Government
of Canada
Department of Communications

STUDY OF THE OCCURRENCE OF LOCAL OSCILLATOR INTERFERENCE ON CATV SYSTEMS

BY:

FERNAND BOUCHARD

JANUARY 1979

CABLE TV STANDARDS AND PRACTICES
TELECOMMUNICATION REGULATORY SERVICE

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CONTENT

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INTRODUCTION

In CATV systems with augmented channel capacity, the local oscillator of TV receivers could cause interference between neighbouring subscribers (1, 2, 10, 11).

The purpose of this report is to determine the probability of local oscillator interference on cable systems.

In order to adequately protect neighbouring subscribers, isolation standards were established for the operators of CATV systems (3) and standard for minimum local oscillator level are being implemented.

In this document, the parameters having an influence on the probability of local oscillator interference are identified and the extent of their influence is carefully evaluated. Only the parameters having a significant effect are considered. The probability of occurence for each of the parameters under consideration is then calculated. Reliability system analysis and iteration techniques are employed to obtain the maximum probability of local oscillator interference (4, 5). A computer program was written for the purpose.

The impact of this interference problem on the overall quality of service that can be provided with existing equipment is evaluated and conclusions and recommendations are drawn up.

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CHAPTER 1

PARAMETERS INFLUENCING THE OCCURENCE OF LOCAL OSCILLATOR INTERFERENCE

In order to be able to evaluate the probability of local oscillator interference as correctly as possible, the various parameters bearing of it were identified and the extent of their effect was evaluated. The following is a list of the most important parameters:

A) Level of local oscillator

B) Isolation

C) Susceptibility of the receivers

D) Receiver type

E) Level of cable signal

F) Channel selection

G) Viewing habits of the subscribers

H) Proximity of the subscribers' receivers

I) Quality factor

J) Chance and wearout failure of the receivers

K) Chance and wearout failure of the taps

The above parameters had to be expressed in a form amendable to probability analysis, leading to the evaluation of the probability of local oscillator interference.

A) Probability function for the level of local oscillator (PLOL):

This function is defined as the "a priori" probability that the local oscillator level is more than what is defined as necessary to have the onset of interference.

B) Probability function for the isolation of the subscriber (PISO):

This is the "a priori" probability that the isolation is less than the minimum needed to protect the subscriber from local oscillator interference.

C) Probability function for the susceptibility of the receivers (PTVS1, PTVS2):

This is the "a priori" probability that the susceptibility level of the receivers is greater than what is required to just protect the subscriber from local oscillator interference.

D) Receiver type (p_1, p_2, p_3):

The receiver set population of the cable system is composed of three type of sets; cable compatible receivers, receivers using a converter and standard receivers. The percentage distribution of each type is expressed as a probability function.

E) Probability function for the level of cable signal (PSL):

This is defined as the "a priori" probability that the level of cable signal is less than the minimum required to protect the subscriber from local oscillator interference.

F) Channel selection function (P_1, P_2, P_3, P_4, P_5, P_6):

A function defined as the probability of listening to an affected channel while the neighbouring subscriber is watching an interfering channel and vice-versa.

G) Viewing habits of subscribers (PVH):

This parameter is defined as the probability that two neighbouring subscribers are watching TV at the same time.

H) Proximity of the receivers (PN):

This parameter is accounted for by evaluating the probability that two subscribers are situated close enough to each other to experience local oscillator interference.

I) Quality factor (FQ):

This parameter, expressed in dB's, is defined in order to take into account the level of local oscillator interference that an average subscriber would be able to tolerate. It is not expressed as a probability function. Variations in the probability of local oscillator interference are observed when the tolerance level is modified.

J) Chance and wearout failure of the receiver:

This parameter could be expressed as the probability that, over the years, the receiver will obey the original "W" curve and therefore maintain its susceptibility level. The same considerations can apply to the local oscillator leakage level available from the TV sets. Since such data are unavailable and since it is a second order effect, it was not considered in this analysis.

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K) Chance and wearout failure of the taps:

This parameter is defined as the probability that over the years, the taps will keep obeying the original probability distribution and maintain their specified isolation level. Data are not available on this parameter and since it can be considered a second order effect, it was ignored.

The last two parameters were considered because the TV receivers and the taps are two components of a CATV system having a direct effect on local oscillator interference, but little or no maintenance action are devoted to them by the system operator. Therefore, their influence on the probability of local oscillator interference must be studied very carefully.

In the second chapter, the mathematical techniques employed to evaluate the probability of local oscillator interference using the parameters described above will be explained.

CHAPTER 2

EVALUATION OF THE PROBABILITY OF OCCURENCE

Since the parameters affecting the probability of L.O. interference were defined in a way that lifted most of their interdependance, standards reliability analysis techniques can be employed in the evaluation of the probability of local oscillator interference. An interference event is occuring when a subscriber can observe local oscillator interference while watching a 30 minutes program. Therefore, the interference event could last up to but not more than 30 minutes.

The model that was studied included only two subscribers. Interactions between three or more subscribers were not considered. Intuitively, one can come to the conclusion that the size of the system should not have any effect on the probability of local oscillator interference. However, as shown latter, it will have an effect on the count of local oscillator interference events. Where assumptions were necessary in the evaluation of the parameters entering in the analysis, worst case estimate were made. Following measurements as well as theorical considerations, the density functions of each of the probability function were obtained (6). All distributions are Gaussians. The random variable of the distribution function for the following parameters; level of local oscillator, isolation of the subscriber and level of cable signal, were assigned selected levels. These levels were defined as the level at which we want to calculate the probability of local oscillator interference. This iterative technique led to the determination of the maximum probability of local oscillator interference. For the susceptibility of the receiver, the value of the random variable that could bring the onset of local oscillator interference was calculated using the following equation:

$$TVS = LOL - SL - FQ - ISO \qquad (1)$$

TVS = Susceptibility of the receivers that will bring the onset of local oscillator interference.

LOL = Level of local oscillator at the onset of local oscillator interference.

SL = Level of cable signal at the onset of local oscillator interference.

FQ = Quality factor.

ISO = Isolation of the subscriber at the onset of local oscillator interference.

The quality factor can be assigned any value up to 5 dB, which was evaluated at the maximum amount of picture degradation that a non-trained observer would tolerate.

The receiver susceptibility was selected as the dependant variable in (1) because it is the only element of the system over which CATV operator has little or no control. It is possible for the operator to adjust signal levels, change taps or drop lines in order to correct interference problems but he has no control over the receiver. Any of the other parameters could be selected as the independant variable but the maximum probability is expected to be the same in all cases.

Since there are three different types of receivers, many channels interfering/channels affected combinations will exist. It is therefore necessary to determine the probability that each of the two subscribers in the model will have a given type of receiver. A multinomial distribution is employed for the case of two subscribers with three different types of TV receivers, uniformely distributed throughout the system.

In order to have interference, one subscriber must listen to an interfering channel while the other is listening to an affected channel. This channel selection probability function is evaluated using standard combinatorial analysis techniques. It is a rather complex function agglomorating the receiver type probability function and the probability function for the susceptibility of the receiver. It depends on the type of TV receivers, the number of channels available on the cable system and the susceptibility of the receivers*.

The probability that the two neighbouring subscribers are watching TV at the same time is difficult to evaluate. Studies have shown that the average Canadians is watching television for 3.5 hours every day. If we assume that for five of these period, both subscribers are watching TV at the same time, we obtain that the probability of watching TV at the same time as the neighbouring subscriber is .71. However, for a worst case evaluation, this probability was set to 1.0. So far, we have considered that the two subscribers are situated close enough to be able to interfere with each other. In a real system, not all subscribers can interfere with each other. However, in the analysis, although a two subscribers model is used, the probability of occurence that is obtained applies to single subscriber and not to a couple. Therefore, we need to know the fraction of the population of the system that is in a position to experience and cause interference. This is a quantity difficult to identify. For a worst case situation, this probability function is set to 1.0, meaning that each and every subscriber in the system can cause or experience interference.

Three distribution functions for local oscillator leakage level were studied:

- distribution function for TV receivers manufactured up to 1976
- distribution function for TV receivers manufactured after 1976
- distribution function for the combination of all above mentioned data.

* Note: See Appendix A and C

For each case, a different distribution of the three types of TV receivers were assumed. They are listed in Table 2.1. The distributions of the receivers are expected to be typical representations of CATV systems, before 1976, nowadays and after 1980. The receivers distribution were somewhat biased towards a large number of standards and cable receivers in order to maintain a worst case estimate. The density functions for isolation, susceptibilities and cable signal level remained the same for all types of local oscillator level distribution function.

TABLE 2.1

Distribution of the TV receivers

LOCAL OSCILLATOR LEAKAGE DATA	PERIOD REPRESENTED BY THE DISTRIBUTION	CABLE RECEIVER (%)	CONVERTER RECEIVER (%)	STANDARD RECEIVER (%)
Up to 1976	Prior to 1976	0	30	70
After 1976	After 1980	10	70	20
Combination of all above data	Nowadays	5	50	45

The characteristics of all the density functions are summarized in Table 2.2

Other operating conditions were as follows:

- Thirty-five (35) operational channels are available on the cable and converter type receivers. None of the channels are off-set.

- Twelve (12) operational channels are available on the standards receivers.

- The probability of selecting any of the 35 channels was assumed to be uniform.

- The interference to FM signals was not considered.

- Interference due to second harmonics of local oscillator was not considered.

Figure 2.1 is the block diagram showing how the probability function just described are treated to obtain the overall probability of local oscillator interference. The details of the analysis are given in Appendix I. The probability of local oscillator interference (PX) is obtained by multiplication of the series elements and addition of the ones in parallel. An iteration process led to the maximum value of the probability function. A computer program, listed in Appendix B, was written for the evaluation of the probability of occurence under varying operating conditions.

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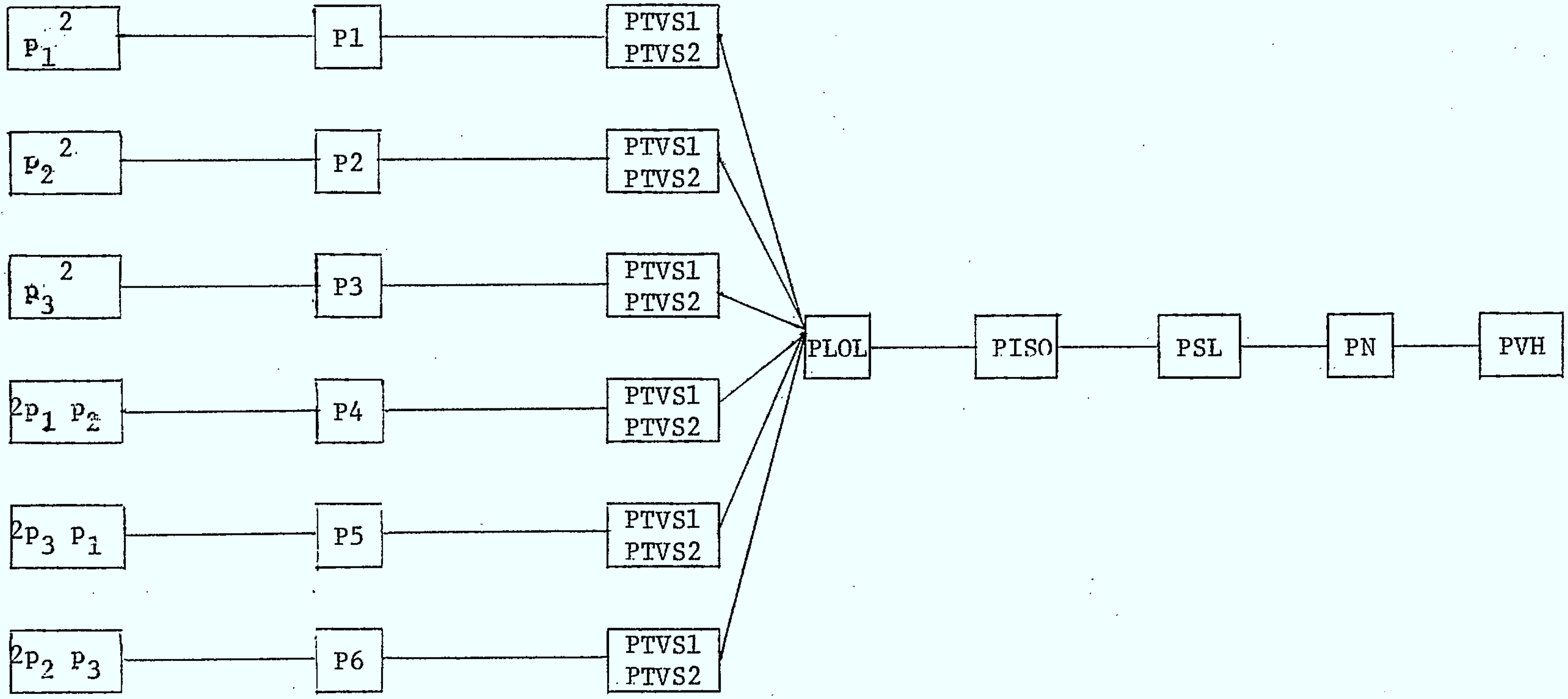
TABLE 2.2

Characteristics of the density functions associated with the parameters controlling local oscillator interference

DENSITY FUNCTION FOR:	MEAN μ	STANDARD DEVIATION σ
Local oscillator level Before 1976 After 1976 Combination of all data (nowadays)	 -14.7 -24.0 -19.1	 14.8 11.8 13.5
Isolation	30	5
Susceptibility for Channels A and B	-46	4
Susceptibility for all other affected channels	-55	4
Cable signal level	6	5

FIGURE 2.1

BLOCK DIAGRAM FOR THE COMPUTATION OF LOCAL OSCILLATOR INTERFERENCE (CASE OF TWO SUBSCRIBERS AND THREE TYPES OF RECEIVERS)*



*Details are given in Appendix A

CHAPTER 3

RESULTS AND DISCUSSION

A large number of measurements were taken, over a period of eight years, to evaluate the level of local oscillator leakage in TV receivers. The characteristics of the density functions associated with the measurements, grouped by year of receiver fabrication, channel type, etc., are summarized in Table D.1 of appendix D. Figure 3.1 shows clearly a large decrease of the mean of the local oscillator density functions over a period of about seven years. Manufacturers of TV receivers managed to significantly reduce local oscillator leakage. Based on the local oscillator data, three types of cable systems were defined and studied.

System of type "A"

Data taken on TV receivers built before 1976 were taken to represent a system operating about the middle of the seventies and having a distribution of standard, cable compatible and converter receivers representative of such a period of time.

