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Field-Strength Measurements (540-1600 kHz)[1]

Vir N. James PE[2]
Vir James Consulting Radio Engineers
Denver, Colorado

In the dawn of broadcasting after its beginning in the early 1920's when wavelength was checked by a Kolster Decremeter, power was estimated from the product of plate voltage and plate current, and antennas were flat tops or cages hung on a roof; broadcasters sought more quantitative means of describing a station's service area. Expressions such as "You're coming in loud and clear" or the more flattering "You're coming in like a ton of bricks" needed to be reduced to a more accurate and uniform system of description.

This quest for precise information about coverage and service spawned the development of the field strength meter. Initially, the meter consisted of a standard signal generator and a stable loop antenna receiver—an apparatus so bulky that usually it was permanently mounted in a car. The question of determining the location of a measurement point was easily resolved since where the car couldn't go, no measurements were made. Later in the twenties, Western Electric packaged the whole field strength meter into one unit about the size of a piano, portable enough to be carried in a medium sized truck.

The metamorphosis of the present day field strength meter began sluggishly in the early thirties when RCA placed the meter unit in two boxes with handles and billed the unit as "portable." One box contained the field strength meter itself and the other held an assortment of dry batteries, loops, and plug-in coils. This "advancement" in the state of the art was analogous to mounting shoulder straps on the regular kitchen refrigerator and calling it a "portable cooler." Although the improvement was small, it signaled the beginning of a trend to develop a truly portable field strength meter. Measurement points, however, still had to be confined to places accessible by car.

In the late thirties Jim McNary in cooperation with Federal Telephone and Radio Corporation reduced the size and weight of the meter to something slightly less than backbreaking, but this meter was still far from what the engineer needed to do a really adequate job. The tripod was heavy and very bulky. The power supply usually consisted of an external motorcycle battery which had to be carried along with the unit and recharged each night. In the early days the measurement field car encountered few power line problems but, with the expansion of rural electrification, more and more locations accessible by car became unsuitable for accurate field strength measurements. This was before the day of the four-wheel drive jeep. Consequently, it became necessary frequently to climb fences and cross fields to reach measurement points which were clear of power or telephone lines. The real problem, therefore, in making directional antenna measurements was to survive the first week of lugging the Federal meter—a week which usually left one in superb physical condition with that good feeling of a man fresh out of boot camp.

Prayers for a really portable field strength meter were answered shortly after World War II in the form of an expensive, calibrated, miniature tube receiver with "A" and "B" batteries, called the 120-A (B, C, D or E), or WX-2 (A, B, C, D or E) depending on whose nameplate it bore. It was developed by Allen Clarke of Silver Spring, Maryland. Self-contained, direct reading throughout the broadcast band and a little larger than the present day meter, it almost made the task of measuring field strength easy. The only apparent

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[1] This chapter on field strength measurements represents a revision of an earlier article by the late Dr. Robert E. L. Kennedy [*NAB Engineering Handbook,* Fifth Edition (1960), Section 2, Part 9], portions of which have been incorporated with some emendation in the present writing. Much new and useful material, however, has been added.

[2] Special thanks to the members of the staff who worked so diligently in the composition of this chapter: Ihor "Slim" Sulyma, Stanley Leslie, Larry Ellis, Stephen Dutka and to the other members of the staff who kept the wheels turning.

drawback of this meter was the fact that it was so portable that measurement points no longer had to be located along roads and cross-county hiking became the vogue.

The 120-E or WX-2E model has been superseded by a slightly smaller, lighter, and completely solid state field strength meter. Present models feature a built-in speaker, meter illumination, and a simpler calibration system. These units are capable of measuring field strength in the 540 to 5000 kilohertz range (to include the third harmonic of a 1600 kHz station) and permit measurement of spurious radiation levels as well as harmonic radiation levels. Typical models such as the Potomac Instruments Type FIM-41 field strength meter use only six D cell batteries as a power source.

The Solar Electronics Co. Model 7007-1 field strength meter, similar to the Potomac Instruments FIM-41, has been developed with a built-in means of verifying the calibration if a calibrated signal generator is used. Such a feature is very useful but the depth of the meter is approximately 14 centimeters greater than that of the FIM-41 when the loop is in the measuring position. Those who are accustomed to holding up the meter with one hand to make a measurement will find the 7007-1 must be handled differently. The loop opens at right angles to the meter front panel permitting a single person to hold the meter firmly against his body even in strong winds.

Wilkinson Electronics, Inc., supplies a Type 4N1 field strength meter with built-in rechargeable batteries and 110-volt ac charger. The batteries also may be charged from a 12-volt dc source.

A much smaller, lighter and less expensive unit developed by Delta Electronics (Model FSM-1) is crystal controlled for a particular station's carrier frequency. Such a unit makes it relatively simple for a station to measure its field voltage since the first step (tuning) of the calibration procedure is eliminated. This particular meter measures only 14 X 20 X 13 centimeters and weighs approximately 2 kilograms.

The meters discussed above are given as typical examples of currently available field strength measuring units to illustrate the different features. Before purchasing a field strength meter, one should consider the latest meters offered.

Although the present field strength meters appear to be quite adequate for the job and emphatically represent a vast improvement over the antiquated units of early broadcasting, unforeseen betterments in the near future may well make today's units old-fashioned. Further improvements such as reductions in size and weight certainly will be made and readily accepted.

FIELD STRENGTH MEASUREMENTS IN GENERAL

Reasons for Measurements

Although there are many reasons for taking field strength measurements, the following are considered the most common:

1. Location of contours of specified strength or the determination of the quality of service;
2. Determination of the interference range of a station;
3. Proof of performance of a directional antenna;
4. Proof of efficiency of a nondirectional antenna;
5. Survey of site—to determine the adequacy of a proposed transmitter site;
6. Determination of the amplitude of the radio frequency harmonic radiation of a station;
7. Determination of the level of spurious radiation from a station;
8. Measurement of the skywave signal strength from a distant station;
9. Determination of ground conductivity;
10. Determination of the source of radio noise or reradiation.

The proper and acceptable procedure for taking field strength measurements is outlined in detail in Section 73.186 of the FCC Rules and Regulations. One might wish to read this section before continuing with this article. Section 73.186, however, only partially details the requirements for good, supportable and accurate field strength measurements. Along with the instructions given in the FCC Technical Standards, there are many more factors to be considered and applied that make the difference between sound and questionable data. Some of these factors are applicable to all field strength measurements and some assume greater importance in specific applications of field strength measurements.

Proofs of Performance

There are three classifications of proofs of performance for AM directional antenna systems presently recognized by the Federal Communications Commission. They are a complete proof of performance, partial proof of performance, and a skeleton proof of performance. The distinction between each is clearly defined in the FCC Rules and Regulations. All three classifications require that field strength measurements be made on all radials specified in the original construction permit plus any selected supplementary radials.

A complete proof of performance is rarely executed except immediately following the original construction of the facility or upon making major changes. FCC Section 73.186(a)(1) clearly points out the spacing of field strength measurement points for a complete proof of performance as:

1. Normal Conditions: up to 2 miles (3.2 km), every .1 mi. (160 m); 2 to 6 mi. (9.6 km), every .5 mi. (800 m); 6 to 15 mi. (24 km) or 20 mi. (32 km), every 2 mi. (3.2 km); beyond 20 mi. (32 km) a few additional measurements (if needed).
2. Favorable Conditions: rural unobstructed areas, 18 to 20 measurements.
3. Unfavorable Conditions: Urban or obstructed areas, as many unobstructed measurements as possible at even smaller intervals than under normal conditions.

It is necessary, therefore, to take approximately 40 measurements per radial under normal conditions (1 above), 18 to 20 measurements per radial under favorable conditions (2 above) or as many unobstructed measurements as possible under unfavorable conditions (3 above). However, it is suggested that as many points as possible be taken so as to allow a few unrepresentative points to be judiciously omitted. In general it is advisable to provide more measurement points on protection or monitor point radials than on other radials.

Partial and skeleton proofs of performance are taken at intervals following the complete proof and are compared with the complete proof to show any change from the original operating conditions of the array. Insofar as possible all reported measurements should be for the same points as originally measured in the complete proof. Monitor point measurements must be included in every proof of performance. A partial proof of performance must have at least ten measurement points on each radial—all normally within 3 to 15 kilometers of the array. A skeleton proof of performance must contain at least three to five points on each radial.

What follows is a discussion of the factors that should be considered to assure that all field strength measurements are valid and consonant with the FCC Technical Standards. It should be noted that there are many fine points that must be considered which make the whole field strength measurement procedure much more complicated than merely following the instructions outlined in Section 73.186.

SYSTEM OF MEASUREMENT

Before covering the particulars of the proper field strength measurement procedure, some clarification should be made on the question of the acceptable measurement system and the proper units of measurement to be used. This is necessary to prevent the use of dimensionally inconsistent forms of measurement.

Unit Symbols

Units of measurement used in this article are consistent with the standard unit symbols from IEEE Standard No. 260 1967 (ANSI Y1019-1969) and amendments to date, and are consistent in nearly all respects with the recommendations of the International Organization for Standardization (ISO) and with the International Electrotechnical Commission (IEC) for International Standard (SI) units.

Metric Measurements

In the early days of radio broadcasting and communications, stations transmitted on a wavelength of so many meters. The international distress frequency for ships at sea was 600 meters. Broadcast stations operated in the range from 200 meters up to 545 meters. There was no thought of transmitting on a wavelength of 750 feet. Instead, metric measurements were utilized. Unfortunately, for the establishment of universal metric measurement units, stations switched to a more recognizable nomenclature using frequency for designating broadcast emissions such as 1000 kilocycles per second instead of wavelengths. The "per second" was frequently dropped and only the term "kilocycles" was commonly used.

Now the standard expression for frequency is "hertz," named for the famous scientist Gustav Hertz and carrying the units of cycles per second. Hence, kilocycles per second became "kilohertz," a preferred term which is now well established. For FM the more convenient term of megahertz (million hertz) rather than the old form of megacycles per second is used. These terms are conveniently abbreviated Hz, kHz, and MHz with the H capitalized in honor of Herr Hertz.

Many broadcasters do not realize that in most other respects broadcasting has been using metric units from its inception. For instance, our transmitters operate with plate currents in amperes, millimperes, and microamperes while our utility power plants operate with megamperes. Similarly, a plate voltage is measured in volts or kilovolts and field strength voltage is given in millivolts or microvolts per meter. These are all units of the metric measurement system—fundamental and deeply entrenched in all aspects of electronics. Similarly power is given in watts, kilowatts, milliwatts, megawatts, or microwatts. Current and voltage units (the amp and volt, respectively) are also named for two greats of science—Andre Marie Ampere and Count Alessandro Volta. These units are conveniently abbreviated as:

Frequency:	Hz	one hertz [formerly cycle per second]

	kHz	1000 hertz—one kilohertz [formerly kilocycle(s) per second]
	MHz	1,000,000 hertz—one megahertz [formerly megacycles per second]
Current:	A	ampere
	mA	milliampere, 1/1000 ampere
	μA	microampere, $1/10^6$ ampere
	MA	megamperes, 1,000,000 amperes
Voltage:	v	volt
	kv	kilovolt, 1000 volts
	mv	millivolt, 1/1000 volt
	μv	microvolt $1/10^6$ volt
Field Strength:	mv/m	millivolts/meter
	μv/m	microvolt/meter

The pertinent prefixes for metric system units used in broadcasting are as follows:

Prefix	*Multiple*	*Symbol*
Giga	10^9	G
Mega	10^6	M
Kilo	10^3	K
centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	μ

You can see it's a case of upper and lower case. A Western Union keyboard will no longer serve and the shift key takes on a new significance. For instance, (mS) is a conductivity we have; (MS) is a conductivity we would like to have; while (ms) is a millisecond. Since most of us don't have megaseconds, (Ms) doesn't even tell us whether a lady is married or single.

