BEST FREQUENCY ASSIGNMENTS FOR MID AND SUPER BAND CHANNELS

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Introduction:

During the past two decades CATV systems have carried, first, three channels of television; then five channels, then twelve channels.

For the past three years we have been advocating twenty to thirty television channels with thoughts of an almost limitless capacity for the future use of cable spectrum. As systems expanded from three to twelve channels the frequency allocation was obvious - we simply duplicated standard VHF television assignments. With the increase in the number of channels beyond twelve, serious consideration must be given to their precise frequency assignment. The purpose of this paper is to discuss some of the problems that might be encountered and to suggest ways of minimizing their effect.

The following presentation is applicable to any system carrying more than twelve channels when the standard twelve VHF channels are on the cable system at the normally prescribed broadcast frequencies, and

A. there are two levels of customer service

   1. customers receiving only the standard VHF channels - thus not requiring a converter.

   2. customers receiving the standard VHF channels plus additional channels via a converter mechanism.

B. all subscribers have a converter but the standard VHF channels are bypassed thru the device so that the television set tuner is used to tune these bypassed channels.

C. all subscribers have a converter which tunes to all programs; but the I.F. frequency of the converter is the same as the standard I.F. frequency of a television set.

D. a broad band converter is used to convert a block of Mid band or Super band programs to standard UHF or VHF channels; the twelve VHF channels on the cable being bypassed thru the converter and tuned via the TV set tuner.

E. cable systems expand to the point that TV set manufacturers build tuners which are compatible with broadcast <u>and cable systems</u>; converting all channels to the standard television set I.F. frequency.

The Problems:

A. Oscillator Leakage

An average television set has a relatively high level of oscillator leakage from its antenna terminals. As can be seen from Table I, the oscillator frequencies associated with the standard VHF channels fall into the Mid Band and Super Band spectrum of our cable systems.

VHF Channel	Oscillator Frequency(Megahertz)
2	101
3	107
4	113
5	123
6	129
7	221
8	227
9	233
10	239
11	245
12	251
13	257

TABLE I

Since none of these oscillator frequencies occur within the limits of the twelve VHF channels, this has not been a problem. However, it is obvious that oscillator leakage from TV sets tuned to channels 5 and 6 fall into the Mid Band and from sets tuned to channels 7 to 13 fall into the Super Band. Figure I depicts a typical method of subscriber connection. The following example shows how the problem occurs.