System of type "B"

To simulate a typical contemporary system, local oscillators data for TV set manufactured before and after (including) 1976 were compiled. The system was analysed for a typical distribution of TV receivers.

System of type "C"

To represent a cable system operating in the eighties, local oscillator data for 1978 TV receivers were utilized. The distribution of the three types of TV receivers in such a cable system was obtained by taking into account the trend towards an increase in the use of set-top converters.

For each of the three types of systems, the maximum probability of local oscillator interference was evaluated. For instance, when studying Table 3.1, one notices that the probability of occurrence decreased by more than three times when comparing a system operating in the mid-seventies with a system of the post 1980 era. However, the number indicating the probability of interference does not give much indication about the impact of local oscillator interference on the quality of the signal in a cable TV system. Also, it is rather difficult, using only the probability of interference, to evaluate the degree of improvement obtained with the lowering of local oscillator leakage.

Therefore, extra functions were derived from the probability of occurrence. They are, the long term probability, the mean time between failure, the mean number of days between failure and the number of events.

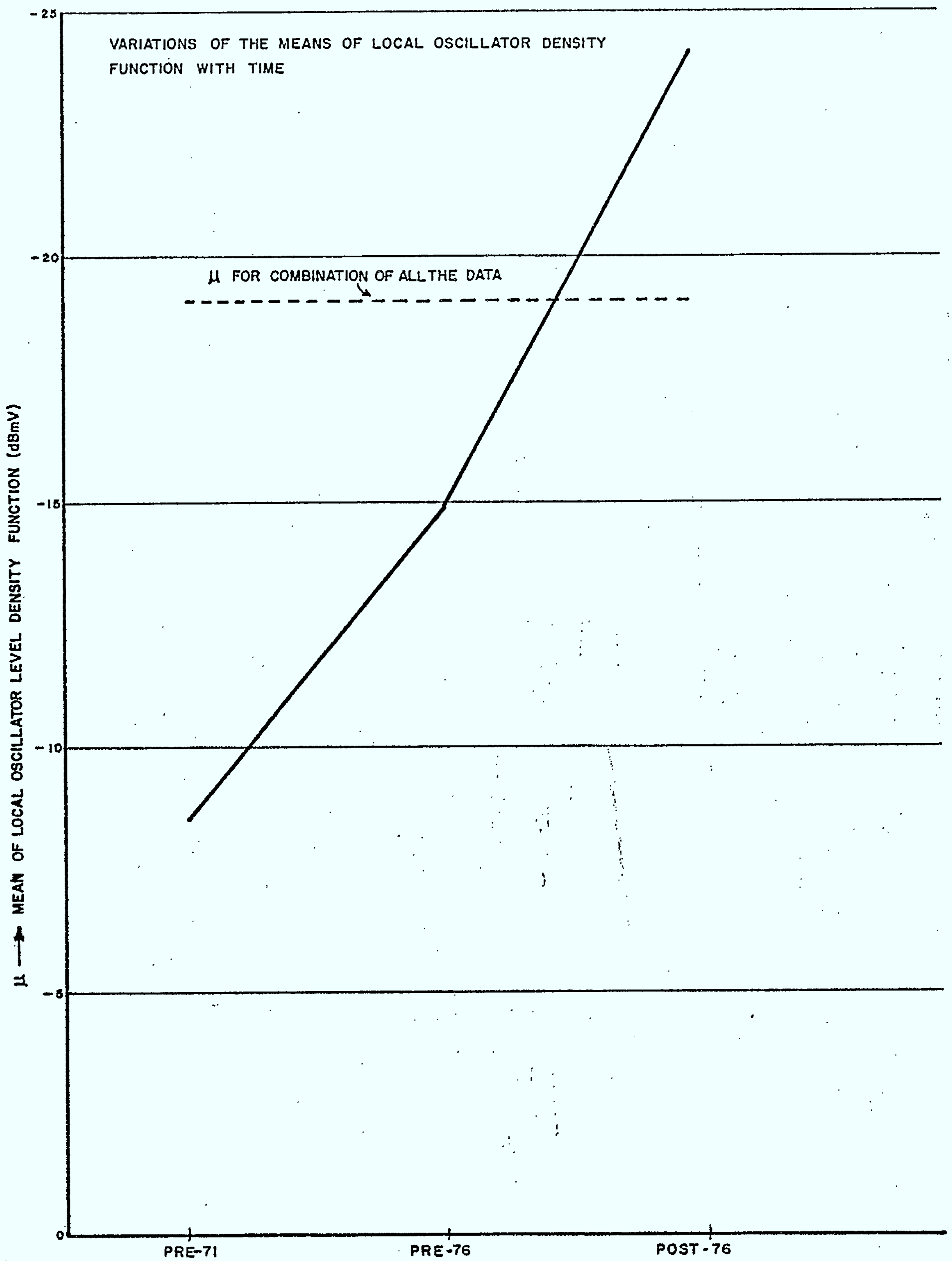


Fig. 3.1 Variation of the Means of the Local Oscillator Density Functions with Time

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The maximum probability of local oscillator interference (PX) has been defined as the "a priori" probability of having an interference event. In other words, this is the probability that at any given instant, any subscriber in any system of any size will observe interference effects while watching television. The long term probability (PLT) is the probability that one subscriber will observe one, two, three... etc., interfering events in a given period of time. As in the case of PX, this probability applies to one subscriber only, but the long term probability introduces the concept of period of operation of a cable system by considering the time spent by the subscriber watching television every day.

In the evaluation of the number of interfering events or outcomes, the number of subscribers, i.e. the size of the system, must enter into the calculations. Therefore, it is a function describing the behaviour of a complete system of a given size.

When proper debugging of the components is practised and good maintenance procedures are in effect, a cable TV system will be kept, throughout its operational life, in a condition where only chance failures can occur (4). Then, it is reasonnable to assume that for the failure condition of local oscillator interference, the exponential function of change failure would apply.

$$R(t) = e^{-\lambda t} = e^{-t/m}$$

Where

R(t) = probability of survival function (or reliability)

It is important to remember that the time "t" is not a measure of the calendar life or the total accumulated operating life of the system since it began service. It applies only to the hours of any arbitrarily chosen operating period of time, regardless of how many hours the system has already been in service before the beginning of the operating period of time. In the exponential case, the mean time between failure or MTBF is

$$m = \text{MTBF*} = \frac{1}{\lambda}$$

where λ = failure rate (= constant)

The knowledge of the mean time between failure is very useful in reliability work since it can often be measured and it defines completely the reliability of systems during their useful life. It represents the statistical mean time at which failure occurs. However, for an operating time t = MTBF, there is a probability of 63.2% (or approximatively 63%) to have the occurrence of local oscillator interference. Since the probability of interference PX is utilized in the evaluation of the MTBF, the latter is the mean time between interference events observed by each and every subscribers.

* Note: Since we are studying systems where maintenance is taking place, the mean time between failure (MTBF), as opposed to mean time to failure (MTTF), is considered, the latter applying for case where no repairs are being performed.

TABLE 3.1

Summary of Results

	MID SEVENTIES		NOWADAYS		POST 1980	
Quality Factor (FQ)	0dB	5dB	0dB	5dB	0dB	5dB
Reliability (%)	99.882	99.922	99.895	99.938	99.954	99.976
Probability of L.O. Interference (PX)	11.8×10^{-4}	7.8×10^{-4}	10.5×10^{-4}	6.2×10^{-4}	4.6×10^{-4}	2.4×10^{-4}
Long term probability (PLT)	.222	.155	.194	.124	.093	.05
MTBF (hours)*	424	634	478	806	1087	2058
Number of events (NE)*	1255	839	1112	660	490	259
Number of days between interference	121	181	137	230	311	588
Operating conditions at the onset of interference for maximum probability of interference						
Local oscillator level (LOL) dBmV	-5	-5	-10	-5	-15	-10
Signal level (SL) dBmV	10	9	9	9	8	8
Isolation (ISO)dB	34	32	32	32	30	30
Probabilities associated with parameters affecting the probability of occurrence						
PCS	6.7×10^{-3}	6.1×10^{-3}	8.7×10^{-3}	8.7×10^{-3}	6.3×10^{-3}	6.3×10^{-3}
PTVS1	.227	.1056	.1056	.1056	.04	.04
PTVS2	.933	.841	.841	.841	.69	.69
PLOL	.272	.272	.272	.15	.223	.118
PISO	.788	.655	.655	.655	.5	.5
PSL	.788	.726	.726	.726	.655	.655

* For a system of 10,000 subscribers and operating for one month.

From the MTBF, the mean number of days is easily obtained and, like the former, it describes the statistical number of days between interfering events observed by a subscriber.

The results are summarized in Table 3.1 along with the operating conditions and the probability associated with each parameters bearing on the probability of occurrence. Table 3.1 shows clearly that the probability PCS, representing the probability of listenning to an affected channel, is the one having the greatest influence on lowering the overall probability of interference. It is also the parameters over which the cable operators has practically no control. The operating conditions of Table 3.1 are the minimum (or maximum) levels for which the probability of occurrence is maximized.

To study more closely the behaviour and trends of the probability of interference, the system of type "B", i.e. the contemporary system, was selected.

Figure 3.2 illustrates the change in the probability of occurrence vs. a function representing the probability associated with local oscillator level, L(LOL) and the isolation of the subscriber, I(ISO). More specifically, it is the level of local oscillator leakage and the isolation of the subscriber, represented as a probability function. The functions L(LOL) and I(ISO) do not represent the absolute value of the local oscillator level or the isolation of the subscriber. It is an arbitrary function that allows an easy and practical comparison of the effect of the probabilities associated with local oscillator and isolation level on the probability of local oscillator interference. Figure 3.2 indicates that the probability of occurrence is varying somewhat more rapidly with L(LOL) than I(ISO). Also demonstrated in Figure 3.2 is the effect of adding a quality factor of 5 dB. Although the mathematically "exact" evaluation of the probability of occurrence is represented by the case where FQ is 0 dB, the interference that would be noted by the subscriber is represented, for all intent of purposes, by the curve for FQ equal to 5 dB. Therefore, the results obtained for the case where the quality factor is 5 dB are a more realistic representation of the local oscillator interference problem as it affects the subscriber. Figure 3.3, as for Figure 3.2, was obtained for the case of maximum probability of occurrence. It also shows that the MTBF is more dependent on the function L(LOL) than on I(ISO).

In Figure 3.4, the relationship between the number of days between interference events vs. L(LOL) and I(ISO) is represented. Since the number of days between interference events is obtained simply by dividing the MTBF by 3.5 hours (for 3.5 hours of TV viewing per subscriber, per day) the curves of Figure 3.4 is similar to Figure 3.3. Figure 3.5 shows the variation in the number of interference events vs. L(LOL) and I(ISO) for a system of 10,000 subscribers in operation for about one month (1/12 of a year). A large reduction in the number of events can be observed when a quality factor of 5 dB is added.

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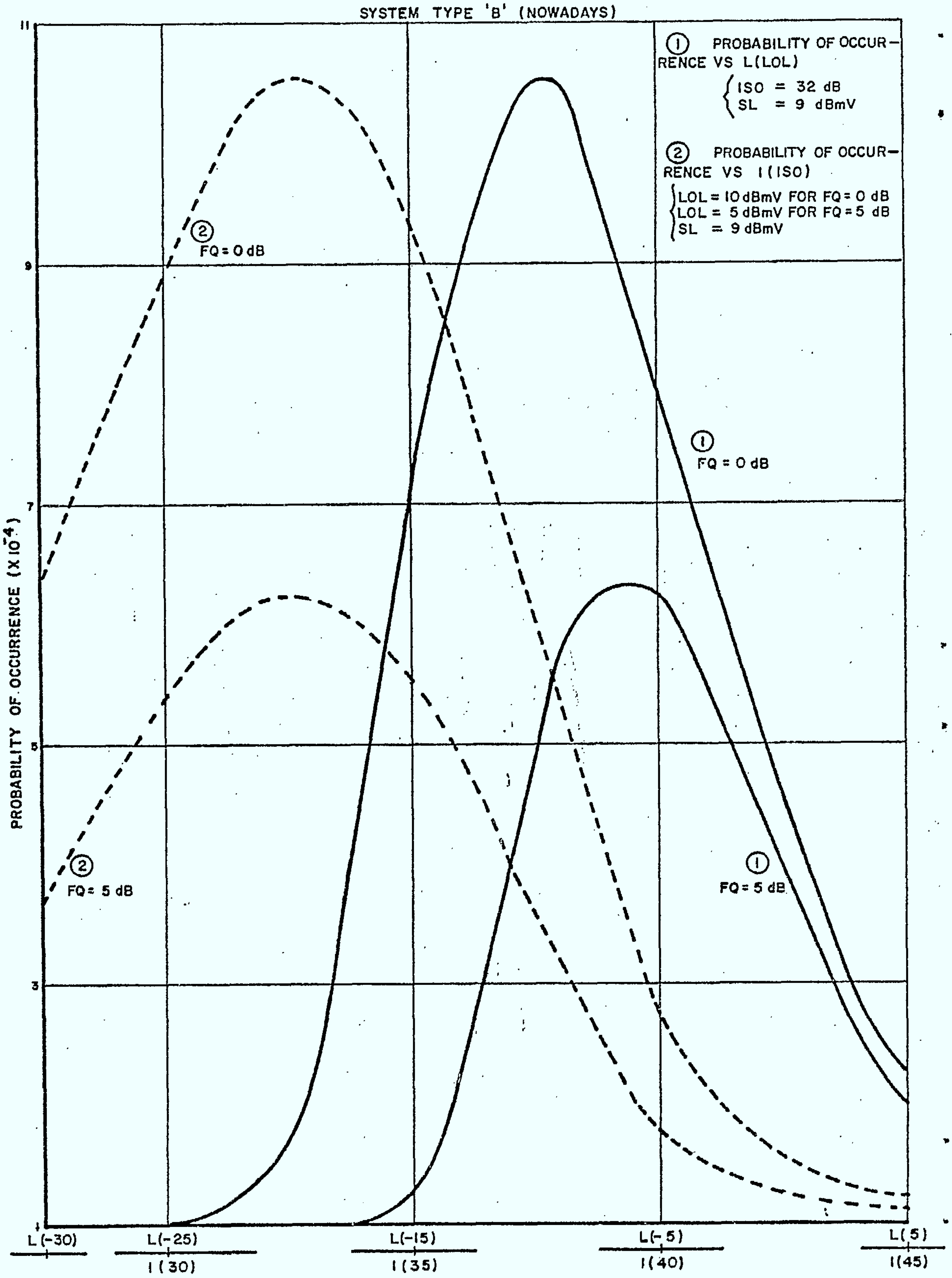

