Increasing the Sensitivity of the Dipole Method: A Case Study

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ABSTRACT

Dipole method sensitivity for electric leak location (ELL) surveys on geomembranes is primarily a function of site conditions. Poor site conditions can completely preclude the functionality of the method. A common misconception introduced by the ASTM D7007 standard practice for dipole method surveys is that increasing the measurement density of a survey will increase the method sensitivity. This has led to engineers to specify measurement density in project specifications for dipole method surveys. In fact, increasing the measurement density increases the survey resolution, but not the sensitivity. The most significant way to increase sensitivity through survey instrumentation is to increase the dipole spacing (Gilson-Beck, 2021). However, if site conditions are poor, no instrument adjustments or procedures can be implemented to cause the method to be effective. The most common cause of poor survey sensitivity is poor isolation along the perimeter of the survey area. This case study details a site where multiple surveys were performed on various phases of the project, with sensitivity continually decreasing with an increasingly dirty perimeter isolation gap. On the final testing event for the project, when sensitivity had completely deteriorated, a novel method of isolating the cover material using a leaf blower was used. Drying the perimeter isolation gap with the leaf blower drastically restored survey area sensitivity. Dipole method specifications should therefore focus on enforceable requirements for proper site isolation and specify the use of the largest practical dipole spacing in order to realize maximum method sensitivity rather than prescribing a minimum measurement density.

INTRODUCTION

The term “sensitivity” when it comes to Electrical Leak Location (ELL) methods is not simple to define. Some factors in method success do not increase the method sensitivity as it is defined in a strictly technical sense, but they can increase the chances of finding a leak. For example, good method procedures do not increase survey area sensitivity, but they can increase the chances of finding a leak through, for example, good data management. For the purposes of this paper, sensitivity is defined as the ability to detect small differences in voltage responses where defects exist in non-conductive (insulating) geomembranes for purposes of locating leaks present in a survey area. The main subject of this paper is to discuss methods for improving dipole method sensitivity.

Another concept that will be discussed in this paper, but which is not the subject of this paper, is ‘functionality testing’. The term ‘functionality testing’ has largely replaced the confusing terms of ‘sensitivity testing’ and/or ‘leak detection distance testing’ that have been used in the ASTM standard guides and practices. Since the latter two terms are misleading, the term ‘functionality testing’ is used throughout this paper to describe procedures used to check for method functionality and survey area conduciveness to testing.

Nine factors influencing method sensitivity are described in depth below in order of descending magnitude of effect. This order is a rough approximation based on two decades of field experience. For each factor, the relationship to other factors is discussed as well as whether and how the relevant ASTM standards address consideration of the factor. ASTM D7007-16 and D8265-21 are referenced. Future revisions of these standards should be checked for the continued validity of the statements made here.

#1 Survey Area Isolation. Without survey area isolation, none of the subsequent factors in sensitivity matter; the method will not work. Method sensitivity has a direct correlation with degree of survey area isolation and the method effectiveness will range from 0% (no leaks detectable) to 100% (every leak detectable). More highly electrically conductive cover material exacerbates isolation issues. Even with excellent perimeter isolation, existing leaks in the lining system can affect survey area isolation to some degree, with larger holes having a larger effect. If extensive damage to the liner is limited to a few specific areas (e.g. one or two locations), the damaged location(s) will be easy to detect, although initial functionality testing on a smaller leak may have indicated “poor sensitivity”. Once the damage is repaired or removed from its connection to the cover material, sensitivity should increase and it warrants repeating the method if a higher level of sensitivity is desired. This consideration is dependent on whether small holes were detectable before the larger damage was uncovered. If damage to the liner is extensive in area (e.g. breaches occurring in many places), the method can have difficulty locating any of the damage, depending on how large the damaged area(s) are relative to the survey area In this situation increased localized measurement density might assist in pinpointing the locations of some of the more significant defects, and once those are repaired then the survey will become more and more sensitive, allowing the location of the smaller defects. In an extreme case, no discrete damage locations are detectable and site response current measurements will reveal that the liner is not able to ~~retain~~ inhibit current flow and the liner should be replaced.

Survey area isolation issues are identifiable by the level of site response current with applied voltage. A well isolated soil-covered survey area should generally not go above 100 mA with an applied voltage of up to 500 V. A poorly isolated survey area will often exceed 300 mA (DC current limit for human safety) at a lower applied voltage.

