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Measurements of Interference Between AM Radios Due to Local Oscillator Radiation

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TABLE OF CONTENTS

LIST OF FIGURES

MEASUREMENTS OF INTERFERENCE BETWEEN AM RADIOS DUE TO LOCAL OSCILLATOR RADIATION

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Interference caused by local oscillator radiation from AM radios is a known problem. It is particularly troublesome when the local oscillator frequency of one radio coincides with the tuned frequency of another, nearby AM radio. This condition produces an annoying tone in the victim receiver whose frequency is dependent on the frequency difference between the local oscillator and tuned frequency of the victim radio. It has been suggested that this source of interference would be more troublesome if AM radio stations were assigned frequencies in 9 kHz channel increments instead of the current 10 kHz increments. These arguments, however, are largely based on idealized assumptions for AM radios. This report describes the measurement of local oscillator radiation from a sample of test radios. Measurements were made of local oscillator frequency for various tuning conditions. Also described in the report are measurements of the separation distance required to produce a given amount of interference in a victim receiver and the image rejection ratio with 9 kHz and 10 kHz spacings. The report concludes that there are no significant differences in interference between 9 kHz and 10 kHz assignments insofar as receiver local oscillator radiation and image frequency susceptibility are concerned.

1. INTRODUCTION

It has been suggested that the effects of AM receiver imperfections, e.g., local oscillator radiation and image frequency susceptibility, will be worse if 9 kHz channeling is adopted in Region 2 than if the current 10 kHz channeling is continued (International Telecommunication Union, 1980). As a result, it has been proposed that pairs of frequencies causing these forms of interference could not be assigned in the same geographic areas. The suggestion arises because of the reduced frequency (1 kHz) of the beats between the interfering and wanted signals with 9 kHz spacing. For example, assume that a receiver is tuned to 540 kHz. Then if its intermediate frequency (IF) is 455 kHz, the local oscillator will radiate on 995 kHz. If a nearby (within a few meters) receiver is tuned to a station on either 990 or 1000 kHz, it will likely have a 5 kHz beat tone superimposed on its audio output. If the channeling plan were changed to 9 kHz spacing, the local oscillator would remain on 995 kHz (because 540 kHz is unchanged) but it would cause interference to stations on the new frequencies of 990 and 999 kHz. The first would be subjected to a 5 kHz beat as before, while the second would be subjected to a 4 kHz beat instead of 5 kHz. The concern is that the 4 kHz beat would be significantly more troublesome to the listener than one at 5 kHz.

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In the case of image frequency interference, with 10 kHz channelization, a receiver tuned to a station on 540 kHz would receive interference from image frequency stations on 540 + 2(455) = 1450 kHz. The beat frequency under these circumstances will then be zero. At 9 kHz channel spacings, however, the image frequency station would be on 1449 kHz, giving rise to a beat of 1 kHz. If there is the change of the zero frequency beat to 1 kHz, then this would be important.

Further examination of these points shows that it is the actual local oscillator frequency rather than the nominal local oscillator (LO) frequency that causes the problem. The actual LO frequency of a receiver tuned to 540 kHz can differ from the nominal 995 kHz local oscillator frequency for several reasons. First, superheterodyne receivers suffer from tracking errors which can cause the LO frequency to be in error by several kHz. Second, the difficulty of tuning receivers precisely can introduce an additional error of as much as ±2 kHz. Third, the local oscillator frequency can drift as much as a few hundred Hz in an hour or so because of voltage and temperature changes. Another factor influencing LO frequency is that a receiver's IF response is not always symmetrical nor is it always centered at 455 kHz.

2. RECEIVER IF RESPONSE

The frequency response of the IF filter is one of the major factors in determining the eventual frequency of the local oscillator. A nonsymmetric frequency response or a response offset from the nominal 455 kHz center frequency will correspondingly bias the local oscillator frequency. This section of the report examines some typical receiver IF characteristics.

Measuring the IF responses of an AM receiver is a difficult task at best. This difficulty is due, at least in part, to the IF automatic gain control (AGC) circuitry which is generally used in AM receivers. A frequency response measured with the AGC enabled is significantly different from one measured with the AGC disabled. Also, a reasonable amount of care must be exercised if any probes or instruments are attached to the IF filter to avoid changing its characteristics.

The frequency response of a typical AM receiver with its AGC disabled is shown in Figure 1(a) through (c). These measurements were made using the test setup shown in Figure 2. Basically, the receiver's AGC circuit is connected to an external power supply so that its level can be held constant at a representative value. The frequency response is then measured by coupling a 450 to 460 kHz swept frequency signal into the receiver IF filter through a loop. The input to the IF is obtained from radiated coupling as no direct connection to the receiver's IF filter

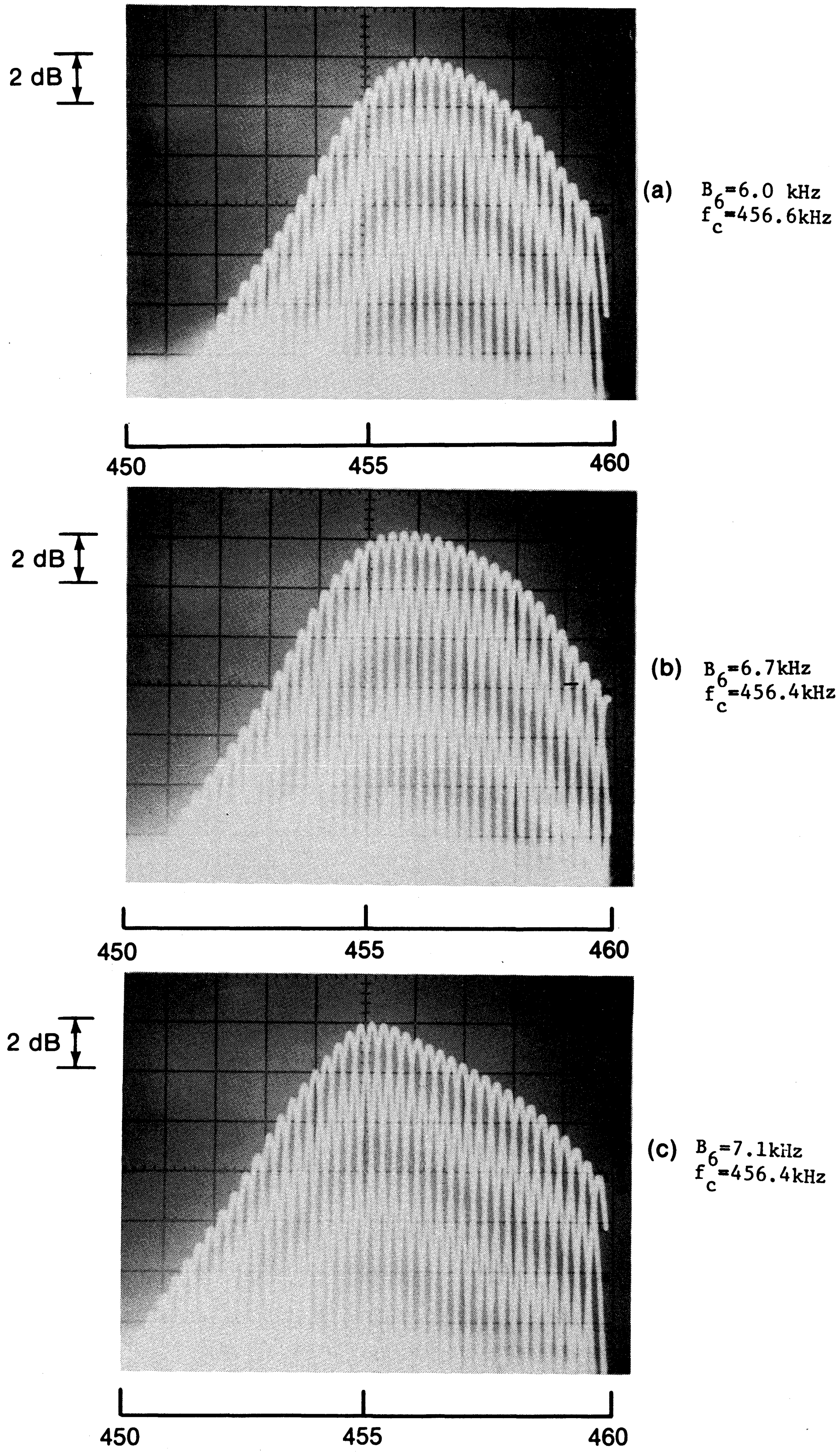

Figure 1. IF frequency response of a typical AM Radio. Measurements were made at 3 different IF AGC levels corresponding to (a) minimum gain, (b) average gain, and (c) maximum gain.

