ADDENDUM

A PRELIMINARY ESTIMATE OF THE EFFECTS OF SPREAD SPECTRUM INTERFERENCE ON TV

John R. Juroshek

The material on pages AD-1, AD-2, and AD-3, AD-4 (inside back cover) is to be appended to Section 5, Adjacent Channel Interference.

It is possible to estimate the extent of interference from a signal in an adjacent channel using standard methods if the emission spectrum of a spread-spectrum system is known. The total interfering power from a single adjacent channel interferer is (CCIR, 1974)

$$I = \int_{f_1}^{f_2} s(f)\ p(f)\ df \quad , \qquad \text{(AD-1)}$$

where f is the radio frequency and p(f) is the power density (watts/hertz) of the interfering emission at the receiver antenna terminals. The selectivity function, s(f), is the fraction of the power at frequency f that is admitted to the receiver. The limits of integration are chosen to include all frequencies with appreciable power.

Figure AD-1 on page AD-3 shows an example TV selectivity curve with an interfering spread-spectrum emission in the upper adjacent channel. Notice that the vertical scale is logarithmic. The in-channel portion of the TV selectivity is the FCC cw protection criteria shown in Figure 8. The adjacent channel (6-12 MHz) portion of the curve was drawn to be above the measured curves in Figure 8. Comparison with data in FCC Report LAB-74-01 (Roberts and Middlekamp, 1974) shows that about 90 percent of the TV receivers measured had adjacent channel rejection this good or better.

The spread-spectrum emission power density in Figure AD-1 is a close approximation to the emission of the Extended Area Test System (EATS) measured by Haakinson et al. (1977). The 4-MHz bandwidth of EATS is near the maximum that could be assigned in a TV channel, and the emission shape has been realized in the prototype hardware. Thus, the emission shown in Figure AD-1 is a realistic possibility.

Figure AD-2 shows the product s(f)p(f). The area under this curve is proportional to the total interfering power in the TV receiver. The large area on the right is due to the main portion of the SS emission, reduced by the TV selectivity. The smaller area on the left is from the "skirt" of the SS emission that overlaps the wanted TV channel. For this case, the area on the right is 1.3 (10^{-4}) and the area on the left is about one-fifth of that--2.5 (10^{-5}).

The emission spectrum of a conventional FM LMR is about 16 kHz wide. To have the same total power as a 4-MHz SS emission, the power density would have to be 250 times as great. If plotted on Figure AD-1, the emission would be about the width of a line and would extend off the top of the page. The 16-kHz channel is so narrow that the TV selectivity is essentially constant over it. If the FM emission is placed in the middle of the adjacent channel at 9 MHz, it produces $1(10^{-4})$ total interference power--about 2 dB less than that of the SS system.

The spread-spectrum system has greater interference power because some of its main emission is very near the wanted TV channel and because some of the skirt of the emission overlaps the channel. If the FM channel were placed nearer the TV channel, it would produce more interference. For example, if it were at 7 MHz, the interference would be 2.5 (10^{-4})--about 2 dB more than the SS system. In either case, the FM LMR system and the SS LMR system with the same total power produce about the same interference.

Now consider the effect of varying some of the parameters. If the SS bandwidth is reduced to 2 MHz with the same total power and emission shape and centered in the adjacent channel, it produces about 1.1 (10^{-4}) interference. This is almost exactly the same interference as the FM system, because now the SS power density does not appreciably overlap the wanted TV channel.

On the other hand, retain the 4-MHz SS emission and suppose that the TV receiver has 20 dB more adjacent channel rejection. [Measurements show that the best 10 percent of the receivers have 20 dB better adjacent channel rejection than the worst 10 percent (Roberts and Middlekamp, 1974).] Then the FM interference would be $1(10^{-6})$ and the adjacent channel SS interference would be 1.3 (10^{-6}). But the SS overlap into the desired channel would still be 2.5 (10^{-5})--14 dB greater than that produced by an FM system centered in the adjacent channel.

(continued on page AD-3, inside back cover)

NTIA-REPORT-78-6

A Preliminary Estimate of the Effects of Spread-Spectrum Interference on TV

J. R. Juroshek

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

Henry Geller, Assistant Secretary-Designate
for Communications and Information

June 1978

PREFACE

This work was supported by the UHF Task Force of the Federal Communications Commission.

Table of Contents

LIST OF FIGURES

A PRELIMINARY ESTIMATE OF THE EFFECTS OF SPREAD-SPECTRUM INTERFERENCE ON TV

John R. Juroshek*

The report examines the conditions under which spread-spectrum, land-mobile radio, and television can share spectrum. After a preliminary assessment, the report concludes that the interference caused by a constant amplitude, spread-spectrum system should be comparable to that caused by a conventional, narrowband, FM, land mobile signal of same total power, provided the spread-spectrum signal has an rf bandwidth less than 2 MHz. With spectrum spreads greater than 6 MHz, the spread-spectrum system should have some advantage because of the out-of-band rejection capabilities of a TV receiver. A limited number of laboratory measurements are also described that support the conclusions of the report.

Key words: Interference; land mobile radio; spread spectrum; television

1. BACKGROUND

This report is an initial assessment of the conditions under which spread-spectrum, land-mobile radio (LMR) and television can share spectrum in the 450-512 MHz frequency band. The report is intended as a quick preliminary study into the potential for interference and leaves many of the more detailed system questions unanswered. It should be noted that this report considers only interference from LMR to television with the reverse situation left to later studies.

2. INTRODUCTION

The question of whether it is an economical use of the spectrum to allow wideband communication systems in a multiuser environment has plagued communication engineers for some time. The debate is also likely to continue into the future since new technological advances often result in changes that make systems, once thought to be wasteful, much more attractive in terms

*The author is with the U.S. Department of Commerce, National Telecommunications and Information Administration, Institute for Telecommunication Sciences, Boulder, Colorado 80303.

of spectrum conservation. Spread-spectrum communications is an example of one such area that has been affected by technological changes. Recent advances in surface acoustic wave (SAW) and charge coupled devices (CCD) have simplified spread-spectrum systems and made them much more attractive for use in services such as land-mobile radio. This report will examine the problems of using spread-spectrum systems in the TV frequency bands.

For this study, we shall arbitrarily assume a direct sequence type of spread-spectrum system (Dixon, 1976). This does not necessarily mean that a direct sequence spread spectrum is the best type of system for land-mobile radio, but only that it is to be used for this interference study. Other types of spread-spectrum systems such as frequency hopping, time hopping, or chirp systems could prove to be more beneficial in terms of the needs of the 450-512 MHz band. However, we do not anticipate a significant difference in the interference characteristics produced by the different types of systems since the amplitude characteristics of a frequency hopping interferer are similar to the amplitude characteristics of a direct sequence interferer.

Figure 1(a) gives one example of a direct sequence, spread-spectrum system. Basically the input to the system is a 3 kHz voice signal. The voice signal is digitized and modulo 2 added to a binary bit stream generated by a pseudorandom noise (PRN) generator. This summed binary waveform is then sent to a balanced modulator where it is multiplied by a carrier of frequency, f_c. This process produces a wideband, bi-phase, phase-shift-keyed (PSK) waveform. At the receiver, the reverse process is implemented which consists of collapsing the wideband PSK waveform back into the narrower bandwidth, digitized, voice signal. The collapsed information bearing signal is then demodulated back into the 3 kHz voice signal. Also, the system could handle digitized information such as a teleprinter or cathode ray display.

A system such as the one shown in Figure 1(a) does have some disadvantages in that the digitizing or voice encoding process also generally expands the bandwidth. The amount of expansion depends on the encoding process used such as delta modulation, linear predictive coding, or pulse code modulation. Fortunately spectrum spreading at this stage is not entirely in

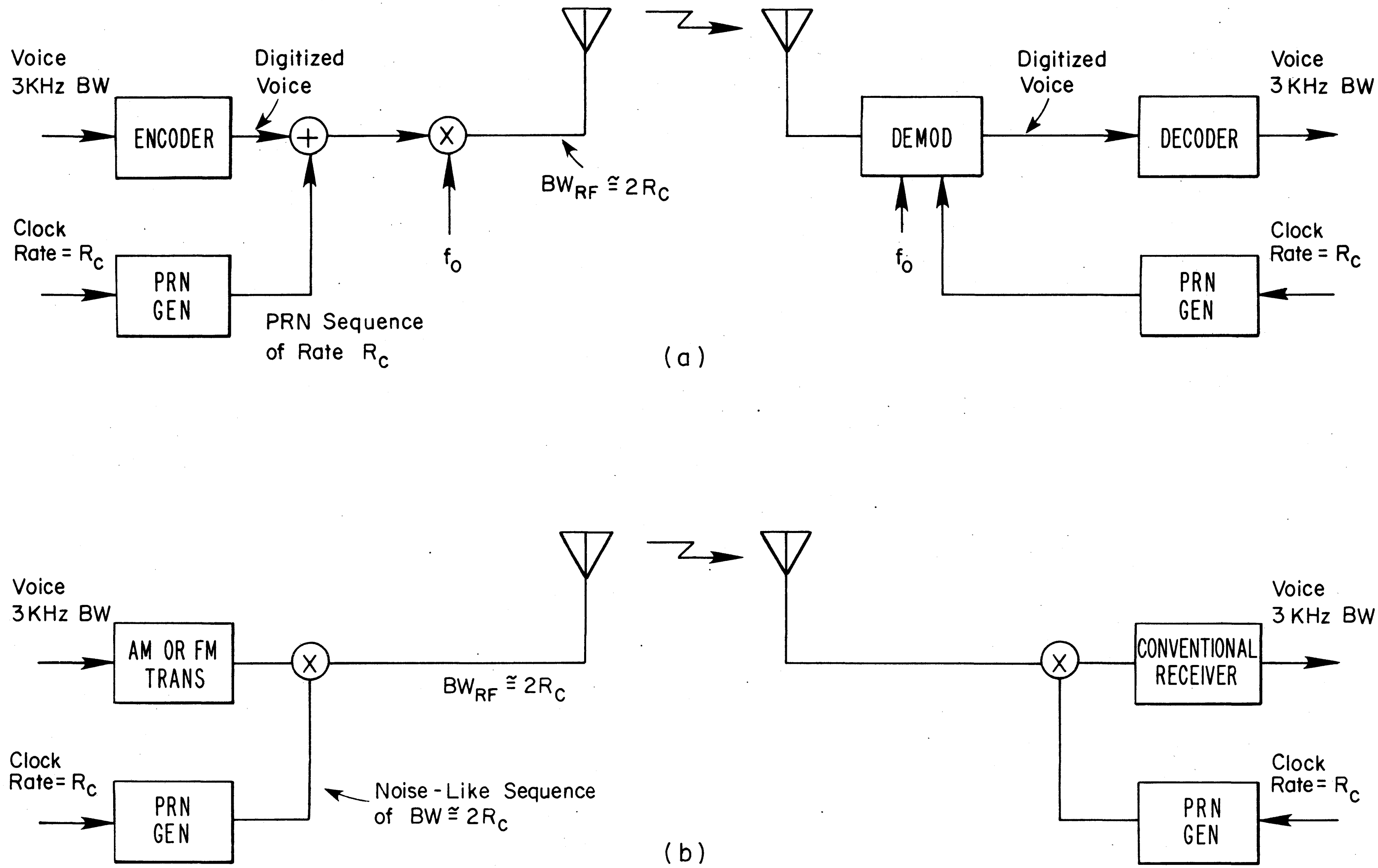


Figure 1. Examples of spread-spectrum systems.

vain in that some degree of additional noise and interference immunity is generally acquired in the digitizing process.

