Descriptions of Representative Past Projects Performed by Richard Tell Associates, Inc.

NOTICE

The following summary of projects is intended to be illustrative of the kinds of work that Richard Tell Associates, Inc. has been engaged in during the past 11 years of private consulting practice. Accordingly, this list is selective and not exhaustive but should provide the reader with a good idea of the level of experience and expertise available from Richard Tell Associates. Hopefully, it will also be educational. Prior to entering into his own consulting business focused on RF safety issues, Mr. Tell acquired 20 years of experience in U.S. Federal government service (Environmental Protection Agency and FDA) working in the areas of electromagnetic fields and RF hazard assessment, RF standards development, antenna modeling and RF instrumentation evaluation. NOTE: All photographs and graphic illustrations contained in this project summary document show project locations, measurement procedures, equipment, analysis results, etc. associated with actual projects conducted by Richard Tell Associates, Inc. Additional details may be found at the Richard Tell Associates web site at http://www.radhaz.com

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Project Synopses Prepared

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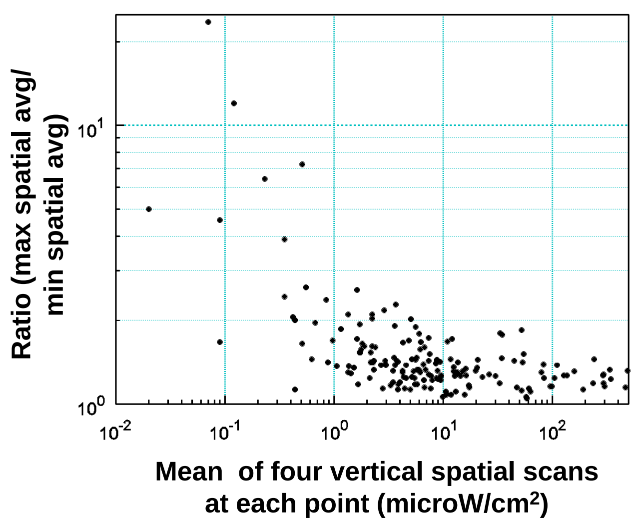
List of Project Summaries

Neighborhood Broadcast Fields in Portland

New KGON broadcast tower on Healy Heights

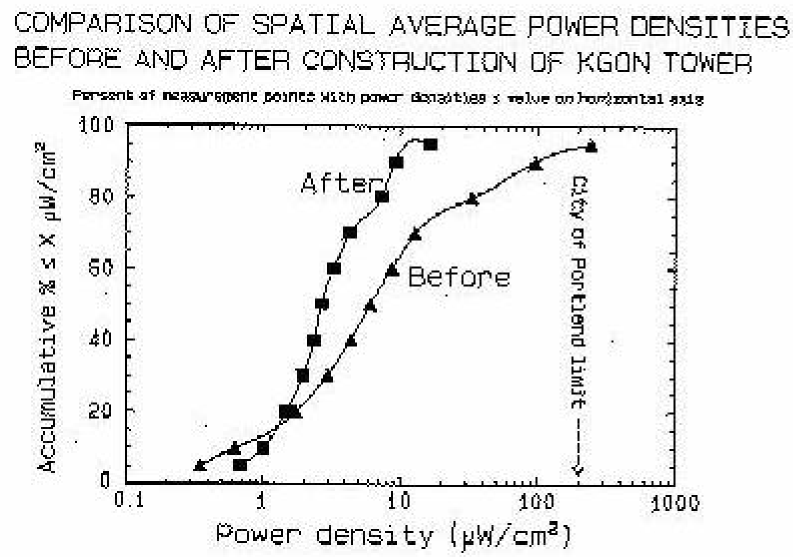
RF fields in highly populated neighborhood areas have been a source of public concern for many years. Prior to the construction of the KGON broadcast tower on Healy Heights in Portland, Oregon, Richard Tell Associates, Inc. was asked by the Planning Department of the City of Portland to conduct a comprehensive 'before' and 'after' study of environmental fields produced by the aggregate broadcast facilities. Prior to the new tower that consolidated most of the broadcast facilities at Healy Heights, a multiplicity of towers supported numerous high-power FM broadcast antennas, some at relatively low heights. A neighborhood RF field survey of the area included measurements at 171 different points in the streets of the neighborhood.

RF fields were measured in terms of spatially averaged values using a broadband field probe and meter with an attached data logger. The measurement approach consisted of determining the spatial average and spatial peak fields at each point with the observer facing the measurement location, sequentially, from each of four directions. This method permitted an assessment of the variability in measured field values caused by body reflections and helped to establish the typical uncertainty that is commonly associated with field survey measurements. These kind of data are useful for understanding how different individuals performing, presumably, the same survey can arrive at apparently different results (see Practical Applications of the ANSI/IEEE C95.1 Radiofrequency Exposure Standard by R. A. Tell, in Advances in Electromagnetic Fields in Living Systems, Vol. 2, ed. J. C. Lin, 255-274, Plenum Press, 1997).



Plot of the ratio of maximum spatial average to minimum spatial average plane wave equivalent power densities at 171 locations on Healy Heights.

An analysis of the field measurements taken before and after construction and operation of the new tower showed a distinct difference in the prevalence of higher level fields. After operation of the new tower, the accumulative percentage of measurement points exhibiting power densities ≤ certain values shifted downward and the maximum measured fields were approximately an order of magnitude lower.



Accumulative percentage of measurement points having spatially averaged plane-wave equivalent power densities ≤ the value shown on the horizontal axis.

Broadcast Measurements at the Meadowlands Sports Complex

This photograph illustrates a series of RF field measurements that were part of an investigation of ambient fields produced by AM radio stations at the Meadowlands Sports Complex in Rutherford, New Jersey. The study was prompted by the observation of several members of the New York Giants football team with, reportedly, various forms of cancer. The close proximity of numerous high-power AM radio stations in the immediate vicinity of the complex and the stadium led to questions of the ambient levels of RF fields that were present. RF fields were characterized in terms of their magnetic field strength, as shown above, and electric field strengths.

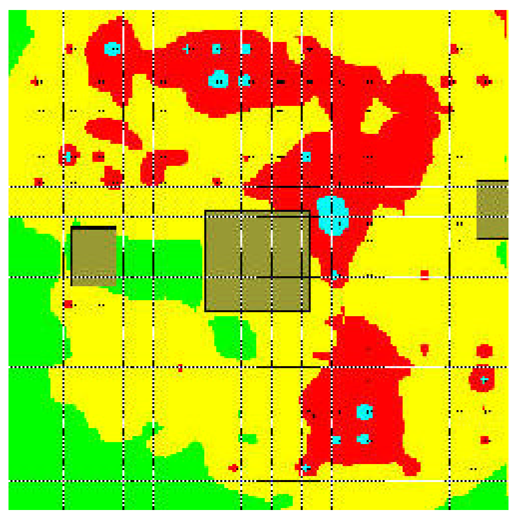
Performing narrow band magnetic field strength measurements in the football stadium at the Meadowlands Sports Complex.

Broadcasting and Wireless Communications at the World Trade Center

Performing RF survey measurements on the roof of the north tower of the World Trade Center. The roof of the south tower can be seen in the background.

Wireless communications sites are commonly collocated with broadcast facilities. Perhaps one of the more obvious examples of this practice is the World Trade Center (WTC) buildings in New York where a major broadcast installation operates from the north tower of the WTC along with approximately 85 telecommunications antennas. A major project was undertaken for Motorola to investigate the ambient RF field environment on the roof of the north WTC tower, taking into account the background fields produced by the many broadcasters at the site as well as the contributions from the numerous, roof-mounted communications antennas.

An intensive series of field measurements over a three day period was obtained of just the broadcast fields using five measurement teams, each equipped with identical broadband, isotropic, frequency shaped probes. Measures of spatially averaged RF fields were obtained at approximately 900 locations on the roof during different modes of broadcast operations, including a tower maintenance mode where certain TV stations operated from lower mounted auxiliary antennas.