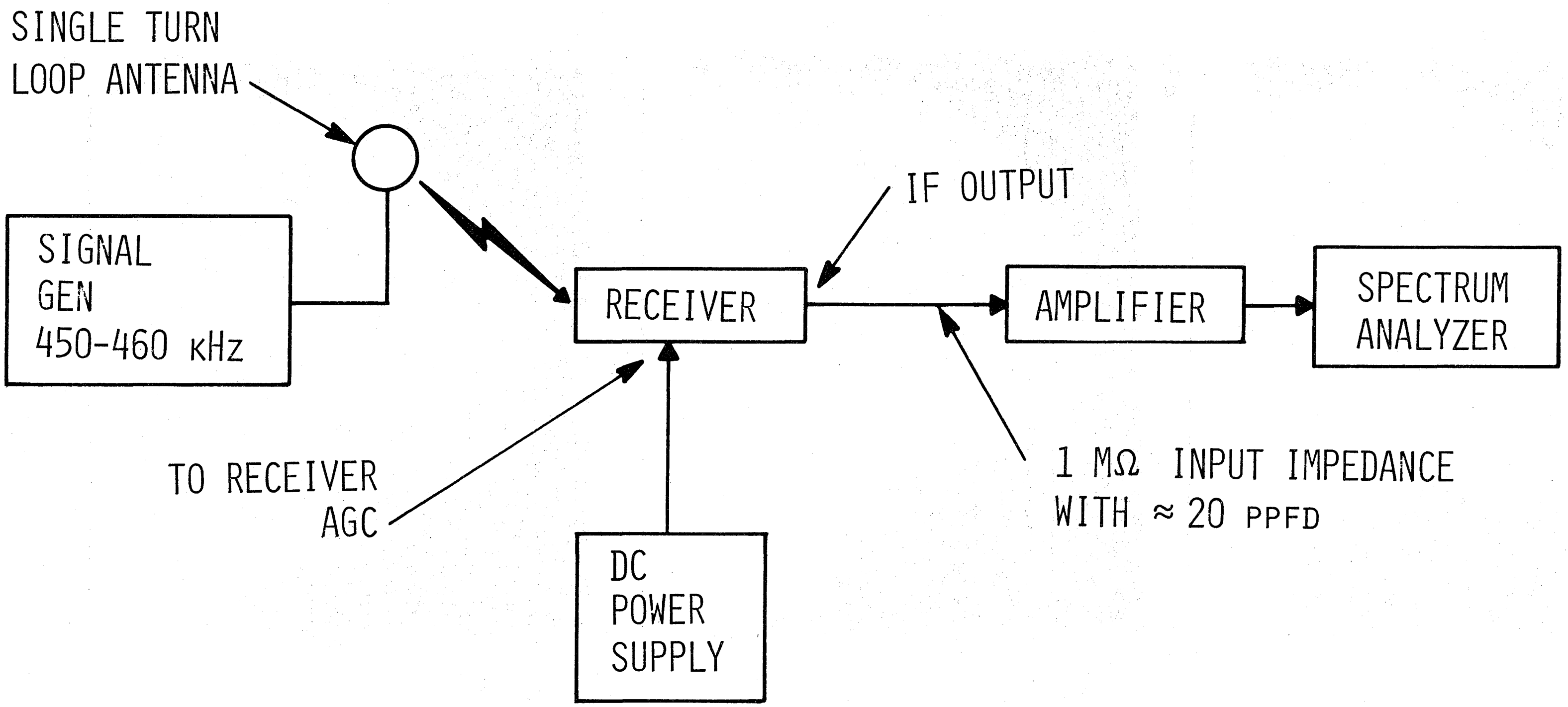

Figure 2. Block diagram of test setup used to measure IF frequency responses.

is used. Next, the IF filter is monitored by attaching a high input impedance amplifier and oscilloscope probe to the IF output. The output from this amplifier is then sent to a spectrum analyzer where the spectrum photographs are recorded.

The photographs in Figure 1(a) through (c) were made on the same receiver at three different AGC voltages. These levels were chosen to span the normal dynamic range of the test receiver, where the figures correspond to IF conditions of (a) minimum gain, (b) average gain, and (c) maximum gain. Note that this change in AGC produces a change in the 6 dB bandwidth (B_6) from 6.0 kHz to 7.1 kHz. The center frequency (f_c) of the IF filter response, which is defined as the average of the two 6 dB frequencies, correspondingly varies from 456.6 kHz to 456.4 kHz.

It should be noted that the IF measurements described here are designed to measure only the IF filter. The effective filtering in the complete receiver is influenced by other factors such as radio frequency (rf) filtering in the receiver frontend as well as any post-detection audio filtering. The rf filtering in an AM radio can be significant and is primarily obtained by tuning the ferrite input antenna with the variable tuning capacitor.

3. LOCAL OSCILLATOR RADIATION

3.1 LO Frequency

Measurements of local oscillator radiation were made on seven receivers for each of six frequencies. The technique used is block diagrammed in Figure 3. In making the measurements an HP 8660C signal generator was first tuned to a test frequency such as 540 kHz.[1] This signal was 30% modulated with a 400 Hz tone. Next, the receiver under test was optimally tuned to this signal. The signal generator was then switched to a frequency 455 kHz higher which, for the example, would be 540 + 455 = 995 kHz. An audible beat note was then observed in the Collins 651-S-1A receiver which had been pretuned to 995 kHz. This beat note is the difference between the frequency of the signal generator (currently set at 995 kHz) and the frequency of the local oscillator in the receiver under test. The precise frequency of the local oscillator radiation can now be determined by manually tuning the signal generator until a zero beat is observed.

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[1] Certain commercial equipment, instruments, or materials are identified in this paper to specify adequately the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Telecommunications and Information Administration, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

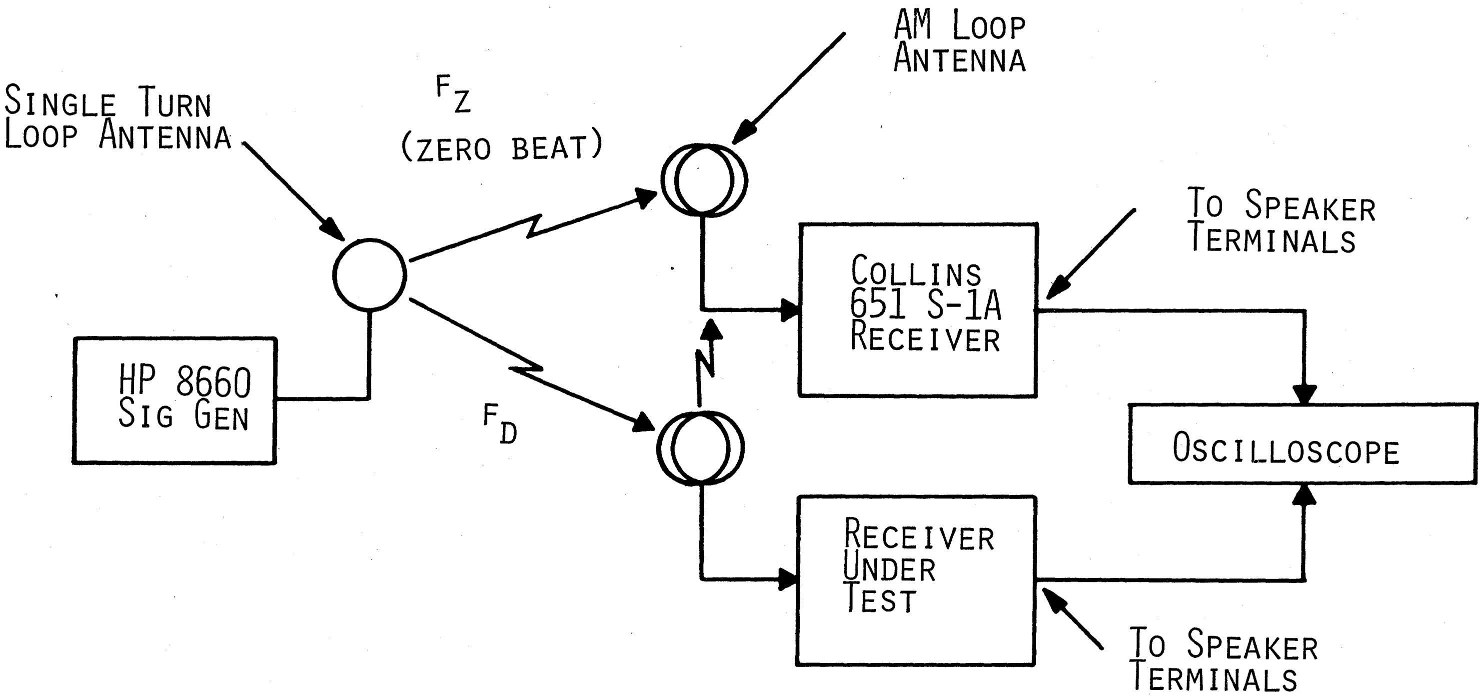

Figure 3. Block diagram for local oscillator radiation measurements.

A summary of the results from these tests is shown in Figure 4. Instead of plotting local oscillator frequency, the results are shown as effective IF filter center frequency; which is simply the zero beat frequency measured minus the test frequency that the radio was tuned to. For example, if a zero beat frequency of 996.234 kHz was measured when the test radio was tuned to 540 kHz, the effective IF filter center frequency plotted would be 996.234 - 540 = 456.234 kHz. The data using 400 Hz modulation are shown with dots. Because of the wide scatter that could have arisen through the use of 400 Hz modulation, the measurements were repeated using 3 kHz modulation. These data are shown by asterisks in Figure 4.

Samples of these measurements for individual radios are shown in Figures 5 through 7. In these figures, three different symbols are used to show the repeatability of the data during measurements taken at different times. For example, all of the data shown with squares were taken on one day. Figures 5 and 6 clearly show the effects that tracking error can have over the AM band. On the other hand, Figure 7 shows the lack of consistency that was observed in some radios.

As a further test of any potential bias introduced by the person tuning the AM receivers or the modulation on the desired signal, a series of tests were made using six nontechnical people to tune each of the radios. For these tests, the AM radios were tuned to local standard broadcast signals at 630, 1090, and 1600 kHz instead of a tone-modulated signal generator. The frequency of the local oscillator was determined by zero beating with the HP 8660C signal generator as described above. Test results using five receivers are shown in Figure 8. As can be seen, the spread of the data is of the order of at least 5 kHz and is not significantly different with nontechnical people tuning to actual AM radio stations.