Many pages have been written verifying the spelling of the metric unit as "meter" although many prefer the spelling of "metre." For the changeover to metric units of length, meter also may be spelled "metre," and the National Bureau of Standards suggests that all combinations be accented on the first syllable, i.e., kil'o·me'ter or simply kilo'-meter.

Adoption of the use of metric measurement units has been recommended by the U.S. Department of Commerce. Legislation to adopt the metric system was passed by the U.S. Senate in 1972 and by several state legislatures in 1974. The Elementary and Secondary Educational Act, signed by President Ford in August 1974, contains in Section 404 the statement that "Increased use of the metric system in the U.S. is inevitable, and such a metric system will become the dominant system of weights and measures in the U.S." Metric distance units such as kilometers and meters instead of miles and feet are being used by such governmental agencies as NASA, the National Park Service (Mesa Verde), the FAA (Obstruction Marking and Lighting, AC 70/7460-1C), etc.

Conversion to metric units by U.S. industry is now accelerating at such a rapid pace that before this handbook is in circulation very long, the old English measurement units may be quite obsolete.

Factors to permit conversion of metric units back to the old English system are presented below:

1. Multiply centimeters by 0.3937 to obtain inches
2. Multiply meters by 3.2808 to obtain feet
3. Multiply kilometers by 0.6214 to obtain miles
4. Multiply square kilometers by 0.3861 to obtain square miles.

The writer has for several years filed FM engineering applications for construction permits and for new standard AM broadcast stations with metric measurement units. Fortunately, the United States Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) maps have metric as well as mileage scales but, unfortunately, until recently all elevation contours have been in feet. Unless military metric maps or the new issue Alaska maps (which have metric contours) are involved, it is necessary to convert the elevation values from feet to meters. A pocket electronic calculator with a constant key or automatic constant feature has greatly facilitated conversion of English contour values to metric units.

The FCC, in conjunction with broadcasters and consulting engineers, should establish new metric standards for broadcast engineering calculations as soon as possible. It would seem the time is long overdue for the broadcasting industry to join with the growing numbers of American industries in converting to the primary use of metric measurement units.

Field Strength versus Field Intensity

Early in the development of broadcasting it was widespread to encounter the term "field strength" of a given broadcast station, but later FCC curves were released initially utilizing the term "field intensity." Hence, for a period of time, it was assumed that field intensity was the more professional term to use when referring to measured or calculated voltage; i.e., Graphs 1 through 20, FCC Rules and Regulations Section 73.184, refer to "Ground Wave Field Intensity vs. Distance" and Fig. 1 of Section 73.190 bears the title "Average Sky-Wave Field Intensity." It should be noted, however, that later FCC graphs do not contain the term "field intensity." The National Bureau of Standards has standardized the use of field *strength* to denote field voltage and reserved the term "intensity" for reference to field power measurement. Since the field strength meter measures the field *voltage* and not the field power, it follows that, according to national standards, field strength is the correct term for such measurements.

Conductivity Symbols

For many years conductance was measured in terms of mhos (ohms spelled backwards) and conductivity was usually measured in millimhos per meter (abbreviated mmhos/m). Such designation appears in FCC Section 73.184 on Graphs 1 through 20. Standardization has altered the correct nomenclature to replace the term mho with the SIEMENS (in honor of Siemens). The correct unit of conductivity is, therefore, millisiemens per meter (abbreviated mS/m) and is so used in this presentation.

TECHNIQUE—AN OVERVIEW

The procedure used in obtaining useful and accurate results in the analysis of field strength data is relatively simple for proofs of performance. First, radials are laid out from the transmitter site on the best available maps (topographic preferred). Discrete unobstructed measurement points are then located along each radial in accordance with the FCC requirements mentioned earlier. Next, measurement data for each radial are obtained with a field strength meter. Field strength then can be plotted against distance for each radial on special charts. These plots enable one to determine the various ground conductivities along a given radial and the unattenuated field at 1 kilometer for a given bearing. Measurements are made for both the nondirectional and directional modes of operation. Final evaluation of the initial complete proof of performance results will enable good monitor point locations and alternatives to be selected.

LAYOUT OF RADIALS AND LOCATION OF MEASUREMENT POINTS

Map Selection

First one obtains the most accurate map or maps available for the path(s) to be measured. US Geological Survey maps are preferable if they are of recent issue and/or are the result of an adequate survey. The most preferred maps are recently issued USGS 7-1/2 minute topographic quadrangle maps. The map should say: "This map complies with National Map Accuracy Standards" on the lower edge. If these are not available, county road maps may be employed.

However, some state or county road maps are not very accurate; consequently, distances should be checked by a calibrated automobile odometer before relying on them. Many cartographical errors in the placement of roads, rivers, bridges, railroads, buildings and other landmarks have been encountered which were incorrectly located by almost a kilometer.

Sometimes 7-1/2 minute topographic maps are not available for the desired location. USGS 15-minute maps often are so old that they do not show present features. In such cases, it may be necessary to lay out the radials on 15-minute maps as well as on country road maps in order to facilitate accurate location of landmarks and/or measurement points. When original measurement point locations are shown on older maps, extensive construction or changes may make it extremely difficult to find landmarks which may no longer exist. Redrafting the radials accurately on late edition maps or even new 7-1/2-minute maps, if presently available, may assist in finding as closely as possible the original points. Sometimes one encounters real dilemmas when the original maps were inaccurately drafted and new county maps and 7-1/2-minute maps show significant discrepancies.

Aerial Photographs

In some areas where roads are almost nonexistent, aerial photographs should be procured. Do not assume that specified scales for these photos are correct but verify the exact scale by correlation with known landmarks or 7-1/2-minute map distances. The radials should be carefully drawn on the aerial photos. Stereo aerial photos may be procured from map-making services with such a scale as to permit the location and identification of objects as small as fence posts.

Surveying

The services of a surveying team have sometimes been required to ascertain measuring point locations in the field when suitable maps or aerial photos could not be obtained.

Nautical Locations

Radial field strength measurement point location determination on lakes or oceans depends on nautical navigational methods, sight bearing and/or automatic direction finder bearings with triangulation calculations. Problems of this nature represent a special case and cannot be covered in sufficient detail in this article.

Precautions

On the map one should carefully locate the transmitting antenna site. Any significant error in the antenna location will result in a distorted pattern and consequently inaccurate radial data. Then a meridian (true north line, 0° True) is projected carefully through the transmitter site. With the site as the origin and with a large protractor, one lays out the radial bearing(s) and continues its projection for at least 30 kilometers from the site.

When measurements are made over a long path, progressive errors may be encountered as the radial extends over a large number of maps. Graphically it is difficult to maintain a bearing with a path covering a large number of maps. It has been found that use of spherical trigonometric calculations to determine accurately the geographical coordinates of several points on a given bearing for each map permits precise radial location. Computer time sharing services readily permit such calculations.

Selection of Measurement Points

After all radials are laid out on the maps and/or photos, one selects along the radial the appropriate number of possible measurement points that the particular job requires. Consideration should be given to accessibility and if it can be determined from the maps, surrounding terrain (see Fig. 1a to 1b). It is always easier going to a measurement point than looking for a good place to make a measurement. Planning the route can greatly speed up the collection of data. If after the measurement of the radial is completed and for one reason or another, there is a need for additional points, one will need only to "look for" those few points.

It is a good idea to mark on the map kilometer points for reference purposes as Point No. 2 on Fig. 1a and Point No. 5 on Fig. 1b. If in the course of running the radial one comes across a good looking point, its distance can be quickly determined in the field by using a small scale and the reference kilometer mark.

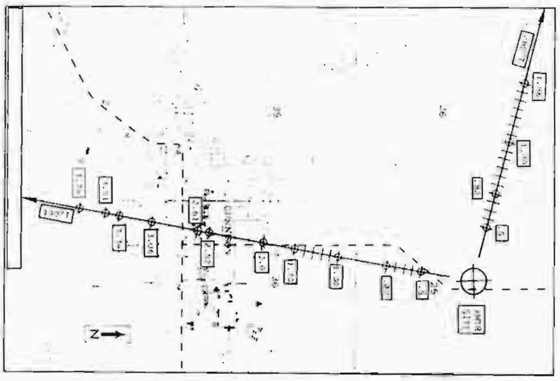


Fig. 1a. Typical radial with number measuring points.

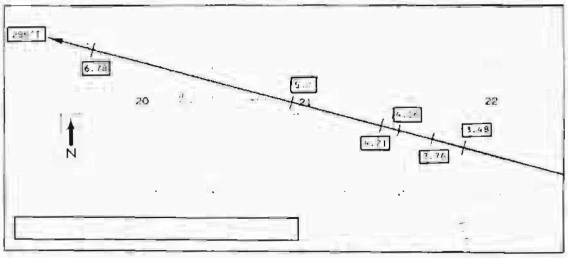


Fig. 1b. Typical radial in rugged terrain.

Retention of Aerial Photos and Field Maps

Notwithstanding the fact that over the years construction changes frequently make the original measurement point maps hopelessly obsolete, a copy of the original proof of performance maps should be retained by one's consultant for a permanent record. Aerial photographs likewise should be carefully preserved.

A set of these exhibits also should be maintained at the broadcast station for use by personnel in conducting annual measurements. Often station copies are mislayed or lost with personnel changes and the consultant's copies may be incorporated in the preparation of a new or updated station set.

LOCATION OF MEASUREMENT POINTS IN THE FIELD

Having accurately located the radials on the proper maps, one must now locate and mark the measurement points in the field. This task usually consists of locating a great number of points close to the antenna system and a lesser number of points at greater distances.

FCC Section 73.186 specifies that measurements be made at approximately 160 meter intervals within 3 kilometers of the antenna system. When topographic conditions permit, many measurement points may be located along a radial using a nonmetallic chain and/or a measuring wheel.

The most useful procedure in locating measurement points in the field is to first lay out the radial using a transit to maintain the proper bearing and surveyor's high visibility vinyl flags to mark the radial. Accurate distance measurements then can be made starting at the tower along the radial using a chain and/or measuring wheel (see 285°T radial on Fig. 1a) whichever terrain or circumstance permits. Measurement points then may be marked with flags of a color different from those marking the radial itself.

To be as accurate as possible in determining measurement points chaining should begin from known distance locations. These locations are points where the radial crosses a road, railroad grading or other pertinent, semipermanent features whose distances are determined from the topographic maps. Chaining then may proceed from this point toward and away from the antenna.

In certain types of terrain it is essential to have three people equipped with hand held two-way radios to facilitate making sure all distance measurements are along the radial.

CONSIDERATIONS AT THE TRANSMITTER

Prior to making the actual field strength measurements some consideration should be given to the antenna system itself to assure that proper operation is attained in both the directional and nondirectional modes. One should also take cognizance of the near field effects of the antenna system. Failure to check these items at the outset of the field work can render the field strength measurement data absolutely useless.

