NTIA TM-91-149

MEASURED CHARACTERISTICS OF SELECTED NON-LICENSED DEVICES

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ABSTRACT

This report includes NTIA measurements of characteristics of nonlicensed devices. These devices are authorized under the FCC Rules in CFR 47, Part 15. The measured values are intended for use by the Government in analysis of potential interference between nonlicensed devices and Government telecommunication systems. Facilities, equipment, and procedures to measure the characteristics of nonlicensed devices are described. Measurements include field intensities, harmonic levels, radiation patterns, emission spectra, receiver thresholds, and saturation levels of nonlicensed devices.

KEY WORDS

Emission Spectra
Radiation Pattern
Receiver Saturation Bandwidth
Receiver Saturation Level
Receiver Threshold
Transmitted Field Intensity
Transmitter Harmonic Level

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INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA) is responsible for managing the Federal Government's use of the radio spectrum. NTIA's responsibilities include establishing policies concerning spectrum assignment, allocation and use, and providing the various departments and agencies with guidance to ensure that their conduct of telecommunications activities is consistent with these policies. In support of these responsibilities, NTIA has undertaken a number of spectrum resource assessments (SRAs). The objectives of these studies are to assess spectrum utilization, identify existing and/or potential compatibility problems between systems of various departments and agencies, provide recommendations for resolving any compatibility conflicts, and recommend changes to promote efficient and effective use of the radio spectrum and to improve spectrum management procedures.

A Draft Notice of Proposed Rulemaking (NPRM) was submitted by the Federal Communications Commission (FCC) to the Interdepartment Radio Advisory Committee (IRAC) on August 1986 (Doc. 25038/1). The NPRM refers to a revision of Parts 2 and 15 of the FCC Rules and Regulations regarding the operation of nonlicensed radio frequency devices. The Technical Subcommittee (TSC) in support of the IRAC participated in drafting the NPRM and proposed recommended comments and reply comments for NTIA.

The TSC performed a preliminary study on the impact of the proposed revisions on Government operations and submitted its initial comments in September 1986 (Doc. 25087), while indicating that further investigation was needed due to the diversity and complexity of the issues involved. The TSC was tasked by IRAC to continue its study on the impact of the proposed revisions on Government operations. From September 1987 to July 1988, the TSC continued to address other pertinent issues regarding the FCC Rules and Regulations on nonlicensed radio frequency devices where technical developments and policy guidelines have been discussed and/or recommended.

The TSC also developed Government policy proposals for the NTIA Manual on Government use and/or development of radio frequency devices such as those described in the CFR 47, Part 15 Rules for (nonlicensed) Radio Frequency Devices.

Based on a TSC request, the NTIA developed: 1) a database of the FCC Part 15 Rules and Regulations on nonlicensed emission devices, along with a dedicated retrieval interface for the database access and record extraction[1]. The interest was to provide for the fast and simple identification of the emission level limits associated with the various device categories and frequency bands, along with other qualitative provisions and text information pertinent to the user, and 2) Standardized procedures, analytic models, and computer algorithms for the assessment of the electromagnetic compatibility between nonlicensed devices and government systems. In particular, single and aggregate emission effects from nonlicensed devices were to be considered with sufficient flexibility to support distinct technical specifications and geographical distributions.

The FCC does not require detailed information on emission and reception characteristics of Part 15 devices. NTIA has been obtaining this information on a limited number of nonlicensed devices through direct measurement of Part 15 devices. These data are needed by the Government to support analysis of potential interference between telecommunication systems and Part 15 devices.

OBJECTIVE

The objective of this report is to document the NTIA/ITS measurement procedures and the resultant measured data on non-licensed device characteristics. The objective is in two parts:

1. Develop an NTIA capability to measure and document technical characteristics of Part 15 nonlicensed devices that operate in or have harmonics in Government bands.

2. Establish an information base of detailed information on emissions and reception characteristics of the Part 15 devices addressed in 1, above.

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[1] NTIA TN-89-1, Part 15 Database and Retrieval, C.A. Filippi, S. Litts, March 1989 (TSC-2393/1-1.4.9)

These measurements are not intended to duplicate any FCC measurements but are to identify transmitter and receiver characteristics of nonlicensed devices for use in Government compatibility analysis studies.

APPROACH

To accomplish the objective, the following approach was used:

1. A remote open-area test site with ground screen, rotating table and tower was developed at NTIA/ITS to aid in measurement of Part 15 devices.

2. The test site was instrumented with calibrated test equipment suitable for making precise measurements of electromagnetic emissions.

3. Measurement techniques for measuring Part 15 devices were developed and tested.

4. Measurements were made on Part 15 devices both at the remote measurement site and in their actual location of operation.

5. Measured characteristics of selected nonlicensed devices were recorded in a suitable format.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

GENERAL CONCLUSIONS

Measurements were made of emission and receiver characteristics of thirteen nonlicensed Part 15 devices. These measurements were made at a facility specially constructed at ITS, Boulder, CO, to support the nonlicensed devices measurement task. Measurement procedures were developed to obtain the type of measurements that would be useful to support an interference analysis involving the nonlicensed device.

SPECIFIC CONCLUSIONS

1. Initial procedures and facilities developed to measure characteristics of nonlicensed devices were found to be effective.

2. Simple non-intrusive procedures using portable measurement equipment can be effective in determining transmitter and receiver characteristics of nonlicensed devices.

3. An initial information base was developed that contains measured characteristics of nineteen nonlicensed devices.

4. The information base and measurement capability provides the Government with the ability to evaluate the interference potential of existing and new nonlicensed products.

5. In many cases, the measured emissions from the nonlicensed devices were higher than the permissible emission limits in the pertinent FCC Part 15 Rules.

6. Measured characteristics of a garage door opener shows that the receiver bandwidth is wider and the sensitivity greater than necessary, and thus is vulnerable to off-tuned signals.

7. A complete list of the number, types, and manufacturers of nonlicensed devices marketed and operating in the environment is not readily available.

RECOMMENDATIONS

The following are NTIA staff recommendations based on the findings of this report. NTIA management will evaluate these recommendations to determine if they can or should be implemented from a policy, regulatory, or procedural viewpoint. Any action to implement the recommendations will be via separate correspondence modifying established rules, regulations, and procedures. It is recommended that NTIA:

1. Update and document the procedures used in this task to make measurements of emissions and other characteristics of nonlicensed devices. This should include a further identification of those parameters necessary for interference analysis.

2. Continue to build the information base of nonlicensed device measured characteristics. Develop a strategy for selecting types and/or specific nonlicensed devices for the measurements program.

3. Document the equipment specifications for NTIA procurement of instrumentation required to make measurements of nonlicensed device characteristics.

4. Determine the feasibility of developing and implementing rules for receiver standards for nonlicensed devices.

5. Develop and maintain a comprehensive list of nonlicensed devices as a function of frequency.

SECTION 3

MEASUREMENT FACILITIES, EQUIPMENT AND PROCEDURES

GENERAL CONSIDERATIONS

Nonlicensed radiation devices are increasing in numbers and functions. Some of these devices may be of special interest because of their numbers and emission characteristics that make them suspect in interference problems. Among such devices are cordless telephones, nursery monitors, garage door openers, auto security alarms, cordless microphones, anti-pilferage systems in retail outlets, field disturbance sensors and video camera microphone systems. These Part 15 devices operate over a wide frequency range, and exhibit diverse emission spectra characteristics, radiated power and patterns. In addition, the receiver characteristics of nonlicensed devices are important in assessing potential interference problems. Therefore, it is necessary to determine characteristics of nonlicensed devices such as:

1. Transmitted field intensity
2. Receiver threshold
3. Receiver saturation level
4. Receiver saturation bandwidth
5. Transmitted harmonic levels
6. Radiation patterns for selected devices
7. Emission spectra.

REMOTE FIELD SITE, LABORATORY AND IN-SITU MEASUREMENT LOCATIONS

The selected remote field site is on a mesa a few hundred meters west of the main DOC Building in Boulder, Colorado. There are few buildings or structures in the vicinity. The area is about 120 meters higher than much of the main business and residential sections of the city so that it is somewhat obscured and isolated from the local RF environment. The site has an oval ground screen about 27 by 56 meters, 120V-60Hz power, a wooden turntable for pattern measurements and a wooden antenna tower for variable height related measurements from 1 to 4 meters.