Fig. 3.2 Probability of Occurrence as a Function of I(ISO) and L(LOL)

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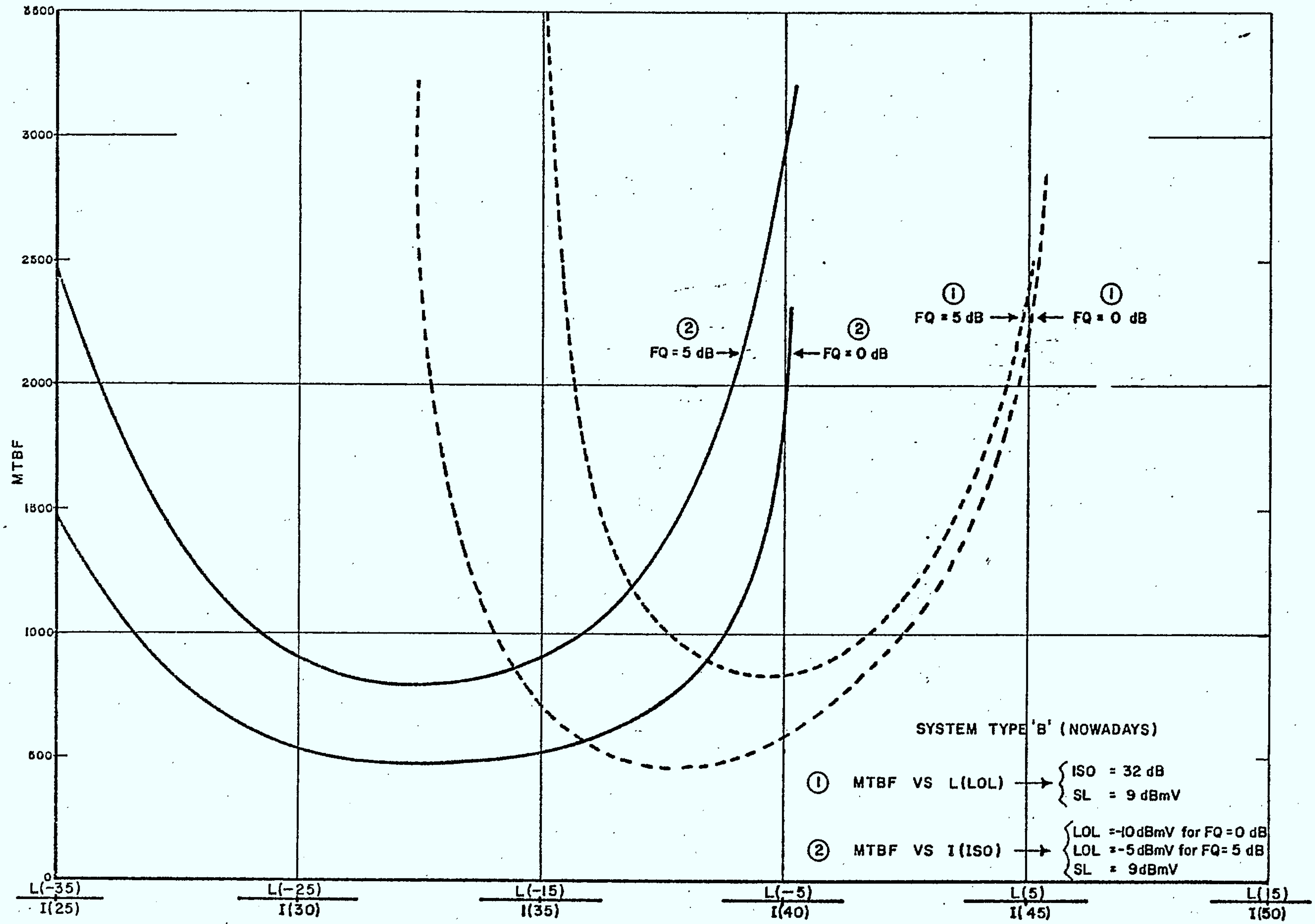

Fig. 3.3 MTBF as a Function of I(ISO) and L(LOL).

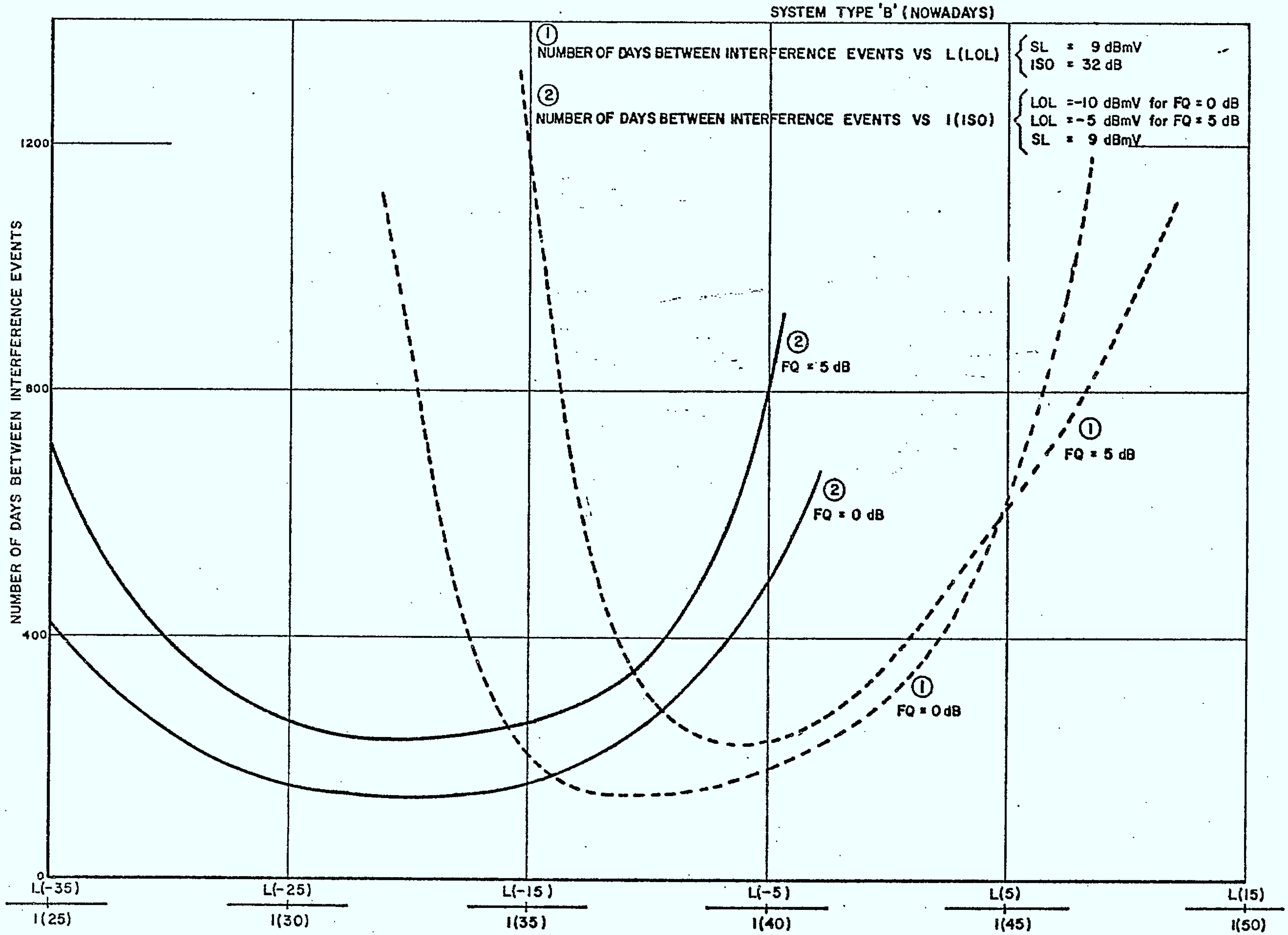

Fig. 3.4 Mean Number of Days Between Interference as a Function of I(ISO) and L(LOL)

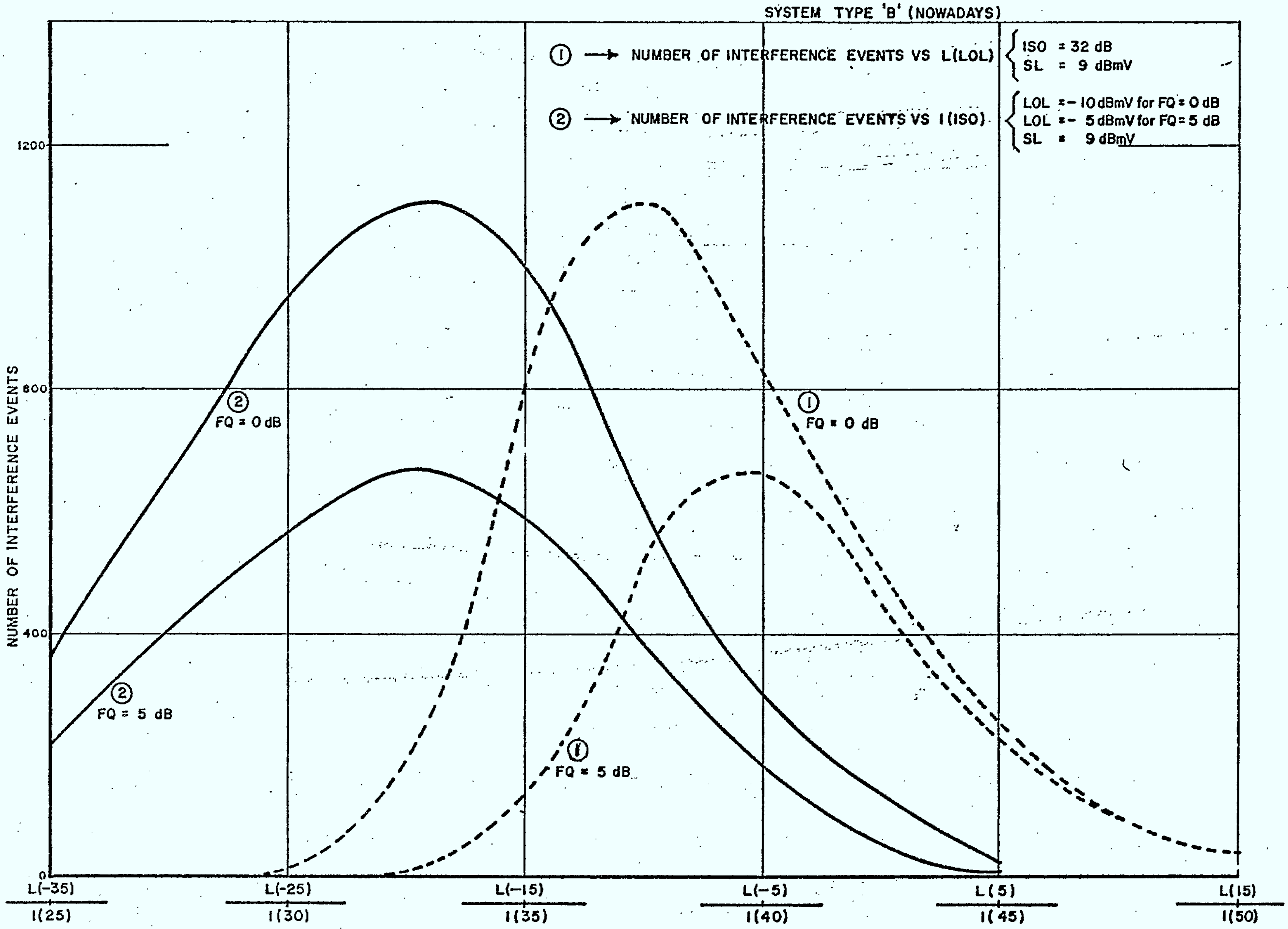

Fig. 3.5 Mean Number of Interference Events as a Function of I(ISO) and L(LOL)

Figure 3.6, 3.7 and 3.8 are comparing the probability of occurrence, the number of interference events and the number of days between interference events for each of the three types of systems that were studied. When the three systems are compared, a rapid decrease in the probability of occurrence and in the number of interference events and a large increase in the number of days between interference is observed. It clearly indicates a very significant improvement in the reliability of the cable systems as the newer TV receivers are replacing the older one and as more converters are being installed.

The variation of the probability of occurrence with the absolute value of local oscillator level was investigated. In order to obtain this information, the probability function associated with a given local oscillator level was fixed to unity. Therefore, if the local oscillator level is -10 dBmV, a probability of 1.0 means that there is a certainty that the leakage is -10 dBmV or more. All the remaining affecting parameters were still treated as a probability function. The same approach was taken to evaluate the variations of the probability of occurrence with the isolation of the subscriber. With such an approach the bell-shaped curves of the previous graphs are not possible, rather curves where the probability increases with increasing local oscillator leakage and decreases with the isolation of the subscriber are obtained.

For comparison purposes, a common set of operating conditions was selected for the three types of cable systems being studied. The operating conditions are as close as possible to the conditions that are maximizing the probability of interference. They are:

Quality factor: 5 dB

Signal level : 9 dBmV

Isolation : 30 dB

Local Oscillator level: -10 dBmV

The curves of Figure 3.9 showing the probability of occurrence, PXI, vs. isolation of the subscriber, clearly indicates a large reduction of interference with maturation of the cable systems. The probability decreased rapidly with increasing isolation, becoming very small for an isolation level of 35 dB.