Impedance Measurement

It is suggested that all types of proofs of performance be made only after an accurate impedance measurement and possible readjustment of the common-point impedance. The calibration accuracy of the common-point ammeter and of all the base current meters must be known. An accurate determination of the input power to the antenna system and the base current ratios is impossible without the above information. Changes in transmitter efficiency may indicate that the common-point or antenna base impedance has changed.

Constant Operating Parameters

Of course, the exact licensed or specifically authorized power must be fed into the common point of the antenna system at all times during which field strength measurements are being made. Hence, the common-point current, plate voltage, and plate current must be constantly observed to insure constant power. Additionally the common-point impedance, the phases, base current, and/or loop ratios and remote base current ratios should be in conformance with the authorized parameters. The field measurements will be of no value if the power into the antenna system is allowed to fluctuate or system parameters are out of tolerance.

Tower Isolation

A satisfactory procedure for making nondirectional measurements on a directional antenna system begins by having all unfed towers in the array properly isolated or detuned. Isolation is achieved in electrically short towers (90° or less) by "floating" them, provided the tower lighting isolation and static drain circuits are of sufficiently high impedance. Towers of electrical height exceeding 1/4 wavelength (90°) must be detuned by the insertion of a detuning circuit from tower to ground to provide isolation. Isolation is necessary to prevent any mutual impedance from being reflected into the input of the nondirectional fed tower. If this isolation is not properly achieved, the "nondirectional" measurement may represent an appreciably directional effect which yields a distorted circular pattern.

However, obtaining nearly equal measured field strength values at equal distances from the tower does not necessarily mean that a nondirectional pattern exists. Careful evaluation of the measurement point values with respect to conductivity variances is required. Normally, a uniformly circular nondirectional pattern verifies proper isolation of unfed towers.

Near Field Measurements

When the electrical height of a vertical antenna differs significantly from 90°, field strength measurements close to the tower must be corrected for proximity effect. It will be found that, in the near field, short towers will provide field strength readings that are too high while very high towers will be characterized by lower than normal field strengths. Hence, field strength readings close to short towers must be corrected (lowered) to obtain the true field and vice versa for high towers. Tower heights between 80° and 100° should not require correction of measured fields at distances beyond two wavelengths. As an example, for tall towers of 225° measured field strength readings should be corrected for proximity effects at distances closer than four wavelengths. Beyond these noted distances measurements require no significant corrections since far field conditions are dominant.

The appendix at the end of this section presents curves of proximity effects from which measured field strength readings may be corrected. The appendix also supplies the equation for calculating the proximity effect corrections which may be programmed for fast and accurate computer calculations.

USE OF THE FIELD STRENGTH METER

Calibration

At the core of making successful field strength measurements is the proper use of the field strength meter. Paramount is the advice that the manufacturer's instructions should be thoroughly studied and closely followed. In addition, the meter should be periodically calibrated against a laboratory standard. Fine adjustments to the meter circuitry are made at this time to insure the accuracy of the meter. A few other comments are in order on the actual use of the field strength meter.

One important consideration is that the field strength meter should be calibrated for the received frequency immediately prior to the making of every field strength measurement. It should be noted also that if the meter is not oriented toward the antenna, an erroneous radial field strength will be obtained.

Extreme caution must be exercised when attempting to calibrate a field strength meter in an area where a high rf field strength (near field) is present. Closely following the manufacturer's instructions will permit the most accurate measurements possible to be made. Often one can calibrate the field strength meter 5 to 8 kHz away from the measured frequency, then simply adjust the receiver for a maximum signal and the calibration will be sufficiently close for an accurate measurement. Failure to insure that high field voltages do not affect the accuracy of meter calibration may lead to very large errors in the measurement of field strengths. Adherence to the manufacturer's standard calibration instructions is sufficient for far field measurements.

In order to expedite the field strength measurements for a proof of performance, several persons may take measurements at different locations simultaneously. To insure that all meters are functioning properly, it is wise to compare readings from all field strength meters at a common measurement point before, during and after the completion of the measurements. If all meters agree closely on all occasions, one may assume that the meters have been functioning properly.

Care of Field Strength Meter

During travel by car, it is advisable to place the field strength meter on the floor. Although a seat may be well padded, a sudden stop may cause the meter to tumble to the floor. When making measurements with a meter mounted on a tripod, a sudden gust of wind may topple the meter. In the presence of high winds, it may be necessary to have an assistant steady the meter; however, it should be verified that the proximity of the assistant does not alter the actual measured field. Meters should be removed from the tripod while being carried in a car to avoid damage due to strain and stress. Repair of a damaged meter and/or recalibration costs may easily exceed one tenth the replacement cost of the meter. The units should not be subjected to rain or snow. Some earlier type units have unsealed meter indicator movements which allow high winds to deflect the needle. In short, field strength meters are delicate instruments and, as such, they should be afforded ample protection against physical damage.

MEASUREMENT TECHNIQUE

The final step in the field work is the collection of the measurement data. The radial bearing is of primary importance but measurement point locations must be described with reference to landmarks so that the distance to each point may be determined accurately. With the bearing and distance to a given point known, it is only necessary then to obtain a sufficient number of measurement points. However, there are a few other things to remember in making measurements or in trying to find a suitable measurement site.

Of immediate concern is the question of just how close to the antenna system one can take field strength measurements that will not have to be corrected for the near field effects of the antenna. Corrections for the near field effects were discussed earlier and for now it will suffice to say that for nondirectional measurements (for towers of 100° or less) one may begin making measurements at a distance from the antenna of approximately five (5) times the height of the tower. For directional measurements about ten (10) times the separation between the extremities of the array should be allowed.

Errors Due to Interference from Other Stations

At the outset extreme caution must be exercised when taking field strength measurements to avoid obtaining erroneous data due to interference from other broadcast stations. To avoid possible problems from skywave interference, field strength measurements should be taken only during noncritical daytime hours (between 2 hours after local sunrise and 2 hours before local sunset). Long distance groundwave field strength measurements should be made about midday when minimum skywave interference occurs. A fluctuating level of field strength is a good indication of interference. Monitoring the audio output of the field strength meter is also an excellent idea since vacillating audio quality at a carrier strength of several millivolts is a good indication of interference. The tuning of the field strength meter may be varied to check for adjacent channel interference.

Effects of Terrain

The most marked effect on field strength is that caused by terrain. The field strength of a radio signal propagating over level ground of uniform soil composition (constant ground conductivity) will be attenuated at a theoretically predictable rate as shown in Graphs 1 through 20 of FCC Section 73.184. Other factors, however, can significantly affect the attentuation rate.

The most predictable effect on the attenuation rate results from changes in ground conductivity along the propagation path of a radio signal. A change in soil type such as from clay soil to gravel will usually result in a change in ground conductivity causing a change in the rate of signal attenuation. Thus a set of field strength measurements along a given radial may reflect attenuation rates characteristic of several different ground conductivities. It should be noted that such geographic features as mountain ranges, oceans, and plains usually present drastic changes in ground conductivity which significantly affect the measured field strength. One can only note the effects of ground conductivity on the measured field strength and accept them since this factor cannot be controlled once a transmitter site has been chosen.

Other factors affecting the measured field strength will have the overall effect of increasing or decreasing the apparent or effective ground conductivity and should therefore be minimized since they have little actual effect on the true ground conductivity.

The terrain along a propagation path will have a significant effect upon the field strength at a given measurement point. Field strength measurements made in rolling or hilly terrain will generally yield higher measured field strengths at higher elevations and lower values at lower elevations. This fluctuation of measured field strength with elevation is due in part to shadowing of the radio signal at standard broadcast frequencies.

In a similar manner, trees or other dense foliage greatly attenuate the signal. When making field strength measurements, one should therefore avoid unusually high or low places as well as heavily foliated areas. In addition field strength measurements should be made beyond such regions if possible to smooth out the effect of exceptionally high or low measurements encountered within these regions. In rolling terrain more measurements should be taken to compensate for the irregularities, and in rugged terrain it is necessary to take as many measurements as possible in spite of the increased difficulty. Sufficient radial measurements must be made to obtain the average or true radial field.

Field strength measurements made from a station in a valley with a path which includes a sharply rising mountain or mesa such that the direct line of sight path extends far above the surface of the ground have yielded excessively high signal strengths. This very high signal strength results from the "bowl" effect of the terrain to be discussed later. At greater distances from the antenna the path may extend to valleys, reverse slopes, and perhaps cross several ridges. Extensive measurements over such an extended path supply an effective conductivity and unattenuated value to confirm the path as a whole.

Radio propagation at standard broadcast and lower frequencies in portions of the inland passage from Seattle to Alaska as well as in other coastal regions of Southeastern Alaska demonstrates the amazing effects of terrain. Often reception or transmission from some regions is almost impossible even when stations are very close to each other. Yet when one station (a ship) moves only a short distance, communication may be achieved and may continue at distances far beyond the normal range of daytime communication without significant attenuation.

Urban areas with buildings, power lines, pavement, and other such construction also provide greater attenuation of radio signals. The main effect of power lines, telephone lines, pipe lines, and large metallic objects (including building structures, automobiles, etc.) is the absorption and/or reradiation of the radio signal producing a locally distorted electric field. When such obstructions lie between the measurement points and the transmitting antenna, the effect is to produce a lower measured field strength than would exist had the signal passed over unobstructed level ground. For these reasons one should avoid making field strength measurements in the vicinity of large buildings, power, or telephone lines (whether buried or not), pipe lines and large metallic objects. It should be noted that underground pipelines may cause exceptionally high measured field strength values and indicate erratic or little attenuation. These nuisances are usually shown on topographic maps and are normally marked with painted stakes where they cross rights of way. Power or telephone lines and pipe lines are particularly troublesome when they run almost radially from the transmitter site and/or parallel to measurement radial bearings. Metallic objects also can be the source of reradiated signals and should be avoided all the more. Minimum distances from commonly encountered objects likely to cause reradiation or distortion of the electric field are as follow:

5 meters (16.4 ft.) from any automobile or wire fence
15 meters (49.2 ft.) from tall trees
25 meters (82.0 ft.) from telephone lines
45 meters (145.6 ft.) from low voltage power lines
230 meters (754.6 ft.) from steel towers or high voltages power lines.

A good rule of thumb is to stay clear of such obstructions by at least 10 times the obstruction height. Care should be taken to avoid having such objects between the field strength meter and the transmitting antenna when making a measurement.

Radial and/or monitor point measurements always must be made with the plane of the field strength meter loop in line with the antenna since, under normal conditions, this yields the maximum field strength reading. This directional feature of the field strength meter can be used to determine if a measurement is being made at sufficient distance from obstacles. One has only to note the direction of the approaching wavefront (the direction of the maximum reading). If the maximum reading is not coming from the direction of the antenna, the presence of reflected signals is probable. One should also note the depth of the null as the unit is rotated. If the null is not sharp and deep, the measurement may be uncertain.

Mountainous terrain, as well as representing a substantial change in ground conductivity, may also produce very strong reflections of radio signals to the extent that the reflected signals may mask the true radial field strength along some parts of a radial. One may partially correct for the reflected signal level by orienting the plane of the field strength meter loop antenna toward the transmitter antenna.

