REPORT ITU-R BT.961-2

TERRESTRIAL TELEVISION BROADCASTING IN BANDS ABOVE 2 GHZ

(Questions ITU-R 1/11 and ITU-R 49/11)

(1982-1986-1994)

1. Introduction

Experimental amplitude-modulation terrestrial television broadcasting systems in Band 10 at 12 GHz have been set up in the Federal Republic of Germany [CCIR, 1974-78a], in the Netherlands [CCIR, 1974-78b], and in Switzerland [CCIR, 1974-78c] for system G, and in Japan for system M [CCIR, 1974-78d and e]. Further, an operational station for the same broadcasting system has been working in Japan since 1979 [CCIR, 1978-82a].

The World Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service (Geneva, 1977) (WARC BS-77) has established for Regions 1 and 3 a frequency and orbital position Assignment Plan for the broadcasting-satellite service in the 12 GHz band shared with the terrestrial broadcasting service. The Regional Administrative Radio Conference, Geneva, 1983 has established an analogous Plan for the broadcasting-satellite service in Region 2.

An efficient means for the provision of television services to relatively small communities, (for example as an alternative to, or as an extension of, cable television networks) is the microwave multipoint video distribution system (MVDS) [Yard, 1992].

Within Europe, the CEPT has recommended 40.5 - 42.5 GHz as a harmonized frequency band for MVDS [CEPT, 1991]. In the United Kingdom a performance specification has been produced for 40 GHz MDVS transmission equipment [United Kingdom RA, 1993], and propagation studies are being undertaken to develop appropriate planning parameters.

2. Technical characteristics

2.1 Systems using amplitude modulation

2.1.1 Characteristics of the radiated signal

Both amplitude modulation and frequency modulation are applicable to terrestrial television broadcasting in the 12 GHz band. A system of amplitude modulation requires higher transmitting powers but will allow more television channels.

Amplitude modulated television signals in the 12 GHz band should conform to the standards given in Recommendation ITU-R BT.470 so that they can be received by a conventional television receiver equipped with a frequency converter.

2.1.2 Protection ratio

The ratio of wanted-to-unwanted signal power at the receiver input is an important factor in planning terrestrial television systems. The protection ratio required when considering interference between two amplitude-modulation vestigial-sideband (AM-VSB) television signals is given in Recommendation ITU-R BT.655. The protection ratio between two frequency modulation television signals can be found in Report ITU-R BO.634.

The required ratios are essentially independent of frequency band. However, in applying them to the planning of a terrestrial system in the 12 GHz band, it is necessary to take into account both signal fading and the frequency stability of transmitters. With regard to the latter, an experiment in Japan has shown that it is not practicable to use precision offset techniques for AM-VSB systems in the 12 GHz band [CCIR, 1978-82b].

2.1.3 Equipment characteristics

2.1.3.1 Transmitter

Specifications of AM-VSB transmitters for a terrestrial television service in the 12 GHz band can be virtually the same as those in Bands III, IV and V.

In order to simplify the transmitters, the vision carrier could be amplified together with its accompanying sound carrier, but this may cause intermodulation. In Japan, the ratio of sound to vision power has been altered from 1/4 in Bands III, IV and V, to 1/10 in the 12 GHz band in order to reduce the 920 kHz beat between the sound carrier and the colour subcarrier.

2.1.3.2 Receiving equipment

In experiments so far reported, the frequency converters used at the receiving points have only to change the frequency from the 12 GHz band to a frequency within Bands IV and V. The converter has been mounted directly behind the parabolic reflector, giving rise to negligible feeder loss. Experience gained has led to the conclusion that a converter noise figure of 7 to 10 dB can be realized without excessive cost, and that considering transmitting power, converter noise figure, mounting facilities, beamwidth and influence of wind, an antenna diameter of 40 cm is reasonable.

For establishing the standards for terrestrial television broadcasting in the 12 GHz band in Japan, a converter with a noise figure of 10 dB, equipped with an antenna of 40 cm diameter, was assumed. In practice, converters with noise figures of 6 to 8 dB have been used in Japan.

2.2 Systems using frequency modulation

For FM television systems further studies are required. However, some tests [CCIR, 1982-86] to determine basic propagation conditions have been carried out in the United States of America.

2.2.1 Characteristics of the radiated signal

Frequency modulation will normally be the preferred analogue modulation method for systems using 40 GHz, taking account of transmitter output power and available bandwidth considerations.