As of the writing of this paper, only D8265-21 requires reporting issues with survey area isolation as part of the final report, however D7007 will likely require it in future revisions. Only ASTM D 8265-21 requires that the site response current and applied voltage be reported with every survey area condition (i.e. before test, after test, with leak(s) present, without leak(s) present), however D7007 will likely require it in future revisions. ASTM D8265-21 also requires that issues with site conditions including isolation be reported before commencing testing and that the issue(s) be ameliorated if possible before testing begins.

#2 Cover material and underlying substrate material electrical conductivity. A minimum level of electrical conductivity is required for the method to be effective. If either the cover material above the geomembrane, or the underlying conductive layer below the geomembrane, is not electrically conductive enough, the method will not work. However, it is very rare for either the cover material (which can be irrigated) or the underlying layer to be insufficiently conductive, as most earthen materials only require a couple of percent of moisture content. However, issues have been noted with insufficient electrical conductivity with some encapsulated geosynthetic clay liners (GCL) when installed as the sole conductive layer between two geomembranes (Beck et. al., 2008).

The electrical conductivity of the cover material affects the voltage drop distribution in the vicinity of a leak. A more conductive material exhibits smaller voltage drops, resulting in a smaller leak signal, since it is based on measured voltage through a distance of cover material (Gilson-Beck et. al., 2023). Conversely, a less conductive material provides a larger leak signal, translating directly in increased sensitivity (Cen, 2020). Therefore, there is a range of electrical conductivity that is conducive to ELL testing, with a minimum under which the testing will not work and an upper limit that causes leak signals to be so weak that they are difficult to detect. This means that the voltage drop is so small that it cannot practically be measured, especially in the presence of "background" oscillations in voltage. There is no maximum conductivity for the underlying substrate, since that layer is simply a return path for the electrical signal. Earthen materials become more electrically conductive with increasing moisture content.

Both ASTM D7007-16 and D8265-21 require reporting issues with the detectability of an actual or artificial leak (whose signal must be able to travel through both the cover material and the underlying conductive layer) as part of final reporting requirements. ASTM D8265-21 also requires that issues with site conditions related to material conductivity be reported before commencing testing, in order to provide the opportunity to improve site conditions before the test begins.

#3 Moisture Content of Material(s) Overlying Geomembrane. Although moisture content of the cover material is an essential component of cover material electrical conductivity as described in #2, this third factor addresses the adequate moisture required to ensure electrical contact at the leak location(s). If a small leak (too small for cover material to fill the void created by the breached geomembrane) is not wet, it will likely evade detection. Additionally, many containment facilities include cushion geotextiles or geocomposite drainage layers over the geomembrane. These plastic materials will not conduct the electrical signal(s) unless they are adequately moist. Additionally, they will tend to bridge small holes and prevent fines from bridging the air gap through the hole. This site condition will not typically be documented by the dipole method, since an artificial leak is most commonly used and the dipole method practitioner is allowed to ensure ideal contact between the artificial leak and the overlying materials. This is obviously not an issue for water-covered geomembranes. It should be noted that functionality testing using an actual leak is detailed in ASTM D7909-21a, which can more realistically gauge moisture directly above a leak.

Only ASTM D8265-21 requires reporting the condition of the material directly above the geomembrane. This requirement is slated for a future publication of ASTM D7007-16.

#4 Dipole Instrument Spacing. The distance between the two measurement points on the dipole determines how many voltage drops are captured by a dipole measurement, with a larger spacing between points capturing a larger magnitude voltage drop and therefore increased leak detection sensitivity. With all other factors being equal, a threefold increase in dipole spacing from one meter to three meters increases signal magnitude by over 300% (Gilson-Beck, 2021). The increase in signal strength as a function of dipole spacing is actually nonlinear, and tends to stabilize after the dipole spacing exceeds the spacing appropriate for the survey area geometry (Cen, 2020). Of course, there are practical limitations to increasing the dipole spacing. Dipoles measuring over three meters long become physically difficult to handle.