The factors mentioned above should be considered collectively. For instance, field strength measurements made on the far side of a mountain range or ranges will be extremely low due to both shadowing of the terrain and the excessively low ground conductivity. Some of the measured field strength could be the result of reflected radiation. Field strength measurements in deep canyons, cutbanks, tunnels, etc., establish very low effective ground conductivity and high signal attenuation.

Environmental Effects

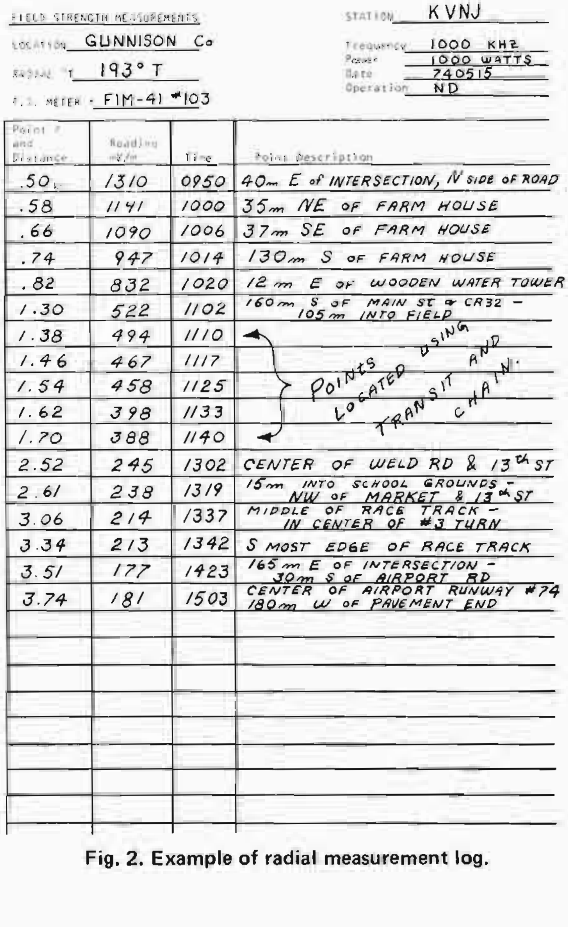
Changes in ambient conditions such as extremely high or low temperature, ice, snow, and changes in soil moisture content or water table depth have been found to adversely affect a directional antenna system. Even a good sampling loop can give an erroneous reading if covered with several centimeters of ice or snow. Often the antenna system anomalies will disappear upon the return of normal environmental conditions. One should keep in mind that if a directional antenna system is tuned and adjusted during abnormal or unusual environmental conditions (such as flooding, heavy wet snow, or drought), it may not be satisfactorily adjusted for normal conditions.

Field strength measurements taken after changes have been made in the antenna system should be accomplished under environmental conditions similar to those existing at the time the original measurements were made. Likewise, both directional and nondirectional measurements must be made under similar environmental conditions.

One way to insure similar environmental conditions is to make initial nondirectional measurements sufficient to establish the actual ground conductivity and permit determination of proper directional fields. Then, the final measurements of nondirectional and directional modes may be made by sequentially switching the antenna system from one mode to the other at specific time intervals. Hence, field strength measurements for all modes of operation may be made at a given point within minutes and under identical environmental conditions.

Logging

For more meaningful tabulation and comprehension of data, the measurement point reference number may preferably be chosen to be the same as its distance from the transmitter. One should, upon making a measurement, record the point number (the distance), field reading, time at which the measurement was made (to the nearest minute), date, and sufficiently describe the exact spot for future measurements (see Fig. 2). The particular point should be marked on the map with a line crossing the radial. Later, if necessary, a more accurate distance may be determined using a precision scale. The true radial bearing likewise should be logged along with the serial number of the field strength meter for each group of measurements.



FIELD STRENGTH MEASUREMENTS

LOCATION GUNNISON Co

RADIAL °T 193° T

F.S. METER - FIM-41 #103

STATION KVNJ

Frequency 1000 KHZ

Power 1000 WATTS

Date 740515

Operation ND

Point # and Distance	Reading mV/m	Time	Point Description
.50	1310	0950	40m E of INTERSECTION, N SIDE OF ROAD
.58	1141	1000	35m NE OF FARM HOUSE
.66	1090	1006	37m SE OF FARM HOUSE
.74	947	1014	130m S OF FARM HOUSE
.82	832	1020	12 m E OF WOODEN WATER TOWER
1.30	522	1102	160m S OF MAIN ST & CR32 – 105m INTO FIELD
1.38	494	1110	POINTS LOCATED USING TRANSIT AND CHAIN.
1.46	467	1117	
1.54	458	1125	
1.62	398	1133	
1.70	388	1140	
2.52	245	1302	CENTER OF WELD RD & 13th ST
2.61	238	1319	15m INTO SCHOOL GROUNDS – NW OF MARKET & 13th ST
3.06	214	1337	MIDDLE OF RACE TRACK – IN CENTER OF #3 TURN
3.34	213	1342	S MOST EDGE OF RACE TRACK
3.51	177	1423	165 m E OF INTERSECTION – 30m S OF AIRPORT RD
3.74	181	1503	CENTER OF AIRPORT RUNWAY #74 180m W OF PAVEMENT END

Fig. 2. Example of radial measurement log.

This logging accuracy must be maintained since the actual field conditions (which cannot be read from the maps) will substantially affect the final selection of measurement points, and one may not always be able to take measurements where originally planned.

PLOTTING AND ANALYSIS OF DATA

Plotting

The values of field strength which have been measured can be plotted now as a function of distance. For this task a commercially available graph paper may be used for the following plotting methods:

1. If one wishes to employ the charts of groundwave field strength found in Part 73 Radio Broadcast Services (September 1972 Edition) or the "FCC Broadcast Engineering Charts" available from the Superintendent of Documents; the data can be plotted on K&E paper No. 359-127G, "Ground Wave Field Intensity." This paper has the same logarithmic scale as that employed in the above FCC documents, and the data which have been measured can be matched directly against the appropriate FCC graph for the frequency involved. By matching the abscissa of the plotted data with that of the FCC graph and by sliding the ordinate information data up and down as described in Section 73.186, the "best fit" may be obtained. This allows determination of both the unattenuated field at 1 mile and the conductivity along the radial path. On a light table or against a window one then marks the inverse distance field and traces the apparent conductivity.

2. For those who prefer a slightly higher order of accuracy, one should refer to Graph 20 of the above publications, "Ground Wave Field Strength vs. Numerical Distance over a Plane Earth." Use of this graph allows construction of a new family of attenuation curves at the exact frequency for any desired value of conductivity and also for several values of dielectric constant. For each value of conductivity and its associated value of dielectric constant, the numerical distance in terms of R[1.61 km (1 mile)] must be computed from the equations shown on Graph 20 for vertical polarization. After drawing the inverse distance line on the graph paper, one must match this line with the equivalent line on Graph 20 while simultaneously holding the 1.61-km distance line on the computed numerical distance value. One then draws the attenuation curve most closely approaching the calculated value of "b" from Graph 20, interpolating where necessary. This is repeated for each value of conductivity and dielectric constant chosen.

For convenience it is most practical to assume one value of dielectric constant, compute the numerical distance for several values of conductivity, and plot this family of curves on one graph sheet. If other values of dielectric constant are assumed, the same conductivities assumed before should be computed and a separate graph employed for this family of curves. The plotted radial data then can be matched to these sets of curves.

3. If a still higher order of accuracy is desired, the curves shown on Graph 20 can be transferred to K&E No. 359-127G. Using this paper and having Graph 20, one can construct the families of attenuation curves as outlined in the second method above. The principal advantage gained by the use of this latter method is that the data are well spread out and can be analyzed more precisely.

If the data have been prepared by the first method above, a radial plot similar to Fig. 3a is obtained. When a sufficient number of such radials have been completed to determine the nondirectional pattern and are analyzed, the directional data can then be accurately plotted and evaluated.

The straight line of negative slope in Fig. 3a and 3b, 4 and 5 is the inverse distance line, the intercept of which at a distance of 1 mile (Fig. 3a) or 1 kilometer (Fig. 3b) gives the unattenuated field in millivolts per meter at that particular distance. The same measured field voltages appear plotted on Figs. 3a and 3b. The ordinate scale of millivolts per meter is common to all figures. The abscissa scale divisions of Fig. 3a are the same as the mileage scale in FCC Section 73.184 Graphs 1 to 19 inclusive. The measured nondirectional fields yield an unattenuated field of 434.959 or approximately 435 mv/m.

The upper plot in all exhibits is the nondirectional data while the lower plot shows the measured directional field voltages. If there is more than one directional pattern utilized at a broadcast facility, all plots for a given radial should be plotted on the same graph to easily facilitate analysis and comparison of directional with nondirectional measurements.

On Fig. 3b a similar horizontal scale has been shifted laterally such that an abscissa of 1 mile on Fig. 3a falls on the 1.609347 value of the kilometer scale of Fig. 3b. The 1 kilometer intercept then becomes 700 mv/m for the nondirectional data plot.

Thus it may be seen that the inverse distance or unattenuated field at 1 kilometer is related to the value at 1 mile by the simple inverse relationship of the two distances which are 1 kilometer and 1.61 kilometer, i.e., 700 = 435 X 1.61. Similarly the 1-mile value may be obtained from the 1-kilometer value as follows: 435 = 700/1.61.

