REPORT ITU-R BT.2139

Diversity reception of digital terrestrial television broadcasting signals

(2008)

1 Abstract

Diversity reception of digital terrestrial television broadcast signals offers substantial improvement in coverage of television services. Planning parameters for mobile reception can be found in Recommendation ITU-R BT.1368-7. The use of diversity receivers is increasing. The results of tests performed in Italy and Japan with mobile reception of digital terrestrial television can be found in this Report.

Part 1 of this Report presents mobile diversity case reception field test regarding present DVB-T. It presents the results of a study carried out by RaiWay on the possibility to receive present digital terrestrial television (DTT) broadcasting (64-QAM, FEC 2/3) in vehicular mobility conditions. Herein is proposed a receiving system capable of properly managing and possibly solving the typical problems concerning the reception of DTT broadcastings in vehicular environments and are outlined the results of a comparison between the performances achieved in several field tests by the proposed receiving system and a reference single antenna professional receiver.

Part 2 of this Report presents mobile reception with four-branch space diversity for ISDB-T. Mobile reception of digital terrestrial broadcasting carrying a digital high definition television (HDTV) signal was successful with four-branch space diversity. The effect of 4-branch diversity reception in a moving vehicle for a 64-QAM-OFDM signal was experimentally investigated by using prototype hardware. Field-based experiments showed evidence of a drastic improvement in reception performance and a reduction in the required minimum field strength as compared to that obtained using single dipole antenna.

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Part 1

Digital terrestrial television: Mobile diversity case reception field test regarding present DVB-T

1 Scope

Verify in a field test, the possibility to receive in vehicular mobility mode the DVB-T emissions broadcasted by the already on air networks, which has been developed and implemented to ensure fixed antenna reception through a complex system of reception.

DVB-T mobile reception can easily achieve at least three major advantages with respect to DVB-H broadcastings:

– seamless use of already existing network infrastructures (no need to further capex);
– remarkably higher reception quality, both in terms of screen resolution and of available bit-rate, compared to the reception quality currently available or expected by DVB-H broadcastings, allowing therefore to install high-quality display up to large-sized screen on board of vehicles (cars, vans, coaches, tramway cabs, trains, …);
– availability for the end user of a wide range of subscription-free contents.

We assumed that this type of mobile DVB-T reception can be achievable by the use of “diversity” receivers with carriers coherent sum (CCS) system.

2 Introduction

Presently, broadcasted TV emissions in DVB-T standard allow Italian operators to cover the majority of the population resident in urban and rural areas. The network planning carried out by all DVB-T operators was targeted to guarantee the so-called “fixed antenna reception”, that is to say by means of a rooftop antenna. Also because of the Italian law constraints concerning electromagnetic pollution, said network planning considered the so-called “indoor reception” (without the use of external antennas) as a far secondary priority, and mobile reception was not included in the scope of work. In this market scenario the DVB-H standard was developed to the scope of allowing an adequate-quality mobile reception of a large number of programmes to be displayed on stand-alone portable receivers approximately sized as mobile phones or PDA, capable of a battery life adequate to the enjoyment of the broadcasted services. The DVB-H Standard practically requires a QPSK or 16-QAM modulation. This limits the available bandwidth per single programme, and in order to broadcast several programmes in the same channel it is commonly accepted to limit the screen resolution of each programme according to the typical resolution performance of the screen generally available on handheld equipments (CIF or similar). Such a compromise can be considered as adequate for pedestrian mobile reception, but limits the achievable performance in the case of vehicular mobile reception (vehicles, bus in city or intercity service, trains...), where larger displays are typically implemented. It is here useful to point out that vehicular reception can take advantage of the on-board electrical power plugs, and therefore any concern about battery duration is superseded.

3 Carriers coherent sum diversity receiver system

A diversity system commonly implies the employment of a receiving system whose main characteristic is the redundancy of some or all of the functional parts included in it. Each of the redounded part is in all capable to carry out its own task independently from the concerned “twin”, and from an overall point of view we can say the redundancy allows to choose dynamically, moment by moment, the part which is offering the best performances. In short, the concept of diversity implies the concept of “choose of the best receiving condition”. The CCS diversity system represents a remarkable step ahead, and it can be adopted thanks to the COFDM modulation used in DVB-T standard. In the CCS case the RF system is completely redounded: Each of the two different antennas is connected to one receiver. Each receiver demodulates the carrier mask of the received signal. The two receivers are linked through a data bus by which receiver A “sends” to receiver B the carrier mask of the received signal. An appropriate circuit allows to re-synchronize (coherent) the two carrier masks to add, carrier by carrier, the amplitude of each pair of matching carriers (sum in phase of carriers amplitude, sum in power of the noise). The idea of “choose” here is definitely replaced by the idea of “merge”: even in case of two received signals, each of them is not lockable by the receiver, it could happen (and it happens!) that a signal, whose carrier content is the sum of the carrier content on each of the received signals, can be perfectly locked and decoded. This receiving mode can be usefully adopted in mobile reception. Our field test testifies the correct operation in vehicular mobility conditions of the CCS receiver under test. Given to the “consumer” nature of CCS receivers nowadays available in the market, it is not yet possible to carry out quantitative objective measurements on the reception quality in vehicular mobility conditions, because of consumer receivers supply no indication on the necessary data to determine the objective quality of reception.

4 Test development

Our field test has been developed in four consequent steps:

Step 1: Choice of the test vehicle and of the best receiving antenna system.

