INSIDE THE FCC: A LOOK AT HOW THE FCC TESTS FOR COMPUTING EQUIPMENT COMPLIANCE

Since the adoption of the FCC rules governing emissions from computing equipment on October 16, 1979, the FCC has made some attempt to publicize the new rules and to guide the industry in their interpretation. The rules themselves can be found in the Code of Federal Regulations, Title 47, Parts 0-19, available from the U.S. Government Printing Office. Also available from the FCC are two interpretive documents, OST-52 and OST-54. The rules governing setting up a site can be found in OST-55. However, despite the existence of these publications, many of the most important details regarding the testing of computing gear remain unpublished. Because of this, controversy has raged in the EMI testing industry surrounding the following issues: What type of equipment should be used for test? Should dipole antennas or broadband antennas, such as biconicals and log periodics, be used? Should a receiver be used, or is a spectrum analyzer better suited for testing? Does my company need an anechoic chamber to test, or is any open field site with a ground screen good enough? The published rules give precious little guidance regarding these important issues.

The purpose of this article is not to add another voice to the plethora of opinions regarding the "right" way of testing. Rather, without much comment, we will explore how the FCC's Equipment Authorization Laboratory has resolved these issues. After all, since the FCC has a final authority to issue sanctions regarding computing equipment, and since no company has ever been successful in challenging in the courts a laboratory-based sanction, knowledge of how the FCC does testing can be considered crucial for compliance. The article will also explore the FCC's new Measurement Procedure 4 (MP-4), which governs the procedures by which testing is performed. Although MP-4 does not change in any way the FCC's previous pattern of testing, it does for the first time give explicit directions to the industry on how computing equipment tests shall be performed.

What Equipment Should be Used?

The FCC rules are concerned with two kinds of emissions from computing equipment. Radiated emissions is the amount of signals broadcast into space from the device under test in the range of 30 - 1000 MHz. Conducted emissions are defined as the energy passed down the ac line in the region from 450 kHz to 30 MHz. While conducted emissions are straightforward and reliable and repeatable measurements can be easily achieved, radiated emissions measurements are more of a problem. Because of questions surrounding the equipment to be used and the test procedures to be performed, radiated emissions tests performed on identical equipment at different sites can vary by substantial margins.

The physical arrangement of the test site can be found in Figure 1. This drawing is from FCC document OST-55 which describes the set up of a radiated emissions test range. (More information on setting up a facility can also be found in FCC document MP-4.) Basically, the radiated test site is quite simple. A ground plane (if required) is laid out sufficient in size to obtain proper site attenuation data. An antenna is mounted on a mast which is capable of raising and lowering the antenna as described in the figure. The equipment under test is placed on a non-conductive structure at one end of the test site. That device is rotated and cables attached to it are moved in order to find the configuration resulting in maximum emissions. The antenna height is raised and lowered and its polarization changed to do the same. Readings are then taken on a measuring device, such as a spectrum analyzer or receiver. All in all, the set up seems, from the FCC documents, to be simple and very straightforward.

In practice, however, many companies have reported great difficulty in repeating the FCC's results. These problems usually arise when the FCC questions the measurements performed by a company and submitted to the FCC under its Class B certification program. The FCC often does test equipment, and the failure rate has in the past approached 50 percent for certain kinds of equipment. These failures are often quite a surprise to the manufacturer, who in good faith submitted the equipment to the Commission after testing at its own laboratory or at an "FCC approved" measurement facility. A second way in which problems arise is when a company attempts to verify its site's performance under the FCC procedure outlined in OST-55. Very few companies have been able to repeat the performance of the FCC's site attenuation curve. Once again, the seemingly simple process of setting up a test site has become more complicated.

These issues can be resolved by carefully considering why the FCC chose the procedures and equipment that it did. It has been the overwhelming experience of people close to the FCC that if their procedures are followed and the same equipment used, the results recorded by the FCC in their testing, both for testing equipment and for site attenuation, are readily repeatable to a high degree of correlation.

