The Permanent GNSS Network and its RTK Application in Israel

Einat SALMON, Israel

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SUMMARY

Following the network upgrading to the highest international standard and thereafter densification of the network in order to cover the entire country, the network of permanent GNSS stations in Israel (APN = Active Permanent Network) has became the basis of the Israeli geodetic network and has made a major impact upon all the survey practice known in Israel.

For years the Israeli coordinates network ITM (Israel Transverse Mercator) was being based on the major triangulation points which were established during the British mandate over Israel (1917-1948) and were measured throughout the years. The accuracy of the ITM network control points was about 10 cm. Due to the course that modernized technology took, it was decided that the permanent stations will serve as basis points for measurements in Israel. Following the changes, a new datum, IGD05, was declared in Israel.

Transformation parameters were published and the surveyors could use GPS measurements and transfer geodetic coordinates (in IGD05) to the improved Israeli grid (IG05).

Furthermore, the Survey of Israel published new survey instructions which allowed surveyors to measure while using a single GNSS receiver based on the permanent stations network. The RTK application was implemented in a later stage. It enabled surveyors to establish control points with RTK measurements using a single GPS receiver and RTK technology, allowing measuring details and boundaries for Cadastral and engineering use.

In addition to the above, a geoid undulation model was developed and assimilated into the RTK and GPS receiving units, which enabled the surveyors receive orthometric height efficiently.

All the changes above resulted in uniformity of the Cadastral measurements in Israel and are the basis for future analytical (coordinate based) Cadastre.

These significant changes, enabling the surveyors to use a leading age technology on one hand and achieving high accuracy demand on the other, have made a major impact upon surveyors daily work. The outstanding effect is described in this article.

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1. UPDATING THE ISRAELI REFERENCE STATION NETWORK AND MODIFYING IT TO THE SURVEYING REVOLUTION.

The first Israeli permanent network stations – GIL, was founded in 1996 in a combined effort of the Israeli Geologic Survey (IGS), Israeli Space Agency, Survey of Israel (SOI) and Tel-Aviv University (Forrai, 2009).
During 2002 the Permanent Network Stations' responsibility for the operation was transferred to the Field division of the Survey of Israel.

At that time the Israeli network contained 11 reference stations. The spreading of the stations is displayed at Fig.1.

7 of the 11 stations were installed on geologic-geodynamic monuments. The structure of the station included a GPS antenna that was placed on the top of a pole that was drilled 5 meters into the ground, and in some cases held by extra poles. The communication cables run underground to a communication block that includes the GPS receiver and the communication modem. (Fig. 2)

The stations that were build on a geodynamic monuments are ELRO, CABR, GILB, JSLM, DRAG, LHAV, and RAMO. During 2008 the LHAV station was changed to the station KLHV and was diverted to a nearby location.

Figure 1. The GIL reference stations at the completion of the combined effort between IGS, Israeli Space Agency, The Survey of Israel and Tel-Aviv University on 2002.