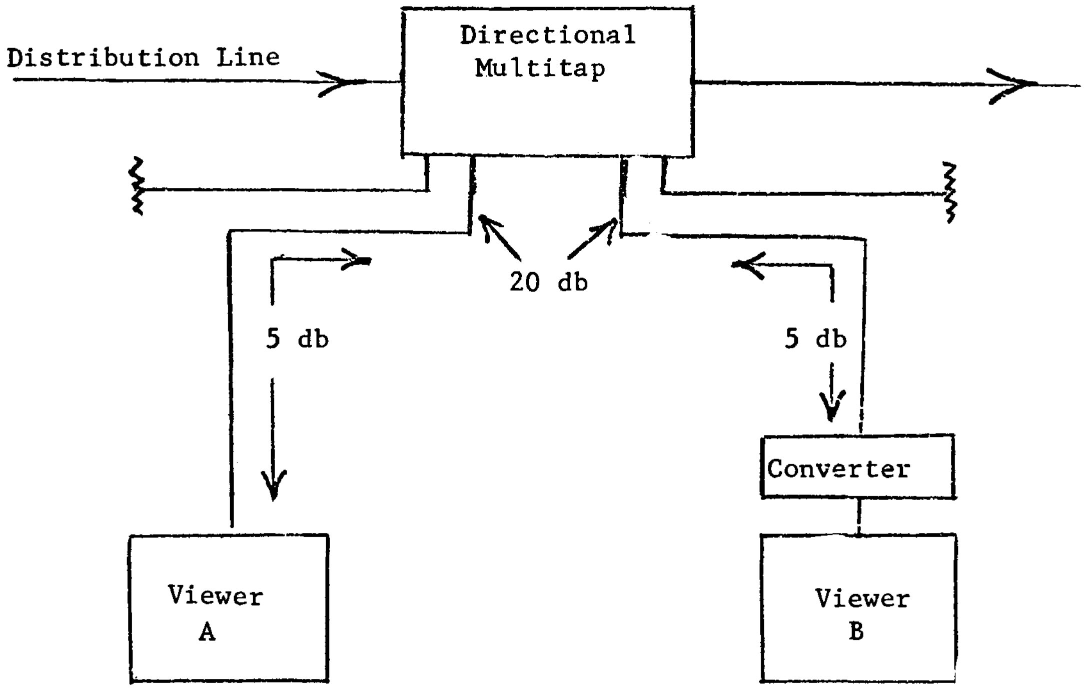

Figure I

Viewer A does not have a set converter to receive the "extra" channels. His TV set is tuned to channel 6 and the oscillator is at 129 megahertz. If Viewer B is tuned to the accepted Mid Band channel B (126 MHz to 132 MHz - video carrier at 127.25 MHz) the oscillator from Viewer A, if strong enough, will cause a beat 1.75 MHz in the channel received by Viewer B. Assume that a typical level at the input of the converter at channel B is +5dbmv and that interference to be unobjectionable must be 55db minimum below this, which is -50dbmv. Allowing 5db for each drop from the multitap and 20db isolation between customer outputs (for a total of 30db isolation); then the level of oscillator leakage from the antenna terminals of Viewer A must be -20dbmv or lower. Similarly, if Viewer A were tuned to Channel 10 and Viewer B were tuned to Channel M (234 to 240 MHz; video carrier 235.25) the oscillator from Channel 10 would appear as a 3.75 MHz beat in Channel M, which could cause a serious color beat. This second case is identical for all high VHF channel oscillators interfering as a color beat with all Super Band channels having the currently accepted frequency assignment.

Table II lists measurements of the level of oscillator leakage from the antenna terminals of several TV sets. A standard 75ohm to 300 ohm transformer was connected to the television set and readings were made with a Signal Level Meter. The tests were made while the set was receiving the desired signal at a level of 5dbmv; however, the oscillator leakage seemed to be completely independent of the input signal level and indeed, gave the same reading with the signal disconnected.

Channel	*A	B	C	D	E	F
4	-22.0	-12.0	-15.0	-12	-13.0	-24.0
5	-14.0	+ 2.0	-13.0	-11	- 8.0	-30.0
6	-11.0	+ 4.0	-13.0	- 9.5	- 7.5	-30.0
7	- 3.0	+19.0	- 4.0	+ 6	- 3.0	-18.0
8	+ 1.0	+21	- 4.0	+ 5.5	- 1.5	-14.0
9	+ 1.0	+21	- 2.0	+ 8.0	- 2.0	-10.0
10	0.0	+24.5	- 3.0	+ 9.0	- 4.0	-20.0
11	- 3.0	+20.0	- 4.0	+10.0	- 8.0	-20.0
12	- 7.0	+11.0	0.0	+ 8.0	- 3.0	-11.0
13	- 5.0	+10.0	- 1.0	+ 6.0	- 4.0	-12.0

*See Appendix for the description of the sets

TABLE II

B. Image:

The use of the spectrum commonly called Mid Band and Super Band generates another problem not encountered in twelve channel systems. The problem is "image." The image of any receiver is an interference that appears at a frequency equal to the desired signal plus or minus twice the I.F. frequency of the receiver. For the standard television receiver (or a converter mechanism whose intermediate frequency is the same as the standard TV set) the tuner oscillator is always above the incoming signal, therefore, the image will occur at a frequency equal to the incoming signal plus twice the I.F. frequency (45.75 MHz video I.F.) or at a frequency of 91.5 MHz above the incoming VHF video carriers. Table III shows the precise image frequency for all VHF video carriers.

Channel	Video Carrier (MHz)	Image Frequency (MHz)
2	55.25	146.75
3	61.25	152.75
4	67.25	158.75
5	77.25	168.75
6	83.25	174.75
7	175.25	266.75
8	181.25	272.75
9	187.25	278.75
10	193.25	284.75

Channel	Video Carrier (MHz)	Image Frequency (MHz)
11	199.25	290.75
12	205.25	296.75
13	211.25	302.75

TABLE III

An example of the image problem is as follows. Assume Viewer A is tuned to Channel 2. Table I shows that the oscillator in his TV set is at 101 MHz.

