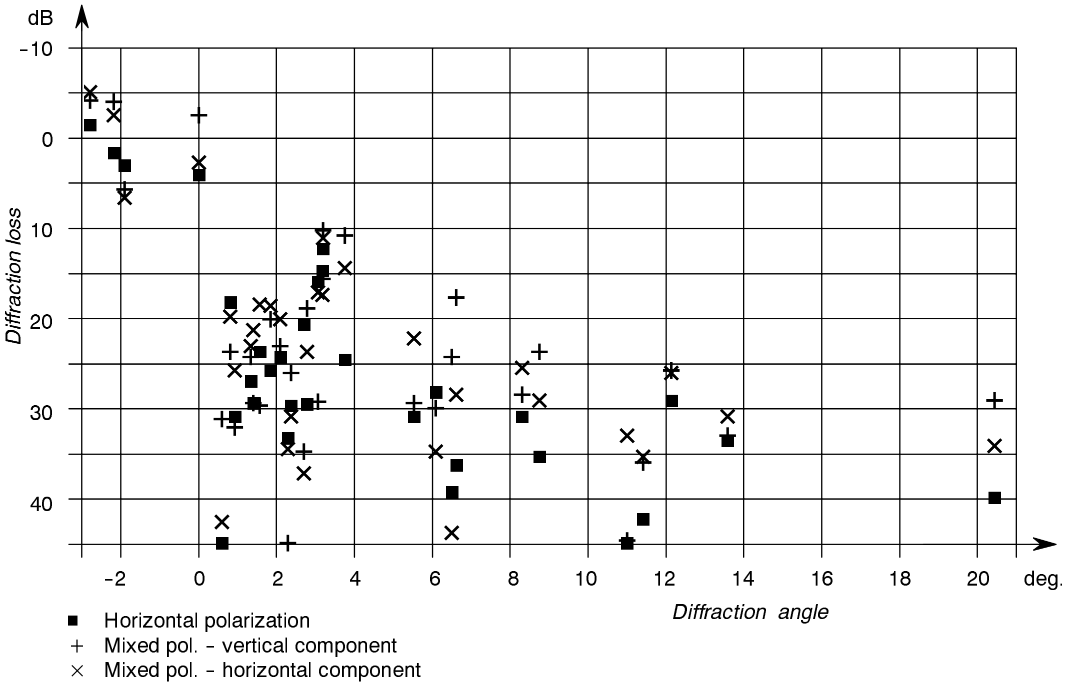
4.1.1. Diffraction loss

The field-strength values measured in the direction of the transmitter were compared with the corresponding free-space values, calculated taking account of the transmitter radiation pattern. The difference is taken as being the diffraction loss. *Fig. 5* shows how this diffraction loss varies with diffraction angle, for the three polarizations considered in this study. Within the line-of-sight area (negative diffraction angle), there are no major differences between the diffraction loss values of the horizontal and vertical E-field components for horizontal and mixed polarization.

Behind one obstacle, the horizontal E-field components of the horizontally and mixed-polarization waves show similar losses, and these are of the same order of magnitude as were found in the earlier study [1]. The vertical E-field component of the mixed-polarization wave shows a diffraction loss which is similar to that affecting the horizontal E-field component, which is less than the diffraction loss for the pure vertically-polarized wave measured in [1].

However, behind two or more obstacles, the vertical E-field component is 3 to 9 dB higher than the horizontal E-field components at seven of the measuring points. The contribution of the horizontally-polarized E-field component of the mixed-polarization wave, whose polarization rotates at each reflection, explains these higher levels.