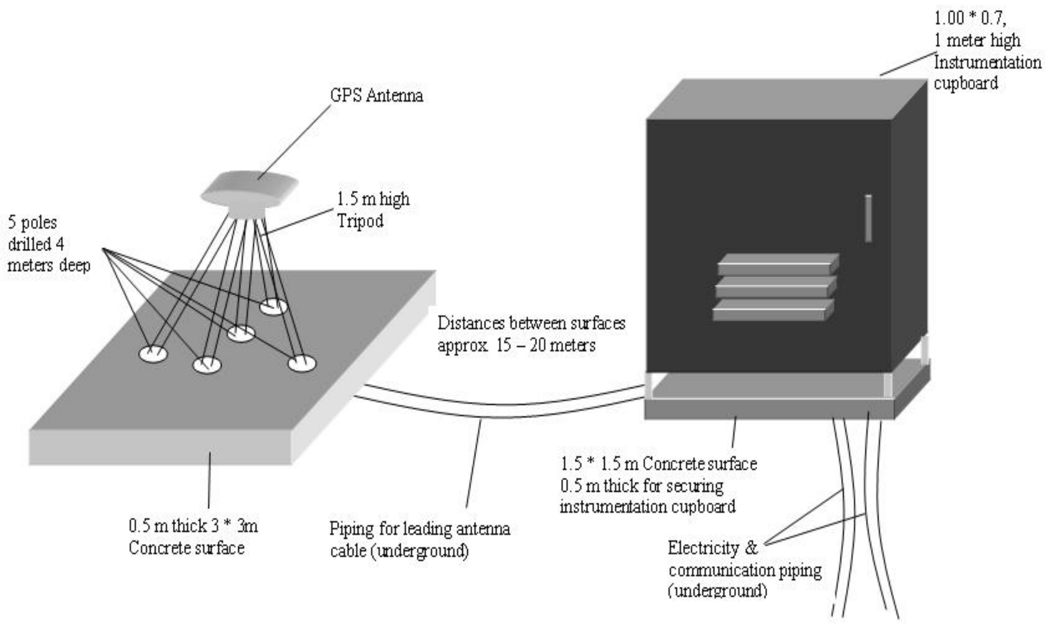


Figure 2. The structure of the geodynamic monument reference stations.

4 of the first 11 permanent stations were built by the Survey of Israel on stable structures: KATZ, BSHM, TELA, and ELAT.

The BSHM station – Established in the city of Haifa in cooperation with the Geodesy faculty at the Technion institute on the civil engineering faculty building to memorize the late professor Benyamin Shmuter.

In 2002, when the SOI gained responsibility for the stations, the network was available for geologic-geodynamic necessities; however the permanent stations network did not affect the geodetic management operation in Israel due to the fact the system included 11 reference stations distributed in a non-uniform manner throughout the country. The information was transferred by old fashion models technological means, saved in unsecured and not user friendly FTP sites. The information intervals were at a sampling rate of 30 seconds.

The turning point began during 2003 when the decision of a full automation of the system was received (Forrai, 2009).

For that purpose, a tender was issued and a sub contractor has been chosen.

Management programs were installed. The network of permanent GPS stations is being controlled by the RTD software (http://www.geodetics.com). It is based on epoch-by-epoch solution which enables monitoring any changes in the station coordinates due to deformation and lost qualities.

A control center was built.

Data sampling rate was gradually increased from 30 seconds to 5 seconds between epochs. The GIL reference station array is shown in Figure 3.

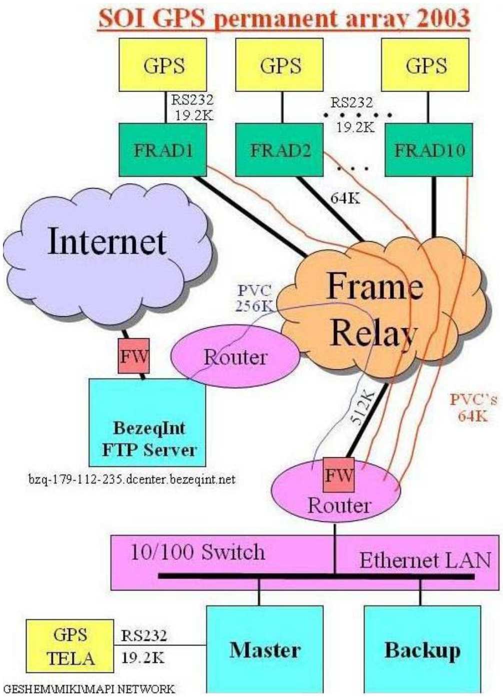


Figure 3. The GIL reference stations component that enabled a full automation activity on 2003.

The information supplied to surveyors on the web site has been transformed to an organized web site.

VRS-Virtual Reference Station software was added, allowing condensing the information for areas far from a permanent station.

The VRS software is developed by the GEO++ Company. As a result of the Survey of Israel request a Post Processing data option was implemented by Geo++ into the package. The internet VRS software web site is shown in Figure 4.

