REPORT 464-5

POLARIZATION OF EMISSIONS IN FREQUENCY-MODULATION BROADCASTING IN BAND 8 (VHF)

(Question 46/10, Study Programme 46C/10)

(1970-1974-1978-1982-1986-1990)

1. Introduction

From the outset of broadcasting in band 8 (VHF), the provision of high quality was a key feature and was given further impetus by the introduction of stereo transmissions. Thus, during the planning of these new services, consideration was given primarily to properly installed receiving installations employing roof-mounted antennas where studies had shown some advantage in the use of horizontal polarization.

The advent of the transistor has led to the mass production of cheap portable VHF/FM radio sets of high sensitivity and capable of satisfactory operation from built-in rod antennas. Also, the use of VHF/FM with car radios is increasing. Generally, these newer categories of receivers enable a mass audience to be reached and, although they are not able to derive the fullest benefit from high-quality transmissions, they are used in such numbers that they cannot be ignored by broadcasters. It must also be mentioned that there is generally a continuing increase in demand for receivers giving high-quality reception, including stereo.

Thus fixed home receivers may employ fixed antennas with the advantage of greater gain and directivity than is the case for a car or portable radio-antenna which has to be nominally omnidirectional in the horizontal plane.

This Report is intended to provide broadcasters with additional data from which they may more easily choose the most appropriate polarization to use for any new service, according to the individual circumstances.

2. Forms of polarization for broadcast services

The polarization employed for broadcast services may take several forms, and these are defined as follows:

Horizontal polarization: with the electric vector in the horizontal plane.

Vertical polarization: with the electric vector in the vertical plane.

Slant polarization: with the electric vector inclined at 45° to the horizontal. This may be considered as the result of equal-amplitude vertically- and horizontally-polarized components combined in the same phase.

The polarization is said to be right or left slant when the electric vector of the propagating wave has been rotated clockwise, or anti-clockwise, respectively, 45° from the vertical position, as seen from the transmitting point.

Elliptical polarization: with the electric vector rotating in a circular motion. This may be considered as the result of vertically- and horizontally-polarized components differing in phase and/or amplitude.

The polarization is said to be right-hand or left-hand elliptical when the electric vector of the propagating wave rotates clockwise, or anti-clockwise, respectively, as seen from the transmitting point.

Circular polarization: with the electric vector rotating in a circular motion. This may be considered as a special case of elliptical polarization where equal-amplitude vertically- and horizontally-polarized components are combined in phase quadrature.

The polarization is said to be right-hand or left-hand circular when the electric vector of the propagating wave rotates clockwise, or anti-clockwise, respectively, as seen from the transmitting point.

Dual polarization: when substantially equal-amplitude vertically- and horizontally-polarized components are radiated without particular control of the phase relation between them. Typically, the vertically- and horizontally-polarized sources may be displaced one from the other so that the resultant polarization varies between circular and slant, according to azimuth angle.

Mixed polarization: the collective term applied when both vertical and horizontal components are radiated, embracing slant, elliptical (including circular) and dual polarization.

In practice, because of the types of antenna employed for domestic reception, one type of mixed polarization is unlikely to have any significant advantage over another.

When the broadcaster wishes to use mixed rather than horizontal or vertical polarization, the choice may be made with regard to the most convenient arrangement for realisation of the transmitting antenna. In such cases, it is necessary to increase the transmitting power by 3 dB when it is intended to provide the same input voltage to receivers employing horizontally- or vertically-polarized receiving antennas. It is to be noted that, where directional antenna patterns are employed, the specified form of polarization is likely to be obtained only within the main beam.

3. Use of horizontal, vertical and mixed polarization

The evidence available suggests that for the type of antenna used with portable and car receivers, there is, in some circumstances, a signal-strength advantage to be gained through the transmission of a vertically polarized component. The use of a vertically polarized component transmitted in addition to the existing horizontal component has become popular in North America and new services frequently use circular polarization. This has been found to offer advantages for car reception in filling in the standing-wave pattern as well as providing generally higher signal strength in open areas. Tests described in [CCIR, 1982-86a] support the above but for flat terrain environment only. In mountainous terrain, coverage is limited by the topography; long-range multipath distortion degrades the service and there is little difference in the average signal level for home reception between the horizontal and circular polarized emissions. In Ireland, most band-8 transmissions are vertically polarized but mixed polarization is used by stations covering major urban areas while in the United Kingdom most stations (including 13 BBC stations each having three or four high power transmissions in the range 130 - 250 kW) now radiate mixed (circular or slant) polarization and the remaining horizontally polarized stations are being converted to mixed polarization.

Tests carried out in Sweden [CCIR 1978-82a] also show that car-radio reception is improved in built-up areas close to the transmitter by using circular or vertical polarization rather than horizontal. However, work in the Federal Republic of Germany and in Italy has shown that horizontally-polarized transmissions are less susceptible to multipath distortions in certain types of terrain and that this is especially important for stereo or other multiplexed signals.