Figure 1(b) gives another example of a direct sequence, spread-spectrum system. In this system, the voice signal modulates a conventional narrowband AM or FM transmitter. The narrowband signal is then spread by multiplying it with a "noise-like" waveform generated by a PRN generator. The noise-like waveform may be either a conventional binary sequence as used in the previous system or an amplitude varying sequence similar to Gaussian noise. The receiver is nearly identical to the one described previously except that now a conventional receiver can be used to demodulate the voice.

The theory of direct sequence spread-spectrum systems tells us that the output power spectrum of this type of system is almost entirely determined by the clocking rate of the PRN generator (Dixon, 1976). In particular, if the PRN generator has a clocking rate of R_c, then the transmitted power spectrum will have a $\left((\sin x)/x\right)^2$ shape with an rf bandwidth of approximately

$$BW = 2\ R_c \quad ,$$

which is the bandwidth between the first two major nulls. Further, the theory states that, in the despreading process, the desired narrowband signal can enjoy a signal-to-noise ratio enhancement of g_p at the output of the receiver as compared to its input signal-to-noise ratio where

$$g_p = \frac{BW}{B_{info}} \quad ,$$

and B_{info} is the bandwidth of the information, which in this case has been arbitrarily chosen as B_{info} = 3 kHz. Figure 2 graphically shows the relationship between BW, g_p, and R_c. For example, we see that, at a chip rate of 1 Mbps, the rf bandwidth required is approximately 2 MHz, with a potential processing gain of 666 or 28 dB. We have labeled the processing gain as potential gain since system implementation losses will prevent full realization of this amount.

Prior to examining the detailed interference calculations, it will perhaps be beneficial to briefly list a few comments on the advantages and disadvantages of spread-spectrum systems in general. Examples of some advantages that are generally attributed to spread spectrum are:

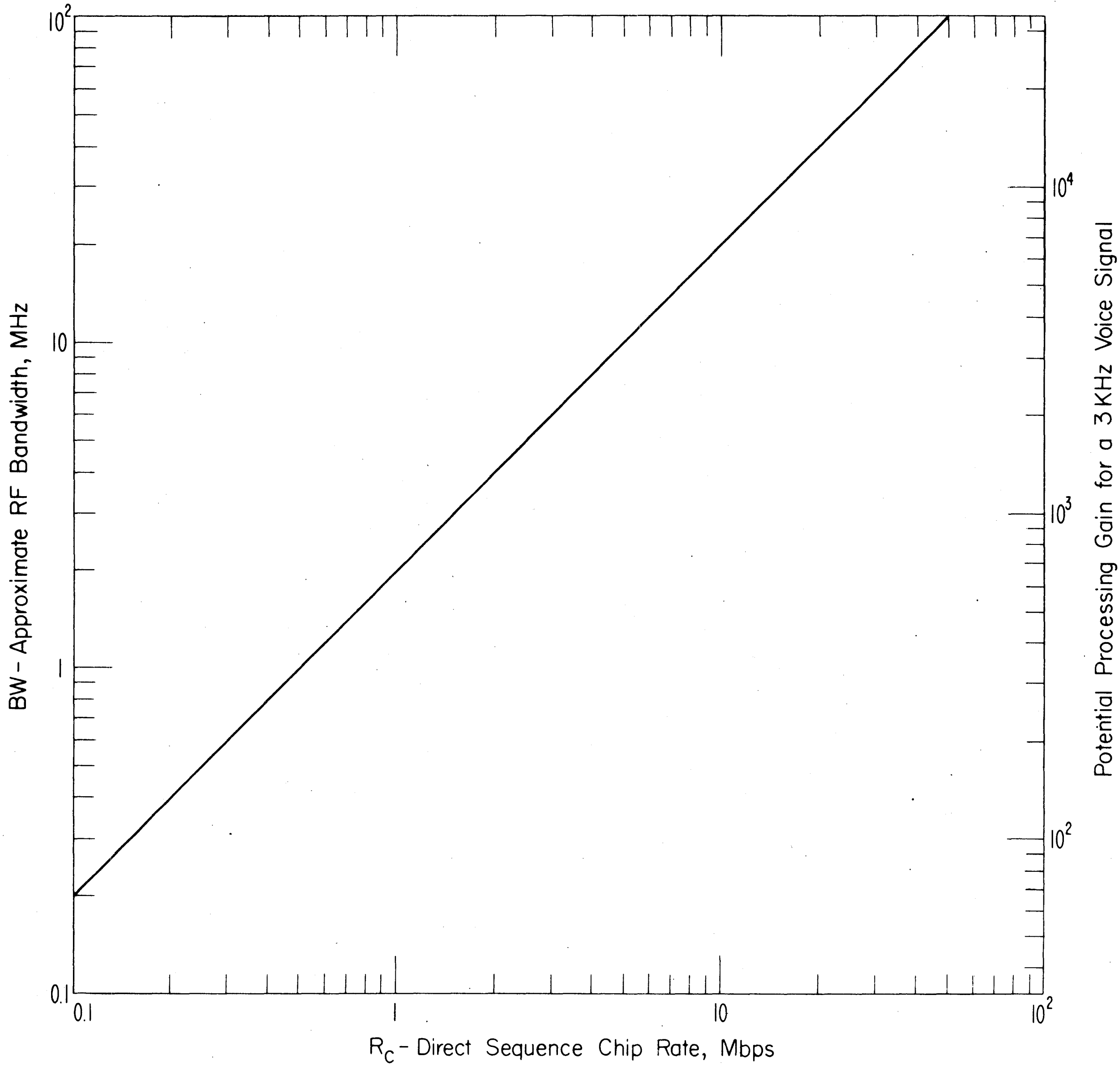


Figure 2. Spread-spectrum bandwidth versus system chip rate.

(a) Resistance to interference and jamming: Perhaps the greatest advantage of spread spectrum is its ability to reject unwanted signals. Uncorrelated signals do not enjoy the benefits of processing gain in the despreading process.

(b) Security: The system has security advantages in that a the power-spectral density can be less than the normal background noise. The system can also use conventional digital encryption techniques.

(c) Graceful degradation: A multiuser spread-spectrum system generally degrades gracefully as the number of users increases. Additional uncorrelated users appear as additional wideband noise.

(d) Relatively low power density: Power spectral density is generally lower than for a comparable narrowband system. Thus, the potential for interference to a narrowband system is also generally less.

(e) Priority: A multiuser system can establish priority simply by letting some users radiate more power than others.

(f) Surface acoustic wave devices: Attractive system implementation options exist with the use of surface acoustic wave devices. Spreading and despreading circuits can be implemented relatively easy.

(g) Resistance to multipath: A wideband, spread-spectrum system exhibits an inherent resistance to multipath. Sufficiently delayed multipath signals appear to be additional noise once synchronization has been established.

Some of the disadvantages are:

(a) Complexity: The complexity of the system generally results in more sophisticated and costly equipment.

(b) Synchronization: Synchronization and acquisition problems are often a major factor in system design and system performance. Synchronization and timing problems are also increased in a doppler environment where one or more of the terminals are in motion and their locations unknown.

(c) Capture by a strong signal: The system can be captured by a strong nearby interfering signal. This could be particularly important to two collocated mobiles where one is trying to transmit while one is trying to receive. A potential for catastrophic failure of an entire system due to a single strong interfering source is always possible.

(d) Bandwidth expansion: A spread-spectrum system requires a reasonably large block of spectrum. Implementation of a system with bandwidth expansion factors much below 100 are probably not practical due to implementation losses and the relatively small processing gain advantages.

3. INTERFERENCE TO TV

So far we have considered two types of direct sequence systems, as shown in Figures 1(a) and (b). Although both transmitted signals are spread with a PRN sequence, the characteristics of the radiated signals are entirely different. In Figure 1(a), a system is shown that essentially transmits a constant amplitude, phase-shift-keyed signal. Figure 1(b), however, considers a system that can transmit an amplitude varying PRN signal. These two types of signals will certainly have a different effect in terms of interference to TV. This report will consider only the constant amplitude type of radiated signal since this form of spreading is simpler to implement and is probably the type that is currently used most often.

As a basis for comparison, we first examined the effects of conventional narrowband, constant amplitude interferers on TV. Figures 3 and 4 (FCC, 1968a) give two such examples. Both of these graphs show the minimum signal-to-interference ratio necessary to achieve acceptable performance with interference from conventional FM land-mobile transmissions. Although it is not the intent of this report to describe the results of the original tests in any detail, it is important to know that both of these curves reflect the minimum signal-to-interference ratio necessary to insure an acceptable level of interference. Acceptable interference is also described as "perceptible" or a level of interference that "ultimately might be adopted in the interest of maximum spectrum sharing." Signal-to-interference ratio, in these two figures, is defined as the ratio of the total