Some tests were conducted in the NTIA laboratory, in Boulder, during inclement weather if time was critical. Garage door openers were tested, in-situ, in residential neighborhoods and antipilferage system transmitters were tested in a shopping mall where time and space conditions limited measurements to field intensity determination.

MEASUREMENT EQUIPMENT

Dipole antennas, balanced and tuned, and double-ridged wave guide antennas can be used with suitable instruments, such as precision spectrum analyzers, in measuring RF field intensities. Three dipoles that were selected cover the frequency range 20 to 1000 MHz, and the selected wave-guide antenna was designed for use from 1 to 18 GHz. With factory calibration, the wave-guide antenna coverage was extended to 26.5 GHz. A spectrum analyzer that was selected was calibrated for use from 10 kHz to 22 GHz. All cables, connectors, filters or preamplifiers were precision quality and of known characteristics. The maximum error to be expected in the spectrum analyzer measurements is about 1 dB.

In crowded areas where pedestrian traffic was heavy, space and time restrictions prohibited the use of a spectrum analyzer and dipole antennas. In these environs, small portable direct-reading field intensity meters were used which cover the bands, 45-225 MHz and 470-960 MHz. These devices, although useful, do not provide extremely accurate frequency information or emission spectra.

MEASUREMENT THEORY AND PROCEDURES

Most of the tests conducted, regardless of specific type, were basically field intensity measurements. The measurements at frequencies below 1000 MHz, in all but a few cases, were obtained with calibrated vertical dipoles and a spectrum analyzer as depicted diagrammatically in Figure 1-A. The RF power input to a spectrum analyzer with a 50 ohm input is $e^2/50$ (usually given in dBm) where e is the voltage across the input resistance. The field intensity E is related to e by the expression:

$$20 \log E = 20 \log e + A_f + C_L \quad , \qquad (1)$$

where the antenna calibration factor A_f(dB), and the cable loss, C_L(dB). The calibration factor was supplied by the manufacturer. In a few cases, measurements at signal frequencies below 1000 MHz were made with direct-reading field intensity meters that employed calibrated dipole antennas.

The nonlicensed devices were measured in conditions similar to those likely to exist in normal use, i.e., hand-held, on counters, or on the manufacturers mounting device, and in a few cases, on ceilings. Potential sources of reflection or parasitic radiation were removed when practical. Most devices were measured at transmitter-to-receiver separations of three meters. Field intensity measurements on antipilferage system transmitters in a shopping mall, were made at separation distances established by considerations of safety and convenience.

Field intensity measurements at frequencies above 1000 MHz were made with a spectrum analyzer and a calibrated horn antenna. These measurements were limited to the Electronic Article Surveillance Tags (EAS Tags) used in conjunction with antipilferage system transmitters and to field disturbance sensing devices. Field disturbance units were of the automatic door opening (motion detectors), or perimeter surveillance types. Equipment configuration for measurements above 1000 MHz is shown in Figure 1-B. When the horn antenna is placed at the calibration distance of one meter from a signal source, the measured field intensity, E in microvolts per meter, is related to the measured power P (dBm), the cable loss C_2(dB), and the antenna calibration factor A_f(dB), by the expression:

$$20 \log E = P + 107 + C_L + A_f \quad \text{dB} \qquad (2)$$

The EAS Tags are small, hard plastic devices which are connected to merchandise in retail stores for antipilferage protection. The tags apparently contain full or half-wave rectifier circuits connected to rudimentary dipole antennas. When illuminated by an electric field at about 900 MHz, they re-radiate at about 1.8 GHz. To find the re-radiated signal, the tags were illuminated by a 900 MHz signal from a signal generator through a 1.8 GHz filter. The filter was needed to eliminate a 1.8 GHz harmonic present in the output from the signal generator. With the filter in place, any 1.8 GHz signal measured would be generated by the EAS Tag alone. The equipment configuration for this investigation is shown in Figure 2. The dipole antenna serves to measure the 900 MHz signal, while the horn antenna couples to the 1.8 GHz signals from the EAS Tags.

Receiver threshold, in the context of this report, is the minimum signal required to activate the receiver's final function such as operate a relay, a servo mechanism, a dialing light, or provide a usable, audible signal as determined by simple observation. The test equipment configuration is shown in Figure 3. The threshold measurements were obtained by locating the receivers and calibrated dipole antennas equidistant from the nonlicensed device transmitters. The transmitters were then brought up from a distance, which in some cases was city blocks, until they began to activate the receivers. The field intensities at this minimum operational level were determined from RF power measurements as described earlier.

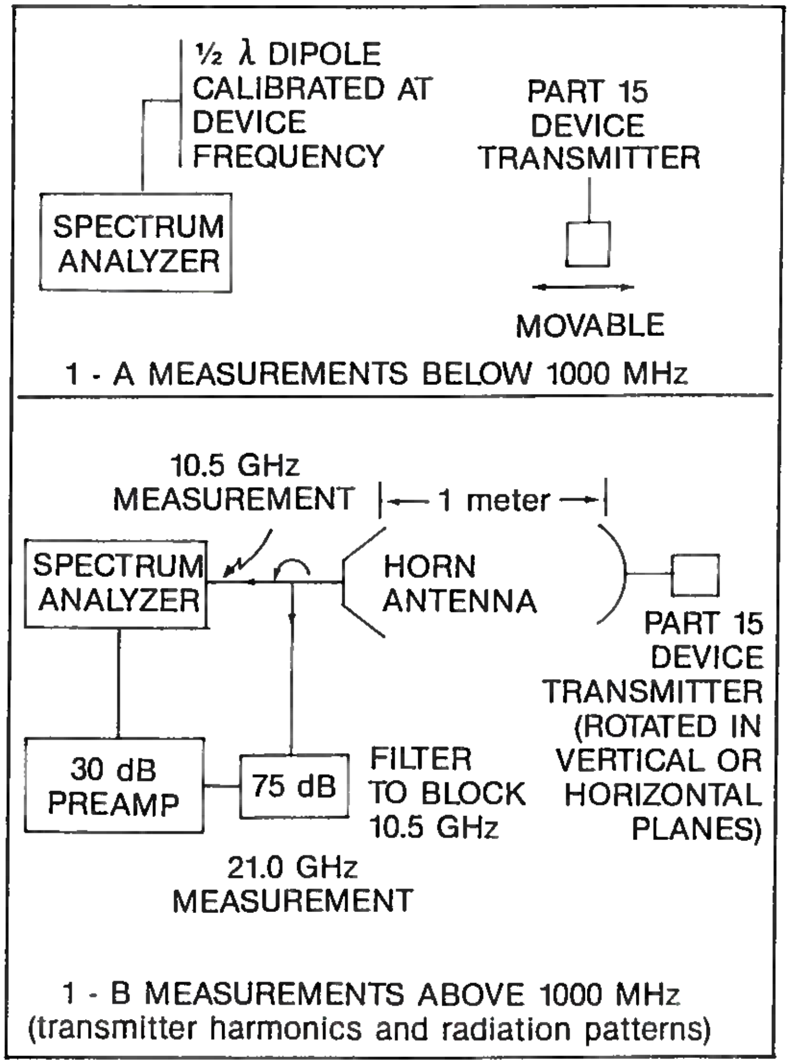


Figure 1. Equipment configuration for field intensity measurements

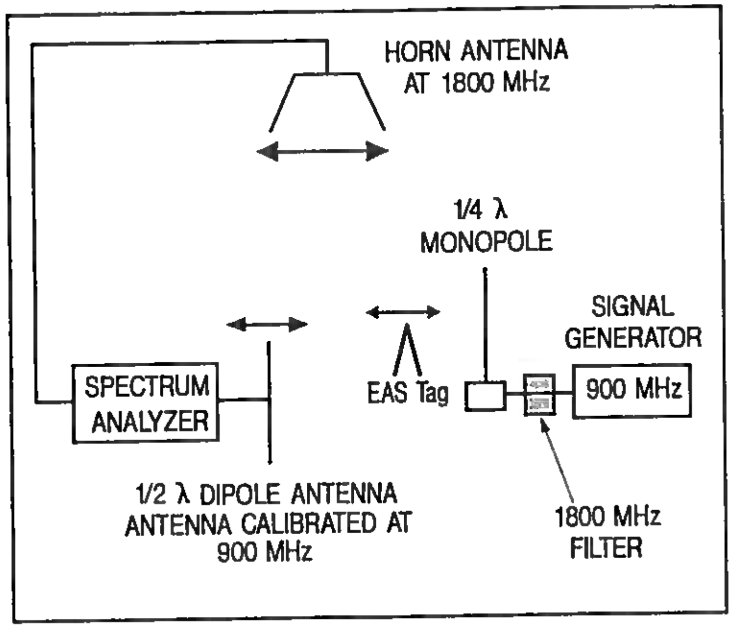


Figure 2. Equipment configuration for measurement of electronic article surveillance TAG characteristics