Frequency modulated television signals in the 40 GHz band should provide for compatibility with those radiated in the Broadcasting-Satellite Service (BSS) or the Fixed-Satellite Service (FSS) to enable existing indoor receiver units to be used in conjunction with 40 GHz antennas and down-converters.

2.2.2 Protection ratio

The protection ratio between two frequency modulated television signals can be found in Recommendation ITU-R BO.792.

2.2.3 Equipment characteristics

2.2.3.1 Transmitters

The transmitter parameters for the 40 GHz analogue MVDS service proposed in the United Kingdom are as shown in Table 2. The limits for the spectrum of the modulated signal, using either I/PAL or D2-MAC signal formats, are as shown in Fig. 1.

For the United Kingdom 40 GHz FM MVDS service it has been proposed that a 64° horn will provide an approximately circular coverage area at the desired service availability (when fed from the perimeter). Such antennas are considered desirable for frequency planning. However, it is likely that omnidirectional antennas may be specified in certain cases. The maximum gain for these types of antenna is shown in Table 3 and the antenna gain reference patterns for the 64° antenna are shown in Figs. 2 and 3.

2.2.3.2 Receiving equipment

The receiver parameters for the 40 GHz analogue FM MVDS service proposed in the United Kingdom are as shown in Table 4. The positions of the local oscillator within the MVDS spectrum are shown in Fig. 4 and the envisaged 40 GHz channel plan is shown in Table 5.

2.3 Systems using digital modulation

It is envisaged that MVDS will be attractive as a delivery medium for digital televisions services, which will benefit from increased spectrum efficiency over analogue systems. Only limited information on the specific application of digital techniques in Bands 10 and 11 is available, and further studies are required.

3. The minimum power-flux density

3.1 AM systems

At frequencies above 1 GHz it is common practice to use the power-flux density, expressed in W/m^2, as a measure for the signal strength.

The signal strength in this band has been calculated taking account of the above considerations and of the necessity of having a figure for the planning of a terrestrial amplitude-modulation broadcasting network in the 12 GHz band.

Table 1 gives the characteristic parameters for the calculation of the minimum power-flux densities, derived from the experimental and operational systems mentioned above.

The power-flux density Φ ($dB(W/m^2)$) at the receiving point is given by:

$$F = F + 10 \log k\,T\,B + (S/N)_{RF} - 10 \log a \qquad dB(W/m^2) \qquad (1)$$

The proposed minimum power-flux densities for a satisfactory grade picture at the receiving antenna range from -85.5 $dB(W/m^2)$ to -70.2 $dB(W/m^2)$ for amplitude-modulation systems. The differences in the values are due to different assumptions for the picture quality, the receiver noise performance and the receiving antenna gain, as shown in Table 1.

A minimum power-flux density of -70 $dB(W/m^2)$ has been adopted for the operational AM system in Japan.

3.2 FM systems

The proposed United Kingdom 40 GHz FM MVDS system has taken as its quality criterion C/N = 12 dB for 1% worst month, which equates to a satisfactory grade picture (ITU-R grade 4). Therefore the equation given in (1) above becomes:

$$F = F + kTB + (C/N) - 10 \log a \qquad dB(W/m^2) \qquad (2)$$

Assuming the receiver characteristics given in Table 4, the proposed minimum power-flux density at the receiver antenna is -85.2 $dB(W/m^2)$.

4. Polarization of transmission

Measurements of scattered waves from objects local to the receiving antenna have been carried out in the 12 GHz band in urban Tokyo. From the results, it has been found that the use of horizontally- or vertically-polarized transmission is advantageous over circularly-polarized transmission to reduce interference to other service areas where orthogonal polarization is used. Although it has been found that there is an advantage in using circularly-polarized transmissions to reduce multipath interference (see Report ITU-R PN.562), in practice multipath interference need not be taken into account. Measurements in urban areas of Tokyo have shown that picture impairment, due to multipath interference alone is no lower than grade 4 on the 5-grade scale (Recommendation ITU-R BT.500), provided that the impairment due to noise is no lower than grade 3 or the field strength is not more than 20 dB below the free space value. This performance can be achieved by using a parabolic reflector receiving antenna of at least 40 cm diameter and a frequency converter having a noise figure of 6 dB [Saito *et al*., 1977].

In Japan, the transmissions are normally horizontally polarized, but where necessary, vertical polarization is used.