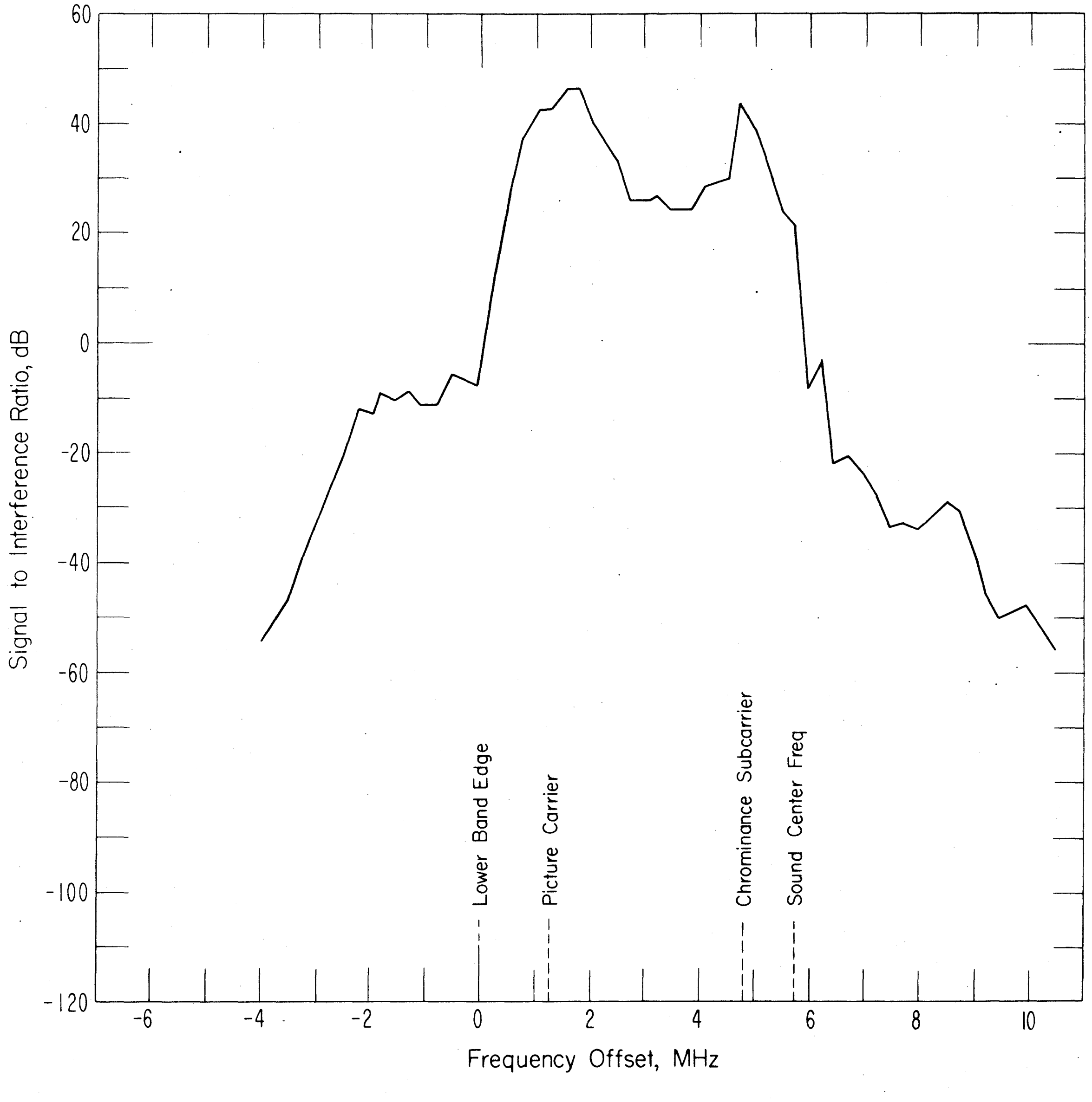


Figure 3. Example of minimum required signal-to-interference ratio for VHF TV. The interfering signal is a voice modulated FM signal with a 5 kHz peak frequency swing.

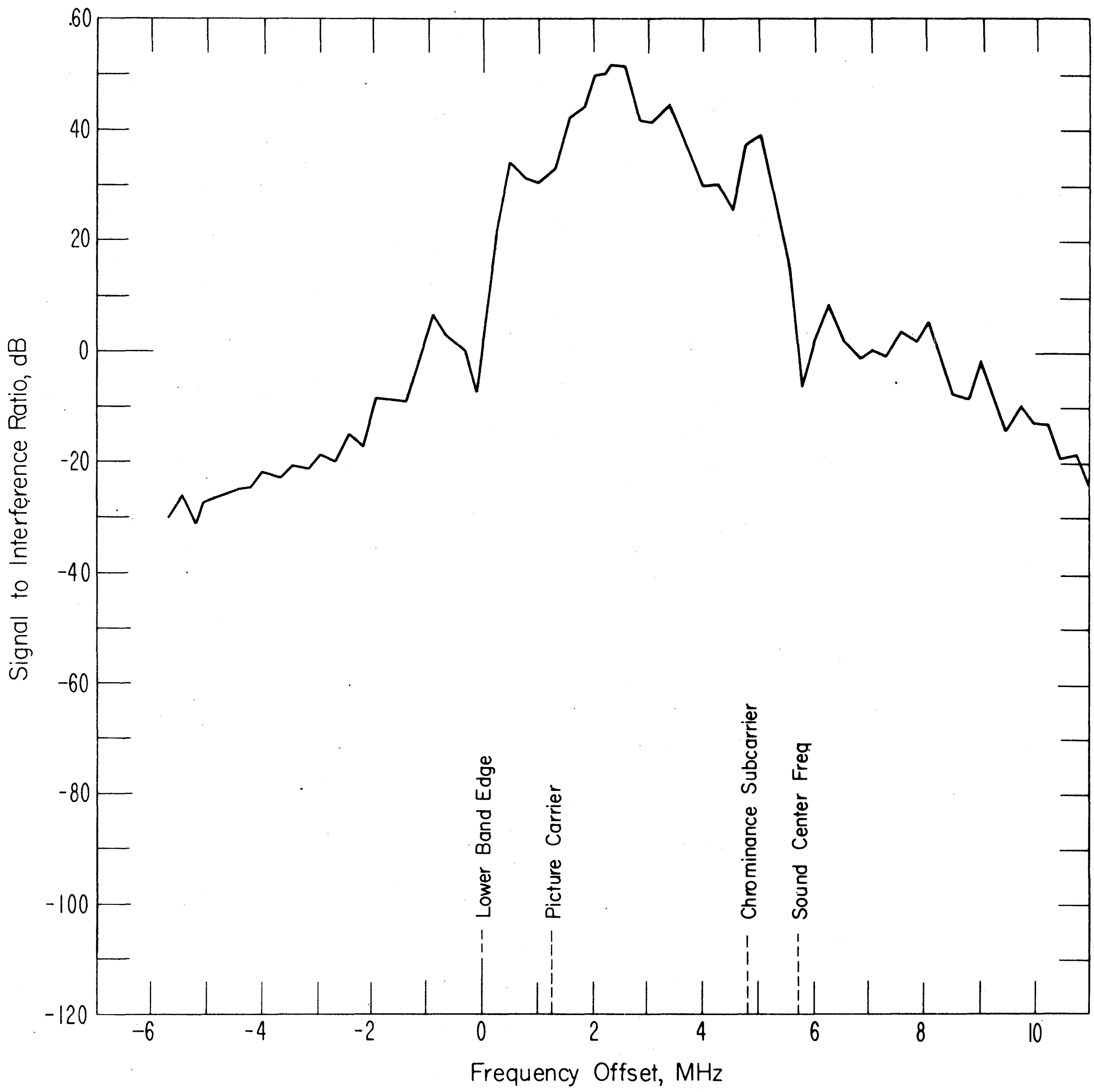


Figure 4. Example of minimum required signal-to-interference ratio for VHF TV. The interfering signal is a voice modulated FM signal plus a second cw interferer of equal strength.

power in the visual signal relative to the total power in the interfering signal in decibels. Frequency offset in these figures is the frequency difference between the interferers center frequency and the lower band edge. It should be noted that the curves in these figures, as well as in some of the others to be described in this report, were obtained by replotting the referenced data in a common format convenient for comparison purposes.

Figure 3 shows the results of FCC laboratory measurements of interference tests conducted with a voice modulated FM signal. The tests in Figure 4 are similar except that now a second cw interfering signal is added to the FM signal at an equal level and with a 15 kHz frequency separation. It is interesting to note that both Figures 3 and 4 show about the same amount of interference whether the interferer is centered over the picture carrier or the chrominance subcarrier.

A third example is shown in Figure 5 (FCC, 1968b) where similar tests were conducted with the interference now composed of three constant amplitude interferers added together (one FM plus two cw signals ±30 kHz from first). This figure essentially shows the minimum signal-to-interference ratio that is necessary to achieve a level of interference that was judged by a panel of observers to be a median of TASO 3, which means the picture quality was judged to be passable (ITT, 1975). The figure is also important since three interferers produce an interference environment that has amplitude variations. This is in contrast to the previous tests that all had constant amplitude interference. Note that all of these examples are similar.

So far this report has examined only interference to VHF TV. The frequency band of interest here is in the UHF frequency band, which might behave differently because of the presence of the UHF converter. Figure 6 differs from the others in that it shows laboratory measurements (Brandel, 1977) of interference to UHF channel 41. Although the frequency of this measurement is above the frequency band of interest in this report, the results do not appear to be drastically different from those reported previously. These curves show the minimum signal-to-interference ratios necessary to insure acceptable TV performance with an FM land-mobile interference.

It is interesting to view a composite of the experimental data along with other current TV interference protection criteria. In Figure 7 we show a composite of Figures 3, 4, 5, and 6 along with the current CCIR recommended

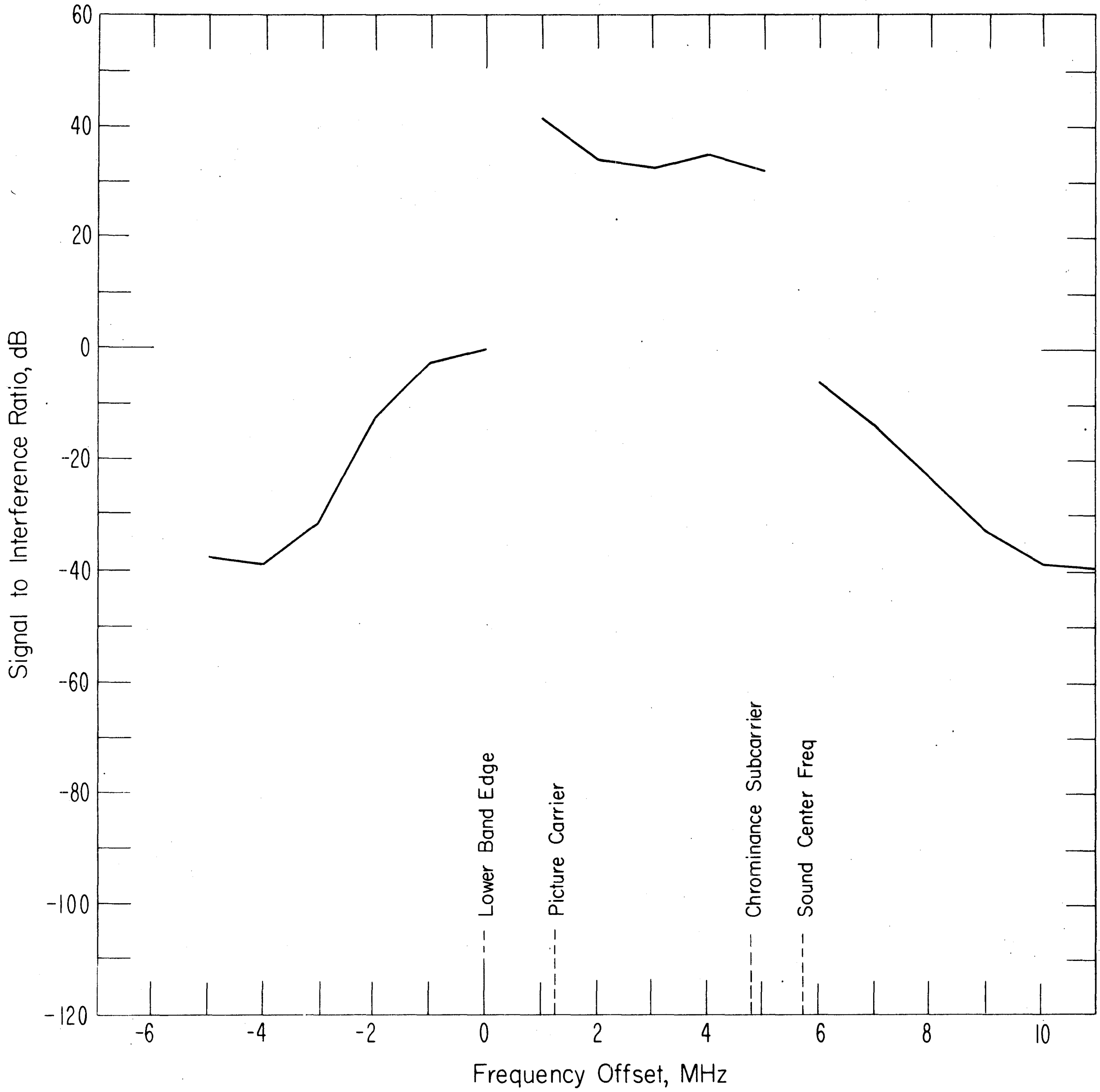


Figure 5. Example of minimum required signal-to-interference ratio for VHF TV. The interfering signal is a voice modulated FM signal plus two cw interferers all of equal strength.