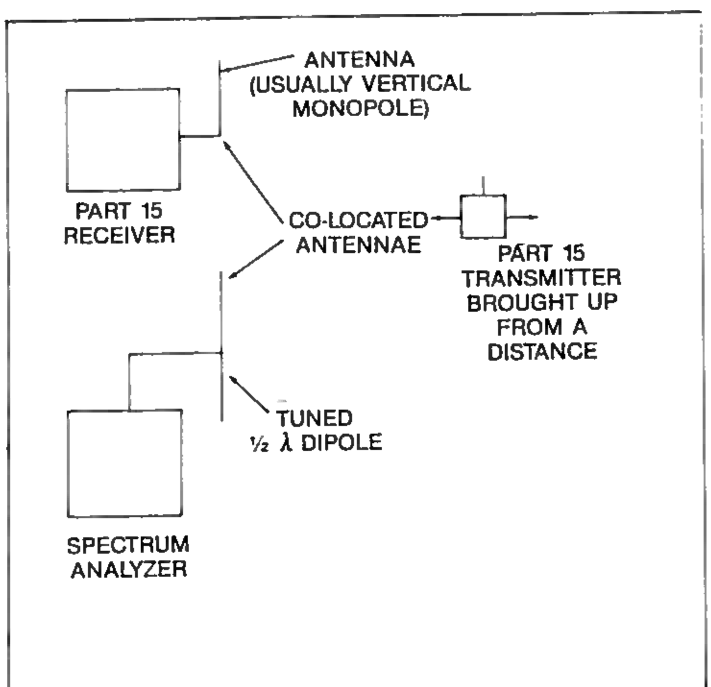


Figure 3. Equipment configuration for receiver threshold measurements

Receiver saturation is the minimum CW signal level of a competing transmission at the nominal frequency of a nonlicensed device, that will render the receiver function inoperable under the influence of the associated transmitter. Test apparatus configuration for this measurement is shown in Figure 4. Measurements were performed by situating the receiver and calibrated measurement dipole antennas equidistant from a CW signal source. The CW signal source was slowly increased in power until the receiver function could not be activated by the device transmitter which was at a constant, normal distance from the receiver. The field intensity of the competing CW signal was then determined from the measured minimum RF power required to saturate the receiver.

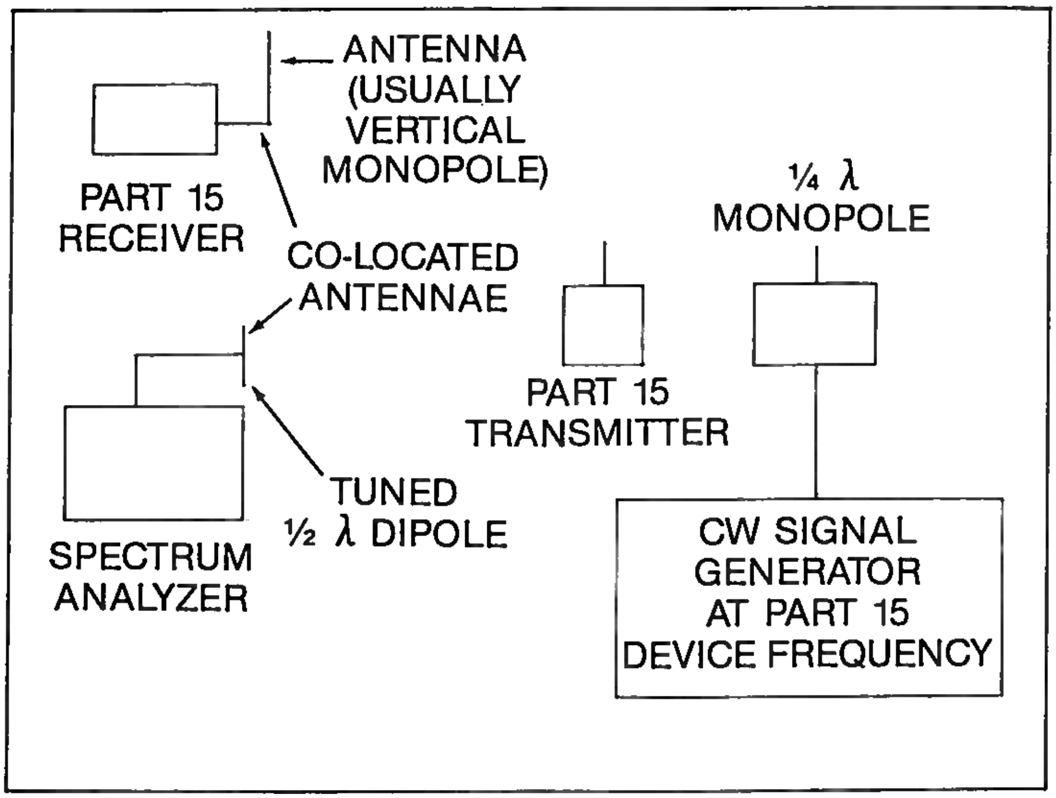


Figure 4. Equipment configuration for receiver saturation measurements

Receiver saturation bandwidth is the frequency range over which a competing CW signal must be at least 3 dB greater than the minimum, at the nominal device frequency, to cause receiver function failure while the associated device transmitter is operating. Figure 4 shows the equipment configuration used in testing. Measurements were made by simultaneously illuminating the receiver with a constant, known signal from the nonlicensed transmitter, and a competing CW signal which was varied in strength and frequency. The competing signal level and frequency at saturation, in relation to the level at the signal from the device transmitter, were used in determining receiver saturation bandwidth. The measurements results shown in Figure 5 are discussed in Section 4.