3.2 Interference from LO Radiation

Measurements were also made of the distance at which receiver local oscillators would reduce the SINAD of a nearby receiver by 6 or 12 dB when the latter receiver is receiving a signal of approximately 1000 μV/m. The word SINAD is an abbreviation that stands for the ratio

$$\text{SINAD} = \frac{\text{signal + noise + distortion}}{\text{noise + distortion}} \quad .$$

The measurement of SINAD during these tests was done automatically with a commercial audio SINAD meter connected to the speaker leads of the monitor receiver. A block diagram of the test setup used in this instance is shown in Figure 9. A 1000 Hz

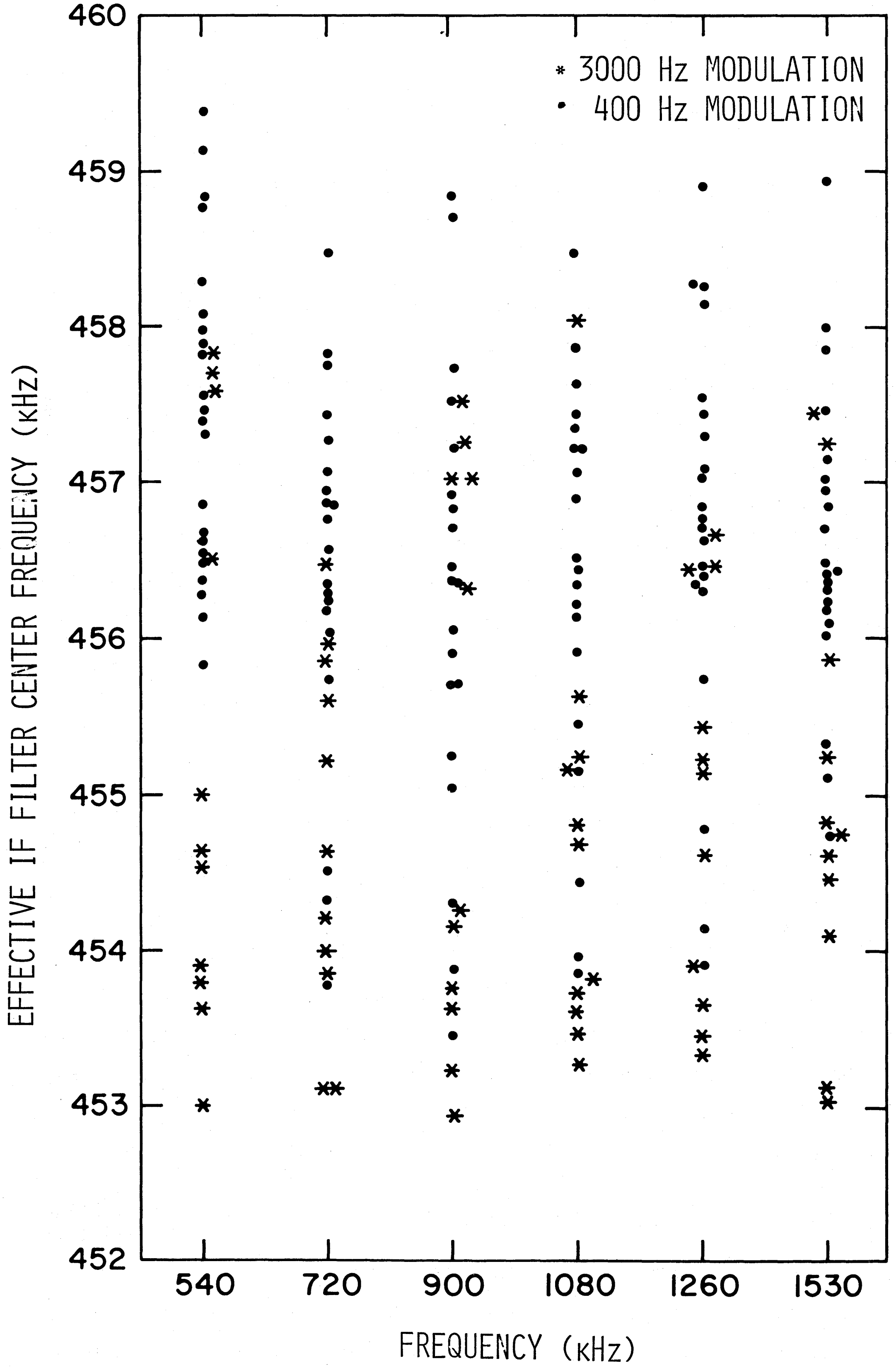

Figure 4. Summary of receiver local oscillator frequency measurements

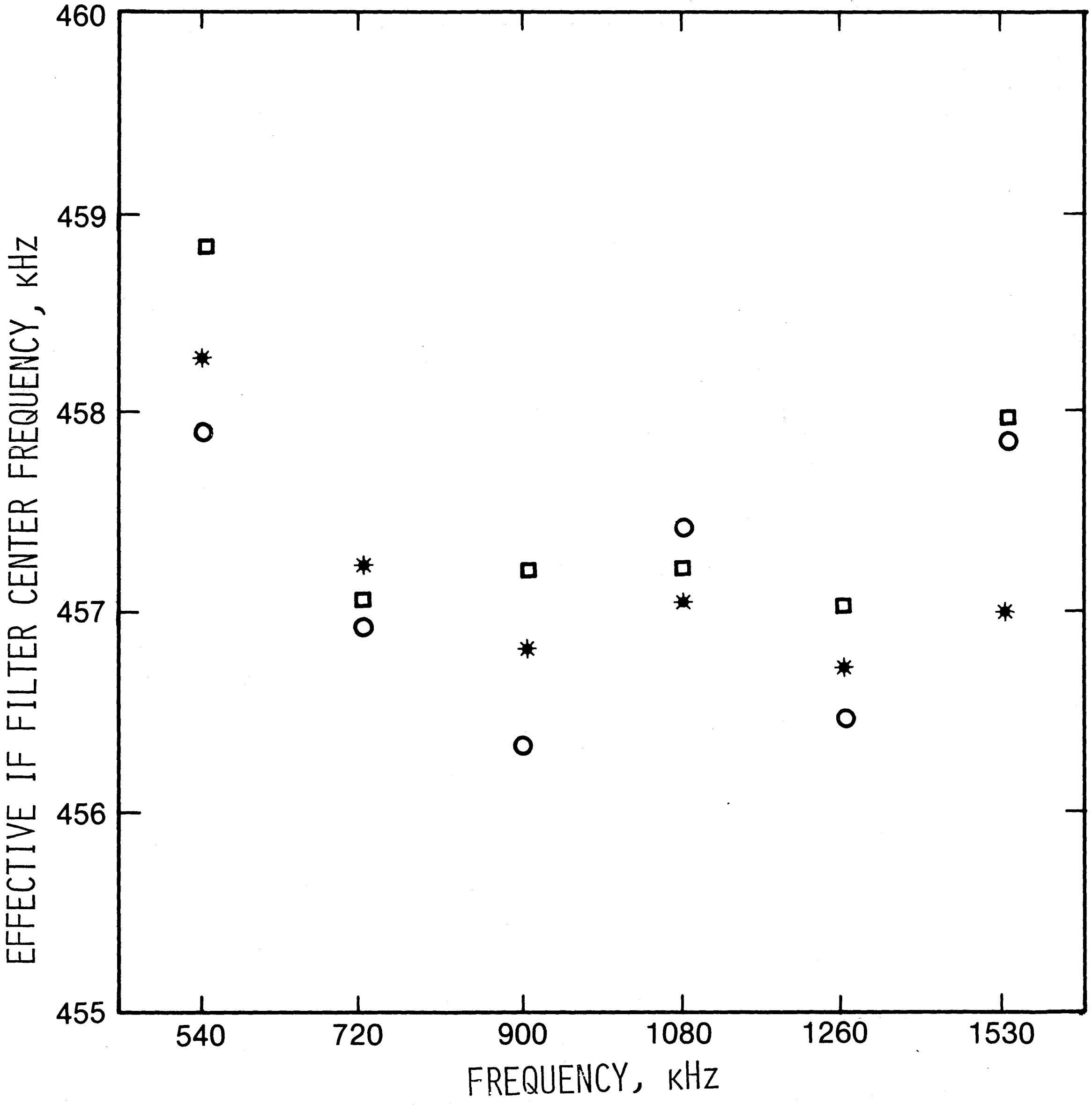

Figure 5. Example of effective IF center frequency measurements for an individual AM radio. The different symbols are used to distinguish between measurements conducted at different times.