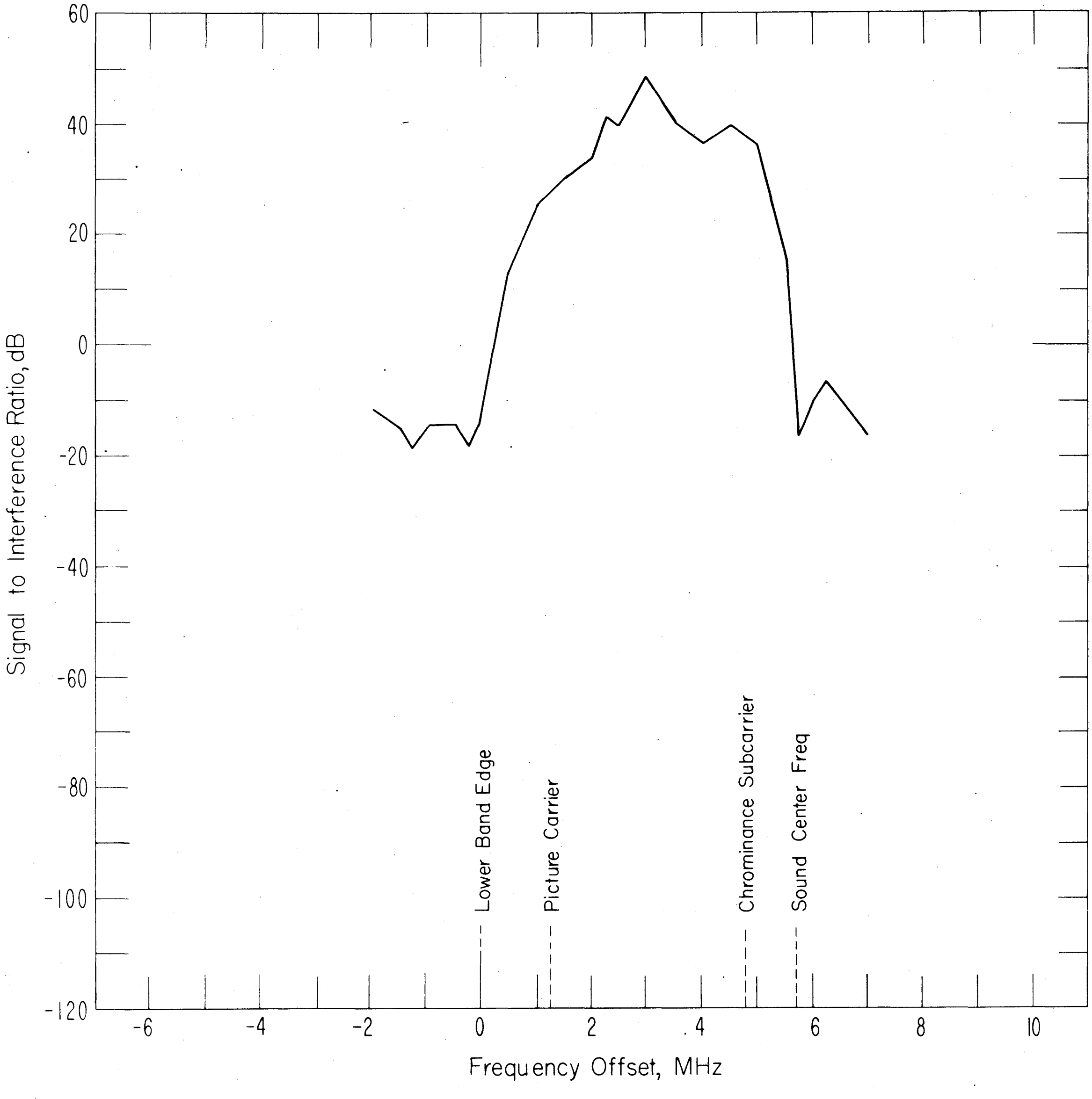


Figure 6. Example of minimum required signal-to-interference ratio for UHF-TV channel 41. The interfering signal is a single FM interfering source.

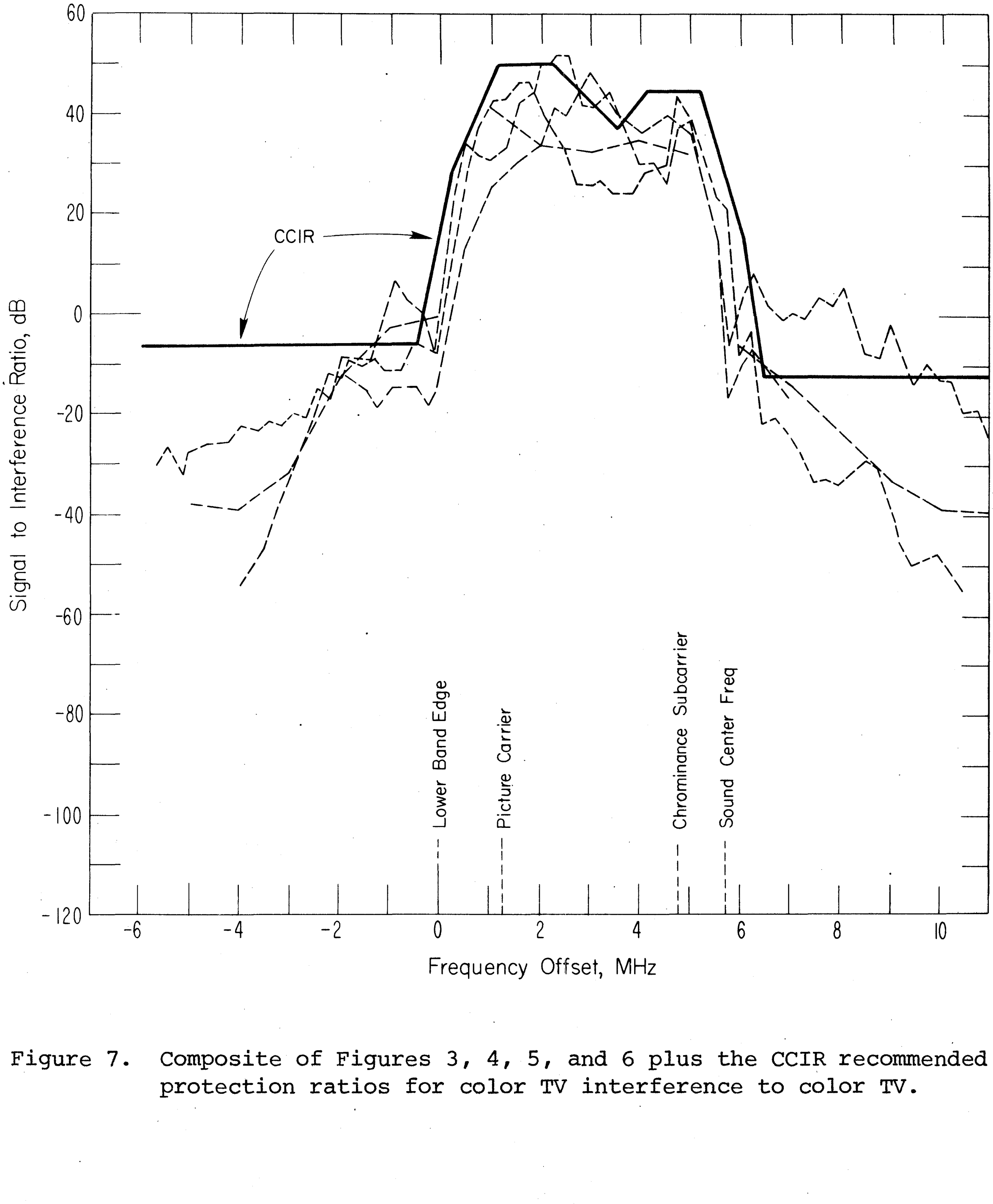


Figure 7. Composite of Figures 3, 4, 5, and 6 plus the CCIR recommended protection ratios for color TV interference to color TV.

protection ratios (CCIR, 1974a) for color TV interference to color TV. Figure 8 is a similar example where we now compare the experimental measurements with the FCC recommended protection ratios for interference to color TV from cw interference (Waldo and Daniel, 1963). Although the results are generally similar, the FCC curve does differ slightly in that it recommends approximately 5 dB more protection be given to the chrominance signal than to the lower frequency video signal. The reason for this needs to be explored in more detail.

It would appear from these tests that the interference mechanism of interest here is a simple interaction between an amplitude-modulated picture or chrominance signal and the interfering signal. Since the rf spectral bandwidths of both the chrominance and picture signals are of the order of 2 MHz, a spread-spectrum signal with a lesser rf bandwidth would be largely unfiltered in the TV receiver and, therefore, should produce interference similar to a conventional FM land-mobile signal. While it is acknowledged that the spectral shape of an interferer can have an effect on the level of interference, the magnitude of the effect is generally felt to be second order in view of the preliminary nature of this study. For example, interference from a noise source with a triangular spectral shape can be approximately 5 dB greater than from a noise source with a flat noise spectrum and still produce the same subjective level of interference (CCIR, 1974b). In other words, the interference produced by a constant envelope, spread-spectrum signal (2 MHz spread or less) should be nearly identical to that produced by a narrowband FM modulated signal of equal power. For spectrum spreads greater than 2 MHz, some additional advantage can be expected since some of the interferers power can be rejected because of filtering in the video and IF circuits. It is difficult to tell exactly where this filtering advantage occurs because of a lack of detailed information on the effects of wideband spread spectrum interference to TV and a lack of detailed information on the filtering characteristics of a typical TV receiver.