Step 2: Analysis of the available instruments (directly by RaiWay and with the cooperation of Rohde & Schwarz Italia) and choice of the data measurement and storage system.

Step 3: Reference vehicle implementation and field test.

Step 4: Analysis of the acquired data.

4.1 Choice of the test vehicle and of the best receiving antenna system

Among the various mobile laboratories in our fleet we chose the medium van Volkswagen Transporter. This vehicle has a footprint like a SW car, but a height like a SUV. This allowed us to use a single vehicle to carry out field tests referable to the majority of the vehicles potential target of such a receiving system. The choice of the receiving antennas has been carried out among consumer level models easy available on the market. One of the goals of this test was to verify whether it is possible to achieve the desired receiving performances by means of a receiving system whose size and costs allows the end user to easily install it on common vehicles, both as factory equipment and after-market one. Some field tests pointed out that the simplest and less visible receiving system, with two pre-amplified film antennas located on the windshield and on the rear window of the vehicle, can allow adequate receiving performance on commercial CCS diversity receivers. As a plus, this double antenna system is practically invisible. The use of one pre-amplified film antenna and one stylus antenna placed on top of the vehicle (a more invasive solution indeed) caused no significant advantages.

4.2 Analysis of available instruments (directly by RaiWay and with the cooperation of Rohde & Schwarz Italia) and the choice of data measurement and storage system

Scope of this test is the evaluation of the advantages that a CCS receiving system can offer in vehicular reception of existing DVB-T broadcastings compared to a single antenna receiver. As previously stated, no measurement instrument capable to perform quality reception measurements in mobility conditions is currently available in the market. Should said instruments appear on the market it will be possible to improve Recommendation ITU-R BT.1735. Therefore our job pursued the way to compare the performance difference between said two receiving systems in everyday conditions. To this scope, RaiWay took advantage of the cooperation with Rohde & Schwarz Italia. As a start, we had to select a reference single antenna receiver; it was strictly requested to select a receiver designed to mobile use. Some high-end measurement instruments, designed to laboratory (stationary) use, revealed themselves definitely not adequate to our purposes, because they lose any signal locking as far as the vehicle speed exceeded 10-20 km/h. To ensure a conservative comparison, the choice of the reference single antenna receiver led us to a professional Rohde & Schwarz TSM-DVB equipment, with ASI out. This receiver, designed for the mobility use, is a diversity receiver with selection of the best received signal (no CCS), but when connected to just one antenna it performs as a single antenna receiver. The choice of the CCS receiver led us to an MB international prototype, not yet on the market, with both decoded video and ASI outs. The ASI out is a rare feature on consumer receivers, but it is a must for us. In fact, the advantages that the CCS configuration can offer affect the “reconstruction” of the carrier mask, while the subsequent MPEG-2 decoding must have no contribution to a trustable comparison between the considered receiving systems. We therefore had to include homogenous MPEG-2 decoding stadiums in our test bed. The ASI out of the two receivers were thus connected to two professional MPEG-2 decoder Rohde & Schwarz DVMD.

4.3 Reference vehicle implementation and field test

The Volkswagen Transporter was equipped with all the items and instruments described above. Further, to allow an immediate comparison between the two receiving systems the video out of each DVMD was connected to a four-way video splitter; the remaining two inputs were connected to the decoded video out of the CCS receiver, in order to compare the performance of the CCS receiver inner decoder Vs. the reference decoder (R&S DVMD), and to the video out of a laptop computer, connected to a GPS receiver and running a Rohde & Schwarz software (ROMES), capable to display on a background map the present position, heading and speed of the vehicle. The four-in-one splitter out was connected to a video recorder for the recording and the subsequent analysis. The complete connection diagram can be found in Fig. 1. Then we determined four reference paths where to perform our field test. Along these paths one can find the most common receiving conditions of urban, suburban, rural and highway routes. Since our receiving systems did not include the automatic search for alternate frequencies, said reference paths had furthermore to allow an adequate coverage by the same DTT signal on the same frequency. The selected paths are:

Path 1: Monza – Dalmine and back along the highway A4; it is an average speed journey (due to traffic congestion) but characterized by frequent obstacles in fast movement across the transmitter line of sight (the vehicles on adjacent tracks and on the opposite tracks) which cause rapid and continuous changes of near reflection conditions.

Path 2: Monza – Sesto Calende and back along the A4, the A8 and the A26 highways; it is a high speed journey (thus compliant with the 130 km/h Italian speed limit) with some passages in earth trench.