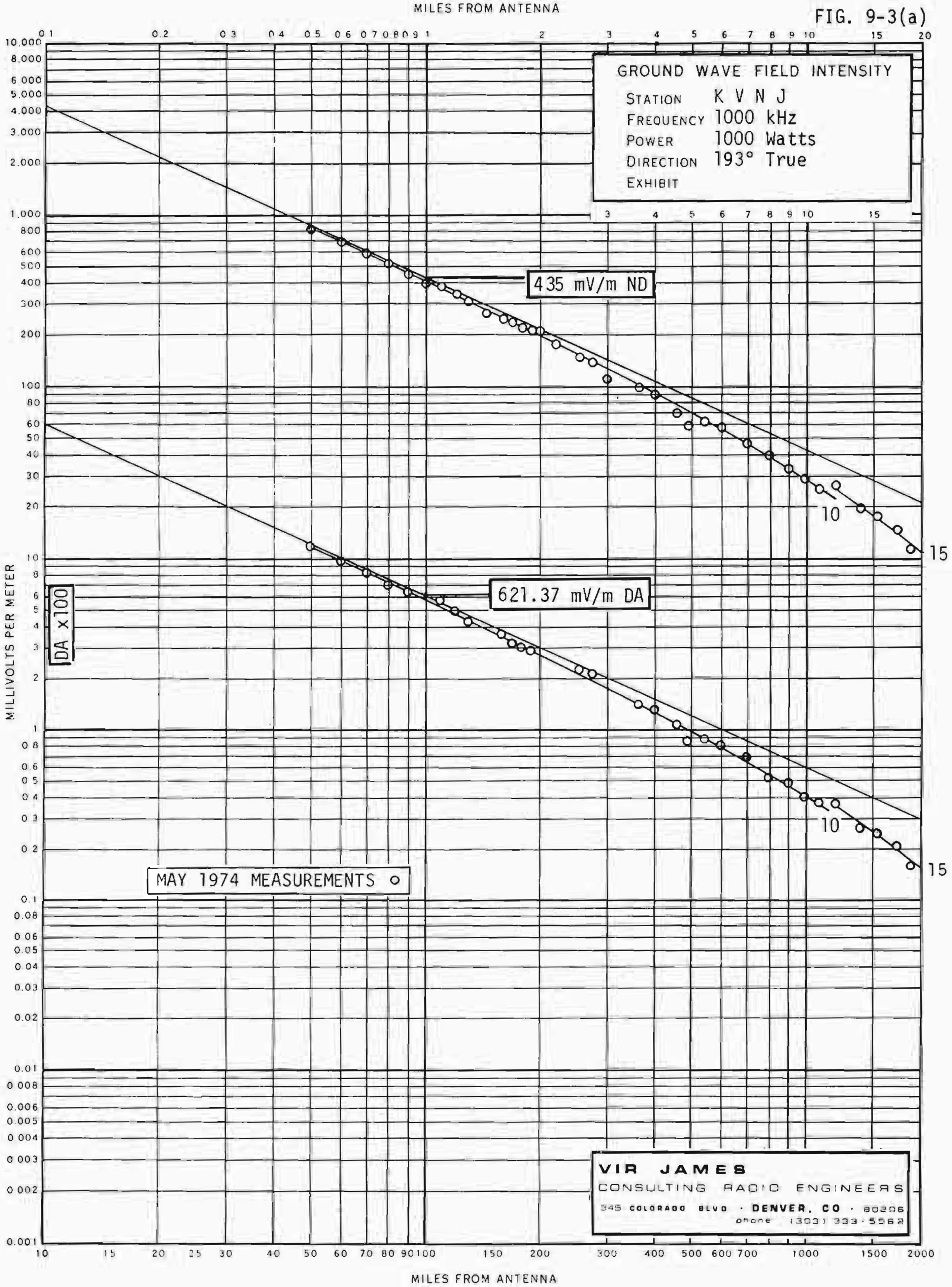


Fig. 3a. Inverse distance and measured fields; nondirectional (upper), directional in major lobe (lower), mileage scale.

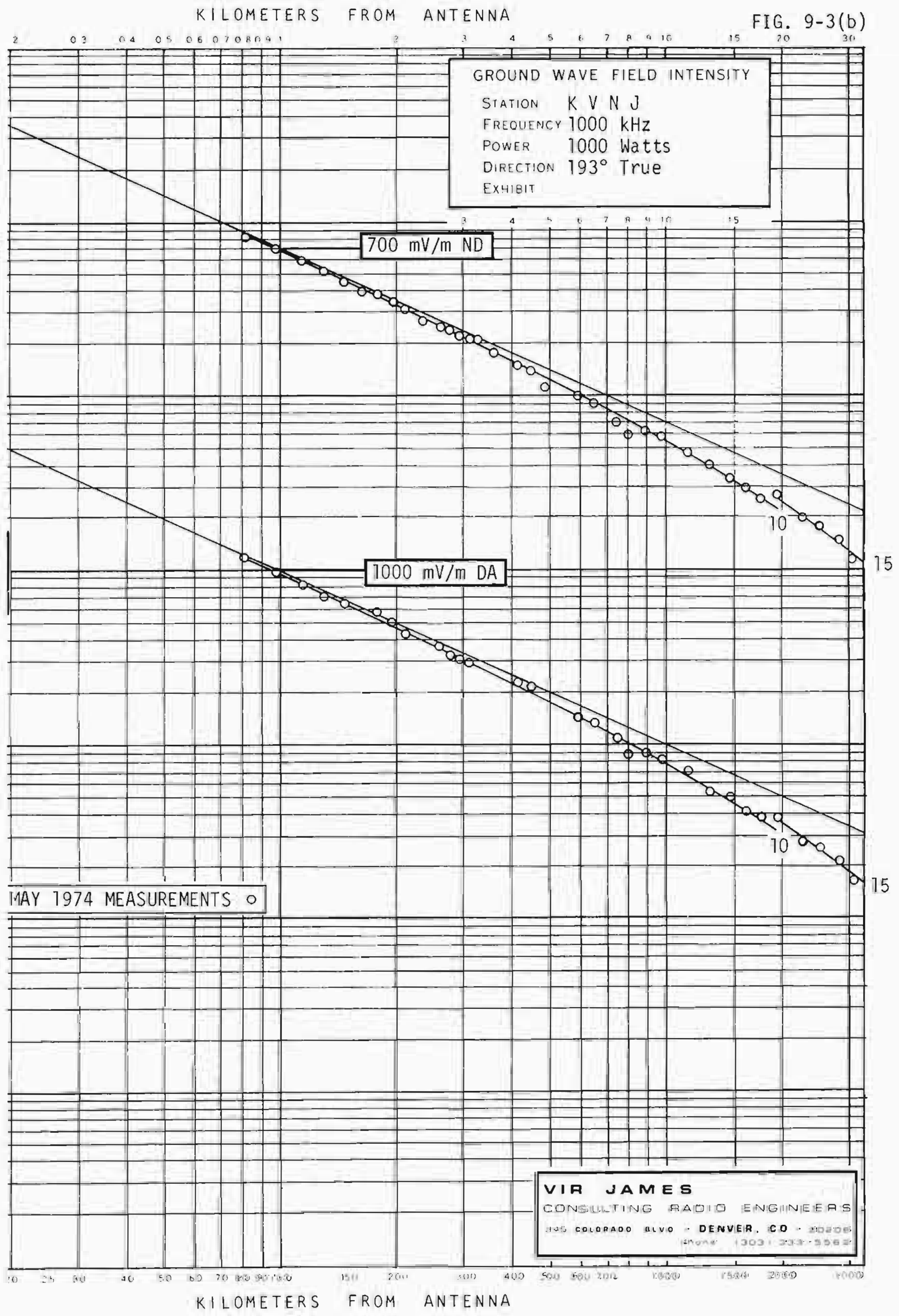


Fig. 3b. Inverse distance and measured fields; nondirectional (upper), directional in major lobe (lower), kilometers scale.

Hence, one may convert the unattenuated values at 1 kilometer to those at 1 mile by dividing by 1.61 and vice versa.

Hence, it may be seen that the FCC Section 73.184 Graphs 1 to 19 may be adapted easily to metric measurements by sliding the mileage scale to the left by a factor of 1.609347 or approximately 1.61 and labeling the shifted mileage scale in kilometers. One must remember then that the 1-kilometer intercept unattenuated field will be approximately 61 percent larger than the 1-mile unattenuated field. These simple factors may be used to relate all unattenuated or pattern values from kilometers to miles or inversely to refer to kilometers.

In view of conversion to metric units, Figs. 4, 5, and 6 have been shown with kilometers as distance units.

Analysis for a Specific Frequency

The FCC has presented common conductivity values in FCC Section 73.190, Fig. R3. Section 73.186 Graphs 1 through 19 were prepared indicating conductivity effects of certain frequency ranges. With a sufficient number of accurate measurement pints, the common conductivity can be determined by the previously mentioned plotting methods. However, for critical interference studies requiring extremely accurate conductivities, Graph 20 should be incorporated for the preparation of conductivities at a particular frequency (see Fig. 4, 10.6 mS/m out to 16 km, 7.3 mS/m to 32 km). Numerous additional measurement points must be taken and critically evaluated to determine the conductivity between the given values.

Analysis of Data with Scattering

The same methods are used in the plotting of the directional data. In some instances, as shown in Fig. 5a, a wide scattering of the measured values will appear and drive one out of one's mind. In most cases, there will be scatter only in the directional data. The scatter (shotgun effect) is usually emphasized where one or more of the following conditions prevail:

1. Widely spaced arrays in terms of frequency;
2. Deep nulls;
3. Poor soil conductivity, rugged or mountainous terrain;
4. Metallic obstacles near the path;
5. Power lines or reradiation from other towers;
6. Reradiation from obstacles near the antenna;
7. Buried pipelines running radially from the antenna near the path.

Under such circumstances it is necessary to obtain as much data as possible and depend upon the most probable grouping of measurements to determine the directional field. Often the points at the greater distances give the best comparison with the nondirectional field values. In contrast, Fig. 3b shows data taken on the same array but in the direction of maximum directional radiation. One should observe that there is little or no scatter in this directional data. These data are typical.

Severe scattering in mountainous terrain on measurements of very deep null radials has been encountered. Here the measured field supported by measured data at 80-meter intervals displays a pronounced standing wave pattern of significant amplitude. This superimposed wave shape effect upon the attenuated signal versus distance plot usually decreases at greater distances from the antenna.

Fig. 5b shows field strength measurement data frequently encountered in mountainous terrain. In the region between 2 and 6 kilometers, measured fields greatly exceed the inverse distance line. Analysis of this measured data clearly illustrates the "bowl" effect of terrain upon field signal strengths. AM broadcast stations usually are located in valleys where the ground conductivity is higher. Situations may exist where the signal path is for the most part high above ground with measuring points up the face of a mountain or mesa; consequently, free space effects rather than ground attenuation predominate. Indeed, the signals seem to be gathered up or amplified by the terrain much as a corner reflector, parabolic or horn antenna increases the effective radiated power. Hence, this region of very high signal level is not indicative of the true overall radial unattenuated field strength and must be disregarded in the overall analysis of the radial.

Data Presentation for Comparison

Field strength measurement data for periodic proofs or specially requested FCC proofs should be compared with the last previous complete proof of performance data. The most effective way to show directional stability or verify the validity of the pattern is to present the original data and the newly measured data in such a manner as to facilitate visual comparison of the plotted data. The following methods greatly facilitate the comparison of plotted data:

1. Screening the original data and graph with the new data plotted in solid color (see Fig. 6a);

2. Drawing different size points corresponding to the various years' measurements (see Fig. 6b);

3. Overprinting with the new data in a different color.

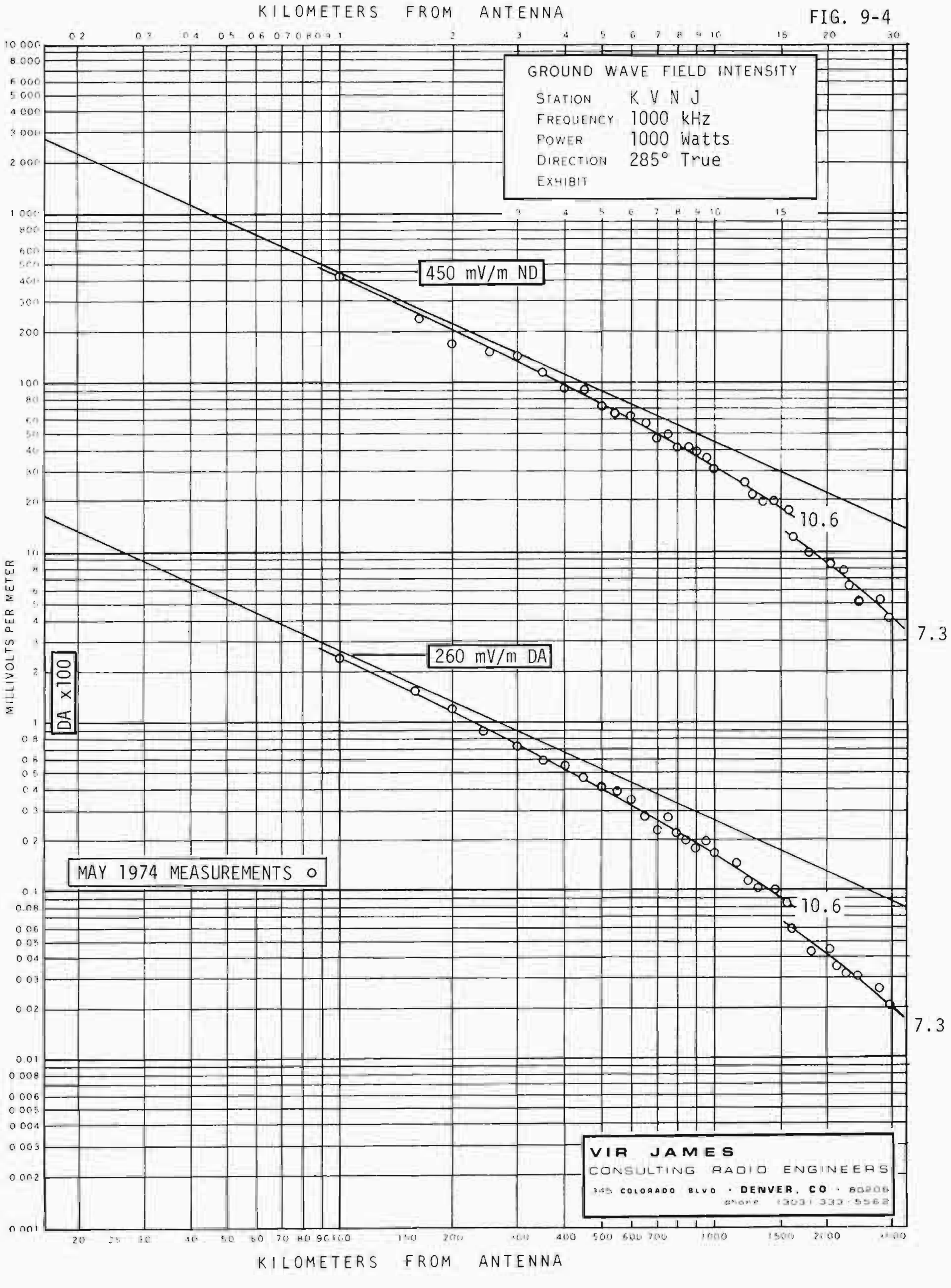


Fig. 4. Inverse distance and measured fields; with computed conductivities.

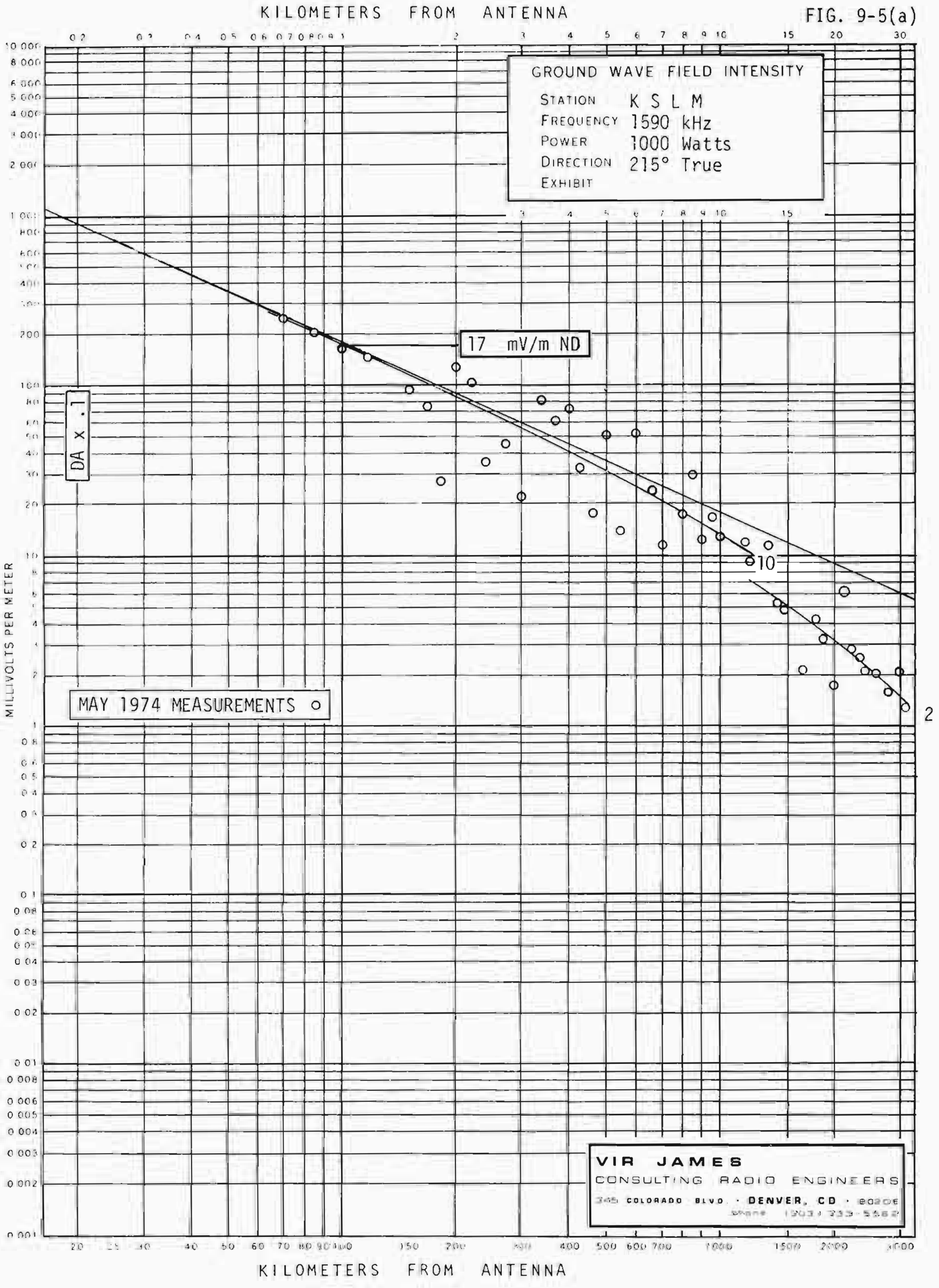


Fig. 5a. Inverse distance and measured fields; directional operation on radial of protected null, showing increased scattering.

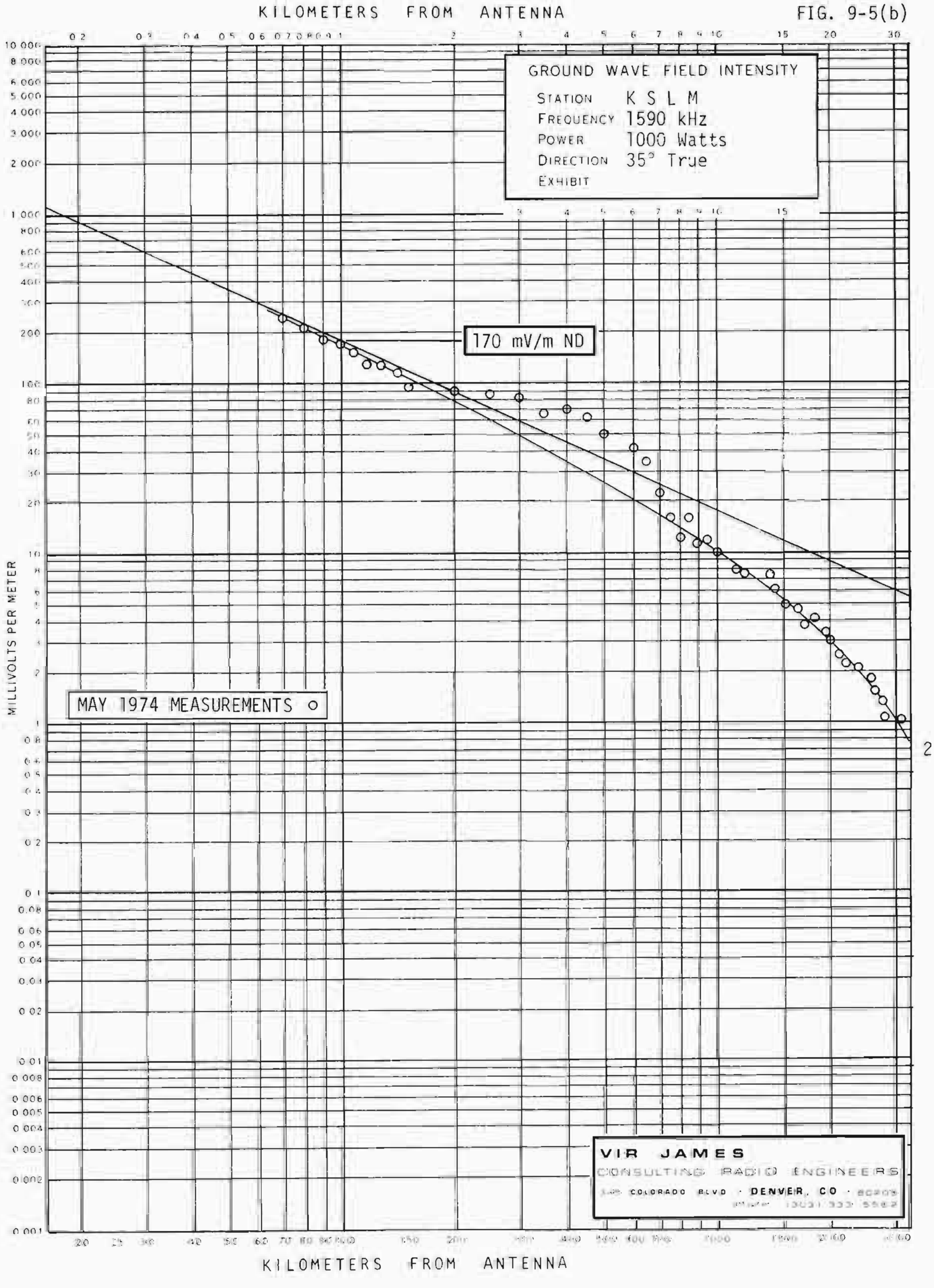


Fig. 5b. Inverse distance and measured fields; directional operation on radial, showing "bowl effect."