The areas of trouble and the areas that have caused great discussion in the trade press have been selection of antennas (dipole versus broadband), the selection of measurement gear (receiver versus spectrum analyzer), the selection of a site (anechoic chamber versus an open field) and the methodology of the test itself (now defined in the FCC's MP-4).

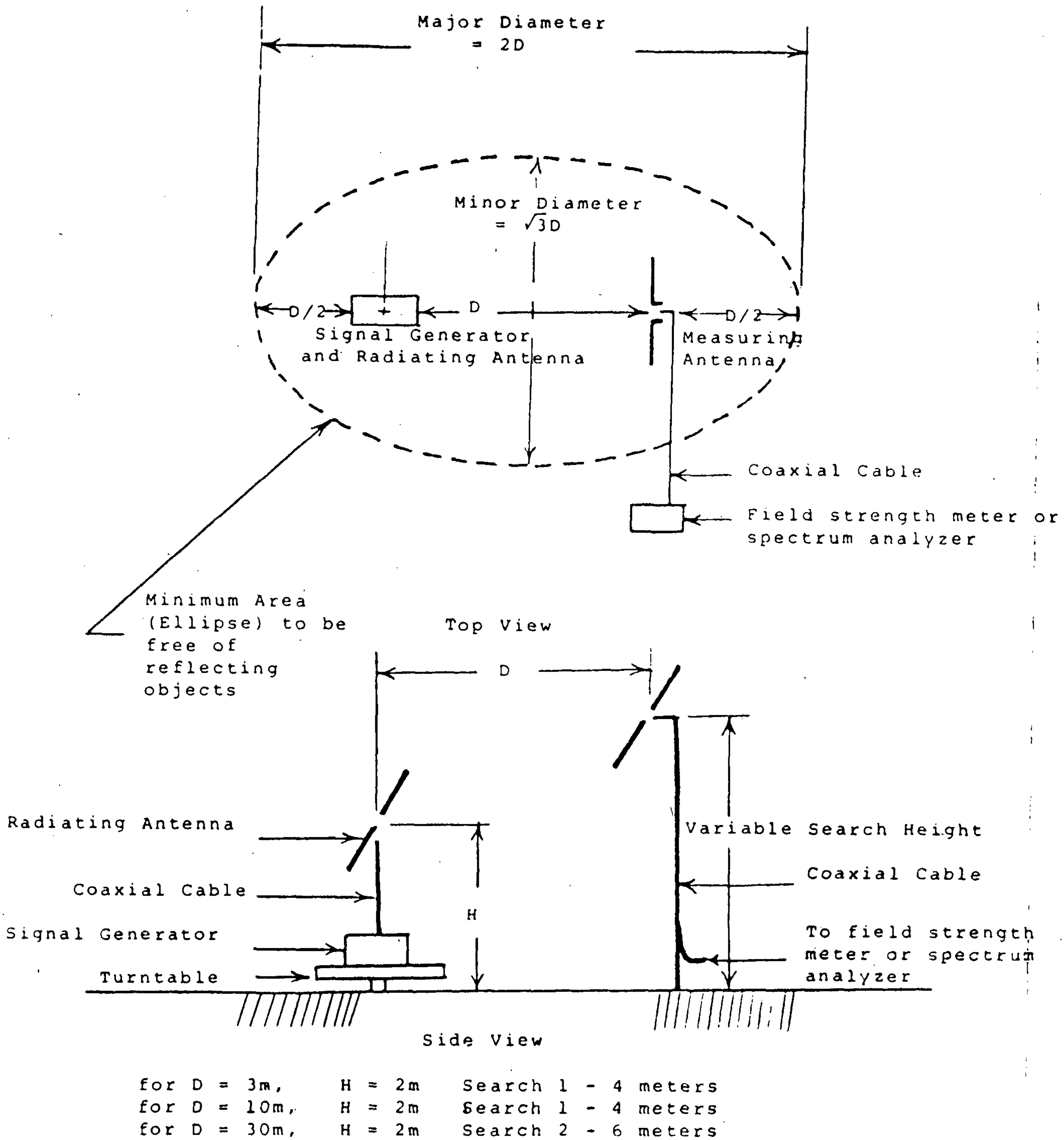

Figure 1. Equipment Arrangement for Measuring Site Attenuation of a Radiation Test Site.