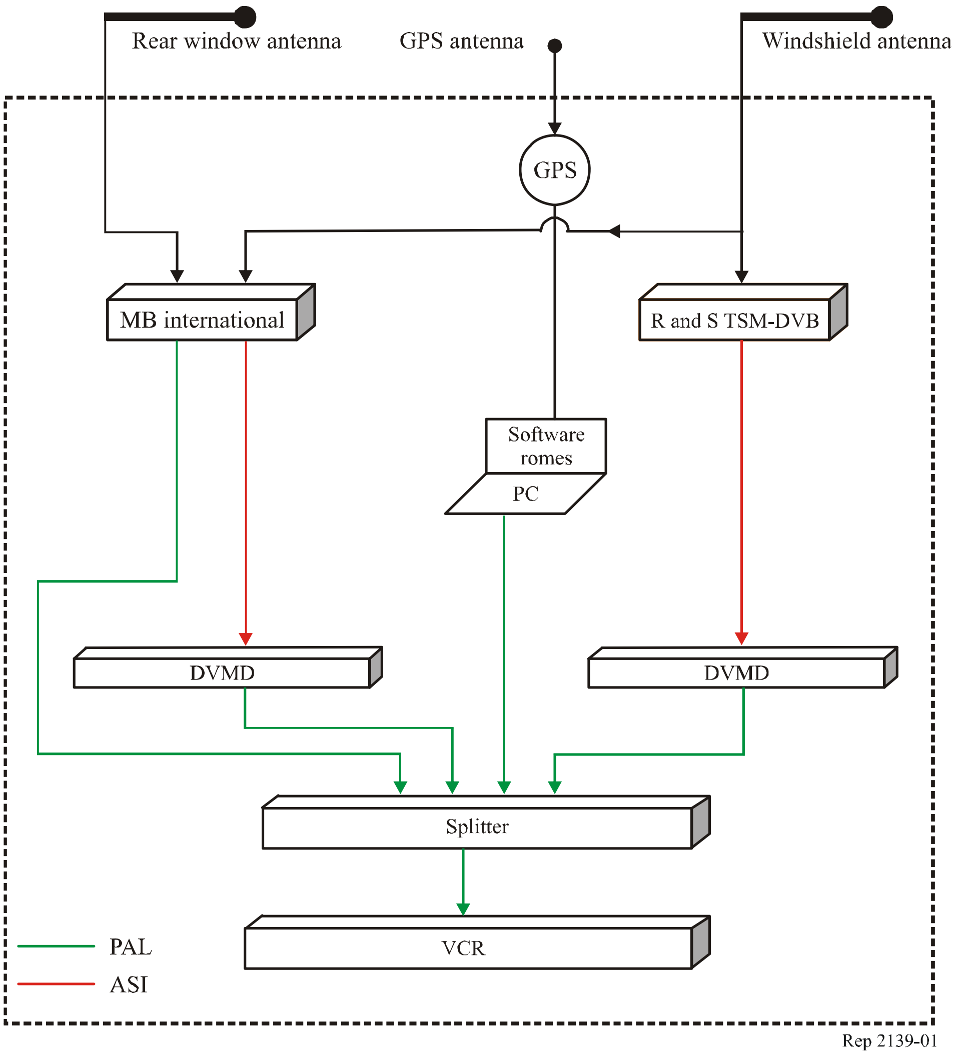
Path 3: A circular route along an urban Milan city ring; medium average speed (70 km/h speed limit in some parts, 50 km/h in the rest), wide roads surrounded by 5/7 storey buildings, one tramway overhead power line in the centre of the track, intense but flowing traffic.

Path 4: A route in the historical centre of Milan; crowded traffic, narrow roads surrounded by high buildings (no direct beam, pure Ricean channel).

For all of the four paths we set the receivers on channel 64, on which the so-called RAI "MUX A" is radiated from the sites of Valcava (mountain site at the borders between the province of Lecco and Bergamo) and from the mountain site of Campo dei Fiori (Varese), operating in SFN with two other systems in Lombardy, with 64-QAM modulation and 2/3 FEC. The field tests were carried out during September and October 2006.

FIGURE 1

Test bed connection diagram



4.4 Analysis of the acquired data

We have herein to testify that the performances shown in this field test by the single antenna receiver have no reference to the proper performances of the diversity receiver Rohde & Schwarz TSM-DVB; the performances shown in this field test refer only to the case of the same professional receiver in a mobile environment, but under the specific conditions in which just one of the two inlets of the diversity receiver is connected to a receiving antenna. Said receiver is composed by two independent receivers and one logic of selection; therefore if connected to a single receiving antenna it performs just in the same way of a single antenna receiver of similar capabilities and quality.

The performance achieved in this field test by the TSM-DVB cannot therefore be used, in any way, even indirectly, in order to estimate the performances of the same receiver when used in its native mode of "diversity receiver".

Path 1: Monza – Dalmine and return along the A4 highway. This path has been evaluated in two parts: outward and return. The outward path has been monitored between the toll stations of Agrate and Dalmine, in order to evaluate the systems in an exclusively highway background. The return path has been monitored between the toll station of Dalmine and the RaiWay Control Centre in Monza, in order to include, beyond to the highway environment, a sample of ordinary, suburban and crowded roads. We have to point out how the single antenna system allows the receiving when the vehicle is still (traffic lights, crossings, queues) or moves itself at a very low speed because of the crowded traffic. As soon as the traffic constraints cease, the single antenna system typically stops working. The CCS system achieve an optimal performance also in typical highway background (looks at the outward path).

Path 2: Monza – Sesto Calende and return along the A4, the A8 and the A26 highway (outward) and Milan North Ring, "Peduncolo", and the Milan/Meda freeway (return). As above, the path has been evaluated in two parts, outward and return. The outward path has been monitored the RaiWay Control Centre in Monza and the highway toll station of Sesto Calende, in order to evaluate the systems in a highway background with heavy traffic (A4), and then with high speed (A8) with various passages in earth trench, mainly after the junction to Sesto Calende (A26). The return path has been monitored between the toll station of Sesto Calende and the RaiWay Control Centre in Monza, leaving the highway A8 at the New Milan Fair junction, going on along the Milan North Ring, the "Peduncolo" and the Milan/Meda freeway until Monza, in order to include, beyond to the highway feature, a sample of a freeway with high traffic and high speed. Like in the previous path, the single antenna system allows the receiving when the vehicle is still (crossings, queues) or moves itself at a very low speed because of the crowded traffic. As soon as the traffic constraints cease, the single antenna system typically stops working. Along fast highway paths (A8/A26) the single antenna system has not been capable to lock any signal for 24 (outward) and 22 (return) minutes. The video interruptions suffered from the CCS system are concentrated close to Sesto Calende, where the highway A26 often runs in earth trenches and where is the fixed antenna reception borderline. In any case the CCS system confirms an outstanding performance in both paths.