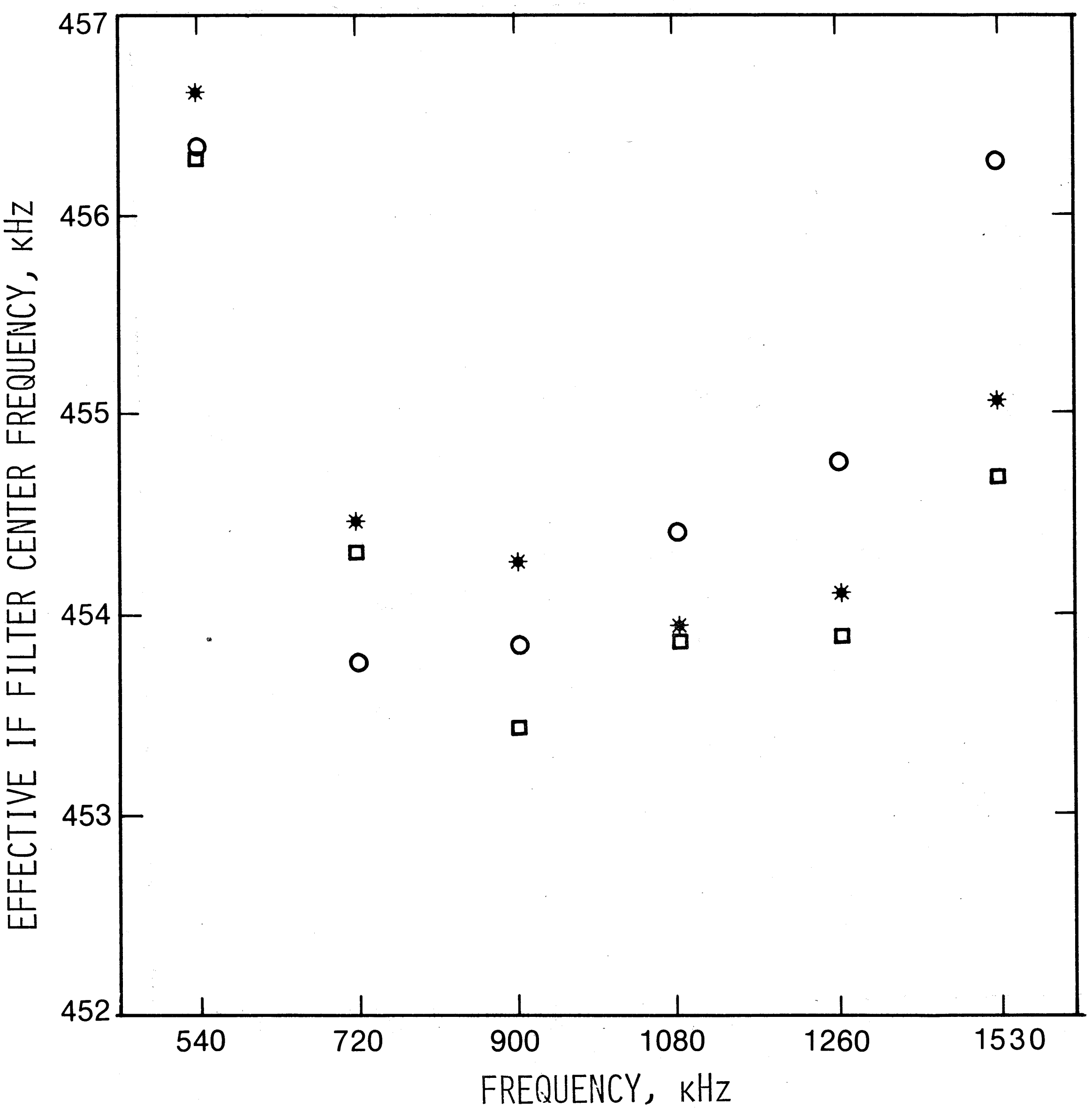

Figure 6. Example of effective IF center frequency measurements for an individual AM radio. The different symbols are used to distinguish between measurements conducted at different times.

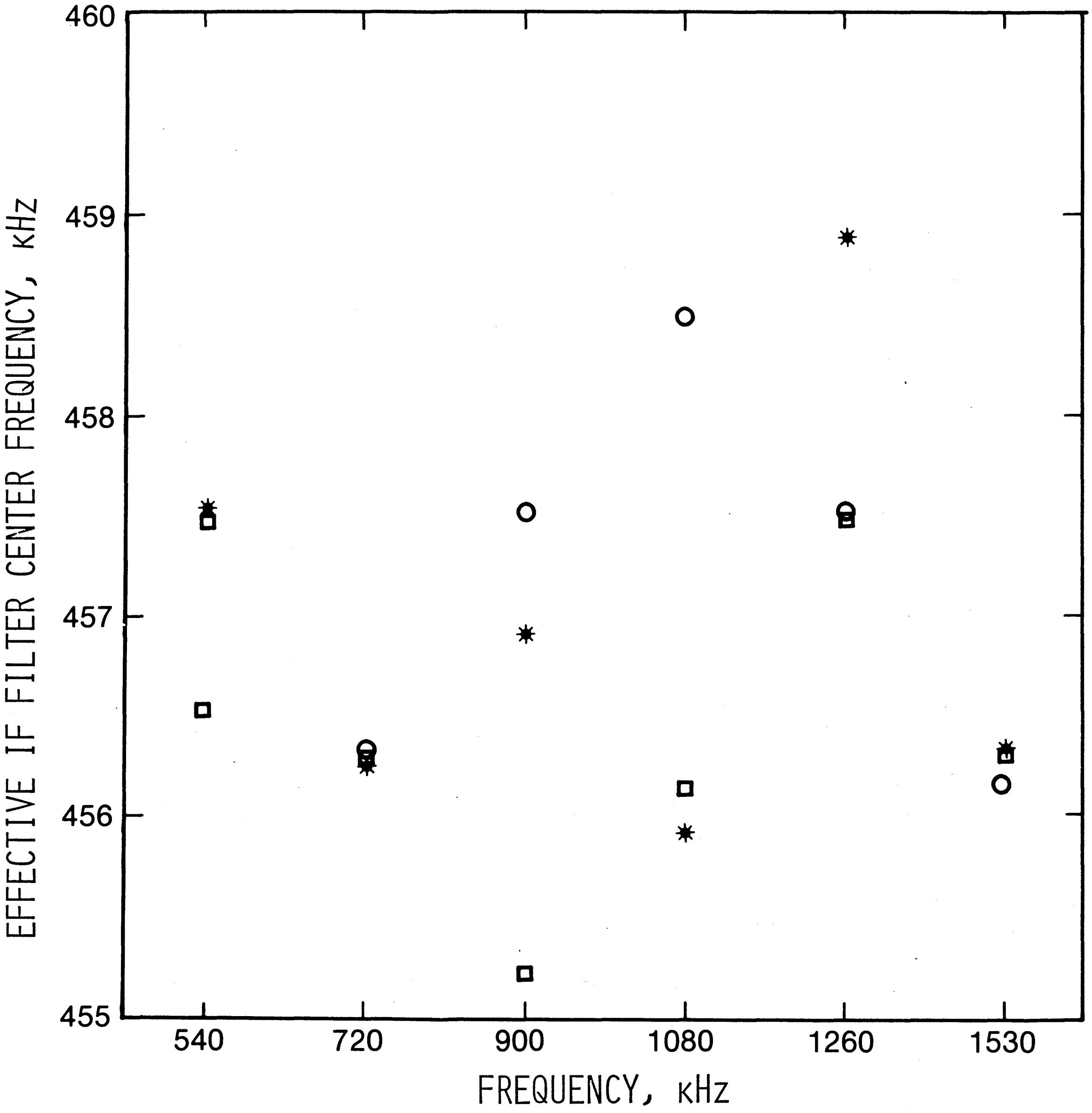

Figure 7. Example of effective IF center frequency measurements for an individual AM radio. The different symbols are used to distinguish between measurements conducted at different times.

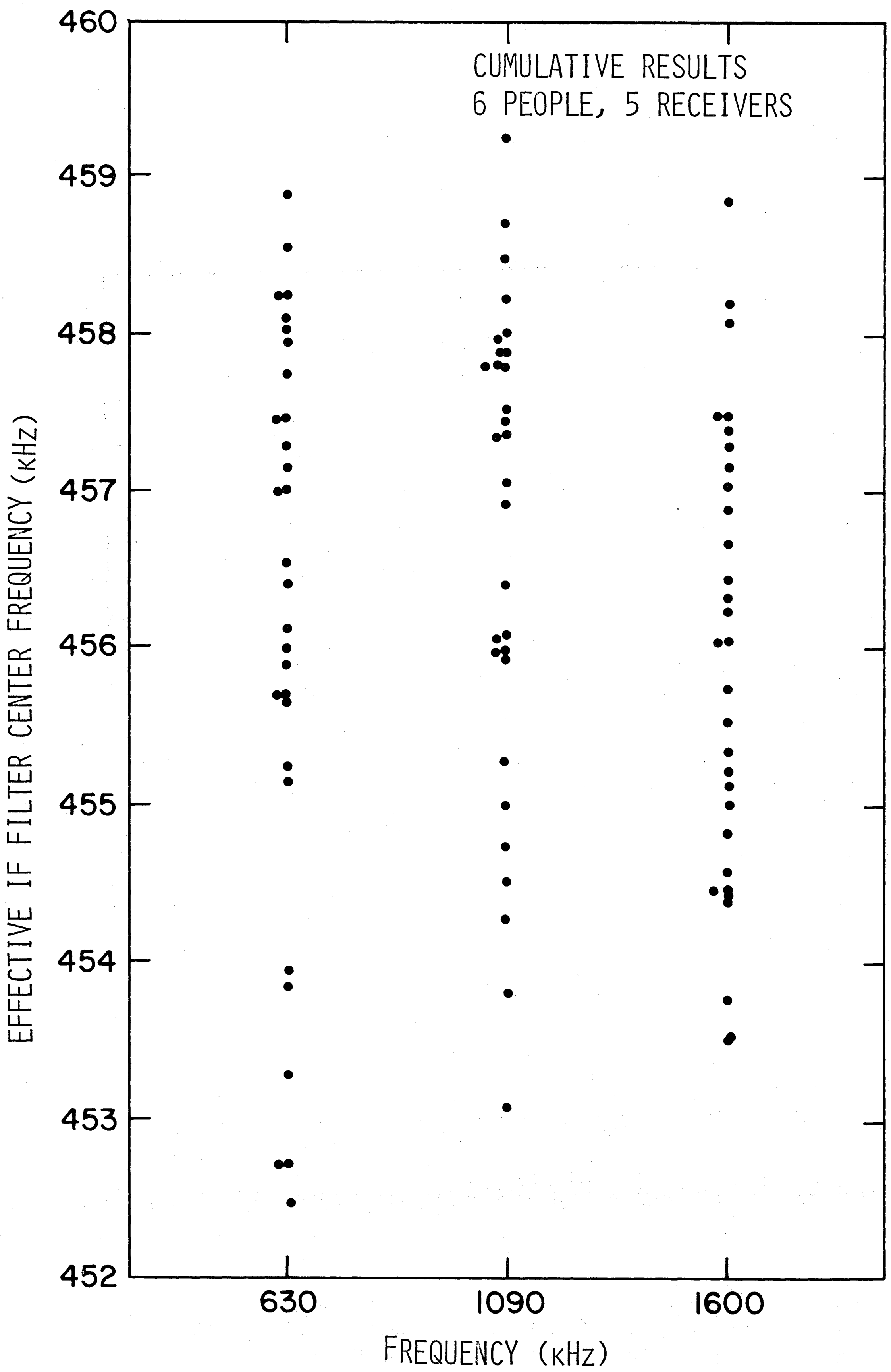

Figure 8. Summary of receiver local oscillator frequency measurements using nontechnical people to tune the AM radios.