The best practice for dipole method surveys is to take measurements throughout the survey area in a grid pattern, spaced the same distance as the dipole instrument. When a larger dipole is used, it is a common misconception that the survey resolution is compromised, especially in the case of multiple leaks that might be spaced closer to each other than the measurement grid spacing. Multiple leaks are revealed during the pinpointing process, when the largest signal between measurement acquisition locations is excavated, then the surrounding area rechecked for additional signals. Pinpointing always uses a much greater measurement density than the bulk survey as well as multiple directions, to locate the exact position(s) of the leaks. This process must be repeated until the entire area encompassing the area of anomalous readings has been restored to background voltage values.

Both ASTM D7007-16 and D8265-21 require reporting the dipole spacing as part of final reporting requirements. Neither standard practice controls dipole instrument spacing, since the spacing used should also take into consideration the survey area size and geometry. For very small survey areas, a large dipole simply will not be able to acquire enough measurements to be meaningful. However, ASTM D8265-21 standardizes sensitivity between various dipole sizes by requiring that the distance between measurement points be no greater than the dipole spacing as detailed in the next section.

#5 Dipole Method Procedures. Survey procedures are strictly defined here as data acquisition methodologies including measurement density and data analysis methodology, even though many other parameters could be listed here, as well, all with minimal effects, assuming that an ASTM based standard practice is being adhered to. Due to the variability in the treatment of measurement density by the ASTM standard practices, this variable is considered the most significant factor in this category.

Leak detection "sensitivity" is shown to be approximately the same for a one meter dipole at a one meter by one meter measurement grid spacing as for a three meter dipole at a three meter by three meter measurement grid spacing (Gilson-Beck, 2021). Dipole spacing must therefore be taken into account when considering measurement density. Using a grid measurement spacing less than the dipole spacing will simply improve survey resolution, not sensitivity. If the grid measurement spacing is greater than the dipole spacing, then increasing the measurement density will increase the sensitivity as defined for this paper. It therefore depends on which ASTM standard practice is being used whether measurement density can be used to increase method "sensitivity".

ASTM D8265-21 requires that the measurement grid spacing be no larger than the dipole spacing. This standardizes the detection sensitivity across all different dipole sizes, so an increase in measurement density will not affect method sensitivity since the prescribed measurement density sufficiently encompasses the survey area. ASTM D7007-16 allows for a larger measurement grid spacing than the dipole spacing upon demonstration of sufficient detection of an actual or artificial leak, which allows for skipping data acquisition locations throughout the survey area. This could result in undetected leaks, especially if the existing leaks are much smaller or drier than the actual or artificial leak used for the demonstration of sensitivity.

Two main data presentation methods for purposes of data analysis exist for soil-covered surveys: two dimensional and three dimensional. Two dimensional presentations consist of plotting voltage values on the Y-axis along the dipole transect (distance) representing the X-axis of a graph. Three dimensional presentations consist of plotting the survey area on the X and Y-axis of a map, with the voltage values shown as the Z-axis. In this manner the voltage values can be contoured, similar to a topographical map, with voltage values rather than surface elevations.

Plotting voltage values on a map not only shows the magnitude of a leak signal, but also the shape as it propagates through the cover material. Low magnitude leak signals are often recognized due to their shape in plan view, whereas the signal magnitude might be lost in the background voltage values when plotted on two-dimensional transect lines. Thus, the analysis of dipole survey data is significantly improved, and more easily understood, when presented in a three-dimensional format compared to a two-dimensional format. Additionally, voltage maps show the geographical relationship between different features. Since each feature will be more highly affected by other features near it, it is useful know, for example, if an artificial leak was installed near a perimeter isolation issue. The requirement to plot data acquisition locations on a voltage map is an additional quality control measure to ensure that the survey area was completely covered and that no data are missing. GPS-based data acquisition has shown that locational referencing of data points using GPS techniques is far quicker and less prone to errors than other methods. In addition, GPS-based data acquisition makes it possible to define non-square edges of the survey area and obtain extra data points, since the data acquisition is not constrained to linear string lines.

ASTM D8265-21 requires data analysis by way of voltage maps (three-dimensional analysis), with data acquisition locations plotted on the map(s). ASTM D7007-16 does not prescribe a data analysis method, but cites two and three dimensional analysis as the most common methods. Neither standard requires GPS-based data acquisition.