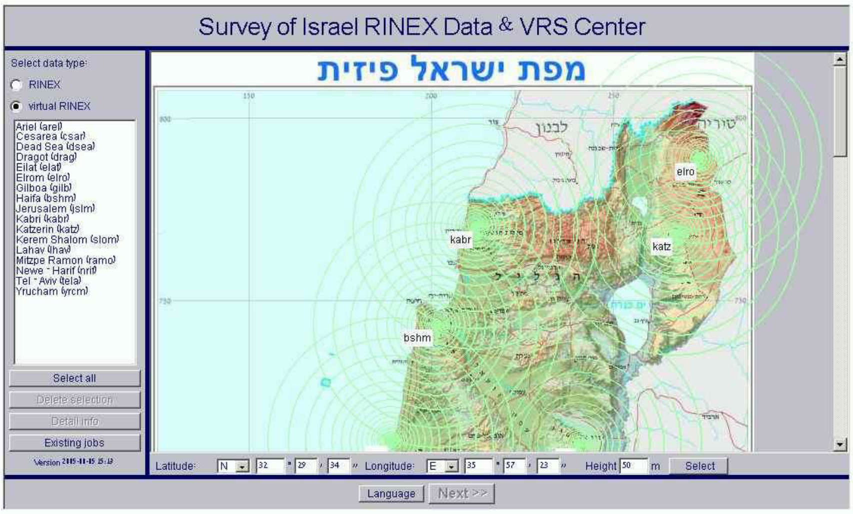


Figure 4. . The internet GN_web module in web (www.mapigps.co.il) enables users to ask for a permanent station data or a user defined VRS station data within the APN.

Throughout the years 8 reference stations were added to the network, all on stable structures, mainly for geodetic uses: Three station established in 2004, CSAR, AREL, SLOM, ALON, 4 station established in 2005, YRCM, DSEA, NRIF. The NZRT station established in 2008.

The AREL station position changed during 2008 and renamed YOSH.
Each of the 19 stations is equipped with a geodetic GPS receiver, chock ring antenna, AC power, and emergency backup power.

Due to the changes mentioned above it was decided in 2005 to rename the network as APN (Active Permanent Station).

To date, the permanent stations network includes 19 stations spread throughout the country (Fig 4.).
The density of the station in the northern region is large due to the fact that most of the surveying activity is performed there; whereas the southern region consists of a number of stations at a lower density.

2. DECLARING NEW BASING NETWORK ISRAEL 2005

After upgrading the network to an international level a revolutionary process changed the entire surveying approach in Israel.

Figure 4. The Israeli APN reference stations spreading on the year 2008.

The first step was deciding to use the permanent stations network as the base points for surveying in Israel (Steinberg and Even-Tzur, 2004, 2005).

In the past the Israeli coordinate network (ITM-Israel transvers Mercator) was based on triangulation points established during the British mandate over Israel and was upgraded throughout the years. Often the network accuracy was 10cm or lower. The results are hereby dependant on the control points used for the profound project. Due to the accuracy of the basic control points, which was low, we can see inconsistencies in the order of up to10-15 cm between neighboring projects which are based on different control points. The SOI set its goal of achieving accuracy of 5 cm with 95% confidence level (Steinberg 2001).

On 1/10/2004 SOI defined a new attribution system for the Israeli permanent stations network (APN).

The new system is called IGD05 (Israel Geodetic Datum 2005). It is a 3D coordinates system using Global Positioning System. Positions and vectors are referenced in the WGS-84.
The reference ellipsoid of this datum is practically equivalent to the reference ellipsoid defined by GRS-80, which is the reference ellipsoid of ITM. Seven parameters were published for transformation from IGD05 system to the Israeli coordinates grid (ITM known as the new Israeli network).

These parameters are based on optimal pre determined equations taken from the permanent station on the new Israeli network (Steinberg and Even-Tzur, 2004, 2005).

The coordinates-set valid for GPS day 275 of the year 2004 was set as fixed coordinates of the permanent GPS stations.

As of now, ITM datum coordinates of control points measured according to the guidelines described below will constitute an upgraded network based on APN permanent stations and is identified as Israel network IG05 (Israel grid 2005).

3. PUBLISHING NEW SURVEYING REGULATIONS AND GUIDELINES

3.1. New Surveying Regulations

Simultaneously with the upgrading of the network and provide services to the surveyors, the need for publishing new guidelines for using the reference system rose.
SOI began writing new surveying regulations for defining new points grade (Steinberg, 2006).

A new order was published. It was decided on hierarchy division of 2 levels. The G order was divided to 3 classes and the S order was divided to 2 classes.
The base points will serve as the permanent stations network and will be called G0 level.
Below them the lower level is level G1, which consists 150 stable and protected geodynamic control points drilled into the ground.
The G1 network was measured in three different campaigns on separate periods, using highly and efficient GPS measuring that provide precise coordinate accuracies. (Ostrowski, 2005) (Fig 6)

The next level contained points from level G2. G2 points network include about 1200 points chosen from thousands of points as stable points allowing GNSS measurements. At present we are conducting a rerun of the measurements and determine the IGD05 coordinate values (Tuchin et al, 2009). The 'G' grades will serve as the base network measured exclusively by SOI.

Beneath them the next grade contains points from level S1 and level S2 and will be measured by private surveyors as well as SOI.