The variation of the probability of occurrence, PXL, with local oscillator level is presented in Figure 3.10. The probability levels at maxima which are different for each type of cable system. Interesting enough, the probability is minimum for cable systems of type "A", the older systems, and maximum for type "B" systems, the contemporary systems, for future system, type "C", the probability decreases. By not treating the parameter local oscillator level as a probability function, the statistical reduction of leakage does not have any effect on decreasing the probability of occurrence. The parameter that was defined as the probability of listenning to an affected channel while the neighbouring subscriber is listenning to an interfering channel, PCS, has now a dominant influence. Table 3.2 indicates that the probability PCS is minimum for type "A" system and maximum for type "B". All the others parameters being identical, the causes of the variations of PCS are the different distribution

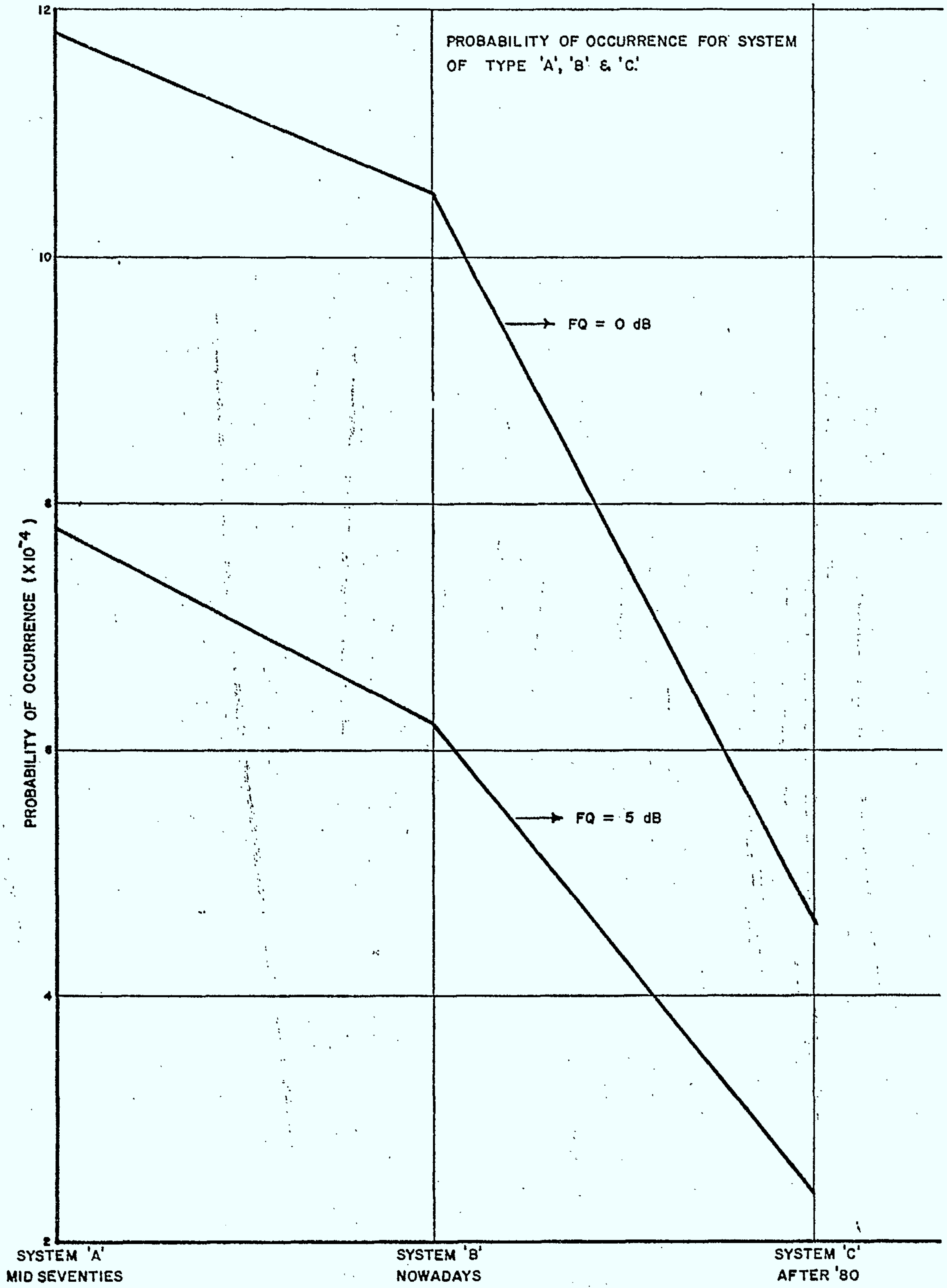

Fig. 3.6 Probability of Occurrence for Mid-seventies, Contemporary and Future Systems

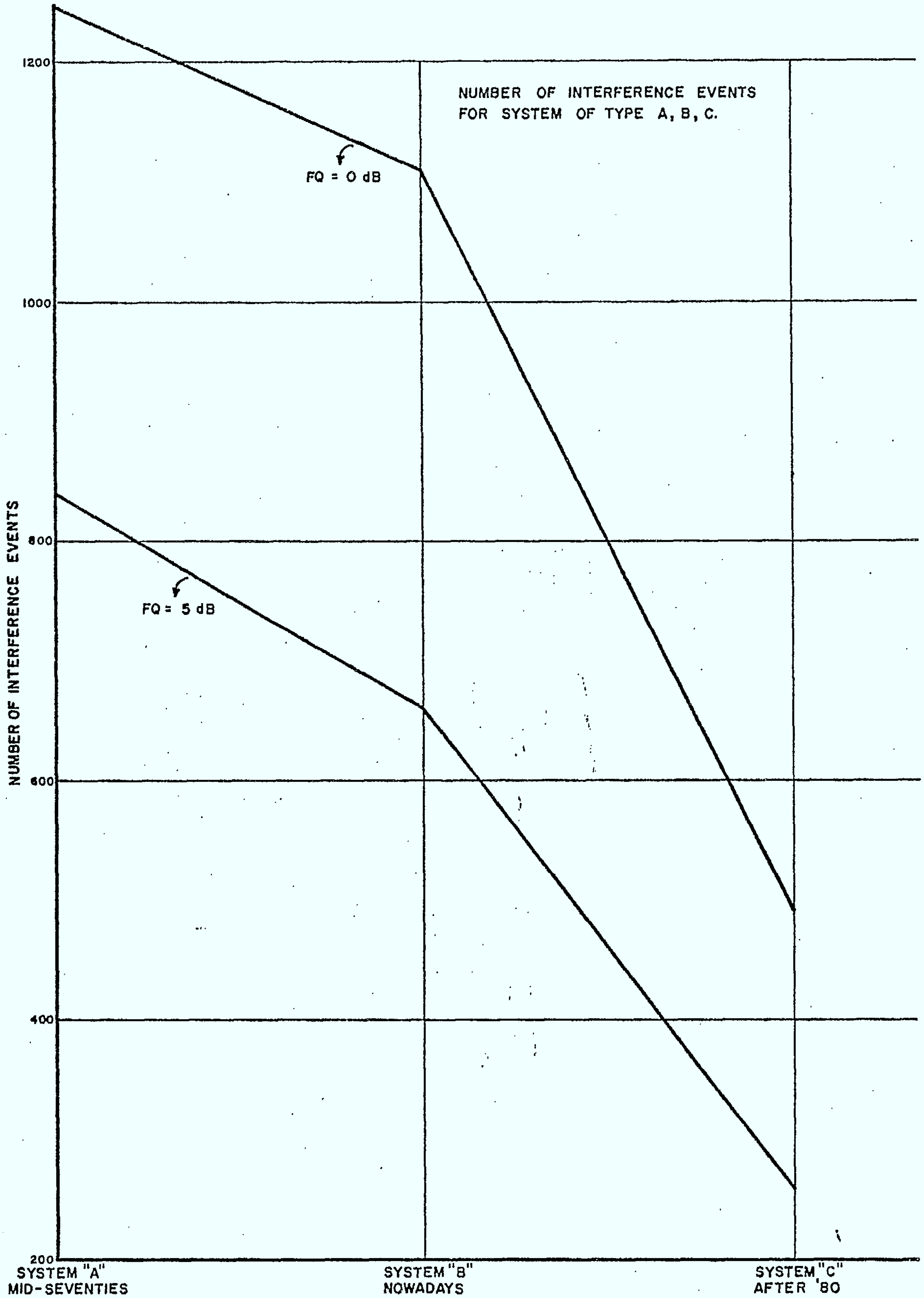

Fig. 3.7 Mean Number of Interference Events for Mid-seventies, Contemporary and Future Systems

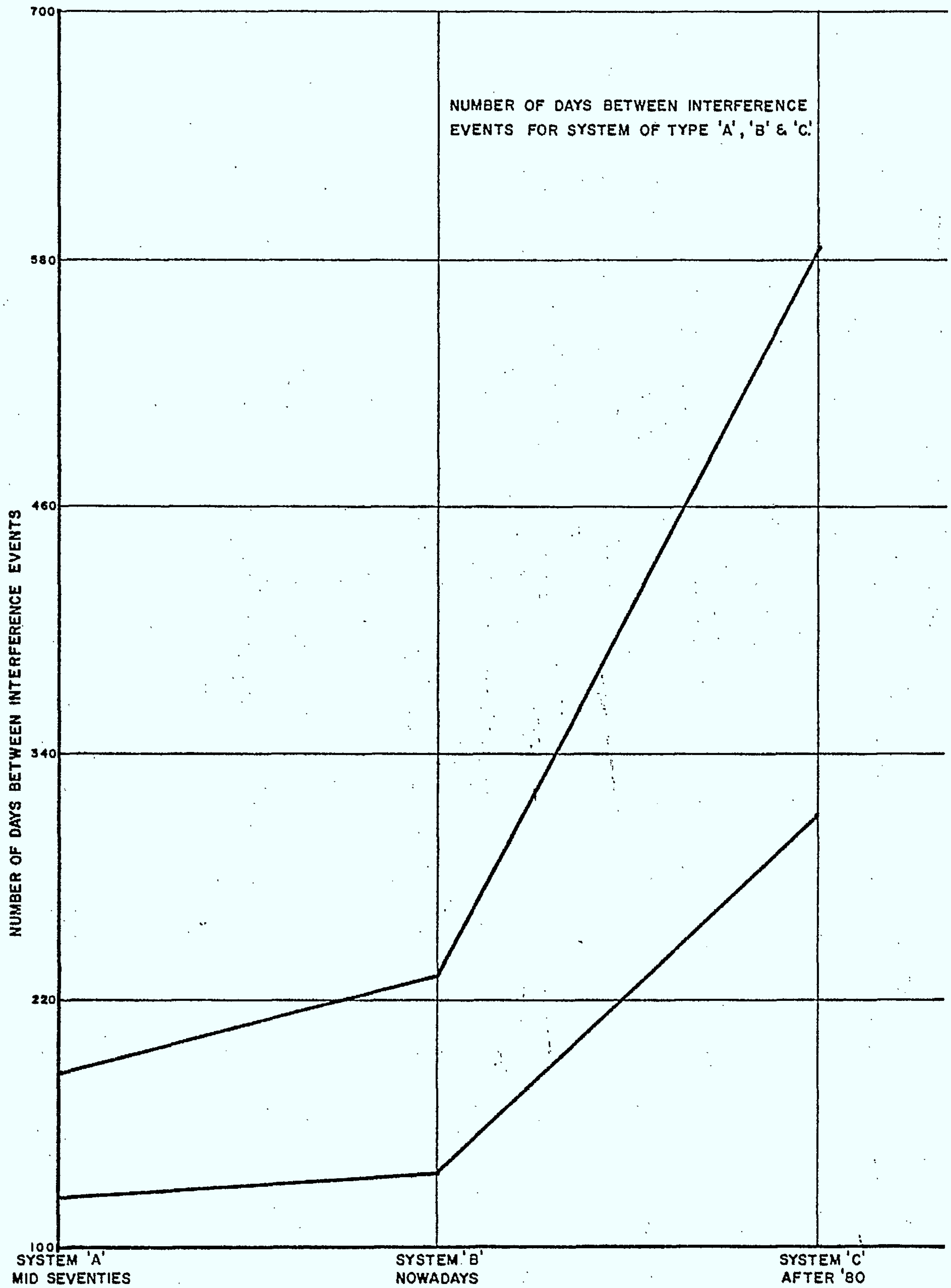

Fig. 3.8 Mean Number of Days Between Interference Events for Mid-seventies, Contemporary and Future Systems.

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of cable compatible, converter and standard receiver among the cable systems, a parameter over which the operator of a cable system has no direct control. Also shown in Table 3.2 are the variation of the long term probability, PLT, and of the mean number of days between interference, ND, with local oscillator level.

With system maturation, there is a net decrease of the overall influence of isolation on the probability of interference as indicated by the decrease in the steepness of the curves of figure 3.9.

However, figure 3.10 seems to indicate that a reverse phenomenom applies in the case of local oscillator leakage. Figure 3.10 also indicates that the probability of occurrence becomes rapidly negligeable for all types of cable systems when the local oscillator level is less than -15 dBmV.

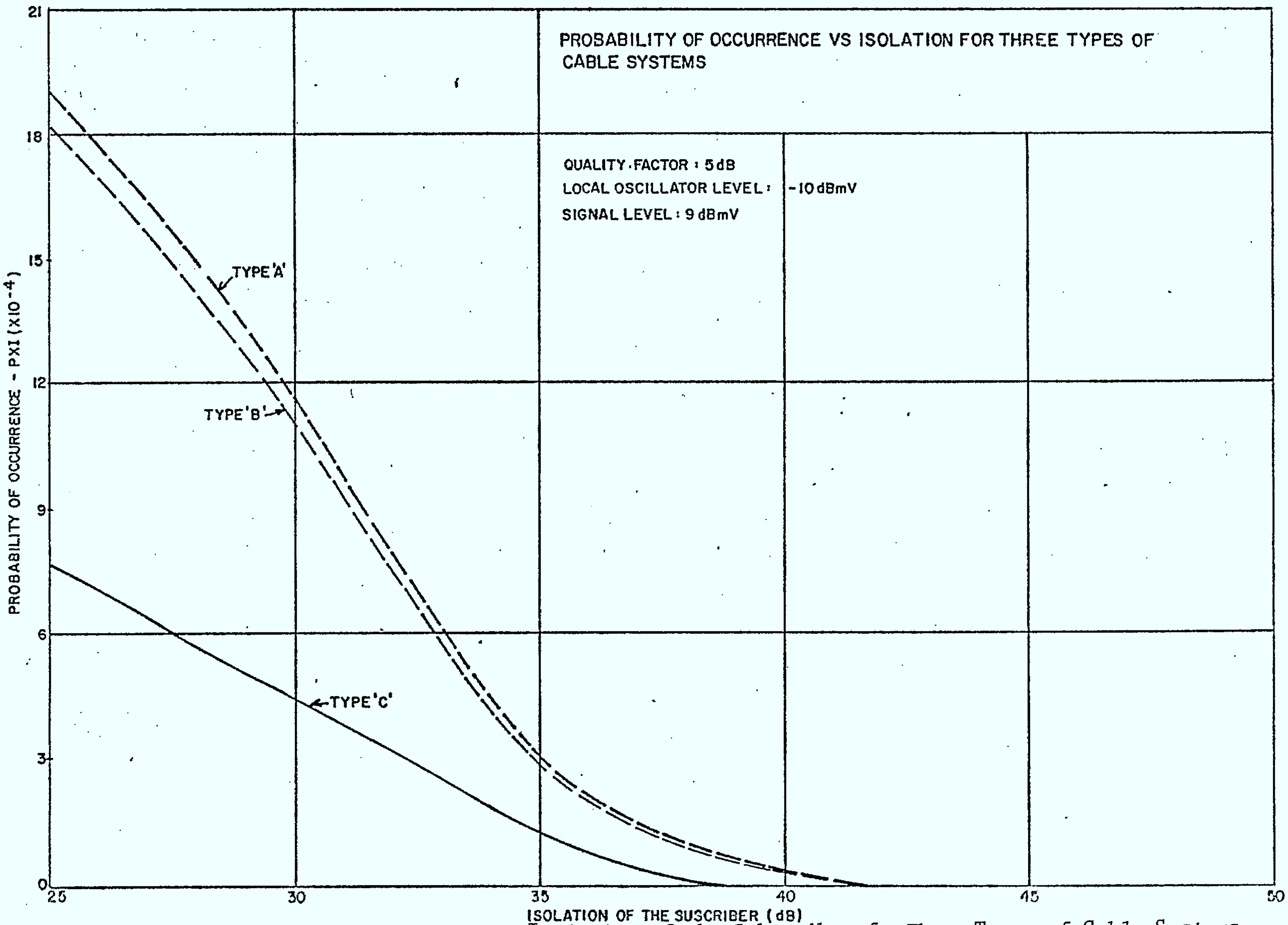

Fig. 3.9 Probability of Occurrence vs Isolation of the Subscriber for Three Types of Cable Systems.