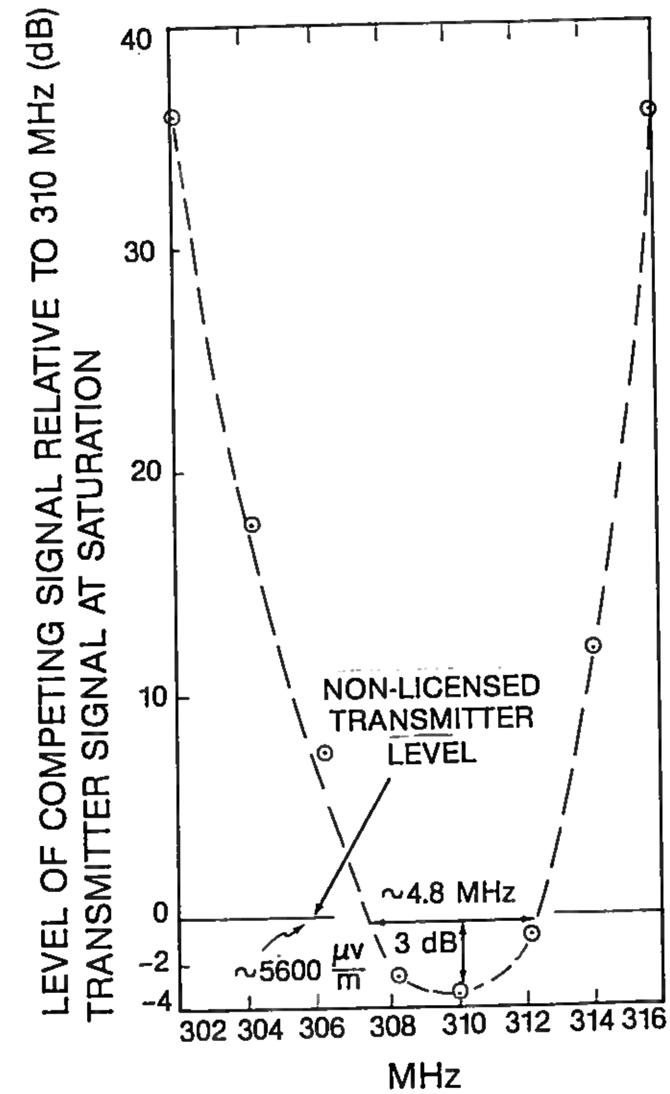


Figure 5. Saturation bandwidth of garage opener receiver

Transmitter harmonic levels were determined for field disturbance sensors with fundamental frequencies of 10.5 GHz. For strong measuring harmonics at 21.0 GHz, the equipment configuration is depicted in Figure 1-B without the filter or preamplifier. In one case, the 21.0 GHz harmonic was weak or nonexistent, and it was then necessary to use a 30 dB gain preamplifier to search for the harmonic. The strong fundamental at 10.5 GHz generated a 21.0 GHz harmonic within the preamplifier, so a 75 dB rejection filter was inserted before the preamplifier to block the fundamental. With this technique, any 21.0 GHz signal observed could originate only at the transmitting unit.

Horizontal and vertical radiation patterns of field disturbance sensors were obtained with measurement equipment configured as shown in Figure 1-B. The nonlicensed field disturbance sensor transmitters were mounted to provide for rotation in both horizontal and vertical planes. Field intensity measurements were then made as outlined earlier at 10 degree rotation increments.

The transmitter emission widths and modulation in formation were obtained with a spectrum analyzer. Since field strengths were already determined, these measurements were conducted primarily in the laboratory with simple uncalibrated antennas. Frequency limits, on the spectrum analyzer were set by the operator to provide the best balance of spectrum detail and spectral width. That is, if inclusion of the 10th harmonic of the fundamental provided little information and sacrificed detail at frequencies near the fundamental, then the frequency limits were narrowed to provide more close-in detail. Finally, the 20 dB emission bandwidth was determined, as shown in Figure 6, by identifying the frequency range where the emission level is 20 dB below the peak value.

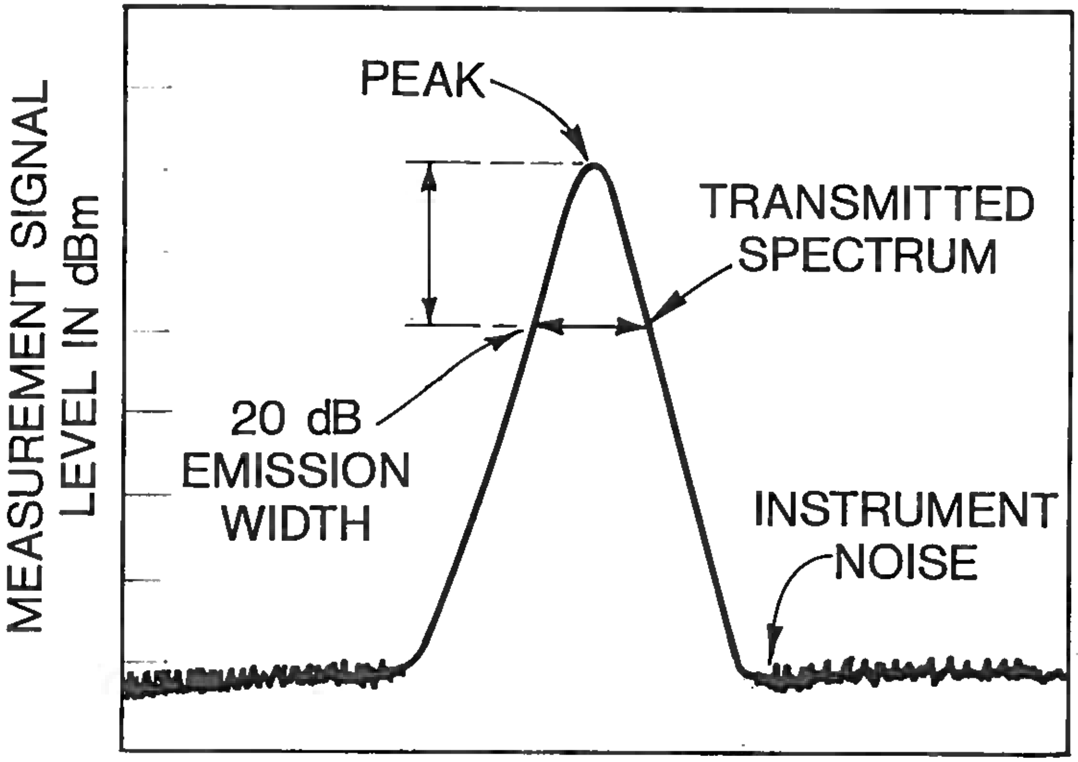


Figure 6. Idealized spectrum of nonlicensed device illustrating emission width measurement

SECTION 4

RESULTS OF MEASUREMENTS OF NONLICENSED DEVICES

GENERAL CONSIDERATIONS

Most of the Part 15 radiating devices were small hand-held units. Under normal use, their small monopole antennas are likely to radiate signals that are predominantly vertically polarized. Vertically polarized signals propagate further over the earth than do horizontally polarized signals and are therefore, more likely to cause interference. Accordingly, most measurements were of the vertical components. In a few cases, which are noted in the tables of measured values, the horizontally polarized component was stronger than the vertical component.

Measurements were made at the fundamental frequencies where emission levels were the greatest. Since the basic unit of measurement was power, variables such as resolution bandwidth of the spectrum analyze were chosen to provide the most useful information.

TRANSMITTED FIELD INTENSITY MEASUREMENTS

Selected nonlicensed devices were measured by methods described earlier. Results of the measurements are shown in Table 1. Type of device, measured frequency, measured field intensity, measurement distance, the authorized emission level, and the relevant section in the FCC revised Part 15 rules are included in the table.

Cordless telephones and nursery monitors are limited by FCC rules to 10,000 µV/m at 3 meters. The measured emission levels for these devices as seen in Table 1 are greater than authorized. An attempt was made to ascertain the maximum range for some of the devices measured. The results were that both the cordless telephone and nursery monitors provided clearly audible signals even when the base and mobile units were separated in excess of 900 meters. This separation distance was not necessarily a maximum range, but rather a maximum practical test distance available given the need for 60 Hz power source for the devices. Both devices operated at far greater ranges than expected. Few would expect a nursery monitor to be removed 900 meters or more from a child's nursery, or for a cordless telephone to be operated over such a distance.

TABLE 1

FIELD INTENSITIES OF SOME NON-LICENSED DEVICES

NON-LICENSED DEVICE	FREQUENCY (MHz)	FIELD INTENSITY μV/m @3m	PART 15 RULE SECTION	PART 15 LIMIT μV/m @3m
Cordless Telephone	49.83	18000.	15.233	10000.
Nursery Monitor	49.89	74000.	15.233	10000.
Garage D. Door A	361.0 362.0	15800. 15800.	15.231	7800. 7800.
Garage D. Door B	317.75	8900.	15.231	5800.
Garage D. Door C	310.0	7700.	15.231	5800.
Garage D. Door D	309.89	3500.	15.231	5800.
Garage D. Door E	308.35	18600.	15.231	5800.
Video Camera Microphone	49.89	3400.	15.233	10000.
Anti-Pilferage Device A	900.2	2,950,000	15.245	500000.
Anti-Pilferage Device B	900.3	117,000.	15.245	500000.
FDS Door Device A	10,550.	1,054,000*	15.245	2,500,000.
FDS Door Device B	10,520.	47,667*	15.245	2,500,000.
FDS Surveillance	10,490.	1,756,667.*	15.245	2,500,000.