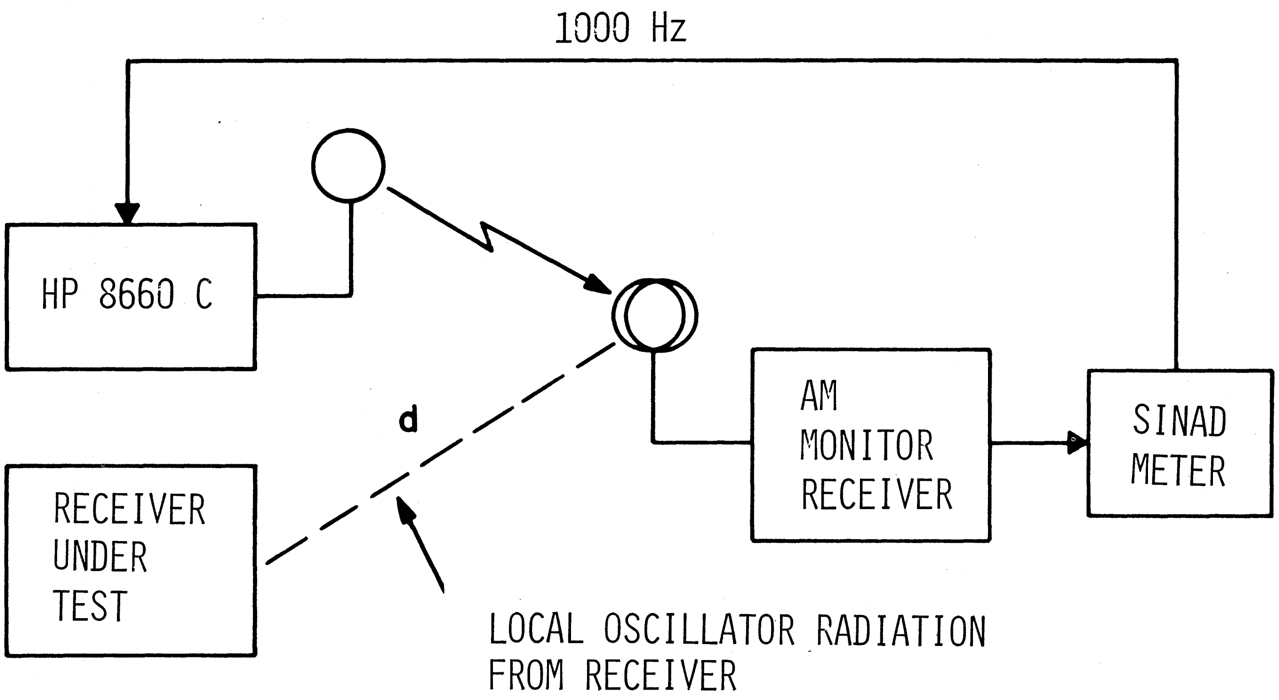

Figure 9. Block diagram of test setup used in measuring separation requirements for local oscillator interference.

tone generator within the SINAD meter is used to amplitude modulate an HP 8660C signal generator by 30%. The receiver under test is both tuned and oriented so that it produces a maximum degradation in SINAD in the monitor receiver. The distance between the receiver under test and monitor receiver is then adjusted to produce either a 6 dB or 12 dB reduction in SINAD. Measurement results for these tests are shown in Figures 10, 11, and 12. Frequencies tested for local oscillator radiation were 1040, 1270, and 1540 kHz which are produced by receiver tunings of approximately 585, 715, and 1085 kHz, respectively. A total of nine receivers were tested during this series.

Identical measurements were made with the AM test receivers replaced by two TV receivers. The distance required to produce 6 and 12 dB SINAD degradations from TV horizontal oscillator radiation is shown in Figures 13, 14, and 15. As in the previous tests, the TV receiver was also oriented for worst case interference conditions. Horizontal oscillator radiation was measured at the AM radio frequencies of 551, 945, and 1530 kHz which correspond to the 35th, 60th, and 96th harmonics of the 15.75 kHz horizontal scanning frequency.

These tests, as in the previous case, were conducted with a single AM monitor receiver in a 1000 μV/m field modulated at 30% by a 1000 Hz tone. All of the measurements were made at frequencies not in use by strong, local AM radio stations. The 1000 μV/m fields were generated by placing the AM receiver's loop stick antenna approximately 60 cm from the center of a single turn loop. The construction of this loop and input voltages required to generate a 1000 μV/m field are as described in the publication "American Standard Methods of Testing Amplitude-Modulation Broadcast Receivers" (1961).

The measurements also show that the effective IF filter center frequency of AM radios can vary between 453 kHz and 459 kHz, which means that a difference in local oscillator frequency of the order of 6 kHz can be expected. Thus, an AM radio tuned to a station at 540 kHz would have its local oscillator at a frequency between 993 kHz and 999 kHz. A nearby radio tuned to a station at 999 kHz, in a 9 kHz assignment plan, could receive interference with an audio beat note between 0 kHz to 6 kHz. This contradicts the argument that the beat note would be near 4 kHz with a 9 kHz assignment plan as opposed to 5 kHz in a 10 kHz assignment plan.

Separation distance between two AM radios of the order of 1 meter produced a 6 dB SINAD degradation due to interference from local oscillator radiation. Similarly it is shown that separation distances of the order of 1 to 4 meters between a TV

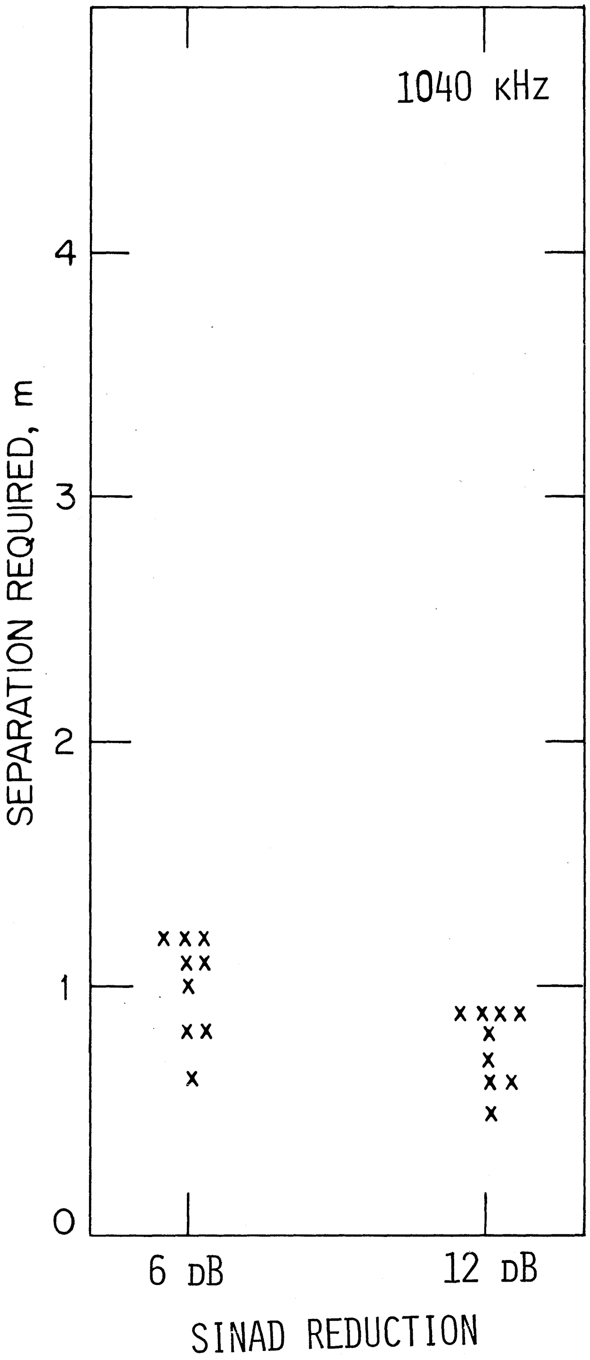

Figure 10. SINAD reduction produced by AM radio local oscillator radiation at 1040 kHz.

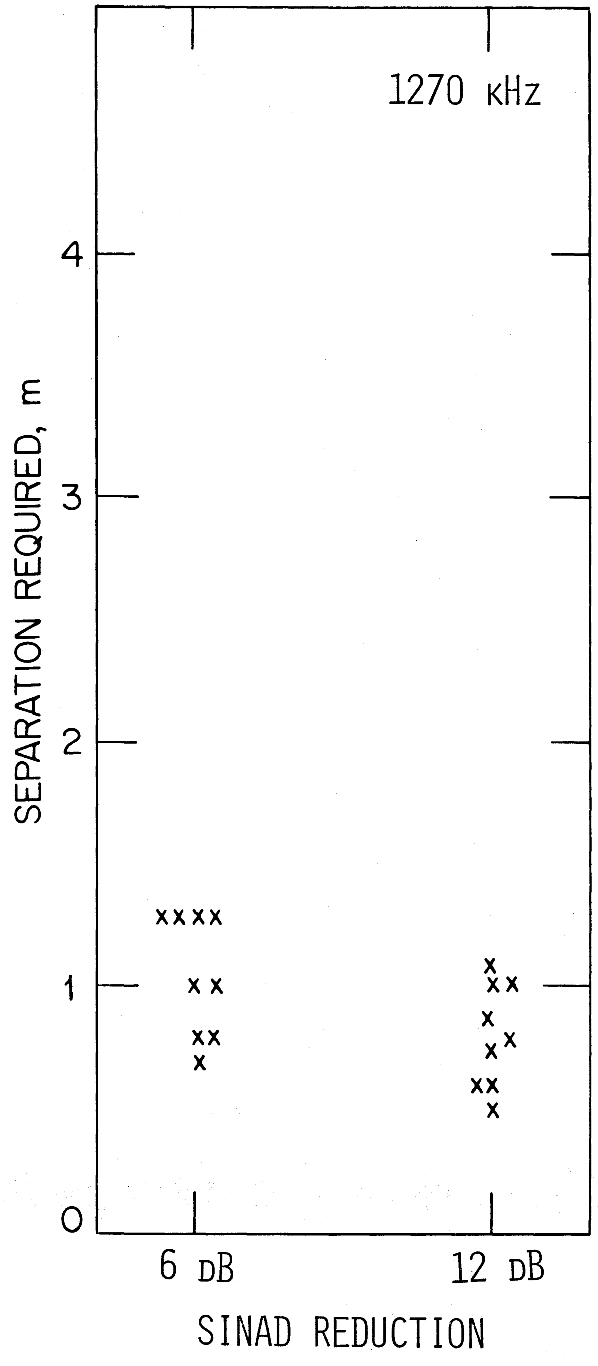

Figure 11. SINAD reduction produced by AM radio local oscillator radiation at 1270 kHz.