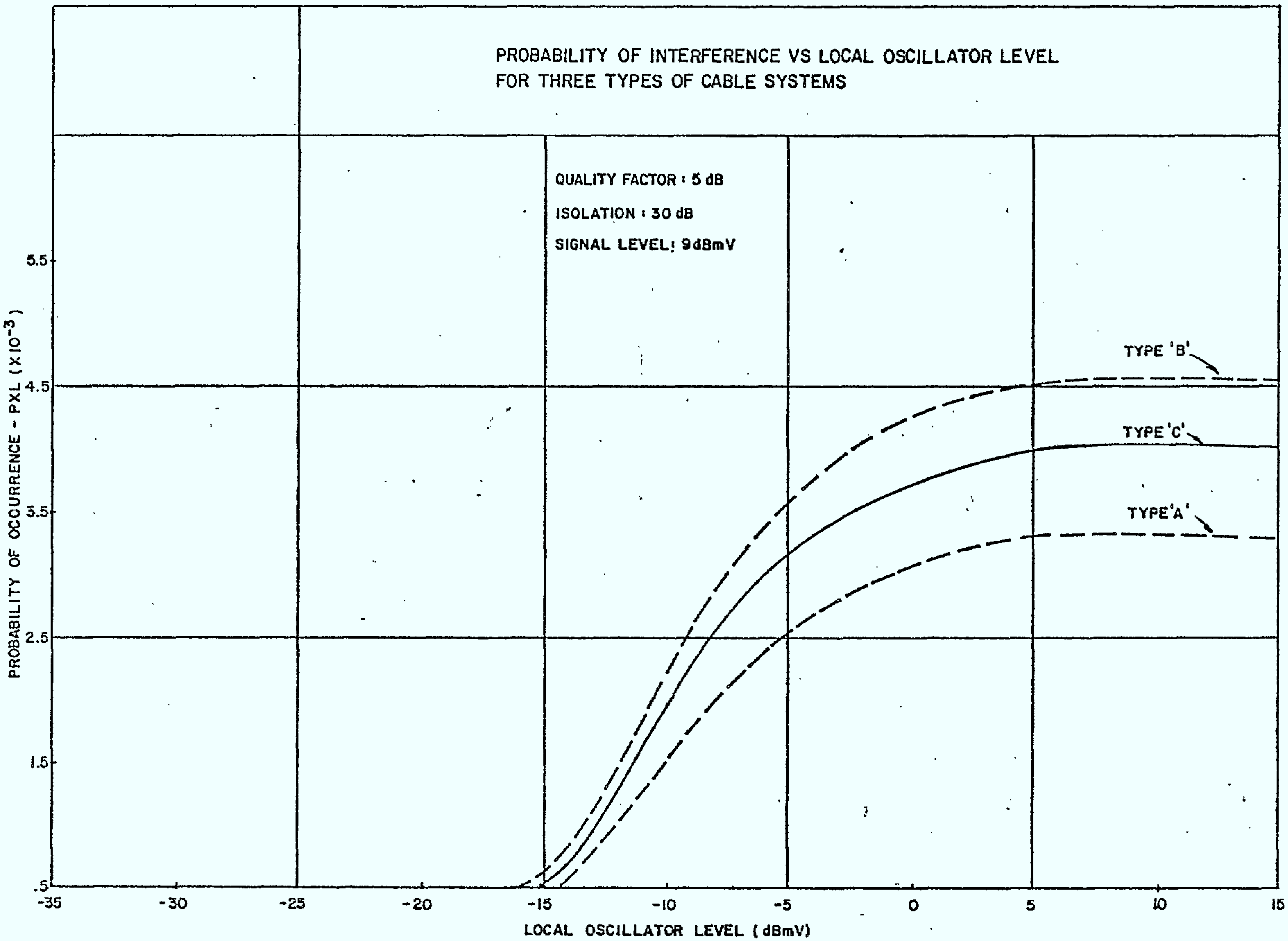

Fig. 3.10 Probability of Occurrence vs Local Oscillators Leakage for Three Types of Cable Systems

TABLE 3.2

SUMMARY OF RESULTS

LOCAL OSCILLATOR LEVEL (dBmV)	MID SEVENTIES			NOWADAYS			AFTER 1980		
	PCS ($\times 10^{-3}$)	PLT	ND	PCS ($\times 10^{-3}$)	PLT	ND	PCS ($\times 10^{-3}$)	PLT	ND
-35	~ 0	~ 0	$>10,000$	~ 0	~ 0	$>10,000$	~ 0	~ 0	$>10,000$
-30	~ 0	~ 0	$>10,000$	~ 0	~ 0	$>10,000$	~ 0	~ 0	$>10,000$
-25	1.6×10^{-3}	1.26×10^{-4}	2.4×10^{3}	2.3×10^{-3}	1.8×10^{-4}	1.7×10^{5}	2.1×10^{-3}	1.6×10^{-4}	1.9×10^{6}
-20	.086	6.6×10^{-3}	4,600	1.22	9.4×10^{-3}	3,210	.011	8.5×10^{-3}	3576
-15	1.1	.082	354	1.6	.116	247	1.4	.105	275
-10	4.2	.279	93	6.0	.374	65	5.4	.343	72
-5	7.0	.418	56	9.92	.536	40	8.8	.494	45
0	8.36	.476	47	11.69	.596	34	10.2	.546	39
5	8.92	.499	44	12.38	.617	32	10.7	.564	37
10	9.0	.502	44	12.5	.62	32	10.8	.566	37
15	9.0	.502	44	12.5	.62	32	10.8	.566	37

Operating conditions:

FQ = 5 dB

ISO = 30 dB

SL = 9 dBmV

CONCLUSION

In the evaluation of the results obtained in this study, one must keep in mind that the calculation of the probability of occurrence was carried out for worst case situations. Very conservative estimates were made of the parameters for which little or no data was available. Although the analysis took into account the effect of most of the hardware related parameters affecting interference, other parameters, more subscribers dependent, where left out or evaluated, wherever possible, as a worst case situation. For instances, the analysis assumes equal popularity for all of the 35 TV channels on the cable systems, hardly the case. However, the popularity of any given channel is too system dependent to be taken into account in such a general analysis. Also, it is assumed that all the subscribers are watching TV at the same time, and that all the subscribers have one neighbour close enough to cause or experience interference, certainly not a very realistic situation. However, any other approach to the problem would greatly limit the generalization of the results. Also not taken into account, is the subscriber's personnal taste for a given program, notwithstanding the previous comments on the overall popularity of the program. For instance, we could easily have a situation where two neighbouring subscribers are watching weekly programs on channels in an interfering/affected relationship, leading, given the appropriate technical conditions, to one subscriber experiencing weekly interference problems. Such a situation could not be taken into account in this analysis but would easily lead to a complaint. However, this analysis should provide an excellent idea of the extent of the local oscillator interference problem and identify the most important affecting parameters.

Throughout the study a strong emphasis was placed on the evaluation of the impact of the local oscillator interference problem on the quality of the picture and its effect on the subscribers. The question is: what level of interference and at which repetition rate will cause enough degradation of the picture quality to generate a complaint?

The reduction of the probability of interference brought about by a general decrease of the local oscillator leakage for recently built receivers was clearly demonstrated by simulation of systems operating over a period of about ten years, i.e. 1975 to 1985. For instance, the analysis has established that the overall probability of occurrence decreased from 7.8×10^{-4} for a typical cable system operating in 1975 to 2.4×10^{-4} for a 1985 system; or the reliability increased from 99.922% to 99.976%.

It is rather difficult to establish if this is a significant improvement. In order to help in this evaluation, functions describing the impact of interference on the subscriber and on the whole cable system were developed. The concepts of length of time spent watching television and the period of operation of a cable system were introduced. Referring to the conditions of the above example, the reliability of 99.922% translated into a probability of 15.5% that a subscriber can observe interference once a month. The number of interference events for a system of 10,000 subscribers operating for one month is then 839 and the mean number of days between interference

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is 181. Remember that there is only a probability of about 37% that there would not be any interference event in 181 days. However, this is a good comparison point. For the post 1980's system, the long term probability is 5%, the number of interference event is now 259 by month and the number of days between interference events is 588 days, or over a year and a half. Therefore, a reliability figure of 99.976% means that each subscriber has approximately one chance out of three to be able to watch television for over 1½ years without observing a local oscillator interference event lasting no more than 30 minutes. The time span for mid-seventies system, under the same odds, was less than half a year. It is safe to assume that few people will complain about interference events occurring at such a low rate.

The influence of the probability of listening to an affected channel while the neighbouring subscriber is listening to an interfering channel (PCS), is clearly demonstrated. This parameter depends on the subscriber's taste for a given program, on the susceptibility of the TV receivers and on the type of receiver in the subscriber's living room, all parameters very hard to control directly by regulations or hardware improvement. Therefore, it tends to limit the extent to which anyone can reduce the overall probability of interference. For cable system operating conditions leading to the maximum probability of interference there is a rapid decrease of the probability of occurrence with augmentation of the subscriber isolation. Total isolation levels around 35 dB are a practical compromise between adequate protection and technical feasibility; thirty dB's are supplied by the tap itself and about five dB's by losses in connectors and drop cables. For the case where the intrinsic value of local oscillator leakage is treated as the independent variable, there is a rapid reduction in the probability of occurrence for leakage below -15 dBmV.

Therefore, it is the opinion of this author that, for adequate protection, the isolation of the taps and the local oscillator leakage of TV receivers should be distributed according to a normal distribution having the following characteristics.

With five dB's of losses in connectors and drop cable, the distribution function for effective isolation of the subscriber should have the following characteristics.

Distribution function for the effective isolation of the subscriber:

mean: 35 dB (± 2 dB)
standard deviation: 5.0 dB (± 1 dB)

Therefore, the distribution function for the isolation of the taps should be specified as follows.

Distribution function for the isolation of the taps:

mean: 30.0 dB (± 2dB)
standard deviation: 5.0 dB (± 1dB)

* See Appendix E for a complete discussion on the selection of the characteristics of the distributions.

Distribution function for local oscillator leakage:

mean:	-25.0 dBmV (± 2 dBmV)
standard deviation:	10.0 dBmV (± 2 dBmV)

Further evaluation of the maximum probability of occurrence for systems having the proposed distribution functions was carried out. The results* clearly indicate that the proposed distribution functions for local oscillator leakage and effective isolation of the subscriber are providing ample protection under the worst conditions of TV receivers distribution in a cable TV system.

* See Appendix F for detailed information.

APPENDIX A

EXAMPLE OF CALCULATIONS OF THE PROBABILITY OF LOCAL OSCILLATOR INTERFERENCE

The following basic operating conditions were assumed throughout the analysis described in the report:

i) 3 types of receivers - standard receivers
- converter receivers
- cable compatible receivers

ii) 35 available channels on cable and converter receivers.

a) Evaluation of PISO, PLOL, PTVS1, PTVS2, PSL, PN and PVH

Where:

PISO : Probability that the isolation is less than what is needed to avoid interference.

PLOL : Probability that the local oscillator level is more than what is needed to have the onset of interference.

PTVS1 : PTVS2 Probability that the TV susceptibility for other affected channels is more than what is required to avoid interference.

PSL : Probability that the signal level is less than what is required to avoid interference.

PN : Probability that the two subscribers are close enough to experience interference.

PVH : Probability that the two subscribers are watching TV at the same time.

In order to evaluate the various probability, we need to know the density functions associated with each of the parameters. Previous studies have shown that all the probability functions were normal. (6). Various levels for each of the parameters were selected and the level of TV susceptibility that would bring the onset of interference was then evaluated using equations(1) of Chapter 2. The independent variable X for each of the normal probability distribution was evaluated using:

$$X = (XR - \mu) / \sigma$$

where XR = random variable distributed normally

μ = mean

σ = standard deviation

The probability P is computed using an approximation by C. Hastings, for digital computers (9).

PN and PVH were given the value of 1.0 at all time for worst case evaluation. Table A.1 summarizes the characteristics of the density functions, the levels of the random variable that will bring the onset of interference, the calculated independent variable associated with each of the distribution functions and the calculated probability.

TABLE A.1

Characteristics of the probability distribution function for this example

PROBABILITY FUNCTION	MEAN μ	STANDARD DEVIATION σ	RANDOM VARIABLE XR	INDEPENDENT VARIABLE X	PROBABILITY
PLOL	-24.0	11.8	-24	0	.5
PTVS1	-46.0	4.0	-54	-2	.02275
PTVS2	-55.0	4.0	-54	.25	.598706
PISO	30	5	30	0	.5
PSL	6	5	0	1.2	.11507
PN	-	-	-	-	1.0
PVH	-	-	-	-	1.0

Table 4.2 gives the value of the other parameters used in the calculations.

TABLE A.2

Levels of the parameters used in this example

PARAMETERS DESCRIPTION	
Calculated TV susceptibility that will bring the onset of local oscillator interference (TVS)	-54
Quality factor (FQ)	0dB
% of cable compatible receivers	10%
% of converter receivers	70%
% of standard receivers	20%
Average number of programs watched per night	7
Average number of nights (per month)	30.42

b) Evaluation of PCS

PCS: Probability of listening to an affected channel while the neighbouring subscriber is listening to an interfering channel.