#6 Dipole Instrument Design. The dipole itself must be designed so that the only point of contact of the voltage measuring apparatus is at the measurement location. The measurement location must be electrically isolated from the rest of the structure that holds the measurement probes in place. Otherwise, current can short circuit the voltmeter. The physical design and materials used to construct the probes to measure voltage at the surface of the survey area are important to the success of the survey. The materials that they are comprised of may exchange electrons with the cover material. Copper sulfate reference electrodes are generally used, but even these can generate a voltage offset of up to 5 mV. These types of probes must be cleaned and/or tested frequently to assure that they are providing clean voltage readings. The voltmeter itself should have a high internal resistance for a most accurate reading.

ASTM D8265-21 requires that the dipole measurement probes be non-reactive with the cover material and that the internal resistance of the voltmeter used be at least 1 giga-ohm. ASTM D7007-16 does not address instrument design.

#7 Cover Material Chemistry. Although mineralogy affects the electrical conductivity of the cover material, this point goes beyond that. Electrons flow between different particles of biologically or chemically reactive cover material. The electron movement will be measured by the dipole as a voltage differential. If the voltage differentials are large enough, they can obscure leak signals.

Neither ASTM D8265-21 nor D7007-16 address this, but this is usually only an issue with active (in use) containment facilities. The dipole method is usually performed on recently constructed containment facilities with chemically and biologically inert cover material. However, for survey areas with dissimilar cover materials, for example a leachate collection trench 'window' composed of gravel while the remainder of the cover material is fine-grained, a voltage gradient is sometimes measured when the dipole instrument has one foot on each of the different materials (e.g. crossing the trench perpendicular to length of trench). Anomalies characteristic of leak signals caused by the dissimilar materials require additional measurements parallel to the anomalous feature to rule out or confirm the presence of a leak.

#8 Survey Direction. The optimal transect direction for detecting a leak depends on where a leak is located in relation to the a) limits of the survey area, b) the current injector, c) other leaks, and d) perimeter isolation issues. It is impossible to know where a leak might be located, so the survey direction is typically arbitrarily chosen and validated by functionality testing. Also, leaks are difficult to detect if a dipole approaches a leak but does not move past it to acquire data on the other side of it. Leaks along the edge of the survey area that runs perpendicular to the direction chosen for the survey are therefore subject to being missed.

ASTM D8265-21 requires that data be acquired parallel to every edge of the survey area. ASTM D7007-16 does not require that data be acquired parallel to every edge of the survey area.

#9 Cover Material Thickness. The further away from a leak voltage measurements are made, the smaller the leak signal will be. This also applies to cover material thickness. The dipole method was developed for relatively thin cover material and is not purported to work for a "deep fill" configuration. ASTM D6747-21 defines a "deep soil fill" configuration as greater than 3 meters in depth. A common rule of thumb is that the cover material thickness should be no greater than the dipole spacing. Increasing the cover material within the "deep fill" limit as defined by ASTM D6747 will have a greater effect if a smaller dipole instrument is used. It will have a nominal effect with a larger dipole instrument.

ASTM D8265-21 states that thickness should be minimized and should not exceed approximately 3 meters (i.e. largest dipole size commonly used). ASTM D7007-16 states that if the cover material thickness exceeds 600 m, then a larger artificial leak than 6.4 mm should be used, but no maximum thickness is recommended.

BACKGROUND

The case study detailed here is a 11-hectare double-lined landfill expansion cell located in Visalia, CA with the following cross section, from top to bottom: 0.6m silty soil operations layer, primary geocomposite drainage layer, 60 mil HDPE geomembrane, GCL, 0.3m silty soil separation layer, secondary geocomposite drainage layer, secondary 60 mil HDPE geomembrane, and 0.2m prepared silty subgrade. The secondary geomembrane was tested using the dipole method after placement of the 0.3m silty soil separation layer. The primary geomembrane was tested while bare using the water puddle method (ASTM D7002) and again after the 0.6m silty soil operations layer placement using the dipole method. Because of the project size and sequencing, the covered secondary geomembrane was tested in three separate campaigns, and the primary geomembrane was tested in four separate campaigns. Only the covered geomembrane testing is discussed herein.

The case study detailed here used the same survey procedures (ASTM D8265-21) and survey instrumentation for every testing event. A three-meter dipole was used with a measurement density spacing of three meters by three meters. The only testing parameter that varied from test to test was the degree of survey area perimeter isolation, since no leaks were found during the surveys that could have affected method sensitivity. The cover materials were profusely sprayed with water during excavation and placement, and on their surface during each testing event, and the same standardized functionality verification with a 6.4 mm diameter artificial leak was used each time.

