CCITT SGXV
Working Party XV/1
Specialists Group on Coding
for Visual Telephony

Doc. # 355
Sept. 1988

Source : JAPAN

Title : IMPROVEMENT OF MOTION COMPENSATION IN RM5

....

Introduction

In RM5, the following motion compensation (MC) algorithm is adopted.

(1) Block size is 16x16 pels.

(2) Range is ±7 pel/frame.

(3) Simple tree search block-matching method is used.

(4) Value of motion vector itself is transmitted.

The modified algorithm described below can improve the number of bits required for the motion vector, and the accuracy of motion.

Method

2.1 Transmission of differential vector

Instead of transmitting the value of the detected vector itself, the differential vector, i.e., the difference between the detected vector and the average vector among neighboring blocks A,B,C,D shown in figure 1, is transmitted using variable length codes shown in table 1. Here, only MC blocks among A,B,C,D are used to calculate the average, and if there are no MC blocks, the value of the motion vector itself is transmitted. Further, when the value of the differential vector exceeds the code range of table 1, it is clipped as shown in figure 3.

This modification would be effective in reducing the number of bits used for the motion vector when the correlation of the neighboring vectors is high. Tha range of MC can also be enlarged.

2.2 Initial shift vector

Before the motion estimation, motion vectors (stored in the encoder independent of the transmitted motion vector) of neighboring 8 blocks shown in figure 2 and a 0 vector are evaluated by the MC error value of the current block, the vector yielding the minimum MC error chosen as the initial shift vector, and the search range of the motion shifted by this initial vector. After that, the two-step block-matching method (step size is 2, 1) is applied.

This method can smooth vector fields, improve motion accuracy, and enlarge the range of MC without increasing calculation requirements. The maximum MC range is, for example, extended to ±15 pel/frame.

Results

Table 2 shows the simulation results of RM5 with these modifications. The number of bits used for the motion vector is reduced.

Conclusions

Modifications of MC algorithm described above are proposed for RM5.

Though part of the MC algorithm is outside the scope of standardization, the motion vector transmission method is important in reducing side information, while the motion estimation method would influence other parts of coding algorithms or parameters. Further, it is also important to improve the simulation algorithms themselves.

Concerning the MC algorithms, therefore, motion estimation with good accuracy, efficient transmission of motion vectors, and optimum block size taking both prediction efficiency and the amount of side information into account should be studied further. For example, the pel-based MC method indicated in the ANNEX is effective when the quantizer step size is small, so it would be worth consideration when the bitrate is high or coding efficiency is improved in the future.