* These values were measured at 1 meter and corrected to 3 meters.

Three garage door opener receivers were tested in-situ for radiation characteristics at their nominal operating frequencies. The results given in Table 2 show that two units radiate low level emissions on 310 MHz at a distance of 0.6 meters, while the third showed no perceptible radiation. Structures or obstructions within the garages prohibited arbitrary measurement distances, 3 meters for example, so for conformity 0.6 meters was chosen so that the units could be compared at identical distances.

TABLE 2

RADIATED FIELDS FROM THREE GARAGE DOOR OPENER RECEIVERS

FREQUENCY (MHz)	RADIATED FIELD (μV/m)	MEASUREMENT DISTANCE (METERS)
310	680	0.6
310	640	0.6
310	Near Noise Floor of Measuring Equipment NOTE: Obstructions within garages prevented arbitrary distances so 0.6 m was chosen for consistency and intercomparability. $0.6 \text{ m} > 2D^2/\lambda$	0.6

Measurements were made of the emissions from antipilferage systems which use EAS Tags that are in common use in many clothing stores. These systems are field disturbance systems authorized under FCC Part 15.245. These systems incorporate nonlicensed transmitters which radiate CW signals of approximately 900 MHz at the entrances of the stores. The EAS Tags. which are about one inch by four inches are affixed to clothing in the store. These EAS Tags contain simple passive diode circuitry in the forms of half or full wave rectifiers connected to rudimentary dipole antennas. When an article of clothing containing an EAS tag is brought near the EAS transmitter at the store entrance, the EAS Tag is illuminated by the transmitter emissions and reradiates a weak signal at twice the EAS transmitter frequency. A nearby receiver tuned to the reradiated frequency located at the store entrance then activates an alarm.

There were twelve of these antipilferage systems in a shopping mall in Boulder, Colorado, all systems operating at 900 to 902 MHz. The surveillance antennas in some cases were visible and appeared to be horizontal metal strips above the store entrance. Two of the systems were selected (with store management approval) for measurements. One transmitter was measured to radiate a horizontally polarized signal of about 2,950,000 µV/m on 900.2 MHz at a distance of 3 meters, while the other transmitter measured 117,000 µV/m on 900.3 MHz at a distance of 3 meters. These values are shown in Table 1. Two EAS Tags were selected at random, and taken to the NTIA laboratory for examination. The EAS Tags were examined to determine the threshold field intensities required to activate the EAS Tags at 900 MHz and emission levels of the reradiated signals at 1800 MHz. The test equipment is depicted in Figure 2.

The EAS Tags were illuminated within a 133,000 µV/m field at 3 meters by a 900 MHz signal generator. Neither of the EAS Tag units would re-radiate in the 133,000 µV/m field. Only when both units were placed in the immediate proximity of the radiating monopole did they re-radiate at 1800 MHz. The units re-radiated about 1100 µV/m and 400 µV/m respectively at 1 meter. Since the calibrated dipole used in measuring the intensity of the illuminating 900 MHz source is calibrated for the far field only, it was impossible to establish the threshold of the EAS Tag units. It is known only that is exceeds 133,000 µV/m. The signal generator, which was operated at maximum power, must be replaced by a more powerful one in order to determine threshold field intensities for the EAS Tags. It is noted that an 1800 MHz filter was inserted before the monopole antenna on the signal generator to block a transmitter-generated harmonic, thus any observed 1800 MHz signal could originate only at the EAS Tag.

The field intensities of five garage door opener transmitters were measured and the results, given in Table 1, show that units by the same manufacturer have a wide range of field intensities. The values in Table 1 show that the strongest signal was about five times stronger than the weakest for the garage door openers measured.

Three motion detectors were examined and the results placed in Table 1. These are field disturbance sensors authorized under FCC Part 15.245. Two units are employed as automatic door openers, and one unit is used as a perimeter surveillance system. One door opener unit signal was measured to be 143,000 µV/m and the other unit was measured to be 3,162,000 µV/m. This difference was due to the fact that the vertical component of one unit was stronger than the horizontal component of the other. It was not known at the time of measurement that the horizontal component was stronger. The field intensity of the perimeter surveillance transmitter was the strongest at 5,270,000 µV/m.

RECEIVER THRESHOLD MEASUREMENTS

Receiver threshold is of considerable significance in assessing interference susceptibility. Threshold values were measured for garage door opener receivers as mentioned in Section 3 and Figure 3. In order to measure the receiver threshold level, a calibrated dipole antenna connected to a spectrum analyzer, was collocated with the receiver monopole antenna as shown in Figure 3. The garage door activator transmitter was then brought up from a considerable distance until the door was activated. With the transmitter remaining at this position, the field strength required to activate the door was measured. These field strength values are the receiver threshold values given in Table 3 as 170, 171, and 215 μV/m.

TABLE 3

MEASURED RECEIVER OPERATING THRESHOLD FOR SOME NON-LICENSED DEVICES

NON-LICENSED DEVICE	OPERATING FREQUENCY (MHz)	MEASURED RECEIVER OPERATING THRESHOLD μV/m
Garage Door Opener B	310	170.0
Garage Door Opener C	310	171.0
Garage Door Opener D	310	215.0
Cordless Telephone	49.83	23.4
Nursery Monitor	49.89	52.4

The receiver threshold for the cordless telephone was ascertained in similar fashion. The handset was brought up from a distance of a few city blocks until it could operate the dialing light on the base unit. The field strength measured at this distance is the threshold value of 23.4 μV/m, as given in Table 3. The receiver threshold of the nursery monitor was determined using a similar procedure. The field intensity, 52.4 μV/m, is thus recorded in Table 3 as the receiver threshold.

RECEIVER SATURATION LEVEL MEASUREMENTS

The level at which a Part 15 device becomes saturated, by a CW signal from an interfering transmitter at the tuned frequency of the unit, is also important in determining interference susceptibility. Receiver saturation level was determined with measurement equipment as shown in Figure 4. The calibrated dipole was collocated with the nonlicensed device receiving antenna, and a one-fourth wavelength monopole energized by a signal generator, was positioned so that it was equidistant from both receiving antennas, and at far-field zone distances. The interfering signal power, at the nonlicensed device frequency, was slowly increased until the receiver could not be activated by the desired transmitter when it was located at the approximate distance of normal use. The measured field intensity of the interfering signal from the signal generator is then the saturation level for the receiver.

Four garage door opener receivers were tested, using the method described above; three were tested in-situ and the other in the NTIA laboratory. The results in Table 4 show that the receivers can be saturated by interfering CW signals as low as 1280 μV/m. This is consistent with reports that some garage door openers have saturated (and not operated) due to low level interference fields.

TABLE 4

MEASURED GARAGE DOOR OPENER RECEIVER SATURATION LEVELS

GARAGE DOOR OPENER RECEIVER FREQUENCY (MHz)	MONOPOLE ANTENNA LENGTH (METERS)	MEASURED SATURATION LEVEL (μV/m)
B 310	0.20	1280
C 310	0.21	12600
E 310	0.22	13800
D 319	0.30	3700
Measurements B, C, and E were made in situ, while measurement D was made in the ITS Laboratory. All measurements were made with vertical polarization.		

RECEIVER SATURATION BANDWIDTH MEASUREMENTS

Receiver saturation bandwidth measurements were made using the equipment shown in Figure 4. The procedure is similar to that used in the on tuned case except that both frequency and power of the interfering signals were varied. The interfering signal at 302 MHz was increased in power until the receiver was saturated and thus the door opener would not operate. The procedure was repeated for frequencies from 302 to 316 MHz in 2 MHz increments. The 310 MHz door opener transmitter was located at a constant distance from the receiver so that its field intensity was constant at about 5600 μV/m at the receiving antenna. The results given in Figure 5 show that the interfering signal must be very strong at frequencies above and below the tuned frequency in order to saturate the receiver. Within a bandwidth of about 4.8 MHz, however, the interfering signal could be 3dB lower than the tuned signal from the door opener transmitter and still saturate the receiver. The results on Figure 5 show that a strong interfering signal could cause receiver saturation at frequencies removed from the nominal device frequency as much as 8 MHz.