Antennas

There exist today two schools of thought regarding the proper kind of antennas used for EMI measurement. Dipole antennas are the traditional choice of those seeking high accuracy measurements. Since a dipole is a very simple physical structure, the performance of a dipole can be easily verified as matching theoretical values. With a lossless balun attached to the dipole (in order to transform the 73 ohm balanced signal at the output of the dipole to a 50 ohm unbalanced commonly used by measuring equipment) the designer of a precision dipole can with a great deal of confidence feel that the signal at the output of the antenna accurately reflects the field strength incident on the antenna if the antenna is used in a location relatively free of nearby reflecting objects. While the dipole has the advantage of high precision, it can be somewhat inconvenient because it has to be tuned to each frequency of use. Furthermore, it cannot be easily vertically polarized at lower frequencies due to its physical size. Alternatively, broadband antennas, such as the biconical and log periodic, avoid the necessity of retuning. However, because their physical structure is somewhat complex, absolute precision in translating from field strength to voltage output cannot be insured by calculation alone. Rather, these types of antennas have to be correlated against a simpler, more precise type, such as a dipole or an isotropic standard. Therefore, dipoles have the advantage of accuracy, and biconicals and log periodics, the advantage of convenience in changing polarity as required by the FCC.

In the 1950s, the FCC went to considerable length to establish a reference test site whose accuracy was beyond dispute. To do this, the FCC derived a theoretical curve which predicted the amount of loss between two antennas mounted as shown in Figure 1. The transmitting antenna is mounted at the height of two meters and the receive antenna lifted from a height of one to four meters. If the antennas were truly lossless, the loss between the signal put out by the signal generator and the signal received by the input of the measuring device should follow the predicted curve, at least at frequencies above 80 MHz (below that frequency, near field effect and effects having to do with the incidence of the transmitted signal and the groundplane make theoretical determination somewhat more difficult). Despite intensive effort, the FCC was unable to generate curves which approached the theoretical curve even at frequencies above 70 MHz. After considerable study, the Chief of the Equipment Authorization Lab, found the source of the problem and its solution.

It had been assumed that dipole antennas available from some manufacturers were precision antennas whose baluns were lossless. The FCC found that this was not the case. Rather, some commercially available dipole antennas were found to have VSWRs in excess of 3:1, resulting in balun losses due to heat dissipation and inaccuracies due to standing waves on the cable between the antenna and the signal generator or receiver. The only solution available to the FCC at that time was to design and build its own antennas which the FCC did for 25 years.*

Using their own antenna, the FCC was able to achieve close agreement between the theoretical curves above 70 MHz and the actual experimental curve. Between 30 and 70 MHz, theoretical consideration gave way to the practical, and the FCC specified an asymptote at 11 dB loss. This asymptote agrees fairly closely with the FCC's experimental results for Laurel, Maryland.

The FCC's experience with biconical antennas and log periodic antennas had been considerably worse. The biconical antenna has an exceptional high VSWR at frequencies between 30 and 40 MHz, making calibration difficult for precision measurement. Likewise, the FCC's experience with log periodics has been difficult. Neither of these antennas are currently in use at the FCC Equipment Authorization Branch for final testing, although the FCC does accept the results when they are used by companies and test labs. Since under new Measurement Procedure 4, cables have to be moved to find the configuration resulting in maximum emissions at each band of frequencies where equipment under test radiates, having to also go over to the antenna and adjust a dipole's elements is not a significant increase in effort. The only inconvenience is vertical polarization at the lower frequencies.