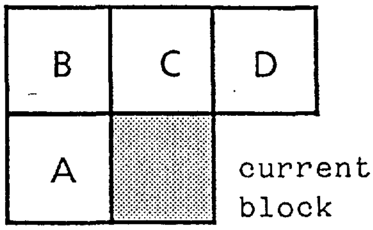

Figure 1 Block allocation used for movement vector transmission

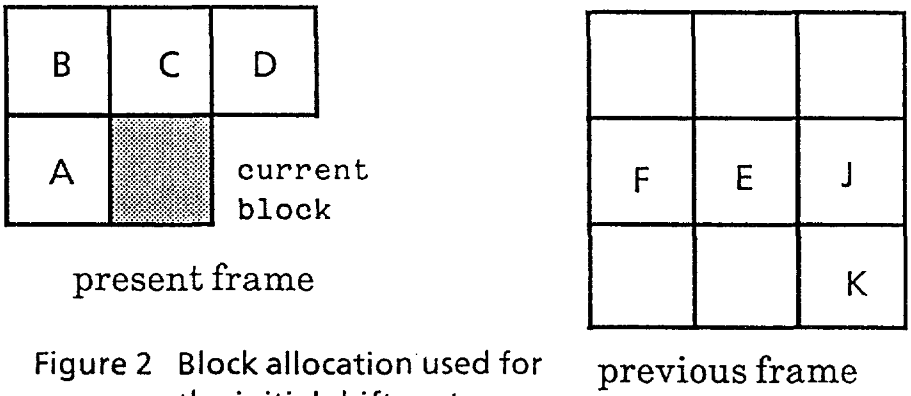

Figure 2 Block allocation used for the initial shift vector

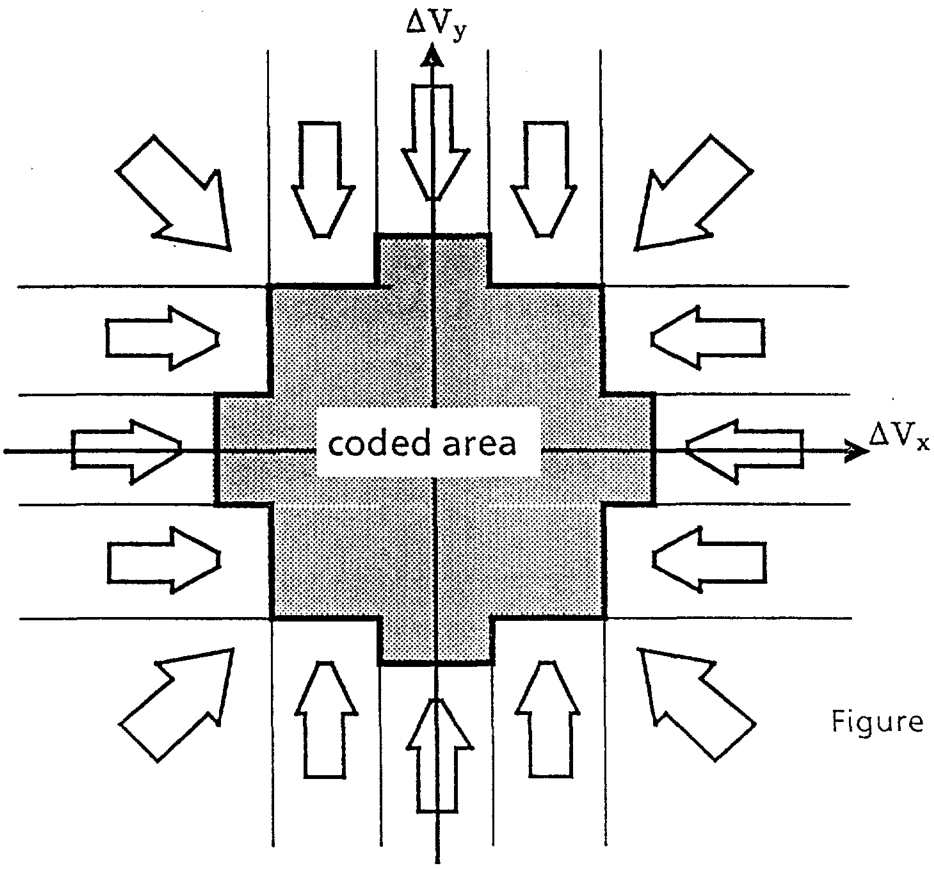

Figure 3 Limitation of differential vectors

Table 1 Bit length of codes assigned to movement vectors

ΔV_x / ΔV_y	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9
-9	x	x	x	x	x	x	x	10	10	10	10	10	x	x	x	x	x	x	x
-8	x	x	x	x	x	x	x	10	10	10	10	10	x	x	x	x	x	x	x
-7	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
-6	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
-5	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
-4	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
-3	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
-2	10	10	10	10	10	10	10	8	7	7	7	9	10	10	10	10	10	10	10
-1	10	10	10	10	10	10	10	7	5	4	5	7	10	10	10	10	10	10	10
0	10	10	10	10	10	10	10	6	4	2	4	6	10	10	10	10	10	10	10
1	10	10	10	10	10	10	10	7	5	4	5	7	10	10	10	10	10	10	10
2	10	10	10	10	10	10	10	9	7	6	8	8	10	10	10	10	10	10	10
3	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
4	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
5	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
6	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
7	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x
8	x	x	x	x	x	x	x	10	10	10	10	10	x	x	x	x	x	x	x
9	x	x	x	x	x	x	x	10	10	10	10	10	x	x	x	x	x	x	x

x : inhibited

Table 2

SEQUENCE :
MODIFICATION :