Figure 5
Diffraction loss as a function of diffraction angle
(Stationary reception, single obstacle)



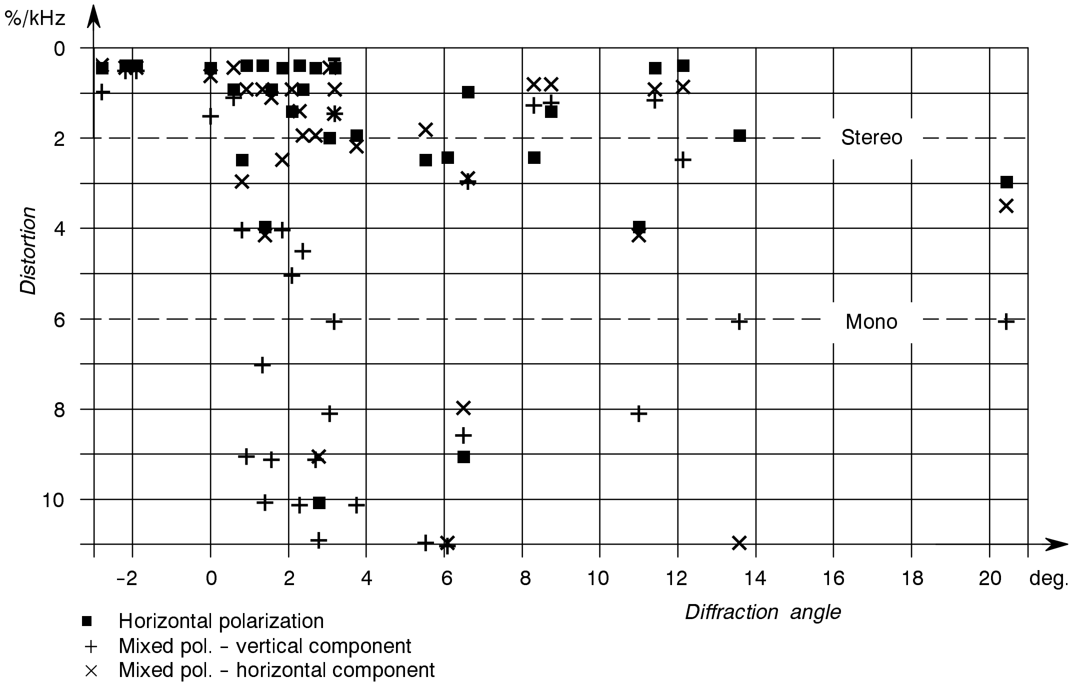


Figure 6
Multipath distortion as a function of diffraction angle
(Stationary reception, single obstacle)

4.1.2. *Multipath distortion*

The distortion corresponding to the maximum field-strength received at the 31 test points in shown in *Fig. 6.*

In line-of-sight conditions, either polarization was able to deliver high-quality reception. In areas situated behind one or more obstacles, high-quality stereo reception was possible at 18% of test points when receiving the vertically-polarized E-field component of the mixed-polarization wave; at an additional 33% of the test points, high-quality reception was possible only in mono. The reception quality for the hoirizontally-polarized E-field components was significantly better. For the horizontally-polarized wave, high-quality stereo reception was possible at 67% of test points; at an additional 26% of test points, high-quality mono reception was possible. Corresponding values for the mixed-polarisation wave were 59% (stereo) and 26% (additional mono).

These results indicate that the use of mixed-polarization offers no performance improvement for stationary reception.

4.2. *Mobile reception*

Measurements were made on 30 test routes, with mean diffraction angles between 0 and 20 degrees.

4.2.1. *Signal level*

According to [2], reception quality is heavily impaired if the time-percentage of signal drop-outs exceeds 2.5%. It would have been reasonable, therefore, to compare the minimum field-strengths at this level of disturbance. However, the variations in received field-strength were greater than the full-scale range of the receiving equipment (60 dB) so, with the equipment adjusted to keep the maximum received field-