Investigations to evaluate the difference in propagation of vertical and horizontal waves were carried out in 1988 within the Socialist Federal Republic of Yugoslavia by RTV Ljubljana and the Institut für Rundfunktechnik (Federal Republic of Germany) [CCIR 1986-90]. The station under test was a high power VHF FM sound broadcasting transmitter within a service area including rolling as well as rugged terrain. The results show that vertical waves have a much stronger diffraction loss at most locations in the measuring area and were found to produce much more diffuse reflections. This caused a perceptible increase of distortions in home reception and a significant multiplication of noisy drop-outs in car reception.

Experience in the United Kingdom [CCIR 1978-82b], particularly as a result of tests carried out in the London area showed that, compared with horizontal polarization, mixed polarization (see § 2) provided an improved service to listeners using portables or car radios without causing a significant degradation to stereo listeners using properly installed, horizontally polarized, outside antennas. Using an e.r.p. of 400 W the measurements were made within a range up to 25 km from the transmitter site and it was found that the addition of a vertical component (of equal power) to an existing horizontally polarized transmission led to an effective increase in signal for portable and car receivers of between 5 and 7 dB. Canadian tests confirm the above for a flat terrain environment and up to approximately 160 km. A circularly polarized antenna was used and station powers varied from 21 kW to 360 kW e.r.p. The advantage of using circular polarization appears to occur mainly for the mobile receivers, in the fringe areas, but the investment and operational costs needed are higher than for horizontally polarized emissions.

4. Use of orthogonal polarization

Report 122-3 (Geneva, 1982) describes advantages which may be obtained by transmitting orthogonally polarized signals (vertical and horizontal) from different stations and using polarization discrimination in reception. In principle, this technique is also applicable in the frequency bands used for FM sound broadcasting. However, full advantage can only be obtained when the polarization of receiving antennas conforms to that of the wanted signal. In cases where the polarization of the receiving antennas is random, e.g. when in VHF/FM sound broadcasting, antennas for domestic and car reception have different polarization, no general advantage can be expected from making systematic use of orthogonal polarization and this may be detrimental to reception under these conditions.

Furthermore, where mixed polarization is used, the opportunity is generally lost for the provision of mutual protection between services through the use of orthogonal polarization (vertical and horizontal). In the case of mixed polarization, no advantage in polarization discrimination can be gained over horizontal or vertical polarization by using, at the receiving site, the same type of antenna as at the site of the wanted transmitter. This would also apply for right and left circular polarization, because the direction of rotation of a signal coming from the back of an antenna is opposite to that of a signal coming from the front.

5. Definition of effective radiated power for interference calculations in the case of mixed polarization [CCIR, 1978-82c]

Any kind of mixed polarization can be represented by a horizontally- and a vertically-polarized component which, depending on the type of receiving antenna used, may provide different input voltages to the receiver. Because of the general loss of mutual protection between services through the use of orthogonal polarization – as mentioned above – it is not important to take the phase relationship between the two components into account when carrying out interference calculations. However, the effective radiated power (e.r.p.) has to be clearly defined. It is therefore appropriate to specify separately the powers associated with the two orthogonal components of the radiated signal (i.e. the horizontally and vertically prolarized components), and not merely to indicate the value of the total e.r.p. only.

6. Propagation factors

6.1 *Direct or diffracted component*

Broadcast signals arriving at a receiving point are normally made up of several components, the strongest of which is either a direct wave or a diffracted wave. The magnitude of this direct or diffracted wave is substantially independent of polarization, except where diffraction occurs over smooth rounded hills (without vegetation or obstructions higher than about one metre), in which case a vertically-polarized wave will be attenuated less than a horizontally polarized wave. Another special case is where propagation is over hills wooded with coniferous trees, as the greater tendency of trees to scatter the vertically-polarized component contributes to a greater loss for this polarization. Close to the ground, the boundary conditions favour a vertically-polarized component, as any horizontally-polarized component is attenuated. Thus, at low antenna heights, vertical polarization will give the stronger signal.

6.2 *Reflected component*

In addition to the direct or diffracted component there will generally be one or more reflected signals, and these may arise from a number of causes which may be categorised into the following three groups:

6.2.1 *Grazing reflections from the ground in front of the receiving point*

The path difference between direct and reflected signals is normally very small, and the echo, in consequence, does not contribute to distortion but only to variation in field strength. In most cases where the grazing angle is not more than a degree or so, the effect is substantially independent of polarization: however, if transmission is between high transmitting and receiving points, e.g. across a valley or bay, the echo delay time may become significant, and horizontal polarization will normally give a rather larger echo.