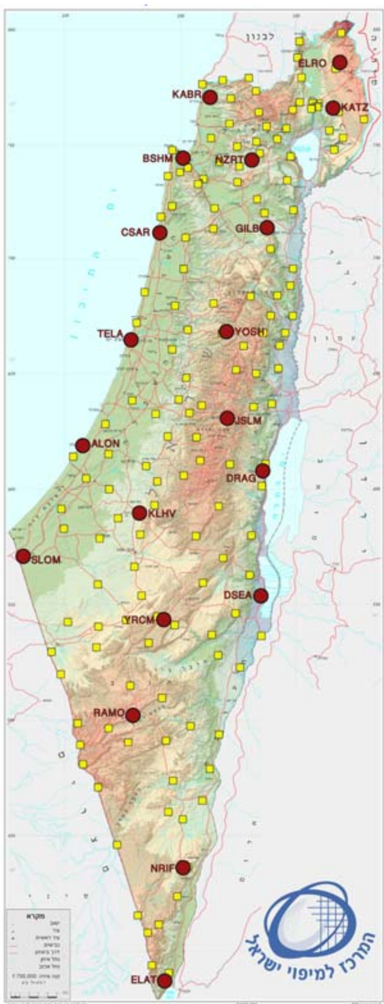


Figure 6. The G1 geodetic-Geodynamic network spreading.

3.2. New Guidelines

Likewise, SOI published new guidelines with demands for very accurate measurements enabling the surveyors to use a single GPS receiver and in addition enabling measuring details and boundaries of lots for cadastral purposes.

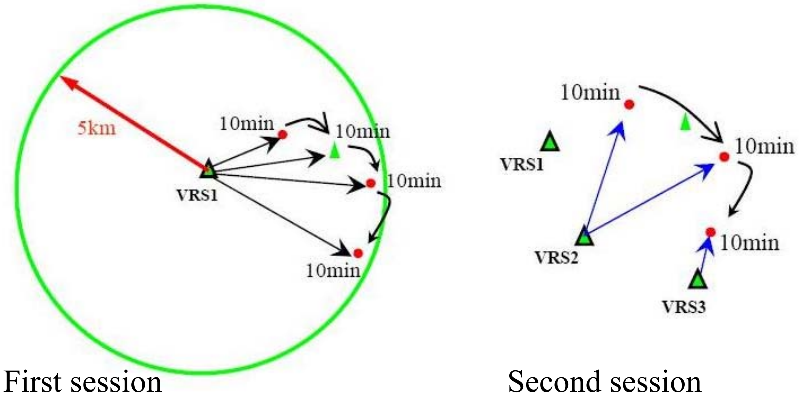
In 2005, guidelines for determining horizontal control points by permanent and VRS GNSS stations were published, as well as official transformation parameters. These regulations are annex to the existing surveying regulations established in1998.

The guidelines provided 4 measuring methods, using APN network, measuring based on a VRS station, using base station and network measuring.

Measurements related to a reference and virtual station, enables determining new control points using a single GNSS receiver.

On the contrary to the past where at least three vectors and three control points were needed in order to determine new control points, nowadays in order to determine, the control point coordinate value it is possible to base the measurement only on a permanent station, a virtual station or a base station.

The guidelines required not less than 10 minutes measurements, using two different sets with a time difference of at least an hour between both sets, in additional a control point need to be measured for checking purposes (Fig 7).



First session Second session

Figure 7: Control points measuring method using the VRS post processing application.

Coordinates calculation was performed in the office using information gathered from the APN web site. If the deviation between the two sets standing on the guidelines demands (less then 40mm between the coordinate values of the two sets and less than 50 mm between the known coordinate values of the control point and the new measurement) the new point values determined as the average of the two sessions.

When measuring according to the network guidelines, it is acceptable to base the measurement on two IG05 control points and not on minimum of three points as determined in the past.