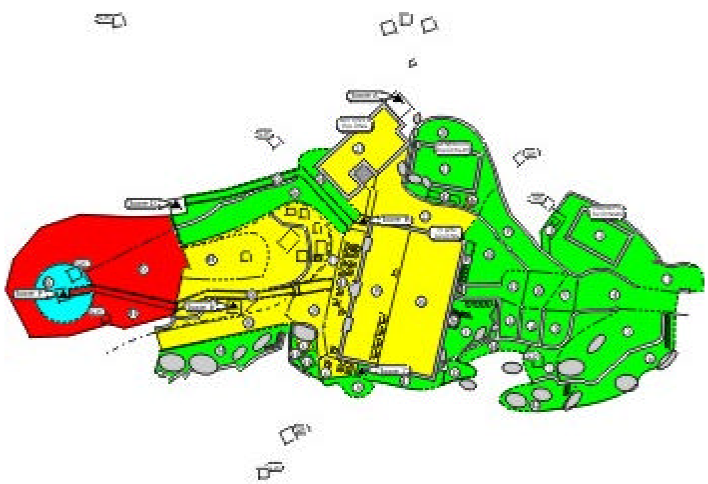
RoofView™ map illustrating composite RF fields produced by broadcasting operations and all wireless communications antennas on the north tower of the WTC.

A specially modified version of the RoofView™ software (developed by Richard Tell Associates, Inc. - see RF Safety Products page on this web site) was employed to perform spatial interpolation of the many measurement values, to compute the expected RF field levels associated with the many wireless antennas and to graphically plot the resulting RF fields determined from the combination of both broadcasting and wireless communications activity.

Broadcast Fields at Tucson Mountain

RF fields at an American Tower Corporation antenna site located on Tucson Mountain, near Tucson, Arizona, were evaluated on the ground and on the six towers that are located in close proximity to each other. A ground level field survey was used to categorize areas of the site according to composite RF field levels produced by six high power FM radio stations and seven high power TV stations.

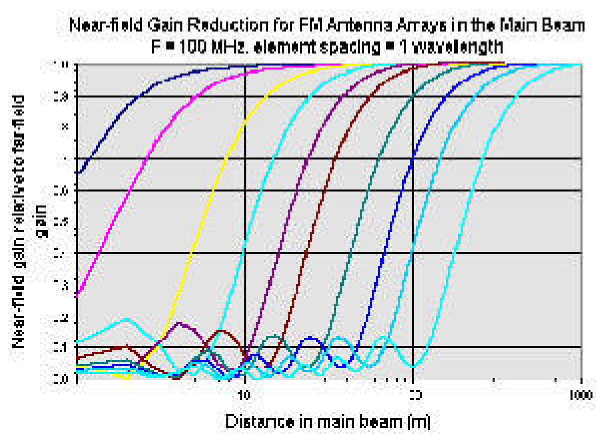
Photograph showing towers at the Tucson Mountain transmitter site.



Site plan showing survey areas according to relative field levels based on area volumetric spatial averages in 48 regions of the site.

Theoretical analysis of near-field levels on each tower were also performed and compared with far-field methods to arrive at practical RF exposure mitigation procedures to apply during tower work. It was shown in the study, for example, how the gain of commonly used

VHF broadcast antenna arrays can exhibit substantial gain reduction in the near field, suggesting that the application of far-field calculation methods can sometimes substantially over-project the magnitude of the actual RF field level near an antenna.



Gain in the near-field of an 8 element FM broadcast antenna compared to that in the far field.

Wireless Telecommunications Studies

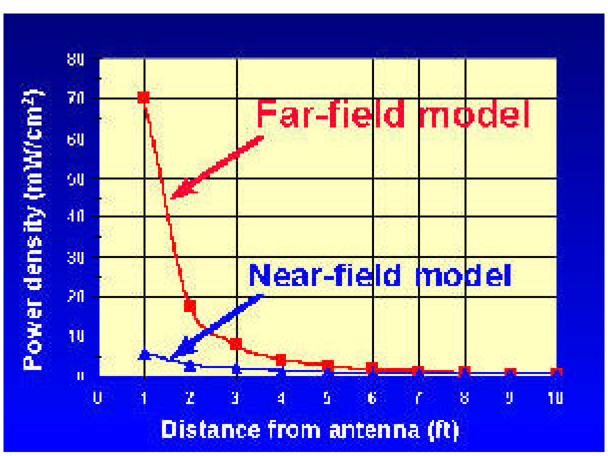
A typical cell site located in a residential neighborhood.

With implementation of the recently revised FCC guidelines on RF exposure, including an emphasis on the wireless telecommunications industry, wireless providers have found an increased need for outside technical support for RF compliance investigations. Typical cell sites, such as the one pictured here, result in only very weak fields at ground level. Nonetheless, even these weak signal levels are often the subject of public hearings.

The real RF safety focus of cellular, PCS, paging, trunked radio and SMR operators, is an occupational one and this is driven by the need for workers to gain immediate access to the radiating elements of active transmitting antennas for maintenance purposes.

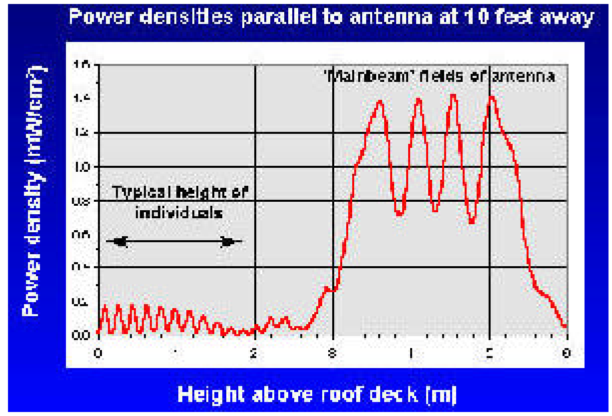
Richard Tell Associates has extensive experience in both on-site (and on-tower) RF measurements and theoretical analysis for electromagnetic field exposure assessments. This work has primarily concentrated on near-field issues since virtually all exposures of any consequence relative to compliance with FCC RF rules occur in the near-field.

A common communications tower site with microwave, cellular, paging and conventional two-way radio antennas.



Another reason for careful examination of the near-field is that the use of conventional far-field modeling methods generally produce gross over-estimates of the field magnitudes near an antenna. This becomes very important when assessing the need for implementing some form of access restriction or re-engineering of the site for compliance. Corrective procedures, based on unrealistic models can be unnecessarily expensive.

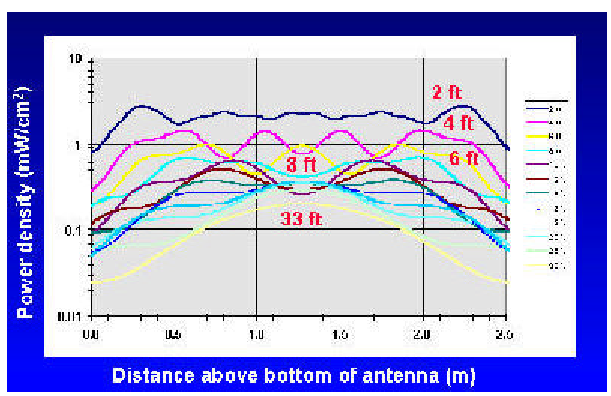
Projects performed by Richard Tell Associates include technical evaluations of the impact of raising antenna mounting heights to reduce roof-level exposure to RF fields at wireless antenna sites. This figure illustrates the strong influence of antenna mounting height on the fields to which an individual standing beneath the antenna can be exposed. Note the roof reflections near the roof surface and the near-field variation of fields near the antenna elements.



Effect of mounting height on plane-wave equivalent power density parallel to antenna aperture as a function of height. Oscillations near the roof are caused by roof reflections while oscillations near aperture of antenna are caused by being so close to individual elements within the antenna.

The same considerations hold for personnel working near but beneath active antennas on towers such as this shot related to a project at a rural cellular site in Puerto Rico.