During each survey, the relevant upper soil layer being surveyed (i.e. the 0.3m separation layer for the secondary liner system, and the 0.6m operations layer for the primary liner system) was stopped short of connecting with the perimeter of the new cell to provide electrical isolation. On three sides of the rectangular cell the perimeter consisted of a permanent anchor trench, and on one side the perimeter consisted of a tie-in to a previous cell. At the base of the unconnected gap between the new soil layers and the other side of the perimeter one could visibly see the exposed geocomposite drainage layer over the geomembrane. Electrical isolation was maintained by keeping the exposed geocomposite and geomembrane in this gap relatively clean and dry (Figure 1).

The method of electrically isolating access roads to maintain survey area truck access for spray-irrigating the cover soil material was to use a geomembrane flap. The flap was placed across the isolation trench and extended up through the access road soils to create an exposed edge, as shown in Figure 2. Such a flap, if used, is best welded to a rubsheet, which in turn should be welded continuously all around to the containment geomembrane, so that the flap weld does not adversely affect the containment geomembrane.

RESULTS

Functionality testing results generated from the seven sequential survey campaigns are shown in Table 1 (three portions for the secondary liner system, and four portions for the primary liner system) in the general order that the testing was performed. Functionality of the survey methodology is evaluated based on the detectability of an artificial leak. The detectability of an artificial leak can be quantified by measuring the voltage when the front dipole probe is directly over the artificial leak and again when the back dipole probe is directly over the artificial leak. For the artificial leak to be considered detectable, the first measurement should be strongly negative and the second measurement should be strongly positive. Other measurements are made at offsets to the artificial leak during functionality testing, but to simplify the reporting of detectability between the various testing events for the purposes of this paper, only these two measurements are reported here. Additionally, a “detectability” column was generated of the difference between the two measured voltages. A positive value indicates that the artificial leak was detectable, with increasingly positive values showing an increased level of sensitivity. A negative value indicates that the artificial leak was not detectable.

Testing Event	Description of Dipole Location During Measurement	Measured Value (V)	Detectability
Secondary (1st Portion)	Front Foot On 1/8” Artificial Leak	-5.397	+10.907
	Back Foot On 1/8” Artificial Leak	+5.510	
Secondary (2nd Portion)	Front Foot On1/4” Artificial Leak	-0.532	+1.576
	Back Foot On 1/4” Artificial Leak	+1.044	
Secondary (3rd Portion)	Front Foot On1/4” Artificial Leak	-0.016	+0.084
	Back Foot On 1/4” Artificial Leak	+0.068	
Primary (1st Portion)	Front Foot On1/4” Artificial Leak	-0.589	+1.134
	Back Foot On 1/4” Artificial Leak	+0.545	
Primary (2nd Portion)	Front Foot On1/4” Artificial Leak	-0.184	+0.228
	Back Foot On 1/4” Artificial Leak	+0.044	
Primary (3rd Portion)	Front Foot On1/4” Artificial Leak	+0.253	+0.128
	Back Foot On 1/4” Artificial Leak	+0.381	
Primary (4th Portion)	Front Foot On1/4” Artificial Leak	+0.215	-0.007
	Back Foot On 1/4” Artificial Leak	+0.208	

Table 1. Functionality Testing Results for Seven Sequential Survey Campaigns.

As shown in Table 1, the detectability of the artificial leak declined with each testing event of the secondary geomembrane as the perimeter isolation gap grew increasingly dirty during the course of construction. The detectability increased when the primary geomembrane started to be tested, which was the beginning of a new survey area since the primary geomembrane isolation gaps would have been newly installed for that layer. However, the same pattern of decreasing detectability was noted with each successive testing campaign in the primary liner system as was noted with the secondary liner system. In both cases, by the time the 3rd portion of the surveys were conducted for each layer, the results of the dipole measurements showed that the artificial leak was weakly detectable.