		Claire				Miss America				Salesman				Swing			
		15th		Mean		15th		Mean		15th		Mean		15th		Mean	
		RM5	Pro-posed	RM5	Pro-posed	RM5	Pro-posed	RM5	Pro-posed	RM5	Pro-posed	RM5	Pro-posed	RM5	Pro-posed	RM5	Pro-posed
1. RMS for Luminance		3.23	3.22	3.27	3.29	3.11	3.10	3.33	3.30	9.13	9.05	8.18	8.30	9.51	9.48	8.80	8.82
2. SNR for Luminance		37.94	37.98	37.70	37.77	38.27	38.32	37.65	37.77	28.92	28.99	29.76	29.74	28.57	28.60	29.24	29.22
for Chrominance (U)		38.75	38.64	38.58	38.65	38.04	38.21	37.70	37.83	36.71	36.82	37.41	37.46	30.24	30.32	32.05	32.08
for Chrominance (V)		41.49	41.42	41.62	41.65	39.22	39.41	38.39	38.55	37.52	37.66	38.18	38.37	31.65	31.64	33.43	33.48
3. Mean value of step size		21.00	20.89	23.24	22.63	20.11	19.67	23.89	22.95	42.22	41.56	35.41	35.34	41.44	42.11	29.16	28.64
4. Mean value of the number of non-zero coefficients	Y	2.88	2.63	2.99	3.00	2.68	2.67	2.26	2.26	1.88	1.77	2.19	2.17	1.45	1.44	2.00	1.93
	C	1.47	1.40	1.41	1.41	1.25	1.34	1.34	1.39	1.00	1.00	1.20	1.16	1.12	1.11	1.72	1.66
5. Mean value of the number of zeros before the last NZ-coefficient	Y	11.27	10.52	8.78	9.00	6.55	7.04	5.89	6.16	9.23	8.52	11.15	11.38	19.77	19.37	20.95	21.51
	C	7.03	7.14	3.70	3.83	2.66	2.72	3.63	3.67	9.88	12.46	1.84	1.91	9.78	9.87	13.43	13.85
6. Block type of macro	Fixed	290	281	287	284	253	244	229	225	243	227	259	257	243	243	274	272
	Coded MC	27	27	47	48	48	48	72	74	47	40	35	36	4	4	8	7
	Fixed MC	4	5	8	7	7	7	27	25	12	14	8	8	0	0	2	2
	Coded	75	83	54	57	88	97	68	72	94	115	94	95	149	149	111	114
7. Block type of Y	Fixed	1327	1309	1274	1271	1292	1296	1131	1124	1213	1193	1258	1256	1394	1386	1377	1377
	Coded MC	70	77	126	127	105	101	124	128	109	93	86	89	5	5	19	17
	Fixed MC	54	51	94	93	115	119	269	270	127	123	86	86	11	11	21	22
	Coded	133	147	90	93	72	68	60	63	135	175	154	154	174	182	166	169
8. Block type of UV	Fixed	758	757	757	755	705	688	701	690	784	779	784	785	773	737	752	753
	Coded	34	35	35	37	87	104	91	102	8	13	8	7	59	55	40	39
9. Number of bit	Macro attributes	529	553	510	516	607	614	630	637	629	664	599	602	703	695	578	589
	End of block	1224	1320	1220	1253	1632	1740	1678	1750	1692	1860	1541	1567	1836	1836	1433	1457
	Motion vectors	248	146	438	281	440	209	787	506	472	317	344	258	32	40	82	76
	DC coefficients	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coefficients Y	3396	3451	3503	3604	2570	2520	2153	2258	2931	2964	3391	3452	2659	2762	3265	3256
	Coefficients U	113	102	71	75	317	388	293	343	60	97	25	22	239	194	187	177
	Coefficients V	192	204	170	183	187	254	307	352	6	28	17	15	291	308	361	349
	Coefficients TOTAL	3701	3757	3745	3863	3074	3162	2753	2953	2997	3089	3433	3490	3189	3264	3813	3782
	TOTAL	5702	5776	5913	5913	5753	5725	5848	5846	5790	5930	5917	5917	5760	5835	5905	5904

ANNEX

TITLE: Pel-based motion compensation

1. Introduction

In RM5, block matching motion estimation is carried out on blocks of 16x16 pels, and the resultant prediction error is coded using the DCT. However we have shown in some cases that using a finer grained motion estimation technique without the DCT is a more effective measure. Here we propose a coding method which switches between the traditional coding method and a finer grained motion estimation method. Thus the advantages of both systems are realized.

2. Method of pel-based motion compensation

In finer grained motion estimation technique we calculate a motion vector for every pel using the following method.

1. A motion vector for each 16x16 block is calculated with the usual block matching method.
2. This vector and the zero displacement vector (0,0) are used as initial vectors in calculating the vector for each pel.
3. To calculate the motion vector for pel X of Figure 2, a group of pels (for example A, B, C, D of Figure 2) surrounding X are matched with corresponding pels in the previous frame (The seach being limited to a small area (1 pel) about the initial vectors).
4. The dispalcement describing the best match between A, B, C, D and the previous frame is used as the motion vector for X.

Note that by using only previously coded pels (such as A, B, C, D) in determining the vector for X, pel motion vectors need not be transmitted. They may be obtained at the receiver using decoded data.

The motion compensation error is quantized by the same quantizer as in RM5 and entropy coded. On a block-by-block basis pel-based motion compensation and the traditional RM5 method are compared, and the method yielding the fewest number of coded bits is chosen as that block's coding method.

3. Result

Table 1 and Figure 3-6 compare RM5 and the RM5 + pel motion compensation method. In general, pel motion compensation tends to be of greater value when the quantizer step size is small. This is because pel-based motion compensation is able to more acccurately obtain vectors at low levels of quantization noise.