One can envision the near-field as an area within which the gain of the antenna has not yet been fully realized. In fact, what happens is that the beam becomes wider and the gain reduces. This figure illustrates an analysis of a typical 800 MHz band paging antenna and shows the plane wave equivalent power density at different distances from the antenna along a line parallel to the aperture of the antenna and in front of it. One can see that at greater distances the beam becomes apparent as a main lobe of radiation while nearer the antenna, though the field is substantially stronger, it is very non-uniform along the aperture. This variability in field level is related to the multiple elements that make up the antenna. This same concept of near-field gain reduction also applies to conventional aperture antennas like microwave dishes.



RF field levels, plane-wave equivalent power density, parallel to aperture of an 8 element, vertical collinear antenna, typical of those used for wireless communications, showing formation of main beam at greater distances.

Microwave dish antennas are aperture antennas that exhibit the same general reduction of gain in the near field as other types of antennas.

Various projects have included characterizing the near-field spatial variation of RF fields via direct measurements. This approach can be a highly cost effective method for deriving empirical models that can be applied generically across large networks using similar antennas without having to conduct expensive field studies for each and every antenna site.

These kinds of studies can be performed by making use of test transmitters and performing careful scans of the RF field levels parallel to the frontal aperture of the antenna. This technique is especially useful for evaluating specific antenna mounting arrangements that may be common to a particular application, such as antennas mounted on electric utility transmission line towers.

Near-field scans of a panel antenna can be used to develop empirical models for estimating RF fields at other antenna sites.

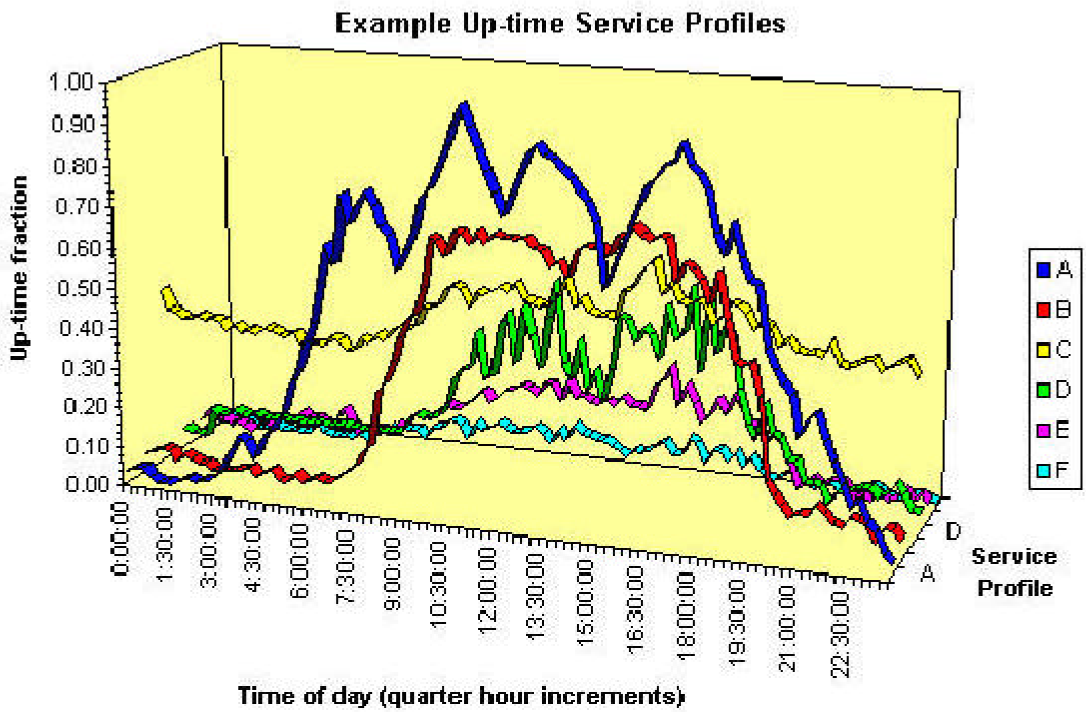
Performing RF compliance measurements at a PCS antenna site.

Sometimes, these measurements can be conducted under contrived conditions, such as a parking lot or other open area and in other cases making use of installed cell site antennas.

On-site RF measurements are generally performed using frequency shaped, isotropic field probes to determine the peak and spatially averaged field levels in accessible areas at the antenna site. An issue of some importance relative to in-situ field measurements is transmitter up-time.

A roof-top RF survey.

This figure, obtained from a study performed for an SMR client to help characterize the transmitter duty cycles, was obtained by interfacing a scanning receiver to a computer using custom developed software for acquiring data on occupied channels at the rate of 100 channels per second. By acquiring data over a prolonged period, like a week at a time, statistically meaningful results were obtained that provided useful insight to the cyclic nature of RF transmissions by intermittent carriers. By associating frequencies to specific antennas located on the roof-top transmitter site, these data permitted a determination of the actual average antenna duty cycle for any 15 minute period throughout the day.

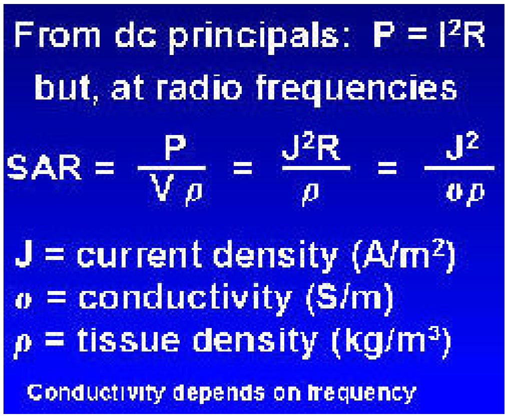


Time-series data from week-long monitoring project to determine average up-time fraction of wireless transmitters at a densely configured transmitter site. An up-time fraction of 1 represents all transmitters connected to a given antenna operating at 100% of maximum possible time.

While many wireless antenna sites occupy building rooftops, there are thousands of communications towers supporting transmitting antennas that may present the possibility of high-level RF exposure of tower climbers. Richard Tell Associates developed the TowerCalc™ software package just for this purpose: to analyze the potential RF field levels that climbers might experience. The software determines the estimated body-averaged power density for every vertical foot of tower height.

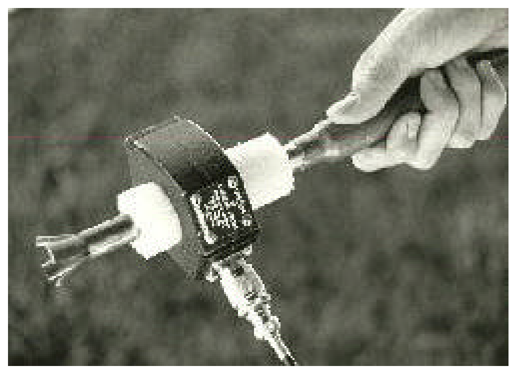
Looking down from a communications tower with side-mounted panel antennas for cellular telephone service.

RF Hot-spot Evaluations



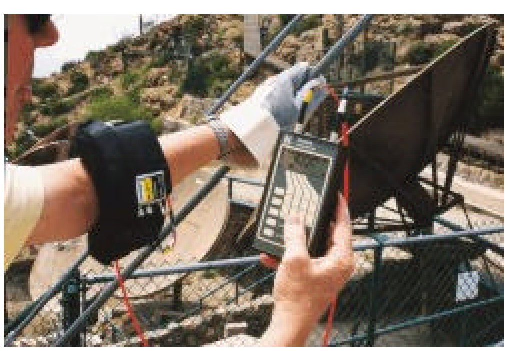
Relationship between current density and SAR.

Conductive objects immersed in relatively weak RF fields can exhibit localized RF field strengths substantially greater than the ambient values only a short distance from the object. Examples include metal curtain rods, stair railings and metallic guy wires. When these localized RF fields are found to exceed applicable exposure limits, how should these apparently excessive fields be interpreted in terms of compliance? One approach to this issue is assessing the magnitude of the localized specific absorption rate (SAR) that could occur when an individual comes into direct contact with the object. Under touching conditions, the maximum RF current will flow between the object and the individual.