The 3rd portion of the primary liner system campaign showed particularly troubling voltage readings in that both of the functionality measurements had positive values. Without the negative voltage value with the front dipole foot over the artificial leak, the artificial leak is not strongly detectable. After reviewing these results, the perimeter isolation gap was inspected and the isolation improved before beginning the testing. A location along the perimeter immediately adjacent to the location of the artificial leak exhibited a strong signal due to the isolation issues shown in Figure 1. This location was determined to be the cause of the isolation issues upon analysis of the voltage mapping. This type of perimeter isolation issue is very typical of landfill expansions. Also it is noteworthy that the silty/clayey soils comprising the upper soil layers at this site are much more electrically conductive than clean sand and gravel layers that might be used for the drainage and operations layers at other sites, and this increased conductivity exacerbates the isolation issues.

Figure 1. Perimeter Isolation Issue at Access Road Location Causing Primary Survey Portion 3 Sensitivity Issues Before Cleaning (Left) and After Cleaning (Right).

For the fourth portion of the covered primary geomembrane testing, the initial functionality testing results shown in Table 1 indicated that the artificial leak was not detectable at all. The slight difference between the voltage readings was likely caused by measurement error, since the first number was slightly higher than the second number. During this final testing event, the entire survey area was complete, and thus the condition of the entire perimeter was influencing the sensitivity. It had rained significantly a few days before the final testing campaign, causing shallow flooding of the materials in the isolation gaps. After the rain event, the geocomposite under the isolation flap at the access road (Figure 2) was saturated, along with the entire bottom layer of geotextile throughout the isolation gap. At other sites, cutting the geocomposite and peeling it back has been used as a solution to increase sensitivity when the geocomposte is saturated. Since the survey area was bounded on three sides by anchor trenches, it was not acceptable to the engineer to cut the geocomposite.

Figure 2. Method of Electrically Isolating Access Roads

The entire perimeter isolation gap was then further cleaned and all of the access roads, such as the one shown in Figure 2, were completely removed. Functionality testing was repeated without any significant improvement. The second author was the approving engineer for this project and insisted that the ¼” artificial leak be detectable before commencing the survey. He suggested the use of a high-powered leaf blower, directed at the geocomposite, proceeding along the entire isolation gap very slowly in order to thoroughly dry out the moisture trapped by the geotextile on the underside, and it would also tend to blow out any loose soil in the gap area. The backpack leaf blower that was used is shown in use in Figure 3.

Functionality testing was repeated after use of the leaf blower and the artificial leak was strongly detectable, as shown in Table 2.

Testing Event	**Description of Dipole Location During Measurement**	**Measured Value (V)**	**Detectability**
Primary (4th Portion), After Leaf Blower	Front Foot On1/4” Artificial Leak	-2.683	+6.507
	Back Foot On 1/4” Artificial Leak	+3.824	

Table 2. Functionality Testing Results After Application of Leaf Blower.

Figure 3. Backpack Leaf Blower Used to Dry out the Geocomposite in the Perimeter Isolation Gap.

CONCLUSIONS

It is clear from the results of the testing sequence on this project that survey area isolation is the single most critical factor in the effectiveness of dipole electrical leak location testing. Since moisture has a direct correlation on electrical conductivity, a focus on drying out the material(s) in the isolation gap rather than completely removing them proved extremely effective on the installed geocomposite. The use of the backpack blower provided a low-cost, speedy and highly effective fix for the perimeter isolation issue encountered in this instance. This method is recommended for the toolbox of any leak location purveyor when conducting a dipole method survey over soils.

Project specifications with the intention of maximizing method sensitivity should focus on site isolation as an enforceable requirement and should be considered as part of the design documents and specifications. Decisions related to dipole spacing should generally be left to the judgement of an experienced leak location specialist, but it is recommended that the measurement density not exceed the dipole spacing. Given that increased sensitivity is typically achieved with a greater dipole spacing (up to reasonable limits), and that increased dipole spacing typically results in quicker and less expensive surveys, there are strong arguments to consider using a dipole spacing on the order of 3m with a corresponding measurement density of 3m by 3m for practical production surveys, allowing that increased measurement densities are useful for evaluating anomalous signals and pinpointing leaks.

Plotting dipole survey data in a three-dimensional format that shows contours of voltage readings, as recommended in the Standard Practice of ASTM D8265-21, provides improved data interpretation that is also more understandable to the client and regulators. Although the georeferencing data required for presentation in this format can be acquired by traditional stringline grid techniques, the advent of GPS technology provides a very expedient, cost-effective, reliable, and more flexible means to perform this task.

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