TABLE 1

Characteristic parameters of experimental and operational 12 GHz systems

Television system		G (Germany, Federal Republic of)	G (Switzerland)	M(1) (Japan)	G/FM (Switzerland)
Noise figure of converter (dB)	F	10	9	10	9
Radio-frequency signal-to-noise ratio at input to television receiver (dB)	$(S/N)_{RF}$	43(2)	40(3)	42	19(4)
Diameter of parabolic reflector (m)	D	0.6	0.6	0.4	0.6
Efficiency of antenna (%)	η	50	-	50	-
Miscellaneous losses in reception (misalignment etc.) (dB)	L	-	-	2	-
Antenna gain (dB rel. isotropic radiator)	G	34.5	34	31	34
Effective antenna area 10 log a (a in m^2)	A	-8.5	-	-14	-
10 log kTB (dBW)	-	-137(5)	-	-136.2(6)	-
Minimum power-flux density ($dB(W/m^2)$)	P	-75.5	-80	-70.2	-101

(1) Operational system.

(2) $(S/N)_{RF}$ at the edge of the service area when using an antenna with a cosecant vertical pattern producing the same field strength in the entire service area.

(3) Corresponds to grade 4.5 of Recommendation ITU-R BT.500.

(4) $(S/N)_{RF}$ at receiver input: modulation index m = 1.

(5) Noise bandwidth B = 7 MHz.

(6) Noise bandwidth B = 6 MHz.

5. Effect of interference

In planning a terrestrial network, interference can be a factor which determines the required flux density of the wanted signal. Methods of calculating field strength or transmission loss which are of interest for assessing interference probabilities are indicated in Reports ITU-R PN.562 and ITU-R PN.569.

6. Effects of propagation

For the planning of a terrestrial broadcasting system in the 12 GHz band, losses due to diffraction by buildings are of particular importance; consideration may also have to be given to attenuation due to precipitation. Relevant information is given in Report ITU-R PN.562.

During investigations in San Francisco using a 20 MHz bandwidth FM system [Bentz, 1982] very little diffraction around obstacles or penetration through obstacles - including foliage - was noted. However, in many cases of obstructed transmission paths, it was possible to use a reflection as a better source of the signal. Because of the highly directional beam of the receiving antenna, whether a horn or parabolic dish, it was possible to select a single reflection. For this reason multipath interference was rarely encountered. Rain attenuation was considerable, as indicated by long-term measurements at fixed locations, and would have to be taken into account in the system design in the form of adequate transmitter power. Based on the parameters of this specific test, satisfactory reception was reported at approximately 70% of the desired target area.

7. Frequency-sharing with the broadcasting-satellite service

Frequency-sharing between the broadcasting-satellite service (BSS) and terrestrial services is discussed in Report ITU-R BO.631. Frequency-sharing between the BSS and the terrestrial television service in the 12 GHz band can be accomplished by operating terrestrial transmitters in those parts of the band not used by the BSS in the area where the transmitters are situated.

It is important from the viewpoint of spectrum utilization to know the factors affecting the required separation between the operating frequencies of both services. In Japan, field and laboratory tests were conducted using Japan's medium-scale broadcasting satellite for experimental purposes (BSE) and terrestrial broadcasting transmitters in the 12 GHz band. The tests have shown that even in the worst case there is a high probability that interference to reception of a broadcasting-satellite service from unwanted signals is not determined by intermodulation in the receiver but by its selectivity. The receivers used for the tests were of a type using a diode-mixer converter (see Report ITU-R BO.473). Interference from the BSE to the terrestrial-broadcasting service in a channel overlapping the BSE signal was not observed during the tests [CCIR, 1978-82b].

8. Operational system

In 1977, eighteen television channels in the frequency range 12.092 GHz to 12.2 GHz were assigned for terrestrial television services in Japan to improve reception in areas where signals in Bands III, IV and V are severely degraded by multipath interference. The first operational translator station started service in an area of Tokyo in 1979. The station provides seven AM-VSB channels at a maximum e.i.r.p. of 6.7 W/channel. The maximum coverage distance from the transmitter is about 1 km, defined by a required power-flux density of -70 dB(W/m^2) [Momoura and Kikuchi, 1979].