Contact current probe made from current transformer and copper pipe.

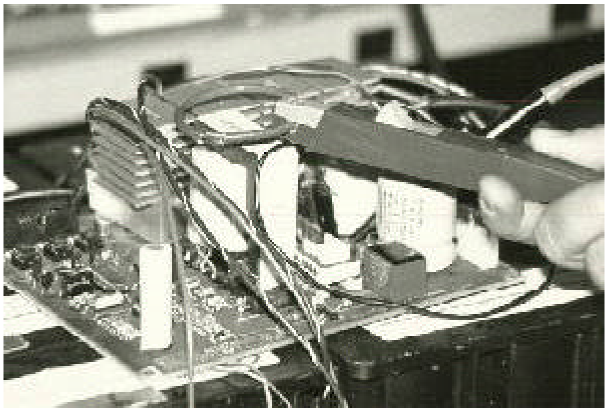
This methodology was developed for a contractual effort to the National Association of Broadcasters. Subsequently, in a separate study of contact currents conducted at the Sutro Tower in San Francisco, narrow-band measurements of current were performed when touching various objects in the immediate neighborhood of the tower. These currents were then used to compute values for the SAR in the wrist of a person making contact with the objects. The wrist represents the point of minimum cross-sectional area and the current flowing in this region will result in the greatest local current density, and, hence, greatest SAR. By taking into account the conductive cross section area of the wrist, the electrical conductivity of the tissue and the measured current, the wrist SAR was able to be estimated and compared to limits recommended by the IEEE C95.1-1991 SAR standard for the extremities. In this case, a conventional, small aperture current transformer is place about a copper pipe probe configuration that is held and brought into contact with the object of interest. The output of the current transformer is detected with either a narrow band or broadband instrument.



With the advent of new contact current meters, the large aperture current transformer fits directly around the wrist (or ankle) to measure the contact current or induced body current as illustrated here in an investigation of compliance with contact current limits at a broadcast site. Metering electronics provide a direct readout of the true rms current.

Switching Power Supply Fields

With the advent of switching power supply technology, the presence of low frequency magnetic fields has led to an interest in evaluating these devices as new sources of electromagnetic energy exposure. A project for a major computer manufacturer was conducted to measure the magnitude of both magnetic and electric fields associated with selected switching power supply designs as they might relate to technician and design engineer exposures. These measurements made use of a displacement current type of electric field sensor and a shorted loop magnetic field sensor. The shorted loop technique made use of small clamp-on current probe to measure the induced current in the loop; the single-turn loop was used to provide for as much bandwidth as possible to capture high frequency harmonics produced by the switching process. The use of rms detection permitted a direct measurement of the magnetic field while a digital oscilloscope was used to acquire time-series samples of the field. An FFT algorithm was used to transform the observed time-domain data into the frequency domain.



Using a single-turn loop sensor to measure surface magnetic fields of a switching power supply.

High Power Radar

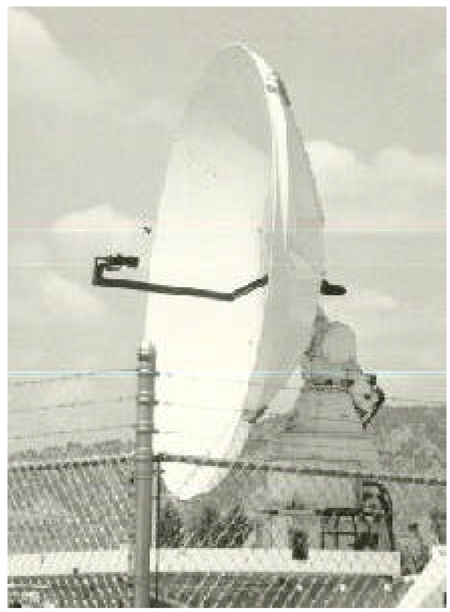
Radar systems that operate with megawatts of transmitter output power, when coupled to high gain antennas, present the possibility of substantial RF field levels, even at significant distances. Representative radar measurement projects include surveys at the MIT operated Altair radar facility on Kwajalein Atoll in the Pacific and high power experimental weather radars and wind profiling systems at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

The Kwajalein Atoll in the Pacific.

The Altair radar antenna on the island of Roi-Namur.

The Altair radar is a combination VHF-UHF radar with very high power. The antenna aperture is 150 feet in diameter and may be used to track space objects to splash-down, with near zero degree elevation angle. Special safety measures have been developed to insure compliance with applicable RF exposure limits. More information about the Altair radar may be found at: <http://www.smdc.army.mil/kwaj/ALT_SPEC.HTM.>

Radars commonly used for weather research or air traffic control systems have been examined in detailed field studies for various clients. Low elevation angle operation and proximity to nearby office buildings present the possibility of strong in-building fields and the desire to better understand the ambient fields that the general public may experience.



A high-power weather radar at the National Center for Atmospheric Research

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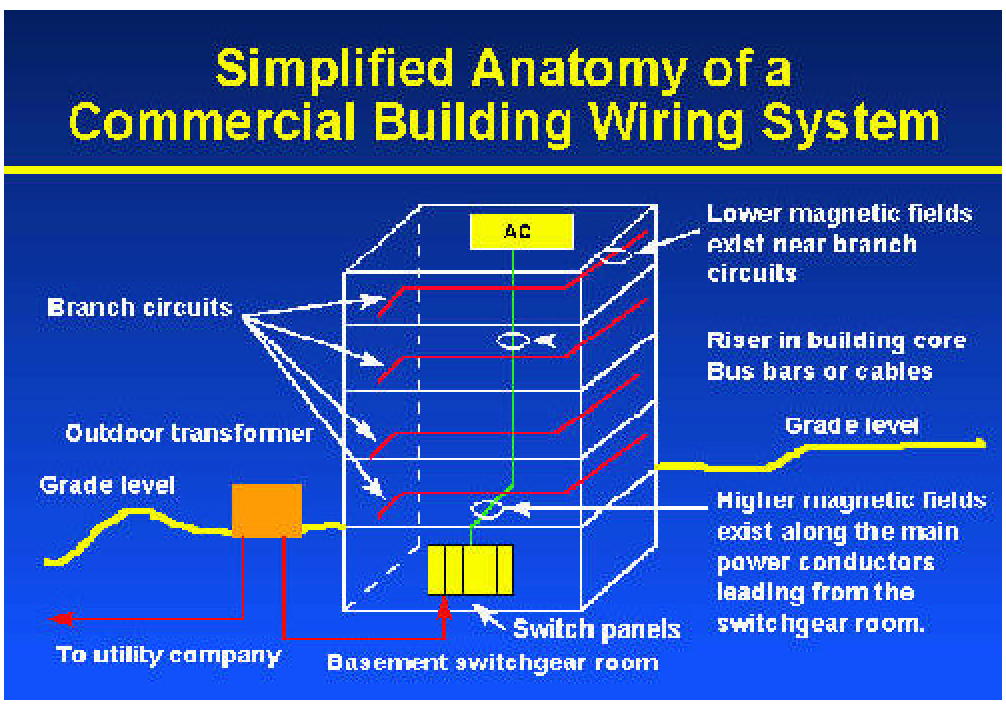
A common FAA air traffic control radar system at the FAA's Oklahoma City Aeronautical Center.

Police Radar

A common Ku band police radar unit typically operates with very low power levels of a some tens of milliwatts.

Because police radar units have been implicated in possible health effects, some community agencies have sought independent evaluation of the RF fields associated with commonly used traffic radar devices. These devices are very low powered and result in RF fields that are substantially lower than the Maximum Permissible Exposure limits contained in most of today's world RF exposure standards. In a representative study conducted for the Division of Risk Assessment of a California city, field measurements were performed on a variety of traffic radar units and a report was prepared that summarized the results and placed them in context relative to existing standards for human exposure to microwave fields and specific absorption rate (SAR).