Since the average quantizer step size at 64kbps is 23.2, there is little improvement. However at 256kbps (p=4), the SNR improves about 0.5dB on the average and 1.3dB maximum over RM5.

To further investigate the relationship of pel motion compensation to quantization noise, we tested the RM5 + pel motion compensation technique and several fixed quantizer step sizes. According to these results (Table 2), pel motion compensation has a sizable effect at step sizes less than 8.

4. Conclusion

We have found that the coding efficiency of RM5 can be increased using pel motion compensation, especially at small quantizer step sizes. Results show that pel motion compensation is certainly not a substitute for DCT coding, but that it can improve overall coding performance by effectively coding in cases where DCT coding is inefficient.

Pel motion compensaiton can thus be viewed as a way to improve the overall performance of RM5.

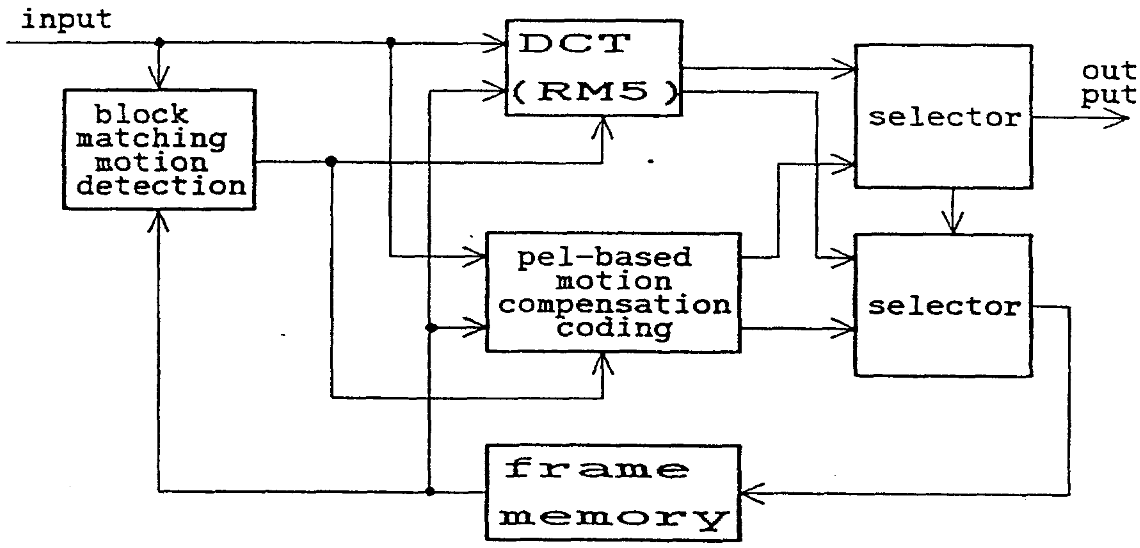

Fig. 1 Block diagram of proposed method

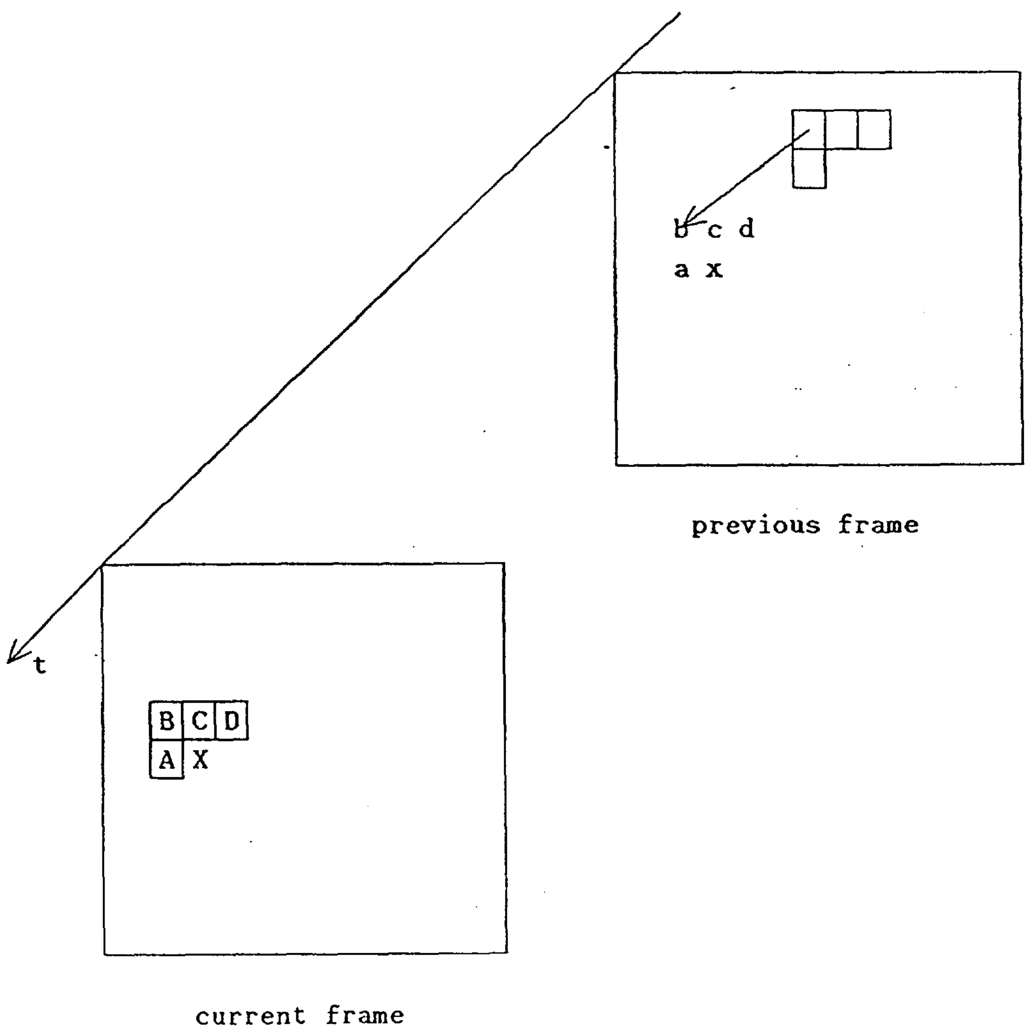

Fig. 2 Pel-based motion compensation

Table 1 The performance of RM5 and proposed method

ITEM			64R	64P	128R	128P	256R	256P
SNR for luminance		Y	37.92	37.85	40.20	40.12	42.23	42.76
SNR for chrominance		U	38.67	38.52	40.71	40.83	43.06	43.77
		V	41.67	41.46	43.61	43.73	45.58	46.10
RMS for luminance		Y	3.26	3.30	2.50	2.52	1.98	1.86