TRANSMITTER HARMONIC LEVEL MEASUREMENTS

Some transmitters used in nonlicensed devices, have been shown to radiate significant power at harmonics of the fundamental carrier frequency. Field disturbance sensors which commonly radiate about 2 V/m at 10.5 GHz are Part 15 devices of special interest because of the significant power they radiate at the 21.0 GHz harmonic. To search for this harmonic, three field disturbance sensors (two automatic door openers and one perimeter surveillance device) were examined using the equipment configured as shown in Figure 1-B. Both of the door opener device transmitters had easily identifiable harmonics. The results, given in Table 5, show that the 21.0 GHz harmonics of the door opener units A and B were respectively 14 and 28 dB lower than the fundamentals at 10.5 GHz. Thus, the two door opener transmitters have harmonic emission levels, both of which are stronger than the current FCC Part 15 requirement of -40 dB. When the perimeter surveillance device (Unit C) was measured, no harmonic emission was detected above the noise level of the spectrum analyzer. To try and detect second harmonic emissions, a 30 dB gain preamplifier was inserted before the spectrum analyzer. Since a nonlinear device such as preamplifier could itself produce a 21.0 GHz harmonic if the 10.5 GHz fundamental were strong, a 75 dB filter was inserted to block any 10.5 GHz signal, thus assuring that any 21.0 GHz signal observed would in fact be generated by the field disturbance sensor. Table 5 shows that no harmonic was detected even at levels about 67 dB lower than the fundamental. The reason the surveillance transmitter had such low harmonic emissions is because it incorporates a waveguide filter to attenuate emissions at 21 GHz and above.

TABLE 5

MEASURED TRANSMITTER HARMONIC LEVELS OF FIELD DISTURBANCE SENSORS

DEVICE	FREQUENCY (GHz)	FIELD INTENSITY (μV/m)	FIELD INTENSITY dB (μV/m)
Field Disturbance Sensor A Fundamental 2nd Harmonic	 10.550 21.098	 124,000 24,700	 102.0 88.0
Field Disturbance Sensor B Fundamental 2nd Harmonic	 10.515 21.032	 144,000 5,600	 103.0 75.0
Field Disturbance Sensor C Fundamental 2nd Harmonic	 10.494 20.988	 4,440,000 *Not Found	*

All measurements made at 1 meter distance, vertical polarization
* Below instrumentation noise floor of -67 dB (μV/m)

RADIATION PATTERNS OF SELECTED DEVICES

Since field disturbance sensors were found to have harmonics emissions that are significant, it was decided to obtain both horizontal and vertical radiation patterns for the devices to aid in assessing interference potential. To obtain the radiation patterns, the field disturbance sensor transmitters were installed on mounts which could be rotated in 10 degree increments in either horizontal or vertical planes. The measuring equipment is depicted in Figure 1-B.

Field disturbance Sensor A (door opener) horn antenna was rotated in both horizontal and vertical planes in 10 degree increments up to 90 degrees. The field intensities of the horizontal component and the associated dB levels are given in Table 6. The horizontal component varies from 0dB down to a minimum of -25 dB in the horizontal plane, while the same component varied from 0 dB down to -29 dB in the vertical plane. During the measurements, the transmitter frequency varied from 10.50 to 10.55 GHz, and the transmitter power level varied 1 dB when the device

TABLE 6

MEASURED RADIATION PATTERNS OF FIELD DISTURBANCE SENSOR A (DOOR OPENER) AT 10.50 TO 10.55 GHz, HORIZONTAL POLARIZATION

ANGLE (Degrees)	HORN ANTENNA PATTERN			
	HORIZONTAL FIELD INTENSITY		VERTICAL FIELD INTENSITY	
	μV/m	Relative dB	μV/m	Relative dB
0	2.818,000	0	3,162,000	0
10	2,512,000	-1	2,818,000	-1
20	1.995,000	-3	1,585,000	-6
30	447,000	-16	794,000	-12
40	282,000	-20	562,000	-15
50	501,000	-15	631,000	-14
60	631,000	-13	112,000	-29
70	631,000	-13	891,000	-11
80	158,000	-25	708,000	-13
90	355,000	-18	562,000	-15

(Measurement Distance = 1 meter, symmetry assumed)

was returned to its original (0 degrees) position between horizontal and vertical rotations.

Antenna pattern measurements were made for Door Opener A at its harmonic frequency which varied from 21.0 to 21.1 GHz during the test. The results, shown in Table 7, indicate that the harmonic emissions are below noise at 90° in the horizontal plane but not in the vertical plane.

The radiation pattern of field disturbance Sensor C (perimeter surveillance device) was measured in both the horizontal and the vertical planes. Since no harmonic emissions were detected, only pattern of the fundamental at 10.494 GHz was measured. The results in Table 8 indicate that the vertically polarized component varied from 0 dB down to -45 dB in the horizontal plane, and it varied from 0 dB down to -41 dB with rotation in the vertical plane. This device had a round parabolic reflector fed by an open rectangular wave guide.

TABLE 7

MEASURED RADIATION PATTERNS OF FIELD DISTURBANCE SENSOR A (DOOR OPENER) AT 21.0 TO 21.1 GHz, HORIZONTAL POLARIZATION

ANGLE (Degrees)	HORN ANTENNA PATTERN			
	HORIZONTAL FIELD INTENSITY		VERTICAL FIELD INTENSITY	
	μV/m	Relative dB	μV/m	Relative dB
0	89,000	0	79,000	0
10	126,000	3	28,000	-9
20	79,000	-1	40,000	-7
30	50,000	-5	20,000	-12
40	28,000	-10	13,000	-16
50	13,000	-17	9,000	-19
60	25,000	-11	28,000	-9
70	8,000	-21	18,000	-13
80	14,000	-16	16,000	-14
90	Noise	Noise	9,000	-19

(Measurement Distance = 1 meter, symmetry assumed)

EMISSION BANDWIDTH OF NONLICENSED TRANSMITTERS

The emission spectra of five nonlicensed devices that were measured using a spectrum analyzer are given in Figures 7 through 12. The 20 dB emission bandwidths were determined from the emission spectra figures as demonstrated on Figure 6. These emission bandwidth values are given in Table 9.

The emission spectra of the video camera microphone system is shown in Figure 12. The 20 dB emission bandwidth is estimated from Figure 12 to be 7 kHz. Unlike any of the other devices, it had four strong spurious emissions in addition to the fundamental at 49.89 MHz. The spurious emissions are at approximately 17.3, 33.9, 66.6, and 83.2 MHz. The spurious at 66.6 MHz was only about 17 dB lower than the fundamental.

TABLE 8

MEASURED RADIATION PATTERNS OF FIELD DISTURBANCE SENSOR C (SURVEILLANCE TRANSMITTER) AT 10.494 GHz, VERTICAL POLARIZATION

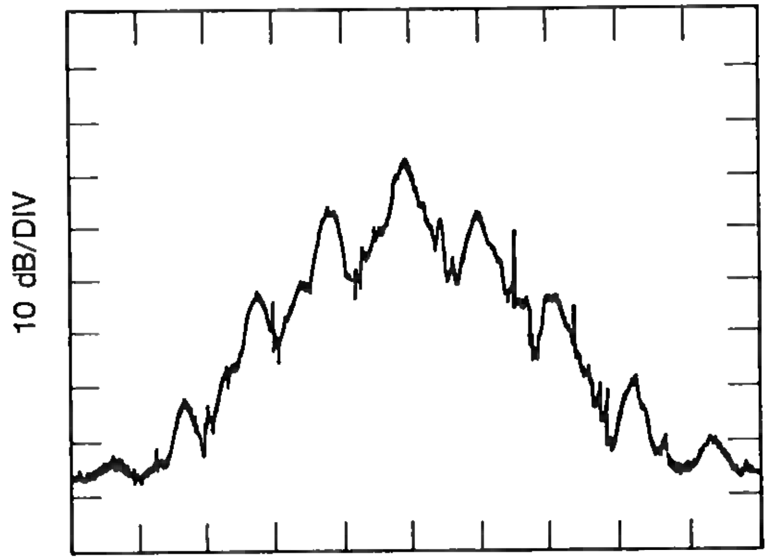
ANGLE (Degrees)	REFLECTOR ANTENNA PATTERN			
	HORIZONTAL FIELD INTENSITY		VERTICAL FIELD INTENSITY	
	μV/m	Relative dB	μV/m	Relative dB
0	5,272,000	0	5,272,000	0
10	745,000	-17	373,000	-23
20	333,000	-24	84,000	-36
30	105,000	-34	149,000	-31
40	296,000	-25	296,000	-25
50	53,000	-40	167,000	-30
60	53,000	-40	264,000	-26
70	94,000	-35	149,000	-31
80	74,000	-37	53,000	-40
90	30,000	-45	47,000	-41