Building EMFs



The use of electricity results in the production of power frequency electric and magnetic fields. These fields are not only associated with overhead or underground power lines but also electrical wiring systems that distribute power within buildings and homes. A number of projects carried out by Richard Tell Associates have been directed toward characterizing the electric and magnetic fields in the interior of commercial office buildings and factories. The concept of how these fields may be distributed throughout a building structure is illustrated in this simplified drawing of the electrical anatomy of a building.

A common finding in these studies is the presence of strong magnetic fields near the electrical switch gear for the building. This is often the case because of the fact that all of the electrical power for the facility normally enters the building through a single electrical room, typically in the basement, and is distributed to other parts of the building through heavy duty switch panels. While the incoming utility power may be contained within cables, the individual current carrying conductors are generally spread apart on the interior of the switch apparatus leading to considerably stronger fields due to less phase cancellation.

Top of a an electrical switch panel with cables in conduit exiting top of cabinet.

A common scenario is for outside utility power to enter the bottom of the switch panels from beneath (but not always) and to exit the panels from the top, whereupon it is distributed via either cables contained within large electrical conduits or via bus bars. It is interesting to note that bus bars generally lead to greater magnetic fields in their vicinity than cables carrying the same currents simply because of the greater separation of the conductors, again reducing the phase cancellation effects afforded by tightly configured bundled cables.

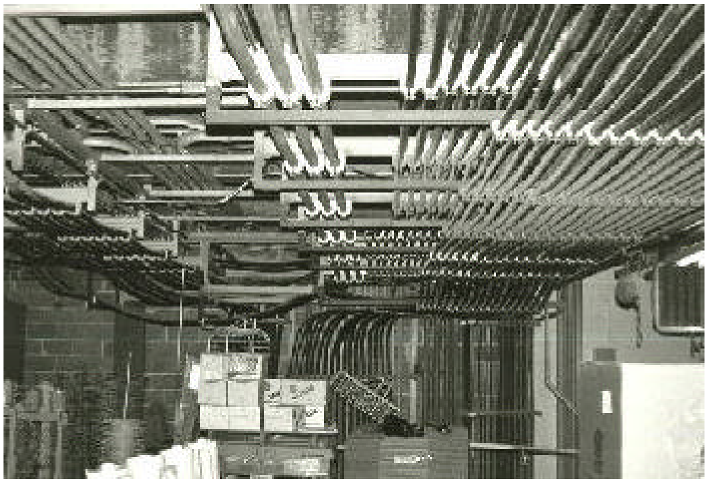


Illustration of power cable configuration in an industrial test facility to bring power from one area of building to test area.

In some cases, unbundled, very high current carrying cables may be used to distribute electrical power through an industrial facility for operating high power test equipment. These cables, such as when attached to the ceiling as shown here, can produce magnetic fields over an extended region.

Short-wave Broadcasting

HF Curtain array at KSDA, Agat, Guam.

International broadcasting in the high-frequency (short-wave) spectrum generally employs high transmitter power, commonly in the 50 kilowatt to 200 kW range, or greater, with either curtain antenna arrays or rhombic antennas fed with open-wire transmission lines from the transmitter. This photo shows the antenna array at a short-wave broadcast station studied in Guam. These systems present the possibility of strong RF fields associated not only with the antenna itself, but also with the switching circuits used to control which antenna is connected to a given transmitter. The open-wire feeders are typically supported about 8-10 feet above the ground.

An interesting aspect of these HF facilities is the presence of vertically polarized electric fields beneath the large, horizontally polarized antenna arrays. These vertically polarized fields come about because of the high RF potential between the elements and the ground. This phenomenon leads to the existence of electric fields that can induce substantial currents in a standing person. In some cases, these induced body currents can exceed the Maximum Permissible Exposure (MPE) limits well before either the electric or magnetic fields exceed their corresponding MPEs. A convenient rule of thumb for computing the induced body current in a bare-footed, adult in good electrical contact with ground is:

$$\mathbf{I(mA) = 0.38xE(V/m)f(MHz)}$$

where:
E is the electric field strength parallel to the body. It's easy to see that at 25 MHz, for example, an electric field of only 10.5 V/m is required to induce 100 mA of body current! This photo shows a single axis electric field sensor commonly used for measuring HF transmitter site fields.

At HF broadcast stations using multiple transmitters and multiple antennas, an antenna switch room (matrix room) provides for the necessary relays to interconnect any transmitter to any antenna. Because the transmission lines are all open structures, high RF fields may be present within the room and both electric and magnetic fields must be measured to properly evaluate exposure.

The matrix switch room at a high power short-wave broadcast station.

Measuring induced body current by standing on a platform flat plate electrode and using a narrow band receiver to 'tune in' the current of interest.

Induced body currents may be measured with different types of equipment. In the case shown here, body current to ground is being measured using a narrow-band receiver to permit separating the current according to frequency. It is important to note that the one-legged current can be almost as great as when standing with both feet in electrical contact with ground. This is because the body current still exits the body through the available conductive contact. A ground rod driven into the ground beneath the platform electrode surface provides the other connection to earth.

Other instrumentation can be also be used for measuring induced body currents. In this photo, a 'bath room scales' type of meter is used to stand on and permits direct indication of the current.

Stand-on body current meters permit direct reading of the induced body current but are subject to unrealistic contact conditions with ground because of the large flat plate electrode on the bottom.

The most effective way of measuring induced body currents, however, is via the use of the clamp-on type of current transformer with a remote readout module that permits direct measurement of current as one walks or stands on a site. In this photograph, ankle current is being measured at a major VHF-UHF broadcast site.

The clamp-on style of current sensor provides a measurement of the actual current flowing to ground without the possibility of displacement current paths associated with flat-plate type body current meters.

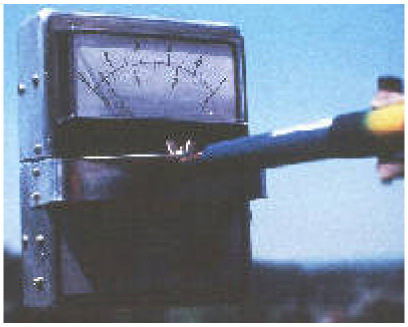
Powerlines

Studies of electric and magnetic fields associated with overhead electric power lines are often commissioned by land development companies prior to purchase or development. Numerous projects have been carried out to assist developers in meeting environmental assessment requirements imposed by planning departments.

These investigations have often included both on-site field measurements as well as computer modeling of expected fields. A representative study in Redwood City, California, using historical line loading data, permitted an insight to the time variation of magnetic fields over long periods of time, assisting in interpretation of actual measurement data taken at specific times.

Although electric field strengths do not vary because of electrical loading like magnetic fields do, accurate measurement of electric fields is more problematic due to the strong propensity of electric fields to be perturbed by the local environment. E-field measurements are typically performed with displacement current sensors that operate on the basis of measuring the displacement current that flows between two closely spaced electrodes immersed in an electric field. Here the sensor is placed on a non-metallic tripod to prevent the influence of the operator's body on the measured field value.

A displacement current type electric field sensor supported on a non-conductive tripod.

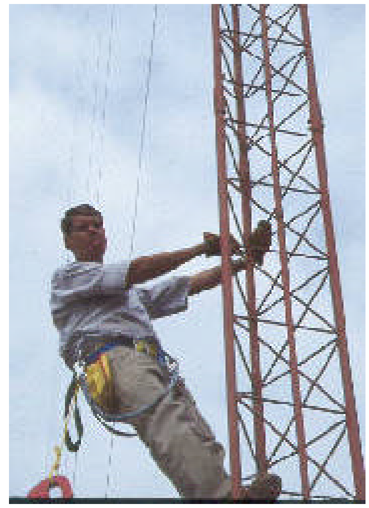


Alternatively, the electric field meter is supported with a long, non-conductive handle (3 to 10 feet in length) to minimize field distortion by the presence of the observer.

A commonly used displacement current type electric field strength sensor used in studies of 60-Hz electric fields beneath overhead power lines.