Path 3: Circular route along an urban Milan city ring, the so-called "third ring". This path allows us to evaluate the performance of the systems in a city background: medium average speed (70 km/h speed limit in some parts, 50 km/h in the rest), wide roads surrounded by 5/7 storey buildings, one tramway overhead power line in the centre of the track, intense but flowing traffic. Once again, we have found that the single antenna system allows the receiving when the vehicle is still (traffic lights, crossings, queues) or moves itself at a very low speed because of the crowded traffic. As soon as the traffic constraints cease, the single antenna system typically stops working. It is useful to consider that the reference single antenna receiver is a professional product specifically designed for mobility use. Further to the overall time of successful receiving, equal to 51% of the total time of the path, the total number of registered breakdowns (114, that is to say one breakdown per every 53 s on average) from a practical point of view prevents any possible audience. Also in this path the CCS system achieves a high-level performance, with 99% total time successful receiving and just 10 breakdowns.

Path 4: Circular path in the historical centre of Milan; crowded traffic, narrow roads surrounded by high buildings (no direct beam, pure Ricean channel) in the narrowest and more winding streets open to private cars in the historical centre of Milan. This type of path has been intentionally chosen in order to test the performance of the systems in really extreme conditions: roads just a little wider than the vehicle itself, and surrounded by high historical buildings with four or five floors, and overhead power lines for the public lighting system. For sure a very challenging test. Beyond the usual indications about the operation of the single antenna system, it is worth pointing out that inside the more critical part of the path, the single antenna system remained continuously unlocked in two major circumstances: the former lasting 22 min and the latter 12 min. The performance of the CCS system is not at all negative (91% total time successful receiving), but suffers for the critical receiving conditions: practically all of the 34 breakdowns, thus of limited duration (all of them lasting a few seconds, with the exception of two, respectively lasting 4' 31" and 1' 15") took place inside of the more critical part of the path. Considering the mountain location of the transmitting sites (Valcava and Campo dei Fiori), we believe that the CCS system achieved in this path an overall performance really beyond any expectations.

5 Conclusions

Being aware of having not performed a test with an absolute reliability from the statistical point of view, we believe that from our experiences it clearly points out that the mobile reception of existing DTT signals (broadcast from already existing network infrastructures) with the parameters normally used in Italy (64-QAM, FEC 2/3, GI 1/32) is a fact, assuming the receiving system is CCS system quality. The experiences performed in the past, in special way in Germany, reached the same result, but with a 16-QAM modulation, for sure “easier” to be managed in mobility. Next table shows the results of our field tests, expressed both as number of video breakdowns and as a percentage of the total time of successful receiving and the total time of the considered path.

Path	Total breakdowns		Percentage T on/T total	
	Single antenna	CCS	Single antenna	CCS
Agrate – Dalmine	5	1	13%	100%
Dalmine – RaiWay Control Centre Monza	18	3	15%	98%
RaiWay Control Centre Monza – Sesto Calende (A4, A8, A26)	22	15	25%	90%
Sesto Calende – RaiWay Control Centre Monza (A26, A8, Tang. Nord)	46	6	43%	95%
Milano – Outer City Path (“terzo anello”)	114	10	51%	99%
Milano – Inner City Path (Historical Centre)	75	34	36%	91%

We would like to point out once more that all the tests have been performed using commercial film antennas of negligible visual impact. The CCS receiver was a prototype, but just we found no CCS receiver in the market equipped with ASI out. Some commercial products already available for sale take advantage of an updated release of the receiving and signal processing chipset which performance has been further improved with respect to the core chipset of the CCS receiver we used in this field test.

Vehicle speed reported in this Report refer to heading direction of the vehicle itself, thus with no relation with Doppler speed reported in Table 46 of Recommendation ITU-R BT.1368-7.

Part 2

Mobile reception with four-branch space diversity for ISDB-T

1 Introduction

Digital terrestrial television broadcasting in Japan was launched in December 2003, and the coverage area is gradually being expanded to cover all of Japan. The system, called integrated services digital broadcasting for terrestrial (ISDB-T) system, is based on orthogonal frequency division multiplexing (OFDM). High definition television (HDTV) programmes are mainly broadcast with 64-quadrature amplitude modulation (QAM) as the carrier modulation and at a coding rate that is 3/4 of the inner code of the convolutional code in each 6 MHz channel. Currently, it is very difficult to receive HDTV broadcast signals without reception problems in a moving vehicle, such as a bus or car, because of frequency-selective fading interference. In this report, we describe a space diversity reception system that uses maximal-ratio combining (MRC) in each OFDM sub-carrier to reduce the influence of frequency-selective fading interference. We also describe the effectiveness of this system in relation to field experiments carried out with the prototype hardware.

2 ISDB-T signal

The OFDM signal transmission parameters used in the transmission of the HDTV signal are listed in Table 1. There are two hierarchies, and the HDTV programme is broadcast in hierarchy B. In this Report, we evaluate the hierarchy B signal received by a mobile vehicle.