In addition the surveyors can measure, resembling to the past, using two receivers or EDM instrument, where the measuring base will be stabilized on a control point with IG05 coordinate values. (fig 8)

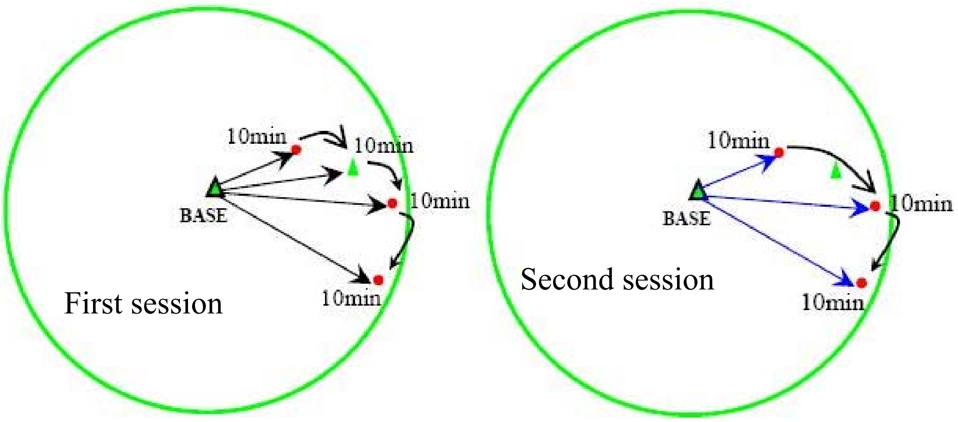


Figure 8: Control points measuring method using private base GNSS receiver.

4. THE REFERENCE STATIONS NETWORK FOR CADASTRAL MEASUREMENTS

Since it was decided to refer to a uniform and reliable coordinate network – IG05, the effect on cadastre, hence the current and the future, was immediate.

One of the main goals set by SOI is to establish a coordinate based cadastre (Steinberg, 2001), and Israel network 2005 sets a foundation for that purpose.

During 2006 the permanent stations array was upgraded and the RTK application was added which made measuring easier (Fig 8).

The GEO++ program was expanded and suited for RTK & DGPS necessities.
Two additional servers which log information at 1 second intervals were installed. The information received by the control center, in addition to the internet site was transferred, also, to a cellular network server and forwarded to the surveyors on site equipped with a cellular modem. The communication with the network is enabled by one of the following methods: VRS, FKP and direct connection to reference station.

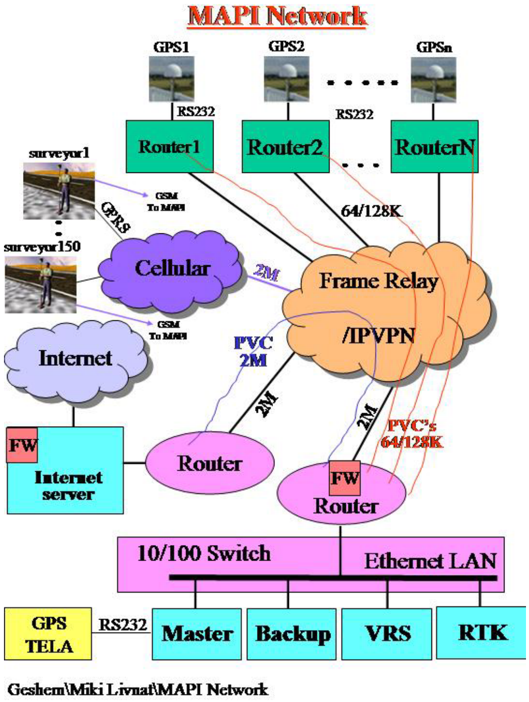


Figure 8. The APN reference stations component including the RTK application that was established in 2006.

Technical guidelines for measuring S2 control points using RTK were published.
The surveyor can stabilize the RTK on a stabilizing device for 180 consecutive seconds, using two different sets with an hour difference between them, and if the results are smaller than 35 mm between both measurements, the average will be determined as the coordinates of the point. Also a control point measurement is required for checking purposes.
In addition to the above technical guidelines for measuring border points and details using RTK were published.

For this type of measurements the surveyor can measure during 4 consecutive seconds at time differences of at least 30 minutes between two sets. The difference between the coordinates in both sets will not exceed 5 cm. Also a control point measurement is required for checking purposes in the beginning and ending of the measuring day. In addition it is required to measure 20% of the border points and well defined details.

In the same manner the SOI published technical guidelines for determining control points for photogrammetry using permanent and virtual GPS stations and official transformation parameters, guidelines for measuring photogrammetry control points using RTK and technical guidelines for measuring height points for topographic mapping using RTK.

In order to expedite the analytical cadastre goal, and achieving cadastre based coordinates with values in a uniform network – IG05, a new project was initiated. The first layer of points that were the control points for borders and cadastral objects in the ITM network are being measured. From those new coordinate values SOI will calculate the cadastral borders values based on 2005 network coordinates.