The three parameters, distribution of receivers, susceptibility of the receivers and channel selection are closely related and the evaluation of an overall probability function PSC must be carried out. The multinomial function is utilised to evaluate the distribution of three types of TV sets among two subscribers. The density function for the multinomial distribution is:

$$f\,(x_1, x_2, \ldots x_n) = \frac{n!}{x_1!\; x_2! \;\ldots\; x_n!} \; p_1^{\;x_1} \, p_2^{\;x_2} \ldots p_n^{\;x_n}$$

This distribution applies to a set of mutually exclusive results $R_1\ R_2 \ldots R_n$ where:

$$P\left(R_i\right) = p_i \text{ and } \sum_{i=1}^{n} p_i = 1$$

In n trials, R_1 occurs x_1 times, R_2 occurs x_2 times etc..., such that

$$x_1 + x_2 + \ldots x_n = n$$

For our purposes we can write:

$P\ (R_1)$ = probability of having a cable compatible set receiver = p_1

$P\ (R_2)$ = probability of having a converter receiver = p_2

$P\ (R_3)$ = probability of having a standard receiver = p_3

n = number of TV sets = 2

$$\sum_{i=1}^{R=3} x_i = x_1 + x_2 + x_3 = 2$$

$$\sum_{i=1}^{n} p_i = p_1 + p_2 + p_3 = 1$$

If we have 3 types of receivers, they can be distributed among two subscribers in six different ways:

$$f\ (2,0,0) = \frac{2!}{2!\ 0!\ 0!} \; p_1^{2}\, p_2^{0}\, p_3^{0} = p_1^{\;2} \text{ (2 cable receivers)}$$

$$f(0,2,0) = \frac{2!}{0!\ 2!\ 0!}\ p_1^0\, p_2^2\, p_3^0 = p_2^{\ 2}$$ (2 converter receivers)

$$f(0,0,2) = \frac{2!}{0!\ 0!\ 2!}\ p_1^0\, p_2^{\ 0} p_3^2 = p_3^{\ 2}$$ (2 standard receivers)

$f(1,1,0) = 2p_1p_2$ (1 cable and 1 converter receiver)

$f(0,1,1) = 2p_2p_3$ (1 cable and 1 standard receiver)

$f(1,0,1) = 2p_2p_3$ (1 converter and 1 standard receiver)

If $p_1 =$ 10%; type 1 = cable TV receivers

$p_2 =$ 70%; type 2 = converter TV receivers

$p_3 =$ 20%; type 3 = standard TV receivers

$p_1^{\ 2} = .01$

$p_2^{\ 2} = .49$

$p_3^{\ 2} = .04$

$2p_1p_2 = .14$

$2p_3p_1 = .04$

$2p_2p_3 = .28$

Defining:

N_1 = number of available channels on type 1: 35 channels

N_2 = number of available channels on type 2: 35 channels

N_3 = number of available channels on type 3: 12 channels

n_1 = number of affected channels on type 1 by type 1 = 25

n_2 = number of affected channels on type 1 by type 2 = 0

n_3 = number of affected channels on type 1 by type 3 = 9

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n_4 = number of affected channels on type 2 by type 1 = 25

n_5 = number of affected channels on type 2 by type 2 = 0

n_6 = number of affected channels on type 2 by type 3 = 9

n_7 = number of affected channels on type 3 by type 1 = 7

n_8 = number of affected channels on type 3 by type 2 = 0

n_9 = number of affected channels on type 3 by type 3 = 0

P_1 = probability for the case of two cable receivers

P_2 = probability for the case of two converter receivers

P_3 = probability for the case of two standard receivers

P_4 = probability for the case of one cable and one converter receiver

P_5 = probability of the case of one cable and one standard receiver

P_6 = probability for the case of one converter and one standard receiver

We have:

$$P_1 = \frac{2n_1}{N_1^2} = \frac{2 \times 25}{35^2} = .040816$$

$$P_2 = \frac{2n_5}{N_2^2} = 0$$

$$P_3 = \frac{2n_9}{N_3^2} = 0$$

$$P_4 = \frac{n_2 + n_4}{N_1 \times N_2} = \frac{0 + 25}{35^2} = .02041$$

$$P_5 = \frac{n_3 + n_7}{N_1 \times N_3} = \frac{9 + 7}{35 \times 12} = .038095$$

$$P_6 = \frac{n_6 + n_8}{N_2 \times N_3} = \frac{9 + 0}{35 \times 12} = .02143$$

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The overall probability is obtained by writting:

$$\sum_{i=1}^{6} P_i$$

However, some modification must be done to the above calculations in order to take into account the susceptibility of the TV sets, which is not uniform for all channels.

For channels A and B, the susceptibility is different from the susceptibility of the other channels.

Defining:

PTVS1 = S' = probability that the susceptibility for channels A and B is less than a certain value X_1 (dB), which is the value that will bring the onset of interference.

PTVS2 = S" = probability that the susceptibility for all other channels will be less than a value X_1 (dB), which is the value that will bring the onset of interference.

$$n_1 = n_1' + n_1''$$

where

n_1 = number of affected channels on type 1 by type 1 (as defined previously)

n_1' = 2, channels A and B.

n_1'' = 23, all other affected channels.

$$P_1 = \frac{2n_1}{N_1^2} = \frac{2(n'_1 + n_1'')}{N_1^2}$$

To take into account the difference in susceptibility, we must write:

$$P_1 = \frac{2n_1' \times S'}{N_1^2} - \frac{2n_1'' \times S''}{N_1^2}$$

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The first term of the equation can be interpreted as the probability that the affected channels on type 1 receiver are channel A and B multiplied by the probability that the susceptibility of the type 1 receiver is less that the value that will bring the onset of interference.

Similar expressions are obtained for

P_2, P_3, P_4 P_5. We then have:

$$PCS = p_1^2P_1 + p_2^2P_2 + p_3^2 P_2 + 2p_1p_2P_4 + 2p_1p_3P_5 + 2p_2p_3P_6$$

Substituting, we find:

PCS = .0054314

c) <u>Evaluation of PX</u>

PX: probability of having an interfering event.

The probability of local oscillator interference is:

PX = PLOL x PISO x PSL x PCS x PN x PVH.

PX = .00015625

PX(%) = .015625%

d) <u>Long term probability</u>

The long term probability is evaluated by using the Binomial Distribution:

$$\binom{n}{r} p^r (1-p)^{n-r}$$

p = probability of having interference.

1-p = probability of not having interference.

r = number of interfering events.

n = number of watching events.

$n = VE \cdot W$

Where

VE = number of programs watched per night per subscriber.

W = number of nights.

For the example under consideration:

VE = 7 programs

W = 30.42 nights

n = 213 watching events

r = 1 interfering event

p = PX = .00015625

q = 1 - p = .9998437

The probability that a subscriber will experience two, three, etc. events a month is evaluated as follows:

P (0) = probability there will be no interference = q^n

P (1) = probability it will happen once = $\frac{n!}{1!\,(n-1)!}\, p^1\, (1-p)^{n-1}$

P (2) = probability it will happen twice = $\frac{n!}{2!\,(n-2)!}\, p^2\, (1-p)^{n-2}$

P (3) = probability it will happen three times = $\frac{n!}{3!\,(n-3)!}\, p^3\, (1-p)^{n-3}$

etc.

The probability that it will happen at least once a month is:

PONCE = 1 - P(0) = .0327

Simarly;

PTWICE = Probability that there will be two interfering events or more.

PTWICE = $1 - \left(P(0) + P(1)\right)$ = .0054

P3TIMES = Probability that there will be three interfering events or more.

P3TIMES = $1 - \left(P(0) + P(1) + P(2)\right)$ = .0000059

P4TIMES = Probability that there will be four interfering events or more.

P4TIMES = $1 - \left(P(0) + P(1) + P(2) + P(3)\right)$ = .00000005

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e) Evaluation of the number of outcomes of interfering events

PX = probability of occurence

$PX = \frac{nx}{NX}$ and $nx = PX \cdot NX$

where nx = number of local oscillator interference events

NX = total number of trials or number of TV watching events in a given period of time.

Only half of the TV watching events in a given period of time are events that can possibly be interfered with. However, two watching events are necessary for one interference event. Then, we can write:

$$NX = \frac{n_e \cdot n_s}{2}$$

Where n_s = number of subscribers in a system

n_e = total number of trials (or watching events) per subscribers.

n_e = VE x W

Where VE = number of programs watched per night per subscribers

W = number of nights

For the example under consideration:

If VE = 7 programs

W = 30.42 nights

n_s = 10,000 subscribers

NX = 1,064,700 watching events

nx = 166 outcomes of local oscillator interference events.

f) Evaluation of the failure rate "λ" and of the mean time between failure "MTBF"

Assuming that the probability of local oscillator interference behaves according to a condition where only chance failures can occur then, the exponential reliability function describes the behaviour of the system for this kind of failure condition (4).

$P_R = e^{-\lambda t}$

P_R = probability that the event of local oscillator interference will not occur.

λ = failure rate

$P_U = 1 - e^{-\lambda t}$

P_U = probability that the event of local oscillator interference will occur.

If: $P_U = .000156248$

$P_R = 1 - P_U = e^{-\lambda t}$

$P_R = .999844$

$\lambda t = .00015624$

Since we are taking about 30 minutes programs,

$t = .5$ hours

$\lambda = .00031251$

$\lambda = 3.125 \times 10^{-4}$ failures/hours

$MTBF = \frac{1}{\lambda} = 3,200$ hours

Since every subscribers is watching 3.5 hours of television per night the mean number of days between interference is:

$D = \frac{MTBF}{3.5} = 914$ days or 2.5 years.

APPENDIX B

COMPUTER PROGRAM

```
EDIT LOI
*TY
C      PROGRAM LOI TO EVALUATE THE PROBABILITY PX OF LOCAL
C      OSCILLATOR INTERFERENCE ON CATV SYSTEMS
C
C
       DOUBLE PRECISION PTVS1,PTTVS2,PSL,PLCL,PISO,PCS,P11,P22,P33,X
       DOUBLE PRECISION P,P21,PP1,PP2,PP3,PP4,TOTAL,VE1
       DOUBLE PRECISION PP,QQ,PO,P1,P2,P3,P4,PONCE
       DOUBLE PRECISION PTWICE,P3TIMES,P4TIMES
       DOUBLE PRECISION PN,PVE,PX
       IMPLICIT DOUBLE PRECISION (A-H,O-Z)
       DIMENSION ITIM(4)
       DIMENSION   SNS(25),SNT(25),SNE(25)
       DIMENSION SMON(3)
C
C
       DATA ITIM/'1','2','3','4'/
       DATA SMON/'1','12','6'/
C
C
C      PARAMETERS DEFINITION
C
C
       COMMON X,P,D
C
C
C      TVS1=TV SUSCEPTIBILITY FOR CHANNEL A AND B
C      TTVS2=TV SUSCEPTIBILITY FOR OTHERS AFFECTED CHANNELS
C      SL=SIGNAL LEVEL
C      LOL=LO LEVEL
C      ISO=ISOLATION
C      FQ=QUALITY FACTOR
C      CA=% OF ORDINARY RECEIVERS
C      CO=% OF CONVERTERS RECEIVERS
C      CTV=% OF CABLE RECEIVERS
C      PLCL=PROB. THAT THE LO LEVEL IS MORE THAN WHAT IS NEEDED TO HA
C      VE THE ONSET OF INTERFERENCE
C
C      PISO=PROB. THAT THE ISOLATION IS LESS THAT WHAT IS NEEDED TO
C      AVOID INTERFERENCE
C
C      PTVS1=PROB. THAT THE TV SUSCEPTIBILITY FOR CHANNEL A AND B
C            IS MORE THAN WHAT WOULD AVOID INTERFERENCE
C
C       PTTVS2=PROB. THAT THE TV SUSCEP. FOR OTHERS AFFECTED CHANNELS
C            IS MORE THAN WHAT WOULD AVOID INTERFERENCE
C
C       PSL=PROB. THAT THE SIGNAL LEVEL IS LESS THAN WHAT IS NEEDED TO
C          AVOID INTERFERENCE
C
C       PN=PROB.THAT TWO SUBSCRIBERS ARE CLOSE ENOUGH TO EXPERIENCE
C          LO INTERFERENCE
C
C       PCS=PROB. OF LISTENNING TO AN AFFECTED CHANNEL WHILE THE
C       NEIGHBOURG IS LISTENNING TO AN INTERFERING CHANNEL
C
C        PVE=PROB. THAT THE TWO SUBSCRIBERS ARE  WATCHING TV AT THE
C           SAME TIME
C      P11=PROB. THAT THE RECEIVER IS CABLE
C      P22=PROB. THAT RECEIVER IS CONVERTER
C      P33=PROB. THAT RECEIVER IS STANDARD
```