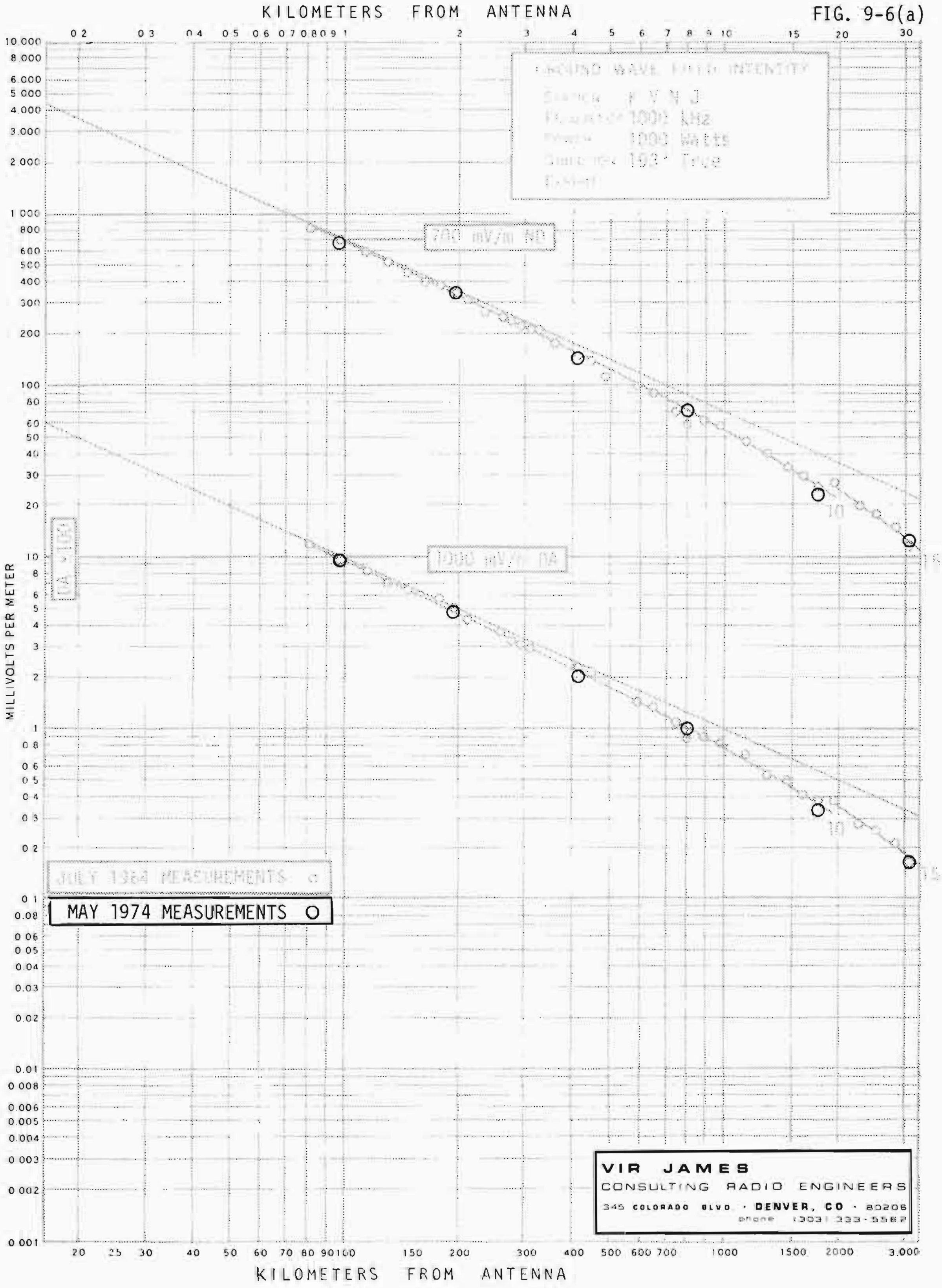


Fig. 6a. Inverse distance and measured fields; comparison of various years data by screening.

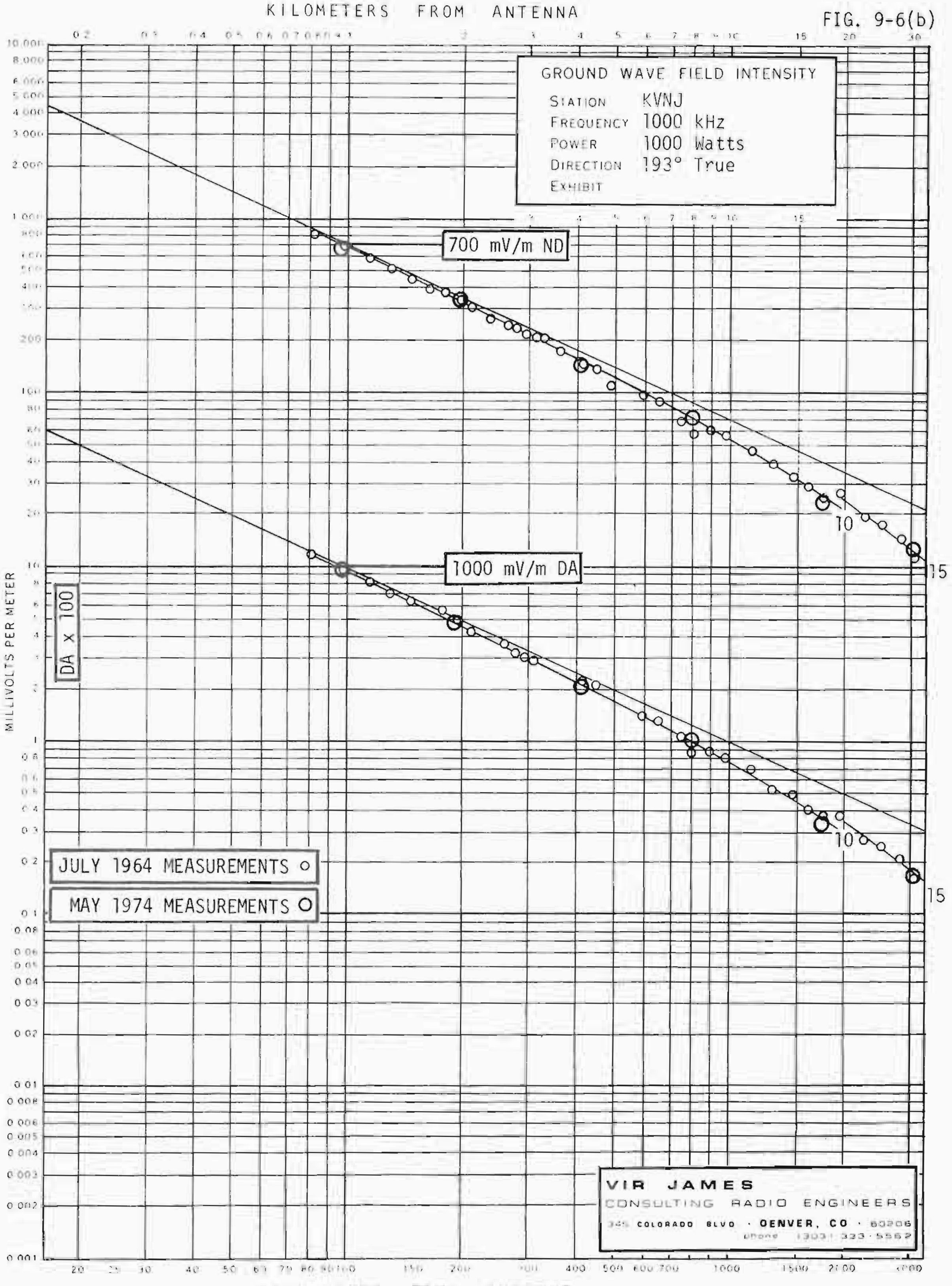


Fig. 6b. Inverse distance and measured fields; comparison of various years data by different size points.

SELECTION OF MONITORING POINTS

The next order of business is to locate the "monitoring points" required on the prescribed radials. At least one such point and preferably one or two alternate points must be established on each such radial. They must be easily accessible, clear of obstacles and likly to remain so. The measured values at the point should lie reasonably close to the attenuation curve shown on the graph of the measured data, and there should be some readily identifiable object nearby that will show in the photograph of the point. The description of the point itself should be clear and the route from the transmitter to the point should be specified along main highways or well-traveled and marked roads. Fig. 7 illustrates a good monitoring point.

OTHER USEFUL MEASUREMENTS WITH A FIELD STRENGTH METER

Establishing Coverage

Most of what has been discussed so far has dealt exclusively with the collection of data for a proof of performance. It should be mentioned that the modern field strength meter has many other useful applications as noted at the beginning of this article.

A station's coverage, for instance, may easily be established by measuring the field strength along a given radial until the desired signal level has been reached and passed by a reasonable margin. Normally eight radials are measured to establish the coverage area. Fairly abrupt changes in conductivity can extend the average contour distance beyond that anticipated on the basis of just passing the desired signal value. Such field conditions can at times yield some surprising coverage results.

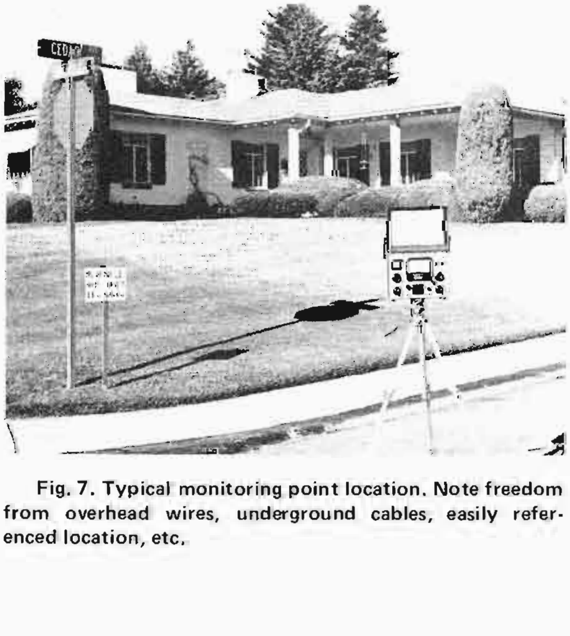


Fig. 7. Typical monitoring point location. Note freedom from overhead wires, underground cables, easily referenced location, etc.

Preliminary and Actual Interference Measurements

The field strength meter is also useful in making preliminary interference measurements. Measurements of interference contours in accordance with FCC Section 73.186 often are both extensive and expensive, the probable outcome of which may be determined by conducting "preliminary" measurements. For such preliminary measurements it is convenient to plot connecting radials between broadcast facilities on charts such as Sectional Aeronautical Chart (SAC) or a World Aeronautical Chart (WAC). Along the routes of the connecting radials nearby airports may be chosen as good sites for these initial measurements. It is helpful to calculate the predicted measured field strength at each airport for two or three assumed ground conductivities. A man with a field strength meter may then conveniently fly to the airport, land, and take a reading in a relatively short time at fairly low cost.

These measurements may ascertain the actual ground conductivity (low to avoid interference, high to prove coverage). Should the preliminary measurements indicate unfavorable conductivity results, the high cost of the detailed measurements would thus be avoided. Favorable results would justify a complete set of measurements along the radial that should be located and recorded similar in procedure to a directional antenna proof of performance extended to the required distances. In addition to the connecting radials between facilities, supplemental radials and/or "stub" radials also should be plotted to confirm conductivities to service areas. Of course, it is necessary to provide all the detailed measurements and analyses for filing with the FCC in accordance with Section 73.186 to substantiate the actual conductivity or contour.

To determine measured service contours or contour overlap of stations A and B, field strength measurements are made from A toward B and from B toward A as outlined in FCC Section 73.186. Field strengths of both stations should be measured at each point if possible, unless interference prevents measurement of both stations. Where pertinent contours subtend significant angles, it may be necessary to measure several radials out from each station to precisely locate critical portions of each contour.

Connecting radials determine a contour location or conductivity along the radial and for a short arc on either side of the radial. If a given service or contour area is not too large, measurements of the connecting radial plus two short or stub radials may be sufficient to delineate the location of the service area or interference contour. Stub radials should begin at field levels of approximately one-half the pertinent contour value and extend to field strengths approaching twice that of the contour. When plotted, field strength values substantiate the connecting radial conductivity and contour. The exact location of the contour may be obtained from the plot of the measured data. Stub radials normally must be measured from each station unless one station has a very small service area such that the connecting radial will verify all necessary portions of the contour.