(Measurement Distance = 1 meter, symmetry assumed)

TABLE 9

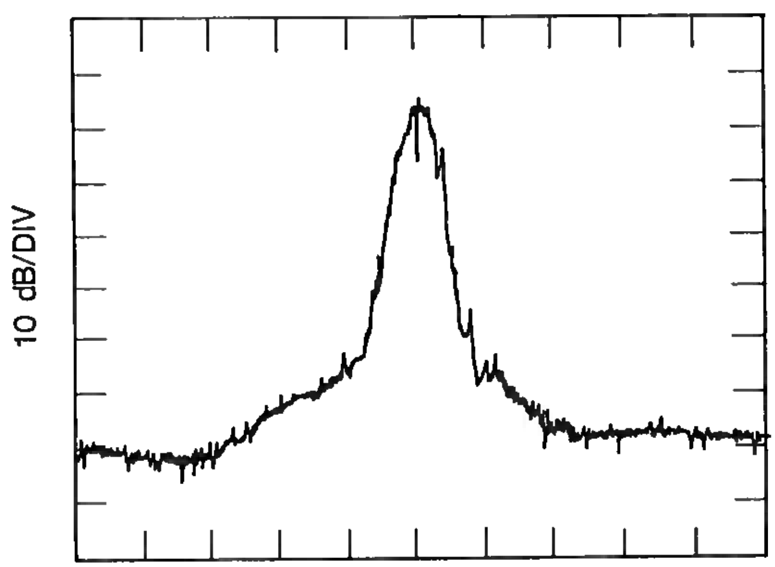
EMISSION SPECTRAL PEAKS AND BANDWIDTHS FOR SOME NONLICENSED DEVICES

DEVICE	FREQUENCY (MHz) @Peak Emission	20 dB EMISSION BANDWIDTH
Cordless Telephone	49.89	15 kHz
Nursery Monitor	49.89	8 kHz
Auto Security Alarm	317.00	500 kHz
Garage Door Opener	310.00	3 MHz
Video Camera Microphone	49.89	7 kHz