TABLE 1

OFDM signal transmission parameters

Used bandwidth	5.572 MHz	
Number of carriers	5 617	
Usable symbol duration	1 008 μs	
Guard interval ratio	1/8	
Hierarchy	A	B
Number of segments	1	12
Carrier modulation	QPSK	64-QAM
Inner coding rate	1/2	3/4
Outer channel coding	RS (204,188)	
Time interleaving length	215 ms	215 ms
Information bit rate	312.06 kbit/s	16.85148 Mbit/s
Required *C*/*N* ratio for reception (AWGN)	4.9 dB	20.1 dB

3 Diversity technology for mobile reception

Frequency selective fading channel is one of the interferences that effects mobile reception in terrestrial broadcasting systems. The propagation characteristics change rapidly. Consequently, the fluctuation in the field strength caused by shadowing or reflection is greater in mobile reception than in fixed reception. An effective way to improve the reception performance is to use space diversity reception technology, in which multiple receiving antennas are used and the received signals are selected or combined.

The Japan Broadcast Corporation (NHK) has been developing a prototype 4-branch diversity receiver, and the carrier-to-noise ratio (CNR) is drastically improved in the mobile environment with such a receiver. Figure 2 shows a block diagram of the diversity system used for OFDM signal reception. There are 4-branch antennas for combining the received signal. Assuming that each signal of the branches is statistically uncorrelated, combining the signals would enhance the CNR of the OFDM signal. To maximize the CNR, MRC is performed after a fast Fourier transform operation for the signals of each branch. The weight for each carrier is derived from the frequency response, which is calculated from the scattered pilot (SP) signal of each branch signal.

The weight of the n^{th}-branch MRC for the i^{th} carrier, $W_n(i)$, is given as:

$$W_n(i) = \frac{H^*{}_n(i)}{\sum_n |H_n(i)|^2} \tag{1}$$

where:

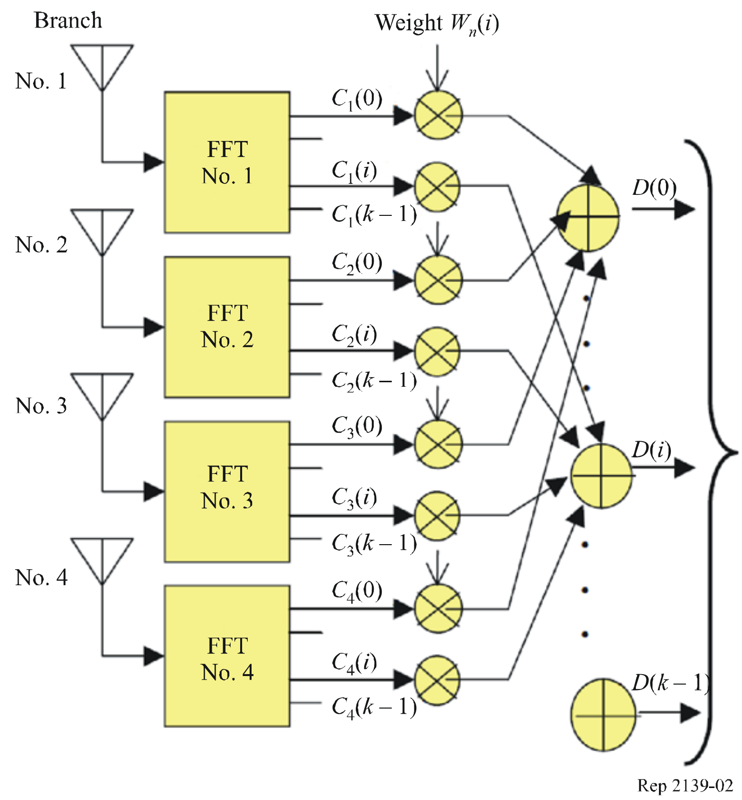
H_n:	frequency response of the channel
$H^*{}_n(i)$:	complex conjugate of $H_n(i)$
$C_n(i)$:	FFT output of the i^{th} carrier.

$$D(i) = \sum_n C_n(i) \cdot W_n(i) \tag{2}$$

where $D(i)$ is the MRC output of the i^{th} carrier.

FIGURE 2

Block diagram of diversity reception system



ISDB-T has SP signals as reference information, and as shown in Fig. 2, the SP carriers are placed every twelfth carrier in the frequency direction and every fourth symbol in the time direction.

The frequency responses of all the carriers (H_n) are estimated by interpolating $H_n(i)$ at the SP carrier position. The diversity receiver calculates the weight by using the estimated frequency response (H_n) from each branch.

4 Performance evaluation

4.1 Mobile reception experiments in the city of Nagoya

We investigated the performance of the 4-branch space diversity receiver in an experimental vehicle travelling in the Nagoya area of Japan. ISDB-T signals from the NHK Nagoya station were used for the field experiments. The OFDM transmission parameters and transmission conditions were the same as those listed in Tables 1 and 2. The 4 reception antennas were horizontal omnidirectional cross dipole antennas mounted 3 m above ground level on the roof of an experimental vehicle. The reception antenna gain was –2 dBd, and the attenuation from the receiving antenna to the diversity receiver was 4.4 dB.