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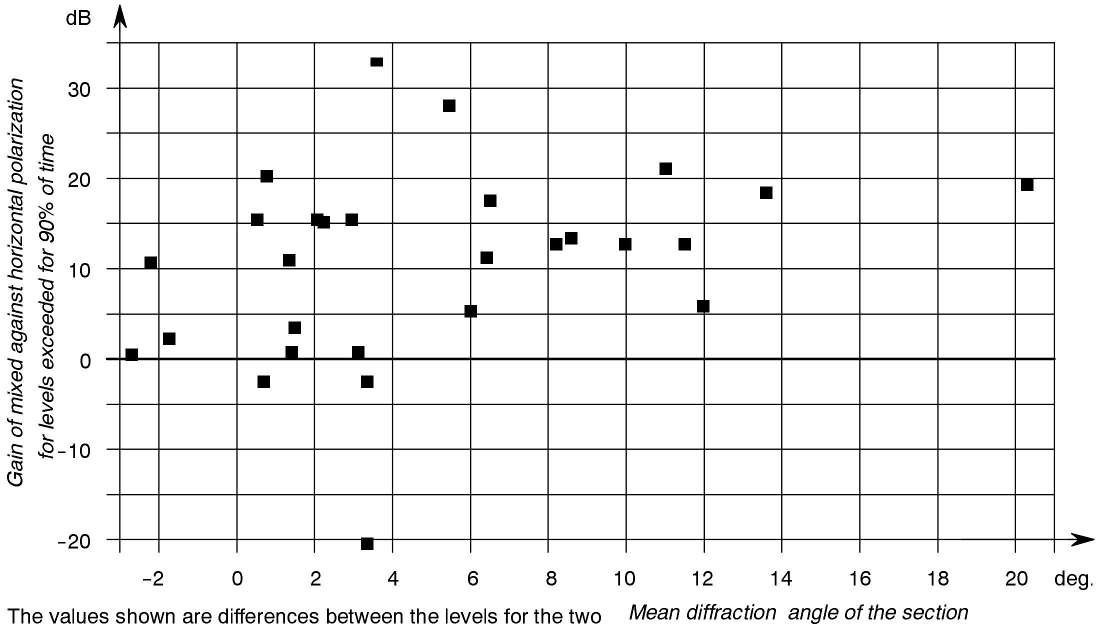
Figure 7
Augmentation in signal strength when using mixed polarization compared with horizontal polartization
(Mobile reception)



The values shown are differences between the levels for the two polarizations which are exceeded for 90% of the time.

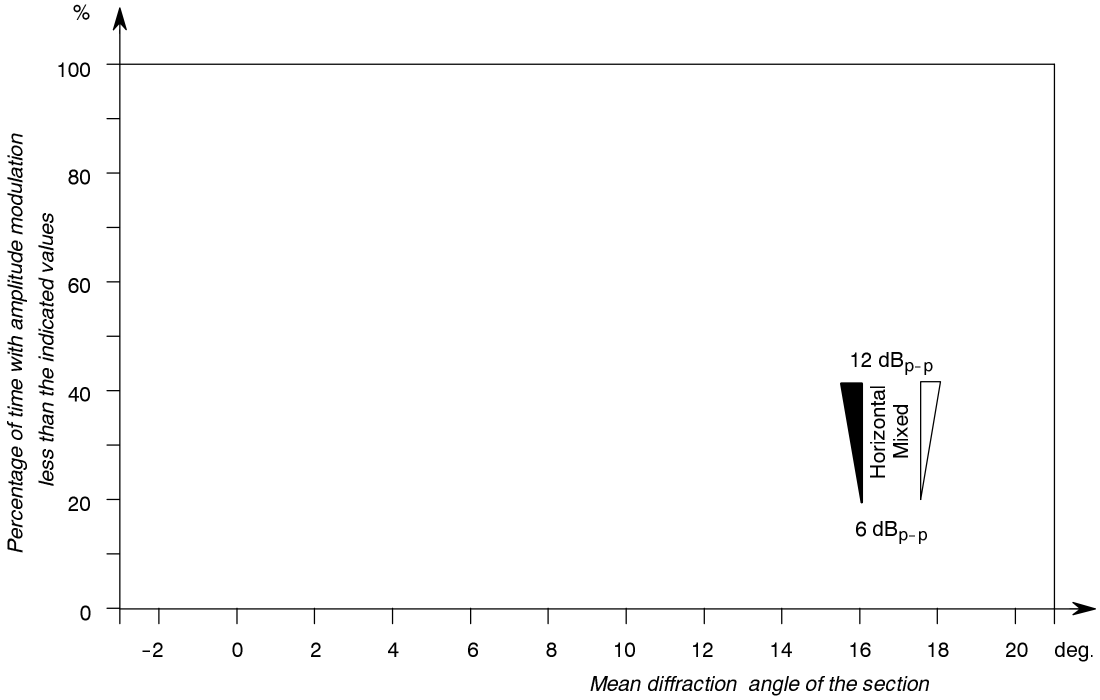
strength in range, the minimum was sometimes out of range. For this reason, the comparison was made using field-strengths which were not reached for 10% of the time (*Fig. 3*).