5. STATUTORY GEOID UNDULATION MODEL

Another user friendly method that promoted thanks to the APN network is the Geoid Undulation Model.
It was decided to move towards 3D Geodetic Control network.

Since most of the surveying is performed using GPS receivers and the height provided by these instruments is an ellipsoidal height, a nation wide Geoid Undulation model was published and suited to convert ellipsoidal heights to orthometric heights in different areas of the country at different accuracies. (Tuchin 2006, Steinberg and Even-Tzur 2006, Steinberg and Tuchin, 2009).

The first undulation model version was called ILUM1.0 (Israel Undulation Model). To date the surveyor's community in Israel can use the ILUM1.2 version. The growing uses of the APN data enhanced publishing the Geoid Undulation Model and encourage surveyors to use it.

The RTK manufacturers provided instrument that enable recognition of Geoid Undulation Model, allowing the surveyors to measure ellipsoidal heights and receive orthometric heights online in the field and examine the results online against control points.

It was decided to use an official Geoid Undulations model (OGUM) as a substitute for orthometric control, i.e. the OGUM is a statutory model and the heights provided by the conversion of the model are legal.

Likewise technical guidelines were published by the SOI for determining vertical control points at levels of 4 and 5 using permanent and virtual GPS stations and official transformation parameters. According to those regulations after measuring two sets for not less than 20 minutes, and checking against a known height, the actual height is determined by the average of the to sessions and converting ellipsoidal height to orthometric height using the ILUM.

In addition to the above technical guidelines were published by the SOI for measuring vertical control points at levels of 4 and 5 using RTK application. This measurement is performed over 120 seconds at 60 minutes differences and the orthometric height is determined based on the ILUM conversion.

6. SURVEY ECONOMICAL ASPECTS

In addition to all the described above, including reliability and accuracy, it is safely said that success or failure of the permanent stations network is measured by financial profitability.
This profitability is proven without any doubt.
The surveyors, need to purchase only one RTK instrument in comparison to purchasing two GPS instruments when using BASE and ROVER using the RTK implantation. Also the decrease in labor costs due to employing two teams and two vehicles whereas often a single

person can perform the job. In addition, the permanent stations method saves valuable time when searching for control points used as the appropriate base in surveying area.

Utilizing the RTK is very efficient for surveyors measuring far from urban areas that make the control points difficult to identify, long distance traveling as well as hard to approach locations and not available private permanent stations.

Accordingly, these changes enable surveyors to base their measurements on the permanents stations network, and thus, more and more users are acquiring information supplied by the network.

Large surveying companies in the past used both instruments for surveying, can today use each instrument separately and double their production.

Surveyors now days possess the ability of using modern technologies, providing highly and accurate measurements on the one hand and influencing their daily work by simplifying it on the other.

The rate of the post processing data from the reference station web site is 0.5 Shekels (about 12$ cents) per minute of information.
RTK information will cost about 25 cents; however the hourly price decreases in direct accordance to the amount of utilizing e.g. for over 100 hours, the rate will be 4.5 cents per minute. If utilizing for above 100 hours, there is an option for an annual price reduction.

Feasibility of using the permanent stations network is expressed in the increasing quantity of surveyors exploiting the systems different applications.
As of the end of 2008 the network is being used by more then 50% of the surveying companies in Israel.

7. SUMMARY FUTURE PLANS

The revolution that occurred in the Israeli Geodetic measuring field consequently to using the permanent stations, affected the surveying quality, efficacy, simplifying the measuring demands and the profession perception.

After the permanent stations achieved a state of the art technology, the revolution led the process of determining APN network as the basis network, declaring new guidelines, using the official Statutory Geoid Undulation Model, and lowering costs and changed the face of Israeli geodesy.

SOI main goal is to determine coordinate based cadastre and our hope is that as of today the level, uniformity and quality will be at a much higher level than the current cadastre.
In order to implement this, the SOI will continue to observe technological development and continue to improve in making the Israeli base network – Permanent Stations Network more efficient.

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BIOGRAPHICAL NOTES

Ms.s. **Einat Salmon,** Graduated B.s.c. in Geodeticc Engineering, at the Israel institute of technology, The Technion, in 2001 and serve as a head division of field geodetic control as of 2005.

CONTACTS

Ms. Einat Salmon
Survey of Israel
1, Lincoln St.
Tel Aviv – 65220
ISRAEL
Tel. + 972-3-6231993
Fax + 972-3-6231815
Email: sade_mapi@int.gov.il
Web site: www.mapi.gov.il