Desired Signal	TV set oscillator	- Ch 2 Video	=	IF Video
	101.0 MHz	- 55.25 MHz	=	45.75 MHz
Undesired Image Signal	Undesired Signal	- TV Set Osc	=	IF Video
	146.75 MHz	- 101.0 MHz	=	45.75 MHz

If a Mid Band signal were placed at 146.75 MHz, a zero beat would occur and the magnitude of the beat would be directly proportional to the attenuation of the tuner mechanism (commonly called "image rejection") to this image frequency. A 55 to 60 db minimum image rejection specification is required for all such tuners to avoid this problem. This is difficult to achieve in vacuum tube type tuners and will be far more difficult in the immediate future with the introduction of solid state tuners using varactor tuning methods. Keep in mind that there is no serious image problem for VHF broadcast TV. It is the cable industry that is using, or is about to use, the spectrum where image problems can occur, that brings this to the forefront.

Table IV shows where the accepted frequency assignments for Mid Band can cause problems.

Channel Effected	Type of Beat	Source of Interference		
2	1.5 MHz	E Video	;	145.25 MHz
3	1.5 MHz	F Video	;	151.25 MHz
3	3.0 MHz	E Sound	;	149.75 MHz
4	1.5 MHz	G Video	;	157.25 MHz
4	3.0 MHz	F Sound	;	155.75 MHz
5	-0.5 MHz	I Video	;	169.25 MHz
5	1.0 MHz	H Sound	;	167.75 MHz
*6	-0.5 MHz	7 Video	;	175.25 MHz
6	1.0 MHz	I Sound	;	173.75 MHz

TABLE IV

*Since this beat exists in cable systems today, and is not a serious problem, we can presume that the identical beat raised on Channel 5 by I video is also not objectionable. A negative beat is fundamentally less objectionable because it has the additional attenuation afforded it by its position on the slope of the IF response.

Since the image interference band for Channels 7 to 13 is 260 to 305 MHz, and although there is the intention of placing channels on the cable in this spectrum in the immediate future, these were not included in Table IV because no firm channel assignment has been in existance.

As a reference for the magnitude of the image problem in present day VHF tuners, the following information was obtained from tuner and set manufacturers:

a. Three circuit tuners: used in low cost TV sets

Image Rejection	Low Band	50db
	High Band	35db

b. Four circuit tuners: used in the better black and white sets and in color sets

Image Rejection		
	All VHF Channels	60db

Suggested Assignment to Minimize The Effect of Oscillator Leakage and Image.

Fortunately there appears to be an assignment to minimize the effects of these problems. Figure II is a graph showing the strength of an interference causing barely preceptible beat versus its location in the side band relative to the video carrier.