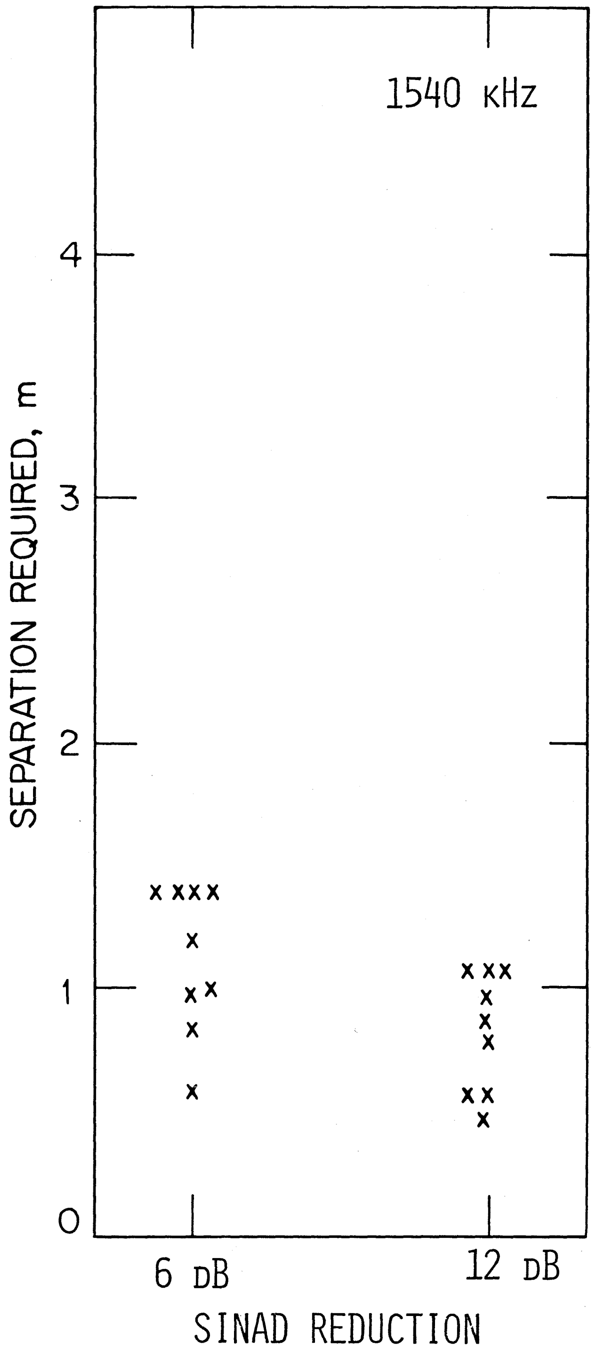

Figure 12. SINAD reduction produced by AM radio local oscillator radiation at 1540 kHz.

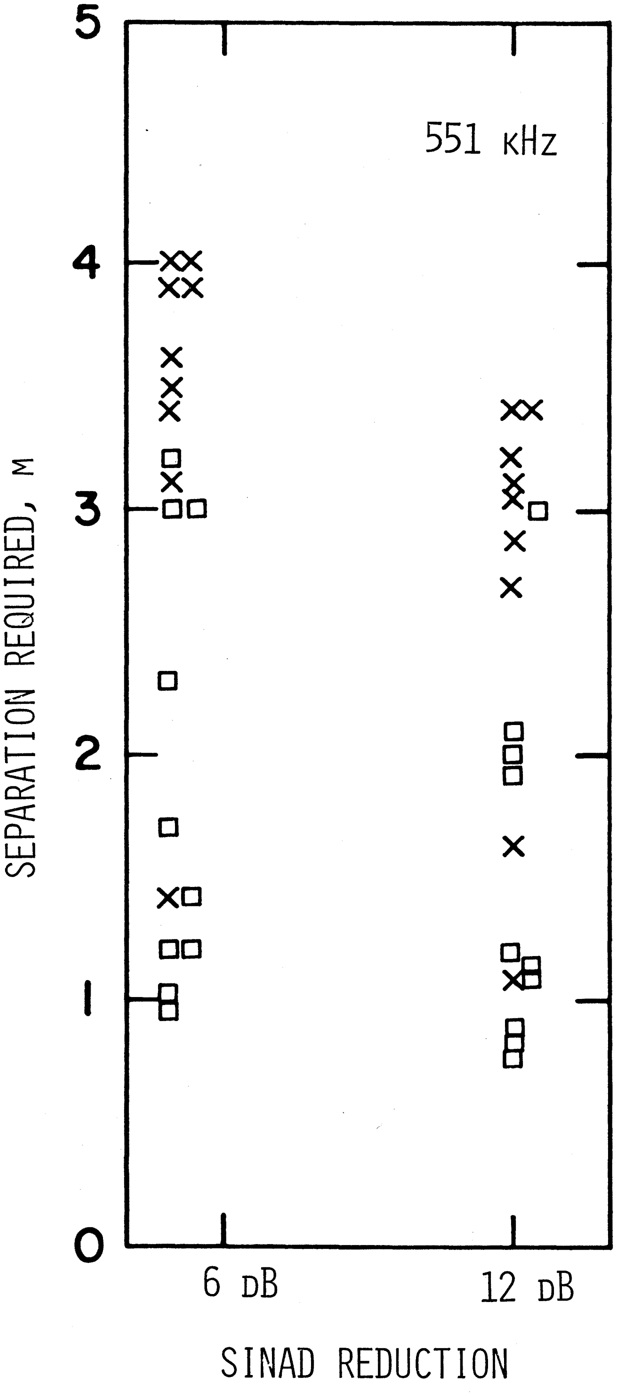

Figure 13. SINAD reduction produced by horizontal oscillator radiation from a TV receiver at 551 kHz. The different symbols are used to distinguish between two television receivers.

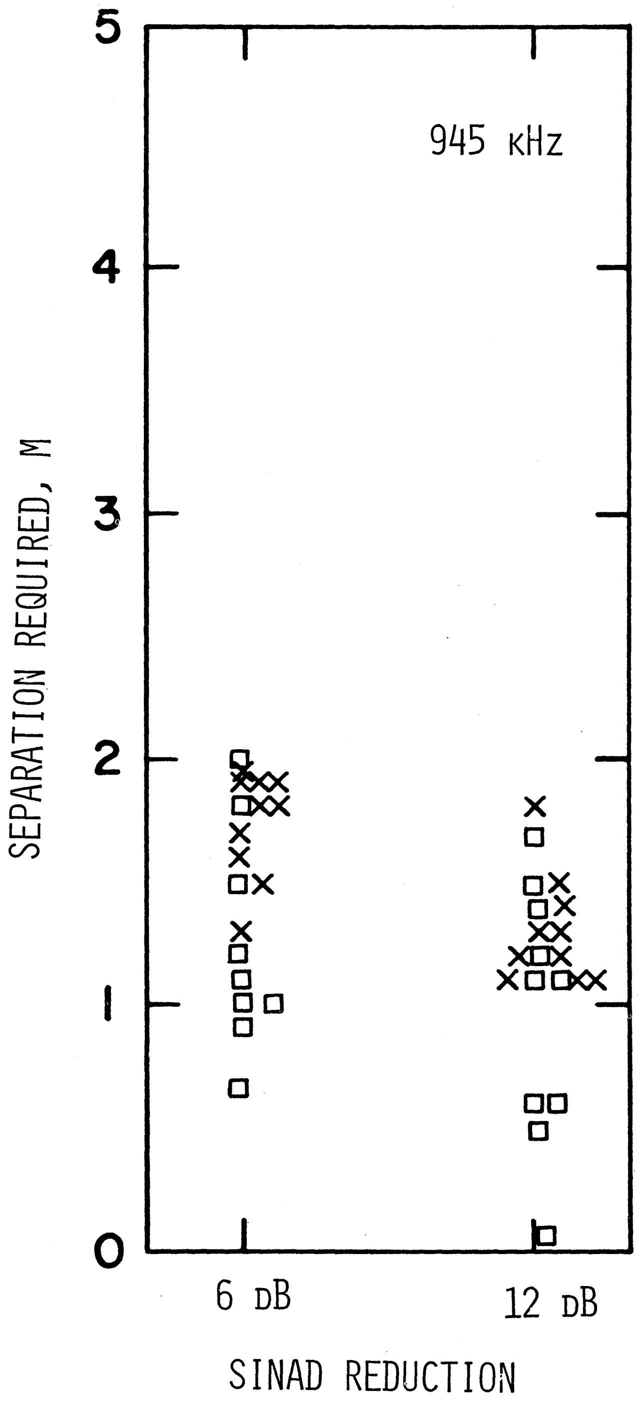

Figure 14. SINAD reduction produced by horizontal oscillator radiation from a TV receiver at 945 kHz. The different symbols are used to distinguish between two television receivers.