RMS for chrominance		U						
		V						
Mean value of step size			23.2	22.9	14.0	13.5	11.5	8.5
Mean value of number of non-zero coefficients		Y	2.8	2.6	3.5	3.2	5.1	4.5
		C						
Mean value of number of zeroes before the last NZ		Y	8.1	7.2	9.8	8.9	14.3	14.2
		C						
Block type of MACRO	Fixed		287.0	260.1	225.4	188.0	198.7	138.7
	Fixed MC		7.7	8.6	2.5	3.6	2.7	2.2
	Coded		54.3	78.7	118.4	154.3	147.2	206.1
	Coded MC		46.9	48.6	49.6	50.1	47.4	48.9
Block type of Y	Fixed		1274.3	1222.9	1171.3	1057.5	1053.0	858.3
	Fixed MC		93.9	100.1	56.2	60.3	44.6	37.4
	Coded		91.1	132.1	204.1	311.7	330.7	521.2
	Coded MC		124.6	128.8	152.4	154.5	155.8	166.9
Block type of C	Fixed		757.9	755.5	717.3	707.7	651.1	613.2
	Coded		34.1	36.5	74.7	84.3	140.9	178.8
Number of bits	Macro attr.		516	427	683	662	731	785
	EOB		1215	1142	2017	1616	2335	1600
	MV		437	458	417	430	401	409
	Coeff. Y		3509	3596	7528	6476	15656	8581
	Coeff. U		166	179	649	429	2122	866
	Coeff. V		71	75	284	170	1017	328
	TOTAL		5914	5913	11578	11505	22261	21471

64R : 64Kbps RM5

64P : 64Kbps RM5 + Pel-based motion compensation coding

Table 2 Efficiency improvement by pel-based motion compensation

G*	No. and ratio of blocks on which PMC** is effiective		Used bits on most effective blocks		
	Number	Ratio	RM5	PMC	RM5-PMC
4	105	26.5%	1033	470	563
8	37	9.3%	292	113	179
12	15	3.8%	190	109	81
16	9	2.3%	130	107	23