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```
C      PX= PROB. OF HAVING AN INTERFERING EVENT
C
C    RANGE OF VALUES
       OUTPUT(108)' '
       OUTPUT(108)' '
       OUTPUT(108)'**********  BY YOUR COMMAND  **********'
       OUTPUT(108)' '
       OUTPUT(108)' '
       OUTPUT(108)' '
       OUTPUT(108)'NOTE: FOR SOME CALCULATIONS THE PROBABILITY FUNCTION'
       OUTPUT(108)'OF THE FOLLOWING PARAMETERS IS NOT EVALUATED :'
       OUTPUT(108)'ISOLATION,LOCAL OSCILLATOR LEVEL,SUSCEPTIBILITY FOR '
       OUTPUT(108)'CHANNEL A AND B,SUSCEPTIBILITY FOR OTHER AFFECTED'
       OUTPUT(108)'CHANNELS,CABLE SIGNAL LEVEL.'
       OUTPUT(108)'IN SUCH CASES, ENTER ZERO(0),FOR THE MEAN,STANDARD'
       OUTPUT(108)'DEVIATION AND VALUE OF THE RELEVANT PARAMETER(S)'
       OUTPUT(108)'THE  PROBABILITY ASSOCIATED WITH THE PARAMETER(S)'
       OUTPUT(108)'WILL BE SET TO ONE(1.0)'
       OUTPUT(108)' '
       OUTPUT(108)' '
       OUTPUT(108)' '
C
        OUTPUT(108)'FOR A RANGE OF PARAMETER VALUE,TYPE 1'
        INPUT(101)ISS
        IF(ISS.EQ.1) GO TO 399
CCCCC
CCCCCCC
        OUTPUT(108)'FOR  DEFAULT CONDITIONS,TYPE 2'
       INPUT(101)INN
       IF(INN.EQ.2) GO TO 100
C
       OUTPUT(108)'************  INPUTS  ************'
C
C
  399  IFLAG=0
       OUTPUT(108)'ENTER MEAN,STANDARD DEVIATION AND LEVEL'
       OUTPUT(108)'OF LOCAL OSCILLATOR LEVEL (DBMV)'
       INPUT(101)MEANLO,STDLO,LOL
C
       OUTPUT(108)'ENTER MEAN,STD. DEV. AND VALUE OF  ISOLATION'
C
       INPUT(101)MEANISO,STDISO,ISO
C
       OUTPUT(108)'ENTER MEAN,STD. DEV. AND VALUE OF TV'
       OUTPUT(108)'SUSCEPTIBILITY FOR CHANNEL A AND B'
       INPUT(101)MEANTVS1,STDTVS1,TVS1
C
       OUTPUT(108)'ENTER MEAN,STD. DEV. AND VALUE OF TV'
       OUTPUT(108)'SUSCEPTIBILITY FOR OTHER AFFECTED CHANNELS'
       INPUT(101)MMEANTVS2,SSTDTVS2,ITVS2
C
       OUTPUT(108)'ENTER MEAN,STD. DEV. AND VALUE OF CABLE SIGNAL'
       OUTPUT(108)'LEVEL'
       INPUT(101)MEANSL,STDSL,SL
C
       OUTPUT(108)'ENTER QUALITY FACTOR'
       INPUT(101)FQ
C
       OUTPUT(108)'ENTER % OF CABLE,CONVERTER AND STANDARD RECEIVERS'
       INPUT(101)CTV,CO,CA
       OUTPUT(108)'ENTER AVERAGE NUMBER OF PROGRAM WATCHED PER NIGHT'
       INPUT(101)VE
C
       OUTPUT(108)'ENTER NUMBER OF NIGHTS'
       INPUT(101)N
C
```

```
          OUTPUT(108)'ENTER PROBABILITY THAT TWO NEIGHBOURS ARE CLOSE'
          OUTPUT(108)'ENOUGH TO INTERFERE WITH EACH OTHER'
          INPUT(101)PN
C
          OUTPUT(108)'ENTER THE PROBABILITY THAT THE TWO SUBSCRIBERS'
          OUTPUT(108)'ARE WATCHING TV AT THE SAME TIME'
          INPUT(101)PVH
C
C
   398    IF(ISS.EQ.1) GO TO 130
          GO TO 101
C
C          DEFAULT VALUES
C
    100    IFLAG=0
          MEANLO=-24
          STDLO=11.8
          LOL=-24
          MEANISO=30
          STDISO=5
          ISO=30
          MEANTVS1=-46
          STDTVS1=4
          TVS1=-46
          MMEANTVS2=-55
          SSTDTVS2=4
          TTVS2=-55
          MEANSL=6
          STDSL=5
          SL=0.
          FQ=0
          CTV=10
          CO=70
          CA=20
          VE=7
          W=30.42
          PN=1.0
          PVH=1.0
          GO TO 101
C
C          RANGE OF VALUES
C
   130    IFLAG=1
          SL=-6.
          LOL=-35
          ISO=25
          FQ=0
C
   101    TVS=LOL-SL-FQ-ISO
C
          OUTPUT(108)' '
          OUTPUT(108)' '
          OUTPUT(108)' '
          OUTPUT(108)' '
          OUTPUT(108)' '
          OUTPUT(108)' '
          OUTPUT(108)'**************************************************'
          OUTPUT(108)'********  OPERATING CONDITIONS ********'
          OUTPUT(108)'**************************************************'
C
          IF(IOFLAG.EQ.1)   GO TO 431
C
          OUTPUT(108)' '
          OUTPUT(108)' '
```

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```
      OUTPUT(108)' '
      OUTPUT(108)'NO. OF CHANNELS ON CABLE AND CONVERTER  RECEIVERS:35'
      OUTPUT(108)'NUMBER OF CHANNELS ON STANDARD RECEIVERS:12'
      OUTPUT(108)'NUMBER OF AFFECTED CHANNELS ON CABLE AND'
      OUTPUT(108)'CONVERTER RECEIVERS(NO OFF-SETTING):25'
      OUTPUT(108)'NUMBER OF AFFECTED CHANNELS ON STANDARD  RECEIVERS:9'
C
      IOFLAG=1
C
431   WRITE(108,530)LOL
530   FORMAT(//,26X,26HLOCAL OSCILLATOR LEVEL IS:,F8.3,1X,
     14HDBMV,3X)
C
      WRITE(108,531)ISO
531   FORMAT(37X,13HISOLATION IS:,F8.3,1X,2HDB)
C
      WRITE(108,532)TVS1
532   FORMAT(16X,38HTV SUSCEPTIBILITY FOR CHANNEL A AND B:,F8.3,1X,
     12HDB)
C
      WRITE(108,533)TTVS2
533   FORMAT(8X,45HTV SUSCEPTIBILITY FOR OTHER AFFECTED CHANNELS,1X,
     14HIS :,F8.3,1X,2HDB)
C
      WRITE(108,534)TVS
534   FORMAT(8X,47HTV SUSCEPTIBILITY FOR THE ONSET OF INTERFERENCE,1X,
     13HIS:,F8.3,1X,2HDB)
C
      WRITE(108,535)SL
535   FORMAT(27X,23HCABLE SIGNAL LEVEL IS:,F8.3,1X,2HDB)
C
      WRITE(108,536)CTV
536   FORMAT(28X,24H% OF CABLE RECEIVERS IS:,F8.3,1X,1H%)
C
      WRITE(108,537)CO
537   FORMAT(24X,28H% OF CONVERTER RECEIVERS IS:,F8.3,1X,1H%)
C
      WRITE(108,538)CA
538   FORMAT(23X,27H% OF STANDARD RECEIVERS IS:,F8.3,1X,1H%)
C
      WRITE(108,539)FQ
539   FORMAT(32X,19HQUALITY FACTOR IS:,F8.3,1X,2HDB)
C
      WRITE(108,540)VE
540   FORMAT(11X,40HNUMBER OF PROGRAMS WATCHED PER NIGHT IS:
     1,F8.3)
C
      WRITE(108,541)W
541   FORMAT(31X,20HNUMBER OF NIGHTS IS:,F8.3)
C
C     EVALUATION OF PLOL,PISO,PTVS1,PTTVS2,PSL,PVE
C
C
      IF(STDLO.EQ.0.0) GO TO 256
      X=(LOL-MEANLO)/(STDLO)
      CALL SNORM(X,P,D)
      PLOL=1.0000000000-P
      IF(PLOL.GT.1.0) PLOL=1.0
      IF(PLOL.LT.0.0000000001) PLOL=0.0000000001
      GO TO 265
256   PLOL=1.0
C
265   IF(STDISO.EQ.0.0) GO TO 257
      X=(ISO-MEANISO)/(STDISO)
```

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```
      CALL SNORM(X,P,D)
      PISO=P
      IF(PISO.GT.1.0) PISO=1.0
      IF(PISO.LT.0.0000000001) PISO=0.0000000001
      GO TO 266
 257  PISO=1.0
C
 266  IF(STDTVS1.EQ.0.0) GO TO 258
      X=(TVS-MEANTVS1)/(STDTVS1)
      CALL SNORM(X,P,D)
      PTVS1=P
      IF(PTVS1.GT.1.0) PTVS1=1.0
      IF(PTVS1.LT.0.0000000001) PTVS1=0.0000000001
      GO TO 267
 258  PTVS1=1.0
C
C
C
 267  IF(SSTDTVS2.EQ.0.0) GO TO 259
      X=(TVS-MMEANTVS2)/(SSTDTVS2)
      CALL SNORM(X,P,D)
      PTTVS2=P
      IF(PTTVS2.GT.1.0) PTTVS2=1.0
      IF(PTTVS2.LT.0.0000000001) PTTVS2=0.0000000001
      GO TO 268
 259  PTTVS2=1.0
C
 268  IF(STDSL.EQ.0.0) GO TO 260
      X=(SL-MEANSL)/(STDSL)
      CALL SNORM(X,P,D)
      PSL=P
      IF(PSL.GT.1.0) PSL=1.0
      IF(PSL.LT.0.0000000001) PSL=0.0000000001
      GO TO 269
 260  PSL=1.0
C
C    EVALUATION OF PCS
C
C
 269  P11=CTV*.01
      P22=CC*.01
      P33=CA*.01
      PZ1=(2*PTVS1)+(23*PTTVS2)
      PP1=PZ1*2
      PP1=PP1/(35*35)
      PP2=PP1/2
      PZ3=2*PTVS1
      PZ3=PZ3+(7*PTTVS2)
      PZ3=PZ3/(35*12)
      PY3=(7*PTTVS2)
      PY3=PY3/(35*12)
      PP3=PZ3+PY3
      PP4=PZ3
      PCS=PP1*P11*P11
      PCS=PCS+2*P11*P22*PP2
      PCS=PCS+2*P11*P33*PP3
      PCS=PCS+2*P22*P33*PP4
C
C   PROB. OF HAVING AN INTERFERING EVENT=PX
C
      PX=PLCL*PISO*PSL
      PX=PX*PCS*PN
      PX=PX*PVH
      PPX=PX*100
```

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```
C
C
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)'*****************************************************'
      OUTPUT(108)'********************OUTPUT **************************'
      OUTPUT(108)'**********************************************************'
C
      WRITE(108,80)PLCL
   80 FORMAT(2X,5HPLCL=,F16.10)
      WRITE(108,81)PISO
   81  FORMAT(1X,5HPISO=,F16.10)
      WRITE(108,82)PTVS1
   82 FORMAT(6HPTVS1=,F16.10)
      WRITE(108,83)PTTVS2
   83 FORMAT(7HPTTVS2=,F16.10)
      WRITE(108,84)PSL
   84 FORMAT(2X,4HPSL=,F16.10)
      WRITE(108,86)PCS
   86 FORMAT(2X,4HPCS=,F16.10)
      WRITE(108,88)PVH
   88 FORMAT(2X,4HPVH=,F16.10)
      WRITE(108,85)PN
   85 FORMAT(3X,3HPN=,F16.10)
      OUTPUT(108)'*********************************************************'
      WRITE(108,87)PPX
   87 FORMAT(2X,31HTHE PROBABILITY THAT THE EVENT ,/,2X,
     147HOF LOCAL OSCILLATOR INTERFERENCE WILL OCCUR IS:,F16.10,1H%)
      OUTPUT(108)'***************************************************'
C
C
C
C
C
C
C   LONG TERM PROBABILITY
C
      OUTPUT(108)'*************LONG TERM PROBABILITY*************'
      OUTPUT(108)' '
       OUTPUT(108)' '
      OUTPUT(108)' '
C
C
      TOTAL=PPX
      VE1=VE*W
      PP=TOTAL/100
      QQ=1.-TOTAL/100
      P0=QQ**VE1
      P1=VE1*PP*(QQ**(VE1-1))
      P2=VE1*(VE1-1)/2
      P2=P2*PP*PP
      P2=P2*(QQ**(VE1-2))
      P3=(VE1*((VE1-1)*(VE1-2)))/6
      P3=P3*PP*PP*PP
      P3=P3*(QQ**(VE1-3))
      PONCE=(1.-P0)*100
      PTWICE=(1.-(P0+P1))*100
      P3TIMES=(1.-(P0+P1+P2))*100
      P4TIMES=(1.-(P0+P1+P2+P3))*100
C
```

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```
      OUTPUT(108)'NUMBER OF    NUMBER OF    NUMBER OF     PROBABILITY OF'
      OUTPUT(108)'EVENTS       NIGHTS       PROGRAMS      OCCURENCE(%)'
C
C
C
C
 36   FORMAT(2X,A4,3X,F7.3,5X,F7.3,5X,F16.10)
C
C
      WRITE(108,36)  ITIM(1),W,VE,PONCE
      WRITE(108,36)  ITIM(2),W,VE,PTWICE
      WRITE(108,36)  ITIM(3),W,VE,P3TIMES
      WRITE(108,36)  ITIM(4),W,VE,P4TIMES
C
C
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)'*****************************************************'
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)'NUMBER OF   NUMBER OF     NUMBER OF     NUMBER OF'
      OUTPUT(108)'SUBSCRIBERS  MONTHS       TRIALS          EVENTS'
      TOTAL=PPX
      PP=TOTAL/100
      DO 801 I=2,6
      OUTPUT(108)' '
      J=1
      SN1=(VE*W)/2
      SNS(I)=10**I
      REPEAT 801,FOR SN1=SN1,SN1*6,SN1*2
      SNT(I)=SNS(I)*SN1
      SNE(I)=SNT(I)*PP
      WRITE(108,802)SNS(I),SMON(J),SNT(I),SNE(I)
 802  FORMAT(F10.1,6X,A3,2X,F17.2,1X,F9.3)
      J=J+1
 801  CONTINUE
C
C
C
      OUTPUT(108)'   '
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)'      FAILURE RATE           MTBF'
      PR=1-PP
      XX=DLOG(PR)
      TT=.5
      AL=-XX/TT
      SMTBF=1/AL
      WRITE(108,505)AL,SMTBF
 505  FORMAT(F16.10,5X,F16.2)
      OUTPUT(108)' '
      OUTPUT(108)' '
      OUTPUT(108)' '
C
C
C
      IF(IFLAG.NE.1) GO TO 99
C
      LOL=LOL+5
      IF(LOL.GT.-5) GO TO 501
      GO TO 101
```

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```
  501  LOL=-35
       ISO=ISO+5
       IF(ISO.GT.45) GO TO 502
       GO TO 101
  502  ISO=25
       SL=SL+5
       IF(SL.GT.14) GO TO 503
       GO TO 101
  503  SL=-6.
       FQ=FQ+5
       IF(FQ.GT.5) GO TO 99
       GO TO 101
  99   END
C
C         SUBROUTINE SNORM
C
C         PURPOSE
C            COMPUTES Y = P(X) = PROBABILITY THAT THE RANDOM VARIABLE  U
C            DISTRIBUTED NORMALLY(0,1), IS LESS THAN OR EQUAL TO X.
C            F(X), THE ORDINATE OF THE NORMAL DENSITY AT X, IS ALSO
C            COMPUTED.
C
C         USAGE
C            CALL SNORM(X,P,D)
C
C         DESCRIPTION OF PARAMETERS
C            X--INPUT SCALAR FOR WHICH P(X) IS COMPUTED.
C            P--OUTPUT PROBABILITY.
C            D--OUTPUT DENSITY.
C
C         REMARKS
C            MAXIMUM ERROR IS 0.0000007.
C
C         SUBROUTINES AND SUBPROGRAMS REQUIRED
C            NONE
C
C         METHOD
C            BASED ON APPROXIMATIONS IN C. HASTINGS, APPROXIMATIONS FOR
C            DIGITAL COMPUTERS, PRINCETON UNIV. PRESS, PRINCETON, N.J.,
C            1955.  SEE EQUATION 26.2.17, HANDBOOK OF MATHEMATICAL
C            FUNCTIONS, ABRAMOWITZ AND STEGUN, DOVER PUBLICATIONS, INC.,
C            NEW YORK.
C
       SUBROUTINE SNORM(X,P,D)
C
       IMPLICIT DOUBLE PRECISION(A-H,O-Z)
       AX=ABS(X)
       T=1.0/(1.0+.2316419*AX)
       D=0.3989423*EXP(-X*X/2.0)
       P = 1.0 - D*T*((((1.330274*T - 1.821256)*T + 1.781478)*T -
      1  0.3565638)*T + 0.3193815)
       IF(X)1,2,2
     1 P=1.0-P
     2 RETURN
       END
--EOF HIT AFTER 498.
```

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APPENDIX C

This is a list of channels that can be affected by various combinations of cable compatible, converter and standard receiver on a 35 channel system without off-setting.