6.2.2 *Reflections from the side of the path, where the reflecting object may be a man-made structure, trees, hills or mountains*

When the reflections are from vertical or near-vertical surfaces, their magnitude will generally be significantly greater for vertically-polarized transmissions as compared with horizontally-polarized ones. It is this factor which is likely to make vertically-polarized transmissions rather more liable to multipath effects when compared with horizontally-polarized transmissions. In practice, the effect is more pronounced when the direct path is obscured and there are strongly illuminated structures or topographical features to the side of the path. The effect can become important where the path difference between direct and reflected signals exceeds about 3 km (10 µs). With this path delay, perceptible distortion may occur at an echo amplitude of about 15% for stereo or 40% for mono, although the actual value will depend upon the amount of AM suppression in the receiver.

6.2.3 *Reflections from behind the receiving point and occurring from vertical or near-vertical surfaces such as buildings, trees or mountains*

Where dimensions of the reflecting object are large in both the vertical and horizontal plane, then polarization is often found to be unimportant, although some evidence has been found in the Federal Republic of Germany that buildings tend to reflect vertically-polarized band 8 signals more than those which are horizontally polarized. Where the reflecting object is a tree, particularly of the coniferous type, vertically-polarized signals will be reflected more strongly. As in §6.2.2 the effects are important only when the path difference exceeds about 3 km.

6.3 *Summary of propagation factors*

It is evident, therefore, that transmissions of a vertical component can result in an increased signal strength where receiving antennas are essentially vertically polarized and used at low heights. Offset against this advantage is the possibility of an increase in multipath distortion in certain types of terrain. This distortion is the more serious when multiplexed signals are transmitted.

Present evidence shows that, in flat or rolling country, multipath effects are minimal, while the increase in received signal strength obtainable by transmitting a vertical component is the greatest. At the other extreme, in rugged mountainous country, the increase in received signal strength is small, whereas multipath effects may be severe, especially when reflections are from mountains with coniferous trees.

Thus, in these extreme cases, it is possible to make a decision as to the most suitable polarization to employ for transmission. For the more general intermediate cases, the decision may be less clear-cut and be dependent upon the type of service the broadcaster is attempting to provide.

7. **Man-made interference**

The main source of interference is from vehicle-ignition systems, and experience seems to show that the magnitude of the interference differs from one country to another. The explanation for this is not known with certainty, but it may be due to the different standards adopted for vehicle electrical system suppression.

Interference radiated from vehicles has a semi-random polarization but with a preponderant vertical component. Thus, where receiving antennas are well above ground level and of the same polarization as the transmissions, it is advantageous to use horizontal polarization. Where the receiving antenna is used near ground level and responds primarily to vertically polarized signals, as is the case at present for portable and car receivers, the signal-to-interference ratio can be improved only by the radiation of a vertical component.

8. **Existing services**

It is important to know whether services already exist in the area to be served. If so, it will presumably be necessary to employ a polarization of transmission such that existing receiving systems can, in most cases, provide satisfactory results. Generally, this is likely to mean that where existing services use horizontal or vertical polarization, the new service should use either the same or mixed polarization.

9. Discussion

The various factors affecting the choice of polarization for new services in band 8 (VHF) have been reviewed. It appears that certain advantages exist for the use of horizontal, vertical or mixed polarization, and that these advantages take on a different weight according to the type of terrain, the type of receiving installation and the type of service being provided. No one type of polarization is best for all circumstances.

Table I is intended, with this in mind, to assist the broadcaster in making a choice according to circumstances.

TABLE I – *Choice of polarization appropriate for new services*

Type of service intended	Polarization of existing services	Type of terrain	Preferred polarization for new services
Primarily for high-quality receiving installations, probably with stereo, with no improvement to reception conditions for portable or car sets envisaged.	**nil**	**any**	**horizontal**
	horizontal	**any**	**horizontal**
	vertical	**flat or rolling**	**vertical**
	vertical(1)	**rugged**	**mixed(2)**
Primarily to reach the largest audience, especially those using portable or car sets. Account to be taken of those installations already equipped to receive any existing transmissions.	**nil or horizontal**	**flat or rolling**	**mixed**
		rugged	**horizontal**
	vertical	**flat or rolling**	**vertical**
	vertical(3)	**rugged**	**mixed**

(1) It would be preferable to change any existing services to horizontal polarization.

(2) Horizontal, if existing services can be changed to horizontal polarization.

(3) It would be preferable to change any existing services to mixed polarization.

REFERENCES

CCIR Documents

[1978-82]: a. 10/61 (Sweden); b. 10/195 (United Kingdom); c. 10/240 (EBU).

[1982-86]: a. 10/42 (Canada) + Add. 1.

[1986-90]: **10/266 (Germany (Federal Republic of))**

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EBU [February, 1976] Choice of polarisation for new Band-II services. *EBU Rev. Tech.*, 155, 21-24.