* step size

** pel-based motion compensation

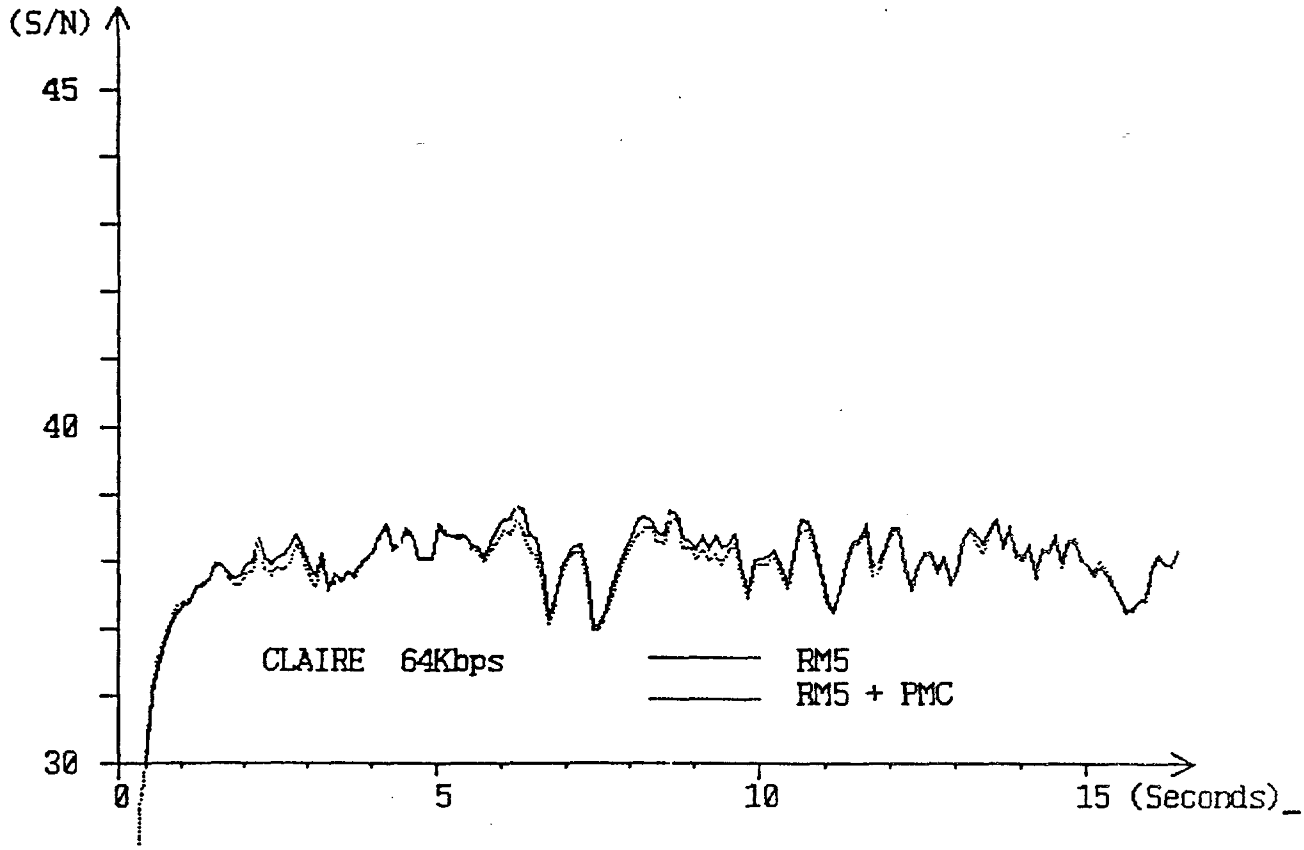

Fig. 3 Comparison of SNR (1)