TABLE 2

Nagoya broadcast station transmission parameters

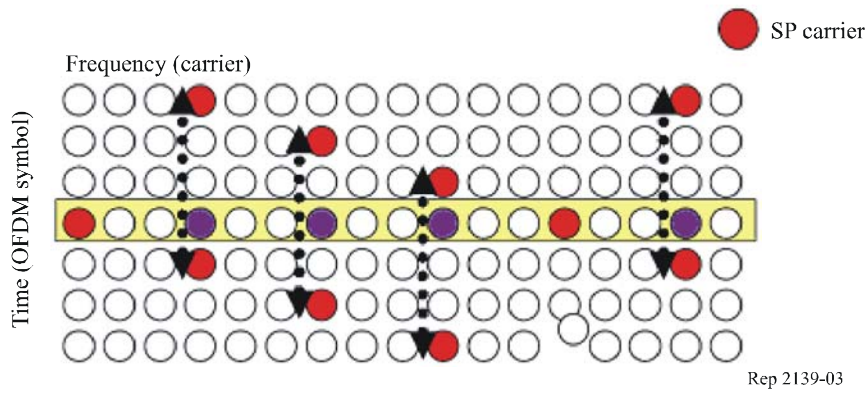
Transmission channel (Centre frequency)	UHF 20 ch (515.143 MHz)
Transmission power	3 kW
Maximum effective radiated power	33 kW
Antenna polarization	Horizontal
Transmitting antenna height	240 m

The mobile reception evaluation was conducted in Nagoya city and the surrounding area. Received field strength, packet error rate, and position information were measured simultaneously. The experimental vehicle covered a total length of about 1 000 km over a period of about 20 h. Samples were excluded if the experimental vehicle stopped or was in tunnel. The experimental vehicle was on high-speed expressways for about 18.5% of the total measurement time.

If a packet error occurred during measurements (approximately 1 s), the sample was judged to be bad. On the other hand, if a packet error did not occur for the same period, the sample was judged to be good. Typical mobile reception results using the 4-branch space diversity receiver are shown in Fig. 3. The fixed reception contour (reception height of ten metres) derived using the field strength prediction software is also shown in Fig. 3. In the urban part of Nagoya, it was possible to receive a steady signal at most measured points. As the experimental vehicle travelled further away, the received field strength weakened and the errors increased.

FIGURE 3

Interpolation of reference information using SPs



The fixed reception contour was divided into 5 dB increments, and the correct reception rates (CRR) of the HDTV for each step are shown in Fig. 4. The CRR can be expressed as:

$$\text{CRR} = \frac{Ncd}{Nsd} \tag{3}$$

where:

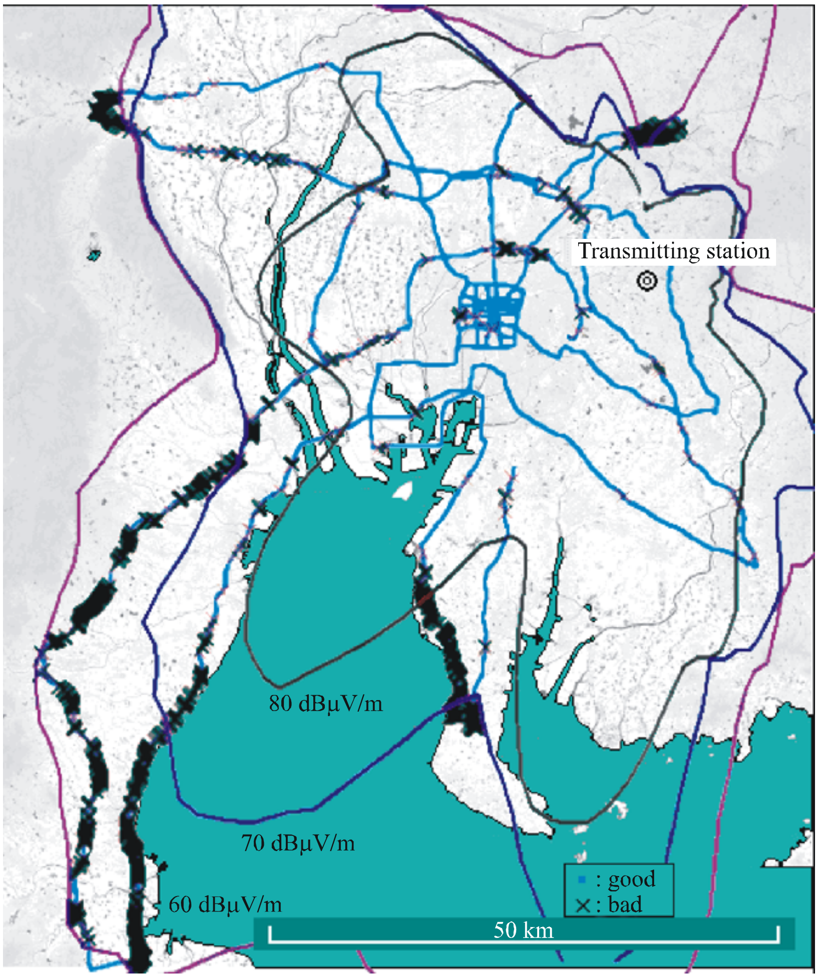
Ncd: number of accurately error corrected packets by the Reed Solomon code

Nsd: number of sampled packets.