TABLE C.1

CHANNELS IN OPERATION IN THE SYSTEM	CHANNELS AFFECTED
2	FM
3	FM
4	
5	A
6	B
A	
B	
C	7
D	8
E	9
F	10
G	11
H	12
I	13
7	J
8	K
9	L
10	M
11	N
12	O
13	P
J	Q
K	R
L	S
M	T
N	U
O	V
P	W
Q	
R	
S	
T	
U	
V	
W	

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TABLE C.2

TYPE OF INTERFERING RECEIVER	TYPE OF AFFECTED RECEIVER	CHANNELS THAT CAN BE AFFECTED	TOTAL
Standard	-	A, B, J, K, L, M, N, O, P	9
Standard	Converter	A, B, J, K, L, M, N, O, P	9
Standard	Cable	A, B, J, K, L, M, N, O, P	9
Standard	Standard	-	0
Cable	-	A, B, H, I, 7, 8, 9, 10, 11, 12, 13, J, K, L, M, N, O, P, Q, R, S, T, U, V, W.	25
Cable	Converter	A, B, H, I, 7, 8, 9, 10, 11, 12, 13, J, K, L, M, N, O, P, Q, R, S, T, U, V, W	25
Cable	Cable	A, B, H, I, 7, 8, 9, 10, 11, 12, 13, J, K, L, M, N, O, P, Q, R, S, T, U, V, W	25
Cable	Standard	7, 8, 9, 10, 11, 12	6
Converter	Standard	-	0
Converter	Cable	-	0
Converter	Converter	-	0

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APPENDIX D

Data on Local Oscillator Leakage Level

The data for the evaluation of the mean and standard deviation for the local oscillator levels were obtained from measurements made over a period of eight years in various locations across the country (7). The data were assembled and classified under various headings and the mean and standard deviation of each classification were evaluated and compared. The results are summarized in Table D.1. The significance of the data was evaluated using t - tables (1) and the following expressions (8).

$$E = \sigma/\sqrt{N}$$

where

E = standard error of the mean

N = number of measurement

σ = standard deviation of the distribution

$$t = \mu/E$$

where

t = t factor (to be compared with values tabulated in t - tables)

μ = mean of the distribution

The calculated t - factor is then compared with tabulated t values to determine the significant point, taking into account the appropriate number of degrees of freedom (usually equal to one minus the number of measurements). All data were found to be significant to at least the .5% level. Therefore, the data are an excellent representation of the existing conditions.

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TABLE D.1

Data on local oscillator leakage level

DESCRIPTION OF DATA		MEAN μ	STANDARD DEVIATION σ	NUMBER OF MEASUREMENTS N
Data obtained in 1971 (Ottawa)		- 8.48	12.4	189
Data obtained in 1976 (Ottawa)	Standard channels	-16.6	9.72	261
	Mid-band channels	-12.8	9.72	165
	Superband channels	-16.7	6.22	50
	Combined data	-15.3	10.3	476
Data obtained from Moncton	pre-76 receivers	-17.8	18.1	407
	post-76 receivers	-26.5	15.1	495
	combined data	-22.6	17.1	902
Data obtained on 1978 receivers (Ottawa)	Standard channels	-22.9	10.6	969
	Mid-band channels	-22.5	6.71	90
	Superband channels	-35.0	9.32	17
	combined data	-23.0	10.4	1,076
Data supplied by Cable TV operator (mixed channels and years)		-15.3	10.9	791
Combined data for pre-76 sets		-14.7	14.8	1,072
Combined data for post-76 sets		-24.0	11.8	1,571
ALL DATA		-19.1	13.5	3,434

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APPENDIX E

SELECTION OF THE CHARACTERISTICS OF THE NORMAL DISTRIBUTION FOR ISOLATION AND LOCAL OSCILLATOR LEAKAGE

Isolation

The previous calculations have shown that with a subscriber isolation level distributed normally and having a mean of 30 dB and standard deviation of 5 dB, adequate protection from interference was given to the subscriber. If we assume that 30 dB of isolation can be provided by the tap alone and five more dB's by losses in the drop cable, we will obtain an effective subscriber isolation with the following characteristics:

mean: 35 dB ($\pm$ 2 dB)
standard deviation: 5 dB ($\pm$ 1 dB)

The probability P_I that the distribution function for the effective isolation of the subscriber could be worst than the one used in the analysis is:

$$P_\mu = P\ (\mu \leqslant 30\ \text{dB})$$
$$= P\left(t \leqslant \frac{30 - (35)}{5}\right)$$
$$\cong 16\%$$

Assuming that the standard error of the standard deviation is 1 dB.

$$P_\sigma = P\ (\sigma \geqslant 6\ \text{dB})$$
$$= P\left(t \geqslant \frac{6 - 5}{1}\right)$$
$$\cong 16\%$$
$$P_I = 16\% \times 16\% \cong 3\%$$

There is a 97% confidence level that the mean and standard deviation of the proposed distribution function for effective isolation of the subscriber will not both be worst than the ones used in the analysis. Then the distribution function for the isolation of the taps becomes:

mean: 30 dB ($\pm$ 2 dB)
standard deviation: 5 dB ($\pm$ 1 dB)

These specifications are already within the technical capabilities of the taps manufacturers.

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Local Oscillator Leakage

The analysis showed that adequate protection from interference is provided when the leakage level is distributed normally with a mean of - 24 dBmV and a standard deviation of 11.8 dBmV. We propose the following characteristics for the distribution of local oscillator leakage of future receivers.

mean: -25 dBmV (± 2 dBmV)
standard deviation: 10 dBmV (± 2 dBmV)

The probability P_L that the local oscillator distribution function will be worst than the one used in the analysis is:

$$P_\mu = P\,(\mu \geqslant -24 \text{ dBmV})$$
$$= P\left(t \geqslant - \frac{24 - (-25)}{10}\right)$$
$$P_\mu = 46\%$$

Using the data of Table D.1, the standard error of the standard deviation was found to be about 3 dBmV. Therefore, the probability that the standard deviation would be 11.8 dBmV or greater is:

$$P_\sigma = P\,(\sigma \geqslant 11.8)$$
$$= P\left(t \geqslant \frac{11.8 - (10)}{3}\right)$$
$$P_\sigma \cong 27.4\%$$
$$P_L = 27.4\% \times 46\% \approx 12.6\%$$

The confidence level for having a distribution function for local oscillator leakage where both mean and standard deviation are better than the one providing adequate protection, as shown in the analysis, is about 87%. The overall confidence level is:

$$Po = 1 - (P_I \times P_L) = 1 - (.126 \times .03) \approx 99.6\%$$

Therefore, there is a probability of 99.6% that the means and standard deviations of both of the proposed distribution will not all be below the means and standard deviations of the distribution used in the analysis.

Similar calculations can be done to evaluate the probability to have worst cases distributions, i.e. distributions with the following characteristics.

Effective isolation	mean:	33 dB
	standard deviation:	6 dB
Local oscillator leakage	mean:	-23 dBmV
	standard deviation:	12 dBmV

The probability to have such distributions is about 1.2%.

Also, the probability that the means and standard deviation of both distributions will be outside the proposed limits is less than .6%.

APPENDIX F

EVALUATION OF THE MAXIMUM PROBABILITY OF OCCURRENCE
FOR SYSTEMS CHARACTERIZED BY THE PROPOSED DISTRIBUTION FUNCTIONS

The evaluation of the maximum probability of occurrence was carried out earlier for local oscillator leakage and effective isolation distribution functions having the following characteristics.

Effective isolation of the subscribers	mean:	30 dB
	standard deviation:	5 dB
Local oscillator leakage	mean:	-24 dBmV
	standard deviation:	11.8 dBmV

These conditions were shown to be able to provide a reliability of 99.97% for the occurrence of interference with 10% cable compatible receiving, 70% converter receivers and 20% standards receivers, which could be typical of a mid-eighties cable TV system. This level of protection was deemed quite adequate and the following distribution functions for effective isolation of the subscriber and local oscillator level are proposed:

Proposed Characteristics of the Distribution Functions

*Effective isolation of the subscriber;	mean:	35 dB (± 2 dB)
	σ :	5 dB (± 11 dB)
Local oscillator leakage;	mean:	-25 dBmV (± 2 dBmV)
	σ :	10 dBmV (± 2 dBmV)

The proposed distribution functions represent an excellent compromise between adequate protection and technical feasibility for both the cable operators and the TV manufacturers. Also, there is a probability of less than 1% that the characteristics of both of the proposed distributions will be below the characteristics of the distributions used in the analysis.

To obtain a better insight of the protection afforded to future cable TV systems, the maximum probability of interference was evaluated for two more hypothetical systems using the techniques described previously. In one case, a system of 50% cable compatible receiver, 40% converters and 10% standard receivers was studied, i.e. system of type "D". The second system, type E, has 100% cable compatible receivers and represents a worst case estimate. The results are summarized in Table F.1 and F.2 where they are compared to results for type C systems. Table F.1 and F.2 clearly indicated that ample protection is provided to system of type "D". Even for type "E" systems, 100% cable receivers, the protection is only marginally lower than what was deemed adequate for type "C".

* Note: The effective isolation of the subscriber included 30 dB of tap isolation and 5 dB of connectors and drop cable losses.

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TABLE F.1

Summary of Results

	SYSTEM OF TYPE "C"				SYSTEM OF TYPE "D"				SYSTEM OF TYPE "E"			
Distribution of receivers	Cable Receiver (%)	Converter Receiver (%)	Standard Receiver (%)		Cable Receiver (%)	Converter Receiver (%)	Standard Receiver (%)		Cable Receiver (%)	Converter Receiver (%)	Standard Receiver (%)	
	10	70	20		50	40	10		100	0	0	
Quality Factor	0 dB		5 dB		0 dB		5 dB		0 dB		5 dB	
Reliability (%)	99.954		99.976		99.964		99.988		99.937		99.974	
Probability of interference	4.6×10^{-4}		2.4×10^{-4}		.00036		.00012		.00063		.0026	
Long term probability	.093		.05		.074		.025		.125		.055	
MTBF (hours)	1087		2058		1385		4197		796		1891	
Number of events	490		259		387		127		669		232	
Number of days between events	311		588		396		1199		227		540	

Operating Conditions at the Onset of Interference for Maximum Probability of Interference

Local oscillator level (dBmV)	-15	- 10	- 15	- 10	- 15	- 10
Signal level (dBmV)	8	8	5	2	5	5
Isolation (dB)	30	30	35	35	35	35

Probabilities Associated with Parameters Affecting the Probability of Occurrence

PCS	6.3×10^{-3}	6.3×10^{-3}	1.08×10^{-2}	1.7×10^{-2}	1.88×10^{-2}	1.88×10^{-2}
PTVS1	.04	.04	.0122	.0668	.0122	.0122
PTVS2	.69	.69	.50	.773	.50	.50
PLOL	.223	.118	.1587	.0668	.1586	.0661
PISO	.5	.5	.501	.50	.50	.50
PSL	.655	.655	.421	.212	.421	.421

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TABLE F.2

Characteristics of the Distribution Functions for Local Oscillator and Effective Isolation of the Subscriber

	SYSTEM OF TYPE "C"		SYSTEM OF TYPE "D" & "E"	
	μ	σ	μ	σ
Local Oscillator Level	-24 dBmV	11.8 dBmV	- 25 dBmV	10 dBmV
Effective Isolation of the Subscriber	30 dB	5 dB	35 dB	5 dB

The probability of occurrence was also calculated for the worst case distribution functions. The probability of having both distributions at this worst case estimate, which is approximatively 1.2%, must be taken into account in the calculations. The results are summarized in Table F.3, clearly showing that ample protection is available to type "C" and "D" systems.

Therefore, the proposed distribution functions for local oscillator leakage and effective isolation of the subscriber will provide ample protection to the subscribers under the worst conditions of TV receivers distribution in a cable TV system.

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TABLE F.3

Summary of Results for Worst Cases Estimates of the Distribution Functions

Distribution of Receivers	SYSTEM OF TYPE "D"			SYSTEM OF TYPE "E"		
	Cable Receiver (%)	Converter Receiver (%)	Standard receiver (%)	Cable Receiver (%)	Converter Receiver (%)	Standard Receiver (%)
	50	40	10	100	0	0

	SYSTEM OF TYPE "D"		SYSTEM OF TYPE "E"	
Quality Factor	0 dB	5 dB	0 dB	5 dB
Reliability	99.9989	99.9995%	99.9982	99.9991
Probability of Occurrence	1.03×10^{-5}	$5. \times 10^{-6}$	1.8×10^{-5}	$9. \times 10^{-6}$

Operating Conditions at the Onset of Interference for Maximum Probability of Interference

Local Oscillator (level dBmV)	-10	-10	-10	-10
Signal level (dBmV)	8	8	8	8
Isolation (dB)	35	30	35	30

Characteristics of the Distribution Fonctions for Local Oscillator Level and Effective Isolation

	μ	σ
Local Oscillator Level (dBmV)	-23 dBmV	12
Effective Isolation (dB)	33	6

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