CENTER: 49.83 MHz
RESOLUTION BANDWIDTH: 1 KHz
SPAN: 50 KHz
VOICE MODULATION

Figure 7. Emission Spectrum of Cordless Telephone



CENTER: 49.89 MHz
RESOLUTION BANDWIDTH: 1 KHz
SPAN: 100 KHz
NO MODULATION

Figure 8. Emission Spectrum of Nursery Monitor

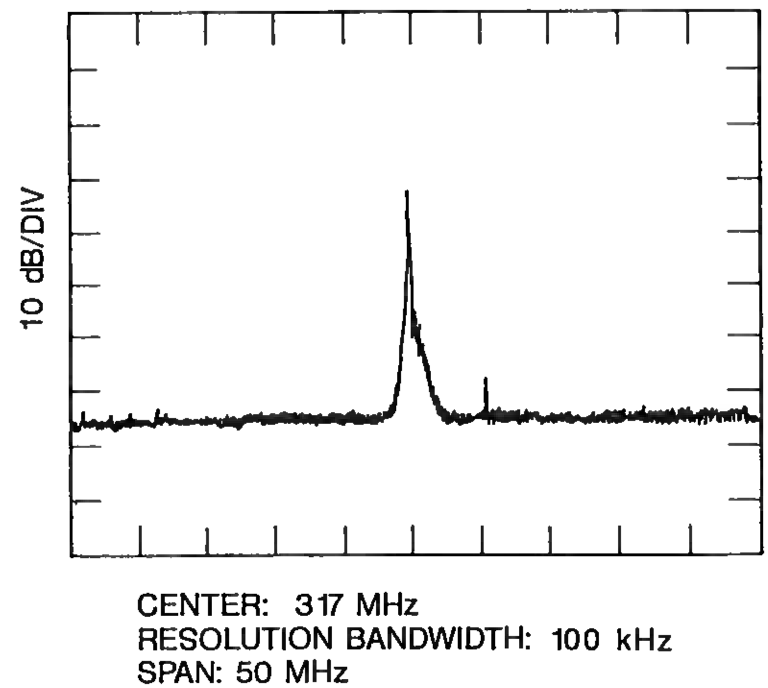


Figure 9. Emission Spectrum of Auto Security Alarm

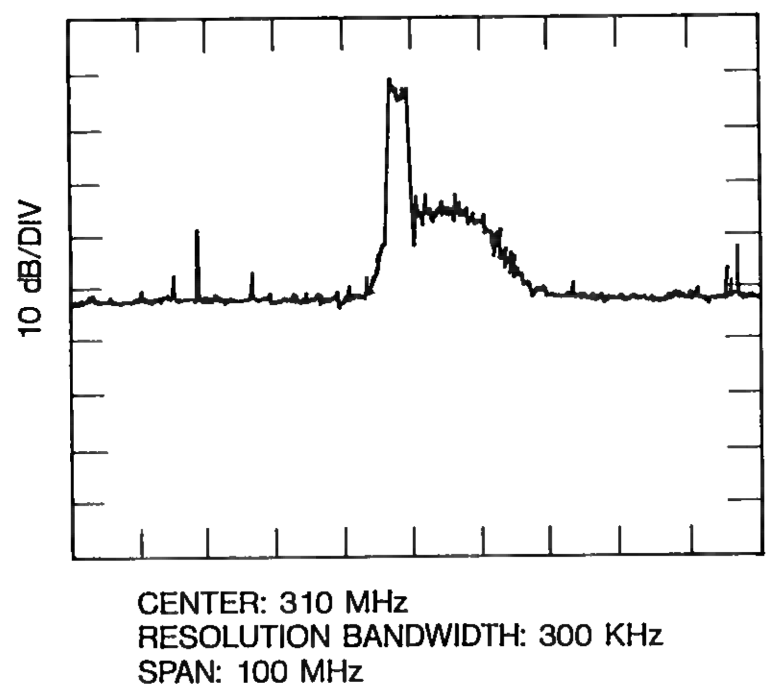


Figure 10. Emission Spectrum of Garage Door Opener

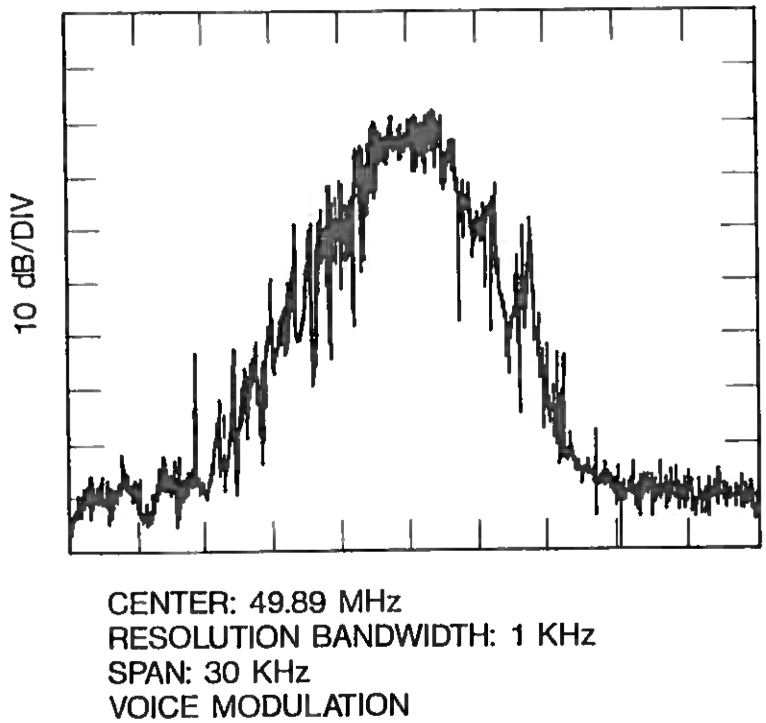


Figure 11. Emission Spectrum of Video Camera Microphone System

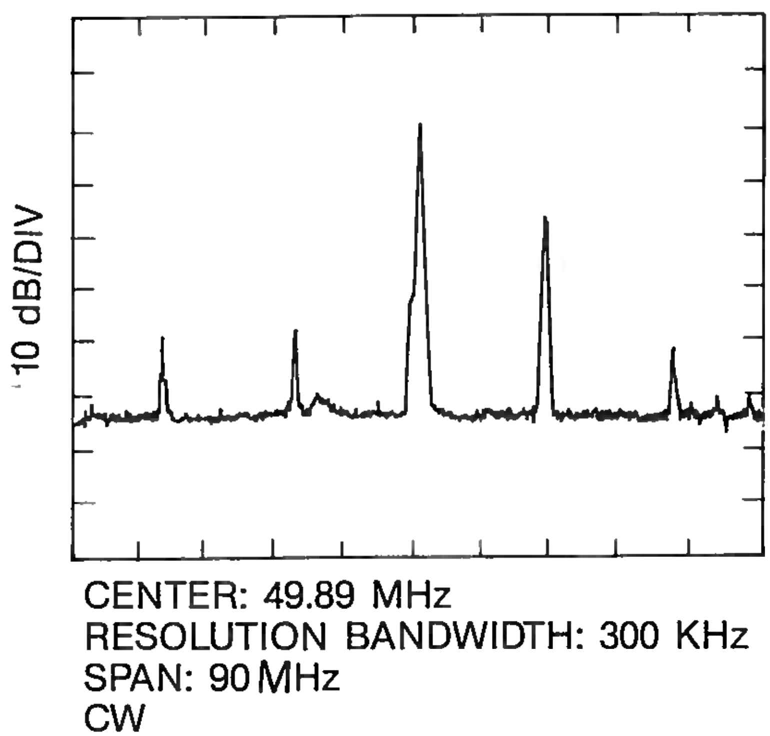


Figure 12. Emission Spectrum of Video Camera Microphone System

SECTION 5
RULES AND REGULATIONS FOR NONLICENSED INTENTIONAL AND UNINTENTIONAL RADIATION DEVICES

Policy for Government purchase, development and use of non-licensed radio frequency radiation devices are given in Sections 7.8 and 7.9 of the NTIA Manual, January 1990 revision, while government standards for nonlicensed devices are given in Annex K, entitled, "Technical Standards for Federal Nonlicensed Devices." Rules for private sector use of such devices are given in Title 47, Part 15 of the FCC Code of Federal Regulations.

The FCC rules and regulations that govern the operations of nonlicensed devices have recently been revised (See FCC Docket 87-389, adopted 1989). Under the old classification, such devices were classified as incidental radiation devices (such as electric motors, ignition systems, and home appliances) or restricted radiation devices (such as cordless telephones, auditory assistance devices and garage door openers). Under the new classification, these devices are labeled unintentional and intentional radiators respectively. Also under Docket No. 87-389, the Commission revised technical standards for a number of frequency bands and types of intentional radiation devices. Changes also included an expanded list of restricted bands where fundamental emissions from intentional nonlicensed devices are not permitted and where harmonic and spurious emissions from any nonlicensed device are limited.

Table 10 lists a number of nonlicensed radio frequency devices as intentional or unintentional radiators. This is certainly not a complete list of such devices but shows types of devices that fall under these headings. Although these devices are not licensed, the manufacturer must notify the FCC of their existence and abide by the appropriate Part 15 rules. Operation of any of these types of devices is subject to the condition that no harmful interference be caused to any authorized radio service and that interference must be accepted from any source. The radiation limits for the fundamental of intentional radiators are given in Table 12.

There are no frequency allocations for and consequently no specific frequency assignments for nonlicensed devices. Under the FCC rules and the NTIA manual, these devices may operate in any band except those designated as restricted bands in Section 15.205 of the Revised Part 15. These restricted bands are listed in Table 11 and the limits for harmonic emissions in the restricted bands are given in Table 12.

TABLE 10

TYPICAL NON-LICENSED DEVICES

INTENTIONAL RADIATORS	UNINTENTIONAL RADIATORS
Auditory Assistance Device	Computing Devices
Control and Security Alarm Devices	Electric Motors
Cordless Telephone	Electric Power Lines
Supermarket Door Openers (Field Disturbance Sensor Radar)	Ignition Systems
Garage Door Openers (Remote Transmitter)	Microwave Ovens
Nursery Monitor Devices	Light Dimmers
TV Interface Devices	Radio and TV Receivers
Telemetering Transmitter	
Video Camera Microphone Transmitter	

TABLE 11

RESTRICTED BANDS FOR NON-LICENSED INTENTIONAL RADIATORS (NTIA MANUAL, ANNEX K, SECTION 3.2)

MHz	MHz	MHz	GHz
0.090-0.110	162.0125-167.17	2310-2390	9.3-9.5
0.49-0.51	167.72-173.2	2483.5-2500	10.6-12.7
2.1735-2.1905	240-285	2655-2900	13.25-13.4
8.362-8.366	322-335.4	3260-3267	14.47-14.5
13.36-13.41	399.9-410	3332-3339	15.35-16.2
25.5-25.67	608-614	3345.8-3358	17.7-21.4
37.5-38.25	960-1240	3600-4400	22.01-23.12
73-75.4	1300-1427	4500-5250	23.6-24.0
108-121.94	1435-1626.5	5350-5460	31.2-31.8
123-128	1660-1710	7250-7750	86.43-36.5
149.9-150.05	1718.8-1722.2	8025-8500	Above 38.6
156.7-156.9	2200-2300	9000-9200	

The Commission in General Docket No. 89-116, released June 19, 1989, gives new procedures for measurement of emissions from intentional radiators (except for periodic and general spectrum devices and devices operating below 30 MHz). This Notice of Proposed Rule Making (NPRM) gives detailed instructions for both new and modified test procedures for setting up and performing measurements for evaluating intentional radiators for compliance to the new Part 15 technical standards.

Two other NPRMs have been released dealing with intentional and unintentional radiators under Part 15 of its rules. In General Docket No. 89-117, the Commission covers intentional radiators with periodic operations and associated regenerative receivers dealing with measurement procedures and standards. In General Docket No. 89-118, the commission covers the measurement procedures and standards for unintentional radiators except digital devices and those operating below 30 MHz.

TABLE 12

FUNDAMENTAL EMISSION LIMITS FOR INTENTIONAL RADIATORS

FREQUENCY (MHz)	FIELD STRENGTH (μV/m)	MEASUREMENT DISTANCE (Meters)
0.009-0.490	2400/F (kHz)	300
0.490-1.705	24000/F (kHz)	30
1.705-30.0	30	30
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

NOTE: Also Emission Limits for Harmonics in the Restricted Bands (NTIA Manual, Annex K, Section 3.4)

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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.)*

This report includes NTIA measurements of characteristics of nonlicensed devices. These devices are authorized under the FCC Rules in CFR 47, Part 15. The measured values are intended for use by the Government in analysis of potential interference between nonlicensed devices and Government telecommunication systems. Facilities, equipment, and procedures to measure the characteristics of nonlicensed devices are described. Measurements include field intensities, harmonic levels, radiation patterns, emission spectra, receiver thresholds, and saturation levels of nonlicensed devices.

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

emission spectra; radiation pattern; receiver saturation bandwith; receiver saturation level; receiver threshold; transmitter field intensity; transmitter harmonic level

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