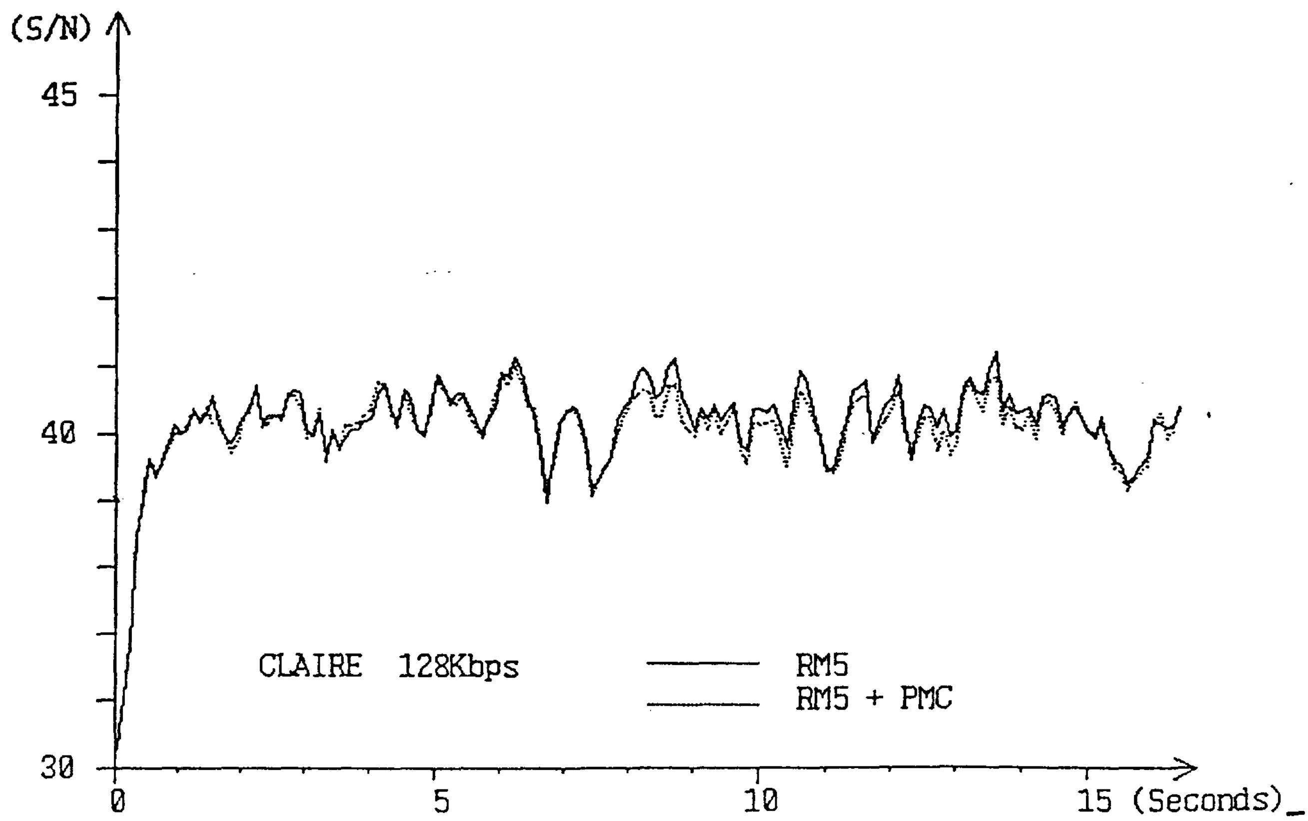

Fig. 4 Comparison of SNR (2)