To obtain a CRR greater than 95%, the fixed reception contour value must be at least 75 dBµV/m for 4-branch reception and at least 80 dBµV/m for 2-branch reception. The 1-branch reception did not satisfy a CRR of 95%. The mobile reception coverage for the 4-branch reception (greater than 75 dBµV/m) was 53% of the fixed reception coverage (greater than 60 dBµV/m) based on the experimental conditions and for 2-branch reception (greater than 80 dBµV/m) was 38% of the fixed reception coverage based on the experimental conditions.

FIGURE 4

Mobile reception results using four-branch space diversity receiver and fixed reception area (City of Nagoya)



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Next, we describe the mobile reception results in the urban part of Nagoya. The urban part of Nagoya is located about 15 km to the west of the transmission station and is inside the 80 dBμV/m contour for the fixed reception. Figure 5 shows the mobile reception results in the urban part of Nagoya. With 1-branch reception, errors occurred in a lot of places; it was difficult to obtain steady reception without using the diversity receiver. Table 3 lists the CRR for the same area for various numbers of branches. In the case of 4-branch reception, a steady signal was received at almost all positions. In the case of 2-branch reception, a steady signal was received at most positions; however errors increased in certain districts, such as the one indicated on the left side of the map in Fig. 5. The radio wave was blocked by a tall building (Nagoya station building), and consequently, the field strength in this district was low. As the required minimum input level of the diversity receiver decreases as the number of branch increases, the 4-branch diversity reception is more effective in districts where the field strength is significantly decreased by structures like this.

FIGURE 5

Correction reception rate for mobile reception divided by calculated field strength for fixed reception

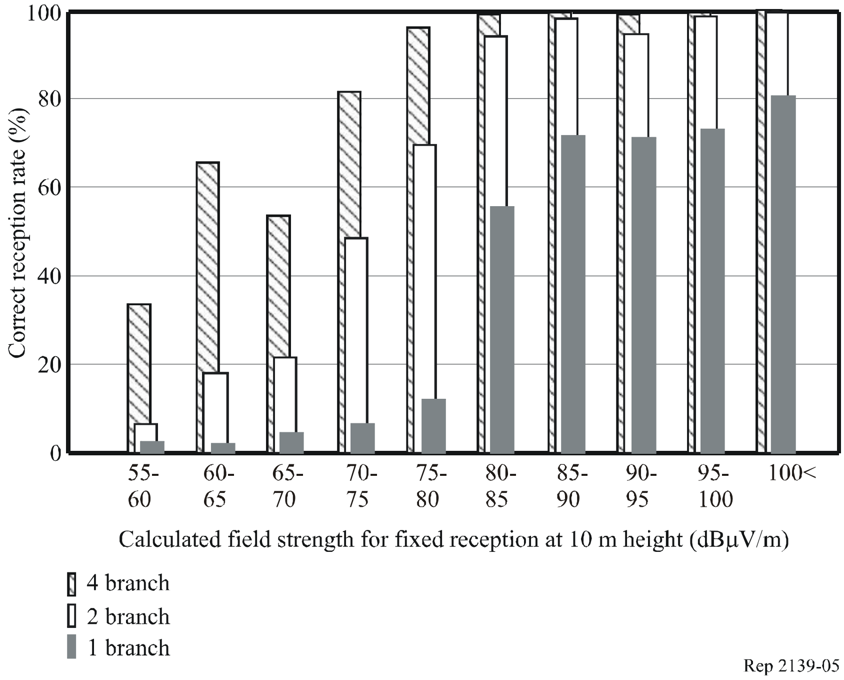

TABLE 3

CRR in the urban part of Nagoya

	4-branch	**2-branch**	**1-branch**
Correct reception rate (%)	99.9	98.3	74.0

4.2 Distribution of received field strength

We analysed the distribution and the relationship between the calculated field strength for fixed reception at a height of ten metres and the received field strength for mobile reception at a height of 3 m. Figures 6 and 7 show the received field strength distributions for a sample at 65-70 dBµV/m and at 75-80 dBµV/m areas for fixed reception. The received field strength distribution for a 4-branch reception sample containing errors is also shown. The CRRs for the 4-branch reception were 54% and 96% under the conditions tested. The received field strength at a reception height of three metres was distributed over 30 dB, although the sample was classified in accordance with the contour for fixed reception within the range of 5 dB. Samples with errors occurred frequently at lower received field strengths, but errors even occurred in samples at relatively high-received field strengths.

FIGURE 6

Mobile reception results in the urban part of Nagoya

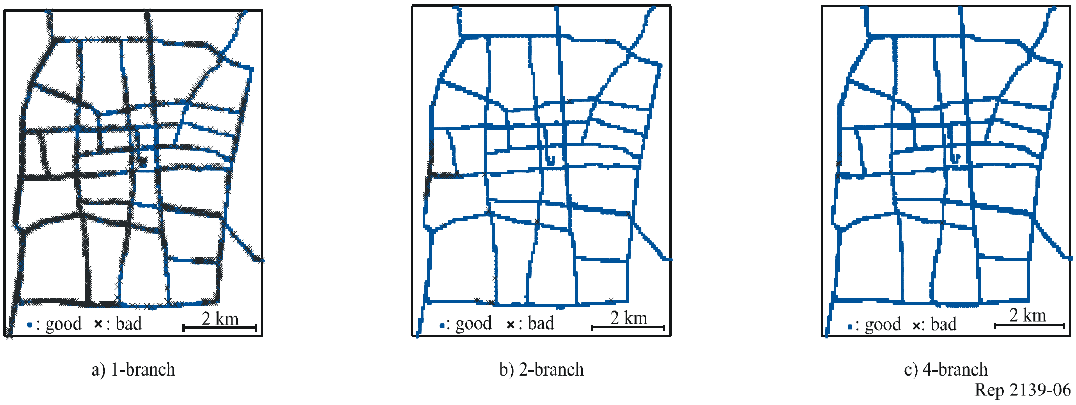

Table 4 lists the median values of the received field strength measured at a reception height of three metres. Comparing the calculated field strength for fixed reception values with the median values, we found that the difference in received field strength ranged from 13.3 dB to 15.9 dB when the calculated field strength for the fixed reception value was over 65 dBµV/m. Reductions in the received field strength in mobile reception were about 15 dB, based on the calculated field strength for fixed reception.