Figure 9 has been prepared as a summary of our estimates of the potential for interference from a spread-spectrum signal. In this figure a plot of the estimated interference effect relative to a narrowband FM land-mobile signal is shown as a function of the direct sequence chip rate (rf bandwidth is also shown at the top of the plot). For chip rates up to 1 Mbps,

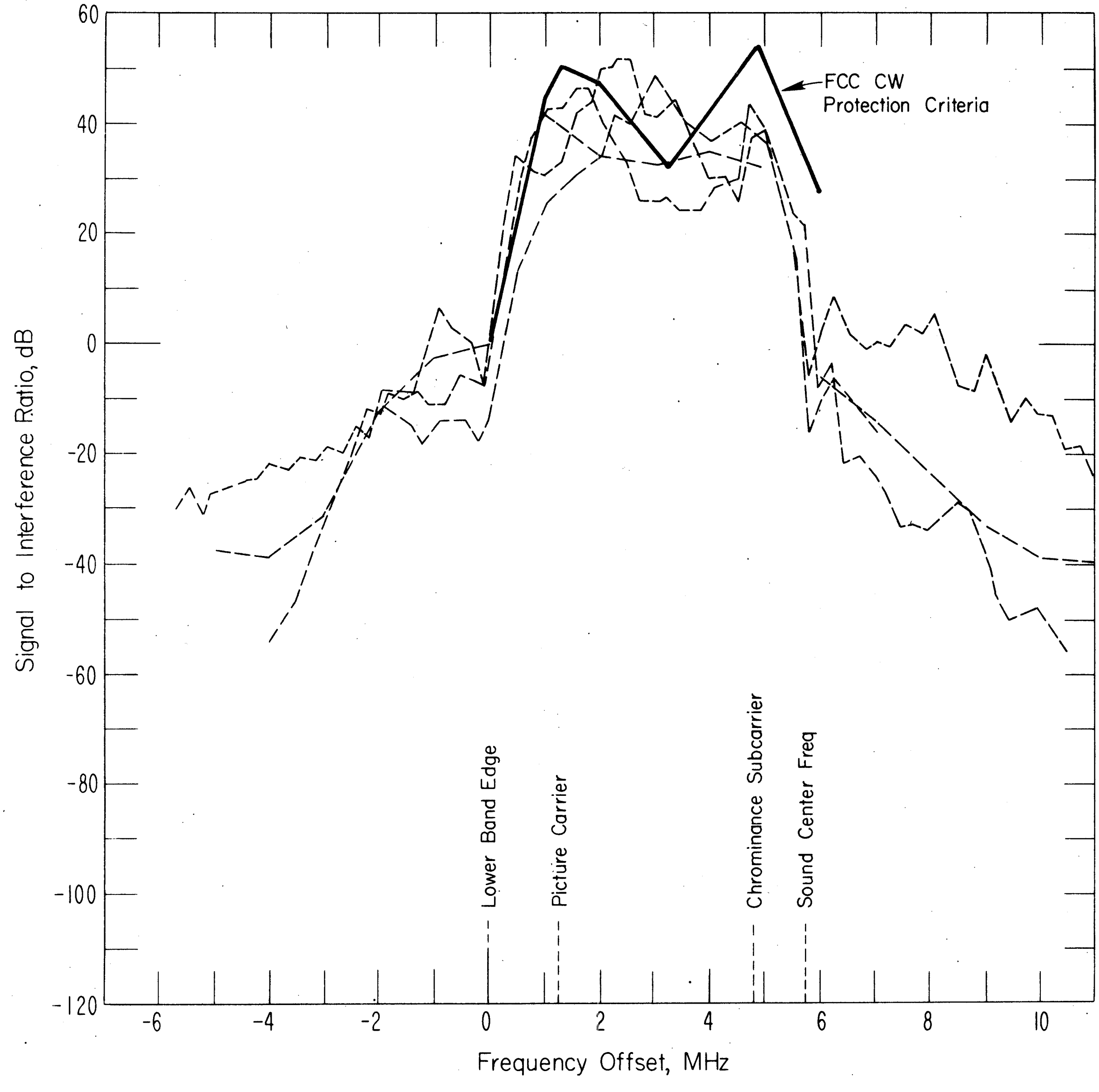


Figure 8. Composite of Figures 3, 4, 5, and 6 plus the FCC recommended protection ratio for cw interference to color TV.

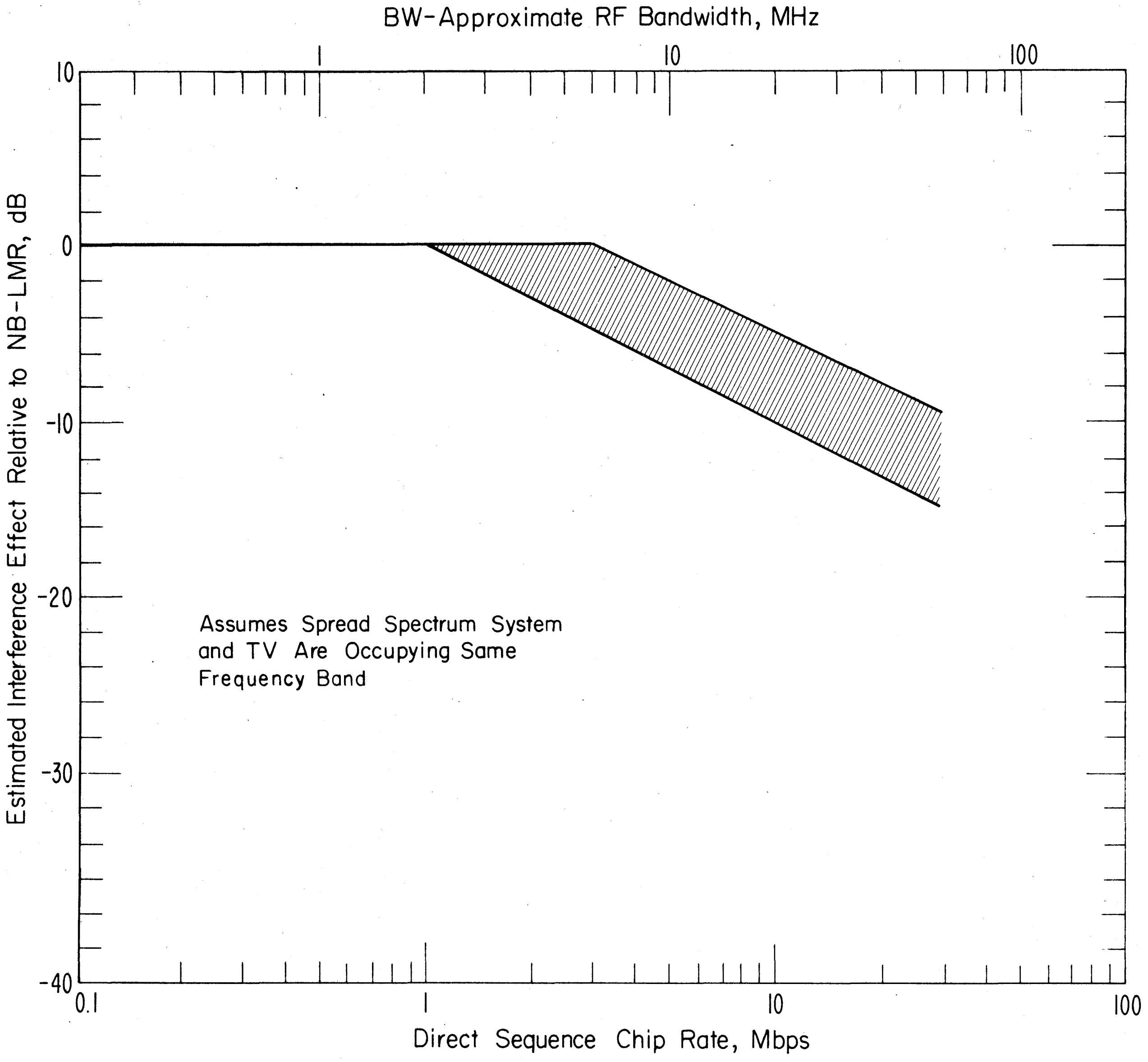


Figure 9. Estimates of the interference potential of a spread-spectrum signal as compared to a narrowband FM, land-mobile radio interferer.

the plot shows 0 dB, which means we expect the degradation produced to be nearly identical to a conventional FM land-mobile signal of the same total power. For bandwidth spreads beyond 2 MHz, a linearly decreasing curve is shown, indicating that the spread-spectrum system is expected to be less detrimental than an FM signal of the same total power since the TV receiver should be able to reject some of the out-of-band portion of the interfering signal. The curve assumes the amount of rejection to be directly proportional to the spreading. A shaded area is shown to acknowledge that it is not clear whether this advantage will begin to occur with chip rates near 1 Mbps (2 MHz rf spectrum) or at chip rates greater than 3 Mbps (6 MHz rf spectrum). The exact values for these estimates depend, of course, on a number of factors such as TV receiver design and can be determined only after experimental measurements. The exact shape of the interfering spectrum will also influence the results.

In view of these conclusions, the rules for protecting TV from spread-spectrum systems operating within a TV band could be as follows:

$$S/I \text{ min} = 50 \text{ dB} \qquad BW \leq 6 \text{ MHz}$$

$$S/I \text{ min} = 50 - 10 \log (BW/6) \text{ dB} \qquad BW \geq 6 \text{ MHz}$$

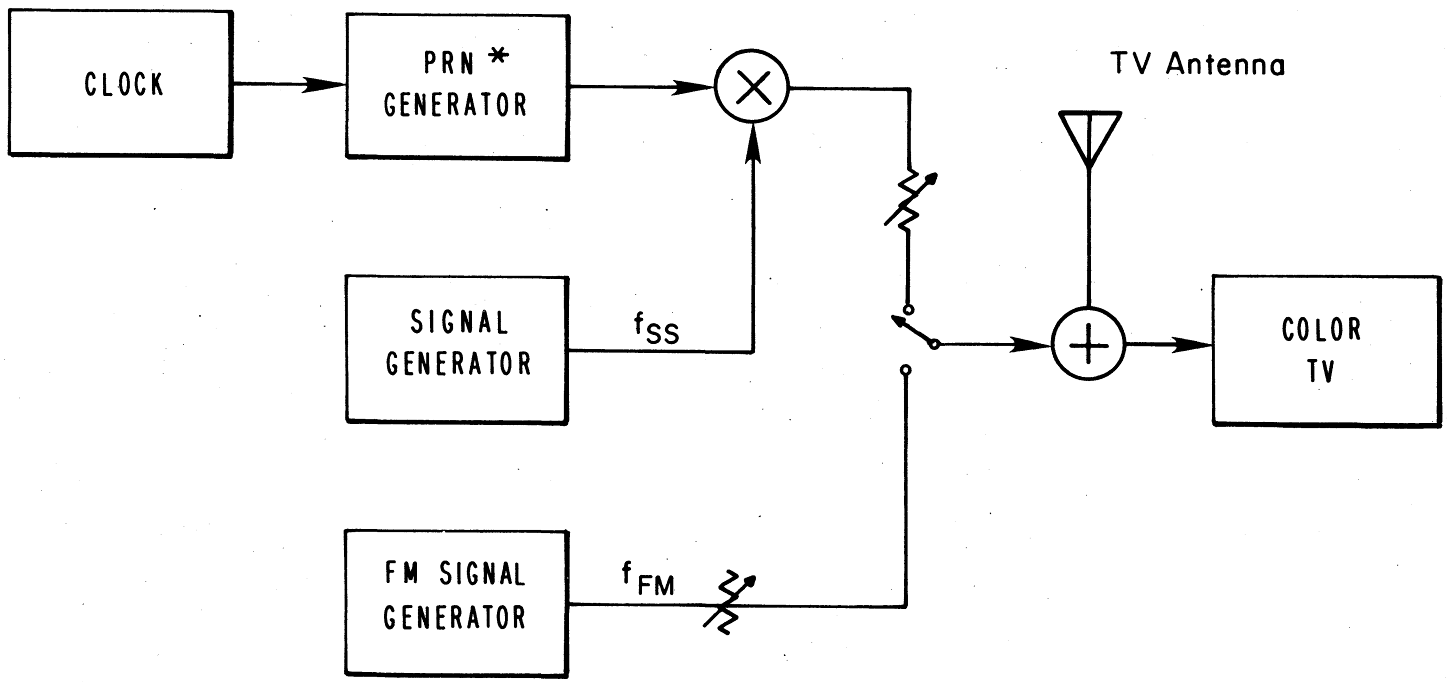
These equations are estimates based on the current protection ratios from cw interferers, and the exact numbers might be modified slightly with additional experimental evidence. For the adjacent channel case, which is taken to be the case where the TV and the spread spectrum's spectral energy does not overlap, the protection ratio would probably be