Receiver Versus Spectrum Analyzer

Receivers have the advantage of sensitivity and the ability to use the CISPR quasi-peak detector. Spectrum analyzers, on the other hand, allow a panoramic display of a wide range of frequencies, simplifying the measurement procedure. While receiver manufacturers frequently point out the fact that the rules specify the use of the quasi-peak detector and seem to require relatively high sensitivity, especially at the high frequencies, the FCC itself uses spectrum analyzers for the bulk of its measurements. In FCC MP-4, the use of a spectrum analyzer is allowed, provided that appropriate accessories are used to provide overload protection, additional sensitivity, and repeatable measurements. As discussed later in this article, the measurement procedures require cables to be attached to equipment under test and for those cables to be moved experimentally in every configuration likely to be found by the end user. It takes approximately five minutes to find the configuration resulting in maximum emissions at any particular frequency. While a spectrum analyzer allows the test engineer to find the configuration resulting in maximum emissions in a whole band of frequencies at one time, a receiver does not. With a receiver, the engineer would have to tune to a certain frequency, verify that the emissions are from the computing equipment and then move the cables to find the configuration resulting in maximum emissions.

By setting up the spectrum analyzer to cover a range of frequencies and then moving the cables to peak the emissions in that range, test time can be reduced. In using the spectrum analyzer, the FCC starts by setting the analyzer to cover a range from 30 to 40 MHz. Then they tune their dipole antenna to the middle of this range, 35 MHz and identify the emissions from the computing equipment by turning it on and off. The cables attached to the equipment are moved in order to peak the emissions in this band and the antenna tuned to the frequency of the highest emissions for recording the measurement. After finishing this process in the 30 to 40 MHz band, it is repeated at a band of 40 to 50 MHz. Above 100 MHz, they widen the band scanned to a 20 MHz range, and above 200 MHz, to a 50 MHz range. Using this procedure, the FCC reports that a good radiated test, including the process of moving cables to find the configuration of maximum emissions by hand, takes only a few hours.

The FCC takes its measurements with a peak detector. When the results indicate that a device is over the limit, then they repeat those tests at the frequency of the offending emissions only with a receiver with a quasi peak detector. However, the FCC has reported that in many cases equipment which fails in radiated emissions with a peak detector will also fail when the quasi peak detector is employed. Peak measurements, as opposed to quasi peak, are also acceptable to the Commission.

Anechoic Chamber Versus an Open Field Site

The FCC Equipment Authorization Lab in Laurel, Maryland, uses an open field test site shown in the photo in Figure 4. This site, while quite simple, is very accurate. Despite the fact that the Equipment Authorization Lab in Laurel, Maryland is located halfway between Baltimore and Washington and in one of the densest broadcast corridors in the country, the FCC has no trouble in performing radiated emissions tests in the open field and has high confidence in the measurements. As mentioned previously, their measurements have never been successfully challenged on appeal.

Companies selling anechoic chamber facilities point out that local broadcast signals can obscure emissions from computing equipment at certain frequencies unless blocked by a shielding chamber. The inside of the chamber is covered with a material which serves to absorb or disburse signals so that the best of both worlds is achieved, low ambient noise and no reflections. Unfortunately, the FCC is very skeptical regarding the chamber's performance. Although the use of anechoic chambers for performing radiated emissions measurements in the range from 30 to 1000 MHz has been proposed for more than 15 years, the FCC has yet to be convinced that any facility accurately reflects the exact performance one would get with an open field test. To be convincing to the FCC, a company using an anechoic chamber will have to show direct correlation to tests performed on an open field site.

Shielded anechoic chambers do provide significant advantages. Beside providing a low ambient, a shielded anechoic chamber provides environmental control, ease of access to the equipment under test, isolation from adjacent equipment and many other time-saving features. It is an excellent facility for engineering model tests, development and suppression work, and audit tests. Since the FCC requires that all products be compliant to its rules, audit or quality assurance tests can be performed in the chamber comparing production line product to the profile obtained from a product originally qualified on an approved open site.

Shielded rooms — that is, shielded enclosures without any absorbing material on the walls — cause severe standing waves to be present in the room. Because of this, the FCC rules flatly state that radiated emissions tests performed in a shielded room are unacceptable for qualification purposes.