Hot AM Tower Climbing

Even with very low power levels, the surface fields on an active antenna can still be substantial. This issue has arisen in connection with the common practice of doing tower rigging, beacon replacement and painting on active (hot) AM radio broadcast towers. A project conducted for the Federal Communications Commission (FCC) took the approach of measuring the current flowing between the tower and the body of a climber as an initial way of exploring the critical parameters involved in hot tower climbing. This study included climbing several different hot towers, including different electrical height towers, and comparing the observed body currents to computed surface near-fields, in particular, the radial component of the electric field on the tower.

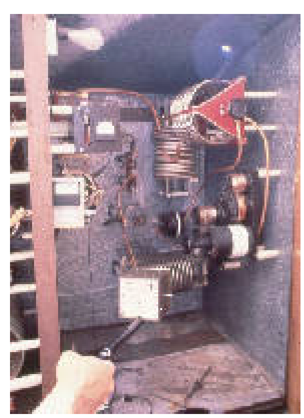


Strong radially directed electric fields on the tower surface drive currents in the arms of the climber.

Making induced current readings on a hot, half-wave tall AM tower.

Interestingly, the measured currents were found to track almost exactly the method-of-moments calculated distribution of the radial electric field component. This is the component that exists on the surface of the tower and provides for most coupling with the extended arm of a tower climber grasping the tower. The study made estimates of the power delivered to the tower that would prevent the induced body currents from exceeding recommended limits. In a separate study, the effectiveness of different kinds of work gloves in reducing the current flowing into the climber was investigated and showed that common cotton gloves can provide for at least a factor of two reduction in bare-handed currents.]

Strong electric and magnetic fields are also associated with the 'doghouse' structure used to house the impedance matching circuit for coupling the transmitter output to the tower. While this is not normally an issue for those climbing the tower, maintenance activities, such as tower base current readings, may present the possibility of high exposure levels. Here, electric fields are being measured near the matching circuit inductors.

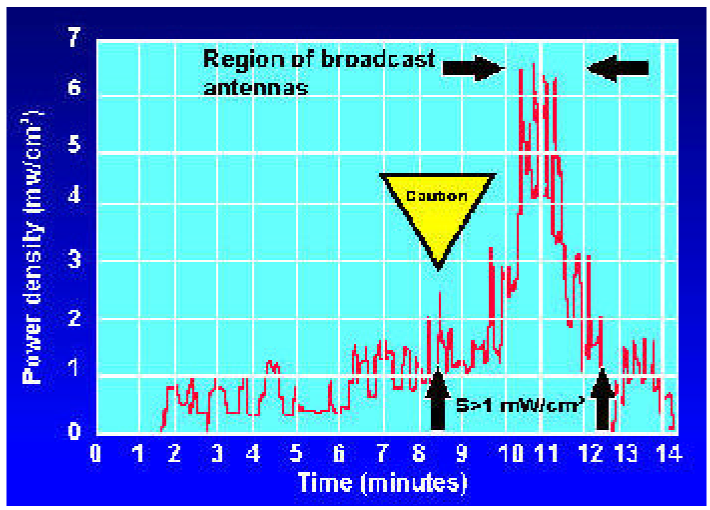


Measuring electric fields inside the doghouse.

Tracking Real World RF Exposure

Using a back-mounted RF field probe to measure exposure while climbing.

In the real world, RF exposure is rarely constant. Workers are exposed to RF fields that are generally substantially nonuniform in their spatial distribution and variable in time. For example, personnel working on broadcast antenna towers are subject to different levels of fields at different heights on the tower. Compliance with RF exposure standards is based on the time-averaged value of exposure. In a project performed at a broadcast site, RF fields were measured using data-logging techniques and a back-mounted, isotropic field probe.



The time averaged exposure is what is relevant to compliance.

By continuously measuring the RF fields as the climber ascends the tower, the instantaneous field levels are determined. Use of appropriate equipment allows for an immediate indication of the running, time-averaged exposure level.

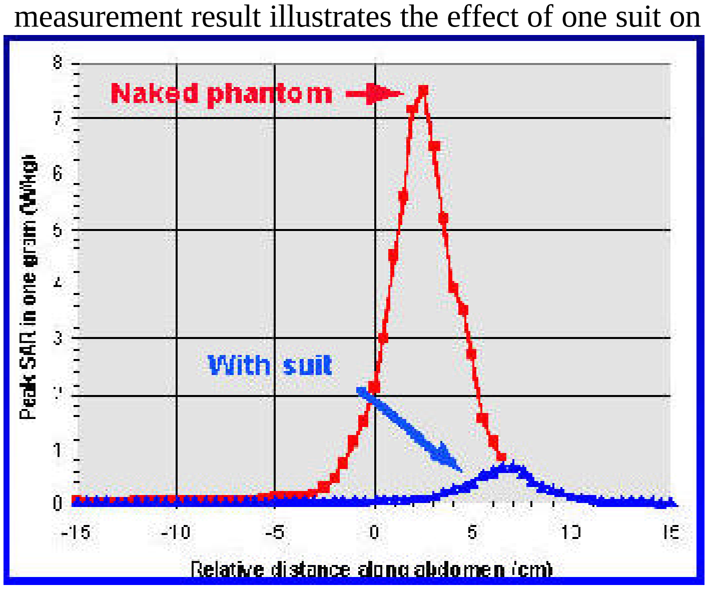
RF Instrument Evaluations

A particular strength of Richard Tell Associates is the long-time background of its founder in RF field instrumentation evaluations. This experience level was applied in a contract from the Federal Communications Commission for assessing certain performance characteristics of selected instruments. The work included examining stand-on body current meters, personal RF monitors and contact current meters. This photo illustrates a laboratory setup for establishing accurately known RF field strengths using transverse electromagnetic (TEM) cells.

RF Protective Clothing Evaluations

One viable means of RF exposure mitigation is the use of RF protective clothing. This is clothing, in the form of overalls, that is constructed from fabric containing microscopic stainless steel fibers. The metallic content of the fabric can afford a substantial reduction in body absorption of RF energy for personnel having to work in the vicinity of powerful transmitting antennas. Richard Tell Associates has participated extensively in the issue of how to perform tests of the effectiveness of RF protective clothing. These studies have included projects with both Motorola and Euclid Garment Manufacturing Company. In this photo, a completely enclosed environment is formed by the suit with hood assembly, gloves and socks.

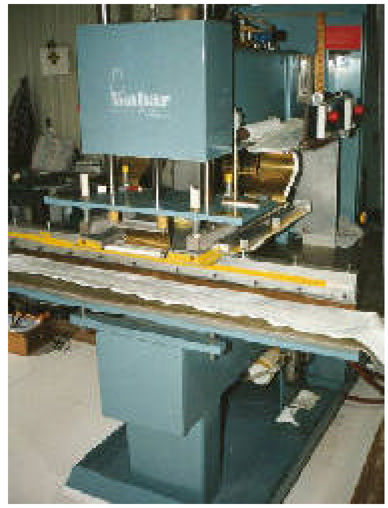
Laboratory investigations of the shielding effectiveness of different RF protective suits were performed by applying state-of-the-art measurement techniques. Using a life-sized phantom model, filled with an RF absorbing liquid to simulate the electrical characteristics of tissue, a small, robotically controlled electric field probe was used to scan the interior of the phantom while it was exposed to known RF field levels. By performing measurements with and without the suit under test on the phantom, direct measurements of the specific absorption rate (SAR) were obtained. Using SAR as the criterion of exposure was deemed to be the most meaningful measure of suit performance when compared to simple measurements of RF field strengths in air. An example measurement result illustrates the effect of one suit on near-field exposure reduction evaluated at 450 MHz. Other studies of the ability of protective clothing to reduce induced body currents and contact currents have been performed. For example, see: http://www.euclidgarment.com/AM.PDF and http://www.euclidgarment.com/VHF.PDF.