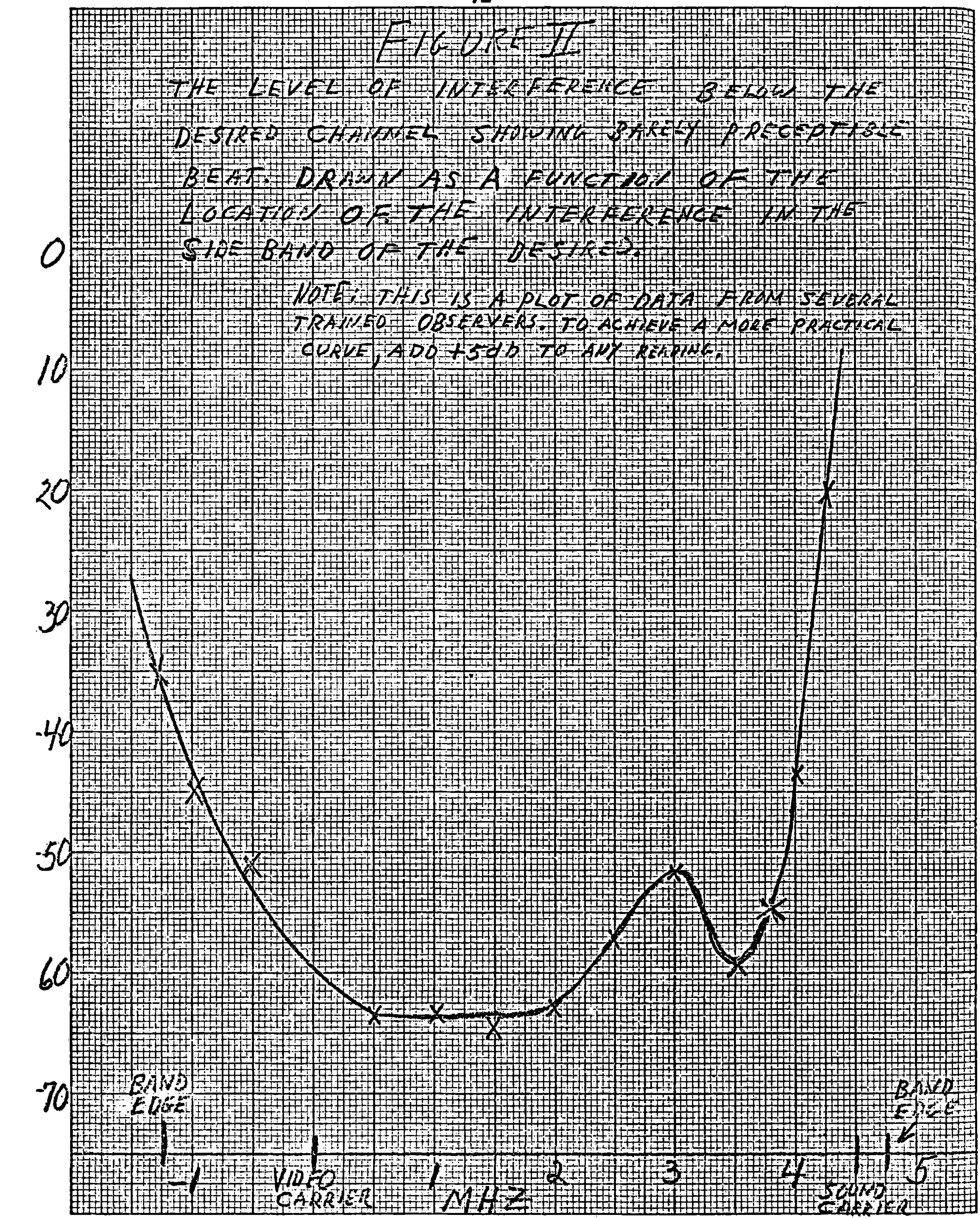

FIGURE II

THE LEVEL OF INTERFERENCE BELOW THE DESIRED CHANNEL SHOWING BARELY PRECEPTIBLE BEAT. DRAWN AS A FUNCTION OF THE LOCATION OF THE INTERFERENCE IN THE SIDE BAND OF THE DESIRED.

Figure II shows that an interference occuring in a desired channel at a frequency of 4.0 MHz above video carrier to the upper band edge or from about 0.5 MHz below the carrier to lower band edge can be much stronger than other interference and still be barely preceptible. This of course is in large measure due to the response shape of the I.F. amplifier of a TV set. In a black and white picture a beat occuring from 2,5 MHz to 4.0 MHz would get progressively less objectionable due to the subjective tolerance of the eye; however, in color, a beat in the region of 2.5 MHz to 4.0 MHz above video carrier begins to cause a very noticeable interference with the color carrier and a pronounced change in the appearance of the interference.

It is with reference to Figure II that I suggest the following Mid Band and Super Band assignment for consideration as a means to minimize the problems that might occur with standard television sets used on cable systems - a limitation over which we have no control at this time.

Suggested Mid Band Assignment

Channel	Lower Band Edge	Video Carrier	Sound Carrier	Upper Band Edge
A	117.0	118.25	122.75	123.0
B	123.0	124.25	128.75	129.0
C	129.0	130.25	134.75	135.0
D	135.0	136.25	140.75	141.0
*E	141.5	142.75	147.25	147.5
F	147.5	148.75	153.25	153.5
G	153.5	154.75	159.25	159.5
H	163.5	164.75	169.25	169.5

*Note: The 0.5 MHz guard band as we go from the assignment for oscillator leakage to the assignment for image.