TABLE 2

Transmitter parameters for 40 GHz FM MVDS system

Frequency band of operation	40.5 GHz to 42.5 GHz
Frequency of transmission (unmodulated)	See Table 5 Channel Plan
Transmitter output power per channel	≤ 200 mW (≤ -7 dBW)
Frequency stability of transmission (unmodulated)	±0.5 MHz of nominal centre frequency
Spurious emissions outside the band 42.5-43.5 GHz	30 MHz to 21.2 GHz < -90 dBW 21.2 GHz to 80 GHz < -60 dBW 80 GHz to 90 GHz < -50 dBW
Spurious emissions within the band 42.5-43.5 GHz	< -80 dBW
Spectral power density referred to nominal carrier frequency	See Fig. 1
Modulation Mode	Frequency Modulation
Television system	CCIR system I/PAL or D2-MAC
Nominal channel spacing	29.5 MHz

TABLE 3

Antenna gain for 40 GHz FM MVDS system

Antenna Type	Gain dBi max
64 Degree	15
Omnidirectional	8

FIGURE 1

Limits of spectral power density for 40 GHz MVDS system

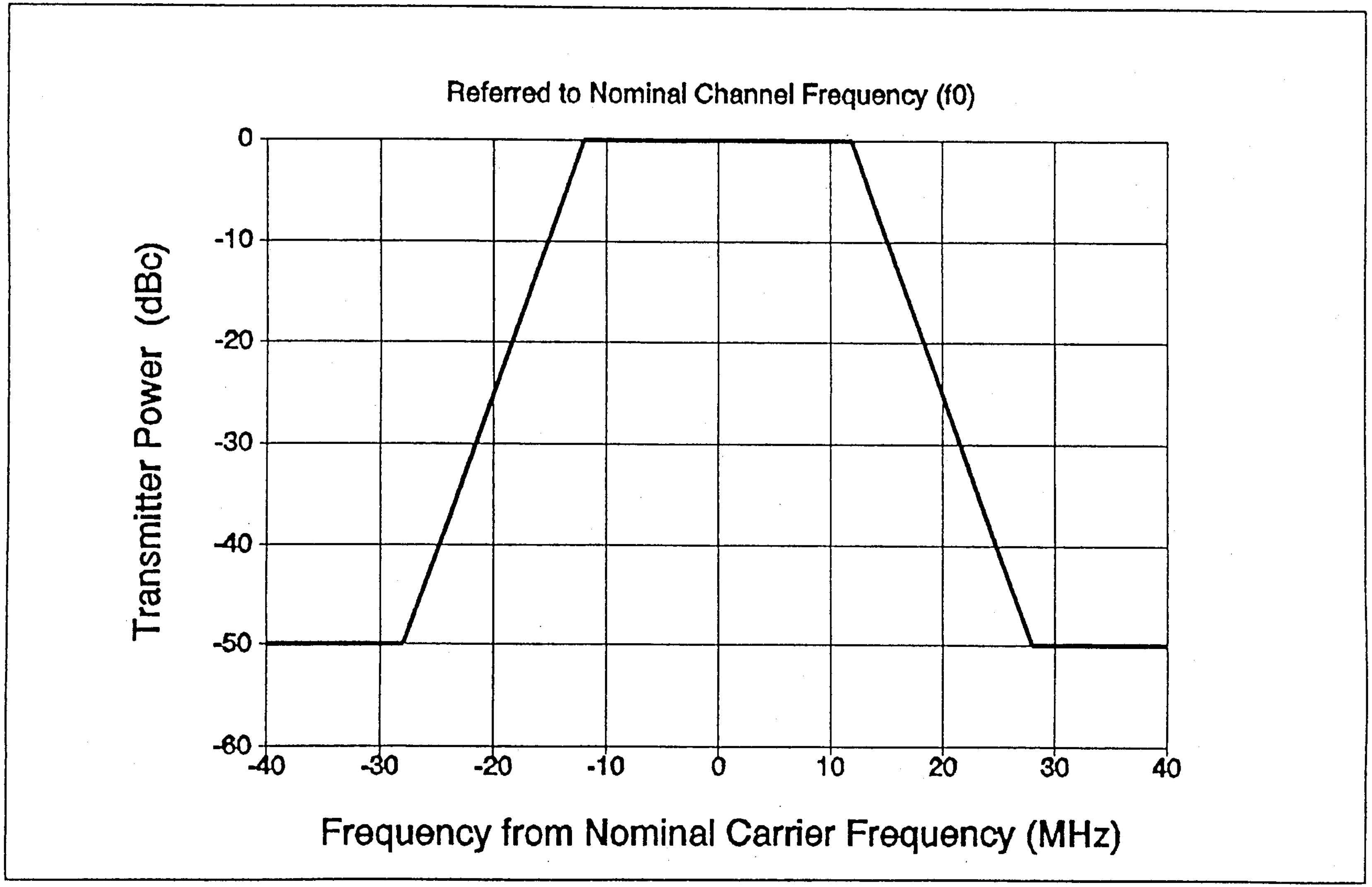


FIGURE 2

Antenna gain reference pattern - 64° angle antenna for 40 GHz MVDS system

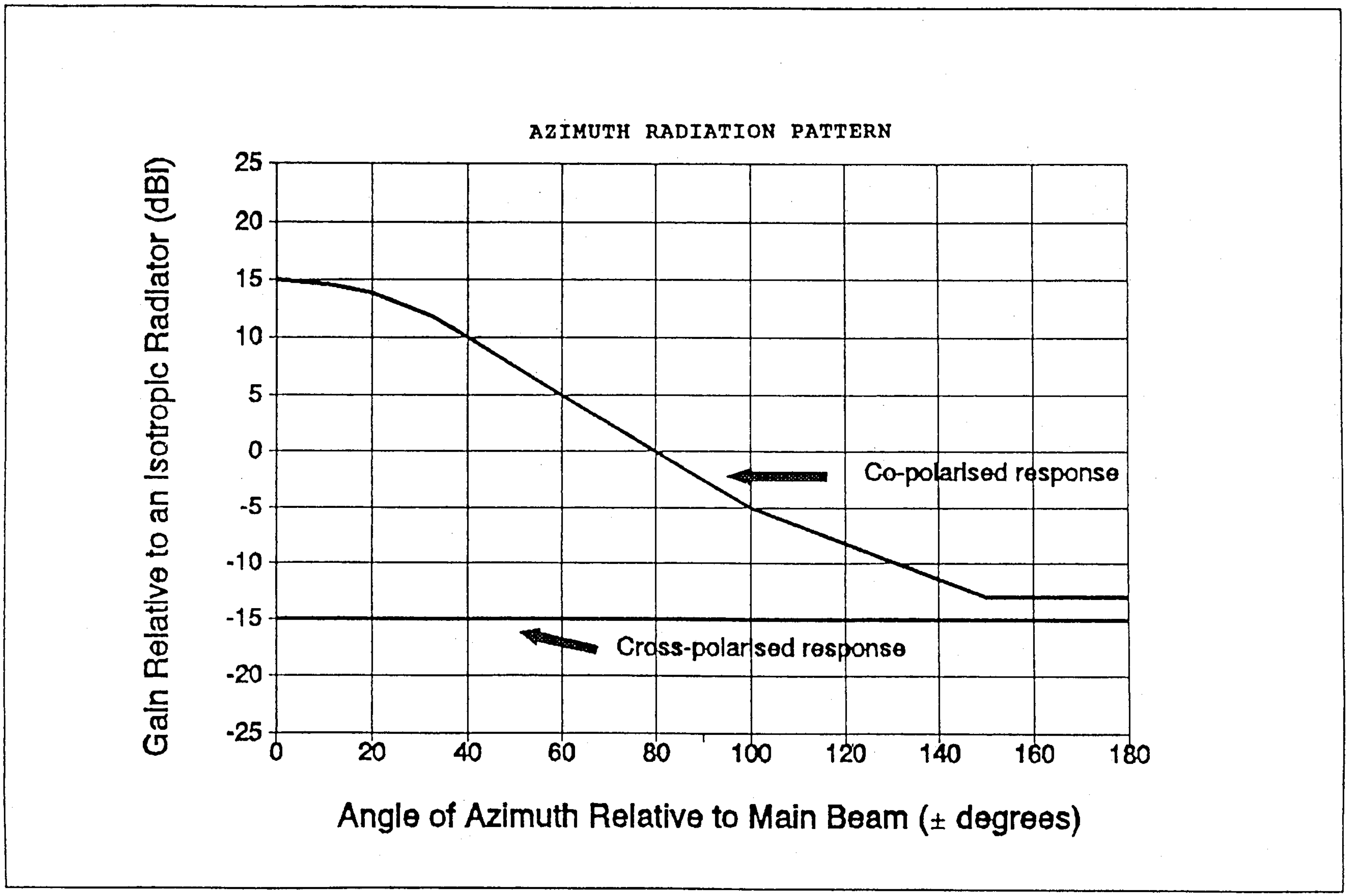


FIGURE 3

Antenna gain reference pattern - 64° angle antenna for 40 GHz MVDS system

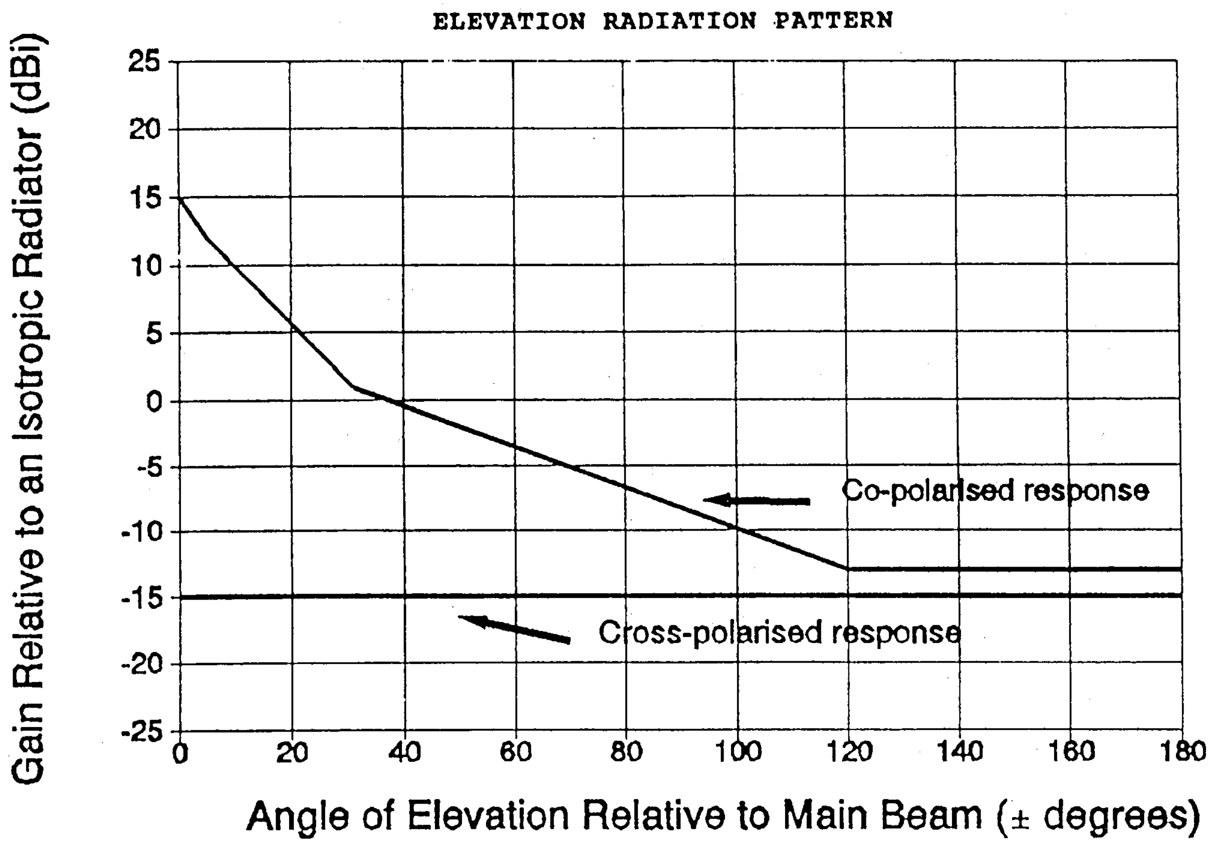
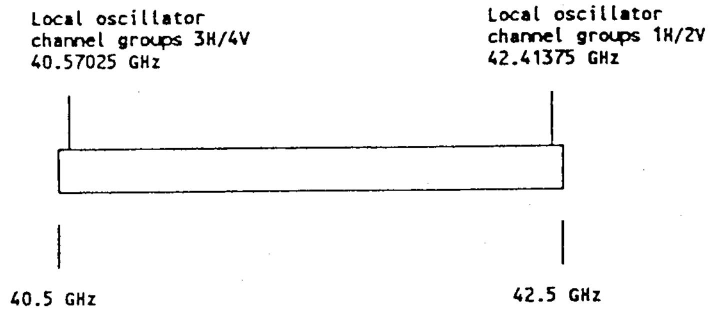
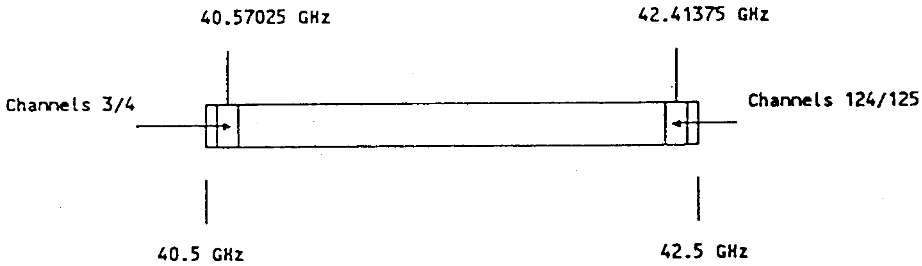