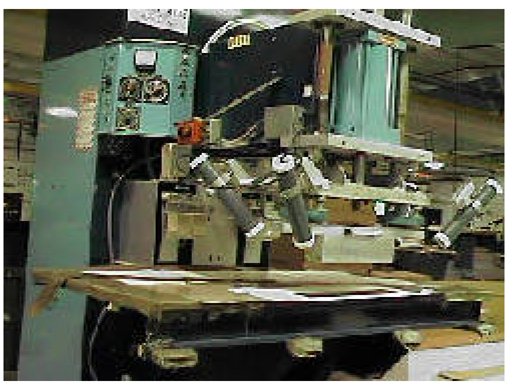
RF Heat Sealers

Broadcast antenna tower workers and dielectric RF heat sealer operators are the two highest exposed occupational groups in the United States. Richard Tell Associates has performed numerous exposure assessments of RF heat sealers, performing measurements of electric and magnetic fields, induced body currents and contact currents.

Heat sealers have the potential of creating extremely strong RF fields because of their design. A high power RF generator applies voltage to a sealing electrode that is brought into contact with the material being sealed, typically some form of vinyl, such that the dielectric losses in the material lead to rapid heating and subsequent melting of the material.

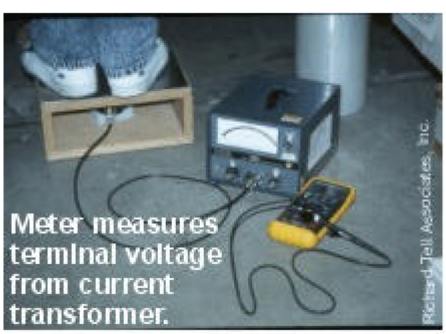


10 kW RF sealer with long sealing electrode for tent manufacturing.



A sealer fitted with a short electrode, spotting lights. The timer controls the seal time.

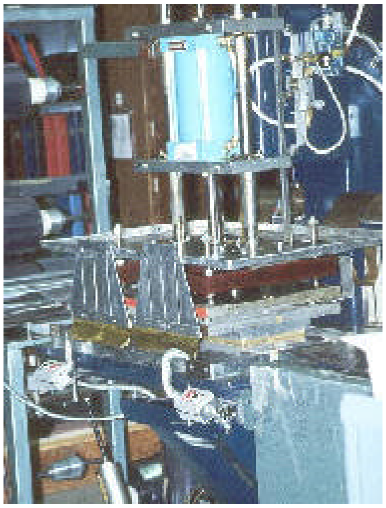
Some sealing machines use long bar type electrodes for creating extended seams, such as in the manufacturing of tents and other large objects. In other cases, smaller electrodes are used to create a customized pattern of sealing such as in producing vinyl protective covers, notebooks, etc. The electric fields are fringing fields that curl around the edges of the sealing electrodes. Hence, operator exposure occurs since these fringing fields emerge outward, away from the electrodes. Generally, the electric fields are predominantly vertically polarized. Strong magnetic fields can exist because of the RF current flow within the material being sealed between the electrodes.



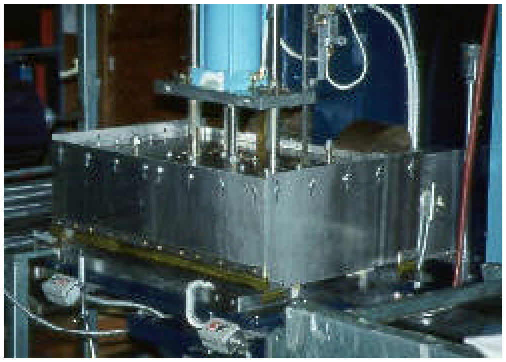
Measuring induced body current in an RF sealer operator.

The strong electric fields result in induced body currents that can be monitored at the foot by measuring the current flow between the operators feet and the floor as shown here. Because of the coupling of the operator's body to the near-field environment of the sealer, the magnitude of the induced body current can often substantially exceed that value that might be predicted on the basis of a uniform field exposure.

In some cases, electric fields can be significantly reduced in strength by fabrication of shields that are attached to the ground of the sealer system.   The photo to the shows an example of a partial shield system while the photo below shows a completely enclosed shielded system. Application of these shielding methods is, however, limited by the production work being accomplished since the shields can interfere with movement and placement of the materials being processed.

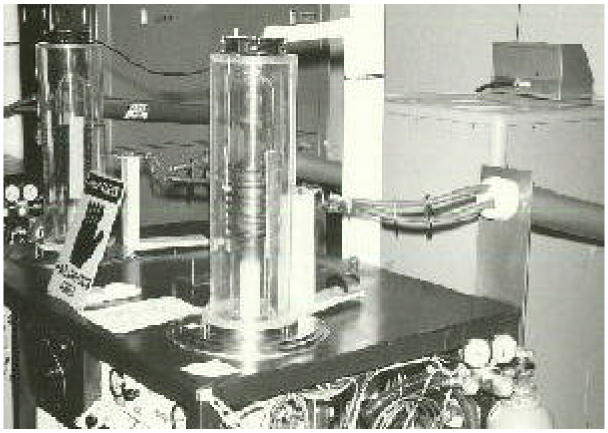


Partial shield on sealer.



Complete box shield on sealer can substantially reduce operator expsoure.

Induction Heaters

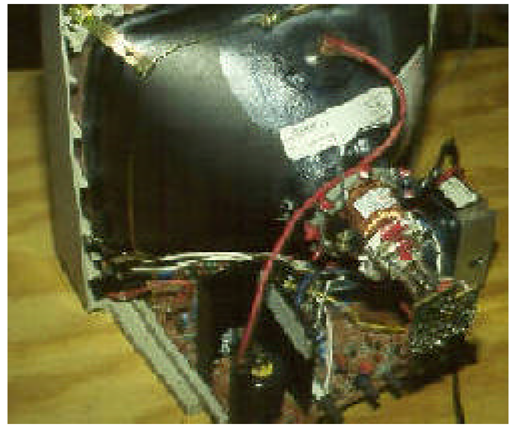


While dielectric heat sealers are predominately electric field sources, induction heaters are produce very strong magnetic fields. High RF currents, typically in the kilohertz to hundreds of kilohertz frequency range are passed through coils that surround conductive materials to be heated. Strong circulating (eddy) currents are produced in the target material and result in substantial heating. Stray magnetic fields in the vicinity of the coils can exceed applicable limits for exposure in some cases. Representative induction heater projects performed by Richard Tell Associates include work at specialized material manufacturers and automotive seat manufacturing facilities where induction heating is used to heat moldable foam materials.

Although magnetic fields are generally the most prominent feature of the induction heating process, strong electric fields can also be encountered near the power leads that extend from the power supply cabinet to the heating coils. Again, with the low frequencies involved, there can be notable coupling between the body and the power-lead electric fields with the result of significant induced body currents.

VDT Electric and Magnetic Fields

Numerous surveys of electric and magnetic fields associated with video display terminals (VDTs) have been accomplished by Richard Tell Associates. These devices produce strong surface electric fields due to the high voltage lead emerging from the fly-back transformer. Because of the various arrangements of this lead, the large red cable in the photo to the right, VDT electric fields are not as easily predicted from one VDT to another. Magnetic fields, however, produced by the fly-back transformer and the deflection yoke located at the rear of the CRT neck (copper colored wire seen in this photo) are generally well characterized by a vertically polarized component due to the horizontal scan on the CRT (typically in the 15 kHz to 65 kHz range) and a horizontal component due to the vertical scan on the CRT (typically in the 45 to 75 Hz range).



The insides of a common VDT showing the high-voltage lead and the deflection yoke at the read of the CRT.

Measuring electric field induced currents in the VDT operator.

Projects carried out under contract to the National Institute for Occupational Safety and Health, for example, beyond the usual measurement of electric and magnetic field strengths, have included measurement of currents flowing in the operator induced by electric fields and investigation of the time-domain waveforms of magnetic fields.

The time-derivative of the magnetic field is related to the magnitude of the induced peripherial eddy currents in the body of the operator.