TABLE 4

Median values of the received field strength measured at a reception height of 3 m

Calculated field strength for fixed reception 10 m high (dBµV/m)	**Median values of received field strength 3 m high (dBµV/m)**	**Ratio (dB)**
55-60	49.7	7.8
60-65	53.2	9.3
65-70	51.6	15.9
70-75	57.7	14.8
75-80	63.5	14
80-85	68.2	14.3
85-90	72.5	15
90-95	79.2	13.3

4.3 Relation between received field strength and correct reception rate

In this section, we analyse the relationship between the measured received field strength and the correct reception rate for a reception height of three metres. Figure 8 shows the received field strengths received at one-second intervals at the three-metre high antenna and the CRR for the 4-branch, 2-branch, and 1-branch reception. The CRR was derived by first categorizing the sample data for all the measurement points into 1 dB units based on different received field strengths, then calculating the percentage of samples for each received field strength having zero packet error after the Reed Solomon code per unit of time (approximately one second).

FIGURE 7

Relationship between calculated field strength (65-70 dBμV/m) and received field strength

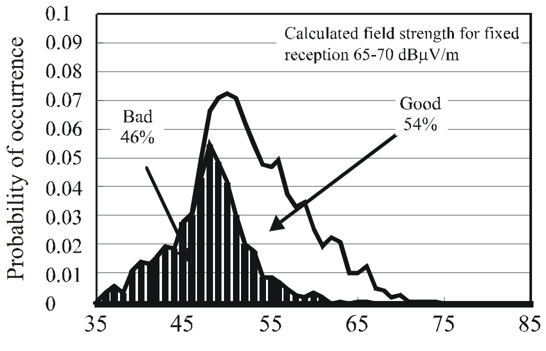

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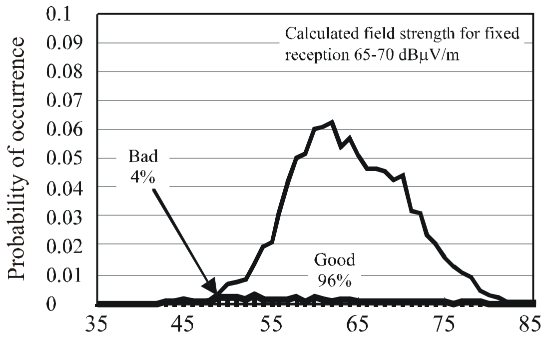
FIGURE 8

Relationship between calculated field strength (75-80 dBμV/m) and received field strength



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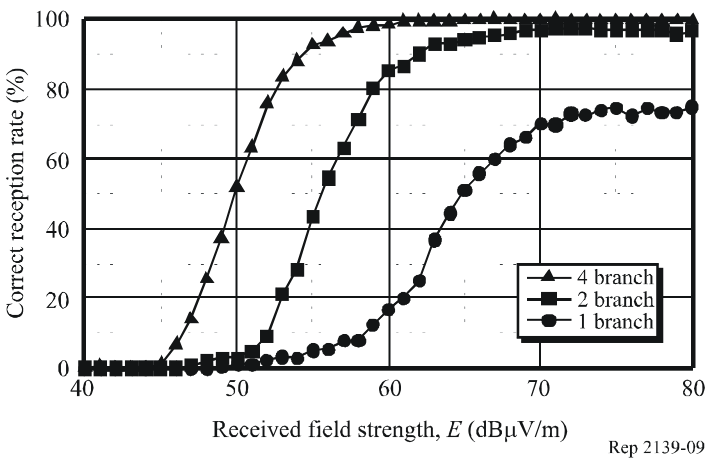
The 4-branch reception needed a received field strength of 56 dBμV/m to achieve a CRR of 95%, while the 2-branch reception needed a received field strength of 65 dBμV/m. The 1-branch reception results did not satisfy a correct reception rate of 95%.

FIGURE 9

Correct reception rate vs. field strength for various numbers of branches (total)



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5 Conclusions

Field experiments were conducted in the Nagoya area to compare coverage of digital terrestrial HDTV broadcasting for mobile and fixed reception with a diversity receiver that used maximal ratio combining (MRC) for each carrier. Evaluated at a reception rate of 95%, mobile reception of HDTV was indeed feasible at a fixed reception contour of more than 75 dBμV/m for 4-branch reception and more than 80 dBμV/m for 2-branch reception.

The results obtained using a mobile vehicle showed significant attenuation of the received signal as compared to those using fixed reception. This was because mobile reception antennas were three metres above the ground while the fixed reception antennas were ten metres high; direct waves to the mobile reception antennas were far more likely to be blocked.

The received field strength of mobile reception was reduced by as much as 15 dB as compared to the calculated field strength of fixed reception.

Bibliography

ITU-R texts

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