Testing in the open field leaves the engineer exposed to local transmission from television and broadcast stations. While signals from these stations can obscure signals from the equipment under test, this problem is not so difficult that it cannot be overcome. According to Richard Fabina, the FCC engineer who is principally responsible for tests on computing equipment, testing in the open field in an area where local broadcast signals are strong can be a meticulous process, to insure that emissions from computing equipment under test aren't sitting under those broadcast stations, but it can be done. Techniques used by the FCC to establish whether such problems exist are the following. First, on narrowband signals, which are the predominate type of emissions from computing equipment, the bandwidth can be narrowed to see if a signal from computing equipment is near a local broadcast carrier. By narrowing the bandwidth down to 10 kHz, signals only a few kHz away from broadcast signals can be easily resolved and identified. Second, the FCC permits moving the antenna to a closer distance, down to one meter if necessary, to establish whether or not emissions are coming from equipment under test. Finally, the FCC recommends testing at night where necessary to establish if emissions are present on the local broadcasting channels. It should also be noted that problems due to local broadcast transmissions are not severe due to 1) the fact that even in dense broadcast areas, less than one percent of the broadcast spectrum is actually used by local broadcasters; and 2) computing equipment generally radiates at so many frequencies that even if one frequency of emissions is missed, if the device violates the rules, another violating signal will probably be found.

While broadcast emissions can be easily distinguished from emissions from computing devices, a factory where computing devices are made could be inundated with signals from other computers, making measurements made at that location impossible. Under these circumstances, a company has one or two choices: either test at a different location away from the factory or test at the factory by building an anechoic chamber. Whenever an anechoic chamber is installed, insist that site attenuation measurements be performed by the manufacturer in the manner specified by OST-55 when its intended use is Equipment Qualification.

How The FCC Tests, MP-4

Having resolved what equipment the FCC uses for tests, it's instructive to look at how these tests are actually performed. Prior to the FCC's publication of Measurement Procedure 4, test methodology varied widely, resulting in readings that varied from one site to another by as much as 20 to 30 dB. To resolve these problems, the FCC published in detail how it performs tests and how it expects tests to be performed by the industry.

Measurement Procedure 4 modifies the previous Commission pronouncements on how computing device tests should be run. It does this by taking the text of the former measurement procedure, Docket 80-284, 47 CFR 15.8 et seq. Appendix A, and making changes where necessary. Some of the changes are procedural, such as adding a new requirement that were shielded cables required for compliance, warnings have to be inserted in the instruction manual to notify the consumer. It also reaffirms OST-55 as the measurement procedure for determining the acceptability of an open field test site and the fact that dipole antennas are the preferred instrument for measuring radiated field strength.

The FCC, however, has tightened the rules considerably regarding the kind of data it finds acceptable. In the laboratory report, the engineer must state how the cables attached to the equipment under test were arranged, and the configuration must be "precisely" reflected in the test report. The Measurement Procedure goes on to say:

> "The configuration that tends to maximize emissions is not intuitively obvious, and in most instances selection will involve some trial and error testing. For example, interface cables may be shifted or equipment reoriented during the initial stages of testing and the effect on results observed.... In any event, there must be a definite justification for selection of a particular configuration [of cable and peripheral placement]."

With regard to what cables must be attached to the equipment under test, the procedure states:

> "It is imperative that interface cables be connected to the available interface ports on the EUT [regardless whether the manufacturer supplies such cables].... The effect of varying the position of the cables must be investigated to find the configuration that produces maximum emissions. The configuration must be precisely noted in the test report."

The implication of this procedure is clear. Cables, regardless of whether they are sold by the manufacturer, must be attached to available ports on the equipment under test, and the cables must be moved to find the configuration resulting in maximum emissions. As mentioned previously, the Commissions has evolved a relatively easy procedure for performing these tests. In order to ease test procedure, the Commission has also stated that where a device under test has many connectors on its rear panel, all of which are the same type and will therefore all have the same signature of emissions when a cable is attached, a cable need only be attached to one of these connectors. The procedure states:

> "Where there are multiple interface ports all the same type, connecting a cable to just one of that type of port is sufficient, provided it can be shown that additional cables would not significantly affect the results."