A digital oscilloscope is used to capture the waveform of the magnetic field for subsequent analysis using FFT techniques.

Automatic Vehicle Identification

At the North Dallas Tollway, AVI antennas are mounted to transmit signals toward approaching vehicles carrying AVI transponding tags.

With the advent of automatic vehicle identification (AVI) systems, there has been an increased concern on the part of state and public agencies implementing AVI technology relative to the issue of public and worker exposure to the associated RF fields. In a project conducted for the Triborough Bridge and Tunnel Authority (TBTA) in New York, RF field measurements were made to determine the intensity of the fields at the toll booth, inside moving vehicles (automobiles and buses) and in the immediate vicinity of the transmitting antenna systems. This photo shows a test system located in Dallas, Texas where moving vehicle measurements were made with the antenna (with the yellow circle) oriented to expose a transponder tag placed just inside the vehicle's front window.

AVI antennas are often mounted from above and directed toward the oncoming traffic stream. This photo shows measurements being performed in New Jersey to assess the variation of RF field strengths with distance from the antenna. Some AVI technologies use of battery powered transponders while others make use of transponders that are powered by the received signal itself!

Satellite Communications Earth Stations

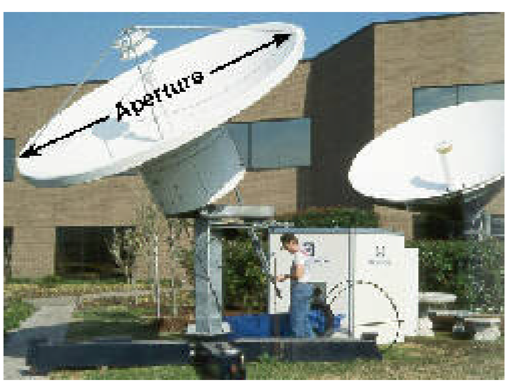
A large satellite earth station dish in Brewster, Washington.

Satellite communications earth stations are perhaps the most visible RF sources found in the environment. Large parabolic dish antennas, normally painted white to minimize heating from the sun and possible surface deformation, can create extremely high <u>effective radiated power</u> (ERP) levels. It is not unusual for the ERP of a high power earth station to approach the terawatt (TW) level.

RF field surveys conducted at numerous earth station facilities by Richard Tell Associates have typically demonstrated very low levels of electromagnetic energy in publicly accessible areas. As with any antenna, despite relatively high input power to the antenna, near-field power densities are directly related to the physical aperture area of the dish and since most of these antennas are large, the power densities found, even directly within the aperture can be surprisingly modest. These observations do not hold, however, for locations directly in front of the feed horn of the dish.

Earth station teleport in New Jersey.

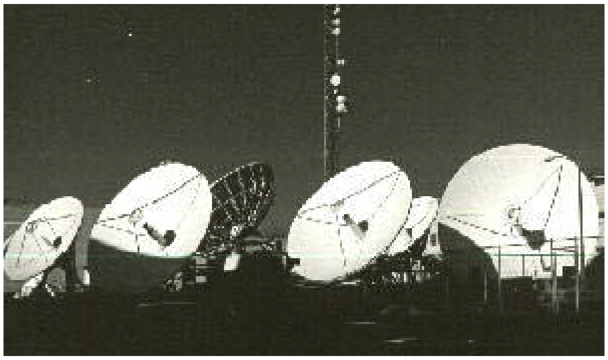
Measurement projects have been conducted at major satellite teleports around the country to support claims of compliance with applicable RF exposure limits. Theoretical studies have also been performed, such as for the FAA's Wide Area Augmentation System, in which near-field analysis methods have been employed.



Portable earth station at an educational facility in Texas.

In a typical sat-com earth station facility, numerous dish antennas may be employed for communications with various satellites, feeding video, data and command and control signals to the satellites orbiting the earth. In other cases, portable sat-com equipment may be situated temporarily close to public access points and require evaluation.

In fact, at some facilities, the antennas may be so densely mounted that the ground is almost always shaded. To properly evaluate the intensity of side-lobe radiation, surveys must be made on the site itself and at nearby locations, such as multi-story buildings that may be located beneath the main beam of the antennas.

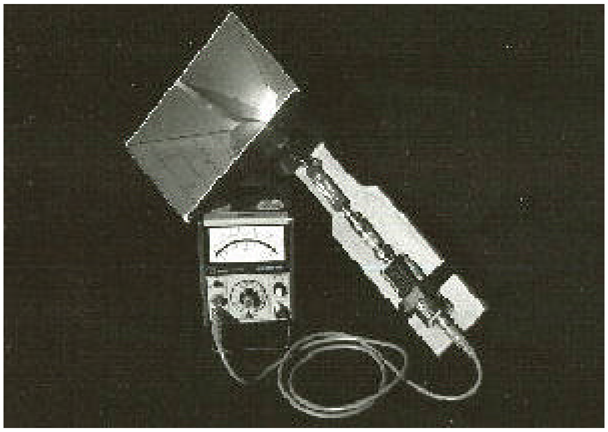


A dense earth station facility in Culver City, California.

Conducting a survey of microwave field levels atop a roof at a government facility that uses an earth station for data transmission to remote locations.

Field surveys at satellite earth stations, except for the aperture of the dish itself, typically require more sensitive equipment than normally used for RF hazard studies. This is because of the high directivity of the antennas with very low side-lobe fields. A useful approach to these measurements has been found to consist of a standard gain (or wide-band) horn antenna connected to a broadband, high sensitivity power detector, inline bandpass filter and portable power meter.

This combination provides for extremely high sensitivity, permitting measurements in the picowatts per square centimeter range. The power density may be determined simply by an accurate measurement of the power captured by the antenna divided by the effective aperture area of the antenna. This combination has been used to advantage in numerous studies and illustrates the utility of assembling the right equipment for the job.



Wideband horn antenna, filter and portable power meter.

Theoretical studies of RF fields produced by circular dish antennas are often used to evaluate potential exposure levels, particularly in the near field. The electromagnetic field, plane wave equivalent power density in front of a dish can be estimated from the input power to the dish, its aperture dimension and distance from the aperture plane. The figure below illustrates the how the power density, designated as S, can be estimated in the near-field, transition zone and far-field regions. Note that the classical engineering definition of the start of the far field at 2 D^2/λ is entirely too conservative; in reality, the power density is found to begin decreasing as inverse square law after only 0.6 D^2/λ. It is also noted that in the true near-field region, the power density can be simply estimated from power and aperture cross-sectional area alone, somewhat analogous to estimating the field adjacent to vertical collinear antennas used in the wireless industry where gain really plays no role.

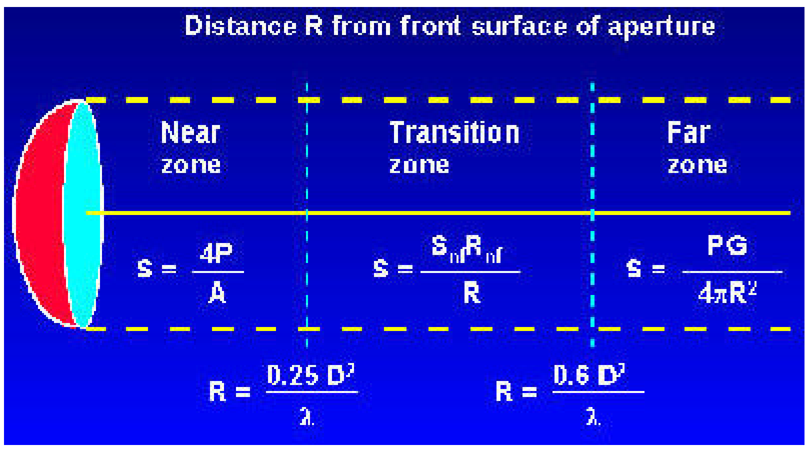


Diagram illustrating RF field zones near a parabolic, microwave dish antenna. Within the near zone where R<0.25 D^2/λ, the peak power density does not vary. Beyond this point, the peak power density decreases with increasing distance.