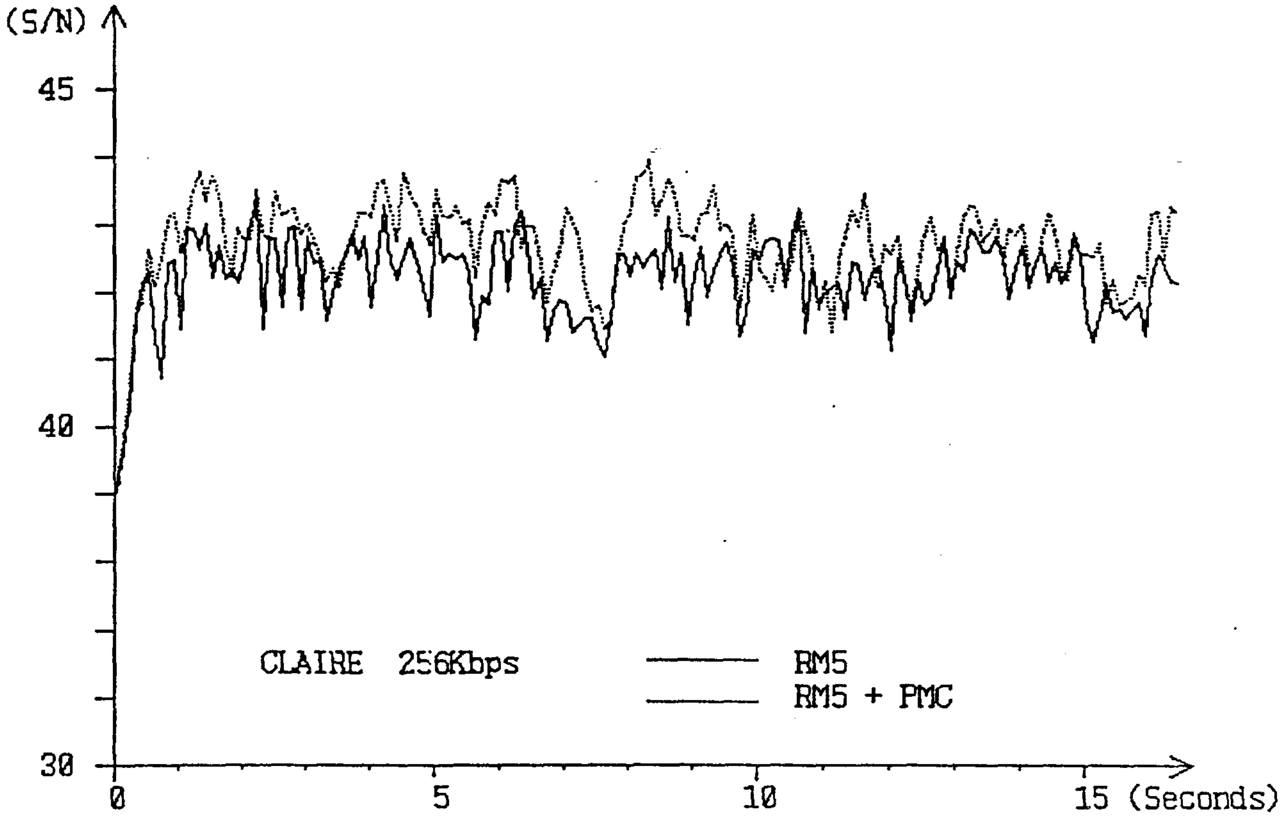

Fig. 5 Comparison of SNR (3)

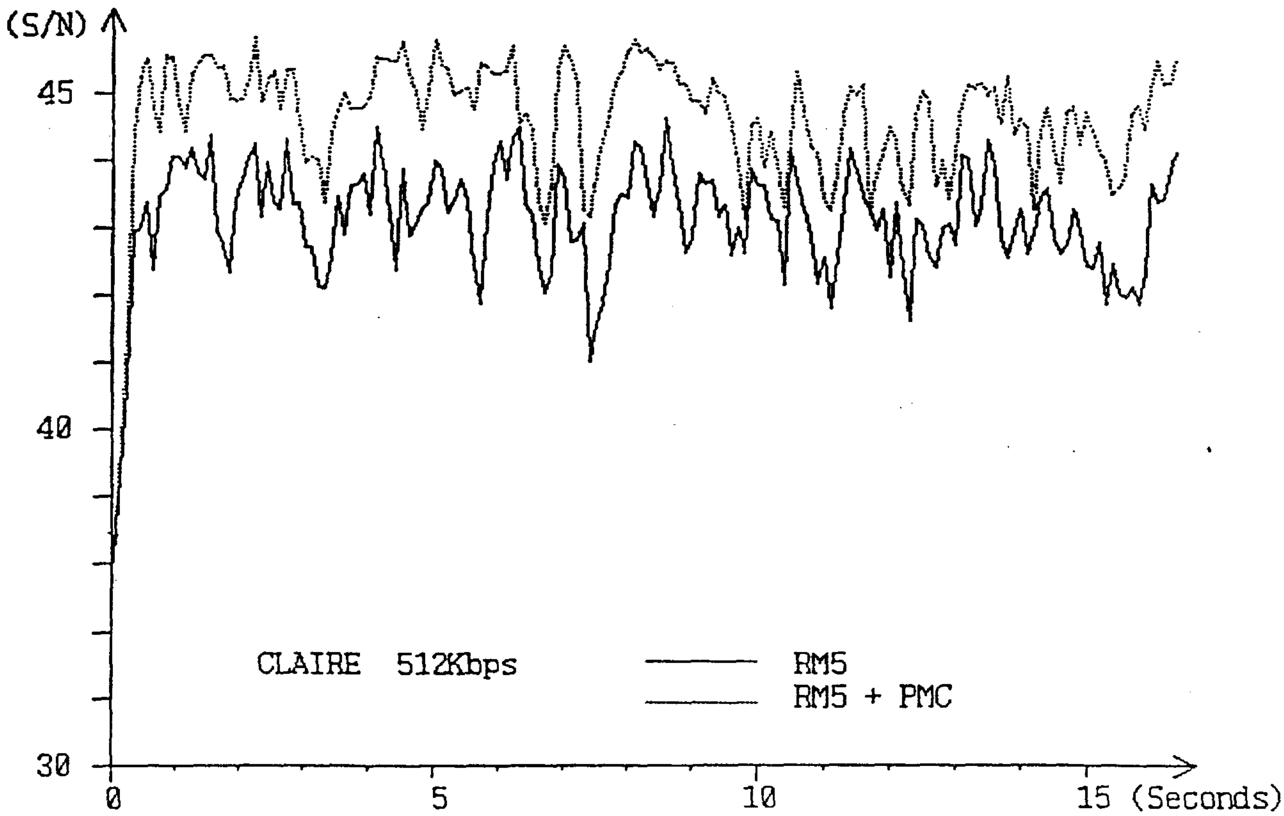

Fig. 6 Comparison of SNR (4)