Interference or service contour measurements in general are similar to proof of performance field strength measurements except that radials are extended as outlined above. The precautionary measures to be observed have been discussed previously. Measurement points beyond 20 kilometers should be taken only at specifically identifiable points. Where landmarks definitely establish a point, a field strength measurement should be taken. Such points may be separated by 6 to 20 kilometers. Inspection of the graph of Fig. 3b will provide a guide for measurement point spacing to insure a satisfactory curve. The field strength versus distance plot may be extended beyond 30 kilometers by also plotting the distance data using the lower kilometer scale (20 to 3000 kilometers).

Site Survey

The use of the field strength meter to conduct a site survey is similar to a nondirectional proof of performance with a low effective radiated power. Usually a short or temporary antenna system is set up at a prospective site with a low power transmitter to permit making field strength measurements on a radial through the major market areas. In some instances a directional proof of performance at low power may be required. In either case, the proof of performance procedures outlined above apply.

Harmonic and Spurious Radiation Measurements

One of the most useful additional applications of the field strength meter is that of measuring the harmonic and spurious radiation levels from a station. Some of the new field strength meters have the capability of measuring field strength on frequencies up to 5.0 MHz. This allows measurements of many of the harmonics of broadcast frequencies at least up to the third harmonic on 1600 kHz. Harmful harmonics above the third are normally not encountered. A good procedure for harmonic radiation measurements is to calibrate the field meter about 1.0 kilometer, or 10 times the separation of the two most distant elements of the array (whichever is the greater), away from the antenna system and measure the magnitude of the fundamental and harmonics radiated. One may then calculate the harmonic attenuation in dB with reference to the fundamental. This is the method preferred by the FCC for ascertaining that harmonic radiation is within the allowable limits of Section 73.40. The limitation for radiation 75 kHz or more from carrier is

$$43 + 10 \log P\,(\text{watts}) \text{ or } 80\text{ dB}$$
$$(\text{whichever is greater}).$$

In the past, attempts have been made to measure harmonic and nonharmonic spurious radiation by using a communications receiver. This has proven to be an inaccurate and therefore futile endeavor. Spurious radiation can be measured most easily with a spectrum analyzer. This permits direct observation of the frequency domain of the transmitter output. A modern well-shielded and highly selective field strength meter also may be used to measure spurious radiation. FCC limitations for spurious radiation are specified as follows:

Greater than 30 kHz from carrier	35 dB below carrier
15-30 kHz from carrier	25 dB below carrier

Older types of field strength meters also may be used to obtain absolute values of harmonic radiation. Such early field meters as the RCA TMV-75B, RCA 308-B, Federal 101 with high-frequency loops or the more recent Stoddard, Empire Devices, Polarad, or equivalent units will serve to provide accurate measurements of harmonic or spurious radiation.

Skywave Signal Measurements

The measurement of skywave signals from distant stations by individuals has lapsed into obsolescence in recent years. The Commission has consistently held that such data will not be admitted in contested hearings and are admissible only in "rule-making" proceedings. Since there have been no such proceedings recently, no skywave data have been required. Moreover, the FCC and the Central Radio Propagation Laboratory of the Bureau of Standards have collected such data for years and have a myriad of data for every bit that an individual could assemble. Hence, there is little reason to collect and analyze the data. Individuals, therefore, need not plan on repetitiously making their own skywave field strength measurements.

SUMMARY OF IMPORTANT CONSIDERATIONS IN FIELD STRENGTH MEASUREMENTS

The preceding material expounds the most important aspects of making accurate and reliable field strength measurements. It should be emphasized, however, that it would be nearly impossible in such a short writing to fully explain all of the details. One should, therefore, at least give full consideration to the following suggestions:

1. Read the rules of the FCC and understand them before beginning;
2. Obtain accurate and up-to-date maps and check them;
3. Verify the antenna site on the maps;
4. Use a recently calibrated meter or check it against another meter which has been recently calibrated;
5. Review the meter calibration procedures;
6. Start out with fresh batteries or have a spare set available;
7. Verify proper operating parameters of the directional array or nondirectional tower;
8. Maintain a constant transmitter output power;
9. Make certain the car odometer used is reading properly;
10. Stay on the radial;
11. Do not skimp on the number of measurement points even at larger distances;
12. Accurately describe each point so that it can be found later;
13. Make certain the meter is tuned to the proper carrier and not receiving interference;
14. Mark measurement points on maps accurately;
15. Record date, time serial number of meter, point number or distance, radial bearing and point description;
16. Treat the meter with tender loving care;
17. Measure field strengths during noncritical daytime hours;
18. If possible, recheck monitor points or other reference points before beginning a long radial measurement trip.

FUTURE ROLE OF FIELD STRENGTH MEASUREMENTS

Since the Fifth Edition of the *NAB Engineering Handbook* was issued in 1960, there have been two "freezes" declared by the FCC covering standard AM broadcast applications. The first was from 1962 to 1964 and the second from 1968 to 1973. The latter AM freeze was only partially lifted effective April 1973. The AM freeze is still frozen essentially solid for over 90 percent of the existing AM stations which might wish to increase their power or change frequency.

Many frequencies remain essentially unused and certainly underused as far as vast areas of the conterminous US is concerned, and it has been truly said that such unused frequencies represent in fact a vast wasteland of channels. Furthermore, at such time as existing stations are permitted to increase their power, change frequencies or to make major changes, additional AM field strength measurements may be required to actually measure service and interference contours.

Not prohibition but utilization provides increased radio services to the American people—more efficient utilization should be the goal to provide radio service for all areas of the country. Field strength measurements will play an ever increasing role in maximizing the utilization of radio broadcasting services. As each new station is authorized, or each power increase approved, the necessity of field strength measurements increases.

In this section an effort has been made to cover most of the facets of field strength measurements which increasingly will be required in the future and to aid engineers in avoiding the most common pitfalls of field strength measurements. It is hoped that the techniques revealed in this section will prove helpful in making the field strength measurement procedure a logical routine rather than an esoteric art.

APPENDIX A

Application of Proximity-Effect Curve[a]

1. The curve in Fig. A shows the amount by which the measured field strength, as measured by a field strength meter which employs a shielded loop, will depart from an inverse distance function because of induction field or proximity effect due to measuring close to the antenna.

2. It is based upon the calculation of the horizontal component of magnetic field close to an antenna, after the manner of Dr. George H. Brown.

3. It can be used first as a guide determining how close one can measure to a given antenna before the correction due to proximity would be expected to exceed a given percentage.

4. It can be used to correct for the error due to proximity before plotting field strength measurements to determine accurately the inverse distance fields. This permits measurements to be made sufficiently close to the tower to eliminate the effects of conductivity.

Derivation

1. G.H. Brown, Directional Antennas, *IRF*, January 1937, on page 81 and in Formula 7 gives the general formula for the magnetic flux density at any point in space from a vertical radiator over a perfectly conducting earth. By restricting this point *P* to the earth's surface, certain simplifica-

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[a] Silliman, Moffet, and Rohrer.

tions can be made in Brown's formula. Specifically Z goes to zero and $r_1 = r_2$ and $r_0 = x$.

2. The simplified formula becomes:

$$B_\phi = \frac{j2 \times 10^{-9} I_0}{r_0 \sin kG} [\epsilon^{-jkr_1} - \epsilon^{-jkr_0} \times \cos kG]$$

where $k = \dfrac{2\pi}{\lambda}$

3. Now when the distance r_0 becomes so great that $r_0 \approx r_1$

$$B_\phi(\text{far field}) = \frac{j2 \times 10^{-9} I_0}{r_0 \sin kG} [1 - \cos kG] \times \epsilon^{-jkr_0}$$

4. Now let $57.3kr_1 = r_1$ (degrees); $57.3kr_0 = r_0$ (degrees); $57.3kg = G$ (degrees).

5. Also convert from exponential to trigonometric form.

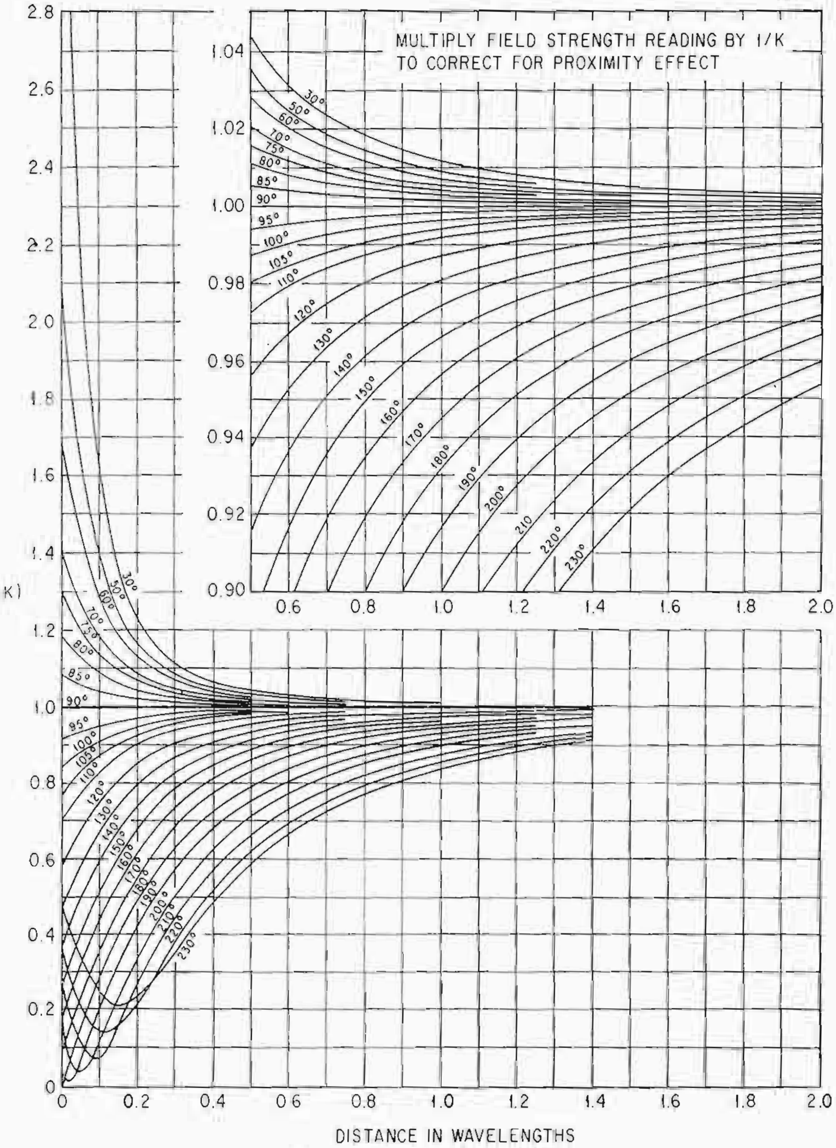

Fig. A. Proximity effect for various tower heights.

6. The resulting ratio is

$$\frac{B_\phi}{B_\phi(\text{far field})} = K = \frac{[\cos r_1 - \cos G \times \cos r_0]^2 + [\sin r_1 - \cos G \times \sin r_0]^2|^{1/2}}{[1 - \cos G]}$$

7. Therefore:

$$\frac{\text{Field measurement}}{K} = \text{adjusted field}$$