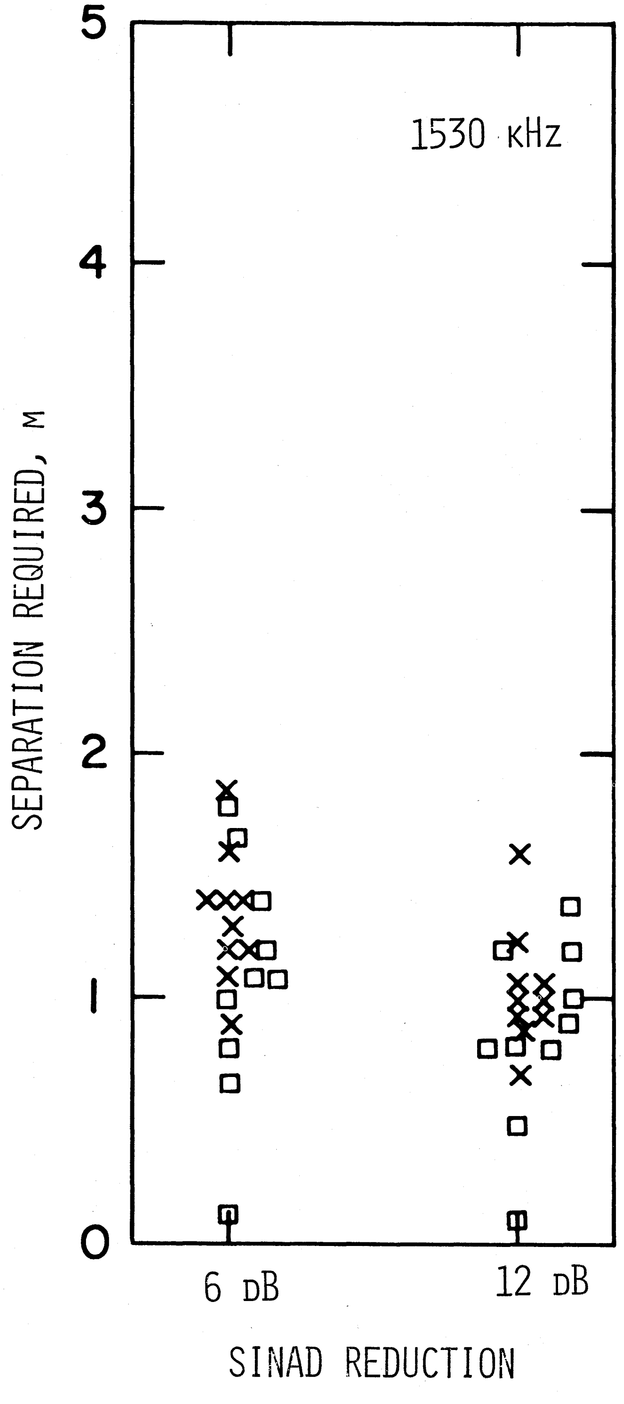

Figure 15. SINAD reduction produced by horizontal oscillator radiation from a TV receiver at 1530 kHz. The different symbols are used to distinguish between two television receivers.

receiver and AM radio can produce a similar 6 dB SINAD degradation. This degradation is due to radiation at harmonics of the 15.75 horizontal scanning oscillator in the TV. Thus if local oscillator radiation from AM radios prohibits the use of certain pairs of frequencies, then TV receiver radio would also prohibit the use of certain frequency assignments that are close to multiples of 15.75 kHz.

4. IMAGE FREQUENCY SUSCEPTIBILITY

Measurements were made on eight receivers in order to compare image rejection obtained with 9 kHz and 10 kHz channel spacings. A block diagram of these tests is shown in Figure 16. As can be seen from the diagram, an image signal and a desired signal are added together in a balanced hybrid network. These two signals are then transmitted through a single turn loop to the receiver under test. The desired signal is modulated 80% by a 1000 Hz tone while the image signal is modulated 80% by a 400 Hz tone. The level of desired signal is set to produce a signal of approximately 1000 μV/m at the AM receiver under test. Measurements of image rejection ratio are then made by increasing the level of the image signal until a 6 dB degradation in SINAD of the receiver under test is observed. The ratio of image signal level to desired signal level (S_I/S_d) at the input to the transmitter loop is defined as the image rejection ratio.

These tests were conducted at the following frequencies:

DESIRED FREQUENCY ASSIGNMENT	NEAREST IMAGE FREQUENCY ASSIGNMENT	ASSIGNMENTS BELOW AND ABOVE NEAREST IMAGE	CHANNEL SPACING
540 kHz	1450 kHz	1440, 1460 kHz	10 kHz
540	1449	1440, 1458	9
640	1550	1540, 1560	10
639	1548	1539, 1557	9
720	1630	1620, 1640	10
720	1629	1620, 1638	9
800	1710	1700, 1720	10
801	1710	1701, 1719	9

For each desired frequency it was necessary to conduct tests at the nearest image frequency as well as at frequency assignments above and below this frequency. The reason for this is that there is no way of predicting which of those three frequencies will produce the worst case (smallest) image rejection ratio.

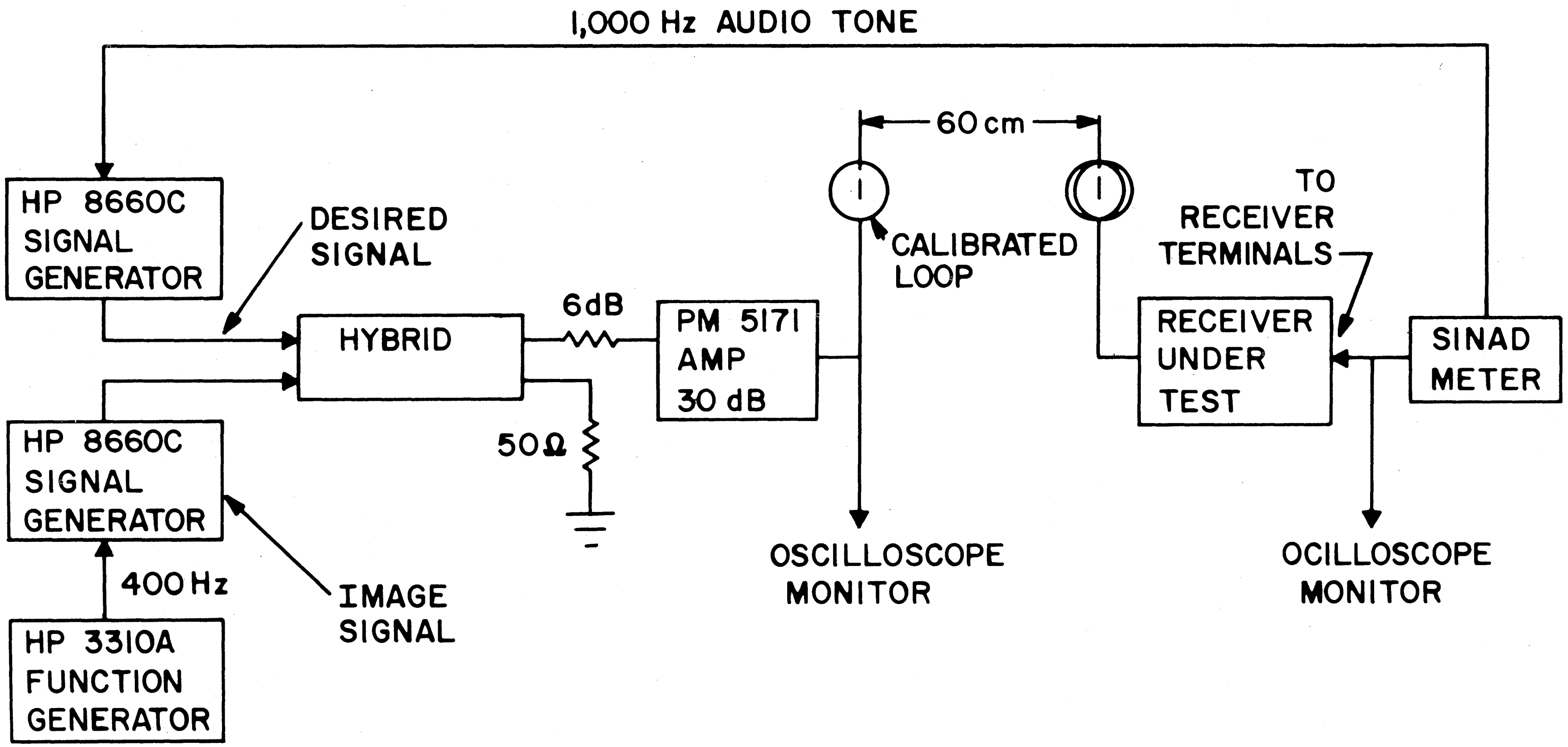

Figure 16. Block diagram of measurement setup for image rejection ratio measurements.

A summary of these measurements is shown in Figure 17. Plotted here is the worst case image ratio for eight receivers. The circles denote those measurements where the smallest case image occurred at the nearest image frequency. The star symbol, on the other hand, means that the worst case image ratio occurred on the frequency below, while the square denotes the image occurred at the frequency above. Because of equipment limitations, the maximum S_I/S_d that could be generated was 48 dB. If a radio was tested at $S_I/S_d = 48$ dB, and a SINAD degradation less than 6 dB was detected, it is shown in Figure 17 as an arrow indicating a potential response greater than 48 dB. One of the eight radios tested had no detectable image response at $S_I/S_d = 48$ dB and therefore is not plotted on the figure.

As described previously, a radio tuned to a station, such as 540 kHz, would receive interference from an image frequency station on 1450 kHz. The beat frequency would be zero if the local oscillator frequency of the radio were precisely 540 + 455 = 995 kHz. However, since the previous tests have already shown that this is not likely to be the case, a nonzero audio beat note will be heard from the radio. Figure 18 shows the frequency of the beat note that was observed for each of the worst case image measurements shown in Figure 17. This measurement was made by simply changing the frequency of the HP 8660 image signal generator until a zero beat was observed and then noting the frequency change necessary to produce the zero beat.