$$S/I \text{ min} = -6 \text{ dB} \quad ,$$

which is based on current minimum adjacent channel rejection capabilities of a TV receiver. Spread-spectrum signals separated more than one channel away may be able to operate at even smaller signal-to-interference ratios.

4. EXPERIMENTAL MEASUREMENTS

A limited set of laboratory measurements were made in order to check the assumptions made in the report. The laboratory setup, as shown in Figure 10, uses a commercial generator to produce a binary PRN waveform. This binary waveform is adjusted so that it has a zero dc component. Next



* Tests were also conducted with a random generator in place of the pseudorandom generator.

Figure 10. Block diagram of laboratory tests.

it is multiplied by a sine wave of frequency f_{ss} in a balanced modulator producing a conventional bi-phase, PSK, direct sequence, spread-spectrum signal. A conventional FM generator is used to simulate an FM land-mobile signal. For simplicity, the FM generator is modulated with a 1000 Hz tone with the peak frequency deviation adjusted to 5 kHz. Both of the simulated signals are routed through adjustable attenuators where they can be adjusted in magnitude. After the attenuators, one or the other of these signals is selected by a coaxial switch, and the selected signal is then added to the TV signal that is received on the laboratory antenna. The result is then viewed on a 19-inch, portable, color TV.

The laboratory tests were conducted by subjecting various personnel to a more-or-less random selection of interference conditions. A comparison method was used where a given level of FM interference was set, and the viewer was then asked to adjust the spread-spectrum attenuator to produce a "comparable" level of interference. The viewer could readily switch between the FM and spread-spectrum interference until he was satisfied that he had adjusted the degradation to be the same. The attenuator settings were then recorded so that the difference between spread-spectrum and FM interference power could be determined. It should be noted that the frequency of both the spread-spectrum and FM signals were set prior to each series of tests by adjusting the attenuators for a moderate level of interference and then asking each viewer to adjust the two frequencies to produce the worst interference conditions. Once these frequencies were set, they were not changed throughout that viewer's sequence of tests.

The main portion of the tests were made with a PRN generator that produced a maximum length sequence of $2^{15}-1$ bits. Clock rates of 0.1, 0.5, 1, and 5 Mbps were used, which produces a spread-spectrum signal with an rf bandwidth of 0.2, 1.0, 2, and 10 MHz, respectively. A limited series of tests were also conducted using a binary generator that produced a random, nonrepeating, binary sequence. Unfortunately, this generator could not be clocked at rates above 0.1 Mbps. In addition to varying the direct sequence clock rate, the ratio of TV signal to FM interference (TV/FM) was also set at either 34 or 39 dB. The power level of the TV signal was measured on a spectrum analyzer as the maximum observed power of video portion of the signal.

The tests with the PRN generator were conducted using three observers. Each observer was subjected to the same combination of clock rate and TV/FM ratio three different times. The tests with the random generator were conducted similarly except that three different observers were used. Also, the PRN tests were conducted using TV channel 6, while the random generator tests used channel 4.

Results of the laboratory tests are shown in Figure 11 with squares and circles connected by vertical lines. The squares and circles denote the median values of nine observations from three observers. The median is used since the observations are the difference between the spread-spectrum and FM interference levels expressed in decibels. The lines on the symbols show the spread of the data with the highest and lowest value of the nine observations removed. A positive number on the figure means that less spread-spectrum power is required to achieve the same level of interference as the FM. Negative numbers are, of course, the reverse situation. As can be seen, the measurements generally agree with the predicted curve shown in Figure 9.

Figure 12 shows the spectrum of the PRN generated signal at clock rates of 0.1 and 5 Mbps. The spectrum using the random generator is similar except that the PRN generated signal contains discrete line spectra while the random signal is continuous. This can be seen by examining expanded views of the spectra. Figure 13(a) shows an expanded view of the PRN generated spectrum at a 5 Mbps clocking rate. As can be seen, discrete line spectra exist at approximately every 100 Hz. If the clocking rate is reduced to 0.1 Mbps, then the frequency separation between components decreases (repetition period of PRN sequence increases) as shown in Figure 13(b). The spectrum analyzer could not resolve the individual components at the lower clocking rate.

It is interesting to note the frequencies that were chosen by the observers as being the "worst" in regards to producing interference. Table 1 lists the frequencies selected by the observers where the first three entries are the frequencies chosen during the PRN interference tests to channel 6, and the last three entries are for the interference tests to channel 4. Note that the frequencies selected are near the video carrier frequency which for channel 6 is 83.25 MHz and for channel 4 is 67.25 MHz. None of

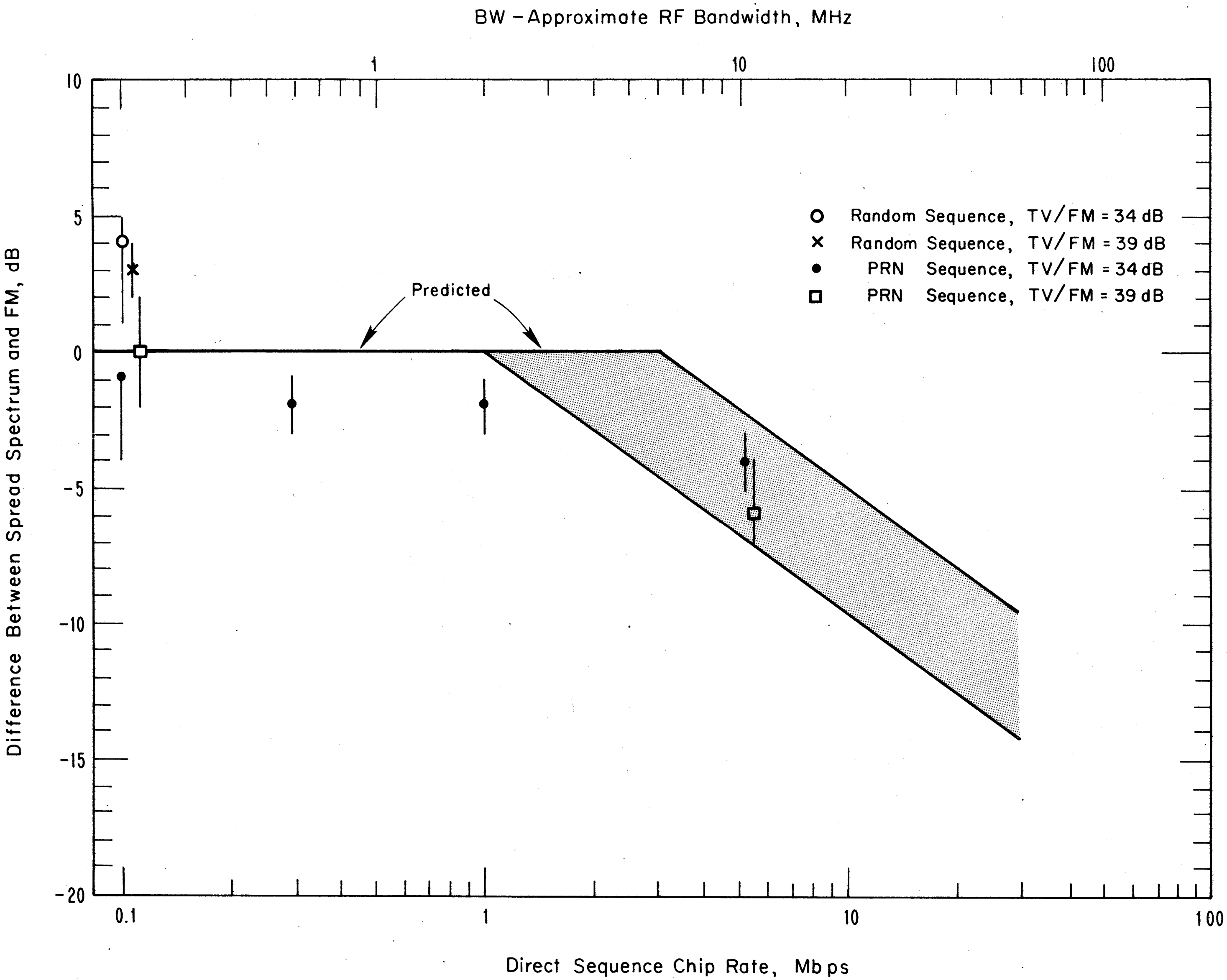


Figure 11. Results of laboratory tests showing median results and variability.