In an unusual move, the Commission has adopted a different procedure for unique interface ports. While most of the ports on computing equipment are standard types (IEEE 488, RS-232, etc.), some are unique to the manufacturer, and peripherals may not yet exist for these ports. In that case, the Commission does not require that cables attached to this port be moved around. Rather,

> "Products that provide a unique interface port for peripherals that are not yet available may be tested by attaching a cable extended one meter vertically above the device and left unterminated."

It should be kept in mind that the purpose of promulgating MP-4 was to describe in more detail how the Commission has performed its tests in Laurel, Maryland. The procedures outlined in MP-4 are not arbitrary — they evolved over a number

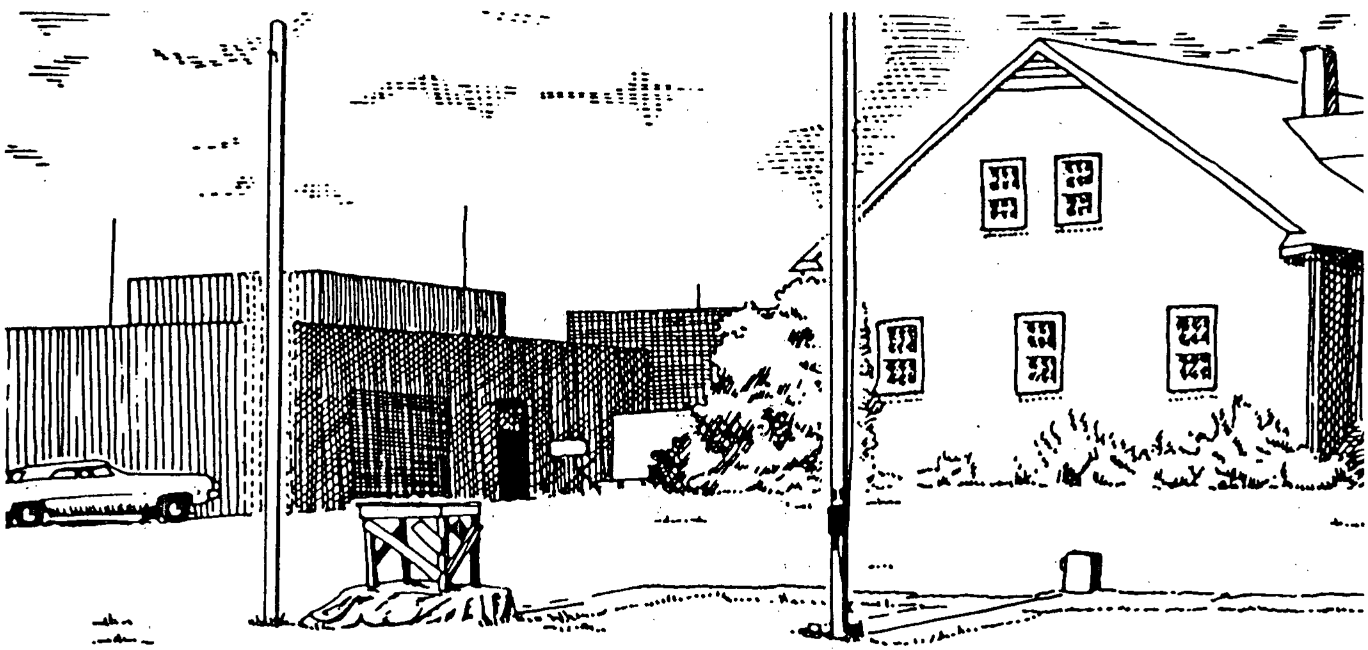

Figure 2. The FCC's own radiated emissions test site is simple, but quite accurate. Equipment to be tested is placed on the table. The mast, 3 meters to the right of the table, is used to raise and lower a dipole antenna.

of years with the Commission carefully considering what test methods were needed for results to be repeatable and for the public interest to be protected. If you or your company has any questions about how tests are to be performed, the Equipment Authorization Laboratory in Laurel, Maryland, is a ready source of information. In any event, in setting up your own test facilities or in using an outside laboratory, be sure that the FCC's procedures are carefully followed, especially in regard to the movement of cables attached to the equipment under test.

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