These tests show that the image rejection ratio, S_I/S_d, is of the order of 20 dB to 45 dB. No appreciable difference were observed in this ratio with 9 kHz channel spacing versus 10 kHz channel spacing.

5. CONCLUSIONS

The measurements show no apparent differences in interference characteristics between 9 kHz assignments and 10 kHz assignments insofar as receiver local oscillator radiation and image frequency susceptibility are concerned. The data obtained do not support the claim that these receiver characteristics would produce significantly different interference characteristics with a 9 kHz frequency assignment plan as compared to the present 10 kHz plan. Tests have shown that differences in local oscillator frequencies of the order of 6 kHz can be expected from AM radios tuned to the same station. These differences are due to receiver design and manufacturing characteristics as well as difference in the way a person tunes a radio. Measurements at the harmonics of horizontal scan frequency of two TV receivers show that this source of interference is comparable or stronger than the local oscillator radiation from the AM radios. Thus, if local oscillator radiation

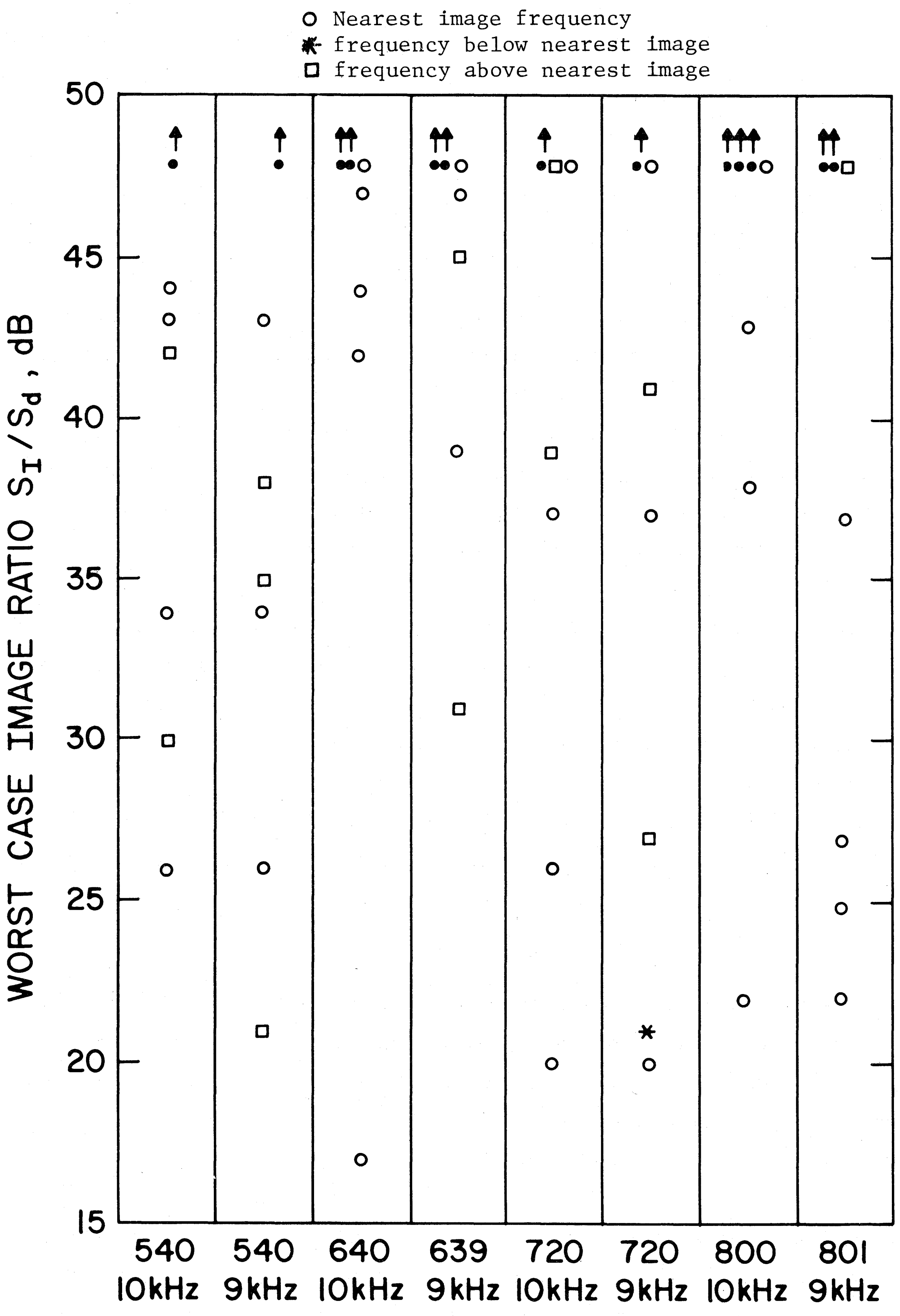

Figure 17. Summary of image rejection ratio measurements.

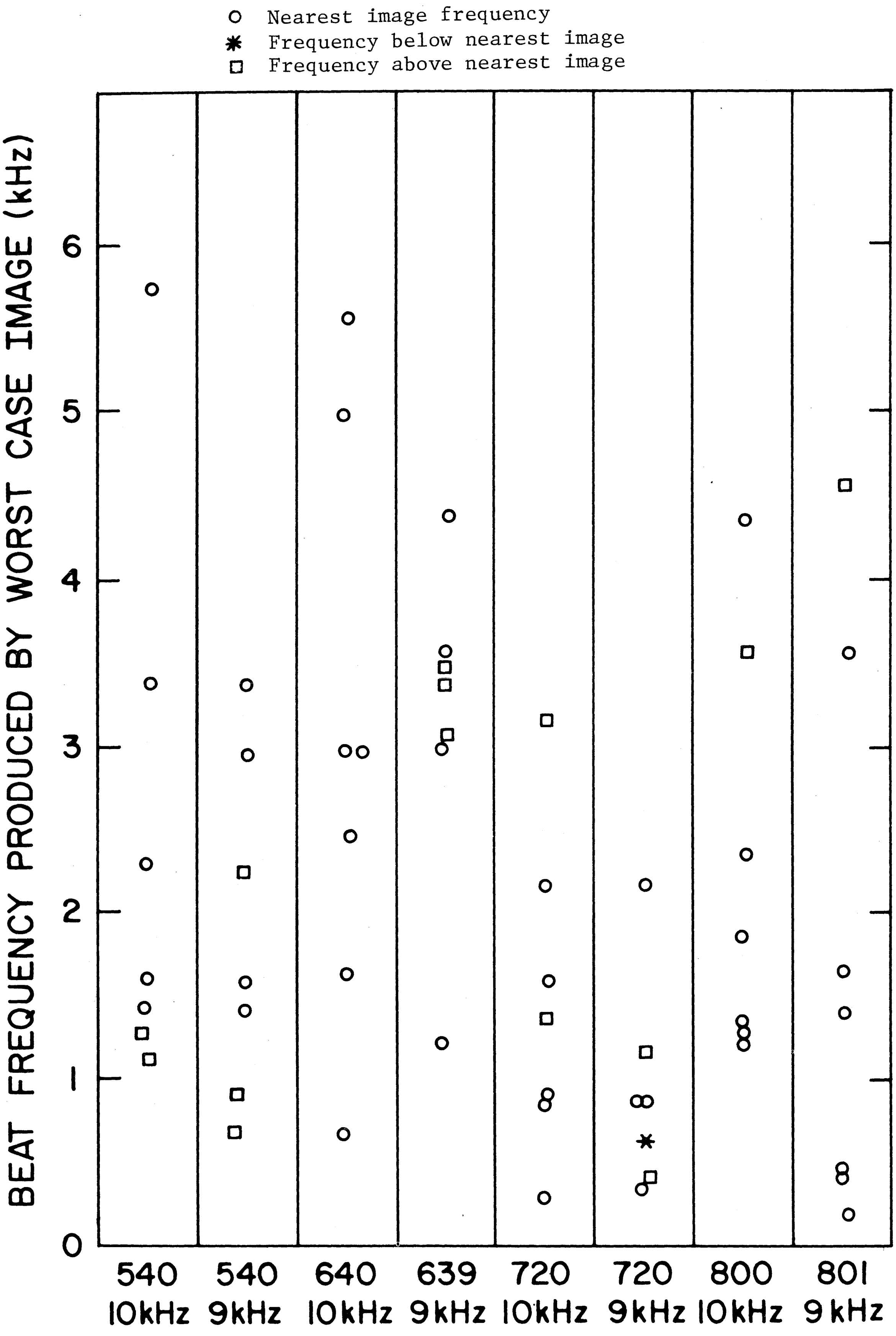

Figure 18. Summary of beat notes observed during image ratio measurements.

from AM radios prohibits the use of certain pairs of frequencies, then TV receiver radiation would also prohibit the use of certain frequency assignments that are close to multiples of the 15.75 kHz horizontal scanning frequency.

6. REFERENCES

American Standards Association, Inc. (1961), American Standard Methods of Testing Amplitude-Modulation Broadcast Receivers, C16.19-1951, pp 1-24.

International Telecommunication Union (1980), Regional Broadcasting Conference, Document No. 34-E, Buenos Ares, Argentina, March 11.

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Interference caused by local oscillator radiation from AM radios is a known problem. It is particularly troublesome when the local oscillator frequency of one radio coincides with the tuned frequency of another, nearby AM radio. This condition produces an annoying tone in the victim receiver whose frequency is dependent on the frequency difference between the local oscillator and tuned frequency of the victim radio. It has been suggested that this source of interference would be more troublesome if AM radio stations were assigned frequencies in 9 kHz channel increments instead of the current 10 kHz increments. These arguments, however, are largely based on idealized assumptions for AM radios. This report describes the measurement of local oscillator radiation from a sample of test radios. Measurements were made of local oscillator frequency for various tuning conditions. Also described in the report are measurements of the separation distance required to produce a given amount of interference in a

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