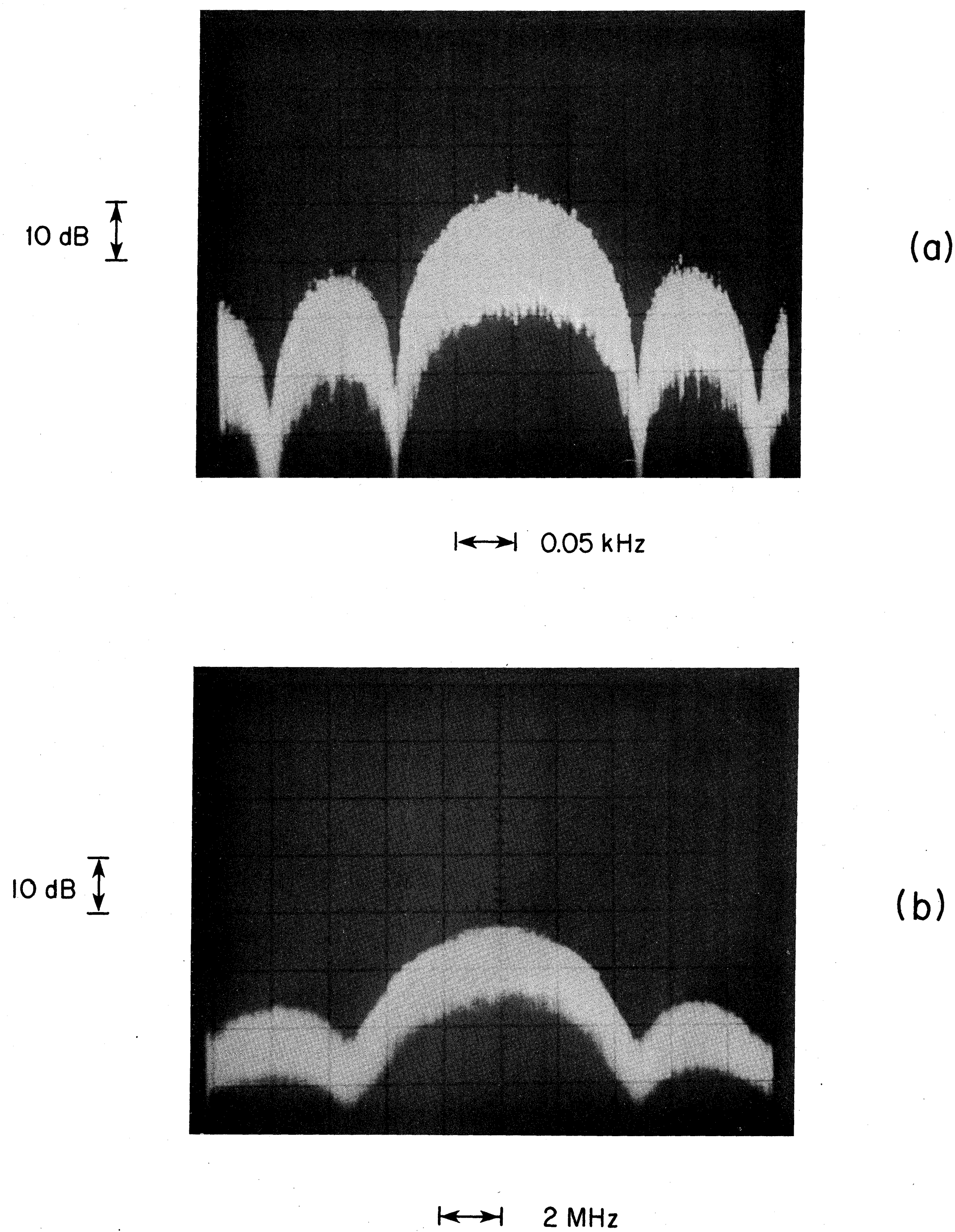


Figure 12. Spectrum of direct sequence PRN signals with clocking rates of (a) 0.1 Mbps and (b) 5 Mbps.

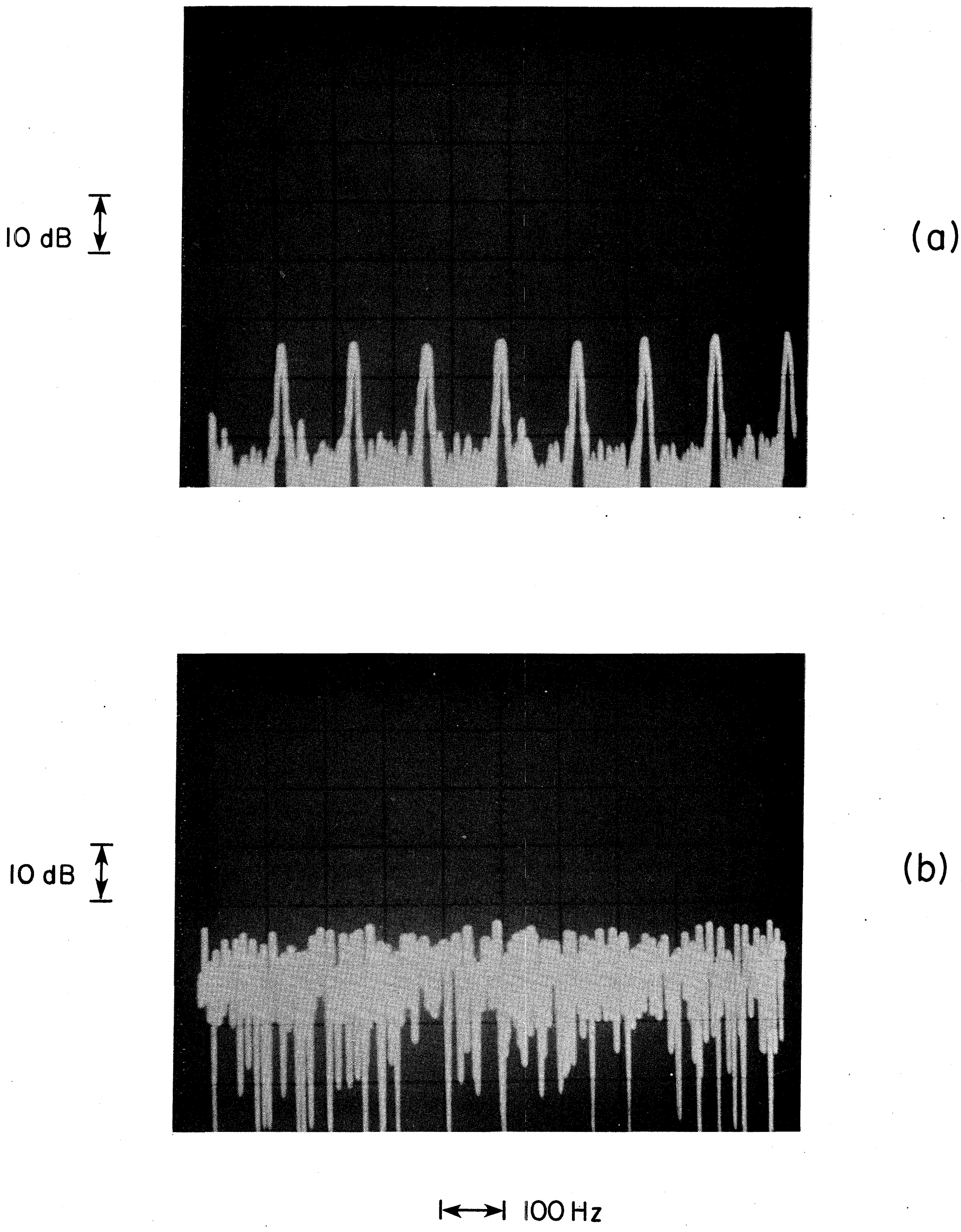


Figure 13. Expanded view of direct sequence PRN signals with clocking rates of (a) 5 Mbps and (b) 0.1 Mbps.

the observers selected frequencies near the chrominance subcarrier frequencies of 86.8295 and 70.8295 MHz.

Table 1. Frequencies Selected by Observers as Producing Worst Interference

Spread Spectrum	FM
83.409	83.934
83.772	84.090
83.118	83.431
68.185	67.472
67.869	68.013
67.475	67.463

5. ADJACENT CHANNEL INTERFERENCE

During the course of the study, we were also asked to consider the case where a spread-spectrum system was operating in a frequency assignment next to an operational TV station. The object being, of course, to compare adjacent channel interference from spread-spectrum systems with adjacent channel interference from conventional, narrowband, FM signals. Although measurements were attempted, they were abandoned because we felt the results were negatively influenced by the experimental setup being used. The reason for this conclusion can be seen by examining Figure 14 where the spectrum of a spread-spectrum signal operating in an adjacent channel is shown. The clock rate of the signals is 0.1 and 1 Mbps, which means the approximate rf bandwidths of the signals is 0.2 and 2 MHz, respectively. The laboratory signals have very poor spectral characteristics since they radiate a significant amount of out-of-band energy. This is due to the fact that no filtering was included in the experimental setup since out-of-band spectral characteristics are not significant to the cochannel tests. The tests were abandoned since the amount of side lobe filtering that can be added involves system tradeoffs that are beyond the scope of this study. These tradeoffs, for example, involve the cost of filters and the amount of degradation to the

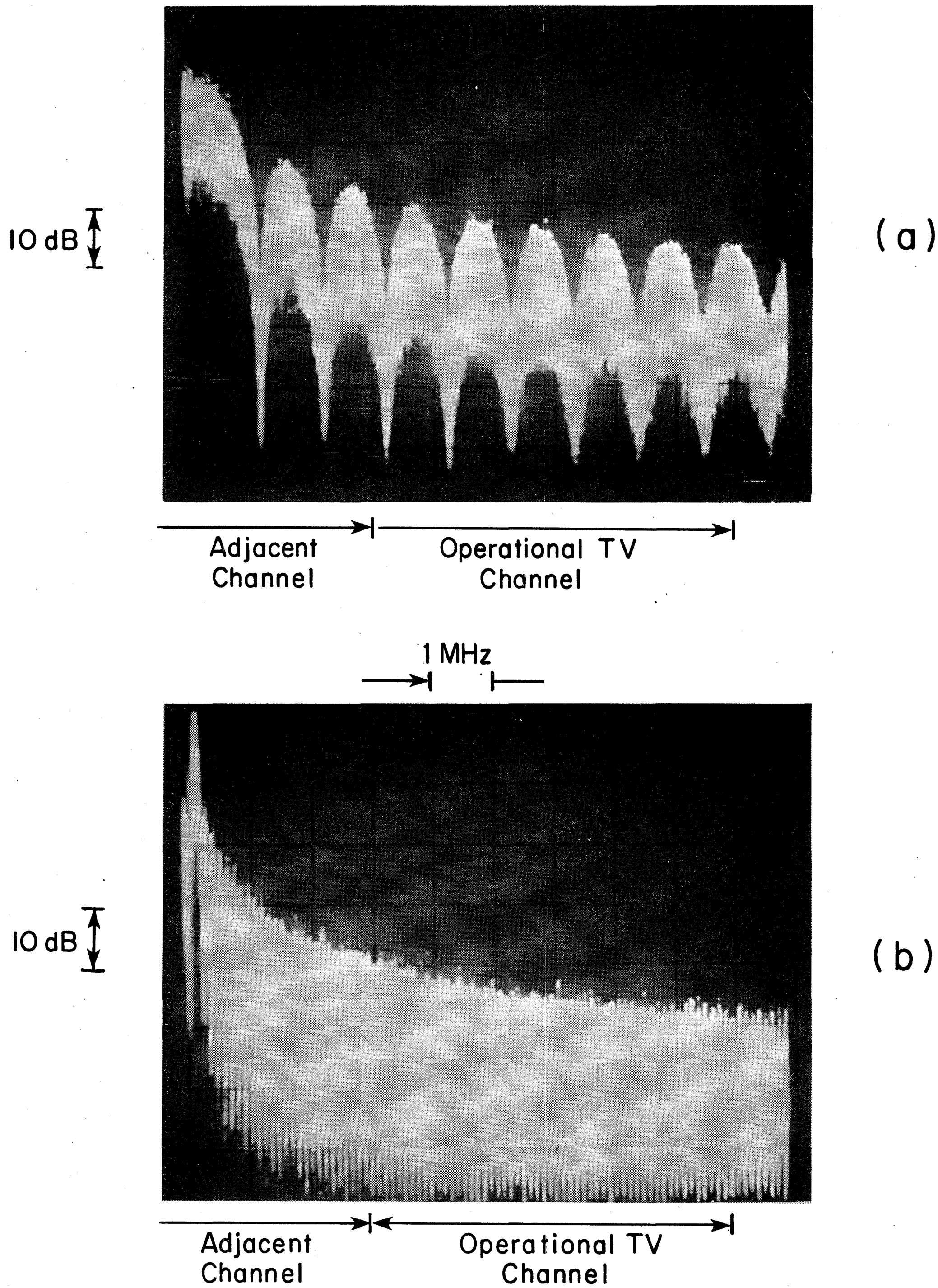


Figure 14. Spectrum of a spread-spectrum signal operating in an adjacent TV channel with clocking rates of (a) 0.1 Mbps and (b) 1 Mbps.

spread-spectrum system, as well as the amount of adjacent channel protection that is desired. For these reasons it was felt that any results obtained with the current experimental setup would not be meaningful.