Suggested Super Band Assignments

Channel	Lower Band Edge	Video Carrier	Sound Carrier	Upper Band Edge
I	221.0	222.25	226.75	227.0
J	227.0	228.25	232.75	233.0
K	233.0	234.25	238.75	239.0

Channel	Lower Band Edge	Video Carrier	Sound Carrier	Upper Band Edge
L	239.0	240.25	244.75	245.0
M	245.0	246.25	250.75	251.0
N	251.0	252.25	256.75	257.0
O	257.0	258.25	262.75	263.0
P	267.5	268.75	273.25	273.5
Q	273.5	274.75	279.25	279.5
R	279.5	280.75	285.25	285.5
S	285.5	286.75	291.25	291.5
T	291.5	292.75	297.25	297.5
U	297.5	298.75	303.25	303.5

Note: All higher assignments are free of oscillator leakage or image problems.

An examination of the suggested assignments listed above shows that I have placed the channels that might be effected by oscillator radiation so that this interference falls at band edge of the newly designated Mid or Super band. This would allow Viewer A to adjust his fine tuner within ± 0.5 MHz and still be within the most tolerable range for interference.

In both the Mid and Super Bands, one can see that the well planned frequency assignment of the VHF television channels by the F.C.C. avoids the possibility that any channel will be effected simultaneously by oscillator leakage while it becomes an image to another VHF channel. In the proposed assignment Channels A, B, and C are positioned to minimize interference from TV set oscillators while Channels E, F, G, and H are positioned to give minimum image effect on Channels 2, 3, 4 and 5. Similarly, in the Super Band, Channels I through N are chosen to avoid oscillator interference and Channels P through U are chosen for minimum image effect on Channels 8 through 13.

In chosing the assignment for least image effect, the following example is given -

Desired	Local Oscillator	-	Channel 3	=	I.F.
	107 MHz	-	(61.25 Vid; 65.75 Aud)	=	(45.75 Vid; 41.25 Aud)

Image	Channel F (148.75 Vid; 153.25 Aud)	-	Local Oscillator 107 MHz	=	I. F. (41.75 Vid; 46.25 Aug)

The frequency on the system is chosen so that the image interference from the video carrier falls at 4.0 MHz or above in the IF and the sound carrier (which is usually 15db weaker than video) falls at -0.5 MHz in the channel.

Conclusion:

Cable systems are capable of carrying channels in the spectrum between VHF Channels 6 and 7 and above Channel 13. The Mid Band should give us no trouble if we chose the best possible assignment to minimize the effects of oscillator leakage and image. The data presented shows that oscillator leakage into this spectrum from the TV set is substantially lower than the leakage into the Super Band. The image rejection of tuners in the low VHF band is also better than in the high band and, in addition, the isolation between customer taps in this range is typically better than the 20db figure quoted in Figure I. The Super Band becomes more of a problem, since oscillator leakage, image rejection and customer tap isolation are all at their poorest performance level. Choosing the best frequency assignment for the Super Band is an appropriate step under any condition. If a particular customer (Viewer A) is causing interference with another (Viewer B) a special low pass filter, passing up to Channel 13 and then dropping off rapidly, could be inserted into the offenders drop line only when such interference exists.

Appendix

Description of Television Sets Used in Table II

TV Set	Description
A	1968 RCA 23inch Color Set
B	1963 Zenith 23inch Black & White
*C	1967 Zenith 23 inch Color Set
D	1967 Motorola 17 inch Color Set
E	1969 Zenith 23 inch Color Set
**F	1964 Zenith 23 inch Black & White

*Two identical sets were tested with almost identic 1 results
**This set appears to have traps at tuner input to minimize leakage. Any adjustment of fine tuner greatly worsens these readings.

DISCUSSION

Mr. Jeffers: Are there any questions? Come up to the microphone, please.

Mr. George Brownstein: I'm a consulting engineer. I've followed with quite a bit of interest the talk you just gave and there's one point which I consider quite important that I notice that you didn't cover and perhaps you have given it consideration, but I also notice that in the general trend of the industry, the industry doesn't seem to be giving it any particular emphasis. This has to do not so much with a particular frequency that you assign for the mid band frequencies, but the area of the spectrum that you assign them in. What do I mean? The area that the frequencies for the mid band being assigned to fall, generally, above the FM band and below Channel 7. That's put them practically in the middle of the aviation band and I notice that in some of your recommendations, some of your frequencies fall in the middle of the aviation band. They range from roughly 108 to 120 megacycles which is used for ILS (Instrument Landing Approach Systems).