With the exception of three test routes, the received signal-strength was greater than for mixed polarization (*Fig. 7*); the median value of the field-strength augmentation over all the test routes being 12 dB.

4.2.2. Multipath distortion

Multipath propagation causes an amplitude variation of the carrier. For each test route, the cumulative frequency distribution of the amplitude modulation (i.e. the difference between the maximum and minimum field-strength values obtained in a burst of measurements) was determined. These cumulative frequency distributions were then used to determine the percentage of time during

Figure 8
Percentage of time with indicated levels of amplitude modulation, as a function of the diffraction angle
(Mobile reception, single obstacle)



which the amplitude modulation was less than 6 or 12 dB (*Fig. 4*). These values are chosen because a 6-dB amplitude variation will reduce the quality of stereo reception below the limit of tolerance while causing only weak, but perceptible, distortion for mono reception; an amplitude variation of 12 dB masks the audio signal completely.

Fig. 8 shows these values as a function of the mean diffraction angle for 29 test routes. With the upper limit of amplitude modulation set at 12 dB peak-to-peak (causing noisy drop-outs) occurring for 5% of the time, it was found that only 10 test routes were within the limit. For these 10 routes, five respected the limit when the horizontally-polarized wave was being received and the other five when receiving the wave having mixed polarization. This shows that, in general, mixed polarization does not improve mobile reception quality, despite the higher signal level.

5. Conclusions

In general, no improvement in the reception quality with mixed polarization was observed, compared to horizontal polarization, for either mobile or stationary reception. The received signal strength with mixed polarization, having a 3:1 ratio of powers in the horizontal and vertical components, is higher, but the amount of multipath propagation is increased and this causes greater distortion. This study therefore supports the conclusion reached in the earlier study [1], to the effect that in hilly and mountainous terrain horizontal polarization is preferable for VHF/FM transmissions.

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Rec. 601: latitude for more width

An important feature of the new 625-line television systems which EBU Members will soon be introducing is the 16:9 picture aspect ratio. While the development of the emission systems - D-MAC and D2-MAC for satellite services and enhanced PAL/SECAM for terrestrial services - continues, attention is turning increasingly to the equipment and technologies which may be needed in broadcast studios and other production facilities. The essential question is: will our existing apparatus be good enough for 16:9 operation, or will major re-equipment be necessary?

A recent study by the EBU Technical Committee has shown that some equipment - routing systems, mixers and VTRs - can be used for 16:9 pictures without any modification. Video displays and television picture sources such as cameras and telecines will have to be modified to suit the wider picture, but this is generally a straightforward job which, in many cases, can be carried out on-site, in the studio. The modifications to certain other sorts of production equipment such as special effects units, graphics and the like will mainly concern their software.

However, such modifications assume not only that the equipment can be modified to work with the new aspect ratio but also that the technical quality will still be sufficient. In theory, extra picture width demands extra performance. An EBU evaluation of the technical characteristics of the new emission systems, and theoretical work to determine the maximum performance they could achieve, has shown that equipment conforming to the existing 625-line digital television production standard (CCIR Recommendation 601) will be fully adequate in the age of 16:9 enhanced television. In other words, however good the enhanced 625-line systems may be, they will make no quality demands in the programme-production area which cannot be satisfied by the existing digital standard. As a consequence, the EBU believes that no action is needed to establish a new enhanced 625-line digital production standard.

The official opinion of the EBU Technical Committee is set out in **EBU Technical Statement D72-1992**, reproduced on *page 74* of this issue.