FIGURE 4

Position of the local oscillator within the spectrum for 40 GHz FM MVDS system



Position of local oscillator frequencies within MVDS spectrum



Position of local oscillator frequencies within MVDS channels

TABLE 4

Receiver parameters for 40 GHz FM MVDS system

a) Outdoor unit

Frequency range	40.5 - 42.5 GHz
Noise figure (including 2 dB filter insertion loss)	≤11 dB
Gain of receiving aerial	32 dBi
Polarization of receiving aerial	Horizontal/Vertical
Frequency of local oscillator (Ch 1 - 64) (Ch 65 - 128)	42.41375 GHz 40.57025 GHz
Stability of local oscillator	±5 MHz
Channel polarization (odd numbers) (even numbers)	Horizontal Vertical
Rejection of 1st image frequency	>35 dB

b) Indoor unit

Frequency range	0.95 - 1.95 GHz
Signal input at 1st I.F. to reach fm demodulation threshold and to achieve 48 dB weighted S/N	-60 dBm (Z_m=75 Ω nominal)
Maximum tuning error for worst selected channel	±0.25 MHz
Rejection of adjacent (N+2) odd or even channels	25 dB
Channel bandwidth	26 MHz nominal
Frequency range of modulated UHF output	Channels 32 - 40
Characteristics of baseband video output:	
Bandwidth	25 Hz - 10.5 MHz ±2 dB to 8.4 MHz ±3 dB to 10.5 MHz
Group delay error	<25 ns
Peak/peak output level	1 Volt nominal
Output impedance	75 Ω nominal (return loss > 20 dB)
De-emphasis	selectable to Rec.ITU-R F.405-1 or EBU MAC/Packet specification Tech. 3258
Baseband video and audio output connection	European Standard EN50049 PERITELEVISION

TABLE 5

Proposed channel plan for 40 GHz FM MVDS system

Groups 1 and 2 channel plan

Channel Group 1 Horizontal Polarization		Channel Group 2 Vertical Polarization	
Channel number	Nominal Centre Frequency of Channel (GHz)	Channel number	Nominal Centre Frequency of Channel (GHz)
1	40.53500	2	40.54975
3	40.56450	4	40.57925
odd channel numbers	increasing in 29.5 MHz steps	even channel numbers	increasing in 29.5 MHz steps
61	41.42000	62	41.43475
63	41.44950	64	41.46425

Frequency of first local oscillator for channel groups 1 and 2 = 42.41375 GHz.

Range of first IF channels for channel group 1 = 964.25 to 1 878.75 MHz (H).

Range of first IF channels for channel group 2 = 979.00 to 1 893.50 MHz (V).

Groups 3 and 4 channel plan

Channel Group 3 Horizontal Polarization		Channel Group 4 Vertical Polarization	
Channel number	Nominal Centre Frequency of Channel (GHz)	Channel number	Nominal Centre Frequency of Channel (GHz)
65	41.53500	66	41.54975
67	41.56450	68	41.57925
odd channel numbers	increasing in 29.5 MHz steps	even channel numbers	increasing in 29.5 MHz steps
125	42.42000	126	42.43475
127	42.44950	128	42.46425

Frequency of first local oscillator for channel groups 3 and 4 = 40.57025 GHz.

Range of first IF channels for channel group 3 = 964.25 to 1 878.75 MHz (H).

Range of first IF channels for channel group 4 = 979.00 to 1 893.50 MHz (V).

References

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[1978-82]: a. 11/79 (Japan); b. 11/247 (Japan).

[1982-86]: 11/320 (United States).