Approximately 10 years ago, a company that I was formerly associated with, did some work and some research in this area. And we were very concerned at that time, of course, we were involved with cable systems in putting two kinds of information on the cable system both of which were video, but one was in the normal 54 to 216 band and the other was in the mid band area and the biggest thing that worried us was not that we couldn't send the signals down the cable, but suppose we did and the fault condition developed on the cable. We could just see an airplane come homing in on one of our carrier frequencies, and you can, of course, imagine what the end result of that would be.

Now I notice with a great deal of disturbance that the industry has sort of bemused itself with these additional frequencies and are doing a lot of arithmetic which makes a certain amount of sense, but what consideration has been given to the fault condition once you go into operation in this area and suppose you have been in operation for five years and a fault condition develops either in the amplifier, or the fitting, or the drop cable going into the subscriber's home? How do you answer questions like that?

Mr. Jeffers: Well, I can give you my opinion, but I am far from an expert in that area. First of all, I think you'll find the ILS band stops at 118 and although the band edge of the lost channel, I indicated, was down into that band that the carrier was up at, I believe, 118¼. Now, there is no question that that channel, I think, in certain instances, might have to be dropped. Another thing, of course, in the last 5 or 6 years with the use of solid sheath cable, the radiation from the systems is down substantially. First of all, remember the worst power level--the highest power level--in this entire CATV is of such a low magnitude that you're really in a complete open circuit probably not putting too much out to the air, although certainly something significant. I think most of the mid band would be in the aviation communications band, not in the navigation aids band. If you'll notice, also, how many millions of oscillators from TV sets are radiating into that band at 113 megahertz right now and apparently it has not been a problem. In addition, I think you'll find the modulation on the ILS is of such a nature that it would probably see through any disturbance that could come from CATV. But again, let me repeat, these are my opinions.

Ken Easton: Toronto, Canada. I'd like to make two comments. First of all, I was interested in the superposition of that curve on the Jerrold curve showing the requirements of broadcast procedure 23 which within the next 3 or 4 months is going to be a mandatory performance standard in Canada for all CATV systems, existing as well as new. I was interested to see the extent to which that curve is above the Jerrold curve by, as far as I can see, about 12 or 15 dB. I would like to make the comment that the Procedure 23 curve is, of course, a minimum performance standard and it would be expected that the design curve, the design standard, would be somewhat better than that---shall we say 12 or 15 or, at least, 10 or 12 which, I guess, would put it pretty close to your Jerrold curve. So I'm gratified to see that.

The second comment I would like to make is in support of George Brownstein's remarks concerning this question of radiation. In Canada, the Department of Communications which, of course, is the technical licensing authority of the cable systems is not, at present, prepared to approve the use of the mid band for this very reason. They are concerned and very concerned about the radiation from systems and by radiation they don't just mean radiation under normal operating condition, but as George pointed out, radiation under any, including fault conditions. There is no question that with solid sheath aluminum cable and the lower power levels which we use now compared with the older tube equipment, that the radiation from a working system in good condition is very much lower than it would have been under the old systems. But we have to concern ourselves with fault conditions and the thing that worries the Department of Communications is the fact that, in Canada, our radiation limit, at the moment, for any frequency--any frequency--including the high VHF band outside of the low VHF channels 2 to 6 is 9 microvolts per meter at 30 feet and they're very concerned about the fact that quite apart from the ILS band that George spoke of, there is a very considerable useage of land mobile within that band and many of these land mobiles have receivers having sensitivity of a half a microvolt and 9 microvolts a meter at 30 feet doesn't do them any good at all and they're looking at this whole question right now and are not prepared to license the use of this band until they have, in fact, substantially modified the radiation limits--to what, I don't know yet, but substantially better than 9 microvolts per meter.

Mr. Jeffers: By the way, again not being an expert on the radiation problem, I'll pass that, but let me emphasize that the so-called Jerrold curve, as I said, is an extremely critical curve. I would guess that a curve about 5 dB less offensive than that would be perfectly adequate. Thank you.