6. CONCLUSIONS

The amount of interference caused by a constant-amplitude, spread-spectrum system should be about the same as that caused by a conventional narrowband FM land mobile signal. This should be true as long as the rf bandwidths are less than 2 MHz. With spectrums greater than 6 MHz, the spread-spectrum system should have some advantage over conventional FM land-mobile signals because of the out-of-band rejection capabilities of the TV receiver.

7. REFERENCES

Brandel, R. W. (1977), Television interference associated with the proposed class E 220 MHz citizen radio service, 27th Annual Conference IEEE Vehicular Technology Group, Orlando, Florida, March 1618.

CCIR (1974a), Broadcasting Service (Television), Vol. XI, XIIIth Plenary Assembly, Geneva, 1974, pp. 106.

CCIR (1974b), Transmission of sound broadcasting and television signals over long distances, Vol. XII, XIIIth Plenary Assembly, Geneva, 1974, p. 62.

Dixon, R. C. (1976), Spread Spectrum Systems (John Wiley & Sons, New York), pp. 13-26.

FCC (1968a), Interference to TV by other services, Pt. I, Project 2229-45, February 8.

FCC (1968b), Interference to TV by other services, Pt. II, Project 2229-45, May 8.

ITT (1975), Reference Data for Radio Engineers, 6th edition, Howard W. Sams & Company, Inc., Indianapoles, Indiana, pp. 30-38.

Waldo, G. V., and W. A. Daniel (1963), A method of estimating the extent of interference to TV broadcast service caused by low-power transmitters operating on VHF TV channels, FCC Report R-6306, December 31.

FORM OT-29
(3-73)

U.S. DEPARTMENT OF COMMERCE
OFFICE OF TELECOMMUNICATIONS

BIBLIOGRAPHIC DATA SHEET

	1. PUBLICATION OR REPORT NO.	2. Gov't Accession No.	3. Recipient's Accession No.
	NTIA-Report-78-6		

4. TITLE AND SUBTITLE A PRELIMINARY ESTIMATE OF THE EFFECTS OF SPREAD-SPECTRUM INTERFERENCE ON TV	5. Publication Date June 1978 6. Performing Organization Code NTIA/ITS, Div. 1
7. AUTHOR(S) John R. Juroshek	9. Project/Task/Work Unit No. 9103517
8. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Department of Commerce National Telecommunications & Information Admin. Institute for Telecommunication Sciences Boulder, CO 80303	10. Contract/Grant No.
11. Sponsoring Organization Name and Address Federal Communications Commission Washington, DC 20554	12. Type of Report and Period Covered NTIA Technical Report 13.

14. SUPPLEMENTARY NOTES

15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The report examines the conditions under which spread-spectrum, land-mobile radio, and television can share spectrum. After a preliminary assessment, the report concludes that the interference caused by a constant amplitude, spread-spectrum system should be comparable to that caused by a conventional, narrowband, FM, land mobile signal of same total power, provided the spread-spectrum signal has an rf bandwidth less than 2 MHz. With spectrum spreads greater than 6 MHz, the spread-spectrum system should have some advantage because of the out-of-band rejection capabilities of a TV receiver. A limited number of laboratory measurements are also described that support the conclusions of the report.

16. Key Words *(Alphabetical order, separated by semicolons)*

Interference; land mobile radio; spread spectrum; television.

17. AVAILABILITY STATEMENT	18. Security Class *(This report)*	20. Number of pages
[X] UNLIMITED.	Unclassified	26
[ ] FOR OFFICIAL DISTRIBUTION.	19. Security Class *(This page)* Unclassified	21. Price:

★U.S. Government Printing Office: 1978-778-192/376 Region 8 USCOMM-DC 29716-P73

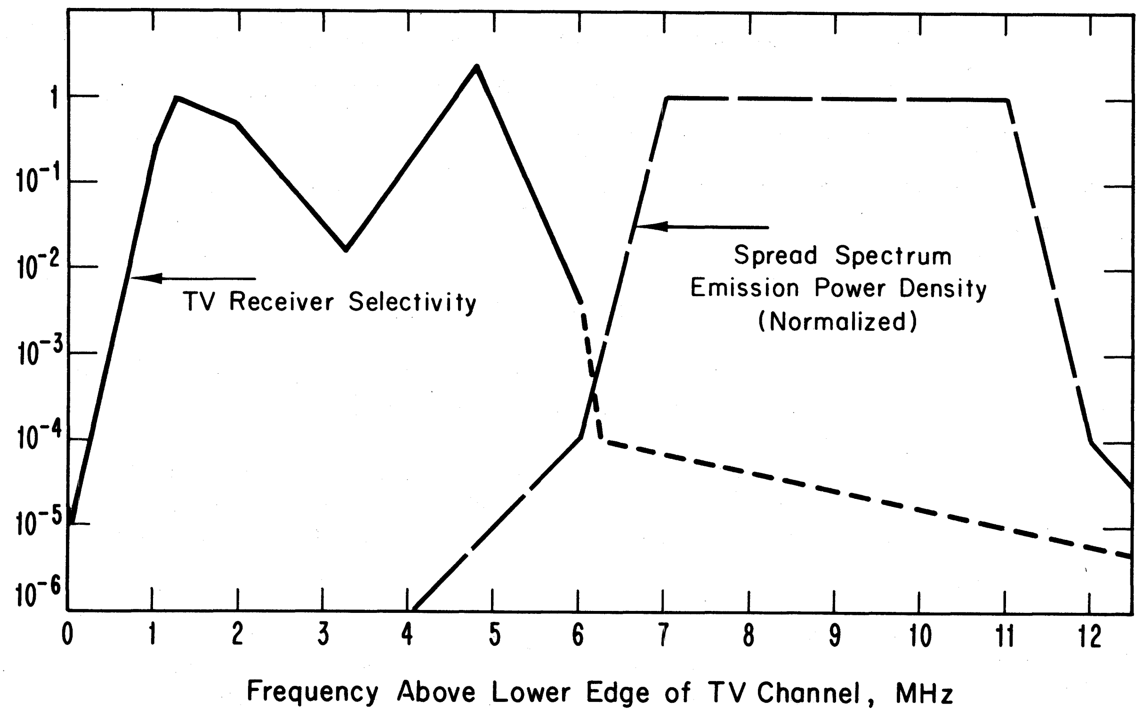


Figure AD-1. TV selectivity function and SS power density in an adjacent channel.

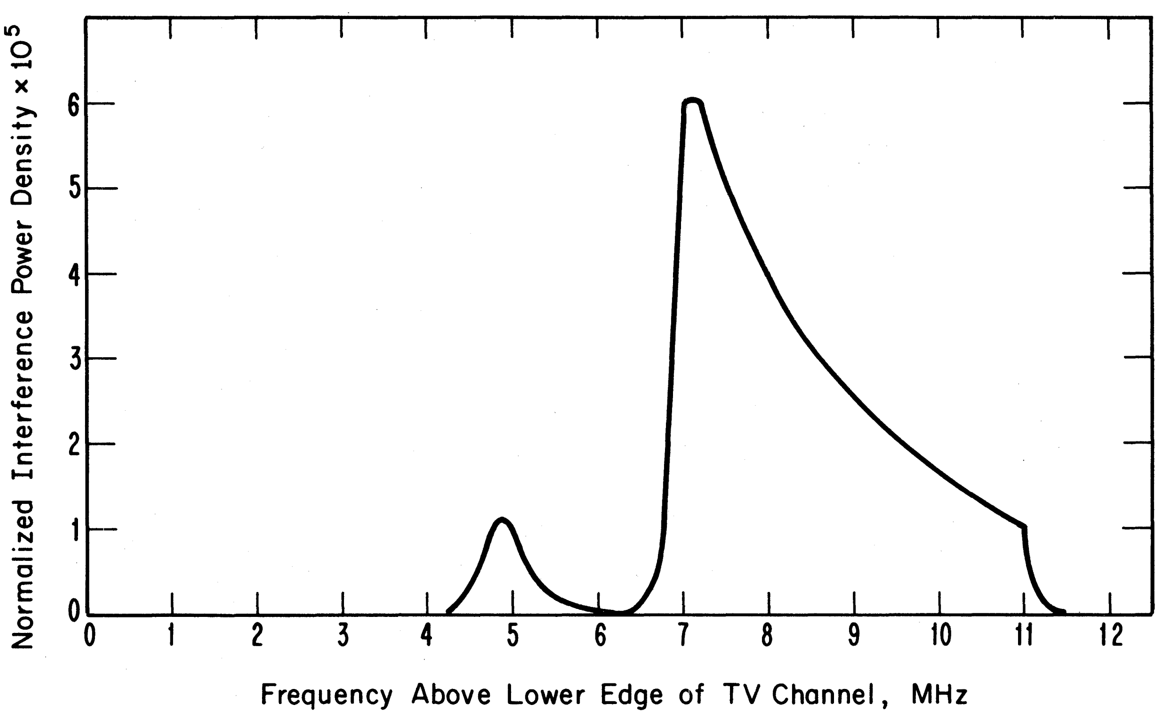


Figure AD-2. The product of the two functions in Figure AD-1.

Equation AD-1 can be used to compare SS and FM interference for other examples. In each case, it will be found that interference to TV from an SS LMR system in an adjacent channel is about equal to, or somewhat greater than, interference from an FM LMR system with the same total power, location, and traffic.

ADDEMDUM REFERENCES

CCIR Report 523 (1974), System Models for the Evaluation of Interference (International Telecommunications Union, Geneva).

Haakinson, E. J., A. C. Stewart, J. E. Adams, and L. E. Vogler (1977), Extended area test system in the 136-148 MHz band--an EMC assessment, OT Report 77-122 (Institute for Telecommunication Sciences, Boulder, CO 80303).

Roberts, W. K., and L. C. Middlekamp (1974), A study of the characteristics of typical television receivers relative to the UHF taboos, FCC Report LAB-74-01 (National Technical Information Service, PB-235 057).